

ESA's new satellite-only gravity field model via the direct approach (GOCE-DIR-R6)

Christoph Förste¹, Oleh Abrykosov^{2,3}, [Sean Bruinsma](#)⁴, Christoph Dahle², Rolf König²

¹GeoForschungsZentrum Potsdam, Dept. 1 Geodesy and Remote Sensing, Potsdam, Germany

²GeoForschungsZentrum Potsdam, Dept. 1 'Geodesy and Remote Sensing, Weßling, Germany

³STI SpaceTech GmbH, Immenstaad, Germany

⁴CNES, Space Geodesy Office, Toulouse, France

Outline:

- Background
- Construction of GOCE-DIR6
- Spatial behaviour / noise characteristics
- Model evaluation: orbit tests, GPS/Leveling and comparison with drifters
- Summary

Background

- The precision of the reprocessed GOCE Satellite Gravity Gradient data is much improved compared to the previous release
- The GOCE High Level Processing Facility (GOCE-HPF) consortium has processed all GOCE mission data and computed final releases (DIR and TIM) of the GOCE Gravity Field models
- Within GOCE-HPF, GFZ Potsdam and CNES Toulouse generated the 6th release of the GOCE gravity field by means of the Direct Approach (GOCE-DIR-R6)

This presentation gives a brief report about the computation and the characteristics of GOCE-DIR-R6

Construction of DIR6

GOCE-DIR-R6 is a satellite-only global gravity field model to d/o 300, which contains the following data:

- **GOCE Satellite Gravity Gradient data, reprocessed in 2018** (GOCE-SGG):
tensor components Txx, Tyy, Tzz and Txz
measurement time span: **09.10.2009 – 20.10.2013**
- GFZ's **GRACE-RL06 data** (GNSS-SST and K-Band-Range Rate):
measurement time span: **200701 – 201411**
- **SLR satellite tracking data**, processed by GFZ
processed according to the GRACE-RL06 standards:
LAGEOS-1/2, AJISAI, STARLETTE, STELLA: **200201 - 201810**
LARES: **201202 - 201810**
- Combination of all of these data was done on normal equation level

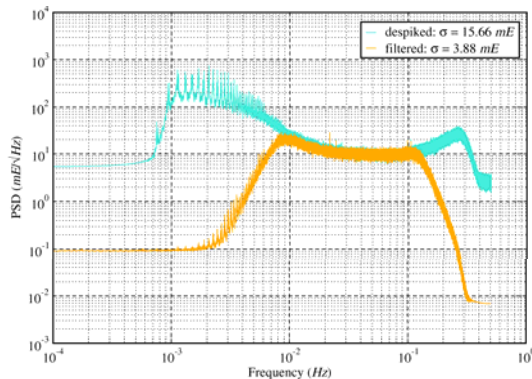
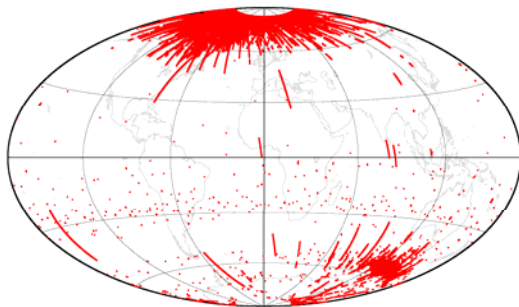
Improvement of the reprocessed GOCE SGG data

Example: The tensor component T_{yy} for the longest time span (20130213 – 20130504)

Result of Level-1b preprocessing:

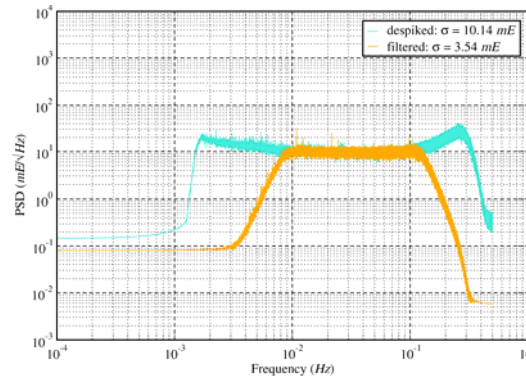
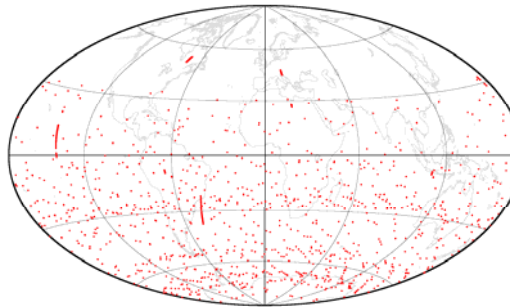
For DIR-R5, 2014:

74276 outliers, 298 revs accepted
Bandpass 125 ... 8 sec.



Reprocessing for DIR-R6, 2018:

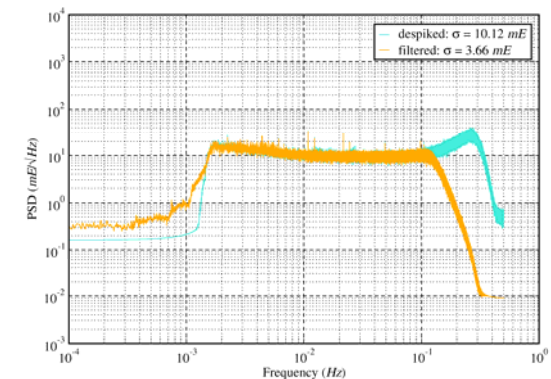
1910 outliers, 1309 revs accepted
Bandpass 125 ... 8 sec.



