Long-term Observations of the Convective Boundary Layer (CBL) and Shallow cumulus Clouds using Cloud Radar at the SGP ARM Climate Research Facility

Arunchandra S. Chandra
Pavlos Kollias
Department of Atmospheric and Oceanic Sciences
McGill University

Stephan A.Klein and Yunyan Zhang
Lawrence Livermore National Laboratory

Outline

- Motivation
- Introduction
- CBL turbulent statistics
- Shallow cumulus cloud statistics
- Summary
- Future Work

Motivation

- ❖Few long-term studies on Boundary Layer Cloud / Sub-Cloud Layer Interaction

- ❖No long-term dataset (in specific vertical velocity) studies for a better representation of Boundary Layer Clouds

- ❖Limited diversity of measurements for highly comprehensive studies and for platform inter-comparisons.

Objectives

- To study the turbulent characteristics of the convective boundary layer (CBL.
- To document long-term statistics (macroscopic and dynamics) of shallow cumulus clouds

Central Facilities at SGP

Ka-band (MMCR: Millimeter Cloud Radar)

35 GHz, 8.6 mm, Vertically pointing

Temporal resolution=10 s, vertical resolution= 45 m

Cloud boundaries (Cloud top and bottom)

Reflectivity, Doppler velocity and Spectral width

W-band: Vertically Pointing **,** 94 GHz, 3.2 mm

Temporal resolution=2 s, vertical resolution= 40 m

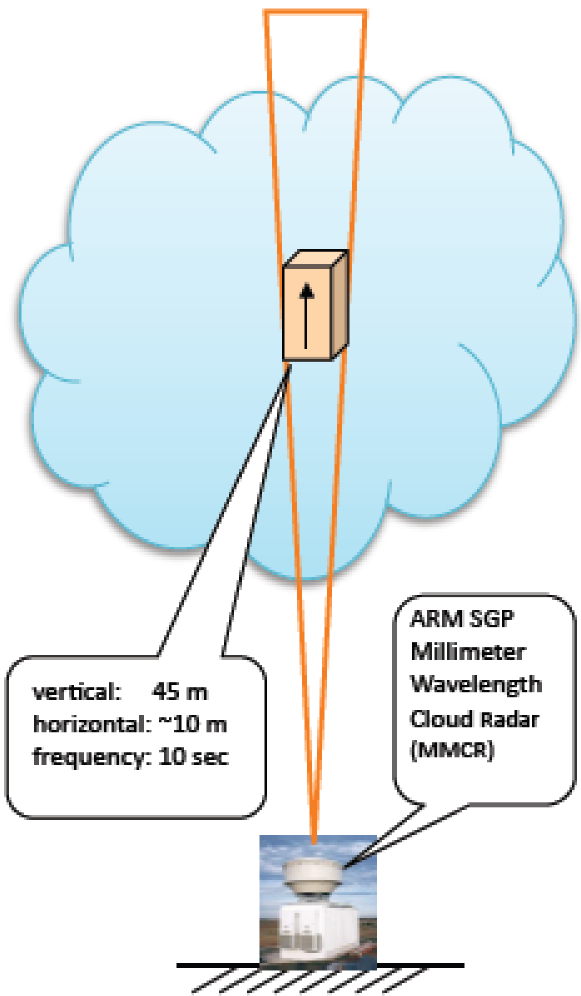
Weather Station: Turbulent and Radiation Fluxes

soil heat flux, Surface Variables (T, q, ws, wdir etc)

Radar Wind Profiler: 915 MHz

Horizontal winds, Backscattered Radiation and Vertical Velocity

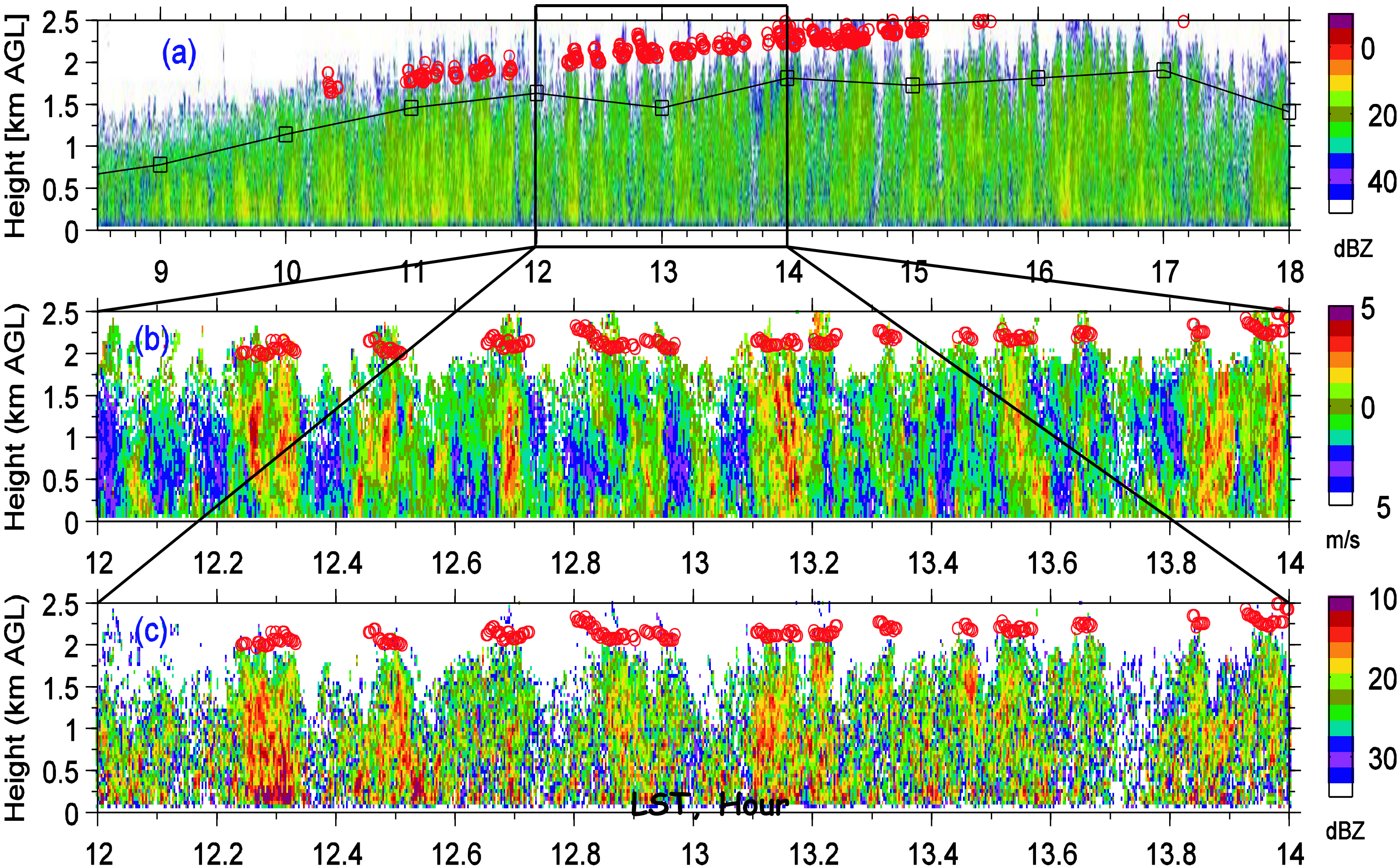
Vertical Velocities From Ground-Based Remote-Sensors



- Doppler millimeter wavelength cloud radars (MMCR) have been operating continuously at a number of sites worldwide (such as ARM) for years
- Millimeter wavelength → Sees cloud particles
- Doppler → measures velocity of the scattering target in the direction of the beam
- Vertically Pointing → the vertical velocity of the scattering target
- Volume → ~10 m x ~10 m x 45 m
- Frequency → Every 10 sec

