GRACE Gravity Model GGM01

GGM01S was estimated with 111 days (spanning April through November of 2002) of GRACE K-band range-rate, attitude, and accelerometer data. No 'Kaula' constraint, no other satellite information, no surface gravity information and no other *a prior* conditioning was applied in generating this solution. The GGM01S field was estimated to degree and order 120, and the solution appears to have 'full power' up to about degree 95 (see Figure 1); discretion is advised on using the higher degree coefficients. The background static field model was TEG4; the ocean tide model was based on CSR4.0 with selected resonant tides from the TEG4 gravity solution; and the solid earth tide model is consistent with the IERS96 elastic earth model. Some additional details are provided below. The estimated parameters along with GGM01S were: 1) initial conditions for daily arcs, 2) accelerometer biases (daily) and scale factors (global), and 3) KBR biases, GPS ambiguities and zenith delays. GGM01S was combined with the TEG4 information equations (created from historical multi-satellite tracking data; surface gravity data and altimetric sea surface heights) to produce a preliminary gravity model (GGM01C) complete to degree and order 200. Various degree variances are shown in Figure 1 and the predicted geoid error as a function of geographic location is shown in Figure 2.

This initial release of GGM01 is being provided as spherical harmonic coefficients and as gridded surfaces in order to assess what product forms best support the analysis community. The file contents and formats are provided below.

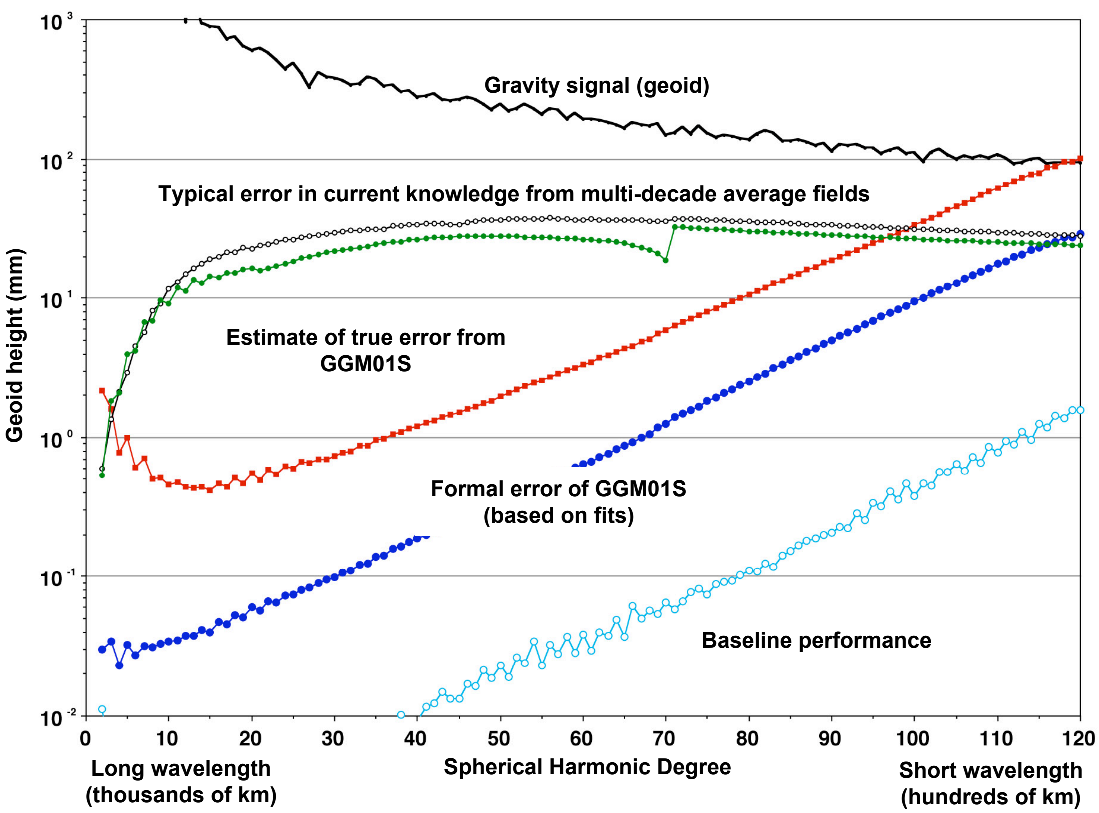

Figure 1: Estimated degree variance and degree error variance for GGM01S and other current global gravity models (TEG4 and EGM96). The calibration of the GGM01S errors is approximate, but it is consistent with comparisons of various subset and independent solutions.

