Comparison of polar motion excitation functions computed from different sets of gravimetric coefficients

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Outline

- Introduction
- Data
  - Gravimetric excitation functions of polar motion.
  - Geodetic residuals.
- Results
  - Comparison of gravimetric excitation functions with each other.
  - Examination of the compatibility of these functions with hydrological signal in observed geodetic excitation function.
  - We focus on subseasonal time scales and seasonal time scales.

Introduction

- Satellite mission Gravity Recovery and Climate Experiment (GRACE) is a source of data on temporal changes in Earth's gravity field. These data are available, in the form of changes in the coefficients ΔC_{mn} ΔS_{mn} - the so-called Level 2 gravity field product.
- These coefficients reflect mainly the impact of the land mass of the hydrosphere on the gravitational field changes.
- To a lesser extent, they reflect changes in ice mass, and changes from seismic events. However they do not include information about the influence of the atmosphere and ocean.

Introduction

- There have been a number of attempts to process releases of Gravity Recovery and Climate Experiment (GRACE) data.
- Here we use the most recently updated solutions of the GRACE based ΔC_{21} ΔS_{21} .
- ΔC_{21} ΔS_{21} coefficients can be also determined from SLR data analysis.
- Recently ΔC_{21} ΔS_{21} were redetermined from analysis of observations of CHAMP satellite mission .

Introduction - Excitation functions of polar motion

χ_1, χ_2 - components (towards longitudes 0^o and 90^oE respectively) of gravimetric~hydrological excitation functions are determined from ΔC_{21}, ΔS_{21} coefficients from the following formulas (Gross, 2013):

$$\chi_1 = -\sqrt{\frac{5}{3}}\frac{1.098 a_E^2 M}{(C-A)}\Delta\widehat{C}_{21} \qquad \chi_2 = -\sqrt{\frac{5}{3}}\frac{1.098 a_E^2 M}{(C-A)}\Delta\widehat{S}_{21}$$

M-mass of the Earth
a_E-average equatorial radius of the Earth
C,A principal moments of inertia

Data used - ΔC_{21}, ΔS_{21}

The following data set were used to estimate the gravimetric excitation functions of polar motion:

GRACE monthly solutions:

- **AIUB** - solution from the Astronomical Institute University of Bern data from July 2003 and December 2009,
- **ITG** - solution from Institut für Geodäsie und Geoinformation Bonn, data from August 2002 to August 2009,
- **Tongji** - monthly solution from the Tongji University, Shanghai, PR China, from January 2003 to December 2010,
- **DMT-1** - solution from the Delft Institute of Earth Observation and Space System of the Delft University of Technology, data from February 2003 to February 2009.

CSR RL05 - RL05 solution from the Center for Space Research (CSR), 2003 - 2013.

- **JPL RL05 -** RL05 solution from the Jet Propulsion Laboratory (JPL), 2003-2013.
- **GFZ RL05 –** RL05 solution from the GeoforschungsZentrum (GFZ) , 2003-2013 .

available on the website: http://icgem.gfz-potsdam.de/ICGEM/.

Data used - ΔC_{21}, ΔS_{21}

GRACE 10 day solution:

•**CNES/GRGS RL02** solution is determined by a combined analysis of the LAGEOS and GRACE observations, January 2003 – December 2012.

GRACE weekly solution

•**GFZ RL05-** is a GRACE weekly solution from the GeoforschungsZentrum (GFZ)

CHAMP monthly solution

•**ULUX** - is a monthly solutions from the CHAMP mission observations the University of Luxembourg, January 2003 – December 2009.

•All these data are available on the website: http://icgem.gfz-potsdam.de/ICGEM/.

SLR monthly solution

•**SLR** obtained from the analysis of SLR data to five geodetic satellites: LAGEOS-1 and 2, Starlette, Stella and Ajisai (Cheng and al., 2012).

Data - Excitation Functions of Polar Motion

- In this way we determined *11* series of χ_1 χ_2 component of gravimetric~hydrological excitation functions of polar motion from the above series of ΔC_{21}, ΔS_{21}

- Next these gravimetric excitation functions of polar motion were compared with so called geodetic residuals (G-A-O) containing the hydrological part of polar motion excitation obtained by removing merged atmospheric (AAM) and oceanic (OAM) excitation from the geodetic excitation function (GAM).

- We used the geodetic residuals available on the website IERS—EOP Product Center http:/hpiers.obspm.fr/eop-pc/

Data - Excitation Functions of Polar Motion

- The gravimetric data were given with monthly, weekly and 10 days sampling

- The geodetic residuals were given with 6-hour sampling.

- All series were smoothed and interpolated with the 30 days or 10 days step in order to harmonize data.

- The seasonal 365.25, 180.0 and 120.0-day oscillations and trend were removed from the time series.

- The main purpose was to explore which from these several gravimetric excitation functions are closed to the geodetic observations.

Analysis Non-Seasonal Variations

- Time series
- Spectra
- Variances
- Correlation coefficients

Excitation Functions of Polar Motion

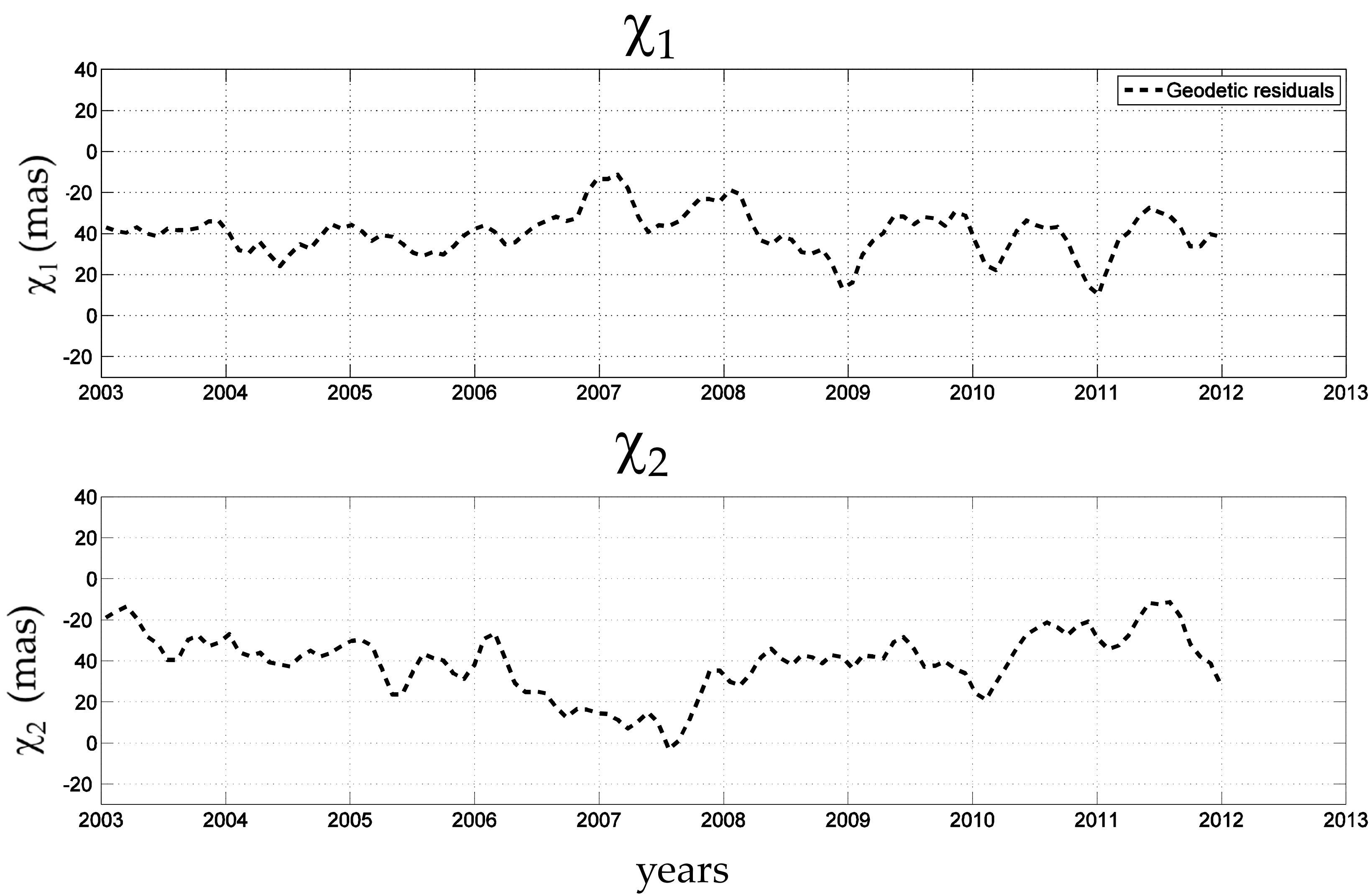
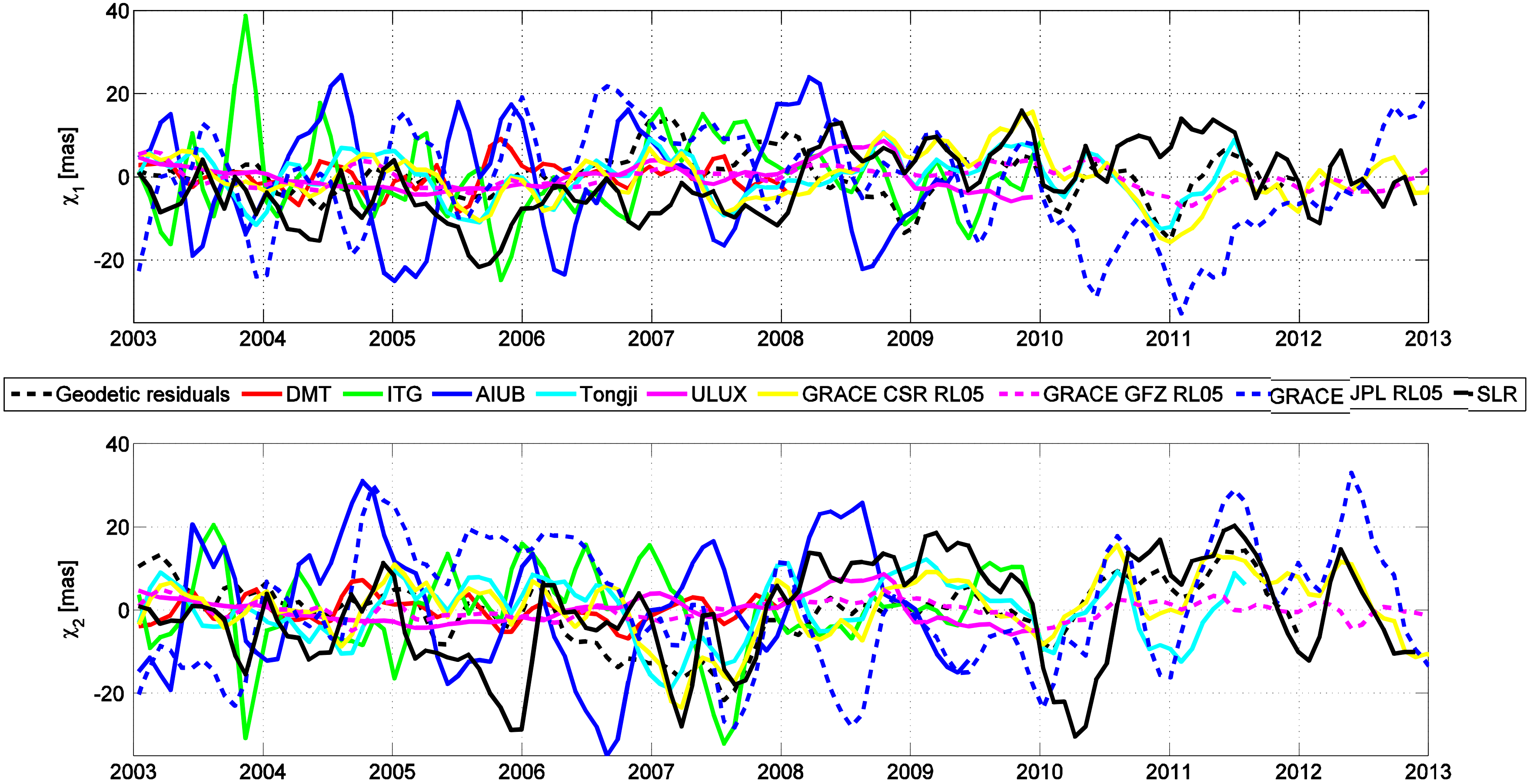


Fig. 1 Comparison of components of the gravimetric excitation functions, χ_1 and χ_2, of polar motion from different gravimetric data and of the geodetic residuals G-A-O being the difference between the geodetic excitation function and sum of the atmospheric and oceanic excitation function of polar motion. All the data were smoothed with a step of 30 days, FWHM=60. The 365.25, 180.0 and 120.0-day oscillations were removed from the time series.

