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# Study of radio refractive index in association with onset of monsoon

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**सार**—1979 से 1987 के वर्षों में अप्रैल से जुलाई माह की अवधि में बम्बई और तिरूअनंतपुरम में निम्न क्षोभमंडल में रेडियो अपवर्तनांक की विविधताओं का अध्ययन किया गया। यह देखा गया है कि इनमें से अधिकांश वर्षों में, केरल (तिरूअनंतपुरम) में मानसून के आरम्भ से पूर्व और बम्बई में मानसून आरम्भ होने के तत्काल पूर्व बम्बई में 850 एच पी ए स्तर पर रेडियो अपवर्तनांक की विविधताओं में कुछ दिनों के पश्चात 900 एच पी ए स्तर की स्थिति की तुलना में उल्लेखनीय वृद्धि का भी पता चला है। उच्च स्तरों पर ऐसे कोई भी उल्लेखनीय परिवर्तन नहीं पाये गए हैं। मानसून पूर्व से लेकर मानसून महीनों तक 900 एच पी ए या 850 एच पी ए पर तिरूअनंतपुरम में रेडियो अपवर्तनांक मान में उल्लेखनीय वृद्धि दिखाई नहीं देती है। उक्त परिणामों से, इस अवधि में किंचित ह्रासमान प्रवृत्ति पाई गई है।

ABSTRACT. Variations of radio refractive index (RRI) in the lower troposphere over Bombay and Thiruvananthapuram have been studied for the months from April to July for the years 1979 to 1987. It is seen that in most of the years, the radio refractive index at 900 hPa over Bombay increased significantly prior to onset of monsoon over Kerala (Thiruvananthapuram) and well in advance of the arrival of monsoon over Bombay. Variation of RRI at 850 hPa level over Bombay also shows significant increase a few days later than at 900 hPa level. At higher levels no such significant changes are observed. The RRI value over Thiruvananthapuram at 900 hPa or at 850 hPa does not show significant rise from pre-monsoon to monsoon months. The results show a slight decreasing trend during the same period.

**Key words** — Radio Refractive Index (RRI), Onset of monsoon.

## 1. Introduction

Advance intimation about the onset of monsoon and its activity over country is very useful information to the farmers as the monsoon rains are of paramount importance to the Indian agricultural economy. In this context, various atmospheric characteristics in the lower, middle and upper atmospheric levels have been studied. Various workers have found relation of the upper tropospheric circulation with the monsoon flow in the lower levels.

With limited data of two years, Sharma and Subramanian (1984) reported that the radio refractive index (RRI) at 900 and 850 hPa over Bombay increases significantly about 2-3 weeks in advance of monsoon over Bombay and thereafter it becomes more or less steady. They also reported the different vertical gradients of RRI in monsoon and non-monsoon months (Sharma and Subramanian 1983). The above study is now carried out with data of 9 years and also extended to another coastal station, Thiruvananthapuram. The results are interpreted in relation with the onset of monsoon over Kerala and its advancement over Bombay.

## 2. Data and calculation

Daily upper air data recorded at 12 UTC by radio sonde (RS/RW) ascents for the years 1979 to 1987 over Bombay and Thiruvananthapuram have been utilized. Data have been obtained from National Data Centre, India Meteorological Department, Pune.

Pressure, temperature and humidity are the three basic meteorological parameters governing the radio refractive index of the atmosphere. Index values have been calculated for individual ascents at different pressure levels in the lower and middle troposphere at intervals of 50 hPa from 1000 hPa to 400 hPa using Bean and Dutton (1966) equation.

$$N = \frac{77.6}{T}\left(p + \frac{4810\ e}{T}\right) \qquad (1)$$

where, $p$ and $e$ are in hectopascals and $T$ is in degree Kelvin and $N$ is modified radio refractive index (Kulshrestha and Chatterjee 1966). The vapour pressure at different levels has been determined from the dew point $T_d$ using Teten's equation.

$$e = \exp\left(1.8099 + \frac{17.27 \times T_d}{T_d + 237.3}\right) \qquad (2)$$

