Observed Updraft & Mass Flux in Shallow Cumulus at SGP

Yunyan Zhang, Steve Klein and Pavlos Kollias

ARM CMWG meeting
November 2008, Princeton

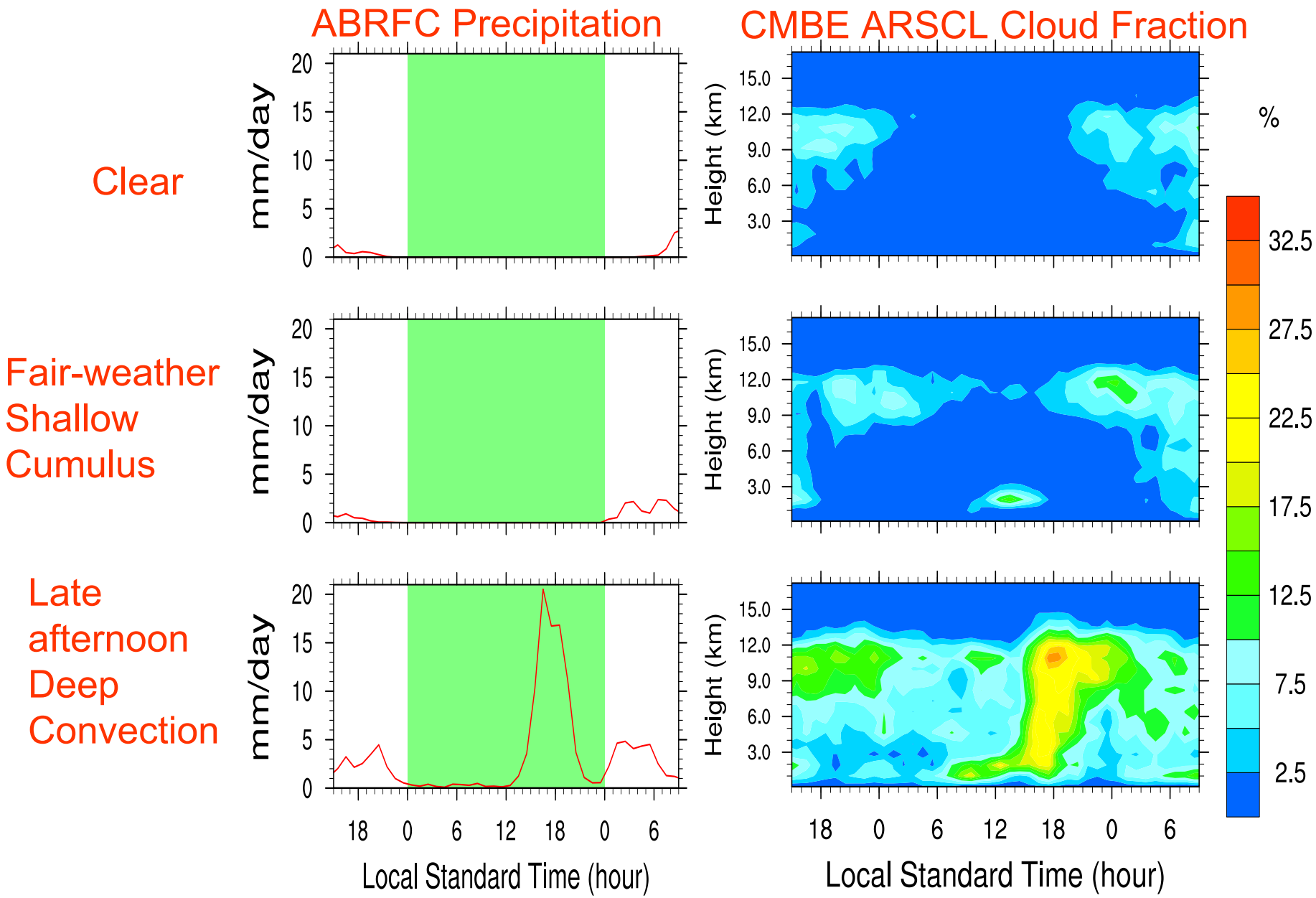
Thanks to Larry Berg, Renata McCoy and Shaocheng Xie

