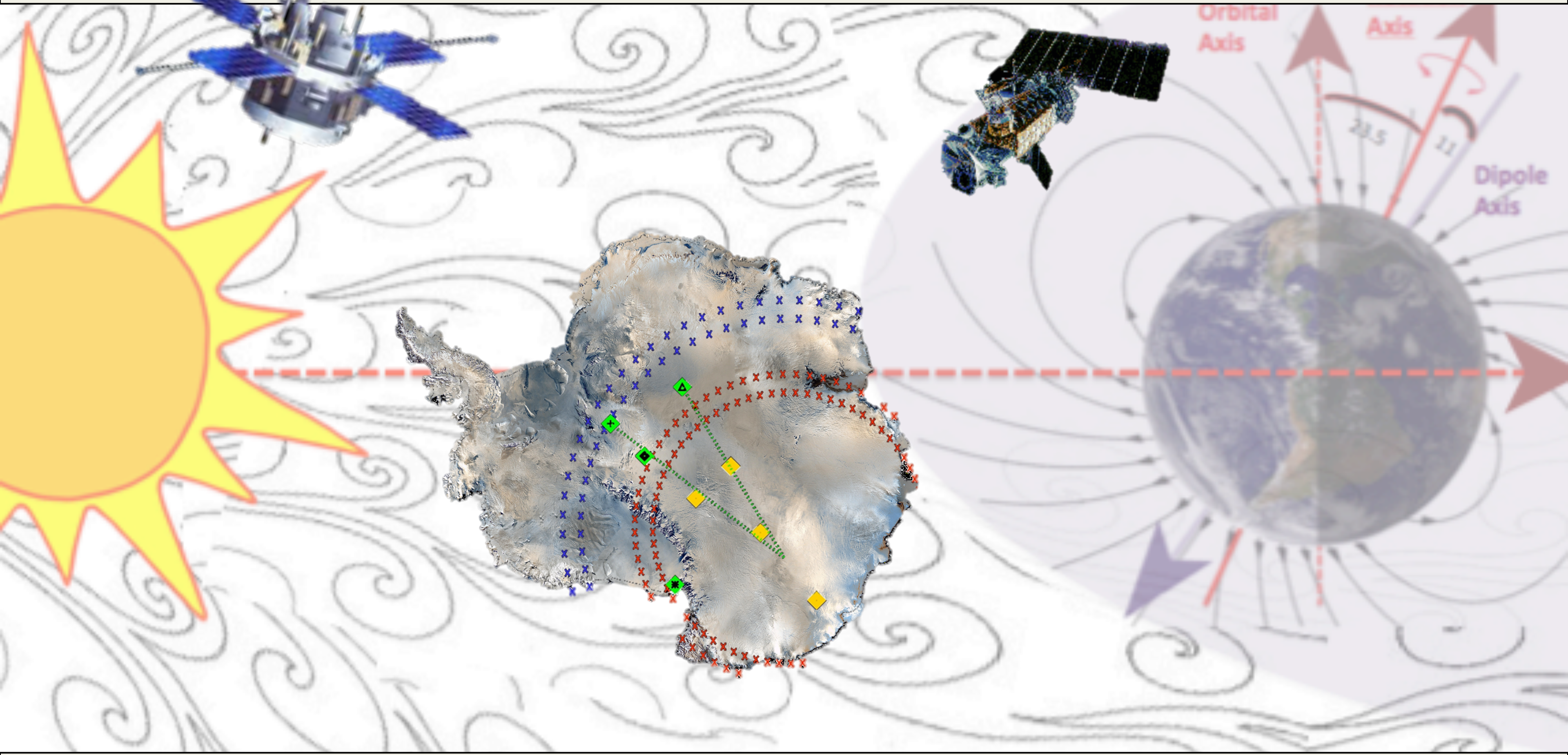
Solar Wind-Polar Cap Open Field Interactions

