A case study on the possible altitude-dependent effects of collisions on sodium airglow emission

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[1] Simultaneous observations of a narrowband sodium (Na) airglow photometer corresponding to the D2 line in conjunction with a Na lidar from Gadanki (13.5°N, 79.2°E), India, reveal episodic enhancements in Na airglow intensity during 1930–0142 Indian standard time (IST; IST = UT + 5.5 h) on 18–19 March 2007. This variation is drastically different from the average Na airglow intensity variation for that duration during that month. Interestingly, the Na airglow intensity variation is found to be well correlated with the Na atom concentration variation only at 93.6 km during the period 2312–0142 IST, a period closer to the measurement of mesospheric ozone by the Sounding of Atmosphere using Broadband Emission Radiometry (SABER) instrument on board the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite. Moreover, the correlation coefficient is not significant at 88.5 km, where the Na concentration is maximum. Estimations of the altitude profiles of the volume emission rate of Na airglow corresponding to the D2 line using measured parameters during local postmidnight hours reveal that the peak of volume emission rate is different from 93.6 km. It is suggested that the altitude variation in collisional quenching is needed to match the peak altitude of emission to the altitude where correlation between the Na atom concentration and Na airglow intensity is maximum. The fact that the measured atmospheric pressure reduces by a factor of ∼2.5 as altitude changes from 88.5 to 93.6 km supports this proposition. The case study brings out the sensitivity of Na airglow intensity to the altitude dependence of the collisional quenching that eventually affects Na airglow emission.


1. Introduction

[2] The emission of airglow from the neutral Na atoms in the terrestrial mesosphere has been known for many years, and Chapman [1939] first suggested that mesospheric ozone plays an important role for this emission. The following chemical scheme was proposed by Chapman [1939] to explain the origin of the Na airglow:

\[
\text{Na} + \text{O}_2 \xrightarrow{k_1} \text{NaO} + \text{O}_2, \quad (1)
\]

\[
\text{NaO} + \text{O} \xrightarrow{k_2} \text{Na}^* (^{2}P) + \text{O}_2 \xrightarrow{(1-\alpha)k_2} \text{Na} (^{2}S) + \text{O}_2; \quad (2)
\]

\[
\text{Na}^* (^{2}P) \rightarrow \text{Na} (^{2}S) + h\nu(589.0, 589.6 \text{ nm}). \quad (3)
\]

In the preceding scheme, \(k_1\) and \(k_2\) are the temperature-dependent reaction rate constants for reactions (1) and (2), respectively, and \(\alpha\) is the branching ratio for reaction (2). The Chapman mechanism explicitly suggested the roles of mesospheric ozone and mesospheric temperature and correctly indicated the formation of an intermediate species, NaO. Multitechnique observations in recent times [e.g., Clemesha et al., 1978, 1979, 1993; Takahashi et al., 1996] directly or indirectly confirmed the veracity of the Chapman mechanism. However, it was realized [e.g., Clemesha et al., 1995; Hecht et al., 2000] that the branching ratio \(\alpha\) involved in reaction (2) of the Chapman mechanism may vary substantially depending on mesospheric conditions. Clemesha et al. [1995], based on rocket-borne photometry and lidar measurements, found the derived \(\alpha\) to lie between 0.05 to 0.2, whereas Hecht et al. [2000], using onboard photometers and ground-based Na lidar as well as an airglow imager, found that the value of \(\alpha\) lies between 0.02 and 0.04. The factor(s) that is (are) responsible for the variations in \(\alpha\) is an important issue to be settled as variable \(\alpha\) also means variations in the yield of Na airglow emission.

[3] Recently, Slanger et al. [2005] proposed that the original Chapman mechanism needs to be modified to accommodate this aspect of variable \(\alpha\). The modified Chapman...