“Floors” in IMF, EUV, and therefore in TSI (?)

Leif Svalgaard

Recent work [1] suggests that the Interplanetary Magnetic Field (IMF) strength, *B*, at each sunspot minimum varies but little (less than a nT). This is clearly seen in Figure 1. The variation of *B* within a solar cycle seems to be due to extra (and likely closed [2]) magnetic flux added by Coronal Mass Ejections (CMEs) riding on top of a “floor” of somewhere between 4 and 5 nT, leading to the conclusion that the open magnetic flux is nearly constant with time, and that, in particular, there is no secular variation of the open flux. Geomagnetic data back to the 1840s [3] further support this conclusion. In fact, *B* for the current cycle 23 matches well *B* for cycle 13, 107 years earlier.

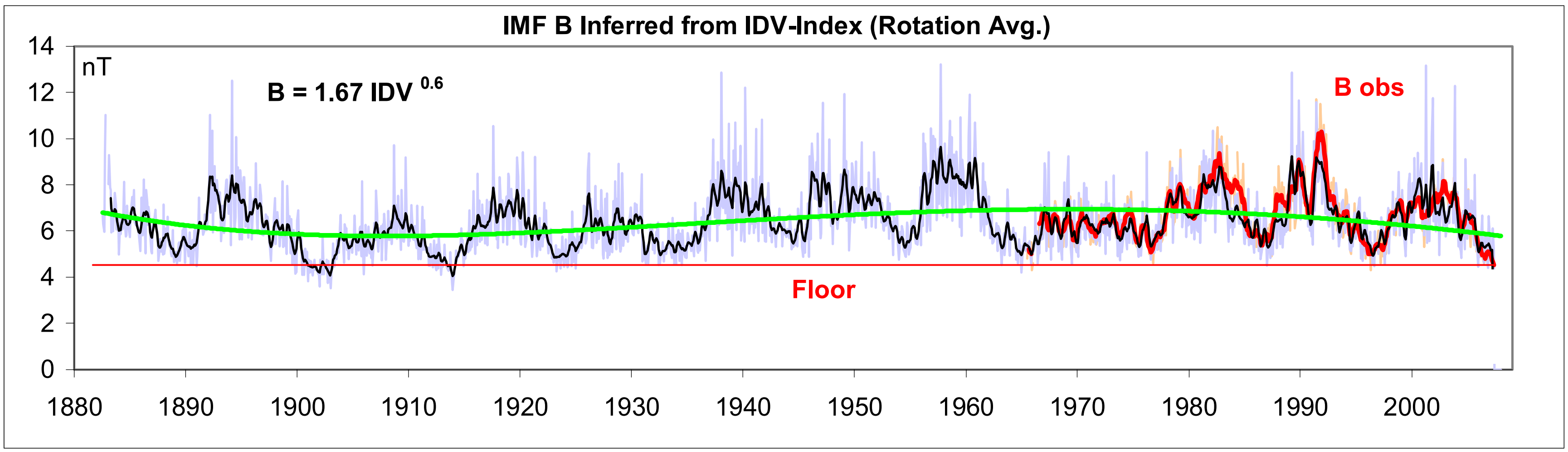

Figure 1. Near-Earth IMF *B* inferred from the *IDV*-index [4] (13-rotation average black curve) and observed by spacecraft (red curve). The green curve is a 4th-order polynomial fit showing the long-term trend of solar cycle averages.

I have earlier in these pages [5] pointed out that the amplitude of the diurnal variation of the geomagnetic *Y*-component is an excellent proxy for the *F10.7* radio flux and thus also for the EUV flux (more precisely, the FUV, as the *Sq* current flows in the E layer). Figure

2 shows a trend in the amplitude of 10% since the 1840s that can be understood as being due to an increase of ionospheric conductance resulting from the 10% decrease of the Earth's main field. Correcting for this effect yields the red curve in Figure 2.