Kevin Urban, NJIT, 2015-June

Co-Authors: Andrew Gerrard, Louis Lanzerotti, Allan Weatherwax



Special thanks to Yanshi Huang & Cheryl Huang

Conclusions

1. Current geomagnetic field models need to be used with caution at high latitudes.

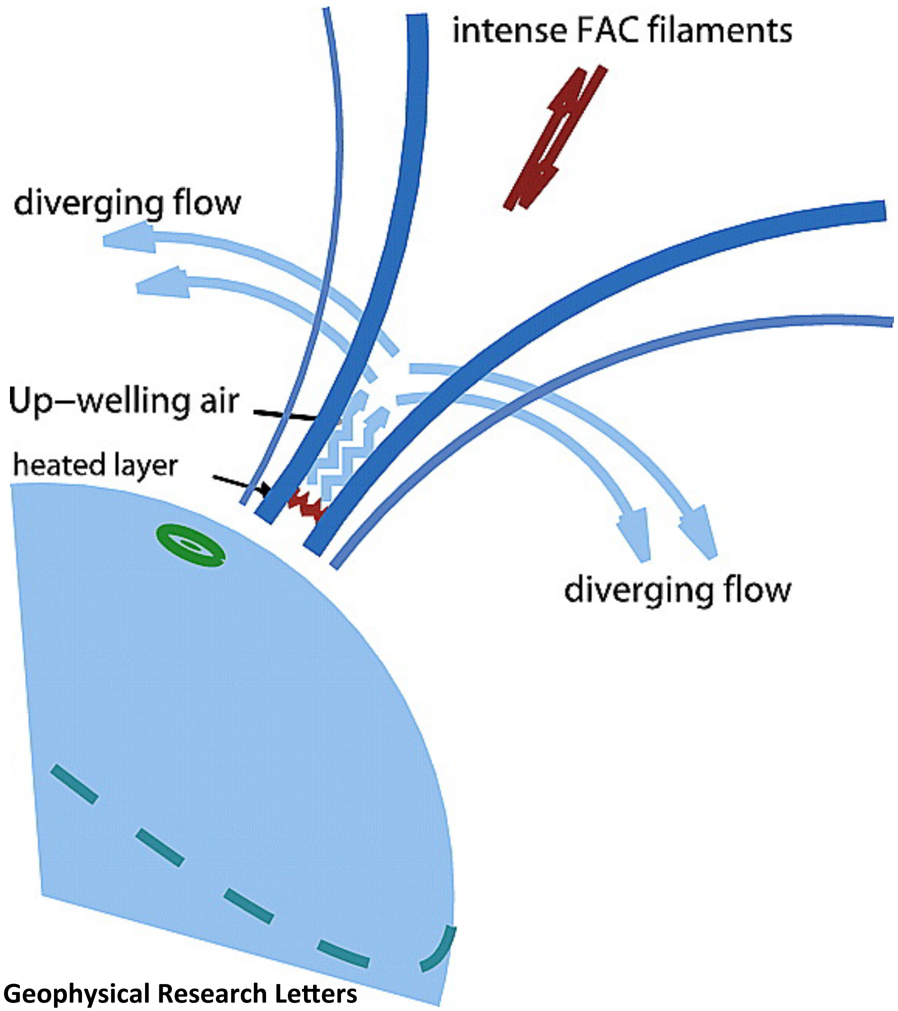
2. Only ULF fluctuations (e.g., Alfven waves) at true polar cap sites can be shown to be directly driven by ULF fluctuations in the solar wind (i.e., via propagation down open field lines) for all but "catastrophic" solar wind conditions (i.e., large CMEs).

3. Although the polar cap is highly powered by the solar wind during large CMEs, the geomagnetic noise from myriad sources during such events prohibits determination of direct solar wind ULF penetration from indirect (i.e., magnetotail or internal resonances) sources.

4. (2) and (3) suggest that **quiet-time studies are necessary to better quantify direct solar wind power dissipation in the ITM system**.

5. Correlation and predictability between solar wind Poynting flux and ground-based total variational power does NOT break down during a CME. However, ground-based ULF power is not the source of this correlation. The power and predictability seem to come from **sub-ULF** periodicities at ground sites in the polar cap.

CHAMP observes thermospheric upwelling on dayside open magnetic field lines



Luhr et al. [2004] showed that **the cusp region**, a dayside open magnetic field region in the polar ionosphere, **exhibits** more or less **continuous air up-flow** and divergence into lower latitudes

This conclusion was supported by CHAMP observations that revealed a frequent occurrence of thermospheric high density structures in the ionospheric cusp

SUGGESTED CAUSE of air up-welling: **Joule heating** – the density enhancements were generally accompanied by intense small-scale FAC filaments and occurred independently of magnetic activity.

