Source regions of irregularities causing GNSS scintillation: An investigation using EISCAT

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Abstract

We present the results of an investigation conducted at the dayside polar ionosphere to identify the source region of irregularities that causes scintillation in GNSS signals. By taking advantage of the fast-scanning capability of the 32-m European Incoherent SCATer (EISCAT) radar on Svalbard (ESR), ionospheric phenomena over a wide range of geographic latitudes are captured in a short span of time. By combining the radar observations with scintillation measurements from a co-located receiver at the Kjell Henriksen Observatory (KHO), the source regions responsible for GNSS scintillation at the dayside auroral/cusp regions are identified and characterized. The results revealed that F region irregularities dominate the dayside auroral/cusp ionosphere with enhanced electron and ion temperatures providing the plausible conditions to producing scintillation causing irregularities. Furthermore, the capability of extending the analysis to the upcoming EISCAT 3D using a simultaneous multi-beam multi-direction pattern is also emphasized.

Background and Motivation

- Scintillations are diffractive and refractive variations imposed on radio signals as they traverse through electron density irregularities (∼350m to tens of km) [1].
- GNSS scintillation has been reported with polar cap patches, auroral substorm events and energetic particle precipitation, which are due to either E or F region structures or both [2].
- Case studies and statistics from the nightside auroral sector predominantly associated GNSS scintillation to irregularities in the E region [3,4].
- The effectiveness of the dayside auroral/cusp irregularities to producing GNSS scintillation as well as the associated ionospheric conditions has yet to be established.

Methodology: Conjunction finder

- A latitudinal and longitudinal separation that do not exceed 0.2° and 0.4°, respectively, between a rapidly scanning radar beam and the GNSS line-of-sight vector (LOS) is imposed at different ionospheric pierce points (IPP) to identify precise conjunctions.
- Following criteria is used to associate scintillation events to irregularities in different ionospheric regions ($\Delta\mathcal{N}$, $\nabla\mathcal{N}$ are density fluctuations and gradients normalized to background, superscripts in different parameters refer to the E and F regions respectively.)

E	F	E&F	Below background
$\Delta\mathcal{N}^E > 1, \nabla\mathcal{N}^E > 1$ & $\Delta\mathcal{N}^E > \Delta\mathcal{N}^F, \Delta\mathcal{N}^F < 1$	$\Delta\mathcal{N}^F > 1, \nabla\mathcal{N}^F > 1$ & $\Delta\mathcal{N}^F > \Delta\mathcal{N}^E, \Delta\mathcal{N}^E < 1$	$\Delta\mathcal{N}^E > 1, \nabla\mathcal{N}^E > 1$ & $\Delta\mathcal{N}^F > 1, \nabla\mathcal{N}^F > 1$	$\Delta\mathcal{N}^E < 1$ & $\Delta\mathcal{N}^F < 1$

