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Variability of Tropical Tropopause Temperature Associated with Convective Activity in Troposphere

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Abstract:-*Changes in tropopause temperature are associated with the convective activity in troposphere and this is an active atmospheric research area. In this paper, we used accurate and high vertical resolution 1-Dimensional Variational (1-DVAR) temperature profiles from Global Positioning System Radio Occultation (GPSRO) Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC) mission to calculate cold point tropopause temperature (CPTT). The analysis is carried out across Indian region to understand CPTT variations during two case events (1) deep convective events (obtained from International Satellite Cloud Climatology Project (ISCCP)) in Andhra Pradesh and neighboring ocean (12^0-20^0N,75^0-85^0E) from January 2008 to May 2008 and (2) heavy rain fall events across different parts of the country from 2008 to 2011. During case study-1, out of 59 collocated COSMIC temperature profiles with ISCCP, 44 profiles exhibit CPTT ≤191K. Similarly, CPTT ≤ 191K occurred more frequently during heavy rain fall locations analyzed in case study-2. Hence, we report that the occurrence of extremely low CPTT ≤ 191K increases during deep convective and heavy rain fall events.

Index Terms: **Atmospheric stability, Cold Point Tropopause Height & Temperature, Deep convective activity,One-dimensional variational analysis, Radio occultation observations.**

I. INTRODUCTION

Among different regions of the atmosphere, tropopause, the topmost layer of troposphere is one of the important regions that play a critical role in the atmospheric structure. It is a transition zone between the convectively mixed tropopause and the stably stratified stratosphere [1] [2]. The structure of the tropopause is intimately related to the mechanisms and rates of exchange of air, moisture and trace chemicals between troposphere and stratosphere [3]. Its height and temperature are sensitive to temperature changes in troposphere and stratosphere and these two parameters are important measures of global climate variability [4]. In addition, accurate determination of the tropopause temperature and height are also important for dynamical weather analysis and forecasting, radiative transfer calculations and the diagnosis of chemical transport in the atmosphere [5]. It also plays an important role in weather phenomena in troposphere like cyclones and jet streams. The changes in the structure of the tropopause have received increased attention in climate processes and as sensitive indicators of human induced climate change [3]. The frequent occurrence of extremely cold point tropopause temperature (CPTT) associated with the convective activity at troposphere is still the area of research, although, some analysis related to the monsoon and the frequency of CPTT in tropics were carried out. For example, Newell et al, [6] noted that tropopause temperature is cold enough to account for observed water vapor mixing ratio's in the lower stratosphere only during certain months and at certain locations. They also have shown that the region of cold tropopause temperature extends towards the Bay of Bengal and the Indian tropical region during pre monsoon and monsoon months. Xuelong et al, [7] found that during the Indian summer monsoon locations of the tropical CPTT are deflected Northward. Jain et al, [11] reported that extreme low CPTT (≤ 191K) are often observed during the monsoon season over Bay of Bengal and adjoining areas. In Global Positioning System (GPS) Radio occultation (RO: GPSRO) experiment, atmosphere acts as a lens and alters the propagation velocity and paths of microwave signals passing through it. Constellation observing system for meteorology ionosphere and climate (COSMIC) GPSRO mission [9] provided an accurate global thermometer that monitor the earth atmosphere in all weather with unprecedented long term stability, resolution, coverage and accuracy. Kursinski et al, [9] predicted RO temperature precision as high as 0.3–0.4K between 12–18km altitude. Anthes et al, [10] use the COSMIC data set to estimate RO temperature precision to be ~0.25 K from10–20Km altitude. These high accurate GPSRO observations have given an opportunity to study the CPTT variations at a better spatial and temporal resolution, which is otherwise not possible with the limited number of radiosonde observations. Jain et al, [11] studied extreme CPTT using GPSRO CHAMP and COSMIC data during ARMEX campaign. Ratnam et al. [12] presented features related to the structure and variability of the tropopause using radio occultation measurements by the Challenging Minisatellite Payload (CHAMP) and GPS during May 2001 to December 2004. Thus these high vertical resolution temperature profiles are ideally suited for observing the dynamics of

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tropopause temperature. Hence, in the present paper, the anlaysis of CPTT across Indian subcontinent is carried out in two case studies (1) deep convective activities along a tropical state, Andhra Pradesh (12^0-20^0N,75^0-85^0E) and the adjoining ocean during January 2008-May 2008 and (2) heavy rain fall events at different parts of the country during 2008-2011.

II. DATA AND METHODOLOGY

COSMIC 1-Dimensional Variational (1-DVAR) temperature and pressure profiles are obtained from http://tacccub.gov.tw. Deep convective events are identified using International Satellite Cloud Climatology Project (ISCCP) convective tracking data base [13]. To understand the variations in CPTT during deep convective activities, following two case studies are carried out:

(1) ISCCP deep convective events data are available from January 2008 to May 2008. Thus, COSMIC 1-DVAR temperature profiles are collocated (spatial scale of ±2° and temporal scale of 3 hours) with ISCCP deep convective events over Andhra Pradesh and adjoining ocean during January 2008 to May 2008 (Fig.1). The continuous daily deep convective events occurred at same latitude and longitude are combined and clubbed as one event. With this criteria total 11 deep convective events are collocated with 59 COSMIC temperature profiles (table-1).

