

Radio refractive index structure over northern India and its synoptic variation

R. C. MAHESHWARI

Meteorological Office, New Delhi

(Received 24 May 1961)

ABSTRACT. Synoptic distribution of radio refractive index over northern India and its variation in association with some winter systems have been studied. Analysis in case of one particular system is presented here. It is noted that the refractive index shows a systematic variation with the passage of the systems and can be utilized as a synoptic parameter. Mean sea level chart of refractive index and its distribution on standard isobaric surfaces might probably be used for forecasting at least qualitatively, the conditions of V.H.F. propagation over northern India.

1. Introduction

Radio refractive index as a synoptic feature has been receiving increasing attention during the recent past because of its significant role in V.H.F. and U.H.F. propagation problems. A number of studies (Bean and Riggs 1959 (a), (b); Jehn 1960) have been undertaken with a view to investigate how best the refractive index could be utilized as a synoptic parameter. Radio refractive index has the advantage of combining the three basic elements, *viz.*, pressure, temperature and humidity and therefore has a considerable potential even in the field of air mass identification. All the previous studies have been concerned with the extra tropical regions where air mass characteristics are well defined. In the tropics where well marked frontal systems are rather few one would not normally expect the radio refractive index variations to follow the pressure systems too closely. However, the propagation problems remain much the same and in order to see if synoptic variation of the refractive index could be utilized as a useful concept, a study of some well defined winter systems over northern India has been undertaken. The choice of winter period systems, to begin with, was made keeping in view the fact that these are the only weather sequences in India which have some resemblance with the extra tropical depressions of the middle latitudes. A detailed study of these pressure systems has been made by Mal and Desai (1947). The

thermal structure of the western disturbances has been investigated by Anantha-krishnan (1950). Analysis of one of the systems which originated as an induced low over north-west India and moved eastwards after becoming a depression, is presented here and some of the notable features of the radio refractive index distribution outlined.

2. Method of analysis

The refractive index in the troposphere and the stratosphere is substantially independent of the radio frequency upto the U.H.F. range and is best expressed in terms of a modified refractive index given by

$$N = (n-1) \times 10^6 \approx \frac{77.6P}{T} \left(1 + \frac{7.71q}{T} \right) \quad (1)$$

where n is the usual refractive index, P is the pressure in millibars, T the temperature in degrees Kelvin and q the specific humidity expressed in gm/kgm. For using refractive index as a synoptic parameter, the surface data has to be reduced to some standard level in order to eliminate the effect of the height of the station, which would otherwise tend to mask any changes in the value of the elements due to synoptic variation alone. The surface refractive index N_s can, therefore, be reduced to mean sea level by using the expression (Bean and Riggs 1959)

$$N_0 = N_s \exp(0.1057 h) \quad (2)$$

where h is station height above mean sea level in kilometres, and the exp. refers to NACA dry standard atmosphere. Another way to utilize the refractive index synoptically is to bring in the potential refractive index—a concept identical to the potential temperature. The potential refractive index can be obtained by using the following expression (Jehn 1960).

$$K = \frac{c}{\theta} \left[1000 + \frac{b e_0}{\theta} \right] \quad (3)$$

where c and b are the usual constants in the formula for radio refractive index, θ is the potential temperature, 1000 (mb) represents the reference pressure level, and e_0 is potential vapour pressure referred to the 1000-mb level on the basis of constant mixing ratio. The values of θ and e_0 can be picked up from the radiosonde data plotted on a tephigram and the value of K can be calculated.

It is, however, found that the reduced to mean sea level value of refractive index is a better indicator in many cases. In case of upper air analysis the refractive index is calculated for standard pressure levels and the data utilized as such on a constant pressure map. In the present analysis the mean sea level refractive index and its distribution at 850 and 700 mb has been analysed in relation to the corresponding synoptic weather charts. The values of the potential refractive index have been calculated using equation (3), to compare the changes observed at different stations with the passage of the system.

