Gravity Field Model UCPH2004 from One Year of CHAMP Data using Energy Conservation

E. Howe and C. C. Tscherning
Department of Geophysics, The University of Copenhagen, Juliane Maries Vej 30, DK-2100 Copenhagen Oe, Denmark. eva@gfy.ku.dk

A gravity field model has been estimated using energy conservation and fast spherical collocation.
Here the energy conservation method is applied to calculate gravity potential values from CHAMP data measured in July 2002 – June 2003. The data are kindly provided by GFZ Potsdam and are Precise Science Orbits (PSO) and accelerometer data. On November 6 and December 9 - 10. 2002, orbit manoeuvres have been made, these periods are removed from the data set. We assume that the accuracy is the same before and after the orbit manoeuvre.
We use energy conservation to calculate height anomalies at satellite height. When doing so we consider the tidal potential corresponding to a rigid earth of the sun and the moon, the explicit time variation of the gravity potential in inertial space and friction. We subtract the earth normal potential, U, without the centrifugal term. The equation reads

$$(\tfrac{1}{2}v^2 \quad V_{moon} \quad V_{sun} \quad (xv_y \quad yv_x) \quad F \quad E_0 \quad U)/g$$

where E_0 is an integration constant.
Only the along-track accelerometer is used and therefore only friction calculated using this information is taken into account and no other non-conservative forces are included. The friction term reads $F \quad |v| a_y dt$
A scale factor has been estimated for each half day in order to calibrate the along-track accelerometer. Fast spherical collocation has then been used to estimate spherical harmonic coefficients to degree and order 90; see Figure 1 and 2.
Fast spherical collocation can be used to compute the error co-variances of the spherical harmonic coefficients. Figure 3 illustrate some typical error correlations for fixed order. The left figure is for degree 90 and order 2 and the right figure is for degree 85 and order 7. The values of the error correlations show interesting patterns. But further investigations are needed in order to explain them.

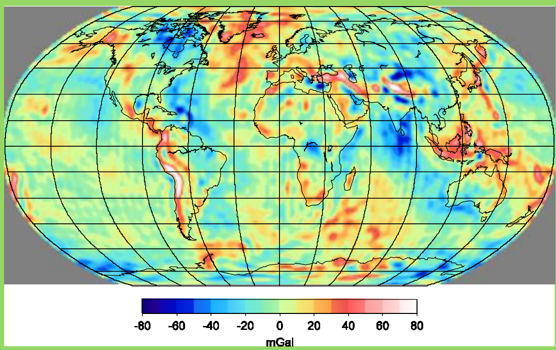

Figure 1. UCPH2004 gravity anomalies in mGal.

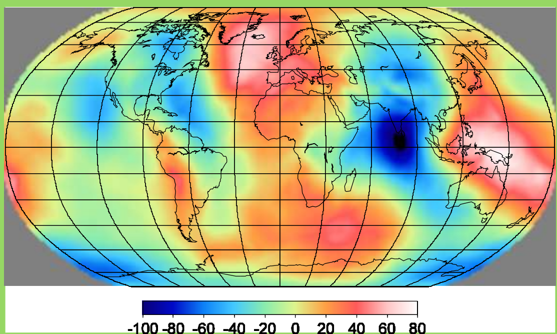

Figure 2. UCPH2004 geoid in metre.

Using general least squares collocation we use only 1% of data. This gives a factor 10 between data and coefficients determined up to degree 60. There are many ways of selecting data. In this study every 100th point is selected.
The result UCPHcoll is compared to UCPH2004 to degree 60; see Figure 4. A mean difference of **0.004 m** and a standard deviation of **0.50 m** are seen. It was not expected to give better result than UCPH2004 since less data have been used. It can be seen though that general least squares collocation gives very good results with only a small amount of data. Further investigations with larger data sets could lead to an improvement of the model UCPH2004.
Least squares collocation gives the opportunity to make a kind of a cross over analysis, where the data do not have to be in the exact same point. It is a good test of the accuracy. A bias parameter is estimated for each day, see Figure 5. It can be seen that the estimated bias parameters are close to their error estimates. This shows consistency in the technique.

The gravity field model is evaluated by comparison with EIGEN-2 and with data from the Arctic Gravity Project.
From error analysis it can be seen that there is not much information left above degree 60. The comparisons are on this basis only made using coefficients up to degree 60. UCPH2004 is compared to Eigen-2. The results are listed in Table 1 and can be seen in Figure 6.
Further analysis show that the main differences are in the polar regions. This could be due to only taking friction in the direction of the velocity vector into account and not sun pressure and cross winds, which are strongest at the poles.
A comparison between the gravity field models and data from the Arctic Gravity Project is conducted to further test the accuracy of the model. A comparison is made in an area where it is seen that the models disagree (70°N -80°N, 50°E - 70°E), see Table 2. Here UCPH2004 has a smaller mean difference to the arctic data than EIGEN-2 and a slightly better standard deviation. UCPHcoll has a very small mean difference of less than 1 mGal to the arctic gravity data but the standard deviation is bigger.

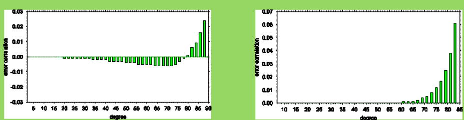

Figure 3. Typical error correlations. The left figure is for degree 90 and fixed order 2 and the right figure is for degree 85 and fixed order 7.

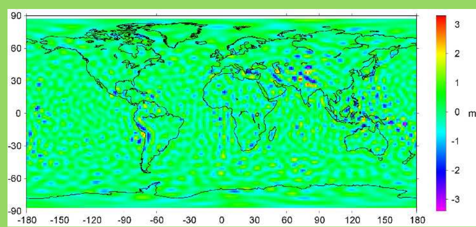

Figure 4. Geoid differences between UCPHcoll and UCPH2004 in metre. Mean difference is 0.004m and standard deviation is 0.50m.

Table 1 Differences between UCPH2004 and EIGEN-2 in metre

Mean	St.dev	Min	Max
-0.008	0.52	-2.76	-2.57

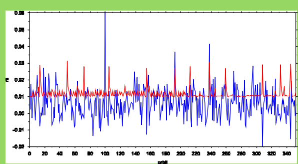

Figure 5. Bias parameters for each day (blue) and their error estimates (red).

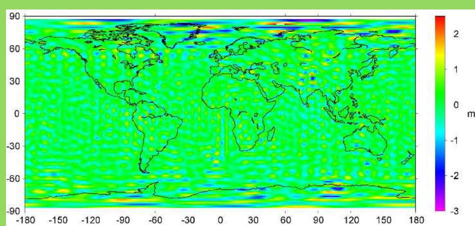

Figure 6. Geoid differences between UCPH2004 and EIGEN-2 in metre. Mean difference is -0.008m and standard deviation is 0.52m.

Table 2 Comparison with ArGP data in the region (70-80°N, 50-70°E). Units are mGal

	Mean	St.dev	Min	Max
UCPH2004	-1.42	16.11	-45.93	79.29
EIGEN-2	-3.05	16.54	-53.21	81.73
UCPHcoll	-0.63	17.11	-45.77	81.69

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Contacts:
Eva Howe, C.C. Tscherning
Department of Geophysics
Juliane Maries Vej 30
DK-2100 Copenhagen OE
eva@gfy.ku.dk

For more information about UCPH2004 and the SAGRADA project please look at
http://www.gfy.ku.dk/~eva

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