Dusk-Dawn Asymmetries in SuperDARN Convection Maps

Physics | Lancaster University

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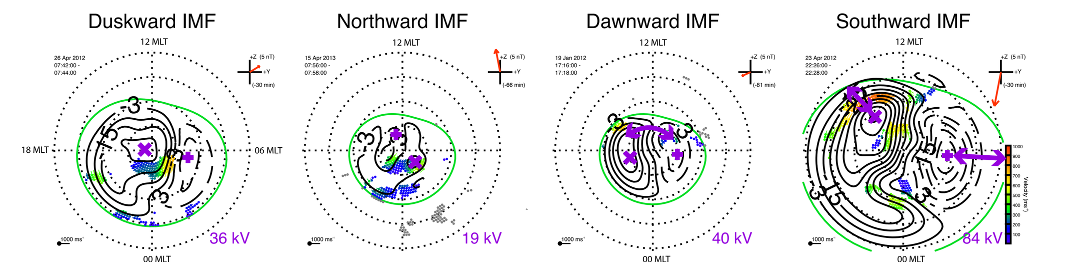
1 Ionospheric Convection Maps

The Super Dual Auroral Radar Network (SuperDARN) system was built to measure ionospheric convection. Spherical Harmonic Functions are fitted to line-of-sight velocities, which allows us to make convection maps. We have 7 years (2012-2018) of data processed in 5 different ways (see Walach et al. 2022 for further detail) to create convection maps. All maps were filtered for n>200, unless stated otherwise. Here we use this state-of-the-art dataset to study ionospheric convection asymmetries and their average behaviour:



Different Interplanetary Magnetic Field (IMF) clock angles affect the convection pattern in different ways. In this study, we look at these asymmetries.

2 Average Asymmetry Distributions

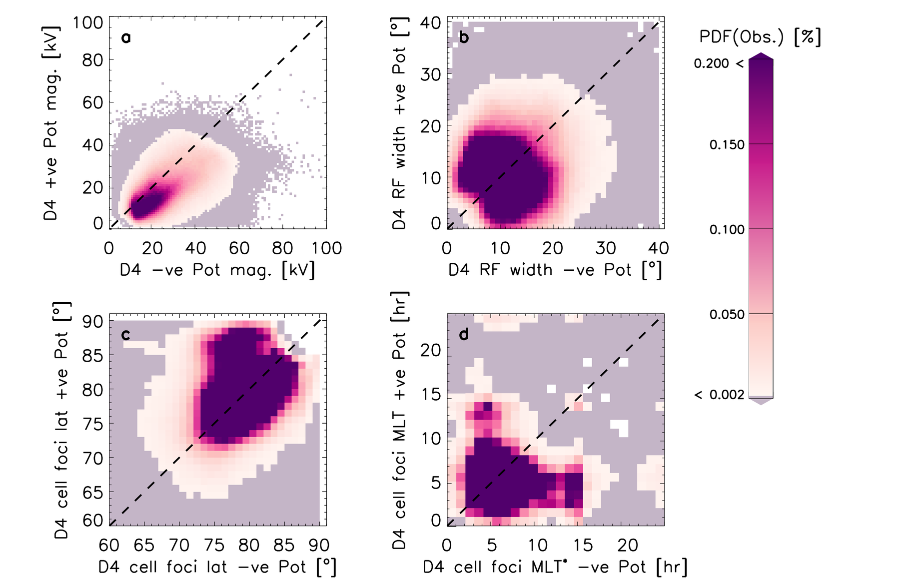
Distributions of asymmetry measures show an asymmetry in the potential (see probability distribution functions below):

a) the dusk side (-ve) tends to be stronger;

b) the return flow width shows little asymmetry;

c) the latitude location of the dawn side (+ve) convection cell tends to be at higher latitudes;

