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**Use of GOCE
TRF vertical gravity gradients
for
spherical harmonic coefficient
estimation.**



GOCE TRF Data Used

Gradient data and error-estimates in North-Oriented Frame
On Tabular Form (TRF) from 2009 – 2011 fetched from
VDA.

27965737 non-flagged rec.

Anomalous Tzz values computed using EGM96/36 without
using spherical approximation.

Mean: 0.000 E, St.dev. 0.115 E.



GOCE TRF Tzz Data Screened

605250 Data removed:

- Tzz values with absolute difference to EGM96/36 > 3 E
- Tzz values with associated standard deviations > 0.5 E

Time	Difference (E)	Error stdv
980985612	1180.518	0.576
980985613	1206.041	0.576
980985614	1231.582	0.576
980985615	-1231.594	0.576
980985616	-1206.061	0.576

Ground gravity Data Used

Ground gravity from Arctic and Ant-Arctic test-areas used in earlier investigations.

(New Ant-Arctic data-set promised for start 2012).

Data with $-82 \text{ deg.} < \text{latitude} < 82 \text{ deg}$ removed.

LSC used to predict values of 15 km altitude in order to avoid Bjerhammer-sphere problem. Error standard deviation typically 3 mgal.

Prediction using LSC of 15 km values from ground data.

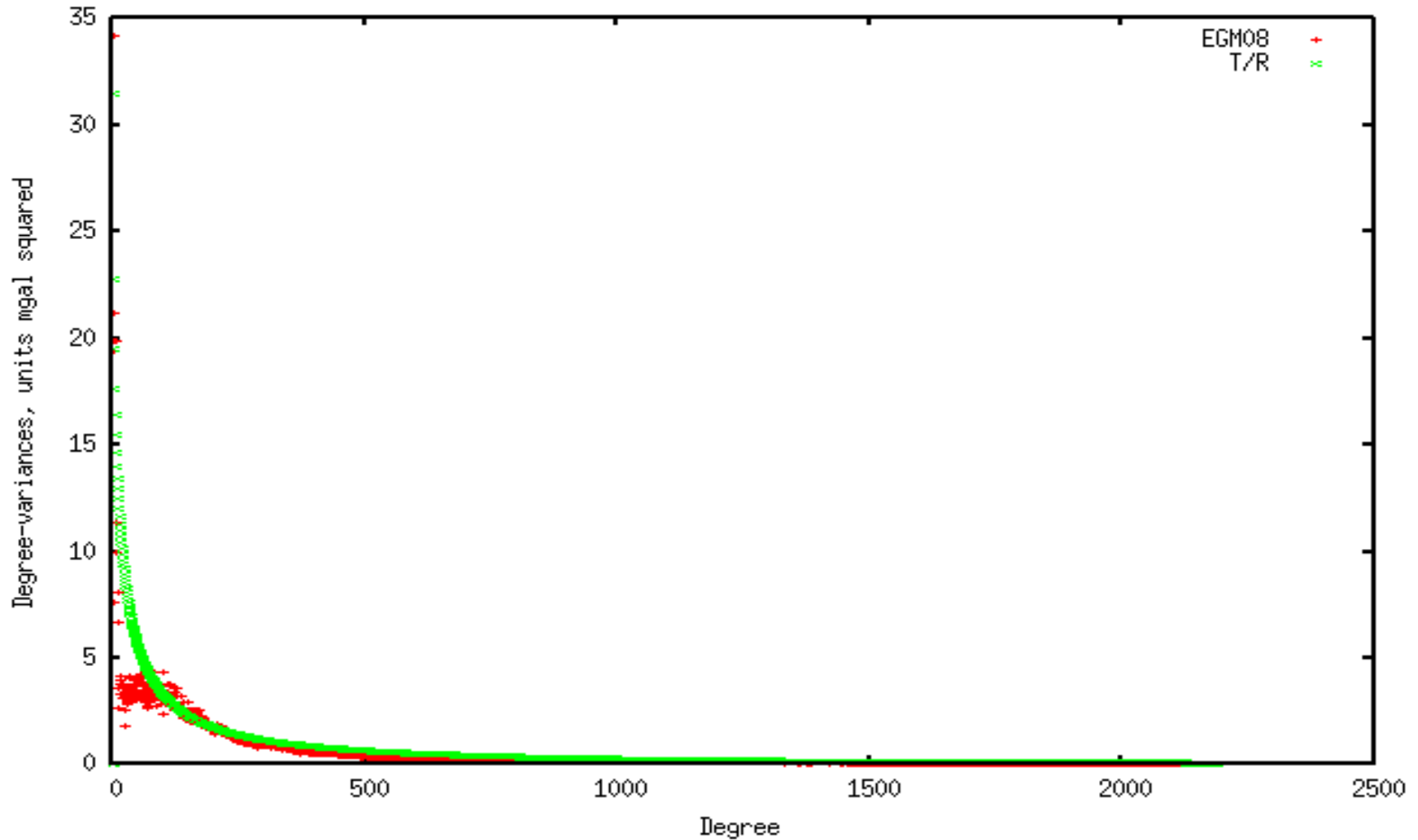
- LSC used in spherical approximation
- Data preprocessed by subtracting EGM96 to degree 36.
- Covariance functions estimated from ground data. (GRAVSOF program EMPCOV).
- Analytic model determined (COVFIT).
- LSC used for prediction and error-estimation (GEOCOL18)
- Bjerhammar-sphere problem avoided when not using spherical approximation

Prediction of coefficients using LSC.

