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Determination of ducted propagation of lightning generated whistlers from Van Allen Probes burst data

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Lightning generated whistlers (LGWs) are very-low-frequency electromagnetic waves emitted from lightning that propagate through the ionosphere into the magnetosphere as whistler mode waves. LGWs can induce pitch-angle scattering and precipitation of trapped energetic electrons (lightning-induced electron precipitation), causing chemical reactions in the atmosphere [1]. LGWs help maintain the slot region between the electron radiation belts. The presence or absence of plasma ducts control LGW propagation, determining where an LGW's energy travels, how long it persists in the magnetosphere, and what effect it has on the electron radiation belt populations. This project assesses the prevalence of ducted vs. non-ducted whistlers using data from the Van Allen Probes (RBSP).

From burst magnetic wave data measured by the RBSP Electric Field and Waves instrument (EFW), we identify all bursts that contain LGWs [2]. To isolate LGWs from background noise, we develop a filtering threshold by fitting the peak noise of the RBSP search coil magnetometer. To remove additional noise and group LGWs with potentially matching sources, we apply a DBSCAN clustering method [5]. We calculate the mean amplitude of each LGW as well as the wave normal angle (WNA) and ellipticity through magnetic spectral analysis [4]. To calculate the WNA (k-vector direction) with respect to the ambient B-field, we rotate the burst data from spacecraft coordinates to field-aligned coordinates using fluxgate magnetometer measurements of the background field [3].

We utilize the calculated WNA of an LGW cluster to identify ducting. LGWs exit the ionosphere with nearly field-aligned k-vectors (low WNAs). If the LGW is non-ducted, the k-vector will quickly become oblique (high WNA) as the wave refracts through the magnetosphere. Ducted whistlers, propagating as if in a waveguide, will remain closer to field aligned, maintaining a low WNA. Based on ray tracing thousands of non-ducted rays at LGW frequencies, we have developed a WNA threshold to separate ducted and non-ducted whistlers that varies with L-shell [6]. For selected events, we calculate the local plasma density from RBSP observations to search for measured ducts at times we identify ducted propagation.

Preliminary results show that LGWs favor lower L-shells (within the plasmasphere) on the nightside. We find the WNA has no dependence on frequency. Of the events analyzed, 20.0% of bursts contain LGWs. Of the bursts containing LGWs, we identified 20,000 LGW clusters; 15.2% of these LGW clusters may be ducted based on their average WNA. We further investigate the dependence of ducting on L-shell, MLT, season, and other parameters.

References

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