

## **Sharp decrease of attenuation of 183.31 GHz water molecule absorption line associated with Nor'wester over Kolkata – may be one important experimental set-up to forecast Nor'wester**

S. K. MIDYA\*, H. SARKAR\*\*, S. SARKAR, D. K. MAITI and M. GHOSH

*Department of Atmospheric Sciences, University of Calcutta, Kolkata - 700 019, India*

*\*Indian Centre for Space Physics, Garia Station Road, Kolkata - 700 084, India*

*\*\*Centre for Microwave and Millimeter Wave Research and Training, Institute of Radio Physics and Electronics, University of Calcutta, Kolkata - 700 009, India*

(Received 4 November 2009, Modified 21 March 2011)

**e mail : drskm06@yahoo.co.in**

**सार** – कोलकाता में काल वैशाखी के शुरू होने से ठीक पहले 183.31 GHz सिग्नल के हल्के पड़ने में तेजी से हुए अवश्रय के बारे में अध्ययन किया गया है। यहाँ इस प्रकार की परिवर्तनशीलता की संभावित व्याख्या की गई है। इससे यह निष्कर्ष निकलता है कि ऐसा काल वैशाखी से संबद्ध भीषण गर्ज भरे तूफानों के पूर्वानुमान की एक संभावित पद्धति के कारण हुआ है। गर्ज भरे तूफानों के बनने, फैलने की प्रक्रिया के आधार पर भौतिक व्याख्या भी इस शोध पत्र में प्रस्तुत की गई है।

**ABSTRACT.** The sharp depletion of attenuation of 183.31GHz signal just before the onset of Nor'wester over Kolkata has been studied. Possible explanations of such type of variation are presented. It is concluded that this may be taken as one possible method of forecasting of severe thunderstorms associated with Nor'wester. Physical explanations based on the formation and dissipation mechanisms of thunderstorms are also presented.

**Key words** – Nor'wester, Attenuation, Radiometer, Thunderstorms.

### **1. Introduction**

Nor'wester is a local severe storm which causes most important meteorological hazard whose destructive off springs are hailstorm, lightning, high wind, heavy rains, squalls etc. It is mesoscale phenomena of most violent convective system which extends up to tropopause. It is small in size with short life span and not possible to detect by present synoptic chart with present network. Hence special observing aids are necessary. Research works have already been carried out on the study of severe thunderstorms over last few years. The studies were initially based on the analysis of the surface and sometimes upper air data before and immediately after occurrence of the thunderstorms (IMD, 1941; Koteswaram *et al.*, 1958; Mukherjee *et al.*, 1979; Normand 1938; Ramaswamy 1956; Chaudhuri *et al.*, 2001;) showed that minimization of Convective Inhibition Energy (CINE) is

more important than maximizations of Convective Available Potential Energy (CAPE) in the genesis of these thunderstorms. North-eastern region of our country is more prone to thunderstorm. They often cause much damage to human settlement and often installations on the ground. The common characteristic features of these thunderstorms are (a) high frequency March to May, (b) associated squall of approximately 150 km/hr, (c) initial development area is near Chotanagpur of Bihar and subsequently movement towards south eastward etc. Their dimensions are much smaller than large scale weather system like monsoon depressions or tropical cyclones. In spite of many years of research in the country we have not yet understood their mechanism of genesis and their subsequent behavior due to lack of observational data from inside these storms. It may be realized that thunderstorms carry heat and moisture to the upper troposphere but actual dynamics within the thunderstorm

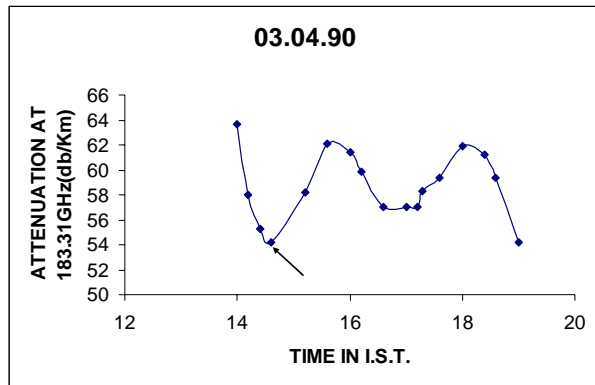


Fig. 1. Variation of attenuation of water molecule absorption line at 183.31 GHz on one Nor'wester day (03 April 1990) over Calcutta. Arrow mark indicates the time of onset of thunderstorm

