EIGEN-5C:

The new GeoForschungsZentrum Potsdam / Groupe de Recherche de Géodésie Spatiale combined gravity field model

C. Förste[1], F. Flechtner[2], R. Stubenvoll[1], M. Rothacher[1], J. Kusche[1], H. Neumayer[2], R. Biancale[3], J.-M. Lemoine[3], F. Barthelmes[1], S. Bruinsma[3], R. König[2] and C. Dahle[2]

[1]GeoForschungsZentrum Potsdam, Dept. 1 ‘Geodesy and Remote Sensing’,Telegrafenberg, D-14473 Potsdam, Germany, e-mail: foer@gfz-potsdam.de, fax: ++49 331 288 1169

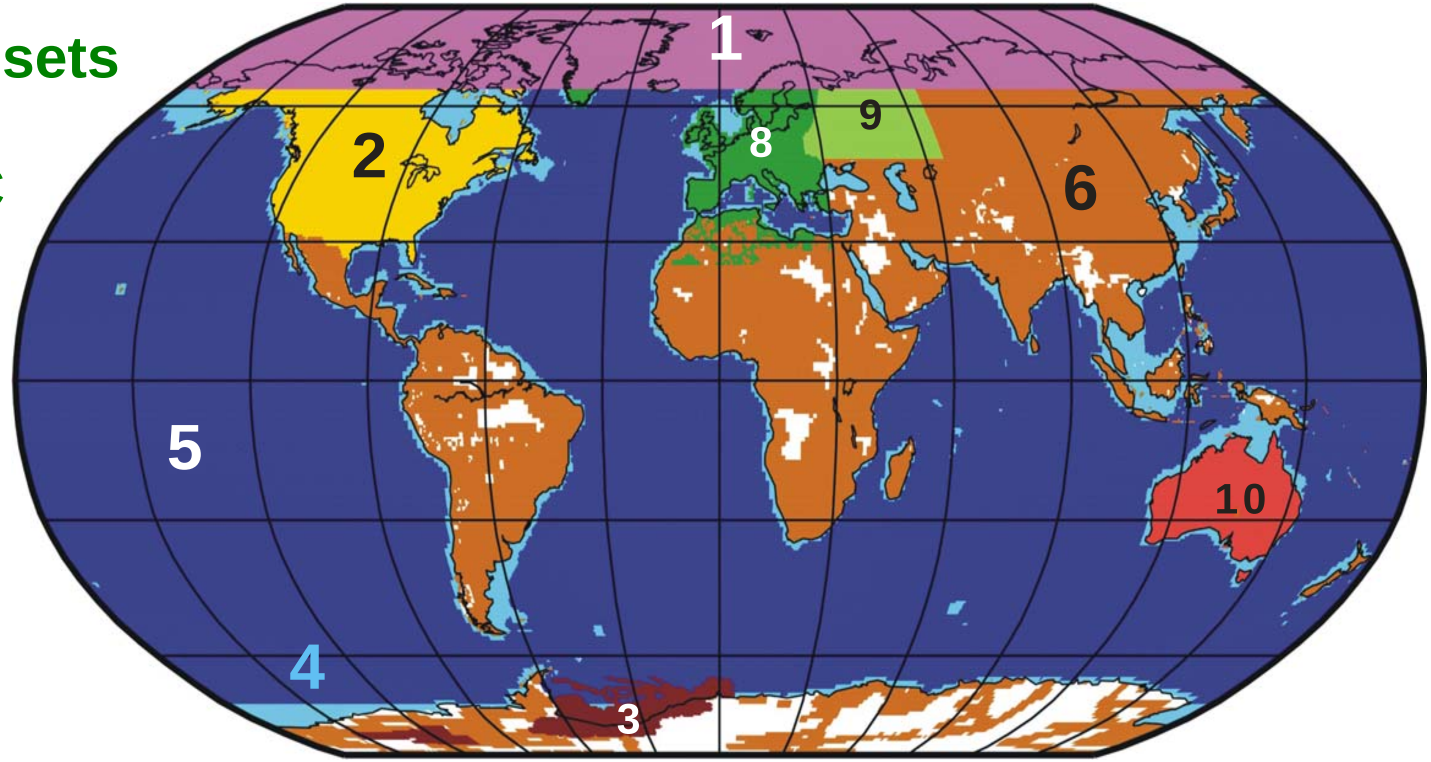
[2]GeoForschungsZentrum Potsdam, Department 1 ‘Geodesy and Remote Sensing’, c/o DLR Oberpfaffenhofen, D-82234 Weßling, Germany, e-mail: flechtne@gfz-potsdam.de, fax: ++49 331 288 1169

[3]Groupe de Recherche de Geodesie Spatiale (18, avenue Edouard Belin, F-31055 Toulouse, France, e-mail: richard.biancale@cnes.fr, fax: ++33 5 61 253098)

Overview over the GFZ/CNES combined gravity field models released during the last years

		EIGEN-CG01C	EIGEN-CG03C	EIGEN-GL04C	EIGEN-5C
Released:		May 2004	March 2005	March 2006	April 2008
Resolution:		360 x 360	360 x 360	360 x 360	360 x 360
Main differences:					
Satellite data	CHAMP	**33 months:** 10/2000 - 06/2003		./.	
	GRACE	**200 days:** 04/2002 - 11/2003	**16 months:** 02/2003 - 07/2004	**30 months:** 02/2003 – 07/2005	**54 months:** 08/2002-01/2007
	LAGEOS	./.	./.	**24 months:** 02/2003 – 02/2005	**14 years:** 1993 - 2006
Ocean data (direct altimetry)		CLS01 sea surface heights		GFZ mean sea surface heights	
Maximum degree of the the full normal matrix		140	140	179	280
Overlapping range [deg] between satellite and terrestrial data:		70 … 109	70 …120	70 …115	70 … 150
Terrestrial data: Grid size for the full normal equations		1° x 1°	1° x 1°	30‘ x 30‘	30‘ x 30‘
Remarks:				including the latest **ArcGP** data (Forsberg 2006)	
					New data of **Europe** and **Australia**

