Variation in radio refractivity index associated with formation of low - pressure systems

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Abstract

Numerous low - pressure systems form in the Arabian Sea and Bay of Bengal. These low-pressure systems are highly useful in bringing the rainfall over the Indian sub continent. The developments of these systems are accompanied by the reduction in air temperature and an increase in atmospheric humidity. The radio refractivity, which is a function of the atmospheric pressure, temperature and humidity, also changes following the development of these systems. Variation of radio refractive index and its vertical gradient are analysed for many low pressure systems formed over the Arabian Sea and Bay of Bengal. It is found that the atmosphere becomes super refractive associated with the formation of these systems, caused by the increase in humidity and decrease in temperature. The maximum gradient is observed near the surface layers, especially in the lowest 1 km. Super refraction leads to increased radar detection range and extension of radio horizon.

Key Words: *Radio refractivity, Anomalous propagation, Super refraction, Low pressure Systems*

1. Introduction

The propagation of radio waves and microwaves through the atmosphere excites interests due to their diverse applications ranging from communications to detection of aircrafts. As the atmospheric density is a function of pressure, temperature and humidity, the changes in the distribution of these variables both in the horizontal and vertical cause a variation in the atmospheric density. When an electromagnetic wave travels through the atmosphere, this density variation causes refraction. As a result, the ray bends towards the earth's surface. This phenomenon is quite common in the atmosphere. However, when the structure of the atmosphere causes abnormal bending of the energy waves, anomalous propagation (AP) occurs. AP takes place when abnormal vertical distribution of temperature, moisture, and pressure exists within the atmosphere. This anomalous propagation significantly affects the quality of the radar data that leads to misinterpretations of parameters like rainfall intensity etc (Moszkowicz et al. 1994). Modern radars are designed in such a way that these anomalous propagations are taken into account and suitable models are developed that filters out the variations caused by the anomalous propagations (eg. Grecu and Krajewski (2000)). The development of these models requires detailed investigation of the actual conditions that causes anomalous propagation in the atmosphere. This information is very much useful to understand the influence of meteorological parameters on radio and radar performance.The refractive index of the atmosphere is a measure of the amount of refraction. The refractive index, n= c/v. where c is the velocity of electromagnetic radiation in free space and v, the velocity in the medium. The normal value of the refractive index, *n*, for the atmosphere near the earth's surface varies between 1.00025 and 1.0004. This is not a convenient number and hence the amount of refraction is expressed in terms of radio refractivity, N, as

$$\mathbf{N=(n -1) \times 10^6} \text{ units.} \tag{1}$$

Bean and Dutton (1968) showed that the atmospheric radio refractivity could be approximated as

N=77.6 p/T + 3.73 x 10^5 e/T^2 (2)

Where, p is the Atmospheric pressure (hPa)

T is the Absolute temperature (K)

e is the Water vapour pressure (hPa)

Since the barometric pressure and water vapour content of the atmosphere decrease rapidly with height while the temperature decreases slowly with height, the index of refraction and therefore refractivity, normally decreases with increasing altitude. The vertical gradient of radio refractivity determines the extent of refraction of the electromagnetic radiation. The different radio refractive conditions and the conditions for their formation are presented in table1. Kulshrestha (1986) computed the radio climatology of India and classified different stations into different groups based on their annual range of surface refractivity. Kulshrestha (1990) observed the presence of all types of ducts viz. surface ducts, surface duct with elevated ducting and elevated ducts over India. He also observed that western India, west coast and adjoining sea areas are more prone to super refraction and ducting.

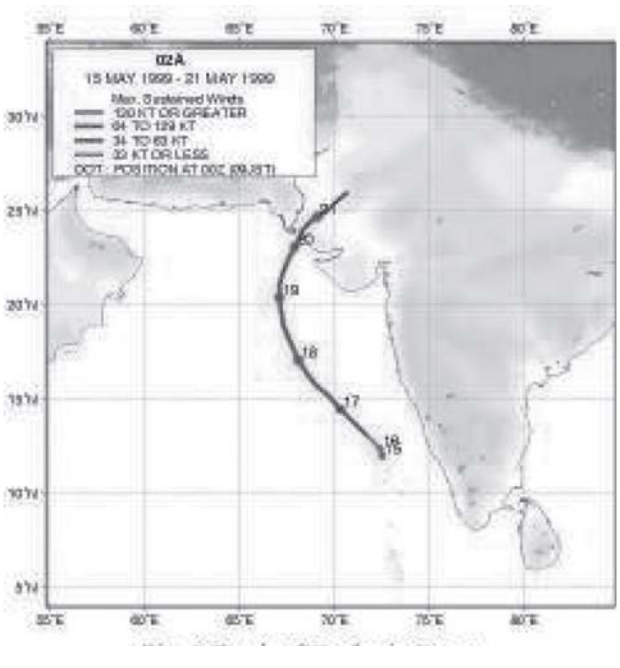

Fig. 1. Track of Cyclonic Storm in Arabian Sea (16 - 22 May 1999)

The objective of the present study is the determination of vertical gradient of radio refractivity during the development of low-pressure systems (LPS). The LPS include monsoon depressions, deep depressions and cyclonic storms.

