Examining the ionospheric sources of reduced coherence streaks in L-band SAR interferograms at high-latitudes

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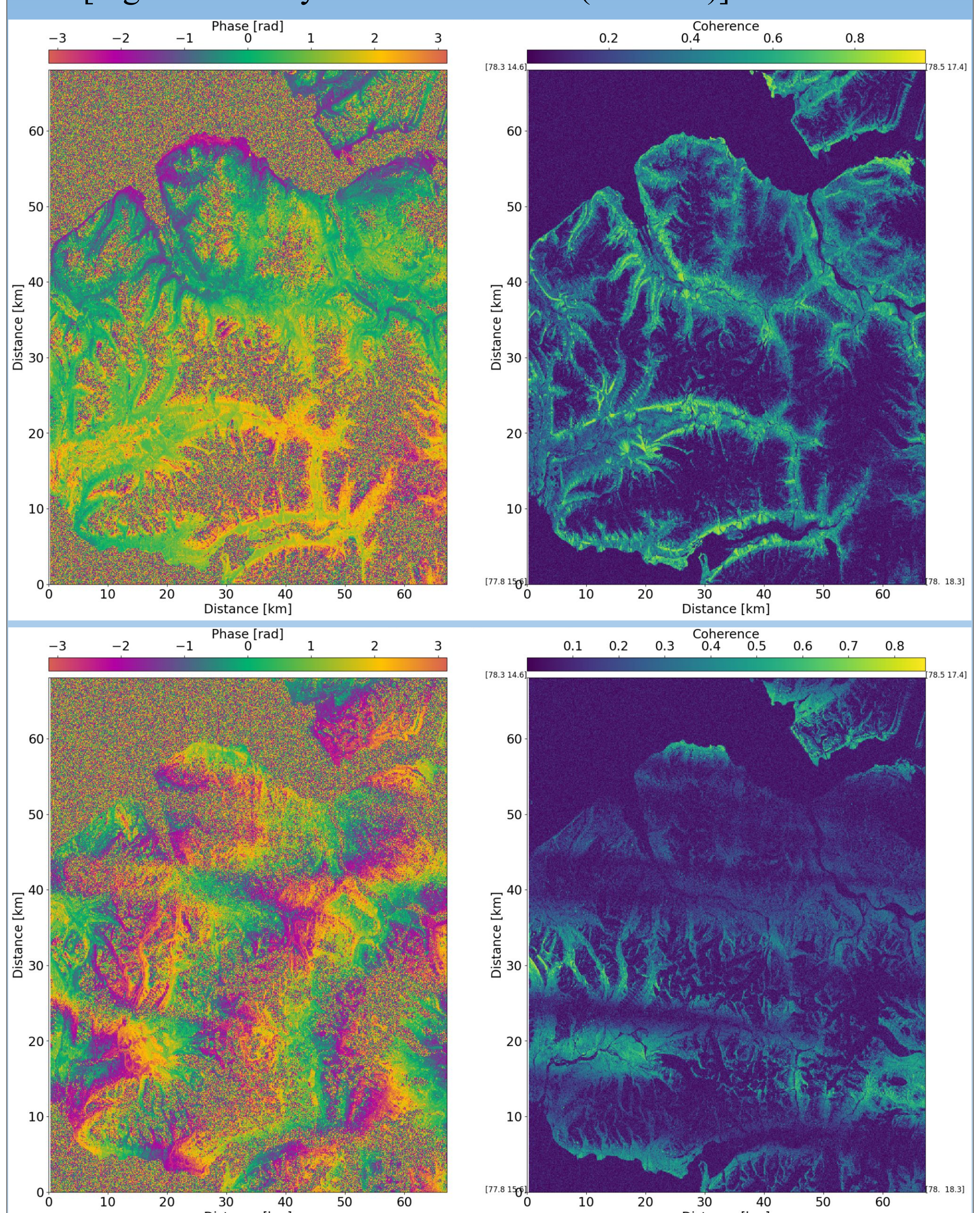
Background and Motivation

