Cloud and Precipitation Fields Around Darwin in the Transition Season

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Introduction

An interesting, and very relevant question, for the Atmospheric Radiation Measurement (ARM) Program is how cloud characteristics and their seasonal and diurnal variation changes across the tropics. In particular, how does he cloud field around the new SRCS site compare with nearby regions. Thus, the aim of this study is to look at the characteristics of clouds and precipitation in the area around Darwin and to compare the cloud statistics estimated from geostationary meteorological satellite (GMS) satellite data with other nearby regions. Towards this end, GMS satellite imagery and radar data from Darwin has been studied for two periods in late 2001. These correspond to the Darwin Waves Experiment (DAWEX), but the methodology will be used to put the ARM observations into a regional context and to link the detailed radar information to the corresponding satellite analyses. These periods correspond to a period of deep convection during the "build up season" in Darwin and the early part of the Monsoon season. It should be noted that at this time, island and coastal effects are at a maximum and significant variations in the cloud characteristics in the different regions are expected.

Three regions have been chosen for analysis: the area around Darwin, an area over New Guinea (NG), and an area in the Maritime Continent (MC) region (Figure 1). Deep convection is frequently seen over the NG Highlands and the MC region has well known climatological importance.

Comparison of Radar and Satellite Imagery

If we are to compare different regions, a first step is to examine a region where wqe have the most complete possible data relating the satellite imagery to the parent convection. Figure 2 shows a GMS infrared (IR) image over Darwin with overlays showing areas where there are areas of heavy rain near the surface (Z > 40 dBZ) and significant radar echoes at 14 km (Z > 5 dBZ). Note that the area of heavy rain is much smaller than the corresponding anvil in both the radar and satellite data. The 210 K isotherm corresponds closely with the 14 km altitude, so it is clear that at this time when there is still active convection that the cloud area corresponds reasonably closely to the radar boundary. However, as will be shown the anvil cloud persists longer than the radar echoes as the larger hydrometeors fall out.

In order to study the overall convective activity areas of reflectivity greater than some threshold have been calculated for each time and as a function of height (Figure 3). This is them plotted as a function of time. Three thresholds have been used, the first close to the minimum detectable reflectivity threshold at 150 km (5 dBZ), the second corresponding to rain areas (20 dBZ) and the third

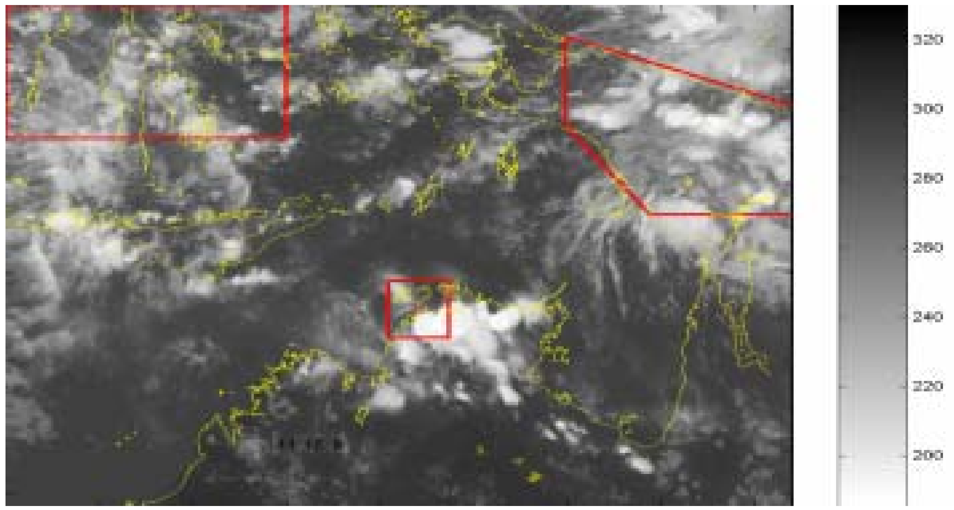

Figure 1. IR image of cloud filed in the MC. The red boxes mark the areas where the cloud statistics have been compiled. These areas correspond to a part of the MC (top left), NG (to right), and a 256 km by 256 km box centered on Darwin (middle).

