

EGSIEM combination of GRACE monthly gravity fields

- U. Meyer¹, Y. Jean¹, A. Jäggi¹, A. Susnik¹, D. Arnold¹, Ch. Dahle², T. Mayer-Gürr³, J.-M. Lemoine⁴
 - ¹ Astronomical Institute, University of Bern
 - ² GeoForschungsZentrum Posdam
 - ³ Institute for Theoretical and Satellite Geodesy, TU Graz
 - ⁴ Groupe de Recherche de Géodésie Spatiale, Toulouse

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EGSIEM Project – Three services shall be established







Scientific Combination Service





- The EGSIEM combination service provides monthly GRACE K-band gravity fields combined on solution / normal equation (NEQ) Level.
- To ensure consistency, a set of common standards for reference frame, Earth rotation, force model and satellite geometry were defined.
- EGSIEM lately was extended to also include SLR and GPS-only NEQs. Why combine results based on the same observations?

Errors in GRACE monthly gravity fields are still dominated by analysis and background model noise, not observation noise!





- Reference frame: reprocessed GPS-constellations and high-rate clock corrections.
- Earth rotation: IERS 2010
- Force model:
 - relativistic corrections (Schwarzschild, Lense-Thirring, de Sitter)
 - Sun and all planets as point masses
- Satellite geometry: common antenna reference points





Individual Contributions: AIUB



- AIUB: Celestial mechanics approach (dynamic approach relying on frequent pseudo-stochastic accelerations)
 - approx. 500000 KRR observations and
 - 500000 kinematic positions (30s) / month





Individual Contributions: ITSG



- **ITSG:** originally short arc approach, empirical noise model
 - approx. 500000 KRR observations and
 - 50000 kinematic positions (300s) / month





Individual Contributions: GFZ



- **GFZ:** dynamic approach, heavy accelerometer parametrization
 - approx. 500000 KRR observations and
 - > 2500000 GPS phase observations / month





Individual Contributions: GRGS



- **GRGS:** magic approach ... but we got free (unconstrained) normal equations and solutions for combination!
 - approx. 500000 KRR observations and
 - 500000 kinematic positions (30s) / month





Individual Contributions: U Lux



• **U Lux:** acceleration approach, still under development ...





Formal errors: 2006/01



Contains main part of signal







Combination on Solution Level

- Comparison of individual contributions
 - Signal content: river basins, Greenland, west Antarctica







Combination on Solution Level

- Comparison of individual contributions
 - Signal content: river basins, Greenland, west Antarctica
 - Noise level: weighted STD of anomalies (with respect to model: bias + trend + annual + semian.) over the oceans







- Comparison of individual contributions
 - Signal content: river basins, Greenland, west Antarctica
 - Noise level: weighted STD of anomalies (with respect to model: bias + trend + annual + semian.) over the oceans
- Rejection of biased series of gravity fields (regularized, pre-filtered)
- Screening of noisy monthly gravity fields
- Relative weights based on comparison to mean
- Iteration using Variance Component Estimation





Combination on Normal Equation Level

- To fully take into account correlations between gravity field, orbit, instrument and stochastic parameters, solutions have to be combined on normal equation level.
- **But:** different noise models make combination difficult. Relative weighting by variance factors is not possible!

$$W = S_0^2 * DOF / v^T Pv$$







	AIUB	GFZ	ITSG	COMB sol	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.45	0.22	0.33				
wSTD	7.7 mm	9.6 mm	4.7 mm				







	AIUB	GFZ	ITSG	COMB sol	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.45	0.22	0.33				
wSTD	7.7 mm	9.6 mm	4.7 mm	5.8 mm			







	AIUB	GFZ	ITSG	COMB sol	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.45	0.22	0.33				
wSTD	7.7 mm	9.6 mm	4.7 mm	5.8 mm	6.6 mm		





Individual contributions (variance factors): 2006/01







Individual contributions (equalized): 2006/01







	AIUB	GFZ	ITSG	COMB sol	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.45	0.22	0.33				
wSTD	7.7 mm	9.6 mm	4.7 mm	5.8 mm	6.6 mm	5.9 mm	







	AIUB	GFZ	ITSG	COMB sol	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.45	0.22	0.33				
wSTD	7.7 mm	9.6 mm	4.7 mm	5.8 mm	6.6 mm	5.9 mm	5.7 mm







