

Potential links between internal & external geodynamics at periods around 6 years

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ITES



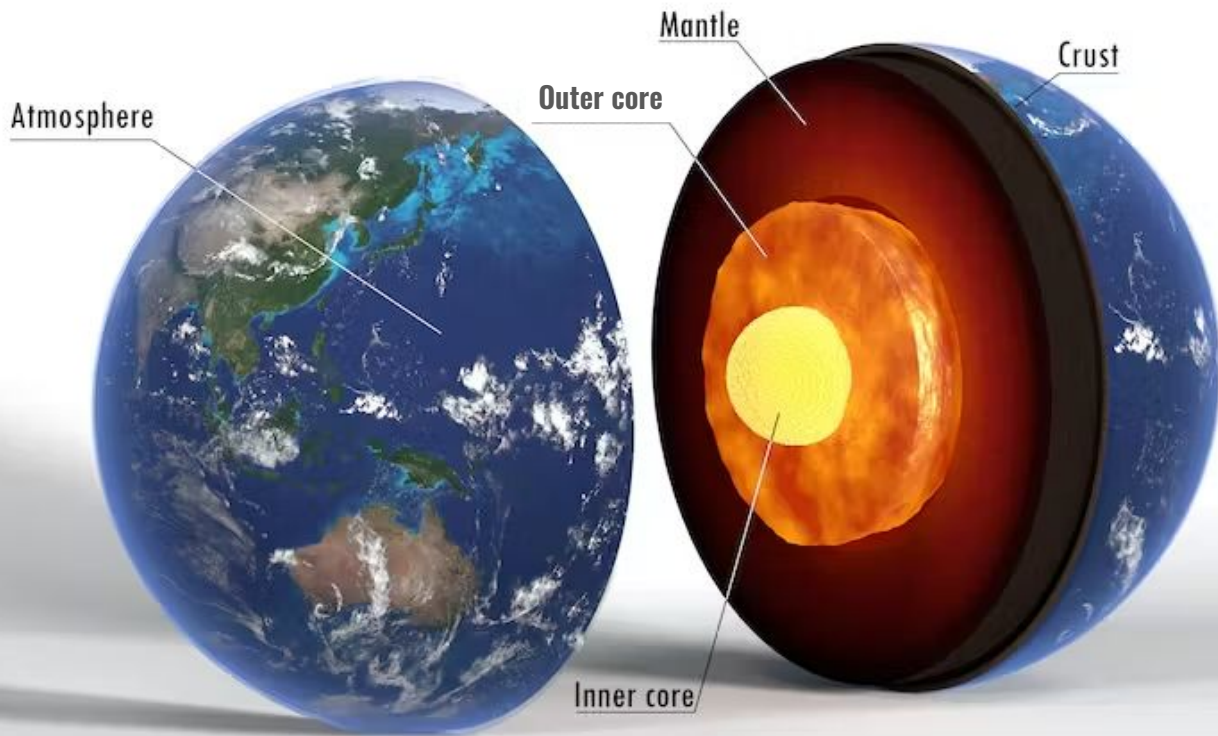
ROYAL OBSERVATORY OF
BELGIUM





GRACEFUL is an ERC Synergy project aiming at better understanding **dynamical processes in the Earth's deep interior** using a combination of satellite observations of the Earth's:

- magnetic field,
- gravity field,
- rotation.





- A 6-yr cycle in the magnetic field
- A 6-yr cycle in the length of day
- A 6-yr cycle in the gravity field
- Potential links between internal and external geodynamics at a 6-yr period

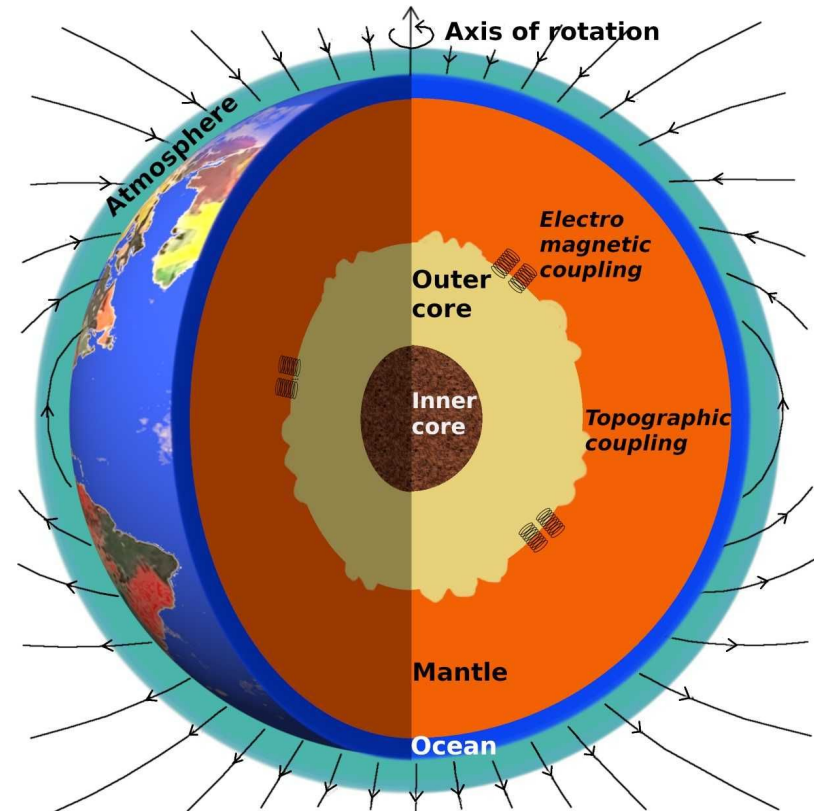
Pfeffer et al. (2023). A 6-year cycle in the Earth system. *Global and Planetary Change*, 229, 104245.

<https://doi.org/10.1016/j.gloplacha.2023.104245>

Cazenave et al. (2023). ESD Ideas: A 6-year oscillation in the whole Earth system? *Earth Syst. Dynam.*, 14, 733–735,

<https://doi.org/10.5194/esd-14-733-2023>

Cazenave et al., (2024)

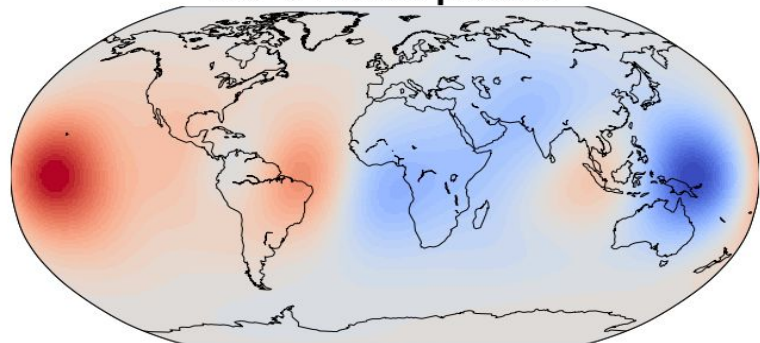




A 6-yr cycle in the Earth's magnetic field

- Satellite and ground observations of the magnetic field are the primary source of information on Earth's core dynamics.
- Evidence of a 6-yr cycle in the geomagnetic field in Dumberry & Mandaia et al., (2021), Saraswati et al., (2023), Pfeffer et al., (2023).

