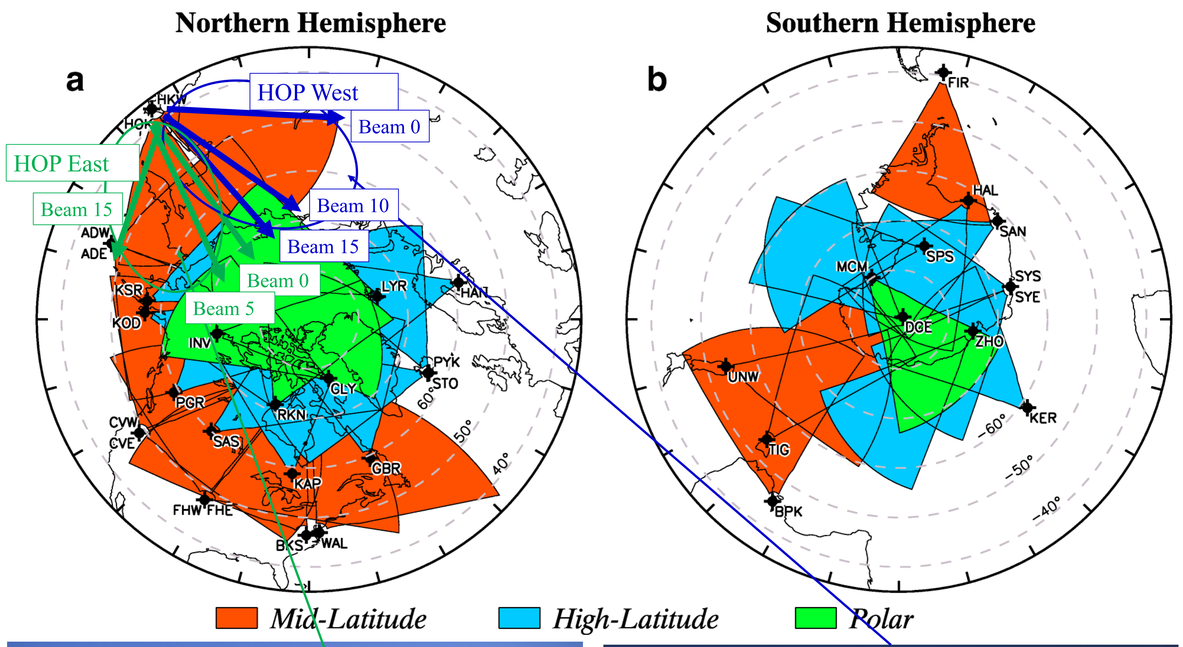
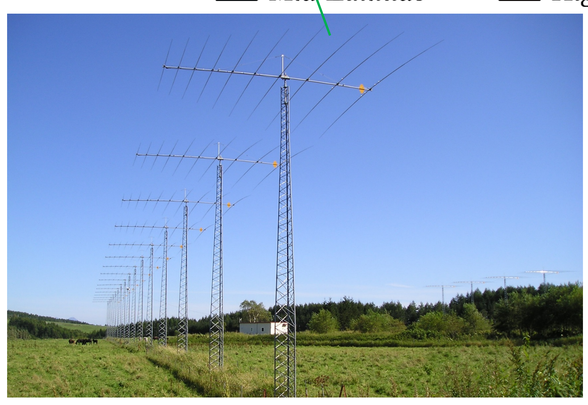
Multi-event analysis of SAPS Wave Structures observed by the SuperDARN Hokkaido Pair of radars

○ Nozomu Nishitani[1], Tomoaki Hori[1], and Mariko Teramoto[2]
[1]Institute for Space-Earth Environmental Research, Nagoya Univ., Japan
[2]Kyushu Institute of Technology, Japan