Motivation

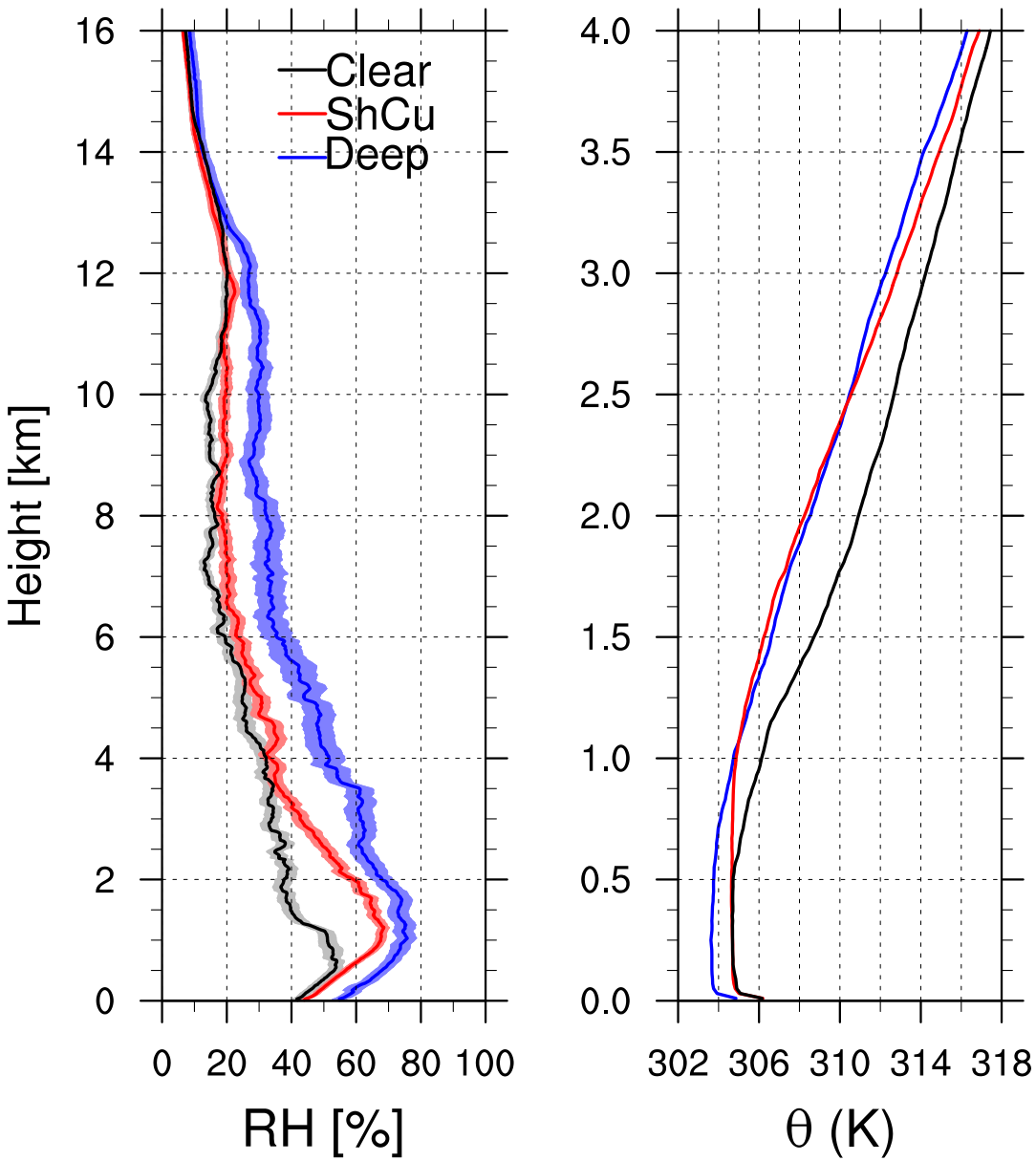
- What conditions favor different summertime convection regimes at SGP? e.g. fair-weather shallow cumulus or late-afternoon deep convection.

- What do observations of updraft / downdraft / mass fluxes look like and are these observations consistent with large-eddy simulation (LES) or traditional cumulus parameterizations?

