- **Suppressed environments favorable for low clouds**
  - significant (but not overwhelming) subsidence ($1 \rightarrow 3\ \mu bar\ s^{-1}$)
  - adequate BL water vapor
  - source of BL TKE
  - saturation beneath inversion
  - shallow clouds dominate regardless of time of day

- **Cloud systems**
  - eastern ocean stratocumulus
  - northern ocean and Arctic stratus
  - wintertime continental stratocumulus
  - continental forced cumulus
  - subtropical ocean trade cumulus

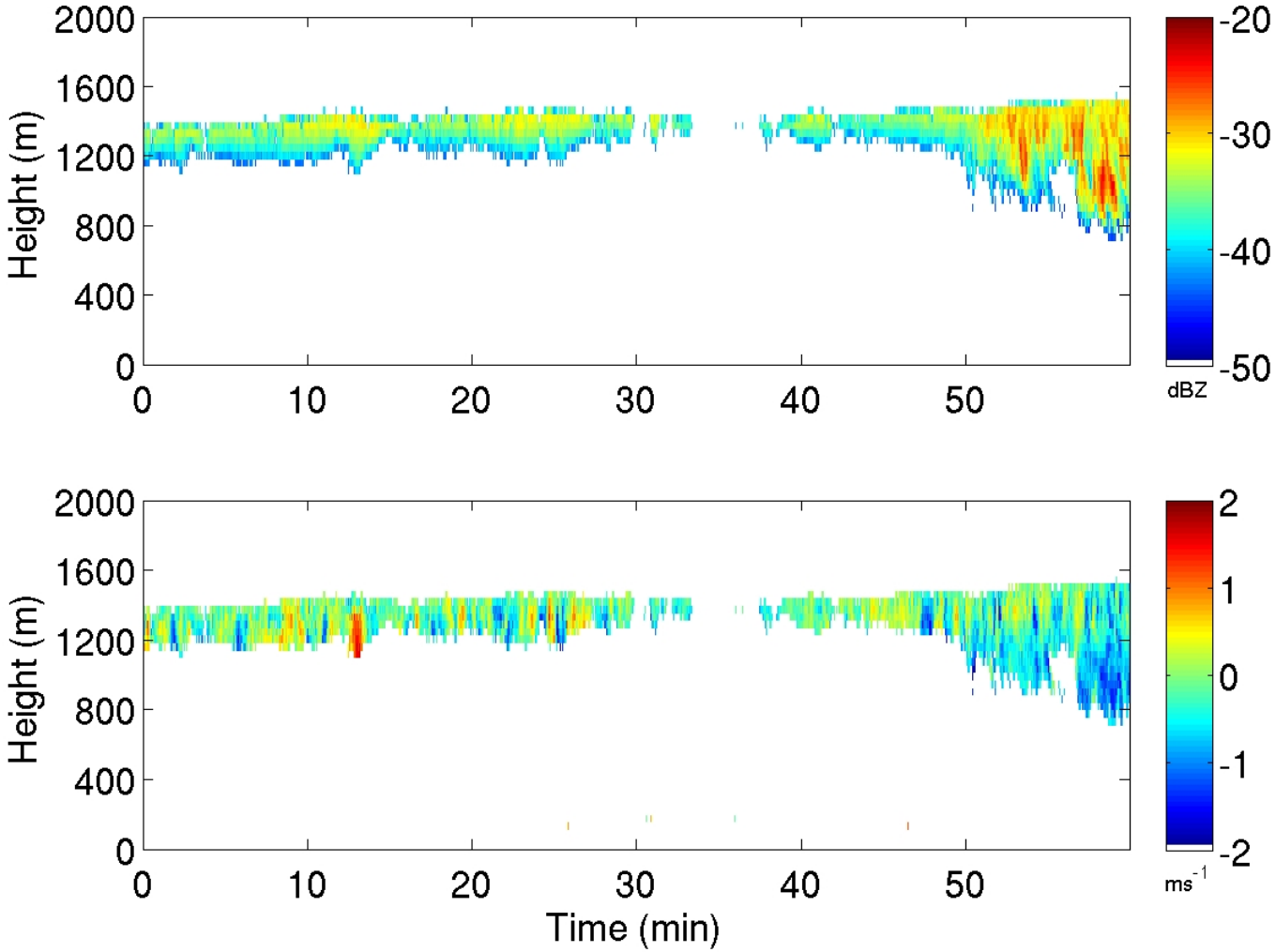
St/Sc/Cu Cloud Processes Agenda

- Robert Wood, University of Washington
- Peter Bogenschutz, NCAR
- Jim Hudson, Desert Research Institute
- Kuanman Xu / Anning Cheng, NASA Langley
- Steve Klein, Lawrence Livermore National Laboratory
- Mark Miller, Rutgers University

Session Goals

- Are there scientific areas of common interest that reach the level of focus group?
  - specific science questions surrounding a single theme
  - important for model development/improvement
  - sufficient confidence that progress can be made
  - organized and accountable effort
    - regularly report findings to SISC and to ASR Science Team
  - product is improved basic physical understanding at a process level
- Intensive Observation Periods (IOPs)?
  - Propose new IOPs or support existing efforts
- Interest groups?

