Studies of the polar lower thermosphere and mesosphere based on simultaneous observations of EISCAT radars and a sodium LIDAR

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We will firstly introduce a sodium LIDAR operated in northern Scandinavia, and secondly present some scientific results obtained by simultaneous observations of EISCAT radars and the sodium LIDAR at Tromsø, and thirdly talk about future developments of the sodium LIDAR for higher accuracy measurements of the upper atmosphere. We have been operating the sodium LIDAR for seven years (mainly polar winter season, i.e. October – March) since October 2010 at Ramfjordmoen, Tromsø, Norway (69.6ºN, 19.2ºE) to study effects of the solar wind energy input into the upper atmosphere as well as the earth atmosphere vertical coupling. The sodium LIDAR can measure temperature, wind velocity, and sodium density with good time and altitude resolutions (typically, 3 min and 500 m for our LIDAR) in the polar mesosphere and lower thermosphere (PMLT). One of the unique characteristics of the sodium LIDAR at Tromsø is a five beam capability which allows us to derive special variations of temperature and sodium density as well as to derive wind velocity. The PMLT is a unique region, because it is affected by the Magnetosphere (i.e. solar wind energy input) as well as by the lower atmosphere (i.e. atmospheric waves and vertical motion). Also, the polar region is thought to be a terminal (both starting and ending) of the meridional circulation in the mesopause height region (about 80-100 km) in the earth's atmosphere. Thus, the understanding of the region will lead us not only to understand the polar region but also the whole atmosphere.

The laser used in our sodium LIDAR is based on injection-locked Nd:YAG lasers with sum frequency generation technique, and the sodium LIDAR laser is characterized by (i) all solid-state laser source based on laser diode end-pumped Nd:YAG lasers, (ii) high laser power and high stability, (iii) capability of measuring mesospheric temperature and wind using a narrowband laser technique, (iv) production of continuous wave (cw) 589 nm light from cw 1064 nm and cw 1319 nm Nd:YAG lasers, (v) Doppler-free absorption spectroscopy using the cw 589 nm light for the absolute frequency monitor, and laser frequency locking and shifting, (vi) simultaneous five-direction observation mode with five sets of receivers, (vii) almost maintenance free system [1, 2].

We have operated the sodium LIDAR between October and March when dark interval (so-called polar winter) is longer than about 8 hours, and we operated the sodium LIDAR laser for, on average, about 2000 hours every year. Bad weather conditions sometimes prevented us from PMLT measurements, and we obtained about 3300 hours of temperature and sodium density data for the 7 seasons between October 2010 and March 2017 as well as about 2200 hours of wind data between October 2012 and March 2017. At Ramfjordmoen, powerful IS radars (EISCAT radars which can measure plasma parameters above 60 km) as well as meteor radar and MF radar are operated together with several optical cameras/imagers. Combination of the sodium LIDAR with the other instruments makes comprehensive measurements of PMLT region possible, which leads us to deeper understanding of phenomena occurring there. During the seven seasons, we run the EISCAT radars as a Japanese special program (SP) and succeeded in obtained simultaneous data for about 20 nights. In addition to these successful SP runs, Common Program (CP) data were also obtained when the sodium LIDAR was operated. In total, simultaneous observations were made for about 50 nights (about 200 hours). By using the simultaneous data, we have studied Joule heating, neutral-ion collision frequency, atmospheric waves, and variations of sodium density. We will show these results.

Several plans of improvement of the LIDAR are in progress or under discussion. For example, to clarify auroral effects on the PMLT more deeply, we need to improve the time resolution of the sodium LIDAR. To make this happen, we need a higher sensitive receiver system and a capability of changing wavelengths more quickly (say 10 sec or so). Next year, we will install a new receiver system with a 60 cm telescope to strengthen the capability of the vertical directional observation. We will present our future plans in more detail.

References

[1] Nozawa, S. et al., 2014, *JGR, 119*, 441-451.
[2] Kawahara, T. et al., *Optics Express, 25*, A491-A501, 2017