Comparison of the hydrological excitation functions HAM of polar motion for the period 1980.0 – 2007.0

Małgorzata Paśnicka, Jolanta Nastula, Barbara Kołaczek

Space Research Center Polish Academy of Science

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Outline

The impact of continental hydrologic signals, from land water, snow and ice on polar motion excitation HAM is not so well known as atmospheric and oceanic ones.

Hydrological angular momentum has been estimated from several models of global land hydrology, based on the observed distribution of surface water, snow, ice and soil moisture.

In the paper comparison of the models of global hydrological excitations from the period 1980.0 to 2007.0 was done. The results are compared also with observed excitations of polar motion GAM and contributions from the atmosphere AAM and ocean OAM excitations.

Phasor diagrams and spectra of the seasonal components of the polar motion excitation functions of all HAM excitation functions as well as of two GRACE solutions were determined.

Excitation functions of polar motion

The following excitation functions of polar motion are considered:

Atmospheric Angular Momentum - AAM
- o NCEP/NCAR reanalysis data

•Oceanic Angular Momentum -OAM
- o ECCO series

•Hydrological Angular Momentum - HAM
- o **CPC, GLDAS, NOAA, NCEP/NCAR, HAM GFZ, WGHM CRU**

•Gravimetric excitation functions of polar motion
- o **GRACE CNES, GRACE CSR**

•Geodetic Angular Momentum - GAM
- o IERS C04 series

•Geodetic residuals – GAM-AAM-OAM

All series were smoothed and interpolated with the 30 days step in order to harmonize data; the HAM data are monthly, the geodetic excitation are given with one day sampling, the atmospheric and oceanic excitation is derived from 6-hour time series; we computed the geodetic residuals (G-A-O) by removing the impact of the atmosphere and ocean from the geodetic excitation of polar motion

Gravity Recovery and Climate Experiment (GRACE) data

The gravimetric excitation of polar motion was computed from harmonic coefficient of the Earth gravity field.

Our investigations use the latest version (Rl04) of time series of the (2,1) normalized spherical harmonic coefficients of the gravity field from:

•Centre for Space Research (CSR)

•Centre National d'Etudes Spatiales/ Groupe de Recherche de Géodésie Spatiale (CNES/GRGS), harmonics coefficients of the gravity field of the GRGS solution are determined by a combined analysis of the LAGEOS and GRACE observations (the LAGEOS observations are the main contributor)

Analysis and results

- Time series comparison
- Spectra
- Time variable spectra
- Phasor diagrams

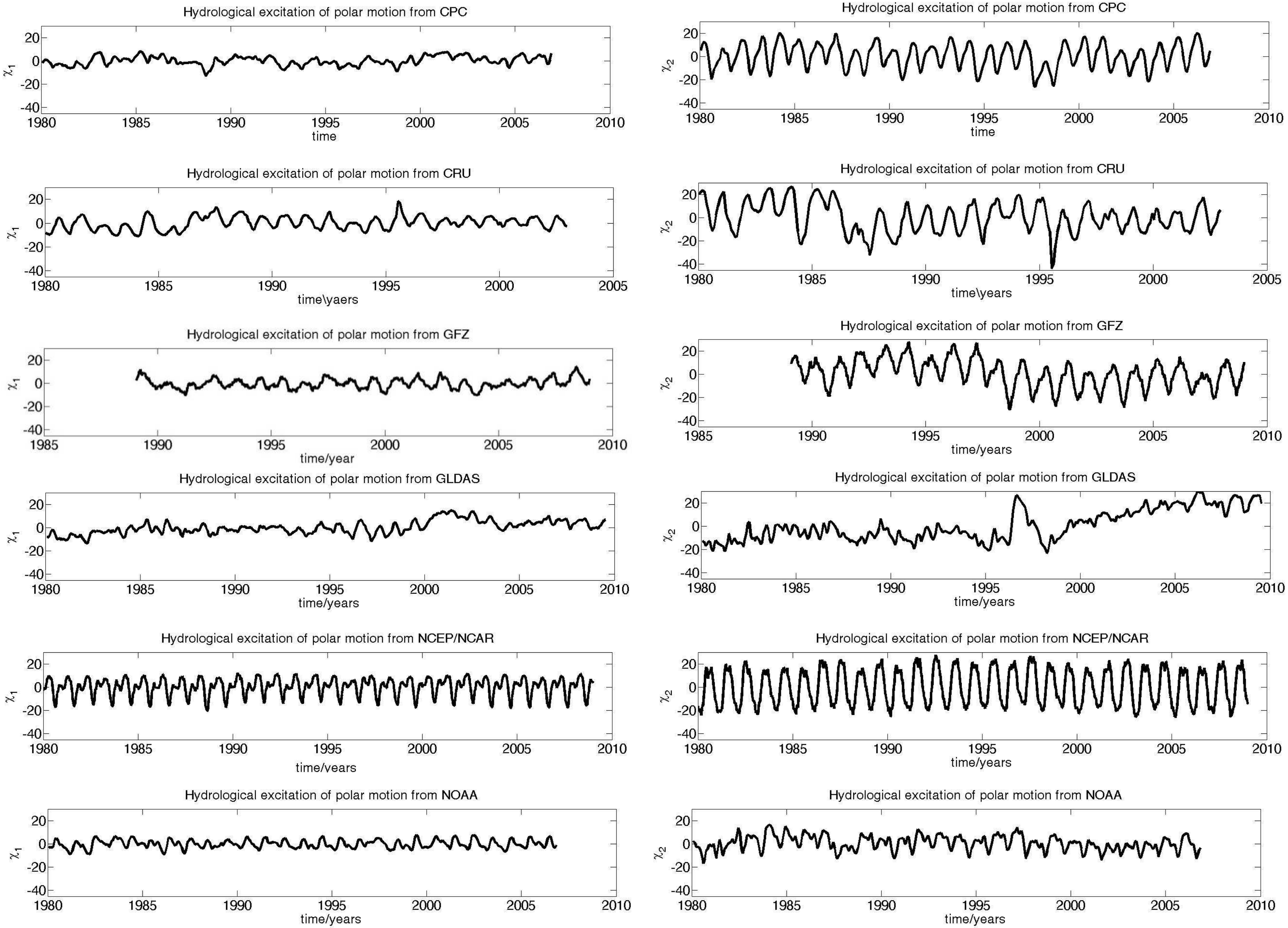

Fig. 1 The hydrological excitation functions χ_1, χ_2 of polar motion computed from different hydrological models.

