Meso-scale ionosphere flows: Characterizing a dynamic link in M-I-T coupling

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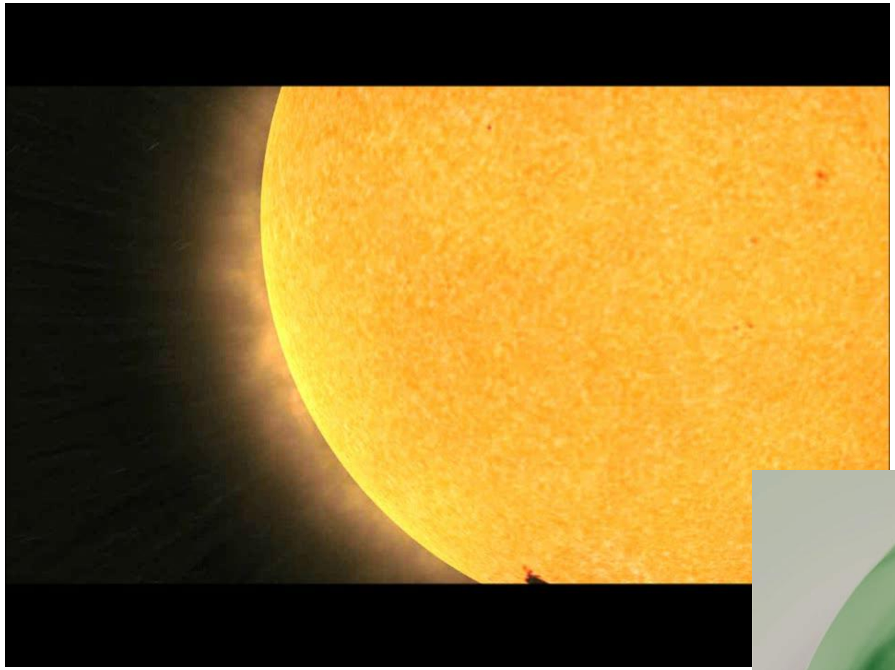
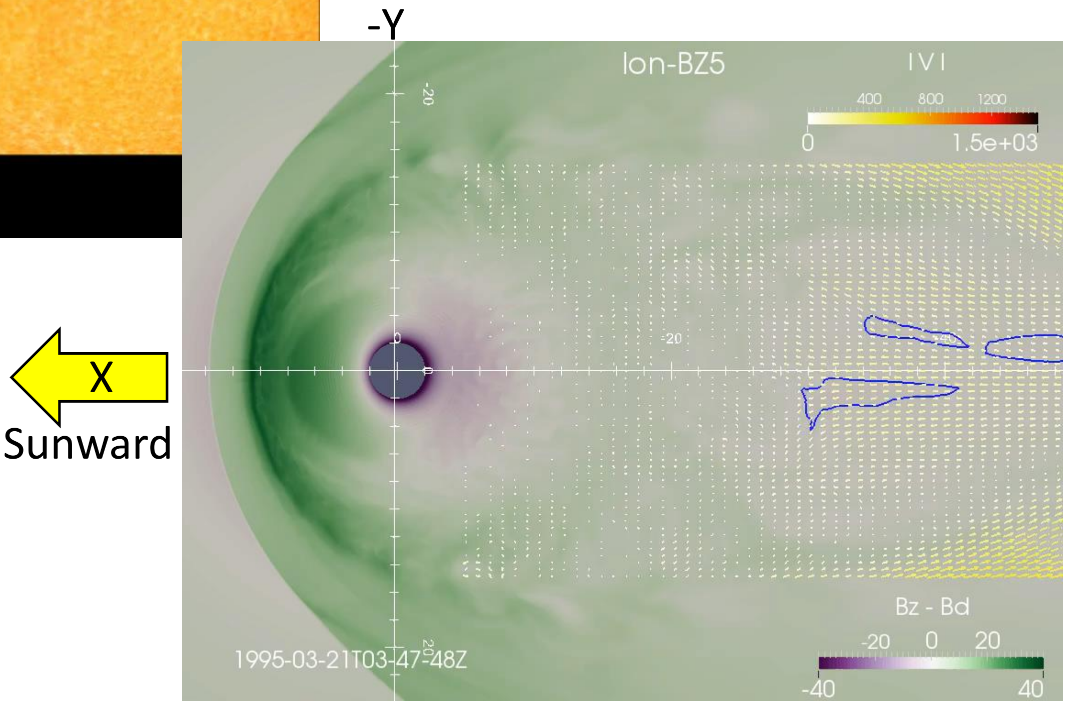
Next Generation Advances in Ionosphere-Thermosphere Coupling at Multiple Scales for Environmental Specification and Prediction

Background





Wiltberger et al. [2015] (LFM)

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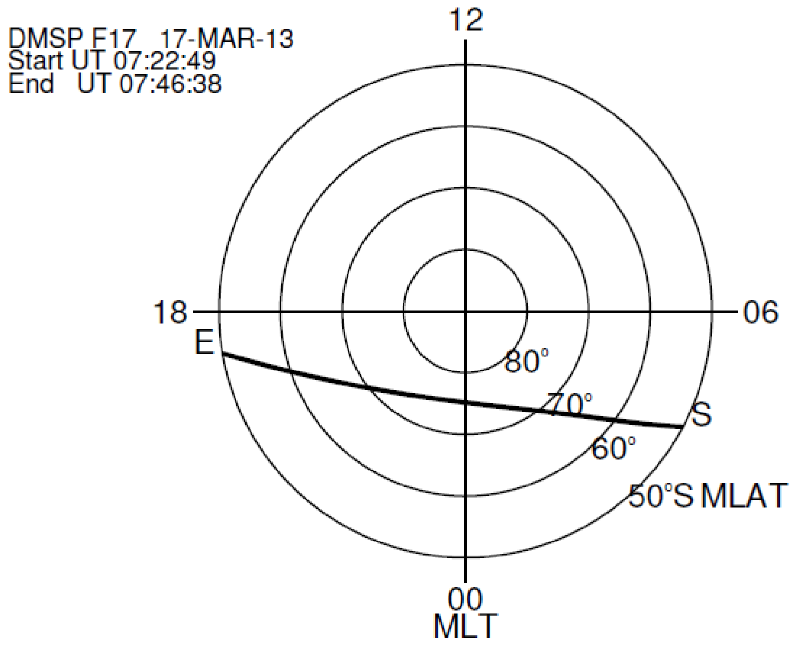
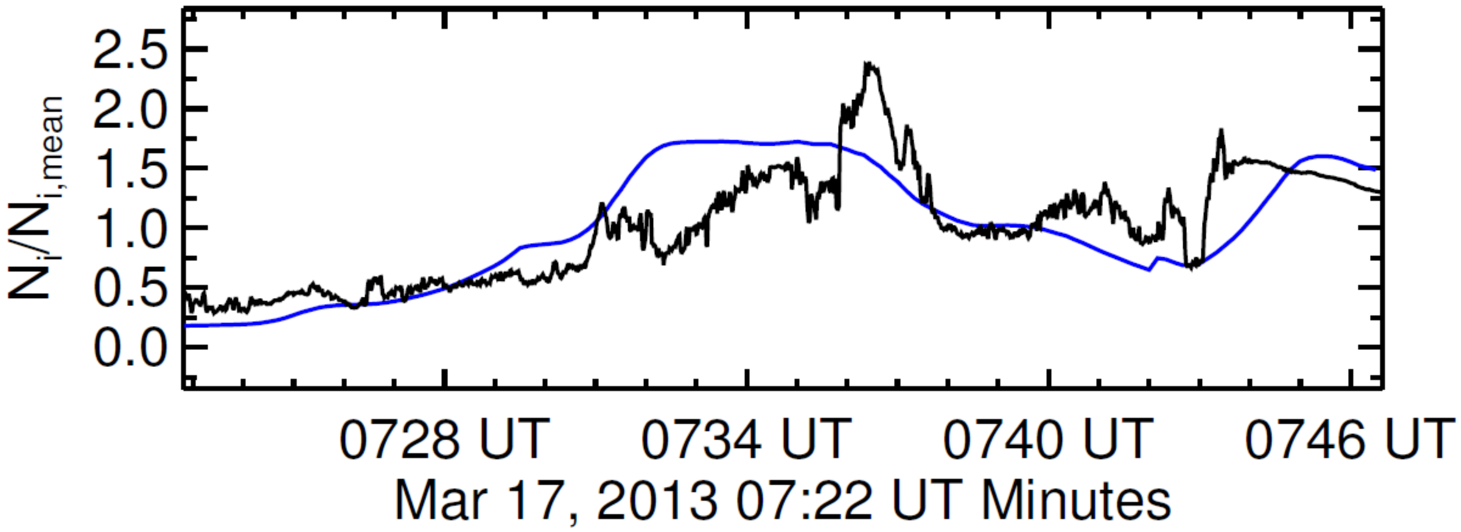
Background

