The GFZ GRACE RL06 Time Series

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Overview of RL05 to RL06 Modifications

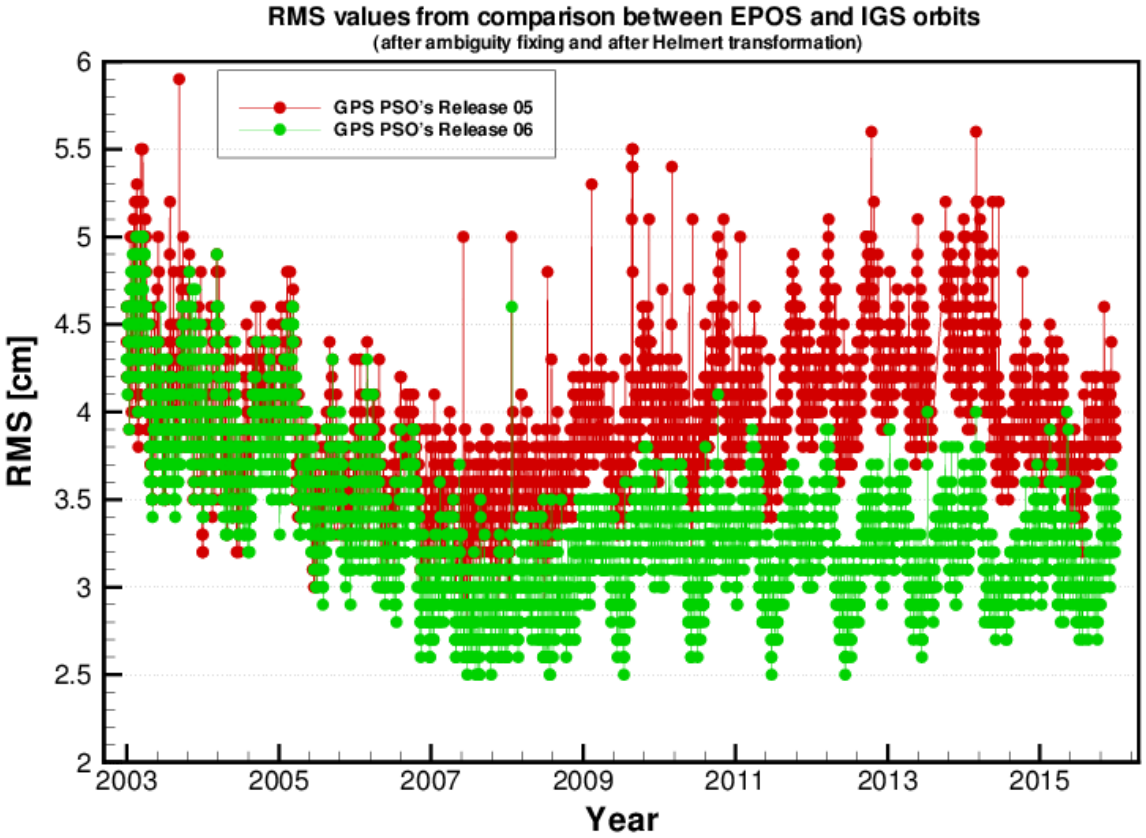
- Reprocessed Level-1B products (provided by JPL)
  - ➢ KBR1B & SCA1B RL03
- Reprocessed GPS constellation
- Background models
- Processing strategy and orbit/instrument parameterization

GPS Constellation

- Complete Reprocessing of GPS constellation for RL06
- Main differences compared to previous RL05 constellation:
  - New reference frame ITRF2014/IGS2014 (instead of ITRF2008/IGS08)
  - Increased number of ground stations (approx. 120 instead of 70)
  - Improved solar radiation pressure parameterization
  - Background models according to GRACE RL06 standards

