Observing Sun-Magnetosphere-Ionosphere Coupling using High-Latitude Incoherent Scatter Radar Observations of Plasma Density Irregularities

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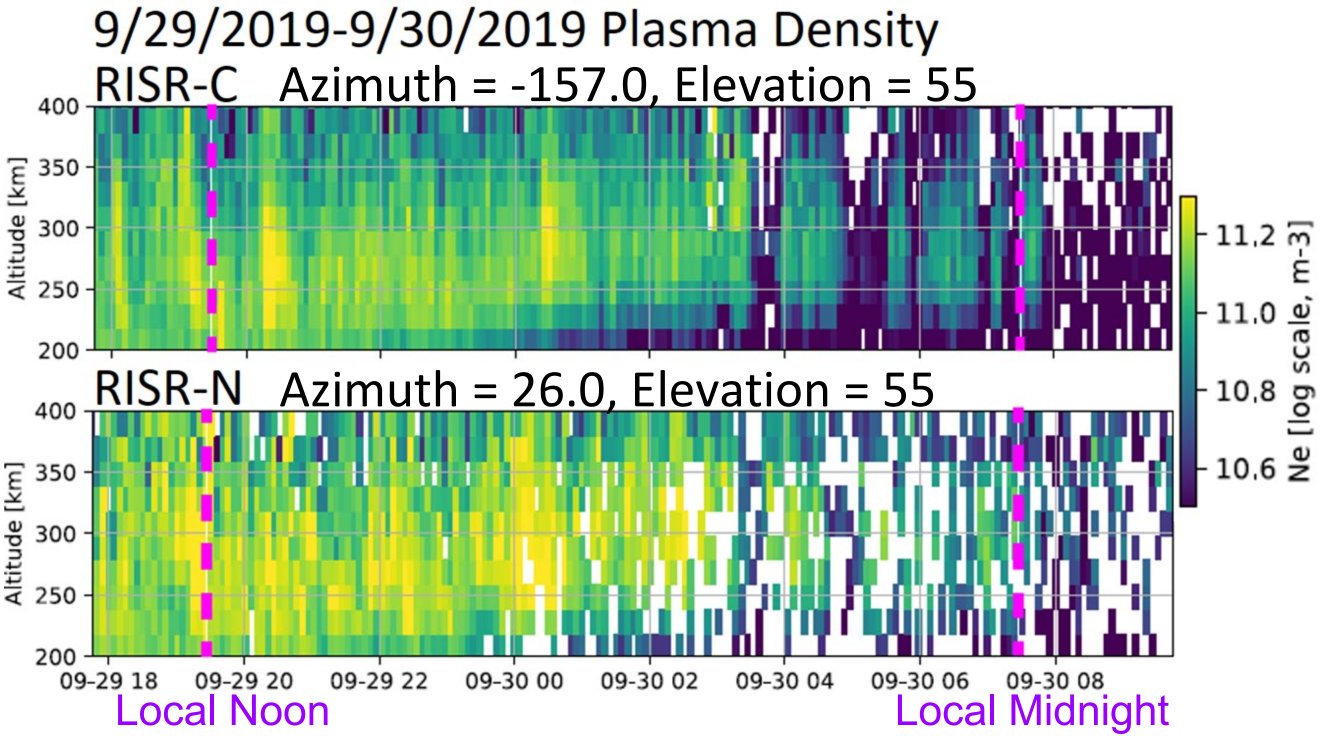
Living Planet Symposium - 5-25-2022



The high-latitude ionosphere is full of irregularities that evolve in shape and properties as they move along the streamlines of convection.

Although we know several ways in which plasma is structured in the ionosphere, there is still a lot we do not know.

9/29/2019-9/30/2019 Plasma Density

Ionospheric plasma is, to **leading order**, controlled by the sun.

In this sense, ionospheric plasma is a signature of the coupling of systems from the sun to the earth.

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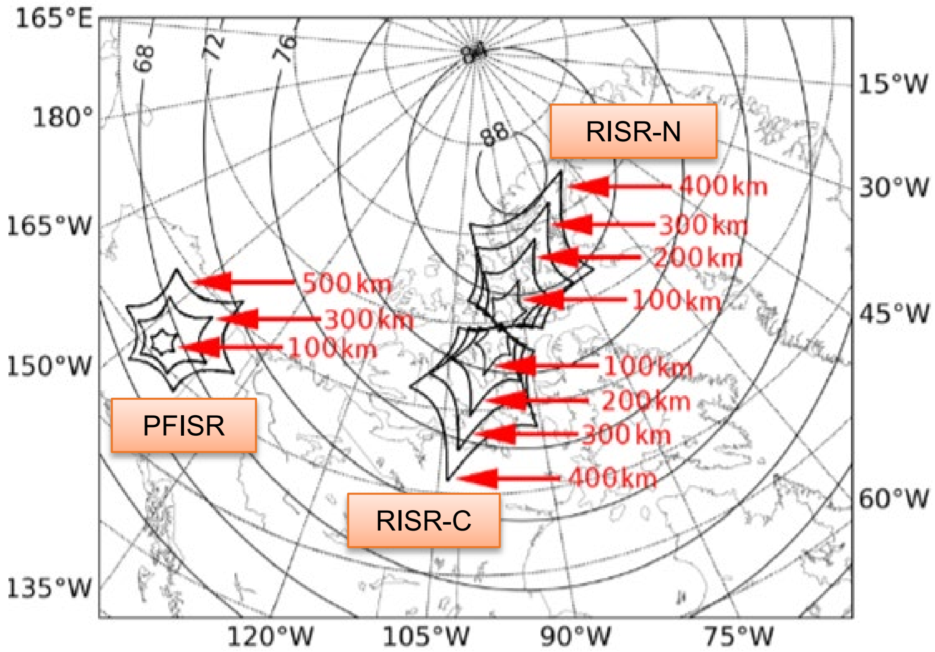
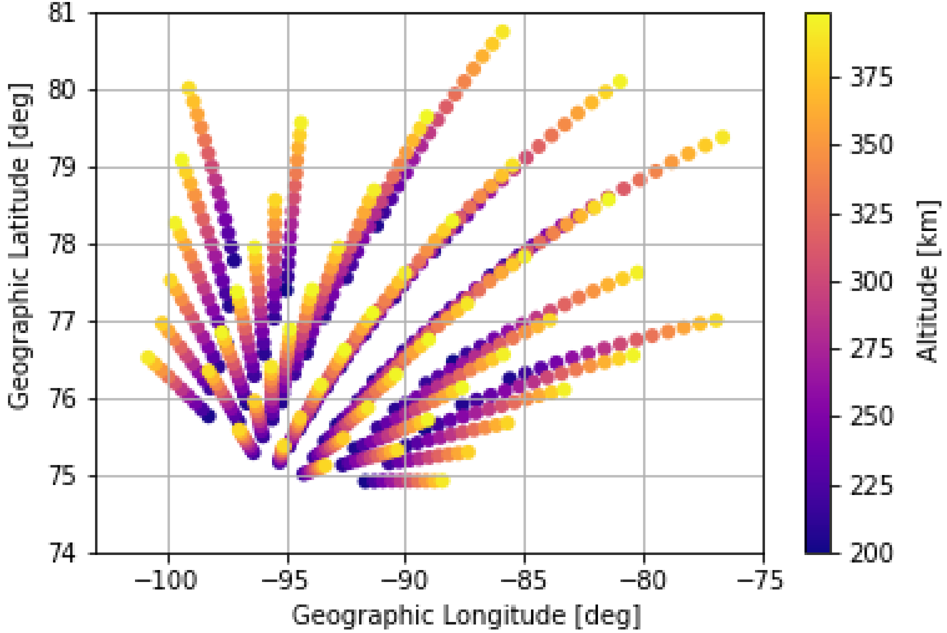
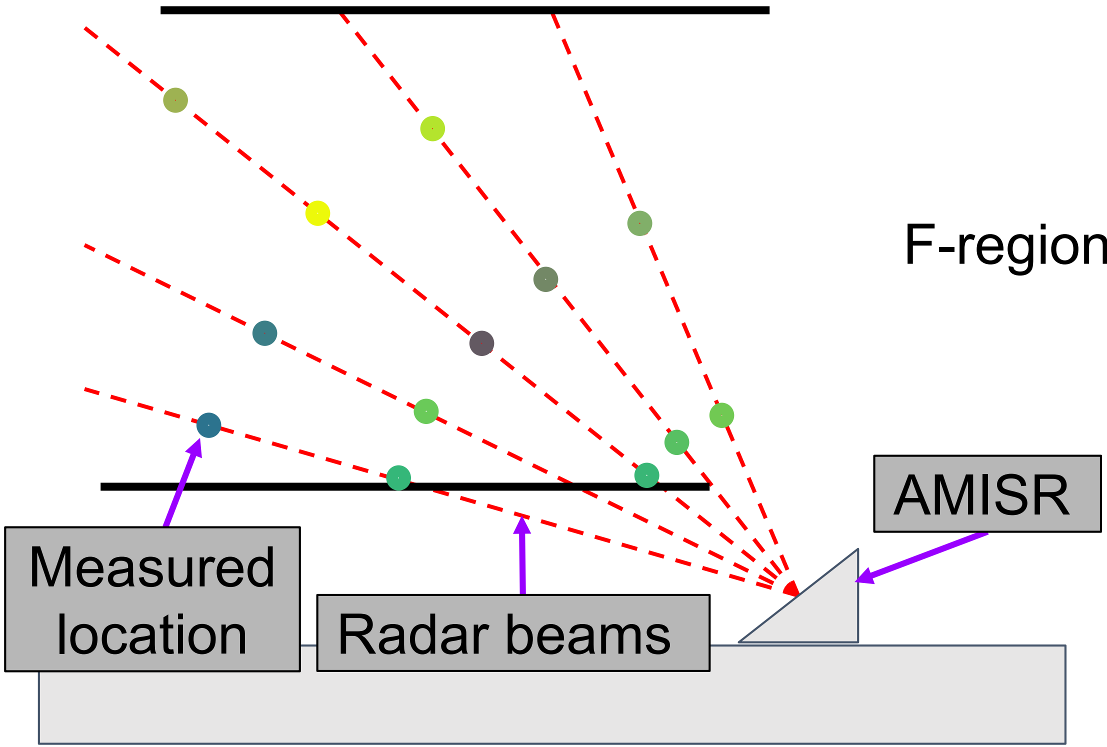
Advanced Modular Incoherent Scatter Radars (AMISRs) can examine multiple directions nearly simultaneously.





