From Polar Faculae to Wolfnumber

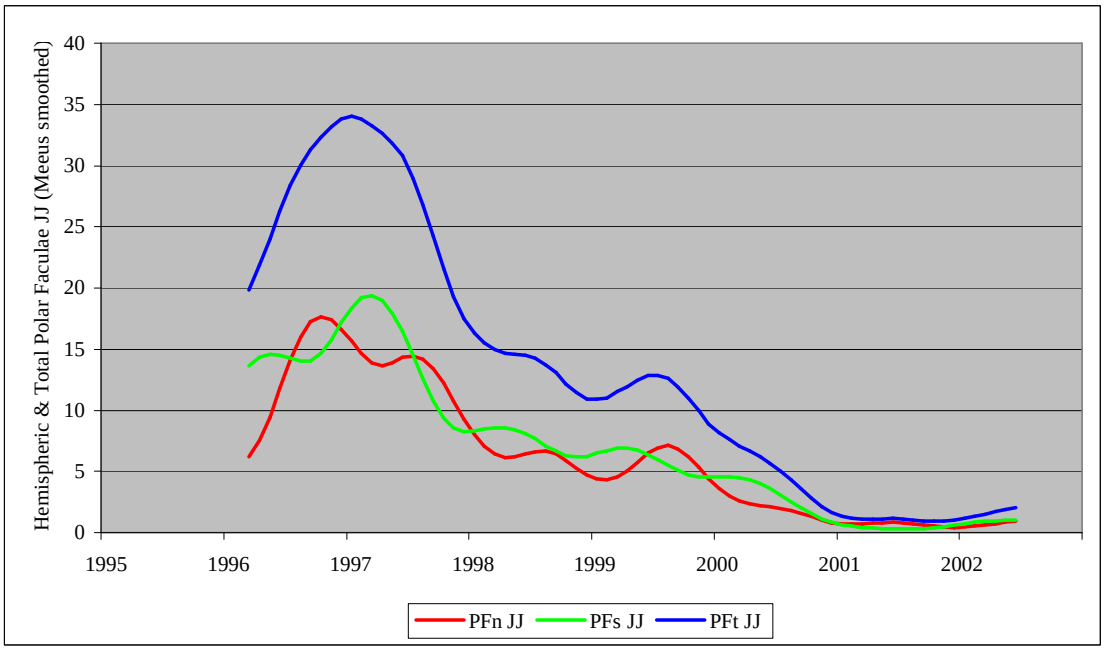
Analysis of Belgian Polar Faculae observations

Ref: 1. Polar Faculae: 1906-1990, N.R. Sheeley, Jr., The Astrophysical Journal, 374:386-389, 1991 June 10
2. Activity Cycle of Polar Faculae, Kejun Li et al., Publ. Astronomical Society of Japan 54, 787-792, 2002 October 25
3. E-mails Kenneth Schatten, Neil Sheeley, Jan Janssens in Apr-Aug 1998
4. Solar Astronomy Handbook, Ch. B.6.3.7.4. pp. 296-297, Beck et al., 1995