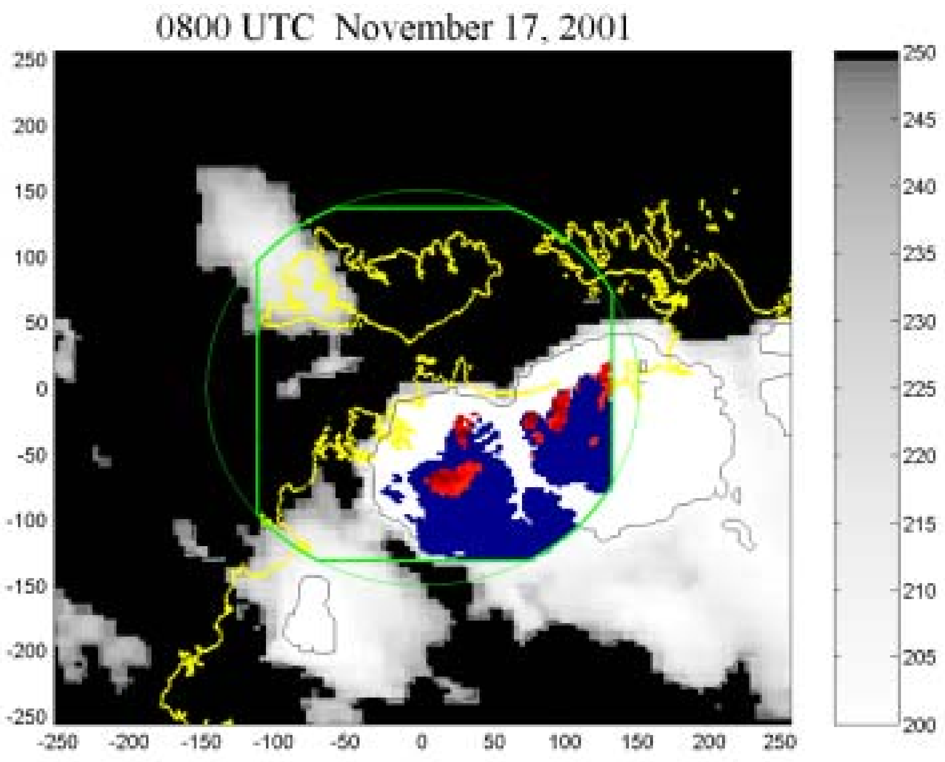

Figure 2. GMS IR satellite image with areas of radar reflectivity greater than 40 dBZ (red) at a height of 1 km and greater than 10 dBZ at 14 km (blue) overlaid. A contour is drawn at 210 K corresponding to a height near 14 km. The rounded off green square marks the radar analysis domain used in this paper. The horizontal scale is km relative to the C-Pol radar.

