EIGEN-6

A new combined global gravity field model including GOCE data from the collaboration of GFZ-Potsdam and GRGS-Toulouse

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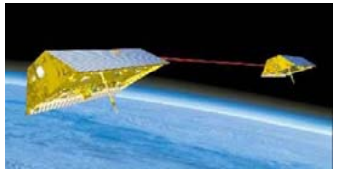
Data used for EIGEN-6S/C

LAGEOS-1/2 SLR dat



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

- **January 2003 … June 2009 (6.5 years)**
- **within the GRGS RL02 GRACE processing**
- **normal equations including 5 time variable parameters for each spher. harm. coeff. up to d/o 50:**

$$G(t)=\mathbf{G}(t0)+\mathbf{DOT}*(t-t0)+\mathbf{C1A}*\cos(\omega a*(t-t0))+\mathbf{S1A}*\sin(\omega a*(t-t0))+\mathbf{C2A}*\cos(\omega sa*(t-t0))+\mathbf{S2A}*\sin(\omega sa*(t-t0))$$

with t0 = 2005.0 = reference epoch

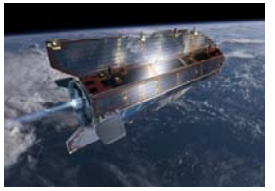
where DOT = drift

C1A, S1A = annual terms

C2A, S2A = semi-annual terms

GOCE:

- **November 2009 … June 2010 (6.7 months)**
- **GOCE SGG data: Txx, Tyy and Tzz**
- **processed by the direct approach (GFZ/GRGS within GOCE-HPF)**
- **individual normal equations for each SGG component**
- **applying a 100–8 sec band pass filter for all three SGG components**
  - ☞ **The SGG signal is filtered-out below degree ~ 50**



Terrestrial data:

DTU10 global gravity anomaly grid (Andersen, Knudsen and Berry 2010 & Anderson 2010)

☞ **This is obtained from altimetry over the oceans and EGM2008 over land**

The combination of the different satellite and surface parts has been done done by a band-limited combination of normal equations, which are obtained from observation equations for the spherical harmonic coefficients.

