

High-Time Resolution Ionospheric Convection Associated with Nightside Auroral Intensifications

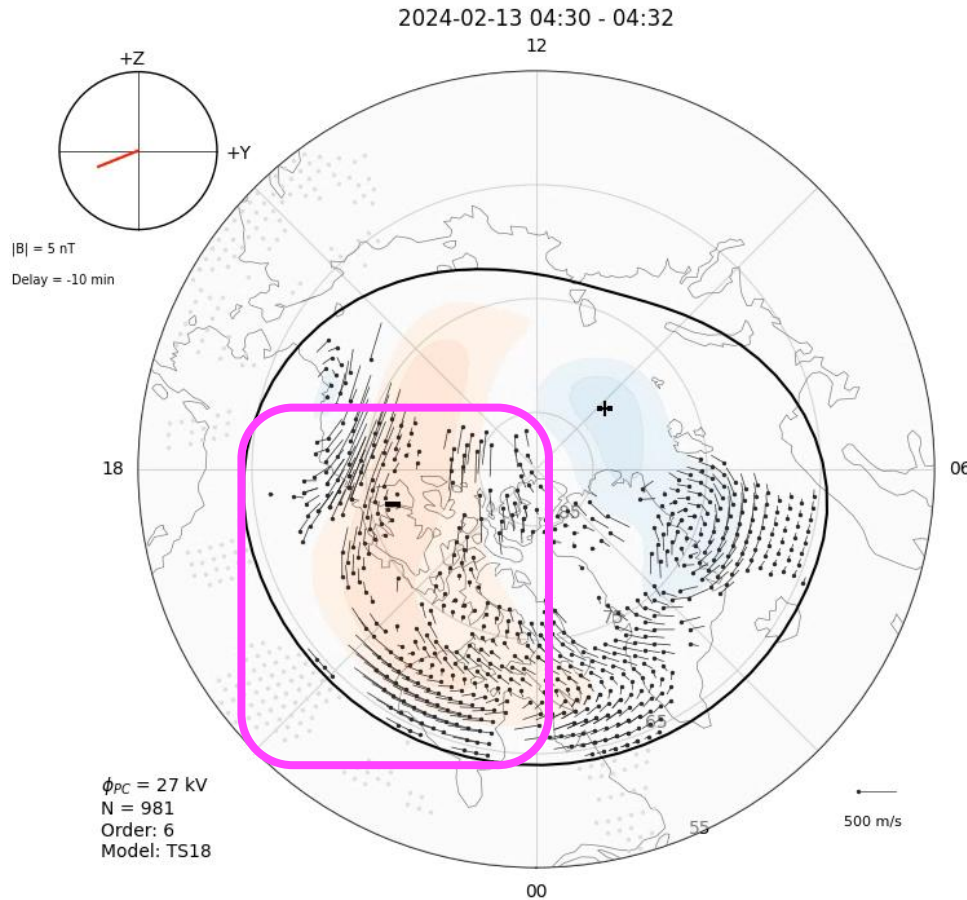
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Tribute to Kathryn McWilliams

- We worked together through 8 papers.
 - Kathryn was very passionate about her radars and science.
 - She often sent us many pages of comments.
- We collaborated through her innovative Borealis system.
 - Started when Larry Lyons met Remmington Rohel.
 - Kathryn liked our science ideas and incorporated them into the operations.

Regional convection map

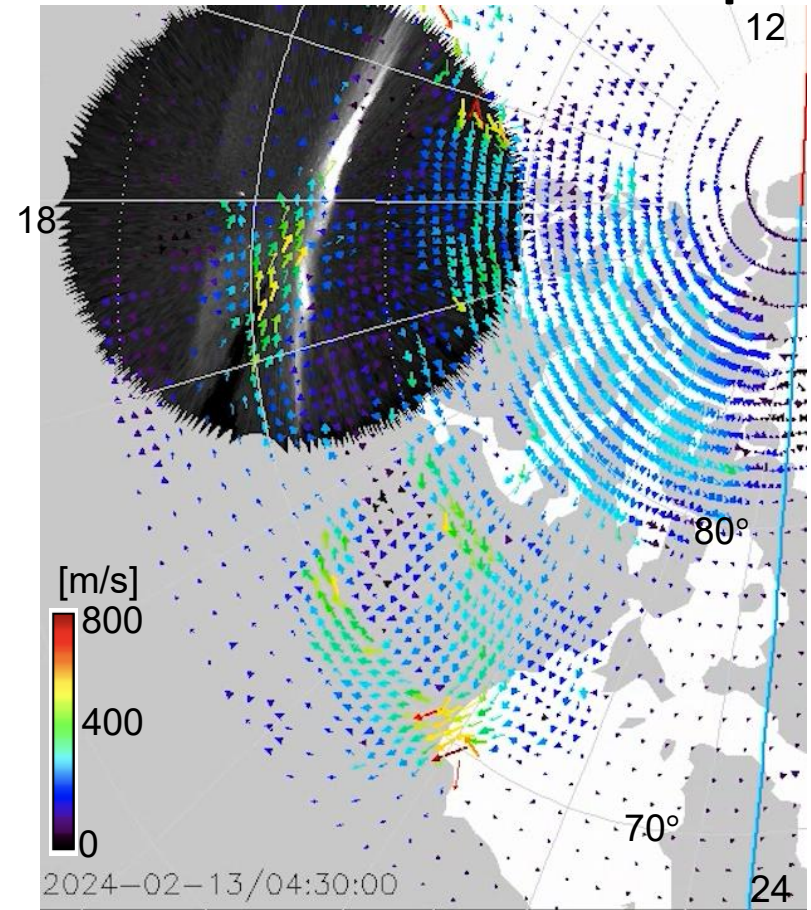
2-min convection map



Widely used, but highly smoothed.

Difficult to use for auroral arcs, flow channels, and ULF.

