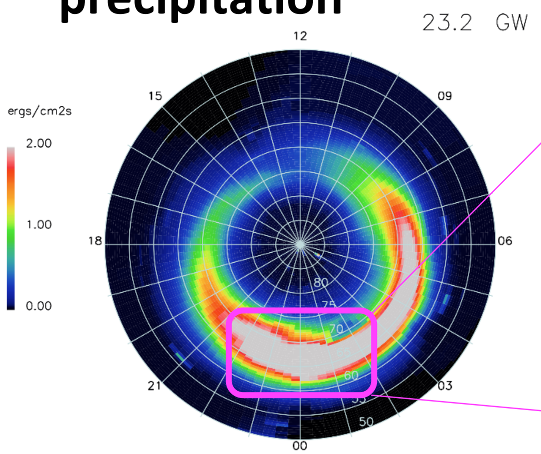
GEM-CEDAR Panel

Multiscale aspects of the energy budget: M-I observation perspective

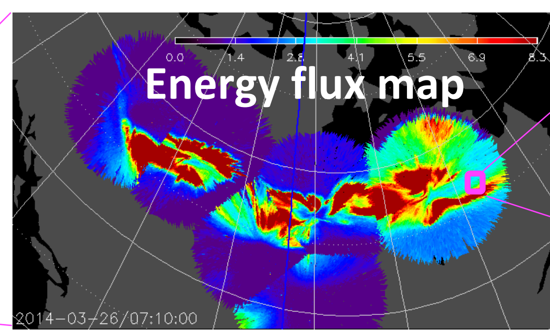
Toshi Nishimura (Boston University)

Largescale (~1000 km) precipitation

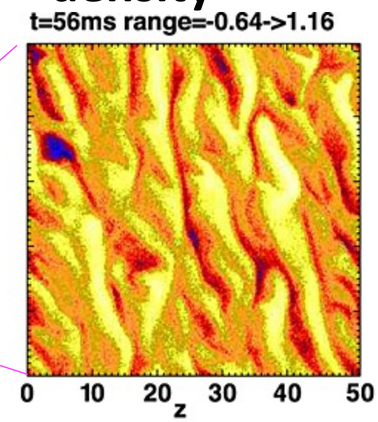


[Newell et al., 2014]

Mesoscale (~100 km) precipitation



Smallscale (<~10 km) density

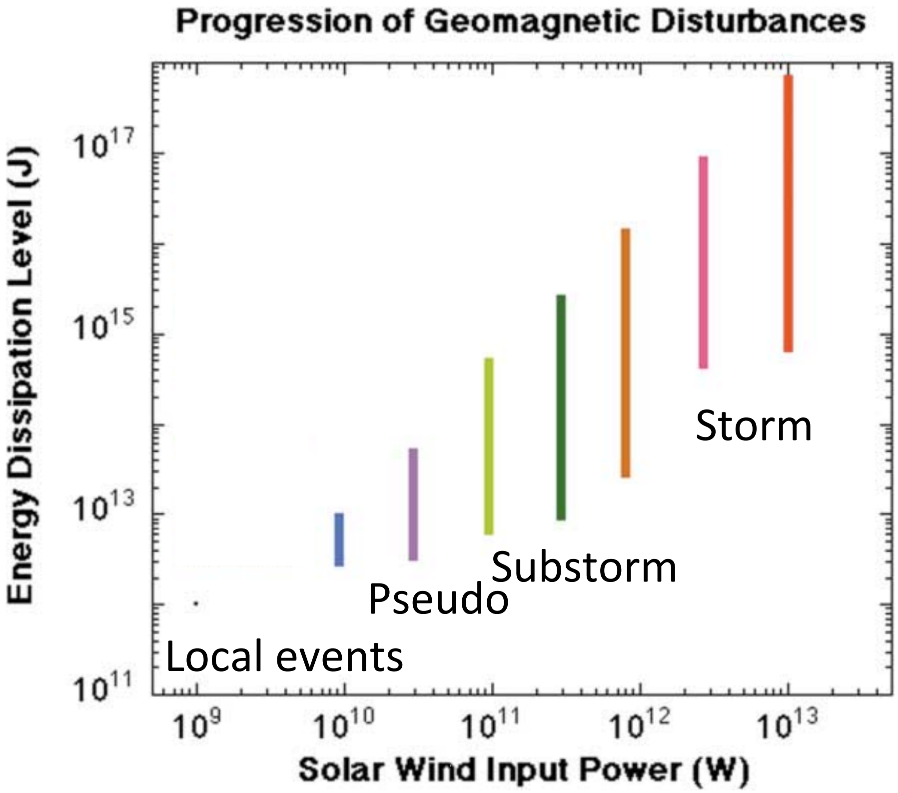


[Oppenheim and Dimant, 2013]

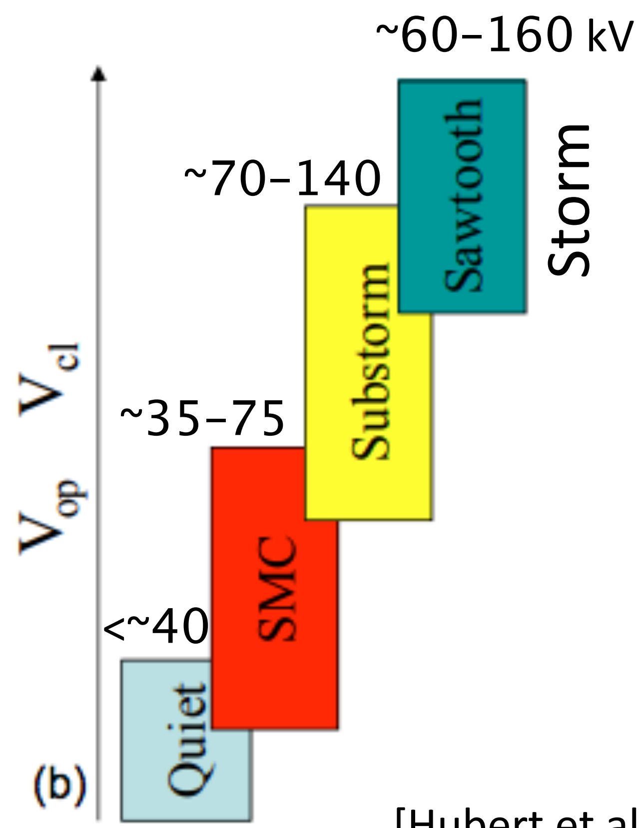
How much energy do mesoscale processes carry compared to largescale?

How can we specify processes in each scale?

