JP3J.2 OCEANIC SHALLOW CUMULI OBSERVATIONS FROM SHIP-BORNE X- AND W-BAND RADARS DURING RICO 2005

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1. INTRODUCTION

Despite ever increasing computational power and model sophistication, the poor representation of cloud processes continues to be one of the major sources of uncertainty in numerical simulations of climate and weather (e.g., Del Genio et al., 1996). The Rain in Cumulus over the Ocean (RICO) field experiment, based at Antigua and Barbuda, focused on various aspects of shallow cumuli formation generation by the trade winds. One of the goals for the field campaign was to assess the impact of precipitation from trade wind cumulus on radiation budgets and moisture and heat fluxes within the tropical atmosphere. The assessment of these impacts depends on our understanding of precipitation processes.

During RICO, 5 radars were operated from different locations for the study of the evolution of shallow cumuli. The CSU-CHILL S-POL-Ka Doppler radar system (S-Band and K-Band), operated by NCAR, was located in Barbuda. The scanning radar provided continuous observations of oceanic shallow cumulus over a 250-km radius around the island. The radar monitored the various stages of development of trade wind cumuli, tracked their motion and mesoscale organization. During the January period, the S-POL-Ka collected approximately 83 complete scan cycles per day, providing a statistical description of the cloud ensembles.

Although S-POL-Ka and satellites provide useful information on the horizontal distributions of cloud imagery, they do not give detailed information of vertical structure (Warner et al., 1998). Vertically pointing radars have been used extensively to study warm clouds. They are well suited to take measurements of boundary layer clouds (Kollias et al, 2001), and to get very weak reflections related to cumulus clouds (Fabry et al., 1992). To address the need for high resolution measurements of the vertical structure of shallow cumuli, the University of Miami Radar Group operated two radars aboard the Research Vessel *Seward Johnson* during RICO. The X-Band collected vertical profiles every 1.1 seconds (f=0.9 Hz) and the W-band every 0.6 seconds (f=1.5 Hz) with vertical resolution of 30 m for both radars. This rapid sampling rate gave us high resolution observations of the three Doppler moments. Rawinsondes were regularly launched every six hours. This payload provides comprehensive measurements of the oceanic shallow cumuli characteristics in a trade wind regime.

2. OBSERVATIONS

Here we will present examples of shallow cumulus observations collected on January 11th. Fig.1 is an illustration of the typical thermodynamic structure of the oceanic trade-wind boundary layer with low level easterly winds (10 m/sec) and an inversion at approximately 2 km.

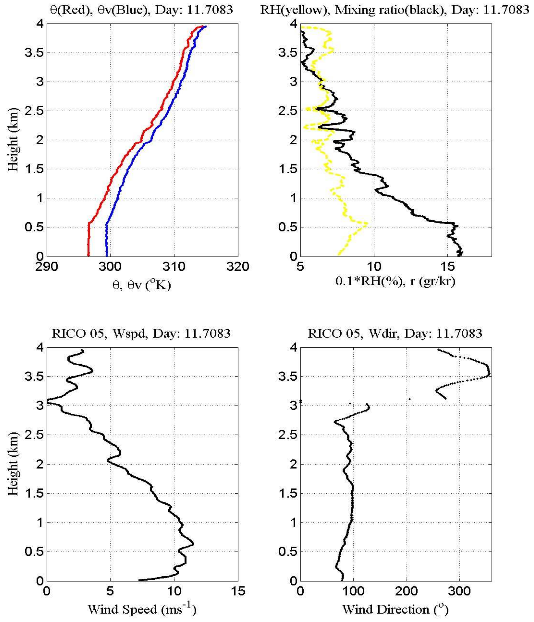

Fig. 1. Thermodynamic profiles from the sounding launched at around 16:00 UTC.

A well mixed sub-cloud layer (500 m) is shown in the potential temperature and mixing ratio profiles, indicative of convective mixing forced by positive heat fluxes at the ocean surface.

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The scanning S-POL-Ka radar observations were used to put the vertically pointing radar measurements from the ship in the context of the large-scale organization of trade-wind cumuli. Fig. 2 shows one quadrant of a complete scan cycle taken by the S-POL-Ka radar and the ship position at that time. The marked area in Figure 2 is blown up in Figure 3, along with the ship track.

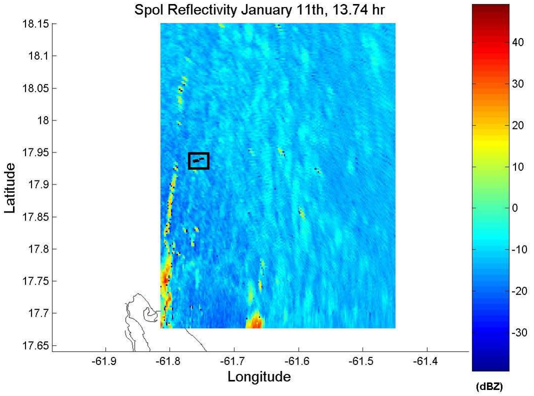

Fig. 2. S-POL-Ka reflectivity and ship position (indicated by the square box).

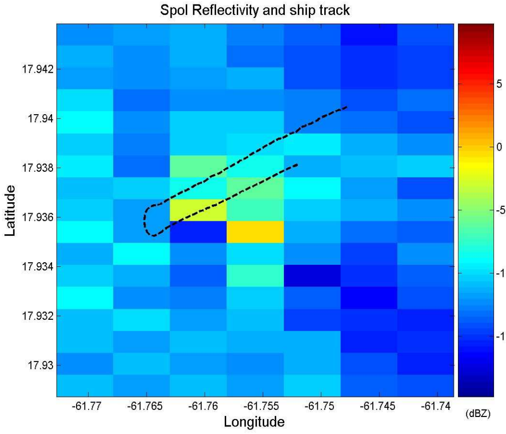

Fig. 3. Detailed ship track and reflectivity in the marked region shown in Fig. 2.

