CHAPTER – 6

STUDY OF VERTICAL DISTRIBUTION OF STRATOSPHERIC AEROSOL NUMBER DENSITY

6.1. INTRODUCTION

The stratospheric aerosols are studied by several workers in all over the world [1]. In the present work aerosol measurements have been carried out at Kolhapur (16°42′N, 74°14′E) by using newly designed Semiautomatic Twilight Photometer during the period 1 January 2009 to 30 December 2011 to study the vertical distribution of the stratospheric aerosol number density per cm$^3$ (AND) (Here after aerosol number density per cm$^3$ is abbreviated as AND). The day to day variability of the vertical distribution of stratospheric AND, monthly and seasonal variations of stratospheric AND have been discussed in the present study. This is being a passive technique; clear sky conditions are preferable for obtaining the vertical profile of aerosols. The days on which low, middle and high level clouds were observed also noted down during the period of observations.

Stratospheric aerosols are known to play an important role in the climate system because they can influence the global chemical and radiation balance in the atmosphere in a number of ways [2, 3]. During volcanically quiescent periods, when stratospheric aerosol can be characterized as in a background state unperturbed by volcanism, the direct radiative impact of stratospheric aerosols tends to be rather small. However, these particles may also play a role in the nucleation of near tropopause cirrus, and thus indirectly affect radiation [4, 5]. Stratospheric background aerosols also play an important role in the chemical balance of the stratosphere. At mid-latitudes they affect the ozone balance indirectly by interacting with both nitrous oxides [6] and chlorine reservoir species. For instance, NO$_x$ increases under low aerosol loading conditions and induces ozone loss from the nitrogen catalytic cycle [7]. These examples provide an insight into the intricate interactions between stratospheric aerosols and the climate system.
The stratospheric aerosol layer was first measured in the late 1950s using balloon-borne impactors [8, 9] and is often called the Junge layer, although its existence was suggested 50 years earlier from twilight observations [10]. The altitudes of the layer of aerosol maximum on measurement days were derived from the aerosol vertical profiles. From these, oscillations of the Junge layer peaks on consecutive days were calculated. One attempt is made to examine the association between oscillations of the stratospheric aerosol layer peaks and weather conditions.

6.2. THE DAY-TO-DAY, MONTHLY AND SEASONAL VARIABILITY OF ‘AND’ IN LOWER STRATOSPHERE

Various types of variability of aerosol loading in terms of AND in between the altitudes 17 to 30 Km (lower stratosphere) are shown in Figure-6.1. The figure shows day-to-day variability in lower stratospheric AND from 1 January 2009 to 31 December 2009 for morning observations. In this figure Y-axis represents aerosol loading (Q, calculated by equ.15 in Chapter-3) and X-axis represents day numbers (i.e. date for each month). The TSM data collection at Kolhapur is generally not possible during ~mid-May to ~mid-October in any year because of the prevailing monsoon conditions (rains and extensive cloud cover). This being a passive technique, clear sky conditions are preferable for obtaining the vertical profile of aerosols. Thus data coverage is for the period ~mid-October of any year to ~mid-May of the succeeding year.
Figure-6.1: Varies types of variability of AND in between the altitudes 17 to 30km
For studying the seasonal variations, the year is divided into four seasons as described in section-5.2 (chapter-5), [11, 12, and 13].

The lower stratosphere (altitudes between 17 Km to 30 Km) showed day-to-day variability from October to May with highest aerosol loading (hereafter abbreviated as $Q_4$) in the month of March and lowest in the January. In the post-monsoon season the $Q_4$ started decreasing from mid-October to end of November. In winter the $Q_4$ started decreasing from early December to the mid-January (11 January 2009). This was the coldest period in the winter having lowest temperature $\sim 14^\circ$C. From 11th January $Q_4$ values increased up to end of the February. The atmosphere started warming in this period. Aerosol loading was highest in March, with many fluctuations due to frequently observed clouds. In the summer the $Q_4$ values started decreasing from end of the March through April up to May, at the face of arrival of south-west summer monsoon season [14]. Deviations from this trend in March were observed for clear days in between cloudy days. Cumulous clouds were observed frequently in March 2009. There was no TSM data available after 15 May 2009 due to extensive cloud cover formed by the active phase of the south-west monsoon. The monthly and seasonal variability of AND ($Q_4$) obtained for very clear days in the present study are very well sound with the aerosol optical depth variations obtained at Mysore by Raju et al.[15]. Results got by Jadhav and Londhe [16] and Khemani et al. [17] are also very good agreements with the results of the present study.

