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Characteristics of pre-monsoon convective activity over two contrasting environments from microwave radiometer data – A case study

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ABSTRACT

In the present study, microwave radiometer observations were used to understand the thermodynamic state of the atmosphere before, during and after the thunderstorm events occurred over two contrasting environments i.e. Pune and Mahabaleshwar. Initially thermodynamic state of atmosphere was analyzed using single cases from each site. Analysis of temporal variability of atmospheric parameters and associated thermodynamic indices of individual events showed significant positive differences between Pune and Mahabaleshwar in surface fields like temperature before thunderstorm, while surface relative humidity (RH) records indicated negative differences. Differences in various thermodynamic indices showed that strength of instability is higher over Pune compared to that over Mahabaleshwar.

Later composite analysis along with difference of the mean was verified so as to confirm the results quantitatively. Among the represented thermodynamic indices lifted index, humidity index and show-alter index showed a negative difference, whereas total index, k-index and convective temperature showed positive difference before and during the storm. However, no significant changes were observed after the thunderstorm activity. Analysis suggested that there is a regional difference in thermodynamic features during the evolution of thunderstorm and also a possibility of thunderstorm potential over Pune compared to Mahabaleshwar. This work also shows the robustness of ground based microwave radiometry for the study of convective events.

Key words: Thunderstorm, Thermodynamic state, Western Ghats and Microwave Radiometer.

INTRODUCTION

Severe convective activities during pre-monsoon season include thunderstorm events, which are mainly associated with heavy precipitation, lightning, strong winds, hailstorms etc. These convective systems are considered as micro-scale or meso-scale phenomena, which will have time scale of the order of less than an hour and length scale limited to 10 km. Even though it has short time span, prediction of these convective systems is very important. Though many approaches of studyare in practice using several modes of observations, most of the dynamical and thermodynamical features of thunderstorms in the literature are based on the mid-latitude systems. Over continental tropics, observations of the genesis of storms are rare. Thus, understanding of storm-time thermodynamic structure, especially in tropical regions is very important.

There are several techniques established for the study of thunderstorms. However, temporal evolutions of these convective events are not well understood, especially over tropics. The possible reason for this may be difficulty in obtaining the vertical structure of the storms or difficulty to forecast the events as the time span of these convective systems is only about 20–30 min. It is well known that short period forecasting of the future location of convective storms has been historically based on the first technique i.e. extrapolation of radar reflectivity echoes. But, generally forecasting using these techniques is not good as their accuracy decreases rapidly due to short life time of individual convective systems. Hence, various studies (Browning 1980; Wilson and Mueller 1993 etc.) suggested that techniques for forecasting initiation, growth as well as dissipation of convective storms are required to produce a forecast beyond 20 minutes. Apart from this, Numerical Weather Prediction (NWP) models have the limitation in representing these storms and vertical structure since the vertical structure is decided by the interaction between the environmental shear and microphysical interactions. Apart from this, during the recent years, many statistical techniques (for e.g. Reap 1994; Lambert et al., 2005 etc.) were developed to forecast thunderstorm. Rajeevan et al., (2012) developed a statistical model based on binary logistic regression for predicting probability of lightning occurrence over southeast India using the perfect prognostic method (PPM).

Though there are several techniques or models, all these were mainly used for the prediction of the severe convective activities with less information on evolution of thermodynamic state of atmosphere. It is well known that in order to study the temporal evolution of these convective events we need continuous observations, which in turn will help in severe convective event prediction. Recently,

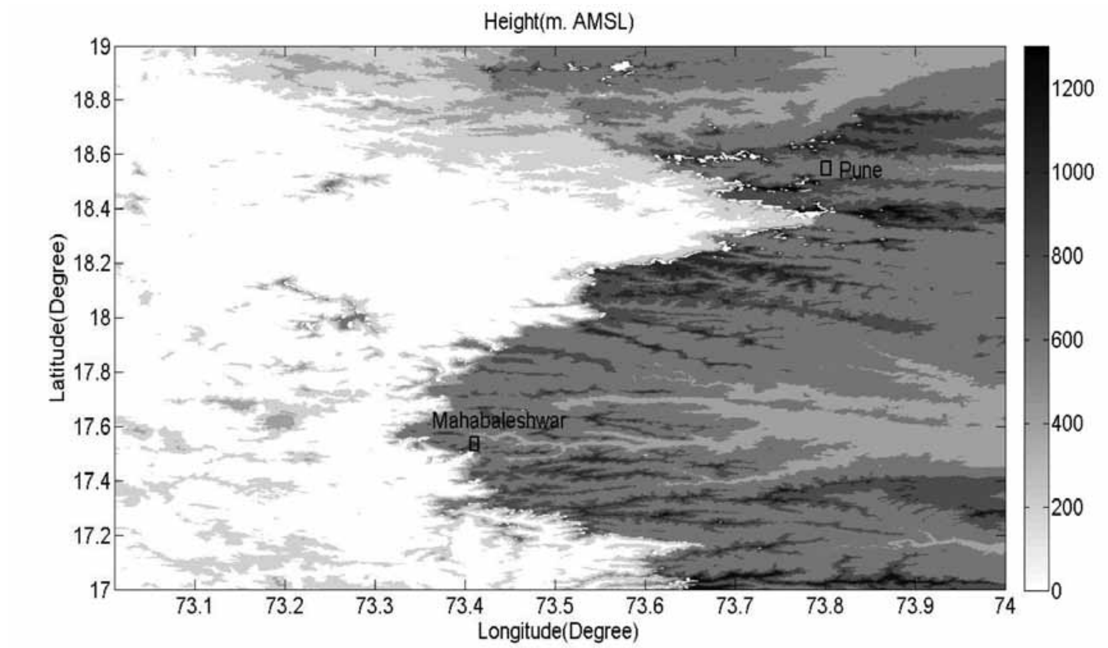

Figure 1. Topography map showing the study region (region highlighted).