Diurnal Cycles in Warm Seasons



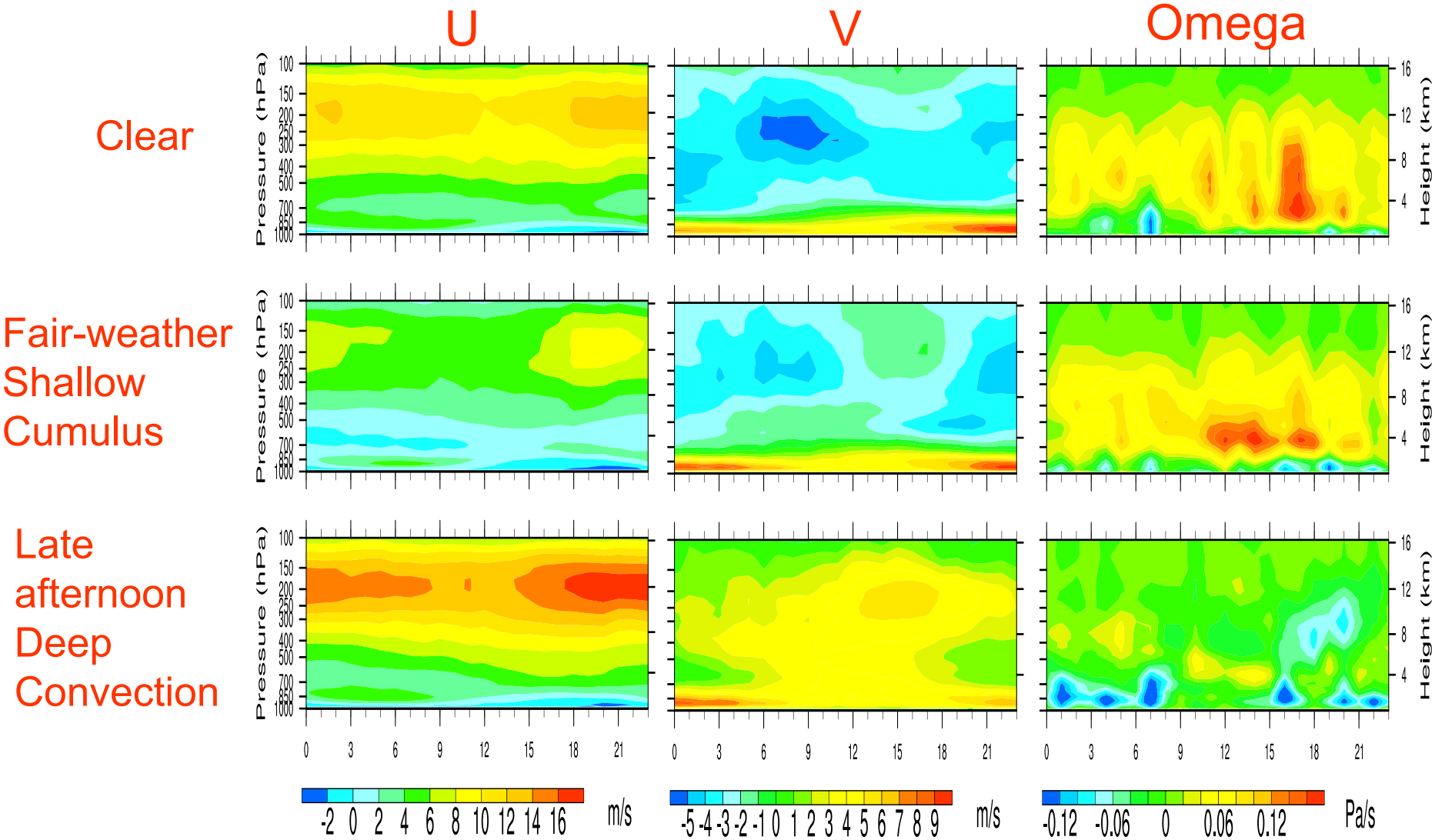
Sounding at 11:30 Local Time



DATA: LSSONDE

- A dry mid-troposphere environment favors shallow cumulus and suppresses deep convection. (Derbyshire, 2004; Kuang, 2006)
- Such moisture signature for different weather regimes is also evident in MWRRET column water vapor and AERI mixing ratio data.

Large-scale Wind Fields



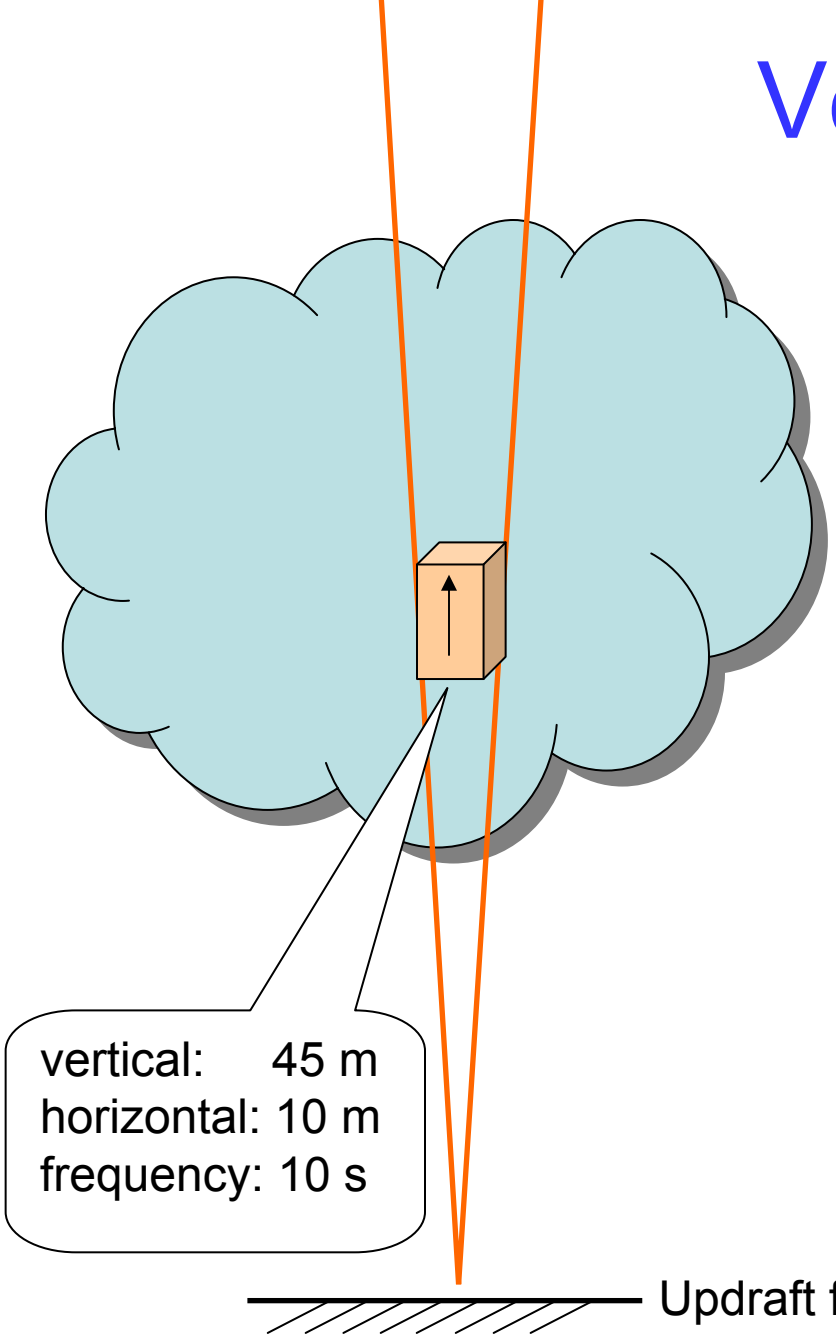
DATA: NCEP MOLTS

Remarks on Diurnal Cycles

- Different weather regimes in summertime at SGP are successfully identified based on ABRFC precipitation and ARSCL cloud fraction.

