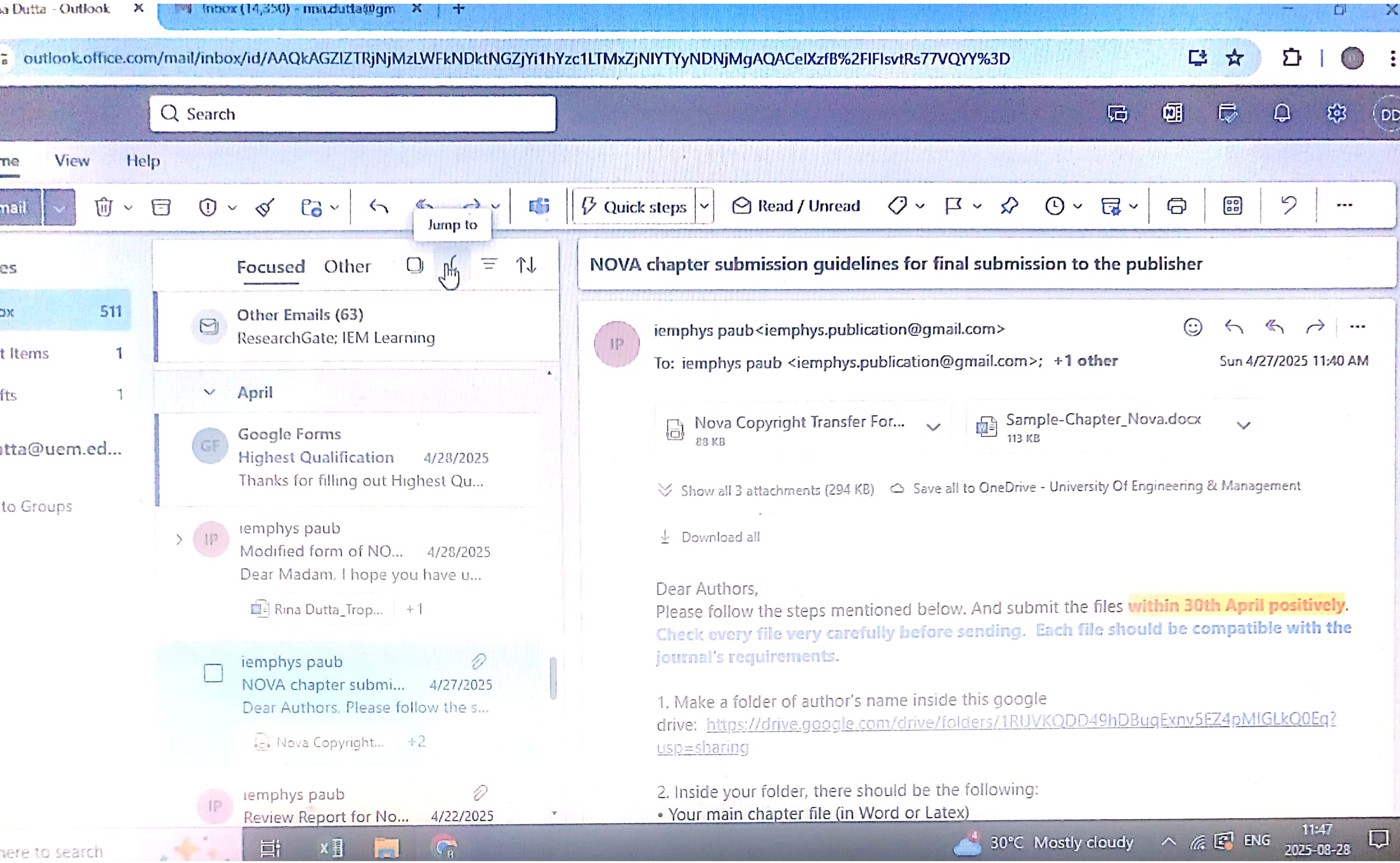
a Dutta - Outlook
Inbox (14,350) - mna.dutta@gm
outlook.office.com/mail/inbox/id/AAQkAGZlZTRjNjMzLWFkNDktNGZjYi1hYzc1LTMxZjNlYTYyNDNjMgAQACelXzfB%2FIFlsvtRs77VQYY%3D
Search
me
View
Help
mail
Jump to
Quick steps
Read / Unread
es
ox 511
t Items 1
fts 1
tta@uem.ed...
to Groups
Focused
Other
Other Emails (63)
ResearchGate; IEM Learning
April
Google Forms
Highest Qualification 4/28/2025
Thanks for filling out Highest Qu...
iemphys paub
Modified form of NO... 4/28/2025
Dear Madam, I hope you have u...
Rina Dutta_Trop... +1
iemphys paub
NOVA chapter submi... 4/27/2025
Dear Authors, Please follow the s...
Nova Copyright... +2
iemphys paub
Review Report for No... 4/22/2025
NOVA chapter submission guidelines for final submission to the publisher
iemphys paub<iemphys.publication@gmail.com>
To: iemphys paub <iemphys.publication@gmail.com>; +1 other
Sun 4/27/2025 11:40 AM
Nova Copyright Transfer For...
88 KB
Sample-Chapter_Nova.docx
113 KB
Show all 3 attachments (294 KB)
Save all to OneDrive - University Of Engineering & Management
Download all
Dear Authors,
Please follow the steps mentioned below. And submit the files within 30th April positively.
Check every file very carefully before sending. Each file should be compatible with the journal's requirements.
1. Make a folder of author's name inside this google drive: https://drive.google.com/drive/folders/1RUVKQDD49hDBuqExnv5EZ4pMIGLkQ0Eq?usp=sharing
2. Inside your folder, there should be the following:
• Your main chapter file (in Word or Latex)
here to search
30°C Mostly cloudy
ENG
11:47
2025-08-28