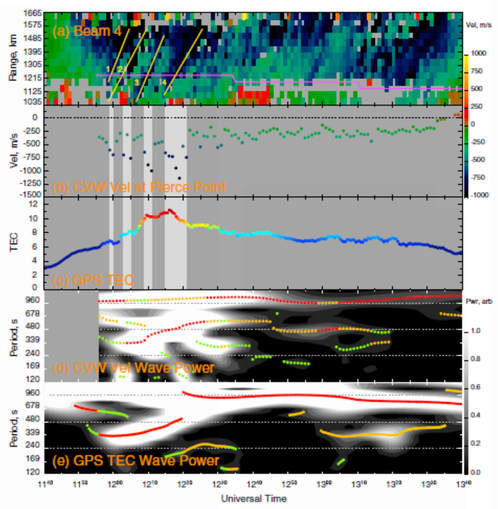
Abstract. The SuperDARN Hokkaido Pair (HOP) of radars data with special operation modes are used to study the wavy variations of plasma flow embedded in larger-scale, fast flow structures at subauroral latitudes (SAPS). Because of the limited number of examples studied so far, their generation mechanism is not fully understood yet. In this paper we focus mainly on the events on Sep 08, 2017 and Aug. 26, 2018. Both events occurred near the peak of large geomagnetic storms. These events were registered by the SuperDARN radars with higher temporal resolution (3 and 12 seconds respectively) camping beams. Using both camping beam data and 2-dimensional data (with 1 to 2 min temporal resolution) enable us to examine the period, wavelength and propagation speed of these wave structures. In addition, using the data with the new fitting algorithm (fitacf Ver. 3) we have more extended coverage of the echo regions. We notice that both events were observed during geomagnetic storms (minimum Dst: -124 nT and -174 nT) and the wave structures have limited spatial extent in magnetic local time. On the other hand, there are several differences between these events such as period, propagation speed and geomagnetic latitude. Their possible generation mechanisms are discussed.

SuperDARN Hokkaido Pair of (HOP) HF radars and other SuperDARN radars in both hemispheres (as of Jan. 2018)





Makarevich and Bristow (2014): mid-latitude SuperDARN observation of Sub-Auroral Polarization Streams (SAPS) wave structure



- SAPS are fast westward flows in the afternoon to postmidnight subauroral ionosphere, presumably generated as a result of both magnetospheric E-field mapping and ionospheric feedback mechanism.
- They discussed the characteristics of wavy structure (with 5-10 mins) signature, originally reported by Foster et al. (2004), together with GPS TEC variations.
- Reported on the relationship between TEC and flow velocities demonstrating the importance of ionospheric feedback process.
- Similar event was studied using the 2D multiple SuperDARN data and Arase / RBSP satellite by Hori et al. (GRL, 2018) and Hori et al. (SGEPSS, 2019).

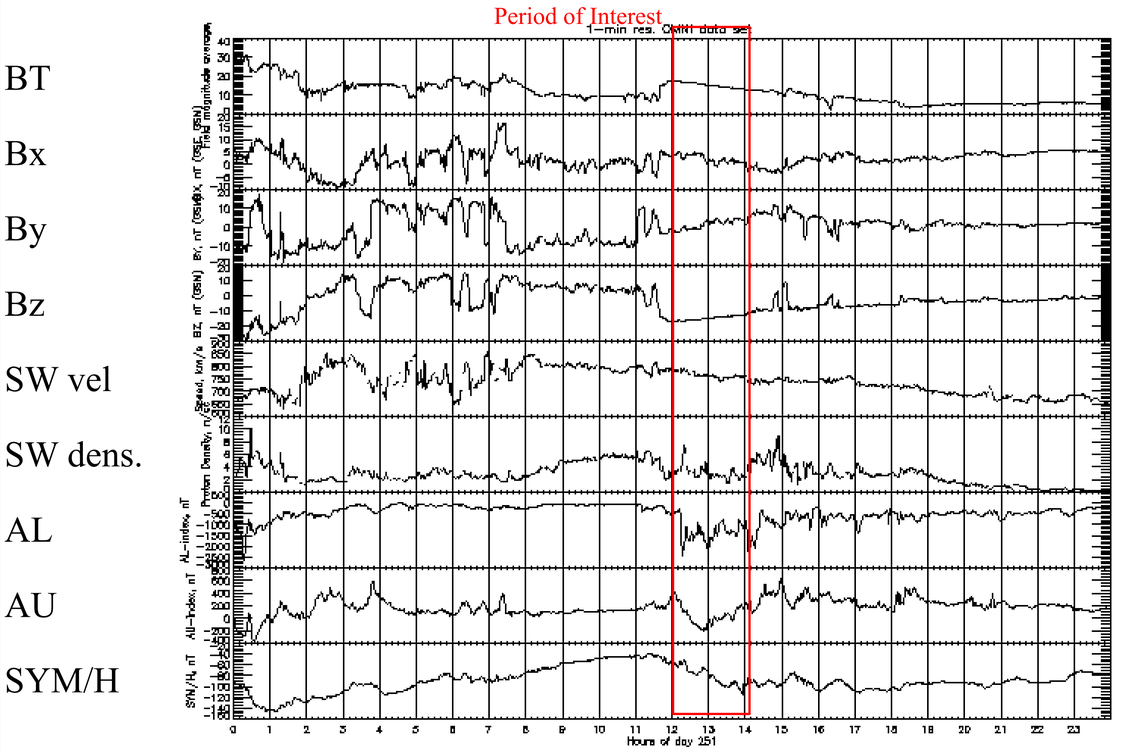
See also the recently published mid-latitude SuperDARN review paper by Nishitani et al. (PEPS, 2019).