3. Weather situation

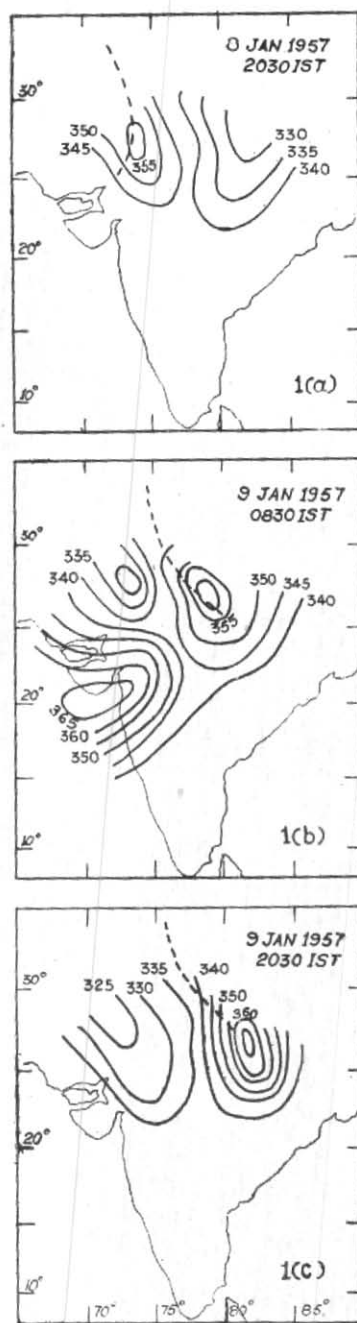
The weather system for which the refractive index analysis is presented here affected the northern parts of the country from 8 to 10 January 1957. A western disturbance moved into Baluchistan on 7 January and induced a low over the Upper Sind. By the morning of the 8th the low moved over north Rajasthan where it deepened into a depression after the 8th evening. On the 9th morning it was lying over the north Punjab and thereafter moved eastwards across the Punjab-

Kumaon hills. In association with this depression fairly widespread rain occurred over the whole of the northwest India. The temperature contrasts associated with the passage of the system were well marked. Although one could possibly put a frontal picture of this depression it is considered more appropriate for the present study, to use the associated upper air trough and consider the advance and wake of the system with reference to this trough line. In the charts presented here, the position of this trough line (at 1 km a.s.l.) is put as a broken line for the purpose of reference.

For upper air analysis the data are admittedly insufficient. Radiosonde data from three stations Jodhpur, New Delhi and Allahabad have been used to examine the progress of the system, while the data from the neighbouring stations Nagpur, Veraval and Karachi have also been utilized for the preparation of the constant pressure charts. Due to this inadequately close network of observations certain amount of subjectivity is bound to come into the upper air analysis, but that is not believed to affect the broad features outlined.

4. N_0 distribution

The mean sea level refractive index distribution corresponding to 2030 IST observations of 8th and 0830 and 2030 IST observations of 9th are shown in Fig. 1(a, b and c). The period relates to the time it took for the depression to form and move across Punjab-Kumaon hills. It can be seen from Fig. 1(a) that the radio refractive index shows a significant variation across the trough line. This change is more markedly brought out in Fig. 1(b) which refers to the morning of 9 January when the system has deepened. The trough line has shifted eastwards since the previous evening and the gradient of the index across it has also steepened. The value of the refractive index shows a marked rise in advance of the system. Another interesting feature is the existence of a high refractive index value distribution over Saurashtra and Gujarat. In a large measure this high is due



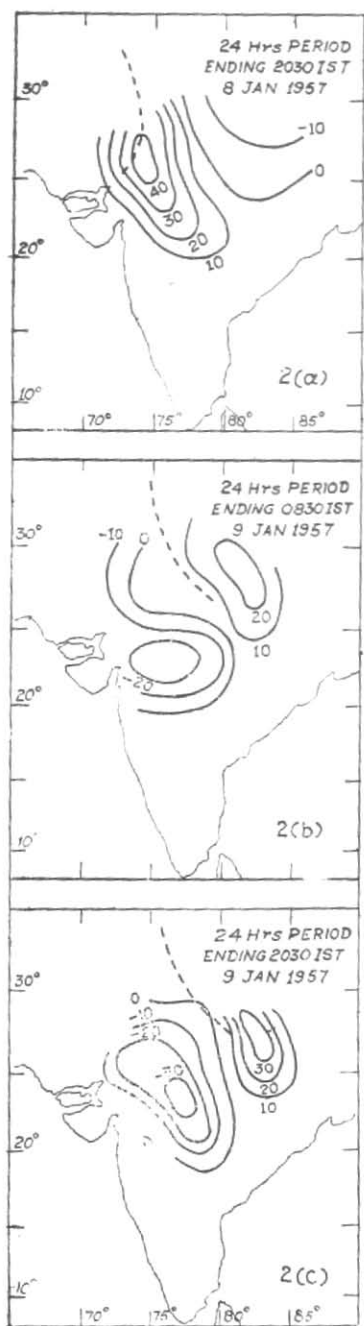
Figs. 1(a) to 1(c). Reduced to mean sea level radio refractive index (N_0 units)
 --- Axis of trough at 1 km a.s.l.

to a considerable influx of moist air from the Arabian Sea, under the influence of the depression. It can also be seen from the same chart that the values of the index have started registering a fall in the rear of the depression. This behaviour of the system is analogous to the extra tropical depressions wherein the refractive index reaches a significantly high value in the warm sector and falls to a markedly low value in the cold sector. By the evening of the same day the trough is moving away across the Punjab-Kumaon hills, as shown in Fig. 1(c) and the region of the maximum value of the index has shifted further east. It is also seen that the index has by now fallen appreciably in the wake of the system as evidenced by Jodhpur values. This characteristic rise and fall in the values of the index has a significant bearing on the thermal structure of the depression.

