To characterize the vertical velocity field in tropical convection in the Indian monsoon system using Indian MST Radar. Characterization of storms include the number of cores, life time or size of the core (in terms of overpass time), convection core height, magnitude of vertical air motion, and shape of the cores, in each category for both updraft and downdraft cores.

### Database and Methodology

The MST radar data during the passage of 20 convective storms chosen from 2000-2005 is observed. Various stages of convection such as shallow, deep, and decay convection are discerned from MST radar time-intensity plots of vertical air velocity. The convective core is identified in which the vertical values of magnitude of vertical air velocity should exceed 1.1 m s⁻¹ for updraft and downdraft core respectively.

Shallow convection - the core top confines to less than 6 km. Deep and Decaying convection - the cores extend to higher levels and the entire troposphere (typically ~7 km at Gadanki). In deep convection, acceleration of the cores in the lower troposphere should exist above the freezing level, and in the subsidence or up- and down-draft couplet should be present. Figure 1(a) depicts the classical conceptual model of MCS structure: active convection (2215-2235 LT) with intense updrafts with amplitudes in excess of 6 m s⁻¹, transition region (2235-2315 LT) with partial convection and freezing, initiation of subsidence (2315-2330 LT) and falling straining after 2330 LT with gradual updrafts and downdraft coupled core. The downdraft cores (below 5 km) are observed in the lower part of the troposphere, while the updraft cores are the result of entrainment and melting of clouds above the freezing level (~4-6 km).

### Magnitude of w

Warm rain processes dominate the shallow convection, therefore, the magnitude of w is seen to be the greatest in the core region (see Figure 2c).

In deep convection (Figure 2b) descent is seen in the lower troposphere and ascent in the middle and upper troposphere. The descent in the lower troposphere could be due to rain evaporation and precipitation leading the ascent. The descent could be due to the latent heat release during glaciation & vapor deposition.

The vertical velocity in the decay phase (Figures 2d) does not show any significant updraft or downdrafts and presumably wind speeds remain unchanged. Among the three types, the distribution is much narrower in decay convection. The magnitude of the vertical motion is found to be larger in deep convection systems than in other categories.

### Composite w of cores

The distribution of vertical air motion in the shallow convection (Figure 3a) is skewed towards negative (positive) velocity side in the lower (above 2.5 km) region of the troposphere. The magnitude of the updraft peak is observed higher than that in the lower troposphere. Among the three types, the distribution is much narrower in decay convection. The depth density of u is observed to be larger in deep convection systems than in other categories.

### Size of core

The size of the cores (Figure 4a) is short lived with 85% of the cores have an overpass time of less than 10 minutes. The median overpass time for downdraft cores (7 min) is slightly less than that of updraft cores (8 min). The updraft cores show a lower peak, but the distribution shows that both up- and downdrafts nearly equally at most of the altitude. The size of the cores indicate that the vertical air motion in deep convection (up- and down-draft cores) in the decaying convection is found to be similar to shallow depth density of w.

### Shape of core

The vertical air motion in the shallow convection (Figure 5a) is skewed towards negative (positive) velocity side in the lower (above 2.5 km) region of the troposphere. The magnitude of the updraft peak is observed higher than that in the lower troposphere. Among the three types, the distribution is much narrower in decay convection. The depth density of u is observed to be larger in deep convection systems than in other categories.

### Height of core

The height of shallow convection (Figure 6a), 75% of the storm tops (both updraft and downdraft) are just below 6 km. Warm rain processes occur in the shallow convection. Therefore, the core-top is in this category remained below 6 km.

In deep convection (Figure 6b), the updraft core has a broad peak around 7-8 km, while the downdraft core has a bimodal distribution, one peak at 4-6 km and another at 7-8 km. The peak in the updraft-core distribution around 5 km may be associated with the subsidence induced by the transition region, and the other peak around 7-8 km is associated with the downdraft-core, except for the height of the broad peak. The peak in the updraft-core distribution in the decaying convection is seen at a slightly higher altitude than in deep convection.

### Magnitude of w in wet & dry spell

The distribution of magnitude of w corresponding to shallow cores (Figure 7a) in both monsoon regimes (dry and wet) shows weak to moderate velocities with about 95% of updraft cores below 2 m s⁻¹ in both the monsoon seasons.

The composite magnitude of w at 5-6 km is lower in the wet spell than in wet spell. There is a significant increase in velocity with depth. The magnitude of w in the wet spell is nearly zero up to an altitude of 5 km, while the dry spell shows weak to moderate velocities near the surface. The magnitude of w for dry spell is significantly weaker than that for wet spell.

### Composite w in wet & dry spell

The composite w profiles in Figure 8 show weak velocities up to an altitude of 5 km, and strong ascending motion above it. The composite magnitude of w in the wet spell is lower in the upper troposphere (at around 13 km) than in the wet spell. Interestingly, many of the composite profiles for dry spell core-top show peak values in the upper troposphere (at around 13 km) than in the wet spell. The composite magnitude of w in the dry spell, while it is wider in the upper troposphere and lower stratosphere for wet spell deep convection, is lower in the dry spell in the lower troposphere. The difference in magnitude of w in the dry spell is narrower than that in the wet spell.

### Identifications of Wet and Dry spells

The distribution of magnitude of w in wet and dry spells (Figure 9a) shows that the magnitude of w decreases in the wet spell from the surface to the tropopause, while it shows a peak value in the upper troposphere in the dry spell. The magnitude of w in the dry spell shows a significant decrease in the upper troposphere, while it is relatively higher in the wet spell.

### Height of core in wet & dry spell

The peak in the distribution for updraft cores in dry phase is at a slightly lower (by 1-2 km) altitude than that in the wet phase as shown in Figure 10. The occurrence percentage in both phases, generally increases with altitude and the maximum occurrence of core-top altitude is found in the upper troposphere. More than 15% of cores reached the lower troposphere (above 17 km) in the wet phase of the monsoon. The occurrence of the cores above the tropopause in dry phase is relatively less (5%).

The height distribution for updraft cores in the decaying convection is similar to that of in deep convection, with cores in the wet spell reaching greater heights compared to the dry spell. Downdraft core-top height distribution is narrower than that of updraft cores in both phases of the monsoon.

### Summary and Conclusions

- Negative cores occur in all types of convection over Gadanki. They exist at all heights underlying updraft cores. They show more coherence than the updraft cores.
- Shallow convection: Cores are short lived and mostly crest in nature, vertical velocity and core top height distribution show peak values in the lower troposphere (7 km) and is nearly equal (within 500 m) in both the monsoon seasons. The median core size, however, is higher by a factor of 1.5 in the middle and upper troposphere and also varies considerably from dry spell to wet spell. The median core size in dry spell (6-7 km) is larger than that in the wet spell (4-5 km) in the middle troposphere (6-12 km).
- Deep convection: Cores are more intense in the wet spell than in the dry spell. The median core size, however, is higher by a factor of 1.5 in the middle and upper troposphere and also varies considerably from dry spell to wet spell.
- The peak in the distribution for updraft cores in dry phase is at a slightly lower (by 1-2 km) altitude than that in the wet phase as shown in Figure 10. The occurrence percentage in both phases, generally increases with altitude and the maximum occurrence of core-top altitude is found in the upper troposphere. More than 15% of cores reached the lower troposphere (above 17 km) in the wet phase of the monsoon. The occurrence of the cores above the tropopause in dry phase is relatively less (5%).

The observed smaller elevation angles in the dry spell are due, therefore, consistent with the size of the cores in the dry spell, which is the size of the cores in the dry spell.

### Indian Space Research Organisation