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BULLETIN D'INFORMATIONS

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Editorial

The IGY was indeed the start of an international cooperation for the study of Earth Tides. As usual Paul Melchior showed a proactive approach in the framework of the Belgian Special Committee for the International Geophysical Year (Comité Spécial pour l'Année Géophysique Internationale, CSAGI). He launched a "Commission pour l'Etude des Marées Terrestres" for the study of Earth Tides and the first issue of the "Bulletin d'Information des Marées Terrestres (BIM)" was published in December 1956. In this 15 pages publication you could find a description of the LaCoste and Romberg tidal gravimeters by G.P. Woollard and a paper in French by Robert Lecolazet on the recording of the gravimetric tides with a North American gravimeter. In 1957 eight issue of the BIM were published but later on the rate of publication was reduced to four issues per year. A Permanent Commission on Earth Tides and the International Centre for Earth Tides (ICET) were officially created by the International Association of Geodesy (IAG) in 1958. The BIM became a publication of this Commission in 1959. The BIM was published at the Royal Observatory of Belgium until 2007 and migrated to the University of French Polynesia later on. Paul Melchior was the editor until 1995, followed by Olivier Francis (1996-1998), Bernard Ducarme (1999-2007) and Jean-Pierre Barriot (2008-2018). During the last decade BIM became an electronic journal.

From the beginning the BIM was used as a tool for the fast publication of technical papers and results of ongoing research. It has been an important link between West and East European scientists during the Cold War era. One originality was indeed the publication of translations of papers written in Russian language by scientist of Eastern countries. These translations have been performed by Anne-Marie Bary, the wife of Paul Melchior, who did learn Russian for that purpose.

The proceedings of the meetings of the Working Groups of the Earth Tides Commission, in Bonn first and in Jena later, have been published in the BIM. Recently we still published several papers presented at the Jena (BIM144, 145, 146) and Warsaw (BIM148, 149) Earth Tides Symposia.

However after 60 years the task of BIM is now completed. Scientific publication evolved to a new era and reviewing became a key stone. We do not have the manpower to set up a performing reviewing system. BIM150 is thus the last issue but it will not be the less interesting one with a standard of our scientific papers: a thorough discussion of the tidal analysis limitations.

Jean-Pierre Barriot

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Obituary

Alexander Kopaev (1962 – 2016)

On February 17 2016 Alexander Kopaev, candidate in physical and mathematical sciences, senior research associate at the Department of gravity measurements of the State Sternberg Astronomical Institute, associate professor of celestial mechanics, astrometry and gravity measurements at the Faculty of Physics of the Lomonosov Moscow State University, passed away.

Alexander Kopaev was the author of about hundred scientific articles, five monographs, numerous reports at conferences, lectures on Gravity measurements, a manual on the "Use of High-precision Gravity Measurements for the Study of Vertical Earth Movements", training courses for university practical studies: "Application of microgravity measurements for the detection of near surface objects", "Use of high-precision gravity measurements for the detection of vertical earth displacements". He defended his PhD thesis on “Spatial reductions of precise gravity measurements” under Professor Marat Sagitov direction.

Alexander Kopaev was a recognized talented researcher in the field of instrumental gravimetric measurements. Its scientific interests covered many areas of Earth sciences, such as geodesy, geophysics, geodynamics, geotectonics. He was an active and regular participant of the International comparisons of absolute ballistic gravity meters, skillfully solving the problem of microgravimetric support for these important metrological campaigns.

Alexander Kopaev was a permanent and active member, and also the secretary, of the Geodesy Section of the National Geophysical Committee of the Russian Academy of Sciences. The last years Alexander Kopaev fruitfully combined teaching activity with work at the Federal State Unitary Enterprise "National Research Institute of Physicotechnical and Radio Engineering Measurements"(FSUE "VNIIFTRI").

Everybody who had the pleasure to work with Alexander, in Russia and abroad, appreciated him as a sincere, sociable and kind person.

The Russian and world scientific community lost a talented researcher and teacher. Kind memory of Alexander Kopaev remains in the hearts of his colleagues and pupils.

VLADIMIR I. KAFTA

A.KOPAEV, Moscow, 1993 (signed photograph to Bernard Ducarme)

The smurf characters and tidal research

B. Ducarme[1], M. van Ruymbeke[2]

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Paul Melchior was a personal friend of the Belgian comics writer Pierre Culliford, better known under the pseudonym "Peyo". His character, a blue friendly gnome called smurf (schtroumpf), dwelling in mushroom shaped houses and eating salsaparilla, became quickly very famous in Belgium. In 1966 Paul Melchior presented for the first time the season's greetings of the International Centre for Earth Tides with a postcard illustrated by Peyo and showing smurfs having fun with Geodynamics. Thanks to this friendly collaboration 18 original works of art were created, each of them directly related with the current researches developed at the Department 1 of the Royal Observatory of Belgium. Among the different characters papa smurf (grand schtroumpf) personifies always Paul Melchior and different members of his team are represented by the smurfette or the brainy smurf. The creation of the smurf characters in 1958 coincides with the beginning of the International Centre for Earth Tides set up by Paul Melchior. To celebrate this common 60th anniversary, we wish to present in this last BIM issue a reproduction of these cards as a tribute to Paul Melchior's sense of humour.

We can roughly combine the cards under different topics:

- Tidal theory and Geodynamics;
- Instrumentation;
- Publications and International Centre for Earth Tides;
- Trans World Tidal Gravity Profiles 1974-1992;
- Scientific education, data processing and analysis;
- Satellite Geodesy, ocean tides modelling and introduction of superconducting gravimeters (SUPRA).

1. Tidal theory and Geodynamics

The influence of tides on Earth rotation on itself and Earth motion in space is illustrated by card 1.1 showing the different families of tides (Melchior, 1983): long period tides (Mf) which are modulating the length of day, semi-diurnal tides (M2) which are slowing down its rotation and diurnal tides (K1) which are triggering the precession-nutation torque. The influence of the internal structure of the Earth (card 1.2) responsible of the NDFW (Dehant and Mathews, 2015) is taken into account in the modelling of the tidal response (card 1.3, Dehant, 1987; Dehant et al., 1999).

2. Instrumentation

The Verbaandert-Melchior horizontal pendulum (VM) was an important instrumental development at the end of the fifties. The horizontal pendulums with metallic wires used in seismology were not stable enough to record tidal signals with a sufficient signal to noise ratio. The main drawbacks were:

- Low sensitivity as it was not possible to reach free periods higher than 30s

- Bad definition of the axis of rotation as the suspension wires were clamped in jaws
- High sensitivity to thermal variations

The VM pendulum structure (card 2.1) was a tetrahedron of fused quartz and the swinging quartz arm was attached by quartz wires (40µm∅) soldered on the structure. The VM pendulum was able to work at a period of 100s and, equipped with a standard photographic recording system, its sensitivity was close to 1mas/mm at a period of 80s. It is equivalent to a vertical pendulum 200km long! A timing precision of 1minute was possible using a chart speed of 6mm/hour and positioning the time marks with a resolution of 0.1mm. The precision of the phase determination was thus better than 0.5° in the semi-diurnal band.

The first instrument was installed in Sclaigneaux (Belgium) in 1959. VM pendulums have been widely used in Europe but also in Australia, Argentina and Quebec. The longest series reached 30 years of observations. As early as 1966 tidal tilt observations allowed the determination of the liquid core resonance effect (Melchior, 1966).

Created in 1968 the Underground Laboratory for Geodynamics of Walferdange (Flick and Stomp, 2002) is the result of a fruitful collaboration between the Royal Observatory of Belgium (ROB) and the Ministry for Cultural Affairs of the Grand Duchy of Luxemburg, joined later on by the Museum of Natural History. Located in a gypsum mine with large and dry horizontal galleries it was an exceptional place for clinometry and extensometry. Beside instruments developed at ROB (cards 2.2 and 2.3) the Laboratory welcomed instruments from France, Germany, United Kingdom, Iceland and even China.

3. Publications and International Centre for Earth Tides

The IGY was indeed the start of an international cooperation for the study of Earth Tides. As usual Paul Melchior showed a proactive approach in the framework of the Belgian Special Committee for the International Geophysical Year (Comité Spécial pour l'Année Géophysique Internationale, CSAGI). He launched a "Commission pour l'Etude des Marées Terrestres" for the study of Earth Tides and the first issue of the "Bulletin d'Information des Marées Terrestres (BIM)" was published in December 1956. From the beginning the BIM was used as a tool for the fast publication of technical papers and results of ongoing research. It has been an important link between West and East European scientists during the Cold War era. One originality was indeed the publication of translations of papers written in Russian language by scientist of Eastern countries (card 3.1). These translations have been performed by Anne-Marie Bary, the wife of Paul Melchior, who did learn Russian for that purpose.

Paul Melchior published an exhaustive description of tidal phenomena in "the Tides of the Planet Earth" (card 3.2, Melchior, 1983)

Prompted by Paul Melchior the International Association of Geodesy (IAG) officially created the "International Centre for Earth Tides" (ICET) in 1958 (card 3.3). Paul Melchior remained Director of ICET until 1995. In 2015 ICET was incorporated in a new IAG Service called "International Gravity and Earth Tides Service" (IGETS, http://igets.u-strasbg.fr/index.php).

4. Trans World Tidal Gravity Profiles 1974-1992

In 1970, J. T. Kuo from *Lamont Doherty Geological Observatory (New York)* is spending several months at ROB during his sabbatical leave. A new era begins for Paul Melchior's team as J.T. Kuo brought with him three highly precise *Geodynamics* gravimeters to measure tidal gravity across Europe. He launched immediately the so called Trans European gravity Profile (TEP) 1970-1974 and installed himself 6 temporary stations in one year. Melchior's team continued this project to reach a total of 20 tidal gravity stations.

In the meantime Paul Melchior prepared an ambitious project aiming to install temporary stations all around the world. This project called Trans World tidal gravity Profile (TWP) was partly sponsored by the US Air Force. The main objective was to obtain tidal factors to check and constrain ocean tides loading effects and improve tidal gravity predictions.

A standard equipment was developed around Geodynamics and LaCoste and Romberg (LCR) model G gravimeters including stabilized power, quartz clock and chart strip recorder. The signal to noise ratio, close to $1nms^{-2}$, was better than 0.1% of the tidal amplitude and a time resolution of 6s allowed a precision of 0.05° in the semi-diurnal band. An observation period of 6 months was planned to allow the separation of waves P1 and K2. The equipment was continuously improved and the LCR instruments were progressively equipped with feedback electronics (van Ruymbeke, 1985, 1989, 1991 a and b). All instruments were intercompared at Brussels and normalized on the results of the long series of observations with ASKANIA GS11 (Ducarme, 1975).

The TWP project started in 1974 (card 4.1) and continued until 1992. On Figure 1 the successive campaigns are labeled following the alphabetical order. Card 4.2 corresponds to campaign F in South Pacific Islands and card 4.3 to China (campaign K). Altogether 142 stations were occupied during 6 months. A description is given in Melchior and Ducarme, 1989.

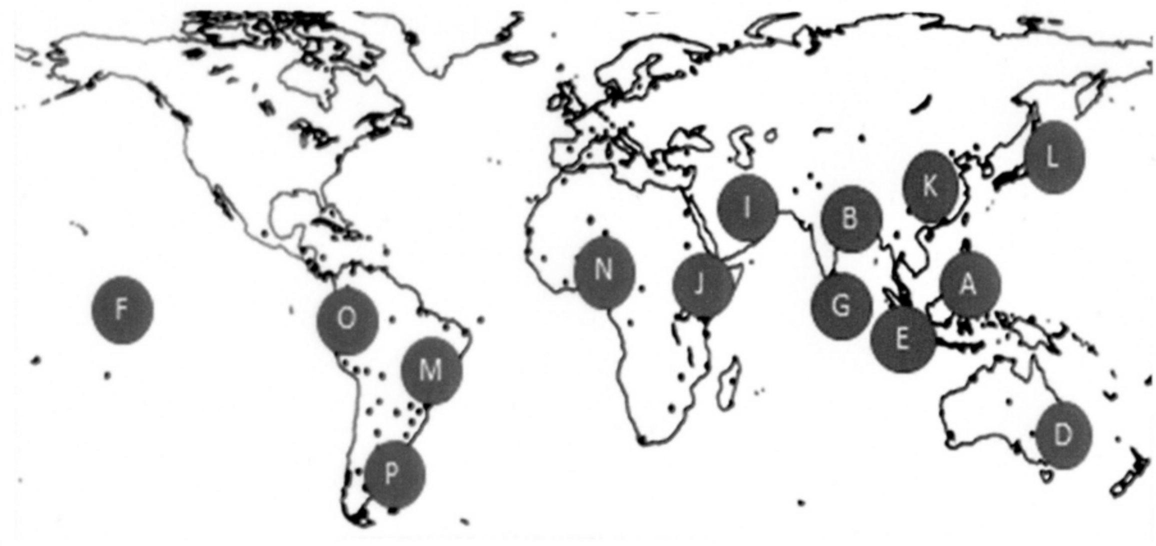


Figure 1: World map showing the areas covered by the TWP. Successive campaigns are labeled following the alphabetical order. *Adapted from Ducarme and van Ruymbeke, 2016*

5. Scientific education, data processing and analysis

Paul Melchior teached Geodesy, Gravimetry and Geodynamics at the Catholic University of Louvain from 1964 to 1990 (card 3.1). Several students became his assistants and started a scientific career at the ROB.

Melchior started computing on IBM650 at the end of the fifties and ROB installed an IBM1620 as early as 1963. He programmed himself the old tidal analysis method of Doodson adapted for Earth tides by R. Lecolazet and welcomed in 1966 A.P. Venedikov (Venedikov, 1961) who developed his Least Squares tidal analysis method allowing gaps in the data. At the beginning of the eighties ICET developed a Data Bank storing analysis results (card 5.2). At the beginning of the nineties this data bank included the results of 352 tidal gravity stations. However it became obvious that the reference value of Brussels was too high and that the amplitude factor of the wave O1 had to be reduced of 1% (card 5.3). This correction was obtained by calibrating LCR gravimeters on an inertial platform (van Ruymbeke, 1985; van Ruymbeke et al., 1995). After adjustment the data bank became homogeneous and Paul Melchior was able to confirm theoretical tidal models after subtraction of ocean tides loading computed with the Schwidersky 1980 ocean tides model (Melchior, 1994).

onde	Latitude moyenne	δ_c	δ_{th} Dehant-Wahr
O1	40°	1,1550±0,0008	1,1543
M2	30°	1,1602±0,0005	1,1593

6. Satellite Geodesy, ocean tides modelling and introduction of superconducting gravimeters

As early as 1966 the ROB participated to the first European geodetic network by space triangulation based on the observation of the first geodetic satellites (Pâquet, 1968). These satellites were just large balloons reflecting the light of the Sun and observed through a ballistic camera on the background of the stars. This expertise was one of the factors which decided the US Navy to install in 1972 a Doppler station of the TraNet network at the ROB (card 6.1) under the responsibility of Paul Pâquet (Pâquet, 1973). This early system was already able to recover the Pole coordinates. TraNet remained operational until 1996, but in the meantime the ORB had already started the GPS observations (Pâquet and Louis, 1988).
Another important input of space Geodesy to Geodynamics in the years nineties was the contribution of satellite altimetry (Topex Poseidon) to the improvement of ocean tides models (card 6.2). It became possible to compute accurate tidal loading effects for the correction of tidal observations. It was a keystone for the interpretation of the observations of the superconducting gravimeters (SUPRA) in the frame of the Global Geodynamics Projects (GGP) started in 1997 (Crossley et al., 1999). Theoretical models of the response of the Earth to tidal forces are now verified with a precision of 0.1% (Ducarme et al., 2009, 2014).
SUPRA are able to record gravity tides with a short term precision better than 0.1 nm/s^2 and a drift rate of 10 nm/s^{2}per year. A first SUPRA GWR TT30 was installed at ROB in 1981. In this non refrigerated model the evaporation of the liquid helium boiling at 4.2°K was keeping the levitating sphere and the coils in a superconducting state. It was thus necessary to refill the 120l liquid helium Dewar every 3 weeks (card 6.3). The Brussels SUPRA was the first one to reach a 12 years recording time (Melchior et al., 1996). The instrument was stopped in 2000 when it reached the 18 years recording time corresponding to the period of the Lunar node.

Acknowledgements

The greetings cards are reproduced hereafter thanks to the courtesy of © Peyo 2018, IMPS (1332 Rixensart, Belgium) http://www.smurf.com.

REFERENCES

Crossley, D., J. Hinderer, G. Casula, O. Francis, H.T. Hsu, Y. Imanishi, G. Jentzsch, J. Kaariainen, J. Merriam, B. Meurers, J. Neumeyer, B. Richter, K. Shibuya, T. Sato, T. Van Dam (1999): Network of Superconducting Gravimeters Benefits a Number of Disciplines*, EOS*, 80,121,125-126.

Dehant, V., 1987: Tidal Parameters for an Inelastic Earth. *Physics of the Earth and Planetary Interiors,* 49, 97-116, 1987.

Dehant V., Defraigne P., Wahr J.M., 1999. Tides for a convective Earth. *J. of Geophys. Res.,*104, B1, 1035-1058. DOI: 10.1029/1998JB900051

Dehant V., Mathews P.M., 2015. Precession, Nutation and Wobble of the Earth. *Cambridge University Press*. ISBN: 9781107092549. 536 pages.

Ducarme B., 1975. A fundamental station for trans world tidal gravity profiles. Obs. Roy. Belg./Comm. A 32, S. Géoph. 126, *Phys. Earth & Planet. Inter.* vol 11 pp 119-127

Ducarme B., Rosat S., Vandercoilden L., Xu J.Q., Sun H.P., 2009. European tidal gravity observations: Comparison with Earth Tides models and estimation of the Free Core Nutation (FCN) parameters. Proceedings of the 2007 IAG General Assembly, Perugia, Italy, July 2 - 13, 2007, Observing our Changing Earth, M.G. Sideris (ed*.), Springer Verlag, International Association of Geodesy Symposia* 133, 523-532*(DOI10.1007/978-3-540-85426-5)*.

Ducarme B.,Pálinkáš V., Meurers B., Cui Xiaoming, Vaľko M. 2014. On the comparison of tidal gravity parameters with tidal models in central Europe. Proc. 17th Int. Symp. On Earth Tides, Warsaw, 15-19 April 2013. S. Pagiatakis ed., *J. Geodynamics*, 80, 12-19. *(DOI: 10.1016/j.jog.2014.02.011)*.

Ducarme B., van Ruymbeke M., 2016. Un demi-siècle d'études géodynamique à l'Observatoire Royal de Belgique et au Centre International des Marées Terrestres: 8. La réalisation des Profils de Marée Gravimétrique*. Ciel et Terre*, 132, 5, 130-139.

Flick J., Stomp N., 2002. Sciences de la Terre au Luxembourg. *Musée National d'Histoire Naturelle, Luxembourg et Centre Européen de Géodynamique et de Séismologie*. ISBN 2-919877-00-8.

Melchior P., 1966. Détermination expérimentale des effets dynamiques du noyau liquide de la Terre dans les Marées Terrestres diurnes*. Ac. Roy. Belg. Comm. B, 4/ Obs. Roy. Belg., série géoph. 73, 93-100/ Bull. Inf. Marées Terrestres, 43, 1688*

Melchior P., 1983. The Tides of the Planet Earth, Oxford, Pergamon Press, 653p

Melchior P., 1994. A new data bank for tidal gravity measurements (DB92). *Physics Earth Planet. Interiors*, **82**, 125-155.

Melchior P., Ducarme B., 1989. L'étude des phénomènes de marée gravimétrique. *Géodynamique*, 4 (1), 3-14, *Observatoire Royal de Belgique, Communications Série A*, N° 99

Melchior P., Ducarme B., Francis O., 1996. The response of the Earth to tidal body forces described by second-and third degree spherical harmonics as derived from a 12 year series of measurements with the superconducting gravimeter GWR/T3 in Brussels. *Phys. Earth & Planet. Inter.*, 93, 223-238

Pâquet P., 1968. La chambre balistique de l'Observatoire Royal de Belgique*, Ciel et Terre*,

84 (9-10)

Pâquet P., 1973. L'observation radioélectrique des satellites artificiels et son rôle en astronomie fondamentale. *Ciel et Terre*, Vol 89 (4).

Pâquet P., Louis L., 1988. Simulations to recover Earth rotation parameters with GPS system. *Proc. of the GPS-Workshop : GPS-Techniques Applied to Geodesy and Surveying*. Springer Verlag, Darmstadt.

van Ruymbeke M., 1985. Calibration of La Coste-Romberg gravimeters by the inertial force resulting from a vertical periodic movement. *Proc. 10th Int. Symp. on Earth Tides, Madrid, Spain*, 35-42.

van Ruymbeke M., 1985. Transformation of nine Lacoste Romberg gravimeters in feedback systems. *Bull. Inf. Marées Terrestres*, 93, 6202-6228.

van Ruymbeke M, 1989. New development of feedback electronics. Working group on High precision tidal data Processing, Bonn, october 4-6 1988. *Bull. Inf. Marées Terrestres*, 104, 7292-7298

van Ruymbeke M, 1991a. A new feedback system for instruments equipped with a capacitive transducer. *XIth Int. Symp. on Earth Tides, Helsinki july 31-august 5, 1989*, 51-60.

van Ruymbeke M., 1991b. New feedback electronics for LaCoste Romberg gravimeters. Proc. of the Workshop Geodynamical Instrumentation Applied to Volcanic Areas, Walferdange, oct. 1-3, 1990*. Cahiers du Centre Européen de Géodynamique et de Séismologie*, 4, 333-338.

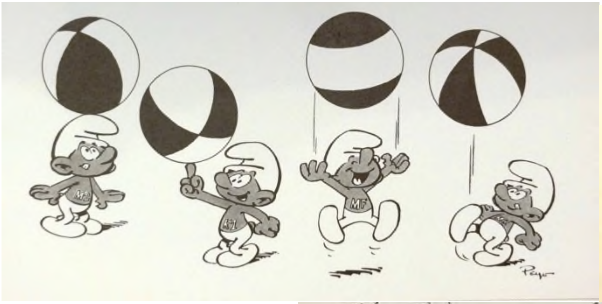
van Ruymbeke M., Somerhausen A. and Grammatica N., 1995. Calibration of gravimeters with the VRR 8601 calibrating platform. *Metrologia*, 32, 3, 209-216.

van Ruymbeke M., Ducarme B. & Somerhausen,A. 2001 Determination of the Scale Factor of LCR-PET1006 Gravimeter and Comparison with Brussels T03 cryogenic gravimeter *Journal of the Geodetic Society of Japan* Vol.47 (2001) N°1 pp 64-69

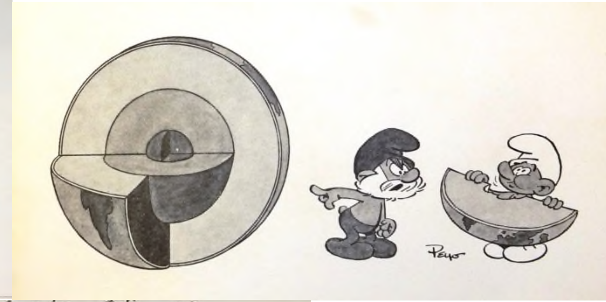
Venedikov A.P., 1961. Application à l'analyse harmonique des observations des marées terrestres de la méthode des moindres carrés. *Comptes Rendus Acad. Bulgare des Sciences, 14*

Topic 1: tidal theory and Geodynamics

1.1



1.2



1.3

1.1 juggling smurfs (Legendre polynomials)

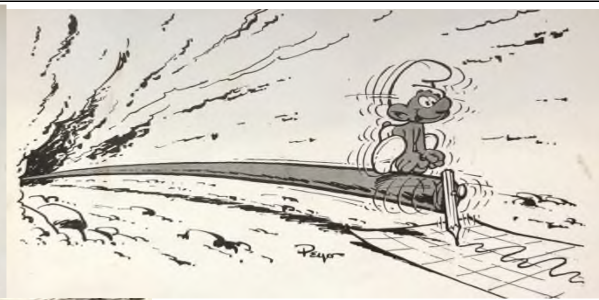
1.2 Greedy smurf (Internal structure of the Earth)

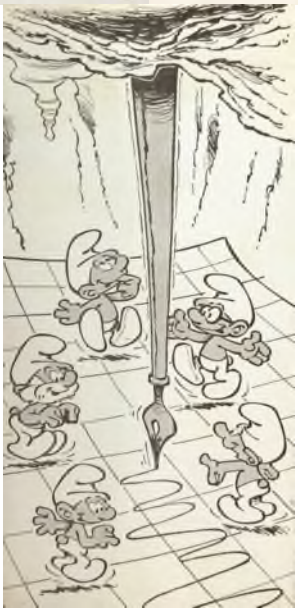
1.3 Hyperactive smurfette (NDFW theory)

Topic 2: Instrumental developments at the Royal Observatory of Belgium and in the Underground Laboratory for Geodynamics of Walferdange (ULGW, Grand Duchy of Luxemburg)

2.1

2.2





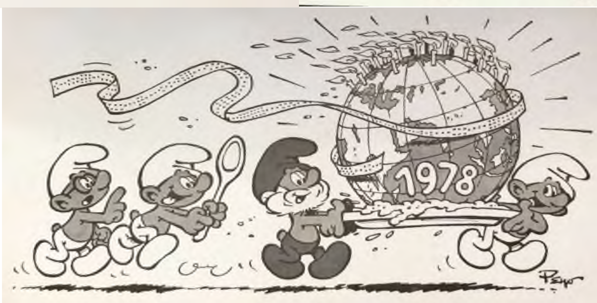
2.3

6.1 adventurous smurfs (Verbaandert- Melchior horizontal Pendulum in Spitsbergen, 1968-1970)
6.2 Swinging smurf (horizontal stainmeter at the ULGW)
6.3 Cheering smurfs (vertical strainmeter at the ULGW))

Topic 3: Publications and International Centre for Earth Tides (ICET)

3.1

3.2



3.3

3.1 Writing smurfette (Russian translations for ”Bulletin d’Information des Marées Terrestres”)

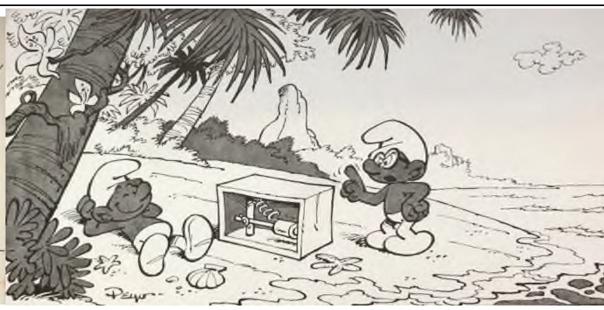
3.2 Puzzled papa schtroumpf (redaction of “The Tides of the Planet Earth”)

3.3 Enthusiastic smurfs (twentieth anniversary of the International Centre for Earth Tides)

Topic 4 : Trans World tidal gravity Profiles 1974-1992 (TWP)

4.1

4.2



4.3

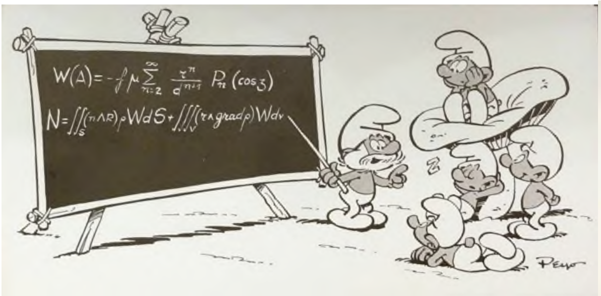
4.1 Sightseeing smurfs (first TWP station in Bangkok, 1974)

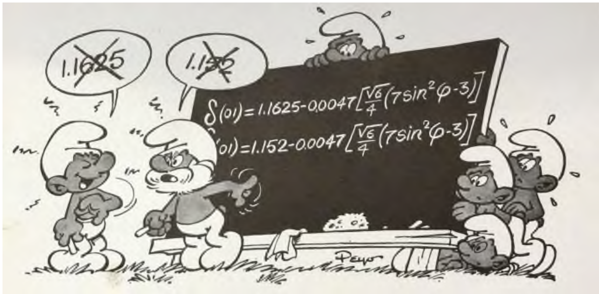
4.2 Lazy smurf (South Pacific Islands, 1976-1977)

4.3 Flying smurf (welcome to China, 1979-1983)

Topic 5 : Data processing and analysis

5.1 5.2





5.3

5.1 Studious smurfs (Paul Melchior teaching at the University)

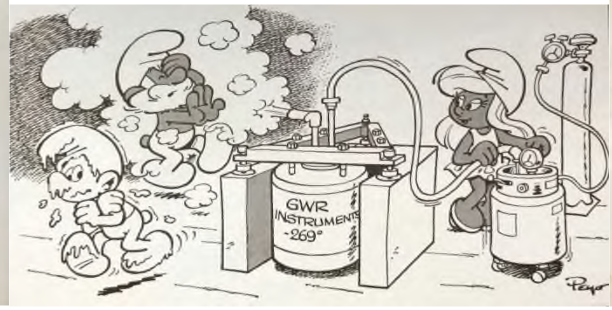
5.2 Absent-minded smurfette (Tidal data processing)

5.3 dissenting smurf (revision of the Brussels reference system for the TWP)

Topic 6: Satellite Geodesy, ocean tides modelling and introduction of superconducting gravimeters (SUPRA)

6.1

6.2



6.3

6.1 Entangled smurf (TRANET Doppler station at the ROB in 1972)

6.2 Scared smurfs (ocean tides models)

6.3 Clumsy smurfette (helium filling of SUPRA GWR T003 at ROB)

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Could superconducting gravimeters detect a gravitational screen effect?

Michel van RUYMBEKE (1,3), Christian Bizouart (2) and Bernard Ducarme (1,3).

(1) Royal Observatory of Belgium, (2) Observatoire de Paris, (3) Université Catholique de Louvain

The origin of the gravitational interaction is still puzzling the scientific community after gravitational waves detection [B.P.Abbott et al., 2017] by LIGO and Virgo observatories [wikipedia].

The measured speed similar to the speed of the light constrains theoretical approaches. It is suggesting a possible relationship with electro-magnetic waves theory.

The problem of absorption of the gravity field when crossing material remains open.

Observations of Solar attraction with a superconducting gravimeter during the total solar eclipse of 1999 [Mansinha, L. 2001; van Ruymbeke & al., 2003] did not show significant signature.

We propose to analyze an alternative to this approach. A gravimeter located at the surface of the Earth is sensing the solar attraction F(sun) in average equal to 6 mm/s² (0,6gal). Moon attraction field is very small compared to the Sun one (< 0.1%).

Let's analyze geometrical patterns associated with an hypothetical absorption [Majorana, Q. 1920] of the gravitational field by the Earth body (Fig1) sensed by a gravimeter set-up at a point P defined by its hourly angle θ. The rotation of the Earth moves the gravimeter along the parallel circle in 24 hours. In addition to classical tidal modulation depending of the combination of the geometry of centrifugal and gravitational field, the Newtonian attraction of the Sun could be modified if a screen effect exists. The gravity is not absorbed for θ value between -90° to +90°for which the Sun is directly seen by gravimeter. So screen effect is acting only at night *(Fig1-left*). When the gravimeter pass in the shadow of the Earth, the Sun action could be absorbed in function of the quantity of mass crossed by the gravitational field.

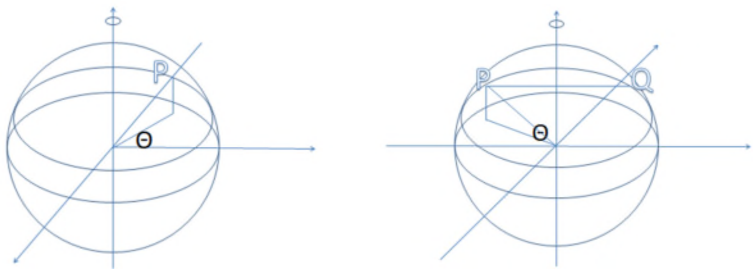

Figure 1 : X-Y axis are paralel to the equatorial plan at equinox with X-axis pointing to the Sun. Z-axis is paralel to the equinoxial Earth rotation axis. Position of a gravimeter is defined by is hourly angle θ *referenced to the meridian circle and its latitude φ. (left) No absorption occurs for* θ *comprised between -90° and +90° (right) For the position P, absorption could be generated by the screen effect depending of the mass crossed along the PQ segment. Effect on the signal recorded by a gravimeter located in P should be a projection on the local vertical of the absorbed force which is corresponding to a decrease of gravitational attraction.*

Let us define absorption A as the relative attenuation of the gravity field F(sun) depending of the mass crossed by this field F(M) and an absorption coefficient γ :

$$A = \gamma F(M)\ F(sun)$$

Assuming that F(M) is proportional to the density ρ of the Earth , a simplified model is considered with a density ρ≅5 from the surface to the core and with ρ≅11 inside the core (r≅2,890km). It is equivalent to add effects of absorption A(E) & A(C) of two bodies with homogeneous densities which have size of the Earth with ρ(E) ~=5 and of the core with its additional density ρ(C) ≅11-5=6 *(Fig2)*. For the gravimeter, the absorption is acting vertically in function of its latitude ϕ.

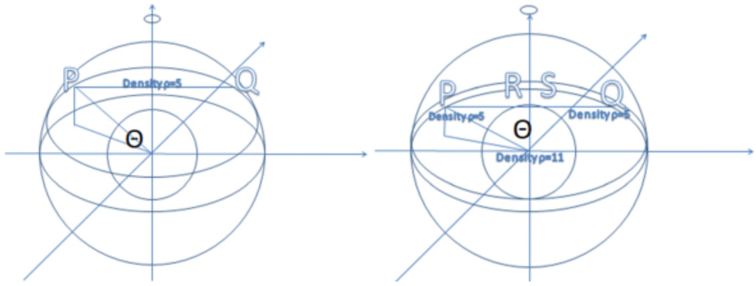

Figure 2 : (left) An hypothetic screen effect would decrease the gravity field induced by the Sun in function of the PQ segment proportionally to a density ρ≅5 (right) For lower latitude, the absorption is larger in the core segment RS, which has an higher density ρ ≅11.

A first step is the computation of the evolution of the total screening mass F(M) during the transit of the Sun behind the Earth body. Figure 3 expresses this mass as the thickness of an equivalent layer of water expressed in kilometer. The absorption effect will be proportional to the computed effect modulated by the absorption coefficient γ. The theoretical model *(Fig3)* shows that the effect has a non-harmonic characteristic which allows to obtain a high signal-to-noise level in detection on very long time interval series of a large quantity of superconducting gravimeters. The influence of the inner core shows up for θ larger than 60°.

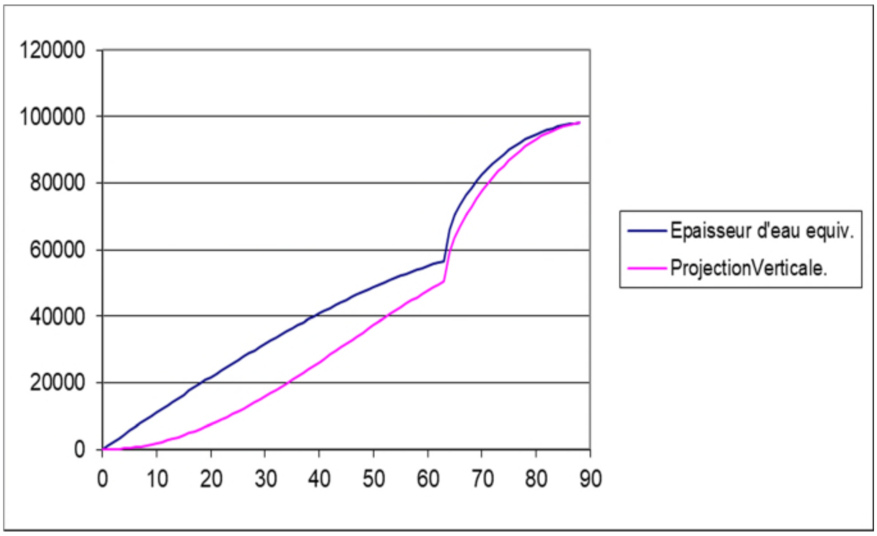

Figure 3 : Elementary model of signal recorded with a gravimeter set-up on the equator. It will feel during its diurnal rotation a theoretical screen effect proportional to F(M) (top curve) projected on the local vertical (bottom curve).

X axis: variation of angle θ between 90° and 180°, *Y axis*: thickness in km of a water layer (*ρ=1)* corresponding to the total screening mass F(M).

Conclusion :

A permanent gravitational field of 6mm/s² induced by the Sun keeps the Earth on its orbit. Gravimeter could sense effects of an eventual gravitational shielding by the mass of the Earth itself. The geometrical patterns of this modulation could be function of Earth density. From simplified hypothesis, we obtain a complex shape due to fact that the gravimeter records this hypothetic screen effect only during half of its orbit. In addition, the effect must be projected on the local vertical. So the research of this modulated signatures, far from classical harmonic functions related to tidal signals, allows to reach very high dynamics within a mean square adjustment. Intercomparison of homogeneous series of superconducting gravimeters (Crossley et al., 1999) on long time intervals becomes an excellent candidate to fix an upper limit for the γ factor.

Aknowlegments :

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They are grateful to Ing. Guy Berthault who contributed to the preparation of this paper.

Bibliography :

[https://fr.wikipedia.org/wiki/Laser_Interferometer_Gravitational-Wave_Observatory].

Abbott B.P. et al., 2017. Multi-messenger observations of a binary neutron star merger. Astrophys. J. Lett., 848, 2, L12 {http://stacks.iop.org/2041-8205/848/i=2/a=L12}

Crossley, D., Hinderer, J., Casula, G., Francis, O., Hsu, H. T., Imanishi, Y., Jentzsch, G., Kääriaïnen, J., Merriam, J., Meurers, B., Neumeyer, J., Richter, B., Shibuya, K., Sato, T., Van Dam, T. (1999). Network of superconducting gravimeters benefits a number of disciplines. *EOS, 80, 11, 121/125-126.*

Majorana,Q.: On gravitation :theoretical and experimental researches *(1920) Philosophical Magazine 39 pp 488-504*

Mansinha, L., Ducarme, B.,Hinderer, J., Meurers B., van Ruymbeke, M. (2001) : Search for the Gravitational absorption effect using superconducting gravimeters during the eclipse of August,11,1999. *Journal of the Geodetic Society of Japan, 47, 1, pp387-391*

van Ruymbeke, M., Liu Shaoming, Mansinha, L., Meurers, B. (2003) Search for the gravitational Absorption Effect Using Spring and Super-conducting Gravimeters during the Total Solar Eclipse of August 11, 1999, *BIM138 pp10967-10976*

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Efficiency of the HICUM method illustrated by the Lanzarote tide-gauges data treatment.

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Abstract:

Several tide gauges were set-up in a very favorable site located inside a lava tube plunging in the Atlantic Ocean in the northern part of Lanzarote Island (Canarian archipelago). The damping of waves is dramatically large, allowing to observe very tiny modulations of the sea level. An original tide gauge equipped with an aneroid cell is sensing the fluctuations of the sea level. The transfer function is determined by comparison of the output signal of the sensors with the direct reading of the water level. We evaluate the performance of our design by analyzing the long series of available records. We draw with the HiCum method the components of sea tides. Concordance of the results between three gauges recording simultaneously the same signal confirms the quality of our design.

Keywords: ocean-tides, tide-gauge, Lanzarote, HiCum, EDAS

1. The HiCum algorithm

The goal of this paper is to show an example of the efficiency of HiCum method [*van Ruymbeke & al., 2003]* when the periodicities present in a signal are perfectly known. We select ocean tides data as an example for stacking different time series parameters for selected astronomical periodicities. It demonstrates the efficient to average tendencies on a huge quantity of data in enhancing the SNR ratio of signals to compare observations with lunisolar excitation.

The HiCum algorithm, which applies an elementary process on a single periodicity with a minimum of data treatment, could be useful in a series of specific situations *(Fig1).* The principle of HiCum is illustrated by the way to extract the average daily temperature variation in climatology: summing up the temperature values for each hour of the day during one year and dividing the 24 values by 365. The amplitude and phase parameters of a cosine function are adjusted to the stacking curve. It could be subtracted to generate a residual curve.

For the project described in this paper, we will select different periodicities in the diurnal, semi-diurnal and the long period tidal bands to illustrate the efficiency of HiCum for the analysis of geophysical data with well determined periodicities.

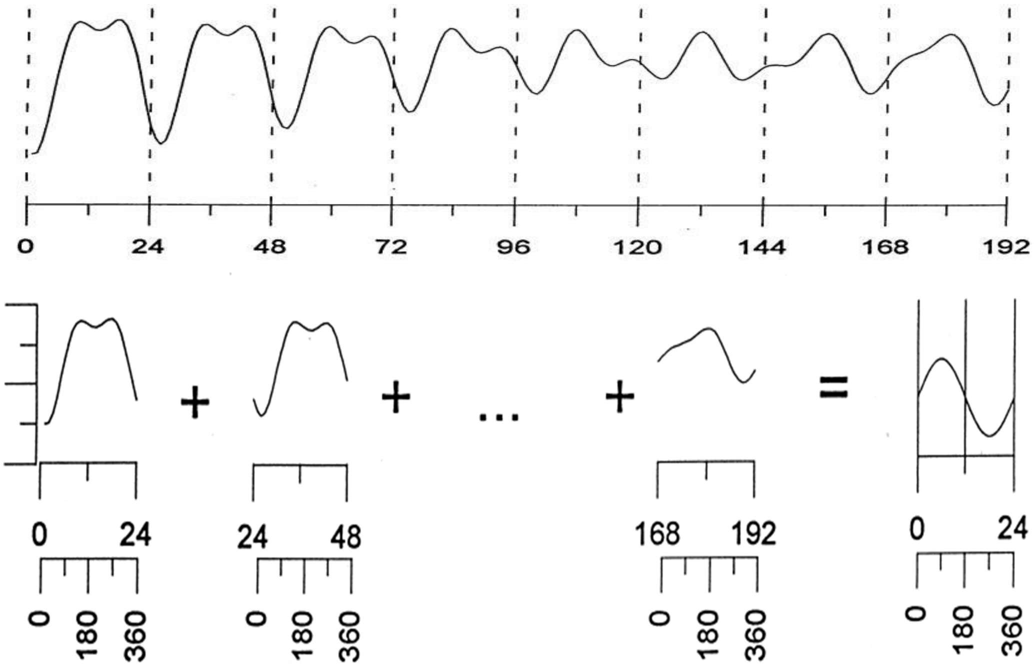

Fig1: Principle of HiCum Stacking applied to an eight day gravimeter signal (hourly scale). The series is cut in constant length time intervals corresponding to the period selected by a Doodson argument (i.e. 360° for 24 hours S1 period). The obtained histograms are simply added to give an average of the concerned component.

2. Lanzarote tide gauges set-up by the Royal Observatory of Belgium

Since 1987 a station called *"Cueva de los Verdes"* was installed inside a lava tunnel of the volcano « *La Corona* » located in the north of the Lanzarote island (Canarian archipelago) *(Fig2, Fernandez et al., 1991).* This tunnel was produced during the cooling of the last eruption few thousand years ago. It is 6 km long from the volcano to the coast line and continues, at least, 2 km more inside the Atlantic Ocean.

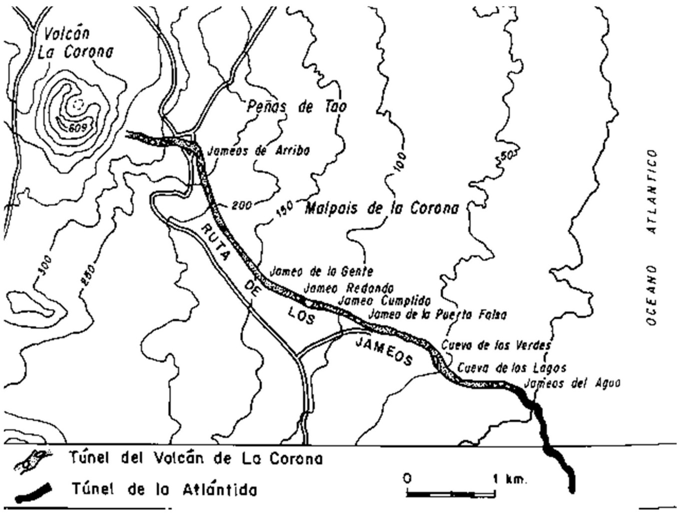

Fig2 : Map of the 6km long lava tube produced by the eruption of the Corona volcano in the northern part of the Lanzarote island (Canarian achipelago-Spain). The tide-gauges are set-up in the Cueva de los jameos del agua Lagos nearby the sea-shore.

Our three tide gauges was set-up in a very favorable site *(Fig3)* located inside the first small lake of the lava tube plunging in the Atlantic Ocean. Permanent sea-water currents induced by the sea level changes, flow through fractured rocks. The damping of wave motion is dramatically large, allowing to observe very tiny modulations of the sea level.

Fig3 : Collapses in part of the tunnel produced underground caves where lakes equipped with tide-gauges are located. Sea-tides modulate the water level with small attenuation and delay.

3. **The EDAS tide-gauge principle**

The EDAS tide-gauge is measuring the pressure at the top of a tube filled with water *(Fig4-left).* The upper end of the tube is closed, while the lower end plunges into the sea. The depression at the top of the tube depends on the height of the water column over the sea surface. The depression p is:

$$p = p_a - \rho g H \quad [1]$$

with p_a the atmospheric pressure, ρ the water density, g the local gravity and H the distance between the sea surface and the sensor.

A perforated aneroid barometric cell filled by the water, is connected to the tube at its top. Its deformation is function of the depression. A fundamental property of this design is the suppression of atmospheric pressure p_a variations, which act simultaneously on the sea surface and on the sensor. Geometrical changes of the cell are recorded with a capacitive sensor connected to an EDAS oscillator. So we avoid mechanical hysteresis for very small excursion of pressure. Filtering is obtained by counting frequency modulated signals during one minute. This is equivalent to a one minute integrator filter without aliasing.

The pressure is therefore a linear function of the height of the water column and also of the height of the sea since this can be written:

$$H_{sea} = H_0 - H \qquad \text{where } H_0 \text{ is constant.}$$

We set up the sensors on the side of the tunnel above the maximum level reached by the sea *(Fig4-right).*

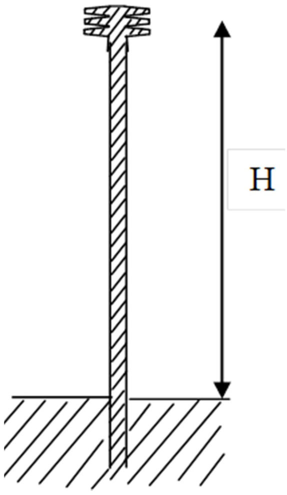

Fig4: (left) The EDAS tide gauge based on the monitoring by a barometric cell of the depression created by the weight of the water column over the sea-surface.
(right) General view of J11 and J31 tide-gauges. The sensing electronics are located outside the water.

The tube plunging in the sea is equipped with a « T » shaped nozzle *(Fig5-left)*. The second output is connected to the pressure sensor and the third one to a large tank of water. To remove air from the tube, we fill it in advance with water. Residual air bubbles moving to the top are extracted. Two switches placed on the tube going to the tank, control water injections. With the higher switch closed, opening of the lower switch allows residual air escape to the part of the tube between the two switches. Closing the lower switch and opening of the top one get out the gas. Generally, we need to exhaust residual gas only once a year. The sensor itself is placed below the T to eliminate the risk of passage of bubbles of gas in the cell *(Fig5-right)*.


Fig 5 : (left) View of the plastic tube plunging in the sea and filled with water (right) The EDAS pressure sensor equipped with capacitive displacement sensor.

4. Calibration procedure

We fix on the top of the tunnel a graduated scale plunging in water *(Fig6)*. The calibration is obtained by the determination during one tidal cycle of the transfer function relating the FM signal of each tide-gauge to the water level noted with 1mm precision, .

Fig 6 : Position of the length scale with photo showing example of readings.

From the table of observations *(Table1)*, the adjustment is expressed by polynomials of different order *(Table2)*, for which H is the computed water level in cm and S the frequency divided by 10000.

Table1: Computed water level obtained with polynomials from one to fourth degree H(1), H(2), H(3) & H(4) for the J11 sea-gage. The third order polynomial with a correlation coefficient of 0.999947, is used for analysis.

Heure	Signal * 1000	Hauteur (cm	H calculé (1)	H calculé (2)	H calculé (3)	H calculé (4)
11:22	13,469430	88,4	82,5396399	87,88669416	87,7567404	87,8741786
11:37	13,259650	98,6	94,5248921	98,49007942	98,3167415	98,2923748
11:52	13,061320	108,5	105,855977	108,0149041	107,844597	107,701963
12:07	12,889230	116,4	115,687906	115,8859125	115,76336	115,575486
12:22	12,740390	122,4	124,191505	122,3985499	122,358112	122,211408
12:37	12,626650	127,35	130,689753	127,1909277	127,242419	127,200157
12:52	12,541820	131	135,536302	130,6611791	130,799342	130,887608
13:07	12,491380	133	138,418064	132,6824609	132,879973	133,070769
13:22	12,475050	133,75	139,351038	133,3301198	133,548142	133,776481
14:08	12,675090	124,3	127,922256	125,1694653	125,178524	125,08276
14:23	12,815760	118,9	119,88543	119,1348574	119,047723	118,868579
14:43	13,031160	108,4	107,579093	109,4207878	109,255544	109,09977
15:03	13,292020	95,7	92,6755136	96,88939152	96,7199966	96,7177886
15:23	13,570460	82,4	76,7675452	82,58620037	82,489718	82,666465
15:43	13,857020	66,7	60,395661	66,86610074	66,8903249	67,1617046
16:03	14,141820	50,4	44,12433	50,23771452	50,388788	50,6156766
16:23	14,416380	34,3	28,4380356	33,25884049	33,5020467	33,5675219
16:45	14,695530	16	12,4895032	15,0416421	15,3116046	15,163633
17:03	14,907350	-0,5	0,38770072	0,576172053	0,79895277	0,53190639
17:23	15,124310	-15	-12,0077627	-14,81477549	-14,7192685	-14,9813524
17:45	15,349790	-31,8	-24,8899948	-31,42616295	-31,5660037	-31,5749187
18:01	15,477080	-40,8	-32,1623885	-41,0810613	-41,4073766	-41,109959
		Corrélation	99,659944%	99,994220%	99,994666%	99,995149%

Table2: Calibration polynomials from degree one to four for the J11 tide gauge.

***Table 2*: degree 1-to-4 polynomials for the transfer function of J11**
H(1) = -1,111834E+00 + 1,533229E+01 * S
H(2) = 4,200630E+01 + -1,289981E+02 * S + 1,183118E+02 * S**2
H(3) = 2,191569E+02 + -1,016922E+03 * S + 1,584327E+03 * S2 -7,976618E+02 * S**3**
H(4) = 4,368424E+01 + 1,608342E+02 * S + -1,355412E+03 * S**2 + 2,436634E+03*S**3 -1,323569E+03 * S**4

The coefficients of the linear adjustments of the signal on a 24 days series for the three tidal gauges J11, J31 and J32 in function of the averaged one: J00= (J11+J31+J32)/3 are:

J11= 0.993x J00 +0.004 J31=1.012xJ00+0.025 J32=1.0047xJ00 – 0.030

These results confirm a coherency on a long time interval between the three independent series of records better than 1.2% for raw signals.

5. HiCum on the M2 period applied to the tide-gauges J11, J31 & J33.

The *Figure 7* shows the stacking of the J11 gauge for M2, which is the largest wave in the sea tides spectrum (Ampl=2x72cm) . The analyzed file cover only 24 days.
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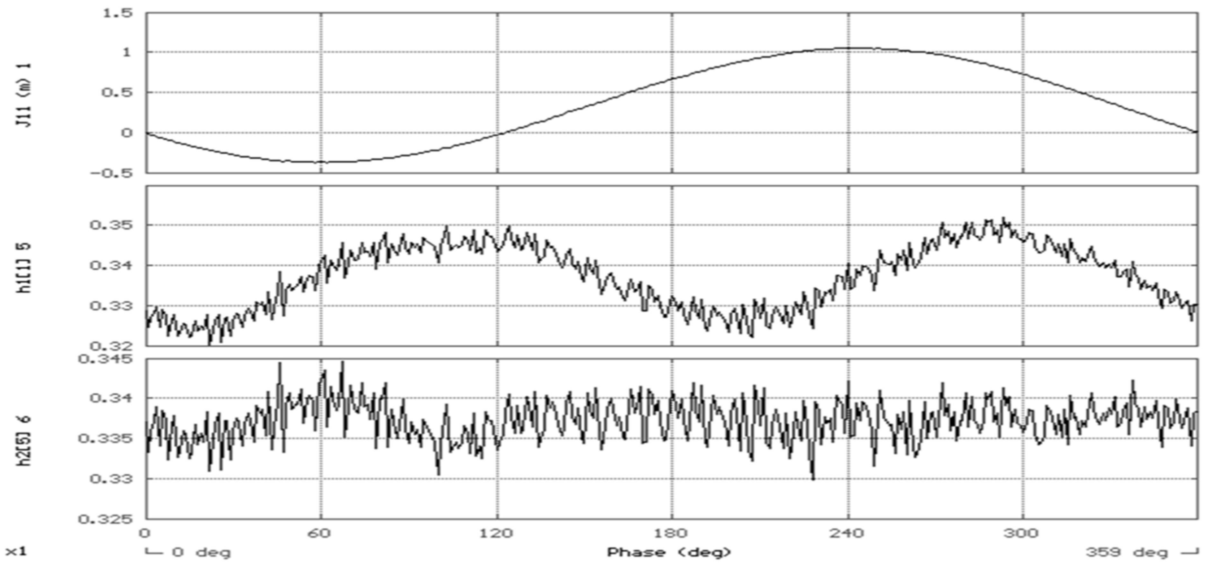

Fig7 : *M2 stacking algorithm applied to J11 : from top to bottom*
Channel 1 : amplitude of M2 ~0.713m ,
Channel 2 : harmonic 2 equivalent to M4 with amplitude of 0.01m.
Channel 3 : after correction of M2, M4, M6 & M8 components, we keep a signature of few mm!

Ratios between amplitudes *(Fig8)* of gages J11, J31 & J32 and their average J00 are:
J11/J00=0.990 J31/J00=1.004 J32/J00=1.005

The 1% Concordance between the results confirms the coherency of the three signals already observed for the raw data.

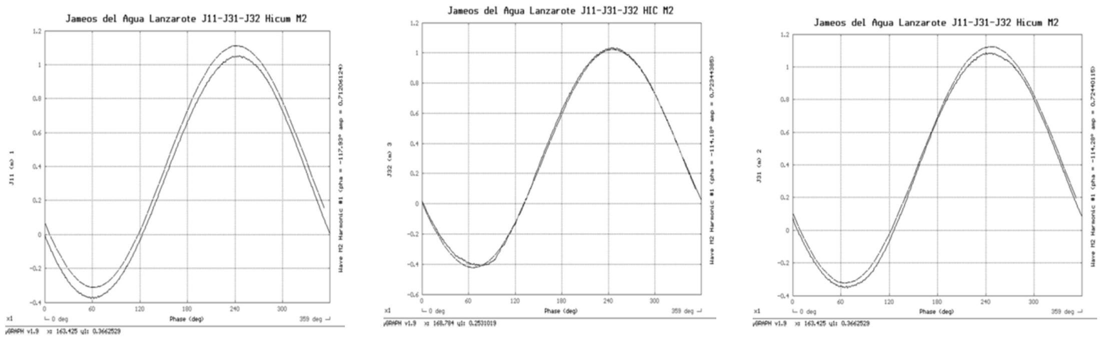

Fig8 : M2-HiCum of the three sea-gages J11,J31&J33 for a 24 day time interval.

6. Analysis with HiCum applied to J11 on the time interval « 2003-2017 ».

We apply the HiCum on the complete series of the raw data of the J11 (Fig9). The maximum observed amplitude exceeded 3m peak-to-peak. The phases are referenced to Universal Time without longitude correction taking in account the localization of the instruments.

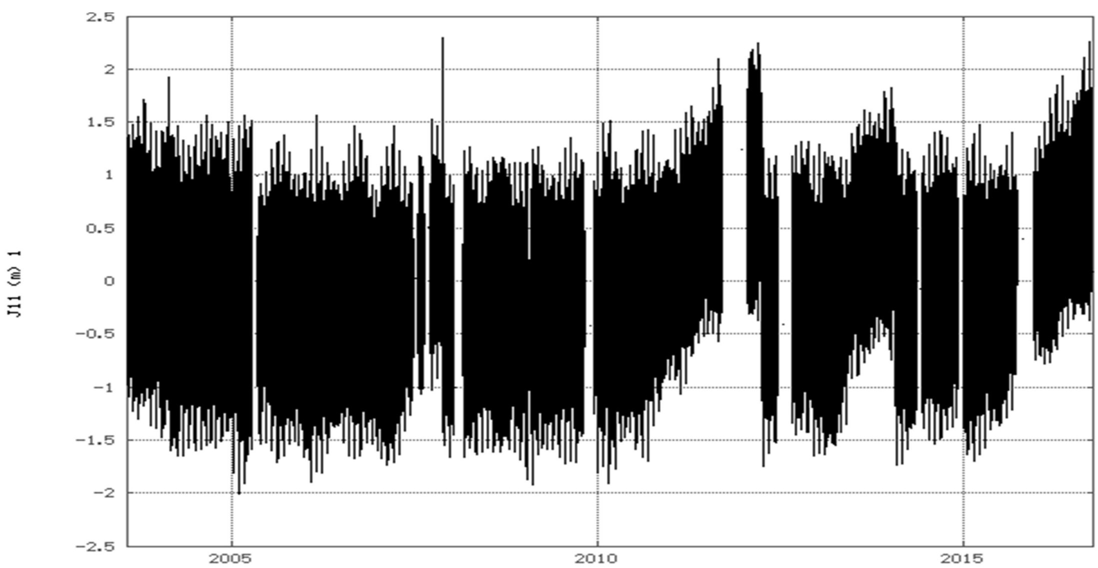

Fig 9 : Raw data of the J11 sensor for the interval « 2003-2017 ». The sea-level is expressed in meter and referenced to its averaged value.

Adjusted amplitudes and phases (smoothed curves) are reported in the Annex 1 showing the HiCum graphs for 18 components. The background noise does not exceed 5mm.

Acknowledgements

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Bibliography

Fernandez J., Van Ruymbeke M., Vieira R., 1991. High precision thermal measurements in the volcanic tube of "La Corona" (Lanzarote). Proc. of the Workshop Geodynamical Instrumentation Applied to Volcanic Areas, Walferdange, oct. 1-3, 1990. Cahiers du Centre Européen de Géodynamique et de Séismologie, vol. 4, pp 215-228.

van Ruymbeke M.,Howard R.,Pütz E.,Beauducel Fr., Somerhausen A,Barriot,J.-P.,2003. An introduction to the use of HICUM for Signal Analysis*, BIM138 pp 10955-10966*

The statue under the Moon of a small blind crab living in the site of the Jameos del Agua symbolizes well our recognition of the privilege to contemplate the mysteries of nature in the formal approach of geophysicists.

Credit Photo M.van Ruymbeke   Fuji X-S1

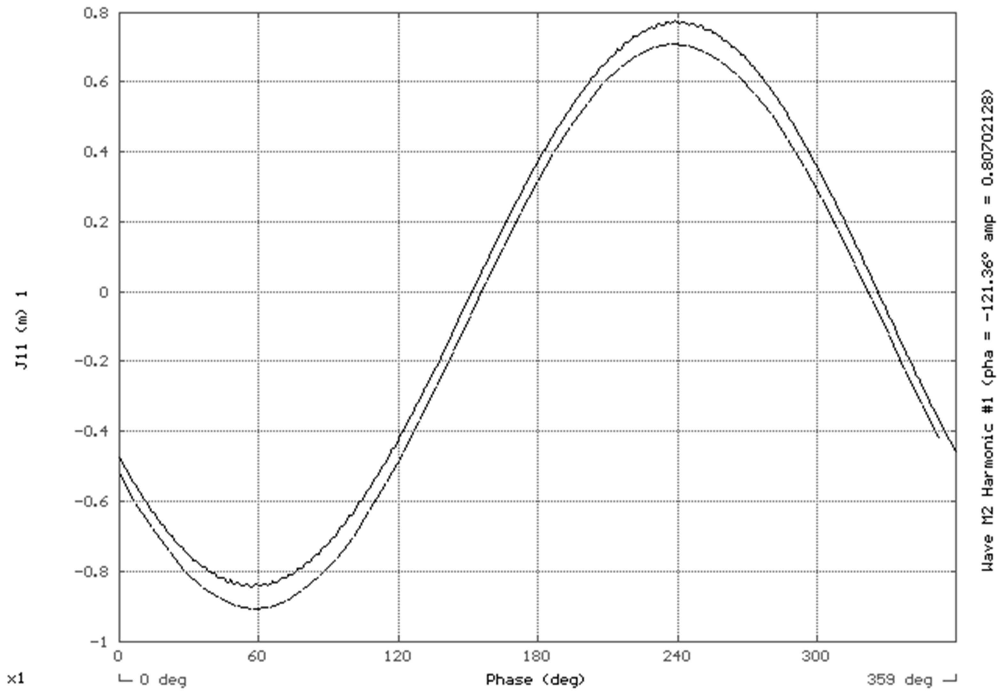
Annex 1

Graphics of the Sea Tides components obtained with HiCum algorithm on the raw signal of J11 tide gauge set-up in the Jameos del Agua (Lanzarote).

The smoothed curve corresponds to the fitted harmonic.

