The new ESA/GOCE geoid model from the direct method and its impact on the computation of the Mean Dynamic Topography

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Data

LAGEOS-1/2 SLR data:

• 1985 – 2010 of GRGS release 2 normal equations to degree/order 30

GRACE GPS-SST and K-band range-rate data:

• Feb 2003 – Dec 2012 of GRGS release 3 normal equations to degree 175

☞ One GRACE/LAGEOS normal equation up to d/o 175, reduced above degree 130 before accumulating with GOCE normal equations

+

GOCE data:

• SGG data (Txx, Tyy, Tzz, Txz) from 01 November 2009 – 20 October 2013

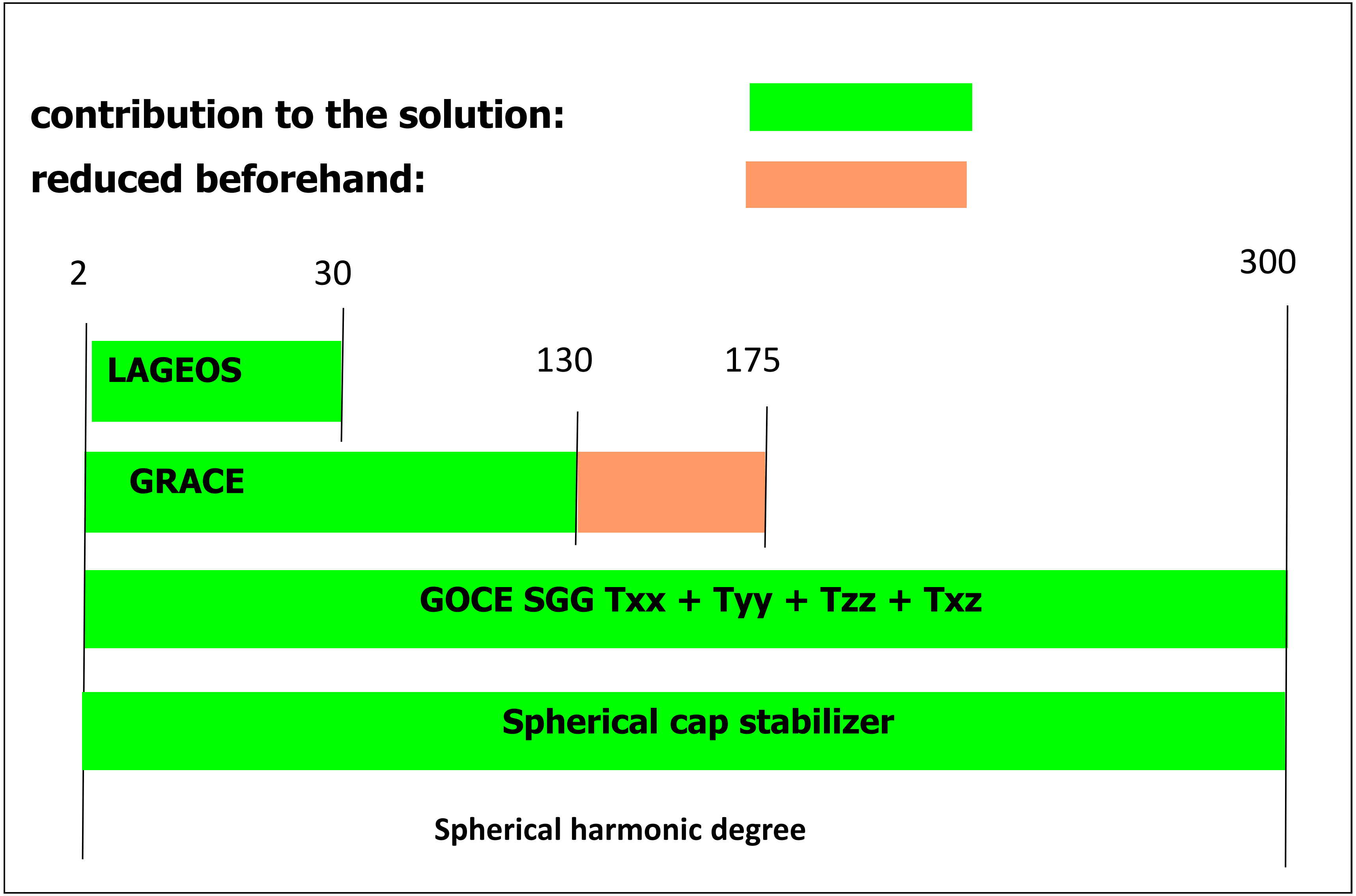
• weighting per measurement (based on RMS of residual), cos-latitude weighting

• normal equations for each SGG component (4) up to degree/order 300

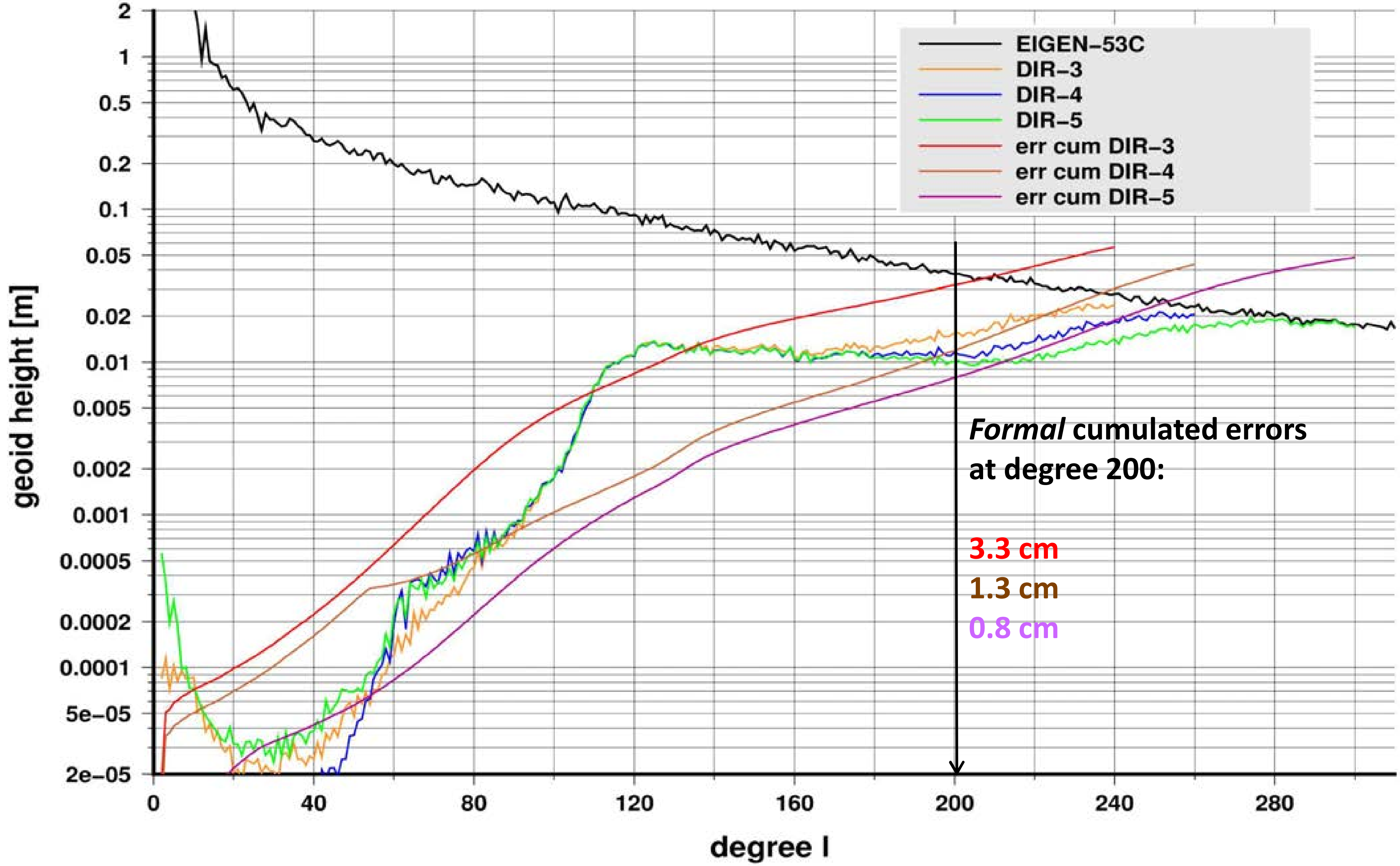
• application of a (120 – 8) s band-pass filter for all four SGG components