Excitation Functions of Polar Motion



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Excitation Functions of Polar Motion
10 days

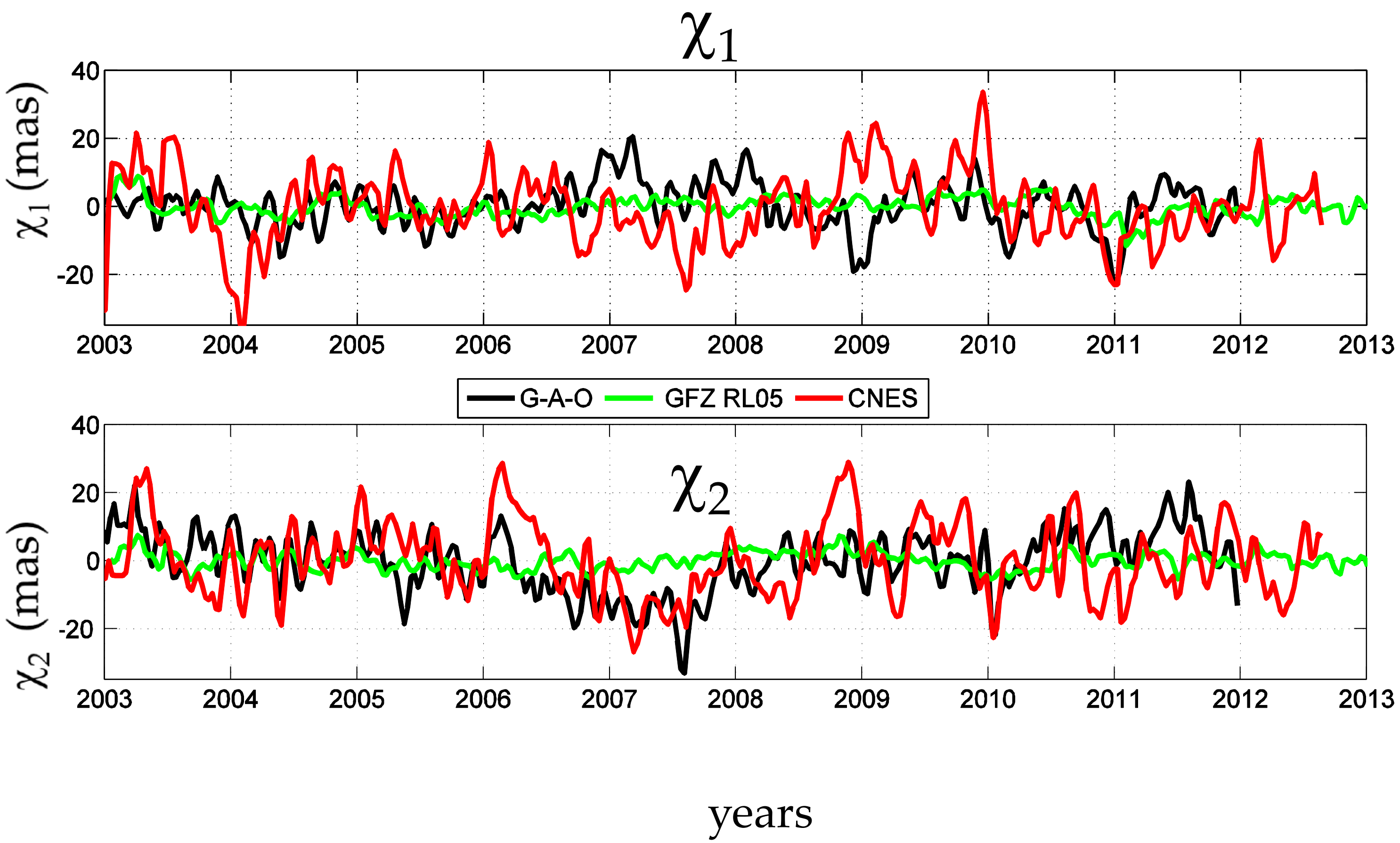


Fig. 2 Comparison of components of the gravimetric excitation functions, χ_1 and χ_2, of polar motion from different gravimetric data and of the geodetic residuals G-A-O being the difference between the geodetic excitation function and sum of the atmospheric and oceanic excitation. All the data were smoothed with a step of 10 days, FWHM=20. The 365.25, 180.0 and 120.0-day oscillations were removed from the time series.

Spectra
G-A-O vs Gravimetric Excitations (30 days)

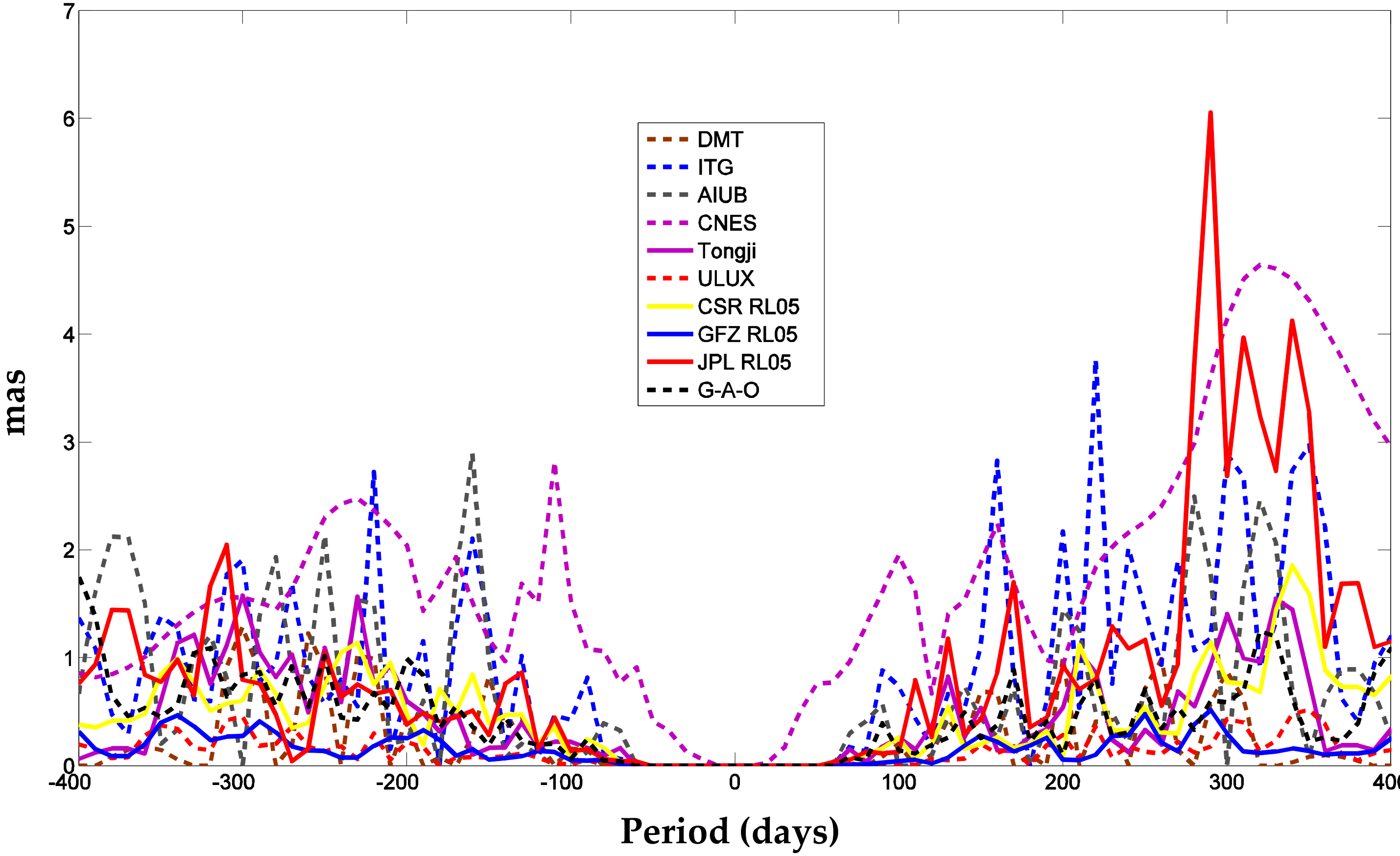
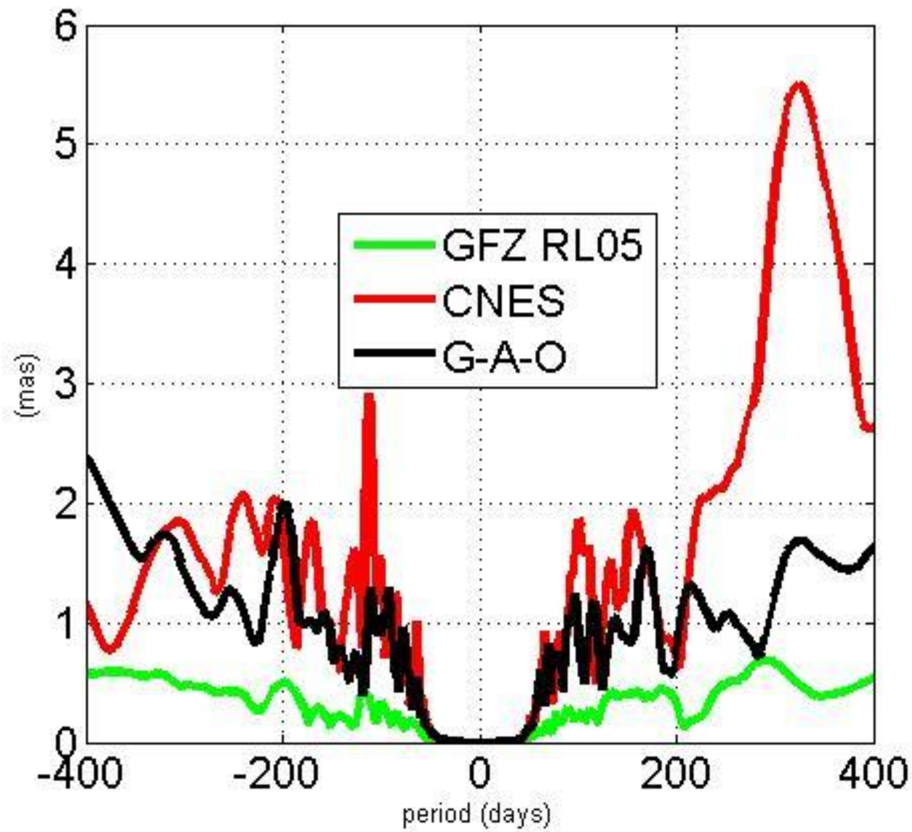


Fig. 3 FTBPF amplitude spectra of the different complex gravimetric excitation functions of polar motion and of geodetic residuals (G-A-O) (functions smoothed with a step of 30 days).

Spectra
G-A-O vs Gravimetric Excitations (10 days)



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Variances Comparison
G-A-O vs Gravimetric Excitations (30 days)

Excitation functions	χ_1 [mas^2]	χ_2 [mas^2]
Geodetic residuals		
G-A-O	***28.3***	***57.1***
Gravimetric excitation functions		
DMT	11.9	9.1
ITG	95.8	104.0
AIUB	179.7	221.7
Tongji	29.9	51.3
GRACE CSR	33.0	60.8
GRACE GFZ	6.9	4.6
GRACE JPL	166.3	211.1
SLR	65.8	145.5
ULUX-Champ	28.1	11.3

Variances Comparison
G-A-O vs Gravimetric Excitations (10 days)

Excitation functions	χ_1 [mas^2]	χ_2 [mas^2]
Geodetic residuals		
G-A-O	***28.3***	***56.6***
Gravimetric excitation functions		
GFZ	8.5	6.4
CNES	121.6	119.1

Correlation Coefficients
G-A-O vs Gravimetric Excitations

Gravimetric excitation	χ_1	χ_2
30 day sampling		
DMT	0.02	0.26
ITG	0.24	0.14
AIUB	0.18	0.15
Tongji	0.35	0.60
CSR RL05	0.24	**0.69**
GFZ RL05	0.30	0.37
JPL RL05	0.25	0.29
SLR	0.10	0.46
ULUX -Champ	0.33	0.01
10 day sampling		
CNES	0.30	0.52
GFZ	0.24	0.26

