Gravity Field Determination at AIUB: From CHAMP and GRACE to GOCE

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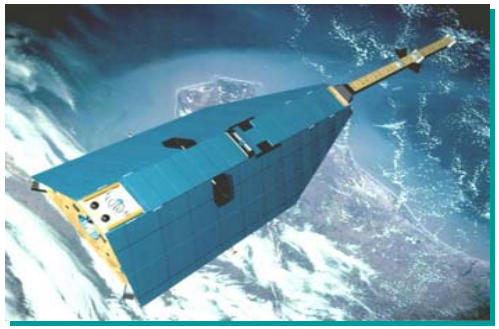
AIUB
Astronomical Institute
University of Bern

9th
Swiss
Geoscience
Meeting

Zurich
Switzerland

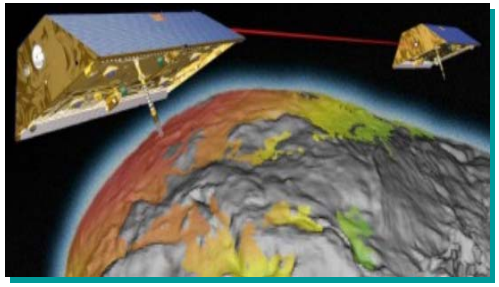
Nov. 11-13

Introduction



CHAMP gravity field recovery using GPS hl-SST

- least-squares adjustment **w/o** empirical error models
- static field (augmented with GOCE GPS)
- time variations (?)



GRACE gravity field recovery using K-band ll-SST

- least-squares adjustment **w/o** empirical error models
- static field
- time variations

GOCE gravity field recovery using gradiometry

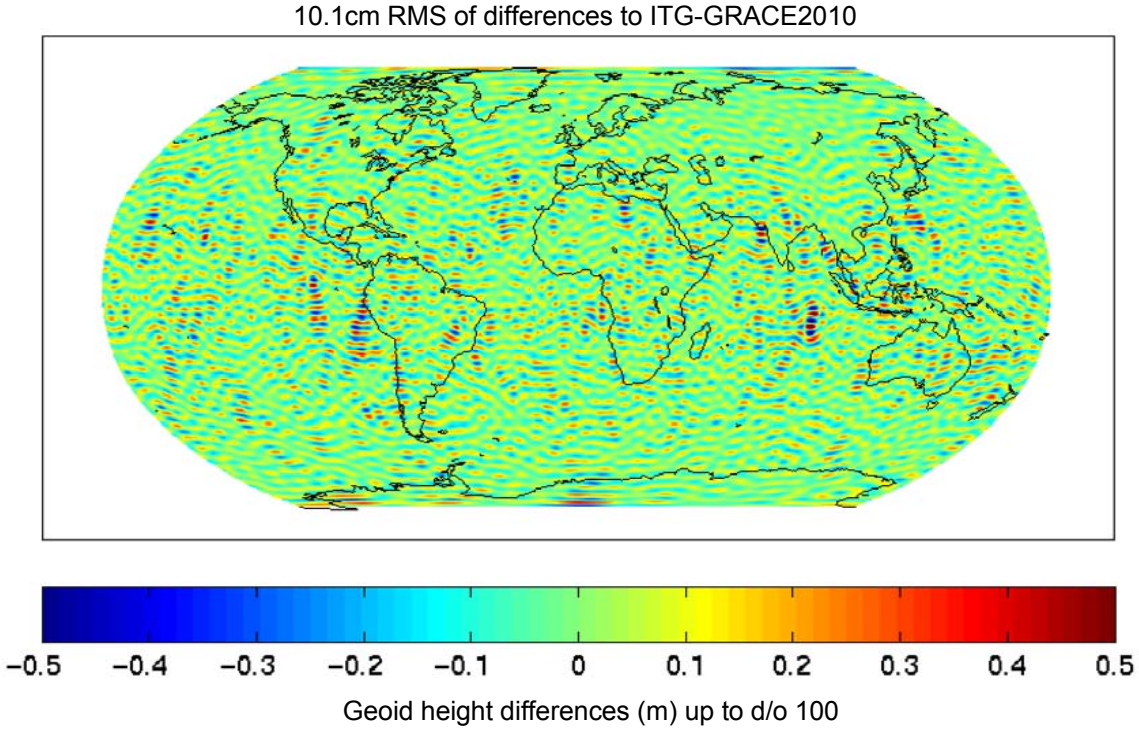
- least-squares adjustment **with** (?) empirical error models
- static field
- no time variations

All solutions are computed without applying any regularization

hl-SST-only solutions

Static fields up to degree 120

- GOCE GPS hl-SST data allows it to significantly improve the quality of the „high“ degrees wrt a CHAMP-only gravity field solution



Reference field:

ITG-GRACE2010

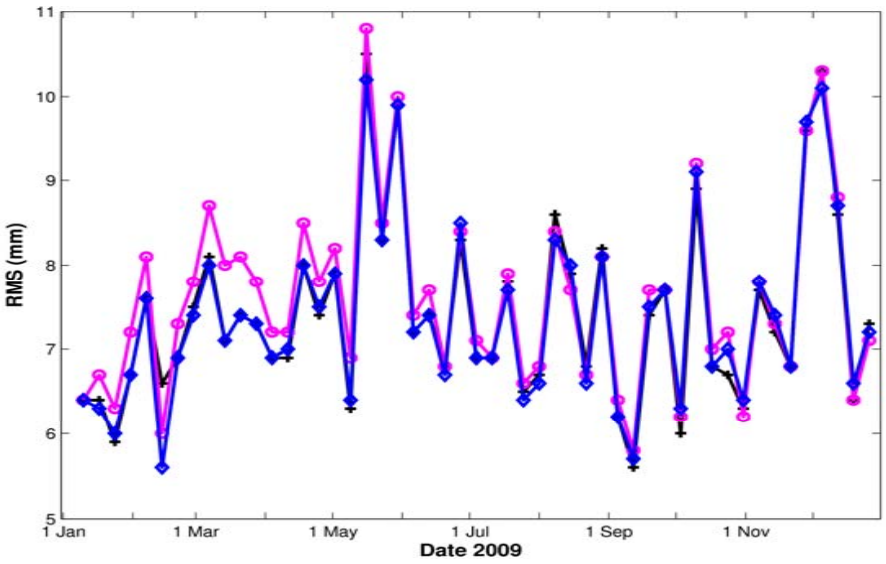
Differences:

CHAMP & GOCE
(8 years & 1.7 years)

- the quality of the low to medium degree coefficients is confirmed by external validations

hl-SST-only solutions

Validation up to degree 60



RMS (cm)	EIGEN 5S	ITG 03S	ITG 2010	AIUB CHAMP	GOCE only	CHAMP GOCE
Australia (GPS)	13.2	13.2	13.2	13.3	13.2	13.1
Germany (EUVN)	1.7	1.6	1.8	2.0	1.9	1.8
Germany (GPS)	2.0	2.0	1.9	2.1	2.1	2.0
Canada (GPS)	8.4	8.5	8.7	8.7	8.0	8.6
EUREF (GPS)	8.9	8.9	9.1	9.0	8.9	9.0
Japan (GPS)	5.9	5.9	5.9	5.8	6.1	5.8

LAGEOS SLR data

Even a slightly better performance for the combined SST-only model than for the GRACE-based models

ITG-GRACE2010 7.60mm

EIGEN-GL04C 7.40mm

CHAMP & GOCE 7.39mm

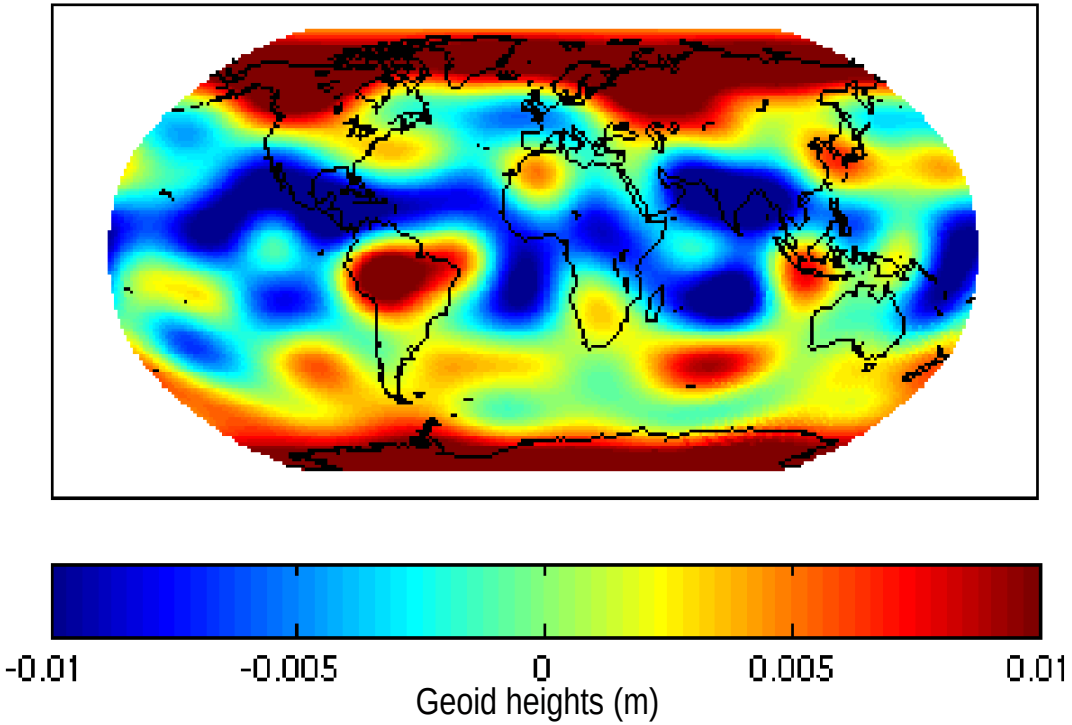
Terrestrial Data

Similar validation results for the combined SST-only model as for the GRACE-based models, especially also for the high-quality data sets from Germany

hl-SST-only solutions

Time variability from CHAMP (1)