This lower stratospheric aerosol loading showed opposite phase relation with that of tropospheric aerosol loading. Upward transport of aerosol from troposphere to stratosphere takes place in the months of January to March; whereas downward transport takes place from April onwards to create privilege conditions for cloud formation process. The observational evidence of this study supported this fact.
6.3. THE DAY-TO-DAY, MONTHLY AND SEASONAL VARIABILITY OF ‘AND’ IN UPPER STRATOSPHERE

Figure-6.2: Varies types of variability of AND in upper stratosphere
Varies types of variability of aerosol loading in terms of AND in between the altitudes 31 to 50 km (upper stratosphere) are shown in the following Figure-6.2. The figure show day-to-day variability in upper stratospheric AND from 1 January 2009 to 31 December 2009 for morning observations. The upper stratospheric aerosol loading values were in between \(~20-30\) particles per cm\(^3\). These values are very much less than that of lower stratospheric aerosol loading; implying decreasing AND with respect to increasing altitude. Upper stratospheric aerosol loading showed day to day variability but there was no specific trend for monthly variability for all the three years. One noticeable point was that for the entire three years upper stratospheric aerosol loading was lowest for the month of February, the period free from strong meteor activities; whereas maximum for the month of December, the period followed by Orionids, Leonids and Geminids activities. Very slight variations were observed in the months of February, March and April, the period of weak meteor showers. The considerable fluctuations were detected in the period of strange meteor activities. The conclusion drown from these observations is that, the upper stratospheric aerosols completely depend on an influx of meteor matter including sporadic asteroidal dust particles and meteor showers. During meteor showers [18] a large amount of dust particles intrude into the mesosphere. These dust particles perturb the middle and upper atmosphere and also contribute to additional scattering in the atmosphere. The observational evidence supported this fact.

### 6.4. COMPARISON BETWEEN THREE YEAR’S STRATOSPHERIC ‘AND’

Figure-6.3 shows comparison between three year’s stratospheric aerosols loading for morning observations in the months of January to May. Also Figure-6.4 shows comparison between three year’s stratospheric aerosols loading for morning observations in the months of October to December. In both of the figures ‘A’ stands for lower stratosphere, whereas ‘B’ signifies upper stratosphere. The black line for both the figures corresponds to annual variation from 1 January 2009 to 31 December 2009, red line from 1 January 2010 to 31 December 2010 and green line from 1 January 2011 to 31 December 2011. In both of the figures Y-axis represents aerosol loading (Q) and X-axis represents day numbers for each year.
The month of January 2011, showed higher aerosol loading than other two years, 2009 and 2010 for lower stratosphere. Both of the remaining two years showed negligible difference. There is ~66% increase in the values of ‘Q’ in February 2009, showing higher ‘Q’ than years 2010 and 2011, which showed very small, difference among them. There are top most aerosols loading in the month of March 2009, which then showed sharp decrease in April 2009. The observations ended at 15 May 2009. After that sky was covered with low level clouds. The starting of rainy season (southwest summer monsoon) was prolonged up to end of June for year 2009. In year 2010, lower stratospheric aerosol loading started decreasing from 7th March and again increased from 28th March onwards. One noticeable feature is that upper stratospheric aerosol loading decreased highly from 28th March onwards. This implies that aerosols perturbed downwards in this period, could be attributed to increase in lower stratospheric aerosol loading. The aerosol observations ended at 6 May 2010 and the rainfall started near about mid June 2010. Lower stratospheric loading started decreasing from 12 March 2011 and observations closed after 6th April. The monsoon started very early, near about end of May for the year 2011. Upper stratospheric aerosol loading showed insignificant difference for three of the years for the months of February, March and beginning of April. The considerable variations were observed after the strong meteor activities of Quadrantids (3rd January), Lyrids (22nd April) and Eta Aquariids (6th May) [19, 20, 21], implying that the dust particles intruded into the mesosphere during meteor showers penetrated downwards causing increase in upper stratospheric aerosol loading. The amount of dust particles added in the atmosphere is not same for every year. Therefore significant deviations were noticed.

Comparison between three year’s stratospheric aerosol loadings for the months of October, November and December resulted with unclear outcomes. The lower stratospheric aerosol loading showed many variations for all of the three months due to frequently observed high, medium and low level clouds in this period. On the other hand the strong meteor activities of Orionids (21st October), Leonids (17th November) and Geminids (14th December) revealed significant fluctuations in the upper stratospheric aerosol loadings.
Figure-6.3: comparison between three year’s stratospheric aerosol loadings
Figure 6.4: comparison between three year’s stratospheric aerosol loadings
6.5. TO EXAMINE THE ASSOCIATION BETWEEN OSCILLATIONS OF THE STRATOSPHERIC AEROSOL LAYER PEAKS AND WEATHER CONDITIONS

Weather is a set of all the phenomena occurring in a given atmosphere at a given time. Weather phenomena lie in the troposphere [22]. Weather refers, generally, to day-to-day temperature and precipitation activity.

