EGSIEM

Title: WP 2 Gravity field analysis

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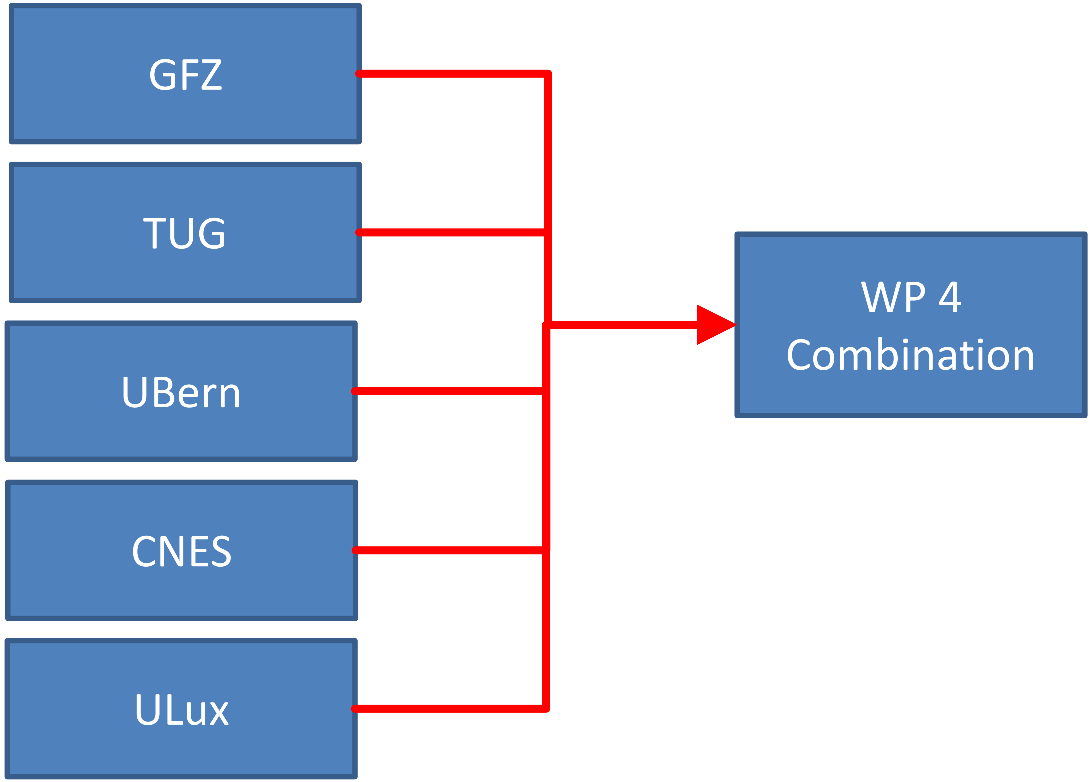
WP2 Overview

Monthly GRACE solutions



GFZ

TUG

UBern

CNES

ULux

WP 4
Combination

WP2 Overview

T2.1 Processing Standards and Models (UBERN, UL, GFZ, TUG, CNES)	M01-M02
T2.2 Improved processing tools (UBERN, UL, GFZ, TUG, LUH, CNES)	M01-M10
T2.3: Data analysis (UBERN, UL, GFZ, TUG, LUH, CNES)	M11-M18
T2.4: Instrumental behaviour and End-to-End Simulator (LUH, GFZ)	M06-M18

T2.2 Improved processing tools
T2.3: Data analysis
(UBERN, UL, GFZ, TUG, LUH, CNES)

GRACE Level-2 Processing at GFZ

- Generation of GRACE Level-2 products based on two-step method:
  - Step 1: Calculation of precise orbits and clocks of GPS satellite constellation using GPS ground station network
  - Step 2: Adjust gravity field (and orbital/instrumental) parameters using fixed GPS reference frame from step 1
- Step 2 is based on orbit perturbation theory using the so-called “dynamic method” (also applied for CHAMP and GOCE)
- The whole processing environment required for generation of Level-2 products is consisting of the following steps:
  - Generation of precise GPS orbits & clocks
  - Preprocessing of Level-1B data (outlier detection, gap filling, reformatting etc.)
  - Definition of orbital arcs to be processed
  - Data screening and orbit determination of GRACE/GRACE-FO spacecrafts
  - Generation of normal equations
  - Solving for gravity field (and orbit/instrumental specific) parameters
  - Validation

GRACE Level-2 Processing at GFZ

- Current GFZ GRACE RL05 standards: IERS2010 conventions, IGS08 (GPS constellation), background models see table below and "GRACE Processing Standards Document for GFZ RL05 Level-2 Data"

GFZ GRACE RL05 Background Models	
Static Gravity Field	**EIGEN-6C**
Time-variable Gravity Field	**Trend / Annual / Semiannual Model from EIGEN-6C till d/o 50x50**
Ocean Tides	**EOT11a**
Atmospheric Tides S1, S2	**Biancale-Bode 2003**
Atmospheric and Oceanic Non-tidal Mass Variations	**AOD1B RL05**
Ocean Pole Tide	**Desai [2002]**
Solid Earth & Pole Tides	**IERS2010**
3rd Body Ephemerides	**JPL DE421**

GRACE Level-2 Processing at GFZ

- Planned further improvements:
  - Use of latest available / best standards and background models
  - Optimized parameterization of accelerometer and K-band observations
  - Optimized screening procedure (definition of orbital arcs, elimination of observations)
  - …
- Required auxiliary products and latencies:

IGS raw data *(for GPS constellation only)*	1 day
Troposphere (VMF) *(for GPS constellation only)*	1 day
IGS final orbits (validation) *(for GPS constellation only)*	2-3 weeks
Ionosphere (IGS daily products)	~3 weeks
AOD1B products	~1 week
EOP 08 C04	~6 weeks

- Required latency for L2-products (GRACE SDS requirement): 2 months

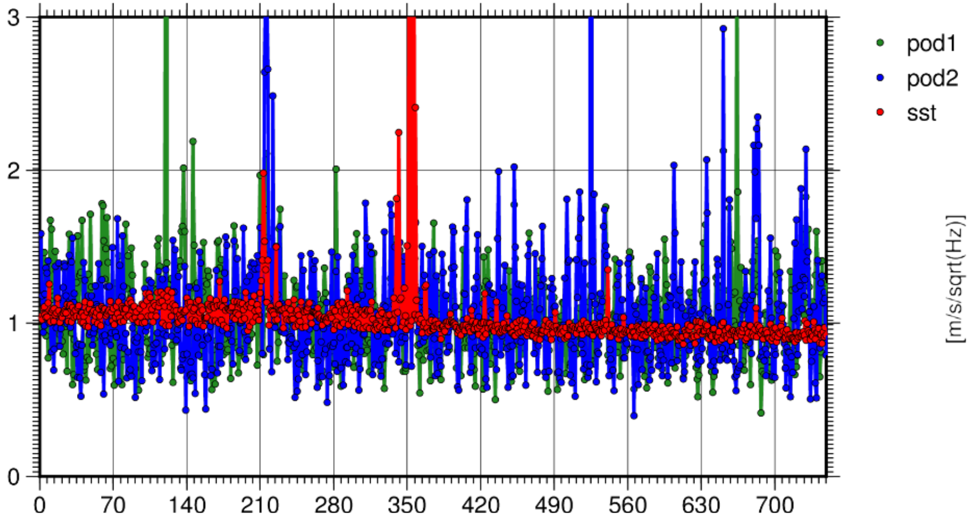
ITSG-Grace: GRACE Processing at TU Graz

- Generation of GRACE Level-2 products based on three-step method:
  - Step 1: Fixed IGS/CODE solution: GPS orbits & clocks
  - Step 2: Estimation of kinematic orbits of GRACE satellites
  - Step 3: Adjust gravity field (and orbital/instrumental) parameters

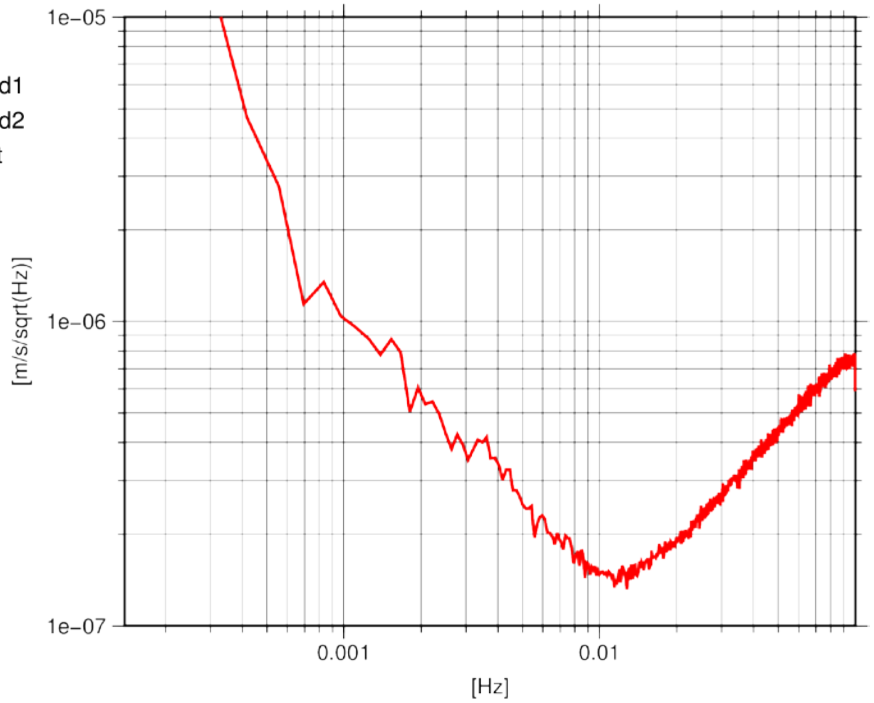
ITSG-Grace: GRACE Processing at TU Graz

- Variance component estimation for 1 hour data:
  - Accuracies/weights for each arc (KBR & orbits)
  - Empirical covariance function (via PSD)