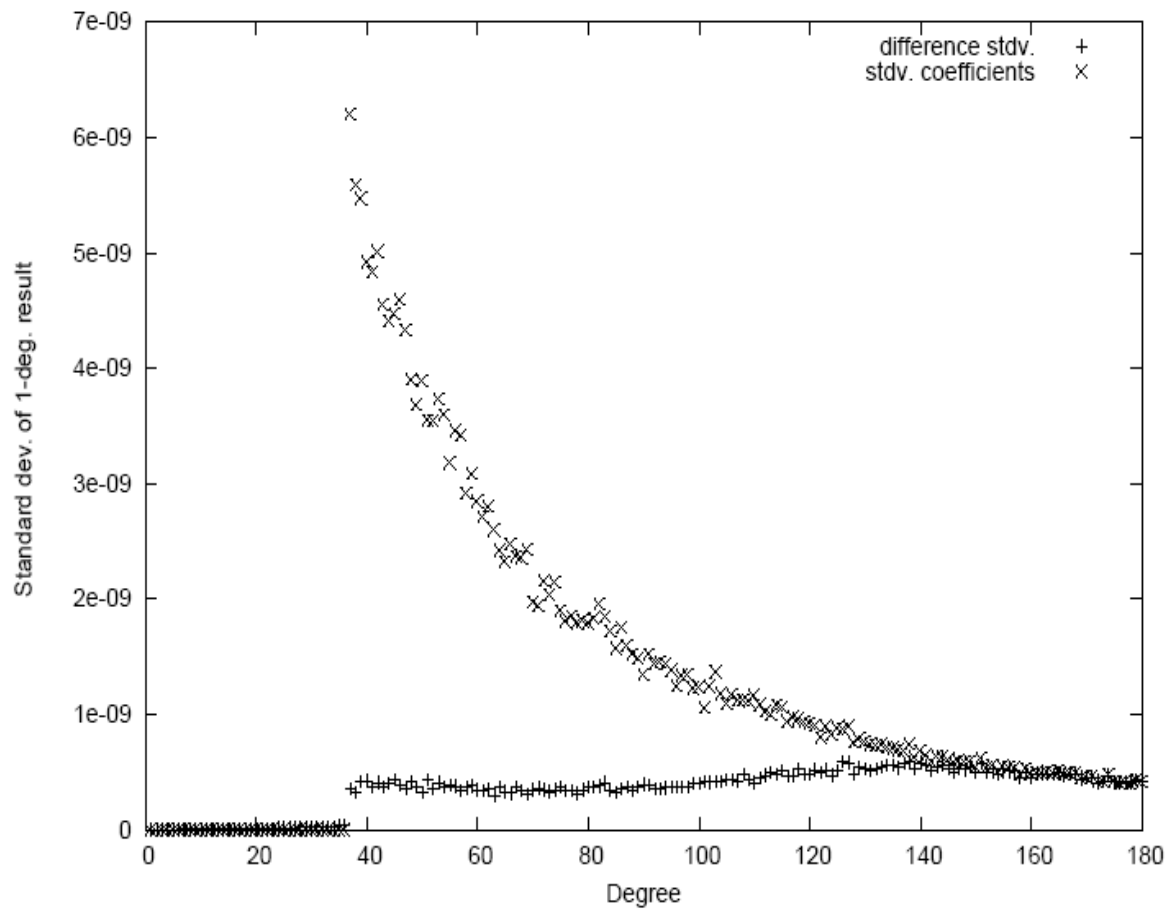
- LSC used **without** spherical approximation
- Global Analytic T/R model used (simplified)
- Data selected close to equal area grid points in order to obtain **uniform** error-estimates and avoid **singularities** close to poles. Assigned error standard deviation of 0.03 E to represent along track means
- LSC used for prediction and error-estimation
- Coefficients and error-estimates predicted
- Gravity data predicted for control purpose (**OK!**)

Analytic T/R model (1974) and EGM08 degree-variances.