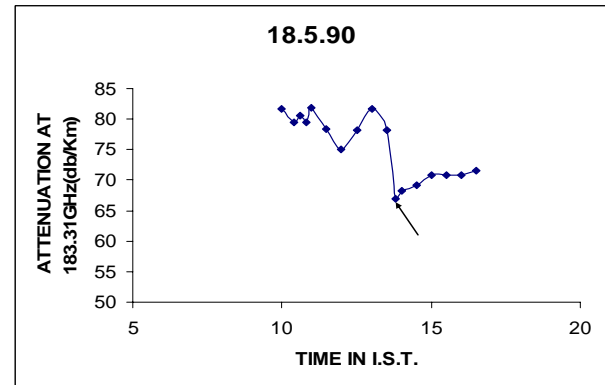


Fig. 2. Variation of attenuation of water molecule absorption line at 183.31GHz on one Nor'wester day (18 May 1990) over Calcutta. Arrow mark indicates the time of onset of thunderstorm

can be quite distinct from that of the environment which is not yet known fully. The interaction between isolated thunderstorms and the environment some time cause the development of a well organized line of thunderstorm called the squall line of large horizontal extent of more than ~ 200 km.

Water vapour distribution controls the attenuation of microwaves and millimeter wave propagation. Sen, 1967 observed enhancement of atmospheric associated with local thunderstorms occurring in a tropical station. Sen *et al.*, 1984 concluded that water vapour is one of the important constituent in the atmosphere which can impose limitations to the propagation in microwave and millimeter wave. Midya and Sarkar, 2007 showed sharp depletion of absolute humidity just before onset of Nor'wester over Kolkata. Water vapour has a strong absorption line at 183.31 GHz frequency. A microwave radiometer tuned to 183.31GHz is capable of detecting and measuring even minute traces of water vapor in the atmosphere. The amount of water vapour change is strongly connected during the thunderstorm event. The study of attenuation at 183.31 GHz is a direct evidence of change of water vapour amount during the onset of thunderstorm event. This type of study is very much important in satellite communication and also in military purpose.

The purpose of the paper is to present a new experimental arrangement to detect this type of mesoscale violent convective atmospheric phenomena. The sharp fall of attenuation at 183.31 GHz signal related to Nor'wester event over Kolkata is presented. Explanations based on physical consideration are also offered.

## 2. Observations

The attenuation rate due to water vapor monomer model in the atmosphere at 183.31 GHz is given by Dennison, 1940; Benedict and Kaplan, 1959.

$$\alpha_{(1.64\text{mm})} = \frac{0.646 N v^2 \exp(-200/T)}{10^{28} T^{5/2}} \left[ \frac{\Delta v_p}{(v-v_0)^2 + (\Delta v_p)^2} + \frac{\Delta v_p}{(v-v_0)^2 + (\Delta v_p)^2} \right] + \frac{1.8 N v^2 \Delta v_p}{10^{52} T^{3/2}} \quad (1)$$

Where, N represents the number of water vapor molecules per cubic centimeter and is related to water vapor density  $\rho$  ( $\text{gm/m}^3$ ) by

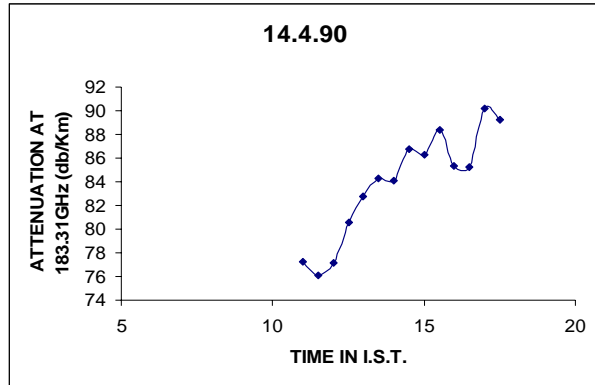
$$N = (\rho/18) \times 6.023 \times 10^{17} \quad (2)$$

$v$  &  $v_0$  are the resonant & non-resonant frequencies in Hz respectively &  $\Delta v_p$  is the pressure-broadened line half-width parameters expressed in  $\text{s}^{-1}$  & is given by

$$\Delta v_p = 2.62 \times 10^9 \frac{P/760}{(T/318)0.625} (1 + 0.0046\rho) \quad (3)$$

