



EGUsphere, author comment AC1
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Reply on CC1, regarding tides other than M2

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Author comment on "Technical note: On seasonal variability of the M₂ tide" by Richard D. Ray, EGU sphere, <https://doi.org/10.5194/egusphere-2022-252-AC1>, 2022

As Haidong Pan notes, there are many tidal constituents in addition to (the usually dominant) M₂ that could be examined for seasonal variability. For lunar tides like O₁ and N₂, any analysis of seasonality should begin by checking for the presence of nearby spectral lines, in the manner laid out in my Note for M₂. In each case there are small astronomical constituents within the relevant tidal group, as well as compound tides and climate-driven lines at frequencies 1 or 2 cpy away from the central constituent. One simply needs to take care not to overlook an important contributor, such as a compound tide (of which there are many possible).

The solar tides, as Haidong Pan points out, are more problematic. For S₂ there is semiannual modulation from K₂, but also annual modulation from T₂ and R₂. Harmonic analysis is probably not recommended in this case, but some rough results can be obtained by a response analysis (e.g., Cartwright, 1968). With a response analysis, the gravitational parts of K₂, T₂, and R₂ can be approximately determined from estimates of the mean S₂ tide. Any residual modulations seen in S₂ can then presumably be attributed to seasonal climate variability. But this is only a "rough" approach, because it overlooks the radiational forcing of S₂, caused by loading by the S₂ atmospheric tide, which itself has significant seasonal variability. The radiational forcing of the S₂ ocean tide has been studied by Arbic (2005) and others. In the end, even with a response analysis, we may isolate a seasonal S₂ signal, but it may not be clear whether it is originating in the ocean (e.g., from seasonal stratification) or in the atmosphere (from air tides).

The diurnal K₁ is just as difficult, if not more so. Again a response analysis may be used to determine the gravitational parts of the neighboring constituents P₁ and psi₁. But the S₁ constituent, 1 cpy from K₁, is almost wholly radiational, with significant temporal variability. In monthly estimates of K₁, modulations from S₁ would be difficult to untangle from other seasonal changes.

For these reasons, analysis of lunar tides is more straightforward. Understanding their seasonality can still be difficult and even the spectral approach requires care. For example, O₁ seasonality was briefly examined at station Lusi (China) in the course of a review of coastal tides (Ray et al., 2011). Small semiannual variations in O₁ (of order 1%) will be induced by the linear constituent tau₁, 2 cpy away, but monthly estimates of O₁ at Lusi revealed significantly larger variations than that. Unfortunately, in our 2011 discussion, we overlooked the possible presence of the compound tide MP₁ (which coincides with tau₁). Because both M₂ and P₁ are large along the China coastline, the compound MP₁ is almost certainly responsible for most of the semiannual oscillation seen in monthly estimates of O₁ at Lusi. Nonetheless, there is still a significant annual variation

in O1, which is probably induced by climatic changes in ocean stratification, in the same manner as seen for M2 in that region (Kang et al., 2002).

Finally, seasonality of the compound KO2 could indeed mimic seasonality in M2. Presumably, in general, the effect is very small, but it is potentially at work in shallow-water regions with large diurnal tides and small M2.

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