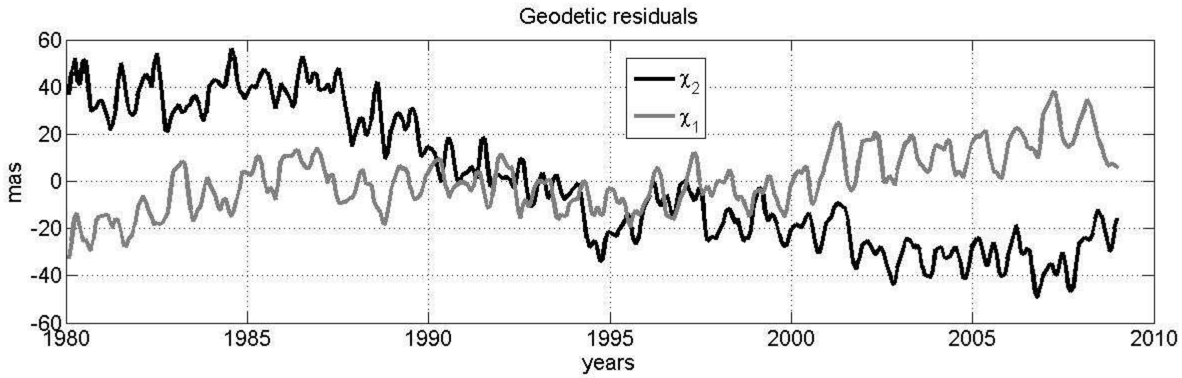

Fig. 2 The χ1, χ2 components of the residuals of the geodetic excitation function G-A-O .

Gravimetric Excitation vs HAM and Geodetic Residuals

The gravimetric excitation of polar motion was computed from harmonic coefficient of the Earth gravity field:

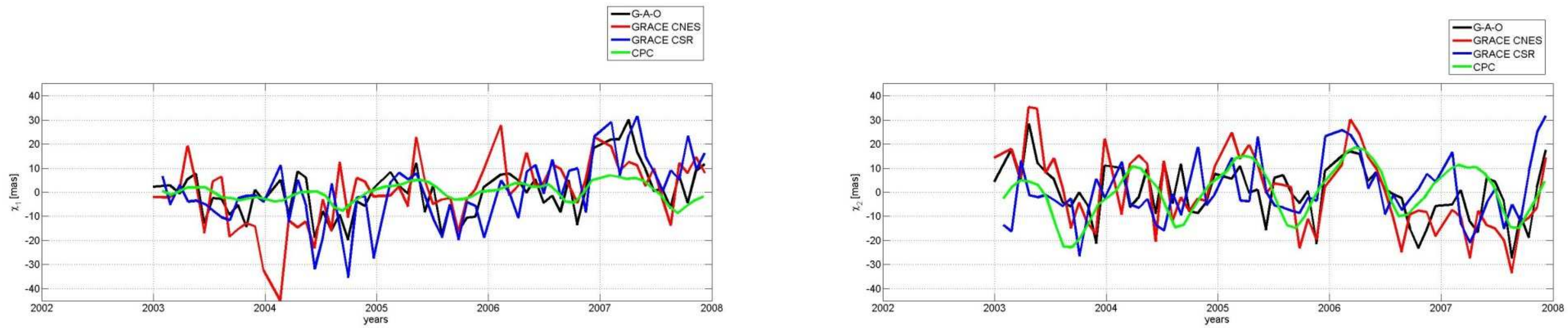

Fig. 3 Comparison of χ1, χ2 components of: gravimetric excitation of polar motion (GRACE CNES, GRACE CSR), residuals of the geodetic excitation function G-A-O and hydrological excitation functions CPC.