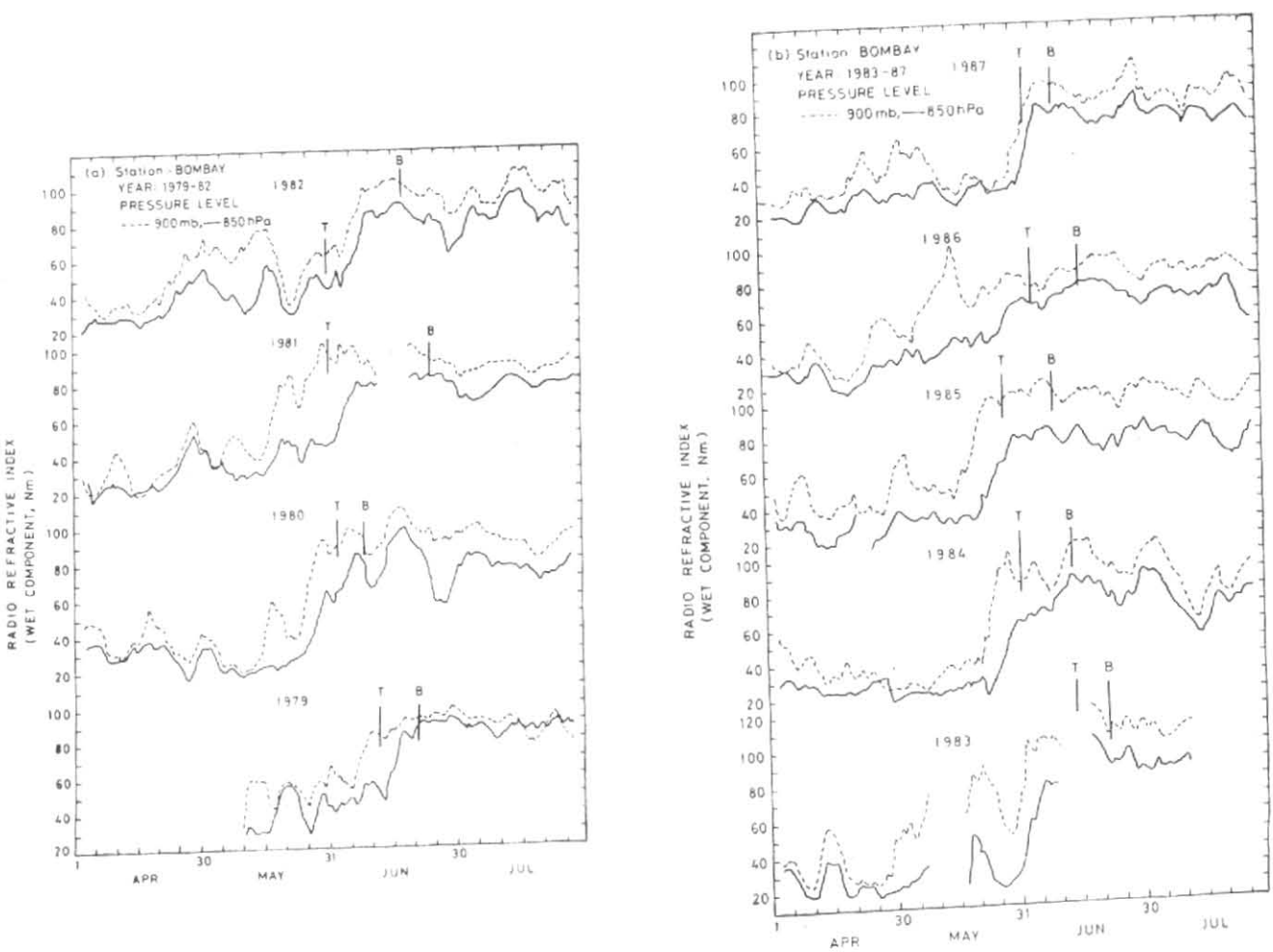
where, $T_d$ is in degree Celsius. The two terms on r.h.s. of Eqn. (1) represent contributions to index value due to dry air ($N_d$) and water vapour ($N_m$) respectively. Thus,