Where,  $P$  &  $T$  are the total atmospheric pressure (mm of Hg) and kinetic temperature (k) respectively. Again,  $\rho$  is related to water vapour  $e$  (hPa) by

$$\rho = (e \times 18 \times 10^2)/(8.31 \times T_D) \quad (4)$$



**Fig. 3.** Variation of attenuation of water molecule absorption line at 183.31 GHz on one normal day (14 April 1990) over Calcutta

Where,  $T_D$  is the dew point temperature in degrees Kelvin. But, on the other hand  $e$  could be expressed as

$$e = 6.1078 \exp [5369 (1/273 - 1/T_D)] \quad (5)$$

A typical record of the attenuation of 183.31 GHz during two Nor'westers on 03 April 1990 and 18 May 1990 are shown in Figs. 1&2. Fig. 3 shows the variations of the said parameter on a normal day 14 April 1990 with no report of thunderstorms associated with Nor'wester. Arrow marks show the time of occurrence of onset of thunderstorms during Nor'wester. Comparisons of figures confirm the dip of attenuation at 1430 IST on 03 April 1990 and at 1370 IST on 18 May 1990 on two selected Nor'westers days around the time of onset of thunderstorms. We have considered almost 22 cases of prominent Nor'westers days for which sharp depletions of attenuation takes place and these are presented in Table 1. On the other hand for normal days we have not obtained such type of depletion.

### 3. Experimental Set-up

Possible experimental arrangement of Dicke's radiometer is shown in Fig. 4. Dicke's radiometer measures the thermal radiation at microwaves or at millimeter waves. The radiation from a black body at a particular temperature is received by an antenna. A modulator wheel of resistance material alternately terminates the wave guide by a reflection less impedance and by the antenna. The received signal is passed through a mixer plus intermediate-frequency amplifier with automatic gain control and detector. The detected modulation is amplified by a narrow-band amplifier and fed into a phase-sensitive detector (balanced mixer); the local oscillator signal for this detector is generated by a generator driven by the same shaft as the modulator wheel. The d-c signal is then amplified and detected.

**TABLE 1**

**Depletion of attenuation of 183.31 GHz water molecule absorption line associated with Nor'wester over Kolkata**

Date of Nor'wester	Depletion of attenuation of 183.31 GHz in percentage
03 April 1990	14.81
18 May 1990	17.91
12 April 2000	19.12
15 April 2000	20.05
21 April 2000	16.25
23 April 2000	18.55
24 April 2000	21.32
29 April 2000	15.78
2 May 2000	13.25
3 May 2000	17.38
14 May 2000	16.85
17 May 2000	14.27
21 May 2000	19.45
25 May 2000	17.81
30 April 2001	20.12
4 May 2001	18.31
5 May 2001	19.76
19 May 2001	20.12
20 May 2001	16.85
21 May 2001	18.56
24 May 2001	17.32
31 May 2001	14.81

### 4. Result and discussions

The earth surface of tropical country is heated during noon time and the heated air in contact to the surface of the earth begins to rise after absorbing water molecules. When the moist air goes upward the air parcel suffers adiabatic expansion and becomes cooler. As a result, clouds are formed and the released latent heat is converted to sensible heat and the pressure level will be increased at higher level. Due to heating at the surface and the increase of high pressure at the upper level there will be pulling and pumping. There is a positive feedback and the system will be vigorous if sufficient moisture is available and CB cloud is formed. The thunderstorm development stage is cumulus stage. During this stage, only updraft is taking place. At this stage no precipitations reaches the ground. Precipitation is produced in the upper parts of the storm and at the matured stage downdraft takes place. So at this stage updraft, downdraft and precipitation take place. Afterwards precipitations predominate and dissipation stage is dominated by downdraft. As updraft decreases, inflow of moist air in the atmosphere decreases. As a result, only rain takes place and the storm dissipates.