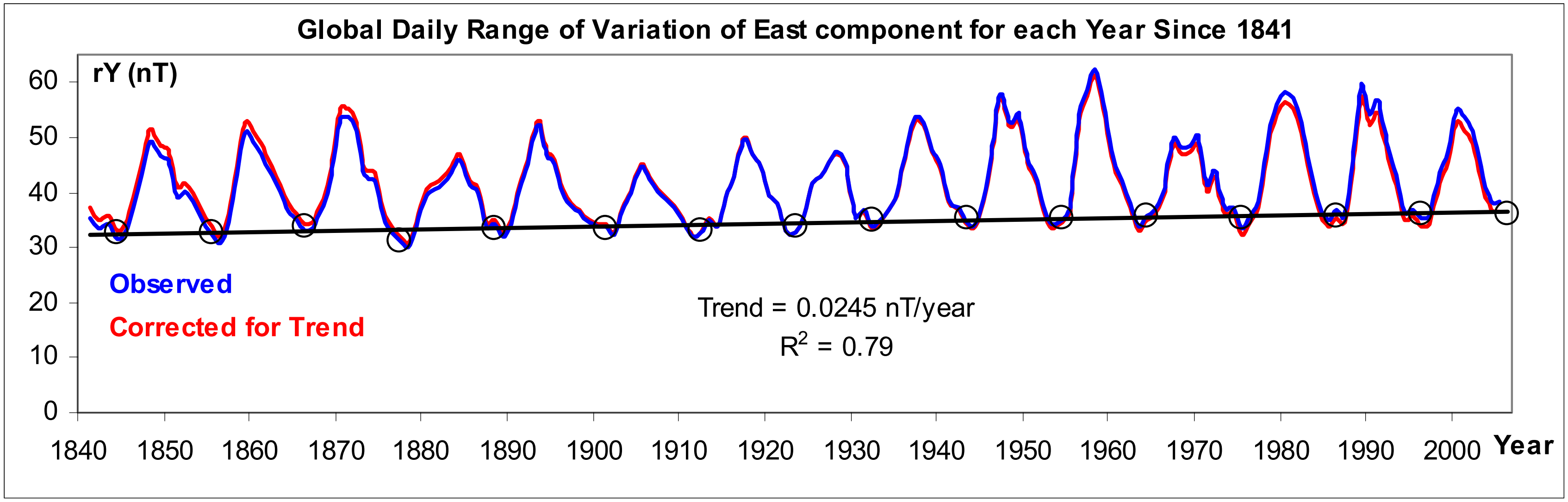

Figure 2. The average yearly range, *rY*, of the daily variation of the East component of the horizontal force of the geomagnetic field.

As for the IMF there seems to be a "floor" in *rY* and hence in *F10.7* and hence in the FUV flux, thus the geomagnetic evidence is that there has been no secular change in the background solar minimum EUV (FUV) flux in the past 165 years.

Direct measurements (although beset by calibration problems) of the Total Solar Irradiance (TSI) from satellites have only been available for 30 years and indicate that solar irradiance increases with solar activity. Correlating mean annual TSI and sunspot numbers allows one to estimate the part of TSI that varies with the sunspot number, as shown in the upper panel of Figure 3. If TSI only depends linearly on the sunspot number then irradiance levels during the Maunder Minimum would be similar to the levels of current solar minima. But TSI is a delicate balance between sunspot darkening and facular brightening, and although both of these increase (in opposite directions) with increasing solar activity, it is not a given that there could not be secular variations in the relative importance of these competing effects. Several reconstructions, reviewed in [6] and reproduced in the lower panel of Figure 3, all postulate a source of long-term irradiance variability on centennial time scales. Each group of researchers have their own preferred additional source of changes of the “background” TSI, such as evidence from geomagnetic activity, open magnetic flux, ephemeral region occurrence, umbral/penumbral ratios, and the like. The existence of “floors” in IMF and FUV over ~1.6 centuries argues for a lack of secular variations of these parameters on that time scale. I would suggest that the lack of such secular variation undermines the circumstantial evidence for a “hidden” source of irradiance variability and that there therefore also might be a floor in TSI, such that TSI during Grand Minima would simply be that observed at current solar minima. This obviously has implications for solar forcing of terrestrial climate.

[1] Svalgaard, L & E. W. Cliver (2007) A Floor in the Solar Wind Magnetic Field, Ap. J. Lett., 661, L203, doi:10.1086/518786.
[2] Owens, M. J. & N. U. Crooker (2006) Coronal Mass Ejections and Magnetic Flux Buildup in the Heliosphere, J. Geophys. Res., 111(A10), A10104, doi:10.1029/2006JA011641.
[3] Svalgaard, L. & E. W. Cliver (2007) Long-term geomagnetic indices and their use in inferring solar wind parameters in the past, J. Adv. Space Res., (in press), doi:10.1016/j.asr.2007.06.066.
[4] Svalgaard, L. & E. W. Cliver (2005) The IDV-Index: Its Derivation and Use in Inferring Long-term Variations of the Interplanetary Magnetic Field Strength, J. Geophys. Res., 110(A12), A12103, doi:10.1029/2005JA011203.
[5] Svalgaard, L. (2007) Calibrating the Sunspot Number using the “Magnetic Needle”, CAWSES News, 4(1), 6.
[6] Fröhlich, C. & J. Lean (2004) Solar Radiative Output and its Variability: Evidence and Mechanisms, Astron..& Astrophys. Rev., 12(4), 273. Doi:10.1007/s00159-004-0024-1.

