A STUDY OF M-PROFILES FOR SOME STATIONS NEAR WESTERN COAST OF INDIA

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A study of modified refractive index profiles derived from radiosonde data relating to four stations located near the Western Coast of India has been made. Structure of some of the profiles and statistics of occurrence of M-inversions over these stations are given. Average monthly variation of Radio refractive index and its diurnal change near the ground surface and at certain fixed isobaric levels have also been described.

Climatic variation of refractive index over the surface of the earth and its variation as a function of height above the surface have been a subject of extensive study [1,2,3]. Bending of radio waves is dependent upon the vertical gradient of the refractive index, particularly in the lowermost region of the atmosphere. Climatic variation of radio refractive index near the ground surface and at certain other isobaric levels has been studied in detail in India and abroad by several workers[4,5]. In particular regions in India, certain meteorological conditions exist which result in the formation of super-refracting layers when the radio waves are trapped and give rise to an increase in the radio range of reception and improved signal strength. Very strong super-refracting conditions were reported near Bombay where 1·5 m radar echoes from very large ranges were observed[1] during the last War. No such effect was observed at that time by 1·5 m radar located at Cochin and Ceylon. Super-refraction in the South Arabian Sea has been investigated by Srivastava & Gupta[6]. From observations made with 10 cm radar located at Cochin, echoes from islands well beyond the normal range were received.

A knowledge about the existence of super-refracting conditions with the help of synoptic meteorological factors in addition to that of surface refractive index values may be of interest and usefulness. With this idea in view, modified radio refractive index profiles and variation of radio refractive index at surface and at some fixed isobaric levels for certain stations located near the Western Coast were studied.

RADIO REFRACTIVE INDEX AND M-PROFILE

The refracting properties of the earth's atmosphere may be expressed by a parameter N known as the radio refractive index[3]:

$$N = (n - 1) \times 10^6 = \frac{79}{T}\left(P + 4800 \times \frac{e}{T}\right) \qquad (1)$$

where T is the absolute temperature, P is the atmospheric pressure in mb and e is the partial vapour pressure in mb. While considering the propagation of radio waves over the curved earth, it is convenient to use the modified refractive index:

$$M = \left[(n - 1) + \frac{h}{a}\right] \times 10^6 \qquad (2)$$

where h is the height above the surface and a is the radius of the earth.

A curve obtained by plotting M against h is called an M-profile. In a standard radio atmosphere, M varies linearly with height above the earth's surface. The gradient has a value of about 0·12 M units per metre. Layers for which dM/dh is less than the standard and also for which dM/dh is negative, are known as super-standard. The latter are referred to as M-inversions. Atmospheric ducts are found to be associated with M-inversions.

Radiosonde data for the period November 1963 to May 1964 in respect of the four stations *viz.* Ahmedabad, Bombay, Minicoy and Trivendrum were obtained from the I.M.D. Poona. Radiosonde data are available twice daily (00 hr and 1200 hrs GMT) for all the above stations except for Minicoy, where only one radiosonde ascent (1200 hrs GMT) is recorded daily. Data for the period November '63 to May '64 were considered suitable for analysis, since this part of the year is the most favourable for the formation of super-refracting layers. Super refraction collapses with the onset of monsoon.

Radio refractive index (N) at surface, 1000 mb, 850 mb, 700 mb and at certain significant levels was calculated from the individual readings of pressure, temperature and dew point using equation (1). Modified refractive index (M) was then calculated using equation (2).

ANALYSIS OF DATA

Monthly mean values of radio refractive index at surface ($\bar{N}_s$) and at the three isobaric levels were found out from the daily values of N at these levels. This variation is shown in Fig. 1–5. Solid line and dotted line curves represent variations at 00 hr GMT and at 1200 hrs. GMT respectively. From the values of M calculated for the surface and other levels, the shape of the daily M-profiles was studied. Some of the profiles at Bombay are shown in Fig. 6.

