P1.4 LIDAR DEPOLARIZATION RATIOS FROM CRYSTAL-FACE THUNDERSTORM ANVILS

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1. INTRODUCTION

The motivation of the 2002 CRYSTAL-FACE field campaign was to study cirrus clouds in the convective environment encompassing southern Florida and the eastern Gulf of Mexico and northern Caribbean. Depolarization lidar instruments were operated both at a ground site near Everglades City, Florida and from an airborne platform. Linear depolarization ratios (δ) in thunderstorm anvil measurements made by these two YAG-based (532 nm) systems, the University of Alaska-Fairbanks Polarization Diversity Lidar (PDL) (Sassen et al., 2001) and the Cloud Physics Lidar (CPL) aboard the NASA ER-2 aircraft (McGill et al., 2001), are reported in this abstract. The lidar linear depolarization ratio provides valuable information on particle scattering characteristics as it is uniquely sensitive to hydrometeor shape, fall orientation, and to a lesser degree particle size (Sassen, 1991). Furthermore δ can be relied upon unambiguously to discriminate between liquid and ice phase regions in clouds. We correlate the occurrence of observed δ values with respect to ambient thermal properties with the goal of characterizing the scattering properties of sub-tropical cirrus. We compare our results to those taken from previous equatorial, tropical and midlatitude campaigns to infer possible cloud microphysical differences and speculate as to why they may occur.

2. DISCUSSION

From 1800 UTC 23 July significant convective development was occurring northeast of Lake Okeechobee along the central eastern coast of Florida in response to the diurnal frontal breeze advancing onshore off the Atlantic. This activity would persist in this area during the afternoon, enhanced by convergence with a similar boundary advancing northward from the Keys. Upper-level winds were northeasterly, and thunderstorm anvil outflow was advected toward the southwest coast of the peninsula directly over the western experiment ground site near Everglades City.

In Fig. 1 are δ values collected with the PDL from 2008 to 0015 UTC plotted between 6.0 and 16.0 km above the ground. Raw data were collected at 1.5 m and 40 Hz resolution, however to minimize noise they have been grouped into 12.0 m and 20 s averages. Intermittent gaps apparent in the image are the result of pulse attenuation by lower-level liquid-phase clouds passing over the instrument. A well-defined 1.0 km thick anvil is observed at the beginning of the period with δ values near 0.40. The layer height descends through 2200 UTC, indicative of less vigorous convection over time. A transition to mixed-phase altostratus can be seen occurring through 2230 UTC, where δ values approach 0.00 and pulse attenuation is intermittently apparent. Toward the end of the period, anvil remnants are seen capped near 14.0 km, with broken layers of cirrus and some altocumulus embedded throughout the lower column (δ values near 0.00 atop slightly depolarizing elements near 0.15 falling below). The reader should not confuse the layer denoted by δ values of 0.00 centered at 7.00 km near 0000 UTC with a liquid-phase mid-level cloud. Horizontally oriented plate crystals with their basal face wafting in resistance to their fall are known to generate little depolarization (Sassen 1991).

In Fig. 2 are δ values collected with the CPL from 2000 to 0000 UTC displayed between the ground and 15.0 km above the ground. Raw data were collected at 30 m and 10 Hz resolution. However, to minimize noise in processed data 1.0 s averages are used. Intermittent gaps apparent in this data are the result of the aircraft banking through turns as part of its flight-track assignments where the lidar is pointed off nadir and data collection is briefly interrupted. The ER-2 flew "racetrack" legs during this period from the convective area downwind and back from both the western and eastern campaign ground sites. For the latter two-thirds of the period the flight track focused exclusively on passes over the western site. Multiple passes of what is roughly the same complex, albeit an evolving one and its anvil extending southeastward are apparent in the image. The ER-2 was equipped with dropsondes that were released intermittently during flight to supplement regular 0000 and

