Comments by Referee #2:

(Responses by the authors are highlighted in blue)

Börger et al. used the outputs of 50 ensemble OGCM simulations, driven by the same atmospheric data from the DRAKKAR forcing set (DFS 5.2) with slightly perturbed initial conditions. Then, the authors computed monthly OAM, separating the three output variables, p_b, and into the common signals to all 50 members and those uncommon signals (eq. 3). Based on those common and uncommon signals, the authors computed a series of OAM data and showed some interesting results. In particular, Figure 2c shows an intriguing peak in the "forced" signal (L169-170), which is clearly not annual but rather broad and significant; the same peak can also be found in Figure 3c; I have never seen such a peak that is unexpected and deserves to be analyzed in more detail. This broad spectral peak between periods of ~1.2 and ~2.5 years, apparent particularly in the mass term (Figure 2c in the main text) is indeed interesting. It is not a peculiarity of the OCCIPUT OAM data, as analyzed here, but a common feature across many ocean models; see **Figure S2**. We are currently writing up results of another study that attributes parts of this interannual OAM signals to specific patterns of ocean mass change. However, this is clearly another paper and does not fit the scope of the present work.

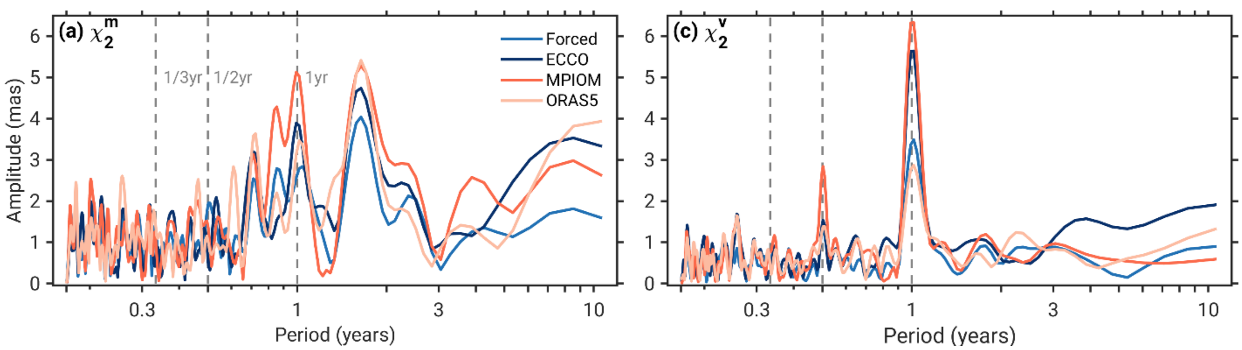

Figure S2: Smoothed amplitude spectra of the χ_2 component of oceanic polar motion excitation (mas), separated into (a) mass and (b) motion terms. Shown are versions from four different models, comprising the OCCIPUT (forced component only), a modern ocean state estimate (ECCOv4 release 4b), MPIOM by GeoForschungZentrum Potsdam (i.e., the series most frequently used in Earth rotation studies), and ORAS5 (as analyzed by Börger et al. 2023).

The goal of this paper is to "separate the ensemble OAM estimates into forced and intrinsic components and assess their contribution to the observed wobble excitation" (L44-45). However, I wonder if the goal can be accomplished from the presented approach. While the authors consider the common signals as "forced" and the uncommon signals as "intrinsic" (or "chaotic" in places), I do not agree with the authors' understanding (or their terminology). I understand that the truly "intrinsic" signals should also be included in the "forced" ones and that the uncommon signals after the ensemble simulations are simply due to different initial and boundary conditions, indicating simply the uncertainties of the OGCM simulations, whereas it is important to quantify the uncertainties. Thus, instead of agreeing with a statement in Line 279 "*variability in χ^o,i is a considerable fraction (43–50%, see Sect. 3.1) of the total oceanic excitation of polar* *motion even on interannual time scales*", I have rather understood that the simulation outputs have considerable uncertainties. I would suggest changing the scope of this work and focusing more on the analysis of the derived interesting "forced" OAM signals.

In relation to the reviewer's main point, we wish to clarify the following:

- **We separate forced and intrinsic variabilities from an ensemble simulation with perturbed initial conditions and same atmospheric forcing, which is a standard and very robust modelling approach in geosciences**. Besides a huge number of atmosphere and climate studies (see, e.g., Nikiéma & Laprise 2016 and Maher et al. 2020, respectively, and references therein), many oceanographic papers have adopted this approach using various models at different resolutions over several regions (e.g., Combes and di Lorenzo 2007, Hirschi et al. 2013, Gehlen et al. 2020, Uchida et al. 2021, Leroux et al. 2022, Benincasa et al. 2024), as well as the 19 OCCIPUT papers published since 2014 (https://meom-group.github.io/projects/occiput/) including those cited in our manuscript.
- The 50 OCCIPUT ensemble members are identical in terms of the underlying model, parameterizations, boundary conditions, and atmospheric forcing. All members share the same uncertainties in these components and whatever impact they may have on OAM: **The ensemble spread does not come from model errors. Instead, it comes from inherently non-linear ocean dynamics**. The spread is triggered by a weak stochastic perturbation that is temporarily applied to the density equation following a common spin-up (cf. lines 110–113, Section 4.2 in Bessières et al. 2017). Growth and saturation of the spread occurs quickly in turbulent, eddy-rich areas (Penduff et al. 2014, Bessières et al. 2017) and more slowly in less unstable regions, as predicted by instability theory. Please check out Figure 2 in Penduff et al. (2014) for a compelling illustration of this concept, and the role of mesoscale instabilities in the origin of the ensemble spread.

