Progresses in time-variable gravity modelling

Results from the CNES/GRGS reprocessing

R. Biancale, J.-M. Lemoine, S. Bruinsma, S. Bourgogne[1], S. Gratton, F. Perosanz, J.-C. Marty, G. Balmino, N. Vales, S. Melachroinos[2]

CNES / GRGS Team of Space Geodesy, Toulouse, France

1) *Noveltis, Ramonville, France*
2) *CNES post-doc at LEGOS, Toulouse, France*

0STST 2008, POD session, November 11, 2008, Nice, France

STANDARDS

Reprocessing, new features:

- A priori gravity field: EIGEN-GL04C to degree and order 160
- Desaï model for the oceanic pole tide (up to degree 100)
- The number of solvable oceanic tide parameters has been increased to maximum degree & order 30 according to a priori sensitivity analysis
- KBR and GPS data editing have been improved (more valid days / 10-day period)
- The solutions are still computed every 10 days, but are based solely on those 10 days.

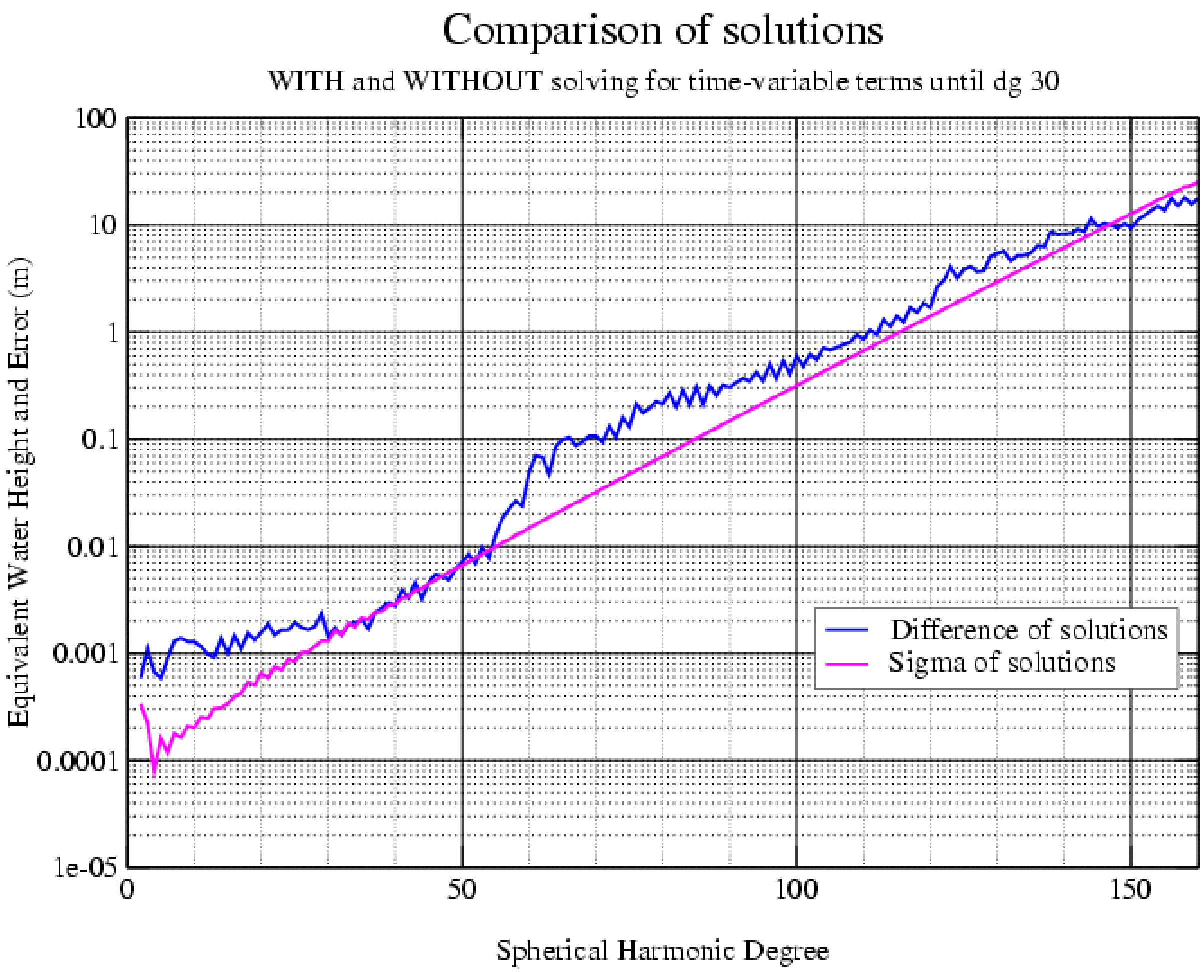
This reprocessing will lead to…

➢ **a new series of 10-day solutions ;**

➢ **a new "mean" (i.e. static+drifts+annual&semi-annual terms) gravity field model: EIGEN-6p (preliminary for the moment).**

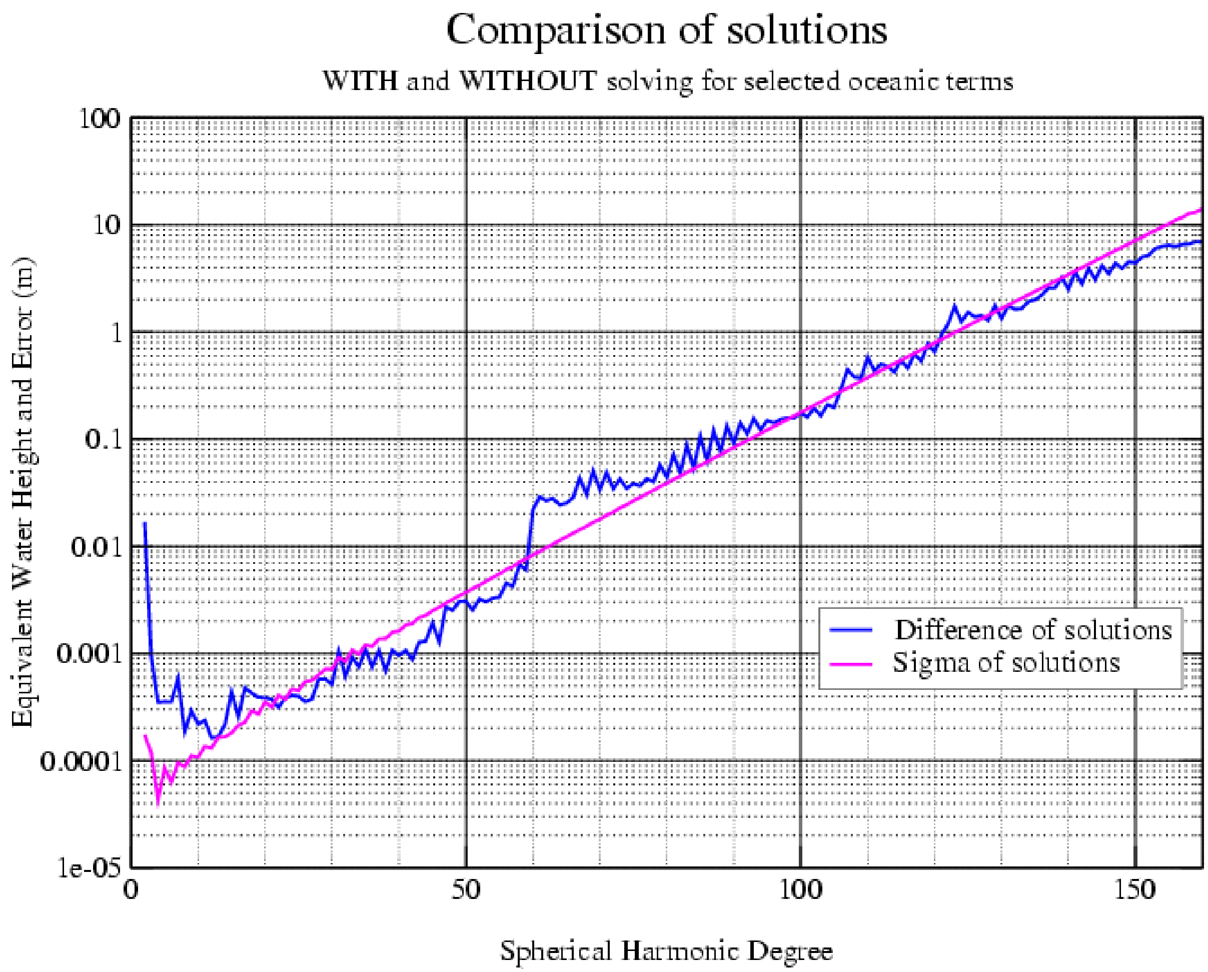
1- Should a time-variable part be solved-for ?