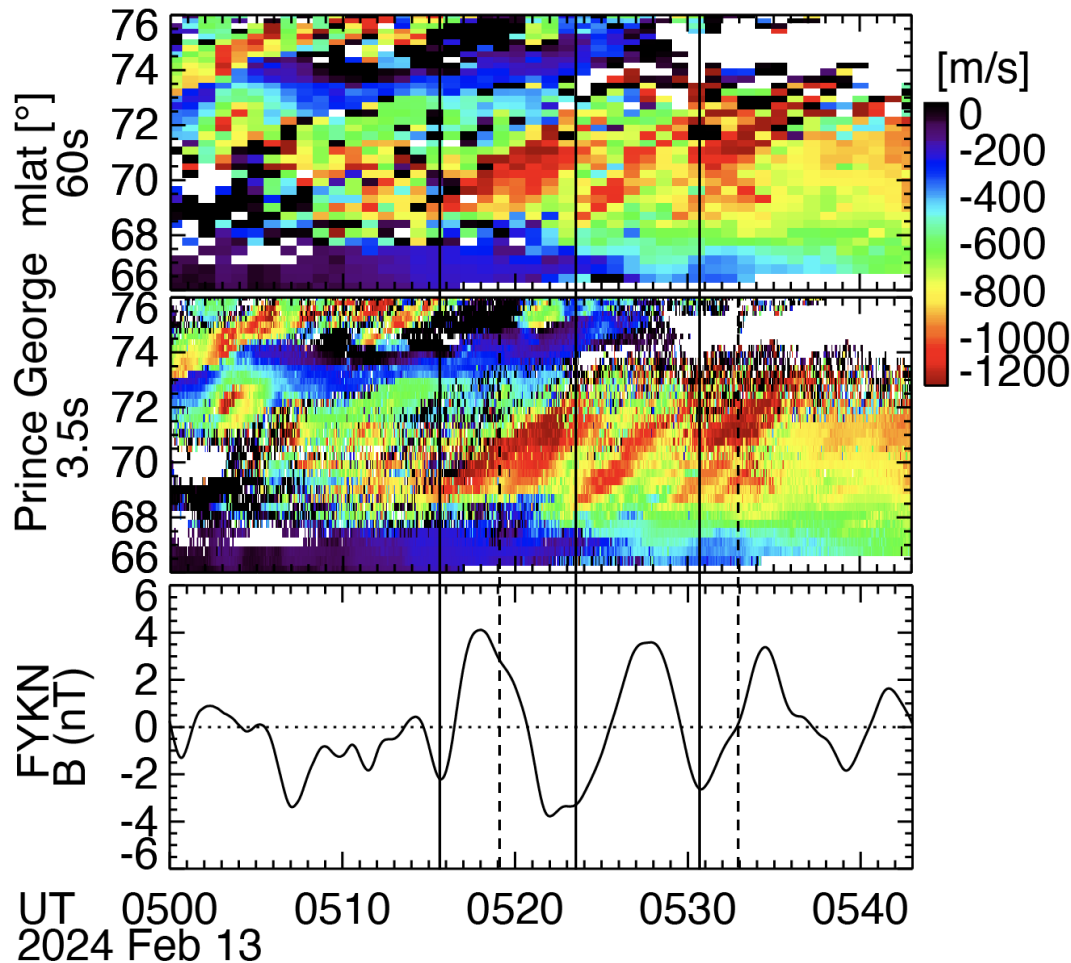
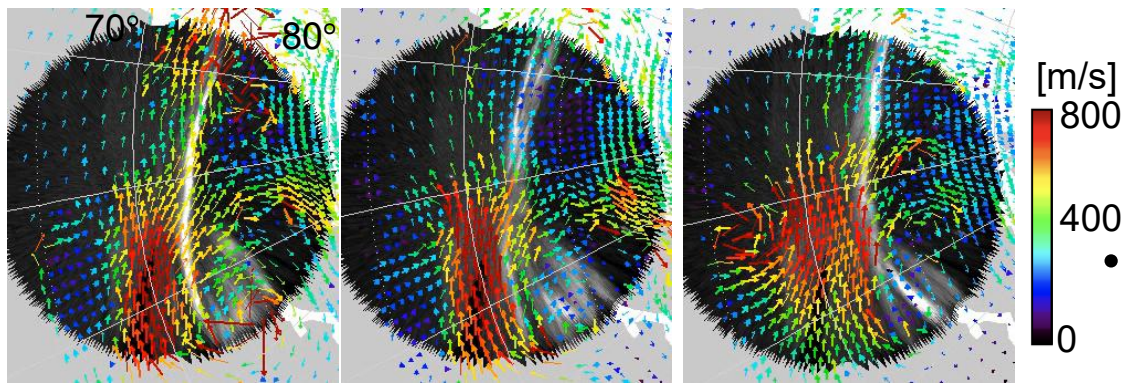
3.5-sec convection map



Also using the divergence-free fitting [Nishimura et al., 2024].

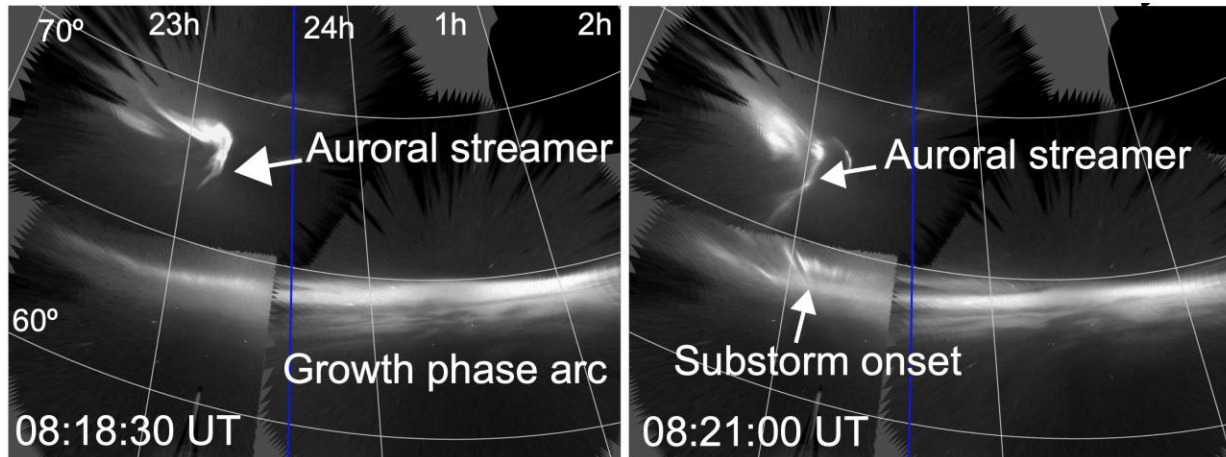
Revealing dynamic variations: Flow channels, shears and ULF.