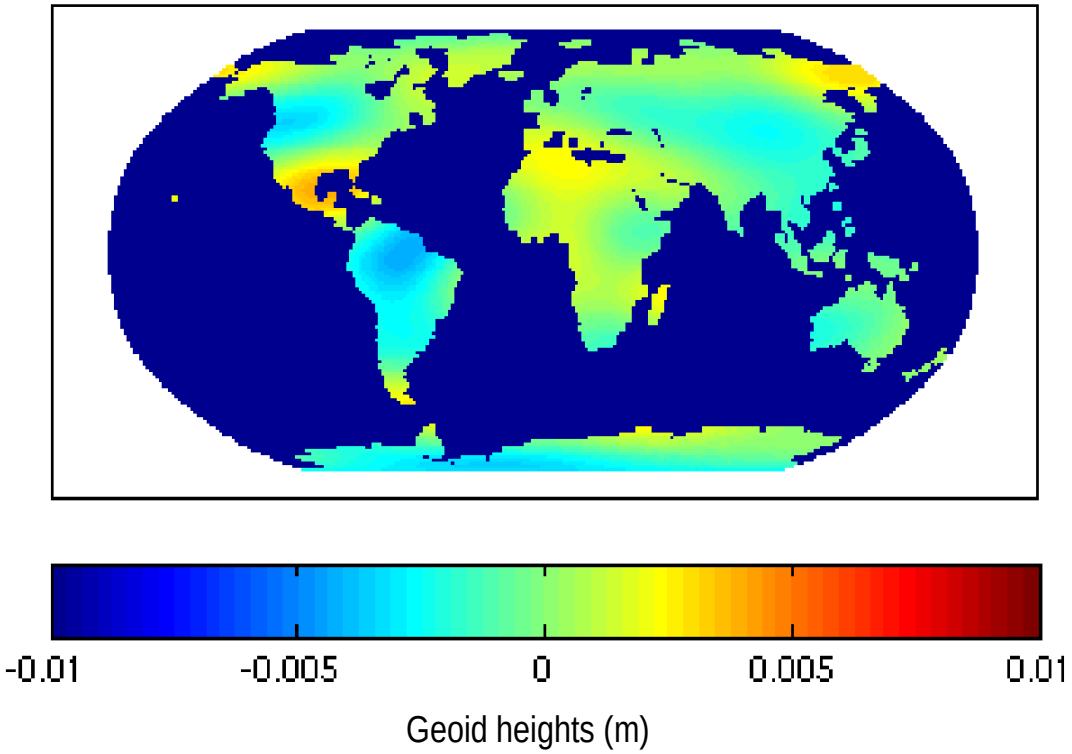
- a single monthly CHAMP solution does not really look very promising …



- … but a long time series of data allows it to either
  - solve for periodic and trend functions, or to
  - „stack“ monthly solutions (each January, each February, etc.), and to apply significance tests (up to d/o 10)

hl-SST-only solutions

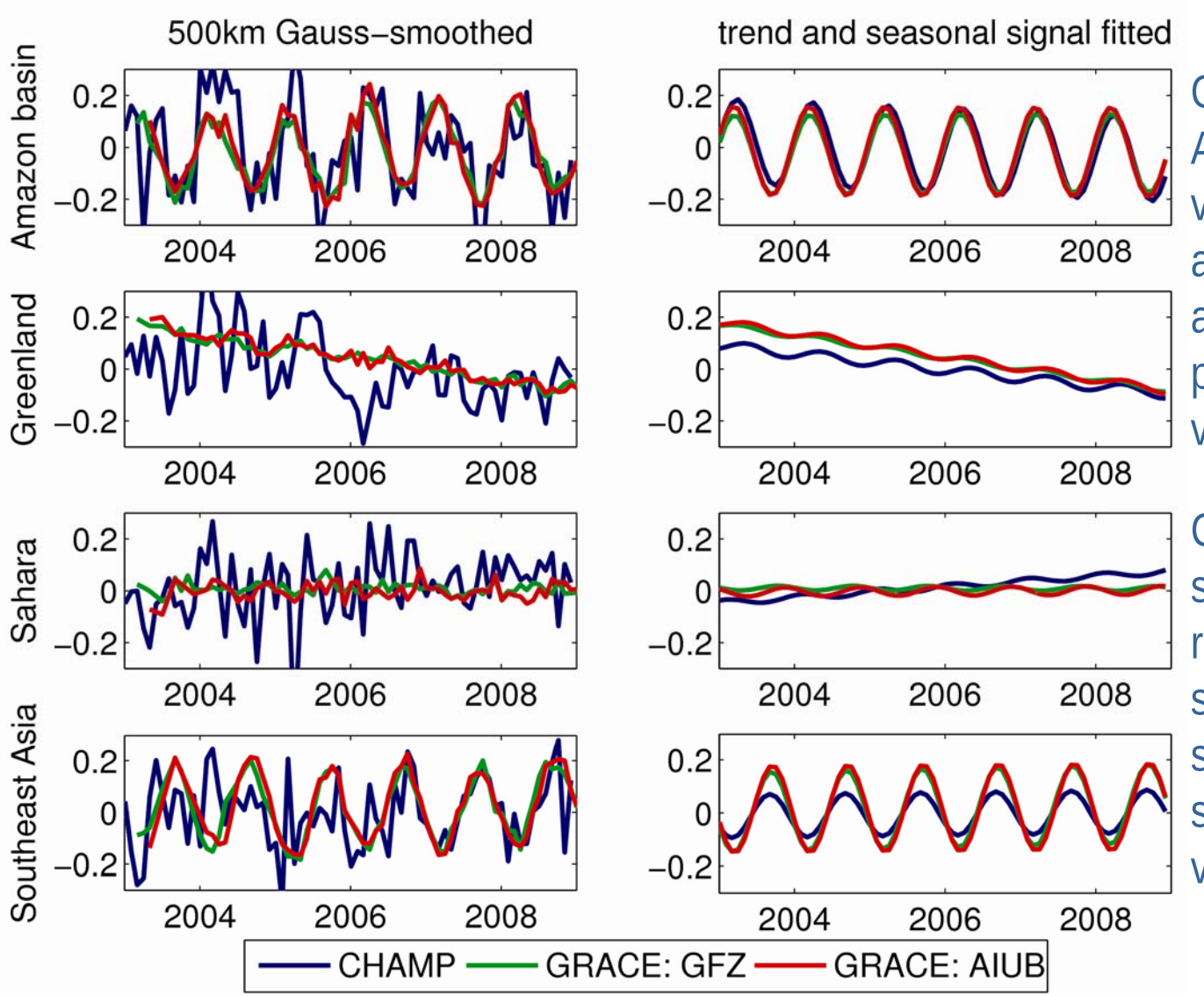
Time variability from CHAMP (2)



