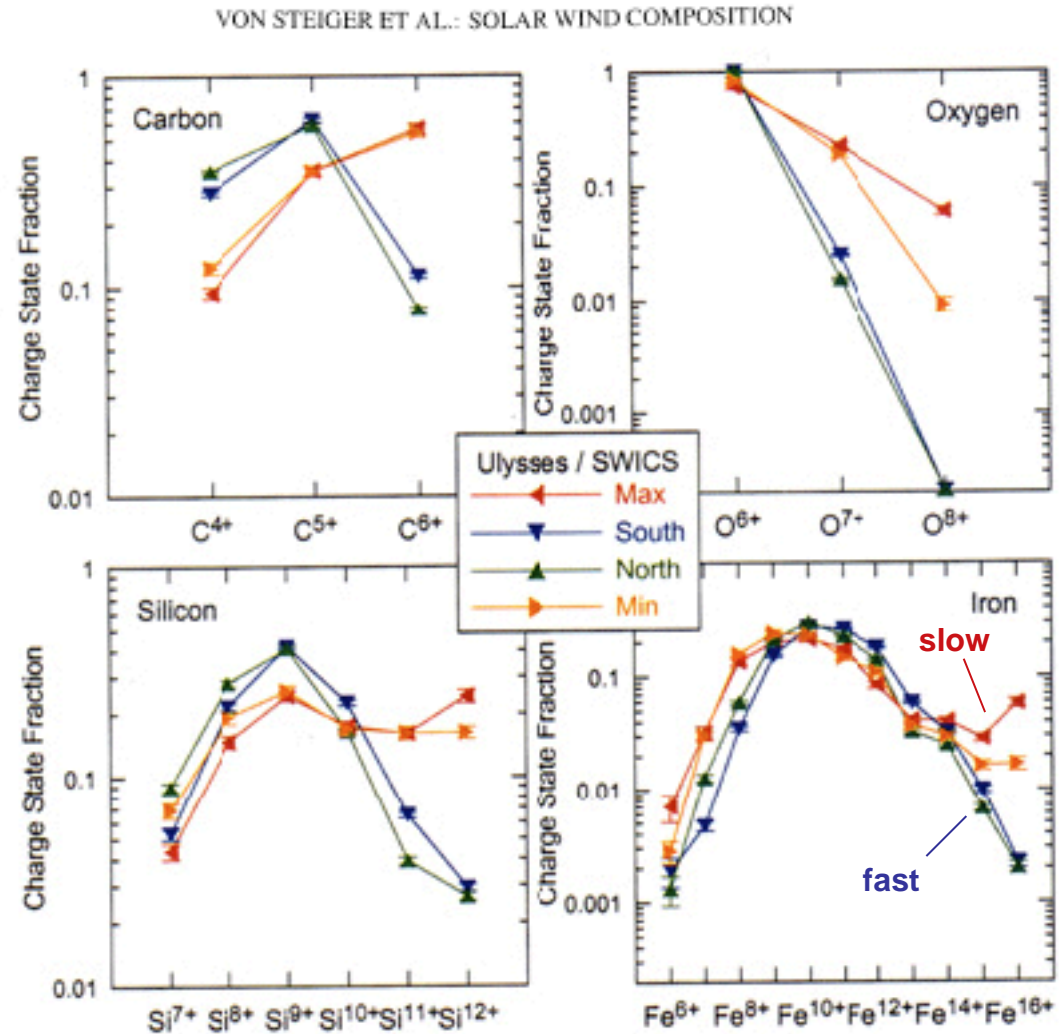


Long Term Measurements of Solar Wind Fe Charge States: Charge State Distributions

Mark Popecki, A. Galvin, L. M. Kistler, H.
Kucharek, E. Moebius, K. Simunac, P. Bochsler,
L. M. Blush, B. Klecker

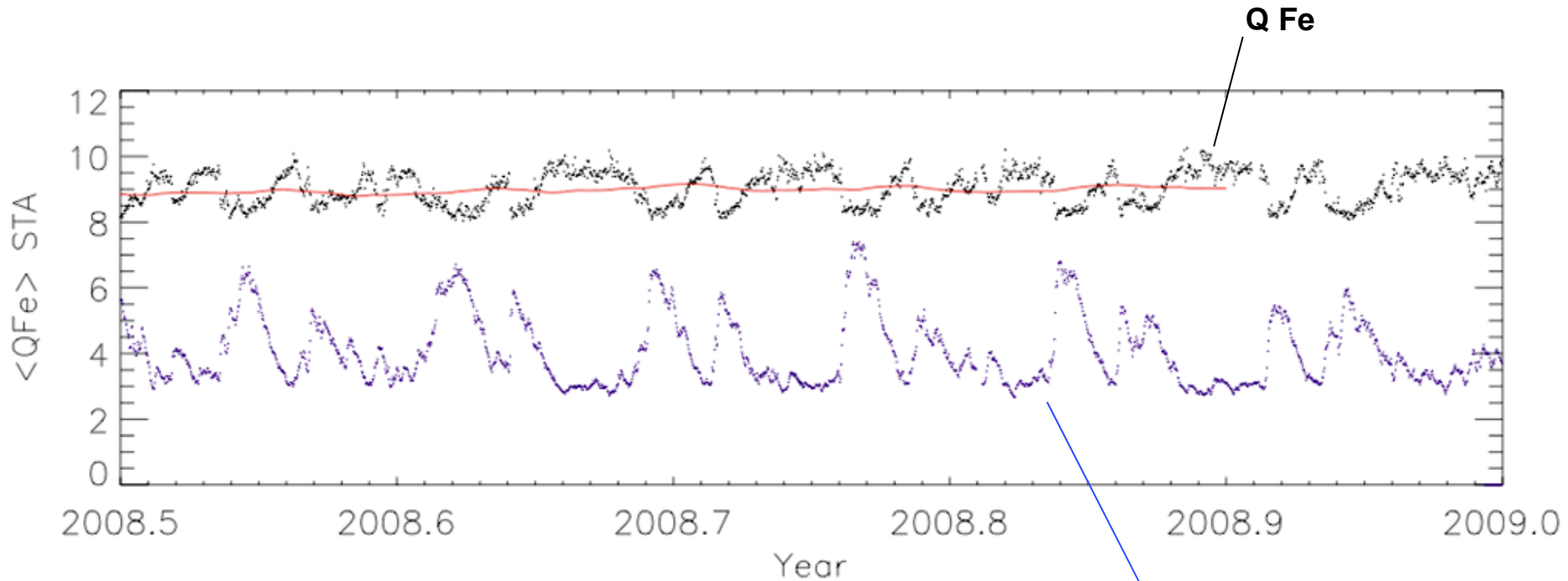
Solar Wind Fe Charge State Expectations

- Four types (Schwenn, 2006)
 - Fast solar wind (coronal holes)
 - Slow solar wind (near helmet streamers)
 - Slow solar wind (active regions)
 - ICME solar wind
- $\langle Q_{Fe} \rangle_{slow} > \langle Q_{Fe} \rangle_{fast}$
- ICME $Q_{Fe} \sim 16+$
- Small variations in mean charge state compared to SEPs