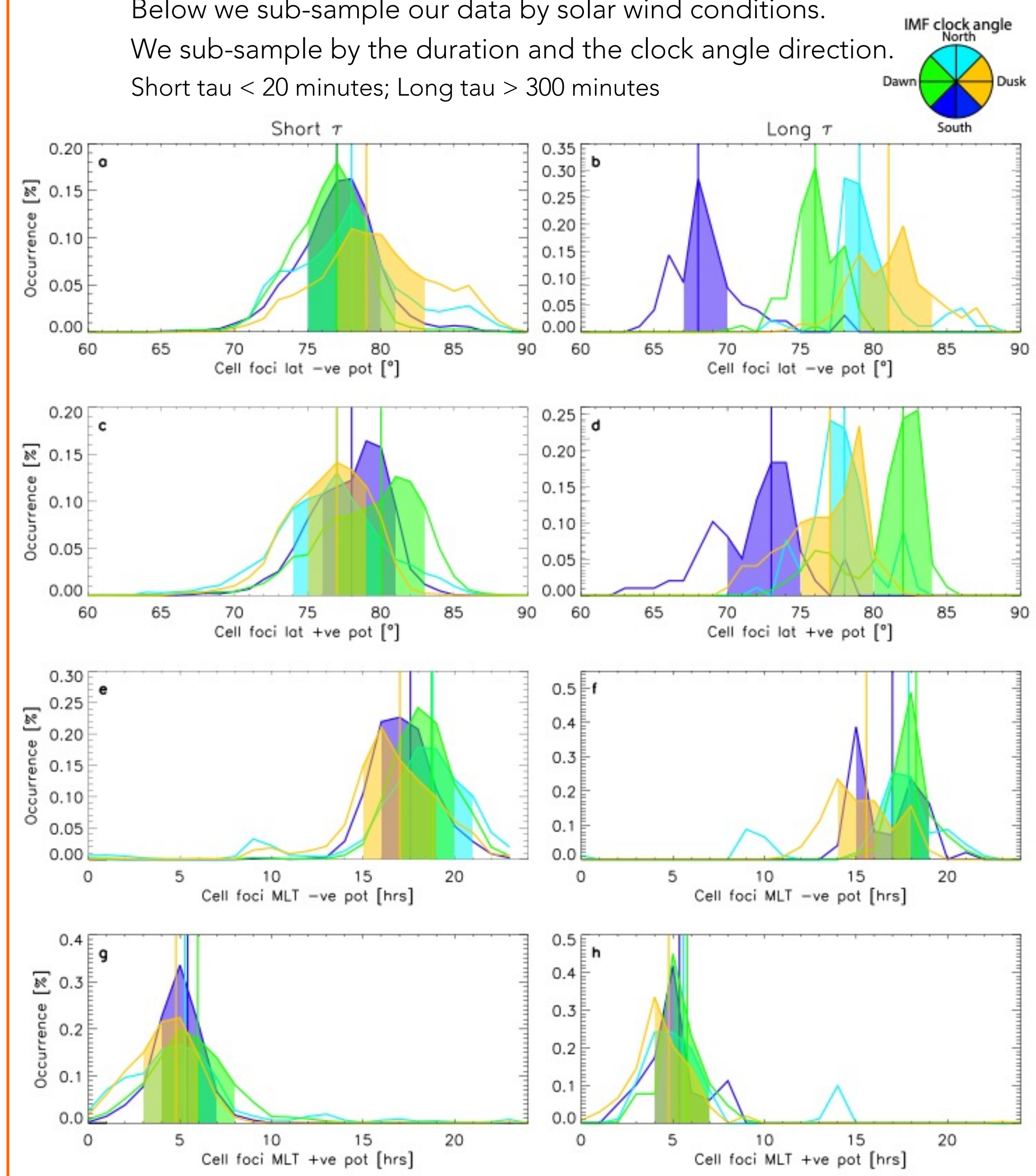
d) the MLT location of the potentials can jump across the noon-midnight meridian.



