Random Long-Term Solar Cycles?

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April 2019

The Paper

Solar activity: intrinsic periodicities beyond 11 years?

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Astronomy & Astrophysics March 14, 2019
https://arxiv.org/pdf/1903.05398.pdf

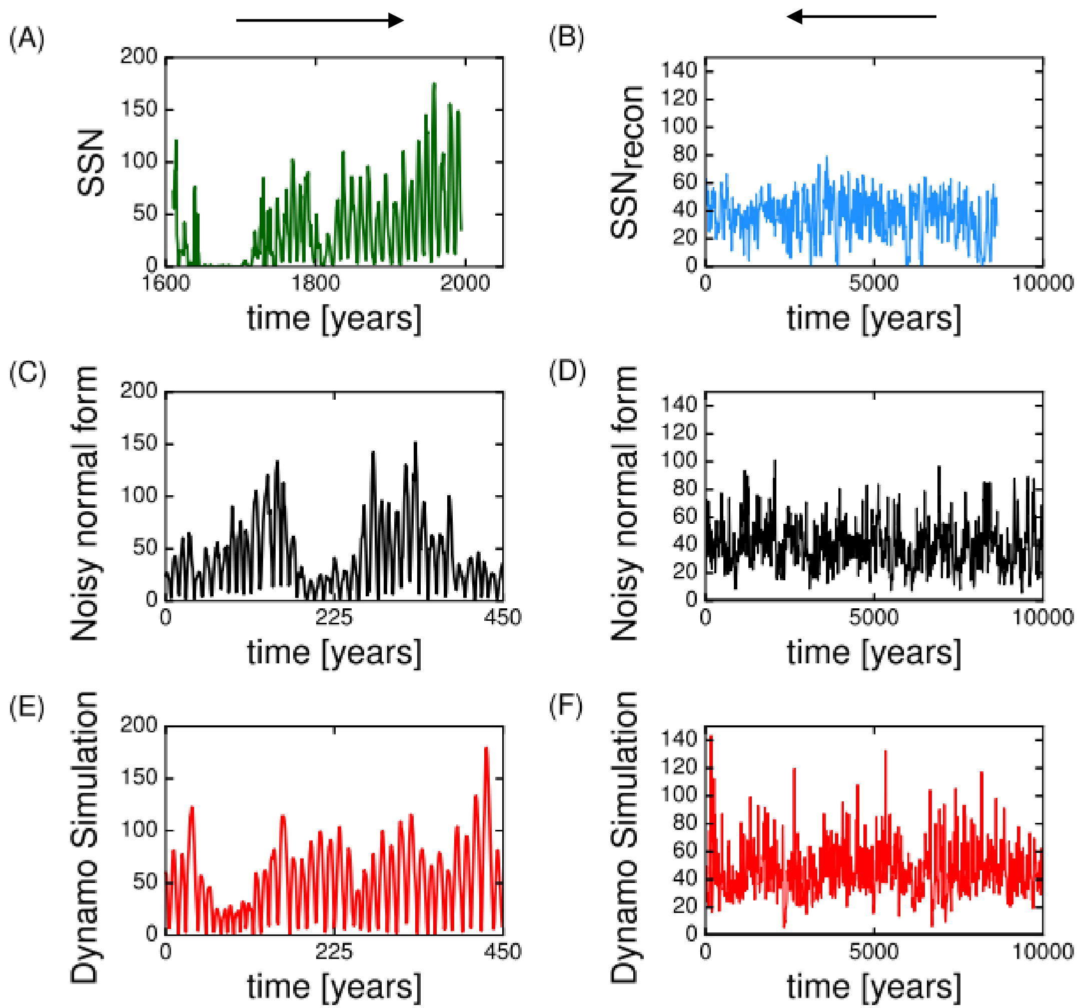
Power spectra of solar activity based on historical records of sunspot numbers and on cosmogenic isotopes show peaks with enhanced power apart from the dominant 11-year solar cycle, such as the 90-year Gleissberg cycle or the 210-year de Vries cycle. In a previous paper we have shown that the overall shape of the power spectrum is well represented by the results of the generic normal form model for a noisy and weakly nonlinear limit cycle, with parameters all determined by observations. Using this model as a null case, we show here that all local peaks with enhanced power, apart from the 11-year band, are consistent with realization noise. Even a 3σ peak is expected to occur with a probability of about 0.25 at least once among the 216 period bins resolved by the cosmogenic isotope data. **This casts doubt upon interpretations of such peaks in terms of intrinsic periodicities of the solar dynamo process**.

The Dynamo Process

Systematic properties of sunspot groups indicate that they originate from a reservoir of organized East-West orientated (toroidal) field in the solar convection zone. This field is generated by winding up a poloidal field (such as a dipole field aligned with the rotation axis) by the differential rotation of the Sun. The poloidal field is (re) generated against the effect of Ohmic decay by the collective effect of loops formed from the toroidal field by convective flows and/or magnetic buoyancy. The loops become twisted owing to the Coriolis force and thus acquire a systematic meridional component. This interplay of toroidal and poloidal magnetic field leads to a 22-year magnetic cycle and an 11-year cycle of sunspot activity.