STEREO A Fe Charge States vs. Solar Wind Speed

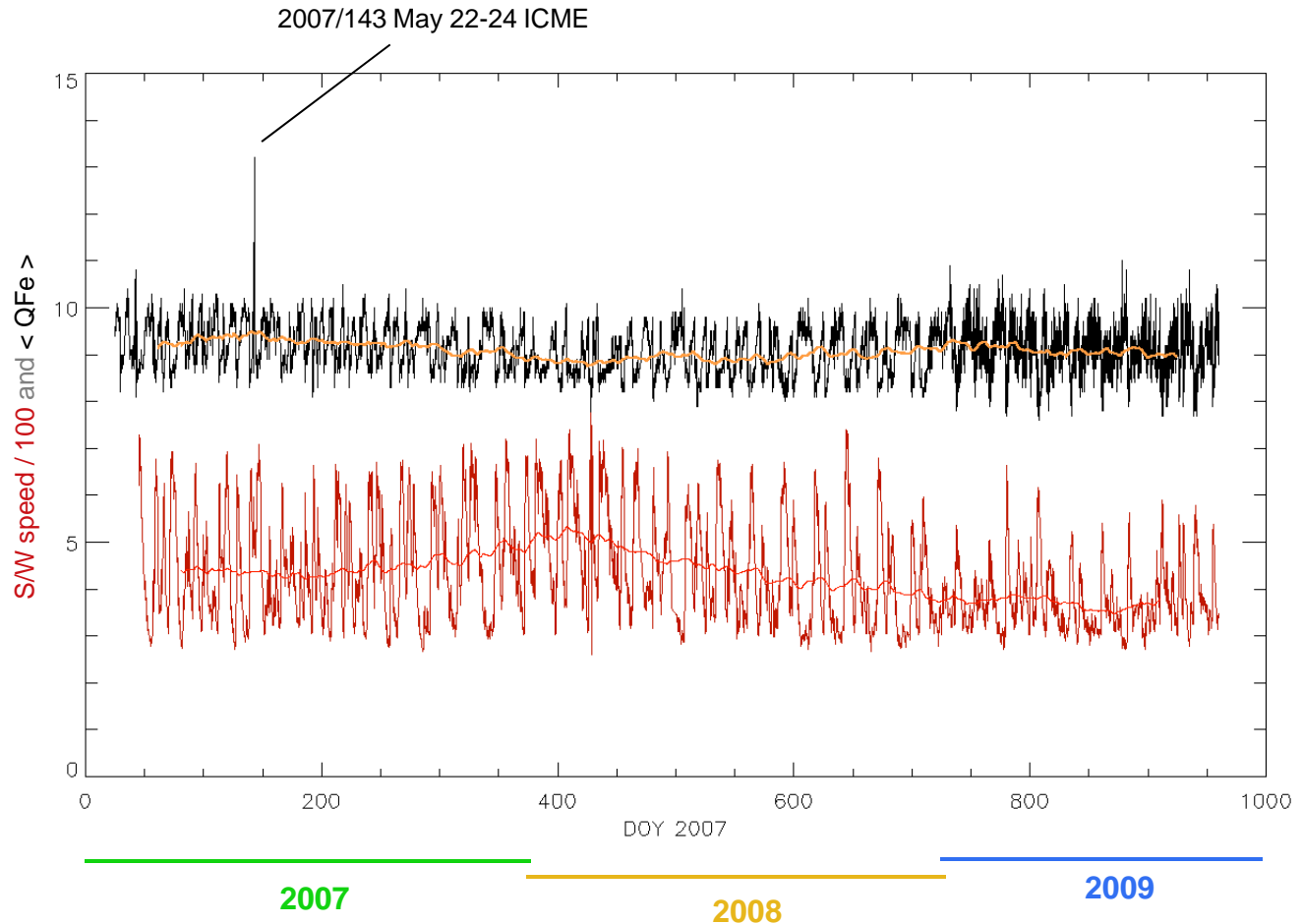
Latter Half of 2008



- Limited period of time
- Solar wind speed is inversely related to Q Fe

Iron charge states and solar wind speeds : 2007 (DOY 022) -2009 (DOY 230), STEREO A

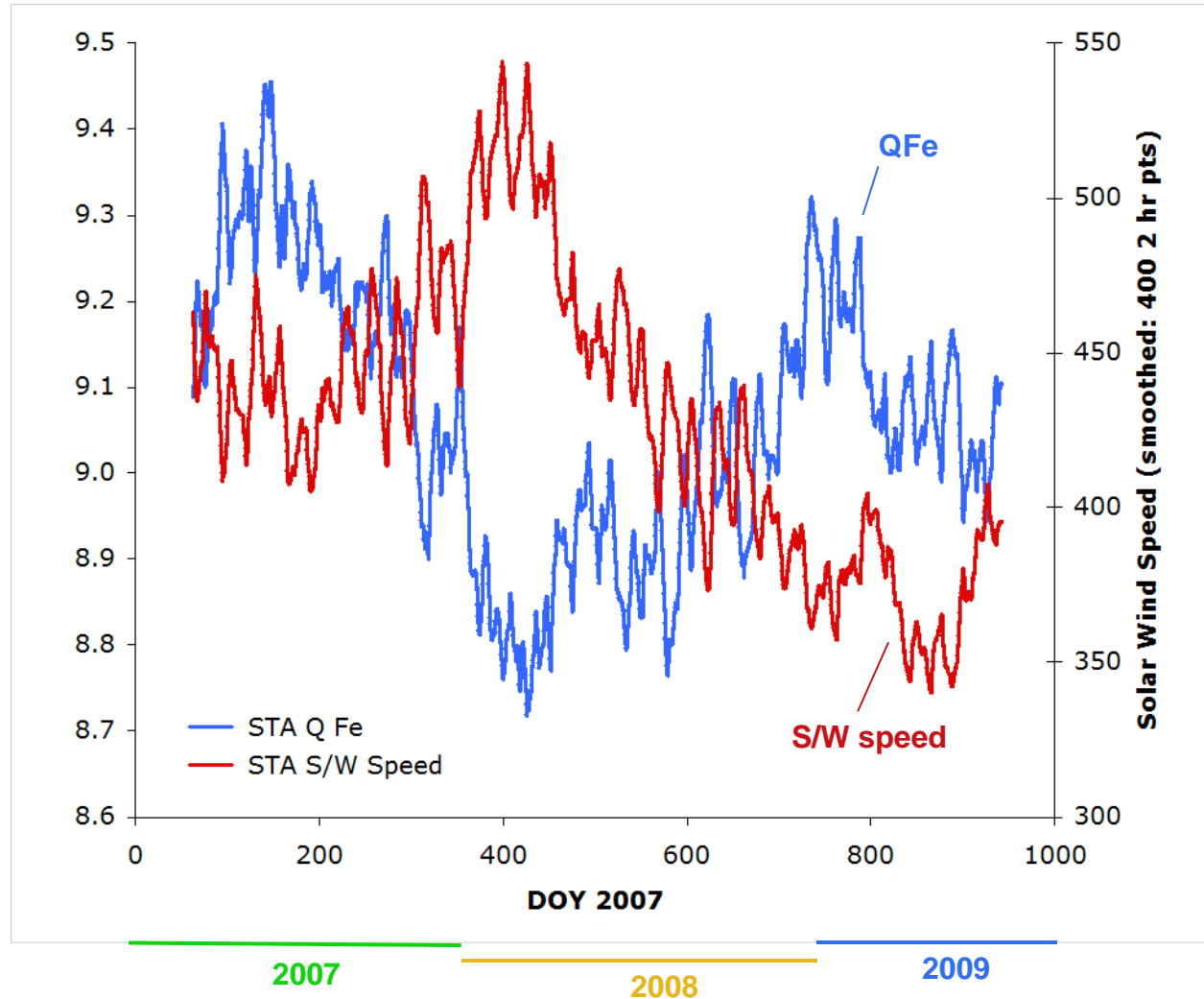
- The top trace is the iron charge state, averaged over 2 hour periods.
 - The average charge states typically ranged between 8+ and 11+.
 - A prominent **exception** occurred during the 2007/143 May 23 ICMEs. The average charge state was ~13+ to 14+.
- The bottom trace is the 2 hour averaged solar wind speed from STEREO A.
 - An upward trend occurred in the beginning of 2008, maximizing at DOY 2007 400 (early February, 2008).
 - A long decline below the 2007 levels followed, until August of 2009.
 - Variations in the solar wind speed have decreased compared to early 2007.



