RAYLEIGH LIDAR OBSERVATIONS OF DOUBLE STRATOPAUSE STRUCTURE

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ABSTRACT

Using four years of Rayleigh lidar data collected from three different northern hemisphere stations (Gadanki 13.5°N, 79.2°E ; Mt. Abu 24.5°N, 72.7°E and Observatoire de Haute Province OHP; 44°N, 6°E), the statistical characteristics of double (separated) stratopause are presented here. The normal stratopause (NS) is positioned between the levels of double stratopause (upper and lower level), and it is closer to the lower level of double stratopause (LDS). The mean stratopause heights (NS, LDS and UDS) are higher in sub-tropics (Mt.Abu) than tropics (Gadanki) and mid-latitudes (OHP). The lower and upper levels of double stratopause are separated by ~2-8 km with high value for tropics and sub-tropics than mid-latitudes.

1. INTRODUCTION

Stratopause, a fairly stable layer in the terminal point of stratosphere and is located in the height region from 45-55 km, over the globe. Any changes in the stratosphere/stratopause could occur due to different propagating atmospheric waves and the presence of chemical constituents (ozone) (*Hitchman et al.,* 1989; *Singh et al.,* 1996). The above sources also play a significant role in modifying the thermal structure at, above and below to the stratopause region (mesosphere and troposphere). Using the rocket measurements, *Gupta et al.,* (1978) have reported the occurrence of double stratopause over Thumba (8.3°N; 76.5°E), in their climatological study. They found that the occurrences of double stratopause are of ~20 % and the stratopause is apart maximum by ~10 km. Using the satellite data, *Hitchman et al.,* (1989) revealed the occurrence of separated stratopause in both the hemispheres and found to be more prominent with persistence during southern winter. By using a 2-D model, they suggested that the gravity wave driving could account for the observed splitting of stratopause by driving circulation in the winter hemisphere. Addition to the above measurements, using lidars, few stations have also addressed the occurrence of double stratopause and reported, subsided with their results (*Leblanc et al.,* 1998; *Sivakumar,* 2002; *Sharma et al.,* 2006). Except the above case studies, there is no statistical studies and no climatological picture on the occurrence of double stratopause.

The present study is focused on an interesting feature of the middle atmosphere temperature profiles, the occurrence of double stratopause structure in the height range of 40-60 km.

2. DATA AND ANALYSIS

The Rayleigh lidar data collected for the 4 years of period from 1998 to 2001 and for the three different stations, such as; Gadanki, Mt. Abu and Observatoire de Haute Province (OHP) are used for identifying and characterizing the double stratopause structure.

The recorded raw data is in the form of photon count profiles and then the temperature profiles are derived by following the method as given by *Hauchecorne and Chanin* (1980). More details on the lidar system and method of analysis may be found from *Sivakumar et al.,* (2001; 2002; 2003), for Gadanki, from *Sharma et al.* (2006) for Mt.Abu and from *Hauchecorne and Chanin* (1980) for OHP. The number of data used for the present study in each month and for the three stations are tabulated in the table-1.

3. RESULTS

Figure-1 shows a typical example of height profile of temperature illustrating single and double stratopause cases. The lidar observations were carried out over night (~ 4 hrs) and the mean temperature profile is displayed in the figure. It appears from the figure that the single/normal stratopause (NS) is located at 48.1 km, 47.7 km and 45.0 km, respectively for Gadanki, Mt. Abu and OHP. Whereas, the double stratopause cases, illustrate their occurrence of the upper level of double stratopause (UDS) at 53.2 km, 54.5 km and 50.0 km, lower level of double stratopause (LDS) at 43.6 km, 47.3 km and 44.0 km, and the distance of separation

Table-1: Monthly distribution of total number of days used for Gadanki, Mt Abu and OHP.

Month	Gadanki	Mt. Abu	OHP
Jan	27	04	56
Feb	42	09	57
Mar	45	09	52
Apr	52	15	43
May	08	07	28
Jun	04	05	54
Jul	03	--	78
Aug	04	--	75
Sep	04	03	67
Oct	11	08	53
Nov	19	05	40
Dec	21	08	48

between them are of 9.6 km, 7.2 km and 6 km. The tropical station, Gadanki, experienced the highest level of separation in comparison with sub-tropics (Mt.Abu) and the mid-latitude station (OHP).

