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A Study of Stable Layers in Lower Atmosphere using the Indian MST Radar

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Abstract

The mesosphere, stratosphere and troposphere (MST) radar, installed at Gadanki (13.47^0N, 79.18^0E) near Tirupati in Andhra Pradesh, was used in the ST mode to study the variability of the tropopause and the stable layers in the atmosphere, For this purpose, the direction of the antenna beam was pointed vertically towards zenith, as the vertically directed radar provides an indication of tropopause. Measurements with 150 m range resolution were taken for two hours (1430-1630 IST) for five days in the afternoons of 24-26 Feb. and 23-24 Mar. 1992. Multilayered structures (3-4 layers) were observed below and above the tropopause. The tropopause height was detected from the radiosonde measurements at Madras, a nearby IMD-station. One or two layers were also always seen in the lower atmosphere in the region of 6.5 – 8.5 km height. Within the observation period, these layers were found to vary in strength (S/N value), but the location remained unchanged, though it varied from one day to another. The layer in the lower atmosphere can be turbulent or stable layer and further experiments are needed to verify the nature of the layer.

Introduction

VHF radars are now used to observe specular echoes on routine basis at vertical incidence [1,2]. These enhanced echoes arise primarily from stable regions of the atmosphere. Comparisons of the magnitude of these specular echoes with balloons soundings have indeed shown a very good correlation with atmosphere stability[3].The ability to detect stable atmosphere regions from enhanced echoes using VHF radars provides a direct and simple technique for determining the height of the tropopause, since a pronounced discontinuity in atmospheric stability is an indication of the tropopause[4]. The Indian MST radar, located at Gadanki (13.47^0N, 79.18^0E) near Tirupati in Andhra Pradesh, was operated in the ST mode for two hours (1430-1630 IST) for five days in the afternoons of 24-26 Feb. and 23-24 Mar. 1992. In this paper we discuss the variability of the tropopause and the stable layers in the lower atmosphere from these radar measurements.

Experimental set-up and method of analysis

The Radar was used in the ST mode and the zenith (X-polarization) beam was pointed vertically during the observation period of two hours. Observations were taken on 24-26 Feb. and 23-24 Mar. 1992 in the afternoon hours from 1430 to 1630 IST on each day. The transmitted pulses of 16 μs were coded with baud length of $1\mu s$ and a duty ratio of 1.6%. The details of the experiment are given in Table 1. The spectra were obtained with a spatial resolution of 150 m covering a height range of 3.6 km to 22.8 km at 129 range bins. Doppler spectra were recorded each 72 s on magnetic tape for off-line analysis. The data were recorded as a function of radar range which was converted

Table 1- Specifications of experiment

Beam used	Z_x, Z_y
Spectra	Doppler power
Observation interval from one beam to another beam	36 s
Transmitted pulse	$16\mu s$ (coded)
Inter-pulse period	1000 μs
Coherent integrations	256
No.of FFT	128
Range Resolution	150 m
Height coverage	3.6 – 22.8 km
Nyquist frequency	1.953 Hz
Doppler frequency resolution	0.0305 Hz
Max. velocity	5.52ms^{-1}
Radial velocity resolution	0.086ms^{-1}
Duration of observation	2h(1430 to 1630 IST)

to height above mean sea level (MSL) using the equation : $h = (r - r_b)\cos(\Psi + h_s)$, where h is the height from MSL, r the range r_b the range bias (= 1.0km), Ψ the zenith angle, and h_s the height of the radar site above MSL (= 0.40km). The height mentioned in the text hereafter is to be taken as the height above the mean sea level. A software was developed at the National Physical Laboratory, New Delhi, on VAX 11/780 computer to process off-line data, which gives received power, radial Doppler shift, Doppler width, and signal-to-noise ratio[5]. The procedure for parameterization of the spectrum in terms of the first three moments adopted is similar to the one for the Poker Flat radar[6]. The average noise power level (i.e. noise power per Hz) for each range bin is determined by adopting an objective method developed by Hildebrand and Sekhon[7].This technique is based on the statistics of a Gaussian random variable and the expected relationship between mean and variance for the spectrum of white noise (for details, see Refs 6-8).