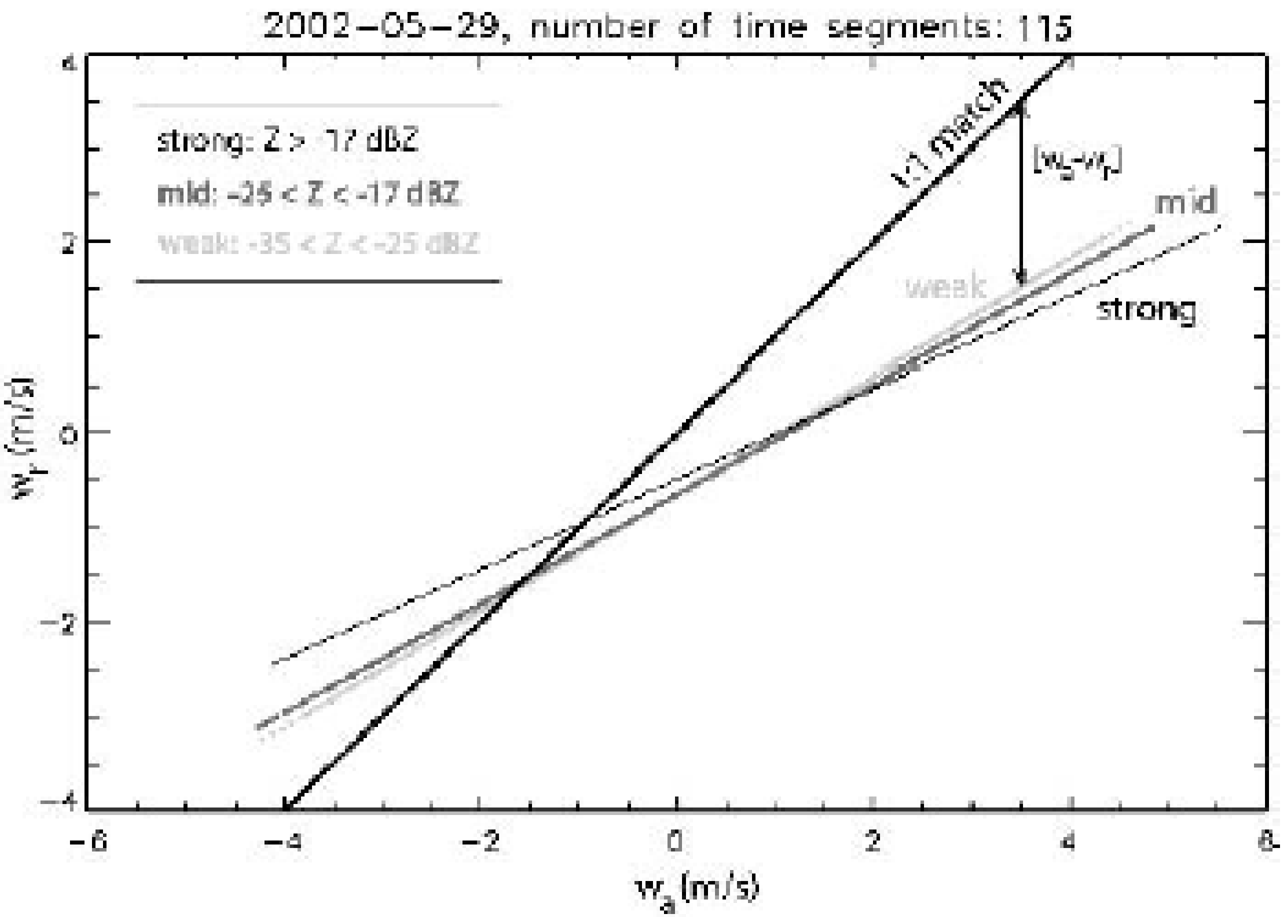
Courtesy of Steve Klein

Insect Echoes from a Cloud Radar (35 GHz)



Chandra et al., 2010

Correction for Doppler Velocity using Aircraft data



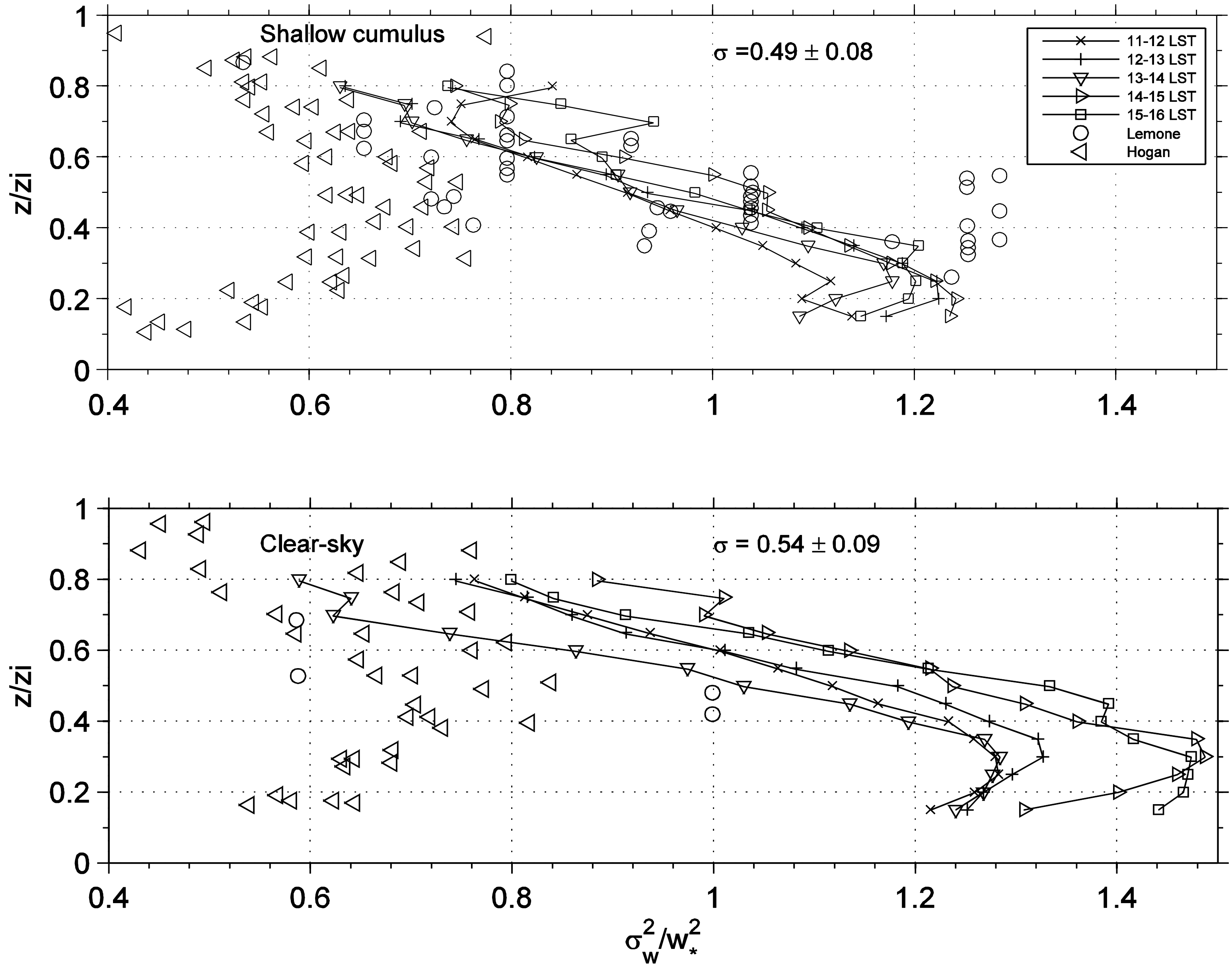
Correction equation: $W_{rc} = 1.96(W_{ru} + 0.42)$