We measure a variety of field-aligned structures with an ISR, each with its own unique history.

Since diffusion is the dominant transport mechanism along magnetic field lines in the F-region ionosphere, we can artificially improve the spatial resolution if we resolve the vertical profile.



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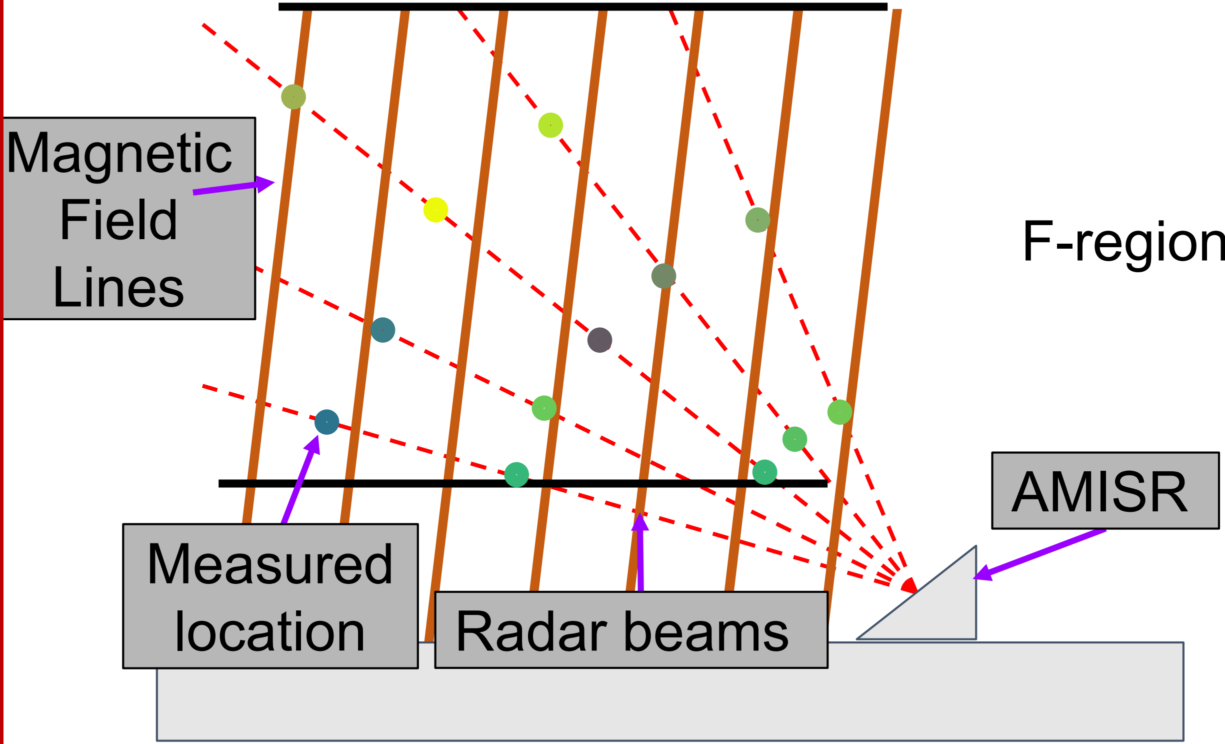

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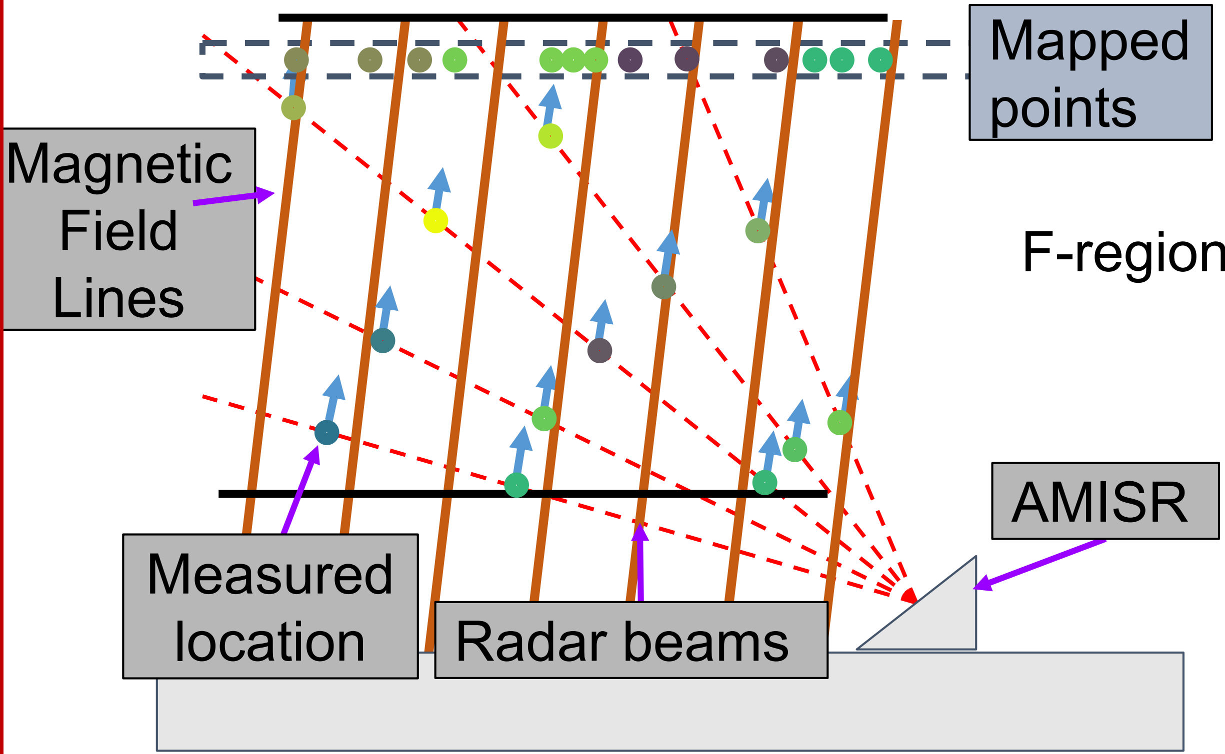
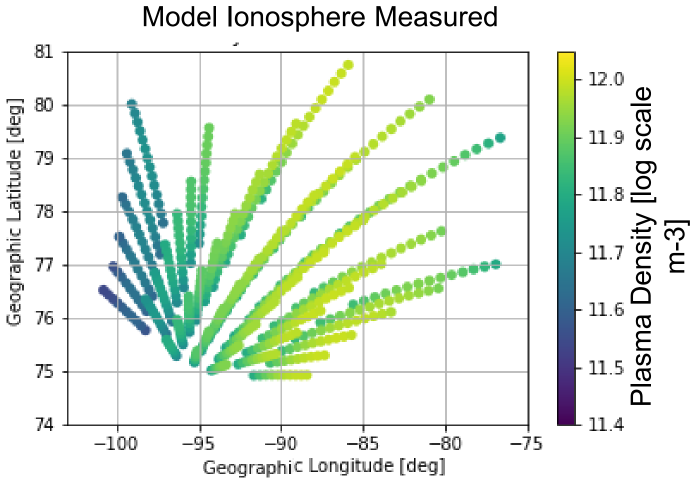
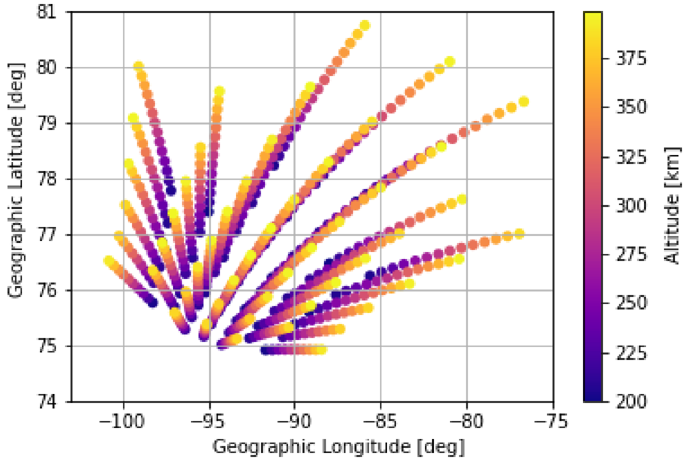