Remaining questions:

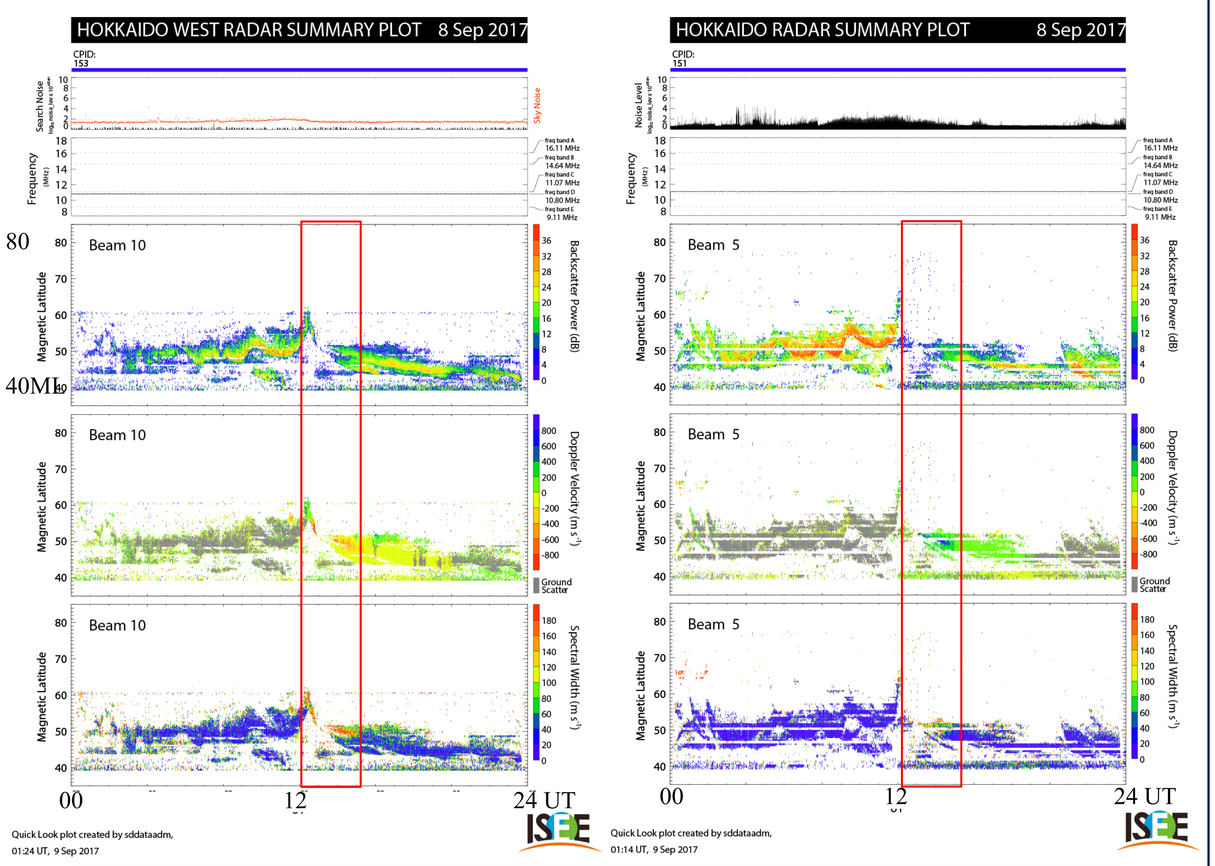
1. What is the relationship between the SAPS / global convection and the IMF changes / substorms?
2. What is the 2-dimensional distribution of SAPS perturbations?
3. What is the relationship between the perturbations in the SAPS structure with different temporal scales?

