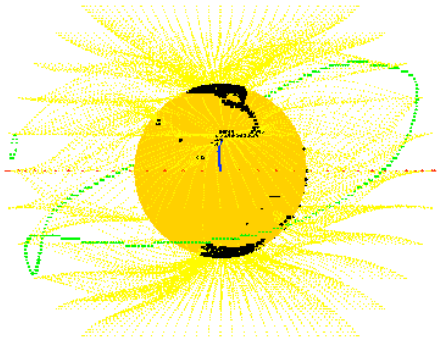
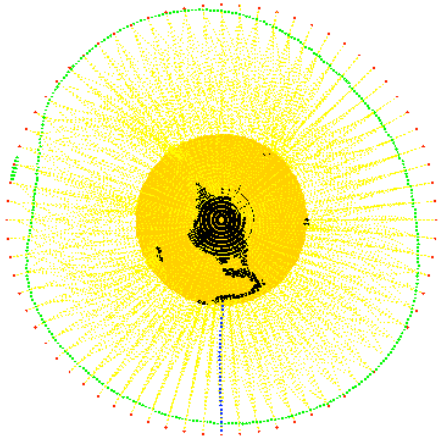
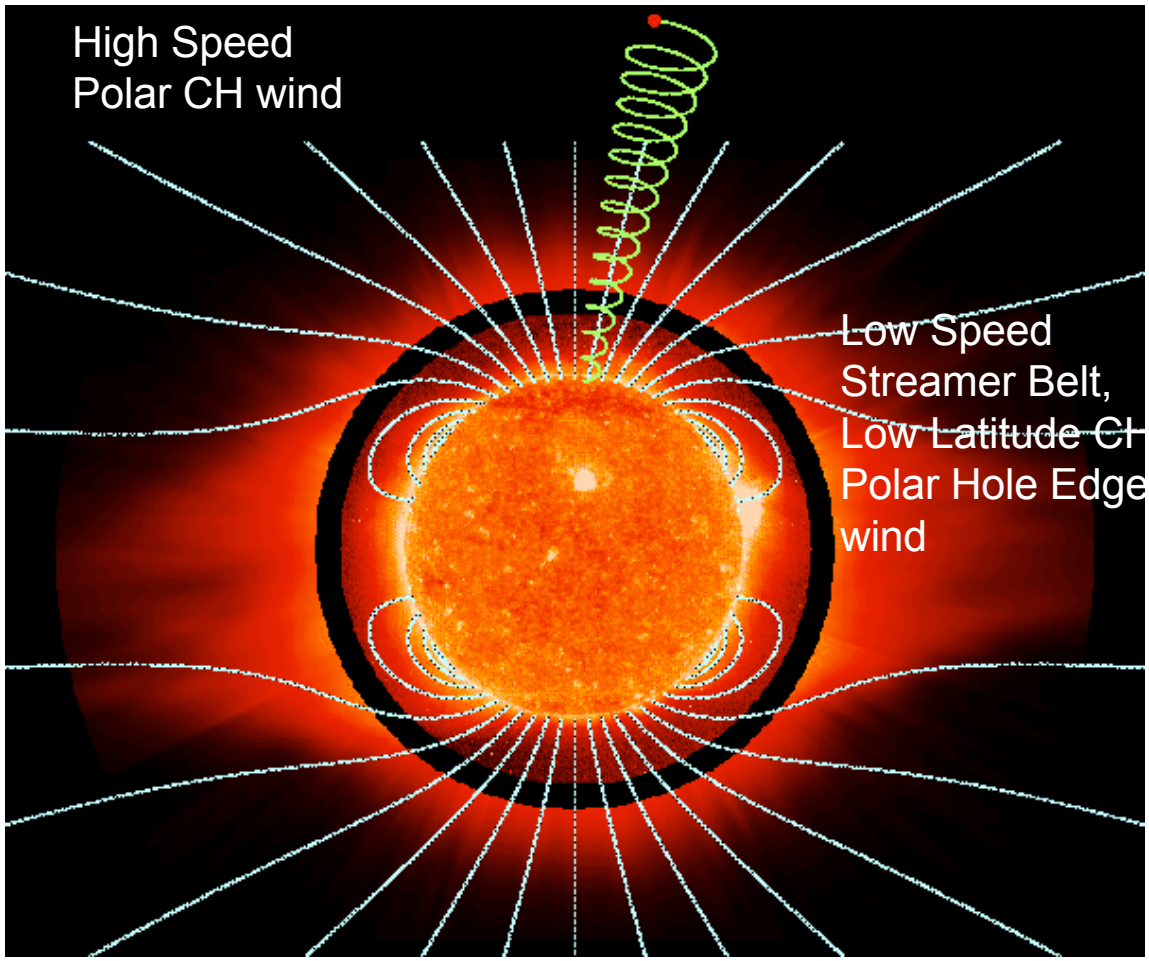
Solar Wind Sources (over the solar cycle): Where are we now?





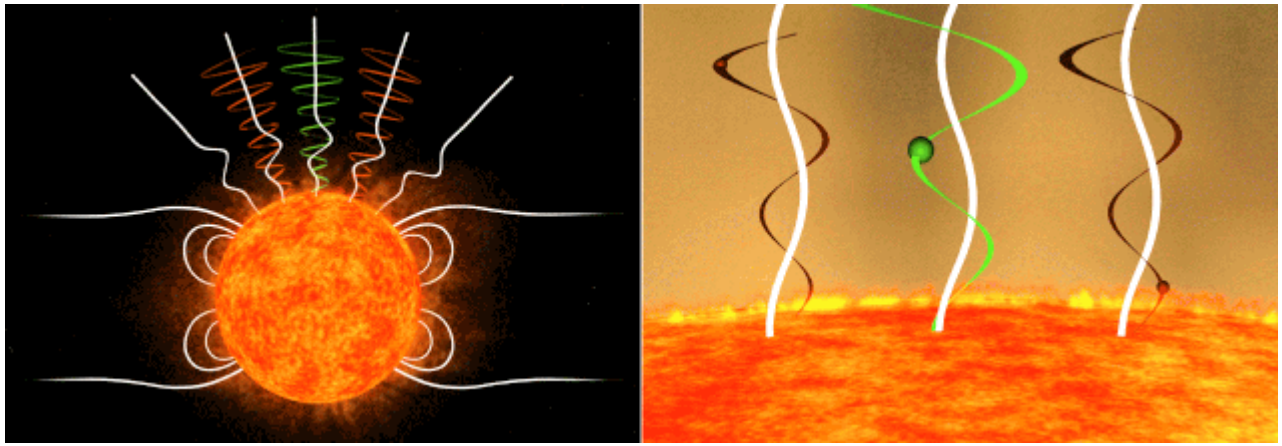
J. Luhmann, SHINE 2005 Workshop

At least four solar wind source types have been identified



UVCS website image

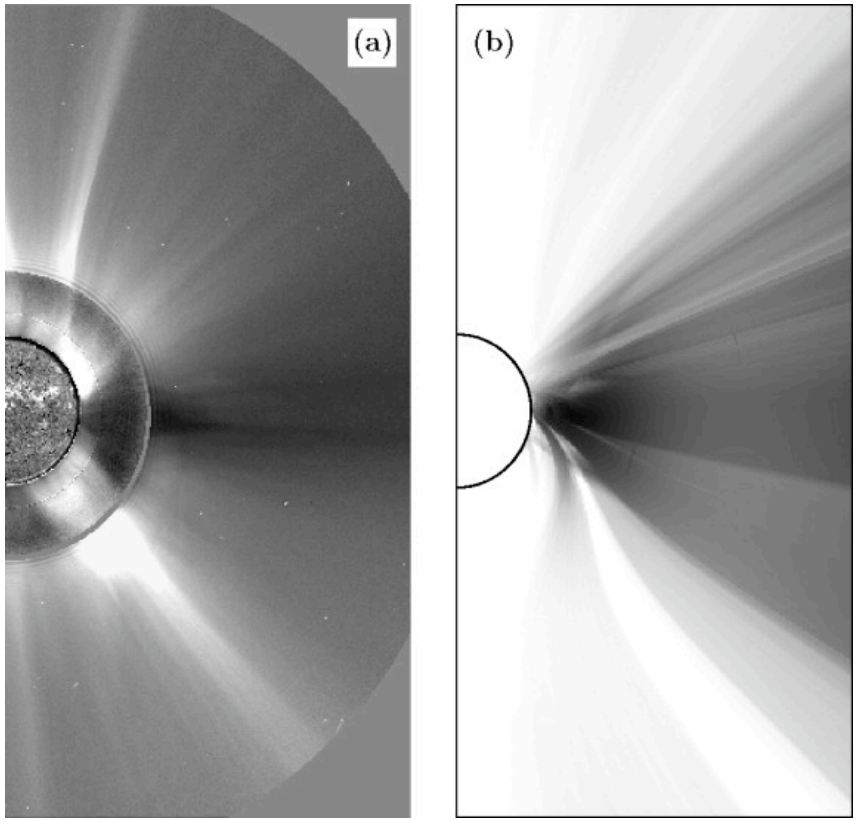
Source 1: Fast Solar Wind Originating in Polar Coronal Holes



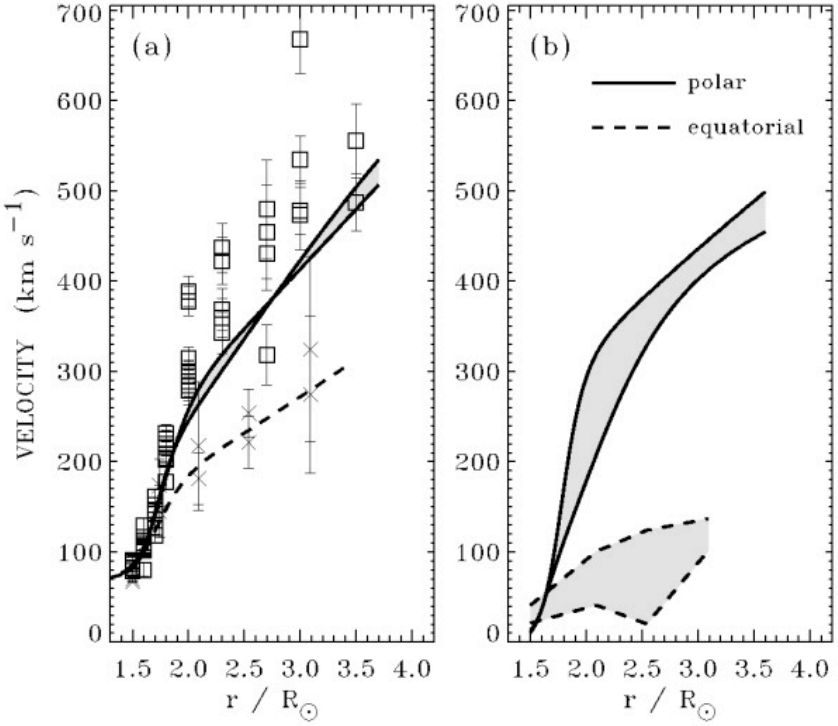
(figure from SOHO UVCS website)

-Associated with “quiet” sun at base
-Associated with highest speed winds from centers of large PCHs
-Inferred large perpendicular temperatures suggesting ion cyclotron wave heating- UVCS results
-PCHs vanish around solar polar field reversal

