# Turbulence Estimates in Continental Stratocumulus Using ARM Cloud Radar Data

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## 1. Introduction

Using spectrum width recorded by the ARM W-band cloud radar and the data recorded by lidar and wind profiler deployed in South Great Plains at Lamont, Oklahoma, this study investigates turbulence and flow structures in The continental stratocumulus.

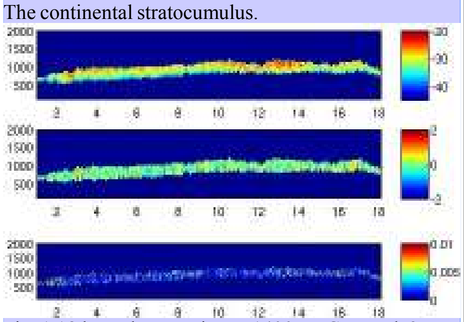

Fig. 1 18 hour data starting at 1400 UTC, March 25, 2005. From top to bottom, reflectivity, Velocity and Energy dissipation rate (EDR).

## 2. EDRs from SW and Power Spectra

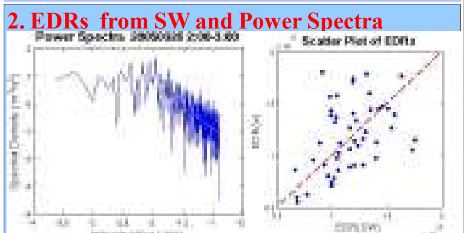


Fig. 2 Left panel shows the power spectra calculated from fluctuations of vertical velocities; Right panel shows a scatter plot between EDR calculated from spectrum width (SW) and that from power spectra.

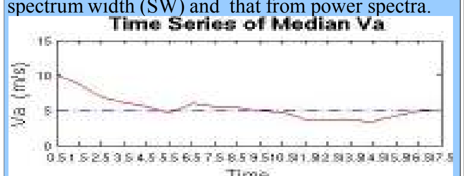


Fig. 3. Hourly median advection velocity in clouds (red); 18 hour median advection velocity (blue). Using hourly data to transform power spectra from frequency domain to wavenumber domain produces better results than using 18 hour median value does.

## 3. Coherent Structure

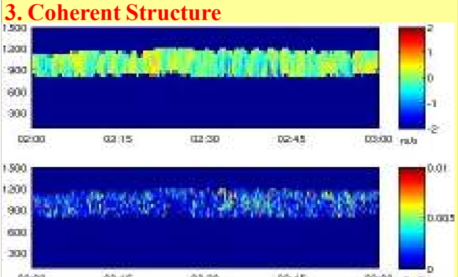

Fig. 4 Velocity and EDR fields between hour 12 and 13. It can be seen that turbulence/EDR is weak in the updraft regions and strong in downdraft regions.

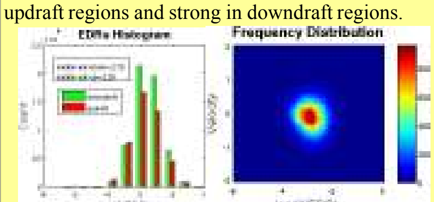


Fig. 5 The left panel shows the histogram log10(EDR); The right panel shows the frequency distribution. They confirm that turbulence/EDR is weak in updrafts and strong in downdrafts.

## 4. Coherent Structure in Normalized Coordinate System

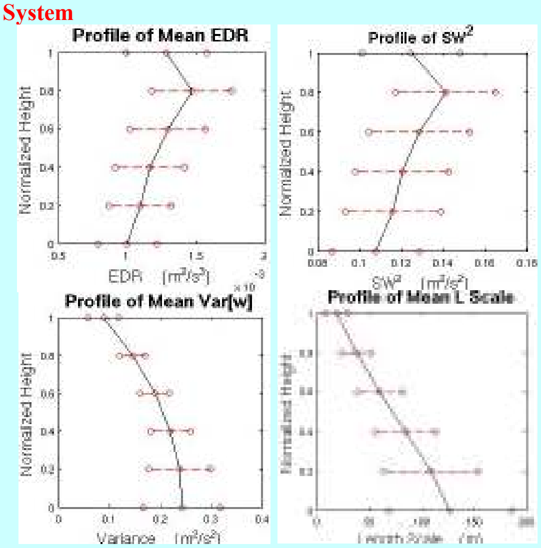


Fig. 6 EDR, $SW^2$, variance, and vertical integral length scale averaged over 18 hours; Note: The ordinate represents the normalized height where 1 is cloud top and 0 is could base.