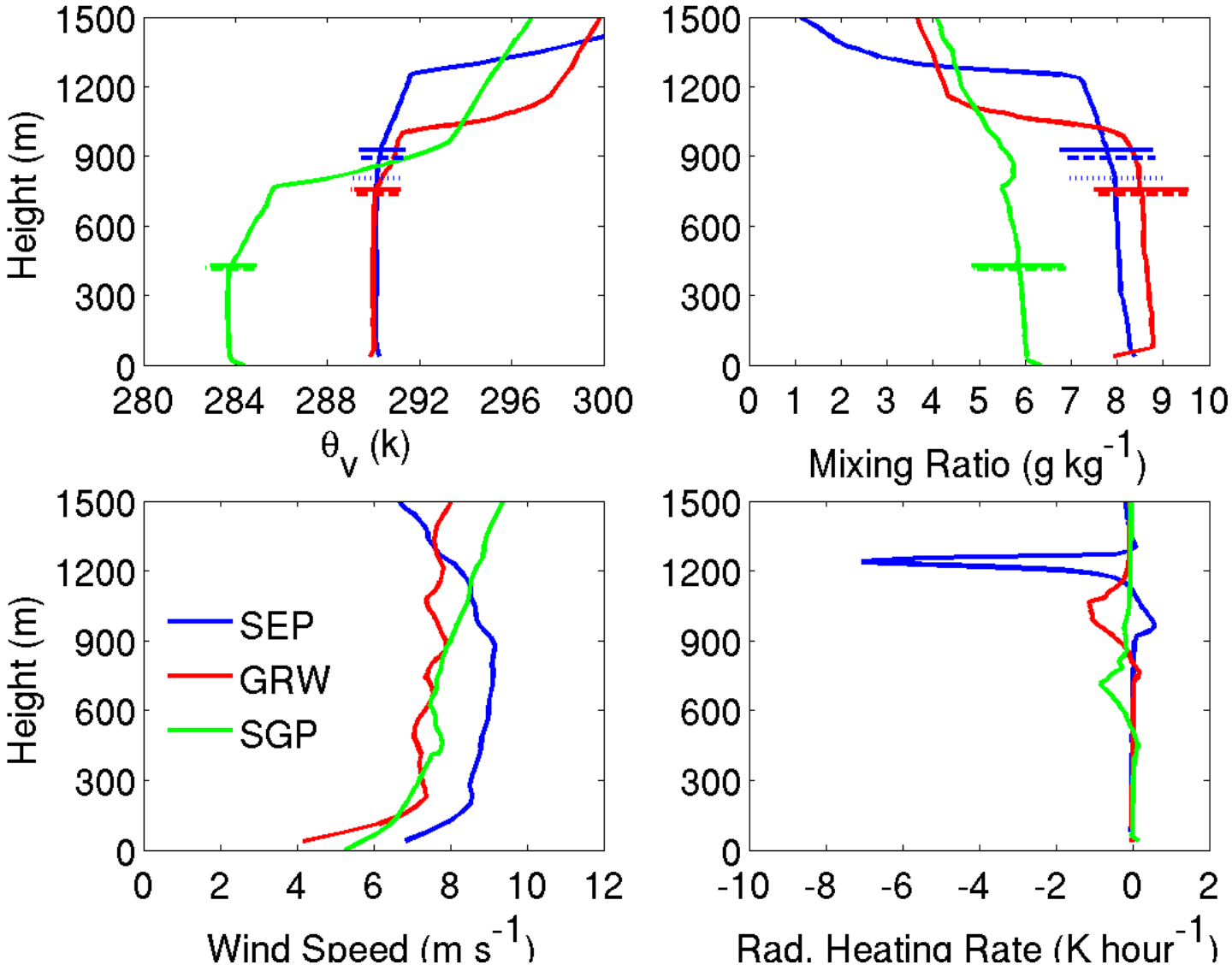
STRATOCUMULUS



BL Classification at GRW

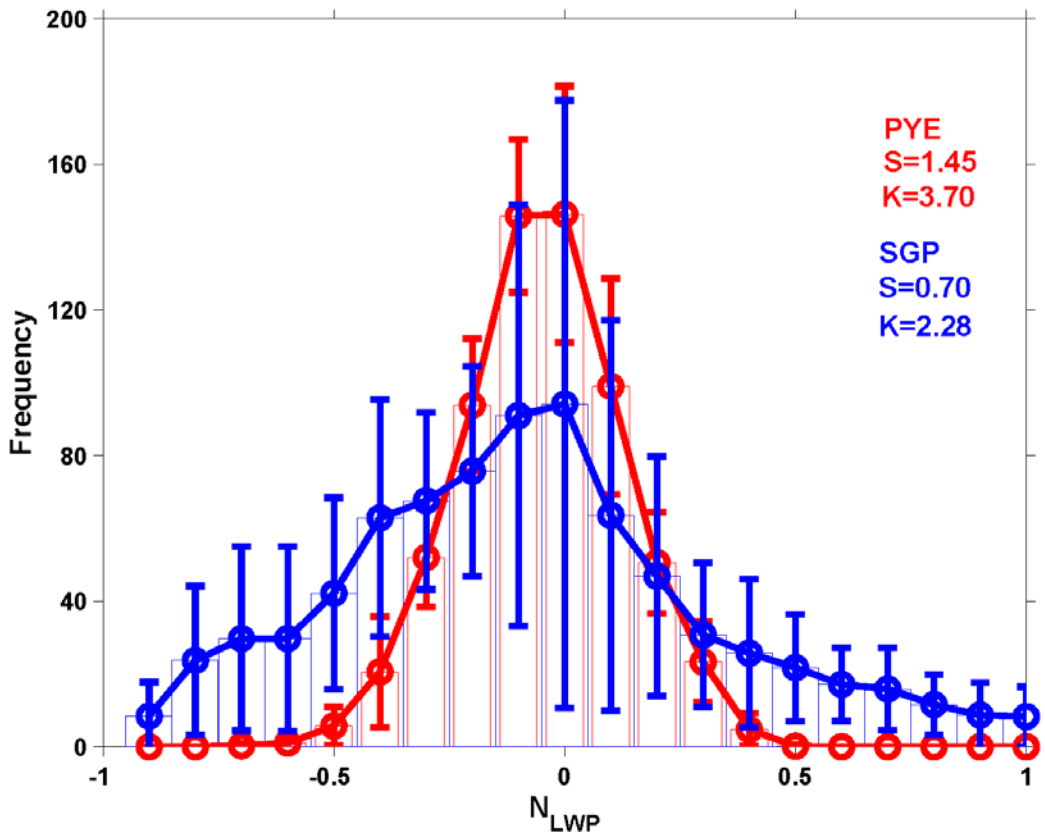
564 Soundings

Regime	Number of Radiosondes		
Clear Sky	292	52%	
Uniform Stratocumulus	104	18%	36%
Broken Stratocumulus	98	18%	
Cumulus	70	12%	



Ghate, Miller, Albrecht, and Fairall

Stratocumulus LWP Variability



Blue: SGP
Red: PYE

Joint PDFs with model predicted variables?

Yoo-Jun Kim et al., 2012

Aerosol Indirect Effects and Static Stability

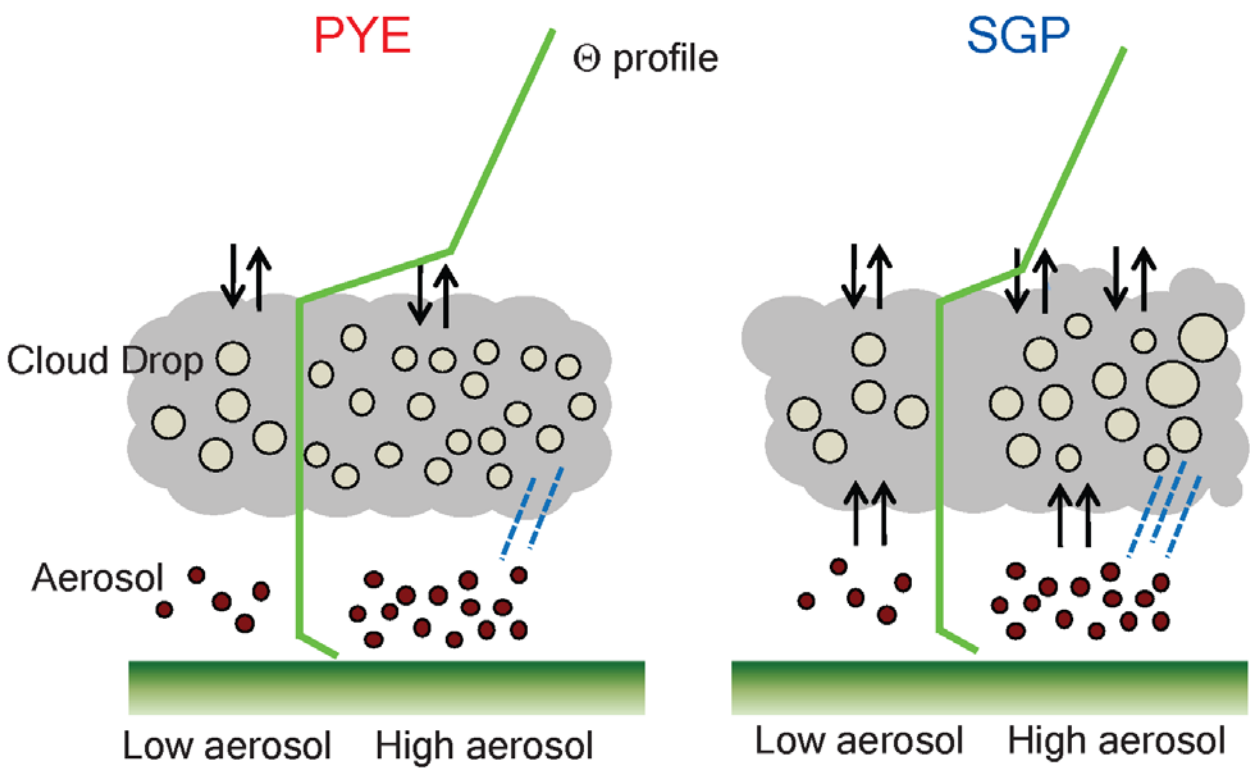
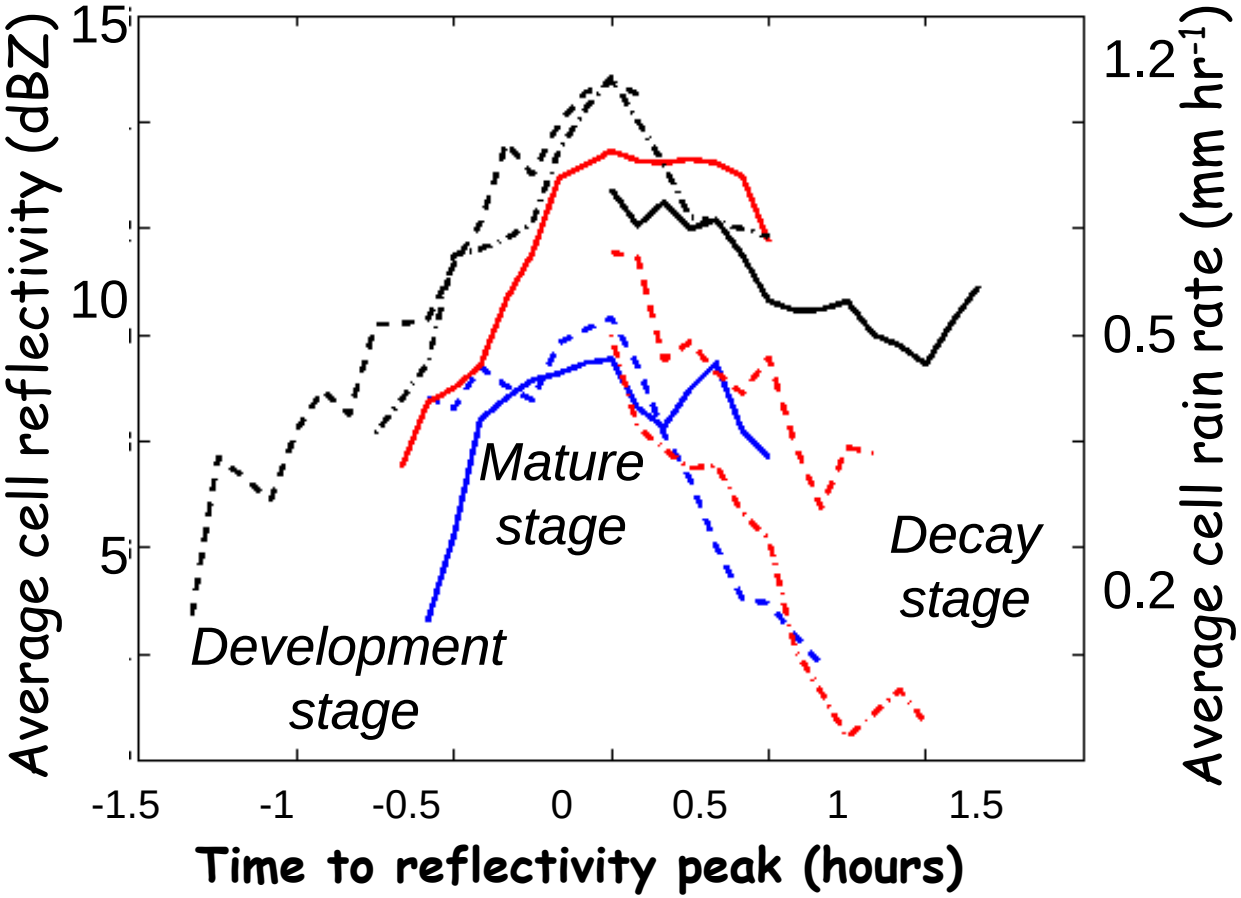


Figure 10

Connections between surface CCN, stability, and cloud droplet distribution?