Surface data sets used for EIGEN-5C



(1) Arctic Gravity Project (ArcGP) gravity anomalies (Forsberg 2006), for regions of latitude > 64°,resolution 5' x 5'
(2) NRCan gravity anomalies (Véronneau 2003), resolution 2' x 2'
(3) AWI (Studinger 1988) and LDO (Bell et al., 1999) gravity anomalies resolution higher than 5' x 5'
(4) NGA altimetric gravity anomalies for regions in the oceans (and adjacent seas) which Are not covered by the GFZ-geoid, resolution 30' x 30', including standard deviations,
(5) Marine geoid undulations from GFZ MSSH (resolution 2' x 2') minus ECCO sea surface topography
(6) NGA terrestrial gravity anomalies (if not covered by data sets 1 to 3), resolution 30' x 30'
(7) NGA ship-borne gravity anomalies over water depths less than 2000 m, resolution 1° x 1°
(8) Gravity anomalies of Europe, resolution 15' x 15' (H. Denker, IfE Hannover, 2007)
(9) Gravity anomalies of East Europe, resolution 30' x 30' (H. Denker, IfE Hannover, 2007)
(10) Gravity Anomaly data of the Australian Region, point data, resolution higher than 5' x 5'

The NGA data sets (Kenyon, Pavlis 1997) are those already incorporated in the EGM96 solution. Data gaps were filled with the satellite-only model EIGEN-5S (white areas)

Combination scheme of EIGEN-5C

<u>contribution to the solution</u>, full normal matrix:

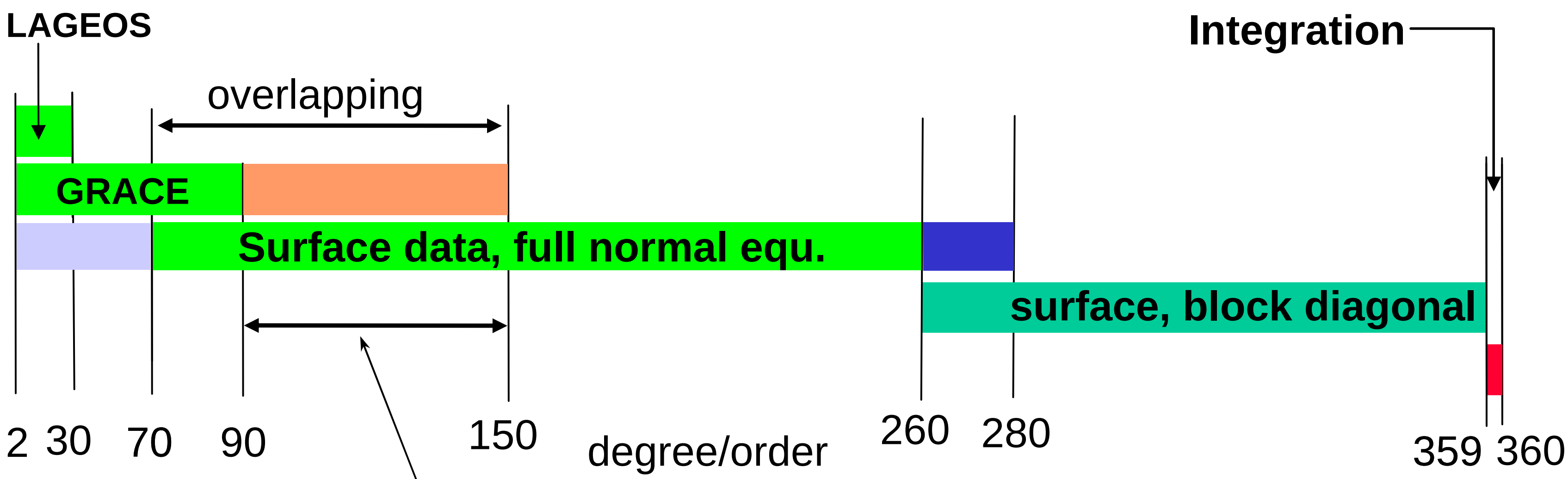
kept separately and bound together with the surface data using constraints):**

kept separately (reduced from the full normal matrix):

not used (low-pass filtered in order to avoid truncation errors) :

<u>contribution to the solution</u>, block diagonal matrix:

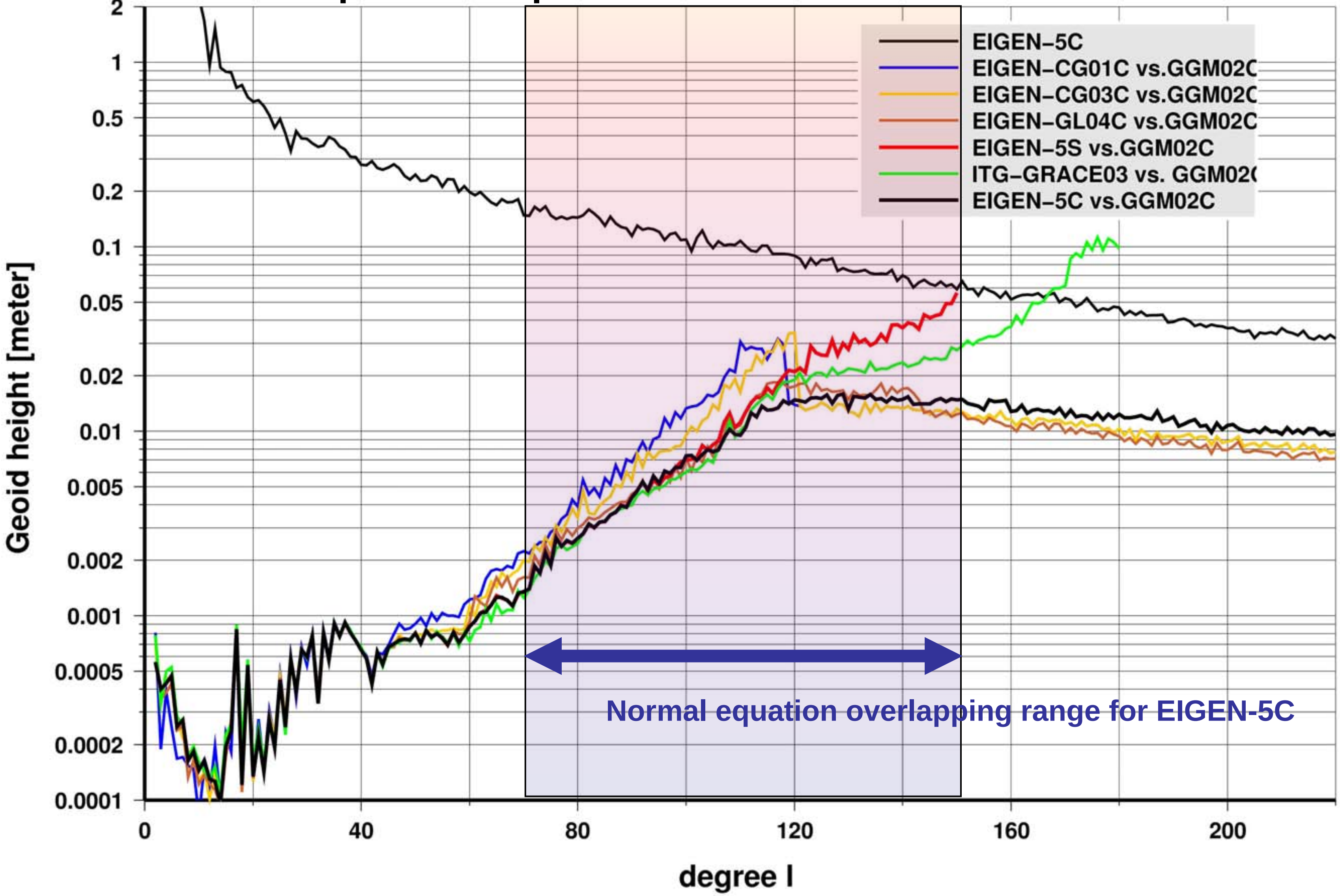
<u>contribution to the solution</u>, numerical integration:



**) constraints (pseudo observations), applied between degree 90 and 150:

$$C/S_{n,m,\text{Surface}} - C/S_{n,m,\text{GRACE + LAG.}} = 0 \pm \sigma \qquad \sigma = 0.8696 \cdot 10^{10} \cdot e^{\frac{l-90}{11.8}}$$

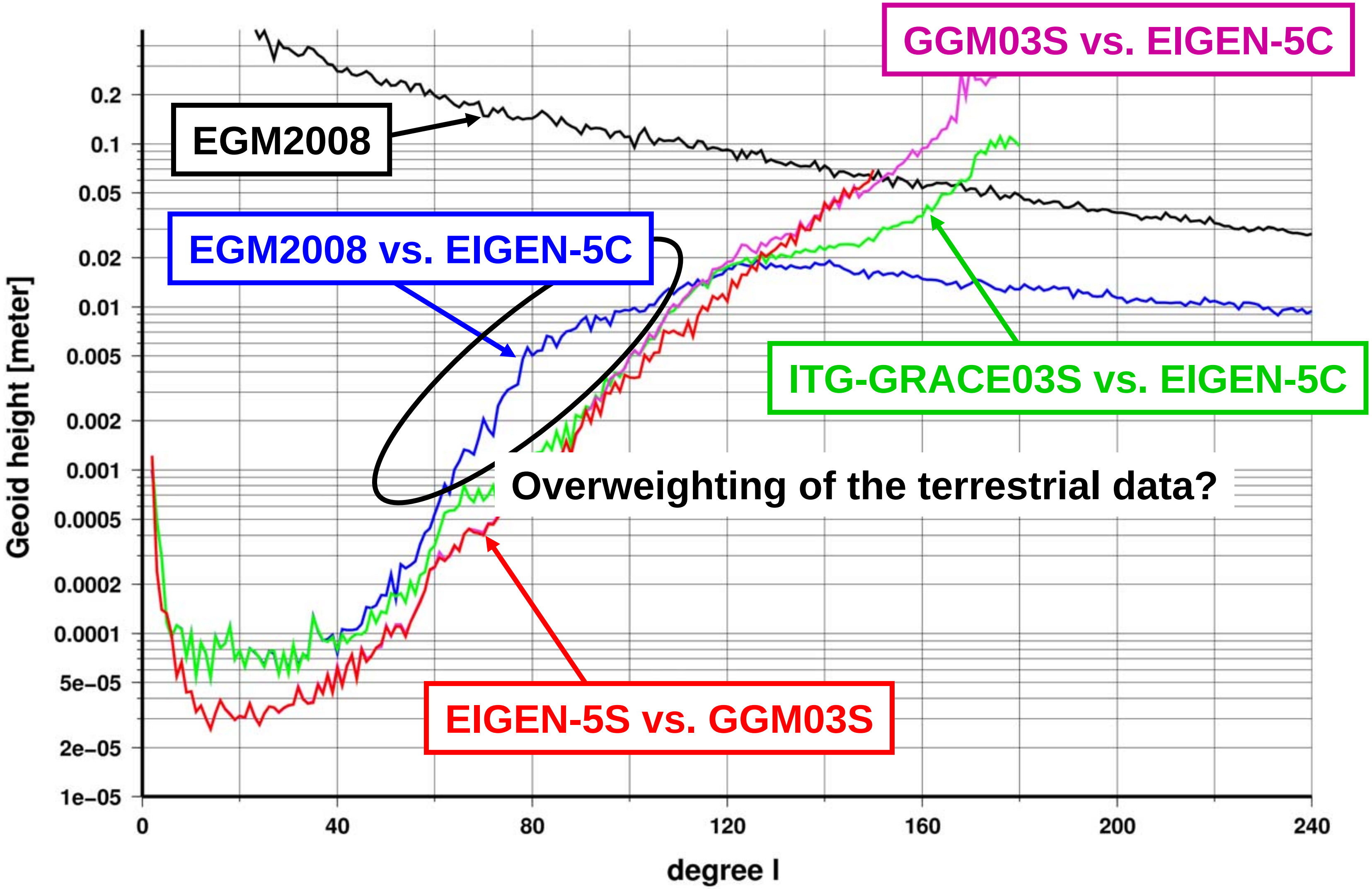
EIGEN-5C: Degree variances (in terms of geoid heights) in comparison to previous EIGEN-models



GFZ Helmholtz Centre POTSDAM

Abstract Nº 032

GRGS Groupe de Recherches de Géodésie Spatiale



EIGEN-5C: Degree variances (in terms of geoid heights) in comparison to other current models including EGM2008

Orbit adjustment tests (1): CHAMP and GRACE

SLR residuals (cm) after an orbit determination based on GPS (CHAMP, GRACE) and K-Band Range-Rate (GRACE) data
The SLR data were not included for the orbit adjustment!
Data: **three 1.5 day arcs** per satellite,
Included SLR normal points: GRACE: **592** CHAMP: **358**

best orbit fit

Satellite	truncation	GGM02C	GGM03S	ITG-GRACE03S	EGM2008	EIGEN-GL04C	EIGEN-5S	EIGEN-5C
CHAMP	120 x 120	5.32	5.45	5.38	5.51	5.44	5.56	5.59
	150 x 150	5.19	5.44	5.30	5.46	5.41	5.58	5.52
GRACE	120 x 120	5.50	5.28	5.39	5.46	5.25	5.16	5.15
	150 x 150	5.54	5.27	5.38	5.43	5.24	5.19	5.14