GPS Constellation

- Complete Reprocessing of GPS constellation for RL06

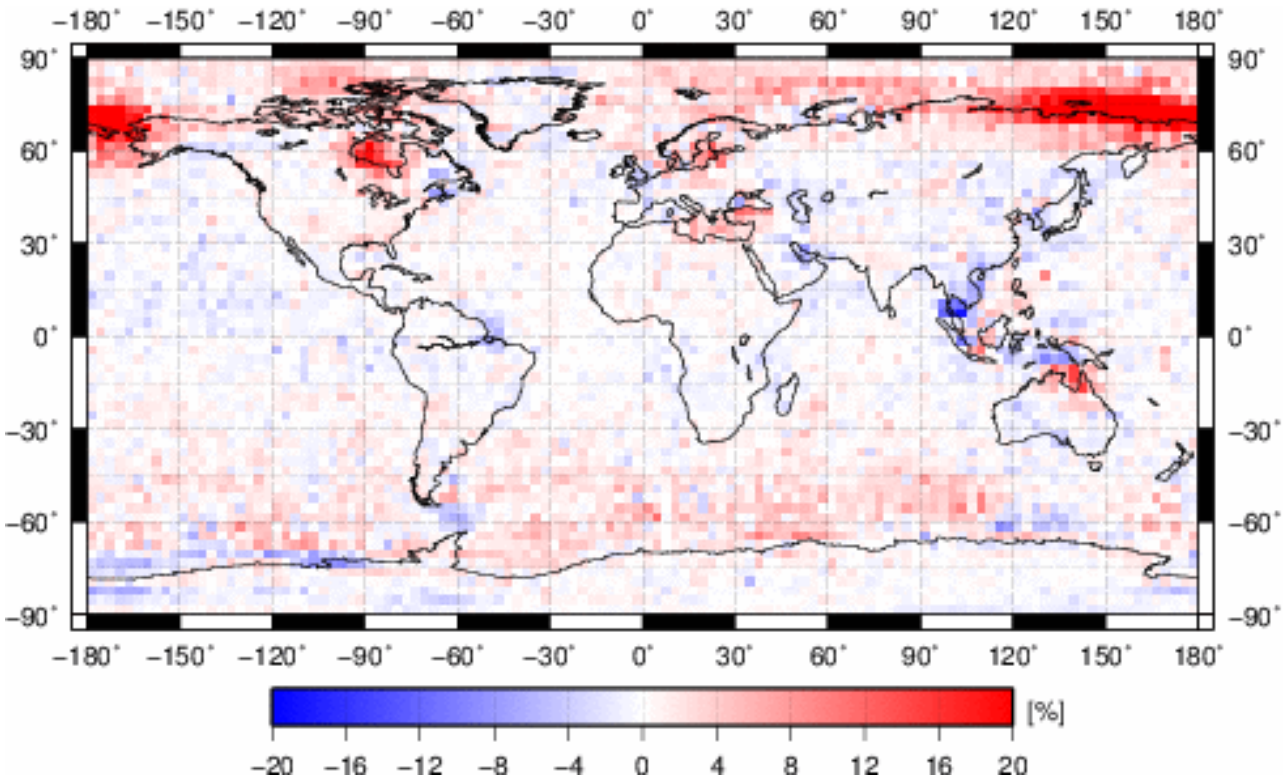


3D RMS of RL05 & RL06 GPS precise orbits wrt IGS final orbit products.

Background Models & Standards

	Currently: RL05	New: RL06
A priori Static Gravity Field	**EIGEN-6C**	**EIGEN-6C4**
A priori time-variable Gravity Field	**Trend/Annual/ Semiannual Coeff. from EIGEN-6C**	**GFZ RL05a (DDK1 filtered)** → only during data screening!
Ocean Tides	**EOT11a**	**FES2014**
Atmospheric Tides S1, S2	Bode-Biancale 2003	Bode-Biancale 2003
Atmospheric and Oceanic Non-tidal Mass Variations	**AOD1B RL05**	**AOD1B RL06**
Ocean Pole Tide	Desai [2002]	Desai [2002]
Solid Earth & Pole Tides	IERS2010	IERS2010
3rd Body Ephemerides	**JPL DE421**	**JPL DE430**

AOD1B RL06



deterioration **improvement**

Relative change of KBRA pre-fit residual variance when using AOD1B RL06 instead of RL05 averaged over the year 2008.

Processing Strategy / Parameterization

RL05	RL06
GPS data screening	
common run for GRACE-A/-B (incl. down-weighted KRR obs.)	fully independent for GRACE-A/-B (no KBR obs.)
KBR data screening	
8-sigma elimination	no automatic screening at all, visual inspection of residuals
further GPS data screening still enabled	no further GPS data screening
a priori orbit determination/gravity field estimation	
weights for GPS and KBR obs. remain unchanged, constant weights throughout whole GRACE mission	arc-wise weighting of GPS and KBR obs. based on pre-fit residuals (GPS: down-weighted by factor 7)
time-variable gravity field model still used as background model	time-variable gravity field background model removed
different parameterization in GPS screening run and rest of processing	**same parameterization during whole processing**

Processing Strategy / Parameterization

Number of parameters (24h arc, GRACE-A/-B together)

RL05	RL06
12 initial orbit elements	**12** initial orbit elements
40 empirical parameters **(GPS screening only)** *cosine/sine coefficients of 1/rev periodical model* *- estimated every 4.8 h in TN* *- no constraint*	**128** empirical parameters *- estimated 1/rev in TN* *- a priori sigma: 1E-5 m/s^2*
48 KBR parameters **(KBR screening only)** *range-rate bias & drift every 90 min* *cosine/sine coefficients of range bias every 180 min*	**no more KBR parameters**
150/108 ACC parameters *25/9 biases per arc in RTN* *0/9 scale factors per arc in RTN*	**36** ACC parameters *3 biases per arc in RT, 9 in N* *1 scale factor per arc in RTN*
202/160 during GPS screening **210/168** during KBR scr./gravity estim.	**176** parameters, same during whole processing

