Prediction of Solar Cycle 25

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The Origin of the Polar Field Precursor Method

USING DYNAMO THEORY TO PREDICT
THE SUNSPOT NUMBER DURING SOLAR CYCLE 21

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Abstract. On physical grounds it is suggested that the sun's polar field strength near a solar minimum is closely related to the following cycle's solar activity. Four methods of estimating the sun's polar magnetic field strength near solar minimum are employed to provide an estimate of cycle 21's yearly mean sunspot number at solar maximum of 140 ± 20. We think of this estimate as a first order attempt to predict the cycle's activity using one parameter of physical importance based upon dynamo theory.
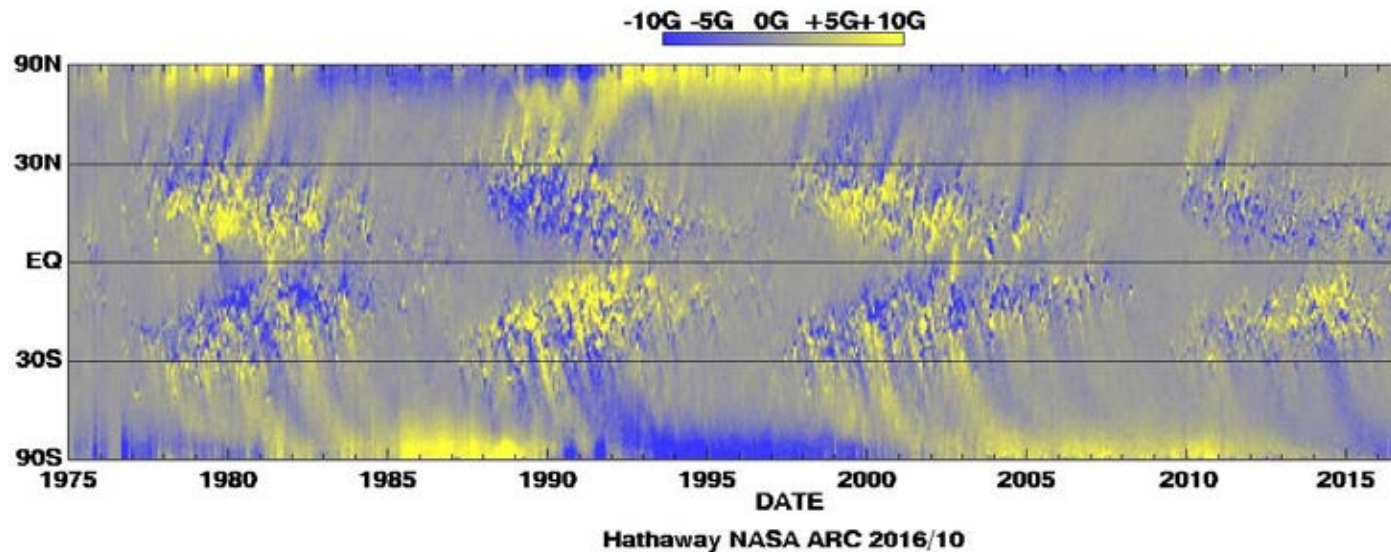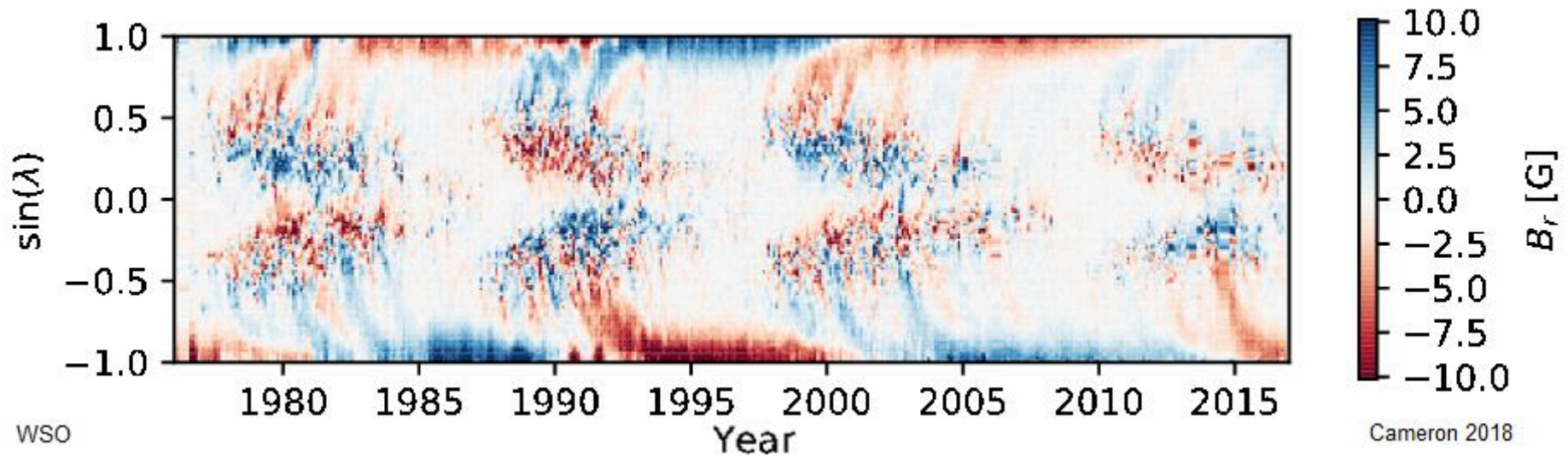
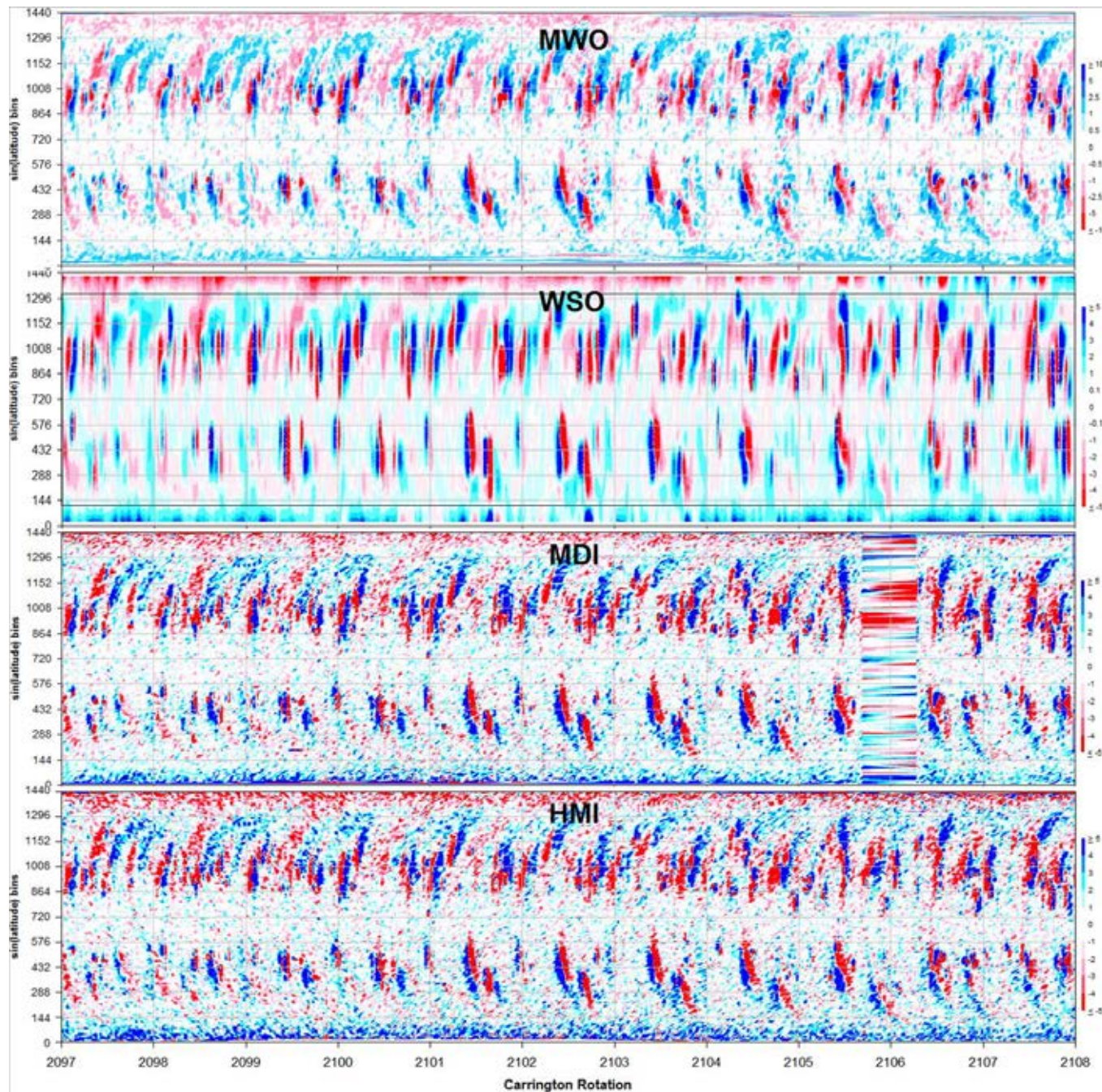Was 165

