WP5: Daily gravity field solutions in near real time

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EGSIEM General Assembly, AIUB
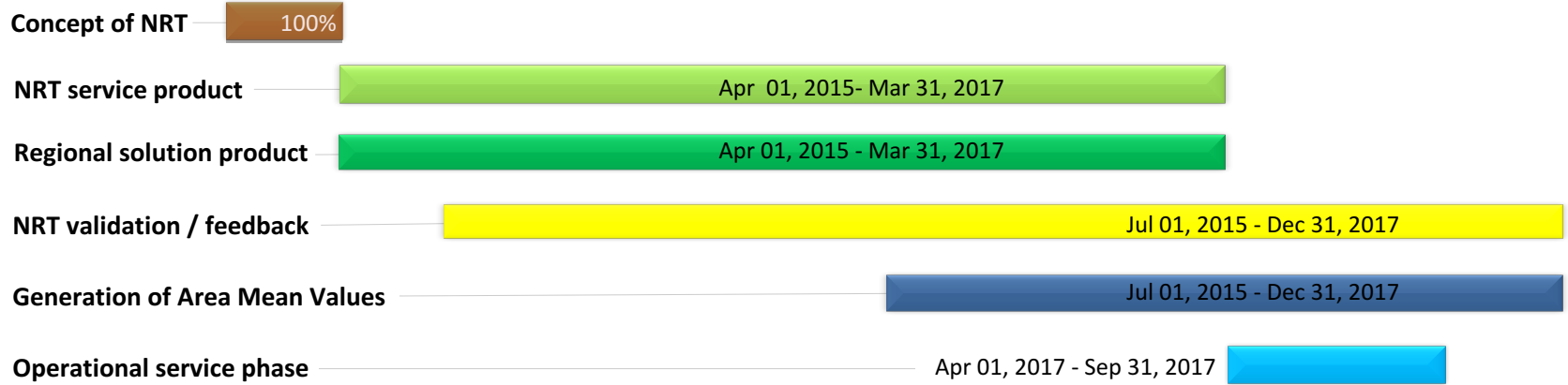
Jan 19-20, 2017

European Gravity Service for Improved Emergency Management

Outline

- Project status / milestones
- Radial Basis Functions & Kalman Filtering for daily updates
- Coherence with WGHM

- Near Real time processing
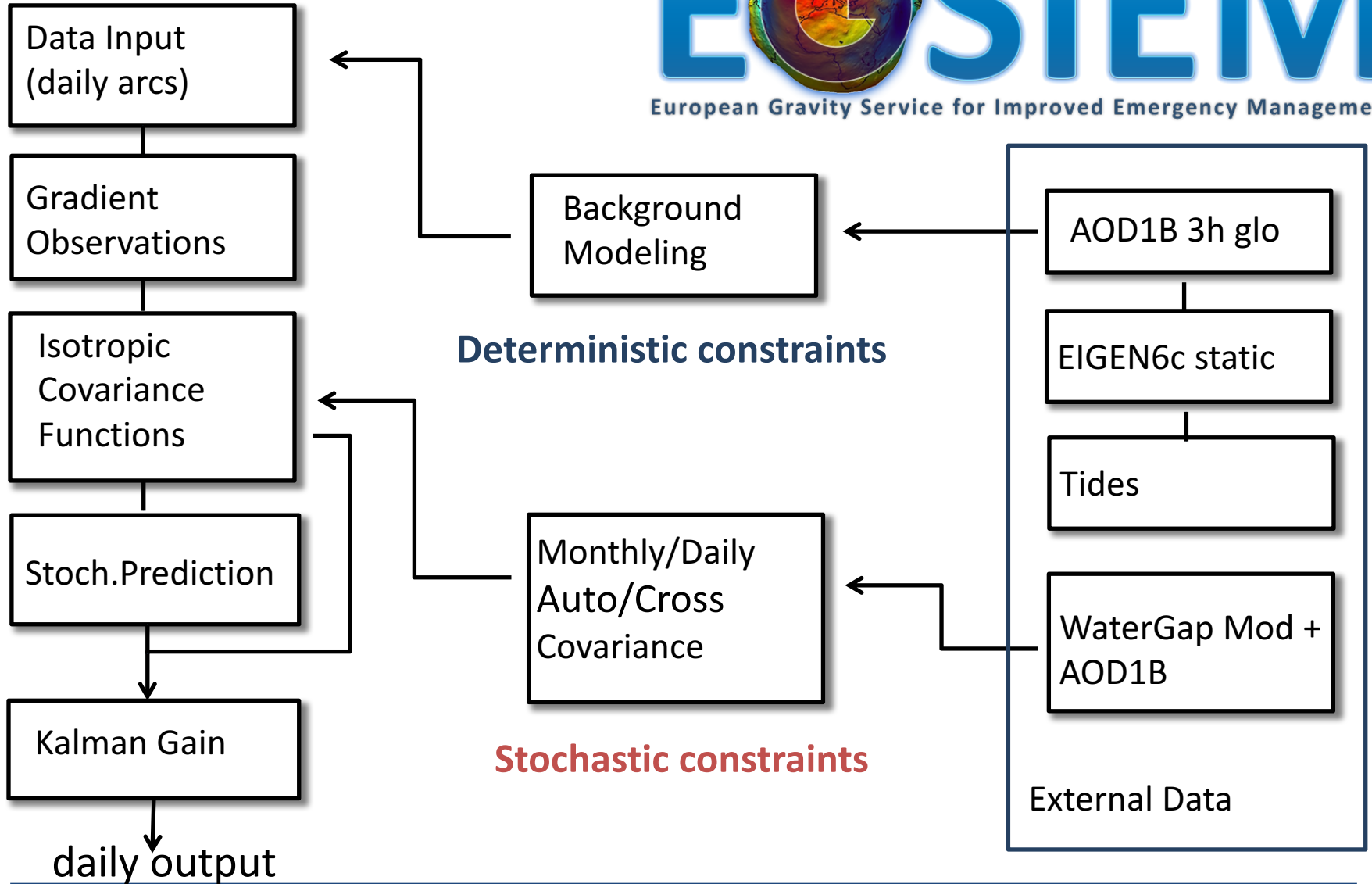- Orbit comparison from NRT PRNs, clocks, EOPs
- Impact on gravity field solution