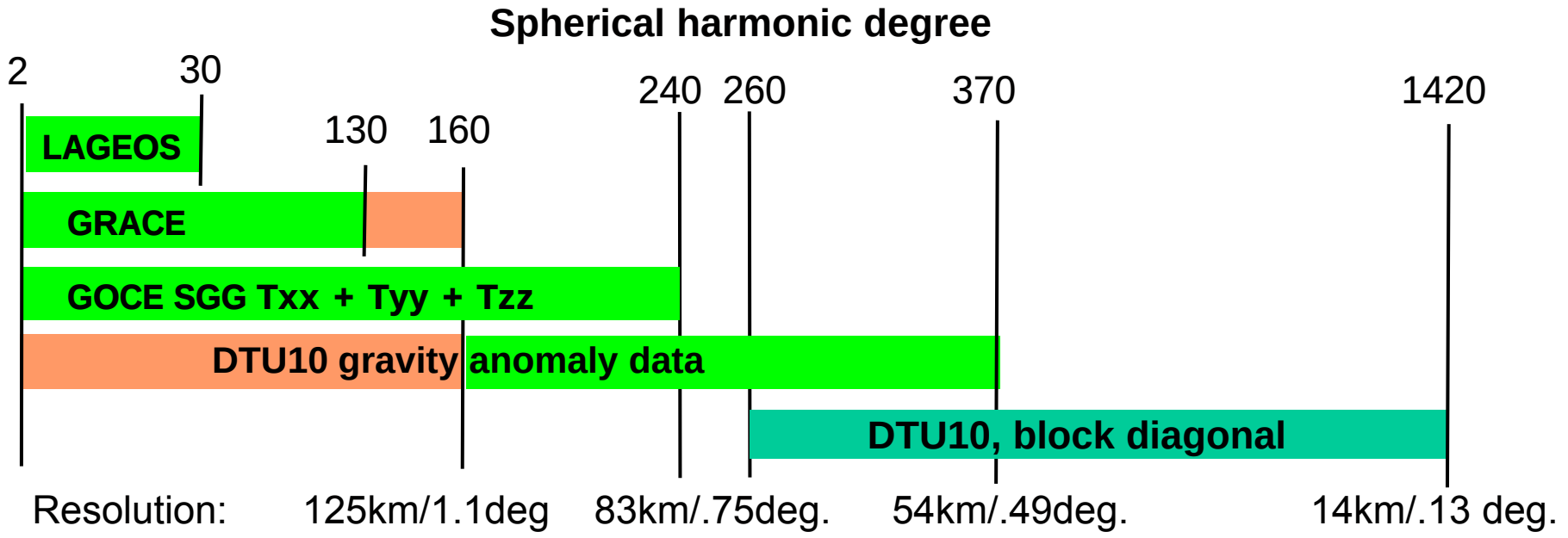
Combination scheme of EIGEN-6C

Accumulation of a full normal matrix up to d/o 370:

~170 000 parameters (~2 000 000 up to degree 1420)

- **contribution to the solution:**
- **kept separately:**

Separate block diagonal solution:



GOCE Orbit adjustment tests

- Observations: **GO_CONS_SST_PKI_2I** (kinematic GOCE orbit positions)
- Dynamic orbit computation
- **60 arcs** (November-December 2009), arc length = 1.25 days
- Accelerometer parameterization:
  - biases: twice per rev for cross track / radial / along track
  - scaling factors: along track fixed (set to 1.0), once per arc for cross track / radial

Rms values [cm] of the orbit fit residuals (mean values from the 60 arcs)

1) Orbit computation with different spherical harmonic maximum degree

Gravity field model / max. d/o	120x120	150x150	180x180	
EGM2008	4.0 →	2.9 →	2.8	
GGM03C	3.6 →	2.4 →	2.3	GRACE
EIGEN-5C	3.4 →	2.3 →	2.2	
EIGEN-51C	3.2 →	2.0 →	1.8	
ITG-GRACE2010S	3.3 →	1.8 →	1.7	
GO_CONS_GCF_2_DIR	3.9 →	2.6 →	2.4	GOCE only
GOCO02S	3.2 →	1.8 →	1.6	GRACE + GOCE
EIGEN-6S (epoch 01.12.2009)	3.2 →	1.6 →	1.5	
EIGEN-6C (epoch 01.12.2009)	3.2 →	1.6 →	1.5	

☞ The best orbit fits for maximum degree 180 for all models

☞ GOCE-GRACE models give better results than GRACE models

Orbit adjustment tests (2)

Mean RMS: SLR and PRARE in **cm**, PRARE-Doppler and DORIS in **mm/sec**
All gravity field models truncated to 120x120,

