Reply to the queries and comments of Dr. Paul Pukite

We very much appreciate Dr. Pukite's comments to our manuscript. In our reply below, we reproduce *the Dr. Pukite's comments in blue italics*, while our replies are in a standard font.

Decades ago Richard Lindzen came to the conclusion that the quasi-biennial oscillation (QBO) could not be caused by tidal forcing, despite it's obvious potential as a driving mechanism. Negative results are often difficult to find in the literature, but Lindzen mentioned this in two passages:

- ***"For oscillations of tidal periods the nature of the forcing is clear"** - Lindzen, Richard D. "Planetary waves on beta-planes." Monthly Weather Review 95.7 (1967): 441-451.*
- ***" .. it is unlikely that lunar periods could be produced by anything other than the lunar tidal potential"** - Lindzen, Richard S., and Siu-shung Hong. "Effects of mean winds and horizontal temperature gradients on solar and lunar semidiurnal tides in the atmosphere." Journal of the atmospheric sciences 31.5 (1974): 1421-1446.*

At this point of QBO historical data there were only 6 to 8 complete cycles to draw from, yet Lindzen apparently missed the possibility of nonlinear aliasing the lunar cycle against the annual cycle. The only candidate due to QBO wavenumber=0 group symmetry arguments is the 27.2122 day nodal (aka draconic) lunar cycle, which generates a (365.242/27.212) mod 1 = 2.37 year physically aliased repeat period. This matches the historical record, continuing decades later from these early Lindzen studies, see Ref [1].

From EGUSPHERE-2024-3270, this passage needs clarification:

- *"It is clear over this record that the QBO differs somewhat from cycle to cycle (e.g. Quiroz, 1981) and there have been efforts to try to see if the cycle-to-cycle variations may systematically depend on such factors as solar activity, volcanic eruptions or the El Niño/Southern Oscillation (ENSO) cycle of the tropical troposphere (Dunkerton, 1983;*

  Geller et al., 1997; Salby and Callahan, 2000; Hamilton, 2002, Kane, 2004; Taguchi, 2010). "

By "solar activity", one can't imply that is related to sunspot activity, as that is minor compared to the annual or seasonal solar cycle. In fact, the annual solar cycle figures into the same nodal symmetry group as the Semi-Annual Oscillation (SAO) which exists directly above the QBO in altitude. The topological similarity in the nodal driving force behind both the SAO and QBO (the former solar nodal, and the latter solar+lunar nodal) is described in detail in Ref [1].

References

[1] Pukite, P., Coyne, D. and Challou, D. (2018). Wind Energy. In Mathematical Geoenergy (John Wiley & Sons). https://doi.org/10.1002/9781119434351.ch11

We appreciate the interest of Dr. Paul Pukite in our paper.
His points seem to be (a) the QBO might be significantly forced by the lunar gravitational effects in the atmosphere, and (b) that the effects of the 11-year solar activity variation on the atmosphere (which we mention in passing as a topic that has been studied by earlier authors as a possible source of inter-cycle variability in the QBO) are less important than the annual cycle of solar heating, and that this point needs clarification in our manuscript.

With respect to (a), note that we are not addressing this issue in our paper which focuses on the effects of ENSO on the QBO.

With respect to (b) note that the interest of this paper is in the cycle-to-cycle variability of the QBO and so the relevant concern is the interannual variability of solar input into the atmosphere, which is what we refer to as "solar variability". Again, this issue only arises in our background discussion, mentioned as a subject that has been addressed in earlier papers.