Variation of EUV Matches that of the Solar Magnetic Field and an Implication for Climate Research

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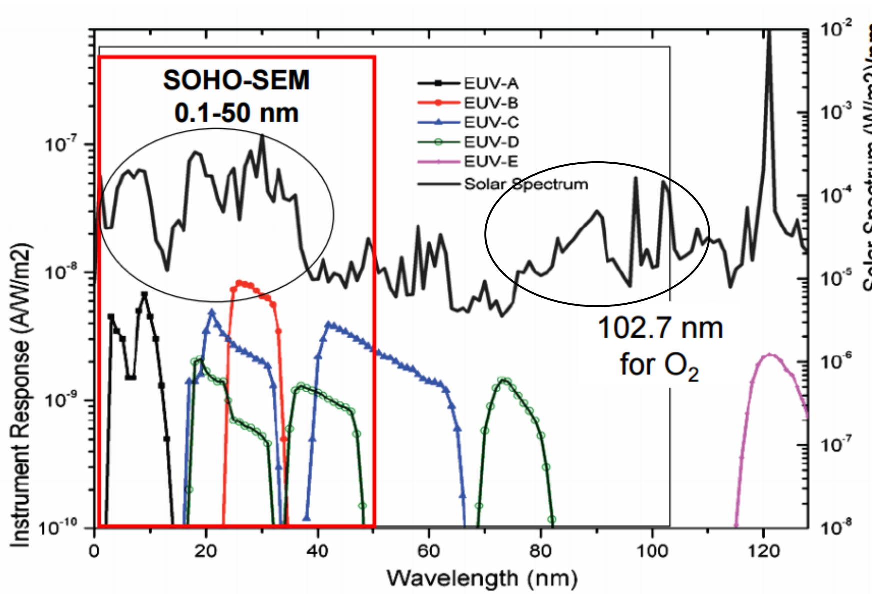
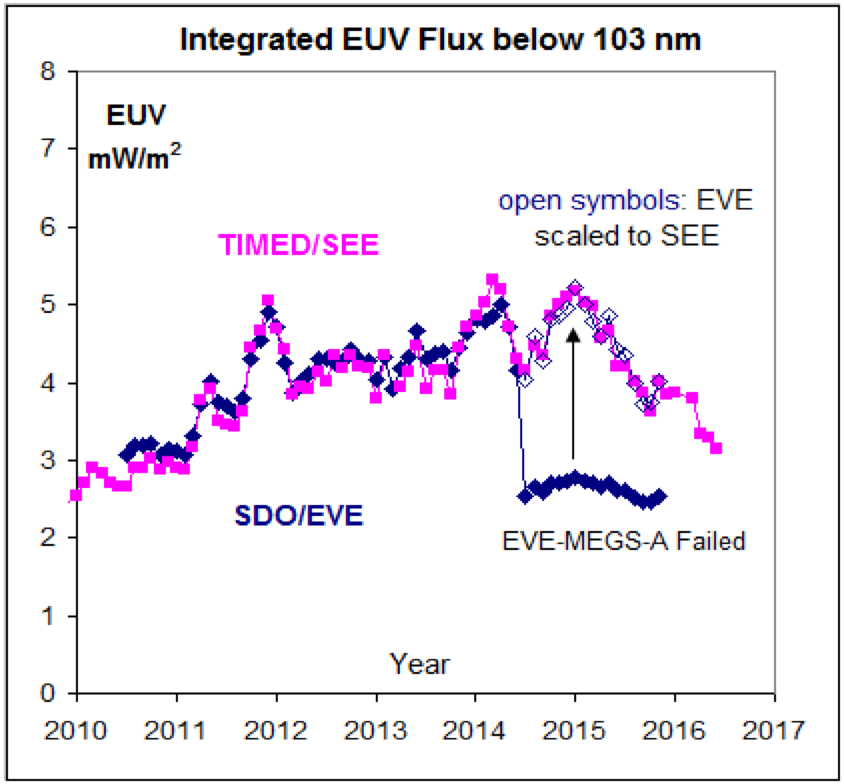
Sources of EUV Data: SEM, SEE, EVE



≤102.7 nm to ionize molecular Oxygen

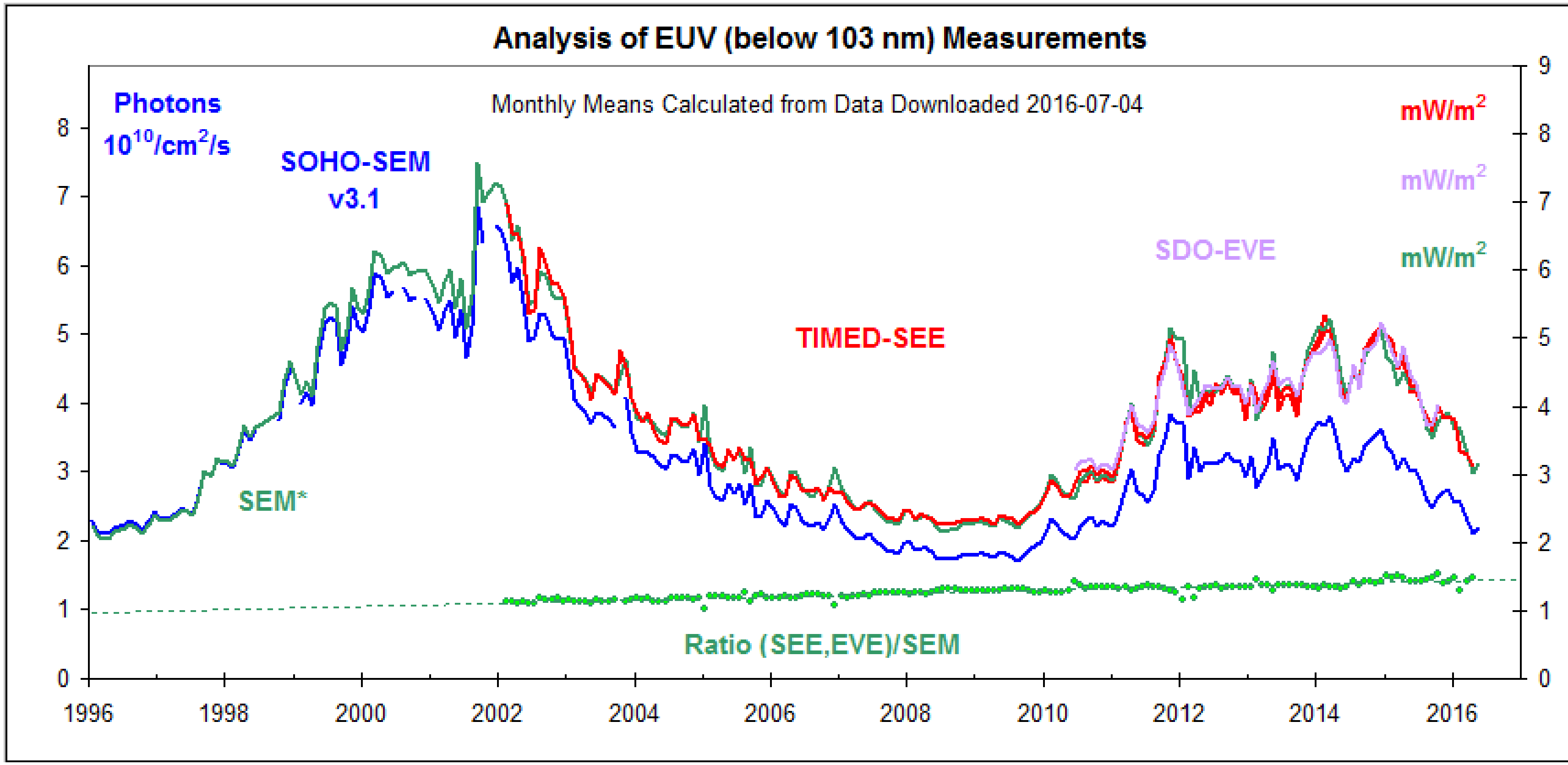
$$O_2 + h\nu \rightarrow O_2^+ + e^-$$

This reaction creates and maintains the conducting E-region of the Ionosphere (at ~105 km altitude)



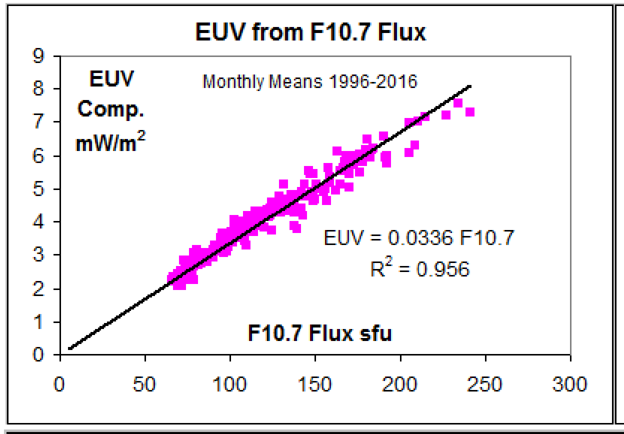
The detectors on the TIMED and SDO satellites agree well until the failure of the high-energy detector on EVE in 2014. We can still scale to earlier levels [open symbols]

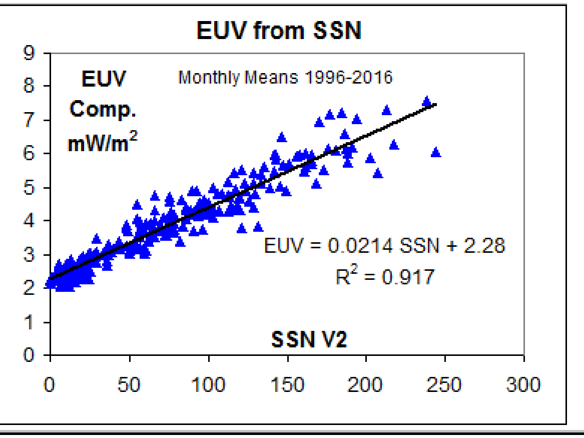
Creating an EUV (<103 nm) Composite



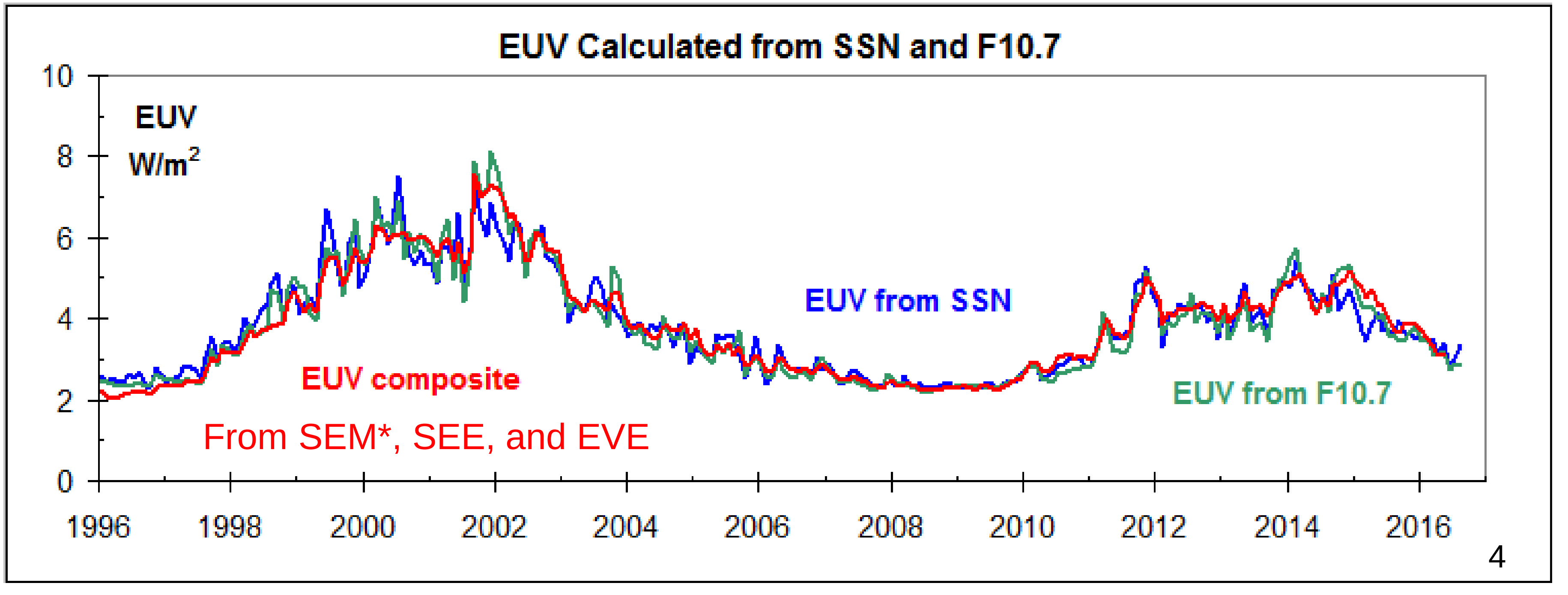
SEE and EVE agree nicely and we can form a composite (SEE,EVE) of them. SEM is on a different scale, but we can convert that scale to the scale of (SEE,EVE). The scale factor [green line] shows what to scale SEM with to match (SEE,EVE) [SEM*. upper green curve], to get a composite of all three (SEM*,SEE,EVE) covering 1996-2016, in particular the two minima in 1996 and 2008.