- Such diurnal cycle categorization is applied to ARM archived observations, especially value-added products, such as LSSOND, NCEP MOLTS, EBBR for surface fluxes, SMOS and OK Mesonet for surface measurement, SWATS for soil moisture, AERI measurement for boundary layer, CMBE TSI, MWRRET PWV and LWP, WP mixed-layer depth and so on.
  - Document diurnal cycles and compare differences
  - Validate known theories from modeling studies

Vertical Velocity Data



- From Pavlos Kollias
- MMCR measures vertical velocity of cloud liquid droplets
- We assume the terminal velocity of a cloud droplet is small (~cm/s), thus the vertical velocity of cloud droplets is equal to the vertical velocity of air
- There is no retrieval in clear air nor the precipitating part of the cloud; it is particularly good for non-precipitating liquid-phase shallow cumulus
- Hourly average, from 1999 to present

Data:

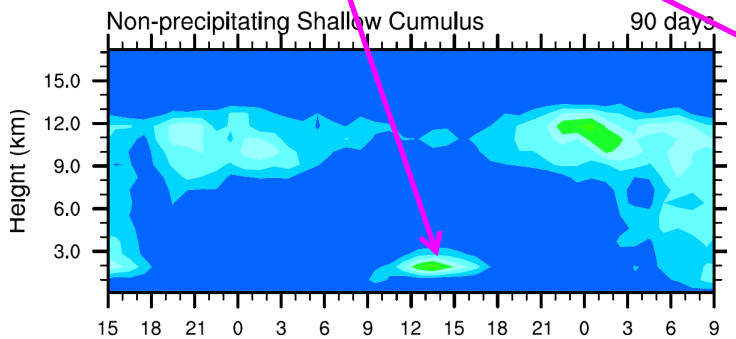
- Hydrometeor fraction / low-dBZ fraction
- In-cloud Updraft / downdraft
- In-cloud updraft / downdraft fraction

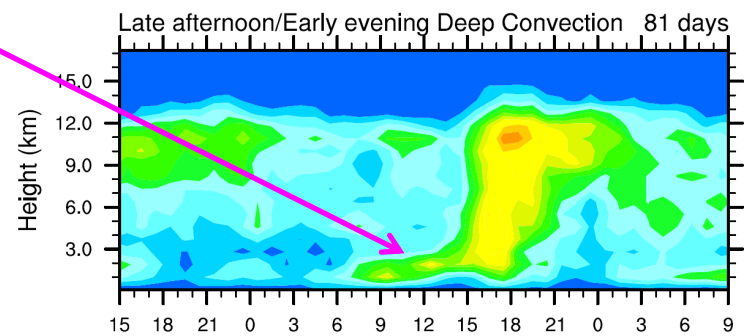
Updraft fraction = cloud fraction * in-cloud updraft fraction

Updraft mass flux = updraft fraction * updraft velocity

Methodology

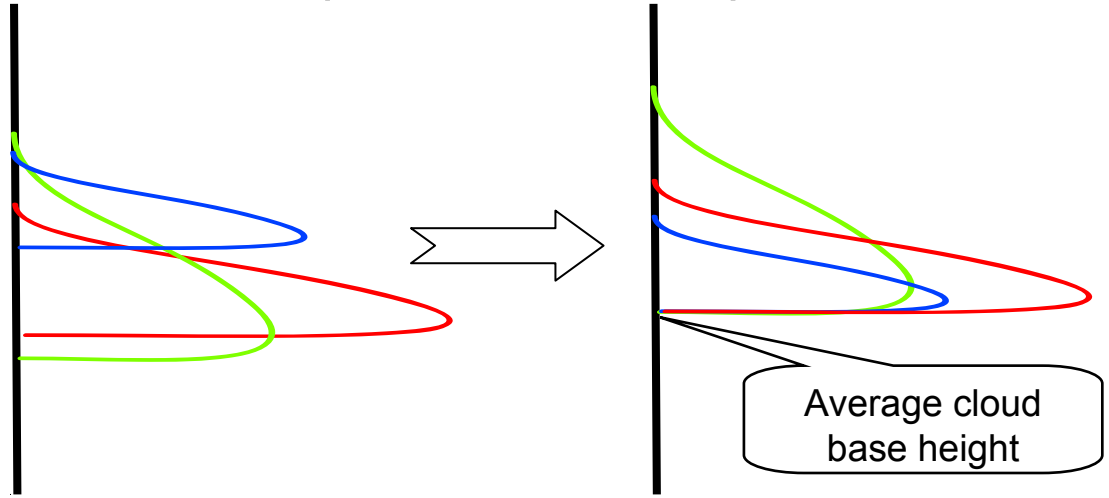
- Make diurnal composites for different categories in warm seasons:
  - Fair-weather non-precipitating shallow cumulus
  - Shallow cumulus before late-afternoon deep convection