(c) Ion density: GITM vs. DMSP



Data: DMSP

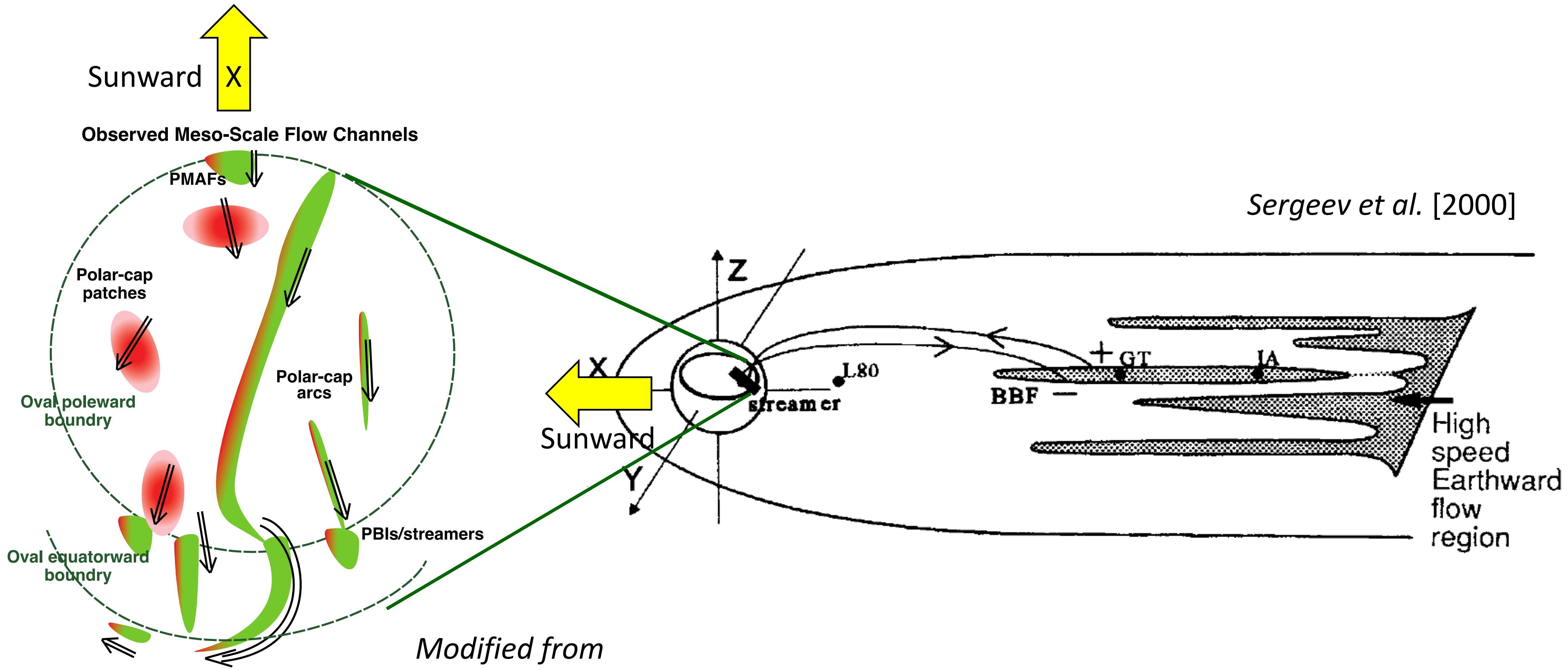
Model: GITM at 550km



Missing meso-scales: ~50-500 km

Background: Sources of Meso-scale Phenomena

UCLA

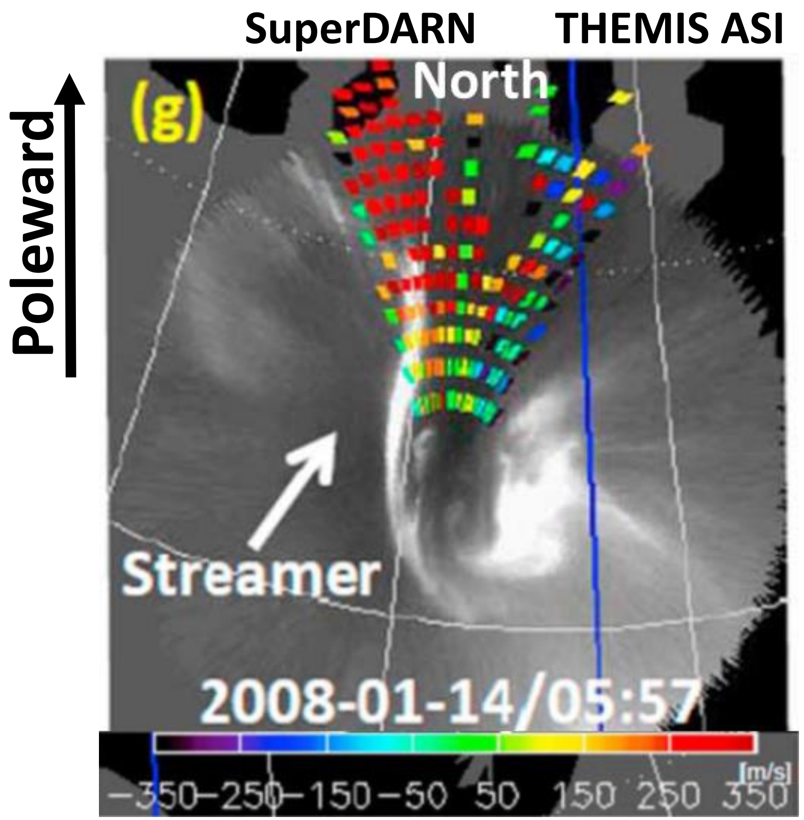


Modified from Lyons al. [2016]

Sergeev et al. [2000]

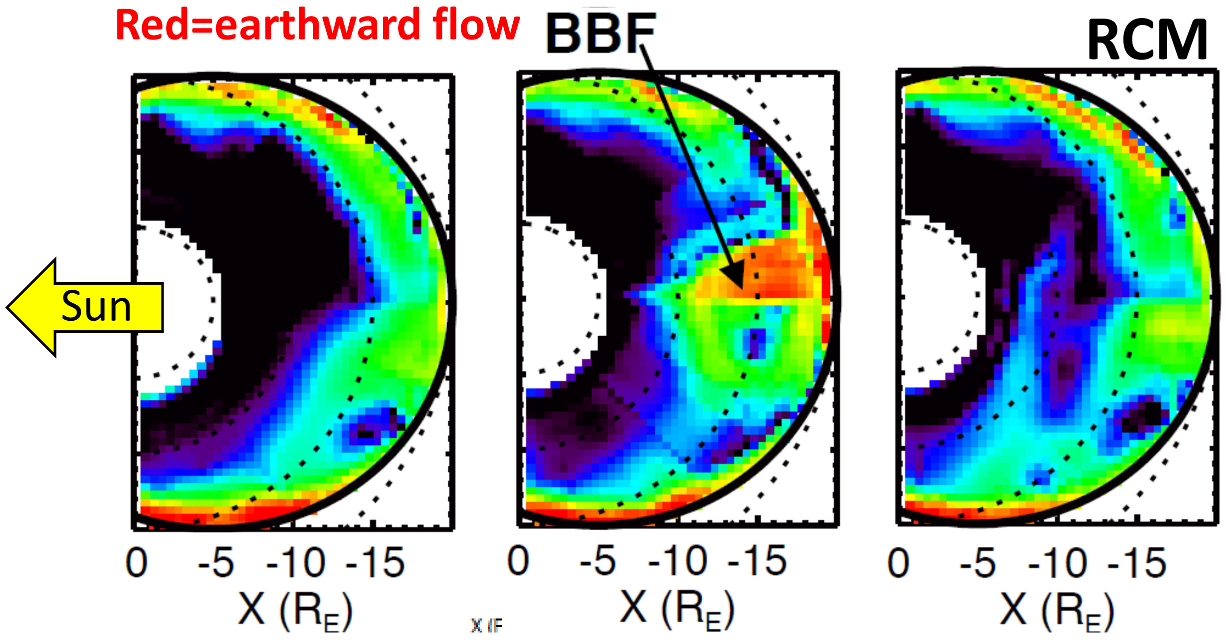
Background: Sources of Meso-scale Phenomena

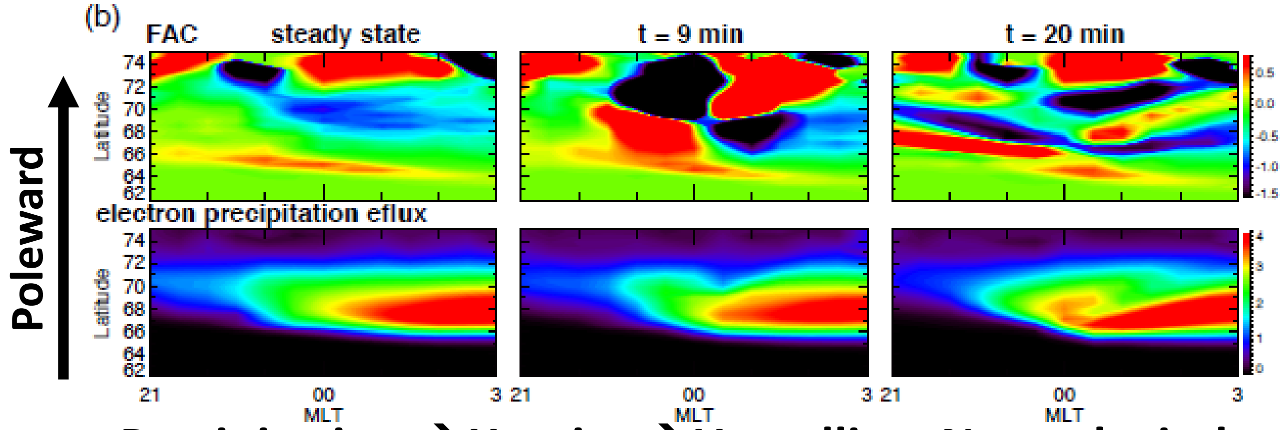
UCLA



Red = Ionosphere flow **towards** radar
equatorward = **earthward**
Blue = Ionosphere flow **away** from radar
poleward = **tailward**