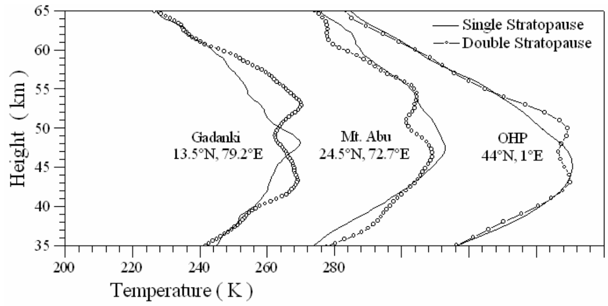

Fig. 1. Height profiles of temperature illustrating the single and double stratopause structure from three different stations. The successive profiles are shifted by 40 K.

The daily averaged temperature profiles from the three stations are used to identify the double stratopause occurrence and to note the heights of occurrences (NS, UDS and LDS). The percentage of double stratopause occurrence is calculated from the total number of observation. It shows that the maximum number of cases is obtained for Gadanki (63.3 %) followed by OHP (43.6 %) and then by Mt. Abu (42.4 %). The prevalence of double stratopause structure in the temperature profile is further evidenced in all stations.

The monthly mean height occurrence of NS, UDS and LDS is obtained by grouping the data in terms of months, irrespective of the years and presented in the figure-2. During few months, the frequencies of observations are less or even zero, due to prevailing monsoons which prevent/discontinue the lidar operation. For the case of Mt.Abu, there was no data during July and August months. Figure-2 illustrates with NS is situated at the centre level of LDS and UDS, for all the three stations. The NS is vertically distributed in 44.8 km-50.3 km, 44.9 km-54.5 km and 43.5 km-51.0 km height range showing the lowest position during May, December and February months and the highest position during July, November and November months, respectively for Gadanki, Mt.Abu and OHP. It is evident from the figure-2 that the LDS variability ranged from 43.2 km to 47.9 km with minimum and maximum during August and July for Gadanki, from 44.4 km to 50.6 km with minimum and maximum during January and November for Mt.Abu, and from 42.3 km to 47.2 km with minimum and maximum during February and October for OHP. The location of UDS is distributed between 49.0 km to 52.8 km, 48.7 km to 56.6 km and 48.1 km to 52.5 km, with minimum during August, January, February and maximum during June, November and October, correspondingly for Gadanki, Mt. Abu and OHP.

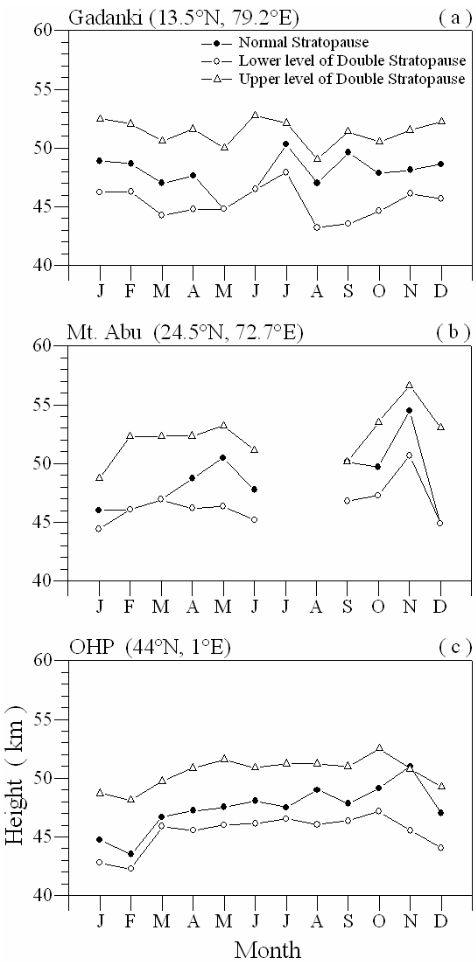

Fig. 2. The monthly mean distribution of heights of occurrence of NS, LDS and UDS, obtained by lidar observations from 1998 to 2001 over (a) Gadanki (b) Mt. Abu and (c) OHP.

The over all mean height distribution of NS, LDS and UDS, highlights the NS at the center level with its location nearer to the LDS than to UDS. The mean stratopause heights (NS, LDS and UDS) show higher values for sub-tropics (Mt.Abu) than tropics (Gadanki) and mid-latitudes (OHP). It also conforms that the distance of separation between UDS and LDS is relatively high for tropics (Gadanki) and sub-tropics than mid-latitude.

