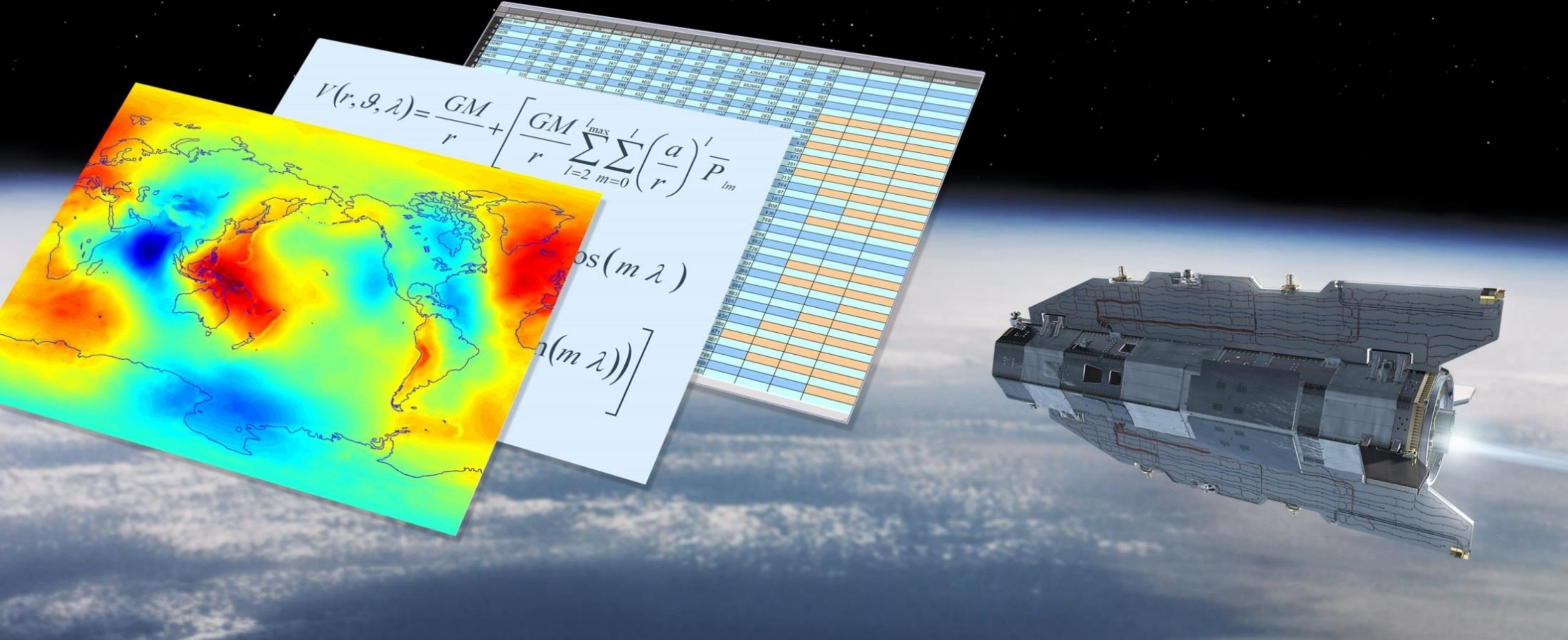
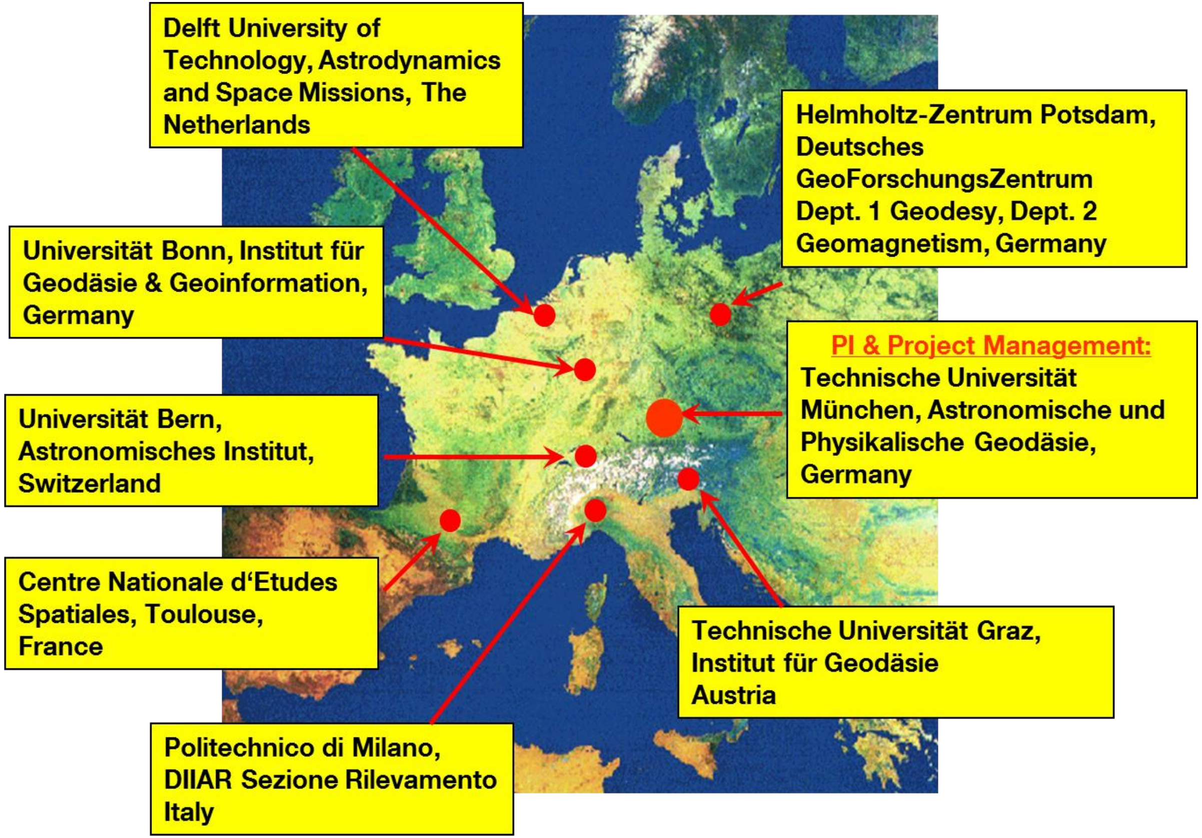
Results of the GOCE Reprocessing Campaign

Th. Gruber & High Level Processing Facility (HPF) Team
Institute of Astronomical & Physical Geodesy (IAPG), Technical University of Munich



High Level Processing Facility

- 15 years of successful Collaboration
- In Charge of complete L1 to L2 Processing and L2 Products
- L2 Products:
  Precise GOCE Orbits
  Gravity Gradients
  GOCE Gravity Field Models
  Ionosphere Products
  Thermosphere Products



Outline

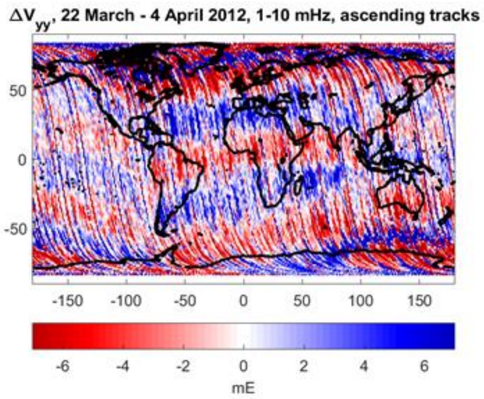
1. GOCE Reprocessing

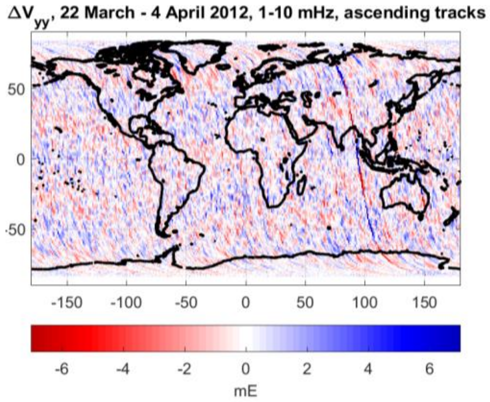
- ❑ Why ?
- ❑ Overview

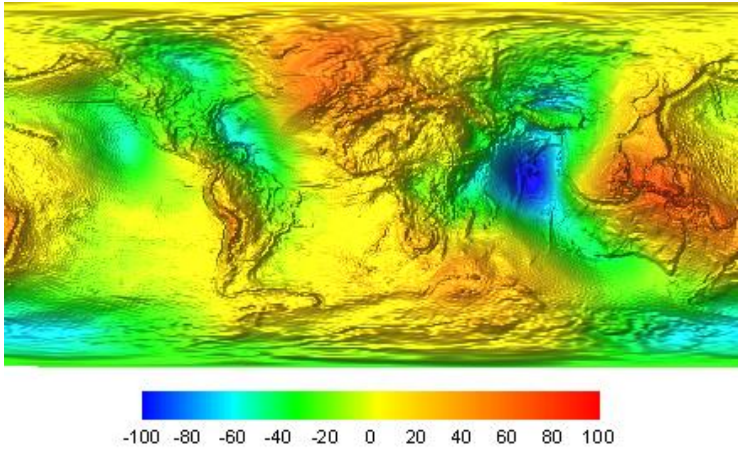
2. Results

- ❑ Orbits
- ❑ Gradients (ref. C. Siemes)
- ❑ Gravity Field Models
  (ref. J.M. Brockmann, C. Förste)
- ❑ New Products

3. Summary & Future Perspective

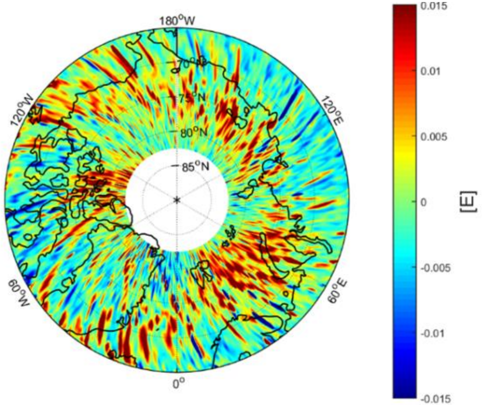






GOCE Reprocessing – Why?