Mean Iron Charge State and Solar Wind Speed:

2007 (DOY 022) -2009 (DOY 230), STEREO A

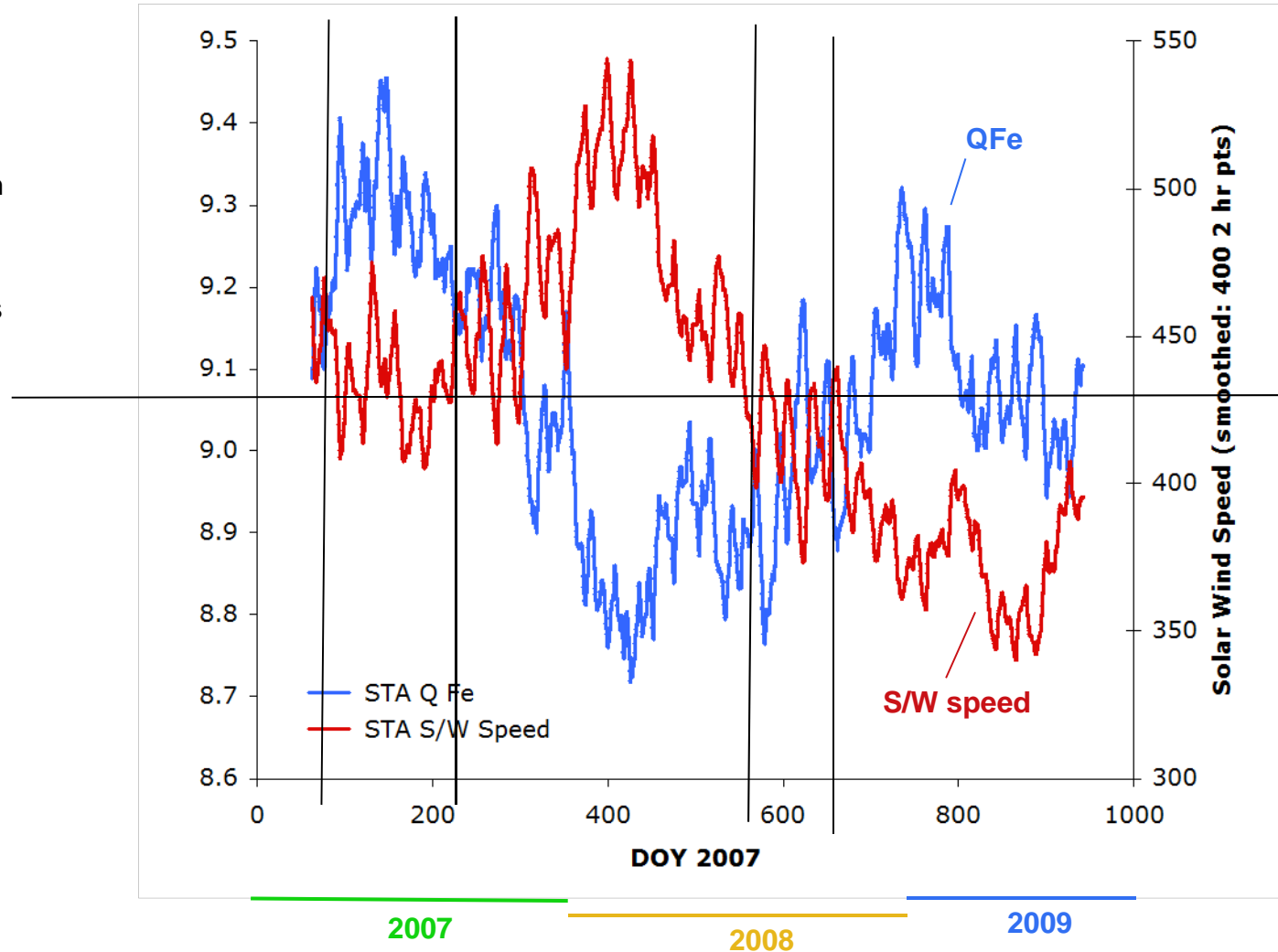
- The smoothed trendline in the iron charge states is shown in blue (left axis) with the smoothed trendline for the solar wind speed.
- The iron charge state tends to move in the opposite direction to the solar wind speed in a large scale sense.
- The charge state in 2008/2009 has not completely recovered to the early 2007 levels, even though the average solar wind speed has gone lower than it was in 2007.