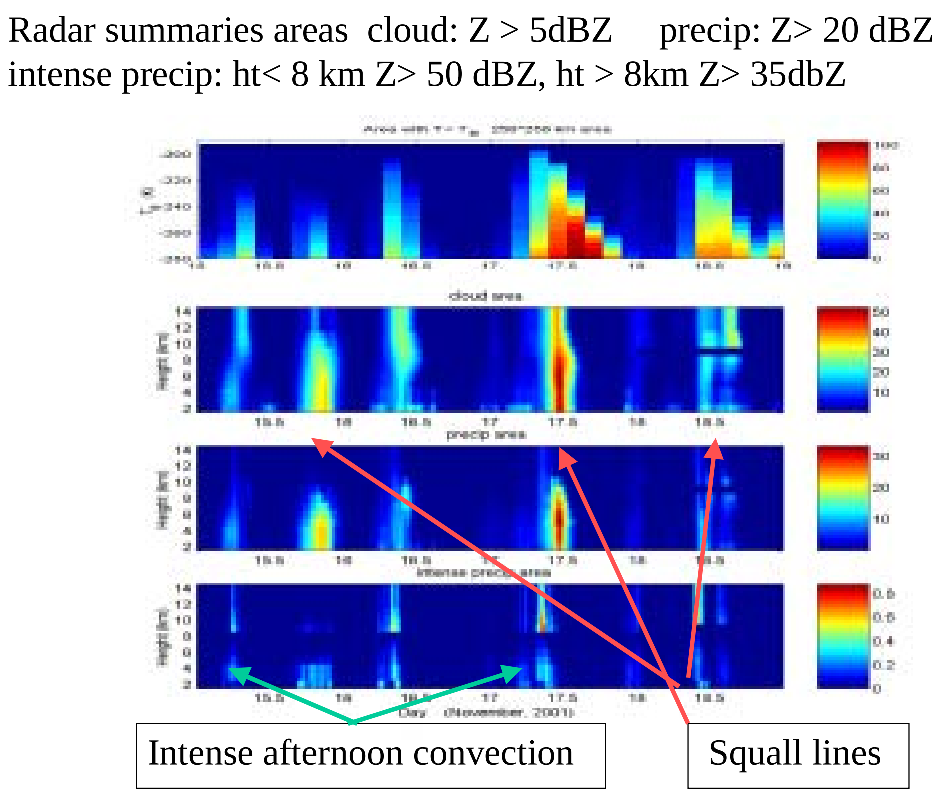

Figure 3. Time-Height/TB cross-sections of the area of the domain covered by significant radar echo at three reflectivity thresholds (lower three panels) and cloud top temperatures in the satellite data (top).

corresponding to intense precipitation (50 dBZ below 8 km and 35 dBZ above). This is a fairly crude measure as it mostly ignores vertical gradients of reflectivity and the different refractive index of ice and water etc but serves as a useful guide for the interpretation of the satellite data. Figure 3 shows such a series for 5 days in November 2001. In the radar domain, most of the intense rain was associated with intense coastal thunderstorms such as the well-known “Hectors” over the Tiwi Islands. However, the rain areas associated with squall lines that came through in the evening had much more extensive areas of rain and even more extensive cloud areas. The maximum in cloud area tended to occur later than the rain area maxima. Note that up to 50% of the domain was covered by anvil cloud in some cases.

A similar analysis has been done for the GMS satellite IR brightness temperatures (Figure 4). The interpretation of the brightness temperatures is of course less straightforward as very cold (high) cloud tops will still have relatively warm temperatures if they are optically thin. However, a consistent picture is painted that the peak in cold cloud area occurs somewhat later than in the radar data (but the satellite data is only 3-hrly), and is smeared out in time as the cirrus shields persist after the radar signals have disappeared. There are some periods where the whole domain is cloud covered.