the availability of microwave radiometric profilers (MWRP or MWR) provided unique opportunity to monitor the thermodynamic state continuously at a location (Ware et al., 2003; Chan, 2009; Rajeevan et al., 2010; Madhulatha et al., 2013). Considering its fine resolution, Chan (2009) has used MWRP in nowcasting of intense convective weather over Hong Kong. Importance of the MWRP derived indices was explored by Chan and Hon (2011) by describing the usage of these indices in nowcasting. Madhulatha et al., (2013) have demonstrated the use of ground-based microwave radiometer for studying severe convective activity over Southeast Indian region. They showed that there are sharp changes in the thermodynamic parameters associated with the storms. Recently, Ware et al., (2014) have also suggested that early stage of convection can be detected in temperature and humidity parameters derived from ground based MWR.

Thus, all these studies using MWR have not only reported the robustness of this observation but also its capability in studying severe convective activity. They have also shown that these data sets provide a unique, real time assessment of the pre-convective atmosphere. Considering this, in the present work thermodynamic state of atmosphere during severe convective activity has been studied using microwave radiometer measurements over two contrasting environments i.e. high and low altitude sites. The main objective of the study is to bring out the pre-monsoon convective event characteristics mainly using radiometer observations and secondly to verify whether they show any regional difference. Unfortunately, during pre-monsoon period the radiometer did not work over the mentioned stations simultaneously. Hence the results presented in the following are derived using available limited cases of severe convective activity. Though the results are convincing and satisfy the objective to maximum extent the same are yet to be established quantitatively. It is believed that this information not only is useful to see the behavior of severe convective events over high and low altitude sites but also can contribute in nowcasting of thunderstorm as well as in developing weather forecast models.

STUDY REGION

To address the above mentioned objective, we have considered pre-monsoon thunderstorm activities occurred at high and low altitude stations with contrasting environment viz., Mahabaleshwar (or Maha) and Pune respectively. Topography map of the study region generated from SRTM (Shuttle Radar Topography Mission) data (Farr et al., 2007) is shown here in Figure 1. Both the sites are located in the Western Ghats, in which Mahabaleshwar (17.56 ^{0}N, 73.4 ^{0}E) is at an altitude of 1348m above mean sea level (AMSL). The low altitude station, Pune (18.5^{0}N, 73.86^{0}E) is at an elevation of 570 m AMSL and situated at the lee side (eastern) of Western Ghats in a Valley.

SYNOPTIC CONDITION

It is well known that March-April-May (MAM) constitute hot weather period which is also called as pre-monsoon. In general, this period is known for severe convective activity such as thunderstorms, hailstorms etc, over land areas. Over Indian region thunderstorms are typically observed during pre-monsoon season (March-May) (Tyagi et al., 2013). In order to study these events in detail first synoptic conditions have to be verified and therefore the same over Pune and Mahabaleshwar are explained in the following.

Pune (Case: 24 April 2011)

During this period in 2011, a maximum temperature of ~ 38ºC was reported over Maharashtra as per India Meterological Department (IMD) Daily Weather Report (IDWR). On 23rd April 2011, the IDWR showed the trough/ wind discontinuity at 0.9 km AMSL from east Rajasthan to Lakshadweep area which persisted across west Madhya Pradesh, Marathwada, south Madhya Maharashtra, north interior Karnataka and coastal Karnataka with an embedded cyclonic circulation over east Rajasthan and neighborhood. Further on 24th the trough/wind discontinuity at 0.9 km AMSL were running from east Rajasthan to Kerala, Madhya Maharashtra and other places with the embedded cyclonic circulation over east Rajasthan and neighborhood. On 25th it is observed that the trough/wind discontinuity at 0.9 km AMSL runs from east Rajasthan to south Tamil Nadu across Madhya Maharashtra with an embedded cyclonic circulation over east Rajasthan and neighborhood. During these days, Pune's weather remained dry (very hot) with a temperature of 38ºC. According to IDWR report Pune experienced a squall at 1610 IST on 24th April from northwest to southeast direction with a wind speed of 68 Kmph, fall in temperature by 14ºCand rise in pressure by 2hPa. It was also reported that, at 0830 hrs IST on 25th April 2011 the Rain gauge in Automatic Weather Station had recorded 25.6mm of rainfall over Pune for the preceding 24hrs.

Mahabaleshwar (Case: 25 April 2013)

On 24th April 2013 the IDWR showed the cyclonic circulation persisted over north Rajasthan and neighbourhood and it was extending upto 1.5km a.s.l. The trough/wind discontinuity in the low levels from the above cyclonic circulation was running over south Tamil Nadu across west Madhya Pradesh, Vidarbha, Marathwada and interior Karnataka. On 25ththe cyclonic circulation had moved spreadingover east Rajasthan and adjoining northwest Madhya Pradesh and it was extending upto 2.1 kms AMSL. The trough/ wind discontinuity in the low levels spreading from the above cyclonic circulation to south Tamil Nadu across same above mentioned regions except west Madhya Pradesh. Further on 26th the cyclonic circulation persisted in the same region as that of 25th and it was extending upto 1.5 kms AMSL. The trough/ wind discontinuity in the lower levels then extended from the above cyclonic circulation to coastal Karnataka across interior Maharashtra and north interior Karnataka. A cyclonic circulation extending up to 0.9 km AMSL was lyingover south Tamil Nadu and adjoining Comorin area. During these days, temperature of 32ºC was noted over Mahabaleshwar. According to IDWR report, observation at 0830 hrs IST on 24th April 2013 had shown a probability (between 51-75%) of rain or thundershower over Pune and neighborhood areas for next 24hrs. Further observation at 0830 hrs IST on 26th April 2013 had shown that Rain gauge in Automatic Weather Station recorded 19.4mm of rainfall over Mahabaleshwar for the preceding 24hrs with a remark that it was a rainy day.

