GRACE Gravity Model GGM03

Please note: GGM03S is available to degree/order 180 but should not be used as is beyond approximately degree 130. Rapidly increasing errors make the coefficients unreliable at higher degrees. Over the polar region, it may be possible to use slightly higher degree coefficients. Depending on the application, the GGM03S field coefficients should be truncated or smoothed to an appropriate level. If a higher resolution gravity model is required, GGM03C, complete to degree/order 360, should be used; no truncation or smoothing should be necessary.

Additional Notes on the GGM03 gravity field solution and background modeling:

C20, C00, C10, C11, S11, C21, S21

C00 is defined to be exactly 1, and the degree one terms are defined to be exactly 0. These coefficients are not explicitly included in the geopotential file.

C20 is a zero-tide value, *i.e.* it includes the zero-frequency (permanent) tide contribution; in order to convert to a tide-free system, add 4.173×10^{-9}. Its epoch is 2005.0, the approximate mid-point of the four years used (2003-2007) in the solution.

C21 and S21 were estimated; they were not fixed to the IERS2003 standard values. They are epoch 2005 values.

Coefficient file description:

The coefficients for GGM03S and GGM03C are normalized according to the so-called "fully-normalized" convention, where the squared norm of a spherical harmonic over a unit sphere is 4π (see below). The standard deviations or 'sigmas' (approximately calibrated, not the formal values) are included with the coefficients. The Earth radius and GM to be used for scaling in the expression for the geopotential are included in the coefficient file.

'GEO' file format specification:

line 1: Format for next line
line 2: 20 character description, GM (km^3/s^2), Ae (m), Epoch (for those terms with rates)
line 3: Format for following lines
line 4+: 6-character string, degree, order, C, S, C-sigma, S-sigma, normalization flag (-1 = normalized)

Comments or Questions ? Please contact grace@csr.utexas.edu

Normalization Convention:

If φ denotes the geographical latitude of a field point (0° at equator, 90° at the North pole, and –90° at the South pole), and if $u = \sin\varphi$, then the un-normalized Legendre Polynomial of degree l is defined by

$$P_l(u) = \frac{1}{2^l \times l!} \times \frac{d^l}{du^l}\left(u^2 - 1\right)^l$$

The definition of the un-normalized Associated Legendre Polynomial is then

$$P_{lm}(u) = \left(1 - u^2\right)^{\frac{m}{2}} \frac{d^m}{du^m} P_l(u)$$

If the normalization factor is defined such that

$$N_{lm}^2 = \frac{(2 - \delta_{0m})(2l+1)(l-m)!}{(l+m)!}$$

and the Associated Legendre Polynomials are normalized by

$$\overline{P}_{lm} = N_{lm} P_{lm}$$

then, over a unit sphere S

$$\int_S \left[\overline{P}_{lm}(\sin\varphi)\begin{Bmatrix}\cos m\lambda \\ \sin m\lambda\end{Bmatrix}\right]^2 dS = 4\pi$$

In this convention, the relationship of the spherical harmonic coefficients to the mass distribution becomes

$$\begin{Bmatrix}\overline{C}_{lm} \\ \overline{S}_{lm}\end{Bmatrix} = \frac{1}{(2l+1)M_e} \times \iiint_{Global} \left(\frac{r'}{a_e}\right)^l \overline{P}_{lm}(\sin\varphi')\begin{Bmatrix}\cos m\lambda' \\ \sin m\lambda'\end{Bmatrix} dM$$

where r', φ' and λ' are the coordinates of the mass element dM in the integrand. The integration is carried out over the entire mass envelope of the Earth system, including its solid and fluid components.

This convention is consistent with the definition of fully-normalized harmonics in NRC (1997), and textbooks such as Heiskanen and Moritz (1966), Torge (1980); as well as in earlier gravity field models such as EGM96.