- **Not solving for low-degree (< degree 30 to 50) terms has a noticeable impact on static solution at higher degrees (between degrees 60 and 100).**



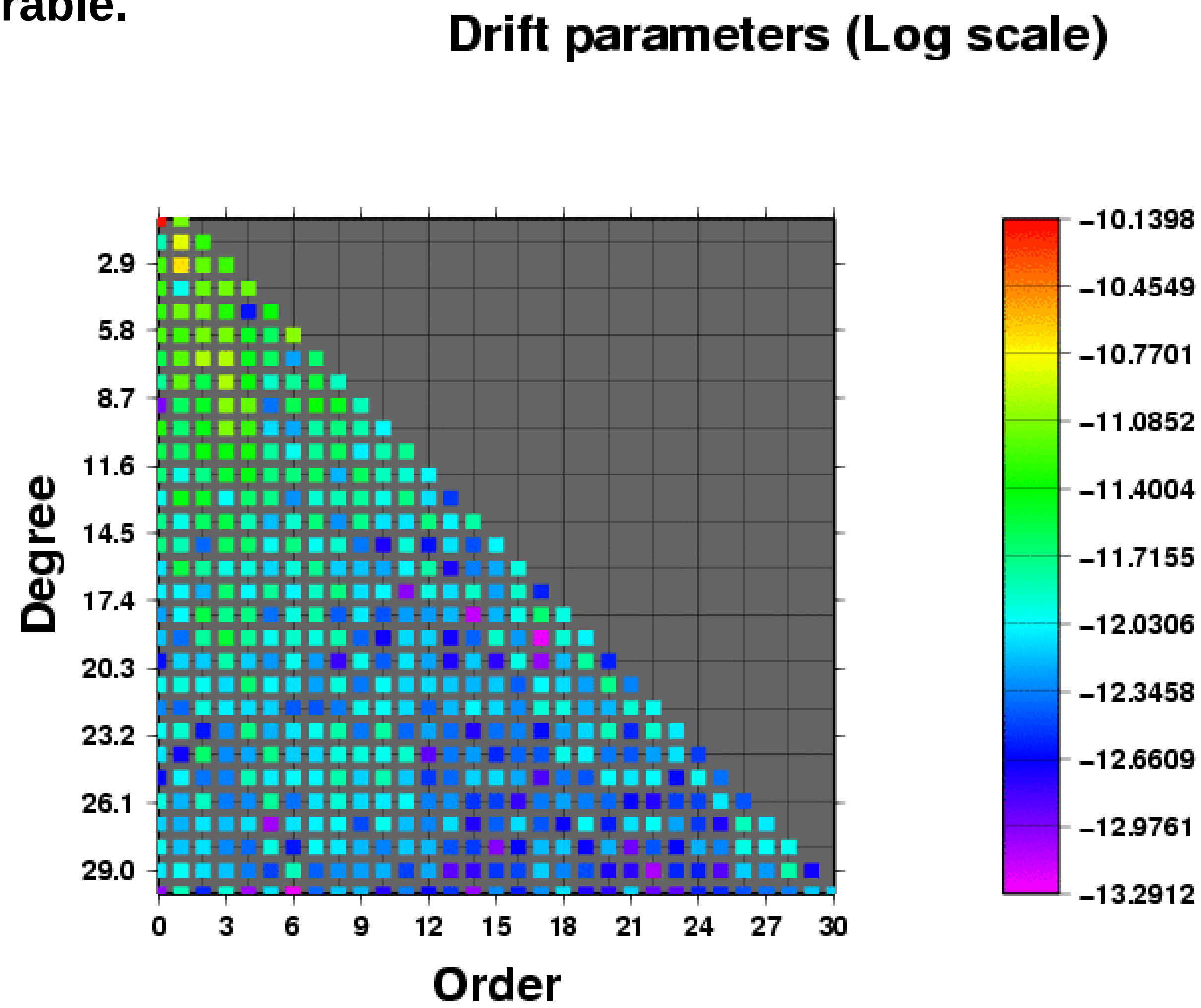
1- Should a time-variable part be solved-for ?

- **Same applies, to a lesser extent, to oceanic tide coefficients.**



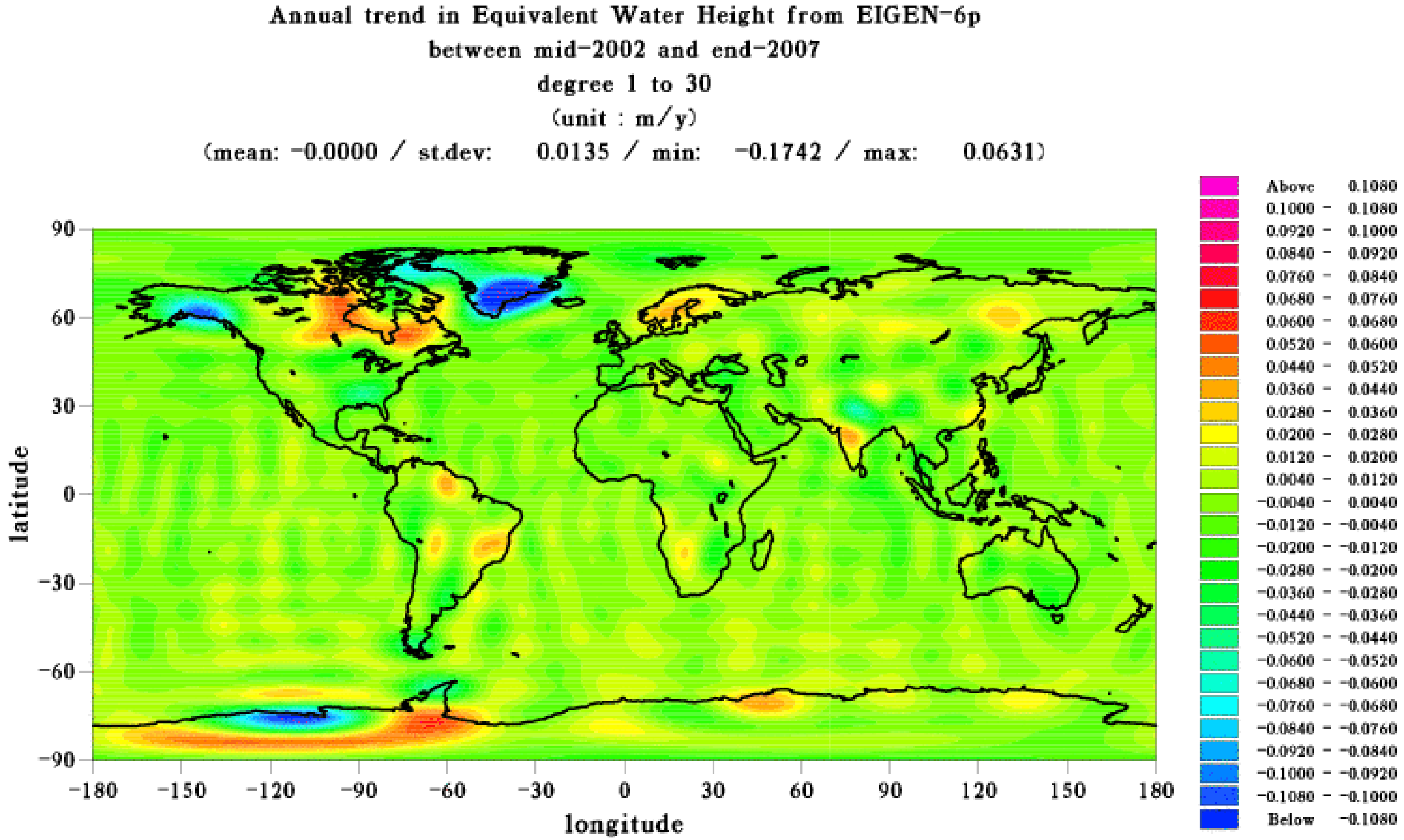
2- Up to which degree should a time-variable part be solved-for ?

➢ **Current configuration: degree 30, but there are indications that 50 would be preferable.**



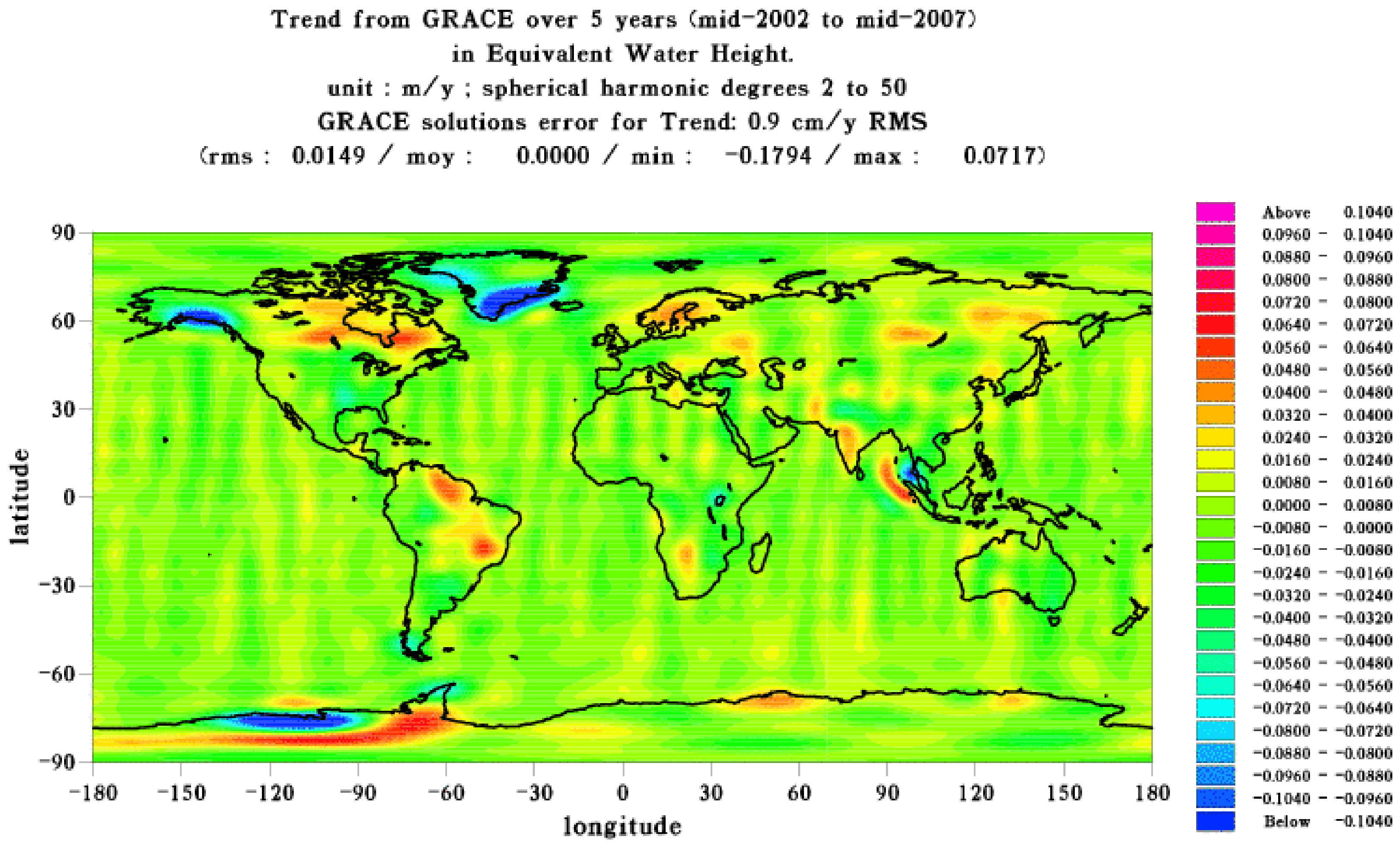
2- Up to which degree should a time-variable part be solved-for ?

