Earth rotation and Earth gravity field from GRACE observations

Lucia Seoane, Christian Bizouard,
Daniel Gambis

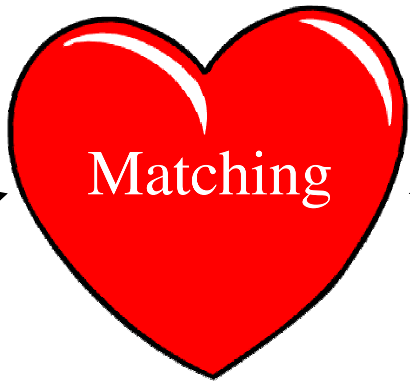
Observatoire de Paris SYRTE, 61 av. de l'Observatoire, 75014 Paris

Introduction

Gravity field changes

now observed with unprecedented accuracy thanks to the satellite mission GRACE (and LAGEOS)

→ changes of the inertia moments of the system «Earth» independent from any model



Earth rotation irregularities

Data and method

Euler-Liouville equation in the equatorial plane :

$$\chi^{G} \;(I) = \chi^{mass} \;(II) + \chi^{motion}$$

- χ^{G}: Geodetic excitation
- χ^{mass}: inertia term ($I\,\omega$)
- χ^{motion}: relative angular momentum

Both terms of this equation are compared using :

◆ EARTH ROTATION MONITORING : χ^{G}

◆ GRAVITY FIELD OBSERVATIONS : χ^{mass}

Polar motion excitation from gravity field

$$\chi_1^{mass} = -1.098 \frac{1}{1+k_2'} \sqrt{\frac{5}{3}} \frac{M_e R_e^2}{C-A} \Delta \overline{C}_{21}$$

$$\chi_2^{mass} = -1.098 \frac{1}{1+k_2'} \sqrt{\frac{5}{3}} \frac{M_e R_e^2}{C-A} \Delta \overline{S}_{21}$$

- M_e and R_e respectively the mass and mean radius of the Earth, C and A : the principal inertia moments of the Earth and $k'_2 = -0.310$: the degree 2 load Love number.
- Non tidal atmospheric and oceanic models to be included into C_{21} and S_{21} variations for a comparison to Earth rotation data.
- Only for GRGS solution degree 2 coefficients given by LAGEOS satellites.

The gravity field observations

Analysis of GRACE data from February 2003 to Mars 2006 carried out by 4 Centres :

- the Centre for Space Research (CSR)
- the GeoForschungsZentrum (GFZ)
- the Jet Propulsion Laboratory (JPL)
- the Groupe de Recherche en Géodésie Spatiale (GRGS/CNES) – combination with LAGEOS Data

"GEODETIC" POLAR MOTION EXCITATION

$$\chi_{\mathrm{G}} = \chi_1 + i\chi_2 = p + i\frac{\dot{p}}{\sigma_c}$$

$p = x - i\,y$ **is the observed polar motion.**

σ_c **is the Chandler period (433 days)**

MOTION PART REMOVED FROM THE GEODETIC EXCITATION

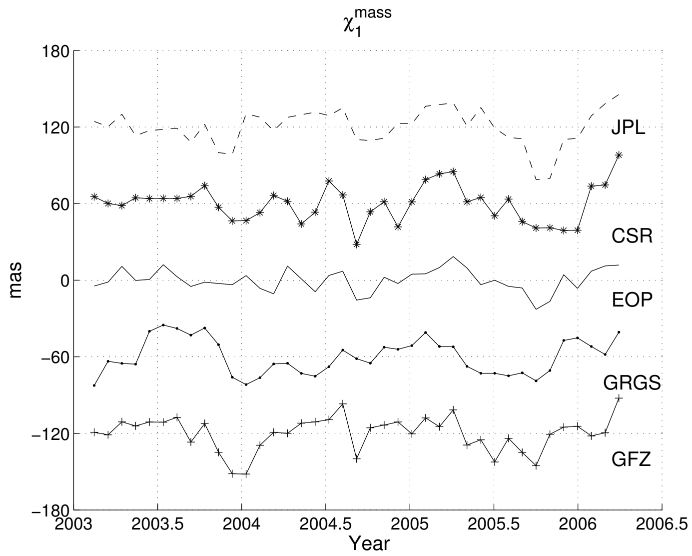
"Gravimetric" Excitation only reflect mass redistribution → removing the motion part of the excitation associated with the atmospheric winds and ocean currents:

$$\chi_G^{mass} = \chi_G - \chi_{atm}^{motion} - \chi_{ocean}^{motion}$$

Motion part :