1. M-I energy budget: Large-scale



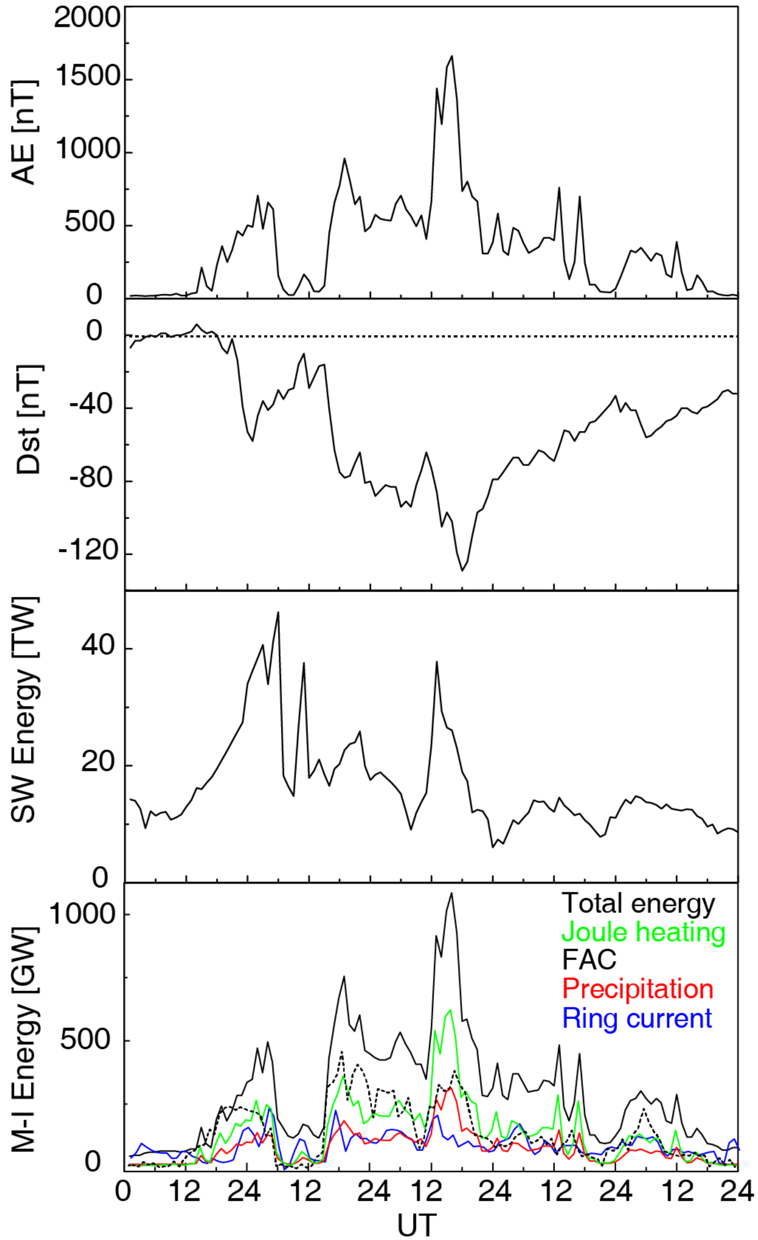
[Baker et al., 2001]



[Hubert et al., 2017]

The large-scale M-I response is determined by the amount of solar wind energy input.

1. M-I energy budget: Large-scale



[Feldstein et al., 2003]

Energy partition

~1% of solar wind energy turns to the **M-I total energy**.

~50% of the energy is lost in the ionosphere by **Joule heating**. (~FAC energy, or Poynting flux)

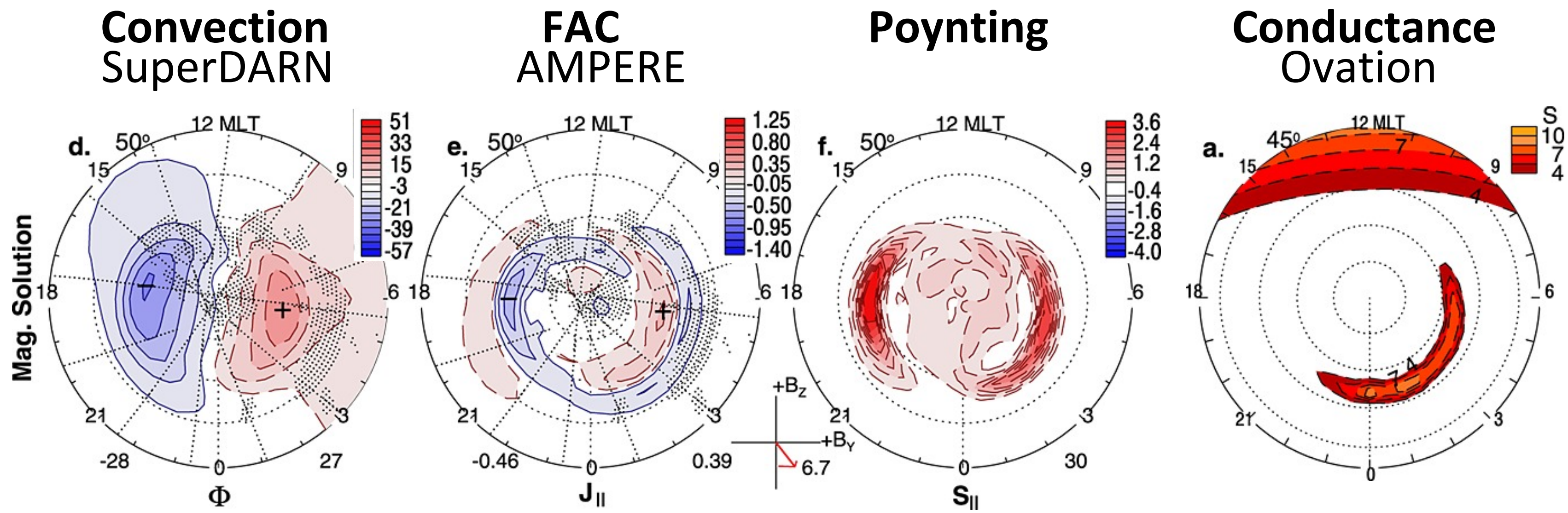
~25% by **precipitation** into the ionosphere

~25% into the **ring current**, dominantly by substorm injection.

Importance of ionosphere dissipation and transient processes

1. M-I energy budget: Large-scale

How do we specify the large-scale state?



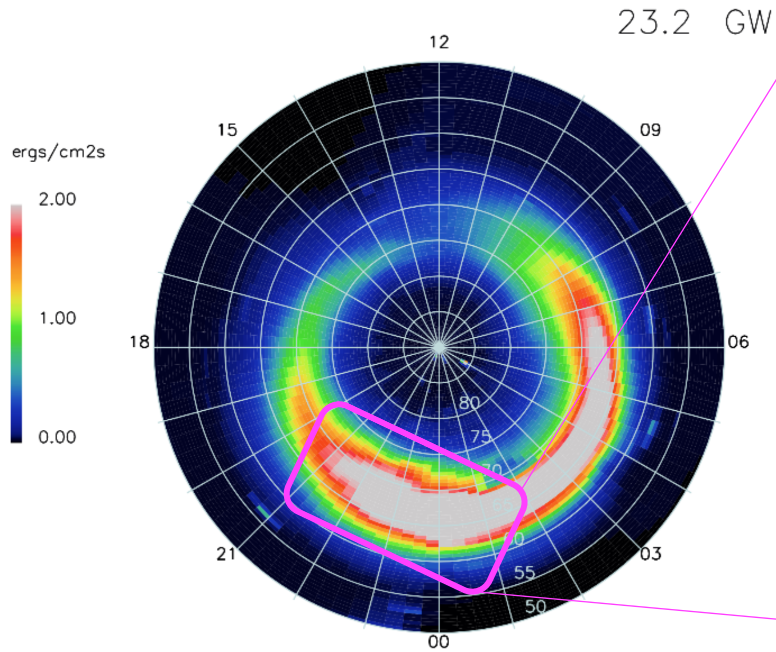
[Cousins et al., 2015]

Data assimilation using AMPERE, SuperDARN and OVATION can provide data-driven global maps of key M-I parameters.