(2) COSMIC temperature profiles are also collocated with heavy rain fall events at different parts of the country during 2008-2011.

The altitude of lowest temperature in the vertical profile (i.e. cold point tropopause (CPT)) is considered as a bottom level of tropopause [11]. The temperature corresponding to this lowest level is calculated and used as a CPTT.

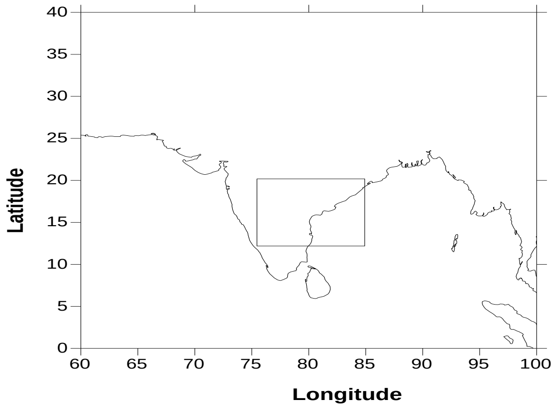

Fig 1. The study region (shown as the square)

Table 1: List of deep convective events identified using ISCCP data during January 2008 to May 2008 across AP region with collocated COSMIC tangent point locations

Event No.	Convective Events in 2008			Collocated RO profiles			CPTT
	Dates	Latitude	Longitude	Date	Latitude	Longitude	
1	28 Jan	(10.3, 10.6)	84.7, 85.9)	28 Jan	12.07	83.22	189.28
				29 Jan	12.99	81.77	188.13
2	9,10 Feb	(10.3, 14.4)	(77.5, 85.2)	9 Feb	10.16	78.52	187.89
					08.03	81.98	185.35
					10.16	78.52	187.89
					11.22	82.76	186.16
				10Feb	10.39	77.13	188.23
					09.03	86.53	185.35
					12.41	86.92	189.29
3	12 Feb	10.1	75.6	12 Feb	12.77	78.69	189.13

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4	09-16 March	(10.2,18.6)	(74, 85.7)	12 Mar	11.00	84.70	191.30
				2 Apr	10.04	81.29	190.20
5	1-10 April	(10.1, 21.8)	(75.1, 86.4)	3 Apr	19.66	85.81	191.86
				6 Apr	18.52	80.59	190.70
				7 Apr	17.26	77.36	192.29
				8 Apr	22.69	78.94	190.23
					16.39	78.94	188.61
6	15 April	(13.1,13.8)	(75.8,76)	15 Apr	12.62	74.42	187.23
7	17,18 April	(13.5, 16.6)	(75.8,76.1)	17 Apr	17.34	76.64	189.51
					17.82	77.52	191.01
				18 Apr	17.21	77.86	191.40
					18.21	78.86	191.02
				24 Apr	15.95	72.20	187.03
8	22-30 April	(10.1, 19.6)	(74.4, 87)	27 Apr	15.61	75.81	187.35
				28 Apr	11.75	75.80	189.30
					11.76	70.91	186.37
				29 Apr	20.25	83.49	189.23
				30 Apr	12.79	84.44	188.52
					19.35	83.46	188.81
9	1-4 May	(10.1, 19.1)	(77.3, 84.8)	1 May	16.23	83.63	190.88
					14.70	85.89	187.19
					09.03	82.84	189.50
					12.38	74.36	186.04

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10	6-15 May	(10.1, 20.9)	(73.7, 86.7)	6 May	11.93	76.03	187.50
					16.90	79.44	187.03
				7 May	12.09	75.14	187.34
					13.79	77.44	187.50
					09.03	82.84	189.50
					09.59	73.66	188.38
				8 May	20.65	86.56	191.09
					12.09	75.14	187.34
					11.94	75.01	189.30
					13.31	80.88	188.40
				9 May	12.66	75.51	191.17
				10 May	11.94	75.01	191.30
				11 May	12.66	75.51	192.05
				12 May	09.47	80.91	188.88
				14 May	09.76	75.54	188.34
11	21-31 May	(10.2, 19.9)	(73.1, 85.8)	21 May	19.91	83.24	189.23
					21.73	85.60	193.02
				23 May	19.01	83.05	192.00
				24 May	13.84	73.93	188.75
				25 May	09.28	71.48	187.67
				26 May	15.24	80.86	191.17
				27 May	13.68	74.99	188.00
				28 May	08.97	76.63	188.54
					19.57	84.85	191.19
				29 May	12.70	80.31	191.73
				31 May	15.80	80.20	188.68