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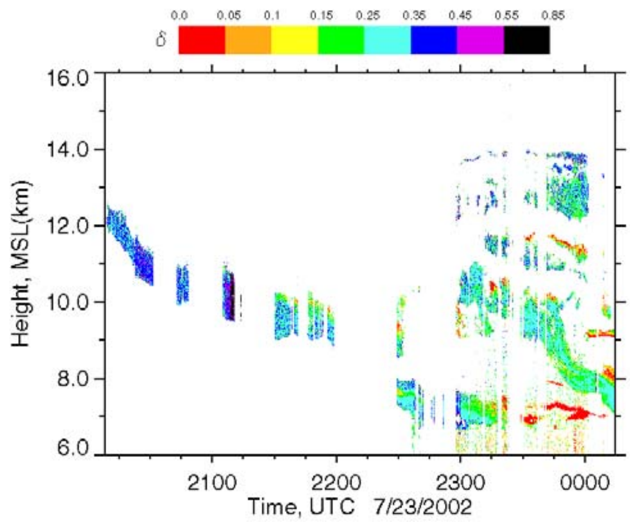

Figure 1. Linear depolarization ratios from the Univ. of Alaska-Fairbanks Polarization Diversity Lidar versus altitude above ground for 2008 – 0015 UTC beginning 23 July 2002. The color table on top maps δ value intensities. Intermittent gaps in the data are due to signal attenuation from lower-level clouds not displayed.

12000 UTC launches at National Weather Service stations at Miami and Key West with more complete information on the thermal environment in and around convection. Data collected at 2300 UTC with a drop off the coast approximately 50 km west of Everglades City are discussed here.

Figure 3 is a histogram depicting frequencies of δ values from cloud layers detected by the CPL on 23 July occurring within 0.025 intervals between 0.05 and 0.50, and 10° intervals between -10° and - 70° C. In Fig. 4 average δ values are plotted in 5° intervals between -10° and - 70° C from both the PDL and CPL. The expected trend of increased depolarization with lower temperatures is visible in both plots. Given the small sample sizes for this single day we consider the two instruments to be in good agreement.

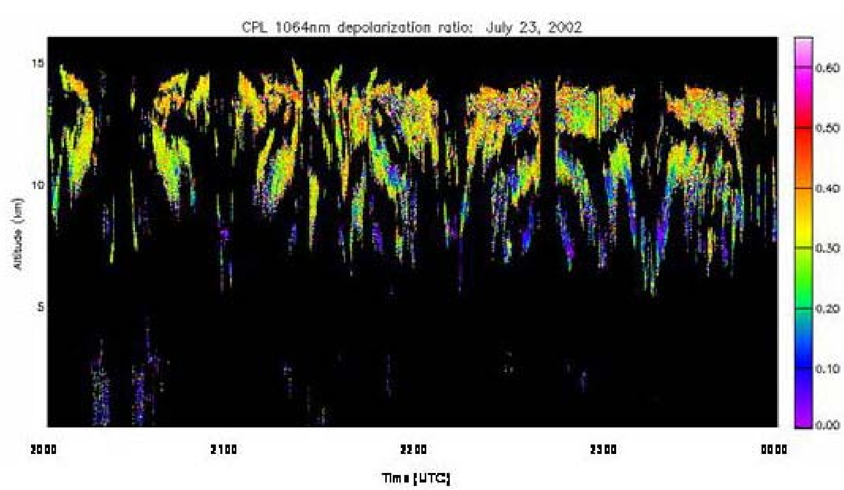

Figure 3. Linear depolarization ratios from the NASA Cloud Physics Lidar versus altitude above ground for 2000 – 0000 UTC beginning 23 July 2002. For this period, the ER-2 flew "racetrack" paths between Lake Okeechobee and Everglades City, Florida. Data gaps represent aircraft turns where the lidar view is appreciably off nadir.