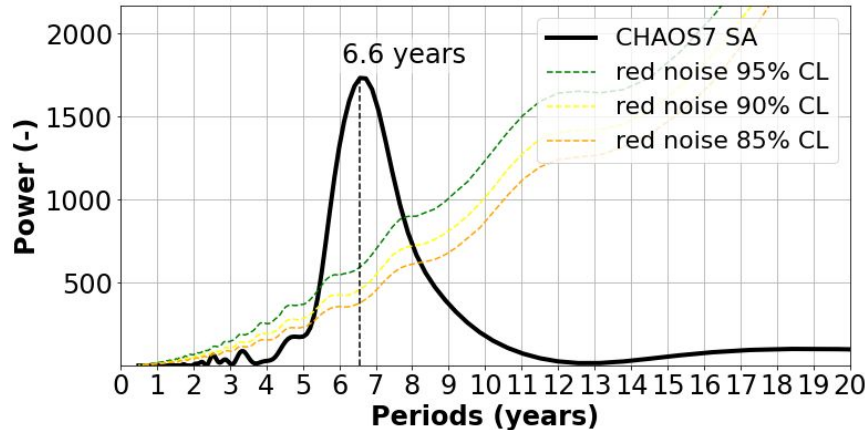
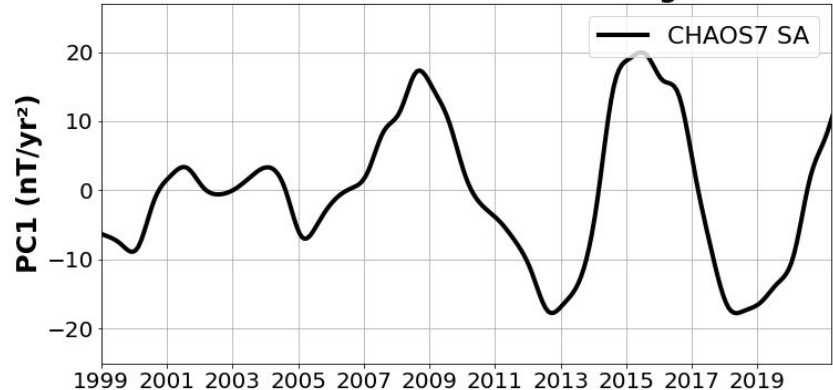
EOF 1 : 31.61 percent

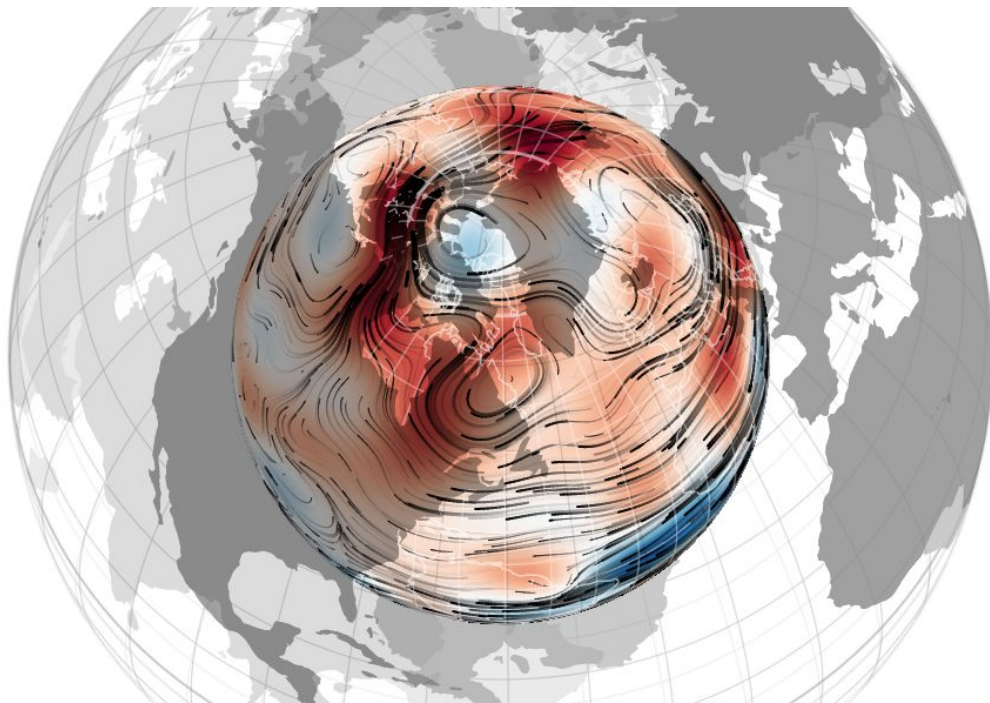


Normalized spatial component of the EOF (-)

-1.00 -0.75 -0.50 -0.25 0.00 0.25 0.50 0.75 1.00

Secular radial acceleration of the magnetic field





<https://geodyn.univ-grenoble-alpes.fr/>

Huder et al. (2019); Gillet et al., (2022)

- Geomagnetic field models
 - COV-OBSx2: 1840–2020
 - CHAOS-7 : 1999 -2021
- Invert for core motions from the radial induction equation at the CMB:

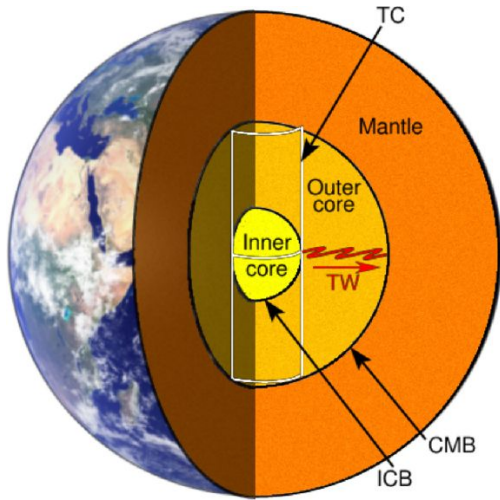
$$dBr/dt = -\text{div}_H(uBr) + er$$

- ill-posed problem : need a priori information
- Here : spatio-temporal cross-covariances from dynamo simulations, plugged into a multivariate stochastic mode



Schematic of torsional waves in the core

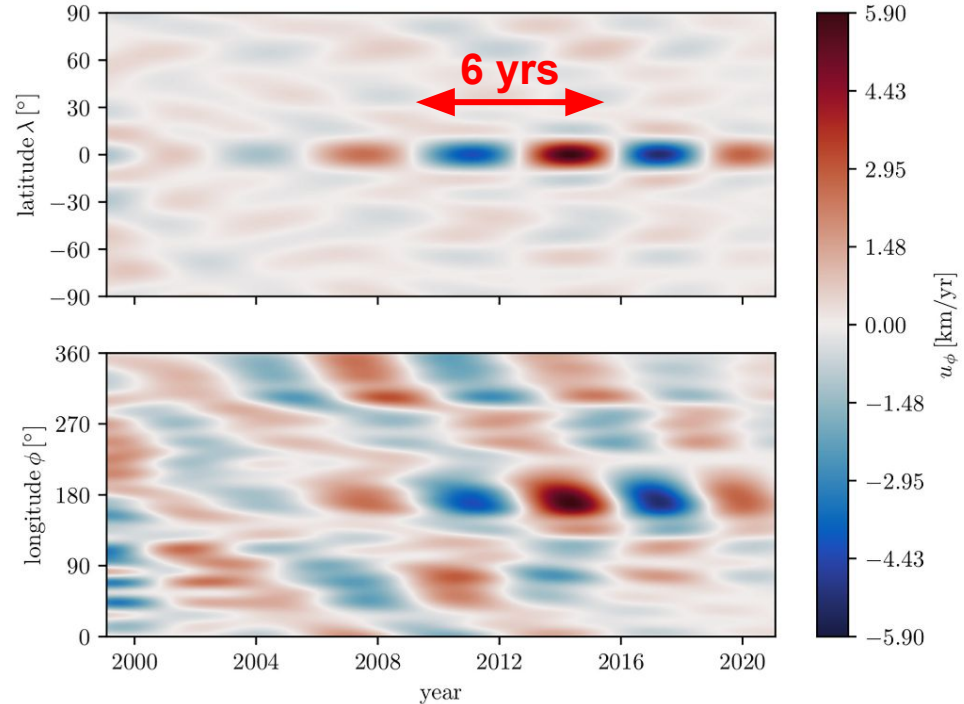
Teed et al., 2018 (GJI)



Several types of waves have been evidenced in core flow models with a period ~ 6 years.

