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Towards a Near Real-Time and Regional Service for EGSIEM

European Gravity Service for Improved Emergency Management

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Introduction.

One of the main objectives of the **EGSIEM** (European Gravity Service for Improved Emergency Management) project is to establish a Near-Real-Time (**NRT**) and Regional Service that aims to reduce the time delay of necessary input data and derived output gravity models to less than 5 days and to increase the time resolution of gravity models to just one day and at the same time to improve their quality towards the accuracy level of the monthly fields. This can be done by adequate regularization and constraining of solutions in terms of Bayesian estimation and **Kalman** filtering on a global scale, and by using dedicated space-localizing radial base functions for applications on a regional scale. The gravity field models of the NRT service will be used to observe and monitor European (and global) water resources and ensures wide access to high level, easy to use products. Current status, evaluations and future plans are presented.

Background.

Besides 'standard' **GFZ RL05a** monthly gravity field solutions that are generated within the frame of the GRACE Science Data System (Dahle et al 2012) also 'alternative' monthly gravity field solutions based on radial base functions (RBF) have been developed and re-analyzed. RBF project the potential of a surface layer on the Earth's sphere to an arbitrary point in external space. The relation between this layer and the GRACE satellite observations is given by Poissons Kernel (Novák 2006). In a first step, daily atmospheric and oceanic mass anomalies as well as continental hydrological variations are estimated by a Kalman filter approach that inverts observed relative acceleration differences between the GRACE twin satellites (Gruber et al. 2014). The main difference to the standard solutions is that the initial value has been estimated during the prediction step in the Kalman filter whereas it is otherwise provided by the time varying background modeling (EIGEN-6C). The differential accelerations are affected by 3rd body forces (sun, moon and other planets), the corresponding solid Earth's, atmospheric and ocean responses (tides), irregularities of the gravity field from the lithosphere and mantle density distribution (static background field) as well as from energy dissipation due to Earth's albedo, solar radiation pressure and atmospheric particle friction. Additionally, short-term atmosphere and ocean mass variations mainly caused by weather-related phenomena with durations below the gravity field estimation period (hourly till weekly) have been removed to avoid aliasing. In order to remove the later variations in the gravity field external data sources derived from surface and ocean bottom pressure records, AOD1B are used.

