Modelisation of oceanic effects on the Earth's polar motion

Robin Paniagua [1], Christian Bizouard [1], Pascal Bonnefond [1], Romain Bourdalle-Badie [2]

1: LTE, Observatoire de Paris - Université PSL ; 2: Mercator Ocean, Toulouse

Introduction

The Earth's rotation is not perfectly stable. Mass redistributions within the Earth's fluid layers modify their angular momentum, inducing opposite changes in the solid Earth and leading to variations in the length of day and polar motion. These effects can be estimated using atmospheric and oceanic circulation models, although oceanic contribution remains more difficult to quantify. Recent advances in satellite altimetry data assimilation, combined with the increasing spatial resolution of ocean circulation models, have significantly improved our ability to assess the hydro-atmospheric excitation of Earth's rotation. In this study, excitations functions were computed over the year 2025 and compared with geodetic observations.

Methods

Study of oceanic excitation of polar motion

- Data provided by **Copernicus Data Store** (GLORYS12)
- Angular momentum is the sum of a mass and a motion term $H = I\omega + h_f$
- Mass term derived from bottom pressure

$$C_f = C_{13} + iC_{23} \longrightarrow \chi_{mass}(t) = \alpha_1\alpha_2 \frac{C_f(t)}{(C-A)}$$

- Motion term derived from current velocities

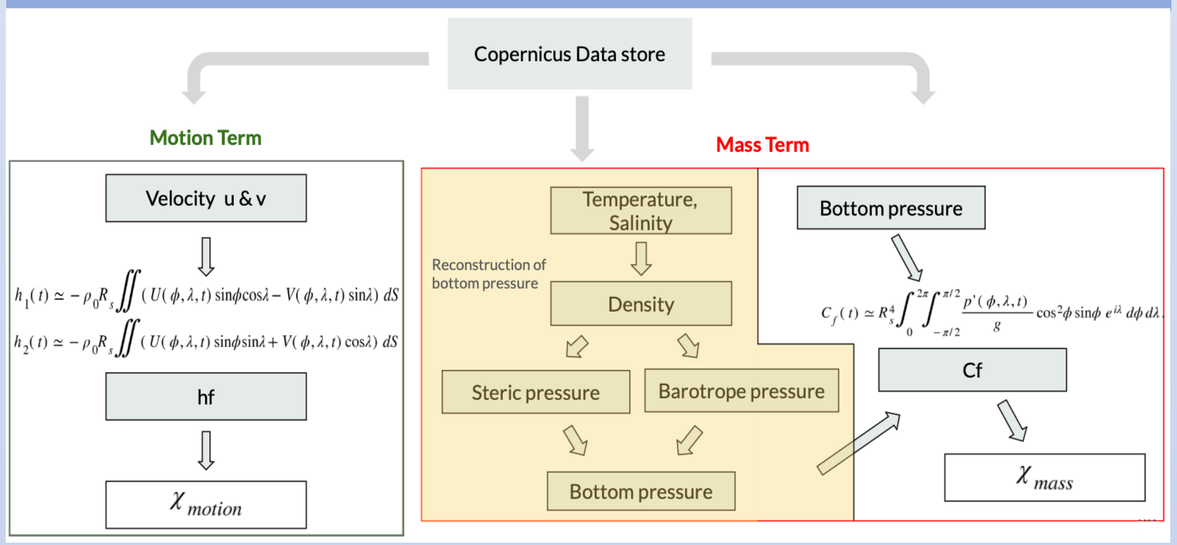
$$h_f = h_1 + ih_2 \longrightarrow \chi_{motion}(t) = \alpha_1 \frac{h_f(t)}{\Omega(C-A)}$$

- 2 methods for bottom pressure: Retrieved via **Copernicus** or Reconstructed
- Daily bottom pressure reconstructed from density, which is computed from temperature and salinity using TEOS-10 and compared with GFZ
- Atmospheric contributions added to obtain total excitations functions
- Total excitations functions compared with geodetic observations from IERS

$$p + \frac{i}{\sigma_0}\frac{\partial p}{\partial t} = \chi_{ma}{}^{e} + \chi_{mo}{}^{e}$$