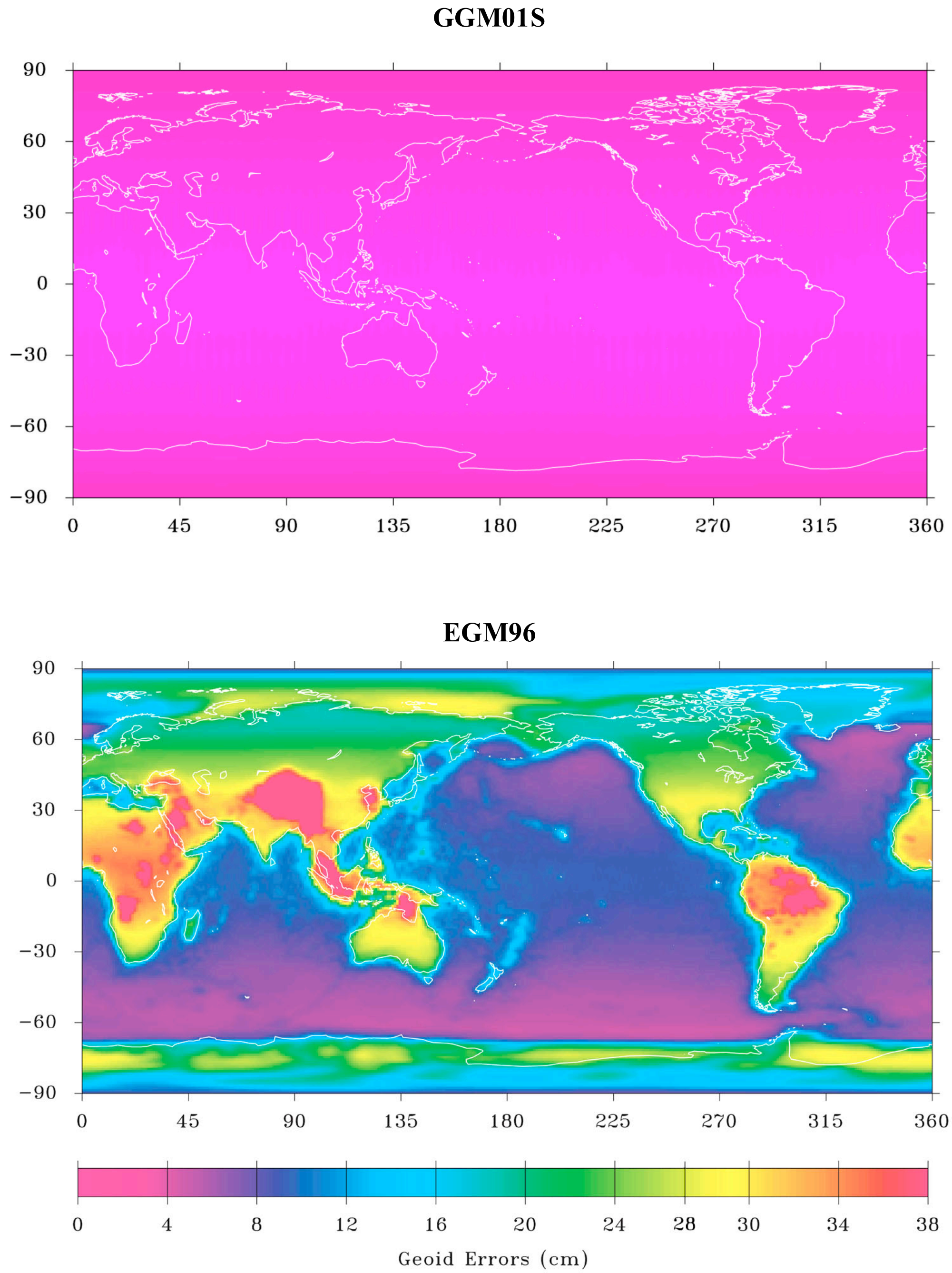

Figure 2: Geoid error predicted by the full covariance as a function of geographic location for GGM01S and EGM96 to degree and order 70 shown on the same scale. Due to the global, homogeneous nature of the GRACE data, the resulting geoid errors show no discrimination between land or sea (upper panel) as do previous gravity models (lower panel). The GGM01S geoid is estimated to be accurate to approximately 2 cm to degree and order 70 (300 km resolution) and 6 cm to degree and order 90 (200 km resolution).

Additional notes on the GGM01 gravity field solution and background modeling:

C20, C00, C10, C11, S11

C20 is a zero-tide value, *i.e.* it includes the zero-frequency (permanent) tide contribution; to convert to a tide-free system, add 4.173×10^{-9}. Its epoch is 2000, and a rate of C20_dot = $+1.162755 \times 10^{-11}$/year (J2_dot = -26×10^{-12}/year) was employed.

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.

Rotational deformation was modeled using IERS2000 conventions:

Based on the new mean pole series, we have for the mean pole and rates:

Xp_mean = 0.054 arcsec at epoch 2000
Yp_mean = 0.357 arcsec at epoch 2000
Xp_mean_dot = 0.00083 arcsec / year
Yp_mean_dot = 0.00395 arcsec / year

C21/S21:

C21 and S21 were estimated; they were not fixed to the IERS2000 standard values. They are epoch 2000 values. The following rates were employed, which are based on the above mean pole rates (from the IERS2000 standards):

C21_dot = -0.337×10^{-11} / year
S21_dot = $+1.606 \times 10^{-11}$ / year

Coefficient file description:

The coefficients for GGM01S and GGM01C are normalized (in accordance with conventions described Appendix A in the 1997 NRC Report – this is also the so-called "fully-normalized" convention, where the squared norm of a spherical harmonics over a unit sphere is 4π). The 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 (they are the same as the standard used for JGM-3 and EGM96).