Mean Iron Charge State and Solar Wind Speed:

2007 (DOY 022) -2009 (DOY 230), STEREO A

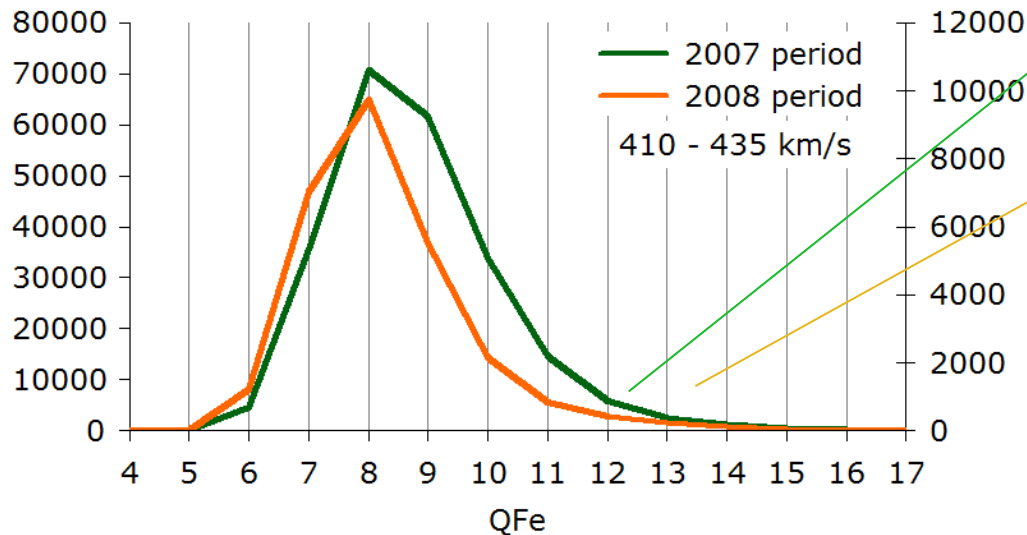
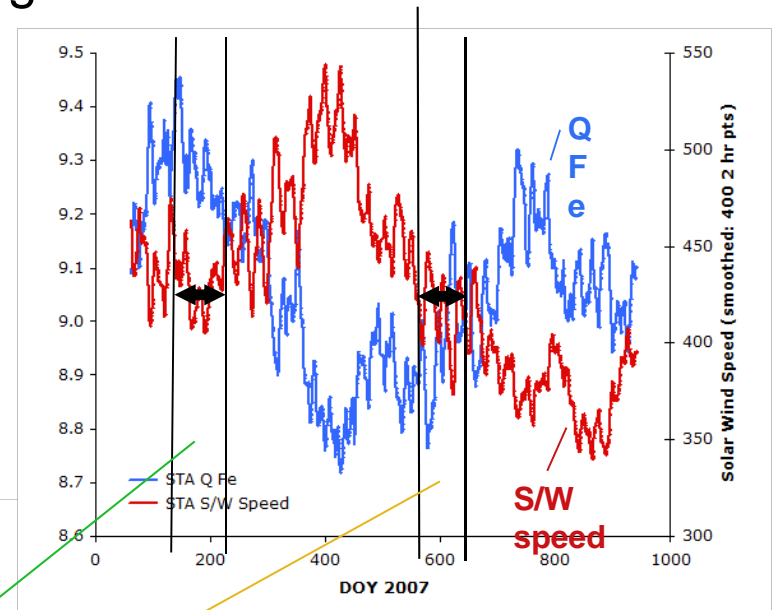
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- The charge state has not completely recovered to the early 2007 levels, even though the average solar wind speed has gone lower than it was in 2007.



Iron Charge State and Solar Wind Speed:

A change in the Fe charge state distribution in the 410-435 km/s
S/W speed range

- Fe charge histograms were calculated for two periods in 2007 and 2008 for which solar wind speeds were 410 - 435 km/s.
- The Fe charge state histogram for 2008 is narrower and has less high charge content than in the 2007 period.