Geophysical Research Letters
[Volume 31, Issue 6,](http://onlinelibrary.wiley.com/doi/10.1029/2003GL019314/full#grl17969-fig-0004) L06805, 18 MAR 2004 DOI: 10.1029/2003GL019314
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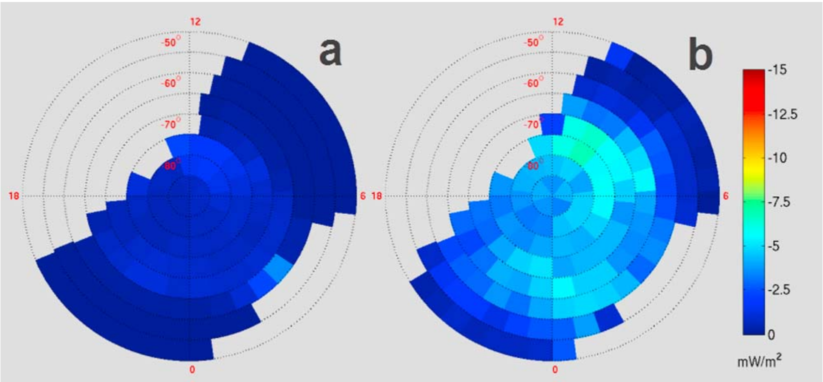
Poynting Flux on Open Field Lines

High Poynting fluxes have been observed in the polar cap comparable to auroral zone fluxes.



- Knipp et al. [2011] showed order-of-magnitude jumps in Poynting flux (up to 170 mW/m^2) deposition in polar cap region
- a large, coherent PF deposition region coincided with the cusp, the energy of which was greater than that supplied by precipitation; the authors concluded that **Poynting flux likely supplied the energy for the CHAMP observations**

- Huang et al. [2014] showeed strong enhancements of Poynting flux in the polar cap comparable (or larger) to PFs observed in the auroral zones
- They concluded that:
  (1) ionospheric energy in the auroral zone cannot account for thermospheric heating
  (2) the primary location for energy input to the IT system may be the open field line region poleward of the aurora

Huang et al (2014), Energy coupling during the August 2011 magnetic storm, JGR
Knipp et al. (2011), Extreme Poynting flux in the dayside thermosphere: Examples and statistics, GRL

How the solar wind contributes to ULF power to the polar cap

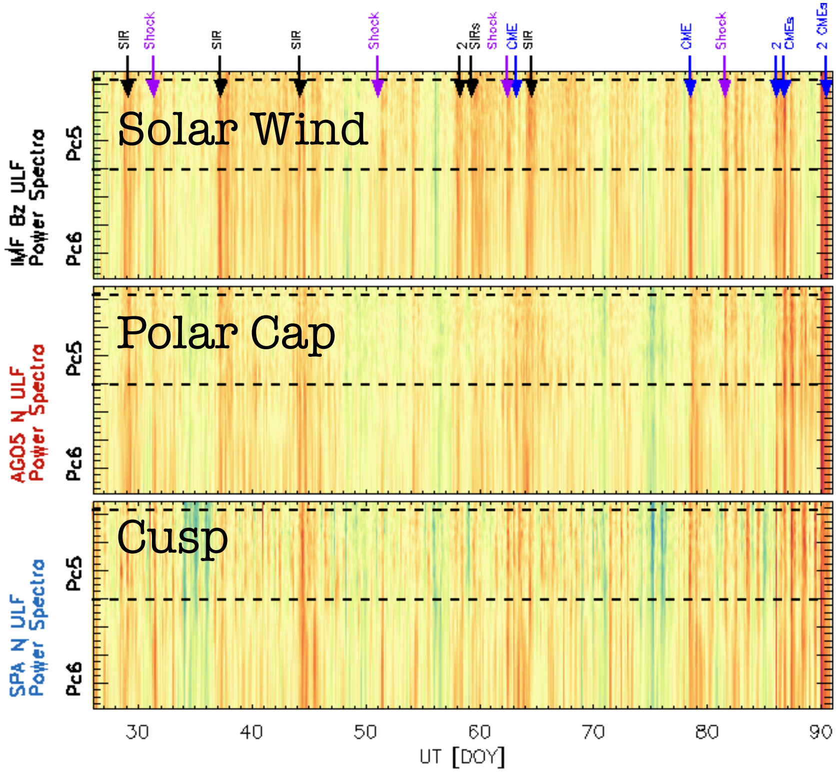
1. In general, the solar wind is a major driver of ULF power at ground sites, from low to high latitudes.