Orbit Quality

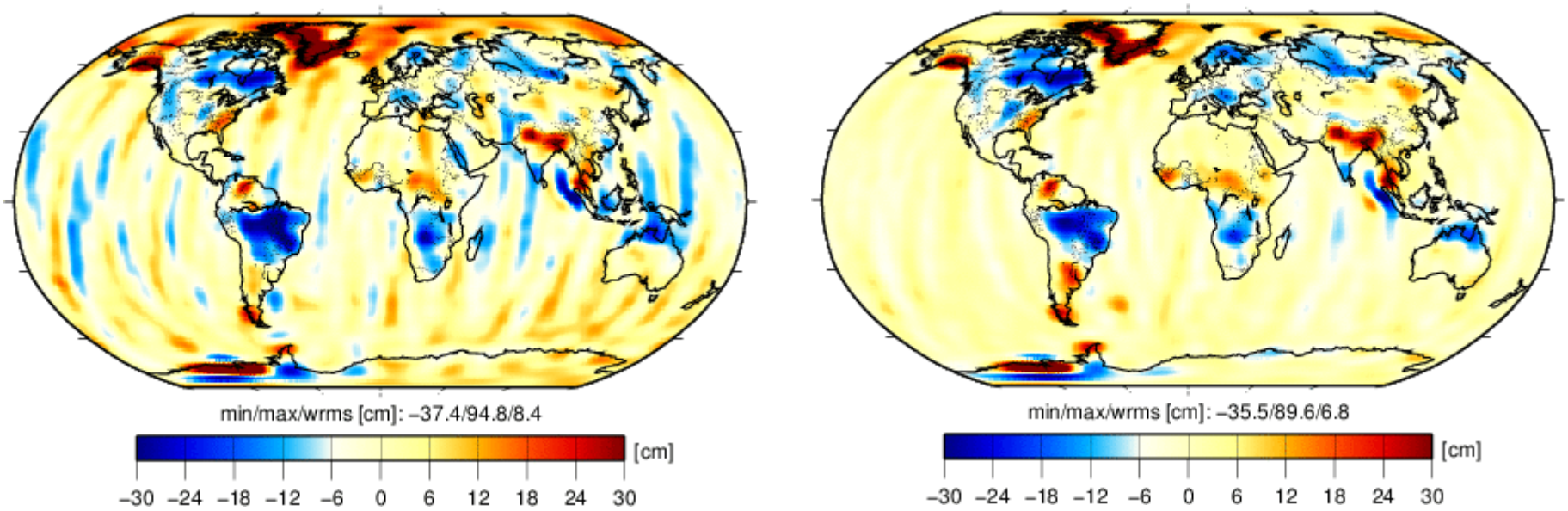
- (absolute) orbit accuracy not in the focus during RL05 processing
- goal for RL06: good gravity fields **and** orbits

	SLR statistics mean [cm] all stat./Yarr.	**RMS [cm] all stat./Yarr.**	**GPS residuals RMS [cm] code / phase**	**KBR res. [μm/s]**
Year 2008				
GRACE-A	-1.330 / -1.195	2.541 / 1.605	42.811 / 0.275	
GRACE-B	-1.459 / -1.409	2.785 / 1.754	35.640 / 0.253	
KBR screening		2.648 / 1.683	39.469 / 0.270	0.260
a priori run		2.824 / 1.996	39.545 / 0.305	0.280
Year 2014				
GRACE-A	-1.190 / -0.575	2.412 / 1.309	40.873 / 0.278	
GRACE-B	-1.311 / -0.582	2.582 / 1.376	35.473 / 0.259	
KBR screening		2.480 / 1.327	38.375 / 0.275	0.213
a priori run		3.578 / 3.254	38.653 / 0.382	0.419

- fairly good orbit quality for GRACE-A/-B GPS-only runs is maintained to a large extent also when KBR obs. are used