Most pronounced time variable signals may be extracted from CHAMP data

Comparison of time variability

Variations at selected locations from CHAMP vs. GRACE

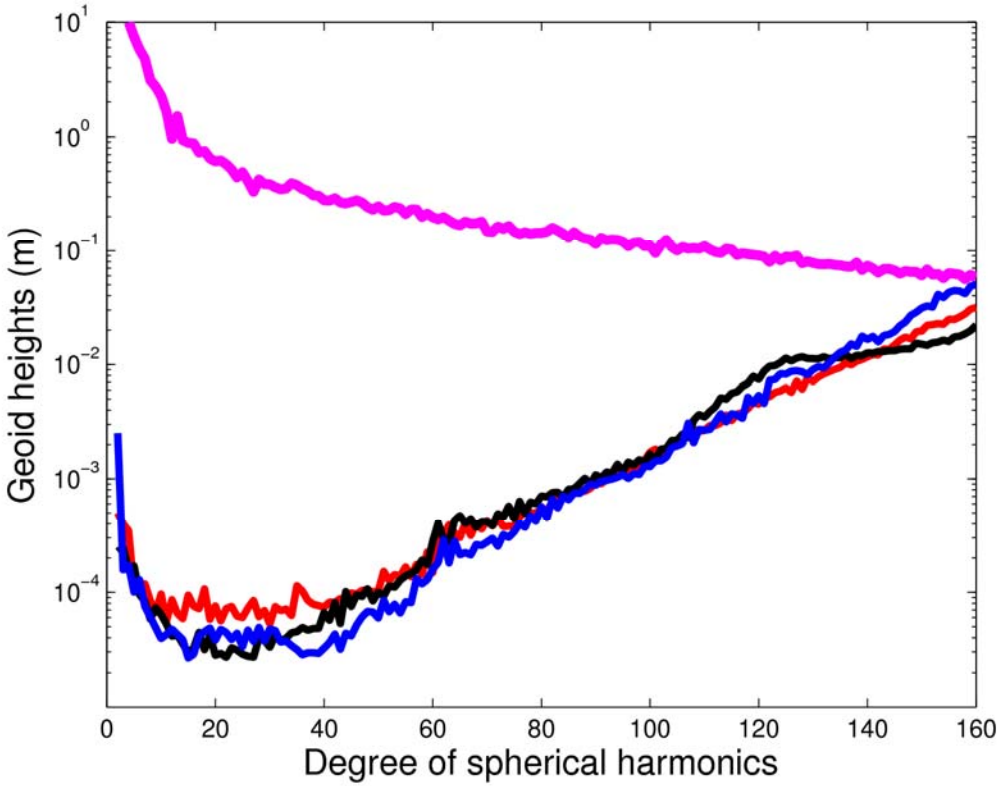


GFZ and AIUB show a very good agreement in amplitude and phase of the variations

CHAMP shows a remarkable sensitivity to seasonal and secular mass variations.

GRACE K-band solutions

AIUB-GRACE03S based on 6 years of data



Reference field:

ITG-GRACE2010

Differences:

ITG-GRACE03S

EIGEN-51C

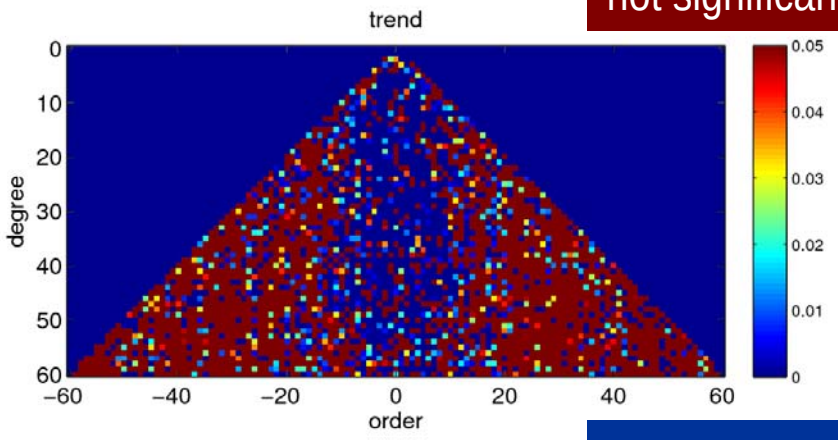
AIUB-GRACE03S

- classical least-squares solution with simultaneously estimated time variations (trends, annual and semi-annual terms up to d/o 30)
- C_{20} cannot be reliably estimated from GRACE K-band data