Chapter 8

VHF Radar and Radiosonde observations of Tropical Tropopause

Rina Dutta[1], PhD *

[1] Department of Basic Science and Humanities, Institute of Engineering and Management (IEM), University of Engineering and Management, Kolkata, India

Abstract

In the present investigation an attempt has been made to study the tropopause height variation over three geographical locations Chennai, Bangalore and Hyderabad. The tropopause height is derived by identifying the coldest temperature in upper troposphere and is referred to as cold point tropopause. Variability of cold point tropopause over different time periods has been studied during the year 2002. Radiosonde and MST radar observations are made to measure the tropopause height and vertical wind variability in the vicinity of tropopause. The Indian MST radar installed at Gadanki (13.47^0 N, 79.18^0 E, and 0.375 km above mean sea level) near Tirupati, Andhra Pradesh. The location of Indian MST radar is well covered the area enclosed by the above mentioned three stations. In this communication we do a comparative study of tropopause height over different time scale day-to-day as well as seasonal variation of cold point tropopause. Finally, our study reveals that the vertical wind variability in the region of tropopause clearly indicates the existence of tropopause oscillation. Moreover, the vertical extent of tropopause increases due to the highly developed thermal mixing and warm temperature. Further, we extend our analysis to correlate the variation of tropopause height with wind variability in the vicinity of tropopause over these three stations.

Keywords: tropopause, MST radar, radiosonde, vertical wind, solar radiation

Introduction

The earth atmosphere is comparatively thin film of gaseous mixture which extends from ground to the upper boundary. Below the height of 100 km, the atmosphere is treated as neutral fluid where as the ionized plasma played a crucial role above it. The structure of the neutral atmosphere strongly depends upon temperature which varies with solar activity. In vertical direction, more than 99% of the atmospheric mass is found below an altitude of 30 km. The atmospheric physical properties such as pressure, density, temperature, water vapor, refractive

* Corresponding Author's Email: rina.dutta@uem.edu.in

index, wind velocity are non uniform in vertical and horizontal direction. These parameters are most sharply varried in vertical direction compared to horizontal direction. Normally there are four different criteria - air composition, thermal condition, dynamics (Gettelman et al., 2011) and chemistry applied for the division of the atmosphere into different layers in the vertical direction. According to composition, the atmosphere is classified into two parts – Heterosphere and Homosphere. In the homosphere from the surface upto 90-95 km level, the proportion of main gases are argon (0.93%), oxygen (20.95%) and nitrogen (78.08%). Approximately 0.04% greenhouse gases such as CO_2, CH_4, O_3 are present within air. Since these greenhouse gases are present in a very little amount, they play a major role in trapping heat radiations and keeping it into our atmosphere. Thereby effect in warming our planet and contributing to earth greenhouse effect. Water vapor is another important greenhouse gas which warms and humid the atmosphere. Tiny liquid and solid particles (aerosols) are generated by naturally or by human activities also present in variable amounts. Solar radiation is the basic source of energy for the earth's atmospheric system. Lower atmosphere is continuously unstable due to variation of its specific heat, atmospheric density and refractive index.