Results

GFZ RL05a **2003/08** **GFZ RL06**

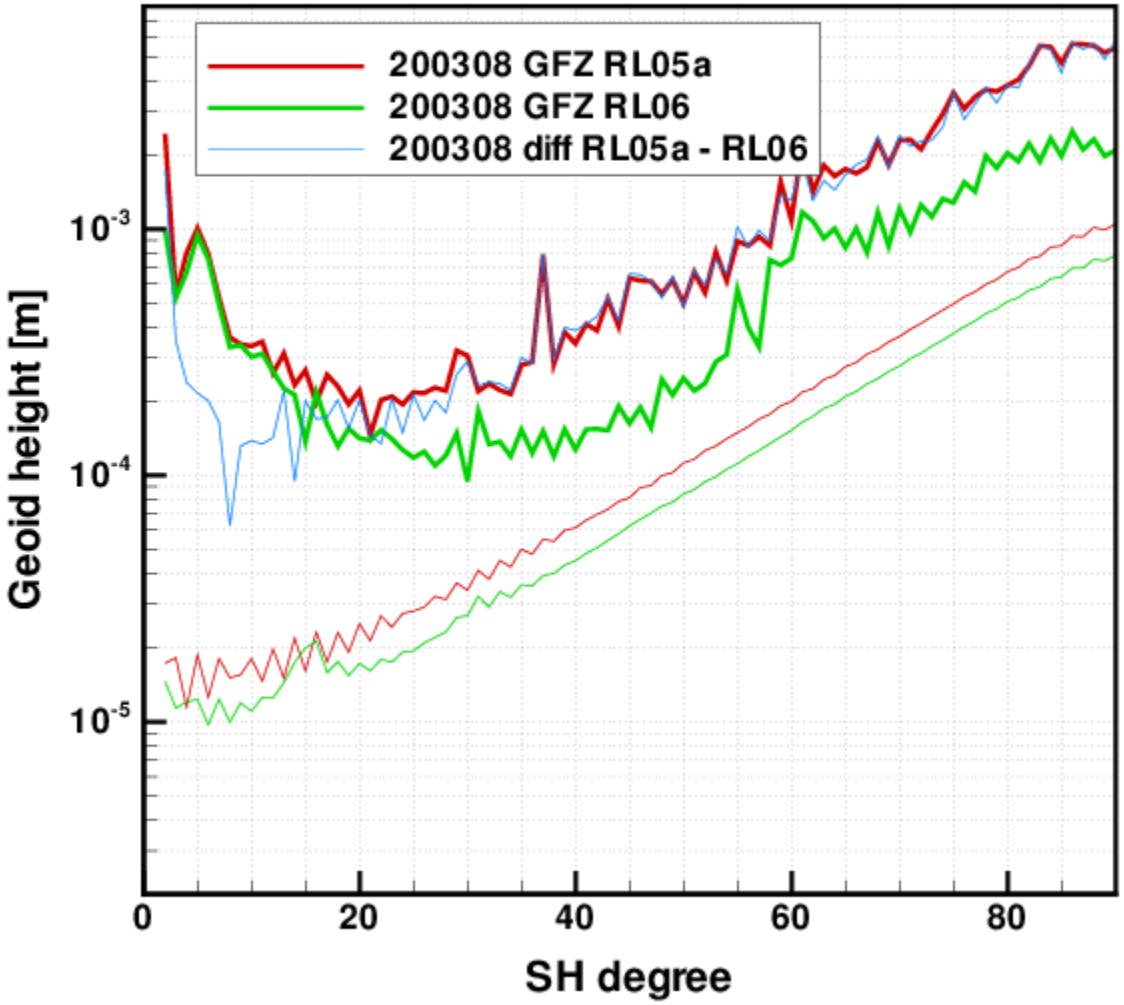


EWH grids wrt EIGEN-6C4, 90x90 solutions, DDK3 filtered

wRMS over ocean in terms of cm EWH, C_{20} excluded:

	unfiltered	**DDK5**	**DDK4**	**DDK3**	**DDK2**	**DDK1**
RL05a	662.8	9.0	5.8	4.9	3.1	2.3
RL06	294.0	4.4	3.1	2.8	1.9	1.5
rel. improv.	**56%**	**51%**	**47%**	**43%**	**39%**	**35%**

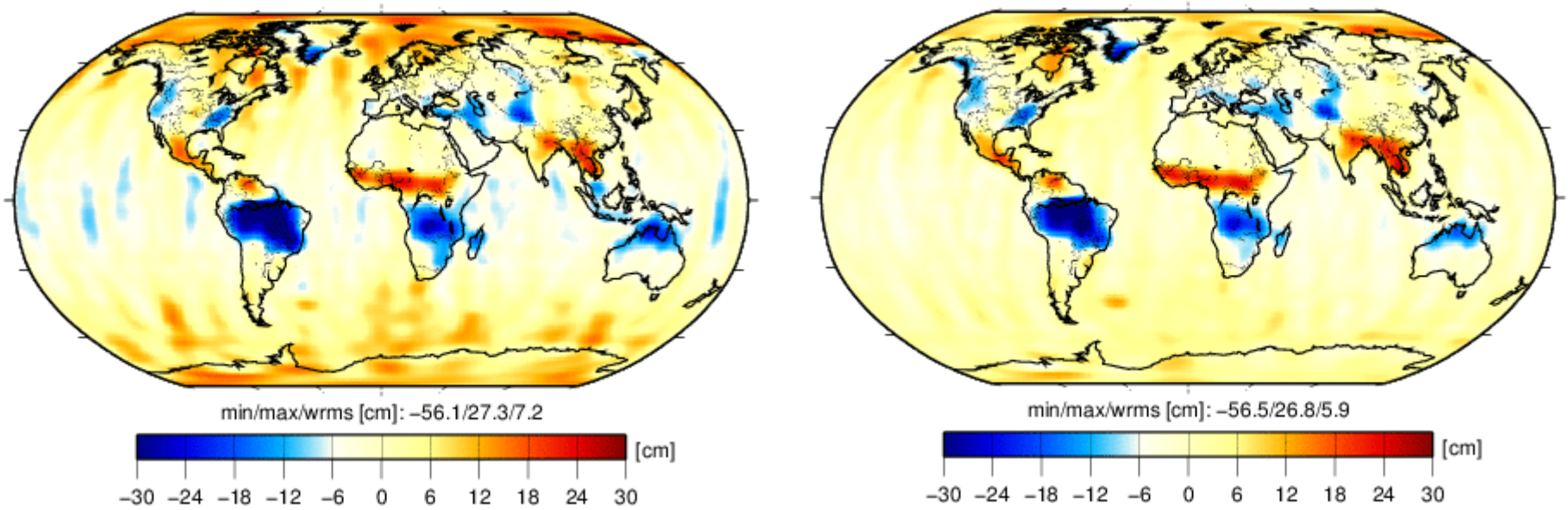
Results



Difference degree amplitudes wrt EIGEN-6C4 and formal error degree amplitudes (thin lines)

