We appreciate your comments once more. Our responses to your questions are as follows:

(1) Previous evidences from different observation data (e.g., ΔLOD, geomagnetic field, GNSS, and polar motion) have indicated that the SYO in ΔLOD is an almost stable oscillation with attenuation larger than 180. This suggests that the SYO persists throughout the entire LOD observation period from 1962 to the present. Thus one should use the observations for an extended duration, preferably in alignment with the ΔLOD time, to verify the existence of a steady ~5.9-year fluctuation before linking it with the SYO in ΔLOD. Moreover, an unstable oscillation signal should not be considered cognate with the SYO in ΔLOD, even though there exists the oscillation energy around 5.9 years in a relatively short time, as observed in Fig. 3 (some stations seem to have signals of ~4-8 years in the SG time windows). In other word, it is possible to say that the hydrology makes a transient contribution to ΔLOD. This is obviously not true. In addition, if the SYO had been generated by the hydrological effects, it would have been evident in the hydrologic observation data over an extended time and in different regions. However, this assertion is contradicted by the findings of Pfeffer et al. (2022) and Pfreffer & Cazennave et al. (2023). From the wavelet spectra analysis, we think it may be a result of noise interference, or energy leakage from nearby signals.

Additionally, you consider it reasonable that the inaccuracy of the current hydrological models is the reason why the possible SYO peaks in the spectra of the hydrological loading data do not precisely exactly align with the 5.9 years period. However, it must be founded on a precondition that the SYO is actually present in the hydrological models. Actually, this precondition has not yet been confirmed precisely because of the inaccuracy of the hydrological model. Your discussions are obviously illogical.

(2) Regarding the verifications using global gridded precipitation data, climate indices, GMST, and GMSL, you both posed questions similar to that in validation using hydrological models. Specifically, all of these validations should be conducted using smaller time windows as for SGs. It is imperative to reiterate that it is necessary to use observations for extended durations, preferably in alignment with the ΔLOD time, to ascertain the presence of a stable ~5.9-year fluctuation before establishing a correlation between it with the SYO in LOD.

(3) Observing Fig. 4(c) in Rosat & Gillet (2023), an extremely weak 5.9-year signal with an amplitude of ~0.012 ms is present in the wavelet transform coefficient spectrum of the HAM data. Nevertheless, it can be observed that the amplitude is nearly congruent with the background noise level of ΔLOD. As depicted in Fig. 1, the background noise level of ΔLOD after removing the AAM and OAM effects is ~0.01 ms. It also can be seen in Fig. 1d of Ding (2019, EPSL) and Fig. 1b of Ding et al. (2021, JGR). That is to say, despite the presence of a ~5.9-year signal in the hydrology-excited LOD, the associated peak is likely to be buried in the background noise (the SNR is very low). Statistically, the signal is unreliable.

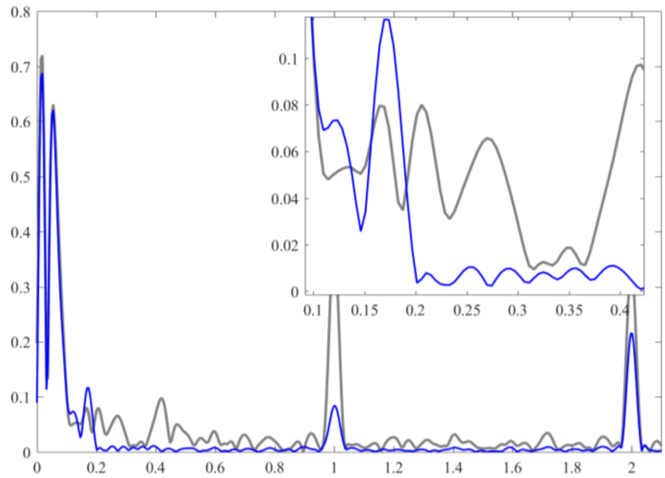

Figure 1. The Fourier amplitude spectra of the original ΔLOD in 1962-2021 (in gray), and the residual (in blue) obtained from the original ΔLOD after removing the AAM and OAM effects.