→ The reprocessed
SGG data show
significantly less
outliers and much
flatter PSD

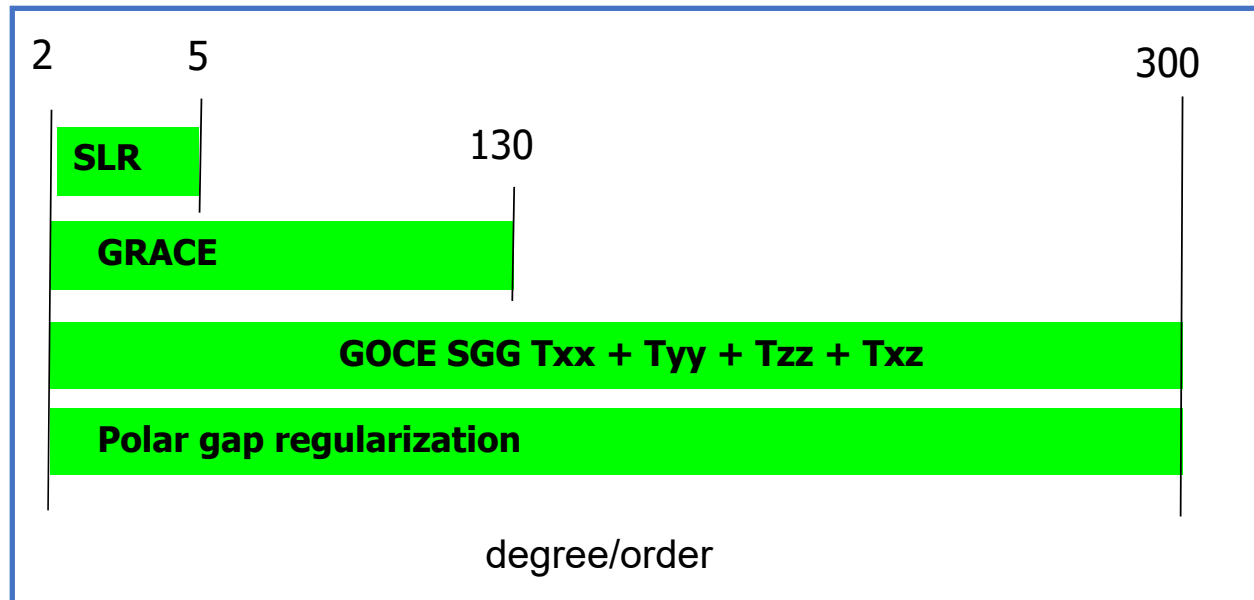


Application of a lowpass filter:
Infinity ... 8 sec.



Power spectral density: Before filtering and after filtering (Butterworth)

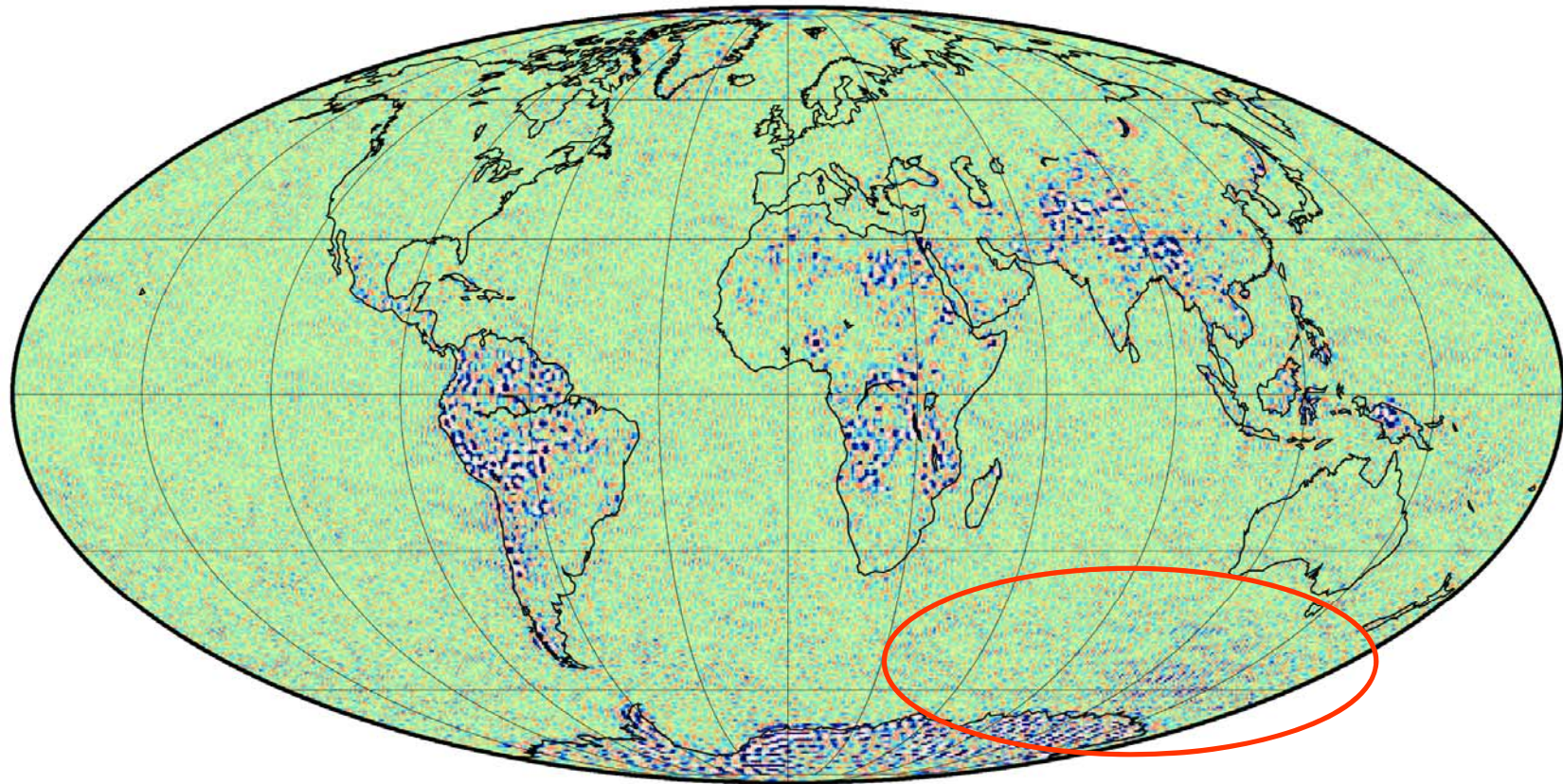
Data combination scheme of the normal equations for GOCE-DIR-R6



