High Frequency Gravity Changes from GRACE and Comparison with Atmospheric and Oceanic Models

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Abstract

Since the launch of the GRACE (Gravity Recovery and Climate Experiment) satellites in March 2002, gravity and background models as well as data quality have been improved significantly. GRACE can provide a large amount of highly accurate and continuous GPS and K-Band Ranging (KBR) data in low orbits in just one days time. Based on such conditions, some of the low degree harmonic coefficients of the Earth's gravity field can be well determined using just one day of GRACE data. Those results can be used to access and/or detect high frequency variations in the Earth's gravity field. Because most the high frequency variations are from atmospheric and oceanic mass redistribution, the results can be used to validate and/or assess atmospheric and oceanic dealiasing models. Daily changes in gravity harmonic coefficients up to degree and order 10 were determined using GRACE data collected from August 1-31, 2003. Comparisons between the GRACE daily gravity solutions and the predictions from different atmosphere and ocean geophysical models show remarkably good agreement. In addition, the daily solutions after applying different atmosphere and ocean models are also compared and analyzed.

Background and Motivations

- Since the launch of GRACE satellite in March 2002, data quality and gravity model as well as background models have been improved significantly.

- In just one days time, GRACE can provide a large mount of highly accurate and continuous GPS and K-Band Ranging (KBR) data in low orbits with good distribution.

- Current GRACE monthly gravity solutions can be used for investigating low frequency gravity changes.

- Is it possible to determine the high frequency gravity changes (such as due to atmospheric and oceanic mass redistribution) using GRACE daily gravity solution?

Objectives

- study GRACE daily gravity solution for low-degree (10X10) Earth's gravity field

- find which coefficients can be well determined from GRACE daily solution

- investigate high frequency gravity variation in the Earth's gravity field coefficients

- compare the solutions with atmospheric and oceanic models

- evaluate atmospheric and oceanic models

Data Processing Strategies

- Dynamic orbit determination method for determining both satellite orbits and parameters for force models (such as Earth's gravity filed model)

- Selection of degree and order of estimated gravity filed based data distributions

- Test of different sub-arc lengths for once-per-revolution dynamic parameters and KBR kinematic parameters in order to get better solutions for low-degree coefficients of the Earth's gravity field

- GRACE daily gravity solutions without the atmospheric and oceanic dealiasing to validate and/or assess models through comparison the solutions with the models

- GRACE daily gravity solutions with different atmospheric and oceanic dealiasings to assess the models based on the orbits fits and daily changes

Climate Model Computation

- Atmospheric and Oceanic Dealiasing (AOD) products from GRACE project

- The products can be applied to the static gravity field during GRACE data processing to de-alias high-frequency variability

- Three different products (AOD RL01, RL03 and 95) used for dealiasing or comparison

- Model daily values obtained by averaging 6-hour time series

Comparison and Discussion

- Test Data: Aug. 1 – 31, 2003

- Test Cases:
  - -- Different ocean tide models: 1) GRC 1 (CSR 4.0); 2) GRC 2 (FES2004)
  - -- Different AOD models: 1) RL01; 2) RL03 (93v4); 3) 95 (GRGS)
  - -- Different daily solutions: 1) without AOD; 2) with AOD