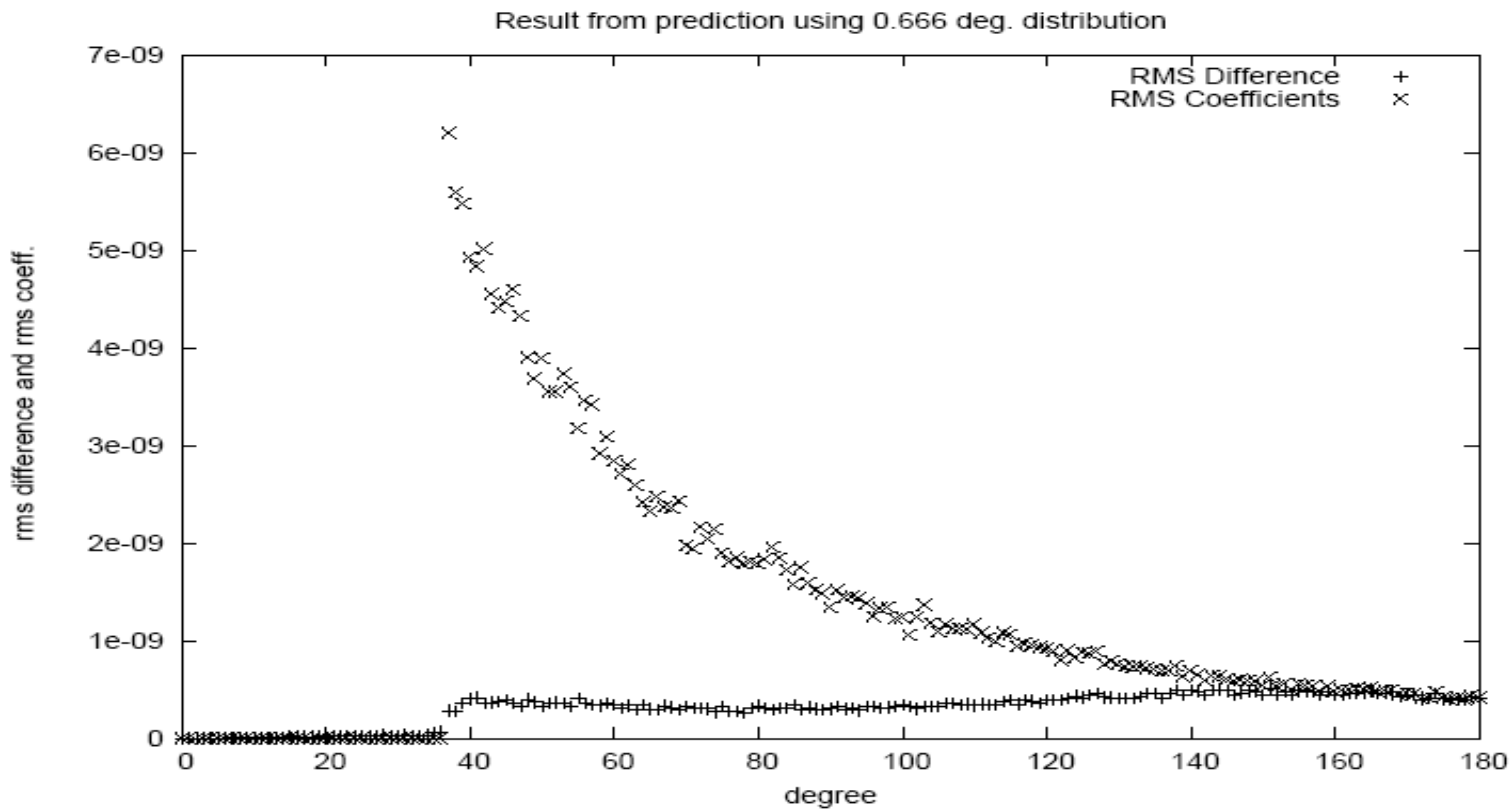
EGM08 empirical gravity anomaly degree variances and model values from the Tscherning/Rapp, 1974, model.



Prediction from approximate 1 deg. equal area values



Prediction from approximate 40' equal area values



Error-estimates

The calculation of error-estimates and correlations is time consuming, but multiprocessing helps when calculating all error-estimates simultaneously

$$e^2 = C_0 - C_P^T \bar{C}^{-1} C_P$$

Uniform (per degree) error-estimates obtained which agreed well with the calculated standard deviation of the differences (observed-EGM96) coefficients.

Coefficients and Error-estimates $C(100,100)*1.0E-8$

Model	Value	Error
EGM96	0.111	0.036
EGM08	0.100	0.012
GCF TIM2	0.105	0.015
LSC 1 deg. 41219 obs	0.120	0.054
LSC 0.5 deg 164212 obs	?	?

Possible improvements (I)

- Use of denser "grid"
- Solve for track biases
- Use of more gradients
- Use new data from Antarctica
- Use ground gravity where GOCE data has gaps, (if available)
- Represent data as along-track filtered values.

Possible improvements (II)

- Use of more sophisticated data-selection procedure
- Reduce computational time by GRID computing
- Use of EGG_NOM_2 gradients (and quaternions)
- Use of error-covariances
- Use remote-restore of topography/bathymetry

Conclusion

- The use of multiprocessing has enabled the use of LSC for coefficient calculation using large data-sets
- LSC with GOCE gradient data enables the direct computation of an EGM and its error-covariances.
- The GOCE TRF product has as high quality as shown by comparing coefficients computed using the data with existing models.