Geerts et al., 2005

CBL Characteristics

- Vertical velocity variance
- Vertical velocity skewness
- Updraft massflux

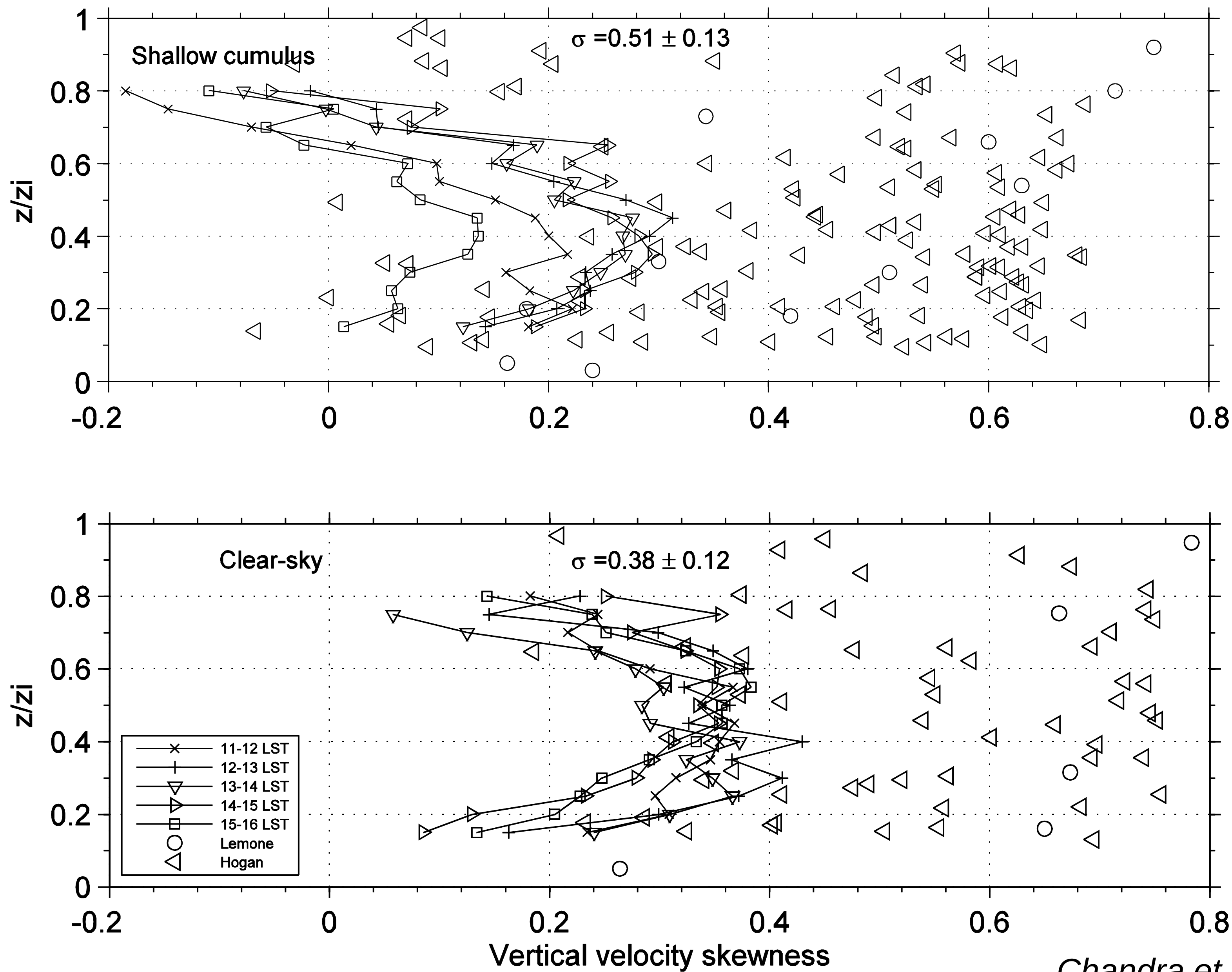
Vertical velocity variance



Total of 4 yrs of observations

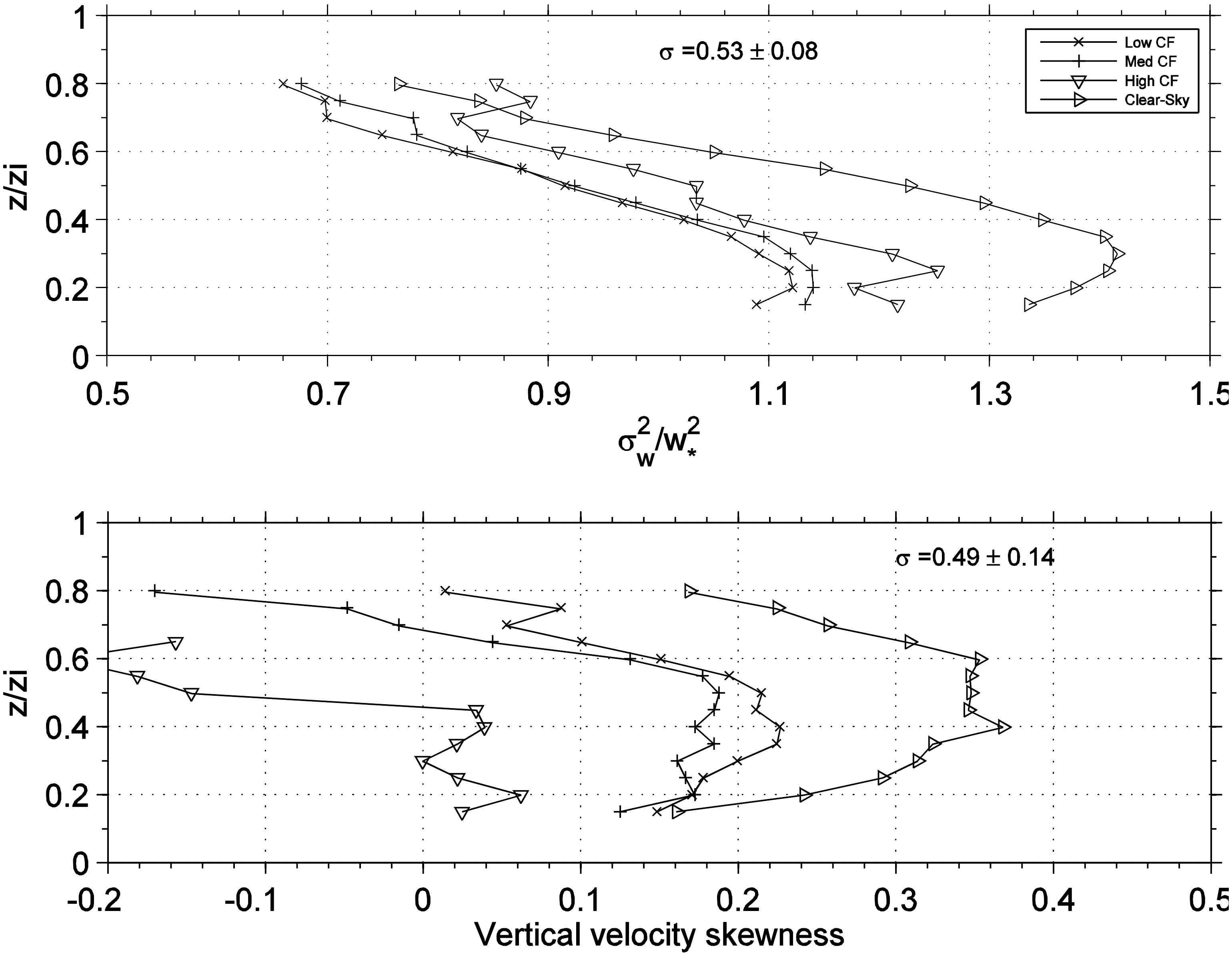
Chandra et al., 2010

Vertical velocity skewness



Chandra et al., 2010

Vertical velocity variance and skewness for different cloud fractions



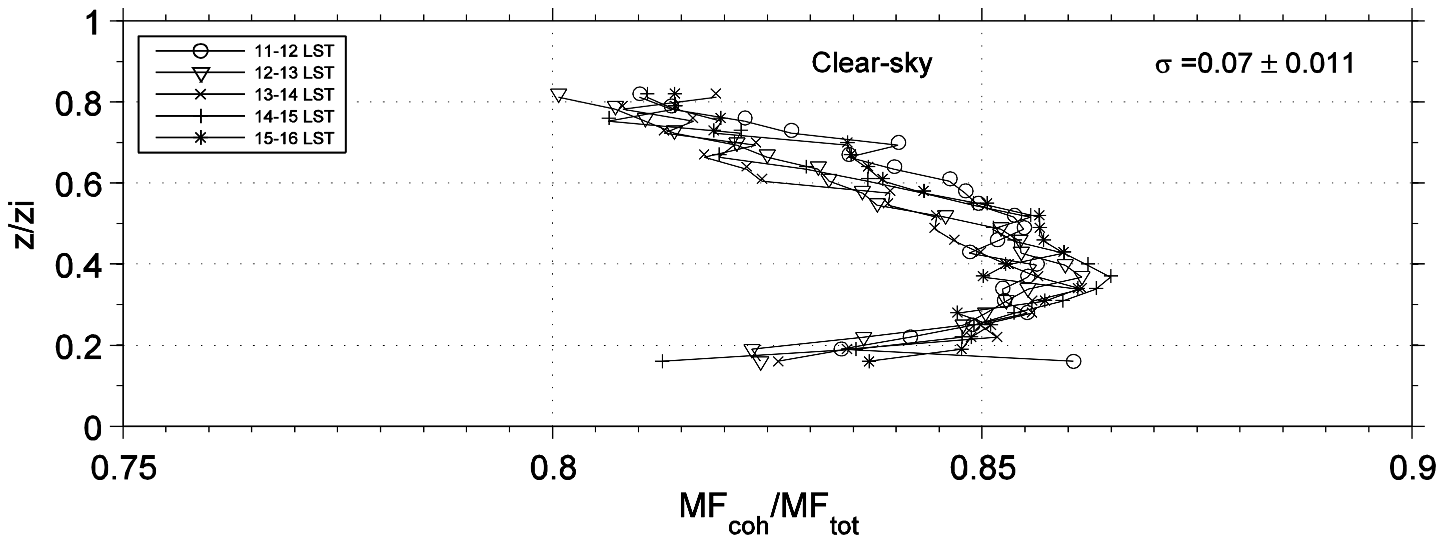
$LowCF = CF <= 0.2$

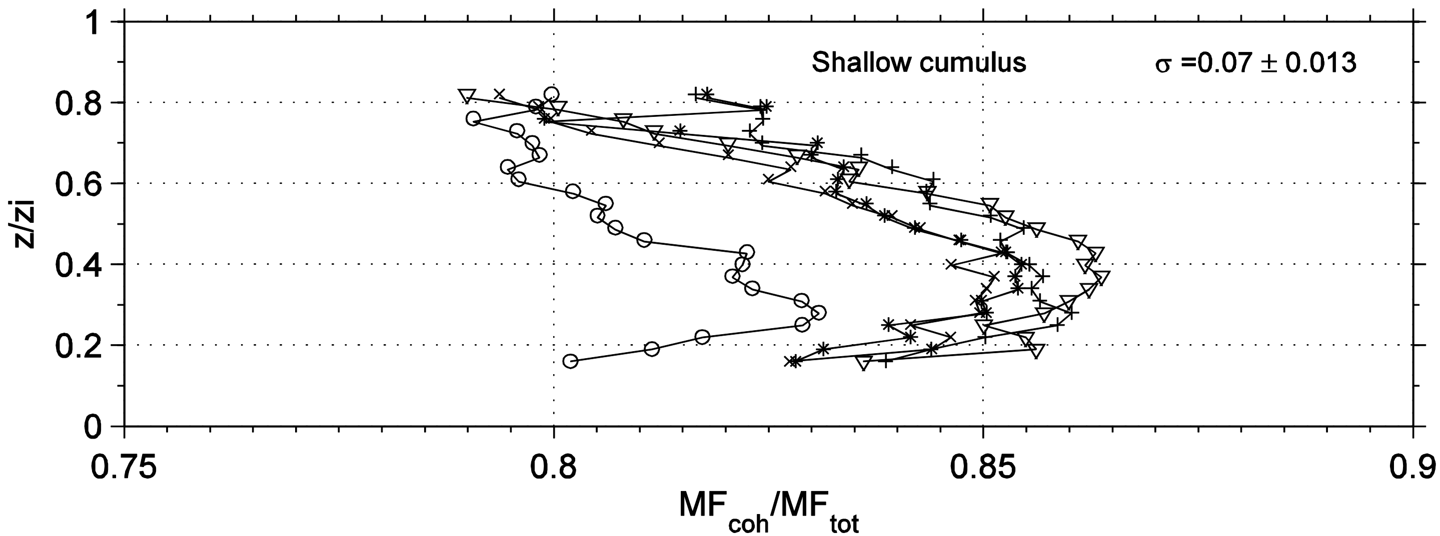
$MedCF = 0.2 < CF <= 0.6$

$HighCF = 0.6 < CF <= 1$

Chandra et al., 2010

