A multi-model assessment of sub-monthly polar motion and the associated ocean bottom pressure variability

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Synopsis

Comparisons of geophysical fluid excitations against space-geodetic observations of sub-monthly polar motion typically reveal residuals with peaks as large as 1–2 cm when projected onto the Earth's surface (**Figure 1**). A possible source for these discrepancies are imperfections in the hydrodynamic models used to derive the required ocean excitation functions. To guide future model improvements, we present a systematic assessment of the oceanic component of sub-monthly polar motion based on simulations (2007–2008) with three global time-stepping models that are forced by the same atmospheric data but considerably differ in their numerical setup and physical parameterizations. A specific question we want to answer is whether daily GRACE solutions – which resolve the broad scales of ocean bottom pressure variability – can help identify the most credible model for studies of short-term polar motion.

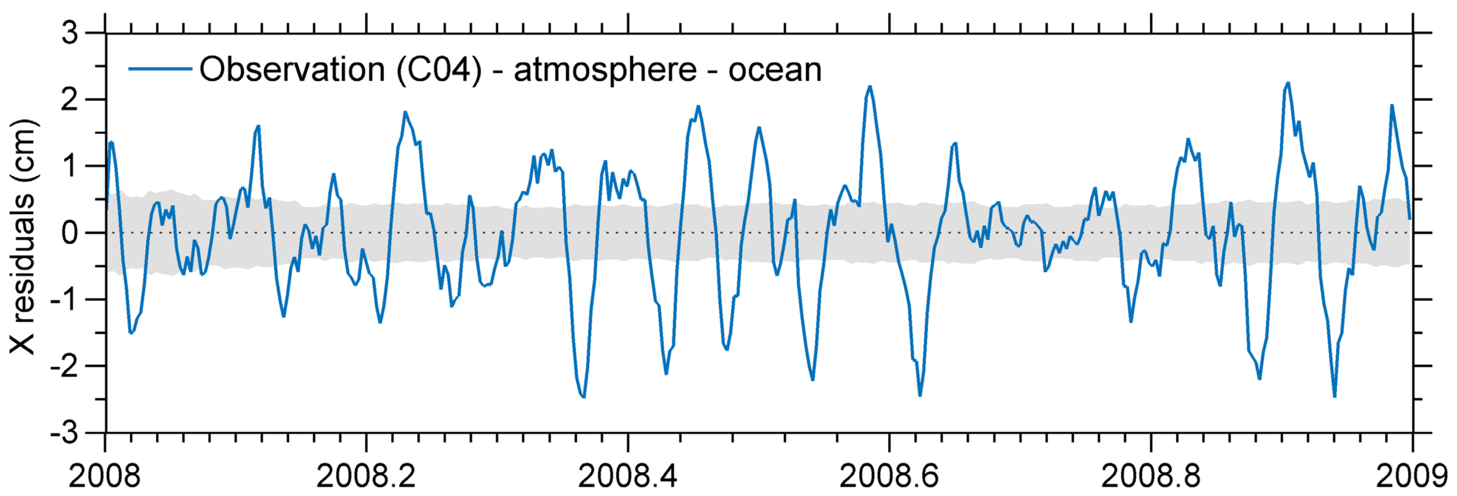

Fig. 1: Polar motion x residuals (cm), obtained by subtracting atmosphere and ocean contributions from the IERS C04 series (high-pass at 30 days). The grey stripe indicates the 3σ level represented by the C04 formal errors.

Models (all global)

- AOD1B RL06 ocean model (Dobslaw et al. 2017), 1° horizontal resolution
- Model energy mostly controlled by turbulent eddy viscosities

MPIOM

- 1/2° shallow-water model with inline treatment of self-attraction and loading (SAL) effects
- Parameterized internal wave drag to dissipate the correct amount of energy

DEBOT

- LLC270 configuration (~1/3° grid, polar cap)
- Eddy-permitting, 50 vertical layers
- Model start uses a pickup file at 1/1/2007 from an ocean state estimate (ECCO version 5)

MITgcm

Bonin, J., and Save, H. (2020), Ocean Sci., 16, 423–434, doi: 10.5194/os-16-423-2020.

Dobslaw H., et al. (2017), *Geophys. J. Int.*, 211, 263–269, doi: 10.1093/gji/ggx302.

Kvas A., et al. (2019), *J. Geophys. Res. Solid Earth*, 124, 9332–9344, doi: 10.1029/2019JB017415.

