Characterising and understanding temporal variability in ionospheric flows using SuperDARN data

15th June 2018 – Whole Atmosphere Modelling WS

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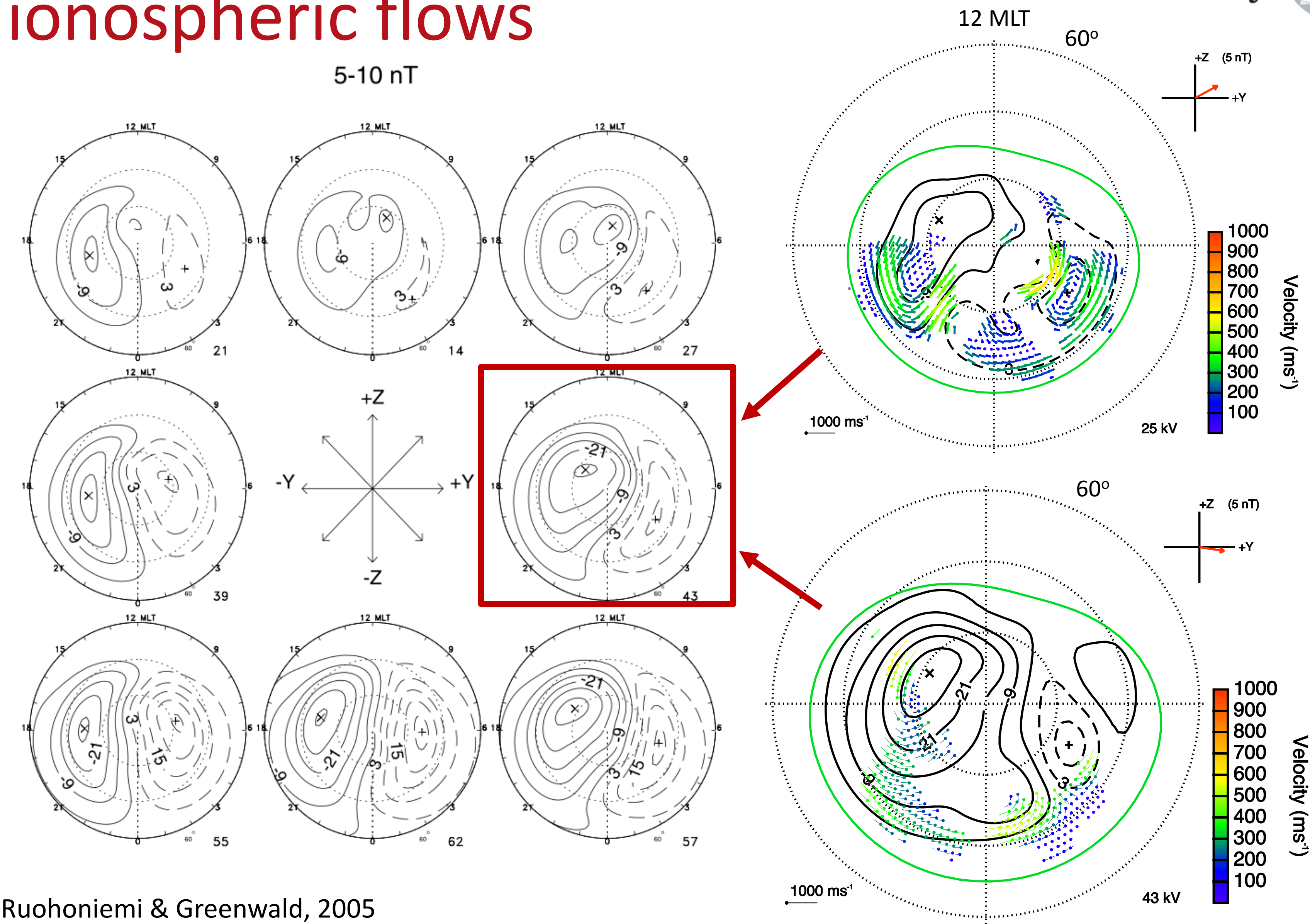
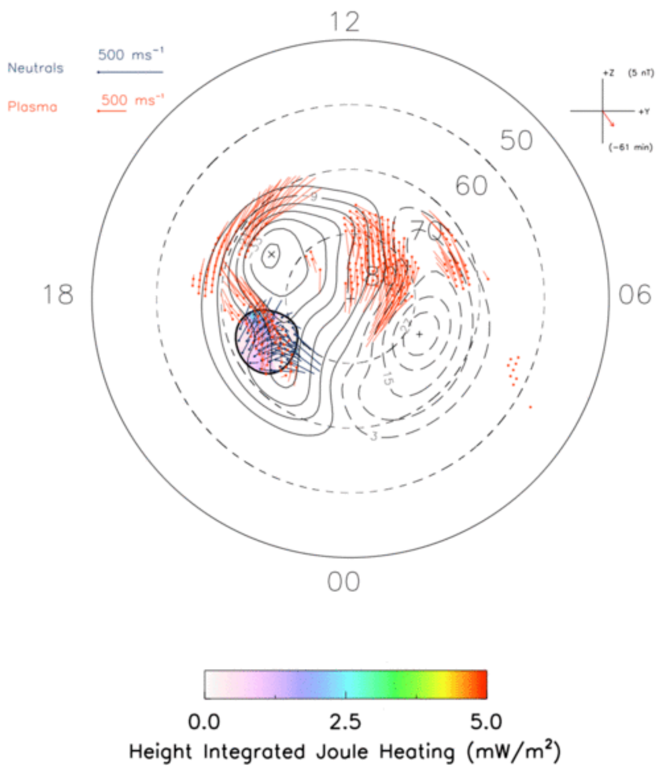
Deviations from average ionospheric flows



Ruohoniemi & Greenwald, 2005

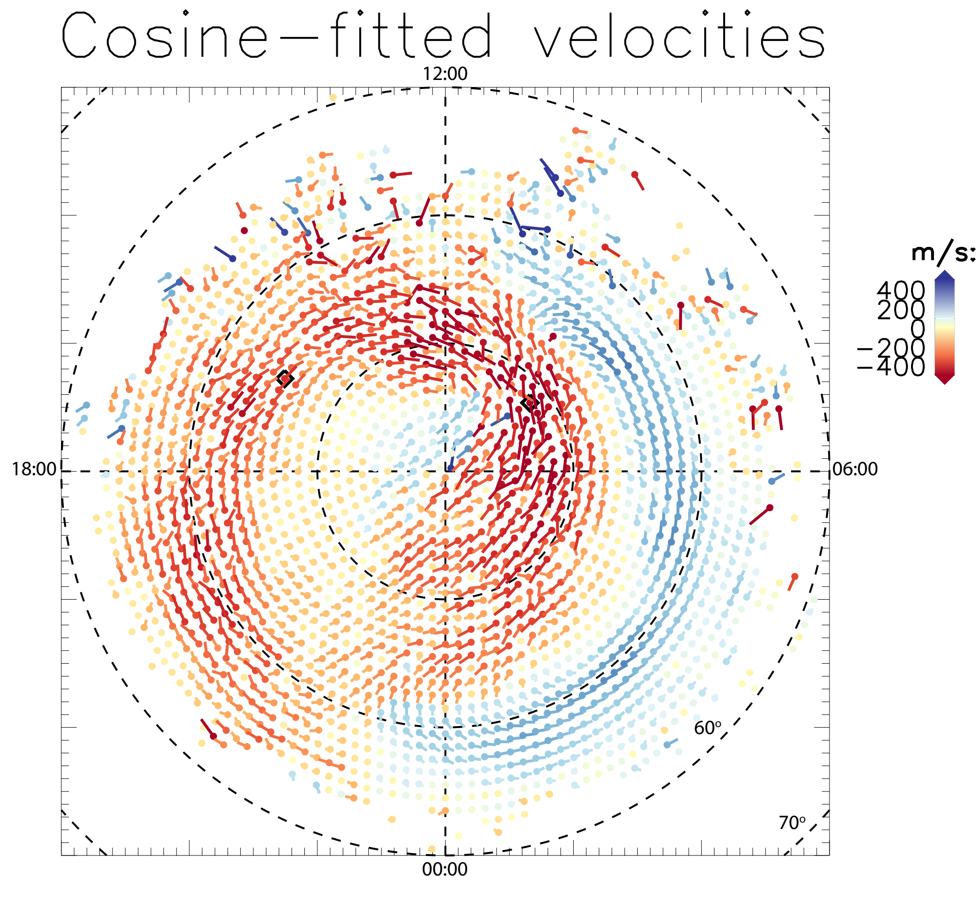
Why is this important?