Application of external gravity field information over the polar gaps:
GRACE/SLR to d/o 130 + zero coefficients to d/o 300

Algorithm: **Spherical cap regularization** (Metzler & Pail 2005)

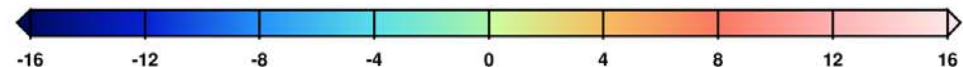
GOCE gravity anomaly differences: DIR-R5 vs. EGM2008 (max d/o 240)



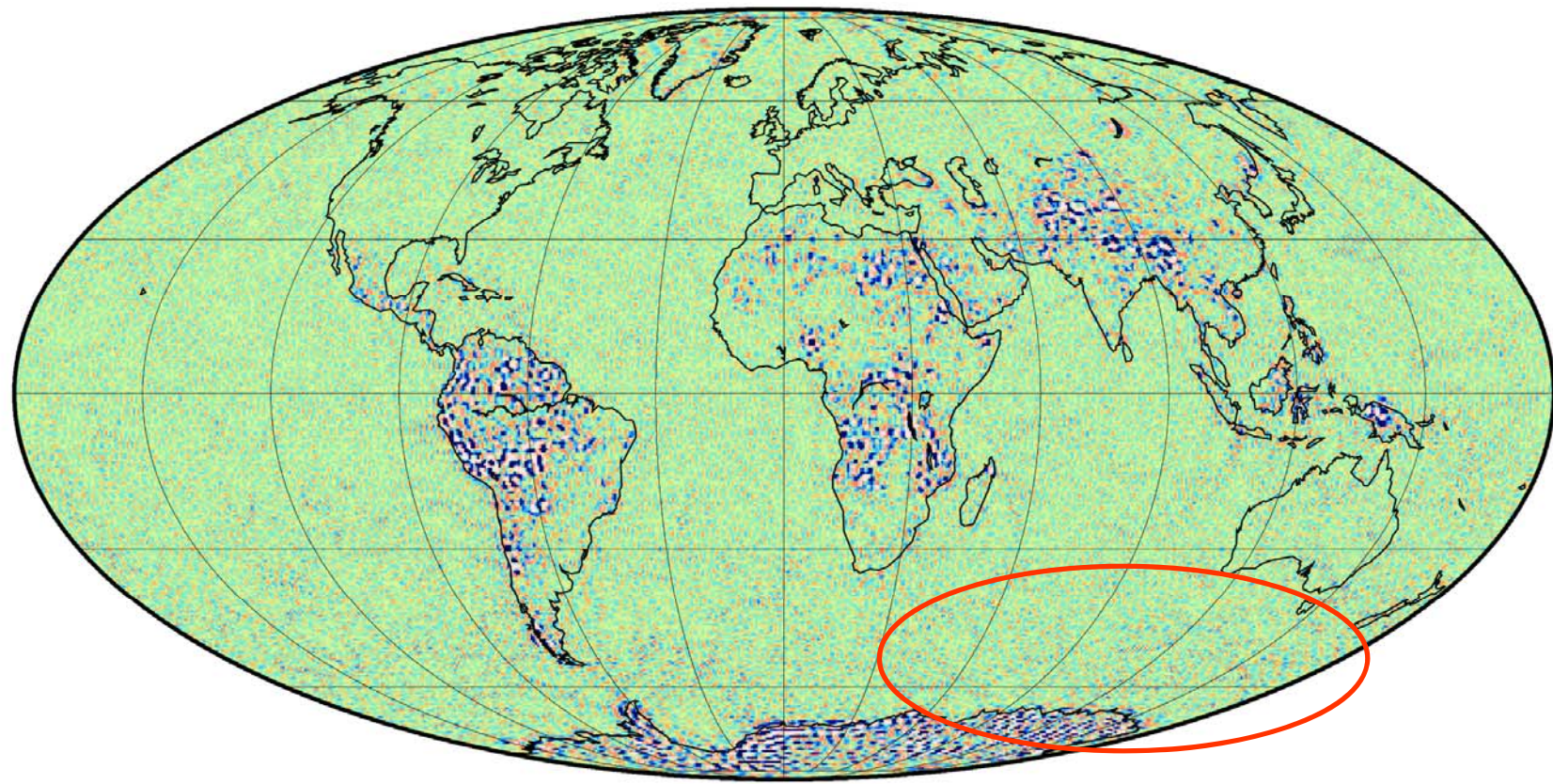
griddif-egm-dir5

$\Delta g_{SA}, 0.5^\circ \times 0.5^\circ$

wrms about mean / min / max = 4.531 / -81.19 / 88.13 mgal



GOCE gravity anomaly differences: DIR-R6 vs. EGM2008 (max d/o 240)



