EGSIEM: scientific combination service for monthly gravity fields

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U. Meyer, Y. Jean, D. Arnold and A. Jäggi

Astronomical Institute
University of Bern, Bern, Switzerland

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. kinematic orbits), but EGSIEM is currently beeing extended to SLR and GPS-only satellite data. EGSIEM is open to all interested processing centers of GRACE-, GPS-, or SLR-based gravity fields.

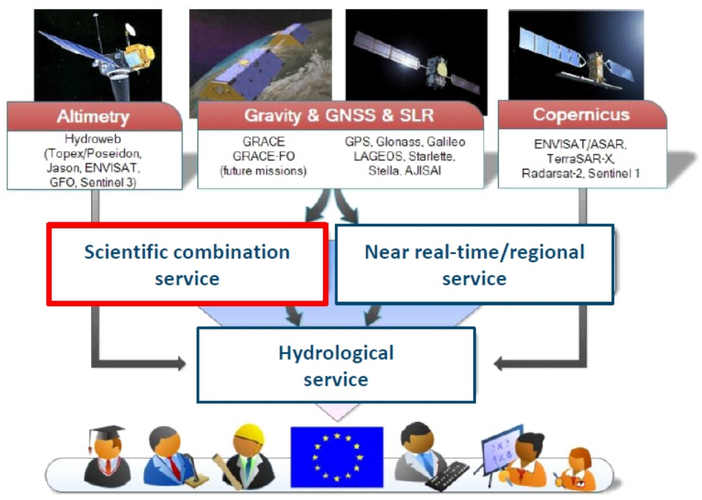


Fig. 1: EGSIEM is installing three services related to temporal gravity field variations. The main goal is early warning in case of floods to improve emergency management.

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.

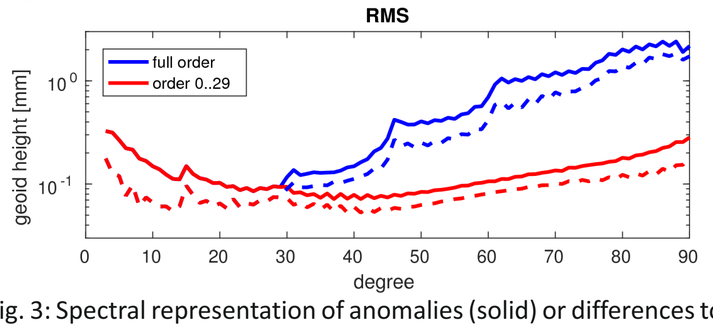


Fig. 3: Spectral representation of anomalies (solid) or differences to mean (dashed) by the RMS of monthly degree amplitudes.

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.

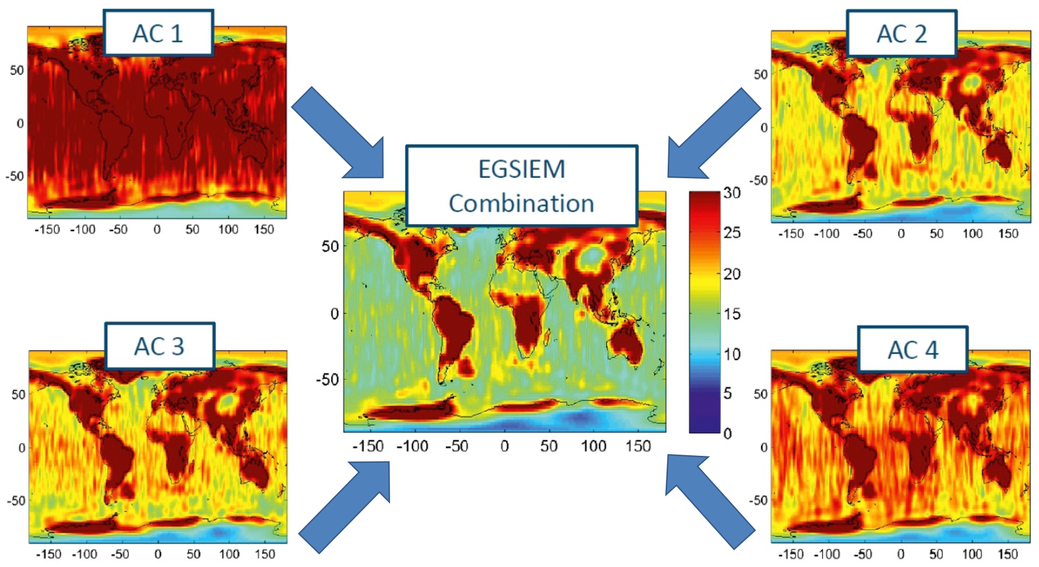


Fig. 6: Noise reduction (visible over oceans) achieved by combination of monthly gravity fields.