Arc sigmas

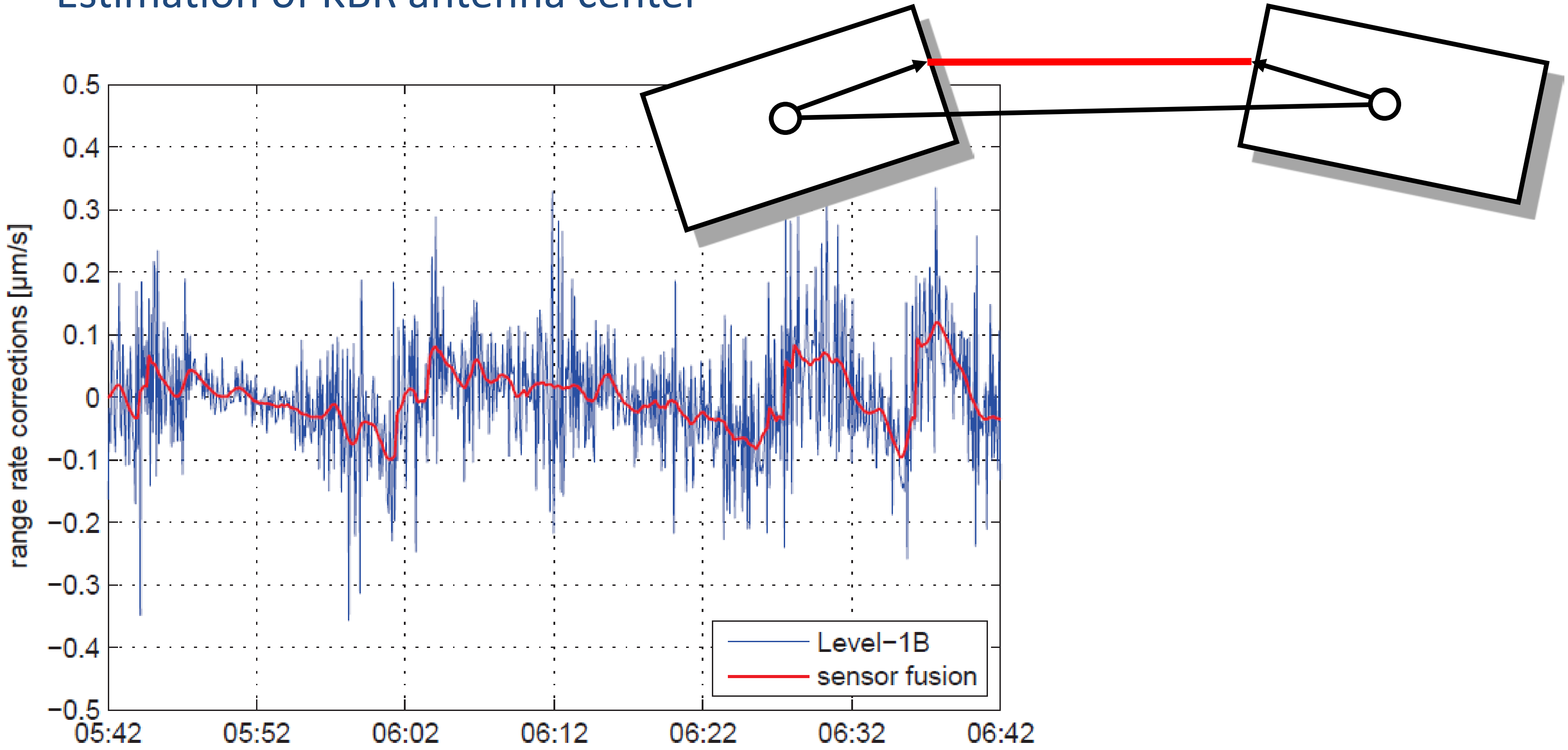


PSD of K-Band residuals



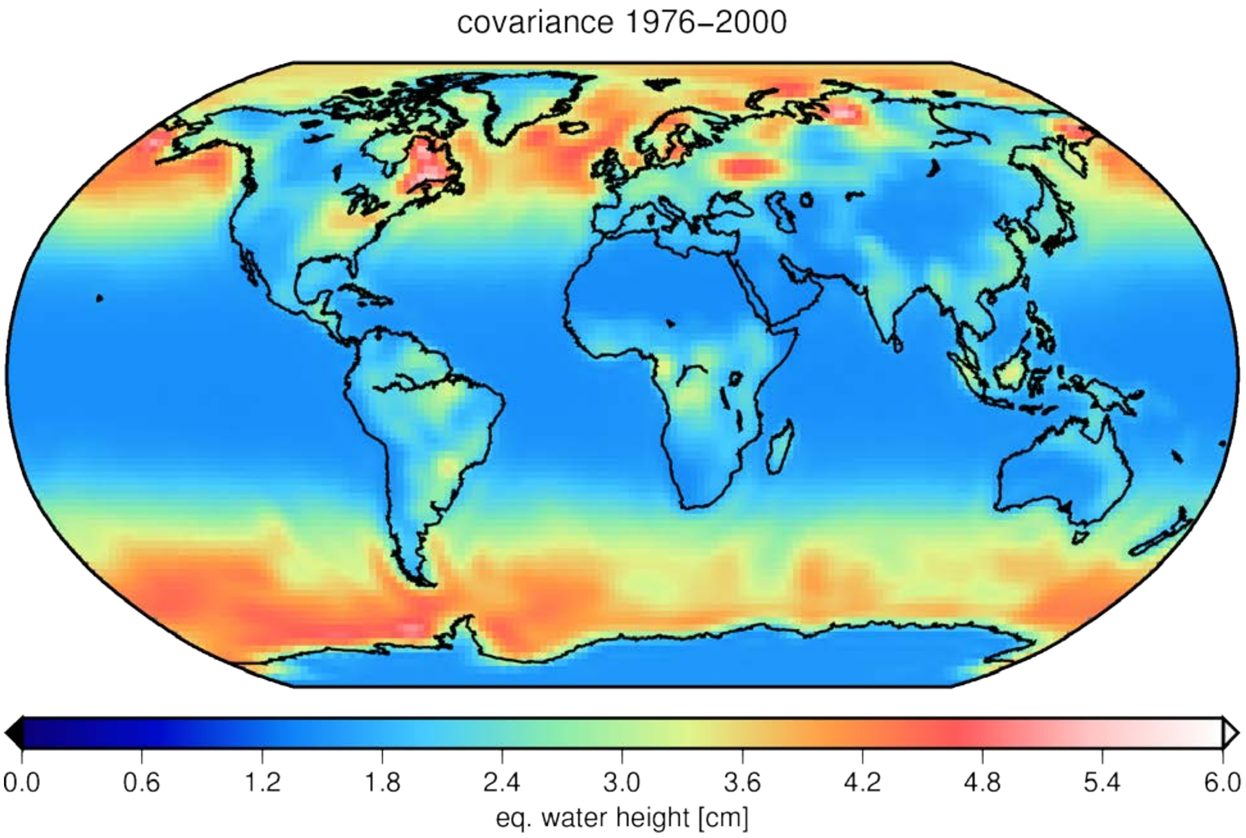
ITSG-Grace: GRACE Processing at TU Graz

- Combination of star camera data and angular variations
- Estimation of KBR antenna center



ITSG-Grace: GRACE Processing at TU Graz

- Estimation of (constrained) daily variations additional to AOD1B
- Constrained derived from geophysical models



ITSG-Grace: GRACE Processing at TU Graz

Planned further improvements

- Stochastic modelling: separation of ACC & KBR noise
- Daily variations: Use of ~3,500 daily normal to separate noise/signal via VCE
- Outlier detection

Auxiliary input:

- GNSS orbits and clock-corrections
- AOD1B products
- EOP 08 C04

CMA – Celestial Mechanics Approach (UBern)

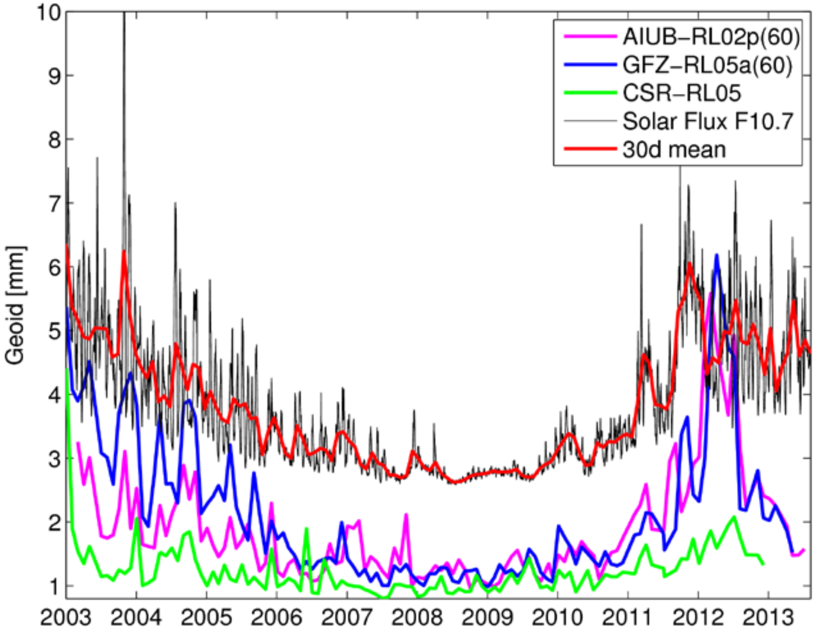
Monthly gravity fields (90)

Data	• GRACE kinematic positions • Level 1B K-band range-rates
Orbits	• Initial conditions every 24h • Accelerations over 15min (constrained)
K-band	• No additional parameters • Correlations not modeled
Accelerometer	• Daily scale-factors in 3 directions
A priori	• AIUB-GRACE03S up to degree 160
Background	• IERS 2010 solid Earth tides • EOT11a ocean tides • RL05 AOD1B dealiasing

CMA – Celestial Mechanics Approach (UBern)

- Planned improvements:
  - Noise model:
    - Tailored constraining of stochastic parameters
    - Stochastic covariances???
    - Down-weighting of bad observations???