Results

GFZ RL05a **2008/10** **GFZ RL06**

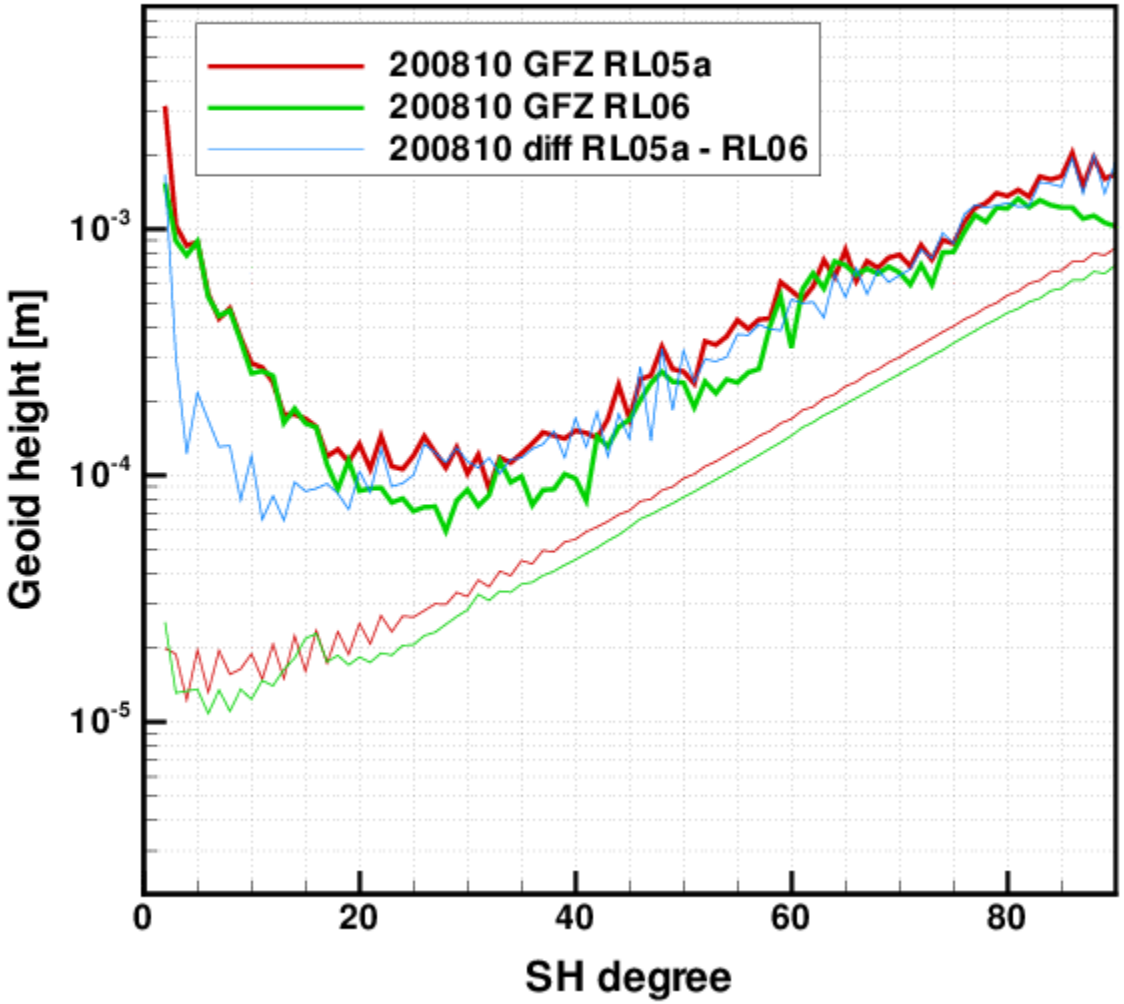


EWH grids wrt EIGEN-6C4, 90x90 solutions, DDK3 filtered

wRMS over ocean in terms of cm EWH, C_{20} excluded:

	unfiltered	**DDK5**	**DDK4**	**DDK3**	**DDK2**	**DDK1**
RL05a	209.1	4.7	3.2	2.8	2.1	1.7
RL06	167.1	3.3	2.4	2.2	1.7	1.5
rel. improv.	**20%**	**30%**	**25%**	**21%**	**19%**	**12%**