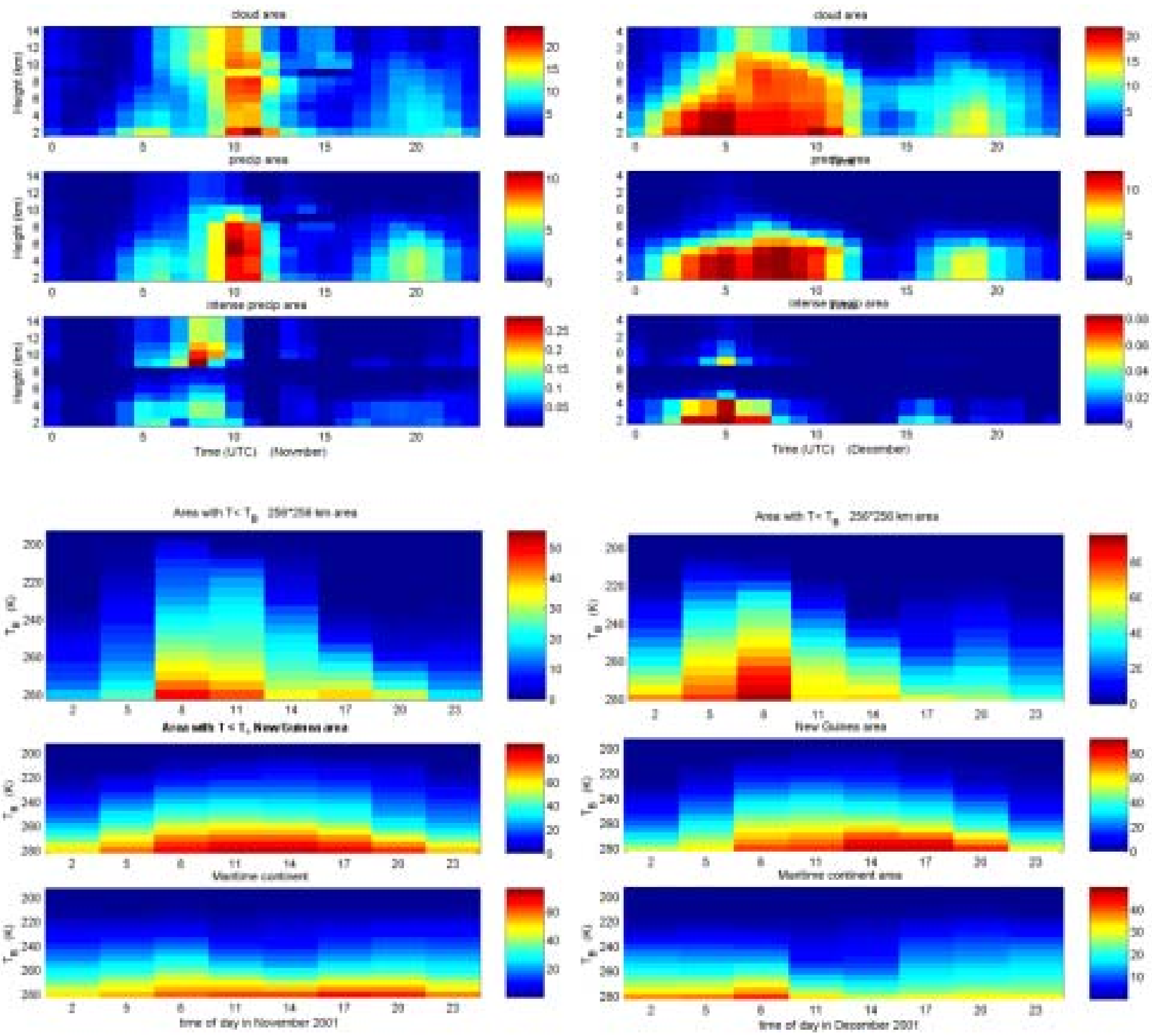

Figure 4. Mean diurnal composites of the radar (top three) and satellite (lower three for the Darwin area, NG, and MC as in Figure 1) data for periods in November (left) and December (right) 2001.

Diurnal Cycle

The diurnal cycle in Darwin is very different during the build up season compared to the monsoon. This is examined next using both radar and satellite data. Then we will examine the satellite signals at some other locations to begin addressing the question of where the Darwin ARCS observations fit with respect to cloud characteristics in the maritime continent area. Note that this analysis is only using two short periods of data and the resulting diurnal signal may be skewed by single large events. For example, the December data had several events more or less uniformly spread out through the day over the first 2 days of the analysis cycle, but the largest of these coincided with the local afternoon. However, the convection was not tied to the land at all in these cases. However, this methodology will be applied to much longer datasets.

The time series of radar areas and brightness temperature areas have been composited to show the mean diurnal cycle (Figure 4). The radar data shows a relatively strong peak in late afternoon in both the monsoon (December 2001) and build up (November 2001) periods, but the monsoon peak is noticeably wider. Examination of individual radar images also shows the initiation of cells occurs fairly evenly through the domain whereas the most of the activity during November was over land. The maximum vertical extent of the cloud and precipitation is also clearly greater during the build up, as expected. There is also an early morning peak evident in both samples. In the build up this is clearly associated with land breeze effects that produce coastal showers through the morning. Again the temporal delay of the maximum cloud areas compared with the intense precipitation is evident throughout.

The mean diurnal signatures near Darwin show similar features to the radar: cooler (deeper) tops in November and a broader cycle in the monsoon. The morning peak is only just seen in the monsoon and is not clear at all in the November data. Note that these coastal showers tend to be small and relatively shallow.

The other two areas that are examined is a region within the maritime continent and over NG. The diurnal signatures in both regions are smeared somewhat by their larger spatial extent. Cloud cover over NG also shows a distinct diurnal cycle, but with a maximum later in the day than around Darwin, about 14 Universal Time Coordinates (UTC). Again in the monsoon there is a tendency for the maximum cover to occur later in the day (early morning local time). The maritime continent region that was sampled has much weaker diurnal signature, but the composite is biased by a single large event.

Summary

This is only a small sample, but as expected the diurnal cycle is very clear in the Darwin data during the build up season and weakens slightly at the onset of the monsoon. The regions of large reflectivity do not reach as high in the monsoonal convection, a feature also indicated in the satellite statistics. Some care needs to be taken in interpreting these results as it is only for a limited period, focusing on a particular field campaign. However, this study is going to be substantially extended so that more global conclusions regarding the representativeness of Darwin versus other areas can be established.

Further steps in this analysis will include examination of the probability distribution functions of the cloud fields in the various regions. Preliminary work (not shown) has shown that the distributions are close to lognormal as expected, but the seasonal and regional differences have yet to be studied.

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