Calibrating 100 Years of Polar Faculae Measurements

Implications for the Evolution of the Heliospheric Magnetic Field

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The modulation of surface magnetic fields by the solar cycle drives space weather and climate

- Solar storms originate within sunspot magnetic structures (and thus are modulated by the solar cycle).

- Solar wind properties are determined by the evolution of the global magnetic field of the Sun.

- The cycle also modulates solar irradiance and cosmic ray flux.
  - Long term variation is relevant for Earth’s climate system.
We have an imbalance in long-term observations of the solar cycle...

Poloidal $r - \theta$

Toroidal $\phi$

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We have an imbalance in long-term observations of the solar cycle...

Poloidal
\[ r - \theta \]

**X**

- 40 Yrs Magnetic Data

Toroidal
\[ \phi \]

**X**

- 40 Yrs Magnetic Data

- 400 Yrs Sunspot numbers

- 150 Yrs Sunspot Areas

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So for all practical purposes we normally study only half a system:

We need a proxy that can allow us to obtain a complete global picture of the long term evolution of the solar magnetic field.
What have we done to address this issue?

• Cross-calibrate four MWO facular data reduction campaigns.

• Validate the MWO methodology (observer subjective) by comparing it with an automatic detection algorithm ran on MDI data.

• Turn facular observations into magnetic field measurements by calibrating them using WSO and MDI magnetic data.
Photospheric patches associated with concentrations of magnetic flux which are brighter than the surrounding quiet Sun. Spruit 1976; 1977; Keller et al. 2004
Neil Sheeley’s MWO Facular Data

• Using plates for daily integrated sunlight of the Mount Wilson Observatory.

• 5 best plates were chosen to maximize polar coverage (Feb-Mar for South and Aug-Sep for North).

• Plates were marked and then randomized in time and orientation.

• Polar Faculae were counted by hand and averaged for each time interval.

- And take advantage of the overlaps across campaigns to calibrate the entire dataset.
- There is very good agreement across campaigns once the calibration is applied.
We validate the MWO methodology by counting faculae automatically on SOHO/MDI intensitygrams.

The facular counts obtained by the two methods are consistent.
We calibrate the WSO facular count using WSO and MDI magnetic measurements...

- There is good agreement between WSO and MDI measurements and the MWO facular measurements of the last two calibrated campaigns

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...and obtain a consolidated database spanning a century worth of polar field variations.
THE POLAR MAGNETIC FLUX AND THE HELIOSPHERIC MAGNETIC FIELD (HMF)

Understanding what determines space conditions at 1AU
Direct HMF measurements exist since 1965, but it can be extrapolated from geomagnetic indexes before that.

- Theoretical studies show that HMF is modulated by the dipolar components of the solar magnetic field.

Wang & Sheeley (2003) and Wang et al. (2005)
Modulation by sunspot area (equatorial dipole) is evident, but what about the polar fields?

Focusing on solar minima we find:

- The HMF drops to values determined by the strength of the polar fields (axial dipole).
Taken together the square root of sunspot area (equatorial dipole) and polar flux (axial dipole) can explain most of the HMF variability during the last century.

- This verifies observationally the theoretical results of Wang & Sheeley (2003) and Wang et al. (2005).
- It also works as a sanity check for our polar flux database.
Concluding remarks

• We standardized, validated and calibrated a long-term facular dataset spanning a hundred years.

• We studied the role of the surface magnetic fields in determining the long-term evolution of the heliospheric magnetic field (HMF).

• HMF was found to be determined primarily by the equatorial and axial dipole moments of the solar magnetic field validating previous theoretical results.

Wang & Sheeley (2003) and Wang et al. (2005)
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