Simulating Ionograms by Compounding Optically Observed Plasma Clouds with Ionospheric Modelling Technology

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Artificial Ionospheric Modification (AIM) can occur through deliberate or incidental injections of aerosols, chemicals or radio (RF) signals into the ionosphere. The Metal Oxide Space Clouds (MOSC) experiment was undertaken in April/May 2013 to investigate chemical AIM. Two sounding rockets were launched from Kwajalein Atoll and each released a cloud of vaporized samarium (Sm). The samarium created a localized plasma cloud that formed an additional ionospheric layer. The effects were measured by a wide range of ground based instrumentation, including optical and HF.

A parametric model developed by AFRL, based on the optical data, was implemented to recreate experimental HF results from the MOSC experiment. In this work the cloud model was added to simulated ionospheric electron density grids to understand the impact on radio propagation in its vicinity.

Ray paths were reconstructed using a Runge – Kutta – Felhberg (RKF) algorithm to find the path of least action through the electron density grid for a given fan of elevation and azimuth firing angles. Ionograms were then produced using the ratio of ray path length to speed of light as an estimation of the delay between transmission and observation for a given frequency of radio wave. This process was repeated for frequencies ranging from 2 to 32 MH_z to build a synthetic ionogram.

Observational ionograms indicated that the presence of the samarium cloud produced two new traces on the ionogram. The maximum frequency of these traces decayed with time indicating a decrease in density. The RKF ray trace method was used in a range of small regions in the firing angle parametric space. The resulting simulations confirmed the two new layers as observed in the experimental ionograms. These new layers were seen to originate from distinct firing angle regions.

Ray paths corresponding to distinct traces on the ionogram were extracted to clarify their propagation route. The layer found between E and F reflections was shown to be a reflection off the base of the cloud which was situated between the two layers in altitude. The second new layer, known as the ‘ghost layer’ was observed on the ionogram at longer delay than the F layer. Its cause is from a ray path which deflected from the cloud to the F layer and down to the receiver. This small deviation added enough delay to represent it as a distinct layer. The delay times of these two new layers was found to be strongly dependent on the geometry of the cloud.