The tropopause is usually defined by meteorologists as the lowest level at which the rate of decrease of temperature with respect to height normally about 6.5^0 C/Km. Strong vertical mixing of turbulent air in the vicinity of tropopause is an essential property of tropopause. Troposphere contains 80% atmospheric masses and all phenomenas of climate are happened in this layer. For each kilometer of altitude increased in troposphere, the temperature naturally decreases by mean lapse rate. Its main characteristic is the atmospheric stability to resists vertical and horizontal movement of air particles. The thichness of troposphere (Fueglistaler et al., 2009) is different and the extension of this layer in the tropics is extended upto 16 km whereas, its thickness in polar region is near about 8-9 km. The vertical extent of tropopause increases due to the highly developed thermal mixing and warm temperature.

The incoming solar radiation acts as the mejor source of energy for the atmosphere. This energy remains responsible for all kinds of weather and climatic processes throughout the globe. Meterologists have divided the weather system into four broad categories. Table 1 represents the scale size of weather system.

Table 1. Different weather systems

Scale of Weather System	Horizontal Scale (km)	Time Scale	Example
Planetary	5000-10000	Weak or more	ITCZ, JET Stream, Rossby waves
Synoptic	1000-5000	2-7 days	Monsoon Depression, Tropcal Cyclone, Low pressure systems, Easterly waves etc.
Mesoscale	100-1000	Few hours	Thunderstorm, Gust, Gale, Squall etc.
Small	Few kms	Hours or less	Dust Storm, Trubulance

Tropopause - the upper boundary of the troposphere which is characterized by hydrostatic stability and plays key role in Stratosphere-Troposphere Exchange (Boothe and Homeyer, 2017). Variation of the height of the tropopause is one of the mechanism through which interactions between tropospheric air and stratospheric air takes place. Oscillations of tropical tropopause (Jaya Rao and Jain, 2000) was observed during the passage of atmospheric waves such as 50-70 days, 30-50 days and 10-20 days oscillation. Both vertical and horizontal propagations are possible for atmospheric waves (Birner, 2006) which can transfer momentum and energy from their originating region to other locations.

Probing of the Atmosphere

Surface instrument and remote sensing technique play important role in the study of different weather phenomena known as atmospheric probing technique. Radiosonde, balloon sounding are examples of instruments which are used to keep in direct contact with the sample air. Measurements those are dependent on position and direction of the flight of radiosonde (Son et al., 2011) are collected in this observation. But they have some drawbacks such as poor height and time resolution. These limitations can be overcome to a very good extent by remote sensing technique. Remote sensing technique denotes the collection of physical data of any object without any direct contact with the object. Radar and satellite are two important remote sensors to probe the atmosphere. The remote sensing technique utilizes electromagnetic energy at different bands of electromagnetic spectrum. Any remote sensing systems consists of three components - the source which generates the electromagnetic signal, the transmitting antenna that transmits the signal into the atmosphere and the sensor which receives the scattered or reflected energy from the target. Satellites, photometers, radiometers are example of passive remote sensors. The main advantage of passive remote sensor is that they are relatively simple in operation both electrically as well as mechanically and also passive remote sensors require less power. But they have certain limitations for preparing good signal due to extreme dependence on good weather conditions. However, different types of active remote sensors are used to probe the atmosphere such as radar, lidar. In case of active remote sensors, electromagnetic radiation transmitted in the form of pulses, interacts with the target. The scattered energy that depends on the characteristics of the target is received and gives the basic information of the atmosphere. The following table represents that radar operated in different electromagnetic bands.

Table 2. Radar operating in different Electromagnetic Bands

Electromagnetic Band	**Operating Wavelength**	**Scatterers**	**Frequency Range**
S-Band	10 cm	Precipitation	2- 4 GHz
Ka- Band	1 cm	Precipitation, Cloud Droplets	18- 27 GHz
UHF	75 cm	Refractive index	300 MHz- 3 GHz
VHF	6 m	Refractive index	30 – 300 MHz

Radar transmitter generates short pulses of signals and the signals are radiated by the antenna. Figure 1. shows the block diagram of radar system. Duplexer permits a single antenna for transmission and reception of electromagnetic signal and protects the receiver from very high-power during transmission of rader pulse. After interception, target re-radiate a portion of the incident radiation (echo) in the radar direction. Few returned signals are collected by the antenna and detected by the receiver. Basically radar echos arise due to variation of refractive index in the atmosphere.