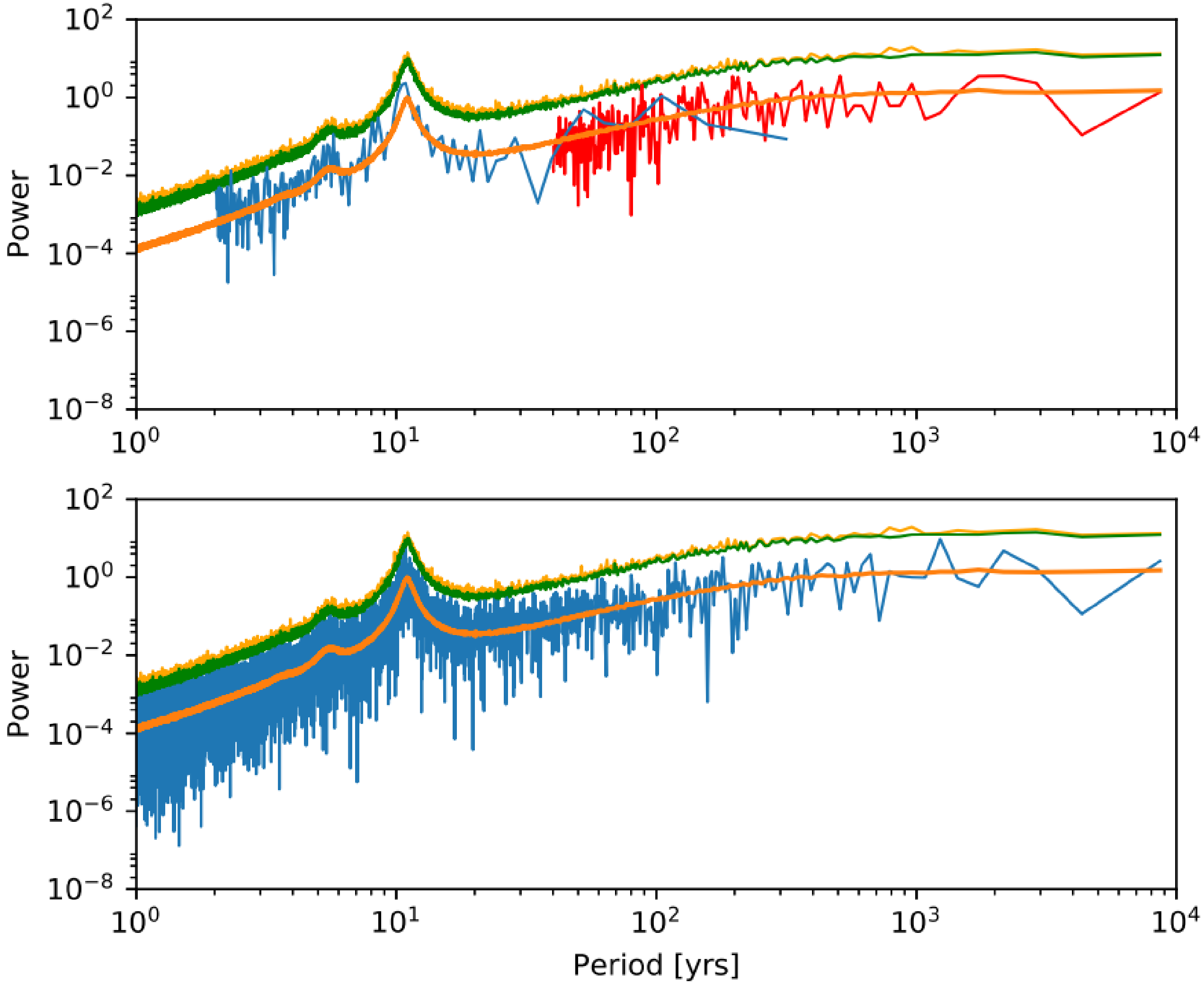
The polar fields result from the emergence of bipolar magnetic regions (sunspot groups) with a systematic average tilt relative to the solar EastWest direction together with the subsequent transport of their magnetic flux across the surface by differential rotation, supergranulation, and meridional flow. Consequently, **any scatter in the properties of the bipolar regions (e.g., emergence latitude, tilt angle) or in the flux-transport process introduces a corresponding scatter in the resulting poloidal dipole field, and therefore in the amplitude of the subsequent cycle**.