- L-band (1-2 GHz) Synthetic Aperture Radar (SAR) signals are sensitive to ionospheric variations, producing phase distortions.
- Degraded SAR doppler phase produces azimuth streaks of reduced coherence in interferograms, which are associated with particle precipitation (Sato et al., 2018).
- **A multi-instrument approach combining interferograms, ground, and in situ measurement is used to explore the link between SAR signatures with plasma structures.**

Dataset and Methodology

- Interferograms obtained from Phased Array L-band Synthetic Aperture Radar (PALSAR-2) aboard Advanced Land Observing Satellite (ALOS-2) are observed from year 2020-2024, to detect events with azimuth streaks of reduced coherence.

Fig. 1: Example interferograms. (Top) Combined observations from July 3, 2021 and October 9, 2021 showing no streaks. (Bottom) Combined observations from September 7, 2024 and September 9, 2023 showing azimuth streaks. [Figure Courtesy: Liliana Macotela (NORCE)]



- ALOS-2/PALSAR-2 observations were made for 70 x 70 km regions in Svalbard, Tromsø, Finnmark, and Southern Norway.
- Range-Time-Intensity (RTI) plots for plasma parameters measured from EISCAT radar (Wannberg et al., 1997) were analyzed around initial ALOS passing time.
- Electron density measurements (2 Hz) from Langmuir Probe (EFIx_LP_1B) onboard Swarm satellites (Olsen et al., 2013) were obtained for a ±30 minute window of ALOS overpass within a 100 km horizontal radius of ionospheric pierce points projected to Swarm altitudes along the ALOS-2 line of sight.
- Continuous wavelet transform (CWT) is performed on the density measurements in the region of interest (Torrence, C., & Compo, G. P., 1998).

Results

Fig. 2: EISCAT observations of ionospheric parameter residuals. (Left) Example event with no azimuth streaks. (Right) Example event showing azimuth streaks. Vertical red line indicates the starting time of ALOS-2 passing over the region of interest.