References

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Automatisation plan

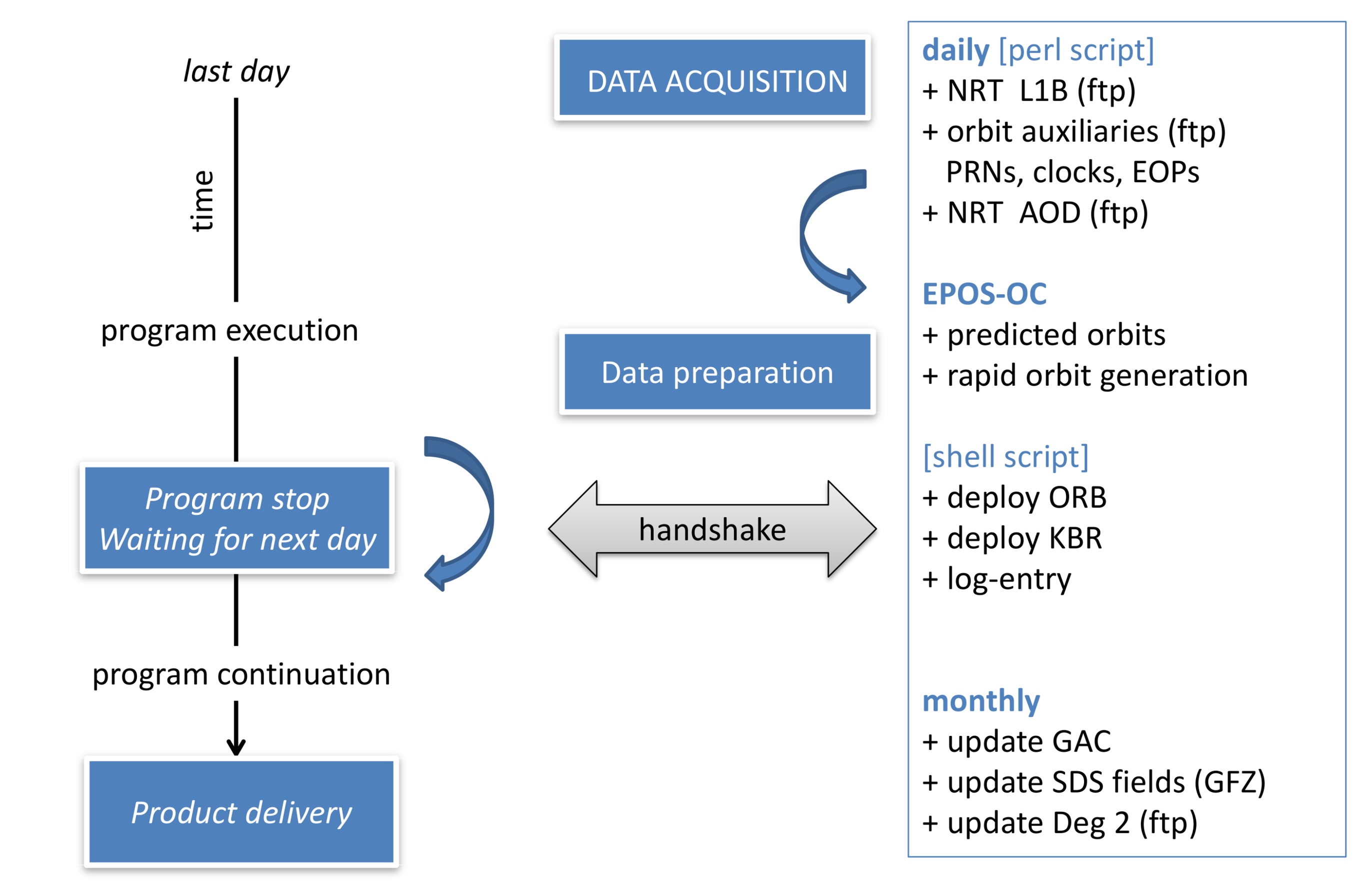

Fig. 1 shows two independent processes. On the left side is the Kalman process waiting for the corresponding data for the next day. On the right side the data acquisition and preparation, especially for the GRACE orbits is displayed. Known bottlenecks are the GPS constellation with preliminary Earth orientation data and the atmosphere and ocean de-aliasing products. From predicted orbits (same day) preliminary orbits are integrated and will trigger the Kalman process to continue.