  • *The SGG signal is filtered-out below degree ~ 45*

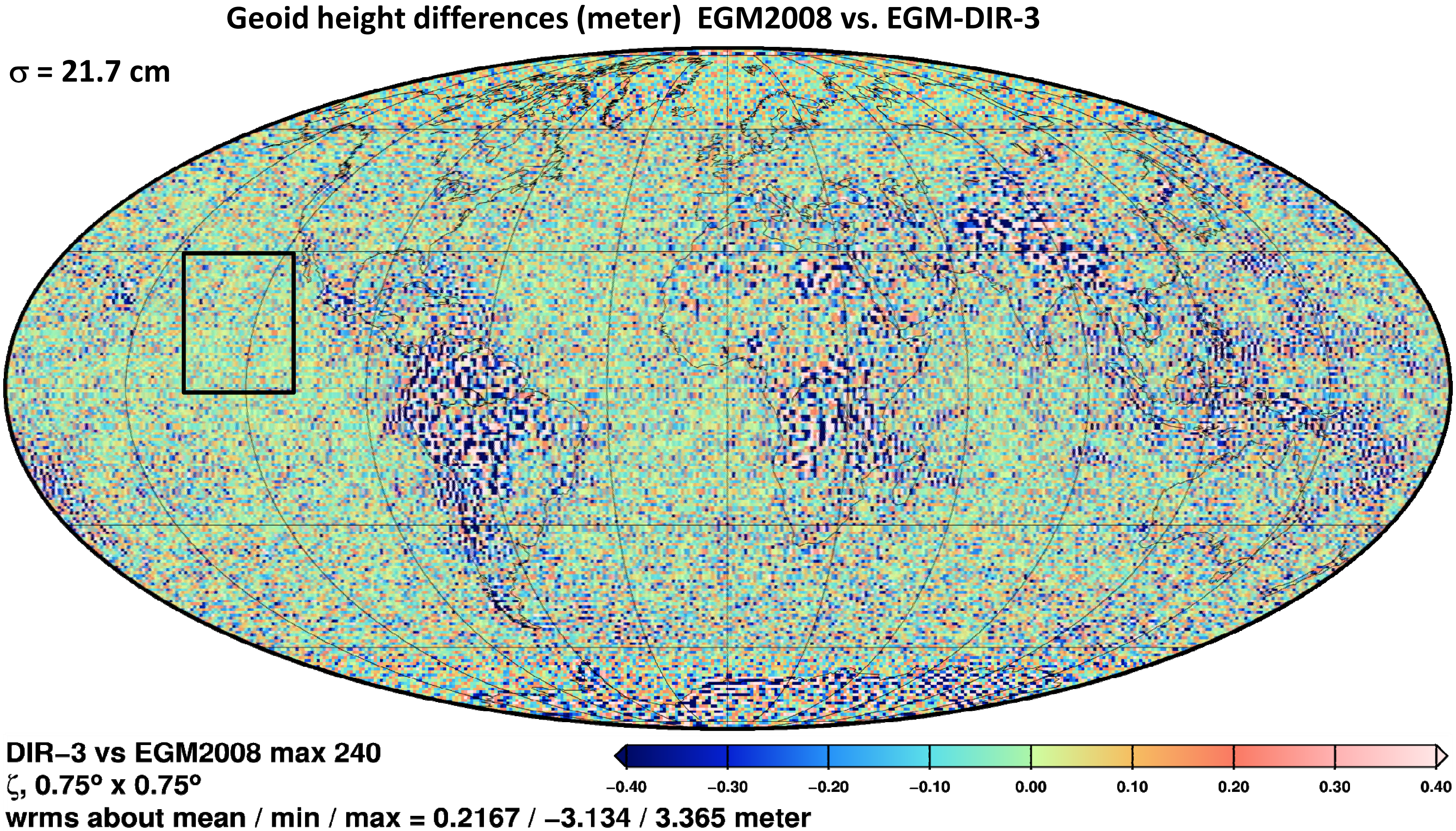
Normal equation combination scheme of EGM-DIR-5



EGM-DIR-5 vs EIGEN-53C: degree amplitude differences



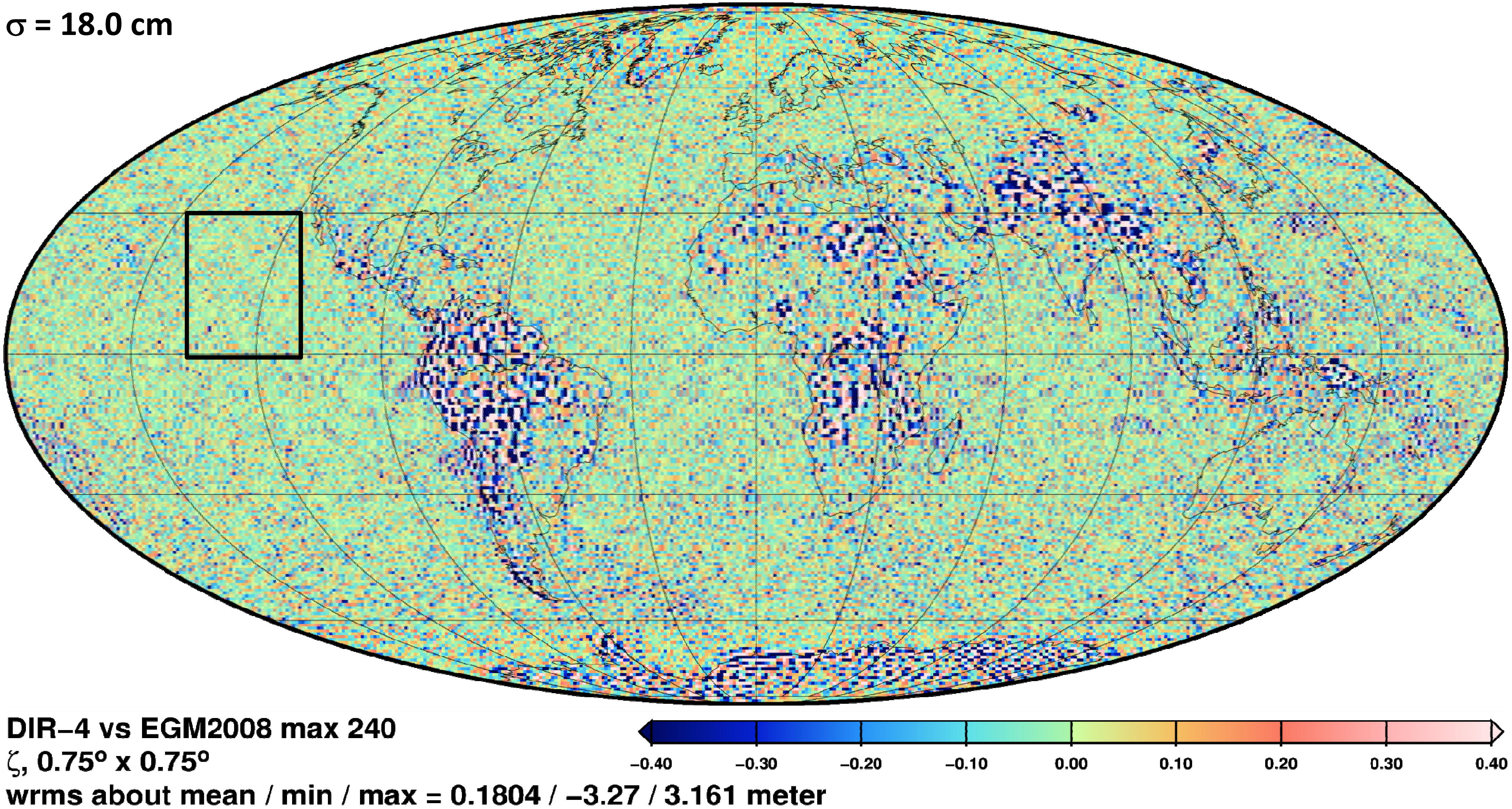
EGM-DIR-3 compared with EGM2008: spatial