SHC-noise (RMS oceans)



- Auxiliary input:
  - GNSS orbits and clock-corrections: in-house (CODE)
  - Kinematic LEO orbits: in-house
  - Atmosphere/Ocean dealiasing
  - SLR data (validation)

CNES/GRGS GRACE processing: current standards of RL03

Dynamical models

Gravity	*EIGEN-GRGS.RL02* → *EIGEN-6S2*
Ocean tide	*FES2004 (degree 80)* → *FES2012 (Legos)*
Atmosphere	*3-D ECMWF pressure grids / 6hrs* → *ERA-interim / 3hrs*
Ocean mass model	*MOG2D (non-IB) / 6hrs* → *TUGO (Legos) / 3hrs*
Atmospheric tides	→ *Not necessary any more*
3rd body	*Sun, Moon, 6 planets (DE405)*
Solid Earth tides	*IERS Conventions 2010*
Pole tides	*IERS Conventions 2010*
Non gravitational	*Accelerometer data (+biases and scale factors)*

CNES/GRGS GRACE processing: current standards of RL03

Geometrical models

SLR stations	*ITRF2008 coordinates → updated*
GPS	*IGS orbits and CODE clock → IGS Repro-1 orbits and clocks*

Other models

Hydrology	Taken into account by the a priori gravity field
Glacial Isostatic Adjustment	

Additional features

Strong down-weighting and spacing of the GPS observations of GRACE (wrt. RL02)
Change of inversion strategy: Choleski → *Truncated SVD*

Known problems of RL03 and planned improvements

Weakness of the sectorials

→ This point was very noticeable in the unconstrained solutions that we provided to Adrian for test purposes (not usable !)

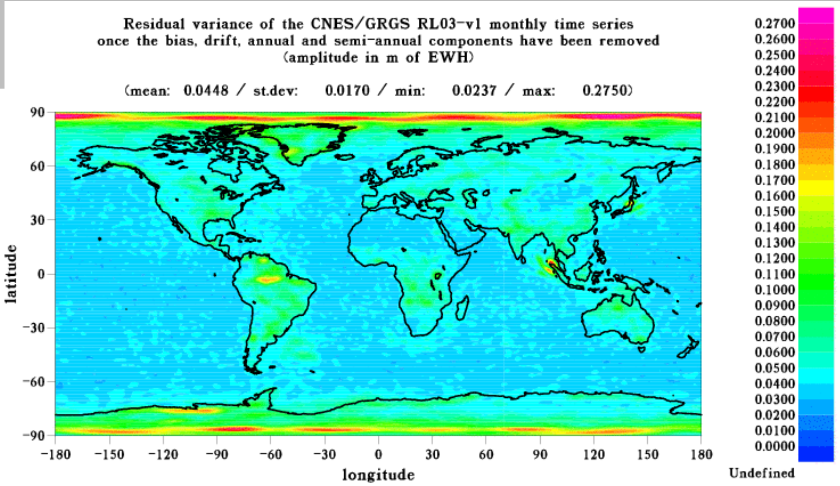
→ **The cause:** a strong down-weighting of the GPS phase and range measurements on GRACE in RL03-v1.

→ **Planned correction in RL03-v2:**

- Adding Starlette and Stella to Lageos-1&2 will strengthen the very low degrees and improve some sectorials;
- The weight of GRACE GPS phase and range data will be brought back to a reasonable value.

Known problems of RL03 and planned improvements

An erroneous mass signal located in two small circular rings close to the Earth's poles:



→ This has lead to our recommendation **<u>not to use</u>** RL03-v1 above 82° latitudes North and South;

→ **The cause:** the SVD inversion strategy which does not allow for a correct solution of the low degree sectorials. These, in turn, perturb all the coefficients of a given order.

→ **Planned correction in RL03-v2:**

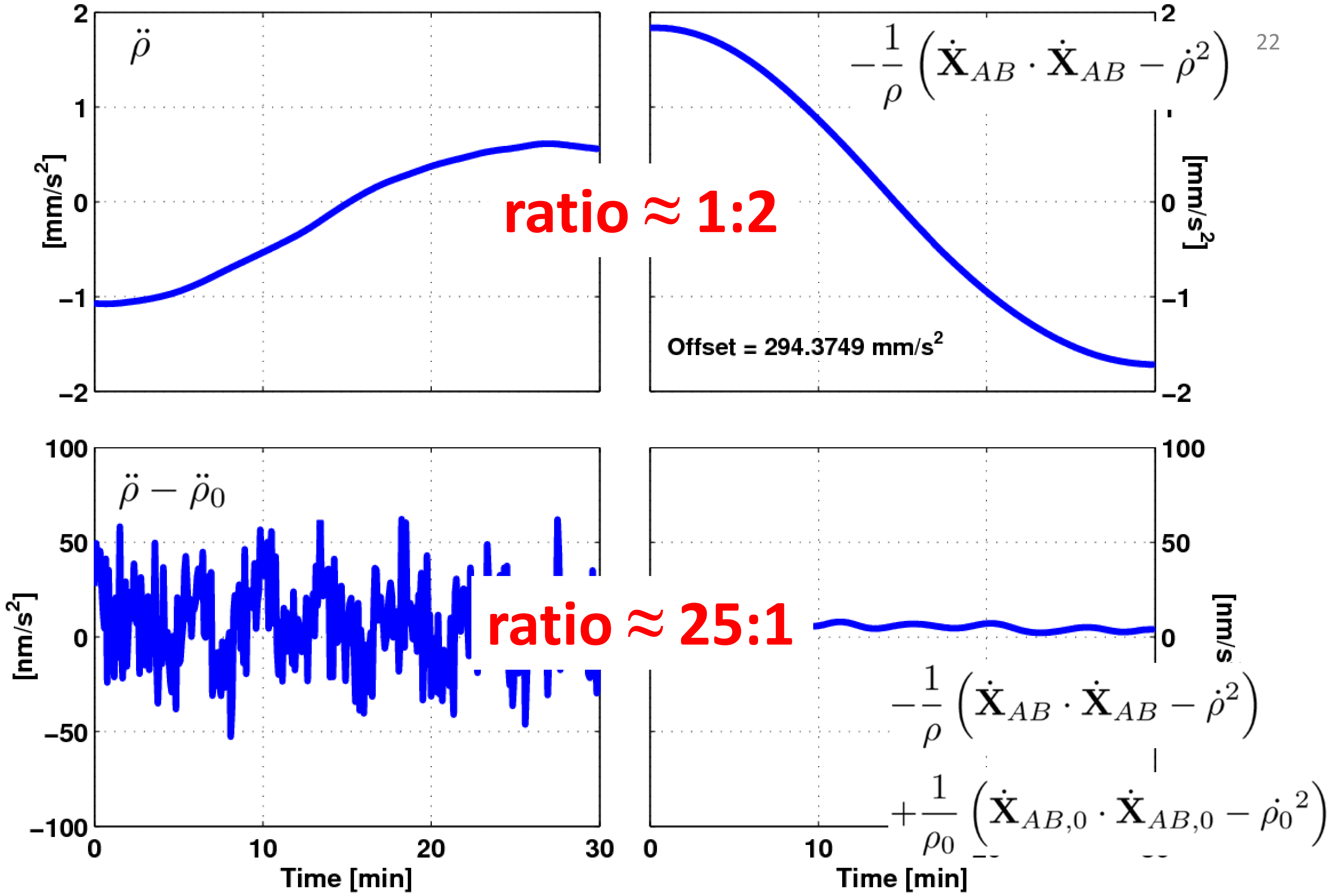
- Switching to a two-step approach: first a Choleski inversion of the low degrees, then injection of this solution in the normals and resolution using truncated SVD.

