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Sporadic sodium layer observed with the Tromso sodium lidar

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The mesospheric and lower thermospheric sodium layer, distributed at 80–110 km height, have been observed for more than 30 years by resonance scattering lidars. During these observations, researchers discovered the sudden formation of dense thin sodium layer superposed on the normal sodium layer. Such an enhanced layer is called a sporadic or sudden sodium layer (SSL). Typical feature of the SSL is a thin layer with a full-width at half maximum (FWHM) of 1–2 km lasting for a tens of minutes to several hours, and its peak sodium density is a few to tens times larger than that of the background sodium density. Several possible mechanisms have been discussed in previous studies. The hypotheses are, for example, direct meteoric input, energetic electron bombardment on meteoric smoke particles, and ion neutralization in the sporadic E layer. Most case studies trying to identify the generation mechanism of SSL seem to focus on only one of the proposed theories. To examine a couple of mechanisms at once, it is essentially valuable to accumulate many kinds of related observations, such as sodium lidar, meteor radar, MF radar, incoherent scatter radar, ionosonde, and auroral camera.

On 11 January 2011, a sporadic sodium layer was observed with a sodium lidar, which was newly installed in the European incoherent scatter (EISCAT) radar site at Tromsø, Norway (69.6N, 19.2E). The SSL observation at the EISCAT radar site is quite suitable for the SSL study because several instruments are working there. In this study, we have investigated the generation mechanism of the observed SSL analyzing data of the sodium lidar, MF radar, meteor radar, auroral camera and so on. As the results, the observed SSL seems to have no connections with the auroral precipitations and the direct meteor inputs, but have a relationship with a sporadic E layer accompanied by a vertical wind shear. Furthermore, the SSL can provide observational data with higher signal-to-noise ratio. Such high quality data is useful for investigating fine structure of the sodium density. In order to investigate fine structure in the observed sporadic sodium layer, we have analyzed the lidar data with 5-sec time resolution and found (quasi) periodic oscillations in the peak height of the sodium density. The observed oscillations had periods of 5–14 min, and its height differences of peak-to-bottom were 288–1152 m. The height change rates were 1.0–3.6 m/s for upward and 1.1–4.8 m/s for downward. From these features, the observed structure seems to be parts of the atmospheric gravity waves and/or Kelvin-Helmholtz billows. We have examined the background atmospheric condition of the sporadic sodium layer using the lidar temperature data as well as the MF radar wind data. Mostly, the estimated Brunt-Vaisala periods were 3–8 min (i.e., no convective instability) and the estimated Richardson numbers were larger than 0.25 (i.e., no wind shear instability). Based on these results, we have discussed the fine structure observed in the SSL.

Keywords: Sporadic sodium layer, Lidar, Polar region, Mesosphere, Lower thermosphere, Atmospheric gravity wave