REeal data AnaLysis GOCE

Gravity field determination from GOCE

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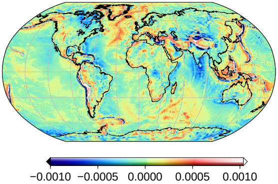
BMBF Geotechnologien Statusseminar:
„Erfassung des Systems Erde aus dem Weltraum III“

Potsdam, 24/05/2012

Motivation

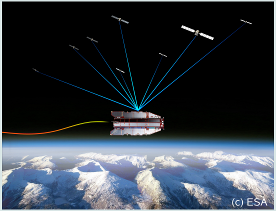
Aim:

Determination of a gravity field with high accuracy and resolution.



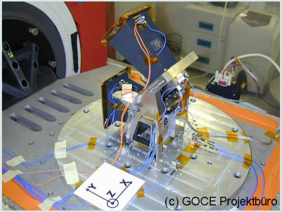
Sensors for gravity field determination:

GPS tracking (SST)

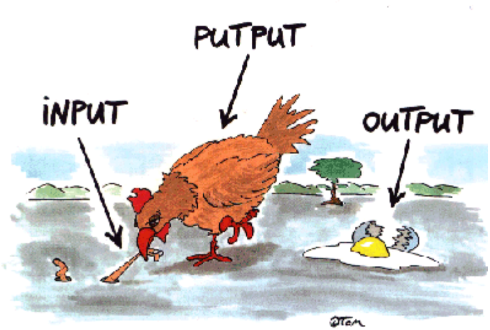


Gradiometry (SGG)

star tracker (STR)



From observations to the gravity field within REAL GOCE



Input:
GOCE observations

Putput:
Gravity field analysis

Output:
Gravity coefficients
+ accuracies

GOCE observations

GOCE observations:

gravity gradients

orbit + accuracies

orientation

Satellite-gravity-gradiometry (SGG) observations:

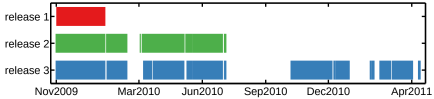
- calibrated gravity gradients $V_{ij}, i, j \in \{\text{x,y,z}\}$
- source: ESA HPF/EGG-C

Satellite-to-Satellite tracking (SST) observations:

- kinematic precise orbits (GPS Code/Phase observations)
- source: ESA HPF/EGG-C or REAL GOCE (IGG-APMG)

GOCE observations

Available SGG Data:



- increasing number of data: $\sim$ 2, 6, 12 months
- sampling rate: 1 sec.

Problems:

- number of observations: 30 Mio. per component
  - $\Longrightarrow$ required memory: e.g. $\boldsymbol{A} \sim 15$ Terabyte
  - $\Longrightarrow$ time-consuming estimation: ~ 1000 Tage

Observation equation

$$\boldsymbol{\ell}_{[30\text{ Mio.}\times 1]} + \boldsymbol{v} = \boldsymbol{A}_{[30\text{ Mio.}\times 63.000]}\boldsymbol{x}$$

Solutions:

- tailored algorithms
- iterative, massive parallel software
- computation on supercomputers
- downsampling (e.g. IGG-APMG: 5 sec.)

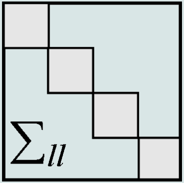
GOCE observations

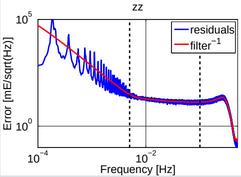
Spectral characteristics of SGG noise:

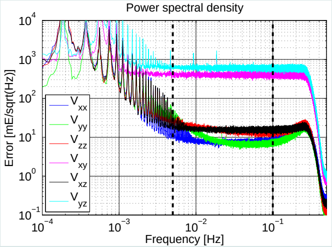
- observations per component are highly correlated
- two gradient components with very high noise levels (V_{xy}, V_{yz})

Problems:

- covariance matrix is fully occupied
- memory requirements per component: 7 PetaByte







Stochastic model

$$\Sigma\{\mathcal{L}\} = \Sigma_{[30\ \text{Mio.} \times 30\ \text{Mio.}]}$$

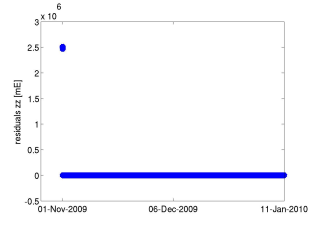
Solutions:

Decorrelation with ...