The Authors One Cycle Ago

SPD 2009

Scherrer

Svalgaard

Schatten

Wilcox

Standard (but Misleading) View of Magnetic Fields Migrating to the Polar Regions

WSO

Cameron 2018

Hathaway NASA ARC 2016/10

Zonal averages in time producing broad uni-polar migrating areas

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Super-Synoptic Maps show what is really going on: The flux is concentrated in narrow 'streaks' and the two polarities move together

The maps are shown for the period of overlap of MWO, WSO, MDI, and HMI

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This is No News, of Course

B.1   <u>Polar Crown Filaments and the Polar Magnetic Field</u>, K. TOPKA and R. L. MOORE, <u>Caltech, BBSO</u>, and B. J. LABONTE and R. HOWARD, <u>Mt. Wilson Obs., Carnegie Institution of Washington</u>. We report on the results of a follow up study to the recent results of Howard and LaBonte (submitted to Solar Physics) concerning the evolution of solar photospheric magnetic fields ....

conclude that the observed behavior of polar crown filaments during the solar activity cycle supports the results of Howard and LaBonte in that the solar polar magnetic field arises from discrete injections of field from active region latitudes and that there exists in the s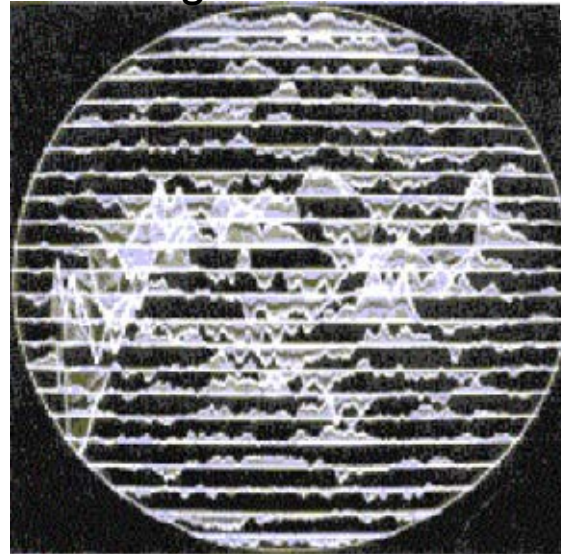un a meridional flow. We further conclude that magnetic field of <u>both</u> polarities must be migrating poleward, but that the following polarity dominates slightly.

SPD Meeting, 1980, BAAS, 12, 893, B1

Early MWO Observations

after Babcock Invented the Magnetograph "by doing everything right"

Strong Polar Fields

Weak Polar Fields

Mt. Wilson Observatory
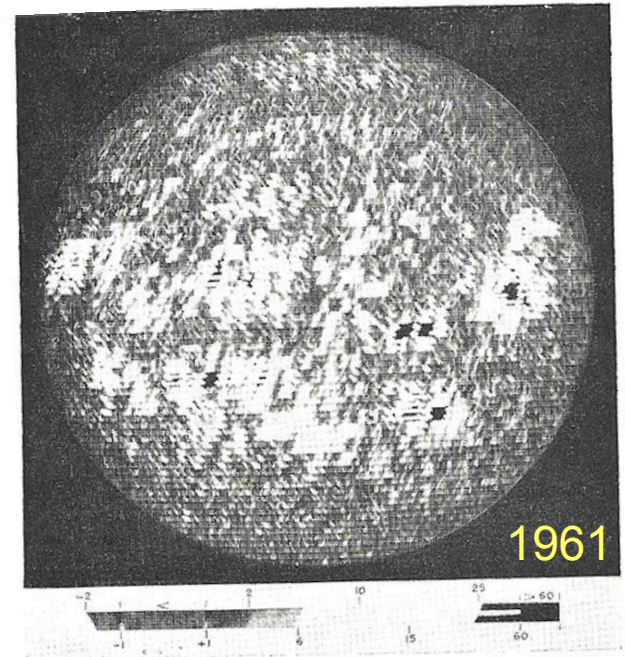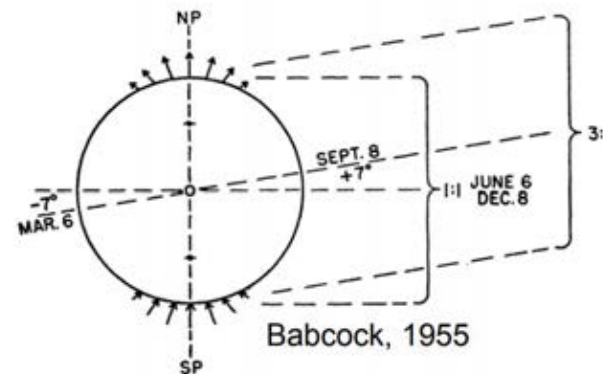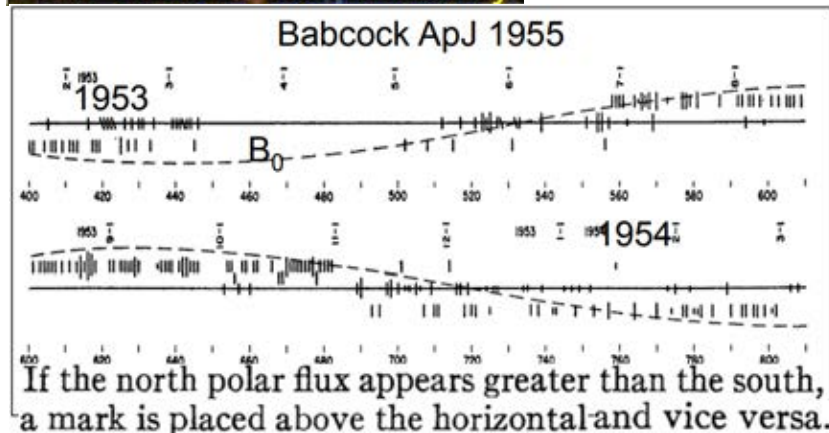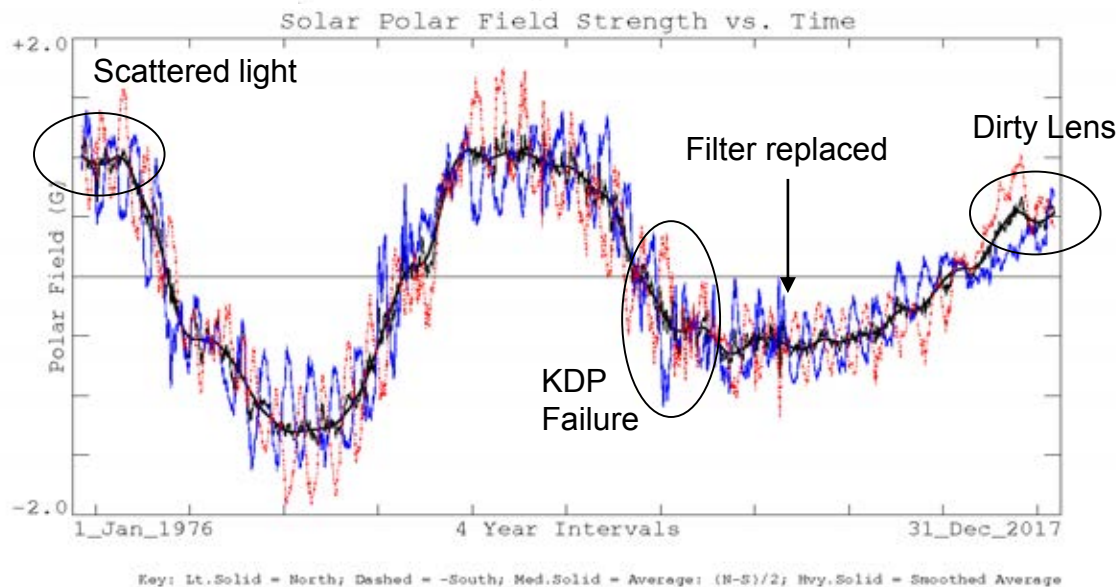
MWO Magnetogram 1953

1961

-2   <   2   10   25   >60|

Fig. 1—The Solar Magnetogram for 21 July 1961.

Babcock ApJ 1955

1953

B_0

1953   1954

1953

If the north polar flux appears greater than the south, a mark is placed above the horizontal and vice versa.