G-A-O vs Gravimetric Excitations

1 DMT
2 ITG
3 AIUB
4 TONGJI
5 CSR
6 GFZ
7 JPL
8 SLR
9 ULUX

10 GFZ
11 CNES

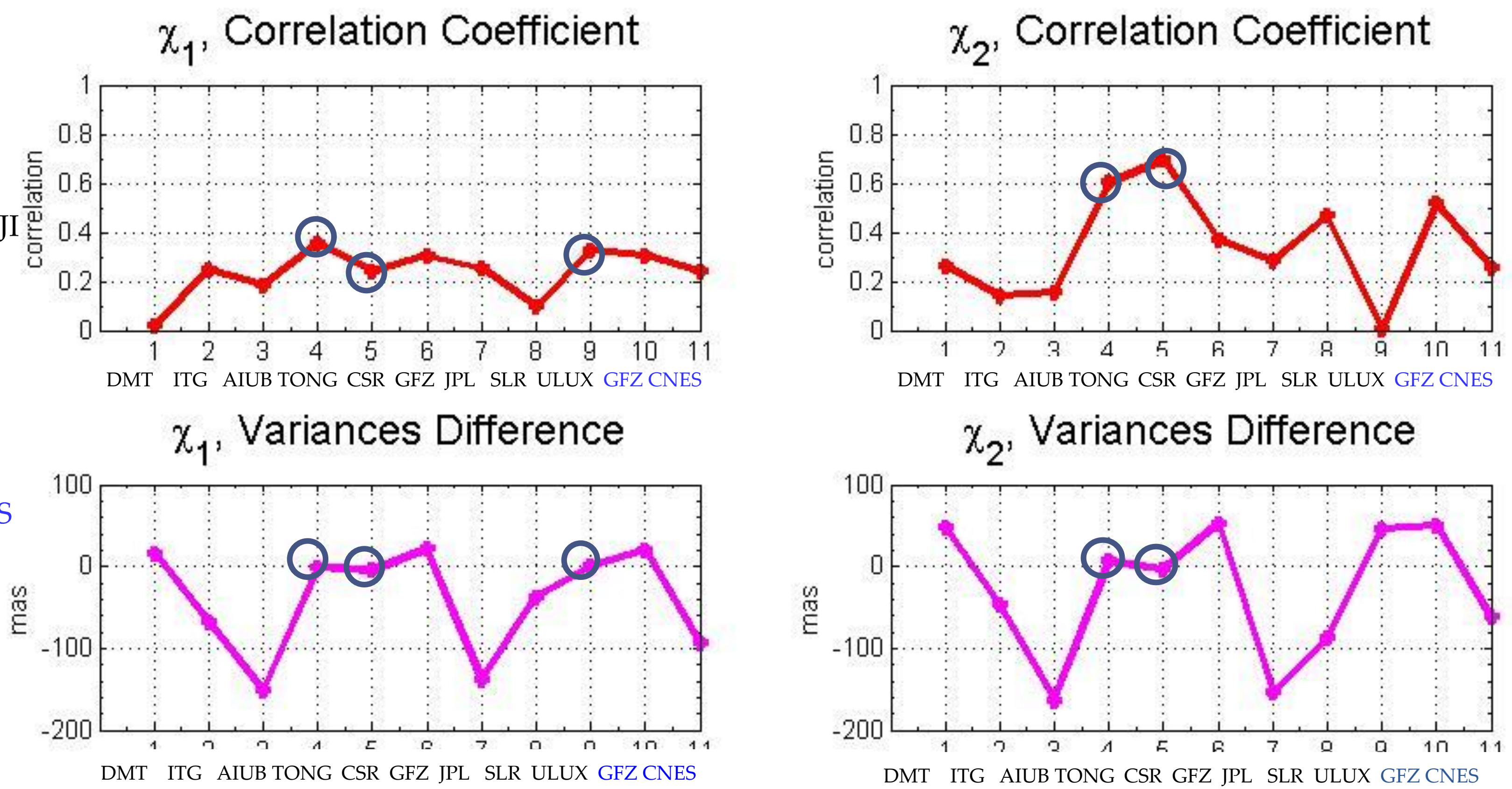


Fig. 5 Comparison of gravimetric excitation functions, χ_1 and χ_2, of polar motion from different gravimetric data and of the geodetic residuals G-A-O.

Annual Oscillations

- Phasor diagrams

Phasor diagrams, annual osciallations

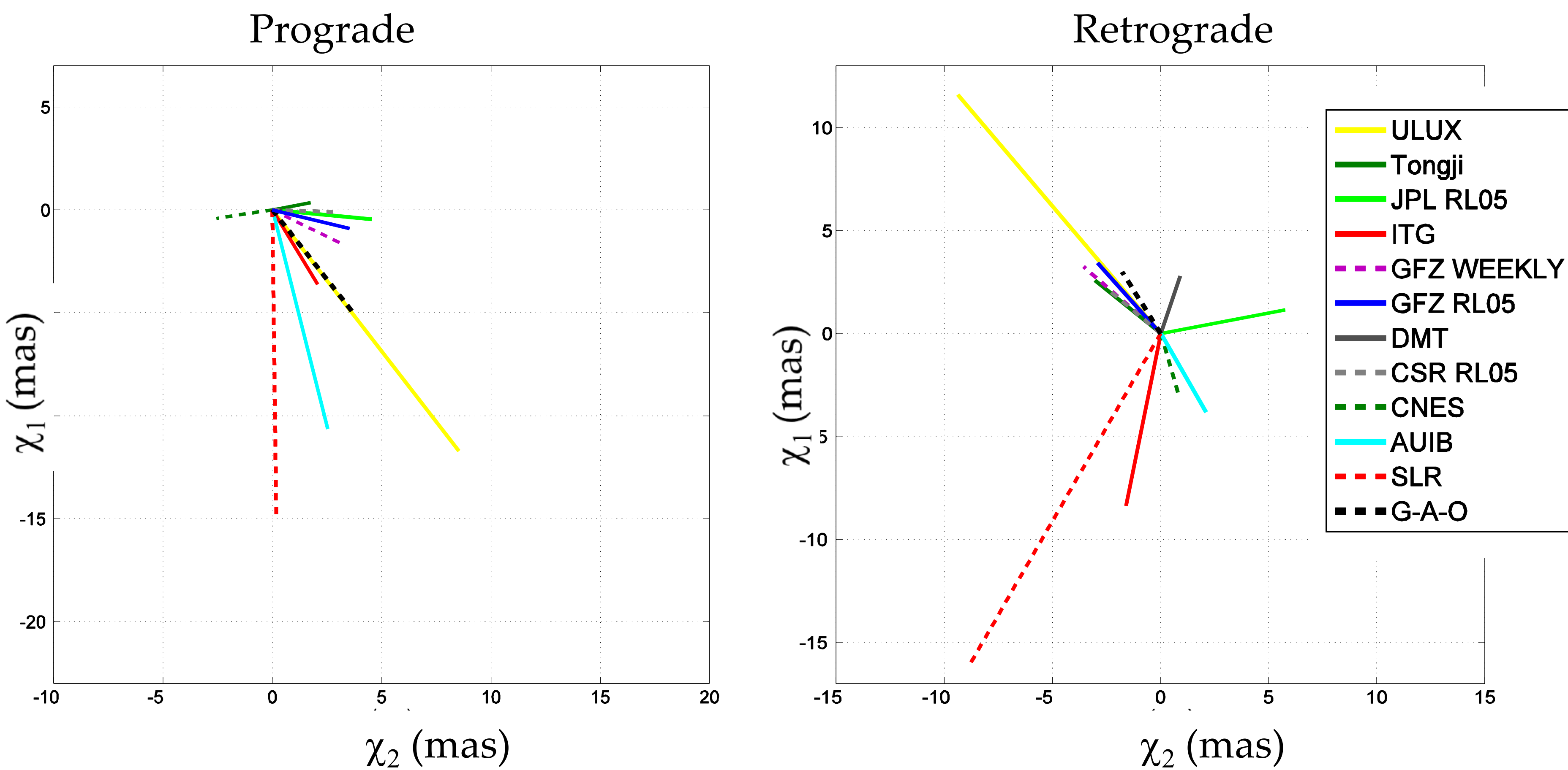


Fig. 3 Phasor diagrams of the prograde and retrograde annaul oscillations of the residuals of the geodetic excitation function (G-A-O) and of the different gravimetric excitation functions. Analysis is done over the period 2003.0 to 2009.5.

Conclusions

- We found that gravimetric-hydrological excitation functions, based on the most recent releases, obtained by the several processing centers still differ significantly.
- One difference is that a greater degree of smoothness is exhibited by GFZ based functions than the other products.
- The best agreement between gravimetric-hydrological excitation functions and geodetic residuals was obtained for the χ_2 component of gravimetric excitation function computed from the CSR, Tongji and CNES data series, and this may be due to some positive attributes in the processing.
- There is some agreement between annual oscillation of G-A-O and of gravimetric excitation based on ITG, GFZ data in the prograde component and between annual oscillation of G-A-O and of gravimetric excitation based on CSR, Tongji, GFZ data in the retrograde component.

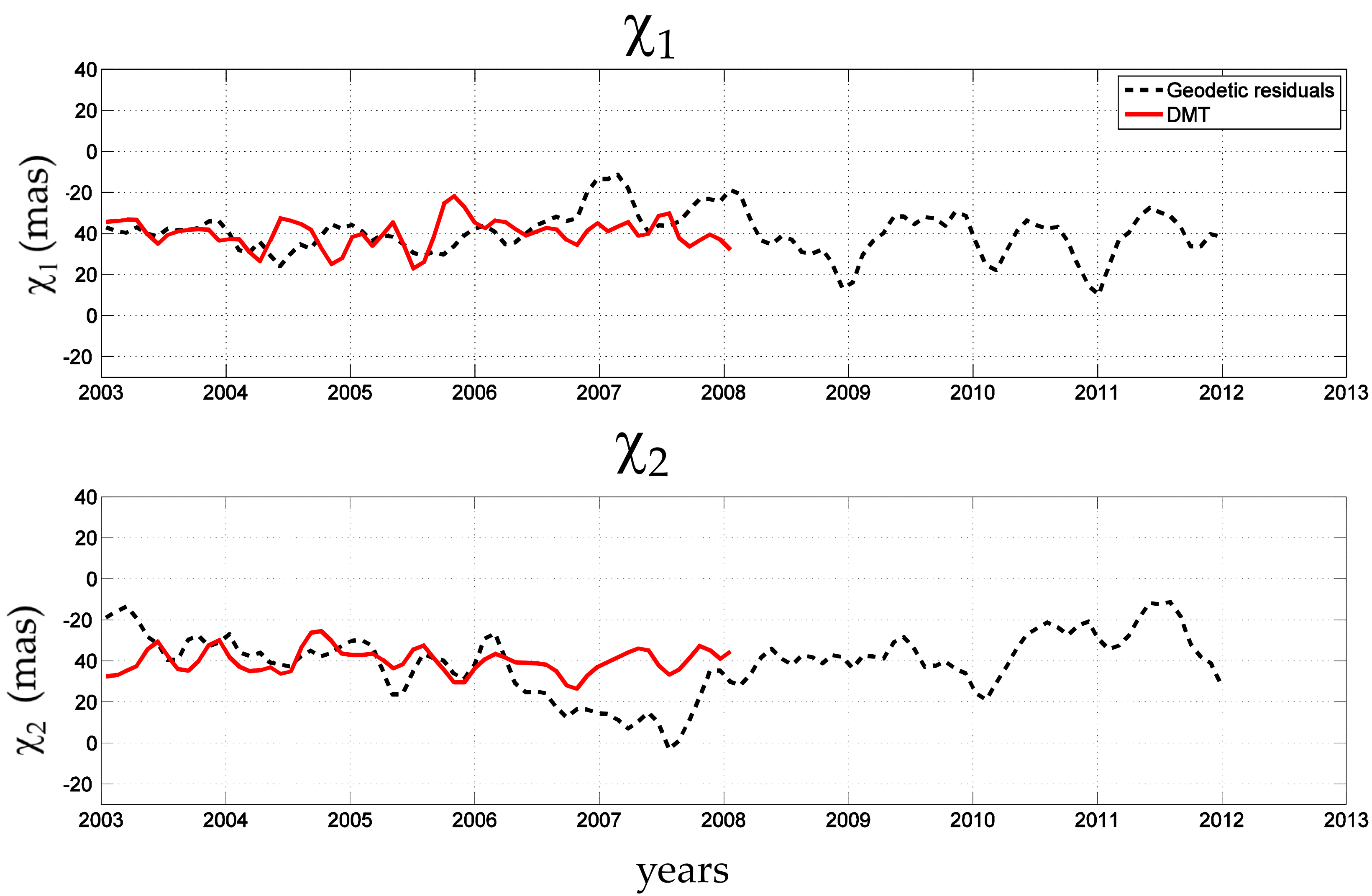
Conclusions

- Analyses show that the use of these new data to compare with geodetic residuals does not bring significant new results from to previous studies [*Seoane et al. 2009, 2011; Jin et al. 2010,2011, 2012; Chen et al. 2012; Nastula et al. 2011*], though confirms the current extent of the differences among the series.

Amplitudes and phases of annual oscillation gravimetric excitations and geodetic residuals

Data	Prograde annual		Retrograde annual	
	Amplitudes [mas]	Phase [o]	Ampli tudes [mas]	Phase [o]
G-A-O	6.37	-53.5	3.48	120.8
TONGJI	1.78	11.7	3.98	139.6
ITG	4.16	-60.2	8.50	-100.9
DMT	0.44	-3.6	2.93	72.0
AIUB	10.93	-76.6	4.35	-61.3
GRACE CSR RL05	2.75	-2.0	3.06	138.7
GRACE GFZ RL05	3.65	-14.3	4.50	130.2
GRACE JPL RL05	4.55	-5.8	5.86	11.2
ULUX	14.49	-53.9	14.91	128.9
SLR	15.00	-89.3	18.35	-118.7
GFZ WEEKLY	3.67	-27.5	4.82	137.7
CNES10	2.59	-170.9	3.25	-74.5