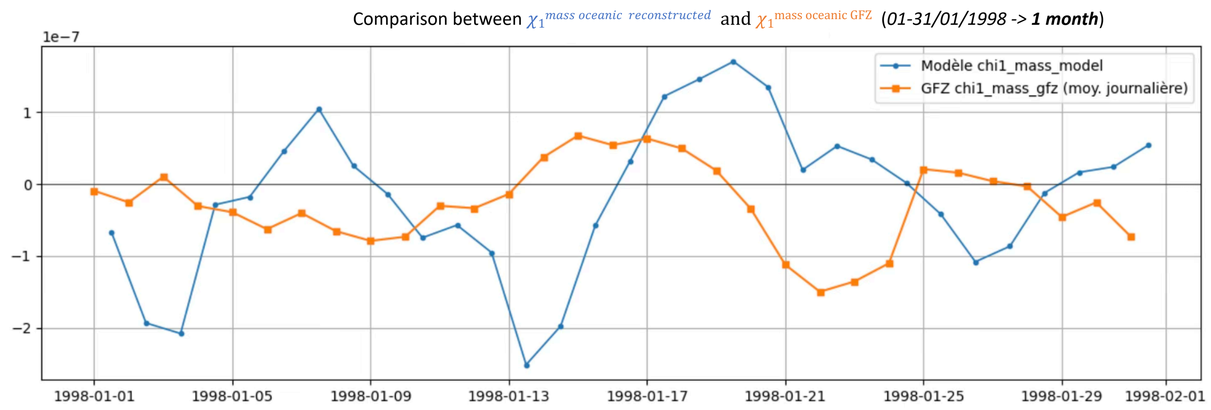
GLORYS12 (COPERNICUS)	MPIOM (GFZ)
Motivated by a better representation of the ocean	Motivated by the calculation of the angular momentum
NEMO model + atmospheric reanalysis (ERA5) + altimetric observations	MPIOM model forced by atmospheric reanalysis ECMWF
High spectral resolution (1/12°), 50 vertical levels	Lower spatial resolution
Captures small spatial scales but exhibits greater noises-induced variability	Smoother variability

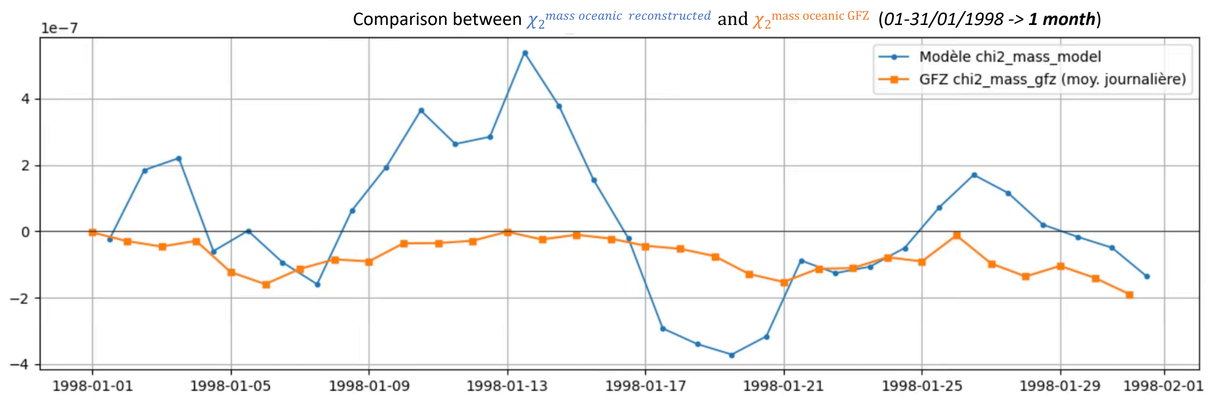
Pipeline



Results

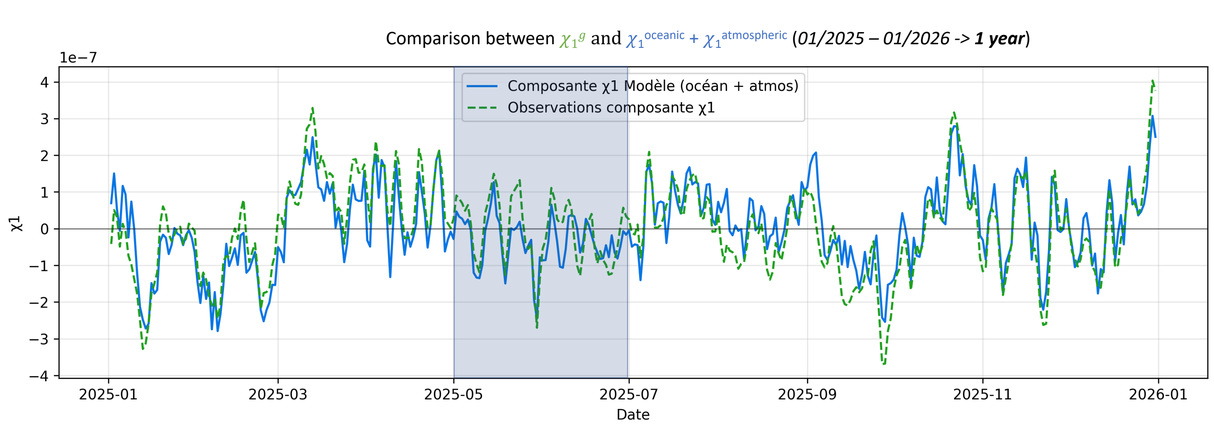
Mass excitation functions: Reconstruction (GLORYS12) vs GFZ