GRACE monthly solutions

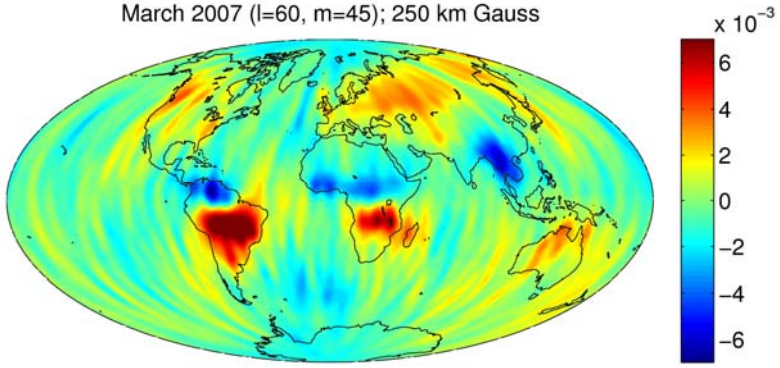
- monthly solutions up to degree 60, background model AIUB-GRACE03S (static part only)
- secular and seasonal variations may be fitted a posteriori to the monthly solutions for analysis
- significance tests for seasonal parameters and trends show sensitivity up to degree 60, but only to a reduced order
- coefficients beyond order 45 are not further estimated, leading to fewer stripes at small smoothing radii