Acceleration approach (Lux)

- Many variants of the *acceleration approach* exist
- Here we refer to the acceleration approach as:

$$\nabla V \cdot \boldsymbol{e}_{AB} = \ddot{\rho} - \frac{1}{\rho}\left(\|\dot{\boldsymbol{X}}_{AB}\|^2 - \dot{\rho}^2\right)$$

- Practical implementation:
  - Reduction to residual quantity
  - Neglecting the "GPS"-term $\nabla V \cdot \boldsymbol{e}_{AB} - \nabla V_0 \cdot \boldsymbol{e}_{AB,0} \approx \ddot{\rho} - \ddot{\rho}_0$
  - Iteration (high numerical effort)
  - currently solutions are not competitive yet (primarily limited by the implementation of the orbit integration)



ratio ≈ 1:2

ratio ≈ 25:1

Future improvements

- Implementation:
  - fix problems with orbit integration
  - add stochastic pulses/constant accelerations
  - fix parameterization
  - migration to cluster
- Methodological:

considering the “GPS” term via variational equation

$$\ddot{\rho} - \ddot{\rho}_0 \approx \nabla V \cdot \boldsymbol{e}_{AB} - \nabla V_0 \cdot \boldsymbol{e}_{AB,0} + \frac{\partial}{\partial \bar{K}_{lm}} \left[\frac{1}{\rho} \left(\|\dot{\boldsymbol{X}}_{AB}\|^2 - \dot{\rho}^2 \right) \right] \Delta \bar{K}_{lm}$$

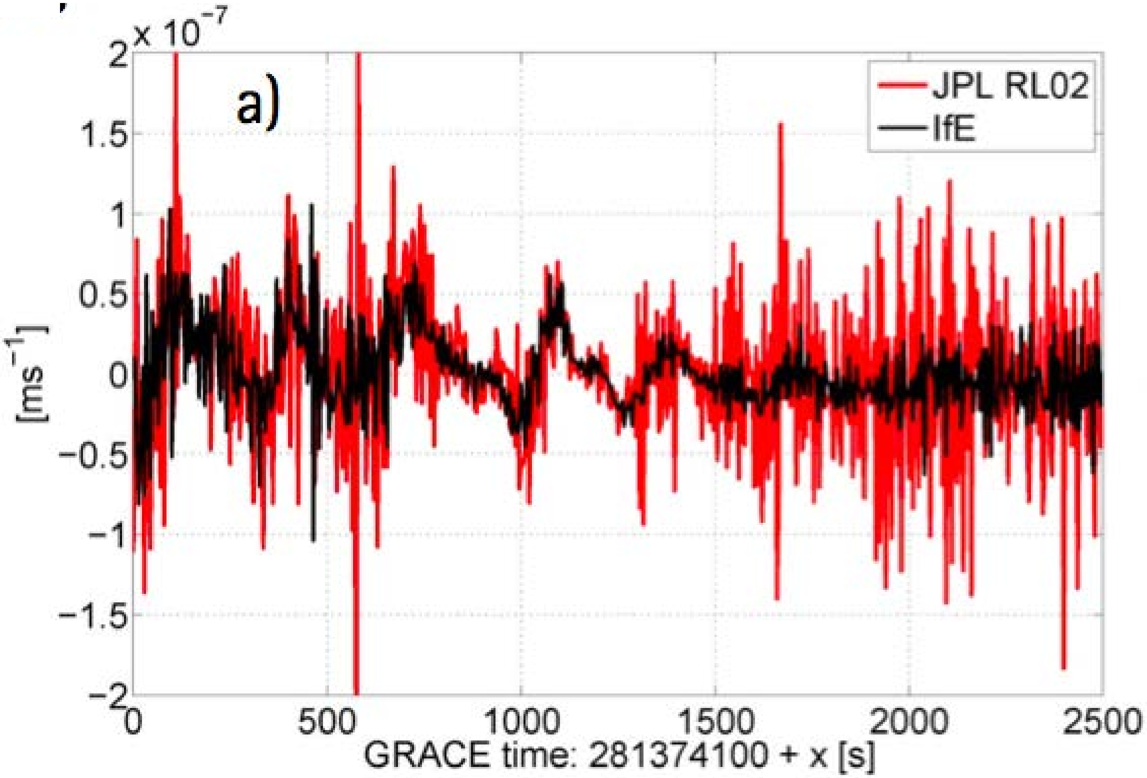
T2.4: Instrumental behavior and End-to-End Simulator

L1B Sensor data analysis (LUH)

- for reprocessing (T2.3)
- for noise time series for E2E simulation (T2.4)
- main topics:
  - accelerometer data
  - attitude data
  - LRI data

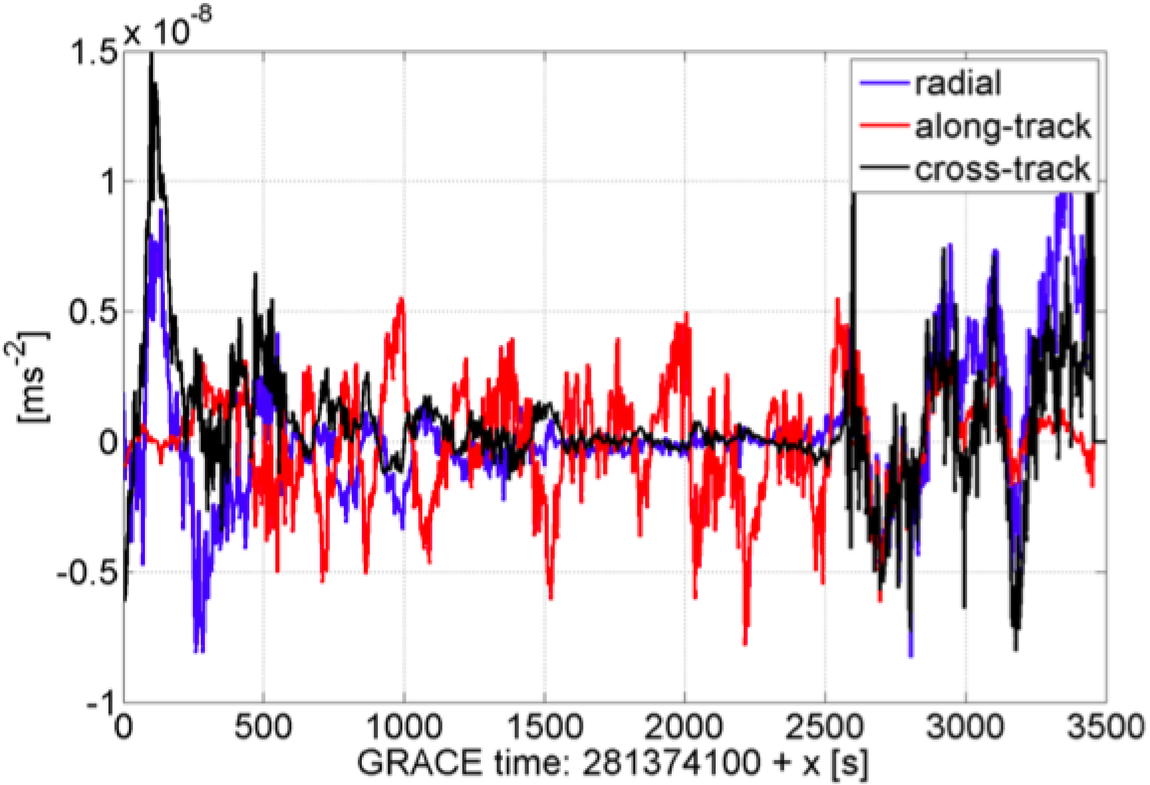
Sensor data analysis: Attitude

- Star camera common frame reprocessing
  - effect on inter-satellite range-rate



Sensor data analysis: Attitude

- Star camera common frame reprocessing
  - effect on non-gravitational accelerations

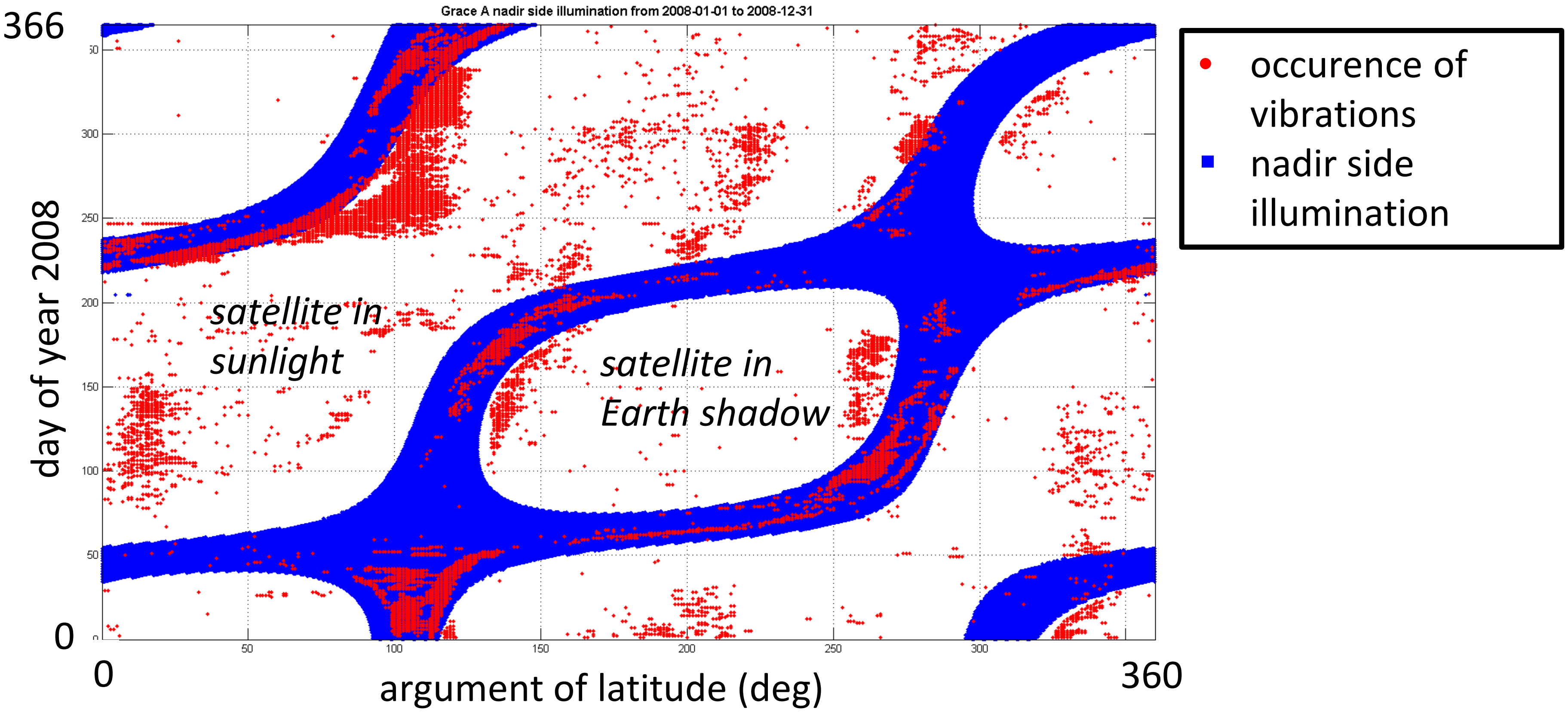


Sensor data analysis: Attitude

- attitude related errors
  - measurement errors
  - alignment errors
  - KBR phase center errors
- research on separation ongoing
- coupled with stochastical modeling
- options for sensor fusion