NP

SEPT. 8 +7°

3:1

JUNE 6 DEC. 8

1:1

-7 MAR. 6

SP

Babcock, 1955

Explanation of the annual variation: concentration at the poles

7

WSO Observations since 1976

Wilcox Solar Obs.

+55°

N

E — O — W

S

+1
O
-1

D = 1919
a = 175"
D/a = 11

-10   0   10

x

2016/07/30

WSO Magnetogram

2nd FLAT
25 cm

GUIDING
LENS
FL. 7.0 m

OBJECTIVE
LENS
FL. 6.5 m
or 2.8 m

COELOSTAT
25 cm

Admit (60 Hz)
alternating
polarizations

KDP
POLARIZER

300Å FILTER

IMAGE SLICER

GUIDING
IMAGE
DIA = 6 cm

IMAGE
DIA = 6.1 cm

SLIT
0.8 mm

XY TABLE

PM TUBES
EM. 9656

EXIT SLIT

INTENSITY

λ —

FROM GRATING

Solar Polar Field Strength vs. Time

Scattered light

Dirty Lens

Filter replaced

KDP
Failure

Littrow
Lens →

DIFFRACTION
GRATING

Same as MWO's

The magnetograph has
never been upgraded

+2.0

Polar Field (G)

-2.0

1_Jan_1976   4 Year Intervals   31_Dec_2017

Key: Lt.Solid = North; Dashed = -South; Med.Solid = Average: (N-S)/2; Hvy.Solid = Smoothed Average
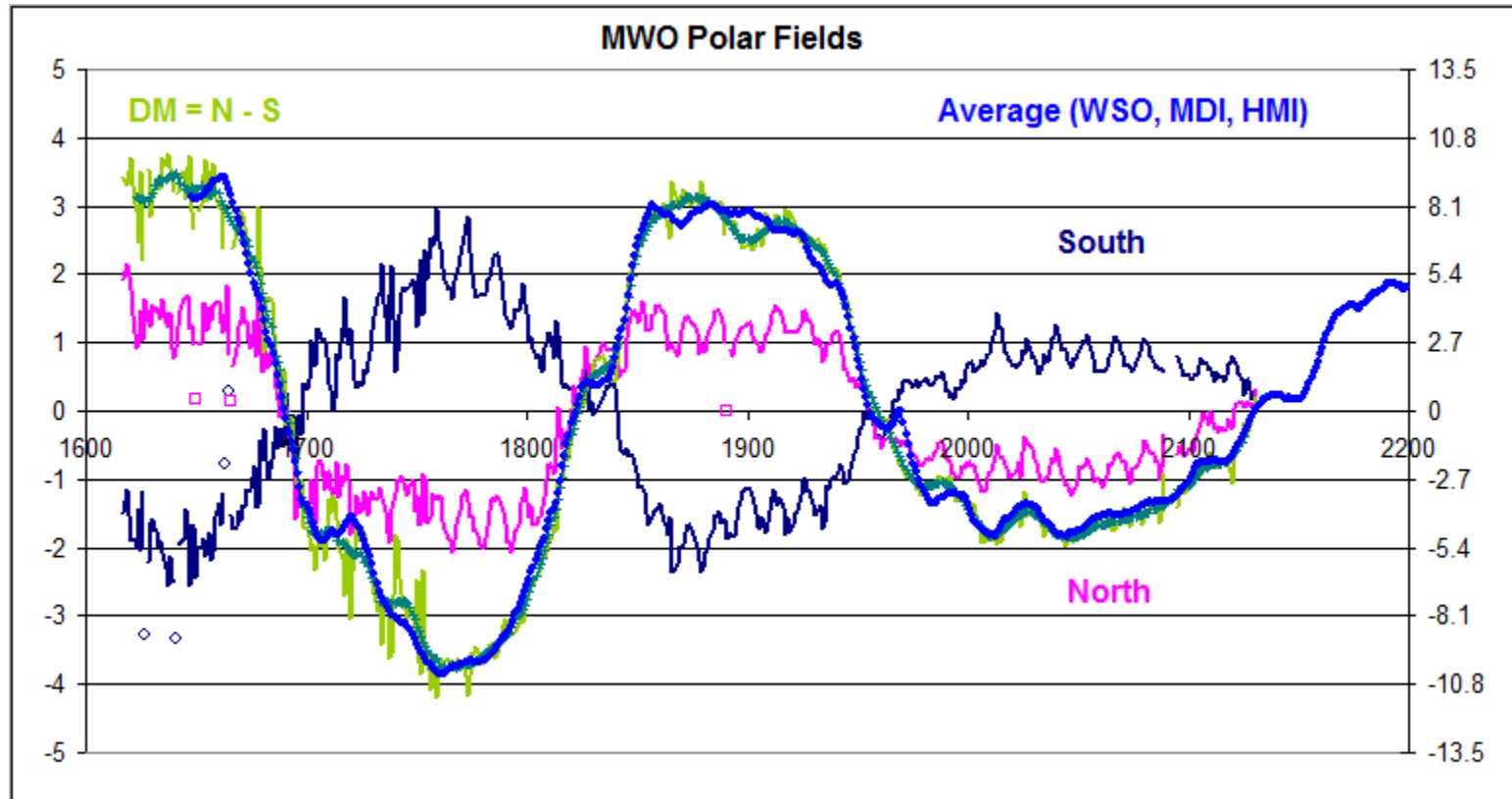
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Polar Fields from WSO, MDI, and HMI from Radial Super-Synoptic Maps
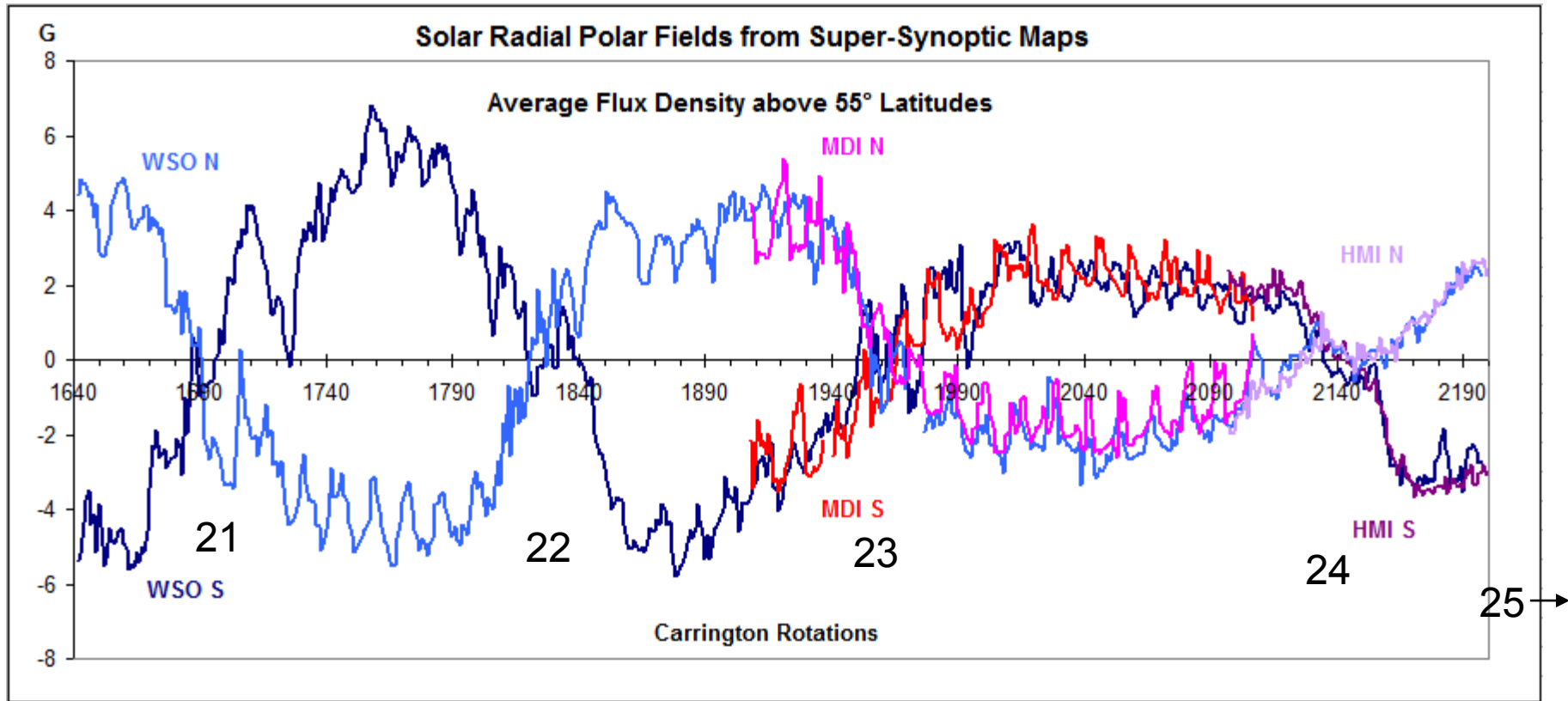
WSO multiplied by 1.8 to correct for saturation.