EGM-DIR-4 compared with EGM2008: spatial

Geoid height differences (meter) EGM2008 vs. EGM-DIR-4

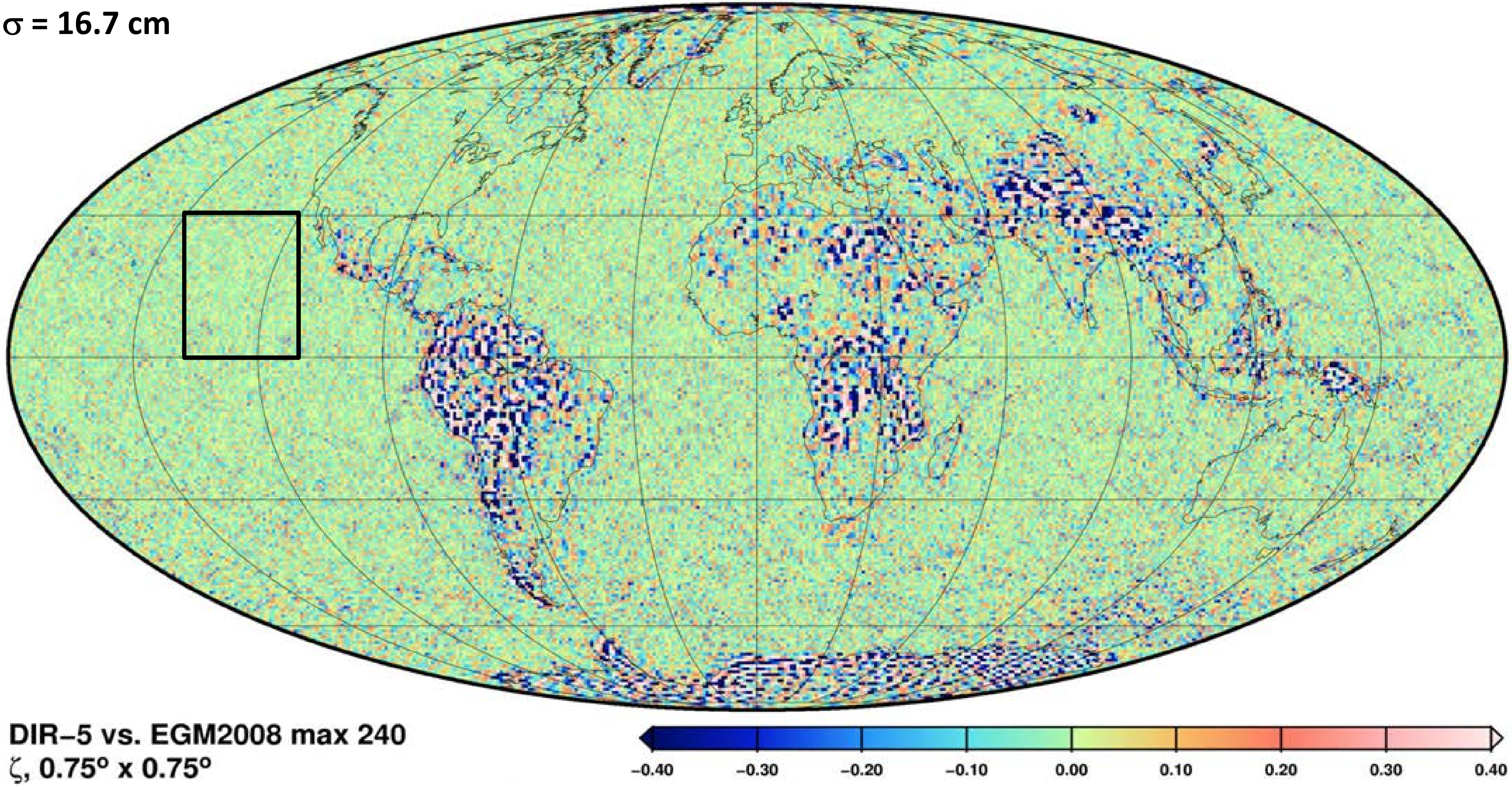
σ = 18.0 cm



EGM-DIR-5 compared with EGM2008: spatial

Geoid height differences (meter) EGM2008 vs. DIR5

σ = 16.7 cm



DIR–5 vs. EGM2008 max 240

ζ, 0.75° x 0.75°

wrms about mean / min / max = 0.1665 / –3.47 / 3.155 meter

Validation: GOCE orbit fit

Dynamic orbit computation

60 arcs, arclength = 1.25 days

Mean RMS values in cm of the orbit fit residuals

Gravity field model / max degree	120	180
EGM2008	4.0	2.8
ITG-Grace2010s	3.3	1.7
GOCO03s	3.2	1.6
EGM-DIR-1	3.9	2.4
EGM-DIR-2	3.5	2.1
EGM-DIR-3	3.2	1.6
EGM-DIR-4	3.2	1.6
EGM-DIR-5	3.1	1.5

Comparison with EGM2008: GPS/leveling

Comparison of geoid heights
(RMS in cm of GPS-Leveling minus model-derived geoid heights)

(Max d/o=360)	EGM2008	DIR2*	DIR3*	DIR4*	DIR5*
Europe (1234)	27.0	33.6	30.5	28.4	27.8
Germany (675)	14.2	28.5	21.2	16.8	15.2
Canada (1930)	22.9	31.0	27.8	24.7	23.7
USA (6169)	31.8	36.8	35.2	32.9	32.4
Australia (201)	23.6	32.6	28.1	26.3	24.9
Japan (816)	27.2	32.8	31.3	30.1	29.0

*model to d/o **240** extended with EGM2008 to d/o 360

Used GPS/Leveling data sets:
- **USA**: (Milbert, 1998)
- **Canada:** (M. Véronneau, personal communication 2003, Natural Resources Canada)
- **Europe/Germany:** (Ihde et al., 2002)
- **Australia:** (G. Johnston, Geoscience Australia and W. Featherstone, Curtin University of Technology, personal communication 2007)
- **Japan**: (Tokuro Kodama, Geospatial Information Authority of Japan, personal
- communication 2013)

Model validation using drifter data - Method

Filtering of the MDT with a gaussian filter

MDT=MSS – EGM_DIR_R5

100 km (DO 200)

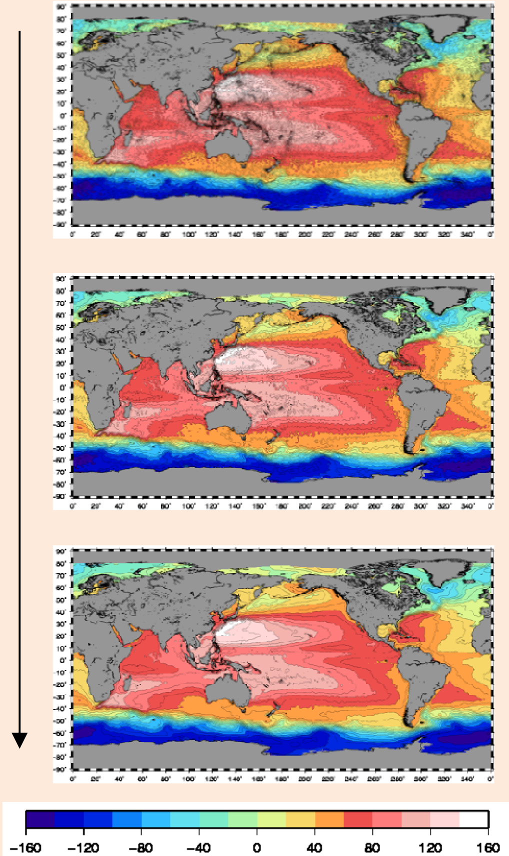
125 km (DO 160)

150 km (DO 133)

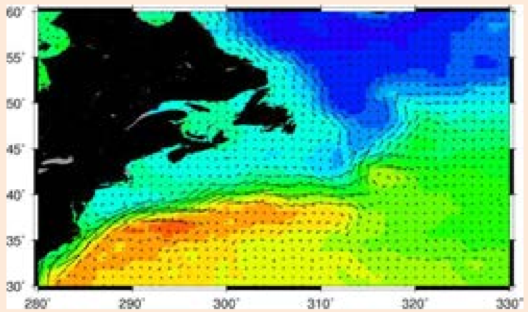
200 km (DO 100)

250 km (DO 80)

350 km (DO 60)

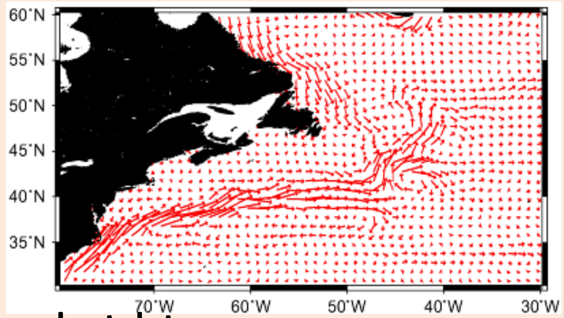


Computation of the mean geostrophic currents



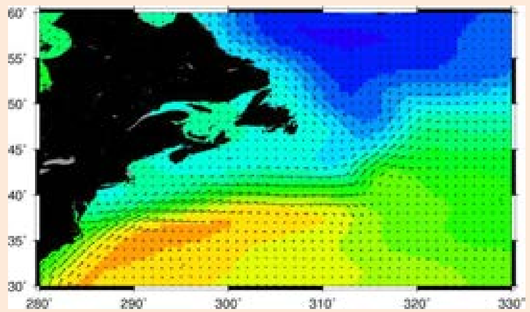
100 km

Computation of **synthetic estimate of mean geostrophic velocities** from in-situ oceanographic measurements and altimetry

