Polar Fields and Solar Cycle 24
(Observational Study)

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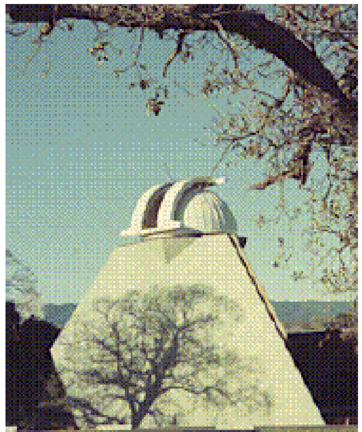
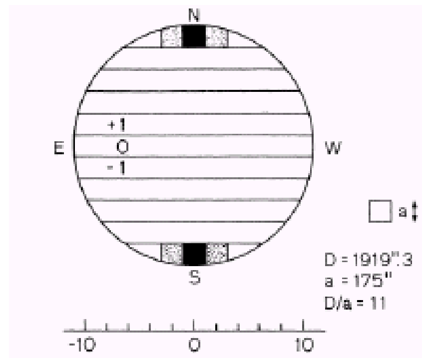
Boulder, Oct. 2006.

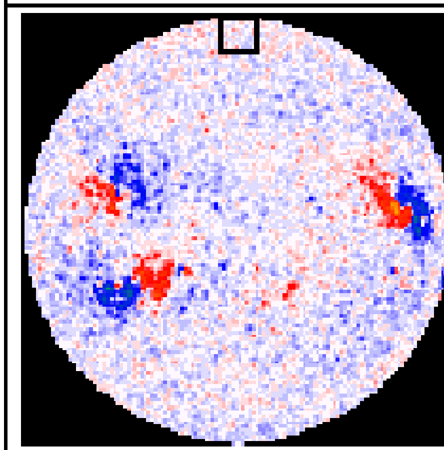




Wilcox Solar Observatory (WSO)

Large aperture: 3’

Operational Definition of Polar Fields:
Average field in pole-most apertures (black squares)

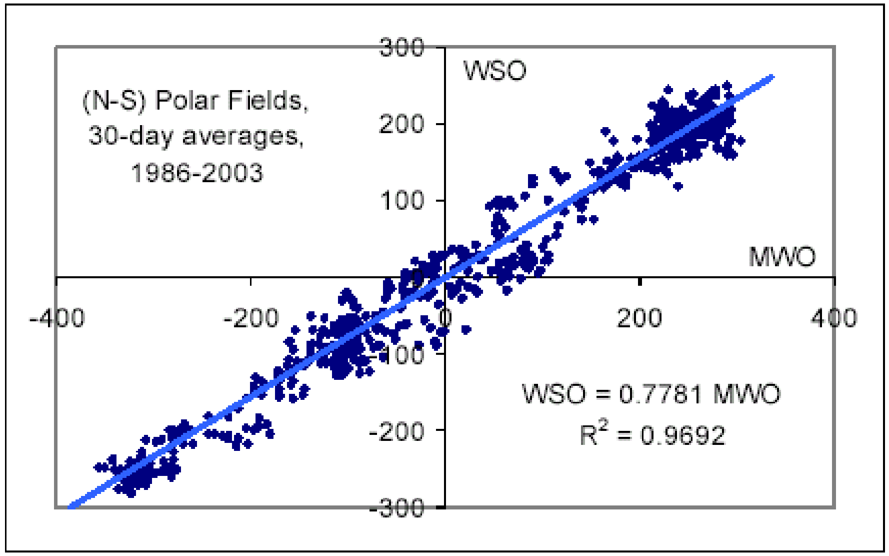


Mount Wilson Observatory (MWO)

Small aperture: 0.2’

Operational Definition of Polar Fields:
Average field of pixels inside aperture that matches that of WSO

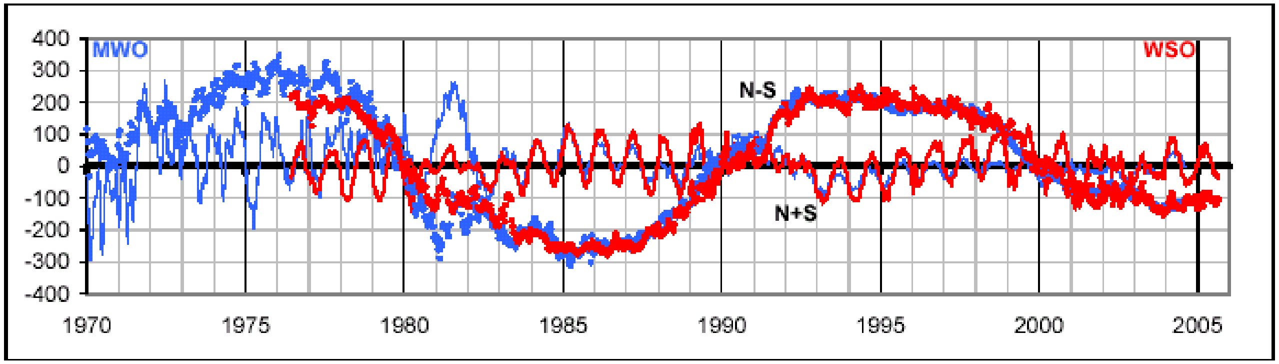
Definition of Solar Polar Fields



A measure of the "dipole moment" is the difference between the polar fields in the two hemispheres (North and South). Taking the difference also compensates for zero-level errors. In spite of the difference in apertures (3' for WSO and 0.2' for MWO), the two observatories agree very well ($R^2 = 0.97$). Before the upgrade of MWO in late 1985, the relationship was different: WSO = 1.325 MWO.

