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Detection of Monsoon Progress Using Relative Humidity Profiles of Troposphere

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Abstract:
Present analysis emphasises on the change in the vertical profiles of relative humidity (RH) with the progress of Indain summer monsoon during 2009, 2010 and 2011. The study is carried out with the onset of monsoon over Kerala and its progress in Mumbai and Delhi. Relative humidity profiles are obtained using NOAA/ERSL radiosonde observations and Global Positioning System Radio Occultation (GPSRO),Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC) derived 1-DVAR temperature, pressure and water vapour pressure profiles. High relative humidity between 5 and 7 Km is observed one day before onset over the above mentioned stations. Whereas, on onset day, a significant dip in RH at the similar altitude can be considered as a signature for monsoon onset.

1. Introduction

Rainfall during the southwest monsoon season (June to September) accounts for the major part of the annual rainfall over the most parts of the country. The onset over Indain station, Kerala coast around the end of May or beginning of June is considered as beginning of south west monsoon(Soman & Kumar 1993). The onset is defined on the basis of sharp and sustained increase in rainfall at a group of adjacent stations along the Kerala coast (Ananthakrishnan et al., 1967). The monsoon onset is highly dynamic in nature and it takes about six weeks to cover the entire India (Soman et al, 1992). The monsoonal rainfall is associated with the high degree of convective activities at lower level of troposphere, due to which the vertical distribution of moisture and temperature changes. The vertical atmospheric structure, day night differences and the thermodynamic heat budget is studied by Krishnamurthy et al (1982) based on data obtained during Monsoon Experiment (MONEX). The synoptic analysis related to the onset phase of south west monsoon is studied by Ananthakrishna et al (1968) and Rao (1976). Rao et al., (2007) studied monsoon onset at single location Gadanki using Ultra High Frequency (UHF) radar winds.

Since the atmospheric moisture significantly increases before the onset of the monsoon at Kerla coast and as it advances to cover the Indian region, vertical profiles of humidity help in predicting monsoon onset as different. Conventionally, these profiles are obtained from radiosonde observations. However an active Global Positioning System Radio Occultation (GPSRO) Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC) mission (kursinski et al, 1997) also provided an accurate global thermometer that monitors the earth atmosphere in all weather with unprecedented long term stability, resolution, coverage and accuracy (Anthes, 1999). The GPSRO measurement has avertical resolu-tion ranging from 400m to 1.4km,which is much higher than that of anyother satellite data (Kursinskietal.,1997). Hou et al. (2009) assessed the COSMIC retrieved atmospheric profiles using Australian radiosonde station data for a period of 13 months. Sun et al. (2010) performed a comparison between COSMIC at-mospheric profiles, refractivity profiles and radiosonde data for 18 months. Sun et al. (2010) reported that, in the troposphere (850–200 hPa), the collocation mismatch impacts on the comparison standard deviation errors for temperature are 0.35 K/3 h and 0.42 K/100 km, and for relative humidity are 3.3 %/3 h and 3.1 %/100 km.

The water vapour is lighter than air at the same temperature so humid air will tend to rise by the natural convection process. Thus, magnitude of relative humidity in the atmosphere is an indicator of precipitation, dew and fog. Higher the humidity, warmer the equilibrium temperature and more chance of precipitation. The impact of 1-DVAR COSMIC pressure and temperature profiles derived relative humidity on rainfall is studied by Sharma et al., 2011.

In the present study, relative humidity profiles derived from radiosonde and COSMIC 1-DVAR temperature, pressure and water vapour profiles are used to analyse the vertical structure of the atmosphere before the onset of monsoon over Kerala and its progress in Mumbai and Delhi stations. The structure of the paper is organized as follows: section 2 introduces the data and methodology used in the analysis, which also include steps for calculation of RH from RS and RO data. Section 3 presents the results and discussion. The summary of results are in section 4.

2. Data and Methodology

COSMIC GPSRO mission has provided a good number of 1-DVAR processed accurate and high resolution vertical profiles of temeprautre, pressure and water vapour pressure around the globe. Since the main interest of the present anlaysis is to study the onset fo Indian summer monsoon, these profiles are obtained from 1st May to 30th June during 2009, 2010 and 2011 (http://tacccub.gov.tw). In addition, vertical profiles of temperature and pressure from NOAA/ ERSL rdaiosonde data base are also used in the present analysis (http://www.esrl.noaa.gov/raobs/). The GPSRO COSMIC observations that are collocated with the radiosonde observations with spatial scale of 2^o latitude and longitude are used in the present study.