Profiles of mass flux ratio for clear-sky and cloudy conditions



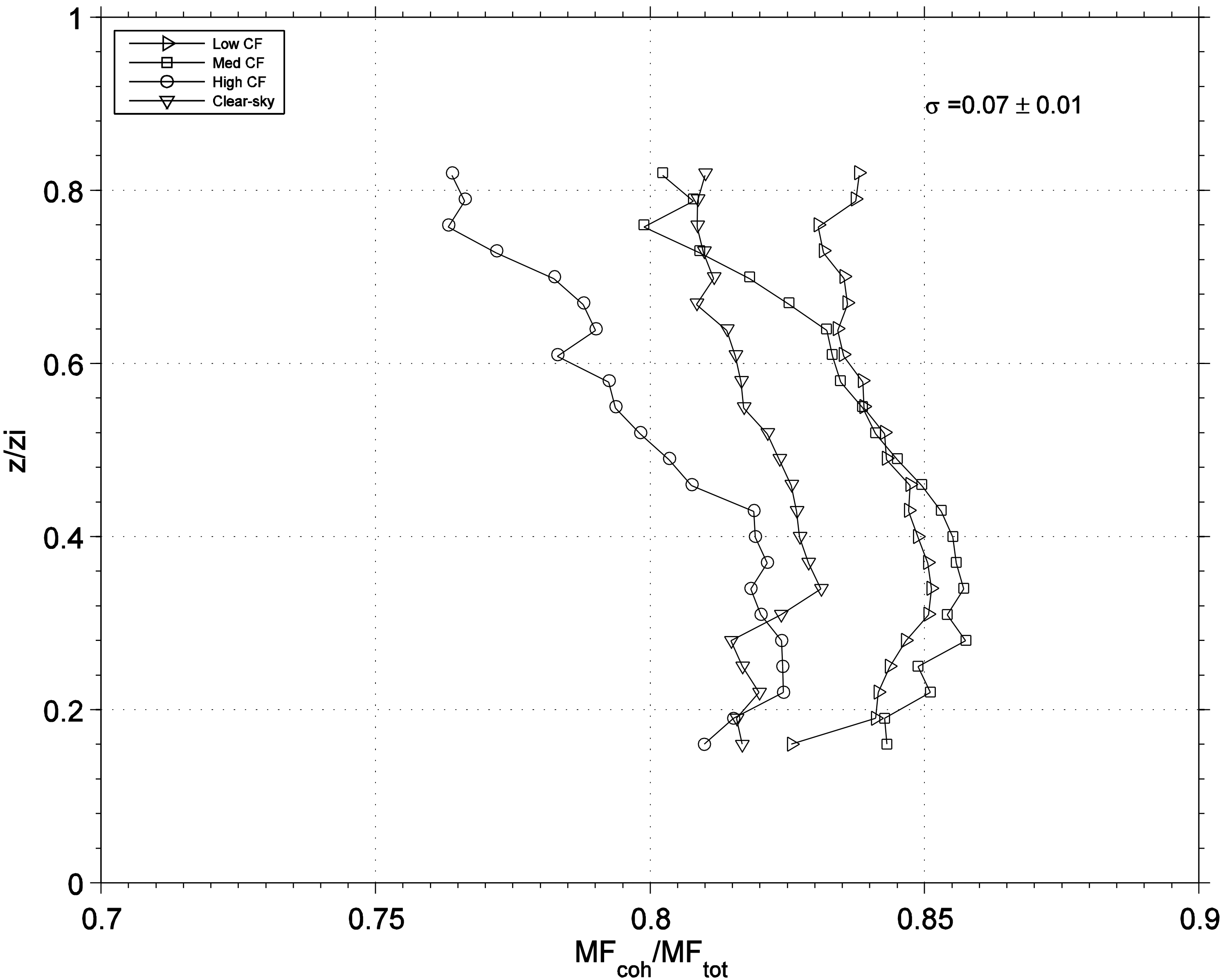


$$\frac{MF_{coh}}{MF_{tot}} = \frac{massflux(coherent\_structures, kgm^2s^{-1})}{massflux(all\_updraft\_values, kgm^2s^{-1})}$$

$$MF = \sum w_{up} \sum upfrac$$

Chandra et al., 2010

Profiles of mass flux ratio for different cloud fractions



Chandra et al., 2010

Highlights

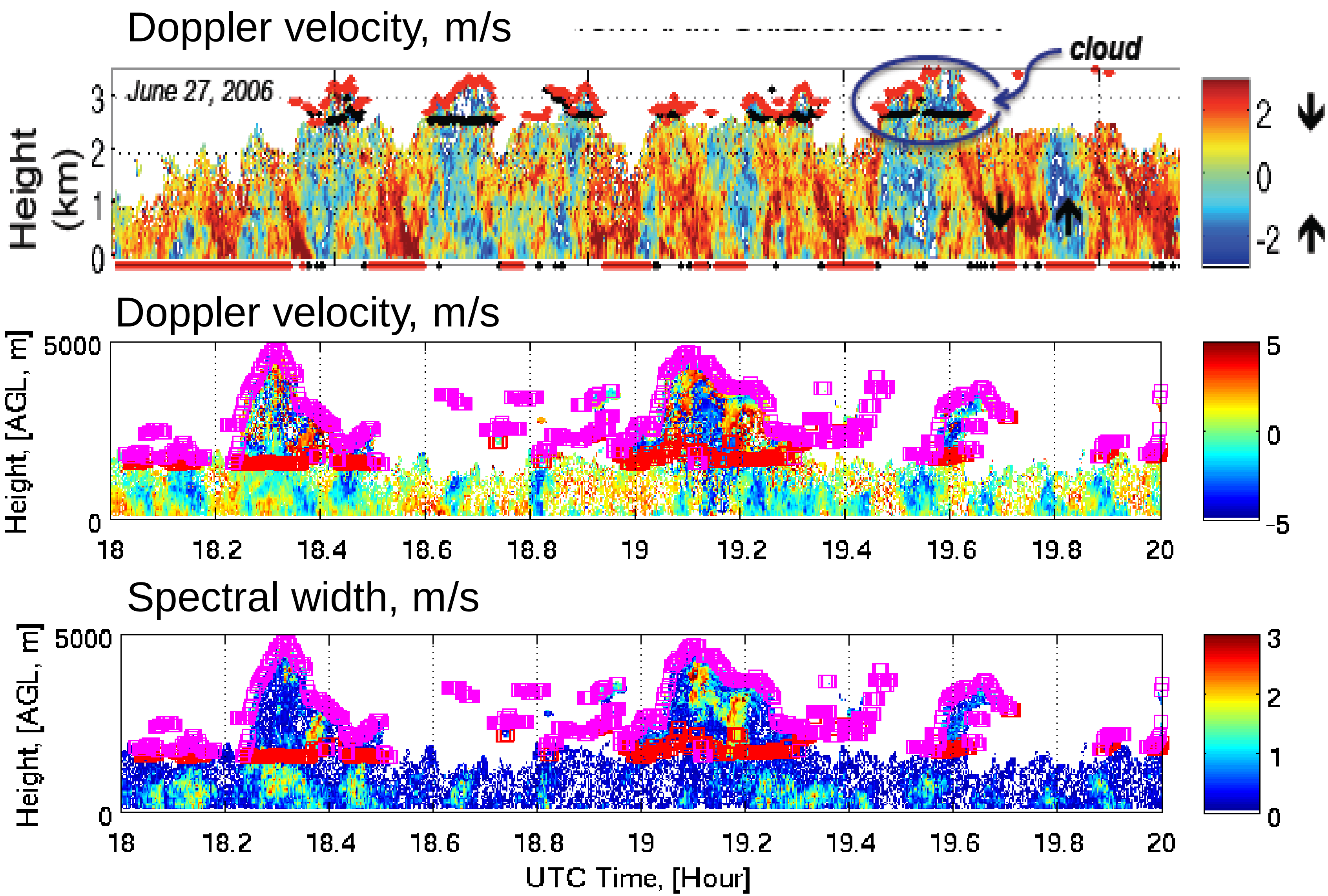
- Coherent structures are responsible for more than 80 % of the total turbulent transport

- The turbulent characteristics observed using cloud radar are consistent with previous measurements