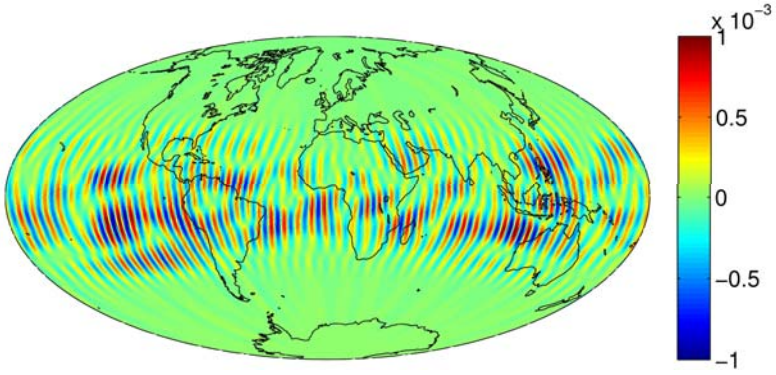
not significant



significant

Effect of orders > 45

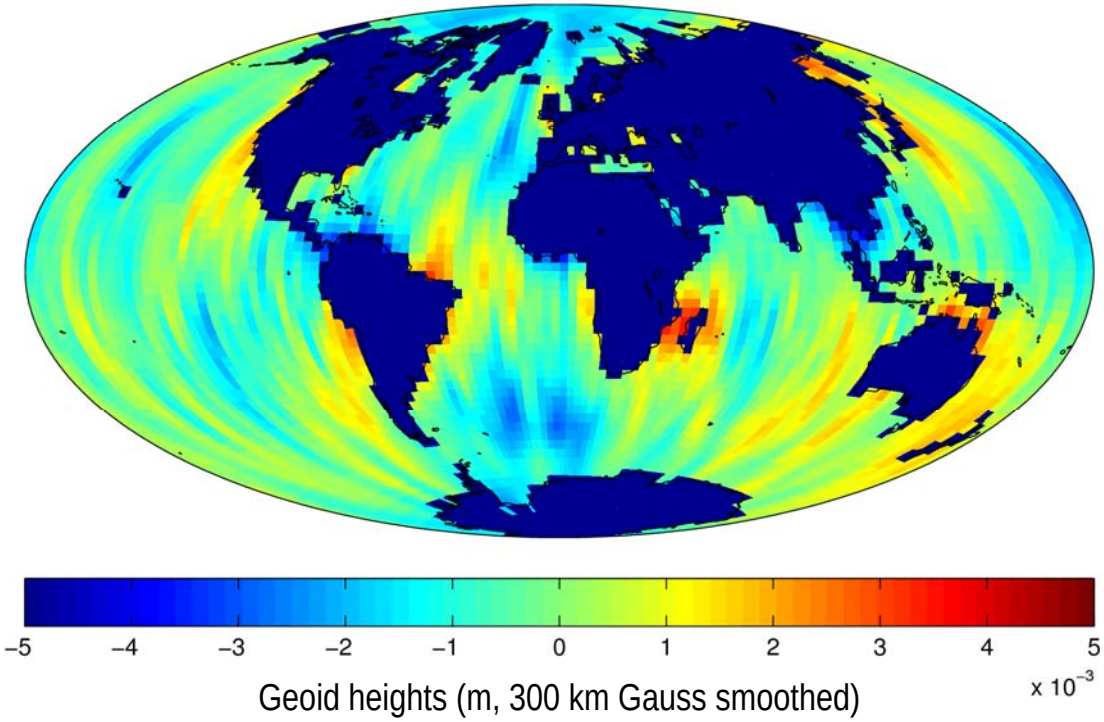




GRACE monthly solutions

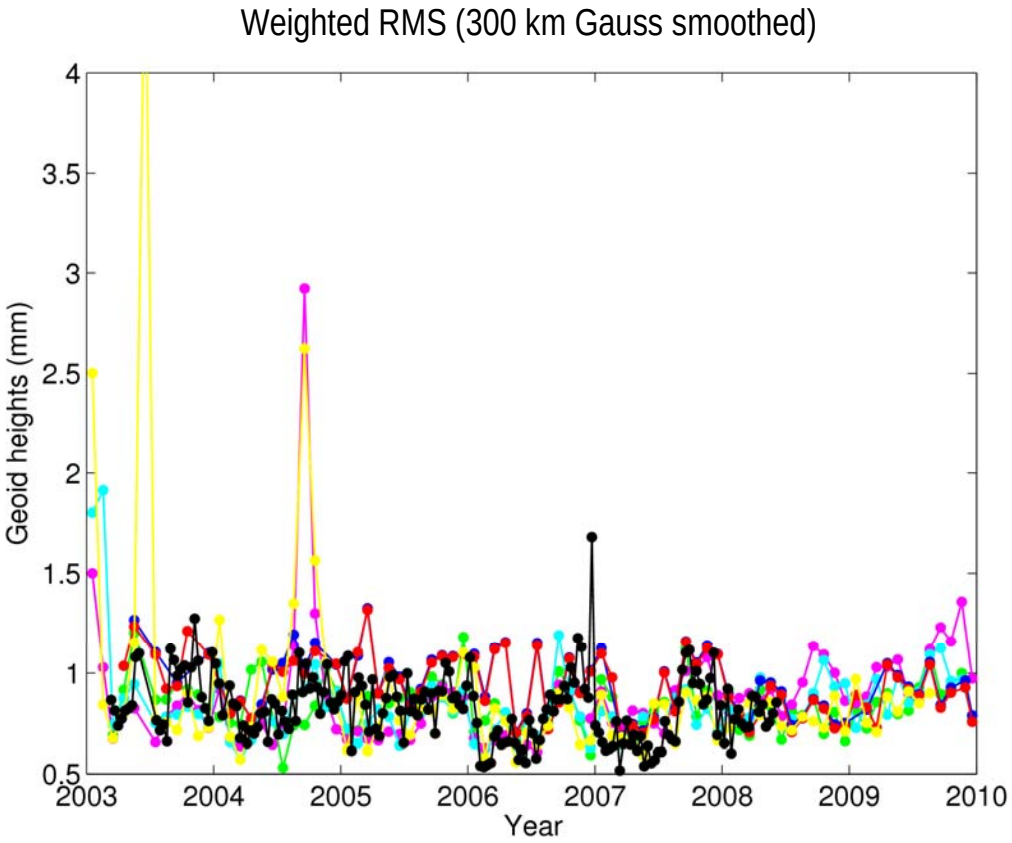
Variability over the oceans

- weighted RMS of the variability over the oceans may be used to compare the quality of the monthly solutions in a simple way



GRACE monthly solutions

Variability over the oceans



60 x 60:

- GFZ
- JPL
- CSR
- AIUB
- ITG

60 x 45:

- AIUB

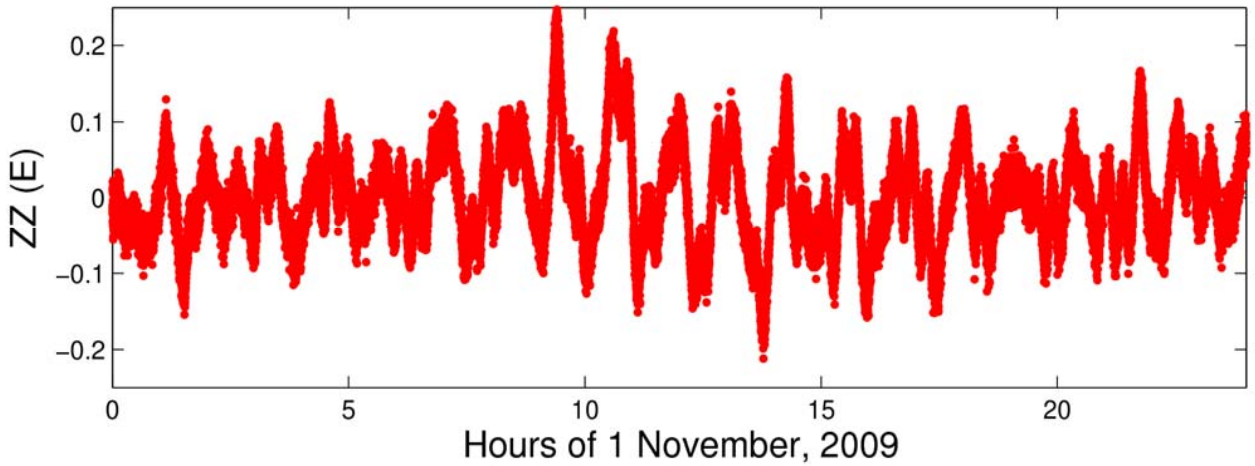
50 x 50:

- GRGS

GOCE gradiometer analysis

GOCE processing strategy (1)

- as opposed to other solutions we use parametric techniques to account for the characteristics of the gradiometer measurements

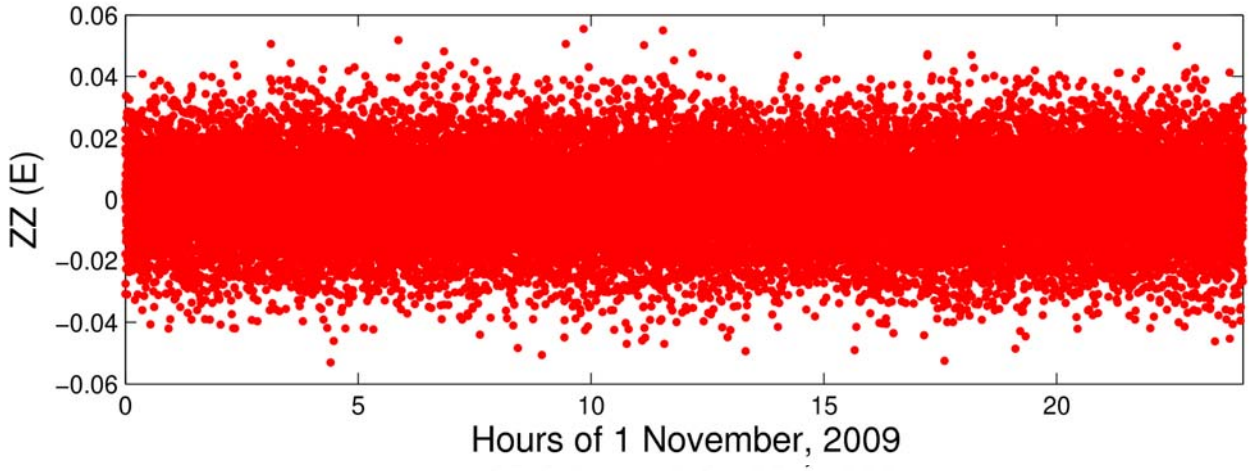


- for each gradiometer component the following parameters are set up (in addition to the SH coefficients up to degree 160)
  - one offset and one drift parameter per day
  - once-, twice-, and three-times-per-rev (-day) parameters per day
- the empirical parameters are pre-eliminated before accumulating the daily normal equations (NEQs) to a combined system