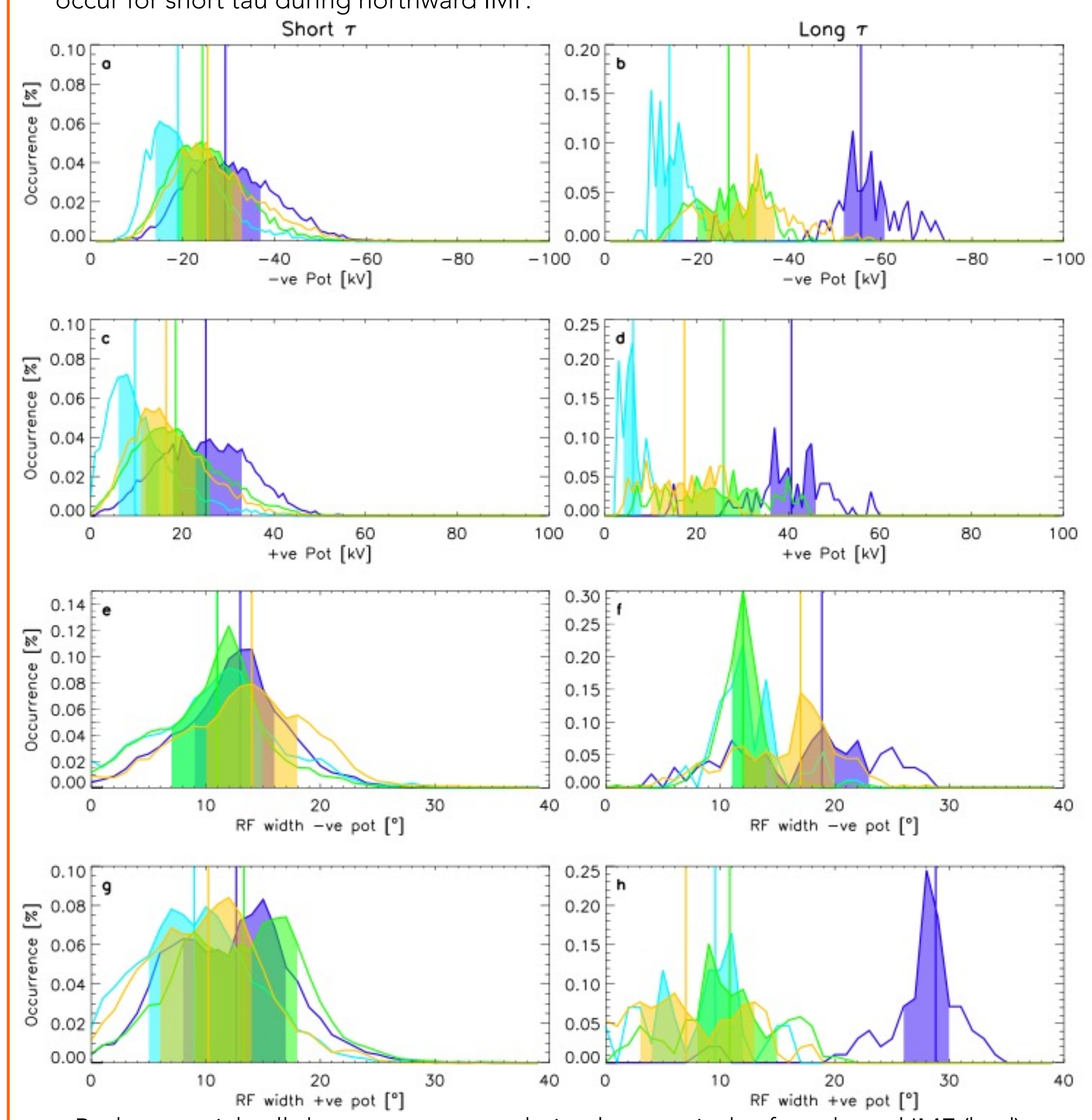
- The –ve potential cell is on average stronger than the +ve, irrespective of background model.
- D1 shows striations in the potentials. This is due to qunatisation of the background model bins in RG96.
- The return flow width shows a strong background model dependence.
- The latitudinal location of the cell foci shows a strong background model dependence. This differs for the –ve and +ve potentials.
- Similarly, the MLT location of the cell foci varies wildly.
- The MLT location of the cell foci shows considerable variability with background model: the TS18 background model makes the convection cells much more mobile.

