ERS Orbit Determination and Gravity Field Model Tailoring: *Recent Developments*

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Summary

The aim of the poster is to give an update on the recent status of ERS precise orbit determination (POD).

Highlights:

- DUT/DEOS developed a new ERS-tailored gravity field model: DGM-E09.
- Reduction of average crossover height differences, both of single (ERS-ERS) and dual (ERS-TOPEX) crossovers, underlines contribution of gravity model to orbit accuracy.
- DGM-E09 compares favourably with other ERS-tailored models: DGM-E04 and TEG3P. Differences between these models are marginal.
- Both DGM-E09 and TEG3P perform significantly better than general-purpose models JGM-3 and EGM96; also much better than the gravity model used for the official ERS orbits provided by ESA (D-PAF).
- Quality assessment based on tracking data residuals provided by the POD shows that tracking data has little effect on orbit accuracy.
- Data set of crossovers in ice covered North Pole region provides fully independent quality assessment.

Recent gravity field models

Year	Institute	Model	Description
1993	NASA+CSR	JGM-3	General-purpose solution, but "tailored" to TOPEX. Large geographically correlated orbit errors, seen in average crossover height differences.
1994	GFZ	PGM055	ERS-tailored version of GRIM4. Performs worse than JGM-3.
1996	DUT/DEOS	DGM-E04	Based on JGM-3. Tailored to ERS by minimisation of average crossover height differences. Significant improvement over JGM-3.
1996	NIMA+NASA	EGM96	General-purpose model based on satellite tracking and surface gravity. For ERS, not much better than JGM-3, worse than DGM-E04.
1996	UT/CSR	TEG-3	Multi-satellite solution with similar performance as EGM96.
1998	UT/CSR	TEG-3P	Based on TEG-3. Tailored to ERS using PRARE tracking residuals.
1999	DUT/DEOS	DGM-E09	Based on EGM96. Tailored to ERS by minimisation of average crossover height differences, SLR and PRARE residuals. Improvement over DGM-E04: lower tracking residuals.

NASA = Goddard Space Flight Center; GFZ = GeoForschungsZentrum;
NIMA = National Imagery and Mapping Agency; UT/CSR = Univ. Texas at Austin, Center for Space Research.

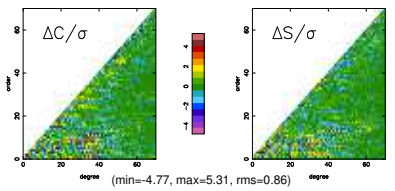
A new gravity field model (DGM-E09) was constructed starting from the general-purpose gravity model EGM96 by adding observation equations for average crossover height difference (ERS-ERS and ERS-TOPEX), SLR and PRARE to its normal matrix. All coefficients up to 70×70 were adjusted.

Although coefficient adjustments are small, the effects on the rms residuals of the SLR and PRARE tracking data is significant.

Gravity Model	Data Used	SLR (cm)	PRARE (cm)	PRARE (mm/s)	Xovers (cm)
EGM96	SLR/Xover	9.41			7.90
	SLR/PRARE	8.10	7.03	0.43	8.58*
	SLR/Xover/PRARE	8.38	7.22	0.46	8.09
DGM-E09	SLR/Xover	5.65			6.51
	SLR/PRARE	6.46	5.61	0.34	6.64*
	SLR/Xover/PRARE	6.48	5.53	0.34	6.29

* Xovers not used in POD

Normalised gravity field coefficient adjustments (DGM-E09)



(min=-4.77, max=5.31, rms=0.86)

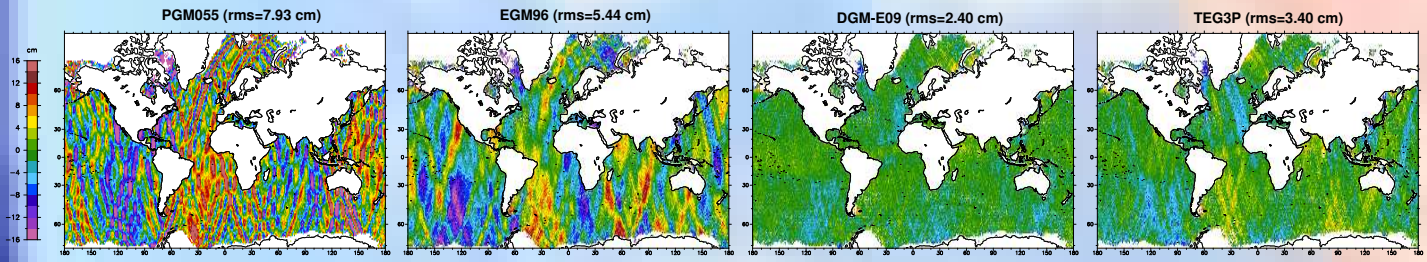
After POD we look at the rms crossover height differences over time periods longer than the POD arcs to analyse the orbit stability. For single (ERS-ERS) crossovers the maximum time difference between ascending and descending passes is 17.5 days. For dual (ERS-TOPEX) crossovers this is 5.0 days.