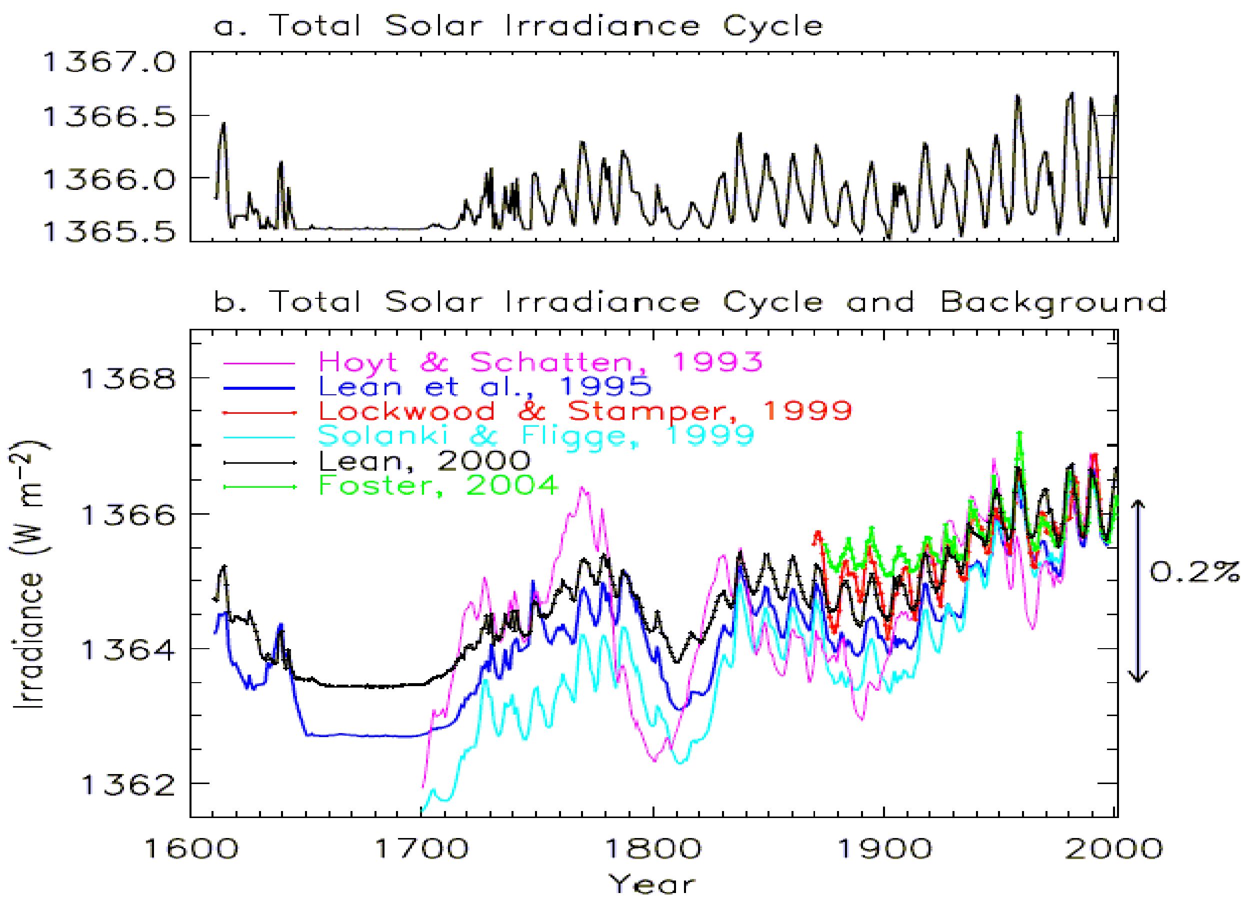

Figure 3. Reconstructions of TSI (From Figure 30, Fröhlich and Lean [6]) since 1600.