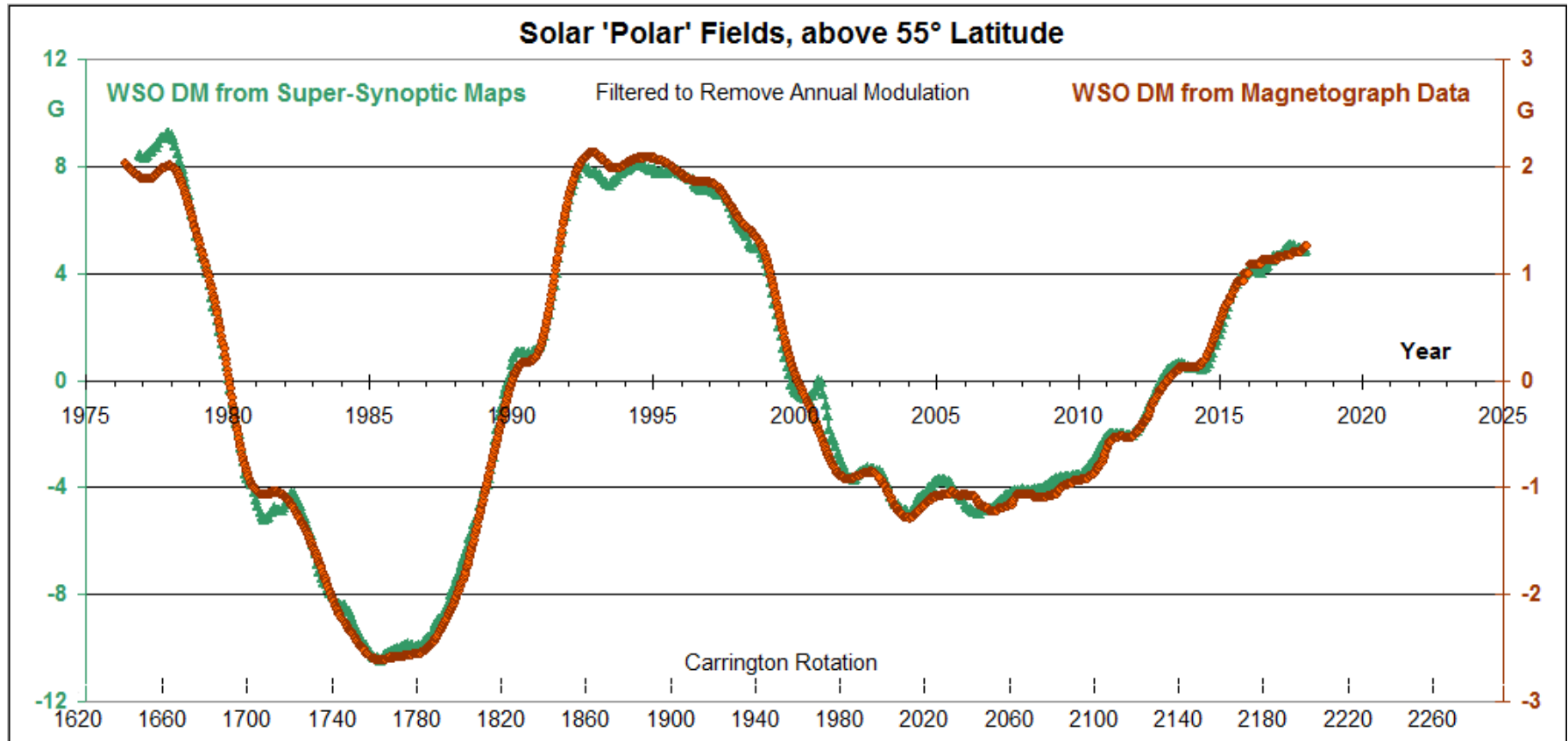MDI multiplied by 0.6 to put on HMI scale [for polar region]

Comparing with MWO Polar Fields

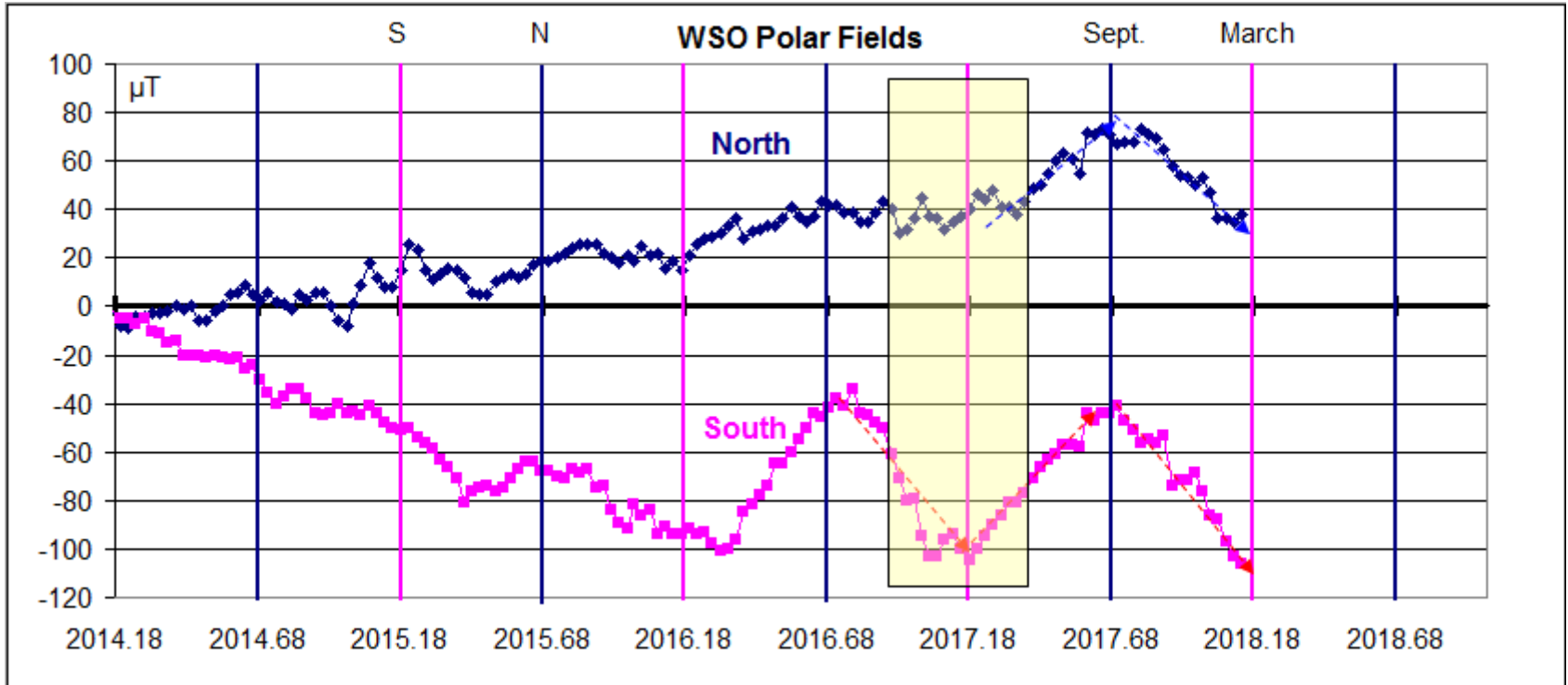It is amazing how good the agreement is (after scaling).