2007 2008 2009

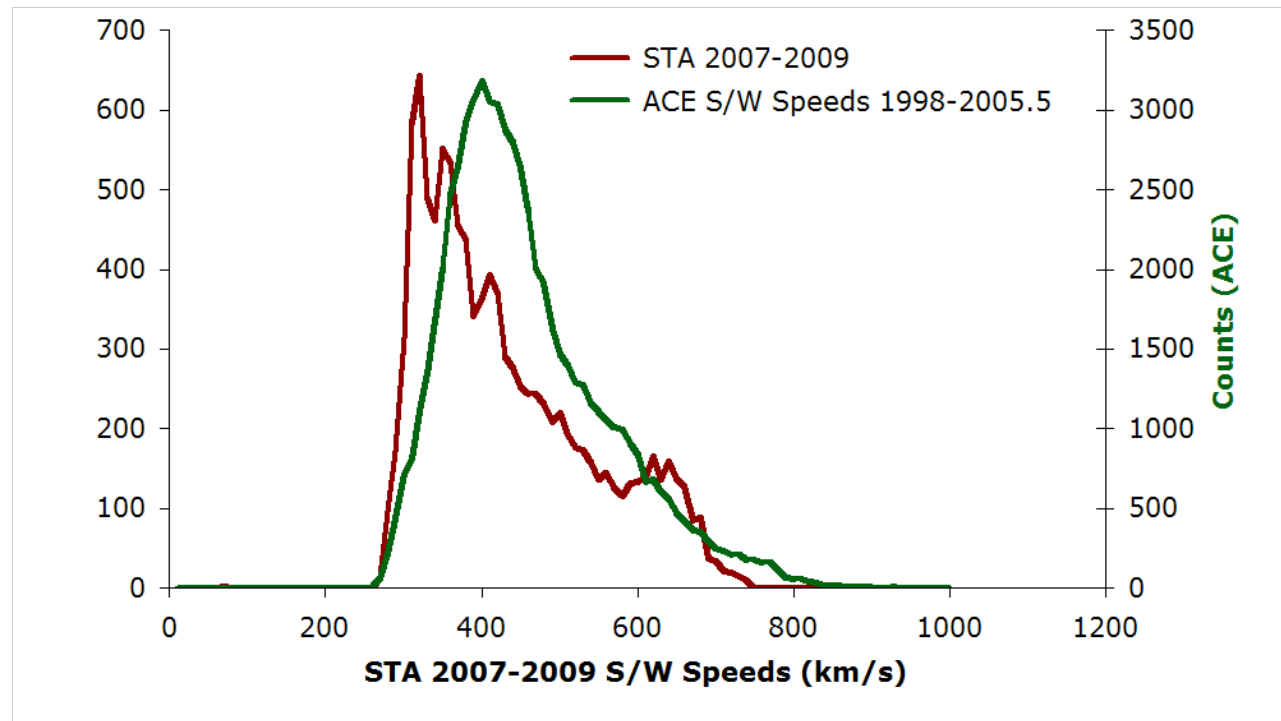
Summary

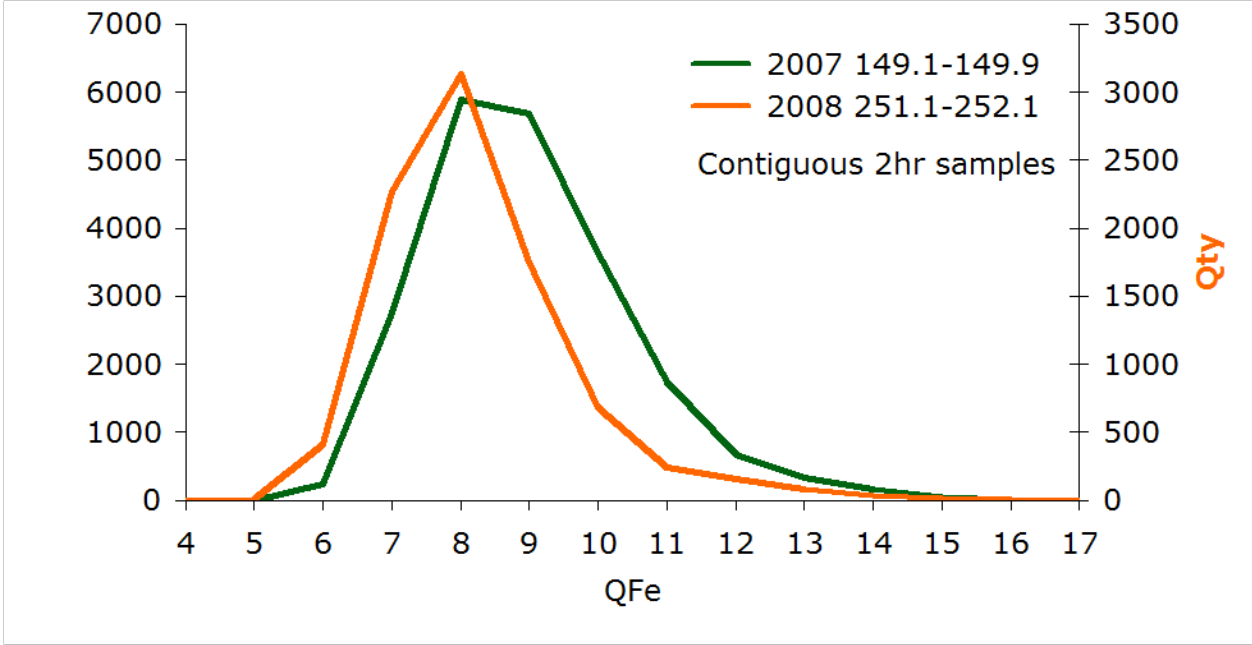
Changes in Fe charge state distributions with solar wind speed

- In the 2007-2009 period, the solar wind speed trended up, then down again.
- The mean Fe charge state varied inversely, consistent with von Steiger et al. (2000).
- However, in the second low speed period, the mean Fe charge state was lower than the first.
- For the speed range 410 - 435 km/s, the Fe charge state distribution in the second period was narrower than in the first, due to a deficit in higher charge states.
- Is the slow solar wind in the second period from a different source than the first?

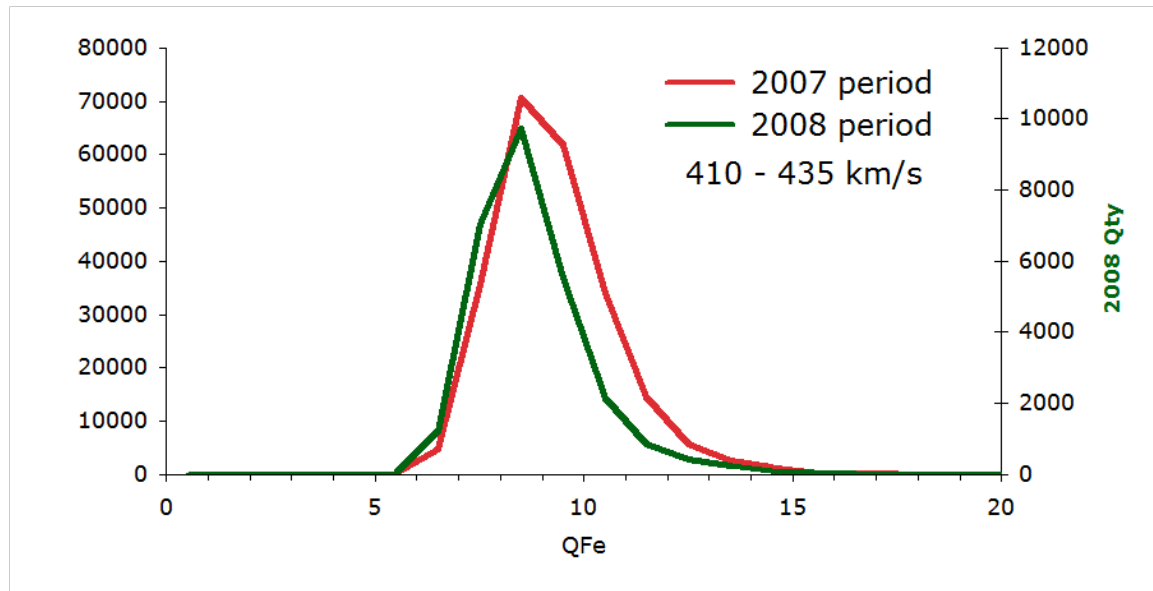
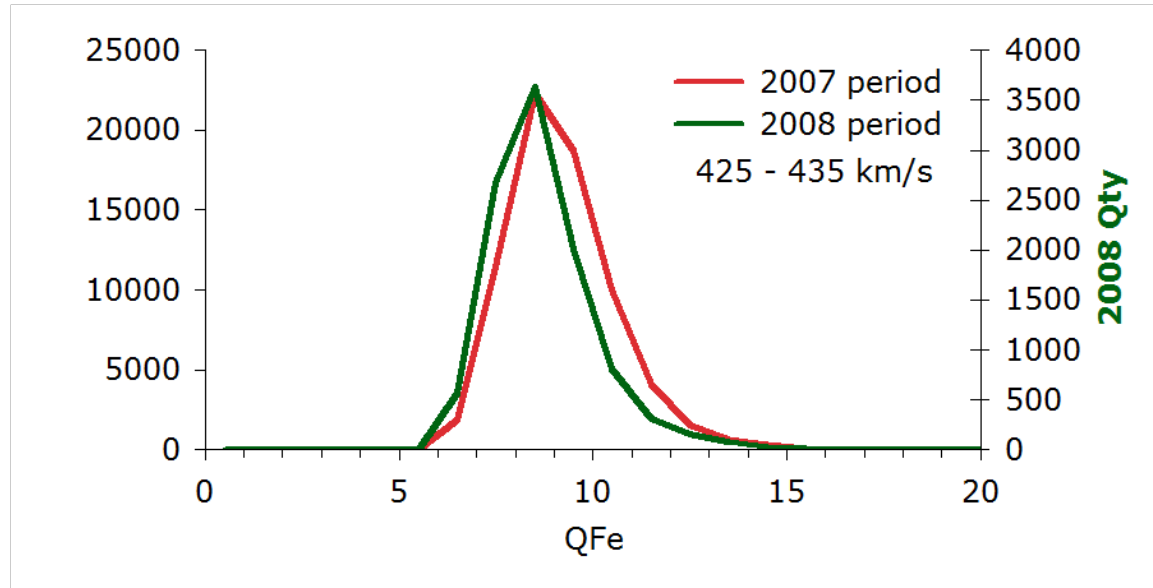
Solar Wind Speeds: Recent Solar Min and Max