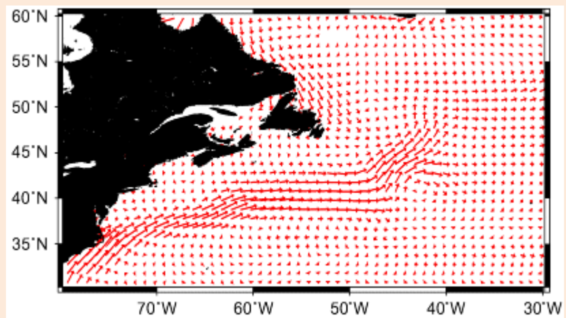


Comparison with independent data

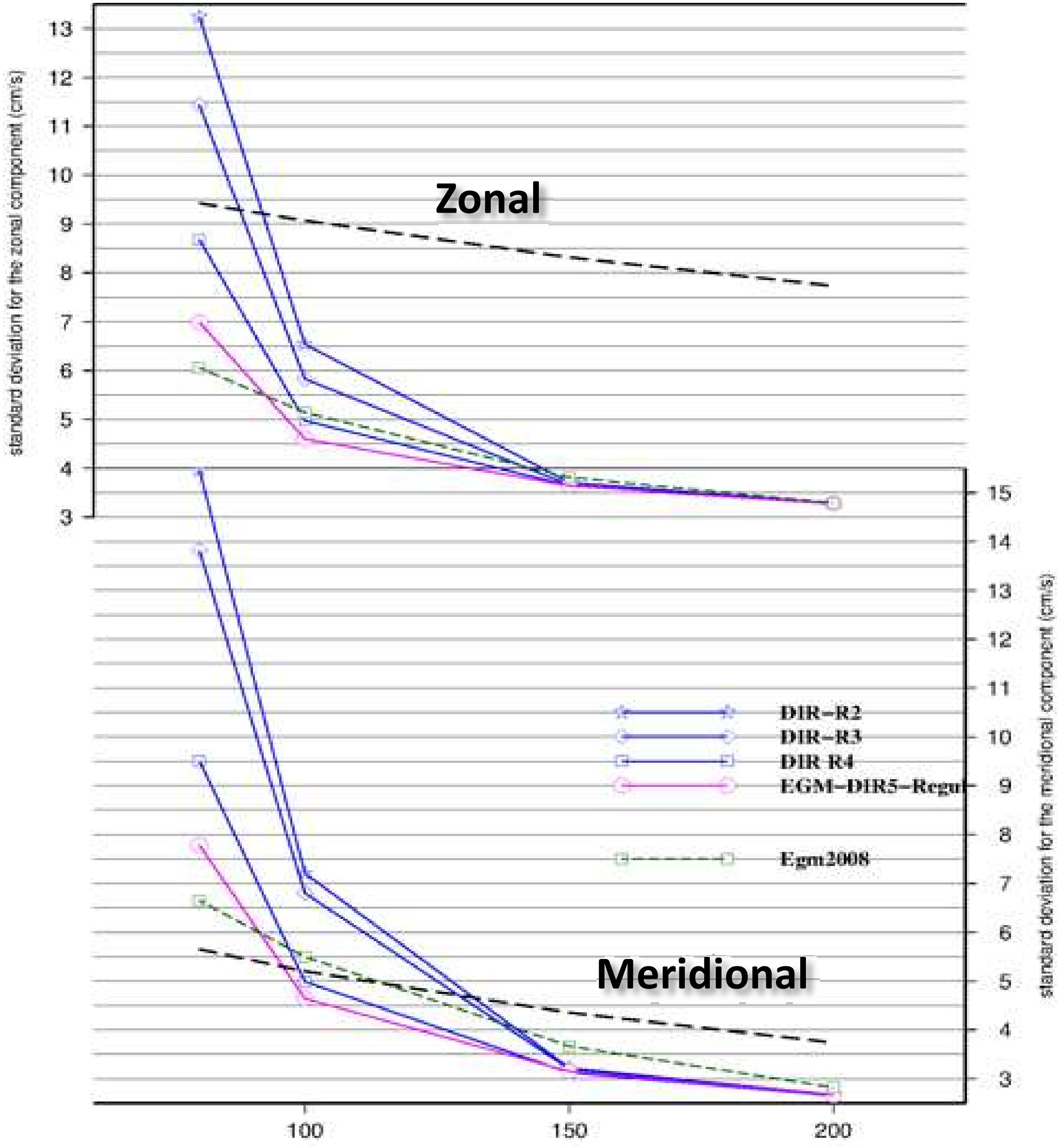
over the global ocean



200 km



Model validation using drifter data



Resolution (km)

Zonal: (80 km)
R2=13.2
R3=11.5
R4=8.7
R5=7.0

24%

89%

Comparison of observed (drifters) with calculated (MSS-geoid) currents

The plots on the left show the *Standard deviation of difference* of geostrophic current velocities, cm/s

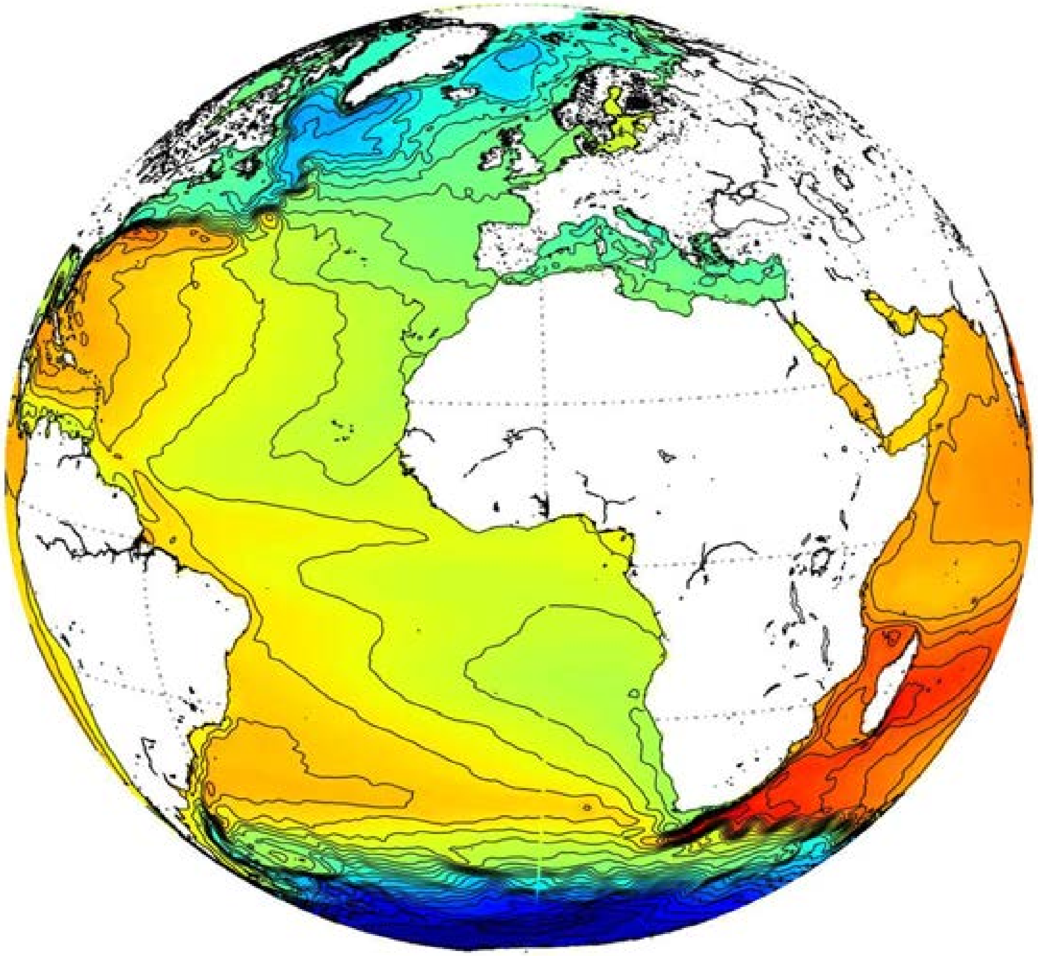
<u>Smallest scale = 80km</u>

Meridional: (80 km)
R2=15.5
R3=13.8
R4=9.5
R5=7.8

22%

99%

How does GOCE help improve the ocean circulation estimate ?