Hence the present study considered the thunderstorm occurred on 24th April 2011 over Pune and the one on 25th April 2013 over Mahabaleshwar to address the present objective initially.

DATA USED

Ground based Microwave Radiometric Profiler used in the present study is MP-3000A (manufactured by Radiometrics Corporation, USA), which is a 35 channel Temperature, Water vapor and liquid water profiler. The MP-3000A incorporates mainly two radio frequency (RF) subsystems in the same cabinet sharing a single antenna and antenna pointing system. Temperature profiles can be obtained by measuring the radiation intensity, or brightness temperature, at points along the side of the oxygen absorption band at 60 GHz, whereas water vapor profiles can be obtained by observing the intensity and shape of emission from pressure broadened water vapor lines. The line near 22 GHz is suitable for ground based profiling in relatively moist areas. Radiometer retrieves temperature and relative humidity profiles with a temporal resolution of 2 minutes and its spatial resolution varies with altitude as follows: up to 500m with 50m, 500m to 2km with 100m and 2 to 10km with 250m. Apart from obtaining the vertical profiles, radiometer also provides surface parameters i.e. temperature and relative humidity, integrated products like vapor and liquid and also cloud base height.

RESULTS AND DISCUSSIONS

As a first step we have analyzed thermodynamic state of atmosphere based on single events from each station i.e. a thunderstorm occurred on 25April 2013 over Mahabaleshwar and 24 April 2011 over Pune. (Synoptic conditions of these events are discussed in Section 3above). Later composite analysis of all the events occurred over both stations has been attempted as a part of comparative study. It is to be noted that in the Variation in surface parameters to Variation in stability indices the results are

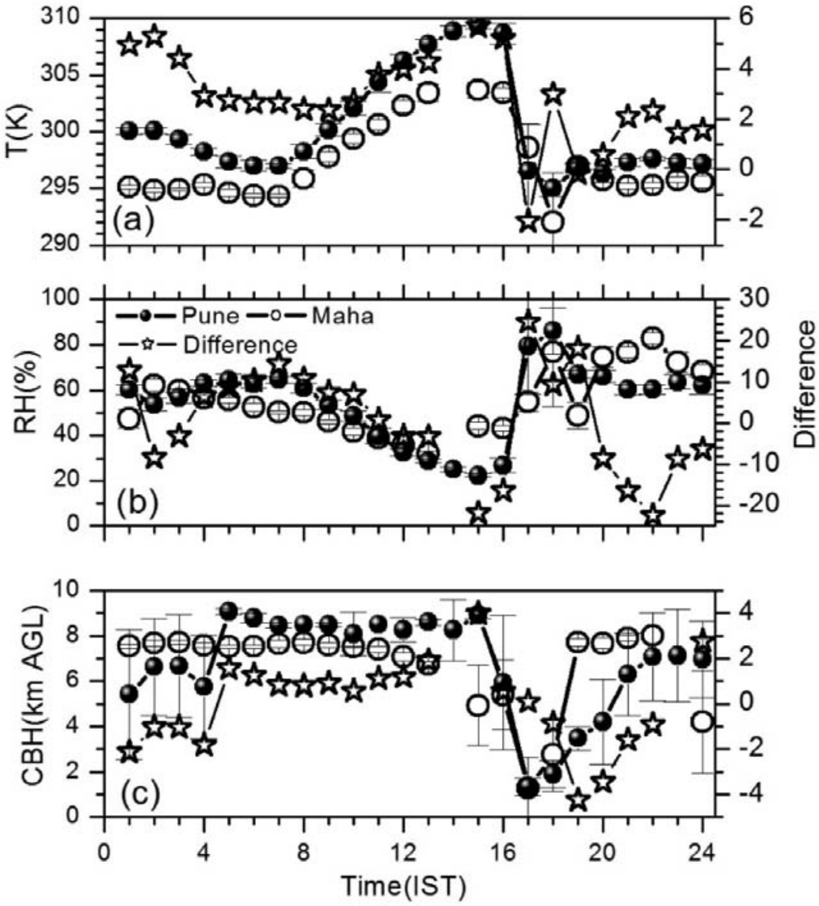

Figure 2. Diurnal variation of atmospheric parameters (temperature, RH and CBH) observed over Mahabaleshwar and Pune along with corresponding differences.

discussed based on individual events and the difference has been calculated as Pune minus Mahabaleshwar.

Variation in surface parameters

It is well known that severe convective activity such as thunderstorms occurring in pre-monsoon is very much dependent on three basic components i.e. moisture, instability and lifting mechanism. As air near the surface is lifted higher in the atmosphere and supersaturated, available water vapor condenses into small water droplets which form clouds. Therefore, studying the variation of background atmospheric field is very important. The variations in surface temperature, RH and cloud base height (CBH) over Mahabaleshwar and Pune are shown in Figure 2. There is a significant variation in all these parameters before, during and after the development of the storm. Our analysis has also brought out the obvious fact of drop in temperature and 100% increase in surface RH during the event. During day time maximum temperature observed was 305 K over Mahabaleshwar but it was ~ 310 K over Pune. During the event the temperature dropped to 297K over Mahabaleshwar and it was~295K over Pune. The difference in temperature observed between Pune and Mahabaleshwar was about 6° K before the thunderstorm, less during the thunderstorm (~-2 °K) and negligible after the storm i.e. ~1-2 °K (see Figure 2). It is seen that before the storm, the RH was between 40-60 % and after the storm it was in the range 60-80% over both the stations. Differences in RH noticed during the storm are~30 % higher over Pune compared to Mahabaleshwar. After the storm it decreased to 10-20% over Pune compared to Mahabaleshwar. Interestingly it is seen that moisture content in morning hours over Pune was 10% higher than that at Mahabaleshwar. This shows that the surface moisture availability was higher over Pune compared to Mahabaleshwar. In the pre environment ~2 hour before the storm the CBH (above ground level) at Mahabaleshwar was low which indicates abundant low-level moisture. But in morning hours it showed presence of ice clouds with CBH as high as 8km. The variation of CBH over Pune was similar to that of Mahabaleshwar showing high CBH in morning hours. CBH difference (~1-1.5 Km) was found to be negligible before and very less during the thunderstorm.