Orbit adjustment tests (2): SLR- and other satellites

Mean RMS: SLR and PRARE in cm, PRARE-Doppler and DORIS in mm/sec
All gravity fields truncated to 120x120,

best orbit fit

Satellite	Data #arcs	Data Typ	GGM02C	GGM03S	EIGEN-GL04C	ITG-GR03S	EGM2008	EIGEN-5S	EIGEN-5C
GFZ-1	5x3 days	SLR	14.31	13.86	13.78	14.11	14.67	13.78	14.10
STELLA	5x3 days	SLR	3.24	2.91	2.97	3.01	2.97	2.92	2.92
STARLETTE	5x3 days	SLR	2.45	2.81	2.56	2.57	2.56	2.53	2.53
AJISAI	5x3 days	SLR	3.18	3.37	3.16	3.15	3.19	3.15	3.15
LAGEOS-1	5x6 days	SLR	1.13	1.03	1.13	1.13	1.15	1.01	1.01
LAGEOS-2	5x6 days	SLR	1.05	1.02	1.05	1.05	1.05	1.02	1.02
ERS-2	6x6 days	SLR	5.86	5.34	5.34	5.34	5.35	5.29	5.29
		PRARE	3.86	3.54	3.56	3.55	3.58	3.54	3.54
		PDO	0.371	0.343	0.346	0.344	0.346	0.343	0.343
ENVISAT	7x4…8 days	SLR	4.30	4.27	4.38	4.20	4.20	4.48	4.49
		DORIS	0.495	0.495	0.496	0.495	0.495	0.496	0.496
WESTPAC	5x6 days	SLR	4.21	4.09	3.97	3.98	3.97	4.12	4.12
JASON		SLR	1.89	1.83	1.88	1.87	1.89	1.82	1.82

GPS/Leveling test

Comparison with geoid heights determined point-wise by GPS positioning and leveling:

- Root mean square (**cm**) about mean of GPS-Leveling minus model-derived geoid heights (number of points in brackets).
- For the topographic correction (Rapp 1997) the DTM2006.0 model (Pavlis et al. 2007) has been used

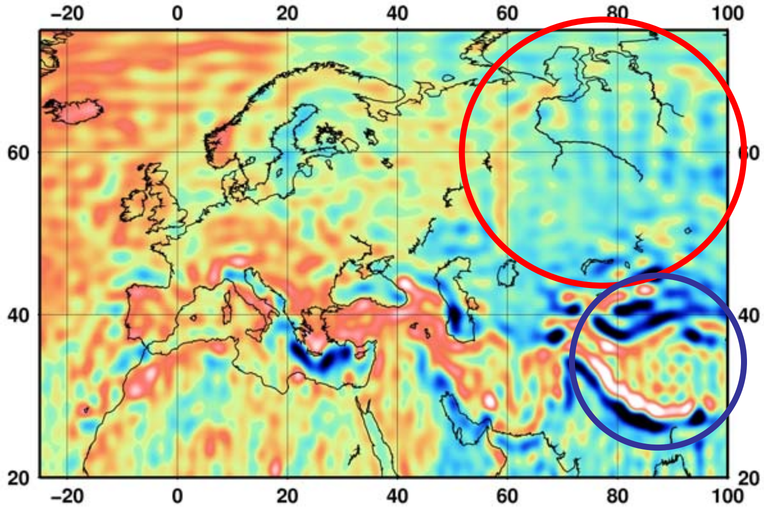
	EGM96	GGM02C/ EGM96*	EIGEN-CG01C	EIGEN-GL04C	EIGEN-5C	EGM2008 (till d/o 360)	EGM2008 (till d/o 2190)
Europe (1234)	48	32	37	34	30	27	21
Germany (675)	29	17	22	18	15	14	4
Canada (1930)	36	26	25	25	25	23	13
USA (6169)	38	33	35	34	34	32	25
Australia (201)	30	25	26	24	24	24	22

EGM2008 fits best for the most data sets

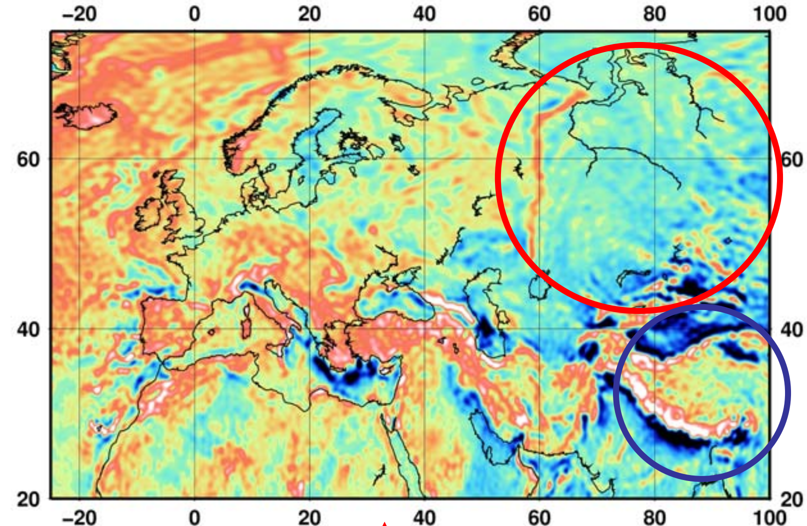
***** GGM02C up to d/o 200; EGM96 degrees > 200

Used GPS/Leveling data sets:
- **USA**: Milbert, 1998
- **Canada:** M. Véronneau, personal communication 2003, Natural Resources Canada
- **Europe/Germany:** Ihde, personal communication 2008
- **Australia:** G. Johnston, Geoscience Australia and W. Featherstone, Curtin University of Technology, personal communication 2007

