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High resolution incoherent scatter observations of electron precipitation and ion frictional heating by means of Bayesian filtering

Ilkka Virtanen (1), Anita Aikio (1), Lassi Roininen (2), Sari Lasanen (2), Björn Gustavsson (3), and Habtamu Tesfaw (1)

(1) Ionospheric Physics, University of Oulu, Oulu, Finland, (2) Lappeenranta University of Technology, Lappeenranta, Finland, (3) UiT the Arctic University of Norway, Tromso, Norway

Electron precipitation and ion frictional heating transfer energy from the magnetosphere to the high-latitude ionosphere. Both processes are facilitated by the almost vertical geomagnetic field, which guides charged particles and maps electric fields perpendicular to the magnetic field from the magnetosphere down to the ionosphere. Incoherent scatter radars are among the most powerful instrument for observing the electron precipitation and ion frictional heating, because they can observe height profiles of properties of the ionospheric plasma along the radar transmitter beam. The plasma parameters typically fitted to incoherent scatter spectra observed by the EISCAT radars are electron density, ion and electron temperatures, and line-of-sight plasma velocity.

While estimates of the electron density can be calculated with high time resolution from the backscattered power, estimation of the other plasma parameters with time resolutions that match with the rapid variations in electron precipitation is very challenging. Another challenge is the so-called ion mass-temperature ambiguity, which prevents one from producing reliable estimates of both ion temperature and ion composition. These are critical issues, because the energy transfer processes cause rapid variations in both ion composition and temperatures.

We propose a novel incoherent scatter analysis technique based on Bayesian filtering. The technique reduces our dependence on empirical ionospheric models, which cannot predict the rapid variations of the high-latitude ionosphere, and replaces them with physics-based models of the ionosphere, enabling ion composition estimation. The filtering approach also allows to reach high time resolutions in the plasma parameter fits and allows us to reject physically unjustified spatial gradients from the results.

We have implemented an initial version of the analysis technique in the standard EISCAT incoherent scatter analysis tool GUISDAP. With the analysis tool plasma parameters, including the ion composition estimates in presence of ion frictional heating, can be fitted with a few second time resolutions. The fitted plasma parameters are subsequently used as inputs to an electron energy spectrum estimation tool ELSPEC, allowing us to calculate high-resolution estimates of electron energy spectra and auroral power.

We show initial results from incoherent scatter analysis with a few second time resolutions, the resolution being limited by the resolution of the raw EISCAT radar data. Electron density, electron and ion temperatures, line-of-sight ion velocity, ion composition, electron energy spectra and auroral power are calculated from data that contain both electron precipitation and ion frictional heating events.