Co-located observations of thermosphere-ionosphere coupling during a substorm

Data from AMPERE, SuperDARN and a Scanning Doppler Imager

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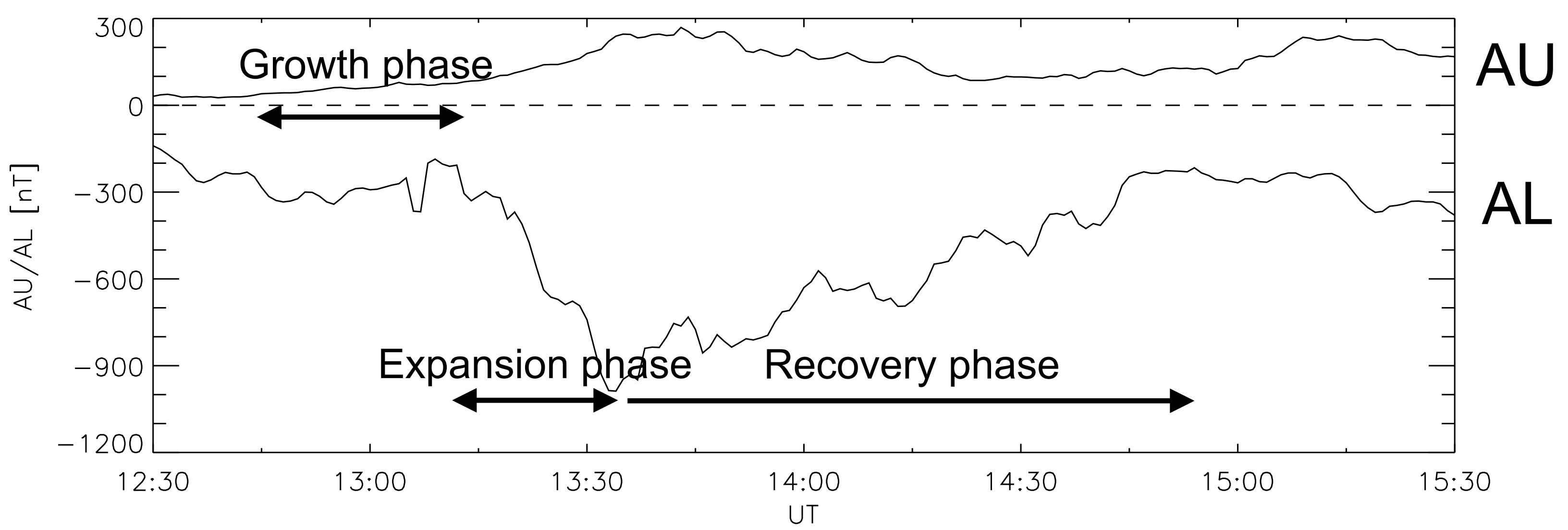
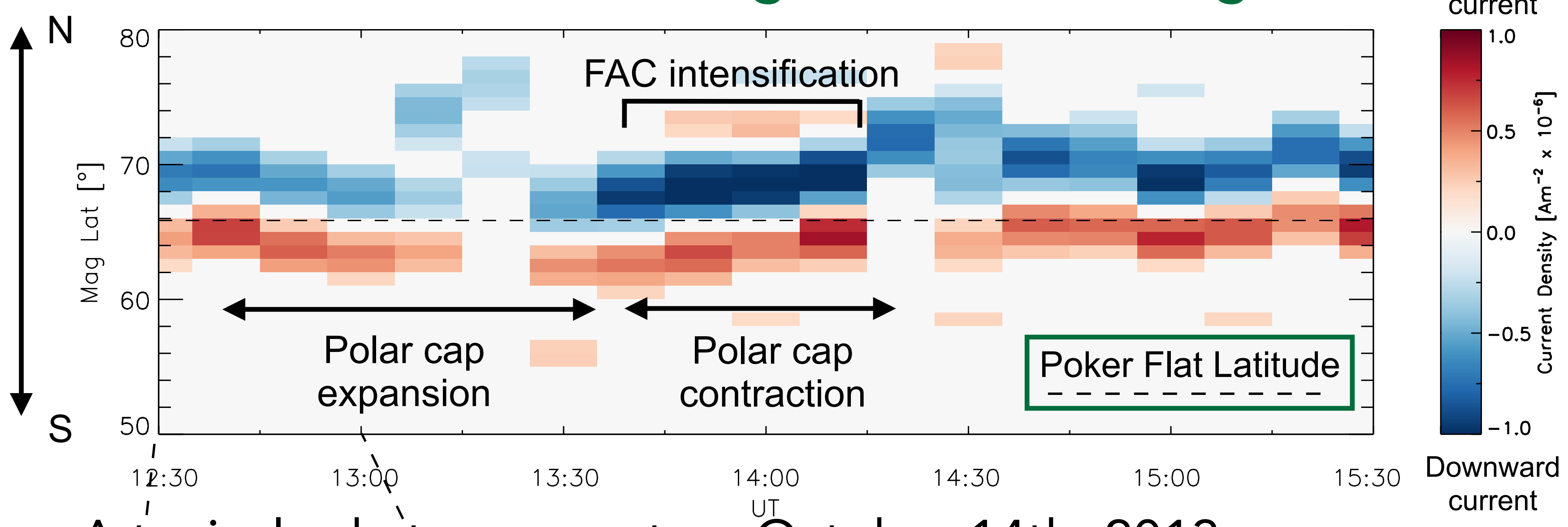
1 - The Substorm above Poker Flat, Alaska

