A COMPREHENSIVE STUDY ON TROPICAL MESOSCALE CONVECTIVE SYSTEMS USING VHF AND UHF RADARS OVER A TROPICAL STATION

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1. Introduction

A vast majority of recent observational studies of mesoscale systems have been signifying a renewed interest in tropical mesoscale convective systems (TMCS) and their impact on general atmospheric circulation and hence the global climate. Tropical convection transports and redistributes the large-scale fields of heat, moisture, mass, radiation and momentum throughout the atmosphere. The redistribution of various quantities affects the troposphere composition and its chemistry, especially the tropospheric air quality. They also alter the flow fields and thermodynamic stratification within the atmosphere such that they affect subsequent convective activity.

Several convection campaigns have been carried out since 1996 at this Radar Facility to explore the TMCS. All these campaigns have been carried out in two regimes, one in South – West monsoon (June –September) and another in North – East monsoon (October-November). This article presents a summary on the observations of convective systems carried out during the convection campaigns over Gadanki. VHF and UHF radars observations of TMCS have been studied extensively to understand its various aspects. The Height-time sections of echo power (in terms of signal to noise ratio), turbulence intensity (in terms of spectral width) and vertical velocity of various types of convective systems are discussed. The interesting features like weak echo regions (WER), vertical velocity cores are also discussed. VHF/UHF radar observations have been used to classify the observed system into convective, transition and stratiform regions. The composite height profiles of vertical velocities in these regions are computed from VHF radar observations for the first time at this latitude. The central objective of this paper is to give an idea of various types of convective systems occurring at this latitude and to study their height-time structures.

2. Database

During the campaign periods, all the collocated facilities (VHF radar, UHF radar, Optical Rain Gauge, Disdrometer and Automatic weather Station) available at Gadanki are operated to monitor the passage of convective systems. For the present study, data collected from three instruments *viz.,* VHF radar, UHF radar and disdrometer are used. However, simultaneous VHF and UHF radar observations are available only during August 1997 – September 2001. After this period, due to some technical problems UHF radar is not operated. Disdrometer observations are available from September 1997-June 2002

3. Results and discussion

Figure 1 (a) shows typical VHF radar vertical beam power spectrum obtained during clear-air conditions. This spectrum shows vertical velocities of the order of a few tens of cm/sec. Figures 1(b) and 1(c) show the power spectra obtained during the passage of a deep convective system. The power spectrum shown in the figure 1(b) shows large vertical velocities of the order of several m/s as indicated by the large Doppler shifts. Another substantial difference in clear air and convective system power spectra is the Doppler widths, which are larger for the spectrum obtained in the convective systems as compared to the clear air spectrum. From figure 1 (c), it is very interesting to note the double traces of the echoes in the height region of 2.4 - 4.5 km. These traces correspond to the clear-air and hydrometeors. The extreme right hand side trace is the hydrometeor fall velocity spectrum due to Rayleigh scattering and the other is the clear-air velocity spectrum due to Bragg scattering. In the present study, only clear-air echoes have been used to explore the structure of the observed convective systems and enough care has been taken to avoid the hydrometeor echoes during the analysis of the present data as suggested by Narayana *Rao et al*. [1999].