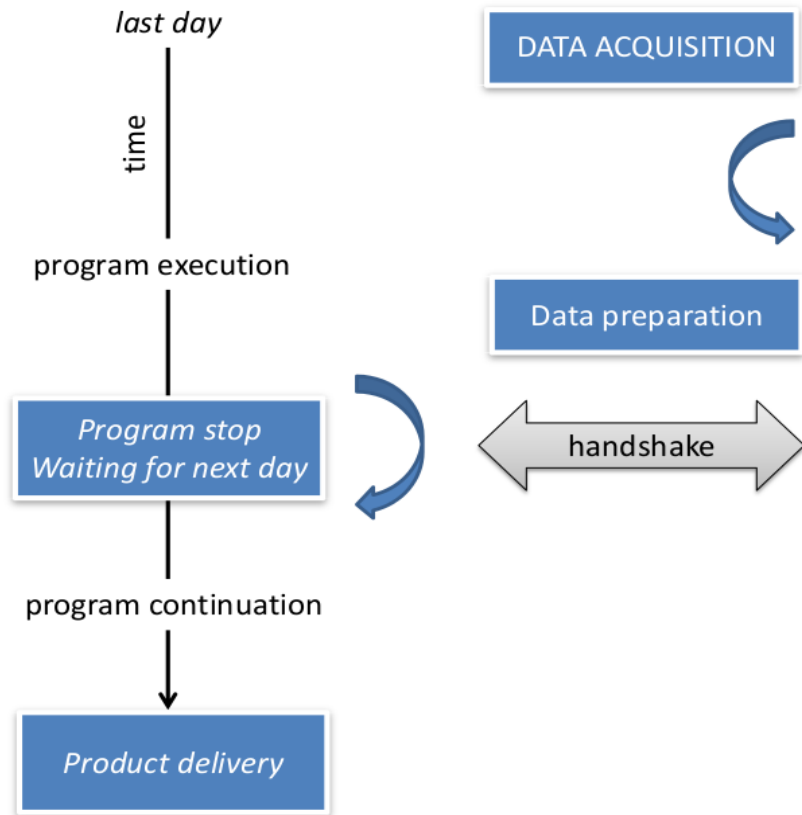HORIZON 2020

Project Plan

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2015

| M03 | M06 | M09 | M12 | M15 | M18 | M21 | M24 | M27 | M30 | M33 | M36 | 2017 |

Milestone 1 — Mar 31

Milestones 2-4 — Mar 31

Milestone 5 — Sep 31

Milestone 6/7 — Dec 31

Today

Concept of NRT — 100%

NRT service product — Apr 01, 2015 - Mar 31, 2017

Regional solution product — Apr 01, 2015 - Mar 31, 2017

NRT validation / feedback — Jul 01, 2015 - Dec 31, 2017

Generation of Area Mean Values — Jul 01, 2015 - Dec 31, 2017

Operational service phase — Apr 01, 2017 - Sep 31, 2017

Data and latencies

Product	Source	Current Latency	Required Latency
EOP	IERS/UBERN	IERS: 1-3 days, UBERN: 14 days	IERS: 1-3days, UBERN: **17 hours**
GPS Orbits/Clocks	UBERN (T3.4)	14 days	**17 hours**
GRACE L1B Data	JPL, Backup: GFZ	11 days	**18 hours**
Dealiasing Product (AOD1B)	GFZ	7 days	**2-4 days**
Monthly gravity field (global)	GFZ/ TU Graz	~ 2 month	**3-5 days (Daily products)**
Specific hydrological basin or region (upon request)	WP3/6	not available	additional **1 day**

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Data Input (daily arcs)

Gradient Observations

Isotropic Covariance Functions

Stoch.Prediction

Kalman Gain

daily output

Background Modeling

Deterministic constraints

Monthly/Daily Auto/Cross Covariance

Stochastic constraints

AOD1B 3h glo

EIGEN6c static

Tides

WaterGap Mod + AOD1B

External Data

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Service mode

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last day

time

program execution

DATA ACQUISITION

Data preparation

Program stop
Waiting for next day

handshake

program continuation

Product delivery

daily [perl script]
+ NRT L1B (ftp)
+ orbit auxiliaries (ftp)
   PRNs, clocks, EOPs
+ NRT AOD (ftp)

EPOS-OC
+ predicted orbits
+ rapid orbit generation
[shell script]
+ deploy ORB
+ deploy KBR
+ log-entry

monthly
+ update GAC
+ update SDS fields (GFZ)
+ update Deg 2 (ftp)

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Production-flow

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Last day 24:00

1. GFZ GPS constellations   +13:00
    UB: CODE constellations, EOPs   +17:00

2. L1B data (KBR, etc.) available   +18:00

first day 24:00

3. GFZ: preliminary dynamic orbit   **1d**+12:00

4. Stochastic prediction   **1d**+18:00

second-fourth day 00:00

5. 3-hourly AOD1B   **4d**+8:00

6. GFZ: final dynamic orbit (iterated)   **4d**+12:00
    TUG: kinematic orbit

7. final Kalman update step   **4d**+12:00

8. plausibility test/ evaluation   **4d**+16:00

9. grid release /SH –coefficients   **4d**+18:00

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GFZ daily solutions

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- Scalar gradient differences from GPS velocities and K-Band accelerations
- Outlier detection (strongly reduced)
- Accelerometer drifts: currently removed by high-pass filtering
- de-correlation length: 2.5 x orbital revolution
- Background modeling (average time-variable model)
  - break points for the linear fits are 2005/01, 2008/06, 2011/03 (Earth quake events)
- Process model derivation is based on
  - hydrology (WGHM), GAC and 15 years of GRACE
  - specific masks for individual contributions, e.g. north/southern hemisphere, land-ocean decoupling, distant dependent damping
  - monthly updated isotropic covariance functions
  + additional rms errors on diagonal ca. 1.5cm
- Process covariance is derived in spatial domain

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Linear Equation Systems

- integration grid (2x2 deg equal areal): 10540 surface tiles
- conversion between surface grid respresentations
- radial basis functions assembly in observation points
- covariance - estimation
  – observation de-correlations
  – external auto/cross covariances for stochastic prediction
- Stochastic prediction
- Daily Kalman filtering
- monthly inversion (under revision for lesser constraining)

Daily Kalman Filter

bias + trend + seasonal fit
average model

Kalman filtered result
time dependent daily results

geoid (mean sea level)
from the "static" gravity field

t i m e

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Background models

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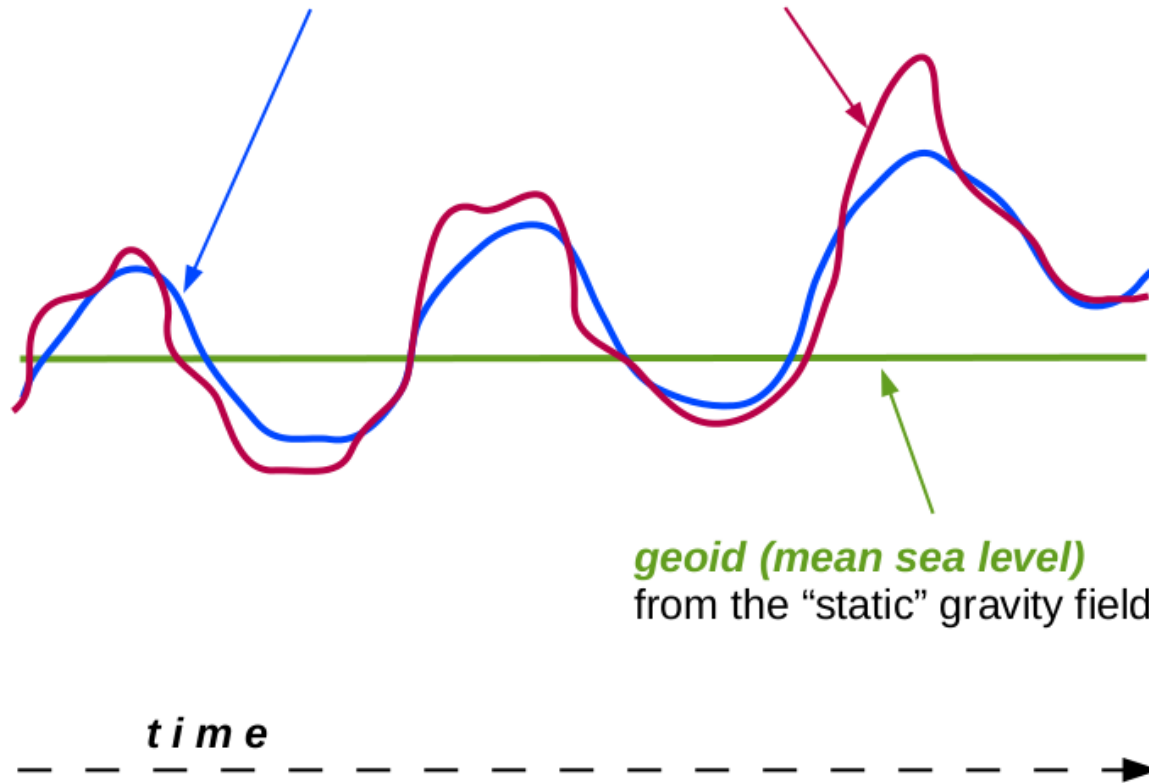
- Ocean tides (EOT11a),
- Atm tides S1,S2 (Bode/Biancale)
- Solid Earth & Pole Tides (Desai)
- 3rd body ephemerides (JPL de421)
- EOP's, GPS clock's / PRN's (EGSIEM, Susnik et al.)
- AOD1B (RL5 $\rightarrow$ RL6)
- **Bias/ trend and annual signal fit with respect to EIGEN-6C**
- **Stochastic modeling**, built of: GAC (2002-2016), WGHM (2002-2013) and GRACE RL05a (2002-2016)