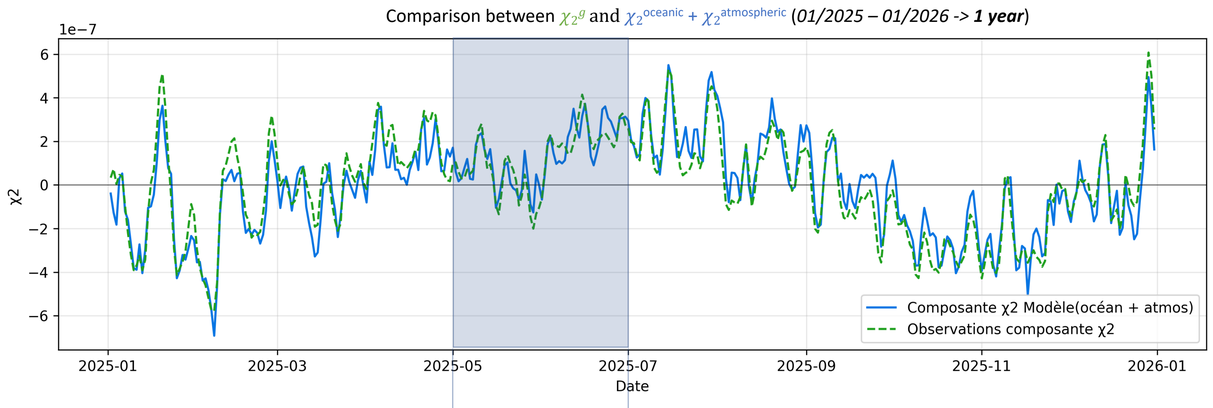




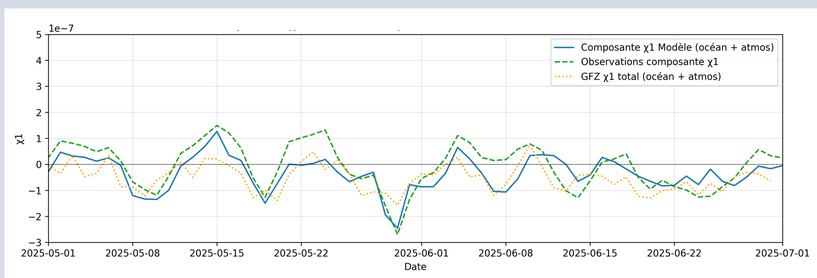
- Improved representation of weekly variations compared to GFZ

Total excitation functions: My model (GLORYS12) vs Geodetic observations

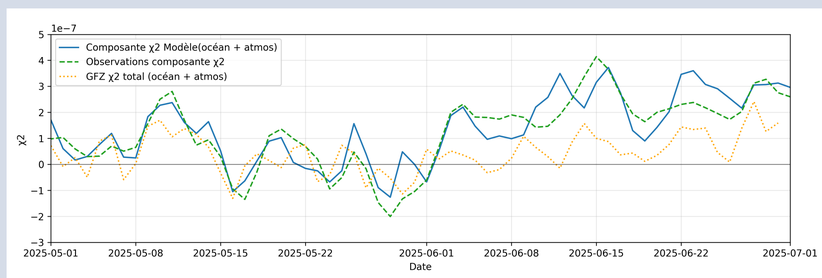




Comparison $\chi_1{}^{g}$ vs $\chi_1{}^{oceanic} + \chi_1{}^{atmospheric}$ vs $\chi_1{}^{GFZ}$ (05/2025 – 07/2025 -> 2 months)



Comparison $\chi_2{}^{g}$ vs $\chi_2{}^{oceanic} + \chi_2{}^{atmospheric}$ vs $\chi_2{}^{GFZ}$ (05/2025 – 07/2025 -> 2 months)



- The improved correlations achieved with GLORYS12 are likely related to its enhanced ability to represent short-term (weekly) variability

Perspectives

- Increase the temporal resolution to 1 hour to improve the characterization of the Free Core Nutation
- Calculate the **axial component** of the Earth's angular momentum
- Improve the predictions from geodetic observations (IERS)

KEY RESULTS	My model GLORYS12 (COPERNICUS)	MPIOM (GFZ)
Correlation $\chi_1{}^{total}$ / $\chi_1{}^{g}$	0.87	0.79
Correlation $\chi_2{}^{total}$ / $\chi_2{}^{g}$	0.94	0.87