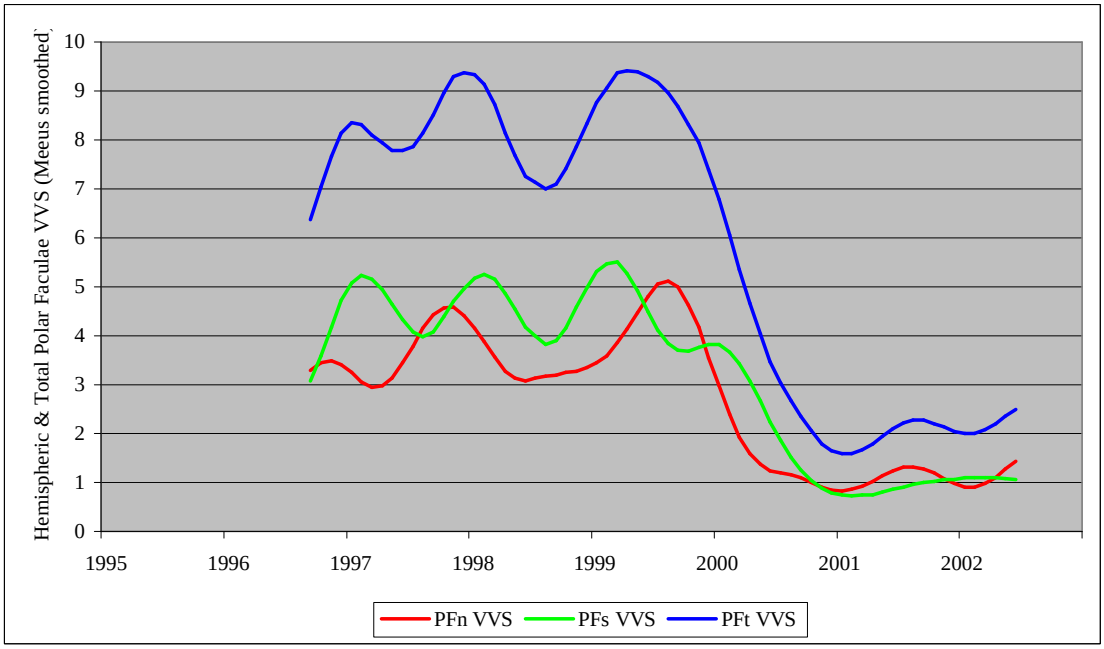
The obvious goal of polar faculae observations is to use the results in a forecasting method for the upcoming solar cycle maximum. This is based on the assumption that according to the solar dynamo model, first signs of the new cycle occur at the poles (polar faculae), then high latitude faculae and chromospheric activity and finally the appearance of sunspots at gradually decreasing latitudes.

Early 1998, I had sufficient data to cover a PF (Polar Faculae) maximum period. Starting with PoF observations in August 94, using a 6 cm refractor, I continued as from September 95 with a Celestron 8" (68x, Glass 1000 Oaks objectif filter, Blue ocular filter). From July 96 till June 00, observing was done from San Antonio, TX, USA. Observing conditions were considerably better during this period (seeing between 3.5 and 4 year round, while before and after around 3). Note all values are determined or smoothed on a monthly base.

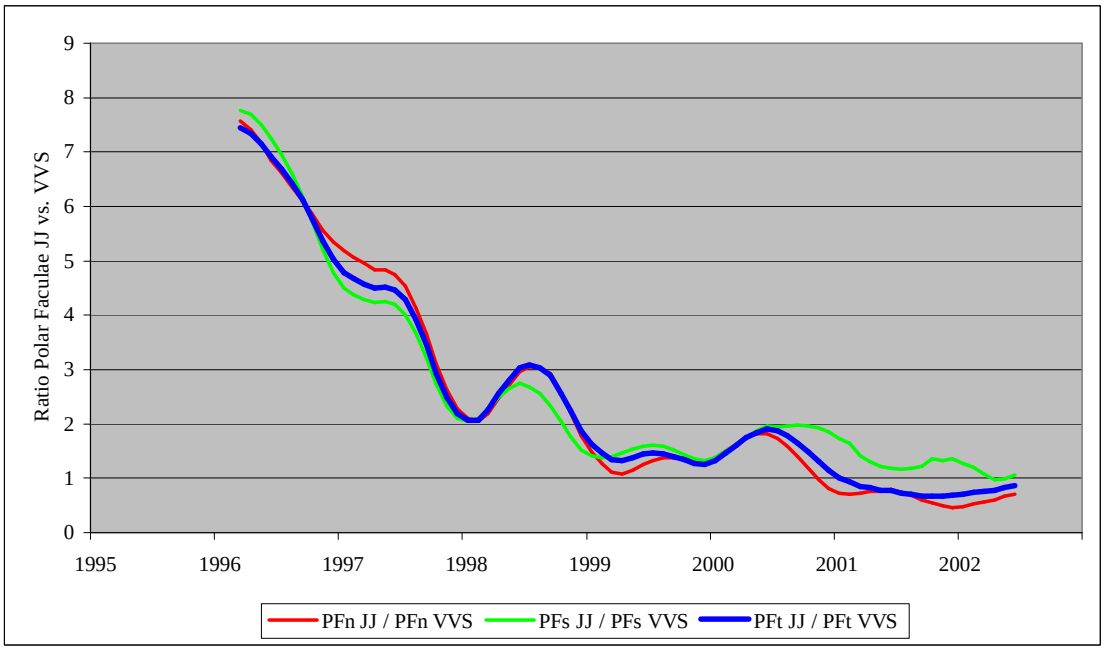
Hemispheric and total PoF-numbers were determined throughout this period, no positions or faculae life times. The results can be found in the chart underneath (C8-observations only). A Meeus-smoothed PF-maximum can be seen to occur at January 1997 (34,06). Seasonal variation is noticeable in the hemispheric numbers, with PFs (south) slightly more intense. Notice the smoothly rounded maximum, the sudden decrease in late 1997, the "bump" mid to late 1999 (northern hemisphere: time of magnetic field inversion at poles!), and the fact that the PF-numbers did not went down to 0 during the years of solar cycle maximum.