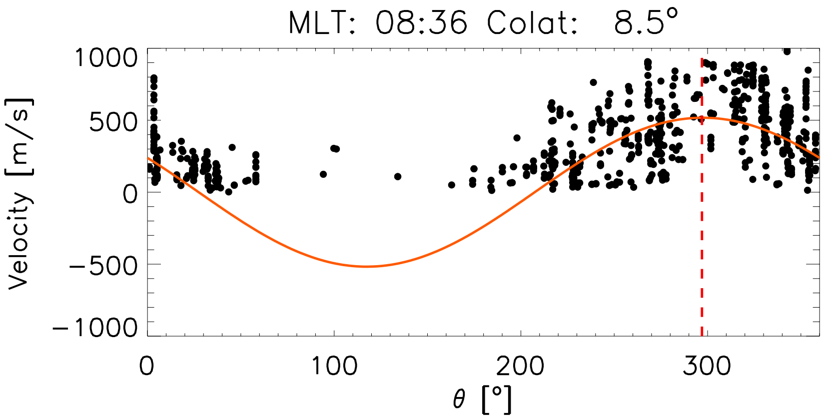


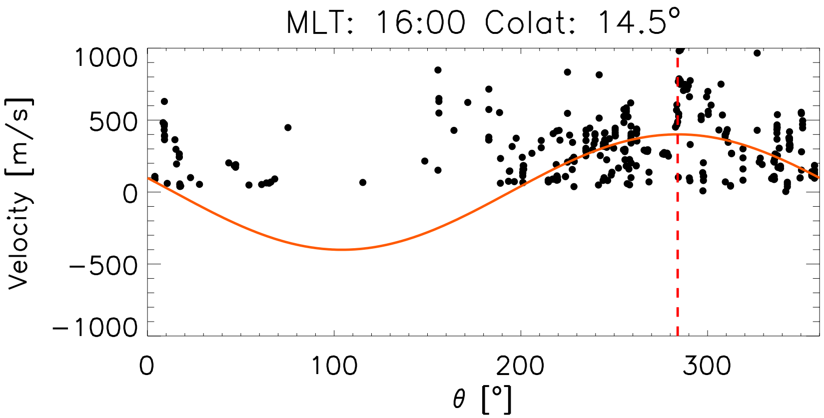
- Direction of neutrals can be controlled by the motion of the plasma → small timescales are important
- Ion drag example scenario from **Daniel Billett**
- Black vectors: motion of neutrals → SCANDI data provided by **Anasuya Aruliah & Amy Ronksley (UCL)**
- Red lines: plasma velocities from SuperDARN

Atmospheric Joule heating varies with $\boldsymbol{E}^2$
→ need to understand variability in ionospheric E-field

Average variability – data spread IMF 5-10 nT, $B_y > 0$







Difficulties with measuring variability using SuperDARN

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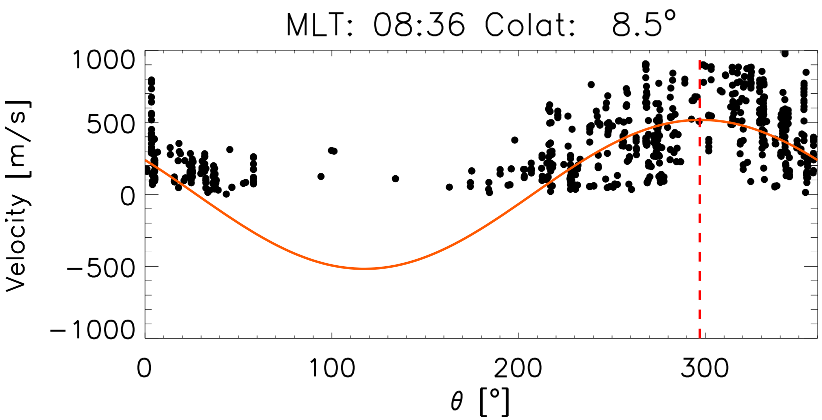
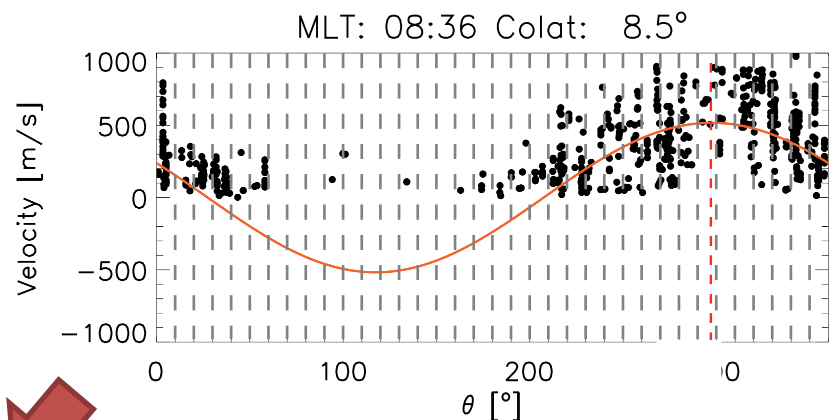
- Measurements are line-of-sight components of convection vectors
  - Need to fit measurements to a **model** to find vector or global pattern
    - ➢ Two variables: **direction** and **magnitude**
- In order to make a model we need to combine data
  - This is typically done by dividing the data up by solar wind conditions
- This **assumes convection is the same** during similar conditions
  - Variability due to this assumption being wrong
  - Variability due to temporal changes

→ Use steady IMF, but without using a model!

Defining variability: Average RMS deviation

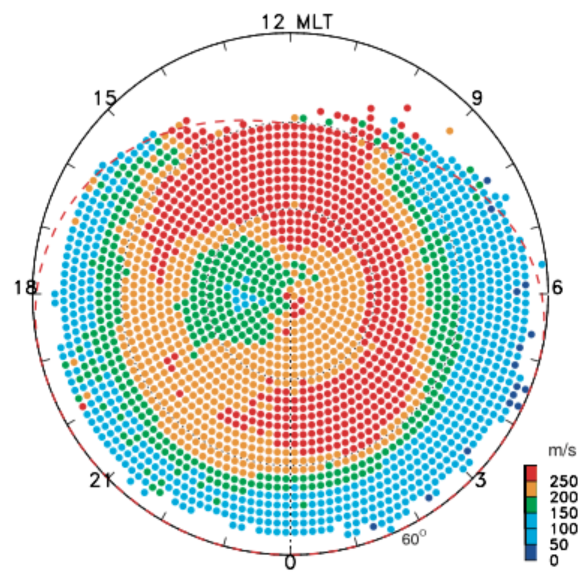




- Calculate RMS deviation for each directional bin, *i*, per grid point:

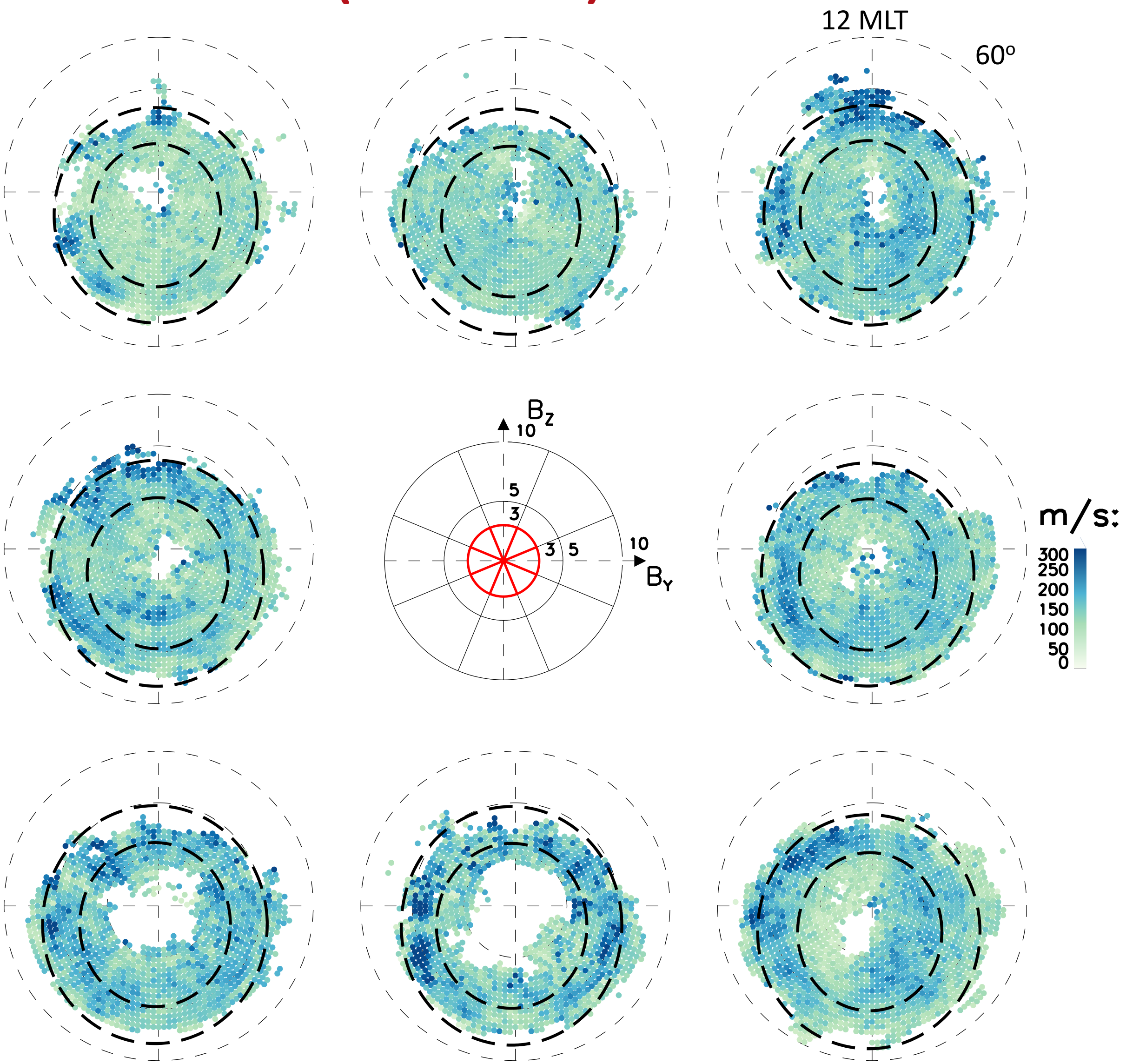
$$RMS_i = \sqrt{\frac{\sum_n (\langle v_i \rangle - v_n)^2}{n}}$$

- Variability is the average RMS (Ruohoniemi & Greenwald 2005)



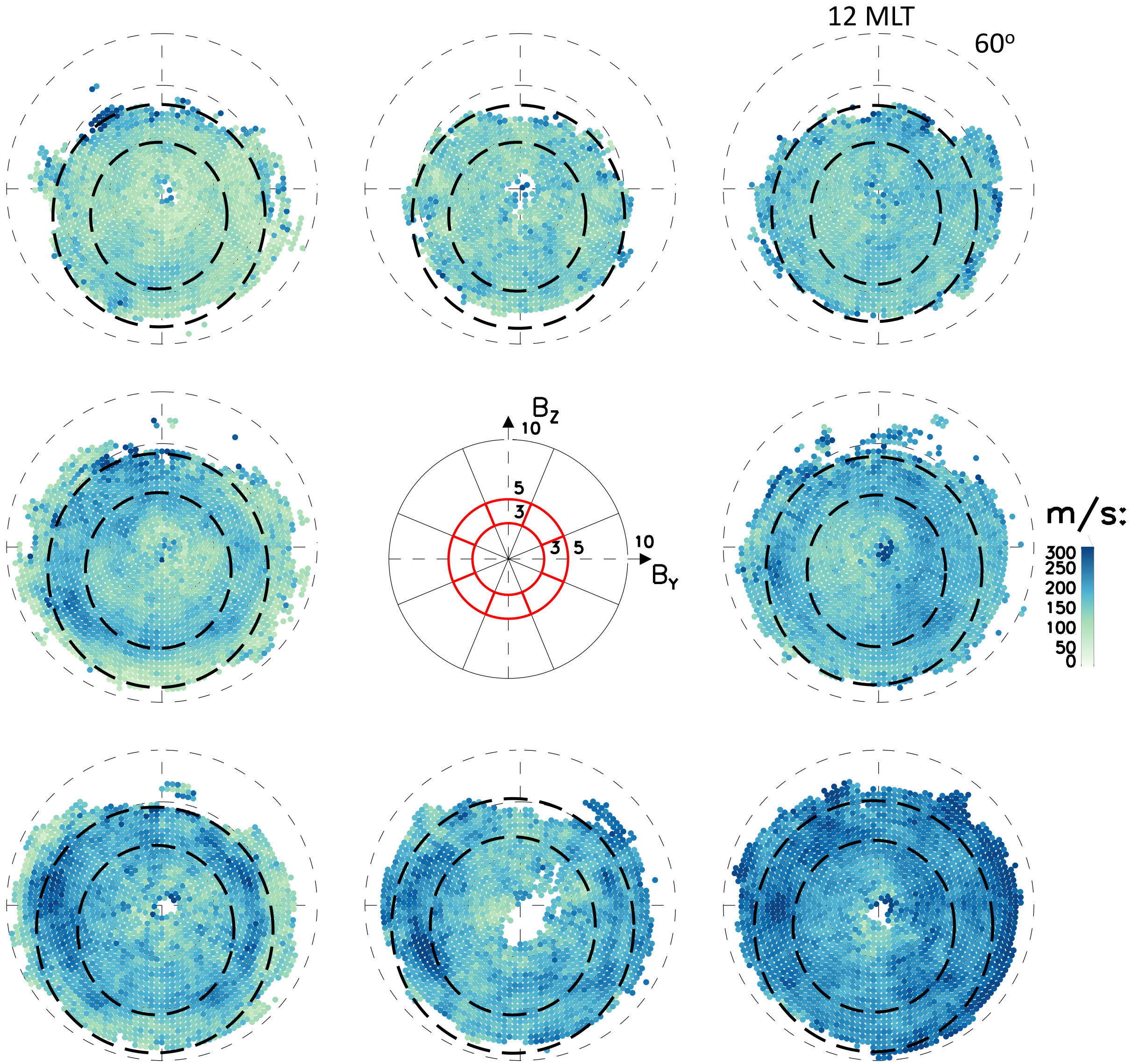
Ruohoniemi & Greenwald, 2005

Weak IMF (0-3 nT):



- Higher deviations from the mean for Southward IMF
- Variability highest at dusk/afternoon sector

Moderate IMF (3-5 nT):



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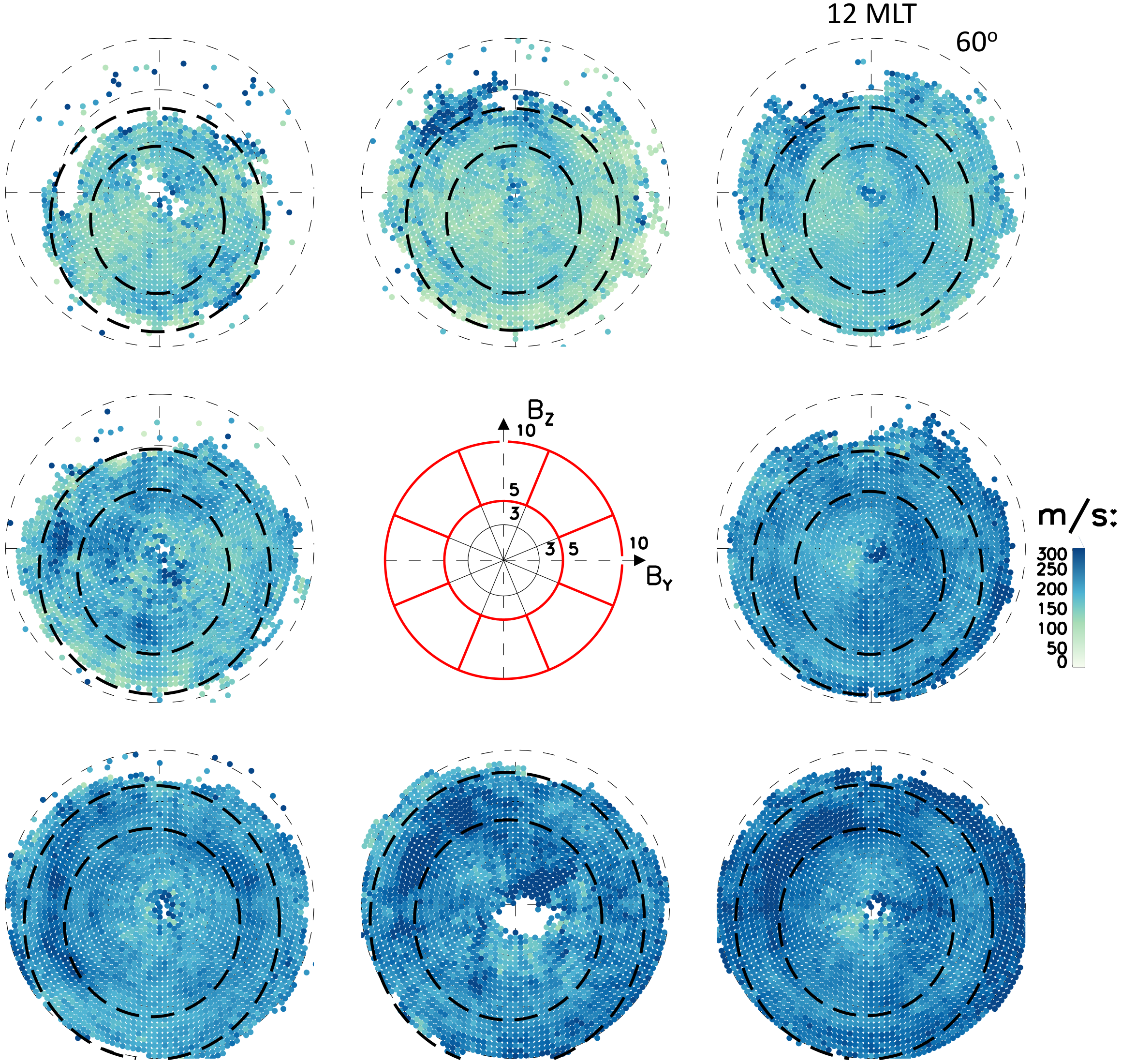
Strong IMF (5-10 nT):