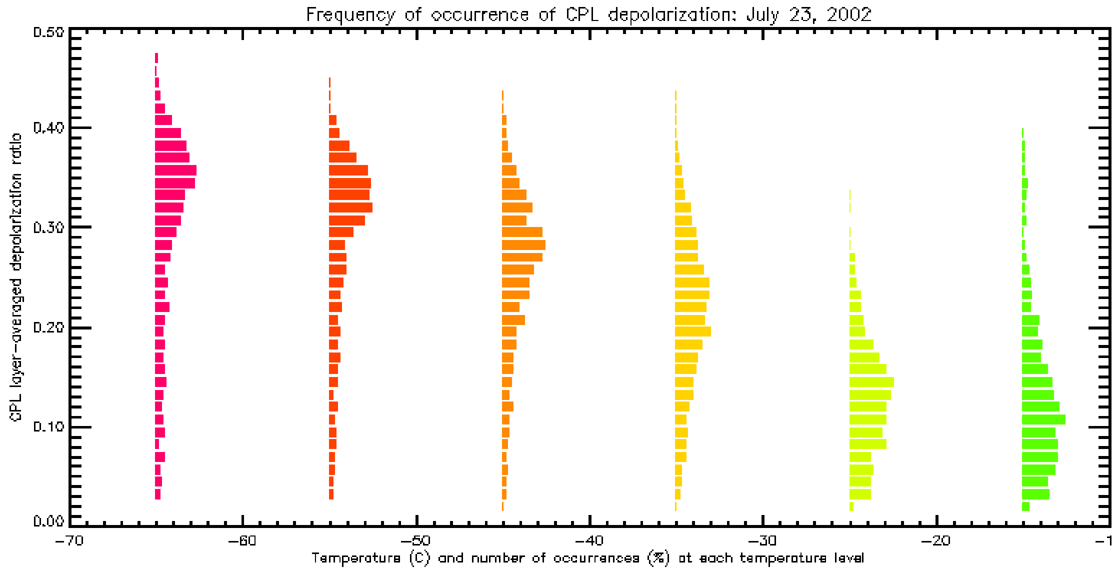

Figure 3. Frequency of occurrence of depolarization measurements from Cloud Physics Lidar data taken 23 July 2002 versus observed temperature (C) in 0.025 ratio bins and ten degree intervals between -70º and -10º C. Temperatures were recorded via dropsondes launched intermittently in flight from the ER-2.

A comparison of the data in Fig. 4 with previous work indicates generally lower δ values. Figure 8 from Sassen and Benson (2001) depicts a similar δ vs. temperature relationship combining numerous studies including equatorial, sub-tropical and midlatitude measurements and these data are slightly lower. However, as this represents just a single day of measurements and additional CRYSTAL data has yet to be considered this comparison cannot be considered robust. Dissimilarities between δ observations from convective and synoptic cases are possible as a function of inherent updraft velocities. Although pristine crystals are found in thunderstorm anvils as well as their aggregates, rimed particles occur as well as smaller crystals with quasi-circular shapes suggesting recently having been frozen (Heymsfield and McFarquhar, 2002). These latter elements could be expected to generate lower depolarization than for pristine crystals alone.

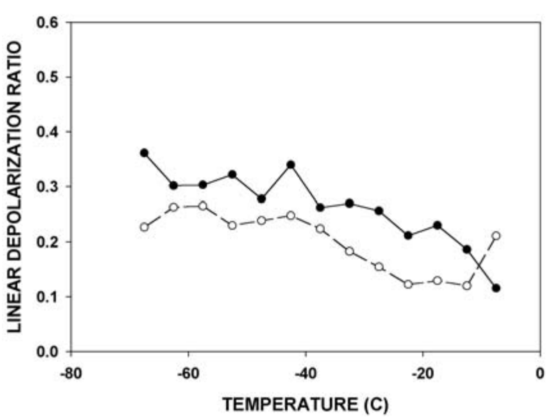

Figure 4. Average δ values as a function of temperature grouped into five degree bins beginning from -70° to - 10° C for the PDL (solid) and CPL (dashed) for cloud observations on 23 July 2002.

3. REFERENCES

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