

***Radio tomographic imaging of the Arctic ionised atmosphere
by the International Ionospheric Tomography Community (IITC)***

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The ionised atmosphere in the polar regions is a highly structured plasma containing irregularities in electron density over a wide range of horizontal scale-sizes. The structure is influenced largely by the solar wind as it sweeps past the Earth, with the coupling of the interplanetary magnetic field in the solar wind to the magnetospheric field leading to a series of complex processes that result in a dynamic and structured ionospheric plasma. During times of disturbed geomagnetic activity, enhancements and gradients in the plasma density can cause severe disruption to transionospheric radio signals, affecting communications and navigation systems.

The basic physics and chemistry of ionisation production and loss in the polar regions are understood reasonably well, including effects of large-scale plasma transport and precipitation of charged particles into the atmosphere. However, the actual structure present in any given situation depends on the relative contributions of the various processes and the balance remains an open question that needs to be addressed by experimental observations. To date measurements of the ionospheric density in the remote polar regions have been scarce. The International Polar Year opens the possibility for increased collaborative observations of the distribution of the polar plasma over large geographic regions and long time intervals.

Radio tomography is a relatively new technique for imaging the ionospheric plasma over extended height-versus-latitude planes. In essence, radio transmissions from polar-orbiting satellites are monitored at a chain of receivers aligned in longitude but separated in latitude. Measurements of the line integral of the electron density along satellite-to-receiver ray paths, the so called total electron content, are inverted in a reconstruction algorithm to yield an image of the spatial distribution of the density over the region of interest. Routine monitoring of transmissions from satellites over an extended period of time lead to coverage of the ionosphere at all Universal Times, seasons, geomagnetic and solar conditions. The technique gives wide spatial coverage from a limited number of ground stations and so is ideal for remote inaccessible polar regions, as has been demonstrated in the Arctic and from preliminary studies by the Aberystwyth group in Antarctica.

Several international research groups have now deployed tomographic chains in different sectors at northern high latitudes, with general co-ordination of the activities taking place under the umbrella of the International Ionospheric Tomography Community (IITC). In the European sector the University of Wales Aberystwyth fields four receivers at sites spanning from Ny Ålesund on Svalbard, to Tromsø on the Norwegian mainland, whilst the chain of the Sodankylä Geophysical Observatory extends to the south east. Receivers deployed at five sites by the NorthWest Research

Associates (NWRA) and the University of Alaska Fairbanks extend throughout Alaska for observations separated by some 12 hours local time from the European observations. Coverage between the two longitude sectors is provided by a receiver chain deployed by the Applied Research Laboratories, University of Texas Austin and NWRA along the western coast of Greenland.

Each individual tomography chain observes prominent, persistent density features of the high-latitude ionosphere. These include a dayside high-latitude trough in the post magnetic-noon sector that migrates to lower latitudes at later times to form the main ionisation trough, the structured auroral region bounded in the evening sector by the persistent boundary blob, and the polar hole in the dark winter ionosphere where plasma is believed to circulate for an extended time period in darkness. On the dayside the tongue-of-ionisation transports plasma from the sun-lit lower latitudes into the polar cap, with fragmentation of the continuous tongue forming the large-scale ionisation patches of the polar cap. Under disturbed conditions, storm enhanced densities at mid-latitudes are transported poleward to create substantially enhanced ionisation levels in the polar regions.

Observations from a single chain can of necessity reveal only a localised, limited view of the density distribution. Taken collectively, the observations from all chains have the potential to provide the spatial distribution of plasma over the extended geographic region. This distribution can then be related to the interaction of space-weather processes. Comparisons of the distributions at different chains can identify the UT dependency of the plasma features that arises because of the offset between the geomagnetic and geographic reference frames.

The International Polar Year offers a unique opportunity and new impetus for focused co-ordinated observations by the IITC, promoting increased collaborations between the international research groups. The science addresses the footprints of space-weather processes over an extended region of the high Arctic and identifies the roles of the physical processes responsible for the structured distribution of the plasma.

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