3 Asymmetries due the Solar Wind

Below we sub-sample our data by solar wind conditions.
We sub-sample by the duration and the clock angle direction.
Short tau < 20 minutes; Long tau > 300 minutes



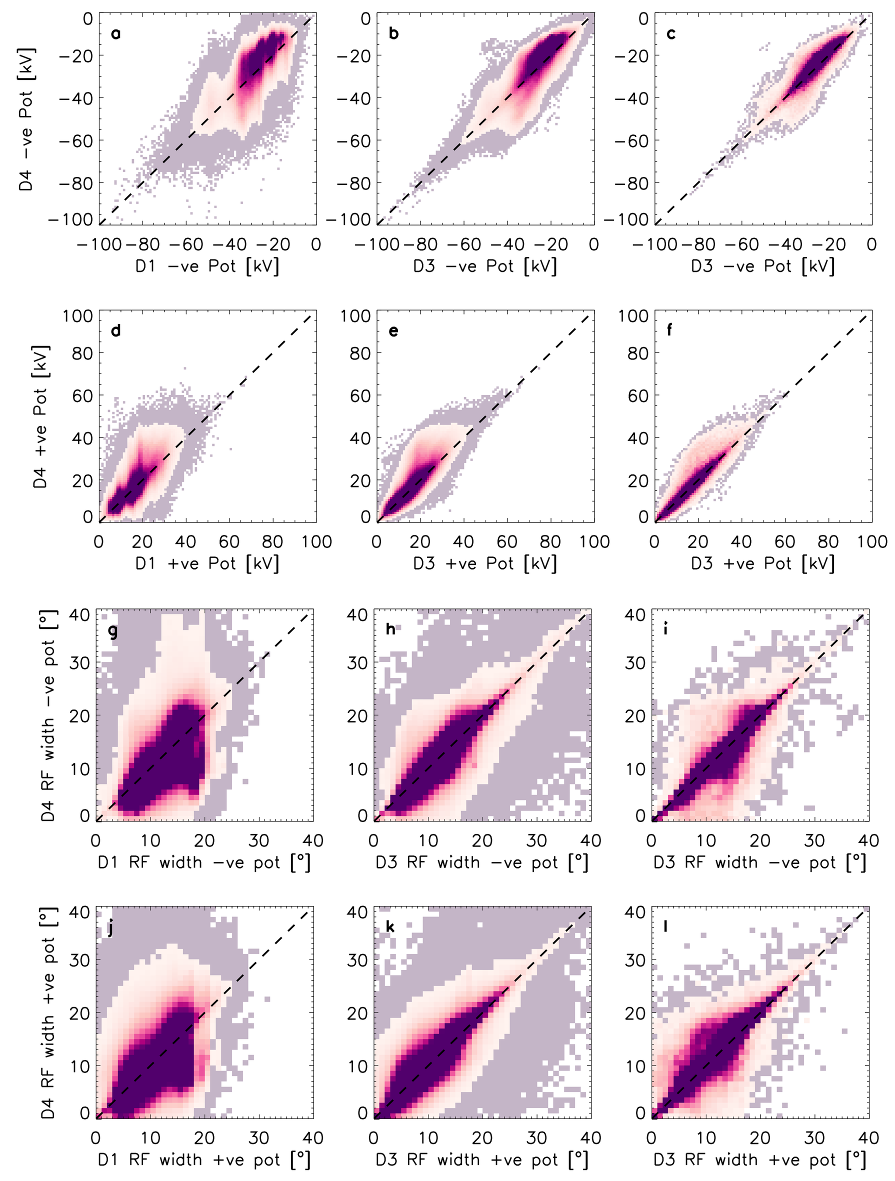
The foci latitudes move equatorward, especially when the IMF has been southward for a long time (compare panels b & d to a & c).
When the IMF is northward, cell foci can move across the noon-midnight meridian to swap sides (e.g. due to lobe stirring via lobe reconnection). This is most likely to occur for short tau during northward IMF.