EUV Composite Matches F10.7 and Sunspot Numbers

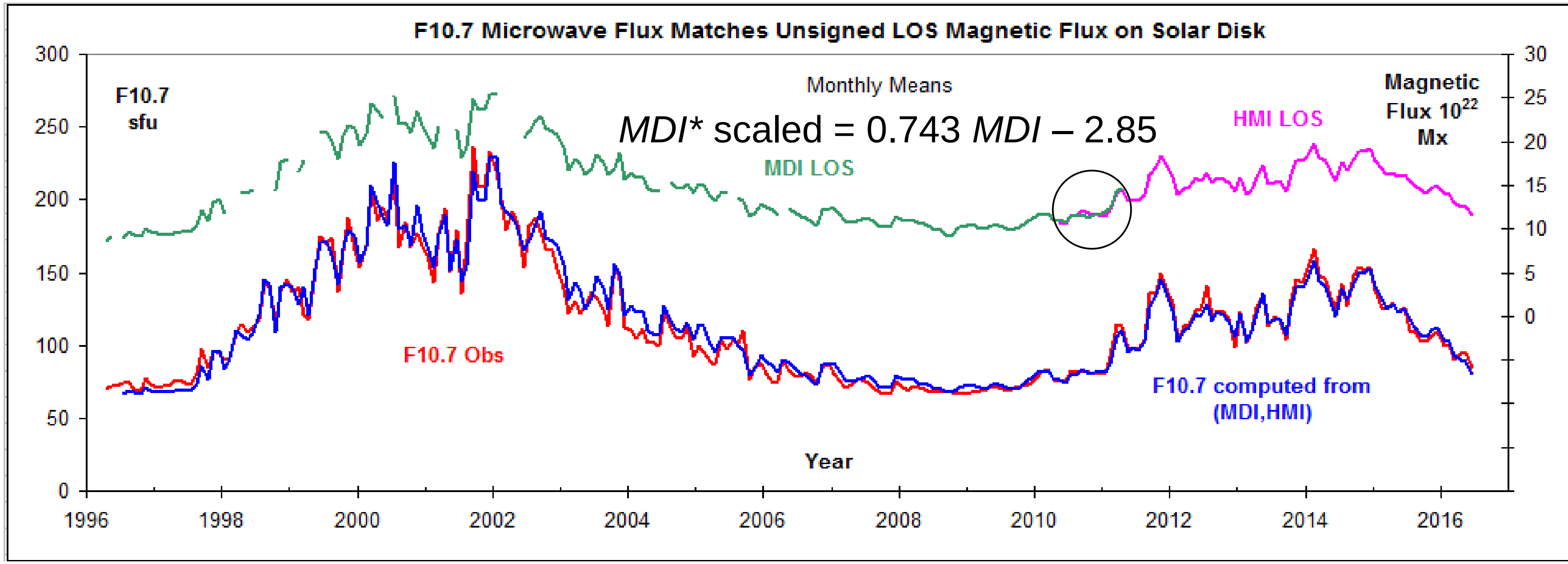


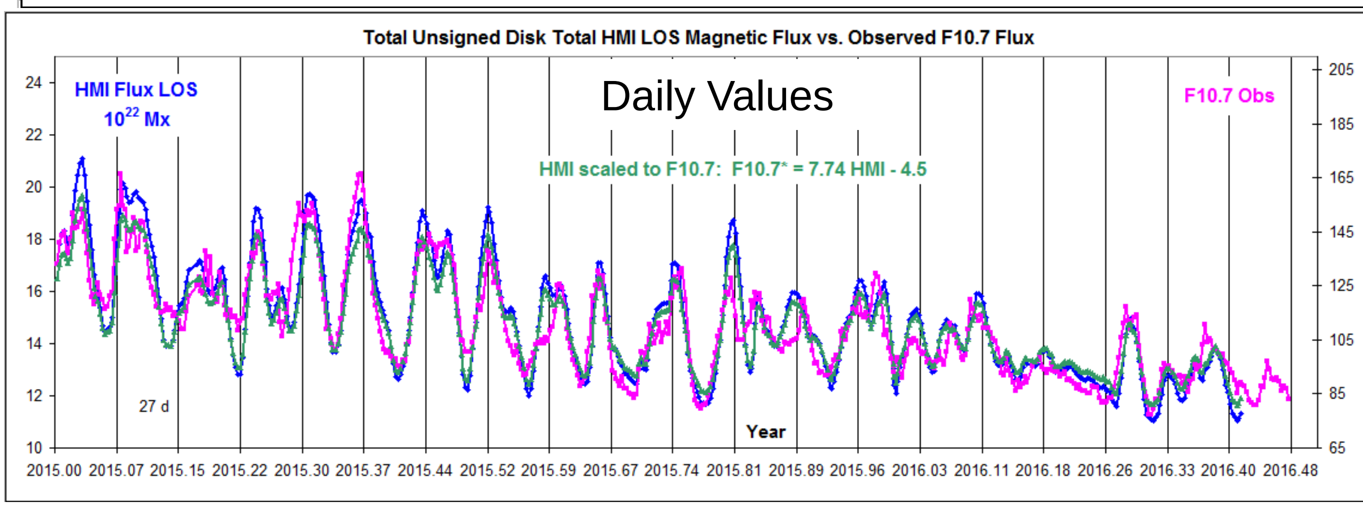


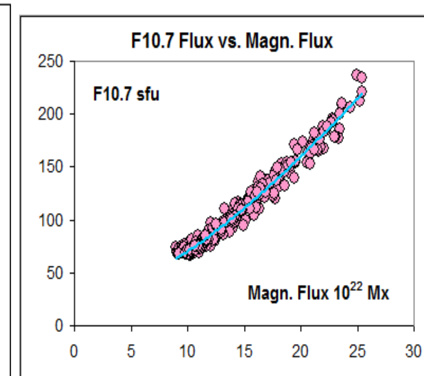
So, we can calculate the EUV flux both from the Sunspot Number and from the F10.7 flux which then is a good proxy for EUV [as is well-known].



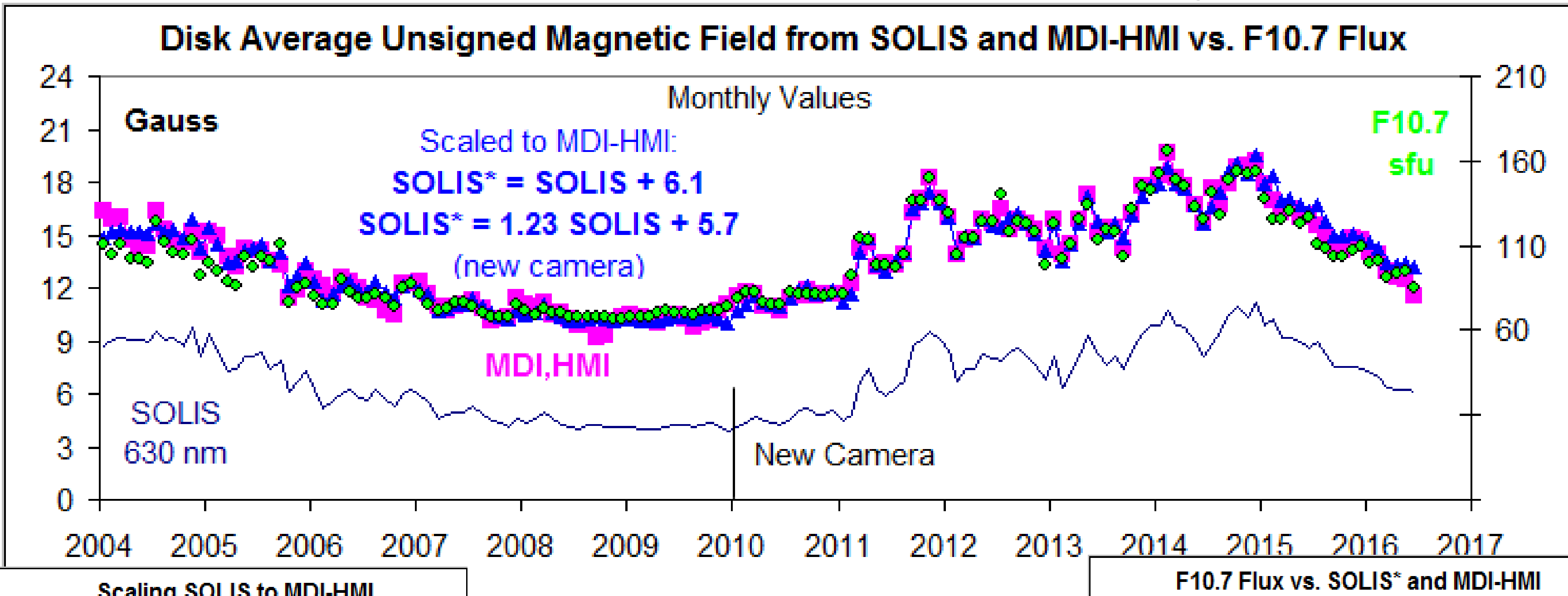
Magnetic Flux from MDI and HMI Match F10.7 Microwave Flux

