RADAR ANALYSIS OF LONG-LIVED TRADE WIND CUMULUS CLOUDS FROM THE RAIN IN CUMULUS OVER THE OCEAN EXPERIMENT (RICO)

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1. INTRODUCTION

The Rain in Cumulus over the Ocean Experiment (RICO) was recently conducted in the Caribbean (11/24/2004 - 01/24/2005) with the goal to characterize and understand the properties of shallow trade wind cumulus clouds on all scales and to determine the importance of precipitation. One of our early findings during RICO was that trade wind cumulus clouds were often unexpectedly long-lived. In a first attempt to understand our observations we track radar echoes using PPI scans from the National Center for Atmospheric Research S-Pol radar. The purpose of this paper is to investigate the radar reflectivity evolution of trade wind cumulus clouds. Multi-parameter radar measurements will be used in combination with aircraft data to determine whether any significant differences are detectable in the time to onset of precipitation that can be associated with the cloud condensation nuclei (CCN) and/or giant and ultragiant aerosol concentration of the boundary layer.

2. THE RICO FIELD PROJECT

During RICO, trade wind cumuli were studied using dual-polarization and dual wavelength radar, three instrumented aircraft, atmospheric soundings, and time-lapse videos. Radar data were collected on 62 consecutive days from 24 November 2004 through 24 January 2005. Aircraft operation began on 7 December 2004 and continued through 24 January 2005 with a break from 21 December 2004 to 3 January 2005.

The data used in this paper were acquired with the National Center for Atmospheric Research (NCAR) S-Pol radar and C-130 aircraft. The radar, which was located on the island of Barbuda, operated at 9 mm (Ka-band) and 10 cm (S-band) wavelengths, with the antennas collocated on the same pedestal and adjusted to the same pointing angle. During RICO, the radar scan strategy was almost exclusively using Plan Position Indicator (PPI) scans over a 180° sector. With a predominantly easterly wind, the sector was frequently chosen to be north of the radar with azimuth angles ranging from 270° to 90°. Aligning the sector according to the current wind direction ensured that the clouds could be tracked by radar for the longest time. The PPI scans were typically spaced about 0.5° to 1.2° apart. Radar volumes were repeated approximately every 3 minutes. Range gates were every 150 m. The beam width in both the azimuthal and elevation directions was approximately 1° for both S- and Ka-band.

The NCAR C-130 performed 17 research flights, each flight starting and ending with a 30 min circle at about 4.5 km altitude with 6 dropsondes launched per circle. At the beginning of each flight, the high altitude circle was followed by two circles of the same dimensions, one 100 m above the ocean and one just below cloud base level. At the end of each flight, these two lower level circles preceded the high altitude dropsonde curtain circle in the reverse order.

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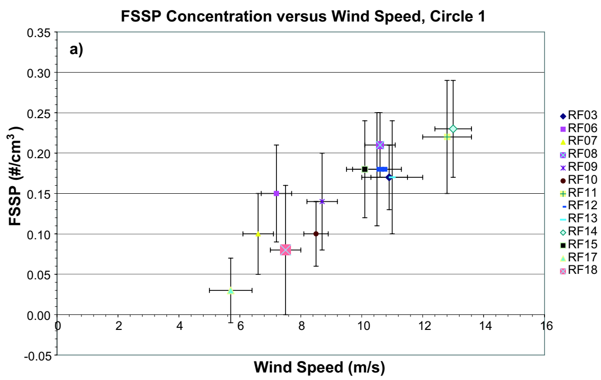
3. DATA ANALYSIS AND RESULTS

We calculated average wind speeds, and average particle concentrations measured in clear air with the forward scattering spectrometer probe (FSSP), and their standard deviations for each circle at 100 m altitude. Figure 1a shows these data for each circle at the beginning of each flight. Figure 1b shows the least square linear fit for all average concentrations as a function of the wind speed (100 m altitude circles at the beginning and end of each research flight). Care has been taken in eliminating all rain-shafts and cold pools when calculating average values.

Figures 1a and b show that the FSSP particle concentration in clear air increases with increasing wind speed. We found a linear relationship for a wind speed interval from 6.0 m s^{-1} to 13.5 m s^{-1}. This is consistent with Woodcock's (1953) findings half a century ago that giant and ultragiant aerosol concentrations are a function of the low-level wind speed because of the action of wind in creating waves and sea spray. To



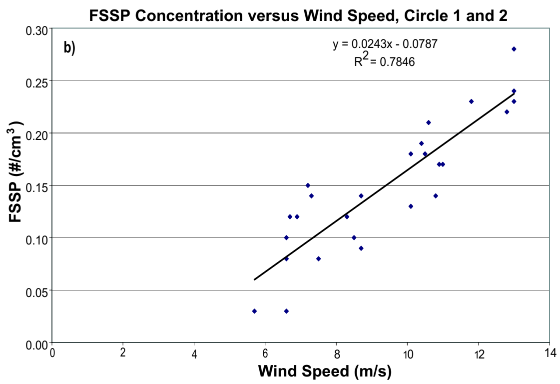


Figure 1: *a) Average FSSP particle concentrations in clear air and their standard deviation for the 100 m altitude circle at the beginning of each research flight as a function of the average wind speed. b) Average FSSP particle concentrations of both 100 m circles (at the beginning and at the end) of each research flight as a function of the average wind speed and the least square linear fit.*

investigate whether or not the radar reflectivity evolution of trade wind cumulus clouds is different on days with different wind speeds and thus different giant and ultragiant aerosol concentrations, we chose three days with different low-level wind speeds to examine: 17 December 2005 with 7 m s^{-1}, 11 January 2005 with 10.5 m s^{-1}, and 14 January 2005 with 13 m s^{-1}.