Excitation Functions of Polar Motion



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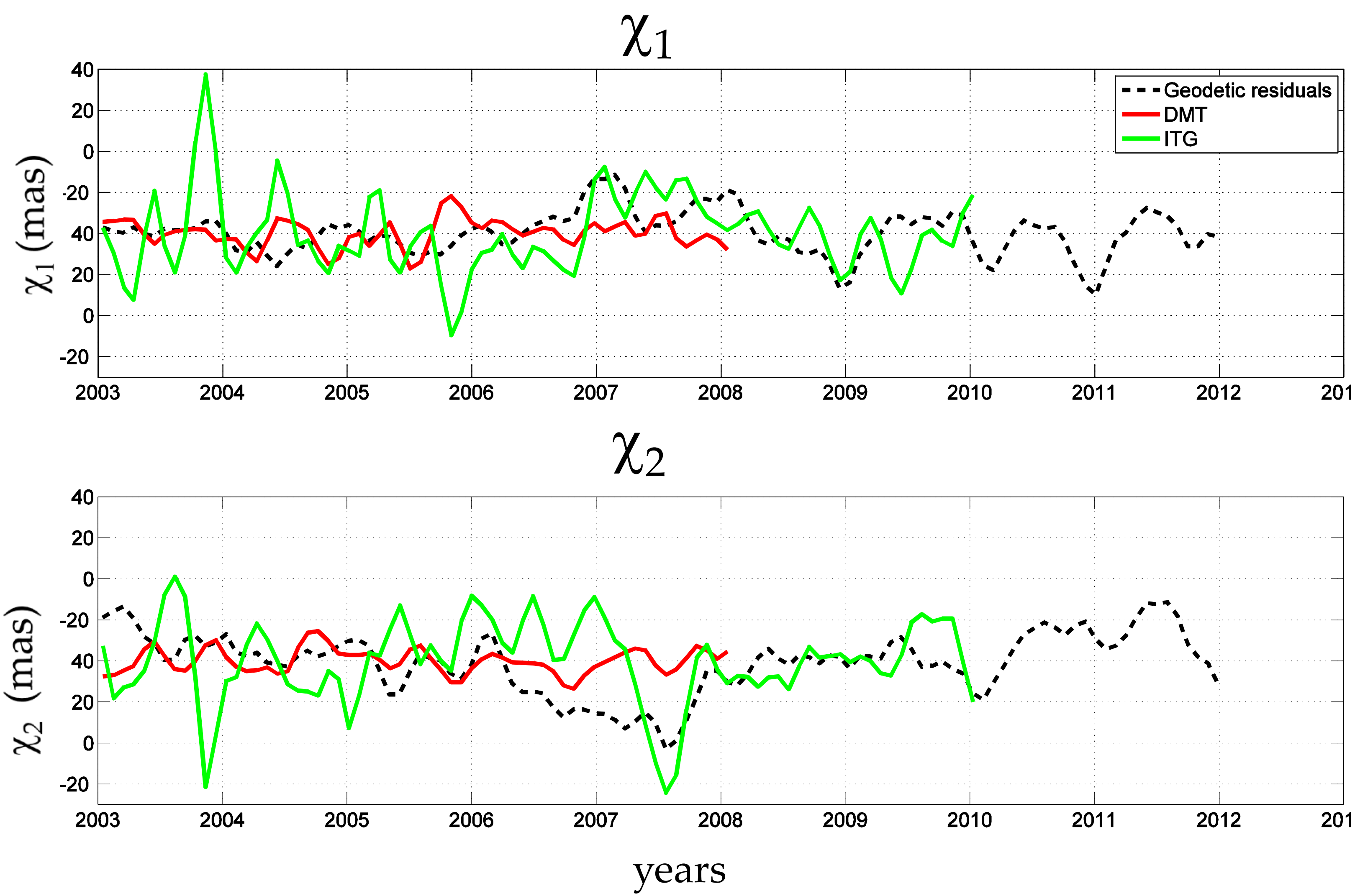

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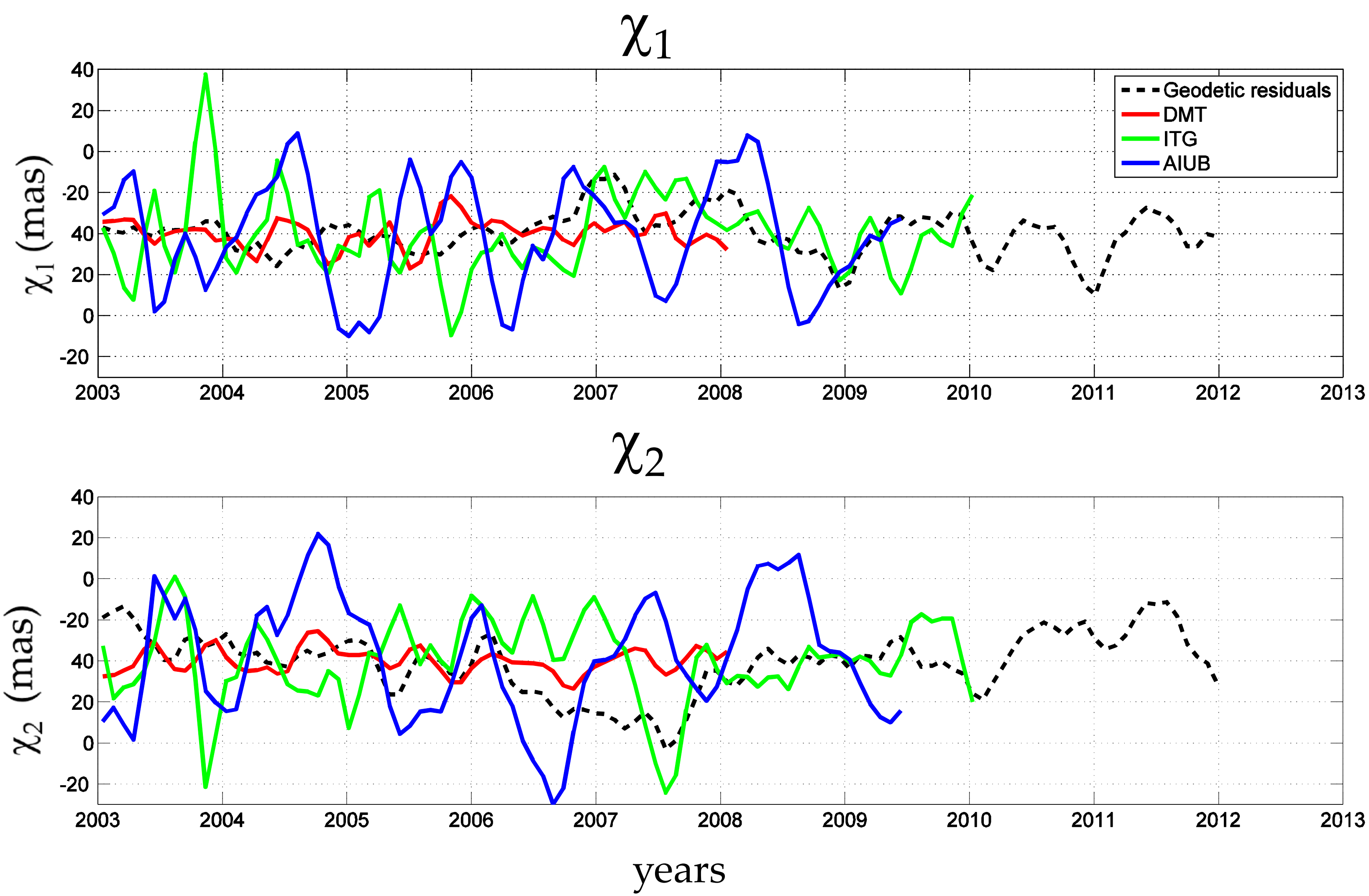

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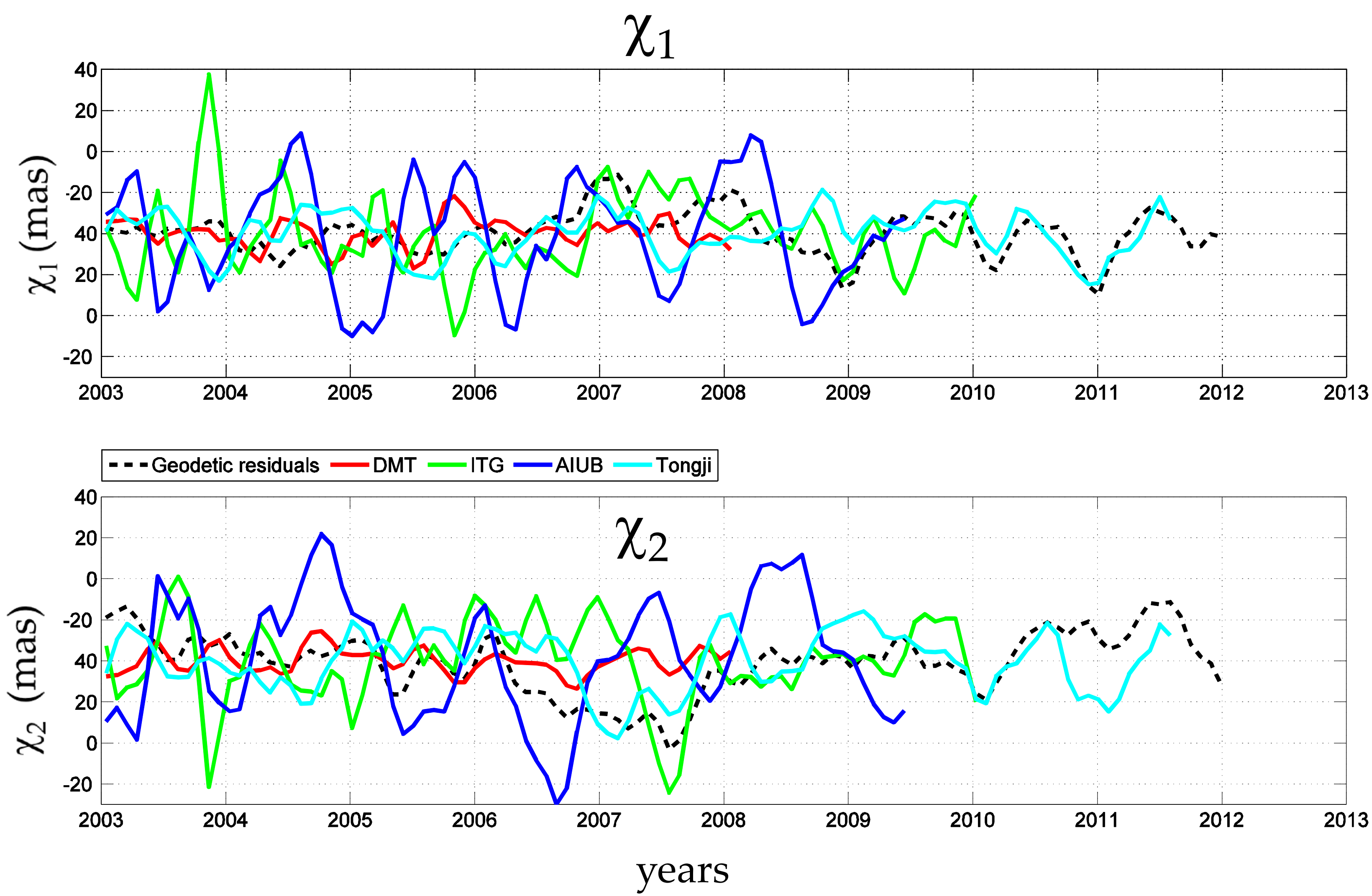

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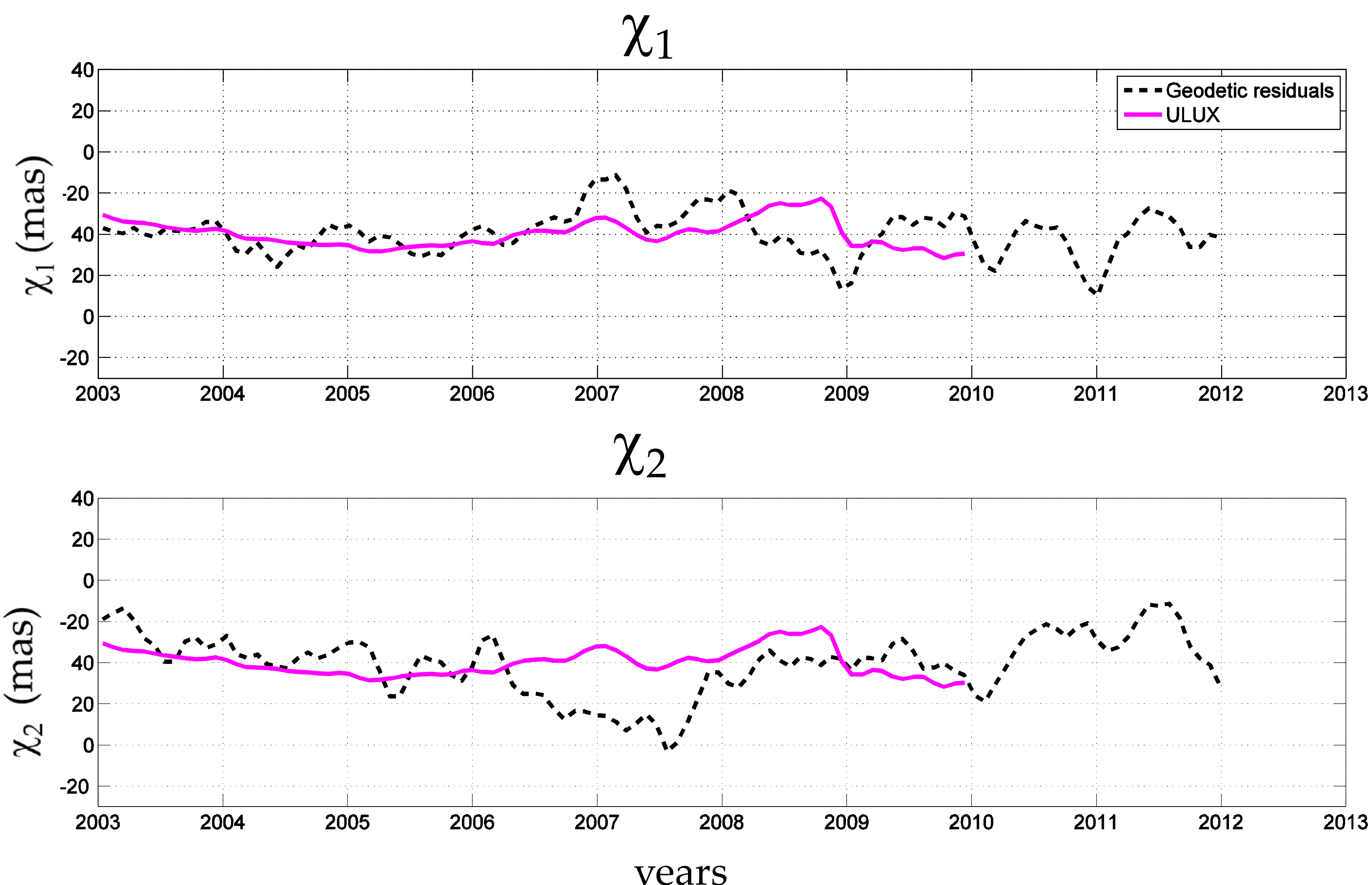