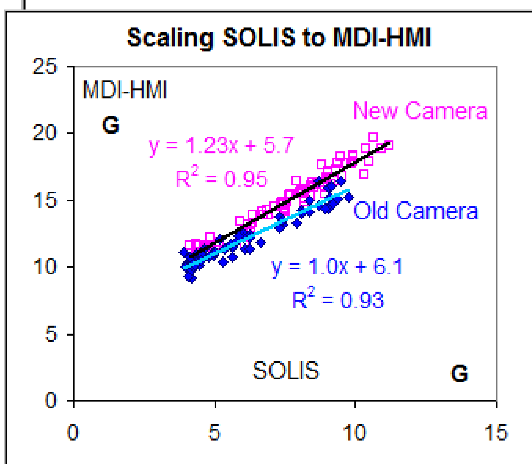




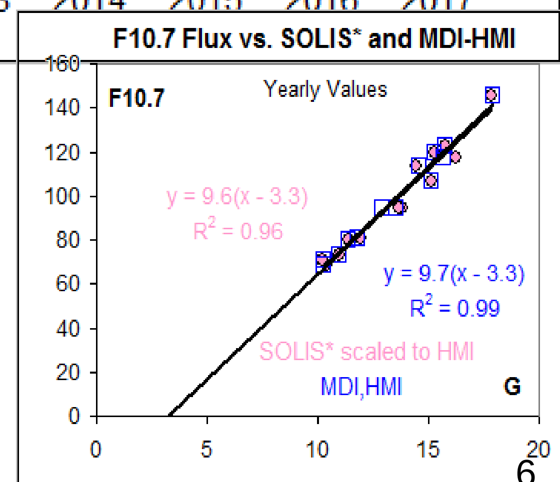


Even Ground-based Observations [SOLIS] Match F10.7 Nicely, but …

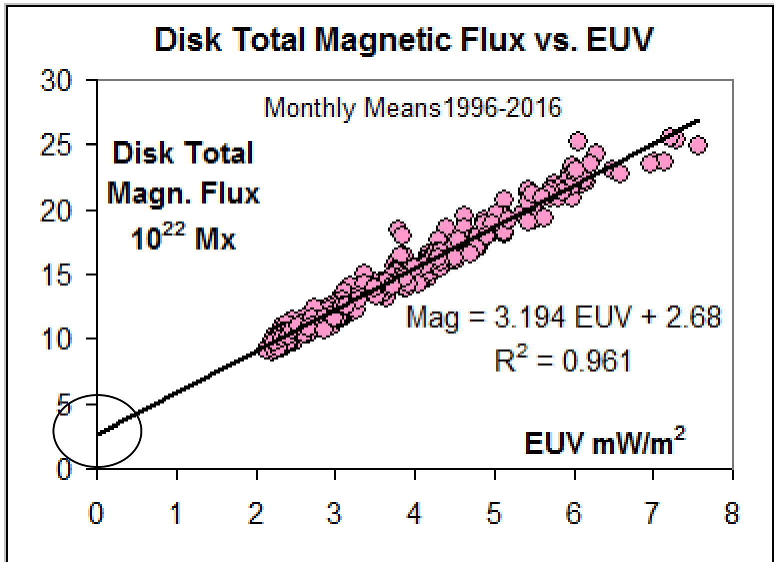


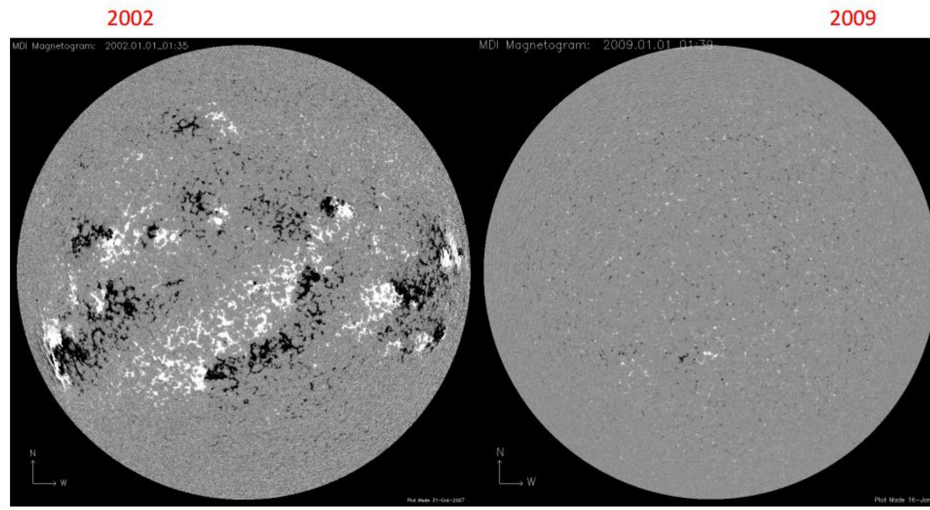


the upgrade to the new camera meant a change of calibration.

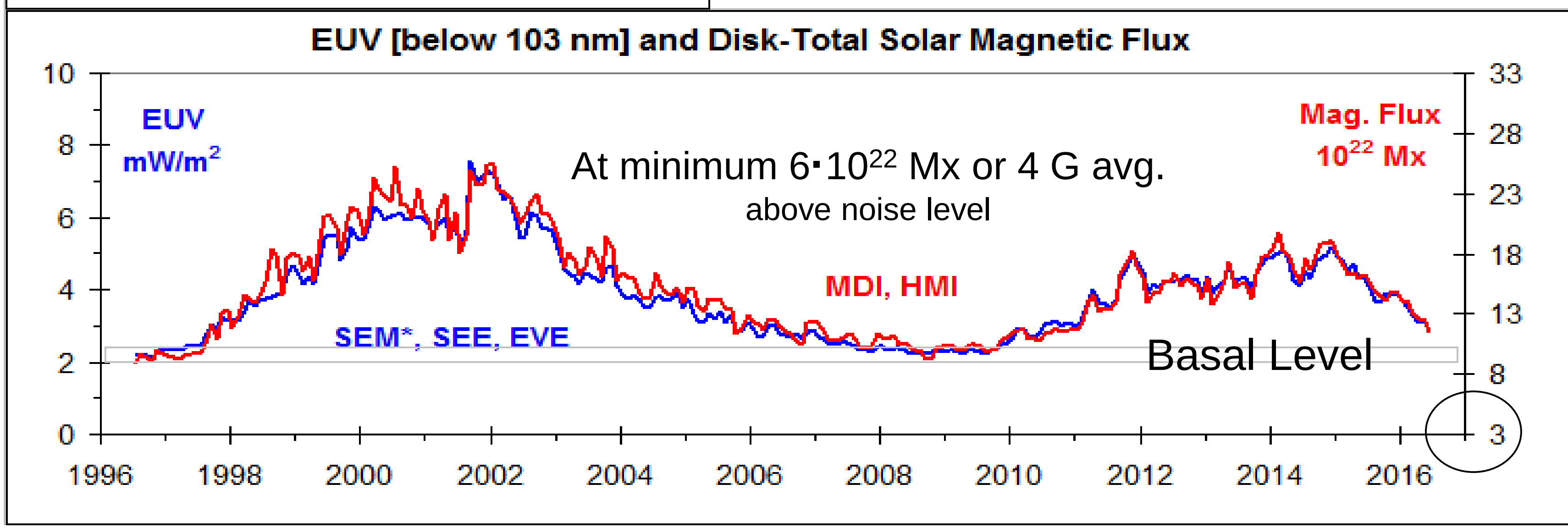


EUV Follows Total Unsigned Magnetic Flux



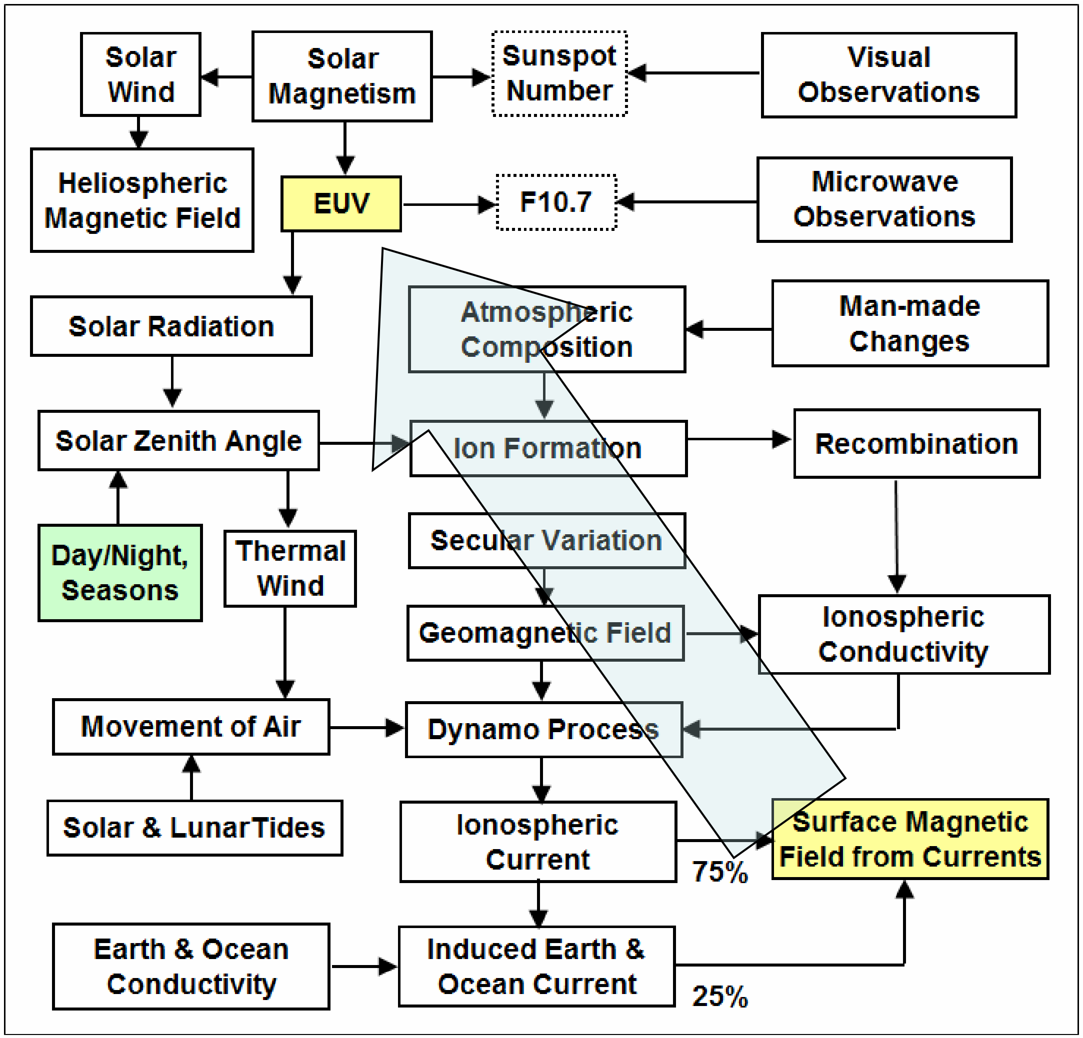


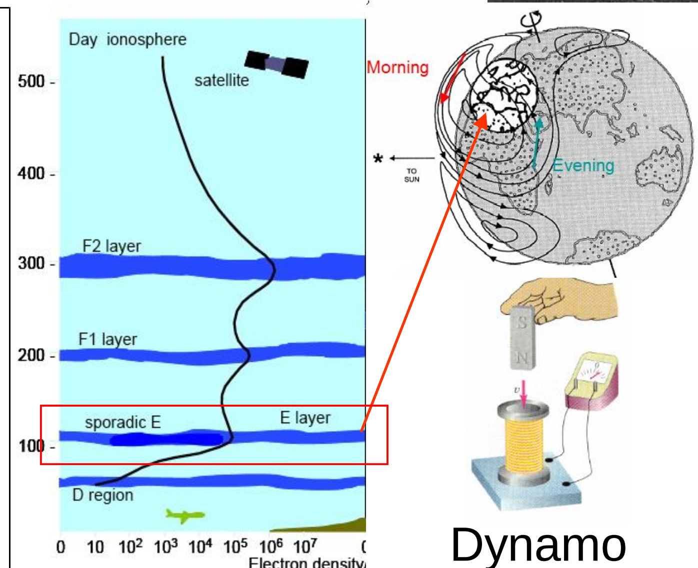
Offset interpreted as Noise Level ≈ $3 \cdot 10^{22}$ Mx

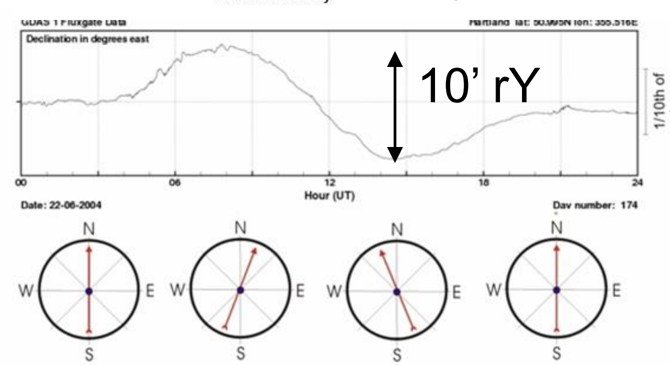


There is a 'basal' level at solar minima. Is this the case at every minimum?