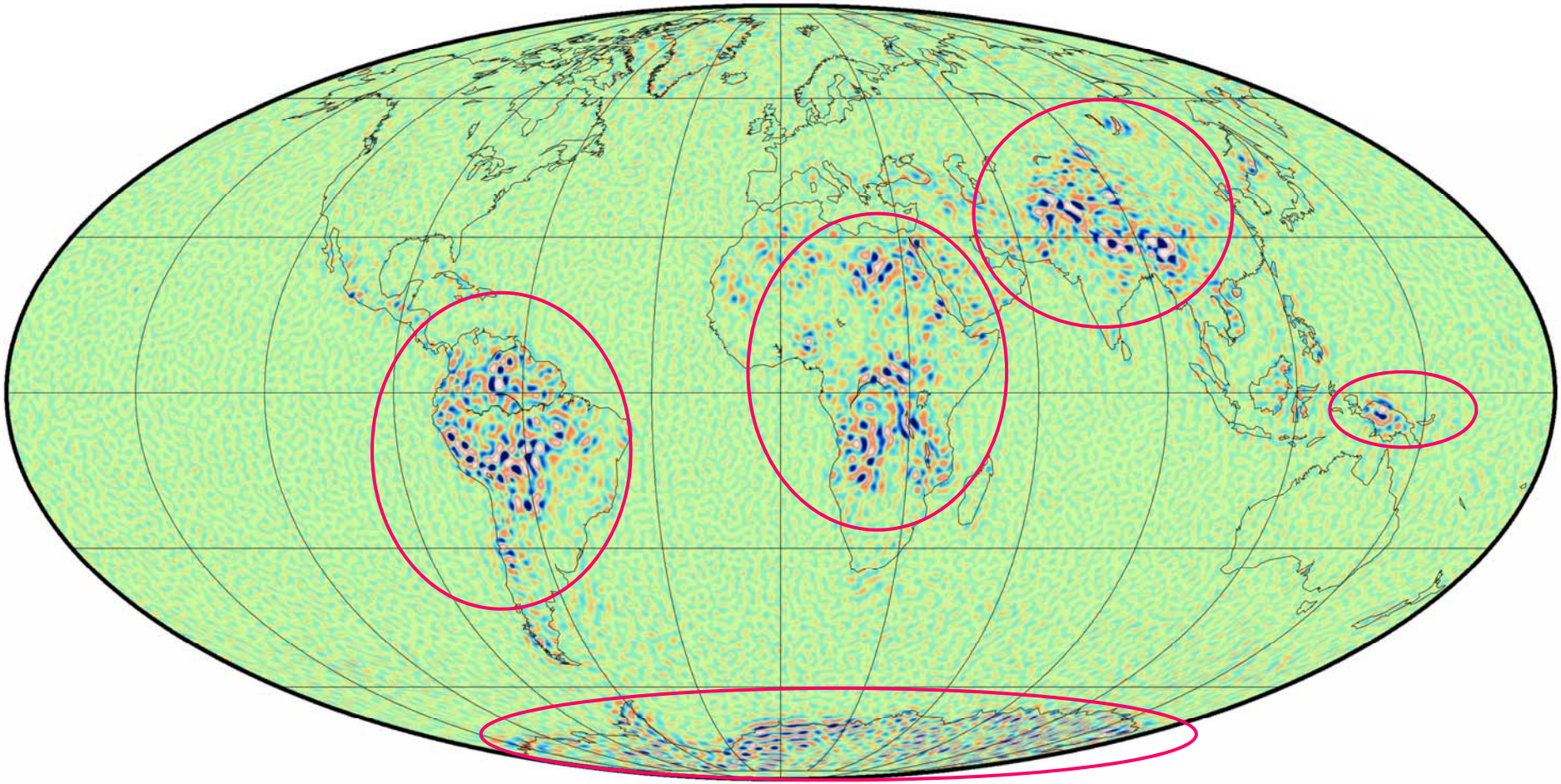
best results
worst results

Satellite	#arcs	Data type	Data	GGM03C	ITG-2010S	EIGEN-5C	EGM2008	GOCO02S	EIGEN-6C
GFZ-1		5x3 days	SLR	**14.05**	**13,96**	**14.10**	**14.70**	**14.0**	**13.97**
STELLA		5x3 days	SLR	**2.91**	**2.98**	**2.92**	**2.92**	**2.87**	**2.87**
STARLETTE	5x3 days			**2.81**	**2.55**	**2.53**	**2.54**	**2.52**	**2.41**
AJISAI		5x3 days		**3.38**	**3.26**	**3.15**	**3.18**	**3.18**	**3.15**
LAGEOS-1		5x6 days		**1.04**	**1.19**	**1.01**	**1.02**	**1.01**	**1.00**
LAGEOS-2		5x6 days		**1.02**	**1.32**	**1.02**	**1.01**	**1.02**	**1.01**
ERS-2		6x6 days	SLR PRARE PDO	**5.36** **3.56** **0.344**	**5.39** **3.53** **0.346**	**5.29** **3.54** **0.343**	**5.31** **3.56** **0.345**	**5.29** **3.53** **0.342**	**5.28** **3.54** **0.343**
ENVISAT		7x4…8 days	SLR DORIS	**4.27** **0.495**	**4.54** **0.496**	**4.49** **0.496**	**4.27** **0.495**	**4.47** **0.496**	**4.41** **0.495**
WESTPAC		5x6 days	SLR	**4.11**	**4.12**	**4.12**	**4.27**	**4.05**	**4.10**
JASON			SLR	**1.83**	**1.88**	**1.82**	**1.84**	**1.80**	**1.78**

☞ **The best orbit fits overall were obtained with the new models which include GOCE data**