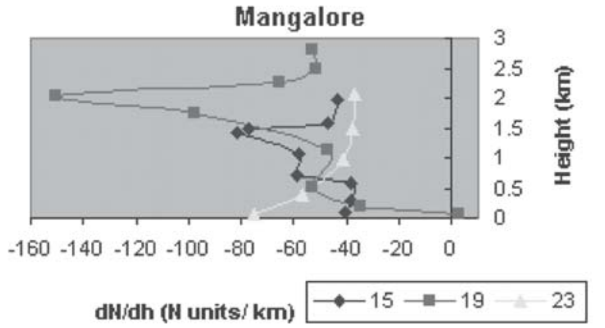

Fig. 2. Vertical gradient of radio refractivity at Mangalore.

2 Data and Methodology

The radiosonde data obtained from the university of Wyoming website http://www.weather.uwyo.edu is utilized for the present study. This study utilizes atmospheric pressure, temperature and humidity at different levels in the lower troposphere (~ 3 km). In most of the earlier studies [eg. Kulshrestha (1986, 1990)] the vertical gradient of radio refractivity is computed using the radiosonde data obtained only from the standard pressure levels (850, 700, 600, 500 hPa etc) of the atmosphere. The advantage of this dataset is that apart from standard pressure levels, it contains data at numerous pressure levels in the vertical approximately at 20 hPa intervals. This facilitates the computation of radio refractive index at different vertical levels using equation (2) and hence the fine structure of radio refractivity of the atmosphere can be studied. For the present study, the vertical gradients of radio refractivity at these levels are computed during periods of low-pressure systems.

3 Results and Discussions

Since the radio refractivity is a function of pressure, temperature and humidity, any change in these variables can significantly affect the propagation characteristics of the radar beam. In this study several cases of low-pressure system

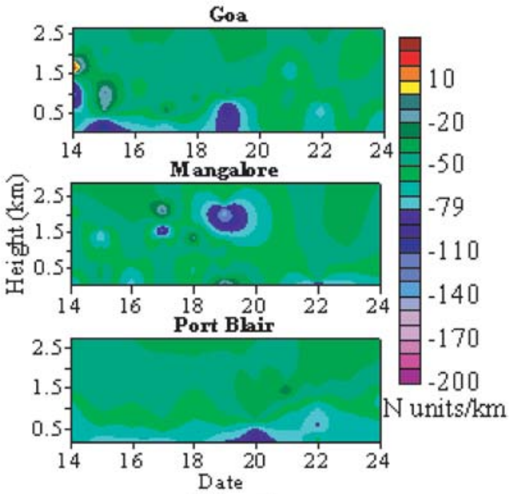

Fig. 3

Fig. 3. Vertical gradient of radio refractivity (dN / dh) at locations near the Cyclonic Storm.

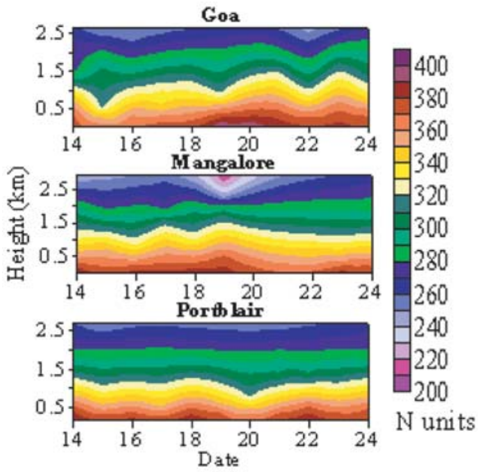

Fig. 4

Fig. 4. Radio refractivity (N) at locations near the Cyclonic Storm.

developments both in the Arabian Sea and Bay of Bengal are considered and their radio refractive properties are analyzed and their common features are discussed below. The LPS include monsoon depressions, deep depressions and cyclonic storms.

3.1 Weather Summary

A well marked low-pressure area formed over Lakshwadeep area and adjoining North Kerala on 15th May 1999. It concentrated into a depression on 16th, 300 km west-southwest of Mangalore. It rapidly intensified into a cyclonic storm about 350 kms west-southwest of Pangim (Goa). It moved in a northwesterly direction and intensified into a severe cyclonic storm, about 670 kms south-southwest of Veravel. It continued to move in a northerly direction and crossed Pakistan coast on 20th. It weakened into a depression on 22nd and into a well marked low pressure area over northwest Rajastan and neighborhood on 23rd. Wide spread heavy rainfall occurred over Konkan and Gujarat coast from 18th to 20th May.

