

GFZ Level-2 Status

Christoph Dahle, Michael Murböck, Frank Flechtner
&
GFZ GRACE/GRACE-FO SDS Team

Level-2 processing since GSTM2016

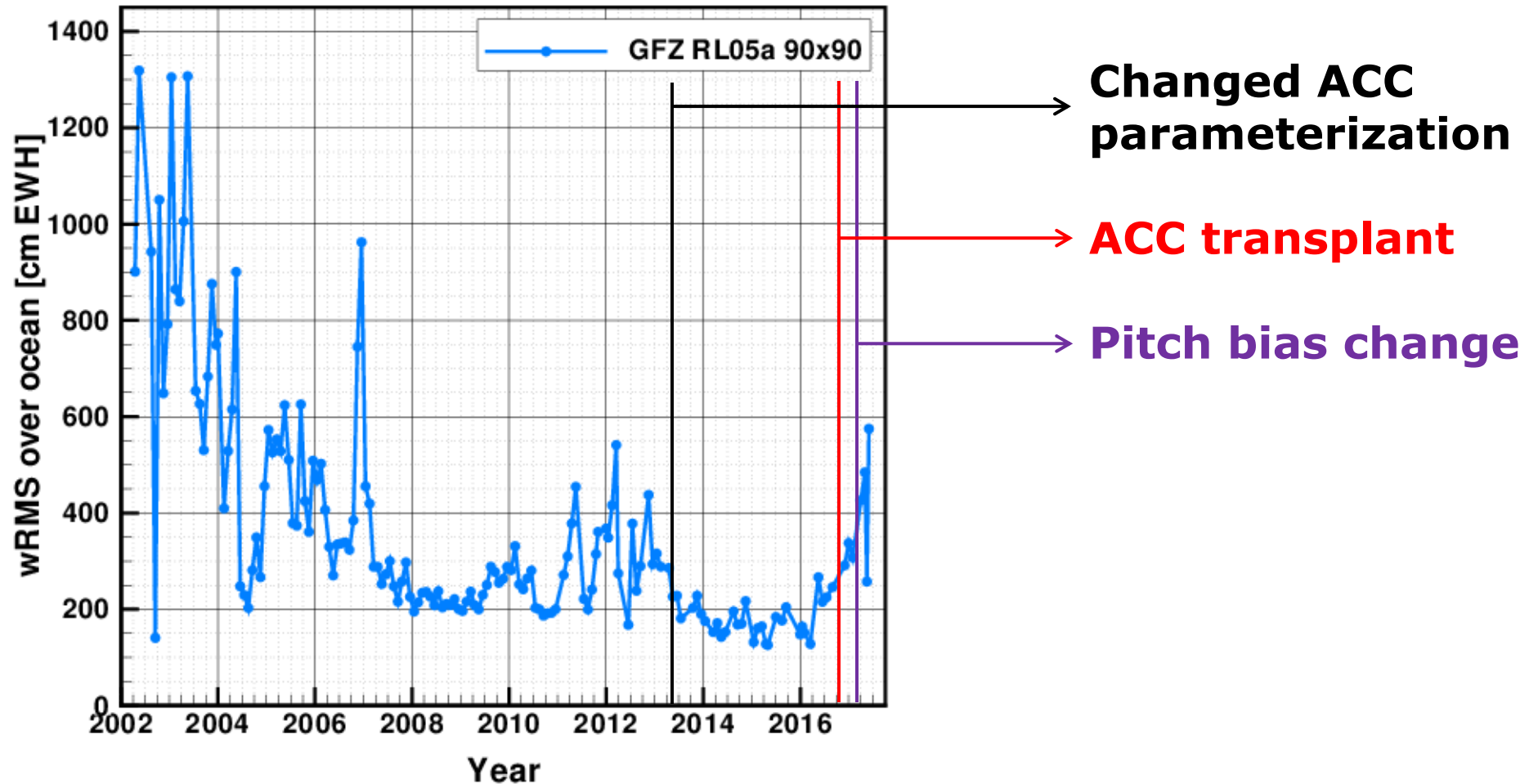
- Processed monthly GFZ RL05a solutions:
 - **2016/07, 2016/08, 2016/11, 2016/12, 2017/01, 2017/03, 2017/04, 2017/05, 2017/06**
 - Solutions since Nov 2016 are affected by: **ACC transplant, ACC transplant + pitch bias change, pitch bias change**
 - none of these solutions covers exactly one calendar month, sometimes data of certain days is used for two solutions
 - For further details see SDS newsletters, release notes, web pages
- Missing solutions (due to non-available science data):
 - **2016/09, 2016/10 , 2017/02**

Current processing status of whole GFZ RL05a time series

- **163** monthly solutions (90x90) from 2002/04 till 2017/06
 - **20** months are **missing** due to missing/anomalous L1B data
 - **13** solutions are **stabilized** due to short-interval repeat orbits

