Atmosphere-Ionosphere-Magnetosphere (AIM) Coupling Inferred from Lidar Observations and Modeling in Antarctica

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Two stunning discoveries emerged from six years of lidar observations at Arrival Heights near McMurdo (77.8S, 166.7E), Antarctica are the thermospheric neutral Fe layers up to nearly 200 km and the persistent gravity waves all year round in the mesosphere and lower thermosphere (MLT). These discoveries provide unique opportunities to study the wave coupling from the lower atmosphere to the thermosphere and the plasma-neutral atmosphere coupling.

The discovery of thermospheric neutral Fe layers by lidar observations in Antarctica has opened a new door to explore the space-atmosphere interactions with ground-based instruments, especially in the least understood but crucially important altitude range of 100-200 km. These neutral metal layers provide excellent tracers for modern resonance lidars to measure the neutral wind and temperature directly, complementing the radar measurements of the ionosphere and the magnetometer measurements of the geomagnetic field. Even more exciting, the neutral metal layers in the thermosphere provide a natural laboratory to test our fundamental understandings of the atmosphere-ionosphere-magnetosphere (AIM) coupling and processes.

Lidar temperature and Fe density measurements have revealed persistent, dominant and large-amplitude gravity waves with non-tidal periods of ~3-10 h and vertical wavelength of ~20-30 km. There has not been any single lidar run that does not show the signature of this 3–10 h wave group during 5 years of lidar observations at McMurdo, and so far we have not seen any inactive wave gap epoch in observed temperature data. The mystery of persistent waves has sparked a wide range of speculation for their sources, e.g., secondary wave generation, or even resonance vibration of Ross ice shelf, etc.

In this paper we combine the lidar observations from the stratosphere and mesosphere to the thermosphere with the University of Colorado Thermosphere-Ionosphere Fe/Fe+ (TIFe) model to explore the possible wave sources and the connections between the TIFe layers and various atmospheric, ionospheric, magnetospheric and solar activities.

Keywords: Thermosphere-Ionosphere Fe and Fe+ Layers, Persistent gravity waves, Atmosphere-Ionosphere-Magnetosphere Coupling, Lidar Observations in Antarctica, Modeling, Wave sources