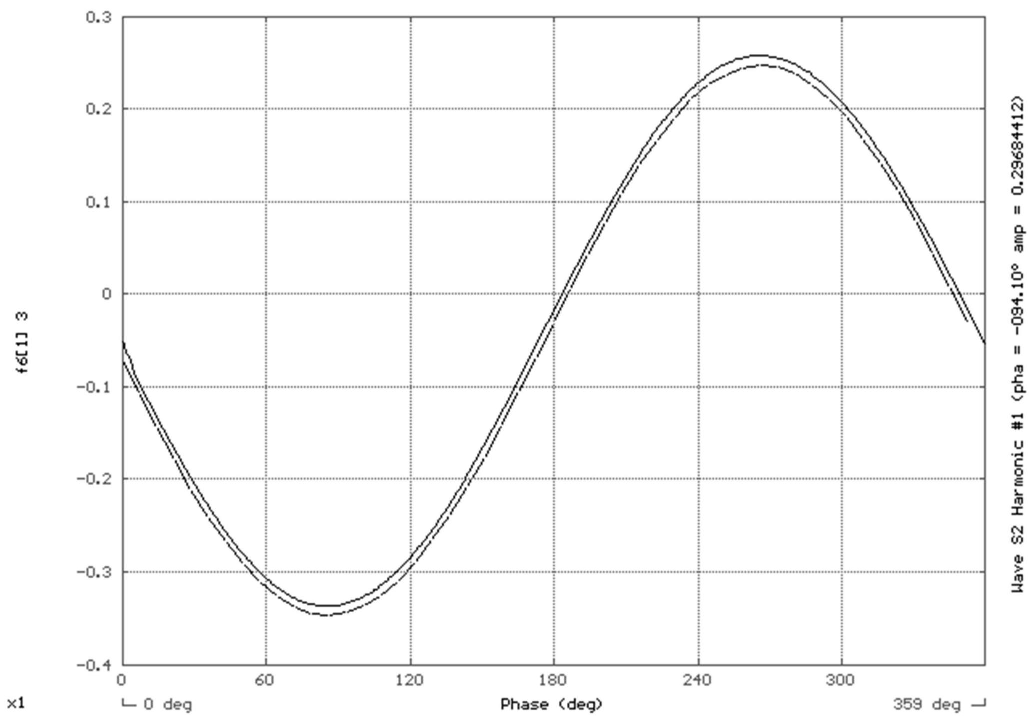
HiCum on the periodicity of the M2 component

M2 Amplitude 80.702cm Phase= -121.36°



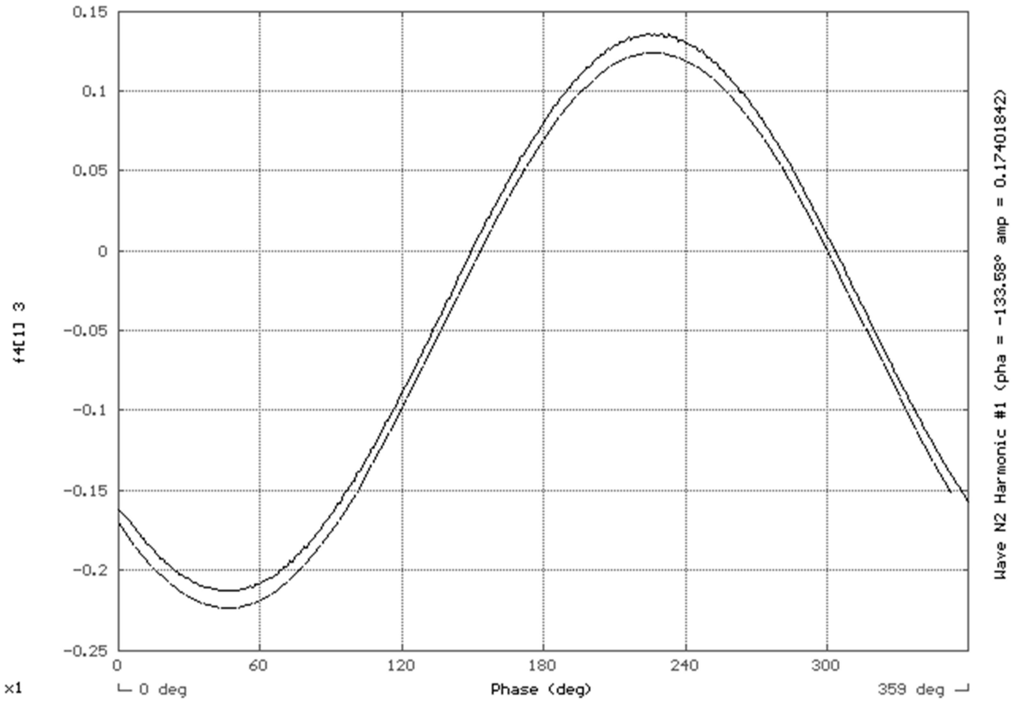
HiCum on the periodicity of the S2 component

S2 Amplitude 29.684cm Phase=-94.10°



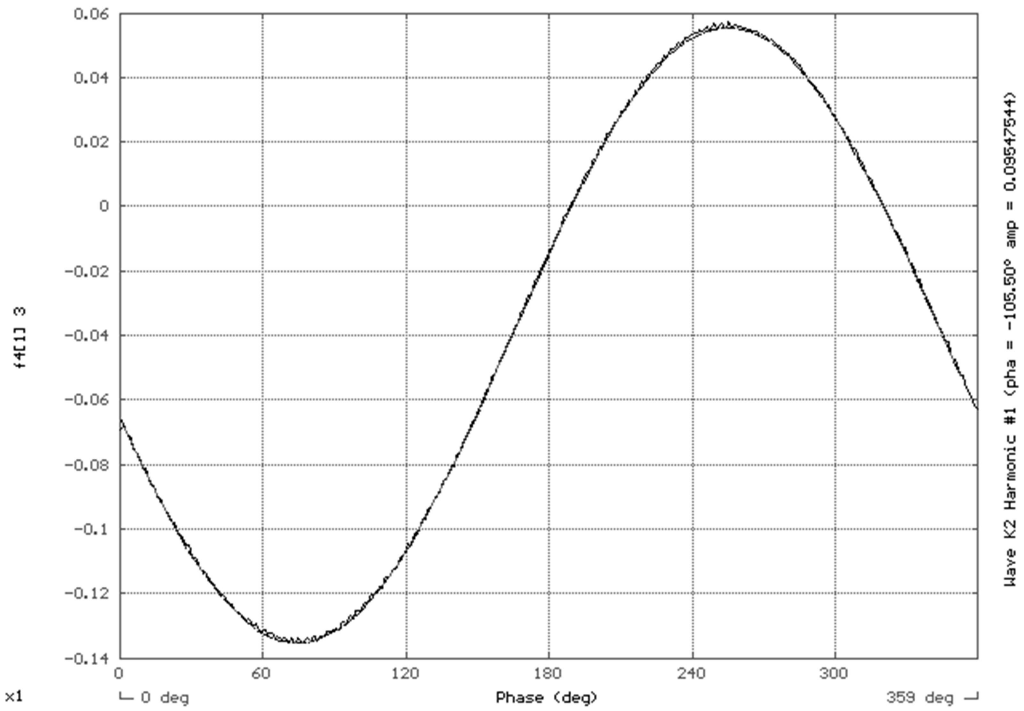
HiCum on the periodicity of the N2 component

N2 Amplitude 17.402cm Phase= -133.58°

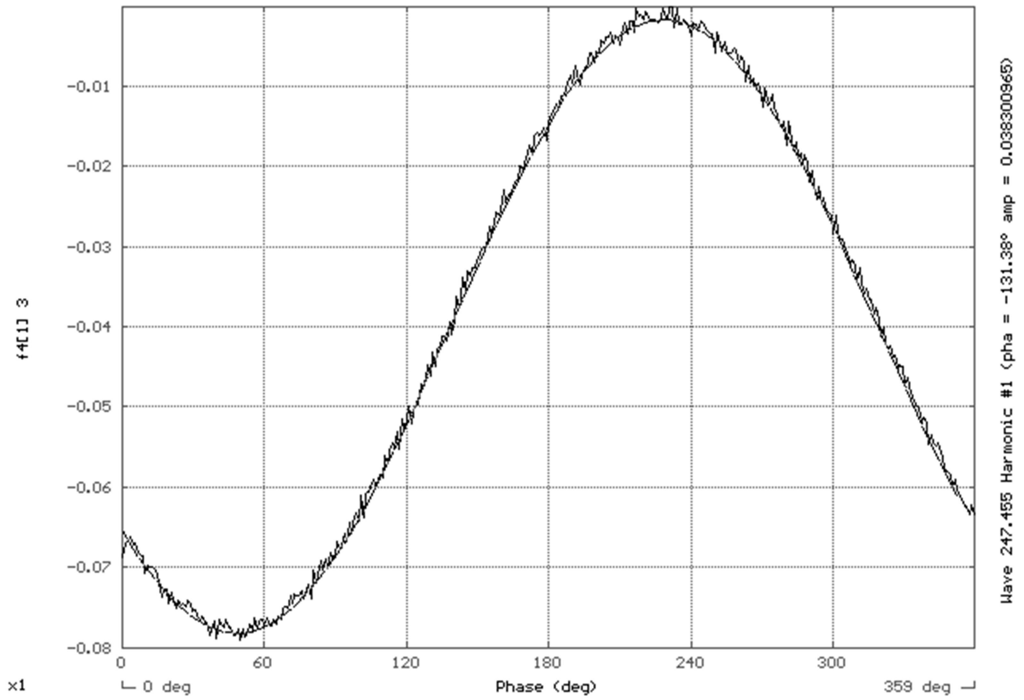


HiCum on the periodicity of the K2 component

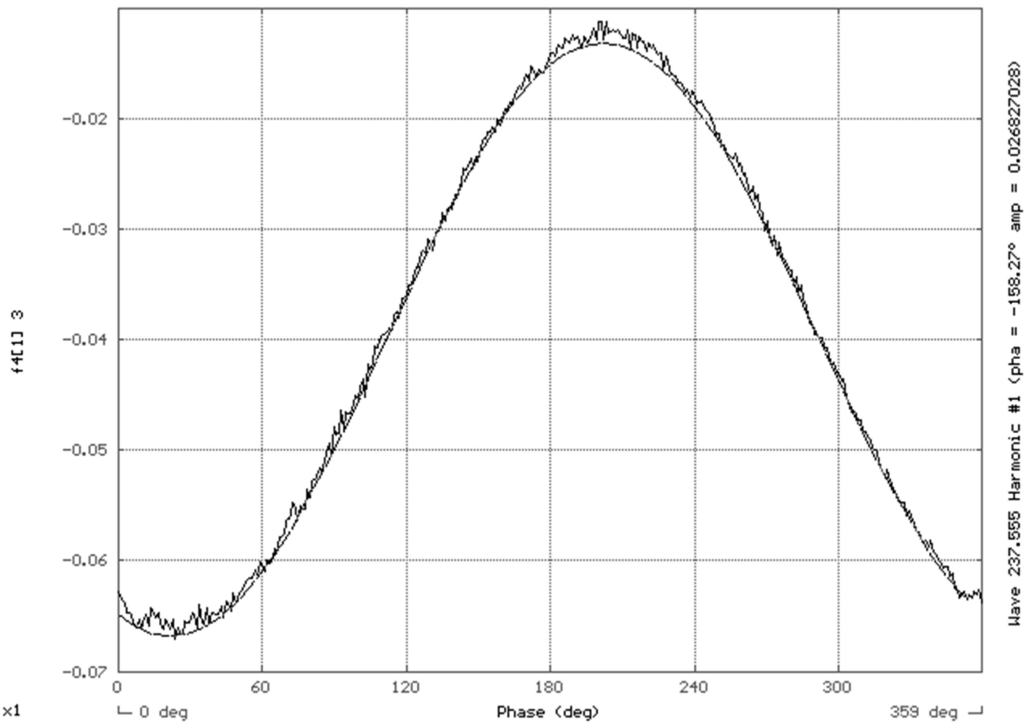
K2 Amplitude 9.547cm Phase=-105.50°



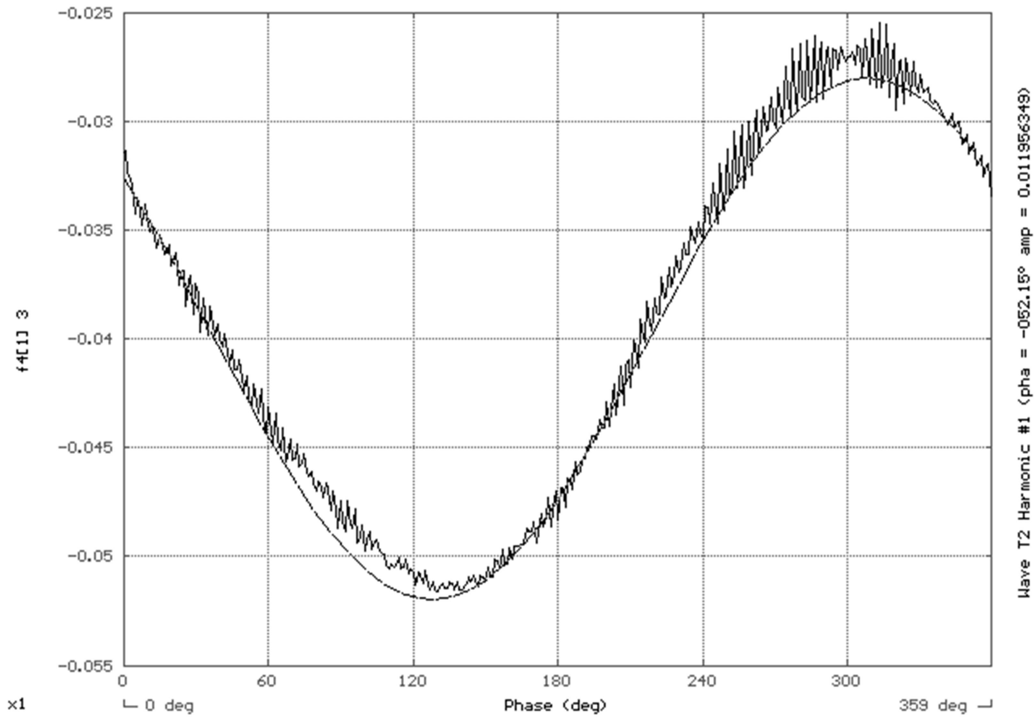
HiCum on the periodicity of the NU2 component
NU2 Amplitude 3.830cm Phase= -131.38°



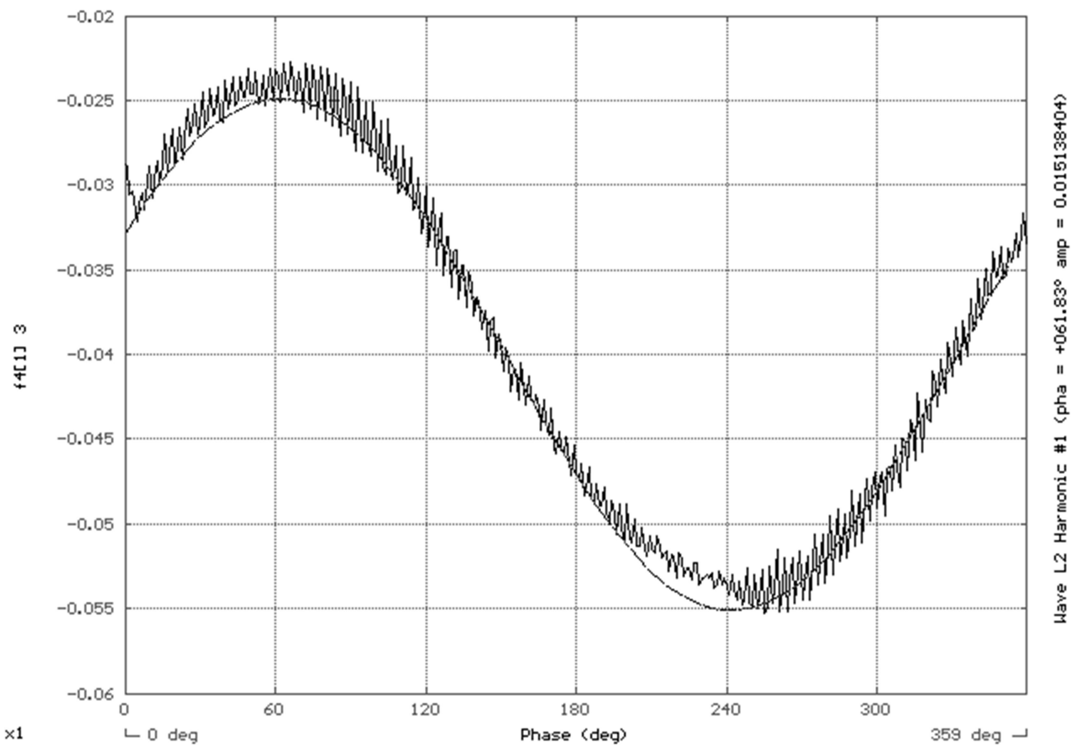
HiCum on the periodicity of the μ2 component
μ2 Amplitude 2.683cm Phase= -158.27°



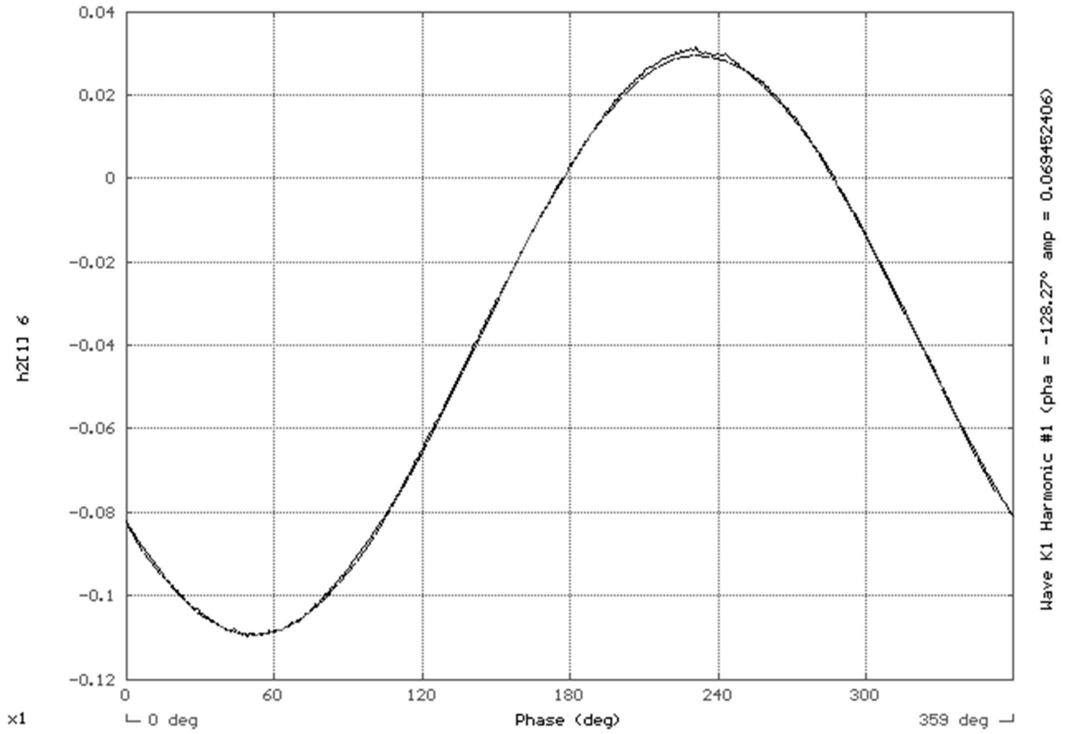
HiCum on the periodicity of the T2 component
T2 Amplitude 1.9563cm Phase= -52.15°



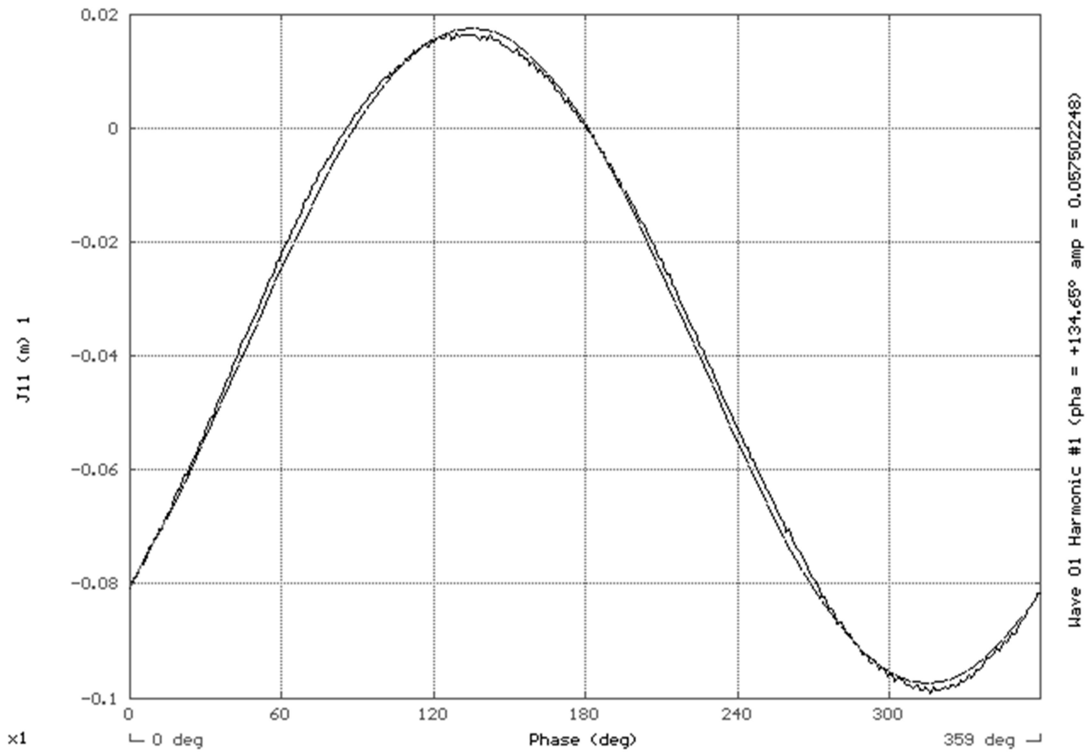
HiCum on the periodicity of the L2 component
L2 Amplitude 1.5138 cm Phase= 61.83°



HiCum on the periodicity of the K1 component
K1 Amplitude 6.945 cm Phase= -128.27°

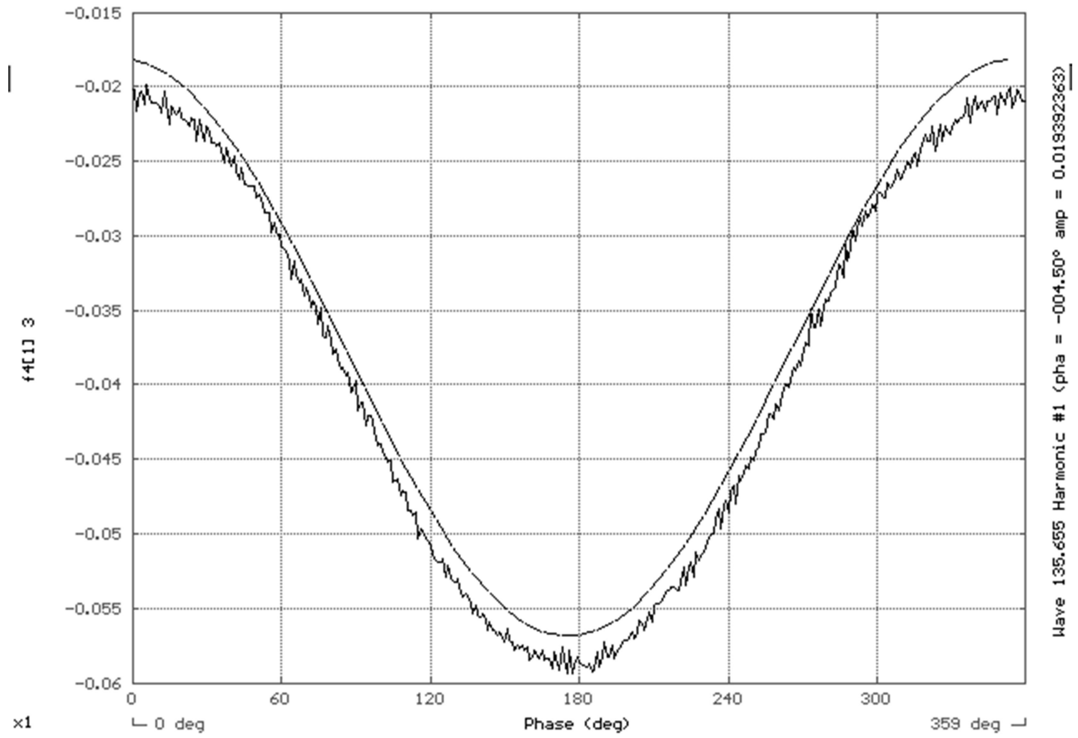


HiCum on the periodicity of the O1 component
O1 Amplitude 5.750cm Phase= -134.65°



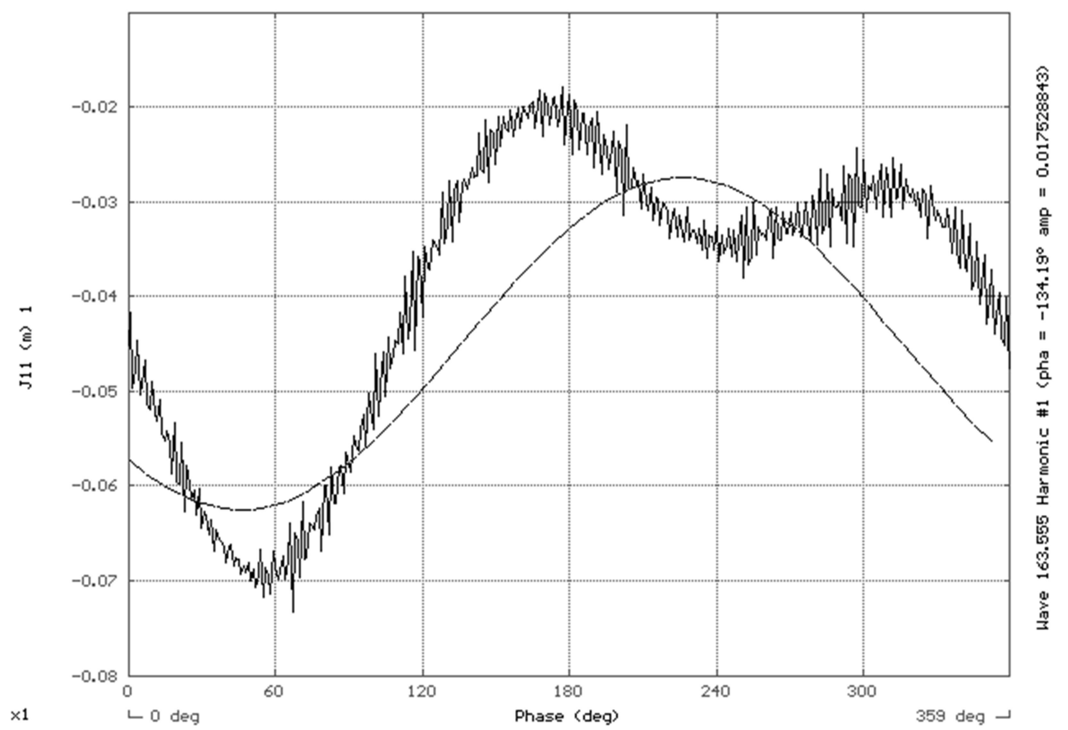
HiCum on the periodicity of the Q1 component

Q1 Amplitude 1.940 cm Phase= -4.50°



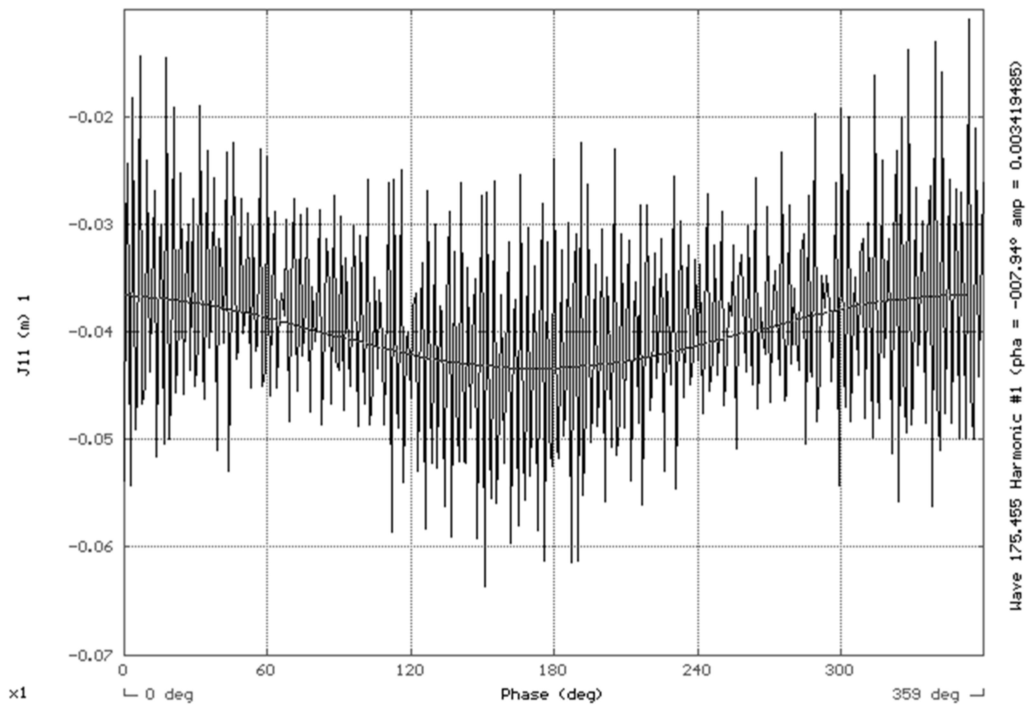
HiCum on the periodicity of the P1 component

P1 Amplitude 1.753 cm Phase= -134.19°



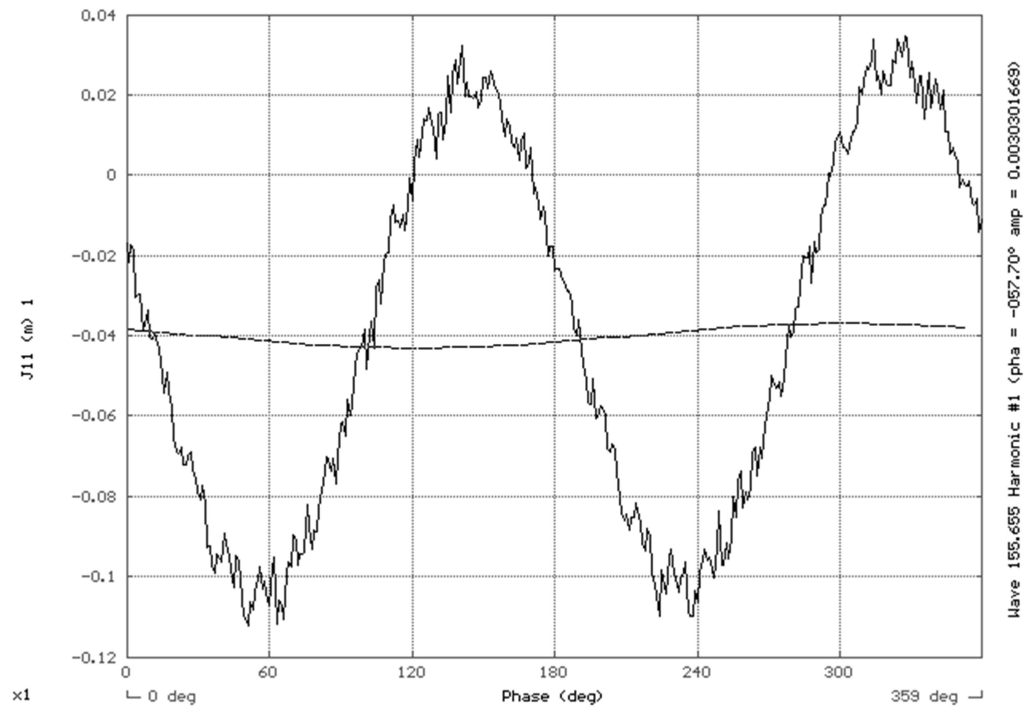
HiCum on the periodicity of the J1 component

J1 Amplitude 0.342cm Phase= -7.94°



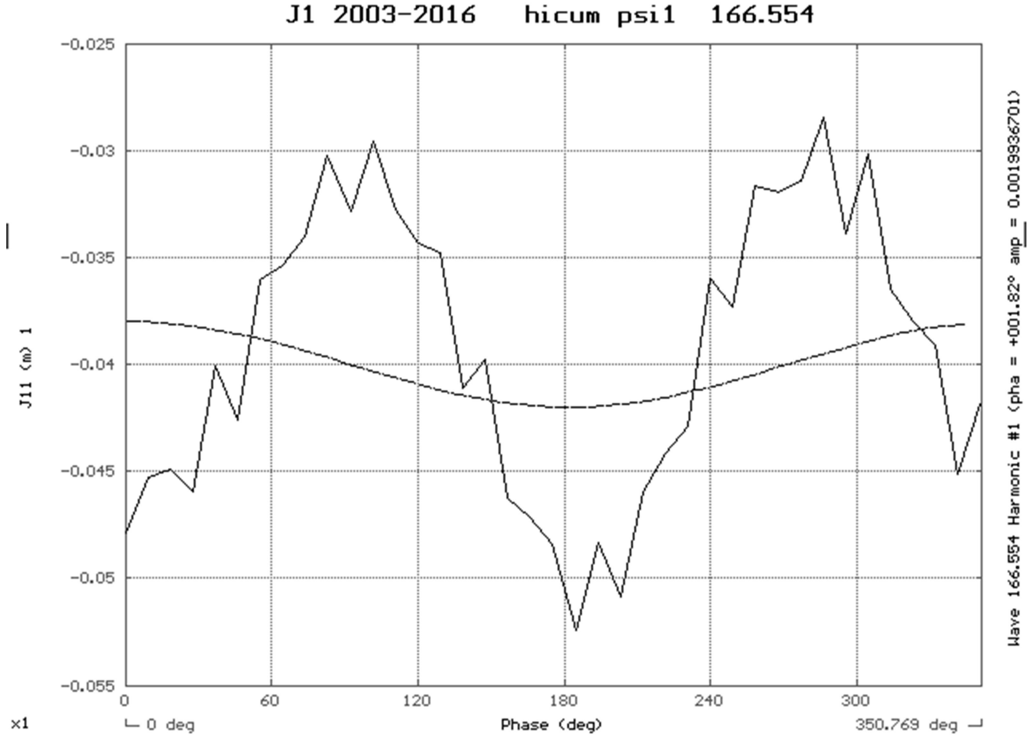
HiCum on the periodicity of the NO1 component

NO1 Amplitude 0.303 cm Phase= -57.70°



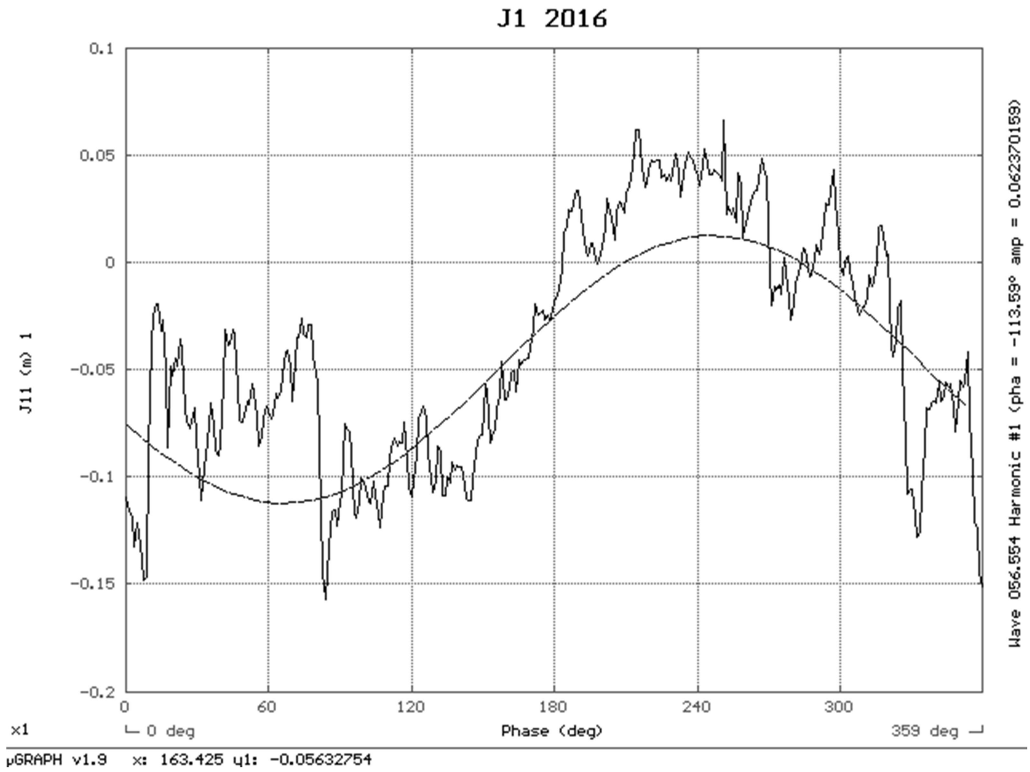
HiCum on the periodicity of the PSI1 component

PSI1 Amplitude 0.199cm Phase= 1.82°



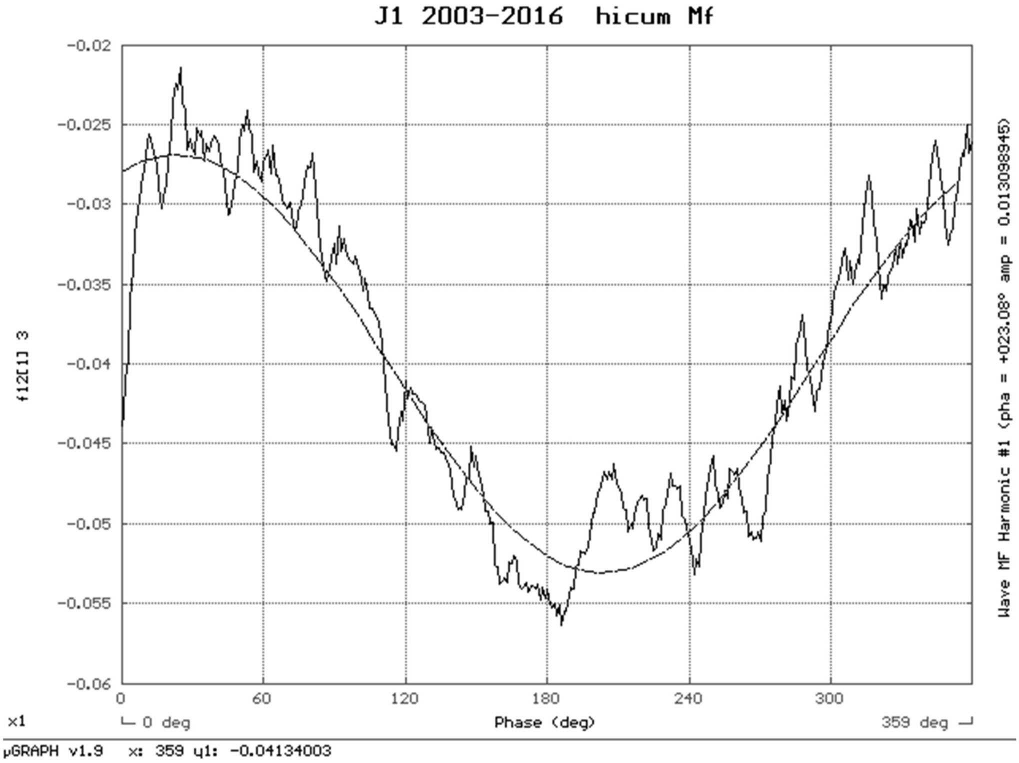
HiCum on the periodicity of the SSA component

SSA Amplitude 6.237cm Phase= -113.59°



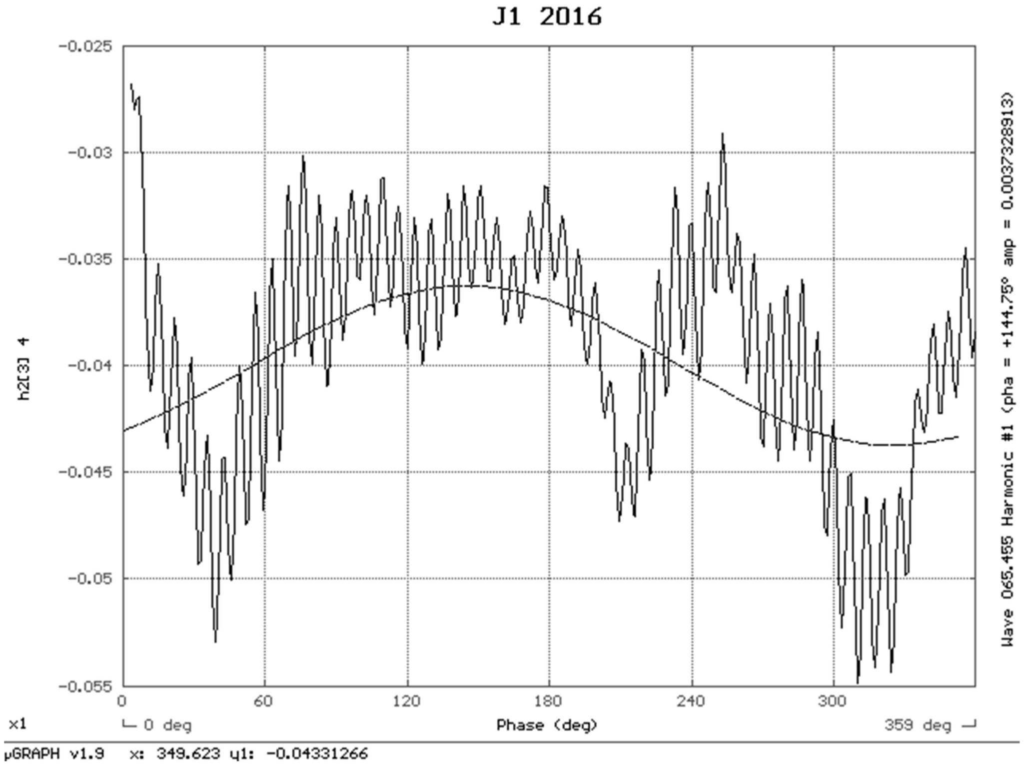
HiCum on the periodicity of the MF component

MF Amplitude 0.131cm Phase= 23.08°



HiCum on the periodicity of the Mm component

Mm Amplitude 0.373 cm Phase= 144.75°



Canonical Wave Grouping as the Key to Optimal Tidal Analysis

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Abstract

In many approaches towards tidal analysis, appropriate wave grouping has been an issue for discussion. However, the proposals presented are often based on experience rather than on a comprehensive theory. This presentation aims at bridging this discrepancy in a presentation consisting of three major parts.

In Part I, the theoretical background of wave grouping is explained. Starting points are the tidal potential and its forces respectively, which deliver the tidal signal contents of different degrees and orders as a large number of harmonic constituents of very close frequencies. It is shown in great detail how to arrange and structure these constituents by symbol names, wave groups and frequencies bands in a complete set of figures and tables. In addition, the impact of shallow water tides with respect to gravimetric records is discussed.

In Part II, it is demonstrated how to derive analytical criteria for estimating the reliability and quality of analysis results. Hereby, the properties of the Least Squares (LS) adjustment method based on the Gauss-Markov model are fully exploited. The traditional method of assuming the same response of all the constituents of a wave group to the tidal force is generalized by taking into account the Earth's reaction to forces of different potential degrees in a comprehensive functional model. The "Correlation Root Mean Square Error Amplifier (CRA)" is introduced as an important criterion to assess the stability by identifying the highly correlated wave group parameters. An elegant new formula of stunning simplicity presents how the relative errors of amplitude quotients is dependent on record length, correlation, observation precision and signal strength. This formula is shown to be expanded for the determination of quality labels of high, medium, and low ratings for the analysis results and how to be used in hypothesis tests for label evaluation

In Part III, proposals for wave group models as quasi standard for a data length of 18.61 tropical years (Moon's ascending node) are presented. Based on these models, optimal wave group separation is proposed also for shorter record lengths by aggregation of the 18.61-years models. The separation of the 9 major tidal wave groups Mf, Q1, O1, P1, K1, N2, M2, S2, K2 is specifically considered as well as associated satellite groups of different degrees. The importance of extracting even tiny waves is illustrated in order to "clean" the wave groups of major interest for ongoing studies. The theoretical predictions are verified by tidal analyses of model series with and without superimposed white noise processes. By assigning quality labels to the analysed tidal parameters, it is possible to identify those of significance to be introduced in subsequent geo-applications. The proposed models and procedures are also applied to a 20 years record of superconducting gravimeter data recorded at the station of Membach (BE). The presented statements and recommendations are supported by a considerable number of detailed tables and annexes.

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1. Introduction

The analysis of Earth tide observations is usually carried out by Least Squares (LS) adjustment based on the Gauss Markov model for parameter estimation and related statistical quantities. A general description of this method and of its advantages can be found in Schueller, 1976, 2015, 2017, Wenzel, 1996, 1997b. The goal of tidal analysis is to determine the so-called tidal parameters, i.e. amplitude factors (ratio between the observed amplitude A_{obs} and the theoretical one A_{th}) and phase differences (difference between the observed phase φ_{obs} and the theoretical one φ_{th}), for the so-called tidal "wave groups", composed of individual waves surrounding a "main" constituent, "main" indicating the one of the highest amplitude in the group. This wave group concept was first proposed in Earth tides by Venedikov (1961) due to the limited resolution of any analysis techniques available. The drawback of this approach is that it implicitly supposes that the same tidal parameters are valid for all the constituents within the frequency range of a group. As in any analysis method, resolution in frequency is limited by the recording length T. According to the Rayleigh criterion, derived from the general concept of spectral window functions (Schueller, 1976, 2015), the separation of the waves is generally guaranteed if $\Delta f \geq 1/T$, the fundamental frequency in Fourier series. The usual rules of wave separation are based on this principle but the Least Squares technique allows to reach resolutions finer than expected by the Rayleigh criterion (Munk and Hasselmann, 1964; Hartmann and Wenzel, 1995; Schueller, 2015) because the frequencies are very well-known a-priori.
Besides the determination of the Earth's response for the constituents near the core resonance (FCN), the main goal of tidal analysis in connection with ocean tide loading remains the determination of the parameters and their statistical properties of the 9 principal waves (Mf, Q1, O1, P1, K1, N2, M2, S2, K2), which are constrained by ocean tide models. The question of resolution remains central even for the determination of the main tidal constituents due to the presence of temporal modulations of their amplitudes and phases. These modulations are expressed by the presence of satellite waves with angular speed differences corresponding to the modulation periods. If the tidal factors of the modulation waves correspond to those of the main constituent, the observed tidal factors of the group will remain constant for any record length, but it is generally not the case as pointed out by Meurers et al., 2016. The most efficient way to solve the problem is to create separate tidal groups with the modulation waves, provided the records lengths are equal or at least close to the modulation periods.
The possibility to determine precisely the tidal parameters of a maximum of tidal waves is not only limited by the lengths of the records but also by the signal to noise ratio, which depend on the quality of the instrument and of its installation. Nowadays, high precision gravity tides series longer than 15 years are available from the Global Geodynamics Project (GGP) network of superconducting gravimeters (SG) (Crossley et al., 1999), with excellent signal to noise ratios. It is a reason why we shall focus this paper on the study of tidal gravity records. The main advantage of the very long series is to allow a precise evaluation of waves with arguments differing only by the Moon perigee argument p (8.847- tropical years period; Ducarme, 2012) or its ascending node argument N' (18.613- tropical years period; Ducarme, 2011). A second advantage is that, due to the SGs very high signal to noise ratios, it is possible to determine even tiny tidal constituents with a very high precision.
Two questions arise however: Which are the smallest waves that can be determined with a precision better than 1% and which is the interest of separating these very tiny constituents?

The present paper is structured in 3 major parts with emphases on

- PART I : Properties of the tidal spectrum
- PART II : Extended functional models and new quality criteria
- PART III : Proposals of optimal tidal wave group models

PART I : Properties of the tidal spectrum

2. Tidal waves generation

First, we are going to consider the origin of the tidal constituents. The tidal spectrum is derived from the time depending part of the tidal potential.
From the potential of degree 2 we get the main tidal bands: Long Period (LP) or zonal, diurnal (D) or tesseral and semi-diurnal (SD) or sectorial (Melchior, 1983):

$$V_2 = \frac{3}{4}\, GM \frac{r^2}{c^3}$$
$$\left\{sin^2\theta cos^2\delta\ cos2AH + sin2\theta sin2\delta\ cosAH + 3\left(cos^2\theta - \frac{1}{3}\right)\left(sin^2\delta - \frac{1}{3}\right)\right\} \quad (1a)$$

For a spherical Earth, the tidal potential development starts with degree two (Melchior, 1983). However, the elliptical shape of the Earth leads to a "fluttering" of the Earth on its orbit around the common centre of gravity of the Earth and the Moon associated with a degree one potential (Wilhelm, 1983, Dahlen, 1993). The associated effect is in the range of nanogals.
Higher degrees of the potential can be expressed in a similar way and so we can write the complete development of the tidal potential due to the Moon under the form (Wenzel, 1997a)

$$V = \sum V_n = \frac{GM}{c}\sum_{n=1}^{\infty}\left(\frac{r}{c}\right)^n \frac{1}{2n+1}\sum_{m=0}^{n} P_{nm}(\cos\theta)P_{nm}(\cos\left(\frac{\pi}{2} - \delta\right))\cos(mAH) \quad (1b)$$

with G gravitational constant, M mass of the Moon, r geocentric distance of the point of observation, c distance from the geocentre to the Moon, θ geocentric colatitude, δ declination of the Moon and *AH* its hour angle. The P_{nm} are the fully normalized Legendre functions of degree n. The order m is associated to the different tidal bands through the hour angle (eq. (1b)). For example, the tidal potential of degree three V_3 is generating tidal waves in the Long Period (LP, m=0), diurnal (D, m=1), Semi-Diurnal (SD, m=2) and Ter-Diurnal (TD, m=3) tidal bands, while the potential of degree two V_2 is limited to orders $m \leq 2$ (LP, D and SD).
Three types of harmonic functions are characterising the distribution of the potential at the surface of Earth

-	zonal	:	n >0, m=0	with parallels as nodal lines
-	tesseral	:	$n - m$ >0, m>0	with parallels and meridians as nodal lines
-	sectorial	:	n=m	with meridians as nodal lines for.

The time variations of the potential are linked to c,δ and AH. Expressing these quantities as a function of the astronomical arguments describing the motion of the celestial bodies inside the solar system, it is possible to develop the tidal potential in a sum of harmonic constituents, under the form

$$V = D\sum_{n=1}^{n_{max}}\sum_{m=0}^{n}\left(\frac{r}{\bar{a}}\right)^m \Gamma_{nm}P_{nm}(\cos(\theta)\sum_i\left[C_i^{nm}(t)\cos\left(\alpha_i(t)\right) + S_i^{nm}(t)\sin\left(\alpha_i(t)\right)\right] \quad (2)$$

with D [Newton.m], so-called " Doodson constant " , $\bar{a}$ mean equatorial radius, Γ_{nm} normalization coefficients, $n_{max} = 6$. The arguments α_i are expressed in function of astronomical arguments. If we consider only Moon and Sun, neglecting the planets of the solar system, we can write

$$\alpha_i = a\tau + bs + ch + dp + eN + fp_s \tag{3}$$

with τ mean local lunar time (*AH*+180°), s mean tropical longitude of the Moon, h mean tropical longitude of the Sun, p mean tropical longitude of the lunar perigee, $N' = -N$ negative mean tropical longitude of the lunar ascending node and p_s mean tropical longitude of the solar perigee. The angular speed of any lunar or solar tidal wave is completely determined by a linear combination of these six arguments with the coefficients (a, b, c, d, e, f). The influence of the planets requires the introduction of two additional arguments.

Among the different developments of the tide generating potential (TGP), the choice is depending on used potential degrees n and number of waves *nw*. Highest accuracy demands are served by HW95 catalogues (Hartmann and Wenzel, 1995, n=1-6, *nw*=12361) and KSM03 (Kudryavtsev,2004, n=1-6, *nw*=28806), while TAM1200 potential (Tamura, 1987, n=2-4, *nw*=1200) can be used in applications in which medium accuracy is sufficient. The TGP is slowly changing with time and it has to be taken into account in its development.

Eq. (1b) reveals that the main tidal waves are generated by known variations of the position of the perturbing bodies: The variation of the declination δ is affecting the arguments s (Moon) or h (Sun) while the factor $(1/c)^{n+1}$ taking into account the variations of the Earth-Moon or Earth-Sun distance and is directly affected by:

- the ellipticity of the orbit with arguments (s-p) or (h-p_s);
- the variation with argument 2(s-h) for the Moon;
- the evection with argument (s-2h+p) for the Moon.

As 2(s-h) = (s-2h+p) + (s-p)

one can state that variation is equivalent to the combination of evection and ellipticity.

The Lunar waves are also affected by the annual solar modulation with the appearance of terms separated by ±(h-p_s). The waves generated by evection and variation are also depending from solar argument h.

Finally, the variations of the lunar perigee (argument p, period 8.847 years) and of the lunar node (N', period 18.613 years) generates additional lunar terms.

On each side of the principal Lunar waves, one can find successively the nodal waves, waves due to variations of the lunar perigee, the annual solar influence, the effects of evection, ellipticity, variation and declination. For M2 in the SD tidal band (Table 1), we find M2- and M2+ (node), 3MNK2 and 3MNO2 (V_{32}, perigee), α2 and β2 (annual solar perturbation), ν2 and λ2 (evection), N2 and L2 (ellipticity), μ2, S2^m (variation), K2^m (declination). There is no declinational wave symmetrical to K2^m. The annual modulation in h-p_s corresponds to the mean anomalistic year (365.26 days).

For V_i, i > 2, the same structure is valid. However, due to small signal amplitudes, some constituents are often missing.

The generation process is illustrated in Figures 1a-c. The spectrum of the solar waves (bottom graphs) is much simpler as it consists only of declinational and elliptical waves. Ellipticity produces cascades of waves such as Mtm, Mqm for Mf (Figure 1a), Q1, 2Q1, 3Q1 for O1 (Figure 1b), N2, 2N2, 3N2 for M2 or T2, 2T2 for S2 (Figure 1c). It should be noted that 3T2 is existing but with a negligible amplitude. A similar situation exists in Figure 1b (middle) for M1 (3ML1 and 3M2L1) and even for 3MK1 (3Mη1, 3M2J1). Some waves can be derived through different mechanisms: from K1^m you can produce ν1 by declination (2s, OO1) followed by ellipticity (s-p) or by ellipticity (J1) followed by declination. It is the same for Sta derived from S0 either through Sa or through Ssa (Figure 1a, bottom). Relations between variation, ellipticity and evection are illustrated by μ2 derived as variation of M2 or as evection of N2 which is an elliptical wave of M2.

Besides the tidal waves directly generated by the tidal potential, tidal interactions in shallow waters produce a lot of non-linear terms with frequencies depending from the same six astronomical arguments. It

should be noted, however, that instrumental non-linearities are producing exactly the same effect in tidal records (Schueller et. al., 1979).
There exist some contradictions in the nomenclature of tidal waves used in oceanography and in Earth tides. Generally, oceanographers reserve compound names for non-linear ocean tide, also called shallow water components. However, the Roman and Greek alphabets being limited compound names are used even for some linear tides derived from V_2. We shall compare here the different lists.

3. Catalogue of tidal waves

The arguments of the Lunar and Solar tidal waves are completely determined by the six numeric coefficients in eq. (3). Doodson introduced the so-called "Doodson Number", which avoids the introduction of negative numbers. The coefficients are replaced by the combination

$$a, b+5, c+5, d+5, e+5, f+5 \tag{3a}$$

However, it fails when a coefficient becomes larger than 4 or lower than -5. It becomes necessary to introduce alphanumeric symbols e.g. A for +6 or / for -6.

In the "United Kingdom Hydrographic Office List of Harmonic Constituents", an alphabetic code is proposed replacing each positive or negative value of the coefficients by a letter under the form

….	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	…
	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	

For example, all long period waves will have a code beginning by Z, the diurnal by A and so on.
For the wave with angular speed 28.51258319 °/h in Table 1 we get:

Doodson number	247400
Alphabetic code	BYBYZZ

Wave names are largely used in parallel according to the following conventions: any tidal wave can be referenced as

$$w_{nm} = \ \mathrm{n.wavename.m} \tag{3b}$$

where n and m are the degree and the order of the generating potential. For the waves derived from V_2, the degree is often not given and the order is sometimes omitted too.
The major waves of the tidal potential were named according to the Latin and Greek alphabets. The compound names were created according to different conventions. Some names refer explicitly to the wave period:

- Mf : Moon fortnightly,
- Mm : Moon monthly,
- Sa : Sun annual,
- Ssa : Sun semi-annual.

Other names refer to the origin of the wave:
- 2Q1 (elliptic wave of Q1 which is an elliptic wave of O1)
- σQ1 (variation of Q1, σ1 being the variation of O1)
- σ2Q1 (variation of 2Q1, σQ1 being the variation of Q1)
- OO1 (declinational wave of $K1^m$, O1 being its symmetric wave with respect to $K1^m$)
- 2ε2 (variation of 2N2, ε2 being a variation wave of N2)

- 2N2 and 3N2 (first and second elliptic wave of N2 which is an elliptic wave of M2)
- 2K2 (declinational wave of $K2^m$ which is first declinational wave of M2)
- 2S2 (argument difference with 2K2 (-2h) same as between S2 and K2)

For the non-linear tides, combinations of different waves are used to build the correct argument. Generally, the name of a constituent of degree n and order m is built in the general form (3b) with additionally using the following equation

$$w_m = (\mathrm{x1w1} \pm \mathrm{x2w2} \pm \mathrm{x3w3} \pm \cdots..)\mathrm{m}$$
(3c)

where x_i are integers ≥0 and w_i are major D or SD components, chosen so that the algebraic sum of their orders is equal to m. This convention is widely used by oceanographers for the non-linear tides (Rossiter and Lennon, 1968; United Kingdom Hydrographic Office List of Harmonic Constituents).
Concerning the V_{ni} ($0\leq i \leq n-1$, $n\neq2$) groups, the degree n is indicated in front of the name and the order i at the end like in eq. (3b) so that eq. (3c) becomes) (see also Table 2)

$$w_{ni} = n(\mathrm{x1w1} \pm \mathrm{x2w2} \pm \mathrm{x3w3} \pm \cdots..)\mathrm{i} \qquad 0\leq i \leq n-1, \quad n\neq2) \qquad (3d)$$

Some minor components of the D and SD spectrum were named following the oceanographic rules e.g. LK1 (L2-K1), NO1 (N2-O1), SO1 (S2-O1), KNO2 (K1+N2-O1).
To be consistent with oceanographic notations OO1 should be actually named 2KO1 (2xK1-O1) and 2S2 (variation of $S2^m$) SKM2 (S2+K2-M2).
In Table 8 we give the combinations of waves corresponding to the principal shallow water tides.
In other lists, the ocean tide components are only numbered e.g. ST38 (alias in Table 8 for 2 , 4, -2, -2, 0, 0), which corresponds to 2MS2N2 (2xM2+S2-2xN2).
For degrees n≥3, only a few constituents have been labelled in the past (Ducarme, 2012) and we propose additional names in Tables 3 to 7 according to the following conventions:
- V31 -> M3-SD, V32-> M3-D, V33-> M1+SD
- V43 ->M4-D, V44 ->M2+SD
- V54 ->M5-D, V55 ->M3+SD

In the new ETERNA version ET34-ANA, it is now possible to use 10 characters for the length of a wave and/or group name xxxx, e.g.

- the nodal waves of a principal constituent are indicated by − or + depending of the sign of the argument N'. Sometimes waves including ±2N' in their argument are also existing. The convention is to identify them with -- (-2N') and ++ (+2N').
- If no other name is existing, the annual modulations on both side of the major tidal waves are indicated by letters a and b, e.g. Oa1, O1, Ob1 (Annex 1).
- Waves with very complex names such as 2MS2N2 can alternatively be represented directly from a 4 characters symbol directly derived from the Doodson number. In this case (2, 4, -2, 2 ,0, 0) becomes S937. The first Doodson argument is replaced by L (Long period), D (Diurnal), S (Semi-diurnal), T (Ter-diurnal) or Q (Quad-diurnal). The fifth and sixth arguments are omitted.

4. Structure of the tidal bands

For each degree of the potential, there are some similarities between the structures of the different orders (Table 2). There are *two principal patterns* depending on the trigonometric dependence in declination δ of the corresponding P_{nm} function (eq. (1a)). Often there is a *principal wave* $M[m]$ *or* $S[m]$ (like M2 or

S2) with argument cos (mτ) or cos(mt) but, if there is a factor sin δ in the P_{nm} (δ) function, the (fictitious) principal wave is replaced by a pair of declinational waves, i.e.

- **d ($\boldsymbol{M[m]-s, M[m]+s}$)** with arguments sin (mτ ± s)

or

- **d ($\boldsymbol{S[m]-h, S[m]+h}$)** with arguments sin (mt ± h),

which are symmetrical with respect to this missing principal wave $M[m]$ or S[m]. The fact that the factor sinδ is equal to zero when the celestial body crosses the equator, is taken into account by the beat of the two declinational waves creating a modulated principal wave. One can find for each degree and order of the potential the corresponding tidal pattern (Table 2).

A rule of the thumb is that if

- *(n + m) is even : the principal wave $M[m]$ or $S[m]$ is existing ,*
- *(n + m) is odd : the principal wave is fictitious and replaced by the 2 declinational ones.*

However, this rule of the thumb does not apply to the 6^{th} degree. The principal waves for the even orders 2m (0 ≤ m ≤2) are declinational waves too with arguments sin (mτ ± 2s).

The other tidal waves are generated by the perturbations listed in the above section and illustrated in Figures 1a-c.

In the diurnal band of V_2 (D, Table 4, Figure 1b), the major Lunar constituents are the declinational waves O1 and $K1^m$ and the major Solar ones the declinational waves P1 and $K1^s$. Their combinations create fictitious M1 (Figure 1) and S1 waves, which disappear when the Moon or the Sun crosses the equator. On the contrary, the term 3M1 is existing for the Moon (Figure 1b, middle) in the third-degree potential V_3 (Table 2). This term is surrounded by the elliptical waves of O1 (LK1) and $K1^m$ (NO1), which are only separable from M1 on the period 8.847 years of the Lunar Perigee p (Ducarme, 2012). This property is common to all the major V_{31} terms (Table 4). On shorter tidal records, the three constituents form one group that was often called M1, although its main constituent is normally NO1. At the equator, however, the diurnal waves derived from V_2 are going through zero, so that in equatorial stations this group should really be called M1. For the Sun, 3S1 is too small to be listed in the Tamura potential with an amplitude less than 0.01 nms^{-2} and the main waves in the so-called S1 group are the elliptic waves of P1 (RK1) and $K1^s$ (TP1). They are only separable on a period of 10,000 years (argument $2p_s$). On a few years of tidal record, it can be considered as a constant phase difference between the two harmonics and the true S1.

The tidal spectra of the Long Period (LP, Table 3, Figure 1a) and the Semi-Diurnal (SD, Table 5, Figure 1c) spectra are similar. In both tidal bands, a principal component is existing for Lunar and Solar waves derived from V_2: M0 and S0 for LP on one side M2 and S2 for SD on the other. The main difference is that the spectrum is roughly symmetric around the principal components in the SD band, while waves with frequency lower than M0S0 (zero frequency) do not exist in the LP band.

For the waves derived from potential of degree 3 (V_3) in LP (Figure 1a, middle) and SD (Figure 1c, middle) bands, the major constituents are declinational waves in ±s: 3MO0 (M1-O1, Table 3), 3MK2 and 3MO2 (Ducarme, 2012; Table 5).

Let us consider now V_3 and V_4. In the Ter-Diurnal (TD) band, the waves derived from V_3 (Table 6) display a spectrum around M3 similar to the SD spectrum around M2. This property was used to name the main ter-diurnal constituents. For example, N2 and L2 being the elliptical waves of M2, the corresponding elliptical waves of M3 are named MN3 and ML3. It is coherent with the general equation with $x_1 = x_2 = 1$, $x_3 = 0$, w_1= M1. The satellite waves coming from V_{43} are derived from the main declinational terms 4MK3 and 4MO3, while the tiny contributions from V_{53}, such as 5M3, coincide with the main V_{33} constituents.

Concerning the terms derived from V_4 (Table 7), M4 is very small (≅0.1nms^{-2} at mid latitudes). The satellite waves are derived from V_{54}.

Most of the V_{4i} - terms, $0 \le i \le 2$, coincide with corresponding V_{2i} - terms. We get

- LP: 4M0, 4Mm, 4Mf, 4Mtm;
- D: 4Q1, 4ρ1, 4O1, 4Nτ1, 4K1, 4J1, 4OO1;
- SD: 4N2, 4M2, 4KNO2, 4K2, 4η2.

The largest waves at mid latitudes are 4Mf ($0.04 nms^{-2}$), 4O1 ($0.09 nms^{-2}$), 4K1 ($0.08 nms^{-2}$), 4M2 ($0.10 nms^{-2}$). There are, however, some waves, generally declinational, which do not coincide with V_2 waves, due to gaps in the corresponding V_{2i} spectrum. For example, the declinational wave of M2 (2, -2, 0, 0) is not existing, as pointed in Table 1, but the declinational wave 4MK2 of 4M2 is present in the spectrum.

- LP: 4K4M0	K4-M4 (0, 4,0,0)	declinational 4Mf;
- D: 4(MK3)1	M4-K3 (1,-3,0,0)	declinational 4O1;
- SD: 4MK2	M4-K2 (2,-2,0,0)	declinational 4M2,
4Mη2	M4-η2 (2, 3,0,1)	elliptic 4MK2.

This situation has a strong impact on the optimal wave grouping (section 7). It will be difficult or impossible to separate third and fourth degree contributions inside the V_2 spectrum. As a matter of fact, the separation of V_3 -terms will require more or less a record length of eight years and V_4 -contributions are only accessible inside the ter-diurnal and quad-diurnal tidal bands. A similar situation exists in the ter-diurnal spectrum Table 6): V_{43} terms are only separable from V_{33} ones on eight years and V_{53} terms overlap V_{33} spectrum.
Following Table 2, these properties can be generalized to the other degrees of the potential:

For a given order m, the main waves of degree n will have "satellite" waves of degree n+1 separable on the 8.847 years period of the Lunar Perigee p, while the main waves of degree n-2 or n+2 will have exactly the same argument.

As a result, the spectra of V_1, V_3 and V_5 on one side and V_2, V_4 and V_6 on the other overlap nearly completely in the tidal bands they have in common.

5. The influence of the shallow water tides in tidal gravity records

Shallow water tides (SWT) are due to non-linear tidal phenomena arising in coastal areas. The shoaling near the coast slows the progress of the tidal waves, increasing its amplitude. The waves become distorted and display a shorter rising tide than falling tide. Mathematically, these nonlinearities give rise to combination frequencies f_c according to the general combination rule $f_c = n_1f_1 \pm n_2f_2$. Higher harmonics with periods 1/2, 1/3 etc. are a special case. Non-linear tides are ubiquitous in estuaries but are also found in extremely shallow shelf regions, particularly those bordered by large intertidal flats.
Table 8 presents a non-exhaustive list of SWT up to sixth order. The waves in bold, identified in Rossiter et al., 1968, are likely to influence tidal gravity records in West European stations such as Membach (BE). A more exhaustive list, up to fourteenth-diurnal, can be found in "United Kingdom Hydrographic Office List of Harmonic Constituents". ETERNA is also providing a more complete list of "non-linear and additional harmonics parameters".
Some SWT with periods lower than the ter-diurnal ones are clearly seen, not only in the residues of the superconducting gravimeters (Florsch et al., 1995; Sun et al., 2003, 2004; Boy et al., 2004; Ducarme et al., 2007), but also of clinometric records (d'Oreye and Zuern, 2006). It is due to the ocean tide loading associated with these terms. A problem can arise in the main tidal bands where SWT are mixed up with the tidal constituents deriving from the potential (Merriam, 1995), especially for a SG at, or near, the coast. The presence of shallow water non-linear tides within any tidal group could be a problem in connection with coincident or nearby waves from the body tide in the same group. The latter depend upon the low degree

body tide Love numbers, but the loading from shallow water tides depends upon medium to high degree loading Love numbers and so the relationship between these is not simple. For an SG at, or near, the coast this would be a problem.

In Tables 3-7 the column "SWT alias" indicates main tidal constituents likely to be affected by shallow water resonance at the same period. The last column of Table 8 indicates the wave group in which the SWT is included. As it not yet worth to create subgroups for V55 and V66 tides we consider only the major fifth and sixth-diurnal SWT in Table 8.

In the LP band, all the main tidal waves could coincide with a SWT as their angular speed can be expressed as the difference between D or SD frequencies (Table 3). Along the West European coast, the diurnal ocean tides are very weak so that only LP tides deriving from the difference of two SD terms are likely to be seriously perturbed. Moreover, all SWT are not necessarily excited together. In the analysis of 60 years of ocean tide records at Oostende (Ducarme et al., 2006b), the most locally resonant components are Sta, SN and MSqm, while for Mf, which is much less amplified, it is a regional behaviour.

In the LP, D, SD and TD bands many SWT are not coinciding with main tidal frequencies (Table 8). Their influence could spoil some minor tidal groups such as SN, MSqm, SKNM0, 2S2, 2K2, ML3 and MK3. For example, in the residues of Membach station (Van Camp et al., 2017) one can find the doublet (SP3, SK3) of two solar declinational waves with an amplitude close to $0.1 nms^{-2}$ and coherent phase (-90°) (Figure 2). These waves are symmetrical with respect to S3 ($0.035 nm/s^2$), which is a pure atmospheric pressure wave. MO3 and 2MO3 are also present with amplitudes below $0.5 nm/s^2$. In the semi-diurnal band, much energy is left at the frequency of $\beta 2$, which is also a known SWT at Oostende (Ducarme et al., 2006b). Some other SWT are detected with amplitudes above $0.25 nm/s^2$: ST37, OP2, MSN2 and 2SM2 (Table 8).

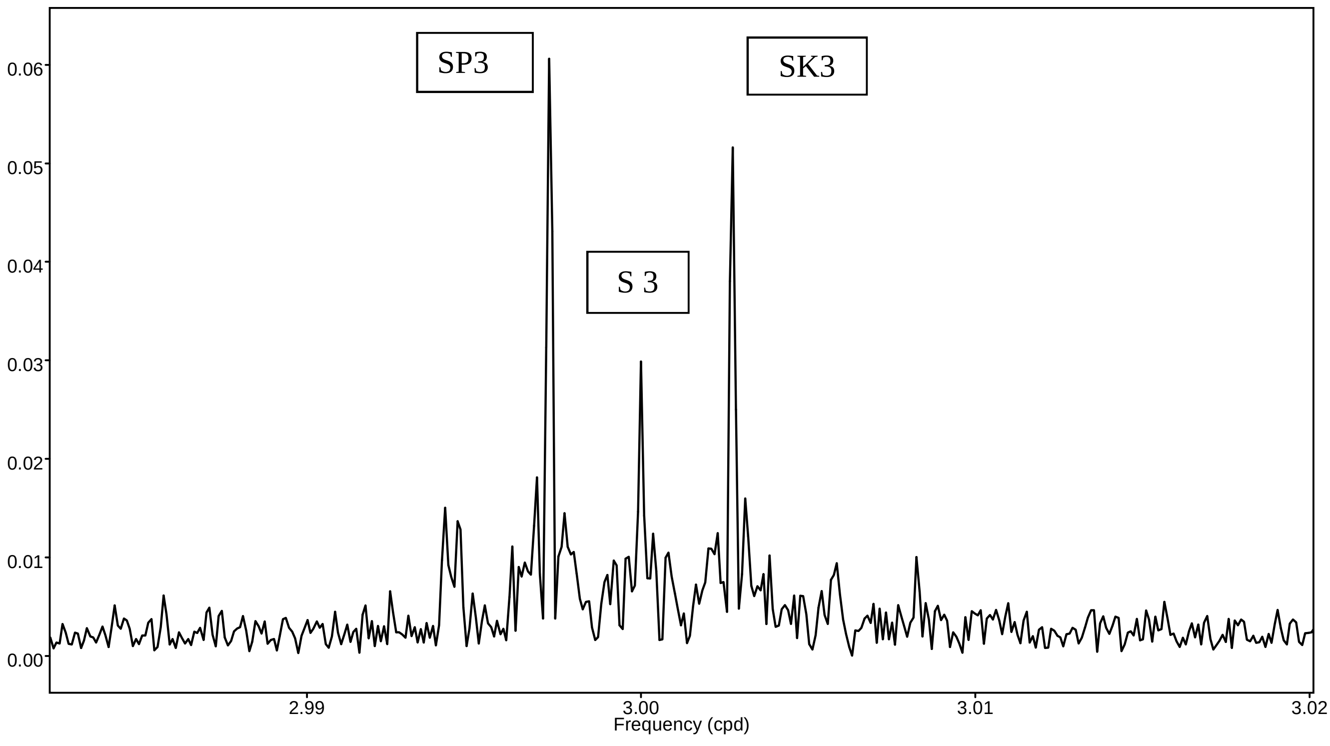


Figure 2: shallow water tides around meteorological wave S3 in Membach residues

PART II : Extended functional models and new quality criteria

6. Tidal analysis procedure

Generally, tidal analyses by the Least Squares approach are performed by using different programs: the ANALYZE (ETERNA) program (Wenzel, 1996, 1997b), the VAV04 software (Venedikov et al., 2001, 2005), BAYTAP-G (Tamura et al., 1991) and more recently the ET34-ANA version of ETERNA (Schueller, 2015, 2017). In this paper, we shall focus on ET34-ANA-V61 and a beta version of ET34-ANA-V70.
There, it is shown that derivatives of the tidal potential of eq. (2) possess the same structure with respect to degree, order, and frequency distribution so that forces like tidal gravity can be expanded as a series of harmonics with unknown transfer functions with respect to an Earth model. To represent actual observations, a stochastic process z(t) has to be added so that the tidal signal $y_{ET}\ (t)$ can be described as

$$
\begin{aligned}
y_{ET}\ (t) &= \sum_{i=1}^{n_{wg}} \delta_i \sum_{j=1}^{k_i} A_{ij}\, cos\big(\omega_{ij}t + \varphi_{ij} + \kappa_i\big) + z(t) \\
&= \sum_{i=1}^{n_{wg}} \delta_i\, cos(\kappa_i) \sum_{j=1}^{k_i} A_{ij}\, cos\big(\omega_{ij}t + \varphi_{ij}\big) - \sum_{i=1}^{n_{wg}} \delta_i sin\,(\kappa_i) \sum_{j=1}^{k_i} A_{ij}\, sin\big(\omega_{ij}t + \varphi_{ij}\big) + z(t)
\end{aligned} \tag{4}
$$

with

- $y_{ET}\ (t)$ - body tide signal over the recording period T, t $\in T$,
- n_{wg} - number of wave groups i, i=1,….., n_{wg}
- $\delta_i\,, \kappa_i$ - tidal parameters (amplitude factor, phase lead)
- k_i - number of tidal constituents j of wave group i, j=1,… k_i
- $A_{ij}, \omega_{ij}, \varphi_{ij}$ - also A_{th} - theoretical amplitudes, angular velocities and phases of the i-th tidal wave group and the j-th constituent for a rigid model Earth, usually taken from the development published by (Hartmann and Wenzel,1995) up to degree l = 6 and order m= 6.
- $A_{obs} = \delta A_{th}$ - observed amplitude of a tidal constituent
- $z(t)$ - realisation of a stochastic process Z(t) with variance σ_{ZZ}^2

(Since the focus of this paper is the modelling of the tidal signal, other signals like instrumental drift, pole and LOD tides, physical regressions channels etc. remain unconsidered in (4) or can be thought of part of z(t). For details on the extended model see Schueller (2017).)