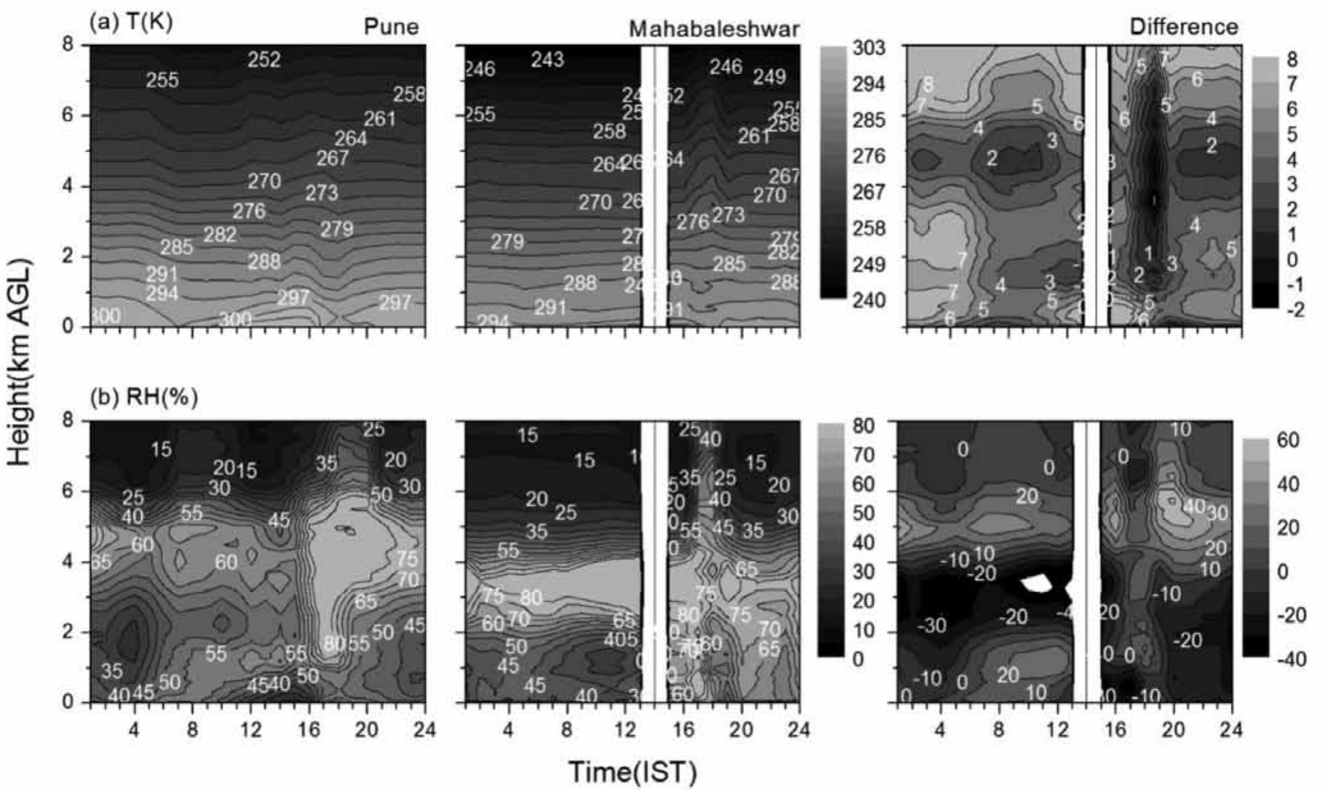

Figure 3. Time-height cross-section of (a) temperature and (b) RH observed over Mahabaleshwar and Pune along with corresponding difference.

Time-height variability of temperature and moisture

A vertical profile (Figure 3) of temperature and RH shows significant diurnal variation over Mahabaleshwar. It is observed that there was not much of variation in temperature before and after the event whereas it was varying significantly during the event over Mahabaleshwar. Over this region, there exists not only a temporal variation but also a vertical variation; i.e. below 2km the temperature variation is similar to surface variability and above that the condition reverses. In case of Pune, the diurnal variation is similar to that of surface temperature but in vertical direction there is a significant variation below 2km altitude. During the storm below 2km and above 6km the temperature over Pune was higher (~8ºK) whereas in the mid layer the condition reverses where the difference was negative (~3ºK).

From the variation of RH, over both the regions there is a significant variation in ~~of~~ moisture content. Over Mahabaleshwar, RH variability clearly showed moistening of middle layer throughout the day. During the event the RH hadincreased to 100% maximum up to 8km altitude. Over Pune, RH variability clearly shows moistening of middle layer throughout the day but the moisture content before the development of storm was less compared to Mahabaleshwar. The vertical extent of moisture over Pune was less compared to Mahabaleshwar. Interestingly over Pune, increase of moisture content below 1km altitude started increasing in early morning hours itself where it was almost 40% higher than Mahabaleshwar (Figure 3 third row). This is even seen between 4-6 km altitudes but from 2-4km the condition reverses.