Pc5 ULF Pulsation

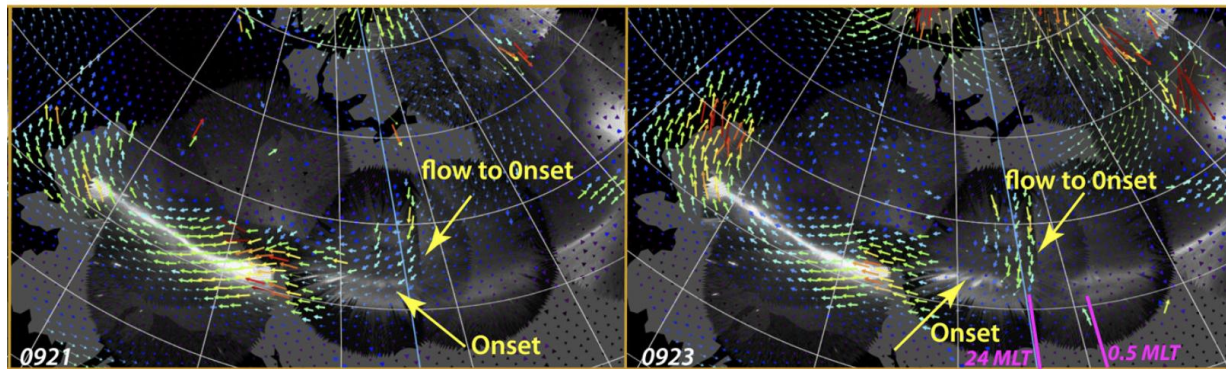


- The 60-sec velocity only shows 3 enhancements.
- The 3.5-sec velocity resolves substructures of ULF.
- The 1-beam THEMIS mode [Shi et al., 2018 with McWilliams] could not see spatial structure.
- The convection map presents a propagating flow vortex.

Substorm pre-onset flows



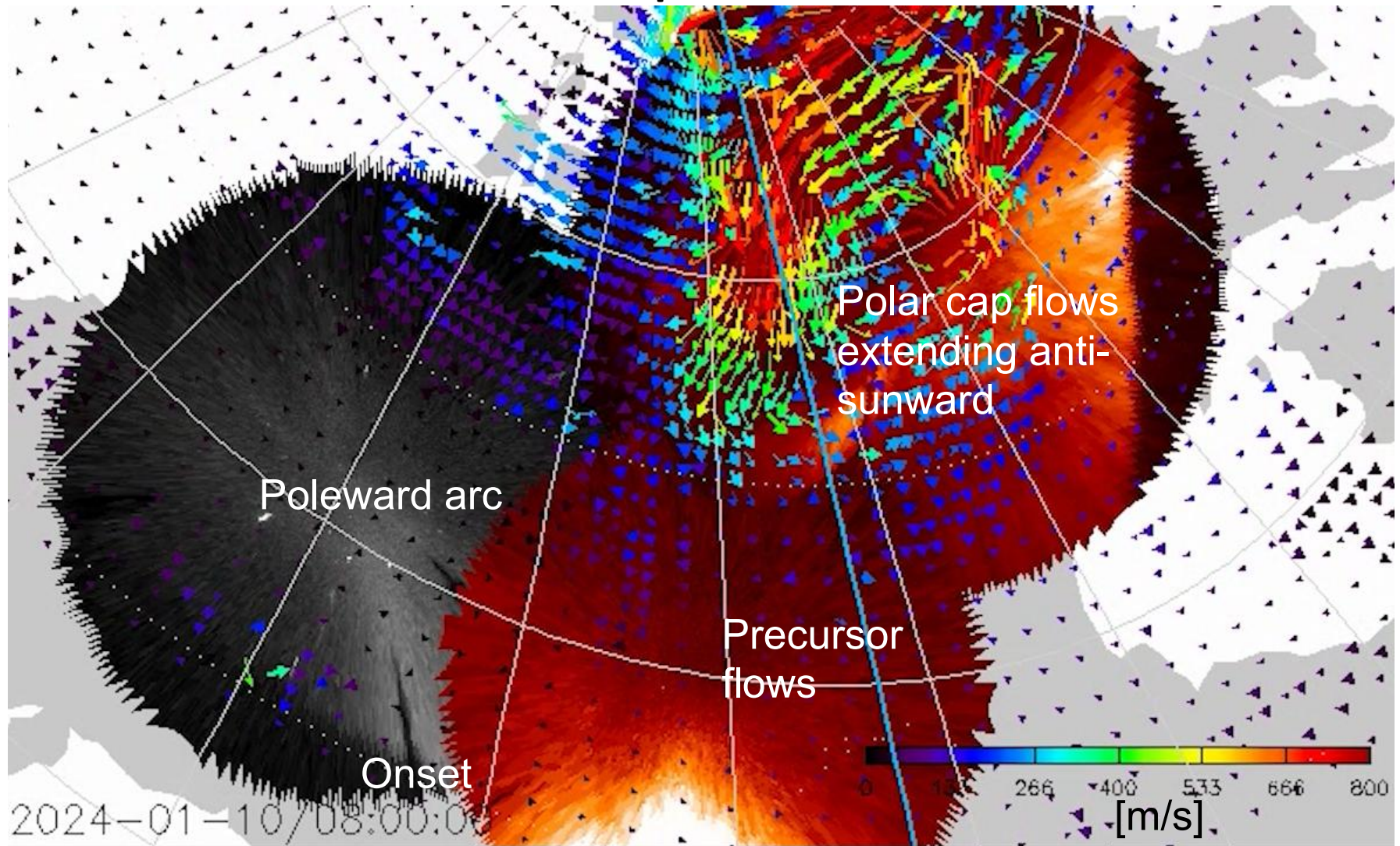
[Nishimura et al., 2010, 2020]



[Lyons et al., 2022, using Bristow et al. (2022)'s method]