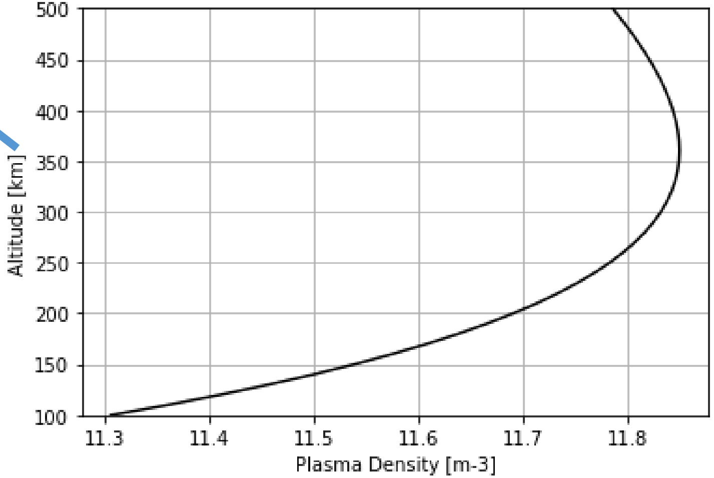
Mapping along field-lines

Observing sun-earth coupling through plasma irregularities





Model ionosphere =
Chapman vertical profile
+
Longitudinal Plasma Density Enhancement



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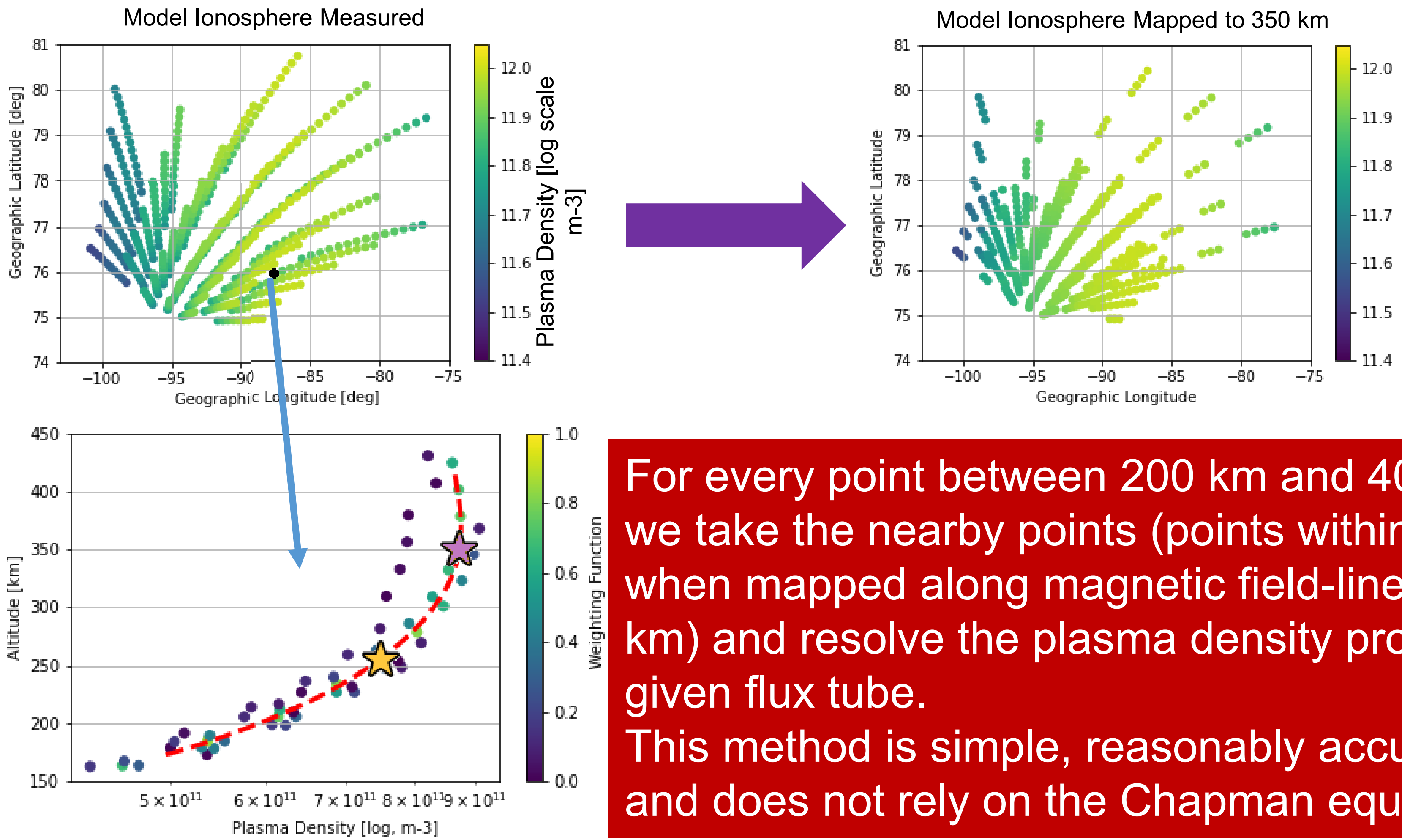
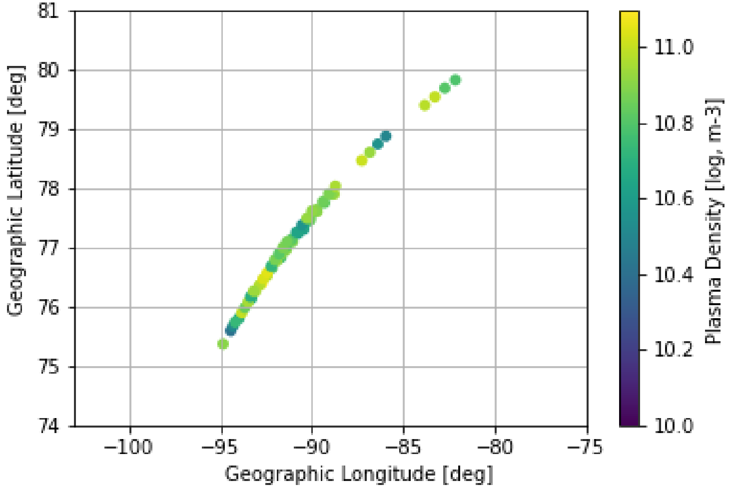