Results (I) - Source regions

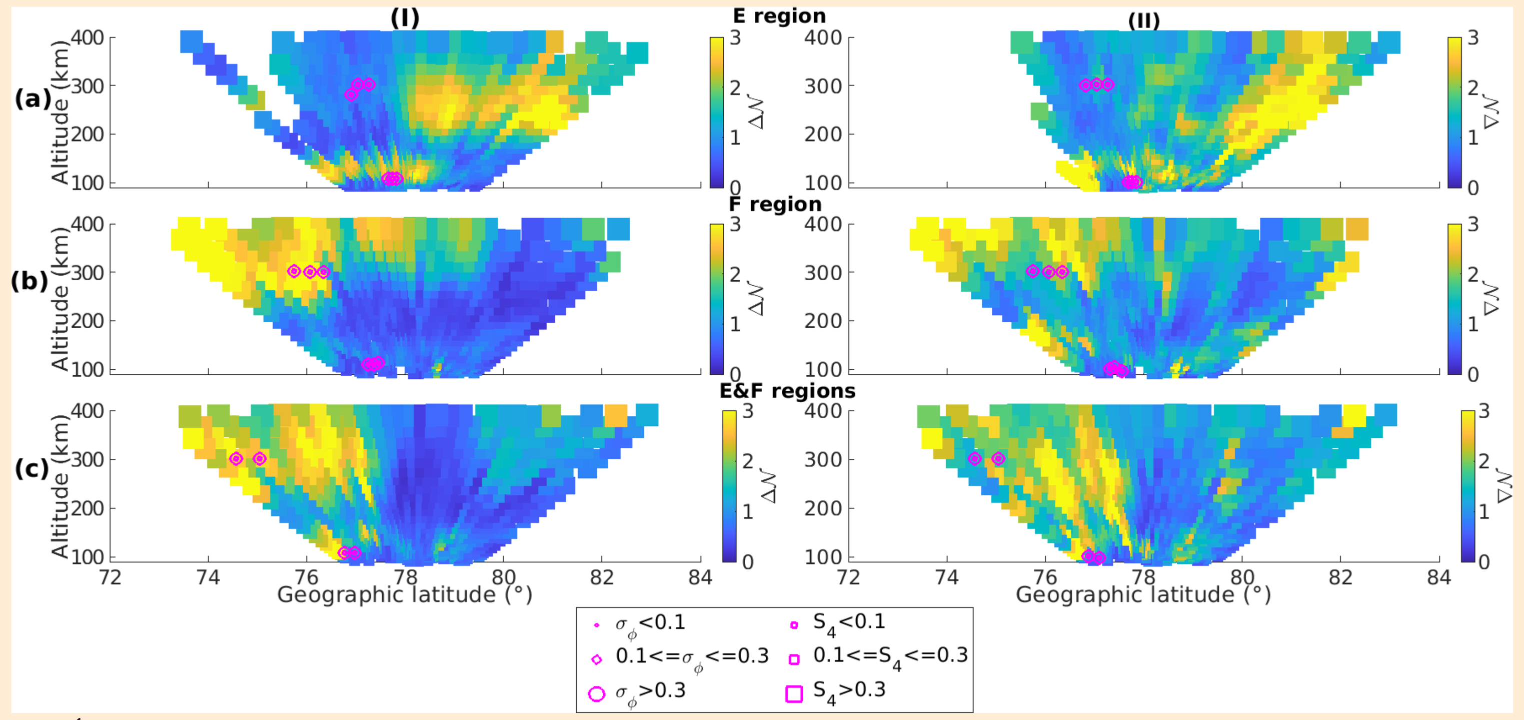

Figure 1. **Column I:** Density enhancement from the background. **Column II:** density gradients with overplotted scintillation levels. **(a)** E region irregularity, **(b)** F region irregularity, **(c)** E and F irregularities.

Statistics from winter months (2013-2014)

