International GNSS Service
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1 EGSiEM: Gravity Field Combination Service
The European Gravity Service for Improved Emergency Management (EGSiEM) is coordinated by the Astronomical Institute of the University of Bern (AIUB) that also provides the scientific combination service. This service aims at consistent, reliable and validated monthly gravity fields that are combined on Normal Equation (NEQ) level taking into account contributions of all associated Analysis Centers (ACs). Considered to date are GRACE inter-satellite K-band range-rate and GPS (resp. inertial orbits), but EGSiEM is currently being extended to SLR and GPS-only satellite data. EGSiEM is open to all interested processing centers of GRACE-, GPS-, or SLR-based gravity fields.

2 Common Standards
To ensure consistency of the individual contributions, EGSiEM defines common standards on:
- reference frame and orientation,
- satellite geometry,
- relativistic effects and third bodies.
The different ACs are free to use their specific approaches and parametrization and the a priori and background models of their choice of:
- ocean, solid Earth and pole tides,
- atmosphere and ocean de-aliasing (AOD).

3 File Formats
Normal equations (NEQs) are exchanged in the Solution-independent Exchange (SINEX) format:
- SOLUTION/STATISTICS,
- SOLUTION/APRIORI,
- SOLUTION/ESTIMATE,
- SOLUTION/NORMAL_EQUATION_VECTOR,
- SOLUTION/NORMAL_EQUATION_MATRIX.
Additional information on Earth radius, GM and tide system is provided in the SOLUTION/COMMENT block. Monthly gravity fields are provided in spherical harmonic coefficients in the GFC-format maintained by the International Center for Global Earth Models (ICGEM).

5 Noise Assessment
Since formal errors do not represent true noise levels, other measures have to be found for relative weighting and quality control. We assume that all contributions contain similar signal, but vary in noise. Relative weights are derived by comparison to the monthly mean, applying VCE on solution level. Independent quality control is based on anomalies (non-secular, non-seasonal variations) over the oceans or in the high-degree part of the spherical harmonics spectrum.

6 Combination on Solution Level
After quality control (tests on signal strength and outlier screening) the monthly gravity fields are first combined on solution level applying field-wise weights derived by Variance Component Estimation (VCE). The combined fields already show significant improvement in terms of the noise level over the oceans, while due to careful quality control the signal strength over the continents is maintained.

7 Combination of Normal Equations
In the final combination of NEQs, the relative weights derived by noise analysis on solution level are applied. Prior to this combination the impact of each NEQ on the combination is equalized by empirical weights based on the analysis of pair-wise combinations:

\[ (N_{\text{ref}} + \omega_i N_i) dx = b_{\text{ref}} + \omega_i b_i \]

The impact of an individual contribution on the combination is computed as the RMS of all differences between the spherical harmonic coefficients \(K_{lm}\) of the combined and the individual gravity fields:

\[ \text{RMS}_i = \sqrt{\sum_{l,m} (K_{lm}^{\text{comb}} - K_{lm}^i)^2 / n_{\text{neq}}} \]

8 Combination Results
Two years 2006 and 2007 were chosen to develop and test the combination strategy and to validate the results. In case of heterogeneous quality the combined fields reach at least the quality of the best individual contribution. In case of more homogeneous quality both, the combinations on solution level and on NEQ level, are clearly superior to the individual contributions in terms of noise. The combination on NEQ level is slightly more robust against artifacts in an individual contribution.