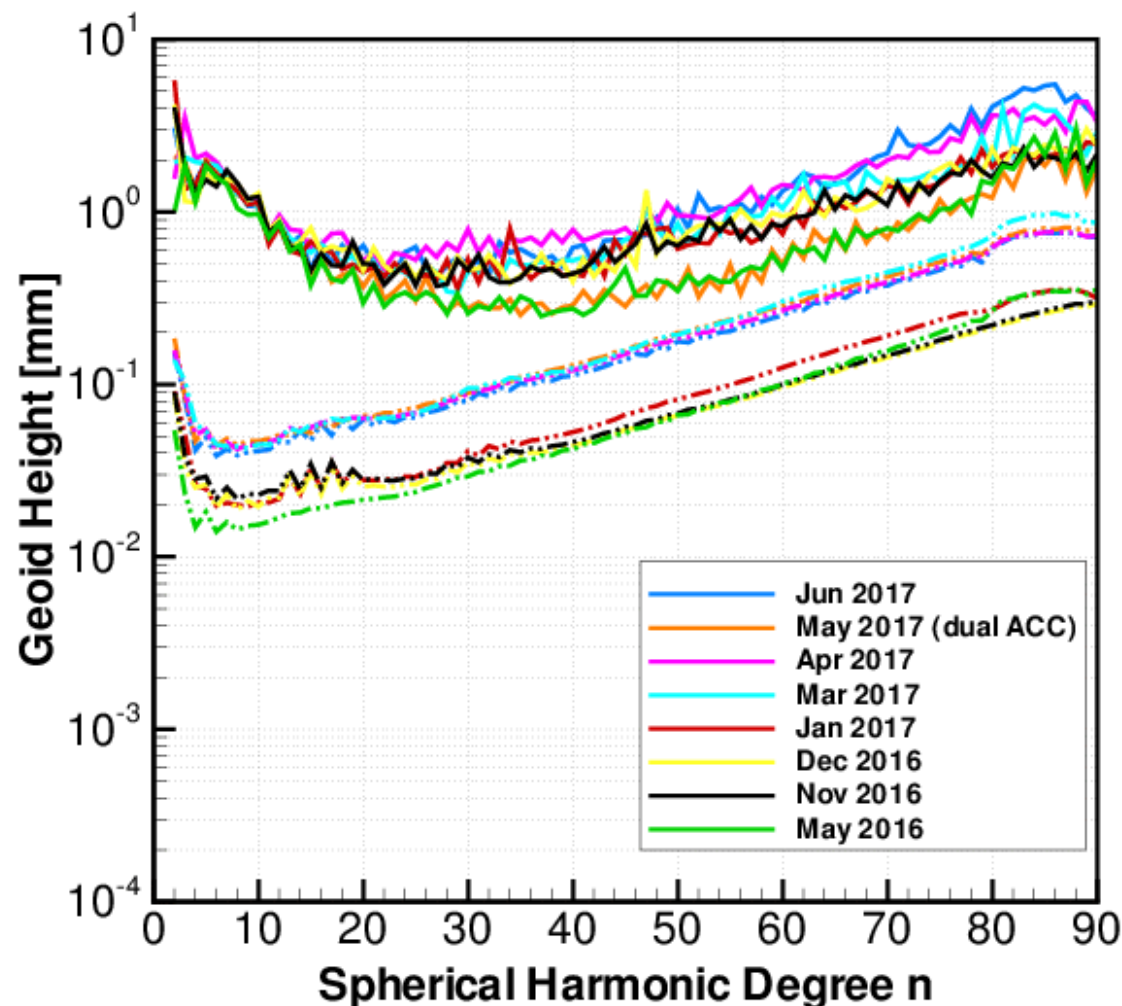
RL05a Overview

Residual (bias, trend, annual removed) wRMS over ocean:



RL05a solutions since Nov 2016

Degree amplitudes w.r.t. EIGEN-6C:



- All ACC transplant solutions are degraded
- Since pitch bias change even more degradation
- May 2017 solution as good as May 2016 solution → dual ACC!
- Formal errors larger since pitch bias change
- **Processing strategy did not change compared to previous RL05a solutions**

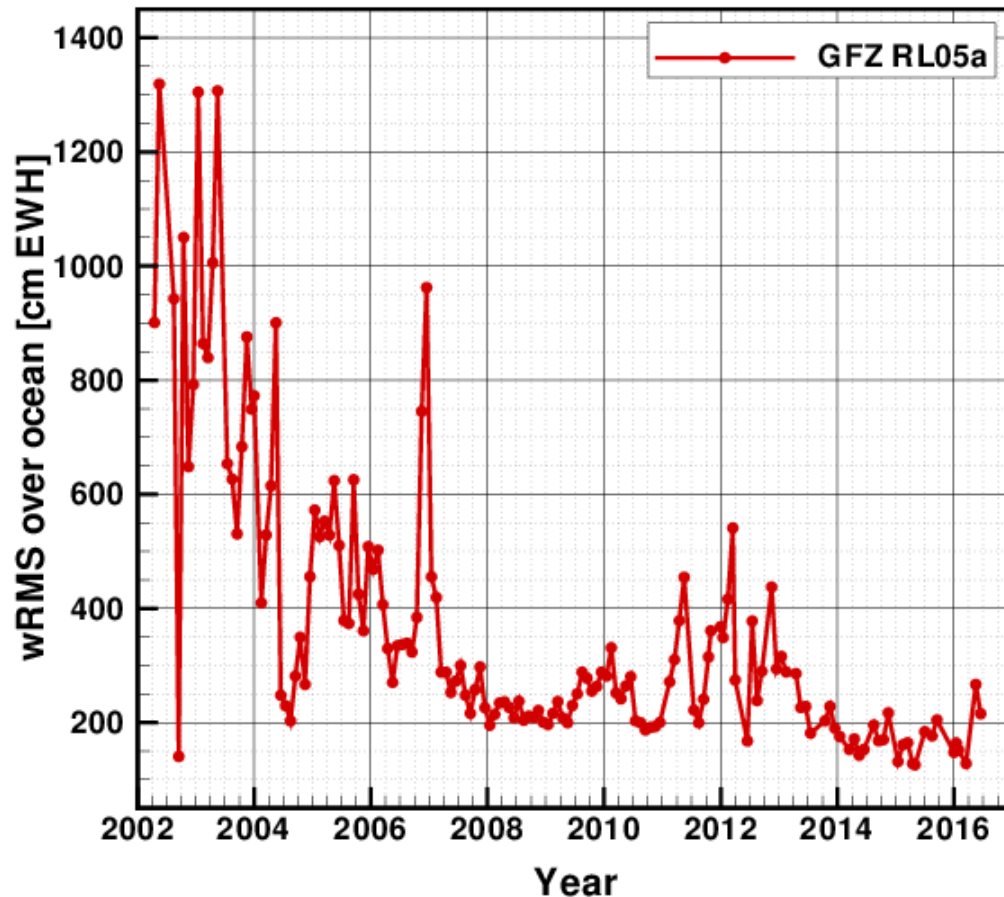
RL06 Plans: Overview

- Target date to have first years of RL06 reprocessed: Dec 2017 (AGU, poster Flechtner et al.)
- So far: several individual tests
- RL05 to RL06 changes **will comprise** / *might comprise*:
 - Background models: **Ocean/atmospheric tides, AOD, static gravity field**
 - **Instrument parameterization** (both ACC and KBR)
 - **Data screening** (both GPS and KBR)
 - **Absolute/relative weighting of GPS and KBR obs.**
 - **Level-1B RL03 products** (KBR1B, SCA1B)
 - **Reprocessed GPS constellation** (consistent with **IGS14**, GRACE **RL06** background model)
 - *Decorrelation of KBR observations*
 - *Daily GRACE solutions as additional De-aliasing product*

RL06 Plans: ACC Parameterization

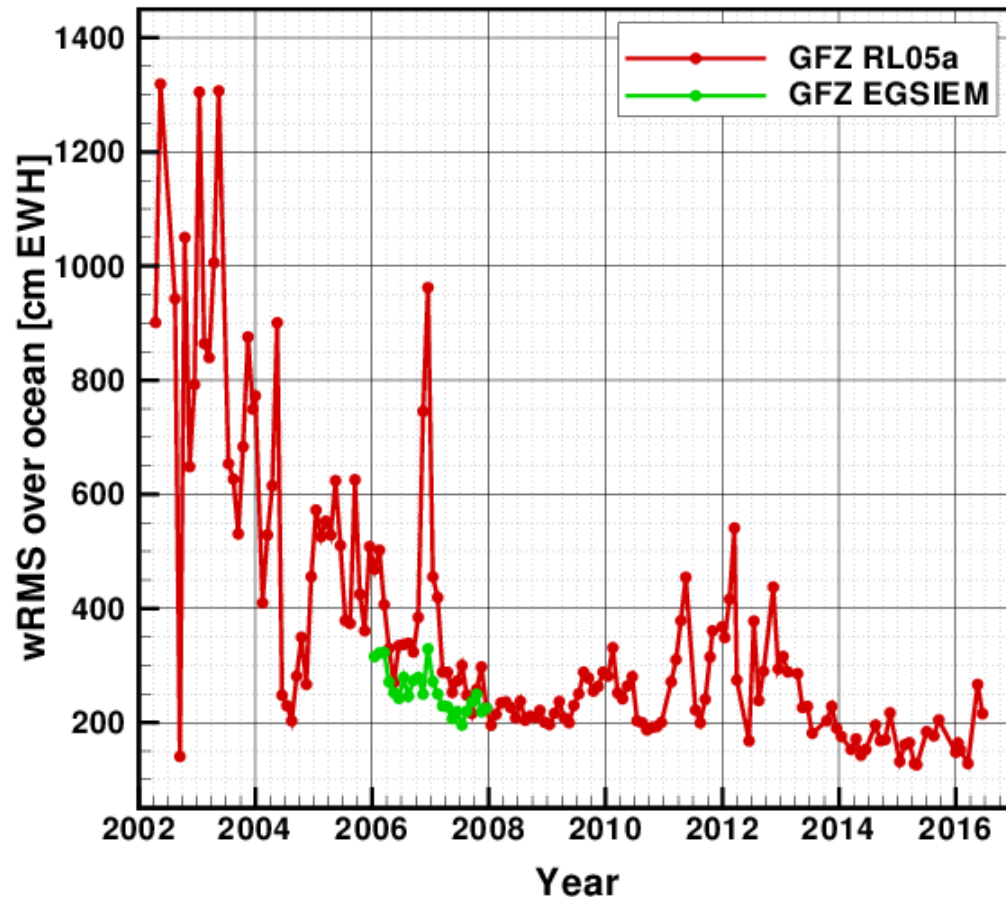
Residual (bias, trend, annual removed) wRMS over ocean:

- During some periods, monthly solutions of the GFZ RL05a time series are significantly worse than for most other months



RL06 Plans: ACC Parameterization

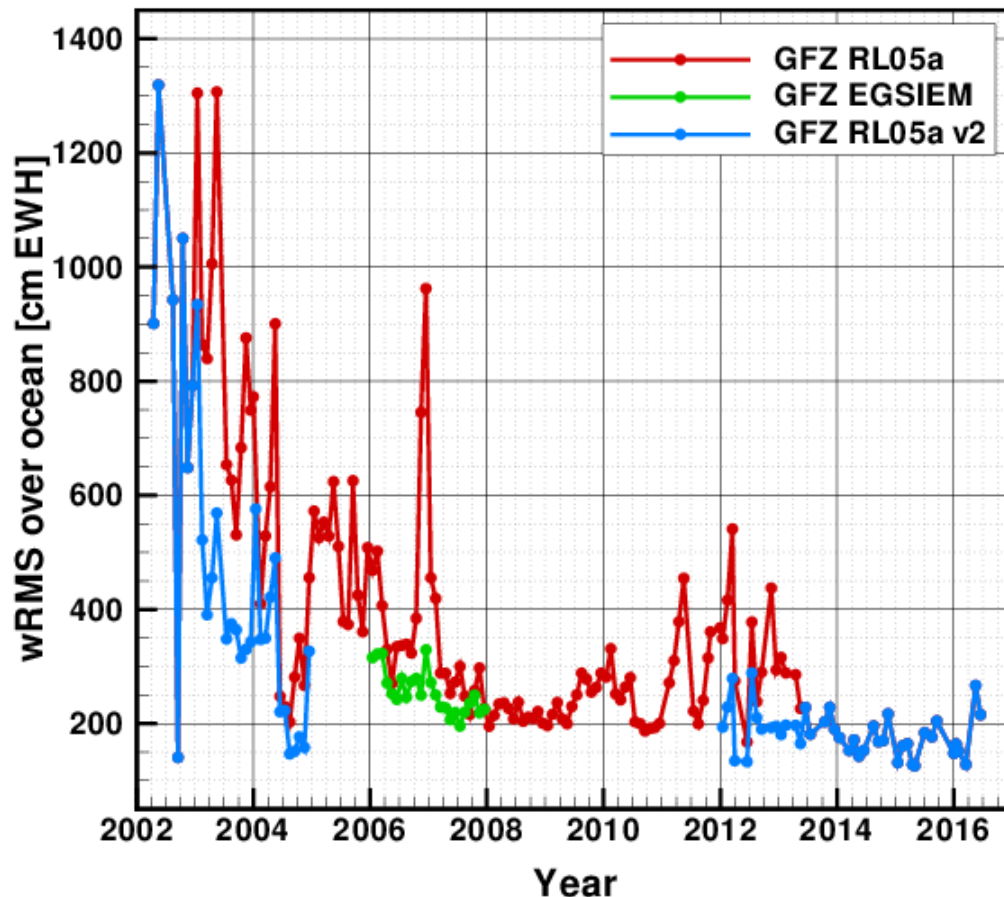
Residual (bias, trend, annual removed) wRMS over ocean:



- During some periods, monthly solutions of the GFZ RL05a time series are significantly worse than for most other months
- Reprocessing of years 2006 & 2007 for the EGSIM project shows that modified ACC parameterization clearly improves the quality of the time series

RL06 Plans: ACC Parameterization

Residual (bias, trend, annual removed) wRMS over ocean:



- During some periods, monthly solutions of the GFZ RL05a time series are significantly worse than for most other months
 - Reprocessing of years 2006 & 2007 for the EGSIM project shows that modified ACC parameterization clearly improves the quality of the time series
 - This has been confirmed for other periods as well
- Quality of RL06 time series will be much more consistent

Models that have been tested:

- EOT11a
 - Used for GFZ RL05
- FES2014
- GGOT4.7-1.0
 - “GRACE + GOT4.7” model
 - Residual tidal signals from GRACE for M2, S2, K1, O1, Mf
 - Presented by R. Ray at GSTM2016
- GOT4.7

Test criteria:

- RMS of binned pre-fit K-band range accel. (KRX) residuals
- Comparison of gravity field results

RL06 Plans: Ocean Tide Model

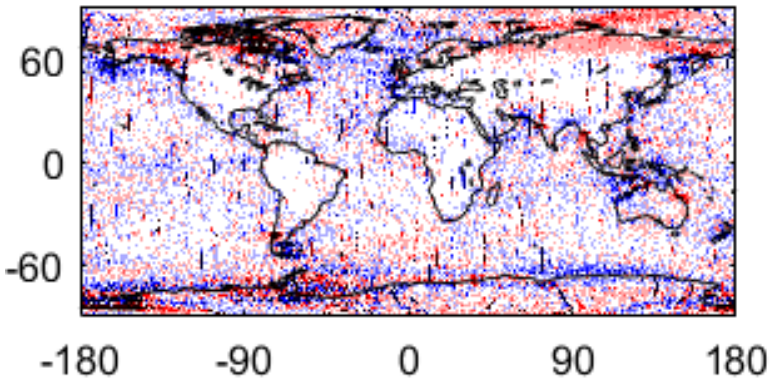
Pre-fit KRX residuals:

rel. improvement [%] FES2014 wrt EOT11a

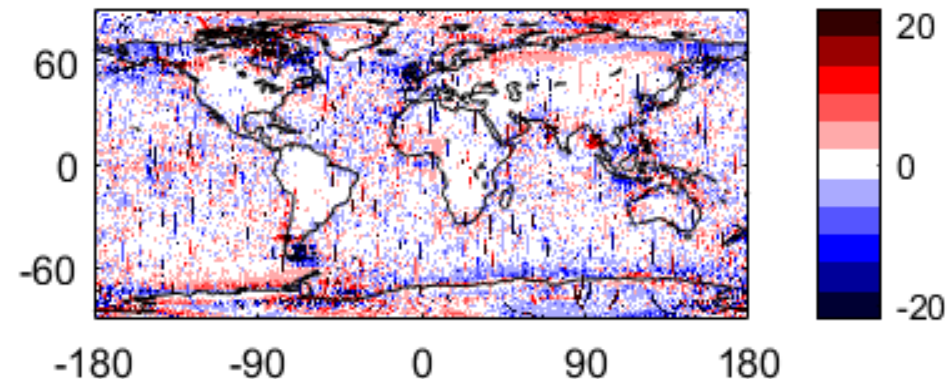
better

worse

2008



2014



- Smaller residuals with FES2014 compared to EOT11a by 10 - 20 % mainly in the polar ocean areas