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Process covariances
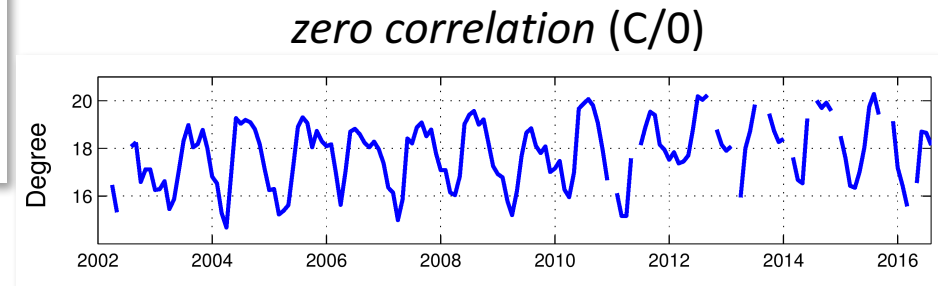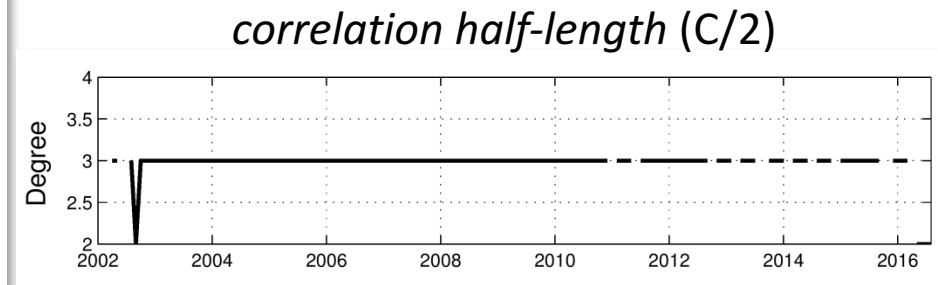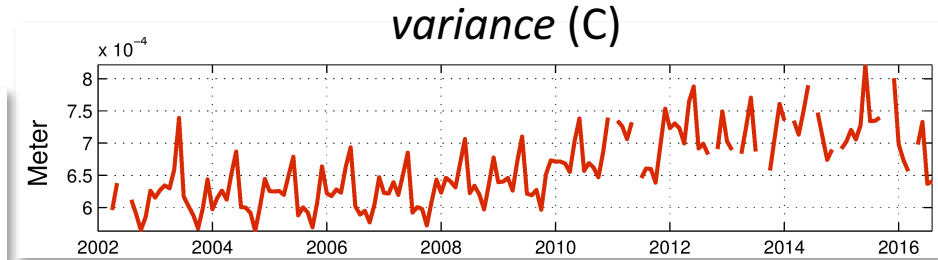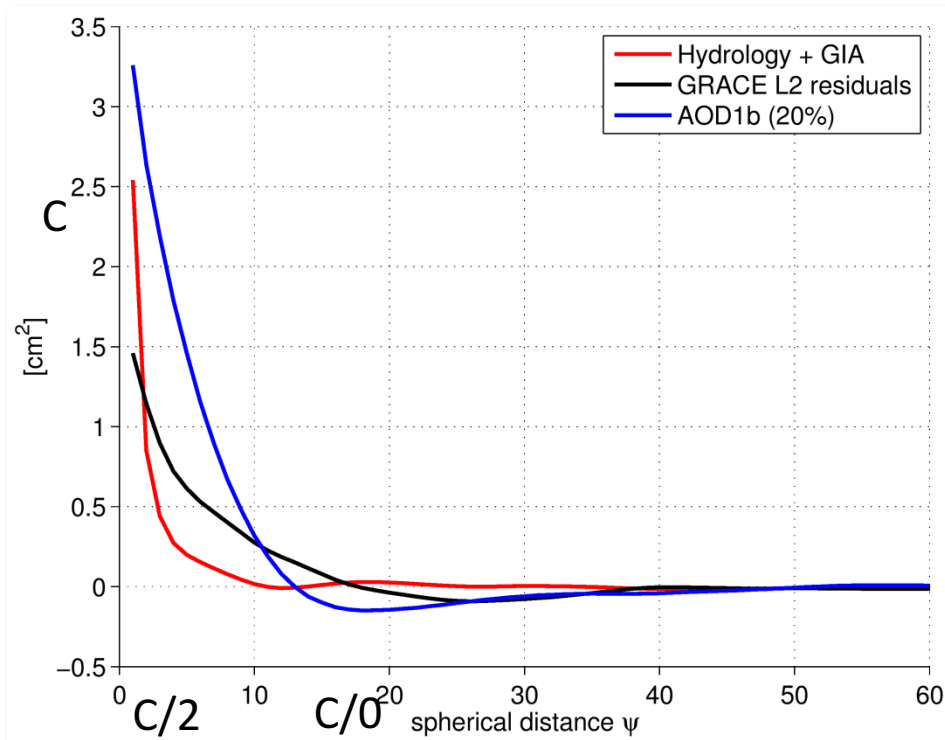
Output products

- Global daily solution on 2x2 deg grid (water equivalent)
- Global 2x2 deg operational average model
- 1x1 deg grid regional product for defined areas of interest (not yet available)
- error estimates for the grid values

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RMS (2002)

RBF

RL05a

0   5   10   15 [cm]

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Trend (2002)