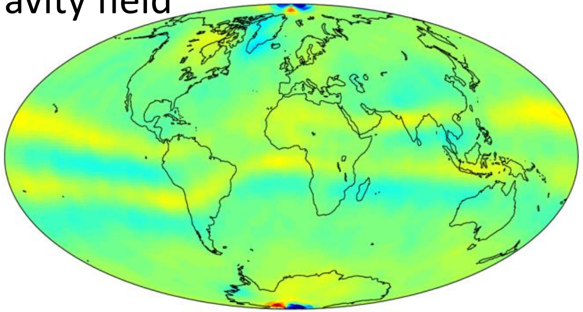
Increased residuals for cross-track gradients (V_{yy}) and others around geomagnetic poles



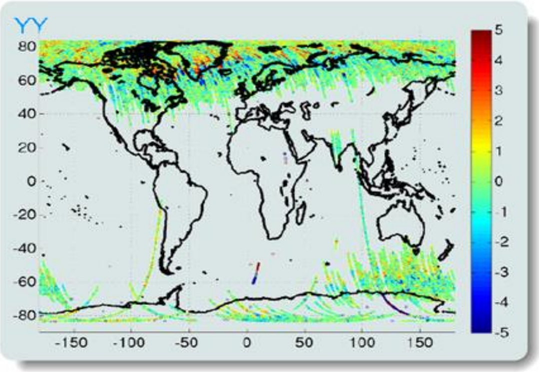
Courtesy: A. Schlicht

Kinematic orbits show systematic effects around the geomagnetic equator because of degraded GPS data – impact on gravity field

Geoid differences (-5 cm +5 cm) wrt. TIM Rel. 4 Model; Courtesy: A. Jäggi



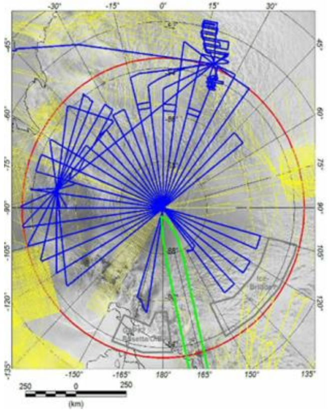
Reduced performance of gravity field in these areas because of outlier rejection i.e. less data for gravity field computation



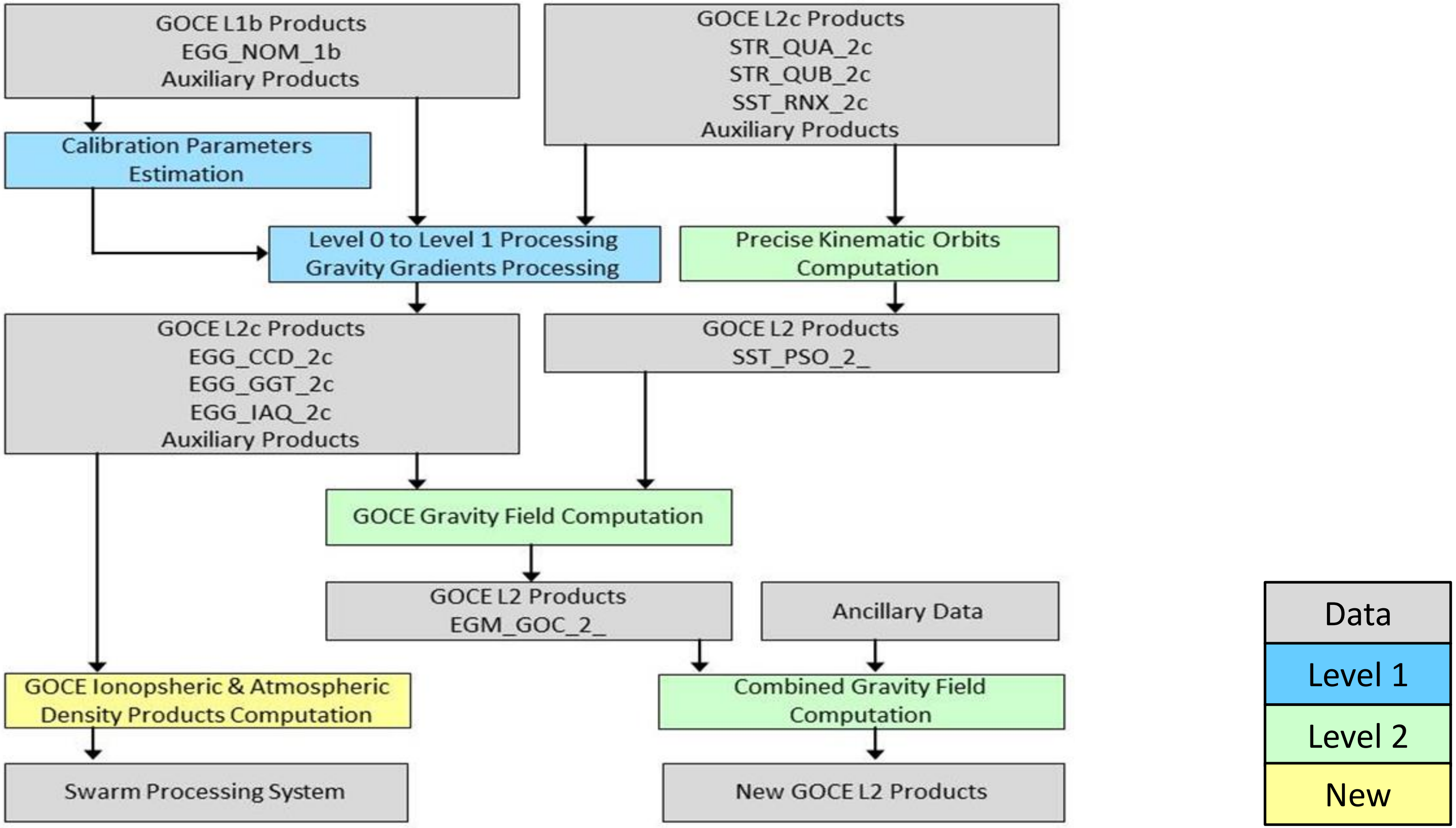
Courtesy: J.M. Brockmann

New applications of GOCE data

- Ionospheric and atmospheric density profiles.
- New combined gravity field models with new gravity data from ESA Antarctic airborne campaign.

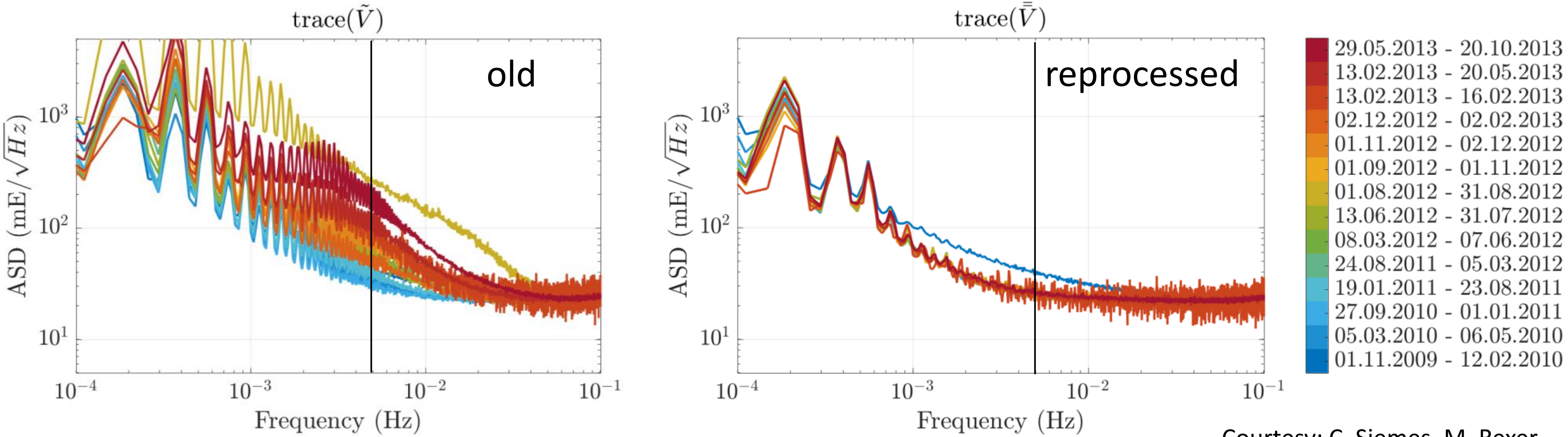


GOCE Reprocessing Overview



GOCE Reprocessing Results - Gradients

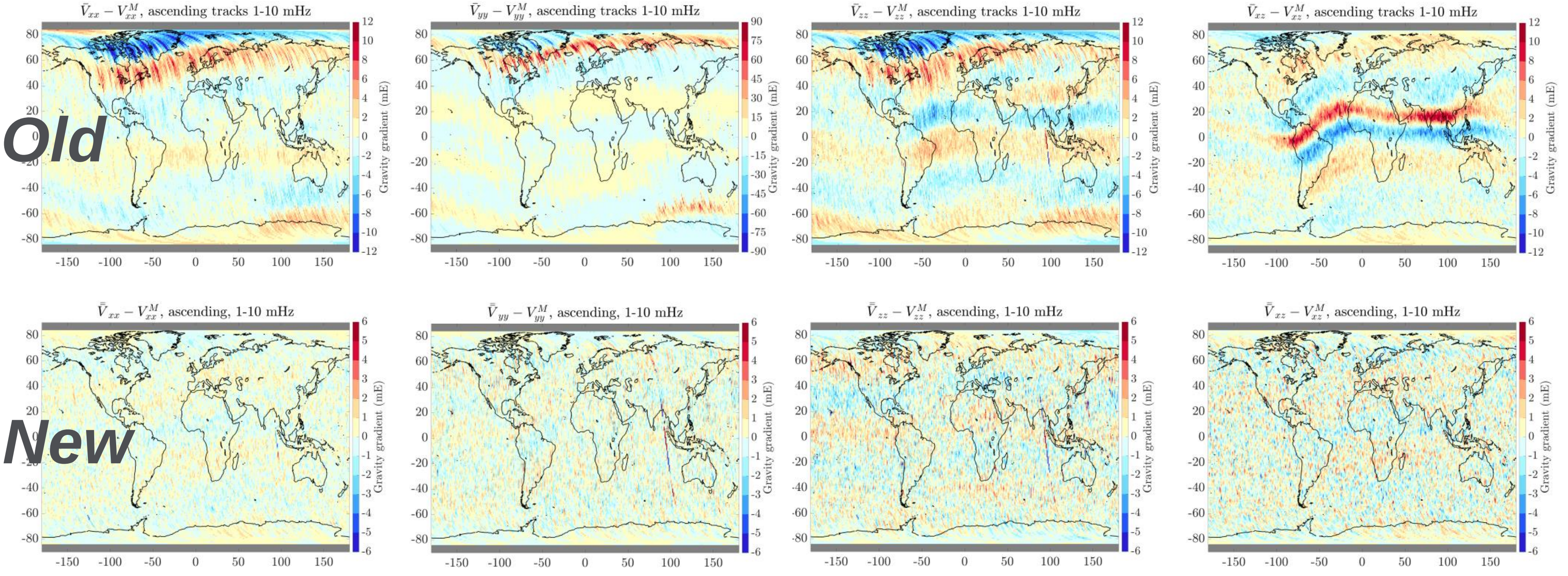
- New gradiometer calibration scheme by estimating additional quadratic factors for the differential mode accelerations.
- Temperature dependent Star tracker attitude bias estimated per measurement epoch.
- Angular rate reconstruction with moving optimal filter frequency between star tracker and gradiometer angular accelerations.