$$N = N_d + N_m \qquad (3)$$

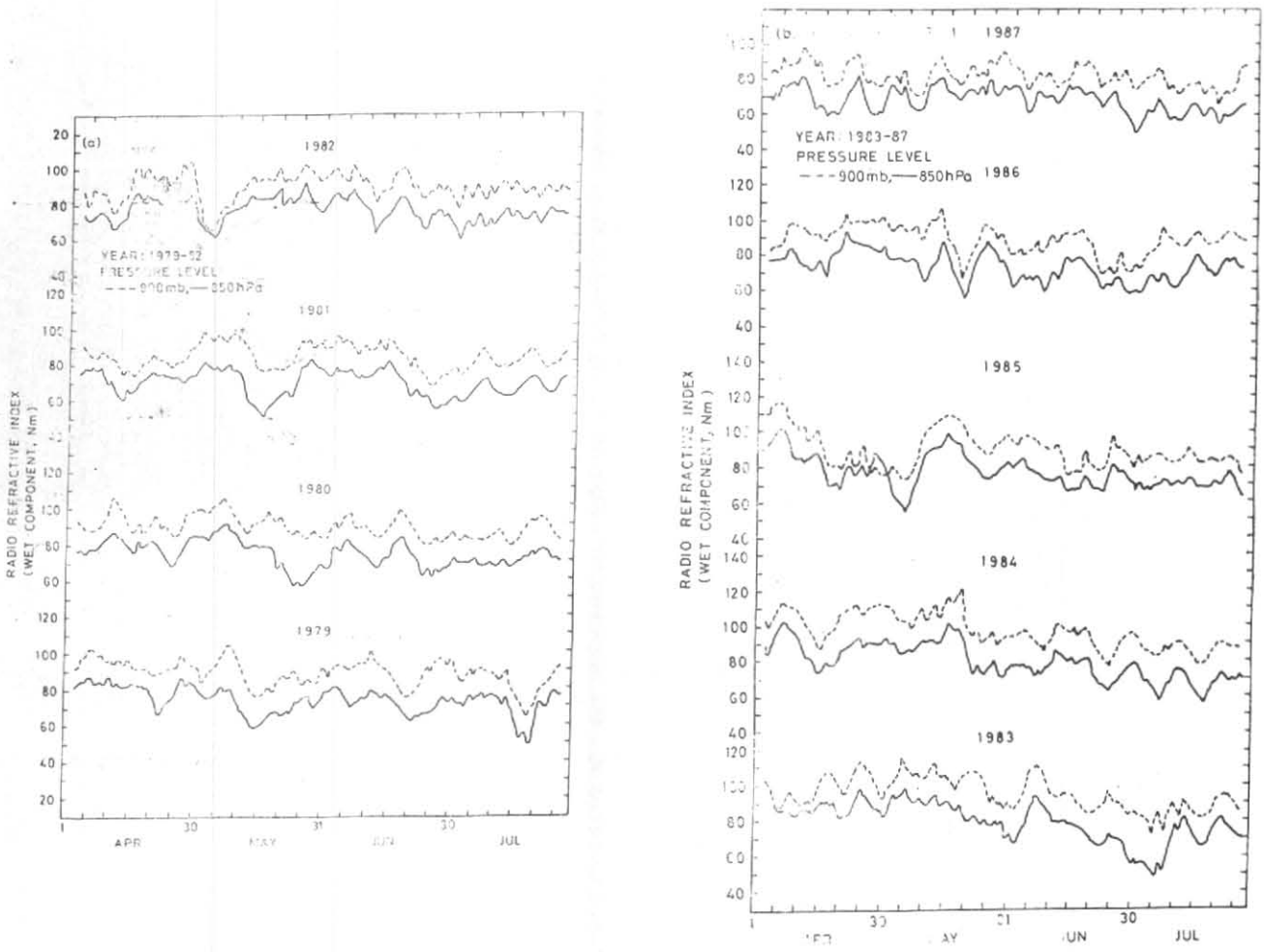
In the present study, two components $N_d$ and $N_m$ have been computed from individual ascents. The components of RRI due to dry air ($N_d$) does not show any

**TABLE 1**

| Year | Dates when RRI attains 75 unit over Bombay at | | Date of onset of monsoon over Kerala | Date of arrival of monsoon over Bombay | Lead-time over | |
|---|---|---|---|---|---|---|
| | 900 hPa (a) | 850 hPa (b) | (c) | (d) | Kerala (a—c) days | Bombay (a—d) days |
| 1979 | 7-6-79 | 15-6-79 | 12-6-79 | 20-6-79 | 5 | 13 |
| 1980 | 27-5-80 | 4-6-80 | 1-6-80 | 7-6-80 | 5 | 11 |
| 1981 | 24-5-81 | 6-6-81 | 30-5-81 | 23-6-81 | 6 | 30 |
| 1982 | 6-6-82 | 9-6-82 | 30-5-82 | 17-6-82 | —7 | 11 |
| 1983 | 30-5-83 | 5-6-83 | 13-6-83 | 20-6-83 | 14 | 21 |
| 1984 | 25-5-84 | 9-6-84 | 31-5-84 | 12-6-84 | 6 | 18 |
| 1985 | 20-5-85 | 29-5-85 | 28-5-85 | 8-6-85 | 8 | 19 |
| 1986 | 26-5-86 | 14-6-86 | 4-6-86 | 15-6-86 | 9 | 20 |
| 1987 | 2-6-87 | 5-6-87 | 2-6-87 | 9-6-87 | 0 | 7 |