AU and AL indices

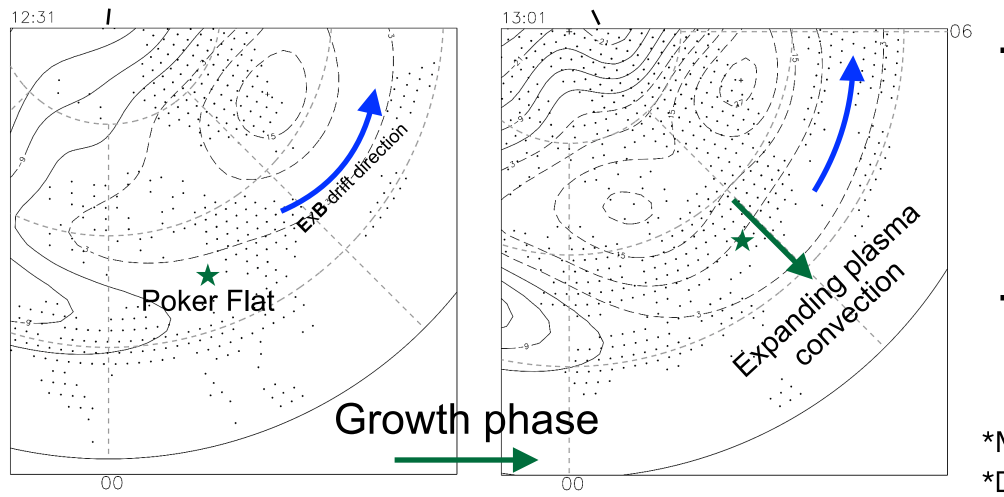


AMPERE Field-Aligned Current Keogram



- A typical substorm event on October 14th, 2013
- AMPERE sees polar cap expanding during substorm growth phase, contracting and **intensifying FAC** after expansion onset