RBF

Std=0.21

Std=0

RL05a

Std=0.3

Std=0

-10   -5   0   5   10 [cm]
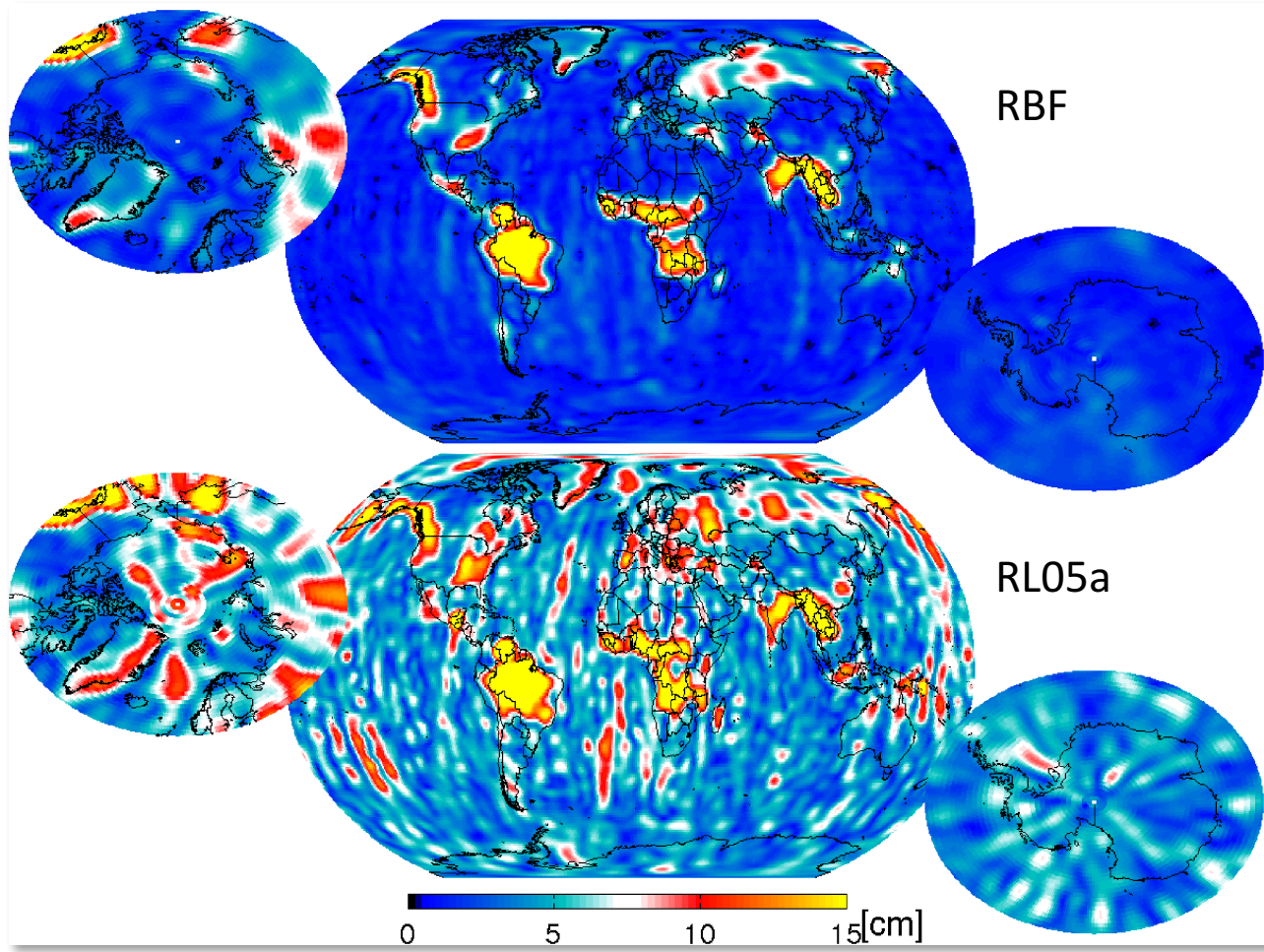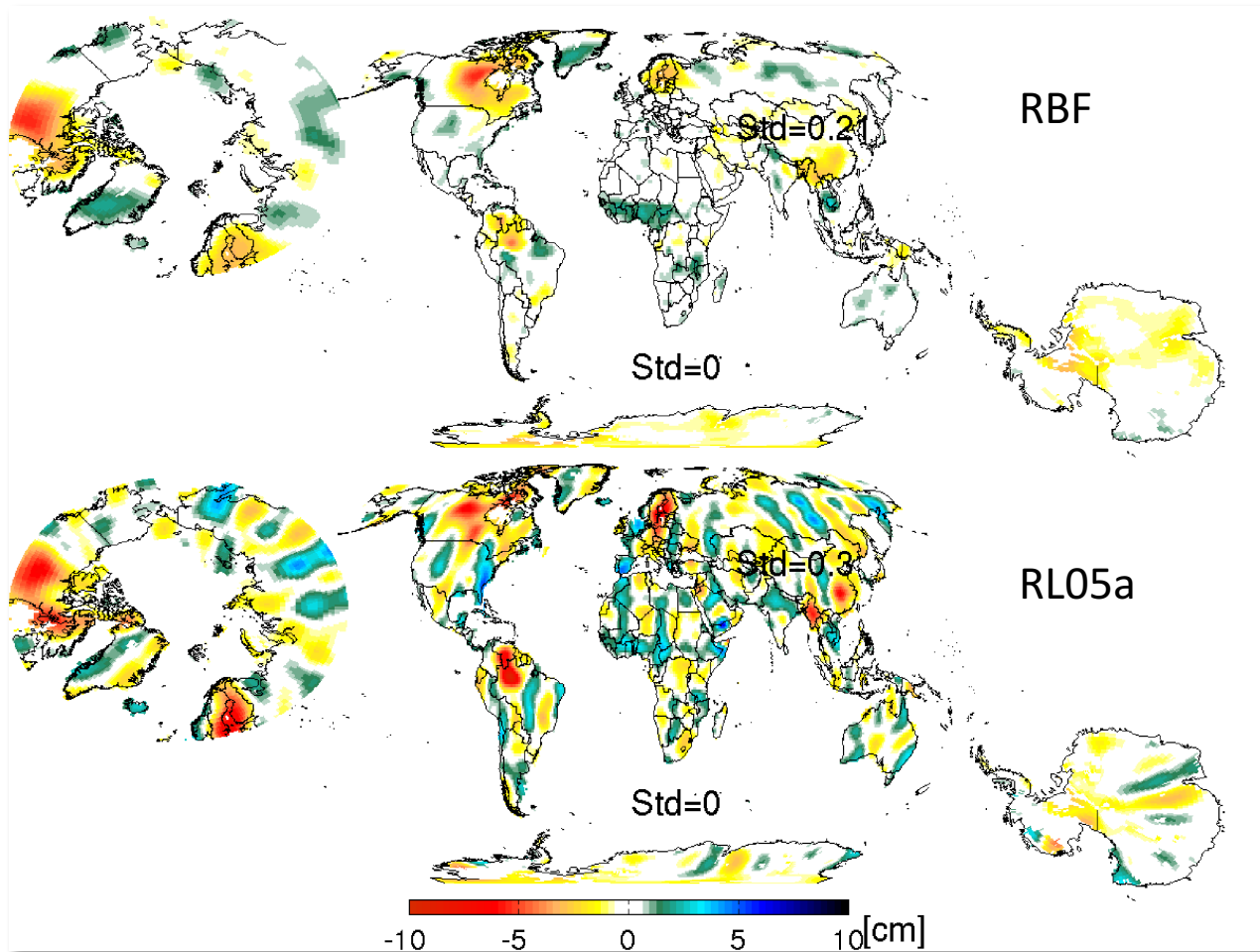
Annual-/Semi year (2002)