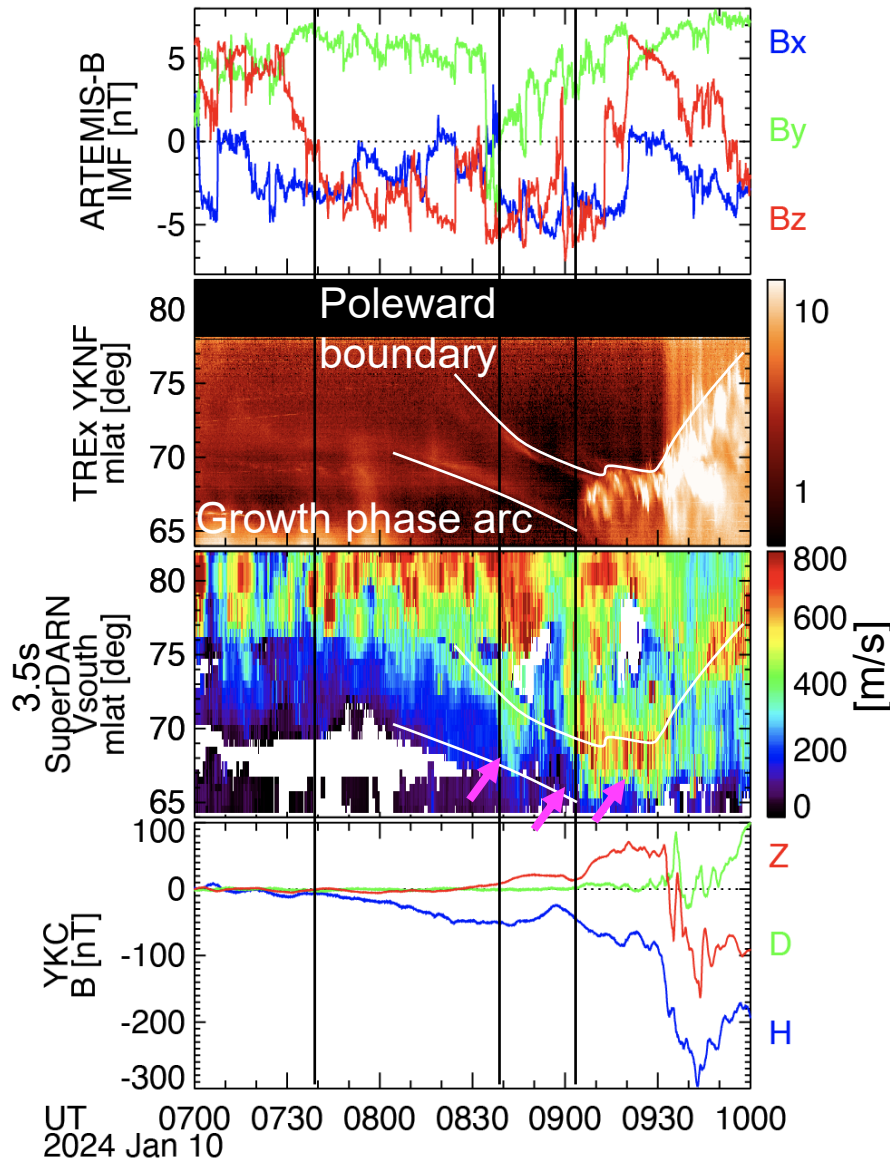
- The sequence of events to substorm onset has been a major question [Angelopoulos, 2009].
- Precursor flows to substorm onset have been suggested.
- But only one scan of data raises a question of the causality.

Substorm pre-onset flow



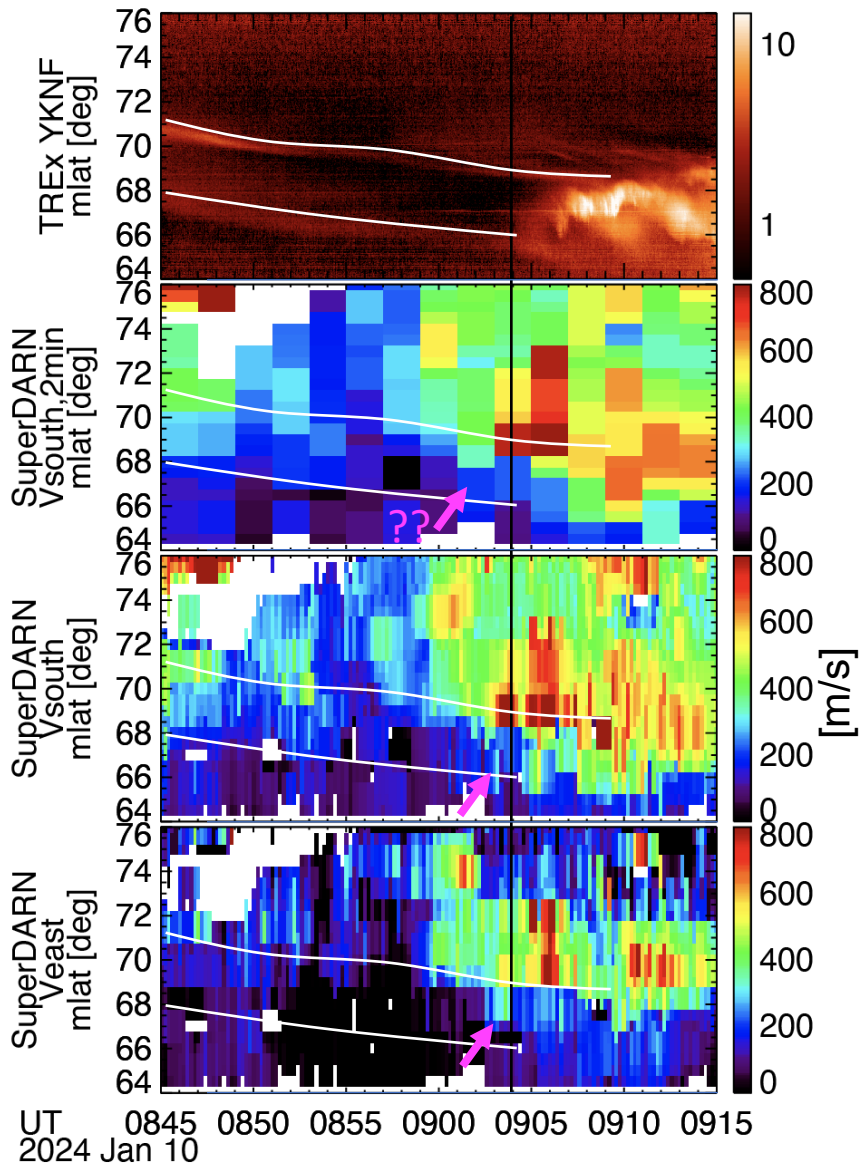
- The 3.5-sec convection map provides unambiguous evidence that flows reach the arc before the substorm onset.