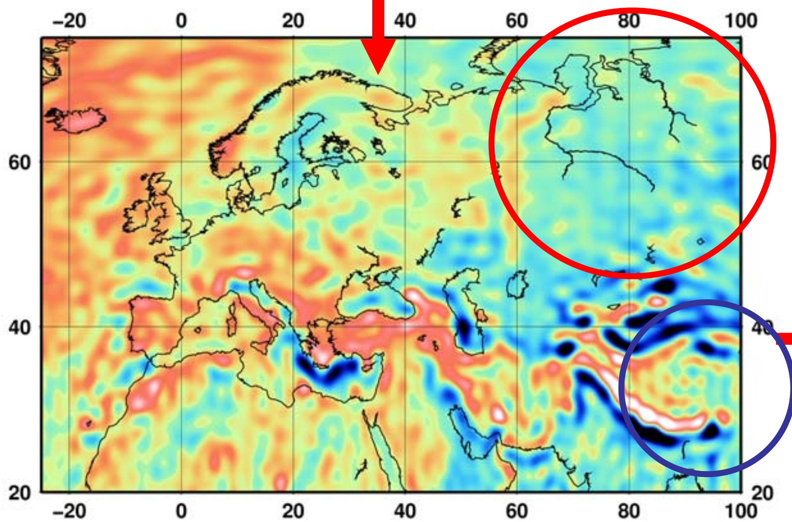
Quality improvement of EIGEN-5C: Reduction of stripes over continents - Europe/East Asia



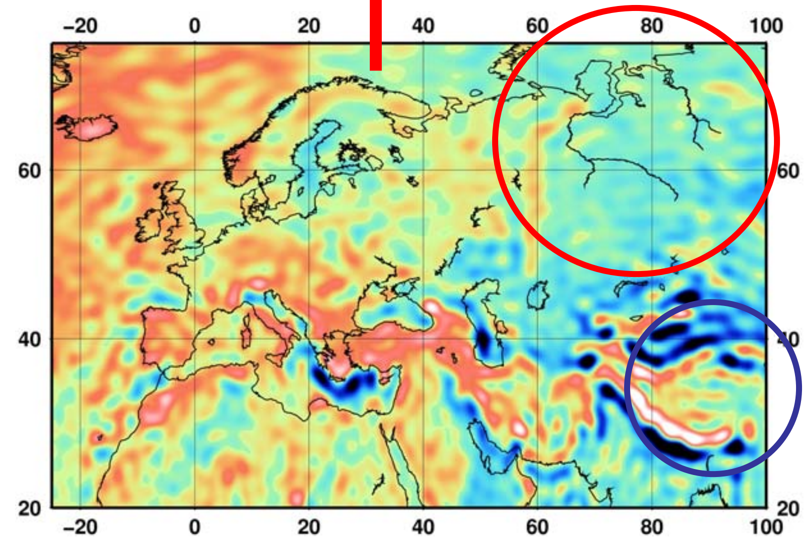
EIGEN-GL04S1 (until d/o 150)



EIGEN-5C (until d/o 360)

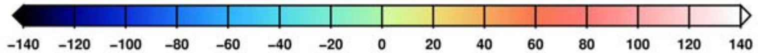


EIGEN-5S (until d/o 150)



EIGEN-5C (until d/o 150)

Gravity anomaly



mGal

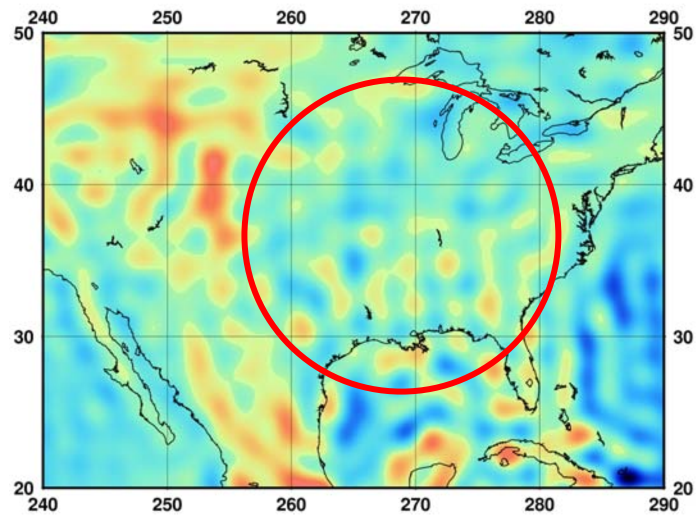
GFZ
Helmholtz Centre Potsdam

Abstract Nº 032

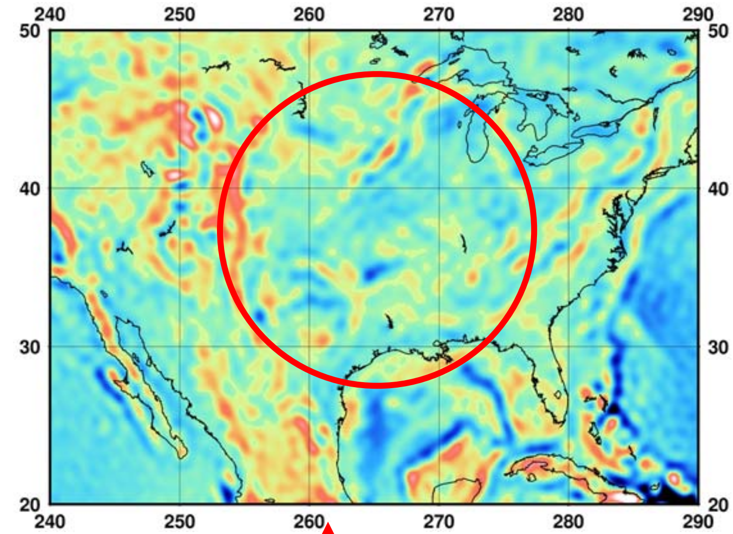
Ocean Surface Topography Science Team meeting, 10-12 November 2008, Nice, France

GRGS
Groupe de Recherches de Géodésie Spatiale

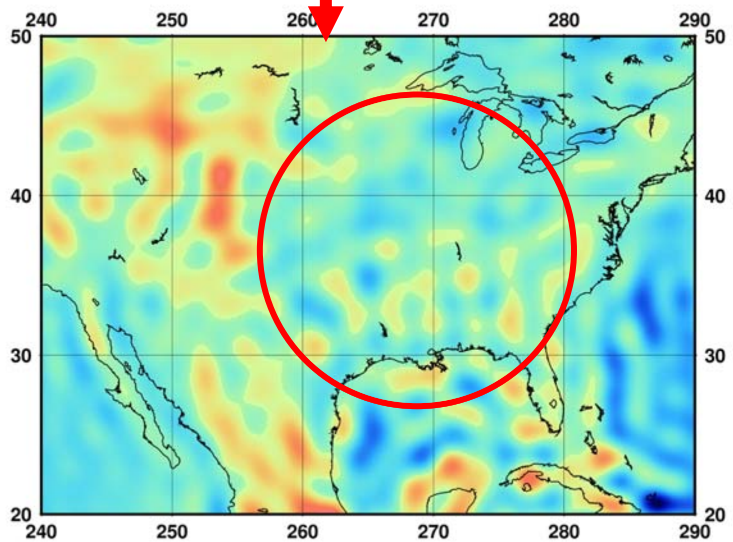
Quality improvement of EIGEN-5C: Reduction of stripes over continents – North America