Yoo-Jun Kim et al., 2012

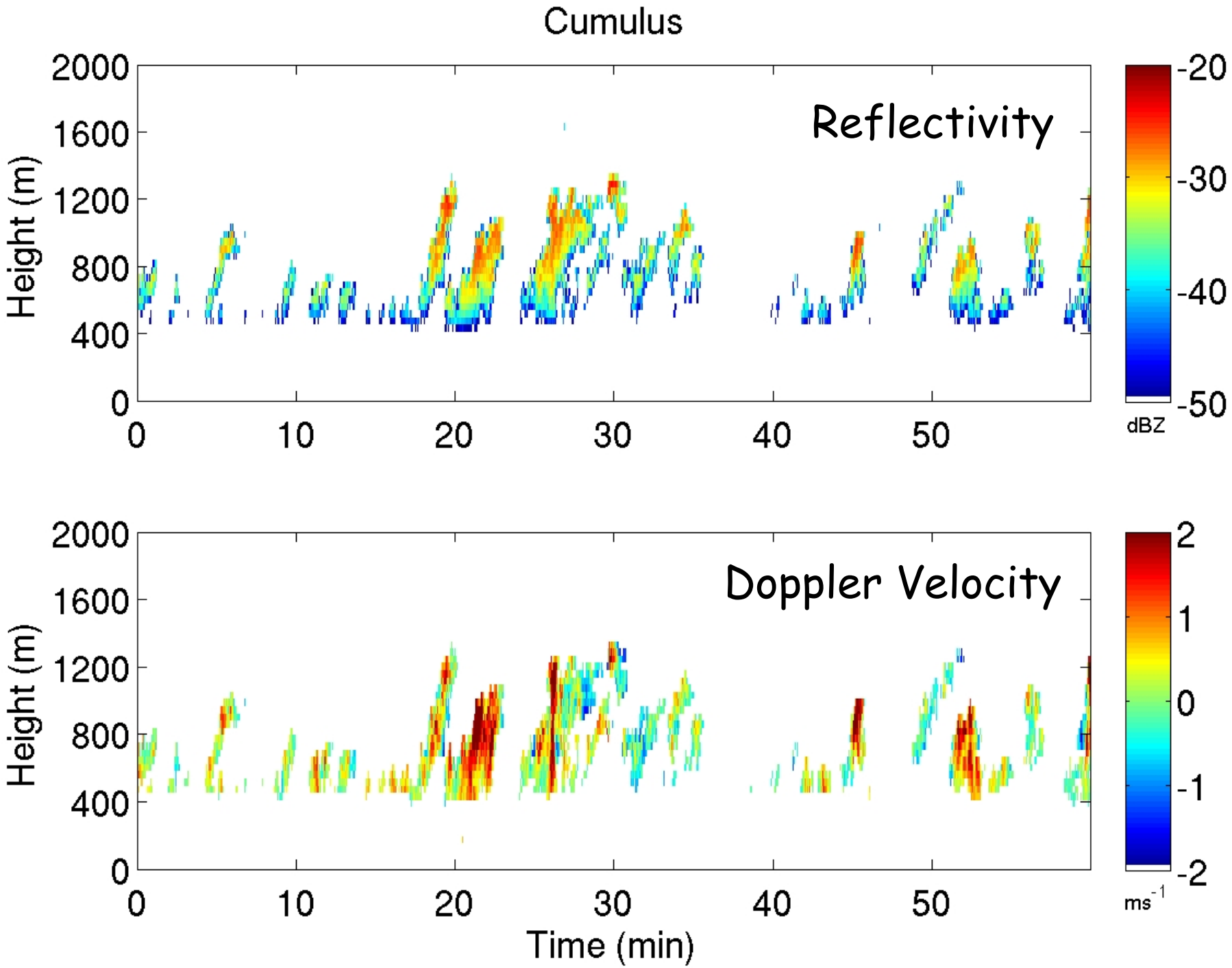
Drizzle cell evolution (EPIC 2001)



- Tracked 8 example cells
- Drizzle cell lifetime 2+ hours
- Time to rain out: t ~ LWP/R ≅ 30-60 min
- Implies replenishing cloud water