Source 2: Low Latitude Coronal Hole Solar Wind

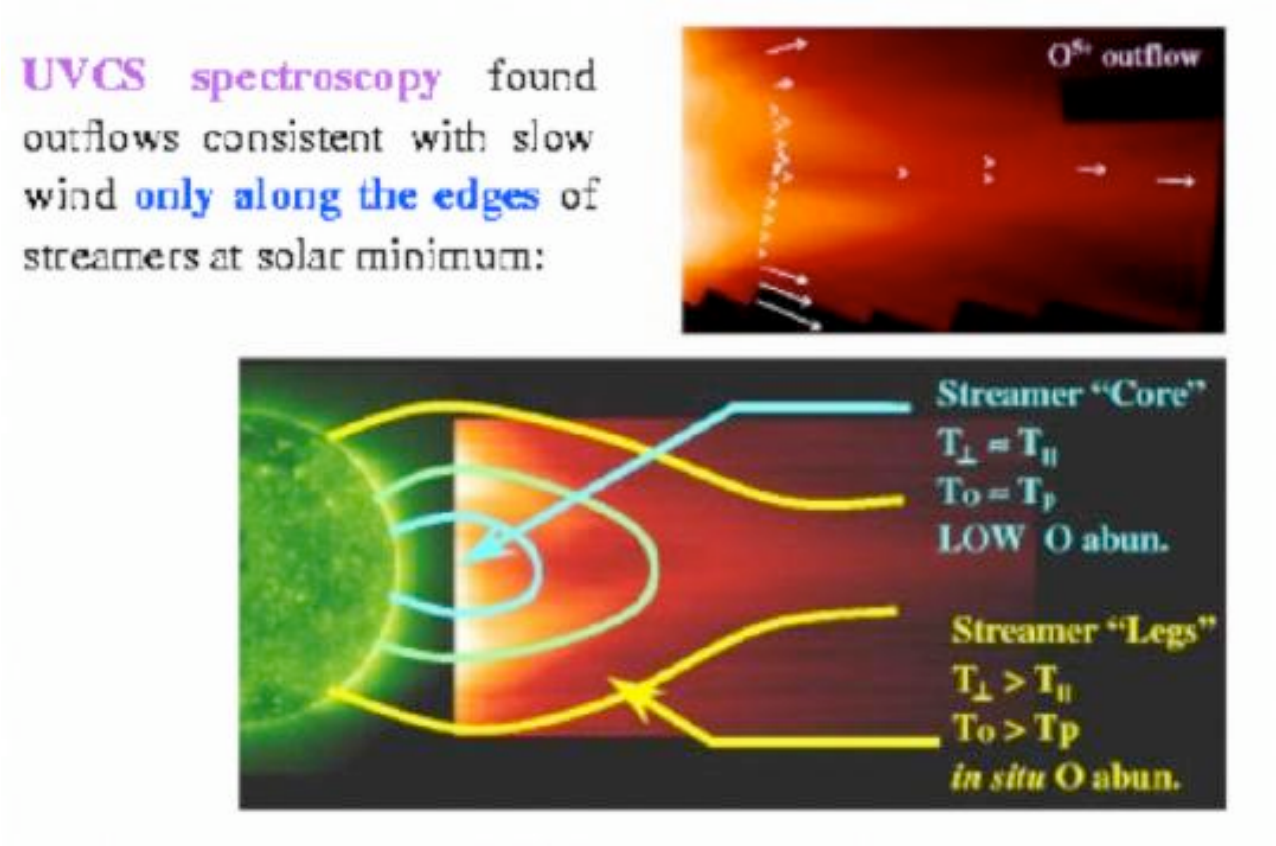


(UVCS results from Miralles et al., ApJ, 2004)



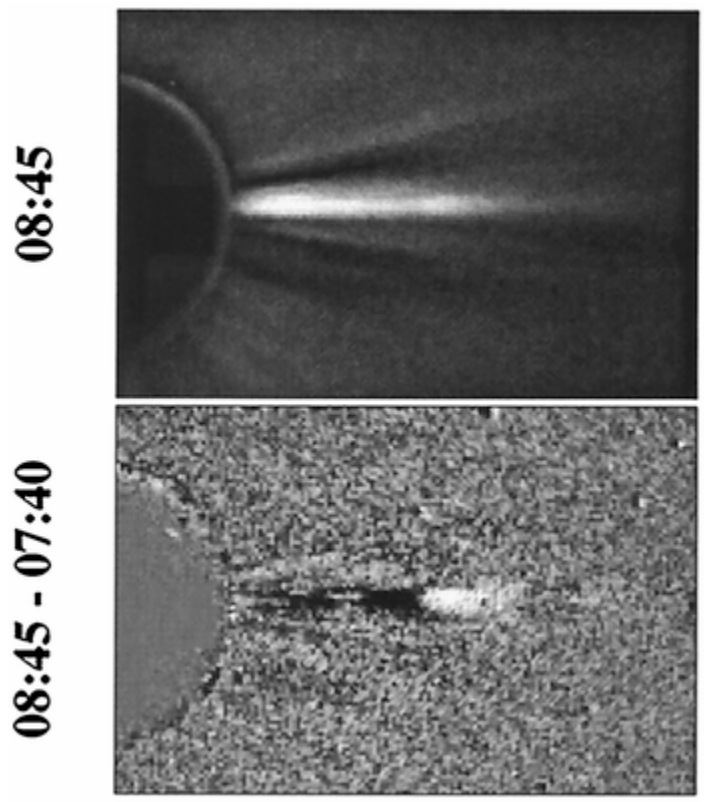
outflow inferred from O+5 ions exhibits different speed vs height profiles than PCH wind

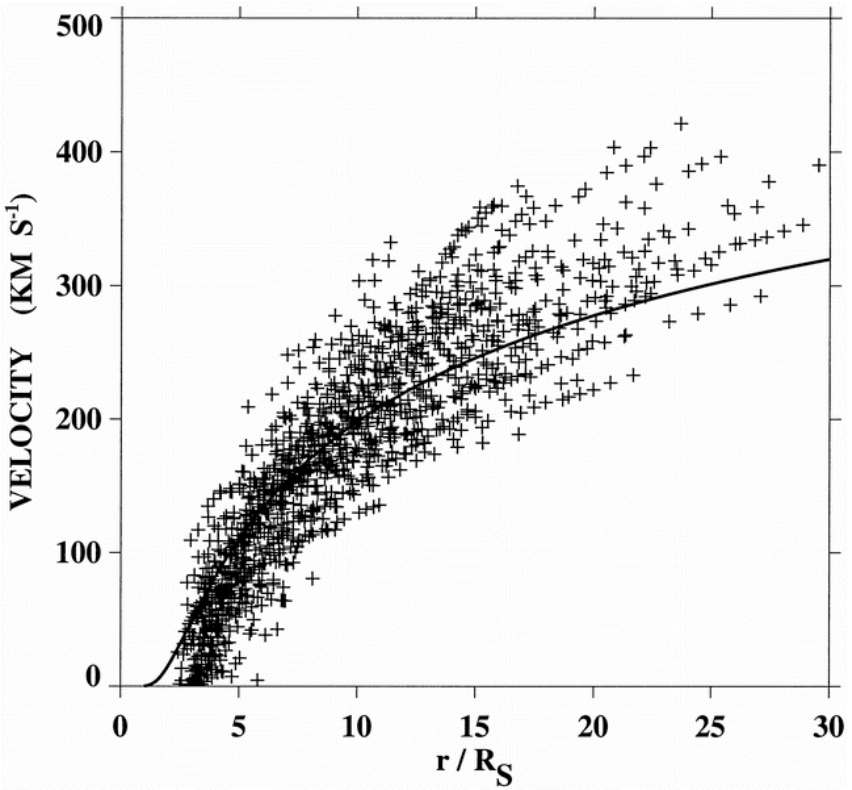
Source 3: Streamer Edge or Coronal Hole Boundary Solar Wind



(Figure from S. Cranmer- UVCS results in Strachan et al., ApJ, Antonnucci et al., A&A)