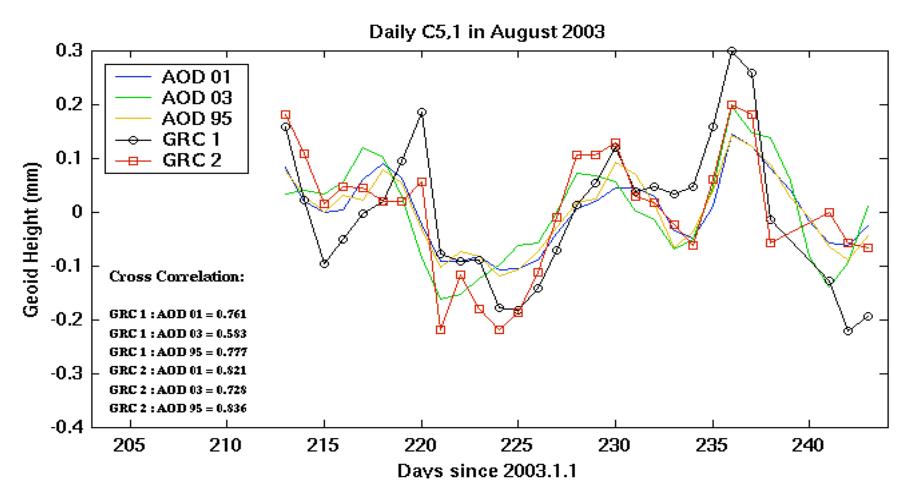

Figure 4. Comparison between different GRACE daily gravity solutions and different AOD for coefficient $C_{5,1}$

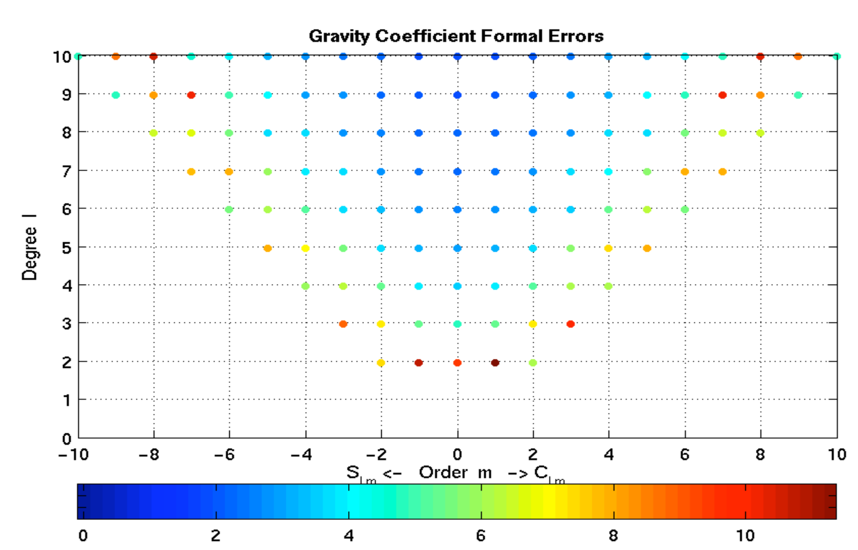

Figure 6. Formal errors for estimated harmonic coefficients from GRACE daily gravity solution

