Unraveling the Life Cycle of Low Clouds

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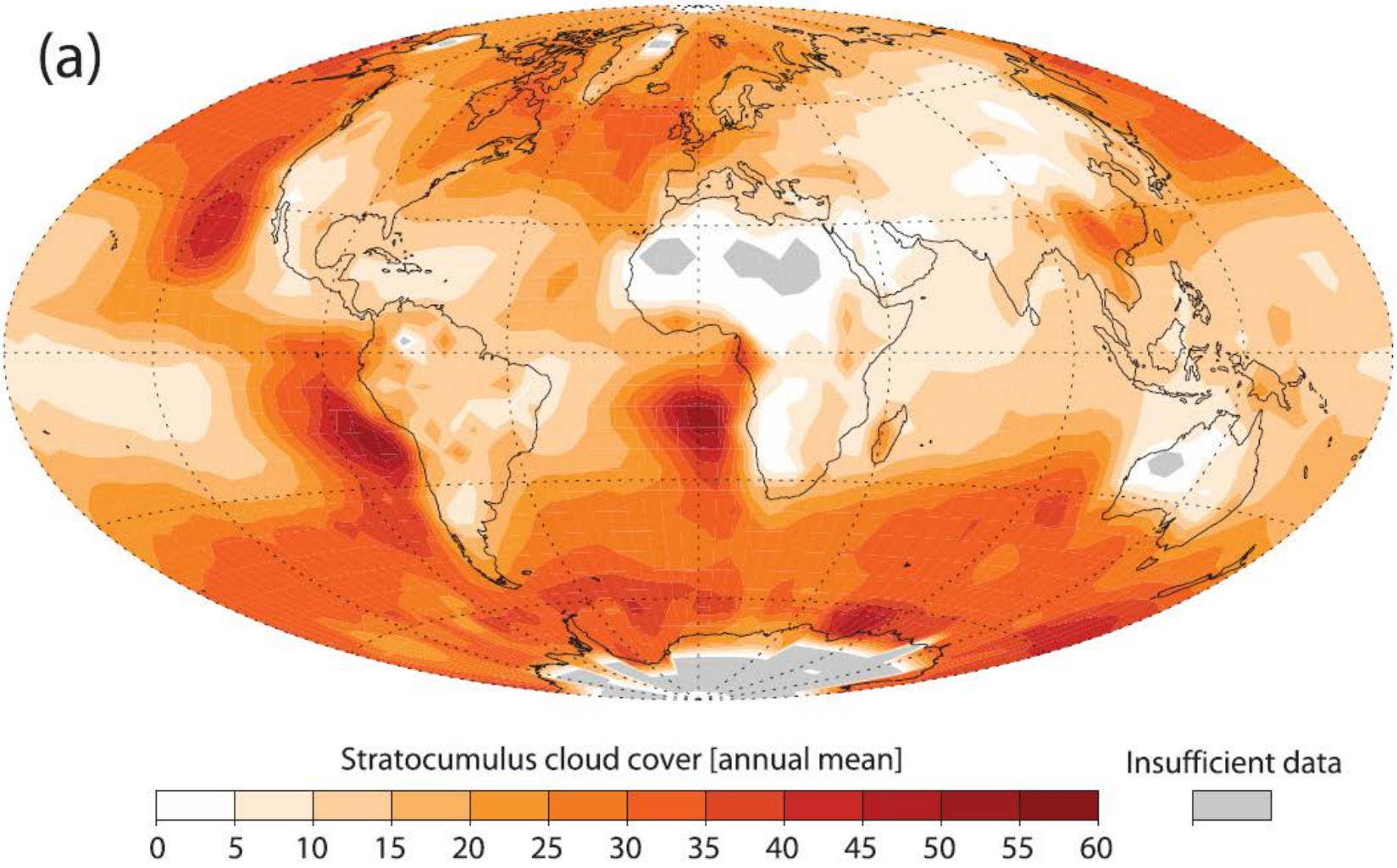
- Suppressed environments favor low clouds
  - Significant (but not overwhelming) subsidence
  - Adequate BL water vapor
  - Source of BL TKE
  - Saturation beneath the inversion
  - Shallow clouds dominate regardless the time of day
- Cloud Systems
  - Eastern Ocean Stratocumulus
  - Northern ocean and Arctic Stratus
  - Wintertime continental stratocumulus
  - Continental Forced Cumulus