This allows us to take the polar fields back to 1974

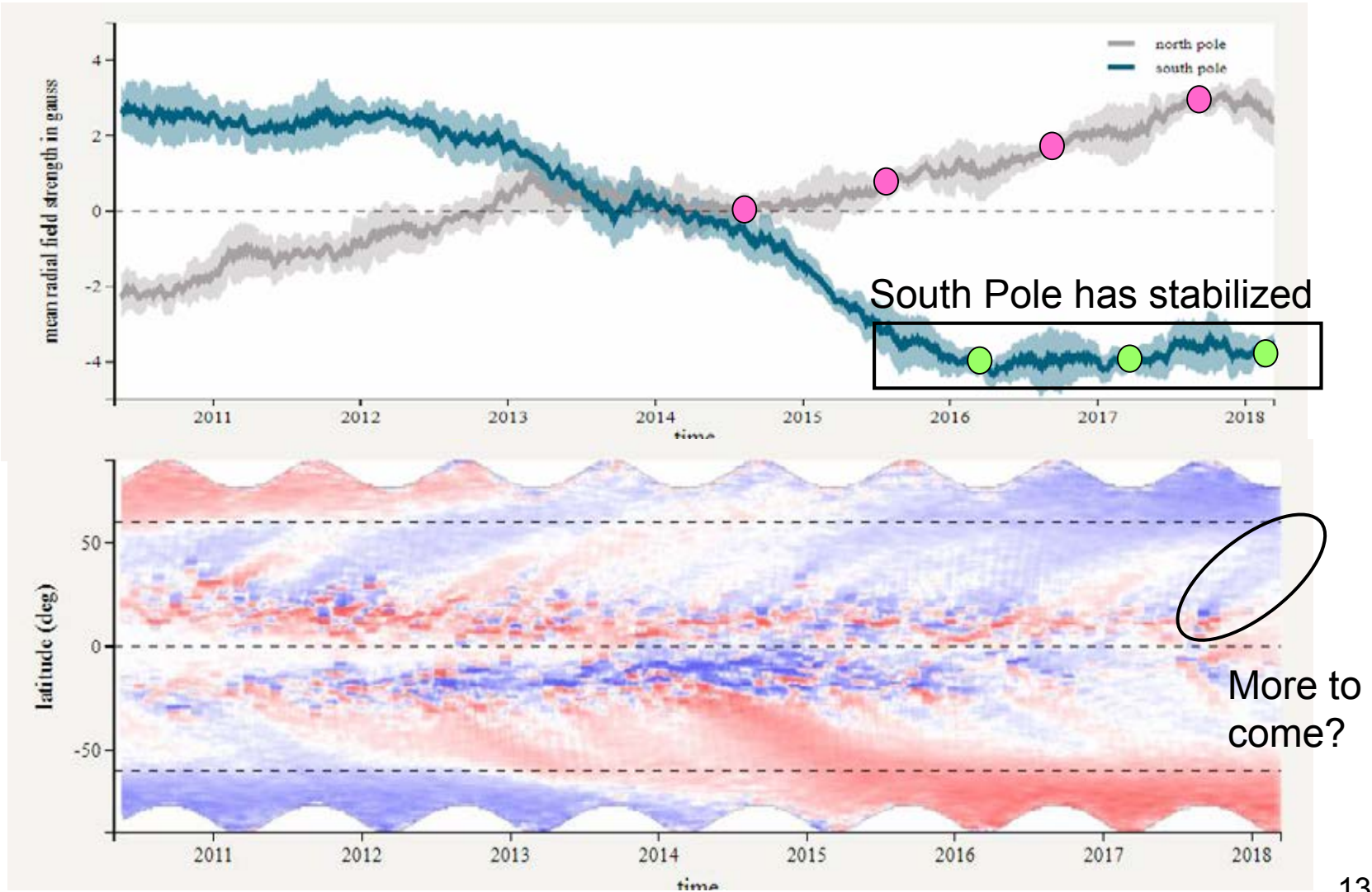# Comparison with Magnetograph Polar 'Pixel' Fields

Conversion factor: WSO Radial = 4.0 WSO Pixel

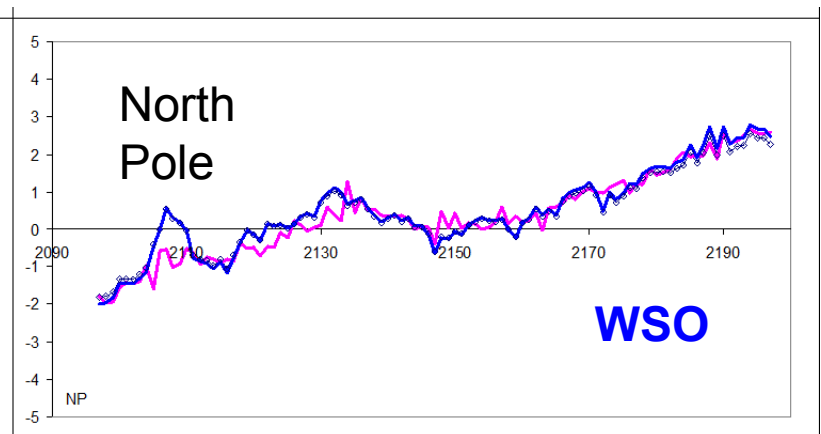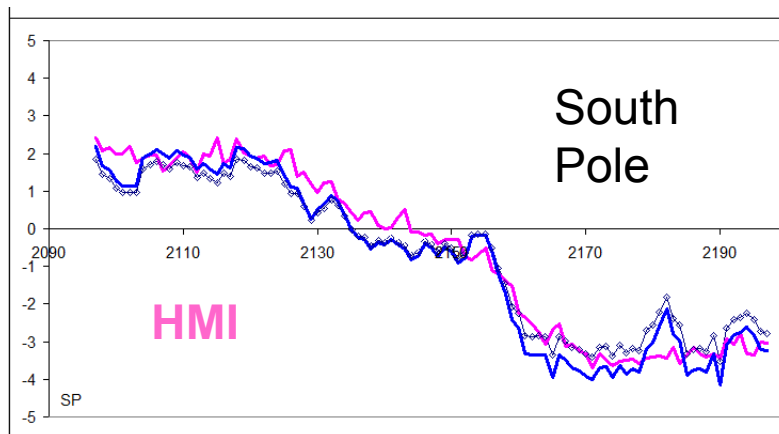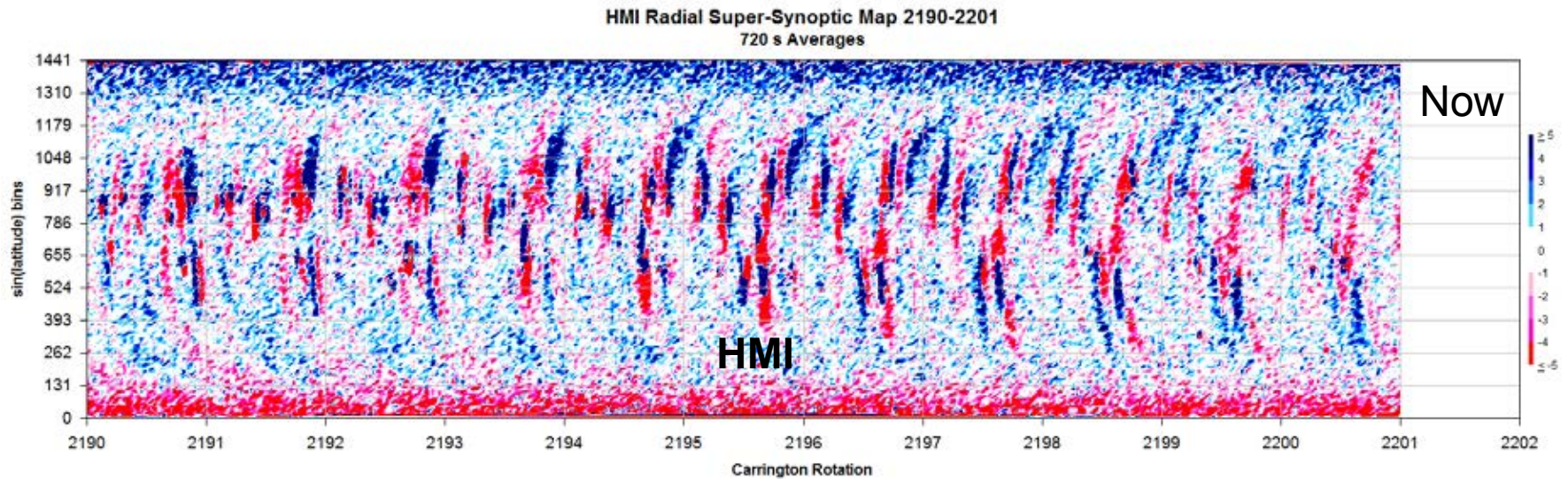# Most Recent WSO 'Pixel' Polar Fields