The objective of tidal analysis is now to determine the transfer functions as so-called tidal parameters, i.e. amplitude factors (ratio between the observed amplitude A_{obs} and the theoretical one A_{th}) and phase differences (difference between the observed phase φ_{obs} and the theoretical one φ_{th}), for the so- called tidal "wave groups", each group composed of individual waves surrounding a main constituent within a predefined frequency range. This wave group concept was first proposed in Earth tide analysis by Venedikov (1961) due to the limited resolution of any analysis techniques available.
In (4), the underlying assumption is that the tidal parameters of the n_{wg} wave groups are constant within these groups. However, this is basically not true, because the tidal potential is composed of different degrees n and orders m (see eq. (2)). From Earth modelling (e.g. Zschau and Wang 1981, Dehant 1987, Dehant et al. 1999) it is known that the tidal gravity factors δ, representing the responses of the Earth to the tidal forces, are different for different degrees what has also been confirmed by high precision tidal measurements. In addition, different responses of δ are caused by latitude dependence and the free core nutation (FCN) effects.
To cope with this problem, the usual practice is to multiply the theoretical amplitudes of waves which are not belonging to the same degree as the main wave of the group by the ratio of their theoretical amplitude factors. Then, for instance in the semi-diurnal band, if the tidal gravity

factors for $V_{22}-$ and $V_{32}-$ terms are δ_2 and δ_3, the theoretical amplitude of any $V_{32}-$ term will be multiplied by δ_3/δ_2. If the observed tidal factor of the group is δ, the contribution of a $V_{32}-$ term is in fact $\delta\cdot\delta_3/\delta_2\approx\delta_3$, if $\delta_2\approx\delta$. Also, the core resonance can be modelled this way. The procedure was first proposed by (Schueller, 1979a) and it was implemented in the HYCON-method (Schueller, 1979b). This approximation is generally valid as the observed and theoretical tidal factors agree within a few per cent. However, the discrepancies between the theoretical factors of different degrees of the TGP are in the range of about 10%. Moreover, the contribution of the components derived from V_2 are much larger than the signals coming from other degrees of the TGP so that the residual effects become generally negligible. However, some residual anomalies have been pointed out in some groups as L2 (Dittfeld, 1991). This procedure should be applied also to the terms generated by V_4. A more accurate solution has been introduced by Venedikov (Venedikov et al., 1997) by the evaluation of the third and fourth degree terms in parallel with the second-degree ones.
Wenzel, 1996, implemented a different approach in his ETERNA program. Instead of using the theoretical (rigid) Earth model, he introduced amplitude factors of a suitable elastic Earth model (EM), the Wahr-Dehant-Zschau hydrostatic, inelastic EM (WDZ-Hi), (Zschau and Wang., 1981), to harmonize the heterogeneous situations of non-constant amplitude factors within the tidal wave groups. As a consequence, the estimated parameters δ_i^* now refer to the WDZ-Hi model which will yield $\delta_i^*=1$ in case of total agreement between WDZ-Hi and observations. In ET34-ANA, 2 additional Earth models are added, namely the Dehant- Defraigne-Wahr hydrostatic elastic EM (DDW-H), (Dehant et.al. 1999), and the Dehant-Defraigne-Wahr non-hydrostatic, inelastic EM (DDW-NHi), (Dehant et.al. 1999).

Introducing an Earth model, into (4) yields

$$
\begin{aligned}
y_{ET}(t) &= \sum_{i=1}^{n_{wg}} \delta_i^* \sum_{j=1}^{k_i} A_{ij}^{EM} \cos(\omega_{ij}t+\varphi_{ij}+\kappa_i) + z(t)\\
&= \sum_{i=1}^{n_{wg}} \delta_i^* \cos(\kappa_i) \sum_{j=1}^{k_i} \delta_{ij}^{EM} A_{ij} \cos(\omega_{ij}t+\varphi_{ij}) - \sum_{i=1}^{n_{wg}} \delta_i^* \sin(\kappa_i) \sum_{j=1}^{k_i} \delta_{ij}^{EM} A_{ij} \sin(\omega_{ij}t+\varphi_{ij}) + z(t)\\
&= \sum_{i=1}^{n_{wg}} \sum_{j=1}^{k_i} x_{c_i}^* \delta_{ij}^{EM} A_{ij} \cos(\omega_{ij}t+\varphi_{ij}) - \sum_{i=1}^{n_{wg}} \sum_{j=1}^{k_i} x_{s_i}^* \delta_{ij}^{EM} A_{ij} \sin(\omega_{ij}t+\varphi_{ij}) + z(t)\\
&= \sum_{i=1}^{n_{wg}} \delta_i^* \cos(\kappa_i) e_i(t) - \sum_{i=1}^{n_{wg}} \delta_i^* \sin(\kappa_i) f_i(t) + \mathrm{z(t)}
\end{aligned}
\tag{5}
$$

with

- δ_{ij}^{EM} = the amplitude factors of an Earth model for each potential degree and order
- A_{ij}^{EM} = Earth model amplitudes
- $\delta_i^* = \frac{\delta_i}{\delta_i^{EM}} =$ quotient between observed and model tide amplitude which is δ_i^*= 1 in case of agreement between Earth model and observations
- $x_{c_i}^* = \delta_i^* \cos(\kappa_i)$, $x_{s_i}^* = \delta_i^* \sin(\kappa_i)$ - auxiliary tidal parameters related to the used Earth model
- $e_i(t), f_i(t)$ - model time signals with Earth model amplitudes, angular velocities and phases of the i-th tidal wave group

Finally, the traditional amplitude factors with respect to a theoretical rigid Earth yield:

$$\delta_i = \delta_i^* \cdot \delta_i^{EM} \tag{6}$$

The approach of (5) is equivalent to take the response δ_i^{EM} of a main wave group i as reference and then, for all constituents ij of this group, normalize their amplitudes relative to the reference responses by a factor c_{ij}:

$$c_{ij} = \delta_{ij}^{EM}/\delta_i^{EM} \tag{6a}$$

as described before.

In eq. (5), resolution in frequency is limited by the recording length T. According to the Rayleigh criterion, the separation of the waves is generally restricted to $\Delta f \geq 1/T$.

The usual rules of wave separation are based on this principle (Munk and Hasselmann, 1964): waves with arguments differing

- by s will be separated on a one-month record;
- by 2h on 6 months, e.g. P1 from S1K1 and S2 from K2;
- by h on one year, e.g. S1 and ψ1 from K1;
- by p on 8.8 years, e.g. M1 from LK1 and NO1 (Ducarme, 2012);
- by N' on 18.6 years, e.g. the nodal waves of K1 (Ducarme, 2011).

However, the Rayleigh criterion should be used as a rule of thumb only. Deriving their TGP catalogue from synthetic tides, Hartmann and Wenzel (1995) resolved spectral details in 300 years, which according to Rayleigh's criterion should only be possible in more than 10.000 years. It is due to the properties of the Least Squares method. For the least squares adjustment method, where the frequencies are known beforehand, the separation depends on the recording length T and on the signal-to-noise ratio. For high signal to noise ratios, as it is the case with SGs, waves with frequency differences $\Delta f < 1/T$ can be often separated. In section 8.3 the theoretical basis for this phenomenon will be presented.
The most general structure of a V_2 - wave group generally denoted by xxxx, discussed in section 3, is presented in Table 9. It should be emphasized that this structure will appear simpler in practical analyses due to insufficient signal strengths, i.e. too low amplitudes of the constituents involved as well as too short record lengths to resolve this structure.

Table 9 : General structure of a V_2- wave group xxxx

- low frequency annual modulation	xxxxa => $\omega - h$ + p_s
o low frequency Moon's perigee	V3:xxxx- => $\omega - p$
▪ low double nodal frequency	xxxx-- => $\omega - 2N'$
• low nodal frequency	xxxx- => $\omega - N'$
o **tidal main constituent**	**xxxx =>** $\boldsymbol{\omega}$
• high nodal frequency	xxxx+ => $\omega + N'$
▪ high double nodal frequency	xxxx++ => $\omega + 2N'$
o high frequency Moon's perigee	V3:xxxx+ => $\omega + p$
- high frequency annual modulation	xxxxb => $\omega + h$ - p_s

Concerning the separation of the constituents involved, one has to be aware of the frequency distances not only reaching from the main tide to the side tides but also of those between each other. Therefore, Table 10 presents the associated separation periods as required record lengths:

Table 10 : Rayleigh-Periods in tropical years for resolving the general wave group structure.
The table values are generated by calculating for each row the difference in angular velocity of the parameters ω, N' ,2N', p of column "Main tide xxxx" and the column parameters ± N', ±2N', ± p, ± (h-p_s) and then replacing the results by the associated periods in tropical years.

-(h-p_s) xxxxa	-p V3:xxxx-	-2N' xxxx--	-N' xxxx-	Main tide xxxx	N' xxxx+	2N' Xxxx++	p V3:xxxx+	h-p_s xxxxb
				frequ.				
1.00005*	8.85	9.31	18.61	**ω**	18.61	9.31	8.85	1.00005*
0.949	6.00	6.20	9.31	**N'**		9.31	16.86	1.06
0.903	4.54	4.65	6.20	**2N'**			**179.34**	1.12
0.898	4.42	4.54	6.00	**p**				1.13

***The annual solar modulation corresponds to the mean anomalistic year of 365.25964 mean solar days**

If one wants to be on the safe side, both nodal frequencies – and + require 18.61 years to be separated from the main tide, while nodal ones need 16.86 years of record length to be separated from V_3, From this table, very high correlations can be anticipated if **waves** of type xxxx++ will be analysed together with V_3 ones (see K1 group), as 179.34 years of record length is required for the separation.

7. Hypothesis-free wave group modelling

To overcome the model assumptions of the previous section, wave grouping must offer a direct technique to model the different potential degree origins and consequently the different responses of the Earth with respect to the driving forces from TGP. From (2), it follows that the different orders of the TGP can uniquely be associated with different frequency bands. If ω is the set of frequencies into which the different orders of the TGP are mapped, we obtain:

$$\omega \in \left\{long\ periodic, diurnal, \frac{1}{2} diurnal, \frac{1}{3}\ diurnal, \frac{1}{4} diurnal, \frac{1}{5} diurnal, \frac{1}{6} diurnal\right\} = \{\quad m=0, \quad m=1, \quad m=2, \quad m=3, \quad m=4, \quad m=5, \quad m=6\,\}$$

The different potential parts of eq. (2), each associated with a certain degree n and order m can then be represented by the following table:

Table 11: Components of the tidal potential

$\boldsymbol{V_{nm}}$	long periodic	1/1-diurnal	1/2- diurnal	1/3-diurnal	1/4-diurnal	1/5-diurnal	1/6-diurnal
Degr.n/ord.m	0	1	2	3	4	5	6
1	V_{10}	V_{11}					
2	$\boldsymbol{V_{20}}$	$\boldsymbol{V_{21}}$	$\boldsymbol{V_{22}}$				
3	V_{30}	V_{31}	V_{32}	$\boldsymbol{V_{33}}$			
4	V_{40}	V_{41}	V_{42}	V_{43}	$\boldsymbol{V_{44}}$		
5	V_{50}	V_{51}	V_{52}	V_{53}	V_{54}	$\boldsymbol{V_{55}}$	
6	V_{60}	V_{61}	V_{62}	V_{63}	V_{64}	V_{65}	$\boldsymbol{V_{66}}$

This table illustrates the distribution of the different degrees of the TGP over the tidal frequency bands. Evidently, the seven $\boldsymbol{V_{20}}, \boldsymbol{V_{21}}, \boldsymbol{V_{22}}, \boldsymbol{V_{33}}, \boldsymbol{V_{44}}, \boldsymbol{V_{55}}, \boldsymbol{V_{66}}$ cover the whole tidal frequency range without overlapping; moreover, they also represent the strongest potential functions. Therefore, they are referred to as (unique) **reference potential functions** for each order m, i.e. each tidal band**.** Analogously to eq. (4), (5), (6), constituents of the same degree as the reference potential functions around a main constituent $xxxx_i$ (see Table 9) will be bundled as reference wave groups $xxxx_i$ (n_i, m_i), (i=1,…,n_{wg}; xxxx being a place holder for unique symbols over all tidal bands; $n_i, m_i = degree\ and\ order$). Consequently, their frequency group domains $\Delta\omega_i$ cover the tidal frequency range completely.

Having defined the reference wave groups $xxxx_i$, care has to be taken of the remaining potential functions V_{nm} in the different columns of Table 11 as **non-reference** potential functions. Although they share the same tidal band, they are exhibiting a different response of the Earth due to belonging to different degrees. To illustrate this effect, Table 12 presents the gravimetric parameters δ_i for the DDW-NHi- Earth model (DDW-Nhi phase shifts κ_i = 0):

Table 12: gravimetric tidal amplitude factors δ_i for DDW-NHi Earth Model

V_{nm}	δ_i –long periodic	δ_i –1/1-diurnal	δ_i –1/2-diurnal	δ_i –1/3-diurnal	δ_i –1/4-diurnal	δ_i –1/5-diurnal	δ_i –1/6-diurnal
Degr.n/ord.m	0	1	2	3	4	5	6
1*	1.00000	1.00000					
2	1.15992	1.15320	1.16199				
3	1.07153	1.06913	1.07186	1.07360			
4	1.03900	1.03900	1.03900	1.03900	1.03900		
5	1.02400	1.02400	1.02400	1.02400	1.02400	1.02400	
6	1.01750	1.01750	1.01750	1.01750	1.01750	1.01750	1.01750

** The elliptical shape of the Earth leads to a "fluttering" of the Earth on its orbit around the common centre of gravity of the Earth and the Moon and therefore causes no deformation of the Earth. The associated variation of g is of equal magnitude everywhere on the Earth at the same time, but, of course, variable with time, and therefore exhibits tidal character. When a homogeneous gravity field is acting on the Earth, no deformations will be generated. As a consequence of this contribution, the Love numbers h, k, l, associated with W1 have to be equal to zero and the amplitude factor δ_i(W1) will be equal to 1* (Wilhelm, 1983).

It should be noted that the long periodic and diurnal gravimetric tidal factors δ_i are frequency dependant for degree 2 due to core resonance and latitude variability. Their table values correspond to the beginning of the LP or diurnal domain.

The degree-wise modelling of the constituents of the non-reference potential functions in separate wave groups is achieved for each reference domain $\Delta\omega_i$ by a flexible wave group generating procedure. For this purpose, a single option O_i for each of the degrees 1 and 3 to 6 has to be chosen so that each $xxxx_i$ is supplied with a 5-digit "option code" (degree 2 is not represented because all degree 2 wave groups are reference groups) with the following meaning:

$$Option\ code \in \{degree\ 1,\ degree\ 3,\ degree\ 4,\ degree\ 5,\ degree\ 6\}$$
$$= \{\ O_1 \quad O_3 \quad O_4 \quad O_5 \quad O_6\ \}$$

$$= O_1O_3O_4O_5O_6$$

with options $O_i \in \{0,1,2,3\},\ i \in \{1,3,4,5,6\}$

Options O_i can therefore take on the values $0, 1, 2\ or\ 3$ as explained in the examples below:
"13211" means: option 1 for V_{1i}, option 3 for V_{3i}, option 2 for V_{4i}, option 1 for V_{5i} and V_{6i}. If there are constituents of other potential degrees with higher amplitudes than the V_2- waves, the V_2- constituent with the highest amplitude will nevertheless give its name to the wave group.

The different options O_i are used to encode the following actions:

- **Option $O_i = 0$: Reference wave group modelling**
  - standard modelling of reference wave group $xxxx_k$ by means of an Earth model like DDW-NHi, DDW-NH, WDZ-Hi, where the constituents of V_{im_k} in $xxxx_k$ are normalized with their amplitude factors according to eq.(6a).

- **Options $O_i > 0$: Non-reference wave group modelling:**

  Option $O_i = 3$: for each reference wave group $xxxx_k$, extended over $\Delta\omega_k$ and belonging to degree n_k, modelling all constituents of degree $i \neq n_k$ in so-called "satellite" wave groups" $Vi\!:xxxx_k$;

  - **Option $O_i = 2$** : for each reference wave group $xxxx_k$, extended over $\Delta\omega_k$ and belonging to degree n_k and order m_k, modelling all constituents of degree i, $i \neq n_k$, and the same order m_k, in (standalone) "band container" wave groups V_{im_k};

  - **Option $O_i = 1$** : for each reference wave group $xxxx_k$, extended over $\Delta\omega_k$ and belonging to a degree n_k , modelling all constituents of degree i, $i \neq n_k$ and arbitrary orders m in (standalone) "degree container" wave groups V_i.

Increasing options 0 - 3 are indicating rising amounts of details in modelling. Depending on the individual records, optimal combinations, possibly in several variants, can be designed. In case that the record lengths are sufficient, option 3 should be taken as first choice. In case of shorter record lengths or if the parameters of the wave groups cannot be determined with required precisions due to small amplitudes, option 3 is not applicable. Instead, options 2, 1 or 0 lead to adequate approximations.

Although all defined options can principally be combined in all variations, one has to take care about a special feature of the tidal potential already emphasized in section 4 and Figure 2: Examining the frequency structures of all wave groups with respect to TGP degrees, 2 subsets can be identified:

- Subset I of even potential degrees : $\{\boldsymbol{V_2}, V_4, V_6\}$ with principle degree $\boldsymbol{V_2}$
- Subset II of odd " : $\{V_1, \boldsymbol{V_3}, V_5\}$ with principle degree $\boldsymbol{V_3}$

The wave groups of the principle degrees 2 (in subset I) and 3 (in subset II) have in common that their main constituents are accompanied by either 1 or 2 constituents of the remaining degrees of their groups, exhibiting the same frequencies (Annex 1). The worst example is the relationship of $V_{10}\ and\ V_{30}$ which consists of constituents of the same frequencies and despite a 180° phase shift are correlated to 100%. Applying the option code procedure would then lead to wave groups within each of the subsets I, II of nearly identical frequencies. Identical frequencies, however, especially for wave groups with narrow frequency ranges, will cause highest and even total correlations of the associated parameters.

The conclusion then is to analyze the cross-overs in subsets I and II, resulting in a set of potential functions of minimum correlations denoted by tier1 priority. The options for this set can be chosen as 2 or 3, depending on the general resolution properties of the record under consideration. The detailed representation will be:

Tier1 priority: V_{20}, V_{21}, V_{22},
V_{30}, V_{31}, V_{32}, V_{33},
V_{43}, V_{44},
V_{54}, V_{55},
V_{65}, V_{66}.

The remaining potential functions, denoted as,

Tier2 priority: V_{10}, V_{11},
V_{40}, V_{41}, V_{42},
V_{50}, V_{51}, V_{52}, V_{53},
V_{60}, V_{61}, V_{62}, V_{63}, V_{64}.

are not that easy to handle because adding any V_{ij} of the tier2 priority set will definitely induce high correlations accompanied by low signal strengths. Options 2 or 1 will be appropriate or option 0 as last resort. In this context, it should be emphasized that a joint analysis with V_{10} and V_{30} is anticipated to deliver troublesome results as the frequencies of their major constituents coincide (see definition of subset II above). For the rest, it is difficult to predict which elements of tier2 priority lead to acceptable results for a specific record. Therefore, an iterative procedure is required which will be discussed in detail in section 9 of part III.

Furthermore, the application of option O = 1 should briefly be considered. Since this option comprises degree-wise wave groups over the total tidal frequency range, correlation is here no problem. But caution is required similarly to option O = 2, because these two options do generate multi-frequency wave group signals. Hence, Pandora's box might be opened in allowing for leakage all over the tidal parameters and thus making it difficult to interpret the results.

Summarising, the general form of a reference wave group $xxxx_i$ is defined as presented in Table 12a:

Table 12a : General form of a degree based wave group definition including an example

Name/ symbol	**lower freq. bound**	**upper freq. bound**	**degree**	**order**	**option code**
$\boldsymbol{xxxx_i}$	$\boldsymbol{f_{l,i}}$	$\boldsymbol{f_{u,i}}$	$\boldsymbol{n_i}$	$\boldsymbol{m_i}$	$\boldsymbol{O_{1i}O_{3i}O_{4i}O_{5i}O_{6i}}$
	cpd	cpd			
O1	0.929390	0.929960	2	1	23221
	Generated	**wave groups**			**Description**
V11	0.58	1.48	1	1	add all V1 tides in O1-range to V11
V3:O1	.929390	.929960	3	1	Satellite wave group
V41	0.58	1.48	4	1	add all V4 tides in O1-range to V41
V51	0.58	1.48	5	1	add all V5 tides in O1-range to V51
V6	0.58	1.48	6		add all V6 tides in O1-range toV6

It should be noted that the option code procedure is implemented in the ET34-ANA version (Schueller, 2015,2017) in such a way that the non-reference wave groups are automatically generated according to the option codes specified.
It should also be mentioned that ET34-ANA allows to introduce the non-linear tides to "clean" the tidal residuals z(t), especially in the ter-diurnal and higher tidal bands. Moreover, the spectral analysis of the residuals z(t), based on its autocovariance function as the only reliable source of spectral information for stochastic processes, provides an automatic detection of the non-linear tides and/or any other additional

residual energy concentrations. Furthermore, ET34-ANA deals with physical regression channels in the most general way by modelling their impulse response functions by causal filters of arbitrary lengths. As a result, frequency transfer functions between Earth tides and physical channels can be analysed. ET34-ANA is now to our knowledge the most versatile analysis method.

8. Crucial determinants of tidal analysis

In the introduction, the question was put under what circumstances it would be possible to achieve a certain precision for tidal parameters. For answering this question some derivations have to be performed first.

In a general form, the RMSE of a tidal amplitude factor yields (Schueller 2017):

$$m_{\delta_i^*} = \frac{m_0}{\delta_i^*} \sqrt{x_{c_i}^{*2} q_{x_{c_i}^*, x_{c_i}^*} + x_{s_i}^{*2} q_{x_{s_i}^*, x_{s_i}^*} + 2 x_{c_i}^*, x_{s_i}^* \, q_{x_{c_i}^*, x_{s_i}^*}} \tag{7a}$$

with the elements $q_{x_{c_i}^*, x_{c_i}^*}$ of the co-factor matrix $\boldsymbol{Q}_{\boldsymbol{x}^*}$ being the inverse of the normal equation matrix.
Without loss of generality and only for simplicity reasons, it is assumed that κ=0 so that

$$m_{\delta_i^*} = m_0 \sqrt{q_{x_{c_i}^*, x_{c_i}^*}} \tag{7b}$$

and

$$m_{\delta_i} = \delta_i^{EM} \, m_0 \sqrt{q_{x_{c_i}^*, x_{c_i}^*}} \tag{7c}$$

Let now be

- N = record length,
- u = number of model signals $e_k(t), f_k(t)$ (see eq. (5))
- m_0 = estimate of the true σ RMSE of a single observation
- A_{xxxx_i} = RMS theoretical amplitude of wave group $xxxx_i$

With these definitions, the key issues for understanding the interactions of the quantities involved will be pursued as follows.

8.1 The impact of correlation

8.1.1 The resolution mechanism

As already stressed, the Rayleigh-criterion is often used to decide, if any 2 harmonics could be separated. This criterion is derived from the general concept of window functions, where the Rayleigh distance in frequency is equal to that of the centre of main lobe of the spectral rectangular window (see Fig.3, narrow window) to its 1st zero crossing. This frequency distance is also equivalent to the fundamental Fourier frequency of a Fourier series expansion.
Other windows like the Hanning window (see Fig.3, broad window) exhibit different resolution properties. Here, the general rule is: higher resolution goes with less convergence of the side lobes, i. e. more leakage and vice versa. In this sense, the spectral window function gives a first indication on the correlation of any two model signals (eq. (5)) of a certain distance in frequency.
It has further to be mentioned that gaps in a record can distort the spectral window function and consequently the resolution pattern considerably. In this case, an analytical anticipation of how the actual resolution would be is not achievable. The only reliable method is to numerically evaluate the window function (as it is done in ET34-ANA).

As a matter of fact, the disadvantageous impacts of gaps on resolution are often overlooked and the window properties are assumed to be similar to those of an uninterrupted record which is definitely not the case.

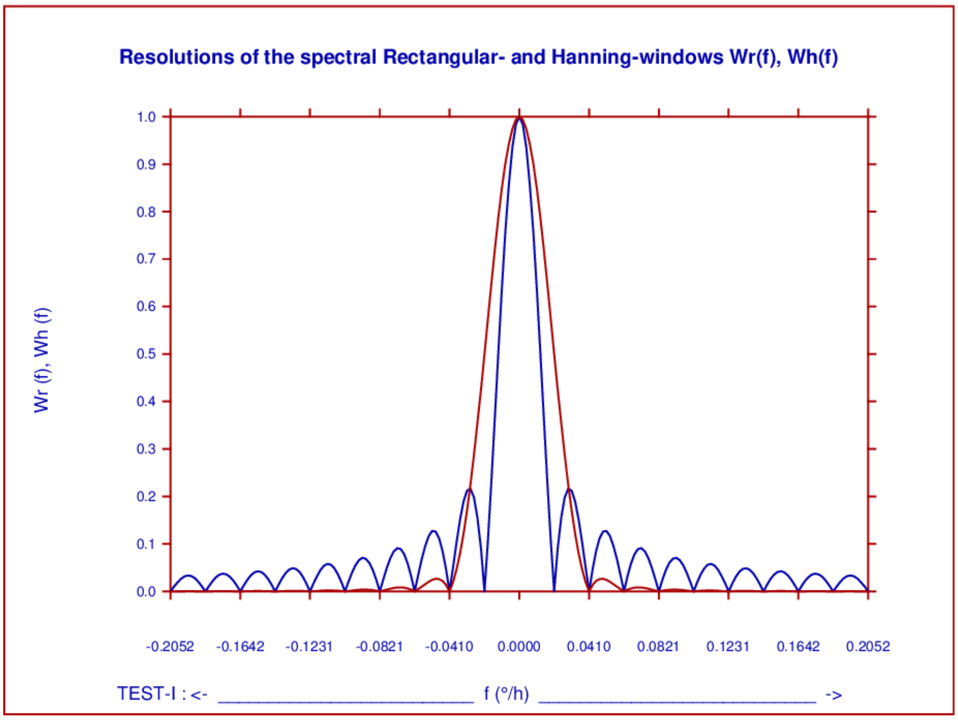


Figure 3: Spectral windows for a 2 years record

8.1.2 Correlation

A more precise measure of the correlation of model signals and subsequently of the unknown parameters of a LS analysis is exposed by their correlation matrix **R**. Given the cofactor matrix $\boldsymbol{Q} = \boldsymbol{N}^{-1}$, in the following notation with cofactors q_{ii}, q_{ij} and correlation coefficients r_{ij} as

$$\boldsymbol{Q} = \begin{bmatrix} q_{11} & r_{12}\sqrt{q_{11}}\sqrt{q_{22}} & \cdots \\ \vdots & \ddots & \vdots \\ \cdots & \cdots & q_{nn} \end{bmatrix} \tag{8}$$

The correlation matrix **R** is then defined as

$$\mathbf{R} = \mathbf{diag}(\boldsymbol{Q}^{-\frac{1}{2}}) \cdot \boldsymbol{Q} \cdot \mathbf{diag}(\boldsymbol{Q}^{-\frac{1}{2}}) \tag{8a}$$

with elements

$$-1 \leq r_{ij} = \frac{q_{ij}}{\sqrt{q_{ii}}\sqrt{q_{jj}}} \leq 1 \tag{8b}$$

If eq. (5) is written in matrix notation as **y=Ax+z** and the least squares principle applied as $\boldsymbol{z}^T\boldsymbol{z} = \boldsymbol{min}$, the estimator for unknown parameters yield

$$\hat{\boldsymbol{x}} = (\boldsymbol{A}^T\boldsymbol{A})^{-1}(\boldsymbol{A}^T\boldsymbol{y}) = \boldsymbol{N}^{-1}\boldsymbol{w} \tag{8c}$$

(see Schueller 2017 for details).

With (8c), a single unknown parameter-estimate $\hat{x}_{c,i}$ can be written as

$$\hat{x}_i = \delta_i^{EM} \sum_{j=1}^{u} q_{ij} w_j \tag{9}$$

In (9), the elements q_{ij} are the cofactors composed of the model signals $e_i(t), f_i(t), e_j(t), f_j(t)$ and w_j as the cross energies of the observations with the model signals. It is evident that if any two analysed parameters i and j are uncorrelated, they only dependent on their own frequency domains i and j. In the correlated case, however, the off-diagonal cofactors q_{ij} for i$\neq j$ are not equal to zero but try together with the w_j to compensate the leakages from other frequency domains as $q_{ij}w_j$-products (see (9)).
When applying the error propagation law to the summands of (9), it is obvious that the RMSE of the parameters must be greater for the correlated case. The more spectral domains participate in providing a leakage-free parameter estimate, the more the associated residual energies accumulate and contribute to the RMSE of the parameter. With eq. (8c), the expression for the variance – covariance matrix of the parameters results in the application of the error propagation law in matrix form as

$$\mathbf{Q}_{\hat{x}} = (\boldsymbol{A^T A})^{-\mathbf{1}} \boldsymbol{A^T Q_y} ((\boldsymbol{A^T A})^{-\mathbf{1}} \boldsymbol{A^T})^{\boldsymbol{T}}$$

and with $\boldsymbol{Q_y} = \boldsymbol{I}$ follows

$$\mathbf{Q}_{\hat{x}} = (\boldsymbol{A^T A})^{-\mathbf{1}} \tag{9a}$$

which is exactly (8). Vice versa, if no correlation is present, only the frequency domain from which a parameter is originated contributes to its co-factor which can directly be taken from the normal equation matrix **N** as $q_{ii} = 1/n_{ii}$.

Basically, these (algebraic) correlations are nothing bad as long as long as it is accounted for and the RMSE can be kept sufficiently small. This exactly happens in LS in contrast to spectral analysis. The difference between these two estimation methods is that spectral analysis simply disregards any correlations of signals. To end up with reliable results from spectral analysis, the signals have to be uncorrelated by nature, which is seldom true. Therefore, the role of window functions with optimal side lobe properties is much more important in spectral analysis because this is the only way to avoid the impacts of correlations or "leakage" as it is called there. Also, long record lengths are needed just because of the convergence of the window side lobes with record length. In LS, windows functions become important, if the functional model is incomplete. Then, the window acts as a shelter reducing the unaccounted energies in the observations from leaking into the parameters to be analysed. As a conclusion, LS and spectral analysis results converge to the same estimates as record lengths go to infinity and no gaps are present.
As conclusion from this discussion: with correlations a disadvantageous fact that has to be taken into account because the RMSEs of correlated quantities are principally higher than in the uncorrelated case. Therefore, the impact of correlation has to be carefully observed, especially, if high accuracies are required. In such a situation, it might be indicated to sacrifice resolution to be rewarded with lower RMSEs.

8.1.3 The Spectral Correlation Viewer

The "Spectral Correlation Viewer (SCV)" of ET34-ANA illustrates how wave groups are correlated with other groups of the same potential order by representing the window function and correlation coefficients related to the parameter estimates. In the example of Figure 4, a wave grouping which should actually require 18.61 tropical years, was analysed from a record length of only half of that length. The dots represent the correlation coefficients in comparison to the spectral rectangular window function.

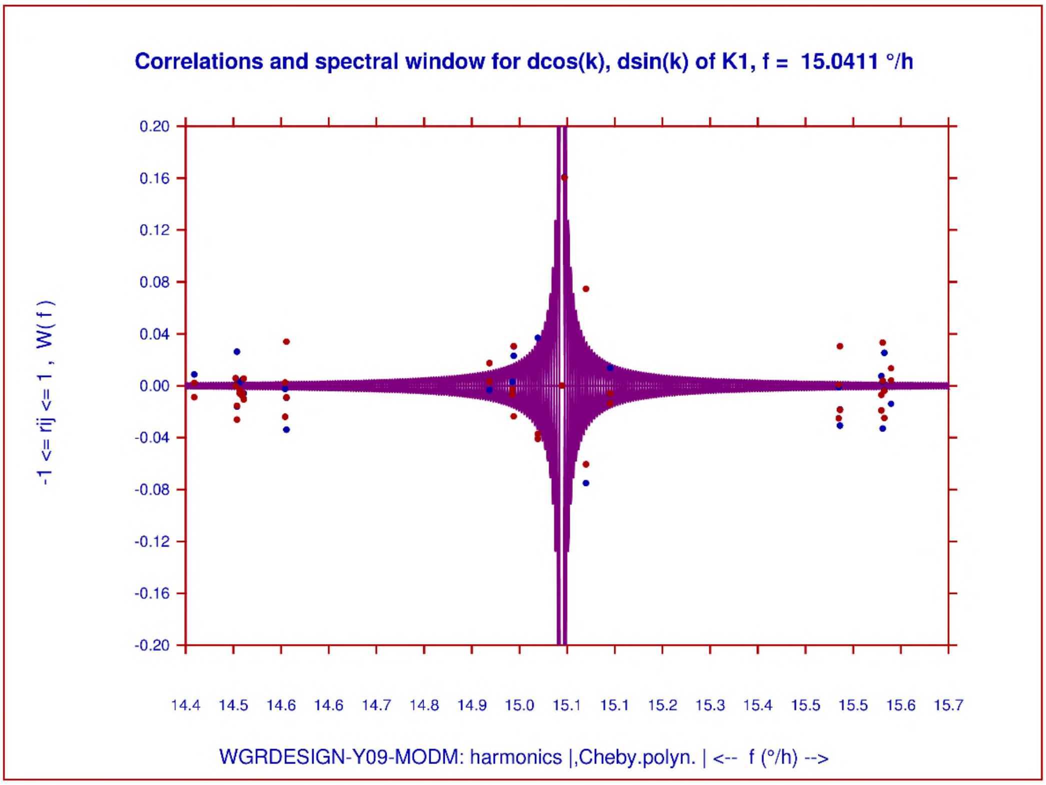


Figure 4: Correlations and spectral rectangular window function for K1 (9 years record length)
Blue dots and red dots correspond to odd and even components of the unknowns

Both the spectral window function values as well as the correlation coefficients are qualitative indicators of interactions between the model signals. If any 2 harmonic model signals are of the same frequencies, their correlation coefficient will be equal to 1, no matter how big the individual signal strengths, i. e. amplitudes, are.
As an overall criterion of the numerical stability with regard to the solution of the normal equations (eq. (8c)), the condition number $k = \frac{\lambda_{max}}{\lambda_{min}}$ with λ_{max} and λ_{min} as the maximum and minimum eigenvalues of $\boldsymbol{N^{-1}}$ in eq. (8c) is used in ET34-ANA.

However, there is an urgent demand for an absolute criterion which indicates to what order of magnitude these interactions will affect the analysis. As already pointed out, resolution determines the reliability of analysis results. If too much resolution is demanded from a certain record length, the price will be paid by less reliability. The question is how much that would be.

8.1.4 The Correlation RMSE Amplifier (CRA)

The introduction of the "**Correlation RMSE Amplifier (CRA)"** will solve this problem (Schueller 2017). It is defined via the CRA as the ratio

$$f_{CRA,i} = \frac{m_{\delta_i}}{m_{\delta_i,uncorr}} \tag{10}$$

The quantity $m_{\delta_i,uncorr}$ will be derived from (7c) not by inverting the normal equation matrix **N** but taking directly the reciprocals as cofactors of the parameters:

$$m_{\delta_{i,uncorr}} = \delta_i^{EM}\, m_0 \sqrt{q_{x^*c_i,x^*c_i}} = \delta_i^{EM} \frac{m_0}{\sqrt{n_{x^*c_i,x^*c_i}}} \approx \frac{m_0\sqrt{2}}{A_{xxxx_i}\sqrt{N}} \qquad (11)$$

In so far, $m_{\delta_{i,uncorr}}$ is the RMSE of a parameter, which would be derived from an analysis of (fictive) observations, only containing the i-th wave group and therefore being free of any correlation impacts. It is clear that under these circumstances, the best correlation situation is achieved. The comparable situation in reality would be if a tidal record would be long enough that all model signals are prove to be uncorrelated. Then

$$m_{\delta_i} = m_{\delta_{i,uncorr}} \quad \text{and consequently} \quad f_{CRA,i} = 1 \qquad (12a)$$

Eq. (12a) shows that $m_{\delta_{i,uncorr}}$ represents the limit to which m_{δ_i} converges under best circumstances. On the other hand, if any 2 wave groups are totally correlated, m_{δ_i} and likewise the CRA, would grow to ∞.

It is remarkable that $f_{CRA,i}$ is not dependent on m_0 (because it is cancelling out as eq. (9) shows), but only on the elements of the co-factor matrix, i.e. on the model signals $e_k(t), f_k(t)$. Hence, the CRA is a real and unbiased metric of the appropriate wave group design.
It has further to be emphasized that, if any 2 correlated model signals to be resolved meet a sufficient record length, CRA will be close to 1 so that correlation does not affect the parameter estimation anymore. The RMSE of the analysed parameters are then only function of $\sqrt{1/\mathrm{N}}$ and will decrease with increasing record lengths N by $1/\sqrt{N}$. Hence, the CRAs derived from an analysis will be used to check whether they are close enough to 1, otherwise further aggregation of the wave groups in question have to be accomplished. Following this procedure, a proposal of wave groupings for certain standard records lengths, e.g. 20, 9, 4, 2, 1 years or even shorter can be elaborated.

8.2 Observation precision

The 2nd quantity, influencing the RMSE of the parameters is the precision of the observations. It is generally denoted as true RMSE σ and reflects the energy of a stochastic process inextricably linked to measurements.
However, σ is generally not known and has to be estimated as m_0 from the residuals of a tidal analysis. Then, it does not only contain the random process initially associated with the observations, but all kinds of additional signals of direct and indirect nature inducing signals of tidal frequencies. If these signals are not properly accounted for, they will remain in the residuals and therefore cause a rise of RMSE m_0, especially around the tidal frequencies (see Munk and Hasselmann 1964 for "tidal cusps"). Also, deficiencies of the functional model (eq. (5)) will be reflected in the residuals. For this reason, all available means of signal modelling should be activated to functionally describe the observations to the highest possible degree. In so far, one should not give a second thought on parameter parsimony for gaining more degrees of freedom.
It often happens in LS that m_0 is assumed to be valid for all parameters with frequencies over the whole Nyquist interval. However, regarding the contents of the residual signals as described above, this assumption cannot be maintained. Instead, the m_0 − estimation has to occur in dedicated frequency domains $\Delta\omega_i$ with ω_i as centre frequency so allow m_0 to become frequency dependent.
The relation between these $m_0(\omega_i)$ and their spectral representations as domain noise amplitudes $A_z(\omega_i)$ and the number of observations N is given by

$$A_z(\omega_i) = 2\,\frac{m_0(\omega_i)}{\sqrt{N}} \qquad (12b)$$

Inserting (12b) into (11) yields:

$$m_{\delta_{i,uncorr}} \approx \frac{m_0(\omega_i)\sqrt{2}}{A_{xxxx_i}\sqrt{N}} = \frac{A_z(\omega_i)}{A_{xxxx_i}\sqrt{2}} \qquad (12c)$$

Eq. (12c) now gives a direct insight into the noise to signal relation of a certain parameter i under consideration which will be further expanded in the next section.

8.3 Quality labels for tidal parameters

With the derivations and definitions of the previous sections, it is now possible to define the meaning of "significance" in a broader sense than it is usually done in statistics. This is achieved by providing quality labels for the analysed tidal parameters so that its use in subsequent applications can be anticipated.
For this purpose, let us define a set of quality labels $\mathbf{\Theta} = \{\Theta_h, \Theta_m, \Theta_l\ , \ldots.\}$ which are linked to associated intervals of the relative RMSE Ψ. In this paper, the following 3-tier label structure is proposed (which can be extended to a more detailed one depending on the objectives of a specific project):

- $\Theta_h\ = high\ quality$ or high significance (e.g. $\Theta_h \leq\ 0.1\ \%$)
- $\Theta_m = medium\ quality$ or acceptable significance (e.g. $0.1\ \% < \Theta_m \leq\ 5\ \%$)
- $\Theta_l\ = low\ quality$ or insufficient significance (e.g. $\Theta_l\ >\ 5\ \%$)

With these predefinitions, a **hypothesis test** can be performed by demanding the following expression to be "true":

$$\Theta_*\ \geq \Psi_i[\%]\ = \frac{100\ m_{\delta_i}}{\delta_i}\ =\ 100\ m_0 * f_{CRA,i} * m_{\delta_i,uncorr} = f_{CRA,i}\ \frac{100\ m_0\ \sqrt{2}}{A_{xxxx_i}\sqrt{N}} \qquad (13)$$

Other than in statistics, where the "critical" interval boundaries to be tested are associated with probability distributions, the labels Θ_* are chosen with respect to boundary conditions imposed by follow-up applications. The advantage of this perception is that it is orientated on the physical meaning of the uncertainty of a parameter estimate. Therefore, it might occur that, although a parameter is significant in a statistical way, it is not precise enough with respect to a certain application. Consequently, the introduced quality labels are primarily governed by an application oriented demands of precision.
With fundamental inequality (13), the meaning of "significance" is immediately obvious: a parameter δ_i is called "significant" if it can be supplied with the highest quality label of the quality set which is equivalent to inequality (13) to be "true" for $\Theta_* = \Theta_h$. In this case, δ_i would be considered as stable and reliable enough to be introduced to further dispositions for explaining physical phenomena (Baker and Bos 2003).
If (13) turns out to be "false", the remaining quality labels of the quality set will be tested successively unless the test delivers a positive outcome or the lowest label is reached.

Vice versa, if instead of the relative parameter errors Ψ_i , the analysed $f_{CRA,i}$ should be constraint by quality labels, the corresponding inequality yields with (13)

$$\Theta_* \geq f_{CRA,i} = \Psi_i[\%] \cdot \left(\frac{100\ m_0\ \sqrt{2}}{A_{xxxx_i}\sqrt{N}}\right)^{-1} \qquad (13a)$$

Since the $f_{CRA,i}$ act as amplifying factors of the best error estimates achievable, the following quality labels
are proposed:

- $\Theta_h\ = acceptable\ result$ (e.g. $1\ \leq \Theta_h\ \leq\ 2$)
- $\Theta_m = take\ result\ with\ care$ (e.g. $2\ < \Theta_m \leq\ 7$)
- $\Theta_l\ = inacceptable\ result$ (e.g. $\Theta_l\ >\ 7$)

By means of (13a), it is easy to assess, if the objectives of a measurement campaign can be confirmed by the analysis results.

Formulas (13) and (13a) impressively illustrate that the influencing quantities can be represented in a surprisingly simple inequality. It is an interaction between (theoretical) signal strength (A_{xxxx_i}), signal correlation ($f_{CRA,i}$) , record length (N) as model quantities, as well as statistical impacts represented by the precision of the observations ($m_0(\omega_i)$).
As an example, with Eq. (13) it can be explained that if m_0 can be made arbitrarily small, the RMSE of the parameters will decrease, even if the model signals are strongly (but not totally) correlated. This effect was visible in the TGP development of Hartmann and Wenzel 1995 by resolving the sun's ascending node frequency by LS techniques within 300 instead of 10000 years. Since the TGP series can be considered as nearly free of noise, the associated $m_0(\omega_i)$ are close to 0. Although the CRAs are considerably high, they are compensated by the high precision of the TGP series (eq. (13)) so that even constituents of comparably close frequencies can be resolved. M.S. Kudryavtsev 2003, however, used spectral technics for his TGP development. Hence, he needed a far longer TGP series (2000 years) to obtain the same resolution, because he has to control in leakage by means of the Hanning window. As pointed out in section 8.1.2, leakage control is directly incorporated in the LS procedure and therefore, LS is the far more suited method for analysing time series, especially, if the frequencies are known in advance.

By assuming typical frequency dependent $m_0(\omega_i)$ - values for a superconducting gravimeter, the following table allows to calculate precise predictions, if parameters can be significantly determined:

	N	A(xxxxi)	m0-LP	m0-month	m0-D	m0-SD (nms**-2)	m0-TD	m0-QD	m0-1/5D	m0-1/6D
years	h	1,00	300,00	40,00	3,00	1,50	0,60	0,50	0,40	0,30
			relative Root Mean Square Errors (rRMSE)							
18,61	163.161		105%	14,00%	1,05%	0,53%	0,21%	0,18%	0,14%	0,11%
9,31	81.581		149%	19,81%	1,49%	0,74%	0,30%	0,25%	0,20%	0,15%
4,65	40.790		210%	28,01%	2,10%	1,05%	0,42%	0,35%	0,28%	0,21%
2,33	20.395		297%	39,61%	2,97%	1,49%	0,59%	0,50%	0,40%	0,30%
1,16	10.198		420%	56,02%	4,20%	2,10%	0,84%	0,70%	0,56%	0,42%

Table 13: Standardized relative RMSE for m0=1 nms^{-2}, signal amplitude A_{xxxx_i}=1 nms^{-2}, $f_{CRA,i}$=1

These values apply directly on the amplitude factors δ. For the phase differences κ a rule of the thumb states that an error of 0.57° in phase is associated with an error of 1% on δ.
Hence, by means of Table 13, any prediction on significance for a special case can be derived by simply multiplying the table values with the case parameters according to inequality (13). For example, it should be possible to determine the amplitude factor of the wave ψ_1 (amplitude 3.42mn/s^2 at 45° latitude) with a precision of 0.3% on 18,61 years series of a standard superconducting gravimeter (m0 = 1 nms^{-2}), as the RMSE is 1.05% for a diurnal wave with an amplitude of 1 nms^{-2}. This table allows also to answer the question raised in the introduction concerning the smallest waves that can be determined with a precision better than 1 %.
As a conclusion, the significance of a certain parameter can be stated, if both resolution and precision can be controlled in such a way that the RMSE of a parameter, derived from a least squares analysis, can be brought below a chosen quality label Θ_h. For instance, if the precision of the observations is high enough, even high algebraic correlations, represented by a high CRA, might not cause rRMSE Ψ to exceed quality label Θ_h and hence "significance" can be stated. It also makes no sense to impose a too low Θ_h value, otherwise one would sacrifice resolution to "overkill significance". The best solution is an optimal compromise between resolution on the one hand and significance on the other.
ET34-ANA is fully supporting this concept by providing the **CRA factors** $\boldsymbol{f_{CRA,i}}$ for all amplitude parameters of the analysed wave groups.

8.4 Rules for a tidal wave group model and subsequent tests

From the theoretical background presented so far, rules for how to proceed in practical tidal analysis are to be derived. In a more general sense, a so-called "wave grouping model" including a data definition and procedural part, is required for all occurrences of tidal observations. Inequality (13) illustrates clearly that the f_{CRA} (in the following also simply referred to as CRA) is the quantity of overall importance because it is the only variable of the wave group model which can be influenced via an alternative wave group design. Hence, the following rules, statements, and actions for designing an optimal wave group model can be formulated as follows:

- **Set up the structure to define a suitable wave group model:**
  - o Characterising the general wave group model by the following denotation: Yyy-Rrr- cccccc-(jjj)
    - ▪ Yyy refers to the record length of yy years,
    - ▪ Rrr refers to the resolution model of the main reference wave groups designed for a data length of rr years and CRAs close or equal to one (Rayleigh-criterion), i.e.
      - R18: resolution model designed for safely resolving the nodal frequencies (-, xxx, +) of wave group xxxx in > 18,61 years
      - R09: aggregation of R18 by dropping the nodal waves (-, +), resolving the Moon's perigee and double nodal waves (--, ++).
      - R04: aggregation of R09: for tides, annual modulations can be safely resolved, for non-tidal harmonics, those of 4 years periods can be resolved.
      - R01, R02: same as R04 but non-tidal periods can be resolved with respect to the record length.
    - ▪ cccccc primarily refers to the resolution model of the non-reference wave groups, also denoted by "option code models" (section 7):
      - for reference wave groups
        - o 00000: pure reference wave grouping (e.g. Y09-R09-00000)
      - for non-reference wave groups
        - o all : 00000 + all wave groups of tier1 <u>and</u> tier2 priorities (section 7)
        - o allopt : 00000 + optimal wave grouping by choosing options for wave groups in such a way that CRAs < 10 are guaranteed
        - o safe : 00000 + only tier1 priority wave grouping
    - ▪ (jjj) means an optional label to describe model variants of a specific wave group model
      - for reference wave groups
        - o Any alpha-numerical label like A01, A02,…. in case of aggregations like Y04-R04-00000-A01, Y04-R04-00000-A02.
      - for non-reference wave groups
        - o Any alpha-numerical label like 01, X02…

- Actually, the complete resolution model consists of 2 parts
  - The resolution model for the reference wave groups
  - The resolution model for the wave groups within the reference wave groups of different degree

- As an **overall principle,** a reasonable compromise between the diverging characteristics of an optimal resolution on the one hand and sufficient reliability on the other hand has to be found. This includes also a compromise of unconstraint wave group parameter modelling or taking advantage of constraining the functional model by introducing the admittances of a specific Earth model.

- The optimal wave group model is exclusively dependent on the correlation pattern illustrated by the CRAs because

  - the record length is always given and must be taken as is
  - the signal strengths are also given for a certain location and cannot be changed
  - the precision of the observations has to be taken as is and cannot be changed
  - **=> wave grouping is the only variable that can be influenced by the analyst**

Moreover:

- Start always with wave group structures with ambitious initial resolutions (about 4 times finer than the Rayleigh criterion postulates). Especially for V_2 on the basis of Tables 9 and 10:
  - Check for application of annual modulation waves xxxa, xxxb
  - Check for the application of double nodal waves xxxx--, xxxx++
  - Check for the application of nodal waves xxxx-, xxxx+

- The fields in the result tables may exhibit colours to illustrate quality labels as defined in section 8.3; the colours are borrowed from traffic light conventions and mean the following:

	Red = Θ_l	**CRA $\geq$ 7**	**unacceptable result**
	Yellow = Θ_m	**2 < CRA < 7**	**take result with caution**
	Green = Θ_h	**CRA $\leq$ 2**	**acceptable result**

- Regard minimum signal strengths for qualifying as candidate of a wave group with option 3:

Tidal bands	**Minimum main amplitudes for O=3**
	(nms^{-2})
Long periodic	1.0000
Diurnal	0.5000
Semi-diurnal	0.3000
Ter-diurnal	0.2000
1/4 diurnal	0.0050
1/5 diurnal	0.0004
1/6 diurnal	0.0001

- Generate pure tidal model data as test data
  - Simulate gaps if present in the real data
  - Simulate precision by superimposing a stochastic process of an a priori RMSE σ

- Test this structure with the standard functional model of eq. (4), i.e. option code "00000"
  - Iterate by aggregations as long as CRAs are too high
  - Stop if an adequate structure is found

- Structure the option code of each wave group with respect to zonal and tesseral potential parts according to the rules of section 7 including <u>all</u> potential parts of tier1 and tier2 priorities.

  - Check the wave grouping with option codes $\neq$ "00000" by a test analysis with the functional model of eq. (5):
    - Check the plausibility of the parameters
    - Check CRAs
    - Check relative RMSE
    - Iterate by modifying the option codes as long as crucial CRAs are too high.

- Apply the total procedure to real observations.

PART III : Proposals of optimal tidal wave group models

9. Standard tidal wave group models

Traditionally, standard wave groups have been defined for record lengths of 30 days, 6 months, one year, 9 years and 18 years and longer following the Rayleigh criterion. However, as shown in the previous sections, there are lots of opportunities to optimize wave grouping using by the techniques developed.
As a working and test environment, 18.61 tropical years of gravimetric tidal data of the DDW-NHi model have been predicted for the mid-latitude GGP-station of Membach (Crossley et al., 1999) with a sampling interval of 1 hour. According to the ETERNA data format, the hourly values are rounded to 3 digits so that an a priori RMSE $\sigma \approx 0.00029\ nms^{-2}$ is a reasonable guess of the acquired precision.
It has to be emphasized that at other locations of the Earth, the signal strengths will be different. At equatorial stations, for example, the diurnal V_{21} tides are not present. Then, the V_{31} constituents as the strongest signals in the diurnal band have to be modelled directly as main wave groups, but with no other option codes than 0000. For other wave groups, the option code has to be adjusted according to the existence of the different non-reference potential functions. For polar stations, all TGP orders besides m=0 are of small amplitudes and converge to 0 as the latitude approaches 90° so that the proposed wave group structures for mid-latitudes have to be adjusted respectively.

9.1 High resolution wave grouping for a record length > 18 year

The results of the preceding sections will now be applied to derive a high-resolution wave grouping pattern for tidal analysis. For this purpose, the different potential degrees and orders are systematically structured and analysed according to the rules of sections 7 and 8.4.
The actual wave grouping is done according to the procedure described in section 7. To demonstrate the impact of parameter correlations for a given record length (Y18) and a reference wave resolution model (R18), different option code models cccccc = $\{00000, \mathrm{all}, \mathrm{allopt}, \mathrm{safe}\}$ are examined and their results are presented in tables.

9.1.1 Reference waving grouping as model Y18-R18-00000

This model is set up according to section 8.4 to find the optimal wave group structure of the reference wave groups by setting the option code to 00000, i.e. no modelling of non-reference wave groups.
As Table 14a exhibits that all CRAs are = 1 which means that there are practically no correlations between the reference wave groups. Hence, Y18-R18-00000 (see Annex 2.1) will be used model for the grouping of the reference wave groups throughout the other model variants concerning resolution and option codes.

9.1.2 Maximum resolution wave group model Y18-R18-all

This model will comprise *Y18-R18-00000 + all potential functions of priority sets tier I+II* (see section 7), resulting in the most complete model available. Table 14 a-d are summarizing the results, from which the following conclusions can be drawn:

- The condition no. of the normal equations shows an extremely high value of $5.77 * 10^9$, indicating the presence of extremely high correlations of some of the modelled satellite and/or container wave groups.
- A detailed evaluation of the analysis results exhibits the (already predicted) nuisance within subset I $= \{V_2, V_4, V_6\}$: most of the wave groups have very high CRAs (see red colours).

- Likewise, the nuisance within subset II = $\{V_1, V_3, V_5\}$ show high CRAs for the container groups V_{10}, V_{11} and V_{30}, V_{31} as well as for the V_{31}-satellite wave groups. These results demonstrate quite well that the predictions of section 7 have been confirmed by experiment.
- As exception, other than expected, the CRAs of wave groups related to $V_3\ and\ V_5$ behave fairly moderate with respect to correlations.

Another striking observation is that a considerable number of wave groups are not affected by high CRAs. This indicates that the impact of correlation is restricted to those groups being too close in frequencies and that correlation does not leak into wave groups of resolvable frequencies. Consequently, each wave group has to be assessed individually and its behaviour cannot be concluded from the behaviour of others.
The analyses further show that for model series without noise, there are no significant deviations of the tidal parameters from their set points (= parameter values used for the generation of the model series) although the CRAs are high. As inequality (13) predicts, this effect is due to the fact that RMSE m_0 is close to zero and thus, the disadvantageous impacts of high CRAs are compensated by the perfect precision of the model series.

9.1.3 Optimal wave group model Y18-R18-allopt

The drawbacks of the model of the previous section can be cured to a great deal by simply discarding those wave groups causing high CRA-values so that CRAs < 10 are guaranteed. In Annex 2.1, the associated wave grouping is listed, while Annex 2.2 presents the corresponding results table from an ET34-ANA-V70-beta tidal analysis. The improvement of the analysis results is outlined by the condition no. of the normal equations, showing a value of 290 and which is much less than that of the full model of section 9.1.2. As Tables 14 a-d demonstrate, the actions undertaken for improvement succeeded in generating reasonable correlation environments and results.
To cure the severest problems with the $\{V_2, V_4, V_6\}$ interactions, V_{40} and V_{60} have been discarded as well as V_{61} and V_{62} by setting the related option = 0. These actions were sufficient for improving the situation on subset I = $\{V_2, V_4, V_6\}$ to a satisfactory state.
For the diminishing the nuisance between V_{10} ,V_{30} and V_{11}, V_{31}, the chains of correlations of the participating wave groups have to be interrupted. To achieve this purpose for V_{10} and V_{30}, option O_3 for Mm+ has been set =0, because V3:Mm+ is the strongest constituent in V_{30}. Likewise, a similar action has been applied to V3:NO1 = M1 for unchaining $V_{11}$and V_{31}. Consequently, the constituents of highest signal strengths and provoking the highest correlations are no longer able to do any harm but have been integrated into the $V_2 -$ reference groups Mm+ and NO1 respectively.
Finally, V_{50} and V_{51} have likewise been integrated into V_2 by setting the crucial options O_5 = 0. Also, the options O_5 at Na2 and KNO2 are set =0, because these groups are highly correlated with V_{52}.

9.1.4 Safe wave group model Y18-R18-safe

The objective of this model variant is to illustrate a safe (i.e. minimum correlated) solution and to show which wave groups might guarantee this effect. In section 7, such a solution points at the tier1 set of potential functions and related wave groups as 1st priority for wave grouping. For this reason, wave group model *Y18-R18-safe* comprises these tier1 priority wave groups. Tables 14 a-d are summarizing the results.

The condition no. = 34 of the normal equations indicates the same optimal circumstances as in the 00000-option code variant. This proofs that the assumptions on minimum correlation of tier 1 priority set is proven to be right.
A minor drawback of this model is that it leaves out the tier2 priority wave groups. Hence, it would be advantageous to analyse *Y18-R18-allopt with Y18-R18-safe* as supporting supplement.

9.1.5 Analysis results and wave grouping recommendation

Tables 14a-d: Results for the CRAs of different resolution models for an 18.6 years long record

wave group model	Cond.no.	Mf	Q1	O1	P1	K1	N2	M2	S2	K2
Y18-R18-	**All nodal wgr** --,-,+,++									
00000	34	1.53	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
all	$5.77 * 10^9$	13483	1.81	21639	1.00	20357	1.17	2.67	1.00	1.43
allopt	290	1.53	1.71	5.73	1.00	5.49	1.06	1.73	1.00	1.38
safe	34	1.53	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

14.a: CRAs of the major $V_2 -$ wave groups of different resolution models

wave group model	Cond.No.	V10	V11	V30	V31	V32	V40	V41	V42	4MK3	4MO3
Y18-R18-										**MN3**	**ML3**
all	$5.77 * 10^9$	1612	823	1612	80	1.05	14	9	3.68	4.45	3.81
allopt	290	1.05	1.23	1.06	1.05	1.02		8	2.09	1.00	1.00
safe	34			1.01	1.04	1.00				1.00	1.00

14b: CRAs of $V_{1x}, V_{3x}, V_{4x} -$ wave groups of different resolution models

wave group model	Cond.No.	3MK1	3ML1	M1	3MO1	3MO1+	3MJ2	3MK2	3M1LK2	3MO2
Y18-R18-		**Qa1**	**O1**	**NO1**	**J1+**	**KLK1**	**2N2**	**Na2**	**M2**	**KNO2**
all	$5.77 * 10^9$	243	117	719	258	105	1.46	3.38	1.19	3.15
allopt	290	1.07	1.03		1.08	1.01	1.20		1.08	
safe	34	1.01	1.00	1.01	1.01	1.00	1.00	1.01	1.00	

14.c: CRAs of $V_{31} - V_{32}$ wave groups of different resolution models (option 3)

wave group model	Cond.No.	V50	V51	V52	V53	V54	V60	V61	V62	V63	V64	V65
Y18-R18-	**k**											
all	$5.77 * 10^9$	3.76	3.39	4.86	1.63	1.0	13490	29707	2.48	5.77	1.35	1.00
allopt	290			3.05	1.63	1.00						
safe	34					1.00						1.00

14d: CRAs of $V_{5x}, V_{6x} -$ wave groups of different resolution models

We would propose to use wave group model <u>Y18-R18-allopt</u> as fine resolution wave grouping for very long observation records with lengths in years N > 9 (see Annex 2), provided the precision of the observations is high enough to yield significant results. If this is not the case, we would propose to use wave group model <u>Y18-R18-safe</u> instead.

9.2 Aggregation of high resolution tidal wave grouping for medium size record lengths

For an example of a medium sized record length, we choose as data length 1/4 of the nodal period = 4,5 years of the same data described above. The actual wave grouping is done according to the general procedure explained in the previous section.

9.2.1 Reference waving grouping as model Y04-R18-00000

According to the rules, the initial reference wave grouping for this 4.5 years record is the same as for the 18.6 years one. Table 15a shows that this model *Y04-R18-00000 is too ambitious* because the nodal waves, especially when appearing in a triple --, -, xxxx, xxxx, +, ++ and even -, xxxx, + could hardly be resolved also see condition no= 5.45*10^7). This effect is particularly visible at the Mf, O1, K1 and K2 wave groups. As a consequence, the wave grouping is aggregated with respect to the nodal waves.
Since the constituents of single nodal frequency difference p from the main constituents are of higher amplitudes than the double nodal distance 2p, the - - and + + wave groups are aggregated resulting in model *Y04-R04-00000*. In case of the -, xxx, + constellation, the nodal waves are aggregated to the main wave group xxxx. Table 15a shows the results this model: the aggregation was successful and the CRAs are of reasonable order of magnitude.
Despite this progress, a further improvement will be reached, if the nodal waves will be totally aggregated like in model *Y04-R04-opt-00000***.** Therefore, this model (see Annex 3.1) is used for grouping the reference wave groups in the further applications.

9.2.2 Maximum component wave group model Y04-R04-all

Like in section 9.1.2 for the very long record, this model will be *Y04-R04-opt-00000 + all potential parts of the two priority sets tier I+I***I** of section 7, i.e. the most complete model. Table 15 a-d is summarizing the results.
First, the condition number of the normal equations shows a value of $2.52 * 10^7$ which is also much too high for an ordinary solution.
The results for this model are similar to those of section 9.1.2, so is not necessary to repeat those statements.
As a striking fact, however, the CRAs of V_4 are much higher than in case of the 18 years and so do the reference wave groups in V_{22} (especially M2, K2). However, although the CRAs of V_{21} went up that of the reference groups are still high but considerably lower compared to the 18 years record. An explanation is that due to the shorter record length and the omission of the nodal waves, the model signals are comparably broader and hence the correlation is lower over a wider wave group than in case of narrow banded signals.
For V_{3i}, the CRAs become higher probably by the impact of the shorter record length with respect to the minor resolution of the constituents of the Moon's perigee.
Like in 9.1.2, the wave groups causing nuisance have to be modified by lowering the related options.

9.2.3 Optimal wave group model Y04-R04-allopt

The drawbacks of the previous section can be cured by simply discarding the wave groups causing the high CRA-values. Annex 3.1 keeps the associated wave grouping while Annex 3.2 presents a results table out of ET34-ANA-V70-beta. The actions taken were similar to those describes in section 9.1.3 for the very long record.
The improved results are first indicated by the condition no of the normal equations, showing a value of 290, much less than before. As Tables 15 a-d demonstrate, all actions to improve the results have been turned out as successful.

9.2.4 Safe wave group model Y04-R04-safe

In the last variant presented, the question is put for an even safer solution. Again, the argumentation points at the tier1 set of potential functions and related wave groups as 1st priority when performing the wave grouping. For this reason, wave group model Y04-R04-safe has been set up, just comprising these tier1 set wave groups. Tables 15 a-d are summarizing the results.
Regarding the condition number of the normal equations at first, it has only slightly improved. This is apparently due to the fact that the departure from optimum of the CRA -values is related to the shortening of the record length from 18.6 to 4.5 years. Since there are still the Moon's perigee waves in the model, a further improvement can only be achieved if option O_3=3 of the respective reference waves is changed to 2 or even to 0.
Tables 15a-d illustrate the correctness of this assumption by the results of variant **safe1**, where for all reference wave groups of V_{21} *and* V_{22} the option is changed to O_3=2. Now, the CRAs of the wave groups for which option O_3=3 has previously been set, become considerably less.

9.2.5 Analysis results and wave group recommendation for medium size record lengths

Table 15: Results for the CRAs of different resolution models for a 4.5 years long record

wave group model	Cond.no.	Mf	Q1	O1	P1	K1	N2	M2	S2	K2
Y04-R18-	All nodal wgr --,-,+,++									
00000	$5.45 * 10^7$	7.02	3.67	8.49	2.32	46	5.20	2.37	1.01	6.33
Y04-R04-00000	Condensation -- and ++									
A1	337	2.83	3.67	2.56	2.29	2.5	5.20	2.37	1.01	2.52
Y04-R04-00000	No nodal wgr									
A2	177	1.26	1.29	1.00	1.01	1.01	1.31	1.01	1.01	1.01
all	$2.52 * 10^7$	18	3.97	22	1.03	21	3.15	11	1.02	4.82
allopt	198	1.65	1.38	2.17	1.01	1.10	1.38	1.17	1.01	1.24
safe	188	1.28	1.38	2.17	1.01	1.10	1.37	1.16	1.01	1.24
safe1	178	1.28	1.05	1.03	1.01	1.01	1.26	1.01	1.01	1.01

15a: CRAs of the major $V_2 -$ wave groups of different resolution models

wave group model	Cond.no.	V10	V11	V30	V31	V32	V40	V41	V42	4MK3	4MO3
Y04-R04-										MN3	ML3
all	$2.52 * 10^7$	1757	1069	1755	91	2.20	22	23	14	18	16
allopt	198	2.59	2.21	2.59	1.41	1.46				1.37	1.59
safe	188			2.38	1.39	1.33				1.35	1.53
safe1	178			2.38	2.30	1.62				1.36	1.53

15b: CRAs of all $V_{1x}, V_{3x}, V_{4x} -$ wave groups of different resolution models

wave group model	Cond.No.	3MK1	3ML1	M1	3MO1	3MO1+	3MJ2	3MK2	3M1LK2	3MO2
Y04-R04-		**Qa1**	**O1**	**NO1**	**J1**	**KLK1**	**2N2**	**Na2**	**M2**	**KNO2**
all	$2.52 * 10^9$	226	153	992	319	121	4.17	7.57	2.69	7.63
allopt	198	1.44	2.76		5.11	5.20	1.65		1.25	
safe	188	1.35	2.75	2.51	5.07	5.20	1.33	1.34	1.15	2.53
safe1	178	1.00	1.00	1.03	1.07	1.06	1.02	1.01	1.01	1.22

15c: CRAs of $V_{31} - V_{32}$ wave groups of different resolution models (option 3)

wave group model	Cond.No.	V50	V51	V52	V53	V54	V60	V61	V62	V63	V64	V65
Y18-R18-												
all	$2.52 * 10^9$	8.51	12	11	3.74	1.18	6.24	26	6.06	23	1.49	1.01
allopt	198			4.25	3.62	1.15						
safe	188					1.15						1.01
safe1	178					1.15						1.01

15d: CRAs of $V_{5x}, V_{6x} -$ wave groups of different resolution models

We would propose to use wave group model <u>Y04-R04-allopt</u> as fine resolution wave grouping for medium size observation records with lengths in years 4 < N < 9 (see Annex 3), provided the precision of the observations is high enough to yield significant results.
If this is not the case, we would propose to use wave group model <u>Y04-R04-safe or Y04-R04-safe1</u> instead.

9.3 Determination of the shortest tolerable record length for options $\neq 0$.

Finally, the question has to be answered about what is the shortest record length for using options $\neq 0$, at least for O_3.

Model data with lengths of 2 and 1 years were examined, each with option codes 00000, 02000, 03000 leading to all in all 7 resolution models. For the 1-year data length, the major wave groups had to be aggregated to fit in a 1 year's resolution pattern.

Tables 16: CRAs for short length records

Wave group model		Cond.no.	Mf	Q1	O1	P1	K1	N2	M2	S2	K2
Y02-	**R04-00000**	958	1.76	2.10	1.56	1.00	1.00	2.55	1.01	1.00	1.00
Y01-	**R04-00000**	114699	3.06	2.92	5.78	1.00	1.00	4.90	1.01	1.00	1.00
Y01-	**R01-00000**	345	1.00	1.02	1.01	1.00	1.00	1.02	1.01	1.00	1.00
Y02-	**R04-02000**	966	1.76	2.22	1.81	1.01	1.20	2.82	1.14	1.00	1.01
Y01-	**R01-02000**	**773**	**1.31**	**2.30**	**1.97**	**1.01**	**1.24**	**3.65**	**1.28**	**1.00**	**1.02**
Y02-	**R04-03000**	4754	1.76	10.45	7.37	1.07	2.18	3.22	5.15	1.03	1.49
Y01-	**R01-03000**	3776	1.31	10.18	10.29	1.45	5.82	7.92	25.76	1.11	2.54

16a: CRAs of the major $V_2 -$ wave groups of different resolution models

Wave group model		Cond.no.	V30	V31	V32
Y02-	R04-02000	966	2.67	12	4.11
Y01-	R01-02000	**773**	5.44	12	5.06
Y02-	R04-03000	4754	2.67	6.37	2.50
Y01-	R01-03000	3776	5.44	8.91	5.41

16b: CRAs of $V_{30}-V_{32}$ wave groups of different resolution models

Wave group model		Cond.no.	3MK1	3ML1	M1	3MO1	3MO1+	3MJ2	3MK2	3M1LK2	3MO2
			Q1	O1	NO1	J1	KLK1	2N2	N2	M2	L2
Y02-	R04-03000	4754	5.86	14	17	26	9.50	2.69	3.21	5.15	15
Y01-	R01-03000	3776	10	10	12	5.69		5.24	7.82	25	4.05

16c: CRAs of $V_{31} - V_{32}$ wave groups of different resolution models (option 3)

These results make clear that with data lengths of 1 year, the maximum resolution for the non-referential potential parts can be achieved with an option code 02000. Higher resolutions lead to enormous error amplification due to correlation of at least 1 order of magnitude.