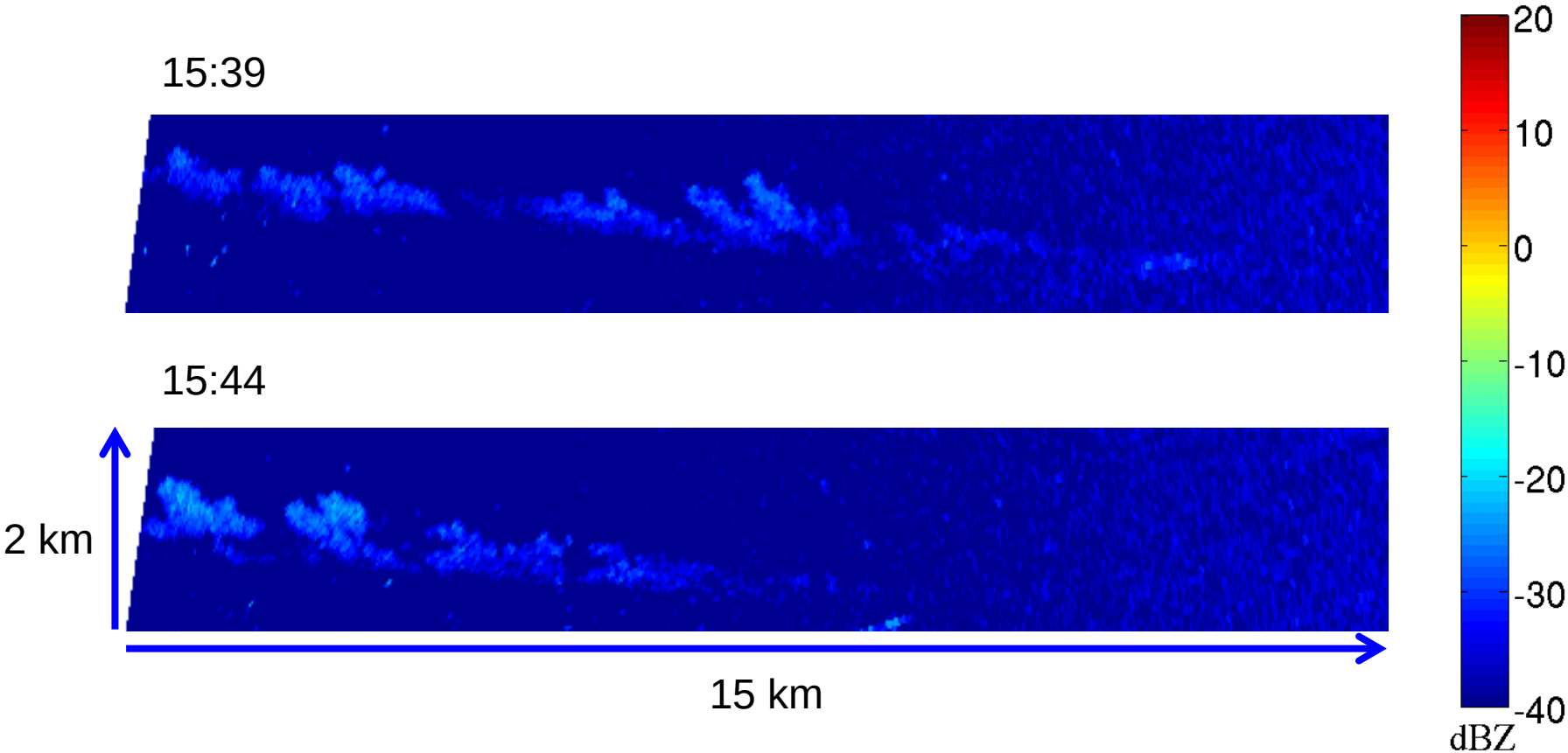
Comstock et al. 2005

FAIR WEATHER CUMULUS

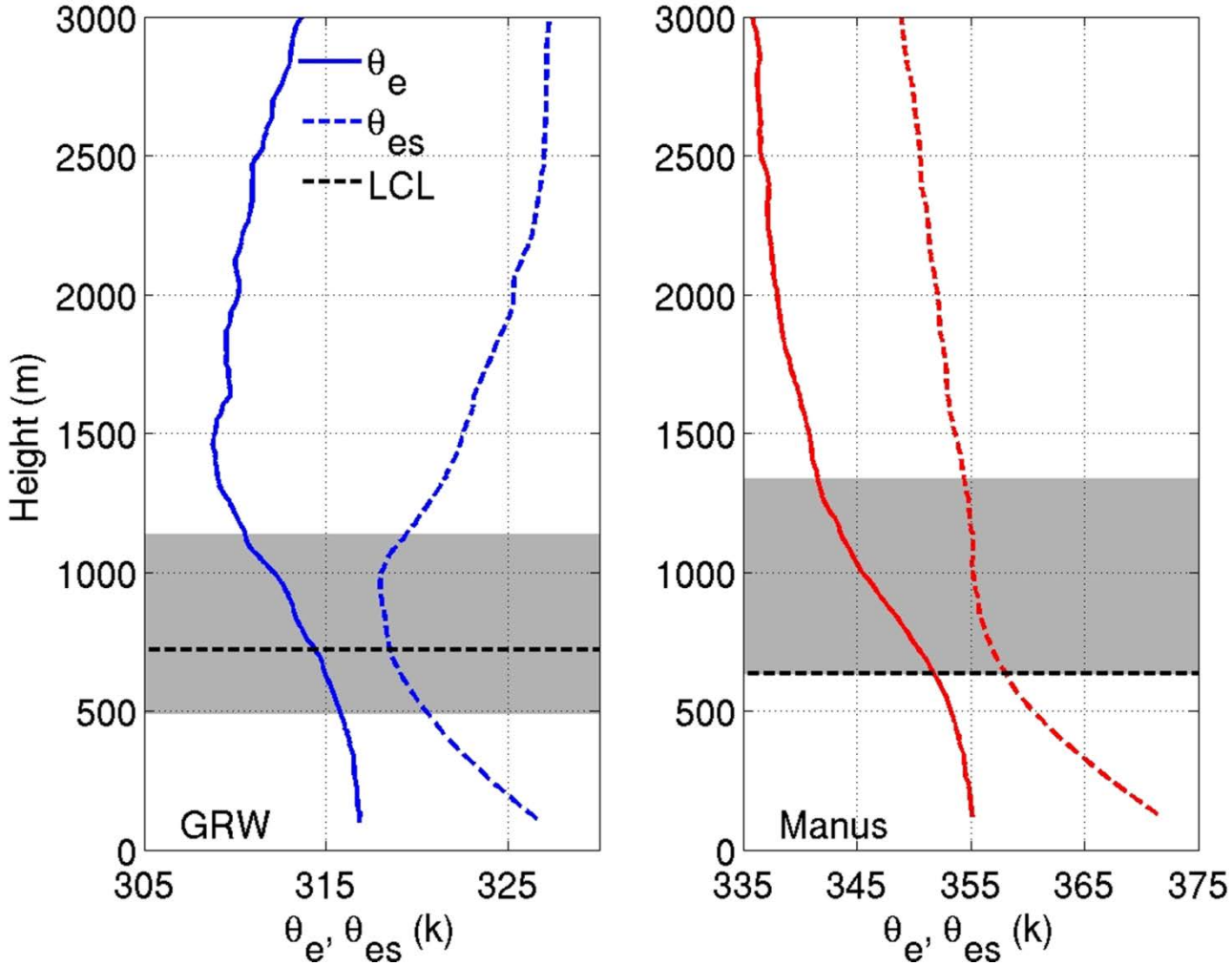

Cumulus
Reflectivity
Height (m)
2000
1600
1200
800
400
0
0
10
20
30
40
50
-20
-30
-40
-50
dBZ
Doppler Velocity
Height (m)
2000
1600
1200
800
400
0
0
10
20
30
40
50
2
1
0
-1
-2
ms-1
Time (min)

A Slice of Life: Shallow Cu

July 24, 2013 TCAP Cape Cod, MA



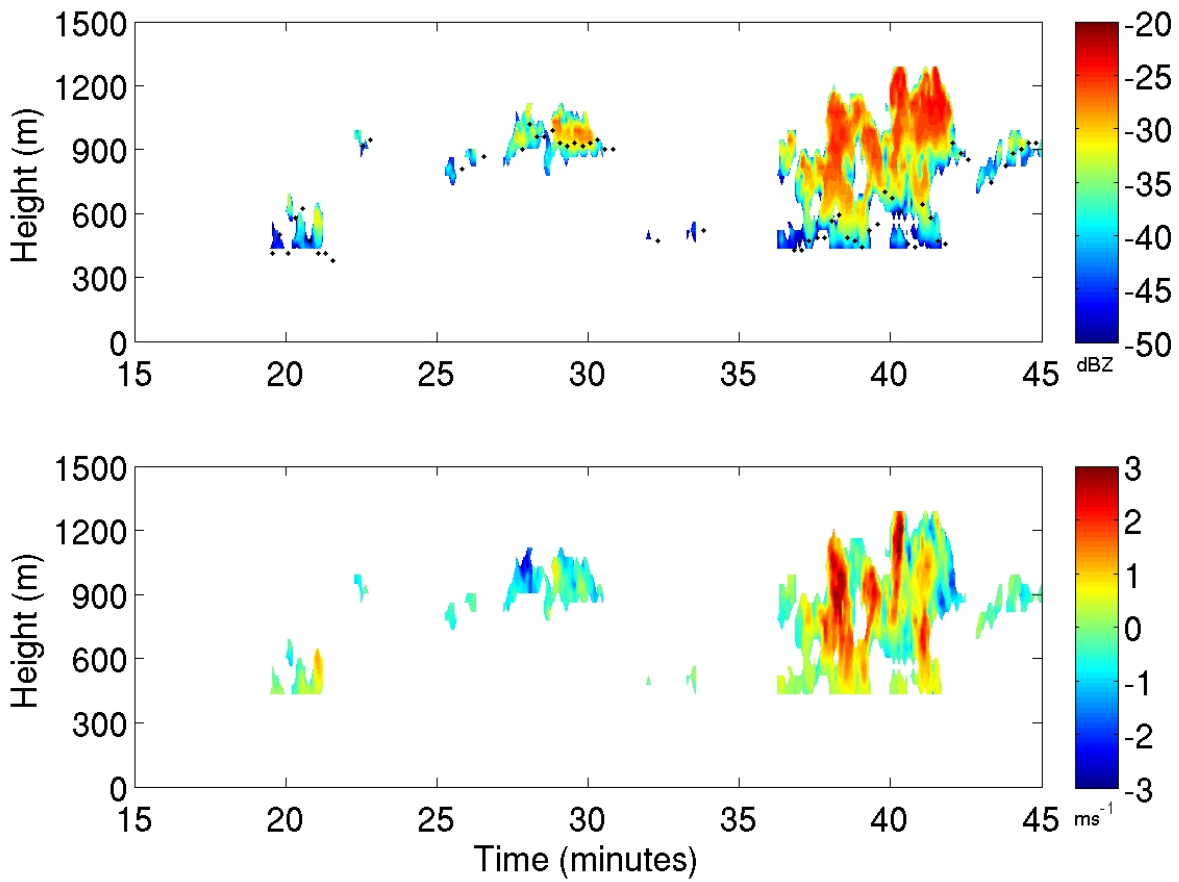
Shallow Cu: GRW and Manus



Ghate et al. 2013

Some Required Observations

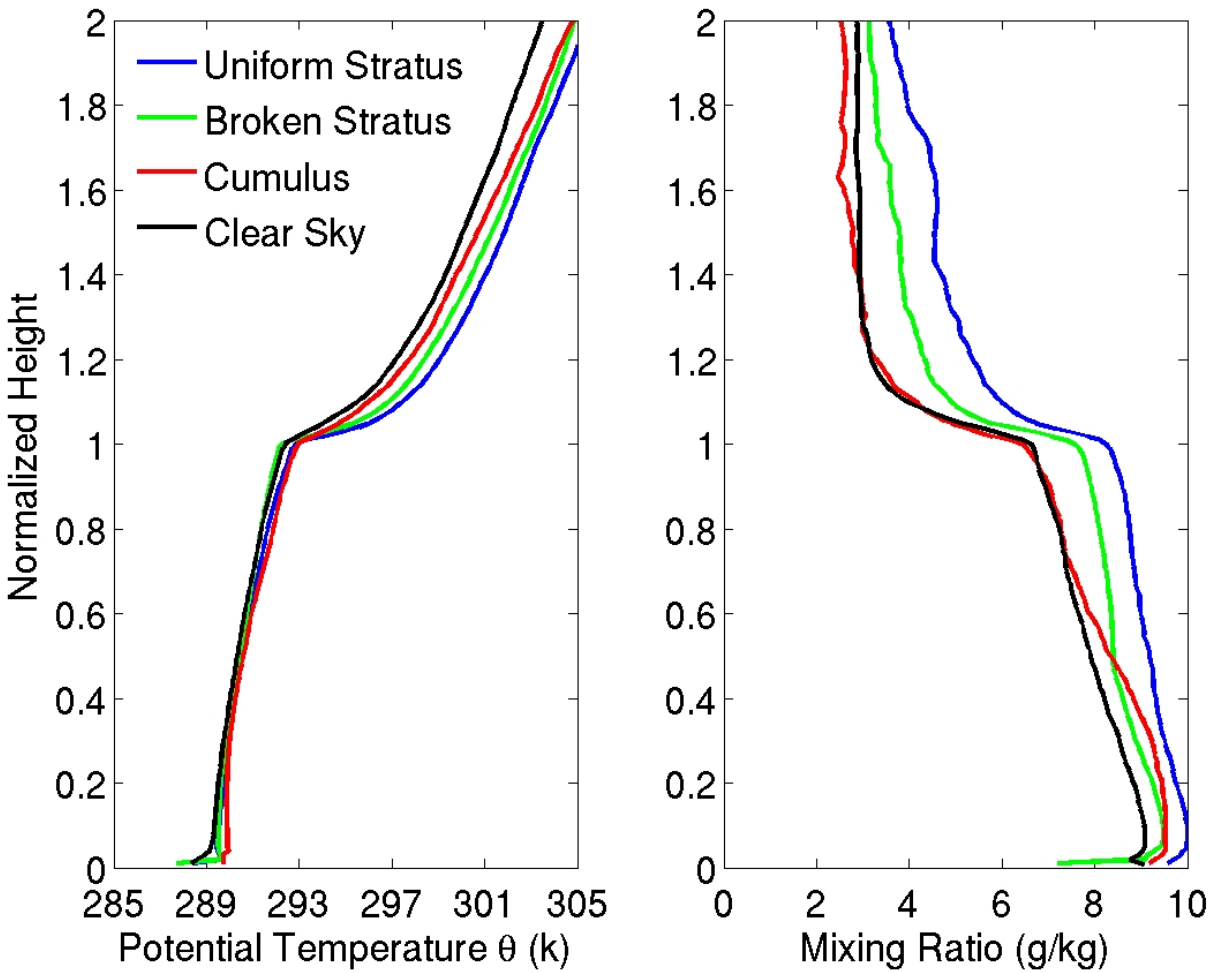
- **Dynamic and Thermodynamic Environment**
  - *continuous profiles of temperature and water vapor*
  - ω_{850} and ω_{700}
  - advections
- **Cloud Boundaries and Cloud Liquid Water Content (LWC)**
  - *accurate and high frequency*
- **Surface Radiation**
  - hemispheric and Narrow-field of View SW and LW
- **Turbulence**
  - *transports in BL (SH and LH fluxes, aerosols, drizzle)*
- **Drizzle**
  - *liquid water flux at cloud base and evaporation rate in subcloud layer*
- **Cloud-Aerosol Interactions**
  - aerosol activation spectrum
- **Mesoscale Structure**
  - *modulation cloud LWC*