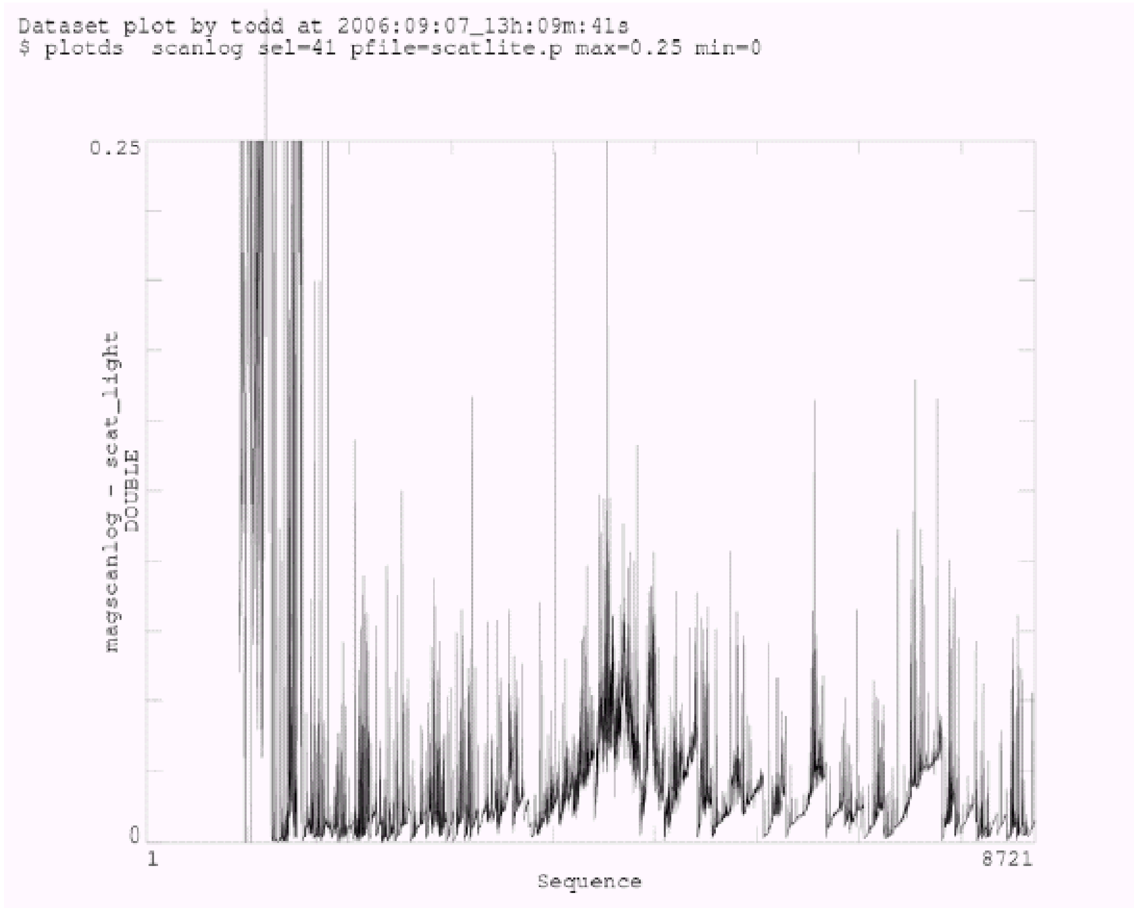
Comparing MWO and WSO Polar Fields

We can now reduce MWO polar fields to the WSO scale. Before 1983, MWO is noisy and has at times large zero-level errors. Before 1980, WSO suffered from scattered light (dirty optics!). So, early data before 1983 are less reliable. From 1986 on, the two observatories agree closely. Here we show the difference (N-S) and the sum (N+S) of the polar fields:

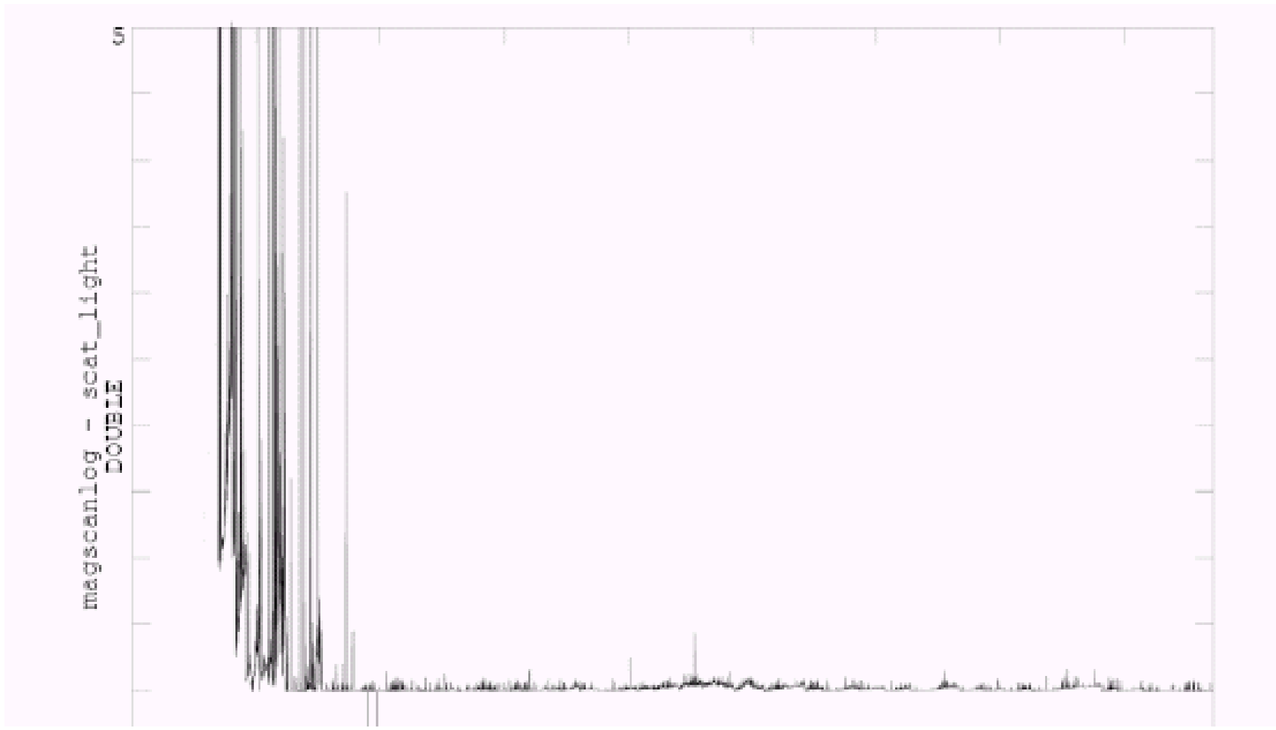


The difference (N-S) shows a measure of the dipolar fields because the annual modulation cancels out, while the sum (N+S) shows a measure of the annual modulation because the solar dipole cancels out. Just after dipole reversal, the annual modulation is not present, but as we approach sunspot minimum (where the dipole is strongest), the modulation sets in.

Four Cycles of Directly Observed Dipole Strength



Scattered Light at WSO (2’ off the limb)



Scattered Light at WSO was high during the early two years.

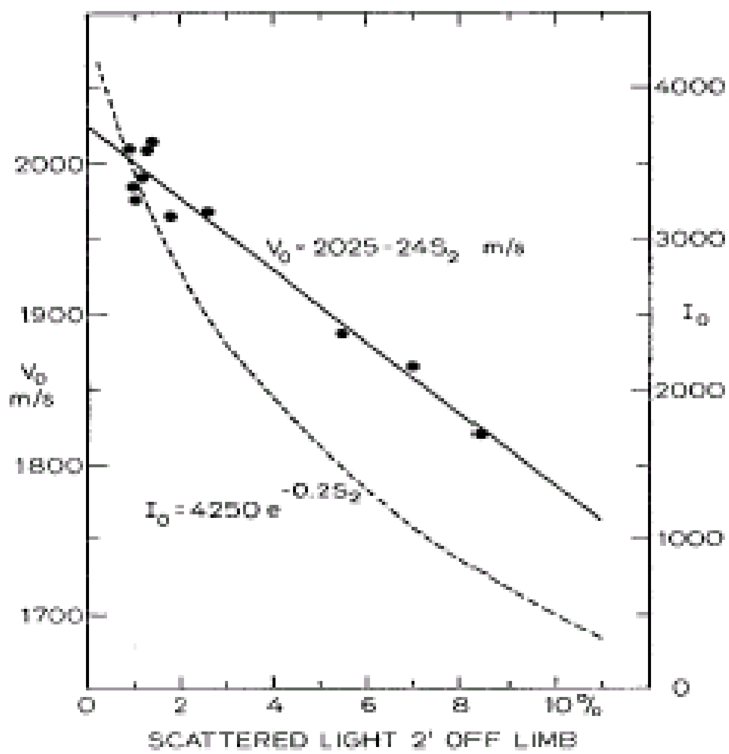
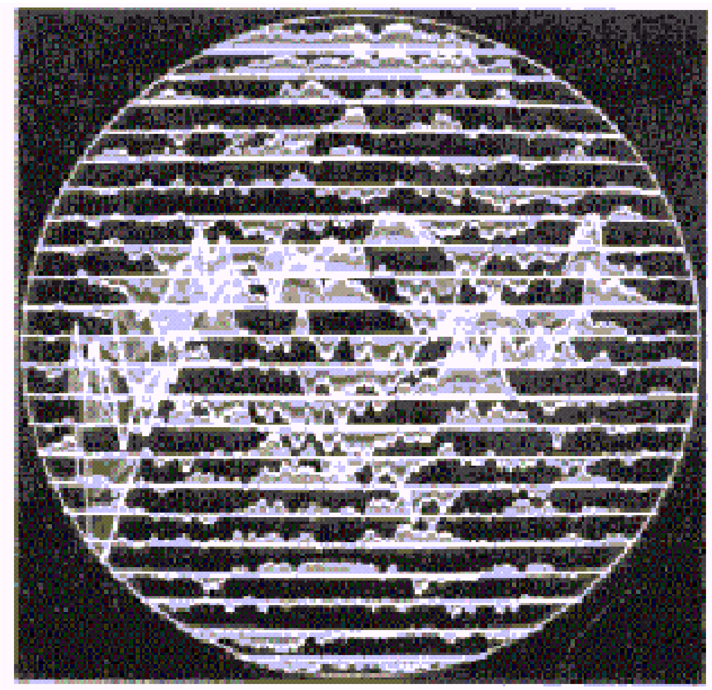


Fig. 2 Equatorial rotation velocity V_0 and intensity at the center of the disk I_0 as a function of scattered light measured 2' off the limb. The amount of scattered light was varied by putting fine chalk dust on the objective lens.