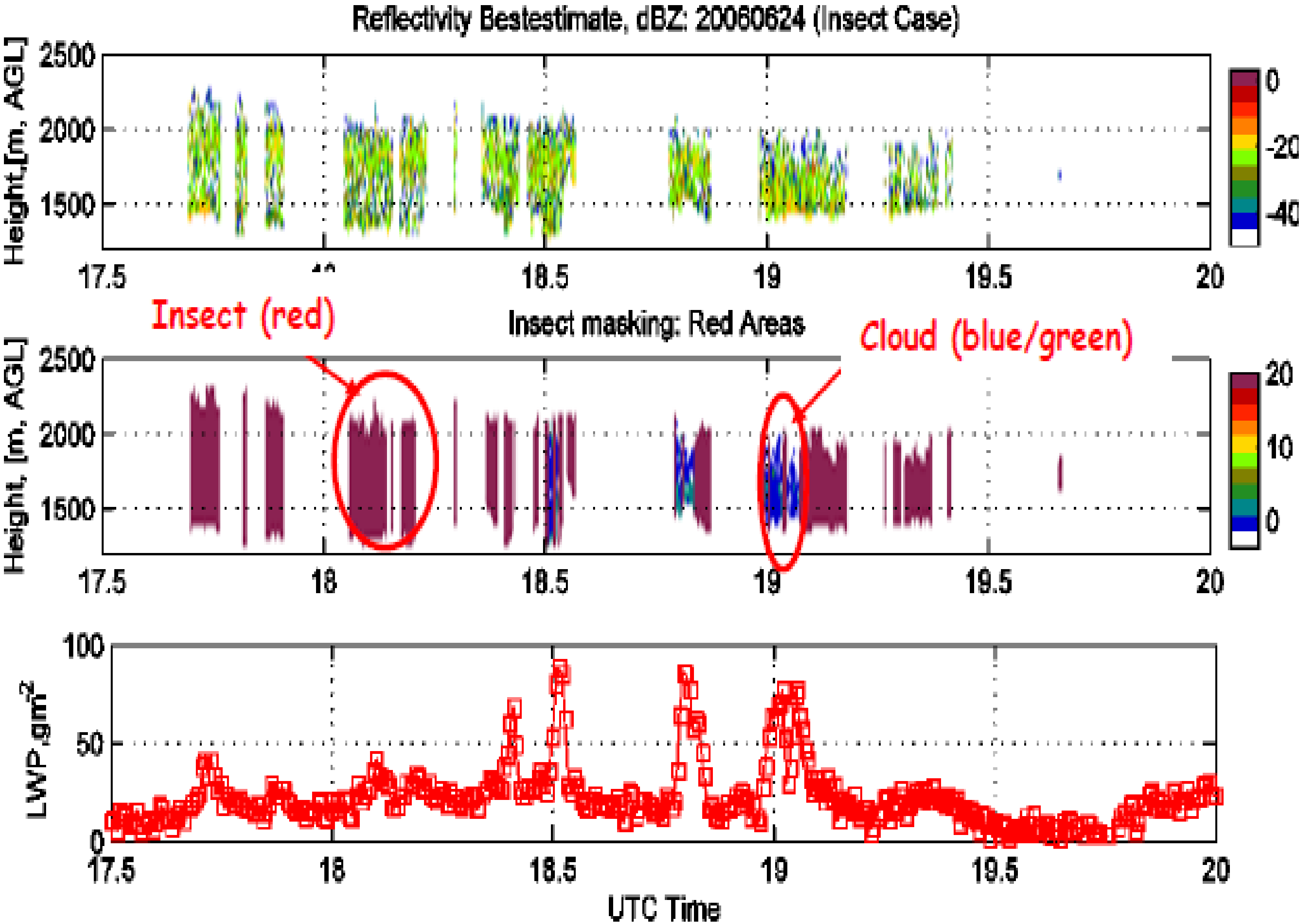
- These long term observations provide unique daytime evolution and indicated the role of increased cloudiness

- This large SGP MMCR dataset makes observations suitable for evaluating Boundary layer parameterization

Clouds observed from a cloud radar (35 GHz)



Insect Clutter Removal Inside Shallow Cumulus Clouds



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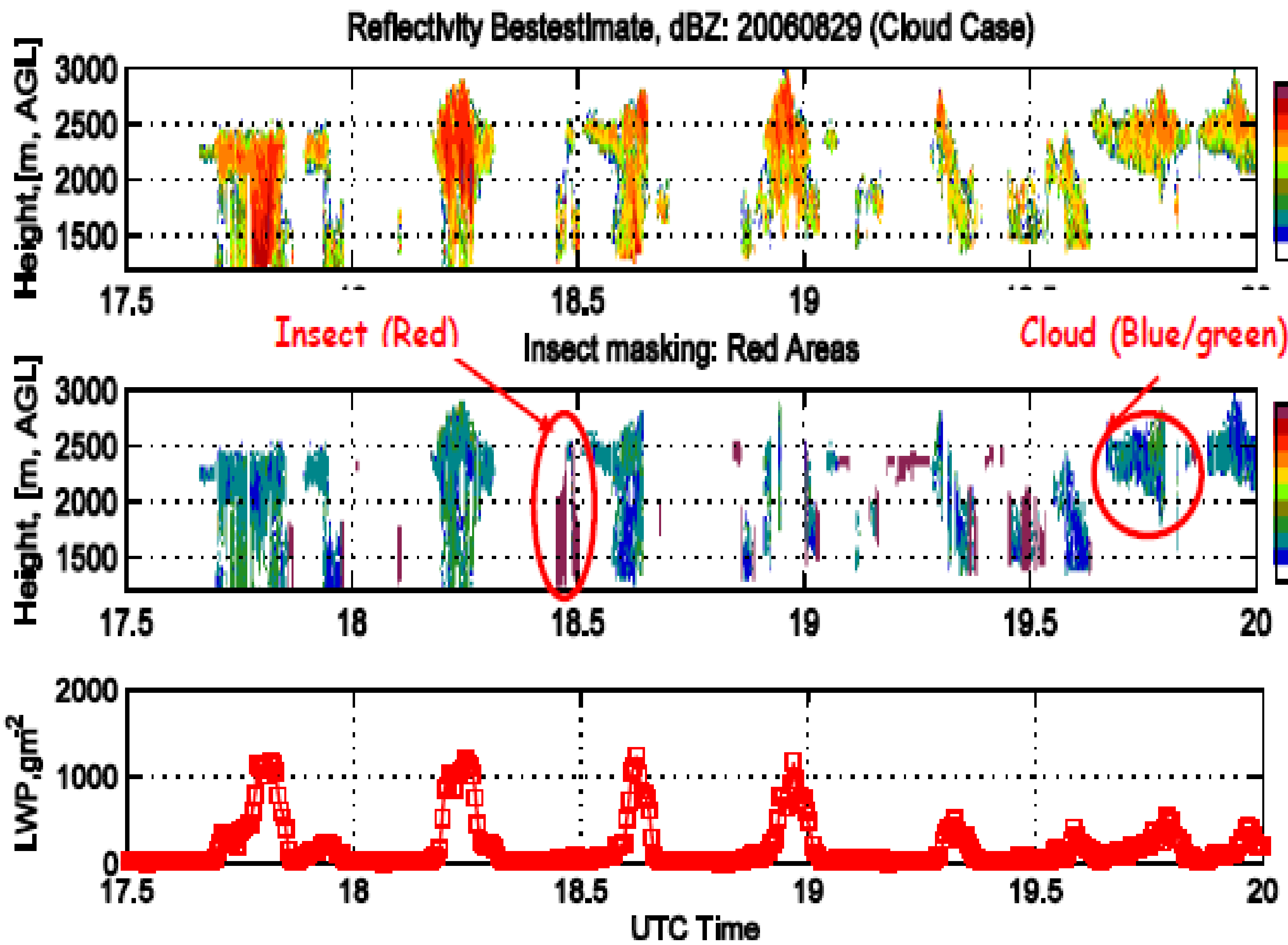
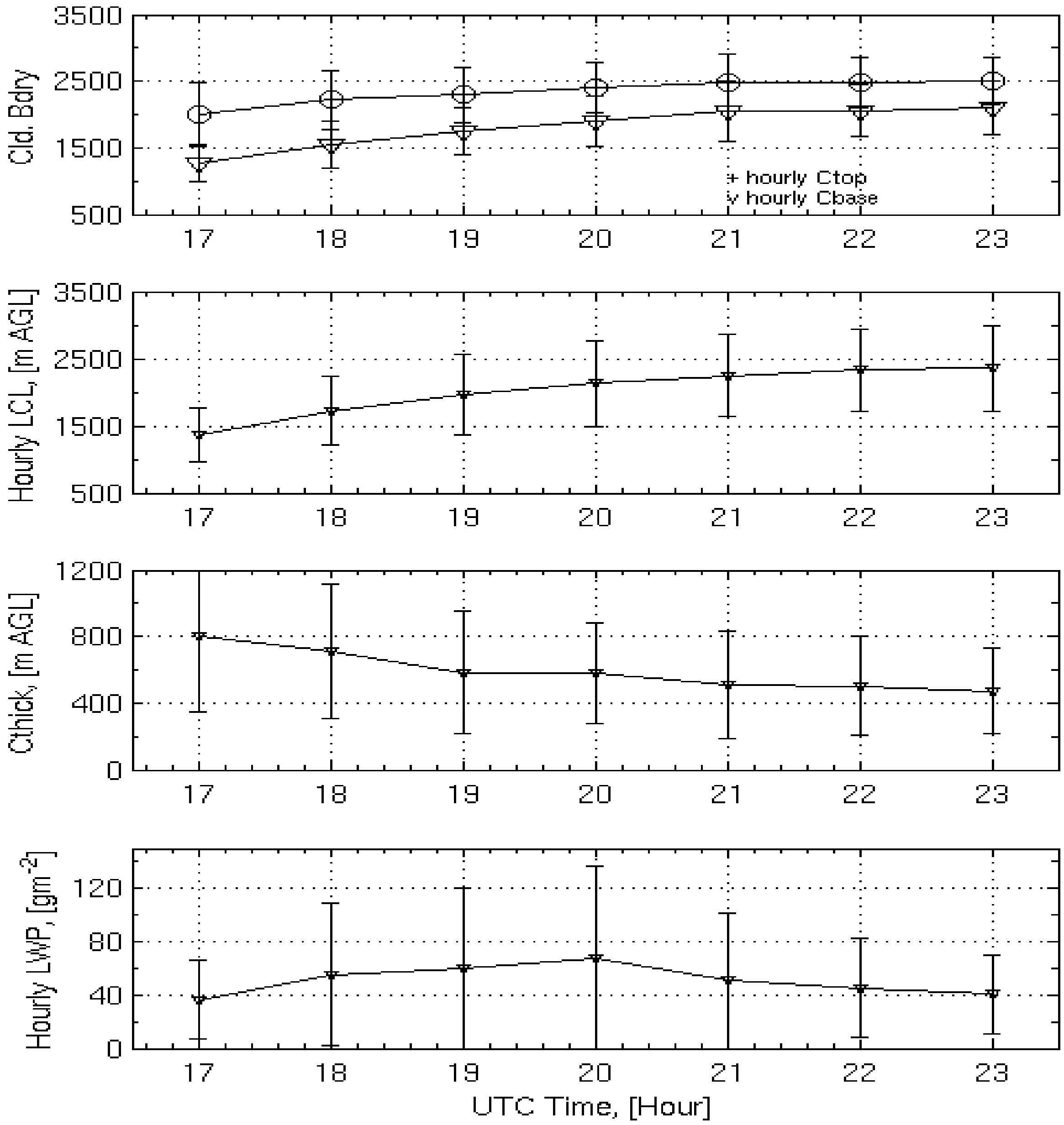
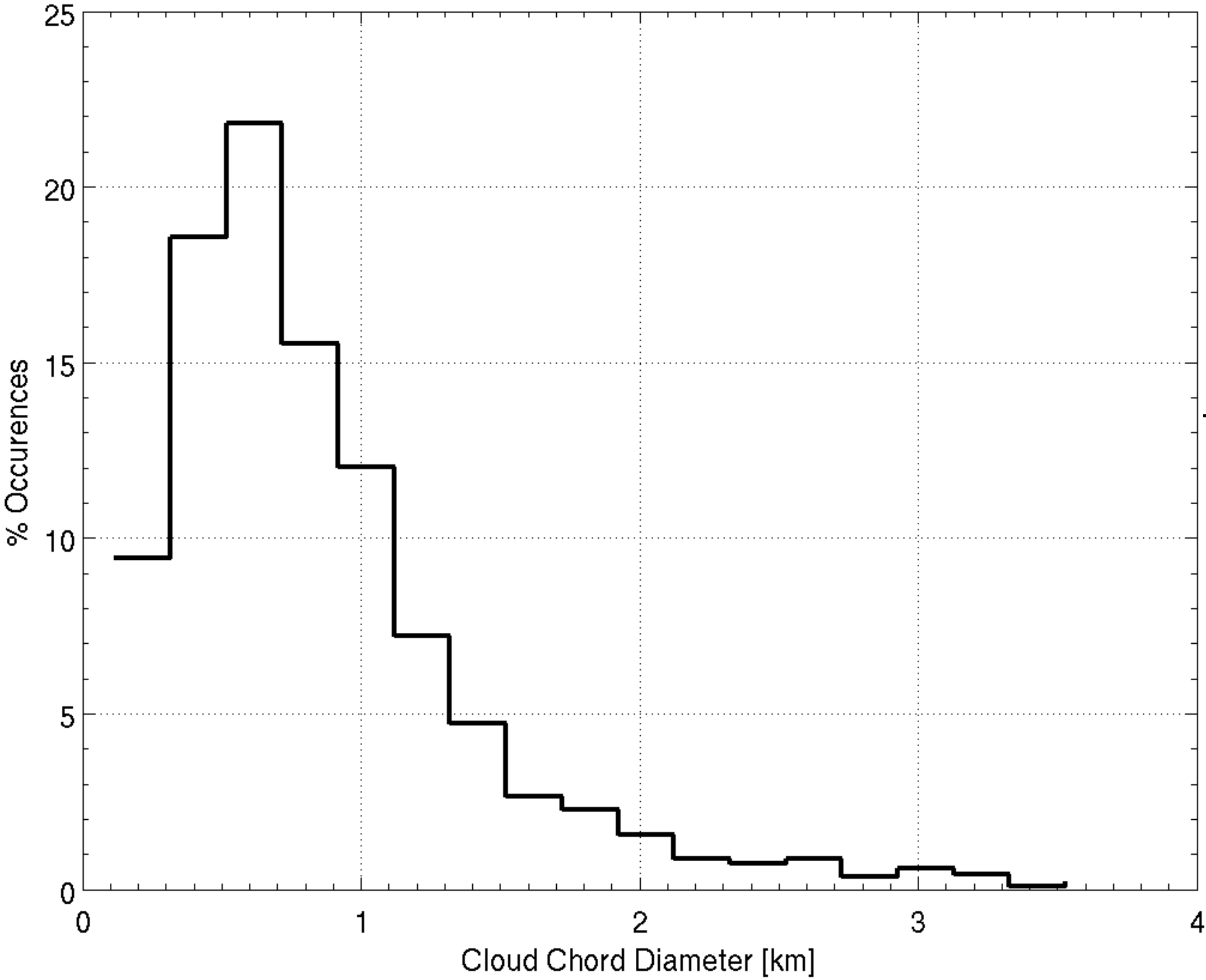