Determining EUV Flux from Geomagnetism (Graham, 1722)

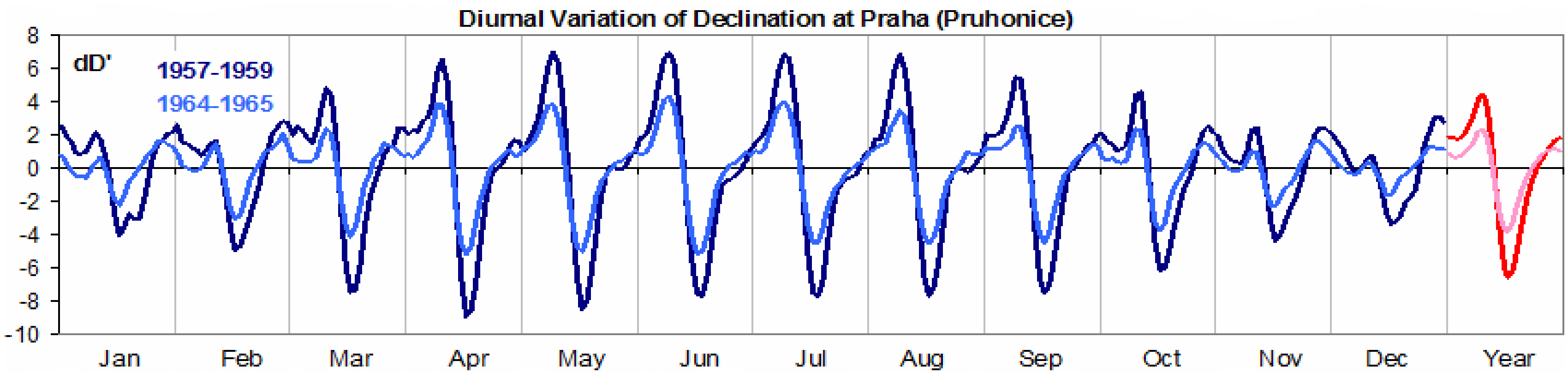


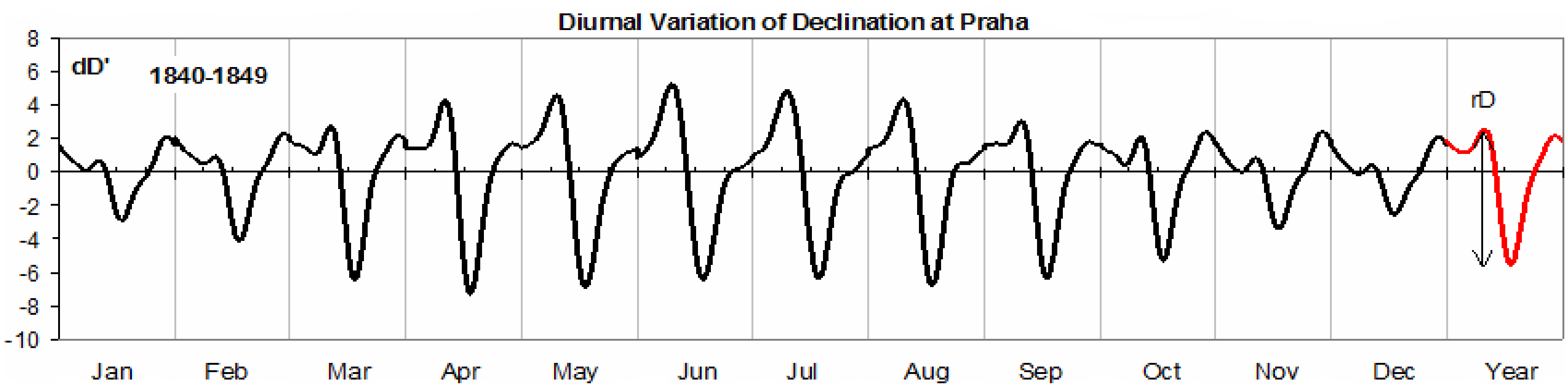


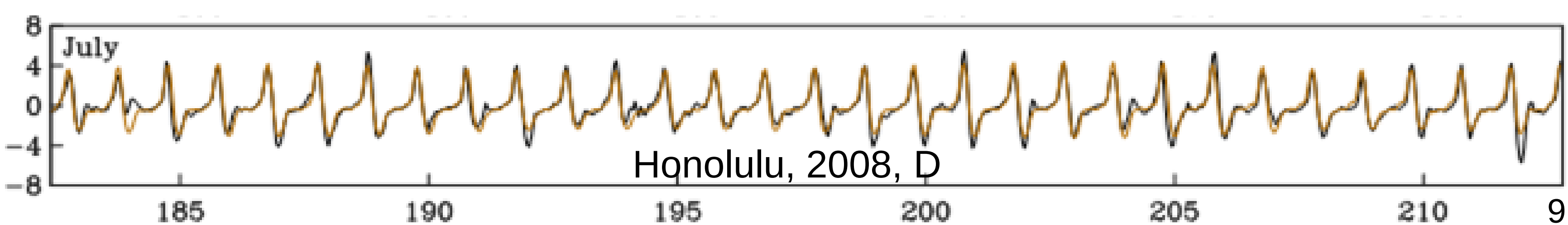


The effect is in the East [the Y] Component: rY

The Diurnal Variation [rY=H cos(D) rD]

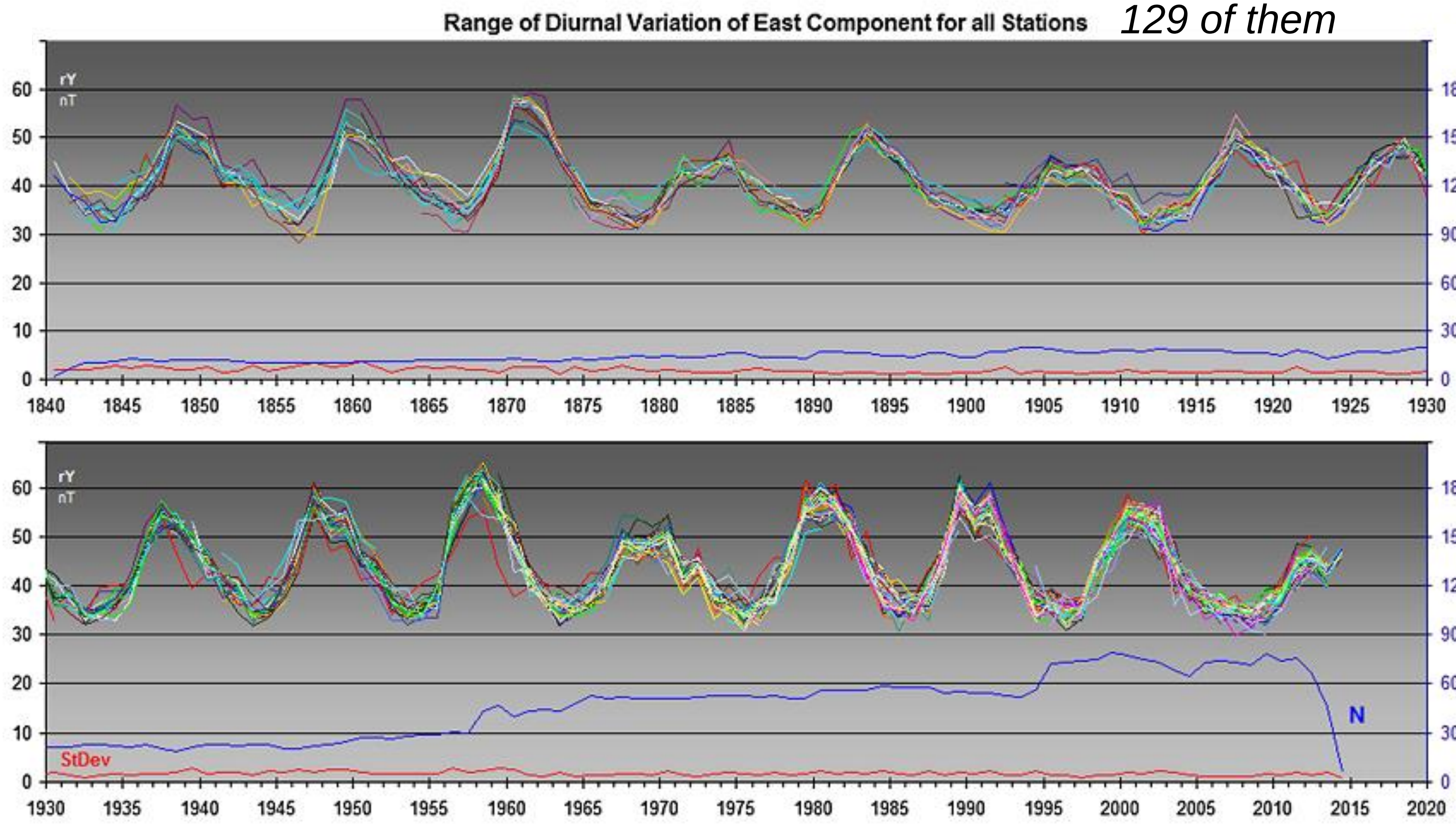






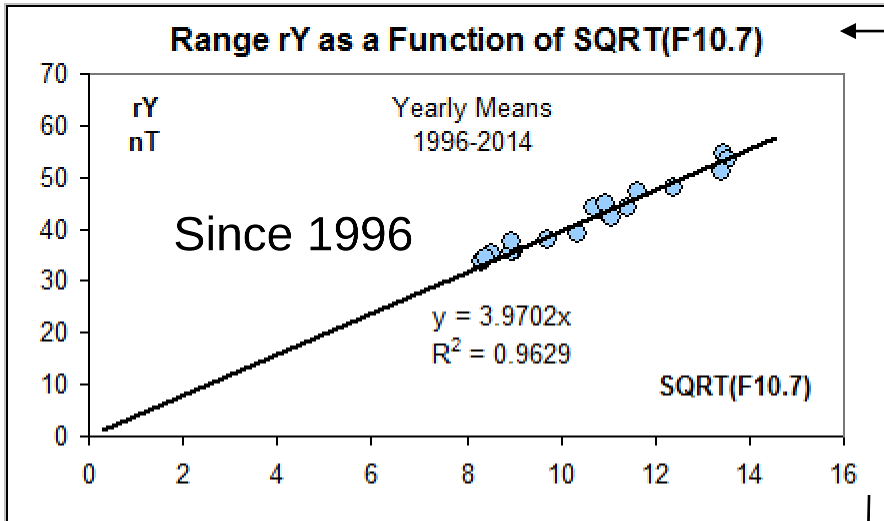
Honolulu, 2008, D

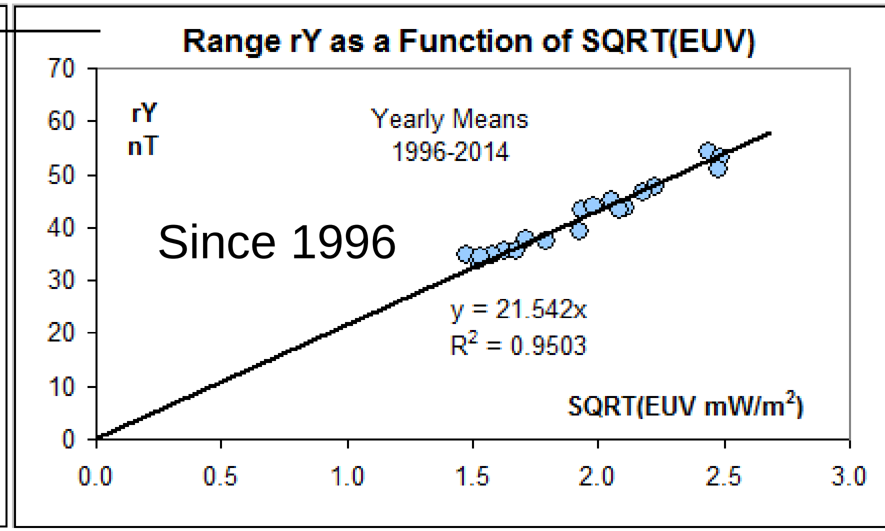
Observed Diurnal Ranges of the Geomagnetic East Component since 1840