The moisture availability over these locations can be clearly seen from vapor as well as equivalent potential temperature (EPT). During the thunderstorm the vapor showed maximum of 16g m-3 over both the regions extending up to ~8 (4) km altitude at Mahabaleshwar (Pune). Interestingly it was observed over Pune that, below 1km altitude the vapor content had started increasing prior to the event and also there existed vapor in lower altitude after the event too. In general, it suggests abundance of low level moisture over Pune as compared to Mahabaleshwar. From the difference (Figure 4) it may be observed that before, during and after the storm lower troposphere records higher availability of vapor at Pune (~8-10 g m-3) when compared to Mahabaleshwar. In general, during stable conditions EPT increases with altitude where as if EPT decreases with height, convection can occur. The equivalent potential temperature of air parcel at different altitudes provides a measure of instability of the air column. Over Pune it is clearly seen that in morning hours, the

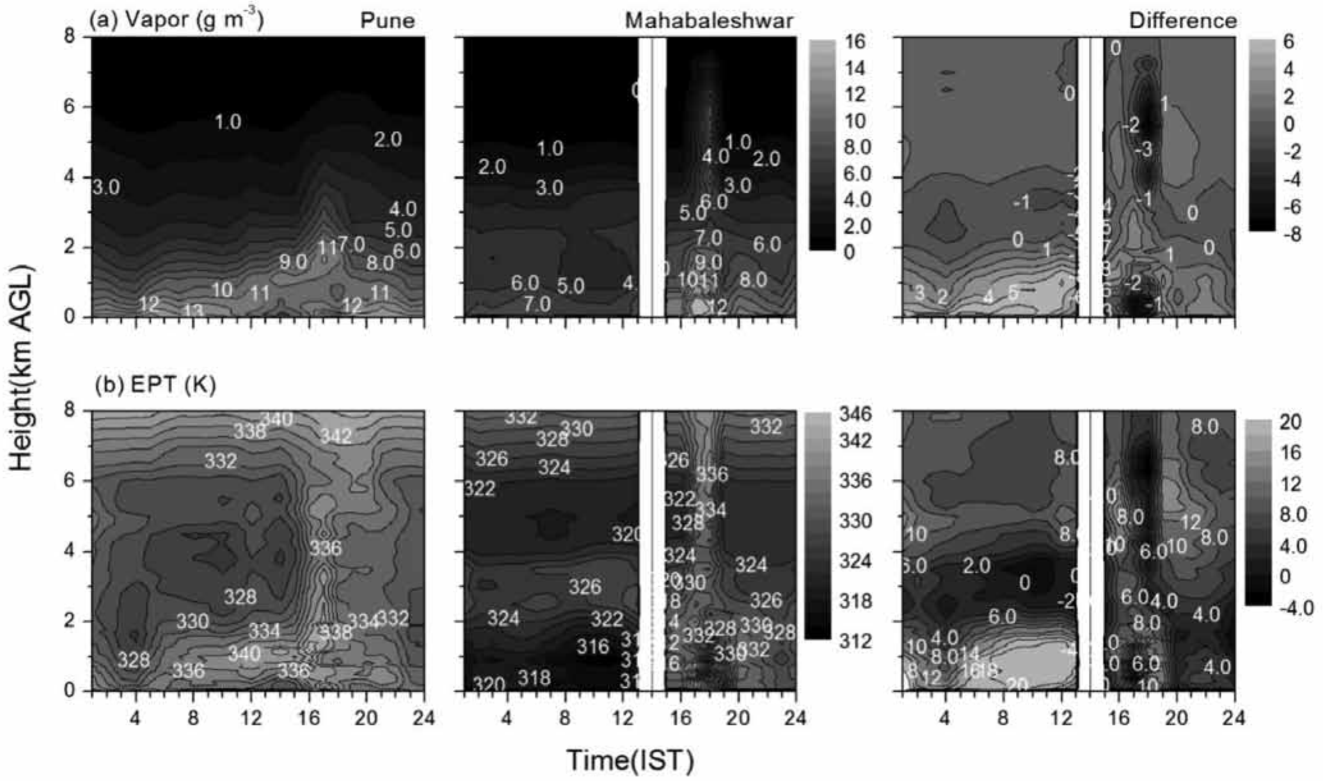

Figure 4. Time-height cross-section of (a) vapor and (b) EPT observed over Mahabaleshwar and Pune along with corresponding difference.

atmosphere was stable and few hours before the storm the instability started developing. The growth of instability is seen building up over Pune from quite early hours unlike that at Mahabaleshwar. Interestingly, the temperature difference between the surface and mid-troposphere was found to be negative (~-4oK), which clearly indicates that the atmosphere was more unstable over low altitude station during thunderstorm compared to high altitude station. This suggests that the abundant moisture content in the mid troposphere over low altitude station helps in formation of deep convective clouds over Pune.

Variation in stability indices

The significant variation in atmospheric parameters before ~2–4 hours of the storm noticed in the earlier section is to be seen as associated with thermodynamic/ stability indices. To understand the thermodynamic evolution of the boundary layer convective instability, variation of thermodynamic indices has to be examined (Feltz et al., 2003) which can also help in explaining the prerequisites necessary for genesis of the thunderstorm activity (Madhulatha et al., 2013). In Figure 5 are presented the variation of stability indices during these two days along with difference between these two stations. A short description of the indices used in the present study is furnished in Table 1.

Initially the variation of dew point temperature at 850hPa, which is an alternative parameter providing information on moisture variability, may be considered. The diurnal variation of T_{d850} and their corresponding difference has shown that, it was almost same before the event over the two stations with negligible difference. During and after the event the difference showed negative (~-10 to -2°K) suggesting that T_d at that particular level is higher at Mahabaleshwar compared to Pune indirectly showing moisturecontent at that level was higher at Mahabaleshwar.