SuperDARN Plasma Convection Contours

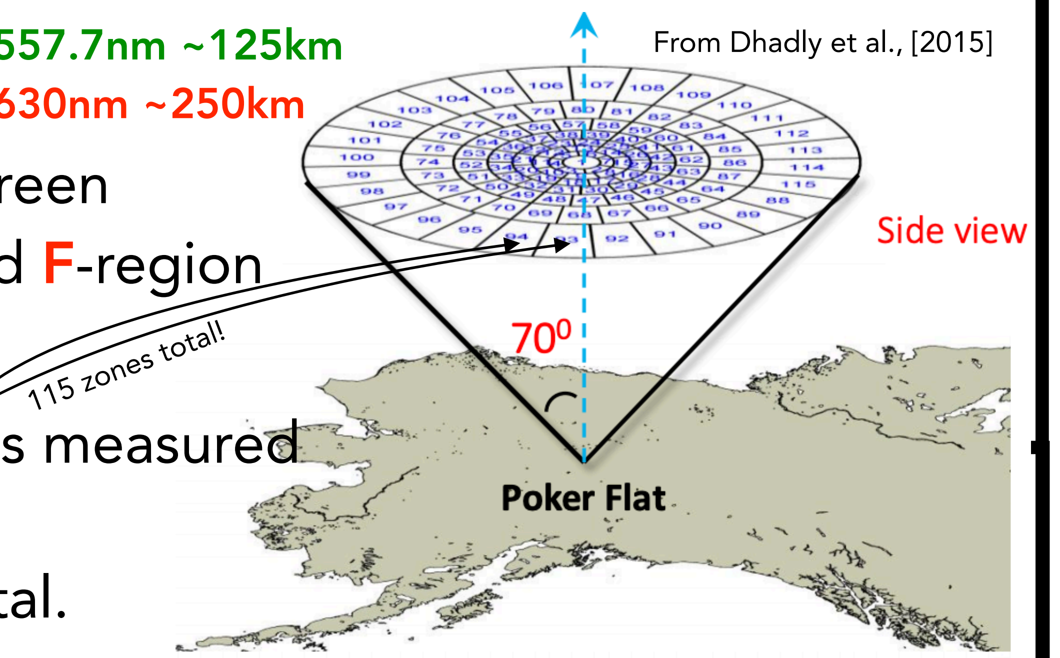


- Plasma convection expands **equatorward** during substorm growth
- Contracts poleward along with AMPERE FACs

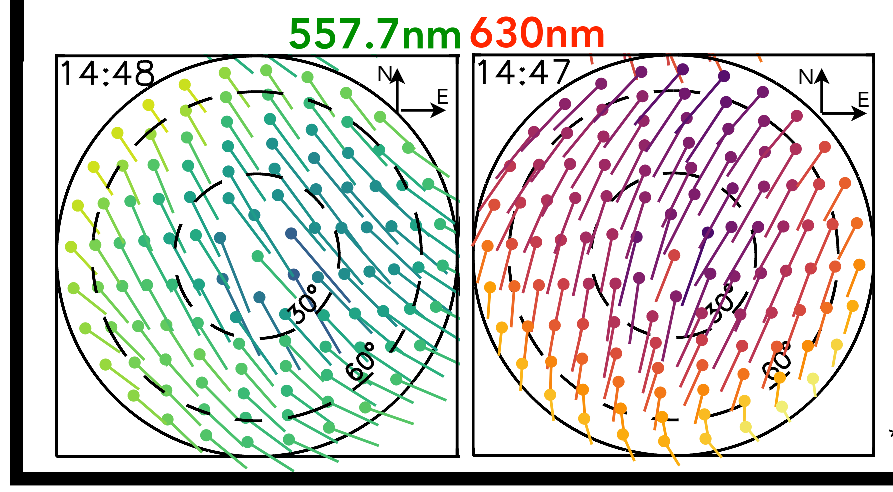
*Magnetic latitude - magnetic local time format