Annual- and Semiannual Signal (RBF)
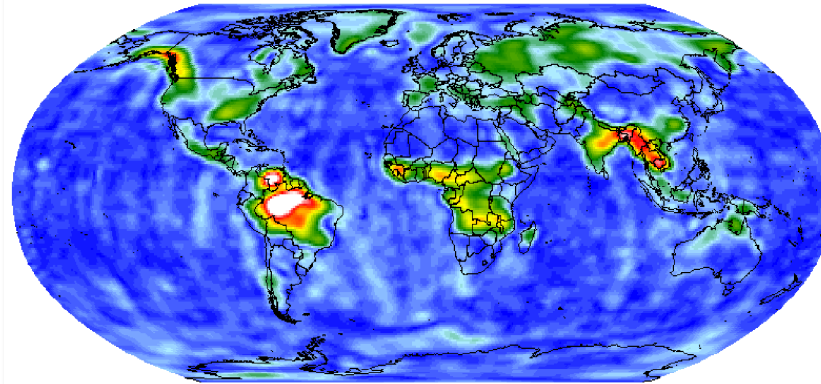
Annual- and Semiannual Signal (RL05a)
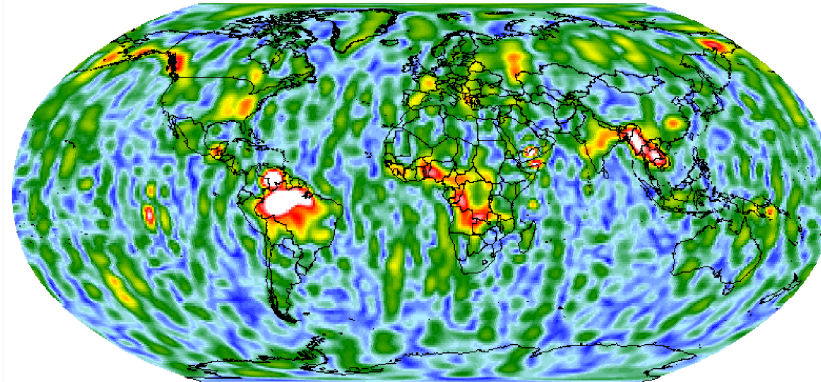
WGHM Coherence

De-seasoned (annual/semi annual) time Series

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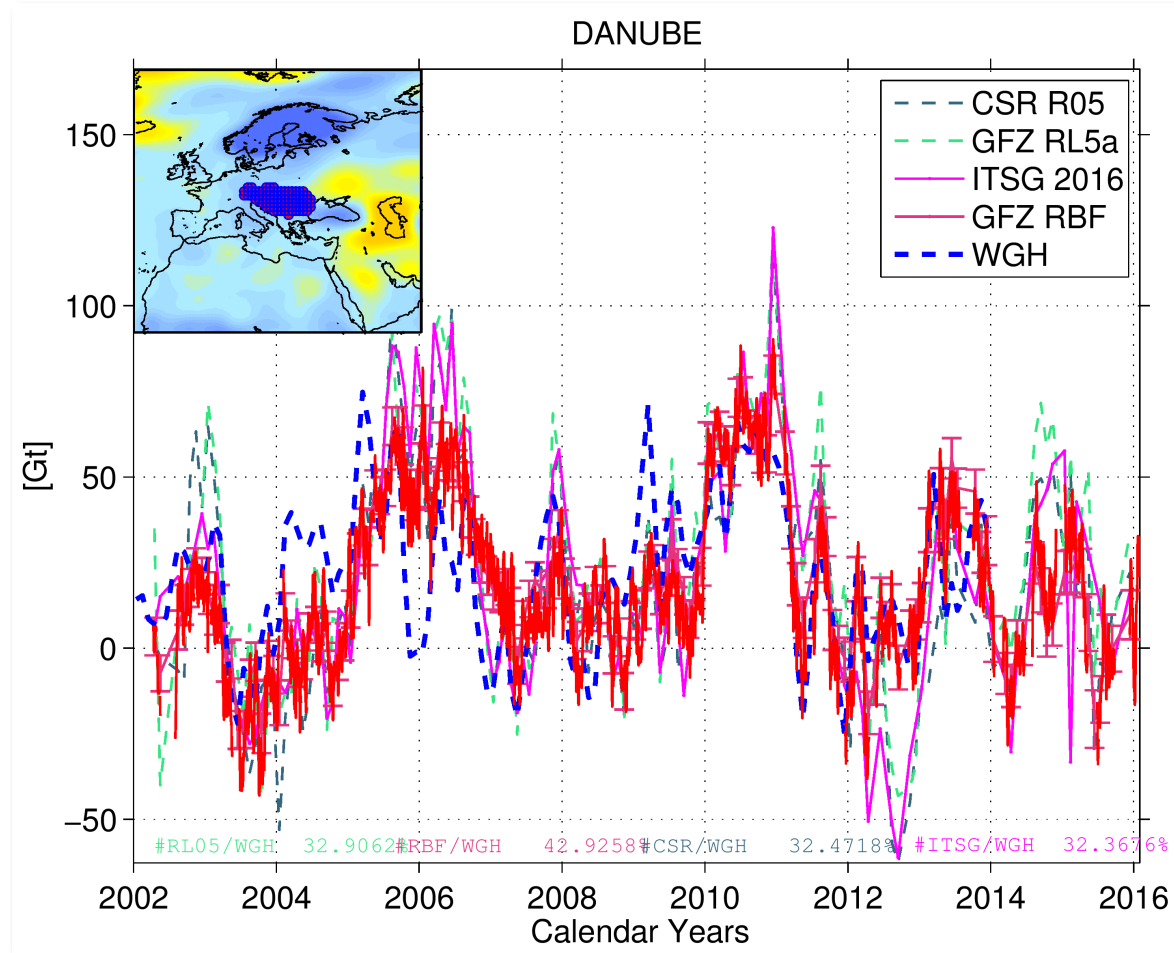
Near Real Time ORBIT

- NRT clocks & GPS constellation from AIUB
- EOPs (AUIB)
- Iterative orbit fit to GPS /observations & K-Band
- substantial differences to original in the respective components (RTN-system)
  3D- orbit : several [cm]
- However, the GPS base-line is in a fair agreement
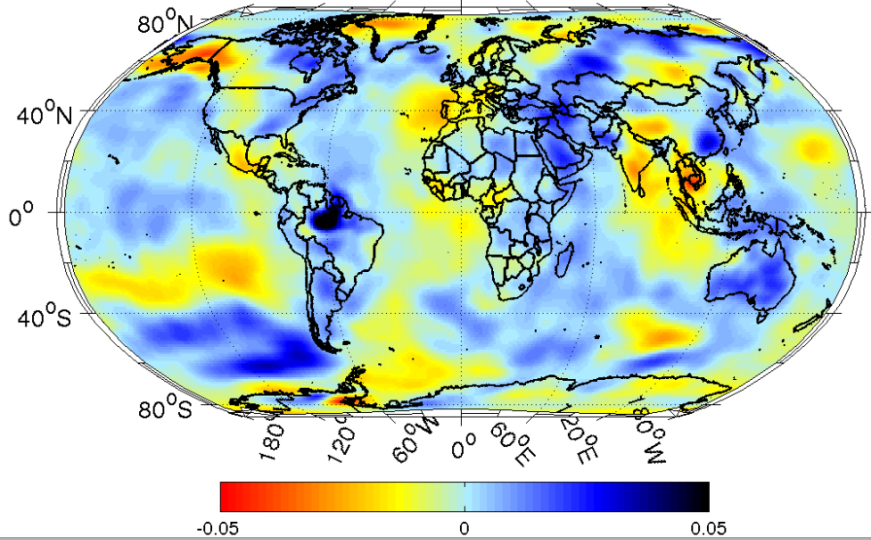