The Data and the Model



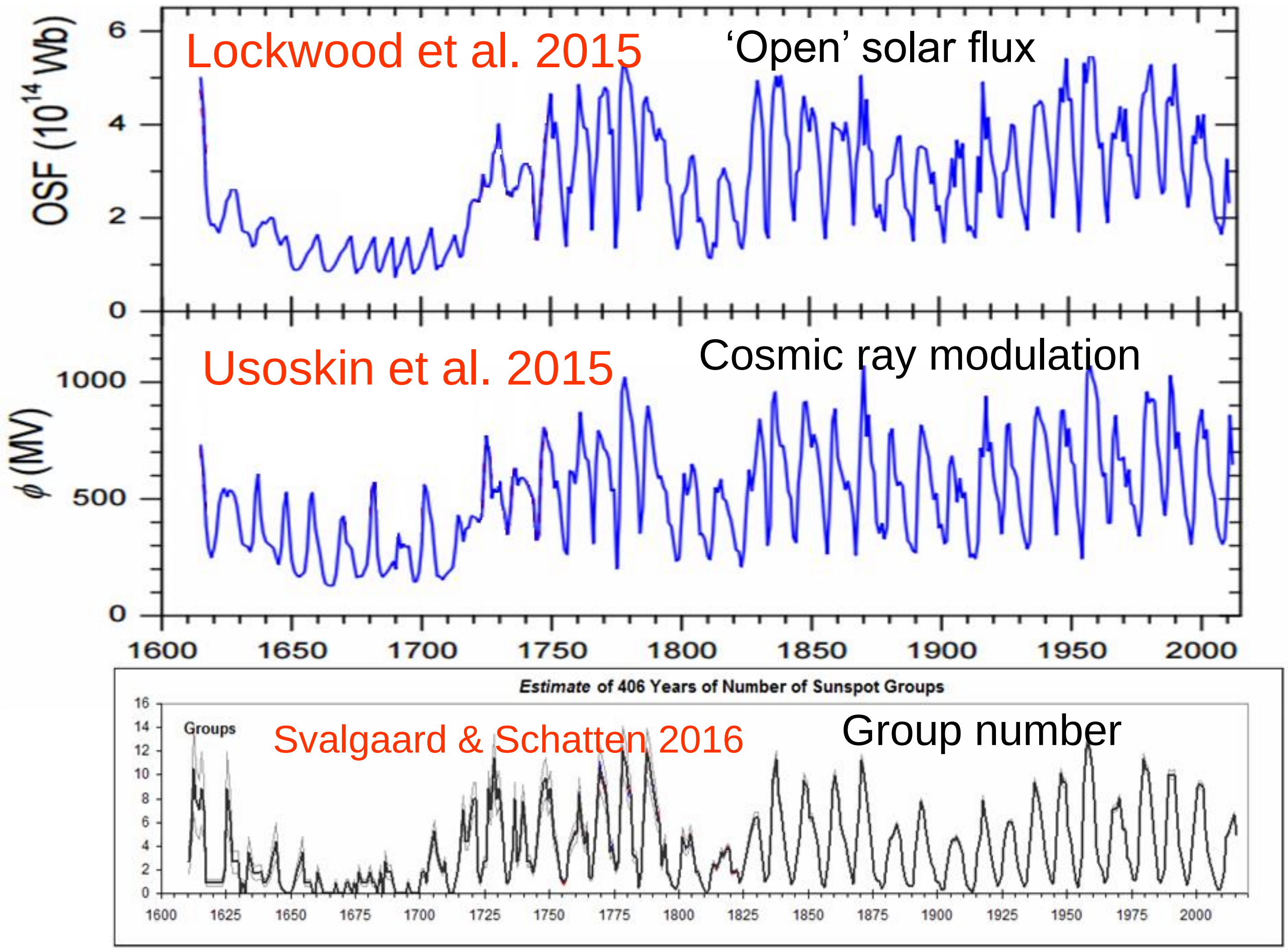
Time series of observed and simulated sunspot numbers (SSN). A: yearly group sunspot numbers (Hoyt & Schatten 1998) obtained from observations between 1610 and 1995. B: sunspot numbers reconstructed from cosmogenic isotopes (Usoskin et al. 2016) with 10-year resolution dating back to 9000 yr BP. C and D: results for time intervals of comparable lengths taken from Monte-Carlo simulations of a weakly nonlinear, noisy limit cycle (normal-form model) with parameters determined from observations. E and F: results obtained using a Babcock–Leighton-type dynamo model with fluctuating sources (Cameron & Schüssler 2017).

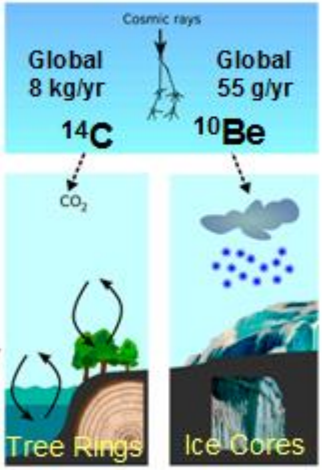
The Power Spectra



Observed and modelled power spectra of solar activity. Upper panel: Spectra based on the historical record of sunspot numbers (blue curve) and on the reconstruction from cosmogenic isotope data (Usoskin et al. 2016, red curve). Lower panel: Spectrum obtained from one realization of the **noisy normal form** model (Cameron & Schüssler 2017b, blue curve). In both panels, the orange curve gives the median from 1000 realizations of the model, the green curve shows the corresponding 99.865% (3σ) upper percentile, and the yellow curve represents the maximum of the 1000 realizations.