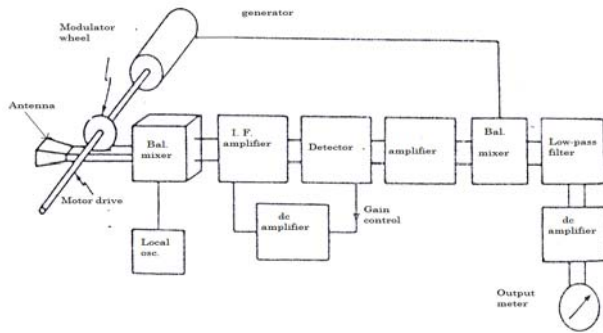


Fig. 4. Experimental arrangement of radiometer

During the mature stage of thunderstorm there will be downdraft of cold dry air coming to the surface. Attenuation becomes minimum due to the minimum availability of water vapour in cold air. So the results obtained in Figs. 1&2 agree fairly well with our physical explanation. It also agrees with our previous results where we have shown that absolute humidity depleted sharply before the onset of thunderstorm over Kolkata (Midya and Sarkar, 2007). It may be mentioned that attenuation values derived from radiometric emission at 183.31 GHz is a good indicator water vapour amount in the atmosphere. The relation between attenuation and water vapour is affected by the liquid water content of the atmosphere. To overcome this difficulty, a dual frequency millimeter wave link, one at the water vapour line at 183.31 GHz and the other away from the line around 31.4 GHz may be utilized. This help us to separate the water vapour and the liquid water content, by using differential sensitivity of millimeter wave links placed at two different stations between 1-2 km interval at above mentioned frequencies for sensing water vapour and liquid water. Thus this type of experimental arrangement is very much helpful for thunderstorm study. In this connection it may be mentioned that Sen, 1967; also observed enhancement of atmospherics (30kc/s) in relation to pre-monsoon and monsoon thunderstorms. During formation of thunderstorms, water vapour gradually increases in the atmosphere. As a result attenuation at 183.31 GHz increases gradually. At the matured stage, *i.e.*, during the onset of thunderstorms, the attenuation decreases sharply indicating a sharp fall of water vapour. It takes place before one to two hours of onset of Nor'wester events. It is clear from Figs. 1&2.

#### 4. Conclusions

It is concluded that sharp depletion of attenuation of 183.31 GHz water molecule absorption line before one to two hours takes place and it is due to minimum

availability of water molecules in vapour state during downdraft of cold dry air before onset of thunderstorms. This may be taken as a possible method of forecasting such mesoscale phenomena. It is clear from Table 1 and the figures that depletion of attenuation of 183.31 GHz water molecule absorption line in percentage before onset of thunderstorm lies between 13 to 21 and absolute value of attenuation lies between 52 to 62 db/km.

#### Acknowledgement

The authors are thankful to India Meteorological Department, Kolkata for providing the necessary meteorological data for such type of study and also like to acknowledge with thanks unknown referee of the paper for his valuable suggestions to improve the manuscript significantly.

#### References

- Benedict, W. S. and Kaplan, L. D., 1959, "Calculation of the line widths in H<sub>2</sub>O-N<sub>2</sub> collisions", *Journal of Chemical Phys.*, **30** 388-392.
- Chaudhuri, S. and Chattopadhyay, S., 2001, "Measure of CINE A relevant parameter for forecasting pre-monsoon thunderstorms over GWB", *Mausam*, **52**, 679-684.
- Denison, D. M., 1940, "The infrared spectra of polyatomic molecules", *Review of Modern Phys.*, **12**, 175-240.
- India Meteorological Department, 1941, "Nor'westers of Bengal", Tech. Note, No.10.
- Koteswaram, P. and Srinivasan, V., 1958, "Thunderstorms over Gangetic West Bengal in the pre-monsoon season and the synoptic factors favourable for their formations", *Indian J. Meteorol. & Geophys.*, **9**, 301-312.
- Midya, S. K. and Sarkar, H., 2007, "Variation of stratospheric ozone with relative humidity and sharp depletion of absolute humidity associated with Nor'wester over Kolkata" *Indian J. Phys.*, **81**, 2, 217-224.
- Mukherjee, A. K. and Chaudhury, A. K., 1979, "Excessive overshooting of Cb", *J. Meteorol. Geophys.*, **30**, 485-492.
- Normand, C. W. B., 1938, "On instability from water vapour", *Q. J. R. Meteorol. Soc.*, **64**, 47-66.
- Ramaswamy, C., 1956, "On the subtropical Jet stream and its role in the development of large scale convection", *Tellus.*, **8**, 26-60.
- Sen, A. K., Karmakar, P. K., Das, T. K., Devgupta, A. K., Chakraborty, P. K. and Devbarman, S., 1984, MAP (Middle Atmospheric Programme) Handbook., **18**, 399-402.
- Sen, A. K., 1967, "Enhancement of atmospherics in relation to pre-monsoon and monsoon Thunderstorms", *Indian J. Meteorol. & Geophys.*, **8**, 447-458.