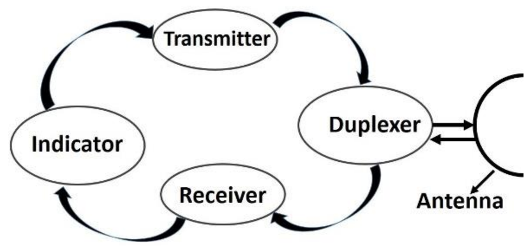

Figure 1. Simple Radar Block Diagram

Data Analysis and Results

The study seeks to investigate the height profile of temperature for three stations Chennai (13^0 N, 80.18^0 E, altitude 16m), Bangalore (12.96^0 N, 77.58^0 E, altitude 921m) and Hyderabad (17.45^0 N, 78.46^0 E, altitude 545m) using radiosonde observational data for the year 2002. In the Figure 2, it is seen that the minimum temperature is reached in the range -77^0 C to -85^0 C for these three stations over a height range 15-17 km. It is clearly noted that the heights of tropopause for Chennai, Bangalore and Hyderabad are near about 15.73 km (-77.7^0 C), 16.52 km (-81.1^0 C) and 15.53 km (-84.3^0 C) respectively. From this comparative study it is clearly understood that tropopause height is maximum in station Bangalore compared to other two stations. Since the elevation from mean sea level for these three stations are different, it represents different environments by identifying cold point tropopause.

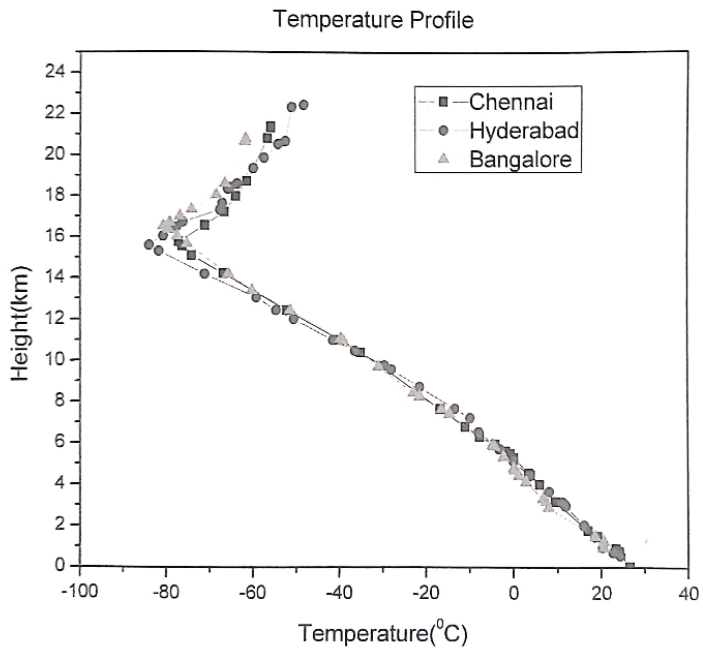

Figure 2. Plot of Height Profile of temperature for Chennai, Bangalore and Hyderabad

Next investigation is day-to-day variation of tropopause height for the station Chennai (shown in Figure 3). By a thorough analysis, it is observed that the tropopause height variation is maximum for the month of May. This clearly indicates that atmosphere is drastically heated during summer as maximum amount of solar radiation incident on the earth surface in this season. The height of the tropopause is observed lower during the period June-August (monsoon) as compared to the pre- monsoon as well as post- monsoon. Due to the cloud cover in monsoon less solar radiation falls on the terrestrial surface which diminishes the tropopause height.