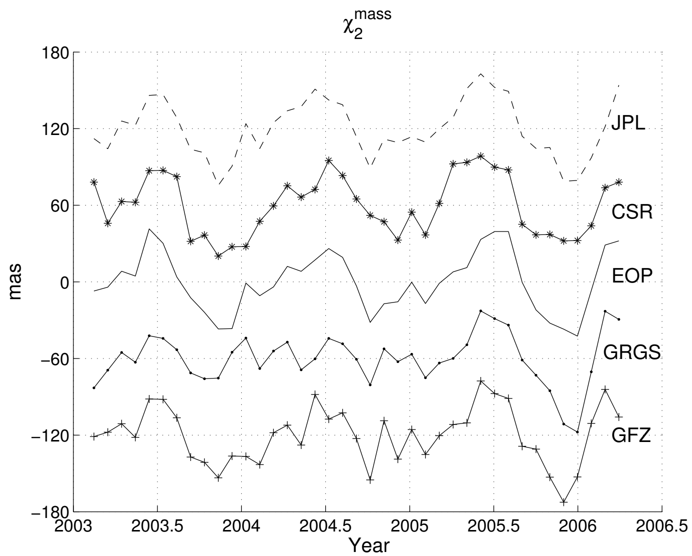
- **atmospheric angular momentum of the National Centre for Environmental Predictions**
- **oceanic angular momentum from ECCO model (JPL/IERS Special Bureau for the Oceans)**

Comparison of geodetic and gravimetric excitation including atmosphere and oceanic effect



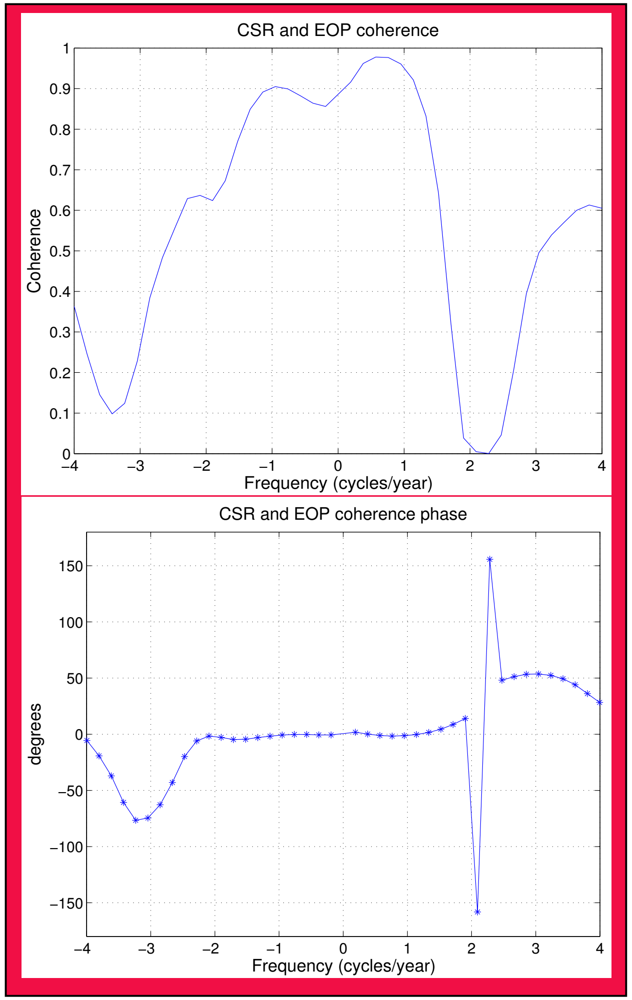
Complex correlations $\chi^{Grav} / \chi^{Geod}$

