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Improving radar remote sensing measurements of D region electron densities at polar latitudes

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The lowermost boundary of the ionosphere, namely the D region, is very sensitive to solar and geomagnetic disturbances modulating the state of ionisation. The upper D region is widely controlled by incident solar UV radiation. During solar flares enhanced Lyman-alpha radiation as well as X-ray are emitted, which can easily ionize NO at altitudes of 70 km and below. Specifically, increased X-ray fluxes may rapidly change the ionization in the lower D region, specifically if they reach enegeries of 10 to 100 keV.

In the auroral zone, particle precipitation events are frequently observed, which represent an efficient source for electron density enhancements in the lower ionosphere down to 50 km altitude. One technique to investigate the ionisation state of the D region are active radar experiments measuring the electron density. Emissions of the polar latitude HF radar at Saura (69°N, 16°E), operated at 3.17 MHz, are partially reflected in the mesosphere, provided that sufficient ionisation exit. The radar measures amplitudes and phases of the incident echoes for both circular polarization senses at each altitude in order to estimate the differential absorption and rotation of the propagating radio wave. Owing to the fairly large antenna array, comprised of 31 half-wavelength dipole antennas in a Mills-cross-configuration, a sufficiently small volume is probed, for which both propagation parameters are measured.

In this study we present a realisation of this measurement technique combined with signal processing tools as well as exploiting interferometric radar capabilities. Time series smoothing and splitting are performed based on correlation times representative for the individual altitudes and current condition. Even though, the antenna array facilitates a half power beam width of less than 7 degrees, substantial radiation pattern side lobes exist. These side lobes contribute to the measurements if sufficiently large gradients in the refractive index exist at their pointing direction. The interferometric capabilities allow to discriminate between vertical and off-zenith radar echoes that introduce additional uncertainty. We furthermore make use of reference profiles for geomagnetic quiet and disturbed conditions to reject unrealistic measurements. Applying these methods robust daytime electron number density profiles are derived. As a case study we analyse data collected during the partial solar eclipse over north eastern Europe in October 2022.