Sep 08, 2017 event

IMF, solar wind and geomagnetic parameters on 08 Sep 2017 (http://omniweb.gsfc.nasa.gov/ow_min.html)

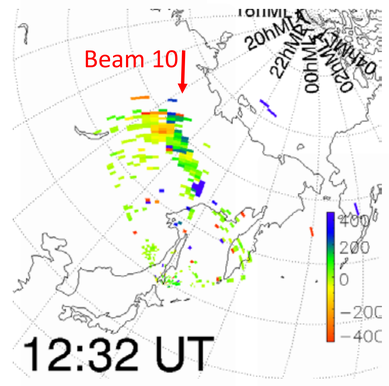


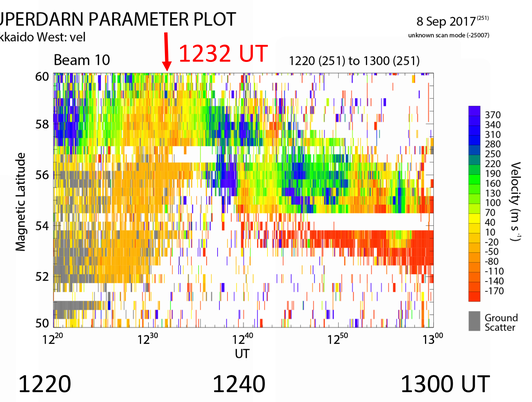
HOP East / West radars quicklook plots
Middle panel: Doppler velocities showing the presence of SAPS structures in between 12 and 15 UT



Stereo-mode observation of SAPS structure using the SuperDARN Hokkaido West radar (8 Sep 2017)

chA (10.8 MHz): 2-D (1 min res) chB (9.2 MHz): fix to b10 (3 s res)





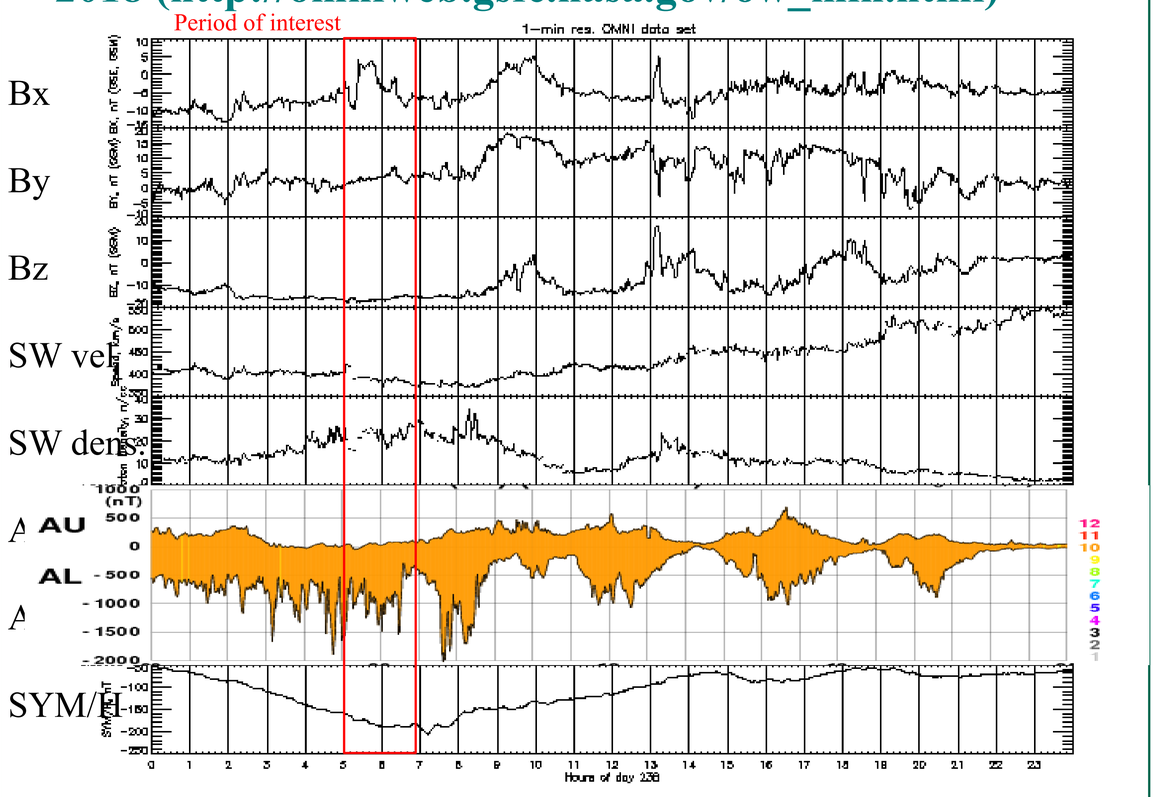
Summary and Discussions: 2017/09/08 event