Gallardo-Lacourt et al. **[2014]**





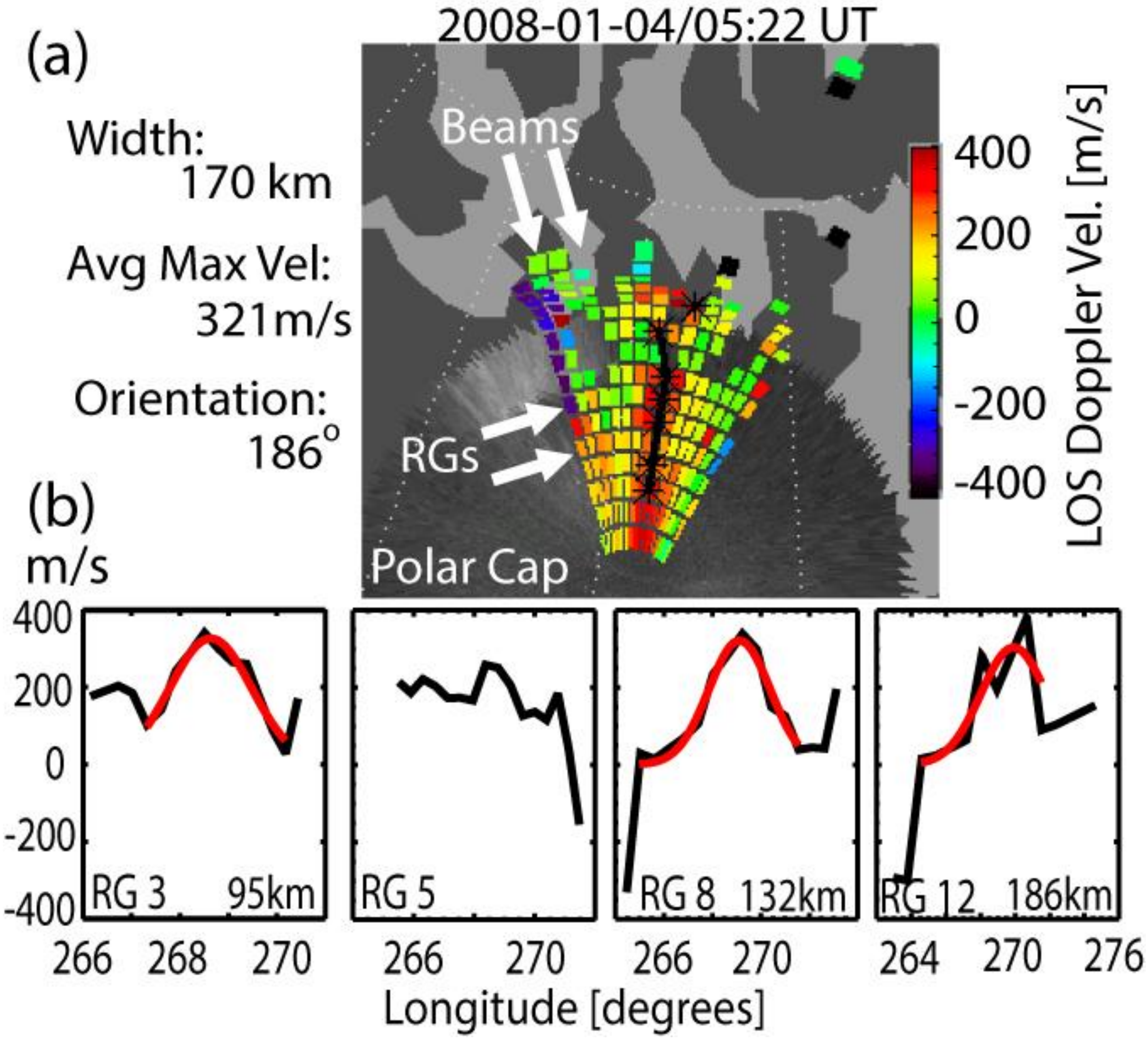
Precipitation →Heating→Upwelling, Neutral winds

Nightside High-Latitude Meso-scale Ionosphere Flows

- **What are their characteristics?**
  - Width
  - Velocity
  - Orientation
  - Duration
- **Where and When do they occur?**
  - Occurrence rates
  - MLT sectors
  - Latitudes
  - Season
  - Solar cycle
  - Space weather activity (AL index)

Methods

- Automatically select nightside flows
- Poleward-directed SuperDARN stations at Rankin Inlet and Saskatoon (2008-2016)
- Fit Gaussian curve to flow data in each RG that meets flow criteria to get FWHM
- Average FWHM from all RGs to get flow width
- Average max velocity from all RGs to get flow speed
- Find average angle between Vmax at neighboring RGs to get flow orientation



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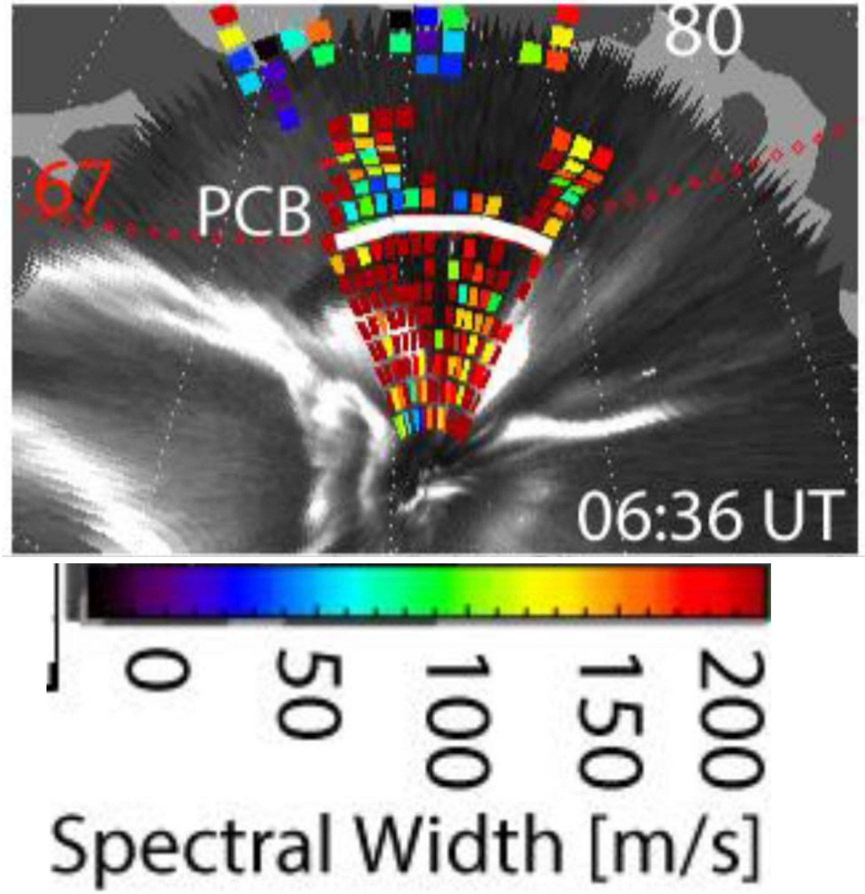
Methods

- **Separate flows into 3 regions:**
  - Polar Cap
  - Auroral Oval (higher latitude at Rankin Inlet)
  - Auroral Oval (lower latitude at Saskatoon)

- **Polar Cap Boundary found via spectral width method:**
  - Chisham et al. [2004]
  - Chisham and Freeman [2003]
  - **Spectral width boundary (SWB)=150 m/s**

- **Preferable to:**
  - DMSP overpass: rare
  - All-sky-imager: inconsistent (moon, clouds, off)



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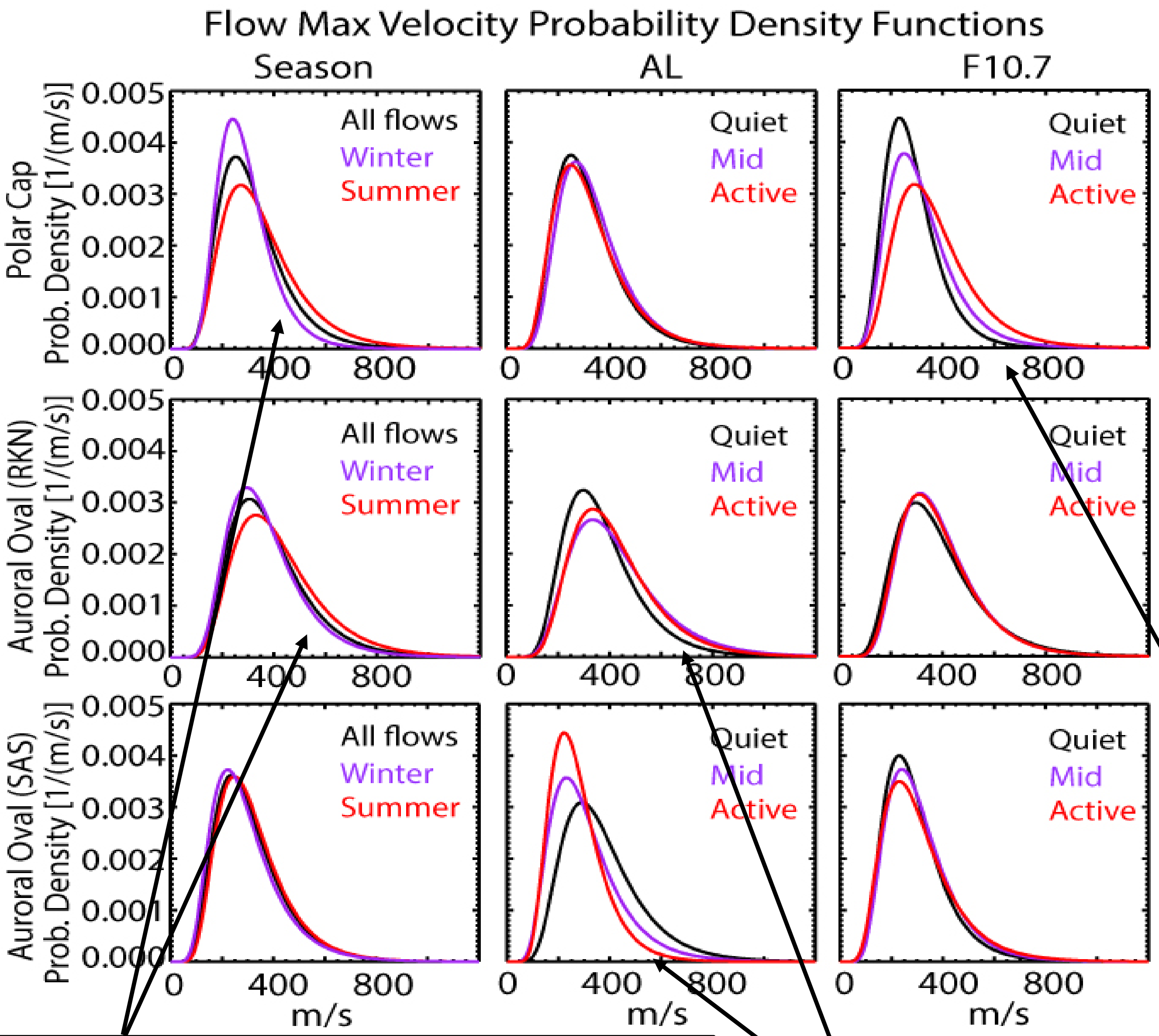