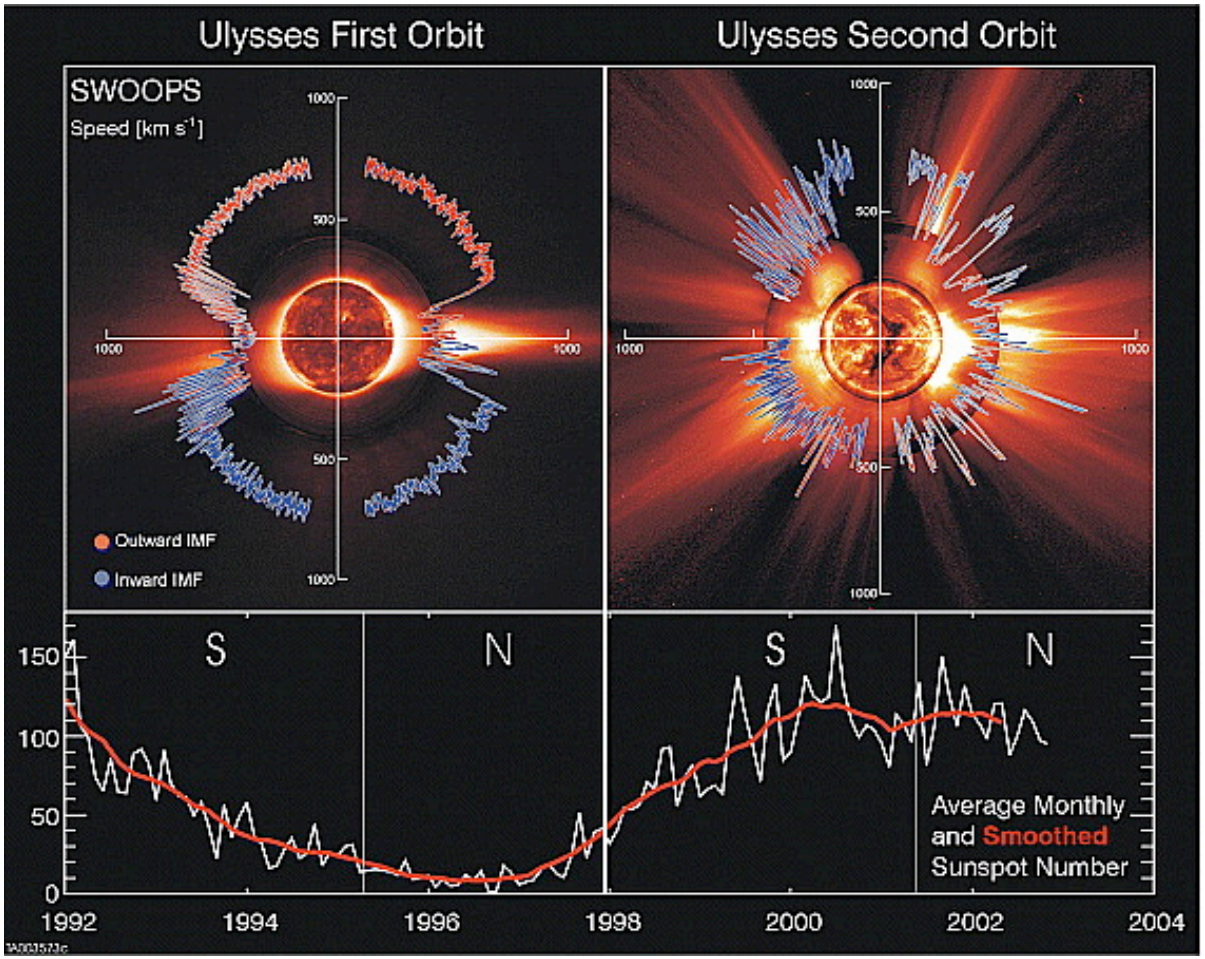
Source 4: Streamer Cusp Solar Wind





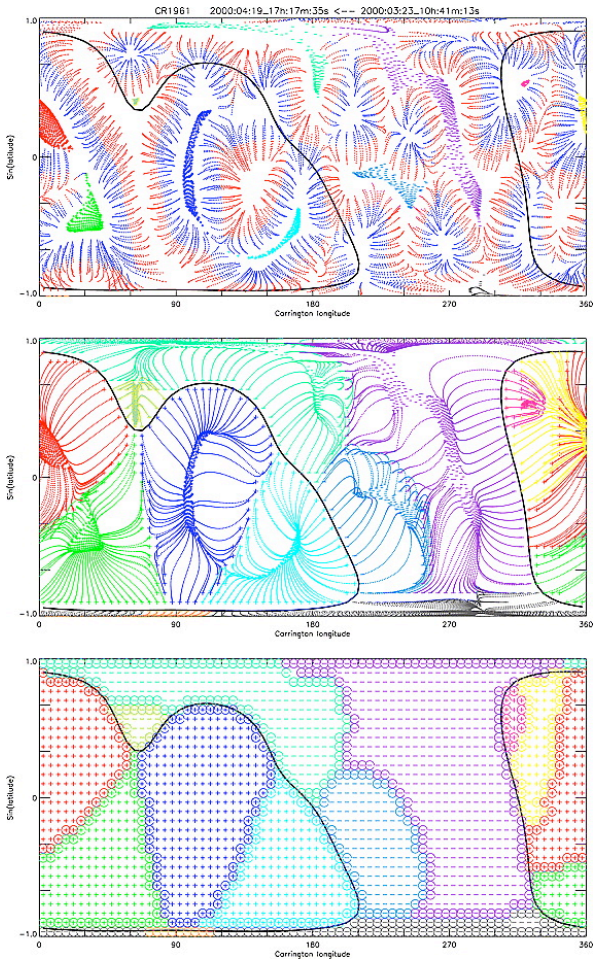
(results from LASCO images, in Wang et al., ApJ, 2000)

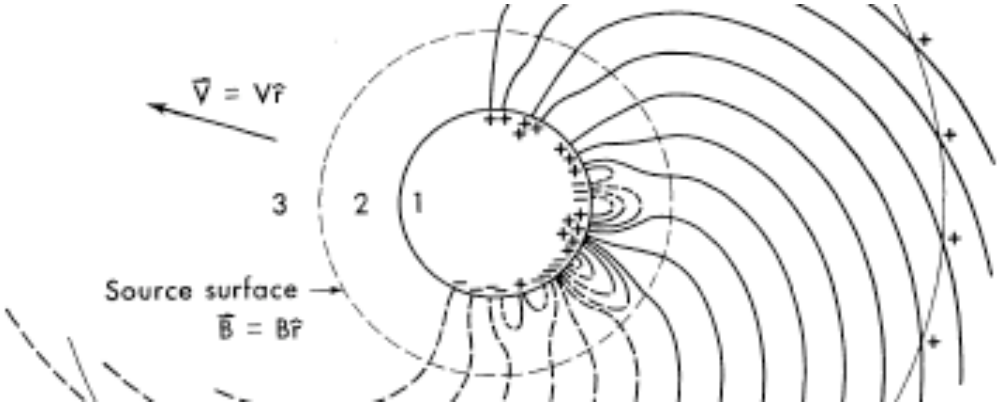
All of these sources contribute to the solar cycle changes in solar wind character



McComas et al. GRL 2003

Solar wind source mapping is an old idea revived by improved computers, data sets and models

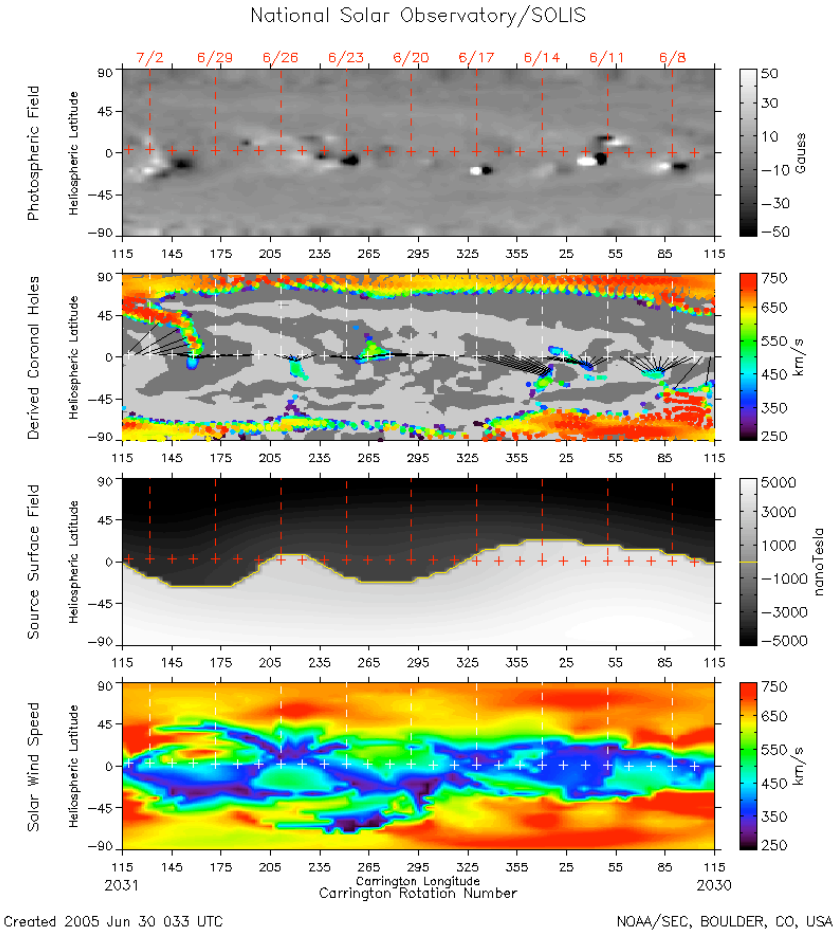


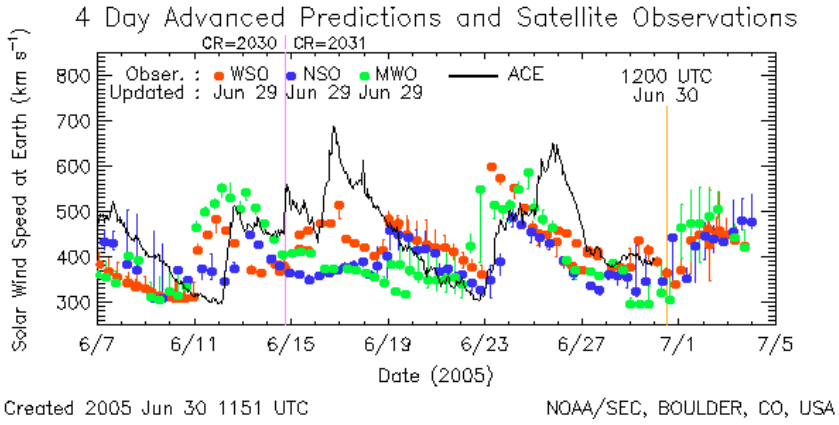


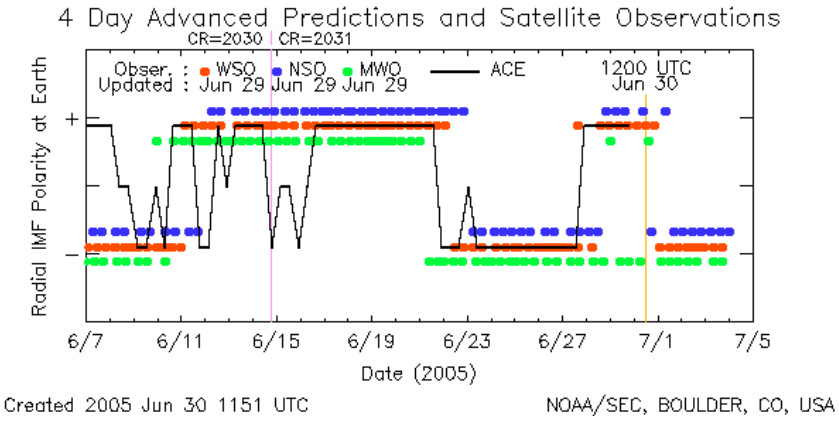
Schatten, Altschuler and Newkirk, Levine, Nolte, and others pioneered the idea and techniques of using magnetogram-based Coronal field Models with XUV images and in-situ data to map Solar Wind Sources. Neugebauer, Arge, Liewer, Schrijver and deRosa, and others follow

(Zhao et al. illustration of open field sources mapped to source surface, JGR, 2003)

WSA Model, now used for routine source mapping to the ecliptic, frequently finds non-polar sources