- **STEREO A:**
2007/045-
2009/230
- **ACE:** 1998-
2005.5
- Speeds in the
2007-2009
period (solar
min) are
typically *lower*
than the 1998-
2005 period
(solar max)

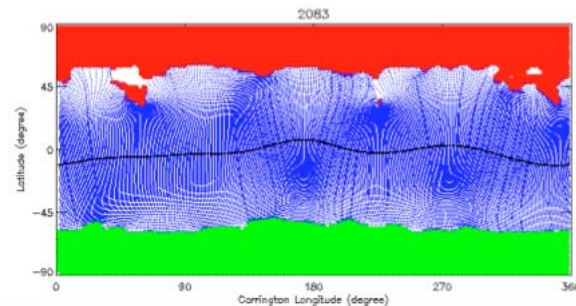
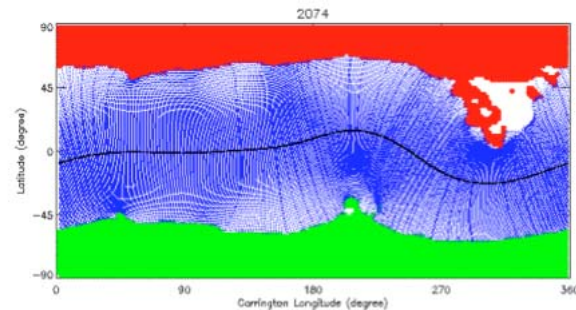
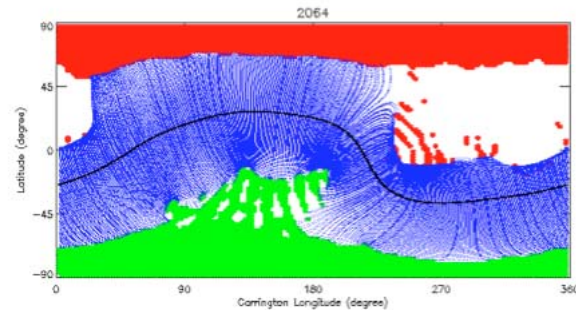
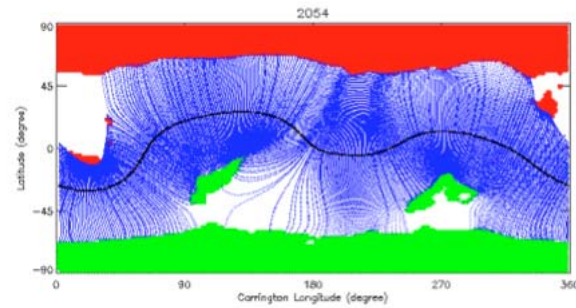