Meanwhile, the Solar section of the VVS (Belgian Astronomical Association) started the PF-observing program in March 1996. The result is reproduced in the chart underneath, and is based on the data that you can find on the Solar section's website: http://www.digilife.be/club/franky.dubois/polar.htm . The 3 peaks are prominent, but so are the very low PF-numbers recorded (Y-axis). My feeling is that a grace period of about 1-2 years (pending amount of observations) must be taken into consideration before reliable numbers can be reported. In our solar section, only Franky Dubois pulled this of. Hence, global VVS-values may show "learning"-effects till early 1998. Note possibility I may have overcounted PF in my initial years due to good seeing!

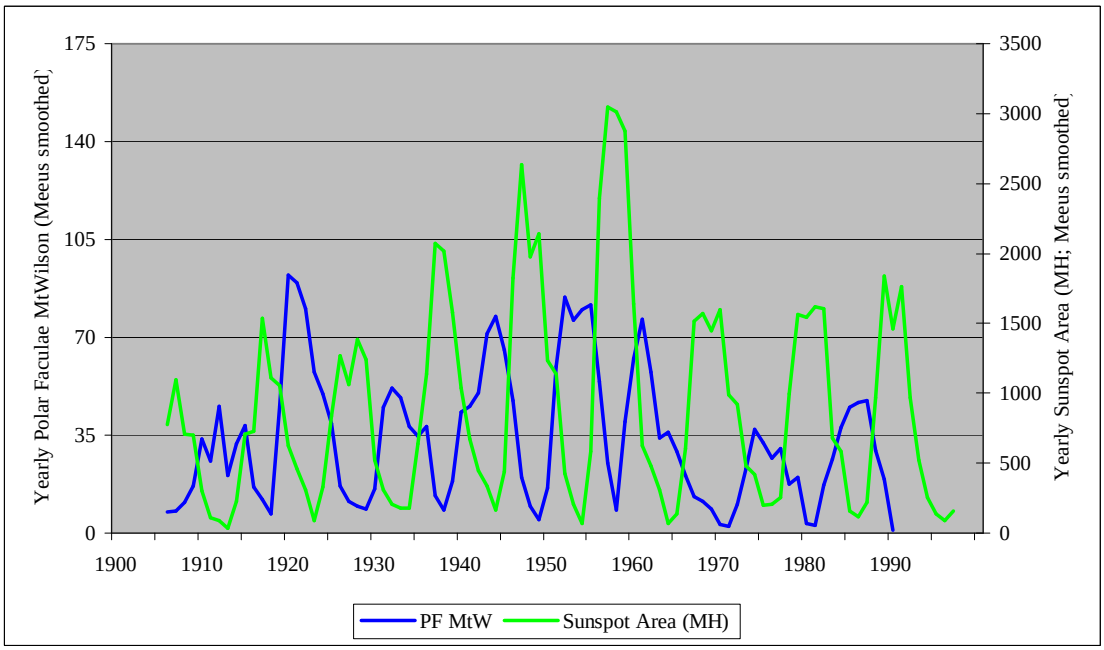


In order to check this, chart underneath represents the ratios of my own observations compared to the PF-numbers as reported by VVS/Solar section. As can be seen,