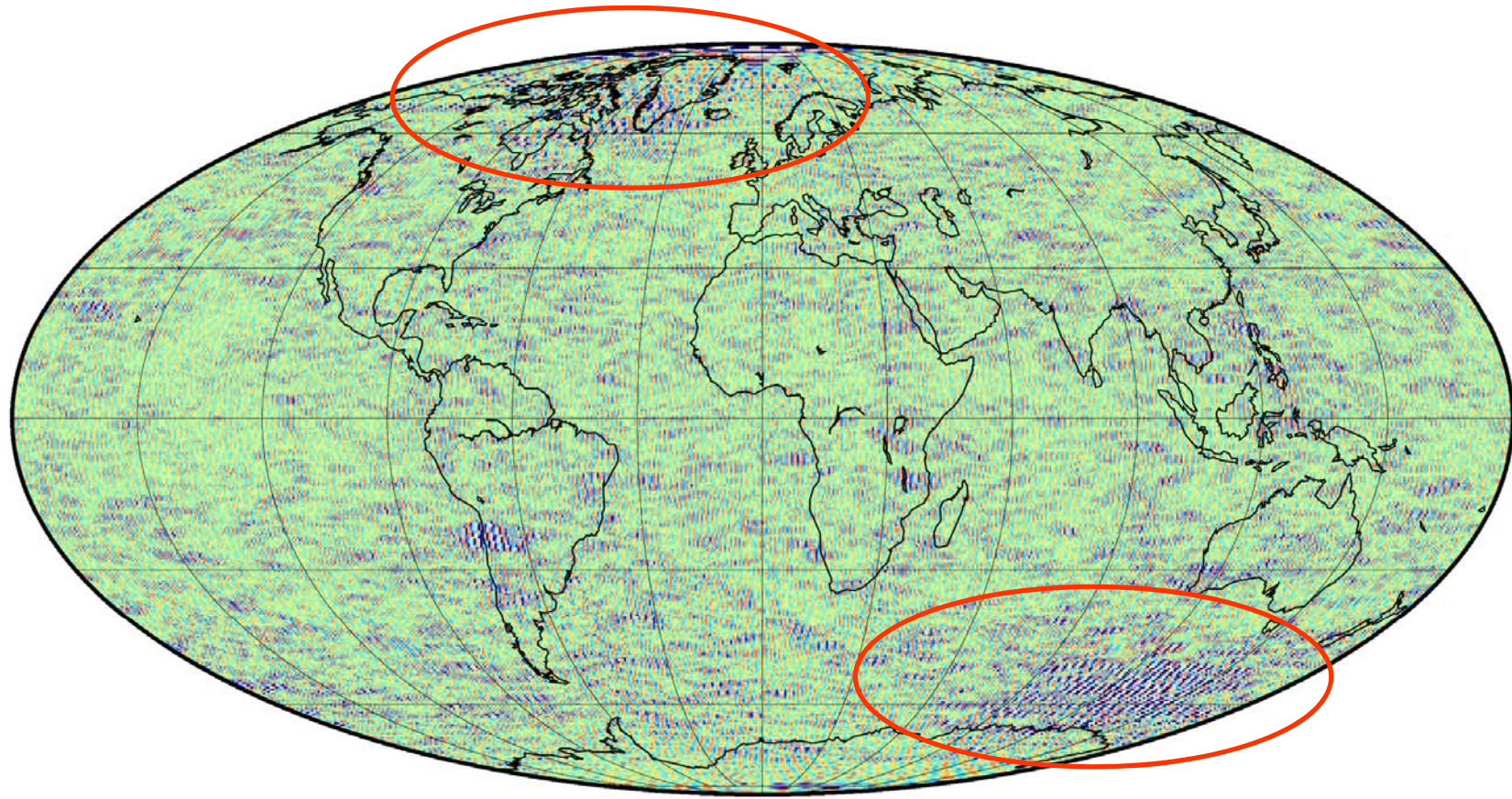
griddif-egm-dir6

$\Delta g_{SA}, 0.5^\circ \times 0.5^\circ$

wrms about mean / min / max = 4.256 / -80.81 / 87.15 mgal



GOCE gravity anomaly differences: DIR-R6 vs. DIR-R5 (max d/o 240)



griddif-dir5-dir6

$\Delta g_{SA}, 0.5^\circ \times 0.5^\circ$

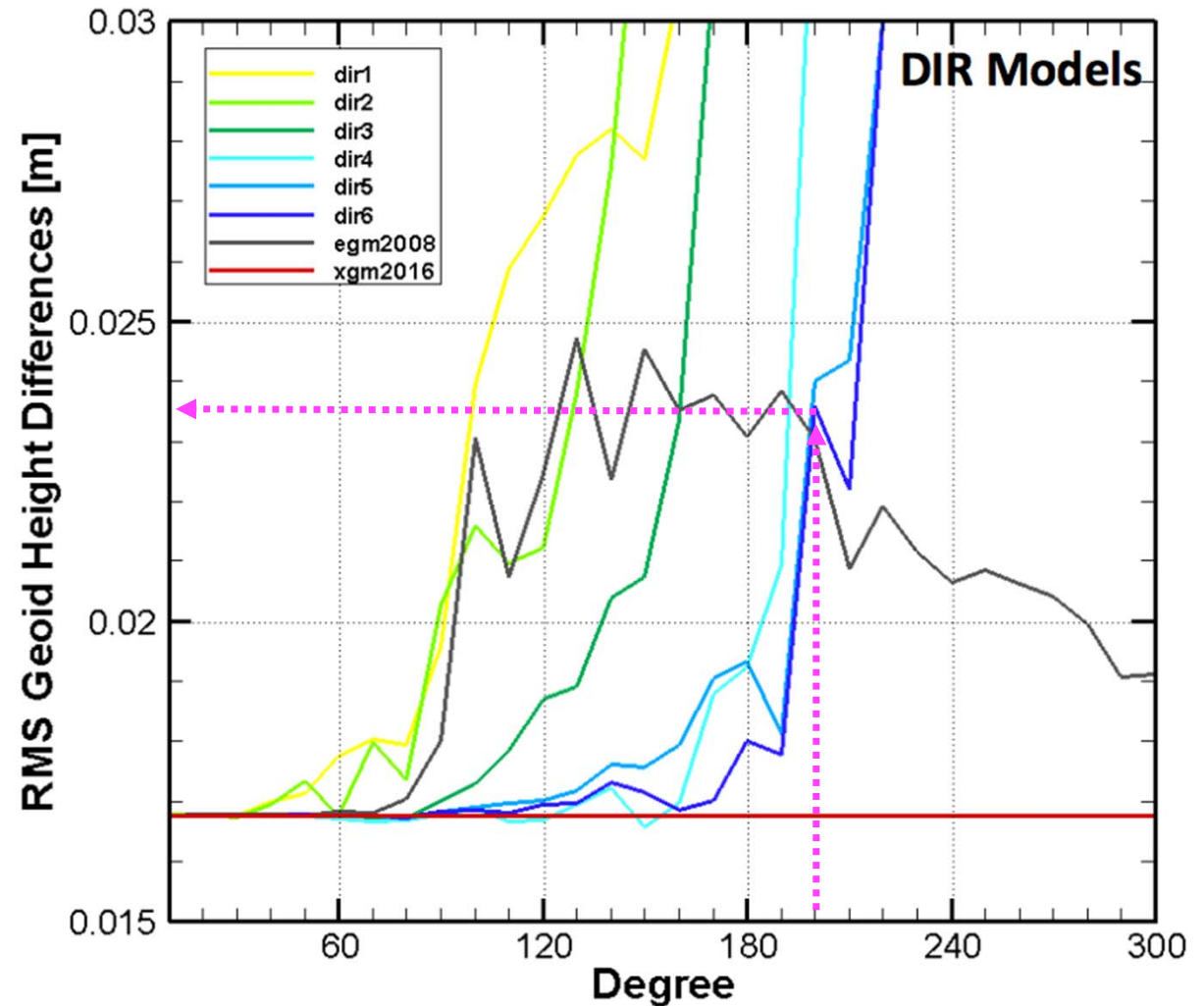
wrms about mean / min / max = 1.632 / -60.56 / 60.25 mgal