Gillet et al., 2010, Gillet et al., 2015; Gillet et al., 2022, Istaş et al., 2023, Rosat and Gillet, 2023; Finlay et al., 2023

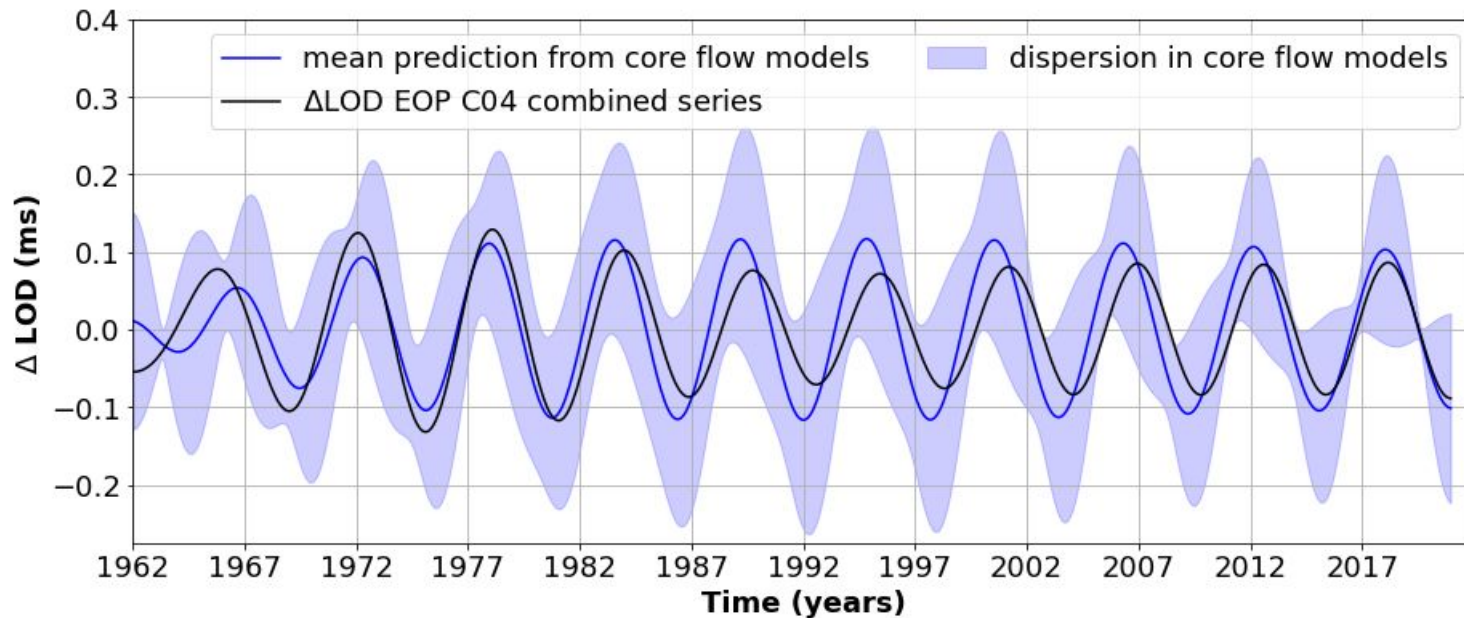
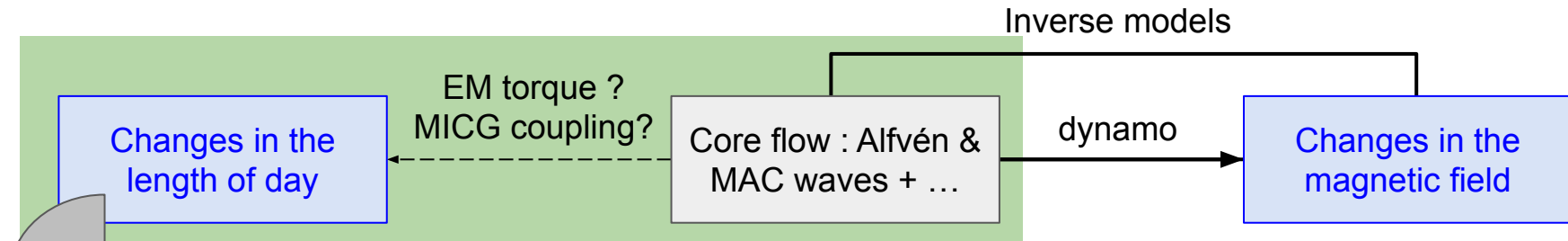
Core flow inverted from satellite geomagnetic observations



Gillet et al., 2022



A 6-yr cycle in the length of day : fast core flow





A 6-yr cycle in the length of day : external fluid envelopes

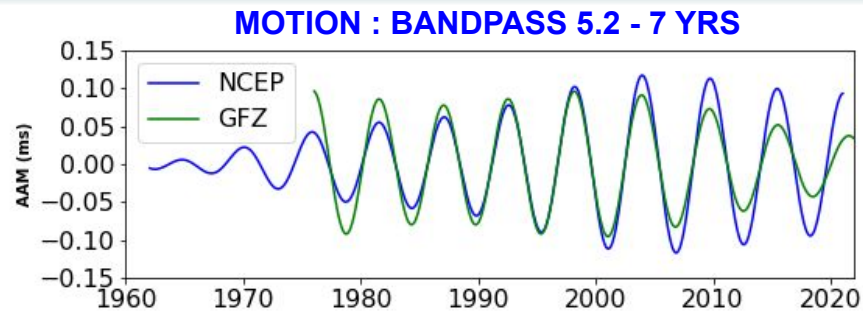
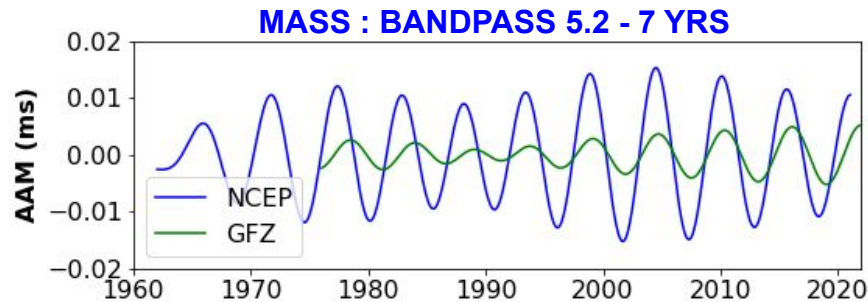
	Mass term	Motion term
Atmosphere	<ul style="list-style-type: none">• NCEP• ECMWF (GFZ)	<ul style="list-style-type: none">• NCEP• ECMWF (GFZ)
Ocean	<ul style="list-style-type: none">• ECCO• MPIOM (GFZ)	<ul style="list-style-type: none">• ECCO• MPIOM (GFZ)
Hydrology	<ul style="list-style-type: none">• LSDM + mass conservation (GFZ)	<ul style="list-style-type: none">• LSDM (GFZ)
Earth System	<ul style="list-style-type: none">• SLR +GAC (Bourda, 2008)	
TOTAL	<ul style="list-style-type: none">• SLR + GAC• NCEP + ECCO + LSDM + mass conservation• NCEP + MPIOM + LSDM + mass conservation• ECMWF + ECCO + LSDM + mass conservation• ECMWF + MPIOM + LSDM + mass conservation	<ul style="list-style-type: none">• NCEP +ECCO + LSDM• NCEP + MPIOM + LSDM• ECMWF + ECCO + LSDM• ECMWF + MPIOM + LSDM

- AAM, OAM and HAM data available on IERS website : <https://datacenter.iers.org/fluids.php>
- SLR : Loomis et al., (2020) & GAC : Shihora et al., (2022)