Cloud radar effective reflectivity factor (dBZ) and optical cloud base (top) and mean Doppler velocity in ms^{-1} (bottom)

Ghate et al., 2011

Low Clouds at GRW



Ghate and Miller, 2011

Tropical Low Clouds

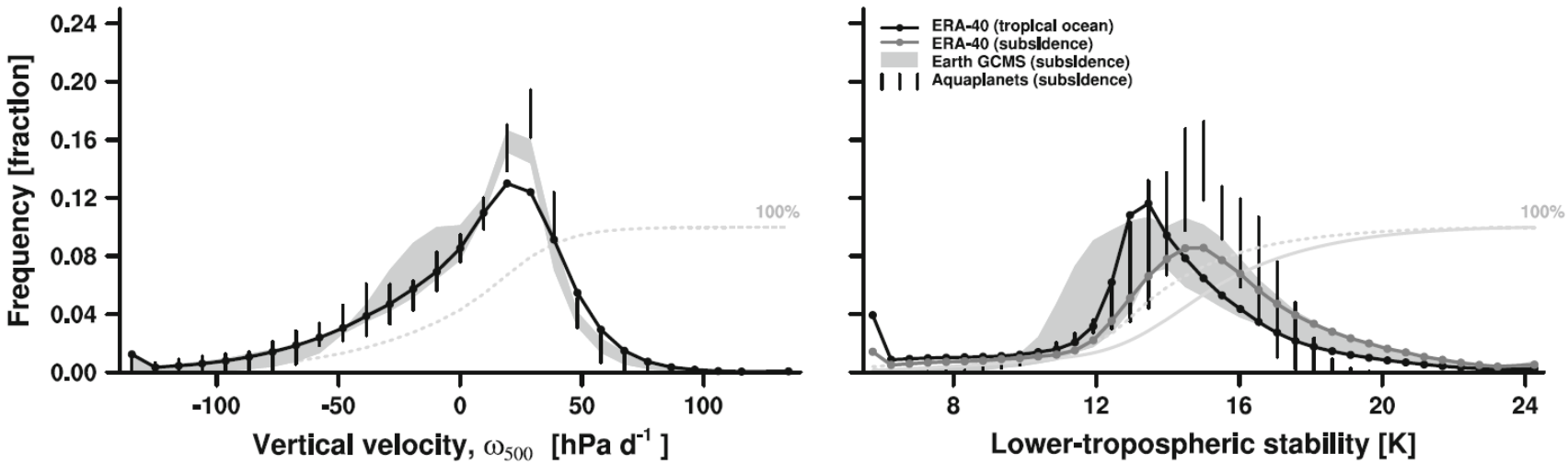
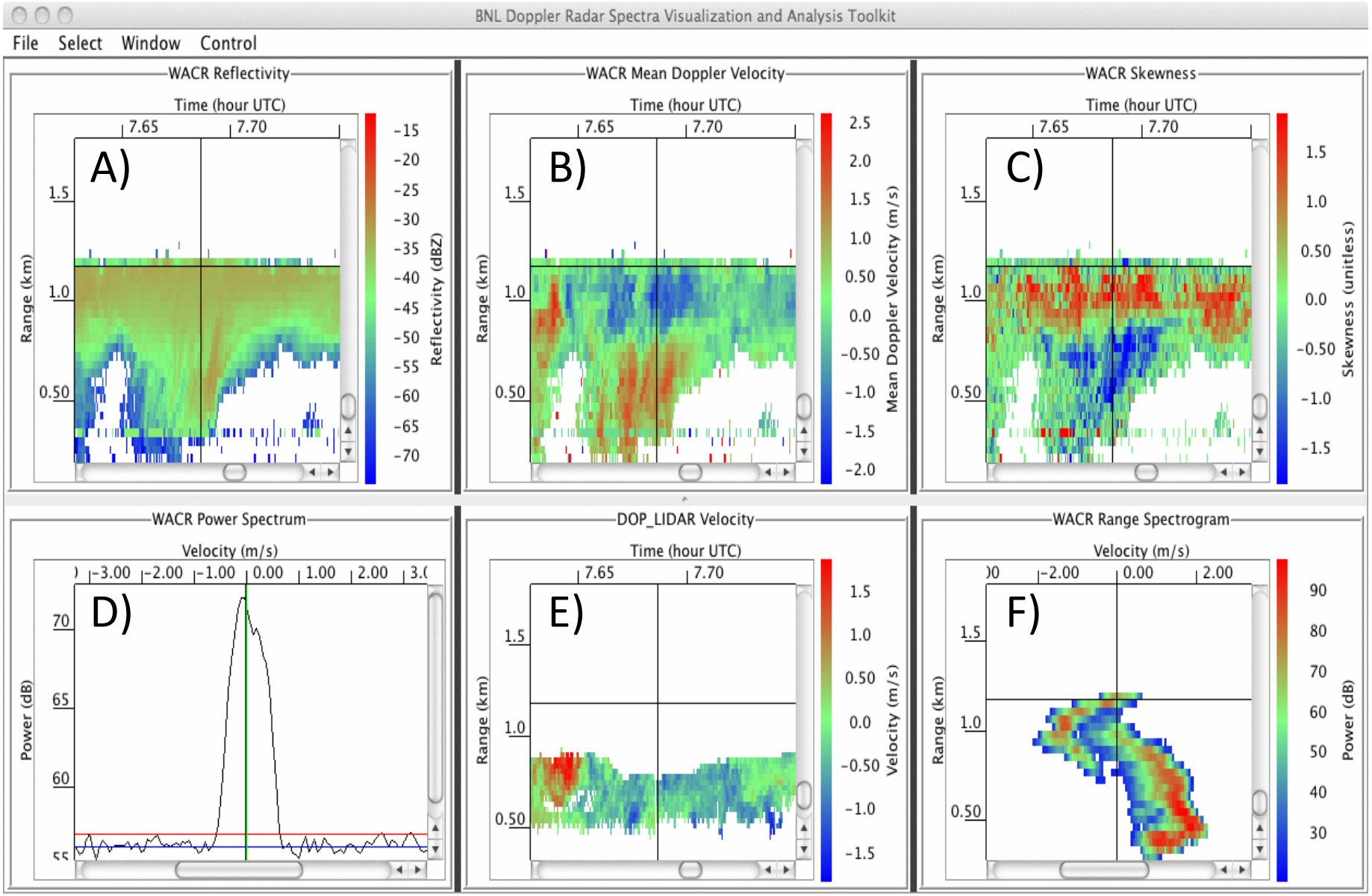


Fig. 1 Distribution of (*left*) vertical velocity at 500 hPa and (*right*) lower-tropospheric stability from ERA-40 reanalysis using tropical marine locations from monthly means for 1984–2001 (*connected black circles* and *connected gray circles* in *right panel* use only points with $\omega_{500} \geq 10$ hPa day^{-1}). *Shading* shows the envelope of the four Earth-like GCM simulations, and *vertical bars* show the envelope from the aquaplanet simulations; only the subsidence points are used in the LTS panel. *Light curves* show the cumulative distribution, *dashed* for entire tropics and *solid* for subsidence only

$$Lower\ Tropospheric\ Stability\ (LTS) \equiv \theta_{700hPa} - \theta_{sfc}$$

Medeiros and Stevens (2011)

