Research Paper Environment

Radio Refractive Index Variability in the Northern Bay of Bengal During the Summer Monsoon 1999

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ABSTRACT

Radiosonde measurements made from onboard ORV Sagar Kanya during the summer monsoon 1999 were utilized to document the influence of atmospheric systems on the radio refractive index variability over the Bay of Bengal. The analysis indicated that the MBL was susceptible to large changes in water vapor content and temperature in association with the evolution of atmospheric systems. Prior to the formation of systems, standard condition was noticed above 400m, followed by super-refraction, and in the lower 100m, trapping, super-refraction, standard and sub-refraction. During the period of weak monsoon, super-refraction was noticed between 25 and 275m and standard condition above. In the case of low pressure, the low boundary of standard conditions was 75, followed by super-refraction between 50 and 75m and trapping in the lower 50m. The scenario changed completely during the rainfall event, the lower boundary of standard condition was 225m, followed by super refraction between 225 and 75, standard condition between 75 and 30m and sub-refraction in the lower 30m.

Keywords : Bay of Bengal, Radio refractive index, Trapping, Standard refraction, Super-refraction, Sub-refraction

Introduction

Information on radio refractive index is of particular interest in the fields of aviation, atmospheric prediction, communication and radar ranging. The variability in refractive index results primarily from the irregularities in temperature and humidity profiles. The variability temperature and humidity causes turbulence related refractive index fluctuation at UHF and SHF frequencies and in producing large refractive index gradients leading to anomalous propagation conditions (Boithias and Battesti, 1983). As a result, radio rays or electromagnetic rays get trapped in the ducts formed in the boundary layer and travel long distances without attenuation. Bean and Dutton (1968) and Hall (1979) noticed that the spatial and temporal variations of the radio refractive index control the propagation of radio waves through the troposphere.

Over the Arabian Sea and Bay of Bengal (BoB), most of the studies on the marine boundary layer (MBL) are based on the data collected during ISMEX-73, MONSOON-77, MONEX-79, MONTBLEX-90 and BOBMEX-99. These data sets were utilized to study the temporal and spatial variability of various boundary layer parameters and other related fields (Ramanathan, 1978; Mohanty and Das, 1986; Holt and Sethuraman, 1987; Rao and Murty, 1992; Bhat et al., 2001). Utilizing airborne microwave refractometer, Sarma and Reddy (1994) designed reliable and efficient systems for strategic, tactical and operational needs. Sarma (1991) documented radio refractive layers and its variability over the tropical waters of India. Most of these studies are either concentrated over the continents or confined to coastal regions. However, studies related to the propagation characteristics of radio waves in the MBL are meager due to lack of sufficient observations. In this paper, the fine resolution radiosonde data collected over the northern BoB during July-August 1999 is utilized to document and describe the refractive index variability in the MBL. The changes induced by the atmospheric systems on the refractive index profiles are also discussed.

Data and methodology

ORV Sagar Kanya occupied a stationary position (Fig. 1) in the northern BoB (17°N, 89°E) during BOBMEX-99 in two phases (27 July-6 August; 13-22 August 1999). Radiosonde measurements were taken at 6 hourly intervals from the stationary location and en-route to Chennai (22-23 August, 24-27 August and 27-30 August). Typical vertical resolution of the measurements is 25 m. During each launch, temperature, humidity and pressure were compared with ground truth and applied corrections (Bhat et al., 2001).

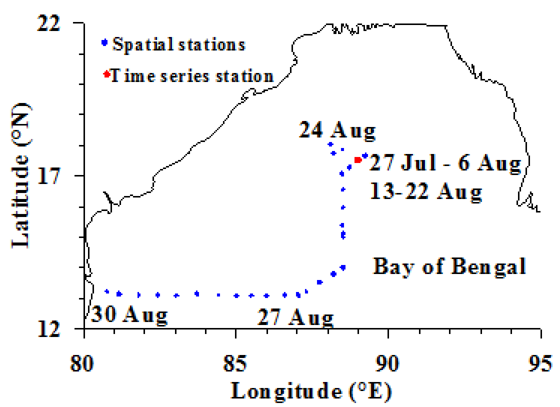

Fig. 1 Location of the Radiosonde measurements

In the atmosphere, propagation of microwave electromagnetic radiation is determined by gradients in the refractive index of air. Bean and Dutton (1968) expressed radio refractivity index (N) in terms of the atmospheric pressure, p (mb), water vapour pressure, e (mb) and temperature, T (oK) following the theory of Debye (1929).

$$N = \frac{77.6}{T}\left(p + \frac{4810e}{T}\right)$$

The refraction of radio waves in the boundary layer is classified into four categories based on the vertical gradients of radio refractive index, dN/dh (Hitney et al., 1985; Table 1).

Table 1 classification based on Hitney et al (1985)

Gradient (N/km)	Condition
dN/dh < -157	Trapping
-157 < dN/dh < -79	Super-refractive
-79 < dN/dh <0	Standard
dN/dh > 0	Sub-refractive

The radio waves propagating in a trapping condition bends downward with a greater curvature than the earth's curvature and propagates long distance along the duct and is ideal for tracking. In super-refraction, the ray bends downward extending the normal horizon, which favours extended radar ranges. In sub-refraction cases, the radio rays bend upwards; result in shortening of the normal horizon. This is a difficult situation, when long range is required such as for tracking airborne targets.

Results and Discussion

Weather summary

The Indian Daily Weather Report reported four weather systems over the northern BoB during July-August 1999. A low-pressure system (LPS) formed on 27 July 21oN, 89oE intensified into a deep depression on 28 July centered at 86.5□E, 23□N and weakened by 30 July. Another LPS formed over northwest BoB on 1 August and weakened after 2 August. The third LPS formed over northwest BoB on 5 August intensified into a depression on 9 August centered at 88.5□E, 21□N. During 31 July-1 August and 14-16 August, there was intense rainfall of 80mm and 200mm respectively (Bhat et al., 2001). Another LPS formed on 24 August over west central Bay centered at 84oE, 16oN and later merged with the LPS formed over northwest Bay.