GRACE A

GRACE B

HORIZON 2020
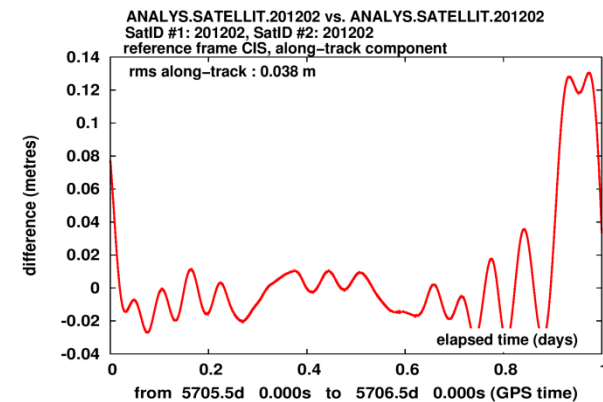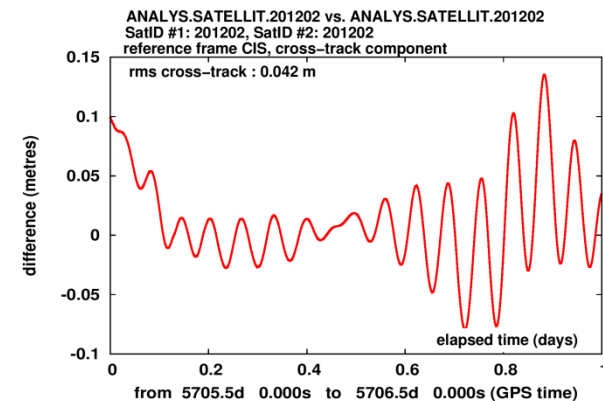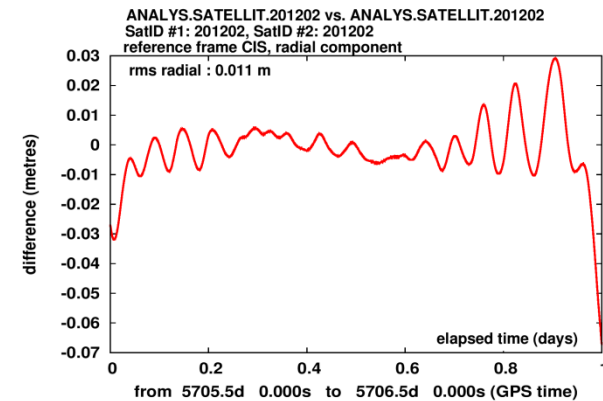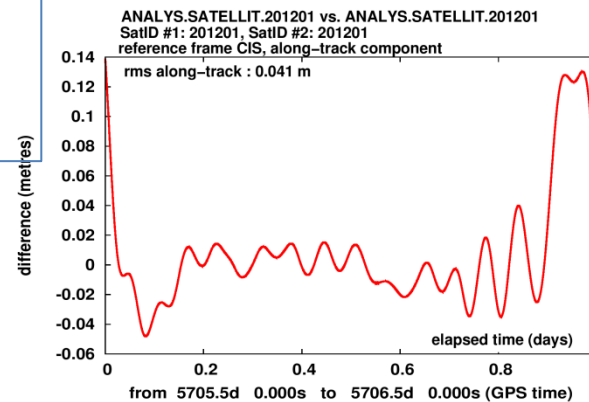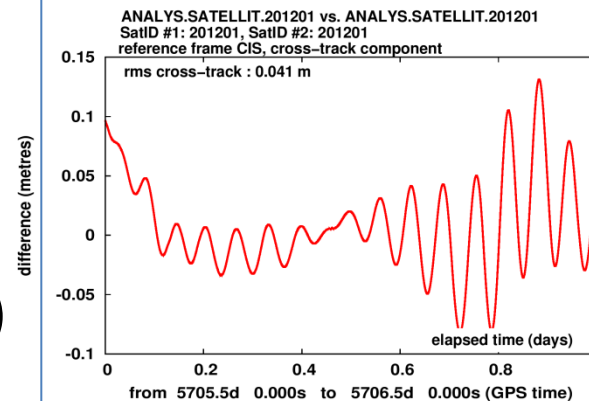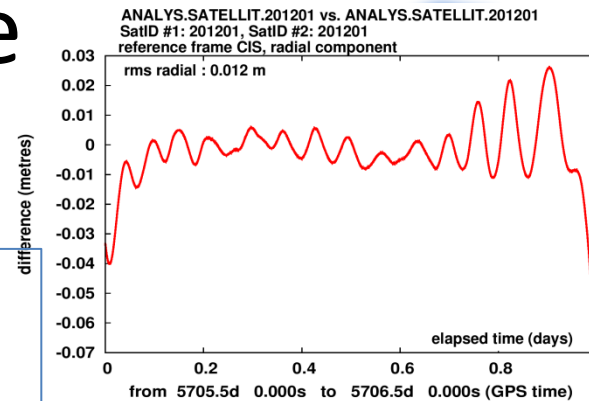
Near Real Time ORBIT

- NRT clocks & GPS constellation from AIUB
- Predicted EOPs (BGI)
- Iterative orbit fit to GPS /observations & K-Band
- substantial differences to original in the respective components (RTN-system)
  3D- orbit : several [cm]
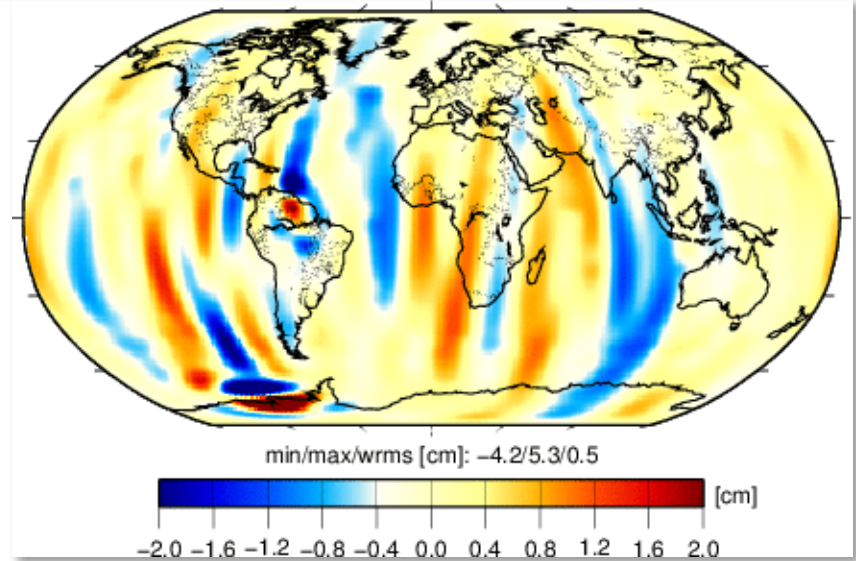- Again, the GPS base-line is in a fair agreement