2. There exist many high-latitude magnetometer sites, but has anyone truly measured anything on the ground in the polar cap? That is, are we sure there are ground-based magnetometers deep inside the polar cap?

2. Given such a deep polar cap magnetometer, how is the ULF activity dependent on solar wind variations?

(i) **Indirectly: e.g.**, via leakage from closed field lines: bulk solar wind speed viscously interacts at dawn/dusk flanks inducing KHI modes, which in turn induce field line resonances; impulses of solar wind dynamic pressure induce compressional modes in subsolar magnetosphere, which also convert to FLRs; geometry-induced (kink) FLRs on open field lines

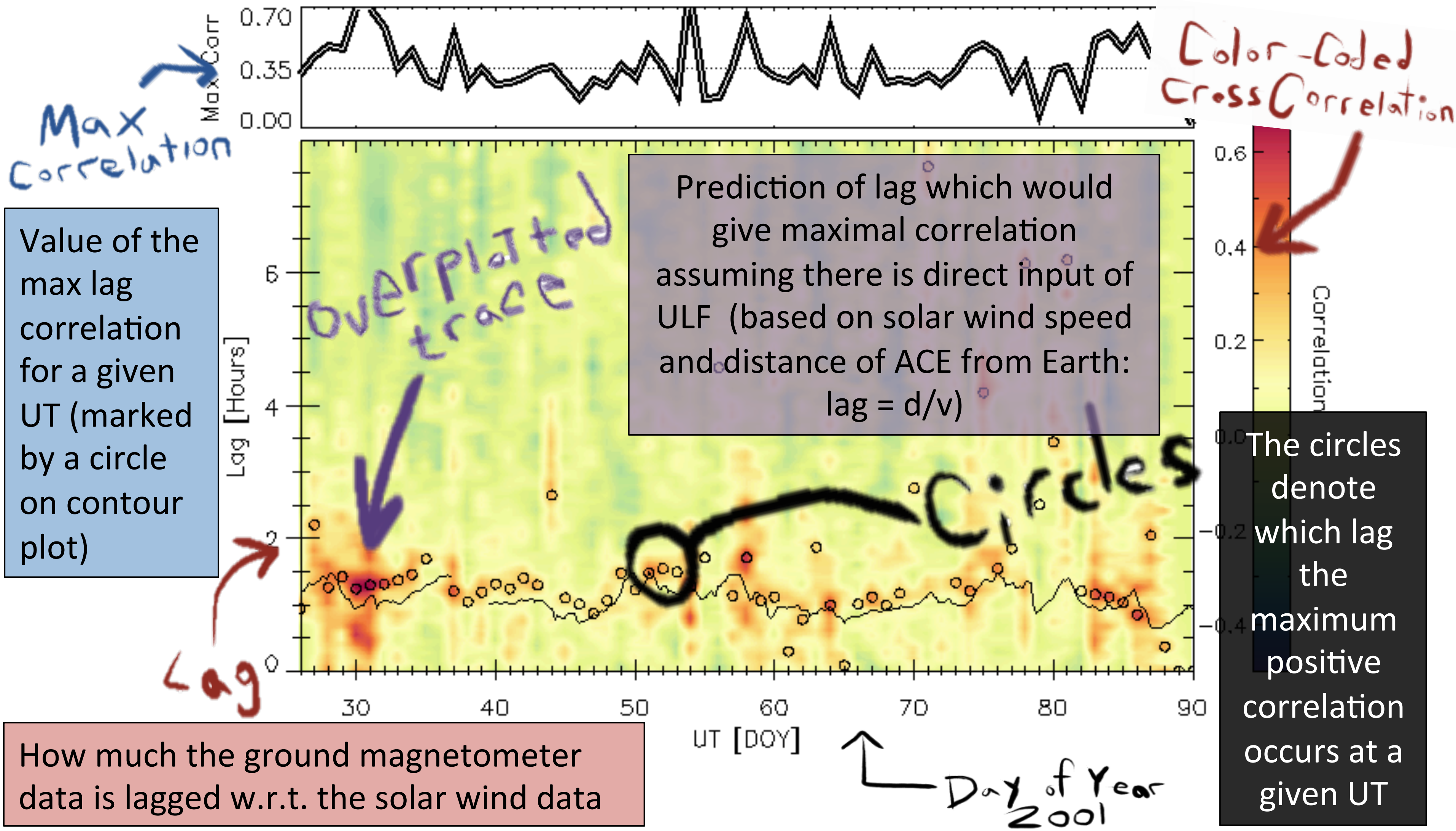
(ii) **Directly**: penetration of ULF waves in the solar wind down open field lines