RL06 Plans: Ocean Tide Model

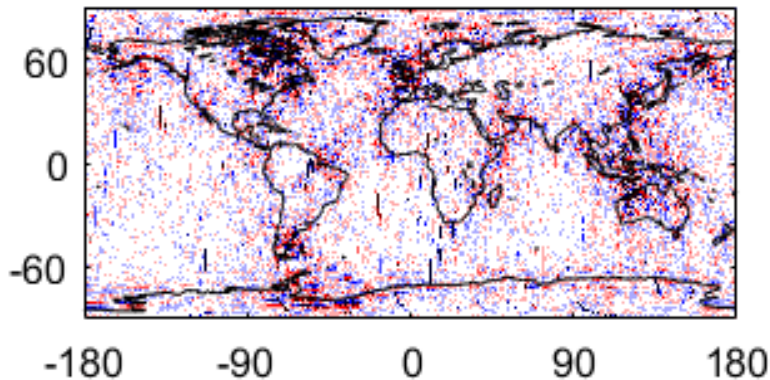
Pre-fit KRX residuals:

rel. improvement [%] FES2014 (180x180) wrt FES2014 (80x80)

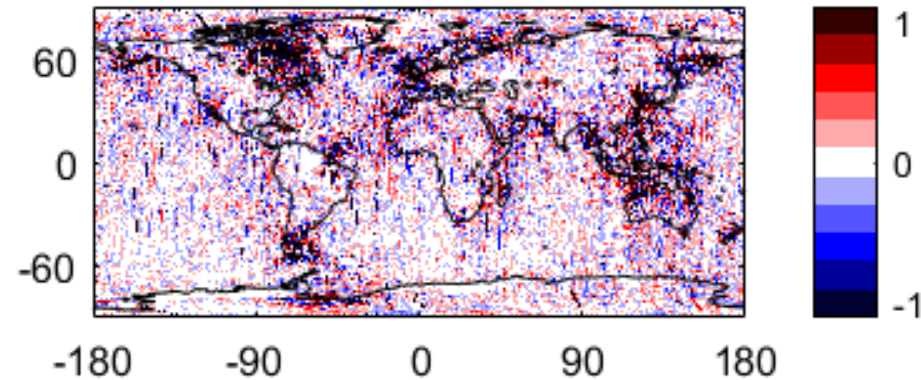
better

worse

2008



2014



- Very small differences (around 1 %) between FES2014 when used up to d/o 180x180 compared to FES2014 truncated at d/o 80x80

RL06 Plans: Ocean Tide Model

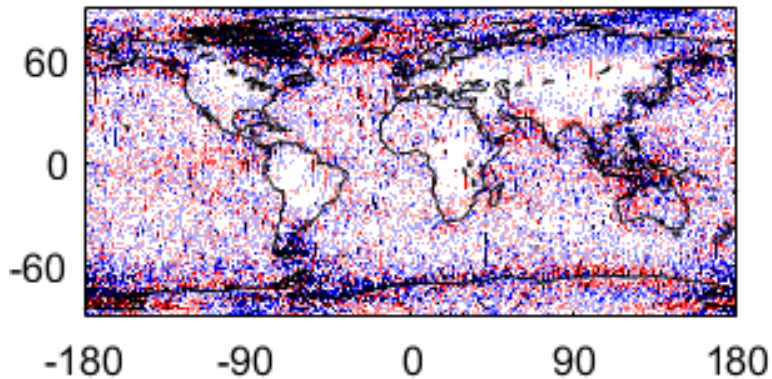
Pre-fit KRX residuals:

rel. improvement [%] GOT4.7 wrt FES2014

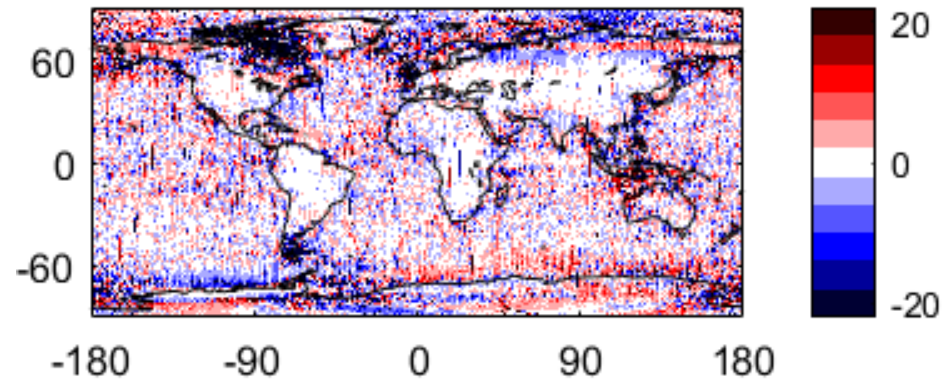
better

worse

2008/01+04+07+10



2014/01+04+06+10



- GGOT4.7-1.0 better than GOT4.7 compared to FES2014

RL06 Plans: Ocean Tide Model

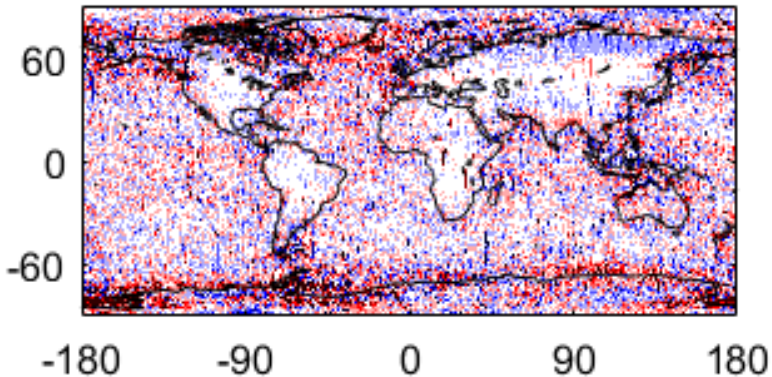
Pre-fit KRX residuals:

rel. improvement [%] GGOT4.7-1.0 wrt FES2014

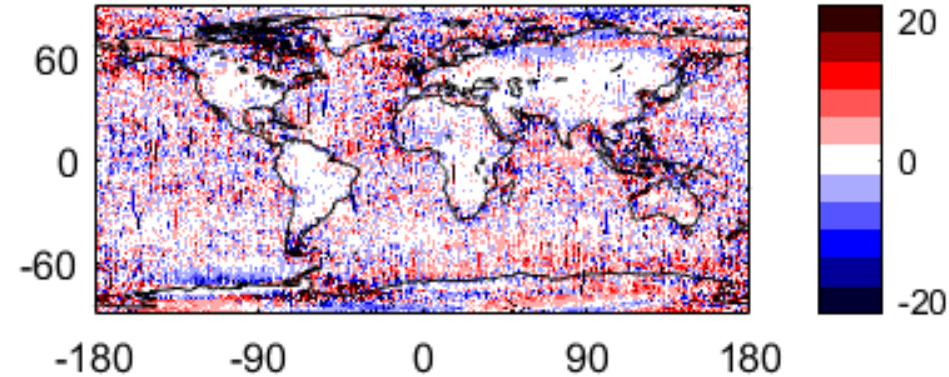
better

worse

2008/01+04+07+10



2014/01+04+06+10



- GGOT4.7-1.0 better than GOT4.7 compared to FES2014
- GGOT4.7-1.0 competitive with FES2014