References

Comparison to GRACE

We use daily ITSG-Grace2018 solutions (Kvas et al. 2019) based on Kalman smoothing with appropriate corrections (e.g., degree 1). Dynamic bottom pressure fields from all models are expanded into spherical harmonics up to degree 40 and discretized on a 1° grid for the comparison (**Figure 2**).

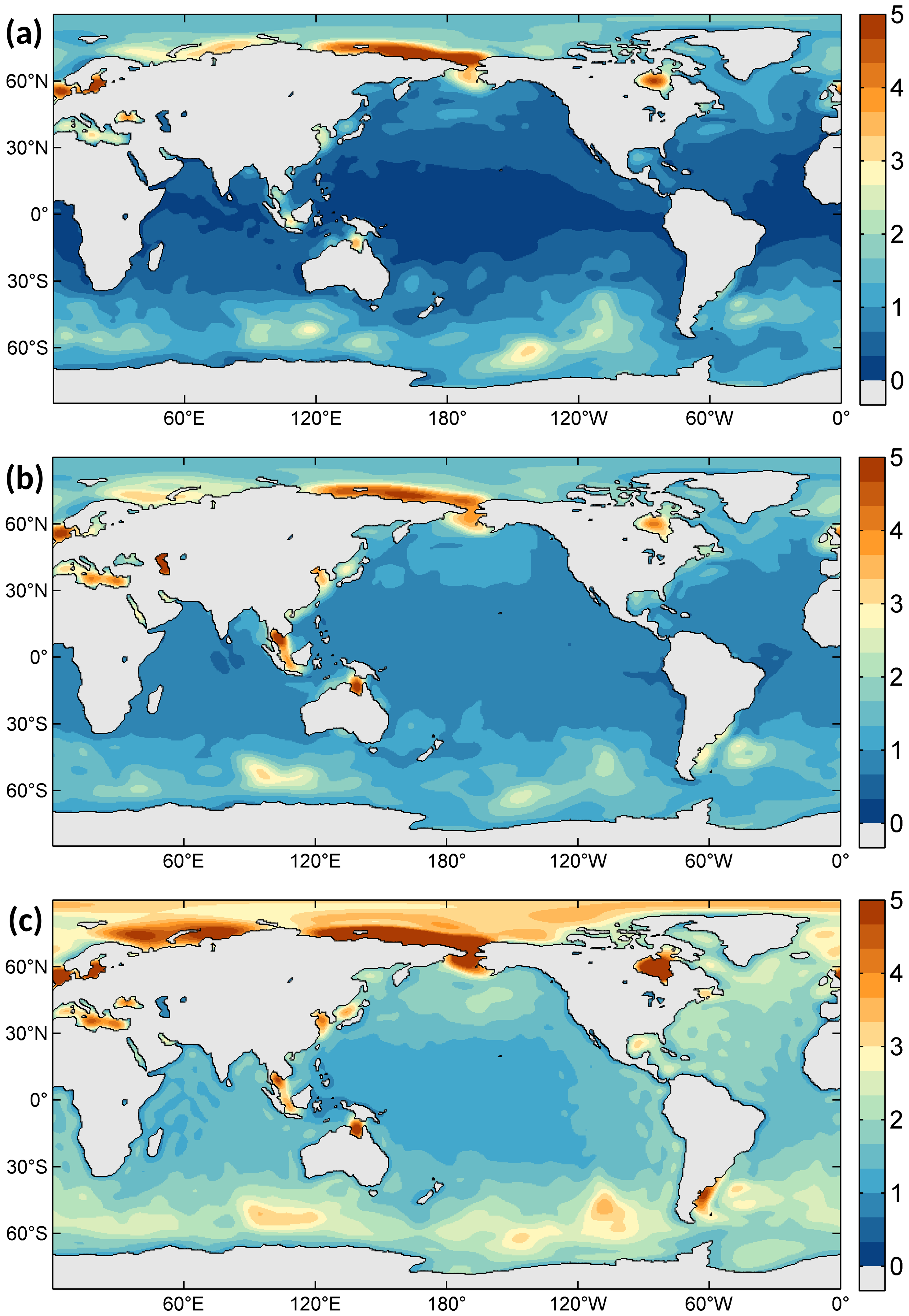

Fig. 2: RMS differences in dynamic bottom pressure (cm) between daily GRACE fields and **(a)** MPIOM, **(b)** DEBOT, **(c)** MITgcm on LLC270 for periods $T \leq 60$ days.