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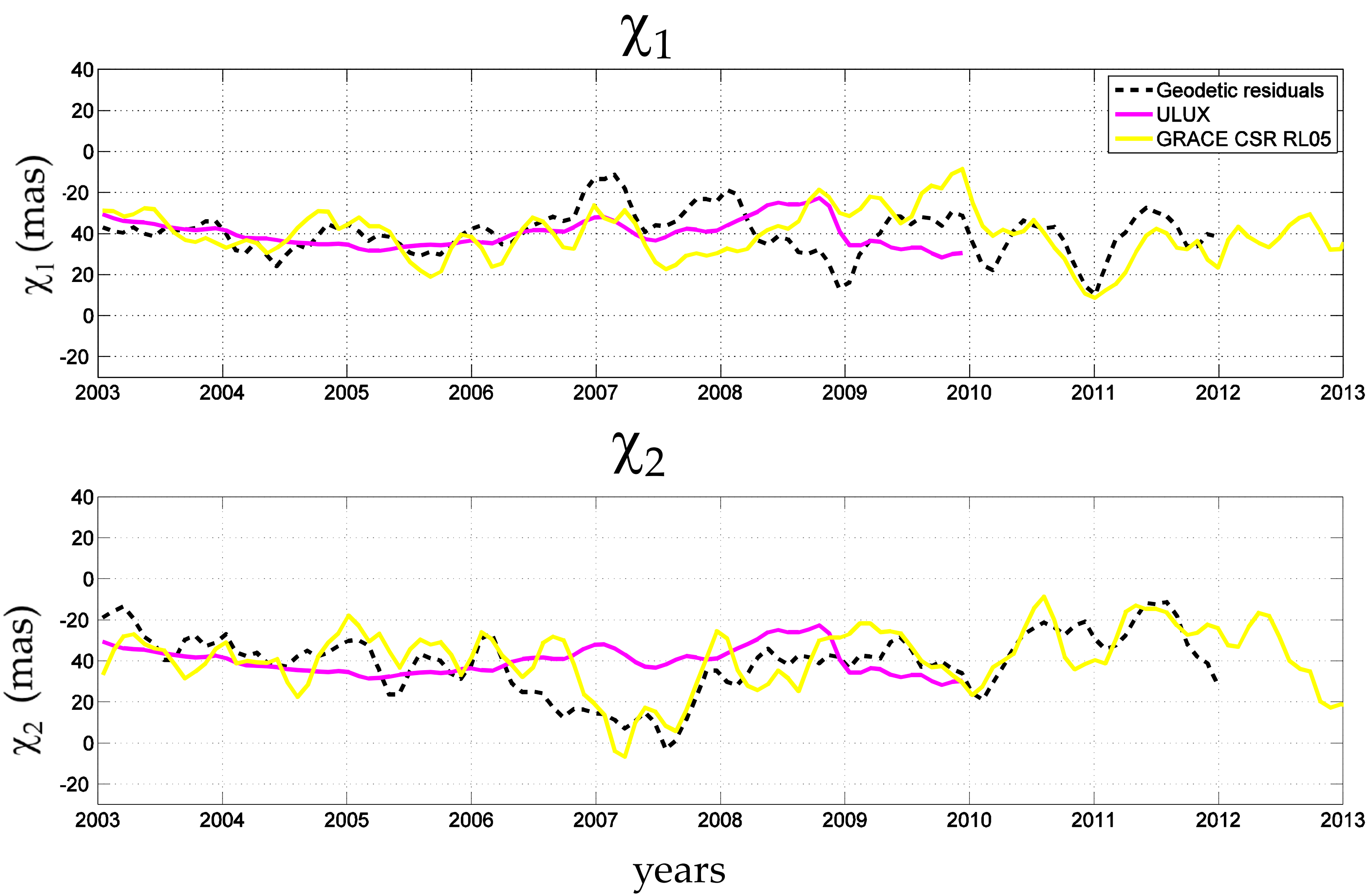

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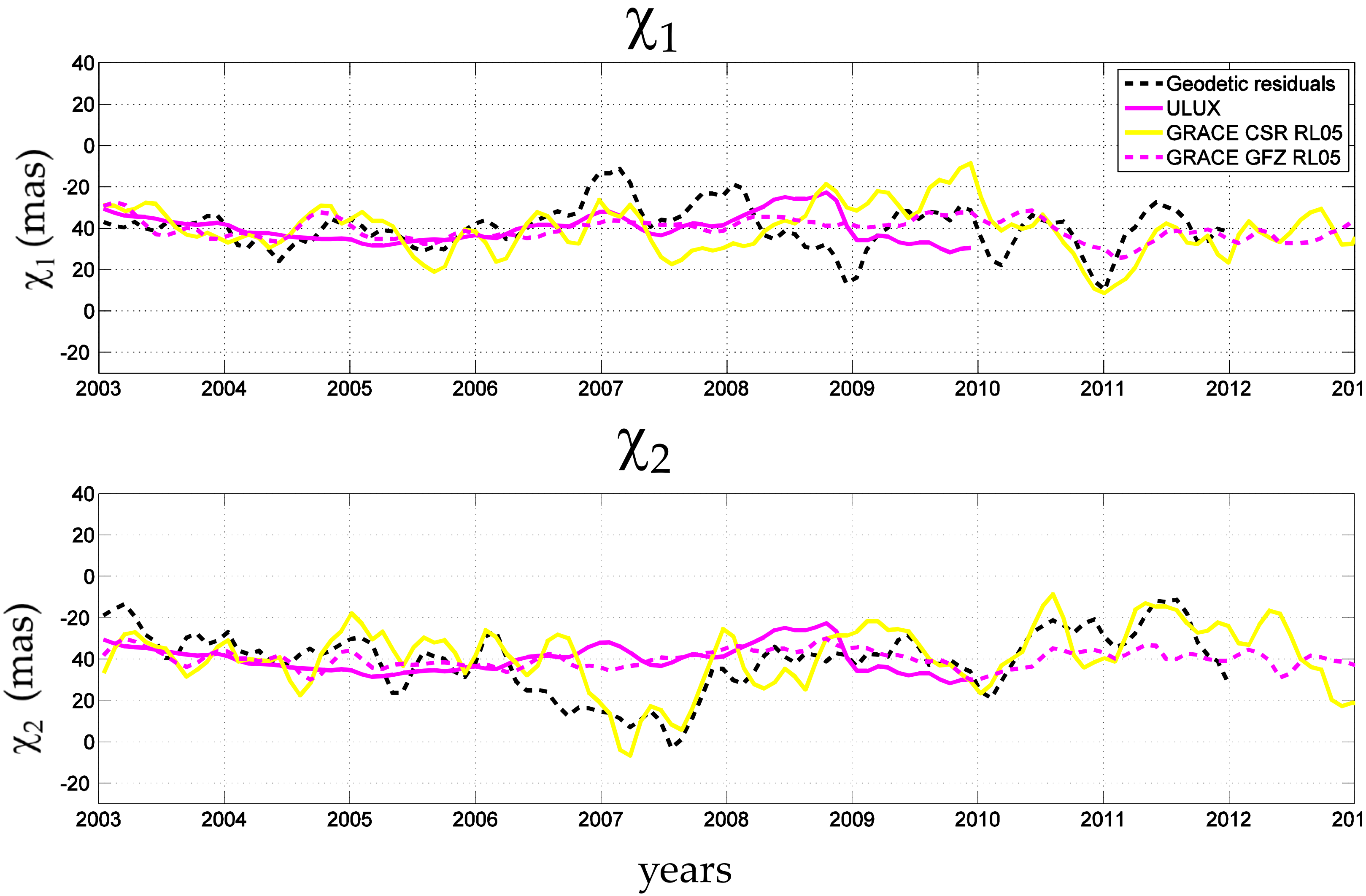

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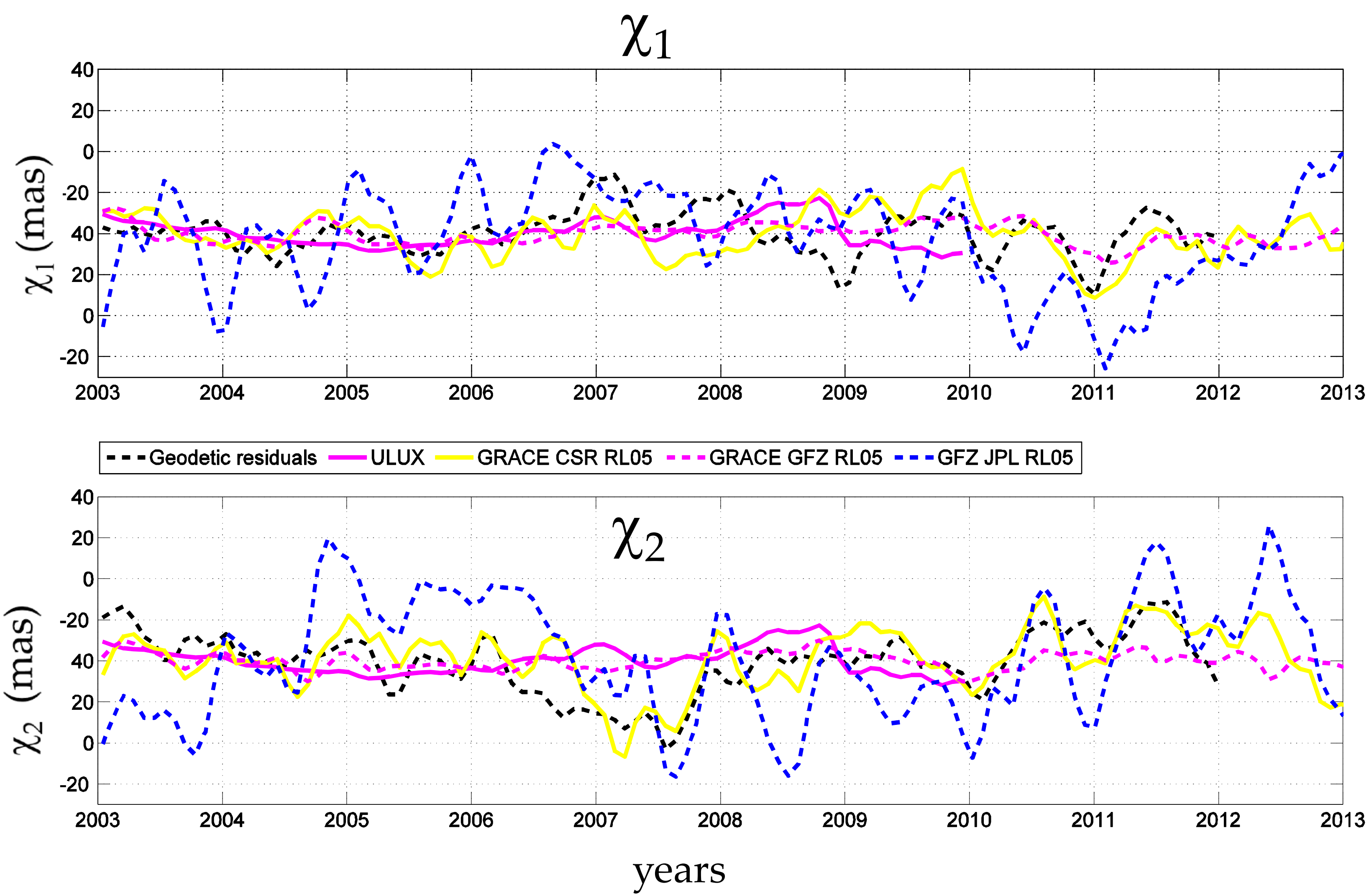