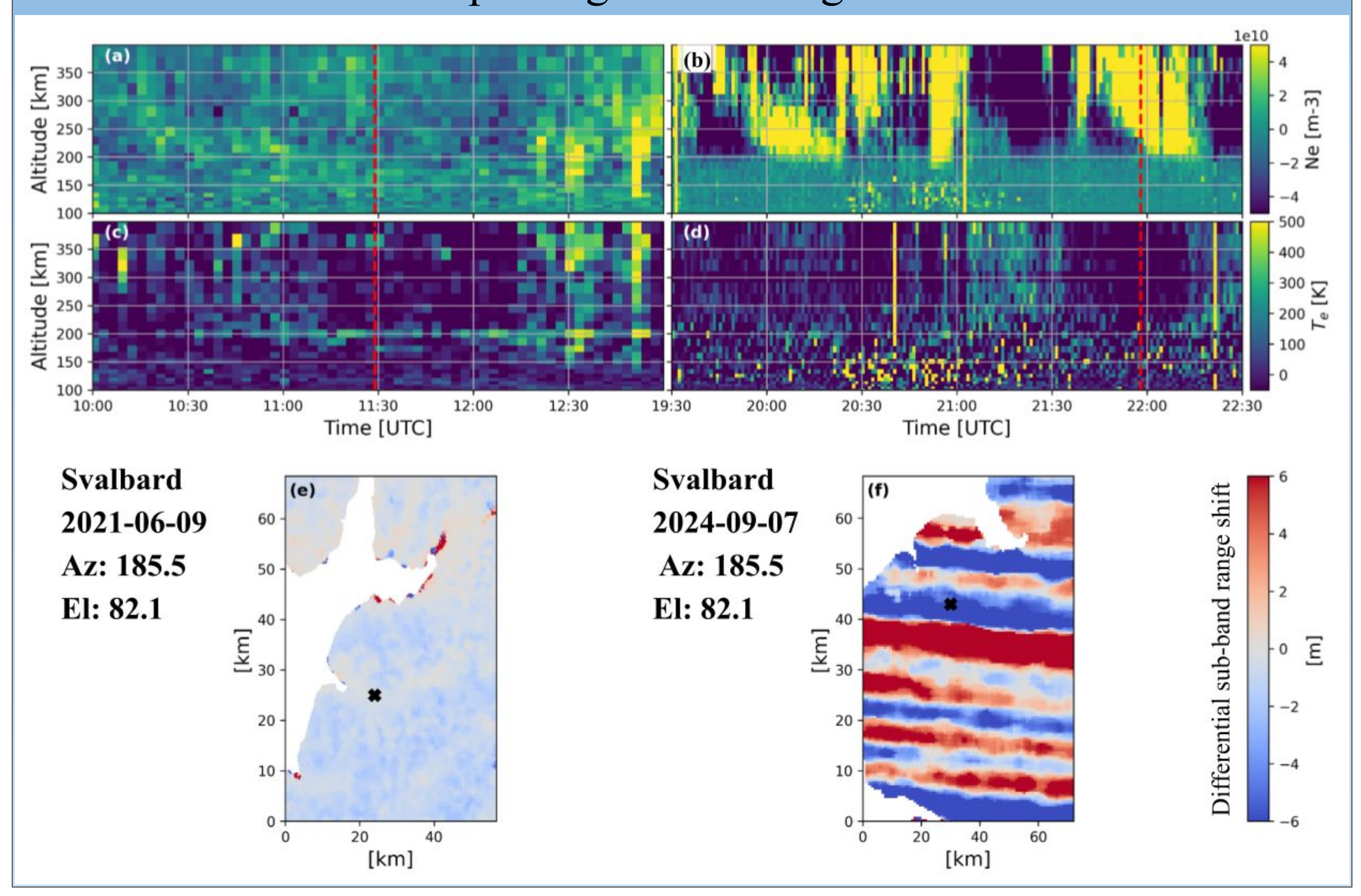