Courtesy: C. Siemes, M. Rexer

GOCE Reprocessing Results - Gradients

Gravity Gradient Residuals to GRACE Gravity Field Model

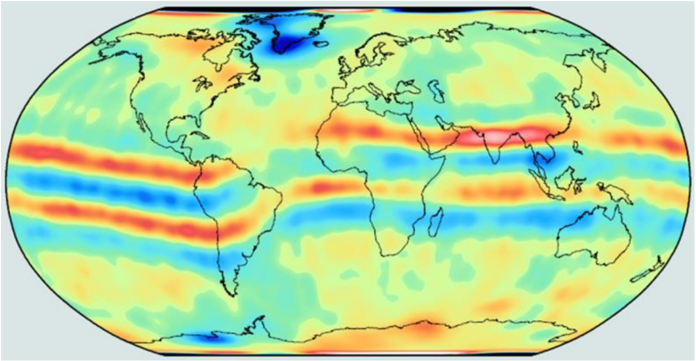


Courtesy: C. Siemes, M. Rexer

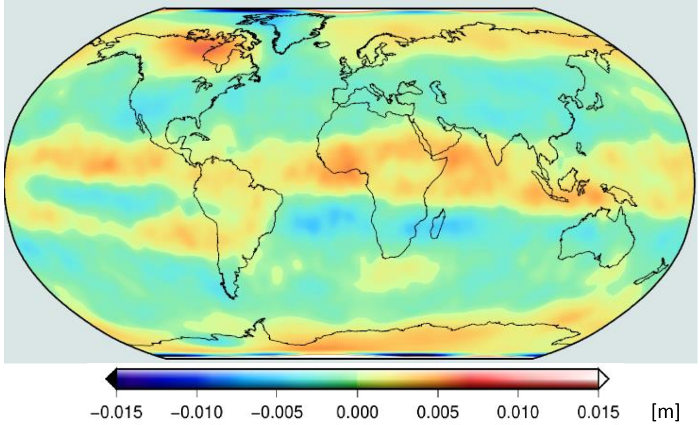
GOCE Reprocessing Results - Orbits

- Orbits for the entire time span (April 7, 2009 - October 20, 2013) have been reprocessed both from unweighted and weighted GPS data
- Improved strategy to mitigate ionosphere-induced artefacts by down-weighting affected GPS observations instead of eliminating.
- Additional screening of kinematic positions based on variances.
- GPS-only gravity field models derived from reprocessed kinematic orbits are significantly improved (see figures with differences to XGM2016)
- See Poster Friday Session B6.01: Precise Orbit Determination

Rel. 5 Precise Science Orbits



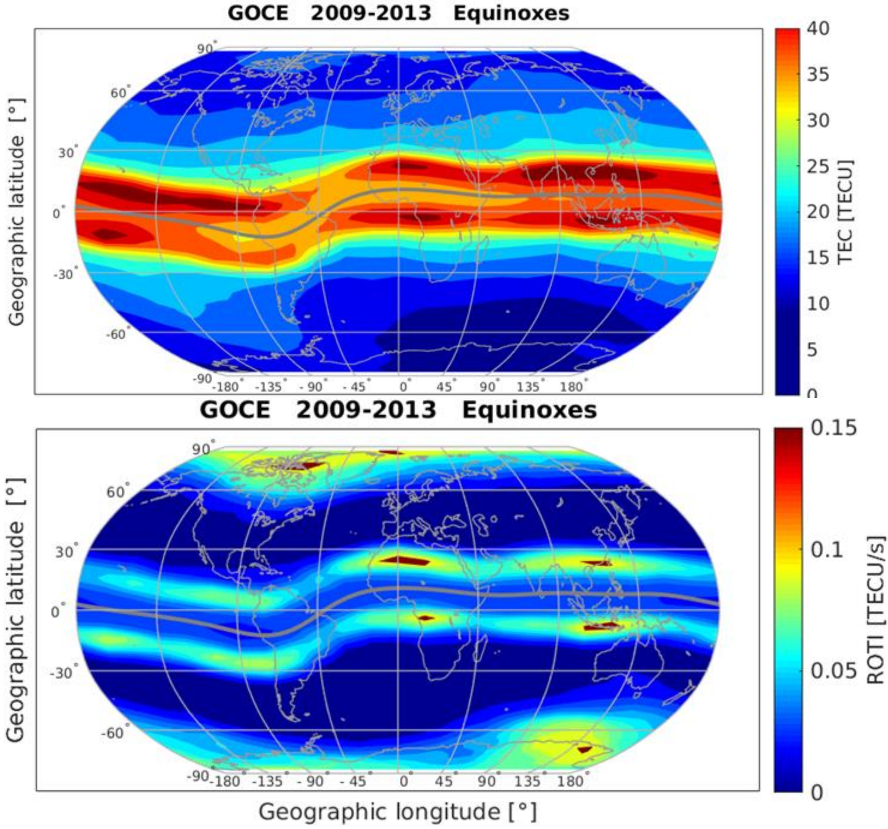
Rel. 6 Precise Science Orbits



Courtesy: D. Arnold, T. Grombein, J.M. Brockmann

GOCE Reprocessing Results – Ionosphere

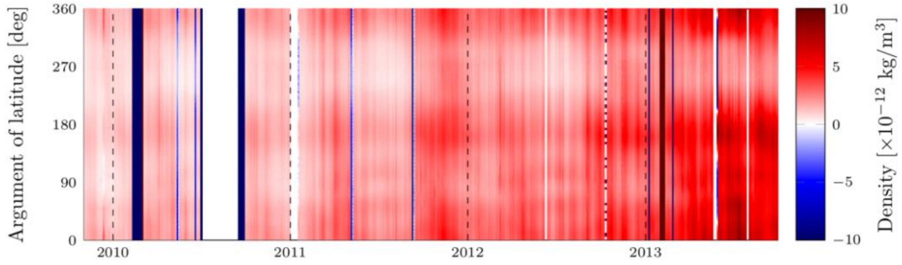
- The TEC and ROTI product has been successfully derived, which provides unique dataset for the space weather study at 250 km.
- The characteristics of TEC and ROTI from GOCE satellite agrees well with previous findings from ground-based and other LEO missions.
- Attention should be paid when using ROTI to identify small-scale ionospheric irregularities.
- Product Access via GOCE Virtual Archive at: http://eo-virtual-archive1.esa.int/Index.html
- See Poster Wednesday Session A7.03: Space Weather



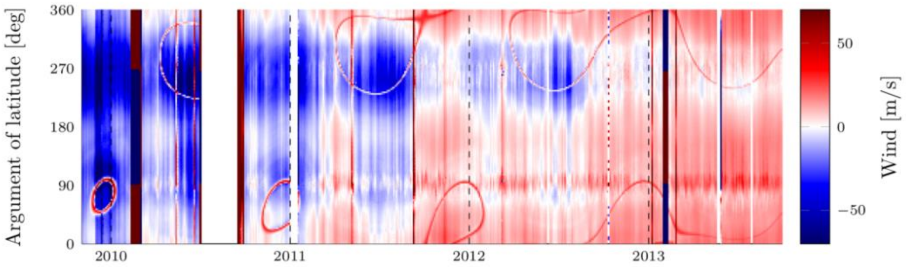
Courtesy: C. Xiong, C. Stolle, G. Kervalishvili – GFZ Potsdam; J. van den Ijssel - TU Delft

GOCE Reprocessing Results – Thermosphere

- Use newly reprocessed GOCE L1B data
- New more flexible processor implemented based on linear and angular accelerations
- New high fidelity satellite geometry model
- Satellite aerodynamic gas-surface interaction model
- New unique acceleration-derived vertical wind data set
- Thermosphere observations from the GOCE deorbit phase special dataset
- Product Access via GOCE Virtual Archive at: http://eo-virtual-archive1.esa.int/Index.html
- See Poster Wednesday Session A7.01: Geospace System Science



Density Differences Reprocessed vs. Original (Signal 0-150)

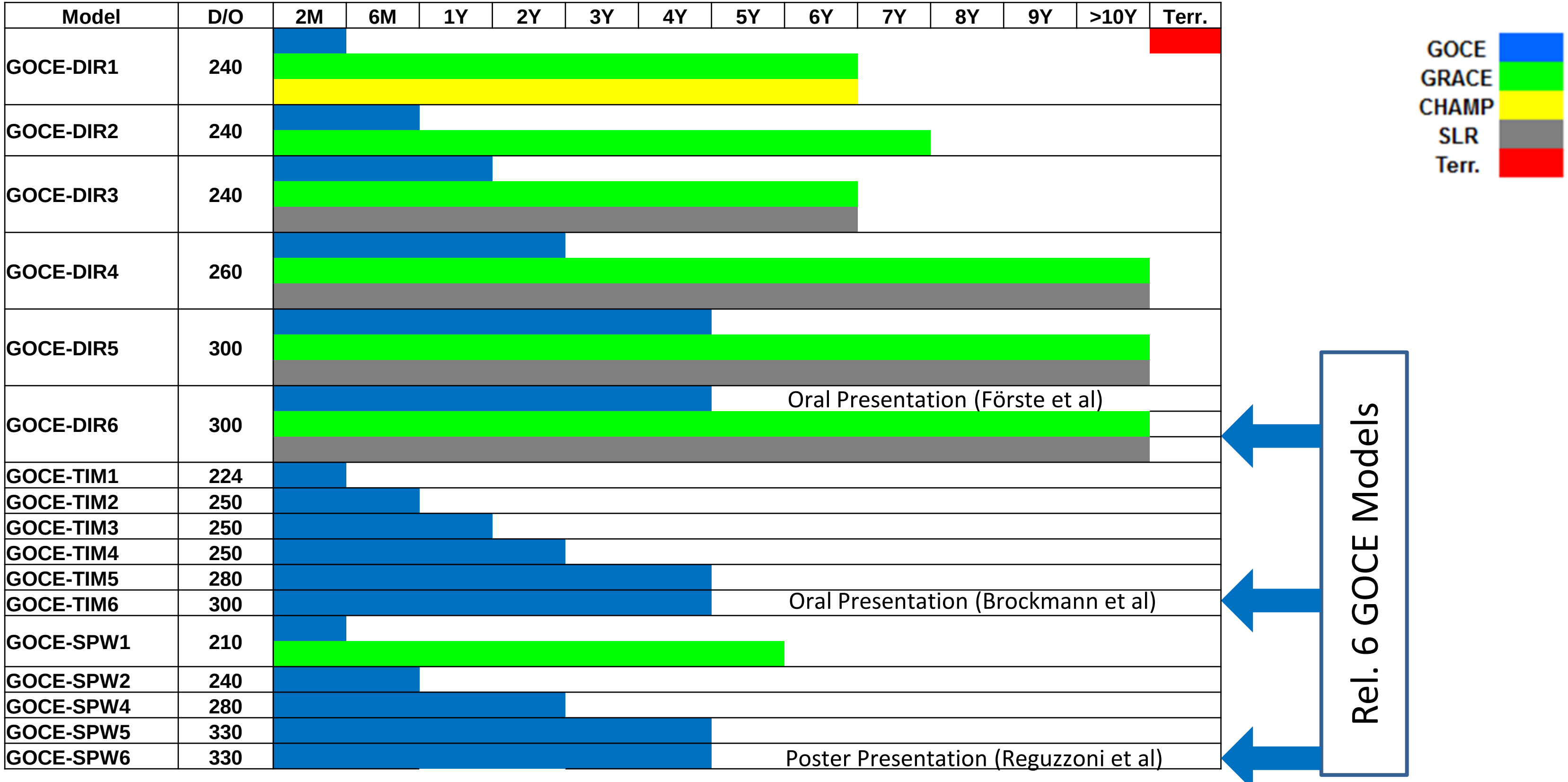


Horizontal Crosswind Differences Reprocessed vs. Original (Signal ±1000)