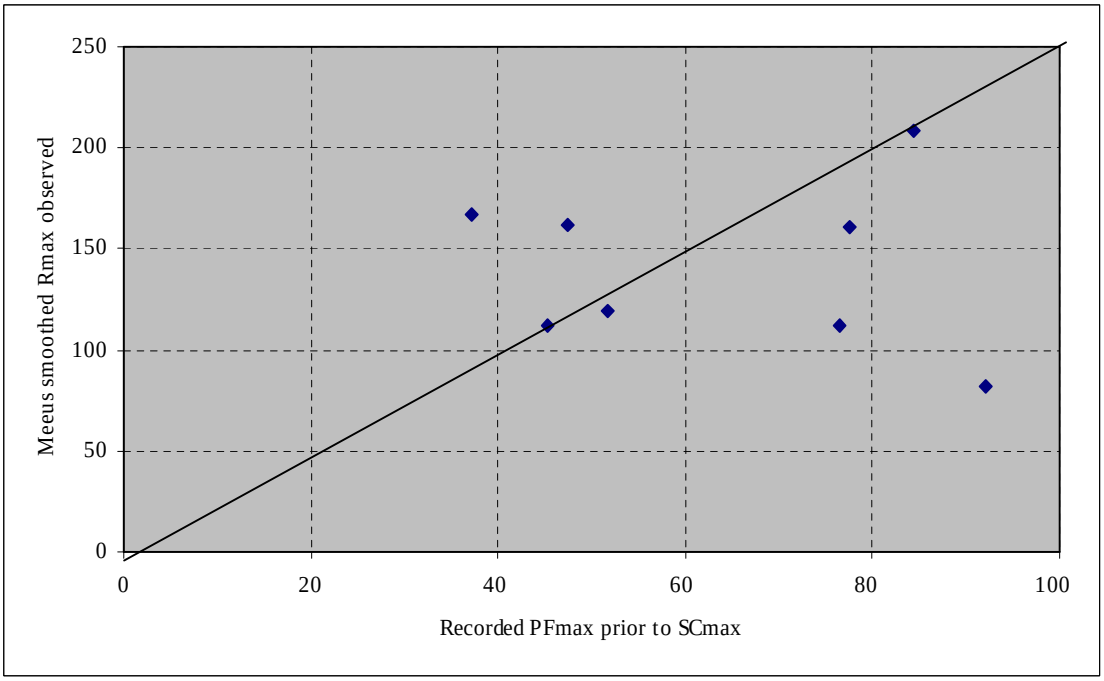
from 1998 onwards, this ratio fluctuates around 2. That as from 2001 this ratio becomes less than 1 (meaning VVS observes more PF than JJ), is entirely on my account. Indeed, from December 2000, I moved to an appartment with view on the East. The combination of less observations with poor seeing conditions is detrimental to accurate PF-numbers. Also, I do not count PF at moderate latitudes (50° or less), which were occasionally observed over the last 2 years. Nonetheless, as from 2001, I do consider PF-values from VVS of a superior quality as my own. My feeling is that for the past PF-maximum, my own observations are best. This is why I'm still using these observations to represent PF-evolution the solar section's "Solar Cycle Tracking page" (http://www.digilife.be/club/franky.dubois/tracking.htm), and why I will use these data in the subsequent discussion.

My last analysis (aside regular updates for the tracking page) dates back from april 2000. I did try to make forecasts in the 1998-timeframe (Ref 3). Unfortunately, there were only yearly PF-numbers available (actually 1 value per season/hemisphere), and there were no data after 1990. Analysis of these data send to me by Neil Sheeley, resulted in the next charts.