Scattered light **reduces** the observed polar fields because it mixes in light from non-polar regions.

Experiment can show by how much. Left is the result of a similar experiment for the speed of the rotation.



MWO magnetogram ca. 1953 by the Babcocks.

The scale is such that the distance between the lines corresponds to 2 Gauss (200 microTesla [uT]) at the limb.

Note the strong (~150 uT) fields in the polar caps.

Observed polar fields prior to cycle 19 were very strong.
The heliospheric current sheet was very flat (corona, missing sector structure, cosmic ray diurnal variation).

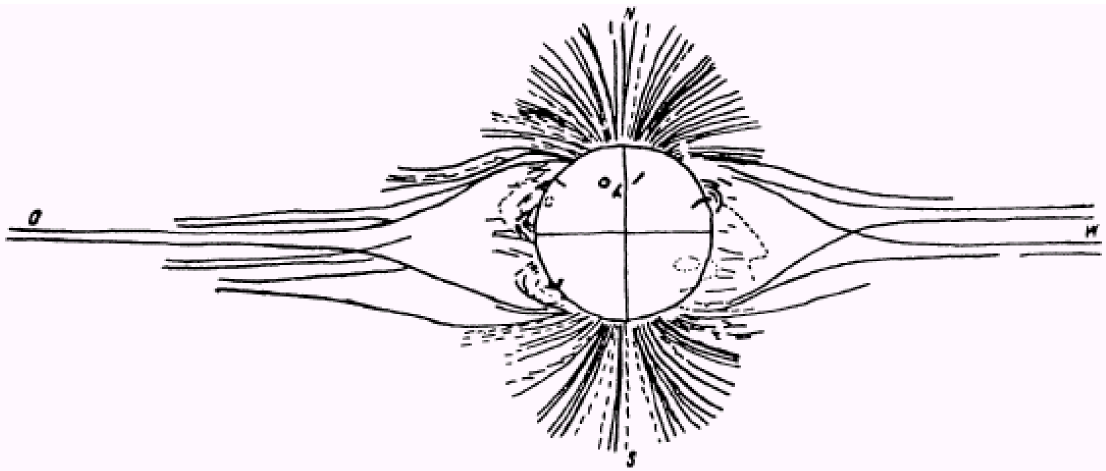
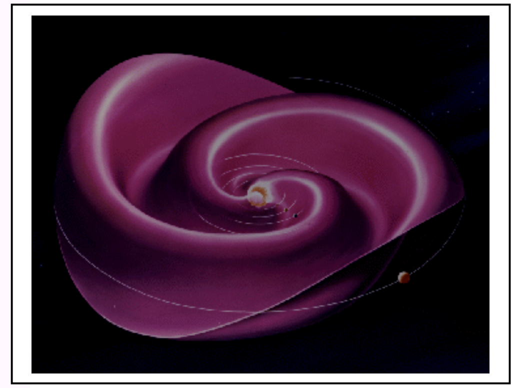
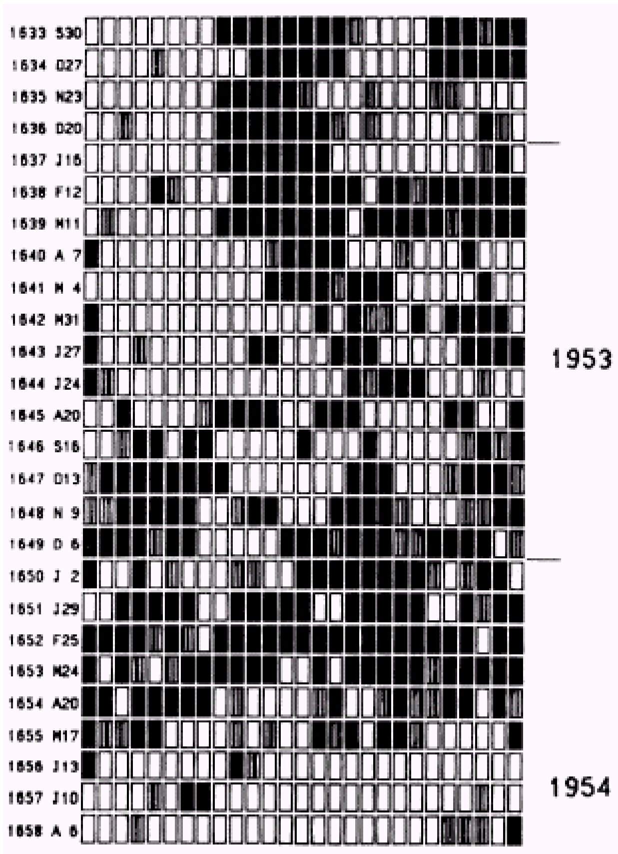
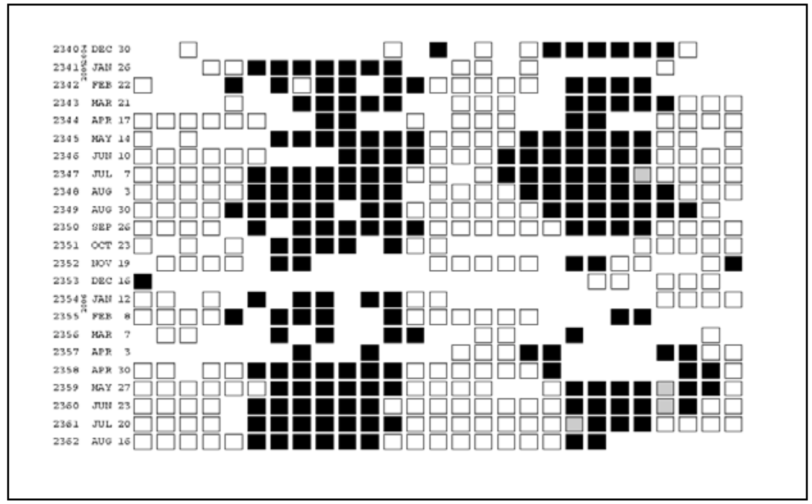