GRACE A
GRACE B

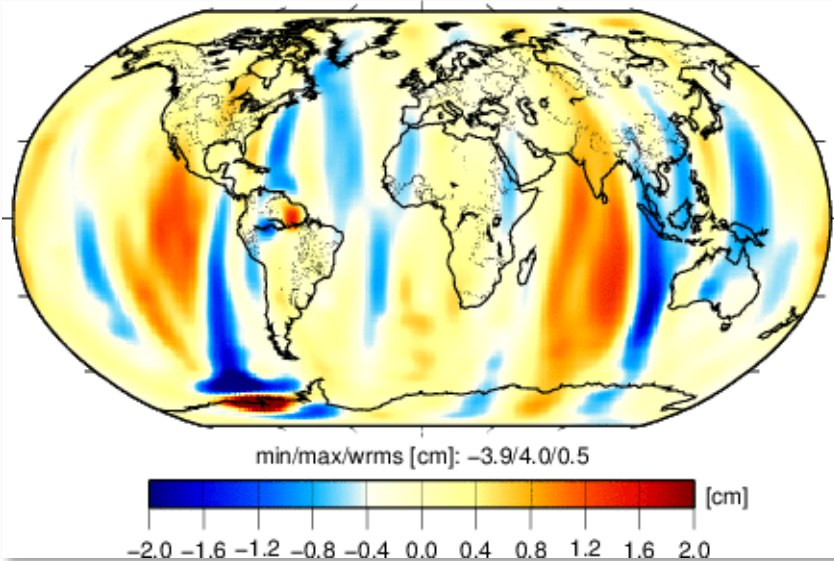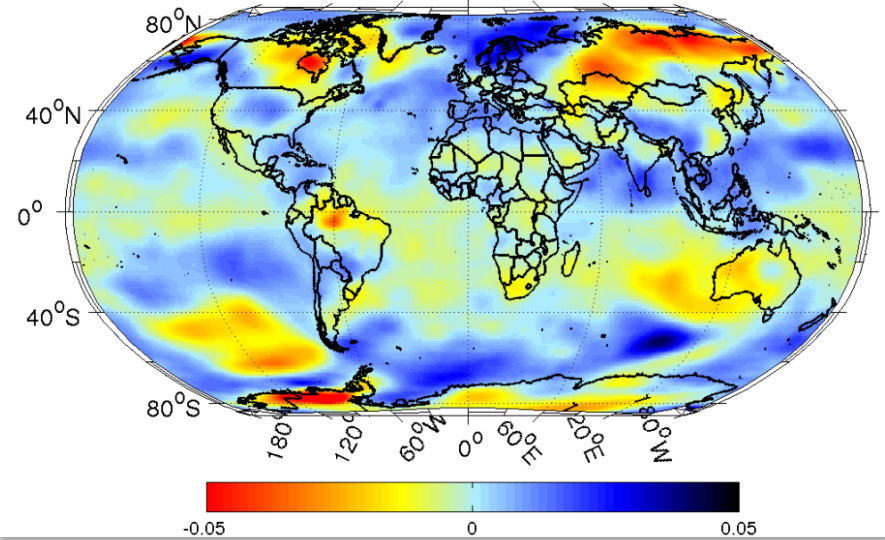HORIZON 2020
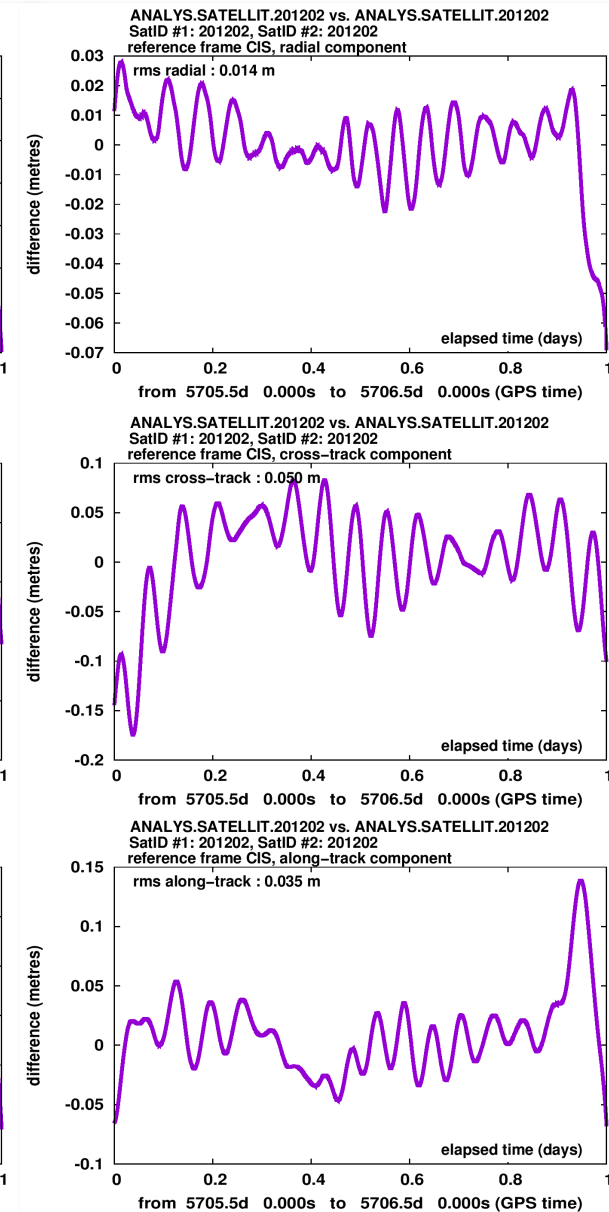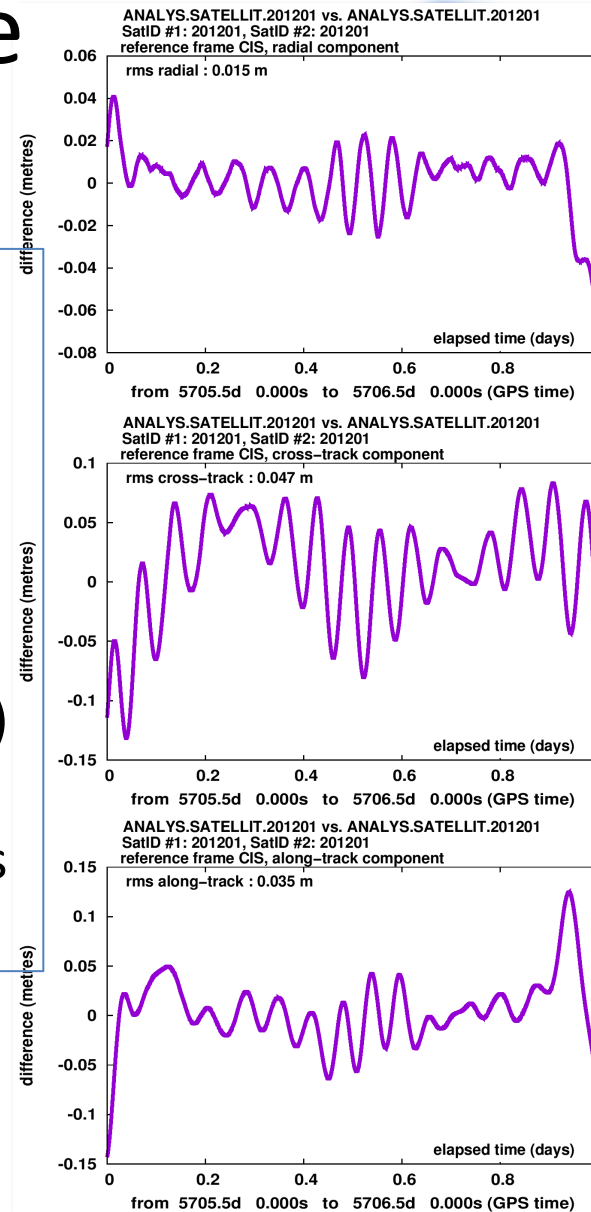
Differences caused by NRT- orbits