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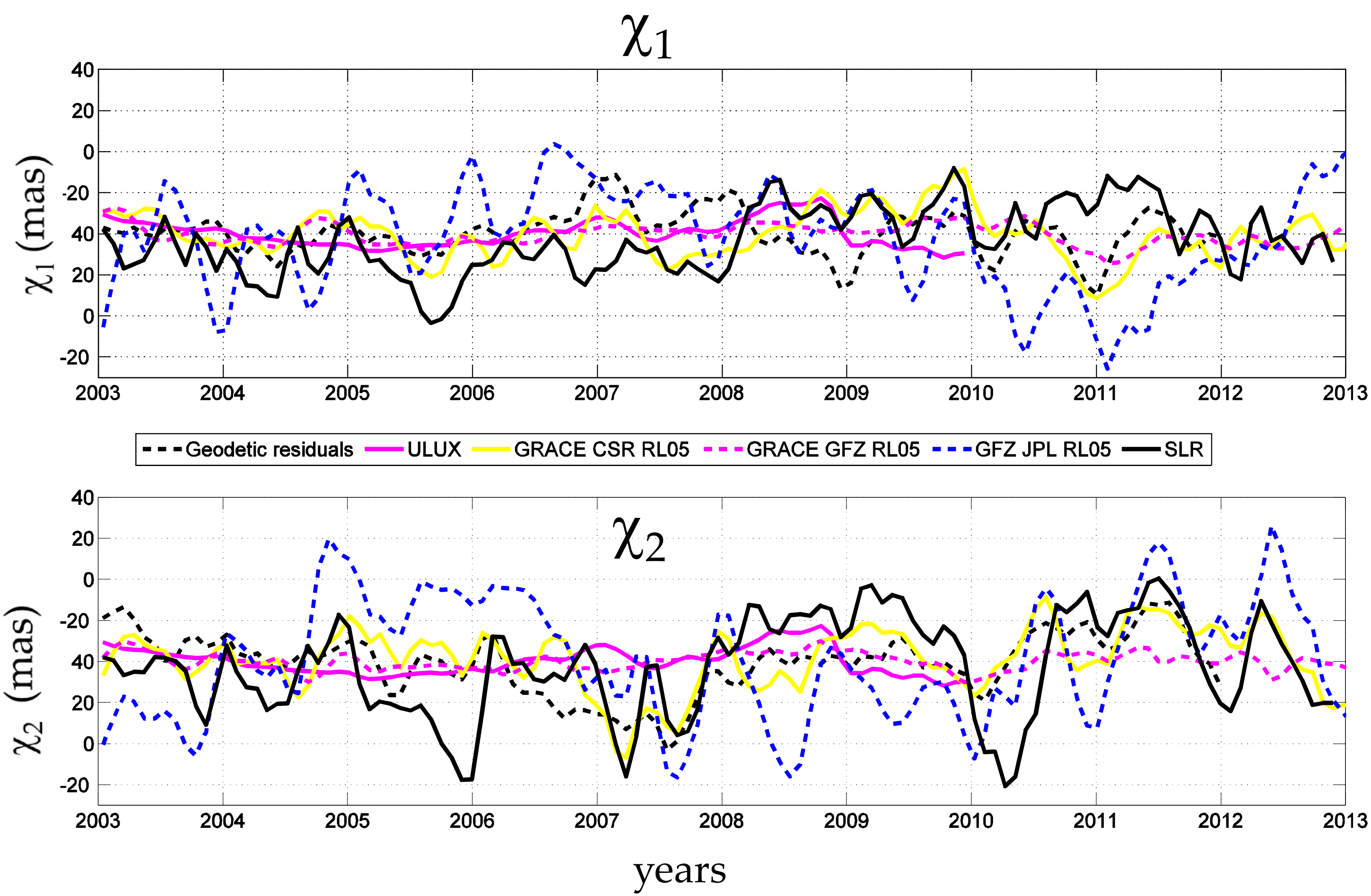

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Spectra
G-A-O vs Gravimetric Excitations

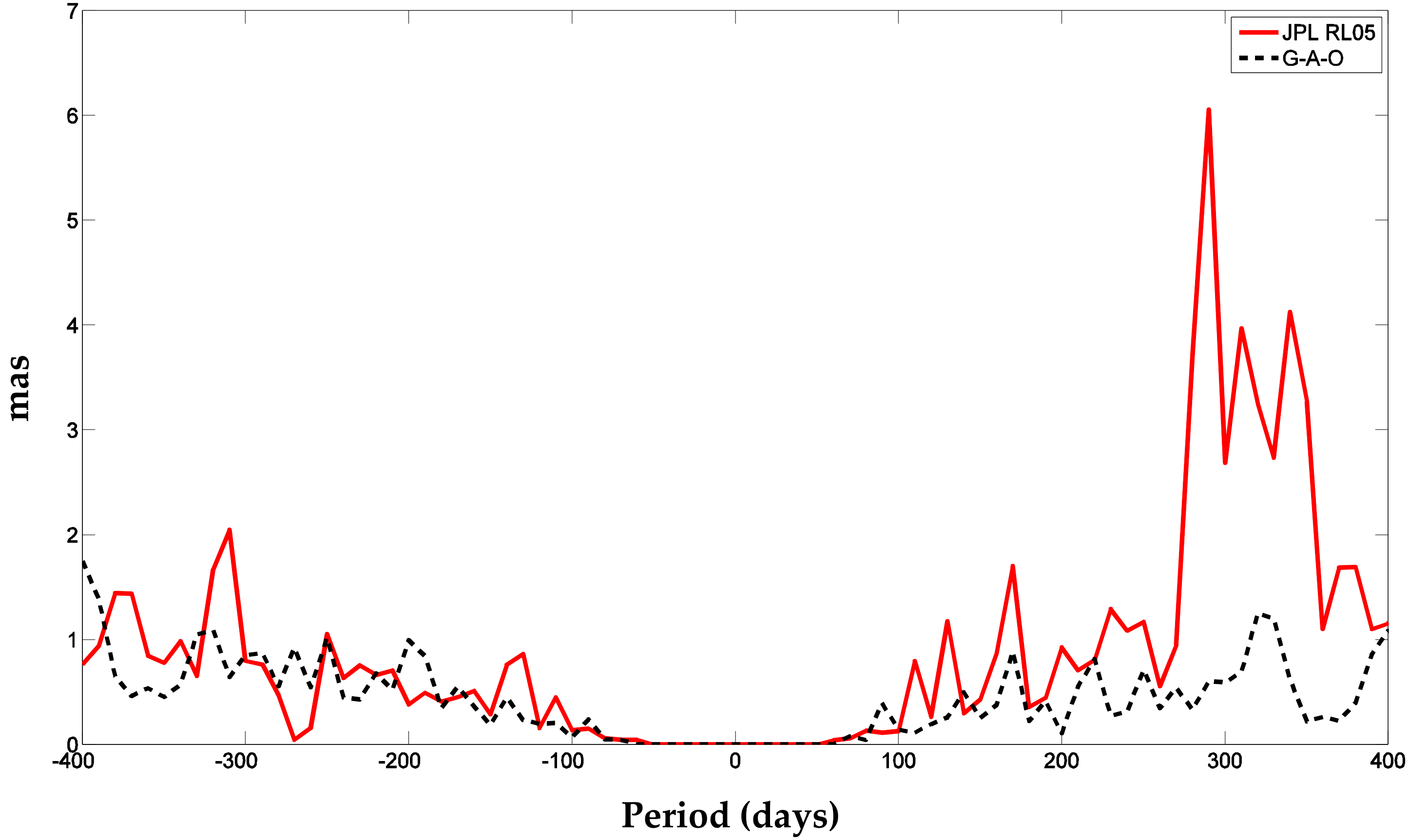
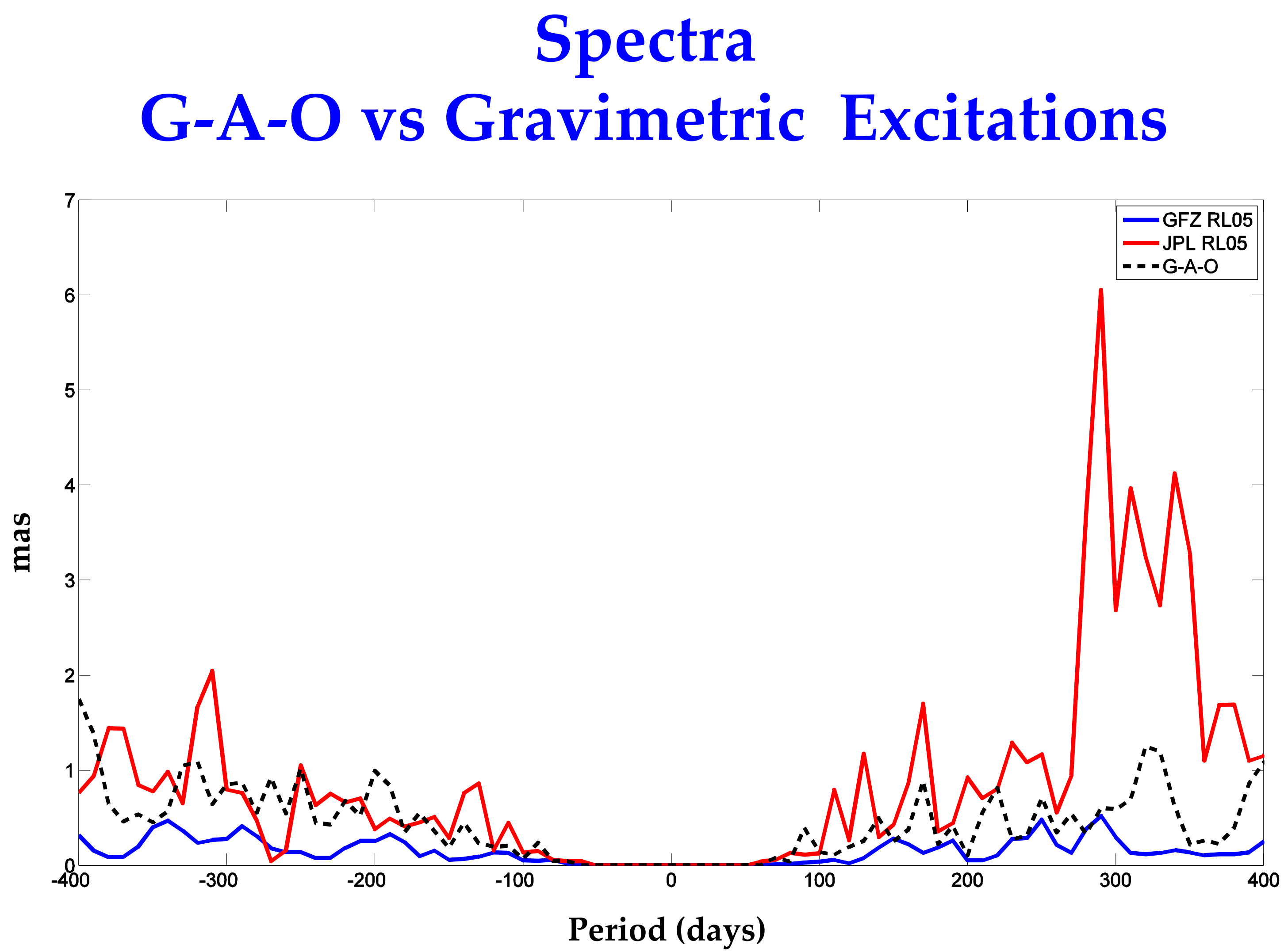


Fig. 4 FTBPF amplitude spectra of the different complex gravimetric excitation functions of polar motion and of geodetic residuals (G-A-O) (functions smoothed with a step of 30 days).



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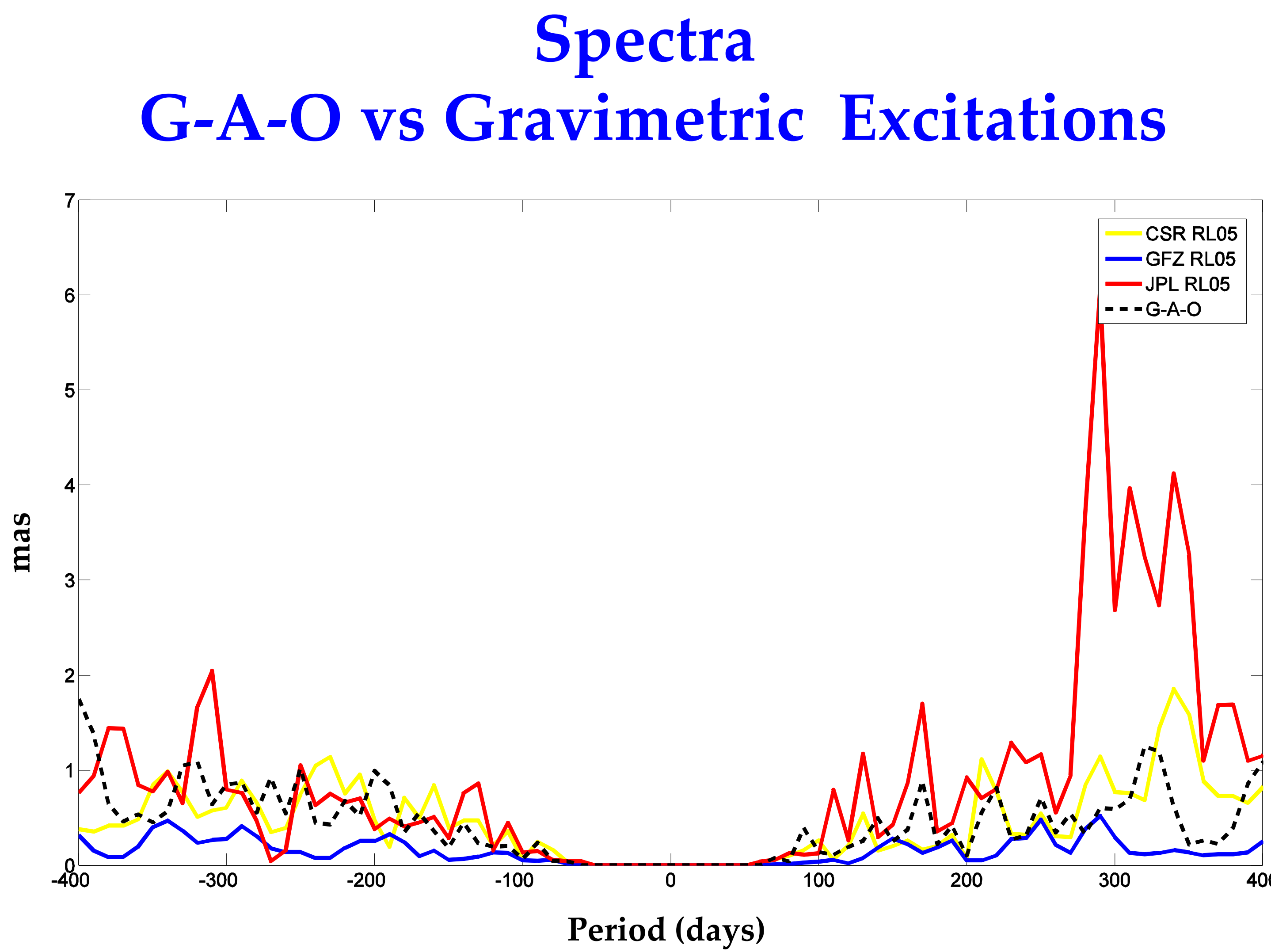