➢ **Image of the drifts at degree 30.**



2- Up to which degree should a time-variable part be solved-for ?

- **Image of the drifts at degree 50 (from regression on 10-day solutions).**

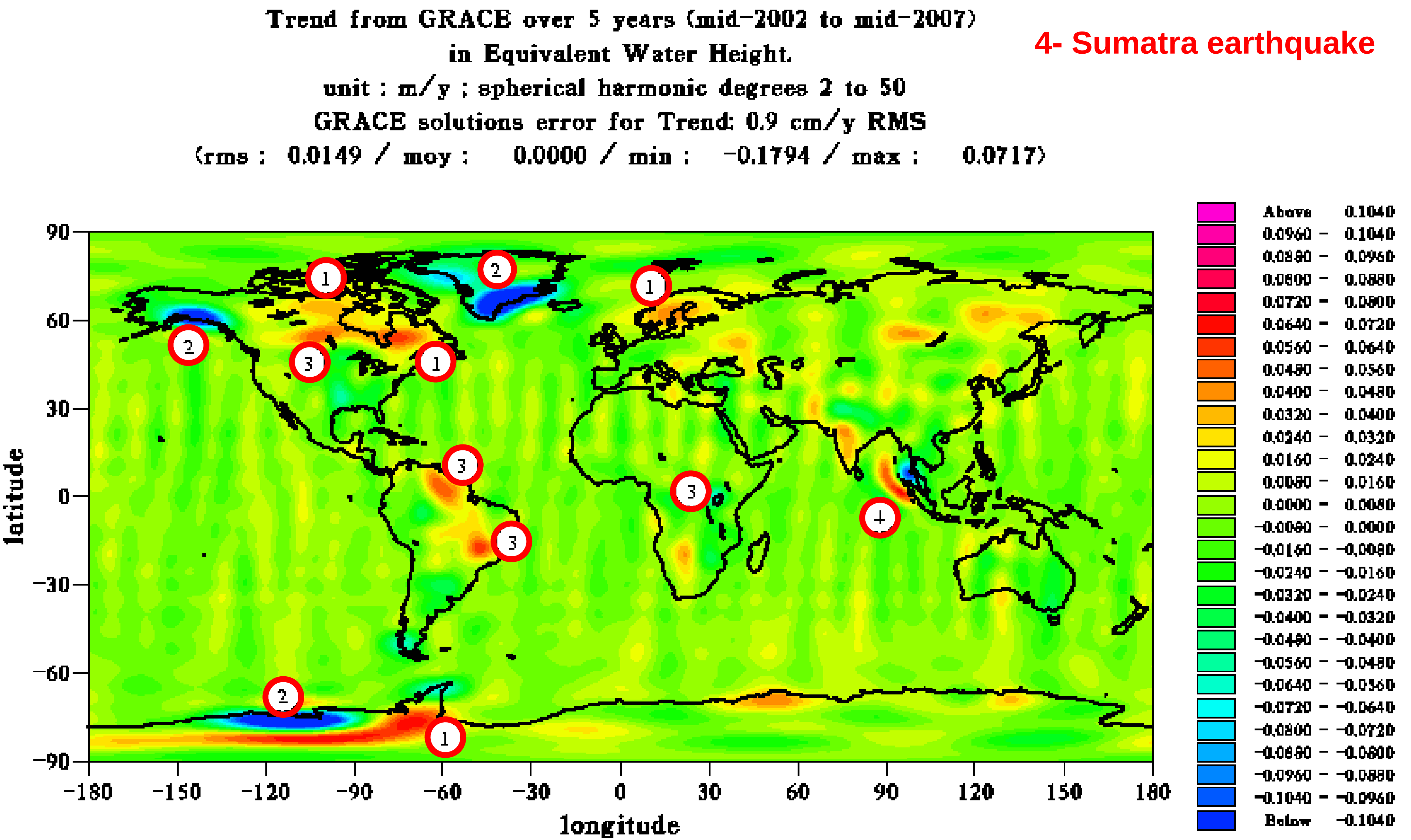


1- Post-glacial rebound

2- Glacier melting

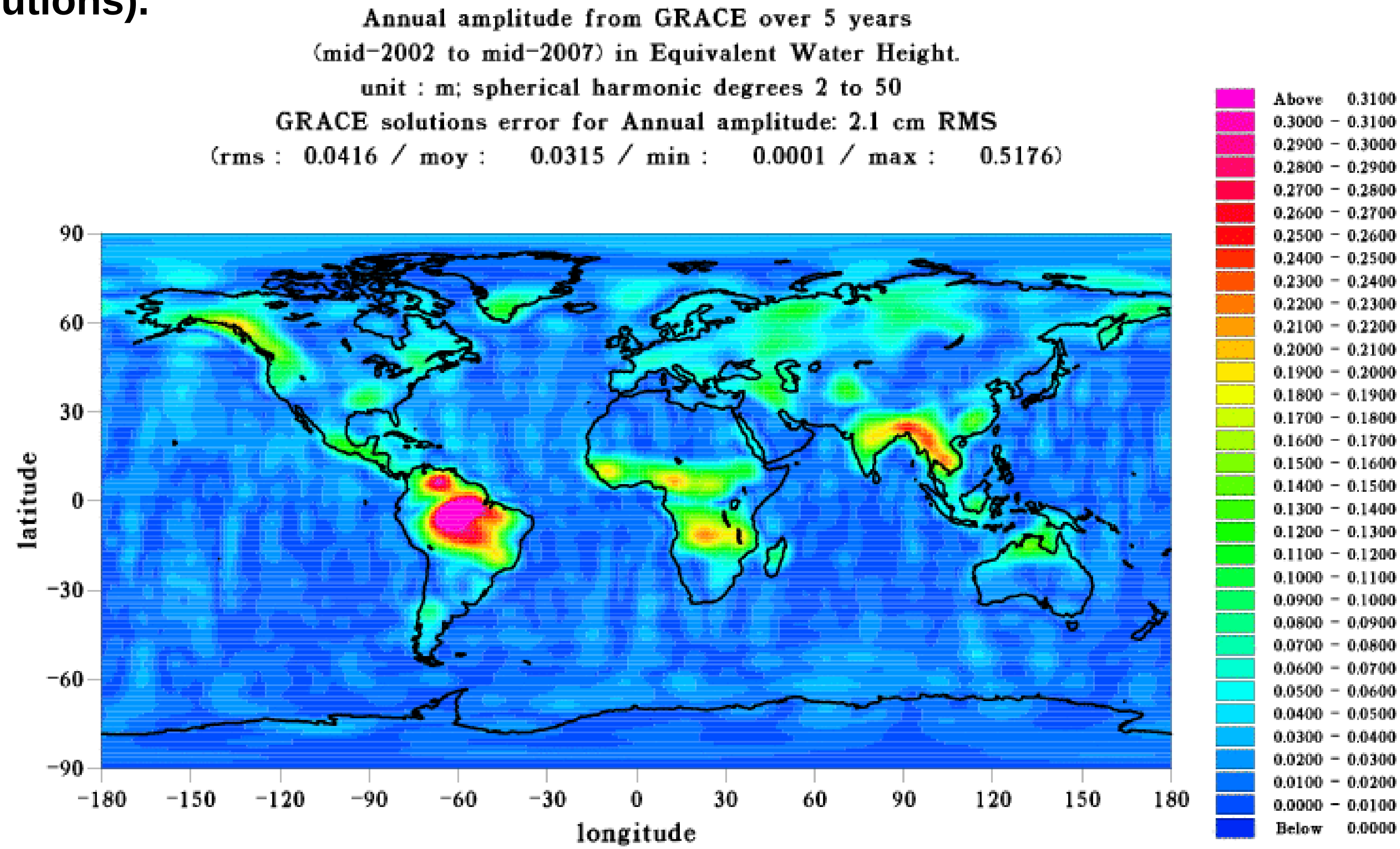
3- Hydrological trends

4- Sumatra earthquake



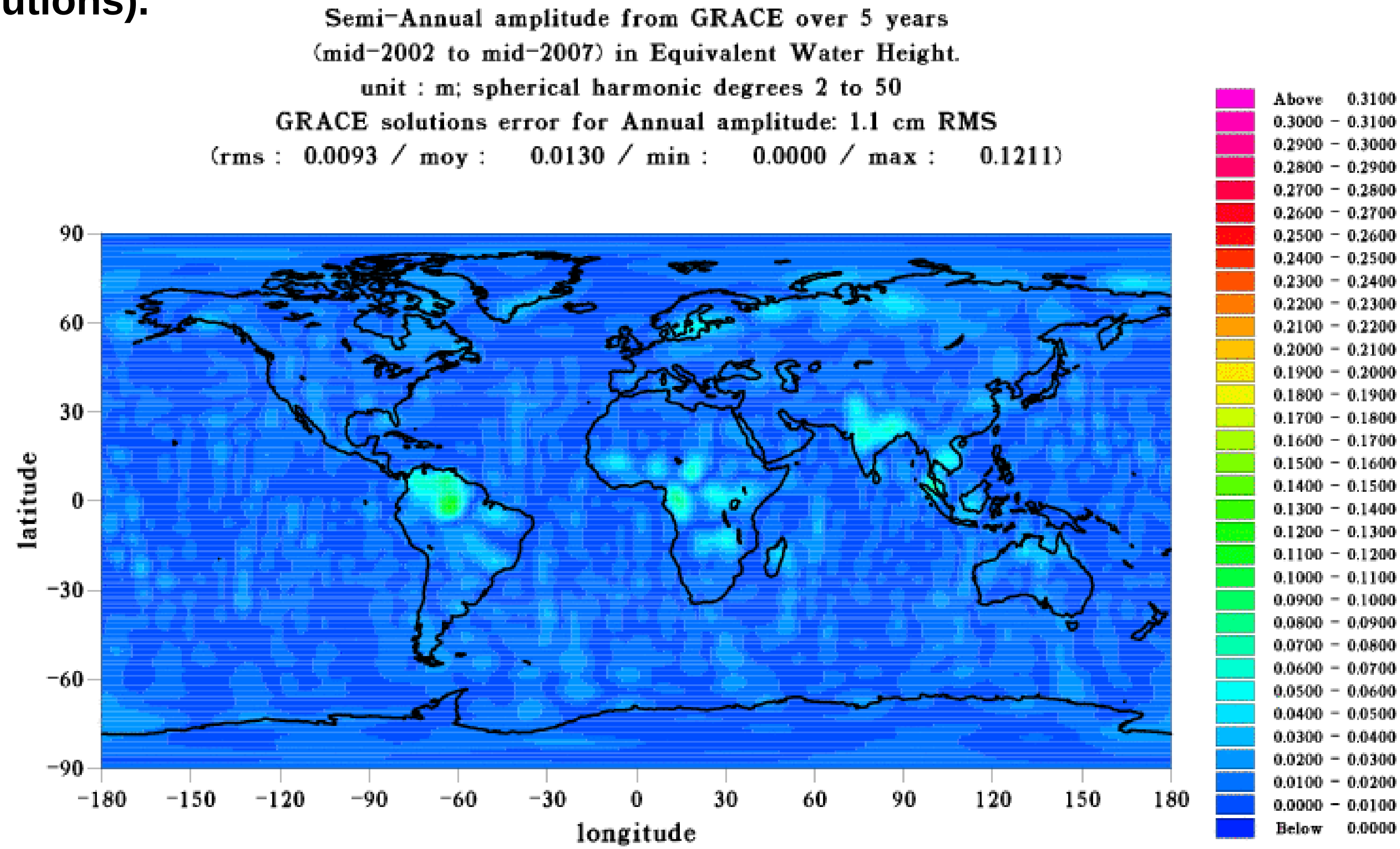
2- Up to which degree should a time-variable part be solved-for ?

➢ **Image of the annual terms at degree 50 (from regression on 10-day solutions).**



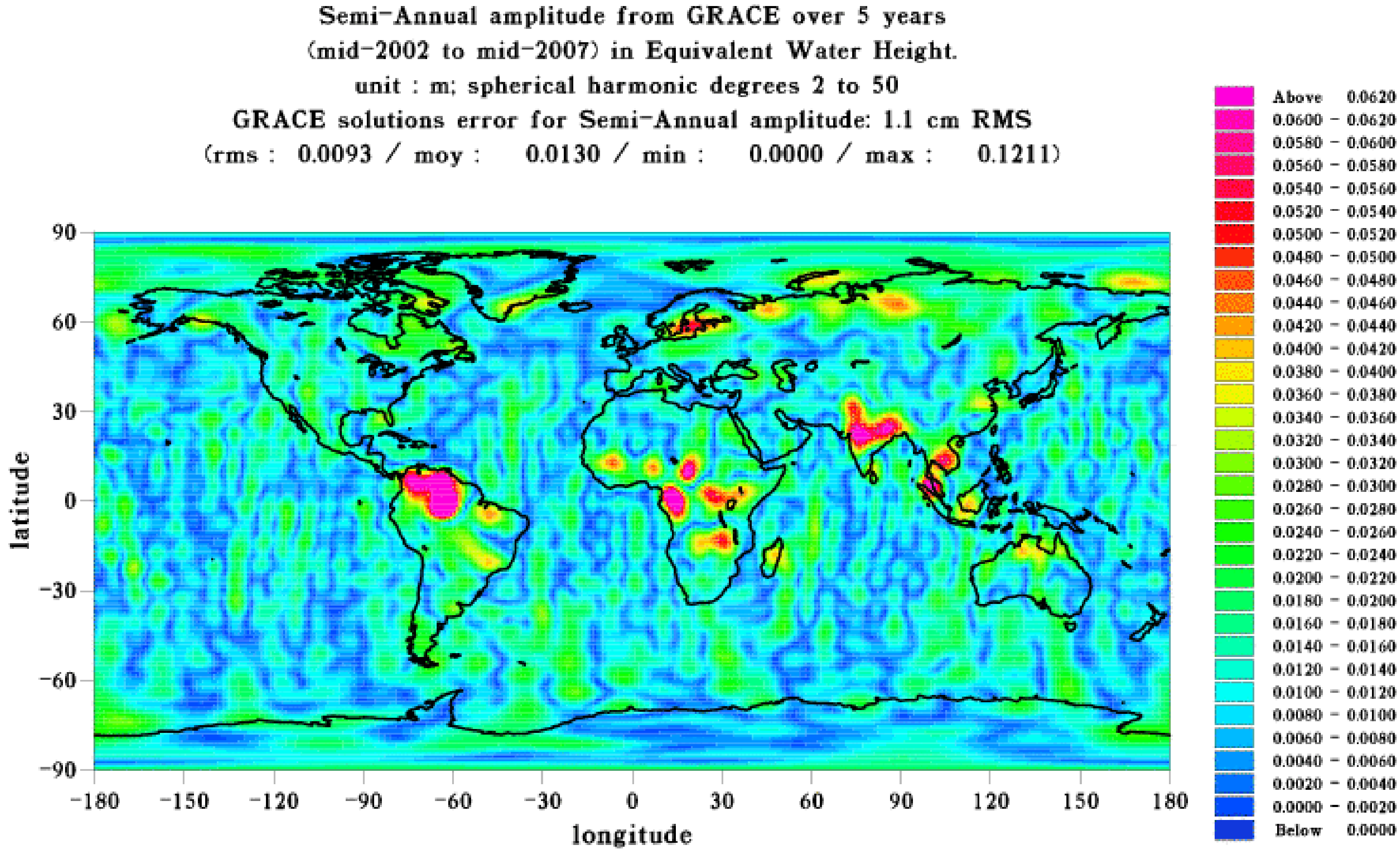
2- Up to which degree should a time-variable part be solved-for ?