Geoid-Height Differences between:
EIGEN-6C and EGM2008

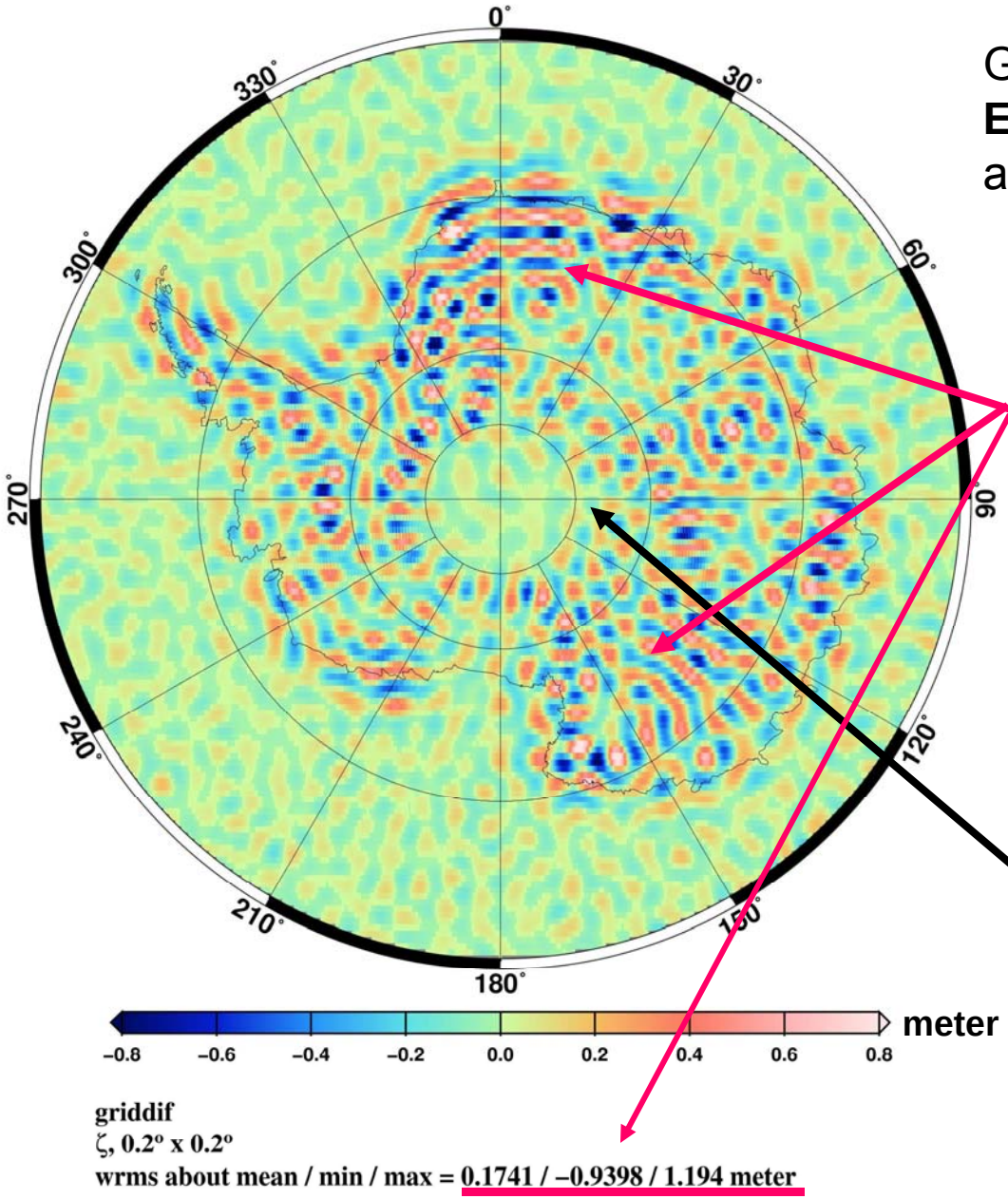
EIGEN-6C „corrects“ EGM2008
→ mainly over continent parts
with bad terrestrial data coverage



EGM2008 vs. EIGEN–6C max 1400
ζ, 0.2° x 0.2°
wrms about mean / min / max = 0.1146 / –2.729 / 2.553 meter