Model evaluation: GPS/Leveling comparison

Comparison with geoid heights determined point-wise by GPS positioning and leveling over Germany (DHHN2016, 470 points)

NB: GOCE models were augmented to d/o 2160 with XGM2016, and above with ERTM2160



Model evaluation: orbit adjustment tests

Dynamic orbit computation

- Observations: **GO CONS SST PKI 2I** (kinematic orbit positions, consolidated product)
- **60 arcs** (01.11. – 31.12.2009), Arclength = **1.25 days**
- Parametrization:
 - **Orbital elements** at the begin of each arc
 - Accelerometer **biases**: 1/arc for cross track / radial / along track
 - Accelerometer **scaling factor**: **fixed** to 1.0 (along track / cross track / radial)

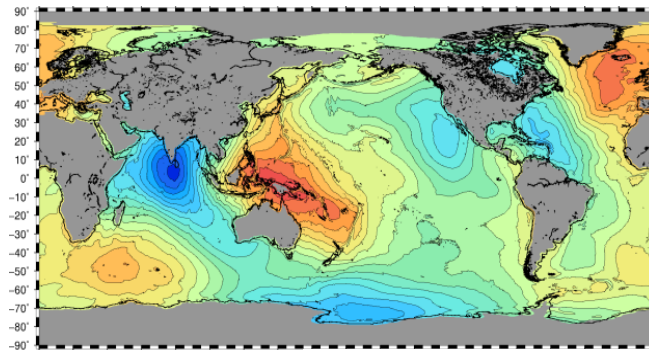
RMS values [cm] of the orbit fit residuals
(3D residuals , mean value of 60 arcs)

Gravity field model d/o 180x180	RMS (cm)
EGM2008	14.17
GGM05C	6.84
XGM2016	3.81
GOCO05C	3.80
EIGEN-6C4	4.01
GOCE-TIM-R5	4.60
GOCE-TIM-R6	4.67
GOCE-DIR-R5	4.00
GOCE-DIR-R6	3.65

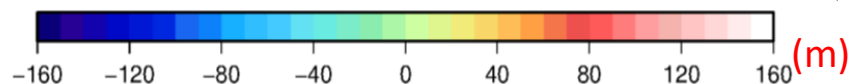
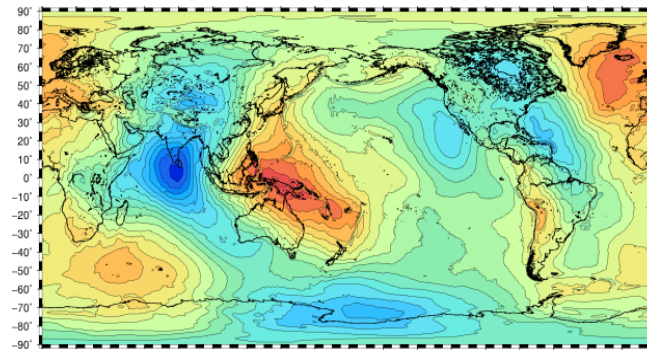
Model evaluation: geostrophic current comparisons

Mean Sea Surface MSS CNES-CLS11

Spatial scale ~ 10km

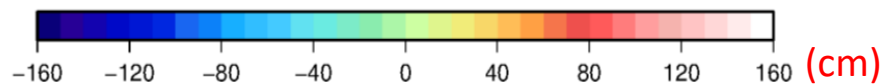
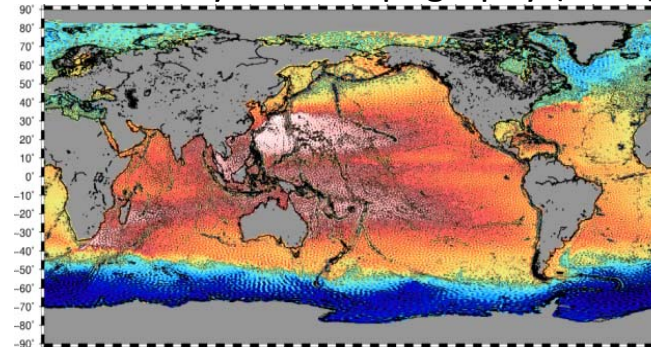


Geoid height DIR5 (Spatial scale ~ 100km)



1 - Computation of a geodetic MDT with a GOCE geoid

Mean Dynamic Topography (MDT)