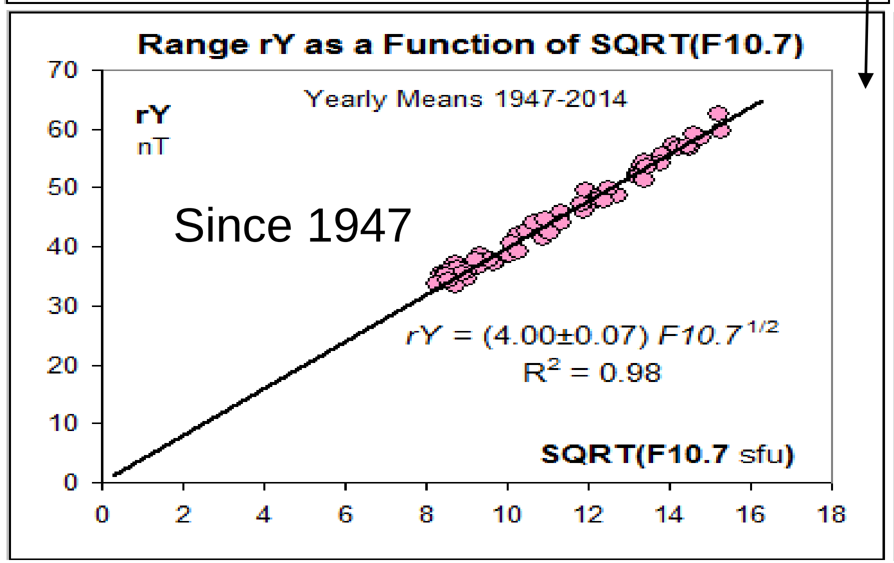


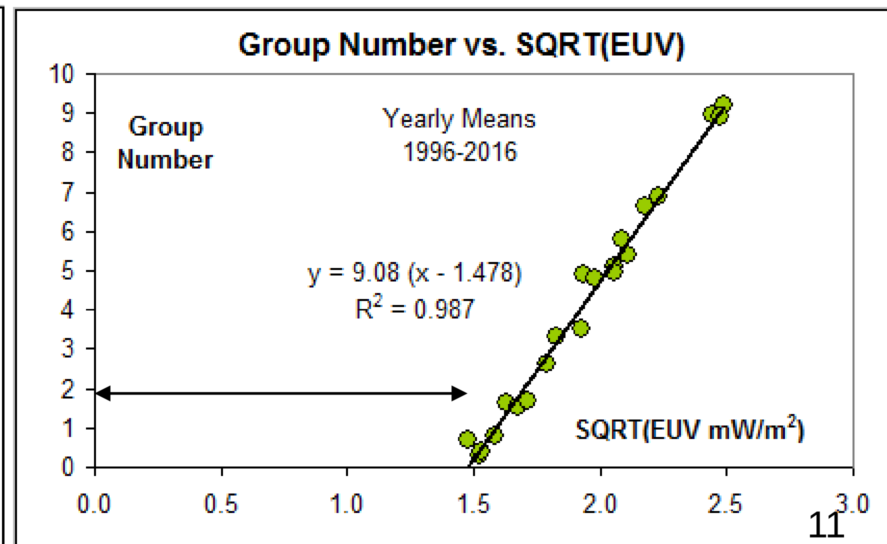
We plot the yearly average range to remove the effect of changing solar zenith angle through the seasons. A slight normalization for latitude and underground conductivity has been performed. The blue curve shows the number of stations

Theory tells us that the conductivity [and thus rY] should vary as the square root of the EUV [and F10.7] flux, and so it does:

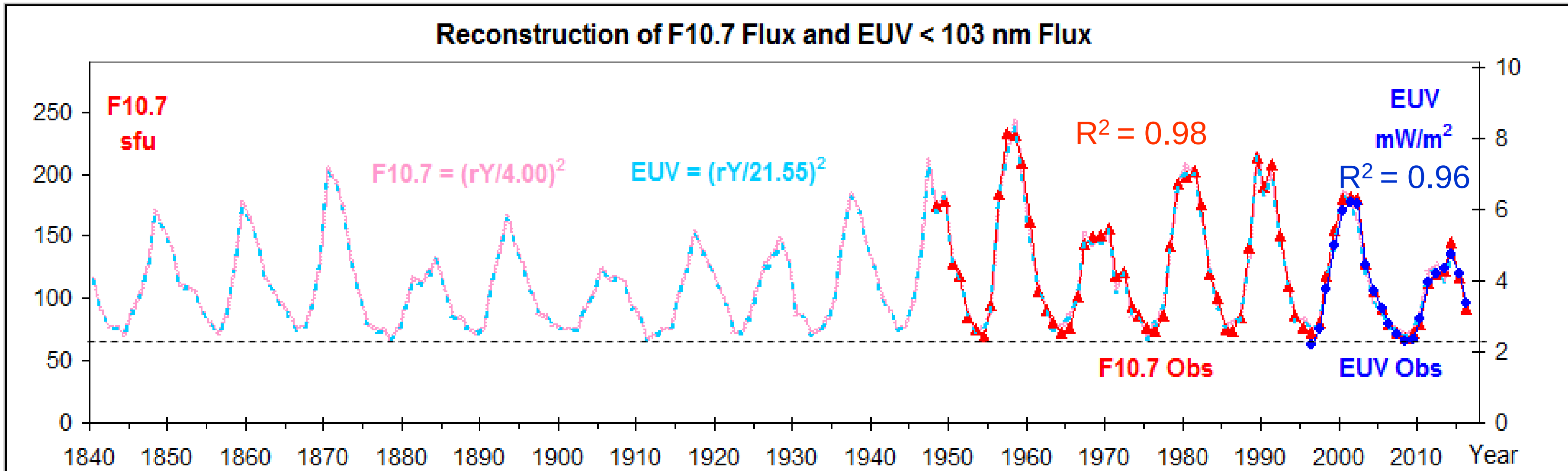


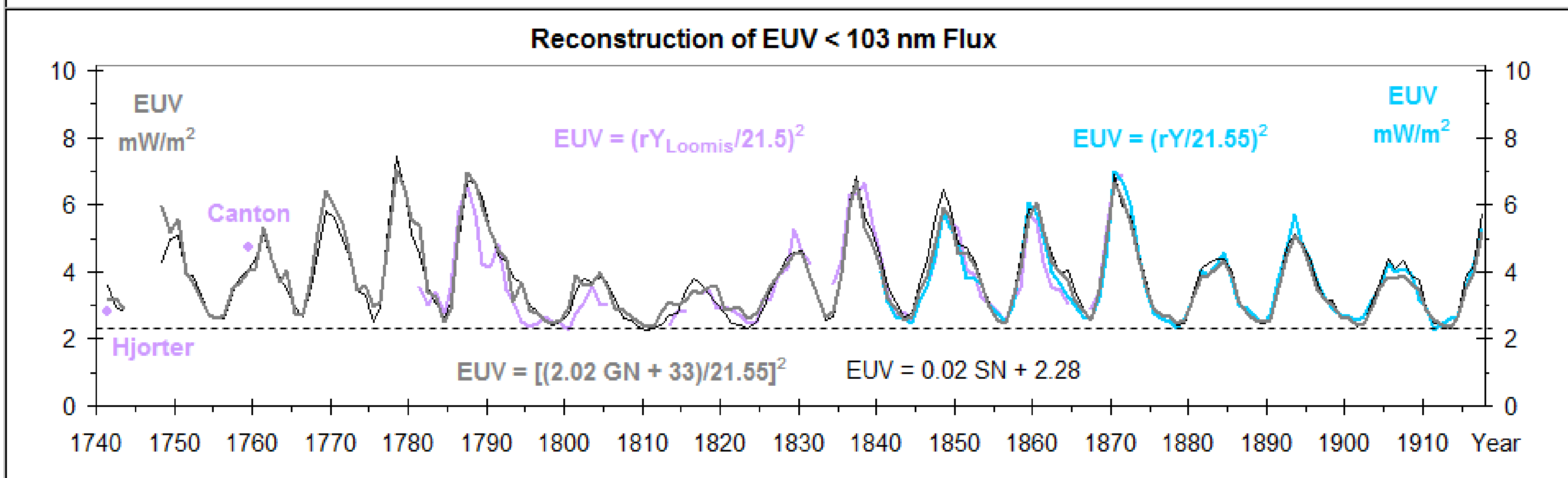






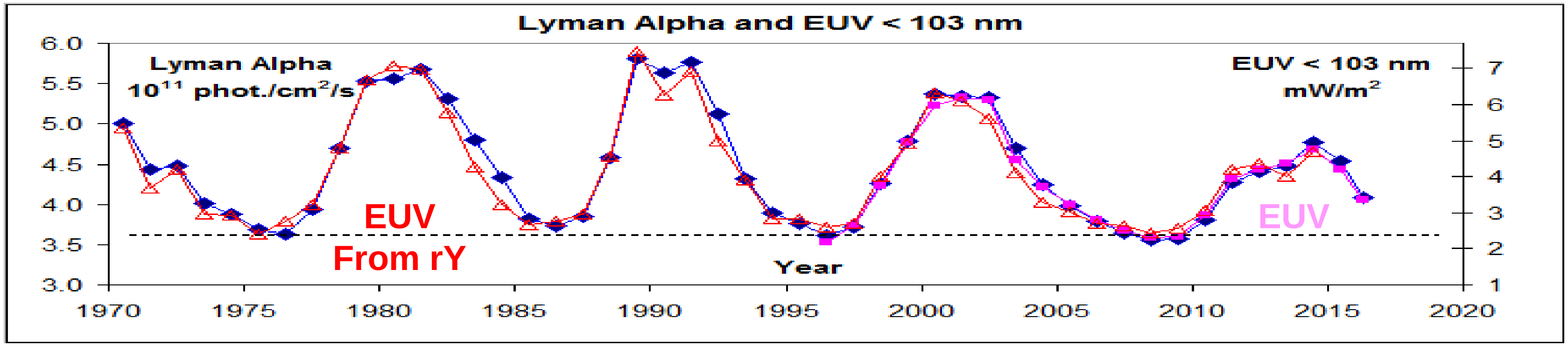
Reconstructions of EUV and F10.7

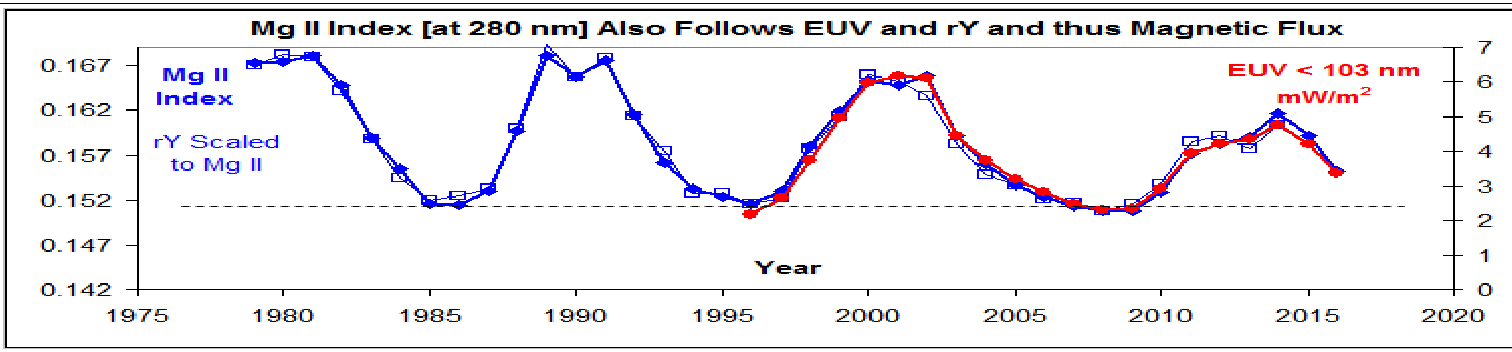


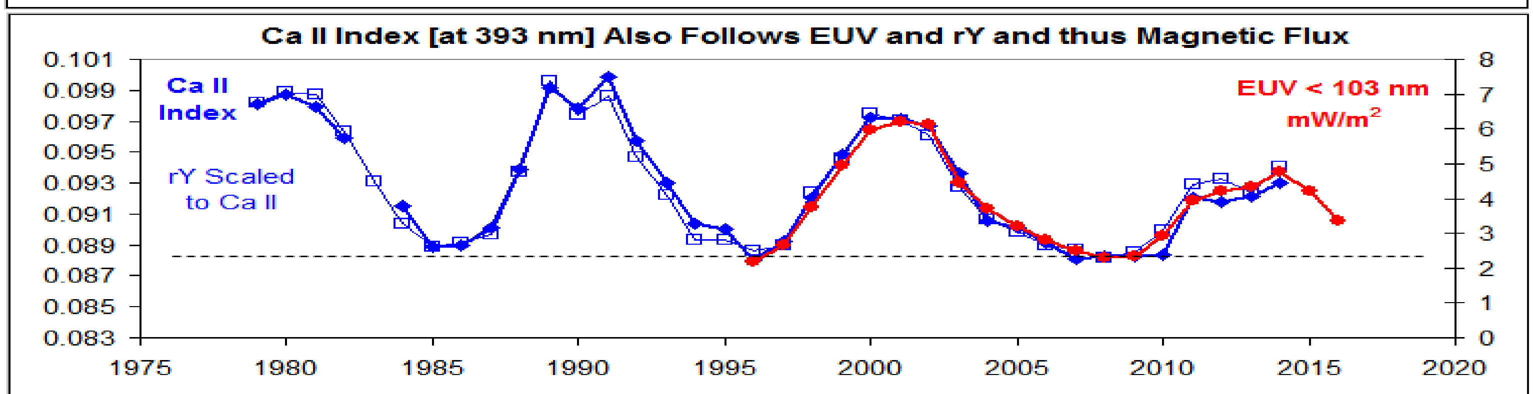


Note the constant basal level at *every* solar minimum

Lyman Alpha, Mg II, and Ca II also Follow the Magnetic Field and EUV

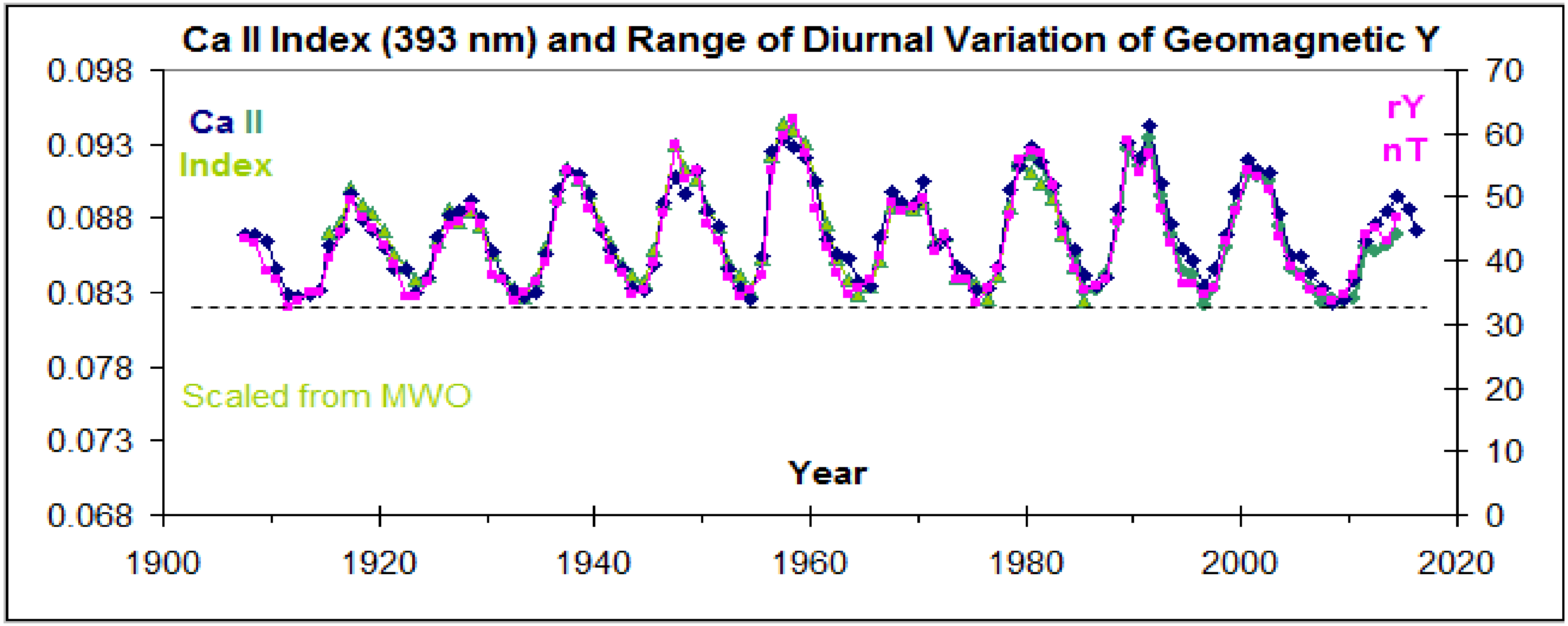






Same Basal Level at all Minima

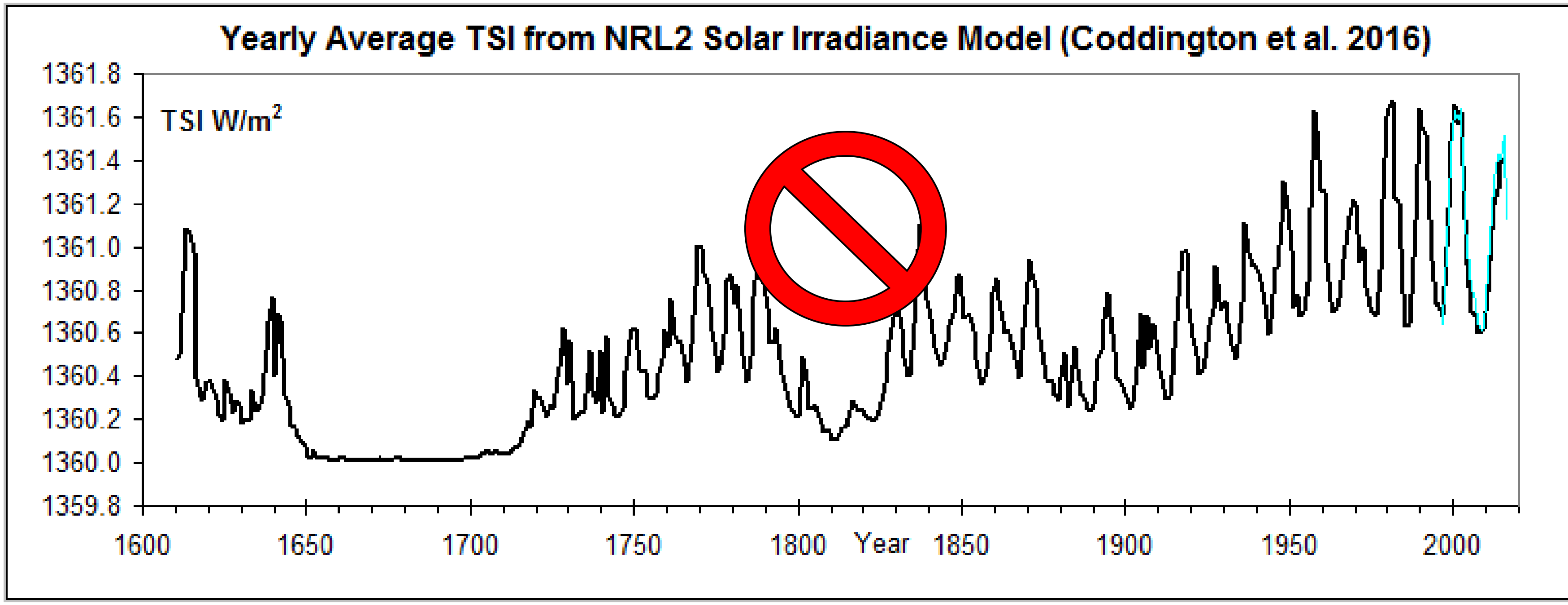
The Ca II Index Shows the Same Basal Floor at Minima as rY and EUV



The long-term **Ca** II Index is constructed from Kodaikanal, Sacramento Peak, and SOLIS/ISS data [Luca Bertello]. Data from Mount Wilson [**Green**] has been scaled to the Kodaikanal series. Calibration of the old spectroheliograms is a difficult and on-going task.

