GOCE Reprocessing towards Rel. 6 Gravity Field Models – Status and First Results

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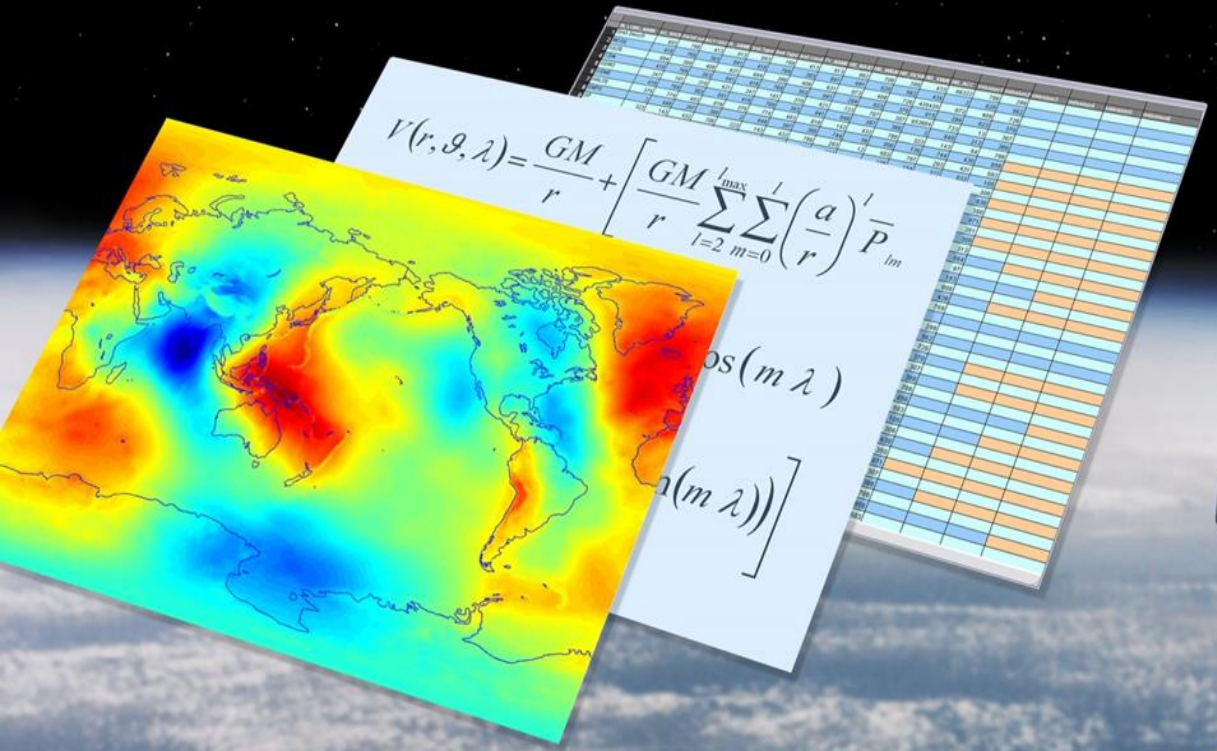
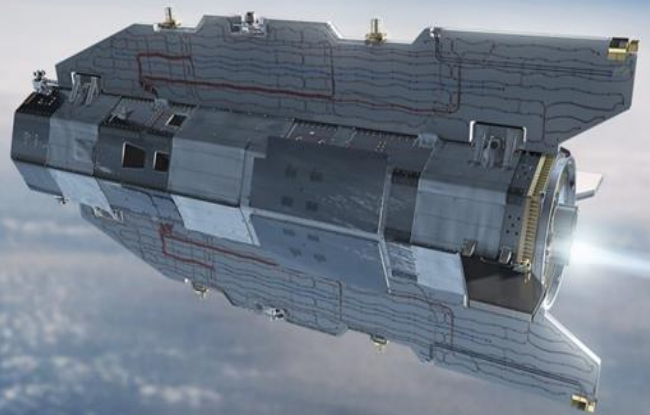




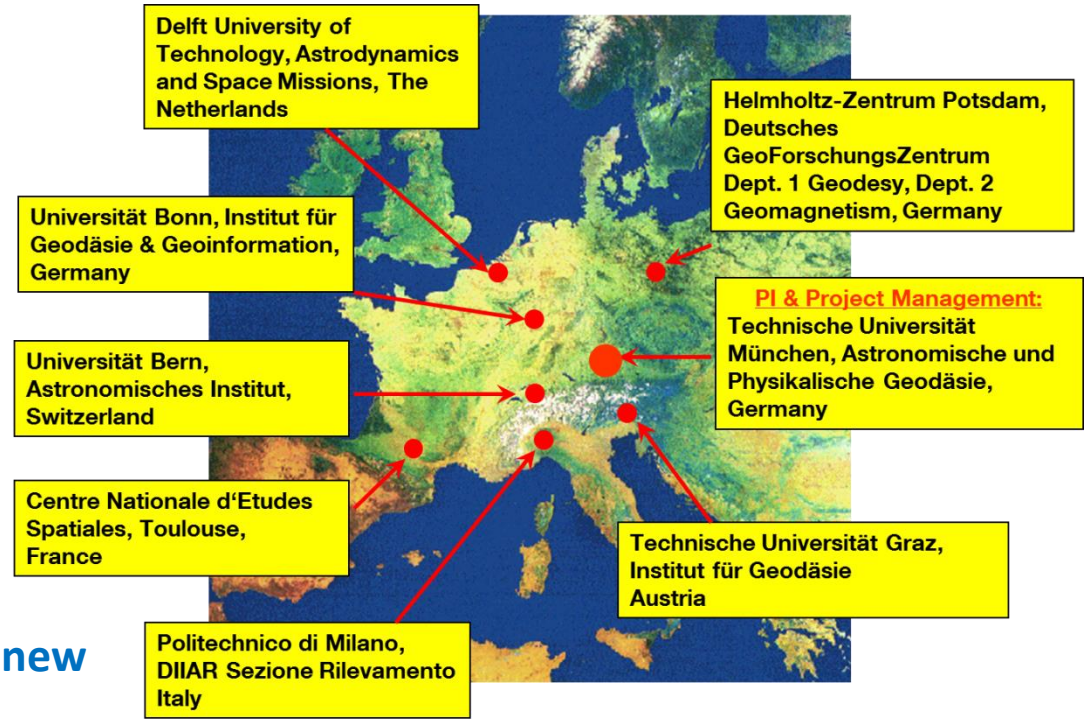
GOCE Reprocessing Campaign

ESA project

- Team: High Level Processing Facility (HPF)
- Start : October 2017
- End: May 2019
- Goal: Improving GOCE products
  - Linear and angular accelerations
  - Gravity gradients
  - Orbit and attitude data
  - GOCE Gravity field models
  - Combined gravity field model
  - Ionosphere models
  - Thermosphere models

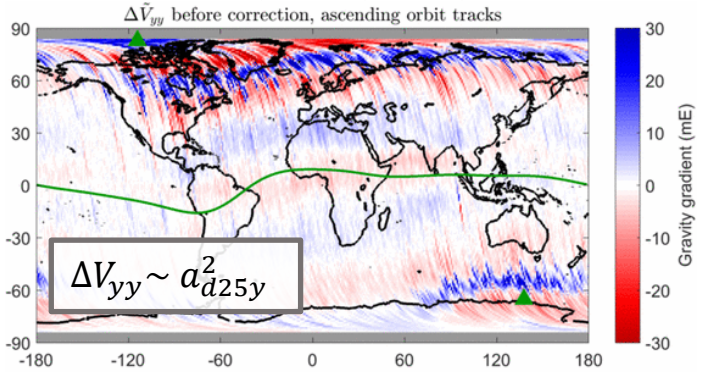
new

GOCE-HPF Consortium

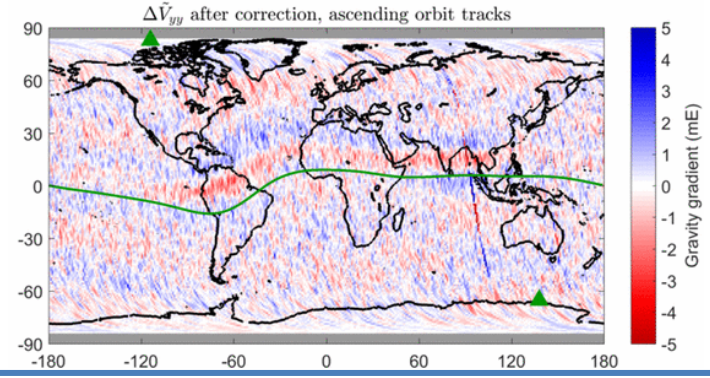


Why GOCE Reprocessing?