Now taking up the variability in the other seven thermodynamic indices:Lifted Index (LI) is calculated assuming the parcel of air near the surface as lifted to 500 hPa. Expected temperature parcel at 500 hPa is then subtracted from the actual (environmental) 500 hPa temperature. This difference in LI can be positive, negative or zero and would indicate the different types of stability of the parcel of air. A positive value of LI means stable atmosphere, negative means possibility of convection and zero means neutral atmosphere. From the variation of LI it is seen that it varied between -2 to +2 during the morning time over Mahabaleshwar but it was negative over Pune. Few hours before the event, LI was more negative ~-10^{0}C over Mahabaleshwar just before the storm and after the storm; LI showed positive values which suggested the atmosphere as stable. Variation over Pune was not as clear

Table 1. List of different thermodynamic indices studied.

S. No	Thermodynamic Indices
1	**Lifted Index (LI)** Mainly considers temperature difference between an air parcel lifted adiabatically T_p and the temperature of the environmentat a given pressure in the troposphere, usually at 500hPa, and is given by T_{p500}- T_{500}
2	**Humidity Index (HI).**, given by $(T\text{-}T_d)_{850}+(T\text{-}T_d)_{700}+(T\text{-}T_d)_{500}$
3	**Total Total Index (TTI).**, given by $T_{850}+T_{d850}\text{-}2T_{500}$
4	**K-Index (KI).**, given by $(T_{850}\text{-}T_{500})+T_{d850}+(T_{700}\text{-}T_{d700})$
5	**Showalter Index (SI)** This index mainly considers the difference between the observed temperature at 500 hPa (T_{500}) and the temperature of an air parcel after it has been lifted pseudo- adiabatically to 500 hPa from 850 hPa.
6	**Convective temperature (Conv Temp)** Mainly explains the surface heating results in rising of parcel without any mechanical lift.
7	**Convective Available Potential Energy [J kg^{-1}]** CAPE is a measure of amount of energy that is available during convection (VenkatRatnam et al., 2013) and it is a potential indicator of the convective activity in the atmosphere.

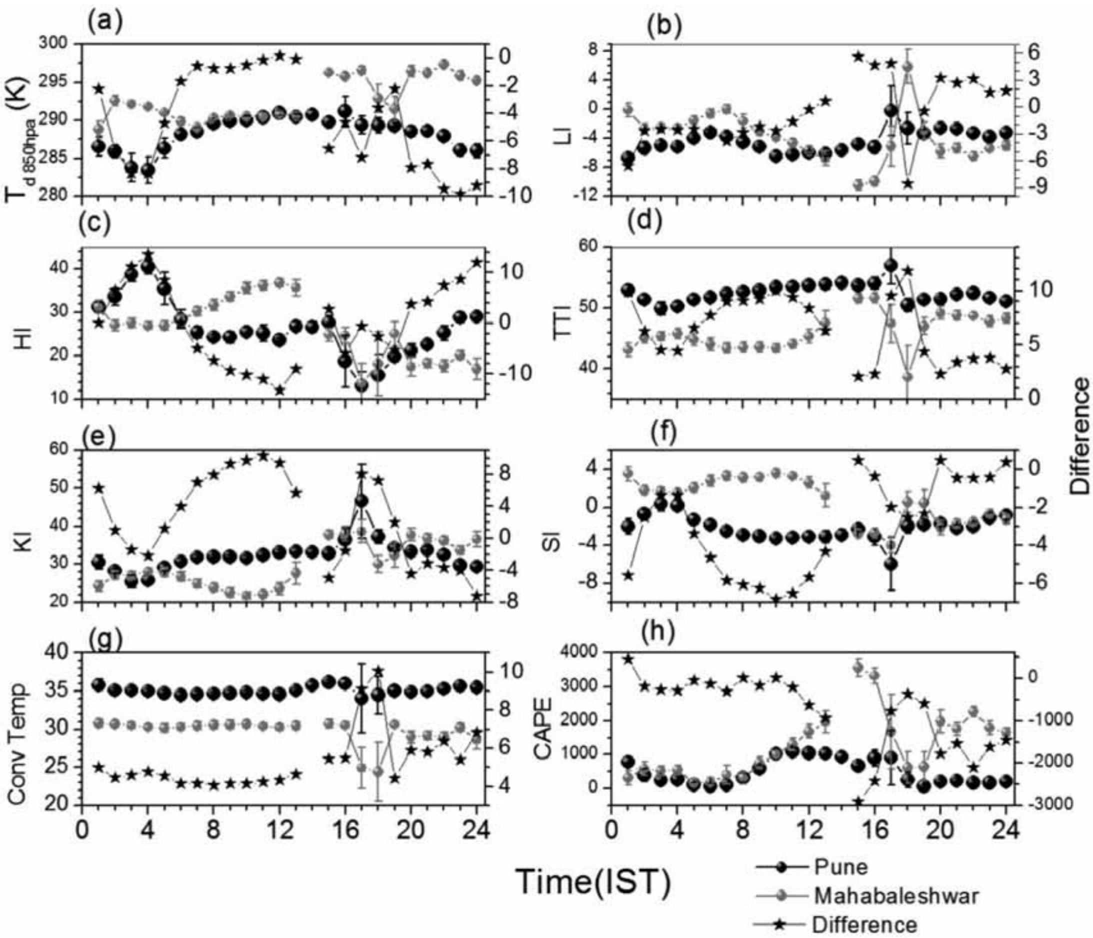

Figure 5. Diurnal variation of eight different thermodynamic indices observed over Mahabaleshwar and Pune along with corresponding differences.

as at Mahabaleshwar but LI showed that the atmosphere was unstable in morning hours itself and later it became stable. These features are even clear from the associated differences.