Revised Solar Activity Records



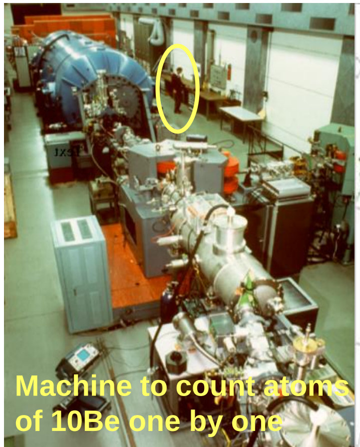


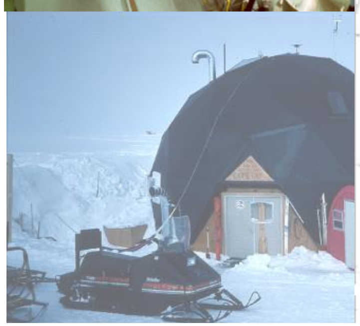
Very good agreement between different reconstructions.

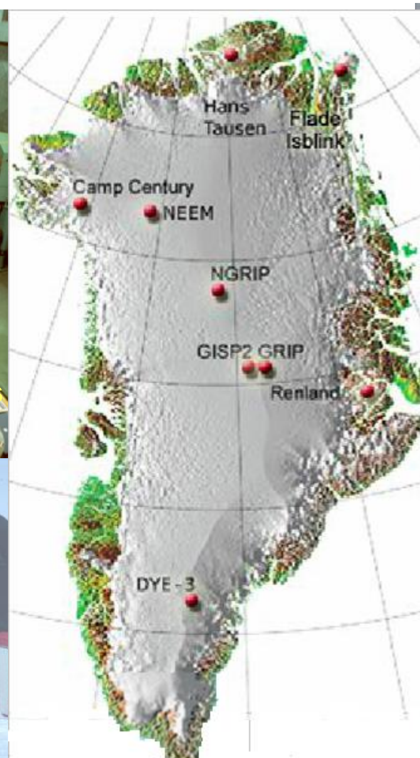
Full Disclosure: There is still a rear-guard debate about the early record

Drilling for Ice Cores

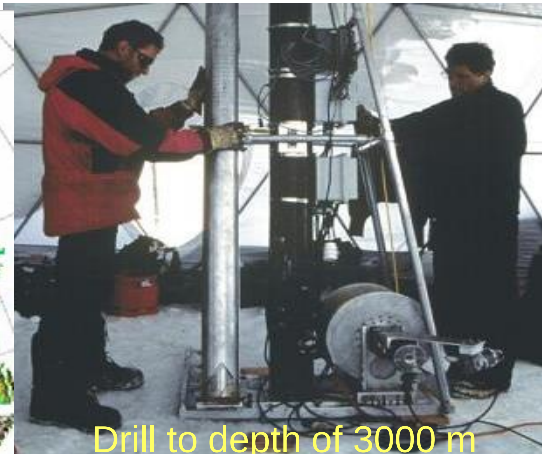
To measure the 10Be concentration and thus the Cosmic Rays thousands of years back in time