Validation against observed polar motion

	MPIOM	DEBOT	MITgcm
x excitation residual, RMS	15.8	**10.9**	16.7
y excitation residual, RMS	21.6	**14.0**	29.9

Table 1: Comparison to geodetic excitation on time scales of less than 30 days. Values are standard deviations of residuals in (mas) as obtained by subtracting atmospheric excitation (ERA-Interim) and oceanic excitation (three model versions) from IERS C04-based geodetic excitation functions.

Ocean self-attraction and loading

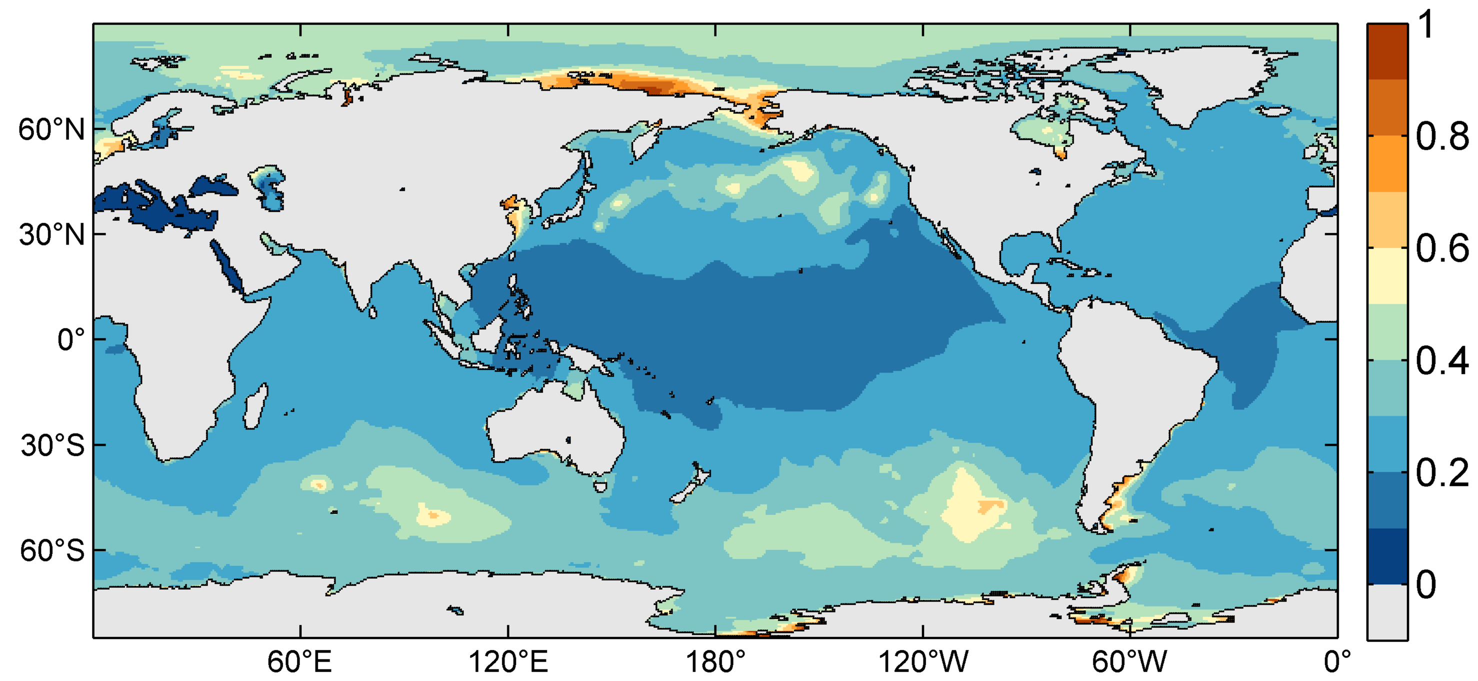

Fig. 3: Standard deviation in dynamic bottom pressure (cm) due to the SAL term (periods $T \leq 60$ days). Results were obtained from two DEBOT simulations with and without the SAL term.