Spectra

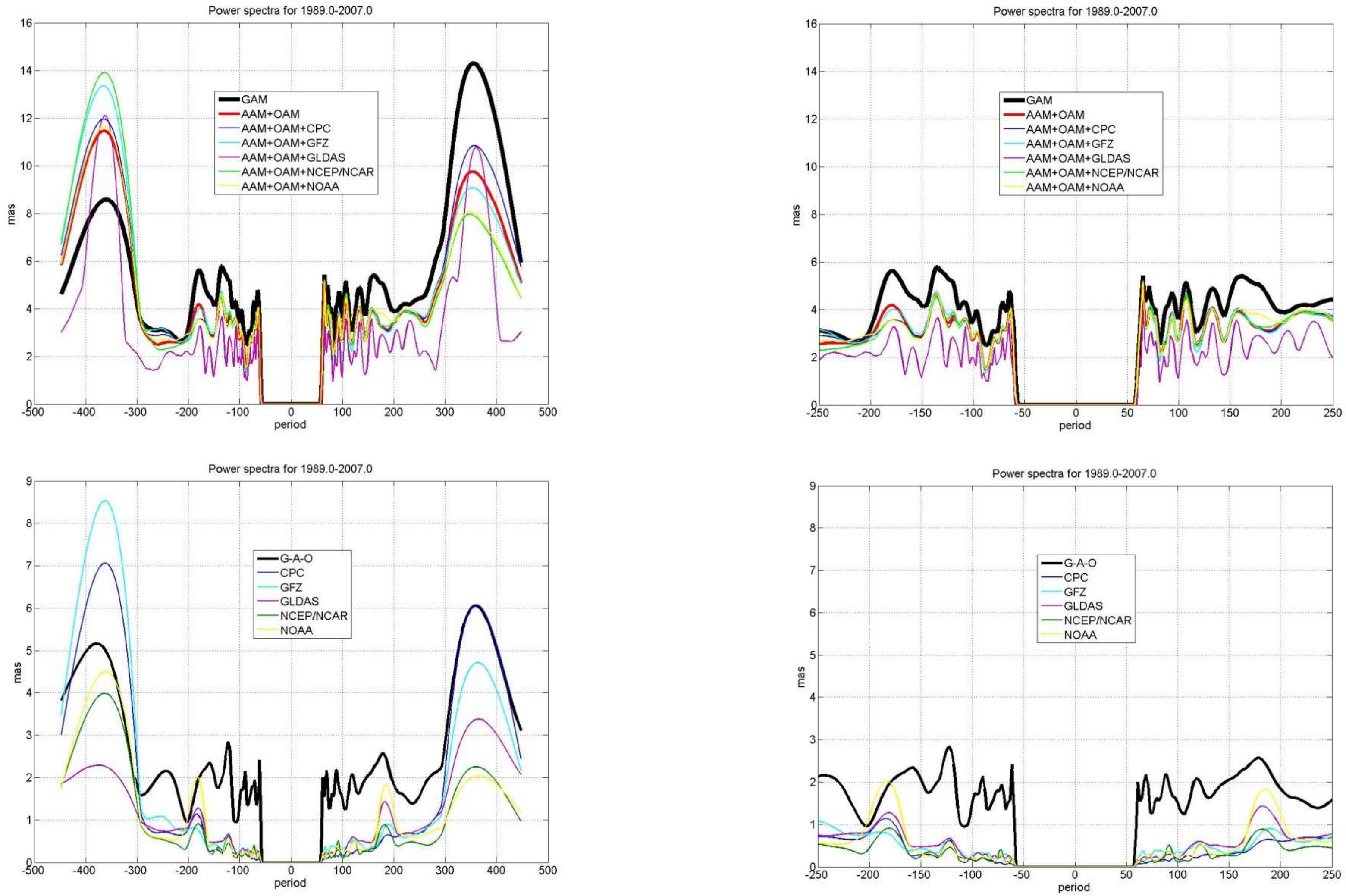

Fig. 4 FTBPF amplitude spectra of the different complex geophysical excitation functions of the polar motion in the period 1989.0-2007. Filtered by the FTBPF with a 200 days (right) and 600 days (left) cutoff.

Time variable spectra

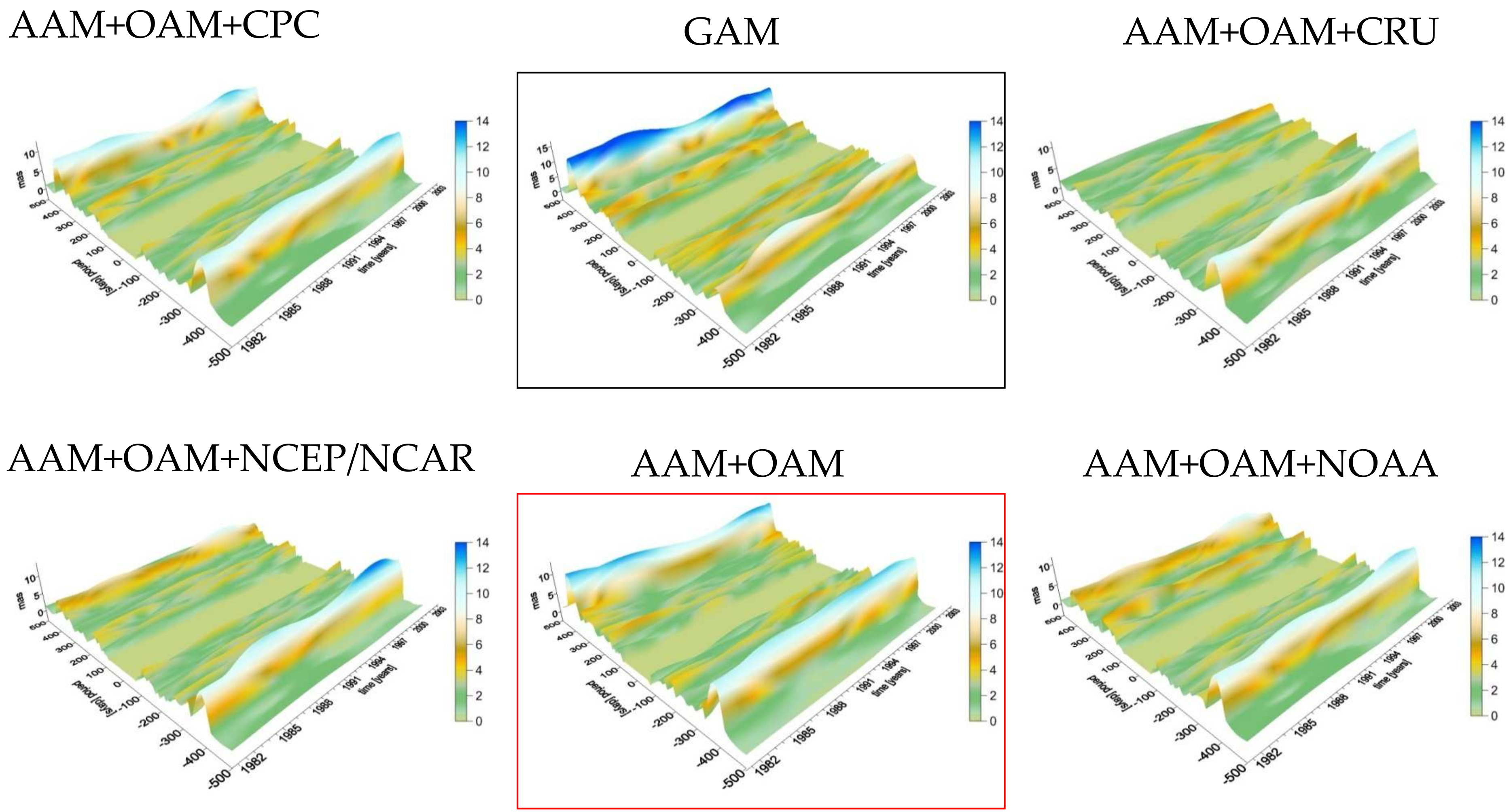

Fig. 5 The time variable spectrum of the 80 – 500 day band of the sum of atmospheric, oceanic and hydrological excitation of polar motion and of geodetic excitation of polar motion computed by the FTBPF. Filtered by the FTBPF with 500 days cutoff and with the parameter λ=0.01; analysis done for the period 1980.0 – 2002.0.