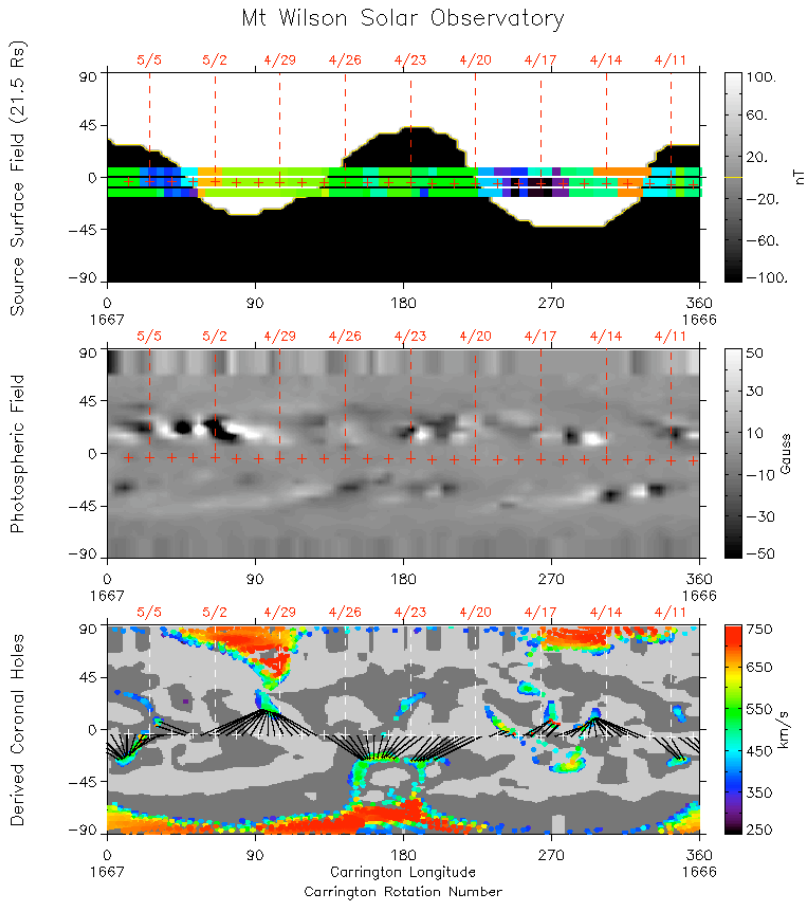


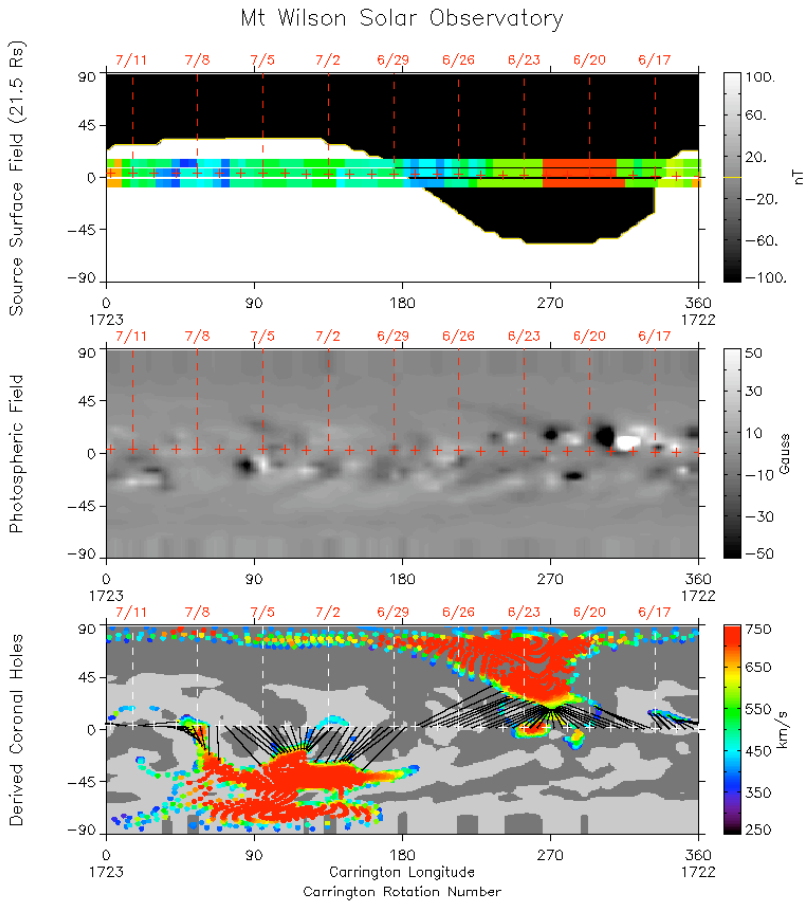




(recent images from WSA website at NOAA SEC)

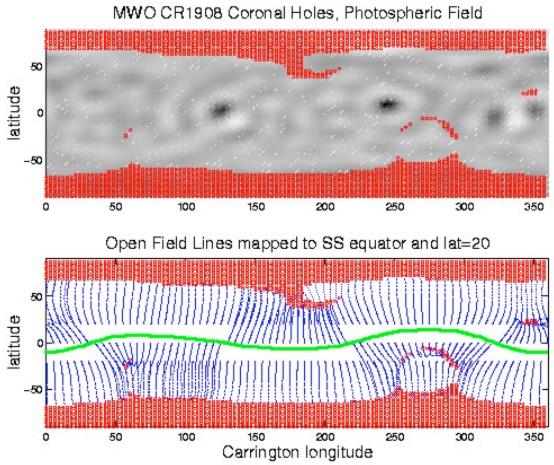
All mapping studies infer an important role for low latitude holes in the near-earth solar wind, and of active region associations

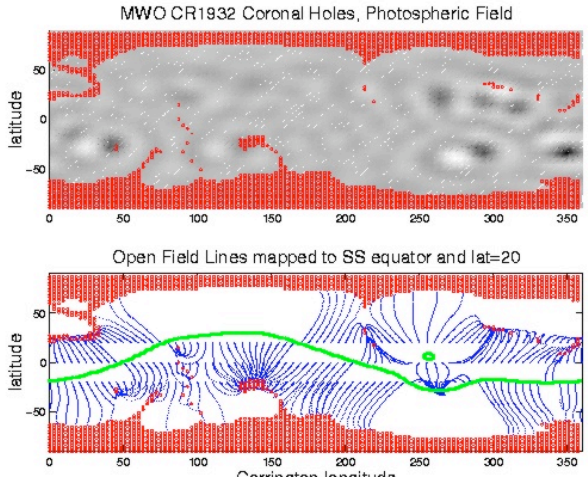


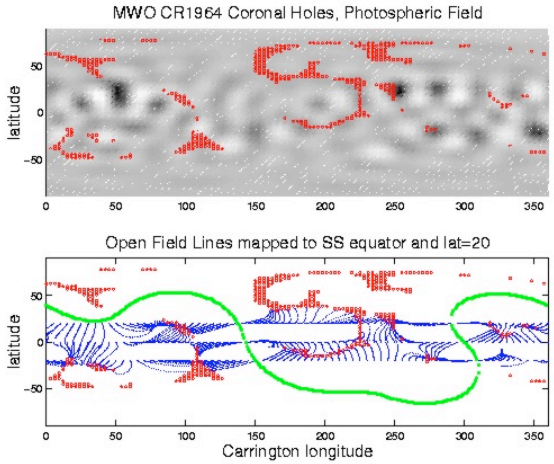


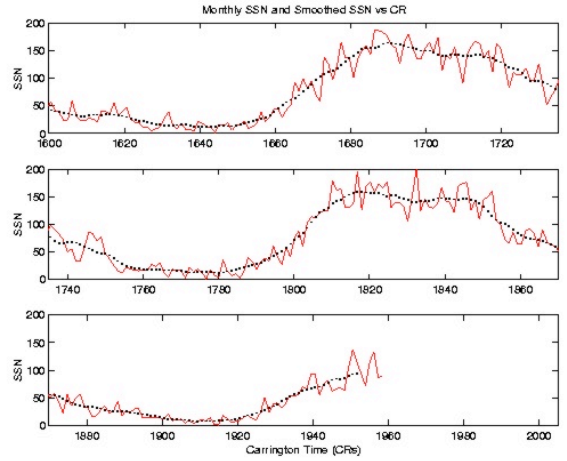
(Image from N. Arge showing connectivity to active region sites using WSA model)

Solar Cycle-long Mapping shows ecliptic sources change from Polar Coronal Holes around solar min to Low Latitude Coronal Holes around solar max (mixed in between)



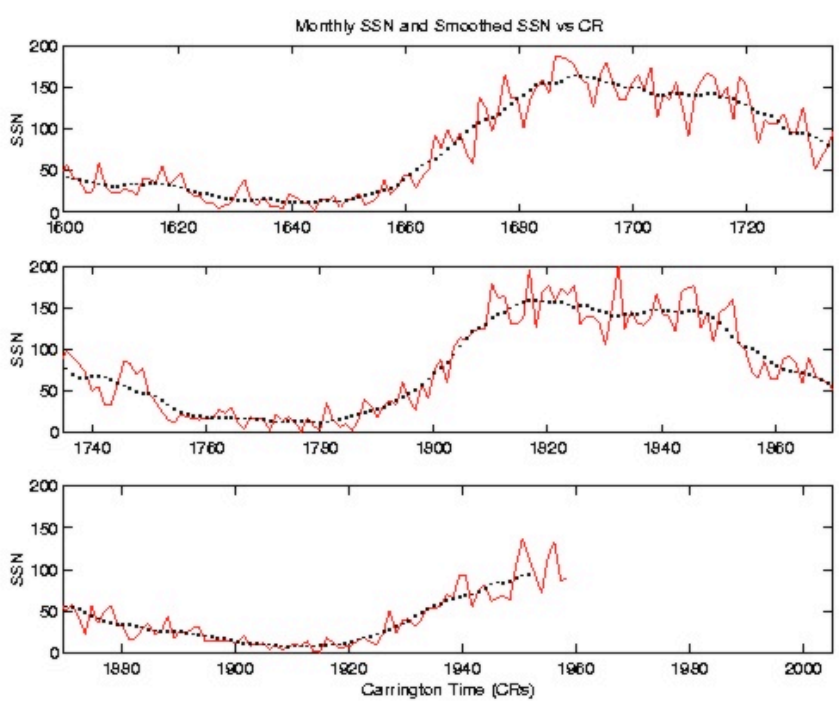


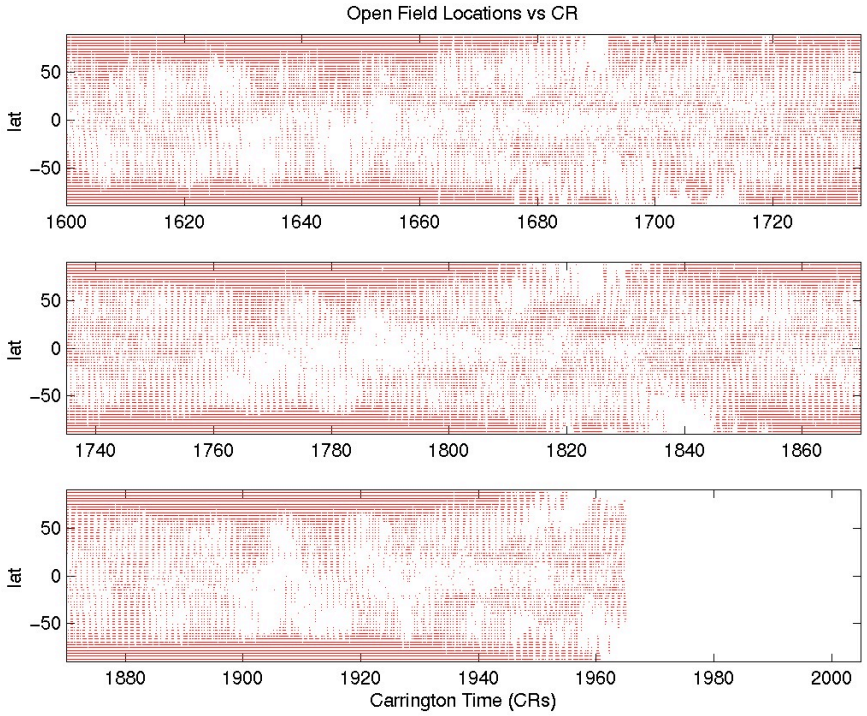




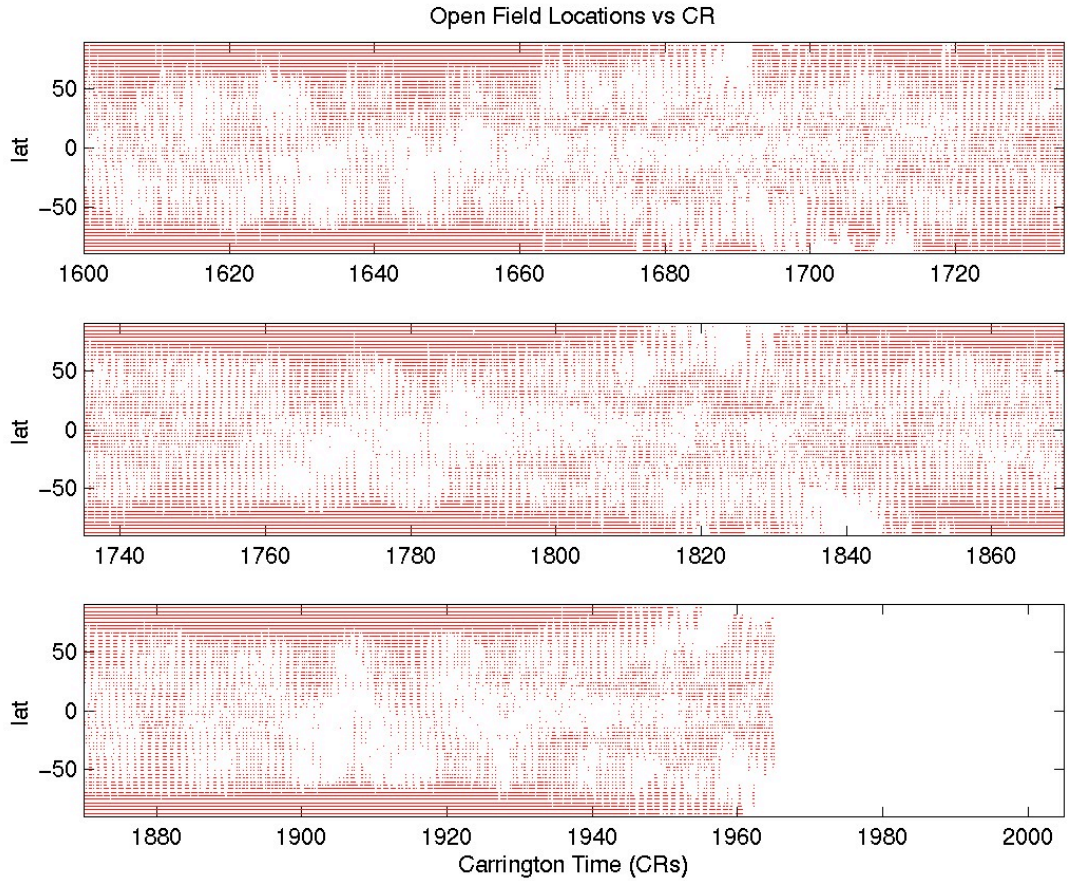
(Luhmann et al., JGR, 2002)