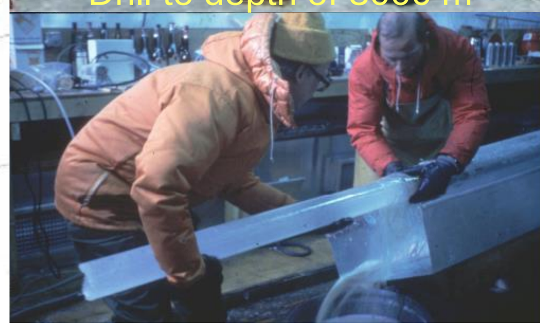


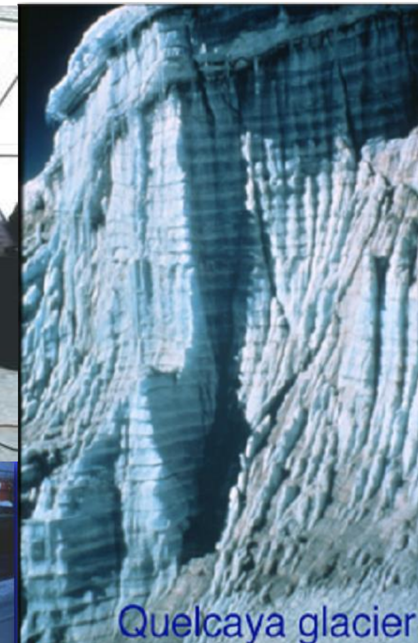




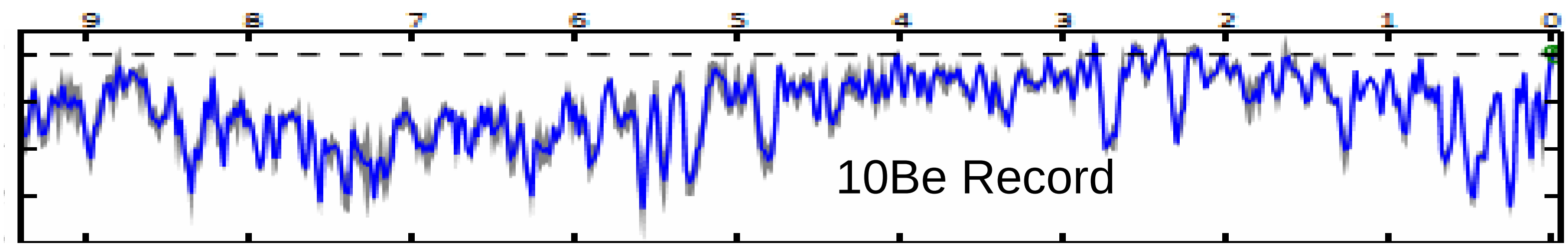
Greenland





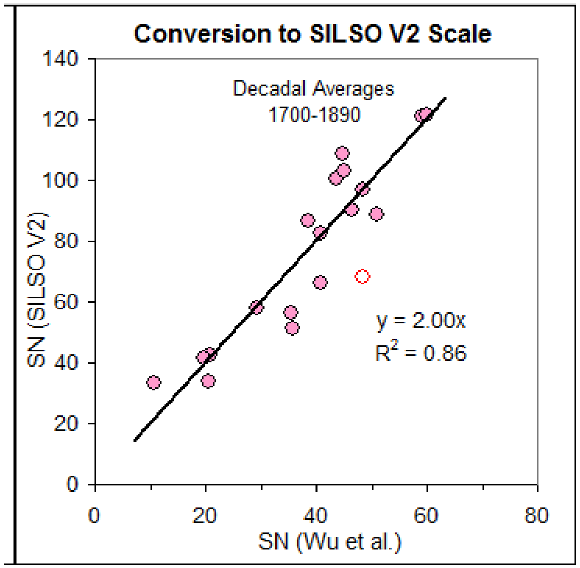