RL06 Plans: Ocean Tide Model

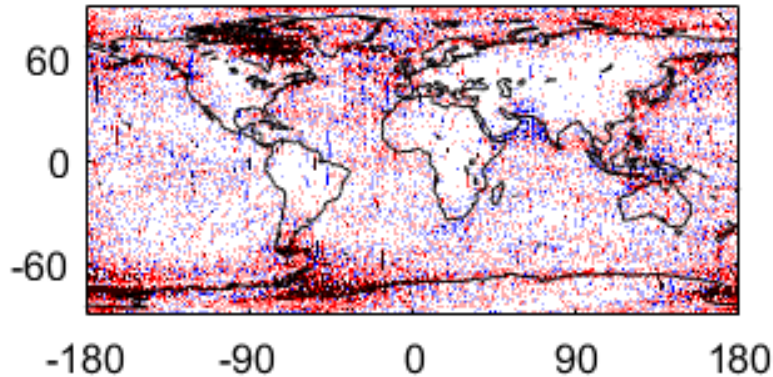
Pre-fit KRX residuals:

rel. improvement [%] GGOT4.7-1.0 wrt GOT4.7

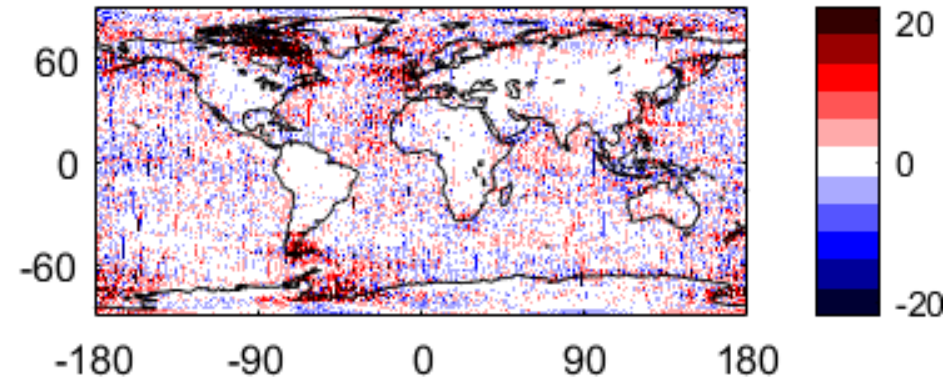
better

worse

2008/01+04+07+10



2014/01+04+06+10



- Residual tidal signals from GRACE improve GOT4.7 significantly

RL06 Plans: Ocean Tide Model

EWB RMS [cm] over ocean:

Unfiltered	08/01	08/04	08/07	08/10	14/01	14/04	14/06	14/10	Mean
EOT11a (80x80)	165	197	208	191	485	181	167	176	183 ± 16
FES2014 (80x80)	168	195	207	188	497	187	163	178	184 ± 15
FES2014 (180x180)	168	195	207	188	497	187	163	179	184 ± 15
GOT4.7 (80x80)	169	200	207	199	452	186	172	179	188 ± 15
GGOT4.7-1.0 (80x80)	168	196	205	197	469	185	169	174	185 ± 16

300 km Gauss	08/01	08/04	08/07	08/10	14/01	14/04	14/06	14/10	Mean
EOT11a (80x80)	42	45	43	44	81	60	62	74	53 ± 12
FES2014 (80x80)	42	44	44	43	81	62	62	74	53 ± 13
FES2014 (180x180)	42	44	44	43	81	62	62	74	53 ± 13
GOT4.7 (80x80)	43	49	46	47	81	61	64	77	55 ± 12
GGOT4.7-1.0 (80x80)	42	48	45	48	80	63	65	69	54 ± 11

Main conclusion: tendency to use **FES2014** (with max. d/o less than 180x180)

RL06 Plans: Atmospheric Tide Model

Models that have been tested:

- Biancale-Bode
 - Used for GFZ RL05
 - Model only contains S1 & S2 tide up to degree/order 8x5
- Atmospheric tides provided with AOD1B RL06
 - Contains 4 main waves (S1, M2, S2, S3) with two additional sidebands for each
 - All tides are up to degree/order 180x180

Test criteria:

- RMS of binned pre-fit K-band range accel. (KRX) residuals
- Comparison of gravity field results

RL06 Plans: Atmospheric Tide Model

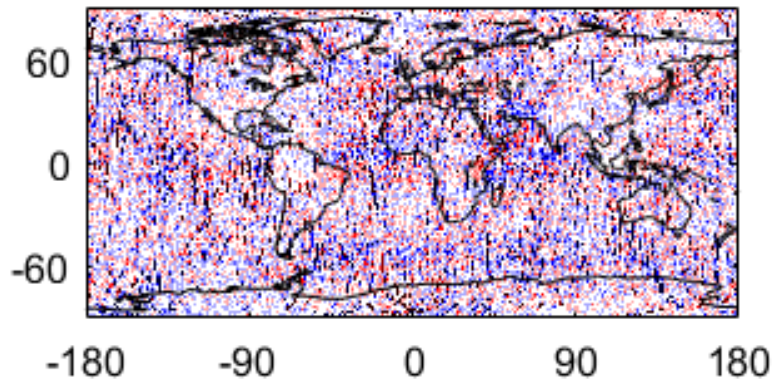
Pre-fit KRX residuals:

rel. improvement [%] AOD S1/S2 only (8x5) wrt Biancale-Bode

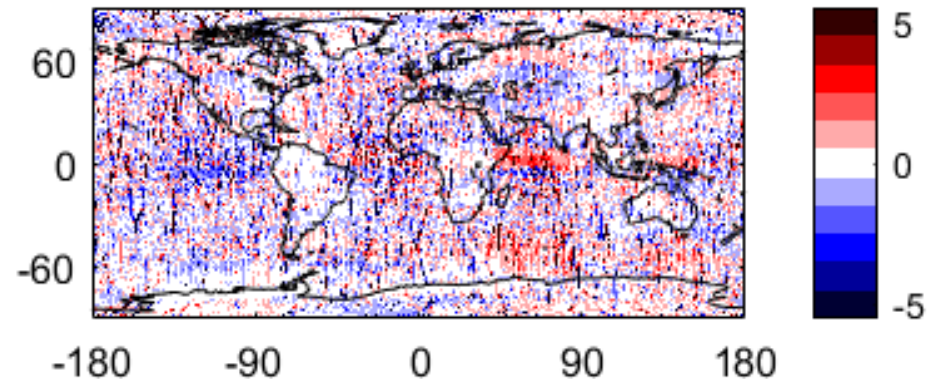
better

worse

2008/01+04+07+10



2014/01+04+06+10



- Differences between $\pm 5\%$ if exactly the same SH coefficients of AOD1B RL06 as given in Biancale-Bode are used

