Review of Unusual in-situ Conditions during the Present Solar Minimum

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Topics

• Solar wind pressure, $nmv^2 r^2$
• Magnetic flux, $B_R r^2$
• Solar wind mass flux, $nmv r^2$
• Solar wind energy/power flux, $nmv^3 r^2 / 2$
• Polar cap magnetic field, $B_P$
• Expansion factor, $f_E = \Omega_f / \Omega_P$
• Field strength, $B$
• Variance in Alfvenic fluctuations, $\sigma_T$
• Inclination of Heliospheric Current Sheet, $\alpha$
Solar wind dynamic pressure, mass and energy flux are lower this minimum because of a decrease in density.  

(McComas et al., 2008)
Solar wind pressure is independent of latitude. It is the same at Ulysses and ACE including the decrease this solar minimum. (McComas et al., 2008)
Ulysses data also show that the magnetic flux is independent of latitude and has decreased this minimum. (Smith and Balogh, 2008)
The explanation: stresses caused by higher magnetic pressure in the Sun’s polar caps deflects the field and plasma equator-ward (super-radial flow) to equalize the pressure. (Smith and Balogh, 1995; Suess and Smith, 1995)
In the fast high latitude wind, the mass flux and magnetic flux are correlated. (Schwadron and McComas, 2008)
The energy flux of the fast wind is also correlated with magnetic flux. (Schwadron and McComas, 2008)
These correlations imply that at the source the solar wind power is proportional to the magnetic flux, a “universal” law. (Schwadron and McComas, 2008)
The polar cap field strength decrease has caused the lower magnetic flux and lower solar wind mass, pressure and energy flux. (Wilcox Solar Observatory)
The magnetic flux, $r^2 B_R$, from the polar cap is related to $B_p$ and $f_E$

- Conservation of flux: $r^2 B_R \Omega_f = r_p^2 B_p \Omega_p$
- Or $r^2 B_R = r_p^2 B_p / f_E$
- The decrease in $B_p$ (40 – 50 %) is larger than the decrease in $r^2 B_R$ (- 34 % ) implying that $f_E$ has decreased.
- The expansion factor is proportional to the polar cap field strength as expected.
- The boundary between the fast and slow wind has moved to higher latitudes.
Recent Ulysses data show that the transition from fast to slow wind occurs at higher latitudes.
TILTED-DIPOLE FLOW GEOMETRY

- Solar Rotation Axis
- Dipole Axis
- East
- West
- Fast
- Slow
- Transition
- Solar Equator
- HCS
In the Parker model, $B$ is proportional to $B_R$. In-ecliptic $B_R$ and $B$ show the past four solar cycle variations including the decreases this minimum.
$B_R$ and $B$ are correlated with $B_\rho$ including decreases when the polar cap field reverses and decreases in SSN from cycle to cycle.
Smoothing eliminates Quasi-periodic variations and shows the correlation between maxima in SSN, $B_R$, B (and $B_p$).
The total power in the high latitude Alfvenic fluctuations has decreased this solar minimum. (Smith and Balogh, 2008)
Galactic cosmic ray flux is unusually high this minimum. (K. Mursula)
Potential field source surface neutral line models over the past three cycles show the tilt angle is anomalously high at $\approx 20^\circ$. (Wilcox Solar Observatory)

**Maximum Inclination of the Current Sheet (N-S Mean): 1976–2009**

Solid=Classic PFSS Model (preferred)  Dashed=Radial Rs=3.25
Ulysses observations of first and last current sheet crossings “calibrate” the SSNL calculations and verify the validity of the "classic" model. (Smith, 2006)
The tilt angle is a measure of the equatorial component of the solar dipole which is still strong. A speculation or bold prediction: $\alpha$ decreases from 20°-30° to minimum (10°) over about 2 years; solar minimum has not yet occurred but will occur in about 2 years.

**Maximum Inclination of the Current Sheet (N-S Mean): 1976-2009**

Solid=Classic PFSS Model (preferred)  Dashed=Radial Rs=3.25
Summary

• The decrease in $B_p$ has caused reductions in magnetic flux which has caused reductions in solar wind mass flux, pressure, energy flux and the expansion factor.

• $B$ is proportional to $B_R$, consistent with the Parker model, both are correlated with $B_p$ over the solar cycle and are unusually low.

• The inclination of the HCS or SSNL is unusually high perhaps indicating that solar minimum is still a year or two in the future.