Courtesy: T. Visser, G. March, E. Doornbos and P. Visser - TU Delft

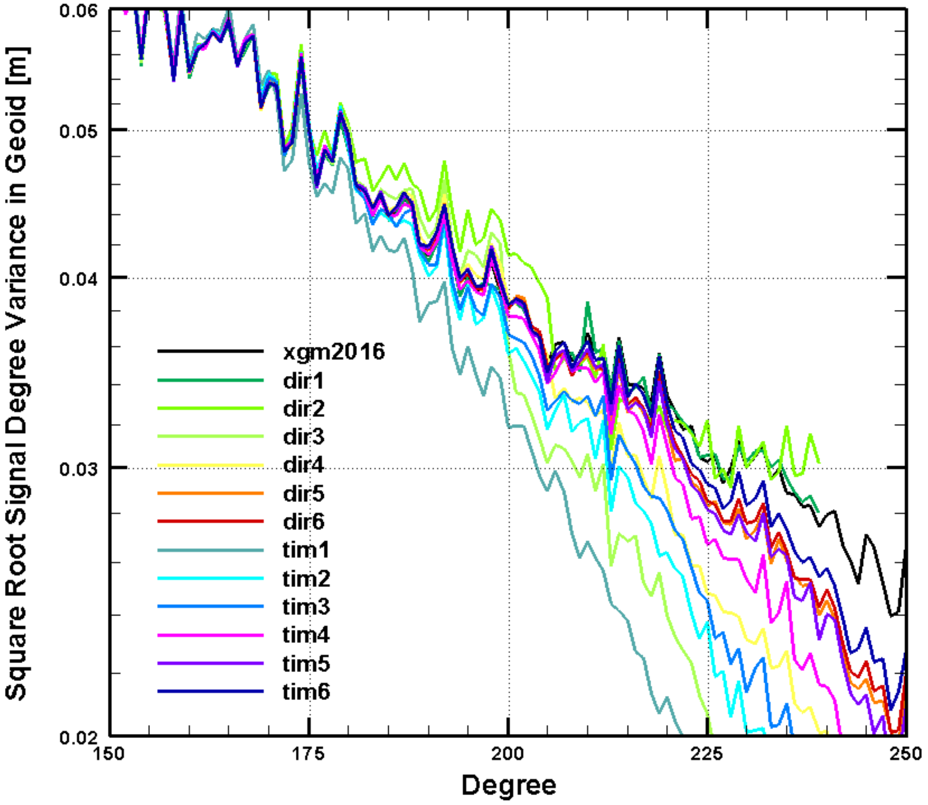
GOCE Reprocessing Results – Gravity Fields

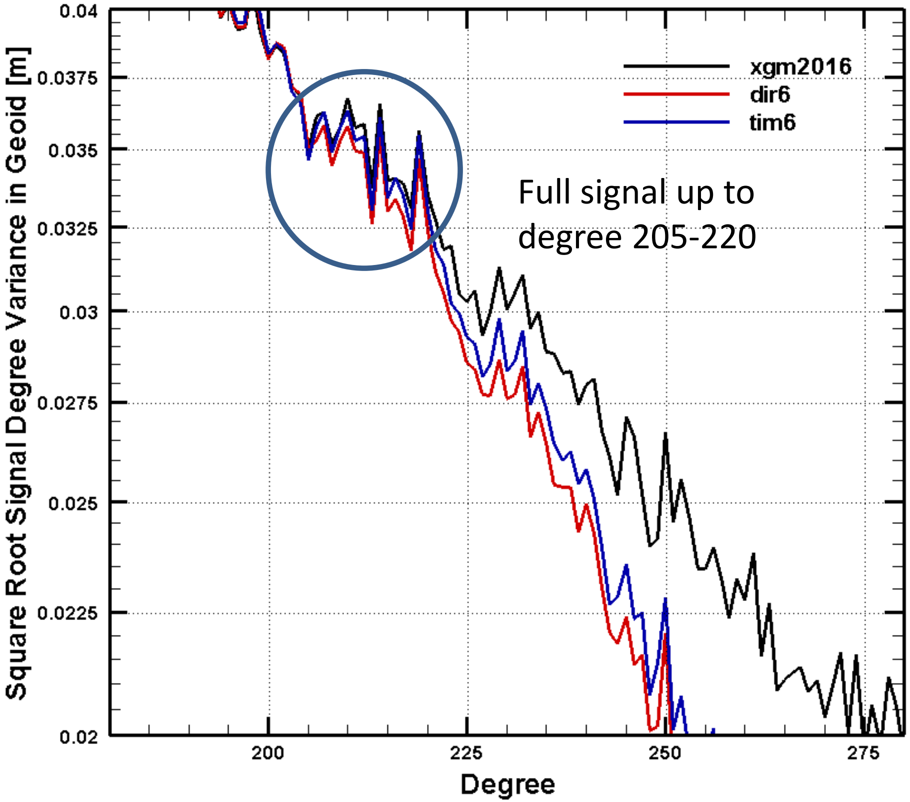
Overview of ESA GOCE Models



GOCE Reprocessing Results – Gravity Fields

Signal GOCE Models

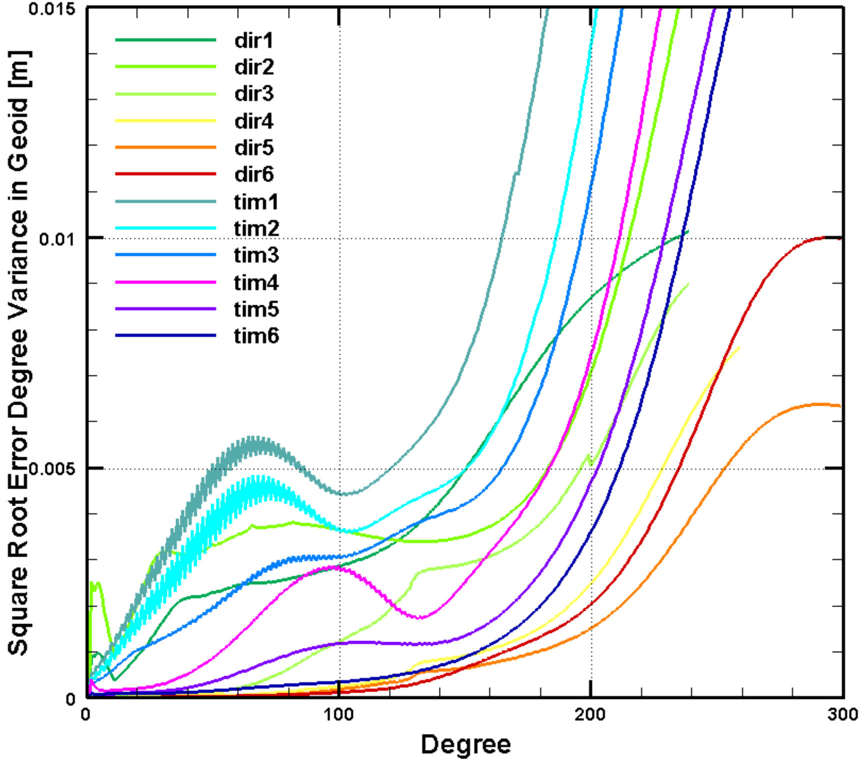




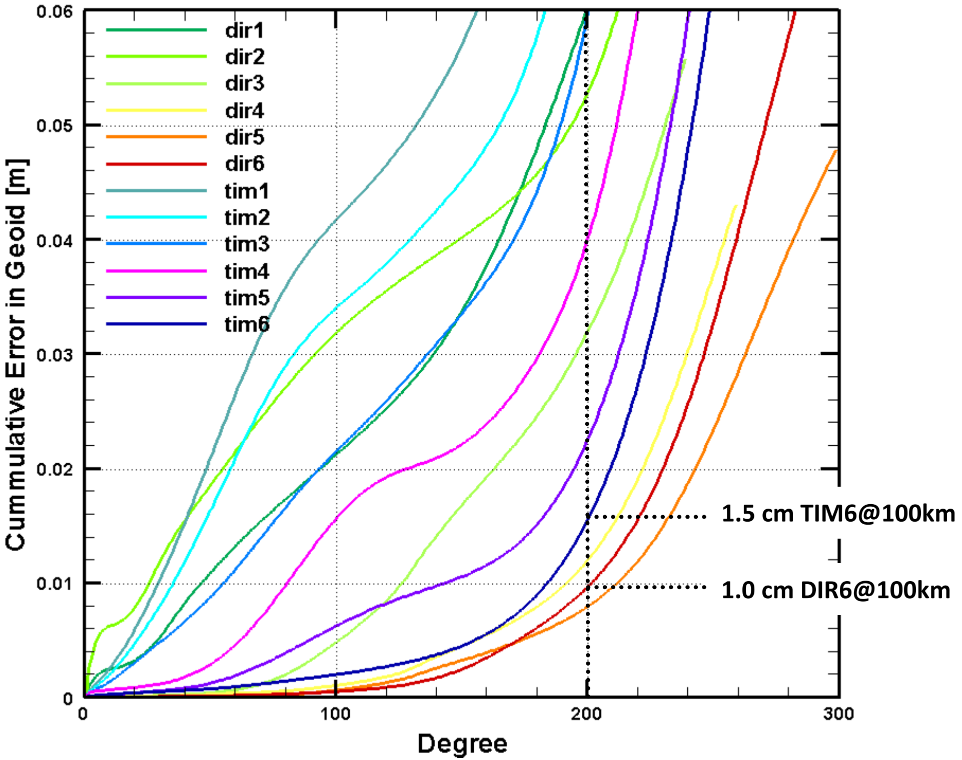
GOCE Reprocessing Results – Gravity Fields

Estimated Errors GOCE Models

per degree (global average)



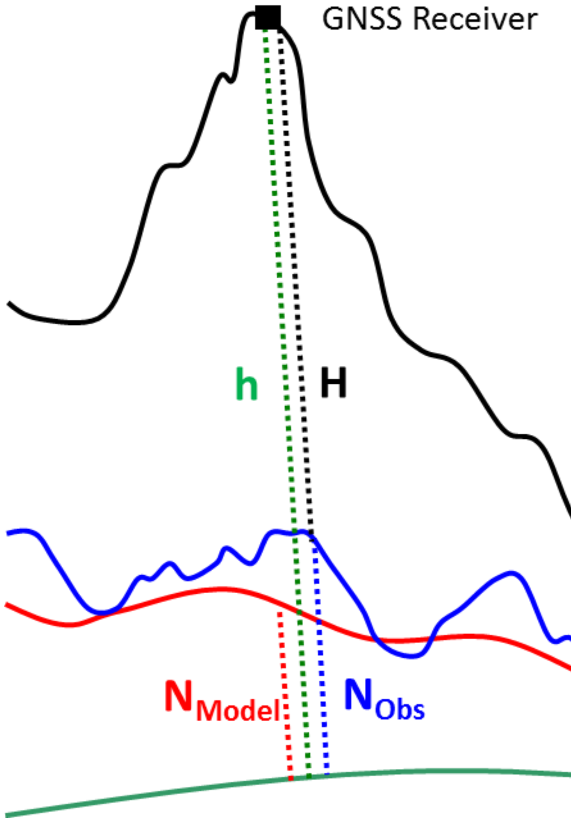
accumulated (global average)