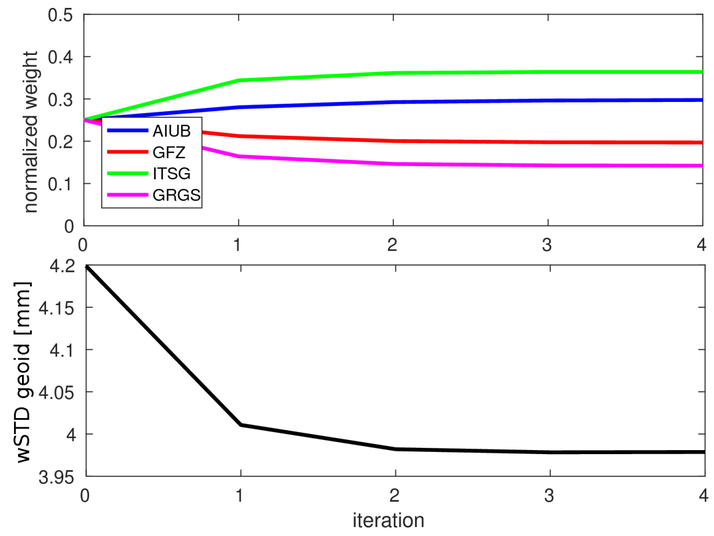


Fig. 5: Weights on solution level are derived iteratively (top). The weighted STD of anomalies over the oceans indicates noise.

4 Formal Errors

The formal errors provided by the individual ACs strongly depend on the applied noise models and generally are optimistic and very diverse.

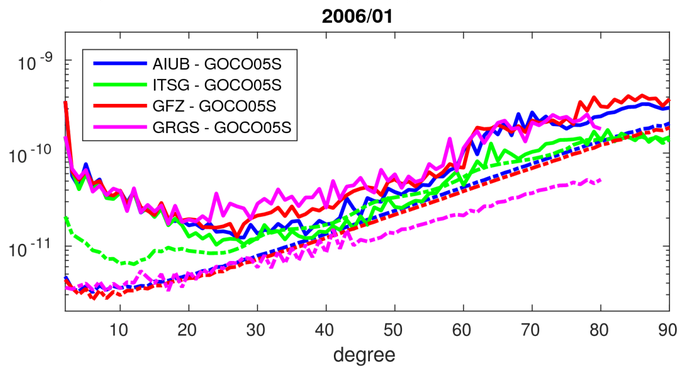
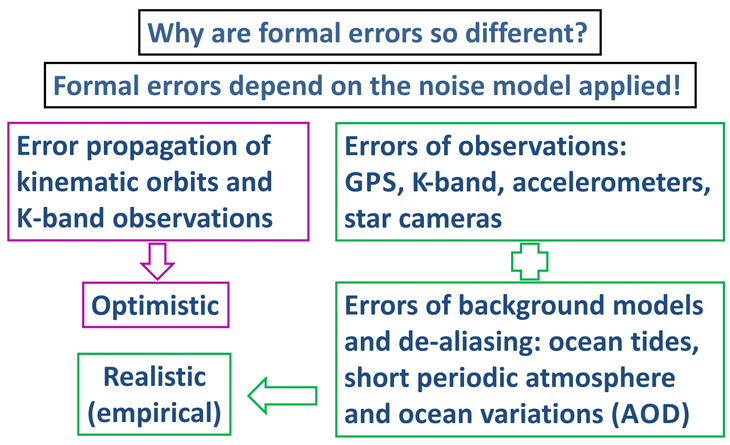


Fig. 2: Degree variances with respect to static reference GOCO05S and formal errors (dashed) of the individual contributions.