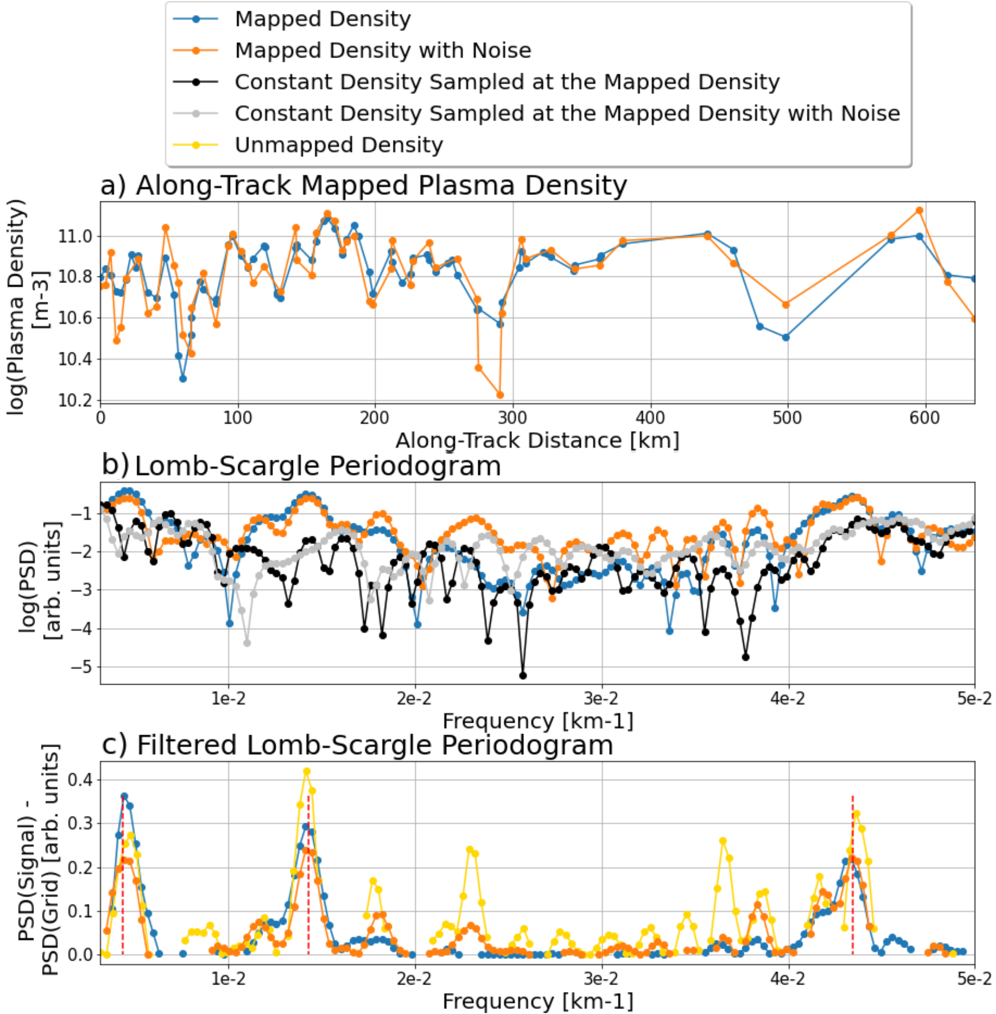
For every point between 200 km and 400 km, we take the nearby points (points within 50 km when mapped along magnetic field-lines to 350 km) and resolve the plasma density profile of a given flux tube.

This method is simple, reasonably accurate, and does not rely on the Chapman equation.

By applying a Lomb-Scargle periodogram to the mapped plasma density, we can resolve the input frequencies (1/23 km^{-1}, 1/70 km^{-1}, and 1/230 km^{-1}).

Peaks associated with sampling an irregular grid are removed.

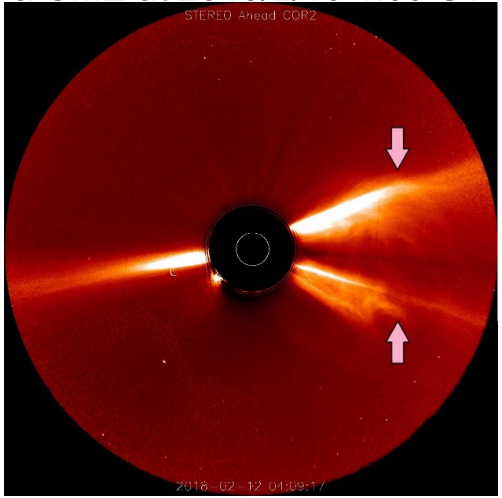




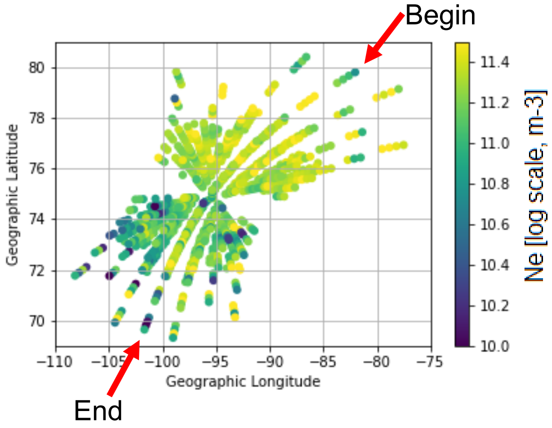
2018/2/15 flare event

Observing sun-earth coupling through plasma irregularities

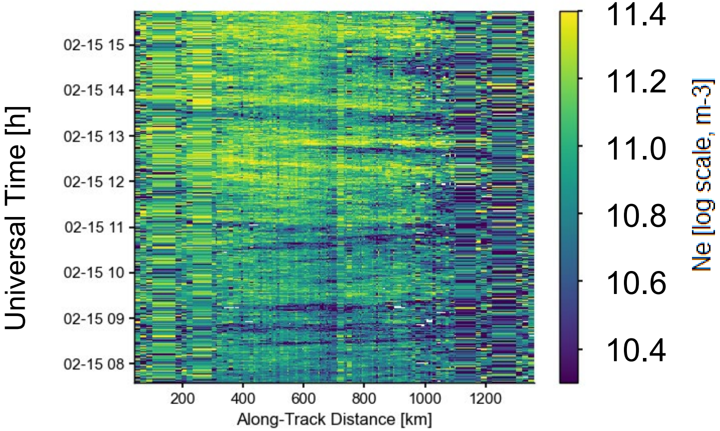
a) Solar TErrestrial REIations Observatory - Ahead (STEREO-A) observations of a CME at 2018/2/15 4:09 UT.



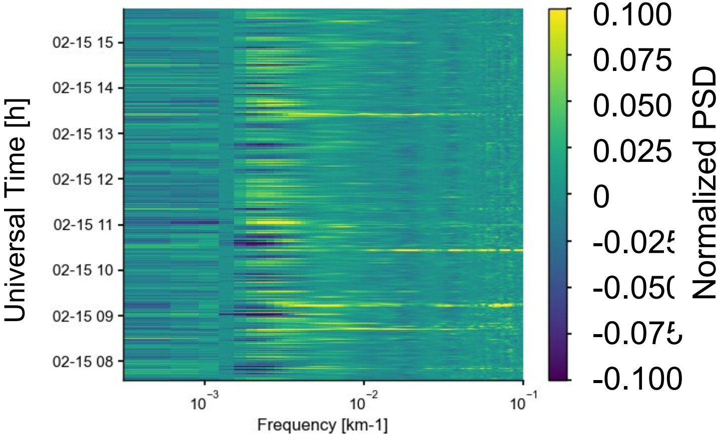
b) 2018/2/14, 18:52 UT mapped plasma density