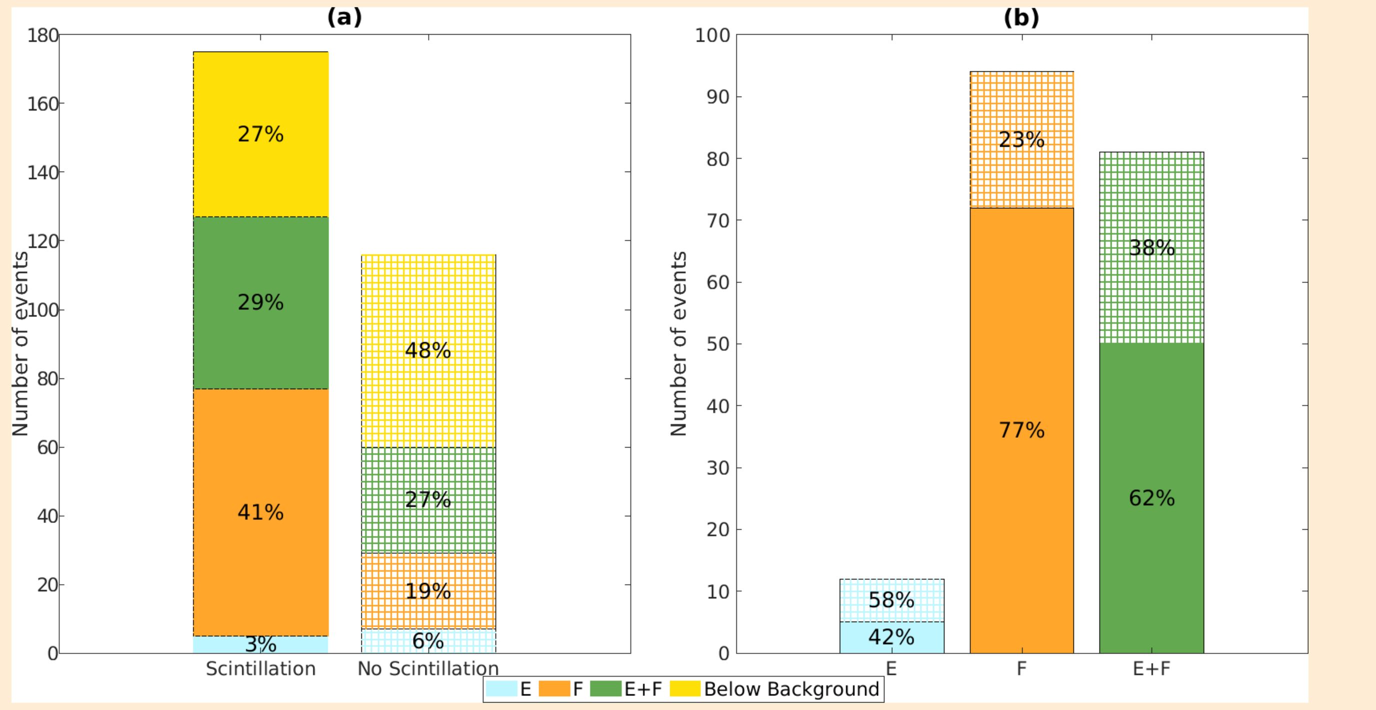

Figure 2. **(a)** Contribution of different regions during intervals of scintillation and no scintillation. **(b)** Occurrence of scintillation and no scintillation, separately for different regions. **Filled graphs** - scintillation, **meshed graphs** - no scintillation.