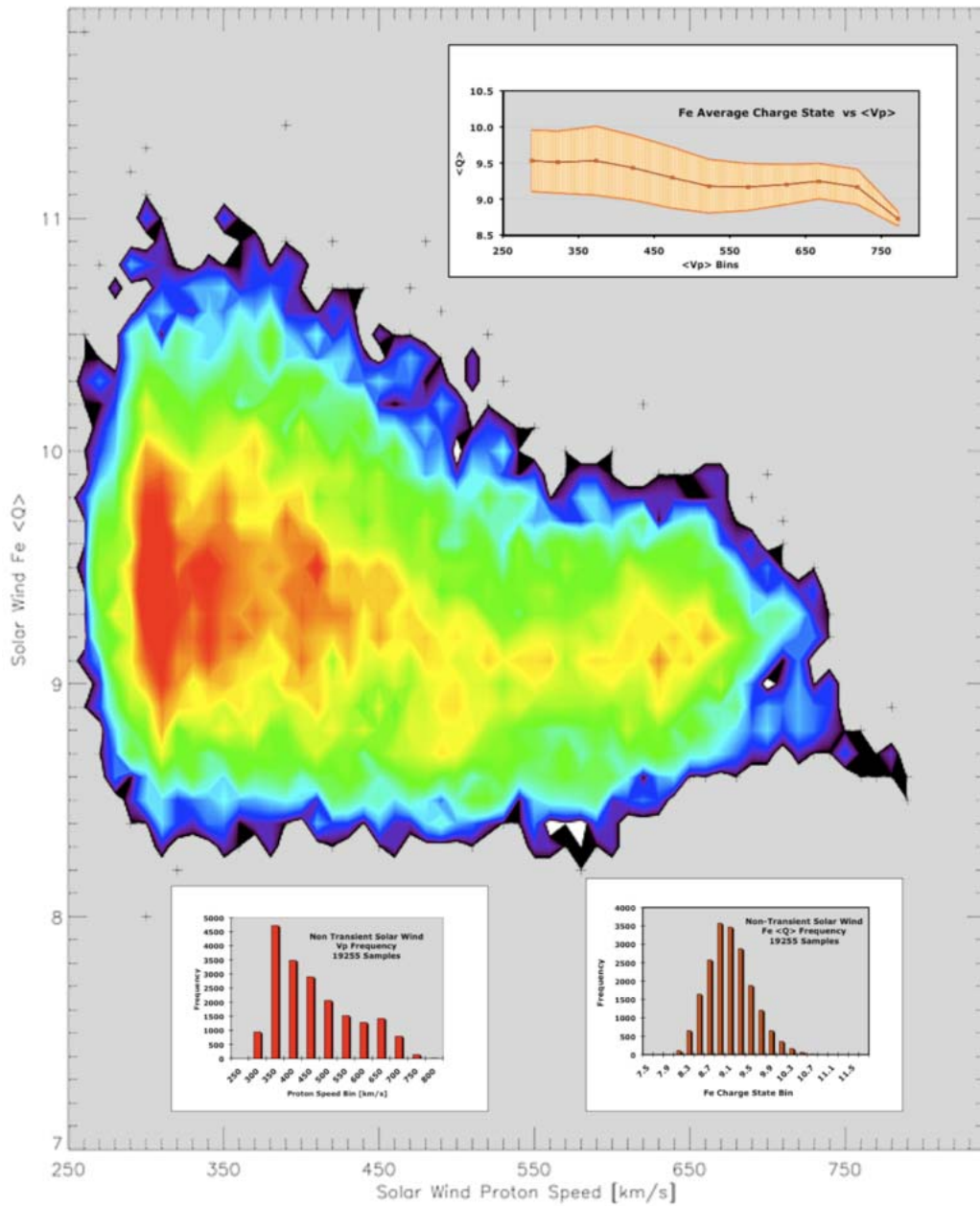


- 2007 vs 2008 for 410-435 km/s

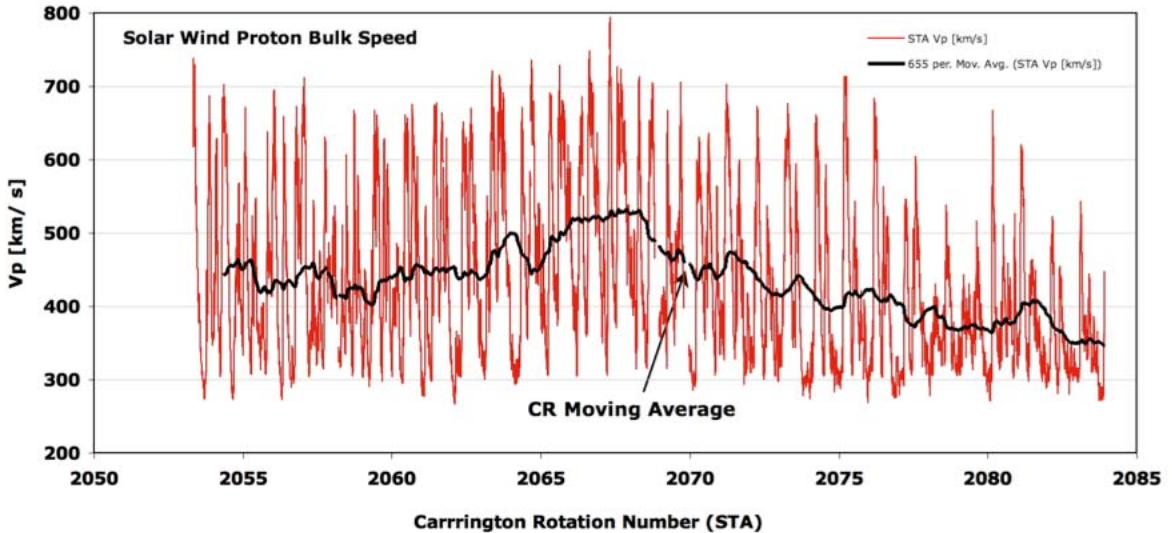


- NSO/GONG synoptic coronal hole plots for selected Carrington rotations
 - Red/green areas are coronal holes: red negative polarity, green positive polarity
 - Neutral line is in black
- Isolated coronal holes disappear with time
- Polar coronal hole extensions shrink
- Neutral line flattens (less tilted current sheet)
- Reduced exposure to coronal hole solar wind?