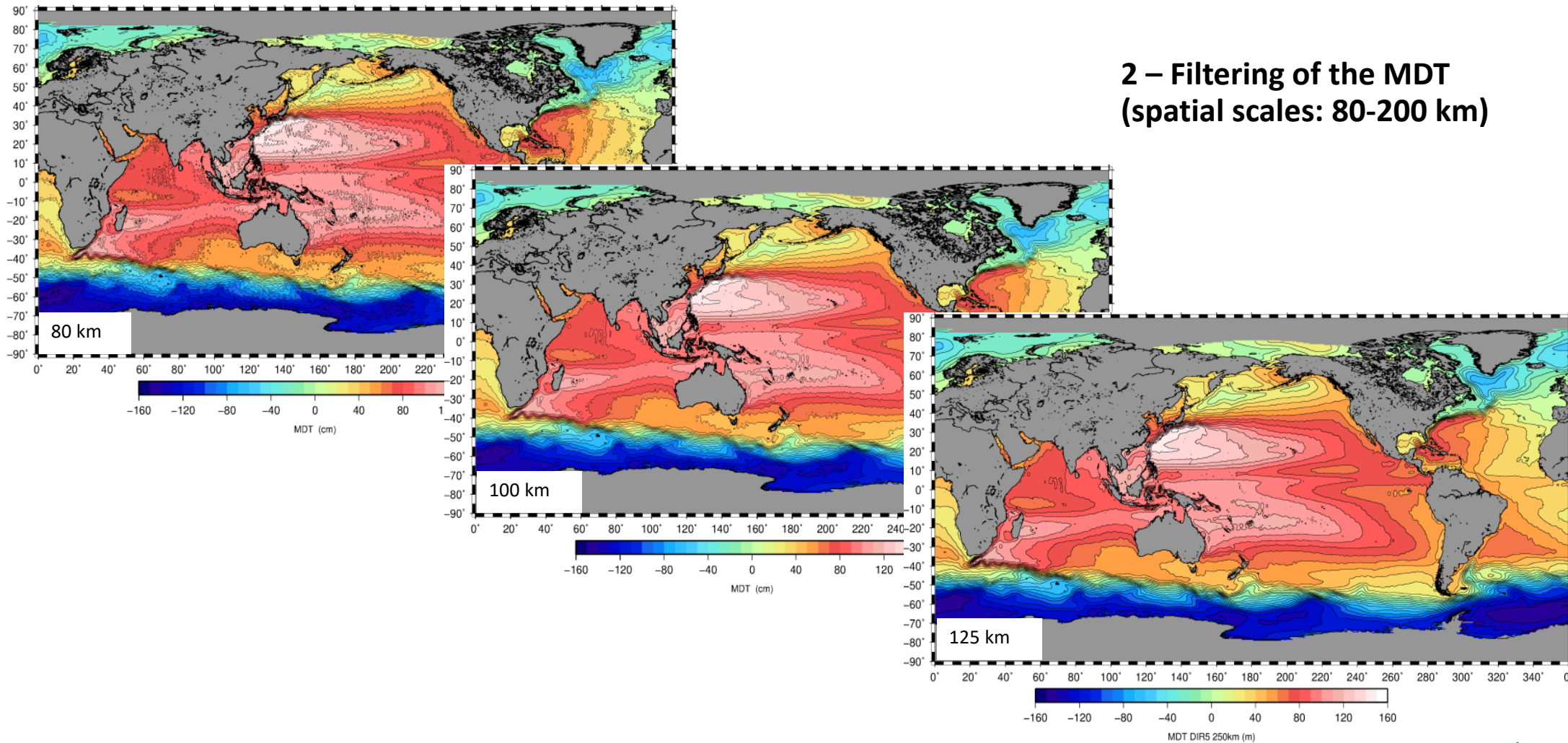


Oceanographic evaluation:
CLS, Sandrine Mulet

Omission and commission errors
- Difficulty in subduction areas
and at the boundary (land/sea)
→ need to be filtered

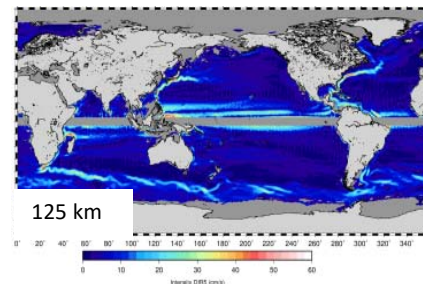
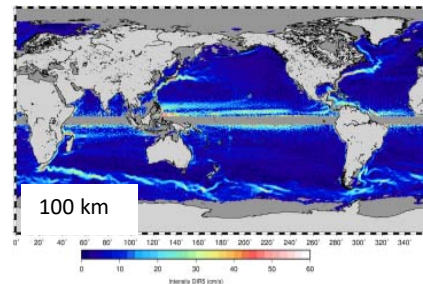
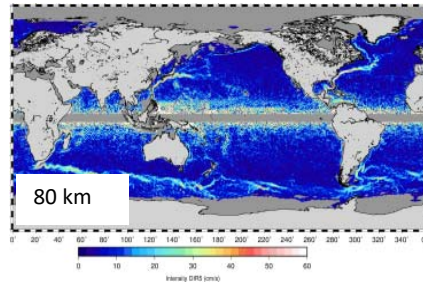
Model evaluation: geostrophic current comparisons

2 – Filtering of the MDT (spatial scales: 80-200 km)

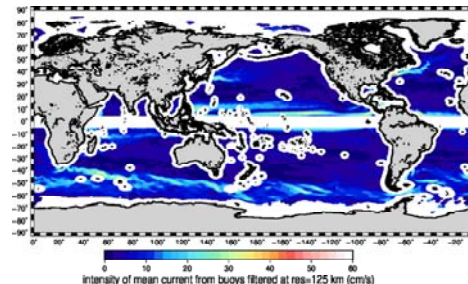
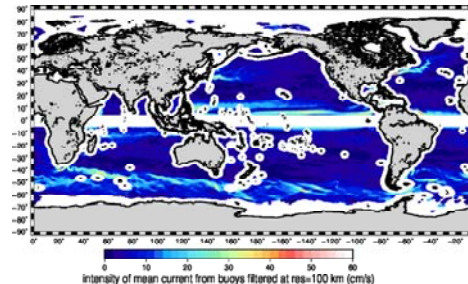
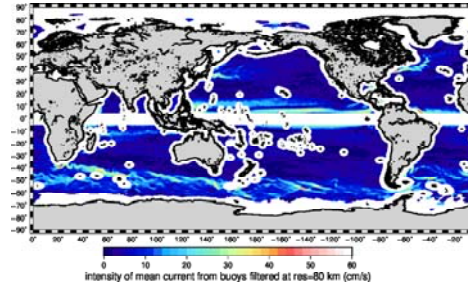