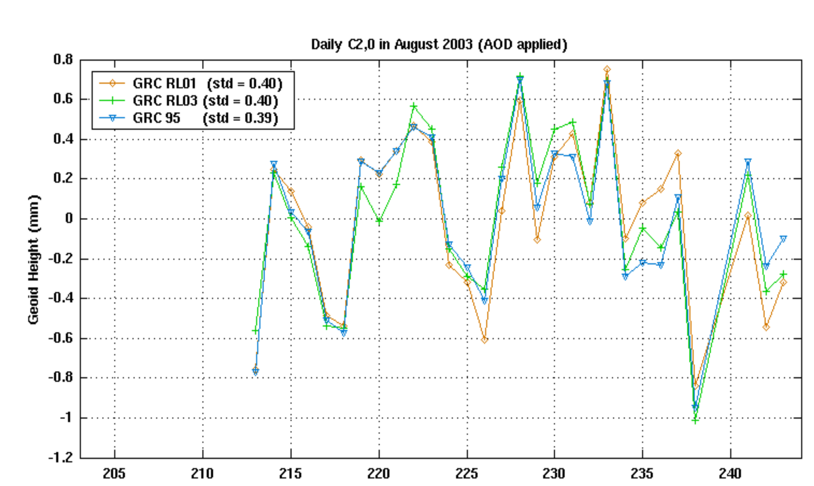

Figure 8. Gravity coefficient $C_{2,0}$ daily changes after applying AOD

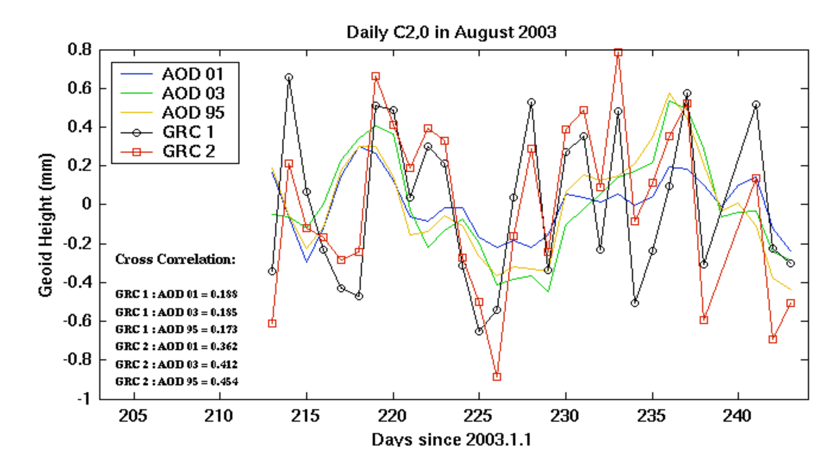

Figure 1. Comparison between different GRACE daily gravity solutions and different AOD for coefficients $C_{2,0}$

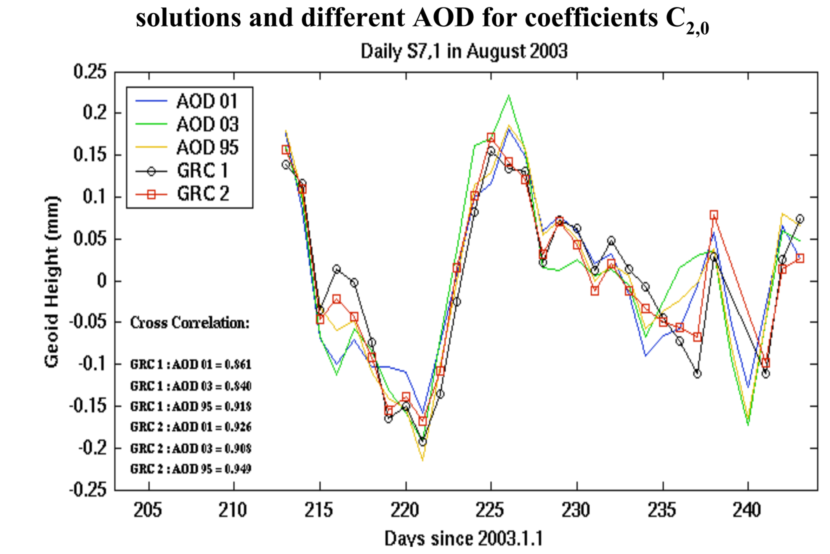

Figure 5. Comparison between different GRACE daily gravity solutions and different AOD for coefficient $S_{7,1}$

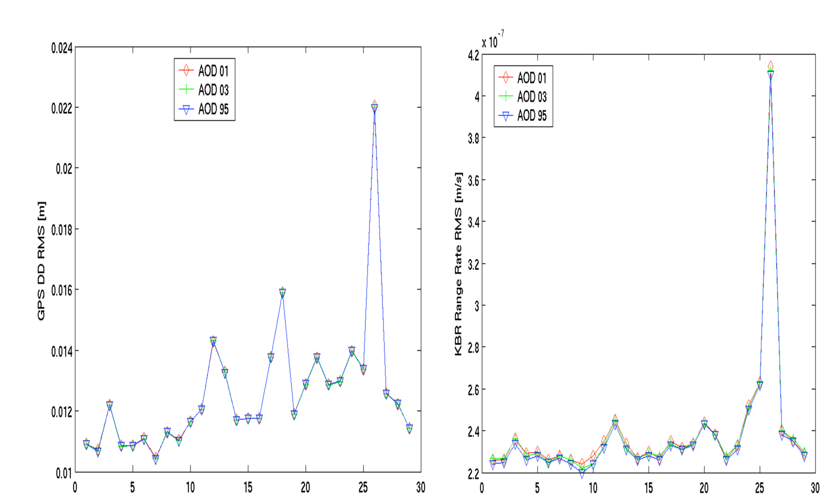

Figure 7. GRACE orbit fits for GPS DD and KBR range rate by applying different AOD models

