Investigation of the Effects of the Weak Fields of Solar Cycle 23

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SOHO-23: Understanding a Peculiar Solar Minimum
The lowering of the Solar Cycle 23 magnetic flux: a whodunnit mystery (?)

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SOHO-23: Understanding a Peculiar Solar Minimum
Our time period of study:
30 April 1994 to 8 April 1996 (SC 22, black) and
31 March 2007 to 9 March 2009 (SC 23, red)

Observations: OMNI data at 1 AU, ecliptic plane
SC 23 minimum period exhibits both lower field magnitudes and densities at 1 AU.
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Lee et al., Solar Phys., 256, 345, 2009
Peak radial field distribution for SC 23 is \(~30\%\) less.

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<th>1 AU, in ecliptic</th>
<th>Ulysses fast scans</th>
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<td>$B_R$</td>
<td>(~30%) lower</td>
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<td>(~36%) lower</td>
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(Smith and Balogh, GRL, 35, L22103, 2008)
Observed lower magnetic flux ($B_{\text{Sun}} \times A_{\text{CH}}$): Is it due to a) weaker surface field, b) interplanetary redistribution of the open flux, or c) changes in coronal hole areas?
Weaker surface field?
The observed polar field for current minimum period is less than half the previous solar minimum value.

Image credit: WSO/Stanford
Overall, the photospheric field is weaker than previous cycle over the entire surface, not just at the poles.
Interplanetary redistribution of flux?
Low IMF is associated with the stream structure for SC 23 (red values: filtered for B ≤ 4 nT)
Global outward mapping of coronal holes supplying the solar wind for CR 1898 (left) and CR 2060 (right)

Lee et al., Solar Phys., 256, 345, 2009
Changes in coronal hole areas?
(Magnetic flux = $B_{\text{Sun}} \times \text{Area}_{\text{CH}}$)

Using $R_{ss} = 2.5$ solar radii, the fractional area of coronal hole regions is $\sim 30\%$ less for SC 23.
But… $R_{SS} = 1.5$ solar radii seems to do much better for SC 23 period (see Poster #33 Luhmann et al. for details…)
So what happens if we shrink down the source surface distance from 2.5 to 1.5 $R_{\odot}$?
Using $1.5 \, R_{\text{Sun}}$ instead of $2.5 \, R_{\text{Sun}}$ for the source surface distance, the fractional coronal hole areas is larger and more comparable to SC 22.
Mystery solved?

Cause(s) for the weaker magnetic flux during SC 23:

- Reduction of the field over the entire photospheric field (not just at the poles) **definitely contribute**

- Redistribution by with solar wind stream structures is stronger since there are more streams arising from low-to-mid latitude coronal holes present **maybe contribute...just a bit?**

- Unchanged coronal hole areas (more or less)
  
  ...only if we shrink down the source surface from $2.5$ to $1.5 R_{Sun}$

This may never had been a mystery to begin with, but we needed to go through these steps to check whether other factors may play a role in the observed weakening of magnetic flux.