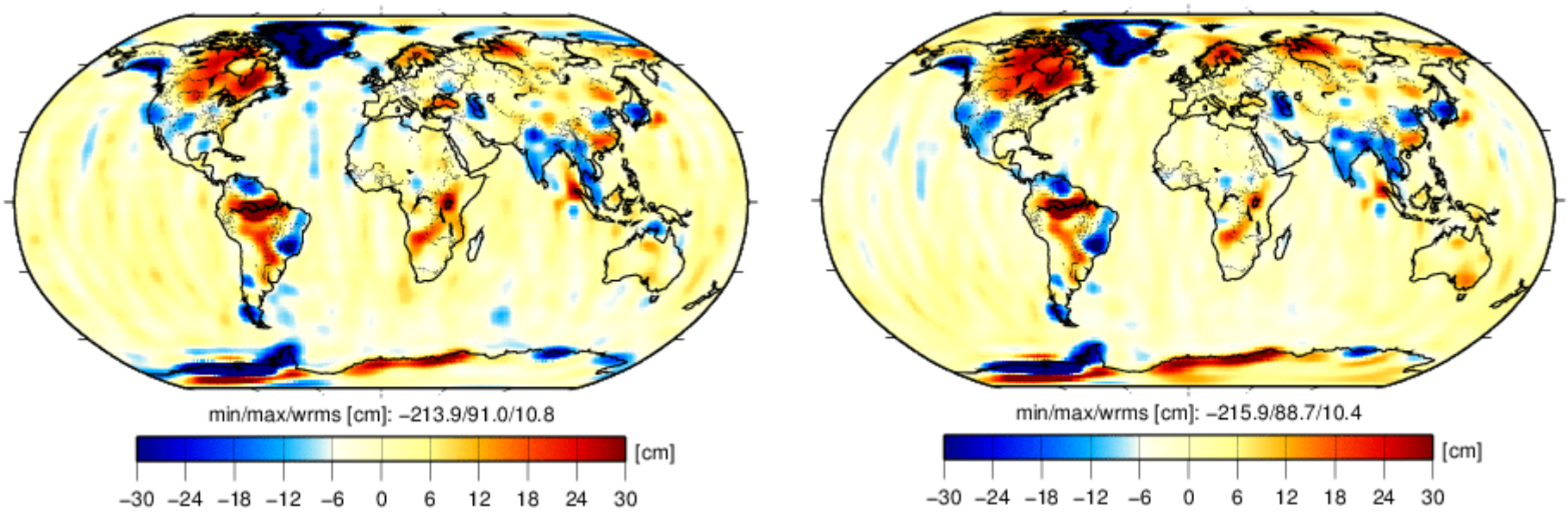
Results



Difference degree amplitudes wrt EIGEN-6C4 and formal error degree amplitudes (thin lines)

Results

GFZ RL05a **2014/06** **GFZ RL06**

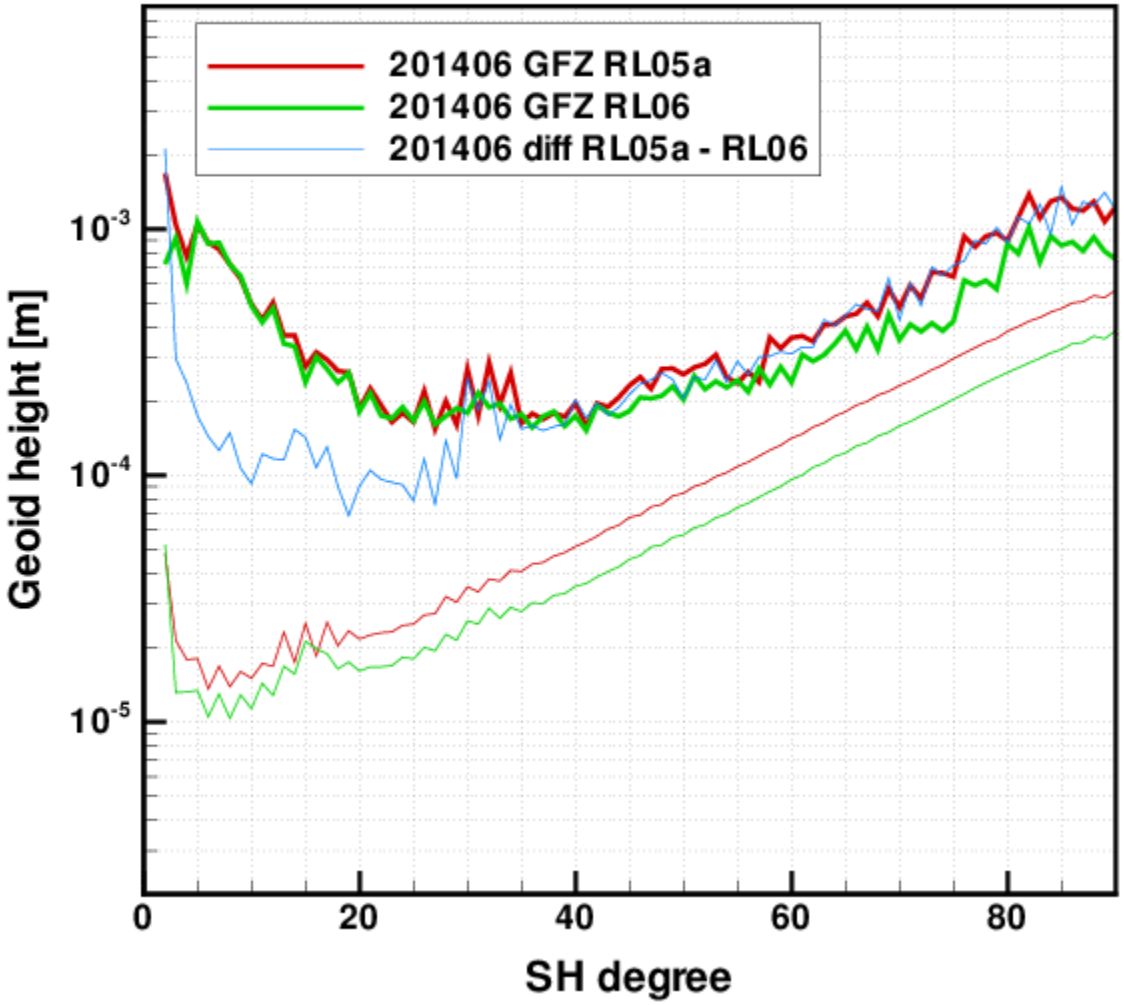


EWH grids wrt EIGEN-6C4, 90x90 solutions, DDK3 filtered

wRMS over ocean in terms of cm EWH, C_{20} excluded:

	unfiltered	**DDK5**	**DDK4**	**DDK3**	**DDK2**	**DDK1**
RL05a	149.5	6.3	4.1	3.6	2.6	2.4
RL06	114.9	5.6	3.6	3.1	2.5	2.5
rel. improv.	**23%**	**11%**	**12%**	**14%**	**4%**	**-4%**