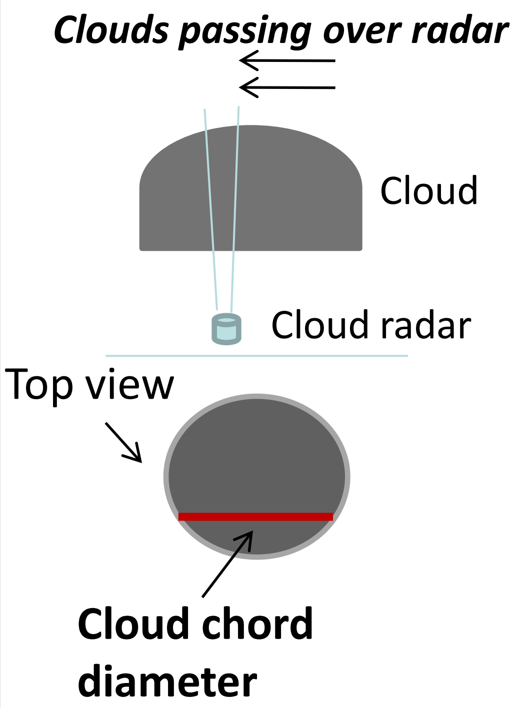
Diurnal variation of Cloud boundaries and Liquid water path



Note: Composite Statistics obtained from 840 shallow cumulus Hours

Histogram of Cloud Chord Diameter (L) of Sh.Cumulus Clouds

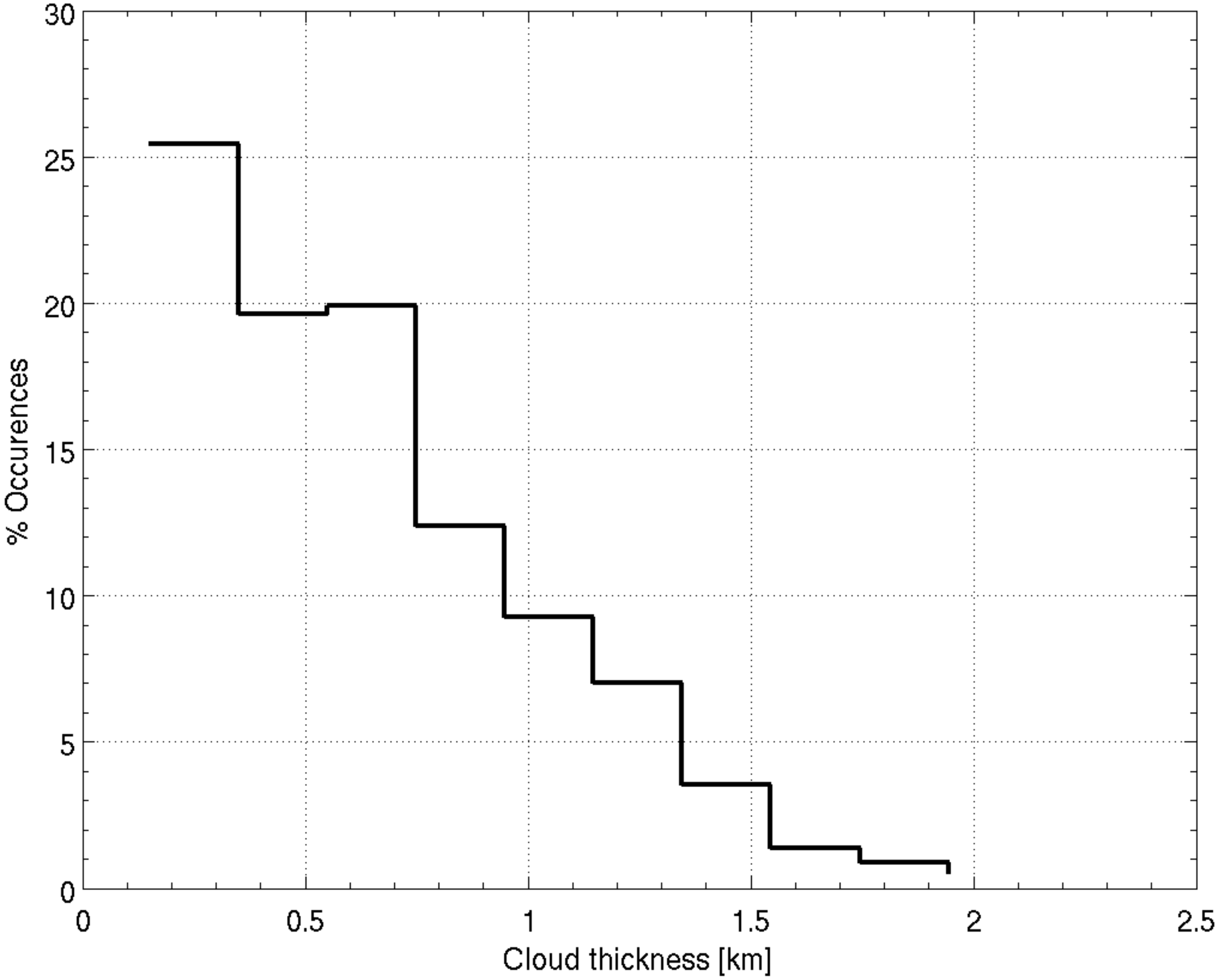




Length scale (m)=timescale (10 sec) x Advection speed(from sounding/profiler)