Findings & Outlook

- The comparison with GRACE is not conclusive yet. Both MPIOM and DEBOT show relatively small bottom pressure residuals (**Figure 2**) but DEBOT outperforms MPIOM in terms of polar motion (**Table 1** and **Figure 4**)
- Oceanic SAL effects on sub-monthly time scales (**Figure 3**) may be important for de-aliasing considerations but have little impact on geophysical excitation functions
- Inclusion of pressure loading in the MITgcm presently degrades the model's performance

Next up:

- Address problems with atmospheric pressure forcing in the MITgcm simulations
- Add the widely used Mog2D model to the comparison
- Validation against alternative daily GRACE solutions (CSR "Swath" series, Bonin and Save 2020)

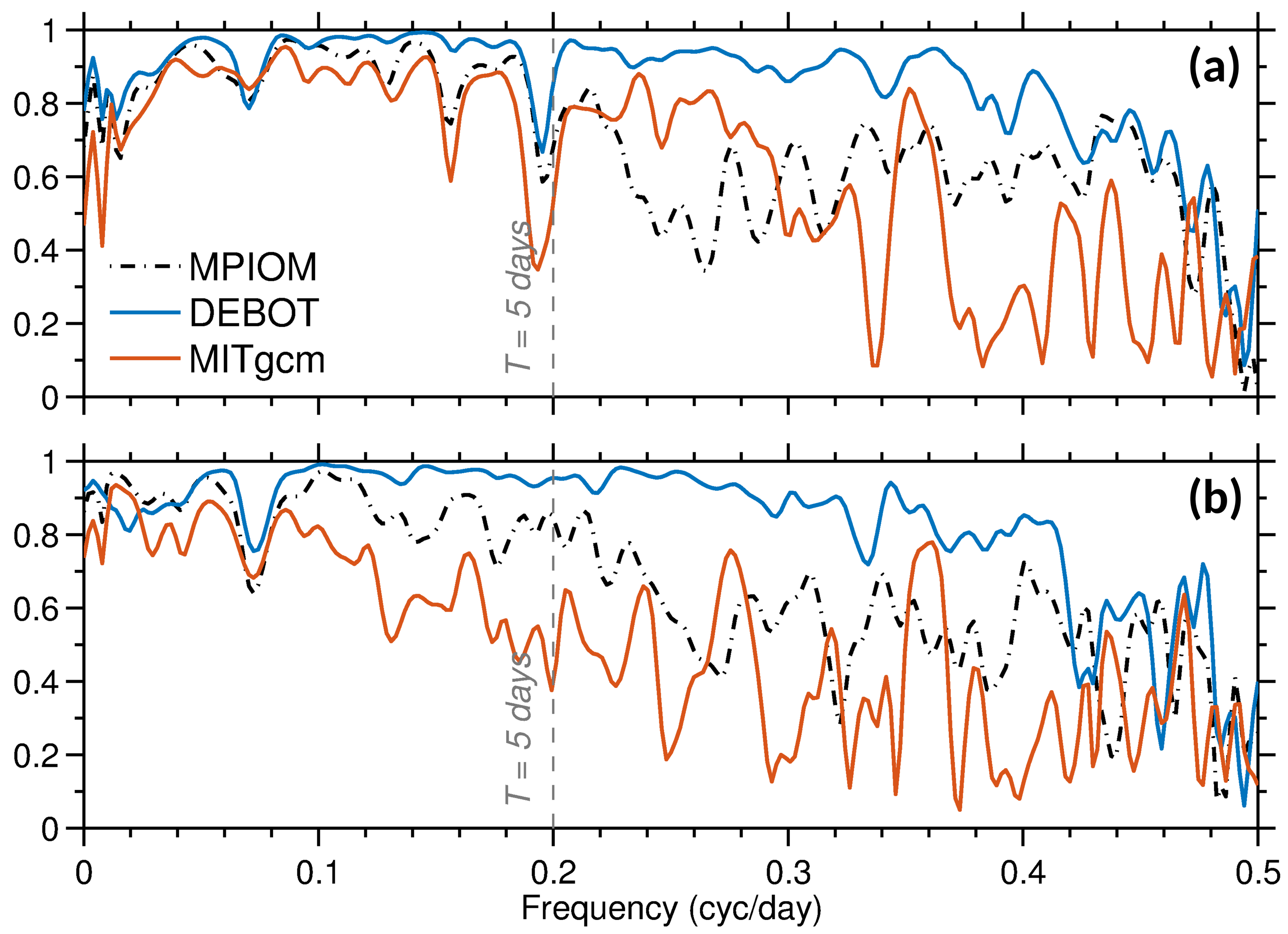

Fig. 4: Coherence spectra between geodetic and geophysical excitation in **(a)** x and **(b)** y direction. Each oceanic excitation function was superimposed on the same atmospheric series from ERA-Interim.

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