GOCE gradiometer analysis

GOCE processing strategy (2)

- in addition parameters of a piecewise linear and continuous function are set up for each gradiometer component with a spacing of 1min

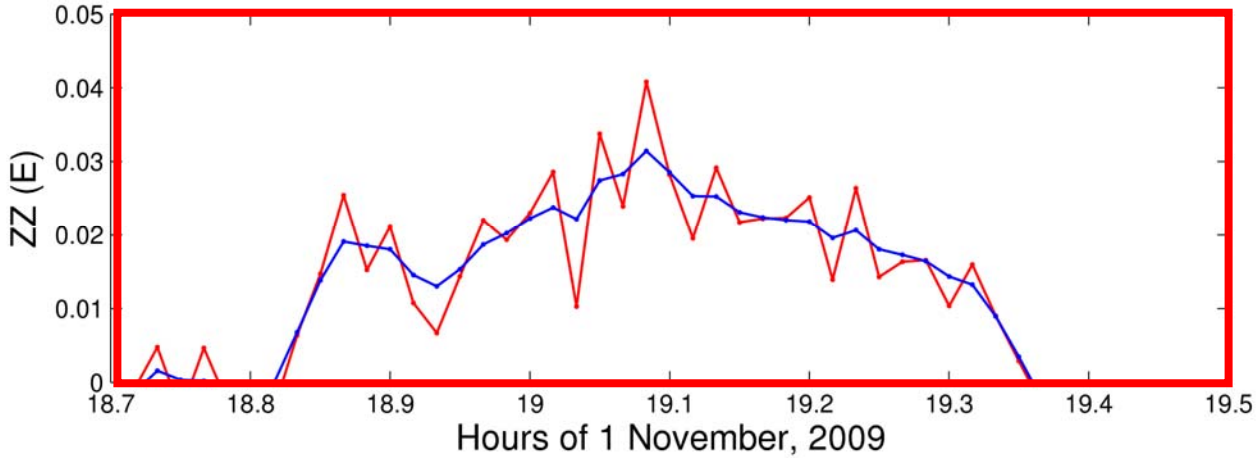


- setting up offset, drift, etc., and the piecewise linear parameters p_i results in a singular NEQ system. The singularity may be removed by
  - pseudo-observations $p_i = 0$ with weights of the order $(\sigma_0 / \sigma_i)^2$
  - σ_0 and σ_i are the user-defined values for the a priori standard deviations of the gradiometer data and the parameters p_i
- the most pronounced signals outside the gradiometer measurement bandwith are captured with this parametrization

GOCE gradiometer analysis

GOCE processing strategy (3)

- a solution is said to be free, if constraints are only set up to remove the singularities



- the free solution may be used to calculate empirical covariances (over user-defined time intervals) associated with the
  - residuals of the gradiometer observations of the free solution
  - piecewise linear parameters p_i of the free solution
- these covariance matrices improve the error model for the gradiometer solution, if introduced in a subsequent solution

GOCE gradiometer analysis

55 days of ZZ data, 3-sec sampling

$$\begin{pmatrix} A_1^T A_1 & A_1^T A_2 \\ A_2^T A_1 & A_2^T A_2 \end{pmatrix} \begin{pmatrix} x \\ p \end{pmatrix} = \begin{pmatrix} A_1^T l \\ A_2^T l \end{pmatrix}$$