Model evaluation: geostrophic current comparisons

3 - Compute associated mean geostrophic currents



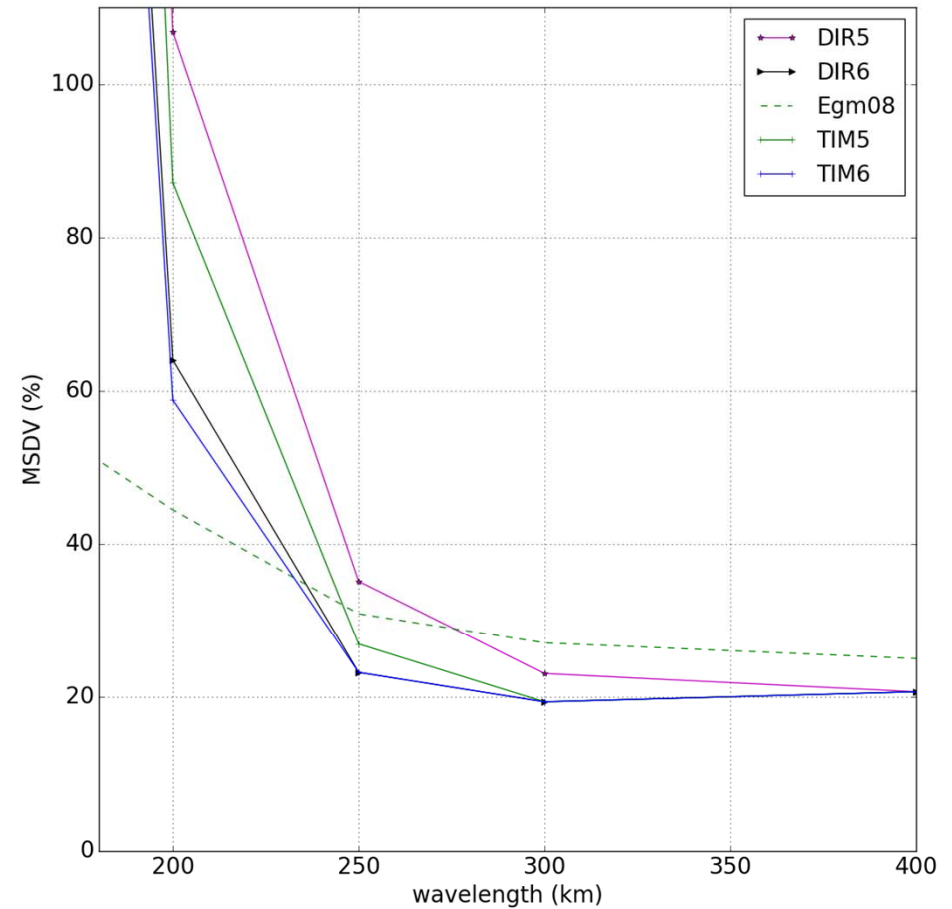
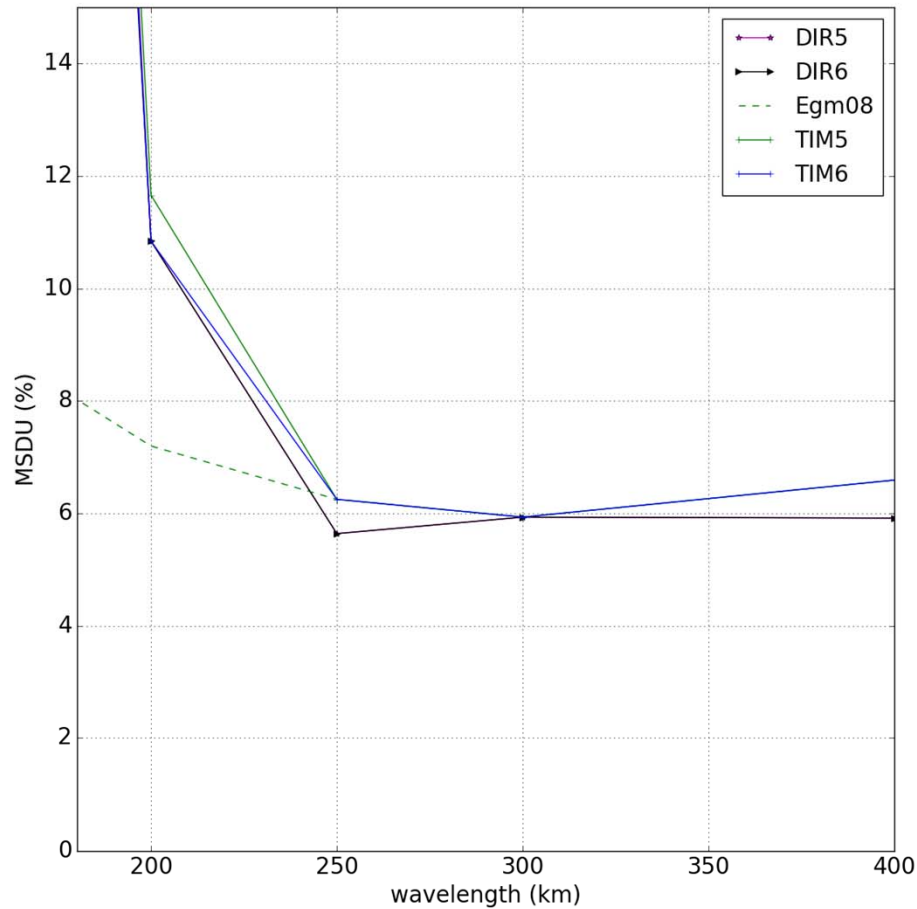
4 - Comparison with *independent estimate*: filtered drifters



Velocity estimate from 1993-2015 **surface drifters** processed by CLS to match the physical content of the mean geostrophic currents at 400 km offshore the coast.