Time variable spectra

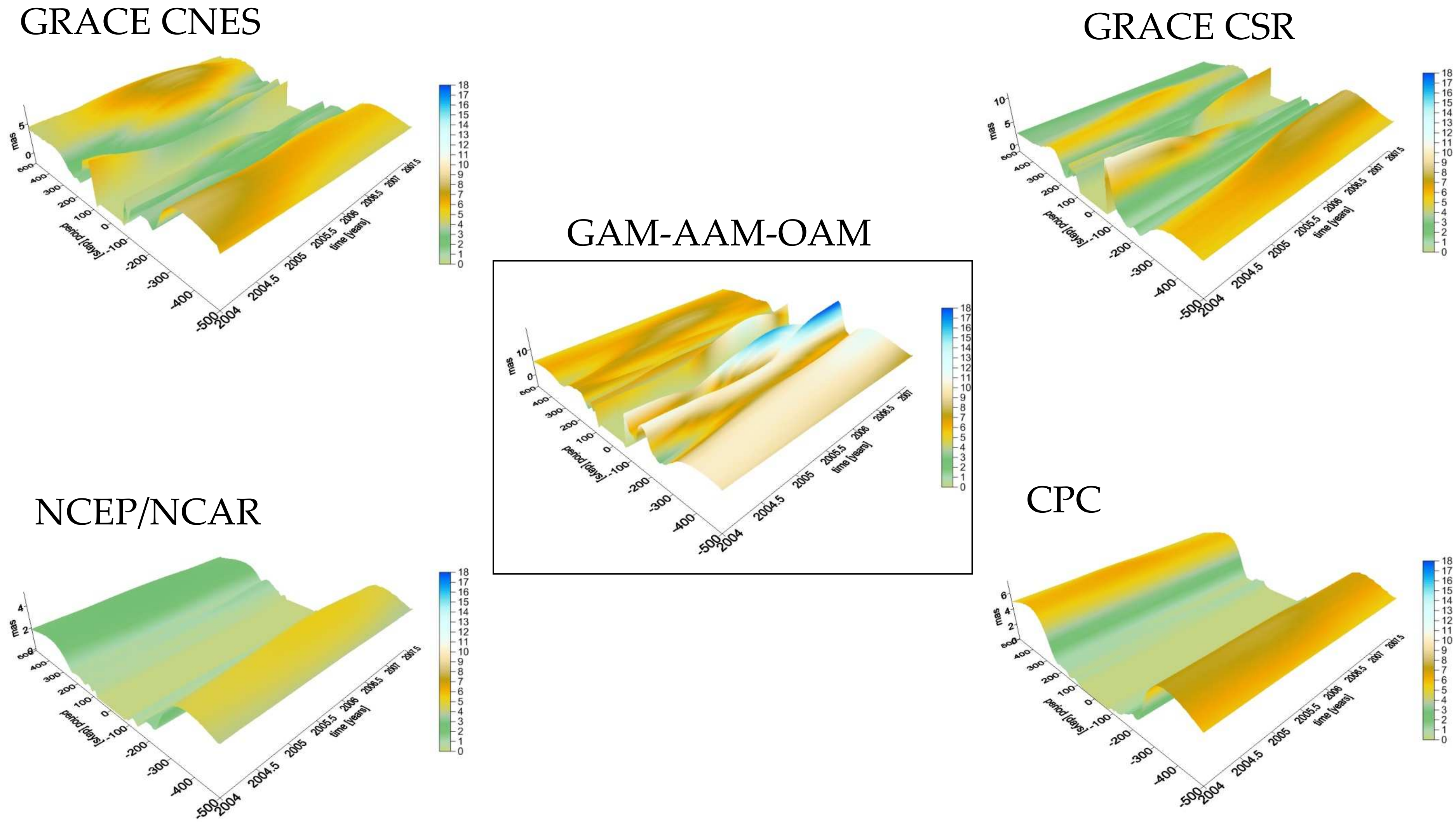

Fig. 6 The time variable spectrum of the 80 – 500 day band of the hydrological excitation of polar motion, gravimetric excitation of the polar motion and of geodetic residualc excitation of polar motion computed by the FTBPF. Filtered by the FTBPF with 500 days cutoff and with the parameter λ=0.05; analysis done for the period 2004.0 – 2007.2.