Carrington Rotation coronal hole footpoint maps, reversed and laid end-to-end, give a long-term picture of global solar wind sources over the cycle

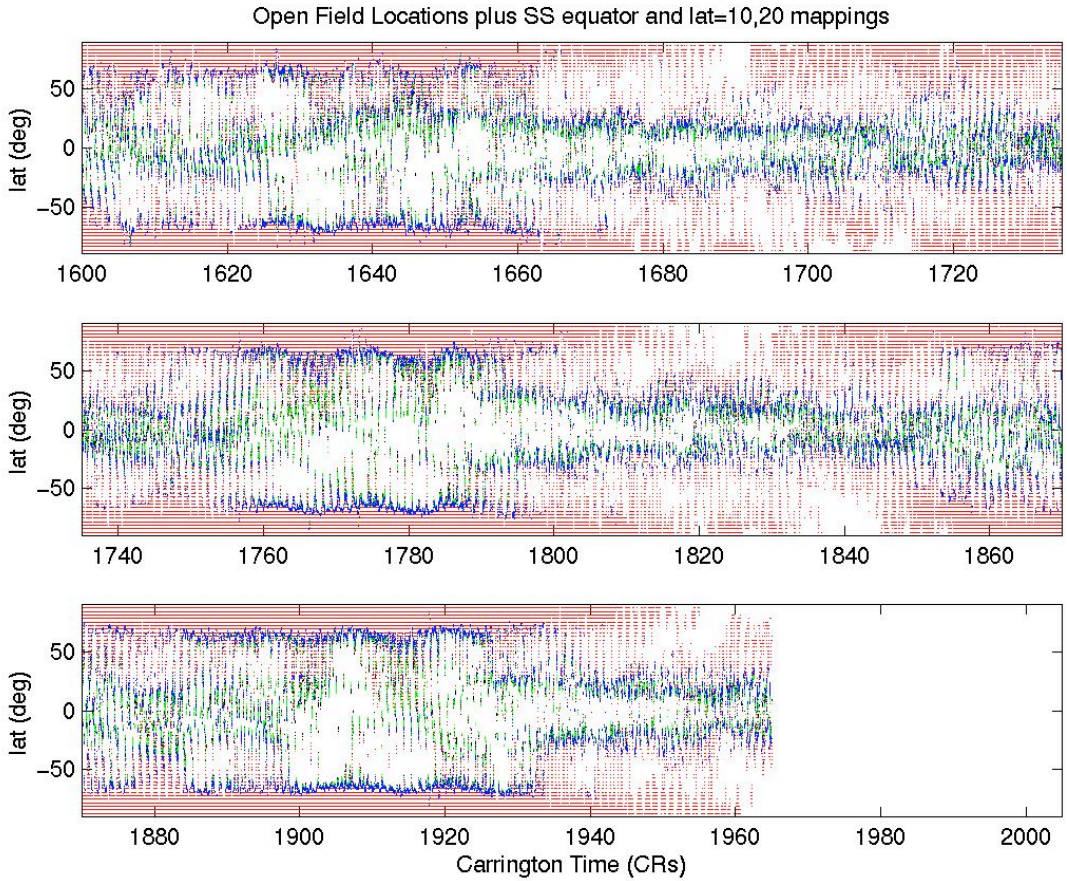




What about the near-ecliptic sources?

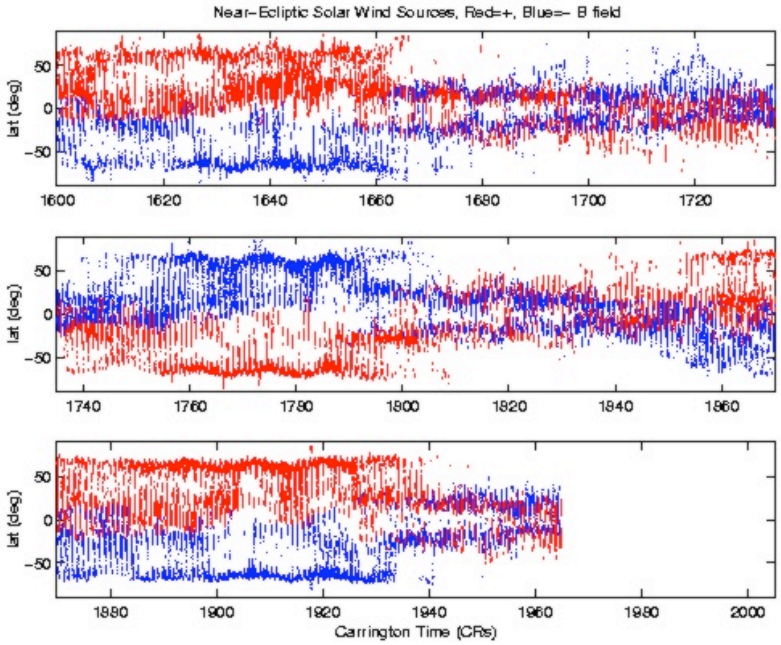


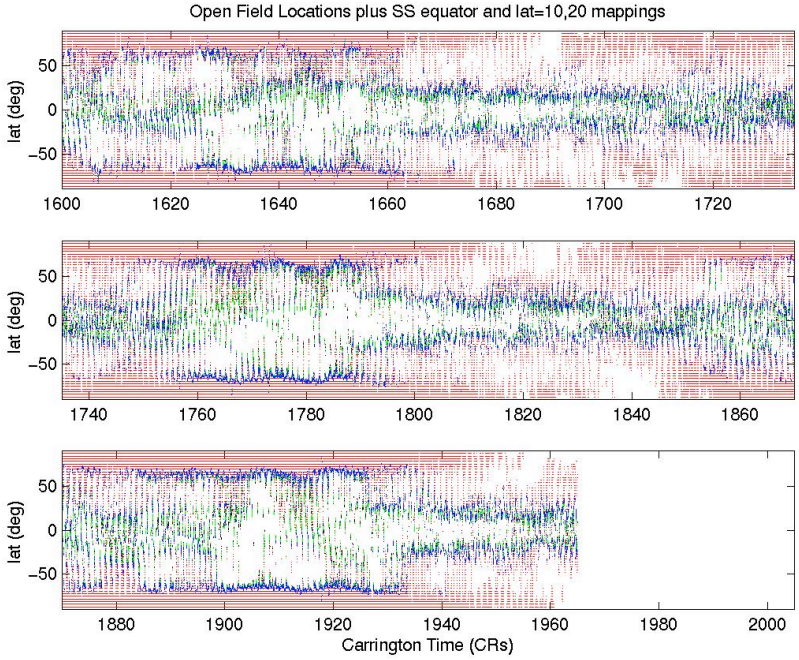
What about the near-ecliptic sources?



(blue,green and black show footpoints of coronal field lines that map to near the ecliptic)

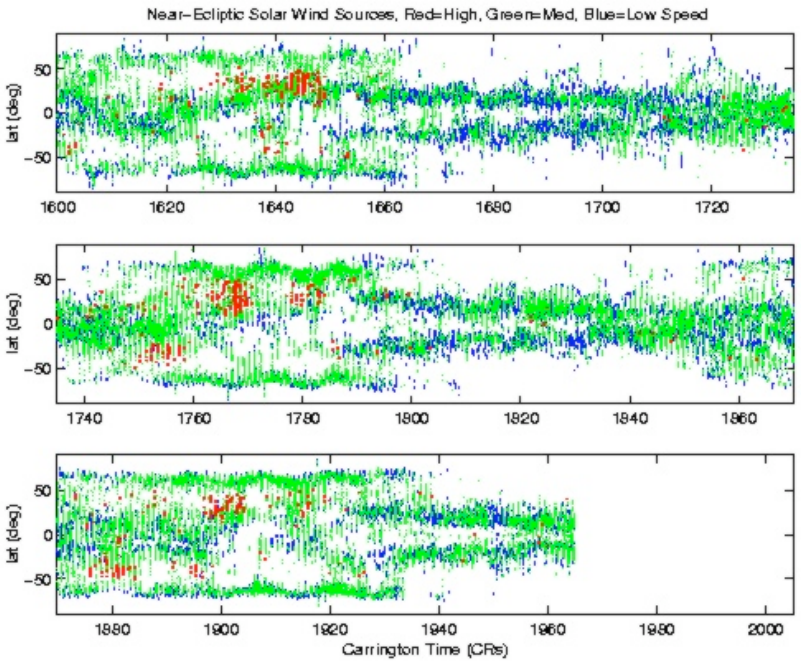
Source Mapping allows IMF polarity origins to be better understood