*Dots indicate SuperDARN radar data locations

General Info: The Poker Flat SDI



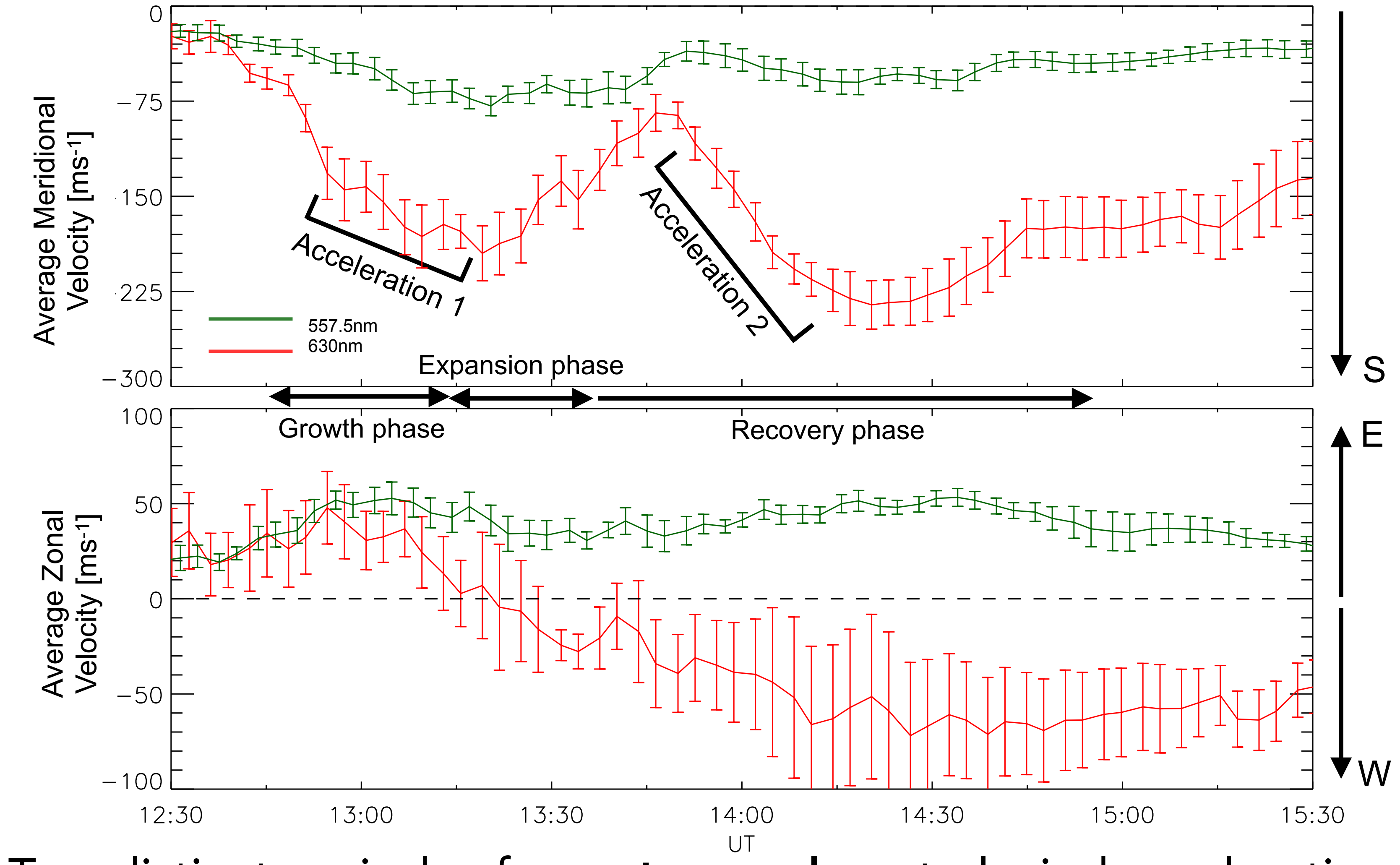
- The **S**canning **D**oppler **I**mager is a wide angle camera that can image both green (**557.7nm**) and red (**630nm**) line auroral emissions. Those correspond to **E**- and **F**-region altitudes, respectively.
- The night sky is split into several regions. The Doppler spectra in each **zone** is measured for both emissions, and LOS neutral wind velocities derived.
- Assuming vertical wind is uniform, LOS winds can be transformed to horizontal.



- SDI alternates imaging of **E** and **F** regions, giving a near simultaneous look at **neutral winds** in **both**.

*Example neutral wind fields, looking down on SDI from above

2 - The Neutral Wind Response

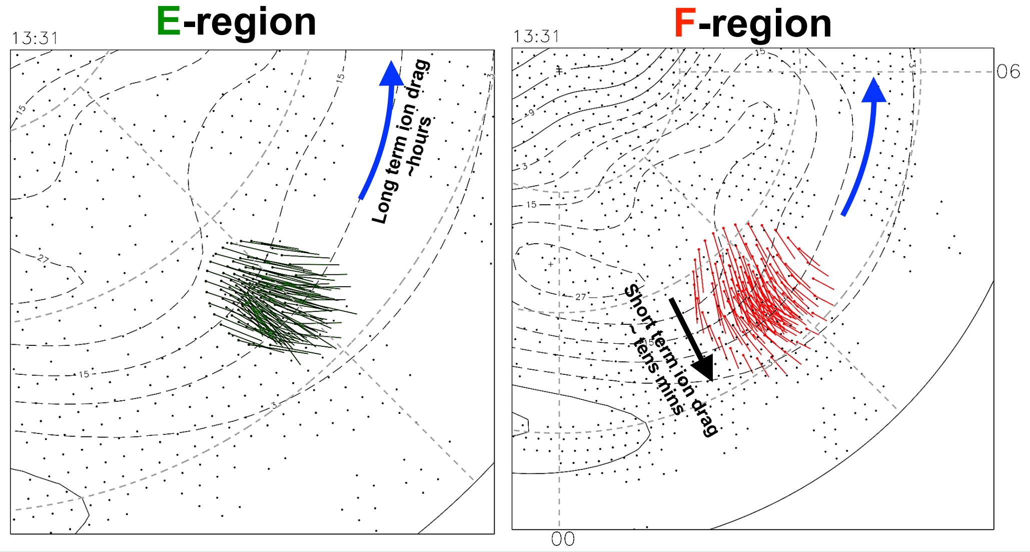


- Two distinct periods of **equatorward** neutral wind acceleration.
- Acceleration 1 overlaps with **substorm growth**, and **polar cap expansion**. Acceleration 2 overlaps with **FAC intensification**.
- Most distinct in the **F**-region winds, much less in **E** region.

