On the proper use of the EIGEN-6 models for altimetric orbit computation over decades

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Summary

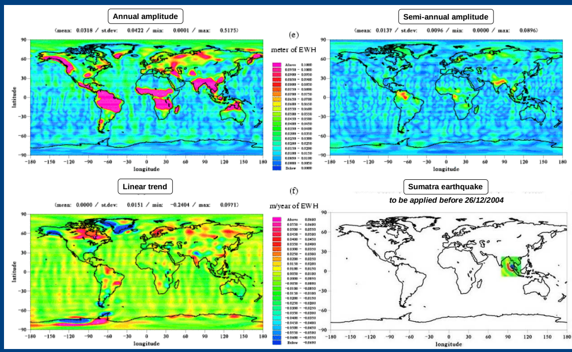
The EIGEN-6S or -6C Earth gravity models are commonly used for altimetric orbit computation. These models are mainly based on GRACE KBR data, with a participation of Lageos-1 and -2 SLR data for the lower spherical harmonics. They are complete to degree and order 160 and contain time variable coefficients for the spherical harmonics up to degree 50 : bias, drift, once and twice per year terms. These terms have been modeled globally over the GRACE period (2002-2012)..

However extrapolating these time variable terms in the past until the beginning of altimetric missions or even in the near future can generate some degradation of the orbital precision which can lead to noticeable radial discrepancies. Furthermore, the 10-year long time series of gravity field solutions we have today shows that a simple bias + drift + periodic terms mean model adjusted over the full data span is not sufficient to optimally represent the non regular features observed in the time series.

This is why we propose a more refined parameterization for the mean model which would at the same time allows to better express the long-term evolution of the first degrees of the gravity field beyond the GRACE era, thanks to information provided by the SLR satellites, and to more closely follow the time evolution of the 10-day gravity field series within the GRACE era.

Current status

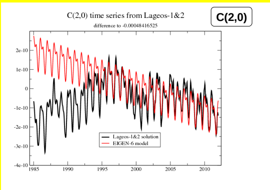
The current EIGEN-6S model contains time variable coefficients (drift, once and twice per year terms) adjusted globally over the GRACE period (2002-2012). The graphs express the amplitude of these time variable coefficients as well as the effect of the Sumatra earthquake to be added before 24 December 2004.

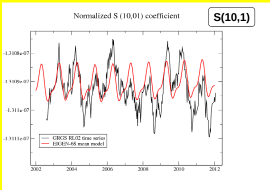


Observed limitations of the current mean models

1) Long-term evolution of the low-degree spherical harmonic coefficients.

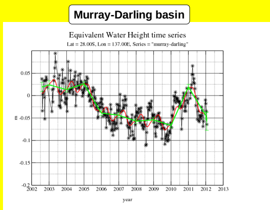
The SLR data give access to the knowledge of the very low-degree coefficients of the gravity field (the ones which have the greatest effect on satellites orbits) much beyond the GRACE era. The C(2,0) coefficient in particular has a behavior very far from linear and its drift rate observed between 2002 and 2012 is very different from the one between 1985 and 1999.

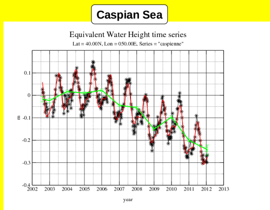




2) Deviations of the 10-day time series from a linear + periodic model

Examples, in Equivalent Water Height (EWH), of areas where the time series does not follow a regular pattern:





New modeling proposed

We propose to improve the modeling by replacing the current bias & drift coefficients, constant over the whole period, by annually adjusted bias & drift coefficients. The format used is the one of the GRCOF2 coefficients in the official GRACE GSM products format. Two new acronyms are introduced: **G_BIAS** and **GDRIFT**. They are defined with two dates, t1 and t2.

G_BIAS is the bias at a reference epoch T_refep.
The first date t1 has a double meaning:
- it is this reference epoch (t1 = T_refep),
- it is also the start of the validity range for this bias coefficient.

The second date t2 is the end of the validity range.

GDRIFT is the rate /year.
The dates t1 and t2 indicate the range of validity.
The coefficient at any date T between t1 and t2 is given by:
coef(T) = G_BIAS(t1,t2) + GDRIFT(t1,t2) * (T - t1)

The resulting modeling of the coefficients can take the shape of a piece-wise-linear function, if the function at the end of an interval coincides with the function at the beginning of the following interval, but it can also be discontinuous in order to account for sudden gravity change, due to earthquake for instance.