Results (II) - Ionospheric conditions

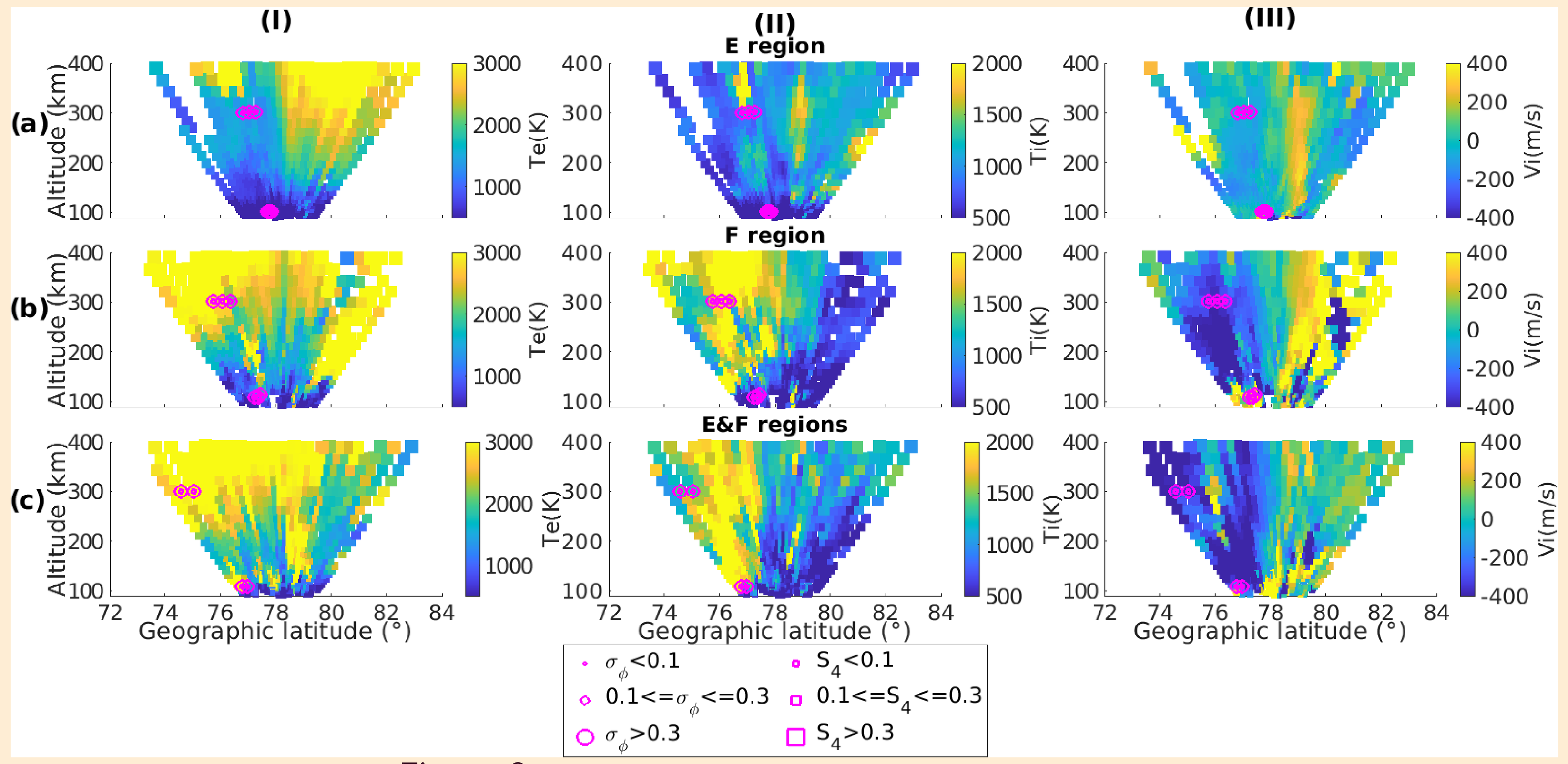

Figure 3. Ionospheric conditions corresponding to Figure 1.

Statistics from winter months (2013-2014)

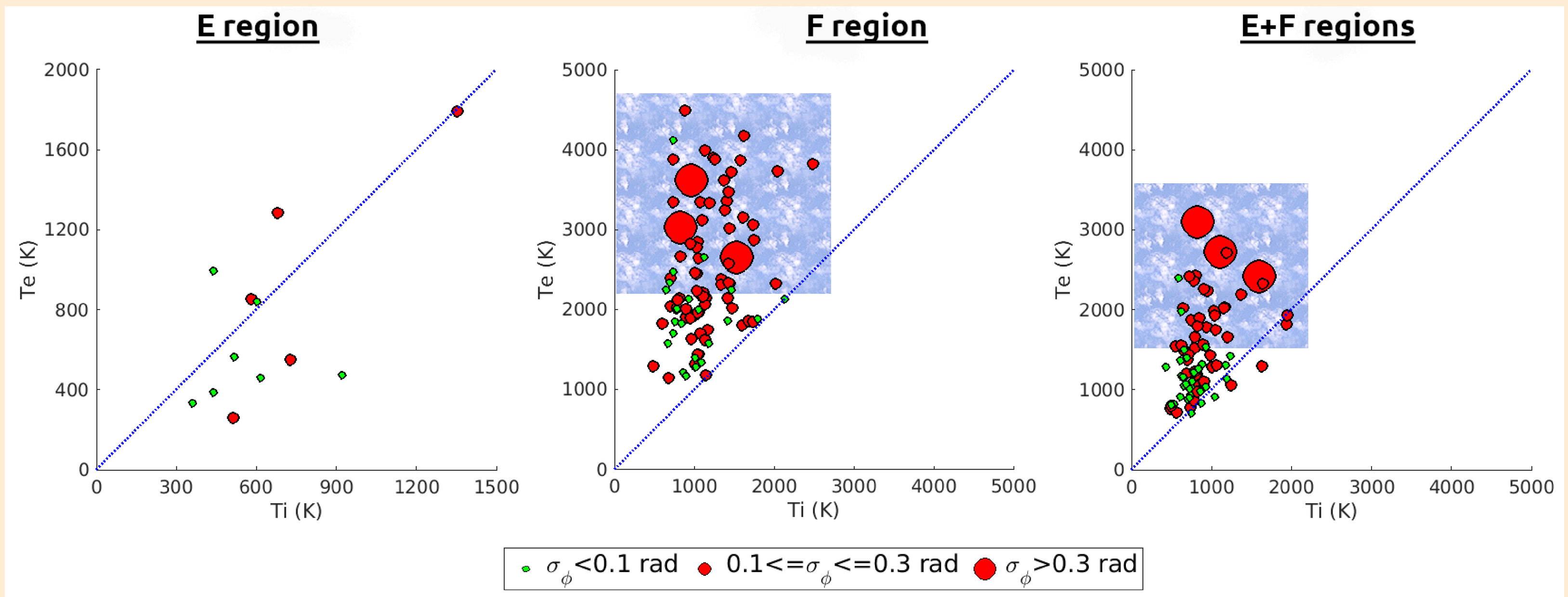

Figure 4. Distribution of σ_ϕ as a function of electron, ion temperatures when the observed scintillation was associated with irregularities in different regions. The dotted blue line indicates the $T_i = T_e$ line.

Conclusions

- A methodology was developed to make precise conjunction measurements of fast scanning EISCAT radar beams and GNSS radio signals to study the source regions of irregularities.
- Dayside polar ionosphere is dominated by F region irregularities that are associated with scintillation majority of the times.
- The likelihood of observing irregularities and associated scintillation in the E region are comparatively less.
- Enhanced electron and ion temperatures in the F region provide the likely conditions to produce irregularities that can cause GNSS scintillation.

References

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