GOCE Reprocessing Results – Gravity Fields

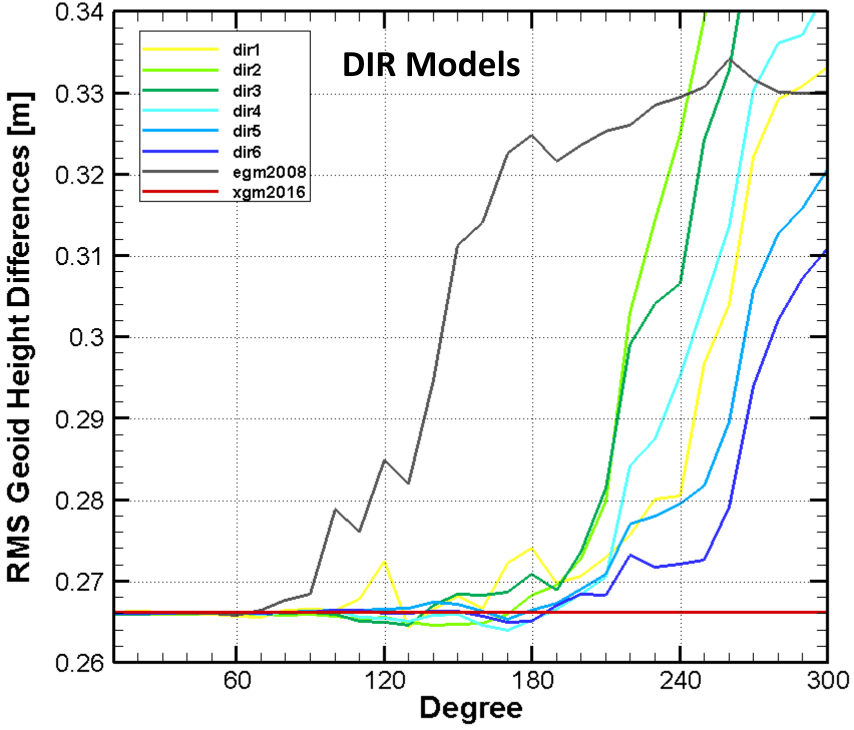
GNSS-Levelling Validation Procedure

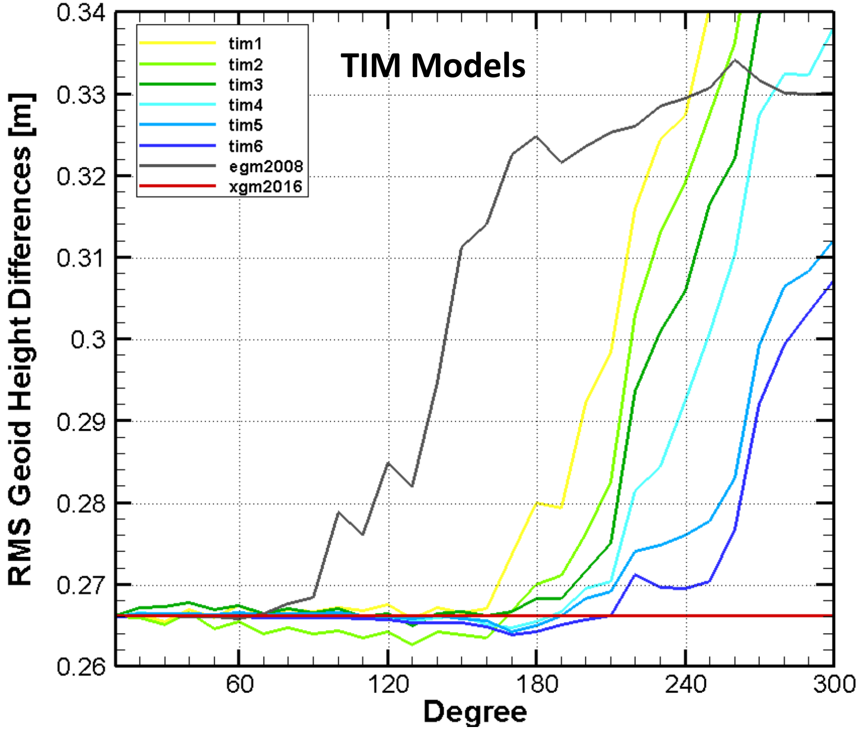
- Compute height anomaly at GNSS-levelling station from global model up to degree and order N.
- Estimate omitted signal from existing HR-model from degree N+1 to 2160 (2190).
- Estimated omitted signal above 2160 from residual topographic gravity field model. (ERTM2160, Hirt et al, 2014)
- If necessary, convert from height anomalies to geoid undulations (Rapp, 1997).
- Compare with geoid height / height anomaly at GNSS-levelling station computed from h-H
- Systematic differences between model and observed geoid heights are possible (definition of local height systems).
- Apply correction surface (planar fit to differences)
- Compute differences of corrected GNSS-levelling geoid heights to model geoid heights.



GOCE Reprocessing Results – Gravity Fields

GNSS-Levelling Differences per Truncation Degree – Brazil*

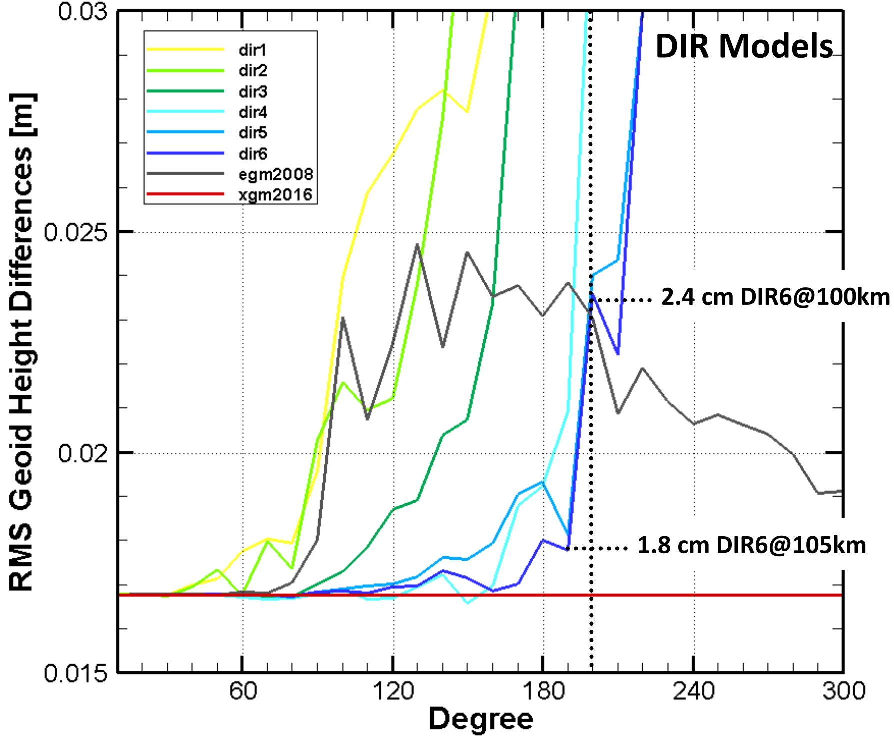


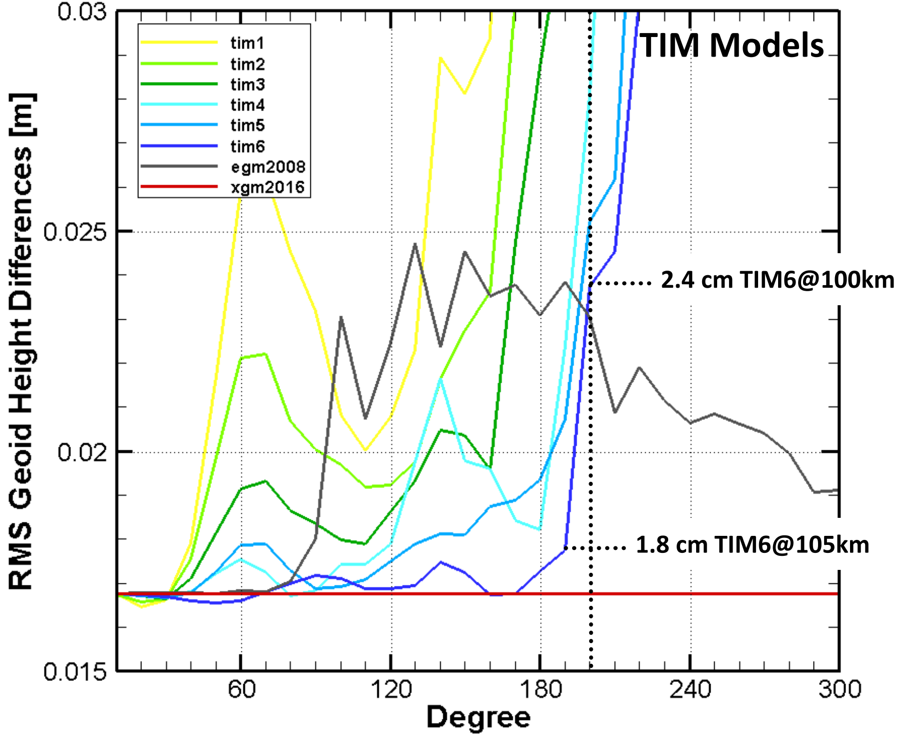


* Brazilian Institute of Geography and Statistics - IBGE, Directorate of Geosciences - DGC, Coordination of Geodesy – CGED, 2012, 683 Points

GOCE Reprocessing Results – Gravity Fields

GNSS-Levelling Differences per Truncation Degree – Germany DHHN2016*





*© GeoBasis-DE / Geobasis NRW, 2018, 470 Points

GOCE Reprocessing Results – Gravity Fields

Error Assessment of GOCE Rel. 6 Model^s in Germany

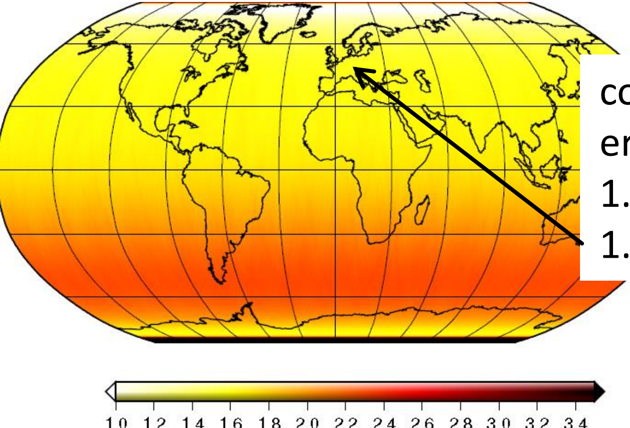
$$\Delta N = h - H - (N + N^{HF})$$

Total Error		GNSS Height Error		Spirit Levelling Error		GOCE Model Error		Residual Omission Error
1.8 cm	=	1.0 cm	+	1.0 cm	+	x cm	+	0.5 cm