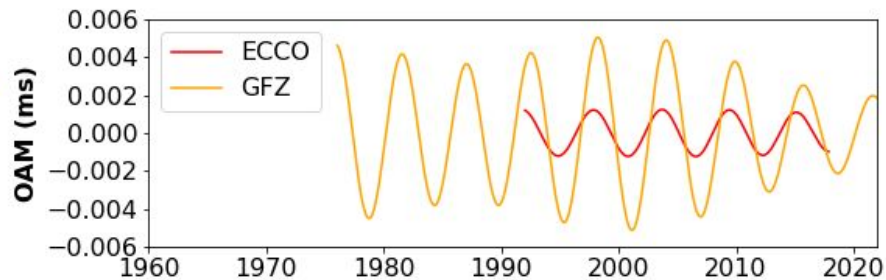
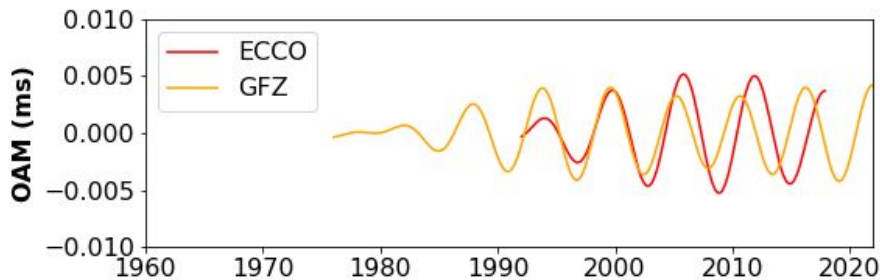


A 6-yr cycle in the length of day : external fluid envelopes

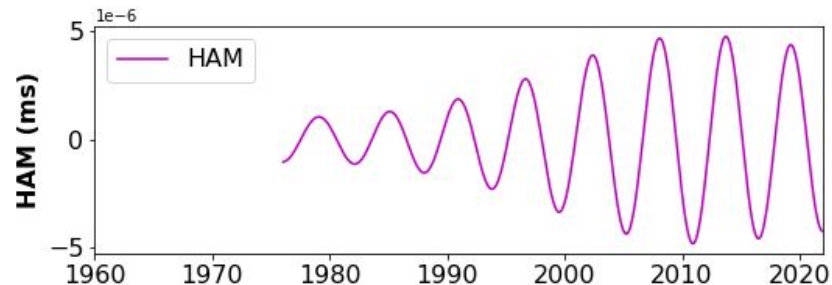
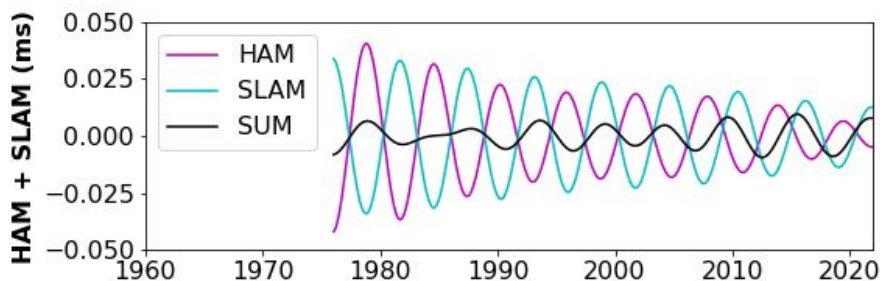
ATMOSPHERE