c) Along-track plasma density

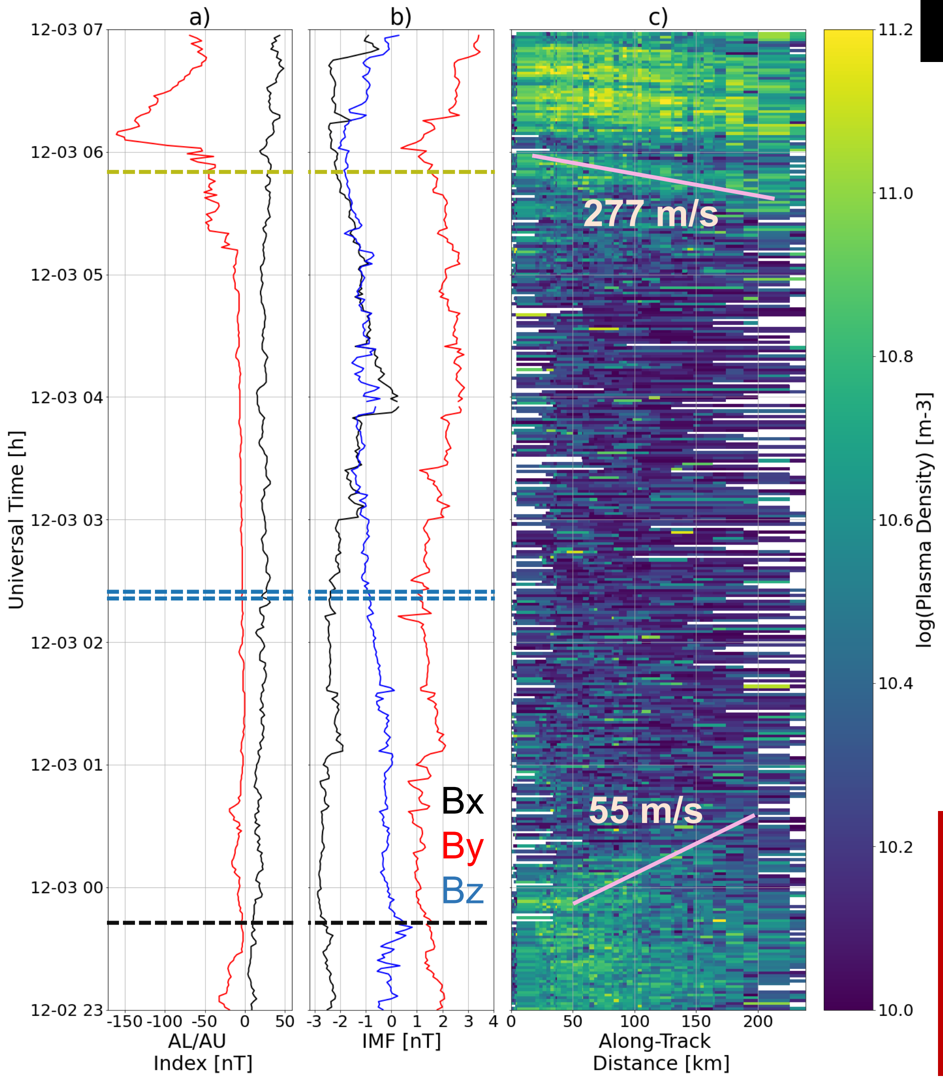


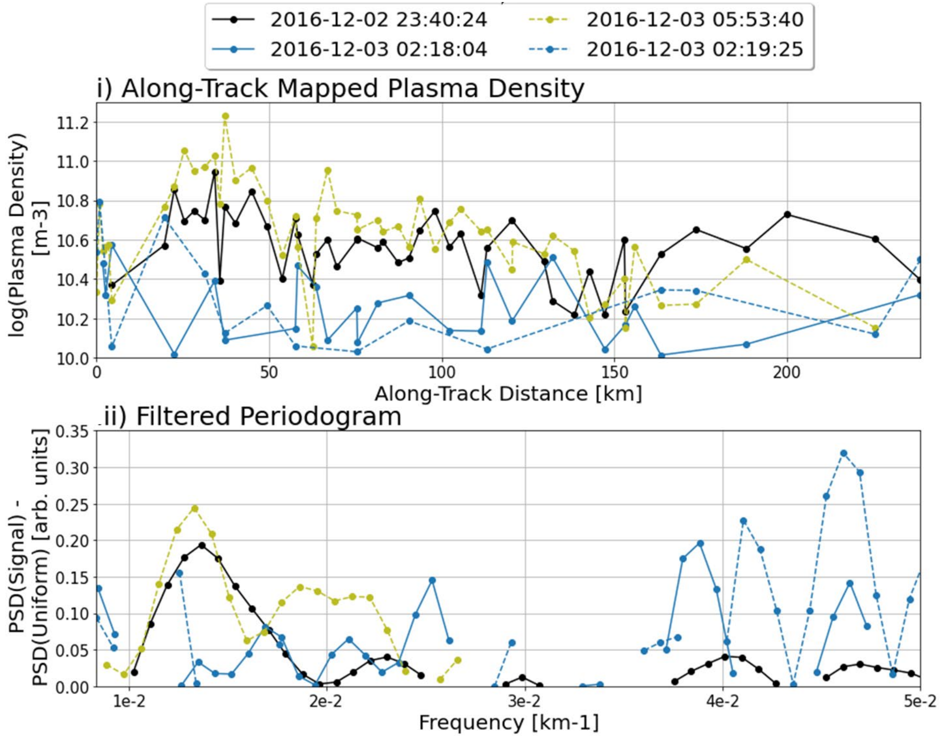
d) Normalized PSD, without artificial features



From RISR-N and RISR-C observations, mapped plasma density values are recovered when a 2018/2/12 Coronal Mass Ejection (CME) impacts the Earth at approximately 9 Universal Time 2018/2/15.