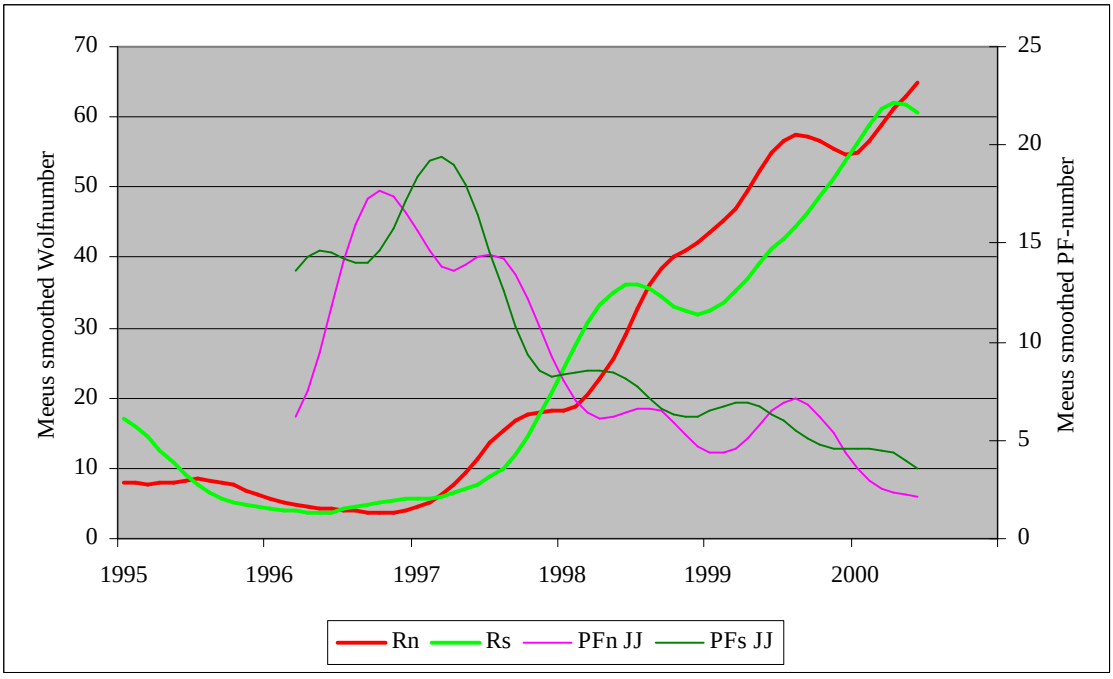


The conclusion's that can be drawn from the above chart, are essentially the same as mentioned in Ref 2 paper (Fig 3). Though maximum PF-numbers do occur at cycle-minima, there most certainly is not a one-to-one correspondance between maximum PF-numbers and solar cycle maxima. High solar maxima can follow PF-cycles that are either weak or strong, and vice-versa (see next chart). There is also no obvious "attractor" to be found. I tried to find a better relation between the 2 parameters by using Rmin, area values up to 2 foregoing cycles, time distance between Scmin and Pfmax (in years...),... but to no avail. I strongly suspect all this is due to the use of only yearly numbers, and the influence of remanent magnetic fields of the previous solar cycle. As I'm writing this, I also suspect the tachocline variation may be a player in this by weakening/enhancing the existing magnetic surface fields. From solar flare fluence studies, it appears to me that the 14-month period is not constant, but changes from one solar cycle to the other. This is however a story altogether different, and besides, I have not find time to include this in my forecasts. Neither did I make charts to compare the evolution of the hemispheric PF-numbers with sunspot areas. This is the by the

way the reason why I used area-numbers: there do not exist longterm official hemispheric Wolfnumbers to compare the PF to.



From the above, I simply did not have the right data to make any forecasts for the upcoming solar cycle maximum. I undertook my final attempt around mid-2000, when there were some discussions if solar maximum would have already taken place late 1999 (Dick Altrock). At that time, more Wolfnumbers were available. So if the sunspot-cycle was to some extent going to mimic the PF-cycle, I could make a forecast based on just part of the sunspot-cycle so far.