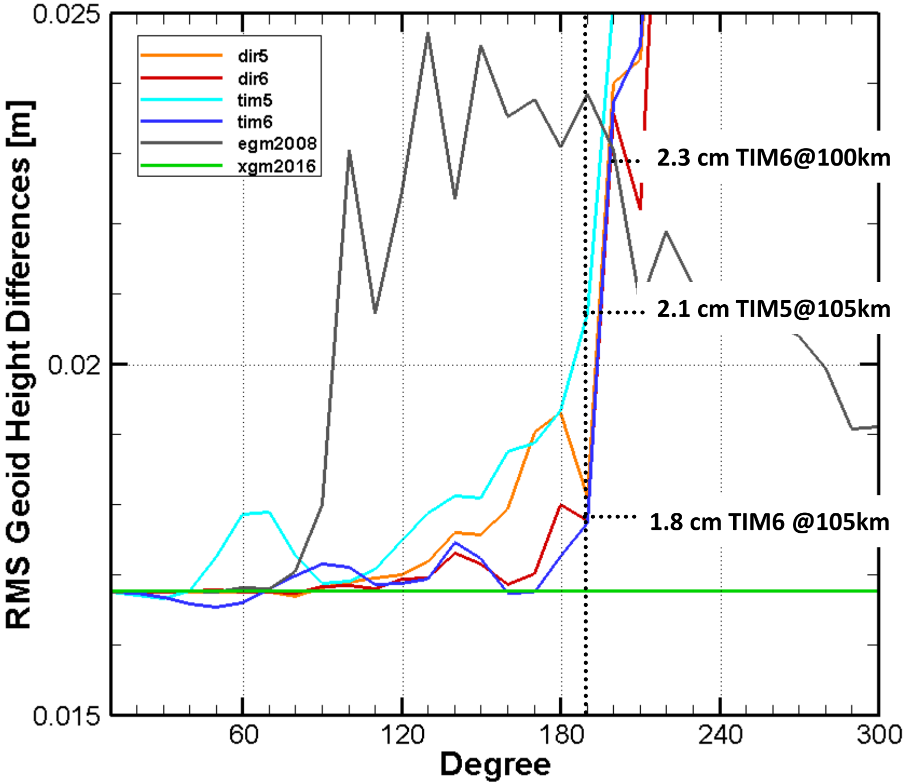
Error Propagation TIM6: **x = 1.0 cm** @ 105 km

TIM6^: **x = 1.7 cm** @ 100 km

TIM5: **x = 1.5 cm** @ 105 km

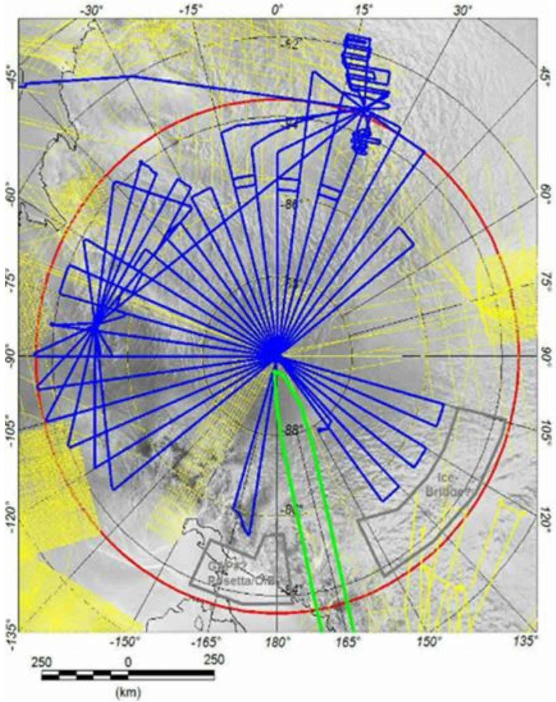


consistent to geoid error map of TIM6:
1.15 cm @105 km
1.55 cm @ 100 km

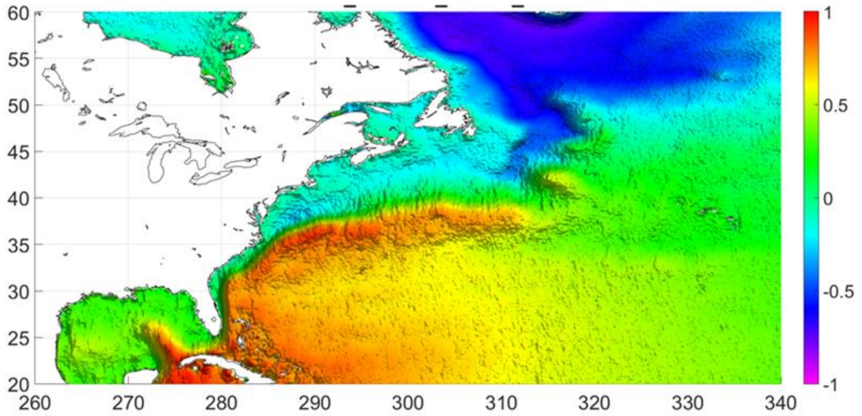


GOCE Reprocessing Results – Gravity Fields

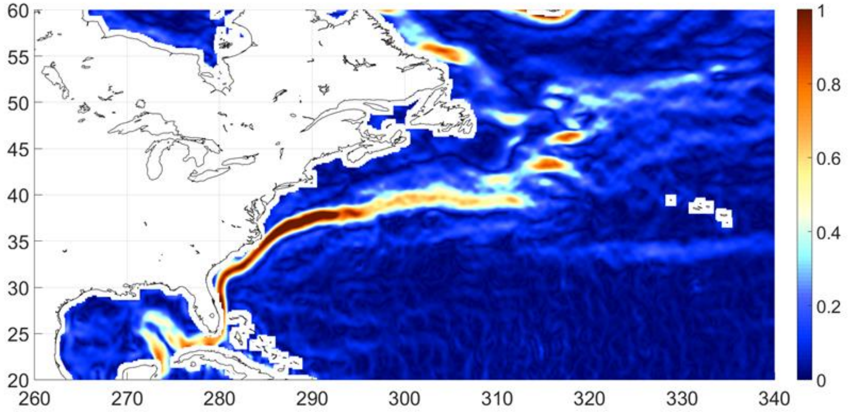
Combined Gravity Fields



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

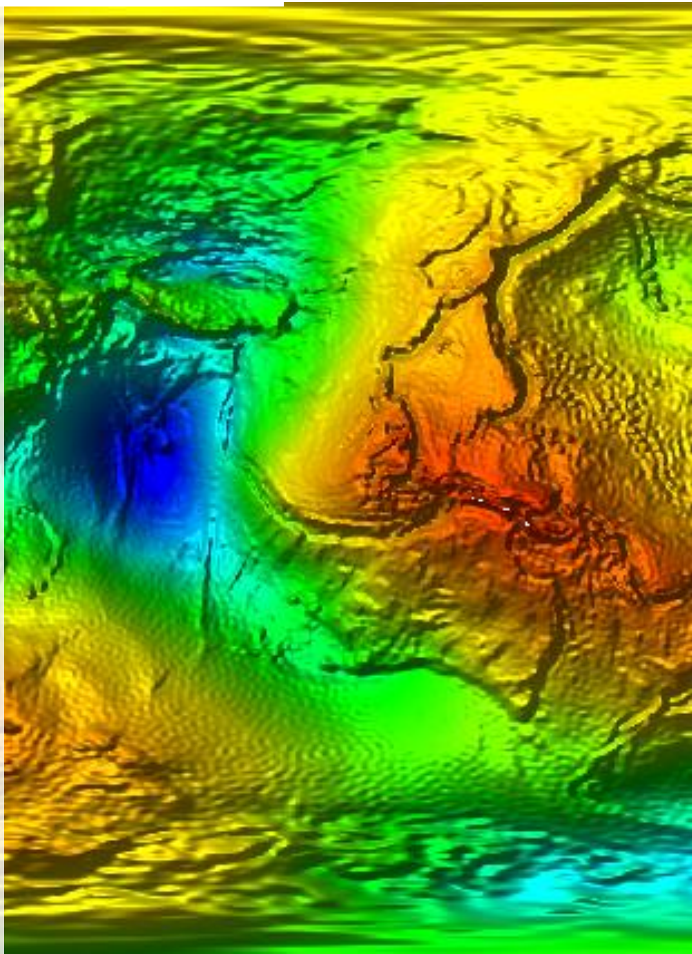


MDT from DTU15MSS and extended XGM2016 [m] and derived Geostrophic current velocities [m/s].



GOCE Reprocessing Summary

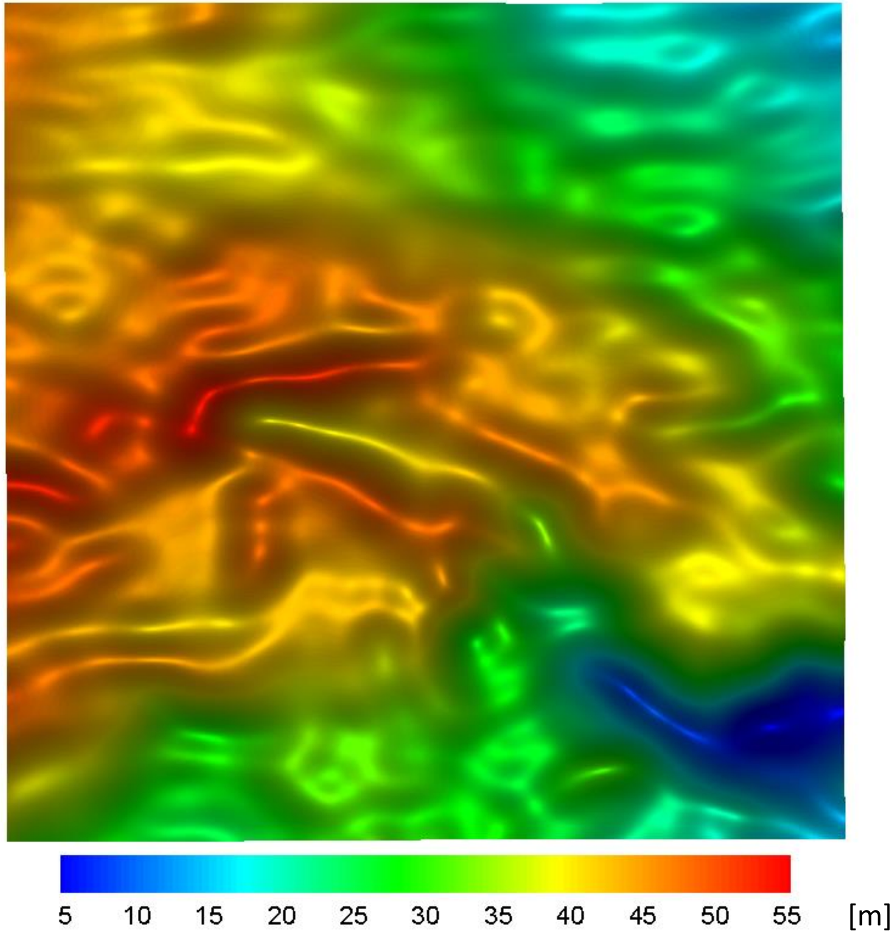
- Rel. 5 GOCE gravity field models already meet mission requirements.
- Reprocessing of L1B gradients by improved calibration scheme, star tracker combination and angular rate reconstruction. Improved GPS data screening.
- Improvements of gravity gradients and GOCE models between 15% and 20%;
- New HPF products based on GOCE+ and SWARM+ studies also reprocessed.
- Reprocessed gravity gradients, orbits ionosphere and thermosphere products already available.
- Rel. 6 GOCE and combined gravity field models available in May/June 2019.
- Reprocessed gravity gradient grids before summer 2019.