** See my poster (MITC-12) for an explanation of why the IGRF magnetic pole is wrongly placed*

Dynamic Correlograms

The dynamic correlograms on the next few slides plot columns cross-correlation sequences between solar wind data and lagged ground-based magnetometer data as a function of time.



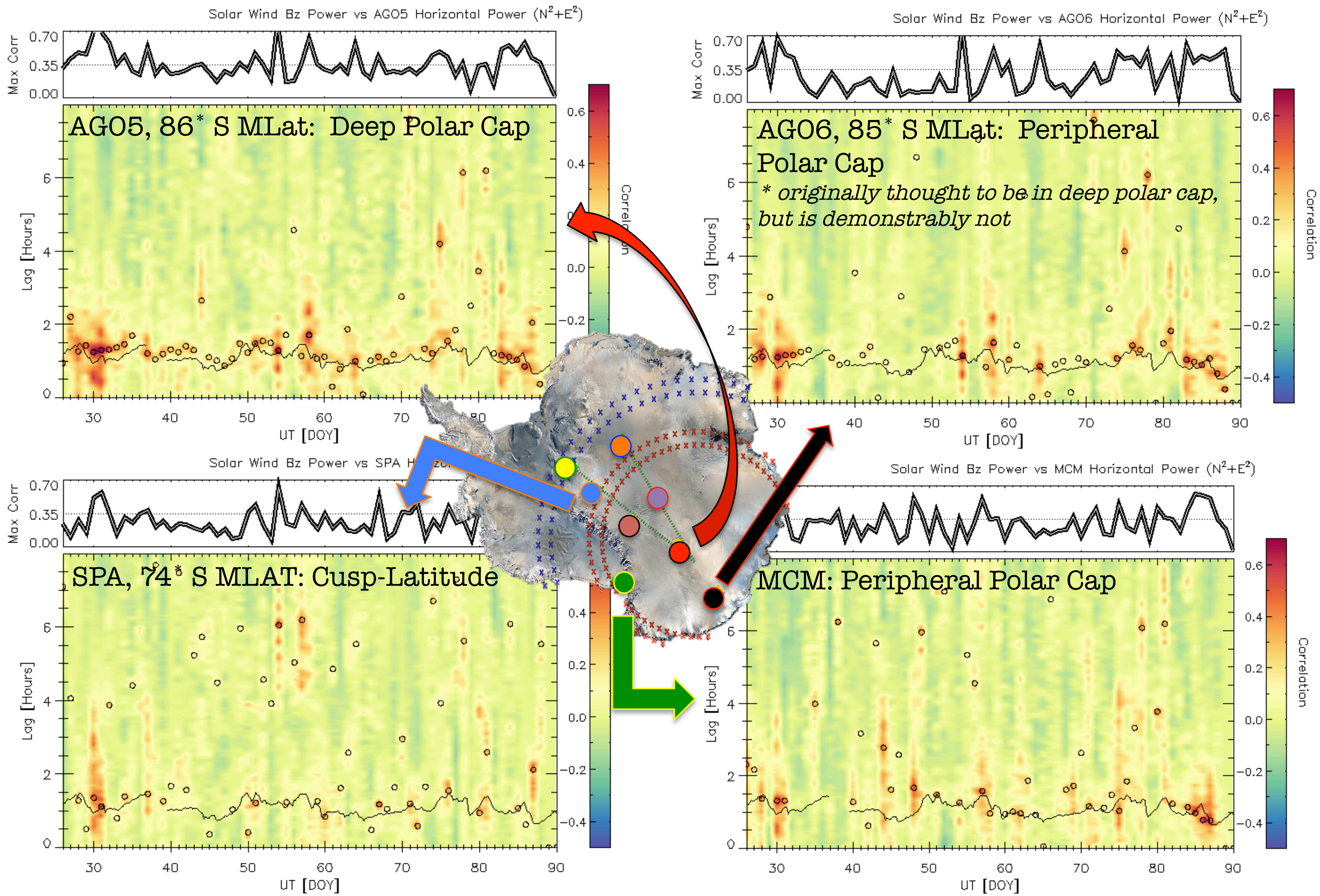
Value of the max lag correlation for a given UT (marked by a circle on contour plot)