- **Image of the semi-annual terms at degree 50 (from regression on 10-day solutions).**



2- Up to which degree should a time-variable part be solved-for ?

- **Image of the semi-annual terms at degree 50 (different scale).**



3- Should we use « secular trends » or « broken line » ?

➢ **In some cases, a "broken line" seems more appropriate (e.g. Greenland)… or C(2,0) ;**

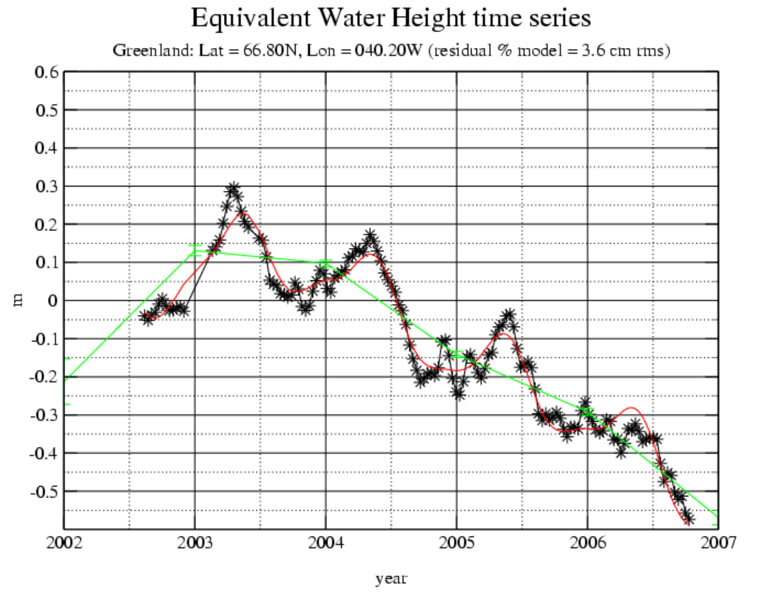
BUT…

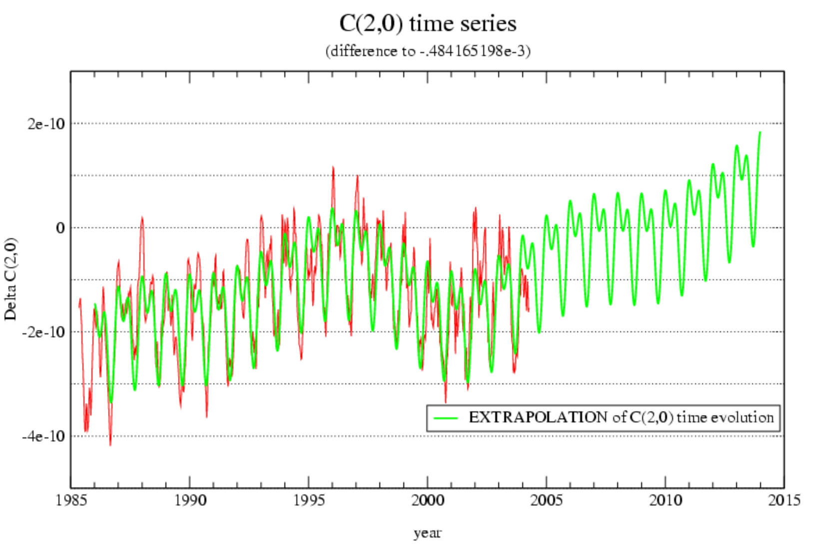
➢ **More parameters → more noise ;**

➢ **More difficult to implement for users ;**

➢ **Problem of predictability (extrapolation) ;**

➢ **If great accuracy is needed, then the time series solution can be used !**





4- Should degree 1 be solved-for ?