Kalman process details

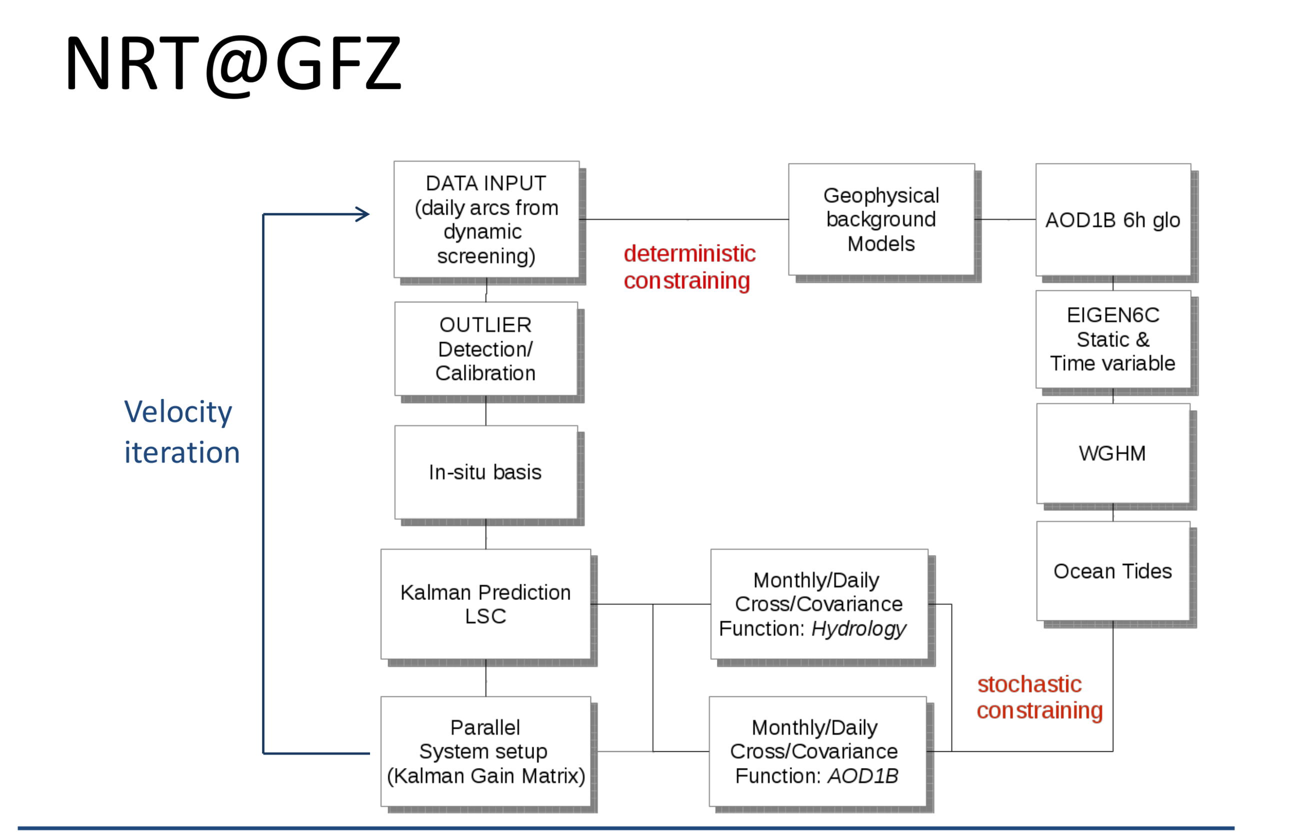

Fig 3. depicts the processing of GRACE KBRR measurements and dynamic orbits. From gravitational acceleration differences static and time variable geophysical background models are reduced leading to residual daily observations. These are then stochastically predicted (LSC) and subsequently updated by the Kalman gain. If necessary the GRACE orbits need to be iteratively re-computed.

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Functional and stochastic model

Grace observations
$$f(\rho,\dot\rho,\ddot\rho,|\delta\dot{\vec r}|) = \langle \nabla\phi(\vec r_A) - \nabla\phi(\vec r_B), \vec e_{\mathrm{LOS}}\rangle \quad (1)$$

Reproducing kernels
$$f(P) = \iint_S \phi(Q)\,\langle \delta\nabla\,\mathrm{K}(P,Q), \vec e_{\mathrm{LOS}}\rangle\,\mathrm{d}S, \quad (2)$$

Poisson's kernel
$$\mathrm{K}(P,Q) = \sum_{n=2}^{\infty}(2n+1)\left(\frac{R}{r_P}\right)^{n+1} P_n(\cos\psi), \quad (3)$$
$$Q\in S,\quad P\in\Sigma$$

Adjustment
$$\left\|\sum_{i=1}^{M} f_i(P) - \sum_{j=1}^{N}\phi_j(Q)\langle\delta\nabla\,\mathrm{K}(P,Q),\vec e_{\mathrm{LOS}}\rangle\right\|_2 \longmapsto min. \quad (4)$$

Adopted objective
$$\|vC^{-1}v\| + \|\phi D\phi\| \longmapsto min. \quad (5)$$

Cov Regularization
$$\phi(Q) = (A^{\mathrm{T}}C^{-1}A+\alpha D)^{-1}A^{\mathrm{T}}C^{-1}f(P) \quad (6)$$