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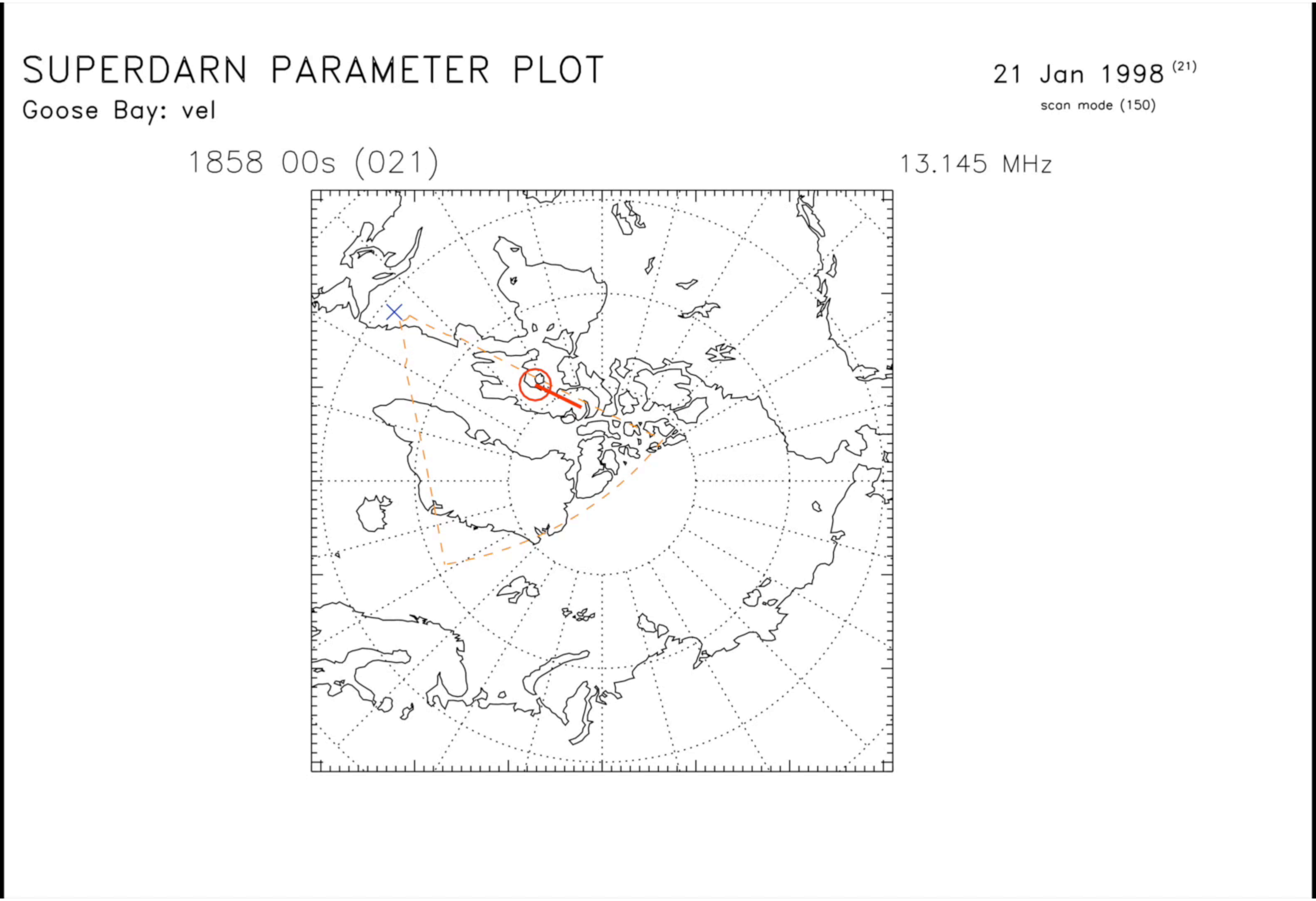
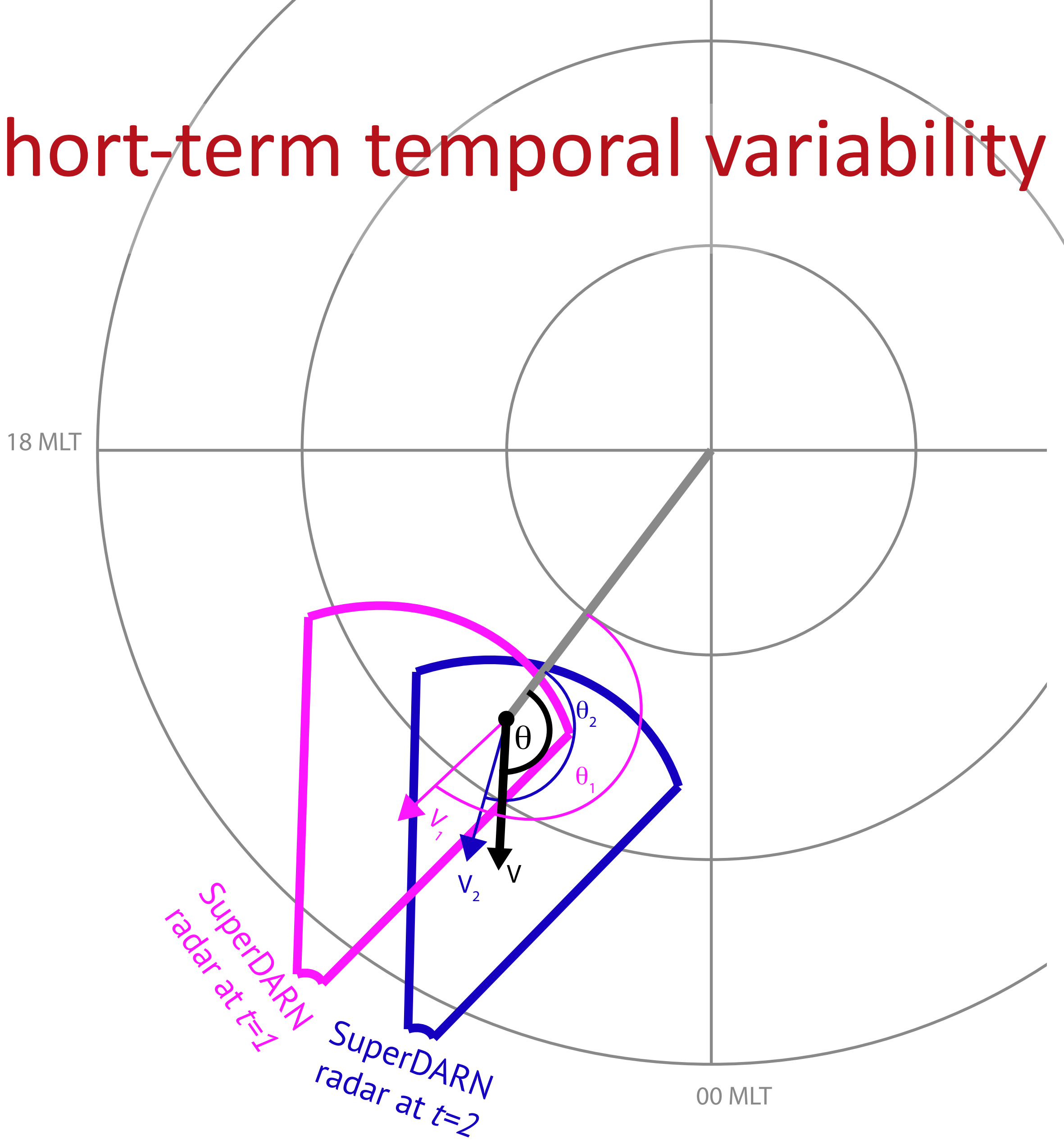
Looking at variability over time