Using COSMIC 1-Dvar temperature, pressrure and water vapour profiles, saturation vapour pressure (e_s) is calculated using Teten's formula (Tetens 1930) using equation (i).

$$e_s = 6.11 exp \frac{\alpha(T-273.16)}{T-\beta} \quad \text{.... (i)}$$

Where for water α=17.26 and β=35.86

Since vertical profile of actual water vapour pressure (e) is known, RH is computed by substituting e_s and e in equation (ii).

$RH=100*e/e_s$ .....(ii)

Along with temperature, dew point temperature is also provided by rdaiosonde data, therefore an August-Roche-Magnus approximation is used to derive RH using equation (iii)

RH=100*(EXP((17.625*TD)/(243.04+TD))/EXP((17.625*T)/(243.04+T))) .. (iii)

Where, T is the ambient temperature and TD is dew point temperature in (^{o}C).

The Indian summer monsoon begins with the onset over Kerala and then it progresses with the time to the different parts of the country. Thus , vertical profiles of RH before monsoon onset over Kerala, Mumbai and Delhi are studied. The onset dates at these #3 stations are obtained from IMD (imd.gov.in). Depending upon the avialabilty of radiosonde and COSMIC GPSRO data RH profiles from #3 days before the monsoon onset at theses three stations are anlaysed. The RH obtained from radiosonde are mentioned as "RH_{rs}" and from COSMIC GPSRO as "RH_{ro}".

3. Results

Onset of summer monsoon over Kerala was on 23rd May, 31st May and 29th May during 2009, 2010 and 2011 respectively. The average RH from 5 to 7 Km from three days (depending upon the availability of data) before onset during 2009, 2010 and 2011 are shown in figure 1(a), 1(b) and 1(c) respectively.

RH on 21st May (2days before) was 69.1 % whereas it increase to 73.2% one day before the onset and it decreases to 65 % on the day of onset. Similar decrease in RH on the onset day is observed during 2010 (Figure 1(b)). COSMIC derived RH was 72.2% on 28th May (3 days before) and dropped to 38.7% on the onset day (31st may). Decrease in RH (5 to 7 Km) is also observed on onset day during 2011 (Figure 1(c)). One day before onset (28th May) RH was 83.1 % whereas it decreases to 24.8% on 29th May.

The monsoon progressed and reached Mumbai on 22ndJune, 11thJune and 4thJune over Mumbai during 2009, 2010 and 2011 respectively.

The variations of RH between 5 and 7 Km before and on onset day over the station during 2009, 2010 and 2011 are shown in figure 2(a), 2(b) and 2(c) respectively.

Three day before (19th June) the 2009 monsoon onset (Figure 2(a)), RH was 26.11% and it increase to 82.4 % and 80.0 % on 20th and 21st June (one day before). Whereas, on onset day the average RH from 5 to 7Km was decreased and lowered down to 66.5%. Similar increase in RH on one day before the onset and decrease on onset day is also observed during 2010 and 2011. The radiosonde (COSMIC) derived RH was 69.3% (67.3%) on 9th (10th) June and it dropped to 31.9 % (48.3%) on 11th June during 2010(Figure 2(b)). During 2011 also RH was low (9.6 % and 48.6 %) # 2 days before the onset (2nd June)and increases to 68.9% and 93.3 % one day before onset and subsequently decrease to 60.6 % on onset day.

Similar enhancement in RH between 5 to 7 Km, one day before the onset and decrease on the onset day is observed in Delhi during 2009, 2010 and 2011 respectively. figure 3 (a), (b) and (c) shows the RH variations in Delhi during 2009, 2010 and 2011 respectively. The monsoon onset over Delhi occurred on 30th June 2009, 5th July 2010 and 8th July 2011. 2 days before onset (28th June)average RH observed from radiosonde (COSMIC) was 32.3 % (66.1 %). Increase in RH on both the data set is observed on 29th June, it increased to 43.9 % in radiosonde and 72.1% in COSMIC. Whereas it decreases to 39.7% on the onset day.

Figure 4 (b) and (c) also shows similar trend in RH during 2010 and 2011 respectively. On 4th July 2010 (Figure 4(b)) average RH was 79.6 % and it decreases to 62 % on 5th July. Similarly decrease in RH on the onset day is observed during 2011, though drop is only 3% (figure 4 (c)).

The analysis of vertical profiles of RH before the onset over Kerala and its progress over Mumbai and Delhi during 2009, 2010 and 2011 shows that loading of water vapour increase the relative humidity between 5 to 7 Km one day before the onset. On the other hand on the onset day of monsoon the strong westerly flow confined the moisture at lower levels only due to which a significant dip is observed in RH between 5 and 7 Km.