Increased residuals for cross-track gradients (V_{yy}) and others around geomagnetic poles



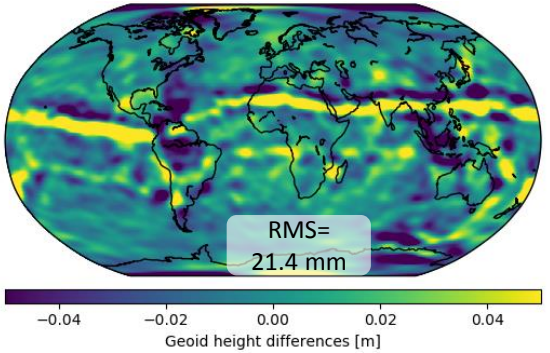
Origin of residuals: missing **quadratic terms** in the calibration of the gradiometer



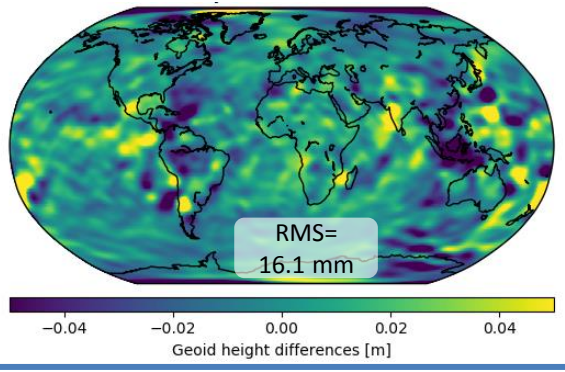
(Siemes 2018, JoG)

Kinematic orbits show systematic effects around the geomagnetic equator because of degraded GPS data

Monthly GOCE hl-SST solution w.r.t. AIUB-GRACE03S



Corrected monthly GOCE hl-SST solution w.r.t. AIUB-GRACE03S



Courtesy: D. Arnold, AIUB

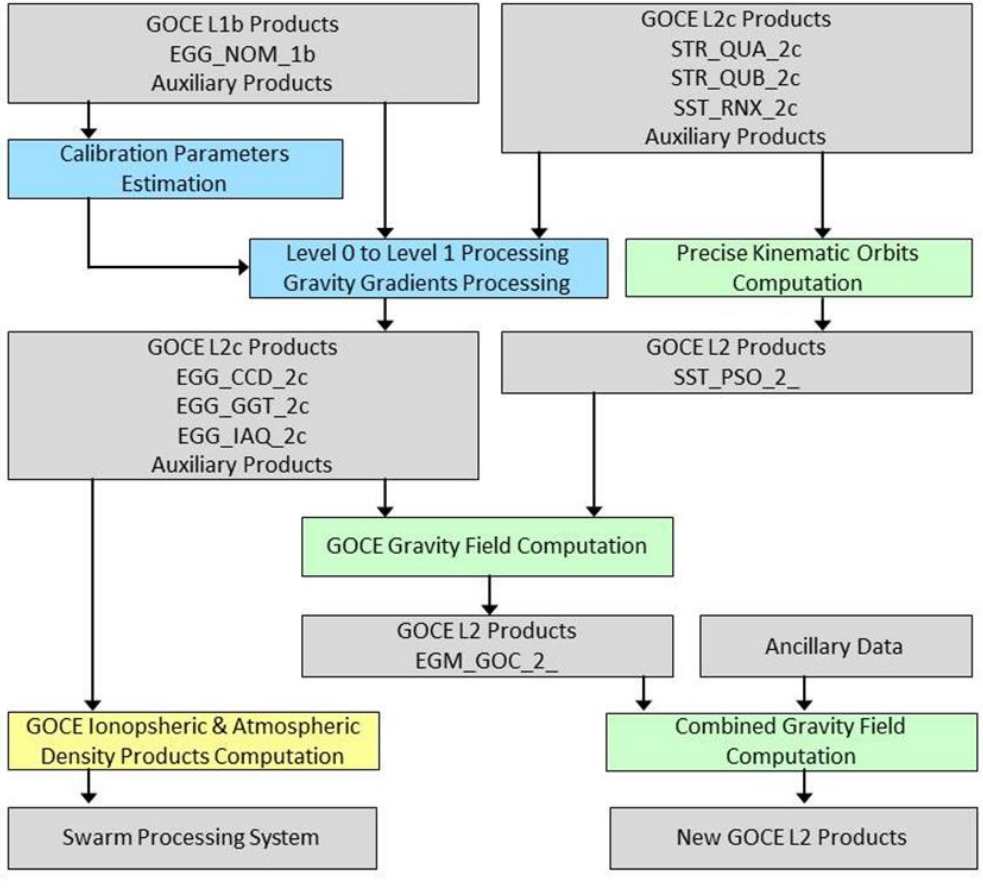
Overview and Status

Input data

Upgrade
L1b processor
(completed)

L1b & L2 data
(completed)

Gravity field
and new
products
(ongoing)



L2 orbits
(ongoing)

Data
Level 1
Level 2
New

New Gradiometer Calibration

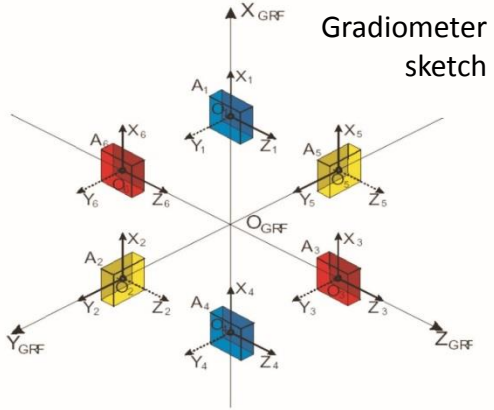
Two step calibration procedure

ICM: Inverse calibration matrix

1) Shaking-mode

$$\begin{bmatrix} \bar{a}_{dij} \\ \bar{a}_{cij} \end{bmatrix} = \hat{M}_{ij} \begin{bmatrix} \hat{a}_{dij} \\ \hat{a}_{cij} \end{bmatrix}$$

ij: 14: along-track (x)
25: cross−track (y)
36: radial (z)



2) Science-mode

accelerometer biases | ICM | quadratic factor matrix | angular coupling matrix

$$\begin{bmatrix} \bar{\bar{a}}_{dij} \\ \bar{\bar{a}}_{cij} \end{bmatrix} = \begin{bmatrix} \bar{\bar{b}}_{dij} \\ \bar{\bar{b}}_{cij} \end{bmatrix} + \bar{M}_{ij} \begin{bmatrix} \bar{a}_{dij} \\ \bar{a}_{cij} \end{bmatrix} + \bar{K}_{ij} \begin{bmatrix} (\bar{a}_{cij} + \bar{a}_{dij})^2 \\ (\bar{a}_{cij} - \bar{a}_{dij})^2 \end{bmatrix} + \bar{W}_{ij}\, \dot{\bar{\omega}} + \begin{bmatrix} \bar{\bar{n}}_{dij} \\ \bar{\bar{n}}_{cij} \end{bmatrix}$$