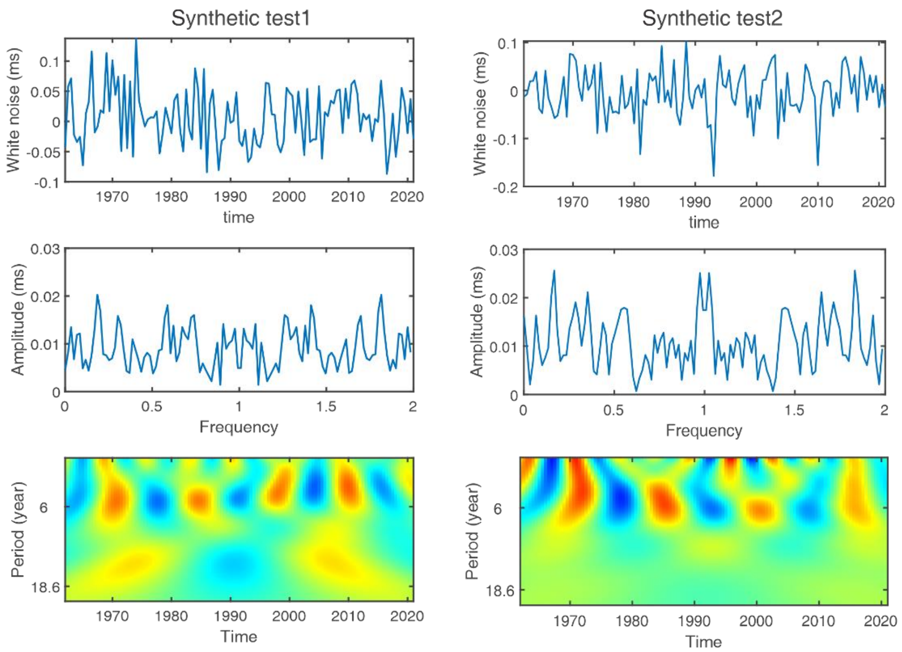

Figure 2. The Fourier amplitude spectra and wavelet spectra of two synthetic white noise time series.

We also carried out a series of synthetic tests. We simulated the random white noises with the mean amplitudes equivalent to the background noise level of ΔLOD in Fig. 1, and subsequently conducted the Fourier and wavelet spectrum analysis on them. Fig. 2 shows two test results for the synthetic white noises. Obviously, the wavelet spectra display clear ~6-year oscillation signals that are definitely fake, while the Fourier amplitude spectra do not manifest any noteworthy signal at all.

Thus, purely from the point of signal analysis, it is reasonable to conclude that the hydrology-excited LOD time series does not contain the SYO signal. To avoid unnecessary misunderstandings, it may be more appropriate to rephrase the statement as follows: The HAM effect made very small contributions to the intradecadal period band in the ΔLOD.

(4) We disagree your claim about the influences of the terrestrial water storage variations on ΔJ_2. The change in the zonal harmonic coefficients ΔJ_2, of the Earth's gravitational field due to the surface-water-induced mass redistribution can be calculated by (Chao et al. 1988):

$$\Delta J_l(t) = -\frac{R^2\rho}{M}(1+k_l')\int [h(\theta,\lambda,t)-\bar{h}(\theta,\lambda)]P_l(\cos\theta)d\Omega \qquad (1)$$

where M is the mass of the Earth, and P_l is the Legendre polynomial of degree l; k_l' are the load Love numbers; ρ =1 g m^{-3}, h is the equivalent depth of liquid water with average $\bar{h}$. The change in ΔLOD due to surface mass redistribution is directly proportional to ΔJ_2, according to

$$\Delta\mathrm{LOD} = \mathrm{LOD}[2MR^2\Delta J_2(t)]/(3C) \qquad (2)$$

where C is the moments of inertia about the Earth's polar.