4. Conclusion

In the present study the vertical profiles of troposphere humidity derived from radiosonde and GPSRO COSMIC data bases are anlaysed from #3 days before the summer monsoon onset day over Kerala and its progress over Mumbai and Delhi during 2009, 2010 and 2011 respectively. Generally high humidity conditions prevails at lower troposphere, with the onset of the monsoon the relative humidity increases at upper levels also. We observed high RH between 5 and 7 Km before one day of monsoon onset at three stations with a significant drop at same altitude on the onset day. Results shows that the dip in RH between 5 and 7Km can give a signature of monsoon onset at different stations.

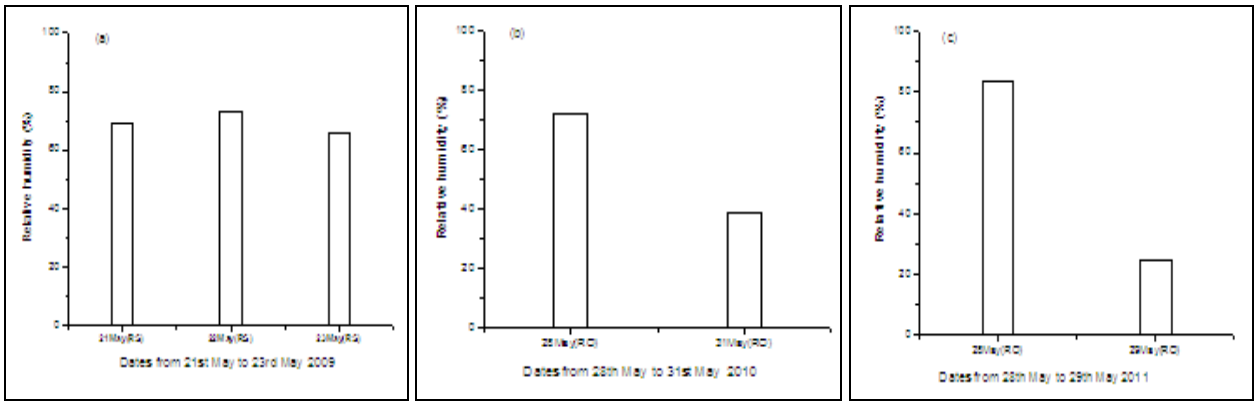

Figure 1: The average relative humidity from 5 to 7 Km over Kerala during (a) 2009, (b) 2010 and (c) 2011

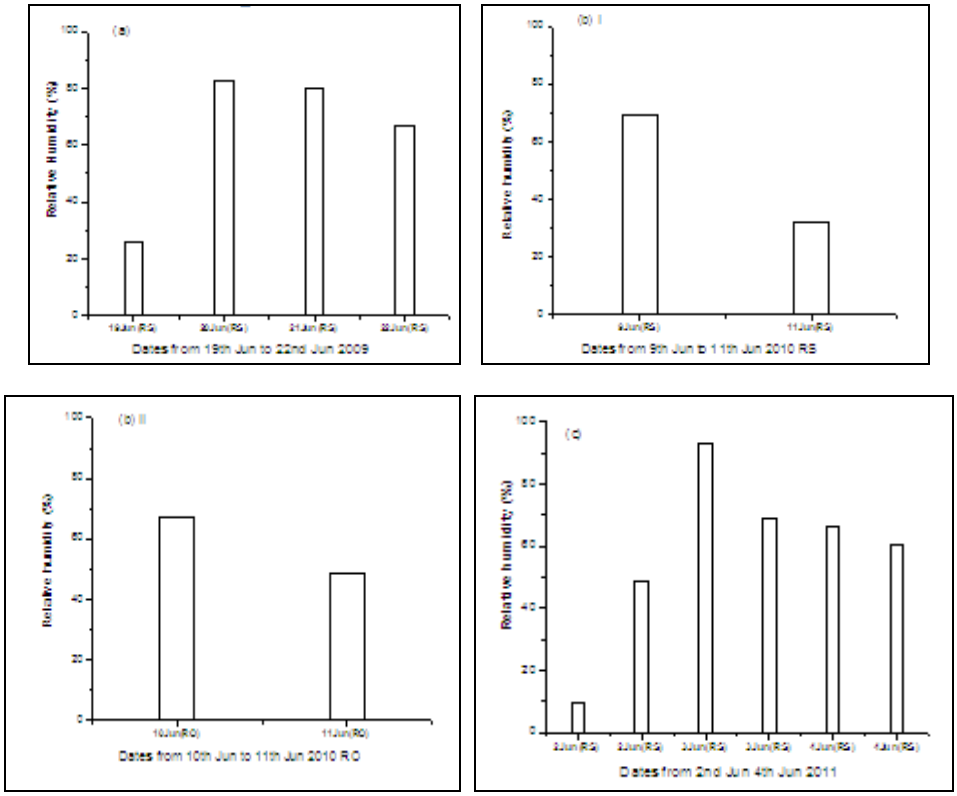

Figure 2: The average relative humidity from 5 to 7 Km before and on onset day over Mumbai during (a) 2009, (b) i & ii 2010 and (c) 2011