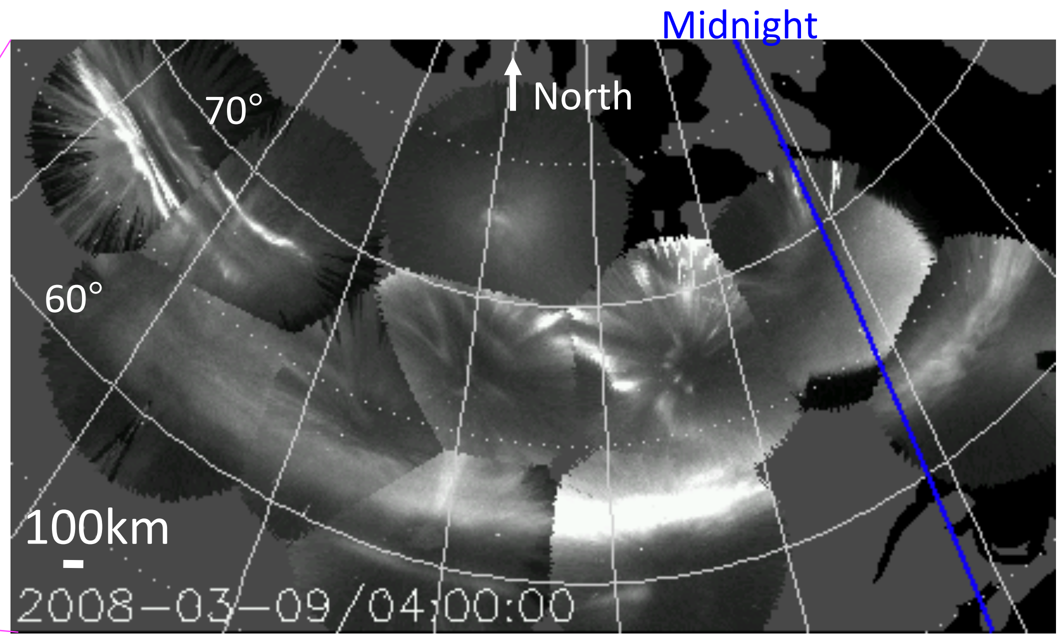
Their property and accuracy should still be examined, but behavior of large-scale M-I parameters are relatively understood.

2. M-I energy budget: Meso-scale

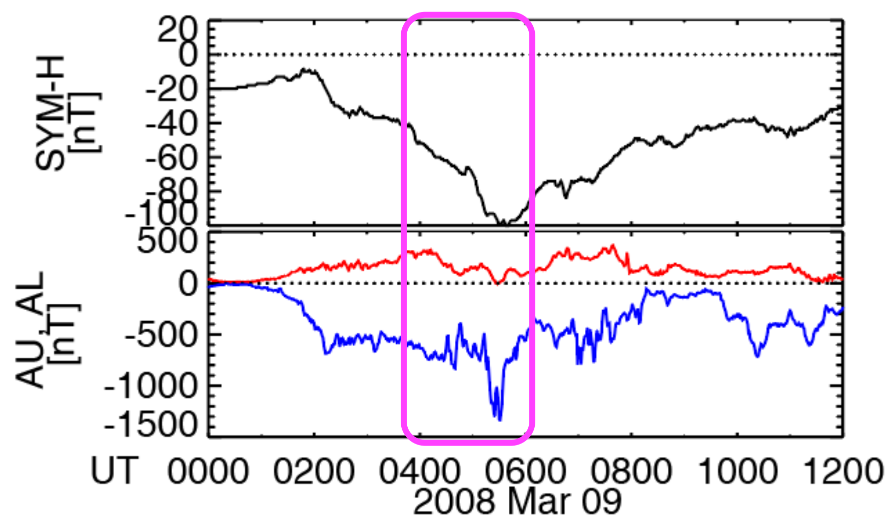
Large-scale model



Regional-scale data



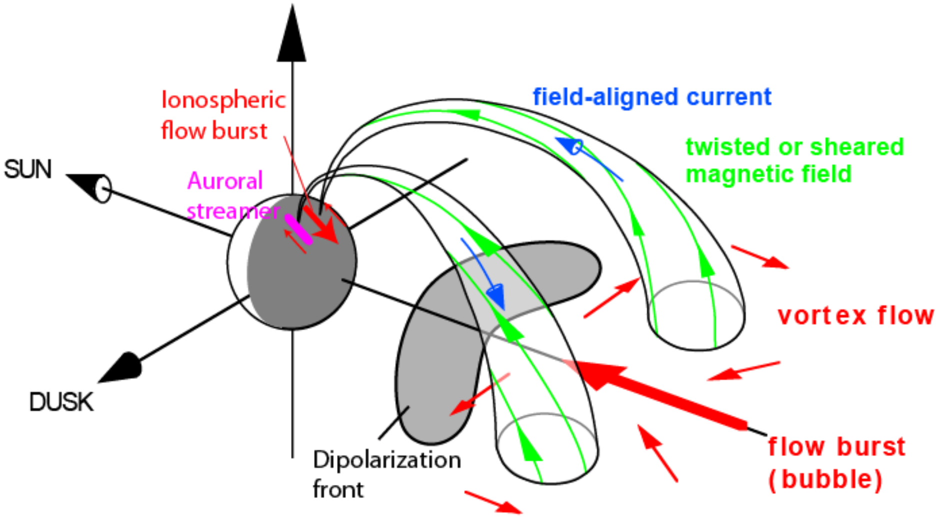
Storm-time aurora is full of localized transients, not described by large-scale data/models.



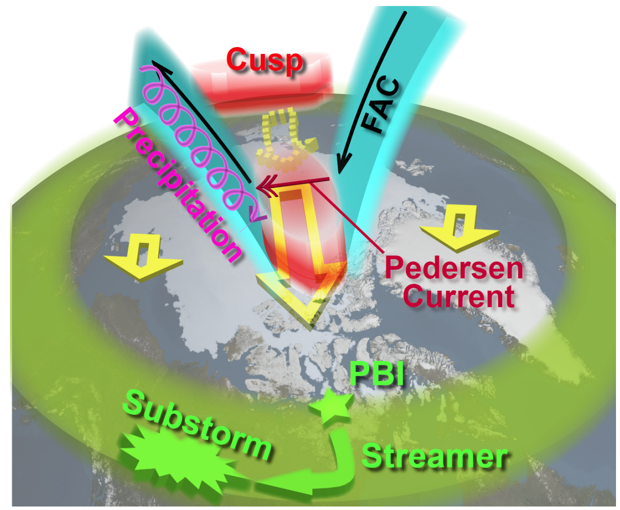
~100 km width, ~10 min duration (More in Gabrielse et al., Monday CEDAR Tutorial)