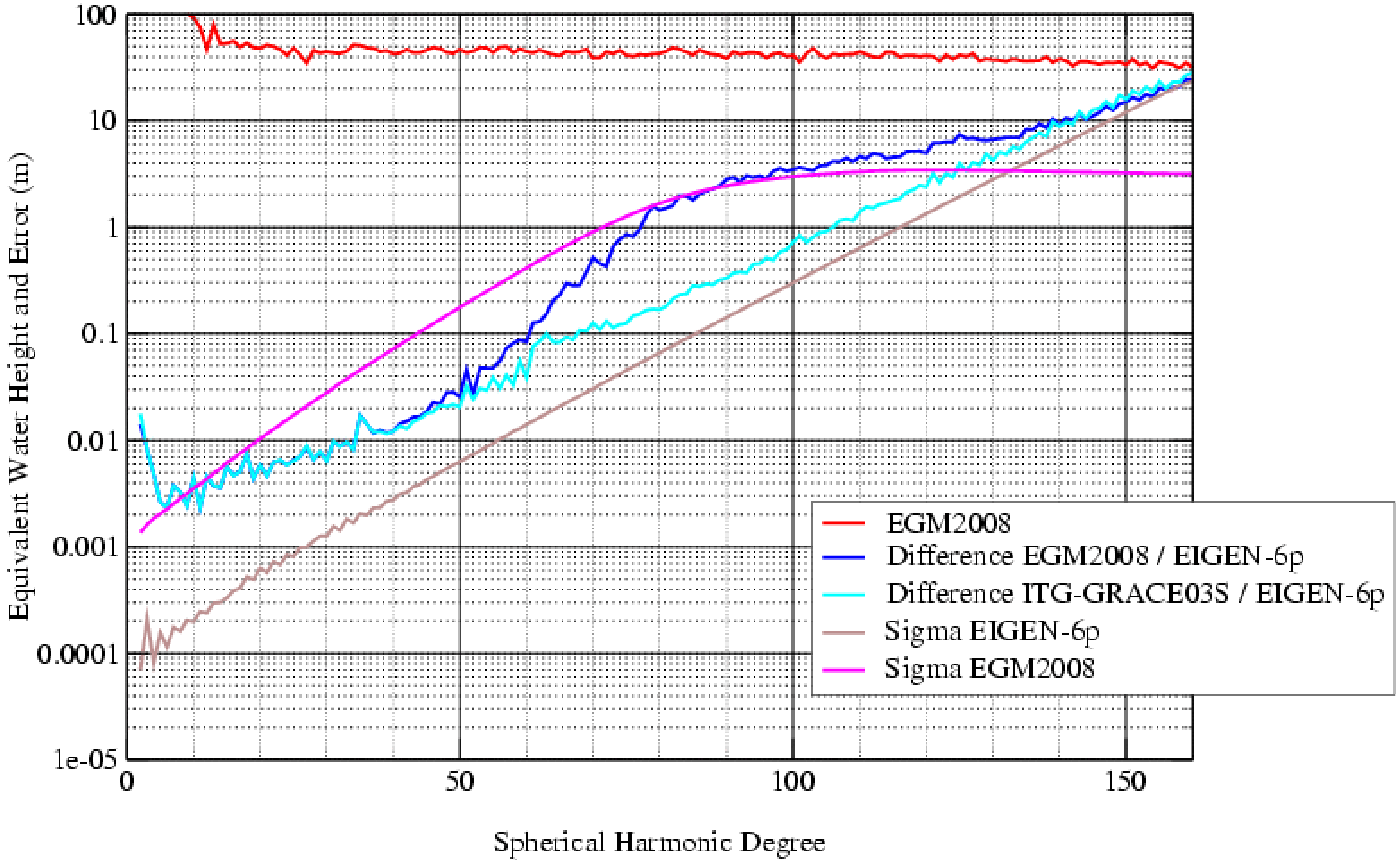
- **It implies the inclusion of Lageos data in the solution. (Same remark applies for degree 2)**
- **The values obtained in the framework of EIGEN-6 are very small:**

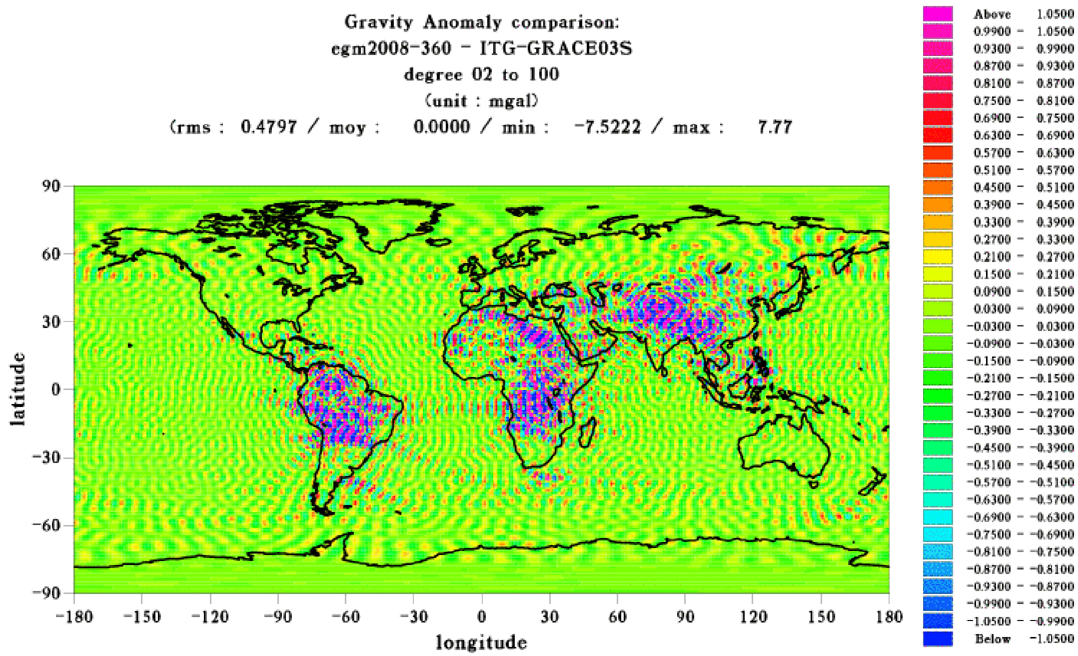
	C(1,0)	C(1,1)	S(1,1)
bias	1 mm	0 mm	0 mm
annual drift	0.6 mm/y	0 mm/y	0 mm/y
annual term	0.2 mm	1 mm	1.8 mm
semi-annual term	0.8 mm	0 mm	0.2 mm

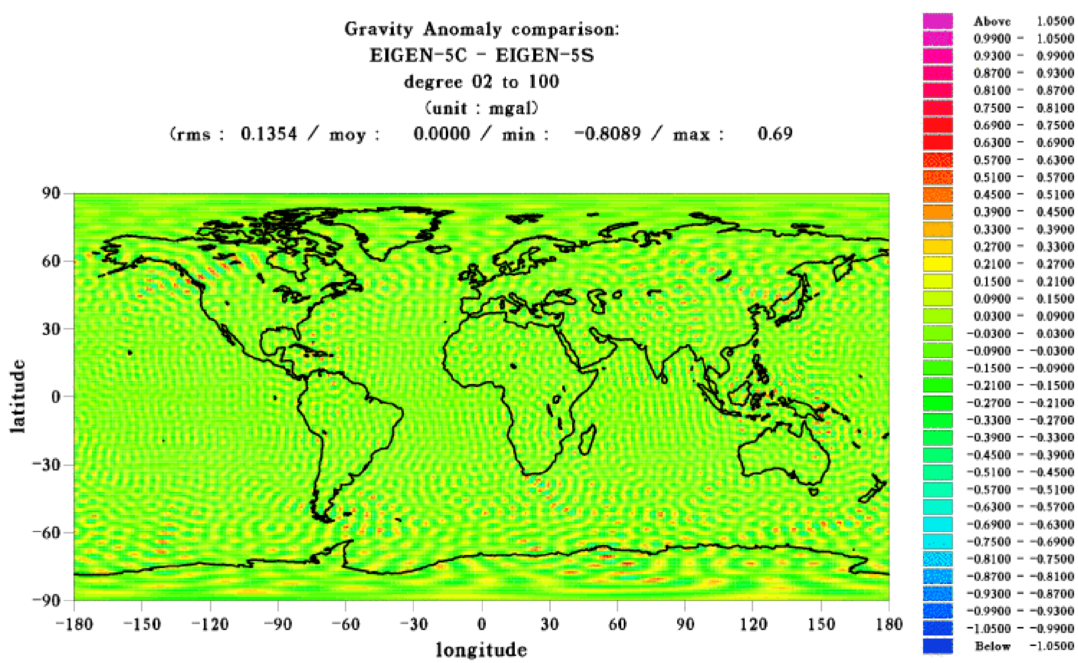
5- Should a « combined » field be used ?