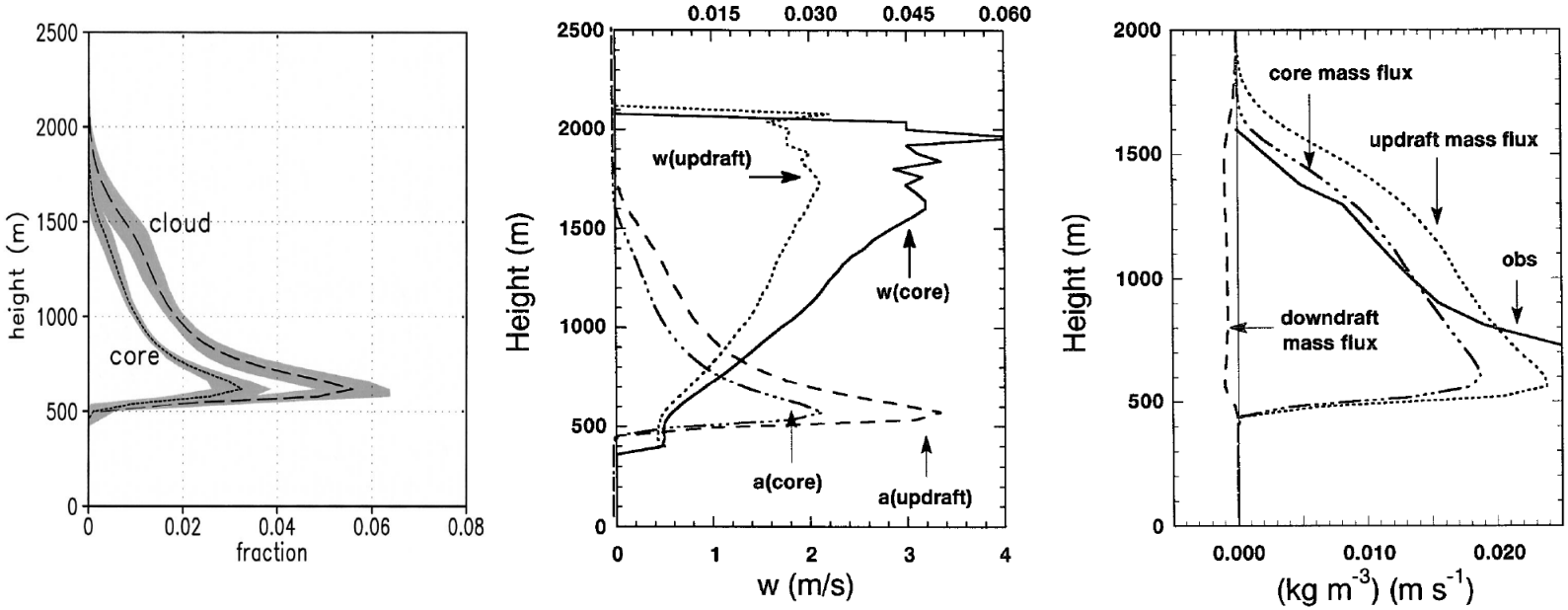
- How to average clouds with different cloud base heights and preserve the intrinsic shape of the vertical profiles?

e.g. Mass Flux



Non-Precipitating Shallow Cumulus

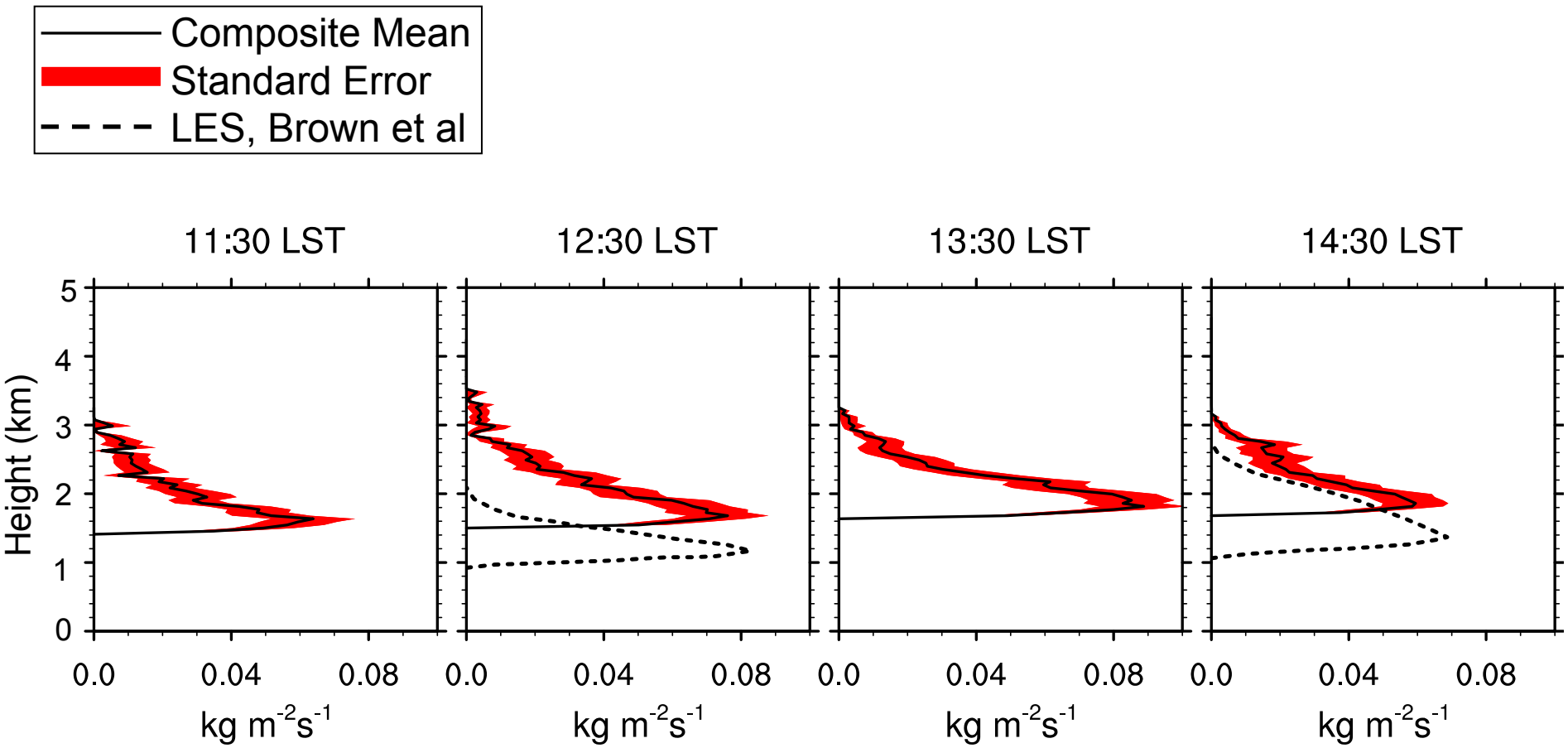
- What do we know from LES? (BOMEX, an ocean case)