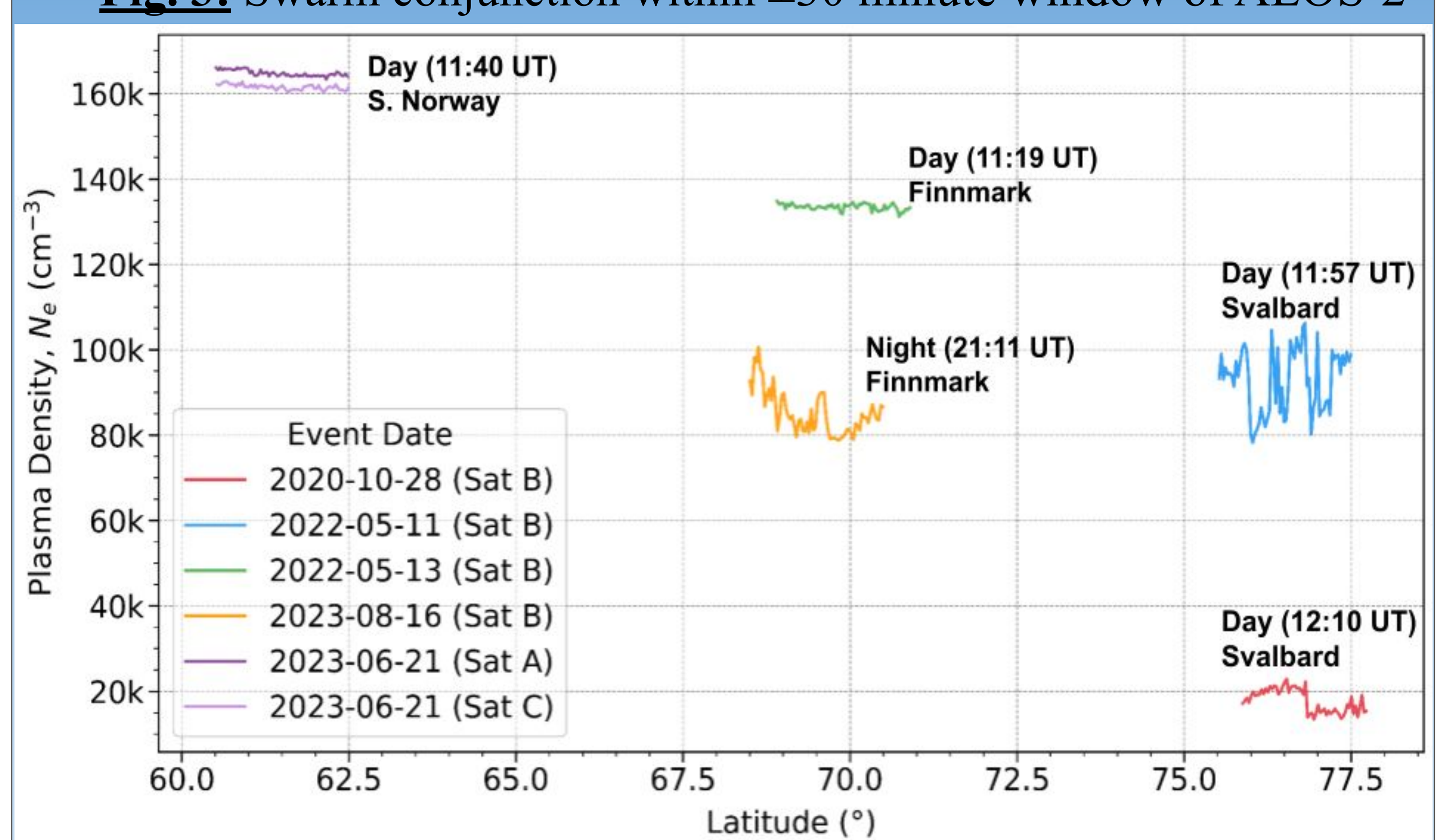