Results



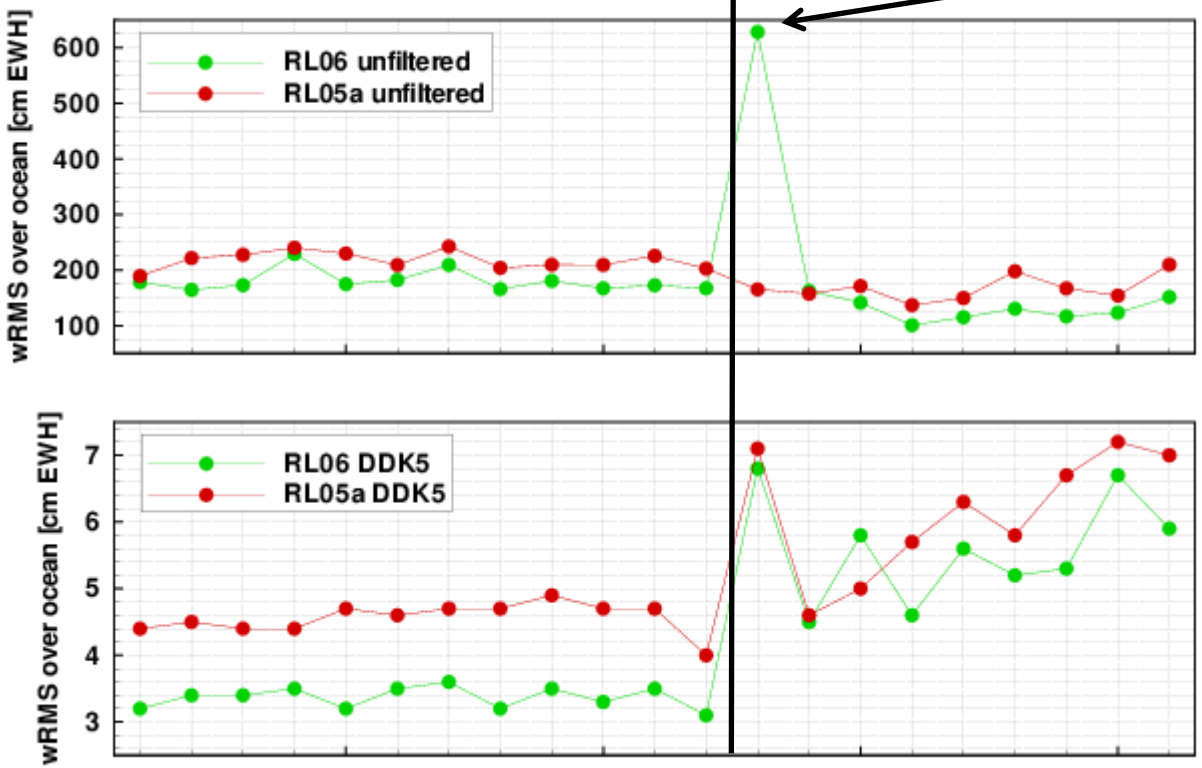
Difference degree amplitudes wrt EIGEN-6C4 and formal error degree amplitudes (thin lines)

Results

2008 solutions

2014 solutions

2014/01: stabilized for RL05a, not stabilized for RL06



Unfiltered:

mean	2008	2014
RL05a	217.4	167.8
RL06	180.2	130.0
rel. improv.	**17.1%**	**22.5%**