Stability of atmosphere as well as moisture variability for different pressure levels can be explained using HI, TTI and KI. HI variation shows significant temporal as well as regional difference. Interestingly over both the stations it was low during the event with negligible differences. Variation of HI had suggested that moisture variability at various pressure levels (or altitudes) play a significant role during these convective events. The difference was negative (~-10 ^{0}C) suggesting the moisture variability over Pune was higher compared to Mahabaleshwar. The TTI and KI showed different variations over these two regions with very high values over Pune. It is well known that the values >44 in TTI indicate the possibility of thunderstorm occurrence. It is interesting to note from Figure 5, that TTI was found to be higher (>50) at Pune as compared to Mahabaleshwar (40-50), which suggest that the thunderstorm potential is higher at Pune. This was even clear from the temporal variation of the difference which was positive throughout varying from 0to10 ^{0}C

Also KI values >40 indicate convective potential. The temporal variation of KI has shown that, over Pune it varied from 30-45 whereas over Mahabaleshwar it was from 20-35 ^{0}C. During the event it was much higher at Pune and even the temporal variation of the regional difference was almost positive. Thus the higher positive KI values at Pune indicate higher thunderstorm potentials as compared to Mahabaleshwar.

Showalter Index (SI) in the present study, was used to assess 850hPa parcel stability/instability. Negative SI indicates that the upper planetary boundary layer (PBL) is unstable with respect to the middle troposphere. The more negative the SI the more unstable the troposphere and the more buoyant the acceleration will be for rising parcels of air from the upper PBL. The values of SI from -4 to -7 indicate the large instability. Negative values (up to ~ -4) before the storm and higher value of SI (~-8) during the thunderstorm at Pune indicate the higher to extreme atmospheric instability over the station. On the other hand, Mahabaleshwar station showed positive values before the storm and less negative (~-3) during the storm which was less compared to Pune. This indicates higher atmospheric instability over Pune before and during the thunderstorm as compared to Mahabaleshwar. This is even clear from the difference, especially before the storm where it showed a negative difference.

Convective temperature mainly, explains the surface heating effect resulting from the rising of an air parcel with no mechanical lifting. Convective temperature at Pune was observed to be ~37^{o}K before, ~33^{o}K during and ~ 34-35^{o}K after the thunderstorm while it was ~30, ~22and 27-30 ^{o}K before, during and after the thunderstorm respectively at Mahabaleshwar. The difference showed positive throughout suggesting the convective temperature over Puneas higher than that at Mahabaleshwar thus confirming the potential of thunderstorm occurrence as higher over Pune compared to Mahabaeshwar. But in the case of CAPE, it showed very high (4000 J kg^{-1}) over Mahabaleshwar prior to the event (~3-4 hours before) whereas over Pune it was comparatively less (~1500 J kg^{-1}). In general, both regions showed the atmosphere was unstable before the event. The difference between Pune and Mahabaleshwar was negative suggesting CAPE was comparatively higher at Mahabaleshwar than at Pune.

Composite analysis of stability indices: a comparison

The discussion thus far presented reveals a significant variation in atmospheric parameters/thermodynamic indices before ~2–6 hours of the storm over both the regions. Now the variations in these eight indices within ±04hours of the occurrence of storm (Figure 6 and 7) may be examined first by verifying individual cases, then mean of all the cases for each region and later difference of the mean (i.e. Pune minus Maha) for the two thunder storms occurred over Pune (24th April and 26th May 2011) and the three over Mahabaleshwar (16th March, 25th April and 01st May 2013). In general, all the indices showed significant temporal as well as regional difference. Also while considering individual cases (Figure 6), most of the variables/indices did not show significant regional difference. Hence for a quantitative analysis mean of all the cases for that particular region along with the corresponding difference (Figure 7) were considered.

It is observed from the mean variation that T_d at 850 hPa was less at Pune compared to Mahabaleshwar. This is even clear from the difference of the mean that it was negative before, during and after the event suggesting that over all amount of moisture at that level was higher at Mahabaleshwar. Among the other represented thermodynamic indices, LI, HI, SI showed a negative difference whereas TTI, KI and Conv Temp showed positive difference. Positive difference in TTI and KI suggested higher low level moisture availability at Pune compared to Mahabaleshwar. Also it is well known that lower (higher) values in LI, HI, SI (TTI, KI and convective temperature) suggest higher instability and therefore higher probability of occurrence of thunderstorm. The difference associated with these variables (graythick line on Figure 7) suggests that the strength of instability is more over Pune compared to Mahabaleshwar. In case of CAPE, it showed negative before the storm suggesting instability is higher over Mahabaleshwar but the condition reverses during and after the storm.