Kalman-Regularization
$$\phi(Q) = \text{Kalman- Filter} \quad (7)$$

NRT Data sequence

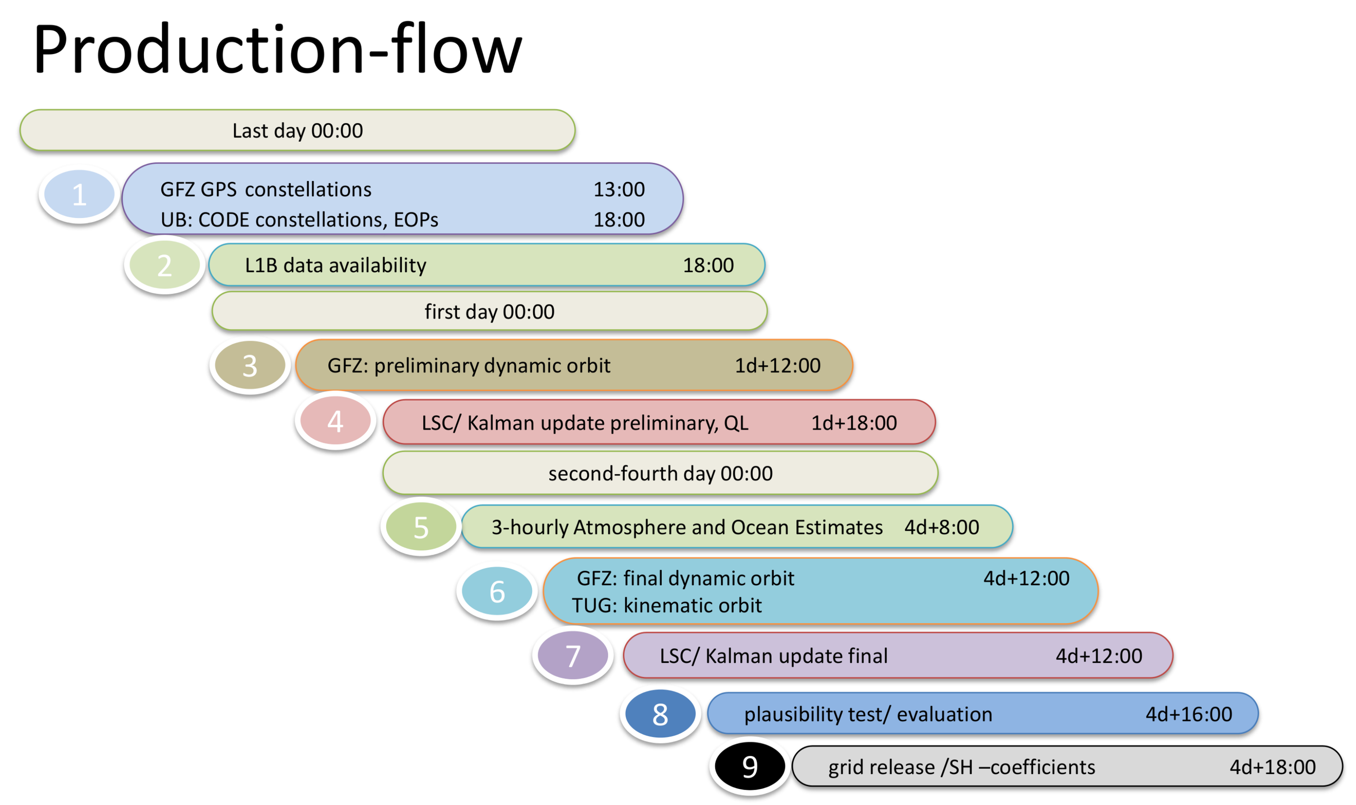

Fig. 2 shows the anticipated time-line during daily gravity field generation

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Summary.