OCEAN

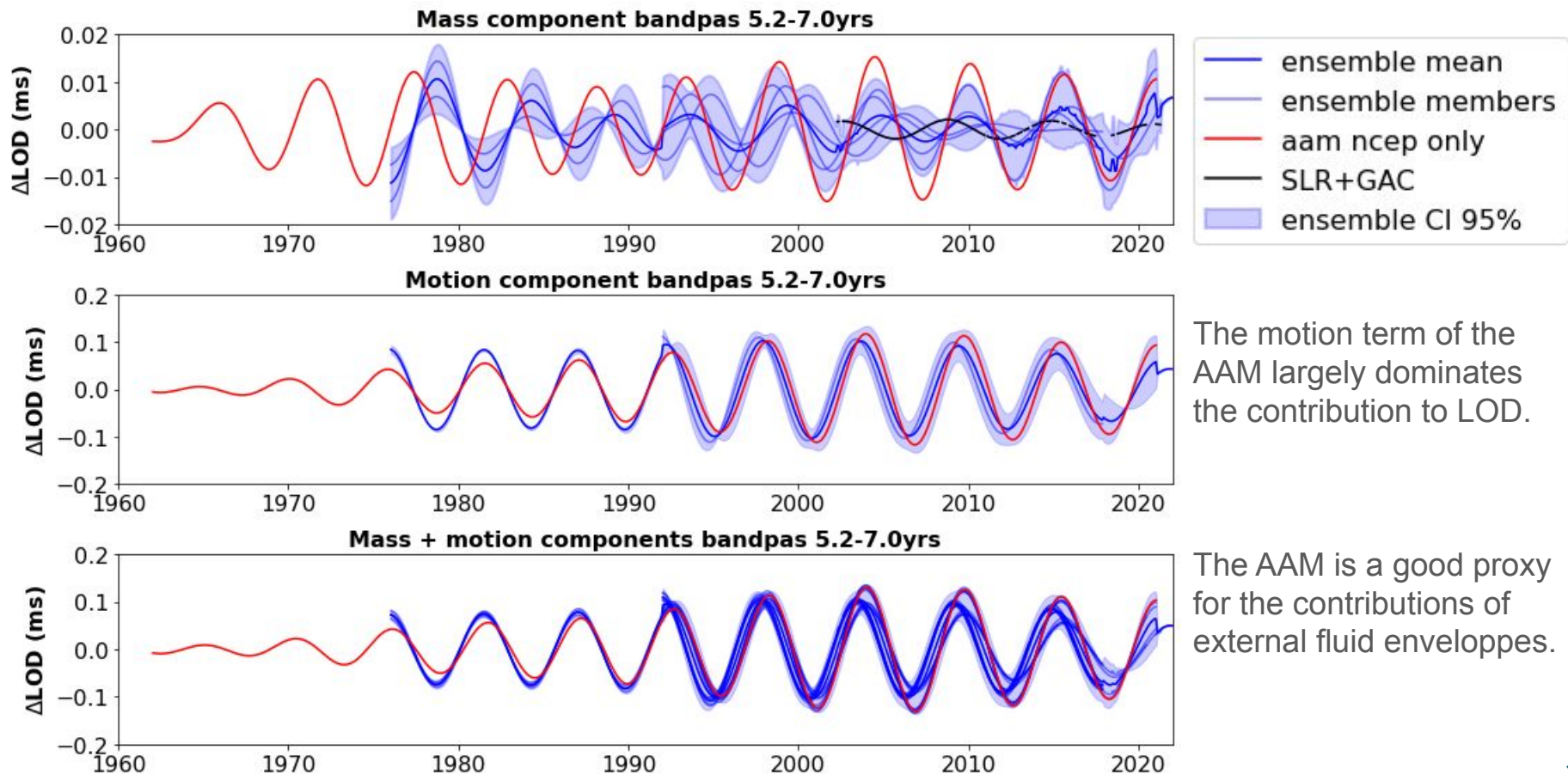


HYDROSPHERE





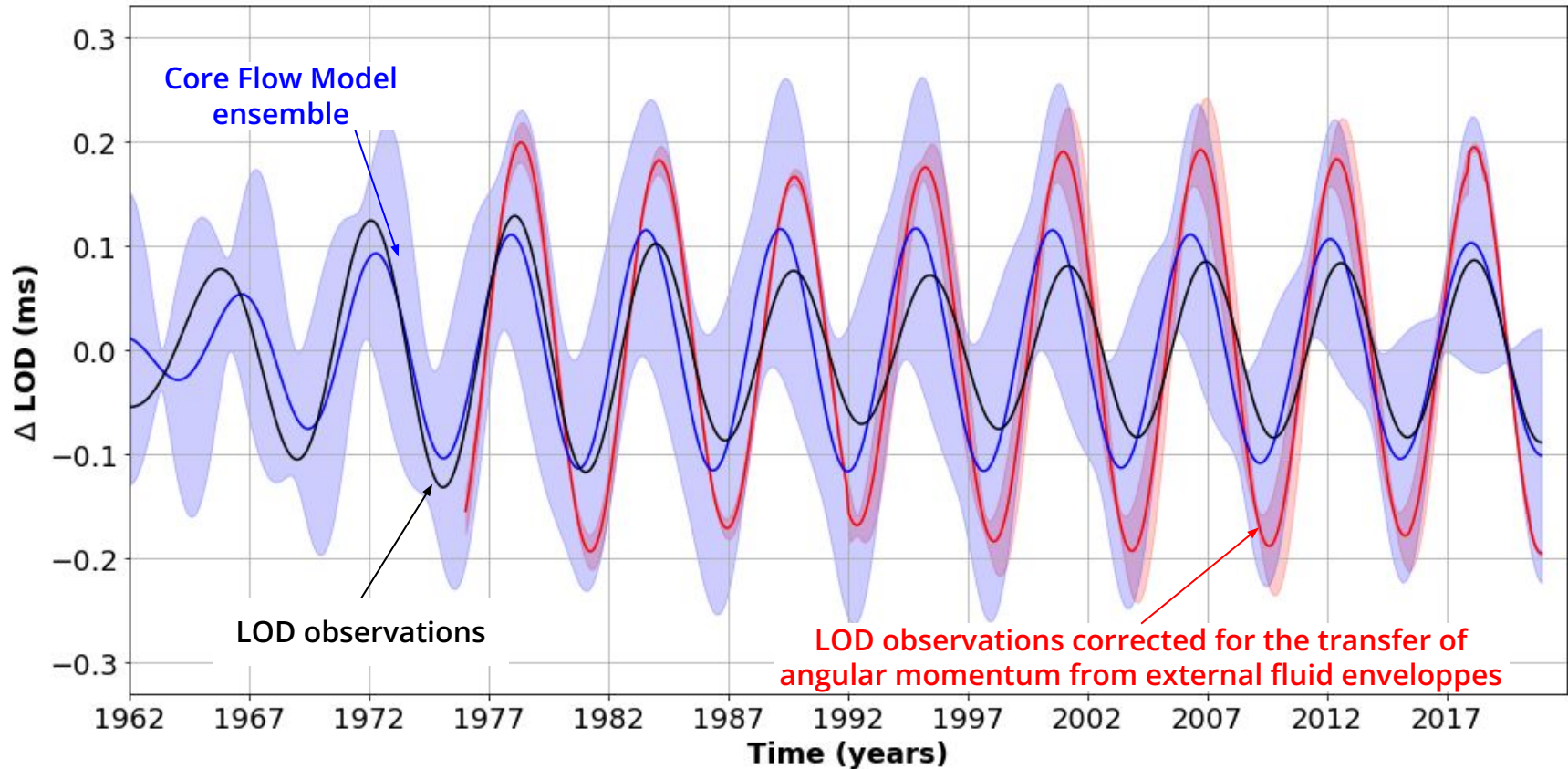
A 6-yr cycle in the length of day : external fluid envelopes





A 6-yr cycle in the length of day : expected core signal

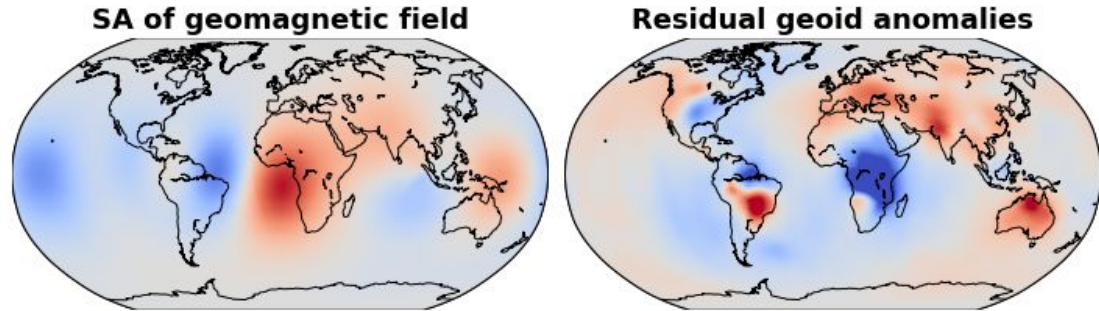
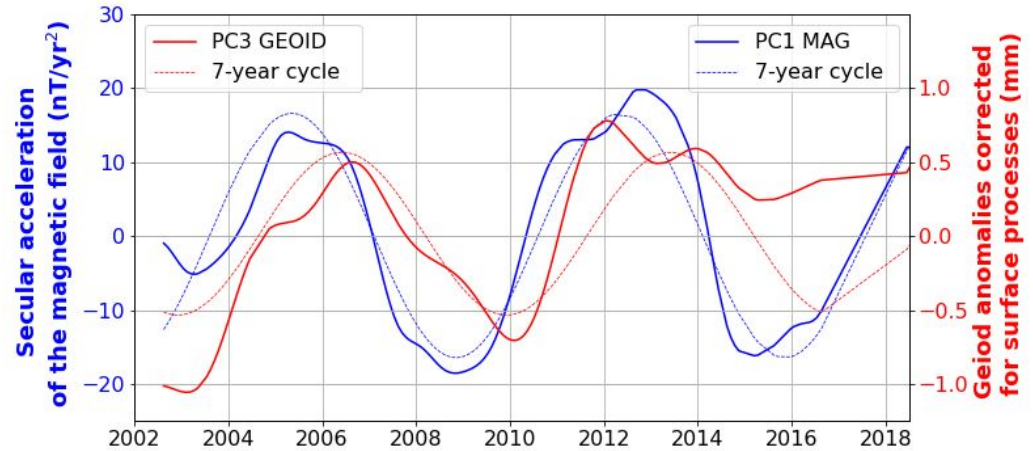
Changes in the length of day at periods ranging from 5.2 to 7 years.





A 6-yr cycle in the gravity field

- **Collection of GRACE and GRACE-FO L2 and L3 data from 6 centers**
- **Corrections of contributions of external fluid envelopes**
 - Removal trend + seasonal
 - Removal hydrology (ISBA)
 - Removal ocean/atmosphere (AOD1B)
 - Removal ice covered regions
 - Removal EQ regions
- **Conversion of the residual GRACE and GRACE-FO data to geoid anomalies**
- **EOF analysis of residual geoid anomaly**
- **EOF analysis of the CHAOS-7 SA magnetic field model**



Pfeffer et al., (2023)

<https://doi.org/10.1016/j.gloplacha.2023.104245>



A 6-yr cycle in the gravity field : contribution from the core

Decadal Amplitude of Mass Variations Due To Core Processes

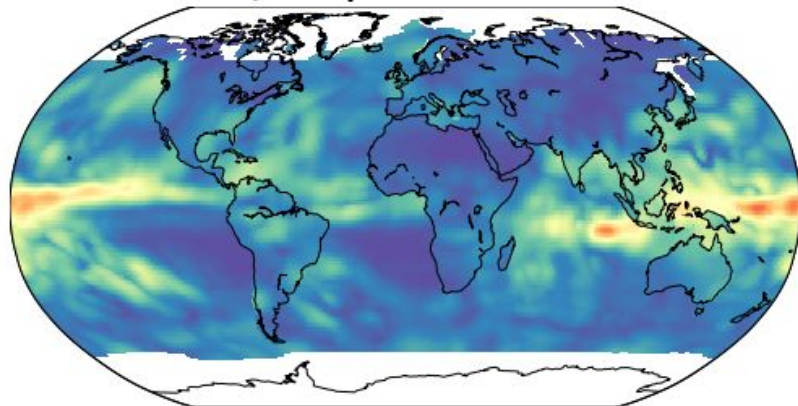
Gravitational effect	EWH (cm)		
	Degree 2	Degree 6	Degree 10
Amplitude observed by GRACE	5	20	15
Density anomalies	0.1	0.006	0.0005
CMB pressure anomalies	0.5	0.04	0.004
Inner core rotation	0.2	X	X

Lecomte, H., Rosat, S., Manda, M., Boy, J.-P., & Pfeffer, J. (2023). *Journal of Geophysical Research: Solid Earth*
<https://doi.org/10.1029/2023JB026503>