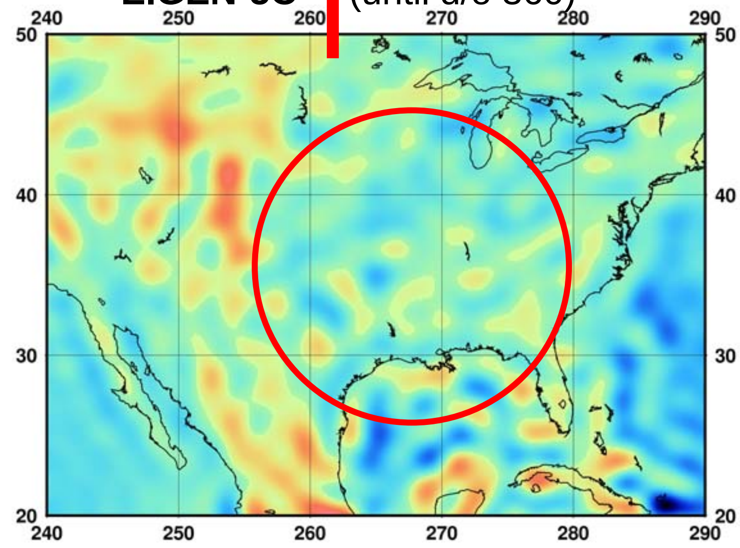
EIGEN-GL04S1 (until d/o 150)



EIGEN-5C (until d/o 360)

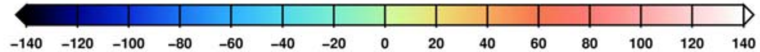


EIGEN-5S (until d/o 150)



EIGEN-5C (until d/o 150)