* Higher spatial resolution through dedicated variance-covariance modeling in specific drainage systems.
* Regular tests on coherence with hydrological models, in-situ inundation volumes and river discharge time series.
* Regular comparison with surface loading variations from geodetic observations (GPS station networks).
* Very short latency for monitoring (forecasting) of extreme events.
* Constraint solutions, spectral/spatial filtering is not necessary.
* Innovative, easy accessible gravity induced mass transport products.
* Improved prediction and monitoring of climate relevant indicators.
* Improved stochastic process understanding and GRACE data calibration and modeling.
* Extendable with complementary (surface observations) or new satellite data (Laser ranging, gradiometry)

Inter-comparison with Hydrology Model WGHM

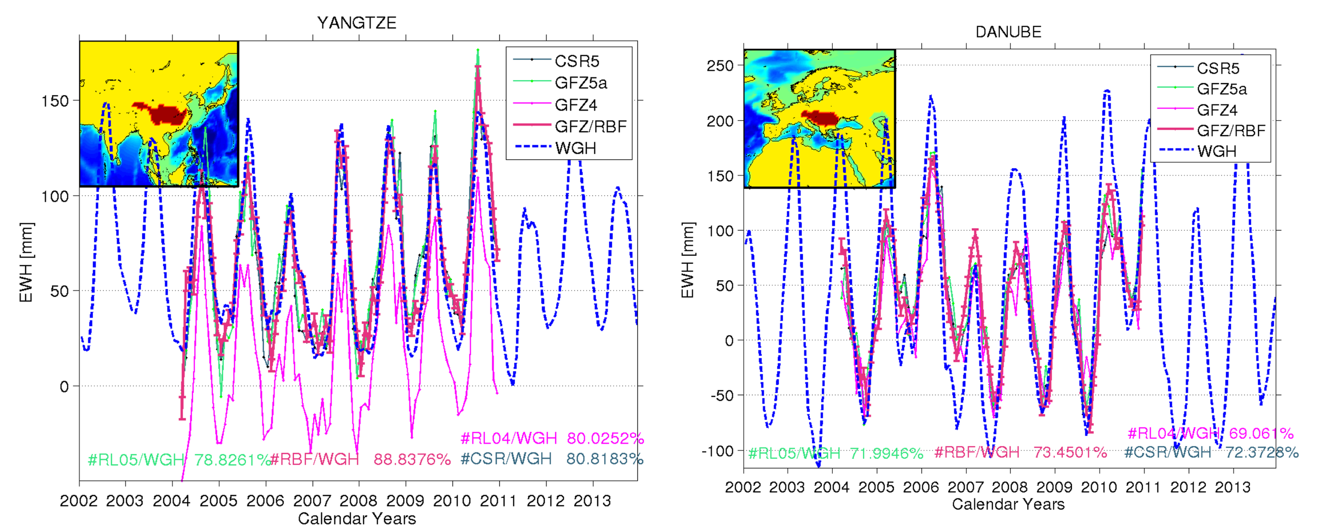

Fig. 4 shows the correspondance of global catchment basins in comparison to hydrological modeling and the coherence with other GRACE solutions. Major drainage systemsshow in general very good accordance.

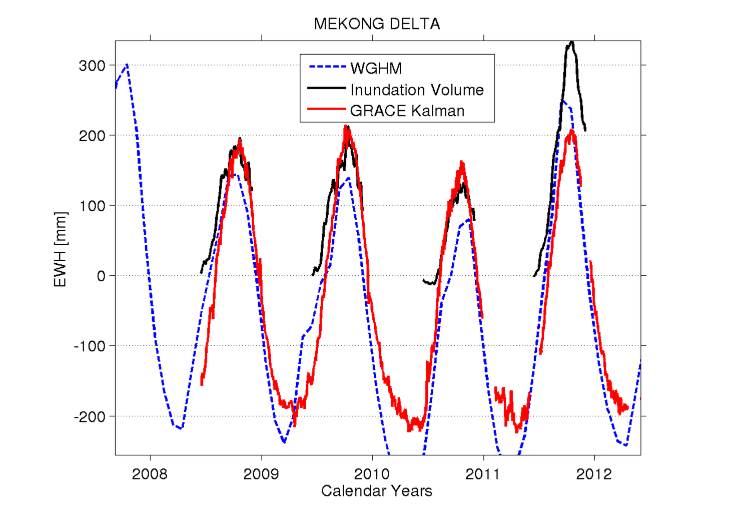

Fig. 5 Comparison to 'ground truth' inundation volumes during 2008-2011. (Dung et al. 2011)