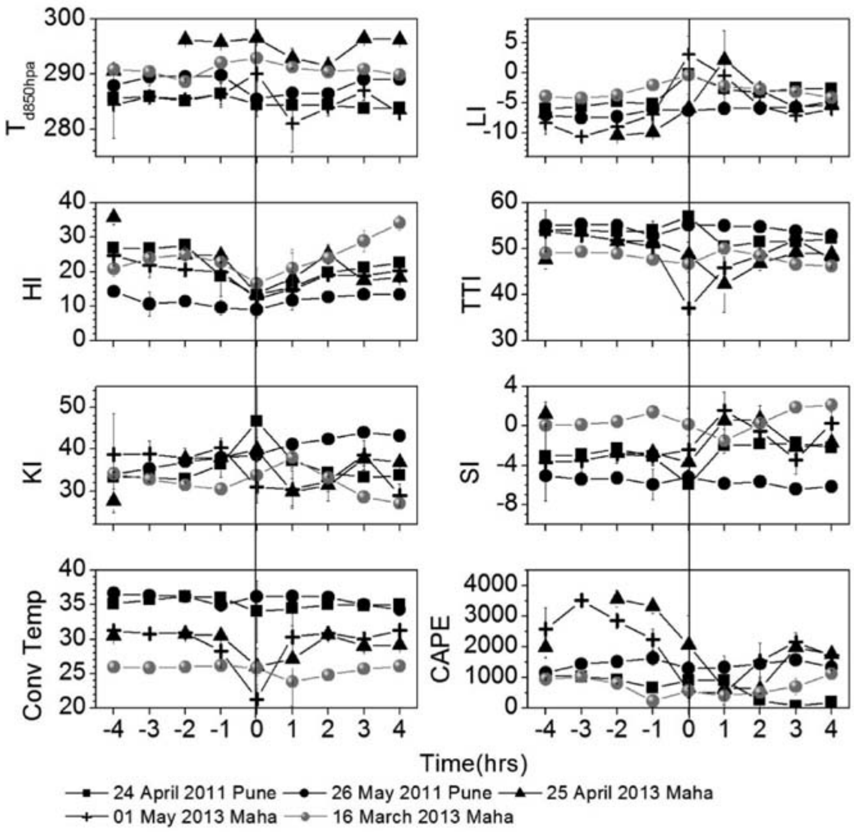

Figure 6. Variation of eight different thermodynamic indices for all individual cases, mean of all cases over Pune and Mahabaleshwar along with difference of the mean within ±04hours of the occurrence of storm.

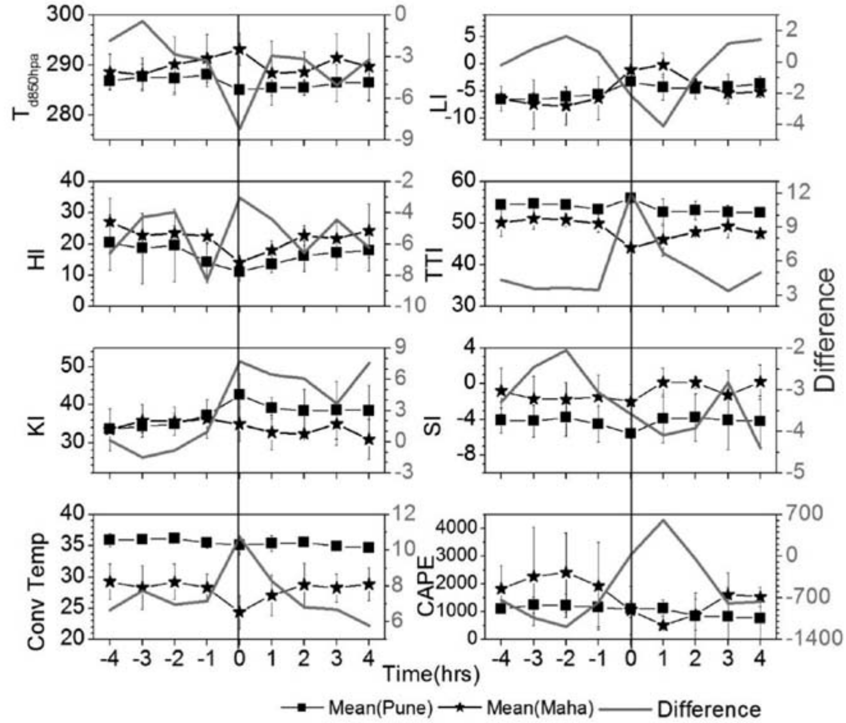

Figure 7. Same as Figure 6 but for mean of all cases over Pune and Mahabaleshwar along with difference of the mean within ±04hours of the occurrence of storm.

Entire analysis (single case and difference of the mean) shows appreciable regional difference in all the atmospheric parameters and thermodynamic indices before, during and after the storm occurrence. This variation may be possibly due to the fact that Pune is a plane surface compared to Mahabaleshwar. There is a possibility of warm air advection to be stronger in lower troposphere creating a potential instability with accumulation of low level moisture and strong radiative heating of the earth's surface leading to the initiation of deep convection. In case of Mahabaleshwar, though there is a warm air advection which is lifted by orography too there lies a possibility of cold air gets advected over that. It is documented in literature that; cold air blowing up to the height of mountain is blocked by mountains but above thatheight (of mountain) cold air flows above the warm air (Van Delden 2001).These processes over the two regions create a difference in the formation of cloud and precipitation i.e. over Pune there is a chance of formation of rain bearing clouds which precipitates heavily and in other place, convective clouds appear in the lower mountain ranges. Also the cold air flow over warm air in the mountain region may limit the clouds from growing deeper over observational site, Mahabaleshwar. All these factors can possibly cause a regional difference.

SUMMARY

The main objectives of the present work are to understand the thermodynamic state of the atmosphere before, during and after the thunderstorm events at two different geographical locations using well established microwave radiometric observations. Initially, we have demonstrated the variability in surface field and vertical profiles of atmospheric parameters over these two regions and later the variations associated with thermodynamic indices using single case. Most of the atmospheric parameters showed significant variations with positive differences between Pune and Mahabaleshwar in surface fields like temperature before thunderstorm, while surface relative humidity (RH) recorded negative differences. Interestingly the thermodynamic indices associated with the storms over both the regions showed significant variation. These differences (single case and difference of the mean) in various indices are significant and suggest a high thunderstorm potential at Pune compared to Mahabaleshwar. The present analysis suggests that there is a regional difference in thermodynamic features during the evolution of thunderstorm and shows the robustness of ground based microwave radiometry for the study of convective events. Further study with more number of cases can help establish the presently obtained results and inferences.

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Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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