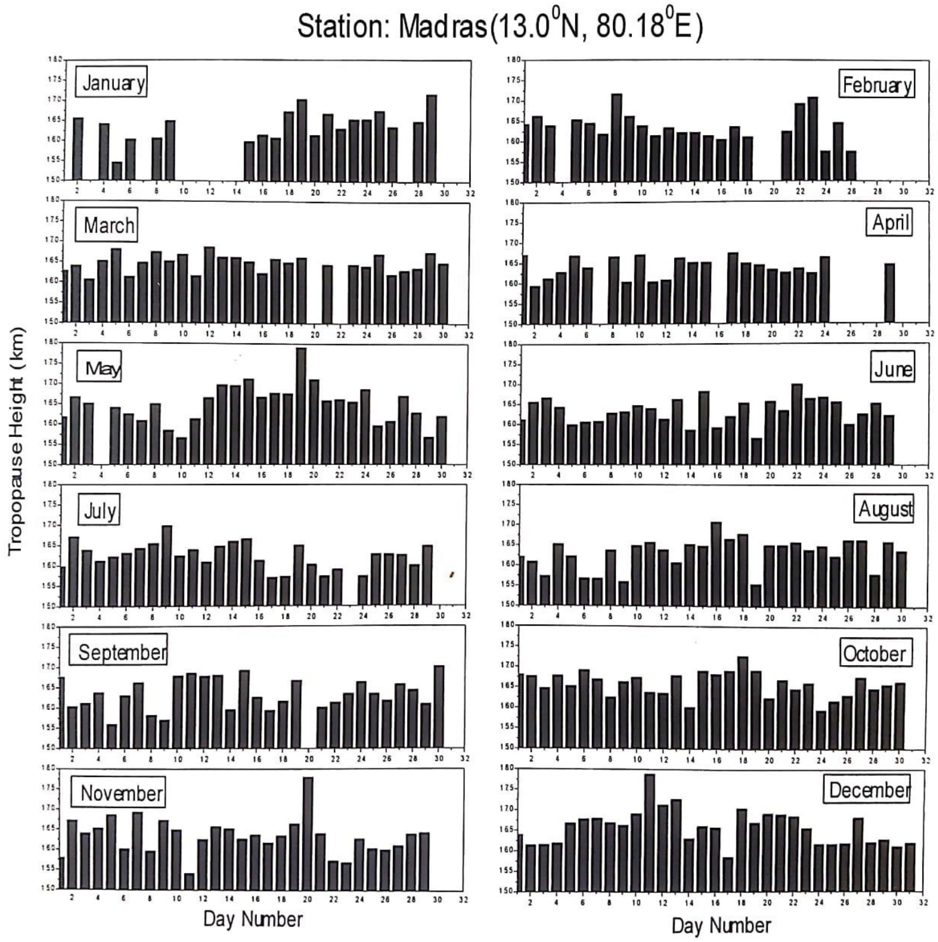

Figure 3. Plot of variation of tropopause height for the station Chennai (Day-to-day)

We also did an interesting compatative study of tropopause oscillation for all these three stations - Chennai, Bangalore and Hyderabad. Tropopause height fluctuation is observed to be more (as seen in Figure 4.) at Hyderabad location as compared to other two stations. Simultaneously similar type of oscillations (Figure 5) are detected in tropopause temperature. The reason for this is found to be the fact that due to the presence of wind circulation in the vicinity of tropopause. This air circulation (Peevey et al., 2014) is responsible for exchange of air masses between the troposphere and the stratosphere. Hadley circulation, jets streams (Manney et al., 2014) are played significant role for wind circulations.

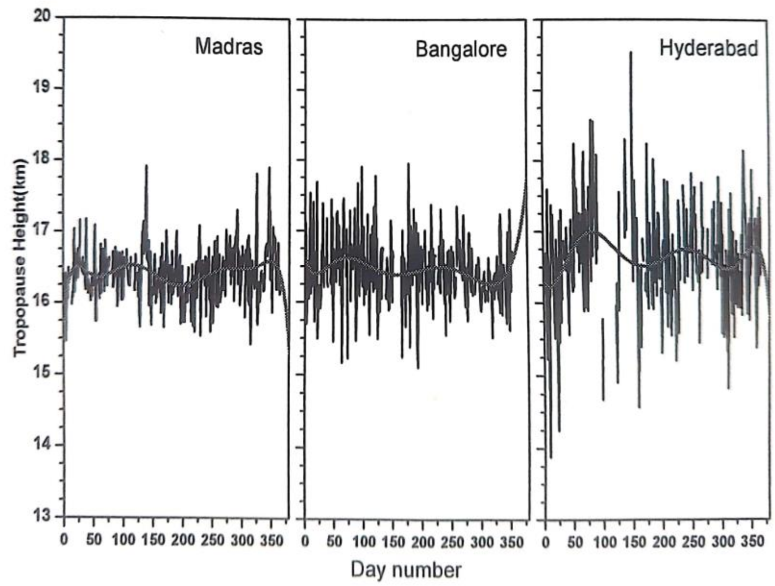

Figure 4. Variation of tropopause height (Day-to-day)