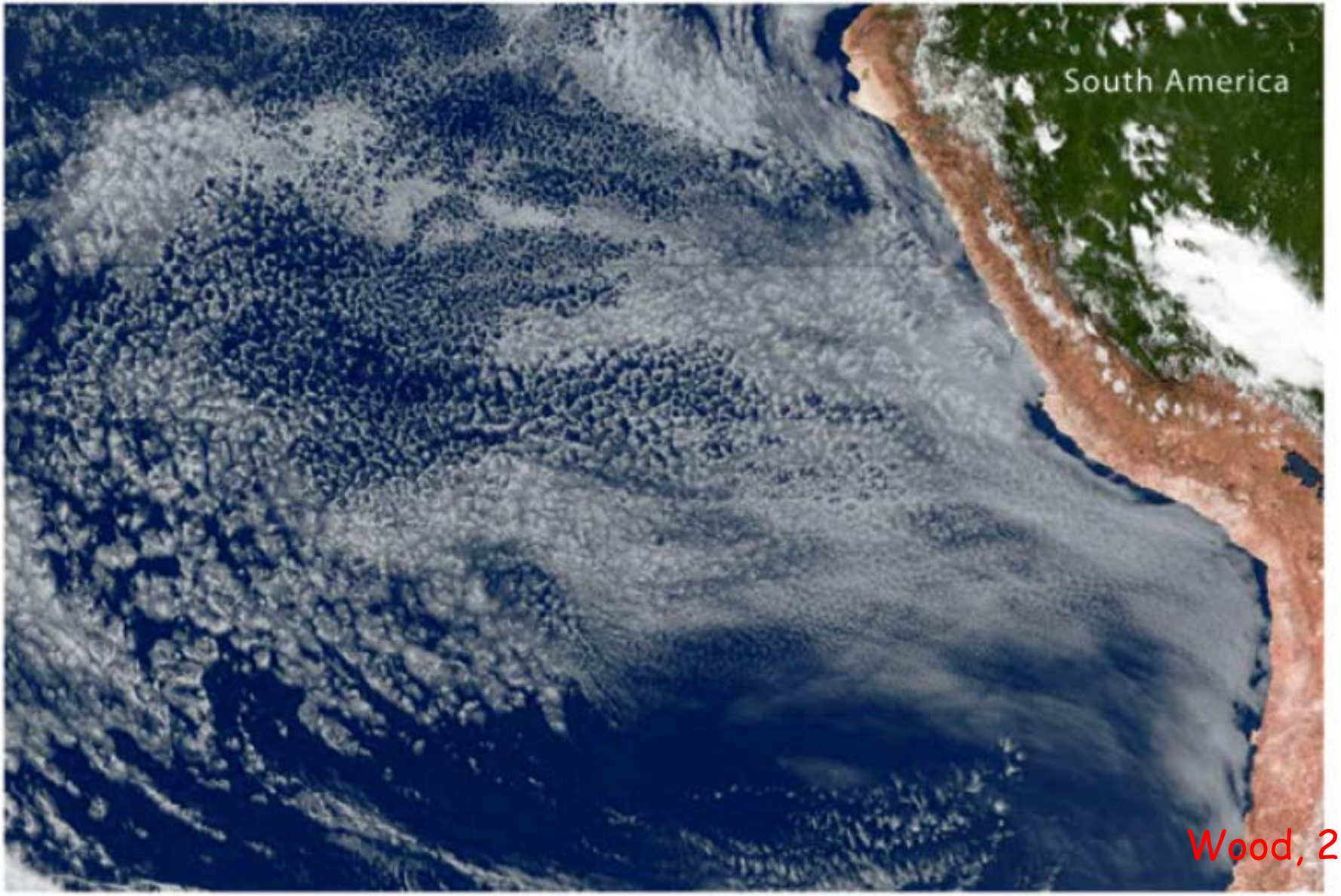
MARINE STRATOCUMULUS



From Wood, 2012 as adapted from Hahn and Warren 2007