Prediction of lag which would give maximal correlation assuming there is direct input of ULF (based on solar wind speed and distance of ACE from Earth: lag = d/v)

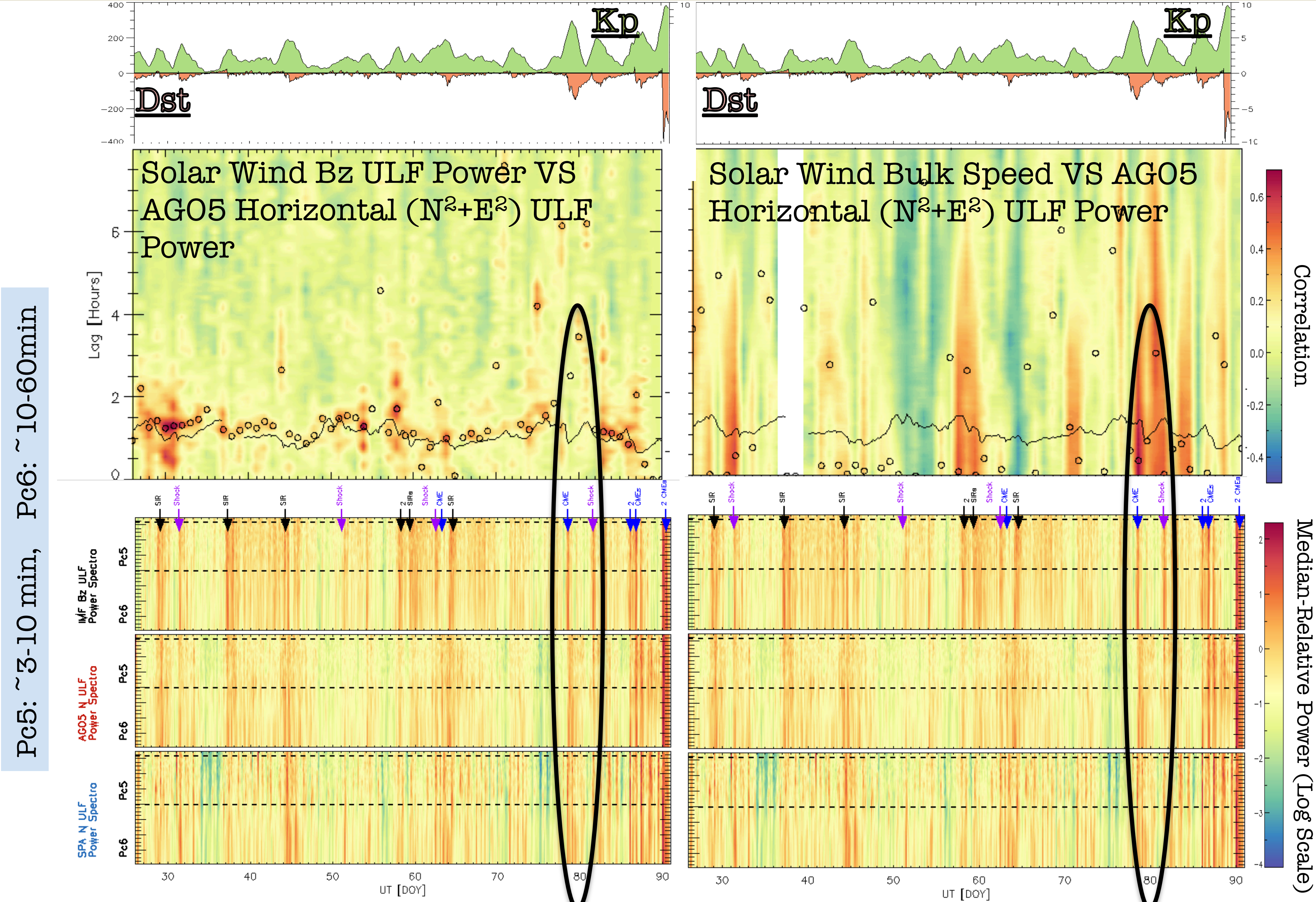
The circles denote which lag the maximum positive correlation occurs at a given UT

