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Methodology for the identification of multiple scales in the ionosphere based on the combination of LOFAR and GNSS observations

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Spatial inhomogeneities in the ionosphere can scatter radio waves propagating through them, thus inducing radio wave scintillation. These inhomogeneities are characterized by an irregular distribution in the electron density: the corresponding gradient in the refractive index induces scattering that produces scintillation. The scattering process at the basis of radio wave scintillation depends upon the wavelength: the scintillation intensity tends to decrease as the wavelength increases.

For radio signals in the L band (typical of Global Navigation Satellite Systems, GNSS) scintillation tends to intensify in the equatorial, polar, and auroral ionospheres. On the other hand, in the case of VHF radio signals scintillation can be found to be high at middle latitudes, as well. The fact that GNSS signals experience very low scintillation in the middle latitudes implies that GNSS signals have lower sensitivity to detect the presence of smaller electron density gradients.

LOFAR (Low-Frequency Array) observations of VHF scintillation can be combined with co-located and simultaneous GNSS observations of L-band scintillation to provide a more complete description of spatial gradients in the electron density distribution as well as insights on their spatial evolution. The combination of simultaneous LOFAR and GNSS observations enables to detect electron density gradients over multiple scales. A comprehensive spatial and temporal description of electron density gradients is necessary to understand their evolution and, hence, the mechanisms driving them.

The advantage of using LOFAR observations relies on the fact that a broad range of VHF radio wave frequencies can be observed simultaneously, hence enabling the identification of changes in the scattering regime that are associated with changes in the features of ionospheric irregularities and their corresponding gradients.