Phasor diagrams

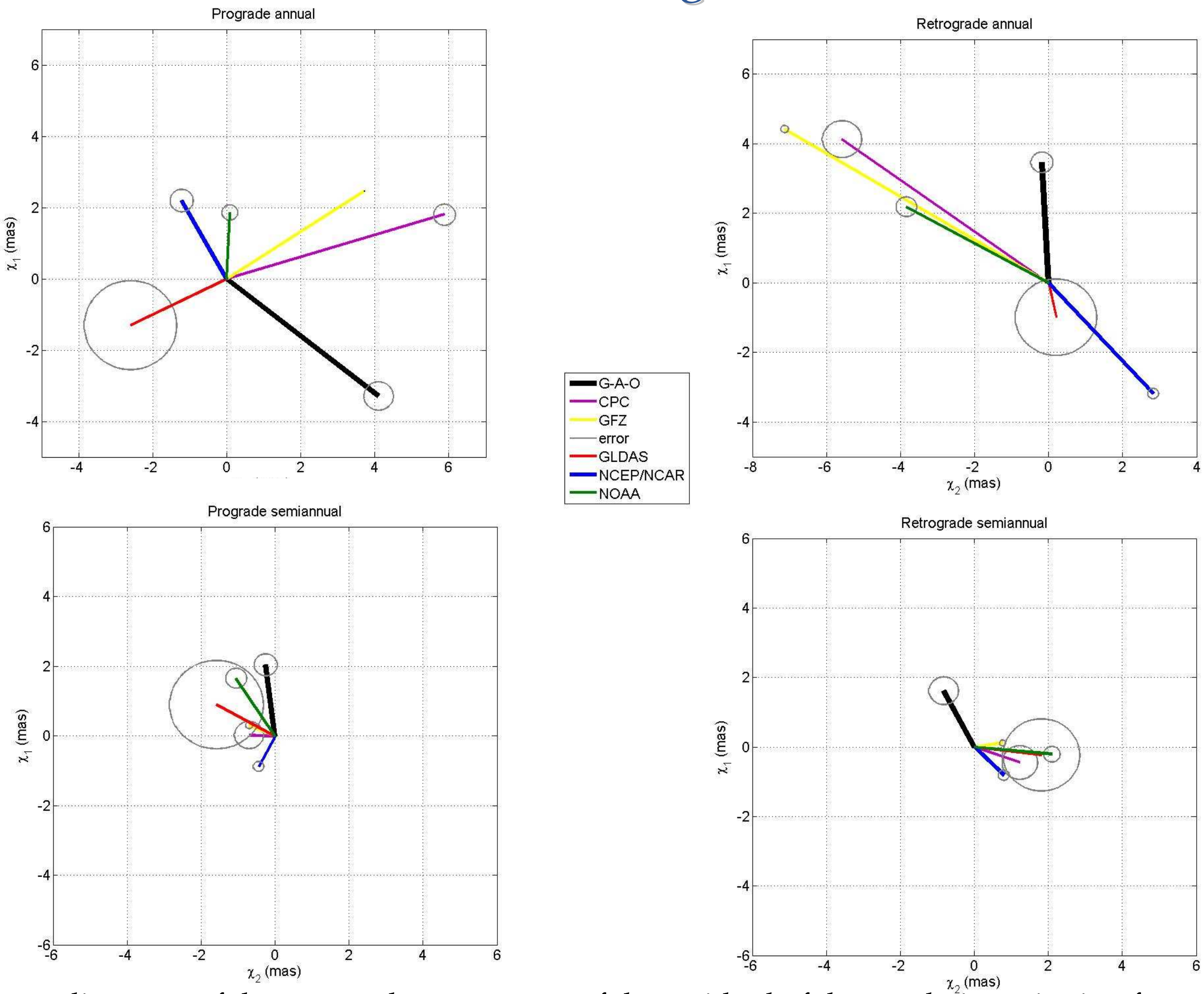

Fig. 7 Phasor diagrams of the seasonal components of the residual of the geodetic excitation function (G-A-O) and different hydrological excitation function (CPC, GFZ, GLDAS, NCEP/NCAR, NOAA). Analysis is done for the period 1989.0-2007.0.

Phasor diagrams

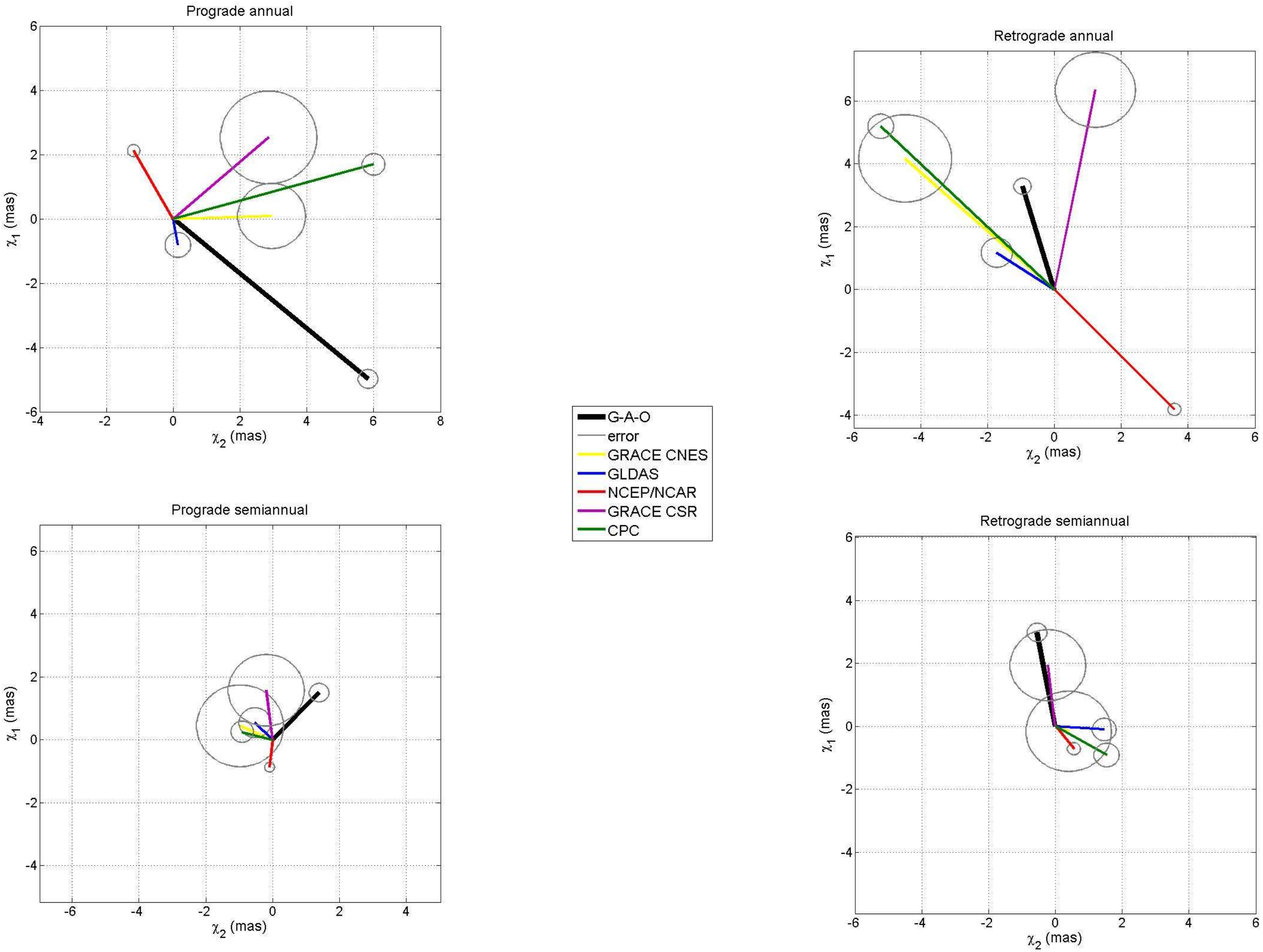

Fig. 8 Phasor diagrams of the seasonal components of the residual of geodetic excitation function (G-A-O), gravimetric excitation function GRACE CNES and GRACE CSR and different hydrological excitation function. Analysis is done for the period 2003.0-2008.0.