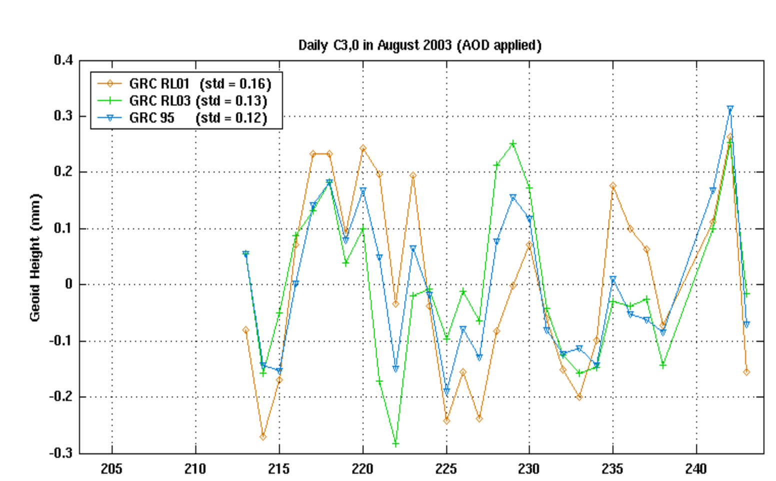

Figure 9. Gravity coefficient $C_{3,0}$ daily changes after applying AOD

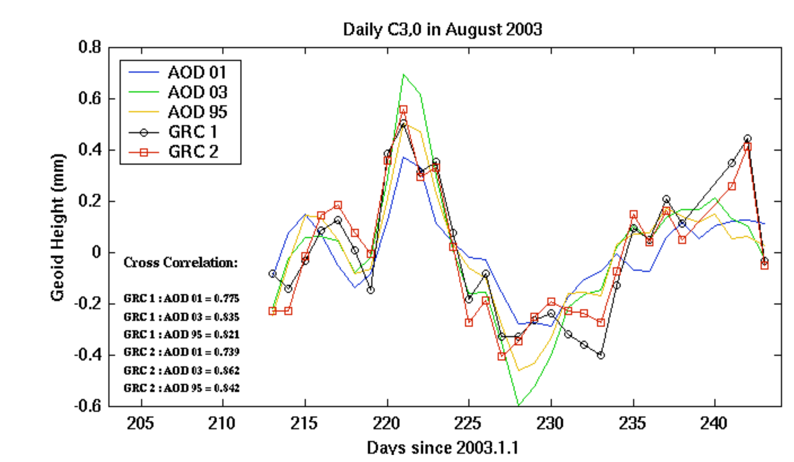

Figure 2. Comparison between different GRACE daily gravity solutions and different AOD for coefficient $C_{3,0}$

Figure 1 shows the comparison between different GRACE daily gravity solutions and different AOD for coefficients $C_{2,0}$. There is a good phase agreement, but the GRACE results have larger variability. The best case is using AOD 95 and FES2004 ocean model.

Figure 2 shows the comparison between different GRACE daily gravity solutions and different AOD for coefficients $C_{3,0}$. There are very good agreement both in phase and amplitude.

Figures 3, 4 and 5 show similar results as Figure 2.

Table 1 gives the maximum cross correlation coefficients between different GRACE daily solutions and different AOD models for $C_{l,0}$ (l=2,10). There are a large correlation coefficients for the zonal harmonic gravity coefficients except $C_{2,0}$. The most of the best cases are using AOD 95 and FES2004 ocean model. But there are only small differences between AOD RL03 and 95 models.

Table 2 shows standard deviation for zonal harmonic coefficient daily changes by applying different AOD models.

Figure 6 is the formal errors for estimated harmonic coefficients from GRACE daily gravity solution. You can see that zonal (except $C_{2,0}$) and some of order one and two terms have small formal errors. This means that those coefficients can be well determined.

Figure 7 shows the GRACE orbit fits for GPS DD and KBR range rate by applying different AOD models. Usually if you apply a good model, you can get good orbit fits. You cannot see the difference on GPS DD data (all mean RMS = 0.0126 m). But there are some differences on GRACE KBR range rate data (mean RMS 0.2398 for RL01; 0.2393 for RL03 and 0.2380 um/s for AOD 95).