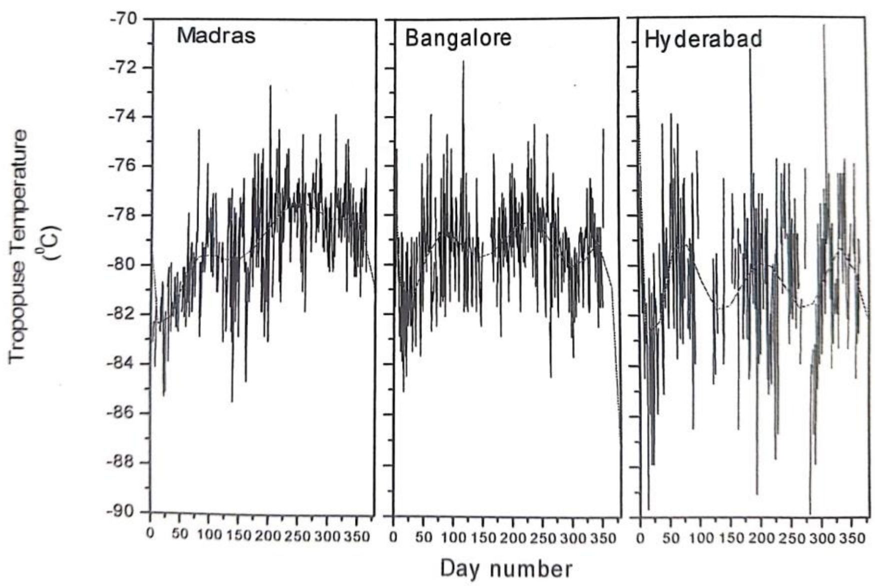

Figure 5. Variation of tropopause temperature (Day-to-day)

In the present communication we have extended our study to monthly variation of mean tropopause height. A comparative study of monthly variation of mean tropopause height has been investigated in Figure 6. From the analysis it is clear to understand that variability in height of the tropopause over Hyderabad is observed to be more as compaed to other two stations.

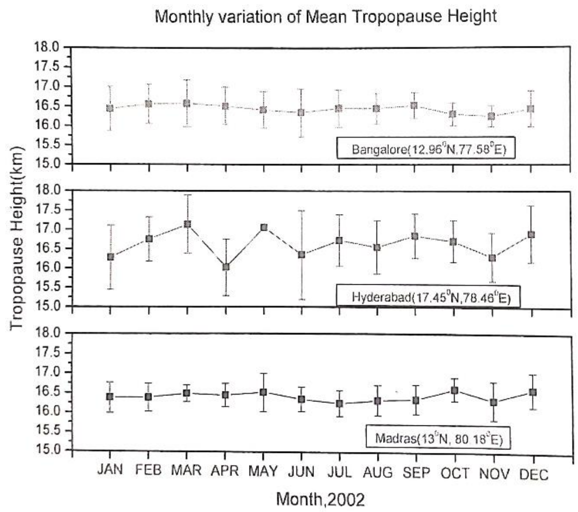

Figure 6. Monthly variation of tropopause height.

Height of the tropopause, for the station Hyderabad shows higher (~17 km) in the month of March with a sudden decrease (~16 km) in next month. To understand such rapid variation of tropopause height (Xian and Homeyer, 2019), wind fluctuations in the vicinity of tropopause have been studied (Figure 7). We analyse mean wind circulation within a height range 13-18 km over these three stations. It is clearly understood that there is enhanced variation of mean wind in Hyderabad station as compared to other two stations. It suggests that wind fluctuation influenced tropopause oscillations. Such observations are very significant as tropopause height variation generates the stratospheric-tropospheric exchange (Berthet, Esler, and Haynes, 2007).