3.2 Radio refractive properties during the development of low-pressure systems

The maximum intensity of the cyclonic storm was on 19-22 May 99. During these days, heavy rainfall of nearly 8 cms is reported at Goa and

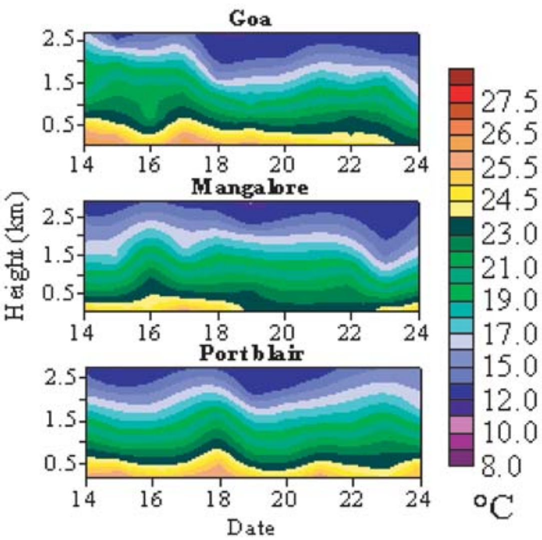

Fig. 5. Air temperature (T) at locations near the Cyclonic Storm.

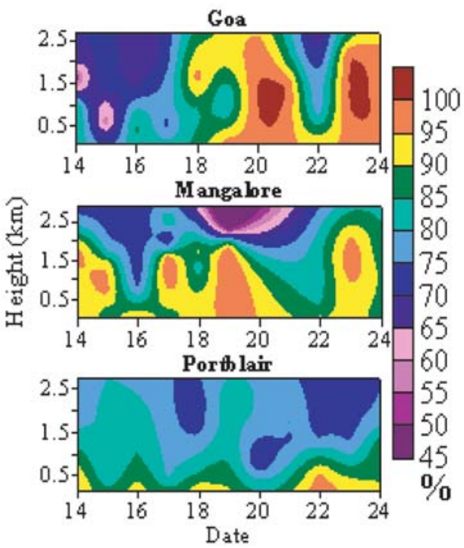

Fig. 6. Relative Humidity (RH) at locations near the Cyclonic Storm.

along the Konkan Coast, Kutch and Saurashtra. The track of the Cyclonic storm is shown in Fig.1. The variation of vertical gradient of radio refractivity at Mangalore on three days (12.85°N, 74.83°E along west coast of India) during the development of the weather system is shown in Fig 2. The variation in vertical gradient of radio refractivity at Mangalore on three days each representing one day before, during and after the formation of weather system (15^{th}, 19^{th} and 23^{rd} May 1999). Before and after the formation of the low-pressure systems, normal refraction prevails in the entire lower 3 kms of the atmosphere. During the formation of the weather systems super refraction is observed between 1.5 and 2.5 kms height. Similar results of occurrence of super refraction either at the surface or aloft are noticed in other locations also near the vicinity of the weather system. The occurrence of super refractive layers in the lower atmosphere during the development of LPS at four location near the weather system can be seen in Fig 3. The radio refractivity (N) variations during LPS are shown in Fig. 4. The surface radio refractivity increases from 350 N units before the development of the weather system to 380 N units during the development of the system. The increase in the radio refractivity is more pronounced in the lower 1 km of the atmosphere. The radio refractivity (N) decreases with increase in altitude. It reduces to nearly 300 N units at 1.5 km height and to 250 N units at 3 km height for all the locations considered. The air temperature and relative humidity during the weather system is shown in Figs.5 and 6 respectively. The sudden decrease in temperature and increase in humidity at all heights following the development of the LPS can be seen clearly in these figures.

4 Conclusion

The radio refractivity increases with the development of the low-pressure systems especially in the lower layers of the atmosphere. The decrease in the air temperature and increase in the moisture content of the atmosphere cause the radio waves to bend more towards the surface of earth than under normal conditions. This causes the occurrence of super refraction and trapping conditions in the atmosphere. Consequently the radar ranges will be enhanced and the situation provides an opportunity for detection of distant targets.

Table 1

Radio refractivity gradient dN/dh (N units/Km)	Condition
>0	Sub-refraction
0< dN/dh > -79	Normal
-79 < dN/dh > -157	Super refraction
< -157	Trapping / Ducting

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References

Bean, B R and E. J. Dutton, Radio Meteorology, Dover Publication Inc., New York, USA), 1968.

Grecu, M. and W.F. Krajewski: An efficient methodology for detection of anomalous propagation echoes in radar reflectivity data using neural networks, Journal of Oceanic and Atmospheric Technology, 17(2), 121-29, 2000.

Kulshrestha S M, Radio Climatology of India, Indian Journal of Radio & Space Physics, 16 (1987).

Kulshrestha S M and Srivastav S. K, Characterization of Indian troposphere in relation to communication: Radio refractivity gradients and ducting, Indian Journal of Radio & Space Physics, 19 (1990).

Moszkowicz, S., G.J. Ciach, and W.F. Krajewski, Statistical detection of anomalous propagation in radar reflectivity patterns, Journal of Atmospheric and Oceanic Technology, 11(4), 1026-1034, 1994.