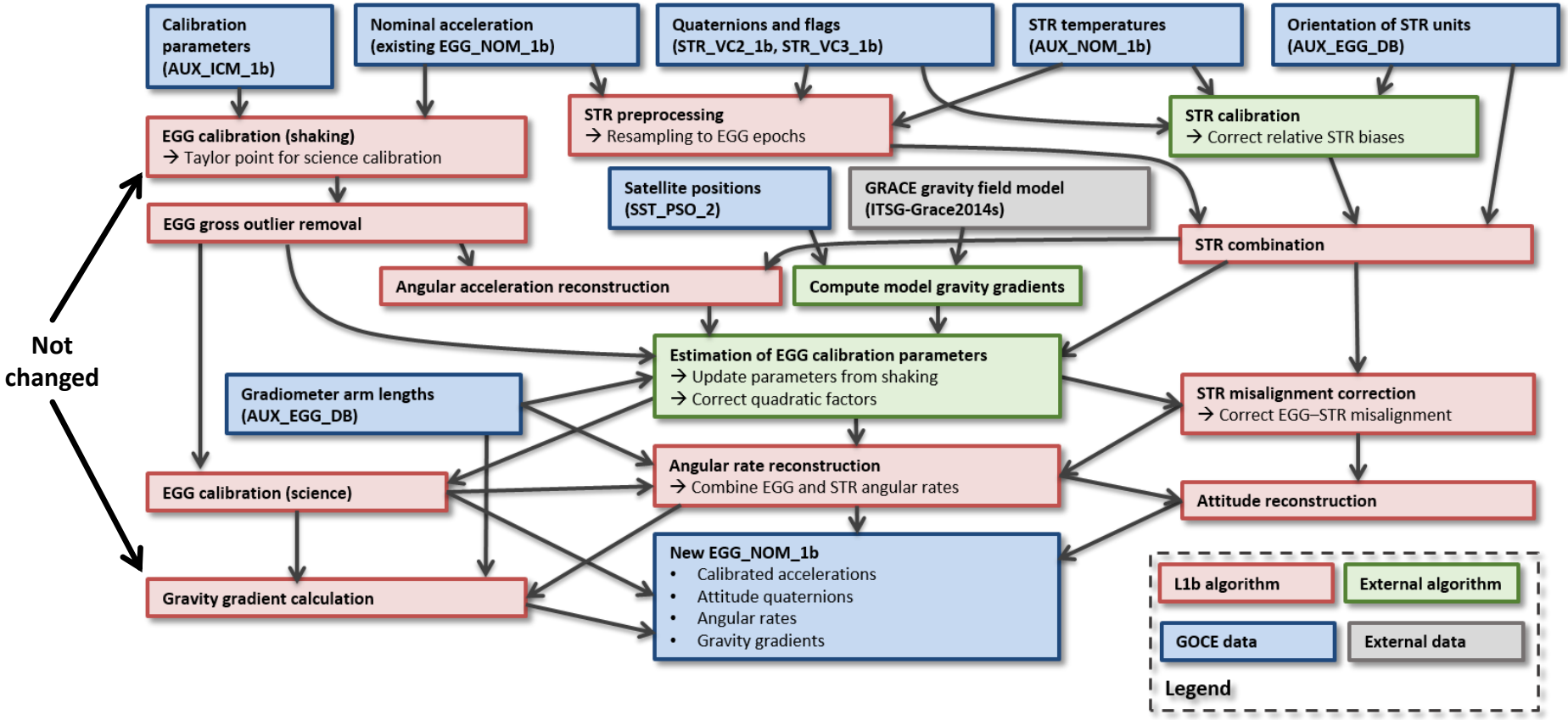
final calibrated accelerations | shaking-mode calibrated accelerations | angular accelerations | noise

Parameter estimation is based on

1. science and shaking-mode data
2. star-tracker angular rates
3. external gravity field model (band filtered : 1-10mHz)

(Siemes 2018, JoG)