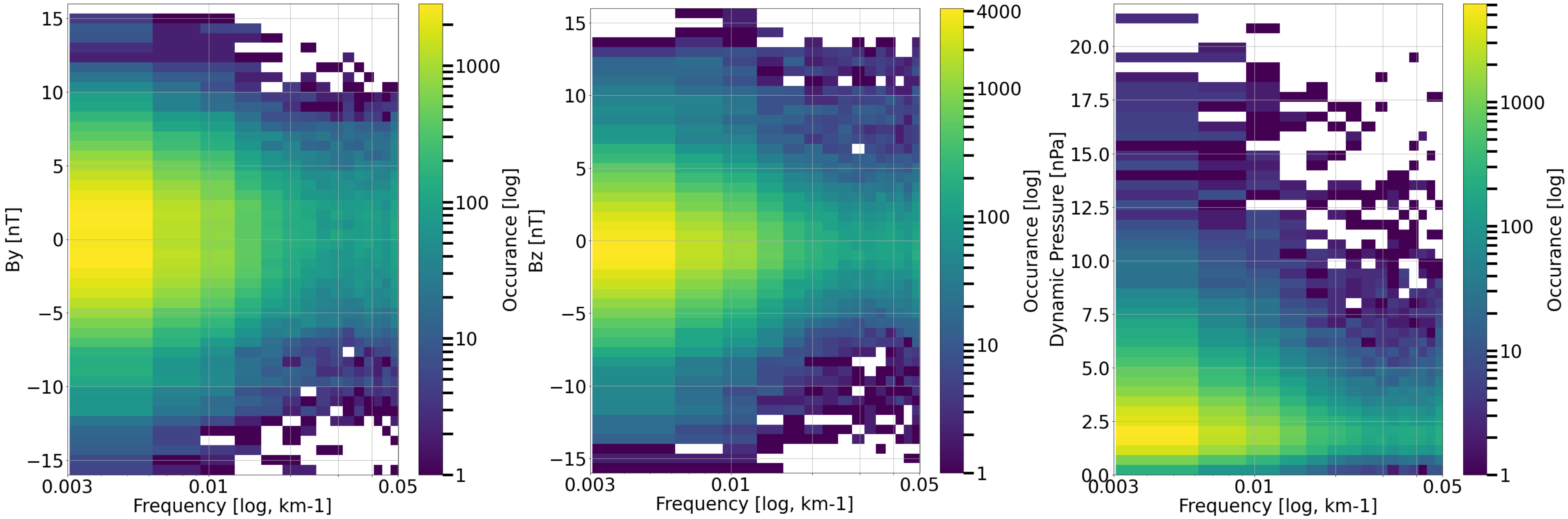
Plasma depletion structures



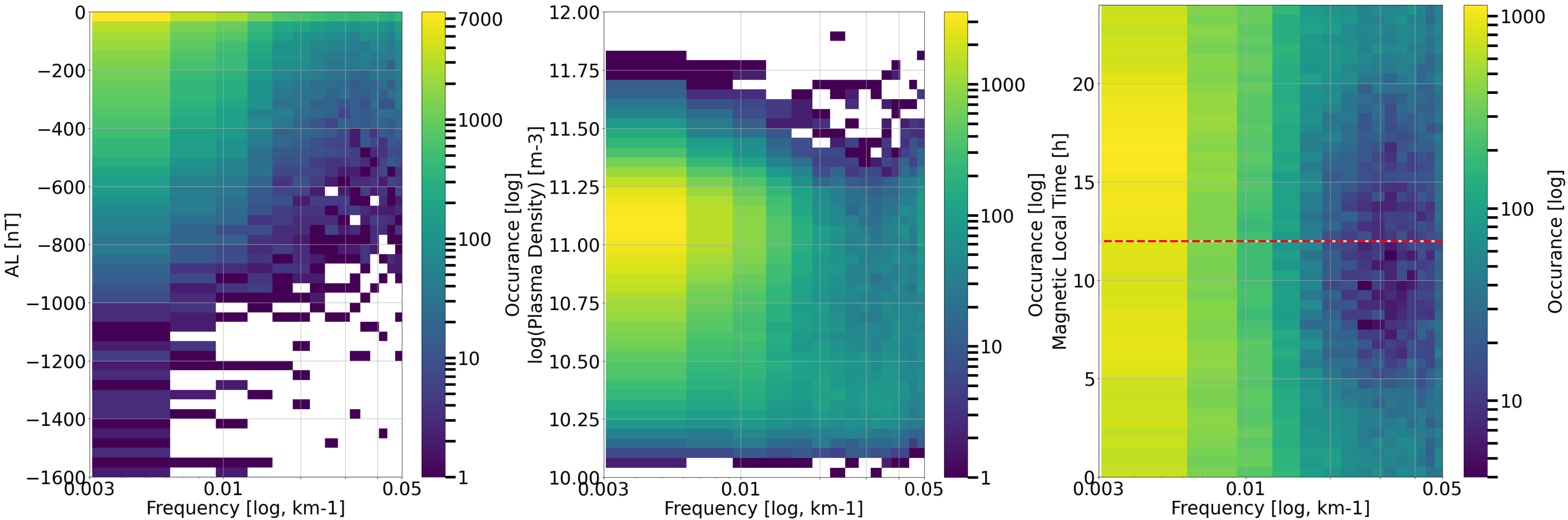


During a geomagnetically quiet period, a large plasma density depletion appears at dusk. Within this depletion, the spectral power shifts to smaller scale structures.

Statistics of dominant structures



Between 2016 and 2018, a 52 beam imaginglp mode ran intermittently on RISR-N for approximately 4600 h (890 h in spring, 225 h in summer, 650 h in fall there are 27279 samples, and 517 h in winter).



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- Using AMISR observations and flexible mapping techniques, it is possible to resolve high-resolution measurements of plasma density at a given altitude.
- This technique does not require the Chapman equation or quantifying plasma production and loss.
- This technique can be used to characterize density structures in the polar cap, which is important because models do not fully capture the structuring here, nor do they account for transient events.
- Large-scale structures (>100km) will be a “dominant” frequency under a variety of conditions
- Small-scale structures (<50km) become a “dominant” frequency during periods of quiet geomagnetic activity, at low densities, and from dusk to dawn

Future work

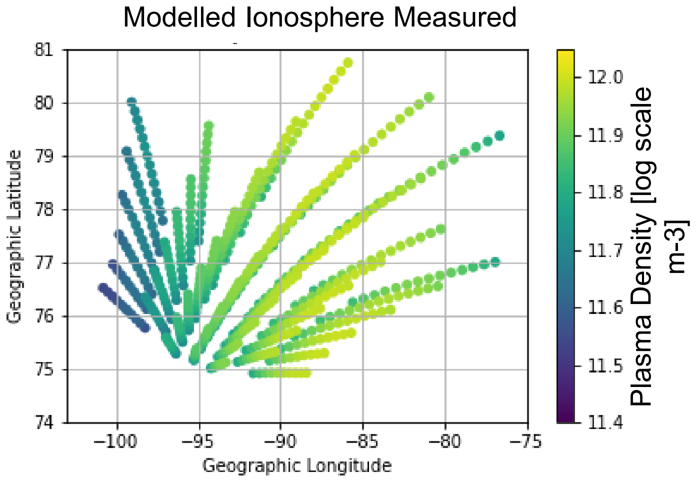
- Examine radio wave propagation data (SuperDARN)

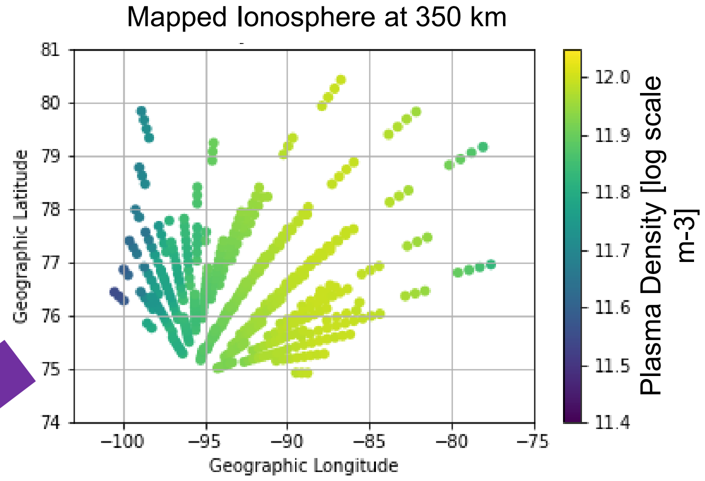
Acknowledgements: SRI International, Kyoto World Data Center, NASA Living With a Star Jack Eddy Postdoctoral Fellowship Program (award NNX16AK22G).

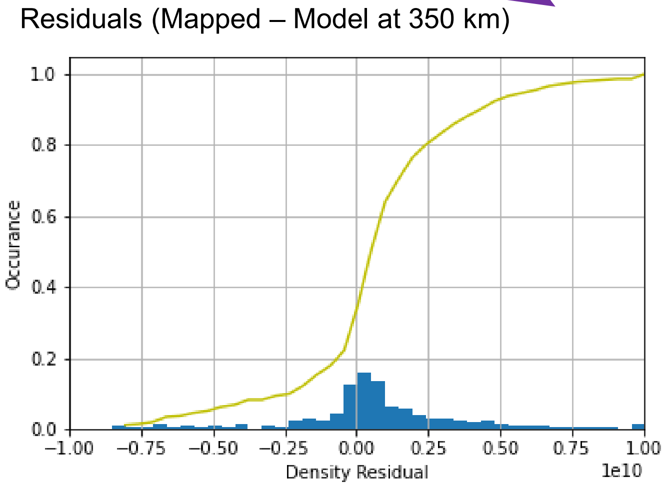

Thank you

Plasma density structuring

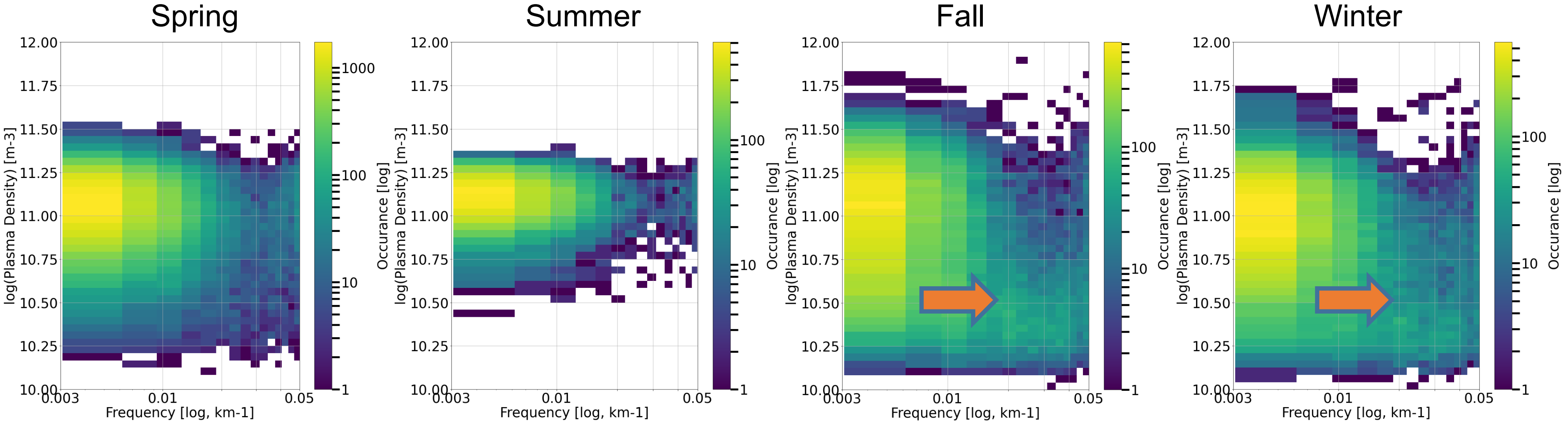
Observing sun-earth coupling through plasma irregularities







Although this method is simple it is also reasonably accurate, and does not rely on the Chapman equation. It is also flexible (we can increase the horizontal bins, and pick any altitude between 200 km- 400 km).