Figure 2 Drawing of the corona at the June 30, 1954 eclipse near sunspot minimum. This drawing clearly shows how the structures extend to lower heliographic latitudes with increasing radial distance (Vseskhsvjatsky 1963).

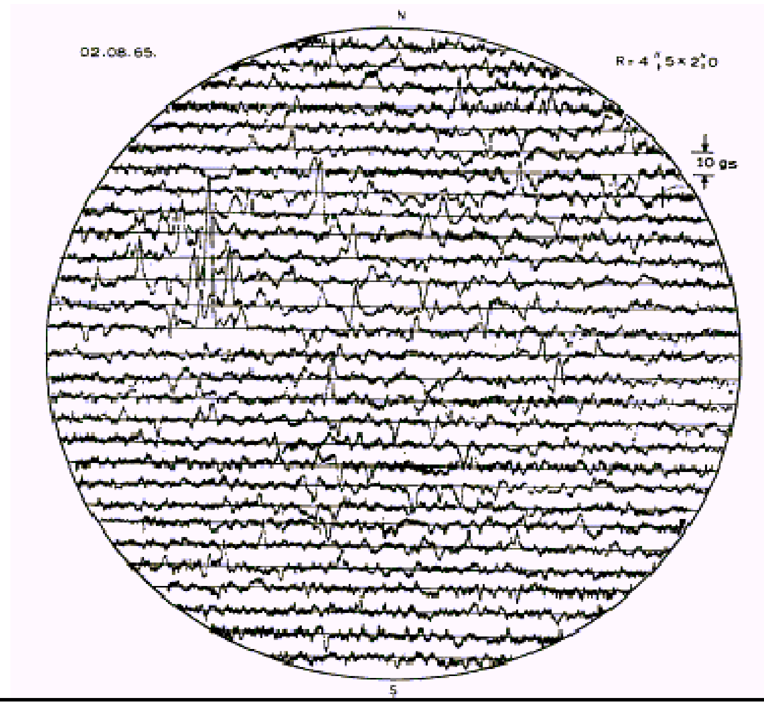


When the Earth is completely above or below the current sheet for a full rotation, the sector structure disappears.





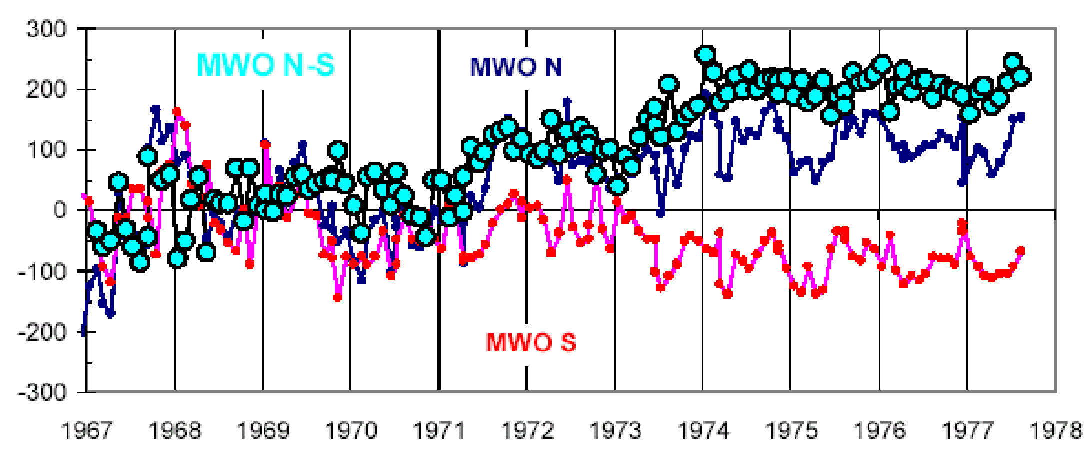
Sector polarities inferred from geomagnetic data and (above) from solar mean field data



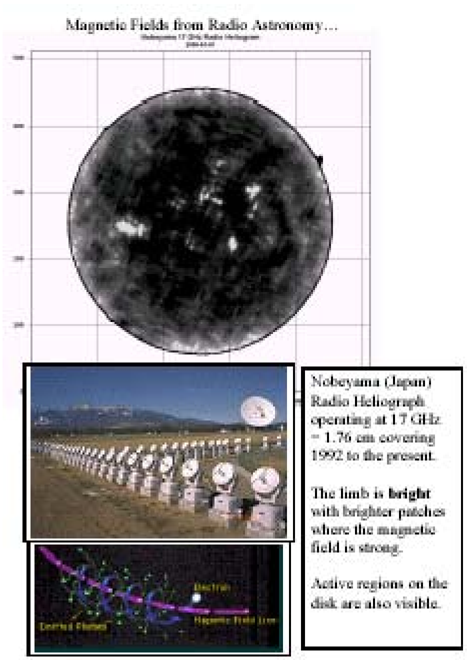
Crimean Astrophysical Observatory magnetogram 2 Aug. 1965. Distance between the lines corresponds to 10 Gauss (1000 microTesla [uT]). Note the very weak (<~100? uT) fields in the polar caps.