2. M-I energy budget: Meso-scale

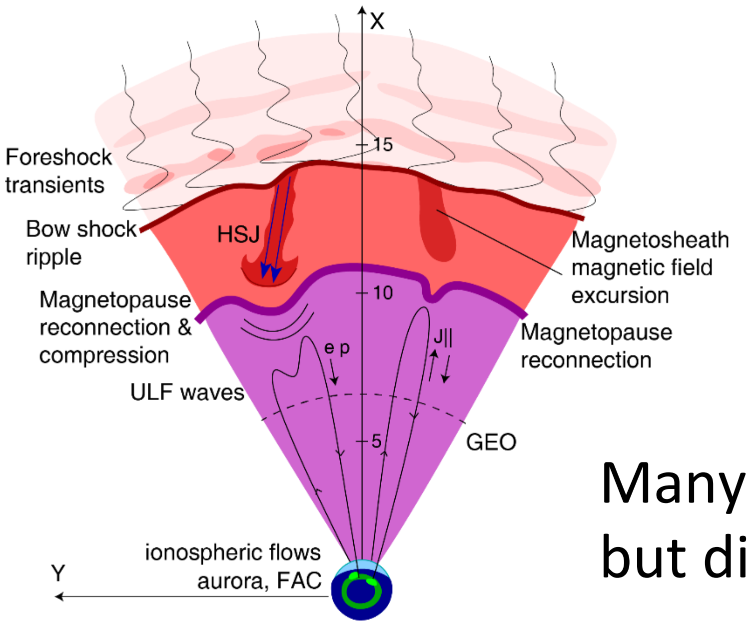
Flow channel/injection [Birn et al., 2004]



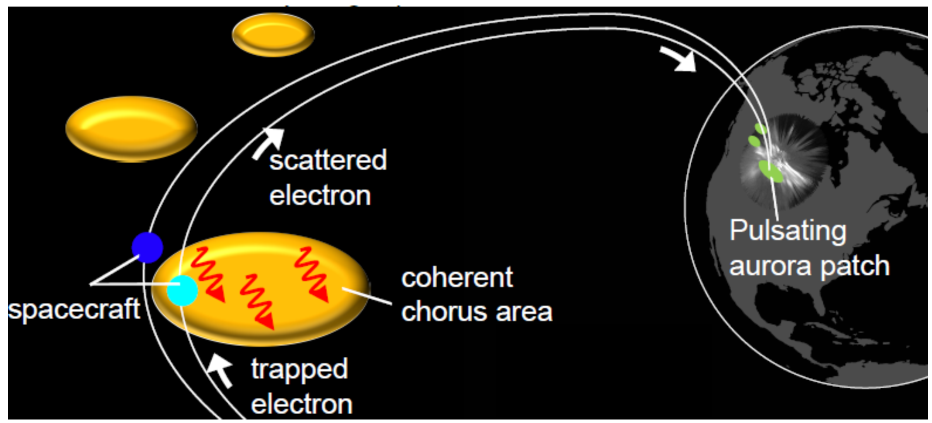
Cusp/Polar cap [courtesy of Y. Zou]



Dayside transients

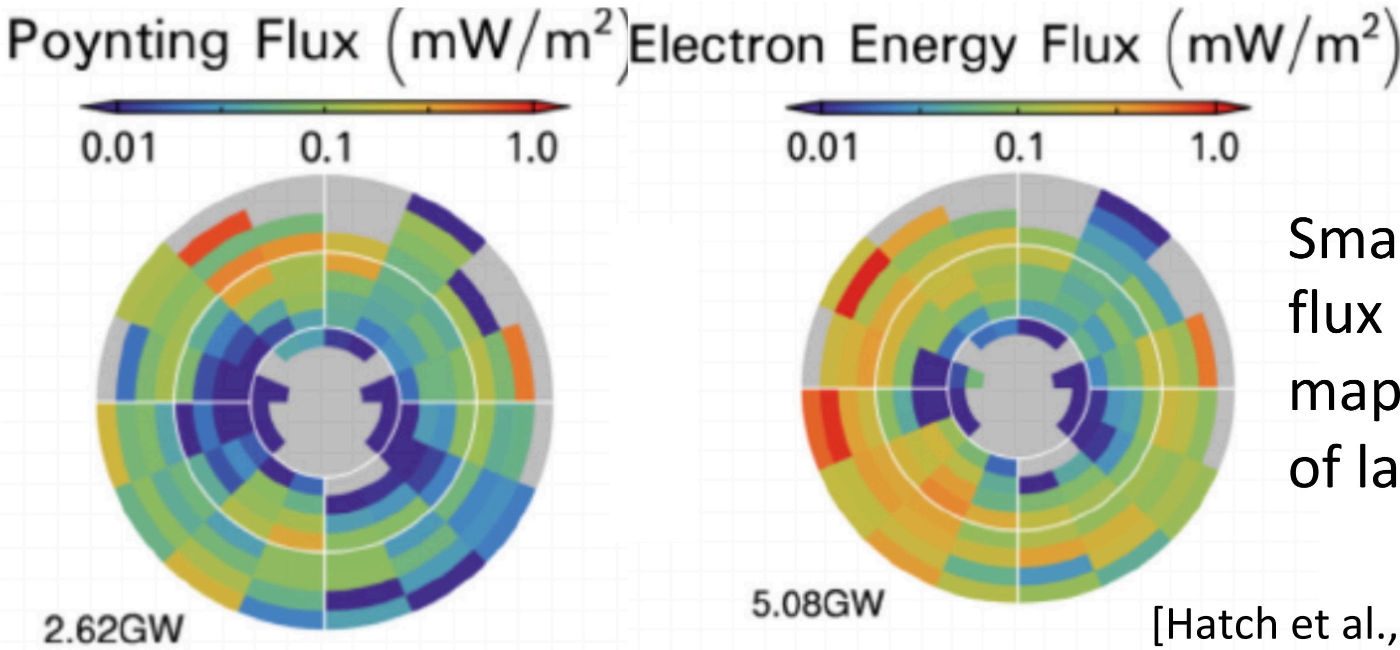


Wave-particle interaction



Many meso-scale M-I structures are identified, but difficult to quantify.

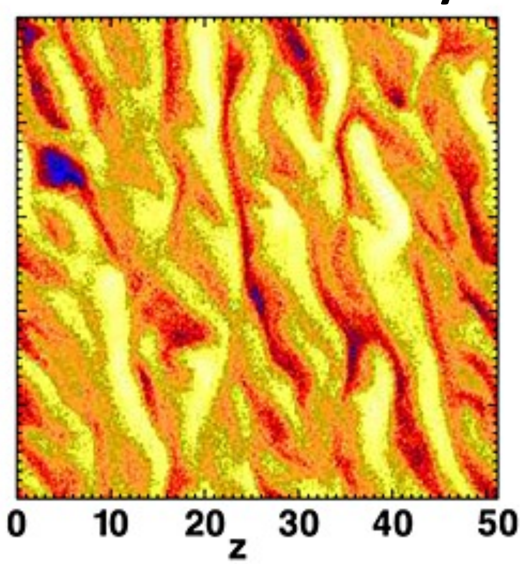
3. M-I energy budget: Small-scale



Small-scale Poynting flux and energy flux maps. Some tens of % of large-scale values.