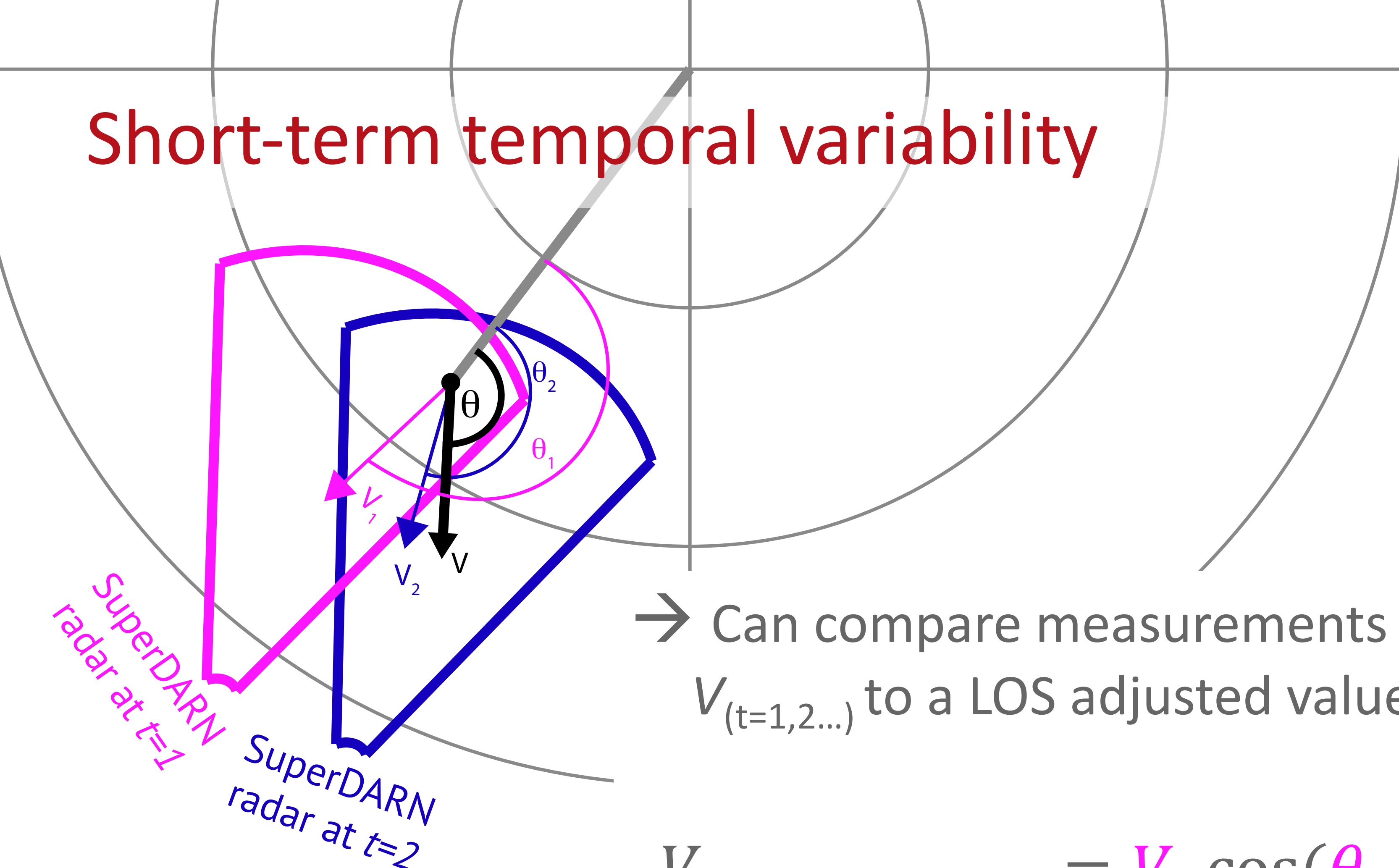


Short-term temporal variability



- Grid points need to be stationary in MLAT-MLT grid
- Find intervals of continuous data coverage of the grid point
- Compare measurements to LOS-adjusted values

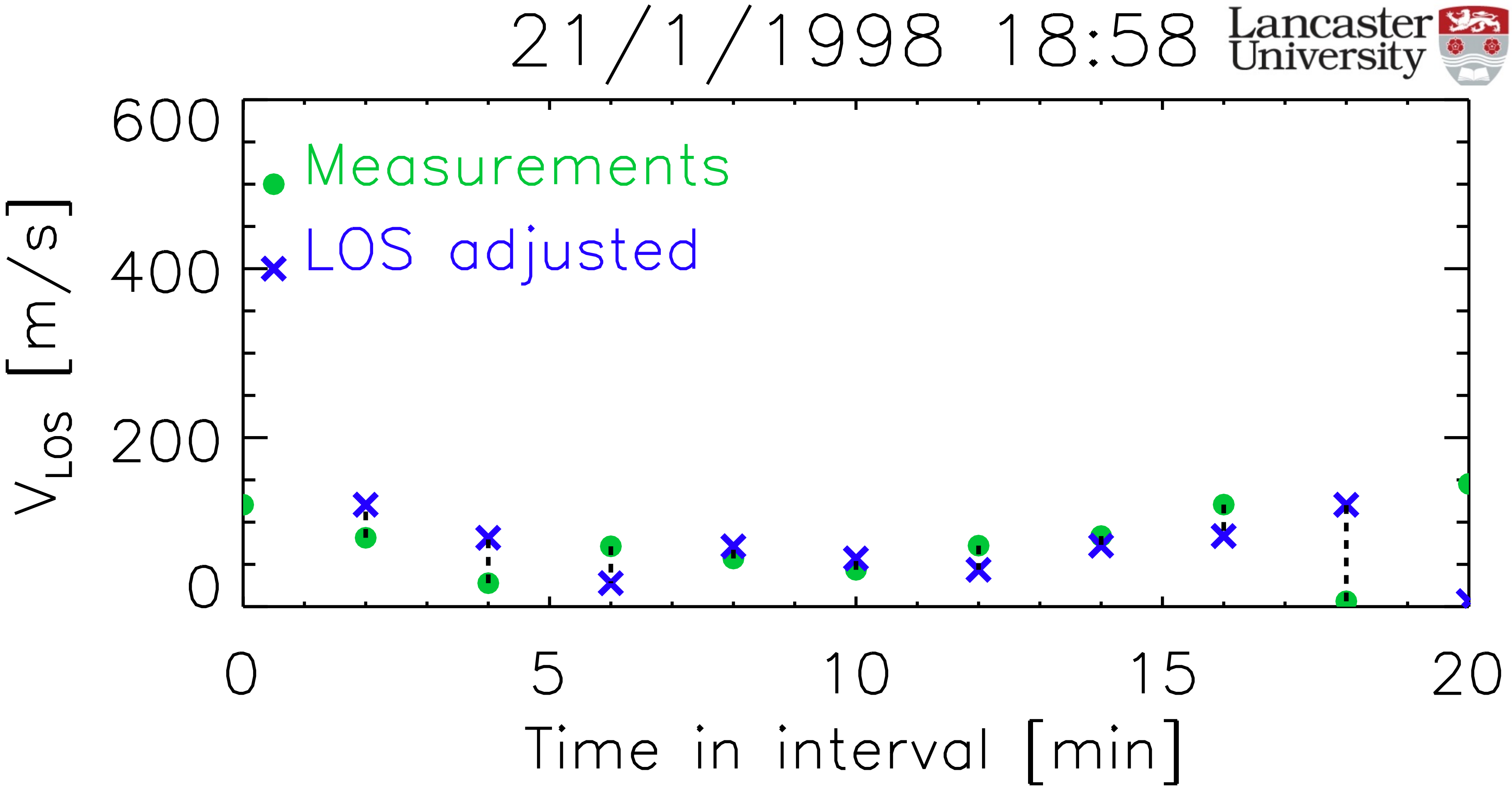
Short-term temporal variability



→ Can compare measurements of $V_{(t=1,2\ldots)}$ to a LOS adjusted value of V:

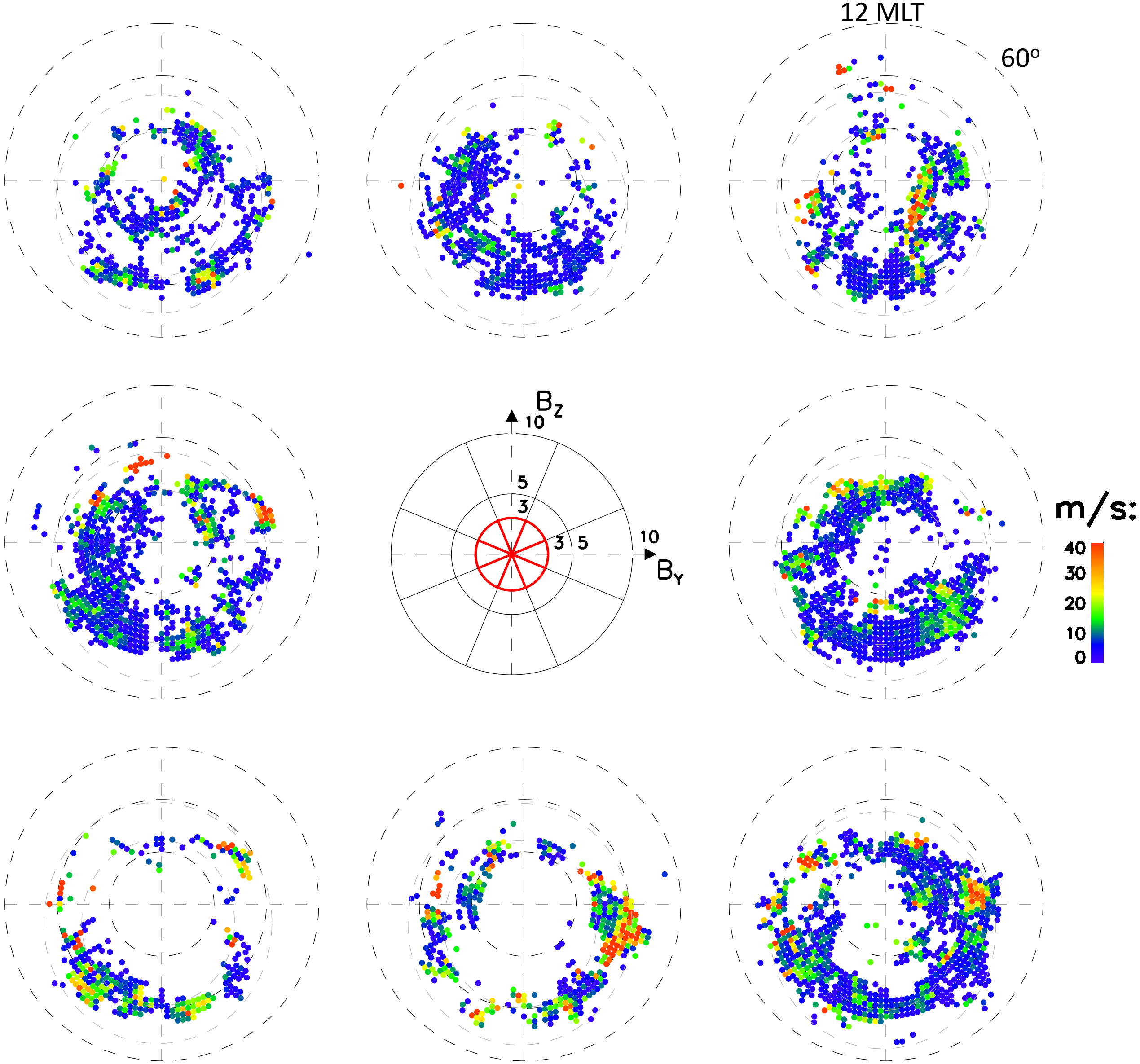
$$V_{LOS\ adj\ at\ t=2} = V_1 \cos(\theta_1 - \theta_2)$$

→ Compare to V_2



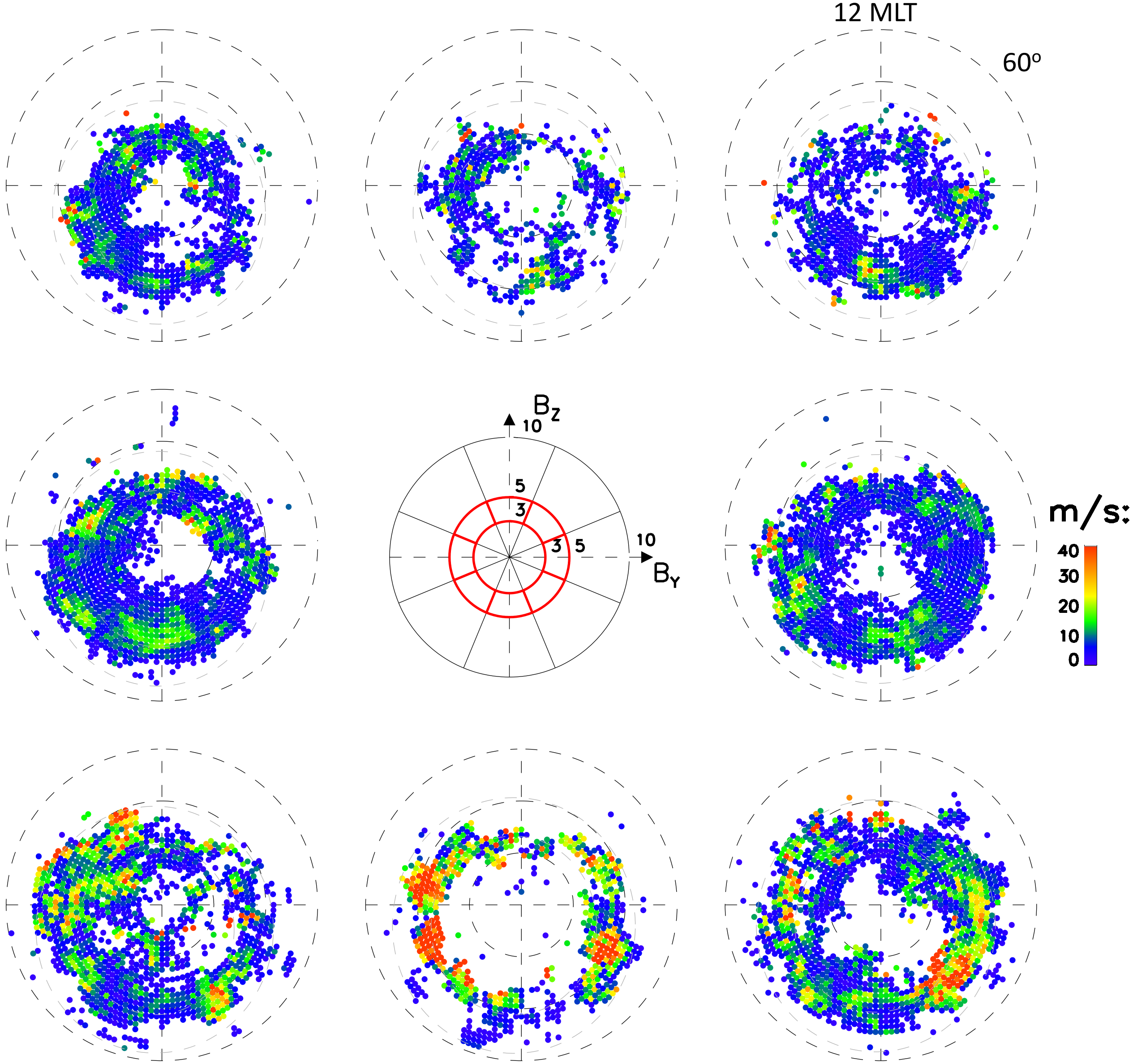
- Average velocity for this interval: 109 m/s
- Average variability for this interval: 87 m/s
- Can utilise this method over many intervals to quantify average variability for 20 minute time interval

