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Multiple ionization scales in the ionosphere investigated through the combination of LOFAR and GNSS measurements

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Radio waves propagating through plasma inhomogeneities in the Earth's ionosphere experience fluctuations in their amplitudes and phases as a result of their wavefront being scattered by the change in refractive index which, in the magnetised ionospheric plasma, is related to the gradient in the electron density. The amount of scattering, or scintillation, resulting from the propagation through plasma inhomogeneities depends upon the gradient in the spatial distribution of the electron density.

Radio wave scintillation depends upon the radio wave frequency. It is indeed observed that the level of scintillation typically decreases with the radio wave frequency. This aspect suggests that there can be various gradients in the ionospheric electron density spatial distribution where different changes in electron density occurs over different spatial scales. For example, ionospheric irregularities in the mid-latitudes ionosphere can generate scintillation on VHF and UHF radio wave frequencies but they appear generally too weak to generate scintillation on L-band. Hence, multiple scales seem to be present in the ionosphere in response to different energy cascade mechanisms in the spatial power spectral density of the electron density.

An opportunity to investigate the presence of multiple scales in the middle-latitudes ionosphere is offered in Poland where three LOFAR (Low-Frequency Array) stations were combined with Global Navigation Satellite Systems (GNSS) ionospheric and geodetic stations in order to investigate the presence of multi-scale ionisation structures originating signatures in VHF and L band.

LOFAR measurements are based on the observation of a dynamic spectrum broadly covering the frequency range $25 - 70$ MHz together with intensity scintillation quantified through the S_4 index over the same frequency interval. GNSS measurements are based on carrier phases with various temporal resolutions as well as on estimates of intensity and phase scintillation indices over different carrier frequencies and for different constellations.

The combination of LOFAR and GNSS observations allows the investigation of multiple ionisation scales present in the middle-latitudes ionosphere and, therefore, on the large-to-small scales energy cascade that characterises the irregularities' spatial spectrum.