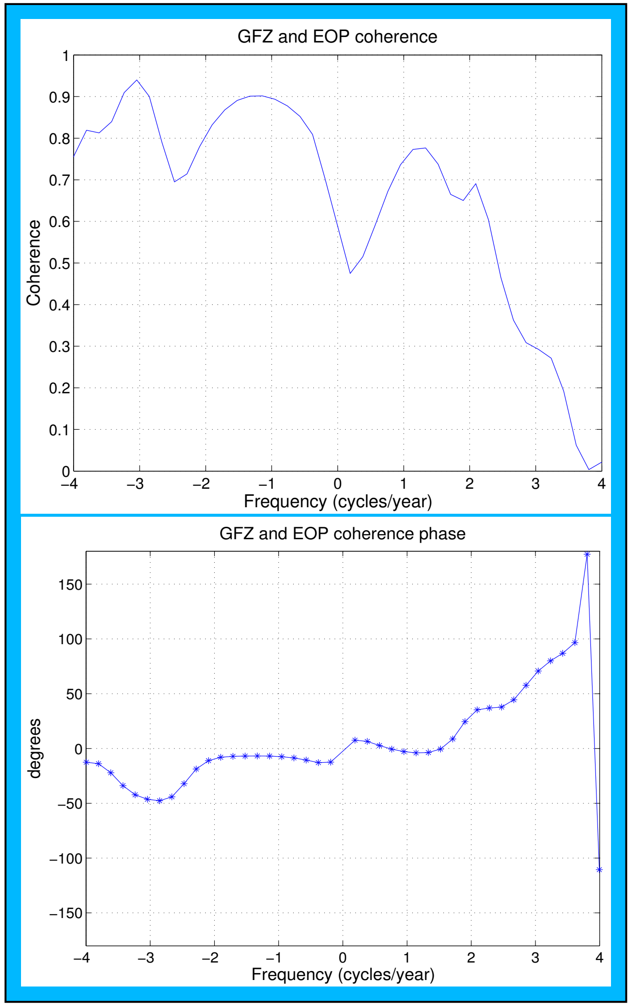
	CSR	GFZ	JPL	GRGS
Amplitude	0.8	0.8	0.9	0.7
phase	7°	0°	11°	-10°

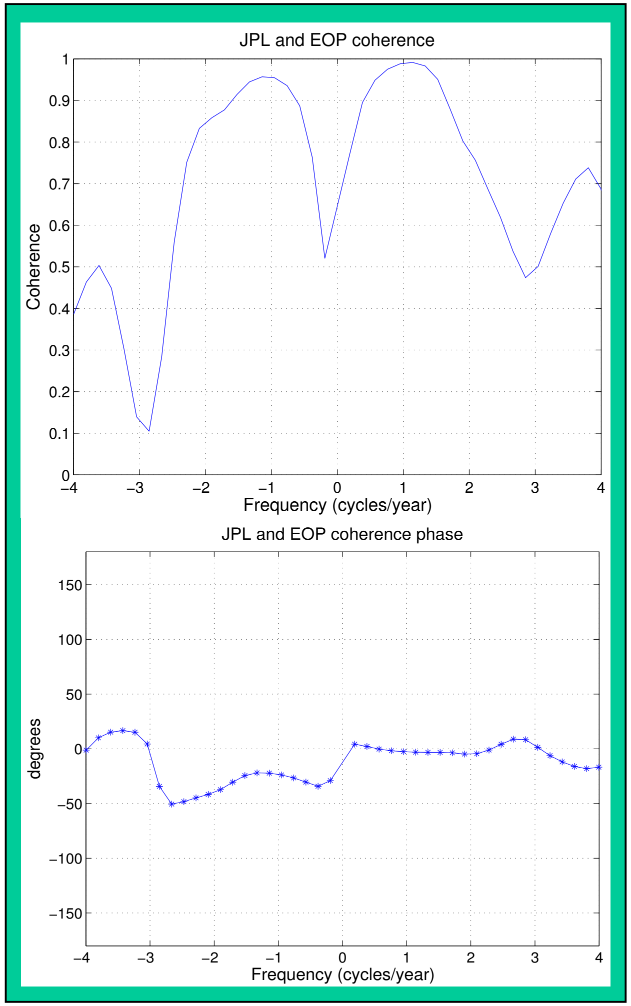


Standard deviation ratio $\chi^{Grav} / \chi^{Geod}$

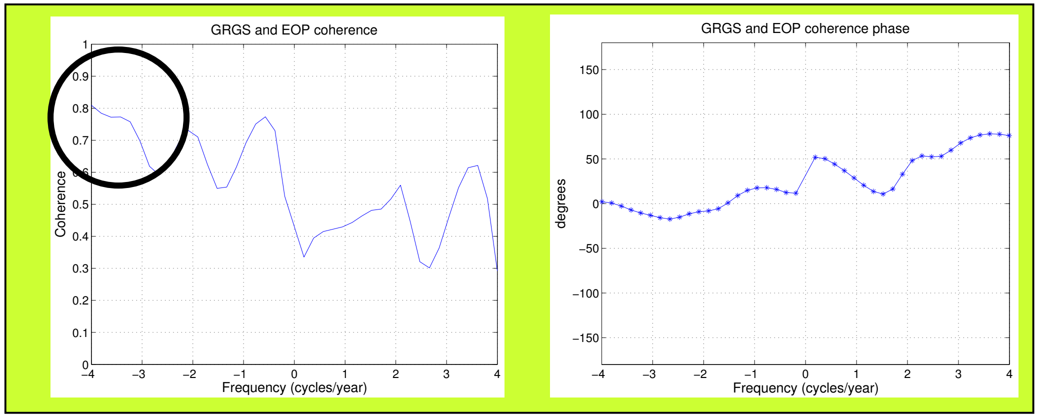
	CSR	GFZ	JPL	GRGS
χ^1	1.6	1.5	1.6	1.5
χ^2	0.9	0.9	0.9	0.8