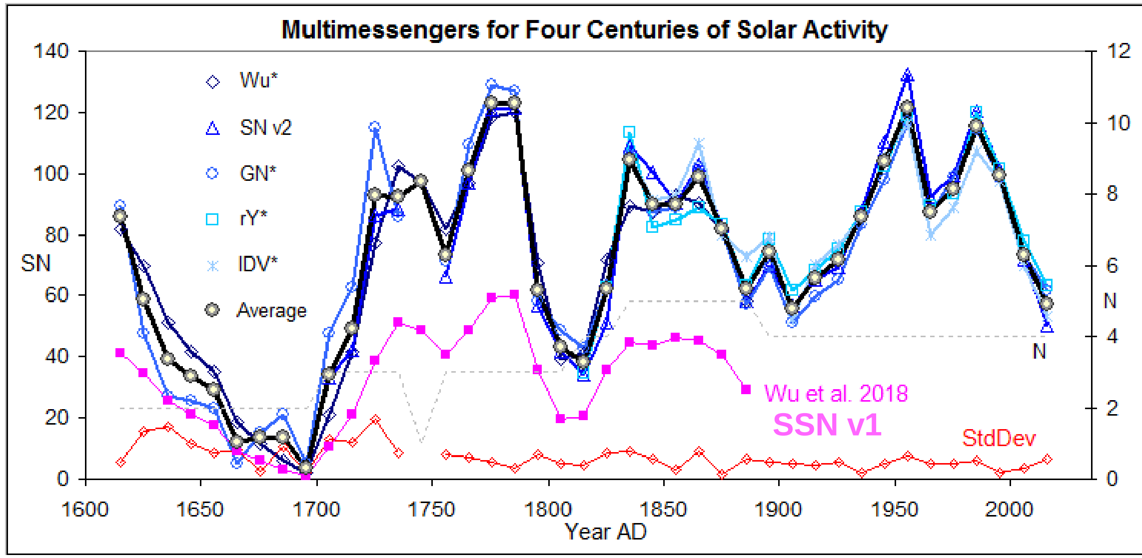
Annual Layers
in the Ice

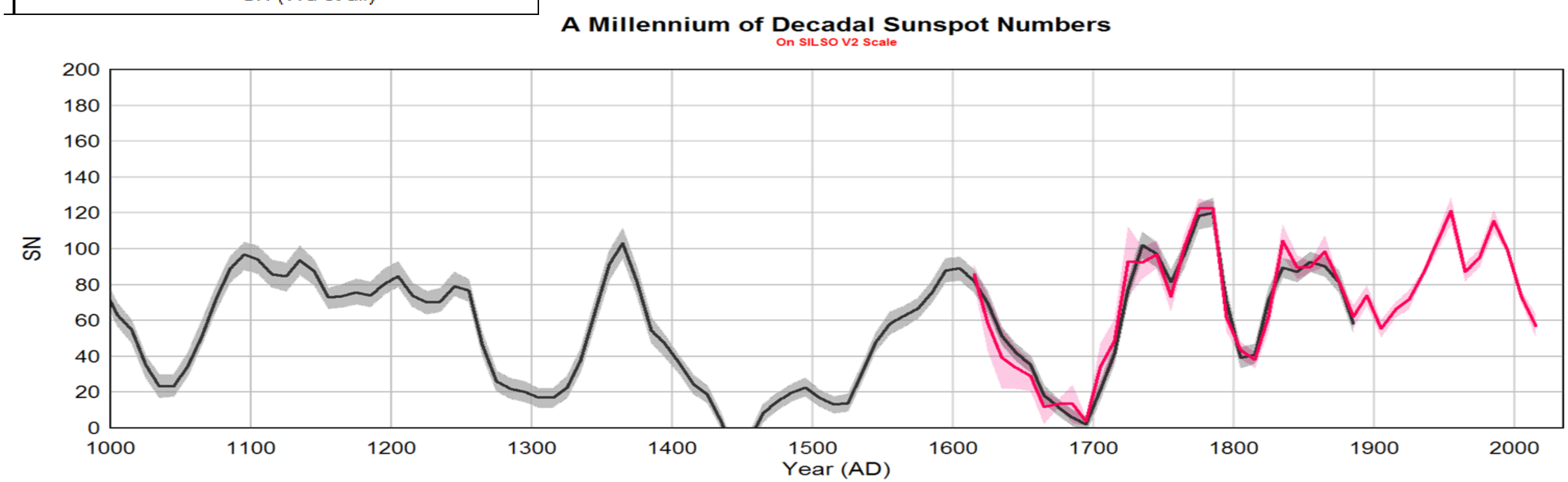


A Millennium of Solar Activity

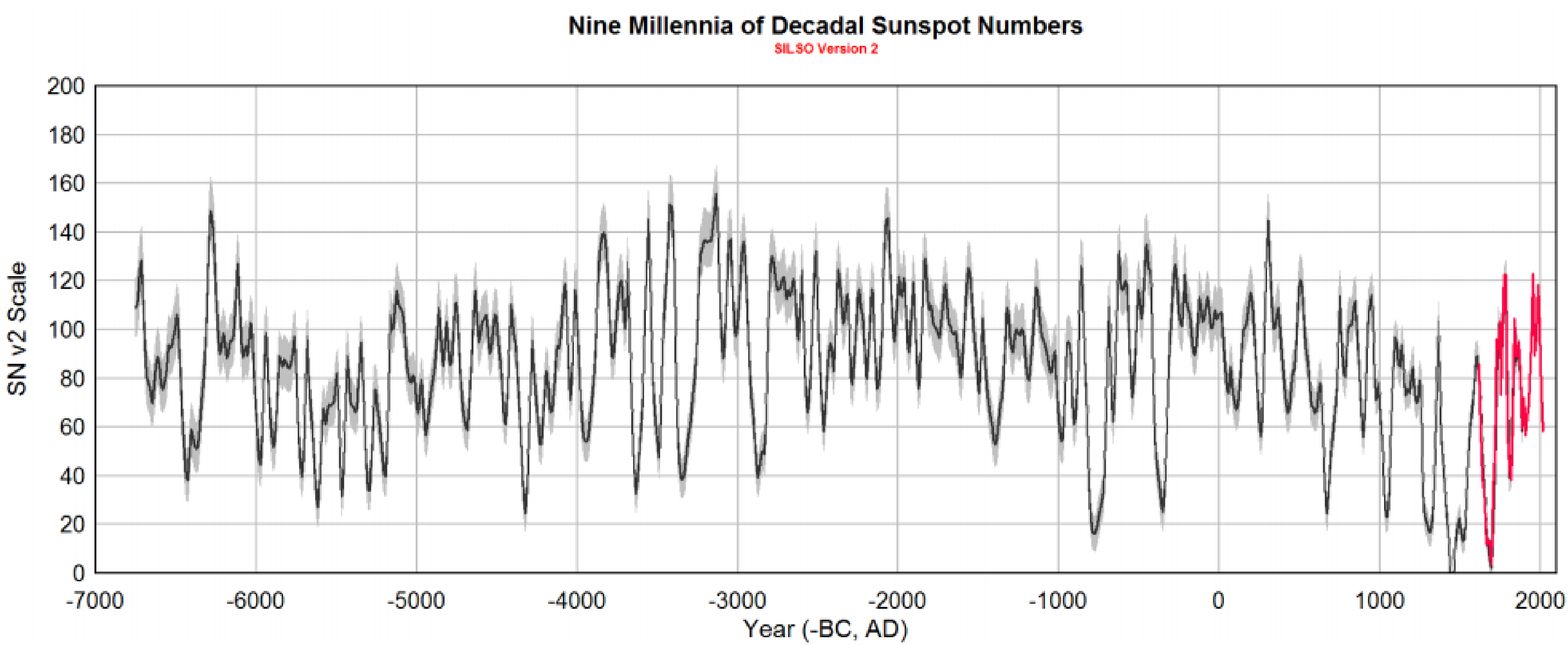
Wu et al. A&A **615**, A93 (2018)