➢ **Why not, if the merging of space data with surface data is well done.**

Comparison EIGEN-6p / ITG-GRACE03S / EGM2008

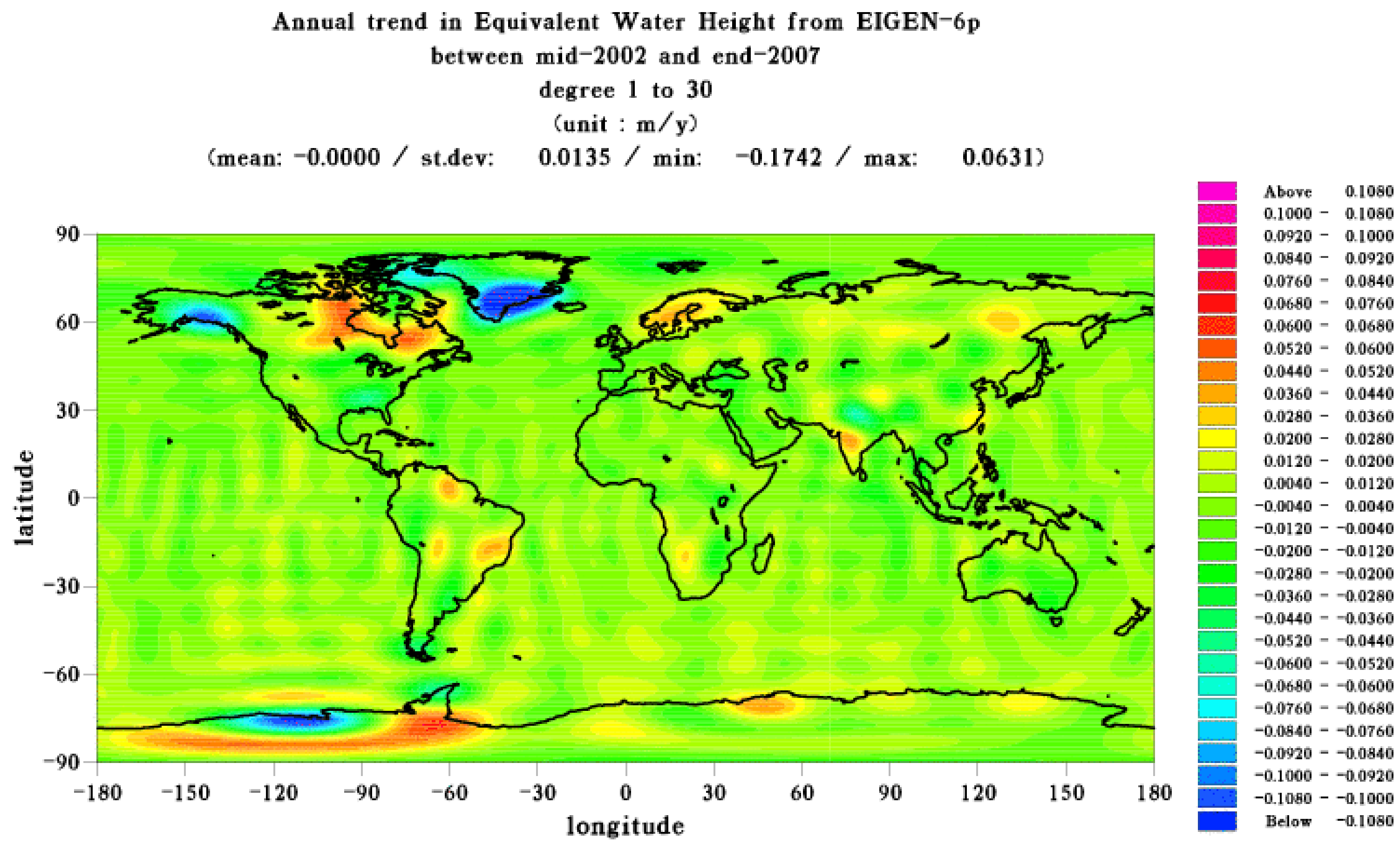



Gravity Anomaly comparison:
egm2008-360 - ITG-GRACE03S
degree 02 to 100
(unit : mgal)
(rms : 0.4797 / moy : 0.0000 / min : -7.5222 / max : 7.77
latitude
longitude
90
60
30
0
-30
-60
-90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
Above 1.0500
0.9900 - 1.0500
0.9300 - 0.9900
0.8700 - 0.9300
0.8100 - 0.8700
0.7500 - 0.8100
0.6900 - 0.7500
0.6300 - 0.6900
0.5700 - 0.6300
0.5100 - 0.5700
0.4500 - 0.5100
0.3900 - 0.4500
0.3300 - 0.3900
0.2700 - 0.3300
0.2100 - 0.2700
0.1500 - 0.2100
0.0900 - 0.1500
0.0300 - 0.0900
-0.0300 - 0.0300
-0.0900 - -0.0300
-0.1500 - -0.0900
-0.2100 - -0.1500
-0.2700 - -0.2100
-0.3300 - -0.2700
-0.3900 - -0.3300
-0.4500 - -0.3900
-0.5100 - -0.4500
-0.5700 - -0.5100
-0.6300 - -0.5700
-0.6900 - -0.6300
-0.7500 - -0.6900
-0.8100 - -0.7500
-0.8700 - -0.8100
-0.9300 - -0.8700
-0.9900 - -0.9300
-1.0500 - -0.9900
Below -1.0500


Gravity Anomaly comparison:
EIGEN-5C - EIGEN-5S
degree 02 to 100
(unit : mgal)
(rms : 0.1354 / moy : 0.0000 / min : -0.8089 / max : 0.69
latitude
longitude
90
60
30
0
-30
-60
-90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
Above 1.0500
0.9900 - 1.0500
0.9300 - 0.9900
0.8700 - 0.9300
0.8100 - 0.8700
0.7500 - 0.8100
0.6900 - 0.7500
0.6300 - 0.6900
0.5700 - 0.6300
0.5100 - 0.5700
0.4500 - 0.5100
0.3900 - 0.4500
0.3300 - 0.3900
0.2700 - 0.3300
0.2100 - 0.2700
0.1500 - 0.2100
0.0900 - 0.1500
0.0300 - 0.0900
-0.0300 - 0.0300
-0.0900 - -0.0300
-0.1500 - -0.0900
-0.2100 - -0.1500
-0.2700 - -0.2100
-0.3300 - -0.2700
-0.3900 - -0.3300
-0.4500 - -0.3900
-0.5100 - -0.4500
-0.5700 - -0.5100
-0.6300 - -0.5700
-0.6900 - -0.6300
-0.7500 - -0.6900
-0.8100 - -0.7500
-0.8700 - -0.8100
-0.9300 - -0.8700
-0.9900 - -0.9300
-1.0500 - -0.9900
Below -1.0500

6- How to deal with “Sumatra-type” events ?

➢ Isolate the long-term change in the gravity field by differencing 2002-2003-2004 and 2005-2006-2007 → compute a correction “before Dec 26, 2004” to the m



SUMMARY

- **Should a time-variable part be solved-for ?**

YES

- **Up to which degree should a time-variable part be solved-for ?**

Degree 50 for drifts and annual terms, 30 to 50 for semi-annual terms.

- **Should we use « secular trends » or « broken line » ?**

Rather « secular trends » ; for more precise solutions it is possible to use time series solutions.

- **Should degree 1 be solved-for ?**

YES, but it depends very much on the reference frame (station coordinates) used.

- **Should a « combined » field be used ?**

Why not, but the connection between space and surface data must be carefully weighted.

- **How to deal with "Sumatra-type" events ?**

For major events, like the Sumatra earthquake, introduce jumps in the gravity field.

C/S(3,1)

	C(3,1)	S(3,1)
EIGEN-GL04S	0.15474352083236E-10	-0.32582549345132E-10
EIGEN-6p	0.25057325754129E-11	0.19656936266564E-10

Orbit tests

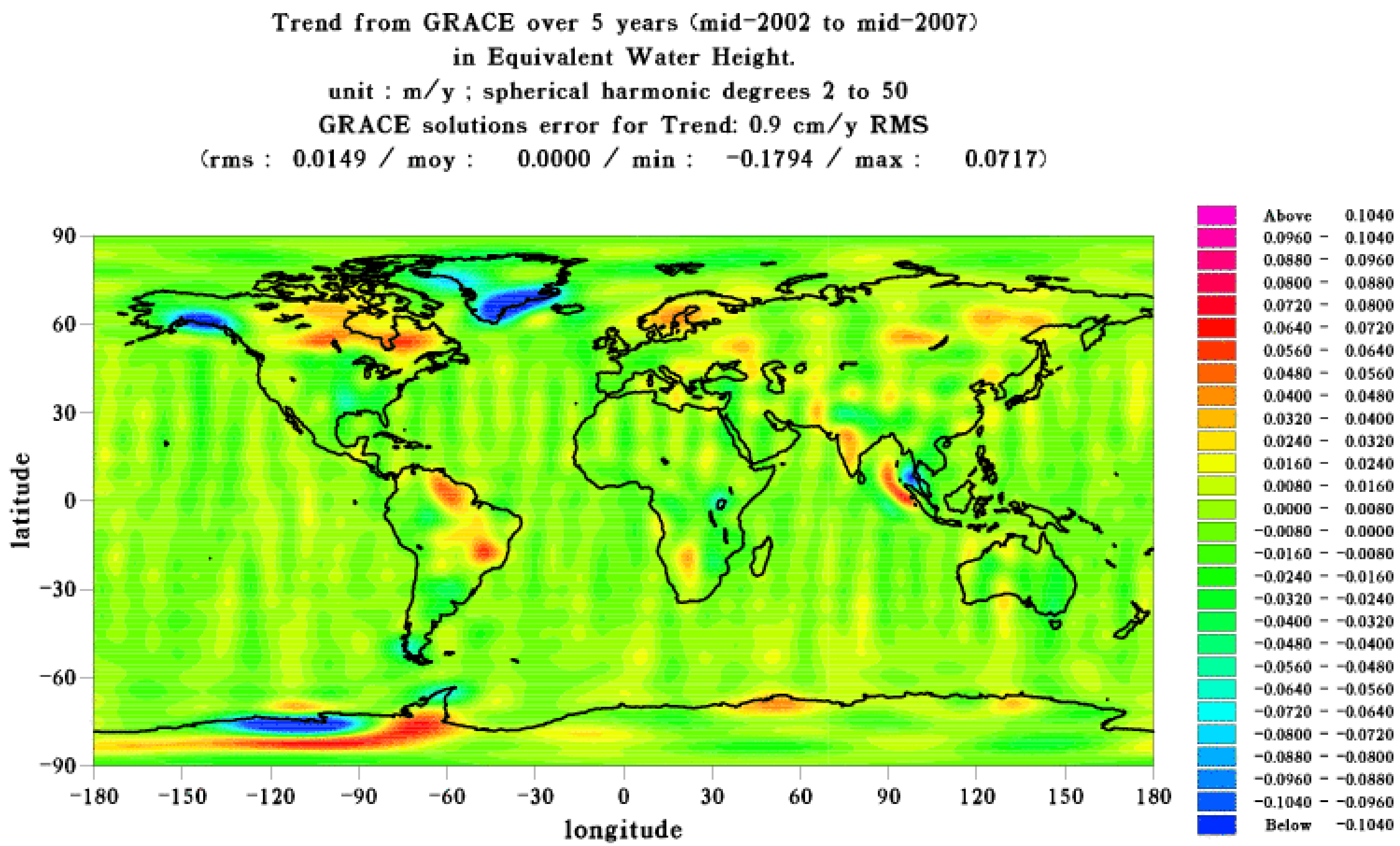
Satellite	max. degree used	GGM02C	GGM03S	JEM1-RL03B	EIGEN-GL04C	EIGEN-5S	EIGEN-5C	ITG-GRACE03S	EGM2008
CHAMP	120 x 120	5.32	5.45	5.35	5.44	5.55	5.51	5.38	5.51
	150 x 150	5.19	5.44	--	5.41	5.56	5.49	5.30	5.46
GRACE	120 x 120	5.50	5.28	5.55	5.25	5.17	5.15	5.39	5.46
	150 x 150	5.54	5.27	--	5.24	5.19	5.14	5.38	5.43