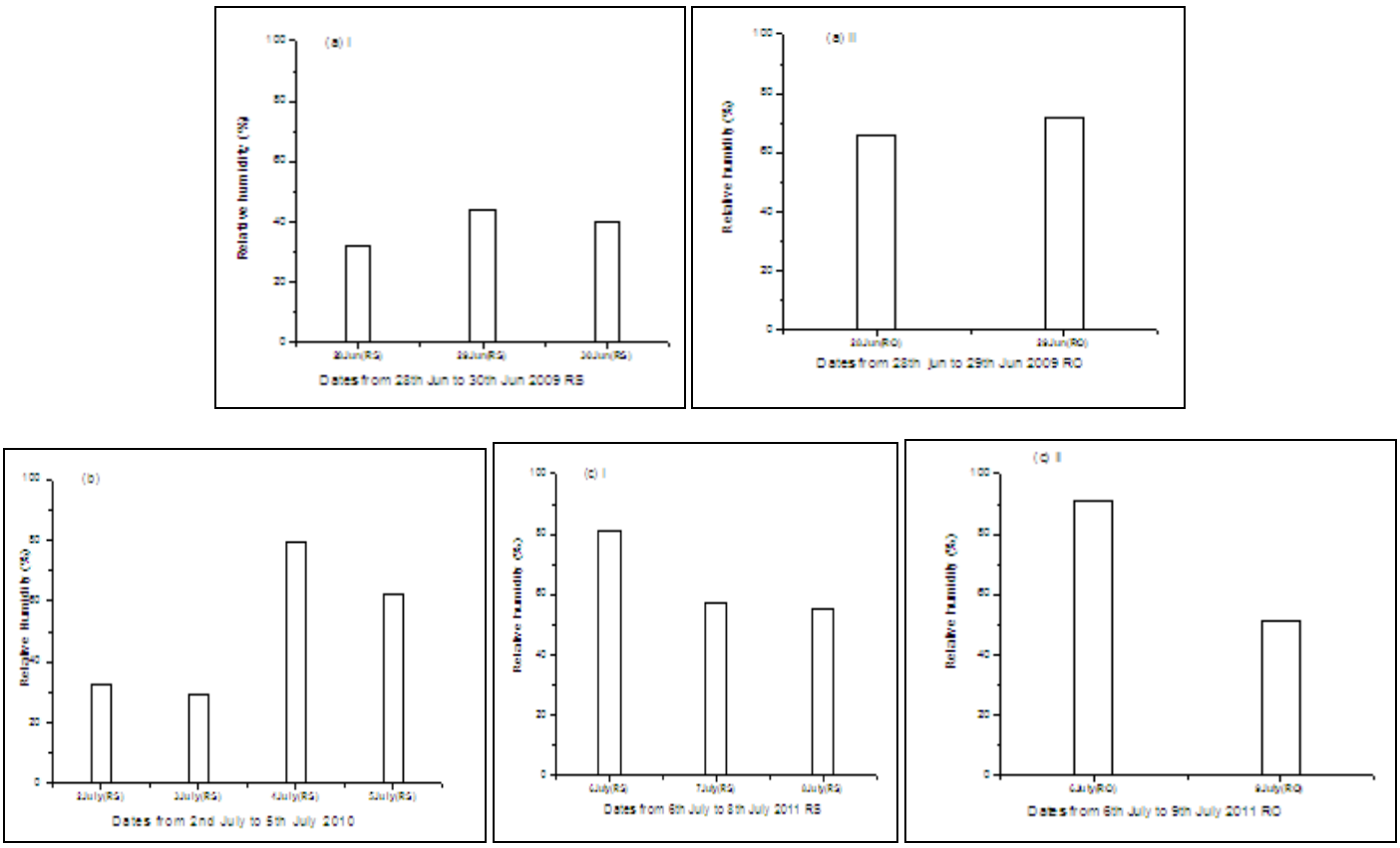

Figure 3: The average relative humidity from 5 to 7 Km before and on onset day over Delhi during (a) i & ii 2009, (b) 2010 and (c) i & ii 2011

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