Example of new format

```
FIRST EIGEN_from_RL02_series_and_LAG12
CMMNT from GRACE-LAGEOS   10-day gravity fields RL02
EARTH 0.3986004415E+15 0.6378136460E+07
SHM     160  160 2.00 fully normalized exclusive permanent tide
GRCOF2    0    0 0.100000000000E+01 0.000000000000E+00 0.0000E+00 0.0000E+00 19500101.0000 20500101.0000 nnnn
G_BIAS    2    0 -.484165479521E-03 0.000000000000E+00 0.1392E-10 0.0000E+00 19500101.0000 19850109.1751 ynyn
GDRIFT    2    0 0.104634158251E-11 0.000000000000E+00 0.5603E-12 0.0000E+00 19500101.0000 19850109.1751 ynyn
G_BIAS    2    0 -.484165442874E-03 0.000000000000E+00 0.1392E-10 0.0000E+00 19850109.1751 19860101.0000 ynyn
GDRIFT    2    0 0.124657017393E-10 0.000000000000E+00 0.2260E-10 0.0000E+00 19850109.1751 19860101.0000 ynyn
G_BIAS    2    0 -.484165430707E-03 0.000000000000E+00 0.8672E-11 0.0000E+00 19860101.0000 19870101.0000 ynyn
GDRIFT    2    0 0.224347107494E-10 0.000000000000E+00 0.1818E-10 0.0000E+00 19860101.0000 19870101.0000 ynyn
G_BIAS    2    0 -.484165408273E-03 0.000000000000E+00 0.9507E-11 0.0000E+00 19870101.0000 19880101.0000 ynyn
GDRIFT    2    0 0.128987611358E-09 0.000000000000E+00 0.1736E-10 0.0000E+00 19870101.0000 19880101.0000 ynyn
G_BIAS    2    0 -.484165279285E-03 0.000000000000E+00 0.7851E-11 0.0000E+00 19880101.0000 19890101.0000 ynyn
GDRIFT    2    0 -.833020306695E-10 0.000000000000E+00 0.1476E-10 0.0000E+00 19880101.0000 19890101.0000 ynyn
G_BIAS    2    0 -.484165362587E-03 0.000000000000E+00 0.6904E-11 0.0000E+00 19890101.0000 19900101.0000 ynyn
GDRIFT    2    0 0.649257734499E-11 0.000000000000E+00 0.1420E-10 0.0000E+00 19890101.0000 19900101.0000 ynyn
G_BIAS    2    0 -.484165356094E-03 0.000000000000E+00 0.7295E-11 0.0000E+00 19900101.0000 19910101.0000 ynyn
GDRIFT    2    0 0.162048658823E-10 0.000000000000E+00 0.1449E-10 0.0000E+00 19900101.0000 19910101.0000 ynyn
GCOS1A    2    0 0.386222759789E-10 0.000000000000E+00 0.3748E-11 0.0000E+00 19500101.0000 20500101.0000 ynyn
GSIN1A    2    0 0.542428904167E-10 0.000000000000E+00 0.3404E-11 0.0000E+00 19500101.0000 20500101.0000 ynyn
GCOS2A    2    0 0.379017840266E-10 0.000000000000E+00 0.3617E-11 0.0000E+00 19500101.0000 20500101.0000 ynyn
GSIN2A    2    0 -.163073508081E-10 0.000000000000E+00 0.3494E-11 0.0000E+00 19500101.0000 20500101.0000 ynyn
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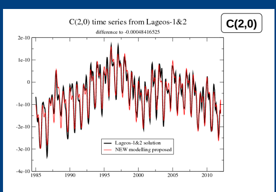

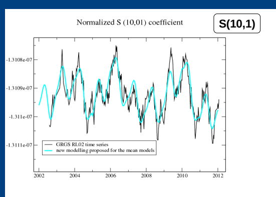

Illustration of the new modeling

Examples of coefficients C(2,0) and S(10,1) modeled as:
- yearly bias & drift
- once & twice per year periodic coefficients averaged over the whole period

The fit to the actual time series is greatly improved.

Impact on Topex orbit

The quality of Topex orbits is assessed through DORIS and SLR residuals from 10-day arcs. Some improvements are noticeable on SLR residuals (a few mm) and on DORIS residuals (a few µm/s) before 1999 when using the new modeling. The right-hand graphs shows differences between EIGEN-6S and the new modeling (positive differences account for improvement).