The substantial and large-scale inter-member differences that are here diagnosed from the saturated ensemble spread are thus only due to the non-linearly induced random phase of intrinsic variability within each member, whose dispersion is triggered by initial perturbations. This standard approach in estimating forced and intrinsic variabilities in the ocean and other components of the climate system is robust and has led to many results in the literature. The work presented here specifically highlights the impact of non-linear ocean dynamics on a globally-integrated quantity relevant to geodesy and solid Earth research.

The problem might be because the authors used "eddy-permitting" model instead of "eddy-resolving" model. If the latter "eddy-resolving" model was used, it would have much finer spatial resolution and allows to more accurately compute the fine-scale ocean dynamics; the "atmospheric-driven" component should also more accurately include the intrinsic chaotic ocean variability. The authors might be recognizing this point in view of the sentence in Lines 279-280, "*A caveat to be acknowledged…*".

Some authors have indeed suggested that fine horizontal resolution may be beneficial for modeling wind-driven OAM changes on intraseasonal time-scales (Afroosa et al. 2021, Harker et al. 2021, Afroosa et al. 2022); see also line 286. However, these benefits are not as clear-cut as your remark implies, and we do not know of any study that has looked into this question on interannual time scales.

More importantly, and for the purpose of the present work, the use of an eddy-permitting (here 1/4°) model instead of an eddy-resolving (e.g., 1/12°) model is not a major limitation: 1/4° and 1/12° ocean model simulations have been shown to be consistent regarding the existence, origin, spatial structure, and spatio-temporal scales of intrinsic variability (Sérazin et al. 2015, Gregorio et al. 2015). The magnitude of intrinsic variability is a bit higher in the 1/12° simulations for certain variables, but only barely so on interannual time scales (see Figure 9 in Sérazin et al. 2015 for the case of sea level). For other variables however, interannual intrinsic variability amplitudes at 1/4° and 1/12° are barely distinguishable (see Figure 7 in Gregorio et al. 2015 for the case of AMOC). Hence, the OCCIPUT large ensemble at eddy-permitting resolution is a good choice for venturing a first look into the effects of oceanic chaos on OAM. Also note that performing the 1/4° OCCIPUT ensemble required 20 million CPU hours: performing the same exercise at 1/12° resolution would cost about 3^3 times more (i.e., about 600 million CPU hours), which lies far beyond the computing power presently available to research teams.

Minor comments:

Line 56: There are still large uncertainties in Qc, and the value 179 is rather high.
Qc = 179 is a standard choice that has been used countless times before. We have rerun our excitation budget analysis with much lower values (e.g., Qc = 50, as advocated for by Yamaguchi and Furuya, 2024) and found negligible impacts on the results: PVE values given Table 2 changed by 0.0 to 0.1%, and by 0.3% in only one case.

Line 248: Is there any evidence for the effect of the core on interannual wobble excitation? While the present work assumes pure elastic deformation, 1.10 and 1.608 in A1, anelastic deformation will rather need to be considered in longer timescales.
Chen et al. (2019), building on work by Kuang et al. (2019), presented tentative evidence for core effects on interannual wobble excitation, particularly near the 6-year period. One of our arguments is that such inferences can be complicated by errors in the corrections for surficial mass redistributions and particularly intrinsic OAM signals; see lines 255–261.

As for the impact of anelastic deformation on the χ functions, Wahr (2005) showed that this would change the real-valued scaling factors (two-digit version of Eq. A1) from 1.10 and 1.61 to (1.10 – i·0.01) and (1.61 – i·0.02), respectively. These changes amount to ≤ 1.5%, comparable to the uncertainty of other numerical constants and assumptions in the excitation formalism (Gross 2007). It is therefore not unjustified to neglect these small imaginary components, as done here. We will add a brief note on this matter just above Eq. (A2) in the revised manuscript.

References: (asterisk marks papers not cited in the main text)

Afroosa et al. (2022): https://link.springer.com/article/10.1007/s10236-022-01518-8 [*]
Benincasa et al. (2024): https://doi.org/10.5194/os-20-1003-2024 [*]
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Chen et al. (2019): https://doi.org/10.1029/2019JB018541
Combes and di Lorenzo (2007): https://doi.org/10.1016/j.pocean.2007.08.011 [*]
Gehlen et al. (2020): https://doi.org/10.1029/2020GL088304 [*]
Gregorio et al. (2015): https://doi.org/10.1175/JPO-D-14-0163.1 [*]
Gross (2007): https://doi.org/10.1016/B978-044452748-6.00057-2
Hirschi et al. (2013): https://doi.org/10.5194/os-9-805-2013 [*]
Kuang et al. (2019): https://doi.org/10.1016/j.geog.2019.06.003
Leroux et al. (2022): https://doi.org/10.5194/os-18-1619-2022 [*]
Maher et al. (2020): https://doi.org/10.5194/esd-12-401-2021 [*]
Nikiéma & Laprise (2016): https://doi.org/10.1007/s00382-015-2604-3 [*]
Penduff et al. (2014): https://www.researchgate.net/publication/283497595_Ensembles_of_eddying_ocean_simulations_for_climate
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