Lognormal Distribution

$$PDF = \frac{log_{10}(e)}{V\sigma\sqrt{2\pi}} exp\left\{-\left[\frac{(log_{10}(V) - \mu)^2}{2\sigma^2}\right]\right\}$$

V = Max Velocity
μ = mean of $log_{10}(V)$
σ = standard deviation of $log_{10}(V)$

Polar Cap
Median: 288m/s +/- 136 m/s

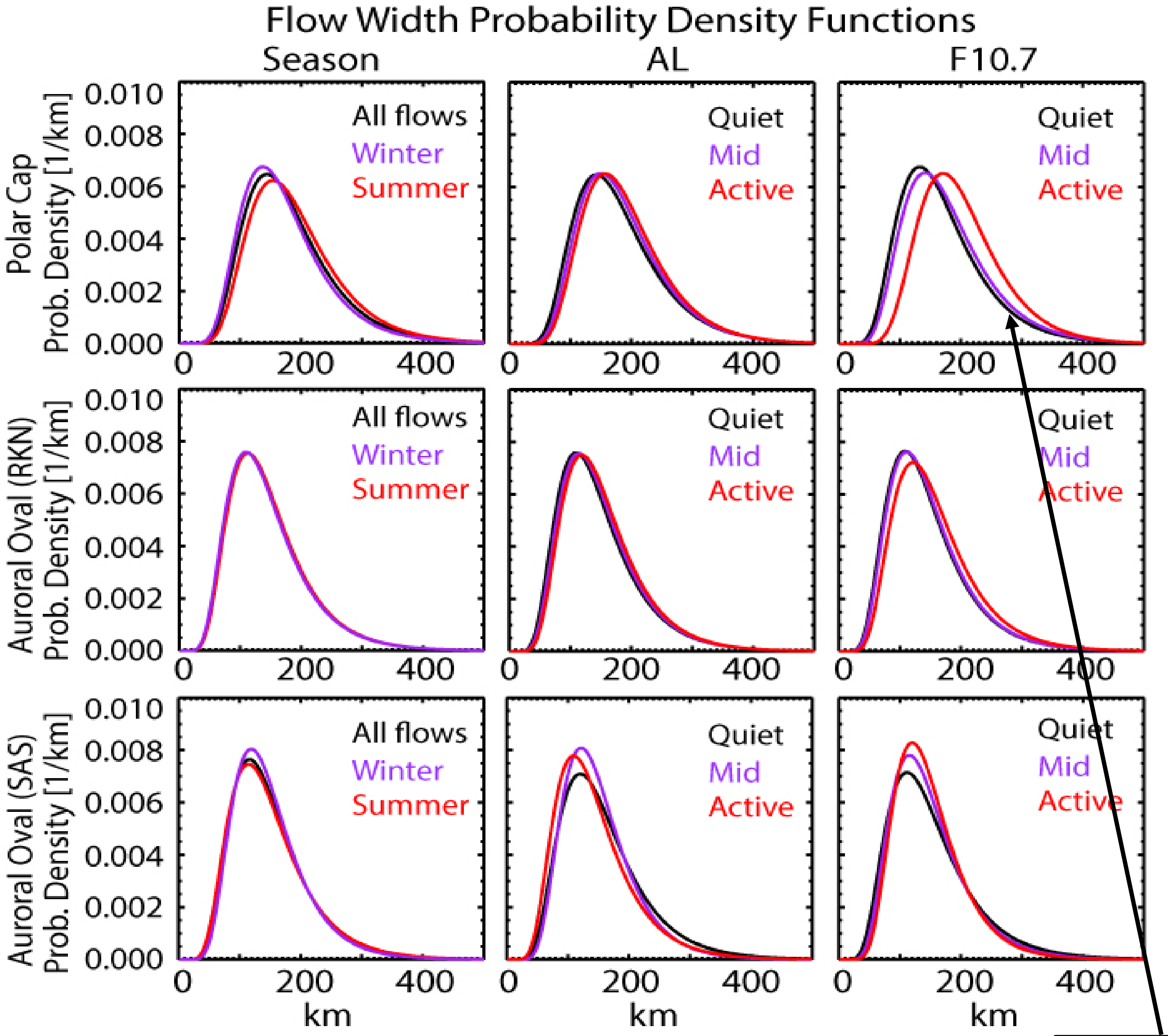
Auroral Oval (RKN)
Median: 357 m/s +/- 157 m/s

Auroral Oval (SAS)
Median: 288 m/s +/- 132 m/s

Faster flows in summer, unlike background convection [e.g., *De la Beaujardiere et al.*, 1991]. *Ohtani et al.* [2009]: Larger σ in nightside winter.

Faster flows in high lat auroral oval during AL activity, but slower flows in low lat oval

Faster flows in polar cap during active F10.7



Lognormal Distribution

$$PDF = \frac{log_{10}(e)}{W\sigma\sqrt{2\pi}} exp\left\{-\left[\frac{(log_{10}(W)-\mu)^2}{2\sigma^2}\right]\right\}$$

W = Width
μ = mean of $log_{10}(W)$
σ = standard deviation of $log_{10}(W)$

Polar Cap
Median: 177 km +/- 65 km

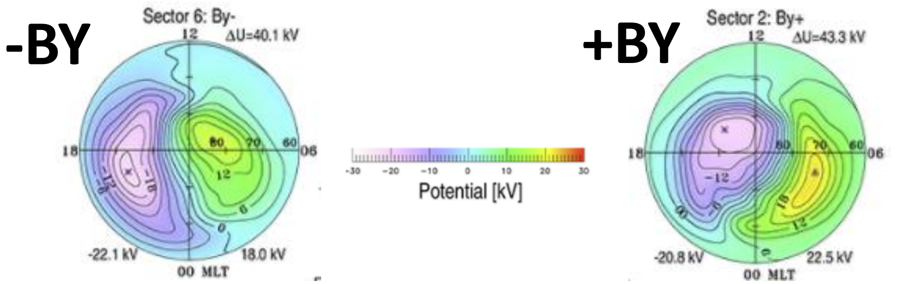
Auroral Oval (RKN)
Median: 139 km +/- 59 km

Auroral Oval (SAS)
Median: 144 km +/- 56 km

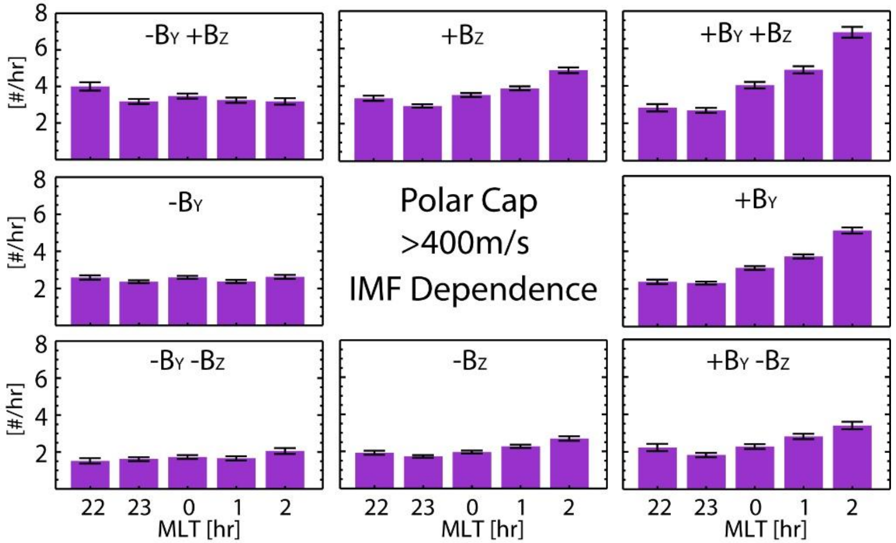
Wider during active F10.7

Flow widths do not vary as much under different drivers/ circumstances.

