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Abstract:

Geoid height information derived from GPS ellipsoidal heights and levelled orthometric / normal heights is one independent source for validating global gravity field solutions. When comparing geoid data derived from both approaches various systematic effects have to be taken into account before the results can be used for quality assessment of global models. Such systematic effects are: (1) the local height datum of levelling, (2) the reference ellipsoid used, and (3) the omission error in global models. These sources of uncertainty have to be considered during the comparison process. Dependent on the GPS-levelling data set, the reference ellipsoid and/or the levelling datum have to be harmonised with the reference system used for the global model. The omission error of the global model has to be quantified and subtracted from the GPS-levelling geoid heights before the two geoid solutions can be intercompared. The paper discusses the available data sets with respect to their information content and their reference systems. Alternative methods for estimating the omission error are presented and compared with their results. Finally the most recent gravity field solutions are compared with the GPS-levelling data sets and the results are presented.

Overview and Comparison of External Gravity Field Validation Tools:

Tool	Test Data Sets	Range of Test	Quality Parameters	Problems
Precise Orbit Determination of Geodetic and Altimeter Satellites with Variety of Orbit Parameters	Satellite Tracking Data: Laser, DORIS, PRARE, GPS, Altimetry	Long Wavelengths: Degree: 0-70 Resolution: 300-20000 km	Residuals with Respect to Tracking Data in Space and Frequency Domain; Altimeter Crossover Differences for Computed Orbits.	Independent Tracking Data; Quality of Altimeter Observations; Sensitivity of Satellites for Gravity Field; Non-gravitational Disturbances.
Comparison with Independent Geoid and Gravity Information	GPS-Levelling Geoid Heights; Point-, Mean Gravity Anomalies	Medium to Short Wavelengths: Degree: 50-250 Resolution: 80-400 km	RMS and Mean of Geoid Height and Gravity Anomalies Differences at the Points of Comparison and Slopes.	Treatment of Omission Error; Filter Model; Impact of long Wavelengths.
Analysis of Sea Surface Topography Solutions	Mean Sea Surfaces from Altimetry; Oceanographic Sea Surface Topography Solutions	Long to Short Wavelengths: Degree: 10-250 Resolution: 80-2000 km	Differences between Geodetic and Oceanographic Solutions; Test for Remaining Oceanographic Signals.	Quality of Mean Sea Surfaces and Oceanographic Sea Surface Topography Models; Filtering; Ocean Boundaries.

Estimation of Omission Error:

One of the major problems for gravity field validation by comparison to GPS-levelling derived geoid heights is the estimation of the omission error for the global model. We have implemented two methods for the estimation of the omission error. These are: (1) Using a very high degree gravity field model derived mainly from a topography/bathymetry data set and removing the high frequency part from the GPS-levelling geoid heights (e.g. GPM98A to degree and order 720 by Wenzel). (2) Filtering the GPS-levelling geoid by least squares collocation. The latter method shortly is described below.

Least Squares Collocation for Geoid Height Filtering

Least-Squares-Collocation is a prediction method interpolating unknown points out of given prediction values and a covariance function (e.g. Tscherning-Rapp, Moritz-Jekeli) as prediction criteria. When predicting with appropriate covariance functions (e.g. degree 2-60 or 61-5000), low-pass or high-pass filtering of the signal is possible. The filtered signal can then be compared with the global gravity field model. As example the filtering of the USA GPS-levelling data set based on 1125 sample points is shown on the right hand side.

Results:

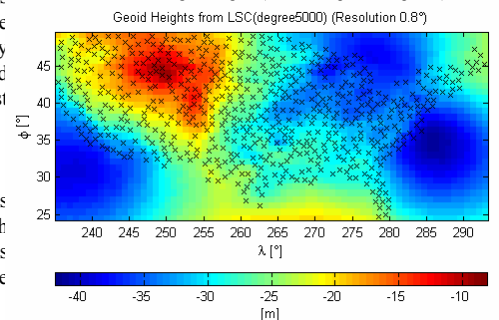
The table shows the RMS values in [m] of the differences between the GPS-levelling and the model geoid heights for different continental areas. All models were truncated at degree 60. The filtering was done by removal of the high degree signal from GPM98A (Wenzel) or alternatively by least squares collocation (collocation).

GPS-Levelling Data Set	Filter	Number Points	GRIM5-C1	TUM-2SP	EIGEN-3P	GRACE 66days (GFZ)
USA	Wenzel	5168	0.453	0.471	0.421	0.416
Canada	Wenzel	1587	0.549	0.600	0.528	0.522
Europe	Wenzel	180	0.397	0.331	0.296	0.283
Germany	Wenzel	675	0.303	0.257	0.194	0.195
Australia	Wenzel	197	0.543	0.527	0.532	0.502
Japan	Wenzel	837	0.594	0.548	0.502	0.515
USA	Collocation	1125	0.512	0.507	0.490	0.502
Germany	Collocation	532	0.384	0.425	0.440	0.433

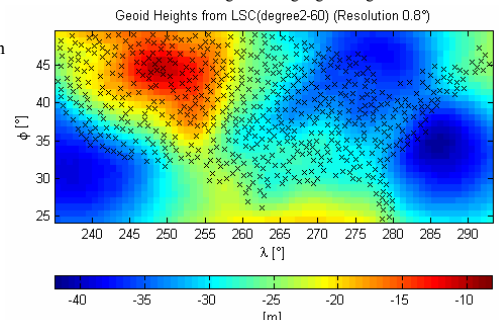
Conclusions:

- For the comparison of GPS-levelling geoid heights or observed gravity anomalies with gravity models a filter is required in order to minimise the omission error. The filter design has strong impact on the results and has to be improved.
- The high degree model filter shows expected results (GRACE best, pre-CHAMP worst).
- The filtering by collocation shows some unexpected results. Further investigations are required in order to identify the reason for this.

Prediction full geoid signal (x mark the predicted points)



Filtered long wavelength geoid signal



Filtered high frequency geoid signal