RL06 Plans: Atmospheric Tide Model

Pre-fit KRX residuals:

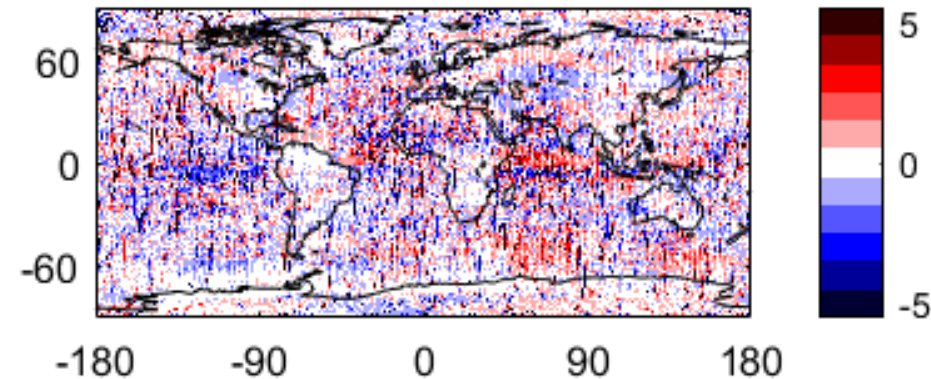
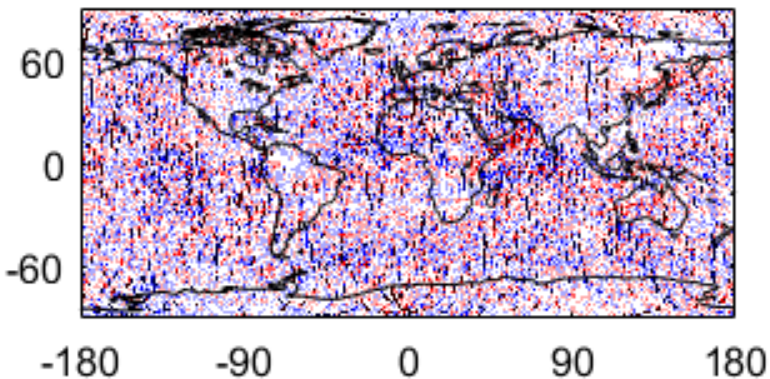
rel. improvement [%] AOD S1/S2 only (180x180) wrt Biancale-Bode

better

worse

2008/01+04+07+10

2014/01+04+06+10



- Differences between $\pm 5\%$ if the same tides (S1 & S2) of AOD1B RL06 as given in Biancale-Bode up to d/o 180x180 are used

RL06 Plans: Atmospheric Tide Model

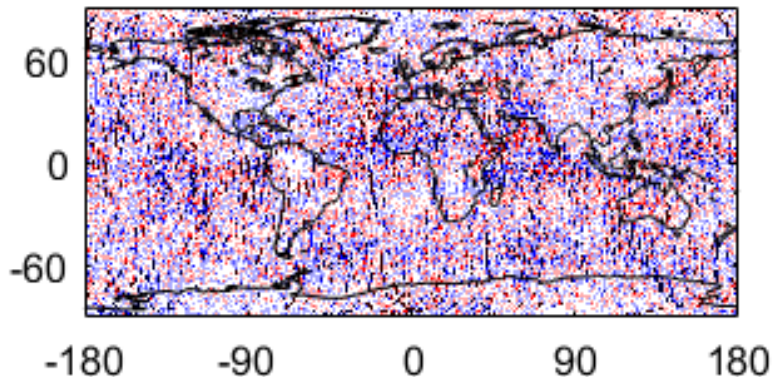
Pre-fit KRX residuals:

rel. improvement [%] AOD (180x180) wrt Biancale-Bode

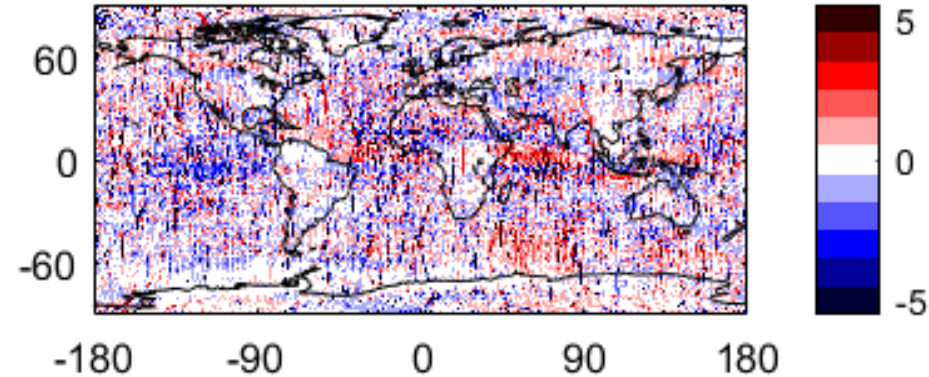
better

worse

2008/01+04+07+10



2014/01+04+06+10



- Differences between $\pm 5\%$ if all available tides from AOD1B RL06 up to d/o 180x180 are used

RL06 Plans: Atmospheric Tide Model

Pre-fit KRX residuals:

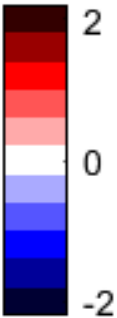
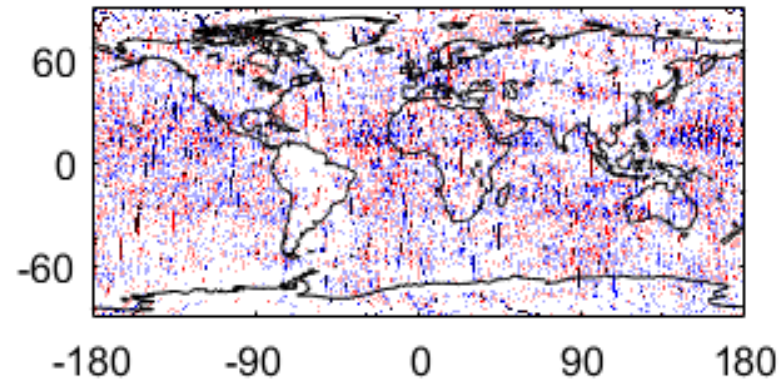
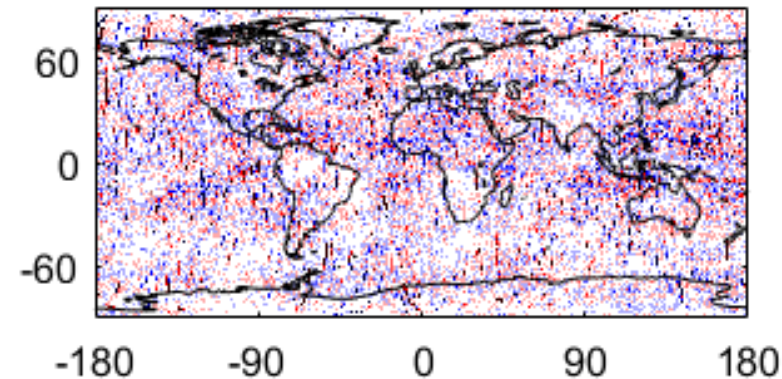
rel. improvement [%] AOD S1/S2 only (180x180) wrt AOD (180x180)

better

worse

2008/01+04+07+10

2014/01+04+06+10



- Very small differences (around 2 %) between using only S1 & S2 and using all available 12 tides of AOD1B RL06