Gravity Model	Data Used	Single Rms	Dual Mean	Dual Std
EGM96	SLR/Xover	10.04	5.42	8.08
	SLR/PRARE	10.60	5.09	8.40
	SLR/Xover/PRARE	10.10	5.08	8.16
DGM-E09	SLR/Xover	8.51	5.56	7.19
	SLR/PRARE	8.96	5.24	7.49
	SLR/Xover/PRARE	8.59	5.23	7.30
DGM-E04	SLR/Xover	8.73	4.98	7.46
TEG-3P (CSR)	SLR/PRARE	9.47	5.09	7.74
PGM055 (GFZ)	SLR/PRARE	12.02	4.05	9.51

(Rms, mean and standard deviation of crossovers in cm)

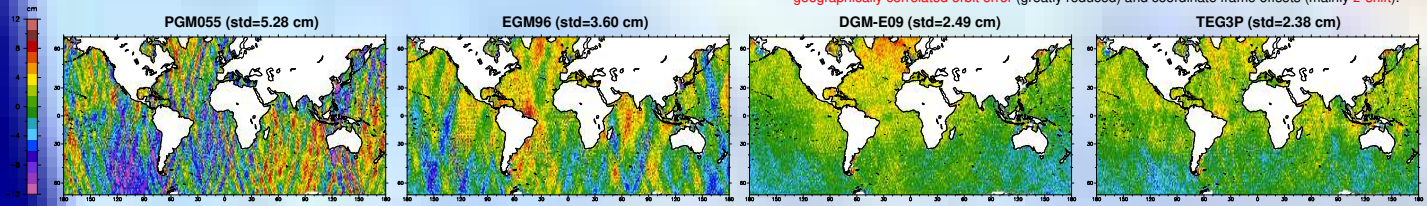
Geographically anti-correlated orbit error (average of single crossovers)

The average of the ERS crossover height differences mainly reflect gravity-induced differences in radial orbit error on crossing tracks. This is twice the geographically anti-correlated orbit error.



Geographically correlated orbit error (average of dual crossovers)

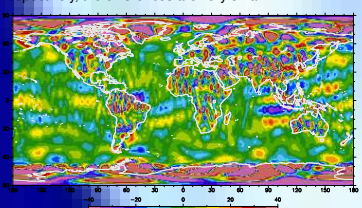
The average of the ERS-TOPEX crossover height differences mainly reflect gravity-induced errors in the ERS orbits, assuming TOPEX orbit errors are much smaller. This a combination of the geographically correlated orbit error (greatly reduced) and coordinate frame offsets (mainly *z*-shift).



Geoid model and radial orbit differences

When the gravity model adjustment (DGM-E09 minus EGM96) is expressed in terms of geoid model differences, we obtain the figure below. Note that adjustments are mainly over areas with few surface gravity data or altimeter data: North and South polar regions.

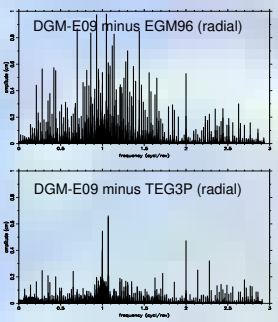
Spectra of radial orbit differences are shown to the right. Although TEG3P and DGM-E09 orbits are determined completely independently at UT/CSR and DUT/DEOS, respectively, the differences are very small.



DGM-E09 minus EGM96 (geoid)

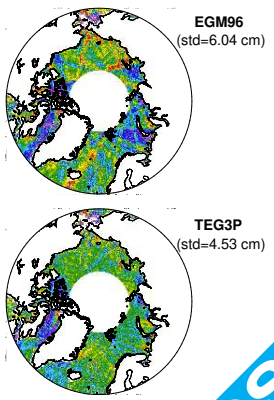
Orbit difference	Along	Cross	Radial
DGM-E09 - EGM96	13.10	10.17	4.04
DGM-E09 - TEG3P	12.21	9.65	2.87

(Rms values in cm)



Average sea-ice crossovers

Altimeter wave forms over the Arctic regions have been processed by a sea-ice algorithm at MSSL. The crossovers over mixed ocean and sea-ice are more noisy, but a stable average can be determined. This data set is unique and provides independent validation of the orbit error reduction.



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