EGUsphere, author comment AC1
https://doi.org/10.5194/egusphere-2022-252-AC1, 2022

Reply on CC1, regarding tides other than M2

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Author comment on "Technical note: On seasonal variability of the M_2 tide" by Richard D. Ray, EGUsphere, 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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