	AIUB	GFZ	ITSG	COMB sol	COMB w * NEQ
weight	0.45	0.22	0.33		
wSTD	7.7 mm	9.6 mm	4.7 mm	5.8 mm	5.7 mm







	AIUB	GFZ	ITSG	COMB sol	COMB w * NEQ
weight	0.45	0.23	0.32		
wSTD	8.0 mm	9.8 mm	4.5 mm	5.9 mm	6.0 mm







	AIUB	GFZ	ITSG	COMB sol	COMB w * NEQ
weight	0.45	0.24	0.31		
wSTD	7.8 mm	9.6 mm	4.3 mm	5.9 mm	5.7 mm







	AIUB	GFZ	ITSG	COMB sol	COMB w * NEQ
weight	0.36	0.22	0.32		
wSTD	6.4 mm	7.7 mm	4.2 mm	4.3 mm	4.3 mm







	AIUB	GFZ	ITSG	COMB sol	COMB w * NEQ
weight	0.40	0.25	0.35		
wSTD	7.1 mm	7.5 mm	4.0 mm	5.0 mm	4.6 mm







	AIUB	GFZ	ITSG	COMB sol	COMB w * NEQ
weight	0.34	0.27	0.339		
wSTD	7.3 mm	7.5 mm	4.6 mm	5.0 mm	4.6 mm







	AIUB	GFZ	ITSG	COMB sol	COMB w * NEQ
weight	0.29	0.32	0.39		
wSTD	9.3 mm	9.1 mm	4.3 mm	5.8 mm	5.6 mm







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.29	0.19	0.38	0.14				
wSTD	5.6 mm	6.6 mm	3.5 mm	6.4 mm				







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.29	0.19	0.38	0.14				
wSTD	5.6 mm	6.6 mm	3.5 mm	6.4 mm	3.9 mm			







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.29	0.19	0.38	0.14				
wSTD	5.6 mm	6.6 mm	3.5 mm	6.4 mm	3.9 mm	4.4 mm		







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.29	0.19	0.38	0.14				
wSTD	5.6 mm	6.6 mm	3.5 mm	6.4 mm	3.9 mm	4.4 mm	4.1 mm	







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB F * NEQ	COMB NEQ	COMB w * NEQ
weight	0.29	0.19	0.38	0.14				
wSTD	5.6 mm	6.6 mm	3.5 mm	6.4 mm	3.9 mm	4.4 mm	4.1 mm	3.9 mm







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB w * NEQ
weight	0.29	0.19	0.38	0.14		
wSTD	5.6 mm	6.6 mm	3.5 mm	6.4 mm	3.9 mm	3.9 mm







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB w * NEQ
weight	0.36	0.21	0.27	0.16		
wSTD	5.6 mm	6.3 mm	3.4 mm	5.4 mm	4.1 mm	3.9 mm







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB w * NEQ
weight	0.37	0.22	0.27	0.14		
wSTD	5.3 mm	6.5 mm	3.4 mm	6.1 mm	4.0 mm	4.0 mm







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB w * NEQ
weight	0.37	0.22	0.29	0.12		
wSTD	4.4 mm	5.2 mm	3.2 mm	5.3 mm	3.3 mm	3.4 mm







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB w * NEQ
weight	0.27	0.26	0.31	0.16		
wSTD	5.0 mm	5.2 mm	3.2 mm	4.9 mm	3.5 mm	3.2 mm







I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB w * NEQ
weight	0.30	0.26	0.30	0.14		
wSTD	5.0 mm	5.2 mm	3.4 mm	5.4 mm	3.6 mm	3.4 mm







Combination is statistics, not magic -> screening (or improve individual contributions!!)

I _{max} = 80	AIUB	GFZ	ITSG	GRGS	COMB solution	COMB w * NEQ
weight	0.25	0.29	0.40	0.06		
wSTD	6.3 mm	6.1 mm	3.2 mm	10.0 mm	4.0 mm	3.8 mm





- The EGSIEM combination service is close to operational (Level-3-grids and GA...-products are still missing).
- Careful validation and screening of individual contributions => combinations are
 - robust
 - reliable
- Combined monthly gravity fields reach level of best individual contributions or outperform them.
- Combination on NEQ-level seems to be more robust against problems in individual contributions.