Light Drizzle Formation in Sc at Cape Cod on November 22, 2012
Luke and Kollias



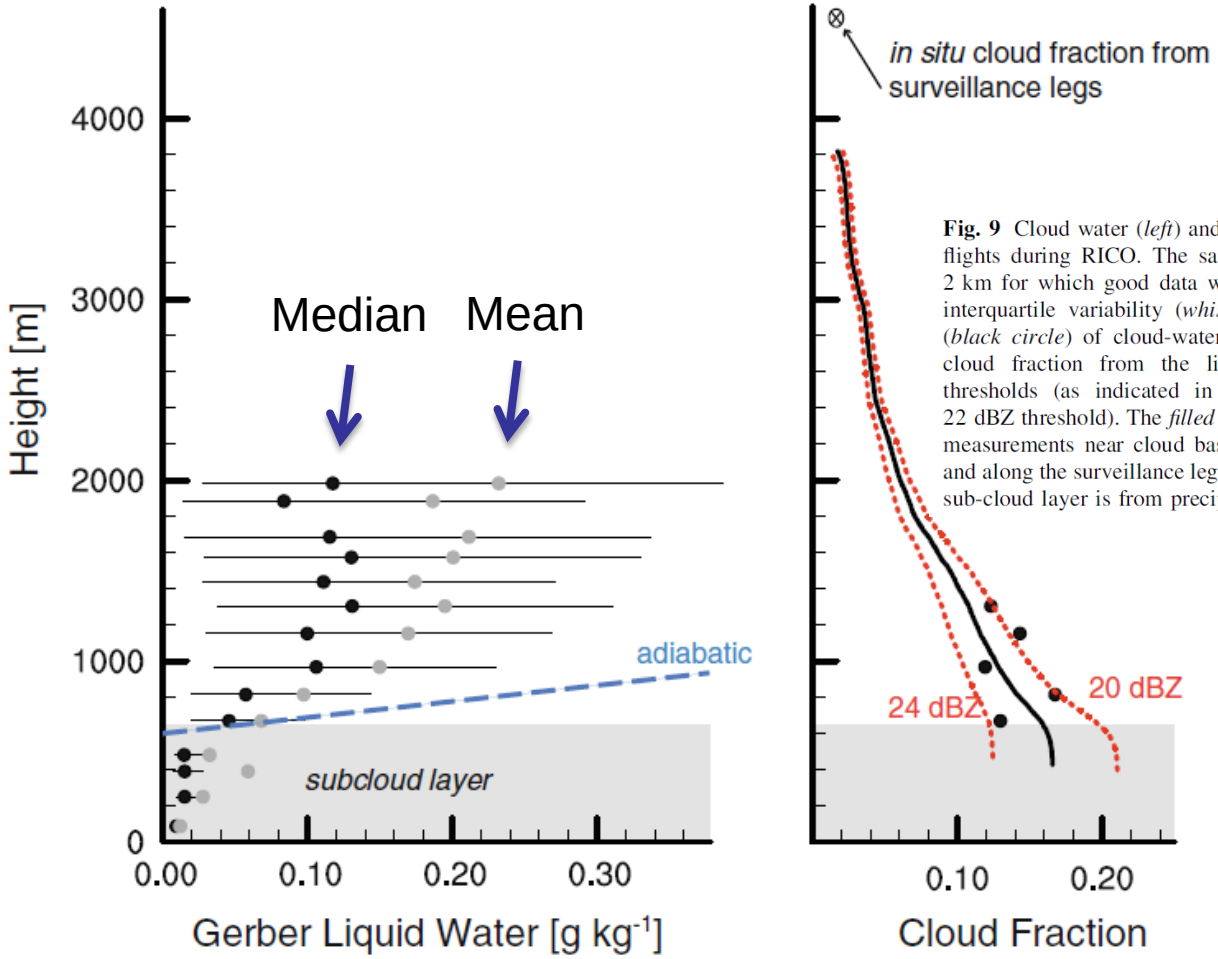
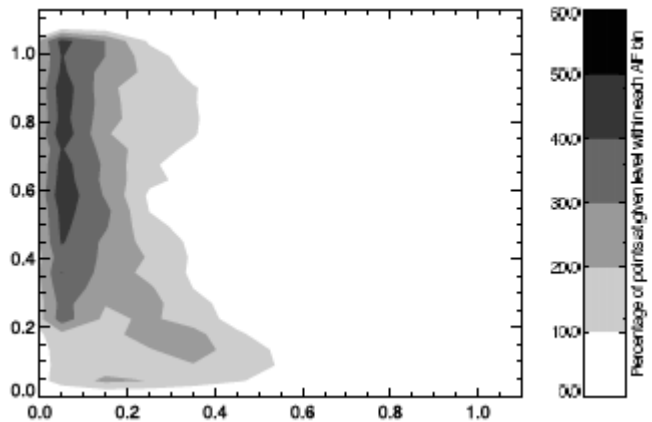


Fig. 9 Cloud water (*left*) and fraction (*right*) profiles from the C130 flights during RICO. The sampling included all flights legs below 2 km for which good data was available. Shown on the *left* is the interquartile variability (*whisker*), mean (*gray circle*) and median (*black circle*) of cloud-water. The *right panel* shows estimates of cloud fraction from the lidar (*lines*) using different detection thresholds (as indicated in *red*, with the *black line* being the 22 dBZ threshold). The *filled circles* show cloud fraction from in situ measurements near cloud base (where sampling was most random) and along the surveillance leg at 4.5 km. Cloud water measured in the sub-cloud layer is from precipitation

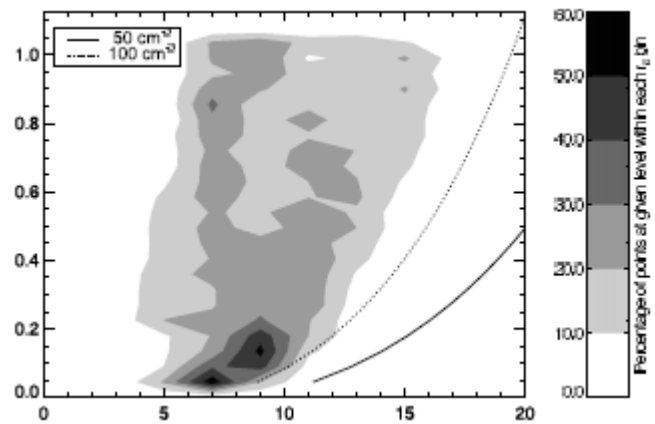
Medeiros and Stevens (2011)

Conditionally-sampled Trade Cumulus from 34,000 hours of data from Nauru

Height Above Cloud Base

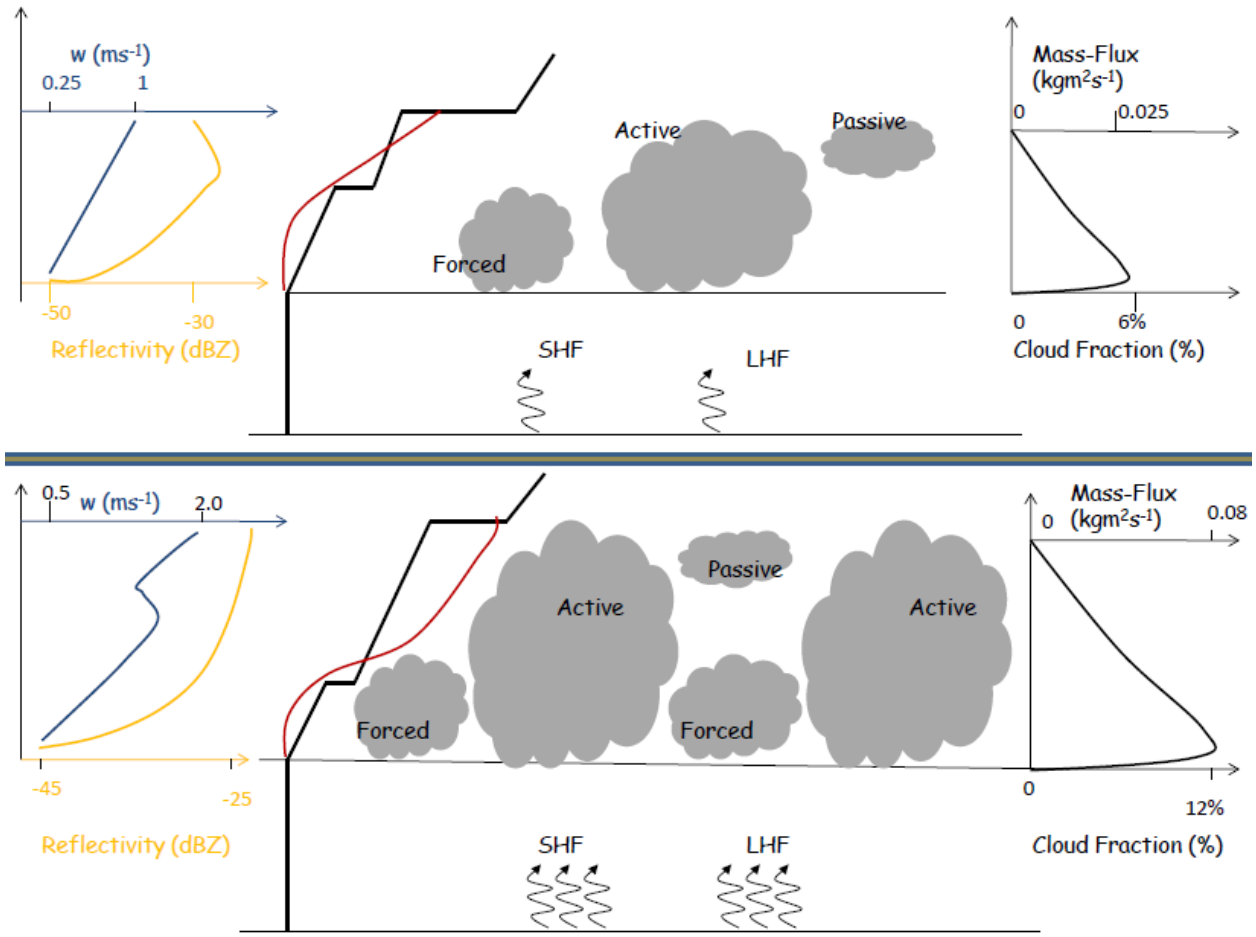


Adiabatic Cloud Fraction



Effective Radius (Bayesian Retrieval)