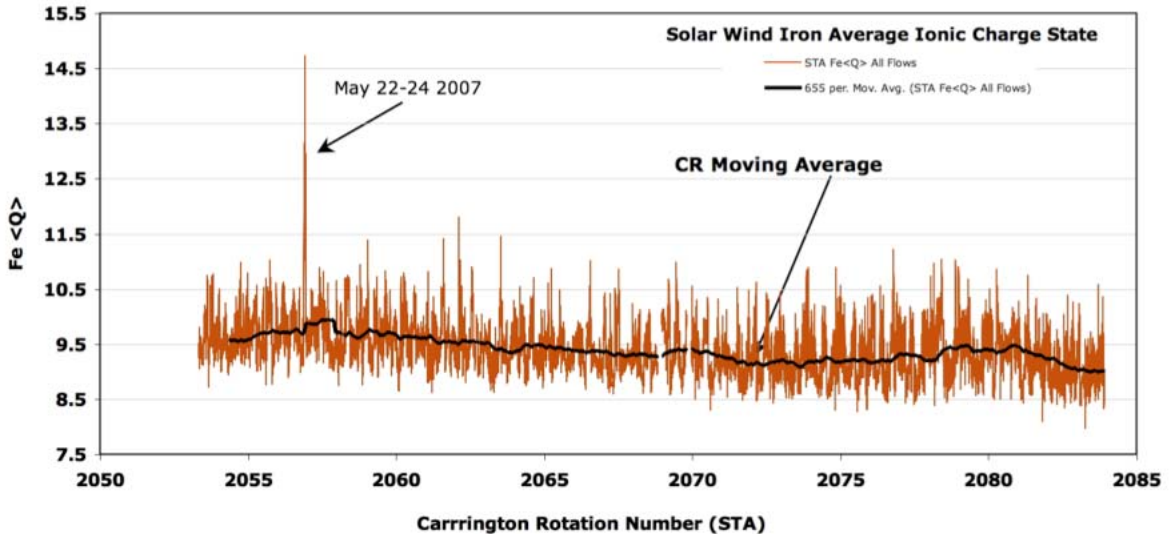




STEREO A PLASTIC
February 2007 - May 2009

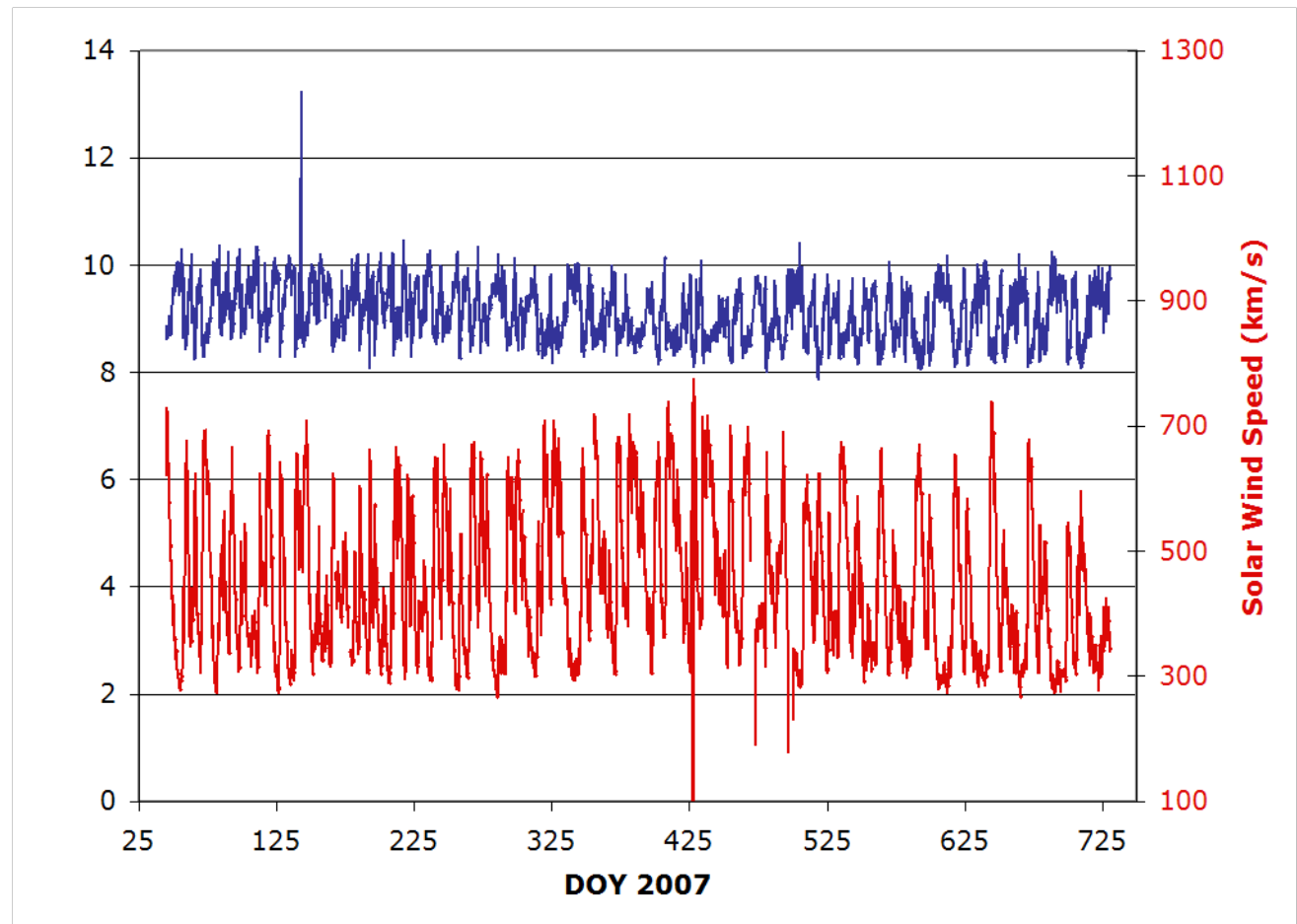


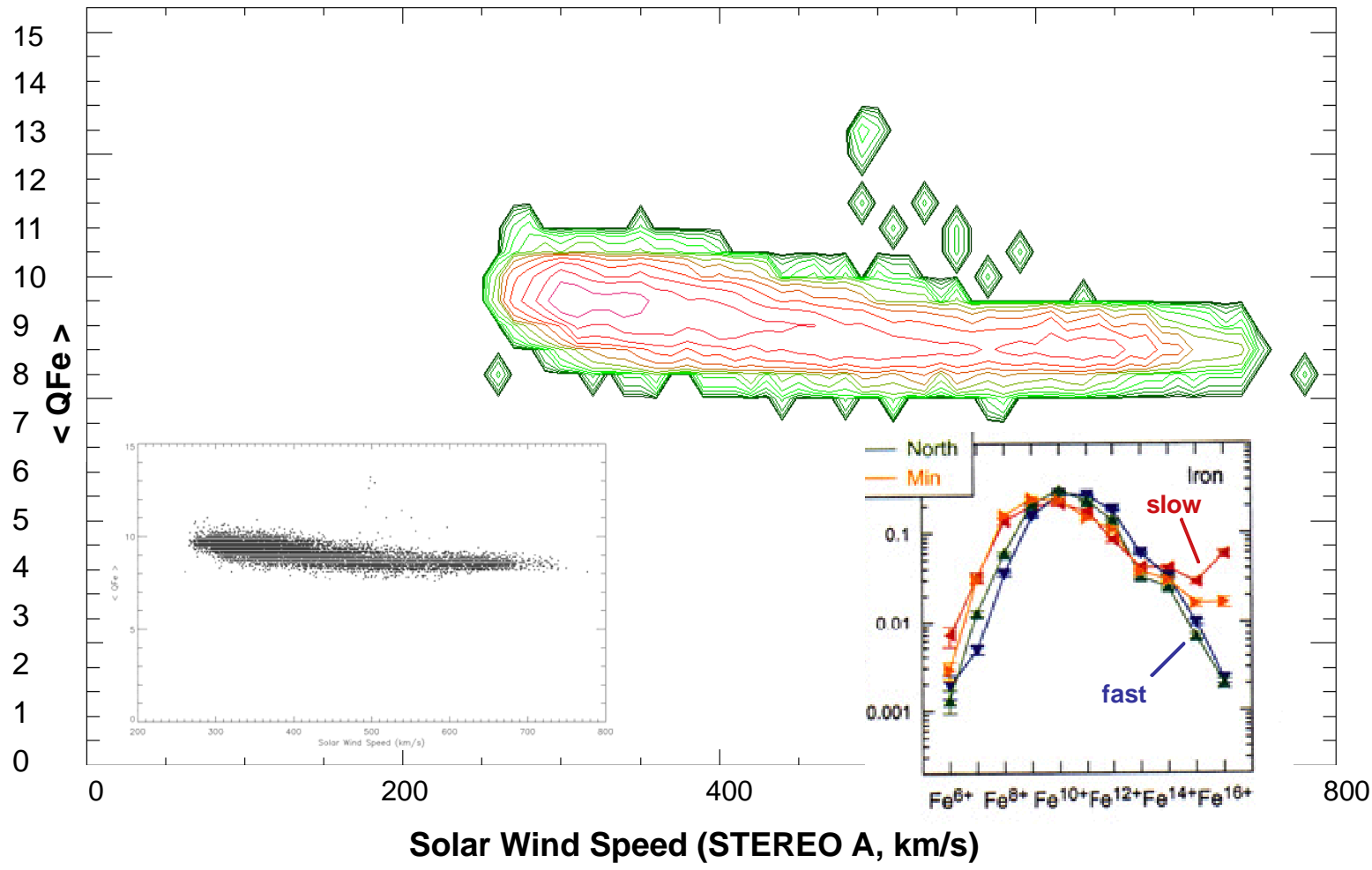
- One hour averages of solar wind speed and iron charge state from STEREO A
- Smoothed lines - 655 hour averages (~Carrington rotation)



STEREO A Fe Charge States vs. Solar Wind Speed

- Average Fe charge state generally shows an anticorrelation with solar wind speed (sources: fast or slow s/w, coronal holes or active region).
- Typical values of charge state are between 9+ and 10+.
- Only one period of high charge states exists: May 22-24, 2007 (ICME).





Solar Wind Speed vs. Iron Charge State

STEREO A 2007-2009

- The mean iron charge states are plotted against corresponding solar wind speeds for the 2007-2009 period.
- Variations in charge state are generally related to solar wind speed, but with a broad spread of approximately 1-2 charge units.
- The **mean** Q_{Fe} goes **up** at low speed, as von Steiger et al. (2000) reported.