Comparison of geodetic and total gravimetric excitation : coherence



Comparison of geodetic and gravimetric excitation : conclusion

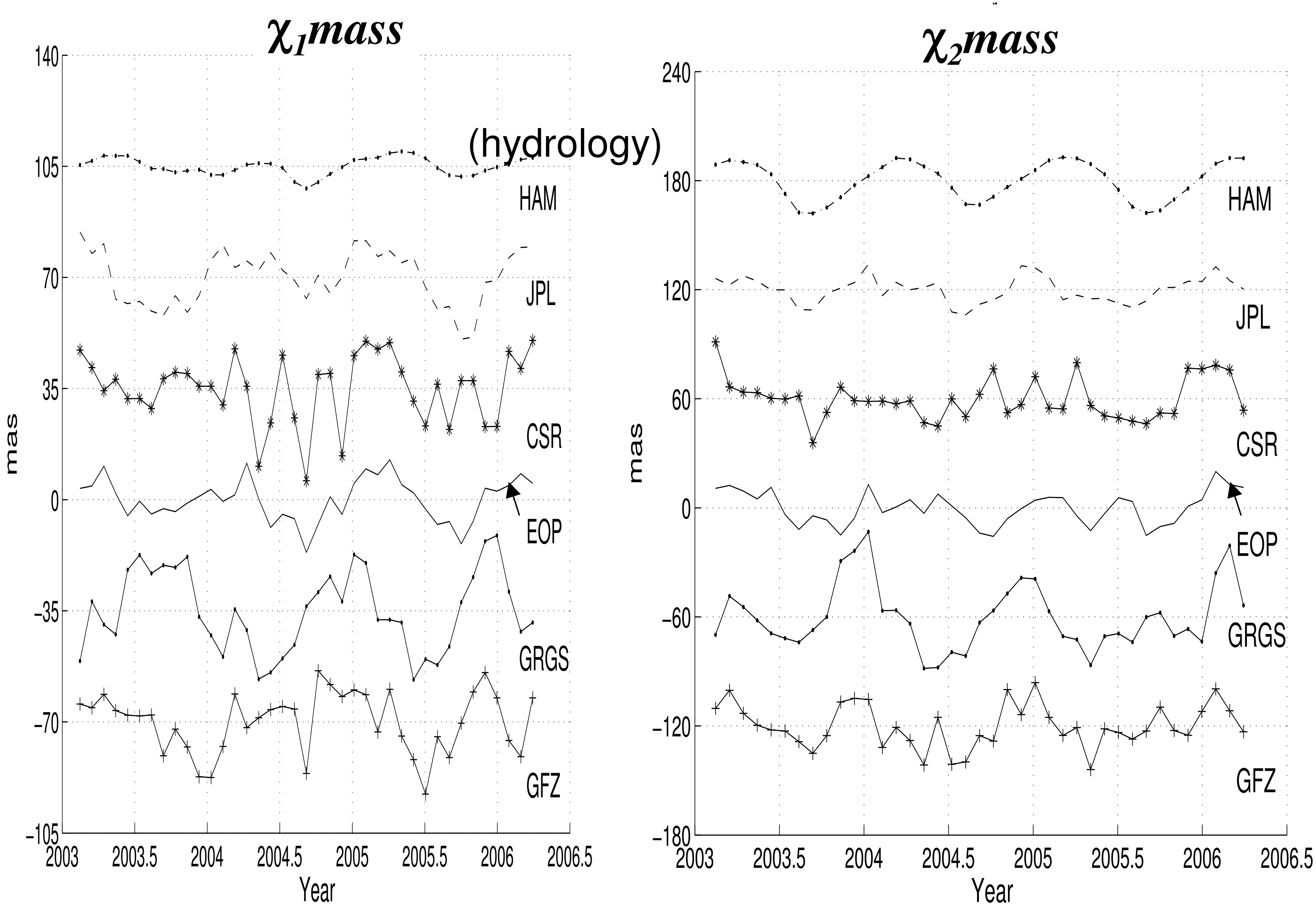
- **Global agreement of polar motion excitation with the (2,1) stokes coefficient determined by GRACE**
- **Better agreement for χ_2^{mass}, especially for seasonal variations.**
- **For χ_1^{mass} too much power (150 %).**