Sensor data analysis: Accelerometer

- environmental disturbances: twangs, vibrations, heater switching spikes, MTQ spikes



Sensor data analysis: Accelerometer

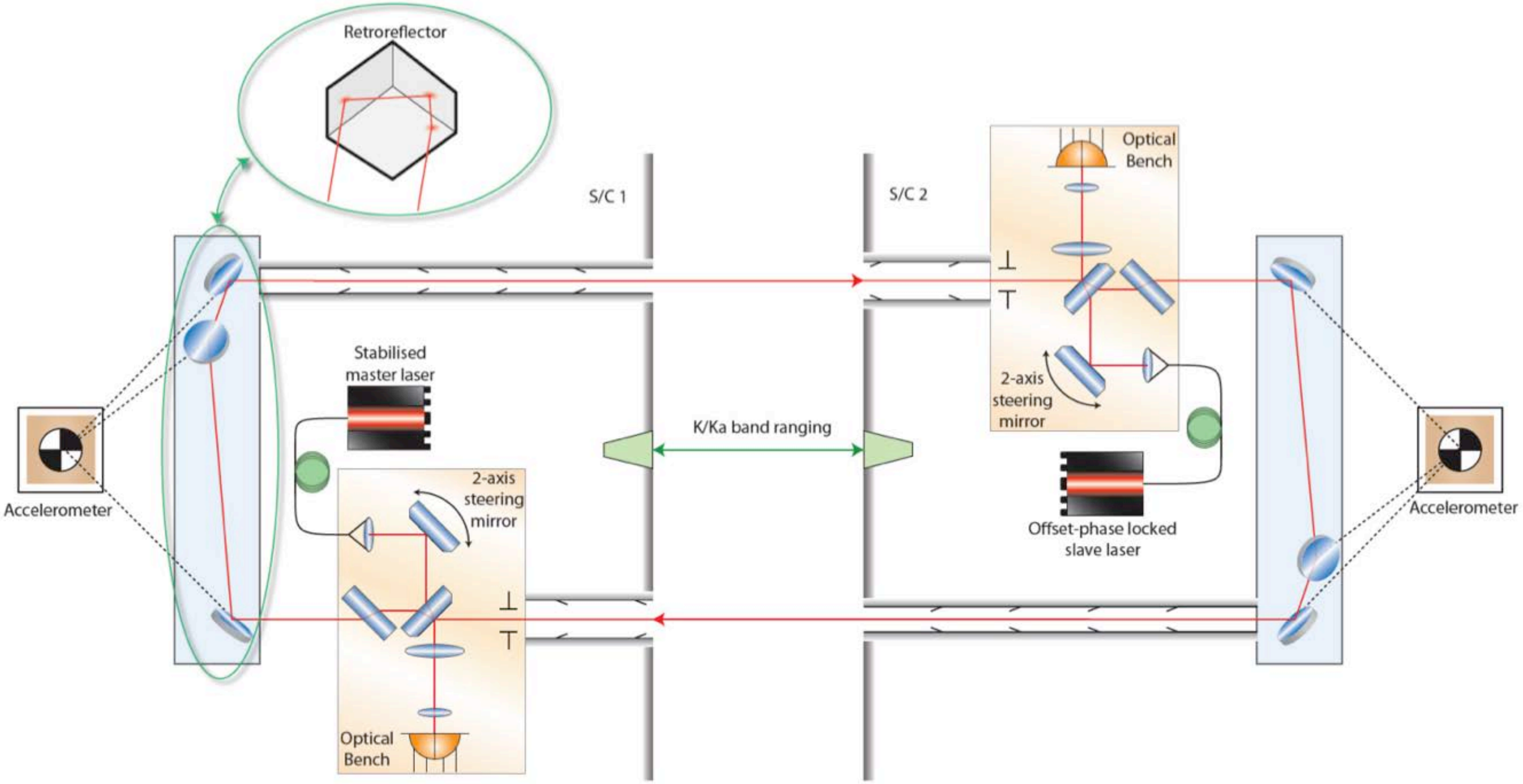
- environmental disturbances
  - re-processing with models for heater switching spikes, MTQ spikes, (twangs tbc), topic of SFB1128 geo-Q
  - noise time series

T2.3 Re-processing of L1B data (M11-M18)

- star camera reprocessing
  - common frame
  - …
- accelerometer
  - reductions for heater switching, MTQ spikes
  - twangs tbc

Sensor data analysis: LRI

- noise modeling



T2.4 Noise time series for E2E simulation (M06 – M18)

- harmonize input with planned E2E rounds and scenarios
- attitude noise time series
  - propagated to range-rate (line of sight)
  - propagated to non-gravitational accelerations (3 axes)
- environmental accelerometer noise time series (3 axes)
- LRI noise time series
- investigate interaction with other effects
  - background model errors
  - orbit parameterization
  - ...

GFZ E2E Simulator: General

- Based on GFZ EPOS (Earth Parameter and Orbit System) S/W used for real data analysis e.g. of gravity (CHAMP, GRACE, GOCE), SLR or altimetry missions

- Has been used for various simulation studies of NGGMs, e.g.
  - ESA study NG2 (2011) „Assessment of a Next Generation Gravity Mission to Monitor the Variations of Earth´s Gravity Field“ by Airbus, GFZ and University of Bonn
  - BMBF study (2013) “Future Gravity Field Satellite Missions” within Geotechnologien Program “Observation of the System Earth from Space - CHAMP, GRACE, GOCE and future missions” (GFZ, industry and various D universities)
  - DLR study (2014) „Next Generation Gravity Mission – Deutschland“ (NGGM-D) (TU Munich, GFZ, industry, various D universities)

GFZ E2E Simulator: 5-Step Approach

- Step 1 (Constellation)
  - Define number of pairs, orbital parameters, mission duration etc.

- Step 2 (Simulation)
  - Define a-priori („true world“) background models (static gravity field, ocean tides, non-tidal mass variations (AOHIS))
  - Simulate daily white noise HL-SST (GPS code and phase)
  - Simulate daily geometric LL-SST (MWI or LRI range rate)
  - Simulate daily non-gravitational forces (from air drag, solar radiation and albedo models) and transform to accelerometer data (ACC)

- Step 3 (Noise)
  - Add realistic (colored) noise to observations (LL-SST, ACC) provided by University Hannover

GFZ E2E Simulator: 5-Step Approach

- Step 4 (Recovery)
  - Exchange „true world“ background models from step 1 by models which describe „best knowledge“ uncertainties and perform monthly gravity field determination using noisy observations from step 3
  - During recovery step similar parameters are adjusted as in real case scenarios (initial state vector, 3h ACC bias and scales, MWI/LRI parameters etc.)

- Step 5 (Analysis)
  - ➢ Compare for all months of missions duration „recovered“ and „true world“ monthly models in the spectral and spatial domain e.g. for independently calculated LRI or MWI cases

GFZ E2E Simulator: Example Background Models

- Step 2 (Simulation)
  - static gravity model (EIGEN-GL04C (Förste et al. 2008) up to degree and order 100
  - Sun and Moon ephemerides (DE405, Standish 1998),
  - ocean tides (8 main constituents Q1, O1, P1, K1, N2, M2, S2 and K2 of EOT08a, Savcenko et al. 2008)
  - non-tidal short-term mass variations for the atmosphere, oceans, hydrology, ice and solid Earth (AOHIS, Dobslaw et al. (2014))

- Step 4 (Recovery)
  - static gravity model EGM96 (Lemoine et al. 1998) up to d/o 100
  - Ocean tides (8 main constituents substituted by GOT4.7 (Ray 2008)
  - errors to the AOHIS model as described in Dobslaw et al. (2014)