20 min timescale – Weak IMF



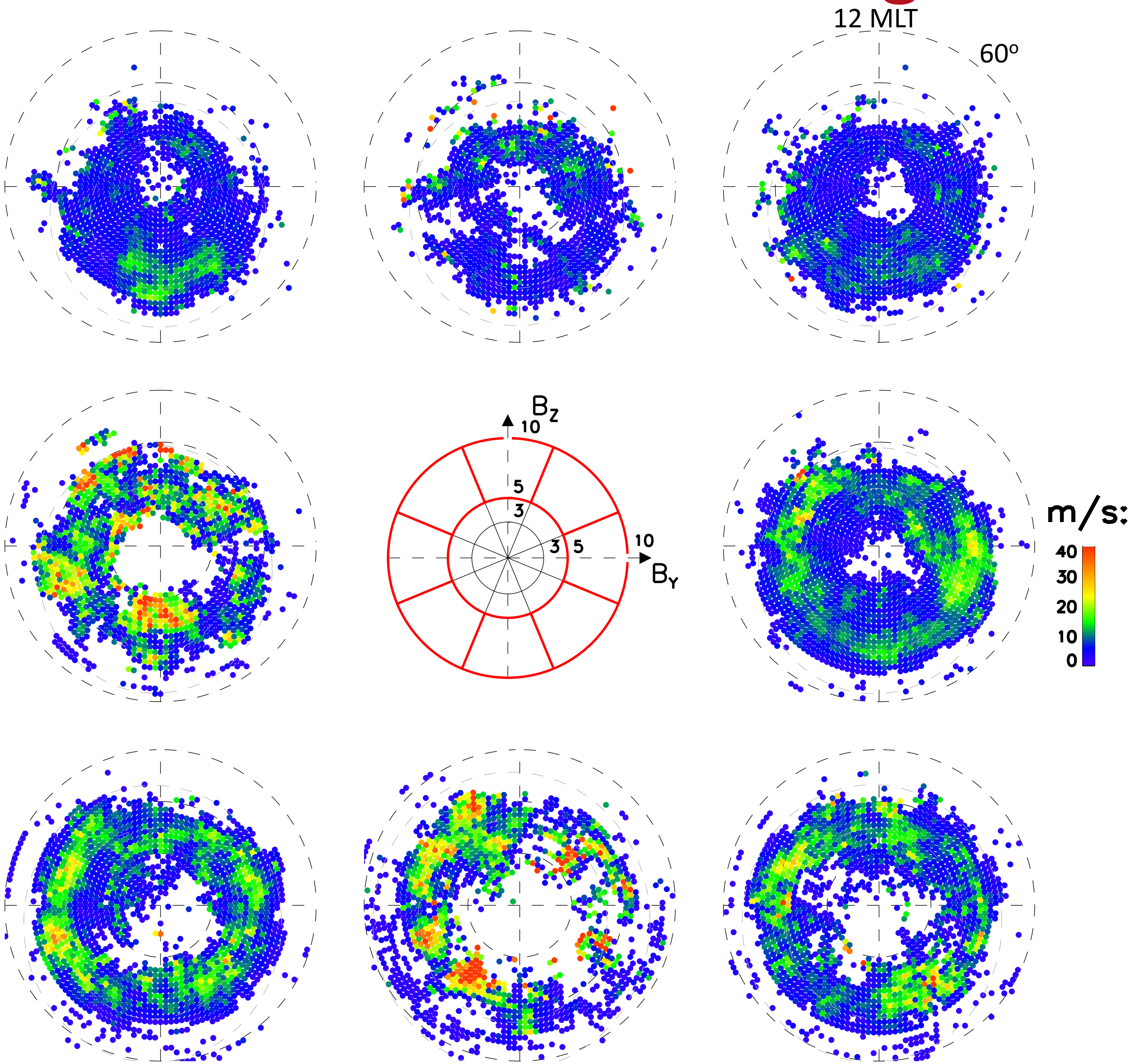
- Higher variability for Southward IMF?

20 min timescale – Moderate IMF



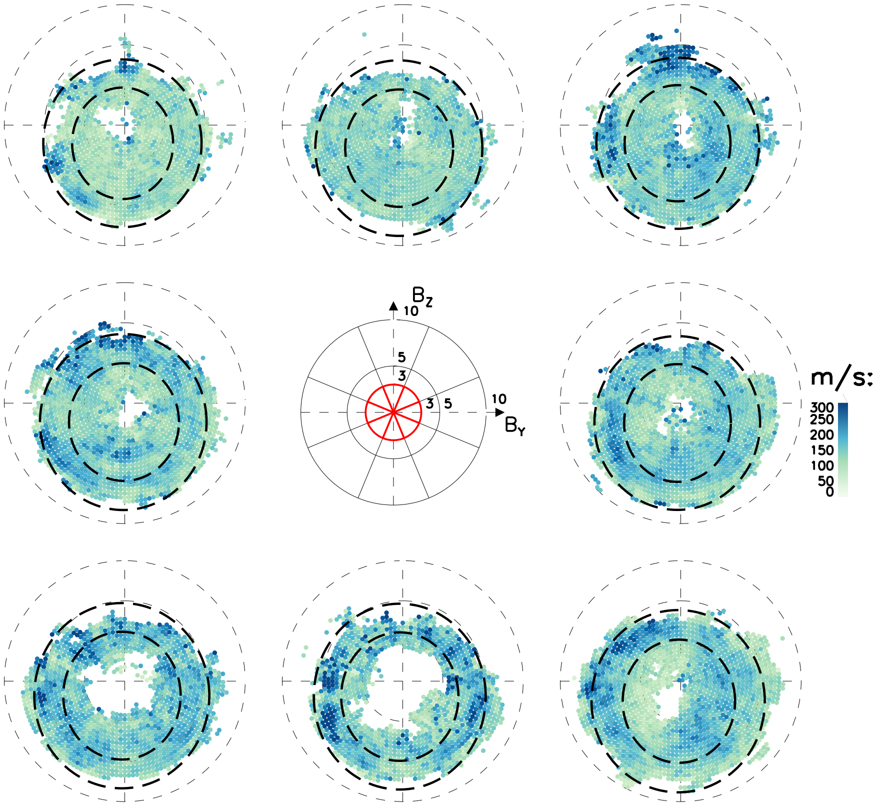
- Higher variability for Southward IMF?
- Dusk/dawn asymmetry