RESIDUAL EXCITATION

- Removing atmospheric and oceanic mass term from gravimetric/geodetic excitation functions → residual excitations reflecting mostly hydrological mass redistribution as far as the main effect is well modelled

- Coherence study between the excitation function from GPS polar motion and the excitation from gravity field

RESIDUAL EXCITATION (II)



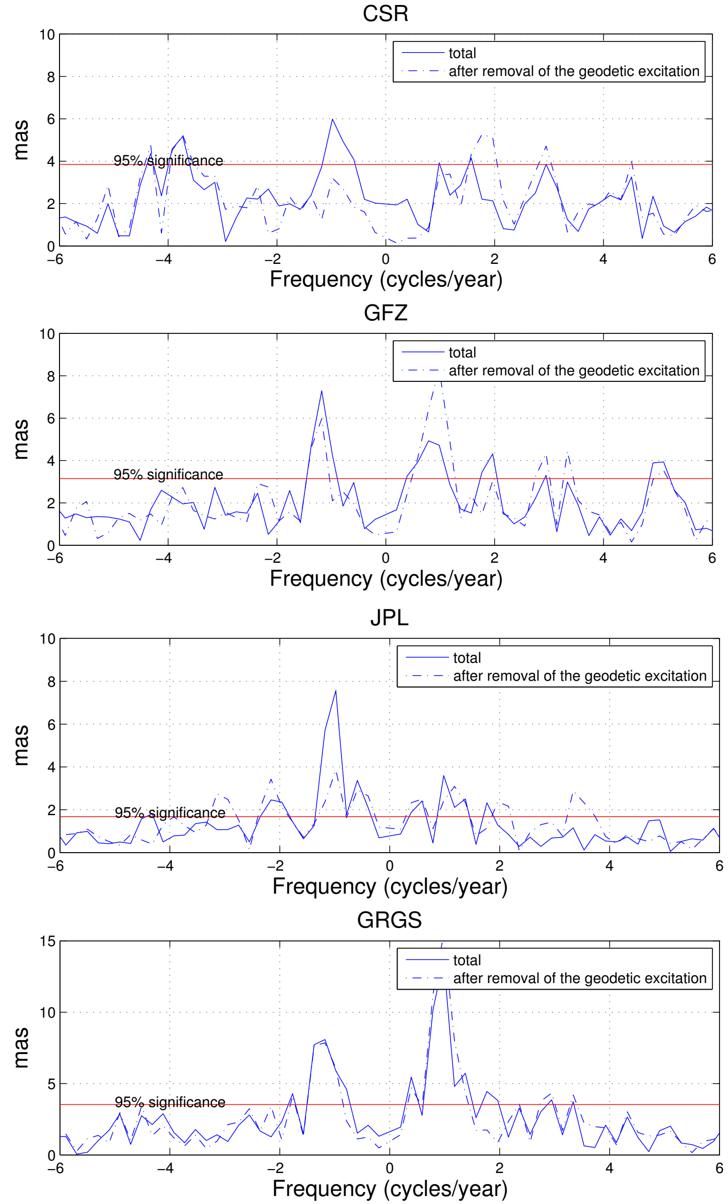
RESIDUAL EXCITATION

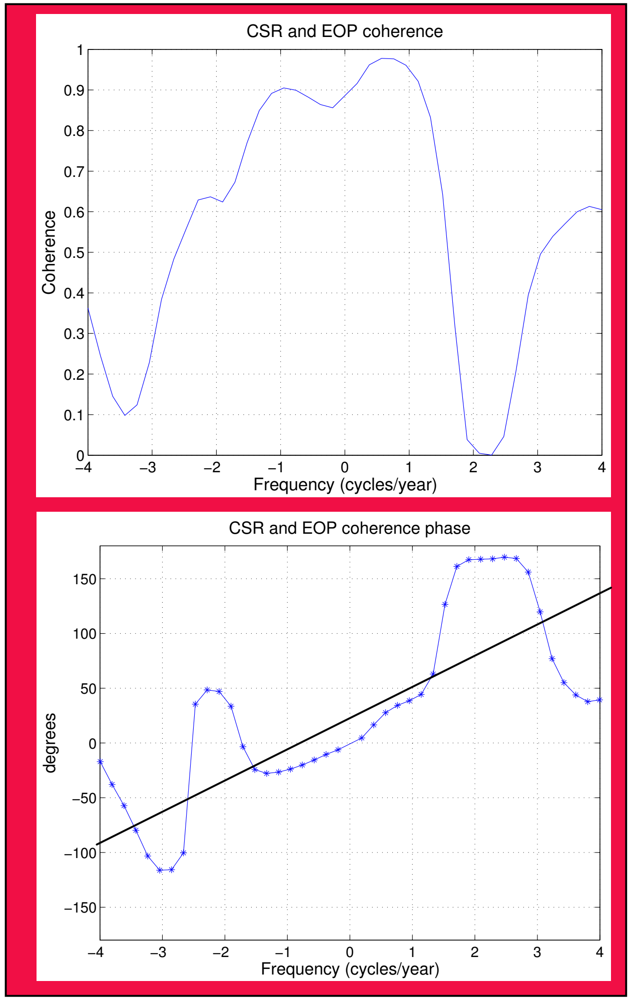
Complex correlations $\chi^{Grav/Hydro} / \chi^{Geod}$