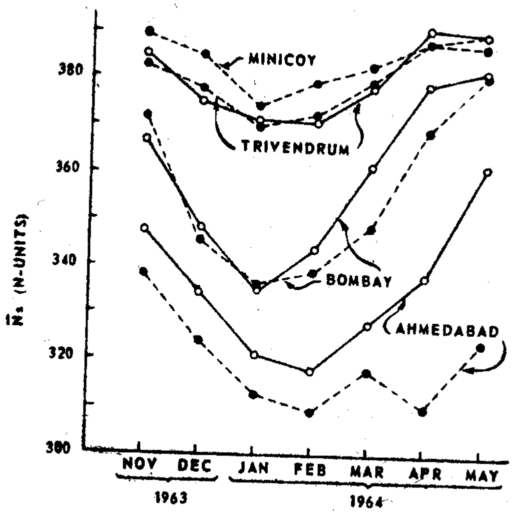

Fig. 1—Variation of $\bar{N}$ at different stations.
———— Variation at 00 hr GMT
- - - - Variation at 1200 hrs GMT

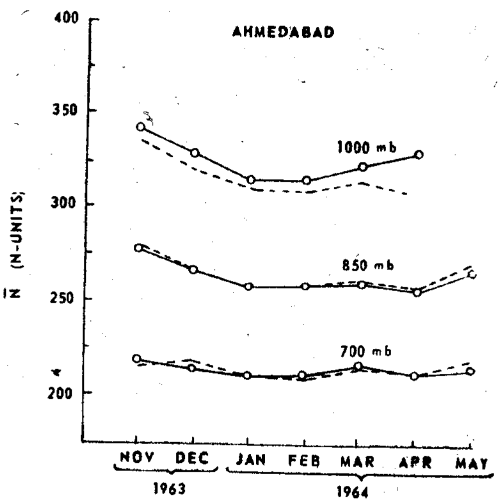

Fig. 2—Variation of $\bar{N}$ at Ahmedabad at different pressure levels.
———— Variation at 00 hr GMT
- - - - Variation at 1200 hrs GMT

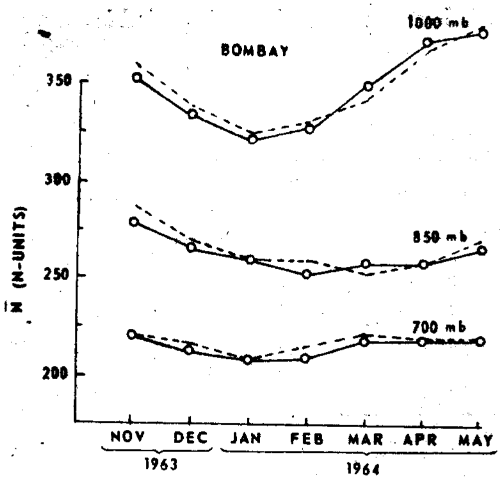

Fig. 3—Variation of $\overline{N}$ at Bombay at different pressure levels.
———Variation at 00 hr GMT
- - - - Variation at 1200 hrs GMT

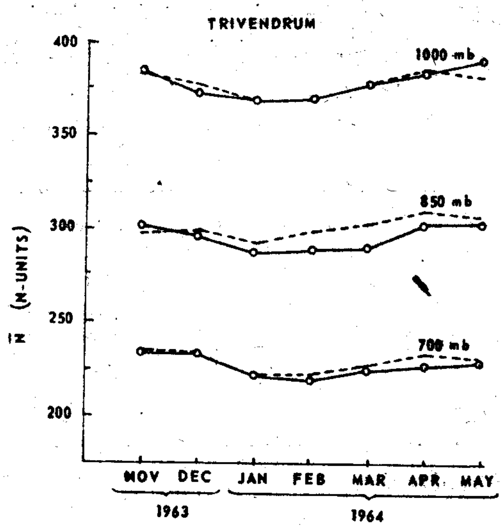

Fig. 4—Variation of $\overline{N}$ at Trivendrum at different pressure levels.
———Variation at 00 hr GMT
- - - - Variation at 1200 hrs GMT

Seasonal variation

The monthly mean value of *Ns* decreased from November onwards and reached the minimum value in the month of January or February for all the four stations. The range of variation of $\overline{Ns}$ is found to be small for Minicoy and Trivendrum as compared to Bombay and Ahmedabad, because of lesser variation in temperature and humidity

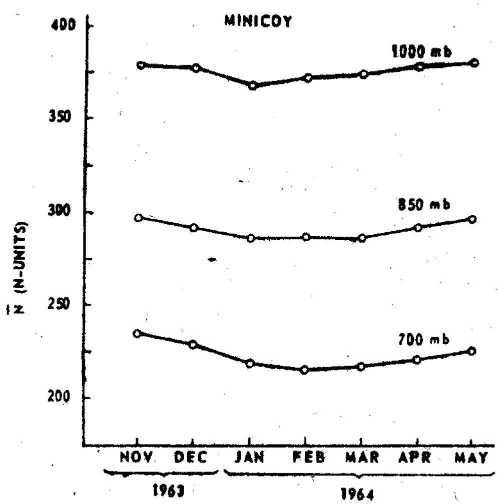

Fig. 5—Variation of $\overline{N}$ at Minicoy at different pressure levels.
———Variation at 00 hr GMT