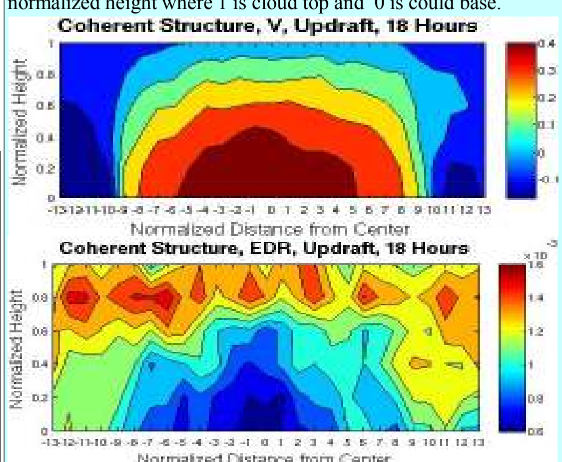


Fig. 7 Upper panel shows vertical velocity for coherent updrafts (> 100 m in horizontal) composited from all 18 hours of observations. Lower panel shows the EDR field. Turbulence is weak in updraft core and larger turbulence appears on the top and edge of the updraft core.

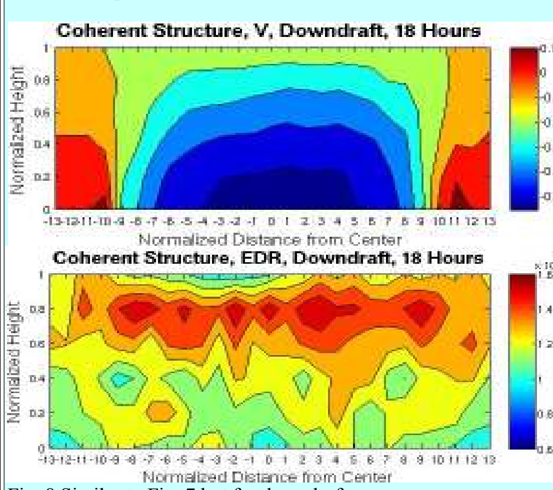


Fig. 8 Similar to Fig. 7 but for downdraft.

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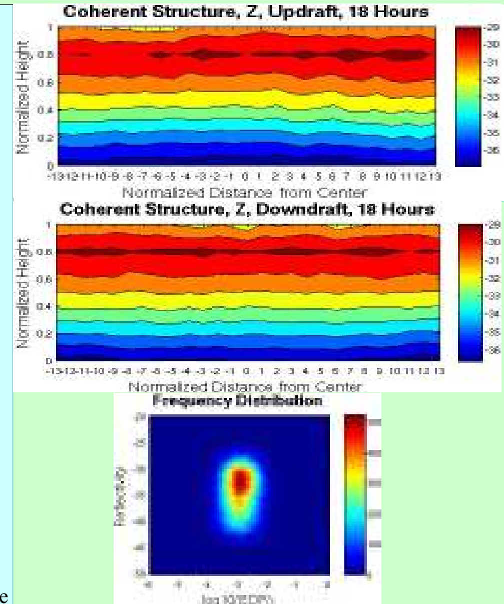


Fig. 9 Two upper panels show reflectivity fields averaged over 18 hours around updraft and downdraft core in a normalized coordinates; The lower panel shows the frequency distribution. Comparing reflectivity fields with EDR fields in Fig. 7 and Fig. 8, the large reflectivity values are well correlated with the large EDR values as shown too in the lower panel. The range of EDR values expends when Z increases. These correlations may indicate that sub-radar volume turbulence increases near cloud top where entrainment may be important.

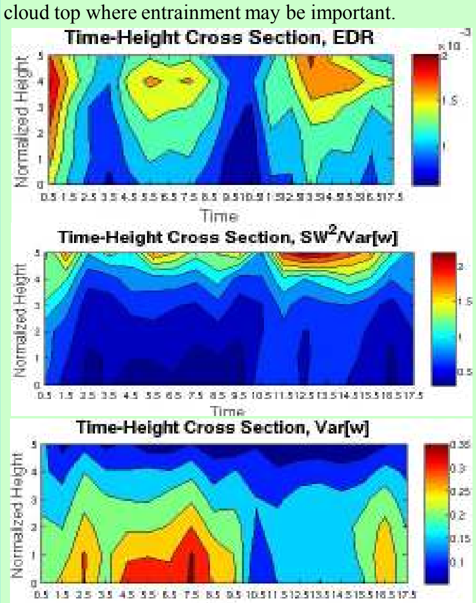


Fig. 10 Time-height cross section of EDR, ratio between spectrum width and variance of vertical velocity, and variance of w. The intensity of resolved turbulence decreases when that of unresolved turbulence increases from cloud base to cloud top.

## 5. Preliminary Results

1. ARM cloud radar measured SW is well suited for turbulence studies and provides turbulence characteristics that could be compared with LES realizations. 2. EDR calculated from SW and velocity agrees with each other. 3. Sub-volume turbulence is stronger in coherent downdrafts than in updrafts. 3. Large reflectivity correlates with larger EDR at cloud top. 4. The resolved turbulence intensity decreases with height and the sub-volume turbulence and the vertical integral length scale decreases from cloud base to top.