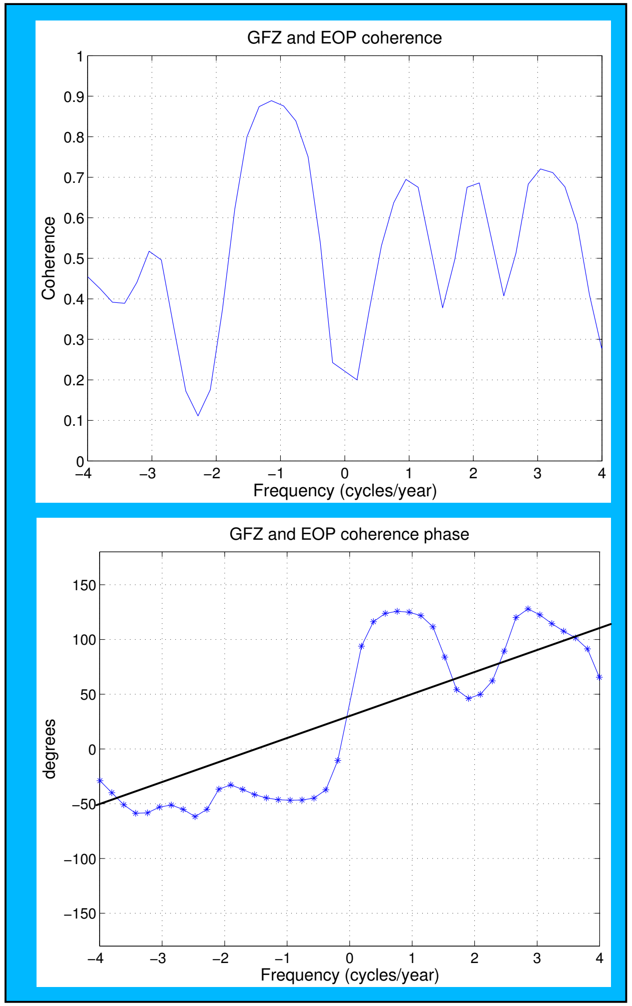
	CSR	GFZ	JPL	GRGS	Hydro-logy
Ampli-tude	0.4	0.3	0.6	0.2	0.7
phase	0°	-15°	19°	-47°	-30°

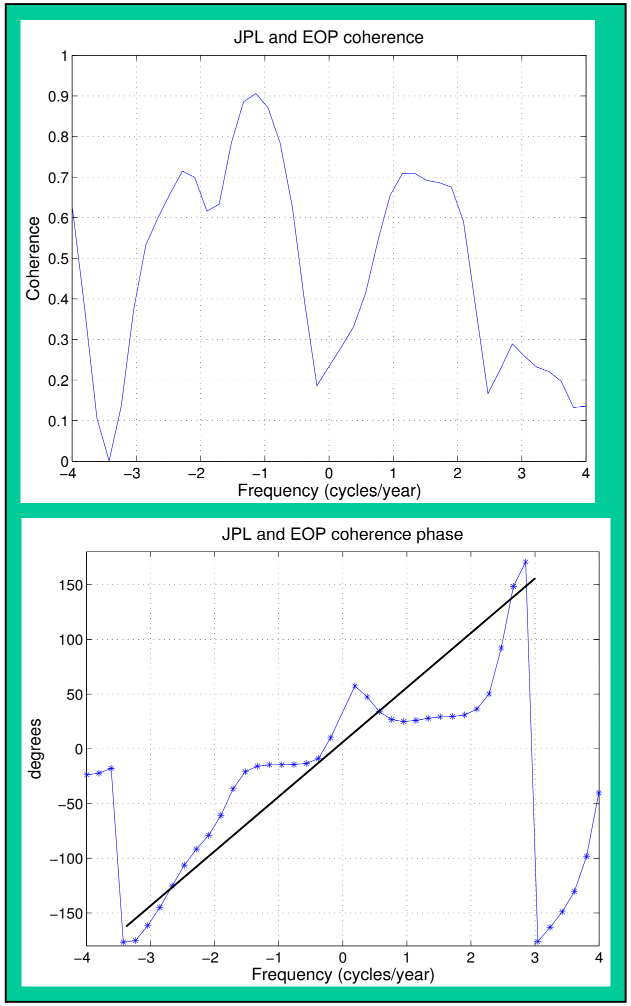
Standard deviation ratio $\chi^{Grav/Hydro} / \chi^{Geod}$