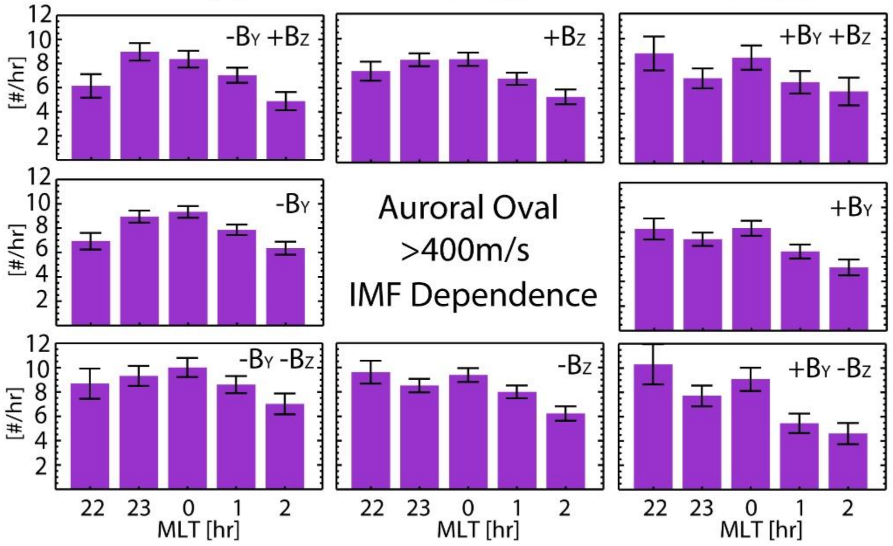
Polar cap median: ~180km
Auroral oval median: ~140-150 km



Flow orientation & occurrence rates imply meso-scale flows generally align with background convection.

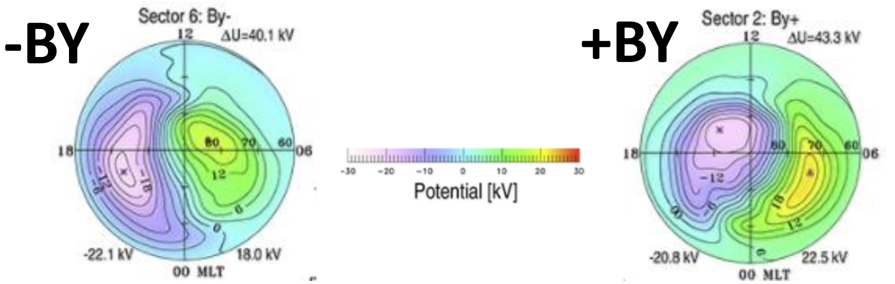


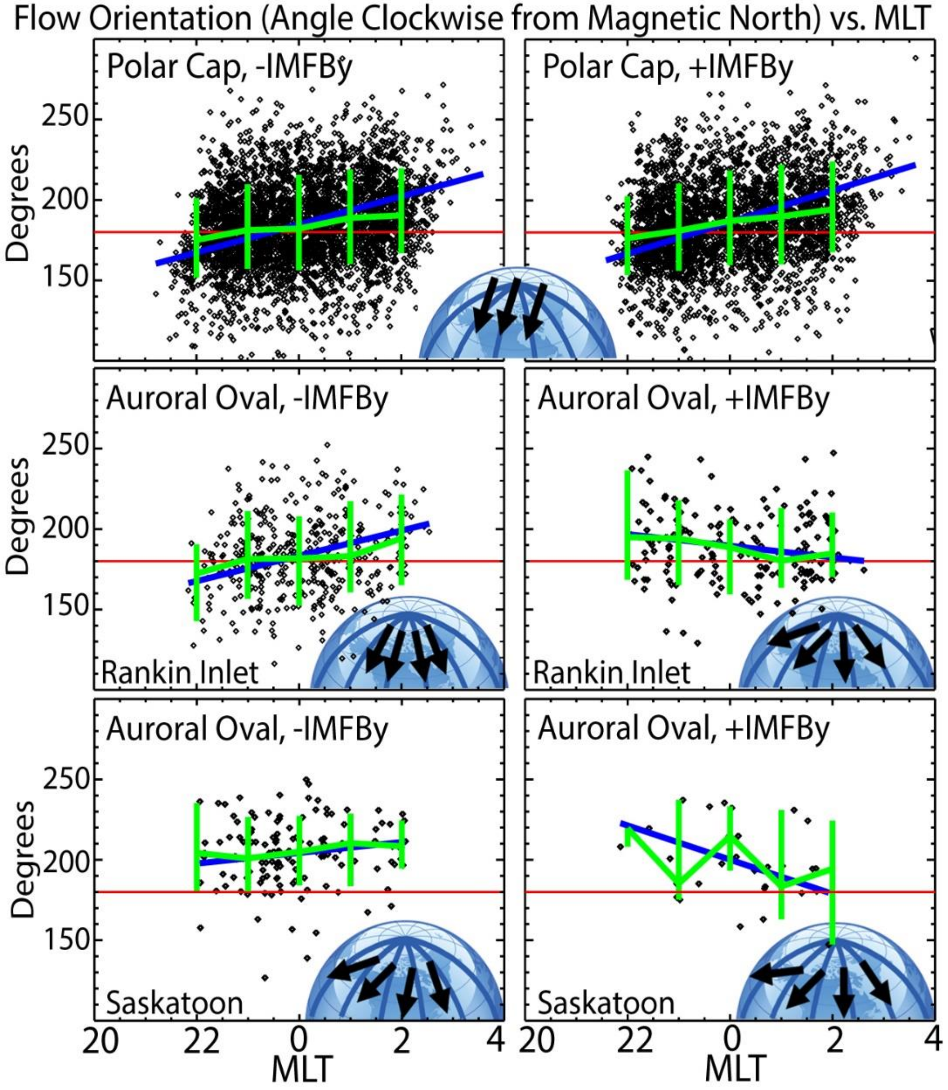
Polar cap:
Post-midnight preference,
More during +Bz like PC arcs



More flows in auroral oval than polar cap

Auroral Oval:
Pre-midnight preference,
Slightly more during -Bz like substorm phenomena





Summary

Meso-scale phenomena, such as ionosphere flows & related streamers, are important to the coupled MIT system; yet they remain poorly characterized. Our study creates an empirical model to address this:

Products:

1. Equatorward flow widths & velocities
2. Poleward flow widths & velocities
3. Flow occurrence distribution
4. Flow orientation
5. Flow duration (lifetime)

Data split between polar cap and two different auroral oval latitudes

AL, F10.7, Season,
Storm-time dependences ←Future work

Selected Results [*Gabrielse et al*. JGR Under Review]:

1. **Show unique results of magnetotail flow properties from ground-based data**, since width statistics are difficult to do with satellites
2. **Faster flows in winter hemisphere**, unlike background convection: *Ohtani et al.* [2009] showed higher conductance on nightside during winter due to enhanced precipitation
3. **Meso-scale flows have characteristic width** (~180 km in polar cap, ~140-150 km in auroral oval)
4. **IMF clock angle dependence**: polar cap flows characteristics similar to polar cap arcs
   - Meso-scale flow orientation matches background convection

Methods

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  - Polar Cap
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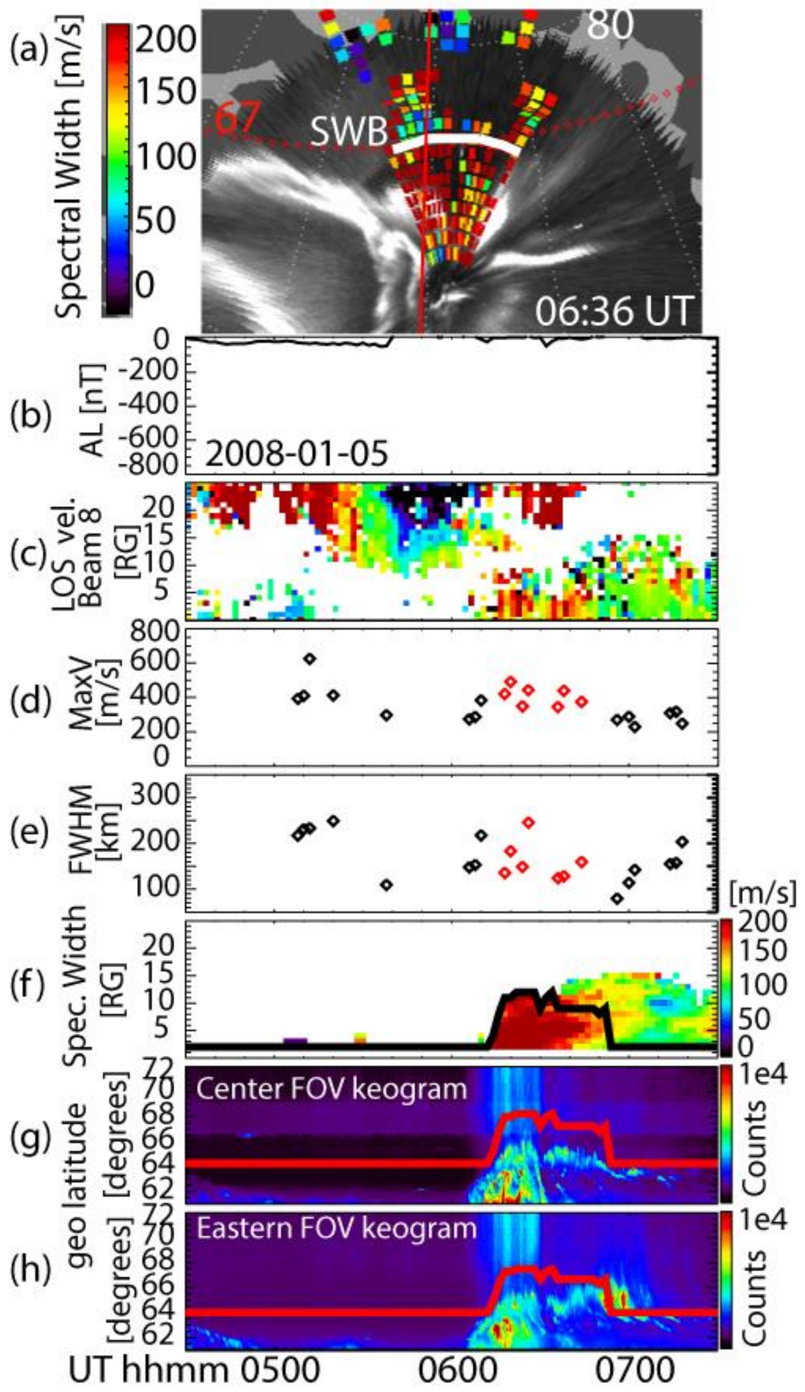