GFZ E2E Simulator: Example NGGM-D

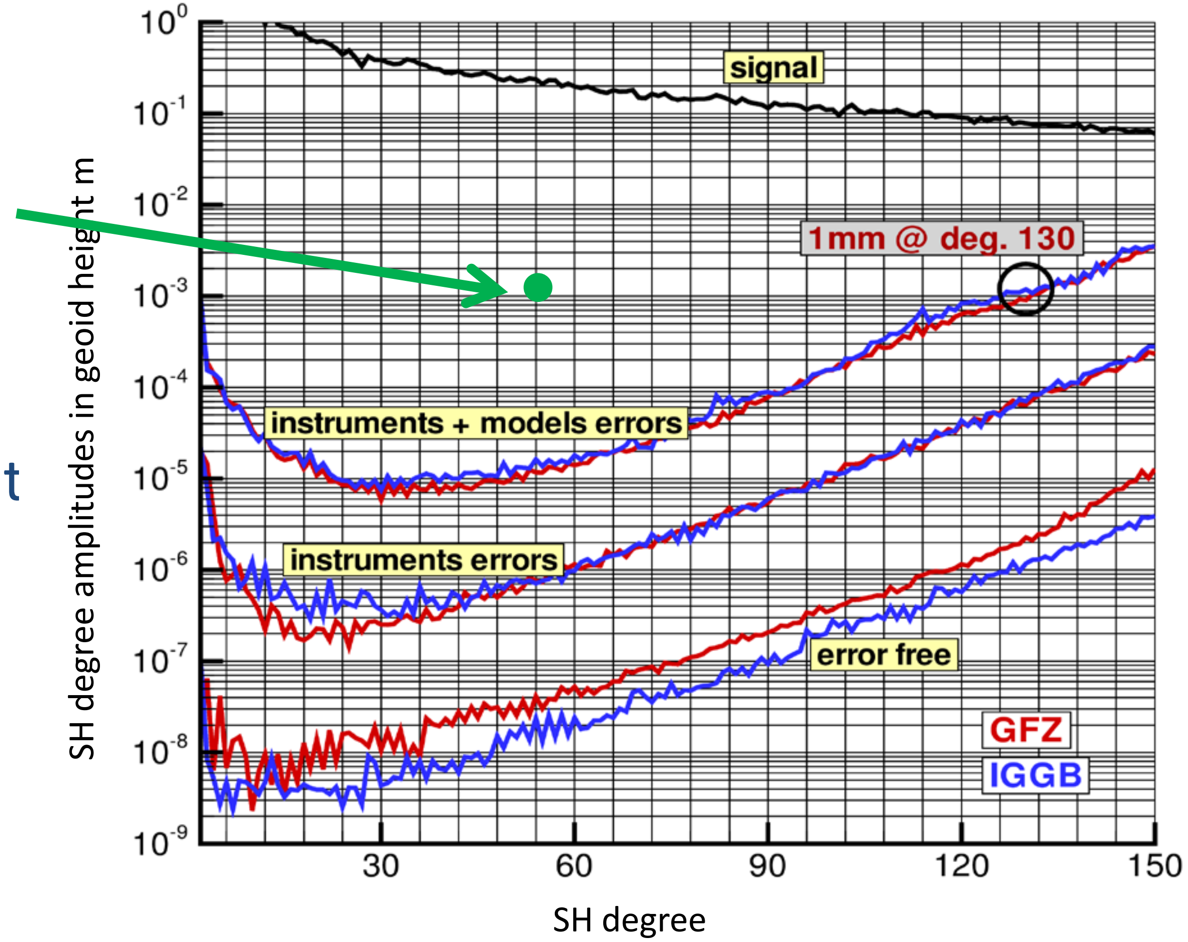
Initial baseline scenario

- Double pair constellation ("Bender")
- Near polar orbit & inclined orbit @ h=420km (2nd pair @ 70°)
- Satellite distance: 100 km
- Maximum spherical harmonic degree: 150 (133 km)
- Monthly period
- SST noise: 10^{-8} m (MBW) (25 nm vs 2000 nm (GRACE))
- ACC noise: 10^{-11} m/s2 (MBW) (10 times GRACE)

Requirements for monthly geoid error (w/o postprocessing)

- 1mm geoid (1 cm EWH) @ 200km (minimum, 10 times better than GRACE)
- 1mm geoid (1 cm EWH) @ 150km (optimum)

GFZ E2E Simulator: Example NGGM-D



- Consistent independent GFZ and IGG Bonn solutions
- Requirements fulfilled!

T2.1 Processing Standards and Models

T2.1 Processing Standards and Models

Goal: Combined gravity field solution based on normal equation level (WP4)

We should define only mimimum requirements

Allow much freedom in processing as possible

Normal equations:

- Unconstrained
- Satellite parameters pre-eliminated
- Background models restored (static field, …)
- GRACE-only solutions (Combination of SLR on normal equation level)
- Format: SINEX?

T2.1.2 Reference system

- Center of mass (CM) :
  Degree 1 coefficients of all background must be zero

- Tidal system:
  Zero tide (as recommended by IERS2010)

- Reference system
  ITRF, no further recommendation needed?
  (GRACE horizontal resolution >>10 km)

T2.1.1 Background models

- Static field, trend, annual, semiannual: Different fields
- Third body forces (sun, moon, planets): JPL DE421
- Solid earth tides: IERS 2003/2010
- Ocean tides: EOT11a / FES2012 / …
(incl. equillibrium tides:
Om1, Om2, Sa, Ssa, …)
- Pole tides: IERS 2010 (w/o equation 6.4)
- Ocean pole tides: IERS 2010
- Atmospheric tides (S1, S2) Bode-Biancale 2003 / …
- Dealiasing: AOD1B RL05 / MOG2D / …
(Atmospheric S1/S2 removed)

T2.1.1 Background models

Different purposes

- Taylor point of Linearization
  - E.g. Static field, trend, annual, semiannual
  - Should be added back to normal equations
- Remove high frequent signals (< 1 month) for dealiasing
  - True signal is unknown: e.g. AOD1B vs. MOG2D
  - Consistency not possible and not meaningful
- Signal separation (>= 1month)
  - Depends on the application
  - GRACE observes the full signal, but at the moment:
    - Tidal effects removed
    - Atmospheric and ocean signals (some parts) are removed
    - Hydrology and Ice included

Tides: Standards required for signals > 1 month)

Add back monthly mean of dealiasing prodcuts before combination

Problem: Some of the background models are use for multiple purposes

T2.1.3 Constraints

Constraints / filtering / regularization / a priori information:

- Helps to improve the solution, BUT:
- Damps always the noise and the signal
- Smooth transition between to much and to less regularization
- Depends on the signal to noise ratio

=> Regularization not allowed before combination

T2.1.3 Constraints / Empirical parameters

Contraints:

Only constraints for pre-eliminated parameters are allowed

Possible empirical parametrization (pre-eliminated):

- Accelerometer (Mandatory: scale and bias estimation)
- KBR parametrization (bias, trend …)
- KBR antenna center variations
- Empirical orbits parameters, stochatic pulses, …
- Full noise variance-covariance matrix

T2.1.4 GPS observations / kinematic orbits

- Reduced-dynamic orbits:
  Not allowed in observation vector
  -> possible bias towards reference gravity field

- Further standards needed here?
  (IGS standards?)

T2.1 Processing Standards and Models

Goal: Combined gravity field solution based on normal equation level (WP4)

We should define only mimimum requirements

Allow much freedom in processing as possible

Normal equations:

- Unconstrained
- Satellite parameters pre-eliminated
- Monthly mean of background models restored
  except tidal effects: Earth tides, long periodic ocean tides, pole tides
- GRACE-only solutions
- Format: SINEX?

Standards: overview

Approaches may differ by:

- Philosophy
- Input data
- Orbit dynamics
  - conventions
  - background models
- Earth kinematics (orientation, reference frame)
- Satellite kinematics (orientation, geom. biases)

Standards: methods, data, solutions

GFZ-RL05a (GFZ L2 Proc. Std. Doc.)	CSR-RL05 (UTCSR L2 Proc. Std. Doc.)	AIUB-RL02
Method: dynamic approach 1h ACC biases no emp. ACC fixed relative weighting	**Method:** dynamic approach ACC biases and scales no emp. ACC optimal KRR-weighting	**Method:** dynamic approach 15 min. emp. ACC, constr. Const. and 1/rev. emp. ACC fixed relative weighting
Data: ACC 5s, ATT, range-rates 5s, no corr.	**Data:** ACC 1s, ATT, range-rates 5s, no corr.	**Data:** ACC 1s, ATT, range-rates 5s, no corr.
GPS code/phase: cutoff 10° undifferenced Offset: 0/0/-444mm, PCVs	**GPS code/phase:** double diff., 2 minutes Offset: 0/0/-490mm, PCVs	**Kin. orbits.:** GPS undifferenced, 30 s Offset: 0/0/-452, PCVs
Solutions: tide-free monthly (90), weekly (30) mostly unconstrained	**Solutions:** zero-tide monthly (96) unconstrained	**Solutions:** tide-free monthly (90) unconstrained

Standards: background models

GFZ-RL05a	CSR-RL05	AIUB-RL02
A priori: EIGEN-6C (200) combined trends + per. var. (50) a_E=6378136.46m	**A priori:** GIF48 (360) combined trends not applied a_E=6378136.3m	**A priori:** AIUB-GRACE03S (160), satellite only tr.+ per. var. (30) not appl. a_E=6378137.0m
Ocean tides: EOT11A (80) M_{tm}, M_{sqm}: FES2004 $\Omega_{1,2}$, $S_{a,sa}$: HW95 admittances interpol.	**Ocean tides:** GOT4.8 (180) M_{tm}, M_{sm}: FES2004 M_m, M_f: Egbert & Ray(2003) admittances interpol.	**Ocean tides:** EOT11a(100) M_{tm}, M_{sqm}: FES2004 $\Omega_{1,2}$, $S_{a,sa}$: HW95 admittances interpol.
Non-tidal variations: AOD1B-RL05 (100) S2 removed	**Non-tidal variations:** AOD1B-RL05 (100) S2 removed	**Non-tidal variations:** AOD1B-RL05 (100)
Atmosphere tides: Bode & Biancale (2006) S1 and S2 (8/5)	**Atmosphere tides:** Ray & Ponte (2003)	**Atmosphere tides:** none

Standards: orbit dynamics

GFZ-RL05a	CSR-RL05	AIUB-RL02
Solid Earth tides: IERS2010 Planetary eph.: DE 421	**Solid Earth tides:** IERS2010 Planetary eph.: DE 405	**Solid Earth tides:** IERS2010 Planetary eph.: DE 405
Pole tide: IERS2010 IERS EOP 08 C04	**Pole tide:** IERS2003 IERS C04	**Pole tide:** IERS2010
Ocean pole tide: Desai (30)	**Ocean pole tide:** Desai (100)	**Ocean pole tide:** Desai (100)
3rd bodies: point masses Sun, moon, 5 planets	**3rd bodies:** point masses Sun, moon, planets	**3rd bodies:** point masses Sun, moon, planets
Relativistic effects: IERS2010, incl. Lense-Thirring and de Sitter	**Relativistic effects:** IERS2010	**Relativistic effects:** IERS2010