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)

Gridded surface file description:

In addition to the geopotential coefficients, two gridded surfaces are also provided as geodetic latitude, longitude, and value(s) at the latitude and longitude. Both surfaces are provided at a 1-degree resolution.

1) GGM01S.GRID is a text file with a grid of the dynamic ocean topography (computed as CSRMSS98-GGM01S). Both fields are computed from spherical harmonics truncated to degree/order 90. For this calculation, the GGM01S geoid is converted to the mean-tide system,

via a change to C20 (to be consistent with the mean sea surface). Values are provided only over the ocean between latitudes of ± 65°. Because smoothing over a radius of ~500 km is suggested; a set of filtered values is also provided on the same file.

There are 6 columns:
column 1 = geodetic latitude (°N)
column 2 = longitude (°E)
column 3 = CSRMSS98 - GGM01S to 90x90 (cm)
column 4 = CSRMSS98 - GGM01S to 90x90, with additional 555 km radius Gaussian filter (cm)
column 5 = CSRMSS98 - GGM01C to 90x90 (cm)
column 6 = CSRMSS98 - GGM01C to 90x90, with additional 555 km radius Gaussian filter (cm)

2) 1) GGM01C.GRID is a grid of the geoid height calculated from GGM01C to degree and order 200. The geoid height is computed as the ellipsoidal normal distance between a reference ellipsoid (defined by Ae = 6378136.3 m, 1/f = 298.257) and the equipotential surface with the same value of W_0 as that specified for the ellipsoid (where W_0 = 62636858.57 m^2/s^2, GM = 398600.4415 km^3/s^2 and $\Omega = 0.7292115 \times 10^{-4}$ rad/sec). Some applications, such as determining dynamic topography from altimetry, have the sea surface data defined in a mean tide system and require the geoid to be in the same system.

There are 4 columns:
column 1 = geodetic latitude (°N)
column 2 = longitude (°E)
column 3 = geoid height in the zero-tide system (m)
column 4 = geoid height in the mean-tide system (m)

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