We would propose to use wave group model Y01-R01-02000 as wave grouping for short observation records with lengths in years: 0.75 < N < 2 (see Annex 4).

9.4 Deviation for the tidal parameters in presence of a white noise process

As it is shown in inequality (13), not only the CRA, i.e. wave grouping, is determining the significance of the tidal parameter but likewise important are precision and signal strength.
To study the impact of a random signal on the tidal wave groups of different signal strengths, the model tides are superimposed by a white noise process of $\sigma_0 = 1$ nm/sec**2, corresponding to a white noise amplitude of 0.0049 nm/sec**2, leading to the models "allz", "alloptz", "safez", "z" indicating the presence of noise.
For the 3 models under investigation, the relative RMSE of the amplitude factors from the analysis are presented as *estimated rRMSE* of the bands in Tables 14-Aa-d**.** In addition, the relative magnitudes A_r of the residual vectors in per cent of the main theoretical amplitudes are shown. Since model data are used, these quantities A_r are definitely *the "true" rRMSE* so that the reliability of the error estimation can be assessed. For comparison, also the CRAs are given as well which are the same as in Table 14, because the functional model is not changed by superimposing the white noise process.
The results illustrate that even with nearly uncorrelated parameters, a reliable significance can only be obtained if the signal strength of beyond a certain limit. Detailed analysis results of this example have shown that a fair threshold turned out to be 0.5 nm/sec**2 in order to stay below a 1% limit for the relative RMSE of the amplitude factor. For the smaller signals, it will be almost impossible with nowadays measurements to obtain significant results. It seems that only the V3:*- constituents of the Moon's perigee will meet these requirements (Annex A5.1). However, with respect to the 9 main wave groups Mf-K2, it will be possible to reach accuracies at the 0.1% level and better. The results also show that, besides huge error values, the discrepancies between analysis results and model parameters are very well represented by about twice the rRMSE.

Even if the model parameters of minor signal like V10, V11 cannot be determined with accuracies required for interpreting phenomena of the Earth, it is absolutely necessary to set up the analysis as complete as achievable in order to extract information from the observations to the highest possible degree and thus whitening the residual process z(t) to a maximum.

In Tables 14-A*, the colours mean the following according to section 8.3:

	Red = Θ_l	**rRMSE, A_r > 5 %**	**unacceptable result**
	Yellow = Θ_m	**0.1% < rRMSE, $A_r \leq$ 5 %**	**take result with caution**
	Green = Θ_h	**rRMSE, $A_r \leq$ 0.1 %**	**acceptable result**

Tables 14-A: Results for CRA, estimated and true rRMSE of an 18.6 years long record of $\sigma_0 = 1$

Wave group model		**Mf**	**Q1**	**O1**	**P1**	**K1**	**N2**	**M2**	**S2**	**K2**
Y18-R18-										
allz	CRA	13483	1.81	21639	1.00	20357	1.17	2.67	1.00	1.43
	rRMSE (%)	241	0.009	17	0.002	13	0.006	0.003	0.002	0.011
	A_r (%)	121	0.008	56	0.002	37	0.014	0.005	0.002	0.020
alloptz	CRA	1.53	1.71	5.73	1.00	5.49	1.06	1.73	1.00	1.38
	rRMSE (%)	0.009	0.009	0.006	0.002	0.004	0.006	0.002	0.002	0.011
	A_r (%)	0.02	0.003	0.004	0.002	0.005	0.013	0.001	0.002	0.018
safez	CRA	1.53	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	rRMSE (%)	0.009	0.005	0.001	0.002	0.001	0.005	0.001	0.002	0.008
	A_r (%)	0.02	0.008	0.003	0.002	0.002	0.011	0.002	0.002	0.016

14-Aa: CRA, estimated and true rRMSE of the major $V_2 -$ wave groups of different resolution models

Wave group model		**V10**	**V11**	**V30**	**V31**	**V32**	**V40**	**V41**	**V42**	**4MK3**	**4MO3**
Y18-R18-										**MN3**	**ML3**
allz	CRA	1612	823	1612	80	1.05	14	9	3.68	4.45	3.81
	rRMSE (%)	136	267	139	34	1.11	32	24	7	22	23
	A_r (%)	37646	16924	3362	12	0.58	204	2.32	20	28	28
alloptz	CRA	1.05	1.23	1.06	1.05	1.02		8	2.09	1.00	1.00
	rRMSE (%)	17	31	12	0.40	1.29		21	4.49	3.88	4.42
	A_r (%)	100	172	30	0.57	0.33		19	9.38	2.02	0.63
safez	CRA			1.01	1.04	1.00				1.00	1.00
	rRMSE (%)			2.89	0.40	1.27				3.88	4.42
	A_r (%)			10	0.67	0.66				2.01	0.64

14-Ab: CRA, estimated and true rRMSE of all V_{1x}, V_{3x}, V_{4x} −wave groups of different resolution models

Wave group model	**Cond.No.**	**3MK1**	**3ML1**	**M1**	**3MO1**	**3MO1+**	**3MJ2**	**3MK2**	**3M1LK2**	**3MO2**
Y18-R18-	**k**	**Qa1**	**O1**	**NO1**	**J1+**	**KLK1**	**2N2**	**Na2**	**M2**	**KNO2**
allz	CRA	243	117	719	258	105	1.46	3.38	1.19	3.15
	rRMSE (%)	34	34	34	34	34	0.30	0.19	0.45	0.19
	A_r (%)	12	12	12	12	12	0.14	0.06	0.66	0.15
alloptz	CRA	1.07	1.03		1.08	1.01	1.20		1.08	
	rRMSE (%)	0.14	0.27		0.13	0.30	0.25		0.41	
	A_r (%)	0.09	0.23		0.23	0.03	0.40		0.59	
safez	CRA	1.01	1.00	1.01	1.01	1.00	1.00	1.01	1.00	1.00
	rRMSE (%)	0.13	0.27	0.04	0.12	0.30	0.21	0.06	0.38	0.06
	A_r (%)	0.13	0.20	0.11	0.12	0.16	0.20	0.04	0.46	0.07

14-Ac: CRA and estimated rRMSE of $V_{31} - V_{32}$ wave groups of different resolution models (option 3)

Wave group model		**V50**	**V51**	**V52**	**V53**	**V54**	**V60**	**V61**	**V62**	**V63**	**V64**	**V65**
Y18-R18-												
allz	CRA	3.76	3.39	4.86	1.63	1.0	13490	29707	2.48	5.77	1.35	1.00
	rRMSE (%)	38	96	332	78	70	78	44	57	61	52	135
	A_r (%)	165 0	10056	246	243	262	*****	*****	61669	63297	32631	11953
alloptz	CRA			3.05	1.63	1.00						
	rRMSE (%)			59	80	70						
	A_r (%)			474	235	260						
safez	CRA					1.00						1.00
	rRMSE (%)					70						135
	A_r (%)					260						11954

14-Ad: CRA, estimated and true rRMSE of $V_{5x} - V_{6x} -$ wave groups of different resolution models

9.5 Recommendations from analysing the model data of different lengths and accuracies.

From the results and experiences of the previous sections, the following statements can be derived:

- Tidal analysis results are primarily influenced by the appropriate tidal wave grouping. Hence, it is of utmost importance to design an appropriate wave group model according to rules of section 8.4.

- The proposed procedure of section 8.4 for setting up the wave group model of an analysis project has proven to deliver optimal processing and results.

- As a general rule, wave group models should tend at representing an optimal compromise between resolution and significance on the one hand and Earth model constraints and unconstrained estimation on the other hand.

- Due to the overlapping frequency ranges of the various degrees, dependencies or correlations of the tidal parameters occur in most cases independent of record lengths.

- The correlation coefficient of any 2 parameters describes dependencies qualitatively not quantitatively.
- The "correlation RMSE Amplifier (CRA)" is the only quantity that quantitatively describes the impact of correlations. High correlations do not necessarily cause high CRAs and vice versa. Therefore, as long as

the condition of the normal equation matrix leads to reasonably numerical precisions, each analysed wave group has to be assessed individually.

- There are wave groups which turn out to be insensitive to correlation impacts exhibiting always low CRAs, like P1, S2 followed by Q1, N2.

- Due to the structure of the tidal potential, optimal and comprehensive results can only be obtained by the combination of different resolution models.

- Despite of high CRAs, the analysed tidal parameters do not exhibit significant departures from their true values in absence of noise or unaccounted signals.

- The distortion of tidal parameters by high CRAs is then observed if the record to be analysed contain signals of deterministic and/or stochastic nature, which are not accounted for by the functional model. The higher the CRAs, the higher are the distortions.

- In addition to CRAs, the residual vectors of the wave groups with respect to the theoretical Earth are an important source of information about the completeness of the functional model and the precision of the observations.

- Due to inevitable stochastic processes superimposing the tidal signal in the observations a threshold of significance, represented by a quality label, is associated with each tidal wave group. Therefore, it is not possible to achieve reliable results for signals below a certain strength.

10. Determination of the 9 principal tidal waves by optimal wave group models

To verify the results from theory and simulation, we tested a 20 years tidal record of the SUPRA C021 in Membach (Van Camp et al., 2017). The data set covers the time interval 1996.08.04-2016.03.03. Data prior to June 1998, preprocessed by B. Ducarme and L. Vandercoilden (International Centre for Earth Tides at Royal Observatory of Belgium), come from the IGETS data base (http://isdc.gfz-potsdam.de/igets-data-base). More recent data (http://seismologie.be/data/MEM_GWRC021.TSF), preprocessed by M. Van Camp and M. Hendricks (Royal Observatory of Belgium), are available on http://seismologie.be/en/gravimetry/observations/online-database. In the beginning several changes of electronics produced modifications of the instrumental constants of the gravimeter (sensitivity and time lag). The situation remained stable since the beginning of 1998, providing an undisturbed 18 years data set. Two non-overlapping 9 years analyses of this series confirm the perfect stability of the tidal parameters within the associated RMS errors.

10.1 Analyses with resolution models Y20-R18-*

The analysis procedure is the same as in section 9.4 with the same resolution models besides the long periodic domain. Because of high pass filtering, only tides with periods less than one month can be analyzed in this band and, due to additional signals like rest drifts etc., all option codes are set to ‘00000’ in the LP band. Air pressure is modelled with an impulse response function of length = 48. The residual amplitudes are not given here, because they contain additional signals like ocean tide, where the true values are unknown.

In Tables 14-Ba-d, the relative RMSE of the amplitude factors from the analysis as estimated errors rRMSE in % are presented for the 3 models under investigation. For comparison, also the CRAs are given too. The precision of the series is described by the various m0 for the different bands and the Nyquist interval as

Analyses	RMSE m0-LP	RMSE m0-D	RMSE m0-SD	RMSE m0 TD	RMSE m0-Nyquist
Y20-R18-*	1.36	2.56	1.08 - 1.12	0.49	0.89

It has to be emphasized that the comparably low RMSE m0-LP is due high pass filtering.

As the results show, the RMSEs are nearly independent of the defined resolution models.
We can state that results generally confirm the rules and recommendation of the previous sections, regarding that due to a number of gaps, the CRAs are expected to be slightly higher than in case of the model series with no gaps.
The most important conclusions from this experiment are (see Tables 14-B):

- The main goal of tidal analysis in connection with ocean tide loading to determine the parameters of the 9 principal waves (Mf, Q1, O1, P1, K1, N2, M2, S2, K2), which are well constrained in ocean tide models, is met by achieving accuracies for the amplitude factors far better than 0.1%.
- The V3 – constituents in the diurnal and semi-diurnal bands can be determined better than 1%.
- Two V4-constituents (4MK3,4MO3) in the ter-diurnal band can be determined better than 2%.
- All other potential constituents, although obliged to be modelled exhibit a signal/noise-ratio far too small to deliver meaningful results for further geophysical applications.

Table 14-B: Results for CRA and estimated rRMSE of a 20 years observation record at Membach station

Wave group model		Mf	Q1	O1	P1	K1	N2	M2	S2	K2
Y20-R18-										
all	CRA	1.01	1.88	20729	1.01	19981	1.19	2.75	1.93	1.47
	rRMSE(%)	0.54	0.024	47	0.005	34	0.006	0.003	0.004	0.012
allopt	CRA	1.01	1.78	6.15	1.01	6.01	1.07	1.79	1.93	1.43
	rRMSE(%)	0.54	0.023	0.015	0.005	0.011	0.006	0.002	0.004	0.012
safe	CRA	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.93	1.03
	rRMSE(%)	0.53	0.013	0.002	0.005	0.002	0.005	0.001	0.004	0.008

14-Ba: CRA and estimated rRMSE of the major $V_2 -$ wave groups of different resolution models

Wave group model		V10	V11	V30	V31	V32	V40	V41	V42	4MK3	4MO3
Y20-R18-										MN3	ML3
all	CRA		857		82	1.05		9.56	3.79	4.48	3.85
	rRMSE(%)		149		57	1.38		24	13	8.33	7.43
allopt	CRA		1.26		1.05	1.03		8.88	2.18	1.01	1.00
	rRMSE(%)		5.93		1.02	1.36		22	8.43	1.82	1.91
safe	CRA				1.05	1.01				1.01	1.00
	rRMSE(%)				1.01	1.34				1.82	1.91

14-Bb: CRA and estimated rRMSE of all V_{1x}, V_{3x}, V_{4x} –wave groups of different resolution models

Wave group model	Cond.No.	3MK1	3ML1	M1	3MO1	3MO1+	3MJ2	3MK2	3M1LK2	3MO2
Y20-R18	**k**	**Qa1**	**O1**	**NO1**	**J1+**	**KLK1**	**2N2**	**Na2**	**M2**	**KNO2**
all	CRA	235	120	757	271	109	1.48	3.42	1.21	3.21
	rRMSE(%)	53	54	55	56	57	0.33	0.21	0.48	0.21
allopt	CRA	1.07	1.04		1.10	1.02	1.22		1.09	
	rRMSE(%)	0.35	0.68		0.33	0.76	0.27		0.44	
safe	CRA	1.02	1.02	1.03	1.03	1.01	1.00	1.02	1.01	1.01
	rRMSE(%)	0.33	0.65	0.11	0.30	0.74	0.22	0.06	0.40	0.07

14-Bc: CRA and estimated rRMSE of $V_{31} - V_{32}$ wave groups of different resolution models (option 3)

Wave group model		V50	V51	V52	V53	V54	V60	V61	V62	V63	V64	V65
Y20-R18-												
all	CRA		3.39	4.96	1.68	1.0		28796	2.46	5.82	1.35	1.23
	rRMSE(%)		77	145	49	58		389	186	228	84	15
allopt	CRA			3.14	1.68	1.00						
	rRMSE(%)			4.43	50	58						
safe	CRA					1.00						1.23
	rRMSE(%)					58						15

14-Bd: CRA and estimated rRMSE of $V_{5x} - V_{6x} -$ wave groups of different resolution models

10.2 Analyses of different record lengths

One of the main goals of tidal analysis in connection with ocean tide loading remains the determination of the parameters of the 9 principal waves (Mf, Q1, O1, P1, K1, N2, M2, S2, K2), which are well constrained in ocean tide models, is met. However, as shown in sections 2 and 7, these waves are additionally affected by different time variations expressed through minor tidal constituents (Table 10).

If the tidal factors of the minor constituents are different from the factors of the main constituent, this one will show variations with the corresponding periods, as shown in Meurers et al., 2016. In Western Europe, a clear annual variation of M2 is present, if α2 and β2 are not separated. It is due to the fact that, in the North Sea, the annual modulation of M2 (expressed by the tidal waves α2 and β2), is larger in the oceanic tide than in the astronomical potential, so that the effect of ocean tide loading is proportionally larger on these waves than on M2 in Western Europe. Therefore, the annual astronomical modulation in Earth tide M2 is perturbed by a larger one in the ocean loading tide M2, leading to an additional variation of M2 which is perturbing its tidal factors. This phenomenon is disappearing for records significantly longer than the annual period (Figure A1, Meurers et al., 2016), but the most efficient way to solve the problem is to create separate tidal groups for the tidal waves α2 and β2 as container for all sorts of perturbations signals with annual periods. Annual variations are effectively present also in the other non-solar waves N2, S2, K2, Q1, O1, K1 and Mf.

Concerning the 8.85-year variation, the analysis programs take into account the systematic difference between the tidal gravity factors of different degrees of the potential, as explained in section 5. However, Meurers et al., 2016 showed that an 8.85-year variation of M2 is still present. It can be explained by the fact that the observed tidal amplitude factors of V_{32} terms do not fit exactly the corresponding models, e.g. if there is a systematic phase difference (Ducarme, 2012) or different amplitude quotients influenced by a variety of causes. However, Table 17 shows that

except for Q1 and N2 the influence is considerably lower than 1% of the main wave amplitude at 45° latitude. Nevertheless, it is indeed better to put theV_{3i} and V_{4i} terms in separate groups, especially on series shorter than 8 years, as explained in sections 6 and 7.
The tidal factors of the nodal waves do not differ significantly from those of the main constituent, with the exception of the (K1-, K1, K1+) triplet, which is submitted to the FCN resonance (Ducarme, 2011). However, the effect on K1 of the non-resolution of the triplet is only of the order of 0.01%. Modulation on the main constituents due to the nodal waves will not occur in tidal analysis.
The goal of this section is to derive the most precise tidal parameters of the 9 principal tidal waves and of their third-degree satellite waves, when it is possible.

From what has been presented so far (section 9.3), it can be concluded that with **series, longer than one years of observations but shorter than the period of the Moon's perigee**, it is possible to extract the 9 principal waves (Mf, Q1, O1, P1, K1, N2, M2, S2, K2) with high significance, provided the following precautions are taken:

- put the annual modulation waves in separate wave groups;
- put V_{3i} terms in two separate wave groups V31 and V32 by setting O_3 = 2 (section 7) which is achieved by using wave group model Yyy-R04-safe1.

The experiment has been designed in such a way that we start with a record length of 1.5 years and then steadily increasing the record length by 1.5 years up to 18 years. In order to study the effect of increasing record lengths we have to use the same wave group model (**R04-safe1** of section 9.2) for the different record lengths.
The corresponding CRA values are given in Tables 18 and 19. The values are decreasing quickly. As it can be anticipated from Table 17, the maximum of correlation is appearing between V31 and NO1 in the diurnal band (Figure 5) and between 3MK2 and N2 on one hand and 3MO2 and L2 on the other in the semi-diurnal band (Figure 6). For the 4.5 year time span, CRA values are in agreement with the corresponding values in Table 15a (Y04-R04-safe1).

Table 18 : Comparison of Correlation RMS Amplifiers for different separation of V31 groups :
1 : one group V31 (O3=2). 2 : 3MK1, M1, 3MO1 (O3=3)+ remaining V31 (O3=2).
N length of the data set in years (all data sets end on 2016/03).
Each second line corresponds to the ratio 2 over 1.

N	Q1		O1		NO1		J1		V3	
	1	2	1	2	1	2	1	2	V31	...M1...
1.5	1.52	4.78	1.40	3.07	6.48	7.60	1.59	3.87	6.78	7.61
	3.14		2.19		1.17		2.43		1.12	
3.0	1.05	1.91	1.04	1.68	2.04	2.16	1.07	1.84	2.11	2.15
	1.82		1.61		1.06		1.72		1.02	
4.5	1.01	1.26	1.01	1.27	1.14	1.16	1.02	1.31	1.17	1.16
	1.25		1.26		1.02		1.28		0.99	
6.0	1.01	1.10	1.0	1.09	1.03	1.03	1.01	1.10	1.04	1.03
	1.09		1.09		1.00		1.10		0.99	
7.5	1.00	1.04	1.00	1.01	1.01	1.01	1.0	1.03	1.01	1.01
	1.04		1.01		1.00		1.03		1.00	
9.0	1.00	1.02	1.00	1.00	1.00	1.00	1.00	1.02	1.01	1.01
	1.02		1.00		1.00		1.02		1.00	

Table 19 : Comparison of Correlation RMS Amplifiers for different separation of V32 groups:
1 : one group V32 (O3=2) 2 : 3MK2, 3MO2(O3=3) + remaining V32 (O3=2).
N length of the data set in years (all data sets end on 2016/03).
Each second line corresponds to the ratio 2 over 1.

N	2N2		N2		M2		L2		V3	
	1	2	1	2	1	2	1	2	V32	3MK2...
1.5	1.17	3.38	2.44	3.73	1.23	2.85	2.36	2.95	3.31	3.70
	2.90		1.53		2.33		1.25		1.12	
3.0	1.04	1.62	1.46	1.86	1.03	1.32	1.42	1.77	1.80	1.86
	1.56		1.27		1.28		1.25		1.03	
4.5	1.02	1.20	1.19	1.34	1.01	1.05	1.21	1.47	1.38	1.34
	1.18		1.13		1.04		1.22		0.97	
6.0	1.00	1.06	1.06	1.11	1.01	1.02	1.07	1.16	1.13	1.11
	1.06		1.05		1.01		1.08		0.98	
7.5	1.00	1.01	1.01	1.02	1.00	1.01	1.00	1.01	1.01	1.02
	1.01		1.01		1.01		1.01		1.01	
9.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1.00		1.00		1.00		1.00		1.00	

Tables 20 and 21 as well as Figures 7 to 18, present the results of the different analyses and it is possible to compare the solutions with and without separation of V_{3i} groups for different time spans. The conclusions are the following:

- Correlation does not affect the results at all if the CRA- values is smaller than 1.10.
- In the *diurnal band*, K1 and the solar wave P1, which are practically not affected by the V_{31} terms are not discussed here. Q1 (Figure 7) and O1 (Figure 8) are only slightly influenced while the major effects concern the minor constituents NO1 (Figure 9) and J1 (Figure 10).

  For O1, the solution with separation of the V_{3i} group does not significantly differ from the final one with a 3 years data set. With a 4.5-year time span, all results are satisfactory except for NO1, which requires 6 years. Moreover, on 9 years, the tidal parameters of NO1 are not correct if the waves derived from the potential of degree three are not separated. It is due to the fact that these waves represent 30 % of the tidal energy in the group.
- In the *semi-diurnal band*, there is no influence of V_{32} potential on S2 and K2 and the effect is very weak on M2 (Figure 13). N2 (Figure 12) is the only major wave affected with a CRA-value of 2.2 on 1.5 year. Among the minor constituents, 2N2 (Figure 11) is slightly and L2 (Figure 14) heavily affected. The solution with separation of the V_{32} - group becomes correct from 4.5 years on. It is interesting to note that even on a time span of 1.5 years, the tidal parameters of N2 are closer to their final value on 9 years when the V_{32} - group is separated. Moreover, on 9 years the tidal parameters of L2 are not correct if the waves derived from the potential of degree three are not separated. It is due to the fact that these waves represent 60 % of the tidal energy in the group.

To summarize, it is possible to derive safely the major tidal constituents for tidal loading studies from a 3 years data span, if model errors due to the individual behavior of the V_{32}-constituents is eliminated through the determination of global V_{31} and V_{32} groups. A global tidal factor for V_{31} and V_{32} is already obtained from a 4.5 years long record (Figures 15 and 16) with CRA-values close to one.

Figure 5: CRA-values (option O_3 =2) in the diurnal band

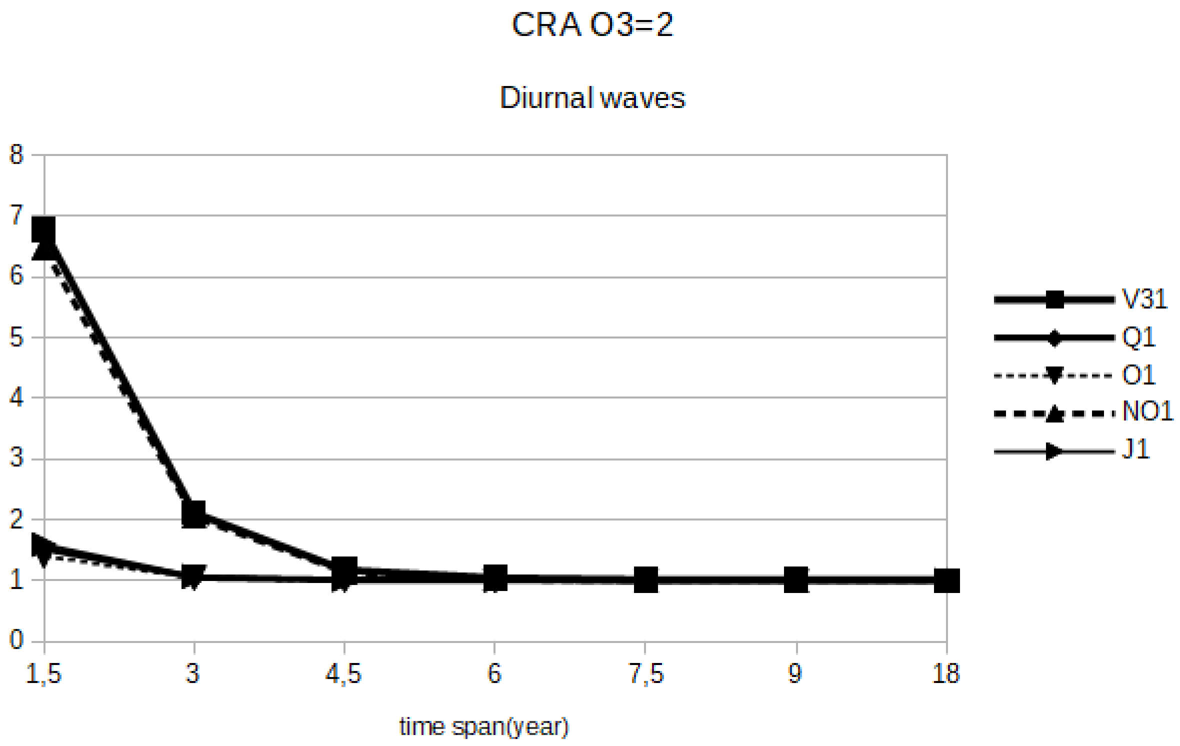


Figure 6: CRA-values (option O_3 =2) in the semi-diurnal band

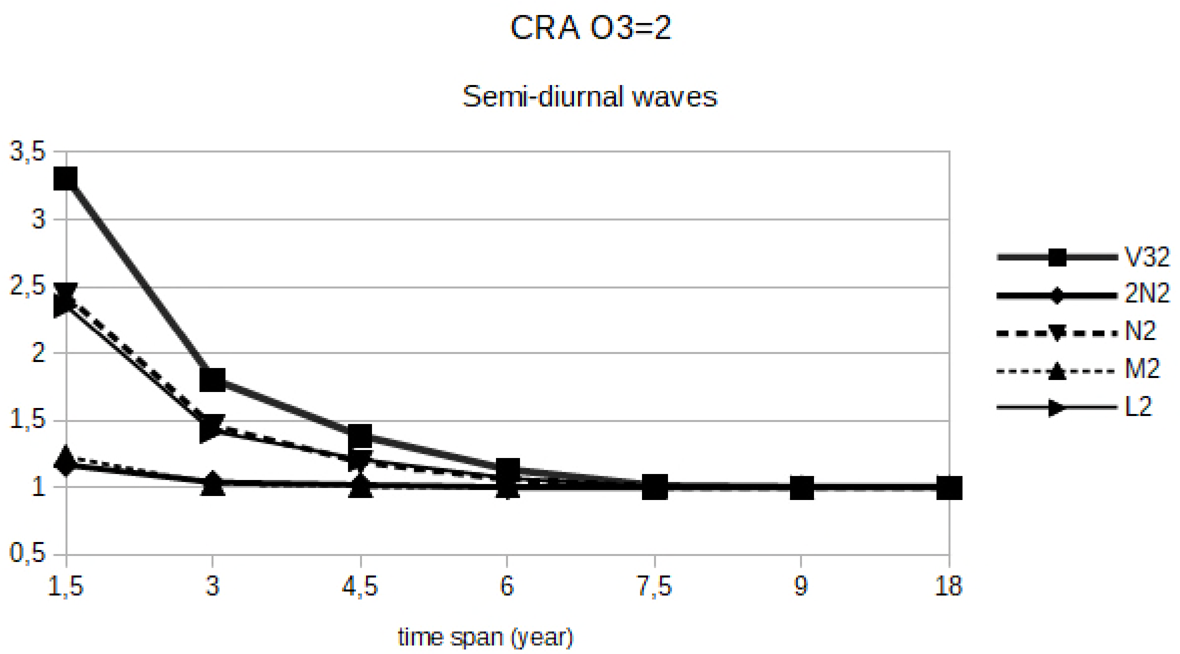


Figure 7: Evolution of Q1 tidal group with increasing data length for C021 at Membach (1σ error bars)

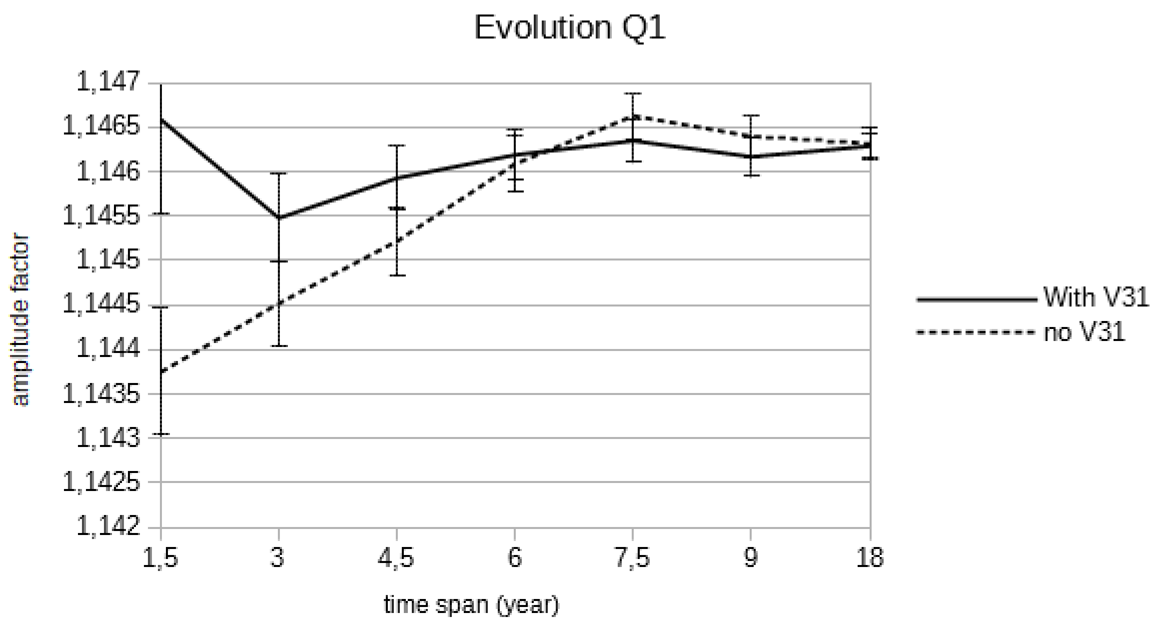


Figure 8: Evolution of O1 tidal group with increasing data length for C021 at Membach (1σ error bars)

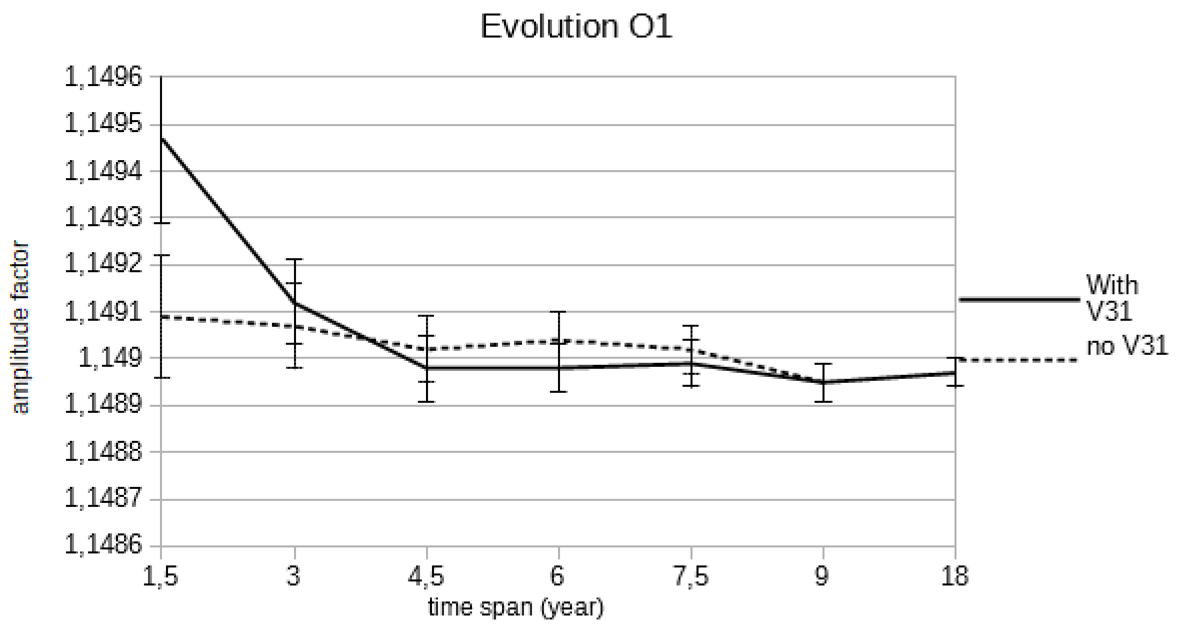


Figure 9: Evolution of NO1 tidal group with increasing data length for C021 at Membach (1σ error bars)

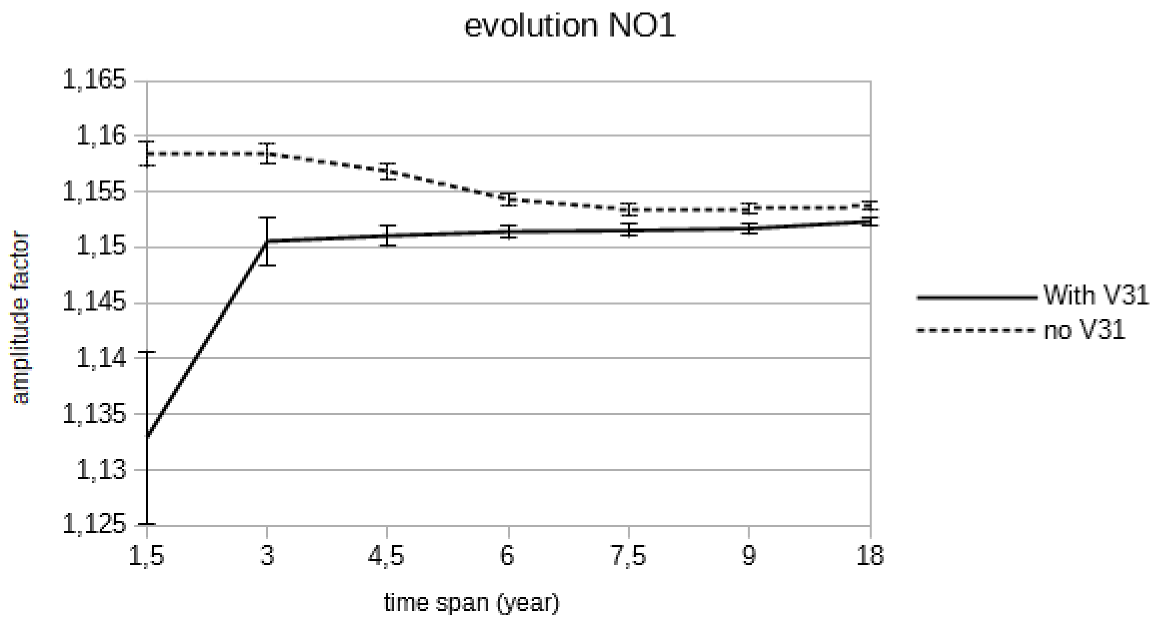


Figure 10: Evolution of J1 tidal group with increasing data length for C021 at Membach ((1σ error bars)

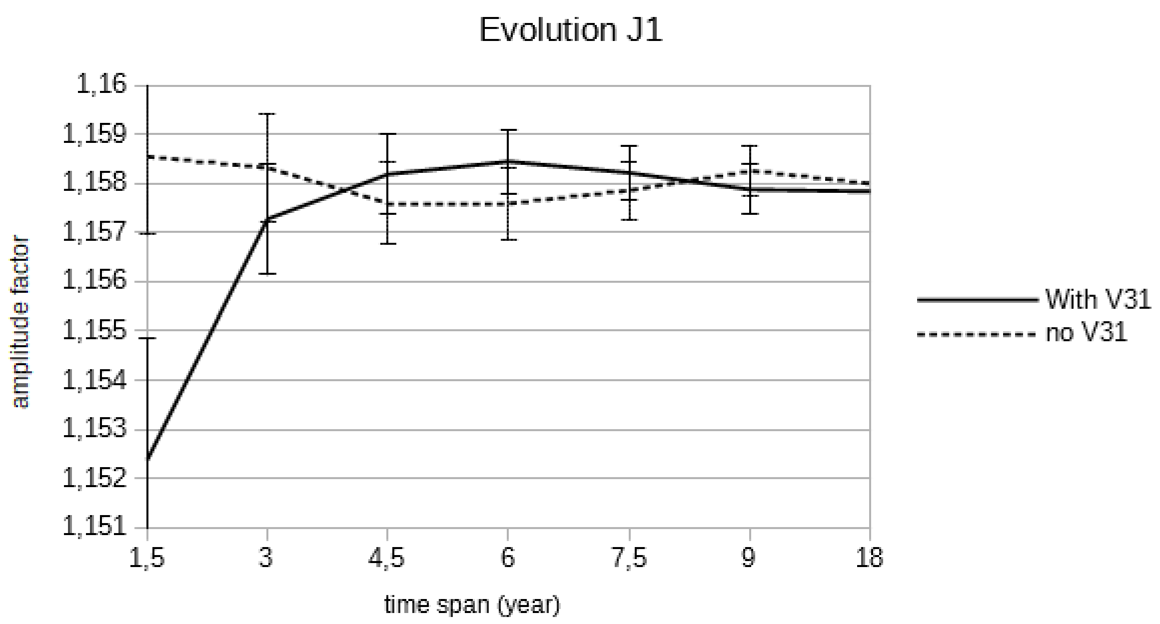


Figure 11: Evolution of 2N2 tidal group with increasing data length for C021 at Membach ((1σ error bars)

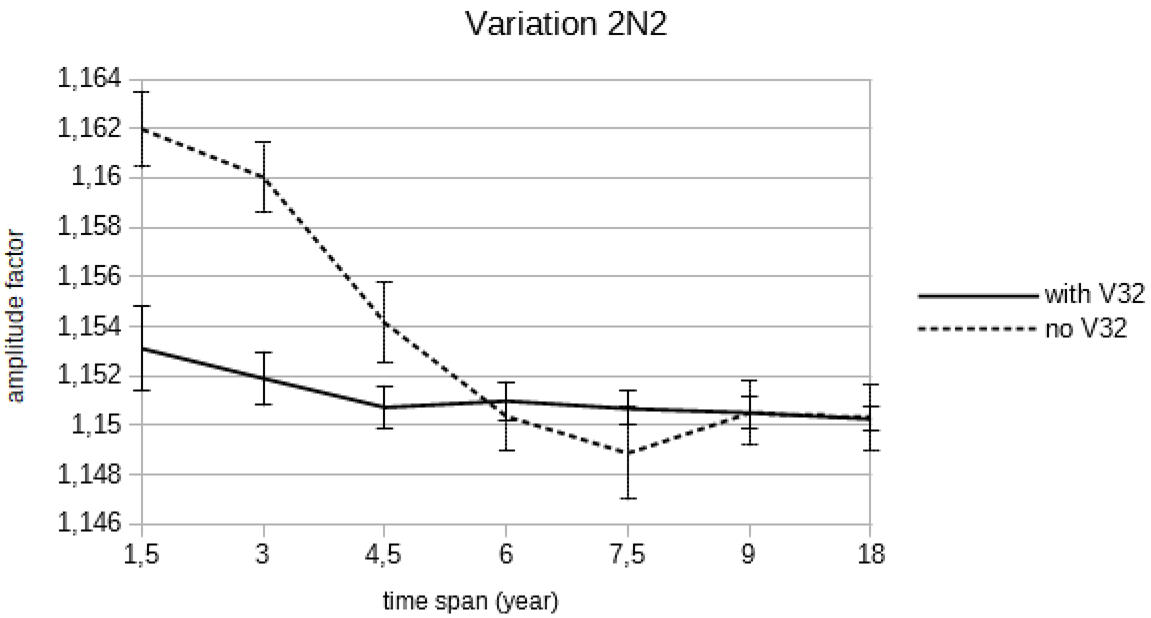


Figure 12: Evolution of N2 tidal group with increasing data length for C021 at Membach (1σ error bars)

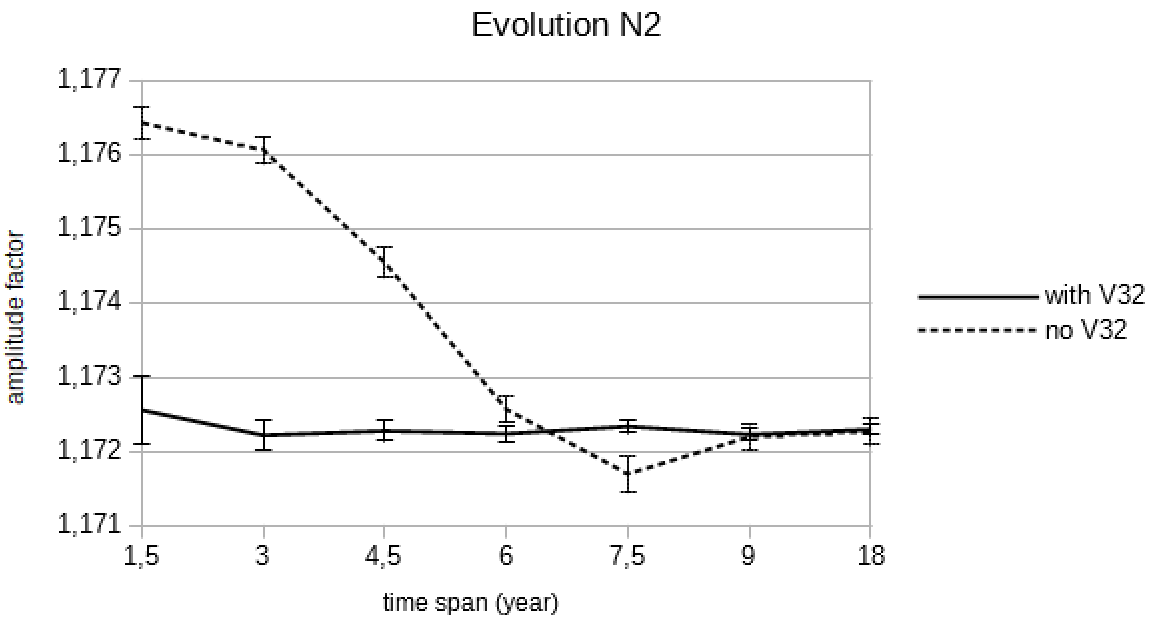


Figure 13: Evolution of M2 tidal group with increasing data length for C021 at Membach (1σ error bars)

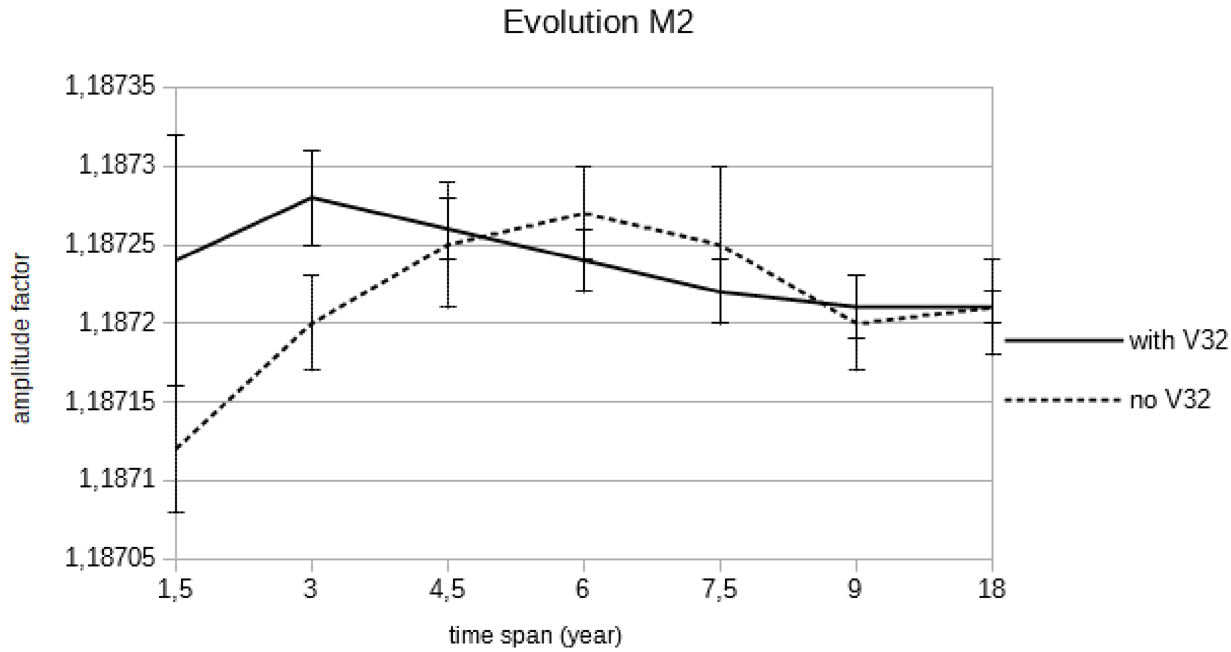


Figure 14: Evolution of L2 tidal group with increasing data length for C021 at Membach (1σ error bars)

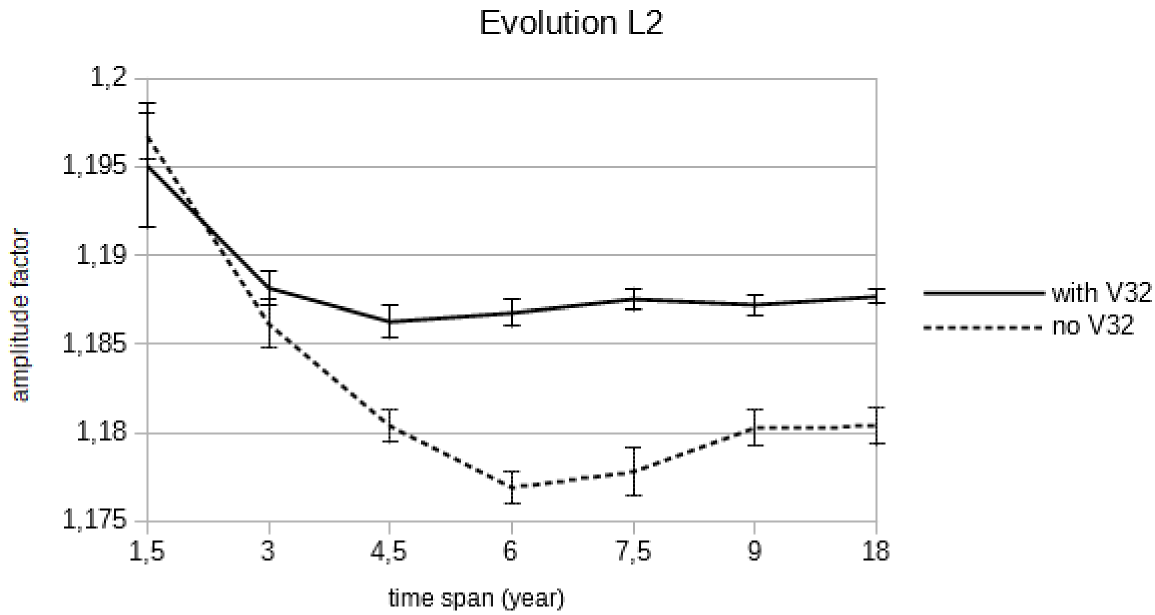


Figure 15: Evolution of V31 global group (O_3 =2) with increasing data length for C021 at Membach, (1σ error bars). The ±2σ lines correspond to the RMS error on 18 years.

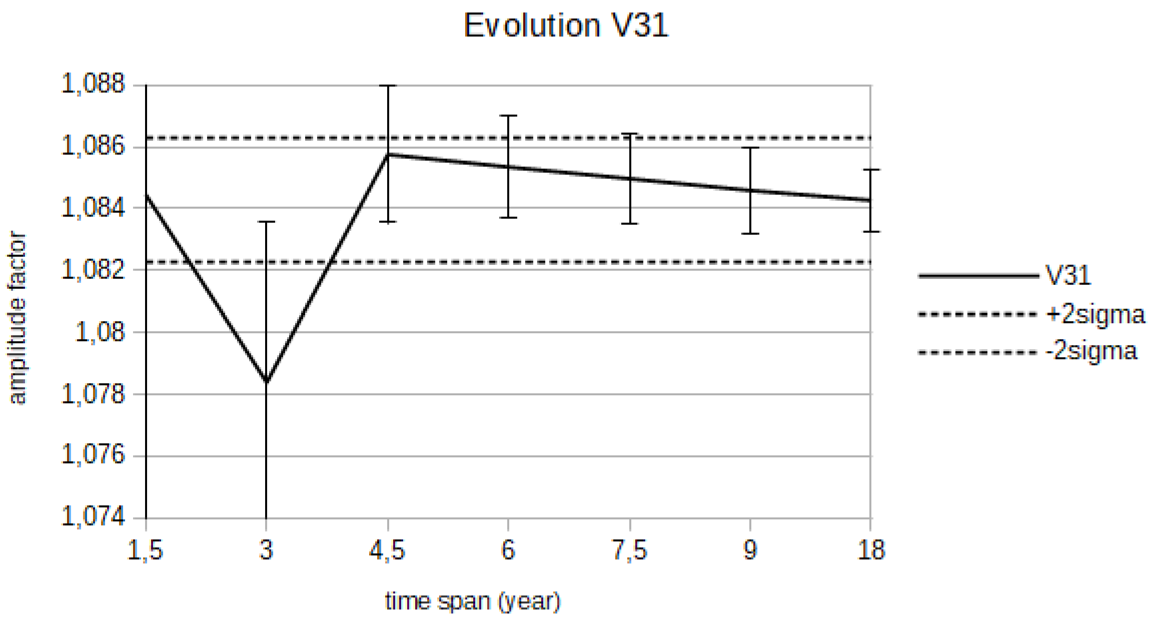


Figure 16: Evolution of V32 global group (O_3 =2) with increasing data length for C021 at Membach, (1σ error bars). The ±2σ lines correspond to the RMS error on 18 years.

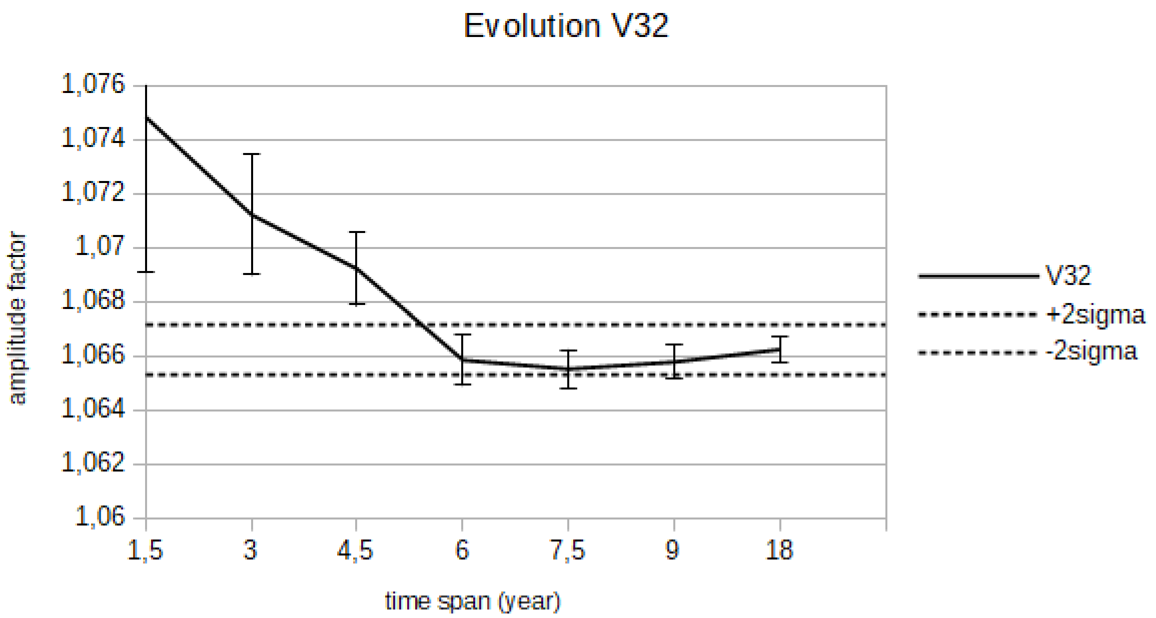


Figure 17: ratio of CRA-values (option O_3 =3/option O_3 =2) in the diurnal band

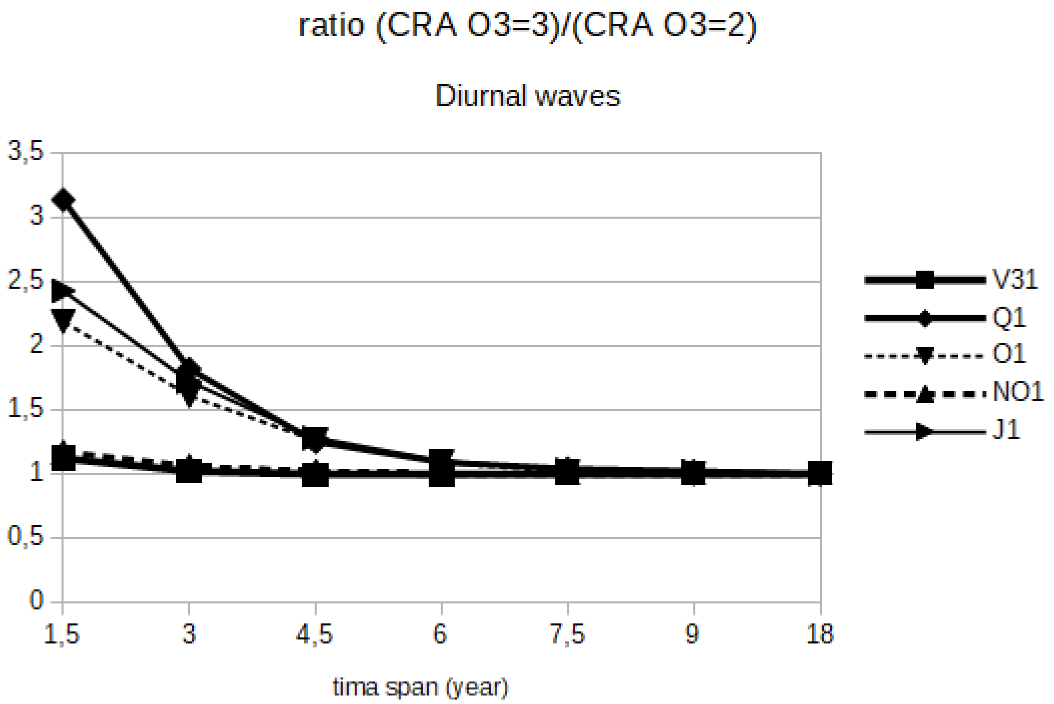
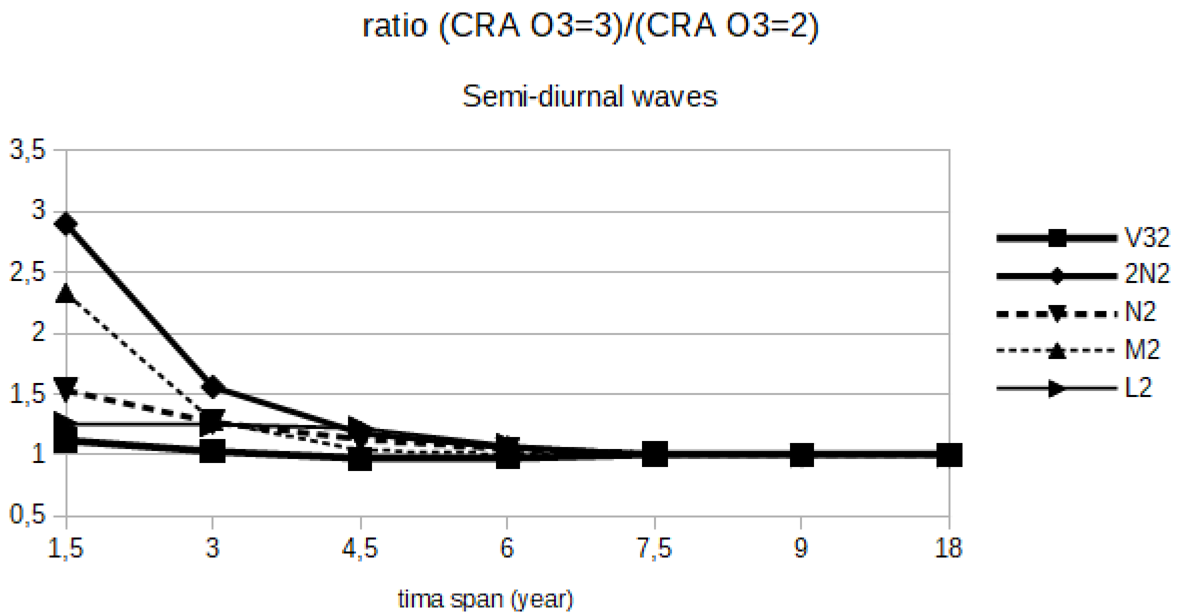


Figure 18: ratio of CRA-values (option O_3 =3/option O_3 =2) in the semi-diurnal band



To investigate more closely the structure of the waves derived from V_3 it is possible to separate the main tidal constituents 3MK1 (V3:Q1), M1 (V3:NO1), 3MO1 (V3:J1), 3MK2 (V3:N2) and 3MO2 (V3:L2), using option O_3 = 3. Reliable results are already obtained with a 4.5 years data set. It should be noted that it increases the CRAs of the corresponding V_2 waves (Figures 17 and 18) due to the relatively high correlations involved. It is already the case in Table 15c (safe and safe1). However, the ratio of CRA- values (option O3=3)/(option O3=2) drops below 1.1 for a 6 years data length. Option O_3 = 3 is thus less suitable for the determination of the major tidal constituents if the record length is shorter than 6 years.
For record lengths greater or equal to 9 years we can take the full O_3 = 3 option of model R04-safe to study in details the spectrum of the V_{31} and V_{32} potential.

The resolution of the K1 nodal triplet is indeed of special interest for the study of the FCN (Ducarme, 2011). As expected, the separation of the nodal waves K1- and K1+ is not changing the tidal parameters of K1. The difference is at the level of 0.001 % for an 18 years record (Table 22).
The separation is already correct on 9 years but the associated RMS error is still three times larger than on 18 years for K1 with CRA- value ~2. On a 12 years record, the CRA-value drops to 1.2.

As a rule of the thumb we can thus state that separation of close frequencies is already valid on a time span corresponding to two-thirds of the commensurability period, as previously illustrated in Ducarme, 2011.

Conclusions

In this paper, a considerable set of definitions and rules have been presented to set up the environment for suitable tidal wave group models in order to serve as standards in further applications.
Starting from the definition of the tide generating potential and its decomposition, the basic determinants of a tidal frequency domain structure have been explained. Striking properties of symmetry between the developments of the different degrees and orders of the tidal potential are showing up. Considering the degrees n of the potential, there are some similarities between the structures of the different orders m. There are two principal patterns depending on the trigonometric dependence in the declination δ of the corresponding P_{nm} function: either a principal wave Mm or Sm with argument cos ($m\tau$) or cos (mt) is existing, or the principal wave is replaced by two declinational waves with arguments sin ($m\tau \pm s$) or sin (mt ± h) symmetrical with respect to the missing principal wave. Moreover, for a given order m, the principal waves of degree n will have “satellite” waves of degree n+1 or n-1 separable on the 8.847 years period of the Lunar Perigee p, while the principal waves of degree n-2 or n+2 will have exactly the same argument. As a result, the spectra of V_1, V_3 and V_5 on one side and V_2, V_4 and V_6 on the other overlap nearly completely in the tidal bands they share. This situation has a strong impact on optimal wave grouping. Taking V_2, it will be difficult or even impossible to separate contributions from other degrees 1,3…6 inside the V_2 spectrum. As a matter of fact, the separation of V_3 terms will require more or less a record length of eight years and V_4 contributions are mainly accessible inside the ter-diurnal and quarter-diurnal tidal bands.
With respect to modelling the tidal signal, it is shown to be of upmost importance to consider the “frequency sharing” of the different potential degrees in the functional model of tidal analysis. In extension to traditional wave grouping, option codes are introduced for each wave group to control the various forms of representing the different responses of the Earth of to the different degrees. The properties of the Least Squares (LS) adjustment method based on the Gauss-Markov model are fully exploited. The application of the newly defined “Correlation RMSE Amplifier (CRA)” opens up a broader perspective how to assess wave group models concerning resolution and reliability. It has been shown that each parameter of the function model can be characterized separately with respect to numerical stability and RMSE by its own CRA. Hence, crucial parameters could easily be identified and special precautions could be undertaken to avoid undesired distortions of the estimated parameters. In an elegant new formula of stunning simplicity, the theoretical relations between record length, correlation, precision, and signal strength have been derived. By means of this formula, an application-oriented quality label has been defined which allows to endow the analysed parameters with ratings about significance.
For supporting our conclusions, test model series of the DDW-NHi-Earth model have primarily been used, because wave grouping is a “configuration” issue by determining the configuration matrix **A** of the error equations, being independent of stochastic quantities. Moreover, examples of most ambitious wave grouping will be illustrated and tested by the ET34-ANA -method.
In proceeding this way, the central objective of this paper is met by proposing “standard wave group models” of most detailed resolution. Initially, a wave group model related to record lengths > 18 years is presented. Out of this most sophisticated basic structure, wave group models applying to shorter record lengths are developed by means of aggregation. In proceeding this way, a complete family of standard wave group models is built up as a hierarchical structure of models with less resolutions but sharing the common wave group boundaries.

Experiences from gravity observations of a 20 years tidal record of the SUPRA C021 in Membach (BE) (section 10) have also been derived. The use of the CRA-factor confirms that the global evaluation of the V_{3i} terms (option O_3 = 2) affects only specific V_{2i} terms, i.e. NO1, N2 and L2, for data set shorter than 6 years. The other principal constituents provide excellent results with option O_3 = 2 for data lengths larger or equal to 3 years. For V_{3i} terms, the CRA is close to 1.1 from 6 years on. However, the values of the tidal factors are also reasonably good with 4.5 years of data. One should be cautious in the application of O_3 = 3 for data shorter than 6 years if it is accompanied by high CRAs of the tidal parameters.
Similar conclusions are valid for the separation of the nodal waves on a time span shorter than 18.613 years. The separation is already correct on 9 years, but actually, 12 years are required to reach high precisions.
The study also confirms the rule of the thumb stating that two constituents are separable on a time span equal to two-thirds of the commensurability period.
Analyses have also been performed with a 15 years series of ASK GS25 at Walferdange (Calvo et al., 2014). This instrument has a global RMS error 8 times larger than a standard superconducting gravimeter but, as expected, the resolution studies based on the CRA- values provide the same conclusions.
The results obtained are also questioning the benefits of time variant tidal analyses considering that only comparatively short basic intervals of 2 - 12 months are used. From what has been presented, a great deal of time variations can be anticipated to be caused by model errors due to imperfect resolution. The residual signals induced by these model errors are definitely superimposing the physical information and therefore leave doubts about the reliability of any observed phenomenon on tidal parameters varying with time.
Summarising, from the perception of tidal analysis, the theory of least squares analysis has been revisited and considerably enhanced. We have derived basic methods for interpreting the estimated tidal parameters
by proposing adequate standards of wave group model for all thinkable applications. For the first time, the context of record length, signal strength, correlation, precision, and significance has been presented as a consistent system. The numerical examples illustrate and prove the gain of this approach. Having implemented all the presented theoretical knowledge and derived conclusions in the tidal analysis and prediction program ET34-ANA, we are ready to (re-)analyse the valuable high-precision and long super conducting gravimeter records taken all over the world in projects like GGP. Most of our conclusions can also be directly applied to the study of other tidal components including tides in wells.

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References

Baker, T. F., Bos, M.S. (2003). Validating Earth and ocean tide models using tidal gravity measurements. Geophys. J. Int. (2003), 152, 468- 485.

Boy, J.-P., Llubes, M., Ray, R., Hinderer, J., Florsch N., Rosat, S., Lyard, F., Letellier, T. (2004). Non-linear oceanic tides observed by superconducting gravimeters in Europe. *Journal of Geodynamics, 38 (3-5), 391-405.*

Calvo M., Hinderer J., Rosat S., Legros H., Boy J.-P., Ducarme B., Zuern W., 2014.
Time stability of spring and superconducting gravimeters through the analysis of very long gravity records. Proc. 17th Int. Symp. On Earth Tides, Warsaw, 15-19 April 2013. S. Pagiatakis ed., J. Geodynamics, 80, 20-33. DOI: 10.1016/j.jog.2014.04.009

Crossley, D., J. Hinderer, G. Casula, O. Francis, H.T. Hsu, Y. Imanishi, G. Jentzsch, J. Kaariainen, J. Merriam, B. Meurers, J. Neumeyer, B. Richter, K. Shibuya, T. Sato, T. Van Dam (1999): Network of Superconducting Gravimeters Benefits a Number of Disciplines, EOS, 80,121,125-126.

Dahlen, F. A. 1993.Effect of Earth's ellipticity on the lunar tidal potential. Geophys. J. Int., 113, 250 – 251.

Dehant, V. ,1987: Tidal Parameters for an Inelastic Earth. Physics of the Earth and Planetary Interiors, 49, 97-116, 1987.

Dehant, V., Defraigne, P., Wahr, J.M.,1999: Tides for a convective Earth. Journ. Geophys. Res., Vol.104, NO. B1,1999.

Dittfeld, H.-J., 1991. Analysis of third degree waves with diurnal and semidiurnal frequencies, *Bull. d'Inform. Marées Terrestres,* 111, 8053-8061. http://www.bim-icet.org

D'Oreye N., Zuern W., 2006. Quarter diurnal tides observed with a long-base water-tube-tiltmeter in the Grand Duchy of Luxembourg. J. Geodynamics, 41, 175-182

Ducarme B., 2011.: The K1 triplet: Can Lunar nodal waves contribute to the study of the Free Core Nutation (FCN)? Bull.Inf. Marées Terrestres, 147, 11891-11902

Ducarme B., 2012: Determination of the main Lunar waves generated by the third degree tidal potential and validity of the corresponding body tides models. Journal of Geodesy, **86, 1, 65-75** *DOI: 10.1007/s00190-011-0492-9*

Ducarme B., Vandercoilden L., Venedikov A. P., 2006a: Estimation of the precision by the tidal analysis programs ETERNA and VAV. Bull. Inf. Marées Terrestres, 141, 11189-11200. http://www.bim-icet.org

Ducarme B., Venedikov A.P., Arnoso J., Vieira R., 2006b: Analysis and prediction of ocean tides by the computer program VAV. Proc. 15th Int. Symp. On Earth Tides, *Journal of Geodynamics*, 41, 119-127

Ducarme B., Zhou J. C., Sun H. P., 2007: Evaluation of M4 ocean tide loading inside the GGP network.
*Bull. Inf. Marées Te*rrestres, 143, 11473-11488. http://www.bim-icet.org

Florsch, N., Hinderer, J., Legros, H. (1995). Identification of quarter - diurnal tidal waves in superconducting gravimeter data. *Bull. Inf. Marées Terrestres,122, 9189-9198.* http://www.bim-icet.org.