- digital, discrete filters
- empirical covariance matrix for data segments, independence of segments

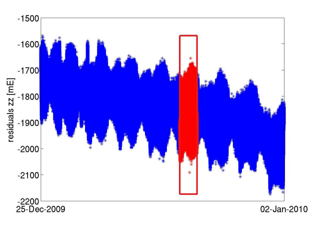
GOCE observations

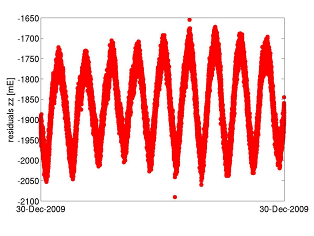
Local characteristics of SGG data: Outliers



Problems:

- noise has a high amplitude and a trend
  - ⟹ outliers not obviously
  - ⟹ automatic search not possible
- robust least squares solution require a datenscreening

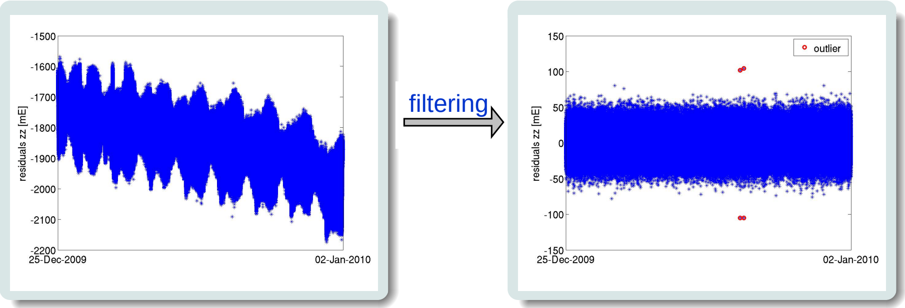




Local characteristics of SGG data: Outliers

Solution:

- filtering with a high-pass filter (e.g. differentiation filter):
  - elimination of the trend
  - outliers are visible $\Longrightarrow$ automatic search possible
  - temporal chances are visible



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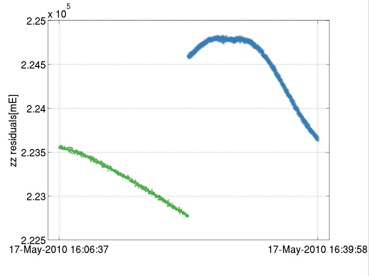
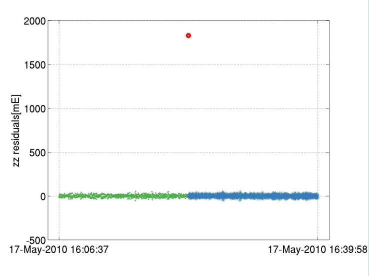
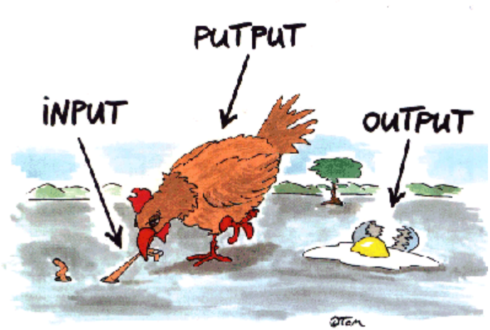


filtering





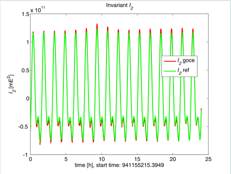
Input:
GOCE observations

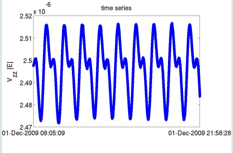
Putput:
Gravity field analysis

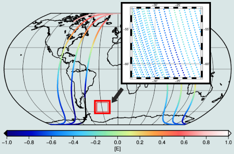
Output:
Gravity coefficients
+ accuracies

SGG - deterministic model:

1. *Invariants Approach (GIS):*
   - rotational invariants of the gradient tensor e.g. $I_2 = \frac{1}{2}(V_{xx}^2 + V_{yy}^2 + V_{zz}^2) - V_{xy}^2 - V_{xz}^2 - V_{yz}^2$
   - invariants as equidistant, gap-less time-series
   - global representation
2. *Time-Wise Approach (IGG-TG):*
   - V_{xx}, V_{yy}, V_{zz} as 2nd derivative of potential in GRF
   - gradients as equidistant, gap-less time-series
   - global representation
3. *Short-Arc Approach (IGG-APMG):*
   - V_{xx}, V_{yy}, V_{zz} as 2nd derivative of potential in GRF
   - analysis of short arcs ($\sim$ 15 min.) with 5 sec. sampling
   - global and local representation

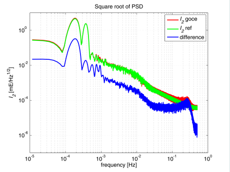






SGG - stochastic model:

1. *Invariants Approach (GIS):*
   - decorrelation by digital MA filter cascades
   - filters are adjusted to invariants



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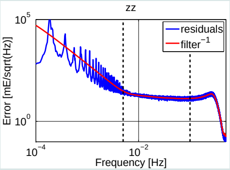
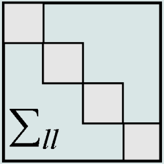


3. *Short-Arc Approach (IGG-APMG):*
   - full variance covariance information per short arc
   - arcs are independent
   - arc-wise reweighting of observations



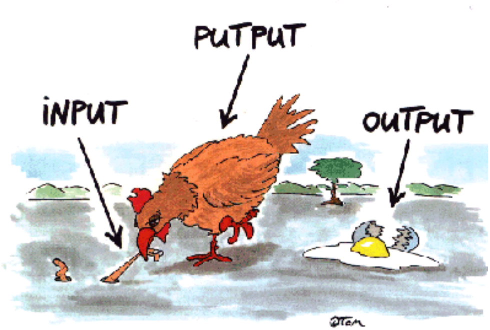
Links within REAL GOCE

Cooperations within the gravity field processing groups:

- **IGG-TG $\Longrightarrow$ GIS:** filter adjustment by invariants
- **IGG-TG $\Longleftrightarrow$ IGG-APMG:** stochastic model analysis, filter vs. covariance function per arcs
- **ALL $\Longrightarrow$ ALL:** outlier information, quality information on gradients
- **ALL $\Longrightarrow$ ALL:** validation of results

Cooperations with other groups within REAL GOCE:

- **IGG-APMG $\Longrightarrow$ WP 150 (KIT):** use of topographic-isostatic reduction of GOCE gravity gradients
- **IGG-APMG/IGG-TG $\Longrightarrow$ WP 310 (BKG) :** validation of gravity fields
- **IGG-TG $\Longrightarrow$ WP 110 (IAPG/DGFI):** validation of reprocessed SGG data
- **All $\Longrightarrow$ WP 220 (IFM) :** application of gravity models to ocean circulation studies



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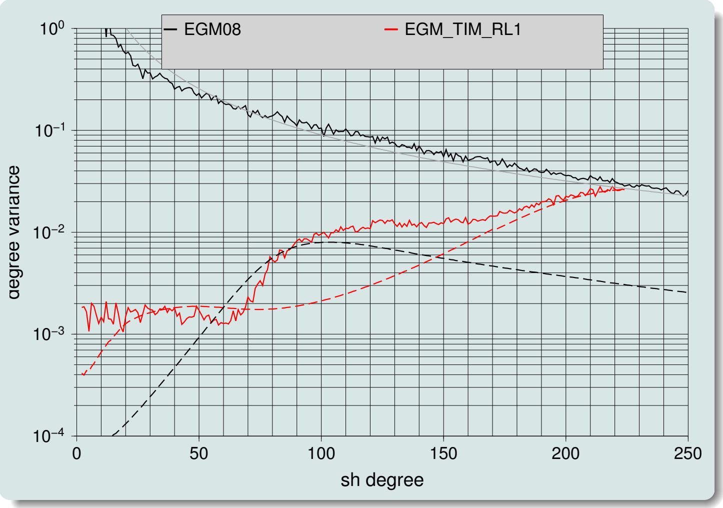
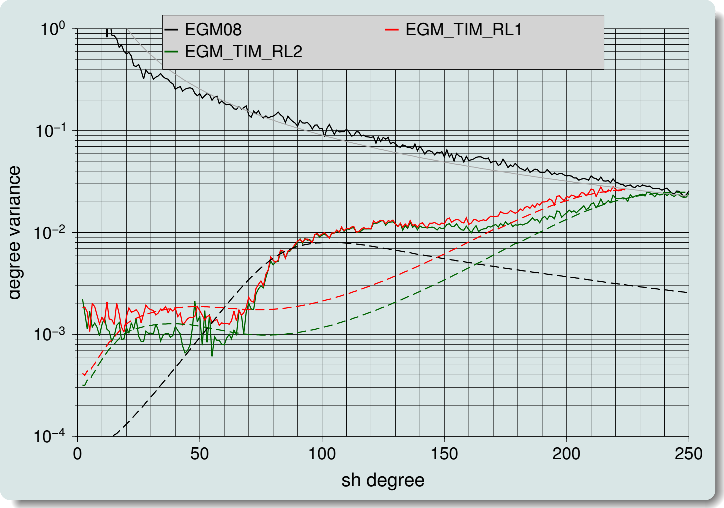
GOCE-only models compared to EGM08: 2 months data