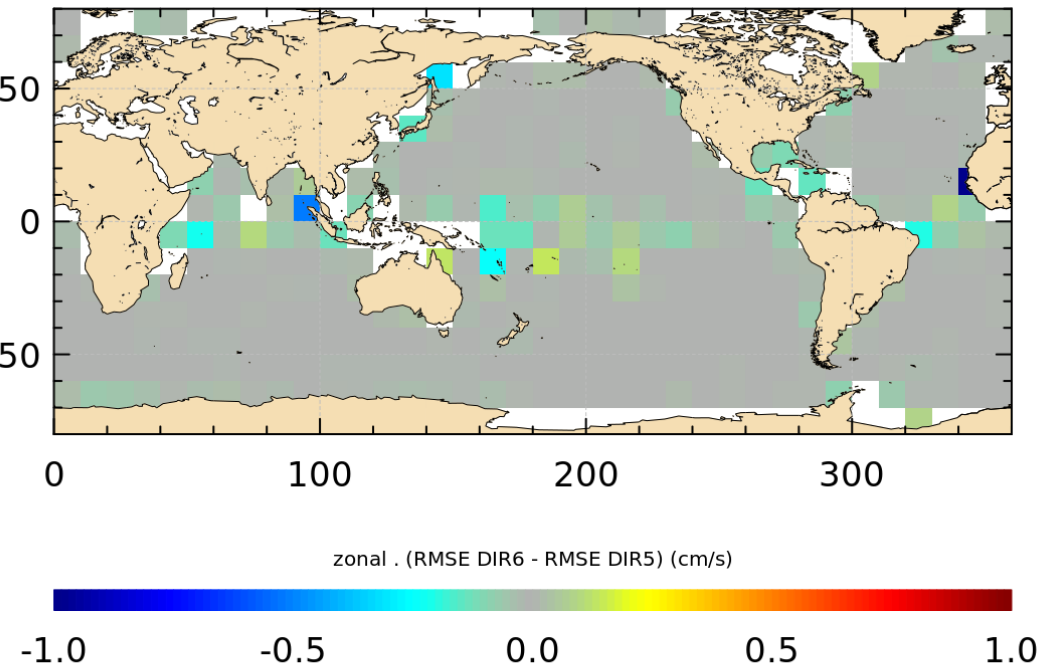
Model evaluation: geostrophic current comparisons

RMS of the difference with drifters (%)

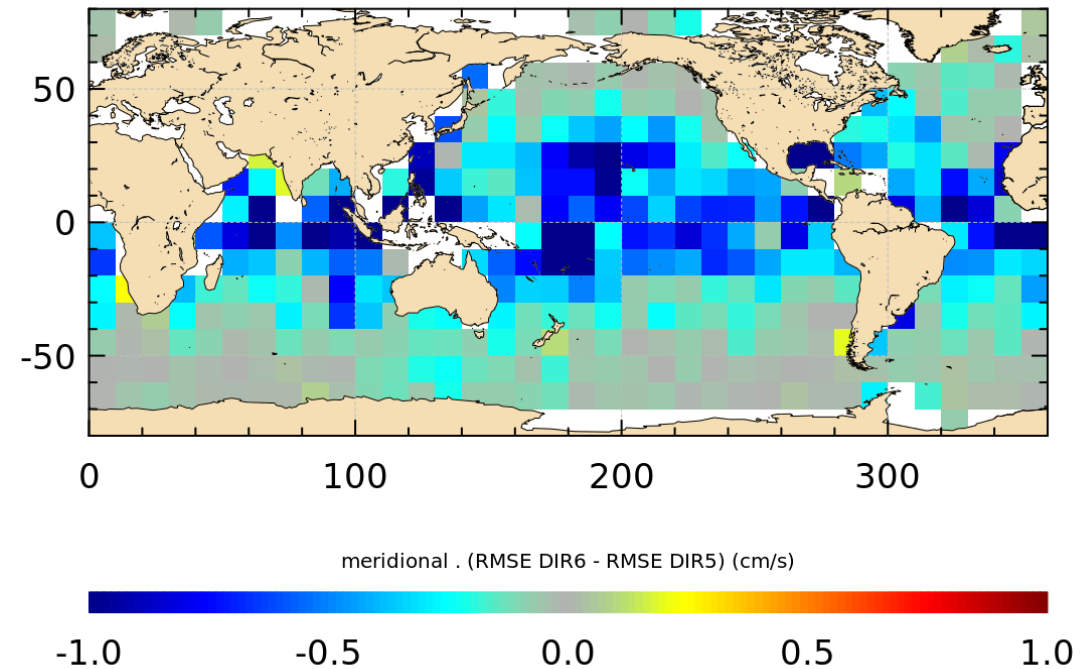


Model evaluation: geostrophic current comparisons

Improvement over GOCE-DIR-R5 (cm/s)



Nbr :	359	Std Dev :	0.074333904	Min :	-1.0485383
Mean :	-0.016221179	Median :	-0.0062061185	Max :	0.14576129



Nbr :	359	Std Dev :	0.37629444	Min :	-2.1788251
Mean :	-0.28983871	Median :	-0.14772823	Max :	0.23701088

Summary

- **GOCE-DIR-R6 is the final release of ESA's GOCE gravity field model's by means of the direct approach.**
- **It is a global satellite-only gravity field model developed in spherical harmonics to d/o 300, computed by GFZ Potsdam and CNES Toulouse within the framework of GOCE High Level Processing Facility.**
- **It has been inferred from the new, reprocessed GOCE Level-1b SGG data in combination with SLR tracking data, and GRACE GPS-SST and K-band range-rate data.**
- **GOCE-DIR-R6 is significantly more accurate than previous GOCE model releases.**

It is available at the International Center of Global Earth Models (ICGEM):

<http://icgem.gfz-potsdam.de>