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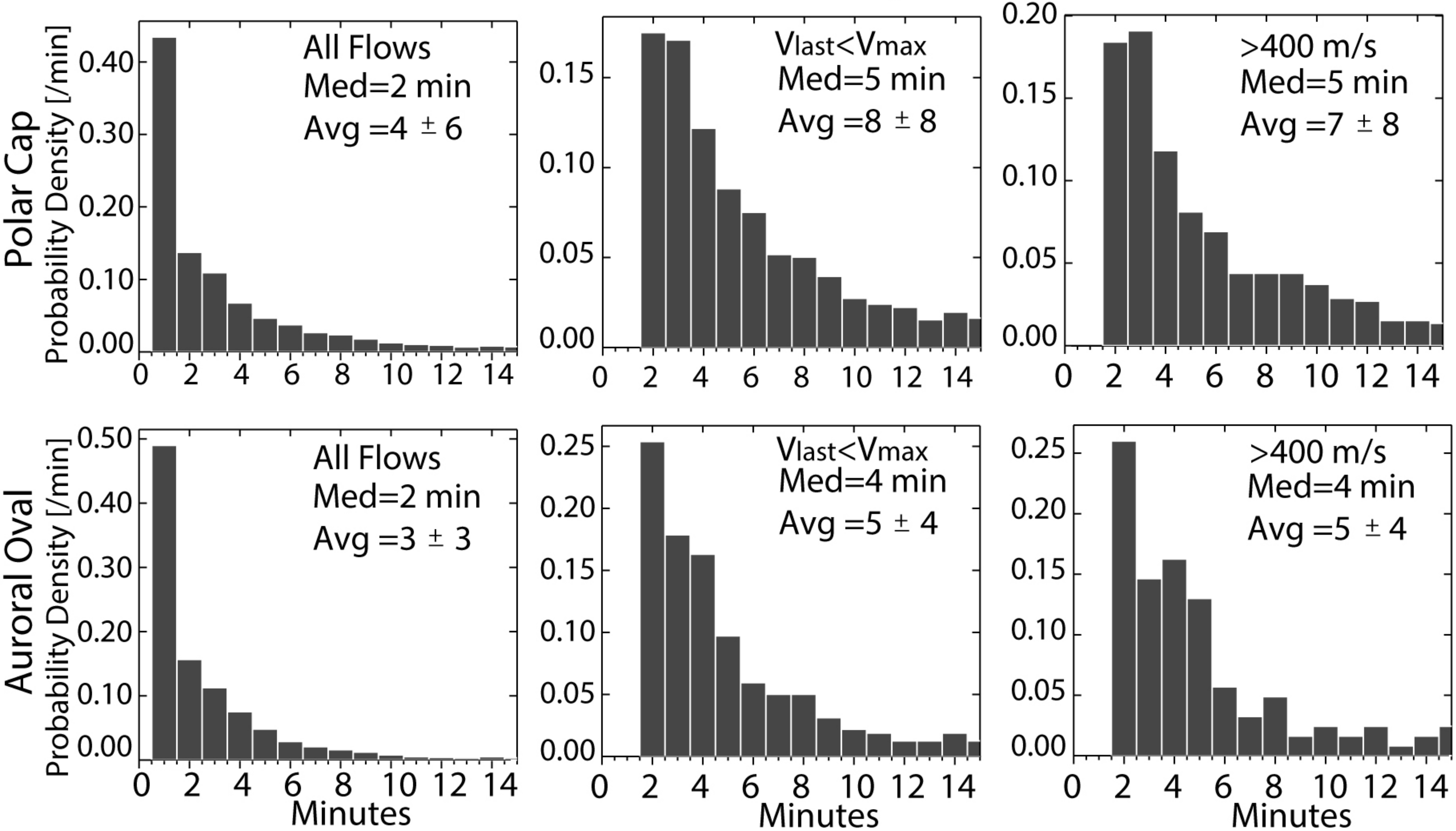
Flow Duration Probability Density

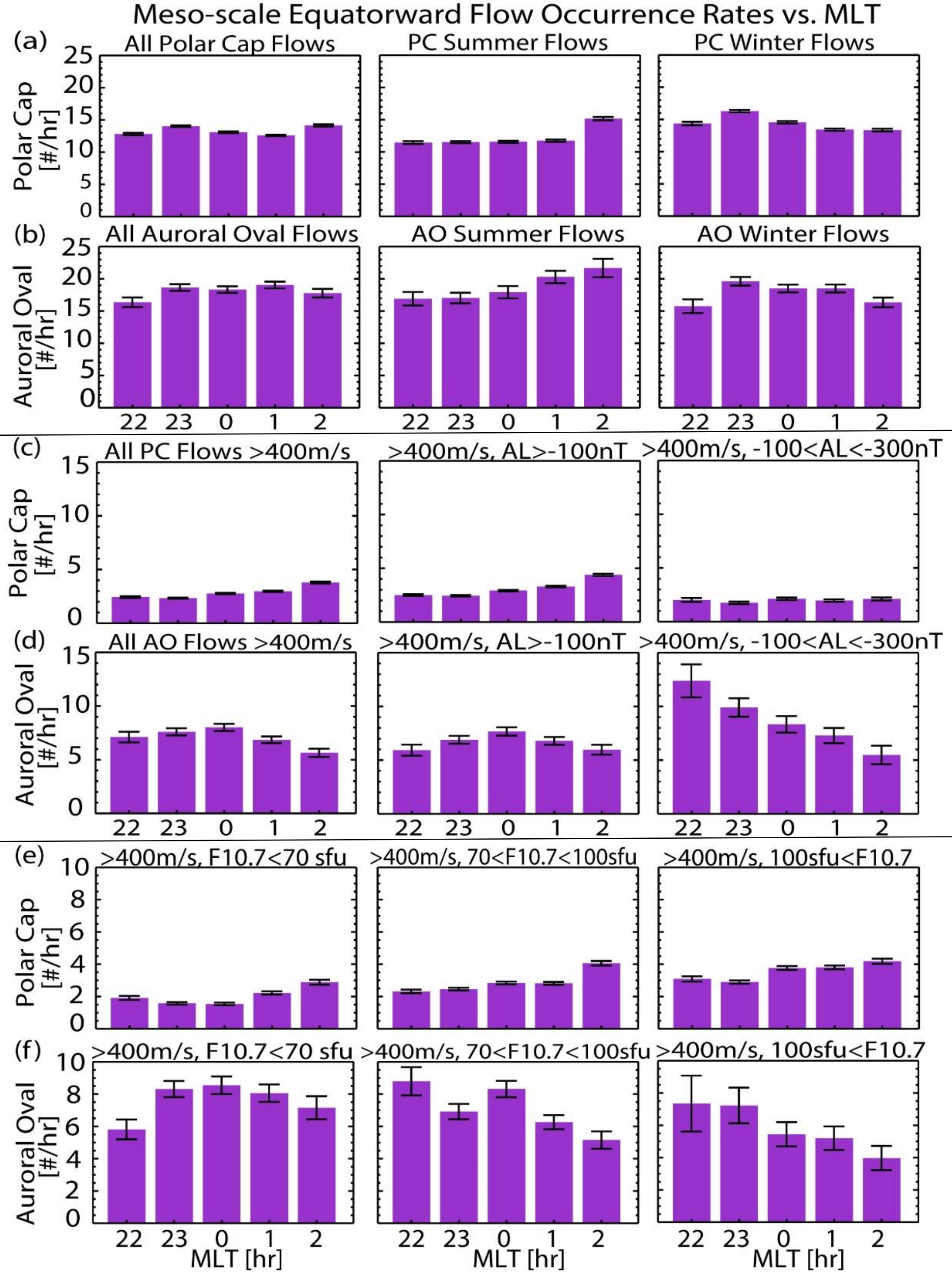


Occurrence Rates

- Seasonal Dependence
- Any speed

Polar Cap

Auroral Oval



More post-midnight flows in the summer.

More pre-midnight flows in the winter.