Using GOCE improves MDT computation like CNES-CLS MDT

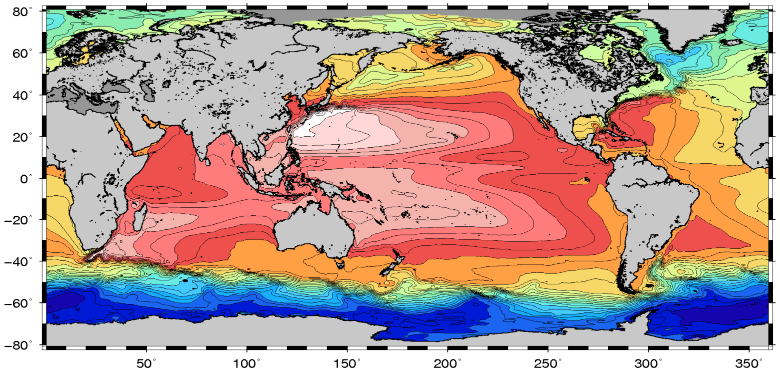
METHOD

Geodetic MDT

MDT=MSS CNES-CLS11 – Geoid (DIR4)

Optimal filter

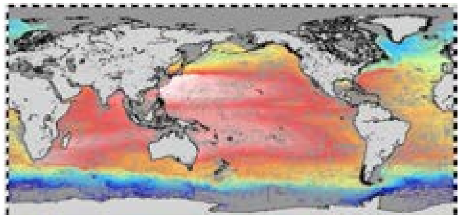
Large scale MDT=First guess

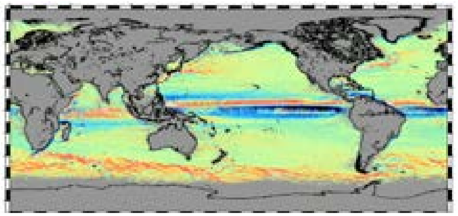


Rio et al., GRL 2014

Synthetic Method

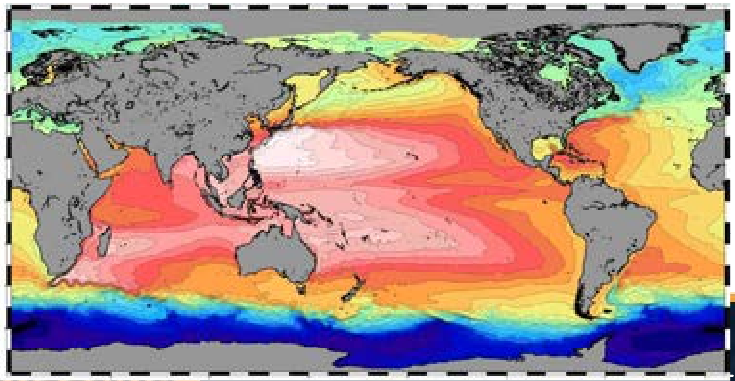
The short scales of the MDT (and corresponding geostrophic currents) are estimated by combining altimetric anomalies and in-situ data





Multivariate Objective Analysis

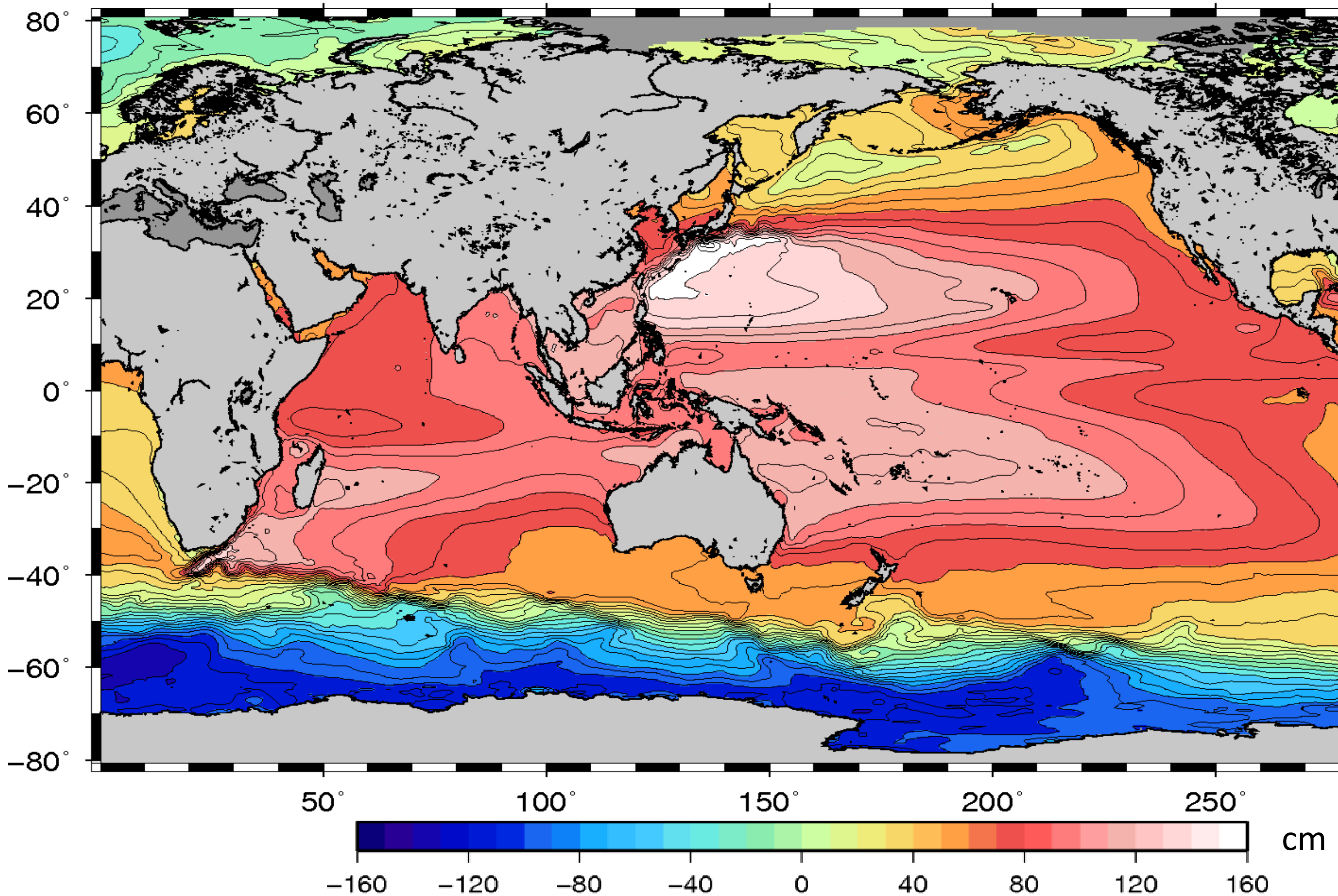
High resolution MDT



MDT first guess with GOCE

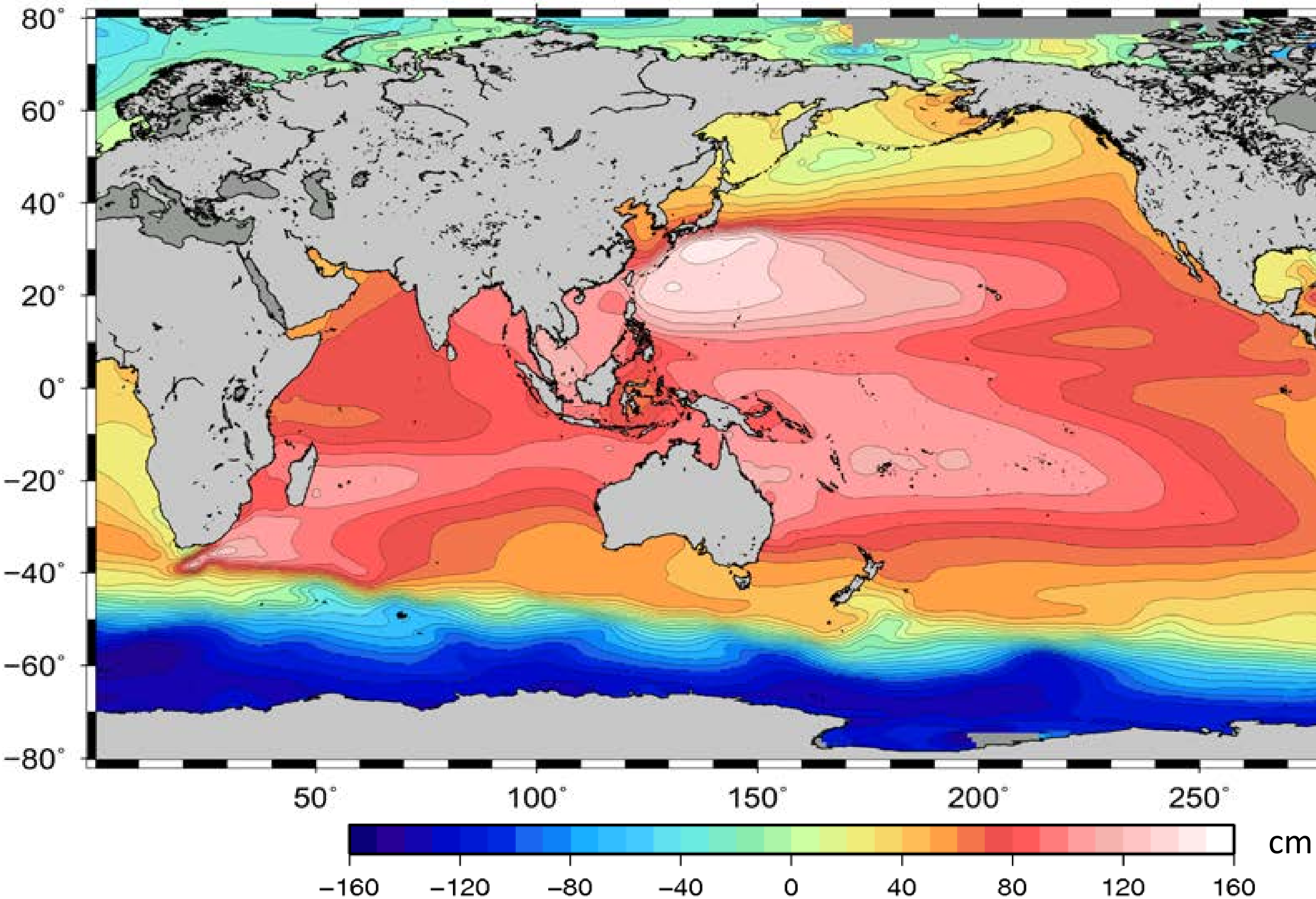
First guess used for the **CNES-CLS13 MDT** computation (GOCE data)