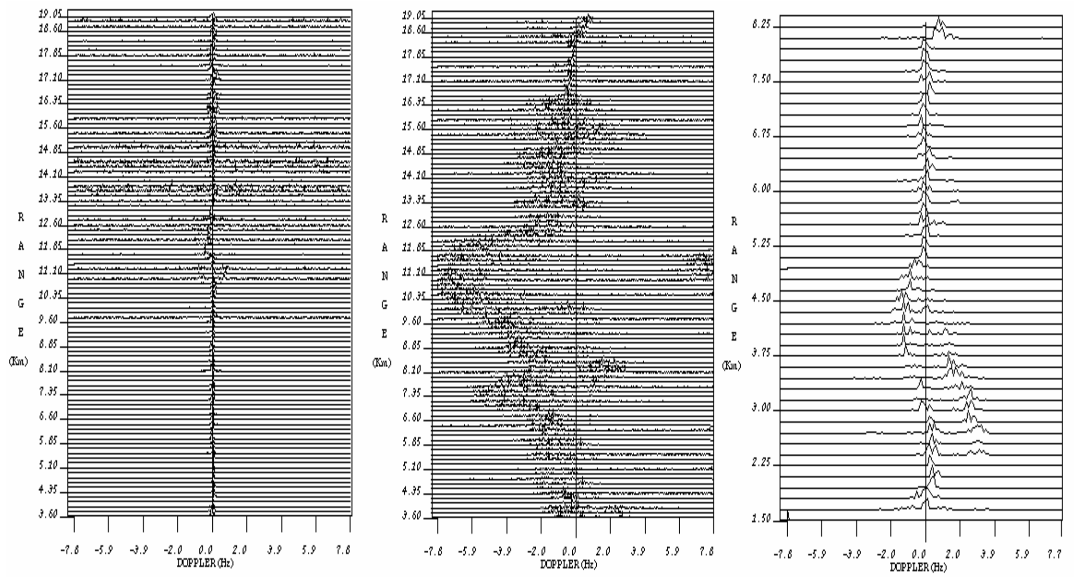

Figure 1: Typical VHF radar power spectra obtained in (a) clear-air, (b) and (c) in convection environments on 25 May 2002.

Deep convection events are classified into single cell, multi cell and super cell events. Out of these, multi cell events are very common at this latitude. Figure 2 shows the typical height-time sections of vertical velocities for the single cell, multi cell and super cell events as observed on 25 May 2002, 15 Sep 2001 and 06 June 1996 respectively. The top panel clearly shows a single vertical velocity core with a maximum velocity of ~15 m/s during 1430-1450 hrs. The vertical extent of this core is of ~ 8km. This plot reveals the structure of a typical single cell convective system occurring at this latitude. The second kind of deep convective system consists of multi cells having more than one vertical velocity core as shown in the middle panel of the figure 2. This panel readily shows three well separated vertical velocity cores with different vertical extents, which make it a multi cell event. It can be noted from this plot that the maximum vertical velocity observed on this day is ~ 10 ms^{-1}.

Most of the height-time sections of vertical velocities of the single/multi cell convective systems observed in the present dataset show one common feature. The vertical velocity cores in these systems are accompanied by downdrafts. These upper level downdrafts (well above the freezing level) adjacent to the updrafts can be attributed to sublimation and condensate loading [*Knupp,* 1987]. Other possibilities for these downdrafts include a blocking effect [*Lemon and Do*swell, 1979], but the downdrafts occur on both sides of the upward cores and other studies show complicated relationship between the upward and downward cores [*Heymsfield and schotz*, 1985]. These studies suggest that the upper-level cores may be driven, at least in part, by pressure perturbations induced by the strong updrafts. The other category of downdraft, which is

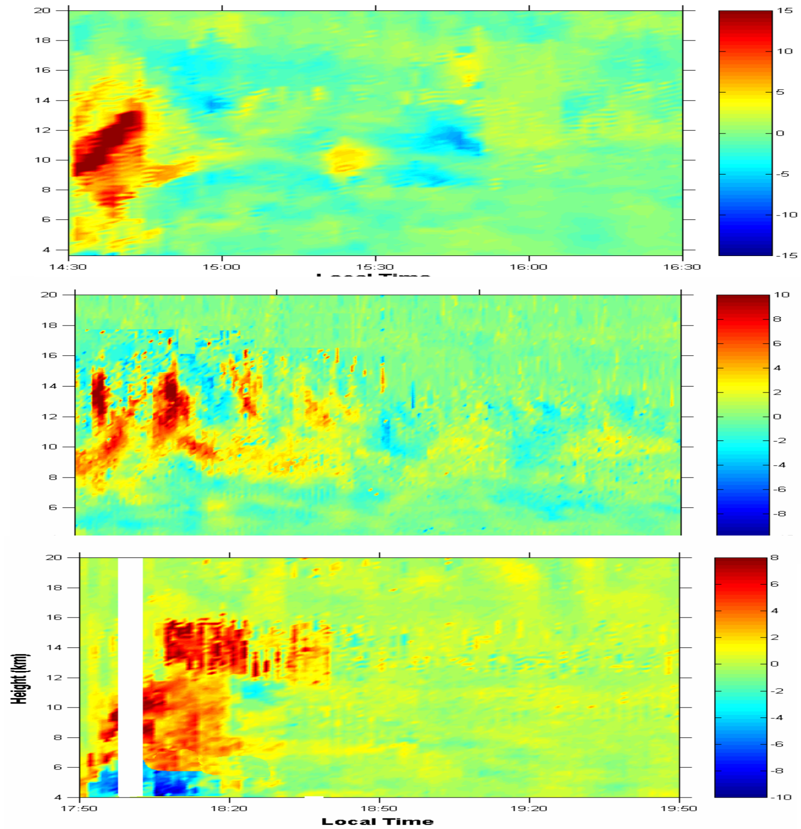

Figure 2: Height time sections of VHF radar observed vertical velocities (m/s) on (a) 25 May 2002 (b) 15 Sep2001 and (c) 06 June 1996.

occurring below the freezing level (low level downdraft), is mainly precipitation/evaporatively driven.