Figures from Siebesma and Cuijpers 1995; Siebesma et al, 2003

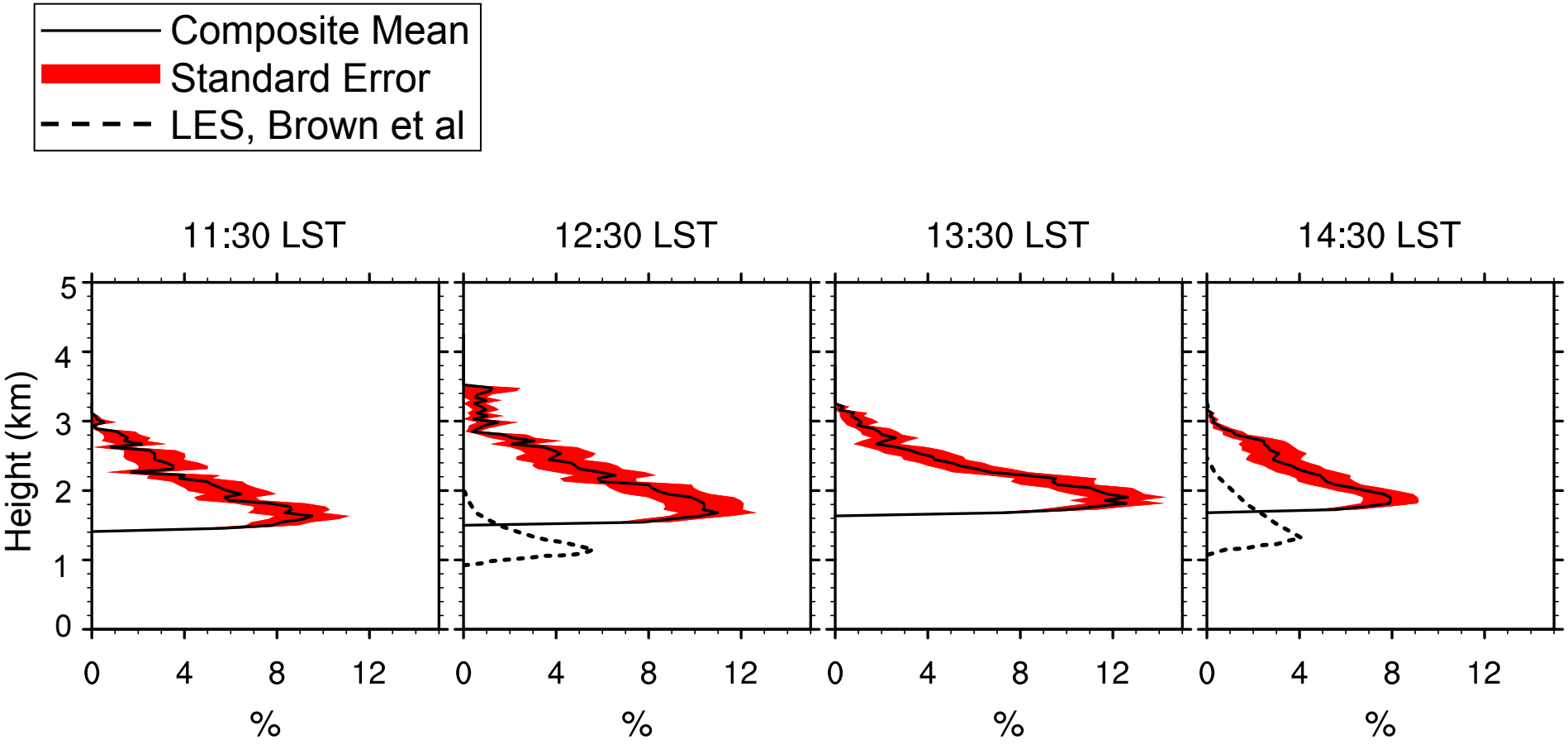
  - Cloud fraction, updraft fraction updraft mass flux peak above cloud base and then decrease with height
  - Updraft velocity increases with height
  - Updraft fraction dominates in cloud fraction
  - Updraft mass flux dominates in net mass flux
- Brown et al, 2002 (SGP, 06/21/1997, a land case)
  - Similar profile shapes are shown for updraft fraction and updraft mass flux
  - This one day simulation will serve as a qualitative comparison in the following