Fig. 3: Swarm conjunction within ±30 minute window of ALOS-2



- Five events were identified for conjunction between ALOS and Swarm satellites around 100 km horizontal radius of ionospheric pierce points projection.

Fig. 4: CWT analysis for event with no azimuth streak (Case 1)

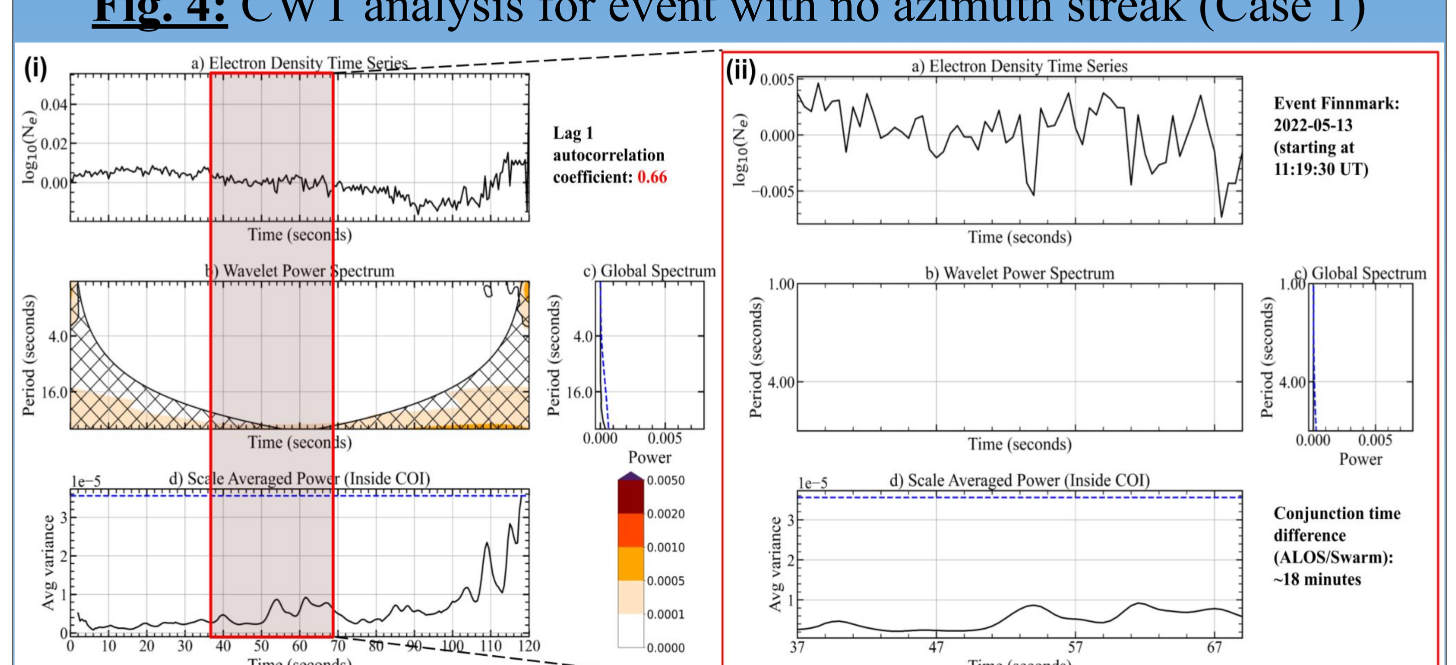
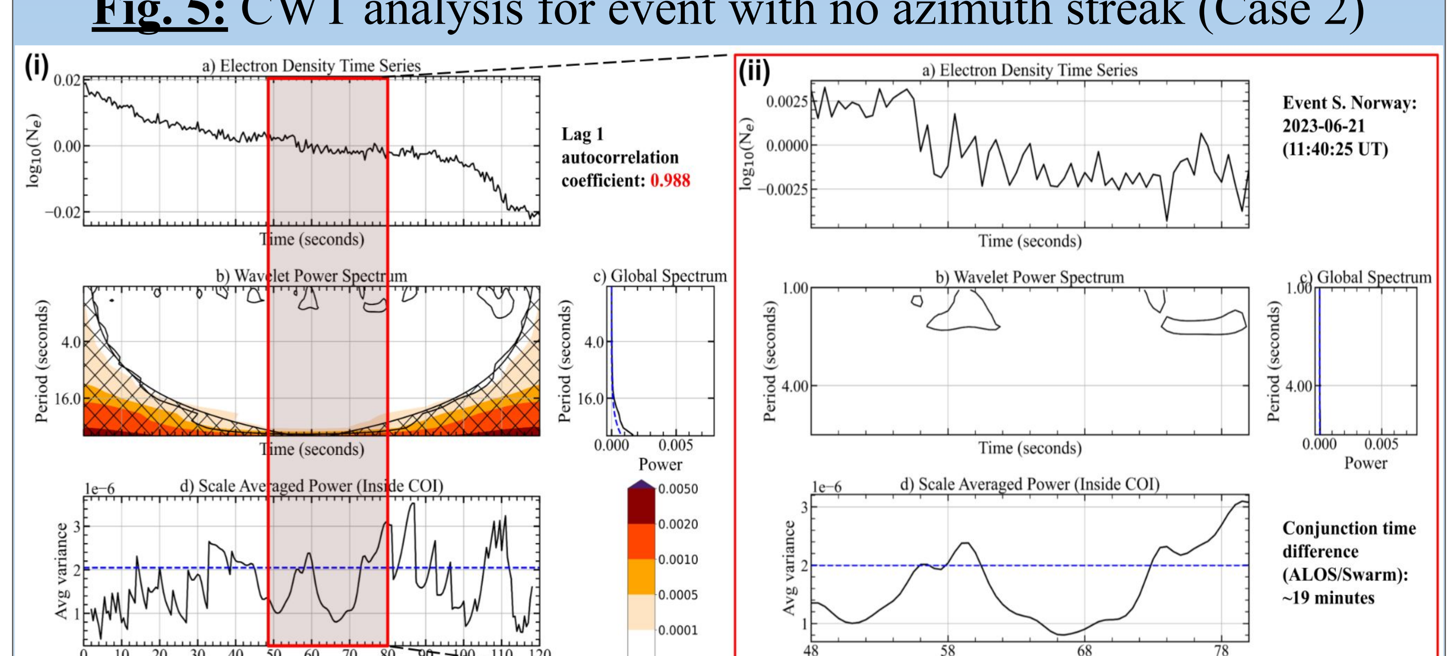