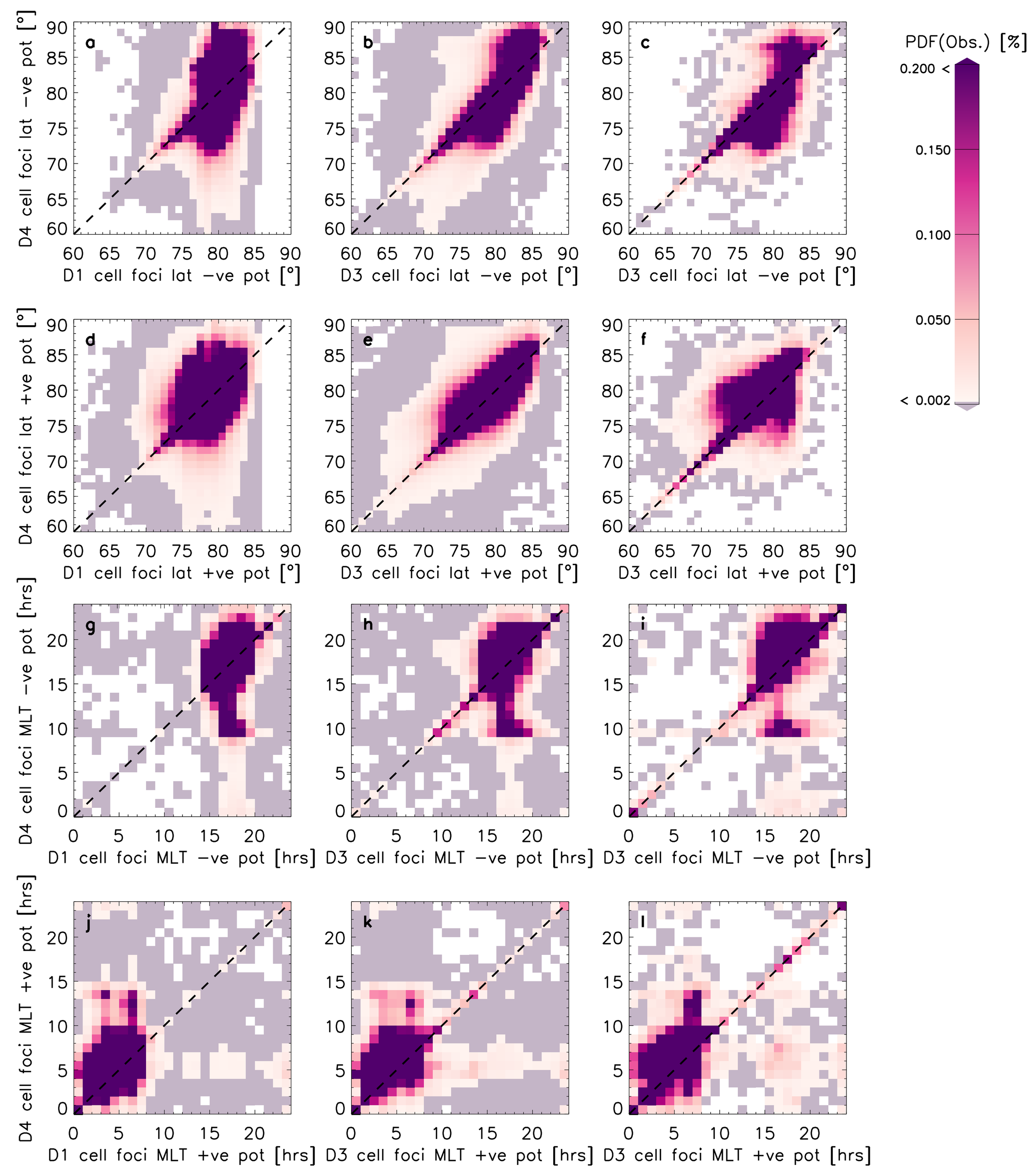


Both potential cells become stronger during long periods of southward IMF (b; d). During long periods of dawnward IMF the +ve cell is the seconds strongest (d) but the second strongest -ve potential is held by duskward IMF (c). This leads to asymmetries in the convection cells.

4 Comparing Different Data Processing Methods

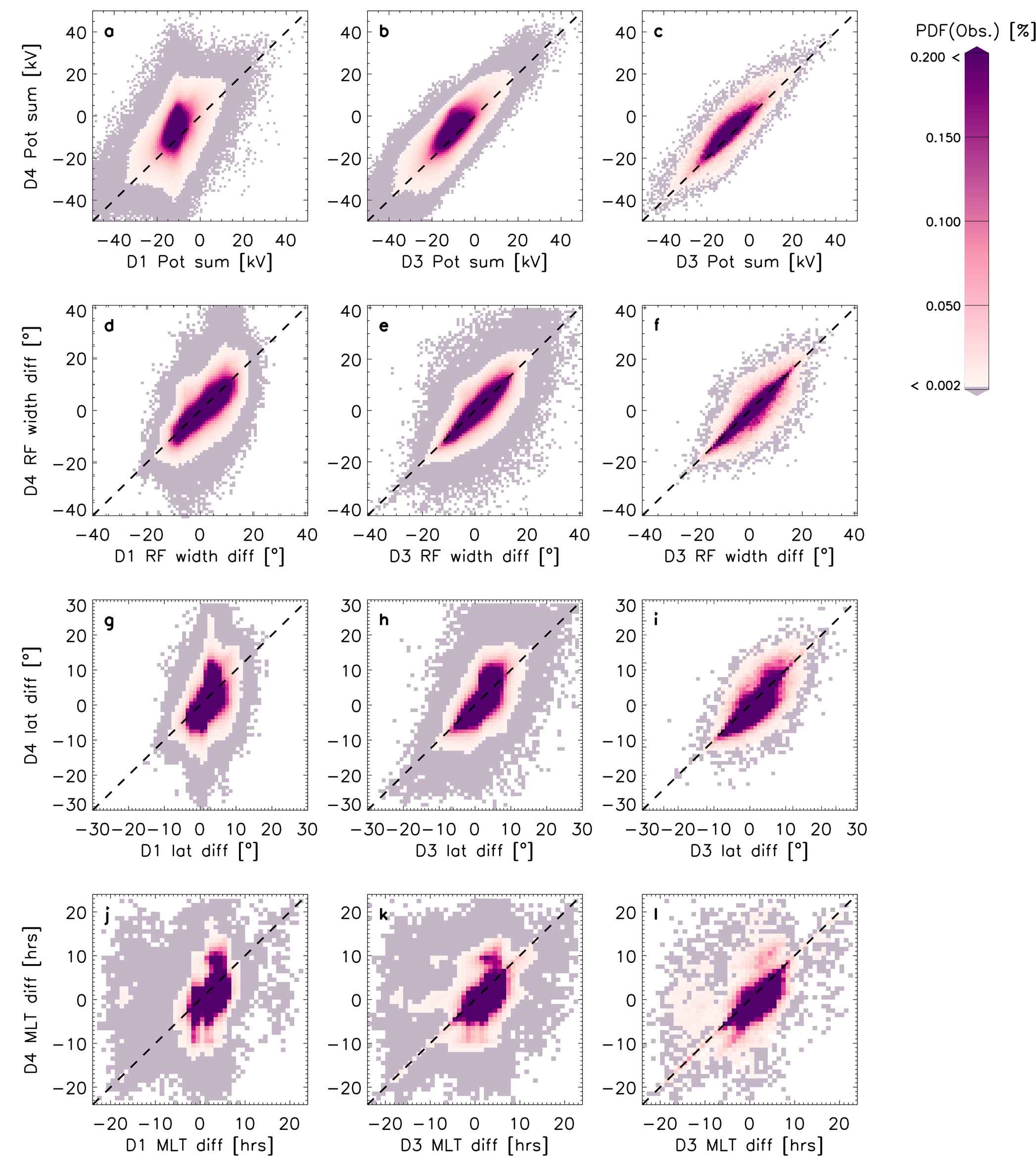
- Different versions of the convection map dataset allow us to check for asymmetries introduced in the map fitting process
- Datasets were processed for Walach et al. 2022:
  D1 only uses radars built before 2001 and a range limit.
  D3 and D4 use the same radars but D3 utilises the Ruohoniemi & Greenwald (1996) background model, whereas D4 uses the Thomas & Shepherd (2018) background model.
- The third column only shows D3 against D4 where n > 200. These maps are considered less reliant on the fitting process (Walach et al. 2022).