solid: degree error variance from difference to EGM08, **dashed:** degree error variance from formal errors

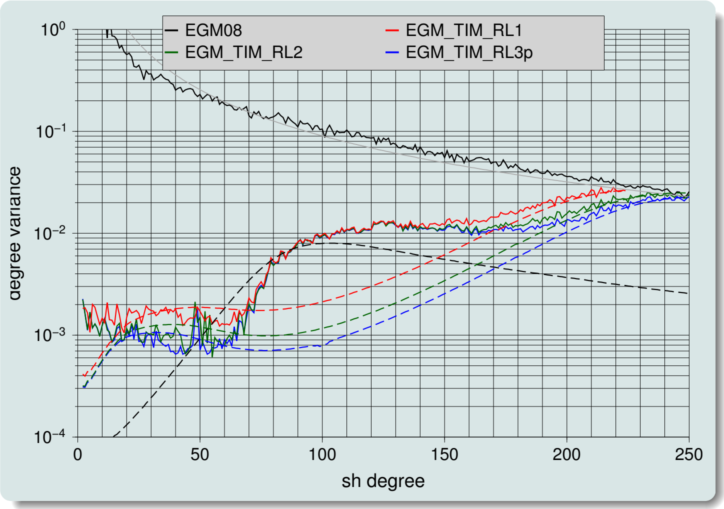
GOCE-only models compared to EGM08: 2, 6 months data



solid: degree error variance from difference to EGM08, **dashed:** degree error variance from formal errors

Models development within REAL GOCE

GOCE-only models compared to EGM08: 2, 6, 12 months data



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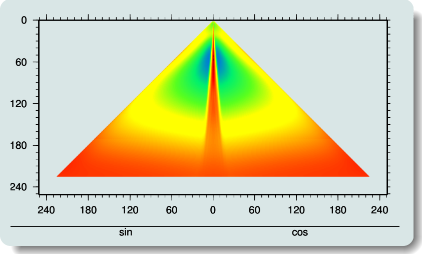
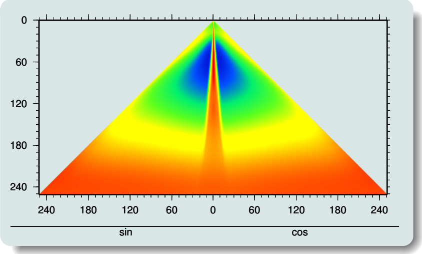
Models development within REAL GOCE

Accuracies of gravity coefficients:

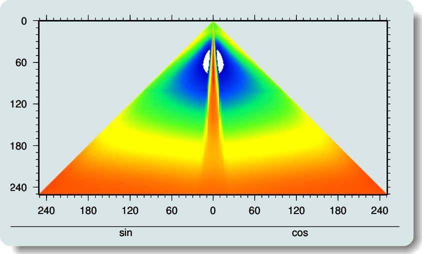
2 months:

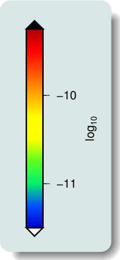


6 months:



12 months:

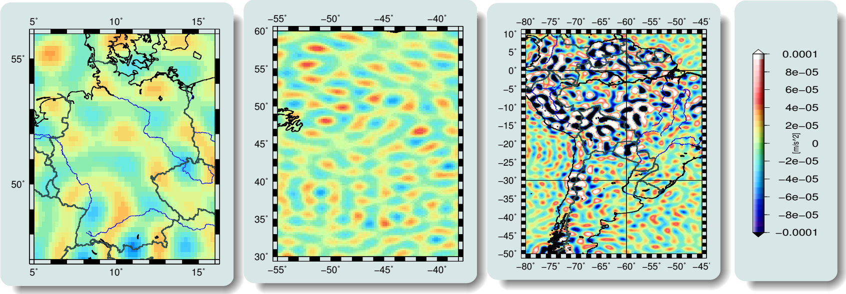




Comparison to EGM08

Anomalies compared to EGM08 (d/o 200, m/s^2) on local scale (12 months data):

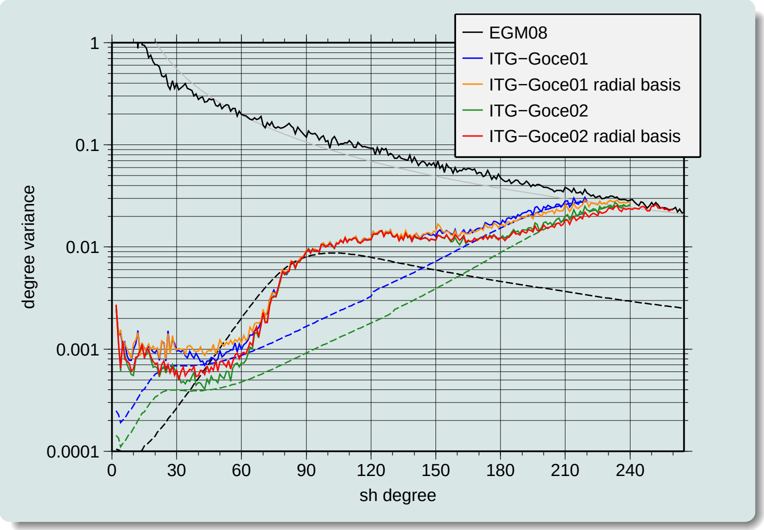
Germany: Ocean: South America:



Germany	Ocean	South America	
$\min: -5.3$ mgal	$\min: -5.0$ mgal	$\min: -65.1$ mgal	diff.EGM08
$\max: +3.3$ mgal	$\max: +5.4$ mgal	$\max: +55.4$ mgal	diff.EGM08
rms : $+1.4$ mgal	rms : $+1.5$ mgal	rms : $+7.1$ mgal	diff.EGM08
$\bar{\sigma}_g : +1.4$ mgal	$\bar{\sigma}_g : +1.4$ mgal	$\bar{\sigma}_g : +1.7$ mgal	var.prop.

Gain by regional refinements

GOCE-only models compared to EGM08:



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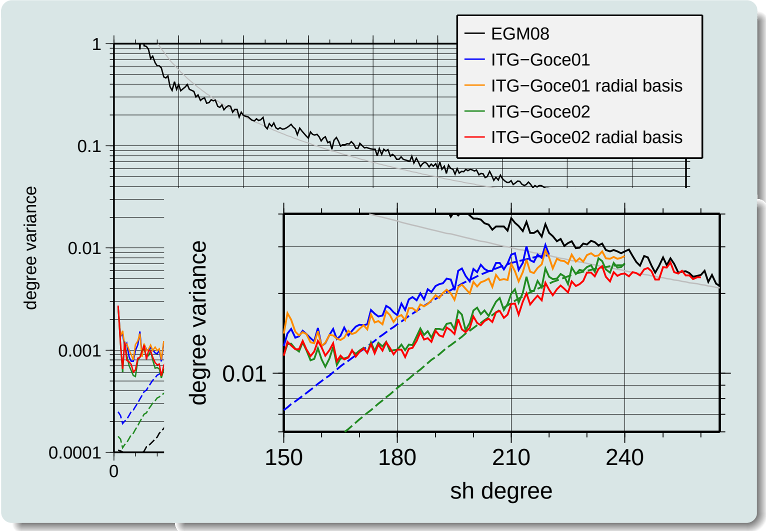
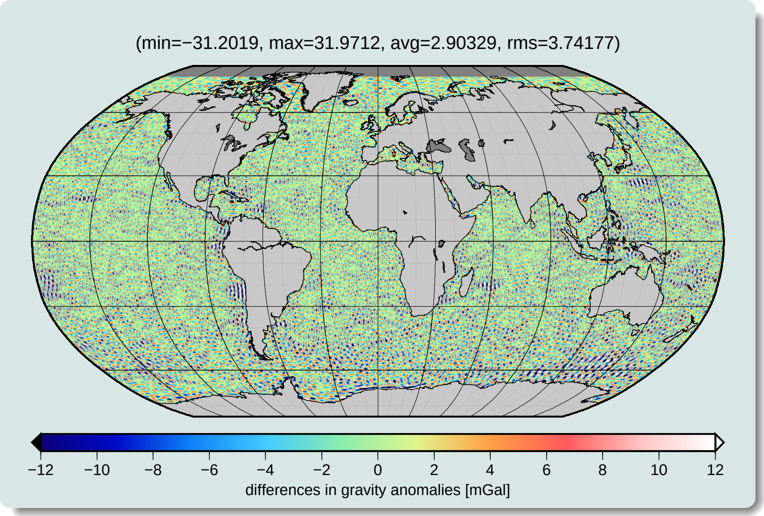
Gain by regional refinements