[Hatch et al., 2018]

Smallscale density



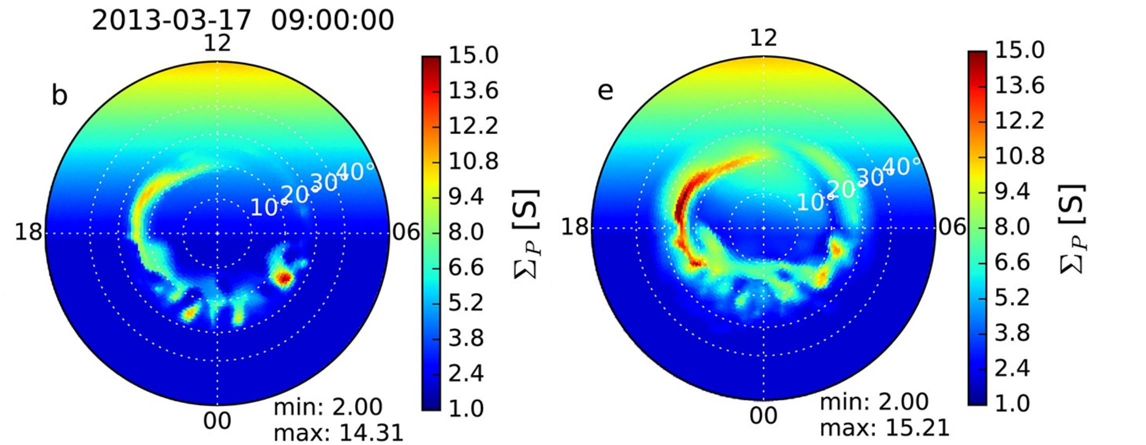
Kinetic instability (e.g, Farley-Bunemann) creates ~km size ionosphere density structures.

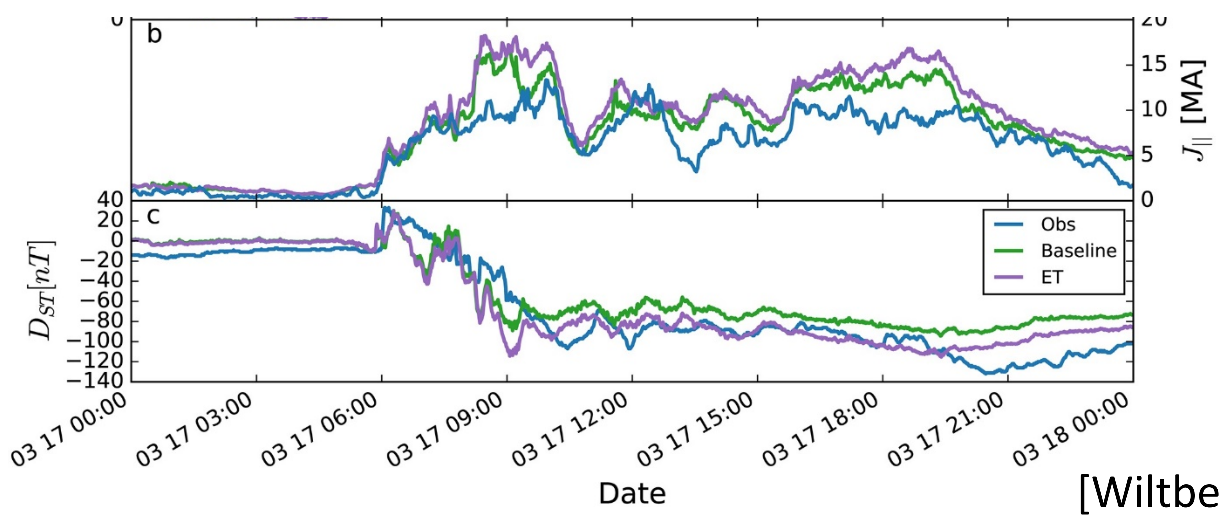
Their systematic properties and effects on the magnetosphere are not well known.

[Oppenheim and Dimant, 2013]

3. M-I energy budget: Small-scale

MHD conductance **MHD + turbulence conductance**





[Wiltberger et al., 2017]

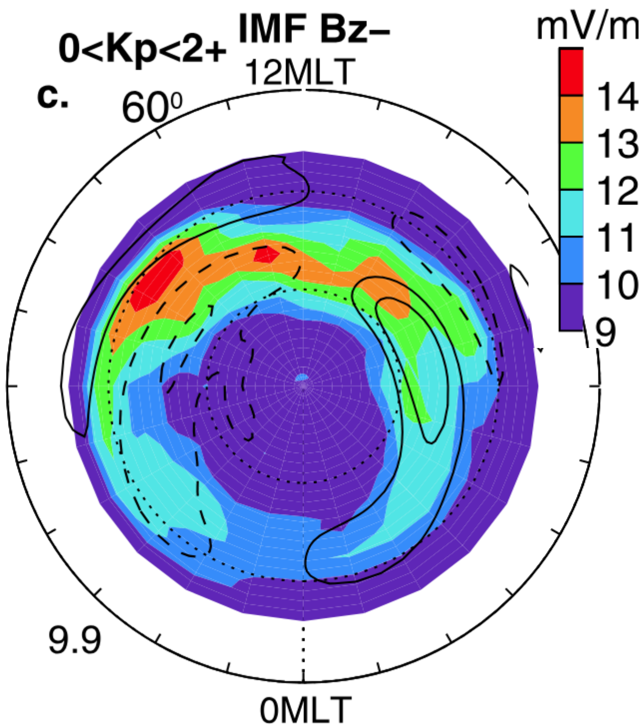
Inclusion of small-scale ionosphere instability substantially increases the conductance.

Has global impact on storm development.

2. M-I energy budget: Meso-scale

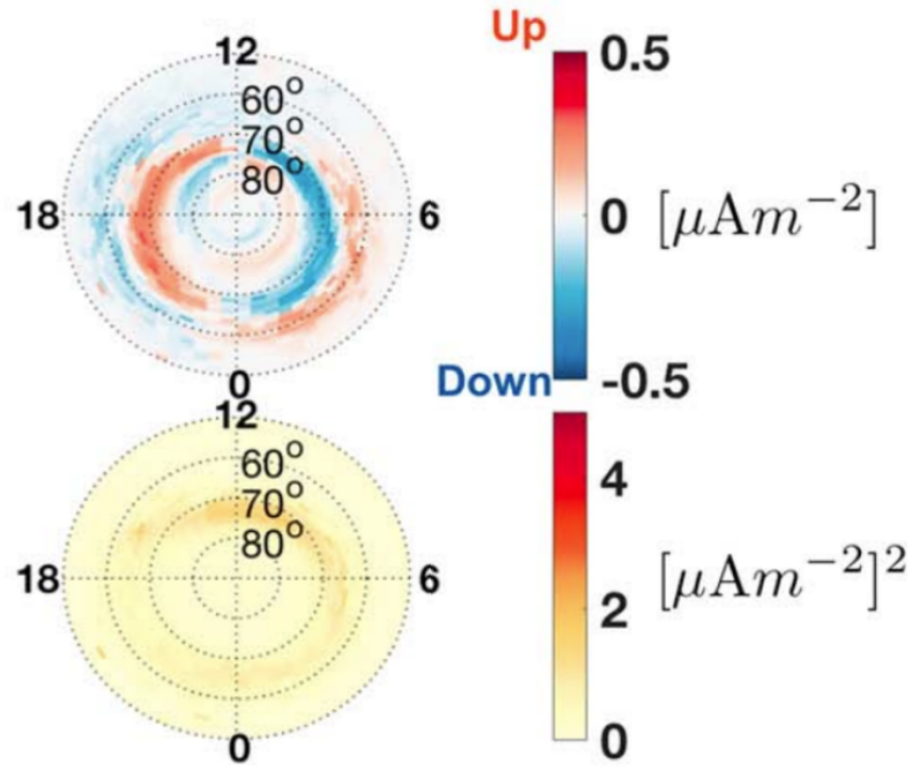
<u>How can we specify and quantify meso-scale driving?</u>