Table 2: SLR residuals (cm) after an orbit determination based on GPS-SST and accelerometer data (CHAMP, GRACE) and K-Band Range-Rate data (GRACE). The SLR data were not included for the orbit adjustment. The best orbit fits are marked red.

Satellite max. degree used 120 x 120	GGM02C	GGM03S	JEM1-RL03B	EIGEN-GL04C	EIGEN-5S	EIGEN-5C	ITG-GRACE03S	EGM2008
GFZ-1	14.31	13.86	13.99	13.78	13.78	14.10	14.11	14.67
STELLA	3.24	2.91	3.13	2.97	2.92	2.92	3.01	2.97
STARLETTE	2.45	2.81	2.58	2.56	2.53	2.53	2.57	2.56
AJISAI	3.18	3.37	3.25	3.16	3.15	3.15	3.15	3.19
LAGEOS-1	1.13	1.03	1.14	1.13	1.01	1.01	1.13	1.15
LAGEOS-2	1.05	1.02	1.05	1.05	1.02	1.02	1.05	1.05
ERS-2	5.86	5.35	5.64	5.34	5.29	5.29	5.34	5.35
ENVISAT	4.30	4.27	4.29	4.38	3.54	3.54	4.20	4.20
WESTPAC	4.21	4.09	4.08	3.97	4.48	4.49	3.98	3.97
JASON-1	1.89	1.83	1.88	1.88	1.82	1.82	1.87	1.89

GLOBAL MAPS IN EWH

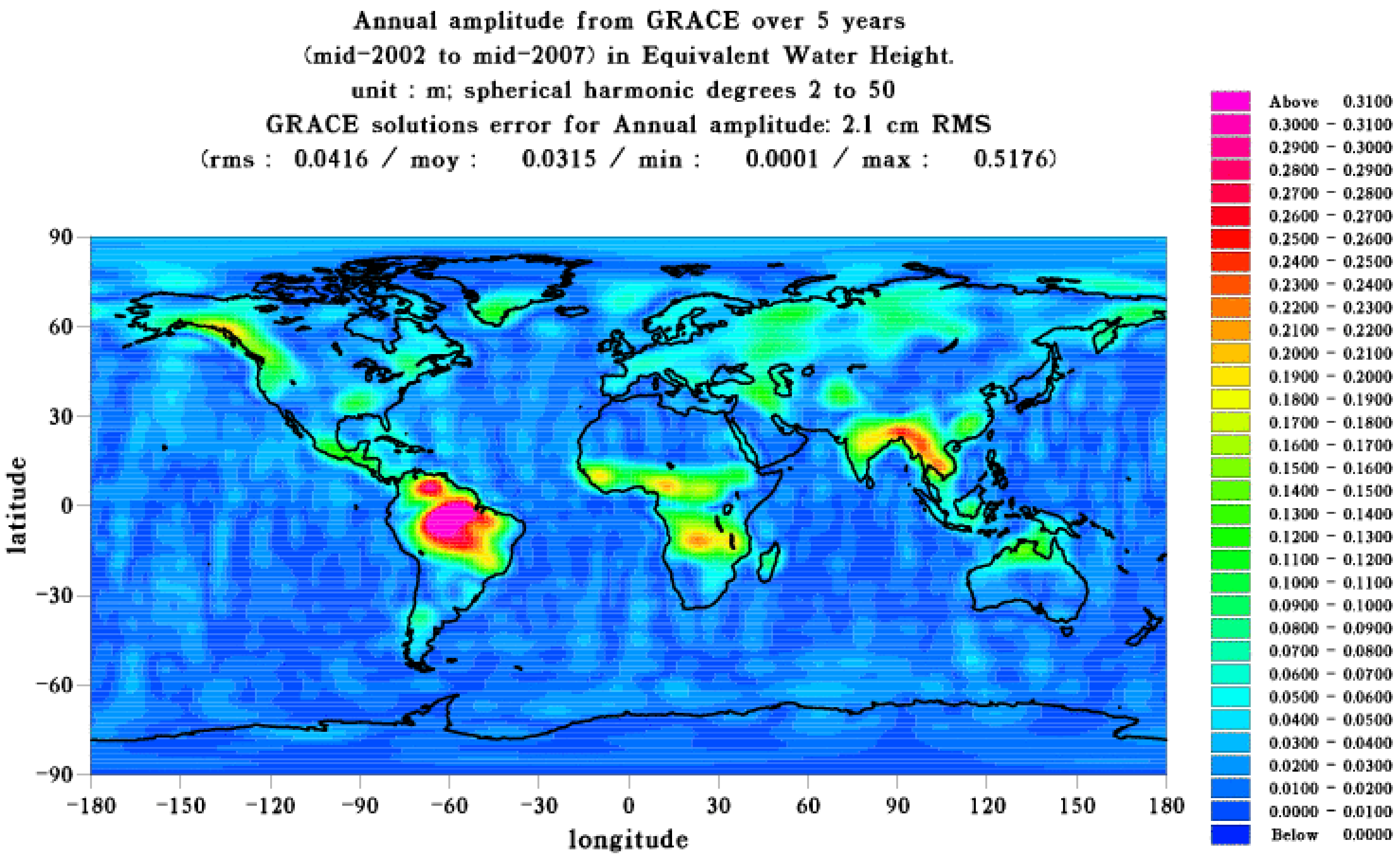
TREND from July 2002 through February 2008