The monthly percentage of occurrence of double stratopause for the three stations are calculated and presented in figure-3. It anticipates the maximum percentage of occurrence during March/April and October/November months for Gadanki/OHP. Though, the figure shows another peak during August for the case of Gadanki, statistically this peak may not be considered due to the number of observations made during August is very few (ref. Table-1).

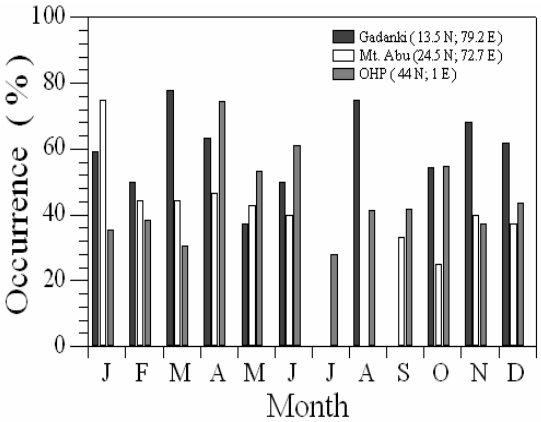

Fig. 3. Histogram representing the percentage of occurrence of double stratopause from the four years of lidar data (1998 to 2001) and for the three stations.

4. DISCUSSION

Here, we discuss the causative mechanism for the observed phenomenon. The perturbations in stratosphere temperature are either due to the propagating waves or the chemical constituents. Though the chemical constituents (like ozone), may play a role in altering the stratospheric temperature, the changes in constituents normally persists for long time period (~ 1-2 month) and may not be reformed to the initial status within a short period (~1-2 days). Hence, we strongly believe that the wave activity could be the main source for altering the temperature and thereby the generating double stratopause. The figure 1 is also in supportive of this view, by evidencing the wave like structure in the temperature profile.

There could be a possibility of propagating planetary wave (PW) and gravity wave (GW) that may act as a source to generate such structure of double stratopause. Gravity waves commonly propagate from troposphere to the mesosphere region, could be a source to generate such structure, when it reforms their energy at stratopause height. Earlier results on GW activity for Gadanki were reported and concluded that the maximum wave activity during equinoctial periods (*Sivakumar et al.,* 2001; 2002; *Ratnam et al.,* 2003), which is in consistency with the percentage of occurrence of double stratopause with peaks during March/April and October/November. Similarly, the GW activities over OHP show that the maximum activity is found to occur during winter (*Hauchecorne et al.,* 1987).

The planetary waves (PW) also contribute for the dynamical changes in the stratosphere temperature, from high- to mid- and low-latitude stations. The recent evidence on stratopause warming reported by *Sivakumar et al.,* (2004), for Gadanki, show that the stratopause temperature may have the magnitude of warming ~18 K due to the planetary wave breaking. The stratospheric warming event occur at northern hemisphere pole had seen at stratopause height over tropics when the dragging of planetary waves moved toward tropics and upwards. Similarly, the result reported from the mid-latitudes stations also similar in kind with higher in amplitude of warming and also predominant PW activity during winter in the stratosphere (*Hauchecorne et al.,* 1983; *Leblanc* et al., 1998). Above results are also suggested that the PW activity is more dense during winter in connection to the stratospheric warming. In other sense, it reflects that the LDS height occurrence may be related to the PW activity, during winter, especially.

However, the sudden changes in the chemical constituents and re-storing force of wave activity also have to be considered for forming the double stratopause; needs further understanding in order to make any conclusion. *Allen et al.,* (1997) presented the Microwave Limb Sounder observed double-peak in temperature consisting one peak near the stratopause and another at lower mesosphere level. They found that the structure was in consistency with three dimensional barotropic/baroclinic instability model predictions, and suggested that the instability dynamics enroll the wave forcing.

5. CONCLUDING REMARKS

For the first time, the Rayleigh lidar observation of double stratopause structure is reported from three different stations over the northern hemisphere. The observations from mid, low latitude and subtropical stations show that the structure exists over the globe, with the variations by seasonally and latitudinal. We trust that the PW and GW activity may play a role in materializing the LDS and UDS. The future work will shade light on the double stratopause formation mechanism by coupling observations with wave dynamics and models.

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