meter

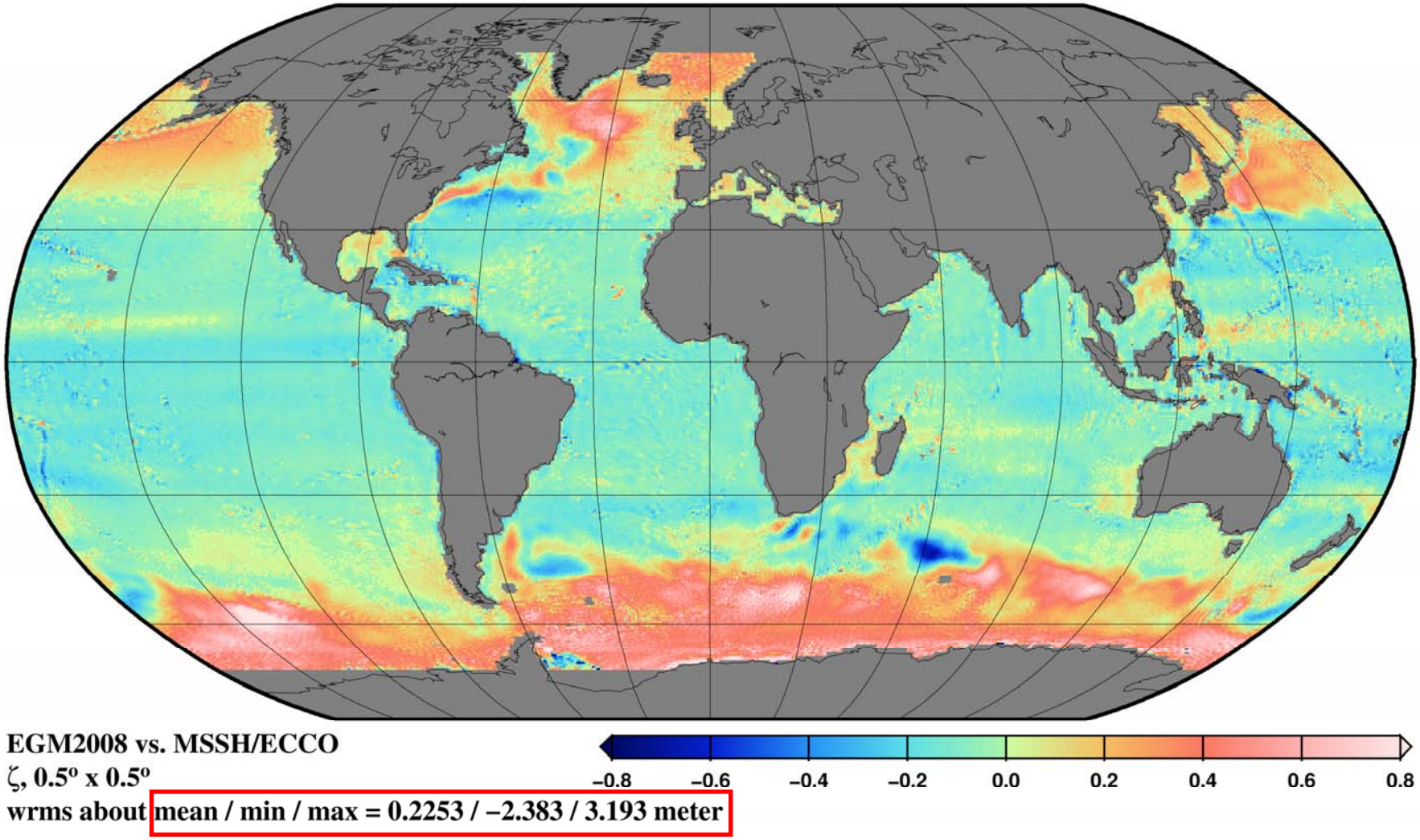
Geoid-Height Differences between:
EIGEN-6C and EGM2008
at the South Polar Region