The last category under the deep convective systems is the super cell storms, which are very rare to be observed at this latitude. However, one such system, which closely resembles this type of storm, has been observed in the present dataset. From the bottom panel of vertical velocity plot, it is very exciting to note a single, steady vertical velocity core of ~10 Km vertical dimension with maximum vertical velocity of ~8m/s. This is one of the rare vertical velocity structures to be observed at this latitude. Under very rare circumstances, when there is both large CAPE and large vertical shear of large-scale horizontal wind, moist convection may assume the form of a single, highly organized, quasi-steady circulation, which is widely known as super cell thunderstorm. Another typical character of these storms is the rotating updrafts. Using the present observations, it would not be possible to draw any conclusions on the rotation of the updrafts.

Figure 3 shows the composite height profiles of clear air vertical velocities observed by the VHF radar in convective, transition and stratiform region of the TMCS. Each deep convective system is classified into the above mentioned regions and then the vertical velocities are averaged in the respective regions. These vertical velocity profiles in the three regions are obtained for the 14 deep convective systems and are averaged to get the composite height profiles. In the present study, the composite vertical velocity profile of convective region is showing a peak in the mid troposphere. This represents that the release of latent heat is more at those height regions. These profiles do give an idea of heating within the convective systems. These vertical velocity profiles are very useful in determining the vertical distribution of diabatic heating in the convective and stratiform regions. These composite vertical velocity height profiles of convective, transition regions and stratiform regions, which vary from one geographical location to other, have very special implications in the mesoscale modeling and in the convective system simulation studies.

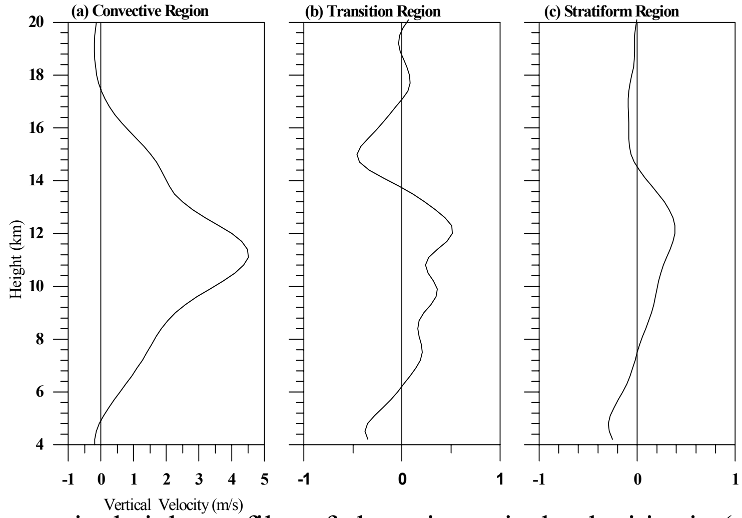

Figure 3: Composite height profiles of clear air vertical velocities in (a) Convective, (b) Transition and (c) Stratiform regions.

4. Summary

The height-time sections of several convective systems are studied to explore their reflectivity, turbulence and vertical velocity structure. The deep convective systems are classified into single, multi and super cell systems and height- time sections of the same are discussed. It is observed that most of the convective systems are multi cell systems at this latitude. Composite height profiles of vertical velocities in convective, transition and stratiform region are obtained and the same are compared with the profiles obtained at other geographical locations. Convective region composite vertical velocity profile of this location is found to have similarities with both middle latitude and other tropical continental MCS. The present stratiform region profile is consistent with other geographical location profiles and the transition region profiles have shown some dissimilarity in the mid troposphere

Acknowledgements

The National MST Radar Facility (NMRF) is operated as an autonomous facility under Department of Space with partial support from Council of Scientific and Industrial Research. The authors are grateful to the NMRF technical staff whose dedicated efforts made possible the observations reported here. UHF radar setup and being operated at NMRF under joint collaborate programme between India and Japan.

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