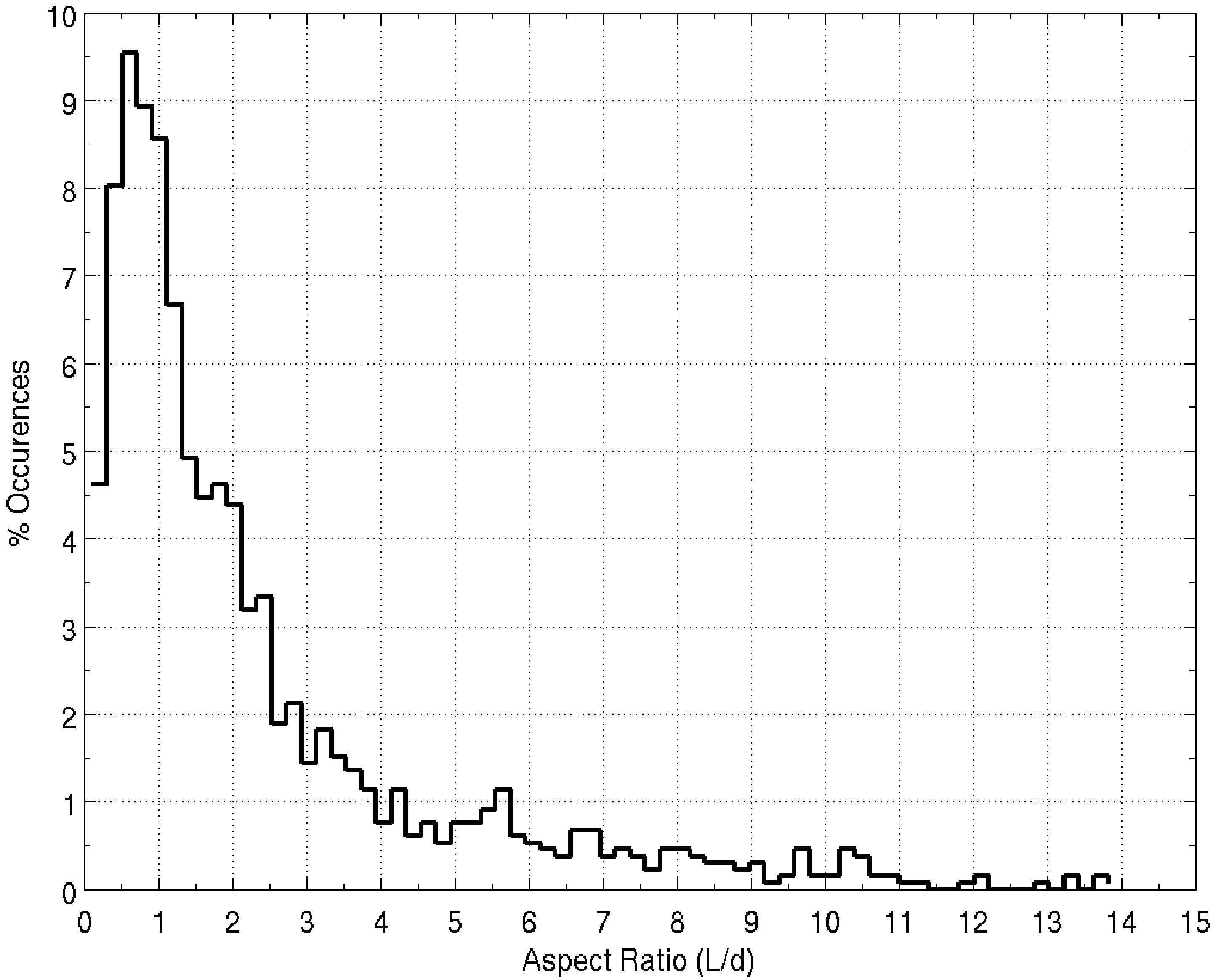
Note: bin size of 200 m and total of 1400 Shallow cumulus clouds.

Histogram of cloud thickness (D) of Sh.Cumulus Clouds



Note: Bin size of 200 m

Histogram of Aspect Ratios (L/D) of Sh.Cumulus Clouds

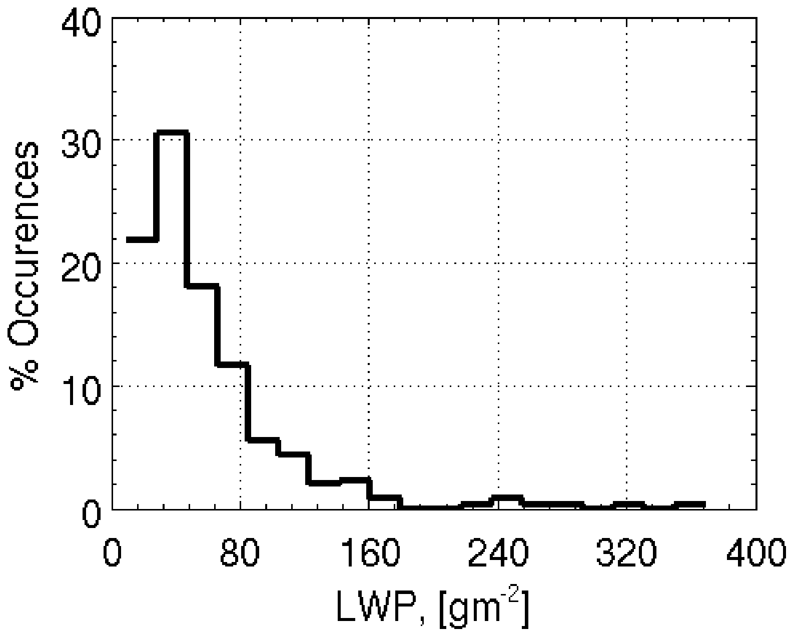


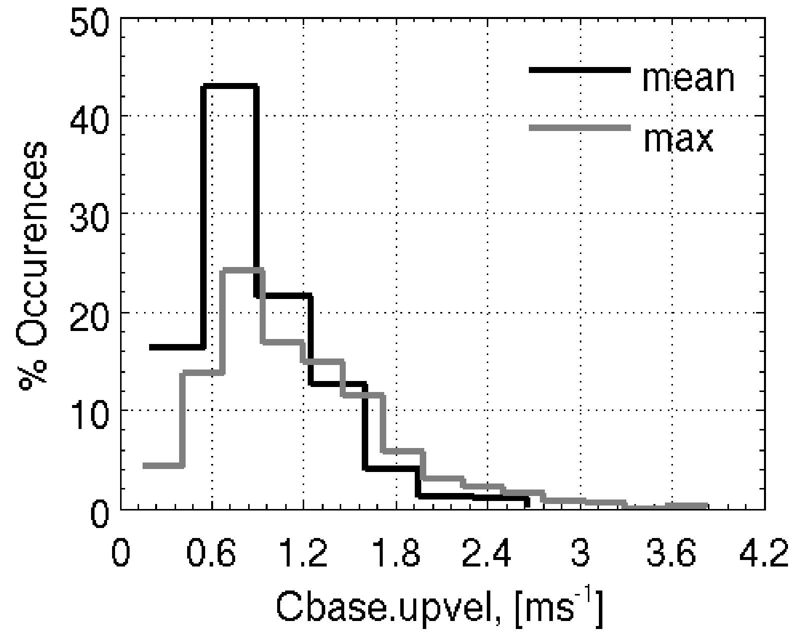
AR ratio<1: D>L

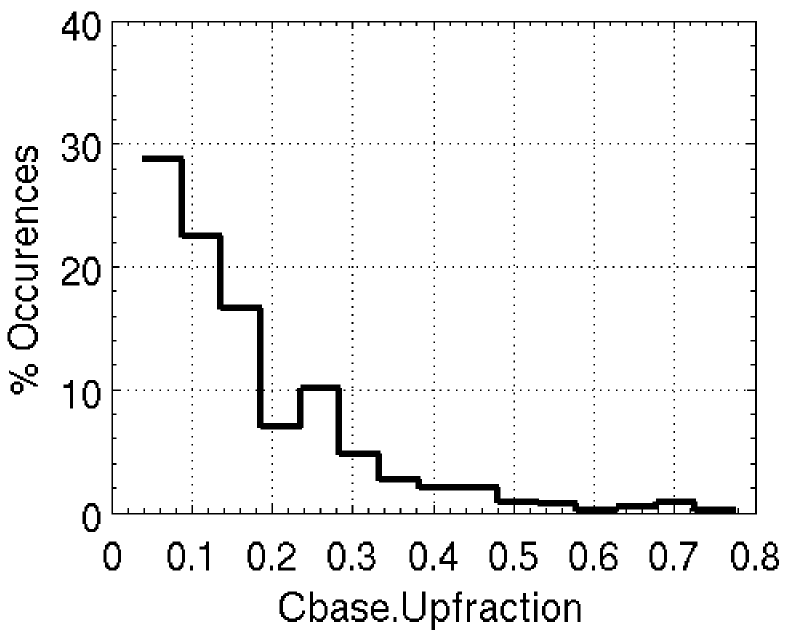
AR ratio>1: L>D

Note: Bin size of 0.1.

