P 4.13 A COMPARISON OF THE MICROPHYSICAL CHARACTERISTICS OF CLOUDS FROM DIFFERENT TROPICAL REGIONS

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1. INTRODUCTION

Although tropical clouds play an important role in several areas of the climate, relatively few observations and measurements of their microstructure are available. Those that are available are from limited geographical regions, altitudes, and cloud types. Little is know about how the microphysical characteristics (e.g. hydrometeor sizes, types and concentrations) from different tropical regions compare or how they are related to the dynamical features of the cloud systems. In this paper we compare microphysical features from clouds in the topical eastern Pacific, with those from clouds in the tropical central Pacific and a tropical continental site in the southern Amazon region of Brazil.

In situ airborne measurements in the southern Amazon and central Pacific were collected in 1999 from the University of North Dakota Citation research aircraft during the Tropical Rainfall Measuring Mission (TRMM) field campaigns in Rondonia, Brazil (TRMM-LBA), and near Kwajalein, Republic of the Marshall Islands (TRMM-Kwajex). In situ airborne measurements in the eastern Pacific were collected in 2001 from the NSF/NCAR C-130 aircraft during the Eastern Pacific Investigation of Climate Processes in the Coupled Ocean-Atmosphere System (EPIC). Both research aircraft carried gust-probe/inertial reference systems for measuring wind and turbulence, a set of Particle Measuring Systems instruments for measuring hydrometeors, and instrumentation for measuring liquid water and state parameters. The Citation also carried a Cloud Particle Imager (SPEC, Inc.), which provides high-resolution (2.3-micron) hydrometeor imagery. Information on the Citation instruments and the results from the TRMM field Campaigns have been recently reported in Stith et al. (2002). Information on the C-130 instrumentation is available at http://raf.atd.ucar.edu/Bulletins/bulletin3.html.

Previous results from the LBA and Kwajex programs are reported in Stith et al., (2002). In that study higher concentrations of small precipitation particles were correlated with updraft velocity for updrafts greater than about 5 m s^{-1}. Rapid glaciation was observed at temperatures colder than –7 °C and most regions with significant supercooled liquid water were found at temperatures warmer than –12 °C. However, traces of supercooled liquid water remained at temperatures as cold as –17.5 °C, suggesting that water saturation is maintained even after most precipitation particles have frozen.

2. Results

2.1 Updraft Regions warmer than freezing

The results from cloud passes at or slightly warmer than the freezing level are presented in Figure 1. All of the clouds had precipitation particles detected by the 2DC instrument, indicating the warm rain process had produced precipitation-sized particles before the cloud updrafts had reached the freezing level. Rather similar cloud droplet