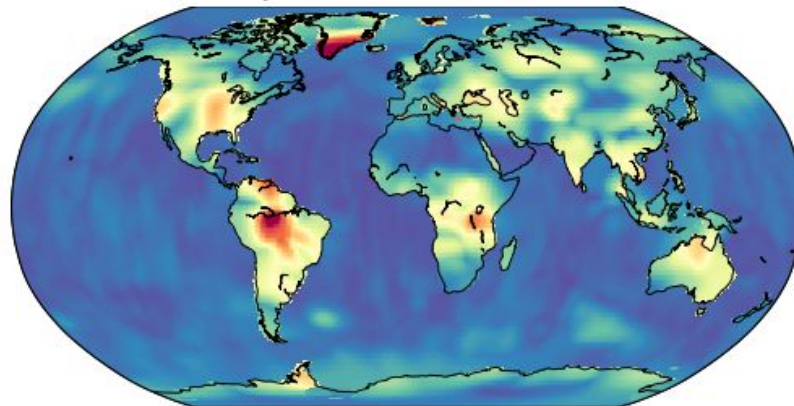


A 6-yr cycle in the global water cycle

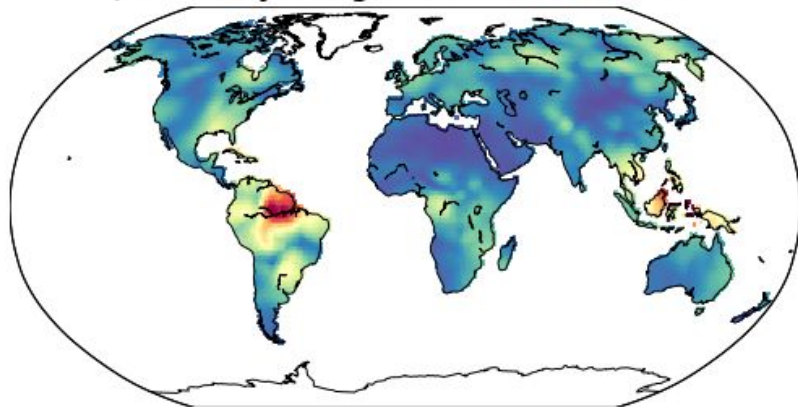
a) Precipitation: IMERG



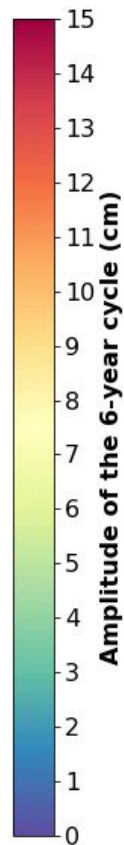
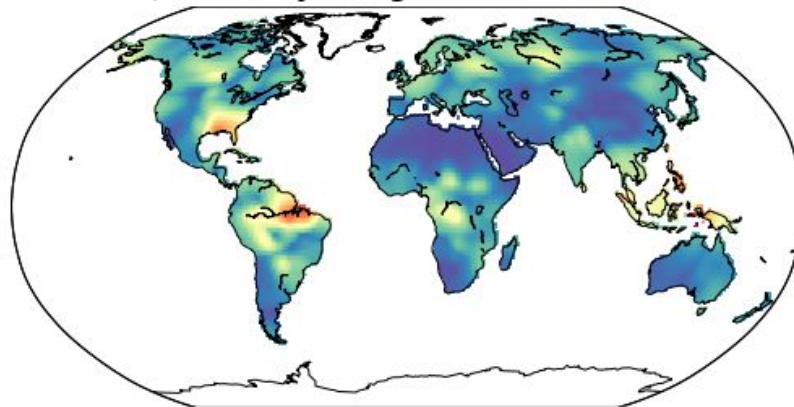
b) GRACE & GRACE-FO



c) Global Hydrological Model : ISBA-CTRIP



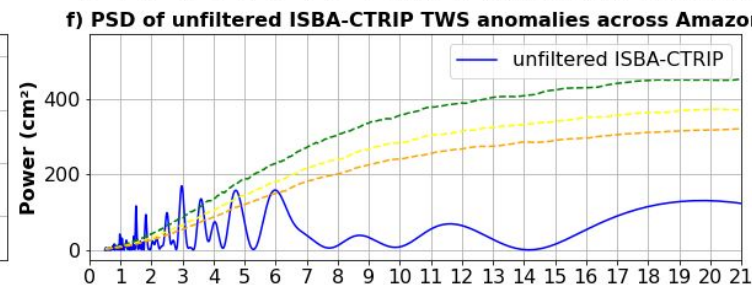
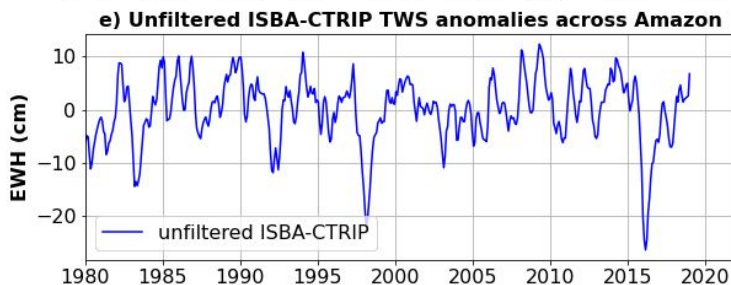
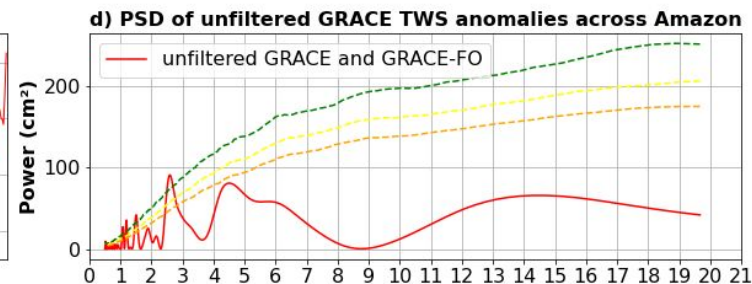
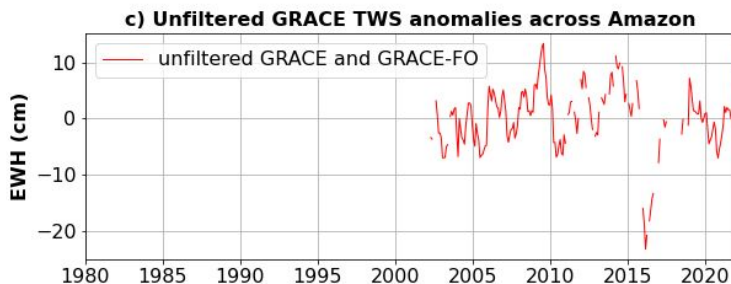
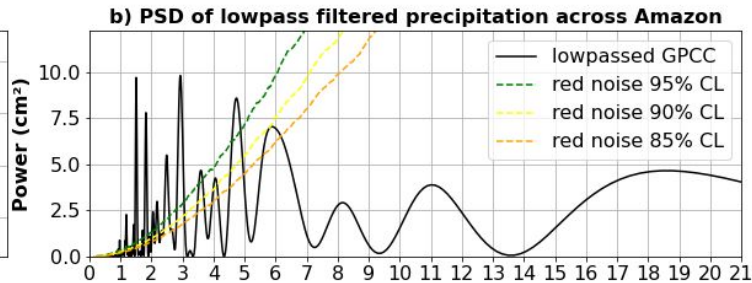
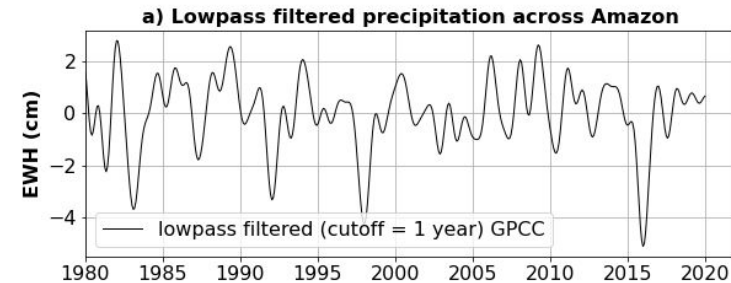
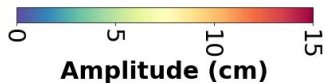
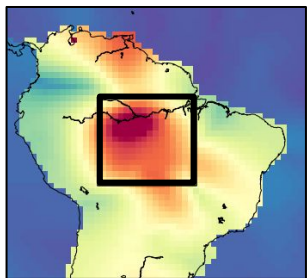
d) Global Hydrological Model : WGHM