MDT=MSS CNES-CLS11 – EGM-DIR-R4 OPTIMALLY FILTERED

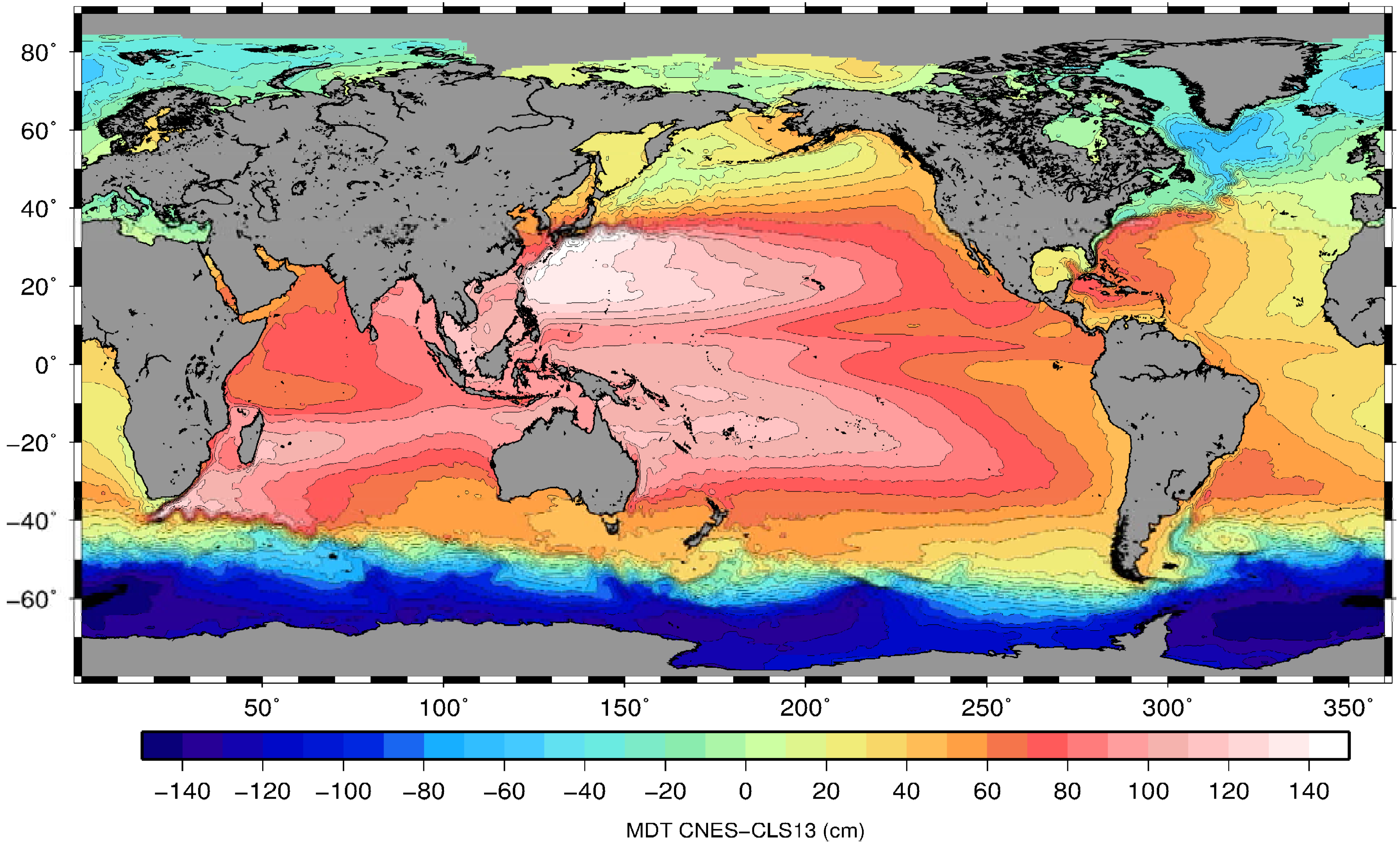


MDT first guess with GRACE

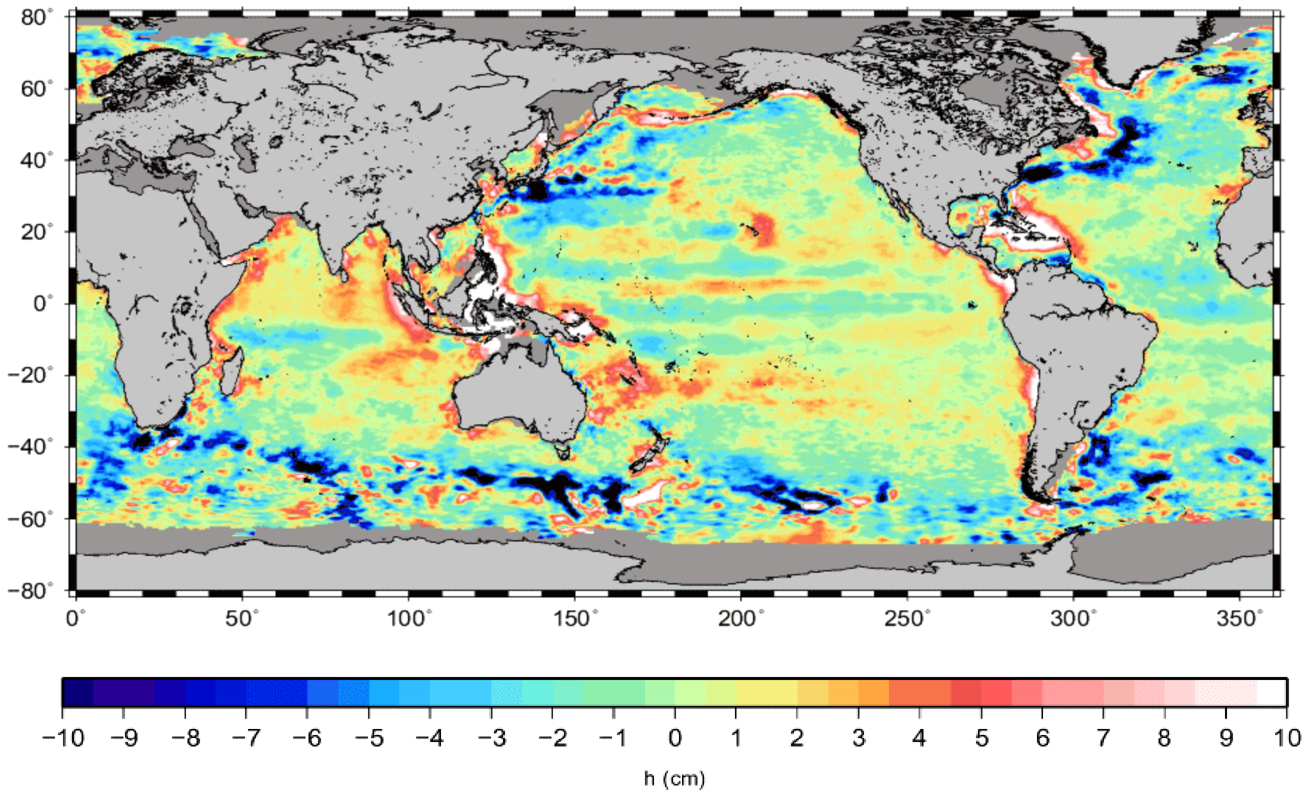
First guess used for the **CNES-CLS09 MDT** computation (GRACE data)