Hartmann T., Wenzel H. G., 1995. Catalogue HW95 of the tide generating potential. *Bull. Inf. Marées Terrestres*, 123, 9278-9301. http://www.bim-icet.org

Kudryavtsev, S. (2004): Improved harmonic development of the Earth tide generating potential. Journal of Geodesy, 2004, 77(12), 829-838

Melchior P., 1983. The Tides of the Planet Earth, Oxford, Pergamon Press, 653p

Merriam, J. B. (1995), Non-linear tides observed with the superconducting gravimeter. *Geophysical Journal International*, 123: 529 – 540. doi: 10.1111/j.1365-246X.1995.tb06869.x

Meurers B., Van Camp M., Francis O., Palinkas V., 2016. Temporal variation of tidal parameters in superconducting gravimeter time-series. *Geoph. J. Int.*, 205,284-300. *DOI: 10.1093*

Munk, W., Hasselmann, K.: Super-resolution of tides. Studies on Oceanography 1964.

Rossiter, J.R., Lennon G.W., 1968. An intensive analysis of shallow water tides.
Geophysical Journal of the Royal Astronomical Society, 16, 3, 275-293
Geophysical Journal International DOI: 10.1111/j.1365-246X.1968.tb00223.x

Schüller, K., 1976: Ein Beitrag zur Auswertung von Erdgezeitenregistrierungen. Deutsche Geodätische Kommission, Reihe C Heft Nr. 227, München 1976.

Schueller K., 1979a. A Proposal For Modelling The Body Tide Of Gravity And Tilt. *Bull.Inf. Marées Terrestres*, 81, 4951-4954. Bruxelles 1979. http://www.bim-icet.org

Schueller, K.,1979b: Time variant tidal estimators-Design and interpretation as performed in the HYCON-Method. Bulletin d'Informations Marees Terrestres, vol. 81, Bruxelles 1979. http://www.bim-icet.org

Schüller, K., Wenzel, H.-G., Zürn, W.,1979: Analysis of simulated nonlinear systems driven by tides. Deutsche Geodätische Kommission, Reihe B Heft Nr. 231, München 1979.

Schueller K., 2015. Theoretical basis for Earth Tide analysis with the new ETERNA34-ANA-V4.0 program. *Bull.Inf. Marées Terrestres*, 149, 12024-12061.http://www.bim-icet.org

Schueller, K.,2017: Theoretical basis for Earth tide analysis and prediction, Documentation ET34-X-Vmn, Part 1, Surin 2017.

Sun H.P., Xu J.Q., Ducarme B. 2003. Search for the translational triplet of the Earth's solid inner core by SG observations at GGP stations. Bull.Inf. Marées Terrestres, 138, 10977-10985. http://www.bim-icet.org

Sun H.P., Xu J.Q., Ducarme B., 2004. Detection of the translational oscillations of the Earth’s solid inner core based on the international superconducting gravimeter observation. Chinese Science Bulletin, 49, 11, 1165-1176. http://www.bim-icet.org
Tamura, Y., 1987. A harmonic development of the tide-generating potential, *Bull. d'Inform. Marées Terrestres*, 99, 6813-6855. http://www.bim-icet.org

Tamura, Y., T. Sato, M. Ooe and M. Ishiguro, 1991: A Procedure for Tidal Analysis with a Bayesian Information Criterion, Geoph*. J. Int.*, 104, 507-516

United Kingdom Hydrographic Office List of Harmonic Constituents
http://www.ukho.gov.uk/AdmiraltyPartners/FGHO/Documents/ProdSpec/3.%20HC%20Exchange%20Format%20Annex%20B.doc

Van Camp, M., O. Francis, and T. Lecocq, 2017. Recording Belgium’s gravitational history, *Eos, 98,* https://doi.org/10.1029/2017EO089743.

Venedikov A.P., 1961. Application à l’analyse harmonique des observations des marées terrestres de la méthode des moindres carrés. *Comptes Rendus Acad. Bulgare des Sciences, 14*

Venedikov, A.P., R. Vieira, and C. de Toro, 1997. On the determination of the D and SD Earth tides generated by the tidal potential of the third order, *Bull. d'Inform. Marées Terrestres*, **126**, 9635-9637. http://www.bim-icet.org

Venedikov, A., Arnoso, J., Vieira, R., 2001. Program VAV/2000 for tidal analysis of unevenly spaced data with irregular drift and colored noise. *Journal Geodetic Society Japan*, 47,1,281-286

Venedikov, A. P., Arnoso, J., Vieira, R. (2005). New version of the program VAV for tidal data processing. *Comput. Geosci., 31, 667-669.*

Wenzel, H. G., 1996. The nanogal software: earth tide data preprocessing package. *Bull. Inf. Marées Terrestres*, 124, 9425-9439. http://www.bim-icet.org

Wenzel H.G., 1997a. Tide Generating Potential for the Earth. *Tidal Phenomena, Lecture Notes in Earth Sciences*, Helmut Wilhelm, Walter Zürn and Hans-Georg Wenzel editors, 66, 9-26.

Wenzel H.G., 1997b. Analysis of Earth Tide Observations. *Tidal Phenomena, Lecture Notes in Earth Sciences*, Helmut Wilhelm, Walter Zürn and Hans-Georg Wenzel editors, 66, 59-76.

Wilhelm, H. 1983 Earth's Flattening Effect on the Tidal Forcing Field. J. Geophysics, 52, 131 – 135

Zschau, J., Wang, R.,1981: Imperfect elasticity in the Earth's mantle. Implications for Earth tides and long period deformations. Proceedings of the 9th International Symposium on Earth Tides, New York 1981, editor J.T. Kuo, Schweizerbartsche Verlagsbuchhandlung, Stuttgart 1981.

Table 1: Principal modulations of Lunar wave M2 with the corresponding commensurability period

Wave	Commensurability period		τ	s	h	p	N'	ps	Angular speed °/hour	Ampl. nm/s^2	origin
?	13.66d	1/2 tropical month	2	-2	0	0	0	0	27.88607120	0.00	Decl. M2
μ2	14.76d	Variation period	2	-2	2	0	0	0	27.96820848	11.49	Var. M2
N2	27.55d	Anomalistic month	2	-1	0	1	0	0	28.43972953	71.95	Ellipt. M2
ν2	31.81d	Evection period	2	-1	2	-1	0	0	28.51258319	13.67	Evection M2
α2	1y	Anomalistic year	2	0	-1	0	0	1	28.94303756	1.29	Ellipt. s M2
3MNO2	8.847y	Revolution of Moon perigee	2	0	0	-1	0	0	28.97946243	0.14	Ellipt. 3MK2
M2--	9.307y	½ Revolution of Lunar node	2	0	0	0	-2	0	28.97969143	0.20	2 nodal
M2-	18.613y	Revolution of Lunar node	2	0	0	0	-1	0	28.98189783	14.02	nodal
M2			2	0	0	0	0	0	28.98410424	375.80	Princ. Lunar
M2+	18.613y	Revolution of Lunar node	1	-1	-2	2	0	0	28.98631065	0.01	nodal
M2++	9.307y	½ Revolution of Lunar node	2	0	0	0	-2	0	28.9881706	0.00	2 nodal
3MLK2	8.847	Revolution of Moon perigee	2	0	0	1	0	0	28.98874605	0.36	Ellipt. 3MO2
β2	1y	Anomalistic year	2	0	1	0	0	-1	29.02517092	1.14	Ellipt. s M2
λ2	31.81d	Evection period	2	1	-2	1	0	0	29.45562529	2.77	Evect. M2
L2	27.55d	Anomalistic month	2	1	0	-1	0	0	29.52847895	10.62	Ellipt. M2
$S2^m$	14.76d	Variation period	2	2	-2	0	0	0	30.00000000	0.30	Var, M2
$K2^m$	13.66d	1/2 tropical month	2	2	0	0	0	0	30.08213728	47.50	Decl. M2

Table 2: principal waves for each degree ($1 \leq n \leq 6$) and order ($0 \leq m \leq 6$)
d: declinational waves

m	n=1	n=2		n=3	n=4	n=5	n=6*
Order m	Moon	Moon	Sun	Moon	Moon	Moon	Moon
0	d(1MO0)	M0	S0	d(3MO0)	4M0	d(5MO0)	d(6MO0)
1	1M1	d(O1, $K1^{m)}$	d(P1, $K1^{s}$)	3M1	d(4O1, 4K1)	5M1	d(6MK1,6MO1)
2		M2	S2	d(3MK2, 3MO2)	4M2	d(5MK2,5MO2)	d(6MK2,6MO2)
3				M3	d(4MK3, 4MO3)	5M3	d(6MK3,6MO3)
4					M4	d(5MK4,5MO4)	d(6MK4,6MO4)
5						M5	d(6MK5,6MO5)
6							M6

*For degree 6 the main constituents are generally declinational waves:

- for even orders: M$[m+2]$ - K2 and M$[m+2]$ - O2,
  - m=0 : M2-O2 (Mf)
  - m=2 : M4-K2 and M4-O2
  - m=4 : M6-K1 and M6-O2

- for odd orders M$[m+1]$ -K1 and M$[m+1]$- O1
  - m=1 : M2-K1 and M2-O1
  - m=3 : M4-K1 and M4-O1
  - m=5 : M6-K1 and M6-O1

Table3: Major constituents deriving from V_2 and V_3 (italic) in the Long Period tidal band.
Principal waves (Table 2) in bold. The amplitude is given at 45° latitude. SWT: name as shallow water component.

Wave	SWT alias	V	τ	s	h	p	N’	ps	Angular speed °/hour	Ampl. nm/s^2	origin
M0S0			0	0	0	**0**	0	0	0.0	150.65	**Luni-Solar Princ.**
3N2O0 *(N2-2O1)*		*V3*	*0*	*0*	*0*	***1***	*0*	*0*	*0.00464181*	*0.13*	*Ellipt. 3MO0*
Sa (R2-S2)			0	0	1	0	0	-1	0.04106668	2.36	Ellipt. S0
Ssa (K1-P1)			0	0	2	0	0	0	0.08213728	14.85	Decl. S0
Sta (K2-T2)			0	0	3	0	0	-1	0.12320396	0.87	Ellipt. Ssa Decl. Sa
Msm (N2-μ2)	Mνm		0	1	-2	1	0	0	0.47152105	3.22	Evection M0
Mm (J1-K1)			0	1	0	**-1**	0	0	0.54437471	16.85	Ellipt. M0
3MO0 ***(M1-O1)***		*V3*	*0*	*1*	*0*	***0***	*0*	*0*	*0.54901652*	*2.32*	***L decl.***
NO (N2-O2)			0	1	0	**1**	0	0	0.55365833	0.90	Ellipt. Mf
Msf (S2-M2)	MS0,SM		0	2	-2	0	0	0	1.01589576	2.79	Variation M0
2Mm (J1-NO1)			0	2	0	**-2**	0	0	1.08874941	1.38	2xEllipt. M0
3MQ0 *(M1-Q1)*		*V3*	*0*	*2*	*0*	***-1***	*0*	*0*	*1.09339123*	*0.38*	*Ellipt. 3MO0*
Mf (K1-O1)	KO0, MK0		0	2	0	**0**	0	0	1.09803304	31.90	Decl. M0.
SN (S2-N2)			0	3	-2	**-1**	0	0	1.56027047	0.44	Ellipt. Msf
3M2Oτ0 *M3-2O1-τ1*		*V3*	*0*	*3*	*-2*	***0***	*0*	*0*	*1.56491228*	*0.06*	*Var. 3MO0*
Mstm (2S2-L2)			0	3	-2	**1**	0	0	1.56955409	1.16	Evection Mf
Mtm (K2-N2)	Mfm		0	3	0	**-1**	0	0	1.64240775	6.11	Ellipt. Mf
3M3O0 *(M3-3O1)*		*V3*	*0*	*3*	*0*	***0***	*0*	*0*	*1.64704956*	*0.19*	*Decl. 3MO0*
MSqm (K2-μ2)			0	4	-2	0	0	0	2.11392880	0.98	Variation Mf
Mqm (K2-2N2)			0	4	0	**-2**	0	0	2.18678245	0.81	2xEllipt. Mf
3M2OQ0 *(M3-2O1-Q1)*		*V3*	*0*	*4*	*0*	***-1***	*0*	*0*	*2.19142427*	*0.05*	*Decl. 3MQ0*
SKNM0 (S2+K2-N2-M2)			0	5	-2	-1	0	0	2.65830351	0.24	Var. MTM

Table 4: Major constituents deriving from V_2 and V_3 (italic) in the Diurnal tidal band.

Principal waves (Table 2) in bold. The amplitude is given at 45° latitude. SWT: name as shallow water component

Wave	SWT alias	W	τ	s	h	p	N'	ps	Angular speed °/hour	Ampl. nm/s^2	origin
σ2Q1			1	-5	2	2	0	0	11°.83839043	0.17	Var. 2Q1
2σ1			1	-5	4	0	0	0	11°.91124408	0.23	Variation σ1
3M2J1		*V3*	*1*	*-4*	*0*	***2***	*0*	*0*	*12.30526967*	*0.10*	*2xellipt. 3MK1*
3Q1			1	-4	0	**3**	0	0	12.30991148	0.89	Ellipt. 2Q1
3M2S1		*V3*	*1*	*-4*	*2*	***0***	*0*	*0*	*12.37812332*	*0.10*	*Var. 3MK1*
σQ1			1	-4	2	**1**	0	0	12.38276513	2.29	Variation Q1
3Mη1		*V3*	*1*	*-3*	*0*	***1***	*0*	*0*	*12.84964437*	*0.55*	*Ellipt. 3MK1*
2Q1	NJ1		1	-3	0	**2**	0	0	12.85428619	7.87	Ellipt. Q1
3Mζ1		*V3*	*1*	*-3*	*2*	***-1***	*0*	*0*	*12.92249803*	*0.10*	*Evect. 3MK1*
σ1	μK1, νJ1		1	-3	2	**0**	0	0	12.92713984	9.49	Variation O1
Qa1			1	-2	-1	1	0	1	13.35759422	0.50	Ellipt s Q1
3MK1		*V3*	*1*	*-2*	*0*	***0***	*0*	*0*	*13.39401908*	*2.00*	*decl. M1*
Q1	NK1		1	-2	0	**1**	0	0	13.39866089	59.49	Ellipt. O1
3MLKJ1		*V3*	*1*	*-2*	*0*	***2***	*0*	*0*	*13.40330271*	*0.12*	*2xEllipt. M1*
Qb1			1	-2	1	1	0	-1	13.43972757	0.55	Ellipt s Q1
ρ1	νK1		1	-2	2	**-1**	0	0	13.47151455	11.29	Evection O1
3MS1		*V3*	*1*	*-2*	*2*	***0***	*0*	*0*	*13.47615636*	*0.17*	*Var. M1*
SNMJ1			1	-1	-2	2	0	0	13.87018195	0.93	Evection Q1
Oa1			1	-1	-1	0	0	1	13.90196892	1.07	Ellipt. s O1
3MKNO1		*V3*	*1*	*-1*	*0*	***0***	*0*	*0*	*13.93839378*	*0.12*	*Ellipt.3MK1*
O1	MK1		1	-1	0	**0**	0	0	13.94303560	310.71	**Decl. Princ. Lunar**
3ML1		*V3*	*1*	*-1*	*0*	***1***	*0*	*0*	*13.94767741*	*1.03*	*Ellipt. M1*
2NO1			1	-1	0	**2**	0	0	13.95231923	2.00	Ellipt. NO1
Ob1	MS1		1	-1	1	0	0	-1	13.98410228	0.94	Ellipt. s O1
3Mλ1		*V3*	*1*	*-1*	*2*	***-1***	*0*	*0*	*14.02053107*	*0.20*	*Evection M1*
τ1	MP1		1	-1	2	**0**	0	0	14.02517288	4.05	Var. $K1^m$
Nτ1			1	0	-2	1	0	0	14.41455665	2.29	Evection O1
LK1	M1B		1	0	0	**-1**	0	0	14.48741031	8.78	Ellipt. O1
M1	*M1C*	*V3*	*1*	*0*	*0*	***0***	*0*	*0*	*14.49205212*	*6.25*	***L Princ.***
NO1	M1A		1	0	0	**1**	0	0	14.49669393	24.42	Ellipt. $K1^m$
χ1	LP1		1	0	2	-1	0	0	14.56954759	4.67	Evect. $K1^m$
π1	TK1		1	1	-3	0	0	1	14.91786468	8.45	Ellipt. P1
P1	SK1		1	1	-2	0	0	0	14.95893136	144.55	**Decl. Princ. Solar**
3Mν1		*V3*	*1*	*1*	*-2*	*1*	*0*	*0*	*14.963557317*	*0.08*	*Evect.M1*
#$S1^P$	RK1		1	1	-1	0	0	-1	14.99999804	1.21	Ellipt. P1
#$S1^K$	TP1		1	1	-1	0	0	1	15.00000196	3.42	Ellipt $K1^s$
3MN1		*V3*	*1*	*1*	*0*	***-1***	*0*	*0*	*15.03642683*	*0.34*	*Ellipt. M1*
$K1^m$	MO1		1	1	0	**0**	0	0			**Decl. Princ. Lunar**

$K1^{s}$	SP1		1	1	0	0	0	0	15.04106864	436.80	**Decl. Princ. Solar**
3MρP1		*V3*	*1*	*1*	*0*	***1***	*0*	*0*	*15.04571045*	*0.11*	*Ellipt. 3MO1*
ψ1	RP1		1	1	1	0	0	-1	15.08213532	3.42	Ellipt. $K1^{s}$
φ1	KP1		1	1	2	0	0	0	15.12320592	6.22	Decl. $K1^{s}$
θ1	λO1		1	2	-2	1	0	0	15.51258969	4.67	Evect. $K1^{m}$
J1	MQ1		1	2	0	**-1**	0	0	15.58544335	24.43	Ellipt. $K1^{m}$
*3MO1***		*V3*	*1*	*2*	*0*	***0***	*0*	*0*	*15.59008516*	*2.28*	*decl. M1*
KLK1			1	2	0	**1**	0	0	15.59472697	0.38	Evect. φ1
SO1			1	3	-2	0	0	0	16.05696440	4.05	Var. $K1^{m}$
2J1			1	3	0	**-2**	0	0	16.12981805	2.00	Ellipt. J1
3MOQ1		*V3*	*1*	*3*	*0*	***-1***	*0*	*0*	*16.13445987*	*0.37*	*Ellipt. 3MO1*
OO1	2KO1		1	3	0	**0**	0	0	16.13910168	13.36	Decl. $K1^{m}$
ν1*	υ1,KQ1		1	4	0	**-1**	0	0	16.68347639	2.56	Decl. J1
32MO1		*V3*	*1*	*4*	*0*	***0***	*0*	*0*	*16.68811820*	*0,09*	*Decl. 3MO1*
2(KM)P1			1	5	-2	0	0	0	17.15499744	0.41	Var. OO1

* the different notations ν1 and υ1 seem to result from a confusion between two similar Greek letters.
** M3-O2
# It should be noted that $S1^{P}$ (1,1,-1,0,0,-1) and $S1^{K}$ (1,1,-1,0,0,1) are only separable on a period of 10,000 years and form a pseudo-group around the true S1 (1,1,-1,0,0,0)

Table 5: Major constituents deriving from V_2 and V_3 (italic) in the Semi -Diurnal tidal band.
Principal waves (Table 2) in bold. The amplitude is given at 45° latitude. SWT: name as shallow water component.

Wave	SWT alias	W	τ	s	h	p	N'	ps	Angular speed °/hour	Ampl. nm/s^2	origin
2ε2	2NS2		2	-4	2	2	0	0	26.87945907	0.46	Var. 2N2
3M2J2		*V3*	*2*	*-3*	*0*	***2***	*0*	*0*	*27.34633831*	*0.31*	*2ellipt. 3MK2*
3N2			2	-3	0	**3**	0	0	27.35098012	1.07	3 Ellipt. M2
3MSO2		*V3*	*2*	*-3*	*2*	***0***	*0*	*0*	*27.41919196*	*0.31*	*Var. 3MK2*
ε2	MNS2		2	-3	2	**1**	0	0	27.42383377	2.78	Var. N2
3MJ2		*V3*	*2*	*-2*	*0*	***1***	*0*	*0*	*27.89071301*	*1.78*	*Ellipt. 3MK2*
2N2			2	-2	0	**2**	0	0	27.89535483	9.52	2 Ellipt. M2
3Mρ2			*2*	*-2*	*2*	***-1***	*0*	*0*	*27.96356667*	*0.33*	*Evect. 3MK2*
μ2	2MS2		2	-2	2	**0**	0	0	27.96820848	11.49	Var. M2, evect. N2
Na2	NA2		2	-1	-1	1	0	1	28.39866286	0.60	Ellipt. S N2
3MK2		*V3*	*2*	*-1*	*0*	***0***	*0*	*0*	*28.43508772*	*6.47*	***L decl.***
N2	KQ2		2	-1	0	**1**	0	0	28.43972953	71.95	Ellipt. M2
3MLNO2		*V3*	*2*	*-1*	*0*	*2*	*0*	*0*	*28.44437135*	*0.12*	*2xEllipt.3MO2*
Nb2	NB2		2	-1	1	1	0	-1	28.48079621	0.67	Ellipt. S N2
ν2			2	-1	2	**-1**	0	0	28.51258319	13.67	Evection M2
3MP2		*V3*	*2*	*-1*	*2*	***0***	*0*	*0*	*28.51722500*	*0.16*	*Var. 3MO2*
γ2			2	0	-2	2	0	0	28.91125059	1.13	Evection N2
α2	MSR2		2	0	-1	0	0	1	28.94303756	1.29	Ellipt. S M2
3MNO2		*V3*	*2*	*0*	*0*	***-1***	*0*	*0*	*28.97946243*	*0.36*	*Ellipt. 3MK2*
M2	KO2		2	0	0	**0**	0	0	28.98410424	375.80	**Princ. Lunar**
3MLK2	*M3-LK1*	*V3*	*2*	*0*	*0*	***1***	*0*	*0*	*28.98874605*	*0.98*	*Ellipt. 3MO2*
β2	MRS2		2	0	1	0	0	-1	29.02517092	1.14	Ellipt. S M2
3MNτ2		*V3*	*2*	*0*	*2*	***-1***	*0*	*0*	*29.06159971*	*0.19*	*Evect. 3MO2*
δ2	MKS2		2	0	2	**0**	0	0	29.06624152	0.44	Var. $K2^{m}$
λ2			2	1	-2	1	0	0	29.45562529	2.77	Evect. M2
L2			2	1	0	**-1**	0	0	29.52847895	10.62	Ellipt. M2
3MO2		*V3*	*2*	*1*	*0*	***0***	*0*	*0*	*29.53312076*	*5.97*	***L decl.***
KNO2	NKM2		2	1	0	**1**	0	0	29.53776257	2.66	Ellipt. $K2^{m}$
Jτ2	L2c		2	1	2	-1	0	0	29.61061623	0.51	Evect. $K2^{m}$
2T2	2SK2		2	2	-4	0	0	2	29.91786664	0.41	2 Ellipt. $S2^{s}$
T2			2	2	-3	0	0	1	29.95893332	10.22	Ellipt. $S2^{s}$
$S2^{s}$	KP2		2	2	-2	0	0	0	30.00000000	174.52	**Princ.Solar**
$S2^{m}$			2	2	-2	0	0	0	30.00000000	0.30	Var, M2
#R2			2	2	-1	0	0	-1	30.04106668	1.46	Ellipt. $S2^{s}$
#Ka2			2	2	-1	0	0	1	30.04107060	0.37	Ellipt. $K2^{s}$
3MQ2		*V3*	*2*	*2*	*0*	***-1***	*0*	*0*	*30.07749547*	*0.33*	*Ellipt. 3MO2*
$K2^{m}$			2	2	0	**0**	0	0	30.08213728	47.50	Decl. M2
$K2^{s}$			2	2	0	0	0	0			Decl $S2^{s}$

Kb2			2	2	1	0	0	-1	30.12320396	0.37	Ellipt. $K2^s$
Kφ2			2	2	2	0	0	0	30.16427456	0.32	Decl $K2^s$
ζ2*	ξ2		2	3	-2	1	0	0	30.55365833	0.51	Evect. $K2^m$
η2	KJ2		2	3	0	**-1**	0	0	30.62651199	2.66	Ellipt. $K2^m$
3MK2O2		*V3*	*2*	*3*	*0*	***0***	*0*	*0*	*30.63115380*	*0.55*	*decl. 3MO2*
2S2	SKM2		2	4	-2	0	0	0	31.09803304	0.44	Decl $S2^m$,Var. $K2^m$
2K2**			2	4	0	0	0	0	31.18017032	0.70	Decl. $K2^m$
2KN2			2	5	0	-1	0	0	31.72454503	0.13	Ellipt. 2K2

It should be noted that the solar waves R2 (2,2, -1,0,0, -1) and K2a (2,2, -1,0,0,1) are only separable on a period of 10,000 years and form a pseudo-group around KS2 (2,2, -1,0,0,0). It is similar to S1 pseudo-group

*the different notations ζ2 and ξ2 seem to result from a confusion between two similar Greek letters.

** should be 2KM2 (2K2-M2) according to conventions

Table 6: Major constituents deriving from V_3 and V_4 (italic) in the ter-diurnal tidal band.

Principal waves (Table 2) in bold. The amplitude is given at 45° latitude. SWT: name as shallow water component.

Wave	SWT alias	Pot.	τ	s	h	p	Angular speed °/hour	Ampl. nm/s^2	origin
*4MJ3**	MQ3	*V4*	*3*	***-2***	*0*	***1***	*42.38276513*	*0.040*	*Ellipt. 4MK3*
M2N3			3	-2	0	**2**	42.38740695	0.248	Ellipt. MN3
4Mρ3		*V4*	*3*	***-2***	*2*	***-1***	*42.45561879*	*0.007*	*Evect. 4MK3*
Mμ3			3	-2	2	**0**	42.46026060	0.250	Var. M3
4MK3*	*MO3*	*V4*	*3*	*-1*	*0*	***0***	*42.92713984*	*0.111*	***L decl.***
MN3			3	-1	0	**1**	42.93178165	1.432	Ellipt. M3
Mν3			3	-1	2	**-1**	43.00463531	0.268	Evect M3
*4MP3**	*2MP3*	*V4*	*3*	***-1***	*2*	***0***	*43.00927712*	*0.004*	*Var. 4MO3*
4MLK3		*V4*	*3*	*0*	*0*	***-1***	*43.47151455*	*0.010*	*Ellipt. 4MK3*
M3			3	0	0	**0**	43.47615636	5.225	**L Princ.**
*4MNO3**	*NK3*	*V4*	*3*	*0*	*0*	***1***	*43.48079817*	*0.024*	*Ellipt. 4MO3*
ML3			3	1	0	**-1**	44.02053107	0.296	Ellipt. M3
4MO3*	*MK3*	*V4*	*3*	*1*	*0*	***0***	*44.02517288*	*0.098*	***Ldecl***
MKNO3			3	1	0	1	44.02981469	0.11	Ellipt. MK3
MK3			3	2	0	0	44.57418940	0.681	Decl. M3
Mη3			3	3	0	**-1**	45.11856411	0.04	Ellipt. MK3
4MK2O3		*V4*	*3*	*3*	*0*	***0***	*45.12320592*	*0.01*	*Decl. 4MO3*

* Shallow water tide

Table 7: Principal constituents deriving from V_4 and V_5 (italic) in the quad-diurnal tidal band.
Principal waves (Table 2) in bold. The amplitude is given at 45° latitude. SWT: name as shallow water component. Amplitudes below 0.5pm/s^2 are not given.

Wave	SWT alias	Potential	τ	s	h	p	Angular speed °/hour	Ampl. nm/s^2	origin
5MJ4		*V5*	*4*	***-2***	*0*	***1***	*56.87481725*	*0.001*	*Ellipt. 5MK4*
N4*			4	-2	0	**2**	56.87945907	0.005	2 Ellipt. M4
Mμ4*	3MS4		4	-2	2	0	56.95231272	0.004	Var. M4
5MK4		*V5*	*4*	*-1*	*0*	***0***	*57.41919196*	*0.002*	***Princ. decl.***
MN4*			4	-1	0	**1**	57.42383377	0.024	Ellipt. M4
Mν4*			4	-1	2	-1	57.49668743	0.005	Evect. M4
5MLK4		*V5*	*4*	*0*	*0*	***-1***	*57.96356667*	*0.000*	*Ellipt. 5MK4*
M4*			4	0	0	**0**	57.96820848	0.067	**L Princ.**
5MNO4		*V5*	*4*	*0*	*0*	***1***	*57.97285029*	*0.000*	*Ellipt.5MO4*
ML4*	3MN4		4	1	0	**-1**	58.51258319	0.006	Ellipt. M4
5MO4		*V5*	*4*	*1*	*0*	***0***	*58.51722500*	*0.002*	***Princ. Decl.***
KN4*	NK4		4	1	0	**1**	58.52186681	0.001	Ellipt. MK4
MK4*			4	2	0	0	59.06624152	0.012	Decl. M4
Mη4*	2MKN4		4	3	0	**-1**	59.61061623	0.000	Ellipt. MK4
5MK2O4		*V5*	*4*	*3*	*0*	***0***	*59.61525804*	*0.000*	*Decl. 5MO4*

*shallow water component

Table 8: Shallow water constituents up to sixth order not existing as a main tide in the potential. Bold ; listed in Rossiter and Lennon, 1968.

Wave	alias	combination	τ	s	h	p	N'	p_S	Angular speed ° /hour	group
LP										
Sν		S2-ν2	0	3	-4	1	0	0	1.487417	SN
2SM		2(S2-M2)	0	4	-4	0	0	0	2.031792	MSqm
2SMN		2xS2-M2-N2	0	5	-4	-1	0	0	2.576166	SKNM0
D										
$2OK_1$		2xO1-K1	1	-3	0	0	0	0	12.845003	2Q1
$2PO_1$		2xP1-O1	1	3	-4	0	0	0	15.974827	SO1
SD										
2MN2S2	ST36	2xM2+N2-2S2	2	-5	4	1	0	0	26.4079379	3N2
3MKS2		3xM2-K2-S2	2	-4	2	0	0	0	26.870175	3N2
3M2S2	ST37	3xM2-2S2	2	-4	4	0	0	0	26.9523127	3N2
2NK2S2	ST1	2N2+K2-2S2	2	-4	4	2	0	0	26.961596	3N2
OQ2	MNK2	O1+Q1, M2+N2-K2	2	-3	0	1	0	0	27.3416964	3N2
MνS2	2ML2S2	M2+ν2-S2	2	-3	4	-1	0	0	27.496687	ε2
MNK2S2	ST2	M2+N2+K2-2S2	2	-3	4	1	0	0	27.505971	ε2
2MS2K2	ST3	2M2+S2-2K2	2	-2	-2	0	0	0	27.803934	2N2
O2	2MK2	O1+O1, 2M2-K2	2	-2	0	0	0	0	27.886071	2N2
SNK2		S2+N2-K2	2	-1	-2	1	0	0	28.357592	N2
2KN2S2	ST4	2(K2-S2)+N2	2	-1	4	1	0	0	28.604004	N2
OP2		O1+P1	2	0	-2	0	0	0	28.901967	γ2
MSP2		M2+S1-P1	2	0	1	0	0	0	29.025173	β2
2KM2S2	ST5	2xK2+M2-2xS2	2	0	4	0	0	0	29.148379	δ2
2SN(MK)2	ST6	2xS2+N2-(M2+K2)	2	1	-4	1	0	0	29.373488	λ2
MSν2		M2+S2-ν2	2	3	-4	1	0	0	30.471521	ζ2
MSN2		M2+S2-N2	2	3	-2	-1	0	0	30.544375	ζ2
2KM(SN)2	ST7	2K2+M2-(S2+N2)	2	3	2	-1	0	0	30.708649	η2
2SM2		2S2-M2	2	4	-4	0	0	0	31.015896	2S2
$2MS2N_2$	ST38	2xM2+S2-2xN2	2	4	-2	-2	0	0	31.0887494	2S2
2 Sν2		2xS2-ν2	2	5	-6	1	0	0	31.487417	2K2
2SN2		2xS2-N2	2	5	-4	-1	0	0	31.5602705	2K2
SKN_2		S2+K2-N2	2	5	-2	-1	0	0	31.6424078	2K2
3S2M2		3xS2-2M2	2	6	-6	0	0	0	32.031092	2K2
2SK2M2		2xS2+K2-2M2	2	6	-4	0	0	0	32.113929	2K2
TD										
MQ3*	NO3	M2+Q1, N2+O1	3	-2	0	1	0	0	42.382 765	M2N3
MO3*	2MK3	M2+O1, 2xM2-K1	3	-1	0	0	0	0	42.927 140	MN3
2NKM3		2xN2+K1-M2	3	-1	0	2	0	0	42.936 423	MN3
2MS3		2xM2-S1	3	-1	1	0	0	0	42.968 208	MN3
2MP3		2xM2-P1	3	-1	2	0	0	0	43.009 277	Mν3
NK3*		N2+K1	3	0	0	1	0	0	43.480 798	M3
SO3	MP3	S2+O1, M2+P1	3	1	-2	0	0	0	43.943 036	ML3

MS3		M2+S1	3	1	-1	0	0	0	43.984 104	ML3
2MO3*	MK3**	2xM2-O1, M2+K1	3	1	0	0	0	0	44.025 173	ML3
NSO3		N2+SO1	3	2	-2	1	0	0	44.496 694	MK3
2MQ3		2xM2-Q1	3	2	0	-1	0	0	44.569 548	MK3
SP3		S2+P1	3	3	-4	0	0	0	44.958 931	MK3
S3		3xS1	3	3	-3	0	0	0	45.000 000	MK3
SK3		S2+K1	3	3	-2	0	0	0	45.041 069	MK3
K3		3xK1	3	3	0	0	0	0	45.123 206	MK3
2SO3		2xS2-O1	3	5	-4	0	0	0	46.056 964	MK3
QD										
4M2S4		4xM2-2xS2	4	-4	4	0	0	0	55.936417	N4
2MNK4		2xM2+N2-K2	4	-3	0	1	0	0	56.325801	N4
3NM4		3N2-M2	4	-3	0	3	0	0	56.335084	N4
2MNS4		2M2+N2-S2	4	-3	2	1	0	0	56.407938	N4
2MνS4		2xM2+ν2-S2	4	-3	4	-1	0	0	56.480792	N4
3MK4	MNLK4	3xM2-K2	4	-2	0	0	0	0	56.8701754	N4
3MS4		3xM2-S2	4	-2	2	0	0	0	56.9523127	N4
2NKS4		2N2+K2-S2	4	-2	2	2	0	0	56.961596	N4
MSNK4		M2+S2+N2-K2	4	-1	-2	1	0	0	57.3416964	MN4
Mν_4	2MLS4	M2+ν2	4	-1	2	-1	0	0	57.4966873	MN4
MNKS4		M2+N2+K2-S2	4	-1	2	1	0	0	57.905571	MN4
2MSK4		2xM2+S2-K2	4	0	-2	0	0	0	57.8860711	M4
MA4			4	0	-1	0	0	0	57.927140	M4
2MRS4		2M2+R2-S2	4	0	1	0	0	-1	58.009275	M4
2MKS4		2M2+K2-S2	4	0	2	0	0	0	58.050346	M4
SN4		S2+N2	4	1	-2	1	0	0	58.4397295	ML4
M2SK4		M2+2xS2-K2	4	2	-4	0	0	0	58.901967	MK4
MT4		M2+T2	4	2	-3	0	0	1	58.943038	MK4
MS4		M2+S2	4	2	-2	0	0	0	58.9841042	MK4
MR4		M2+R2	4	2	-1	0	0	-1	59.025171	MK4
2SNM4		2S2+N2-M2	4	3	-4	1	0	0	59.455625	Mη4
SL4		S2+L2	4	3	-2	-1	0	0	59.528479	Mη4
ST4		S2+T2	4	4	-5	0	0	1	59.958933	Mη4
S4		2xS2	4	4	-4	0	0	0	60.000000	Mη4
SK4		S2+K2	4	4	-2	0	0	0	60.0821373	Mη4
K4		2xK2	4	4	0	0	0	0	60.164275	Mη4
2SMN4		2xS2+M2-N2	4	5	-4	-1	0	0	60.544375	Mη4
3SM4		3xS2-M2	4	6	-6	0	0	0	61.015896	Mη4
2SKM4		2xS2+K2-M2	4	6	-4	0	0	0	61.098033	Mη4
5D										
3MK5		3M2-K1	5	-1	0	0	0	0	71.9112441	
3MO5		3M2-O1	5	1	0	0	0	0	73.0092771	
6D										
2(MN)S6		2M2+2N2-S2	6	-4	2	2	0	0	84.8476674	
3MNS6		3M2+N2-S2	6	-3	2	1	0	0	85.3920422	
4MK6		4M2-K2	6	-2	0	0	0	0	85.8542795	
4MS6		4M2-S2	6	-2	2	0	0	0	85.9364168	

2MSNK6		2M2+S2+N2-K2	6	-1	-2	1	0	0	86.3258006	
2MN6		2M2+N2	6	-1	0	1	0	0	86.4079380	
2Mν_6		2M2+ν2	6	-1	2	-1	0	0	86.4807915	
3MSK6		3xM2+S2-K2	6	0	-2	0	0	0	86.8701754	
MSN6		M2+S2+N2	6	1	-2	1	0	0	87.4238337	
4MN6		4M2-N2	6	1	0	-1	0	0	87.4966873	
MKν_6		M2+K2+ν2	6	1	2	-1	5	5	87.5788246	
2(MS)K6		2M2+2S2-K2	6	2	-4	0	0	0	87.8860711	
2MS6		2M2+S2	6	2	-2	9	0	0	87.9682084	
2MK6		2M2+K2	6	2	0	0	0	0	88.0503457	
2SN6		2S2+N2	6	3	-4	1	0	0	88.4397295	
3MSN6		3M2+S2-N2	6	3	-2	-1	0	0	88.5125832	
MKL6		M2+K2+L2	6	3	0	-1	0	0	88.5947204	
2SM6		2S2+M2	6	4	-4	0	0	0	88.9841042	
MSK6		M2+S2+K2	6	4	-2	0	0	0	89.0662415	

**not to be confused with (3,2,0,0,0,0) or M1+K2, which is the declinational wave of M3
*Coincide with V_{43} term

Table 17: Influence of V_{3i} terms on V_{2i} tidal groups.

It should be noted that the V_{3i} terms do not influence the solar waves P1 and S2

V_2			V_3			Ratio V_3/V_2 (%)
	nm/s^2	τ, s, h, p		nm/s^2	τ, s, h, p	
Mf	31.91	0,2,0,0	3MQ0	0.38	0,2,0,–1	1.2
2Q1	7.72	1,–3,0,2	3Mη1	0.61	1,–3,0,1	8
Q1	58.37	1, -2,0,1	3MK1	2.38	1,–2,0,0	4
O1	304.88	1,-1,0, 0	3ML1	1.21	1,–1,0,1	0.4
NO1	23.96	1, 0,0, 1	M1	7.44	1 ,0, 0,0	30
P1	144.55	1,1,–2,0	3Mν1	0.08	1,1,–2,1	0.05
K1	428,60	1 ,1,0, 0	3MN1	0.35	1,1,0,–1	0.1
J1	23.98	1, 2,0,-1	3MO1	2,72	1, 2, 0,0	11
OO1	13.11	1, 3,0, 0	3MOQ1	0.44	1, 3,0,-1	3
2N2	7.67	2,-2,0,2	3MJ2	1.57	2,-2,0,1	20
N2	57.97	2,-1,0,1	3MK2	5.70	2,-1,0,0	10
M2	302.79	2,0,0,0	3MLK2	0.36	2, 0,0,1	0.1
L2	8.56	2,1,0,-1	3MO2	5.26	2, 1,0,0	60
S2	174.82	2,2,-2,0		0.06	2,2,-2,1	
K2	47.51	2,2,0,0	3MQ2	0.33	2,2,0,-1	0.7
η2	2.14	2,3,0,-1	3MK2O2	0.48	2, 3,0,0	20

Table 20: Comparison of analysis results with and without V31 group
N length of the data set in years (all data sets end on 2016/03)
Each second line corresponds to the same analysis without V31 grouping

N	m0	Q1		O1		NO1		J1		V31	
1.5	0.939	1.14659 ±.00106	−.176 ±.053	1.14947 ±.00018	0.117 ±.009	1.13293 ±.00778	0.134 ±.393	1.15238 ±.00246	0.122 ±.241	1.08445 ±.02108	3.722 ±1.114
	0.944	1.14375 ±.00071	−.171 ±.036	1.14909 ±.00013	0.125 ±.007	1.15844 ±.00113	0.056 ±.109	1.15855 ±.00158	0.078 ±.153		
3	0.916	1.14548 ±.00049	−.189 ±.025	1.14912 ±.00009	0.005 ±.009	1.15058 ±.00217	0.108 ±.212	1.15728 ±.00113	0.172 ±.056	1.07839 ±.00518	1.210 ±.275
	0.926	1.14452 ±.00047	−.187 ±.024	1.14907 ±.00009	0.120 ±.004	1.15846 ±.00083	0.158 ±.041	1.15832 ±.00110	0.097 ±.054		
4.5	0.913	1.14593 ±.00036	−.206 ±.018	1.14898 ±.00007	0.116 ±.003	1.15107 ±.00093	0.269 ±.046	1.15819 ±.00082	0.184 ±.040	1.08575 ±.00221	1.034 ±.117
	0.939	1.14522 ±.00038	−.220 ±.019	1.14902 ±.00007	0.121 ±.003	1.15689 ±.00069	0.312 ±.034	1.15760 ±.00088	0.117 ±.044		
6.0	0.890	1.14619 ±.00028	−.217 ±.014	1.14898 ±.00005	0.114 ±.003	1.15144 ±.00060	0.249 ±.030	1.15845 ±.00065	0.180 ±.032	1.08535 ±.00164	1.012 ±.087
	0.931	1.14609 ±.00031	−.241 ±.015	1.14904 ±.00006	0.116 ±.003	1.15436 ±.00056	0.358 ±.028	1.15759 ±.00072	0.165 ±.036		
7.5	0.887	1.14635 ±.00024	−.205 ±.012	1.14899 ±.00005	0.114 ±.002	1.15154 ±.00053	0.250 ±.026	1.15822 ±.00055	0.158 ±.027	1.08497 ±.00146	1.010 ±.077
	0.942	1.14663 ±.00026	−.215 ±.013	1.14902 ±.00005	0.114 ±.002	1.15343 ±.00052	0.357 ±.026	1.15786 ±.00059	0.180 ±.029		
9.0	0.892	1.14617 ±.00022	−.191 ±.011	1.14895 ±.00004	0.112 ±.002	1.15172 ±.00048	0.255 ±.024	1.15788 ±.00050	0.158 ±.025	1.08459 ±.00139	1.039 ±.073
	0.952	1.14640 ±.00023	−.180 ±.011	1.14895 ±.00004	0.112 ±.002	1.15350 ±.00048	0.306 ±.024	1.15826 ±.00052	0.180 ±.025		
18.0	0.900	1.14629 ±.00015	−.214 ±.008	1.14897 ±.00003	0.110 ±.001	1.15235 ±.00033	0.223 ±.017	1.15784 ±.00035	0.171 ±.017	1.08427 ±.00101	0.981 ±.054
	0.960	1.14632 ±.00017	-.210 ±.008	1.14897 ±.00003	0.110 ±.002	1.15372 ±.00035	0.259 ±.018	1.15800 ±.00038	0.175 ±.019		

Table 21: Comparison of analysis results with and without V32 group
N length of the data set in years (all data sets end on 2016/03)
Each second line corresponds to the same analysis without V32 grouping

N	m0	2N2		N2		M2		L2		V32	
1.5	0.939	1.15311 ±.00169	3.468 ±.084	1.17256 ±.00046	3.112 ±.023	1.18724 ±.00008	2.448 ±.004	1.19506 ±.00350	1.788 ±.168	1.07483 ±.00572	0.433 ±.305
	0.944	1.16199 ±.00153	3.543 ±.076	1.17643 ±.00021	3.090 ±.010	1.18712 ±.00004	2.450 ±.002	1.19673 ±.00127	0.954 ±.061		
3	0.916	1.15190 ±.00108	3.491 ±.054	1.17222 ±.00020	3.099 ±.010	1.18728 ±.00003	2.447 ±.001	1.18816 ±.00092	1.840 ±.065	1.07122 ±.00222	0.007 ±.119
	0.926	1.16004 ±.00142	3.760 ±.070	1.17606 ±.00018	3.173 ±.009	1.18720 ±.00003	2.452 ±.002	1.18616 ±.00135	1.087 ±.043		
4.5	0.913	1.15073 ±.00087	3.450 ±.043	1.17228 ±.00014	3.104 ±.007	1.18726 ±.00002	2.446 ±.001	1.18627 ±.00092	1.851 ±.044	1.06921 ±.00134	−.087 ±.072
	0.939	1.15416 ±.00160	3.787 ±.079	1.17454 ±.00020	3.239 ±.010	1.18725 ±.00004	2.450 ±.002	1.18038 ±.00091	1.164 ±.044		
6.0	0.890	1.15099 ±.00077	3.485 ±.038	1.17224 ±.00011	3.113 ±.005	1.18724 ±.00002	2.445 ±.001	1.18676 ±.00075	1.915 ±.036	1.06585 ±.00092	−.099 ±.049
	0.931	1.15037 ±.00136	3.698 ±.068	1.17257 ±.00017	3.221 ±.009	1.18727 ±.00003	2.447 ±.002	1.17690 ±.00085	1.259 ±.041		
7.5	0.887	1.15068 ±.00069	3.495 ±.034	1.17234 ±.00009	3.114 ±.005	1.18722 ±.00002	2.446 ±.001	1.18753 ±.00061	1.959 ±.029	1.06552 ±.00071	−.116 ±.038
	0.942	1.14887 ±.00185	3.494 ±.092	1.17170 ±.00025	3.146 ±.012	1.18725 ±.00005	2.446 ±.002	1.17780 ±.00132	1.422 ±.064		
9.0	0.892	1.15051 ±.00064	3.468 ±.032	1.17223 ±.00008	3.122 ±.004	1.18721 ±.00002	2.447 ±.001	1.18720 ±.00055	1.974 ±.027	1.06578 ±.00061	−.060 ±.033
	0.952	1.15050 ±.00129	3.352 ±.064	1.17220 ±.00017	3.092 0.008	1.18720 ±.00003	2.447 ±.002	1.18029 ±.00101	1.448 ±.049		
18.0	0.900	1.15026 ±.00049	3.489 ±.025	1.17230 ±.00007	3.122 ±.003	1.18721 ±.00001	2.445 ±.001	1.18767 ±.00042	1.998 ±.020	1.06624 ±.00046	−.054 ±.025
	0.960	1.15033 ±.00135	3.369 ±.067	1.17227 ±.00018	3.094 ±.009	1.18721 ±.00003	2.445 ±.002	1.18037 ±.00104	1.429 ±.050		

Table 22: stability of resolution of K1 triplet

N length of the data set in years (all data sets end on 2016/03)

Each second line corresponds to the same analysis without triplet separation

N	m0	K1-		K1		K1+	
3	0.916	1.09318 ±03344	0.123 ±1.753	1.13825 ±.00125	0.315 ±.063	1.13905 ±.00473	0.480 ±.238
	0.916			1.13684 ±.00006	0.281 ±.003		
6	0.889	1.13736 ±.00606	0.355 ±.305	1.13690 ±.00020	0.287 ±.010	1.13550 ±.00087	0.330 ±.044
	0.890			1.13679 ±.00004	0.285 ±.002		
9	0.892	1.13831 ±.00256	0.406 ±.129	1.13686 ±.00007	0.285 ±.003	1.13539 ±.00037	0.313 ±.019
	0.892			1.13678 ±.00003	0.285 ±.001		
12	0.889	1.14008 ±.00153	0.348 ±.077	1.13681 ±.00003	0.283 ±.002	1.13545 ±.00022	0.299 ±.011
	0.889			1.13678 ±.00002	0.284 ±.001		
18	0.900	1.13994 ±.00102	0.298 ±.051	1.13679 ±.00002	0.282 ±.001	1.13578 ±.00015	0.293 ±.008
	0.900			1.13680 ±.00002	0.282 ±.001		

Figure 1a-c

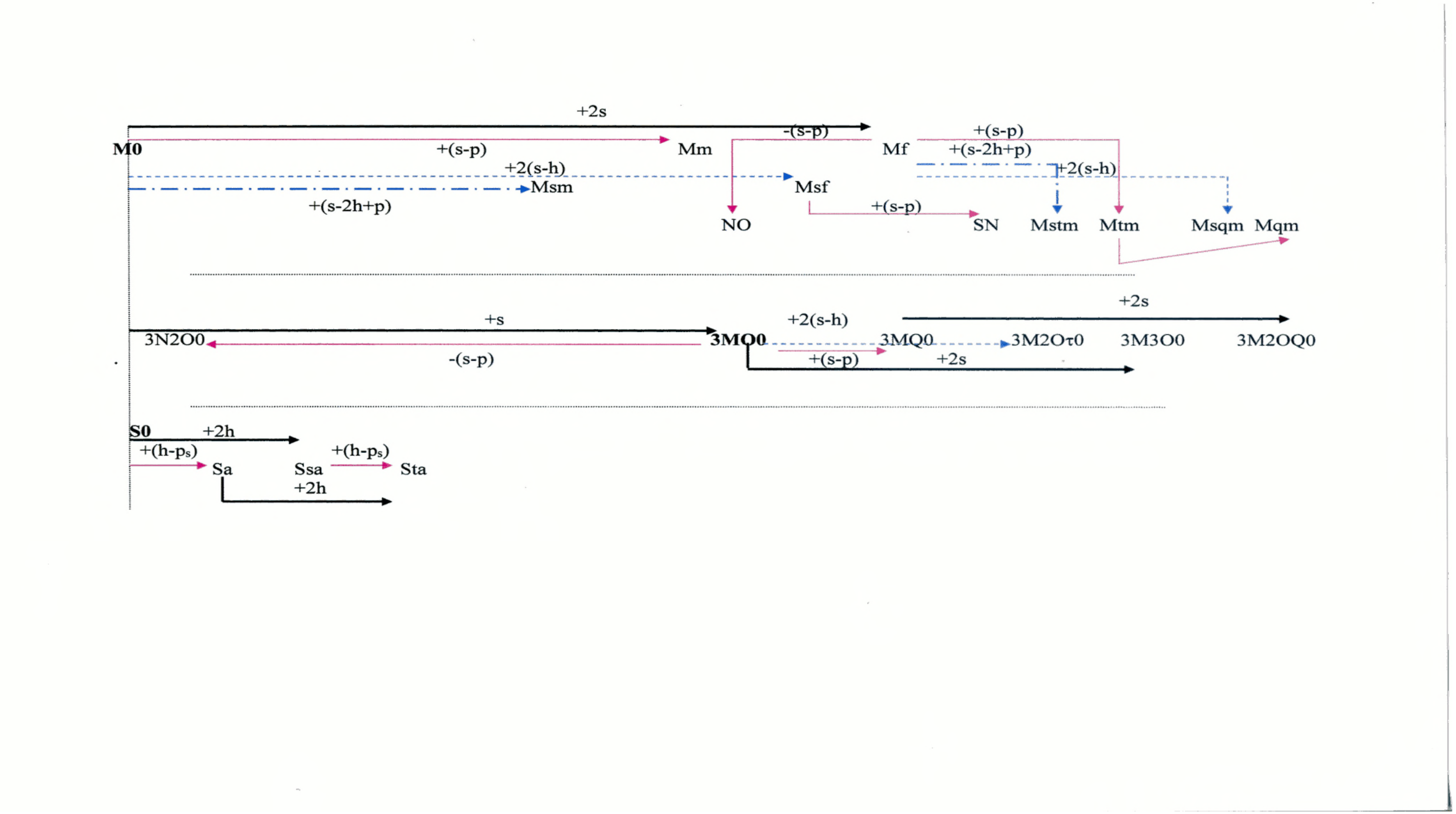

Figure 1a: Generation of long period tidal waves (upper Lunar V_{20}, middle Lunar V_{30}, lower Solar V_{20})

Declination ellipticity variation evection

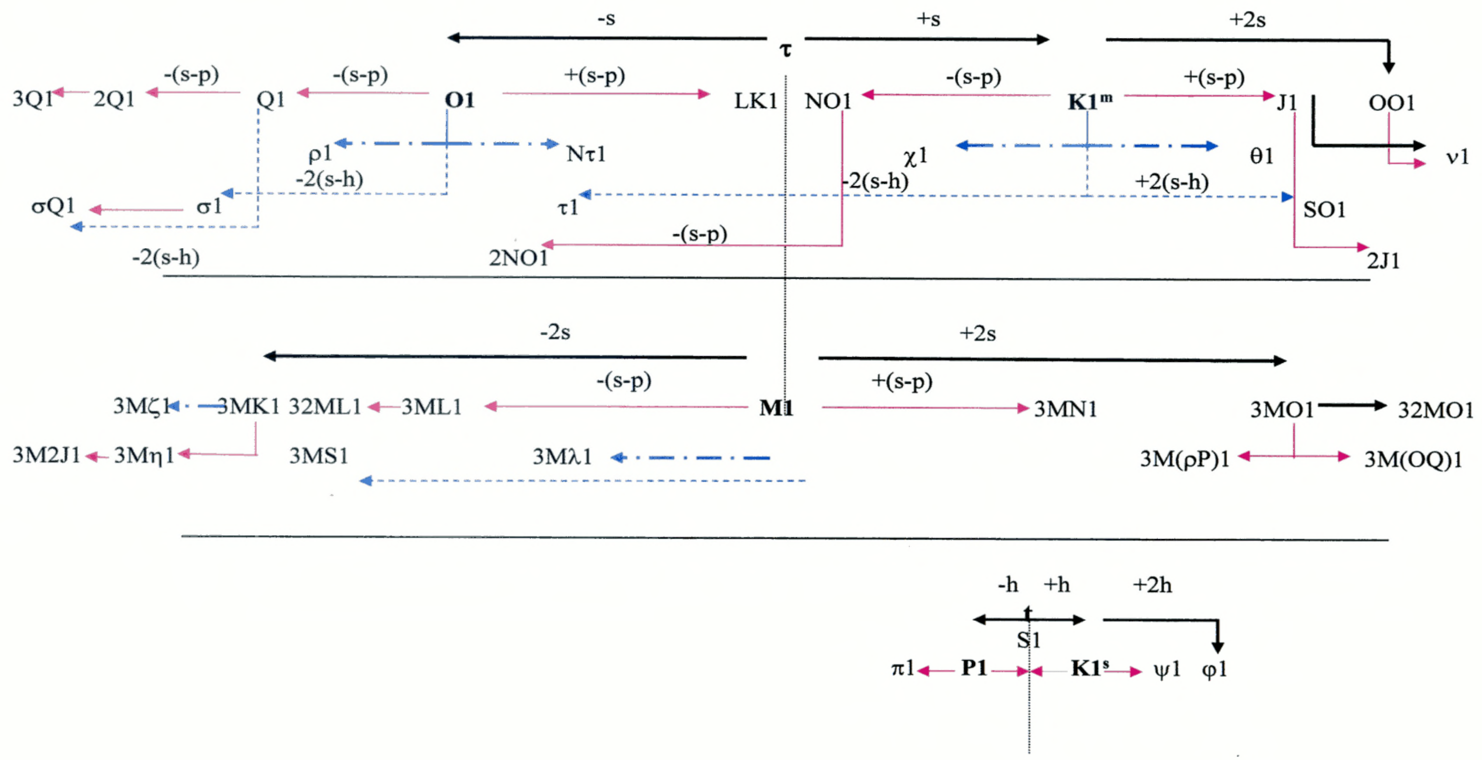

Figure 1b: Generation of diurnal tidal waves (upper Lunar V_{21}, middle Lunar V_{31}, lower Solar V_{21})

Declination ellipticity variation evection

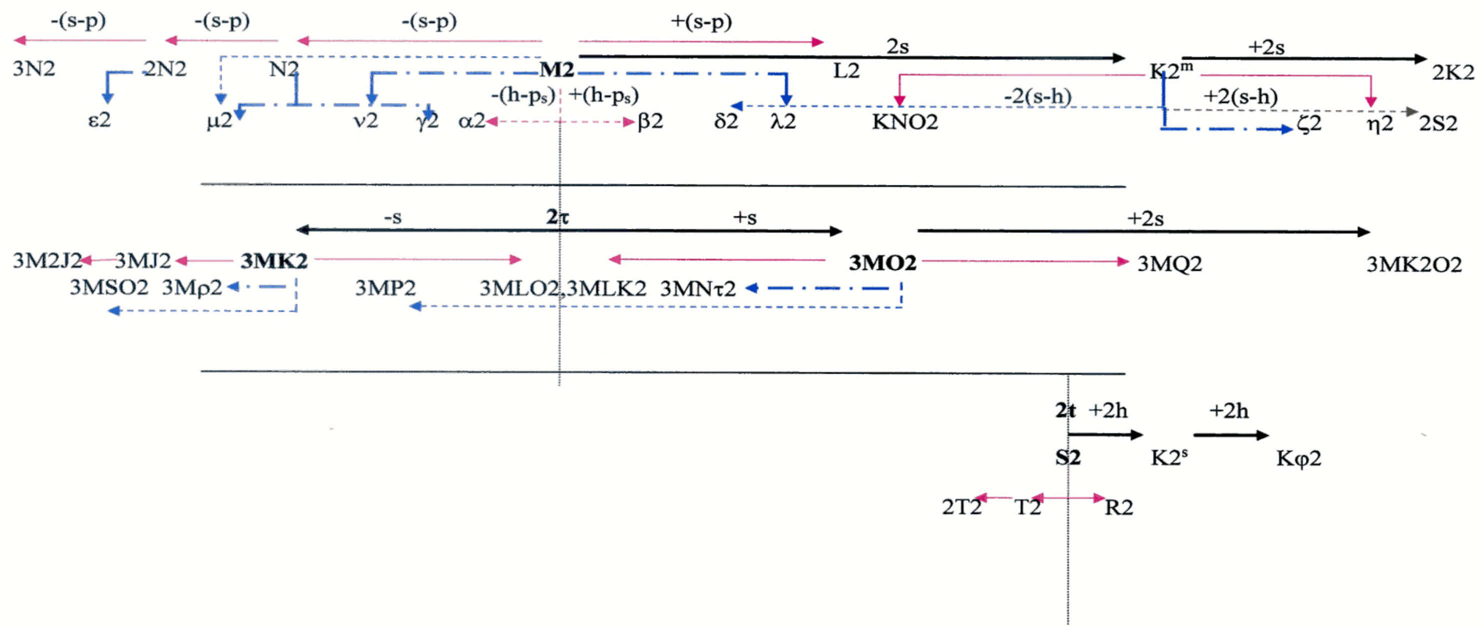

Figure 1c: Generation of semi-diurnal tidal waves (upper Lunar V_{22}, middle Lunar V_{32}, lower Solar V_{22})

Declination ellipticity variation evection

ANNEXES

ANNEX 1: Example of the gravity component of the TGP of Hartmann-Wenzel sorted by degree and frequency

Wave groups and parameters for main waves of V20,V40,V60

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	RMS-wgr.freq. [°/h]	main wgr.freq. [cpd]	main wgr.freq. [°/h]	symb	freq.transf.func.	freq.transf.func.	EM-amp.fac	frequency band [°/h]	frequency band [°/h]	waves/ group	RMS-a/ M-a %
1	4	24	1.00000	21.25700	21.25700	7.64	0.000147	0.002206	0.000147	0.002206	M0+	1.0000	0.000	1.15992	0.00003000	0.00292500	15	100.0
26	4	24	1.00000	0.01642	0.01642	7.64	0.000147	0.002206	0.000147	0.002206	V4:M0+	1.0000	0.000	1.03900	0.00003000	0.00292500	1	100.0
2	25	36	1.00000	0.20750	0.20750	15.28	0.000294	0.004413	0.000294	0.004413	M0++	1.0000	0.000	1.15979	0.00294000	0.00495000	7	100.0
31	25	36	1.00000	0.00082	0.00082	15.28	0.000294	0.004413	0.000294	0.004413	V4:M0++	1.0000	0.000	1.03900	0.00294000	0.00495000	1	100.0
3	37	202	1.00000	3.75153	3.74598	196.90	0.002738	0.041065	0.002738	0.041067	Sa	1.0000	0.000	1.15774	0.00496500	0.06100500	138	100.1
36	37	202	1.00000	0.00011	0.00010	327.63	0.000850	0.012751	0.000619	0.009284	V4:Sa	1.0000	0.000	1.03900	0.00496500	0.06100500	6	108.0
4	203	315	1.00000	23.59513	23.58618	239.58	0.005476	0.082138	0.005476	0.082137	Ssa	1.0000	0.000	1.15734	0.06102000	0.09900000	87	100.0
41	203	315	1.00000	0.00054	0.00042	239.58	0.005490	0.082357	0.005476	0.082137	V4:Ssa	1.0000	0.000	1.03900	0.06102000	0.09900000	8	129.9
5	316	505	1.00000	1.38021	1.37883	76.48	0.008218	0.123272	0.008214	0.123204	Sta	1.0000	0.000	1.15725	0.09901500	0.29400000	171	100.1
46	316	505	1.00000	0.00003	0.00003	76.48	0.008232	0.123487	0.008214	0.123204	V4:Sta	1.0000	0.000	1.03900	0.09901500	0.29400000	2	107.1
6	506	772	1.00000	5.15444	5.12058	69.45	0.031434	0.471507	0.031435	0.471521	Msm	1.0000	0.000	1.15650	0.29401500	0.52800000	194	100.7
51	506	772	1.00000	0.00134	0.00117	69.45	0.031431	0.471465	0.031435	0.471521	V4:Msm	1.0000	0.000	1.03900	0.29401500	0.52800000	19	114.0
7	773	805	1.00000	1.75801	1.75787	333.76	0.036145	0.542168	0.036145	0.542168	Mm-	1.0000	0.000	1.15644	0.52801500	0.54240000	22	100.0
56	773	805	1.00000	0.00225	0.00225	333.76	0.036144	0.542163	0.036145	0.542168	V4:Mm-	1.0000	0.000	1.03900	0.52801500	0.54240000	3	100.1
8	806	829	1.00000	26.77854	26.77854	341.40	0.036292	0.544375	0.036292	0.544375	Mm	1.0000	0.000	1.15644	0.54241500	0.54589500	19	100.0
61	806	829	1.00000	0.00588	0.00588	341.40	0.036292	0.544375	0.036292	0.544375	V4:Mm	1.0000	0.000	1.03900	0.54241500	0.54589500	1	100.0
9	830	865	1.00000	1.73805	1.73783	349.04	0.036439	0.546582	0.036439	0.546581	Mm+	1.0000	0.000	1.15644	0.54591000	0.55050000	19	100.0
66	830	865	1.00000	0.00224	0.00223	349.04	0.036439	0.546587	0.036439	0.546581	V4:Mm+	1.0000	0.000	1.03900	0.54591000	0.55050000	2	100.1
10	866	1038	1.00000	1.61658	1.43312	129.03	0.037277	0.559162	0.036911	0.553658	NO	1.0000	0.000	1.15644	0.55051500	0.76999500	105	112.8
71	866	1038	1.00000	0.00128	0.00118	309.03	0.037044	0.555662	0.036911	0.553658	V4:NO	1.0000	0.000	1.03900	0.55051500	0.76999500	14	108.3
11	1039	1227	1.00000	4.47323	4.44229	50.85	0.067713	1.015691	0.067726	1.015896	Msf	1.0000	0.000	1.15621	0.77001000	1.03863000	120	100.7
76	1039	1227	1.00000	0.00114	0.00106	50.85	0.067731	1.015963	0.067726	1.015896	V4:Msf	1.0000	0.000	1.03900	0.77001000	1.03863000	16	107.3
12	1228	1342	1.00000	2.20892	2.19472	322.80	0.072571	1.088565	0.072583	1.088749	2Mm	1.0000	0.000	1.15619	1.03864500	1.09500000	68	100.6
81	1228	1342	1.00000	0.00074	0.00064	322.80	0.072518	1.087772	0.072583	1.088749	V4:2Mm	1.0000	0.000	1.03900	1.03864500	1.09500000	11	114.4
13	1343	1382	1.00000	50.69610	50.69610	290.43	0.073202	1.098033	0.073202	1.098033	Mf	1.0000	0.000	1.15618	1.09501500	1.10010000	25	100.0
86	1343	1382	1.00000	0.04359	0.04354	290.43	0.073202	1.098028	0.073202	1.098033	V4:Mf	1.0000	0.000	1.03900	1.09501500	1.10010000	2	100.1
87	1343	1382	1.00000	0.00002	0.00002	110.43	0.073202	1.098033	0.073202	1.098033	V6:Mf	1.0000	0.000	1.01750	1.09501500	1.10010000	1	100.0
14	1383	1386	1.00000	21.01906	21.01906	118.07	0.073349	1.100239	0.073349	1.100239	Mf+	1.0000	0.000	1.15618	1.10011500	1.10025000	2	100.0
91	1383	1386	1.00000	0.01624	0.01624	118.07	0.073349	1.100239	0.073349	1.100239	V4:Mf+	1.0000	0.000	1.03900	1.10011500	1.10025000	1	100.0
15	1387	1536	1.00000	1.98149	1.96575	305.71	0.073549	1.103235	0.073496	1.102446	Mf++	1.0000	0.000	1.15618	1.10026500	1.33999500	96	100.8
96	1387	1536	1.00000	0.00091	0.00088	305.71	0.073633	1.104498	0.073496	1.102446	V4:Mf++	1.0000	0.000	1.03900	1.10026500	1.33999500	11	102.9
16	1537	1700	1.00000	0.73020	0.70408	32.25	0.103795	1.556921	0.104018	1.560270	SN	1.0000	0.000	1.15606	1.34001000	1.56550500	103	103.7
101	1537	1700	1.00000	0.00026	0.00022	32.25	0.103550	1.553252	0.104018	1.560270	V4:SN	1.0000	0.000	1.03900	1.34001000	1.56550500	13	120.0
17	1701	1741	1.00000	1.99649	1.84323	359.88	0.104659	1.569882	0.104637	1.569554	Mstm	1.0000	0.000	1.15605	1.56552000	1.58370000	25	108.3
106	1701	1741	1.00000	0.00221	0.00207	359.88	0.104655	1.569820	0.104637	1.569554	V4:Mstm	1.0000	0.000	1.03900	1.56552000	1.58370000	5	106.9
18	1742	1850	1.00000	9.70897	9.70669	271.83	0.109493	1.642399	0.109494	1.642408	Mtm	1.0000	0.000	1.15604	1.58371500	1.64449500	65	100.0
111	1742	1850	1.00000	0.01069	0.01068	271.83	0.109493	1.642397	0.109494	1.642408	V4:Mtm	1.0000	0.000	1.03900	1.58371500	1.64449500	12	100.1
19	1851	2004	1.00000	4.04185	4.02294	99.48	0.109644	1.644658	0.109641	1.644614	Mtm+	1.0000	0.000	1.15604	1.64451000	1.84201500	85	100.5
116	1851	2004	1.00000	0.00400	0.00398	99.48	0.109648	1.644721	0.109641	1.644614	V4:Mtm+	1.0000	0.000	1.03900	1.64451000	1.84201500	17	100.5
20	2005	2256	1.00000	1.68779	1.55034	341.28	0.140923	2.113850	0.140929	2.113929	MSqm	1.0000	0.000	1.15595	1.84203000	2.16735000	151	108.9

121	2005	2256	1.00000	0.00204	0.00191	341.28	0.140929	2.113938	0.140929	2.113929	V4:MSqm	1.0000	0.000	1.03900	1.84203000	2.16735000	25	107.0
21	2257	2380	1.00000	1.39127	1.28415	253.24	0.145808	2.187119	0.145785	2.186782	Mqm	1.0000	0.000	1.15594	2.16736500	2.40000000	61	108.3
126	2257	2380	1.00000	0.00370	0.00243	220.86	0.146309	2.194637	0.146404	2.196066	V4:Mqm	1.0000	0.000	1.03900	2.16736500	2.40000000	17	152.2
22	2381	3018	1.00000	0.45109	0.37459	322.68	0.178873	2.683100	0.177220	2.658304	SKNMO	1.0000	0.000	1.15583	2.40001500	6.00000000	354	120.4
131	2381	3018	1.00000	0.00138	0.00087	202.27	0.184127	2.761910	0.182696	2.740441	V4:SKNMO	1.0000	0.000	1.03900	2.40001500	6.00000000	68	158.8