There are various temporal scales of the subauroral flow variations, with main scales at several **tens of mins, ~10 min and ~1 min.**

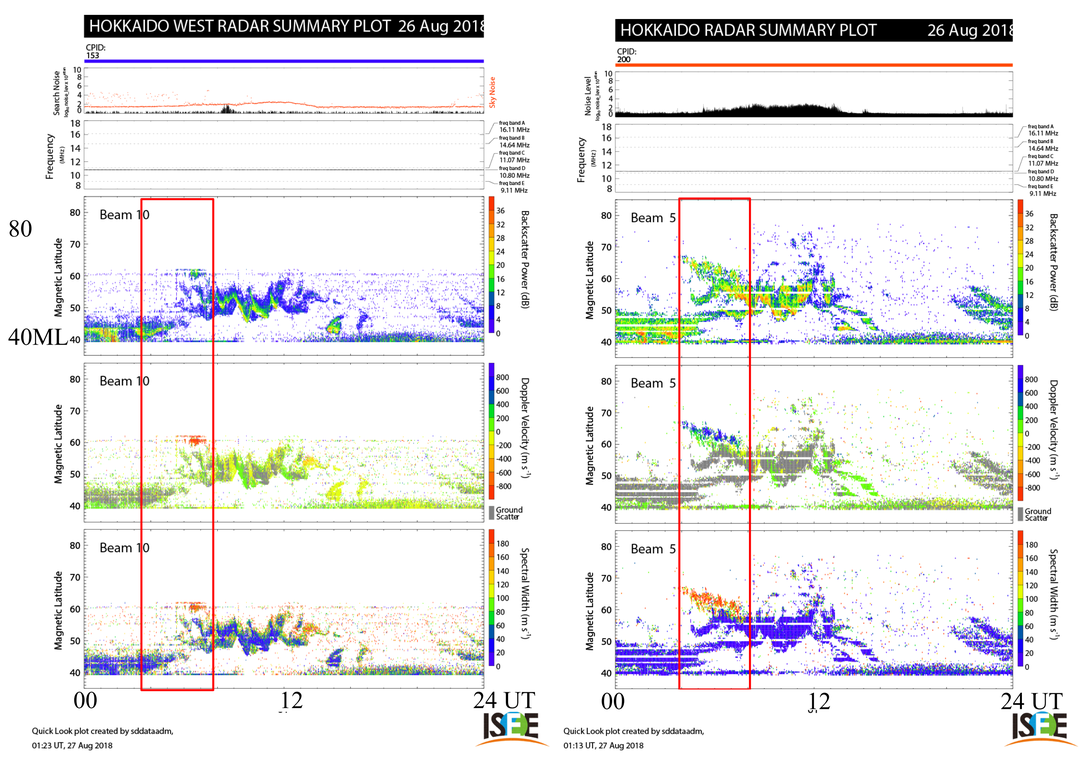
- **Several tens of mins variations**
  - Seem to be directly related to the solar wind pressure pulse and concurring substorm expansion.
- **10 min variations**
  - Similar to Foster et al. (2004) and Makarevich and Bristow (2014) SAPSWS although the present event has slightly longer period.
- **1 to 1.5 min variations**
  - Very similar to Pi2 pulsations, but…
    - The longitudinal wavelength (~ 10 degrees: m-number ~ 36, corresponding to propagation speed of 0.85 km/s) is much smaller than the typical Pi2 pulsations.
    - The Pi2 pulsation peak in the geomagnetic data is about 10 minute earlier (Norlisk magnetometer data, courtesy of Alexey Pashinin at ISTP RAS SB).
  - High m-number poloidal waves (e.g., Le et al., 2017 GRL and references therein)?
    - Similar period (>~ 100 s) and m-number (>~15), whereas their event continues longer (up to ~45 min) than the present event (~ 10 min).
  - Intermittent particle injection (e.g., Hori et al., 2018 GRL)?
- All of these variations seem to be associated with solar wind dynamic pressure pulse or substorm expansion onset, although further investigation is necessary.