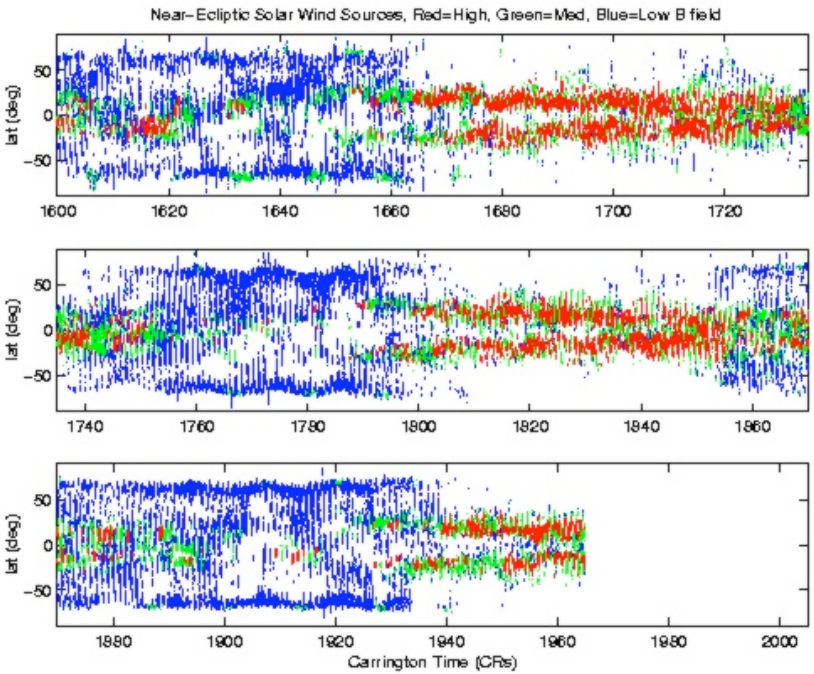




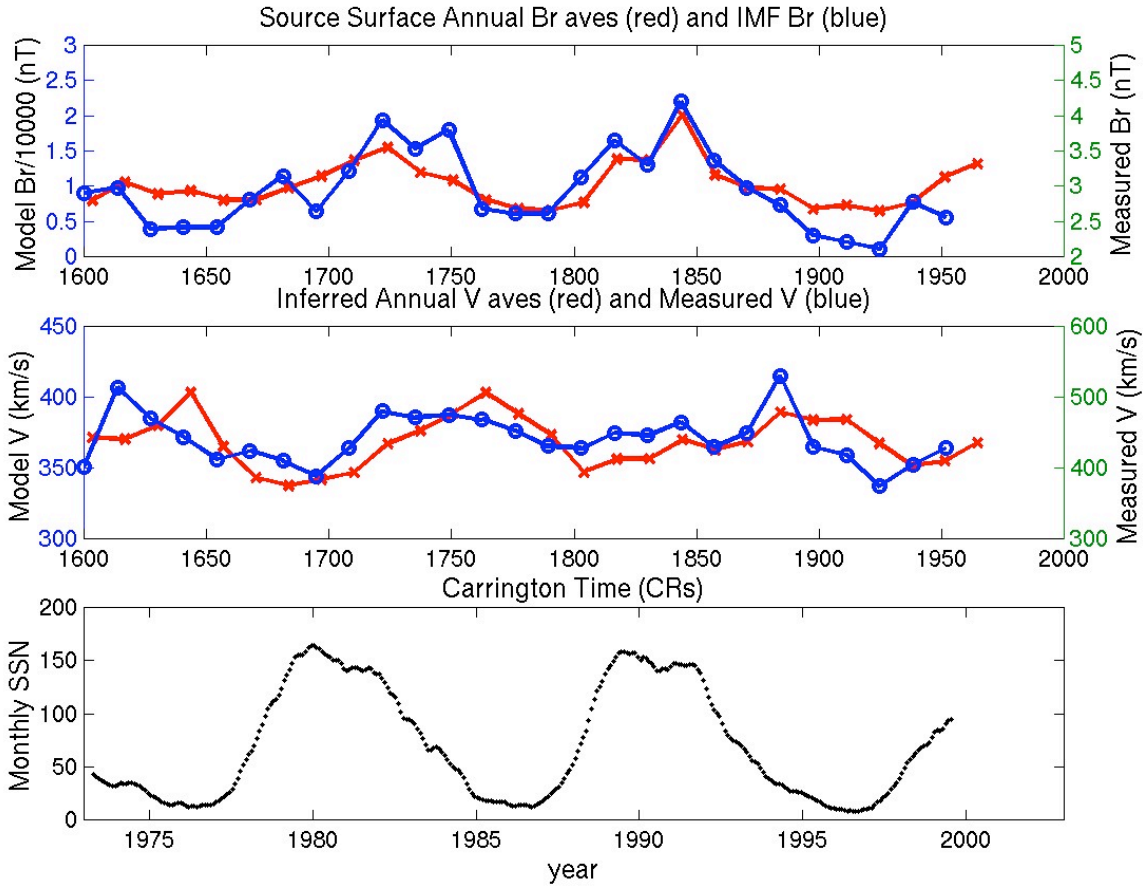
Footpoint radial field signs
(red=outward, blue=inward)

Photospheric field strength and inferred velocity mapping (latter based on Wang-Sheeley method)

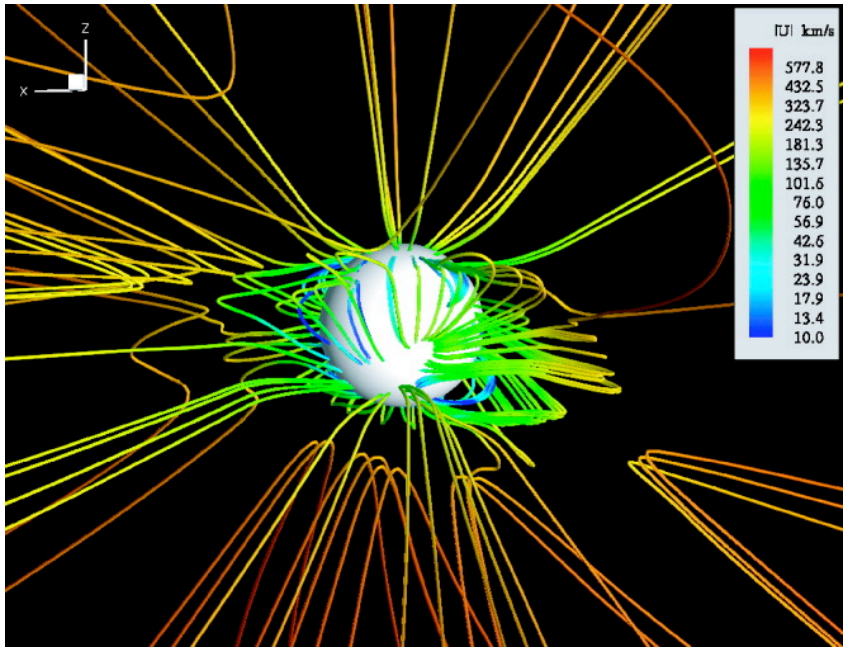




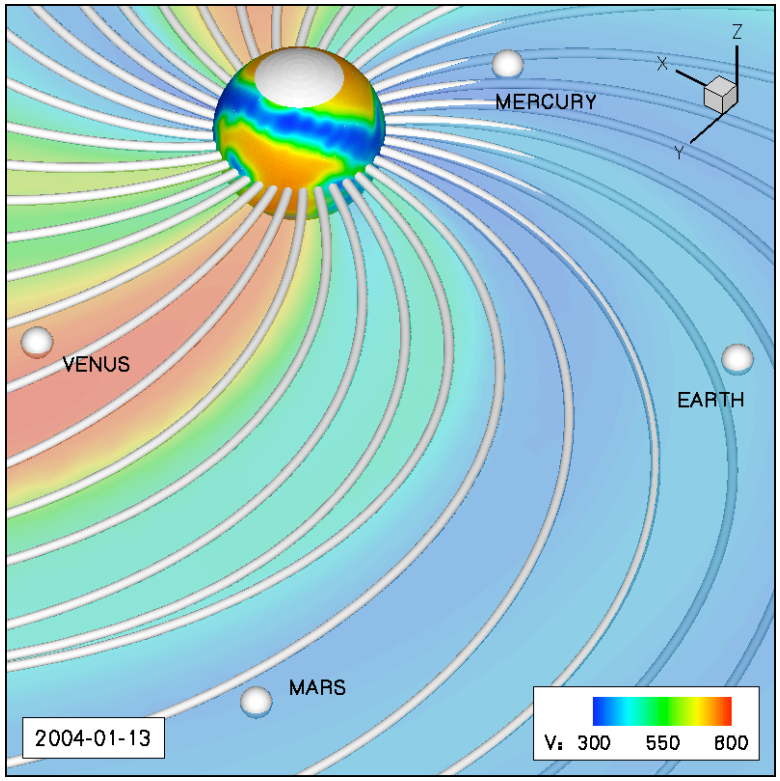
Comparisons of mapped field strengths and velocities with annual measurements at 1 AU



magnetogram-based MHD models have the potential to improve solar wind source mapping and ask further questions…but…

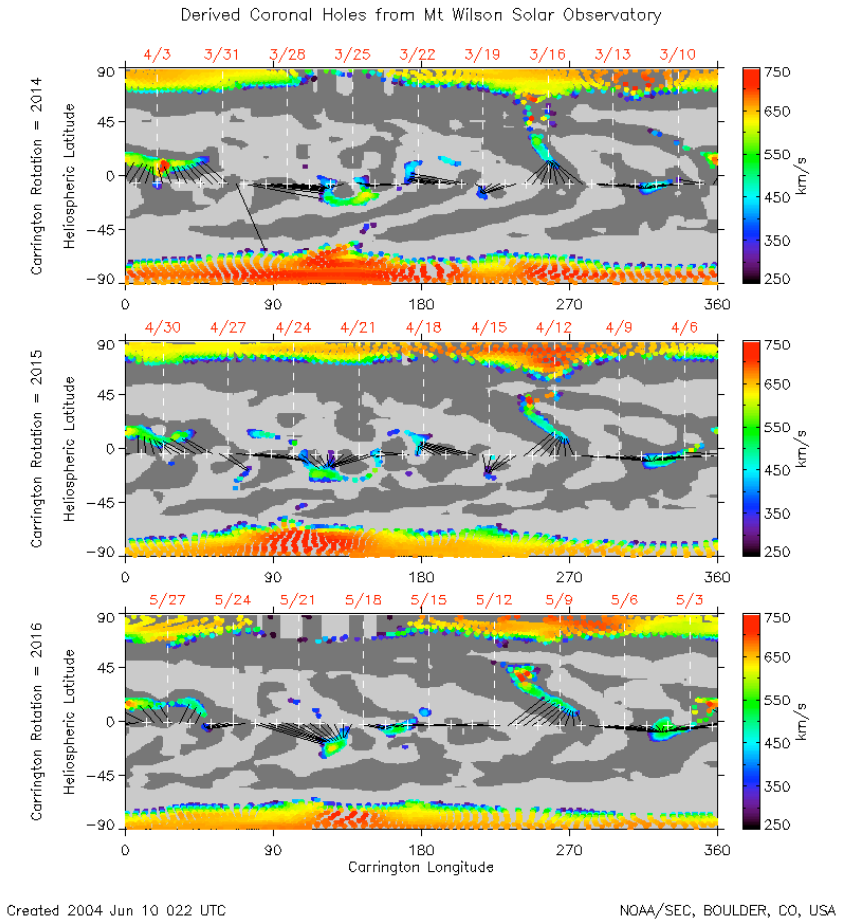


(Roussev et al. BATS-R-US model)