free

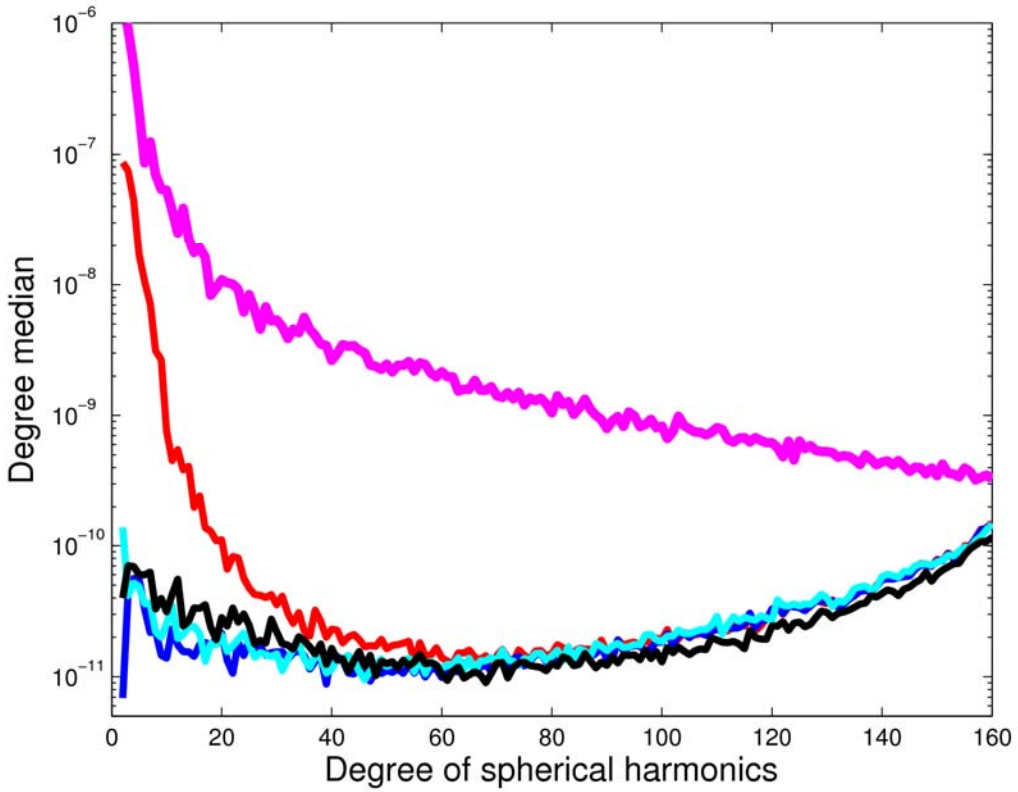
$$\Rightarrow \begin{pmatrix} A_1^T A_1 & A_1^T A_2 \\ A_2^T A_1 & A_2^T A_2 + P \end{pmatrix} \begin{pmatrix} x \\ p \end{pmatrix} = \begin{pmatrix} A_1^T l \\ A_2^T l \end{pmatrix}$$

cov (param. p_i)

Very flexible handling of emp. covariances on the level of normal equations

GOCE gradiometer analysis

71 days of XX, YY, ZZ data, 1-sec sampling



Reference field:

ITG-GRACE2010

Differences:

Gradio-only

Gradio & GPS

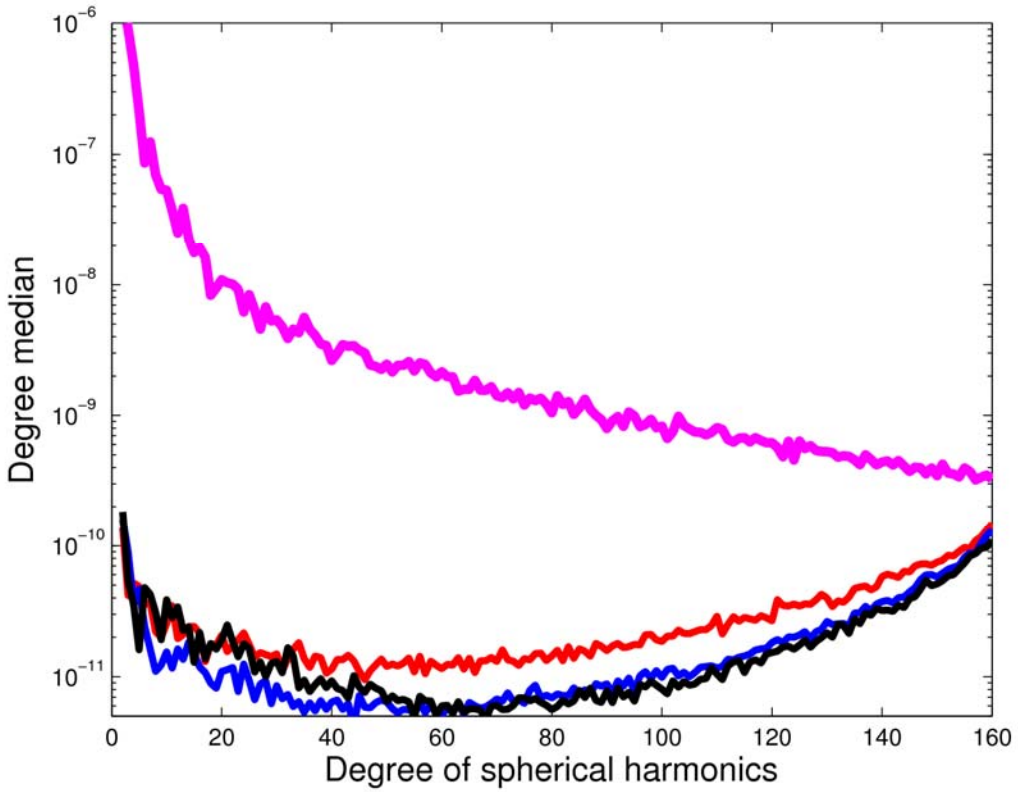
constr. 2nd deriv.

Time-wise solution

Promising performance compared to the time-wise model from release-1

GOCE gradiometer analysis

Impact of data accumulation, 1-sec sampling



Reference field:

ITG-GRACE2010

Differences:

AIUB (2 months)

AIUB (8 months)

Time-wise solution

Similar performance as the time-wise model from release-2

Conclusions

- High-quality SST-only solutions may be computed with CHAMP and GOCE GPS data
  - CHAMP even allows to recover the most pronounced time variable signals due to the long data series available
- GRACE static solutions up to degree and order 160 are computed with simultaneously solved for time variations
  - Based on sensitivity analyses the monthly fields are solved up to degree 60 and order 45
- GOCE static solutions based on a parametric approach are so far computed up to degree and order 160
  - Empirical covariances are either derived from the residuals of the free solution, or from the piecewise linear parameters co-estimated with the free solution. A similar performance may be obtained by constraining subsequent differences of piecewise linear parameters