Temporal variation in the MBL

Temperature and humidity are the two prime factors that influence the radio refractive index in the atmosphere. To show their temporal and spatial variability, time-height sections of potential temperature gradient (Fig. 2A), relative humidity (Fig. 2B) and refractive index gradient (Fig.2C) for the lower 500m are presented. Potential temperature gradient, a measure of stability, indicates unstable condition in the lower 100m and stable conditions above. The lower layer becomes more unstable (-0.03oC.m-1) during the periods of weather systems (31 July-2 August, 5 and 25 August). On the other hand, intense rainfall during 14-17 August makes the lower atmosphere more stable.

In general, relative humidity (RH) is low in the lower atmosphere and it increases upward (Fig. 2B). The weather systems and rain events increase RH in the lower atmosphere (upto 30 m) to near saturation (>85%). Here, pockets of high humidity regime (>85%) are observed during the periods of deep depression (end July) and LPS. The high humidity regime penetrates down to the sea level on 1-3 August when an LPS form over the northwestern BoB. During the periods of heavy rainfall (14-17 August), near saturated conditions (>85%) prevail in the lower 50m. Before and after rainfall, RH is very low (<80%) between 25 and 125m. After 24 August, RH further decreases to 75% in the central BoB. Close to the east coast of India, RH less than 80% extends from the sea level beyond 500m.

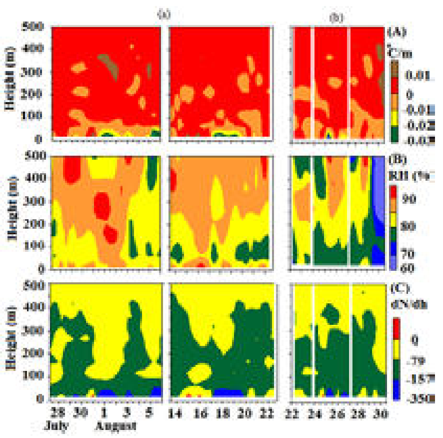

Fig.2 Height-time sections of (A) potential temperature gradient, (B) relative humidity and (C) refractive index gradients at the stationary location (a) and along the spatial transects (b).

The time-height sections of N-gradients (Fig. 2C) indicate standard condition above 400m at the time series station and above 300m in the central BoB (24-27 August). During the periods of systems, its lower boundary penetrates even down to 100m, as evident during 31 July-2 August and 5 August, when two weather systems were reported over the northwestern BoB. In the case of rainfall, the lower boundary of standard refraction is limited to ~250m. After the withdrawal of systems, the standard refraction regains its pre-system levels.

In the lower 50m, atmosphere, trapping (dN/dh<-157), super-refraction, standard and sub-refraction (dN/dh>0) are observed. Trapping exists in the lower most layers (~50m) during 29 July, 1 August, 3 August, 5 August, 17-19 August and 25 August, which coincides with the unstable conditions in the lower atmosphere (Fig. 2). In this situation, the radio rays traveling at this height bend downwards with a greater curvature than the earth, get trapped in the duct and travel long distances in the duct. Sub-refraction is also noticed in the lower 25m during 31 July, 15-16 August and 24 August. Just above the sub-refractive zone and below 50m, standard refraction also exists prior to formation of systems.

Influence of atmospheric disturbances on Radio Refractive Index

The analysis indicates that the MBL is susceptible to large changes in water vapor content and temperature in association with the evolution of atmospheric systems. The profiles of N-gradient show large variability, especially in the lower atmosphere, in association with the low pressure, rain event and weak monsoon conditions (Fig. 3). During the period of weak monsoon, super-refraction is noticed between 25 and 275m and standard condition above. In the case of low pressure, trapping in the lower 50m, super-refraction between 50 and 75m and standard condition above 75m is noticed. The scenario is totally different during the rainfall event as the sub-refraction (<30m) and standard conditions (30-75m) prevails in the lower 75m. Above this level, super refraction between 75 and 225m and standard condition above 225m are noticed.

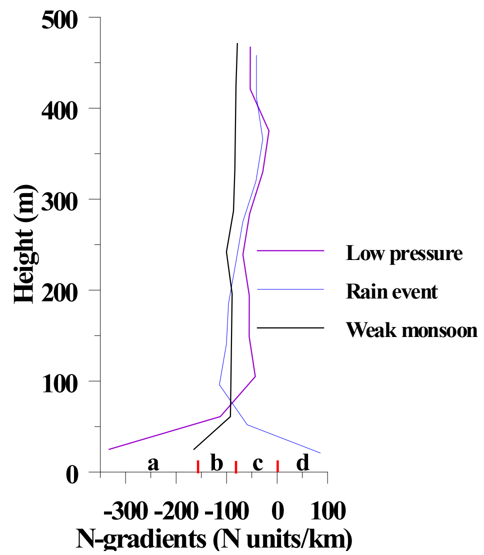

Fig.3 Profiles of refractive index gradients corresponding to low pressure, weak monsoon and rain events. a, b, c and d represents the conditions of Trapping, Super refractive, Standard and Sub-refractive conditions respectively.

The refractive index variations are inhomogeneous, especially in the lower layers and showed large variability in association with the systems. In general, trapping, super refraction and standard conditions prevailed in the lower atmosphere and favoured communication. Intermittent sub-refraction observed in the lower atmosphere during heavy rainfall is a difficult situation to obtain long range communication.

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