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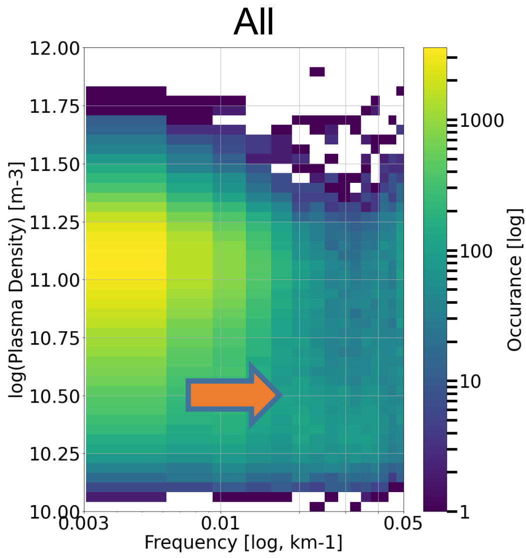
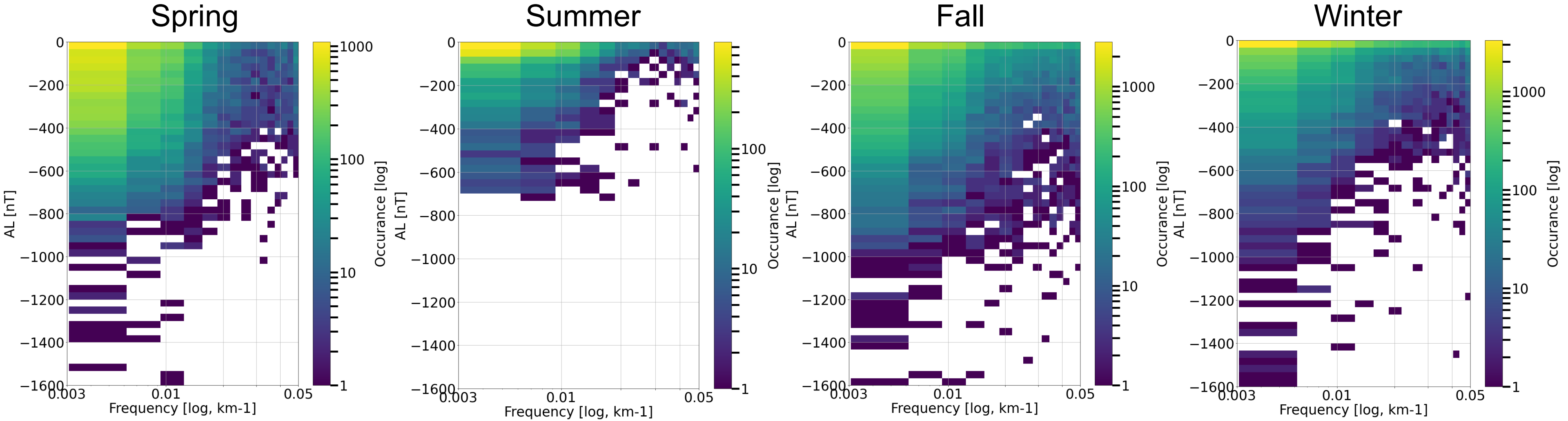
The spectral power goes to smaller scales (<50 km) during lower plasma densities.





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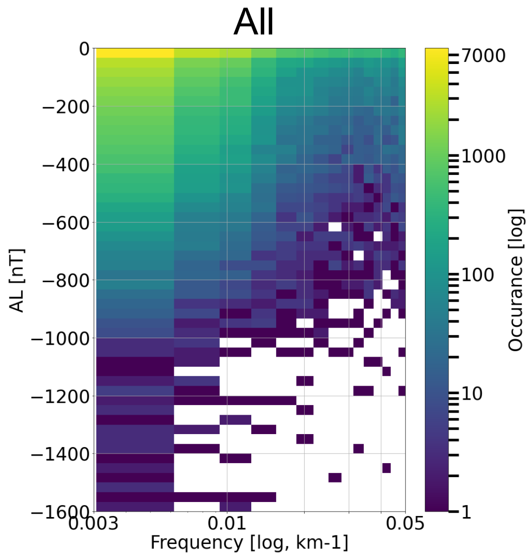
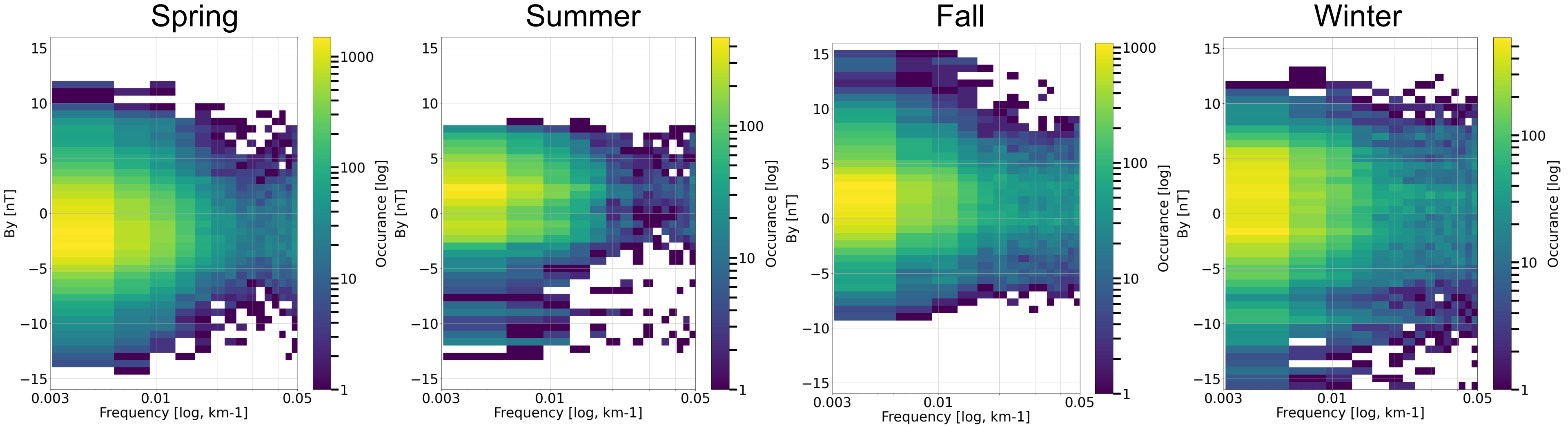
The spectral power goes to smaller scales (<50 km) during geomagnetically quieter periods.





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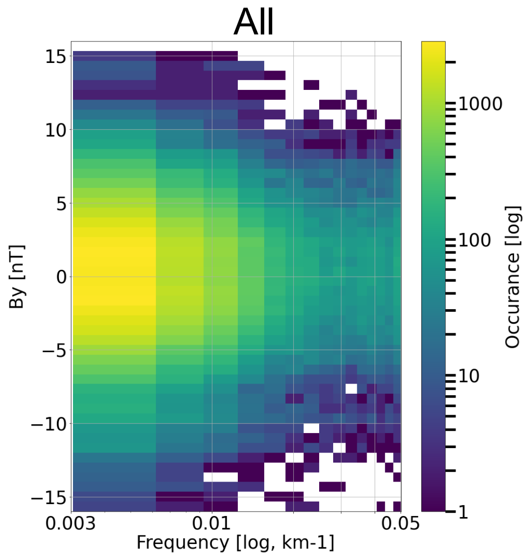