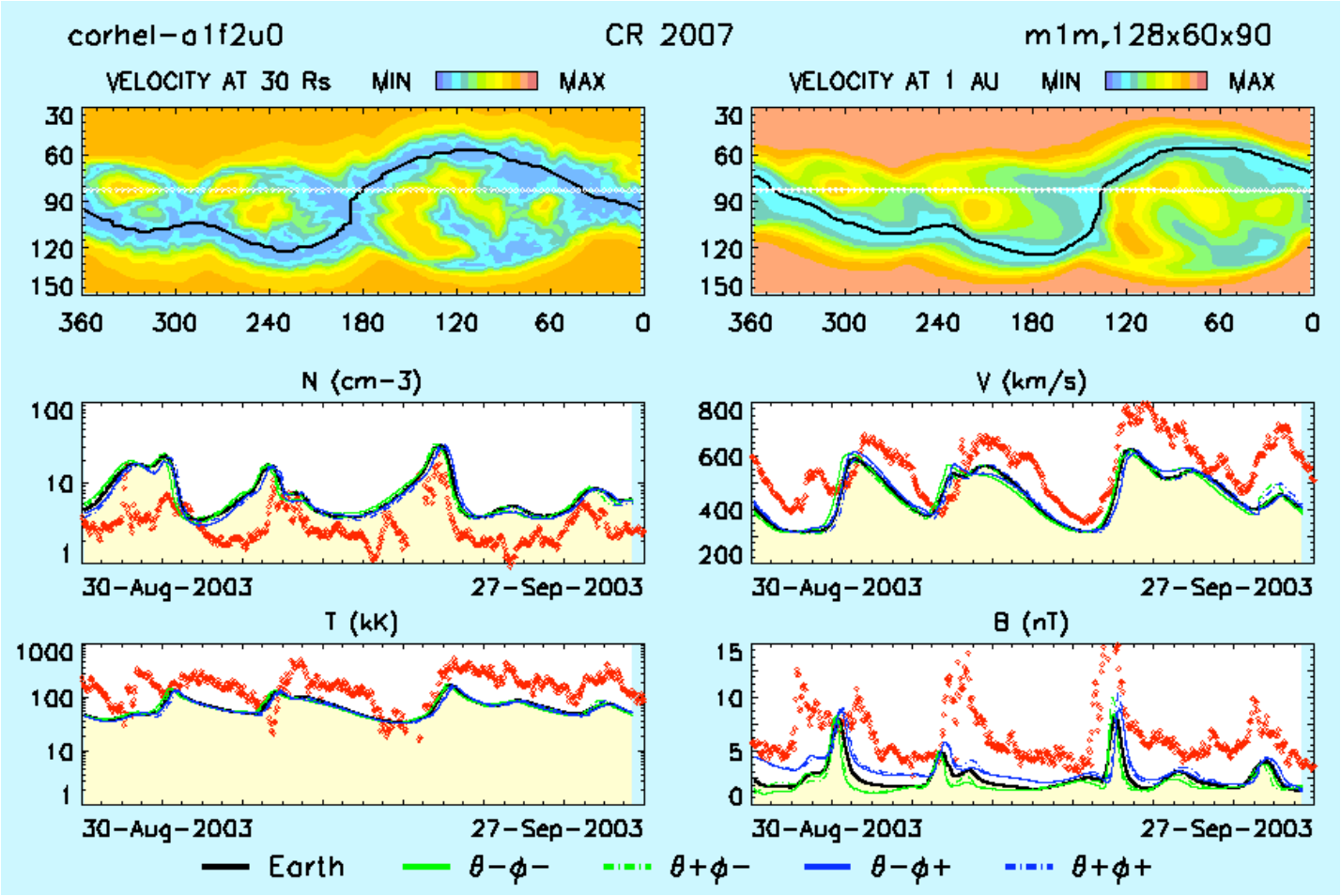


CISM Model- MAS/ENLIL

They must have spatial resolution sufficient for simulating the low latitude sources…

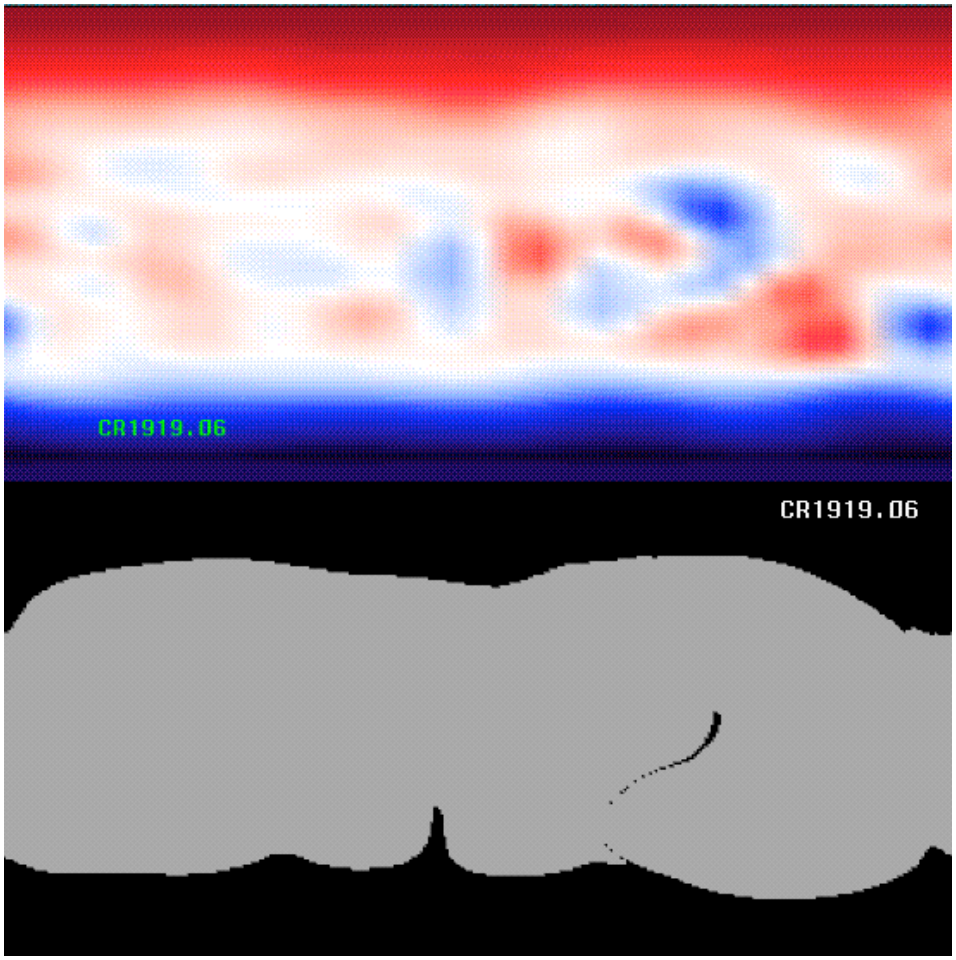


e.g.-as in this CISM Model result



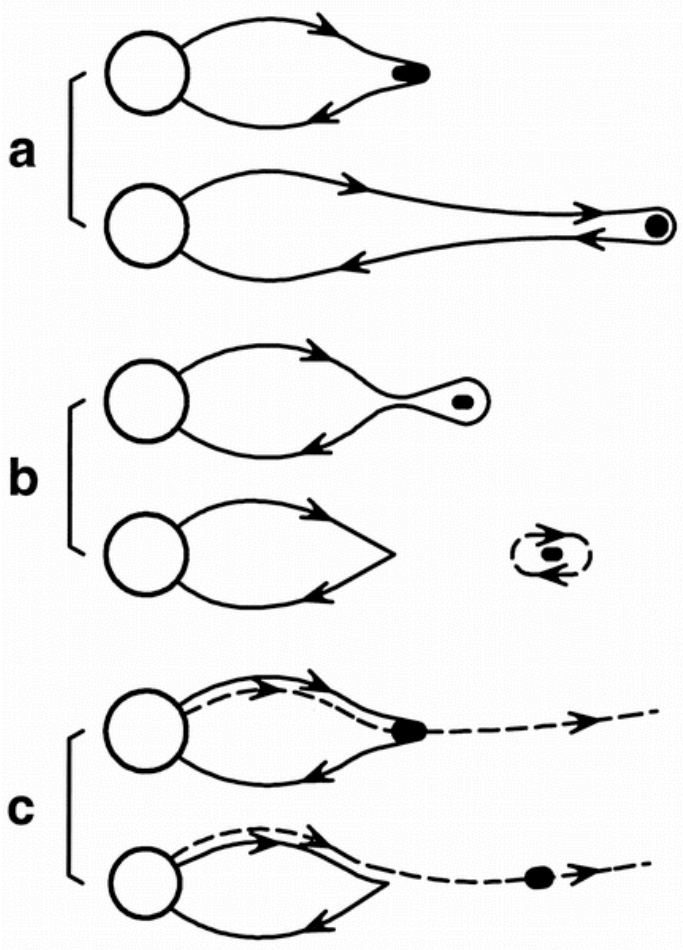
(MAS/ENLIL result from Odstrcil et al.)

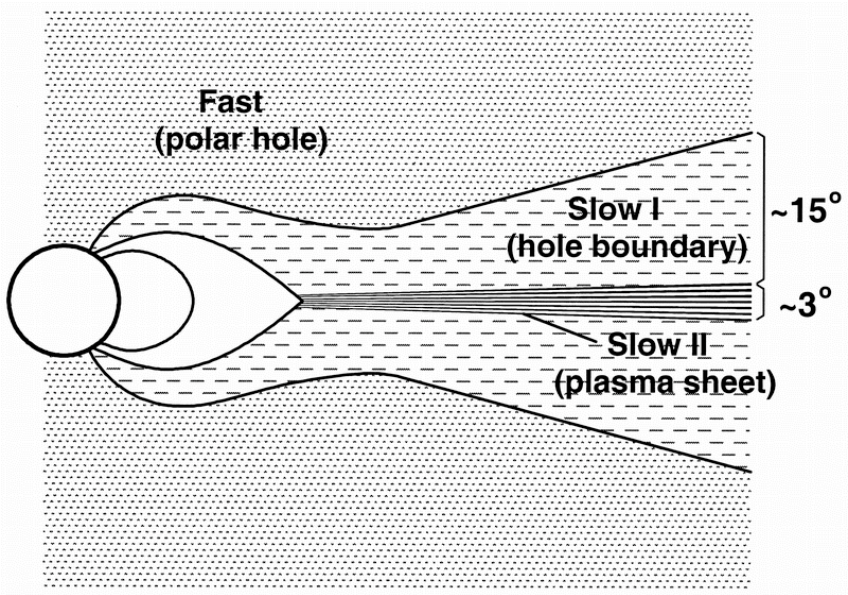
They must also allow for the time-dependent source(s) at the closed/open field region boundaries…



(MAS coronal model movie from Jon Linker of closed and open field regions)

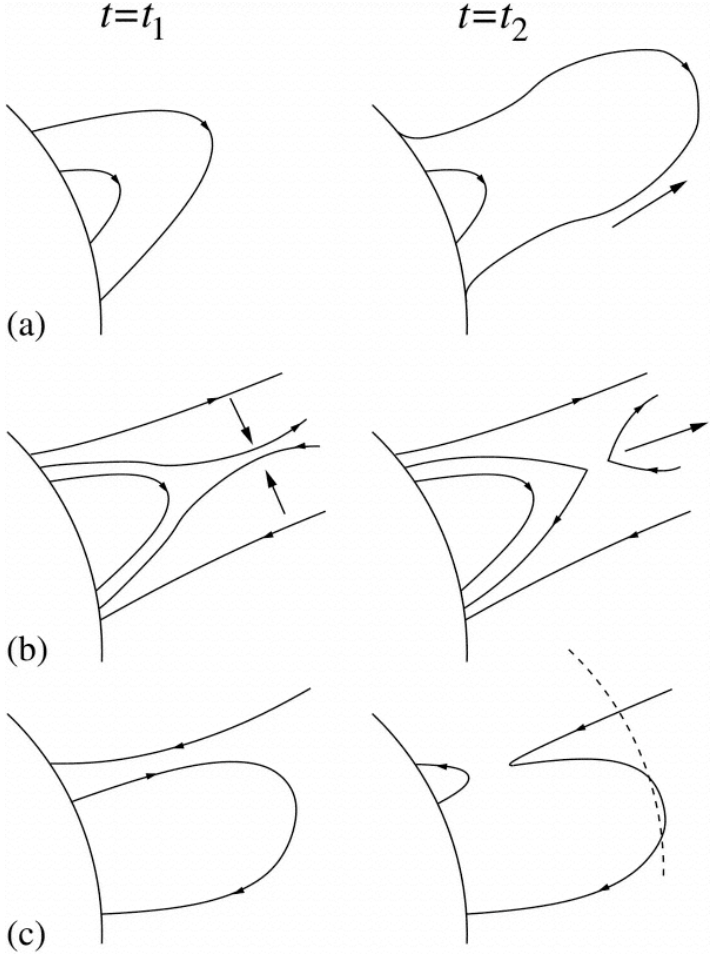
Which means they must also have sufficient resolution and understanding of simulation behavior at current sheets and null points..