3 - Summary/Conclusions

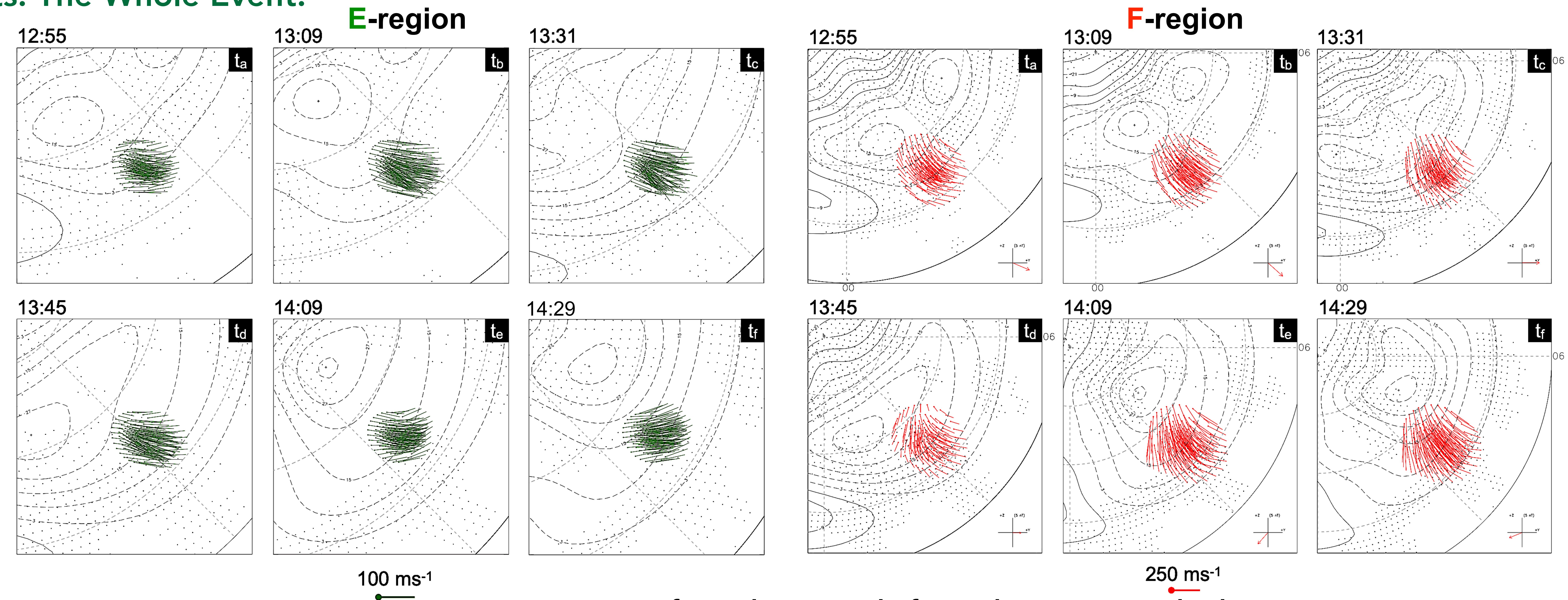
- During substorm growth when the convection pattern expands, there are **two** forms of ion drag occurring.
- **Long term** ion drag, which is always acting in the **ExB** direction. **Short term** ion drag, which acts **equatorward** with expanding convection.
- Ion drag causes neutrals to accelerate in the direction it acts, but **neutral density** varies drastically between **E** and **F** regions.
- **Result:** **E**-region neutral winds require ion-drag to act **long term**, thus they do not respond strongly to the **short term** expanding plasma convection pattern. **F**-region neutrals are less dense, and so respond quicker to an ion drag change.