III. RESULTS

A. *ISCCP convective events and CPTT*

Total of 59 COSMIC tangent point locations collocated are with the 11 deep convective events (Table-1). Since Lifted Index (LI) is a measure of stability and instability in the atmosphere, dynamic state of the atmosphere during deep convective events are confirmed by analyzing changes in LI during, one day before and one day after the convective events (Fig.2). LI is estimated from COSMIC 1-DVAR temperature and pressure profiles as mentioned in Sharma et al. [14]. The negative (positive) LI indicates the instability (stability) in the atmosphere. During all convective events LI values are negative and less than -2 most of the time. Thus, the atmosphere is highly unstable during convective events. Whereas, LI is positive with a stable atmosphere during one day before and one day after the convective events. Deep convective activities during highly unstable atmospheric conditions also influence tropopause dynamics. Therefore, to see the impact of deep convective activity on tropopause, the frequency distribution of CPTT at 59 collocated observations is analyzed (Fig. 3).

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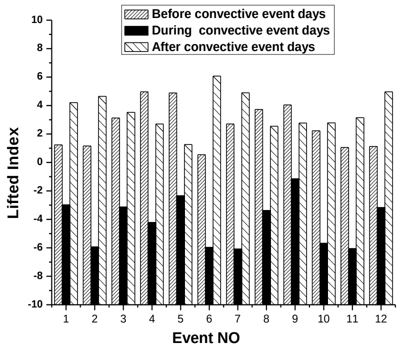

Fig 3. The variations of LI during, before, and after convective event days

CPTT less than 191K occur more frequently during all the deep convective events. Out of 59 profiles, 44 profiles show CPTT $\leq$ 191K. In addition, the frequency of CPTT between 187K and 189K is more during deep convective activities.

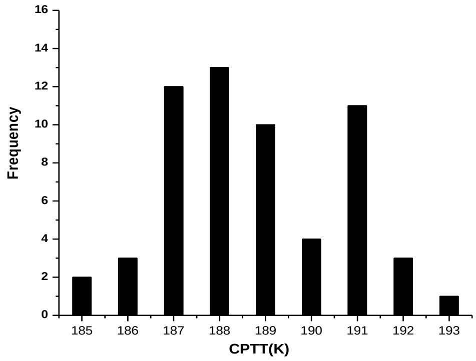

Fig. 4 The frequency distribution of CPTT during 59 collocated COSMIC and ISCCP deep convective events

B. *Heavy rainfall and CPTT*

In addition, the COSMIC observations are also collocated during heavy rain fall events at different parts of the country during 2008-2011. The dates, latitude and longitude of the events, collocated COSMIC locations and CPTT are shown in table-2. Out of 11 COSMIC collocated locations, CPTT is greater than 191K only at 3 locations and it is less than this value at rest of the places.

Table 2: List of collocated heavy rainfall events with COSMIC profiles and CPTT during Jan 2009 - December 2010

Event No.	Rainfall events			Collocated COSMIC RO profiles			CPTT (K)
	Dates(Location)	Latitude	Longitude	Date	Latitude	Longitude	
1	06-10 Jun, 2008 (Hyderabad)	17.23	78.29	7 June	17.23	79.30	186.8
2	11-15 May,2009 (Kolkata)	22.34	88.21	11 May 12 May 13 May 14 May	20.71 22.63 21.79 20.09	89.74 88.08 89.72 87.60	186.8 191.0 190.5 190.0
3	30 May, 2009 (Kolkata)	22.34	88.21	30 May	20.07	87.35	199.2
4	30 June, 2009 (Kolkata)	22.34	88.21	30 June	23.55	87.77	192.5
5	10 Nov,2009 (Gujarat)	22.15	77.11	10 Nov	22.84	76.85	190.3
6	13 April, 2010 (Bangladesh)	23.41	90.21	13 April	21.51	90.72	192.3
7	30 April 2010 (west Coast of India)	10.28	79.34	30 April	8.82 11.17	78.39 79.63	188.5 187.9
8	23 may, 2011 (Luck now)	26.5	80.56	23 May	24.96	78.28	193.5

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IV. SUMMARY AND CONCLUSION

The present study examine the occurrence of cold point tropopause temperature CPTT ≤ 191K using accurate and high vertical resolution COSMIC GPSRO derived 1-DVAR temperature profiles. CPTT variations are analysed during two case studies (1) ISCCP deep convective events from January 2008 to May 2008 along Andhra Pradesh (12^0 -20^0N ; 75^0 - 85^0E) and adjoining ocean from January 2008 to May 2008 and (2) during heavy rain fall events observed at different parts of the country during 2008 -2011. The negative values of LI on the days of convective events shows the atmospheric instability conditions. The analysis of these two case studies show that the occurrence of extremely cold point tropopause (CPTT ≤ 191K) is frequent during a majority of the deep convective activities and during heavy rain fall events. Such deep convections in atmosphere may be associated with the thunderstorms, cyclones and monsoonal activities. Earlier, Jain et al, [11] reported that extreme low CPTT ≤ 191K are often observed during the monsoon season over Bay of Bengal and adjoining areas.

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