In this case, the UM profiling radars were able to sample a shallow cumulus cloud that was also observed by the S-POL-Ka radar. A small non-precipitating shallow cumulus is shown in figure 4. As is evident in the figure both radars detect the low level cloud, but the X-Band is unable to resolve targets below 500 m, due to clutters related to the structure of the ship.

The reflectivity at W-Band is reduced compared with the X-Band since at these reflectivity levels the W-band is affected by Mie effects compared with pure Rayleigh scattering at X-Band. The attenuation at W-Band is higher than it is at X-Band.

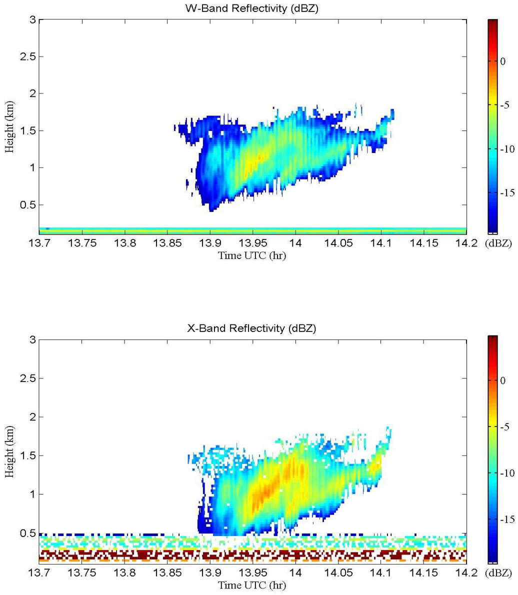

Fig. 4. W-Band (upper panel) and X-Band (lower panel) reflectivity.

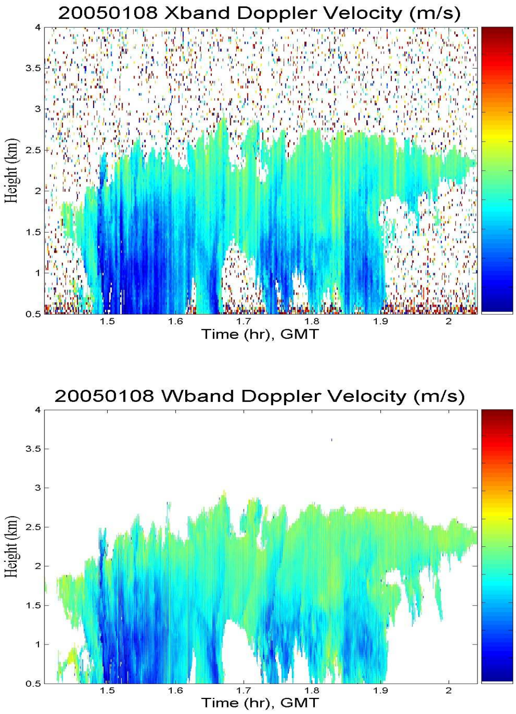

Fig. 5. Doppler velocity for X-Band (upper panel) and W-Band (lower panel).

Fig. 5 shows Doppler velocity from the X- and W-Band radars for a 38-minute period of observations on January 8th. Although there is excellent correspondence between the vertical velocity fields, the W-Band plot clearly shows details missing from the X-Band plot. The cloud top is clearly below the trade wind inversion layer which prevents convection to develop further. Our group is currently working on improving the X-Band hardware for better performance.

X-Band Doppler velocity is higher than the Doppler velocity recorded by the W-Band because the later one was in the Mie scattering regime while the X-Band was in the Rayleigh scattering regime. The main problem observed during this cruise was the data contamination due to the ship motion. The W-Band was equipped with a motion stabilizer; however its poor time response to the ship motion made the stabilizer not suitable under the severe ship motions experienced. More work is needed to prevent the radar data from ship motion contamination.

3. FUTURE WORK

The recent RICO experiment provides us with unprecedented active and passive remote sensing measurements of oceanic shallow cumuli and their formation in the trade wind regime.

This study shows the ability of cm-wavelength radars for cloud studies. Current work is focused on comparing both radars Doppler moments and describing the internal structure of shallow cumuli throughout their different lifetime stages. Further study will focus on relating their lifecycle to the fractional cloud amount in such region.

In the future, we will complement the S-POL-Ka data with the UM cloud radars data to study in detail the onset of precipitation as well as the microphysical processes that are important as clouds undergo and complete the transition to a mature rainshaft.

Acknowledgments

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REFERENCES

Del Genio, A.D., M. S. Yao, W. Kovari, and K. W. Lo., 1996: A prognostic cloud water parameterization for global climate models. *Journal of Climate*, **9**, 270-304.

Fabry, F., G.L. Austin, and A. Singh, 1992: High resolution observations of precipitation with a vertically pointing radar. Proceedings, *11th Int. Conf. on Clouds and Precipitation*, Montreal, Canada, ICCP/IAMAS, 258-259.

Kollias, P., B. A. Albrecht, R. Lhermitte and A. Savtchenko, 2001: Radar Observations of Updrafts, Downdrafts, and Turbulence in Fair-Weather Cumuli. *Journal of the Atmospheric Sciences*, Vol. 58, No. 13, pp. 1750–1766.

Warner L. E., C. R. Williams, P. E. Johnston, and K. S. Gage, 1999: A 3-GHz Profiler for Precipitating Cloud Studies. *Journal of Atmospheric and Oceanic Technology*: Vol. 16, No. 3, pp. 309–322.