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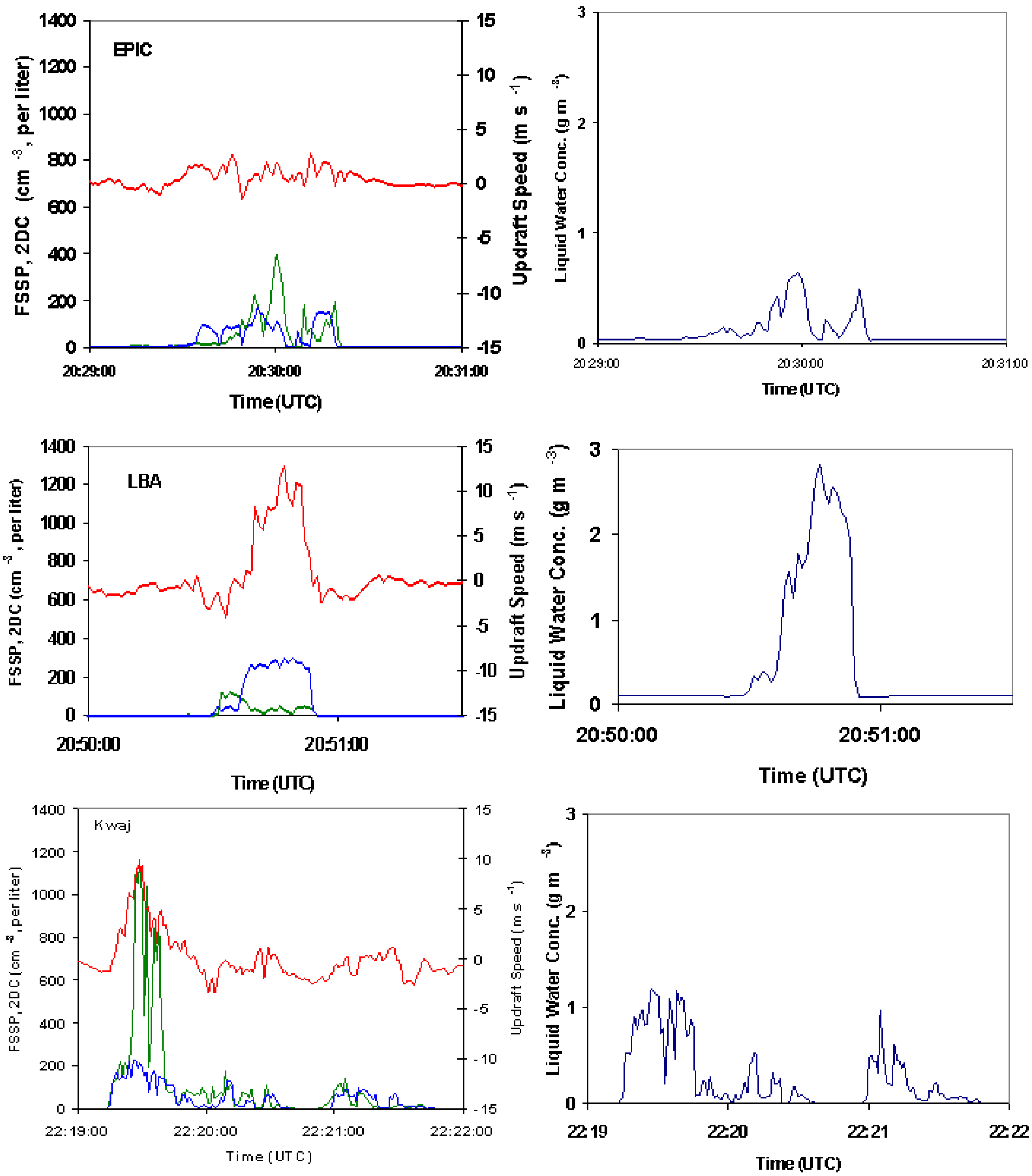

Figure 1. The results from sampling at altitudes just warmer than the freezing level in EPIC, LBA and Kwajalein. The concentrations of droplets (from the FSSP, in blue), precipitation particles (from the 2DC, in green), updraft speed (red), and liquid water concentrations (from the King instrument for EPIC and LBA and the FSSP for Kwajalein). Temperatures at the sampling altitude were approximately +3 C forthe EPIC and LBA pass and +5 C for the Kwajalein pass.

concentrations were observed from the FSSP, with maximum values of about 150, 200, and 300 cm^{-3} for the cases from EPIC (5 September 2001), Kwajalein (11 September 1999), and LBA (26 January 1999), respectively. The case from LBA was from a tropical squall line system, with a large updraft. The Kwajex case had an updraft of smaller horizontal dimension, but of similar magnitude. In each of the tropical clouds sampled, precipitation was observed in the updraft regions, although the LBA case had a greater amount of liquid water, suggesting that not as much had been lost by accretion as had occurred in the oceanic tropical cases.

2.2 Updraft regions at – 6 °C and colder

The region near – 6 °C is a transition region where both liquid phase and ice phase precipitation is found in tropical updraft regions (e.g. Stith et al., 2002). This is illustrated in Fig. 2, which compares measurements made in two updrafts of similar horizontal size and magnitude from the Kwajex (22 August 1999) and EPIC (5 September 2001) campaigns. Temperatures just outside the cloud were approximately – 6 ° C for each cloud. Peak drop concentration from the FSSP in the strongest part of the updraft during the EPIC pass in Fig. 2 was about 400 cm^{-3} (not shown). Several features are evident:

- Both updrafts contained similar concentrations of supercooled liquid water. (FSSP data were not available for the Kwajex case on this day).

