

Study on generation and sustaining mechanism for an SSL during a night of high auroral activity above Tromsø

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We will report observational results about an SSL (Sporadic Sodium Layer) that appeared on 22 January 2012 above Tromsø, Norway (69.6deg N, 19.2deg E). An SSL is sudden formation (more precisely, from observer's viewpoint) of a dense thin sodium layer superposed on a normal sodium layer. Characteristic of an SSL is suitable for investigating, in particular, fine structures in the atmosphere such as small scale waves and turbulences. For example, Tsuda et al., GRL, 2011GL048685 [2011] found out a short-period wavelike structure on an SSL with sodium lidar operated Tromsø, Norway.

Some generation mechanisms for SSLs have been proposed and discussed. A high correlation between an SSL and a sporadic E (Es) layer occurrences has been reported, and several authors proposed mechanisms how SSLs are generated by association of the Es layers [e.g., von Zahn and Hansen, JATP, 50, 93-104, 1988]. Kirkwood and von Zahn, JAP, 53, 389-407 [1991] have suggested that a strong electric field that generates an Es layer plays an important role for generation of an SSL as well in the auroral region. Recently, Matuura et al. JGR, 118, 1-12, jgra.50414 [2013] have proposed another mechanism that an electric current loop plays an important role for the convergence of positive ions including metallic ions.

Altitudinal temperature gradients have been also discussed as a candidate for an SSL generation. Clemesha et al., JASTP, j.jastp.2010.03.017 [2010] showed that an SSL tended to be located in the region where the temperature gradient is negative. A sodium lidar measurement exhibited a 40 K temperature increase on the topside of the SSL [Gardner et al., JGR, 98, 16,865-16,873, 1993].

We like to point out two concerns to be improved for the previous studies. First, although an SSL is complex phenomenon resulting from the confluence of various mechanisms, most studies focused on one mechanism alone. Second is a temporal resolution to calculate the neutral temperature and sodium density. Since the sodium density inside an SSL varies largely and quickly in an order of seconds, data with insufficient resolution mislead our understanding. The temporal resolutions of five minutes used in previous studies are insufficient. In this study, we have derived neutral temperature and sodium density with a 15 second. Furthermore, we have used data obtained with the EISCAT UHF radar, meteor radar and photometer together with the sodium LIDAR at Tromsø.

On 22 January 2012, an SSL was observed by the sodium lidar at about 94 km about 19 minutes after hard auroral precipitations. From 2118 UT to 2142 UT, the sodium density inside the SSL was from 2 and 6 times greater than the background sodium density. After 2142 UT the peak of the SSL went up to 96 km and the SSL became thinner than it was. The peak sodium density decreased, but it was still a few times higher than the background sodium density from 2142 UT to 2400 UT. We have calculated the temperature with a 15 second resolution, and have found that there are no remarkable enhancements in temperature profiles inside the SSL from 2118 to 2142 UT. It would be worth to point out that from 2200 to 2400 UT the SSL stayed in the local temperature minimum of the background atmosphere. Gardner et al. JGR. 2004JD005670 [2005] argued that the sodium density has a negative correlation with temperature at topside of the sodium layer. Therefore, our result is likely to indicate that the temperature profile contributes sustentation of the SSL in this event. To investigate other candidate mechanisms for the SSL generation, we have analyzed the EISCAT radar data. The EISCAT radar detected an Es layer simultaneously with the SSL. The Es layer was located on about 94 km altitude where the SSL was located from 2118 UT to 2200 UT. However, after 2200 UT the Es layer was located on 2 km below the SSL. This result is likely to indicate that the Es layer contributes the SSL generation.

Keywords: Sporadic sodium layer, sodium lidar, aurora, EISCAT radar, meteor radar