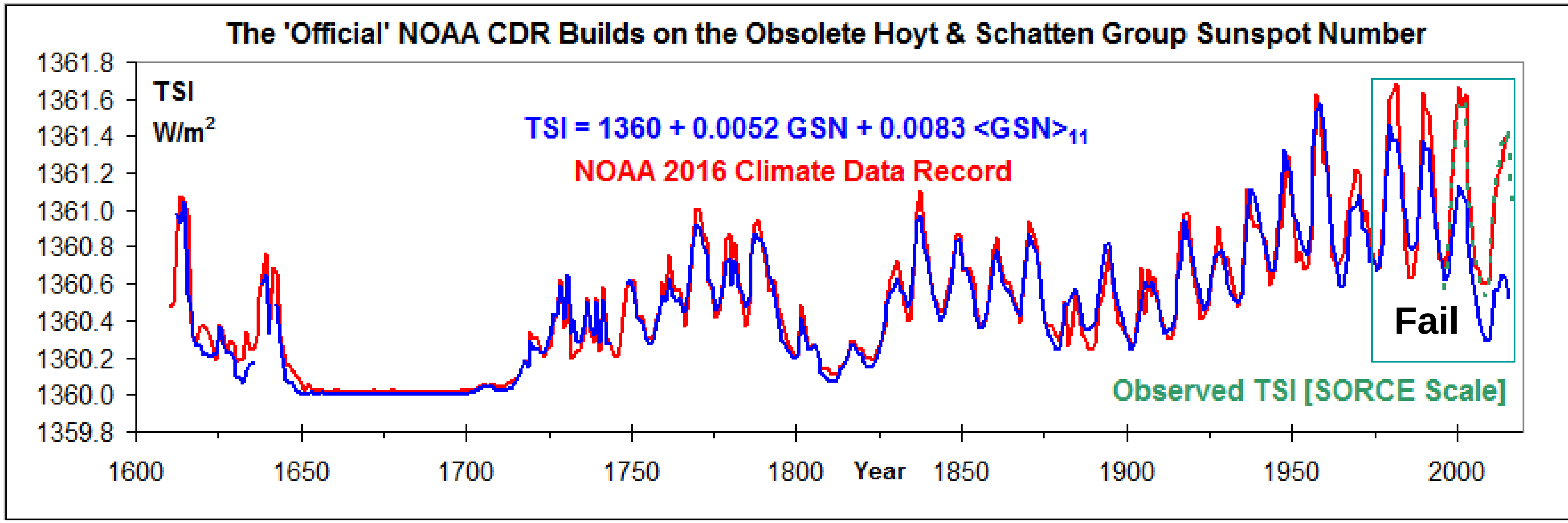
Bottom Line: All our solar indices show that solar activity [magnetic field] is constant at every solar minimum. [except for *tiny* residual variation]

The Official TSI Climate Data Record (CDR)



"The data record, which is part of the National Oceanic and Atmospheric Administration's (NOAA) Climate Data Record (CDR) program, provides a **robust, sustainable, and scientifically defensible** record of solar irradiance that is of sufficient length, consistency, and continuity for use in studies of climate variability and climate change on multiple time scales and for user groups spanning climate modeling, remote sensing, and natural resource and renewable energy industries." [LASP, NRL: http://dx.doi.org/10.1175/BAMS-D-14-00265.1]

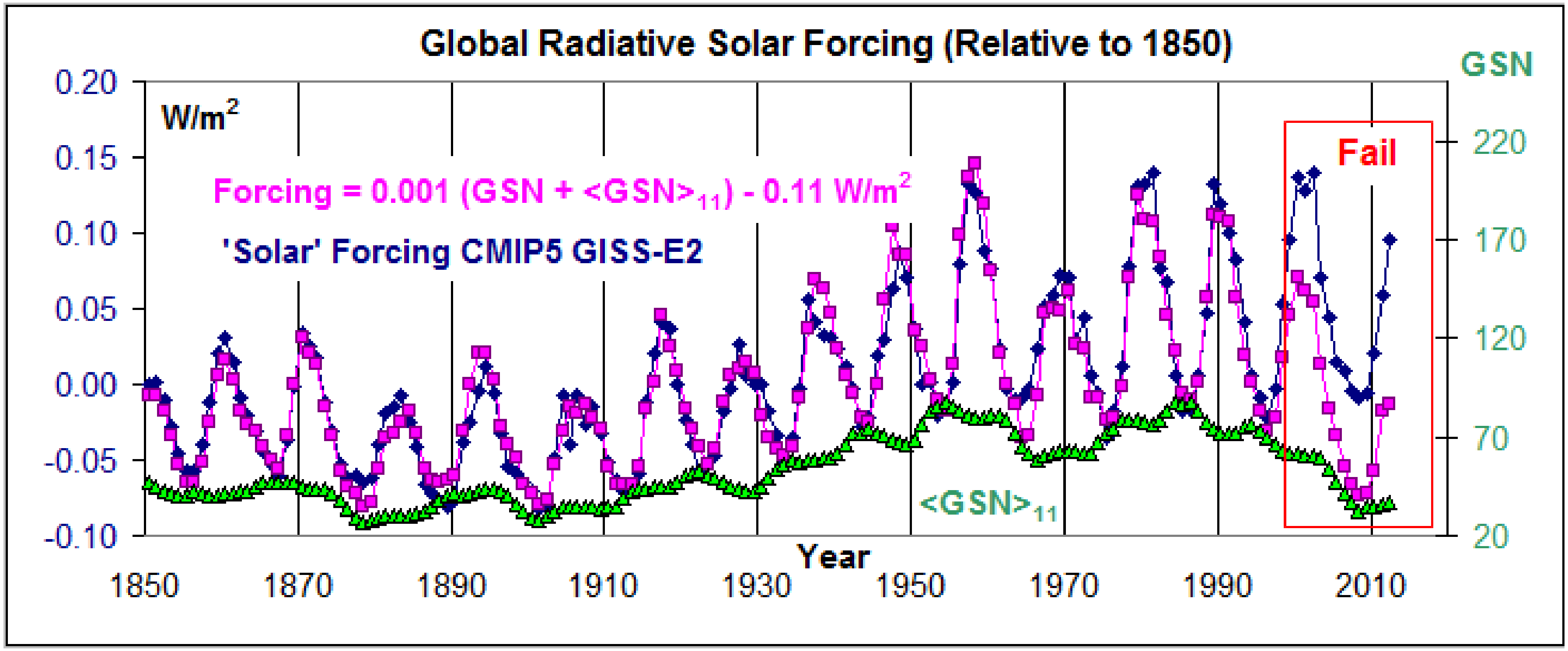
Shaky Justification for Using a ‘Background’ Component in TSI



“A third component of irradiance variability is an **assumed** long-term facular contribution that is **speculated** (Solanki et al. 2013) to produce the **secular** irradiance change *underlying* the solar activity cycle on historical time scales (**Obsolete H&S** prior to 1978). According to **simulations** from a magnetic flux transport **model** (with **variable** meridional flow) of eruption, transport, and accumulation of magnetic flux on the sun’s surface since 1617, a small accumulation of total magnetic flux and **possibly** the rate of emergence of small bipolar magnetic regions on the quiet sun (called ephemeral regions) produce a net increase in facular brightness.”

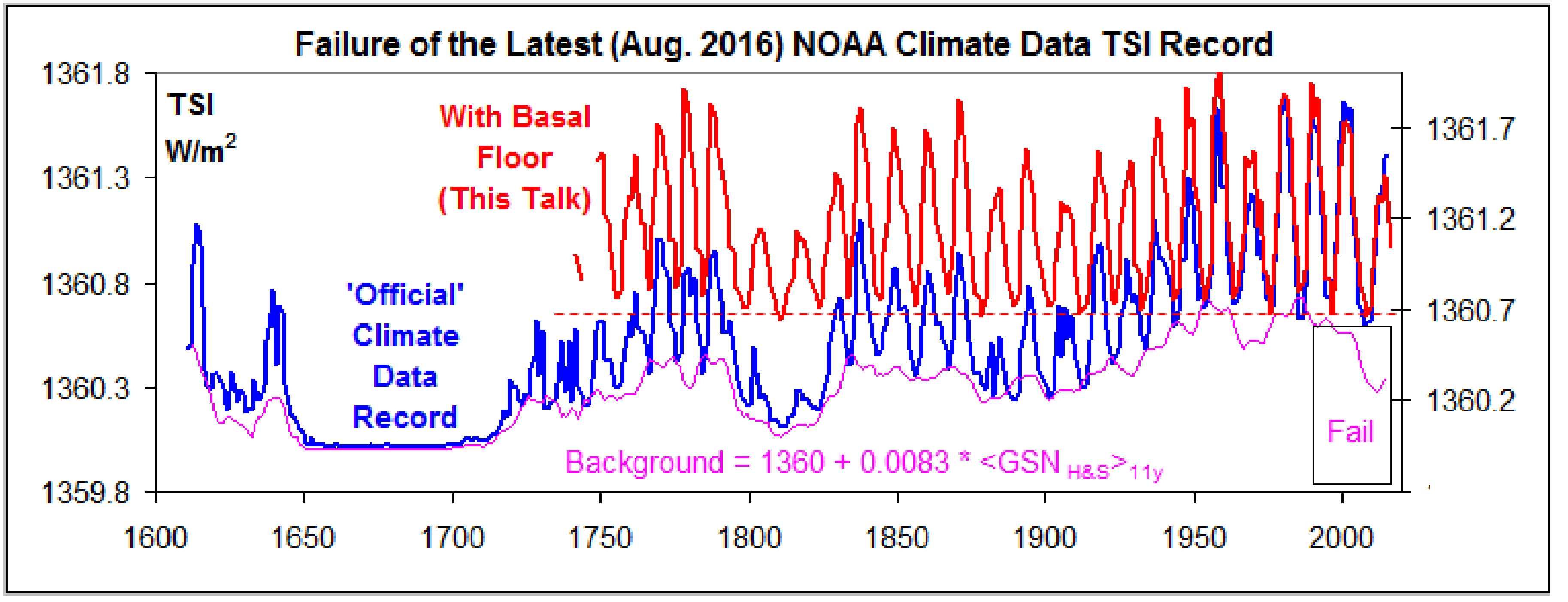
It seems to me that all that advanced [?] physics and sophisticated modeling only added a bit of noise to a simple linear combination of H&S’s GSN and <GSN>$_{11}$, even failing for modeling the recent instrumental spacecraft record.

Yet Another Climate Model Input



GISS 5th Coupled Model Intercomparison Project includes simulations for the historic period, future simulations out to 2300, and past simulations for the last 1000 years, the last glacial maximum and the mid-Holocene, and also uses (Miller, 2014) the same ‘background’ idea, based on the same [H&S] obsolete Group Sunspot Number, and also failing for the modern instrumental record where the background has been dropped.

The Basal EUV and Magnetic Flux Records Do Not Support the NOAA Climate Data Record, CDR

