High Altitude Echoes in the Equatorial Topside Ionosphere at Extremely Low Solar Flux

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We describe a newly observed phenomenon in the early morning topside ionosphere consisting of high altitude coherent echoes in the range of 1000 - 2200 km. It is distinct from ESF in terms of its coherence, spectral width, altitudes of occurrence and the predominance of Lower Hybrid (LH) electrostatic waves.

The echoes are observed from data obtained from a series of high altitude ISR experiments at Jicamarca using two transmitters of 1 MW each, pointing towards different positions on a magnetic field line above Jicamarca, separated zonally by an angle of ~ 1.5 degrees. The difference in pointing positions allows for an estimation of the drifting speed of the structures in the direction of the magnetic field. The transmitted signal consists of a 2 ms long pulse which ensures a scattering volume of sufficient height to provide adequate SNR and an IPP of 40 ms to prevent range aliasing up to 6000 km. The sampling rate is set to 1 MHz to permit sufficient spectral resolution and prevent aliasing with the assumption that frequencies are in the range $0 < f < 500$ KHz.

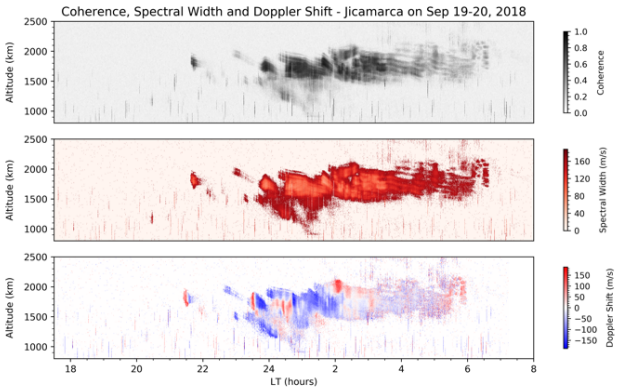

Figure 2: Coherence plot of high altitude echoes. Echoes appear predominantly between 11pm – 4 am from Sept 19 – 20, 2018. Coherence, spectral width and Doppler is shown, , see Derghazarian et al. (2021).

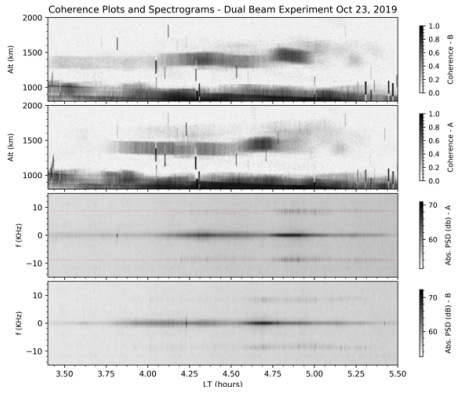

Figure 1: Spectrogram of echoes 1300 - 1450 km. LH lines clearly visible. Theoretical LH frequency superimposed with thin red lines, assuming an H^+ only atmosphere, see Derghazarian et al. (2021).

A key feature observed within the echoes is the presence of LH electrostatic waves which appear as prominent sidebands in the spectrogram of the backscatter. The spectrograms are plotted for a specific altitude with axes of local time and frequency. With a finite beamwidth, **k** will be approximately perpendicular to **B** for all of the altitudes of interest, which is why the experiment is able to capture LH electrostatic waves, specifically those with wavelengths of ~ 3 m (Bragg wavelength).

Several possible theories are advanced that could explain the origin of the structures and the generation of the LH waves observed such as Lower Hybrid Solitary Structures (LHSS), VLF conversion to LH frequencies in the presence of density depletions, and lower hybrid drift instability. The dispersion relation of the waves and growth rate is derived theoretically.

Future work is in progress to draw comparisons with satellite data and several new modifications in the experiments are proposed to further develop the theoretical framework.

References

[1] Derghazarian, S., Hysell, D. L., Kuyeng, K., & Milla, M. A. (2021). High altitude echoes from the equatorial topside ionosphere during solar minimum. *Journal of Geophysical Research: Space Physics*, *126*, e2020JA028424. https:// doi.org/10.1029/2020JA028424