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Global influences of the 18.61 year lunar nodal cycle and 8.85 year cycle of lunar perigee on coastal flooding

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When extreme sea level events occur along low-lying, highly populated and/or developed coastlines the impacts can be devastating, including: considerable loss of life; billions of dollars worth of damage; and drastic changes to coastal landforms. As a society, we have become increasingly vulnerable to extreme high sea levels due to the rapid growth in coastal populations and the accompanied increased investment in infrastructure at the coastal zone. The occurrence of major coastal floods in the last decade (i.e. those arising from hurricanes Katrina, Sidr and Nargis), have dramatically emphasized the damage that extreme sea level events are capable of, particularly when combined with the rise in coastal population.

Extreme sea levels (exclusive of surface gravity waves) arise as a combination of three factors: mean sea level, tide and surge. Extreme sea levels are most often viewed in the context of storm surges, but the impacts of storm events in many coastal areas are strongly modulated by the tide. Over inter-annual time-scales, variations in high tides arise as a result of the 18.61 year lunar nodal cycle and the 8.85 year cycle of lunar perigee, the latter of which influences sea level as a quasi-4.4 year cycle. A global assessment of when these tidal modulations occur allows for prediction of periods when enhanced risk of coastal flooding/inundation is likely in different coastal regions.

The aim of this study is to determine the influence of the 18.61 year lunar nodal cycle and 8.85 year cycle of lunar perigee on coastal flooding on a global scale. Tidal constituents from the TPXO7.2 global tidal model are used, with satellite modulation corrections based on equilibrium expectations, to predict multi-decadal hourly tidal time series. From these long time-series, the amplitude and phase of the two inter-annual tidal cycles and their sub-harmonics are calculated for different high tidal levels, using harmonic analysis fitted to 18.61, 9.305, 8.85, and 4.425 year sinusoidal signals. The results are compared to the "GESLA" (Global Extreme Sea Level Analysis) quasi-global tide gauge dataset, which comprises of 675 sea level records from around the world.

The locations where the inter-annual tidal modulations most influence extreme sea levels are identified and the spatial variations in the range and phase of the two cycles are related to the global distribution of the main tidal constituents and tidal characteristics (diurnal/semi-diurnal and tidal range). Results show that the nodal cycle is largest (between 0.4 and 0.8 m) in diurnal regions with tidal ranges > 4 m and the 4.4 year cycle is largest (between 0.3 and 0.6 m) in semi-diurnal regions where the tidal range is > 6 m. In areas where the form factor of the tide is $>\sim 0.6$, the nodal cycle dominates high tidal levels and the phase of the nodal cycle correlates with maximum lunar declination. In these regions the nodal cycle last peaked in 2006 and will peak again in 2024. In regions where the form factor of the tides is $<\sim 0.6$, the phase of the nodal cycle correlates with minimum lunar declination. In these areas, the nodal cycle last peaked in 1997 and will peak again in 2015. The 4.4 year cycle dominates high tidal levels in regions with tides with form factors $<\sim 0.6$. The phase of the 4.4 year cycle also relates to the form of the tide.