Figures 8 and 9 give the gravity coefficient daily changes for $C_{2,0}$ and $C_{3,0}$ after applying AOD models. If the all used models were perfect and the solutions were good enough, there should be no changes. Therefore the changes are due to model errors in high frequency parts and uncertainty of the solutions.

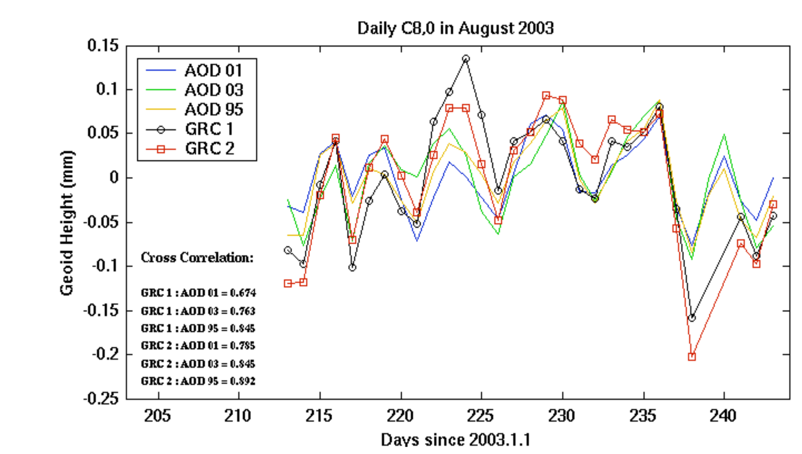

Figure 3. Comparison between different GRACE daily gravity solutions and different AOD for coefficient $C_{8,0}$

Table 1. Correlation coefficients between GRACE daily solutions and models for $C_{l,0}$ (l=2,10)

	GRC1			GRC2		
	RL01	RL03	95	RL01	RL03	95
$C_{2,0}$	0.19	0.18	0.17	0.36	0.41	0.45
$C_{3,0}$	0.75	0.83	0.82	0.73	0.86	0.84
$C_{4,0}$	0.89	0.91	0.90	0.89	0.91	0.93
$C_{5,0}$	0.67	0.65	0.72	0.80	0.82	0.91
$C_{6,0}$	0.79	0.72	0.83	0.79	0.73	0.82
$C_{7,0}$	0.84	0.76	0.80	0.83	0.85	0.88
$C_{8,0}$	0.67	0.76	0.84	0.78	0.84	0.89
$C_{9,0}$	0.87	0.89	0.94	0.87	0.91	0.94
$C_{10,0}$	0.81	0.83	0.89	0.76	0.89	0.87

Table 2. Standard deviation [mm] for zonal harmonic coefficient changes by applying different AOD models

Coefficient	RL01	RL03	95
$C_{2,0}$	0.40	0.40	0.39
$C_{3,0}$	0.16	0.13	0.12
$C_{4,0}$	0.12	0.09	0.08
$C_{5,0}$	0.08	0.06	0.05
$C_{6,0}$	0.06	0.06	0.05
$C_{7,0}$	0.03	0.03	0.02
$C_{8,0}$	0.04	0.04	0.03
$C_{9,0}$	0.03	0.02	0.02
$C_{10,0}$	0.04	0.03	0.02

Summary and Conclusions

The GRACE daily gravity solution for 10X10 Earth's gravity filed model has been carried out. From the formal errors of estimated coefficients and comparison with the computed coefficients from AOD models, we know that the zonal harmonic coefficients (except $C_{2,0}$) and some of order one and two terms can be well determined from the GRACE daily gravity solution.

The accuracy of some estimated coefficients is the same as the atmospheric and oceanic models based on the different GRACE daily gravity solutions and comparison between different AOD models.

Comparison between the GRACE daily gravity solutions and the predictions from different atmosphere and ocean geophysical models shows remarkably good agreement.

GRACE KBR range rate measurements are accurate enough to evaluate AOD models. According to the orbital fits, standard deviations of gravity coefficient daily changes and comparison between the GRACE daily gravity solution and models, AOD RL03 and 95 models are better than RL01, and 95 is little better than RL03.