Wave groups and parameters for main waves V10,V30,V50

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl.	main ampl.+	phase	RMS-wgr.freq.		main wgr.freq.		symb	freq.transf.func.		EM-amp.fac	frequency band		waves/	RMS-a/
				nm/s**2		°	[cpd]	[°/h]	[cpd]	[°/h]					[°/h]		group	M-a %
23	4	24	1.00000	0.00003	0.00003	246.17	0.000162	0.002435	0.000162	0.002435	V1:MO+	1.0000	0.000	1.00000	0.00003000	0.00292500	1	100.0
24	4	24	1.00000	0.00034	0.00034	66.17	0.000162	0.002435	0.000162	0.002435	V3:MO+	1.0000	0.000	1.07153	0.00003000	0.00292500	3	100.0
25	4	24	1.00000	0.00004	0.00004	246.17	0.000162	0.002435	0.000162	0.002435	V5:MO+	1.0000	0.000	1.02400	0.00003000	0.00292500	1	100.0
28	25	36	1.00000	0.00059	0.00059	253.81	0.000309	0.004642	0.000309	0.004642	V1:MO++	1.0000	0.000	1.00000	0.00294000	0.00495000	1	100.0
29	25	36	1.00000	0.00659	0.00659	73.81	0.000309	0.004642	0.000309	0.004642	V3:MO++	1.0000	0.000	1.07153	0.00294000	0.00495000	2	100.0
30	25	36	1.00000	0.00021	0.00021	253.81	0.000309	0.004642	0.000309	0.004642	V5:MO++	1.0000	0.000	1.02400	0.00294000	0.00495000	1	100.0
33	37	202	1.00000	0.00009	0.00009	81.46	0.000486	0.007287	0.000457	0.006848	V1:Sa	1.0000	0.000	1.00000	0.00496500	0.06100500	5	100.8
34	37	202	1.00000	0.00106	0.00105	261.46	0.000486	0.007284	0.000457	0.006848	V3:Sa	1.0000	0.000	1.07153	0.00496500	0.06100500	17	100.8
38	203	315	1.00000	0.00011	0.00011	165.77	0.005169	0.077536	0.005166	0.077495	V1:Ssa	1.0000	0.000	1.00000	0.06102000	0.09900000	3	101.2
39	203	315	1.00000	0.00124	0.00123	345.77	0.005169	0.077538	0.005166	0.077495	V3:Ssa	1.0000	0.000	1.07153	0.06102000	0.09900000	14	101.2
40	203	315	1.00000	0.00004	0.00004	165.77	0.005166	0.077495	0.005166	0.077495	V5:Ssa	1.0000	0.000	1.02400	0.06102000	0.09900000	1	100.0
43	316	505	1.00000	0.00000	0.00000	2.66	0.007921	0.118818	0.007904	0.118562	V1:Sta	1.0000	0.000	1.00000	0.09901500	0.29400000	2	102.9
44	316	505	1.00000	0.00005	0.00005	182.66	0.007935	0.119032	0.007904	0.118562	V3:Sta	1.0000	0.000	1.07153	0.09901500	0.29400000	15	104.5
48	506	772	1.00000	0.00013	0.00012	175.63	0.031150	0.467243	0.031125	0.466879	V1:Msm	1.0000	0.000	1.00000	0.29401500	0.52800000	9	104.7
49	506	772	1.00000	0.00145	0.00138	355.63	0.031155	0.467331	0.031125	0.466879	V3:Msm	1.0000	0.000	1.07153	0.29401500	0.52800000	44	104.9
50	506	772	1.00000	0.00004	0.00004	175.63	0.031125	0.466879	0.031125	0.466879	V5:Msm	1.0000	0.000	1.02400	0.29401500	0.52800000	1	100.0
53	773	805	1.00000	0.00004	0.00004	87.59	0.035981	0.539713	0.035982	0.539733	V1:Mm-	1.0000	0.000	1.00000	0.52801500	0.54240000	3	100.7
54	773	805	1.00000	0.00050	0.00050	267.59	0.035981	0.539713	0.035982	0.539733	V3:Mm-	1.0000	0.000	1.07153	0.52801500	0.54240000	4	100.7
55	773	805	1.00000	0.00002	0.00002	87.59	0.035982	0.539733	0.035982	0.539733	V5:Mm-	1.0000	0.000	1.02400	0.52801500	0.54240000	1	100.0
58	806	829	1.00000	0.00001	0.00001	219.93	0.036307	0.544604	0.036307	0.544604	V1:Mm	1.0000	0.000	1.00000	0.54241500	0.54589500	1	100.0
59	806	829	1.00000	0.00006	0.00006	39.93	0.036307	0.544604	0.036307	0.544604	V3:Mm	1.0000	0.000	1.07153	0.54241500	0.54589500	2	100.0
60	806	829	1.00000	0.00001	0.00001	219.93	0.036307	0.544604	0.036307	0.544604	V5:Mm	1.0000	0.000	1.02400	0.54241500	0.54589500	1	100.0
63	830	865	1.00000	0.01081	0.01080	235.22	0.036601	0.549011	0.036601	0.549017	V1:Mm+	1.0000	0.000	1.00000	0.54591000	0.55050000	2	100.1
64	830	865	1.00000	0.12121	0.12105	55.22	0.036601	0.549011	0.036601	0.549017	V3:Mm+	1.0000	0.000	1.07153	0.54591000	0.55050000	11	100.1
65	830	865	1.00000	0.00195	0.00192	235.22	0.036597	0.548950	0.036601	0.549017	V5:Mm+	1.0000	0.000	1.02400	0.54591000	0.55050000	2	101.5
68	866	1038	1.00000	0.00171	0.00170	62.86	0.036750	0.551251	0.036748	0.551223	V1:NO	1.0000	0.000	1.00000	0.55051500	0.76999500	9	100.3
69	866	1038	1.00000	0.01916	0.01910	242.86	0.036750	0.551252	0.036748	0.551223	V3:NO	1.0000	0.000	1.07153	0.55051500	0.76999500	43	100.3
70	866	1038	1.00000	0.00009	0.00007	62.86	0.036809	0.552138	0.036748	0.551223	V5:NO	1.0000	0.000	1.02400	0.55051500	0.76999500	2	130.7
73	1039	1227	1.00000	0.00035	0.00034	304.66	0.068031	1.020468	0.068036	1.020538	V1:Msf	1.0000	0.000	1.00000	0.77001000	1.03863000	10	101.6
74	1039	1227	1.00000	0.00392	0.00385	124.66	0.068031	1.020468	0.068036	1.020538	V3:Msf	1.0000	0.000	1.07153	0.77001000	1.03863000	41	101.6
75	1039	1227	1.00000	0.00009	0.00008	304.66	0.068031	1.020468	0.068036	1.020538	V5:Msf	1.0000	0.000	1.02400	0.77001000	1.03863000	2	101.6
78	1228	1342	1.00000	0.00177	0.00177	216.62	0.072892	1.093382	0.072893	1.093391	V1:2Mm	1.0000	0.000	1.00000	1.03864500	1.09500000	8	100.1
79	1228	1342	1.00000	0.01981	0.01979	36.62	0.072892	1.093382	0.072893	1.093391	V3:2Mm	1.0000	0.000	1.07153	1.03864500	1.09500000	26	100.1
80	1228	1342	1.00000	0.00042	0.00042	216.62	0.072888	1.093324	0.072893	1.093391	V5:2Mm	1.0000	0.000	1.02400	1.03864500	1.09500000	2	101.6
83	1343	1382	1.00000	0.00028	0.00028	44.26	0.073041	1.095611	0.073040	1.095598	V1:Mf	1.0000	0.000	1.00000	1.09501500	1.10010000	3	100.3
84	1343	1382	1.00000	0.00313	0.00312	224.26	0.073041	1.095611	0.073040	1.095598	V3:Mf	1.0000	0.000	1.07153	1.09501500	1.10010000	7	100.3
85	1343	1382	1.00000	0.00002	0.00002	44.26	0.073101	1.096520	0.073040	1.095598	V5:Mf	1.0000	0.000	1.02400	1.09501500	1.10010000	2	131.1
89	1383	1386	1.00000	0.00000	0.00000	285.18	0.073349	1.100237	0.073349	1.100237	V3:Mf+	1.0000	0.000	1.07153	1.10011500	1.10025000	1	100.0
93	1387	1536	1.00000	0.00006	0.00005	4.25	0.073954	1.109304	0.073512	1.102675	V1:Mf++	1.0000	0.000	1.00000	1.10026500	1.33999500	10	127.2
94	1387	1536	1.00000	0.00071	0.00055	184.25	0.073955	1.109321	0.073512	1.102675	V3:Mf++	1.0000	0.000	1.07153	1.10026500	1.33999500	33	127.3
98	1537	1700	1.00000	0.00030	0.00030	286.07	0.104311	1.564668	0.104327	1.564912	V1:SN	1.0000	0.000	1.00000	1.34001000	1.56550500	7	100.3
99	1537	1700	1.00000	0.00333	0.00332	106.07	0.104311	1.564668	0.104327	1.564912	V3:SN	1.0000	0.000	1.07153	1.34001000	1.56550500	40	100.3
100	1537	1700	1.00000	0.00008	0.00008	286.07	0.104327	1.564912	0.104327	1.564912	V5:SN	1.0000	0.000	1.02400	1.34001000	1.56550500	1	100.0

103	1701	1741	1.00000	0.00005	0.00005	113.71	0.104476	1.567144	0.104475	1.567119	V1:Mstm	1.0000	0.000	1.00000	1.56552000	1.58370000	3	100.4
104	1701	1741	1.00000	0.00052	0.00052	293.71	0.104477	1.567151	0.104475	1.567119	V3:Mstm	1.0000	0.000	1.07153	1.56552000	1.58370000	8	100.4
108	1742	1850	1.00000	0.00022	0.00021	198.02	0.109184	1.637763	0.109184	1.637766	V1:Mtm	1.0000	0.000	1.00000	1.58371500	1.64449500	8	101.4
109	1742	1850	1.00000	0.00242	0.00238	18.02	0.109185	1.637780	0.109184	1.637766	V3:Mtm	1.0000	0.000	1.07153	1.58371500	1.64449500	22	101.4
110	1742	1850	1.00000	0.00006	0.00006	198.02	0.109180	1.637703	0.109184	1.637766	V5:Mtm	1.0000	0.000	1.02400	1.58371500	1.64449500	2	101.5
113	1851	2004	1.00000	0.00104	0.00088	165.65	0.109847	1.647709	0.109803	1.647050	V1:Mtm+	1.0000	0.000	1.00000	1.64451000	1.84201500	9	118.4
114	1851	2004	1.00000	0.01167	0.00985	345.65	0.109847	1.647709	0.109803	1.647050	V3:Mtm+	1.0000	0.000	1.07153	1.64451000	1.84201500	39	118.4
115	1851	2004	1.00000	0.00066	0.00056	165.65	0.109843	1.647638	0.109803	1.647050	V5:Mtm+	1.0000	0.000	1.02400	1.64451000	1.84201500	4	116.5
118	2005	2256	1.00000	0.00009	0.00007	267.47	0.140757	2.111359	0.140619	2.109287	V1:MSqm	1.0000	0.000	1.00000	1.84203000	2.16735000	14	131.4
119	2005	2256	1.00000	0.00097	0.00074	87.47	0.140754	2.111313	0.140619	2.109287	V3:MSqm	1.0000	0.000	1.07153	1.84203000	2.16735000	59	131.4
120	2005	2256	1.00000	0.00005	0.00004	235.10	0.141143	2.117151	0.141238	2.118571	V5:MSqm	1.0000	0.000	1.02400	1.84203000	2.16735000	3	130.0
123	2257	2380	1.00000	0.00029	0.00024	147.05	0.146135	2.192023	0.146095	2.191424	V1:Mqm	1.0000	0.000	1.00000	2.16736500	2.40000000	9	118.8
124	2257	2380	1.00000	0.00321	0.00270	327.05	0.146135	2.192024	0.146095	2.191424	V3:Mqm	1.0000	0.000	1.07153	2.16736500	2.40000000	34	118.8
125	2257	2380	1.00000	0.00022	0.00018	147.05	0.146134	2.192017	0.146095	2.191424	V5:Mqm	1.0000	0.000	1.02400	2.16736500	2.40000000	3	116.4
128	2381	3018	1.00000	0.00007	0.00004	216.50	0.181817	2.727256	0.177530	2.662945	V1:SKNMO	1.0000	0.000	1.00000	2.40001500	6.00000000	25	174.8
129	2381	3018	1.00000	0.00082	0.00047	36.50	0.181854	2.727812	0.177530	2.662945	V3:SKNMO	1.0000	0.000	1.07153	2.40001500	6.00000000	182	175.0
130	2381	3018	1.00000	0.00007	0.00004	128.45	0.183587	2.753799	0.182387	2.735799	V5:SKNMO	1.0000	0.000	1.02400	2.40001500	6.00000000	9	192.6

Wave groups and parameters for main waves V21,V41,V61

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
1	3019	3287	1.00000	0.39933	0.37286	271.71	0.787427	11.811410	0.789226	11.838390	SGM2Q1	1.0000	0.000	1.15391	8.70000000	11.87400000	123	107.1
57	3019	3287	1.00000	0.00138	0.00084	212.13	0.783283	11.749252	0.783750	11.756253	V4:SGM2Q1	1.0000	0.000	1.03900	8.70000000	11.87400000	37	164.7
2	3288	3359	1.00000	0.23995	0.23132	183.67	0.794105	11.911581	0.794083	11.911244	2SGM1	1.0000	0.000	1.15394	11.87401500	12.15000000	43	103.7
62	3288	3359	1.00000	0.00013	0.00012	3.67	0.794041	11.910621	0.794083	11.911244	V4:2SGM1	1.0000	0.000	1.03900	11.87401500	12.15000000	6	106.0
3	3360	3432	1.00000	0.88431	0.86878	341.16	0.820655	12.309819	0.820661	12.309911	3Q1	1.0000	0.000	1.15407	12.15001500	12.31950000	26	101.8
67	3360	3432	1.00000	0.00460	0.00390	193.53	0.820006	12.300092	0.820042	12.300628	V4:3Q1	1.0000	0.000	1.03900	12.15001500	12.31950000	15	117.9
4	3433	3622	1.00000	2.34034	2.25054	253.12	0.825704	12.385565	0.825518	12.382765	SGMQ1	1.0000	0.000	1.15409	12.31951500	12.63220500	97	104.0
72	3433	3622	1.00000	0.00140	0.00108	73.12	0.825397	12.380948	0.825518	12.382765	V4:SGMQ1	1.0000	0.000	1.03900	12.31951500	12.63220500	23	128.9
5	3623	3725	1.00000	1.46244	1.45677	134.92	0.856789	12.851829	0.856805	12.852080	2Q1-	1.0000	0.000	1.15421	12.63222000	12.85225500	43	100.4
77	3623	3725	1.00000	0.01277	0.01088	174.93	0.856292	12.844378	0.856334	12.845003	V4:2Q1-	1.0000	0.000	1.03900	12.63222000	12.85225500	14	117.3
6	3726	3796	1.00000	7.72716	7.72459	322.56	0.856954	12.854310	0.856952	12.854286	2Q1	1.0000	0.000	1.15421	12.85227000	12.90750000	32	100.0
82	3726	3796	1.00000	0.00343	0.00342	142.56	0.856956	12.854335	0.856952	12.854286	V4:2Q1	1.0000	0.000	1.03900	12.85227000	12.90750000	8	100.3
7	3797	3827	1.00000	1.75795	1.75709	46.88	0.861662	12.924931	0.861662	12.924933	SGM1-	1.0000	0.000	1.15423	12.90751500	12.92520000	16	100.0
87	3797	3827	1.00000	0.00044	0.00043	226.88	0.861648	12.924724	0.861662	12.924933	V4:SGM1-	1.0000	0.000	1.03900	12.90751500	12.92520000	5	102.4
8	3828	3858	1.00000	9.31532	9.31496	234.52	0.861809	12.927141	0.861809	12.927140	SGM1	1.0000	0.000	1.15423	12.92521500	12.94500000	16	100.0
92	3828	3858	1.00000	0.00381	0.00381	54.52	0.861810	12.927144	0.861809	12.927140	V4:SGM1	1.0000	0.000	1.03900	12.92521500	12.94500000	3	100.1
9	3859	3963	1.00000	0.70745	0.62903	71.41	0.864939	12.974080	0.864547	12.968207	SGM1b	1.0000	0.000	1.15424	12.94501500	13.18012500	66	112.5
97	3859	3963	1.00000	0.00029	0.00025	251.41	0.865090	12.976348	0.864547	12.968207	V4:SGM1b	1.0000	0.000	1.03900	12.94501500	13.18012500	9	115.9
10	3964	4091	1.00000	0.58349	0.49086	287.07	0.890548	13.358219	0.890506	13.357594	Q1a	1.0000	0.000	1.15431	13.18014000	13.39402500	61	118.9
102	3964	4091	1.00000	0.00116	0.00093	336.34	0.892209	13.383138	0.892625	13.389377	V4:Q1a	1.0000	0.000	1.03900	13.18014000	13.39402500	14	124.4
11	4092	4107	1.00000	11.01357	11.00837	116.32	0.893097	13.396452	0.893097	13.396454	Q1-	1.0000	0.000	1.15431	13.39404000	13.39699500	10	100.0
107	4092	4107	1.00000	0.00246	0.00242	296.32	0.893093	13.396391	0.893097	13.396454	V4:Q1-	1.0000	0.000	1.03900	13.39404000	13.39699500	2	101.5
12	4108	4159	1.00000	58.37346	58.37324	303.96	0.893244	13.398661	0.893244	13.398661	Q1	1.0000	0.000	1.15431	13.39701000	13.42500000	33	100.0
112	4108	4159	1.00000	0.02138	0.02131	123.96	0.893245	13.398675	0.893244	13.398661	V4:Q1	1.0000	0.000	1.03900	13.39701000	13.42500000	6	100.3
13	4160	4212	1.00000	0.64743	0.54475	140.86	0.895884	13.438266	0.895982	13.439728	Q1b	1.0000	0.000	1.15432	13.42501500	13.45200000	28	118.8
117	4160	4212	1.00000	0.00023	0.00019	320.86	0.895883	13.438246	0.895982	13.439728	V4:Q1b	1.0000	0.000	1.03900	13.42501500	13.45200000	7	119.6
14	4213	4232	1.00000	2.09071	2.08980	28.28	0.897954	13.469306	0.897954	13.469308	RO1-	1.0000	0.000	1.15432	13.45201500	13.47000000	12	100.0
122	4213	4232	1.00000	0.00048	0.00047	208.28	0.897950	13.469247	0.897954	13.469308	V4:RO1-	1.0000	0.000	1.03900	13.45201500	13.47000000	2	101.4
15	4233	4271	1.00000	11.09941	11.07975	215.92	0.898103	13.471548	0.898101	13.471515	RO1	1.0000	0.000	1.15432	13.47001500	13.48500000	24	100.2
127	4233	4271	1.00000	0.00417	0.00413	35.92	0.898108	13.471626	0.898101	13.471515	V4:RO1	1.0000	0.000	1.03900	13.47001500	13.48500000	5	100.9

16	4272	4367	1.00000	0.53830	0.51176	52.81	0.901001	13.515012	0.900839	13.512581	RO1b	1.0000	0.000	1.15432	13.48501500	13.72500000	55	105.2
132	4272	4367	1.00000	0.00021	0.00019	232.81	0.901317	13.519762	0.900839	13.512581	V4:RO1b	1.0000	0.000	1.03900	13.48501500	13.72500000	7	112.6
17	4368	4477	1.00000	1.41446	1.04792	268.47	0.925848	13.887727	0.926798	13.901969	O1a	1.0000	0.000	1.15431	13.72501500	13.92472500	61	135.0
137	4368	4477	1.00000	0.00040	0.00031	88.47	0.925694	13.885413	0.926798	13.901969	V4:O1a	1.0000	0.000	1.03900	13.72501500	13.92472500	12	129.6
18	4478	4506	1.00000	1.76210	1.76199	90.08	0.929241	13.938622	0.929242	13.938623	O1--	1.0000	0.000	1.15430	13.92474000	13.93990500	17	100.0
142	4478	4506	1.00000	0.00170	0.00170	270.08	0.929241	13.938619	0.929242	13.938623	V4:O1--	1.0000	0.000	1.03900	13.92474000	13.93990500	3	100.1
19	4507	4515	1.00000	57.51446	57.51446	97.73	0.929389	13.940829	0.929389	13.940829	O1-	1.0000	0.000	1.15430	13.93992000	13.94083500	6	100.0
147	4507	4515	1.00000	0.00988	0.00988	277.73	0.929389	13.940829	0.929389	13.940829	V4:O1-	1.0000	0.000	1.03900	13.93992000	13.94083500	1	100.0
20	4516	4569	1.00000	304.87745	304.87743	285.37	0.929536	13.943036	0.929536	13.943036	O1	1.0000	0.000	1.15430	13.94085000	13.94940000	32	100.0
152	4516	4569	1.00000	0.08721	0.08694	105.37	0.929537	13.943049	0.929536	13.943036	V4:O1	1.0000	0.000	1.03900	13.94085000	13.94940000	4	100.3
153	4516	4569	1.00000	0.00002	0.00002	105.37	0.929536	13.943036	0.929536	13.943036	V6:O1	1.0000	0.000	1.01750	13.94085000	13.94940000	1	100.0
21	4570	4598	1.00000	1.99090	1.96415	73.00	0.930158	13.952375	0.930155	13.952319	2NO1	1.0000	0.000	1.15430	13.94941500	13.96500000	15	101.4
157	4570	4598	1.00000	0.00125	0.00124	253.00	0.930155	13.952320	0.930155	13.952319	V4:2NO1	1.0000	0.000	1.03900	13.94941500	13.96500000	4	101.2
22	4599	4651	1.00000	0.92995	0.92287	122.26	0.932273	13.984089	0.932273	13.984102	O1b	1.0000	0.000	1.15429	13.96501500	13.99800000	29	100.8
162	4599	4651	1.00000	0.00026	0.00026	302.26	0.932277	13.984153	0.932273	13.984102	V4:O1b	1.0000	0.000	1.03900	13.96501500	13.99800000	7	101.5
23	4652	4772	1.00000	4.08231	3.97392	344.95	0.935030	14.025451	0.935012	14.025173	TAU1	1.0000	0.000	1.15428	13.99801500	14.21986500	67	102.7
167	4652	4772	1.00000	0.00207	0.00205	164.95	0.935022	14.025326	0.935012	14.025173	V4:TAU1	1.0000	0.000	1.03900	13.99801500	14.21986500	10	101.0
24	4773	4876	1.00000	2.31238	2.24824	174.81	0.960967	14.414505	0.960970	14.414557	NTAU1	1.0000	0.000	1.15401	14.21988000	14.46690000	64	102.9
172	4773	4876	1.00000	0.00039	0.00039	174.81	0.961036	14.415534	0.960970	14.414557	V4:NTAU1	1.0000	0.000	1.03900	14.21988000	14.46690000	9	101.7
25	4877	4891	1.00000	1.60126	1.59511	259.13	0.965679	14.485187	0.965680	14.485204	LK1-	1.0000	0.000	1.15390	14.46691500	14.48550000	9	100.4
177	4877	4891	1.00000	0.00027	0.00027	259.13	0.965680	14.485204	0.965680	14.485204	V4:LK1-	1.0000	0.000	1.03900	14.46691500	14.48550000	1	100.0
26	4892	4901	1.00000	8.61919	8.61919	86.77	0.965827	14.487410	0.965827	14.487410	LK1	1.0000	0.000	1.15390	14.48551500	14.48899500	5	100.0
182	4892	4901	1.00000	0.00235	0.00235	86.77	0.965827	14.487410	0.965827	14.487410	V4:LK1	1.0000	0.000	1.03900	14.48551500	14.48899500	1	100.0
27	4902	4947	1.00000	23.97494	23.96487	54.40	0.966446	14.496692	0.966446	14.496694	NO1	1.0000	0.000	1.15388	14.48901000	14.49763500	21	100.0
187	4902	4947	1.00000	0.01137	0.01130	234.40	0.966444	14.496665	0.966446	14.496694	V4:NO1	1.0000	0.000	1.03900	14.48901000	14.49763500	5	100.6
28	4948	4963	1.00000	4.81134	4.80947	242.04	0.966593	14.498902	0.966593	14.498900	NO1+	1.0000	0.000	1.15388	14.49765000	14.50279500	10	100.0
192	4948	4963	1.00000	0.00138	0.00137	62.04	0.966597	14.498954	0.966593	14.498900	V4:NO1+	1.0000	0.000	1.03900	14.49765000	14.50279500	2	101.2
29	4964	5042	1.00000	4.59236	4.58579	326.35	0.971298	14.569477	0.971303	14.569548	CHI1	1.0000	0.000	1.15373	14.50281000	14.57166000	45	100.1
197	4964	5042	1.00000	0.00227	0.00226	146.35	0.971297	14.569461	0.971303	14.569548	V4:CHI1	1.0000	0.000	1.03900	14.50281000	14.57166000	7	100.7
30	5043	5056	1.00000	1.00641	1.00614	153.99	0.971450	14.571755	0.971450	14.571754	CHI1+	1.0000	0.000	1.15372	14.57167500	14.57500500	7	100.0
202	5043	5056	1.00000	0.00028	0.00027	333.99	0.971454	14.571811	0.971450	14.571754	V4:CHI1+	1.0000	0.000	1.03900	14.57167500	14.57500500	2	101.3
31	5057	5391	1.00000	8.30098	8.29140	139.32	0.994508	14.917613	0.994524	14.917865	PI1	1.0000	0.000	1.15069	14.57502000	14.95399500	288	100.1
207	5057	5391	1.00000	0.00012	0.00010	343.25	0.977883	14.668243	0.974041	14.610614	V4:PI1	1.0000	0.000	1.03900	14.57502000	14.95399500	9	119.8
32	5392	5403	1.00000	1.59867	1.59447	328.57	0.997114	14.956713	0.997115	14.956725	P1-	1.0000	0.000	1.14920	14.95401000	14.95674000	10	100.3
212	5392	5403	1.00000	0.00021	0.00019	148.57	0.997088	14.956323	0.997115	14.956725	V4:P1-	1.0000	0.000	1.03900	14.95401000	14.95674000	2	110.6
33	5404	5485	1.00000	141.83549	141.83530	336.22	0.997262	14.958931	0.997262	14.958931	P1	1.0000	0.000	1.14909	14.95675500	14.97946500	65	100.0
217	5404	5485	1.00000	0.00087	0.00083	156.22	0.997305	14.959577	0.997262	14.958931	V4:P1	1.0000	0.000	1.03900	14.95675500	14.97946500	5	103.9
34	5486	5613	1.00000	3.55882	3.35298	198.90	1.000001	15.000017	1.000000	15.000002	S1	1.0000	0.000	1.14574	14.97948000	15.03499500	105	106.1
222	5486	5613	1.00000	0.00020	0.00020	68.17	1.002074	15.031105	1.002119	15.031785	V4:S1	1.0000	0.000	1.03900	14.97948000	15.03499500	5	101.5
35	5614	5637	1.00000	8.48772	8.48755	28.16	1.002591	15.038862	1.002591	15.038862	K1-	1.0000	0.000	1.13573	15.03501000	15.03907500	14	100.0
227	5614	5637	1.00000	0.00918	0.00918	208.16	1.002591	15.038860	1.002591	15.038862	V4:K1-	1.0000	0.000	1.03900	15.03501000	15.03907500	2	100.0
36	5638	5654	1.00000	428.59688	428.59688	35.80	1.002738	15.041069	1.002738	15.041069	K1	1.0000	0.000	1.13449	15.03909000	15.04290000	11	100.0
232	5638	5654	1.00000	0.08310	0.08310	215.80	1.002738	15.041069	1.002738	15.041069	V4:K1	1.0000	0.000	1.03900	15.03909000	15.04290000	1	100.0
233	5638	5654	1.00000	0.00002	0.00002	215.80	1.002738	15.041069	1.002738	15.041069	V6:K1	1.0000	0.000	1.01750	15.03909000	15.04290000	1	100.0
37	5655	5665	1.00000	58.16640	58.16640	223.44	1.002885	15.043275	1.002885	15.043275	K1+	1.0000	0.000	1.13308	15.04291500	15.04351500	5	100.0
237	5655	5665	1.00000	0.00999	0.00999	43.44	1.002885	15.043275	1.002885	15.043275	V4:K1+	1.0000	0.000	1.03900	15.04291500	15.04351500	1	100.0
38	5666	5720	1.00000	1.24987	1.24977	231.08	1.003032	15.045483	1.003032	15.045481	K1++	1.0000	0.000	1.13147	15.04353000	15.06300000	42	100.0
242	5666	5720	1.00000	0.00163	0.00163	51.08	1.003032	15.045485	1.003032	15.045481	V4:K1++	1.0000	0.000	1.03900	15.04353000	15.06300000	4	100.1
39	5721	5812	1.00000	3.35561	3.35456	232.69	1.005476	15.082136	1.005476	15.082135	PSI1	1.0000	0.000	1.27250	15.06301500	15.10267500	80	100.0
247	5721	5812	1.00000	0.00002	0.00002	232.69	1.005417	15.081252	1.005476	15.082135	V4:PSI1	1.0000	0.000	1.03900	15.06301500	15.10267500	2	129.1
40	5813	6094	1.00000	6.12387	6.10328	275.38	1.008223	15.123339	1.008214	15.123206	PHI1	1.0000	0.000	1.17072	15.10269000	15.35433000	250	100.3

252	5813	6094	1.00000	0.00033	0.00022	127.75	1.007994	15.119912	1.007595	15.113922	V4:PHI1	1.0000	0.000	1.03900	15.10269000	15.35433000	8	149.3
41	6095	6236	1.00000	4.59331	4.58442	105.25	1.034166	15.512496	1.034173	15.512590	TET1	1.0000	0.000	1.15714	15.35434500	15.51400500	107	100.2
257	6095	6236	1.00000	0.00227	0.00226	285.25	1.034164	15.512458	1.034173	15.512590	V4:TET1	1.0000	0.000	1.03900	15.35434500	15.51400500	9	100.8
42	6237	6254	1.00000	0.90953	0.90932	292.89	1.034320	15.514797	1.034320	15.514796	TET1+	1.0000	0.000	1.15714	15.51402000	15.53068500	10	100.0
262	6237	6254	1.00000	0.00027	0.00027	112.89	1.034324	15.514853	1.034320	15.514796	V4:TET1+	1.0000	0.000	1.03900	15.51402000	15.53068500	2	101.3
43	6255	6337	1.00000	23.98470	23.97357	17.20	1.039029	15.585439	1.039030	15.585443	J1	1.0000	0.000	1.15693	15.53070000	15.58723500	51	100.0
267	6255	6337	1.00000	0.01137	0.01130	197.20	1.039028	15.585414	1.039030	15.585443	V4:J1	1.0000	0.000	1.03900	15.53070000	15.58723500	8	100.6
44	6338	6361	1.00000	4.75293	4.75179	204.84	1.039177	15.587651	1.039177	15.587650	J1+	1.0000	0.000	1.15692	15.58725000	15.59100000	12	100.0
272	6338	6361	1.00000	0.00138	0.00136	24.84	1.039180	15.587707	1.039177	15.587650	V4:J1+	1.0000	0.000	1.03900	15.58725000	15.59100000	3	101.3
45	6362	6483	1.00000	0.49299	0.37068	164.83	1.040161	15.602415	1.039648	15.594727	KLK1	1.0000	0.000	1.15691	15.59101500	15.82500000	76	133.0
277	6362	6483	1.00000	0.00048	0.00040	164.83	1.039820	15.597303	1.039648	15.594727	V4:KLK1	1.0000	0.000	1.03900	15.59101500	15.82500000	9	120.0
46	6484	6591	1.00000	4.06294	3.97582	86.65	1.070456	16.056838	1.070464	16.056964	SO1	1.0000	0.000	1.15640	15.82501500	16.06300500	64	102.2
282	6484	6591	1.00000	0.00206	0.00204	266.65	1.070452	16.056779	1.070464	16.056964	V4:SO1	1.0000	0.000	1.03900	15.82501500	16.06300500	9	101.0
47	6592	6677	1.00000	2.00515	1.96519	358.60	1.075324	16.129859	1.075321	16.129818	2J1	1.0000	0.000	1.15637	16.06302000	16.13449500	42	102.0
287	6592	6677	1.00000	0.00125	0.00124	178.60	1.075316	16.129739	1.075321	16.129818	V4:2J1	1.0000	0.000	1.03900	16.06302000	16.13449500	11	101.4
48	6678	6691	1.00000	13.11360	13.11360	326.23	1.075940	16.139102	1.075940	16.139102	OO1	1.0000	0.000	1.15637	16.13451000	16.14103500	6	100.0
292	6678	6691	1.00000	0.01476	0.01475	146.23	1.075940	16.139099	1.075940	16.139102	V4:OO1	1.0000	0.000	1.03900	16.13451000	16.14103500	2	100.1
49	6692	6698	1.00000	8.40251	8.40251	153.87	1.076087	16.141308	1.076087	16.141308	OO1+	1.0000	0.000	1.15637	16.14105000	16.14150000	4	100.0
297	6692	6698	1.00000	0.00908	0.00908	333.87	1.076087	16.141308	1.076087	16.141308	V4:OO1+	1.0000	0.000	1.03900	16.14105000	16.14150000	1	100.0
50	6699	6773	1.00000	1.76552	1.76037	341.51	1.076240	16.143604	1.076234	16.143514	OO1++	1.0000	0.000	1.15637	16.14151500	16.29000000	38	100.3
302	6699	6773	1.00000	0.00170	0.00170	161.51	1.076239	16.143584	1.076234	16.143514	V4:OO1++	1.0000	0.000	1.03900	16.14151500	16.29000000	9	100.1
51	6774	6950	1.00000	2.66247	2.51126	307.63	1.111665	16.674971	1.112232	16.683476	NU1	1.0000	0.000	1.15631	16.29001500	16.68538500	88	106.0
307	6774	6950	1.00000	0.00374	0.00362	127.63	1.111919	16.678780	1.112232	16.683476	V4:NU1	1.0000	0.000	1.03900	16.29001500	16.68538500	22	103.4
52	6951	6963	1.00000	1.64299	1.60796	135.27	1.112385	16.685776	1.112379	16.685683	NU1+	1.0000	0.000	1.15631	16.68540000	16.68900000	6	102.2
312	6951	6963	1.00000	0.00226	0.00223	315.27	1.112384	16.685757	1.112379	16.685683	V4:NU1+	1.0000	0.000	1.03900	16.68540000	16.68900000	2	101.7
53	6964	7506	1.00000	0.64566	0.40100	17.08	1.146913	17.203688	1.143666	17.154997	2(KM)P1	1.0000	0.000	1.15636	16.68901500	22.05364500	279	161.0
317	6964	7506	1.00000	0.00130	0.00065	197.08	1.149802	17.247024	1.143666	17.154997	V4:2(KM)P1	1.0000	0.000	1.03900	16.68901500	22.05364500	62	201.7

Wave groups and parameters for main waves V11,V31,V51

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl.	main ampl.+ nm/s**2	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
54	3019	3287	1.00000	0.00003	0.00003	17.90	0.786523	11.797847	0.788917	11.833749	V1:SGM2Q1	1.0000	0.000	1.00000	8.70000000	11.87400000	9	121.1
55	3019	3287	1.00000	0.04163	0.03429	17.90	0.786364	11.795459	0.788917	11.833749	V3:SGM2Q1	1.0000	0.000	1.06913	8.70000000	11.87400000	97	121.4
56	3019	3287	1.00000	0.00000	0.00000	318.32	0.784469	11.767029	0.783441	11.751611	V5:SGM2Q1	1.0000	0.000	1.02400	8.70000000	11.87400000	3	143.4
59	3288	3359	1.00000	0.00001	0.00000	289.85	0.793497	11.902451	0.793773	11.906602	V1:2SGM1	1.0000	0.000	1.00000	11.87401500	12.15000000	3	114.7
60	3288	3359	1.00000	0.00767	0.00657	289.85	0.793551	11.903270	0.793773	11.906602	V3:2SGM1	1.0000	0.000	1.06913	11.87401500	12.15000000	20	116.7
64	3360	3432	1.00000	0.00009	0.00008	87.35	0.820331	12.304961	0.820351	12.305270	V1:3Q1	1.0000	0.000	1.00000	12.15001500	12.31950000	5	107.6
65	3360	3432	1.00000	0.12162	0.11301	87.35	0.820330	12.304956	0.820351	12.305270	V3:3Q1	1.0000	0.000	1.06913	12.15001500	12.31950000	22	107.6
66	3360	3432	1.00000	0.00001	0.00001	299.72	0.819887	12.298299	0.819732	12.295986	V5:3Q1	1.0000	0.000	1.02400	12.15001500	12.31950000	5	159.4
69	3433	3622	1.00000	0.00009	0.00008	359.30	0.825215	12.378224	0.825208	12.378123	V1:SGMQ1	1.0000	0.000	1.00000	12.31951500	12.63220500	11	108.2
70	3433	3622	1.00000	0.12294	0.11363	359.30	0.825214	12.378214	0.825208	12.378123	V3:SGMQ1	1.0000	0.000	1.06913	12.31951500	12.63220500	57	108.2
71	3433	3622	1.00000	0.00000	0.00000	179.30	0.825193	12.377898	0.825208	12.378123	V5:SGMQ1	1.0000	0.000	1.02400	12.31951500	12.63220500	2	105.5
74	3623	3725	1.00000	0.00051	0.00048	68.75	0.856622	12.849336	0.856643	12.849644	V1:2Q1-	1.0000	0.000	1.00000	12.63222000	12.85225500	7	107.6
75	3623	3725	1.00000	0.70229	0.65266	68.75	0.856622	12.849336	0.856643	12.849644	V3:2Q1-	1.0000	0.000	1.06913	12.63222000	12.85225500	36	107.6
76	3623	3725	1.00000	0.00003	0.00002	248.75	0.856628	12.849426	0.856643	12.849644	V5:2Q1-	1.0000	0.000	1.02400	12.63222000	12.85225500	3	105.8
79	3726	3796	1.00000	0.00001	0.00001	36.38	0.857759	12.866381	0.857262	12.858928	V1:2Q1	1.0000	0.000	1.00000	12.85227000	12.90750000	6	116.8
80	3726	3796	1.00000	0.01790	0.01546	36.38	0.857724	12.865857	0.857262	12.858928	V3:2Q1	1.0000	0.000	1.06913	12.85227000	12.90750000	25	115.8
84	3797	3827	1.00000	0.00010	0.00009	340.70	0.861480	12.922196	0.861500	12.922498	V1:SGM1-	1.0000	0.000	1.00000	12.90751500	12.92520000	3	107.6

85	3797	3827	1.00000	0.13133	0.12207	340.70	0.861480	12.922196	0.861500	12.922498	V3:SGM1-	1.0000	0.000	1.06913	12.90751500	12.92520000	5	107.6
86	3797	3827	1.00000	0.00000	0.00000	160.70	0.861485	12.922270	0.861500	12.922498	V5:SGM1-	1.0000	0.000	1.02400	12.90751500	12.92520000	2	105.6
89	3828	3858	1.00000	0.00003	0.00003	308.33	0.862116	12.931738	0.862119	12.931782	V1:SGM1	1.0000	0.000	1.00000	12.92521500	12.94500000	3	101.1
90	3828	3858	1.00000	0.04592	0.04539	308.33	0.862116	12.931738	0.862119	12.931782	V3:SGM1	1.0000	0.000	1.06913	12.92521500	12.94500000	9	101.2
94	3859	3963	1.00000	0.00001	0.00001	220.29	0.865917	12.988757	0.866976	13.004635	V1:SGM1b	1.0000	0.000	1.00000	12.94501500	13.18012500	4	129.6
95	3859	3963	1.00000	0.01120	0.00850	220.29	0.865956	12.989341	0.866976	13.004635	V3:SGM1b	1.0000	0.000	1.06913	12.94501500	13.18012500	26	131.8
99	3964	4091	1.00000	0.00187	0.00174	50.15	0.892914	13.393713	0.892935	13.394019	V1:Q1a	1.0000	0.000	1.00000	13.18014000	13.39402500	10	107.6
100	3964	4091	1.00000	2.56008	2.37943	50.15	0.892914	13.393713	0.892935	13.394019	V3:Q1a	1.0000	0.000	1.06913	13.18014000	13.39402500	41	107.6
101	3964	4091	1.00000	0.00008	0.00007	230.15	0.892919	13.393791	0.892935	13.394019	V5:Q1a	1.0000	0.000	1.02400	13.18014000	13.39402500	2	105.6
105	4092	4107	1.00000	0.00030	0.00025	348.61	0.892987	13.394810	0.892946	13.394183	V3:Q1-	1.0000	0.000	1.06913	13.39404000	13.39699500	3	120.1
106	4092	4107	1.00000	0.00000	0.00000	237.79	0.893082	13.396225	0.893082	13.396225	V5:Q1-	1.0000	0.000	1.02400	13.39404000	13.39699500	1	100.0
109	4108	4159	1.00000	0.00011	0.00011	17.78	0.893553	13.403288	0.893554	13.403303	V1:Q1	1.0000	0.000	1.00000	13.39701000	13.42500000	3	101.8
110	4108	4159	1.00000	0.14921	0.14654	17.78	0.893553	13.403288	0.893554	13.403303	V3:Q1	1.0000	0.000	1.06913	13.39701000	13.42500000	8	101.8
111	4108	4159	1.00000	0.00000	0.00000	190.14	0.893548	13.403214	0.893406	13.401096	V5:Q1	1.0000	0.000	1.02400	13.39701000	13.42500000	2	138.7
114	4160	4212	1.00000	0.00001	0.00001	247.05	0.895685	13.435271	0.895672	13.435086	V1:Q1b	1.0000	0.000	1.00000	13.42501500	13.45200000	4	103.9
115	4160	4212	1.00000	0.01182	0.01081	247.05	0.895688	13.435320	0.895672	13.435086	V3:Q1b	1.0000	0.000	1.06913	13.42501500	13.45200000	14	109.3
119	4213	4232	1.00000	0.00000	0.00000	142.10	0.897772	13.466574	0.897792	13.466873	V1:RO1-	1.0000	0.000	1.00000	13.45201500	13.47000000	2	107.5
120	4213	4232	1.00000	0.00558	0.00517	142.10	0.897770	13.466556	0.897792	13.466873	V3:RO1-	1.0000	0.000	1.06913	13.45201500	13.47000000	4	107.8
124	4233	4271	1.00000	0.00015	0.00015	289.73	0.898407	13.476110	0.898410	13.476156	V1:RO1	1.0000	0.000	1.00000	13.47001500	13.48500000	2	101.1
125	4233	4271	1.00000	0.20605	0.20387	289.73	0.898407	13.476110	0.898410	13.476156	V3:RO1	1.0000	0.000	1.06913	13.47001500	13.48500000	7	101.1
126	4233	4271	1.00000	0.00000	0.00000	102.09	0.898263	13.473950	0.898263	13.473950	V5:RO1	1.0000	0.000	1.02400	13.47001500	13.48500000	1	100.0
129	4272	4367	1.00000	0.00001	0.00001	126.63	0.901461	13.521909	0.901148	13.517223	V1:RO1b	1.0000	0.000	1.00000	13.48501500	13.72500000	3	109.5
130	4272	4367	1.00000	0.01484	0.01346	126.63	0.901477	13.522154	0.901148	13.517223	V3:RO1b	1.0000	0.000	1.06913	13.48501500	13.72500000	31	110.3
134	4368	4477	1.00000	0.00003	0.00002	299.60	0.924464	13.866967	0.924369	13.865540	V1:O1a	1.0000	0.000	1.00000	13.72501500	13.92472500	5	115.2
135	4368	4477	1.00000	0.03825	0.03318	299.60	0.924469	13.867041	0.924369	13.865540	V3:O1a	1.0000	0.000	1.06913	13.72501500	13.92472500	32	115.3
139	4478	4506	1.00000	0.00011	0.00010	211.55	0.929205	13.938081	0.929226	13.938394	V1:O1--	1.0000	0.000	1.00000	13.92474000	13.93990500	3	107.7
140	4478	4506	1.00000	0.14513	0.13476	211.55	0.929205	13.938081	0.929226	13.938394	V3:O1--	1.0000	0.000	1.06913	13.92474000	13.93990500	6	107.7
145	4507	4515	1.00000	0.00033	0.00024	7.73	0.929389	13.940831	0.929389	13.940829	V3:O1-	1.0000	0.000	1.06913	13.93992000	13.94083500	2	136.9
149	4516	4569	1.00000	0.00090	0.00089	359.18	0.929842	13.947630	0.929845	13.947677	V1:O1	1.0000	0.000	1.00000	13.94085000	13.94940000	3	101.1
150	4516	4569	1.00000	1.22991	1.21666	359.18	0.929842	13.947630	0.929845	13.947677	V3:O1	1.0000	0.000	1.06913	13.94085000	13.94940000	12	101.1
151	4516	4569	1.00000	0.00001	0.00001	171.54	0.929749	13.946241	0.929698	13.945471	V5:O1	1.0000	0.000	1.02400	13.94085000	13.94940000	2	123.9
154	4570	4598	1.00000	0.00012	0.00012	6.82	0.929992	13.949885	0.929992	13.949884	V1:2NO1	1.0000	0.000	1.00000	13.94941500	13.96500000	2	100.0
155	4570	4598	1.00000	0.15844	0.15841	6.82	0.929992	13.949885	0.929992	13.949884	V3:2NO1	1.0000	0.000	1.06913	13.94941500	13.96500000	7	100.0
156	4570	4598	1.00000	0.00001	0.00001	186.82	0.929992	13.949884	0.929992	13.949884	V5:2NO1	1.0000	0.000	1.02400	13.94941500	13.96500000	1	100.0
159	4599	4651	1.00000	0.00001	0.00001	196.08	0.932473	13.987102	0.932583	13.988744	V1:O1b	1.0000	0.000	1.00000	13.96501500	13.99800000	4	124.4
160	4599	4651	1.00000	0.01188	0.00944	196.08	0.932469	13.987036	0.932583	13.988744	V3:O1b	1.0000	0.000	1.06913	13.96501500	13.99800000	13	125.9
164	4652	4772	1.00000	0.00018	0.00017	271.13	0.934707	14.020612	0.934702	14.020531	V1:TAU1	1.0000	0.000	1.00000	13.99801500	14.21986500	7	102.2
165	4652	4772	1.00000	0.24218	0.23703	271.13	0.934708	14.020615	0.934702	14.020531	V3:TAU1	1.0000	0.000	1.06913	13.99801500	14.21986500	34	102.2
166	4652	4772	1.00000	0.00000	0.00000	98.78	0.934703	14.020544	0.934849	14.022737	V5:TAU1	1.0000	0.000	1.02400	13.99801500	14.21986500	3	158.6
169	4773	4876	1.00000	0.00002	0.00002	93.36	0.961070	14.416046	0.960514	14.407708	V1:NTAU1	1.0000	0.000	1.00000	14.21988000	14.46690000	5	114.7
170	4773	4876	1.00000	0.03173	0.02762	93.36	0.961066	14.415991	0.960514	14.407708	V3:NTAU1	1.0000	0.000	1.06913	14.21988000	14.46690000	26	114.9
175	4877	4891	1.00000	0.00149	0.00103	12.95	0.965452	14.481778	0.965518	14.482768	V3:LK1-	1.0000	0.000	1.06913	14.46691500	14.48550000	5	145.0
179	4892	4901	1.00000	0.00002	0.00002	325.30	0.965843	14.487639	0.965843	14.487639	V1:LK1	1.0000	0.000	1.00000	14.48551500	14.48899500	1	100.0
180	4892	4901	1.00000	0.03337	0.03337	325.30	0.965843	14.487639	0.965843	14.487639	V3:LK1	1.0000	0.000	1.06913	14.48551500	14.48899500	2	100.0
181	4892	4901	1.00000	0.00000	0.00000	145.30	0.965843	14.487639	0.965843	14.487639	V5:LK1	1.0000	0.000	1.02400	14.48551500	14.48899500	1	100.0
184	4902	4947	1.00000	0.00555	0.00544	340.58	0.966136	14.492041	0.966137	14.492052	V1:NO1	1.0000	0.000	1.00000	14.48901000	14.49763500	4	101.9
185	4902	4947	1.00000	7.58645	7.44410	340.58	0.966136	14.492041	0.966137	14.492052	V3:NO1	1.0000	0.000	1.06913	14.48901000	14.49763500	12	101.9
186	4902	4947	1.00000	0.00004	0.00003	152.94	0.966136	14.492041	0.965990	14.489846	V5:NO1	1.0000	0.000	1.02400	14.48901000	14.49763500	4	158.6
189	4948	4963	1.00000	0.00001	0.00001	308.21	0.966756	14.501336	0.966756	14.501336	V1:NO1+	1.0000	0.000	1.00000	14.49765000	14.50279500	1	100.0
190	4948	4963	1.00000	0.01122	0.01121	308.21	0.966756	14.501333	0.966756	14.501336	V3:NO1+	1.0000	0.000	1.06913	14.49765000	14.50279500	2	100.1
191	4948	4963	1.00000	0.00000	0.00000	128.21	0.966756	14.501336	0.966756	14.501336	V5:NO1+	1.0000	0.000	1.02400	14.49765000	14.50279500	1	100.0
194	4964	5042	1.00000	0.00001	0.00001	252.54	0.969868	14.548022	0.970994	14.564906	V1:CHI1	1.0000	0.000	1.00000	14.50281000	14.57166000	6	144.5
195	4964	5042	1.00000	0.01618	0.01135	252.54	0.969896	14.548439	0.970994	14.564906	V3:CHI1	1.0000	0.000	1.06913	14.50281000	14.57166000	21	142.5

199	5043	5056	1.00000	0.00002	0.00002	220.17	0.971613	14.574189	0.971613	14.574189	V1:CHI1+	1.0000	0.000	1.00000	14.57167500	14.57500500	1	100.0
200	5043	5056	1.00000	0.03086	0.03084	220.17	0.971612	14.574187	0.971613	14.574189	V3:CHI1+	1.0000	0.000	1.06913	14.57167500	14.57500500	3	100.1
201	5043	5056	1.00000	0.00000	0.00000	40.17	0.971613	14.574189	0.971613	14.574189	V5:CHI1+	1.0000	0.000	1.02400	14.57167500	14.57500500	1	100.0
204	5057	5391	1.00000	0.00001	0.00001	227.81	0.972923	14.593850	0.971760	14.576396	V1:PI1	1.0000	0.000	1.00000	14.57502000	14.95399500	6	104.5
205	5057	5391	1.00000	0.01997	0.01907	227.81	0.972977	14.594658	0.971760	14.576396	V3:PI1	1.0000	0.000	1.06913	14.57502000	14.95399500	32	104.7
214	5404	5485	1.00000	0.00006	0.00006	50.03	0.997571	14.963568	0.997572	14.963573	V1:P1	1.0000	0.000	1.00000	14.95675500	14.97946500	3	101.8
215	5404	5485	1.00000	0.07689	0.07555	50.03	0.997571	14.963568	0.997572	14.963573	V3:P1	1.0000	0.000	1.06913	14.95675500	14.97946500	9	101.8
219	5486	5613	1.00000	0.00004	0.00004	314.34	1.002250	15.033754	1.002281	15.034220	V1:S1	1.0000	0.000	1.00000	14.97948000	15.03499500	3	100.7
220	5486	5613	1.00000	0.06109	0.06066	314.34	1.002250	15.033745	1.002281	15.034220	V3:S1	1.0000	0.000	1.06913	14.97948000	15.03499500	14	100.7
221	5486	5613	1.00000	0.00000	0.00000	134.34	1.002281	15.034220	1.002281	15.034220	V5:S1	1.0000	0.000	1.02400	14.97948000	15.03499500	1	100.0
224	5614	5637	1.00000	0.00030	0.00030	321.98	1.002431	15.036463	1.002428	15.036427	V1:K1-	1.0000	0.000	1.00000	15.03501000	15.03907500	2	100.8
225	5614	5637	1.00000	0.40882	0.40545	321.98	1.002431	15.036463	1.002428	15.036427	V3:K1-	1.0000	0.000	1.06913	15.03501000	15.03907500	4	100.8
226	5614	5637	1.00000	0.00000	0.00000	149.63	1.002523	15.037849	1.002576	15.038633	V5:K1-	1.0000	0.000	1.02400	15.03501000	15.03907500	2	124.6
230	5638	5654	1.00000	0.00095	0.00080	337.27	1.002727	15.040903	1.002723	15.040840	V3:K1	1.0000	0.000	1.06913	15.03909000	15.04290000	4	117.6
234	5655	5665	1.00000	0.00000	0.00000	281.97	1.002900	15.043504	1.002900	15.043504	V1:K1+	1.0000	0.000	1.00000	15.04291500	15.04351500	1	100.0
235	5655	5665	1.00000	0.00483	0.00483	281.97	1.002900	15.043504	1.002900	15.043504	V3:K1+	1.0000	0.000	1.06913	15.04291500	15.04351500	3	100.0
236	5655	5665	1.00000	0.00000	0.00000	101.97	1.002900	15.043504	1.002900	15.043504	V5:K1+	1.0000	0.000	1.02400	15.04291500	15.04351500	1	100.0
239	5666	5720	1.00000	0.00012	0.00011	289.61	1.003069	15.046030	1.003047	15.045710	V1:K1++	1.0000	0.000	1.00000	15.04353000	15.06300000	3	108.1
240	5666	5720	1.00000	0.16005	0.14807	289.61	1.003069	15.046029	1.003047	15.045710	V3:K1++	1.0000	0.000	1.06913	15.04353000	15.06300000	4	108.1
241	5666	5720	1.00000	0.00001	0.00001	109.61	1.003063	15.045948	1.003047	15.045710	V5:K1++	1.0000	0.000	1.02400	15.04353000	15.06300000	2	105.9
244	5721	5812	1.00000	0.00000	0.00000	65.59	1.005476	15.082137	1.005476	15.082137	V1:PSI1	1.0000	0.000	1.00000	15.06301500	15.10267500	1	100.0
245	5721	5812	1.00000	0.00304	0.00251	65.59	1.005421	15.081308	1.005476	15.082137	V3:PSI1	1.0000	0.000	1.06913	15.06301500	15.10267500	9	121.1
249	5813	6094	1.00000	0.00002	0.00002	201.57	1.007923	15.118839	1.007904	15.118564	V1:PHI1	1.0000	0.000	1.00000	15.10269000	15.35433000	2	106.9
250	5813	6094	1.00000	0.02954	0.02759	201.57	1.007927	15.118904	1.007904	15.118564	V3:PHI1	1.0000	0.000	1.06913	15.10269000	15.35433000	21	107.1
251	5813	6094	1.00000	0.00000	0.00000	21.57	1.007904	15.118564	1.007904	15.118564	V5:PHI1	1.0000	0.000	1.02400	15.10269000	15.35433000	1	100.0
254	6095	6236	1.00000	0.00006	0.00006	31.43	1.033848	15.507720	1.033863	15.507948	V1:TET1	1.0000	0.000	1.00000	15.35434500	15.51400500	4	103.5
255	6095	6236	1.00000	0.08797	0.08502	31.43	1.033847	15.507701	1.033863	15.507948	V3:TET1	1.0000	0.000	1.06913	15.35434500	15.51400500	22	103.5
259	6237	6254	1.00000	0.00000	0.00000	359.06	1.034503	15.517548	1.034482	15.517232	V1:TET1+	1.0000	0.000	1.00000	15.51402000	15.53068500	2	108.0
260	6237	6254	1.00000	0.00448	0.00414	359.06	1.034503	15.517545	1.034482	15.517232	V3:TET1+	1.0000	0.000	1.06913	15.51402000	15.53068500	4	108.1
264	6255	6337	1.00000	0.00002	0.00002	303.39	1.038676	15.580144	1.038720	15.580802	V1:J1	1.0000	0.000	1.00000	15.53070000	15.58723500	4	102.4
265	6255	6337	1.00000	0.03139	0.03072	303.39	1.038687	15.580300	1.038720	15.580802	V3:J1	1.0000	0.000	1.06913	15.53070000	15.58723500	20	102.
269	6338	6361	1.00000	0.00199	0.00199	271.01	1.039339	15.590083	1.039339	15.590085	V1:J1+	1.0000	0.000	1.00000	15.58725000	15.59100000	2	100.1
270	6338	6361	1.00000	2.71844	2.71700	271.01	1.039339	15.590083	1.039339	15.590085	V3:J1+	1.0000	0.000	1.06913	15.58725000	15.59100000	5	100.1
271	6338	6361	1.00000	0.00007	0.00007	91.01	1.039338	15.590063	1.039339	15.590085	V5:J1+	1.0000	0.000	1.02400	15.58725000	15.59100000	2	100.5
274	6362	6483	1.00000	0.00081	0.00081	98.66	1.039487	15.592308	1.039486	15.592292	V1:KLK1	1.0000	0.000	1.00000	15.59101500	15.82500000	6	100.3
275	6362	6483	1.00000	1.10470	1.10089	98.66	1.039487	15.592308	1.039486	15.592292	V3:KLK1	1.0000	0.000	1.06913	15.59101500	15.82500000	30	100.3
276	6362	6483	1.00000	0.00003	0.00003	278.66	1.039486	15.592292	1.039486	15.592292	V5:KLK1	1.0000	0.000	1.02400	15.59101500	15.82500000	1	100.0
279	6484	6591	1.00000	0.00006	0.00006	340.46	1.070752	16.061276	1.070774	16.061606	V1:SO1	1.0000	0.000	1.00000	15.82501500	16.06300500	7	101.2
280	6484	6591	1.00000	0.08756	0.08650	340.46	1.070750	16.061255	1.070774	16.061606	V3:SO1	1.0000	0.000	1.06913	15.82501500	16.06300500	27	101.2
281	6484	6591	1.00000	0.00000	0.00000	160.46	1.070774	16.061606	1.070774	16.061606	V5:SO1	1.0000	0.000	1.02400	15.82501500	16.06300500	1	100.
284	6592	6677	1.00000	0.00033	0.00032	252.42	1.075601	16.134014	1.075631	16.134460	V1:2J1	1.0000	0.000	1.00000	16.06302000	16.13449500	7	100.4
285	6592	6677	1.00000	0.44576	0.44410	252.42	1.075601	16.134013	1.075631	16.134460	V3:2J1	1.0000	0.000	1.06913	16.06302000	16.13449500	23	100.4
286	6592	6677	1.00000	0.00002	0.00002	72.42	1.075607	16.134100	1.075631	16.134460	V5:2J1	1.0000	0.000	1.02400	16.06302000	16.13449500	3	100.7
289	6678	6691	1.00000	0.00013	0.00013	80.06	1.075779	16.136681	1.075778	16.136666	V1:OO1	1.0000	0.000	1.00000	16.13451000	16.14103500	2	100.3
290	6678	6691	1.00000	0.18051	0.17989	80.06	1.075779	16.136681	1.075778	16.136666	V3:OO1	1.0000	0.000	1.06913	16.13451000	16.14103500	3	100.3
291	6678	6691	1.00000	0.00001	0.00001	260.06	1.075778	16.136666	1.075778	16.136666	V5:OO1	1.0000	0.000	1.02400	16.13451000	16.14103500	1	100.0
295	6692	6698	1.00000	0.00065	0.00064	275.34	1.076073	16.141091	1.076072	16.141079	V3:OO1+	1.0000	0.000	1.06913	16.14105000	16.14150000	2	102.
299	6699	6773	1.00000	0.00001	0.00000	40.05	1.076725	16.150875	1.076250	16.143743	V1:OO1++	1.0000	0.000	1.00000	16.14151500	16.29000000	5	154.1
300	6699	6773	1.00000	0.00914	0.00575	40.05	1.076905	16.153570	1.076250	16.143743	V3:OO1++	1.0000	0.000	1.06913	16.14151500	16.29000000	23	159.0
304	6774	6950	1.00000	0.00007	0.00005	321.86	1.108727	16.630906	1.107065	16.605981	V1:NU1	1.0000	0.000	1.00000	16.29001500	16.68538500	10	133.0
305	6774	6950	1.00000	0.09907	0.07445	321.86	1.108726	16.630883	1.107065	16.605981	V3:NU1	1.0000	0.000	1.06913	16.29001500	16.68538500	53	133.1
306	6774	6950	1.00000	0.00000	0.00000	141.86	1.108973	16.634601	1.107065	16.605981	V5:NU1	1.0000	0.000	1.02400	16.29001500	16.68538500	4	135.2
309	6951	6963	1.00000	0.00007	0.00007	201.45	1.112541	16.688118	1.112541	16.688118	V1:NU1+	1.0000	0.000	1.00000	16.68540000	16.68900000	1	100.0

310	6951	6963	1.00000	0.10237	0.10237	201.45	1.112541	16.688118	1.112541	16.688118	V3:NU1+	1.0000	0.000	1.06913	16.68540000	16.68900000	3	100.0
311	6951	6963	1.00000	0.00001	0.00001	21.45	1.112541	16.688118	1.112541	16.688118	V5:NU1+	1.0000	0.000	1.02400	16.68540000	16.68900000	1	100.0
314	6964	7506	1.00000	0.00007	0.00006	29.09	1.119631	16.794468	1.112688	16.690325	V1:2(KM)P1	1.0000	0.000	1.00000	16.68901500	22.05364500	20	116.3
315	6964	7506	1.00000	0.10100	0.08677	29.09	1.119716	16.795742	1.112688	16.690325	V3:2(KM)P1	1.0000	0.000	1.06913	16.68901500	22.05364500	177	116.4
316	6964	7506	1.00000	0.00001	0.00001	209.09	1.119997	16.799950	1.112688	16.690325	V5:2(KM)P1	1.0000	0.000	1.02400	16.68901500	22.05364500	5	116.6

Wave groups and parameters for main waves V22,V42,V62

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
1	7507	7863	1.00000	0.45445	0.36985	127.51	1.791938	26.879077	1.791964	26.879459	2EPS2	1.0000	0.000	1.16199	22.05366000	27.12000000	147	122.9
55	7507	7863	1.00000	0.00671	0.00452	67.93	1.785945	26.789169	1.786488	26.797322	V4:2EPS2	1.0000	0.000	1.03900	22.05366000	27.12000000	60	148.4
2	7864	7940	1.00000	0.86391	0.86312	196.96	1.823397	27.350960	1.823399	27.350980	3N2	1.0000	0.000	1.16199	27.12001500	27.36687000	28	100.1
60	7864	7940	1.00000	0.02257	0.02110	49.33	1.822761	27.341415	1.822780	27.341696	V4:3N2	1.0000	0.000	1.03900	27.12001500	27.36687000	15	106.9
3	7941	8103	1.00000	2.28752	2.23724	108.91	1.828446	27.426693	1.828256	27.423834	EPS2	1.0000	0.000	1.16199	27.36688500	27.68916000	80	102.2
65	7941	8103	1.00000	0.00436	0.00387	321.29	1.827688	27.415325	1.827637	27.414550	V4:EPS2	1.0000	0.000	1.03900	27.36688500	27.68916000	21	112.7
4	8104	8270	1.00000	7.68035	7.67164	178.36	1.859691	27.895366	1.859690	27.895355	2N2	1.0000	0.000	1.16199	27.68917500	27.94539000	70	100.1
70	8104	8270	1.00000	0.06303	0.05883	30.73	1.859055	27.885829	1.859071	27.886071	V4:2N2	1.0000	0.000	1.03900	27.68917500	27.94539000	27	107.2
71	8104	8270	1.00000	0.00002	0.00002	210.73	1.859071	27.886071	1.859071	27.886071	V6:2N2	1.0000	0.000	1.01750	27.68917500	27.94539000	1	100.0
5	8271	8417	1.00000	9.29097	9.25906	90.32	1.864564	27.968461	1.864547	27.968208	MUE2	1.0000	0.000	1.16199	27.94540500	28.20396000	85	100.3
75	8271	8417	1.00000	0.00462	0.00444	270.32	1.864554	27.968317	1.864547	27.968208	V4:MUE2	1.0000	0.000	1.03900	27.94540500	28.20396000	17	104.2
6	8418	8535	1.00000	0.57176	0.48735	142.87	1.893288	28.399315	1.893244	28.398663	N2a	1.0000	0.000	1.16199	28.20397500	28.43520000	59	117.3
80	8418	8535	1.00000	0.00556	0.00504	192.14	1.895048	28.425722	1.895363	28.430446	V4:N2a	1.0000	0.000	1.03900	28.20397500	28.43520000	14	110.4
7	8536	8551	1.00000	2.16458	2.16437	152.12	1.895835	28.437523	1.895835	28.437523	N2-	1.0000	0.000	1.16199	28.43521500	28.43790000	10	100.0
85	8536	8551	1.00000	0.00655	0.00654	332.12	1.895834	28.437517	1.895835	28.437523	V4:N2-	1.0000	0.000	1.03900	28.43521500	28.43790000	2	100.1
8	8552	8595	1.00000	57.97340	57.97339	159.76	1.895982	28.439730	1.895982	28.439730	N2	1.0000	0.000	1.16199	28.43791500	28.46026500	30	100.0
90	8552	8595	1.00000	0.02547	0.02484	339.76	1.895989	28.439838	1.895982	28.439730	V4:N2	1.0000	0.000	1.03900	28.43791500	28.46026500	5	102.6
9	8596	8646	1.00000	0.63445	0.54105	356.66	1.898627	28.479398	1.898720	28.480796	N2b	1.0000	0.000	1.16199	28.46028000	28.49250000	26	117.3
95	8596	8646	1.00000	0.00029	0.00024	176.66	1.898634	28.479515	1.898720	28.480796	V4:N2b	1.0000	0.000	1.03900	28.46028000	28.49250000	8	123.3
10	8647	8701	1.00000	11.02033	11.01246	71.72	1.900839	28.512581	1.900839	28.512583	NUE2	1.0000	0.000	1.16199	28.49251500	28.53450000	31	100.1
100	8647	8701	1.00000	0.00513	0.00482	251.72	1.900840	28.512604	1.900839	28.512583	V4:NUE2	1.0000	0.000	1.03900	28.49251500	28.53450000	9	106.5
11	8702	8770	1.00000	0.50892	0.50806	268.61	1.903582	28.553729	1.903577	28.553650	NUE2b	1.0000	0.000	1.16199	28.53451500	28.72671000	43	100.2
105	8702	8770	1.00000	0.00025	0.00022	88.61	1.903746	28.556184	1.903577	28.553650	V4:NUE2b	1.0000	0.000	1.03900	28.53451500	28.72671000	5	110.1
12	8771	8830	1.00000	0.91980	0.90898	49.21	1.927393	28.910899	1.927417	28.911251	GAM2	1.0000	0.000	1.16199	28.72672500	28.92603000	33	101.2
110	8771	8830	1.00000	0.00070	0.00067	73.94	1.926662	28.899925	1.926651	28.899761	V4:GAM2	1.0000	0.000	1.03900	28.72672500	28.92603000	8	103.9
13	8831	8872	1.00000	1.04181	1.04049	124.27	1.929536	28.943046	1.929536	28.943038	ALF2	1.0000	0.000	1.16199	28.92604500	28.96000500	25	100.1
115	8831	8872	1.00000	0.00038	0.00036	304.27	1.929546	28.943191	1.929536	28.943038	V4:ALF2	1.0000	0.000	1.03900	28.92604500	28.96000500	3	105.8
14	8873	8907	1.00000	11.29880	11.29769	133.52	1.932126	28.981897	1.932127	28.981898	M2-	1.0000	0.000	1.16199	28.96002000	28.98225000	22	100.0
120	8873	8907	1.00000	0.02671	0.02667	313.52	1.932126	28.981892	1.932127	28.981898	V4:M2-	1.0000	0.000	1.03900	28.96002000	28.98225000	4	100.1
15	8908	8973	1.00000	302.78685	302.78675	141.17	1.932274	28.984104	1.932274	28.984104	M2	1.0000	0.000	1.16199	28.98226500	29.00685000	39	100.0
125	8908	8973	1.00000	0.10391	0.10134	321.17	1.932281	28.984213	1.932274	28.984104	V4:M2	1.0000	0.000	1.03900	28.98226500	29.00685000	8	102.5
16	8974	9015	1.00000	0.91694	0.91665	338.06	1.935011	29.025169	1.935011	29.025171	BET2	1.0000	0.000	1.16199	29.00686500	29.04228000	26	100.0
130	8974	9015	1.00000	0.00034	0.00032	158.06	1.935023	29.025351	1.935011	29.025171	V4:BET2	1.0000	0.000	1.03900	29.00686500	29.04228000	3	106.3
17	9016	9098	1.00000	0.43470	0.35500	20.75	1.937690	29.065345	1.937749	29.066242	DEL2	1.0000	0.000	1.16199	29.04229500	29.25628500	43	122.4
135	9016	9098	1.00000	0.00170	0.00168	200.75	1.937759	29.066382	1.937749	29.066242	V4:DEL2	1.0000	0.000	1.03900	29.04229500	29.25628500	10	101.1
18	9099	9152	1.00000	2.23755	2.23274	30.61	1.963702	29.455526	1.963708	29.455625	LAM2	1.0000	0.000	1.16199	29.25630000	29.47150500	31	100.2
140	9099	9152	1.00000	0.00047	0.00045	30.61	1.963710	29.455657	1.963708	29.455625	V4:LAM2	1.0000	0.000	1.03900	29.25630000	29.47150500	5	102.9
19	9153	9202	1.00000	8.56514	8.55917	302.57	1.968565	29.528474	1.968565	29.528479	L2	1.0000	0.000	1.16199	29.47152000	29.52900000	27	100.1
145	9153	9202	1.00000	0.00284	0.00274	302.57	1.968555	29.528322	1.968565	29.528479	V4:L2	1.0000	0.000	1.03900	29.47152000	29.52900000	4	103.5
20	9203	9235	1.00000	2.13991	2.13952	90.20	1.969184	29.537762	1.969184	29.537763	KNO2	1.0000	0.000	1.16199	29.52901500	29.53930500	14	100.0
150	9203	9235	1.00000	0.00934	0.00930	270.20	1.969181	29.537722	1.969184	29.537763	V4:KNO2	1.0000	0.000	1.03900	29.52901500	29.53930500	4	100.4