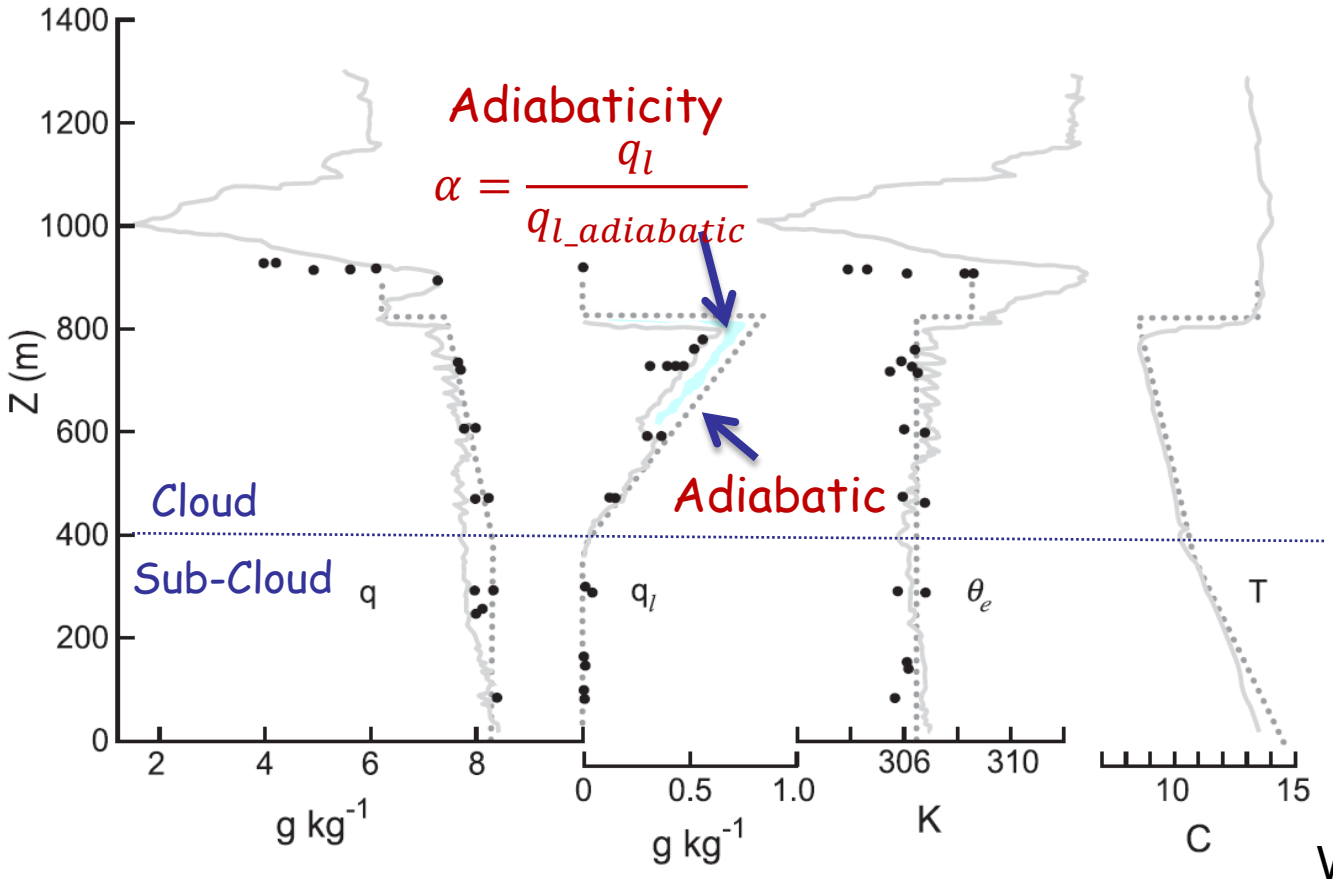
McFarlane and Grabowski (2007)



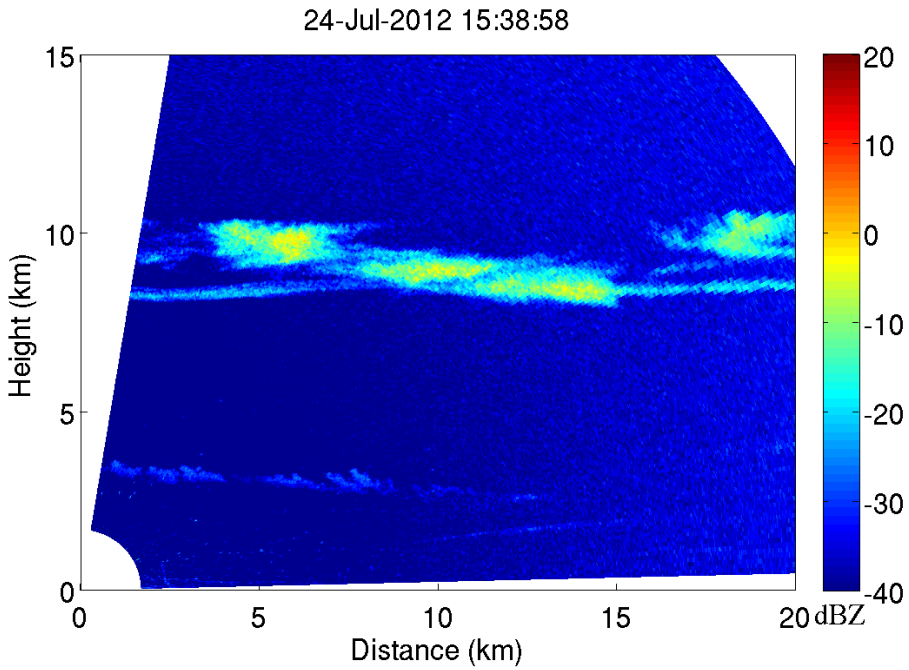
Fair weather boundary layer structure during low turbulence conditions (top) and high turbulence conditions (bottom)