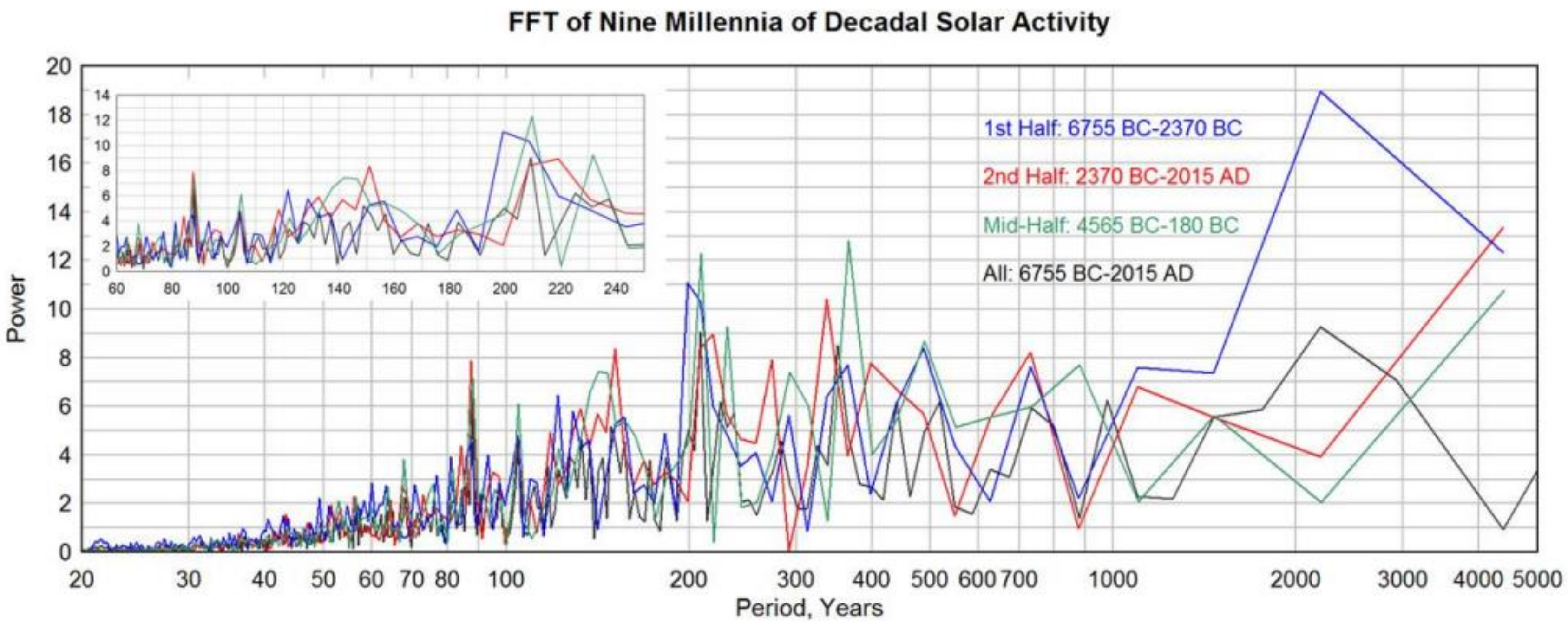




The Full Composite Wu et al. Dataset (From ^{14}C and ^{10}Be)