The altitudes of the layer of aerosol maximum on measurement days were derived from the aerosol vertical profiles. From these, oscillations of the Junge layer peaks on consecutive days were calculated. The association between oscillations of the stratospheric aerosol layer peaks and different level clouds [23, 24] was examined in this study. The altitudes of the Junge layer maximum on measurement days were derived from the aerosol vertical profiles. The oscillations of the Junge layer peaks on consecutive days were calculated. The graph between the altitudes of Junge layer peak obtained at clear sky days and day numbers was plotted. High, medium and low level cloudy days also noted down and they were included in this graph. Thus the relation between the altitudes of Junge layer peak and cloudy days was expressed in the following Figure-6.5. The black line in this graph represents the altitudes of Junge layer peak for clear sky days. The red, green and blue points stand for high, medium and low level cloudy days respectively.

The aerosol number density per cm$^3$ (AND) for peak point of the Junge layer was also calculated for every clear sky day. A graph between AND at peak point of Junge layer and day numbers was also plotted. High, medium and low level cloudy days also noted down and they were included in this graph also. The graph between AND at Junge layer peak point and day numbers was shown in the Figure-6.6. The black line in this graph corresponds to the AND of Junge layer peak for clear sky days. These graphs were plotted for the morning observations from 1 January 2011 to 31 December 2011. Both the graphs studied carefully and results were noted.
Figure-6.5: Comparison between altitude of Junge layer peaks and cloudy days
Figure-6.6: Comparison between AND (Aerosol Number Density per cm$^3$) of Junge layer peaks and cloudy days
The results acquired reveal that the altitudes of Junge layer peak for clear sky days lies between ~18 to 23 Km in the month of January and decreased slowly up to ~15 Km for the month of April. The AND of Junge layer peak for clear sky days increased slowly form ~4-6 particles/cm$^3$ for the month of January to ~7-8 particles/cm$^3$ for the month of April.

The sky was almost clear in January and March. In February all the three types of clouds observed frequently. It is seen from the above Figure-6.5 that the altitude of Junge layer peak for clear sky day, preceding the cloudy sky day lowered down to 11 Km and increased up to 19 Km on the clear sky day following the high level cloudy sky day. The some examples of high level cloudy days were 11 February (day number-42), 16 February (47), 14 March (72). Middle and low level clouds were frequently observed following with high level clouds. It implies that the CCN particles perturb downwards. In very rare cases middle level cloudy days were noticed separately after any clear sky day. The altitude of Junge layer peak decreased one day before the low level cloudy day and value of AND increased too much (three times the normal values). In winter The AND of Junge layer peak increased nearly three times for clear sky days prior to the days on which fog or dew drops were observed. From the curve it was expected that the aerosol layer would come down to a lower altitude to create favorable conditions for high level cloud development on the following day. The observational evidence supported this fact. However, at present the definite relation between variations in the altitude of Junge layer peak and weather conditions could not be established with so few data events. But it is possible if a greater number of events are available.

The annual variation of the altitude of the peak of Junge layer was also shown in the above Figure-6.5. This layer appeared to be drifting downward as the monsoon season approached. During the post monsoon season the variations were large between 12 to 28 Km. The altitude of Junge layer peak for clear sky days is maximum, ~23 Km in the month of January. However, a steady decrease in this from 23 to 15 Km was noticed during January-April 2011. The annual variation of the altitude of the peak of Junge layer and the AND of Junge layer peak showed opposite phase relation.
Nighut et.al. [16] Suggested that the aerosol layer maxima shows downward drifting before cloudy days and upward drifting after cloudy days. The results obtained by this study are very well matching with the earlier obtained results. They were unable to distinguish between different types of clouds and their association with aerosol loading. This is achieved in the present work with the help of semiautomatic twilight photometer.

6.6. SUMMARY AND CONCLUSIONS

The measurements using the twilight scattering method presented in this section suggest the following,

I. There is an annual variation in aerosol loading. Its maximum at lower stratospheric levels is observed during March.

II. The lower stratospheric aerosol loading shows seasonal variations and it decreases at the face of arrival of south-west monsoon season.

III. The lower stratospheric aerosol loading showed opposite phase relation with that of tropospheric aerosol loading.

IV. The dust particles intruded into the mesosphere during meteor showers penetrate downwards causing increase in upper stratospheric aerosol loading.

V. The peak of Junge layer on the clear sky days preceding the cloudy sky days is at a lower altitude than on clear sky days following cloudy sky days.

VI. There is an annual variation in the altitude of the peak of Junge layer also. Its maximum is observed during January.

VII. The annual variation of the altitude of the peak of Junge layer and the AND of Junge layer peak showed opposite phase relation.

VIII. It will be possible to establish the definite relation between oscillations of the stratospheric aerosol layer peaks and weather conditions, if a greater number of events are available.
REFERENCES


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Figure-6.3: comparison between three year’s stratospheric aerosol loadings
Figure-6.4: comparison between three year’s stratospheric aerosol loadings
Figure 6.5: Comparison between altitude of Junge layer peaks and cloudy days
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