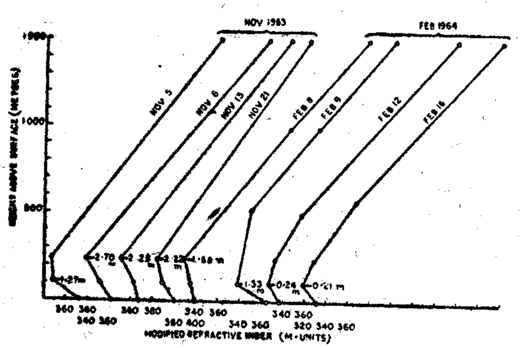

Fig. 6—Structure of some M-profiles at Bombay (00 hr GMT) capable of trapping one mode of wavelengths (in metres) indicated against arrows. The arrows mark the height of inversion.

at these places. The variation of $\overline{N}$ at other isobaric levels followed a pattern similar to that of $\overline{N}s$. The range of variation of $\overline{N}$ (N-units) at various levels during this period is shown in Table. 1.

TABLE 1

VARIATION OF $\overline{N}$ (N-UNITS) AT VARIOUS LEVELS

Station	Surface	1000 mb	850 mb	700 mb
Ahmedabad	30	28	22	7
Bombay	47	54	26	13
Minicoy	16	16	12	17
Trivendrum	19	17	15	14

Diurnal variation

The mean monthly diurnal variation, $\overline{N}s$ (00 hr)—$\overline{N}s$(1200 hrs) for the three stations is shown in Fig. 7. The diurnal variation was minimum for all the three stations in the month of January. Also, the diurnal variation in $\overline{N}s$ was small for Trivendrum in all the months as compared to Bombay and Ahmedabad, because of the former having a less diurnal change in temperature and humidity. The diurnal change in $\overline{N}$ at 1000 mb, 850 mb and 700 mb pressure levels can be seen from Fig. 2, 3 and 5. The range of the diurnal variation in $\overline{N}$ (N-units) is given in Table 2.

The range of diurnal variation in $\overline{N}$ at 700 mb level was found to be small and more or less same for the three stations. It was also observed that the mean diurnal variation of the radio refractive index did not depend on the mean values of the index.

TABLE 2

RANGE OF DIURNAL VARIATION OF $\overline{N}$ (N-UNITS) AT VARIOUS LEVELS

Station	Surface	1000 mb	850 mb	700 mb
Ahmedabad	8 — 38	5 — 26	0 — 4	1 — 4
Bombay	1 — 13	2 — 9	0 — 8	1 — 5
Trivendrum	1 — 3	0 — 6	2 — 12	1 — 6

M-Profiles

The routine meteorological soundings made by radiosonde are inadequate for a careful study, because they do not report in such detail the structure of the atmosphere as is required for this kind of study. The meteorological data given at the surface, 1000 mb 850 mb, and at significant levels between 1000 mb and 800 mb levels can give only a rough idea about the shape of M-profiles. Analysis of the data shows the existence of superstandard layers with surface based M-inversions. A general indication of the frequency of occurence, strength and height of M-inversions is given in Table 3.

TABLE 3

FREQUENCY OF OCCURENCE, STRENGTH AND HEIGHT OF M-INVERSIONS

Details	Time	Ahmedabad	Bombay	Minicoy	Trivendrum
No. of profiles studied	00 hr 1200 hrs	147 147	212 212	— 213	201 141
No. of days on which M-inversions were observed	00 hr 1200 hrs	8 Nil	86 43	— 16	7 Nil
Average elevations at which inversions were observed (metres)		206	81 & 25	75	194
Average decrease of M/100 met. observed through the M-inversion		3	12 & 5	7	5

The height of the inversion has been taken to be the height corresponding to the pressure level. It may be noticed that out of the four stations studied, only at Bombay there is more frequent existence of M-inversions. At other stations, the inversions were not so frequently reflected by the radiosonde observations. Nevertheless, the possibility of finding more frequent inversions at other places may not be ruled out. The frequency and magnitude of inversion might have been higher but for the slow response of radiosonde.