A 6-yr cycle in the global water cycle

Amplitude of the 6-yr cycle in GRACE-based TWS over the Amazon region



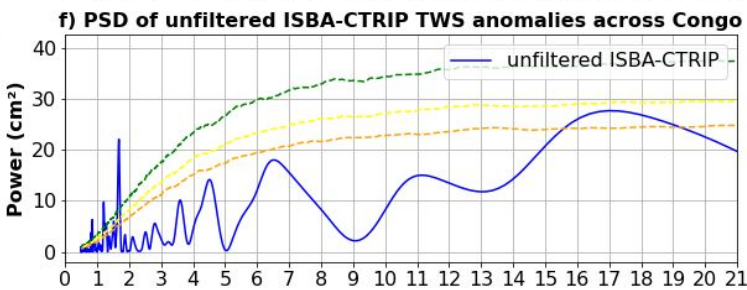
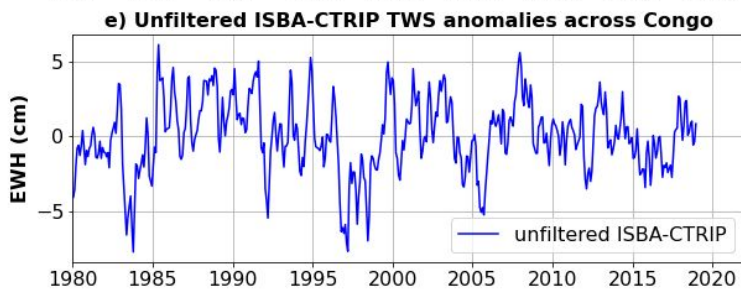
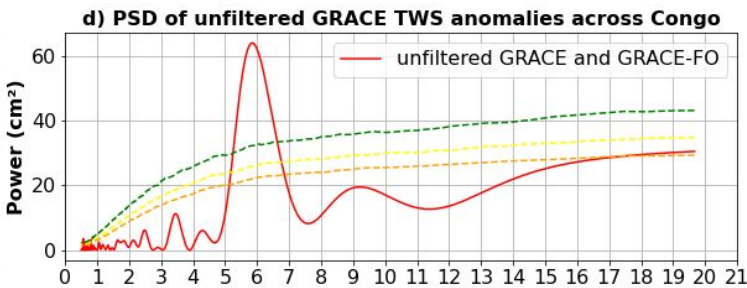
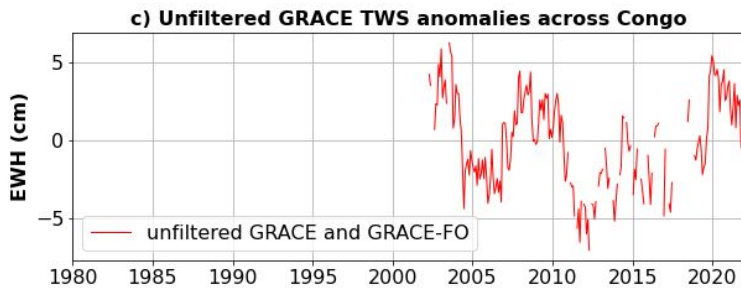
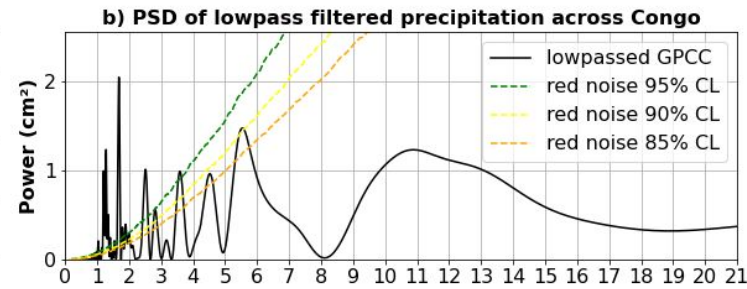
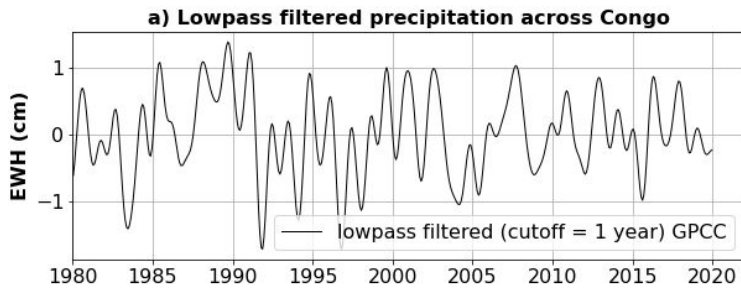
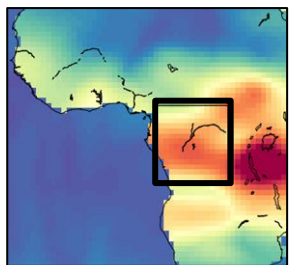
Time (years)

Periods (years)



A 6-yr cycle in the global water cycle

Amplitude of the 6-yr cycle in GRACE-based TWS over the Congo region



Time (years)

Periods (years)