	CSR	GFZ	JPL	GRGS	Hydro
χ^1	1.6	1.4	1.3	1.9	0.4
χ^2	1.2	1.3	0.8	1.9	1.1

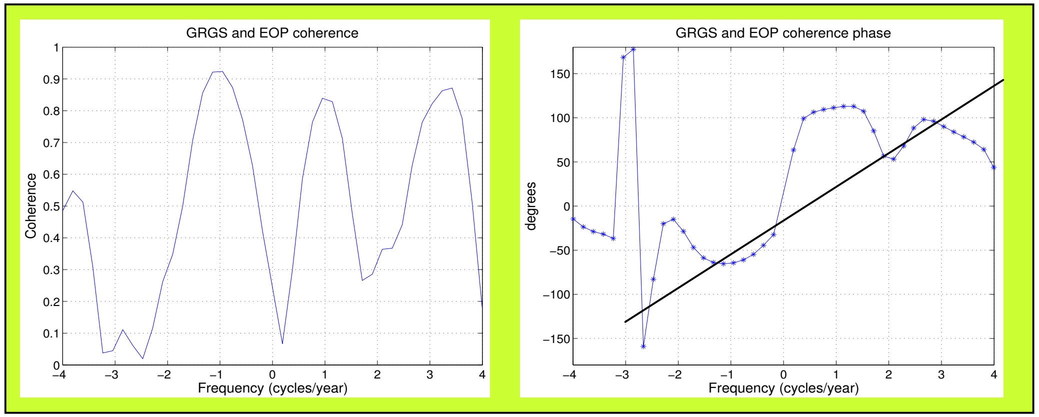








RESIDUAL EXCITATION : coherence



RESIDUAL EXCITATION : summary

Overall correlation drops but :

- Coherence maintained in seasonal band, more strongly in the **retrograde seasonal band** (no interpretation) (magnitude : 0.7, delay < 50 days)
- Systematic phase lag drift → systematic error in the gravimetric data ? in the geodetic polar motion excitation?
- In the latter case : poor modelling of the motion term. Atmospheric wind and oceanic currents not sufficient ? Bad modeled ?
- The JPL and EOP excitations well compare with the hydrological excitation (ability of GRACE to track global hydrological excitation?)

Conclusive remarks

- Significant differences between GRACE solutions CSR, GFZ, JPL but some common features in the seasonal bands
- GRGS solution seems to better reproduce high-frequency part (monthly) of the EOP excitation
- Possibility to track poor modeling of the motion term ?
- Mission and analysis still in progress. Wait and see.

The gravity field solutions are residuals :