It can be affirmed that the terrestrial water storage (TWS) variations can result in the C20 variations, which are directly reflected in ΔLOD. Besides, it is worth noting that Chao and Eanes (1995) demonstrated global gravitational changes due to atmospheric mass redistribution, which can also manifest in the C20 variations. Therefore, if an SYO in the TWS variations is observed, it must appear in ΔJ_2, and further will be reflected in ΔLOD. However, in our last reply, it has been determined that there is no observable SYO signal present within ΔJ_2. Given the stable SYO signal present in ΔLOD, the only explanation is that the SYO signal in ΔLOD does not have any correlation with the TWS variations.

In addition, we have carefully read the relevant results in Meyssignac et al. (2013). You claimed that "The hydrological content at interannual time-scales is mostly related to degree-2 order-2 geographical pattern". This is definitely incorrect. Meyssignac et al. (2013) have clearly indicated that "*Variations in land water storage (hereafter LWS) also play a role in S2,2 variations (see Figure 1c). But both hydrological models agree to show that the LWS contribution to S2,2 interannual variations is rather small*", "*As a result, C2,2 variations estimated from SLR tracking data and the combination of ocean mass and LWS contributions are quite different. Nevertheless, we note that both estimations agree on showing small C2,2 variations*", and "*But unlike the ocean mass contribution, they show an important role of LWS on C2,0 variations over the whole record*." They showed that the hydrological content at interannual time scales is mostly related to degree-2 order-0 geographical pattern. This is the exact opposite of what you said.

Besides, you claimed that "Only a certain distribution of terrestrial water storage variations would result in ΔJ_2." It has no basis at all. According to Chao et al. (2020), "*J_2 is the (normalized) zonal quadrupole of the Earth's density.*" "*The zonal [degree-2, order-0] component of any mass redistribution will contribute to the time variation ΔJ_2. Besides the seasonal water cycle in the surface geophysical fluids (atmosphere + hydrosphere + cryosphere), a host of geophysical processes cause mass redistribution on/in the Earth ranging from tides to atmosphere-ocean circulations, to denudation of glaciers/ice sheets and sea level rise, and to internal phenomena like earthquakes, glacial isostatic adjustment (GIA), and core flows.*"

(5) The revised manuscript will present the results of implementing AR-z into some better hydrological models like ERA5_land.

(6) As demonstrated in our last reply, both current global hydrological models and global precipitation data do not indicate the presence of a stable and consecutive ~5.9-year oscillation. To verify the local contribution of hydrological mass changes, we can only use the in-suit groundwater level data from a few SG stations to to illustrate it. Fig. 3 shows the Fourier amplitude spectra of six groundwater level records, indicating no ~5.9-year signal exists. To get the accurate local contribution of hydrological mass changes, more extensive global in-suit hydrological observations (including precipitation and

soil moisture) should be joint for comprehensive verification in the future.