Electric field variability



[Cousins and Shepherd, 2017]

FAC variability

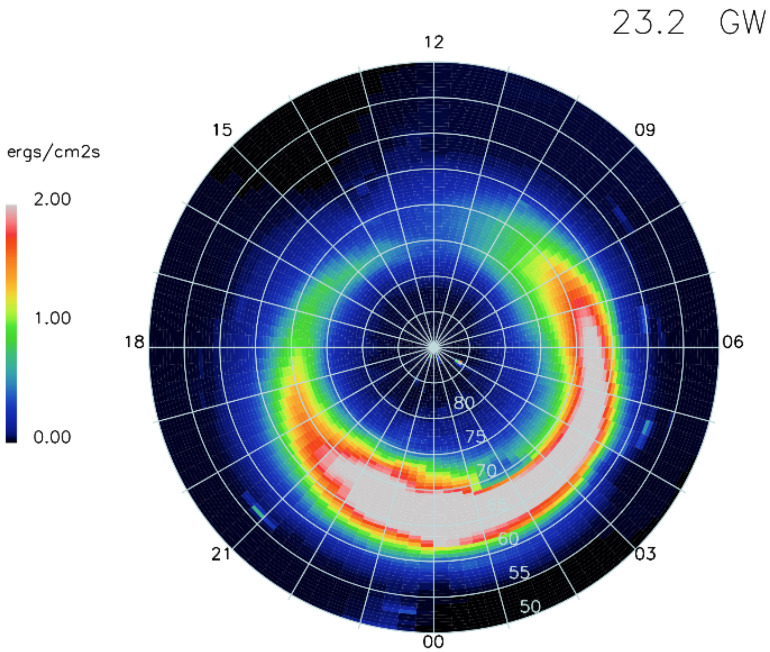


[McGranaghan et al. 2017]

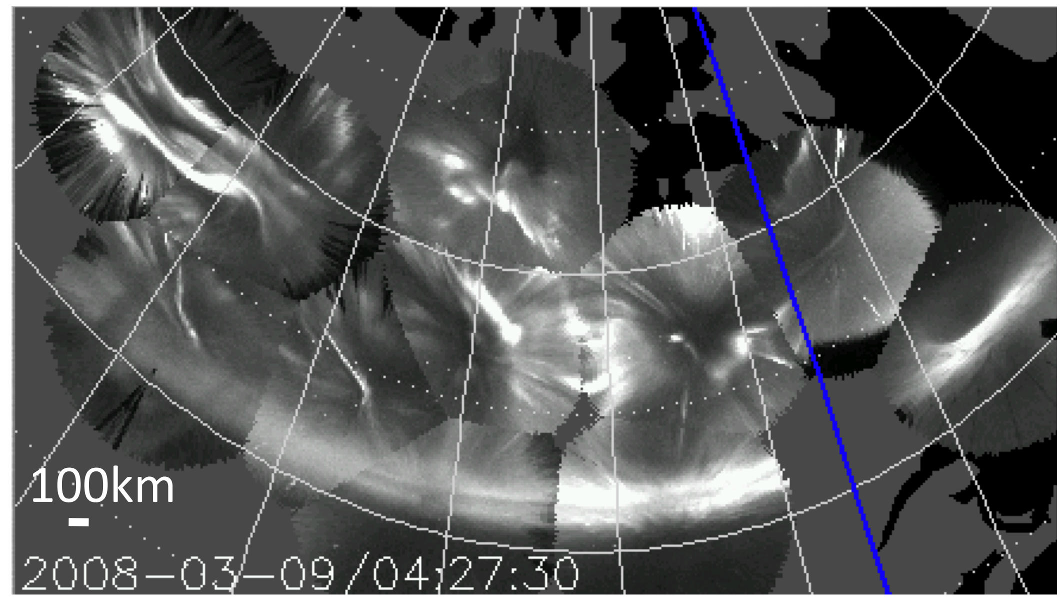
Statistical parameterization of ~100 km size features.
Can be used for modeling, but it’s difficult to parameterize.
Often underestimated. Coherence among parameters are lost.