The CNES-CLS13 MDT



Difference of CNES-CLS13(GOCE) – CNES-CLS09(GRACE) MDTs



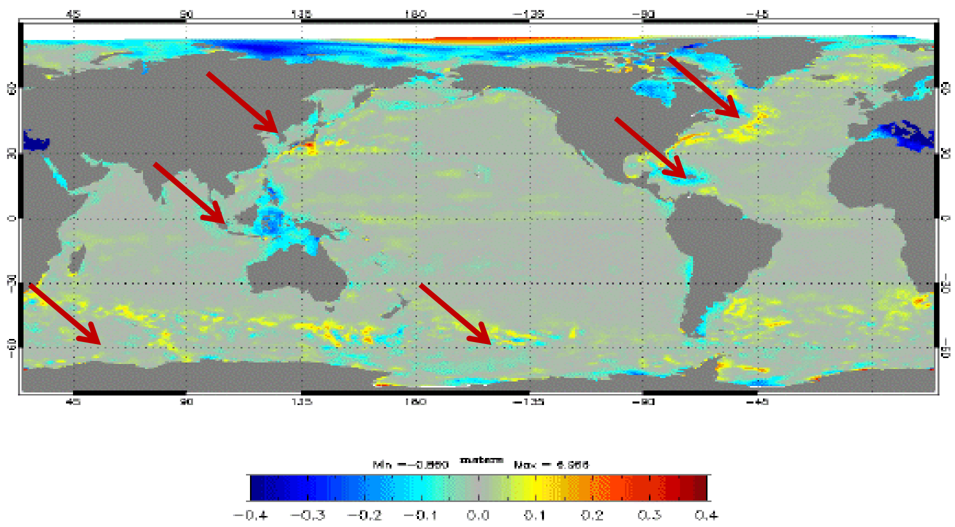
Improvement of the first guess using GOCE involves:

→ More consistency between scales seen by satellite and in-situ data, thus small scales are better resolved

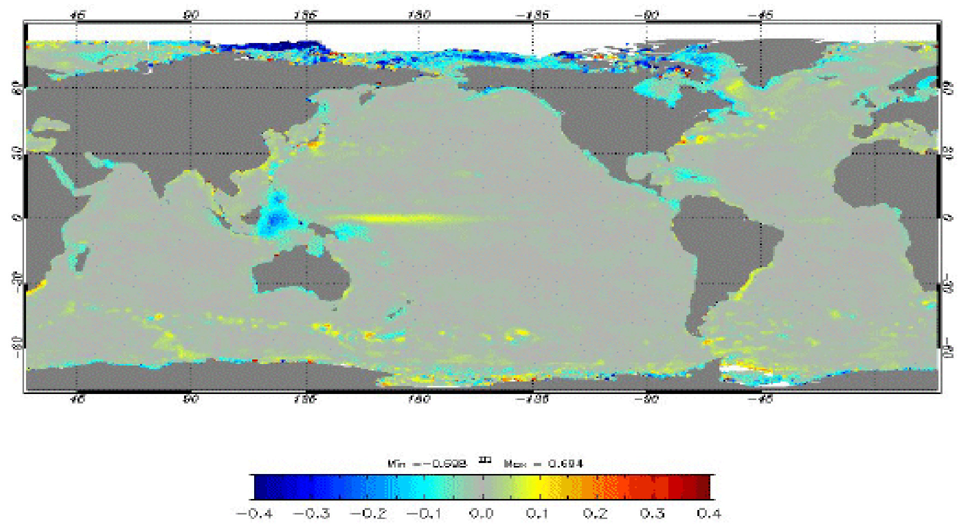
→ Huge improvement near the coast especially in Indonesia and Bahamas

Positive impact on altimeter data assimilation in the Mercator-Ocean system

Difference between the MDT currently used at Mercator-Ocean for SLA assimilation and the CNES-CLS13 MDT

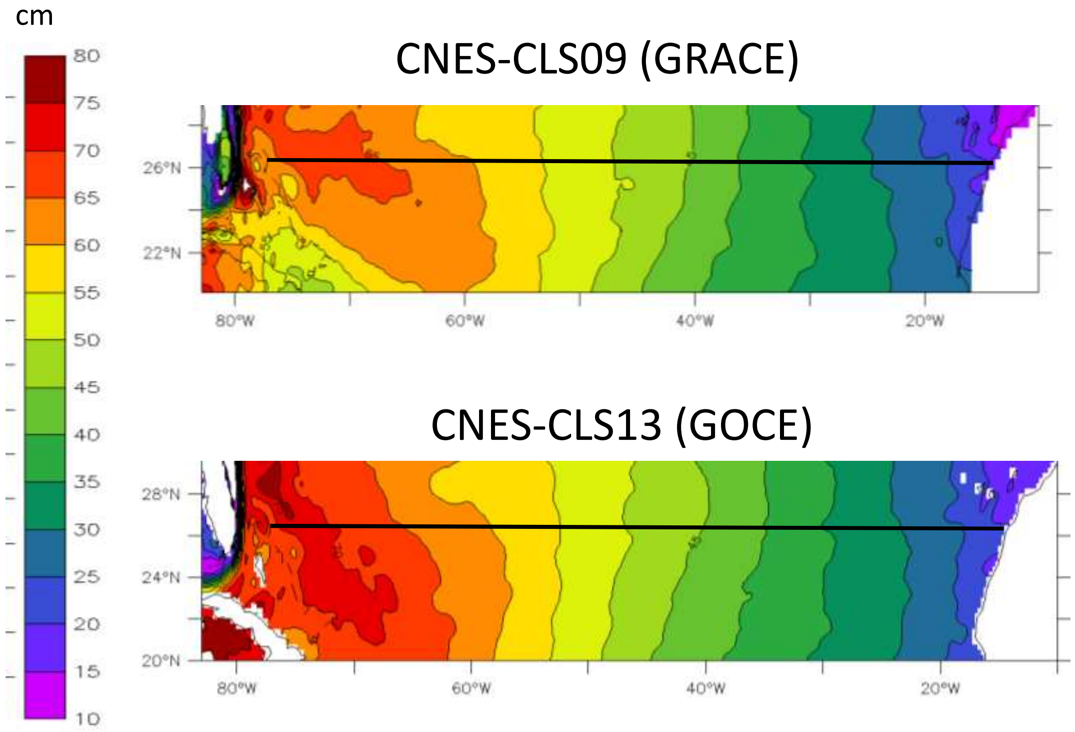


SLA innovation computed during the latest Mercator-Ocean reanalysis run (GLORYS2V3) = information given by the dynamic of the model that correct the observations



Similarities between the two plots mean that the use of the CNES-CLS13 MDT will lead to improvements o the altimeter SLA assimilation into the Mercator-Ocean forecasting system

Improvement of the Meridional Overturning Circulation in the North Atlantic



- Combination of MDT with SLA and T/S profiles to compute 3D geostrophic currents and then transport.

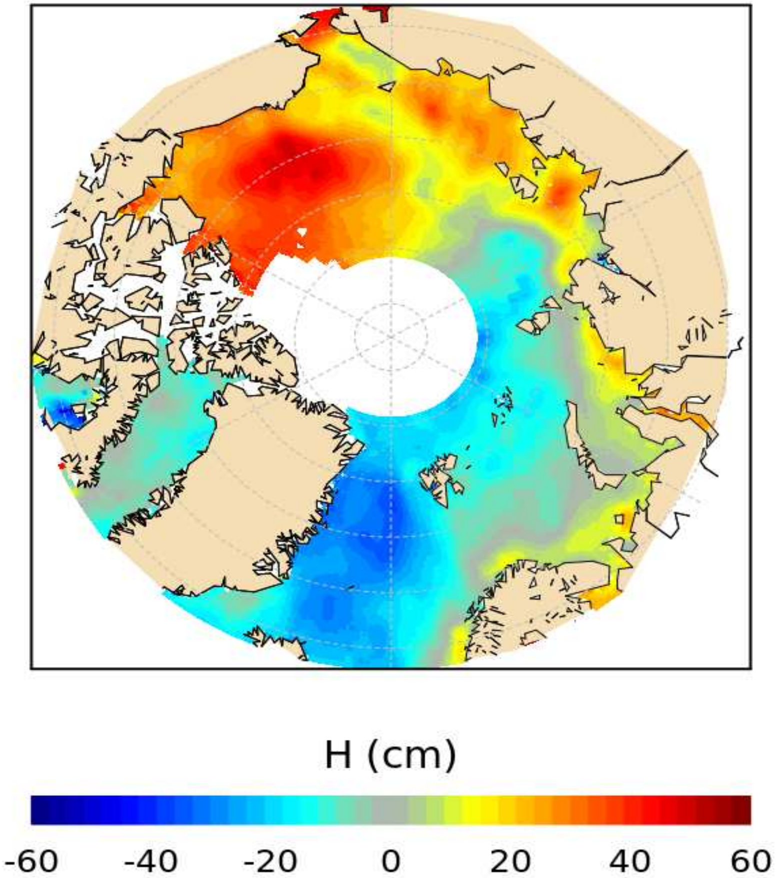
- Mean interior geostrophic transport calculated over 2006
  - 7 Sv when using the **CNES-CLS09** MDT
  - 12 Sv with the **CNES-CLS13** MDT.