- AL Dependence
- >400 m/s criterion

Polar Cap

Auroral Oval

More auroral oval flows during AL activity, especially in pre-midnight sector

- F10.7 Dependence
- >400 m/s criterion

Polar Cap

Auroral Oval

More polar cap flows in post-midnight sector during higher solar activity

More auroral oval flows in pre-midnight sector during higher solar activity

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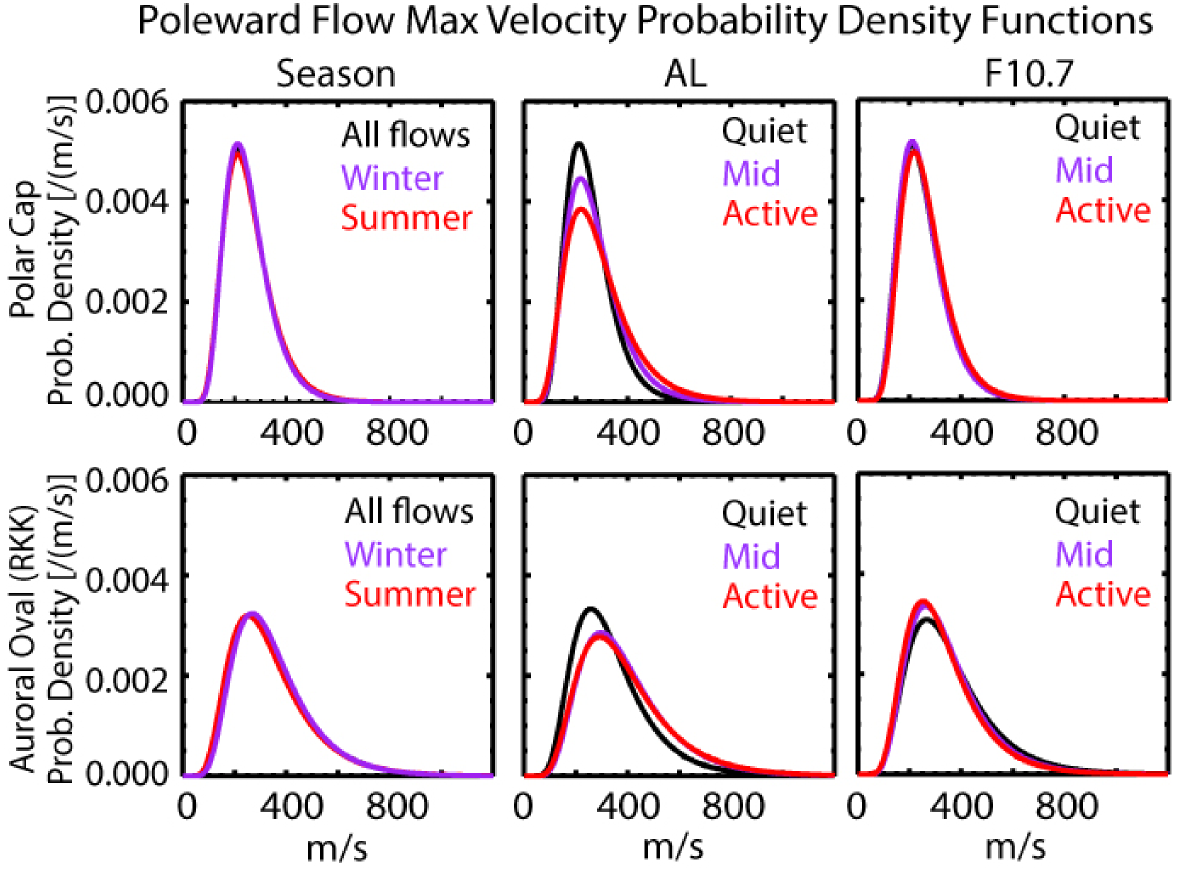
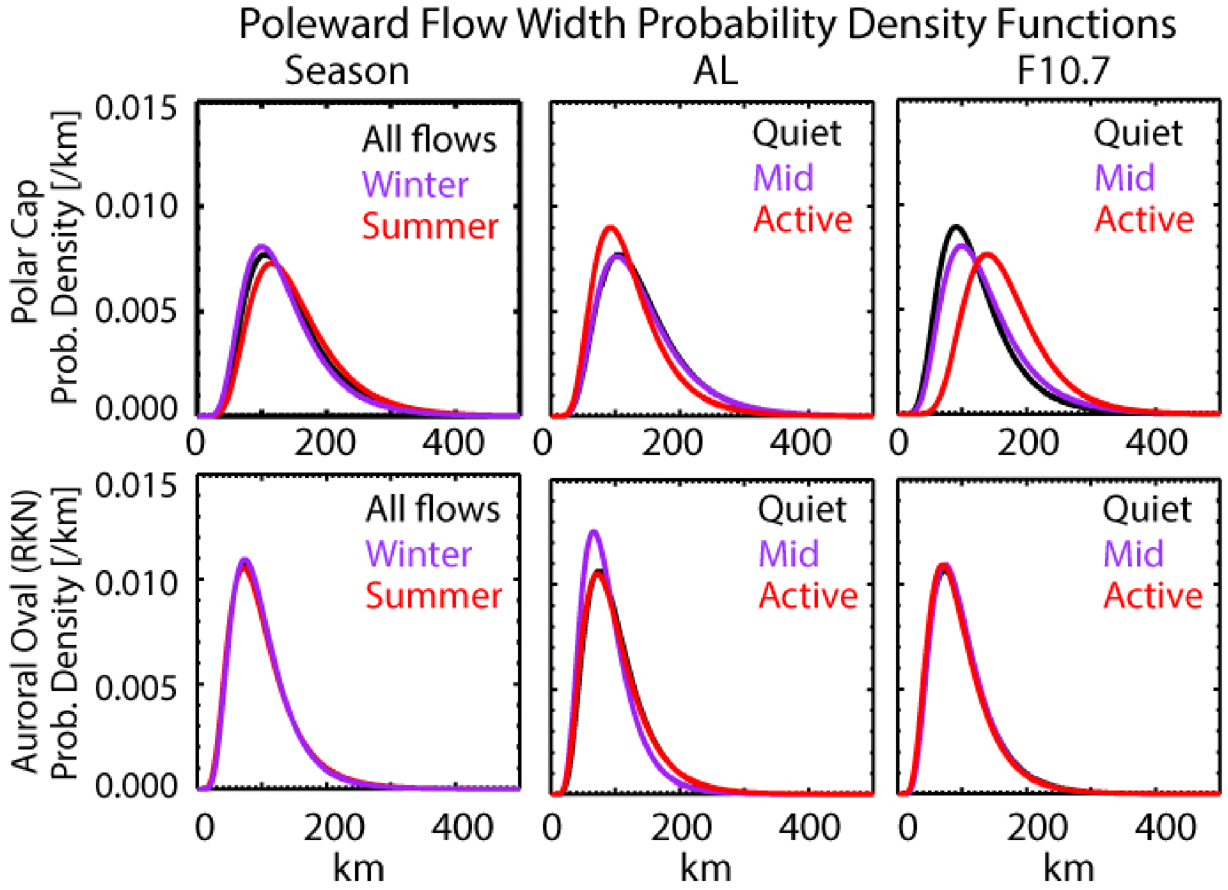
Poleward flows are narrower and slower than equatorward flows