Figs. 1 (a & b). Five-day moving average of radio refractive index, $N_m$ over station Bombay




Figs. 2(a & b). Five-day moving average of radio refractive index, $N_m$, over station Thiruvananthapuram

significant variation, hence the results are presented only for wet component, $N_m$. RRI has been found to vary in the lower layers only, hence results at higher levels have not been discussed in the present communication. Further, 5-day moving averages were calculated to filter out day to day fluctuations and results, thus obtained, at 900 and 850 hPa levels are presented.

### 3. Results and discussion

3.1. *RRI variation over Bombay* — Figs. 1 ( a & b) depict the five-day moving average of wet component of radio refractive index ($N_m$) at 900 and 850 hPa over Bombay for the years from 1979 to 1987. It is noticed that during April, the mean value of radio refractive index $N_m$ at 850 and 900 hPa is about 30 and 40 units with minor fluctuations. In the first fortnight of May, the mean value of $N_m$ in some years shows slight increase in the value with large fluctuations. However there is a marked rise in the values of RRI from pre-monsoon month to monsoon months and significant increase ($25 \pm 5$ units) occurs during second fortnight of May or early June. Further, it is observed that after the significant rise of about $25 \pm 5$ units, the index value remains sustained for the rest of the period of June and July with minor fluctuations. The radio refractive index at 900 hPa is persistently higher than those at 850 hPa and the difference shows varying vertical gradient during these months. The significant rise in RRI at 900 hPa is prior to that at 850 hPa and remarkably sharp increase has been noticed in most of the years.

The significant increase in RRI is observed a few days before the onset of monsoon over Kerala (Thiruvananthapuram) except in 1982 and 1987. Further, the delay in significant rise in RRI value in 1979 is consistent with the delayed monsoon in that year. The date of onset of monsoon and corresponding dates for the significant increase of RRI at 900 and 850 hPa over Bombay have been shown in Table 1. The dates of onset of monsoon over Bombay and Thiruvananthapuram are also indicated in Figs. 1 (a & b) by vertical lines marked 'B' and 'T' respectively.

3.2. *RRI variation over Thiruvananthapuram*— Figs. 2 (a & b) depict 5-day moving average of RRI at 900 and 850 hPa over Thiruvananthapuram from April to July for the years 1979 to 1987. It is noticed that the index value at 900 hPa is always more by $15 \pm 5$ units than that at 850 hPa. Short period fluctuations are found similar at both the levels. Further there seems to be slight decreasing trend of RRI value from April to July. The RRI does not show significant rise from pre-monsoon to monsoon months as observed over Bombay.

The sudden increase of about $25 \pm 5$ units in RRI over Bombay is considered as a significant rise. On an average, the mean value of RRI during April and first

fortnight of May has been around 50 unit whereas it becomes 75 unit or more after significant rise. Thus, the dates when it reaches a threshold of 75 unit have been taken as the dates for the purpose of calculating lead time with reference to the onset of monsoon. The results thus obtained from the study are listed in Table 1 alongwith the declared dates of onset of monsoon. The following inferences are drawn from the Table 1 and Figs. 1 and 2.

(*i*) A time lag of about 2-3 weeks is observed between the RRI value at 900 hPa reaching 75 unit and arrival of monsoon over Bombay.

(*ii*) Over Bombay, RRI at 850 hPa level attains value of 75 unit a few days later than it reaches at 900 hPa.

(*iii*) Variations of the refractive index give sufficient advance indication not only for the arrival of monsoon over Bombay but also about its outbreak over Thiruvananthapuram. Out of 9 years study, RRI has been found to give one week advance indication of onset of monsoon over Kerala in 7 years and only during 2 years (1982 and 1987) when the monsoon has come as a feeble current, these indications are not seen.

(*iv*) The values of RRI which are markedly lower over Bombay as compared to those over Thiruvananthapuram during April and May attain more or less the same value during the onset phase of monsoon and remain so afterwards.

## 4. Conclusion

The study shows that there exists a correlation between RRI changes in the lower atmosphere over Bombay and onset of monsoon. The index at 900 hPa shows significant increase well in advance of the arrival of monsoon over Bombay. The delay in significant rise of RRI is indicative of the delay in onset of monsoon.

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