

First Discovery of Regular Occurrence of Mid-Latitude Thermosphere-Ionosphere Na (TINa) Layers Observed with High-Sensitivity Na Doppler Lidar and New Data Processing Techniques over Boulder

Yingfei Chen⁽¹⁾, Xinzhao Chu⁽¹⁾

⁽¹⁾ *Cooperative Institute of Research in Environmental Sciences & Department of Aerospace Engineering Sciences, University of Colorado Boulder, 216 UCB, Boulder, CO 80309, USA, E-mail: Yingfei.Chen@colorado.edu, Xinzhao.Chu@colorado.edu*

After more than 30 years of lidar observations at mid-latitudes, only intermittent occurrence of thermosphere-ionosphere Na (TINa) layers had been reported from a few observations following the first discovery of these layers in Antarctica in 2011. Since then, the first discovery of regularly occurring mid-latitude TINa layers has been made over Boulder, Colorado. For the first time, Na layers have been observed regularly descending from ~125 km after dusk and from ~150 km before dawn every day. Such regular occurring observations are very challenging as their observation demands high detection sensitivity of lidars and creative data processing techniques. Only by combining the two can this decades-long problem be solved.

Detection of tenuous Na layers was enabled by an advanced, high-sensitivity resonance-fluorescence Na Doppler lidar. The lidar system uses an 81-cm diameter prime-focus Newtonian telescope with high-efficiency receiver architecture and was set up at Table Mountain Observatory (40.13°N, 105.24°W), north of Boulder, Colorado. It employed a narrowband laser transmitter tuned to the D2a absorption line at 589 nm, and a 3-frequency Doppler-ratio technique to measure Na density, temperature, and vertical wind simultaneously. High-sensitivity detections were achieved by further updates to the laser transmitter which greatly increased Na signal levels.

Na volume mixing ratio calculations are fantastic data analysis techniques which also paved the way for the first discovery of regularly occurring TINa layers. This creative calculation method can be achieved by dividing the Na density profiles with the corresponding total atmospheric number density profiles provided by the MSISE00 model (Picone et al., 2002). Using these attractive data processing techniques is likely to help more clearly exhibit the TINa layer features of downward-phase-progressing semidiurnal tidal waves. With the combination of lidar's high detection sensitivity and the Na volume mixing ratio calculations, observations reveal pre-dawn TINa layers with nearly 100% occurrence rate (159 out of 163 nights of observations).

TINa layers provide new tracers to profile neutral temperature and winds in the E and lower F regions (~100 to 200 km altitude) where neutral measurements are very rare but extremely important. These layers themselves also pose intriguing questions about the mechanisms of ion transport and plasma-neutral coupling in the E to F regions, as leading theories hypothesize that such neutral TINa layers are formed via the neutralization of converged TINa^+ ion layers.