From the above graph, 2 features are significant. The first is the standstill in the southern hemisphere's activity, both in PF (mid 1996, assuming this was not based on erroneous observation of my own...) as in Wolfnumber (mid to late 1998). The other one is the seasonal variation of the PF that tends to blur global evolution.
So, in a first step, I removed all PF-values that did not belong to a 4 month period centered on the season for which each hemisphere was best suited for observation. In clear, it means I only used the May-August PF-values for the northern hemisphere, and November-February PF-values for the southern hemisphere.
I then calibrated my forecast on the "stand-still" feature using a simple parabolic formula:

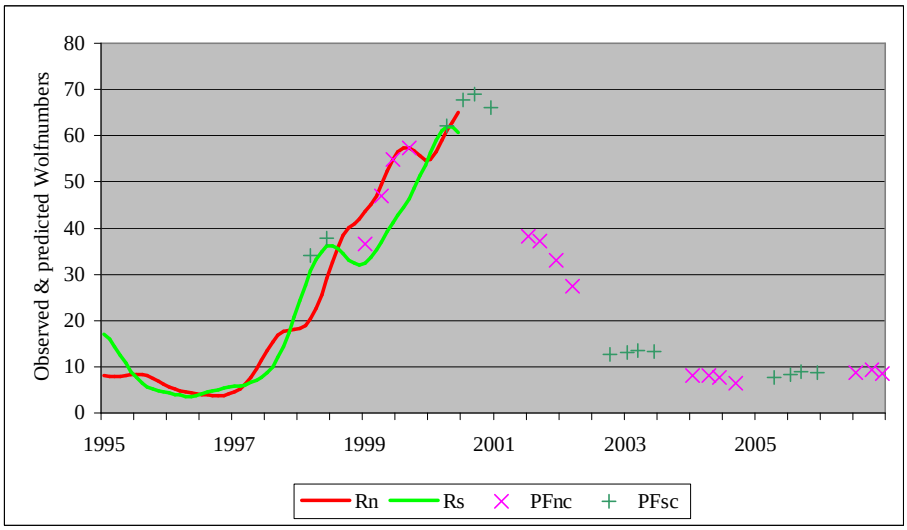
$R_{ic} = 0.1387 * (PF_i)^2$,

with "c" standing for "calculated", and "i" being either n or s (north or south). The value 0.1837 was slightly finetuned to also match some features on Rn-evolution. I used a square and not a linear approach, because it's my feeling that magnetic fields tend to enhance each other more than just adding up.
In order to calculate timings for the different PF-values, I assumed the "true" PF-cycle started in mid-1995 (start increase PF-numbers: just a hunch, no observational support!), and ended around mid- to late 1999. I did this for a mix of reasons. Most notably of course the evolution of PF-values, and my assumption that the poles "deliver" some mass of magnetic field during a few years and then keep quiet (so PF activity after 2000 is just some background-scatter). Today I believe there may be a true physical reason, which is that this timeframe coincides with the time of the magnetic field reversals at the poles! Anyway, this corresponds to a "true" PF-cycle of about 4 years, that has to be matched with an average solarcycle length of 11 years. I used the resulting factor (2.5) in the following formula:

$T_{new} = 1996.55 + 2.5 * (T_{old} - 1995.55)$,

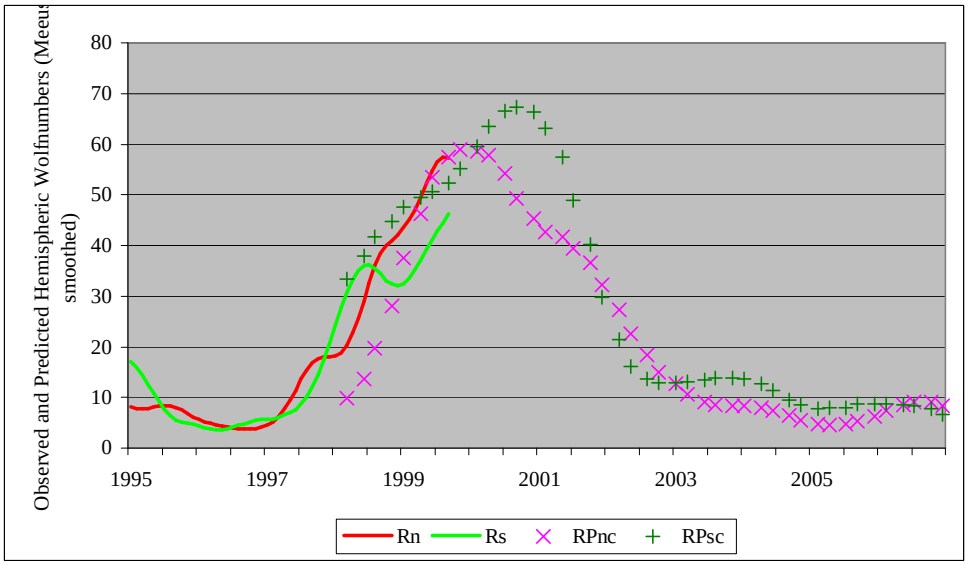
with T_{old} the timing for which the PF-value is known, and T_{new} the resulting time in the sunspotcycle. 1996.55 corresponds to SIDC's calculated sunspot-minimum (their calculation takes into account that cycle-rise is at a faster rate than cycle-decrease, an effect the smoothed formulaes can not acount for). Anyway, the formula gives an optimum match for the "stand-still" feature on the southern hemisphere.