How much the ground magnetometer data is lagged w.r.t. the solar wind data

Solar Wind Bz ULF Power vs Ground-based Horizontal (N^2+E^2) ULF Power



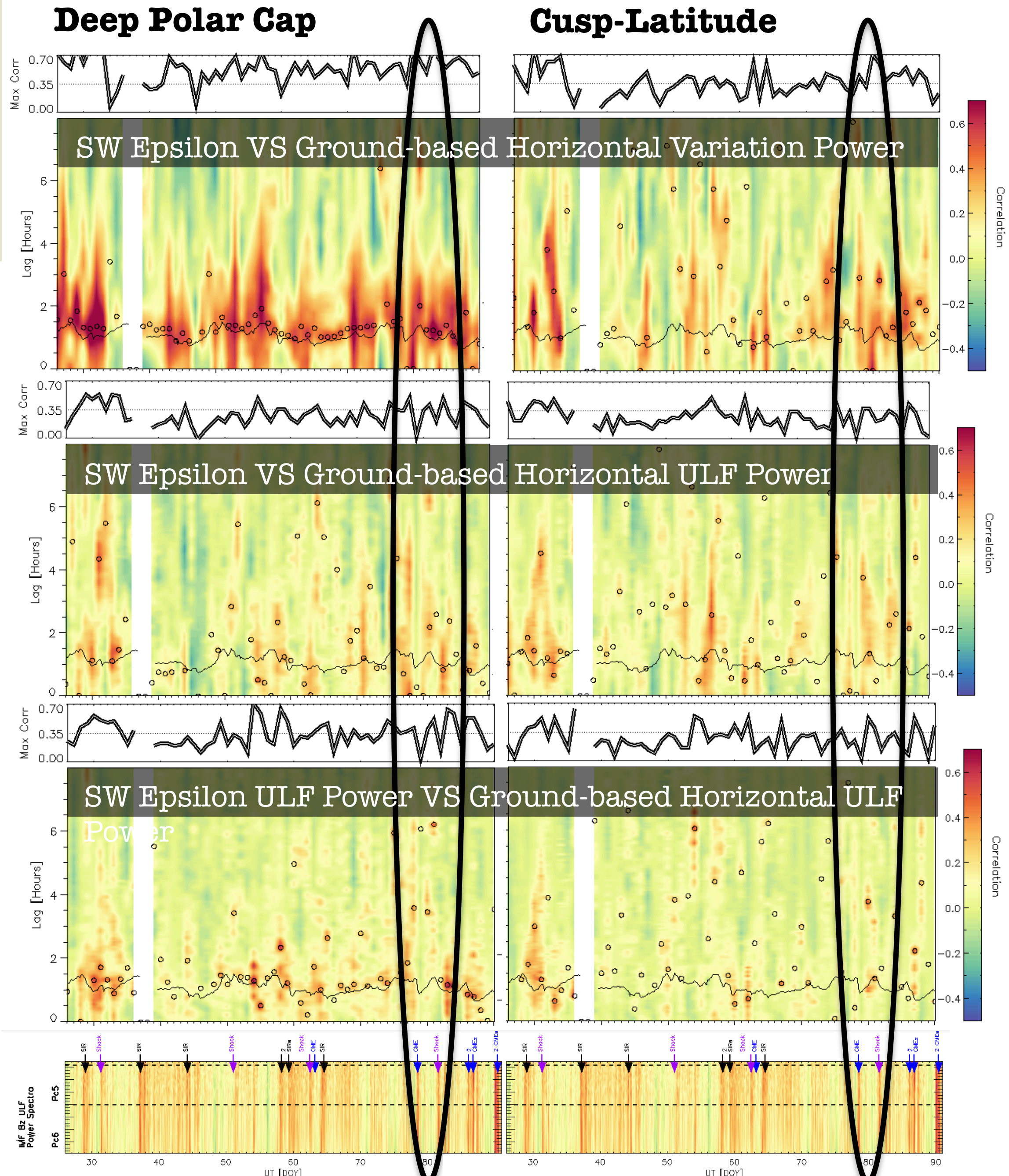
Dynamic Correlograms VS Dynamic ULF Spectra