Aug 26, 2018 event

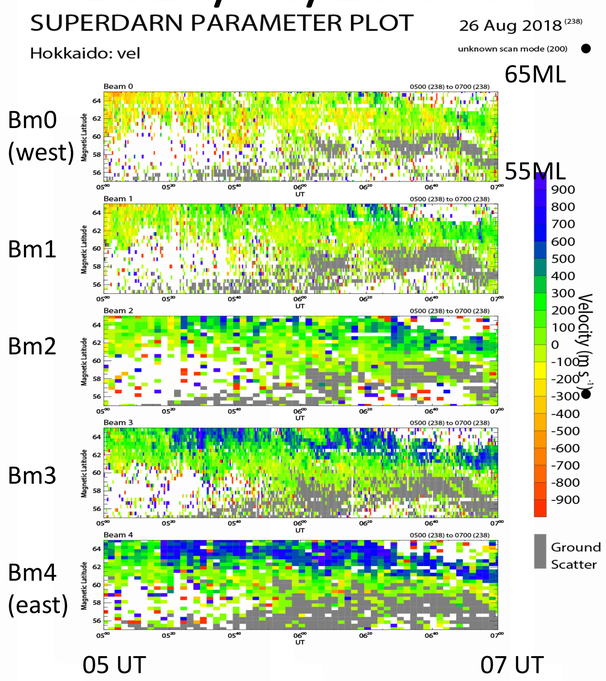
IMF, solar wind and geomagnetic parameters on 26 Aug 2018 (http://omniweb.gsfc.nasa.gov/ow_min.html)



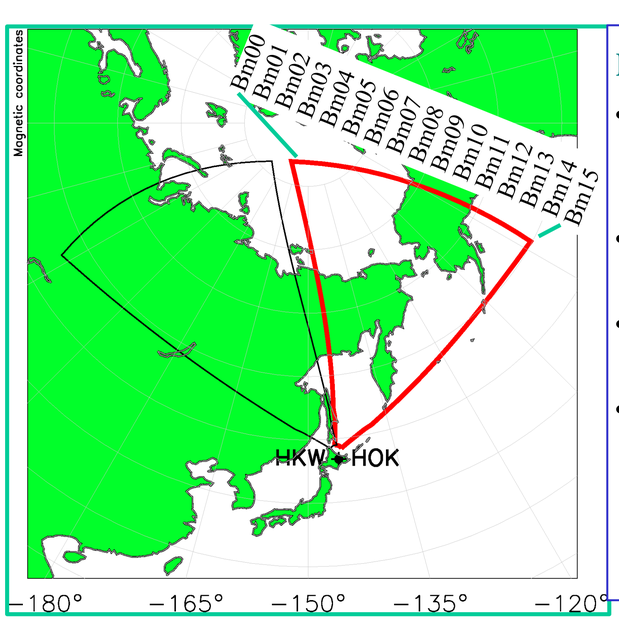
HOP East / West radars quicklook plots
Middle panel: Doppler velocities showing the presence of SAPS structures between 04 and 08 UT



2018/08/26 event characteristics



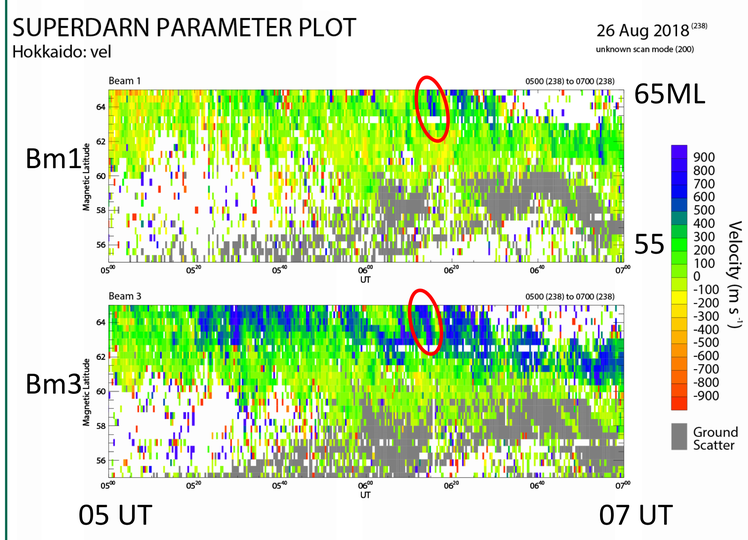
- During this event, the SD HOP East radar was (by accident!) operating with 'rbspscan' mode, where beams 0,1,3 were camping beams (12 s resolution) whereas other beams had 2 min resolution.
- This operation mode was run by mistake (storm-trigger mode should have been terminated!), but fortunately we can discuss the detailed characteristics of wave propagation.