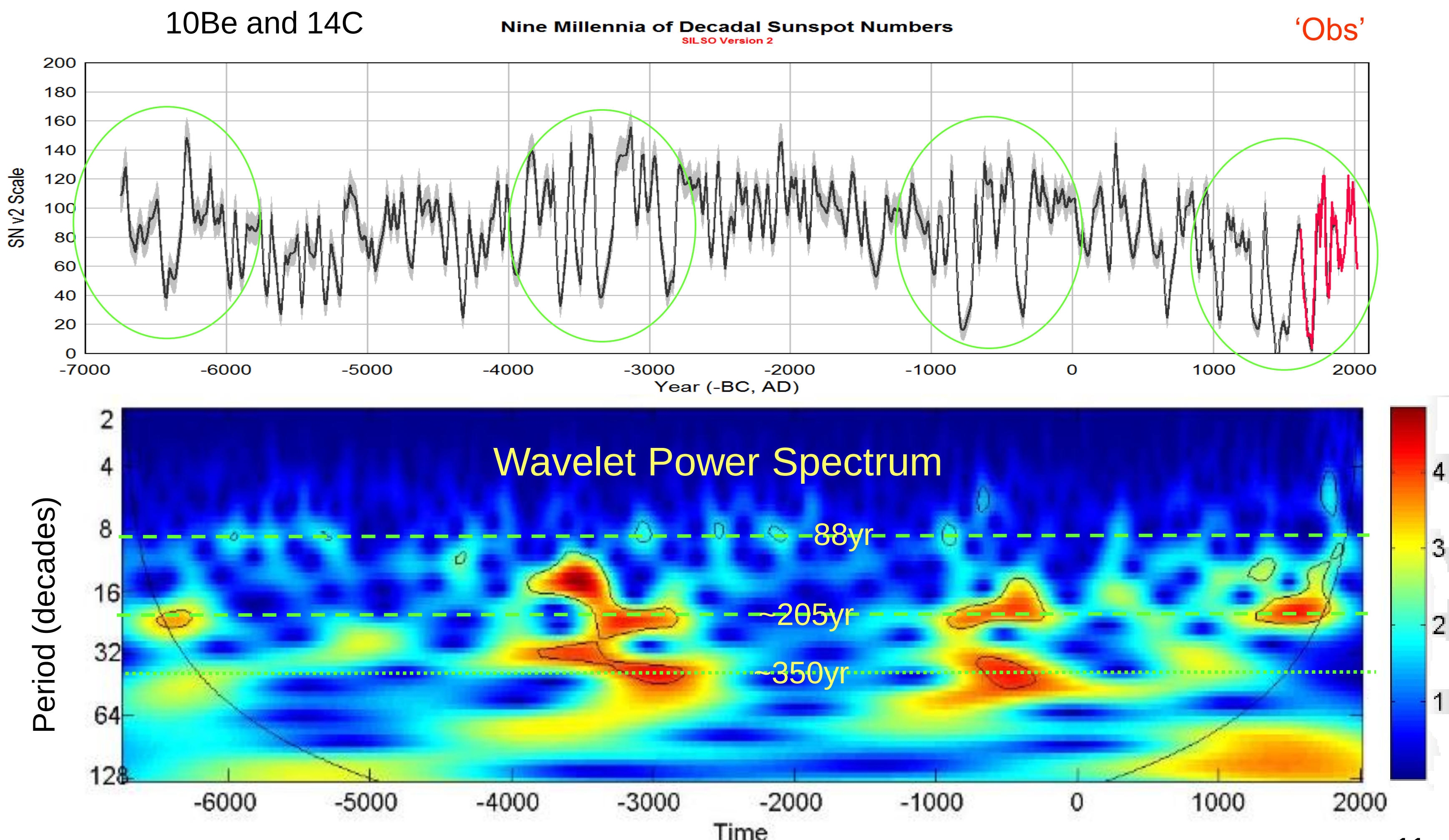


Nine millennia of reconstructed decadal sunspot numbers on the SILSO V2 scale. The WEA reconstruction is shown by the black curve with the stated uncertainty indicated by gray shading. The average Multimessenger reconstruction for 1615-2015 AD is shown by the red curve. The combined time series from 6755 BC to 2015 AD is available as an Excel file at https://leif.org/research/Nine-Millennia-SN.xls.



Fast Fourier Transform of the combined nine-millennia decadal sunspot number and of three subsets: first half, last half, and middle half. The insert shows the interval from 60 to 250 years in more detail. Three long-term cycles are often assumed to exist: the ~2300-year Hallstatt (or Bray) Cycle, the 208-year de Vries (or Suess) Cycle, and the 88-year Gleissberg Cycle. The Figure shows that the Hallstatt Cycle (found in climate records) is not significant in the solar record. There does seem to be power at periods between 200 and 240 years, but the power is perhaps too broadly distributed to qualify as a strong periodicity. With lots of peaks between 250 and 1200 years it is no surprise that some of them just coincide around 350 years. On the other hand, the 87.6-year Gleissberg peak is sharp and prevalent in the whole series and in all three sub-intervals, although being absent in recent data.

Nine Millennia of Solar Activity



Non-stationary and intermittent 'periodicities' [if any]

Conclusion

- Variation of the amplitude of solar cycles can be mimicked by suitably varying random data
- It thus seems possible (likely?) that the 11-year Schwabe Cycle is the only real cycle; all the other (putative) ones due to intermittent stochastic variation of the properties of the cycle