6 Asymmetries Introduced by the Background Model

- The Figure on the right shows the differences between each negative and positive potential cell's variables (except the top row, which shows the sum between the negative potential and the positive potential).
- First column (D1 data) shows most spread: older convection maps may show more asymmetries that are removed when more radars are added.
- Some asymmetries remain when more data is added (D3), but are reduced/removed when the background model is changed.
- The negative cell's potential (dusk cell) is generally stronger than the positive cell, but this is not dependent on the background model.
- The foci locations (latitudinal and MLT placement of the cells) are asymmetric. This asymmetry is very susceptible to which background model is used.
- The asymmetry in MLT location is generally higher for the TS18 background model.



Summary

- Both the solar wind and data processing can introduce asymmetries in convection maps. The latter may be particularly important when studying old convection maps (e.g. using RG96 background model or when mid-latitude radars were not available).
- We recommend particular care with case studies or when comparing to other dataset.s
- Asymmetries due to the background model are likely to occur in the locations of the convection cells.
- Asymmetries due to the IMF clock angle can occur in strength and location of the convection cells and return flow width.
- The TS18 background model (D4) allows for more mobile convection cell foci in comparison to the RG96 background model (D1 and D3). The +ve potential cell (dawn cell) tends to be more mobile than the –ve cell.
- The return flow width under different IMF directions is more variable for the +ve potential cell than the -ve potential cell. This is because the +ve cell is more mobile and the +ve cell foci tend to lie closer to midnight.

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References

- Ruohoniemi, J. M., and Greenwald, R. A. (1996), Statistical patterns of high-latitude convection obtained from Goose Bay HF radar observations, *J. Geophys. Res.*, 101(A10), 21743– 21763, doi:10.1029/96JA01584.
- Thomas, E. G., & Shepherd, S. G. (2018). Statistical patterns of ionospheric convection derived from mid-latitude, high-latitude, and polar SuperDARN HF radar observations. *Journal of Geophysical Research: Space Physics*, 123, 3196– 3216. https://doi.org/10.1002/2018JA025280
- Walach, M.-T., Grocott, A., Staples, F., & Thomas, E. G. (2022). Super dual auroral radar network expansion and its influence on the derived ionospheric convection pattern. *Journal of Geophysical Research: Space Physics*, 127, e2021JA029559. https://doi.org/10.1029/2021JA029559