21	9236	9248	1.00000	0.95364	0.94425	277.84	1.969334	29.540012	1.969331	29.539969	KNO2+	1.0000	0.000	1.16199	29.53932000	29.55450000	5	101.0
155	9236	9248	1.00000	0.00370	0.00369	97.84	1.969332	29.539979	1.969331	29.539969	V4:KNO2+	1.0000	0.000	1.03900	29.53932000	29.55450000	3	100.2
22	9249	9356	1.00000	0.45613	0.40928	2.15	1.974069	29.611032	1.974041	29.610616	JTAU2	1.0000	0.000	1.16199	29.55451500	29.76423000	69	111.4
160	9249	9356	1.00000	0.00200	0.00186	182.15	1.974062	29.610930	1.974041	29.610616	V4:JTAU2	1.0000	0.000	1.03900	29.55451500	29.76423000	12	108.0
23	9357	9462	1.00000	0.33443	0.33420	158.22	1.994521	29.917818	1.994524	29.917867	2T2	1.0000	0.000	1.16199	29.76424500	29.93250000	98	100.1
24	9463	9542	1.00000	8.23421	8.23420	355.12	1.997262	29.958933	1.997262	29.958933	T2	1.0000	0.000	1.16199	29.93251500	29.98494000	71	100.0
170	9463	9542	1.00000	0.00006	0.00006	175.12	1.997252	29.958787	1.997262	29.958933	V4:T2	1.0000	0.000	1.03900	29.93251500	29.98494000	2	103.5
25	9543	9657	1.00000	140.85978	140.85942	192.02	2.000000	30.000000	2.000000	30.000000	S2	1.0000	0.000	1.16199	29.98495500	30.02517000	96	100.0
175	9543	9657	1.00000	0.00114	0.00097	12.02	1.999992	29.999887	2.000000	30.000000	V4:S2	1.0000	0.000	1.03900	29.98495500	30.02517000	7	117.3
26	9658	9728	1.00000	1.21442	1.17587	208.91	2.002738	30.041067	2.002738	30.041067	R2	1.0000	0.000	1.16199	30.02518500	30.06570000	61	103.3
180	9658	9728	1.00000	0.00004	0.00004	62.34	2.002885	30.043277	2.002885	30.043277	V4:R2	1.0000	0.000	1.03900	30.02518500	30.06570000	1	100.0
27	9729	9778	1.00000	38.27835	38.27522	71.60	2.005476	30.082137	2.005476	30.082137	K2	1.0000	0.000	1.16199	30.06571500	30.08400000	31	100.0
185	9729	9778	1.00000	0.06850	0.06835	251.60	2.005475	30.082127	2.005476	30.082137	V4:K2	1.0000	0.000	1.03900	30.06571500	30.08400000	6	100.2
186	9729	9778	1.00000	0.00002	0.00002	71.60	2.005476	30.082137	2.005476	30.082137	V6:K2	1.0000	0.000	1.01750	30.06571500	30.08400000	1	100.0
28	9779	9786	1.00000	11.40721	11.40720	259.24	2.005623	30.084344	2.005623	30.084344	K2+	1.0000	0.000	1.16199	30.08401500	30.08625000	5	100.0
190	9779	9786	1.00000	0.02696	0.02696	79.24	2.005623	30.084344	2.005623	30.084344	V4:K2+	1.0000	0.000	1.03900	30.08401500	30.08625000	1	100.0
29	9787	9793	1.00000	1.23994	1.23994	86.88	2.005770	30.086550	2.005770	30.086550	K2++	1.0000	0.000	1.16199	30.08626500	30.08700000	3	100.0
195	9787	9793	1.00000	0.00190	0.00190	266.88	2.005770	30.086550	2.005770	30.086550	V4:K2++	1.0000	0.000	1.03900	30.08626500	30.08700000	1	100.0
30	9794	9910	1.00000	0.30076	0.29962	268.49	2.008226	30.123388	2.008214	30.123204	K2b	1.0000	0.000	1.16199	30.08701500	30.15952500	97	100.4
200	9794	9910	1.00000	0.00025	0.00018	163.55	2.008868	30.133017	2.010333	30.154991	V4:K2b	1.0000	0.000	1.03900	30.08701500	30.15952500	7	135.0
31	9911	10068	1.00000	0.26190	0.26077	311.18	2.010962	30.164430	2.010952	30.164275	KPHI2	1.0000	0.000	1.16199	30.15954000	30.33732000	145	100.4
205	9911	10068	1.00000	0.00013	0.00009	138.82	2.011130	30.166944	2.011099	30.166481	V4: KPHI2	1.0000	0.000	1.03900	30.15954000	30.33732000	4	144.3
32	10069	10203	1.00000	0.44892	0.40934	141.05	2.036922	30.553837	2.036911	30.553658	ZETA2	1.0000	0.000	1.16199	30.33733500	30.57600000	96	109.7
210	10069	10203	1.00000	0.00201	0.00185	321.05	2.036921	30.553809	2.036911	30.553658	V4:ZETA2	1.0000	0.000	1.03900	30.33733500	30.57600000	12	108.1
33	10204	10261	1.00000	2.14151	2.14104	53.00	2.041767	30.626508	2.041767	30.626512	ETA2	1.0000	0.000	1.16199	30.57601500	30.62848500	33	100.0
215	10204	10261	1.00000	0.00932	0.00930	233.00	2.041767	30.626499	2.041767	30.626512	V4:ETA2	1.0000	0.000	1.03900	30.57601500	30.62848500	8	100.2
34	10262	10353	1.00000	0.93822	0.93232	240.64	2.041917	30.628760	2.041915	30.628718	ETA2+	1.0000	0.000	1.16199	30.62850000	30.84000000	58	100.6
220	10262	10353	1.00000	0.00368	0.00367	60.64	2.041917	30.628762	2.041915	30.628718	V4:ETA2+	1.0000	0.000	1.03900	30.62850000	30.84000000	8	100.4
35	10354	10439	1.00000	0.38797	0.35509	122.45	2.073211	31.098164	2.073202	31.098033	2S2	1.0000	0.000	1.16199	30.84001500	31.13700000	47	109.3
225	10354	10439	1.00000	0.00181	0.00168	302.45	2.073207	31.098102	2.073202	31.098033	V4:2S2	1.0000	0.000	1.03900	30.84001500	31.13700000	9	107.5
36	10440	10481	1.00000	0.59206	0.56020	2.03	2.078616	31.179234	2.078678	31.180170	2K2	1.0000	0.000	1.16199	31.13701500	31.18110000	18	105.7
230	10440	10481	1.00000	0.00543	0.00531	182.03	2.078653	31.179801	2.078678	31.180170	V4:2K2	1.0000	0.000	1.03900	31.13701500	31.18110000	7	102.1
37	10482	10525	1.00000	0.51106	0.48576	189.67	2.078840	31.182597	2.078825	31.182377	2K2+	1.0000	0.000	1.16199	31.18111500	31.39000500	23	105.2
235	10482	10525	1.00000	0.00474	0.00453	9.67	2.078838	31.182575	2.078825	31.182377	V4:2K2+	1.0000	0.000	1.03900	31.18111500	31.39000500	4	104.7
38	10526	10879	1.00000	0.16445	0.10729	343.43	2.115396	31.730942	2.114970	31.724545	2KN2	1.0000	0.000	1.16199	31.39002000	35.94000000	179	153.3
240	10526	10879	1.00000	0.00188	0.00130	163.43	2.117009	31.755133	2.114970	31.724545	V4:2KN2	1.0000	0.000	1.03900	31.39002000	35.94000000	39	144.6

Wave groups and parameters for main waves V33,V53

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
39	10880	11168	1.00000	0.19041	0.17954	158.94	2.822188	42.332814	2.825827	42.387407	M2N3	1.0000	0.000	1.07360	38.70000000	42.39900000	164	106.1
242	10880	11168	1.00000	0.00133	0.00112	11.32	2.817821	42.267312	2.825208	42.378123	V5:M2N3	1.0000	0.000	1.02400	38.70000000	42.39900000	19	118.0
40	11169	11242	1.00000	0.18136	0.18049	70.90	2.830701	42.460511	2.830684	42.460261	MMUE3	1.0000	0.000	1.07360	42.39901500	42.75000000	48	100.5
245	11169	11242	1.00000	0.00008	0.00007	250.90	2.830666	42.459992	2.830684	42.460261	V5:MMUE3	1.0000	0.000	1.02400	42.39901500	42.75000000	3	111.6
41	11243	11318	1.00000	1.03734	1.03563	140.35	2.862118	42.931768	2.862119	42.931782	MN3	1.0000	0.000	1.07360	42.75001500	42.96450000	45	100.2
248	11243	11318	1.00000	0.00043	0.00035	320.35	2.862015	42.930225	2.862119	42.931782	V5:MN3	1.0000	0.000	1.02400	42.75001500	42.96450000	7	123.2
42	11319	11390	1.00000	0.19483	0.19388	52.30	2.866972	43.004587	2.866976	43.004635	MNUE3	1.0000	0.000	1.07360	42.96451500	43.20000000	44	100.5
251	11319	11390	1.00000	0.00008	0.00007	232.30	2.866991	43.004870	2.866976	43.004635	V5:MNUE3	1.0000	0.000	1.02400	42.96451500	43.20000000	4	119.0
43	11391	11447	1.00000	0.21368	0.21145	114.11	2.898186	43.472786	2.898263	43.473950	M3-	1.0000	0.000	1.07360	43.20001500	43.47420000	37	101.1

254	11391	11447	1.00000	0.00048	0.00048	294.11	2.898262	43.473937	2.898263	43.473950	V5:M3-	1.0000	0.000	1.02400	43.20001500	43.47420000	2	100.3
44	11448	11535	1.00000	3.77918	3.77909	121.75	2.898411	43.476159	2.898410	43.476156	M3	1.0000	0.000	1.07360	43.47421500	43.73244000	58	100.0
257	11448	11535	1.00000	0.00116	0.00108	301.75	2.898442	43.476627	2.898410	43.476156	V5:M3	1.0000	0.000	1.02400	43.47421500	43.73244000	5	107.6
45	11536	11655	1.00000	0.23835	0.21402	283.15	2.934580	44.018693	2.934702	44.020531	ML3	1.0000	0.000	1.07360	43.73245500	44.29735500	78	111.4
260	11536	11655	1.00000	0.00031	0.00028	250.78	2.935526	44.032889	2.935321	44.029815	V5:ML3	1.0000	0.000	1.02400	43.73245500	44.29735500	5	109.7
46	11656	12009	1.00000	0.54015	0.49231	52.18	2.971976	44.579641	2.971613	44.574189	MK3	1.0000	0.000	1.07360	44.29737000	50.10000000	228	109.7
263	11656	12009	1.00000	0.00141	0.00128	232.18	2.973804	44.607059	2.971613	44.574189	V5:MK3	1.0000	0.000	1.02400	44.29737000	50.10000000	17	109.5

Wave groups and parameters for main waves V44,V64

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
47	12010	12145	1.00000	0.01669	0.01571	120.93	3.825510	57.382650	3.828256	57.423834	MN4	1.0000	0.000	1.03900	54.30000000	57.73134000	101	106.2
267	12010	12145	1.00000	0.00002	0.00002	351.90	3.791345	56.870175	3.791345	56.870175	V6:MN4	1.0000	0.000	1.01750	54.30000000	57.73134000	1	100.0
48	12146	12222	1.00000	0.04415	0.04380	102.33	3.864907	57.973599	3.864547	57.968208	M4	1.0000	0.000	1.03900	57.73135500	58.65000000	60	100.8
49	12223	12303	1.00000	0.00840	0.00764	32.76	3.938302	59.074535	3.937749	59.066242	MK4	1.0000	0.000	1.03900	58.65001500	63.45000000	65	110.0
271	12223	12303	1.00000	0.00002	0.00002	212.76	3.937749	59.066242	3.937749	59.066242	V6:MK4	1.0000	0.000	1.01750	58.65001500	63.45000000	1	100.0

Wave groups and parameters for main waves V55,V66

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
50	12304	12359	1.00000	0.00056	0.00049	82.91	4.827580	72.413707	4.830684	72.460261	M5	1.0000	0.000	1.02400	70.20000000	76.35000000	53	114.8
51	12360	12361	1.00000	0.00001	0.00001	63.50	5.788762	86.831424	5.796821	86.952313	M6	1.0000	0.000	1.01750	86.25000000	87.00000000	2	113.4

Wave groups and parameters for main waves V32,V52

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
53	7507	7863	1.00000	0.09559	0.08219	233.70	1.789352	26.840275	1.791654	26.874817	V3:2EPS2	1.0000	0.000	1.07186	22.05366000	27.12000000	138	116.3
54	7507	7863	1.00000	0.00023	0.00018	174.12	1.783211	26.748172	1.786179	26.792680	V5:2EPS2	1.0000	0.000	1.02400	22.05366000	27.12000000	12	127.9
58	7864	7940	1.00000	0.27468	0.27074	303.15	1.823084	27.346264	1.823089	27.346338	V3:3N2	1.0000	0.000	1.07186	27.12001500	27.36687000	29	101.5
59	7864	7940	1.00000	0.00050	0.00041	155.52	1.822492	27.337386	1.822470	27.337055	V5:3N2	1.0000	0.000	1.02400	27.12001500	27.36687000	5	122.0
63	7941	8103	1.00000	0.27703	0.27212	215.10	1.827961	27.419418	1.827946	27.419192	V3:EPS2	1.0000	0.000	1.07186	27.36688500	27.68916000	61	101.8
64	7941	8103	1.00000	0.00014	0.00014	35.10	1.827946	27.419192	1.827946	27.419192	V5:EPS2	1.0000	0.000	1.02400	27.36688500	27.68916000	1	100.0
68	8104	8270	1.00000	1.58738	1.56462	284.55	1.859377	27.890651	1.859381	27.890713	V3:2N2	1.0000	0.000	1.07186	27.68917500	27.94539000	63	101.5
69	8104	8270	1.00000	0.00076	0.00075	104.55	1.859378	27.890676	1.859381	27.890713	V5:2N2	1.0000	0.000	1.02400	27.68917500	27.94539000	6	101.1
73	8271	8417	1.00000	0.29885	0.29241	196.50	1.864251	27.963760	1.864238	27.963567	V3:MUE2	1.0000	0.000	1.07186	27.94540500	28.20396000	42	102.2
74	8271	8417	1.00000	0.00015	0.00014	16.50	1.864254	27.963815	1.864238	27.963567	V5:MUE2	1.0000	0.000	1.02400	27.94540500	28.20396000	3	101.9
78	8418	8535	1.00000	5.78346	5.70133	265.95	1.895668	28.435022	1.895673	28.435088	V3:N2a	1.0000	0.000	1.07186	28.20397500	28.43520000	42	101.4
79	8418	8535	1.00000	0.00229	0.00229	85.95	1.895672	28.435075	1.895673	28.435088	V5:N2a	1.0000	0.000	1.02400	28.20397500	28.43520000	3	100.2
83	8536	8551	1.00000	0.00063	0.00056	200.33	1.895711	28.435660	1.895683	28.435252	V3:N2-	1.0000	0.000	1.07186	28.43521500	28.43790000	3	112.1
84	8536	8551	1.00000	0.00025	0.00025	93.59	1.895820	28.437294	1.895820	28.437294	V5:N2-	1.0000	0.000	1.02400	28.43521500	28.43790000	1	100.0
88	8552	8595	1.00000	0.10537	0.10356	53.58	1.896295	28.444432	1.896291	28.444371	V3:N2	1.0000	0.000	1.07186	28.43791500	28.46026500	8	101.7
89	8552	8595	1.00000	0.00007	0.00007	233.58	1.896291	28.444371	1.896291	28.444371	V5:N2	1.0000	0.000	1.02400	28.43791500	28.46026500	1	100.0

93	8596	8646	1.00000	0.02622	0.02590	102.85	1.898411	28.476162	1.898410	28.476154	V3:N2b	1.0000	0.000	1.07186	28.46028000	28.49250000	17	101.2
98	8647	8701	1.00000	0.14552	0.14471	325.53	1.901143	28.517149	1.901148	28.517225	V3:NUE2	1.0000	0.000	1.07186	28.49251500	28.53450000	13	100.6
99	8647	8701	1.00000	0.00009	0.00008	145.53	1.901144	28.517160	1.901148	28.517225	V5:NUE2	1.0000	0.000	1.02400	28.49251500	28.53450000	2	101.5
108	8771	8830	1.00000	0.08147	0.07952	155.40	1.927095	28.906425	1.927107	28.906609	V3:GAM2	1.0000	0.000	1.07186	28.72672500	28.92603000	19	102.4
113	8831	8872	1.00000	0.00632	0.00582	18.08	1.929813	28.947199	1.929845	28.947679	V3:ALF2	1.0000	0.000	1.07186	28.92604500	28.96000500	14	108.6
118	8873	8907	1.00000	0.32750	0.32285	67.35	1.931960	28.979399	1.931964	28.979462	V3:M2-	1.0000	0.000	1.07186	28.96002000	28.98225000	9	101.4
123	8908	8973	1.00000	0.87631	0.85948	34.98	1.932588	28.988815	1.932583	28.988746	V3:M2	1.0000	0.000	1.07186	28.98226500	29.00685000	16	102.0
124	8908	8973	1.00000	0.00046	0.00045	214.98	1.932579	28.988690	1.932583	28.988746	V5:M2	1.0000	0.000	1.02400	28.98226500	29.00685000	3	101.9
128	8974	9015	1.00000	0.00844	0.00667	231.88	1.935212	29.028185	1.935321	29.029813	V3:BET2	1.0000	0.000	1.07186	29.00686500	29.04228000	13	126.5
133	9016	9098	1.00000	0.17133	0.16744	306.93	1.937451	29.061763	1.937440	29.061600	V3:DEL2	1.0000	0.000	1.07186	29.04229500	29.25628500	28	102.3
134	9016	9098	1.00000	0.00009	0.00009	126.93	1.937435	29.061531	1.937440	29.061600	V5:DEL2	1.0000	0.000	1.02400	29.04229500	29.25628500	2	101.6
138	9099	9152	1.00000	0.02892	0.02840	309.16	1.963247	29.448703	1.963252	29.448777	V3:LAM2	1.0000	0.000	1.07186	29.25630000	29.47150500	17	101.8
139	9099	9152	1.00000	0.00002	0.00002	136.80	1.963399	29.450983	1.963399	29.450983	V5:LAM2	1.0000	0.000	1.02400	29.25630000	29.47150500	1	100.0
143	9153	9202	1.00000	0.01204	0.00962	359.49	1.966842	29.502636	1.966137	29.492054	V3:L2	1.0000	0.000	1.07186	29.47152000	29.52900000	18	125.2
144	9153	9202	1.00000	0.00002	0.00002	181.10	1.968581	29.528708	1.968581	29.528708	V5:L2	1.0000	0.000	1.02400	29.47152000	29.52900000	1	100.0
148	9203	9235	1.00000	5.36041	5.25877	16.38	1.968879	29.533189	1.968875	29.533121	V3:KNO2	1.0000	0.000	1.07186	29.52901500	29.53930500	11	101.9
149	9203	9235	1.00000	0.00212	0.00208	196.38	1.968871	29.533068	1.968875	29.533121	V5:KNO2	1.0000	0.000	1.02400	29.52901500	29.53930500	4	101.9
153	9236	9248	1.00000	0.00219	0.00200	344.01	1.969518	29.542765	1.969494	29.542404	V3:KNO2+	1.0000	0.000	1.07186	29.53932000	29.55450000	5	109.3
158	9249	9356	1.00000	0.01397	0.00802	288.34	1.973306	29.599596	1.973732	29.605974	V3:JTAU2	1.0000	0.000	1.07186	29.55451500	29.76423000	27	174.2
163	9357	9462	1.00000	0.00066	0.00058	325.33	1.994559	29.918386	1.994524	29.917865	V3:2T2	1.0000	0.000	1.07186	29.76424500	29.93250000	8	114.2
168	9463	9542	1.00000	0.00723	0.00691	162.22	1.997290	29.959348	1.997262	29.958931	V3:T2	1.0000	0.000	1.07186	29.93251500	29.98494000	7	104.8
173	9543	9657	1.00000	0.05440	0.05336	85.83	2.000313	30.004700	2.000309	30.004642	V3:S2	1.0000	0.000	1.07186	29.98495500	30.02517000	11	102.0
174	9543	9657	1.00000	0.00005	0.00005	265.83	2.000309	30.004642	2.000309	30.004642	V5:S2	1.0000	0.000	1.02400	29.98495500	30.02517000	1	100.0
178	9658	9728	1.00000	0.00504	0.00486	221.81	2.002720	30.040803	2.002738	30.041069	V3:R2	1.0000	0.000	1.07186	30.02518500	30.06570000	9	103.7
183	9729	9778	1.00000	0.29196	0.28642	357.78	2.005171	30.077563	2.005166	30.077495	V3:K2	1.0000	0.000	1.07186	30.06571500	30.08400000	9	101.9
184	9729	9778	1.00000	0.00023	0.00023	177.78	2.005163	30.077439	2.005166	30.077495	V5:K2	1.0000	0.000	1.02400	30.06571500	30.08400000	3	101.9
188	9779	9786	1.00000	0.00063	0.00063	317.77	2.005638	30.084572	2.005638	30.084573	V3:K2+	1.0000	0.000	1.07186	30.08401500	30.08625000	2	100.1
193	9787	9793	1.00000	0.02644	0.02644	325.41	2.005785	30.086779	2.005785	30.086779	V3:K2++	1.0000	0.000	1.07186	30.08626500	30.08700000	2	100.0
194	9787	9793	1.00000	0.00007	0.00007	145.41	2.005785	30.086779	2.005785	30.086779	V5:K2++	1.0000	0.000	1.02400	30.08626500	30.08700000	1	100.0
198	9794	9910	1.00000	0.01737	0.01715	153.05	2.005946	30.089194	2.005932	30.088986	V3:K2b	1.0000	0.000	1.07186	30.08701500	30.15952500	12	101.3
199	9794	9910	1.00000	0.00004	0.00004	333.05	2.005932	30.088986	2.005932	30.088986	V5:K2b	1.0000	0.000	1.02400	30.08701500	30.15952500	1	100.0
203	9911	10068	1.00000	0.00577	0.00493	237.37	2.010687	30.160308	2.010642	30.159633	V3:KPHI2	1.0000	0.000	1.07186	30.15954000	30.33732000	9	117.0
208	10069	10203	1.00000	0.06143	0.06006	67.23	2.036593	30.548891	2.036601	30.549017	V3:ZETA2	1.0000	0.000	1.07186	30.33733500	30.57600000	26	102.3
209	10069	10203	1.00000	0.00005	0.00005	247.23	2.036601	30.549017	2.036601	30.549017	V5:ZETA2	1.0000	0.000	1.02400	30.33733500	30.57600000	1	100.0
213	10204	10261	1.00000	0.02212	0.02170	339.19	2.041459	30.621878	2.041458	30.621870	V3:ETA2	1.0000	0.000	1.07186	30.57601500	30.62848500	16	101.9
214	10204	10261	1.00000	0.00002	0.00002	159.19	2.041458	30.621870	2.041458	30.621870	V5:ETA2	1.0000	0.000	1.02400	30.57601500	30.62848500	1	100.0
218	10262	10353	1.00000	0.57951	0.48448	306.81	2.042123	30.631844	2.042077	30.631154	V3:ETA2+	1.0000	0.000	1.07186	30.62850000	30.84000000	22	119.6
219	10262	10353	1.00000	0.00072	0.00061	126.81	2.042118	30.631770	2.042077	30.631154	V5:ETA2+	1.0000	0.000	1.02400	30.62850000	30.84000000	4	117.7
223	10354	10439	1.00000	0.02041	0.01542	16.26	2.073403	31.101045	2.073512	31.102675	V3:2S2	1.0000	0.000	1.07186	30.84001500	31.13700000	28	132.3
224	10354	10439	1.00000	0.00003	0.00003	196.26	2.073552	31.103273	2.073512	31.102675	V5:2S2	1.0000	0.000	1.02400	30.84001500	31.13700000	2	117.1
228	10440	10481	1.00000	0.09471	0.07917	288.22	2.078414	31.176214	2.078369	31.175529	V3:2K2	1.0000	0.000	1.07186	31.13701500	31.18110000	14	119.6
229	10440	10481	1.00000	0.00016	0.00013	108.22	2.078410	31.176154	2.078369	31.175529	V5:2K2	1.0000	0.000	1.02400	31.13701500	31.18110000	3	117.5
233	10482	10525	1.00000	0.00143	0.00065	131.14	2.079659	31.194878	2.078810	31.182148	V3:2K2+	1.0000	0.000	1.07186	31.18111500	31.39000500	17	218.4
238	10526	10879	1.00000	0.02615	0.01327	357.66	2.115115	31.726724	2.109803	31.647050	V3:2KN2	1.0000	0.000	1.07186	31.39002000	35.94000000	129	197.0
239	10526	10879	1.00000	0.00007	0.00004	244.89	2.115817	31.737252	2.115426	31.731393	V5:2KN2	1.0000	0.000	1.02400	31.39002000	35.94000000	7	168.0

Wave groups and parameters for main waves V43,V63

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
243	10880	11168	1.00000	0.03334	0.03159	265.13	2.822532	42.337978	2.825518	42.382765	V4:M2N3	1.0000	0.000	1.03900	38.70000000	42.39900000	106	105.5
246	11169	11242	1.00000	0.00596	0.00578	177.08	2.830389	42.455838	2.830375	42.455619	V4:MMUE3	1.0000	0.000	1.03900	42.39901500	42.75000000	23	103.0
249	11243	11318	1.00000	0.08913	0.08806	246.53	2.861806	42.927092	2.861809	42.927140	V4:MN3	1.0000	0.000	1.03900	42.75001500	42.96450000	23	101.2
250	11243	11318	1.00000	0.00004	0.00004	66.53	2.861809	42.927140	2.861809	42.927140	V6:MN3	1.0000	0.000	1.01750	42.75001500	42.96450000	1	100.0
252	11319	11390	1.00000	0.00351	0.00341	306.11	2.867228	43.008421	2.867285	43.009277	V4:MNUE3	1.0000	0.000	1.03900	42.96451500	43.20000000	24	102.9
255	11391	11447	1.00000	0.00786	0.00754	47.93	2.897822	43.467325	2.898101	43.471515	V4:M3-	1.0000	0.000	1.03900	43.20001500	43.47420000	18	104.2
258	11448	11535	1.00000	0.01980	0.01906	15.56	2.898901	43.483511	2.898720	43.480798	V4:M3	1.0000	0.000	1.03900	43.47421500	43.73244000	25	103.9
261	11536	11655	1.00000	0.07930	0.07777	356.96	2.935015	44.025221	2.935012	44.025173	V4:ML3	1.0000	0.000	1.03900	43.73245500	44.29735500	36	102.0
262	11536	11655	1.00000	0.00003	0.00003	176.96	2.935012	44.025173	2.935012	44.025173	V6:ML3	1.0000	0.000	1.01750	43.73245500	44.29735500	1	100.0
264	11656	12009	1.00000	0.01374	0.01107	287.40	3.007613	45.114191	3.008214	45.123206	V4:MK3	1.0000	0.000	1.03900	44.29737000	50.10000000	109	124.1

Wave groups and parameters for main waves V54

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
266	12010	12145	1.00000	0.00137	0.00122	227.11	3.820567	57.308509	3.827946	57.419192	V5:MN4	1.0000	0.000	1.02400	54.30000000	57.73134000	34	112.1
268	12146	12222	1.00000	0.00112	0.00103	337.55	3.896958	58.454369	3.901148	58.517225	V5:M4	1.0000	0.000	1.02400	57.73135500	58.65000000	17	108.6
270	12223	12303	1.00000	0.00025	0.00020	267.98	3.973654	59.604817	3.974351	59.615258	V5:MK4	1.0000	0.000	1.02400	58.65001500	63.45000000	15	124.0

Wave groups and parameters for main waves V65

EM amp.fac: a priori Earth model amplitude factor

No.	from	to	Gain	RMS-ampl. nm/s**2	main ampl.+	phase °	RMS-wgr.freq. [cpd]	[°/h]	main wgr.freq. [cpd]	[°/h]	symb	freq.transf.func.		EM-amp.fac	frequency band [°/h]		waves/ group	RMS-a/ M-a %
272	12304	12359	1.00000	0.00002	0.00002	207.70	4.813262	72.198933	4.794083	71.911244	V6:M5	1.0000	0.000	1.01750	70.20000000	76.35000000	3	139.0

ANNEX 2: Standard wave grouping > 18 years

A2.1 Tidal wave group parameters for model Y18-R18-allopt

```
#                                                   #  SYMB    #VVVVV#  V3-symbols
#                                                   #1234567890#34561#  Alias naming
# long periodic
#
WAVEGROUPI=  0.000002  0.000195  1.000000   .000000 M0+        22000#
WAVEGROUPI=   .000196   .000330  1.000000   .000000 M0++       22000#  3N200
WAVEGROUPI=   .000331   .004067  1.000000   .000000 Sa         22000#
WAVEGROUPI=   .004068   .006600  1.000000   .000000 Ssa        22000#
WAVEGROUPI=   .006601   .019600  1.000000   .000000 Sta        22000#
#
# Monthly

WAVEGROUPI=   .019601   .035200  1.000000   .000000 Msm        22000#

WAVEGROUPI=   .035201   .036160  1.000000   .000000 Mm-        22000#
WAVEGROUPI=   .036161   .036393  1.000000   .000000 Mm         22000#
WAVEGROUPI=   .036394   .036700  1.000000   .000000 Mm+        20000#  3M00

WAVEGROUPI=   .036701   .051333  1.000000   .000000 NO         22000#
WAVEGROUPI=   .051334   .069242  1.000000   .000000 Msf        22000#
WAVEGROUPI=   .069243   .073000  1.000000   .000000 2Mm        22000#

WAVEGROUPI=   .073001   .073340  1.000000   .000000 Mf         22000#  3MQ0
WAVEGROUPI=   .073341   .073350  1.000000   .000000 Mf+        22000#
WAVEGROUPI=   .073351   .089333  1.000000   .000000 Mf++       22000#

WAVEGROUPI=   .089334   .104367  1.000000   .000000 SN         22000#  3M2OTAU0
WAVEGROUPI=   .104368   .105580  1.000000   .000000 Mstm       22000#

WAVEGROUPI=   .105581   .109633  1.000000   .000000 Mtm        22000#  3M300
WAVEGROUPI=   .109634   .122801  1.000000   .000000 Mtm+       22000#
```

```
WAVEGROUPI=   .122802   .144490  1.000000   .000000 MSqm        22000#
WAVEGROUPI=   .144491   .160000  1.000000   .000000 Mqm         22000#  3M2OQ0
WAVEGROUPI=   .160001   .400000  1.000000   .000000 SKNMO       22000#
#
# Diurnal
#
WAVEGROUPI=   .580000   .791600  1.000000   .000000 SGM2Q1     22200#
WAVEGROUPI=   .791601   .810000  1.000000   .000000 2SGM1       22200#
WAVEGROUPI=   .810001   .821300  1.000000   .000000 3Q1         22200#
WAVEGROUPI=   .821301   .842147  1.000000   .000000 SGMQ1       22200#  3M2J1

WAVEGROUPI=   .842148   .856817  1.000000   .000000 2Q1-        23200#  3META1
WAVEGROUPI=   .856818   .860500  1.000000   .000000 2Q1         22200#

WAVEGROUPI=   .860501   .861680  1.000000   .000000 SGM1-       20200#  3MZETA1
WAVEGROUPI=   .861681   .863000  1.000000   .000000 SGM1        22200#
WAVEGROUPI=   .863001   .878675  1.000000   .000000 SGMb1       22200#

WAVEGROUPI=   .878676   .892935  1.000000   .000000 Qa1         23200#  3MK1
WAVEGROUPI=   .892936   .893133  1.000000   .000000 Q1-         22200#
WAVEGROUPI=   .893134   .895000  1.000000   .000000 Q1          22200#  3MLKJ1
WAVEGROUPI=   .895001   .896800  1.000000   .000000 Qb1         22200#

WAVEGROUPI=   .896801   .898000  1.000000   .000000 RO1-        22200#
WAVEGROUPI=   .898001   .899000  1.000000   .000000 RO1         22200#  3MS1
WAVEGROUPI=   .899001   .915000  1.000000   .000000 ROb1        22200#

WAVEGROUPI=   .915001   .928315  1.000000   .000000 Oa1         22200#
WAVEGROUPI=   .928316   .929327  1.000000   .000000 O1--        22200#  3MKNO1
WAVEGROUPI=   .929328   .929389  1.000000   .000000 O1-         22200#
WAVEGROUPI=   .929390   .929960  1.000000   .000000 O1          23200#  3ML1
WAVEGROUPI=   .929961   .931000  1.000000   .000000 2NO1        22200#
WAVEGROUPI=   .931001   .933200  1.000000   .000000 Ob1         22200#
```

```
WAVEGROUPI=   .933201   .947991  1.000000   .000000 TAU1       22200#  3MLAMB1
WAVEGROUPI=   .947992   .964460  1.000000   .000000 NTAU1      22200#

WAVEGROUPI=   .964461   .965700  1.000000   .000000 LK1-       22200#
WAVEGROUPI=   .965701   .965933  1.000000   .000000 LK1        22200#

WAVEGROUPI=   .965934   .966509  1.000000   .000000 NO1        20200#  M1
WAVEGROUPI=   .966510   .966853  1.000000   .000000 NO1+       22200#

WAVEGROUPI=   .966854   .971444  1.000000   .000000 CHI1       22200#
WAVEGROUPI=   .971445   .971667  1.000000   .000000 CHI1+      22200#

WAVEGROUPI=   .971668   .996933  1.000000   .000000 PI1        22200#      = P1a
WAVEGROUPI=   .996934   .997116  1.000000   .000000 P1-        22200#
WAVEGROUPI=   .997117   .998631  1.000000   .000000 P1         22200#      = PI1b
WAVEGROUPI=   .998632  1.002333  1.000000   .000000 S1         22200#      = K1a,P1b
WAVEGROUPI=  1.002334  1.002605  1.000000   .000000 K1-        22200#  3MN1
WAVEGROUPI=  1.002606  1.002860  1.000000   .000000 K1         22200#
WAVEGROUPI=  1.002861  1.002901  1.000000   .000000 K1+        22200#
WAVEGROUPI=  1.002902  1.004200  1.000000   .000000 K1++       22200#  3MROP1
WAVEGROUPI=  1.004201  1.006845  1.000000   .000000 PSI1       22200#      = K1b

WAVEGROUPI=  1.006846  1.023622  1.000000   .000000 PHI1       22200#

WAVEGROUPI=  1.023623  1.034267  1.000000   .000000 TET1       22200#
WAVEGROUPI=  1.034268  1.035379  1.000000   .000000 TET1+      22200#

WAVEGROUPI=  1.035380  1.039149  1.000000   .000000 J1         22200#
WAVEGROUPI=  1.039150  1.039400  1.000000   .000000 J1+        23200#  3MO1

WAVEGROUPI=  1.039401  1.055000  1.000000   .000000 KLK1       23200#  3MO1+
WAVEGROUPI=  1.055001  1.070867  1.000000   .000000 SO1        22200#
WAVEGROUPI=  1.070868  1.075633  1.000000   .000000 2J1        22200#  3MOQ1

WAVEGROUPI=  1.075634  1.076069  1.000000   .000000 OO1        22200#
```

```
WAVEGROUPI=  1.076070  1.076100  1.000000   .000000 OO1+       22200#
WAVEGROUPI=  1.076101  1.086000  1.000000   .000000 OO1++      22200#

WAVEGROUPI=  1.086001  1.112359  1.000000   .000000 NU1        22200#
WAVEGROUPI=  1.112360  1.112600  1.000000   .000000 NU1+       22200#  32MO1

WAVEGROUPI=  1.112601  1.470243  1.000000   .000000 2(KM)P1    22200#
#
# Semi-diurnal
WAVEGROUPI=  1.470244  1.808000  1.000000   .000000 2EPS2      02220#
WAVEGROUPI=  1.808001  1.824458  1.000000   .000000 3N2        03220#  3M2J2
WAVEGROUPI=  1.824459  1.845944  1.000000   .000000 EPS2       03220#  3MSO2
WAVEGROUPI=  1.845945  1.863026  1.000000   .000000 2N2        03220#  3MJ2
WAVEGROUPI=  1.863027  1.880264  1.000000   .000000 MUE2       03220#  3MRO2

WAVEGROUPI=  1.880265  1.895680  1.000000   .000000 Na2        00220#  3MK2
WAVEGROUPI=  1.895681  1.895860  1.000000   .000000 N2-        02220#
WAVEGROUPI=  1.895861  1.897351  1.000000   .000000 N2         02220#  3MNLO2
WAVEGROUPI=  1.897352  1.899500  1.000000   .000000 Nb2        02220#

WAVEGROUPI=  1.899501  1.902300  1.000000   .000000 NUE2       02220#  3MP2
WAVEGROUPI=  1.902301  1.915114  1.000000   .000000 NUEb2      02220#

WAVEGROUPI=  1.915115  1.928402  1.000000   .000000 GAM2       02220#
WAVEGROUPI=  1.928403  1.930667  1.000000   .000000 ALF2       02220#
WAVEGROUPI=  1.930668  1.932150  1.000000   .000000 M2-        03220#  3MNO2
WAVEGROUPI=  1.932151  1.933790  1.000000   .000000 M2         03220#  3MLK2
WAVEGROUPI=  1.933791  1.936152  1.000000   .000000 BET2       02220#
WAVEGROUPI=  1.936153  1.950419  1.000000   .000000 DEL2       03220#  3MNTAU2

WAVEGROUPI=  1.950420  1.964767  1.000000   .000000 LAM2       02220#
WAVEGROUPI=  1.964768  1.968600  1.000000   .000000 L2         02220#
WAVEGROUPI=  1.968601  1.969287  1.000000   .000000 KNO2       00220#  3MO2
WAVEGROUPI=  1.969288  1.970300  1.000000   .000000 KNO2+      02220#
WAVEGROUPI=  1.970301  1.984282  1.000000   .000000 JTAU2      02220#
```

```
WAVEGROUPI=  1.984283  1.995500  1.000000   .000000 2T2        02220#
WAVEGROUPI=  1.995501  1.998996  1.000000   .000000 T2         02220#
WAVEGROUPI=  1.998997  2.001678  1.000000   .000000 S2         02220#
WAVEGROUPI=  2.001679  2.004380  1.000000   .000000 R2         02220#
WAVEGROUPI=  2.004381  2.005600  1.000000   .000000 K2         03220#  3MQ2
WAVEGROUPI=  2.005601  2.005750  1.000000   .000000 K2+        02220#
WAVEGROUPI=  2.005751  2.005800  1.000000   .000000 K2++       02220#
WAVEGROUPI=  2.005801  2.010635  1.000000   .000000 Kb2        02220#

WAVEGROUPI=  2.010636  2.022488  1.000000   .000000 KPHI2      02220#
WAVEGROUPI=  2.022489  2.038400  1.000000   .000000 ZETA2      02220#

WAVEGROUPI=  2.038401  2.041899  1.000000   .000000 ETA2       02220#
WAVEGROUPI=  2.041900  2.056000  1.000000   .000000 ETA2+      03220#  3MK2O2

WAVEGROUPI=  2.056001  2.075800  1.000000   .000000 2S2        02220#

WAVEGROUPI=  2.075801  2.078740  1.000000   .000000 2K2        02220#
WAVEGROUPI=  2.078741  2.092667  1.000000   .000000 2K2+       02220#

WAVEGROUPI=  2.092668  2.396000  1.000000   .000000 2KN2       02220#

# Ter-diurnal
WAVEGROUPI=  2.58      2.826600  1.000000   .000000 M2N3       00320#
WAVEGROUPI=  2.826601  2.850000  1.000000   .000000 MMUE3      00320#
WAVEGROUPI=  2.850001  2.864300  1.000000   .000000 MN3        00320#
WAVEGROUPI=  2.864301  2.880000  1.000000   .000000 MNUE3      00320#

WAVEGROUPI=  2.880001  2.898280  1.000000   .000000 M3-        00320#
WAVEGROUPI=  2.898281  2.915496  1.000000   .000000 M3         00320#

WAVEGROUPI=  2.915497  2.953157  1.000000   .000000 ML3        00320#
WAVEGROUPI=  2.953158  3.34      1.000000   .000000 MK3        00320#
```

```
# Quad-diurnal
WAVEGROUPI=  3.62      3.848756  1.000000   .000000 MN4        00020#
WAVEGROUPI=  3.848757  3.910000  1.000000   .000000 M4         00020#
WAVEGROUPI=  3.910001  4.230000  1.000000   .000000 MK4        00020#
#
# 1   1/5  -diurnal (check potential development first)
WAVEGROUPI=  4.68      5.09      1.000000   .000000 M5         00000#
#
# 1   1/6  -diurnal (check potential development first)
WAVEGROUPI=  5.75      5.80      1.000000   .000000 M6         00000#
```

A2.2 Result table for model Y18-R18-allopt

```
==================================================================================================================
  1 MODMEM-Y18-R18-allopt: A15: Output: Final analysis results + statistics  1072.88 s
==================================================================================================================


      Program , version ET34-ANA-V70
      Variant: MODMEM-Y18-R18-allopt
     ######################################################################################
     #                                                                                    #
     # GLOBAL GEODYNAMICS PROJECT-SUPERCONDUCTING GRAVIMETERS NETWORK                     #
     # STATION 0243 MEMBACH (BAELEN)      BELGIQUE                                        #
     #  50 36 33.3 N  06 00 23.8 E   H  250 M   D 210 KM  G = 9.81071                     #
     # OBSERVATOIRE ROYAL DE BELGIQUE                                                     #
     # Gravimetric TEST data                                                              #
     #                                                                                    #
     ######################################################################################
      Latitude: 50.6093  °  , longitude:  6.0061  °  , azimuth:  0.0000  °  .
      19970722...20160302     1 blocks. Recorded days in total:   6798.417
      Original sampling interval of the observations:     3600. s
      Numerical filter is : no filter    with    0 coefficients.
      Hartmann+Wenzel (1995) TGP, threshold:-0.100D-11     12361 waves. Component   0
      ET-Analysis with "DEHANT-DEFRAIGNE-WAHR non-hydrostatic inelastic Earth model" (DDW-NHi).
      ========================================================================================
      RECTANGULAR window used for least squares adjustment.
      Pole tide regression applied.
      Length of day tide regression applied.


      A15.1 Adjusted tidal and non-tidal parameters :
      ===============================================
```

Frequencies from	to [cpd]	main [° /h]	Wave group symb.	Amplitudes theor. [nm/s**2]	ana.	Amplitude factors	RMSE	C.-Int. 95%	Phase leads [°]	RMSE [°]	C.-Int. 95% [°]	Correlation RMSE amplifier	rel. best	RMSE ana. %	Signal/noise dB
0.000002	0.000195	0.002206	M0+	21.25700	24.65639	1.15992	0.00000	0.00000	0.000	0.000	0.000	1.48	0.0000	0.0000	143.96
0.000196	0.000330	0.004413	M0++	0.20750	0.24065	1.15980	0.00001	0.00001	0.000	0.000	0.001	1.29	0.0004	0.0006	105.01
0.000331	0.004067	0.041067	Sa	3.74598	4.33688	1.15774	0.00000	0.00000	0.000	0.000	0.000	1.68	0.0000	0.0000	128.20
0.004068	0.006600	0.082137	Ssa	23.58618	27.29726	1.15734	0.00000	0.00000	0.000	0.000	0.000	1.16	0.0000	0.0000	146.90

0.006601	0.019600	0.123204	Sta	1.37883	1.59566	1.15725	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	123.57
0.019601	0.035200	0.471521	Msm	5.12058	5.92195	1.15650	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	134.96
0.035201	0.036160	0.542168	Mm-	1.75787	2.03287	1.15644	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	125.69
0.036161	0.036393	0.544375	Mm	26.77854	30.96781	1.15644	0.00000	0.00000	0.000	0.000	0.000	1.18	0.0000	0.0000	147.95
0.036394	0.036700	0.546581	Mm+	1.73783	2.00970	1.15644	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0001	0.0001	125.49
0.036701	0.051333	0.553658	NO	1.43312	1.65731	1.15644	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	124.90
0.051334	0.069242	1.015896	Msf	4.44229	5.13624	1.15621	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	133.77
0.069243	0.073000	1.088749	2Mm	2.19472	2.53750	1.15619	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	127.66
0.073001	0.073340	1.098033	Mf	50.69610	58.61396	1.15618	0.00000	0.00000	0.000	0.000	0.000	1.53	0.0000	0.0000	151.22
0.073341	0.073350	1.100239	Mf+	21.01906	24.30186	1.15618	0.00000	0.00000	0.000	0.000	0.000	1.11	0.0000	0.0000	146.38
0.073351	0.089333	1.102446	Mf++	1.96575	2.27277	1.15618	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	126.72
0.089334	0.104367	1.560270	SN	0.70408	0.81396	1.15606	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	118.05
0.104368	0.105580	1.569554	Mstm	1.84323	2.13087	1.15605	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	126.79
0.105581	0.109633	1.642408	Mtm	9.70669	11.22135	1.15604	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0000	0.0000	140.34
0.109634	0.122801	1.644614	Mtm+	4.02294	4.65069	1.15604	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	132.90
0.122802	0.144490	2.113929	MSqm	1.55034	1.79211	1.15595	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	125.35
0.144491	0.160000	2.186782	Mqm	1.28415	1.48441	1.15594	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	123.67
0.160001	0.400000	2.658304	SKNM0	0.37459	0.43296	1.15584	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	113.89
0.580000	0.791600	11.838390	SGM2Q1	0.37286	0.43024	1.15391	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0002	0.0002	112.70
0.791601	0.810000	11.911244	2SGM1	0.23132	0.26693	1.15393	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0004	0.0004	108.26
0.810001	0.821300	12.309911	3Q1	0.86878	1.00262	1.15407	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	119.60
0.821301	0.842147	12.382765	SGMQ1	2.25054	2.59732	1.15409	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	128.04
0.842148	0.856817	12.852080	2Q1-	1.45677	1.68142	1.15421	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	123.95
0.856818	0.860500	12.854286	2Q1	7.72459	8.91583	1.15421	0.00000	0.00000	0.000	0.000	0.000	1.03	0.0000	0.0000	138.19
0.860501	0.861680	12.924933	SGM1-	1.75709	2.02808	1.15423	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	125.61
0.861681	0.863000	12.927140	SGM1	9.31496	10.75162	1.15423	0.00000	0.00000	0.000	0.000	0.000	1.03	0.0000	0.0000	139.80
0.863001	0.878675	12.968207	SGMb1	0.62903	0.72605	1.15424	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	117.64
0.878676	0.892935	13.357594	Qa1	0.49086	0.56661	1.15431	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	115.95
0.892936	0.893133	13.396454	Q1-	11.00837	12.70709	1.15431	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0000	0.0000	141.37
0.893134	0.895000	13.398661	Q1	58.37324	67.38096	1.15431	0.00000	0.00000	0.000	0.000	0.000	1.71	0.0000	0.0000	151.35
0.895001	0.896800	13.439728	Qb1	0.54475	0.62881	1.15432	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	116.81
0.896801	0.898000	13.469308	RO1-	2.08980	2.41229	1.15432	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	127.08
0.898001	0.899000	13.471515	RO1	11.07975	12.78957	1.15432	0.00000	0.00000	0.000	0.000	0.000	1.04	0.0000	0.0000	141.26
0.899001	0.915000	13.512581	ROb1	0.51176	0.59073	1.15432	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	115.32
0.915001	0.928315	13.901969	Oa1	1.04792	1.20962	1.15431	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	123.63
0.928316	0.929327	13.938623	O1--	1.76199	2.03386	1.15430	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0001	0.0001	125.43
0.929328	0.929389	13.940829	O1-	57.51446	66.38905	1.15430	0.00000	0.00000	0.000	0.000	0.000	1.19	0.0000	0.0000	154.34
0.929390	0.929960	13.943036	O1	304.87743	351.92046	1.15430	0.00000	0.00000	0.000	0.000	0.000	5.73	0.0000	0.0000	155.20
0.929961	0.931000	13.952319	2NO1	1.96415	2.26722	1.15430	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	126.62
0.931001	0.933200	13.984102	Ob1	0.92287	1.06525	1.15429	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	119.65
0.933201	0.947991	14.025173	TAU1	3.97392	4.58702	1.15428	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	132.87
0.947992	0.964460	14.414557	NTAU1	2.24824	2.59449	1.15401	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	127.96
0.964461	0.965700	14.485204	LK1-	1.59511	1.84060	1.15390	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	124.75

0.965701	0.965933	14.487410	LK1	8.61919	9.94567	1.15390	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0000	0.0000	139.25
0.965934	0.966509	14.496694	NO1	23.96487	27.65265	1.15388	0.00000	0.00000	0.000	0.000	0.000	1.30	0.0000	0.0000	146.38
0.966510	0.966853	14.498900	NO1+	4.80947	5.54954	1.15388	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	134.27
0.966854	0.971444	14.569548	CHI1	4.58579	5.29075	1.15373	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	133.82
0.971445	0.971667	14.571754	CHI1+	1.00614	1.16080	1.15372	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	120.73
0.971668	0.996933	14.917865	PI1	8.29140	9.54079	1.15069	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	139.03
0.996934	0.997116	14.956725	P1-	1.59447	1.83236	1.14920	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	124.71
0.997117	0.998631	14.958931	P1	141.83530	162.98099	1.14909	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	163.66
0.998632	1.002333	15.000002	S1	3.35298	3.84164	1.14574	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	128.02
1.002334	1.002605	15.038862	K1-	8.48755	9.63954	1.13573	0.00000	0.00000	0.000	0.000	0.000	1.17	0.0000	0.0000	137.74
1.002606	1.002860	15.041069	K1	428.59688	486.23824	1.13449	0.00000	0.00000	0.000	0.000	0.000	5.49	0.0000	0.0000	158.38
1.002861	1.002901	15.043275	K1+	58.16640	65.90729	1.13308	0.00000	0.00000	0.000	0.000	0.000	1.19	0.0000	0.0000	154.27
1.002902	1.004200	15.045481	K1++	1.24977	1.41408	1.13147	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0001	0.0001	122.23
1.004201	1.006845	15.082135	PSI1	3.35456	4.26868	1.27250	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	132.15
1.006846	1.023622	15.123206	PHI1	6.10328	7.14521	1.17072	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	136.44
1.023623	1.034267	15.512590	TET1	4.58442	5.30483	1.15714	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	133.84
1.034268	1.035379	15.514796	TET1+	0.90932	1.05221	1.15714	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	119.88
1.035380	1.039149	15.585443	J1	23.97357	27.73573	1.15693	0.00000	0.00000	0.000	0.000	0.000	1.24	0.0000	0.0000	146.40
1.039150	1.039400	15.587650	J1+	4.75179	5.49746	1.15692	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0000	0.0000	134.10
1.039401	1.055000	15.594727	KLK1	0.37068	0.42884	1.15691	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	114.51
1.055001	1.070867	16.056964	SO1	3.97582	4.59764	1.15640	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	132.80
1.070868	1.075633	16.129818	2J1	1.96519	2.27248	1.15637	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	126.70
1.075634	1.076069	16.139102	OO1	13.11360	15.16415	1.15637	0.00000	0.00000	0.000	0.000	0.000	1.39	0.0000	0.0000	140.21
1.076070	1.076100	16.141308	OO1+	8.40251	9.71639	1.15637	0.00000	0.00000	0.000	0.000	0.000	1.16	0.0000	0.0000	137.88
1.076101	1.086000	16.143514	OO1++	1.76037	2.03563	1.15637	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	125.57
1.086001	1.112359	16.683476	NU1	2.51126	2.90379	1.15631	0.00000	0.00000	0.000	0.000	0.000	1.03	0.0000	0.0000	128.98
1.112360	1.112600	16.685683	NU1+	1.60796	1.85930	1.15631	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	124.91
1.112601	1.470243	17.154997	2(KM)P1	0.40100	0.46370	1.15636	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	116.89
1.470244	1.808000	26.879459	2EPS2	0.36985	0.42976	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	113.98
1.808001	1.824458	27.350980	3N2	0.86312	1.00293	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	119.54
1.824459	1.845944	27.423834	EPS2	2.23724	2.59966	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	128.00
1.845945	1.863026	27.895355	2N2	7.67164	8.91439	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	138.49
1.863027	1.880264	27.968208	MUE2	9.25906	10.75897	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	140.17
1.880265	1.895680	28.398663	Na2	0.48735	0.56629	1.16199	0.00000	0.00000	0.000	0.000	0.000	2.25	0.0000	0.0000	128.28
1.895681	1.895860	28.437523	N2-	2.16437	2.51498	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.04	0.0000	0.0000	127.21
1.895861	1.897351	28.439730	N2	57.97339	67.36470	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.06	0.0000	0.0000	155.59
1.897352	1.899500	28.480796	Nb2	0.54105	0.62869	1.16200	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	116.89
1.899501	1.902300	28.512583	NUE2	11.01246	12.79641	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	141.64
1.902301	1.915114	28.553650	NUEb2	0.50806	0.59036	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	114.95
1.915115	1.928402	28.911251	GAM2	0.90898	1.05623	1.16200	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	120.14
1.928403	1.930667	28.943038	ALF2	1.04049	1.20904	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	121.17
1.930668	1.932150	28.981898	M2-	11.29769	13.12785	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.07	0.0000	0.0000	141.29
1.932151	1.933790	28.984104	M2	302.78675	351.83624	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.73	0.0000	0.0000	165.69

1.933791	1.936152	29.025171	BET2	0.91665	1.06514	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	120.09
1.936153	1.950419	29.066242	DEL2	0.35500	0.41251	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	113.22
1.950420	1.964767	29.455625	LAM2	2.23274	2.59442	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	127.82
1.964768	1.968600	29.528479	L2	8.55917	9.94570	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	139.44
1.968601	1.969287	29.537763	KNO2	2.13952	2.48611	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.99	0.0000	0.0000	129.46
1.969288	1.970300	29.539969	KNO2+	0.94425	1.09721	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	120.39
1.970301	1.984282	29.610616	JTAU2	0.40928	0.47558	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	114.00
1.984283	1.995500	29.917867	2T2	0.33420	0.38835	1.16200	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0003	0.0003	111.30
1.995501	1.998996	29.958933	T2	8.23420	9.56808	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	139.13
1.998997	2.001678	30.000000	S2	140.85942	163.67773	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	163.80
2.001679	2.004380	30.041067	R2	1.17587	1.36635	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	124.06
2.004381	2.005600	30.082137	K2	38.27522	44.47555	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.38	0.0000	0.0000	149.68
2.005601	2.005750	30.084344	K2+	11.40720	13.25510	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.07	0.0000	0.0000	141.40
2.005751	2.005800	30.086550	K2++	1.23994	1.44080	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	122.64
2.005801	2.010635	30.123204	Kb2	0.29962	0.34815	1.16200	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0003	0.0003	110.42
2.010636	2.022488	30.164275	KPHI2	0.26077	0.30301	1.16200	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0004	0.0004	108.96
2.022489	2.038400	30.553658	ZETA2	0.40934	0.47565	1.16200	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	113.87
2.038401	2.041899	30.626512	ETA2	2.14104	2.48788	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	127.36
2.041900	2.056000	30.628718	ETA2+	0.93232	1.08335	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	120.27
2.056001	2.075800	31.098033	2S2	0.35509	0.41261	1.16200	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0002	0.0002	112.60
2.075801	2.078740	31.180170	2K2	0.56020	0.65095	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	116.30
2.078741	2.092667	31.182377	2K2+	0.48576	0.56445	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	114.97
2.092668	2.396000	31.724545	2KN2	0.10729	0.12467	1.16200	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0006	0.0006	105.15
2.580000	2.826600	42.387407	M2N3	0.17954	0.19276	1.07359	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0005	0.0005	105.76
2.826601	2.850000	42.460261	MMUE3	0.18049	0.19377	1.07359	0.00001	0.00001	0.001	0.000	0.001	1.00	0.0005	0.0005	105.36
2.850001	2.864300	42.931782	MN3	1.03563	1.11185	1.07360	0.00000	0.00000	0.000	0.000	0.000	1.03	0.0001	0.0001	120.27
2.864301	2.880000	43.004635	MNUE3	0.19388	0.20815	1.07360	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0005	0.0005	105.97
2.880001	2.898280	43.473950	M3-	0.21145	0.22701	1.07360	0.00001	0.00001	0.000	0.000	0.001	1.06	0.0005	0.0005	106.32
2.898281	2.915496	43.476156	M3	3.77909	4.05722	1.07360	0.00000	0.00000	0.000	0.000	0.000	1.24	0.0000	0.0000	129.86
2.915497	2.953157	44.020531	ML3	0.21402	0.22977	1.07359	0.00000	0.00001	0.001	0.000	0.000	1.00	0.0004	0.0004	107.63
2.953158	3.340000	44.574189	MK3	0.49231	0.52855	1.07359	0.00000	0.00001	0.000	0.000	0.000	1.38	0.0002	0.0003	112.03
3.620000	3.848756	57.423834	MN4	0.01571	0.01633	1.03906	0.00006	0.00012	0.001	0.003	0.007	1.00	0.0060	0.0060	84.46
3.848757	3.910000	57.968208	M4	0.04380	0.04551	1.03903	0.00002	0.00005	0.001	0.001	0.003	1.00	0.0023	0.0023	92.91
3.910001	4.230000	59.066242	MK4	0.00764	0.00794	1.03889	0.00012	0.00024	-0.001	0.007	0.013	1.00	0.0119	0.0119	78.49
4.680000	5.090000	72.460261	M5	0.00049	0.00050	1.02383	0.00192	0.00376	0.019	0.107	0.211	1.00	0.1875	0.1875	54.54
5.750000	5.800000	86.952313	M6	0.00001	0.00001	1.05476	0.17623	0.34545	-9.339	9.573	18.765	1.00	16.7084	16.7084	15.54
0.842148	0.856817	12.849644	V3:2Q1-	0.65266	0.69778	1.06913	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	116.86
0.878676	0.892935	13.394019	V3:Qa1	2.37943	2.54392	1.06913	0.00000	0.00000	0.000	0.000	0.000	1.07	0.0000	0.0000	127.57
0.929390	0.929960	13.947677	V3:O1	1.21666	1.30077	1.06913	0.00000	0.00000	0.000	0.000	0.000	1.03	0.0001	0.0001	121.59

1.039150	1.039400	15.590085	V3:J1+	2.71700	2.90483	1.06913	0.00000	0.00000	0.000	0.000	0.000	1.08	0.0000	0.0000	128.01
1.039401	1.055000	15.592292	V3:KLK1	1.10089	1.17699	1.06913	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	120.76
1.808001	1.824458	27.346338	V3:3N2	0.27074	0.29019	1.07186	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0004	0.0004	108.80
1.824459	1.845944	27.419192	V3:EPS2	0.27212	0.29167	1.07186	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0004	0.0004	108.89
1.845945	1.863026	27.890713	V3:2N2	1.56462	1.67706	1.07186	0.00000	0.00000	0.000	0.000	0.000	1.20	0.0001	0.0001	122.51
1.863027	1.880264	27.963567	V3:MUE2	0.29241	0.31342	1.07186	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0003	0.0003	109.52
1.930668	1.932150	28.979462	V3:M2-	0.32285	0.34605	1.07187	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0003	0.0003	110.38
1.932151	1.933790	28.988746	V3:M2	0.85948	0.92124	1.07186	0.00000	0.00000	0.000	0.000	0.000	1.08	0.0001	0.0001	118.29
1.936153	1.950419	29.061600	V3:DEL2	0.16744	0.17948	1.07186	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0006	0.0006	104.77
2.004381	2.005600	30.077495	V3:K2	0.28642	0.30701	1.07186	0.00000	0.00001	0.000	0.000	0.000	1.02	0.0003	0.0003	109.25
2.041900	2.056000	30.631154	V3:ETA2+	0.48448	0.51929	1.07186	0.00000	0.00000	0.000	0.000	0.000	1.19	0.0002	0.0002	113.87
2.580000	2.826600	42.382765	V4:M2N3	0.03159	0.03282	1.03894	0.00003	0.00006	-0.002	0.002	0.003	1.00	0.0030	0.0030	90.36
2.826601	2.850000	42.455619	V4:MMUE3	0.00578	0.00601	1.03881	0.00018	0.00035	-0.007	0.010	0.019	1.00	0.0171	0.0171	75.36
2.850001	2.864300	42.927140	V4:MN3	0.08806	0.09149	1.03901	0.00001	0.00002	0.002	0.001	0.001	1.00	0.0011	0.0011	98.90
2.864301	2.880000	43.009277	V4:MNUE3	0.00341	0.00355	1.03929	0.00030	0.00058	0.003	0.016	0.032	1.00	0.0286	0.0286	70.86
2.880001	2.898280	43.471515	V4:M3-	0.00754	0.00784	1.03905	0.00013	0.00026	0.005	0.007	0.015	1.01	0.0128	0.0129	77.77
2.898281	2.915496	43.480798	V4:M3	0.01906	0.01980	1.03901	0.00005	0.00010	0.001	0.003	0.006	1.00	0.0051	0.0051	85.83
2.915497	2.953157	44.025173	V4:ML3	0.07777	0.08081	1.03901	0.00001	0.00003	0.001	0.001	0.001	1.00	0.0013	0.0013	97.90
2.953158	3.340000	45.123206	V4:MK3	0.01107	0.01151	1.03888	0.00008	0.00015	-0.003	0.004	0.008	1.00	0.0073	0.0073	82.69
0.000002	0.391000	0.549017	V10	0.01080	0.01080	1.00009	0.00010	0.00020	-0.013	0.006	0.011	1.05	0.0094	0.0099	80.05
0.580000	1.430000	14.492052	V11	0.00544	0.00544	0.99992	0.00021	0.00040	0.001	0.012	0.023	1.22	0.0168	0.0206	73.73
0.000002	0.391000	1.093391	V30	0.01979	0.02120	1.07150	0.00004	0.00007	0.000	0.002	0.004	1.06	0.0031	0.0033	89.60
0.580000	1.430000	16.134460	V31	0.44410	0.47480	1.06913	0.00000	0.00000	0.000	0.000	0.000	1.05	0.0001	0.0001	118.03
1.470244	2.396000	28.517225	V32	0.14471	0.15511	1.07186	0.00000	0.00001	0.000	0.000	0.000	1.02	0.0004	0.0004	108.30
0.580000	1.430000	13.943036	V41	0.08694	0.09033	1.03899	0.00007	0.00014	0.004	0.004	0.007	8.24	0.0008	0.0067	83.51
1.470244	2.396000	28.984104	V42	0.10134	0.10530	1.03898	0.00001	0.00003	0.000	0.001	0.002	2.09	0.0007	0.0014	96.98
1.470244	2.396000	28.435088	V52	0.00229	0.00234	1.02341	0.00095	0.00186	0.000	0.053	0.104	3.05	0.0304	0.0928	60.64
2.580000	3.340000	44.574189	V53	0.00128	0.00131	1.02347	0.00072	0.00141	-0.027	0.040	0.079	1.63	0.0432	0.0704	63.05
3.620000	4.230000	57.419192	V54	0.00122	0.00125	1.02358	0.00058	0.00114	-0.040	0.032	0.064	1.00	0.0567	0.0567	64.92

Annex 3: Standard wave grouping 4.5 years

A3.1 Tidal wave group parameters for model Y04-R04-allopt

```
#                                                   #  SYMB    #VVVVV#  V3-symbols
#                                                   #1234567890#34561#  Alias naming
# long periodic
#

WAVEGROUPI=   .000002   .004067  1.000000   .000000 Sa         22000#
WAVEGROUPI=   .004068   .006600  1.000000   .000000 Ssa        22000#
WAVEGROUPI=   .006601   .019600  1.000000   .000000 Sta        22000#
#
# Monthly

WAVEGROUPI=   .019601   .035200  1.000000   .000000 Msm        22000#

WAVEGROUPI=   .035201   .036700  1.000000   .000000 Mm         20000#

WAVEGROUPI=   .036701   .051333  1.000000   .000000 NO         22000#
WAVEGROUPI=   .051334   .069242  1.000000   .000000 Msf        22000#
WAVEGROUPI=   .069243   .073000  1.000000   .000000 2Mm        22000#

WAVEGROUPI=   .073001   .089333  1.000000   .000000 Mf         22000#  3MQ0

WAVEGROUPI=   .089334   .104367  1.000000   .000000 SN         22000#  3M2OTAU0
WAVEGROUPI=   .104368   .105580  1.000000   .000000 Mstm       22000#

WAVEGROUPI=   .105581   .122801  1.000000   .000000 Mtm        22000#  3M3O0

WAVEGROUPI=   .122802   .144490  1.000000   .000000 MSqm       22000#
WAVEGROUPI=   .144491   .160000  1.000000   .000000 Mqm        22000#  3M2OQ0
WAVEGROUPI=   .160001   .400000  1.000000   .000000 SKNMO      22000#
#
# Diurnal
#
WAVEGROUPI=   .580000   .791600  1.000000   .000000 SGM2Q1     22000#
WAVEGROUPI=   .791601   .810000  1.000000   .000000 2SGM1      22000#
WAVEGROUPI=   .810001   .821300  1.000000   .000000 3Q1        22000#
WAVEGROUPI=   .821301   .842147  1.000000   .000000 SGMQ1      22000#  3M2J1

WAVEGROUPI=   .842148   .860500  1.000000   .000000 2Q1        23000#

WAVEGROUPI=   .860501   .863000  1.000000   .000000 SGM1       22000#
WAVEGROUPI=   .863001   .878675  1.000000   .000000 SGMb1      22000#

WAVEGROUPI=   .878676   .892935  1.000000   .000000 Qa1        23000#  3MK1
WAVEGROUPI=   .892936   .895000  1.000000   .000000 Q1         22000#  3MLKJ1
WAVEGROUPI=   .895001   .896800  1.000000   .000000 Qb1        22000#

WAVEGROUPI=   .896801   .899000  1.000000   .000000 RO1        22000#  3MS1
WAVEGROUPI=   .899001   .915000  1.000000   .000000 ROb1       22000#

WAVEGROUPI=   .915001   .928315  1.000000   .000000 Oa1        22000#
```

```
WAVEGROUPI=   .928316   .929960  1.000000   .000000 O1         23000#  3ML1
WAVEGROUPI=   .929961   .931000  1.000000   .000000 2NO1       22000#
WAVEGROUPI=   .931001   .933200  1.000000   .000000 Ob1        22000#

WAVEGROUPI=   .933201   .947991  1.000000   .000000 TAU1       22000#  3MLAMB1
WAVEGROUPI=   .947992   .964460  1.000000   .000000 NTAU1      22000#

WAVEGROUPI=   .964461   .965933  1.000000   .000000 LK1        22000#

WAVEGROUPI=   .965934   .966853  1.000000   .000000 NO1        20000#  M1

WAVEGROUPI=   .966854   .971667  1.000000   .000000 CHI1       22000#

WAVEGROUPI=   .971668   .996933  1.000000   .000000 PI1        22000#      = P1a
WAVEGROUPI=   .996934   .998631  1.000000   .000000 P1         22000#      = PI1b
WAVEGROUPI=   .998632  1.002333  1.000000   .000000 S1         22000#      = K1a,P1b
WAVEGROUPI=  1.002334  1.004200  1.000000   .000000 K1         22000#  3MN1,3MROP1

WAVEGROUPI=  1.004201  1.006845  1.000000   .000000 PSI1       22000#      = K1b

WAVEGROUPI=  1.006846  1.023622  1.000000   .000000 PHI1       22000#
WAVEGROUPI=  1.023623  1.035379  1.000000   .000000 TET1       22000#
WAVEGROUPI=  1.035380  1.039400  1.000000   .000000 J1         23000#  3MO1

WAVEGROUPI=  1.039401  1.055000  1.000000   .000000 KLK1       23000#  3MO1+
WAVEGROUPI=  1.055001  1.070867  1.000000   .000000 SO1        22000#
WAVEGROUPI=  1.070868  1.075633  1.000000   .000000 2J1        22000#  3MOQ1

WAVEGROUPI=  1.075634  1.086000  1.000000   .000000 OO1        22000#

WAVEGROUPI=  1.086001  1.112600  1.000000   .000000 NU1        22000#  32MO1

WAVEGROUPI=  1.112601  1.470243  1.000000   .000000 2(KM)P1    22000#
#
# Semi-diurnal
WAVEGROUPI=  1.470244  1.808000  1.000000   .000000 2EPS2      02020#
WAVEGROUPI=  1.808001  1.824458  1.000000   .000000 3N2        03020#  3M2J2
WAVEGROUPI=  1.824459  1.845944  1.000000   .000000 EPS2       03020#  3MSO2
WAVEGROUPI=  1.845945  1.863026  1.000000   .000000 2N2        03020#  3MJ2
WAVEGROUPI=  1.863027  1.880264  1.000000   .000000 MUE2       03020#  3MRO2

WAVEGROUPI=  1.880265  1.895680  1.000000   .000000 Na2        00020#  3MK2
WAVEGROUPI=  1.895681  1.897351  1.000000   .000000 N2         02020#  3MLNO2
WAVEGROUPI=  1.897352  1.899500  1.000000   .000000 Nb2        02020#

WAVEGROUPI=  1.899501  1.902300  1.000000   .000000 NUE2       02020#  3MP2
WAVEGROUPI=  1.902301  1.915114  1.000000   .000000 NUEb2      02020#

WAVEGROUPI=  1.915115  1.928402  1.000000   .000000 GAM2       02020#
WAVEGROUPI=  1.928403  1.930667  1.000000   .000000 ALF2       02020#
WAVEGROUPI=  1.930668  1.933790  1.000000   .000000 M2         03020#  3MLK2
WAVEGROUPI=  1.933791  1.936152  1.000000   .000000 BET2       02020#
WAVEGROUPI=  1.936153  1.950419  1.000000   .000000 DEL2       03020#  3MNTAU2
```

```
WAVEGROUPI=  1.950420  1.964767  1.000000   .000000 LAM2       02020#
WAVEGROUPI=  1.964768  1.968600  1.000000   .000000 L2         02020#
WAVEGROUPI=  1.968601  1.970300  1.000000   .000000 KNO2       00020#  3MO2
WAVEGROUPI=  1.970301  1.984282  1.000000   .000000 JTAU2      02020#

WAVEGROUPI=  1.984283  1.995500  1.000000   .000000 2T2        02020#
WAVEGROUPI=  1.995501  1.998996  1.000000   .000000 T2         02020#
WAVEGROUPI=  1.998997  2.001678  1.000000   .000000 S2         02020#
WAVEGROUPI=  2.001679  2.004380  1.000000   .000000 R2         02020#
WAVEGROUPI=  2.004381  2.005800  1.000000   .000000 K2         03020#  3MQ2

WAVEGROUPI=  2.005801  2.010635  1.000000   .000000 Kb2        02020#

WAVEGROUPI=  2.010636  2.022488  1.000000   .000000 KPHI2      02020#
WAVEGROUPI=  2.022489  2.038400  1.000000   .000000 ZETA2      02020#

WAVEGROUPI=  2.038401  2.056000  1.000000   .000000 ETA2       02020#  3MK2O2

WAVEGROUPI=  2.056001  2.075800  1.000000   .000000 2S2        02020#

WAVEGROUPI=  2.075801  2.092667  1.000000   .000000 2K2        02020#

WAVEGROUPI=  2.092668  2.396000  1.000000   .000000 2KN2       02020#

# Ter-diurnal
WAVEGROUPI=  2.58      2.826600  1.000000   .000000 M2N3       00320#
WAVEGROUPI=  2.826601  2.850000  1.000000   .000000 MMUE3      00320#
WAVEGROUPI=  2.850001  2.864300  1.000000   .000000 MN3        00320#
WAVEGROUPI=  2.864301  2.880000  1.000000   .000000 MNUE3      00320#

WAVEGROUPI=  2.880001  2.915496  1.000000   .000000 M3         00320#

WAVEGROUPI=  2.915497  2.953157  1.000000   .000000 ML3        00320#
WAVEGROUPI=  2.953158  3.34      1.000000   .000000 MK3        00320#

# Quad-diurnal
WAVEGROUPI=  3.62      3.848756  1.000000   .000000 MN4        00020#
WAVEGROUPI=  3.848757  3.910000  1.000000   .000000 M4         00020#
WAVEGROUPI=  3.910001  4.230000  1.000000   .000000 MK4        00020#
#
# 1   1/5  -diurnal (check potential development first)
WAVEGROUPI=  4.68      5.09      1.000000   .000000 M5         00000#
#
# 1   1/6  -diurnal (check potential development first)
WAVEGROUPI=  5.75      5.80      1.000000   .000000 M6         00000#
```