2. M-I energy budget: Meso-scale

Statistical model

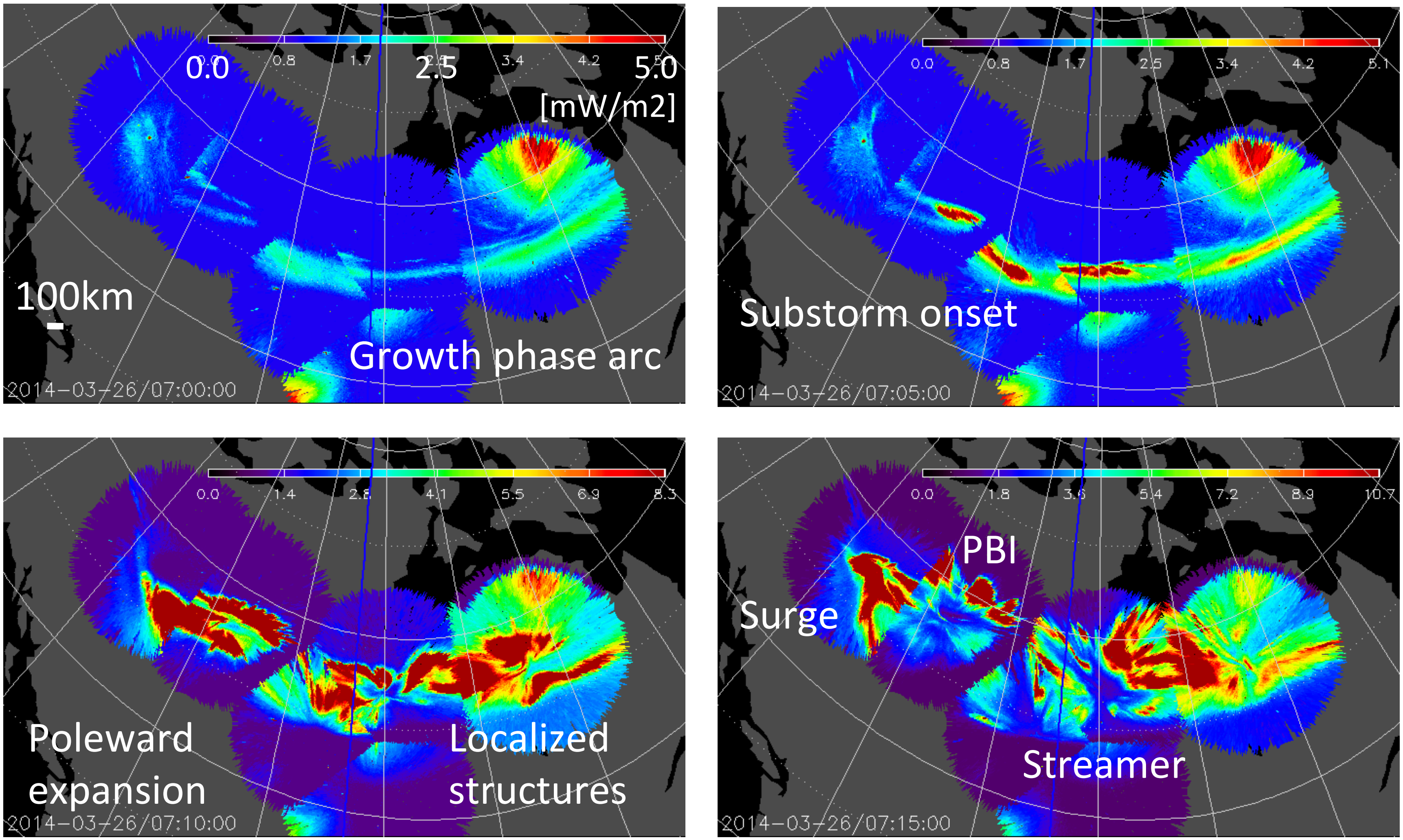


Data snapshot



Can we obtain an instantaneous map of meso-scale magnetospheric energy input without statistical averaging?

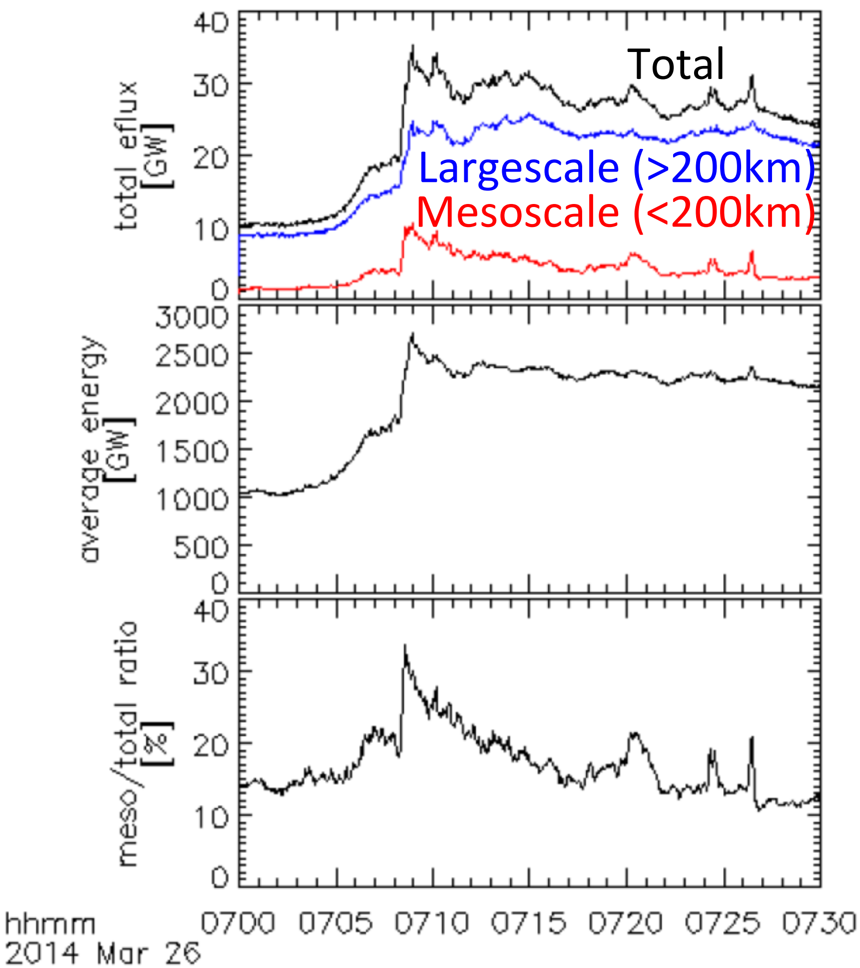
Time evolution of energy flux pattern

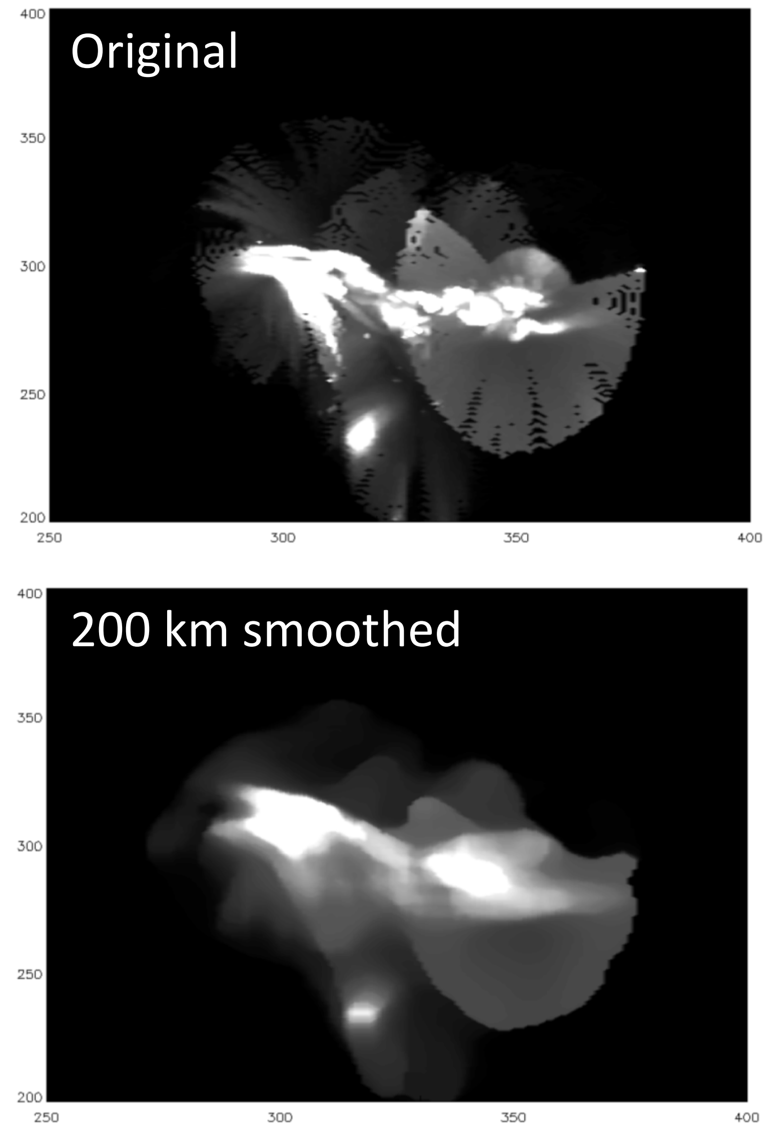


The dynamic nature of precipitating energy flux (and conductance) can be reconstructed without statistical averaging.

