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Modelling large-scale structures in the high-latitude ionosphere

Alan Wood, Golnaz Shahtahmassebi, and Gareth Dorrian
School of Science and Technology, Nottingham Trent University, Nottingham, United Kingdom (alan.wood@ntu.ac.uk)

The ionosphere is a highly complex plasma containing electron density structures with a wide range of spatial scale sizes. Large-scale structures with horizontal extents of tens to hundreds of km exhibit variation with time of day, season, solar cycle, geomagnetic activity, solar wind conditions, and location. Whilst the processes driving these large-scale structures are well understood, the relative importance of these driving processes is a fundamental, unanswered question. The large-scale structures can also cause smaller-scale irregularities that arise due to instability processes. These smaller scale structures can disrupt trans-ionospheric radio signals, including those used by Global Navigation Satellite Systems (GNSS).

Statistical modelling techniques have been used to generate models of various measures of large-scale plasma structuring in the polar ionosphere using 15 years of data gathered by the EISCAT (European Incoherent Scatter) Svalbard Radar. These models quantify the relative importance of the dominant driving processes in four time sectors (noon, dusk, midnight and dawn). In every sector the dominant process is the seasonal variation, and this difference is attributed to both the variation in the chemical composition of the atmosphere and the maintenance of the background ionosphere by photoionization in summer. Secondary processes vary with time sector, but include variations with the solar cycle, geomagnetic activity, and the strength, orientation and variation of the Interplanetary Magnetic Field.

The same statistical modelling techniques have been applied to the auroral ionosphere using data from both Incoherent Scatter Radars and GNSS scintillation receivers. The dominant driving processes of these models are compared to those observed for large-scale plasma structures in the polar ionosphere. The models have the potential to make real time predictions for GNSS applications. The steps required to develop predictive models are discussed.