The data in the yellow rectangle [and reported on the WSO website] were faulty [too small by factor 1.55] due to dirty Littrow lens, but have **now** (two days ago) been corrected. The onset of the annual modulation can now be clearly seen.
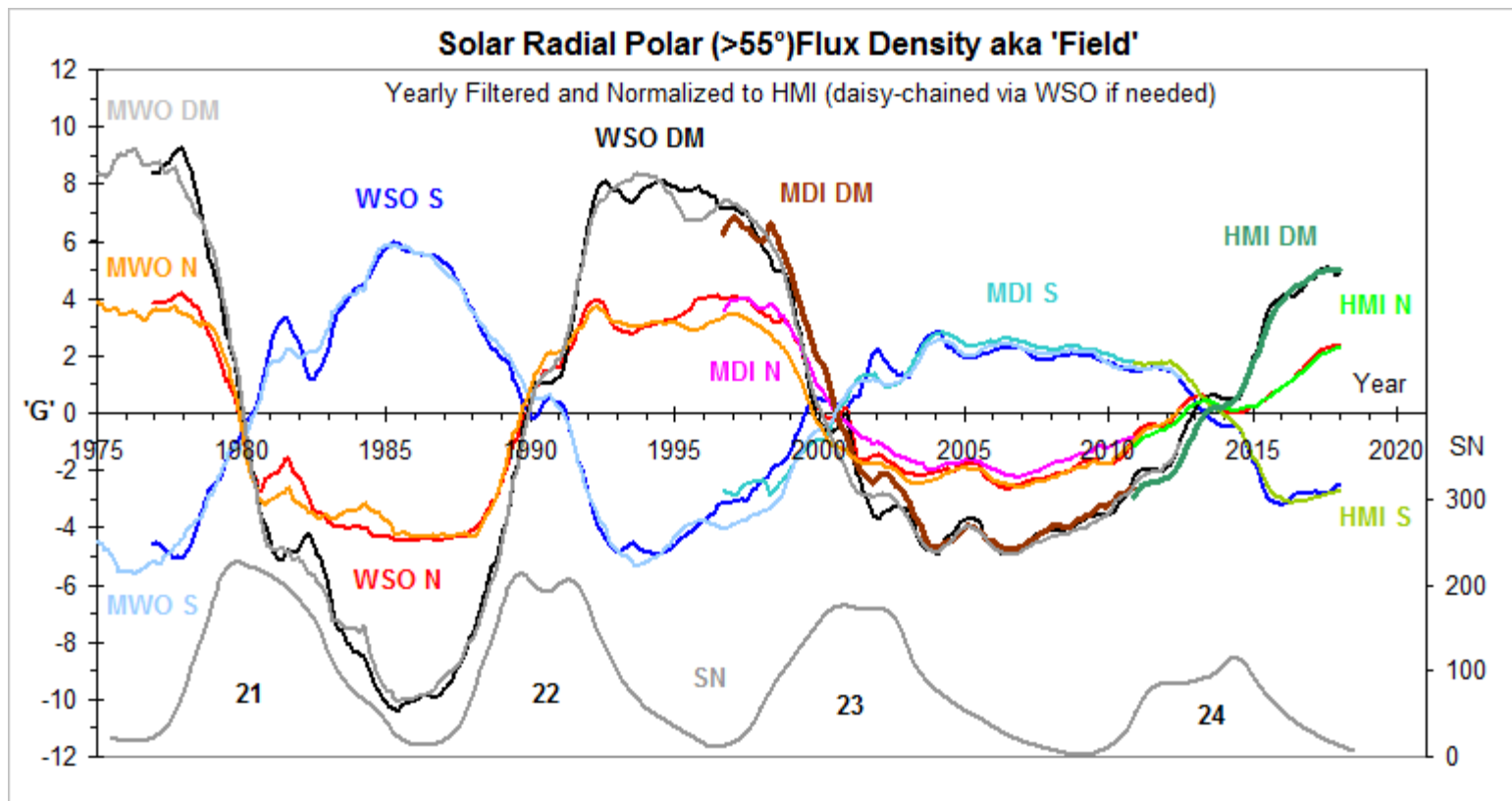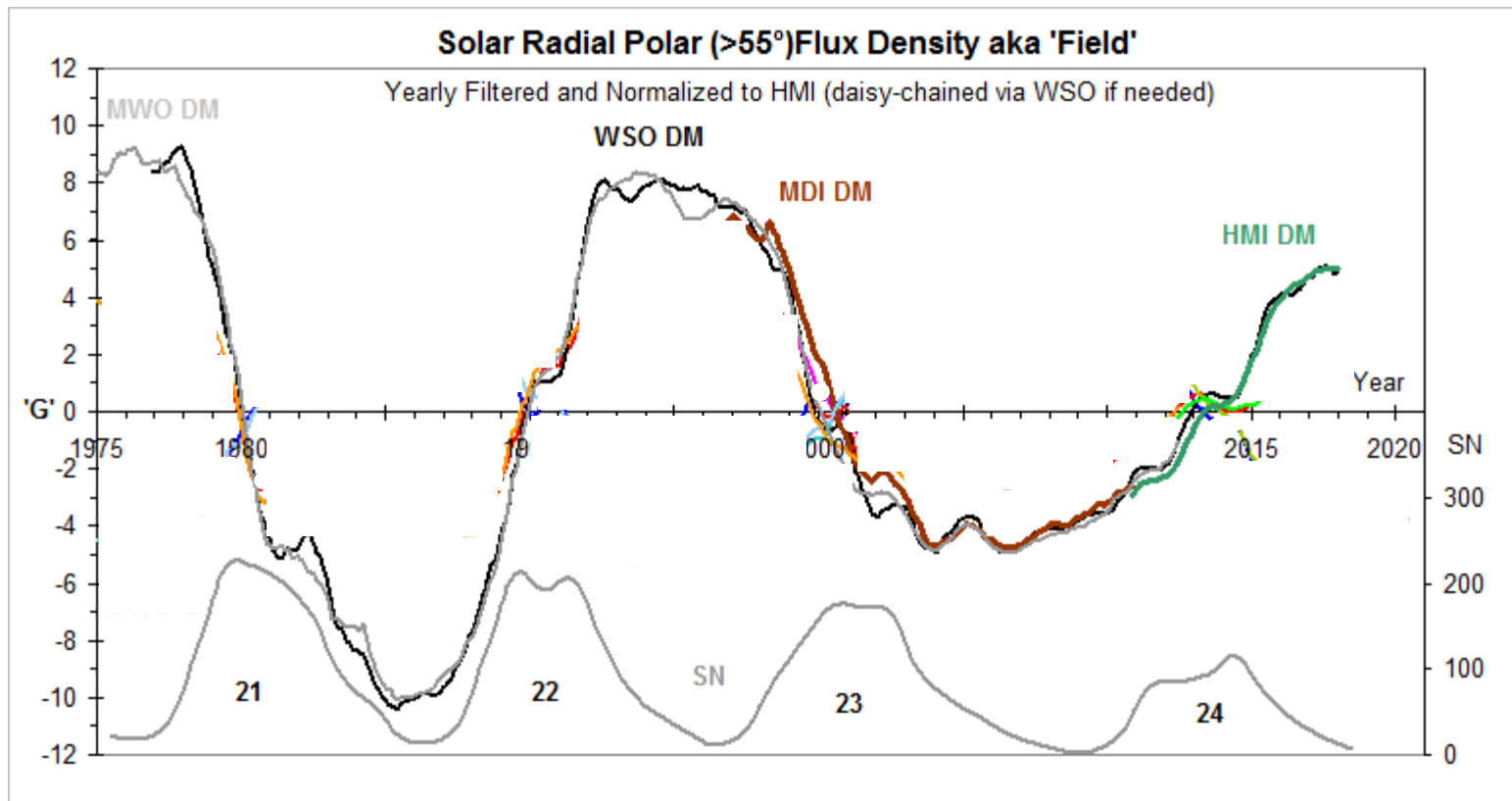
Latest HMI Polar Fields

South Pole has stabilized

More to come?

HMI Super-Synoptic Map Now

HMI Radial Super-Synoptic Map 2190-2201
720 s Averages

Now

HMI

South Pole

North Pole

HMI

WSO

Remove the Annual Modulation by 1-yr Boxcar Averaging

Solar Radial Polar (>55°)Flux Density aka 'Field'

