Was the recent solar minimum unique?

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Motivation

- Was the Sun’s behavior unexpected?
- Was the strange behavior a solar minimum phenomena?
- Was it unique?
Sun's behavior during this minimum was unexpected
Spotless days at Solar Minima
Radial IMF Distribution

The field was different at two minima even during 25 spotless days!
When did unexpected behavior begin?
Solar Wind Helium Disappearing

The difference was evident at previous minimum
Sunspot Field Strength Declining

Umbral magnetic field
(Livingston & Penn, 2009)
Solar Polar fields weakening

Onset of weakening in 1996
Onset Summary

<table>
<thead>
<tr>
<th>Cycle 23-24 onset of minimum (R &lt; 20)</th>
<th>Sunspot field decrease</th>
<th>SW Alpha/proton ratio decrease</th>
<th>Solar Polar field weakens</th>
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Sun’s unexpected behavior was not confined to solar minimum. Anomalous behavior begins at least 10 years earlier.
Did this behavior happen in the past?
A century of geomagnetic activity

Comparing $\text{aa}$ with IHV (Svalgaard et al. 2000)

2009 values: $\text{aa}$ was like 1912, IHV was like 1900

Sun in 23/24 minimum was like it was at beginning of 20$^{\text{th}}$ century
90 yr variation in auroral frequency
Sunspot History

- Decadal sunspot numbers smoothed to remove Gleissberg cycle
- **Grand minima** (17%)
- **Grand maxima** (9%)
- **Normal** 75% of 7,000 yrs

Usoskin, Solanki & Kovaltsov, 2007
Conclusions

• The Sun’s behavior at this minimum was not predicted

• The unusual behavior started well before the cycle 23 maximum

• Weak minima repeatedly occurred in the past, secular variation observed

• Current dynamo models are designed to not predict this behavior
Earth’s temperature (Aumann) and sunspot reconstruction
Solanki

![Graphs showing temperature and sunspot activity over time.](image)