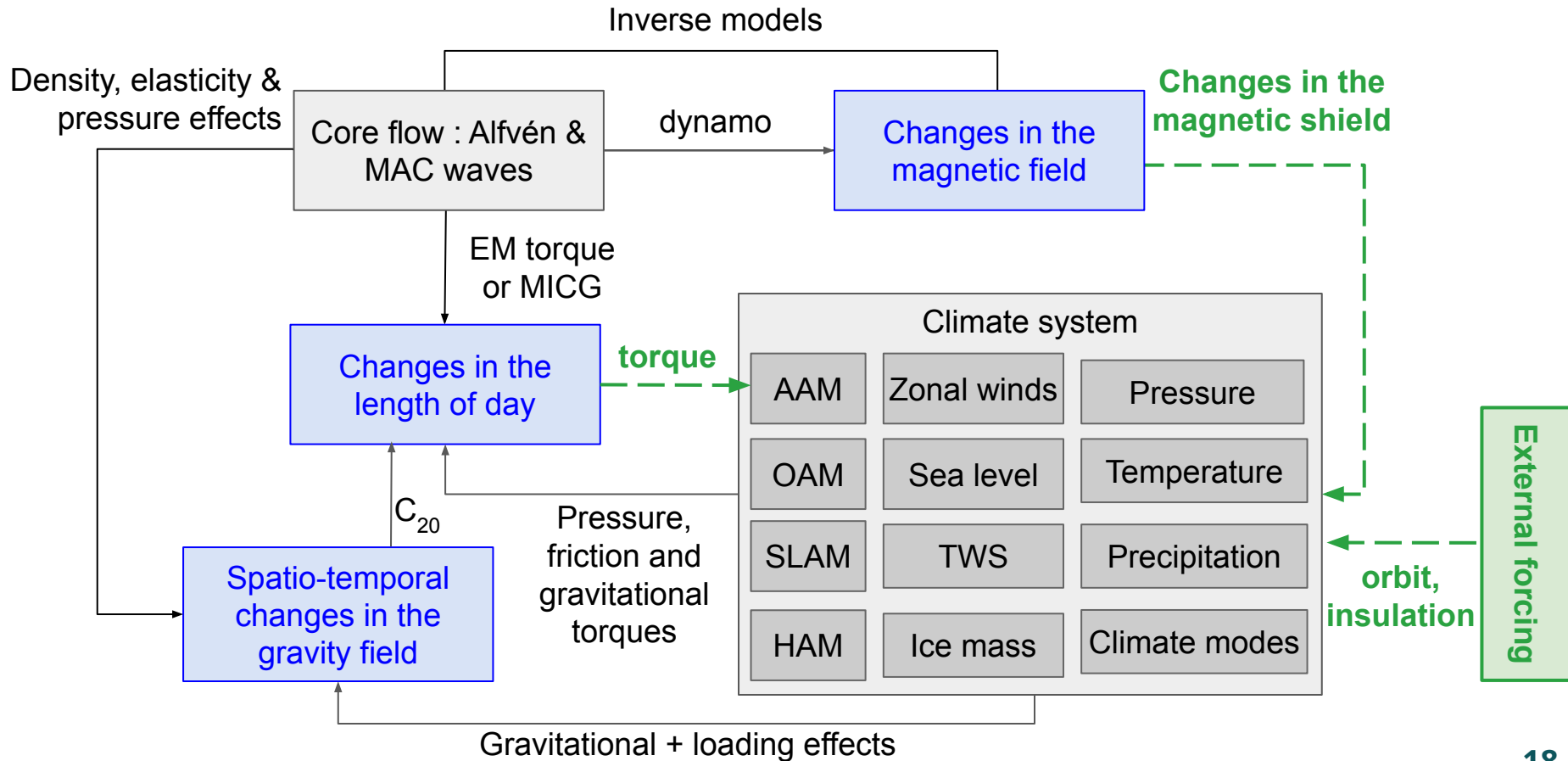


A 6-yr cycle in the magnetic field, length of day & gravity field

- Fast variations in the **geomagnetic field** occur at a 6-yr period.
- Several types of waves (torsional, QG MC, MAC) with a recurring period of 6 years have been evidenced in **core flow models** inferred from geomagnetic data.
- A 6-year cycle in the **length of day** (LOD) has been observed in many different studies and attributed to dynamical processes occurring in the Earth's core.
- A 6-year cycle is also observed in the **climate system**, impacting both the LOD and the gravity field.
- The expected signal from the core on the **gravity field** is too small to be detected by GRACE and GRACE-FO measurements. The residual gravity signal related to the global water cycle but unexplained by global hydrological models is still one order of magnitude larger than the signal expected from the core.
- Satellite gravimetry data can be used to constrain the redistribution of mass in the external fluid envelopes and correct LOD observations for surface processes. This way, we can use LOD observations to constrain internal geodynamics only.

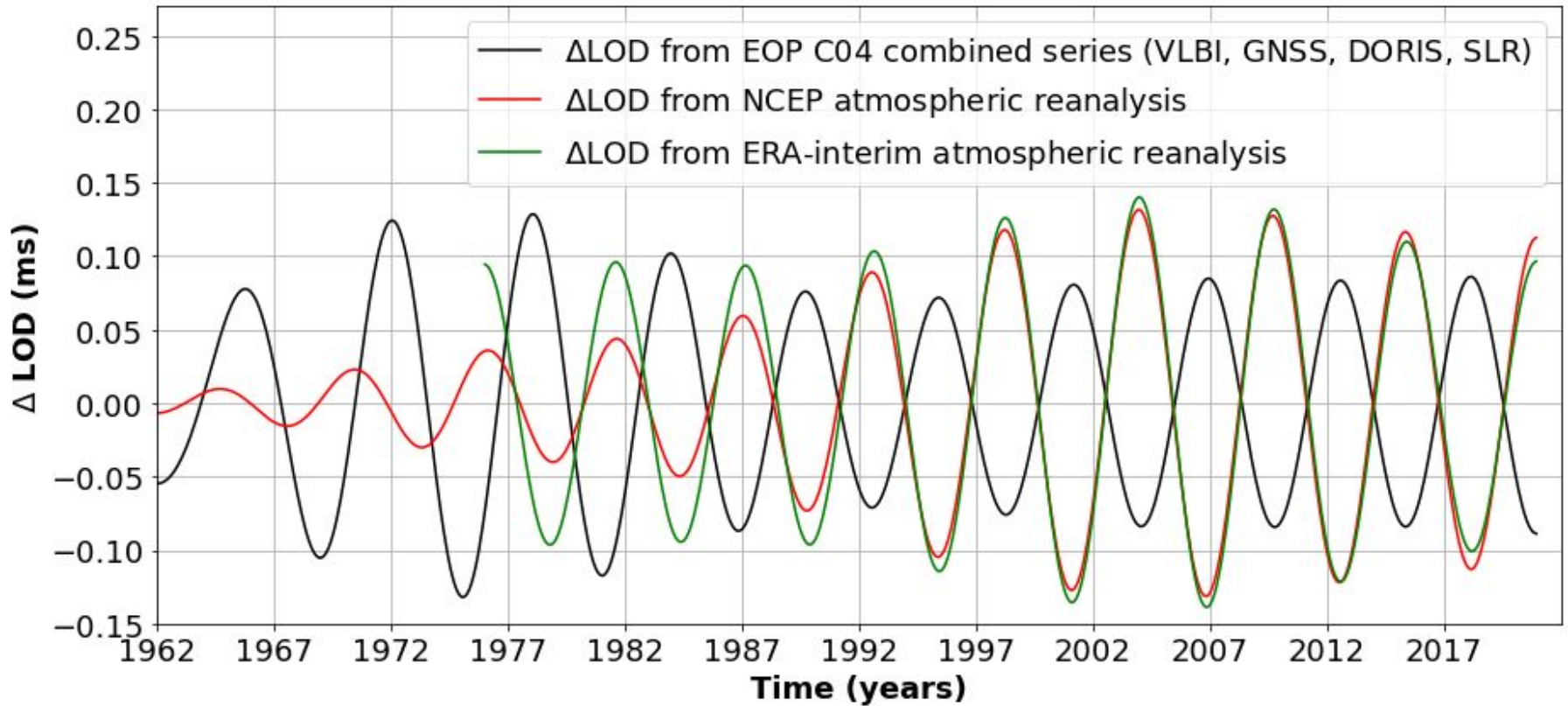


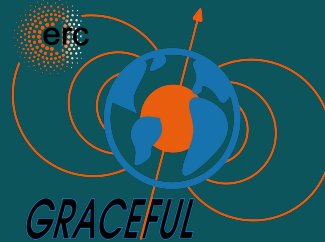
Potential links between internal and external geodynamics ?





Potential links between internal and external geodynamics ?





Thank you for your
attention.

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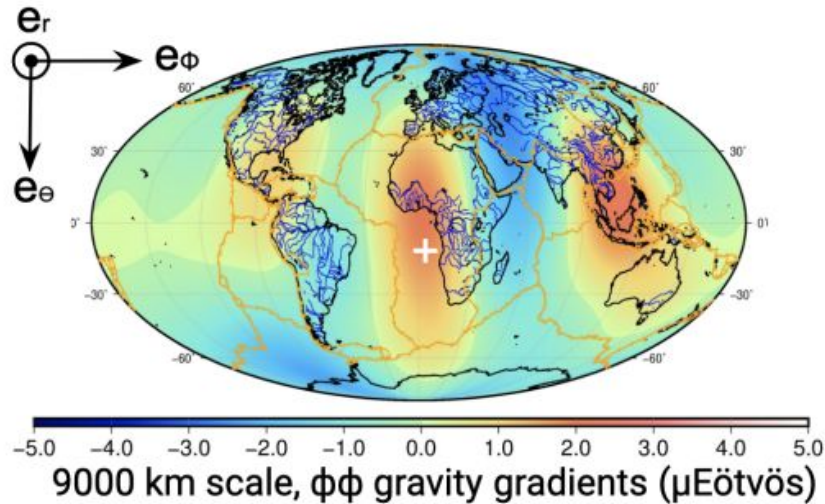


<https://graceful.oma.be/>



A new way to look at large spatial scales in the gravity field

Map of 9000 km scale $\phi\phi$ gravity gradients in January 2007



Time series of the 9000 km scale $\phi\phi$ gravity gradients at 0°E 14°S (white cross on map)