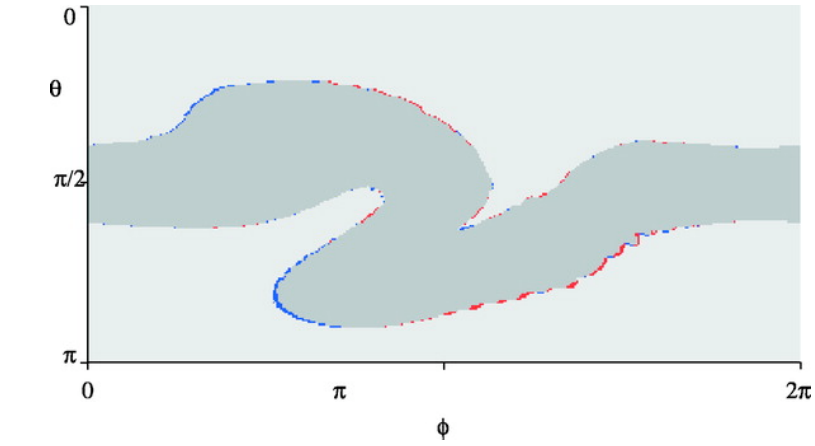


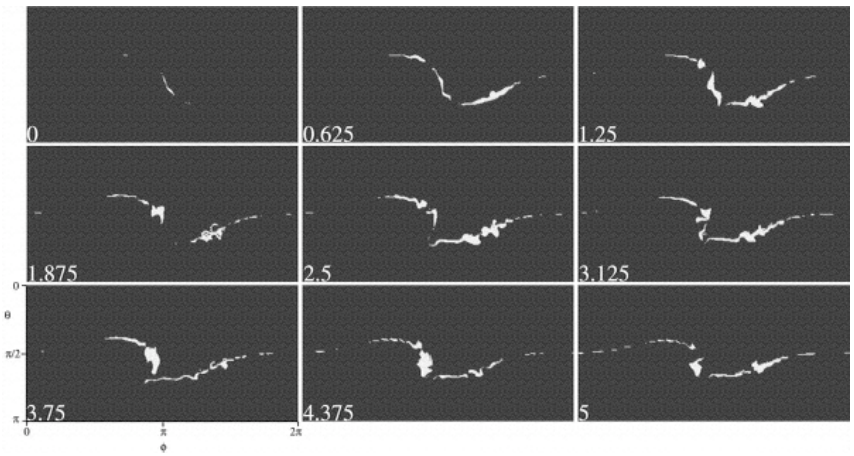


(Cartoons from Wang et al., ApJ paper)

e.g. as in this MAS model evolving by differential rotation in the photosphere from Lionello et al.,…

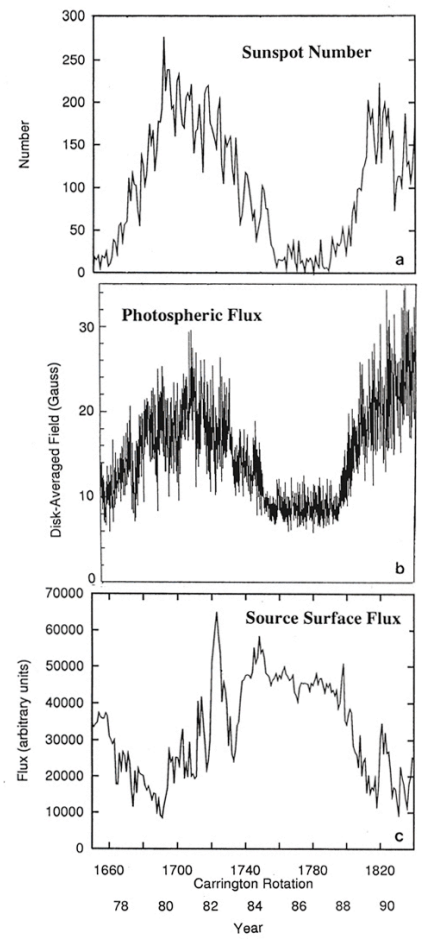


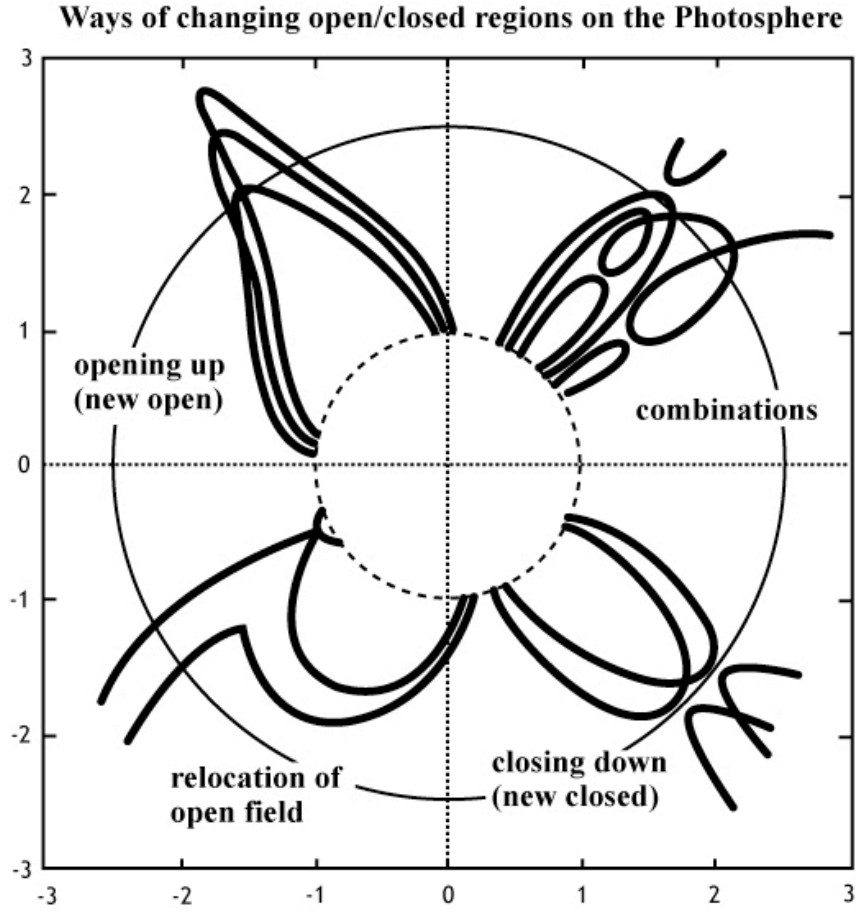




(figures from Lionello et al., ApJ, 2004)

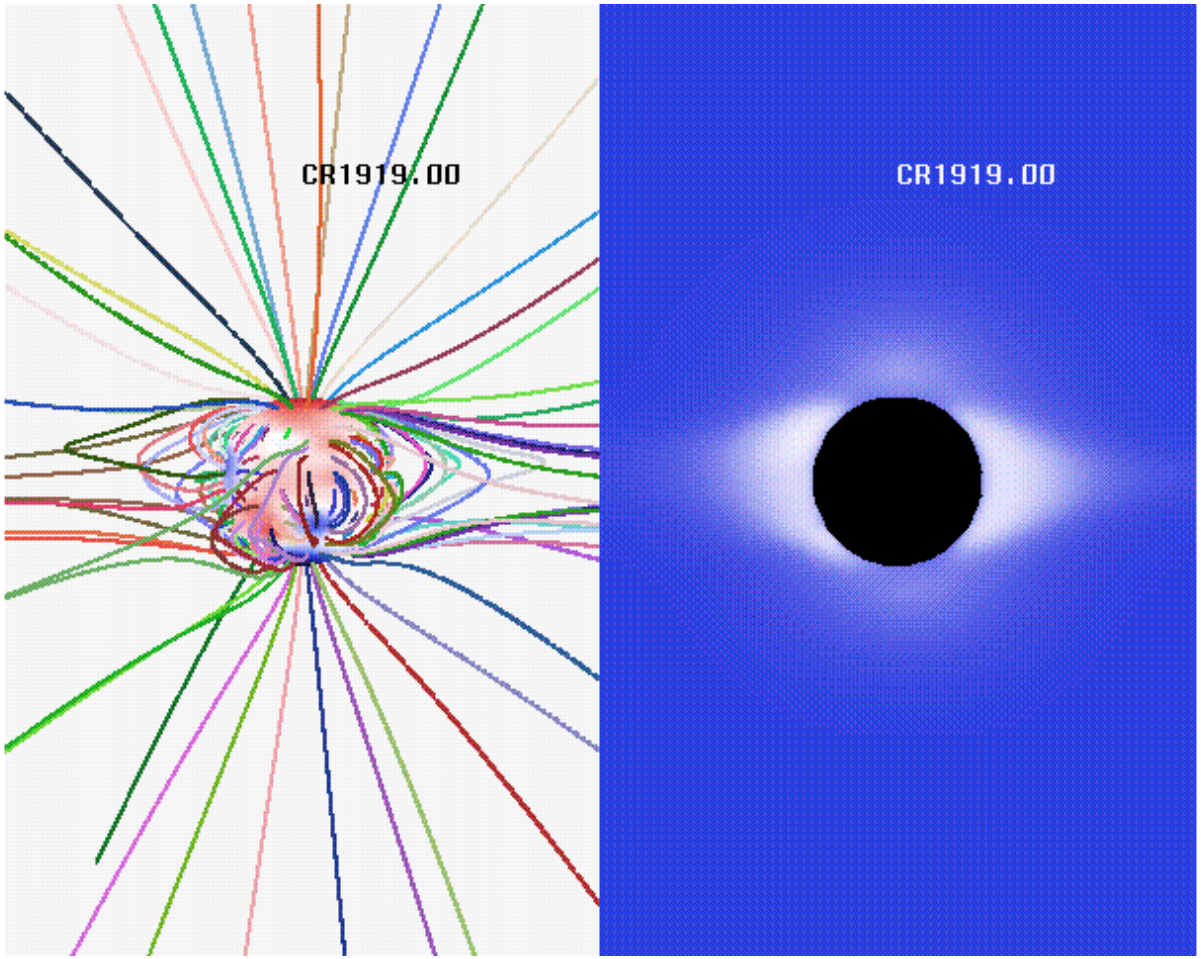
These should ultimately be able to reproduce the observed solar cycle variations in solar wind variables such as IMF magnitude and show the contributions of the various transient component styles





(from Luhmann et al., JGR 1998)

Time-dependent coronal simulation “experiments” may eventually include CMEs as a natural part of the constantly evolving corona and solar wind



(movie from Jon Linker)

So where does one go from here as far as solar cycle dependent wind sources studies go?

- Need (MHD) coronal source models that have sufficient spatial resolution to model smaller, low latitude open fields and are time dependent. Also need to worry about appropriate heating.
- Need data analyses that separate transient component of solar wind (e.g. using suprathermal electron anisotropies) from “steady” component(s). e.g. Need to determine how much of slow solar wind is NOT transient.
- Need to reconsider looking at CMEs in the solar wind as simply a particularly energized time-dependent component of it, prevalent at solar max