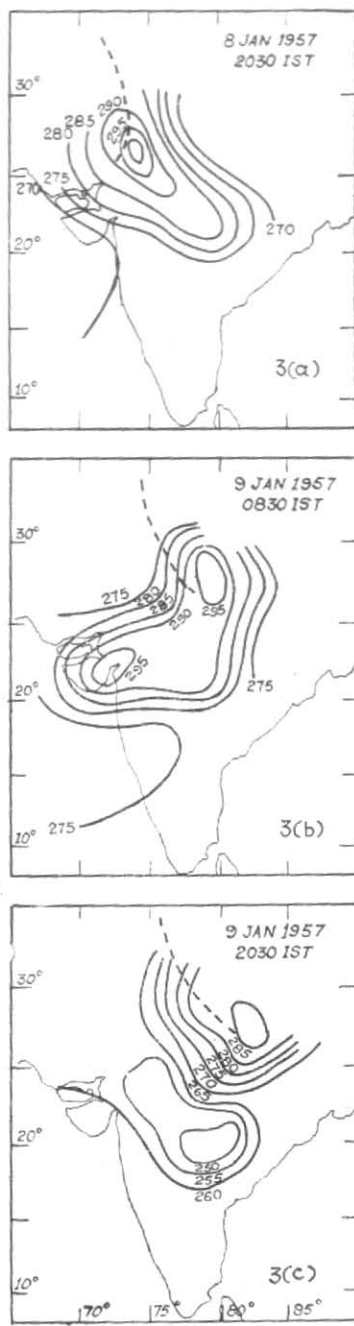
To bring out more clearly the variations of N_0 due to the movement of the system, 24 hour changes of N_0 have been plotted in Fig. 2(a, b and c). The 24-hour change ΔN_0 is obtained by subtracting from the present value of the index, the value existing 24 hours earlier. The ΔN_0 charts also follow the same pattern of changes as exhibited by the N_0 charts. ΔN_0 has high positive values in advance of the system and low negative values in the rear. The maximum rise is shown by Jodhpur on the evening of 8 January amounting to $+44 N_0$ units (Fig. 2a) accompanied by a fall of $24 N_0$ units on the evening of the 9th (Fig. 2c), when cold and dry winds sweep the plains in the rear of the disturbance. The fall in the values of the index in the rear of the system, though not so steep as behind a cold front in the middle latitudes, is none the less quite significant. It is thus seen that the ΔN_0 patterns closely follow the passage of the system.

5. Upper air analysis

For the upper air analysis the values of the refractive index have been calculated from the available radiosonde data for 850- and 700-mb surfaces. The 850-mb charts (Figs. 3 a, b and c) have been prepared for



Figs. 2(a) to 2(c). Change in the reduced to mean sea level refractive index (ΔN_0)



Figs. 3(a) to 3(c). Radio refractive index at 850 mb level

--- Axis of trough at 1 km a.s.l.

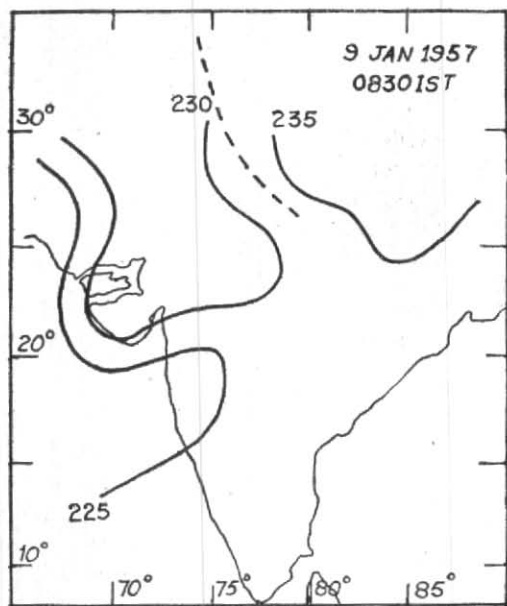


Fig. 4. Radio refractive index at 700 mb level
 --- Axis of trough at 1 km a.s.l.

the same hours as the mean sea level charts. 700-mb charts (Fig. 4) has been made for the morning of 9 January only. It is clearly seen from 850-mb chart that the same pattern is followed at this level also—a rise in the value of the index in advance of the system and a marked fall in the rear. The different refractive properties of the air masses can easily be identified. As pointed out under the heading 'N₀ distribution' about the existence of a high refractive index distribution over Saurashtra and Gujarat on the morning of 9 January, it can be seen from Fig. 3(b) that this high value distribution over that region persists at 850-mb level also, suggesting the transport of moisture upto and possibly above this level. It is, however, seen that the system becomes rather flat at 700-mb level (Fig. 4), but the general pattern of refractive index distribution and ΔN_0 is similar to mean sea level and 850-mb charts.