RL06 Plans: Atmospheric Tide Model

EWB RMS [cm] over ocean:

Unfiltered	08/01	08/04	08/07	08/10	14/01	14/04	14/06	14/10	Mean
Biancale-Bode	168	195	207	188	497	187	163	178	180 ± 12
AOD RL06, S1/S2 only (8x5)	176	201	269	201	601	192	152	182	184 ± 19
AOD RL06, S1/S2 only (180x180)	176	201	270	201	602	192	152	182	184 ± 19
AOD RL06 (180x180)	178	201	266	202	576	192	152	182	185 ± 19

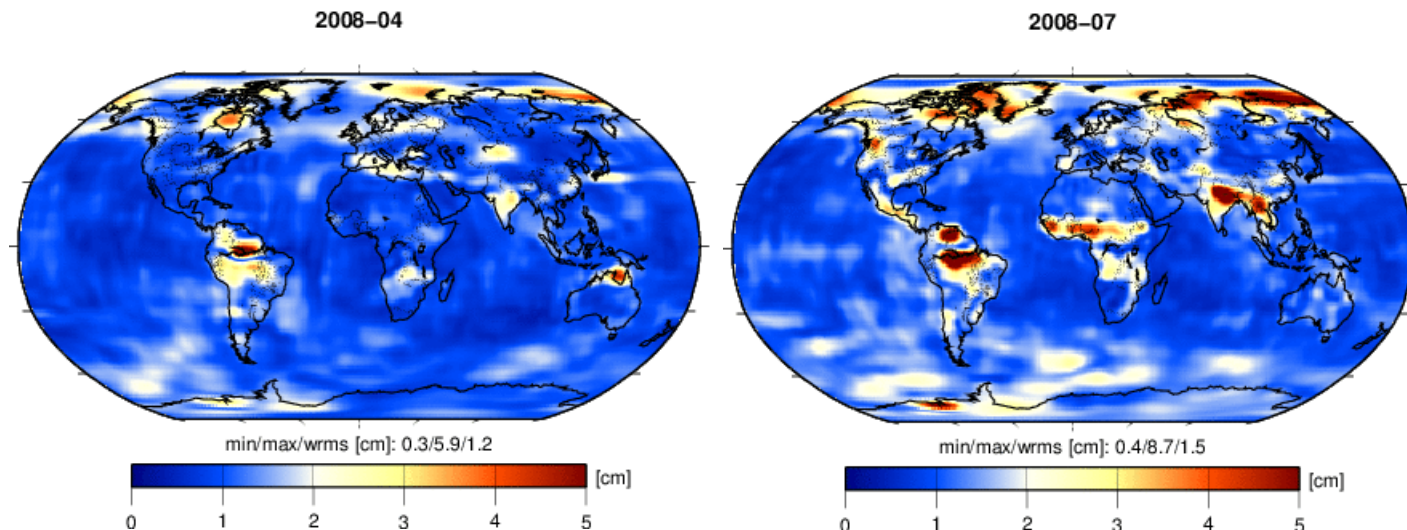
300 km Gauss	08/01	08/04	08/07	08/10	14/01	14/04	14/06	14/10	Mean
Biancale-Bode	42	45	43	44	81	60	62	74	55 ± 13
AOD RL06, S1/S2 only (8x5)	45	45	62	47	84	65	61	75	56 ± 13
AOD RL06, S1/S2 only (180x180)	45	45	62	47	84	65	61	75	56 ± 13
AOD RL06 (180x180)	45	45	61	47	83	64	61	76	56 ± 13

Main conclusion: no significant differences between both models, slight tendency to keep **Biancale-Bode**

RL06 Plans: Daily Solutions as De-aliasing

- Kalman filtered RBF solutions from GFZ (also used for EGSIM NRT service) are used
 - see talk on Thursday by Flechtner et al.: *EGSIEM's Near Realtime Mass Transport Products For Monitoring of Hydrological Extreme Events*
- Monthly means of daily solutions are subtracted in order to only use sub-monthly variations as background model
- Sub-monthly variations consist of short-term hydrological signals and errors still present in AOD

sub-monthly variability of daily solutions usually reaches up to max. 10 cm EWH (global wRMS ~1.5 cm)

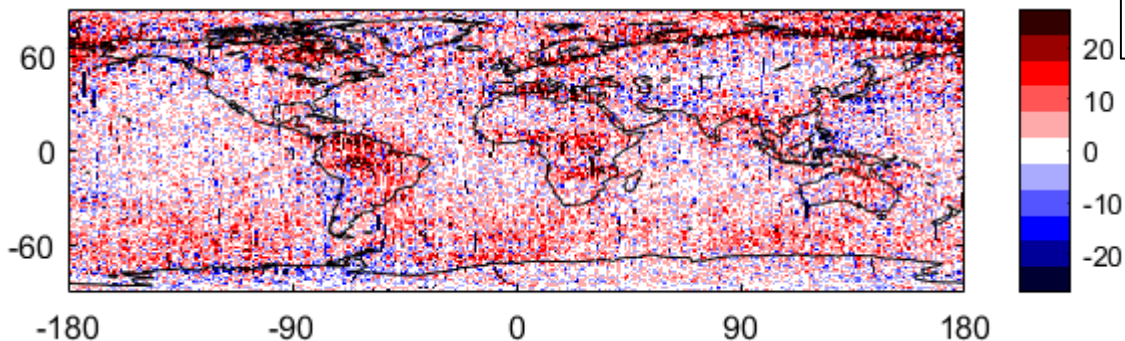


RL06 Plans: Daily Solutions as De-aliasing

Pre-fit KRX residuals:

rel. improvement [%] additional de-aliasing applied wrt not applied

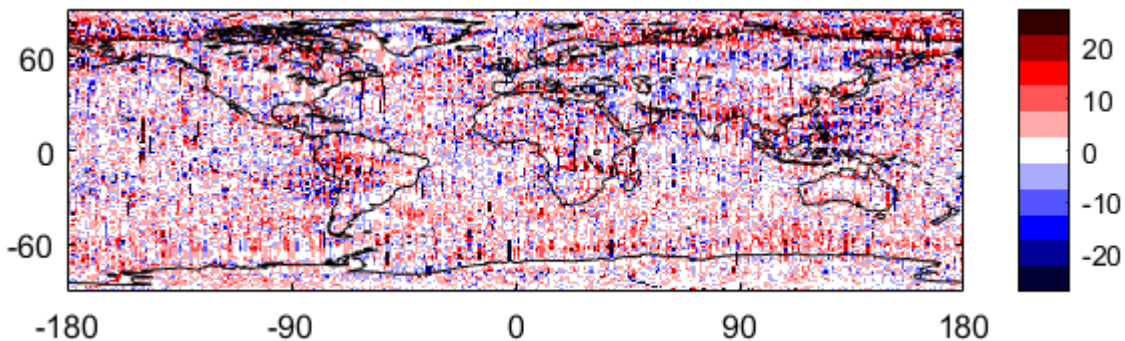
2008/01+04+07+10



better

worse

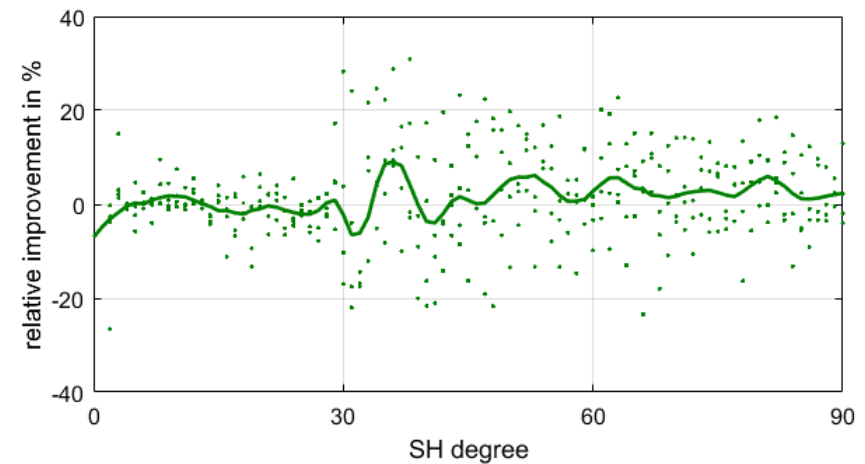
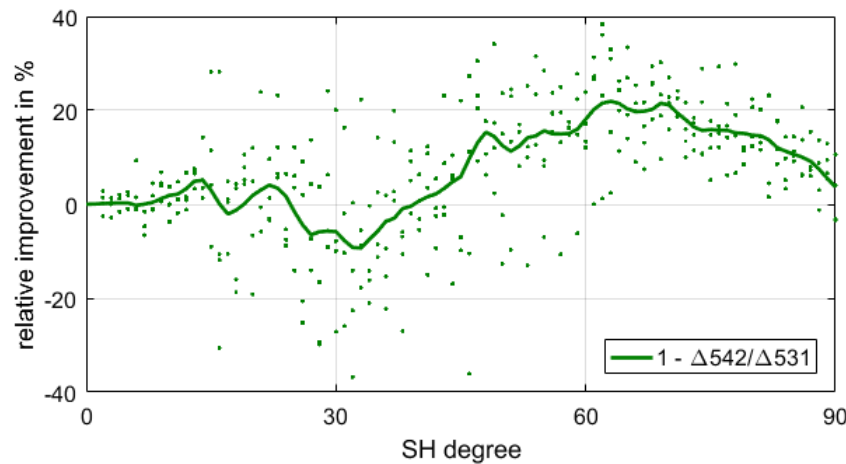
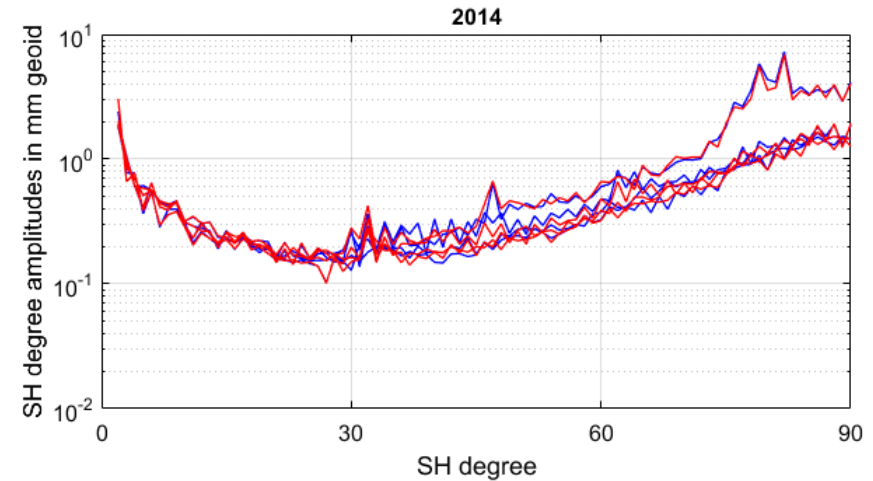
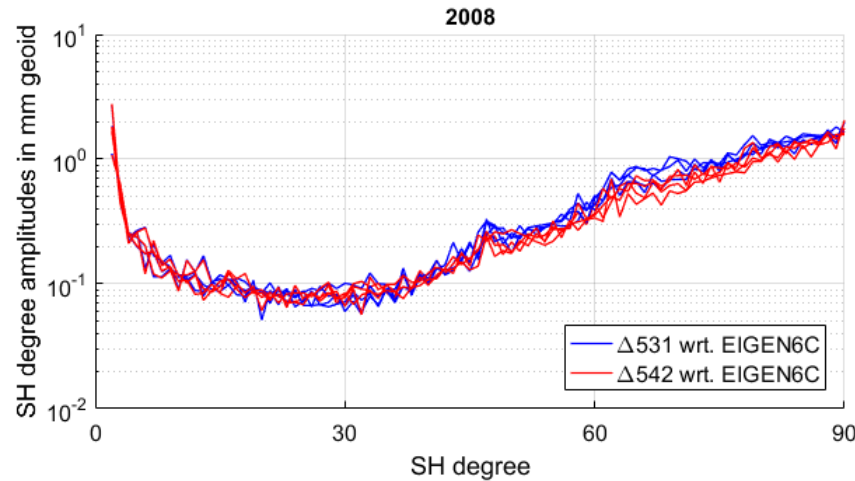
2014/01+04+06+10



- Smaller residuals with daily RBF as de-aliasing in areas with high sub-monthly variations (20-30 % improvement)
- Results for 2014 not as clear as for 2008: test needs to be repeated for other test months

RL06 Plans: Daily Solutions as De-aliasing

Degree amplitudes and their relative improvement:



RL06 Plans: Daily Solutions as De-aliasing

- Additional de-aliasing by using daily RBF solutions is able to significantly reduce (10 - 30 %) difference degree amplitudes at medium to high SH degrees
- RBF solutions need to be reprocessed using AOD1B RL06 to be consistent with Level-2 processing

Summary

- GFZ has processed RL05a solutions for all months with available science data
- **Users shall be aware that quality of solutions since Nov 2016 is significantly degraded**
 - No GRACE-B ACC data available, ACC transplant is used instead (exception: May 2017 solution)
 - Additional degradation visible since pitch bias change (30 Mar 2017)
 - Optimal processing of these solutions will be more thoroughly assessed within RL06 reprocessing (and thus they will likely be the last solutions to be distributed to the users)
- Several tests for RL06 have been completed, others are still to come
 - Besides overall improvement of gravity field solution quality, the focus needs also to be on achieving better consistency within the monthly time series
 - First RL06 results to be presented at AGU 2017
 - RL06 standards will be used for initial GRACE-FO release as well