Very weak polar fields before cycle 20.

What about the polar fields observed at MWO before 1970?

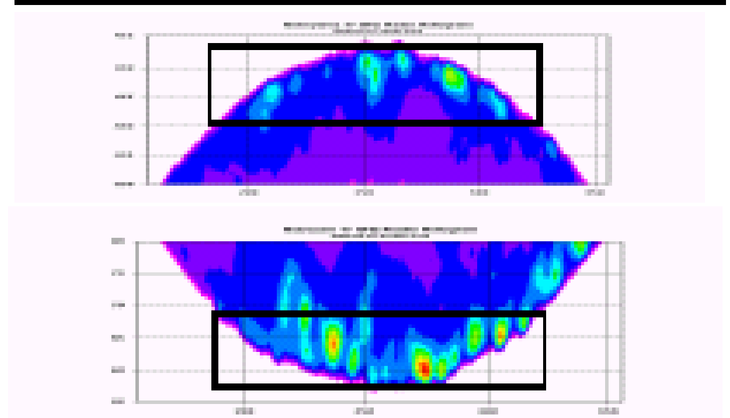


The MWO data before the polar field reversal in 1970 was very noisy with significant zero-level errors. The ***difference*** between the North polar fields and the South polar fields is less sensitive to zero-level errors. It seems that the polar fields 1967-1968 are weak, consistent with the fields being weak for the minimum before cycle 20.

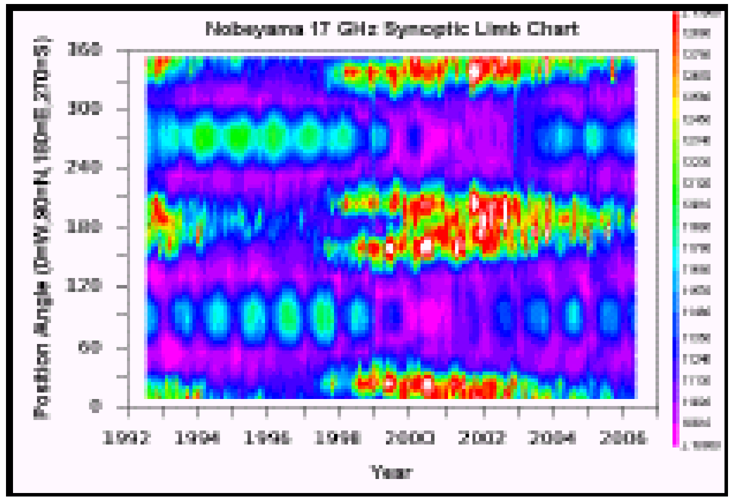


Polar Faculae can be observed at 17GHz radio waves.

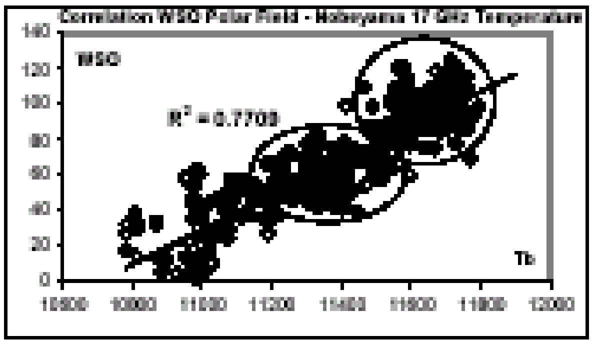
Close up of Northern and Southern polar regions



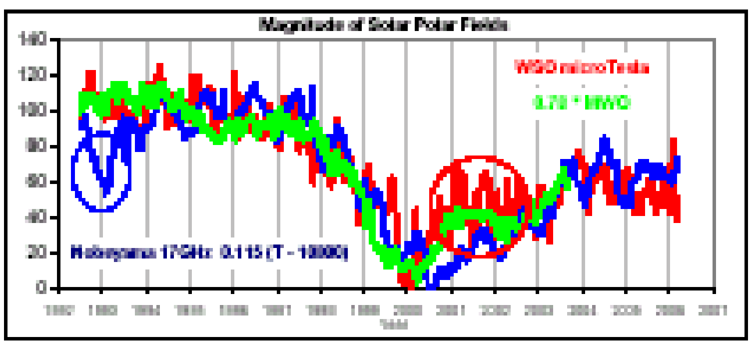
Here is how the patches evolve over time. Note the annual modulation and also the usual active region areas.



The bright patches are locations of strong *magnetic* fields. Brightness integrated over WSO aperture correlates strongly (correlation coefficient R = 0.88) with strength of magnetic field measured over the aperture (averaged over a rotation). Note the clustering for data near the current and the previous solar minima.



To eliminate the annual modulation we have averaged the North and the South. We can now convert the temperature (using the correlation) to a magnetic field and compare directly with measurements from WSO and MWO:



The polar faculae count has a strong correlation with the polar magnetic field (simply different manifestations of the same phenomenon?).

This is independent confirmation of the difficult magnetic measurements. Since the radio flux is an integration along the line-of-sight, we see the flux best when we see the magnetic flux the worst.

We also see the same annual modulation.

