Dynamics of mid-latitude sporadic-E and its impact on HF propagation in the North American sector

Bharat S. R. Kunduri[(1)], Philip J. Erickson[(2)], Joseph B. H. Baker*[(1)], J. Michael Ruohoniemi[(1)], Kevin T. Sterne[(1)], and Ivan A. Galkin[(3)]

(1) Virginia Tech, Blacksburg, Virginia, USA; e-mail: bharatr@vt.edu; bakerjb@vt.edu; mikeruo@vt.edu; ksterne@vt.edu

(2) MIT Haystack Observatory, Westford, MA, USA; e-mail: pje@mit.edu

(3) University of Massachusetts, Lowell, MA, USA; e-mail: Ivan_Galkin@uml.edu

Sporadic-E (Es) are vertically thin layers of enhanced metallic ionization that form in the E region ionosphere. They are usually observed between 95 and 120 km altitude and have a typical thickness of ~1-2 km in altitude. While Es layers have a small vertical extent, they have a large horizontal scale, typically spanning hundreds of kilometers. Electron densities in Es can at times exceed the peak electron densities observed in the F-region. Consequently, Es layers play an important role in controlling the dynamics of the upper atmosphere and have a strong impact on communication systems, especially those operating in the High Frequency (HF) range. It is therefore necessary to understand the geophysical factors influencing Es from both the scientific and operational perspectives. While the wind-shear theory is widely accepted as an important mechanism for the generation of Es, there are gaps in the current state of our knowledge. For example, the wind-shear theory doesn't explain the strong summer peak observed in Es occurrence rates. Instead, the summer maximum in Es has been found to be correlated with a similar peak in meteor influx rates, which may be a source for metallic ions. In this study, we report results from a coordinated experimental campaign between the Millstone Hill Incoherent Scatter Radar (MH-ISR), the Millstone Hill ionosonde, and the Super Dual Auroral Radar Network (SuperDARN) HF radar at Blackstone, Virginia (BKS). Figure 1 summarizes the observations of Es by the Millstone Hill ionosonde along with electron densities and line-of-sight ion velocities measured by MH-ISR during our experimental campaign. It shows that the height of the Es layer is collocated with strong vertical shears produced by shifting atmospheric tides. Additional analysis found the Es layers have a strong impact on the location and intensity of SuperDARN ground scatter, which moves to significantly closer ranges in the presence of Es, suggesting Es can enable short range HF communication links. Finally, we found a strong correlation between SuperDARN meteor echo counts and Es occurrence rates consistent with increased meteor influx rates being responsible for enhancing the occurrence of Es layers during summer.

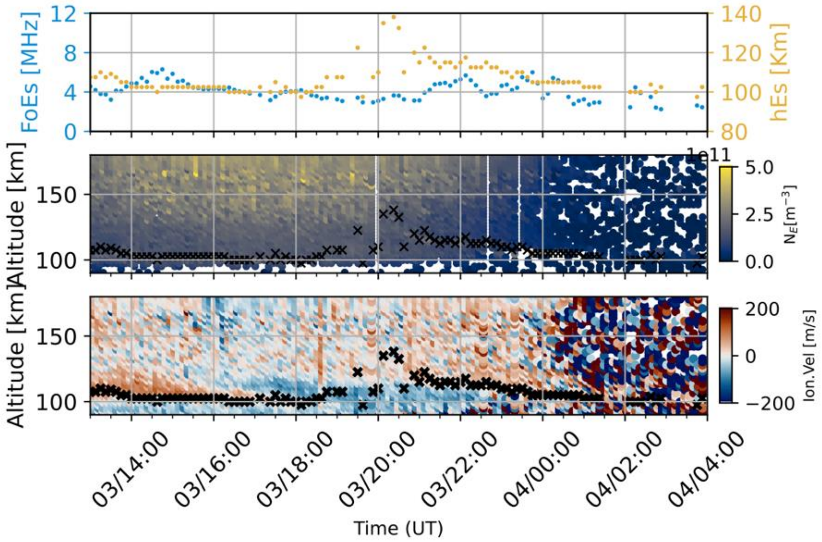

Figure 1. Time series plot showing observations by the Millstone Hill ISR's MISA antenna and the Millstone Hill ionosonde on June 3-4, 2022. The top panel shows the critical frequency and the height of the Es layer observed by the ionosonde. The middle and bottom panels show electron densities and ion velocities measured by MISA; 'x' indicates the height of the Es layer measured by the ionosonde.