Remove the Annual Modulation by 1-yr Boxcar Averaging

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Prediction of Cycle 25

Estimate of Sunspot Cycle 25 Maximum

$DM(G)^{0.8} / SN_{max}$ Derived from Radial Super-Synoptic Maps from WSO, MDI, and HMI   Feb. 2018
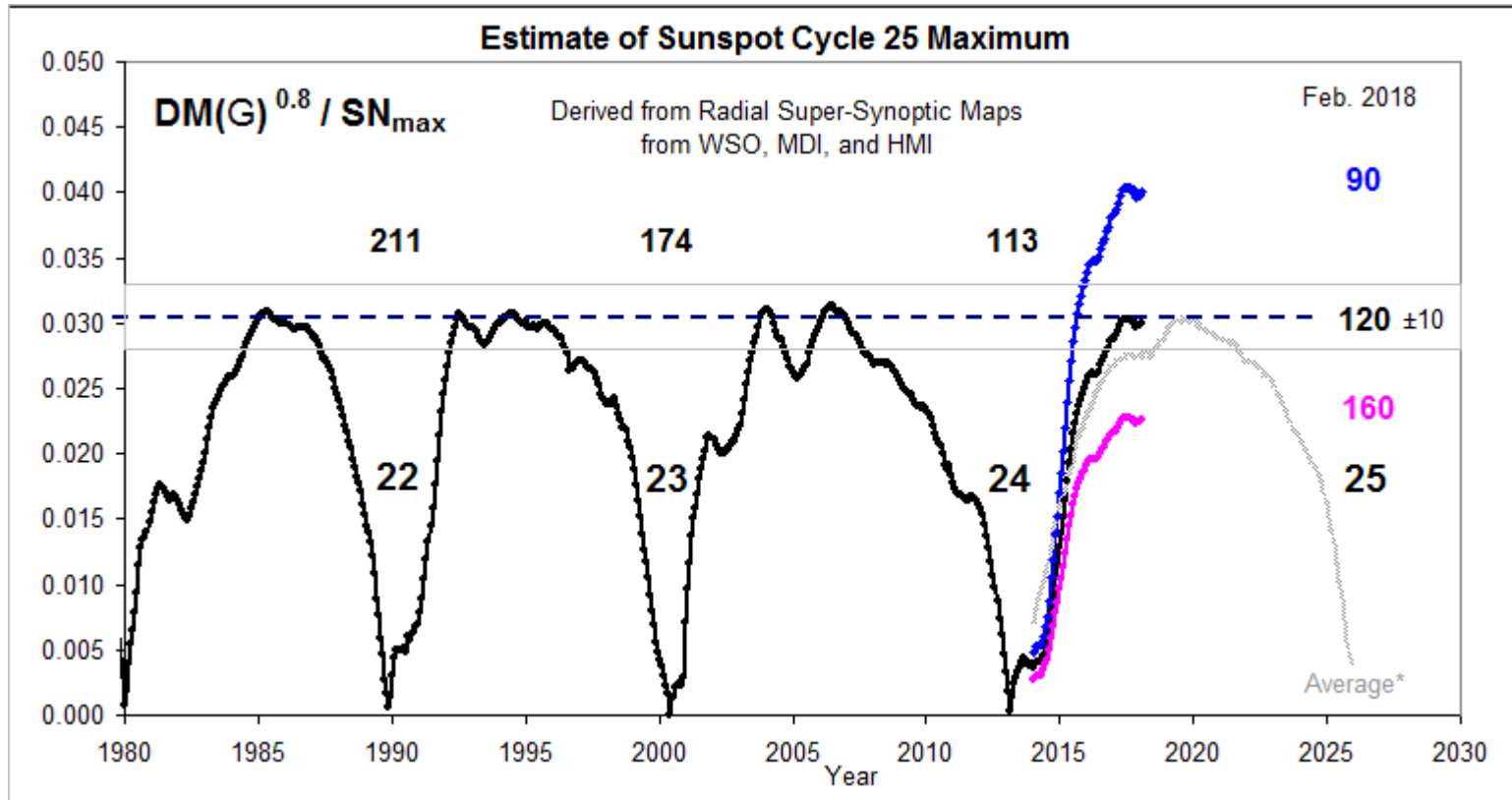
Should the polar fields increase further, SC25 would be correspondingly higher

Hindcasting Polar Fields in Time

WSO Polar Fields vs. SN max

PF µT — SNmax

$y = 0.5138x^{1.1533}$
$R^2 = 0.9984$
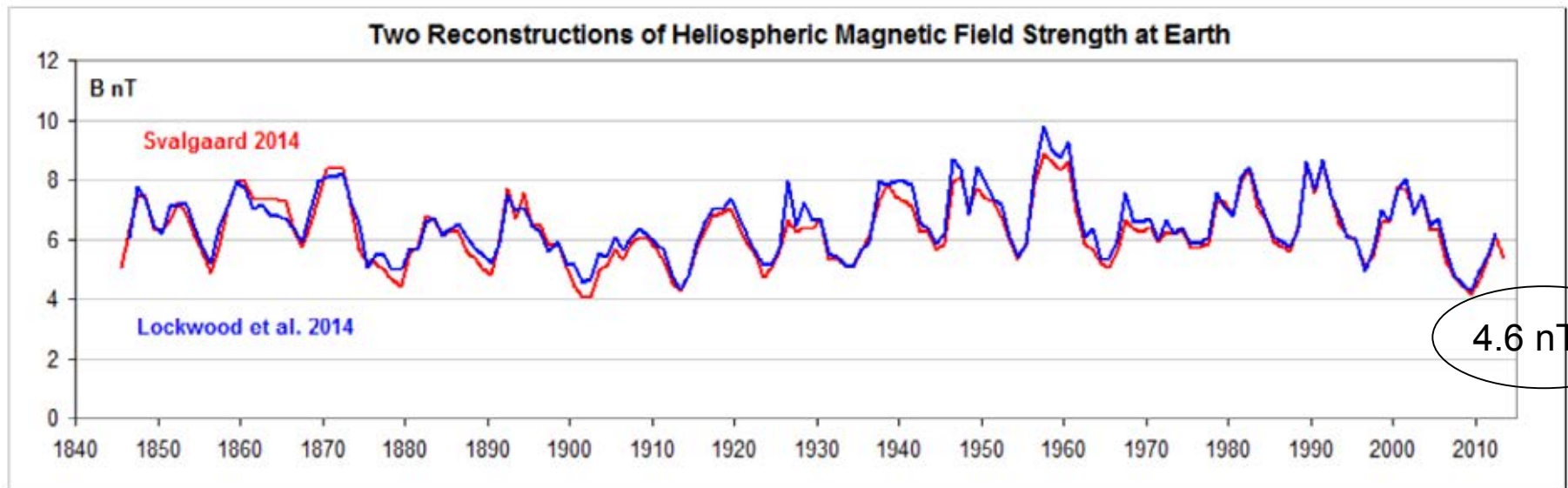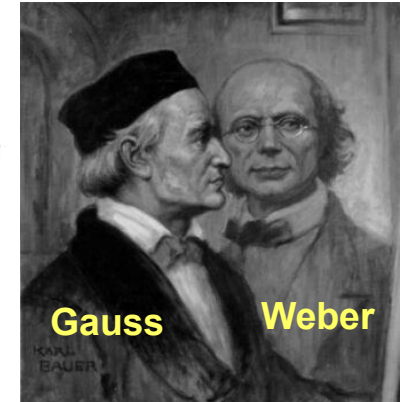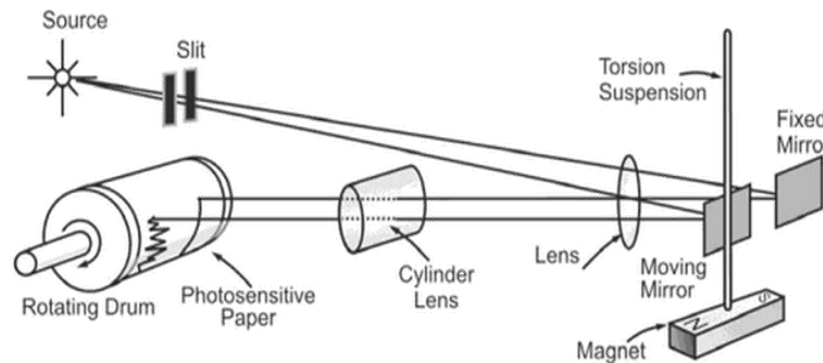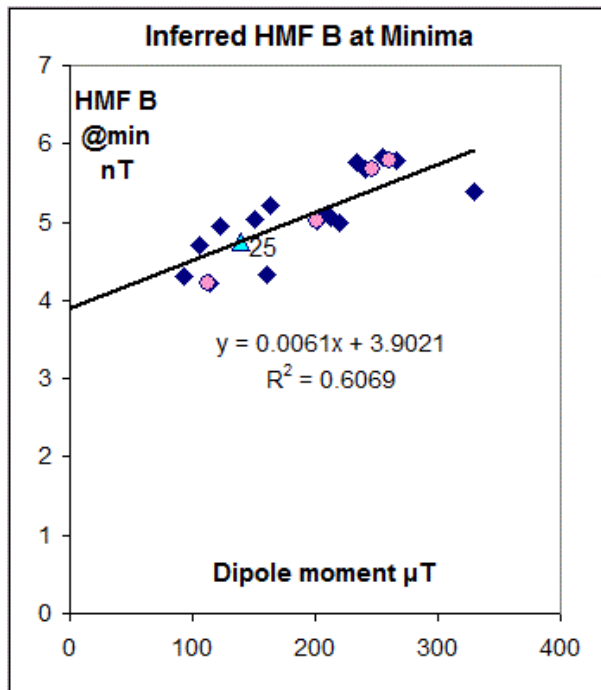
WSO Polar Fields vs. GN max