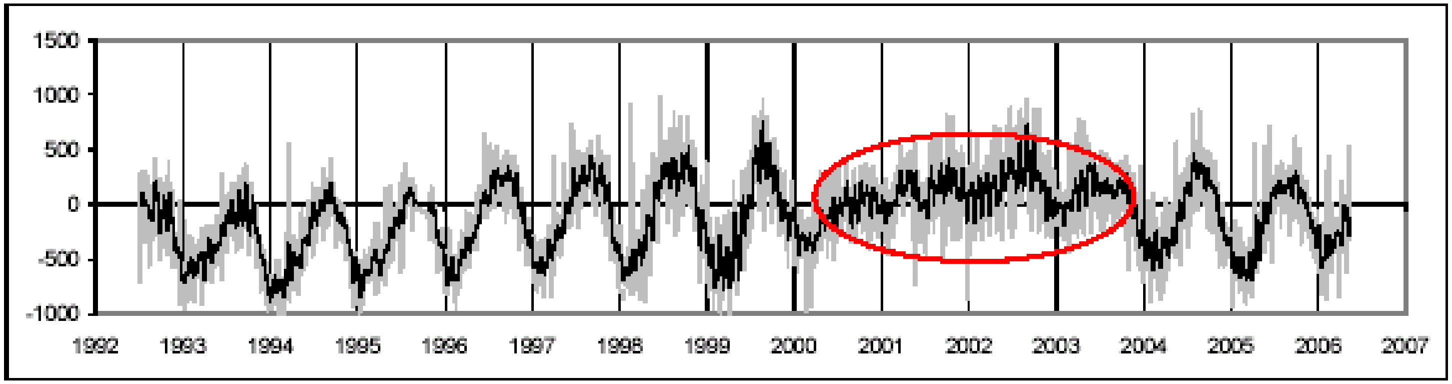
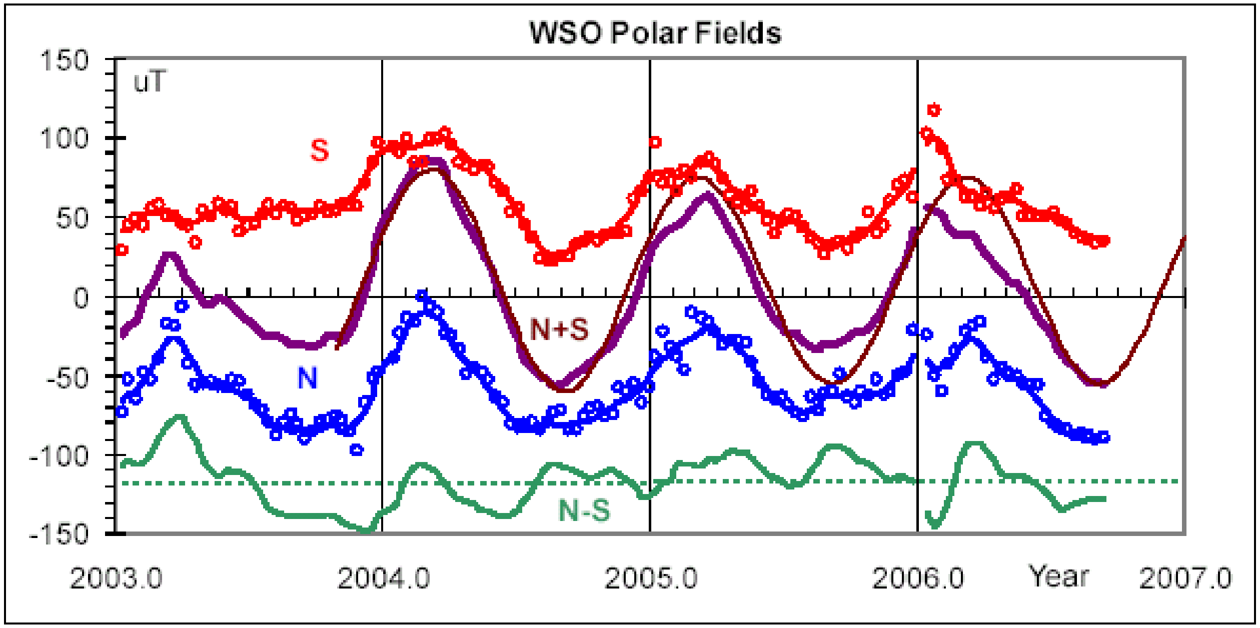


Figure 2. Difference, T_BN - T_BS, between daily values of the Nobeyama 17 GHz (R+L) emission brightness temperatures (light-grey curve). The 11-day running mean (offset 11 days as in Figure 1) is shown with a black line. The time of polar field reversal is indicated by the red oval.

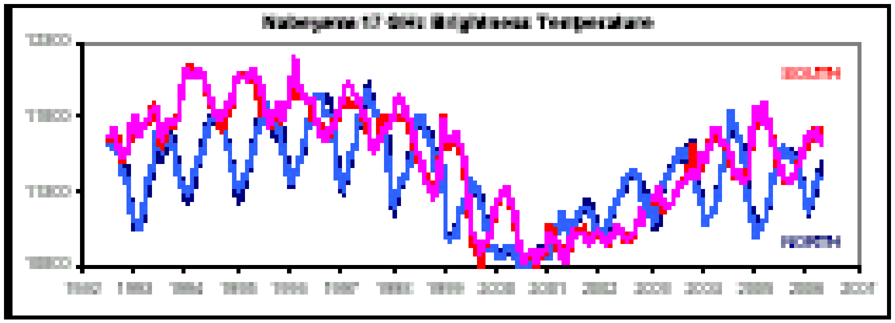
The annual modulation is probably caused by a "bunching up" of flux due to the meridional circulation and may be a proxy of the strength of the circulation.