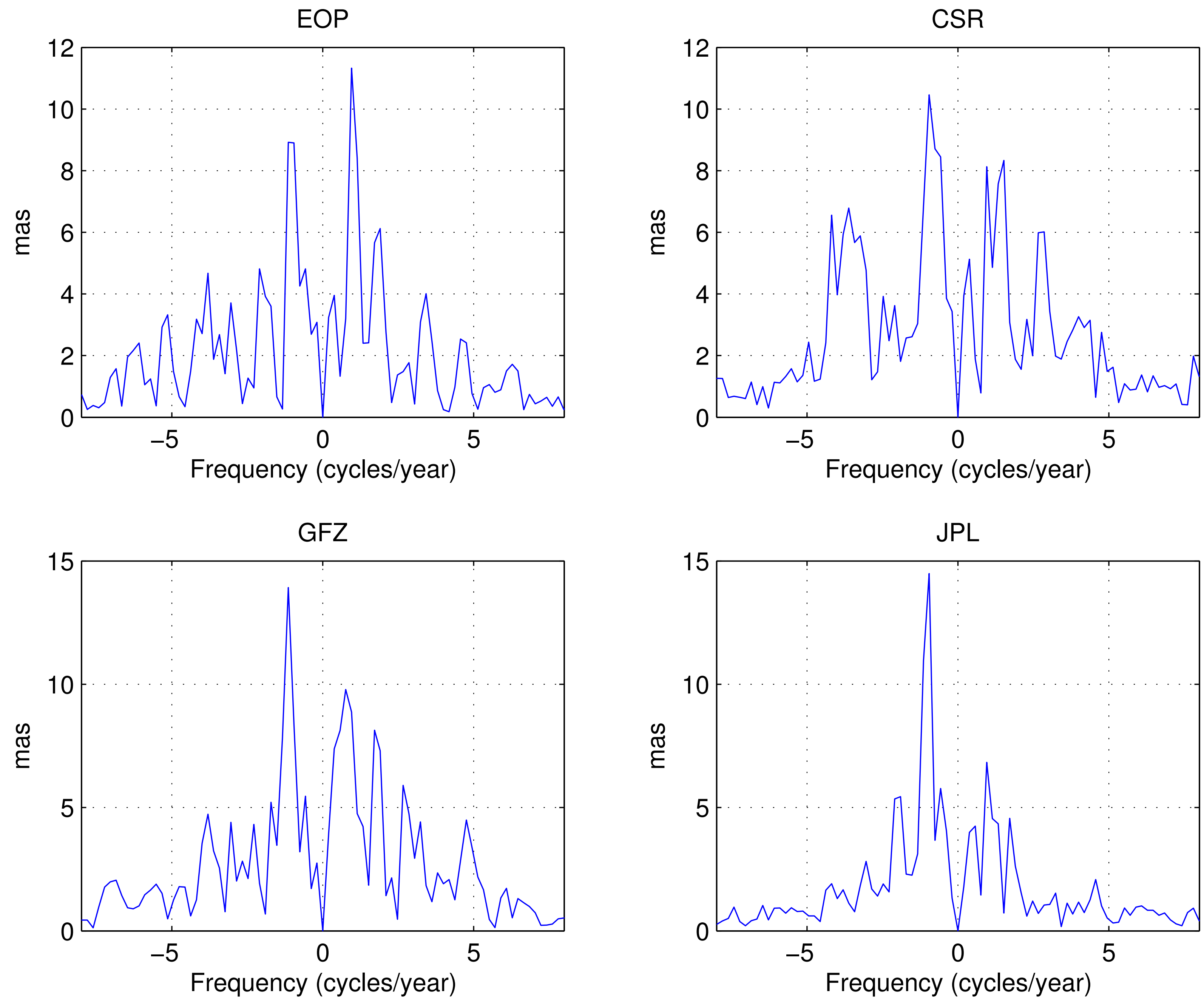
centre / models	CSR RL04	GFZ RL04	GRGS
Mean Field	GIF22a	EIGEN_GL04	EIGEN_GL04
Solid Earth Tides	IERS Convention 2003	IERS Conventions 2003	IERS Conventions 2003
Ocean Tide	FES-2004 (Lefèvre 2005)	FES-2004 (Lefèvre 2005)	FES-2004 (Lefèvre 2005)
Pole Tide	IERS Conventions 2003	IERS Conventions 2003	IERS Conventions 2003
Ocean Pole tide	Desai's model, 2002	Desai's model, 2002	Desai's model, 2002
Non Tidal Atmospheric and Oceanic Model	ECMWF atmospheric model + **OMCT baroclinic ocean model (Thomas, 2002)**	ECMWF atmospheric model + **OMCT baroclinic ocean model (Thomas, 2002)**	3D pressure field of ECMWF + **MOG2D barotropic ocean model (Carrère and Lyard, 2003)**

Amplitude and phase of the seasonal variations

Excitation		Annual Amp. mas	Annual Phase deg.	Semi-annual Amp. mas	Semi-annual Phase deg.
χ_1^{mass}	CSR	5±2	324±18	3±2	345±27
	GFZ	5±3	323±29	1±3	339±260
	GRGS	3±2	190±37	3±2	319±43
	OBS	8±1	342±10	1±1	23±59
χ_2^{mass}	CSR	22±2	287±5	5±2	34±23
	GFZ	21±3	290±7	7±3	25±23
	GRGS	19±2	292±7	5±2	14±29
	OBS	29±2	300±4	9±2	43±14

Time origin for the phase : 1/1/2004

Comparison of geodetic and gravimetric excitation (II)



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Polar motion excitation from gravity field (I)

$\chi^{mass} \sim (I_{13} + i\, I_{23}) / (C-A)$

- C, A main inertia moments of the Earth
- $I^{13} = - M R_e^2 C_{21}$ $\quad\quad I_{23} = - M R_e^2 S_{21}$

where C_{21}, S_{21} are the (2,1) spherical harmonics coefficients of the geopotential determined by GRACE