Results

From off-line analysis, signal-to-noise ratio (hereafter S/N value) was calculated by keeping a threshold of - 10 dB. The six averaged S/N height profiles are shown in Figs. 1-3. The S/N values are mentioned on X-axis, and for the subsequent profiles a unit of 10 is added to displace each profile on X-axis. These profiles were obtained by taking an average of about 15 scans

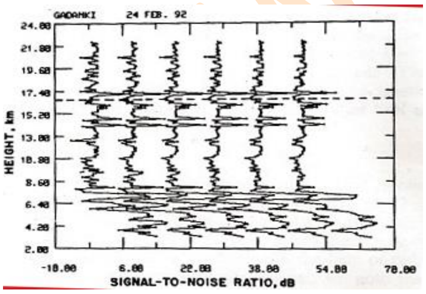

Fig. 1- Height profiles of signal-to-noise ratio (S/N value) obtained from the Indian MST radar in the ST mode on 24 Feb. 1992. The S/N values for the subsequent profiles are displaced on X-axis by adding unit of 10 in each profile. The 15 scans are averaged to get one profile. The dashed line indicates the tropopause height detected from radiosonde measurements.

(Approximately at every 17min)of observations. This number could be smaller at altitudes in the upper troposphere, especially in-between the stable layers where S/N value was low. Whenever the S/N value was less than – 10dB, that measurement was not included in obtaining the average. At some altitudes (viz. 10.0 – 14.0 km and a few other heights), the S/N values were always found to be less than – 10dB during the two-hour observation period. In such cases, the S/N value is shown as zero in the figures. On 24 Feb. 1992 (Fig.1), the S/N value was observed to decrease between 3.15 and 3.75 km, and then it started to increase and remained almost constant up to 5.55 km. In this region, not much temporal variation in the S/N value was noticed during the observations. Above 5.55 km the S/N value started to decrease up to 6.75 km and then there was a sharp enhancement for

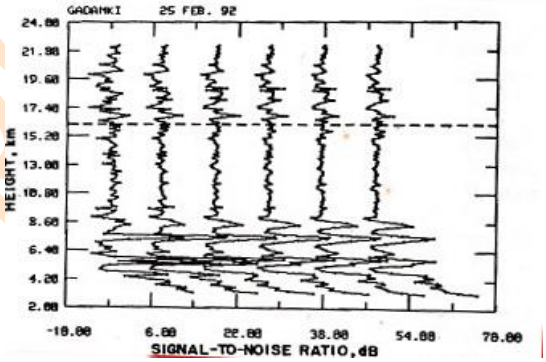

Fig-2 Same as Fig. 1 but for 25 Feb. 1992. The 16 Scans are averaged to get one profile one profile.

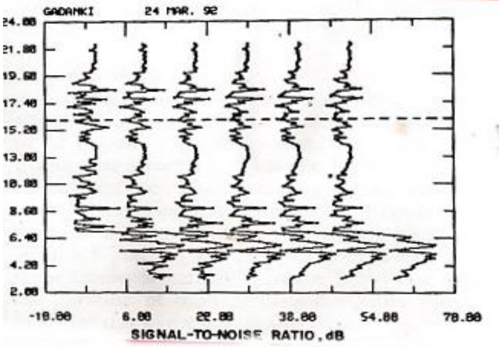

Fig. 3- Same as Fig. 1 but for 24 Mar. 1992. The 16 Scans are averaged to get one profile.