GOCE European Geoid

TIM1 (d/o 224)

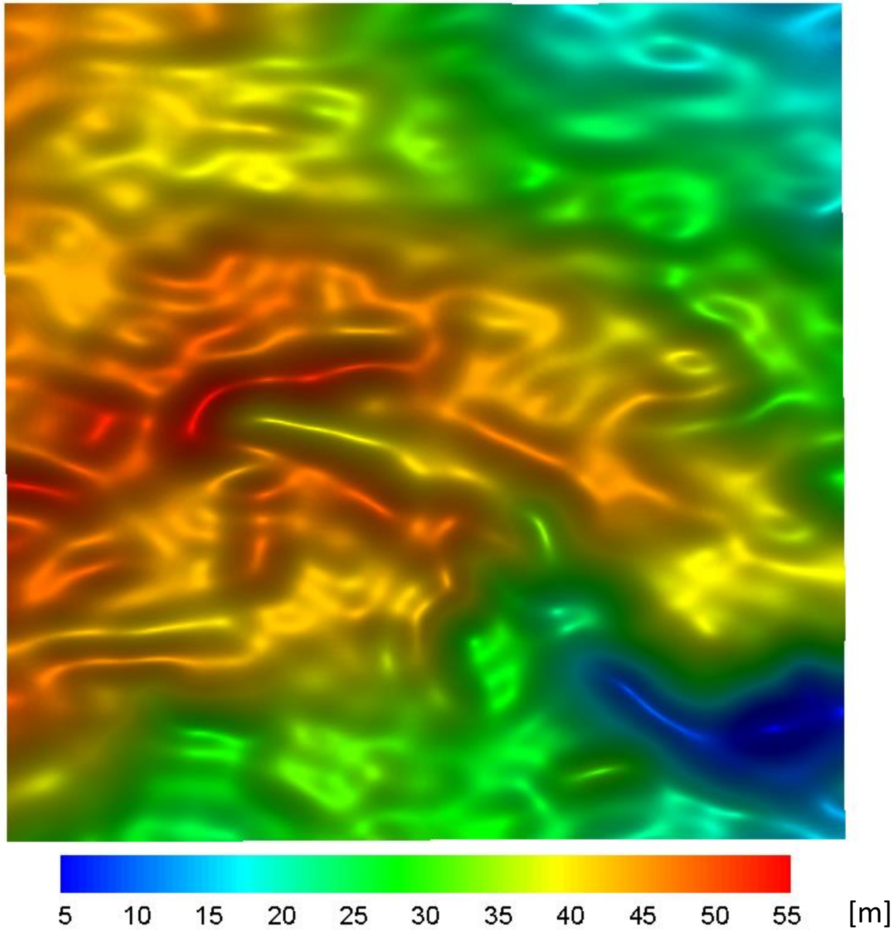
Data: 2 Months GOCE



GOCE European Geoid

TIM2 (d/o 250)

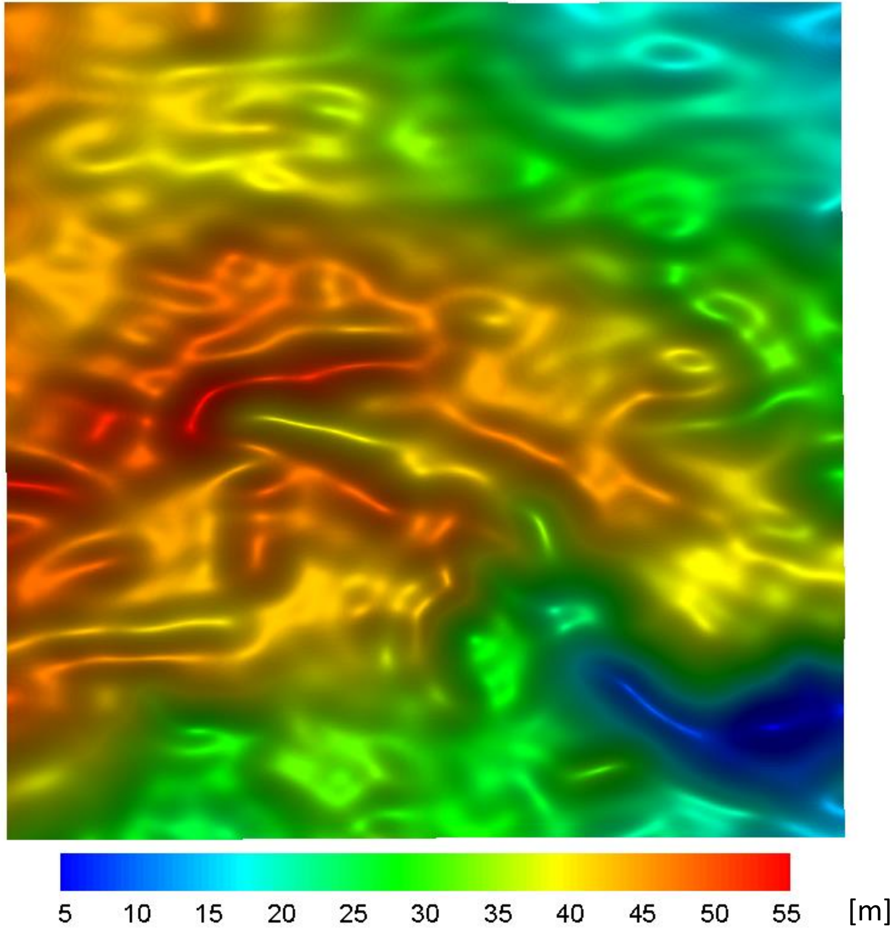
Data: 6 Months GOCE



GOCE European Geoid

TIM3 (d/o 250)

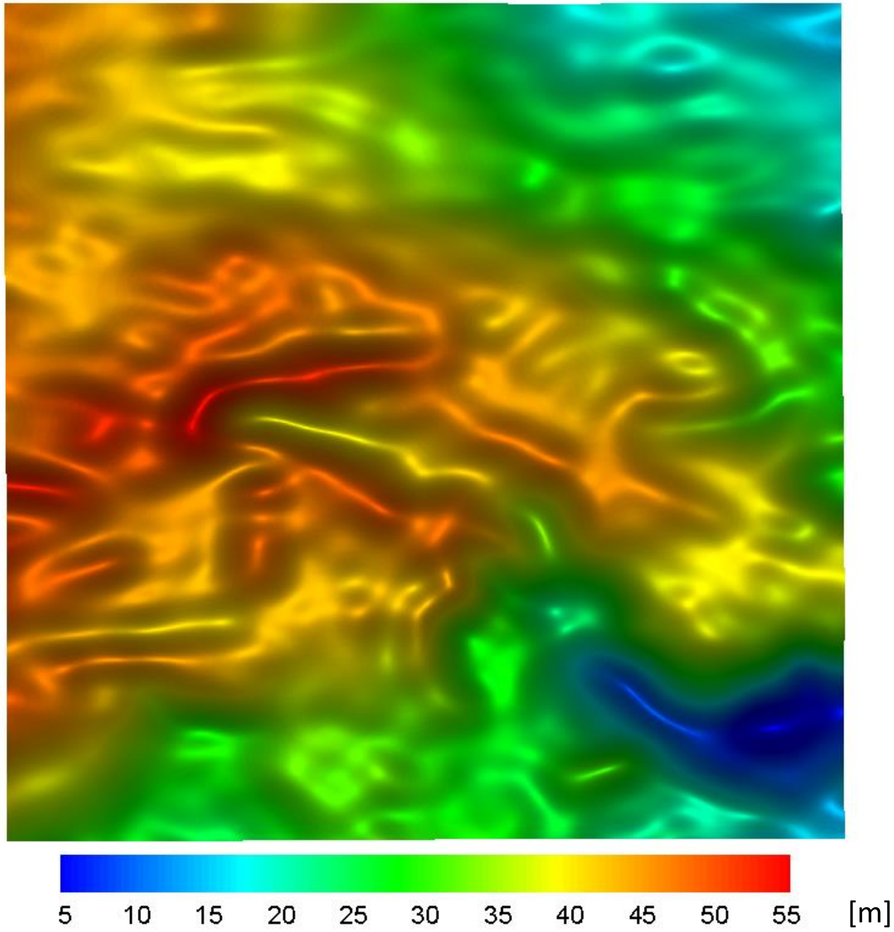
Data: 1 Year GOCE



GOCE European Geoid

TIM4 (d/o 250)

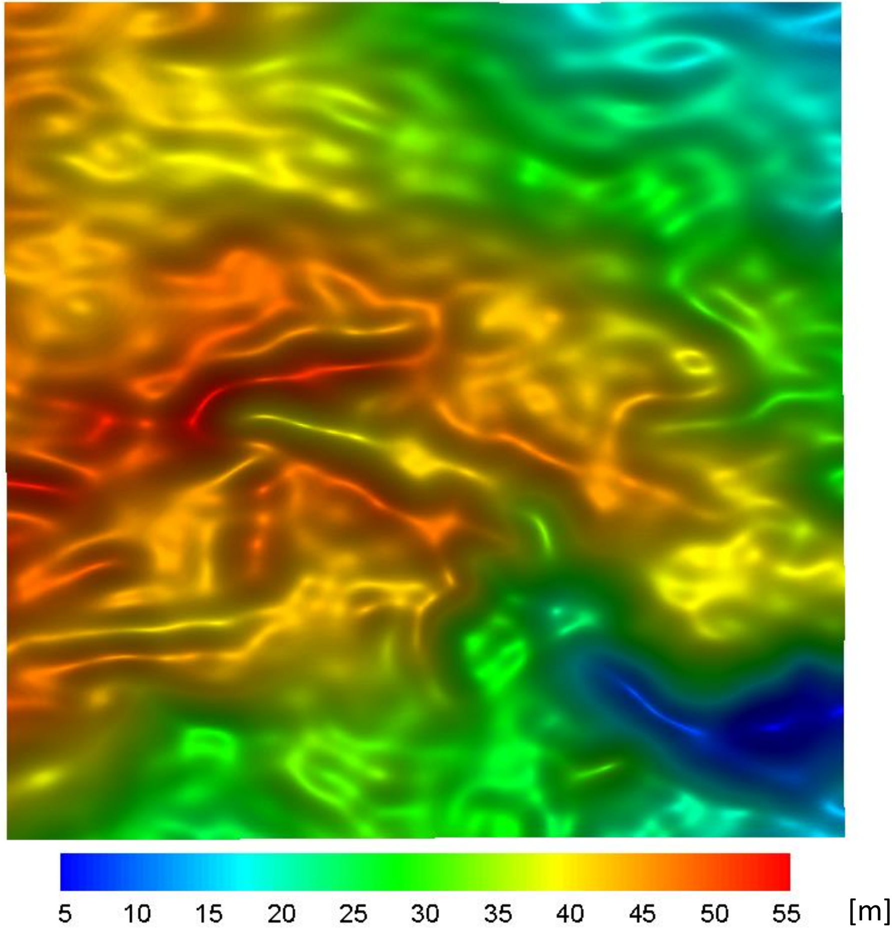
Data: 2 Years GOCE



GOCE European Geoid

TIM5 (d/o 280)