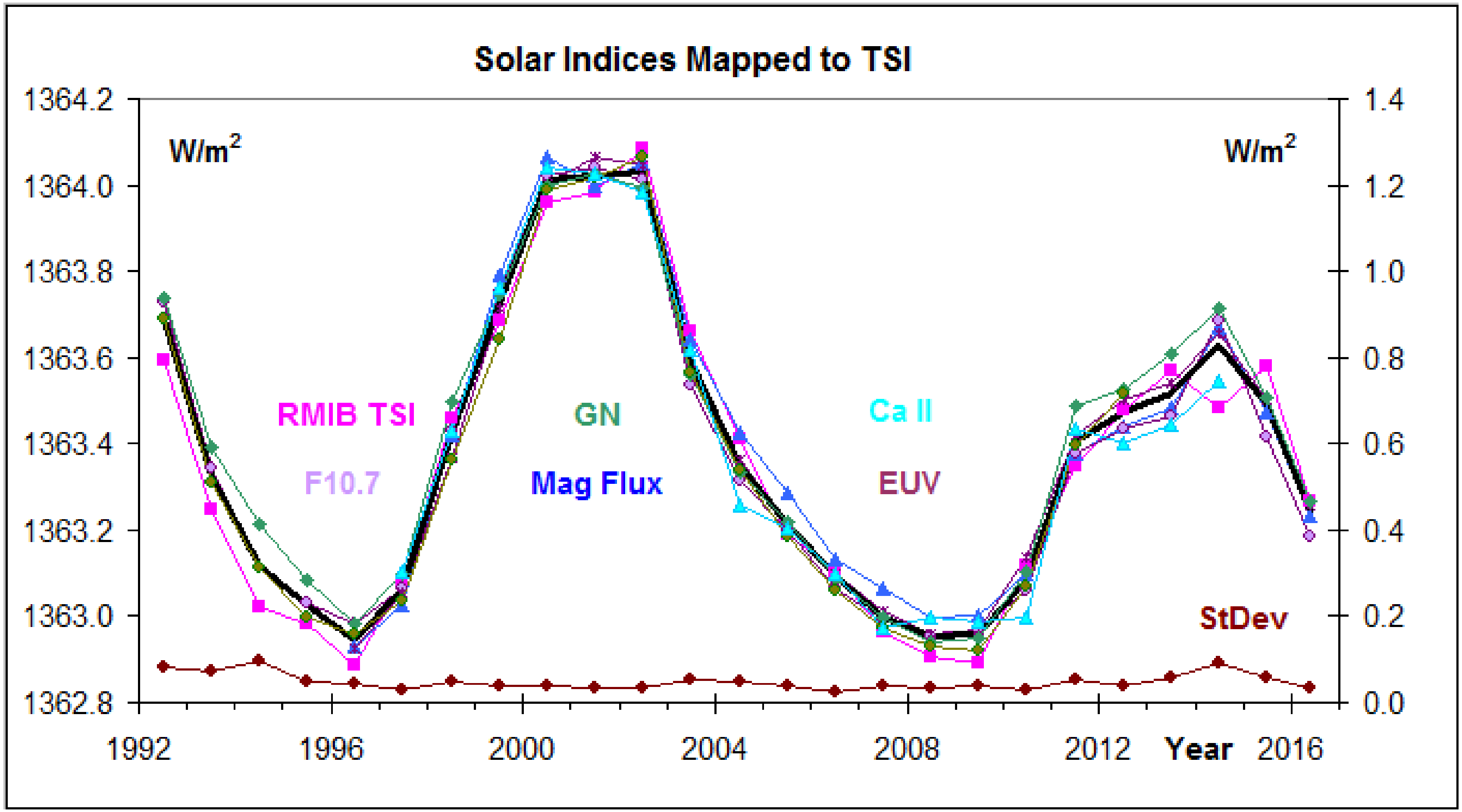


1: **One can fit EUV to the instrumental part of NOAA's Climate Data Record**
2: There is no support for a variable 'Background' (pink curve) and surely not
3: if constructed from the obsolete Hoyt & Schatten Group Sunspot Number
4: which the CDR didn't even use during the 'instrumental era' (SORCE)
5: The current CDR is not helpful to Climate Research and to "climate modeling, remote sensing, and natural resource and renewable energy industries"
6: **The analysis reported in this talk invalidates the TSI CDR before ~1978**

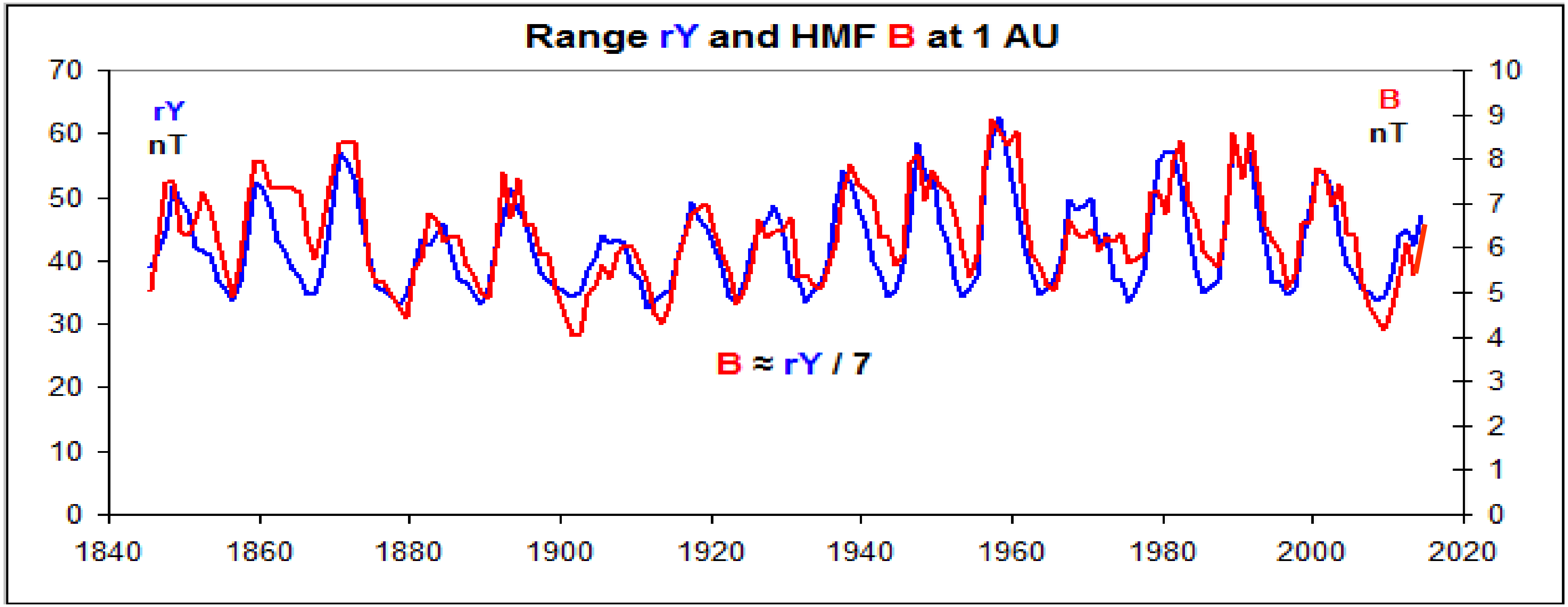
The End

Extra Slides for Q/A

Solar Indices Mapped to TSI



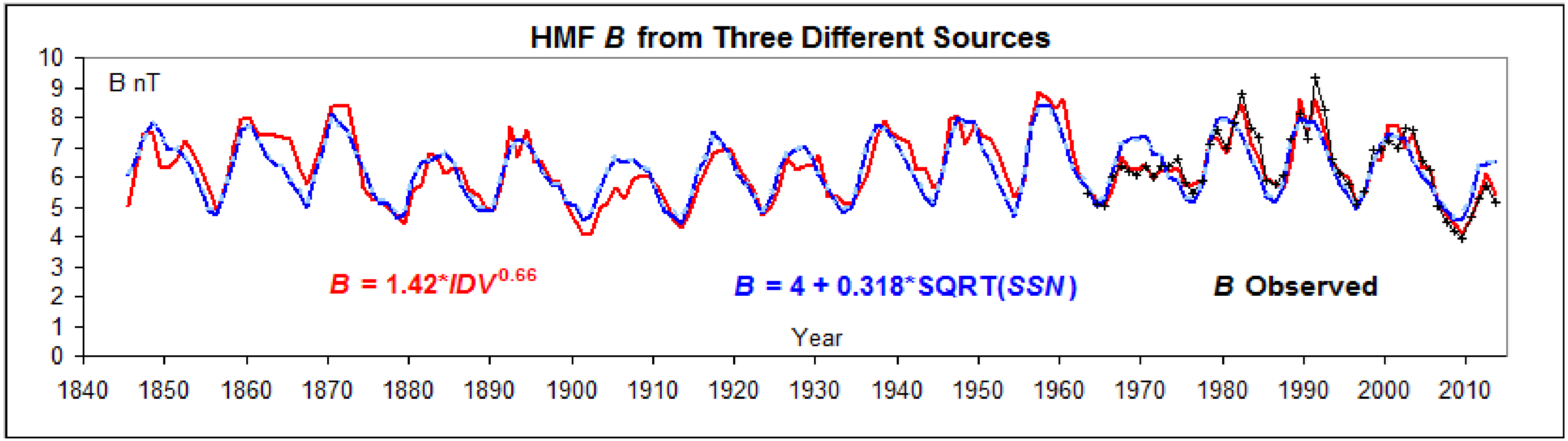
Network Field and Solar Wind Field

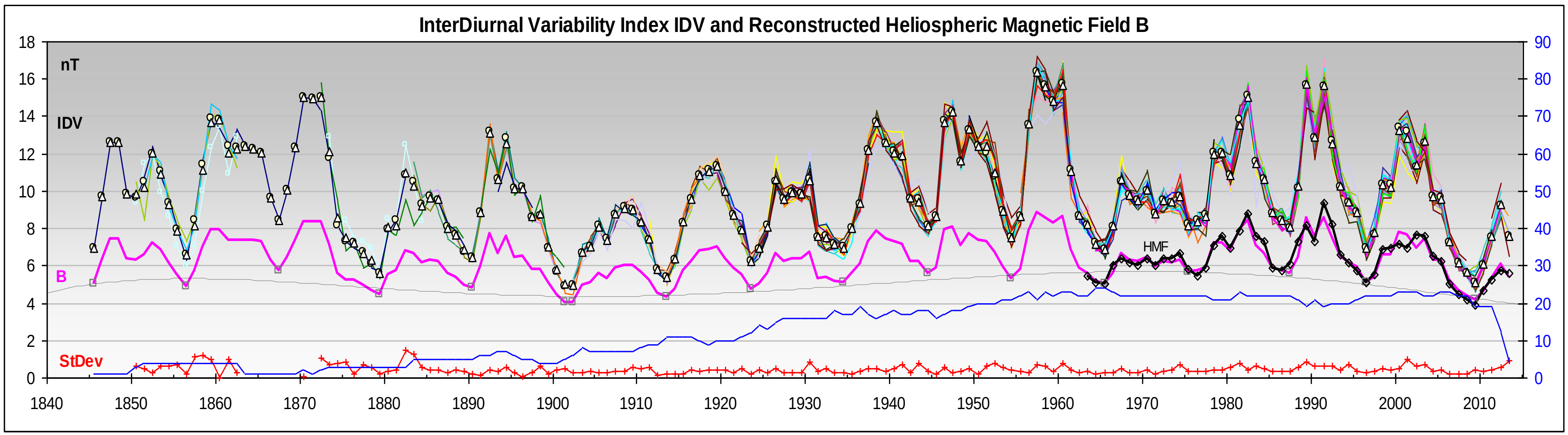


The magnetic field in the solar wind (the Heliosphere) ultimately arises from the magnetic field on the solar surface filtered through the corona, and one would expect an approximate relationship between the network field (EUV and rY) and the Heliospheric field, as observed.

The flux transport model simulates the eruption, transport, and accumulation of magnetic flux on the Sun's surface from the Maunder Minimum to the present in strengths and numbers proportional to the [group?] sunspot number. The model estimated variations in both open and total flux. The open flux is claimed to compare reasonably well with the geomagnetic and cosmogenic isotopes, which gives confidence that the approach is plausible. It actually does not, as the reconstruction of the magnetic field B since 1840 shows.

Reconstruction of Hemispheric Magnetic Field





Electron Density due to EUV

< 102.7 nm

$$O_2 + h\nu \xrightarrow{J} O_2^+ + e^-$$

$$O_2^+ + e^- \xrightarrow{\alpha} O + O$$

The conductivity at a given height is proportional to the electron number density N_e. In the dynamo region the ionospheric plasma is largely in photochemical equilibrium. The dominant plasma species is O^+_2, which is produced by photo ionization at a rate J (s^{-1}) and lost through recombination with electrons at a rate α (s^{-1}), producing the Airglow.

The rate of change of the number of ions N_i, dN_i/dt and in the number of electrons N_e, dN_e/dt are given by $dN_i/dt = J \cos(\chi) - \alpha N_i N_e$ and $dN_e/dt = J \cos(\chi) - \alpha N_e N_i$. Because the Zenith angle χ changes slowly we have a quasi steady-state, in which there is no net electric charge, so $N_i = N_e = N$. In a steady-state $dN/dt = 0$, so the equations can be written $0 = J \cos(\chi) - \alpha N^2$, and so finally

$$N = \sqrt{(J \alpha^{-1} \cos(\chi))}$$

Since the conductivity, Σ, depends on the number of electrons N, we expect that Σ scales with the square root $\sqrt{(\boldsymbol{J})}$ of the overhead EUV flux with $\lambda < 102.7$ nm.