6. Potential radio refractive index study

A time section of the potential refractive index for Jodhpur, New Delhi and Allahabad is given in Fig. 5. At each of these stations

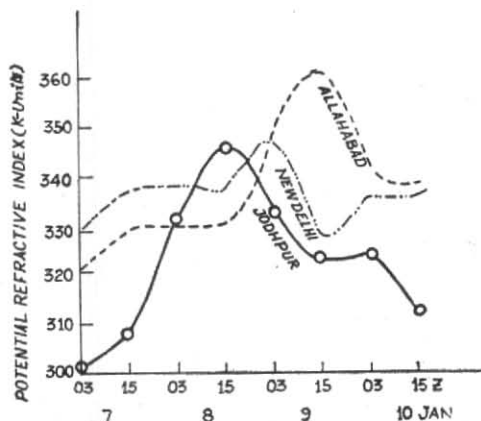


Fig. 5. Time section of potential refractive index for Jodhpur, New Delhi and Allahabad from 7 to 10 Jan 1957

the sharp rise and fall in the refractivity in advance and wake of the systems is clearly shown. On the evening of the 8th the refractive index has reached a maximum at Jodhpur and started falling later. The values at New Delhi show a corresponding maximum on the 9th morning while at Allahabad the maximum is reached on the evening of the same day. The lower initial and final values at Jodhpur as compared to those at New Delhi and Allahabad indicate that the refractive index as a climatological feature also may have considerable significance in propagation problems in particular regions. With a view to study the three dimensional structure associated with the movement of this pressure system a vertical cross-section of the radio refractive index from Jodhpur to Allahabad through New Delhi on the morning of the 9 January at 0830 IST is shown in Fig. 6, wherein the different air mass contrasts are clearly delineated. The changes in the refractive index shown in advance and wake of the system are carried over upto 850-mb level as already discussed. Above this level the maximum in the advance

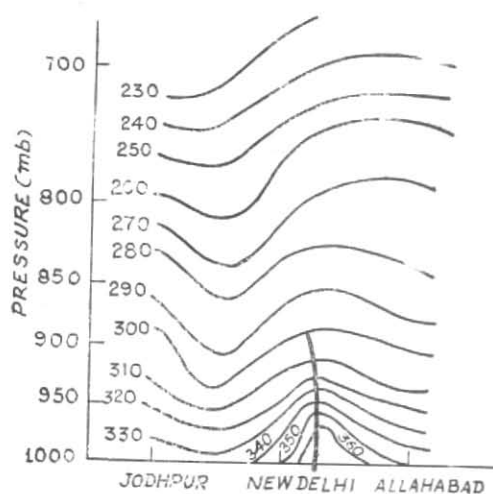


Fig. 6. Vertical cross-section of potential refractive index (K-units) from Jodhpur to Allahabad through New Delhi on 9 Jan 1957, 0830 IST

gets smoothed out, though the minimum shown at lower levels still persists. The low index values in the wake even upto 700-mb level are quite conspicuous, but it is not possible to put forth any definite suggestions of the manner in which the values in the wake are affected upto higher levels.

7. Conclusions

It is seen from the above analysis of a characteristic winter depression that the rapid movement of the trough line is very prominently reflected in the changes of the value of the radio refractive index. The rise in advance of the system is of the order of $+44 N_0$ units and the fall in the rear is of the order of $24 N_0$ units.

The refractive index variations follow a systematic pattern and the present analysis indicates the potential role of the refractive index as a synoptic parameter. Although analysis of large number of such cases is needed for putting forth definite suggestions, it is believed that synoptic refractive index charts can be utilized for a qualitative prediction of V.H.F. propagation conditions atleast in association with the passage of well defined weather systems.

8. Acknowledgement

The author wishes to express his gratitude to Shri Dharm Bir Rai for suggesting the problem and giving helpful suggestions from time to time.

REFERENCES

- | | | |
|--|---------|--|
| Bean, B.R. and Riggs, L. P. | 1959(a) | <i>J. Res. nat. Bur. Stand.</i> , 63D(1), pp. 91-97. |
| Bean, B. R., Riggs, L. P. and
Horn, J. D. | 1959(b) | <i>Ibid.</i> , 63D(2), p. 249. |
| Jehn, K. H. | 1960 | <i>J. Met.</i> , 17, p. 264. |
| Mal, S. and Desai, B. N. | 1947 | <i>India met. Dep. Tech. Note</i> , 25. |
| Ananthakrishnan, R. | 1950 | <i>Indian J. Met. Geophys.</i> , 1, p. 45. |