- Substantial concentrations of precipitation-sized particles were evident in both cases, as measured by the 2DC instrument. As with the other tropical cases 2DC concentrations were correlated with updraft strength, reflecting an abundance of smaller precipitation particles in the stronger updraft regions. The high concentrations of small particles were evident in the 2DC imagery as zero element images and images with one or only a few pixels shadowed. The slightly higher concentrations in the EPIC case are likely due to the smaller pixel resolution for the instrument used in that case, compared to that used in Kwajex (25 vs 35 microns, respectively).

- Large graupel particles were found in weaker updraft regions in both clouds, especially in weak updrafts in the interior of the clouds.

- Columnar ice crystals, the preferred growth habit for this temperature, were found only on the edges of the clouds in both cases. Some of the reasons for this observation are discussed below.

- An isolated cumulus updraft (peak value 5 m s^{-1}) in LBA at – 7 °C, contained peak values of about 800 $liter^{-1}$ of particles measured by the 2DC, 1.2 g m^{-3} of liquid water, and 140 cm^{-3} from the FSSP (Stith et al., 2002, Fig. 6). 2DC and CPI imagery were consistent with pure water particles. These 2DC and liquid water concentrations are comparable with those in Fig. 2 while the FSSP concentrations were significantly less, perhaps due to the weaker updraft.

The 2DC imagery in Fig. 2 and in Stith et al., suggests that a variety of precipitation types are present at the – 6 °C level. Graupel, supercooled rain and drizzle drops, and columnar ice particles are observed. However, the form of smaller precipitation particles, such as those found in the updrafts (Fig. 2), are difficult to determine from the 2DC imagery due to the its limited resolution. Figure 3 presents results from the CPI for the Kwajex case presented in Fig. 2, utilizing SPEC software to classify the images as spherical or non-spherical. At – 6 °C, only about 20 to 10 percent of the images in the updraft are non-spherical (Fig. 3, bottom), suggesting that the small precipitation particles are dominated either by droplets or by droplets that had only recently frozen and were still mostly spherical. At – 11 °C nearly 40% of the particles in the main updraft are non-spherical, similar to regions outside the updraft (Fig. 3, top). Significant liquid water was found at – 6 °C (Fig. 2), but only a trace of supercooled liquid water was found at – 11 °C (not shown). This suggests that the bulk of the ice formation had likely occurred between – 6 and –11 °C. Frozen droplets were a common particle type at even colder temperatures during LBA and Kwajex. Evidently, frozen drops are able to retain their shape for substantial periods of time and must, therefore, exist near ice saturation for these periods.

We suspect that the reason why columnar crystals were found only in weak updraft regions on the edges of the clouds is due to the time available for ice formation and growth. The majority of the particles in the stronger updrafts had not frozen (or had not had time to grow significantly) before being lifted above the temperature regions for columnar growth. Weaker updrafts may have provided time for ice formation and columnar growth.