The New L1B Processor - Overview

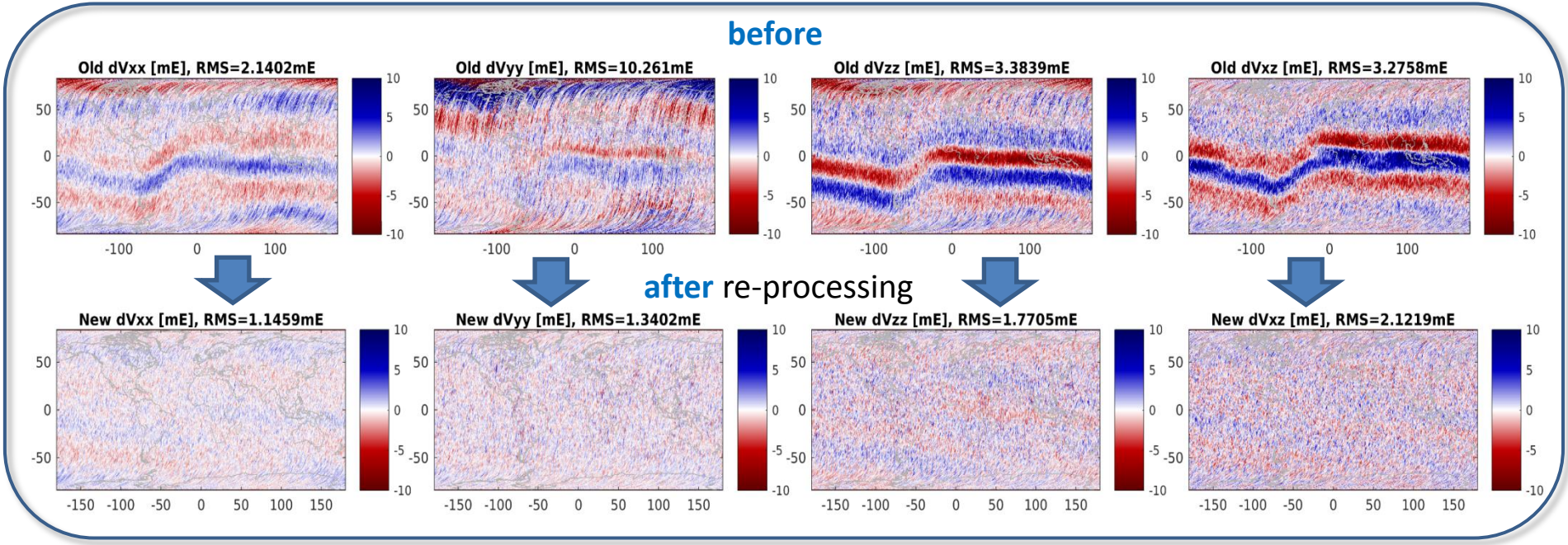


Improved GOCE Products – Gravity Gradients

GGT residuals w.r.t ITSG-GRACE2014k along the orbit

→ filtering: **1 -10 mHz**

→ ascending tracks only



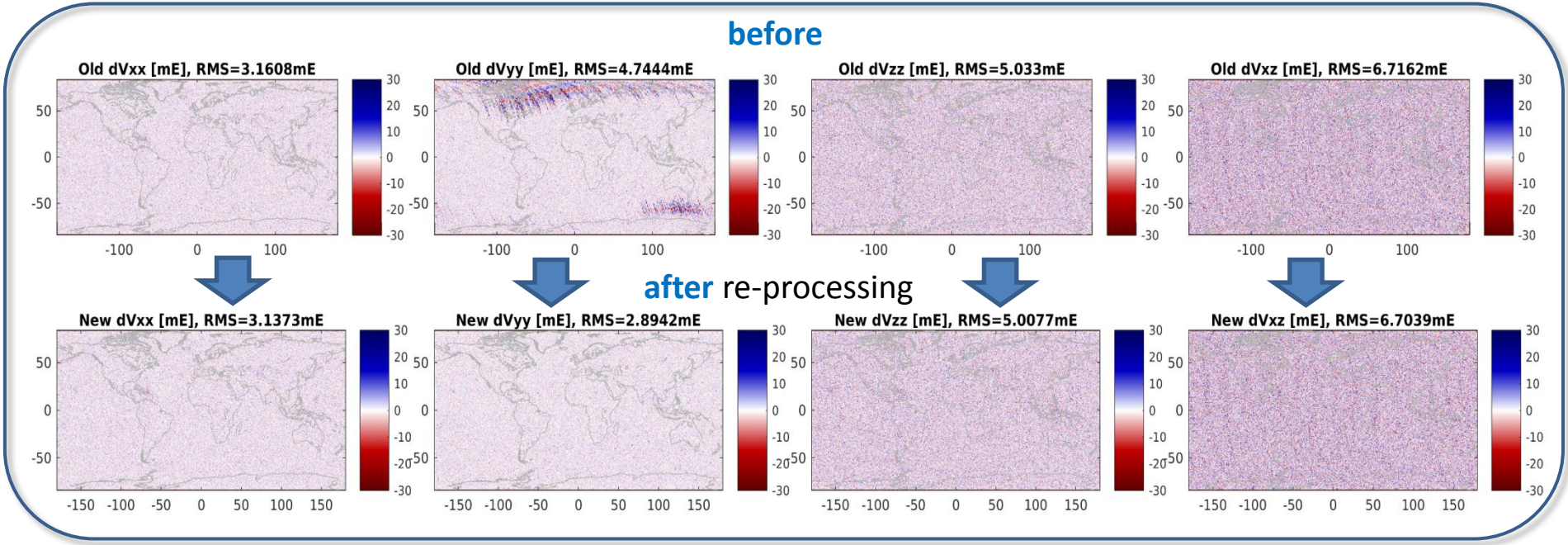
Period : 2012/03/16 to 2012/05/22

Improved GOCE Products – Gravity Gradients

GGT residuals w.r.t ITSG-GRACE2014k along the orbit

→ filtering: **5 -100 mHz (MBW)**

→ ascending tracks only

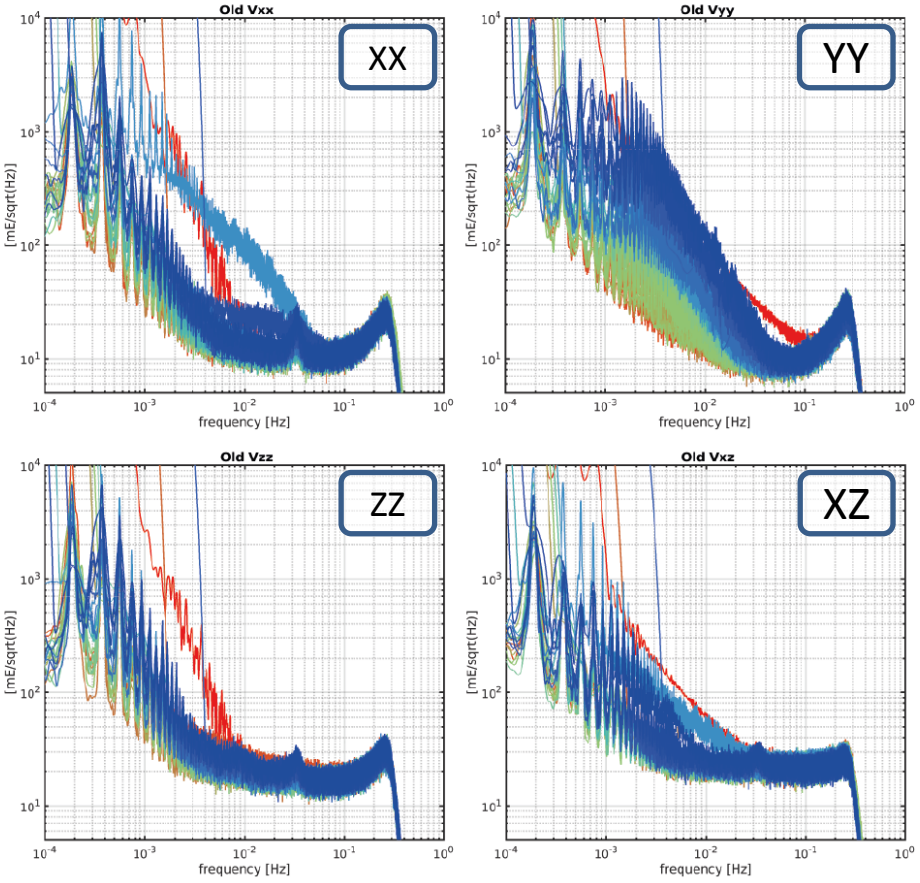


Period : 2012/03/16 to 2012/05/22

Improved GOCE Products – Gravity Gradients

Performance of gradients (w.r.t. ITSG-GRACE2014k) over entire GOCE mission

before re-processing



data segments

20091009T112952 - 20091018T045148
20091026T011542 - 20091028T130428
20091028T130431 - 20091028T233235
20091028T233236 - 20100111T073815
20100112T073815 - 20100212T064840
20100302T022735 - 20100304T081741
20100305T081741 - 20100506T064253
20100507T064253 - 20100708T020748
20100910T071433 - 20101005T010950
20101006T010950 - 20101207T040336
20101208T052859 - 20110101T201131
20110119T082112 - 20110127T061647
20110128T061225 - 20110404T085333
20110405T071928 - 20110607T071408
20110608T070947 - 20110823T073725
20110824T073303 - 20111025T060202
20111026T055741 - 20120117T055355
20120118T055355 - 20120305T035400
20120308T080924 - 20120315T103737
20120316T090332 - 20120522T054026
20120523T053604 - 20120607T132845
20120613T053258 - 20120619T050632
20120620T050208 - 20120911T064523
20120912T063812 - 20121108T071546
20121109T083739 - 20130204T115242
20130205T131252 - 20130212T060348
20130213T055311 - 20130507T083709
20130508T065654 - 20130522T012430
20130528T192632 - 20130731T143819
20130801T142404 - 20131001T055109
20131002T055109 - 20131020T035500

Improved GOCE Products – Gravity Gradients

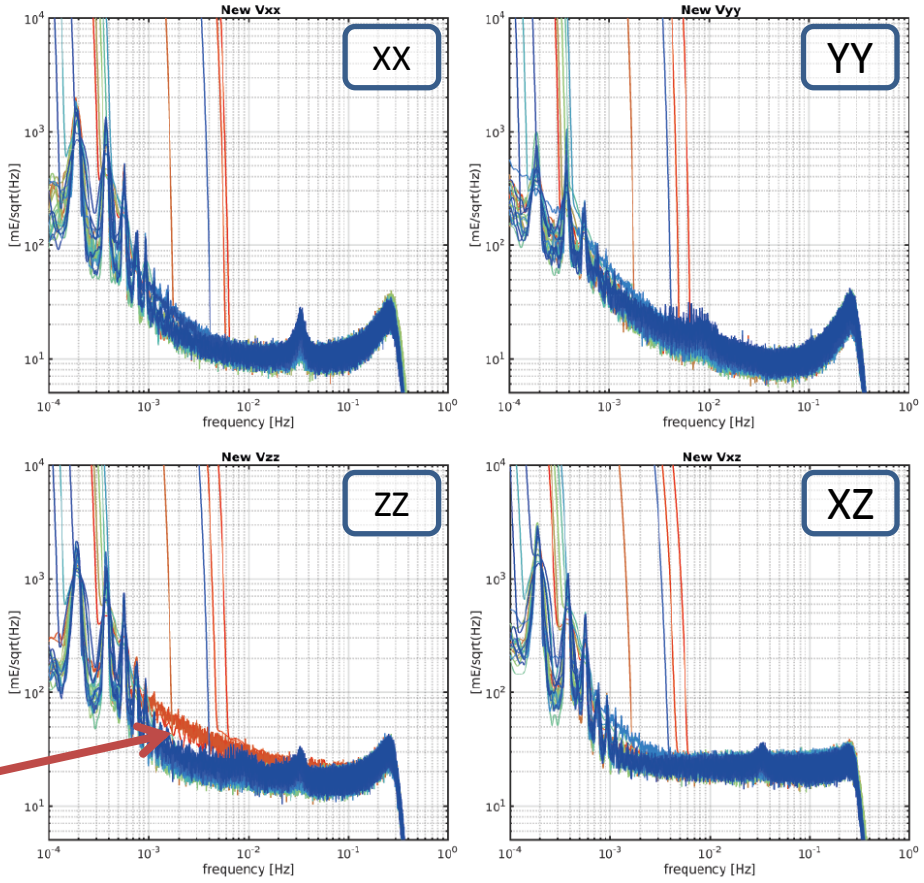
Performance of gradients (w.r.t. ITSG-GRACE2014k) over entire GOCE mission