Aug 2015 NRT differences (Orig-NRT)

Sep 2015 NRT differences (Orig-NRT)

min/max/wrms [cm]: −3.9/4.0/0.5

min/max/wrms [cm]: −4.2/5.3/0.5

[cm]

−2.0 −1.6 −1.2 −0.8 −0.4 0.0 0.4 0.8 1.2 1.6 2.0

Outlook

until operational readiness (M27):

- Minimize differences between NRT input data vs. standard data processing, work is ongoing
- Investigate the impact of the iterated dynamic orbit using the actual (Kalman) day against using the average background model
- comparisons of (Kalman) regularized solutions w.r.t standard monthly (SDS) fields
- Minor fixes (grid conversions, process model derivation) → /v201
- Compute the regional refinements (1 x 1 deg) in selected basins

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Grace RBF results are accessible:

Index of ftp://egsiem@gfzop.gfz-potsdam.de/v200/

⌂ Up to higher level directory

Name	Size	Last Modified	
📁 2002		12/15/2016	09:50:00 AM
📁 2003		12/15/2016	03:37:00 PM
📁 2004		12/17/2016	12:31:00 PM
📁 2005		12/18/2016	10:09:00 AM
📁 2006		12/19/2016	07:29:00 PM
📁 2007		12/21/2016	08:25:00 AM
📁 2008		12/22/2016	05:36:00 PM
📁 2009		12/25/2016	11:38:00 AM
📁 2010		12/25/2016	04:03:00 PM
📁 2011		12/26/2016	04:31:00 PM
📁 2012		12/28/2016	10:03:00 AM
📁 2013		12/29/2016	09:59:00 AM
📁 2014		12/30/2016	09:22:00 AM
📁 2015		12/31/2016	09:51:00 AM
📁 2016		12/31/2016	10:00:00 AM

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Thanks for your attention!

Global RMS

RBF

RL05a

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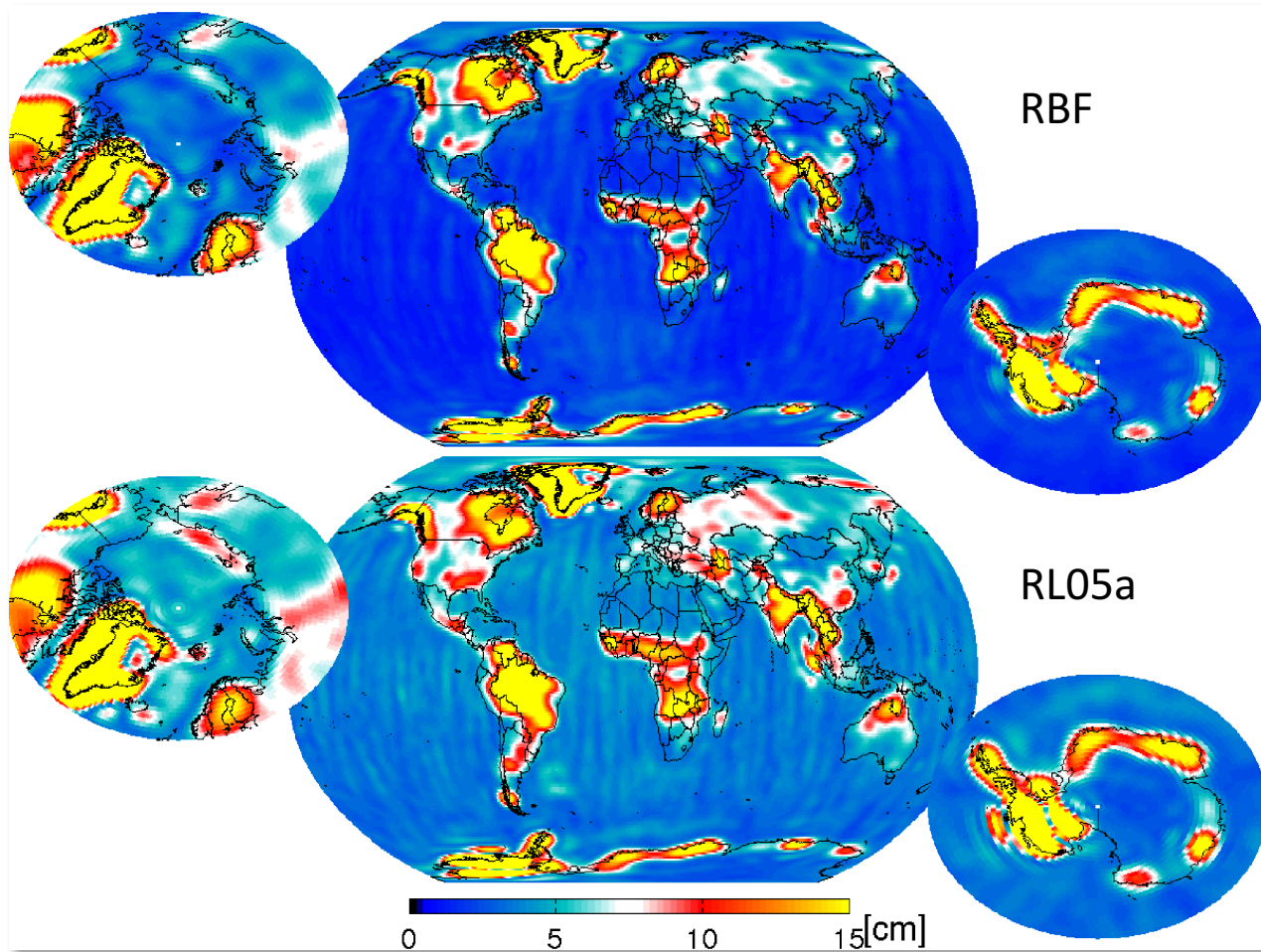
RBF Status

- Kalman/RBF time series of available GRACE days has been produced!
- main keys to success:
  - observation de-correlation reduced to < 2.5 rev.
  - vast limitation of outliers: only very few observations are discarded
  - accelerometer pre-processing for all 3 axis (high-pass)
  - modifications of the process model (stability)
- interfaces for NRT service readiness are developed
  - ftp, shell/perl scripts, conversions, formatings, etc.

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