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A clock for the Sun's magnetic Hale cycle and 27 day recurrences in the aa geomagnetic index

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We construct a new solar cycle phase clock which maps each of the last 18 solar cycles onto a single normalized epoch for the approximately 22 year Hale (magnetic polarity) cycle, using the Hilbert transform of daily sunspot numbers (SSN) since 1818. We use the clock to study solar and geomagnetic climatology as seen in datasets available over multiple solar cycles. The occurrence of solar maxima on the clock shows almost no Hale cycle dependence, confirming that the clock is synchronized with polarity reversals. The odd cycle minima lead the even cycle minima by ~ 1.1 normalized years, whereas the odd cycle terminators (when sunspot bands from opposite hemispheres have moved to the equator and coincide, thus terminating the cycle, McIntosh(2019)) lag the even cycle terminators by ~ 2.3 normalized years. The average interval between each minimum and terminator is thus relatively extended for odd cycles and shortened for even ones. We re-engineer the R27 index that was orignally proposed by Sargent(1985) to parameterize 27 day recurrences in the aa index. We perform an epoch analysis of autocovariance in the aa index using the Hale cycle clock to obtain a high time resolution parameter for 27 day recurrence, <acv(27)>. This reveals that the transition to recurrence, that is, to an ordered solar wind dominated by high speed streams, is fast, occurring within 2-3 solar rotations or less. It resolves an extended late declining phase which is approximately twice as long on even Schwabe cycles as odd ones. We find that Galactic Cosmic Ray flux rises in step with <acv(27)> but then stays high. Our analysis also identifies a slow timescale trend in SSN that simply tracks the Gleissberg cycle. We find that this trend is in phase with the slow timescale trend in the modulus of sunspot latitudes, and in antiphase with that of the R27 index.