Standards: Earth kinematics

GFZ-RL05a	CSR-RL05	AIUB-RL02
Reference frame: J2000.0, IGS08	**Reference frame:** J2000.0, IGS08	**Reference frame:** J2000.0, IGS08
Precession and nutation: IERS2010 (IAU2006/2000)	**Precession and nutation:** IERS2003 (IAU2000A)	**Precession and nutation:** IERS2010 (IAU2006/2000)
Sidereal rotation: ERA: IERS2010	**Sidereal rotation:** GMST: IERS2003 diurnal tide corr.: IERS1996	**Sidereal rotation:** IERS2010
Polar motion: IERS2010 including s‘ (TEO)	**Polar motion:** IERS2003 ocean tidal var.: IERS1996	**Polar motion:** IERS2010

Standards within the IGS

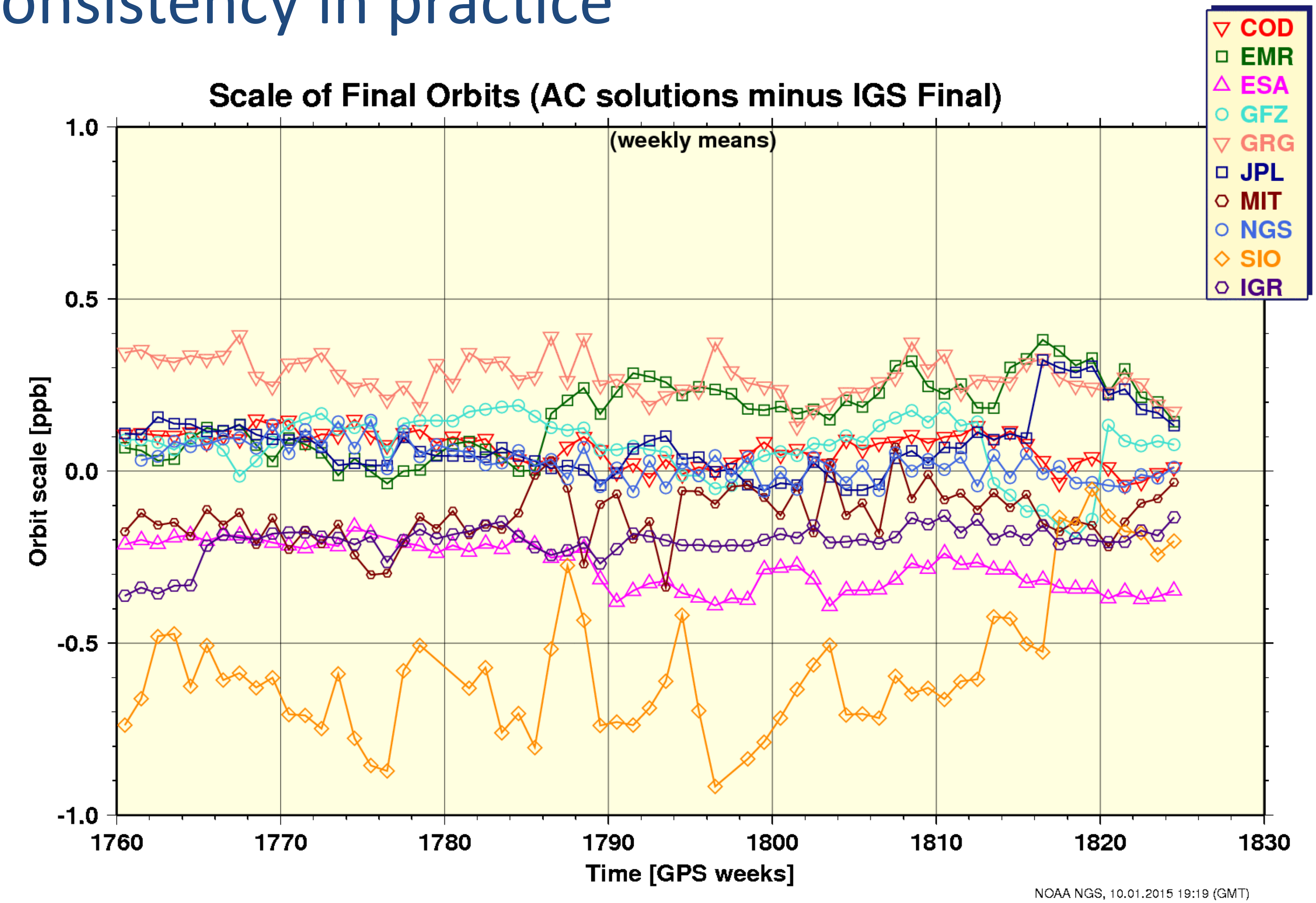
Standards within the IGS

The IGS analysis centers are asked to provide solutions

- following the latest IERS convention and
- refering to the most recent ITRF

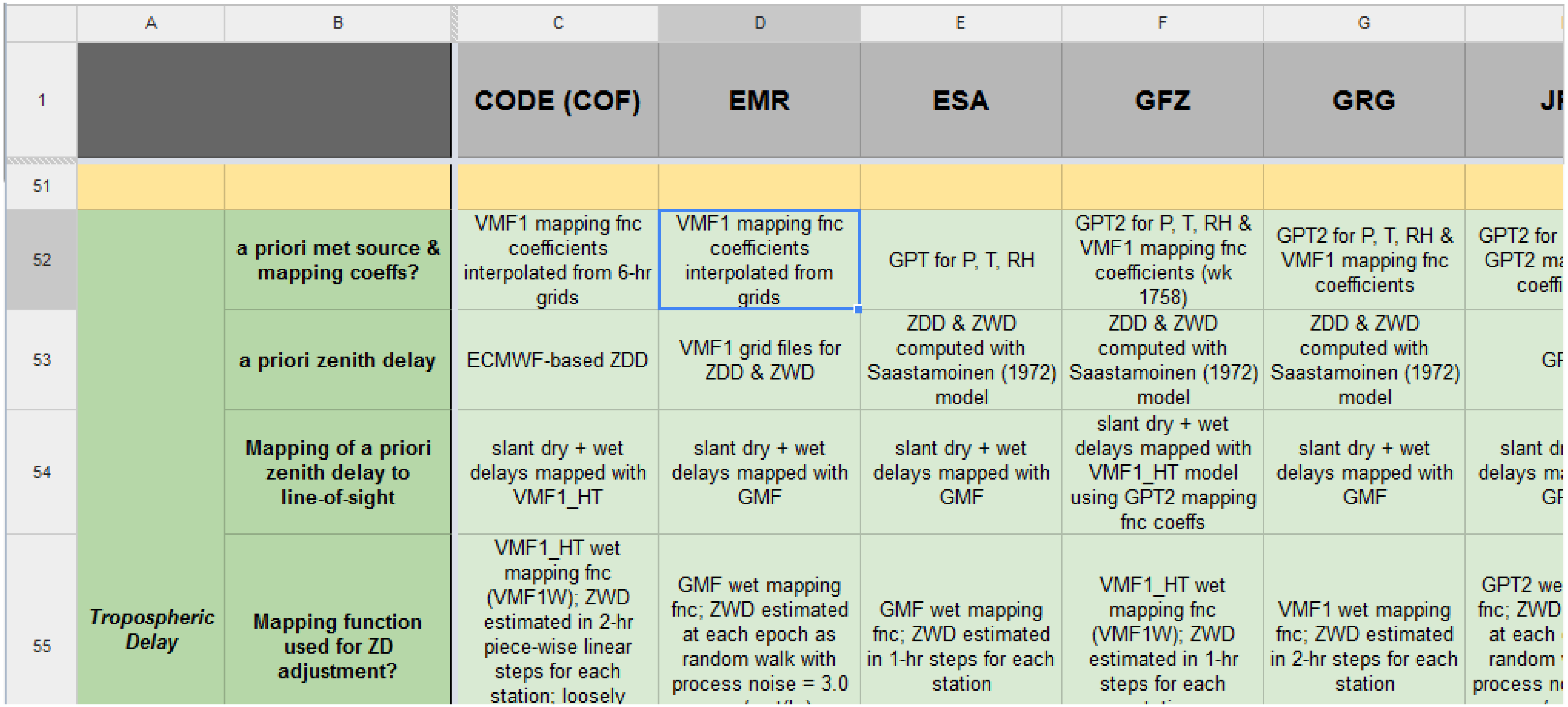
to obtain a consistent set of solutions allowing a reasonable combination.