Substorm pre-onset flow



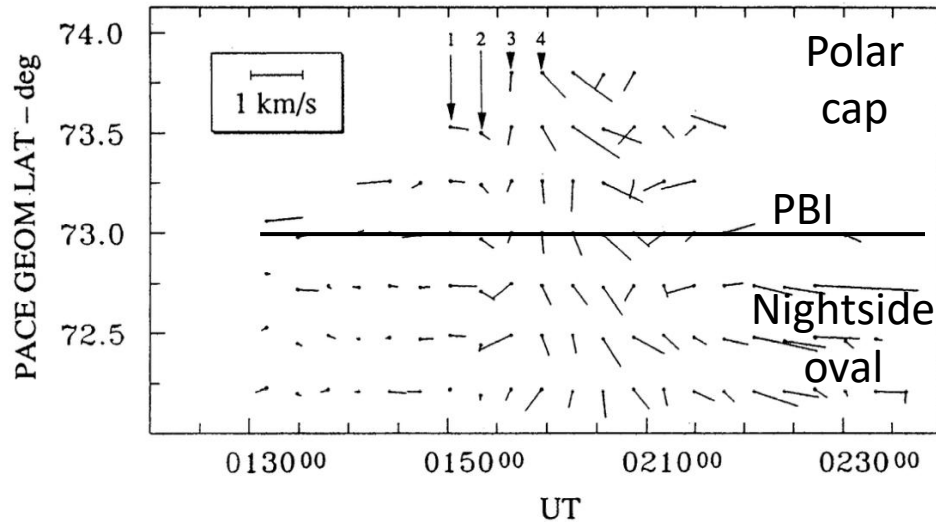
- Unlike the conventional notion, the polar cap flows rapid variations every ~5 min.
- The polar cap flows are suddenly enhanced and penetrate to the auroral oval.
- The oval poleward boundary intensifies (PBI).
- Post-onset flows show periodic enhancements with auroral streamers [c.f., Gallardo-Lacourt et al., 2014 with McWilliams].

Substorm pre-onset flow

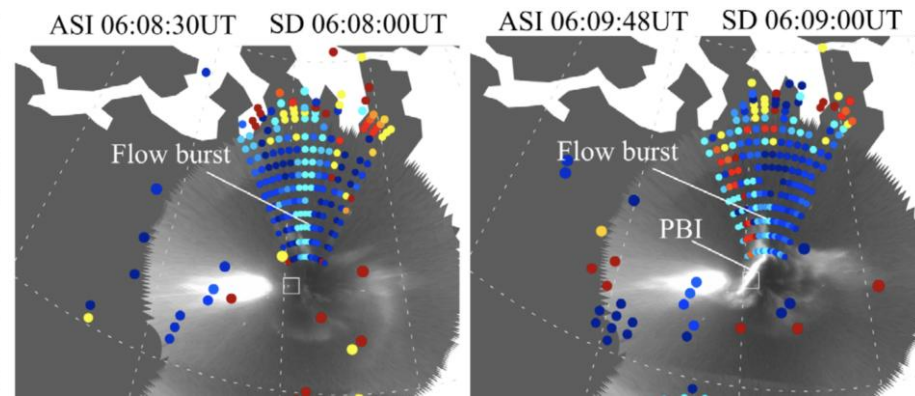


- 2-min data only shows only 1 scan showing an enhanced flow.
- 3.5-sec data clearly shows an enhanced flow 1.5 minutes before onset.

Poleward boundary intensification (PBI)



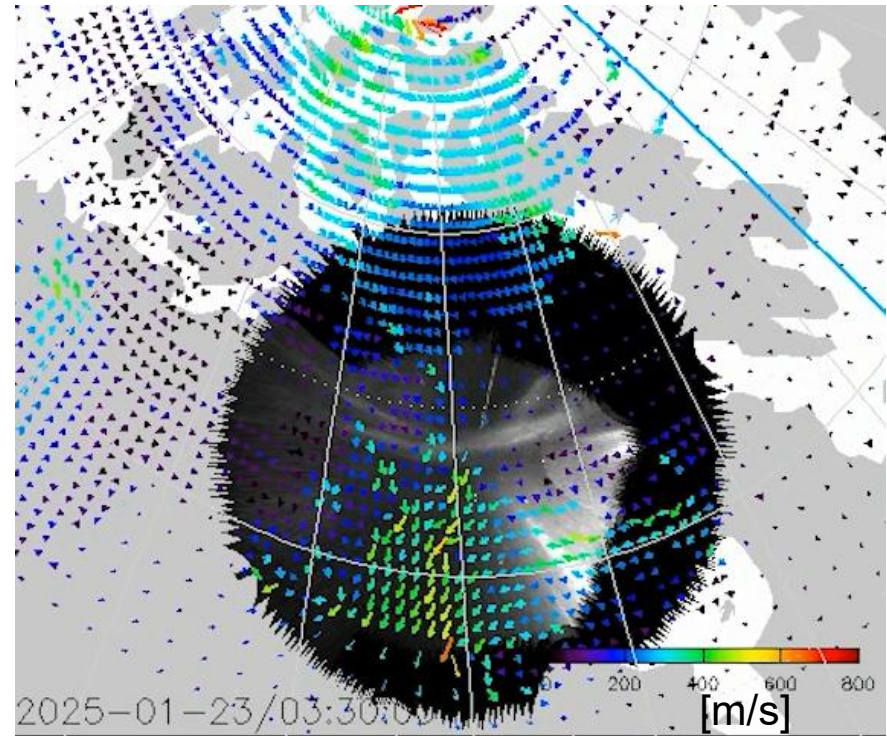
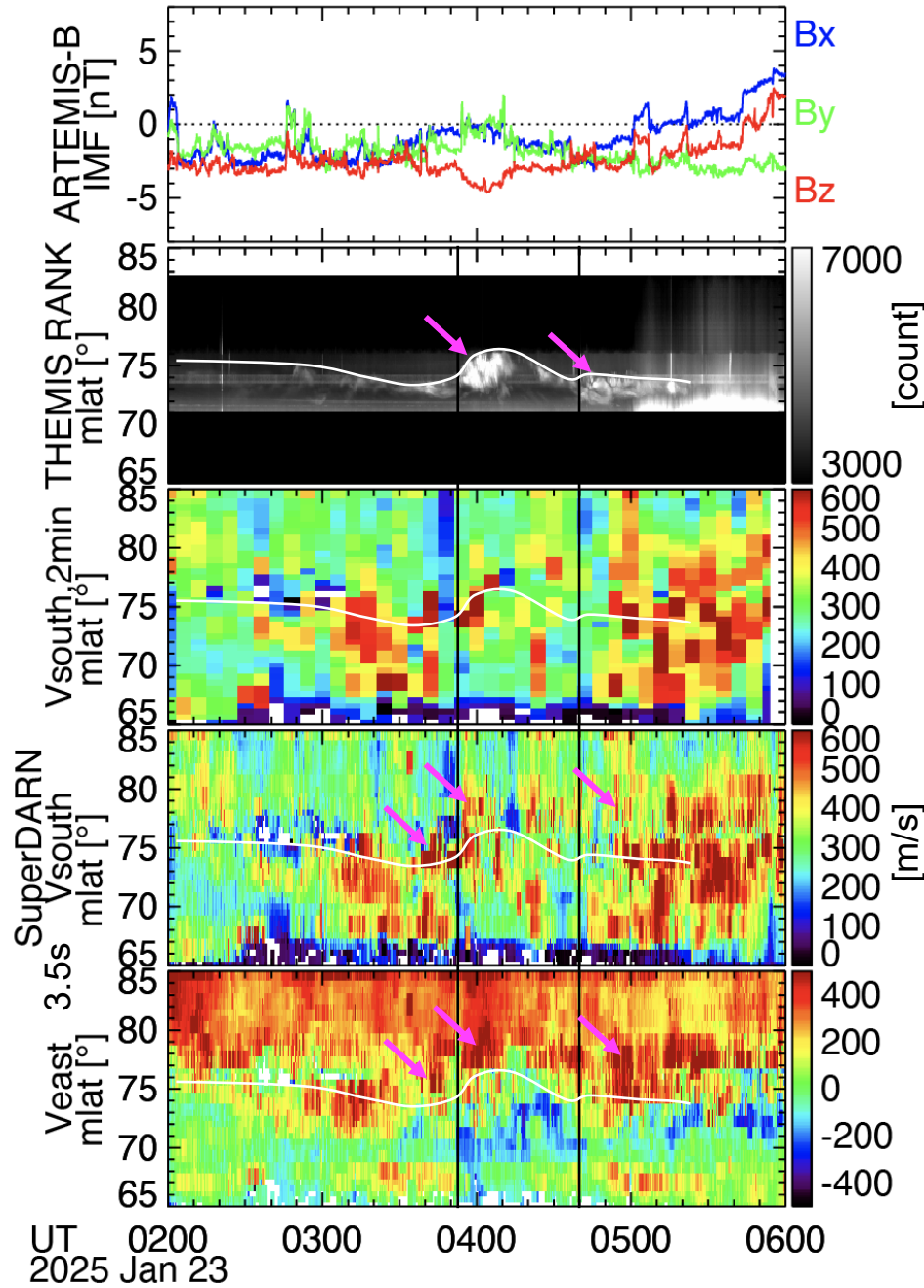
[de la Beaujardiere et al., 1994]