The **RAPID-MOCHA** array (Kanzow et al., 2007) gives an **independent estimate of -14 Sv** thanks to moorings that monitor temperature, salinity and currents.

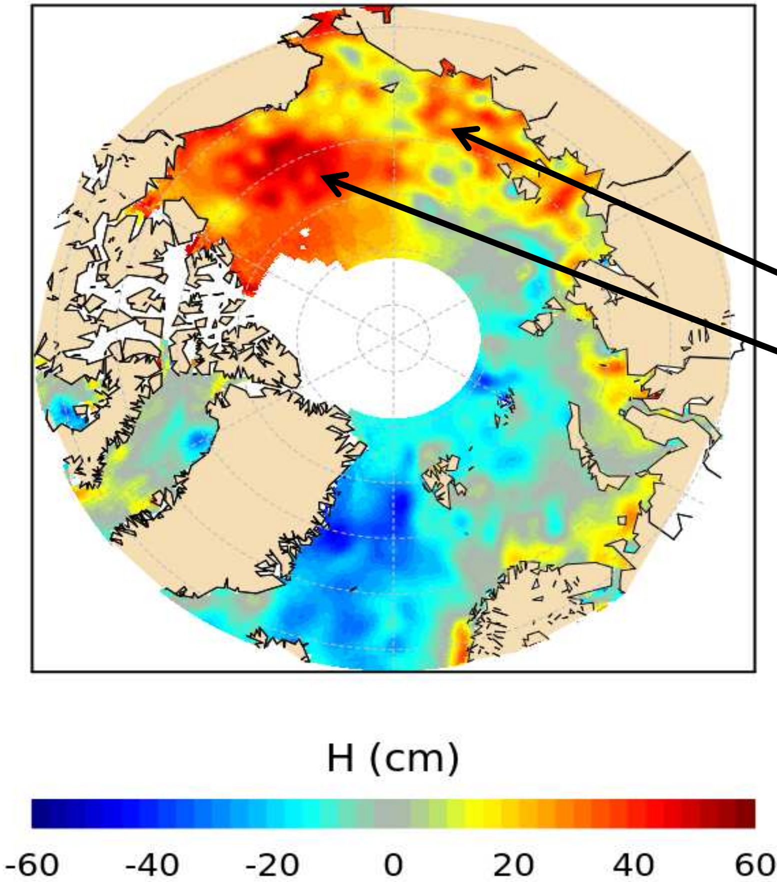
Possibility to directly compute Absolute Dynamic Topography

See POSTER Mulet et al.

Map of SSH_c2 - **GOCE** (DIR5)
125 km ; 12 September 2012



Map of SSH_c2 - **GRACE** (ItgGrace2010s)
125 km ; 12 September 2012



Much more noise

Gravity field model EGM-DIR-5: summary and conclusions

- Model to d/o 300 constructed with LAGEOS, GRACE and GOCE data;

- Best satellite-only model when comparing with GPS/leveling data, POD, and geostrophic current velocities;

- Formal accumulated geoid error at degree 200 (100 km): 0.8 cm (mission objective: 1.0 - 2.0 cm). Estimation over Germany: 1.8 cm

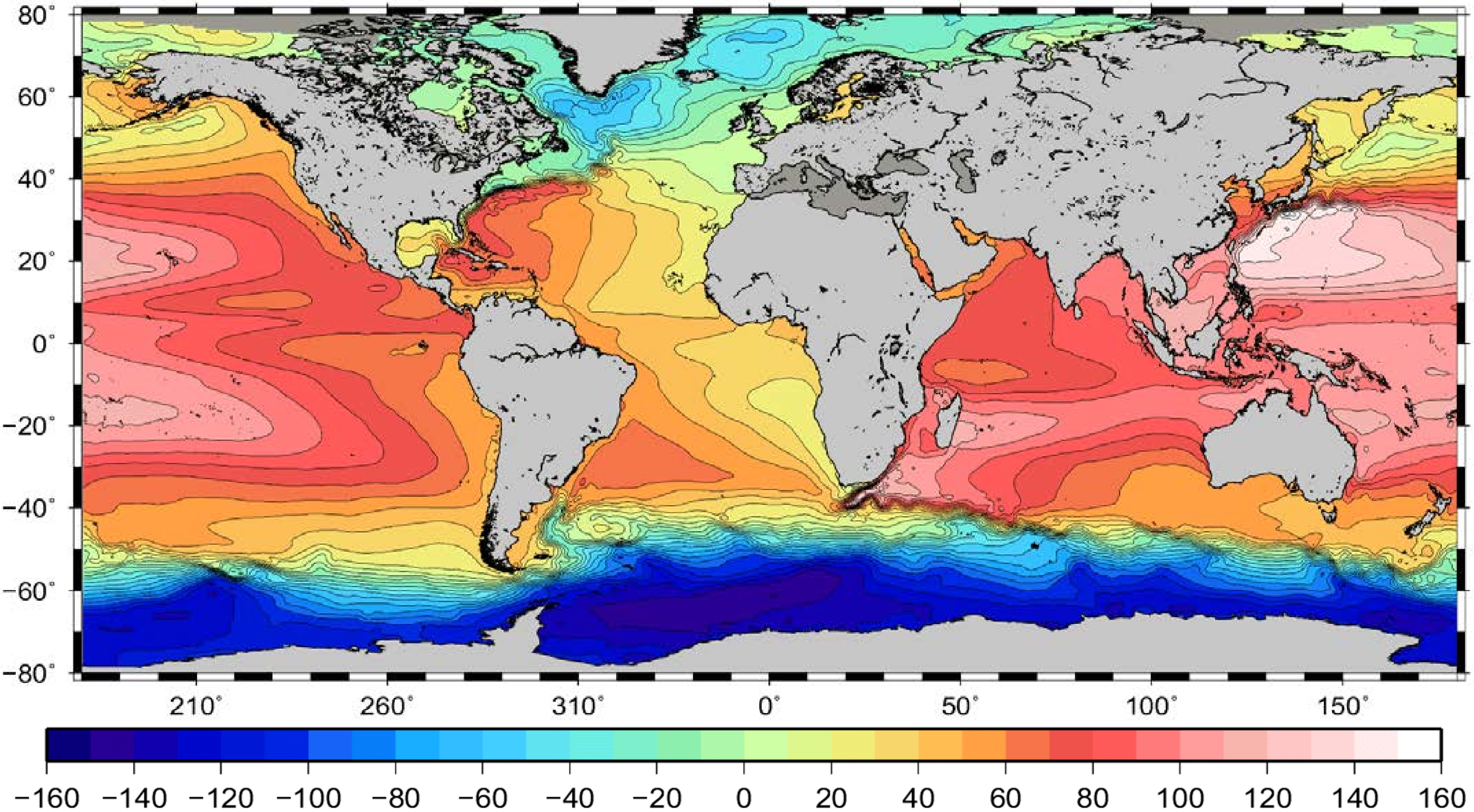
- The geostrophic current comparisons reveal that GOCE can provide accurate current information at 100 km scale; at 80 km, only the zonal component is accurate enough.

Bruinsma et al., GRL 2014

Significant improvement of the oceanic circulation estimate thanks to GOCE

- **Improvement of surface circulation but also transport estimate (AMOC)**
- **Improvement of high resolution products**
  - **Combined MDT like CNES-CLS**
  - **GOCE geodetic MDT is more consistent with drifters than EGM2008 geodetic MDT between 100 and 200 km of resolution**
- **Positive impact for SLA assimilation in numerical model**
- **Possibility to map directly SSH – geoid height (instead of computing MSS and MDT) at ≈ 100 km**

The GOCE only MDT (First Guess)



The CNES-CLS13 MDT