Large-scale vs. Meso-scale

How much energy do meso-scale structures carry?

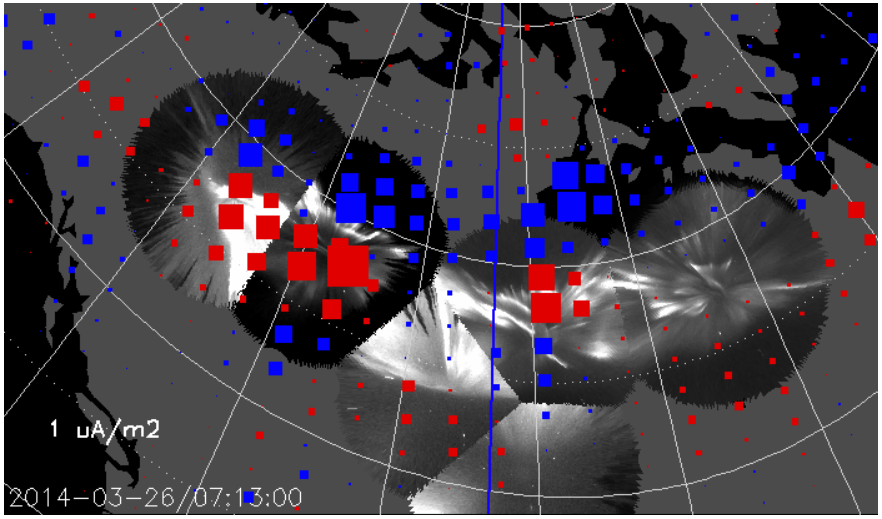




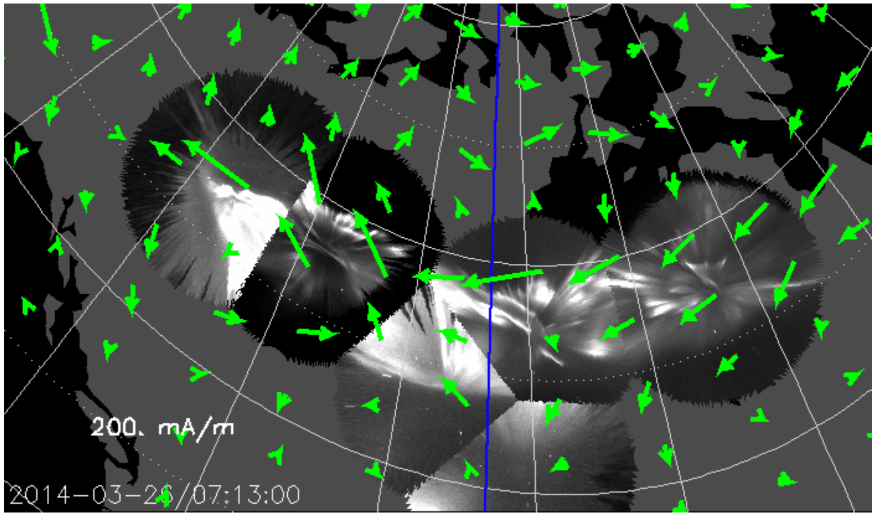
~15-35% of the total energy flux are carried by meso-scale structures. Higher contribution during intense aurora.

What else we need?

FAC



Horizontal current



(Courtesy of James Weygand)

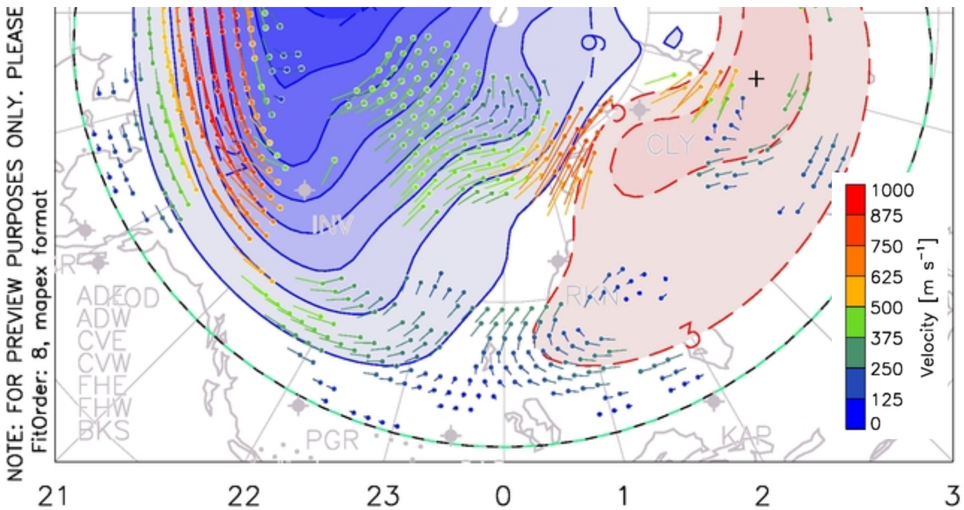
A dense magnetometer array is needed to detect the meso-scale FAC and horizontal current structures in 2-d.

The existing magnetometers can catch some of the structures, but still many structures are missed.

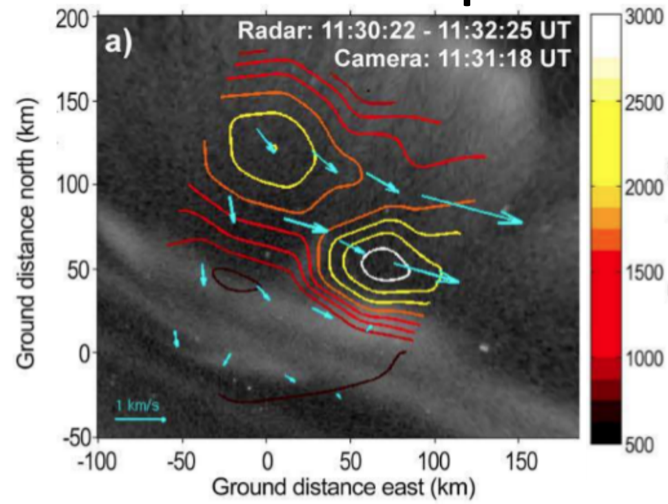
→ **A dense array of magnetometers are needed.**

What else we need?

Convection



Convection&Temperature



[Semeter et al., 2010]

Convection measurements are even more limited.

SuperDARN: Echoes are usually sparse. Convection maps smooth out mesoscale structures.

ISRs: Fields of view are very small.

→ **Need 2-d high-resolution convection at a regional scale.**

Small-scale structures are far less specified (high-speed imaging, GPS scintillation…).