GLOBAL MAPS IN EWH

ANNUAL SIGNAL

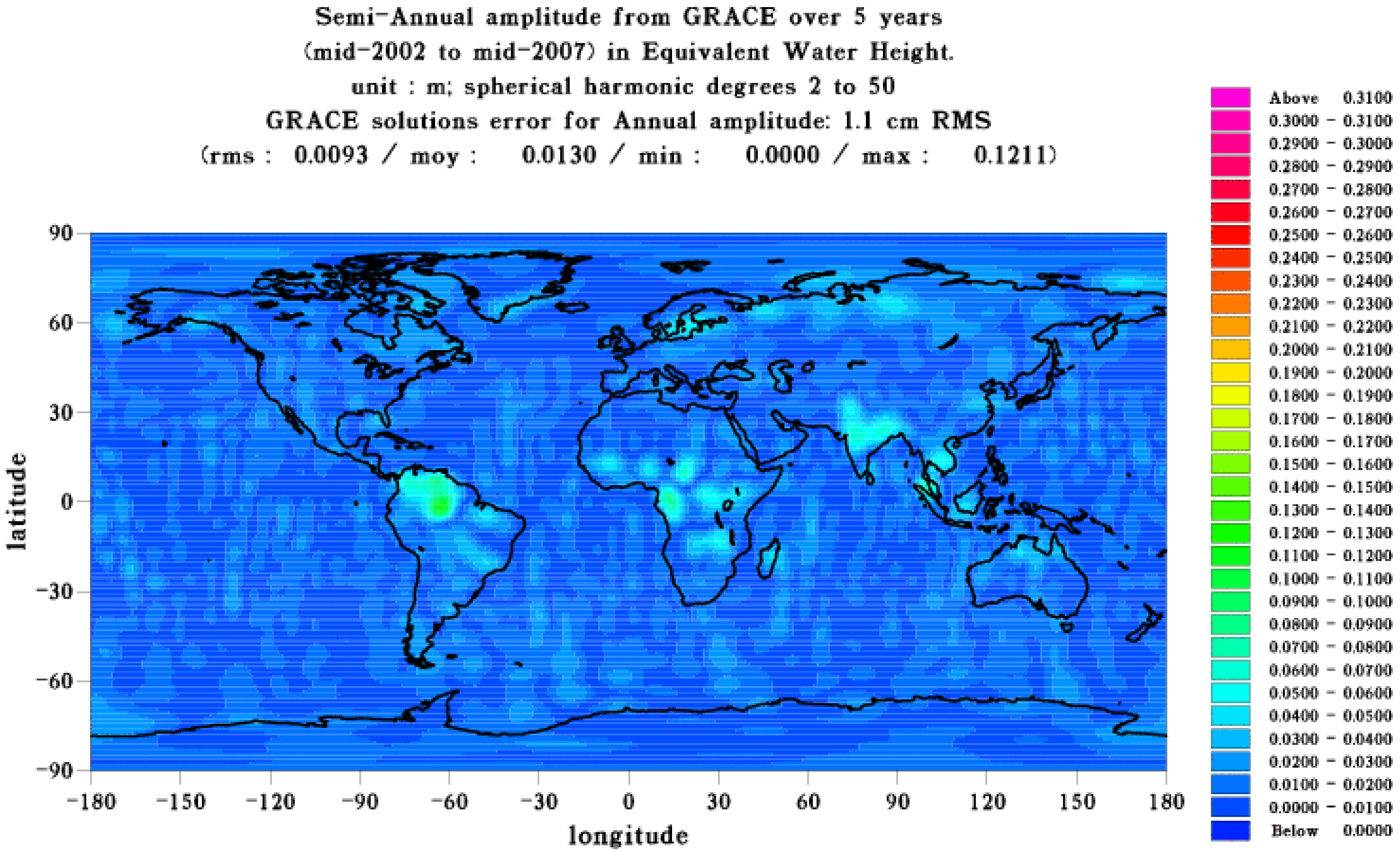
Maximum amplitude 52 cm EWH



GLOBAL MAPS IN EWH

SEMI-ANNUAL SIGNAL

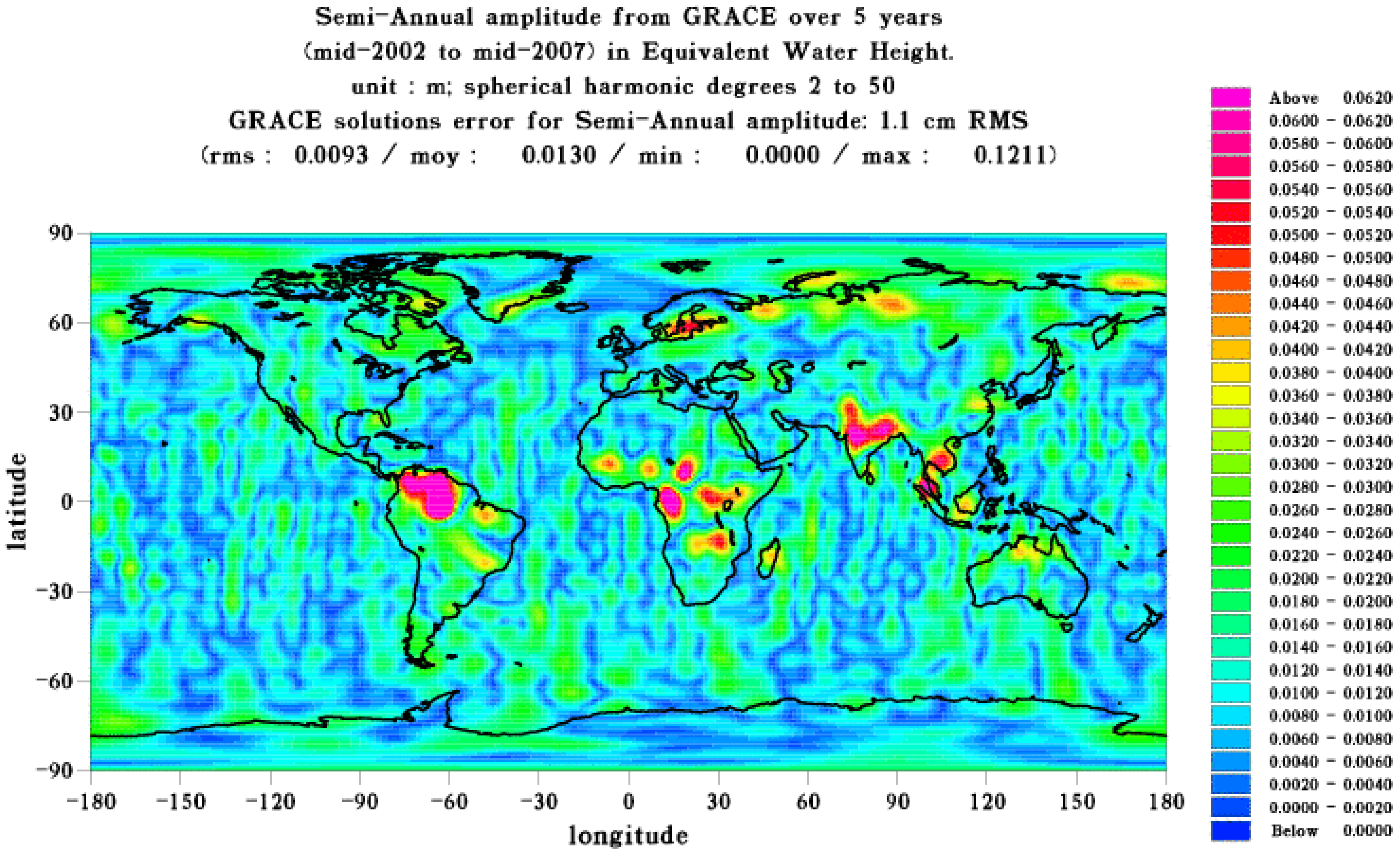
Maximum amplitude 12 cm EWH



GLOBAL MAPS IN EWH

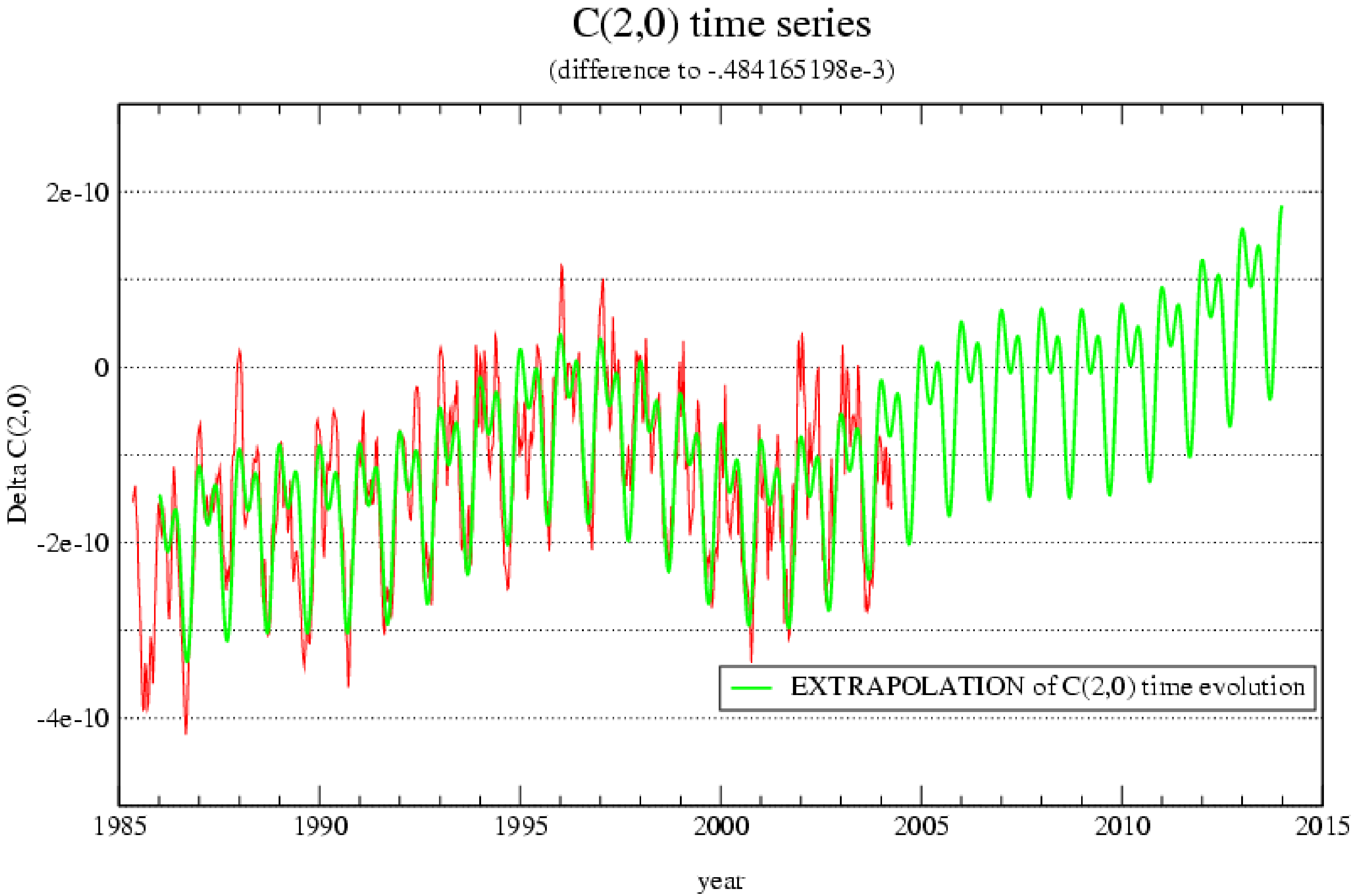
SEMI-ANNUAL SIGNAL (different scale)

Maximum amplitude 12 cm EWH



CONCLUSIONS

- The reprocessing of all GRACE data (from 2002 till end of 2007) has been completed by CNES/GRGS with homogeneous standards.
- The new time series will be provided every 10 days (as the current one) but will only be based on 10 days of data.
- The stabilization constraint used allows the recovery of the solutions with very limited striations and with no attenuation until degree 30 (resolution 666 km). Above this limit, and until degree 50, there is a gradual decrease in the power of the solutions, which means that the signal will be damped for resolutions below 666 km.
- For the study of mass balance over glacial regions, particularly Antarctica, two points need a special attention:
    - the uncertainties of the PGR models, which are still very large;
    - a careful consideration of the degrees 1 and 2 of the gravity field, implying the inclusion of SLR measurements on other geodetic satellites in the solutions.
- As a consequence of this reprocessing, a new mean field including 6 years of data has been derived up to degree 160. It contains drift, annual and semi-annual periodic terms up to degree 30.
- The new 10-day series will be available on the BGI web site in the coming months.



C(2,0) time series
(difference to -.484165198e-3)
2e-10
0
-2e-10
-4e-10
Delta C(2,0)
1985
1990
1995
2000
2005
2010
2015
year
EXTRAPOLATION of C(2,0) time evolution