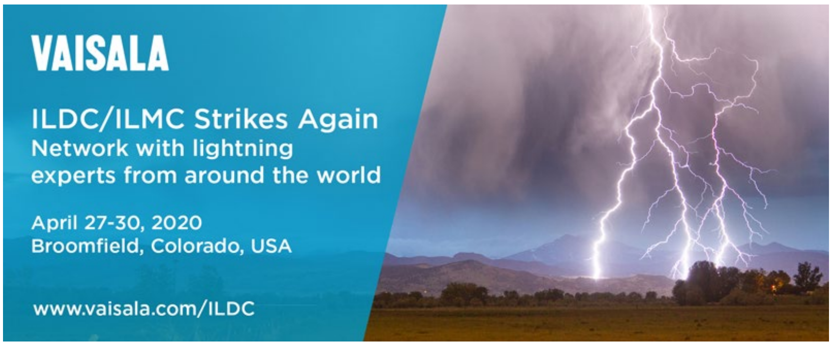


# D Region Tomography: A Technique for Ionospheric Imaging Using Lightning-Generated Sferics and Inverse Modeling

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## Abstract

The *D* region of the ionosphere (60-90 km altitude) is a layer of the atmosphere defined by a relatively weakly ionized and collisional plasma. It is primarily driven by solar activity, but it is maintained at night by background energetic radiation. Due to varying solar conditions (e.g. diurnal, seasonal, or solar cycle) the present state of the ionosphere also varies. In addition to the predictable solar flux, there are many other unpredictable drivers such as atmospheric gravity waves, solar flares, lightning-ionosphere coupling, electron precipitation, etc. Despite the myriad of effects and perturbations, the *D* region is still relatively poorly understood and sparsely studied. This is in part due to the difficulty of making direct measurements. The neutral atmosphere of the *D* region is too dense for in-situ satellite measurements, but not dense enough to support weather balloons. Understanding the spatial and temporal structure of the *D* region is crucial to the operation and improvement of dependent technologies, such as long-distance lightning geolocation, but it is difficult due to the limitations of existing measurement techniques.

To respond to the inherent challenges of studying the *D* region, many workers use remote sensing of very low frequency electromagnetic waves (VLF, 3-30 kHz). VLF waves are a unique tool for *D* region studies because they reflect efficiently from both the *D* region and the earth ground forming the earth ionosphere waveguide (EIWG). Therefore, VLF waves propagate to global distances with low attenuation, modulated by the present state of the *D* region along the transmitter-receiver path. There are two dominant sources of VLF energy: manmade communication transmitters and lightning. In this work we consider lighting-generated VLF wave packet known as radio atmospherics or 'sferics'.

By combining sferic observations with a VLF propagation model capable of predicting EIWG propagation (e.g. the long-wavelength propagation capability or LWPC), we infer a large set of ionospheric measurements which we interpret as path-averaged information. Tomography is a technique concerned with imaging objects where it is not possible to make direct measurements using with indirect line-integral measurements. Therefore, we introduce *D* region tomography, a technique to produce 4D maps of the electron density by combining inverse modeling, the natural constellation of lightning, and a network of VLF receivers.

## Topic Areas

Lightning Detection Systems Technology and Performance, Applications of Lightning Data: Insurance Claims, Fire Risk, Mining, Wind Farms, etc.

**Submission Format**

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