SW Perreault-Akasofu Epsilon vs Horizontal Power

What is Epsilon?
A solar-wind derived parameter often used as a measure of solar wind Poynting flux input into the magnetosphere.

One might not be able to track direct penetration of ULF from the CME starting on DOY 78 into the polar cap, but total horizontal variation power correlates with Epsilon very well deep inside the polar cap during this CME and in general.

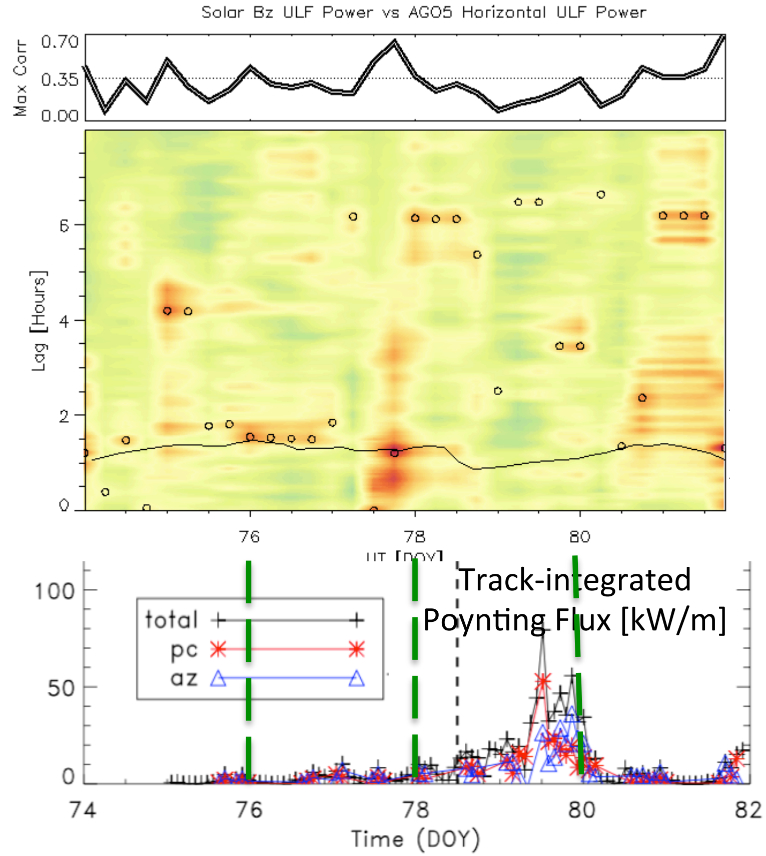


Conclusions

1. Current geomagnetic field models need to used with caution at high latitudes.
2. Only polar cap ULF fluctuations (e.g., Alfven waves) can be shown to be directly driven (i.e., via open field lines) by ULF fluctuations in the solar wind for all but “catastrophic” solar wind conditions (i.e., large CMEs).
3. Although the polar cap is highly powered by the solar wind during large CMEs, the geomagnetic noise from myriad sources during such events prohibits one to determine direct solar wind ULF penetration from indirect (i.e., magnetotail or internal resonances) sources.
4. (2) and (3) suggest that **quiet-time studies are necessary to better quantify direct solar wind power dissipation in the ITM system**.
5. Correlation and predictability between solar wind Poynting flux and ground-based total variational power does NOT break down during a CME. However, ULF power does not correlate as well with or have high predictability from the total SWPF measurements. The power and predictability seem to come from much lower periodicities at ground sites in the polar cap.

Ongoing Work

Come see my poster (MITC-12) tonight!



The work presented here was supported by the National Science Foundation Office of Polar Programs. We gratefully acknowledge NSF grant ANT-0840158 that supports AGO field operations on the Antarctic plateau.