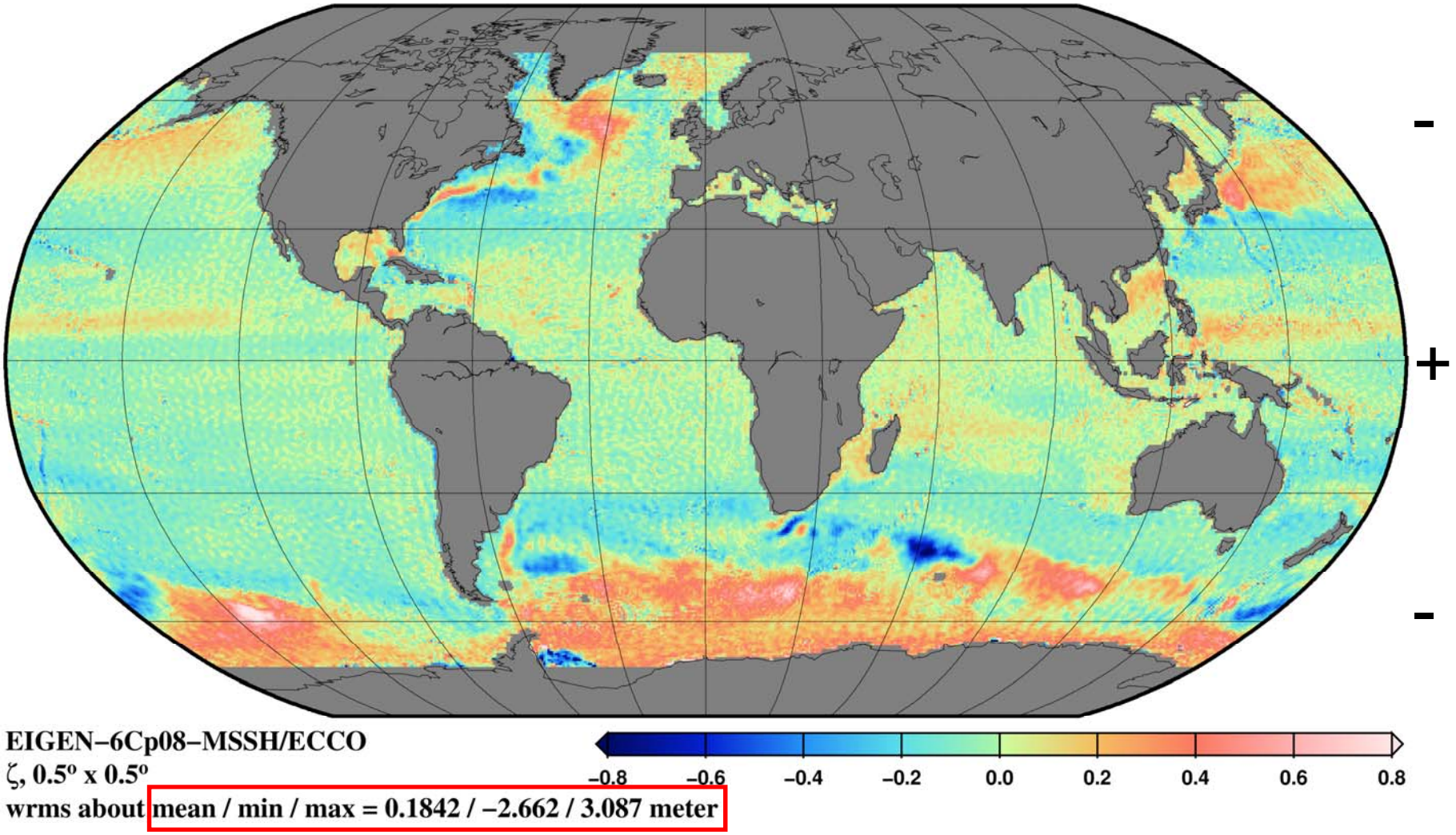
EIGEN-6C „corrects“ EGM2008 in Antarctica (outside the GOCE polar gap)

GOCE polar gap

Residual Dynamic Ocean Topography (non-filtered): EGM2008 – (MSSH/GFZ - ECCO)



Residual Dynamic Ocean Topography (non-filtered): EIGEN-6C – (MSSH/GFZ - ECCO)