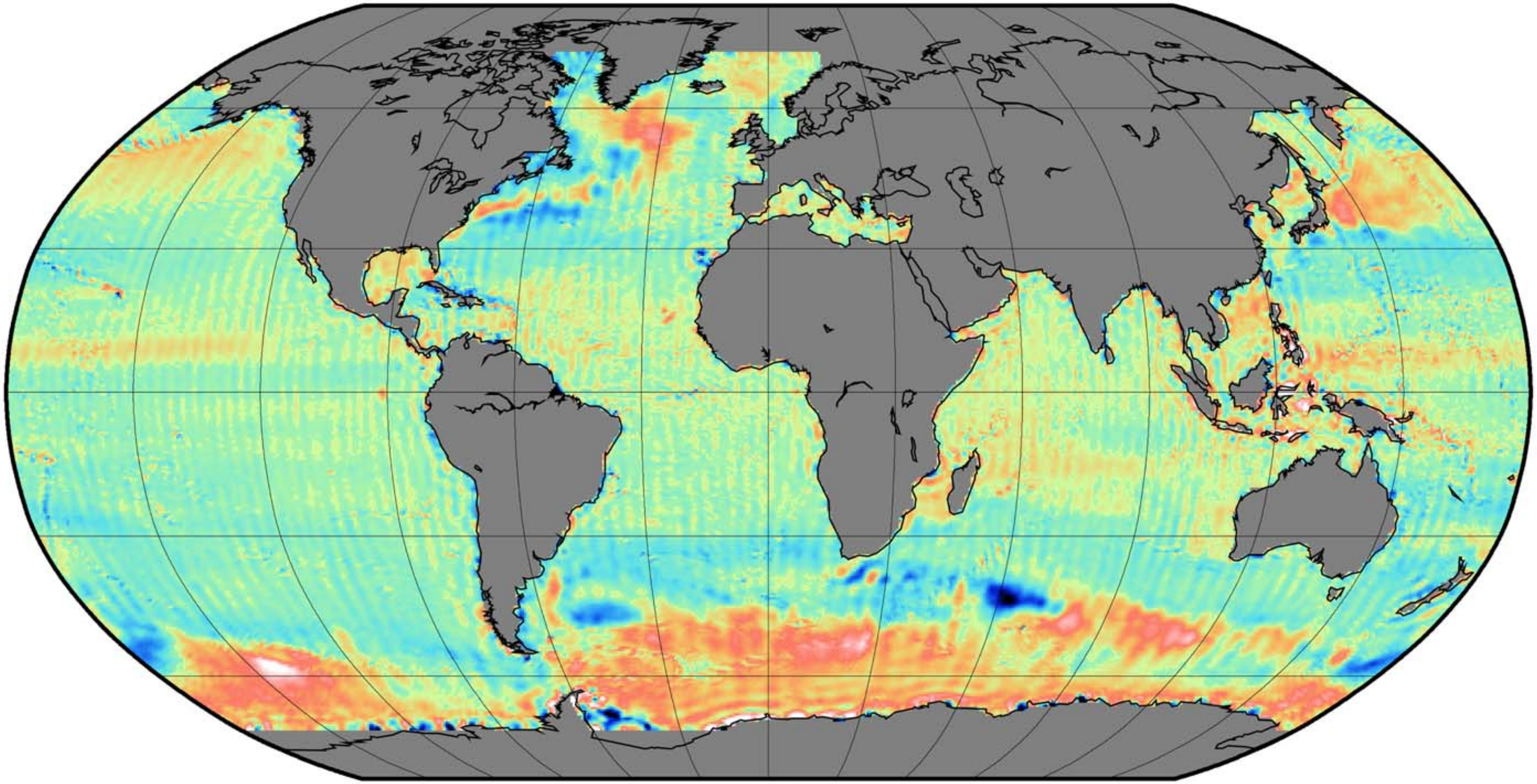
Gravity anomaly



mGal

Testing for meridional stripes: Residual ocean geoid

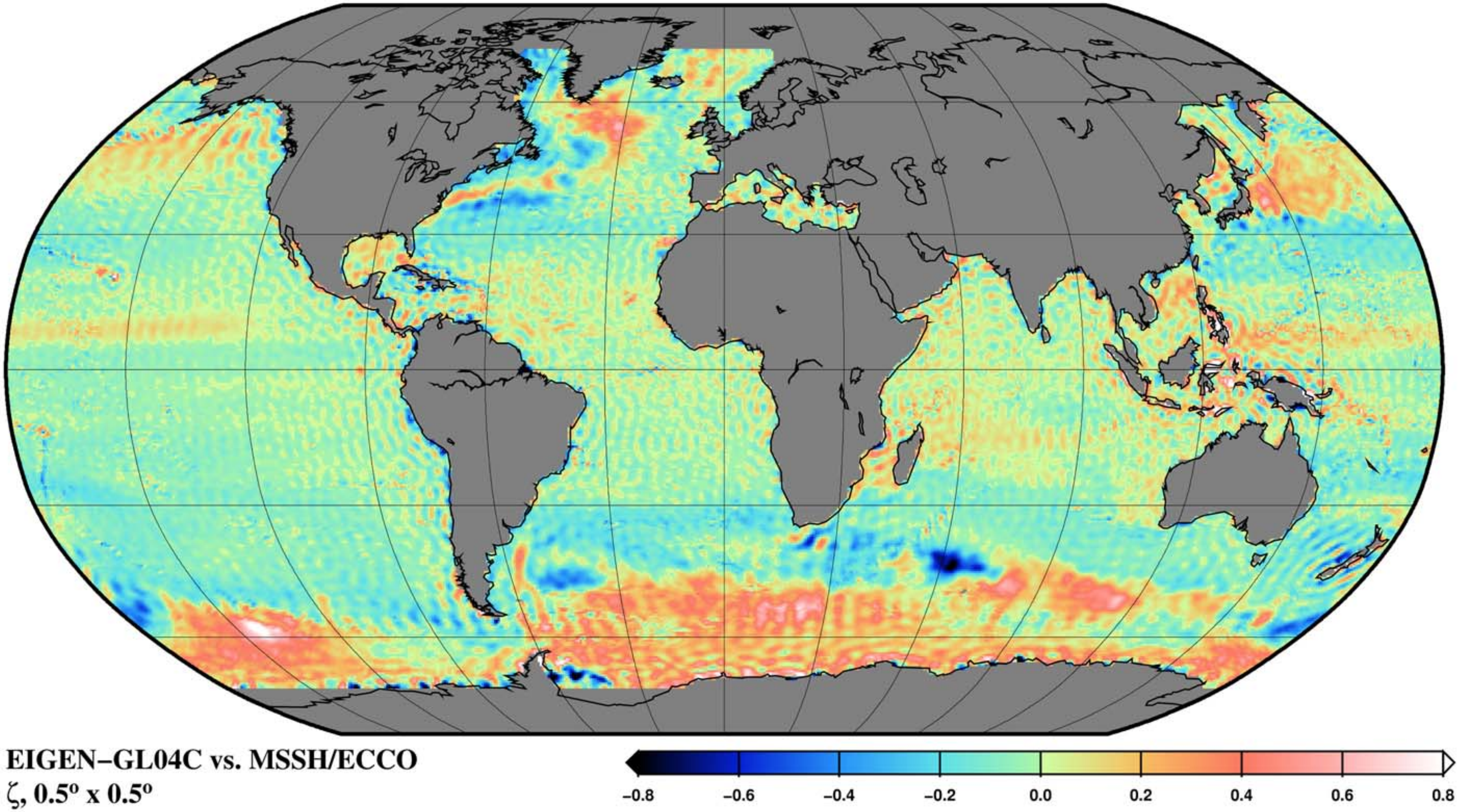
GGM02C – (MSSH(GFZ) - DOT (ECCO))



GGM02C/EGM96 vs. MSSH/ECCO
ζ, 0.5° x 0.5°
wrms about mean / min / max = 0.213 / –2.088 / 3.046 meter

Testing for meridional stripes: Residual ocean geoid

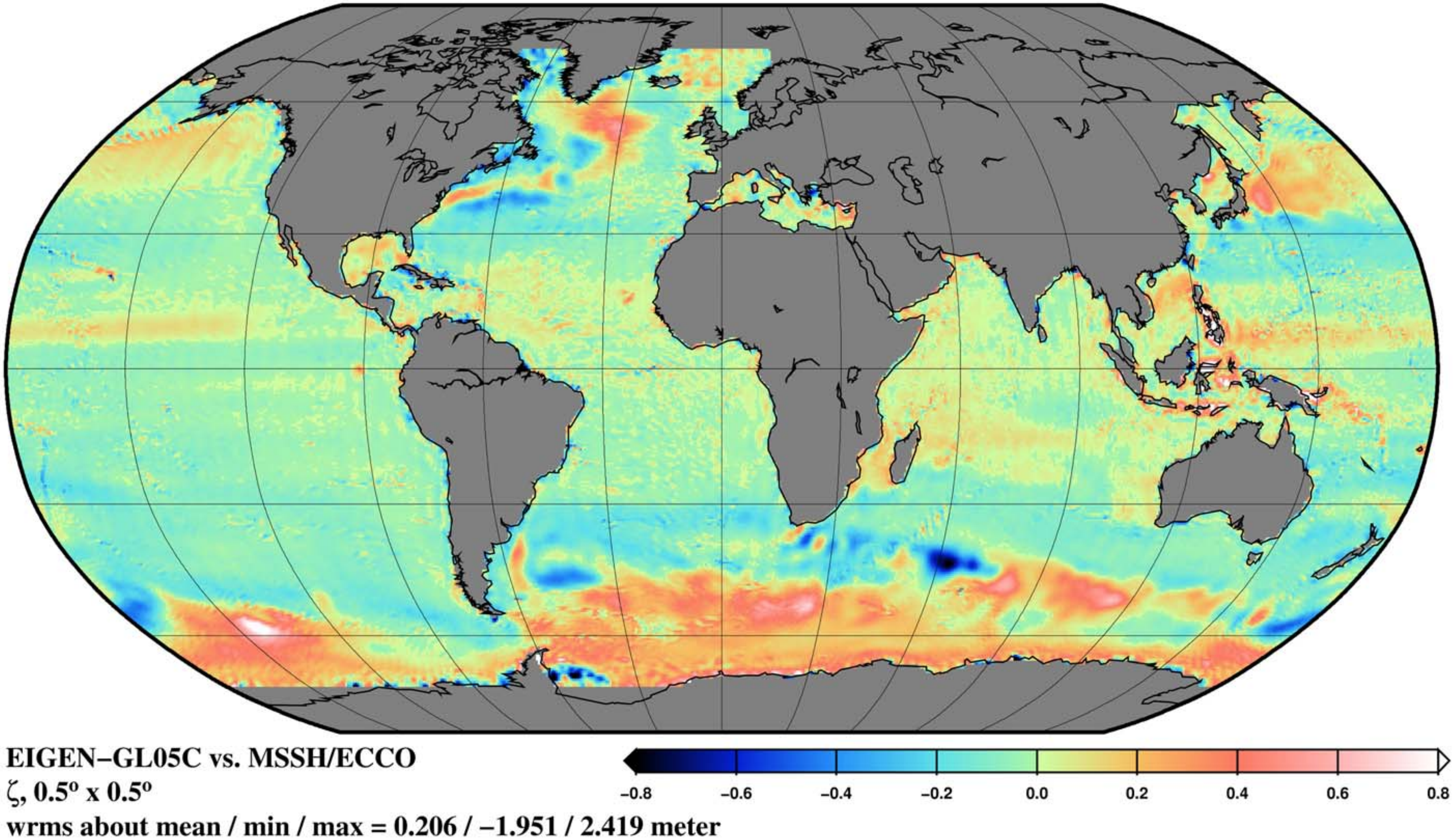
EIGEN-GL04C – (MSSH(GFZ) - DOT (ECCO))



