Monitoring Perturbations in the Lower-Ionosphere Using GNSS Radio Occultation Observed from Spire's Cubesat Constellation

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The lower altitude region of the ionosphere (60-150 km) is characterized by a strong coupling between the neutral atmosphere and ionospheric plasma. Due to the high ion-neutral collision rate the plasma at these altitudes is less constrained to follow the magnetic field lines compared to plasma at higher altitudes in the ionosphere. This both permits the development of the windshear mechanism responsible for the formation of sporadic E (Es) layers and affects the coupling between atmospheric gravity waves (AGWs) and the ionospheric plasma.

AGWs transport energy from the lower atmosphere upward to higher altitudes. The wave amplitudes increase with altitude and eventually couple to the ionospheric plasma generating electron density perturbations or travelling ionospheric disturbances (TIDs).

Es layers are high-density, narrow-altitude layers of enhanced electron density in the ionosphere's E region. Contrary to what the name would suggest, Es occurs relatively frequently and its climatology has been characterised through ionosonde studies. Furthermore, the vertical structure of Es has been studied using sounding rockets. However, such measurements are very sparse and cannot be used to routine monitoring or for detecting the Es occurrence at a particular time and location.

Monitoring AGW and Es layers is of great interest to many terrestrial applications, such as natural hazard warning systems, radio communications, and global navigation satellite system (GNSS) users. Recently, the coupling between Es layers and AGWs has also seen increased research attention.

Spire operates a large constellation of 3U cubesats which carry a radio occultation (RO) GNSS receiver. For ionospheric studies, the satellites measure Total Electron Content (TEC) data in both zenith-looking and RO geometries using dual frequency observations. Furthermore, the high rate (50Hz) phase measurements that are generally used for neutral atmosphere RO can also be used to produce relative TEC profiles of the lower ionosphere with high vertical resolution (approximately 100m at E region altitudes). In this talk, we review recent results describing the
coverage and quality of E region ionospheric measurements collected by Spire. Furthermore, we describe Spire’s Es and AGW automated detection algorithm that is based on a Hilbert–Huang transform (HHT) of the relative TEC profiles and we compare our results with time coincident and co-located ionosonde data. We also look toward the future and describe how low cost cubesat constellations can be used for global monitoring of AGWs and Es layers. These first results also open the way to near real-time monitoring and classification of more general ionospheric anomalies.