PF µT — GNmax

$y = 7.1624x^{1.497}$
$R^2 = 0.9715$

WSO Polar Fields vs. HMF B min

PF µT — Bmin

$y = 428.08\ln(x) - 495.06$
$R^2 = 0.9954$

Polar Fields in Time

B nT @min — Polar Fields µT

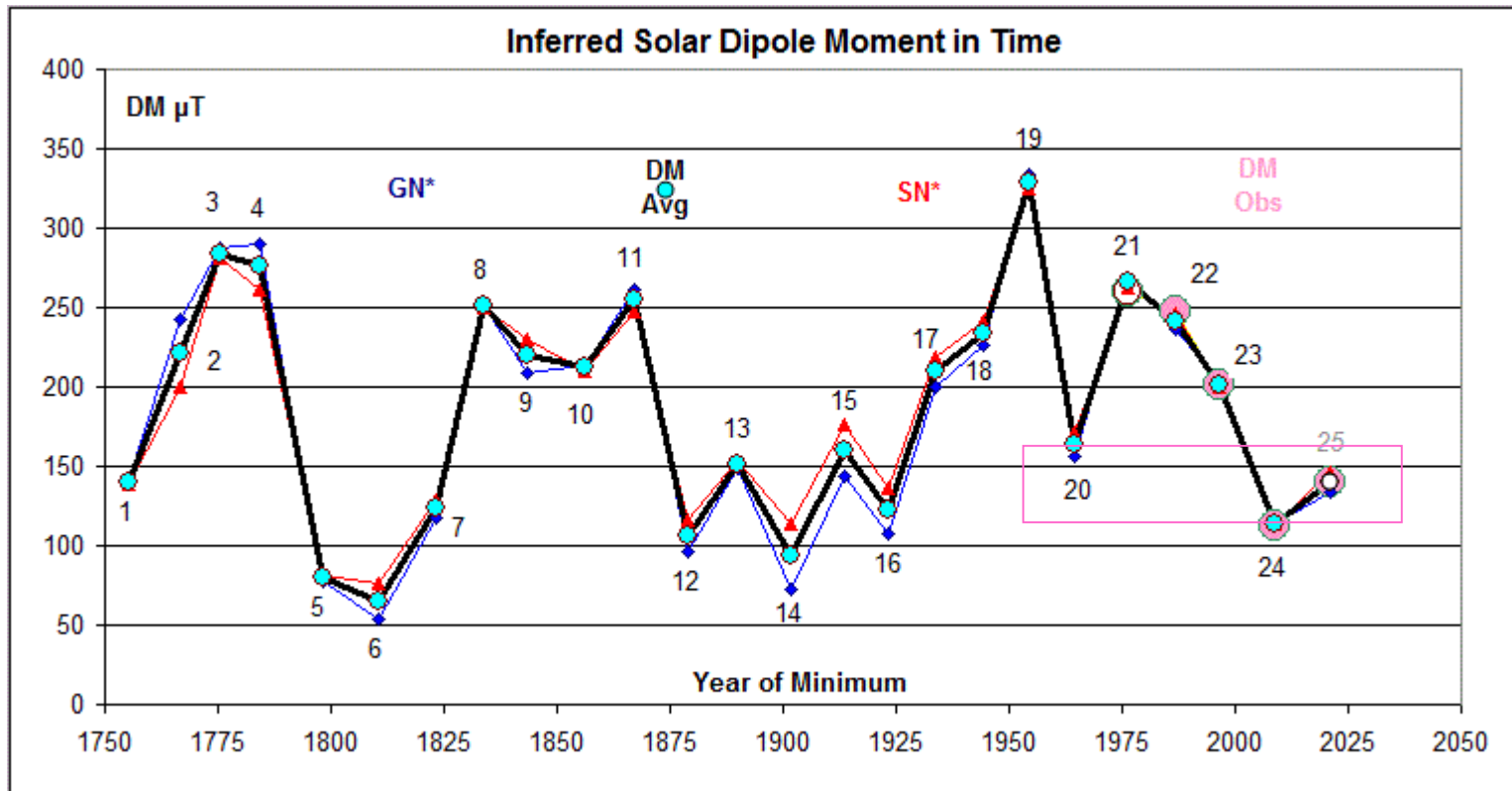Lockwood, Average, Svalgaard, WSO, Avg, GN, SN, B
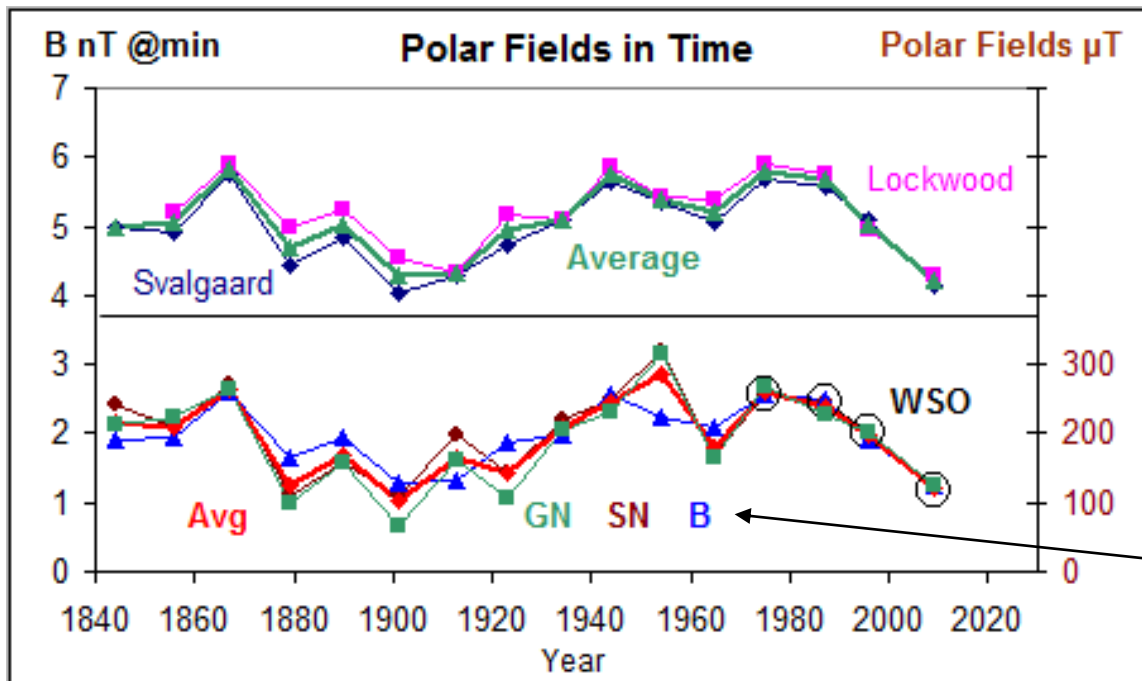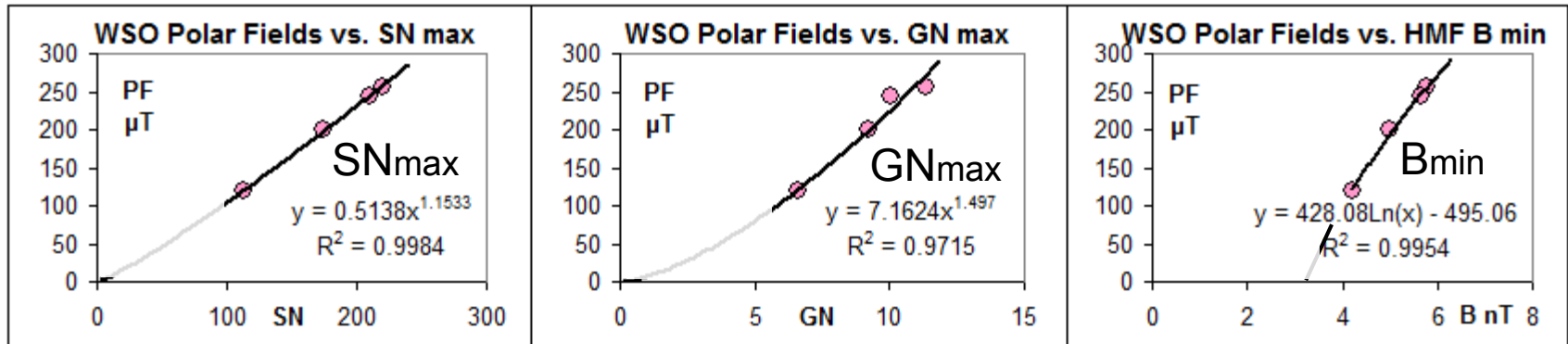
If we can forecast cycle maximum activity from the polar fields, we should be able to hindcast the polar fields from the cycle's maximum activity. If HMF *B* at minimum (proxy for polar fields) forecasts activity maximum, then such maxima hindcast HMF *B*. How do we get *B* for the past?

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From the Geomagnetic Record we can reconstruct HMF magnetic field B with Confidence

Inferred HMF B at Minima

HMF B @min nT

$y = 0.0061x + 3.9021$
$R^2 = 0.6069$

Dipole moment µT

Source, Slit, Torsion Suspension, Fixed Mirror, Lens, Moving Mirror, Cylinder Lens, Photosensitive Paper, Rotating Drum, Magnet

Gauss   **Weber**

Two Reconstructions of Heliospheric Magnetic Field Strength at Earth

B nT

Svalgaard 2014

Lockwood et al. 2014

4.6 nT →

The Prediction (At Last)

SC25 will be somewhere between SC24 and SC20, provided the Polar Field Precursor Relationship holds.