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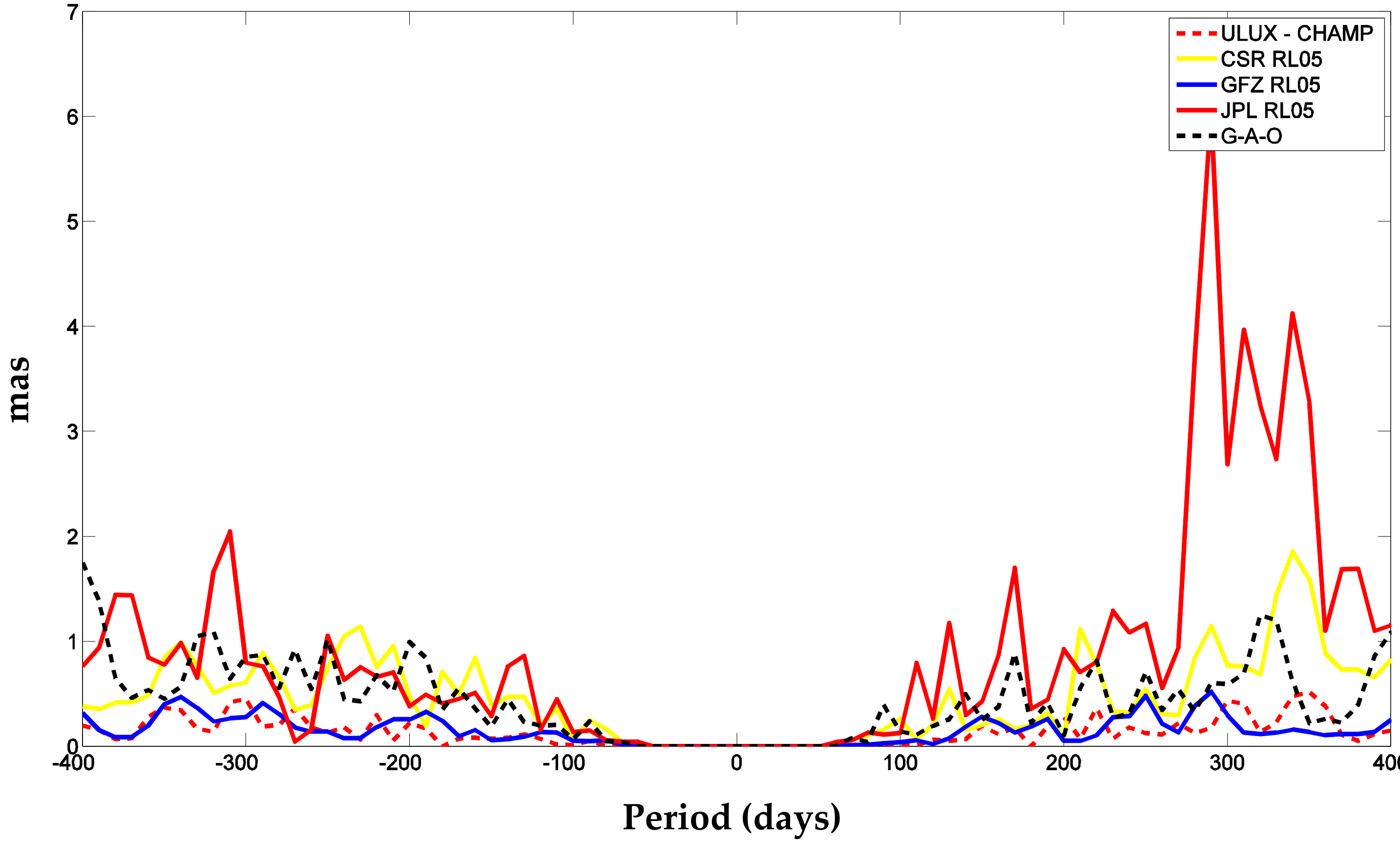

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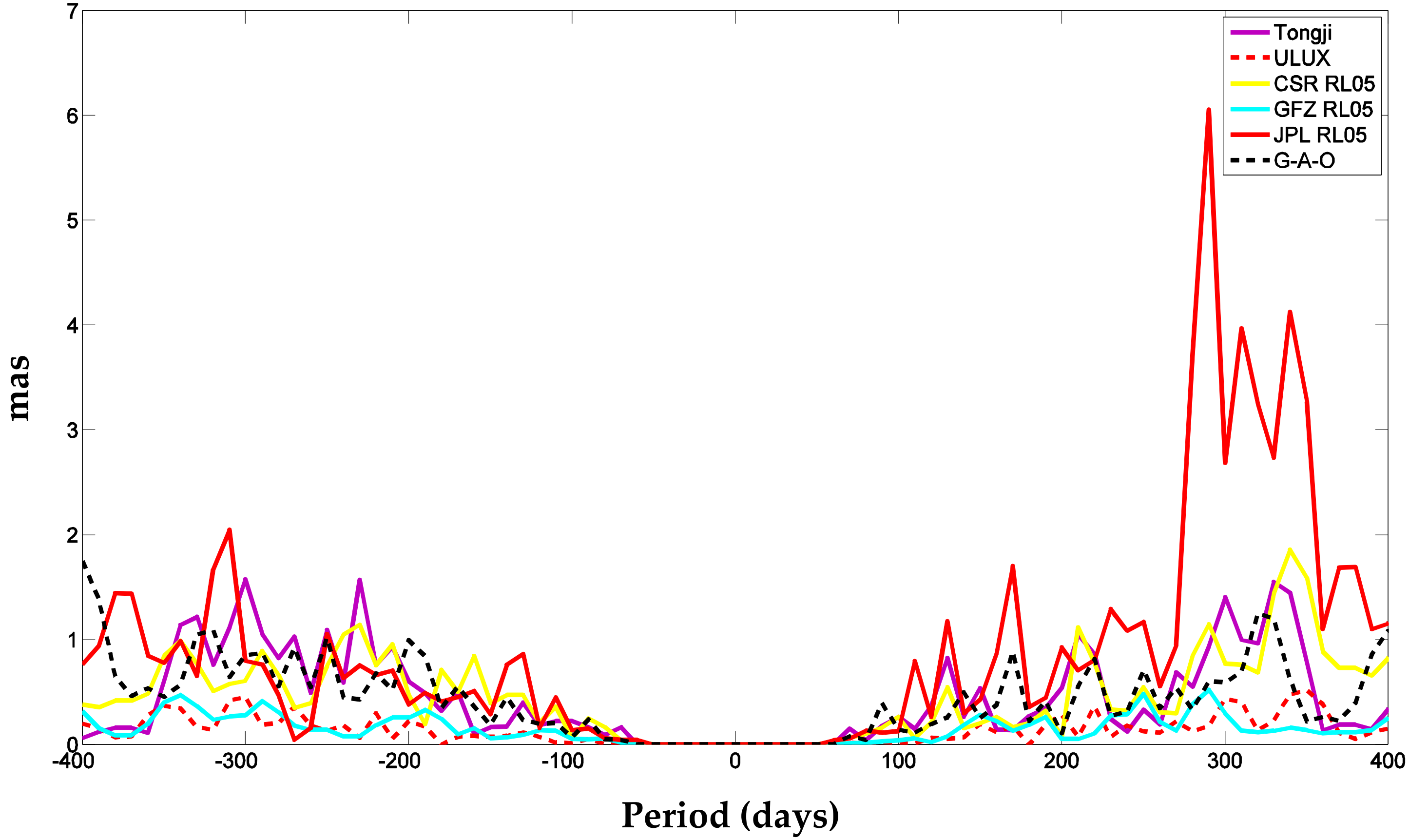

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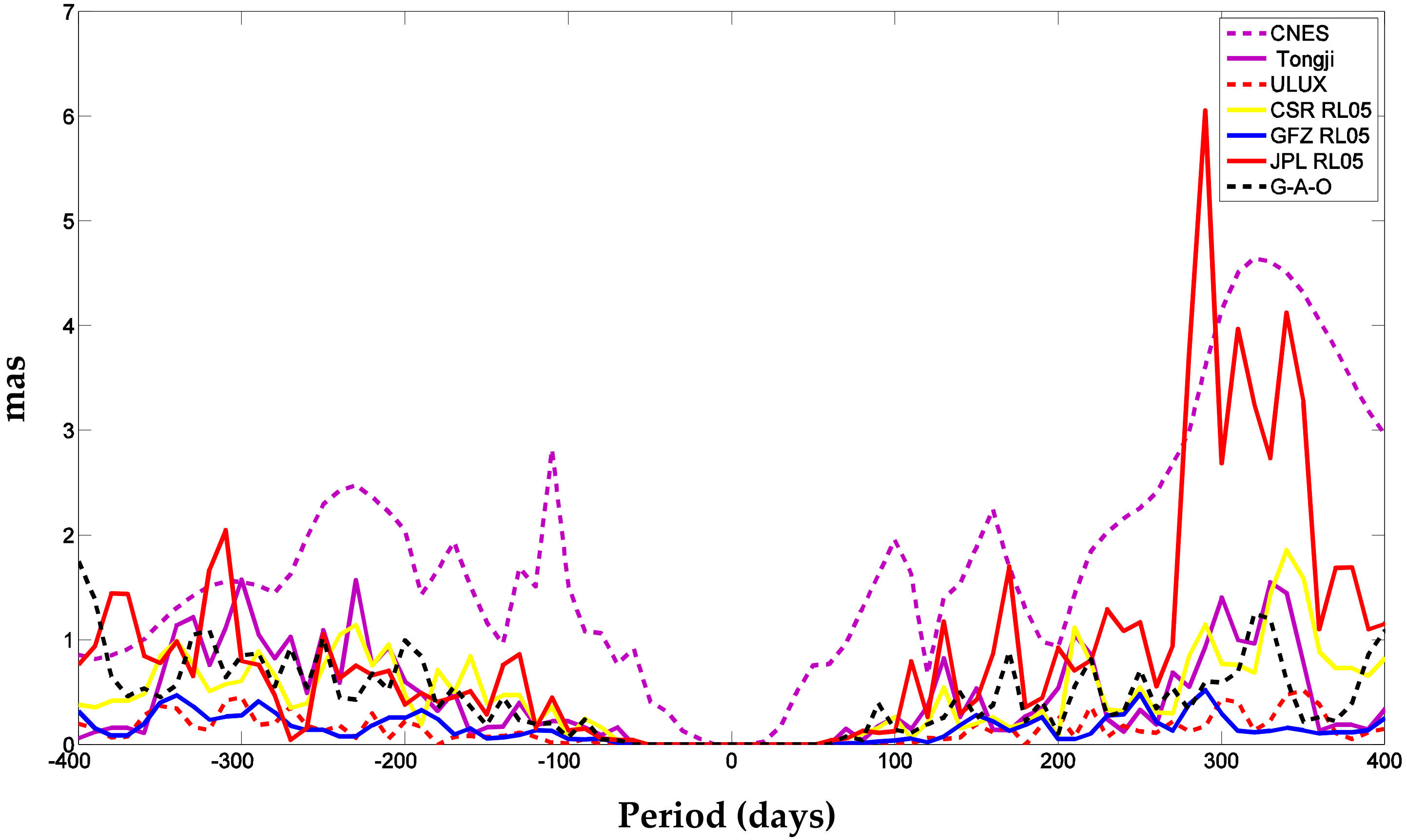

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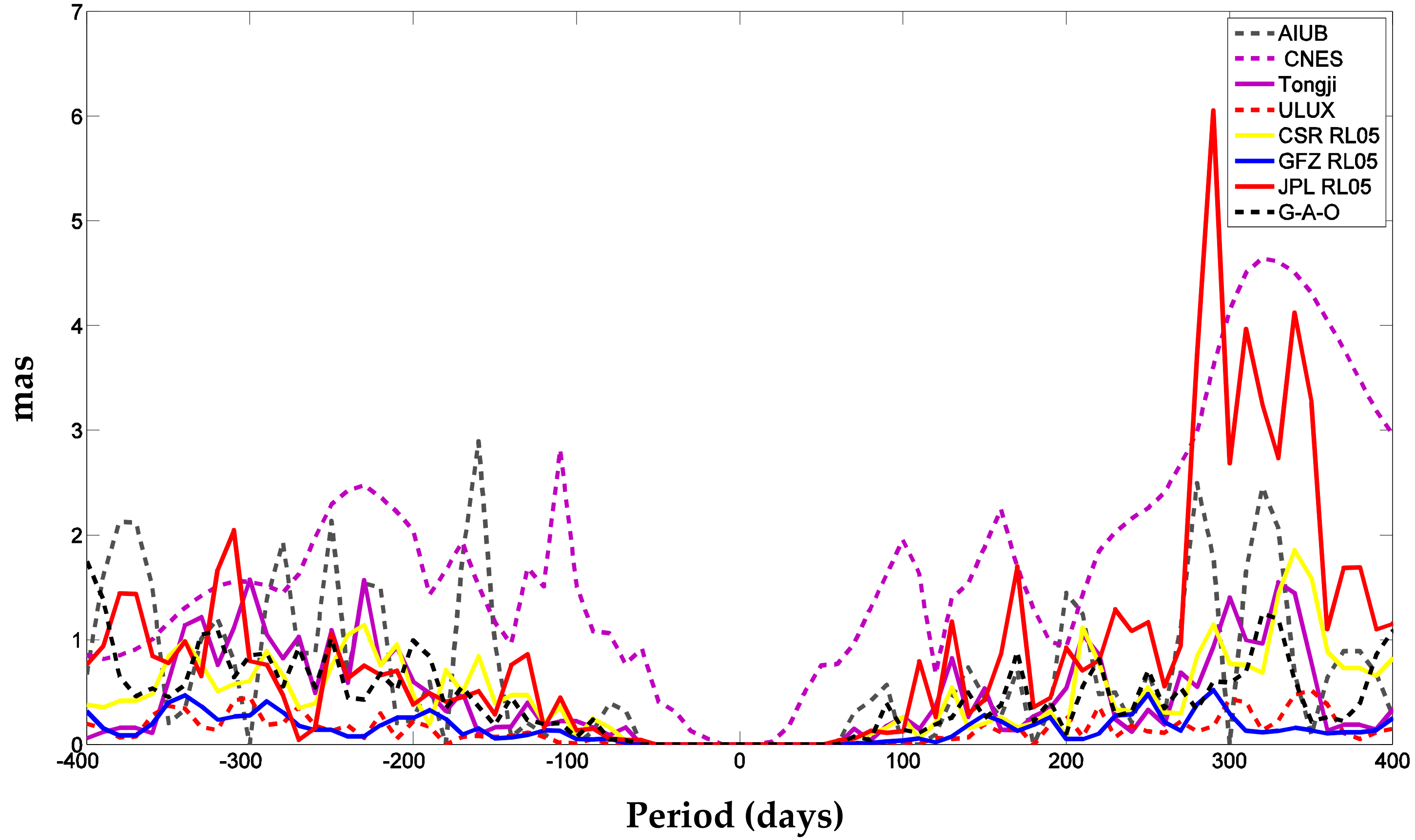