after re-processing

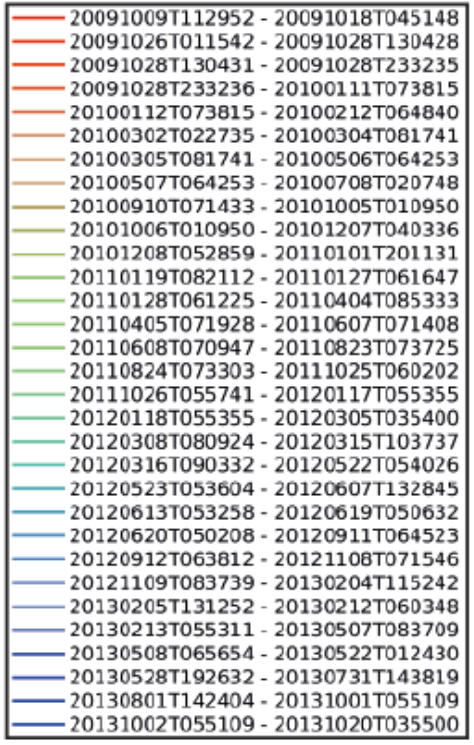
→ Stationary noise over entire mission

Except:

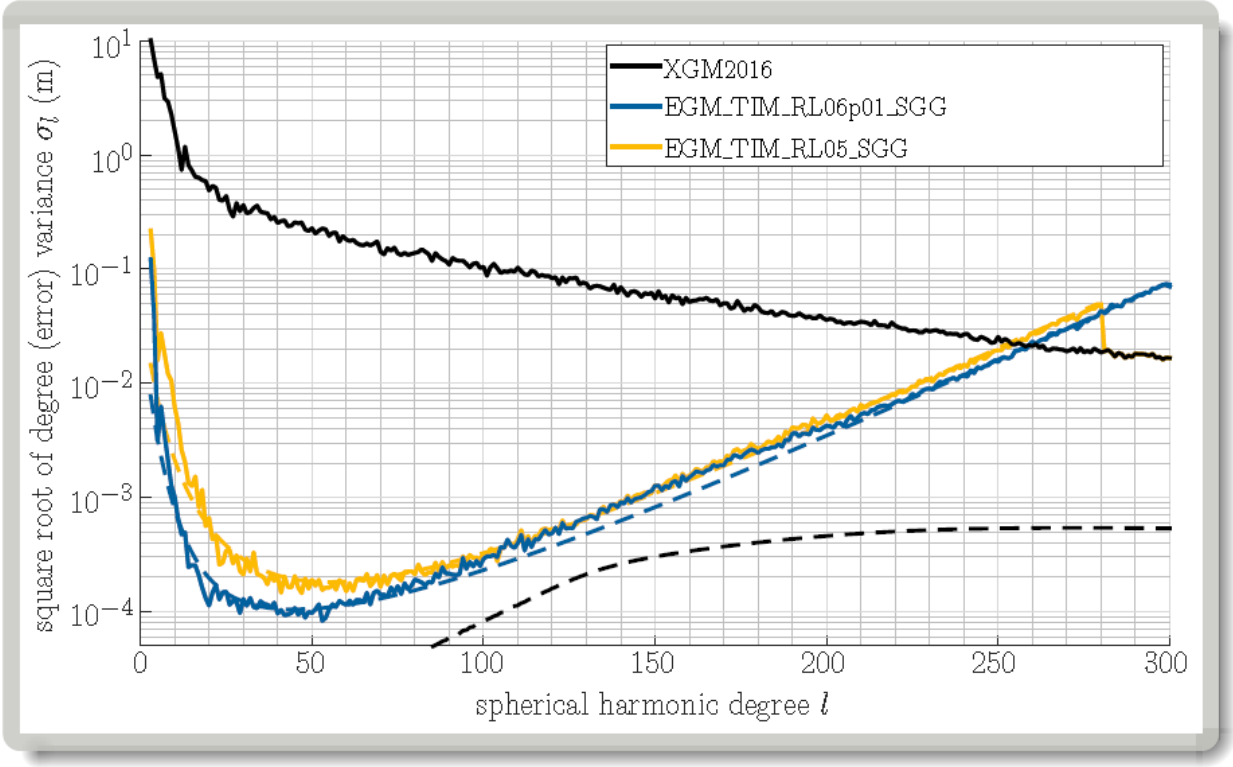
→ Vzz before satellite anomaly in February 2010



data segments



Improved GOCE Products – Gravity Models



solid: empirical from difference, dashed: formal from covariance

- near zonal coefficients excluded
- combination of all patches and components (weights by VCE $0.99 < w_i < 1.01$)
- improvements compared to EGM_TIM_RL05
- consistent formal & empirical errors for degree 2-90 and 220-300

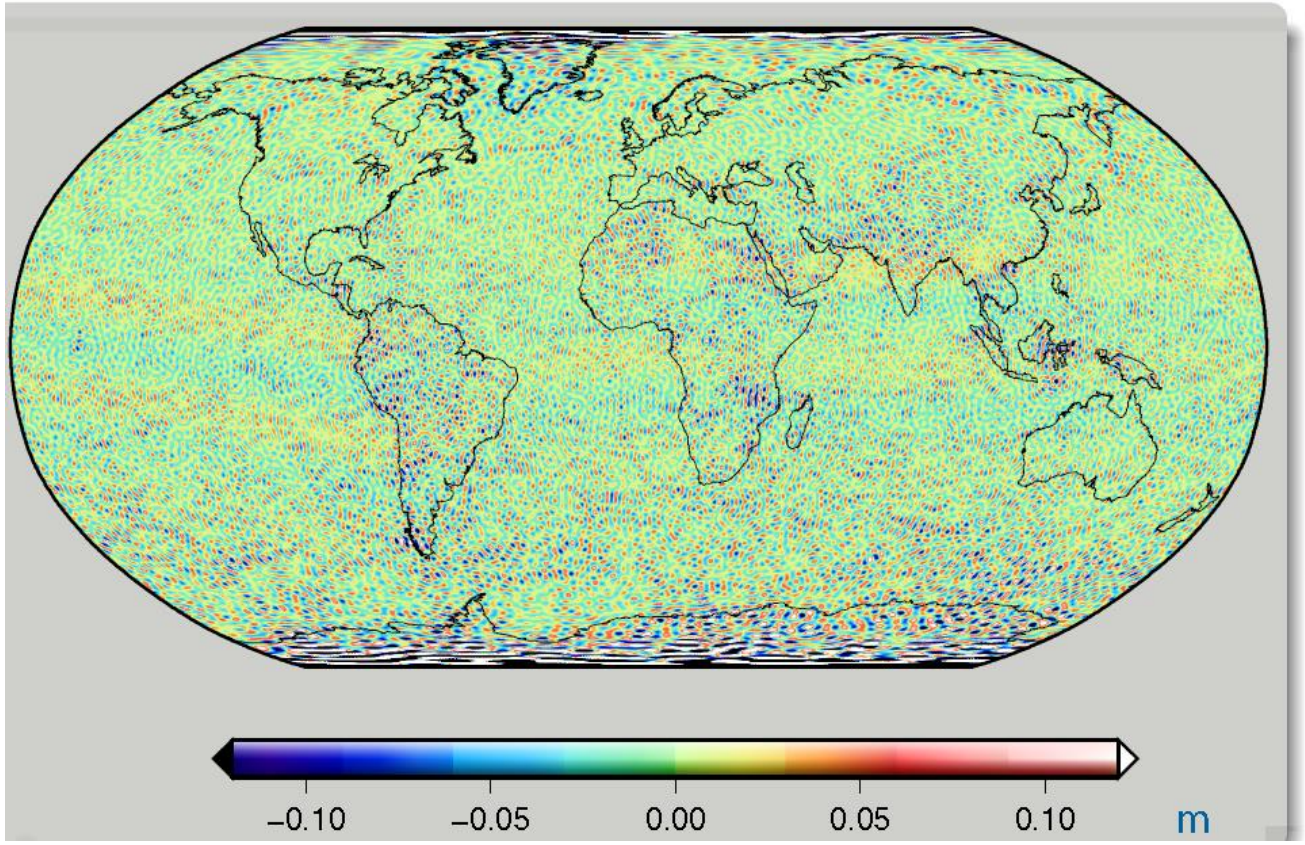
⇒ deficits of XGM for degrees 90-220 visible?