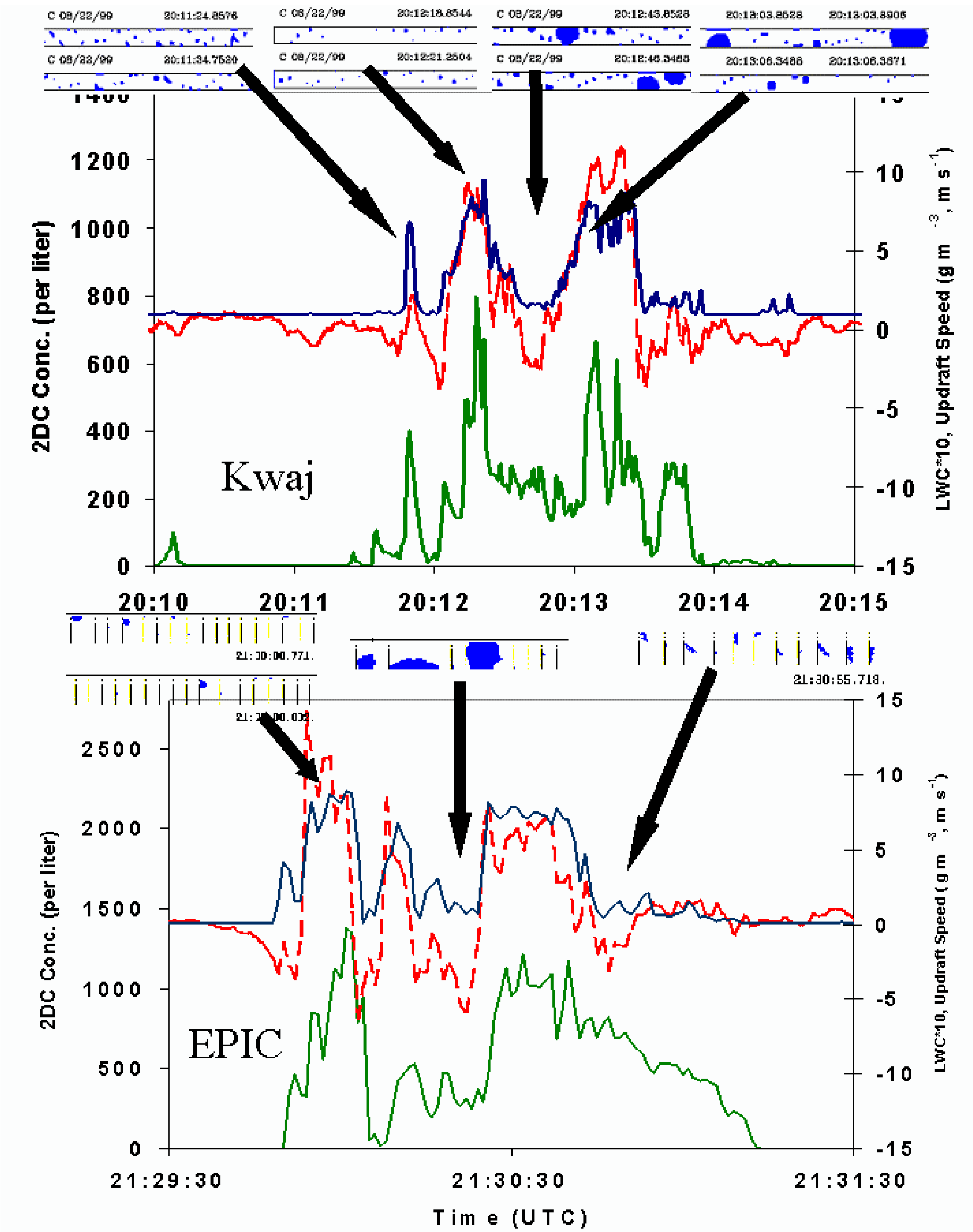

Figure 2. The concentrations of particles sampled by the 2DC (green), updraft speed (red), and liquid water concentration (LWC, blue) during passes at -6 ° C during the Kwajex and EPIC programs. Examples of 2DC particles are given. The widths of the 2DC image boundaries are 1 mm and 0.8 mm for Kwajex and Epic, respectively.

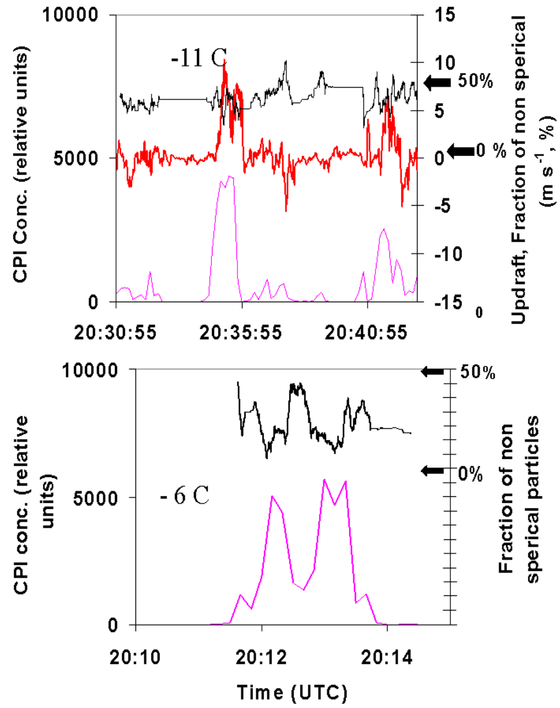

Figure 3. CPI relative concentrations and the fraction of non spherical particles (black line) for the -6 and -11 regions of a Kwajalein cloud on 22 August. The lower figure corresponds to the data in Fig. 2. The updraft speed has been added to the - 11 C pass (red line).

Future studies will examine more of these cases to explore the variability and consistency of these microphysical features and processes in tropical clouds.

3. ACKNOWLEDGEMENTS

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