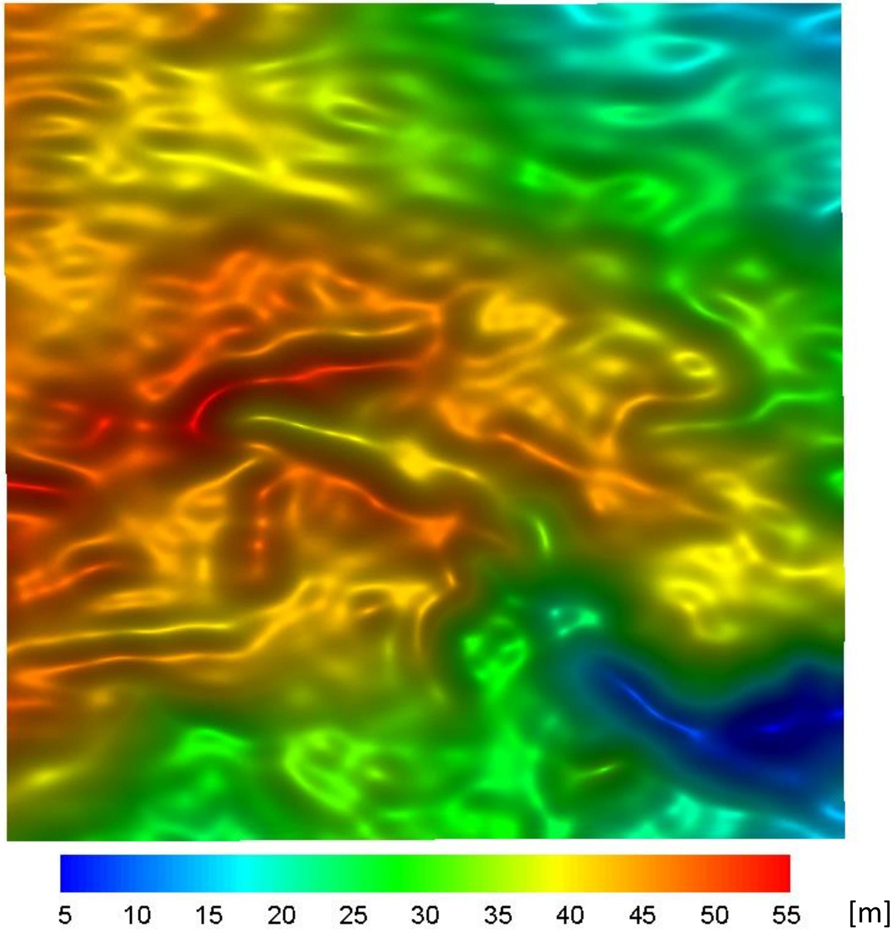
Data: 4 Years GOCE



GOCE European Geoid

TIM6 (d/o 300)

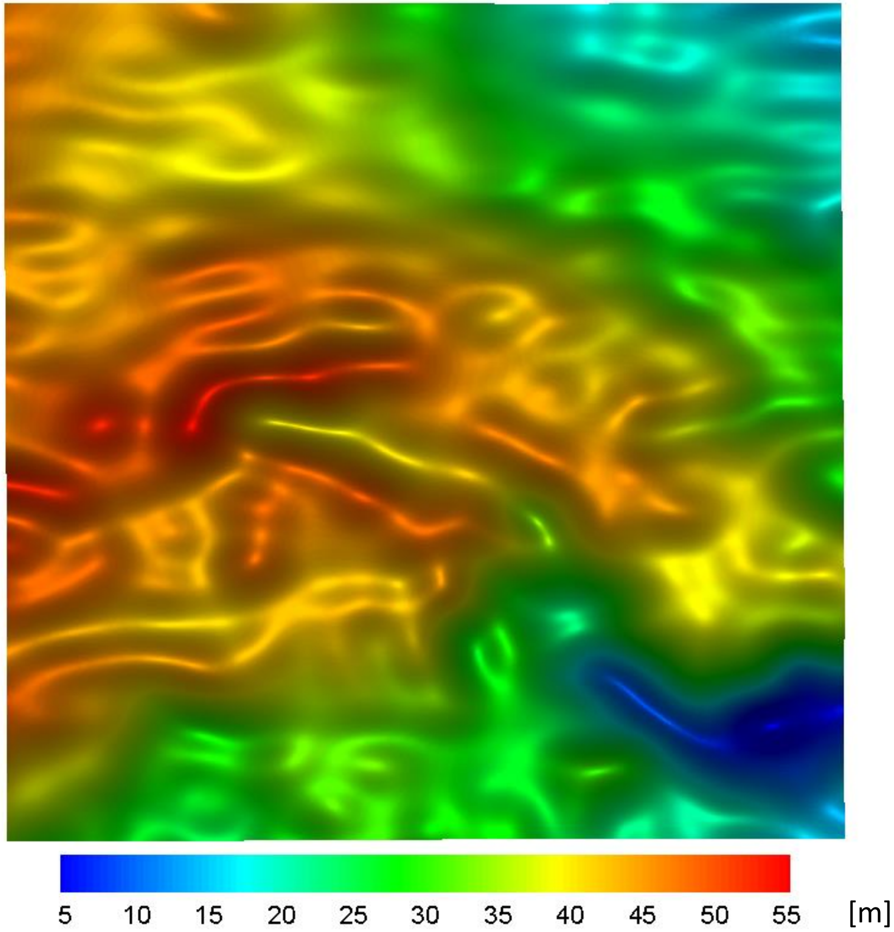
Data: 4 Years GOCE (Reprocessed)



GOCE European Geoid

ITG-GRACE2018 (d/o 200)

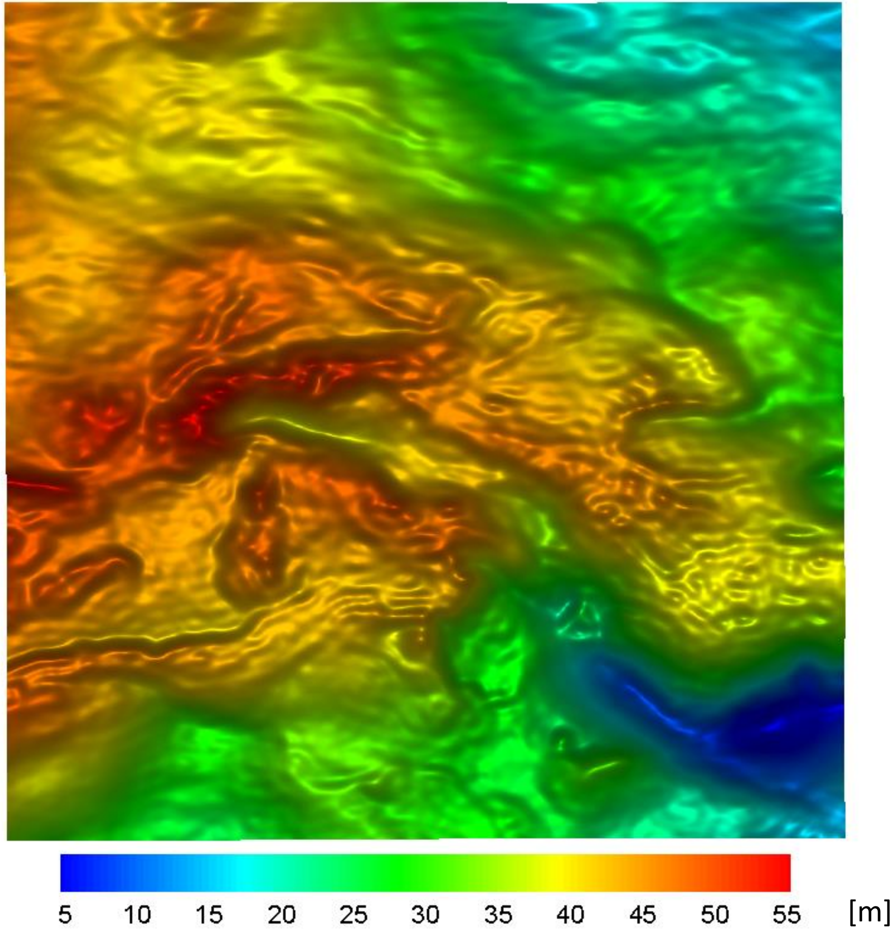
Data: 15 Years GRACE



GOCE European Geoid

XGM2016 (d/o 719)

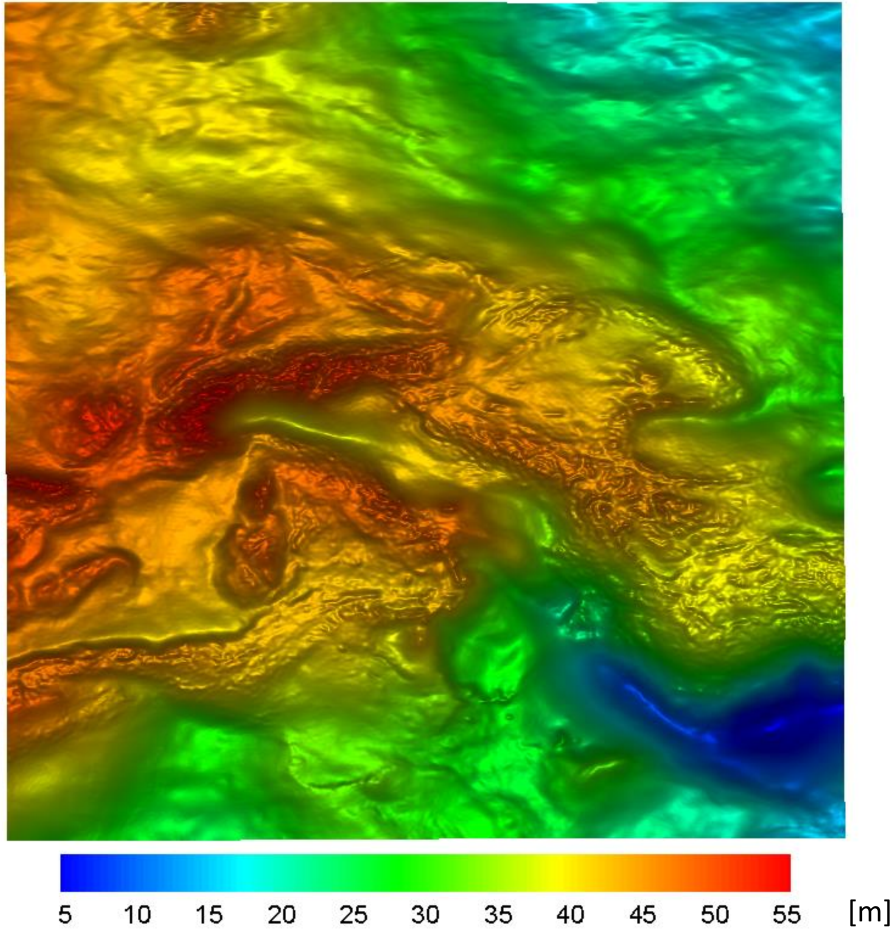
Data:
13 Years GRACE
4 Years GOCE
Terrestrial Gravity (15‘)
Altimetric Gravity (15‘)



GOCE European Geoid

PGM2017 (d/o 2190)

Data:
13 Years GRACE
4 Years GOCE
Terrestrial Gravity (5‘)
Altimetric Gravity (5‘)



Gravity Field from Space – Future Perspective

Time-variable Field

- ❑ Decades of observations needed for Earth system monitoring (GRACE, GRACE-FO, NGGM, MOBILE, Gradiometry) – see Poster Pail et al.
- ❑ Mission & instrument concepts:
  - Multi-pair SST missions (low-low, high-low) and/or gradiometer missions;
  - Laser ranging; Cold-atom accelerometers.

Static Field

- ❑ Increased spatial resolution needed for homogeneous global observations.
- ❑ Mission and instrument concept:
  - Gradiometer; very low orbit
  - Accelerometers: higher sensitivity; extended measurement bandwidth (long and short wavelengths)