Histogram of LWP and Cloud base variables

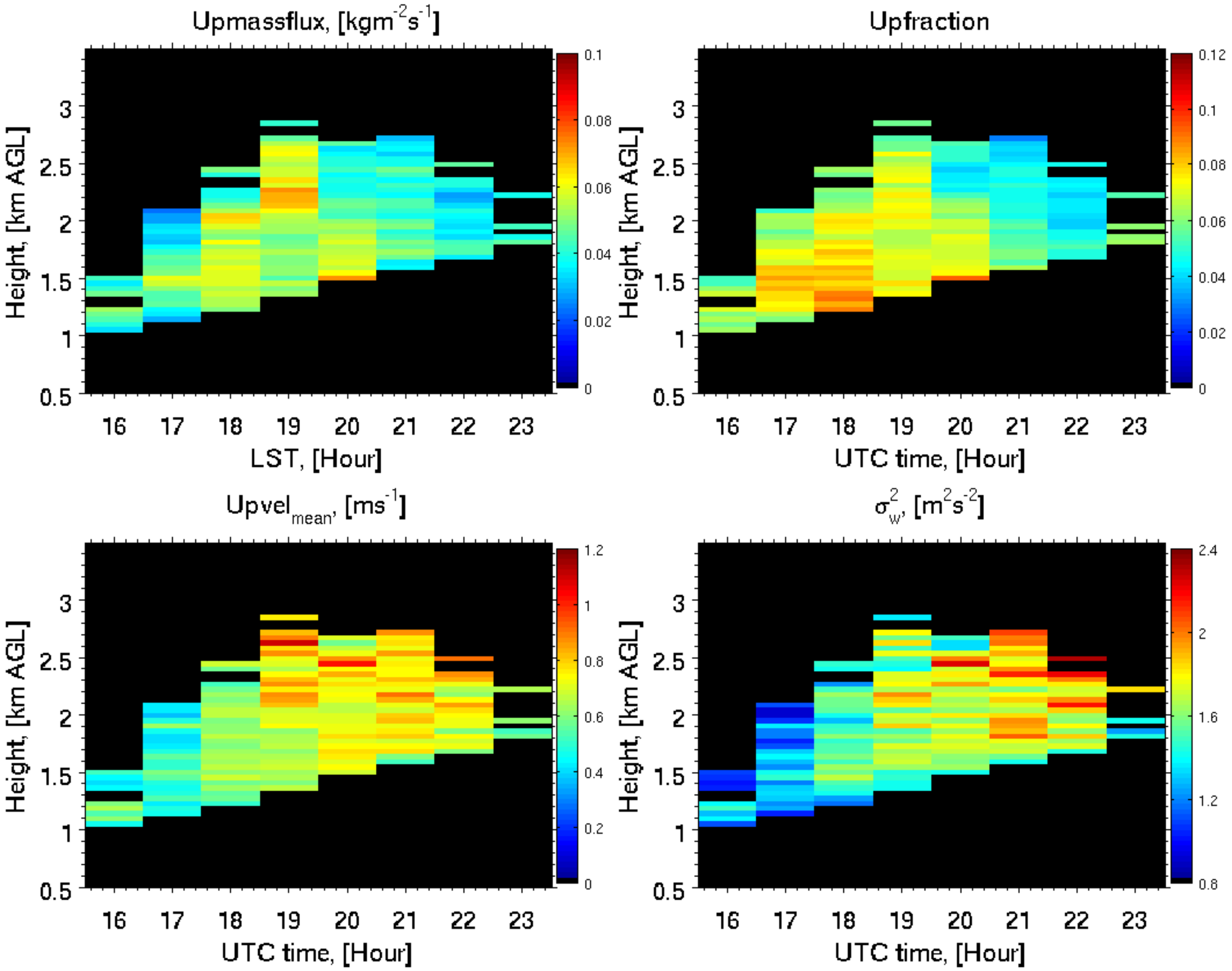






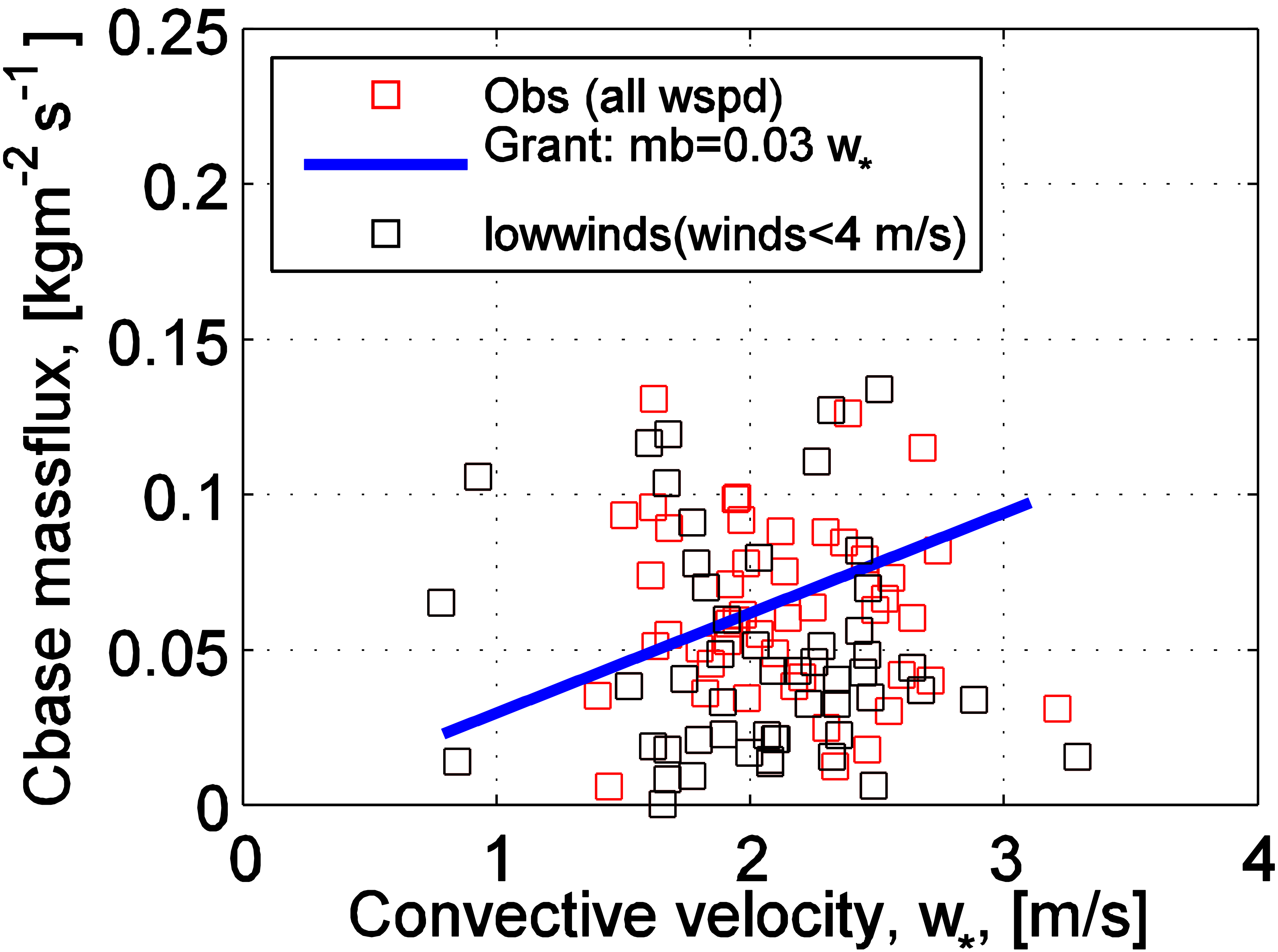
Histograms of a) Liquid water path (bin size of 20 g/m^2), b) Cloud base updraft velocity (bin size of 0.2 m/s), and c) Cloud base updraft fraction (bin size of 0.05) from 840 shallow cumulus hours.

Incloud composite turbulent statistics



a) Updraft massflux, b) Updraft Fraction, c) Mean upward velocity and d) Variance of vertical velocity inside shallow cumulus clouds

Comparison of updraft mass flux



Future work

- Study the possible factors (windshear, transition layer strength, tropospheric humidity, stability) which controlls the cloud-base massflux.

- Setting up a composite case study to simulate these observations in LES models.

Thank you !!

Questions & Suggestions ??