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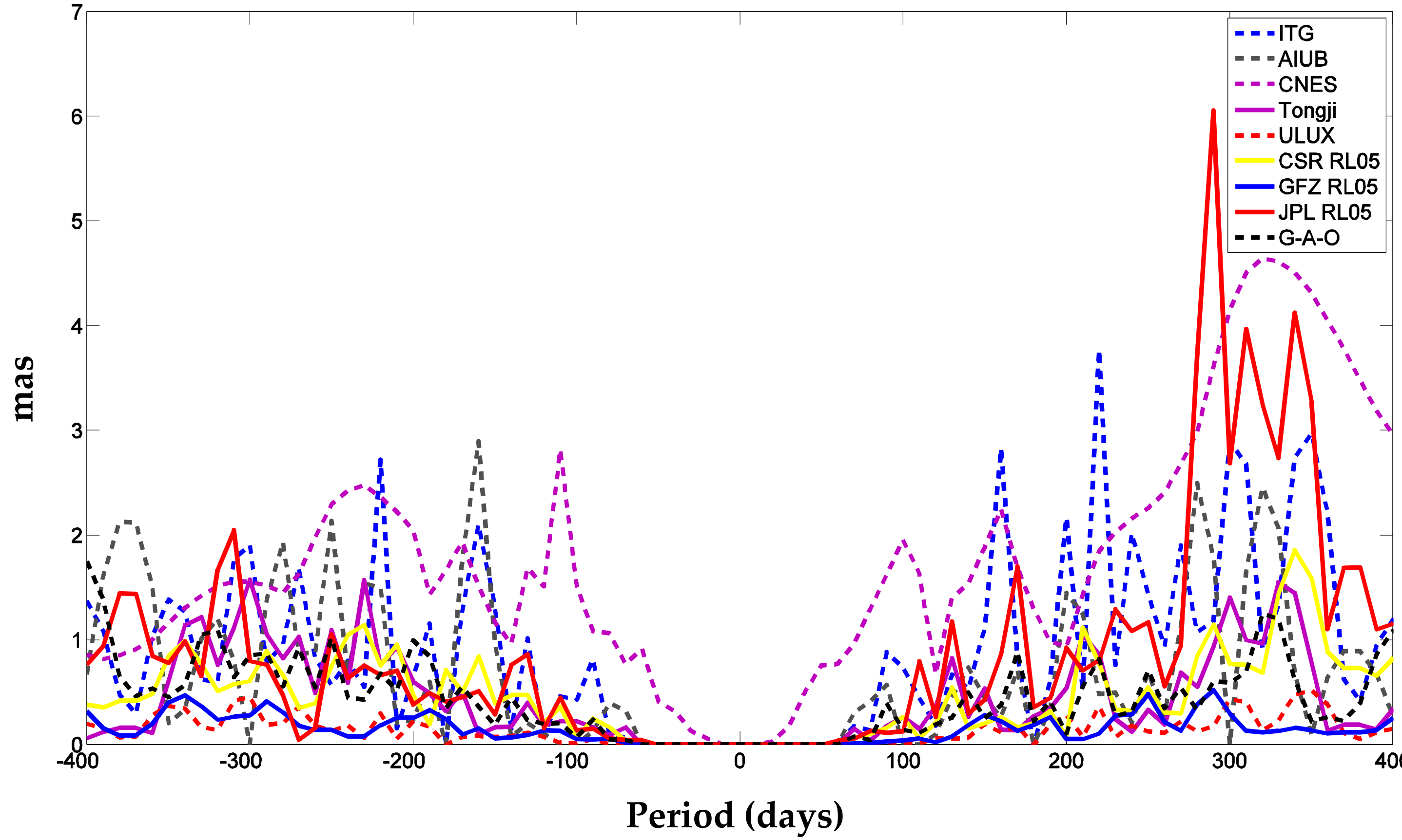

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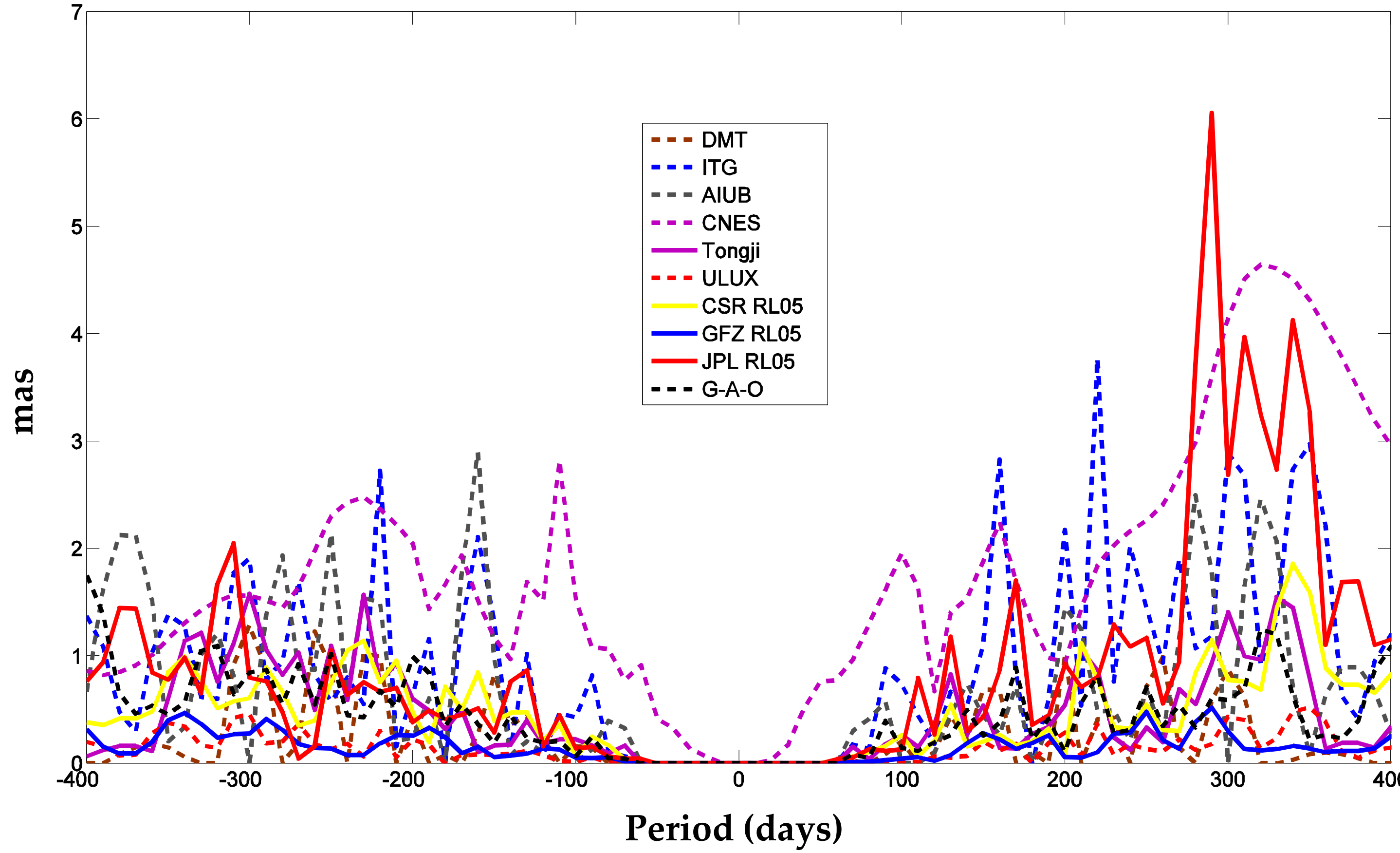

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Phasor diagrams, annual oscillations

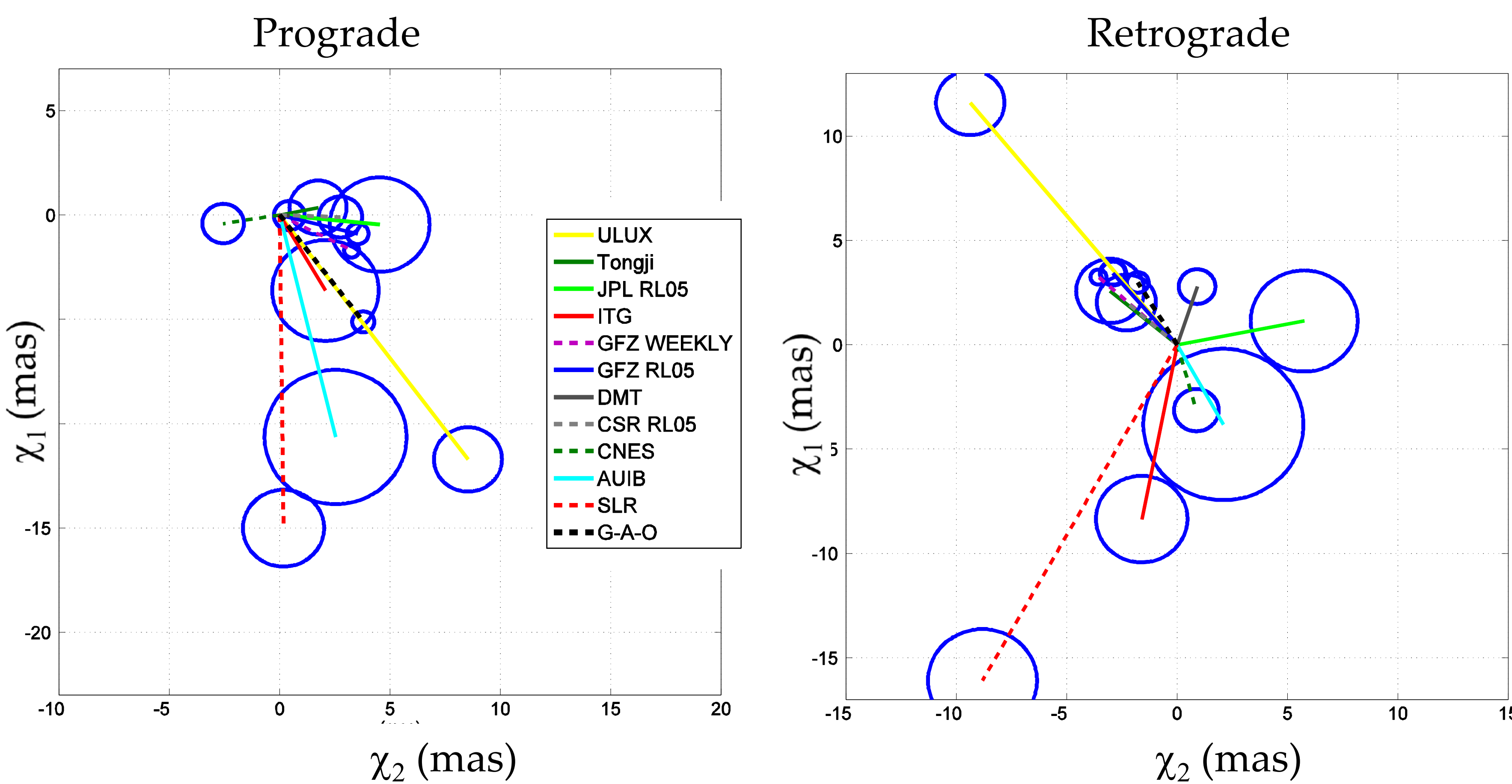

Fig. 3 Phasor diagrams of the prograde and retrograde annaul oscillations of the residuals of the geodetic excitation function (G-A-O) and of the different gravimetric excitation functions. Analysis is done over the period 2003.0 to 2009.5.

Conclusions

- The fluids around the Earth, atmosphere, ocean, land-based hydrosphere, change their distribution and hence their angular momentum.
- Angular momentum exchanges with the solid Earth lead to small but measurable changes in our planet's rotation. They cause changes in the speed of rotation (reckoned in changes in Length-of-day) and the wobble of the Earth, known as polar motion.
- The gravity field from satellite-based measurements can help us quantify such changes in mass, needed especially for the hydrosphere, since atmosphere and ocean distributions are reasonably well-known through observations and models.