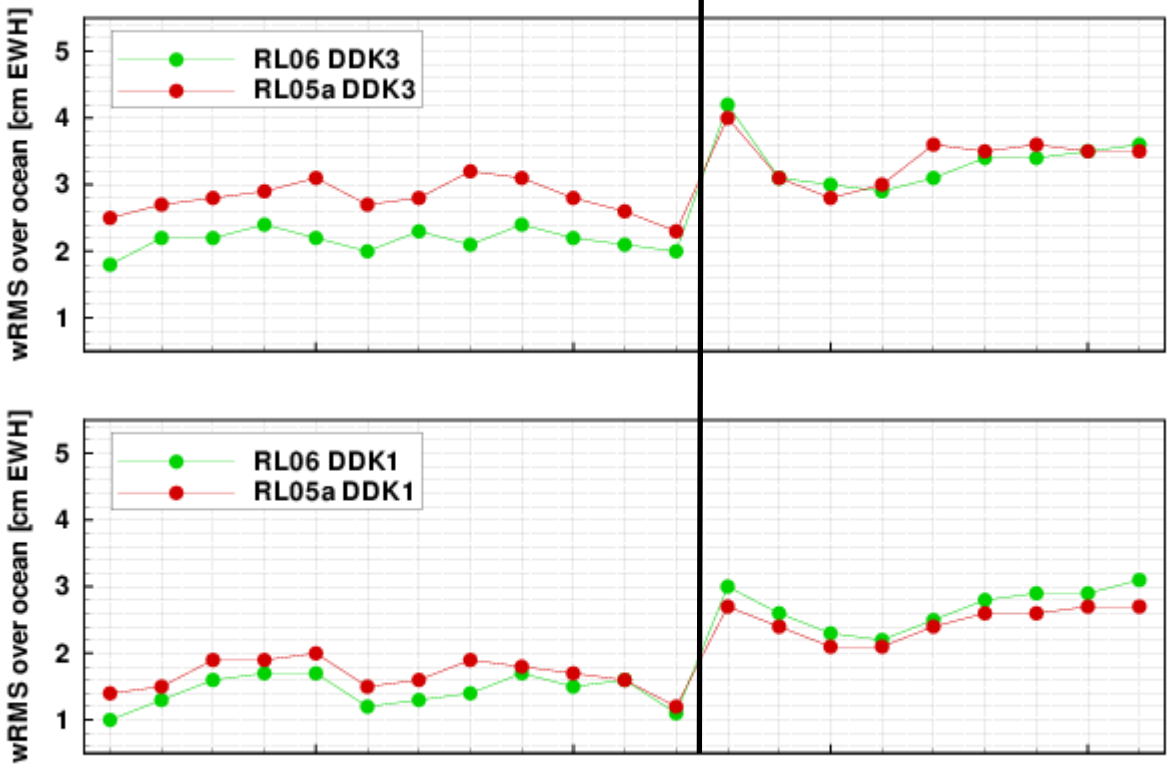
DDK5:

mean	2008	2014
RL05a	4.56	6.04
RL06	3.37	5.45
rel. improv.	**26.1%**	**9.7%**

wRMS over ocean in terms of cm EWH, C_{20} excluded

Results

2008 solutions | 2014 solutions



DDK3:

mean	2008	2014
RL05a	2.79	3.33
RL06	2.16	3.25
rel. improv.	**22.7%**	**2.3%**

DDK1:

mean	2008	2014
RL05a	1.67	2.45
RL06	1.43	2.66
rel. improv.	**14.5%**	**-8.7%**

wRMS over ocean in terms of cm EWH, C_{20} excluded

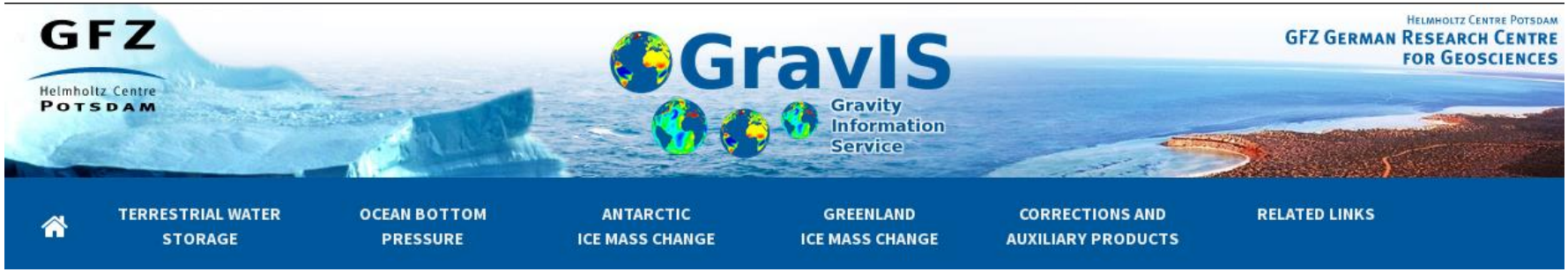
General Remarks

- Current RL06 reprocessing status:
  - completed: 2003-08, 2007-02/03/04/05/07/08, 2008, 2014
  - some of these solutions might be revised (= final editing to get rid of particular artefacts)
  - reprocessing of all missing months ongoing 24/7
  - years 2002, 2016 and 2017 will be reprocessed last

- Notes on Level-2 products:
  - GFZ will deliver 60x60 and 96x96 solutions (consistent within GRACE SDS)
  - the type of Level-2 products remains unchanged: GSM, GAA, GAB, GAC, GAD
  - the SDS introduces new filenames and new product headers, see new version of GRACE Level-2 documentation to be published soon!

General Remarks

- New Level-3 portal at GFZ in collaboration with AWI/TU Dresden:



  - At GravIS, Level-3 products based on the latest GRACE/GRACE-FO release of GFZ are visualized and described
  - Level-3 products comprise dedicated globally gridded mass anomalies as well as basin average time series for terrestrial water storage over non-glaciated regions, bottom pressure variations in ocean basins and ice mass changes in both Antarctica and Greenland
  - products will be available for download via GFZ's ISDC archive

  - **http://gravis.gfz-potsdam.de**
  - for more information: see **poster EGU2018-17878** later this afternoon during G4.3 poster session

Summary

- GFZ is currently reprocessing RL06 solutions for all months with available science data
- Beside some new background models, major changes consist of different processing strategy with different and (for most months) even less parameters
- GFZ RL06 solutions are traditional unconstrained SH solutions
- First results are promising: noise level has decreased, signals seem to be well captured
- RL06 standards will be used for initial GRACE-FO release as well
- GFZ will publish first RL06 solutions asap, but only after sufficient number of consecutive years is available and successful internal/external validation