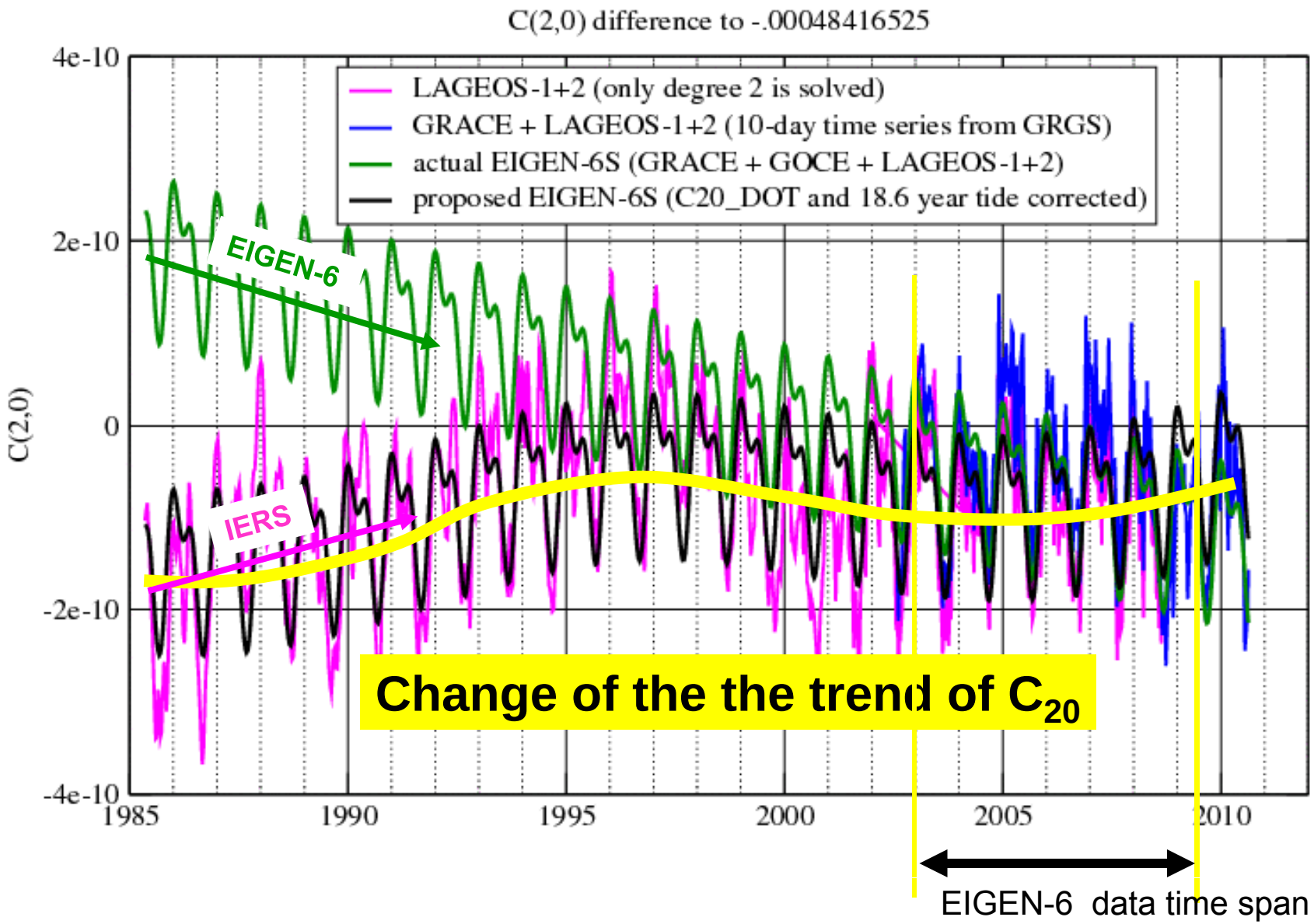


The trend of (normalized) C_{20} in EIGEN-6S/C

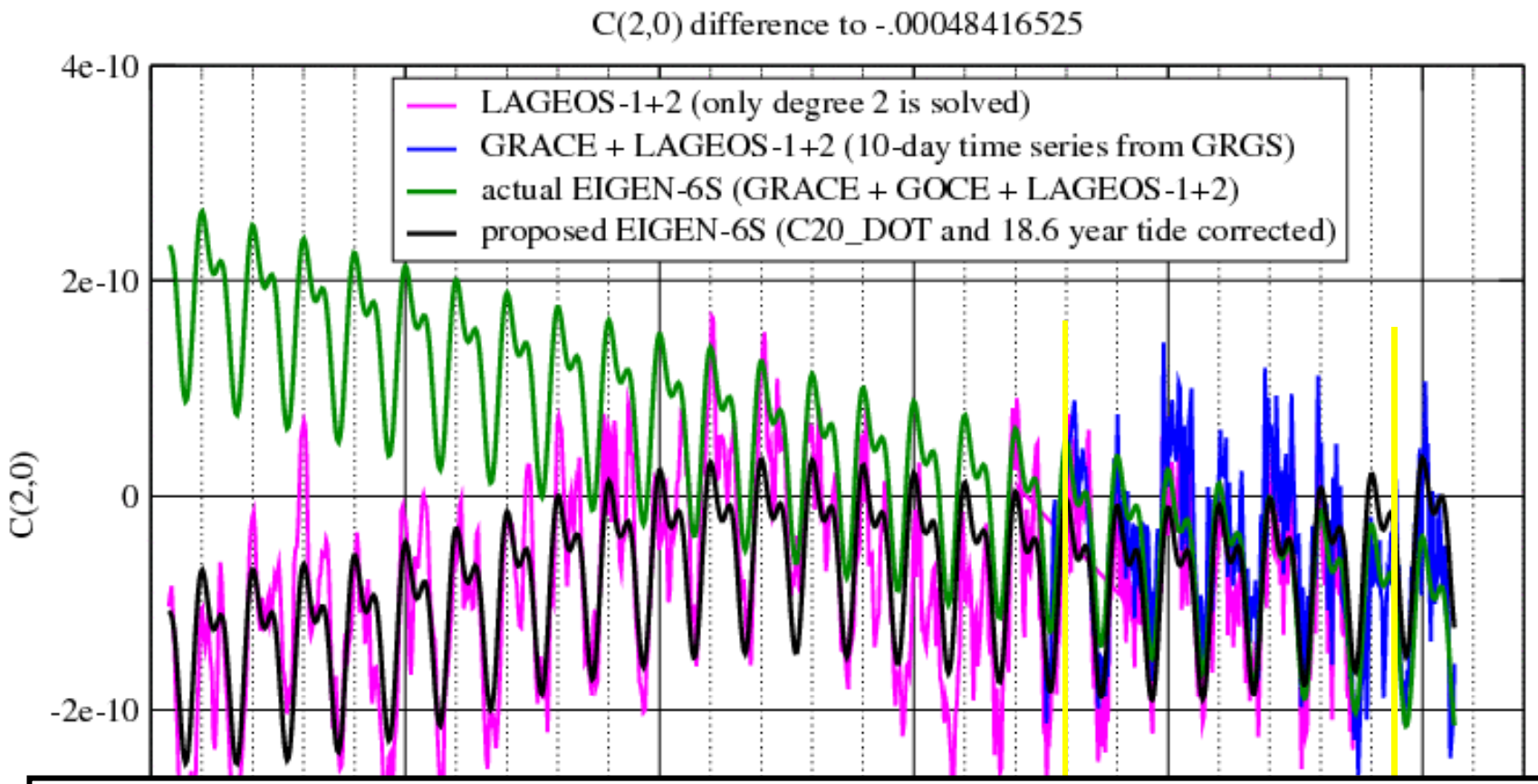
IERS conventions: $11.6\ 10^{-12}$
becoming rounder

EIGEN-6S/C: $-\ 12.6\ 10^{-12}$
becoming flatter

Time variability of C_{20}



Time variability of C_{20}



Proposal (black curve): Empirically corrected values for

- **C_{20}**
- **C_{20}-trend : ~+3.2 10^{-12}**
- **the 18.6 year tide : ~0.32 cm**

(could be expressed as an additional time variable C_{20} correction)

Summary / Conclusion

- **EIGEN-6S** is new satellite-only model from LAGEOS, GRACE & GOCE data (**up to deg. 240**).
- **EIGEN-6C** is a new combined gravity field model from the EIGEN-6S satellite data and the DTU10 global gravity anomaly grid of a **maximum degree 1420**.
- **Over land and beyond degree 240**, EIGEN-6C is in principle a reconstruction of EGM2008 (due to the inclusion of DTU10)
- EIGEN-6S/C contain **time variable parameters** for all spherical harmonic coefficients **up to degree 50** (drift, annual and semi-annual terms).

- EIGEN-6S/C has been published on the ICGEM data base at GFZ Potsdam:
http://icgem.gfz-potsdam.de

We plan to release a second version of EIGEN-6C soon (December 2011)
- adding 2 more years of GRACE SST and KBR data
- using data from the full time span of the GOCE nominal mission (Nov. 2009 – Apr. 2011)
- including corrected values for the time variable parameters of C_{20}
- extended to a higher maximum degree/order (up to degree/order ~1900)

For consistency we advise to adopt the same model for orbit computation and geoid reference (time variable parts affect mainly the geoid over continents)