Long-term Solar Activity Studies using Microwave Imaging Observations and Prediction for Cycle 25

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Polar B and Microwave Tb are correlated

- Coronal holes are bright in microwaves
- Brightness enhancement is associated with enhanced unipolar B
- B and Tb are correlated in low-latitude and polar coronal holes (G et al 2000; 2012)
- For the interval 1992-2017:
  - \[ B = 88*T - 93 \text{ G}, \text{ T in } 10^4 \text{ K} \]

Gopalswamy et al. 2018
- B – Tb correlation in butterfly diagrams
- Even plumes can be seen in Tb
- NS asymmetry in the polar field is obvious

HL prominence eruptions during 2011-2015

SDO only; SDO & NoRH; NoRH only
HL Tb and LL Tb

- Low-latitude Tb peaks at SSN maximum
- S and N hemispheres are different and contribute to the double peak and NS asymmetry
- High-latitude Tb peaks at SSN minimum
- High- and Low-latitude Tbs are anti-correlated
- HL Tb at the minimum of a cycle, is correlated with the LL Tb at the max of next cycle (similar to other proxies such as # polar faculae & SSN – Makarov & Makarova 1996)
Cross Correlation between HL and LL Tb

Makarov & Makarova (1996) obtained a lag of \(~6\) years between monthly polar faculae & SSN
Predicting Cycle 25 Strength

From Tb Value at the Poles

- N 59 (61)
- S 89 (80 in C24)
- Hem. average 78 (71)

Updated

- Hem. average 87 (71)

NOAA/NASA Panel: 95 -140

NS asymmetry will continue (south will be dominant again)

Gopalswamy et al. 2018 JASTP
HL prominences during 2011-2015

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Fight Between Incumbent and Insurgent Fluxes

- After reversal, no bipolar regions – No eruptions -- polar Tb increases above quiet Sun level (new polarity B)
- Delayed reversal: the surges of “wrong polarity” N2, N4, N5 (Cameron et al. 2013; Jiang et al. 2014; Sun et al. 2015)
- After sign reversal → increase in HL Tb indicating buildup of new polarity field

Gopalswamy et al. 2016 ApJL
Rush to the Poles (RTTP)

- High-latitude prominences/filaments and their poleward migration were discovered by Secchi in 1872.
- RTTP refers to filament locations systematically moving toward the poles in both hemispheres (Lockyer 1931).
- “Dash to the poles” (Evershed and Evershed 1917) and “Rush to the poles” (Ananthakrishnan 1954).
- Synchronism between RTTP and the sign reversal at solar poles (Waldmeier 1960; Hyder 1965).
- Locations of prominence eruptions (PEs) as proxy to the locations of prominences/filaments (G. et al. 2003; 2012).
Rush to the Poles of Filaments & Polarity Reversal

1971 April 29
1981 Jan 21
1990 Dec 11
2000.9

1970.0
1981.0
1991
2000.9

1970.5 1981.5 1992.5 2002

Lorenc et al. 2003
Historical RTTPs

10-20: Stix (compiled from Lockyer 1931; Kiepenhauer 1953; Waldmier 1968; 1973)

Cycle 16 has similar RTTP behavior as cycle 24; the reversal asymmetry also changes.
Historical RTTPs

10-20: Stix (compiled from Lockyer 1931; Kiepenhauer 1953; Waldmier 1968; 1973)

Cycle 16 has similar RTTP behavior as cycle 24; the reversal asymmetry also changes.

Fujimori 1984
Pojoga & Huang 2003
Bocchino 1933 in Cliver 2014; also Evershed & Evershed 1917 (Kodaikanal)
Historical RTTPs

Reversal asymmetry changes every 3-5 cycles
Extended period of HL Prominences in cycle 16, 20 maxima

10-20: Stix (compiled from Lockyer 1931; Kiepenhauer 1953; Waldmier 1968; 1973)

Cycle 16 has similar RTTP behavior as cycle 24; the reversal asymmetry also changes
Microwave Tb is also a measure of solar activity.

The prolonged zero-field conditions in the north pole will delay the onset of cycle 25 in the northern hemisphere.

SC 24 is already weak, so it may not add too much new flux to the north polar region. Caveat: a huge active region can still emerge in the declining phase and build the polar field.

In the south the maximum was normal. The cycle is likely to start around 2021.0.

Reversal precedence switched between the poles.

- Reversal asymmetry to follow sunspot hemispheric asymmetry Svalgaard and Kamide (2013)
- Large scatter in the distribution of tilt → large variability in the polar B → the variability in the amplitude and phase of the new cycle (e.g. Nagy et al. 2017)
Summary

• Unusual polar conditions prevailed in the north polar region of the Sun until recently (extended PE, low polar Tb, B~0)

• A similar situation prevailed in cycle 16

• In cycles 24 and 16, the reversal asymmetry switched from NS to SN

• In 14 cycles, there were three switches, indicating a 3-5 cycle periodicity

• The extended PE activity is due to plumes of wrong polarity heading to the poles (due to wrong tilt angles) and contributes to prediction uncertainty

• Using microwave polar Tb, we predict SC 25 will be similar to SC 24, may be slightly larger, but a huge hemispheric asymmetry is expected.