Once Upon a Sunspot Number
Ken, 29/06/2007

Following the thinking of Solanki and others, the variability in total solar irradiance has been divided into two contributions: a *cyclic* contribution, describing the irradiance variability over the solar activity cycle, and a *secular* contribution, describing longer-term variability. Having the two separate components makes sense because a plot of irradiance and an activity index shows little sign of a phase shift, which is what we would see if the secular component were continuous with the cyclic one.

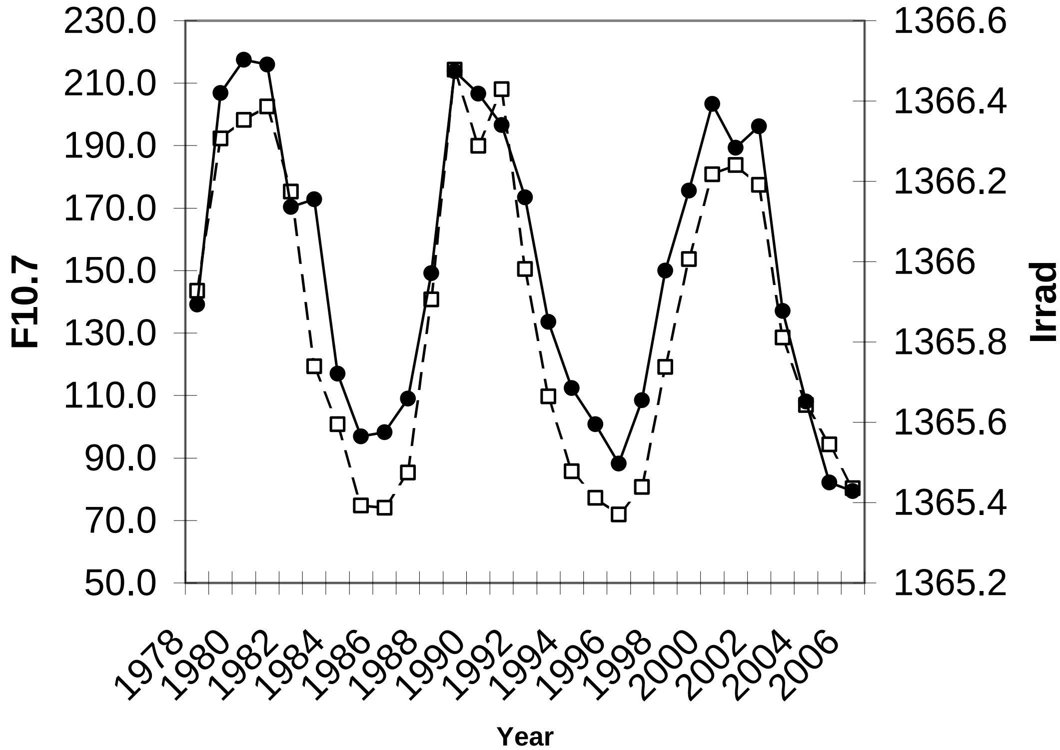

Figure 1: Plot of annual averages of total irradiance and F10.7 against time.

If we are starting with sunspot number (or F10.7) as the input parameter for models, then everything is basically expressed as functions of sunspot number. For example, Lean and others, and we, used sunspot number as the input for the cyclic component and a smoothed function of sunspot number for the secular component. If one is blunt, one has the equation:

$$I(t) = I(t)_{secular} + I(t)_{cyclic} = f(N_s) + g\left(\int_{t-\Delta t/2}^{t+\Delta t/2} N_s\,dt\right)$$

where *f* and *g* are functions of sunspot number and the integral indicates some sort of running mean averaging.

Whether the secular component is photospheric, modulation of energy flow or whatever, the model as expressed above, is still what is happening. If we assume the functions can be expressed as polynomials:

$$I(t) = I_0 + \sum_{i=1}^{\infty} a_i N_s^i + \sum_{j=1}^{\infty} b_j \left(\int_{t-\Delta t/2}^{t+\Delta t/2} N_s\,dt\right)^j$$

If our sunspot number smoothing is done elsewhere, and the running mean is simply put into the equation,

$$I(t) = I_0 + \sum_{i=1}^{\infty} a_i N_s^i + \sum_{j=1}^{\infty} b_j \overline{N}^j$$

Remembering that we are doing a lot of fitting and forming empirical rules, and that, as per Figure 1, the correlation between the irradiance and the 10.7 cm solar radio flux is good, but if you were making an equation giving the cyclic component in terms of F10.7, how many terms would YOU go to? Fitting a straight line got a correlation coefficient of 0.913. Fitting a second-degree polynomial got 0.915. Making it a 5th degree polynomial (augmentio ad absurdum) got a correlation coefficient of 0.92. No matter what your physical model is, if one is starting with a fit to sunspot number, one is not really justified in going beyond:

$$I(t)_{cyclic} = aN_s$$

one just has to bite the bullet and accept that.

Assuming all the cyclic stuff has gone into the cyclic term, we see to it there is no cyclic component in the secular term. Whether or not the physics has any in there, the fitting has included that cyclic variation. Therefore the secular component - as we define it - must not contain a cyclic component. Maybe, seeing that the science as to the Sun’s internal workings is still evolving, we are still left with some informed guessing. How about smoothing sunspot number with some sort of binomial (asymptotes to a Gaussian) weighting to the running mean shows only (say) 1% of the cycle.

No matter what the model is, one step is looking at the irradiance record and trying to get an idea of the baseline, and then "fitting" that somewhere, to that running mean. This is even more problematic that the case of the cyclic component.

Therefore, for empirical models for irradiance, the models, no matter what the origin, reduce to:

$$I(t) = I_0 + a_i N_s + b\overline{N}_s$$

Basically, the Foukal and Lean, Lean *et al.* papers, along with many others, and ours, reduce once one takes the padding away, to the above equation, with *a* and *b* being determined by fits.

Obviously models must have internal credibility and be sufficiently quantitative to get useful numbers.

As long as one uses sunspot number alone, one has the same quagmire to deal with. One needs to fold in other numbers.

Conclusions

Models cannot therefore stand or fall on their fit with three cycles or so of irradiance data. They must start with physics, justify themselves in the physics, and then be fitted to the irradiance, but their fit to the irradiance data cannot be the justification for the model.

On the plus side, it means we probably can use existing models to estimate irradiance for climate etc. investigations, because by the time we've done all the fitting and guessing, all models fit the observations and in all probability, it is going to take a long time to reduce the error bars significantly (more solar cycles).

One the negative side, we will have to start modelling right from the physics and not with indices that correlate with solar irradiance.