4. OUTLOOK

We are currently tracking radar echoes of long-lived trade wind cumulus clouds during the above mentioned three days with different low level wind speeds. Care will be taken to insure that the environmental conditions (shear, stability, and moisture) are reasonably comparable on these three days. Figure 2 shows an example of series of 3.5° elevation PPI scans, which represents a temporal evolution of a RICO trade wind cumulus cloud in S-band radar reflectivity and differential reflecyivity. The cloud could be tracked over 1.5 hours and reached its maximum reflectivity of 36 dBZ at 15:06:34 UTC. We will construct time-height cross-sections for each cloud that was tracked. This time-height approach was successfully used by Knight and Miller (1998) to study precipitation development in convective clouds.

Since RICO recently ended, the results of this analysis are ongoing. We will present our latest findings at the conference. We further attempt to study how these long-lived trade wind cumulus clouds differ in their microphysical evolution from tropical cumulus clouds observed during past field campaigns in Florida (Göke *et al.* 2005)

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14 January 2005 S-band Radar

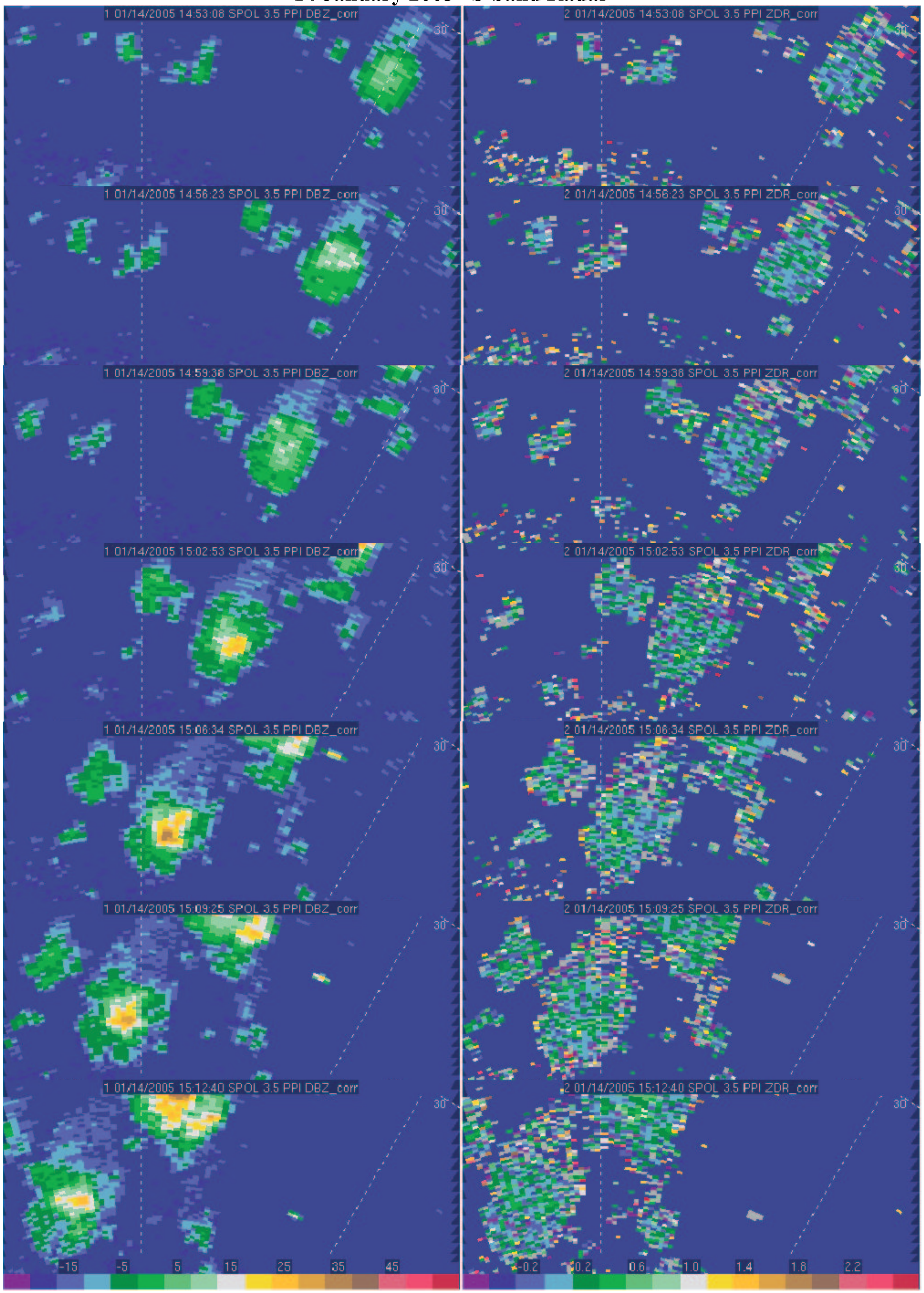

Figure 2: *Series of 3.5° elevation PPI scans representing the time evolution in S-band radar reflectivity and differential reflectivity of a trade wind cumulus cloud on 14 January 2005.*