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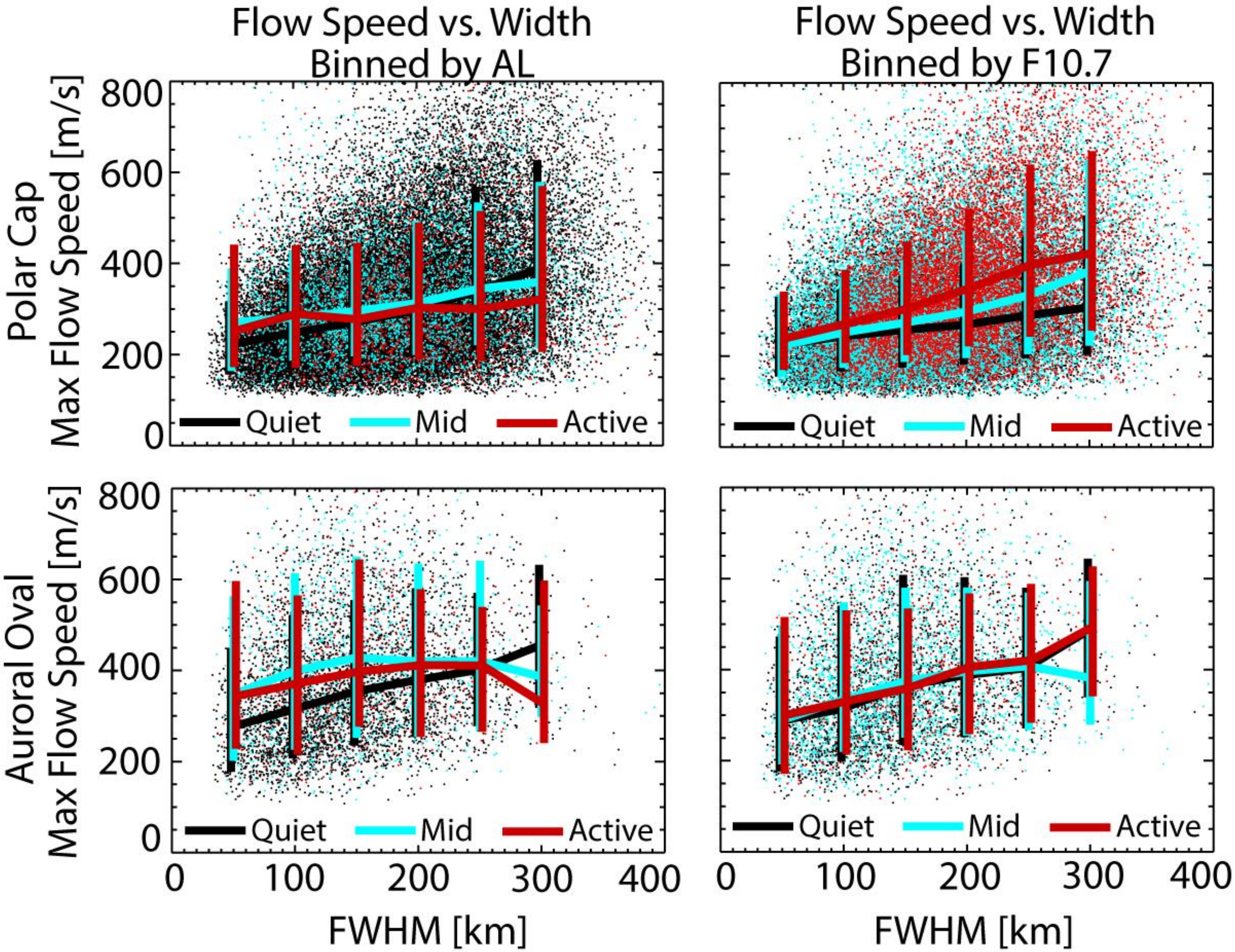
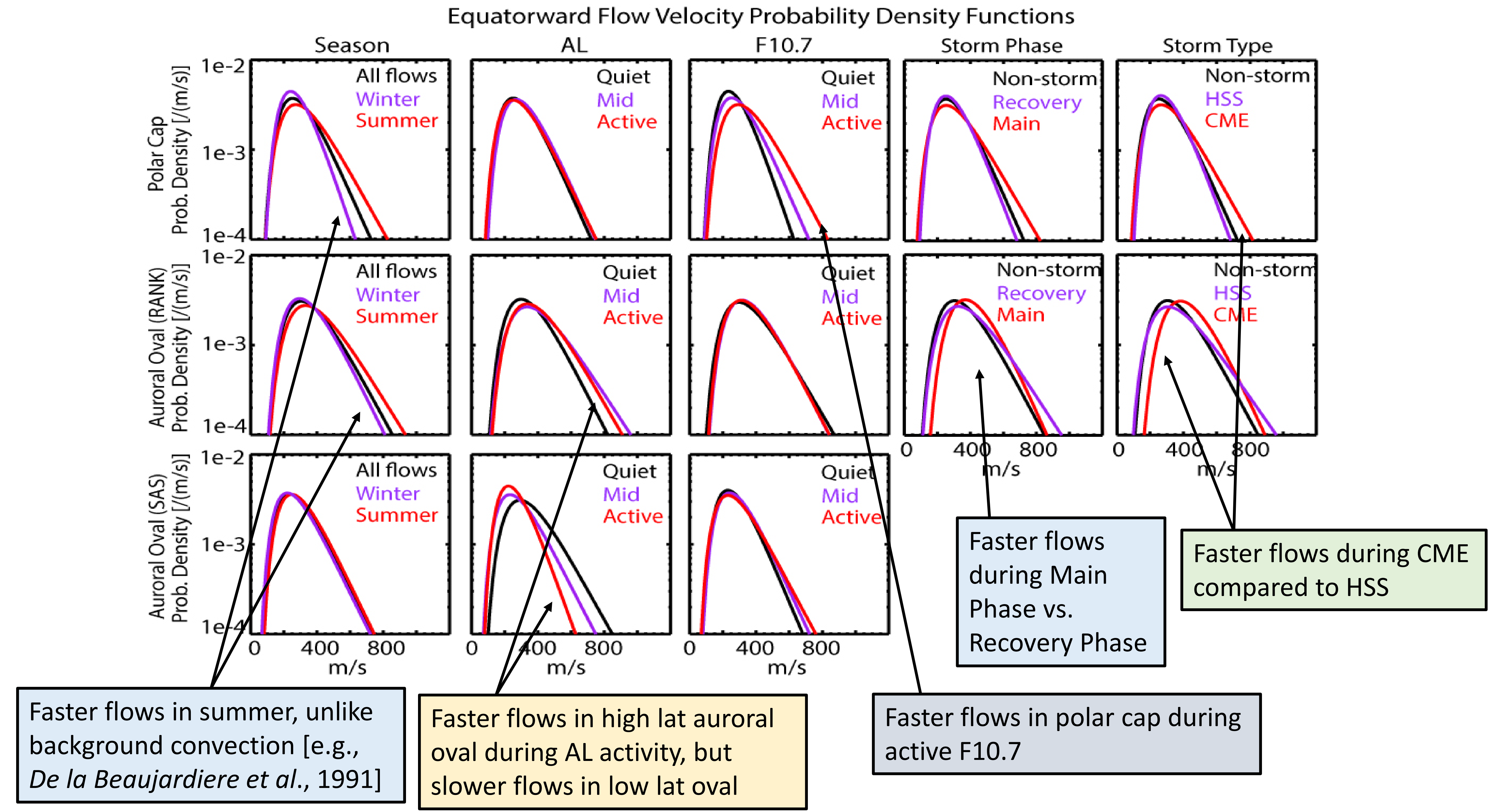


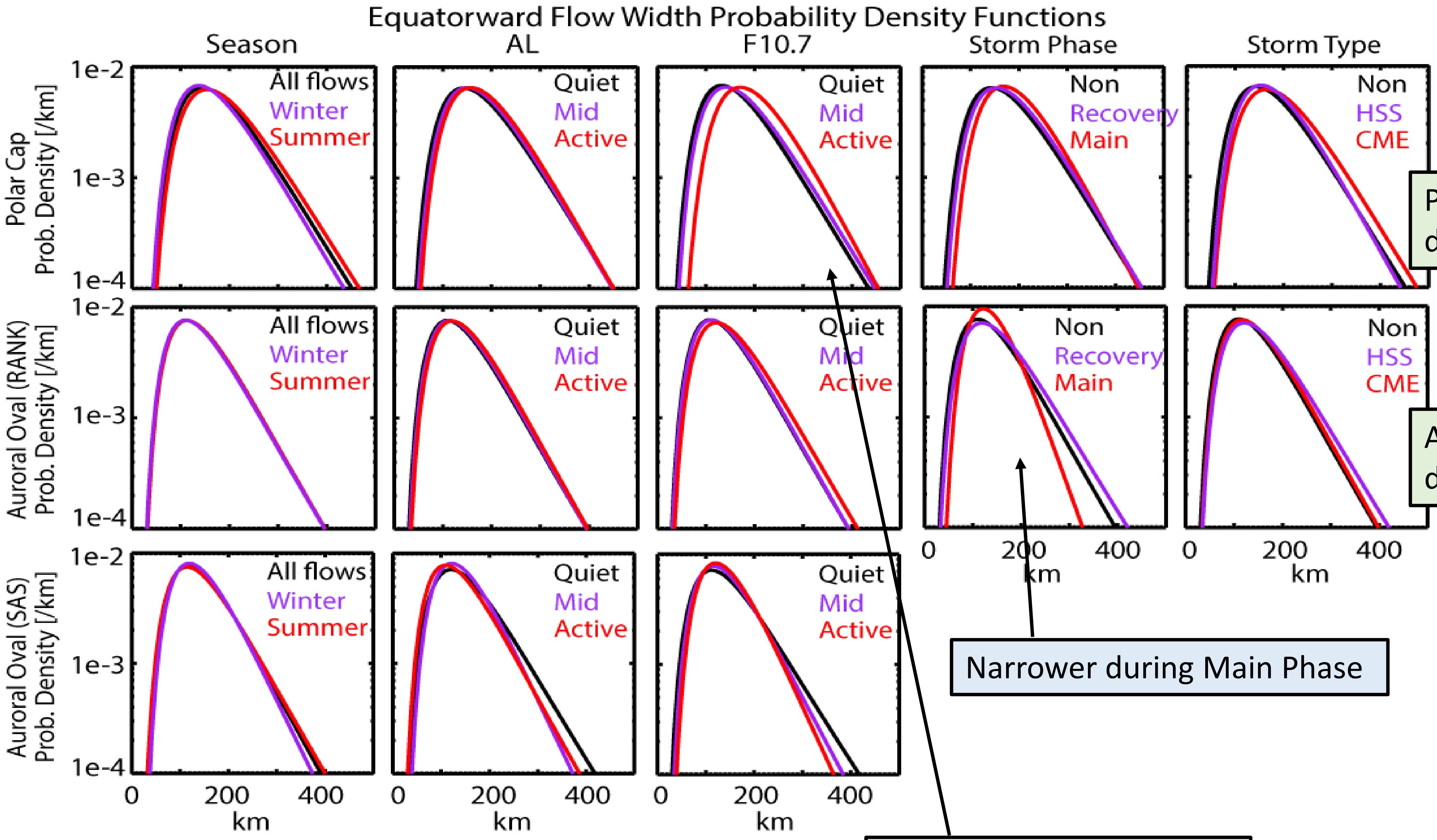
Quiet: AL>-100nT,
Mid: -300<AL<-100
Active: AL<-300

Quiet: F10.7>70
Mid: 70<F10.7<100
Active: F10.7<100

Wider flows are loosely faster than narrow flows



Equatorward Flow Velocity Probability Density Functions
Season
AL
F10.7
Storm Phase
Storm Type
Polar Cap
Prob. Density [/(m/s)]
Auroral Oval (RANK)
Prob. Density [/(m/s)]
Auroral Oval (SAS)
Prob. Density [/(m/s)]
1e-2
1e-3
1e-4
All flows
Winter
Summer
Quiet
Mid
Active
Non-storm
Recovery
Main
Non-storm
HSS
CME
0
400
800
m/s
Faster flows in summer, unlike background convection [e.g., *De la Beaujardiere et al.*, 1991]
Faster flows in high lat auroral oval during AL activity, but slower flows in low lat oval
Faster flows in polar cap during active F10.7
Faster flows during Main Phase vs. Recovery Phase
Faster flows during CME compared to HSS



PC: Wider during CME

AO: Wider during HSS

Narrower during Main Phase

Wider during active F10.7

Flow widths do not vary as much under different drivers/ circumstances.

Polar cap median: ~180km
Auroral oval median: ~140-150 km