GOCE-only models compared to EGM08:



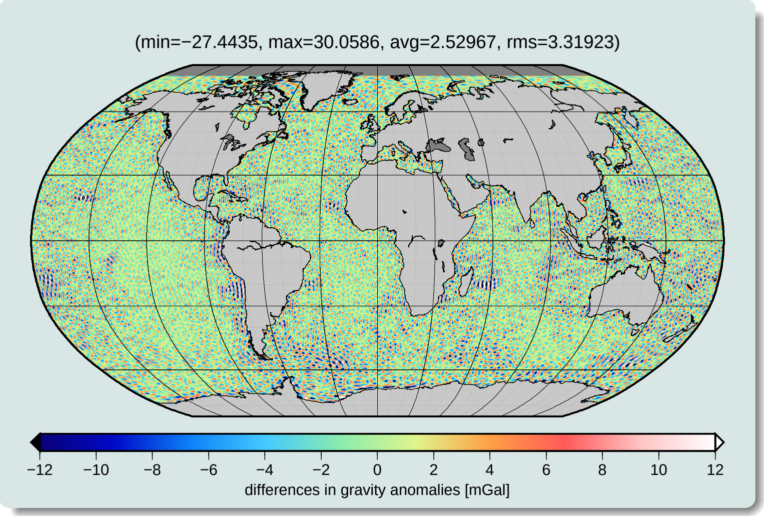
solid: degree error variance from difference to EGM08, **dashed:** degree error variance from formal errors

2 months anomalies compared to EGM08 (d/o 200, m/s^2):



Gain by regional refinements

2 months refined anomalies compared to EGM08 (d/o 200, m/s^2)



Summary and outlook

Summary:

- consistent gravity field solutions from all three approaches
- improvements with 12 months data
- EGM08 improvement d/o 60-180
- improvements with regional refinement

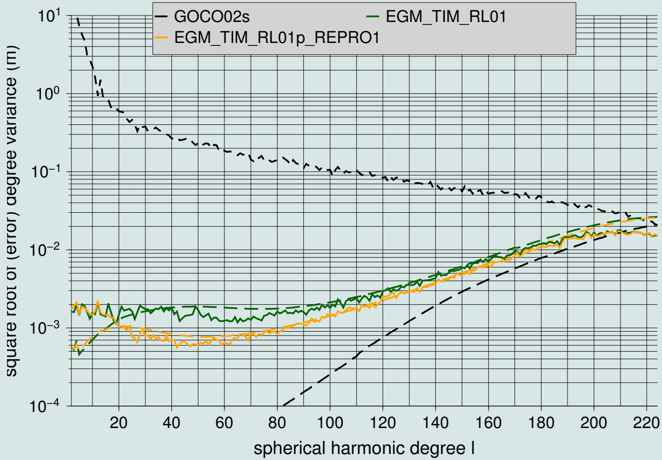
Outlook:

- data up to at least end of 2012
- ESA reprocesses L1b gravity gradients
- first promising results

Reprocessed data - first results

GOCE-only models compared to GOCO02s:

2 months, 2 months reprocessed



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