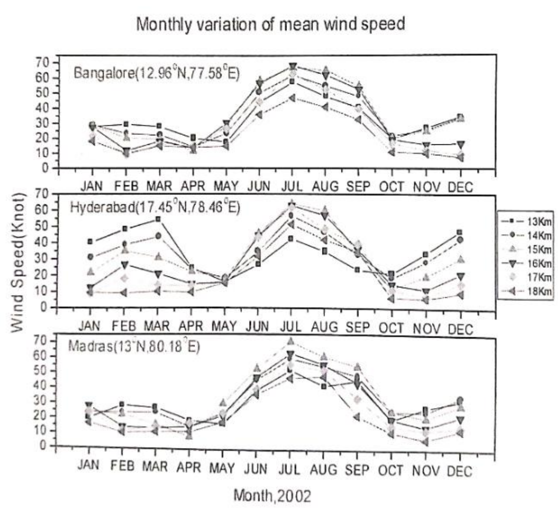

Figure 7. Monthly variation of mean wind speed in the height region 13-18 km

Discussion

In the present study, we investigate the variability of tropopause height over different locations-Chennai (13^0 N, 80.18^0 E, altitude 16m), Bangalore (12.96^0 N, 77.58^0 E, altitude 921m) and Hyderabad (17.45^0 N, 78.46^0 E, altitude 545m). Observations clearly demonstrate the enhanced variation of tropopause height in Hyderabad station as compared to the variations over Chennai and Bangalore. The meteorological parameters such as solar radiation, cloud cover, long wave radiation, and wind field also play a very important role to maintain the equilibrium of the troposphere. Our compatrative analysis clearly correlate between the tropopause height and vertical wind velocity in the vicinity of tropopause. In the present work MST radar observed vertical winds obviously display variation both in magnitude and direction over a height range 13-18 km. The goal of this study is to investigate the occurance of strong vertical wind shear within this height range. The existence of such tropopause boundary is created on the basis of thermal equilibrium of the troposphere without taking into consideration of the stratosphere and its variations. The air circulations are responsible for exchange of air between the troposphere and the stratosphere. Further when stratospheric air is transported isentropically downward, the tropopause boundary moves three dimensionally with air. The troposphere influences the stratosphere mainly through a variety of atmospheric waves that propagate upward. Recent evidence clearly shows that the stratospheric air exchange can affect the weather and climate in the troposphere. Overall, this analysis presents a thorough understanding of dynamical structure of the transition region between the troposphere and the stratosphere.

Acknowledgments

I thank to (IITM) Indian Institute of Tropical Meteorology, Pune, India for providing the Radiosonde and MST radar data.

References

Gettelman, A., Hoor, P., Pan, L. L., Randel, W. J., Hegglin, M. I., and Birner, T.: The Extratropical Upper Troposphere and Lower Stratosphere, *Rev. Geophys*. (2011) 49: RG3003.

Fueglistaler S, Dessler A. E, Dunkerton T. J, Folkins I, Fu. Q, Mote P. W, Tropical tropopause layer, *Rev. Geophys.* (2009) 47: 1-31.

Boothe, A. C. and Homeyer, C. R.: Global large-scale stratosphere–troposphere exchange in modern reanalyses, *Atmos. Chem. Phys*. (2017), 17: 5537–5559.

Jaya Rao. Y, Jain A. R. Oscillation of Tropical Tropopause during passage of atmospheric waves. *Indian Journal of Radio & Space Physics* (2000) 29:203-209.

Birner T. Fine-scale structure of the extratropical tropopause region. *J. Geophys. Res.-Atoms.* (2006) 111:1-14.

Son, S.-W., Tandon, N. F., and Polvani, L. M.: The fine-scale structure of the global tropopause derived from COSMIC GPS radio occultation measurements, *J. Geophys. Res* (2011) 116: D20113.

Peevey, T. R., Gille, J. C., Homeyer, C. R., and Manney, G. L.: The double tropopause and its dynamical relationship to the tropopause inversion layer in storm track regions, *J. Geophys. Res*. (2014) 119:10194–10212.

Manney, G. L., Hegglin, M. I., Daffer, W. H., Schwartz, M. J., Santee, M. L., and Pawson, S.: Climatology of Upper Tropospheric–Lower Stratospheric (UTLS) Jets and Tropopauses in MERRA, *J. Climate*. (2014) 27:3248–3271.

Xian, T. and Homeyer, C. R.: Global tropopause altitudes in radiosondes and reanalyses, *Atmos. Chem. Phys*. (2019) 19: 5661–5678.

Berthet G, Esler J. G, Haynes P. H. A Lagrangian perspective of the tropopause and the ventilation of the lowermost stratosphere, *J. Geophys. Res.-Atoms.* (2007) 112:1-14.