Fig. 8 shows the days in November to March on which M-deficits of various magnitude were observed at different heights in radiosonde ascents at Bombay at 00 hr *GMT*. These M-inversions are associated with temperature inversions supported by the humidity-lapse rate near the surface. It may be seen that there are considerable day to day variations in the height of inversions and the strength of the duct. Seasonal trends are not very apparent. There was no indication of the inversion at one place being extended to another place. It may probably be due to these stations being wide apart.

PROPAGATION IN DUCTS

It is difficult to find out exactly what wavelengths can be trapped in the ducts formed under the existing conditions as it is not possible to estimate correctly the height, depth and strength of these ducts. An attempt has, however, been made to get a rough idea of the wavelengths which could be trapped. According to Booker[2], when the height of M-inversion equals the track width of the first transmission mode, the associated wave is propagated to great distances. The track width of the first transmission mode under ducting condition is given by,

$$W_1 = 54 \cdot 1 \ \lambda^{2/3} \left[- \frac{dM}{dh} \right]^{-1/3}$$

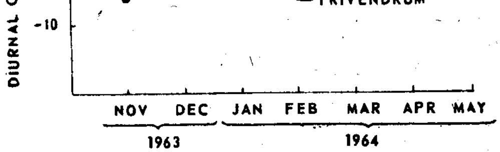

Fig. 7—Mean monthly diurnal variation in $\bar{N}_s$ [$\bar{N}_s$ (00 hr)—$\bar{N}_s$ (1200 hrs)] for Ahmedabad, Bombay and Trivandrum.

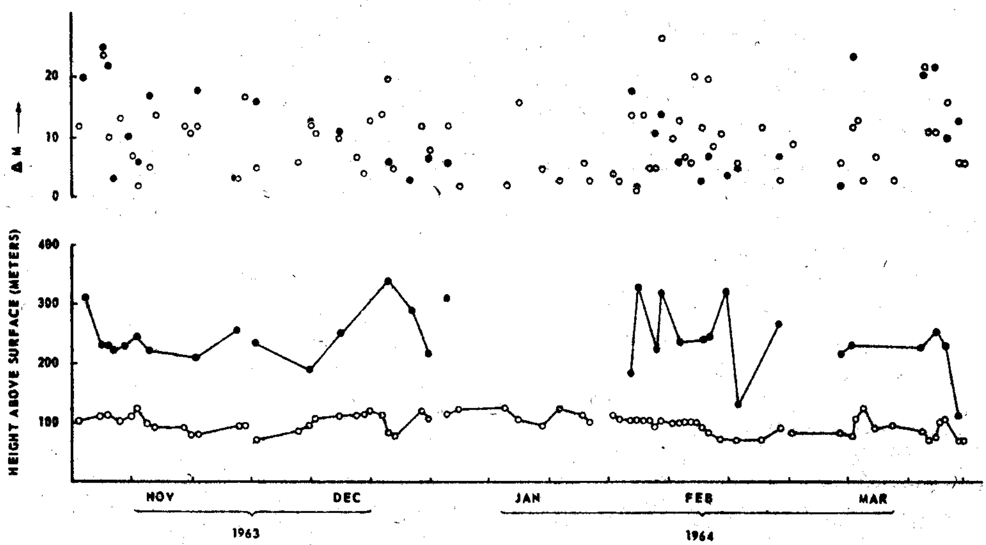

Fig. 8—Plot of inversion heights and corresponding decrease of M through the inversions at Bombay (00 hr GMT).

where λ is the wavelength in metres, dM/dh is the modified refractive index gradient in M-units per metre and W_1 is in metres. Using the above formula for the M-profiles shown in Fig. 6, the wavelengths having their first mode trapped in the ducts formed were calculated. The wavelengths were found to lie between 0·21 m to 2·70 m.

CONCLUSIONS

The refractive index structure in the lower region of troposphere, which has been examined here is important and requires closer examination in determining the degree of super-refraction existent in various seasons along the coast. When more data become available it may be possible to draw valid conclusions about the statistical and structural aspect of the formation of surface based inversions at the coastal stations. The routine radiosonde ascent, however, does not give the values of temperature, pressure and humidity in such details as are normally necessary for the duct propagation study and for other quantitative considerations of radio wave propagation problems. A much more detailed knowledge of the vertical and horizontal structure of the refractive index in the lower troposphere is required for estimating the persistance of ducts in coastal region and their influence in wave propagation studies.

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