Regional HAM CPC

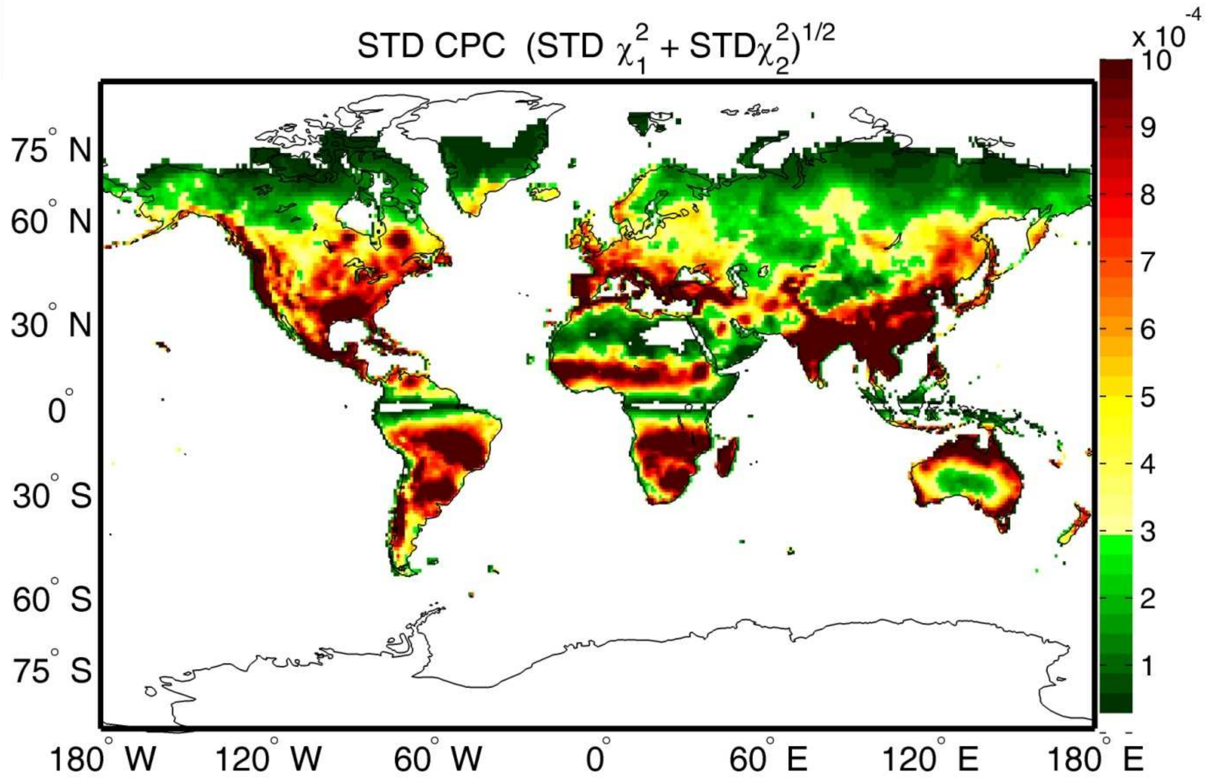

Fig. 9 Map of STD magnitude $(\chi_1{}^2 + \chi_2{}^2)^{1/2}$ of complex valued hydrological excitation function computed from the water storage CPC model.