[Nishimura et al., 2010]

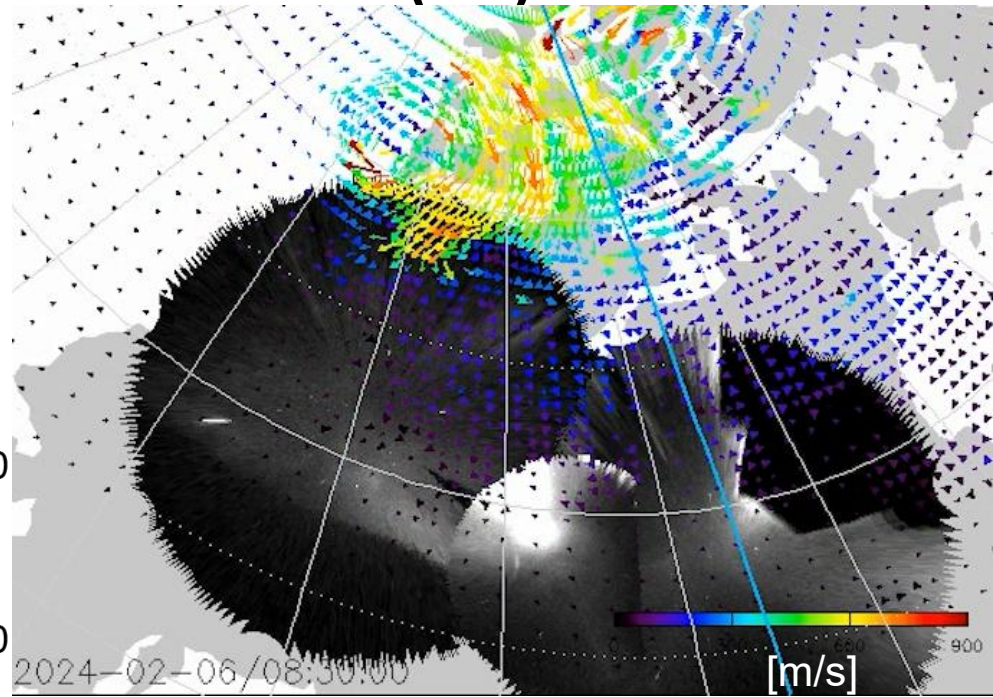
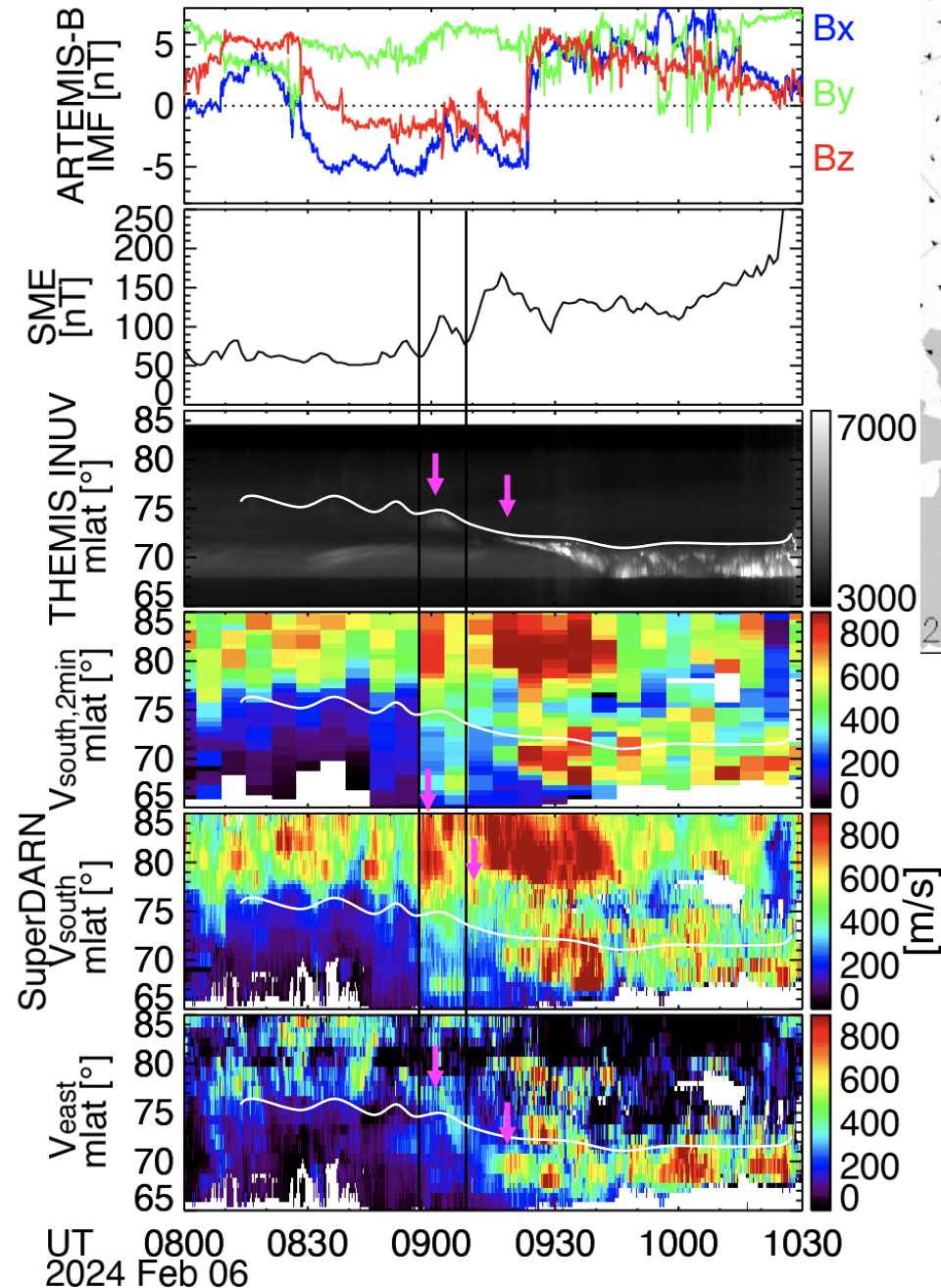
- Polar cap flows enter the nightside oval, and turn azimuthally.
- Polar cap flows are suggested to drive PBIs, ionospheric signature of nightside reconnection.
- The same question about the causality exists due to the limited time resolution.