⇒ GOCO05S based, i.e. EGM_TIM_RL05 error in that range

Courtesy: J.M. Brockmann, Univ. Bonn

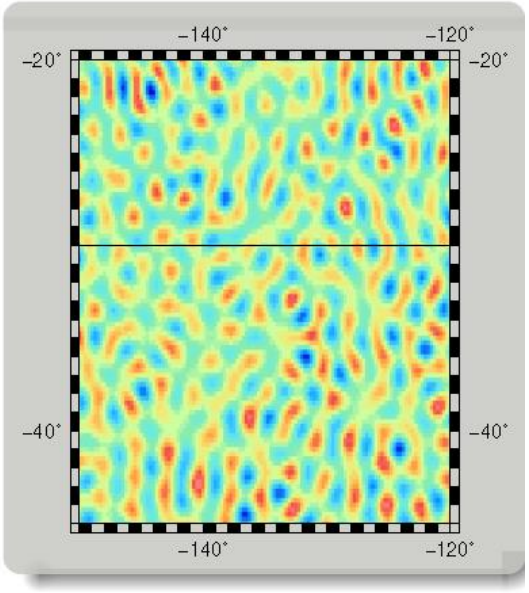
Improved GOCE Products – Gravity Models

Combined Geoid (SGG & SST) compared to XGM2016 (d/200)



Courtesy: J.M. Brockmann, Univ. Bonn

EGM_TIM_RL05

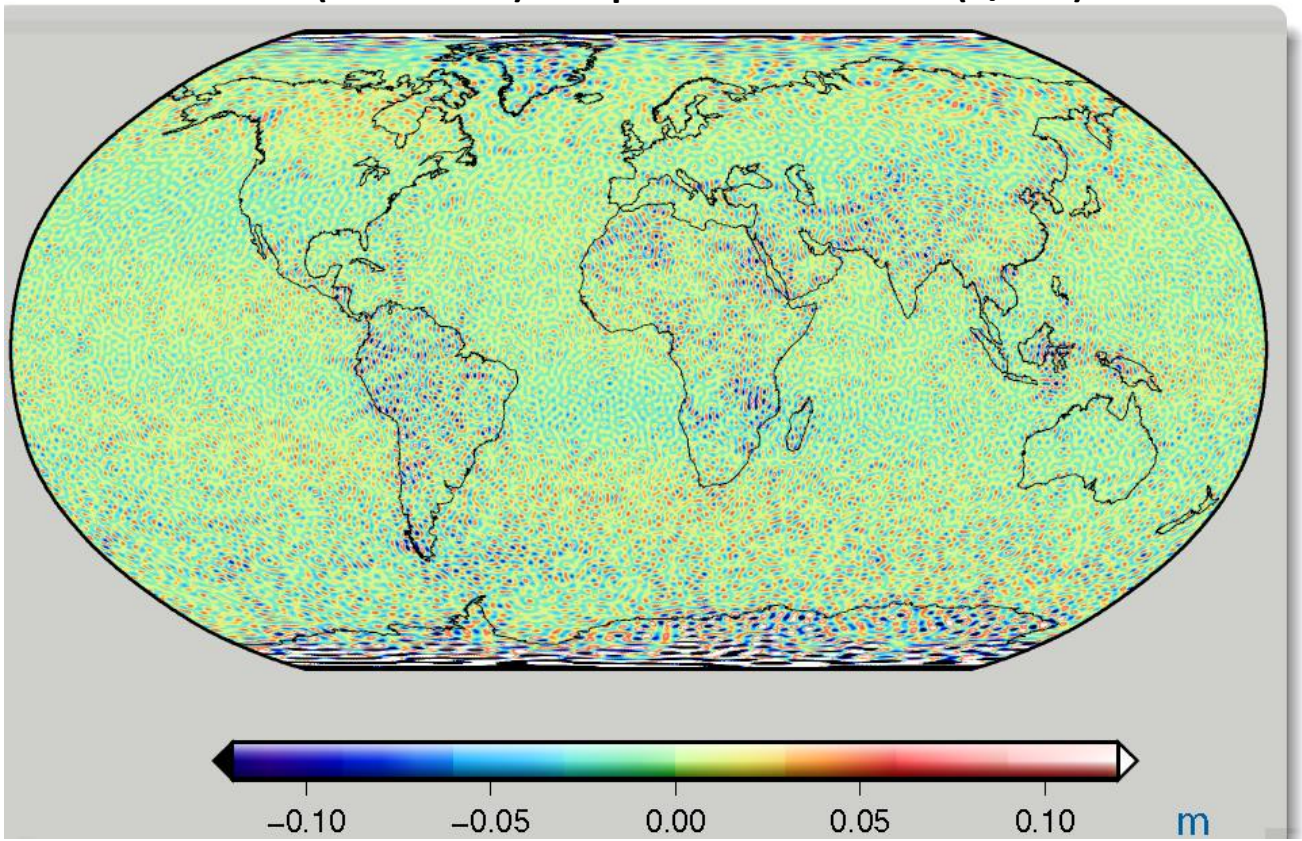


area in South Pacific

RL	RMS cm	VCM cm	RMS mGal	VCM mGal
TIM5	2.45	2.70	0.69	0.76

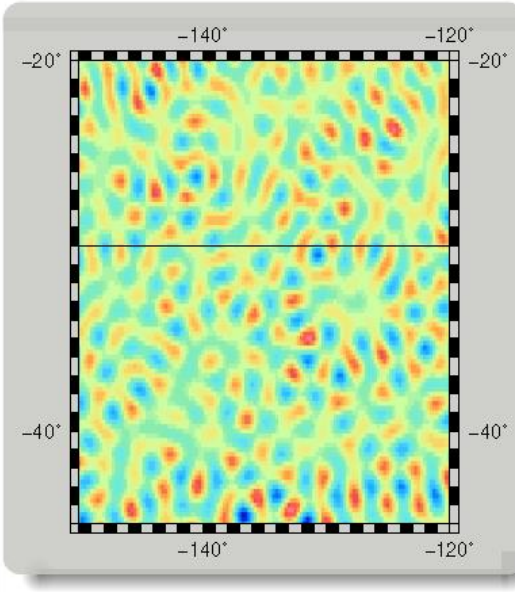
Improved GOCE Products – Gravity Models

Combined Geoid (SGG & SST) compared to XGM2016 (d/200)