A3.2 Result table for model Y04-R04-allopt

```
=====================================================================================================================================
  1 MODMEM-Y04-R04-allopt: A15: Output: Final analysis results + statistics   123.47 s
=====================================================================================================================================


      Program , version ET34-ANA-V70
      Variant: MODMEM-Y04-R04-allopt
     ####################################################################################
     #                                                                                  #
     # GLOBAL GEODYNAMICS PROJECT-SUPERCONDUCTING GRAVIMETERS NETWORK                   #
     # STATION 0243 MEMBACH (BAELEN)      BELGIQUE                                      #
     #  50 36 33.3 N  06 00 23.8 E   H  250 M   D 210 KM  G = 9.81071                   #
     # OBSERVATOIRE ROYAL DE BELGIQUE                                                   #
     # Gravimetric TEST data                                                            #
     #                                                                                  #
     ####################################################################################
      Latitude: 50.6093  °  , longitude:  6.0061  °  , azimuth:  0.0000  °  .
      19970722...20020120     1 blocks. Recorded days in total:   1644.000
      Original sampling interval of the observations:     3600. s
      Numerical filter is : no filter    with    0 coefficients.
      Hartmann+Wenzel (1995) TGP, threshold:-0.100D-11     12361 waves. Component   0
      ET-Analysis with "DEHANT-DEFRAIGNE-WAHR non-hydrostatic inelastic Earth model" (DDW-NHi).
      ========================================================================================
      RECTANGULAR window used for least squares adjustment.
      Pole tide regression applied.
      Length of day tide regression applied.


      A15.1 Adjusted tidal and non-tidal parameters :
      ===============================================
```

from	to	main	Wave group	Amplitudes theor.	Amplitudes ana.	Amplitude factors	RMSE	C.-Int. 95%	Phase leads	RMSE	C.-Int. 95%	Correlation RMSE amplifier	rel. best	RMSE ana.	Signal/ noise
[cpd]		[° /h]	symb.	[nm/s**2]					[°]	[°]	[°]			%	dB
0.000002	0.004067	0.002206	Sa	21.25700	24.65640	1.15992	0.00000	0.00000	0.000	0.000	0.000	5.97	0.0000	0.0001	125.71
0.004068	0.006600	0.082137	Ssa	23.58618	27.29726	1.15734	0.00000	0.00000	0.000	0.000	0.000	1.10	0.0000	0.0000	141.82
0.006601	0.019600	0.123204	Sta	1.37883	1.59565	1.15725	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	117.90
0.019601	0.035200	0.471521	Msm	5.12058	5.92196	1.15650	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	129.81

0.035201	0.036700	0.544375	Mm	26.77854	30.96781	1.15644	0.00000	0.00000	0.000	0.000	0.000	1.88	0.0000	0.0000	138.75
0.036701	0.051333	0.553658	NO	1.43312	1.65731	1.15644	0.00000	0.00001	0.000	0.000	0.000	2.00	0.0001	0.0003	110.53
0.051334	0.069242	1.015896	Msf	4.44229	5.13624	1.15621	0.00000	0.00000	0.000	0.000	0.000	1.03	0.0000	0.0000	127.80
0.069243	0.073000	1.088749	2Mm	2.19472	2.53750	1.15619	0.00000	0.00000	0.000	0.000	0.000	1.49	0.0001	0.0001	119.07
0.073001	0.089333	1.098033	Mf	50.69610	58.61396	1.15618	0.00000	0.00000	0.000	0.000	0.000	1.65	0.0000	0.0000	143.14
0.089334	0.104367	1.560270	SN	0.70408	0.81396	1.15605	0.00000	0.00001	0.000	0.000	0.000	1.02	0.0002	0.0003	112.03
0.104368	0.105580	1.569554	Mstm	1.84323	2.13087	1.15605	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0001	0.0001	118.46
0.105581	0.122801	1.642408	Mtm	9.70669	11.22136	1.15604	0.00000	0.00000	0.000	0.000	0.000	1.07	0.0000	0.0000	132.47
0.122802	0.144490	2.113929	MSqm	1.55034	1.79211	1.15595	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	117.15
0.144491	0.160000	2.186782	Mqm	1.28415	1.48441	1.15594	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0002	0.0002	115.44
0.160001	0.400000	2.658304	SKNMO	0.37459	0.43296	1.15584	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0005	0.0005	105.60

0.580000	0.791600	11.838390	SGM2Q1	0.37286	0.43025	1.15392	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0005	0.0005	105.60
0.791601	0.810000	11.911244	2SGM1	0.23132	0.26692	1.15392	0.00001	0.00002	0.000	0.001	0.001	1.00	0.0009	0.0009	101.14
0.810001	0.821300	12.309911	3Q1	0.86878	1.00263	1.15407	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0002	0.0002	112.49
0.821301	0.842147	12.382765	SGMQ1	2.25054	2.59732	1.15409	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	120.94
0.842148	0.860500	12.854286	2Q1	7.72459	8.91583	1.15421	0.00000	0.00000	0.000	0.000	0.000	1.31	0.0000	0.0000	129.21
0.860501	0.863000	12.927140	SGM1	9.31496	10.75162	1.15423	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	133.10
0.863001	0.878675	12.968207	SGMb1	0.62903	0.72605	1.15424	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0003	0.0003	110.57
0.878676	0.892935	13.357594	Qa1	0.49086	0.56660	1.15430	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0004	0.0004	108.96
0.892936	0.895000	13.398661	Q1	58.37324	67.38096	1.15431	0.00000	0.00000	0.000	0.000	0.000	1.38	0.0000	0.0000	146.31
0.895001	0.896800	13.439728	Qb1	0.54475	0.62881	1.15432	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0003	0.0003	111.18
0.896801	0.899000	13.471515	RO1	11.07975	12.78957	1.15432	0.00000	0.00000	0.000	0.000	0.000	1.05	0.0000	0.0000	134.28
0.899001	0.915000	13.512581	ROb1	0.51176	0.59073	1.15432	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0004	0.0004	108.61
0.915001	0.928315	13.901969	Oa1	1.04792	1.20962	1.15431	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	116.64
0.928316	0.929960	13.943036	O1	304.87743	351.92046	1.15430	0.00000	0.00000	0.000	0.000	0.000	2.17	0.0000	0.0000	156.73
0.929961	0.931000	13.952319	2NO1	1.96415	2.26722	1.15430	0.00000	0.00000	0.000	0.000	0.000	1.92	0.0001	0.0002	114.26
0.931001	0.933200	13.984102	Ob1	0.92287	1.06525	1.15429	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0002	0.0002	113.07
0.933201	0.947991	14.025173	TAU1	3.97392	4.58702	1.15428	0.00000	0.00000	0.000	0.000	0.000	1.05	0.0000	0.0000	127.50
0.947992	0.964460	14.414557	NTAU1	2.24824	2.59450	1.15401	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	120.70
0.964461	0.965933	14.487410	LK1	8.61919	9.94568	1.15390	0.00000	0.00000	0.000	0.000	0.000	1.90	0.0000	0.0000	126.95
0.965934	0.966853	14.496694	NO1	23.96487	27.65265	1.15388	0.00000	0.00000	0.000	0.000	0.000	1.60	0.0000	0.0000	135.91
0.966854	0.971667	14.569548	CHI1	4.58579	5.29075	1.15373	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	127.01
0.971668	0.996933	14.917865	PI1	8.29140	9.54079	1.15069	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	133.00
0.996934	0.998631	14.958931	P1	141.83530	162.98099	1.14909	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	157.59
0.998632	1.002333	15.000002	S1	3.35298	3.84164	1.14574	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	122.17
1.002334	1.004200	15.041069	K1	428.59688	486.23824	1.13449	0.00000	0.00000	0.000	0.000	0.000	1.10	0.0000	0.0000	165.79
1.004201	1.006845	15.082135	PSI1	3.35456	4.26868	1.27250	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	125.95
1.006846	1.023622	15.123206	PHI1	6.10328	7.14521	1.17072	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	130.57
1.023623	1.035379	15.512590	TET1	4.58442	5.30483	1.15714	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	127.07
1.035380	1.039400	15.585443	J1	23.97357	27.73573	1.15693	0.00000	0.00000	0.000	0.000	0.000	2.06	0.0000	0.0000	135.25
1.039401	1.055000	15.594727	KLK1	0.37068	0.42884	1.15691	0.00002	0.00003	-0.001	0.001	0.002	2.16	0.0006	0.0014	97.16
1.055001	1.070867	16.056964	SO1	3.97582	4.59763	1.15640	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	125.55
1.070868	1.075633	16.129818	2J1	1.96519	2.27248	1.15637	0.00000	0.00000	0.000	0.000	0.000	1.10	0.0001	0.0001	119.00

1.075634	1.086000	16.139102	OO1	13.11360	15.16415	1.15637	0.00000	0.00000	0.000	0.000	0.000	1.10	0.0000	0.0000	133.67
1.086001	1.112600	16.683476	NU1	2.51126	2.90379	1.15631	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	120.45
1.112601	1.470243	17.154997	2(KM)P1	0.40100	0.46370	1.15636	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0005	0.0005	106.54
1.470244	1.808000	26.879459	2EPS2	0.36985	0.42976	1.16199	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0004	0.0004	108.25
1.808001	1.824458	27.350980	3N2	0.86312	1.00293	1.16199	0.00000	0.00001	0.000	0.000	0.000	1.35	0.0002	0.0003	111.31
1.824459	1.845944	27.423834	EPS2	2.23724	2.59966	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.33	0.0001	0.0001	119.90
1.845945	1.863026	27.895355	2N2	7.67164	8.91439	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.34	0.0000	0.0000	130.42
1.863027	1.880264	27.968208	MUE2	9.25906	10.75898	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.43	0.0000	0.0000	131.51
1.880265	1.895680	28.398663	Na2	0.48735	0.56629	1.16200	0.00000	0.00000	0.000	0.000	0.000	3.13	0.0000	0.0001	118.75
1.895681	1.897351	28.439730	N2	57.97339	67.36470	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.38	0.0000	0.0000	147.68
1.897352	1.899500	28.480796	Nb2	0.54105	0.62870	1.16200	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0002	0.0002	112.58
1.899501	1.902300	28.512583	NUE2	11.01246	12.79641	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.04	0.0000	0.0000	135.70
1.902301	1.915114	28.553650	NUEb2	0.50806	0.59036	1.16199	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0003	0.0003	109.34
1.915115	1.928402	28.911251	GAM2	0.90898	1.05623	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0002	0.0002	114.42
1.928403	1.930667	28.943038	ALF2	1.04049	1.20904	1.16200	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0002	0.0002	115.65
1.930668	1.933790	28.984104	M2	302.78675	351.83625	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.17	0.0000	0.0000	163.47
1.933791	1.936152	29.025171	BET2	0.91665	1.06514	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0002	0.0002	114.42
1.936153	1.950419	29.066242	DEL2	0.35500	0.41251	1.16199	0.00001	0.00001	0.000	0.000	0.001	1.38	0.0004	0.0005	106.14
1.950420	1.964767	29.455625	LAM2	2.23274	2.59442	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	122.23
1.964768	1.968600	29.528479	L2	8.55917	9.94570	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.78	0.0000	0.0000	128.88
1.968601	1.970300	29.537763	KNO2	2.13952	2.48612	1.16200	0.00000	0.00000	0.000	0.000	0.000	3.52	0.0000	0.0002	115.51
1.970301	1.984282	29.610616	JTAU2	0.40928	0.47558	1.16199	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0005	0.0005	105.43
1.984283	1.995500	29.917867	2T2	0.33420	0.38835	1.16200	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0005	0.0005	105.49
1.995501	1.998996	29.958933	T2	8.23420	9.56808	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	133.30
1.998997	2.001678	30.000000	S2	140.85942	163.67773	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	157.91
2.001679	2.004380	30.041067	R2	1.17587	1.36635	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	118.25
2.004381	2.005800	30.082137	K2	38.27522	44.47555	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.24	0.0000	0.0000	143.54
2.005801	2.010635	30.123204	Kb2	0.29962	0.34815	1.16199	0.00001	0.00001	0.000	0.000	0.001	1.01	0.0006	0.0006	104.31
2.010636	2.022488	30.164275	KPHI2	0.26077	0.30301	1.16199	0.00001	0.00002	0.001	0.000	0.001	1.00	0.0007	0.0007	103.44
2.022489	2.038400	30.553658	ZETA2	0.40934	0.47565	1.16200	0.00001	0.00001	0.000	0.000	0.001	1.01	0.0005	0.0005	105.41
2.038401	2.056000	30.626512	ETA2	2.14104	2.48788	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.24	0.0001	0.0001	118.09
2.056001	2.075800	31.098033	2S2	0.35509	0.41261	1.16200	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0006	0.0006	104.06
2.075801	2.092667	31.180170	2K2	0.56020	0.65095	1.16199	0.00001	0.00001	0.000	0.000	0.001	1.00	0.0004	0.0004	106.96
2.092668	2.396000	31.724545	2KN2	0.10729	0.12467	1.16200	0.00002	0.00005	-0.001	0.001	0.002	1.00	0.0021	0.0021	93.75
2.580000	2.826600	42.387407	M2N3	0.17954	0.19276	1.07361	0.00002	0.00004	-0.001	0.001	0.002	1.81	0.0010	0.0017	95.17
2.826601	2.850000	42.460261	MMUE3	0.18049	0.19377	1.07360	0.00002	0.00003	-0.001	0.001	0.002	1.49	0.0010	0.0015	96.50
2.850001	2.864300	42.931782	MN3	1.03563	1.11185	1.07359	0.00000	0.00001	0.000	0.000	0.000	1.53	0.0002	0.0003	111.40
2.864301	2.880000	43.004635	MNUE3	0.19388	0.20815	1.07360	0.00001	0.00002	0.000	0.001	0.001	1.25	0.0009	0.0012	98.64
2.880001	2.915496	43.476156	M3	3.77909	4.05722	1.07360	0.00000	0.00000	0.000	0.000	0.000	2.61	0.0000	0.0001	118.01
2.915497	2.953157	44.020531	ML3	0.21402	0.22978	1.07361	0.00001	0.00003	0.001	0.001	0.001	1.56	0.0008	0.0012	98.33
2.953158	3.340000	44.574189	MK3	0.49231	0.52855	1.07360	0.00001	0.00002	-0.001	0.001	0.001	2.07	0.0005	0.0009	100.53

3.620000	3.848756	57.423834	MN4	0.01571	0.01632	1.03891	0.00014	0.00027	-0.001	0.008	0.015	1.15	0.0117	0.0135	77.41
3.848757	3.910000	57.968208	M4	0.04380	0.04551	1.03900	0.00005	0.00009	0.000	0.003	0.005	1.00	0.0044	0.0044	87.06
3.910001	4.230000	59.066242	MK4	0.00764	0.00794	1.03929	0.00032	0.00063	-0.001	0.018	0.035	1.00	0.0311	0.0311	70.13
4.680000	5.090000	72.460261	M5	0.00049	0.00050	1.02524	0.00363	0.00712	0.096	0.203	0.398	1.00	0.3542	0.3542	49.01
5.750000	5.800000	86.952313	M6	0.00001	0.00001	1.07439	0.36339	0.71275	-20.506	19.379	38.010	1.00	33.8231	33.8230	9.42
0.842148	0.860500	12.849644	V3:2Q1	0.65266	0.69778	1.06913	0.00001	0.00001	0.000	0.000	0.001	1.31	0.0004	0.0005	106.22
0.878676	0.892935	13.394019	V3:Qa1	2.37943	2.54393	1.06914	0.00000	0.00000	0.000	0.000	0.000	1.44	0.0001	0.0001	116.68
0.928316	0.929960	13.947677	V3:O1	1.21666	1.30077	1.06913	0.00000	0.00001	0.000	0.000	0.000	2.76	0.0001	0.0004	107.66
1.035380	1.039400	15.590085	V3:J1	2.71700	2.90483	1.06913	0.00000	0.00001	0.000	0.000	0.000	5.11	0.0001	0.0004	108.63
1.039401	1.055000	15.592292	V3:KLK1	1.10089	1.17698	1.06912	0.00001	0.00002	-0.001	0.001	0.001	5.20	0.0002	0.0010	100.07
1.808001	1.824458	27.346338	V3:3N2	0.27074	0.29020	1.07188	0.00001	0.00002	0.000	0.001	0.001	1.35	0.0008	0.0010	99.66
1.824459	1.845944	27.419192	V3:EPS2	0.27212	0.29167	1.07187	0.00001	0.00002	0.000	0.001	0.001	1.35	0.0008	0.0010	99.73
1.845945	1.863026	27.890713	V3:2N2	1.56462	1.67706	1.07186	0.00000	0.00000	0.000	0.000	0.000	1.65	0.0001	0.0002	113.13
1.863027	1.880264	27.963567	V3:MUE2	0.29241	0.31342	1.07185	0.00001	0.00002	0.000	0.001	0.001	1.44	0.0007	0.0010	99.85
1.930668	1.933790	28.988746	V3:M2	0.85948	0.92125	1.07186	0.00000	0.00001	0.000	0.000	0.000	1.25	0.0002	0.0003	111.02
1.936153	1.950419	29.061600	V3:DEL2	0.16744	0.17948	1.07186	0.00002	0.00004	0.001	0.001	0.002	1.39	0.0012	0.0017	95.50
2.004381	2.005800	30.077495	V3:K2	0.28642	0.30701	1.07186	0.00001	0.00002	0.000	0.001	0.001	1.28	0.0007	0.0009	100.93
2.580000	2.826600	42.382765	V4:M2N3	0.03159	0.03282	1.03891	0.00015	0.00029	0.006	0.008	0.016	2.21	0.0064	0.0141	77.01
2.826601	2.850000	42.455619	V4:MMUE3	0.00578	0.00601	1.03841	0.00055	0.00108	0.029	0.030	0.059	1.49	0.0355	0.0529	65.54
2.850001	2.864300	42.927140	V4:MN3	0.08806	0.09149	1.03904	0.00003	0.00007	0.001	0.002	0.004	1.37	0.0024	0.0033	89.76
2.864301	2.880000	43.009277	V4:MNUE3	0.00341	0.00355	1.03921	0.00070	0.00137	0.037	0.038	0.075	1.23	0.0544	0.0671	63.47
2.880001	2.915496	43.480798	V4:M3	0.01906	0.01981	1.03920	0.00013	0.00025	0.013	0.007	0.014	1.25	0.0098	0.0122	78.28
2.915497	2.953157	44.025173	V4:ML3	0.07777	0.08081	1.03905	0.00004	0.00008	0.001	0.002	0.005	1.59	0.0026	0.0041	87.78
2.953158	3.340000	45.123206	V4:MK3	0.01107	0.01151	1.03906	0.00022	0.00043	0.011	0.012	0.024	1.00	0.0212	0.0212	73.46
0.000002	0.391000	0.549017	V10	0.01080	0.01079	0.99951	0.00050	0.00099	-0.004	0.029	0.056	2.59	0.0194	0.0503	65.97
0.580000	1.430000	14.492052	V11	0.00544	0.00544	0.99944	0.00069	0.00136	-0.008	0.040	0.078	2.21	0.0315	0.0695	63.16
0.000002	0.391000	1.093391	V30	0.01979	0.02120	1.07137	0.00018	0.00035	-0.010	0.010	0.019	2.59	0.0064	0.0165	75.64
0.580000	1.430000	16.134460	V31	0.44410	0.47480	1.06913	0.00000	0.00001	0.000	0.000	0.000	1.41	0.0003	0.0004	108.96
1.470244	2.396000	30.631154	V32	0.48448	0.51929	1.07185	0.00001	0.00001	0.000	0.000	0.001	1.46	0.0004	0.0006	103.98
1.470244	2.396000	28.435088	V52	0.00229	0.00235	1.02714	0.00251	0.00493	0.186	0.140	0.275	4.25	0.0576	0.2445	52.23
2.580000	3.340000	44.574189	V53	0.00128	0.00132	1.02523	0.00311	0.00610	-0.224	0.174	0.341	3.62	0.0837	0.3032	50.36
3.620000	4.230000	57.419192	V54	0.00122	0.00125	1.02460	0.00144	0.00283	0.066	0.081	0.158	1.15	0.1221	0.1408	57.03

Annex 4 : Standard wave grouping 0.75 - 2 years

A4.1 Tidal wave group parameters for model Y01-R01-02000

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#                                                   #  SYMB     #VVVVV#  V3-symbols
#                                                   #1234567890#34561#  Alias naming
#                                                   #1234567890#34561#  Alias naming
# long periodic
#
WAVEGROUPI=   .000002   .004067  1.000000   .000000 Sa          02000#
WAVEGROUPI=   .004068   .006600  1.000000   .000000 Ssa         02000#
WAVEGROUPI=   .006601   .019600  1.000000   .000000 Sta         02000#
#
# Monthly

WAVEGROUPI=   .019601   .035200  1.000000   .000000 Msm         02000#
WAVEGROUPI=   .035201   .051333  1.000000   .000000 Mm          02000#  3MO0
WAVEGROUPI=   .051334   .069242  1.000000   .000000 Msf         02000#
WAVEGROUPI=   .069243   .089333  1.000000   .000000 Mf          02000#  3MQ0
WAVEGROUPI=   .089334   .105580  1.000000   .000000 Mstm        02000#
WAVEGROUPI=   .105581   .122801  1.000000   .000000 Mtm         02000#  3M3O0
WAVEGROUPI=   .122802   .144490  1.000000   .000000 MSqm        02000#
WAVEGROUPI=   .144491   .160000  1.000000   .000000 Mqm         02000#  3M2OQ0
WAVEGROUPI=   .160001   .400000  1.000000   .000000 SKNMO       02000#
#
# Diurnal
#
WAVEGROUPI=   .580000   .791600  1.000000   .000000 SGM2Q1      02000#
WAVEGROUPI=   .791601   .810000  1.000000   .000000 2SGM1       02000#

WAVEGROUPI=   .810001   .821300  1.000000   .000000 3Q1         02000#
WAVEGROUPI=   .821301   .842147  1.000000   .000000 SGMQ1       02000#  3M2J1

WAVEGROUPI=   .842148   .860500  1.000000   .000000 2Q1         02000#  3META1

WAVEGROUPI=   .860501   .863000  1.000000   .000000 SGM1        02000#  3MZETA1
WAVEGROUPI=   .863001   .878675  1.000000   .000000 SGMb1       02000#

WAVEGROUPI=   .878676   .895000  1.000000   .000000 Q1          02000#  3MK1
WAVEGROUPI=   .895001   .896800  1.000000   .000000 Qb1         02000#

WAVEGROUPI=   .896801   .899000  1.000000   .000000 RO1         02000#  3MS1
WAVEGROUPI=   .899001   .915000  1.000000   .000000 ROb1        02000#

WAVEGROUPI=   .915001   .928315  1.000000   .000000 Oa1         02000#
WAVEGROUPI=   .928316   .931000  1.000000   .000000 O1          02000#  3ML1
WAVEGROUPI=   .931001   .933200  1.000000   .000000 Ob1         02000#

WAVEGROUPI=   .933201   .947991  1.000000   .000000 TAU1        02000#  3MLAMB1
WAVEGROUPI=   .947992   .964460  1.000000   .000000 NTAU1       02000#

#WAVEGROUPI=   .964461   .965933  1.000000   .000000 LK1         02000#

WAVEGROUPI=   .964461   .966853  1.000000   .000000 NO1         02000#  M1
```

```
WAVEGROUPI=   .966854   .971667  1.000000   .000000 CHI1       02000#

WAVEGROUPI=   .971668   .996933  1.000000   .000000 PI1        02000#      = P1a
WAVEGROUPI=   .996934   .998631  1.000000   .000000 P1         02000#      = PI1b
WAVEGROUPI=   .998632  1.002333  1.000000   .000000 S1         02000#      = K1a,P1b
WAVEGROUPI=  1.002334  1.004200  1.000000   .000000 K1         02000#  3MN1,3MROP1
WAVEGROUPI=  1.004201  1.006845  1.000000   .000000 PSI1       02000#      = K1b

WAVEGROUPI=  1.006846  1.023622  1.000000   .000000 PHI1       02000#
WAVEGROUPI=  1.023623  1.035379  1.000000   .000000 TET1       02000#

WAVEGROUPI=  1.035380  1.055000  1.000000   .000000 J1         02000#  3MO1,3MO1+

WAVEGROUPI=  1.055001  1.075633  1.000000   .000000 SO1        02000#

WAVEGROUPI=  1.075634  1.086000  1.000000   .000000 OO1        02000#

WAVEGROUPI=  1.086001  1.112600  1.000000   .000000 NU1        02000# 32MO1

WAVEGROUPI=  1.112601  1.470243  1.000000   .000000 2(KM)P1    02000#
#
# Semi-diurnal
WAVEGROUPI=  1.470244  1.808000  1.000000   .000000 2EPS2      02000#
WAVEGROUPI=  1.808001  1.824458  1.000000   .000000 3N2        02000#  3M2J2
WAVEGROUPI=  1.824459  1.845944  1.000000   .000000 EPS2       02000#  3MSO2
WAVEGROUPI=  1.845945  1.863026  1.000000   .000000 2N2        02000#  3MJ2
WAVEGROUPI=  1.863027  1.880264  1.000000   .000000 MUE2       02000#  3MRO2

WAVEGROUPI=  1.880265  1.897351  1.000000   .000000 N2         02000#  3MLNO2
WAVEGROUPI=  1.897352  1.899500  1.000000   .000000 Nb2        02000#

WAVEGROUPI=  1.899501  1.902300  1.000000   .000000 NUE2       02000#  3MP2
WAVEGROUPI=  1.902301  1.915114  1.000000   .000000 NUEb2      02000#

WAVEGROUPI=  1.915115  1.928402  1.000000   .000000 GAM2       02000#

WAVEGROUPI=  1.928403  1.930667  1.000000   .000000 ALF2       02000#
WAVEGROUPI=  1.930668  1.933790  1.000000   .000000 M2         02000#  3MNO2,3MLK2
WAVEGROUPI=  1.933791  1.936152  1.000000   .000000 BET2       02000#

WAVEGROUPI=  1.936153  1.950419  1.000000   .000000 DEL2       02000#  3MNTAU2

WAVEGROUPI=  1.950420  1.964767  1.000000   .000000 LAM2       02000#
WAVEGROUPI=  1.964768  1.984282  1.000000   .000000 L2         02000#  3MO2
WAVEGROUPI=  1.984283  1.995500  1.000000   .000000 2T2        02000#
WAVEGROUPI=  1.995501  1.998996  1.000000   .000000 T2         02000#
WAVEGROUPI=  1.998997  2.001678  1.000000   .000000 S2         02000#
WAVEGROUPI=  2.001679  2.004380  1.000000   .000000 R2         02000#
WAVEGROUPI=  2.004381  2.005800  1.000000   .000000 K2         02000#  3MQ2
WAVEGROUPI=  2.005801  2.010635  1.000000   .000000 Kb2        02000#

WAVEGROUPI=  2.010636  2.022488  1.000000   .000000 KPHI2      02000#
```

```
WAVEGROUPI=  2.022489  2.038400  1.000000   .000000 ZETA2      02000#

WAVEGROUPI=  2.038401  2.056000  1.000000   .000000 ETA2       02000# 3MK2O2
WAVEGROUPI=  2.056001  2.075800  1.000000   .000000 2S2        02000#

WAVEGROUPI=  2.075801  2.092667  1.000000   .000000 2K2        02000#

WAVEGROUPI=  2.092668  2.396000  1.000000   .000000 2KN2       02000#

# Ter-diurnal
WAVEGROUPI=  2.58      2.826600  1.000000   .000000 M2N3       00000#
WAVEGROUPI=  2.826601  2.850000  1.000000   .000000 MMUE3      00000#
WAVEGROUPI=  2.850001  2.864300  1.000000   .000000 MN3        00000#
WAVEGROUPI=  2.864301  2.880000  1.000000   .000000 MNUE3      00000#

WAVEGROUPI=  2.880001  2.915496  1.000000   .000000 M3         00000#

WAVEGROUPI=  2.915497  2.953157  1.000000   .000000 ML3        00000#
WAVEGROUPI=  2.953158  3.34      1.000000   .000000 MK3        00000#

# Quad-diurnal
WAVEGROUPI=  3.62      3.848756  1.000000   .000000 MN4        00000#
WAVEGROUPI=  3.848757  3.910000  1.000000   .000000 M4         00000#
WAVEGROUPI=  3.910001  4.230000  1.000000   .000000 MK4        00000#
#
# 1   1/5  -diurnal (check potential development first)
WAVEGROUPI=  4.68      5.09      1.000000   .000000 M5         00000#
#
# 1   1/6  -diurnal (check potential development first)
WAVEGROUPI=  5.75      5.80      1.000000   .000000 M6         00000#
```

A4.2 Result table for model Y01-R01-02000

```
==============================================================================================================================================
  1 MODMEM-Y01-R01-02000: A15: Output: Final analysis results + statistics    16.55 s
==============================================================================================================================================

      Program , version ET34-ANA-V70
      Variant: MODMEM-Y01-R01-02000
     ####################################################################################
     #                                                                                  #
     # GLOBAL GEODYNAMICS PROJECT-SUPERCONDUCTING GRAVIMETERS NETWORK                   #
     # STATION 0243 MEMBACH (BAELEN)      BELGIQUE                                      #
     #  50 36 33.3 N  06 00 23.8 E   H  250 M   D 210 KM  G = 9.81071                    #
     # OBSERVATOIRE ROYAL DE BELGIQUE                                                   #
     # Gravimetric TEST data, RMSE m0=1.0                                               #
     #                                                                                  #
     ####################################################################################
      Latitude: 50.6093  °  , longitude:  6.0061  °  , azimuth:  0.0000  °  .
      19970722...19980722     1 blocks. Recorded days in total:    366.000
      Original sampling interval of the observations:     3600. s
      Numerical filter is : no filter    with    0 coefficients.
      Hartmann+Wenzel (1995) TGP, threshold:-0.100D-11     12361 waves. Component   0
      ET-Analysis with "DEHANT-DEFRAIGNE-WAHR non-hydrostatic inelastic Earth model" (DDW-NHi).
      ==========================================================================================
      RECTANGULAR window used for least squares adjustment.
      Pole tide     reduction for an elastic Earth with d= 1.1600 applied.
      Pole tide     reduction for an elastic Earth with d= 1.1600 applied.


      A15.1 Adjusted tidal and non-tidal parameters :
      ===============================================
```

Frequencies from	to [cpd]	main [° /h]	Wave group symb.	Amplitudes theor. [nm/s**2]	ana.	Amplitude factors	RMSE	C.-Int. 95%	Phase leads [°]	RMSE [°]	C.-Int. 95% [°]	Correla-tion RMSE amplifier	rel. best	RMSE ana. %	Signal/ noise dB
0.000002	0.004067	0.002206	Sa	21.25700	24.65638	1.15992	0.00000	0.00000	0.000	0.000	0.000	8.54	0.0000	0.0001	118.81
0.004068	0.006600	0.082137	Ssa	23.58618	27.29726	1.15734	0.00000	0.00000	0.000	0.000	0.000	1.29	0.0000	0.0000	133.56
0.006601	0.019600	0.123204	Sta	1.37883	1.59566	1.15725	0.00000	0.00001	0.000	0.000	0.000	1.17	0.0003	0.0003	109.74
0.019601	0.035200	0.471521	Msm	5.12058	5.92196	1.15650	0.00000	0.00000	0.000	0.000	0.000	1.07	0.0001	0.0001	122.80
0.035201	0.051333	0.544375	Mm	26.77854	30.96784	1.15644	0.00000	0.00000	0.000	0.000	0.000	5.41	0.0000	0.0001	122.79

0.051334	0.069242	1.015896	Msf	4.44229	5.13624	1.15621	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0001	0.0001	120.82
0.069243	0.089333	1.098033	Mf	50.69610	58.61397	1.15618	0.00000	0.00000	0.000	0.000	0.000	1.31	0.0000	0.0000	136.70
0.089334	0.105580	1.569554	Mstm	1.84323	2.13087	1.15605	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0002	0.0002	113.38
0.105581	0.122801	1.642408	Mtm	9.70669	11.22136	1.15604	0.00000	0.00000	0.000	0.000	0.000	1.07	0.0001	0.0001	123.73
0.122802	0.144490	2.113929	MSqm	1.55034	1.79211	1.15595	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0004	0.0004	108.73
0.144491	0.160000	2.186782	Mqm	1.28415	1.48441	1.15595	0.00001	0.00001	0.000	0.000	0.001	1.01	0.0005	0.0005	106.56
0.160001	0.400000	2.658304	SKNM0	0.37459	0.43296	1.15583	0.00002	0.00003	0.001	0.001	0.002	1.00	0.0014	0.0014	97.23
0.580000	0.791600	11.838390	SGM2Q1	0.37286	0.43025	1.15392	0.00001	0.00003	0.001	0.001	0.001	1.01	0.0011	0.0012	98.74
0.791601	0.810000	11.911244	2SGM1	0.23132	0.26694	1.15398	0.00002	0.00005	0.001	0.001	0.002	1.01	0.0020	0.0020	93.79
0.810001	0.821300	12.309911	3Q1	0.86878	1.00261	1.15405	0.00001	0.00001	0.000	0.000	0.001	1.01	0.0005	0.0005	105.47
0.821301	0.842147	12.382765	SGMQ1	2.25054	2.59732	1.15409	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0002	0.0002	113.96
0.842148	0.860500	12.854286	2Q1	7.72459	8.91583	1.15421	0.00000	0.00000	0.000	0.000	0.000	1.13	0.0001	0.0001	123.49
0.860501	0.863000	12.927140	SGM1	9.31496	10.75162	1.15423	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0000	0.0001	125.93
0.863001	0.878675	12.968207	SGMb1	0.62903	0.72605	1.15425	0.00001	0.00002	0.000	0.000	0.001	1.01	0.0008	0.0008	102.06
0.878676	0.895000	13.398661	Q1	58.37324	67.38095	1.15431	0.00000	0.00000	0.000	0.000	0.000	2.30	0.0000	0.0000	134.89
0.895001	0.896800	13.439728	Qb1	0.54475	0.62881	1.15432	0.00001	0.00002	-0.001	0.000	0.001	1.06	0.0007	0.0007	102.98
0.896801	0.899000	13.471515	RO1	11.07975	12.78957	1.15432	0.00000	0.00000	0.000	0.000	0.000	1.06	0.0000	0.0000	126.46
0.899001	0.915000	13.512581	ROb1	0.51176	0.59073	1.15433	0.00001	0.00002	0.000	0.001	0.001	1.01	0.0009	0.0009	100.57
0.915001	0.928315	13.901969	Oa1	1.04792	1.20962	1.15431	0.00000	0.00001	0.000	0.000	0.000	1.03	0.0003	0.0004	109.09
0.928316	0.931000	13.943036	O1	304.87743	351.92045	1.15430	0.00000	0.00000	0.000	0.000	0.000	1.97	0.0000	0.0000	150.59
0.931001	0.933200	13.984102	Ob1	0.92287	1.06525	1.15428	0.00001	0.00001	0.000	0.000	0.001	1.02	0.0005	0.0005	105.94
0.933201	0.947991	14.025173	TAU1	3.97392	4.58702	1.15428	0.00000	0.00000	0.000	0.000	0.000	1.09	0.0001	0.0001	121.86
0.947992	0.964460	14.414557	NTAU1	2.24824	2.59450	1.15401	0.00000	0.00001	0.000	0.000	0.000	1.04	0.0002	0.0002	113.07
0.964461	0.966853	14.496694	NO1	23.96487	27.65270	1.15388	0.00000	0.00000	0.000	0.000	0.000	11.11	0.0000	0.0002	116.21
0.966854	0.971667	14.569548	CHI1	4.58579	5.29075	1.15373	0.00000	0.00000	0.000	0.000	0.000	1.05	0.0001	0.0001	119.63
0.971668	0.996933	14.917865	PI1	8.29140	9.54079	1.15069	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	127.01
0.996934	0.998631	14.958931	P1	141.83530	162.98099	1.14909	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0000	0.0000	151.62
0.998632	1.002333	15.000002	S1	3.35298	3.84164	1.14574	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0002	0.0002	116.10
1.002334	1.004200	15.041069	K1	428.59688	486.23825	1.13449	0.00000	0.00000	0.000	0.000	0.000	1.24	0.0000	0.0000	158.17
1.004201	1.006845	15.082135	PSI1	3.35456	4.26868	1.27250	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	119.86
1.006846	1.023622	15.123206	PHI1	6.10328	7.14522	1.17072	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	124.70
1.023623	1.035379	15.512590	TET1	4.58442	5.30483	1.15714	0.00000	0.00000	0.000	0.000	0.000	1.01	0.0001	0.0001	119.90
1.035380	1.055000	15.585443	J1	23.97357	27.73574	1.15693	0.00000	0.00000	0.000	0.000	0.000	2.42	0.0000	0.0000	126.92
1.055001	1.075633	16.056964	SO1	3.97582	4.59763	1.15640	0.00000	0.00000	0.000	0.000	0.000	1.11	0.0001	0.0001	118.83
1.075634	1.086000	16.139102	OO1	13.11360	15.16415	1.15637	0.00000	0.00000	0.000	0.000	0.000	1.14	0.0001	0.0001	123.95
1.086001	1.112600	16.683476	NU1	2.51126	2.90378	1.15631	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0002	0.0002	112.65
1.112601	1.470243	17.154997	2(KM)P1	0.40100	0.46371	1.15638	0.00001	0.00003	0.000	0.001	0.001	1.00	0.0011	0.0011	99.08
1.470244	1.808000	26.879459	2EPS2	0.36985	0.42976	1.16199	0.00001	0.00002	0.000	0.000	0.001	1.00	0.0007	0.0007	102.84
1.808001	1.824458	27.350980	3N2	0.86312	1.00293	1.16199	0.00000	0.00001	0.000	0.000	0.000	1.02	0.0004	0.0004	107.87
1.824459	1.845944	27.423834	EPS2	2.23724	2.59966	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0001	0.0001	116.54
1.845945	1.863026	27.895355	2N2	7.67164	8.91439	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.37	0.0000	0.0001	124.40
1.863027	1.880264	27.968208	MUE2	9.25906	10.75898	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0000	0.0000	128.69

1.880265	1.897351	28.439730	N2	57.97339	67.36471	1.16199	0.00000	0.00000	0.000	0.000	0.000	3.65	0.0000	0.0000	133.48
1.897352	1.899500	28.480796	Nb2	0.54105	0.62869	1.16199	0.00001	0.00001	0.000	0.000	0.001	1.13	0.0005	0.0006	105.06
1.899501	1.902300	28.512583	NUE2	11.01246	12.79642	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.11	0.0000	0.0000	129.48
1.902301	1.915114	28.553650	NUEb2	0.50806	0.59037	1.16200	0.00001	0.00002	0.000	0.000	0.001	1.03	0.0007	0.0007	103.43
1.915115	1.928402	28.911251	GAM2	0.90898	1.05623	1.16199	0.00000	0.00001	0.000	0.000	0.000	1.04	0.0003	0.0004	108.98
1.928403	1.930667	28.943038	ALF2	1.04049	1.20905	1.16200	0.00000	0.00001	0.000	0.000	0.000	1.04	0.0003	0.0003	109.32
1.930668	1.933790	28.984104	M2	302.78675	351.83625	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.28	0.0000	0.0000	156.97
1.933791	1.936152	29.025171	BET2	0.91665	1.06513	1.16199	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0004	0.0004	108.50
1.936153	1.950419	29.066242	DEL2	0.35500	0.41251	1.16200	0.00001	0.00002	0.000	0.000	0.001	1.02	0.0008	0.0008	101.52
1.950420	1.964767	29.455625	LAM2	2.23274	2.59442	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.04	0.0001	0.0002	116.18
1.964768	1.984282	29.528479	L2	8.55917	9.94571	1.16199	0.00000	0.00000	0.000	0.000	0.000	3.50	0.0000	0.0002	115.88
1.984283	1.995500	29.917867	2T2	0.33420	0.38834	1.16199	0.00001	0.00002	0.001	0.001	0.001	1.00	0.0010	0.0011	99.57
1.995501	1.998996	29.958933	T2	8.23420	9.56809	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	127.45
1.998997	2.001678	30.000000	S2	140.85942	163.67773	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0000	0.0000	152.10
2.001679	2.004380	30.041067	R2	1.17587	1.36635	1.16199	0.00000	0.00001	0.000	0.000	0.000	1.00	0.0002	0.0002	112.44
2.004381	2.005800	30.082137	K2	38.27522	44.47555	1.16199	0.00000	0.00000	0.000	0.000	0.000	1.02	0.0000	0.0000	138.26
2.005801	2.010635	30.123204	Kb2	0.29962	0.34814	1.16197	0.00001	0.00003	-0.001	0.001	0.001	1.00	0.0012	0.0012	98.31
2.010636	2.022488	30.164275	KPHI2	0.26077	0.30301	1.16200	0.00002	0.00003	0.000	0.001	0.002	1.00	0.0013	0.0013	97.45
2.022489	2.038400	30.553658	ZETA2	0.40934	0.47565	1.16199	0.00002	0.00003	0.000	0.001	0.002	1.01	0.0013	0.0013	97.47
2.038401	2.056000	30.626512	ETA2	2.14104	2.48788	1.16199	0.00000	0.00001	0.000	0.000	0.000	1.03	0.0003	0.0003	111.71
2.056001	2.075800	31.098033	2S2	0.35509	0.41261	1.16200	0.00002	0.00004	-0.002	0.001	0.002	1.00	0.0016	0.0016	95.92
2.075801	2.092667	31.180170	2K2	0.56020	0.65095	1.16200	0.00001	0.00002	0.000	0.001	0.001	1.00	0.0010	0.0010	99.58
2.092668	2.396000	31.724545	2KN2	0.10729	0.12467	1.16198	0.00006	0.00012	0.002	0.003	0.006	1.00	0.0051	0.0051	85.88
2.580000	2.826600	42.387407	M2N3	0.17954	0.19276	1.07359	0.00002	0.00004	-0.001	0.001	0.002	1.01	0.0019	0.0019	94.39
2.826601	2.850000	42.460261	MMUE3	0.18049	0.19377	1.07360	0.00002	0.00004	-0.003	0.001	0.002	1.01	0.0020	0.0020	93.95
2.850001	2.864300	42.931782	MN3	1.03563	1.11185	1.07359	0.00000	0.00001	0.000	0.000	0.000	1.01	0.0003	0.0004	109.11
2.864301	2.880000	43.004635	MNUE3	0.19388	0.20815	1.07359	0.00002	0.00004	-0.001	0.001	0.002	1.01	0.0019	0.0019	94.58
2.880001	2.915496	43.476156	M3	3.77909	4.05722	1.07360	0.00000	0.00000	0.000	0.000	0.000	1.00	0.0001	0.0001	120.41
2.915497	2.953157	44.020531	ML3	0.21402	0.22978	1.07360	0.00002	0.00004	0.001	0.001	0.002	1.00	0.0019	0.0019	94.48
2.953158	3.340000	44.574189	MK3	0.49231	0.52855	1.07361	0.00001	0.00002	0.001	0.001	0.001	1.00	0.0011	0.0011	98.80
3.620000	3.848756	57.423834	MN4	0.01571	0.01633	1.03904	0.00024	0.00047	0.014	0.013	0.026	1.00	0.0229	0.0229	72.81
3.848757	3.910000	57.968208	M4	0.04380	0.04551	1.03895	0.00009	0.00018	0.007	0.005	0.010	1.00	0.0088	0.0088	81.14
3.910001	4.230000	59.066242	MK4	0.00764	0.00793	1.03847	0.00081	0.00159	0.006	0.045	0.088	1.00	0.0781	0.0781	62.15
4.680000	5.090000	72.460261	M5	0.00049	0.00050	1.02058	0.00716	0.01408	0.448	0.402	0.791	1.00	0.7017	0.7017	43.08
5.750000	5.800000	86.952313	M6	0.00001	0.00001	2.03591	0.72613	1.42795	-14.158	20.436	40.187	1.00	35.6666	35.6662	8.95
0.000002	0.391000	0.549017	V30	0.12105	0.12969	1.07144	0.00023	0.00045	0.016	0.012	0.024	5.44	0.0039	0.0211	73.51
0.580000	1.430000	14.492052	V31	7.44410	7.95875	1.06913	0.00001	0.00001	0.000	0.000	0.001	11.76	0.0000	0.0005	106.52
1.470244	2.396000	28.435088	V32	5.70133	6.11103	1.07186	0.00000	0.00001	0.000	0.000	0.000	5.06	0.0001	0.0003	111.02

Annex 5 : Standard wave grouping > 18 years including white noise process z(t)

A5.1 Result table for model Y18-R18-alloptz

Marked row : residual vector length > 1 %

A15.5 Residual vectors for the main tidal constituents
Observed -theor. Earth model

from [cpd]	to [cpd]	main frequency [° /h]	wave	EM-ampl. [nm/s**2]	length	vector %	RMSE	C.-Int. 95%	phase lead [°]	RMSE [°]	C.-Int. 95%
0.000002	0.000195	0.002206	MO+	21.257	0.004	0.017	0.000	0.001	-126.72	2.99	5.86
0.000196	0.000330	0.004413	MO++	0.207	0.004	1.765	0.020	0.039	-57.27	286.72	562.14
0.000331	0.004067	0.041067	Sa	3.746	0.008	0.225	0.001	0.003	-15.78	7.09	13.90
0.004068	0.006600	0.082137	Ssa	23.586	0.006	0.026	0.000	0.000	-33.12	1.27	2.49
0.006601	0.019600	0.123204	Sta	1.379	0.002	0.151	0.002	0.004	-57.54	60.71	119.03
0.019601	0.035200	0.471521	Msm	5.121	0.004	0.079	0.001	0.001	38.02	8.37	16.41
0.035201	0.036160	0.542168	Mm-	1.758	0.007	0.423	0.002	0.003	38.67	13.40	26.28
0.036161	0.036393	0.544375	Mm	26.779	0.002	0.007	0.000	0.000	-73.66	3.88	7.61
0.036394	0.036700	0.546581	Mm+	1.738	0.002	0.116	0.002	0.003	-31.41	50.56	99.13
0.036701	0.051333	0.553658	NO	1.433	0.008	0.556	0.002	0.004	-131.65	13.66	26.79
0.051334	0.069242	1.015896	Msf	4.442	0.004	0.082	0.001	0.001	-13.43	10.79	21.16
0.069243	0.073000	1.088749	2Mm	2.195	0.007	0.305	0.001	0.003	-5.81	11.84	23.20
0.073001	0.073340	1.098033	Mf	50.696	0.010	0.020	0.000	0.000	2.99	0.34	0.66
0.073341	0.073350	1.100239	Mf+	21.019	0.006	0.027	0.000	0.000	-51.35	1.56	3.06
0.073351	0.089333	1.102446	Mf++	1.966	0.002	0.107	0.002	0.003	108.60	41.92	82.18
0.089334	0.104367	1.560270	SN	0.704	0.006	0.832	0.004	0.008	-50.69	40.94	80.27
0.104368	0.105580	1.569554	Mstm	1.843	0.002	0.089	0.002	0.003	136.58	53.32	104.55

0.105581	0.109633	1.642408	Mtm	9.707	0.002	0.017	0.000	0.001	6.84	10.72	21.01
0.109634	0.122801	1.644614	Mtm+	4.023	0.000	0.004	0.001	0.001	-39.81	291.20	570.93
0.122802	0.144490	2.113929	MSqm	1.550	0.002	0.107	0.002	0.004	-140.58	62.62	122.77
0.144491	0.160000	2.186782	Mqm	1.284	0.006	0.483	0.002	0.004	44.62	20.26	39.72
0.160001	0.400000	2.658304	SKNM0	0.375	0.007	1.747	0.007	0.013	-110.21	59.15	115.97
0.580000	0.791600	11.838390	SGM2Q1	0.373	0.004	1.142	0.008	0.015	-175.41	102.51	200.94
0.791601	0.810000	11.911244	2SGM1	0.231	0.004	1.623	0.013	0.025	-0.82	193.66	379.62
0.810001	0.821300	12.309911	3Q1	0.869	0.002	0.180	0.003	0.007	-38.90	125.96	246.92
0.821301	0.842147	12.382765	SGMQ1	2.251	0.004	0.170	0.001	0.003	139.61	19.53	38.28
0.842148	0.856817	12.852080	2Q1-	1.457	0.002	0.140	0.002	0.004	-136.83	58.53	114.73
0.856818	0.860500	12.854286	2Q1	7.725	0.007	0.090	0.000	0.001	-6.56	3.35	6.57
0.860501	0.861680	12.924933	SGM1-	1.757	0.009	0.500	0.002	0.003	39.30	11.28	22.11
0.861681	0.863000	12.927140	SGM1	9.315	0.002	0.026	0.000	0.001	-135.86	8.02	15.71
0.863001	0.878675	12.968207	SGMb1	0.629	0.002	0.328	0.004	0.008	93.30	119.78	234.80
0.878676	0.892935	13.357594	Qa1	0.491	0.003	0.688	0.005	0.010	-59.66	88.88	174.22
0.892936	0.893133	13.396454	Q1-	11.008	0.003	0.030	0.000	0.001	-4.35	4.93	9.66
0.893134	0.895000	13.398661	Q1	58.373	0.002	0.003	0.000	0.000	0.61	2.54	4.99
0.895001	0.896800	13.439728	Qb1	0.545	0.002	0.424	0.005	0.009	-153.15	117.55	230.42
0.896801	0.898000	13.469308	RO1-	2.090	0.004	0.191	0.001	0.003	142.90	20.89	40.95
0.898001	0.899000	13.471515	RO1	11.080	0.004	0.036	0.000	0.001	178.04	4.11	8.06
0.899001	0.915000	13.512581	ROb1	0.512	0.005	0.988	0.006	0.011	-21.25	63.84	125.15
0.915001	0.928315	13.901969	Oa1	1.048	0.001	0.138	0.002	0.004	89.18	85.54	167.69
0.928316	0.929327	13.938623	O1--	1.762	0.004	0.218	0.002	0.003	-134.77	26.17	51.31
0.929328	0.929389	13.940829	O1-	57.514	0.003	0.005	0.000	0.000	-145.84	1.22	2.39
0.929390	0.929960	13.943036	O1	304.877	0.013	0.004	0.000	0.000	122.03	0.25	0.48
0.929961	0.931000	13.952319	2NO1	1.964	0.009	0.456	0.002	0.003	-153.54	9.81	19.23
0.931001	0.933200	13.984102	Ob1	0.923	0.003	0.307	0.003	0.007	103.01	69.15	135.56
0.933201	0.947991	14.025173	TAU1	3.974	0.007	0.179	0.001	0.001	-174.49	6.01	11.77
0.947992	0.964460	14.414557	NTAU1	2.248	0.004	0.196	0.001	0.003	21.19	17.05	33.43
0.964461	0.965700	14.485204	LK1-	1.595	0.003	0.218	0.002	0.004	139.46	31.37	61.50
0.965701	0.965933	14.487410	LK1	8.619	0.001	0.016	0.000	0.001	67.74	15.26	29.91
0.965934	0.966509	14.496694	NO1	23.965	0.006	0.026	0.000	0.000	49.89	1.46	2.86
0.966510	0.966853	14.498900	NO1+	4.809	0.002	0.035	0.001	0.001	-117.90	21.54	42.23

0.966854	0.971444	14.569548	CHI1	4.586	0.001	0.030	0.001	0.001	-177.68	27.66	54.23
0.971445	0.971667	14.571754	CHI1+	1.006	0.001	0.051	0.003	0.006	-18.54	334.43	655.57
0.971668	0.996933	14.917865	PI1	8.291	0.004	0.054	0.000	0.001	-91.90	4.70	9.22
0.996934	0.997116	14.956725	P1-	1.594	0.004	0.261	0.002	0.004	169.01	26.27	51.50
0.997117	0.998631	14.958931	P1	141.835	0.003	0.002	0.000	0.000	-41.68	0.45	0.88
0.998632	1.002333	15.000002	S1	3.353	0.005	0.143	0.001	0.003	-163.45	15.63	30.64
1.002334	1.002605	15.038862	K1-	8.488	0.002	0.027	0.000	0.001	56.70	10.61	20.79
1.002606	1.002860	15.041069	K1	428.597	0.022	0.005	0.000	0.000	100.70	0.10	0.20
1.002861	1.002901	15.043275	K1+	58.166	0.002	0.003	0.000	0.000	80.52	2.05	4.01
1.002902	1.004200	15.045481	K1++	1.250	0.007	0.564	0.003	0.005	-125.42	20.65	40.47
1.004201	1.006845	15.082135	PSI1	3.355	0.003	0.083	0.001	0.002	-73.24	16.77	32.88
1.006846	1.023622	15.123206	PHI1	6.103	0.010	0.159	0.000	0.001	56.01	2.93	5.73
1.023623	1.034267	15.512590	TET1	4.584	0.005	0.116	0.001	0.001	102.66	7.18	14.07
1.034268	1.035379	15.514796	TET1+	0.909	0.007	0.824	0.003	0.007	-0.41	25.49	49.97
1.035380	1.039149	15.585443	J1	23.974	0.001	0.004	0.000	0.000	145.58	9.02	17.68
1.039150	1.039400	15.587650	J1+	4.752	0.005	0.110	0.001	0.001	-163.48	7.13	13.98
1.039401	1.055000	15.594727	KLK1	0.371	0.001	0.167	0.006	0.012	-23.94	572.56	1122.36
1.055001	1.070867	16.056964	SO1	3.976	0.004	0.101	0.001	0.001	-124.50	10.71	21.00
1.070868	1.075633	16.129818	2J1	1.965	0.005	0.250	0.002	0.003	-106.87	17.70	34.69
1.075634	1.076069	16.139102	OO1	13.114	0.005	0.037	0.000	0.001	50.25	3.76	7.37
1.076070	1.076100	16.141308	OO1+	8.403	0.005	0.065	0.000	0.001	-1.15	4.38	8.59
1.076101	1.086000	16.143514	OO1++	1.760	0.005	0.265	0.002	0.003	-172.81	21.20	41.56
1.086001	1.112359	16.683476	NU1	2.511	0.002	0.089	0.001	0.002	-132.70	30.08	58.97
1.112360	1.112600	16.685683	NU1+	1.608	0.004	0.226	0.002	0.004	-48.07	29.44	57.71
1.112601	1.470243	17.154997	2(KM)P1	0.401	0.001	0.373	0.005	0.009	-42.34	180.12	353.08
1.470244	1.808000	26.879459	2EPS2	0.370	0.002	0.610	0.007	0.013	-57.47	169.78	332.80
1.808001	1.824458	27.350980	3N2	0.863	0.004	0.429	0.004	0.007	-130.22	54.55	106.94
1.824459	1.845944	27.423834	EPS2	2.237	0.004	0.184	0.001	0.003	55.72	18.46	36.19
1.845945	1.863026	27.895355	2N2	7.672	0.005	0.063	0.000	0.001	113.65	4.71	9.24
1.863027	1.880264	27.968208	MUE2	9.259	0.008	0.081	0.000	0.001	-39.31	2.49	4.89
1.880265	1.895680	28.398663	Na2	0.487	0.001	0.211	0.001	0.003	46.31	71.78	140.71
1.895681	1.895860	28.437523	N2-	2.164	0.004	0.192	0.001	0.003	-86.55	20.08	39.37
1.895861	1.897351	28.439730	N2	57.973	0.008	0.013	0.000	0.000	98.60	0.41	0.80
1.897352	1.899500	28.480796	Nb2	0.541	0.003	0.626	0.005	0.009	83.21	80.84	158.47

1.899501	1.902300	28.512583	NUE2	11.012	0.004	0.032	0.000	0.001	47.65	4.51	8.84
1.902301	1.915114	28.553650	NUEb2	0.508	0.004	0.747	0.006	0.012	29.00	90.20	176.82
1.915115	1.928402	28.911251	GAM2	0.909	0.003	0.305	0.003	0.006	-47.24	67.90	133.09
1.928403	1.930667	28.943038	ALF2	1.040	0.001	0.087	0.003	0.006	-86.12	184.08	360.85
1.930668	1.932150	28.981898	M2-	11.298	0.010	0.087	0.000	0.001	-33.10	1.68	3.29
1.932151	1.933790	28.984104	M2	302.787	0.003	0.001	0.000	0.000	35.75	0.30	0.59
1.933791	1.936152	29.025171	BET2	0.917	0.005	0.562	0.003	0.006	-34.44	36.78	72.10
1.936153	1.950419	29.066242	DEL2	0.355	0.001	0.151	0.007	0.014	-157.41	779.08	1527.18
1.950420	1.964767	29.455625	LAM2	2.233	0.008	0.375	0.001	0.003	-31.48	9.28	18.19
1.964768	1.968600	29.528479	L2	8.559	0.004	0.047	0.000	0.001	-164.22	5.10	10.00
1.968601	1.969287	29.537763	KNO2	2.140	0.003	0.153	0.001	0.002	63.18	19.69	38.59
1.969288	1.970300	29.539969	KNO2+	0.944	0.003	0.298	0.003	0.006	62.42	65.01	127.43
1.970301	1.984282	29.610616	JTAU2	0.409	0.006	1.359	0.007	0.013	19.83	68.65	134.57
1.984283	1.995500	29.917867	2T2	0.334	0.007	2.205	0.009	0.018	171.44	70.70	138.58
1.995501	1.998996	29.958933	T2	8.234	0.006	0.077	0.000	0.001	-67.39	3.32	6.50
1.998997	2.001678	30.000000	S2	140.859	0.003	0.002	0.000	0.000	26.20	0.43	0.84
2.001679	2.004380	30.041067	R2	1.176	0.006	0.550	0.002	0.004	-97.81	18.55	36.36
2.004381	2.005600	30.082137	K2	38.275	0.007	0.018	0.000	0.000	110.63	0.91	1.78
2.005601	2.005750	30.084344	K2+	11.407	0.005	0.044	0.000	0.001	-85.22	3.27	6.42
2.005751	2.005800	30.086550	K2++	1.240	0.005	0.384	0.002	0.005	103.52	29.65	58.13
2.005801	2.010635	30.123204	Kb2	0.300	0.005	1.763	0.010	0.020	75.81	109.15	213.95
2.010636	2.022488	30.164275	KPHI2	0.261	0.002	0.687	0.012	0.023	141.66	380.69	746.23
2.022489	2.038400	30.553658	ZETA2	0.409	0.006	1.432	0.007	0.013	173.21	66.14	129.66
2.038401	2.041899	30.626512	ETA2	2.141	0.005	0.220	0.001	0.003	-16.36	17.43	34.17
2.041900	2.056000	30.628718	ETA2+	0.932	0.004	0.468	0.003	0.006	-179.33	42.56	83.42
2.056001	2.075800	31.098033	2S2	0.355	0.002	0.575	0.008	0.015	-63.23	219.67	430.59
2.075801	2.078740	31.180170	2K2	0.560	0.004	0.629	0.005	0.010	26.17	83.11	162.91
2.078741	2.092667	31.182377	2K2+	0.486	0.007	1.466	0.006	0.012	110.14	47.94	93.97
2.092668	2.396000	31.724545	2KN2	0.107	0.001	0.764	0.018	0.036	-72.52	1290.23	2529.15
2.580000	2.826600	42.387407	M2N3	0.180	0.006	3.349	0.018	0.035	-55.64	169.63	332.51
2.826601	2.850000	42.460261	MMUE3	0.180	0.004	2.011	0.019	0.037	-106.80	294.09	576.48
2.850001	2.864300	42.931782	MN3	1.036	0.004	0.414	0.003	0.007	69.41	44.76	87.73
2.864301	2.880000	43.004635	MNUE3	0.194	0.005	2.426	0.017	0.034	163.09	211.47	414.53
2.880001	2.898280	43.473950	M3-	0.211	0.003	1.439	0.017	0.033	-157.82	314.35	616.20

2.898281	2.915496	43.476156	M3	3.779	0.010	0.252	0.001	0.002	-30.84	6.69	13.11
2.915497	2.953157	44.020531	ML3	0.214	0.002	1.071	0.014	0.028	130.26	358.81	703.36
2.953158	3.340000	44.574189	MK3	0.492	0.001	0.298	0.009	0.017	102.32	337.39	661.36
3.620000	3.848756	57.423834	MN4	0.016	0.009	54.410	0.202	0.396	162.34	1354.51	2655.05
3.848757	3.910000	57.968208	M4	0.044	0.006	14.282	0.076	0.150	161.42	699.29	1370.71
3.910001	4.230000	59.066242	MK4	0.008	0.001	13.255	0.402	0.787	76.99	22728.79	44551.84
4.680000	5.090000	72.460261	M5	0.000	0.004	745.651	6.161	12.077	91.59	97289.15190706.18	
5.750000	5.800000	86.952313	M6	0.000	0.002	28953.231	582.660	1142.130	-82.70******************		
0.842148	0.856817	12.849644	V3:2Q1-	0.653	0.005	0.770	0.005	0.009	146.50	53.77	105.40
0.878676	0.892935	13.394019	V3:Qa1	2.379	0.002	0.092	0.001	0.003	172.04	36.00	70.56
0.929390	0.929960	13.947677	V3:O1	1.217	0.003	0.232	0.003	0.005	148.35	55.44	108.68
1.039150	1.039400	15.590085	V3:J1+	2.717	0.006	0.225	0.001	0.003	123.45	12.24	23.99
1.039401	1.055000	15.592292	V3:KLK1	1.101	0.000	0.032	0.003	0.006	-94.00	494.38	969.12
1.808001	1.824458	27.346338	V3:3N2	0.271	0.003	1.115	0.012	0.024	-69.27	230.13	451.10
1.824459	1.845944	27.419192	V3:EPS2	0.272	0.002	0.792	0.012	0.024	-122.66	318.92	625.16
1.845945	1.863026	27.890713	V3:2N2	1.565	0.006	0.401	0.003	0.005	39.69	22.83	44.75
1.863027	1.880264	27.963567	V3:MUE2	0.292	0.003	1.142	0.011	0.022	-175.56	191.68	375.73
1.930668	1.932150	28.979462	V3:M2-	0.323	0.009	2.732	0.010	0.020	-22.54	65.70	128.79
1.932151	1.933790	28.988746	V3:M2	0.859	0.005	0.587	0.004	0.008	114.19	46.19	90.55
1.936153	1.950419	29.061600	V3:DEL2	0.167	0.001	0.351	0.019	0.038	112.32	1880.78	3686.76
2.004381	2.005600	30.077495	V3:K2	0.286	0.004	1.304	0.012	0.023	160.86	176.71	346.38
2.041900	2.056000	30.631154	V3:ETA2+	0.484	0.006	1.182	0.007	0.013	80.05	67.67	132.65
2.580000	2.826600	42.382765	V4:M2N3	0.032	0.007	21.652	0.105	0.205	29.67	877.43	1719.96
2.826601	2.850000	42.455619	V4:MMUE3	0.006	0.003	51.435	0.589	1.155	160.19	11352.83	22254.05
2.850001	2.864300	42.927140	V4:MN3	0.088	0.002	2.018	0.039	0.077	-60.29	1264.08	2477.87
2.864301	2.880000	43.009277	V4:MNUE3	0.003	0.006	162.009	0.989	1.939	161.34	10249.73	20091.72
2.880001	2.898280	43.471515	V4:M3-	0.008	0.002	24.792	0.446	0.875	177.27	13671.97	26800.07
2.898281	2.915496	43.480798	V4:M3	0.019	0.006	29.975	0.176	0.346	39.50	1769.69	3468.98

2.915497	2.953157	44.025173	V4:ML3	0.078	0.000	0.627	0.044	0.086	-167.45	5168.40	10131.20
2.953158	3.340000	45.123206	V4:MK3	0.011	0.003	26.569	0.253	0.497	-66.01	4933.78	9671.29
0.000002	0.391000	0.549017	V10	0.011	0.011	99.523	0.333	0.652	-27.94	1772.59	3475.39
0.580000	1.430000	14.492052	V11	0.005	0.009	172.363	0.676	1.325	-76.94	4127.74	8091.44
0.000002	0.391000	1.093391	V30	0.020	0.006	30.263	0.111	0.217	112.10	1059.11	2076.52
0.580000	1.430000	16.134460	V31	0.444	0.003	0.569	0.004	0.008	-39.27	92.22	180.77
1.470244	2.396000	28.517225	V32	0.145	0.000	0.332	0.013	0.025	-129.81	1530.66	3000.45
0.580000	1.430000	13.943036	V41	0.087	0.017	19.214	0.219	0.430	85.61	752.13	1474.37
1.470244	2.396000	28.984104	V42	0.101	0.010	9.383	0.047	0.093	56.44	285.03	558.72
1.470244	2.396000	28.435088	V52	0.002	0.011	473.801	3.099	6.076	56.56	16381.99	32112.48
2.580000	3.340000	44.574189	V53	0.001	0.003	235.482	2.429	4.762	-50.11	46063.31	90294.23
3.620000	4.230000	57.419192	V54	0.001	0.003	260.285	1.915	3.753	-90.73	34470.29	67566.93

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