Two range bins at 7.05 and 7.20 km. Within the two-hour period of observations, enhancements in S/N values were also noticed at range bin at 6.9 km, in addition to the other two range bins.There was a noticeable spatial and temporal variation in the S/N value. Above 7.2 km the S/N value was very low. But, in the upper troposphere and around the tropopause, five distinct stable layers located at 14.10, 14.70, 15.75, 16.05 and 17.10 km. were observed. In these layers, no spatial variations were noticed in S/N value but temporal variations were noticed. The height of tropopause, obtained from radiosonde measurements at Madras, a nearby IMD station, was 16.57 km and is indicated in the figures for comparison.

On the second day (i.e. 25 Feb. 1992), the S/N value was observed to decrease between the region 3.15 and 4.20 km, and then two layers were noticed at 4.50 and 5.70 km. Subsequently, a few more layers were also noticed at 7.35, 7.50 and 8.40 km. These layers showed the temporal variation (i.e. the S/N value sometimes decreased and sometimes increased). The height of tropopause, obtained from radiosonde measurements was 16.15 km. A layer above the tropopause, at a height of 16.80 km, was seen (Fig.2). Here the value of S/N varied with time.

On 24 Mar. 1992 (Fig.3), the S/N value was nearly constant for the first two profiles up to a height of 5.25 km. Subsequently, for the remaining four profiles, the S/N value was observed to increase continuously up to 5.25 km. After that layer were observed at 5.85, 6.60, 7.35, 7.65 and 8.85 km. This indicates the temporal variation in the S/N value. In the upper troposphere and around tropopause, three layers at 15.45, 17.70 and 18.45 km were seen. The tropopause height detected from the radiosonde data was at 16.03 km. Again, the value of S/N in the layers was seen to vary with time.

Discussion

The radar measurements, with a spatial resolution of 150 m and temporal resolution of 72 s, have shown very interesting results on the tropopause structure and the stable layers. Such type of study could not be possible with the help of radiosonde. From these measurements, we note that in most of the cases 3-4 distinct layers are present. These layers show temporal variation in their strength on each day of measurement, but not much of spatial variation. However day-to-day variability in the heights of the layers is noticed. These layers are seen below and above the tropopause height (the tropopause height is deduced from the radiosonde measurements). In the lower troposphere, one or more layers are always present in the region between 6.5 and 8.5 km height. These layers also show day to day spatial variability. Temporal variation is also noted during the same experiment, within a period of about two hours.

Using the data from these experiments, Kumar et al[9] have studied short-period waves in the vertical wind velocity and compared these with the radiosonde measurements taken at Madras, a nearby IMD station. They have found that waves of 4-7 min periods are present in the upper troposphere and at altitudes of stable layers. However, in the lower troposphere, in the region between 6.5 and 8.5 km, a wide fluctuation in the periodicity (4-20 min) is noted. Singh et al[10], from radar observations at Gadanki, have concluded that significant shears are present only above an altitude of 6.0 km. In view of this result, we think that the layers present in the region from 6.5 to 8.5 km may be due to wind shear generated turbulence. However, further experiments are needed to verify the nature of the layers.

Stable layers around the tropopause have been observed at several radar locations[11].However, not many reports exist about the stable layers in the lower troposphere. Chu and Franke[12] studied the characteristics of a very thin atmospheric layer structure by using the Chung-Li VHF radar. They applied a frequency domain interferometry technique and found two prominent and lasting peaks around 7.5 km with a fairly strong echo power. They also noticed that the magnitude of the echo power at these layers was comparable to that below 5.0 km. These layers were seen at heights of 7.2 and 7.8 km and according to Chu and Franke[12], these layers were at least 86 and 124m thick.

Conclusion

The MST radar used in the ST mode with spatial resolution of 150m and temporal resolution of 72s shows some very interesting results on the tropopause structure and stable layers in the lower atmosphere. Multilayered structure (3-4 distinct layers) near and above the tropopause is seen. In addition, one or two strong layers between 6.5 and 8.5 km are also seen. These layers show temporal variability in the S/N value within the duration of the observation. Spatial variation from one day to the next is also seen.

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