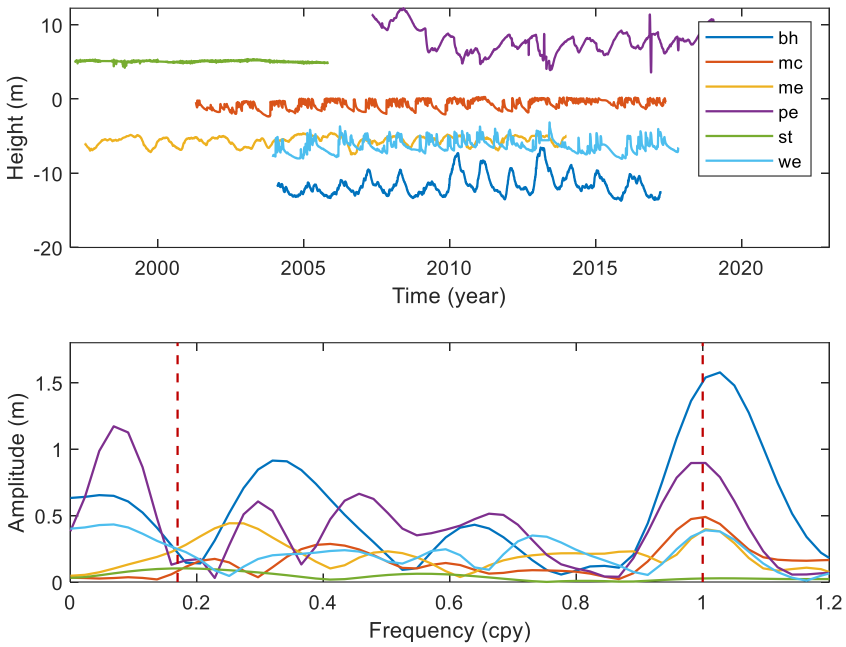

Figure 3. The Fourier amplitude spectra of six groundwater level records.

(7) Indeed, as you said, the pre-processing process, especially the repair of gaps and steps, is the main challenge to detect long-period signals using SG data. Manual corrections using Tsoft will lead to significant differences of the Fourier spectra results due to operational differences. So it is not surprising that you observed the 4-yr, 5-yr, or 7-yr periodic signals in different SG residual series. To address this unavoidable problem, we have conducted a very careful pre-processing work (see Fig.1 in the manuscript) and analyzed the errors of step corrections (see our Supplement).

You found the SYO clearly for Strasbourg and Metsahovi with a nice anti-correlation with the hydrological loading. In fact, thus good negative correlations were also observed by us. However, it is not sufficient to prove that there is an anti-phase SYO in hydrology corresponding to that in the SG residuals. Because we have verified that there are irregular fluctuations at ~4-8 years in the hydrological model data, which makes the time series appear to be inversely approximate to the long-period fluctuations in the SG residuals.

In addition, we can only obtain the SG data with lengths about 3-4 cycles of the SYO period, which are enough to describe the SYO information. Any unreasonable step correction (very different from the actual situation) will cause a significant deviation of the SYO spectral peak in the Fourier spectrum.

References

Chao, B. F. and O'Connor, W. P.: Global surface-water-induced seasonal variations in the Earth's rotation and gravitational field, Geophysical Journal, 94, 263-270, 1988.

Chao, B. F. and Eanes, R.: Global gravitational changes due to atmospheric mass redistribution as observed by the Lageos nodal residual, Geophys. J. Int., 122,755-764, 1995.

Chao, B. F., Yu, Y., & Chung, C. H.: Variation of Earth's oblateness J2 on interannual-to-decadal timescales. J. Geophys. Res.: Solid Earth, 125, e2020JB019421, https://doi.org/10.1029/2020JB019421, 2020.

Ding, H.: Attenuation and excitation of the ~6-year oscillation in the length-of-day variation, Earth 363 Planet. Sci. Lett., 507, 131-139, https://doi.org/10.1016/j.epsl.2018.12.003, 2019.

Ding, H., An, Y., and Shen, W.: New evidence for the fluctuation characteristics of intradecadal 365 periodic signals in length-of-day variation, J. Geophys. Res. Solid Earth, 126, e2020JB020990, 366 https://doi.org/10.1029/2020JB020990, 2021

Meyssignac, B., Lemoine, J. M., Cheng, M., Cazenave, A., Gégout, P. and Maisongrande, P.: Interannual variations in degree-2 Earth's gravity coefficients C2,0, C2,2, and S2,2 reveal large-scale mass transfers of climatic origin, Geophys. Res. Lett., 40, 4060-4065, https://doi.org/10.1002/grl.50772, 2013.

Rosat, S. , and Gillet, N.: Intradecadal variations in length of day: Coherence with models of the Earth's core dynamics, Phys. Earth Planet. Inter., 41, 107053, 2023.