Fig. 5: CWT analysis for event with no azimuth streak (Case 2)



Results

Fig. 6: CWT analysis for event with azimuth streak (Case 1)

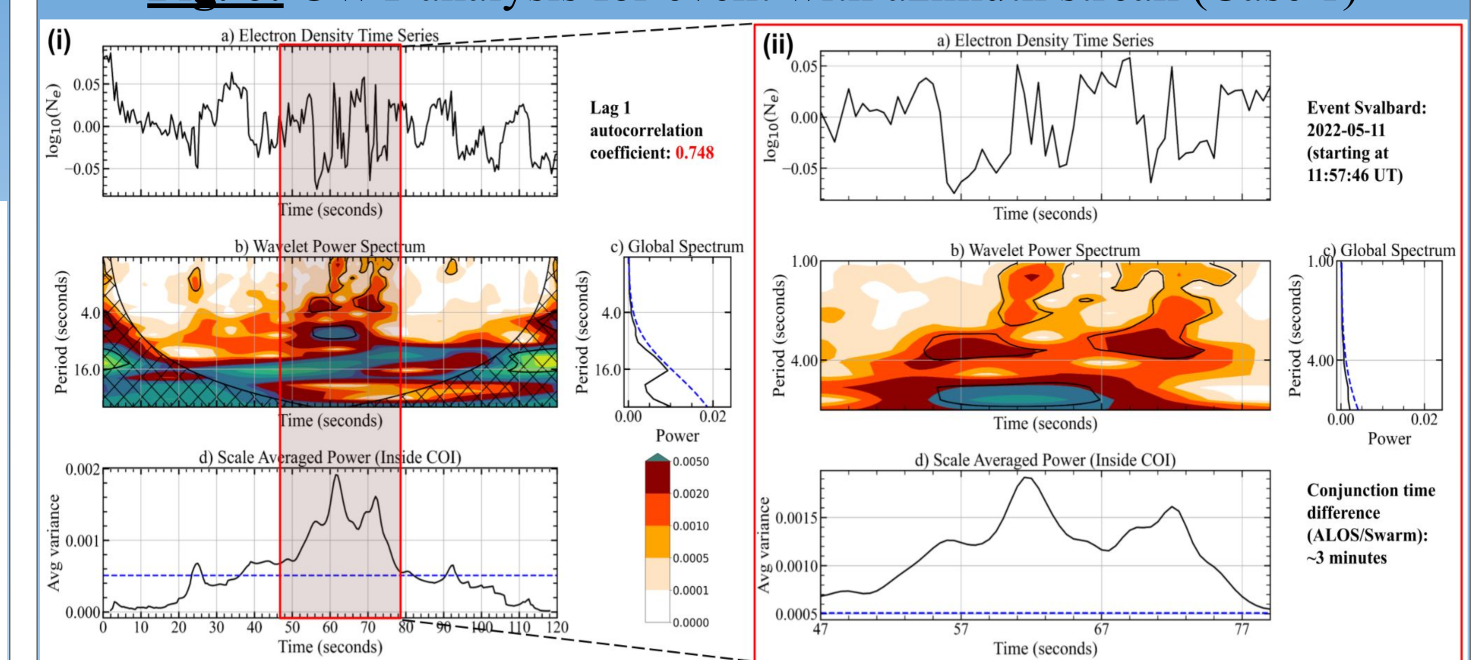


Fig. 7: CWT analysis for event with azimuth streak (Case 2)

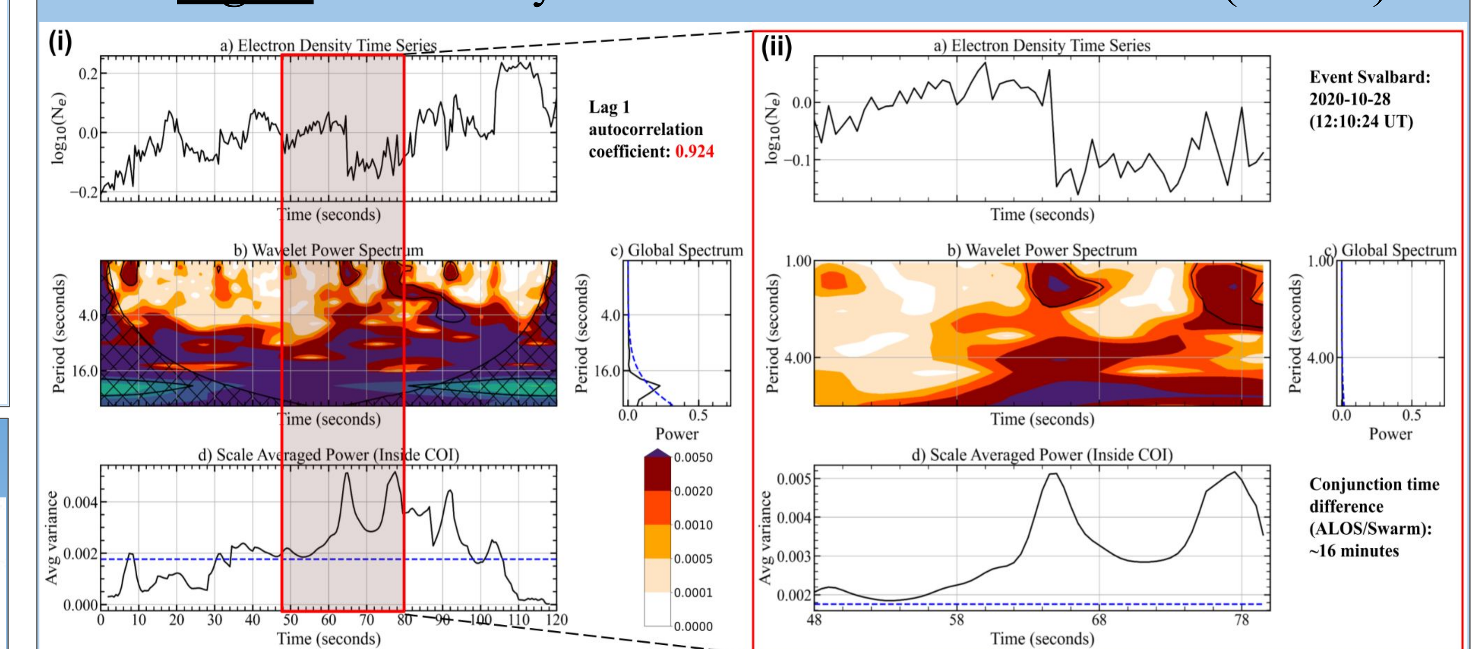
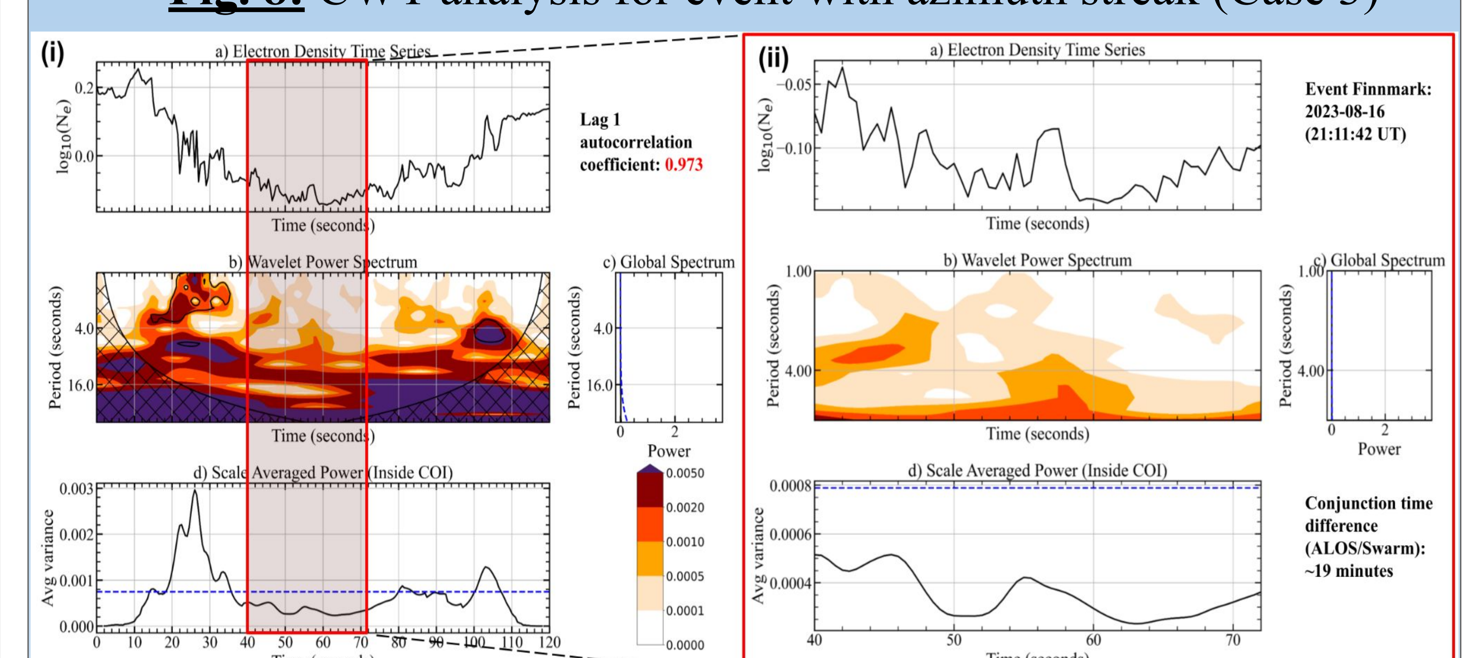


Fig. 8: CWT analysis for event with azimuth streak (Case 3)



- Density time series are normalized and mean centered before convolving the time series with Morlet wavelet.
- Lag 1 autocorrelation coefficient is calculated to characterize the background red noise spectrum.
- Significant structures are marked if observed power exceeds the 95% confidence level derived from the red noise spectrum.

Conclusions

- Reduced coherence structures are observed even during events with no detectable particle precipitation, indicating that coherence loss is likely associated with density features and structures rather than direct precipitation driven ionization.
- No significant structures or structures of negligible wavelet power are observed for events without azimuth streaks features, while significant density structures of medium scale and decent wavelet power are observed for events associated with reduced coherence features in the interferograms.

Acknowledgements

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References

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