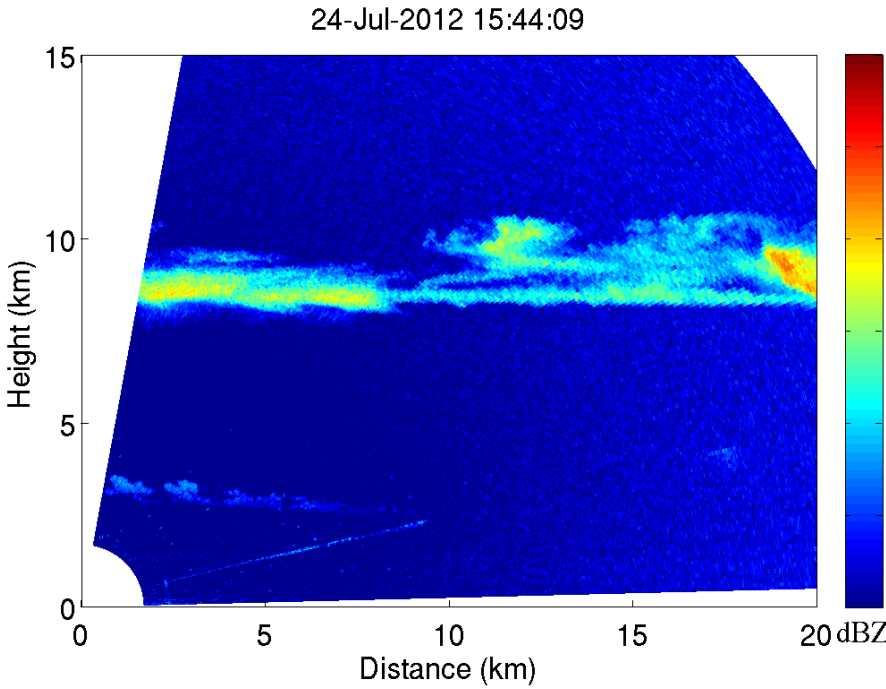
Ghate and Miller, unpublished

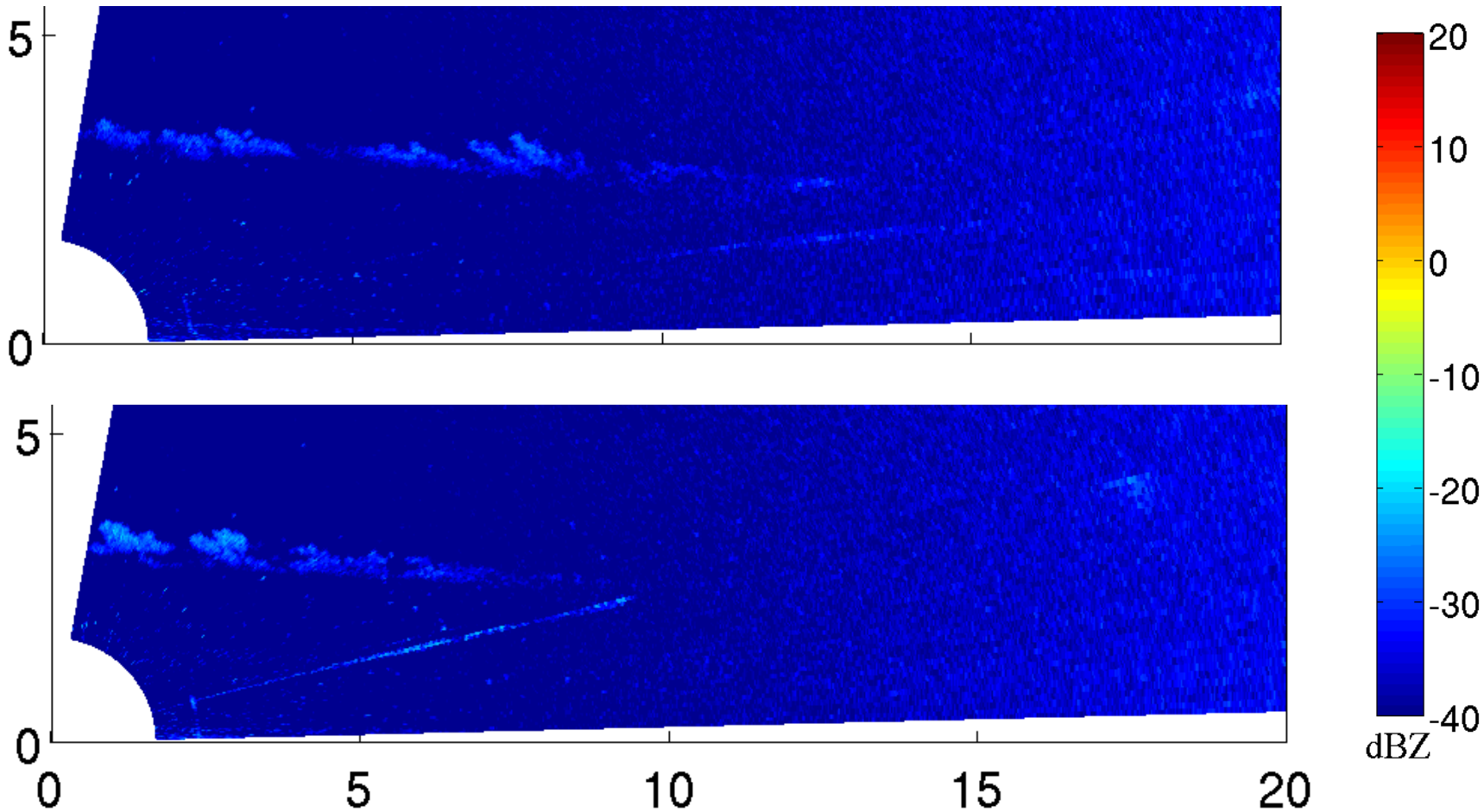
Thermodynamic Profile in Stratocumulus

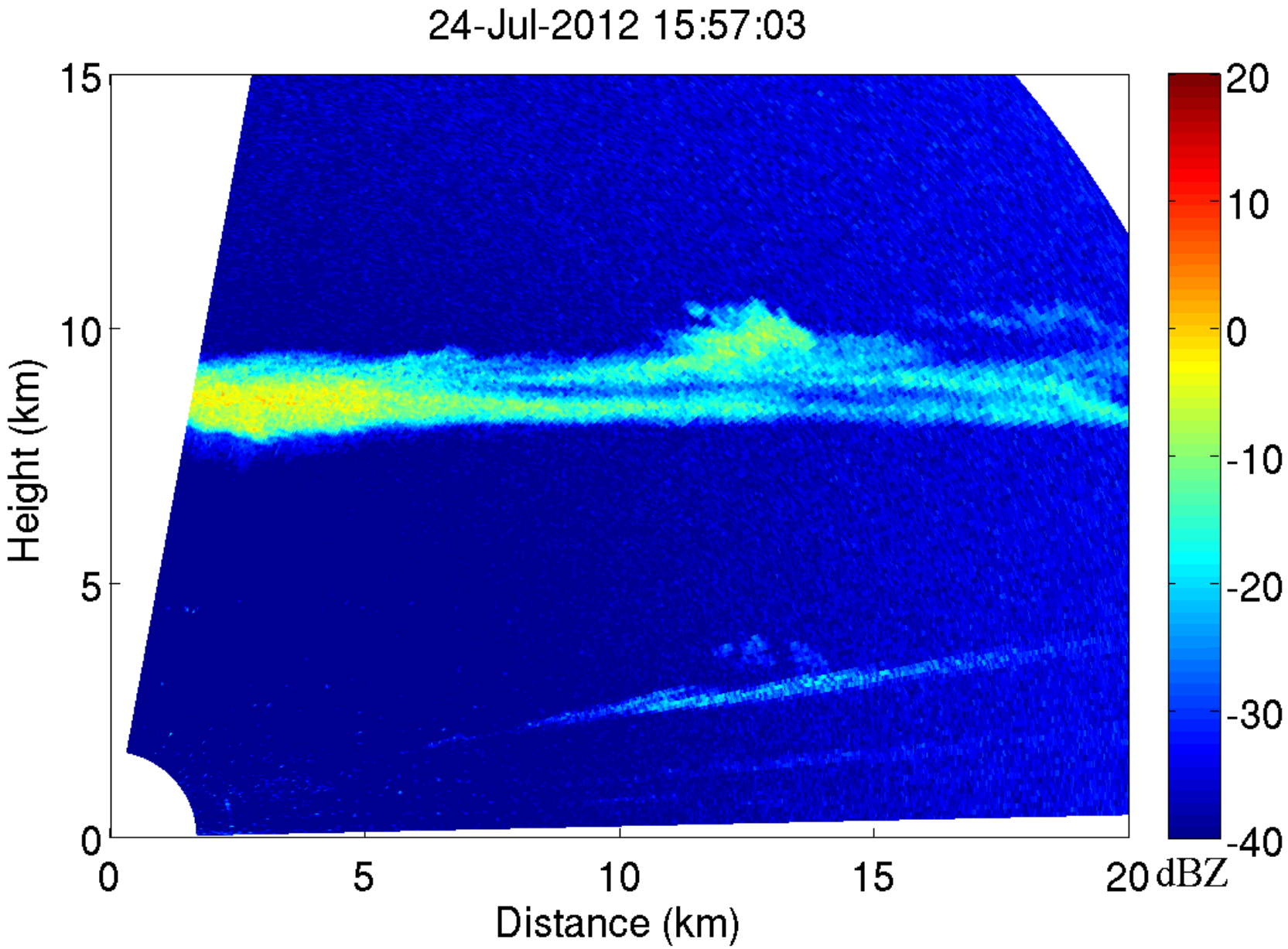


Wood 2012
Nicholls 1984

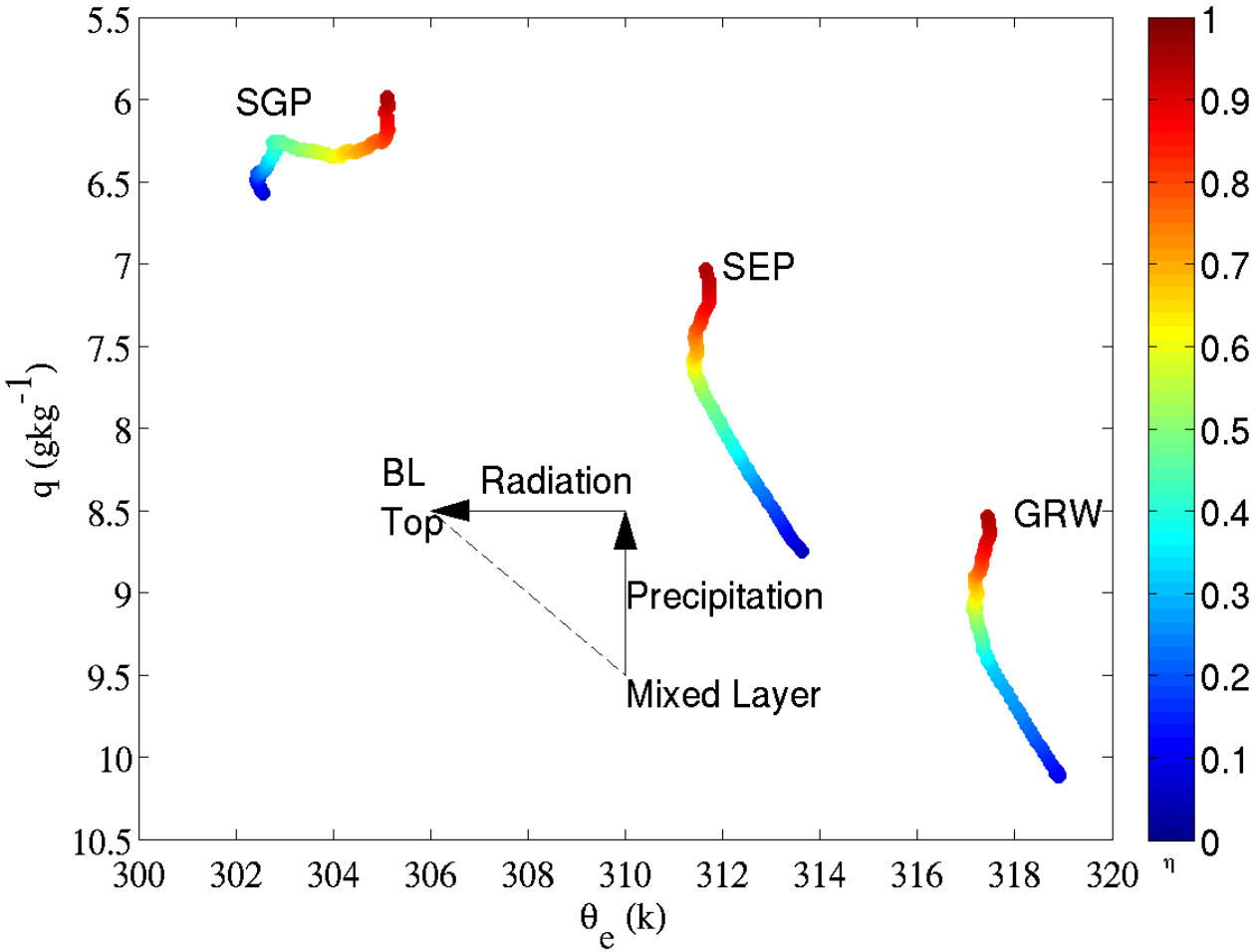

24-Jul-2012 15:38:58
Height (km)
Distance (km)
0
5
10
15
20
dBZ
20
10
0
-10
-20
-30
-40


24-Jul-2012 15:44:09
Height (km)
Distance (km)
0
5
10
15
20
dBZ


5
0
5
0
0
5
10
15
20
20
10
0
-10
-20
-30
-40
dBZ


24-Jul-2012 15:57:03
Height (km)
Distance (km)
0
5
10
15
20
dBZ
-40
-30
-20
-10
0
10
20

Sc Regimes: Conserved Variables



Ghate, 2011