Updraft Mass Flux



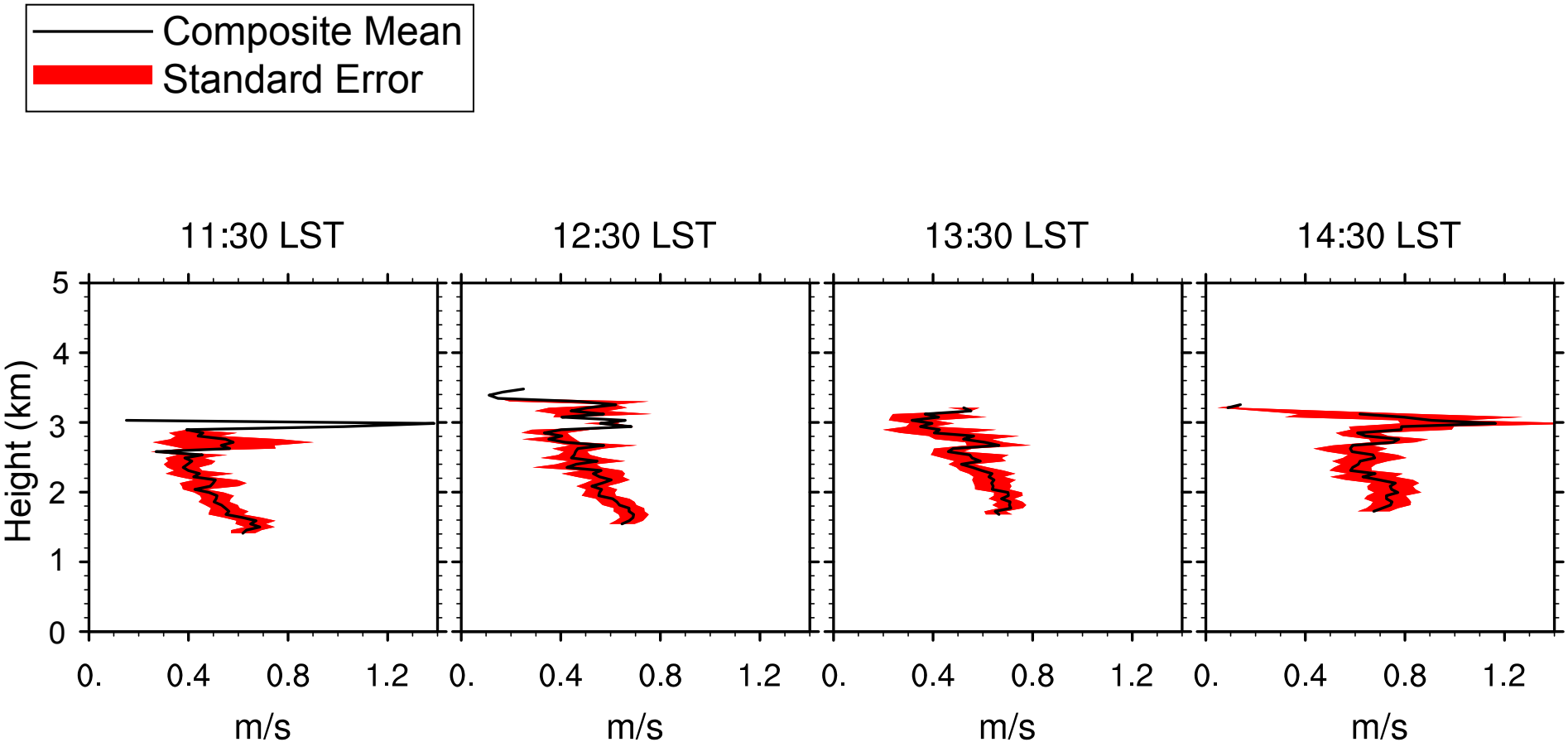
Updraft mass flux = updraft fraction * updraft velocity