Poleward boundary intensification (PBI)



- Quasi-steady southward IMF.
- The 2-min velocity only represents overall flow variations.
- The 3.5 sec velocity shows,
 - Rapid flow variations
 - Precursor flows to PBIs
 - Flow shear with PBIs

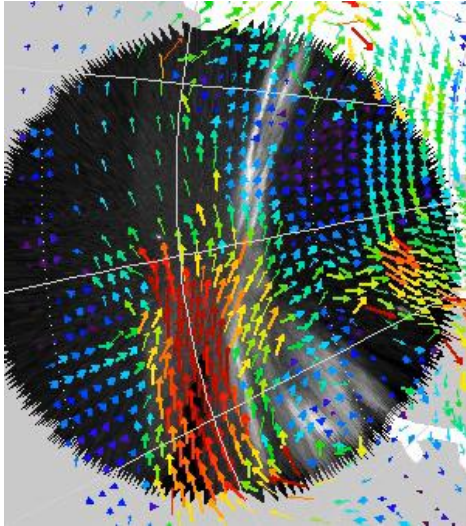
Poleward boundary intensification (PBI)



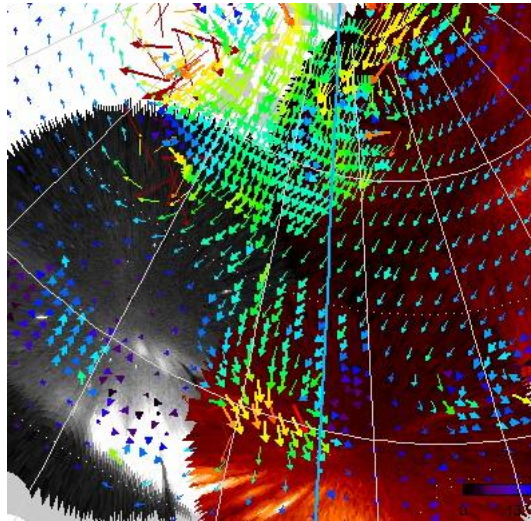
- Briefly southward IMF and 2 PBIs.
- The 2-min velocity only roughly shows 2 flow enhancements.
- The 3.5 sec velocity resolves 2 precursor flows.
- The convection map shows flow shear at the poleward boundary.