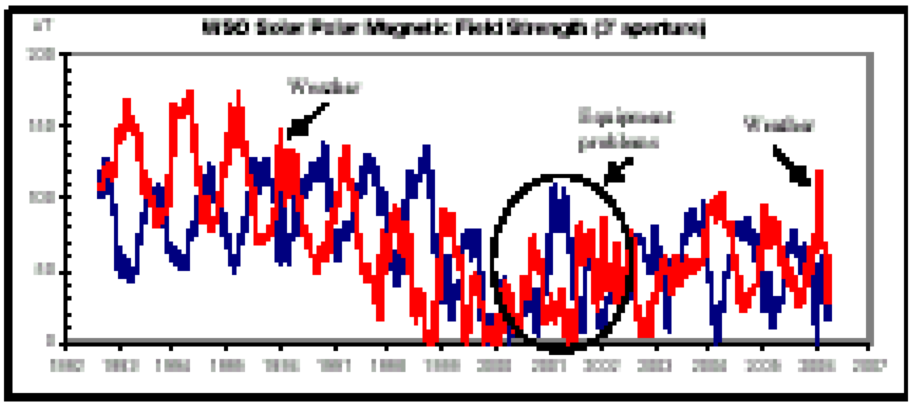


This is what the modulation looks like in the magnetic field. We take the onset of the modulation as a sign that stable polar fields have been established.

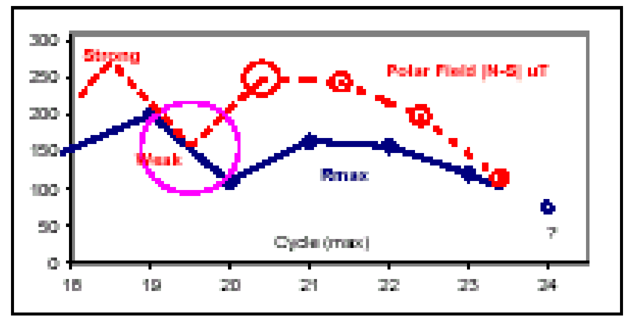
The radio data thus serves as an independent check on the (difficult) optical magnetograph data and confirms the weakening of the polar fields leading up to cycle 24.

The annual modulation rather than being a nuisance gives us an extra degree of freedom and carries additional information. We can compare with the modulation measured at WSO:



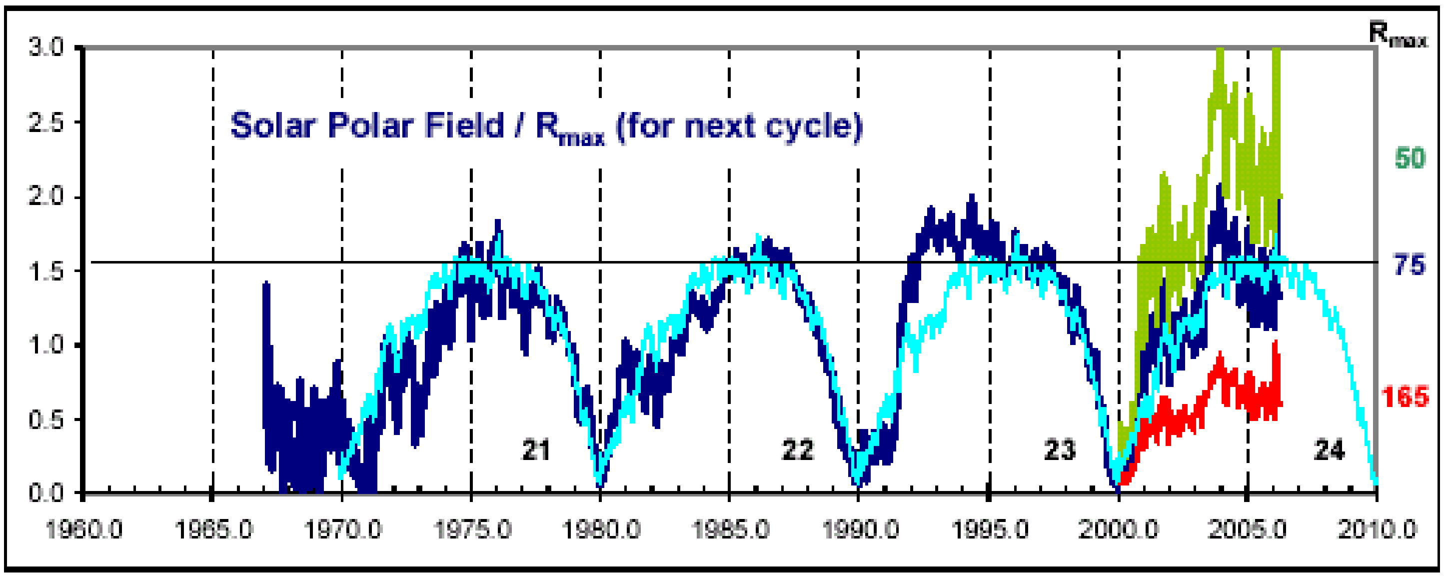


There is little doubt that the polar fields right now are the weakest ever directly observed.



This is the observational fact on which we base our prediction of a weak cycle 24.

How weak?



Normalizing each “polar field cycle” [from reversal to reversal] by the size of the following cycle leads to similar looking curves. $Rmax_{24} = 75$ brings the current cycle into line with the previous cycles.