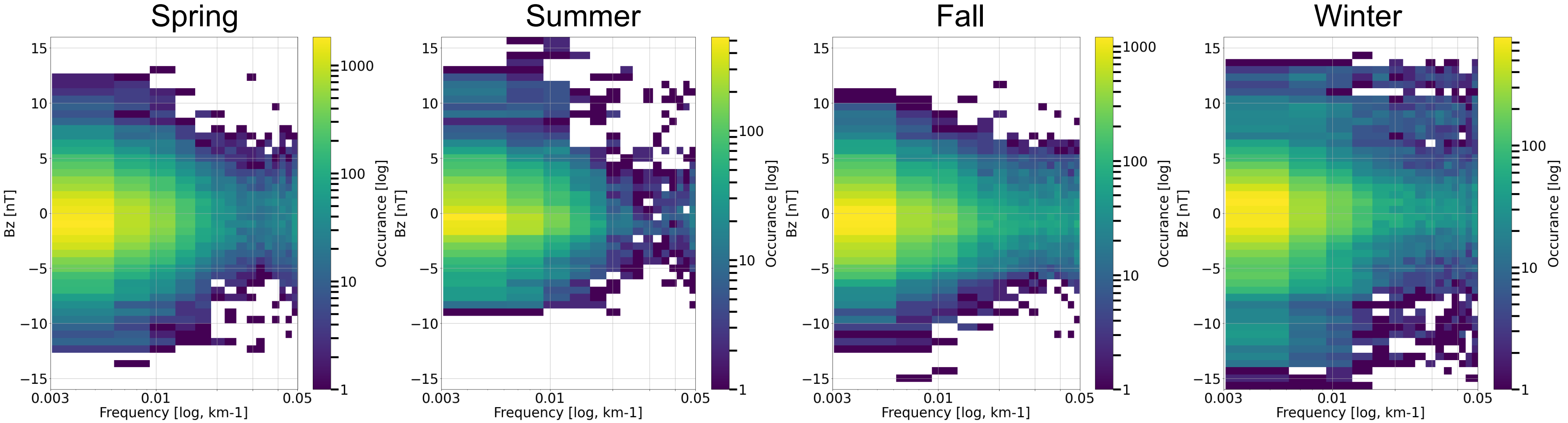

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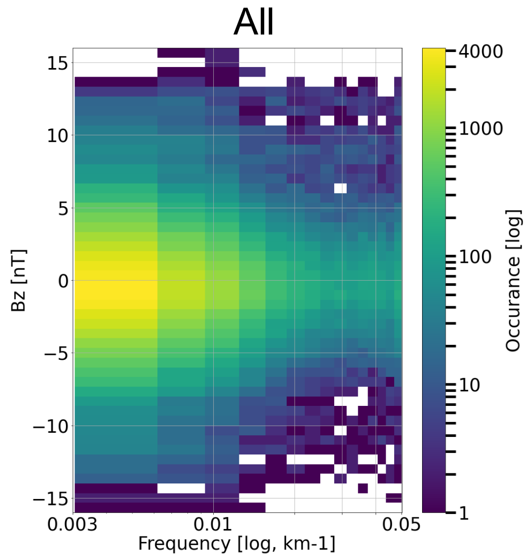

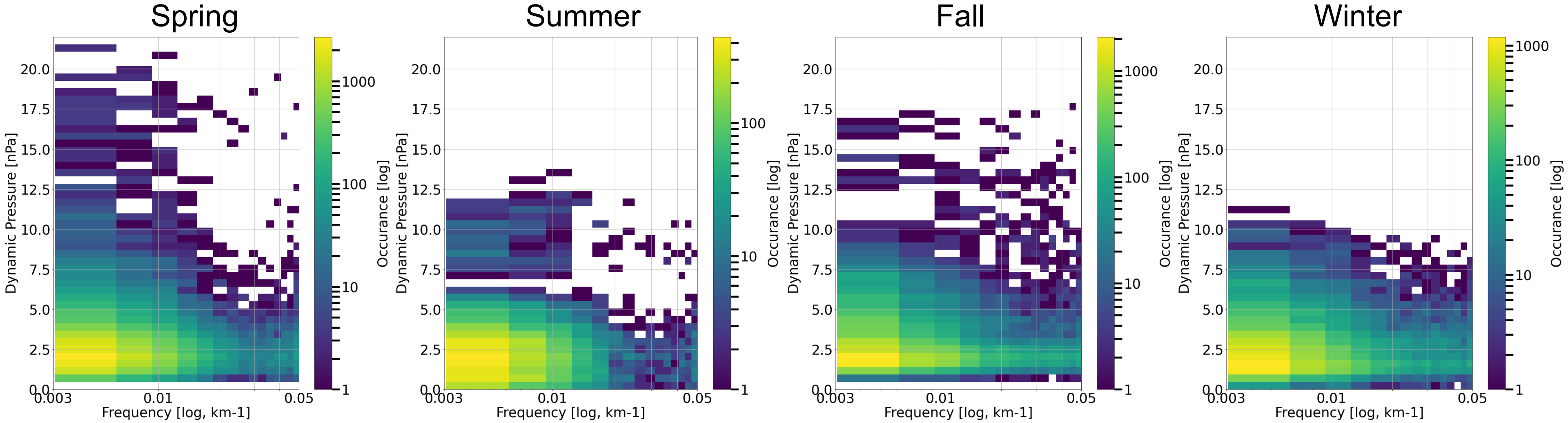

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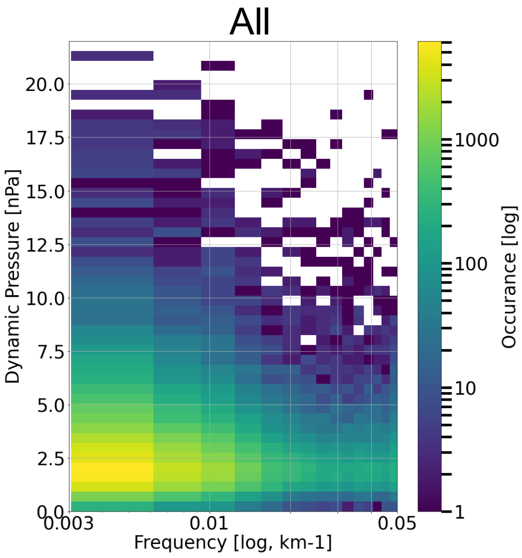

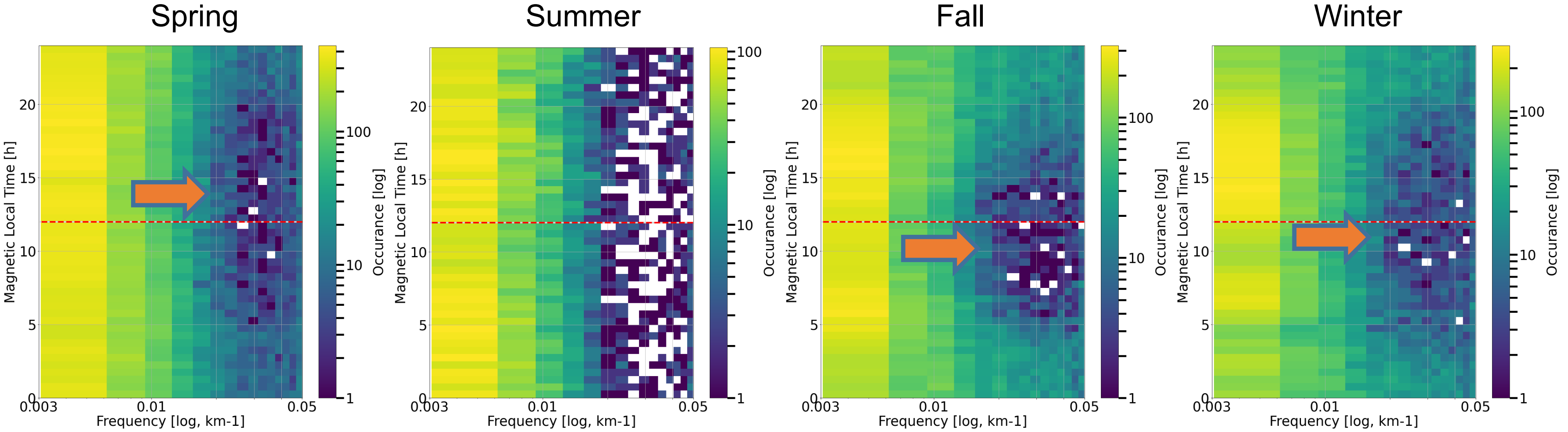

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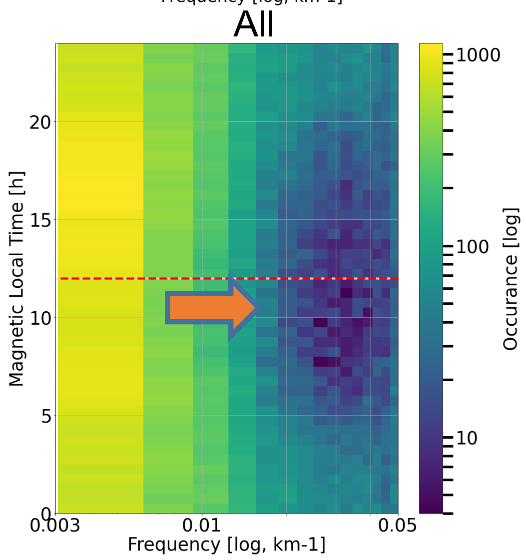

The "snap-shot" we wish we could see