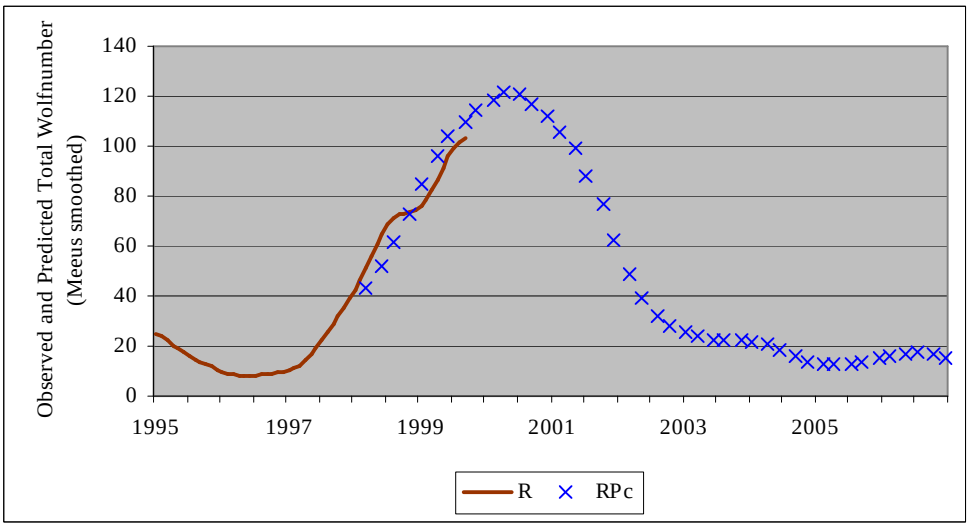
Applying the foregoing formulaes on the reduced data, results in the next chart:



In order to get total Wolfnumbers, I took just the PF-value for the other hemisphere at that time. E.g. for the spring-values of PFs, I took also the corresponding PFn, then applied the same formulae (see above). Of course to get true Wolfnumbers (they are not hampered by tilting of the solar axis, angle B), I had to compensate for the varying hemispheric area. I based my formula on the assumption that most polar faculae appear at 70° latitude (Ref 4, and my own observations). I need to take a good look again at my notes how exactly I did it. From a first look, it does not seem evident (so, no guarantee it used the correct "correction"-formulaes).