Updraft Fraction

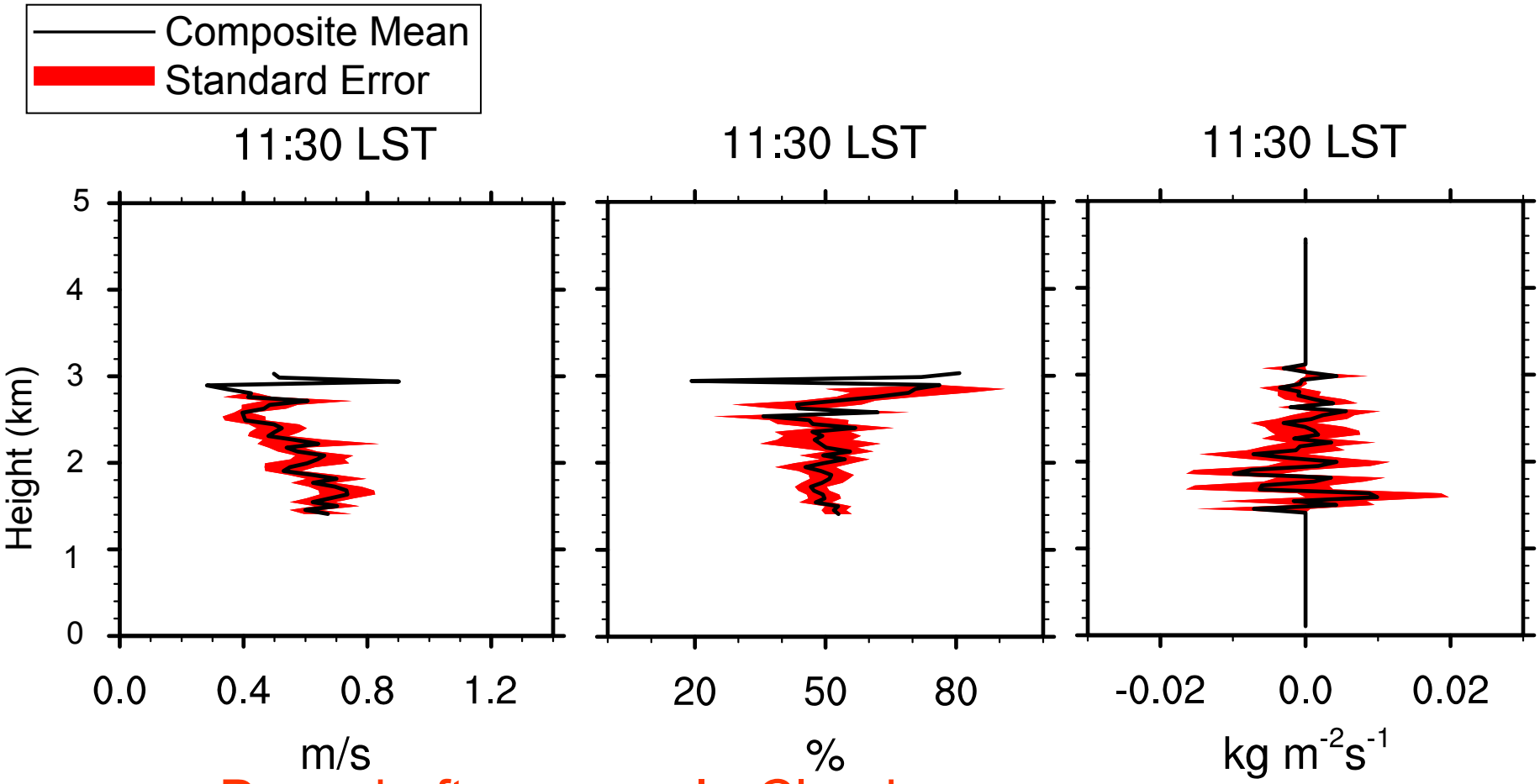


Updraft fraction = cloud fraction * in-cloud updraft fraction

In-Cloud Updraft



Downdraft & Net Mass Flux

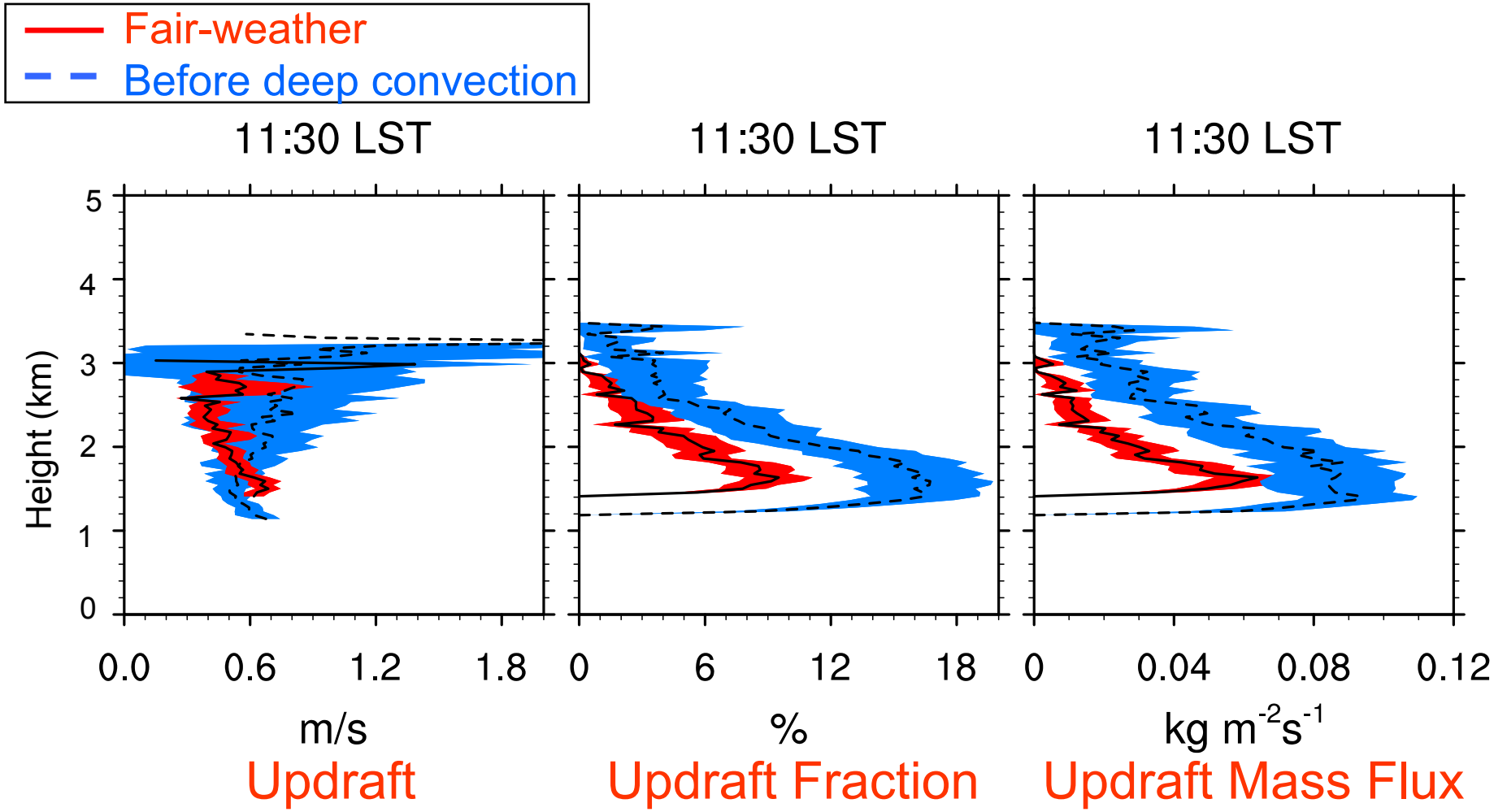


Downdraft

In-Cloud Downdraft Fraction

Net Mass Flux

Fair-weather vs. before Deep Convection



Remarks on Shallow Cumulus

- Observed composite updraft fraction and updraft mass flux are comparable to LES results in both magnitudes and the shapes of vertical profile.

- Observed composite updraft has magnitude below 1m/s and decreases with height. The composite updraft mass flux does not dominate in the composite net mass flux; this is because observed downdraft and updraft have very similar statistics.
  - These observations are not what we expected according to BOMEX, an ocean case.
  - Are these specific features for shallow cumulus over land? If so, how do we explain it?
  - Will LES help if we try similar sampling and compositing as observations?