EIGEN–GL04C vs. MSSH/ECCO
ζ, 0.5° x 0.5°
wrms about mean / min / max = 0.2277 / –2.012 / 2.706 meter

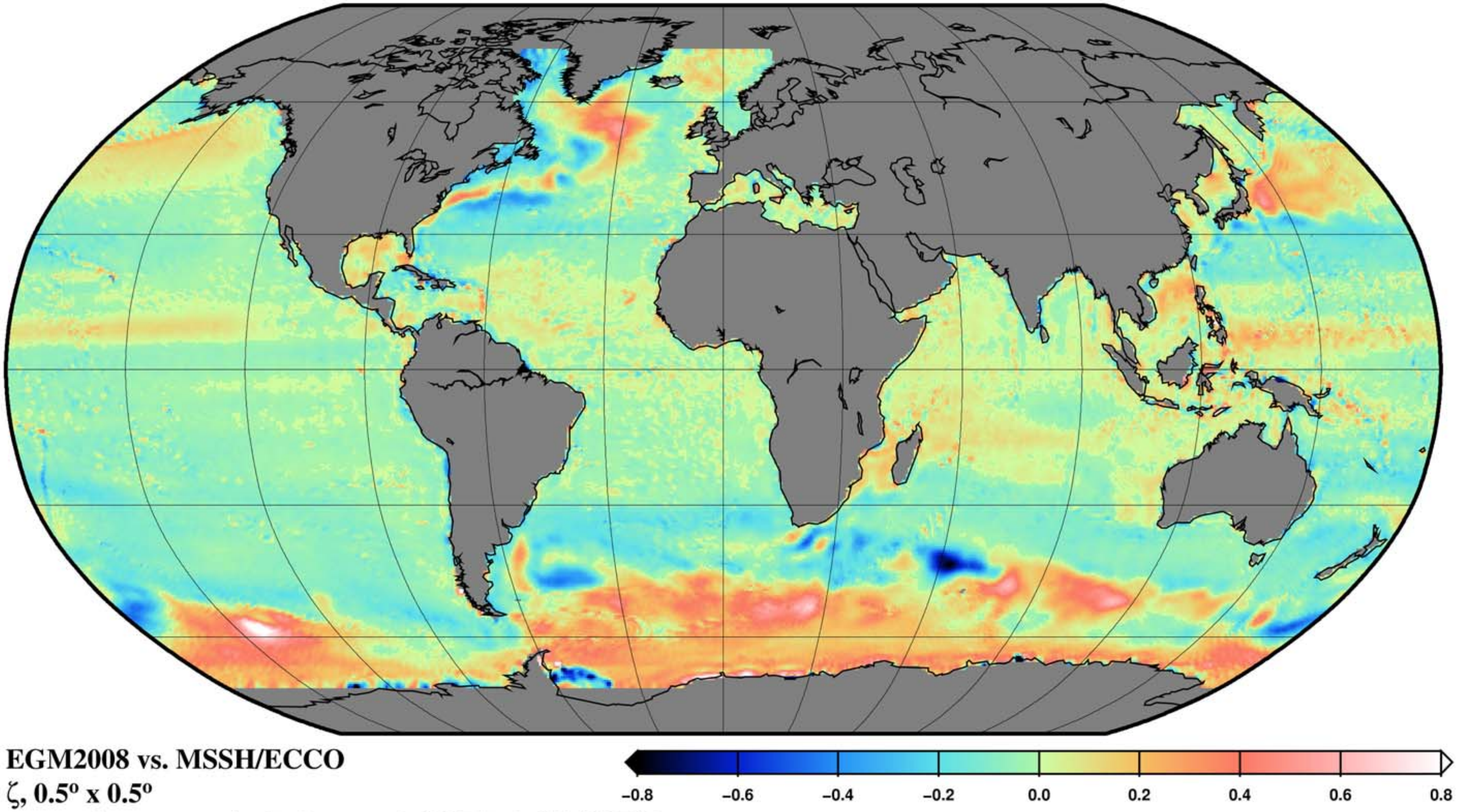
Testing for meridional stripes: Residual ocean geoid

EIGEN-5C – (MSSH(GFZ) - DOT (ECCO))



Testing for meridional stripes: Residual ocean geoid

EGM2008 (till d/o 360) – (MSSH(GFZ) - DOT (ECCO))



EGM2008 vs. MSSH/ECCO
ζ, 0.5° x 0.5°
wrms about mean / min / max = 0.1787 / –2.179 / 3.718 meter

Summary

The new combined gravity field model **EIGEN-5C** has been obtained from the combination of GRACE & LAGEOS satellite data (= **EIGEN-5S** satellite-only model) and surface data.

EIGEN-5C shows the following improvements compared to previously released models:

- better orbit fits for GRACE and SLR satellites
- smoother spectral behaviour
- better reduction of meridional stripes
- better fit in GPS/Leveling comparisons

The **EIGEN-5C/S** coefficients are available for download at the **ICGEM*** data base at **GFZ Potsdam:**

http://icgem.gfz-potsdam.de/ICGEM/ICGEM.html

***ICGEM =** The **I**nternational **C**enter of **G**lobal **E**arth **M**odels at **GFZ Potsdam** is one of the six data centers of the **International Gravity Field Service** (**IGFS**) of the **IAG**