rbspscan

- Beam sequence is such as: 15,1,0,14,13,3,12,1,0,11,10,3,9,1, 0,8,7,3,6,1,0,5,4,3,2,1,0,3,…
- Beams 0, 1 and 3 were scanned every 12 seconds
- Other beams were scanned every 2 mins
- With this mode it is possible to monitor the period, propagation speed and azimuthal wavelength of the pulsations of a few minutes

2018/08/26 event characteristics



- Using the rbspscan mode (12 s resolution for camping beams) we can discuss detailed characteristics of the wavy variations:
  - **Period** : ~5 min
  - **Propagation speed** (judging from beam 1/3 delay of 1.7 min): ~2.5 km/s westward
  - **Wavelength**: ~750 km (1 hr MLT) -> **M number**: ~24
  - **Stronger vlos for beam 3 (more eastward)**: toroidal mode?

Summary and Discussions: 2018/08/26 event

- The variation is characterized by ~ 5 min period wavy changes.
  - ➢ Similar to Foster et al. (2004) and Makarevich and Bristow (2014) SAPSWS.
  - ➢ Could be related to Pc5 variations
    - Propagation speed: ~250 km/s (westward)
    - wavelength: ~750 km (1 hr MLT)
    - m-number: ~24
    - Poloidal or toroidal? : not easy to identify because all camping beams are n-s oriented approximately, but more eastward beams have stronger vlos whereas both have max vlos of ~ 1000 m/s.
  - ➢ The generation mechanisms of these variations have not been fully understood.
- Variations could be triggered by small changes in IMF Bz / solar wind velocity, although further investigation is necessary.
- Further investigation is necessary to see whether the event is exactly located at auroral or subauroral region.

Summary of 26 Aug 2018 / 8 Sep 2017 events

Event date (min Dst)	UT/LT (max v)	Wave T	Speed (westward)	λ (m-number)	Possible trigger
2018/08/26 (-174 nT)	06UT / 16MLT	~5 min	~2.4 km/s	~750 km (m: ~24)	IMF Bz / SW velocity change
2017/09/08 (-109 nT)	12UT / 20MLT	~1-2min	~0.85 km/s	~500 km (m: ~36)	Pressure pulse / Substorm expansion onset
		~10min	-	-	
		~several 10mins	-	-	

Summary and conclusions

- (Mid-latitude) SuperDARN is a powerful tool for investigating the ionospheric convection dynamics at subauroral and mid-latitudes.
- Using the special operation modes (e.g., stereoscan@HKW / rbspscan@HOK) it is possible to investigate detailed characteristics of wavy flow variations mainly at subauroral latitudes.
- New data fitting algorithm (fitacf3) significantly increase the amount of echoes, which enables more detailed data analysis.
- Further discussion of their possible generation mechanisms is a subject of future studies.
- Comparison with spacecraft data (e.g., Arase, RBSP) is under way.

Another topic:

Mid-latitude SuperDARN review paper now published online!

Nishitani, N. J.M. Ruohoniemi, M. Lester, J.B.H. Baker, A.V. Koustov, S.G. Shepherd, G. Chisham, T. Hori, E.G. Thomas, R.A. Makarevich, A. Marchaudon, P. Ponomarenko, J.A. Wild, S.E. Milan, W.A. Bristow, J. Devlin, E. Miller, R.A. Greenwald, T. Ogawa, and T. Kikuchi (2019), Review of the accomplishments of mid-latitude Super Dual Auroral Radar Network (SuperDARN) HF radars, Prog Earth Planet Sci, 6:27.