Summary

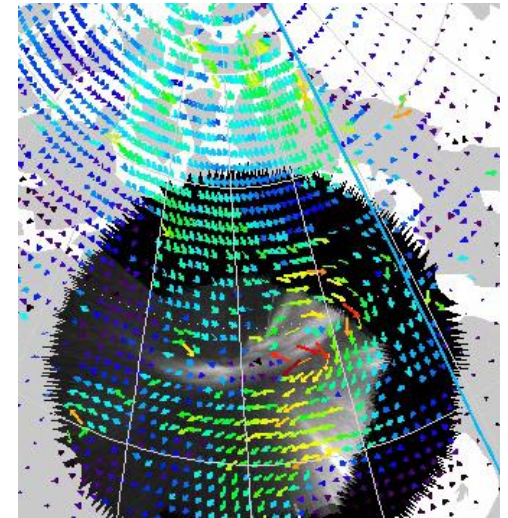
ULF



Substorm onset



PBI and surge

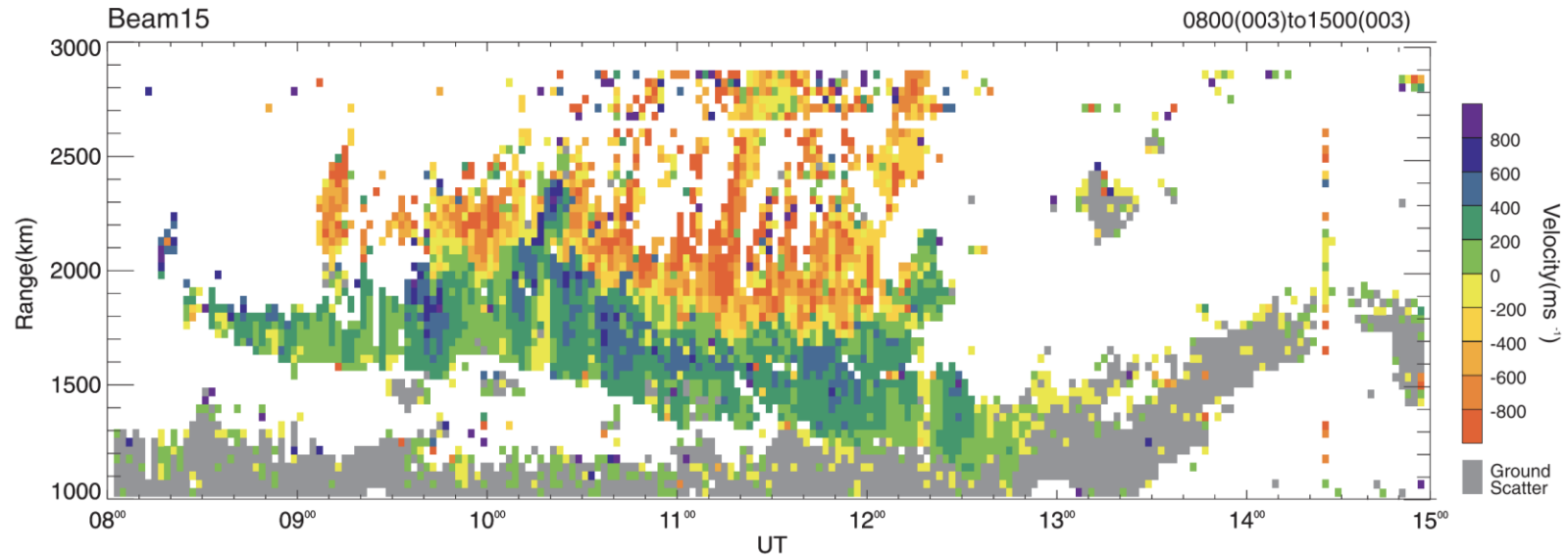


- Kathryn's Borealis system has made a major breakthrough in convection measurements.
- The 3.5-sec convection maps revealed rapid flow variations and their structures that couldn't be seen before.
- We presented three highlights (ULF, onset and PBI) for nightside auroral research.

Summary

K. A. McWilliams *et al.*: A statistical survey of dayside pulsed ionospheric flows

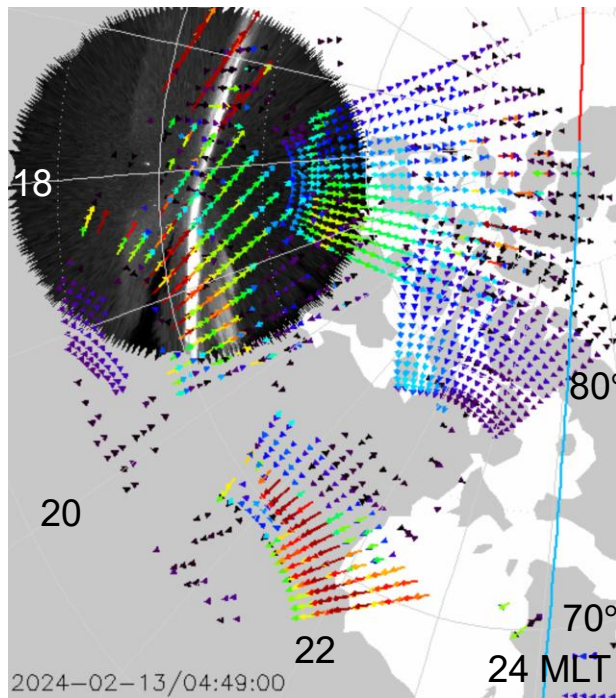
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- The Borealis system also provides excellent data for dayside flows. Will be presented in future opportunities.
- We truly appreciate Kathryn's contributions to our collaborations, and her leadership to the Borealis system.
- Her legacy will keep enable new and exciting research.

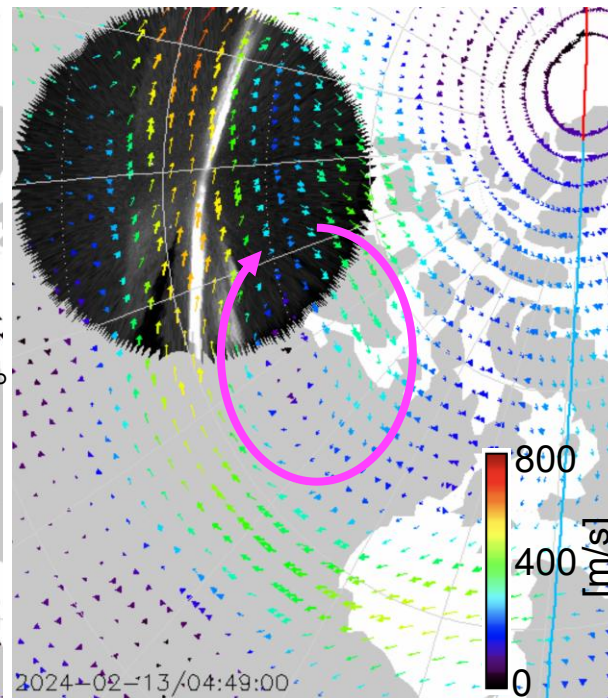
Creating high-resolution convection maps

Line-of-sight velocity



Showing fast flows, but sparse and limited to line-of-sight directions.

Spherical harmonic fit

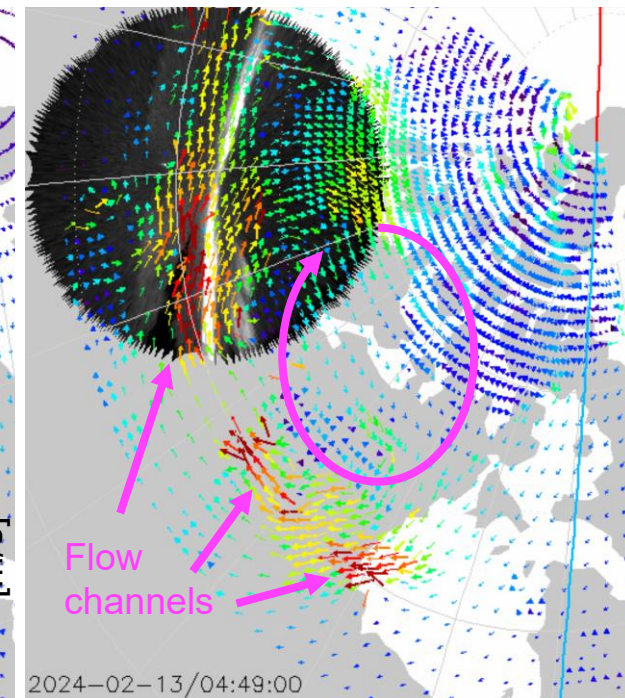


Smooth large-scale convection cell.

Slower flows.

Flows not aligned with the arc.

Divergence-free fit



High-resolution convection that satisfies $\nabla \cdot \mathbf{v} = 0$

[Nishimura et al., submitted].

The flow channels are resolved and aligned with aurora better.