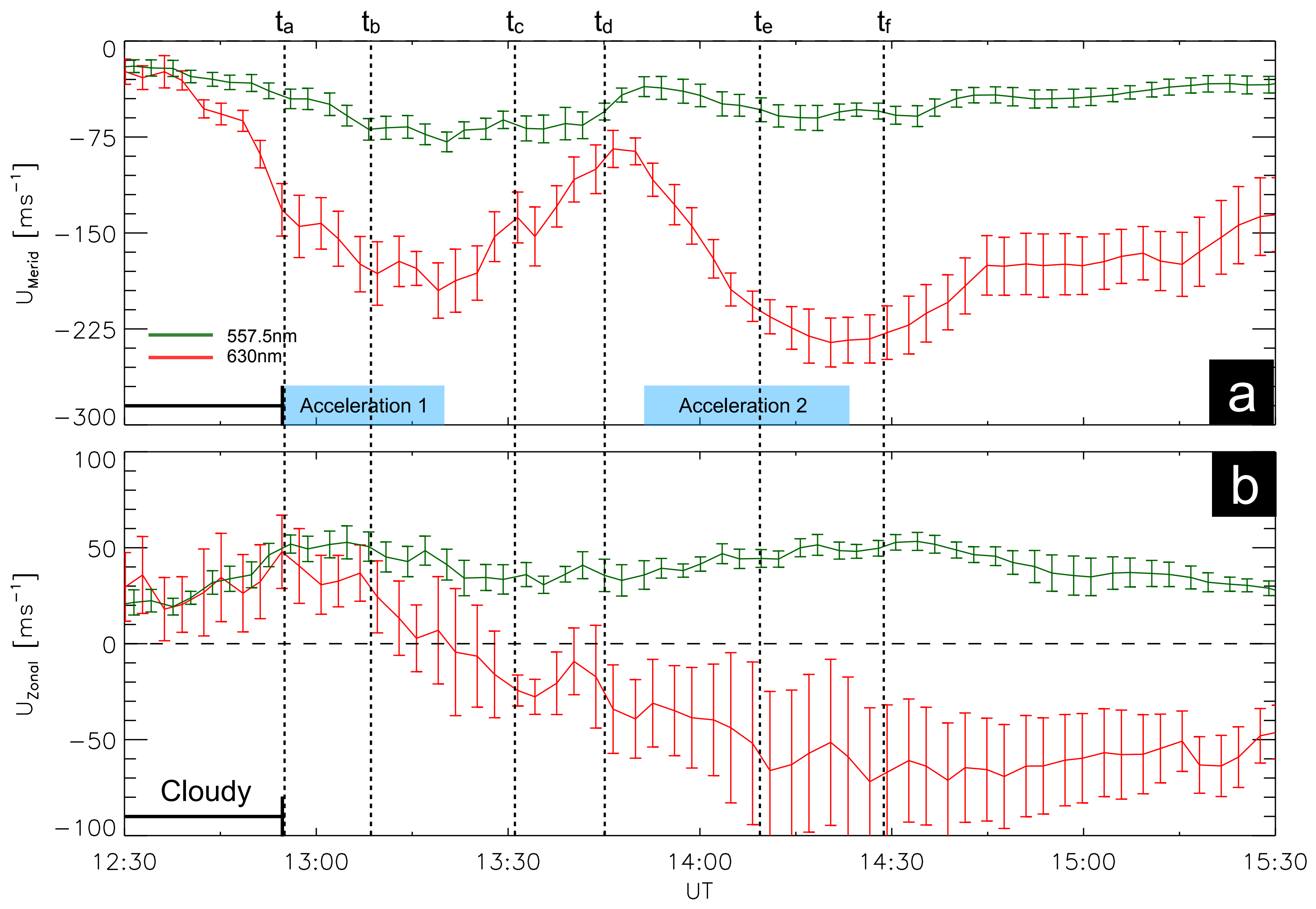
Conditions after substorm growth:



*E-region plots more zoomed in (lower altitude projection)

Bonus Plots: The Whole Event!





t_a, t_b t_c: Before, during and after substorm growth phase

The plasma convection boundaries move equatorward. Winds in the F region accelerate strongly with ion drag in that direction. E-region winds less so. The convection pattern expansion occurs over a period of ~20 minutes, which is long enough to affect F-region winds (typical e folding time on order of tens of minutes), but not E-region winds (typical e folding time of hours).

t_d, t_e t_f: Before, during and after substorm recovery phase

This is when FACs became enhanced, and correspondingly, the SuperDARN electric potential contours are also enhanced (dawn cell peak of 27kV vs 15kV in t_a). We infer strong Joule heating induced pressure gradients drives this second F-region acceleration. High E-region densities stop neutrals there accelerating quickly.