Courtesy: J.M. Brockmann, Univ. Bonn

EGM_TIM_RL06p01



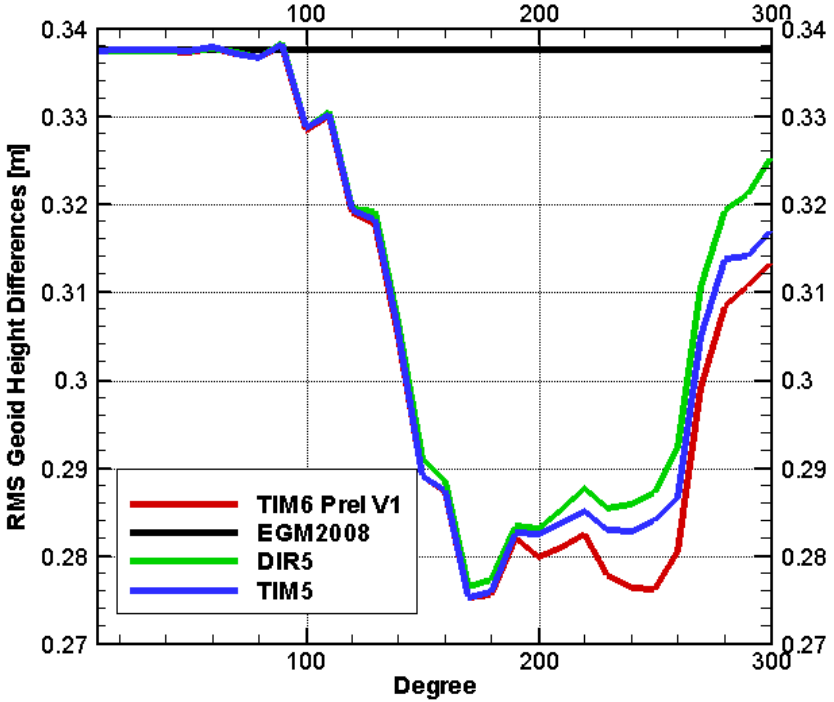
area in South Pacific

RL	RMS cm	VCM cm	RMS mGal	VCM mGal
TIM5	2.45	2.70	0.69	0.76
TIM6p1	2.12	2.11	0.60	0.60