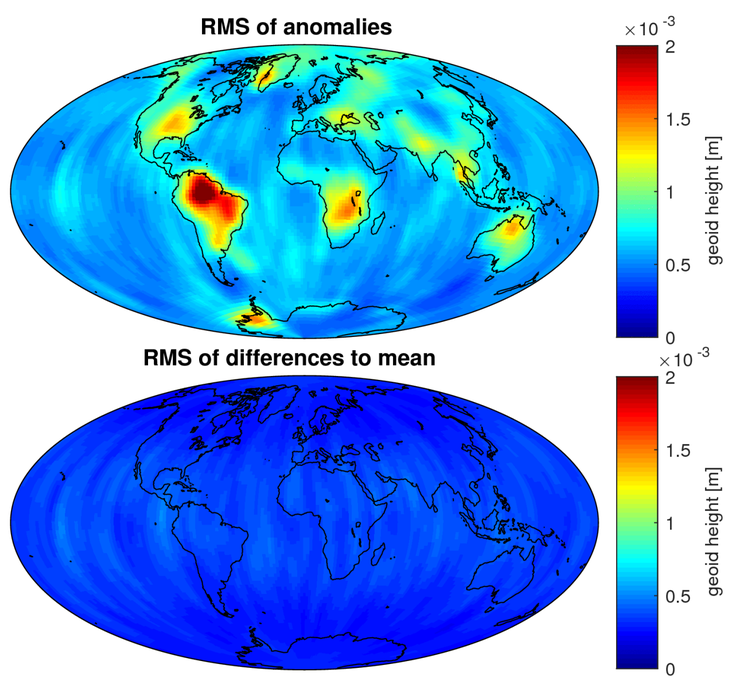


Fig. 4: Spatial distribution of non-secular, non seasonal signal (anomalies, top) or differences to the arithmetic mean (bottom).

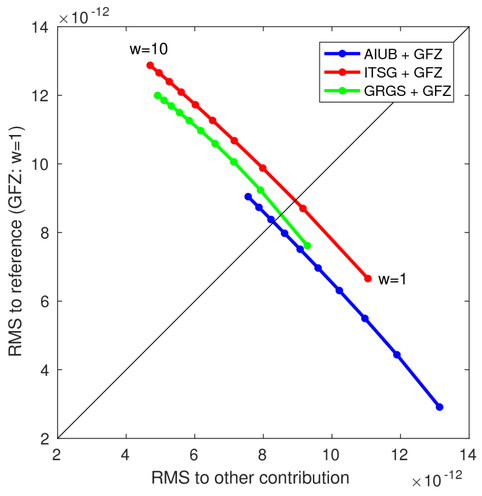
7 Combination of Normal Equations

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:

$$(\boldsymbol{N}_{\mathrm{ref}} + w_i \boldsymbol{N}_i)\boldsymbol{dx} = \boldsymbol{b}_{\mathrm{ref}} + w_i \boldsymbol{b}_i$$

The impact of an individual contribution on the combination is computed as the RMS of all differences between the spherical harmonic coefficients $K_{l,m}$ of the combined and the individual gravity fields:

$$\mathrm{RMS}_i = \sqrt{\frac{\sum_{l,m}(K^{\mathrm{comb}}_{l,m} - K^{i}_{l,m})^2}{n_{\mathrm{coef}}}}$$



Equal impact is achieved for:

$$\frac{\mathrm{RMS}_i}{\mathrm{RMS}_{\mathrm{ref}}} = 1$$

Fig. 7: Equal contribution of individual NEQs is achieved prior to final combination by empirical tests of pair-wise combinations.

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.

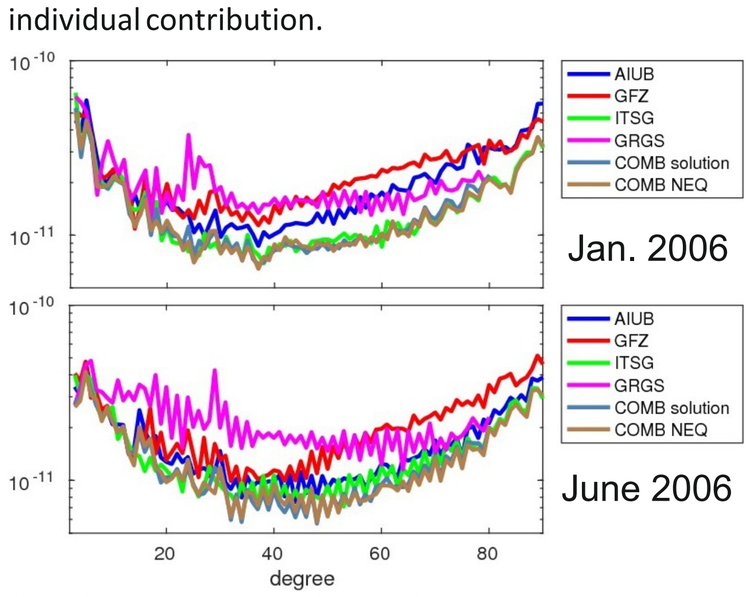


Fig. 8: Degree amplitudes of anomalies of individual contributions and combined monthly gravity fields for January 2006 (top) and June 2006 (bottom).

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