Consistency in practice



Important is to know, what people are doing:

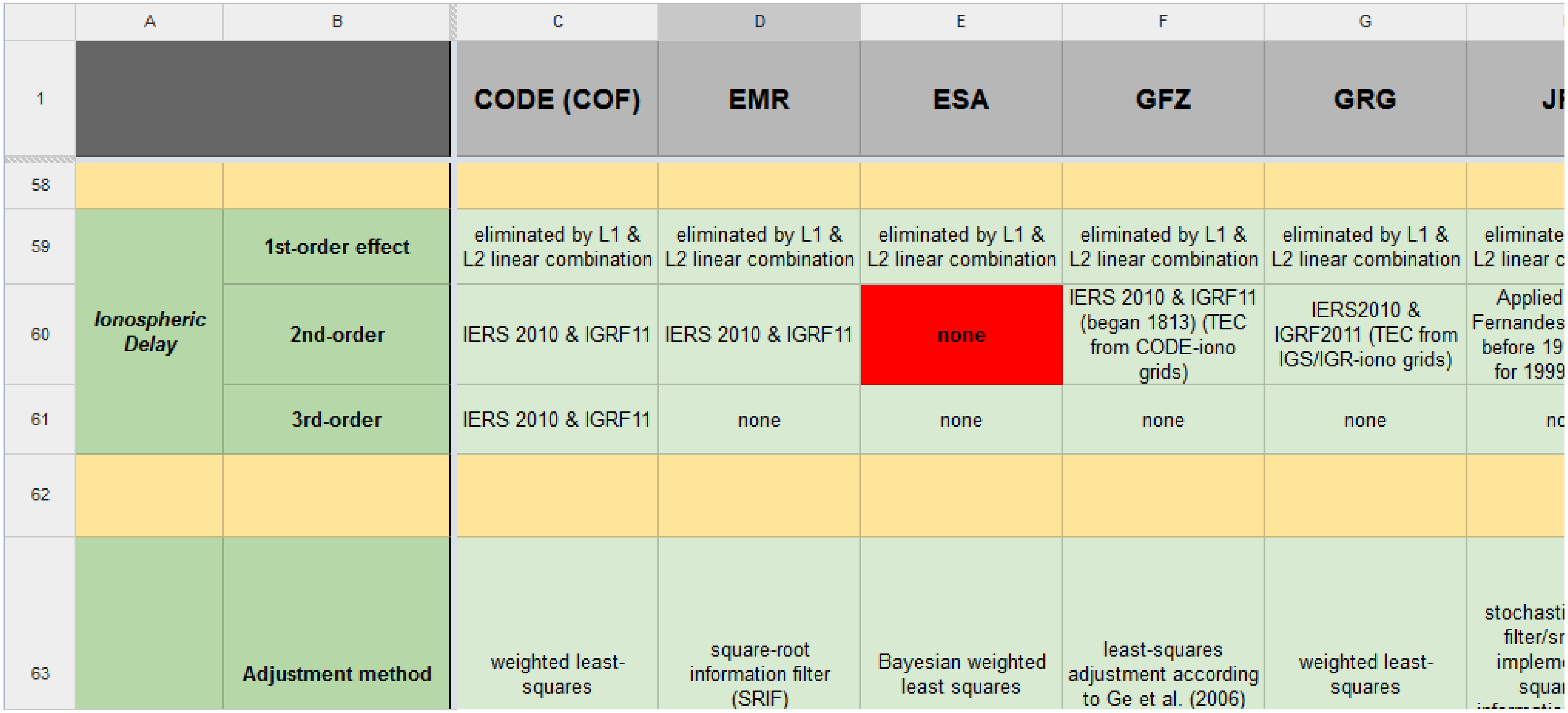
- Exchange of most important information:



	A	B	C	D	E	F	G	
1			**CODE (COF)**	**EMR**	**ESA**	**GFZ**	**GRG**	**J**
51								
52	***Tropospheric Delay***	**a priori met source & mapping coeffs?**	VMF1 mapping fnc coefficients interpolated from 6-hr grids	VMF1 mapping fnc coefficients interpolated from grids	GPT for P, T, RH	GPT2 for P, T, RH & VMF1 mapping fnc coefficients (wk 1758)	GPT2 for P, T, RH & VMF1 mapping fnc coefficients	GPT2 for GPT2 ma coeffi
53		**a priori zenith delay**	ECMWF-based ZDD	VMF1 grid files for ZDD & ZWD	ZDD & ZWD computed with Saastamoinen (1972) model	ZDD & ZWD computed with Saastamoinen (1972) model	ZDD & ZWD computed with Saastamoinen (1972) model	GF
54		**Mapping of a priori zenith delay to line-of-sight**	slant dry + wet delays mapped with VMF1_HT	slant dry + wet delays mapped with GMF	slant dry + wet delays mapped with GMF	slant dry + wet delays mapped with VMF1_HT model using GPT2 mapping fnc coeffs	slant dry + wet delays mapped with GMF	slant dr delays ma GF
55		**Mapping function used for ZD adjustment?**	VMF1_HT wet mapping fnc (VMF1W); ZWD estimated in 2-hr piece-wise linear steps for each station; loosely	GMF wet mapping fnc; ZWD estimated at each epoch as random walk with process noise = 3.0	GMF wet mapping fnc; ZWD estimated in 1-hr steps for each station	VMF1_HT wet mapping fnc (VMF1W); ZWD estimated in 1-hr steps for each	VMF1 wet mapping fnc; ZWD estimated in 2-hr steps for each station	GPT2 we fnc; ZWD at each random process n

Important is to know, what people are doing:

- Differences are indicated and discussed:



	A	B	C	D	E	F	G	
1			**CODE (COF)**	**EMR**	**ESA**	**GFZ**	**GRG**	**J**
58								
59	***Ionospheric Delay***	**1st-order effect**	eliminated by L1 & L2 linear combination	eliminated by L1 & L2 linear combination	eliminated by L1 & L2 linear combination	eliminated by L1 & L2 linear combination	eliminated by L1 & L2 linear combination	eliminate L2 linear c
60		**2nd-order**	IERS 2010 & IGRF11	IERS 2010 & IGRF11	**none**	IERS 2010 & IGRF11 (began 1813) (TEC from CODE-iono grids)	IERS2010 & IGRF2011 (TEC from IGS/IGR-iono grids)	Applied Fernandes before 19 for 1999
61		**3rd-order**	IERS 2010 & IGRF11	none	none	none	none	no
62								
63		**Adjustment method**	weighted least-squares	square-root information filter (SRIF)	Bayesian weighted least squares	least-squares adjustment according to Ge et al. (2006)	weighted least-squares	stochasti filter/sr impleme squar

Usual practice in the IGS:

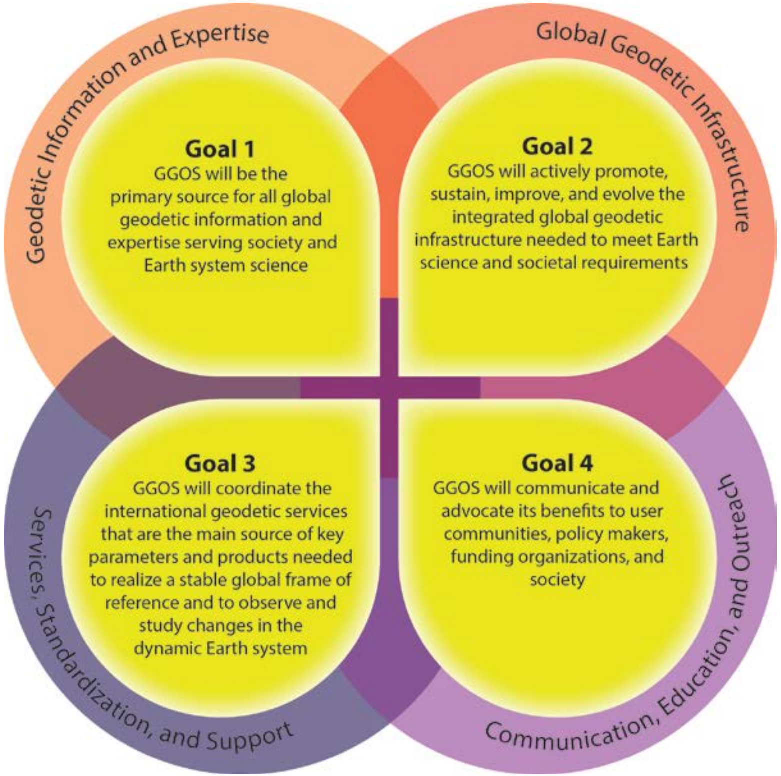
- The coordinator keeps track on the changes at all analysis centers.
- Significant differences are discussed between the analysis centers at regular meetings.
- If a model change is an improvement all oter groups become aware of this and follow the development (or adapt it).
  Keyword: «Friendly competition»

Achievements in the IGS

TUM-IAPG Expertise relevant to EGSIEM

Products & Standards

- Together with TUM-DGFI, IAPG is operating the GGOS Bureau for Products and Standards (GGOS-BPS).
- GGOS is an initaitive of IAG with 4 major goals.



Goal 1
GGOS will be the primary source for all global geodetic information and expertise serving society and Earth system science

Goal 2
GGOS will actively promote, sustain, improve, and evolve the integrated global geodetic infrastructure needed to meet Earth science and societal requirements

Goal 3
GGOS will coordinate the international geodetic services that are the main source of key parameters and products needed to realize a stable global frame of reference and to observe and study changes in the dynamic Earth system

Goal 4
GGOS will communicate and advocate its benefits to user communities, policy makers, funding organizations, and society

Products & Standards

- GGOS-BPS shall act as „**contact & coordinating point**“ regarding homogenization of standards and IAG/GGOS products.
- IAG Services shall keep their full responsibility and visibility.

Objective 3-1
Standardization

Goal 3
GGOS will coordinate the international geodetic services that are the main source of key parameters and products needed to realize a stable global frame of reference and to observe and study changes in the dynamic Earth system

Objective 3-2
Coordination and Development of IAG Services

Products & Standards

GGOS-BPS Tasks:

- Ensure consistent standards across all IAG components. „Inventory of Standards and Conventions“ (Issue 1 under review).
- Identify user needs and requirements for products.
- Initiate steps and procedures for the development of new and integrated products.
- GGOS-BPS includes GGOS-WG „Contributions to Earth SystemModelling“.

Proposal for Standards

Proposal

- Action Item (End of January):
  - GFZ, UBERN, (CSR): Review the comparison table
  - TUG, CNES, UL: Fill out the comparison table
  - UBERN: Summarize KO outcome of Standards harmonization
  - UBERN, UL, GFZ, TUG, CNES: Provide input to other processing details (parametrization, …) identified at KO

- Action Item (Mid of February):
  - UBERN: Create the EGSIEM Standards document (inspired by the GRACE Standards from GFZ/CSR) and point out commonalities/differences between individual EGSIEM ACs
  - TELECON UBERN, GFZ, TUG, CNES, UL

- Action Item (End of February):
  - UBERN, UL, GFZ, TUG, CNES: Review and Finalization of EGSIEM Standards Document