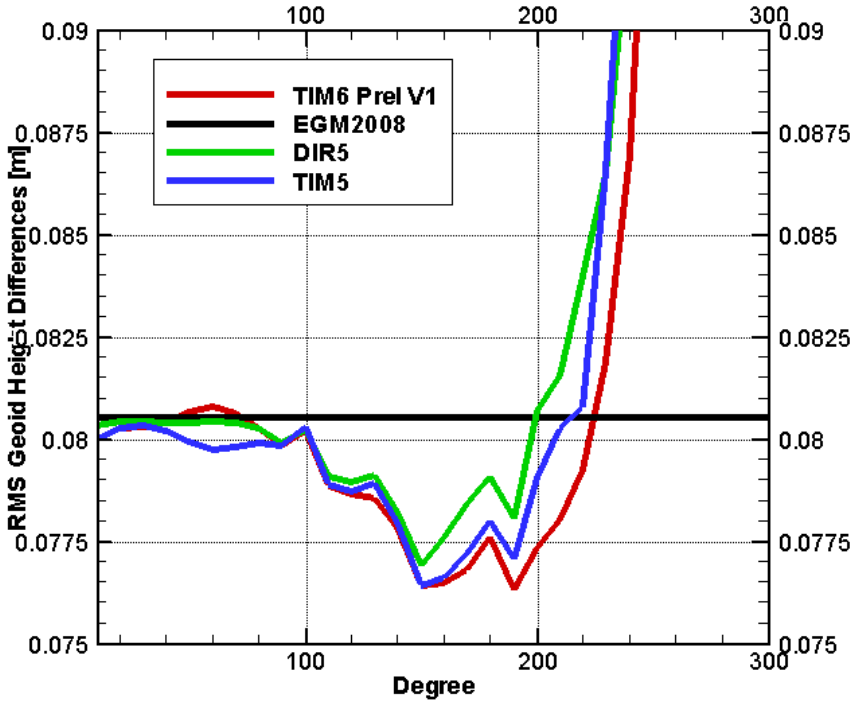
Improved GOCE Products – Gravity Models

Combined Solution (SGG & SST) GPS-Levelling Comparisons

Brazil



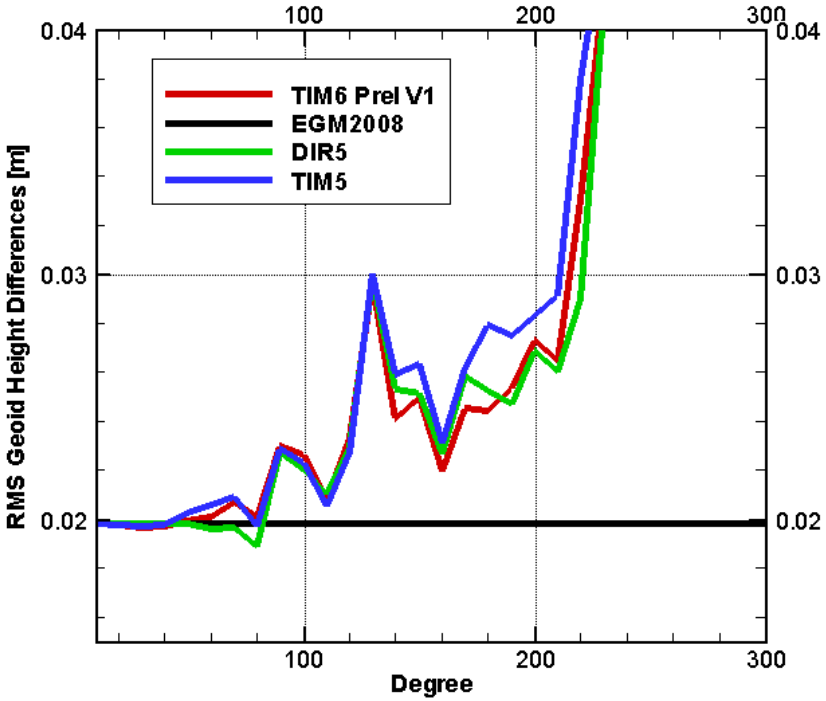
Canada



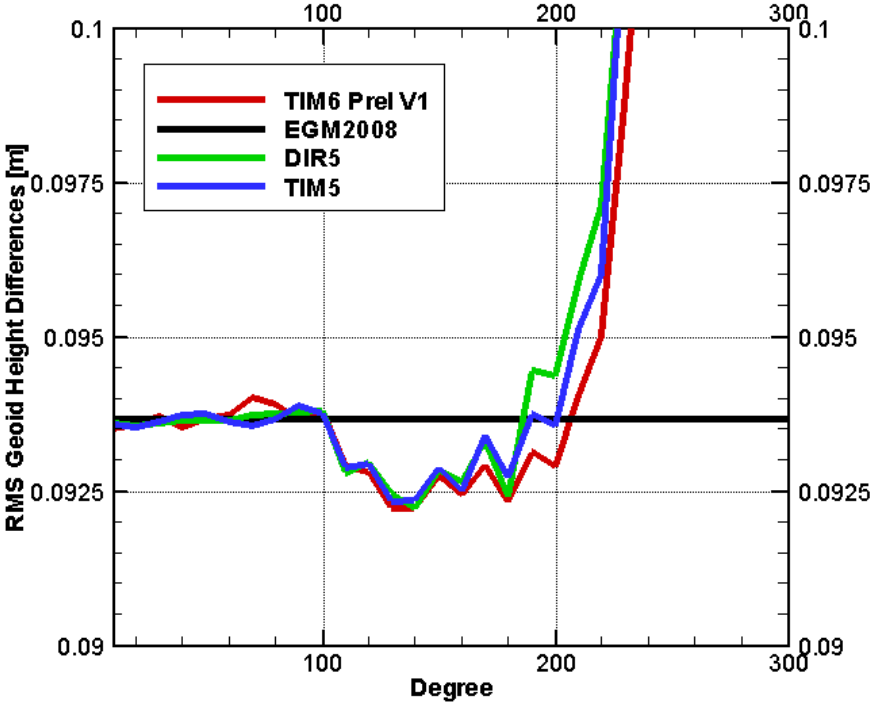
Improved GOCE Products – Gravity Models

Combined Solution (SGG & SST) GPS-Levelling Comparisons

Germany

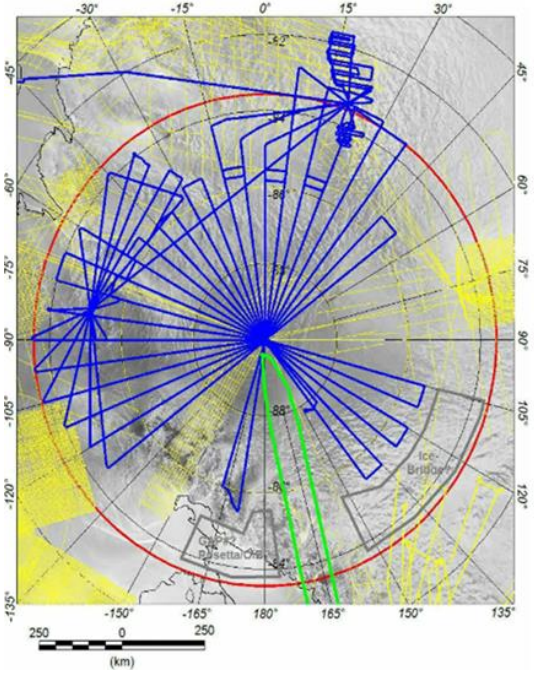


USA

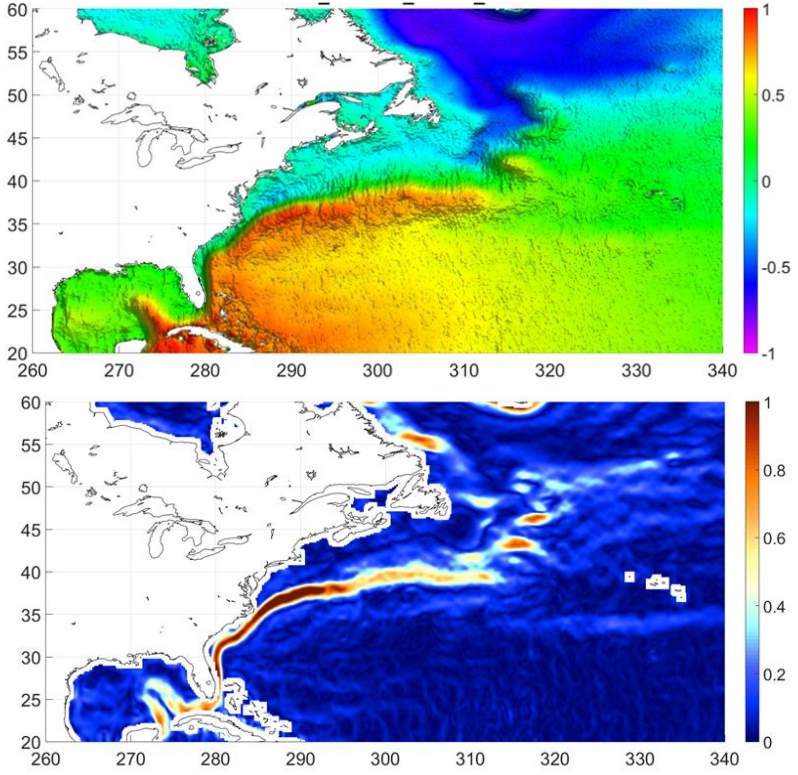


New Products – Combined Gravity Field

- PolarGap data Antarctica – Fill the polar gap of GOCE and ideally to make any regularization obsolete.
- Optimized high resolution ocean geoid – Combination of reprocessed GOCE model and up-to-date altimetric gravity data – Computation of geodetic MDT (OGMOC project).



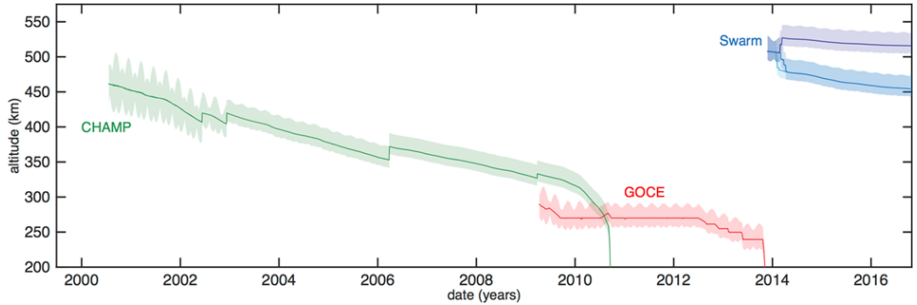
Airborne gravity observations taken by the PolarGAP project (10-2015 to 04-2017)



MDT from DTU15MSS and extended XGM2016 [m] and derived geostrophic current velocities [m/s].

New Products – Ionopshere & Thermosphere

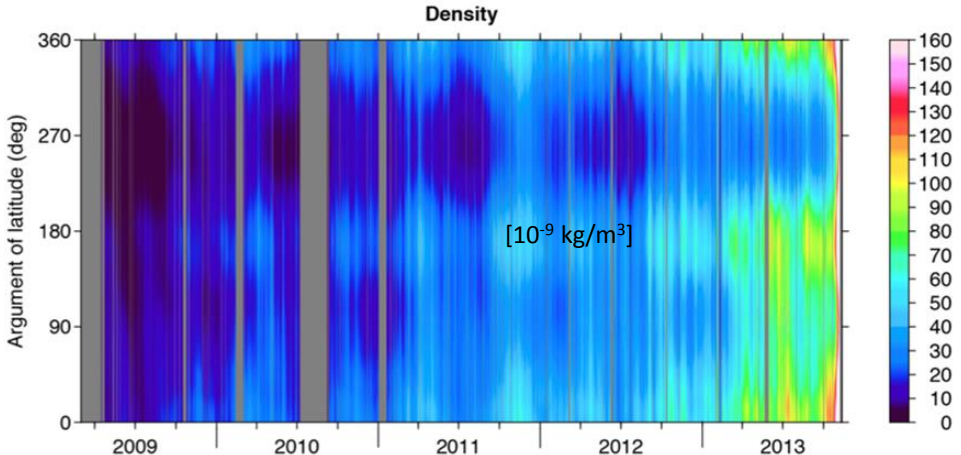
- Slant Total Electron Content (TEC) & Rate of TEC index (ROTI) from the GOCE GPS (low near polar orbit & post-sunset local time for high latitude and equatorial irregularities).



Evolution of the orbits of CHAMP, GOCE and Swarm
Courtesy van den Ijssel TU Delft

- For 2009 to 2013 GOCE gradiometry based thermosphere density and wind data sets were produced. Improvements with reprocessed data and from lessons learned are expected.

Density estimates from GOCE for the complete mission duration
Courtesy Doornbos, TU Delft



Summary & Schedule

Summary

- Higher noise in gradients and GPS observations identified, which is correlated to the magnetic field (magnetic poles and geomagnetic equator).
- Reprocessing of L1B gravity gradients by improved calibration scheme, star tracker combination and angular rate reconstruction. Improved screening of GPS data.
- Improvements: Gravity gradients between 15% and 20%; Elimination of correlations to geomagnetic equator in kinematic positions.
- Improvements in GOCE gravity field models 15% to 25%.

Schedule

- Complete set of new gradient products in February 2019.
- Reprocessed precise science orbits by end of 2018.
- Rel. 6 GOCE and combined gravity field models in May 2019.
- Ionosphere products ready and delivered to ESA.
- Thermosphere products in May 2019