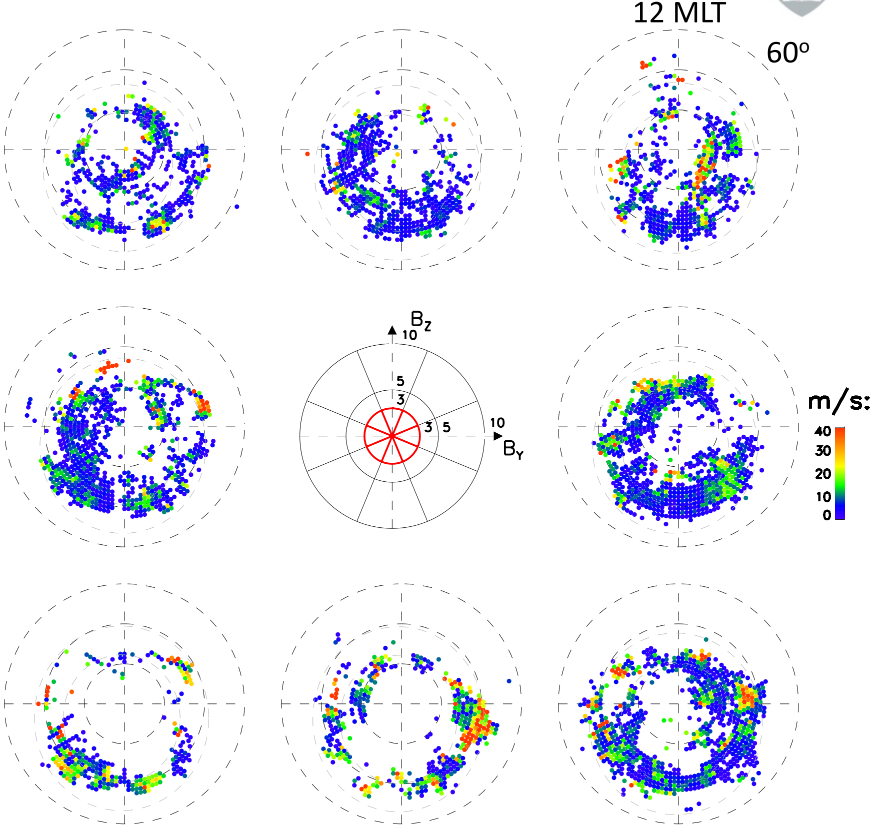
20 min timescale – Strong IMF



- Higher variability for Southward IMF
- Dusk/dawn asymmetry

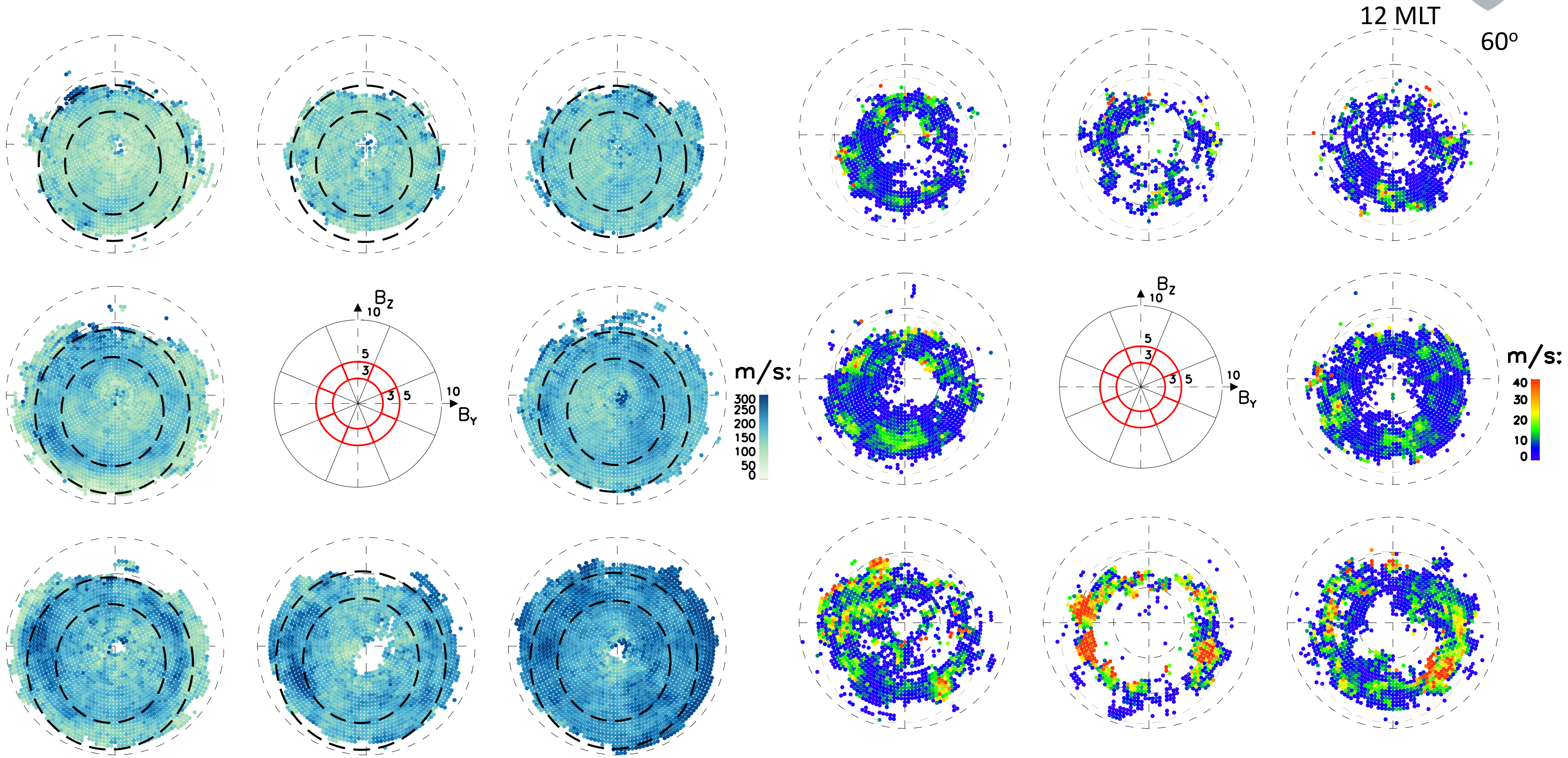
Weak IMF (0-3 nT):





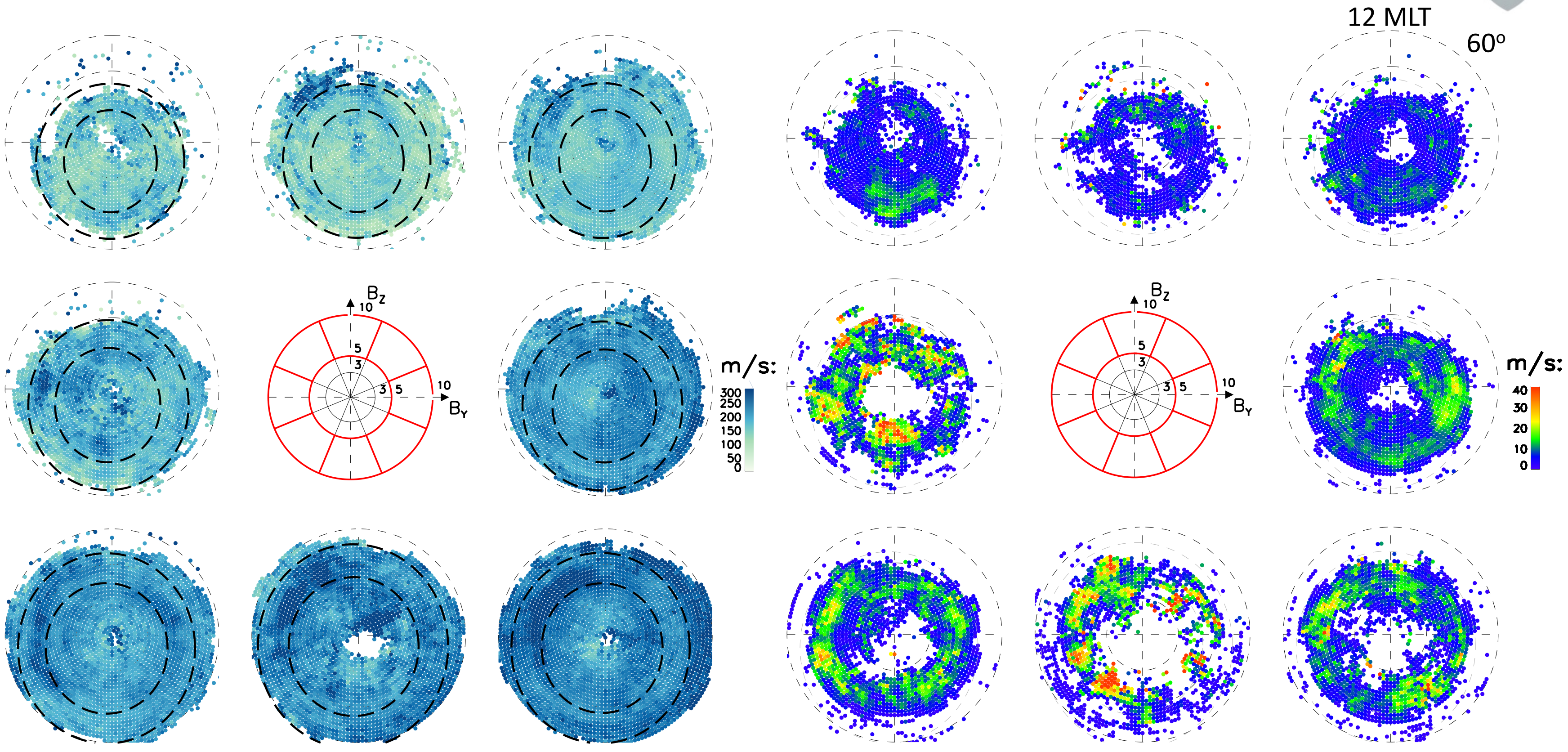
- Highest variability for Southward IMF

Moderate IMF (3-5 nT):



- Variability for 20 minute timescale is generally higher than for weak IMF
- Variability highest at dusk & dawn

Strong IMF (5-10 nT):



- Variability is highest for Southward IMF
- Short term temporal variability shows a dusk-dawn asymmetry
- Regions of variability for short temporal scales coincide with average variability

Summary

- Compared average RMS deviation to variability over 20 minute timescale
- As solar wind becomes stronger, variability increases
- Variability is higher for southward IMF than for northward IMF
- Areas of high variability appears to coincide where we expect to see strong electric fields → auroral zones
  - Future work: investigate drivers of variability in more detail & quantify atmospheric coupling using SCANDI data
- **Average variability during steady IMF conditions is significant (order of 100 m/s), especially when the IMF is stronger**
  - **Variability over a 20 minute timescale ~10% of average RMS deviation**
  - **Short timescale variability occurs in same places as average variability**