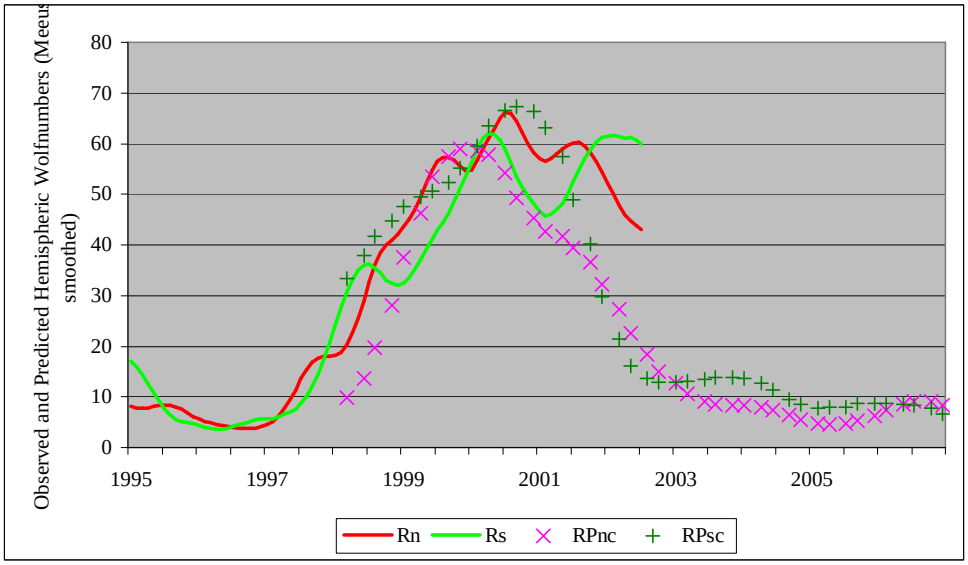
Applying these, resulted in the next 2 graphs (one for hemispheric, one for total Wolfnumbers). I was disappointed by the "disappearance" of the stand-still feature on the southern hemisphere, the time-lag of the predictions for the northern hemisphere in 1998 & 1999, as well as the much to sudden drop to very low levels as already from 2002. However, I did not search anyfurther, because the total Wolfnumber corresponded very well with the v18 prediction method (Rmax predicted = 120 +/- 21, 90% correlation with previous cycles). As I obtained the value of 121.2 around April 2000, I left it there.

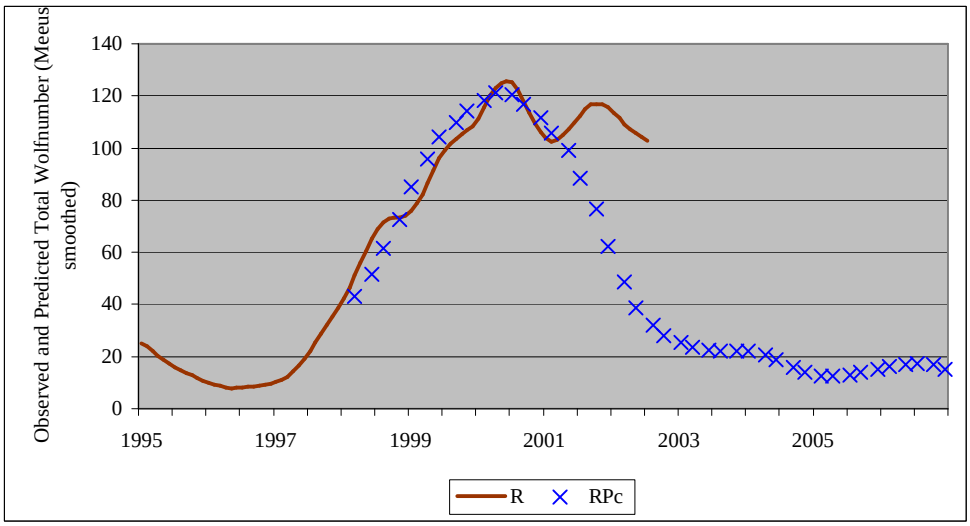




The next 2 charts show how solar cycle activity (Wolfnumbers!) evolved over the next 30 months (Wolfnumber-data till January 2003 included). The solar maximum occured in June 2000, at 125,60. That seems really good, but it do consider it more as some luck due of course

to the disagreements with hemispheric numbers and the fast drop off. I will cross-check with solar flare fluence.





My feeling is that the sudden drop-off is a correct representation of solar activity induced by Polar Faculae/Magnetic fields, but that as the hemispheric spotzones wander gradually closer to each other, I think they start influencing each other, and as such creates additional activity that would otherwise not be possible. Several other explanations are possible.

In the near future (late this year at the earliest), I will reanalyse the entire data-set (of myself, and of VVS), to which I will add data-analysis of SOHO and BBSO. I'll also try to incorporate some formulaes to include other effects (e.g. post-maximum evolution). All this of course to get a better handle on the prediction of solar cyle 24. Some observers are considering to make position measurements and lifetime studies of polar faculae during the upcoming cycle. This will add to our understanding of PF-behaviour and solar dynamo.

Jan Janssens
03 Feb 2003