Phasor diagrams

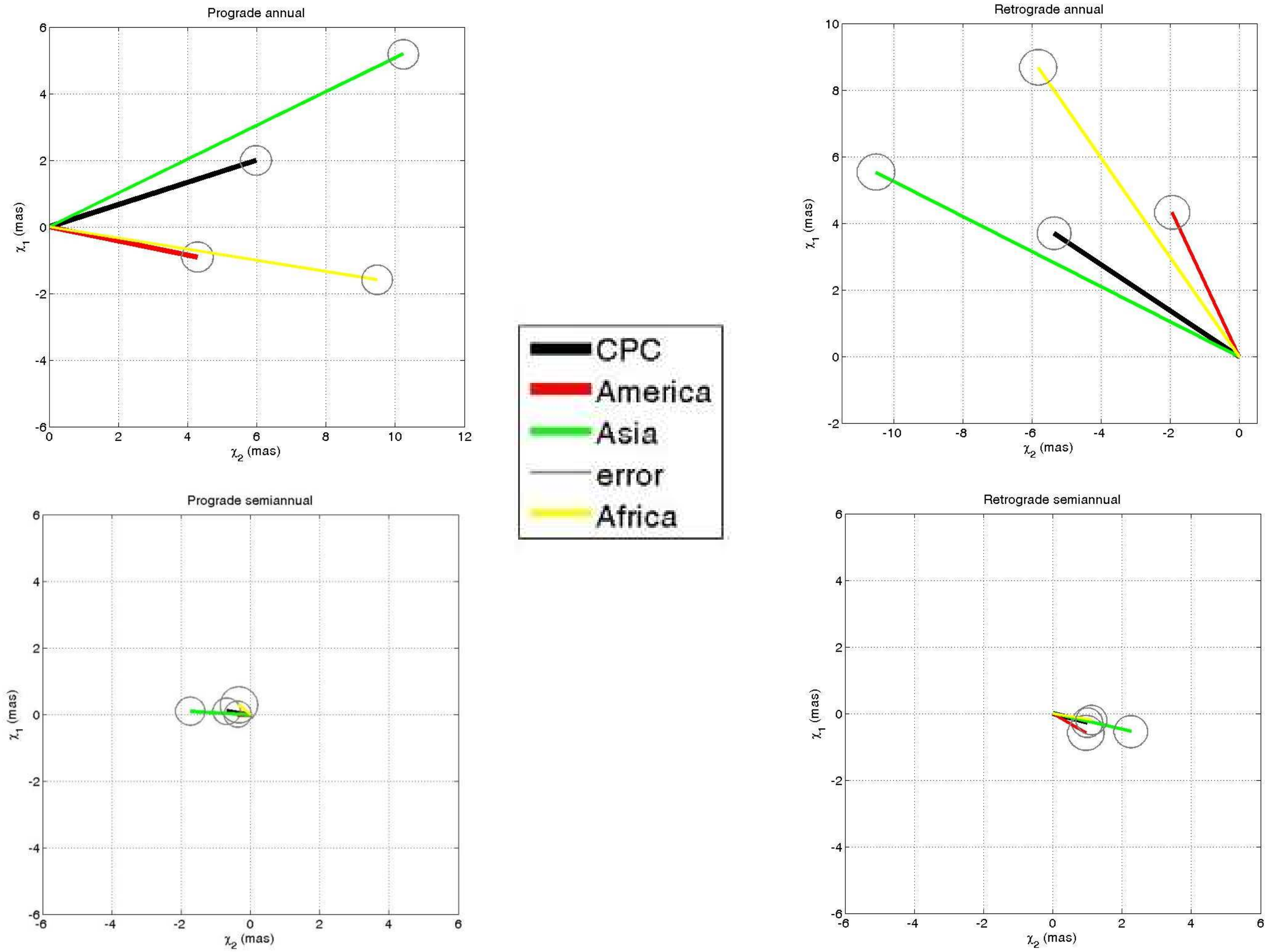

Fig. 10 Phasor diagrams of the seasonal components of the global CPC hydrological excitation function for the period 1980.0-2007.0. Comparison between global and regional hydrological excitation of polar motion. The regonal excitations were computed after removing the impacts of America, Africa and Asia, respectively.

Conclusions 1

- Phasor diagrams of annual and semiannual oscillations of polar motion show that different models of HAM excitation functions differ significantly in amplitudes and phases and temporal characteristics in their spectra.

- None of the HAM functions do close the budget of the needed global geophysical excitation function of polar motion. The gravimetric excitation functions of polar motion based on GRACE data also not close this budget.

- Spectra of seasonal oscillations of geophysical fluids excitation functions mainly annual and semiannual are different too. The annual oscillation is the strongest one.

- Prograde annual and semiannual oscillations of geophysical fluids excitation functions are smaller than of geodetic ones.

Conclusions 2

•The sum of AAM+OAM+CPC, shown in the spectra, is closest to the geodetic excitation GAM among all of functions

•The gravimetric excitations functions spectra for the GRACE CNES and GRACE CSR are different; for the GRACE CSR occur very strong signal for the 120 day; this signal is apparent also for the geodetic residuals

•After removing the impact of the hydrological regions from the global hydrological model, the HAM change in the amplitudes and phases

•The models of land hydrology are still under development. At present it is difficult to say, which hydrological model is the best and which combination AAM+OAM+HAM is the best for improvement the agreement with geodetic excitation function GAM.

Thank you for your attention

Gravimetric excitation functions

The equatorial components of the gravimetric excitation of polar motion were computed from harmonic coefficients of the Earth gravity field C_{21}, S_{21}:

$$\chi_1^{mass} = -\frac{\Delta C_{21}}{(1+k_2^{'})\sqrt{\frac{3}{5}} \cdot \frac{C-A}{1.098 \cdot R^2 M}}$$

$$\chi_2^{mass} = -\frac{\Delta S_{21}}{(1+k_2^{'})\sqrt{\frac{3}{5}} \cdot \frac{C-A}{1.098 \cdot R^2 M}}$$

M – mass of the Earth
R - mean radius of the Earth
C and A - the Earth's principal moments of inertia
k2' - degree-2 Love number (-0.301) accounting for elastic deformational effects on gravitational change
ΔC_{21}, ΔS_{21} - Stokes coefficients of the gravity field

Hydrological excitation of polar motion

The equatorial components of HAM excitation function of polar motion due to water storage variations:

$$\begin{bmatrix} \chi_1 \\ \chi_2 \end{bmatrix} = -\frac{1.098 R_e^2}{C - A} \iint \Delta q(\varphi, \lambda, t) \sin(\varphi) \cos(\varphi) \begin{bmatrix} \cos(\lambda) \\ \sin(\lambda) \end{bmatrix} dS$$

Where:
$\Delta q(\phi,\lambda,t)$ - changes in water storage in unit area (in kg m^{-2})
R_e - the Earth's mean radius
dS - the surface elements area
C and A - the Earth's principal moments of inertia

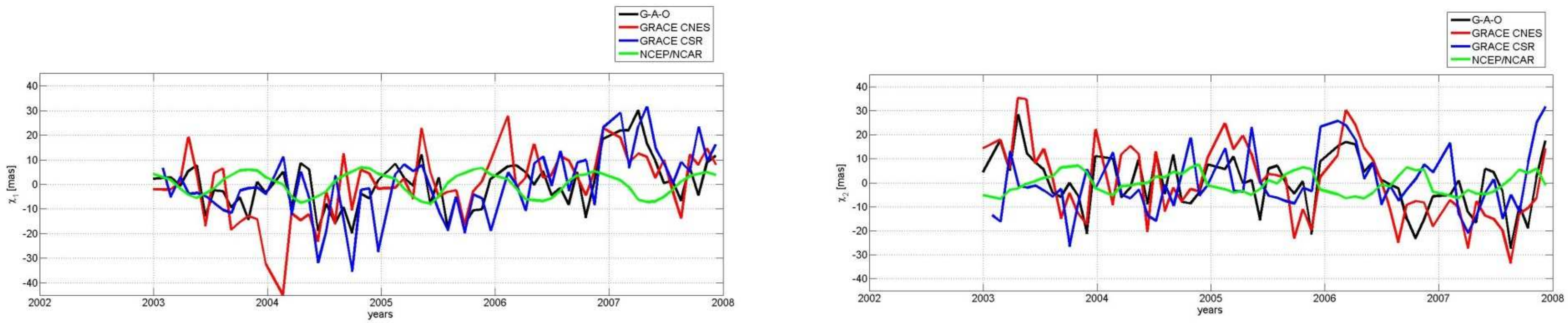

Fig. 1 Comparison of χ1, χ2 components of: gravimetric excitation of polar motion (GRACE CNES, GRACE CSR), residuals of the geodetic excitation function G-A-O and hydrological excitation functions NCEP/NCAR.

Time variable spectra

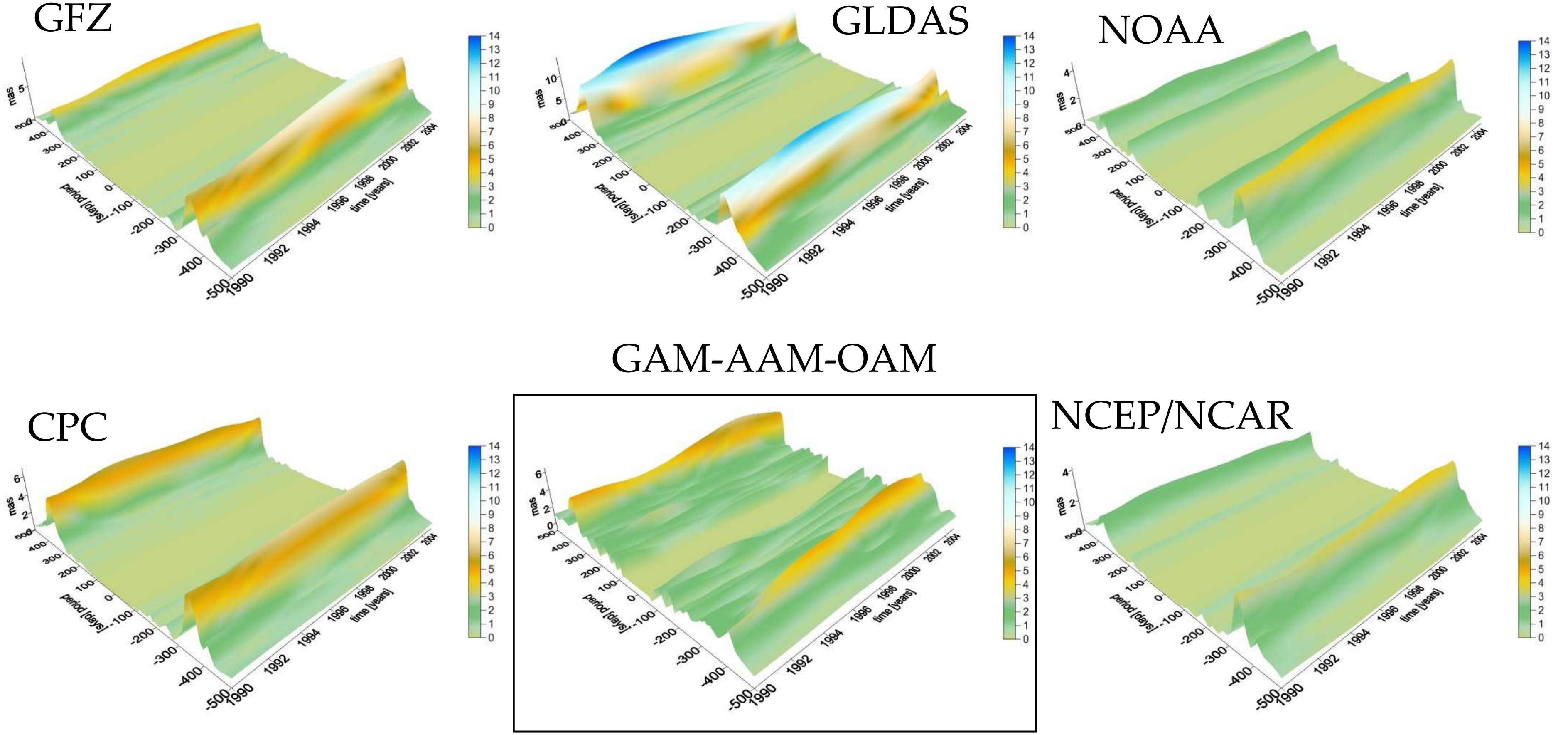

Fig. 6 The time variable spectrum of the 80 – 500 day band of the hydrological excitation of polar motion and of geodetic residualc excitation of polar motion computed by the FTBPF. Filtered by the FTBPF with 500 days cutoff and with the parameter λ=0.01; analysis done for the period 1989.0 – 2007.0.

Models of global land hydrology

Models	Description
CPC (Climate Prediction Centre)	The CPC HAM is computed based on the land data assimilation system LDAS. LDAS is forced by observed precipitation, derived from CPC daily and hourly precipitation analyses, downward solar and long-wave radiation, surface pressure, humidity, 2-m temperature and horizontal wind speed from NCEP reanalysis
GLDAS (Global Land Assimilation System)	The water storage is the sum of soil moisture, snow water equivalent and canopy surface water not counting changes in groundwater below the depth defined by the model.
NOAA (National Oceanic and Atmospheric Association)	Model includes snow water equivalent, soil water, shallow ground water, soil temperature, evapotranspiration, runoff and stream flow
NCEP/NCAR (National Centers for Environmental Prediction/National Centers for Atmospheric Research)	Numerical model, designed mainly for atmospheric studies; The hydrologic part of this model is mainly employed as a lower boundary condition in the model, and reflects a combination of an imposed (non data-assimilating) hydrologic cycle, and interaction with the atmosphere.
LSDM (Land Surface Discharge Model)	Based on the ERA-interim atmospheric data; model take into account the measurements of soil moisture, snow, runoff, drainage, rivers, lakes, swamps; (personal communication)
WGHM CRU (Water GAP Global Hydrology Model Climate Research Unit)	Model simulated the continental water cycle (human water consumption is considered); (personal communication)