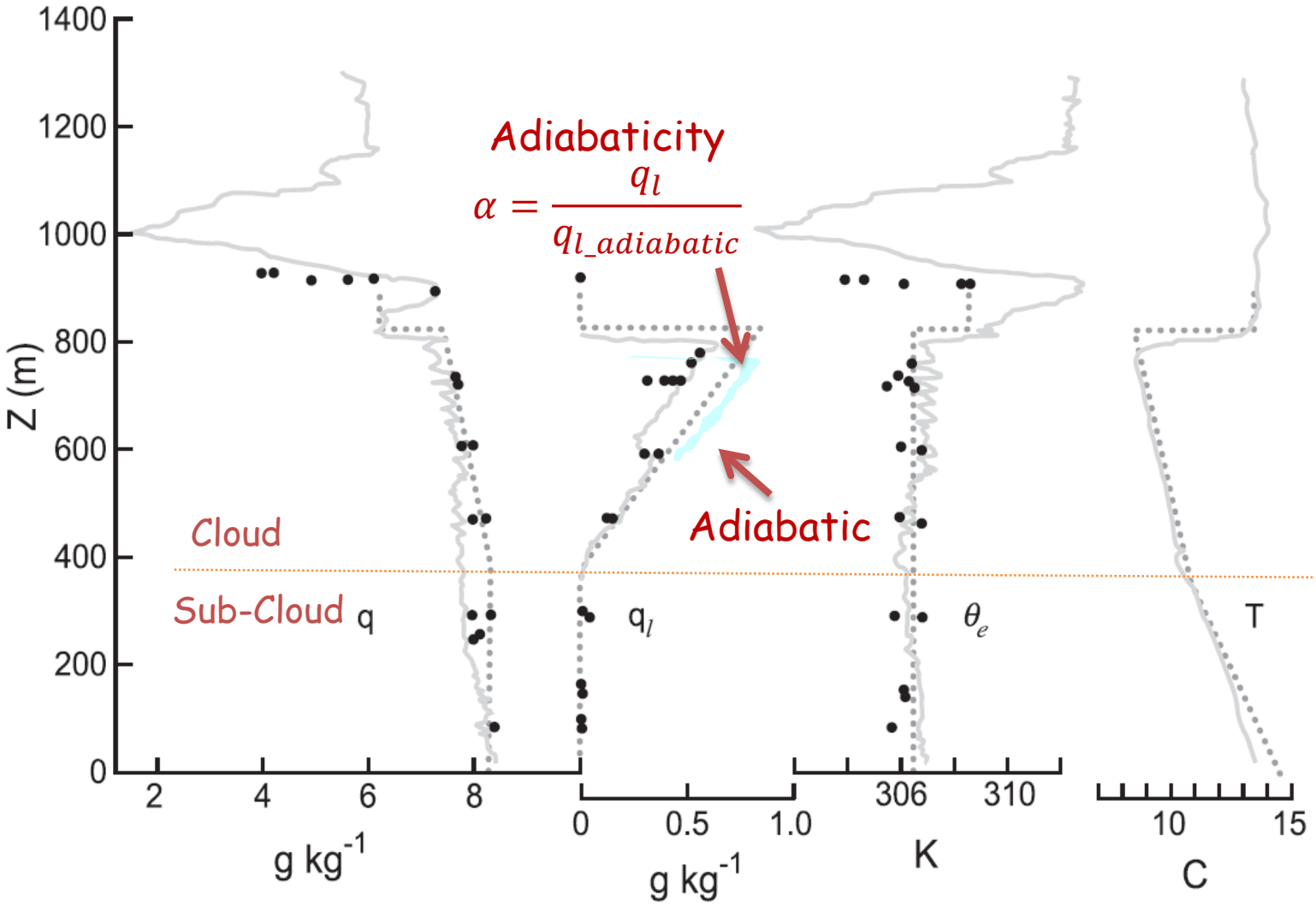
Subtropical stratocumulus

4 September 2009 at 20:45 UTC



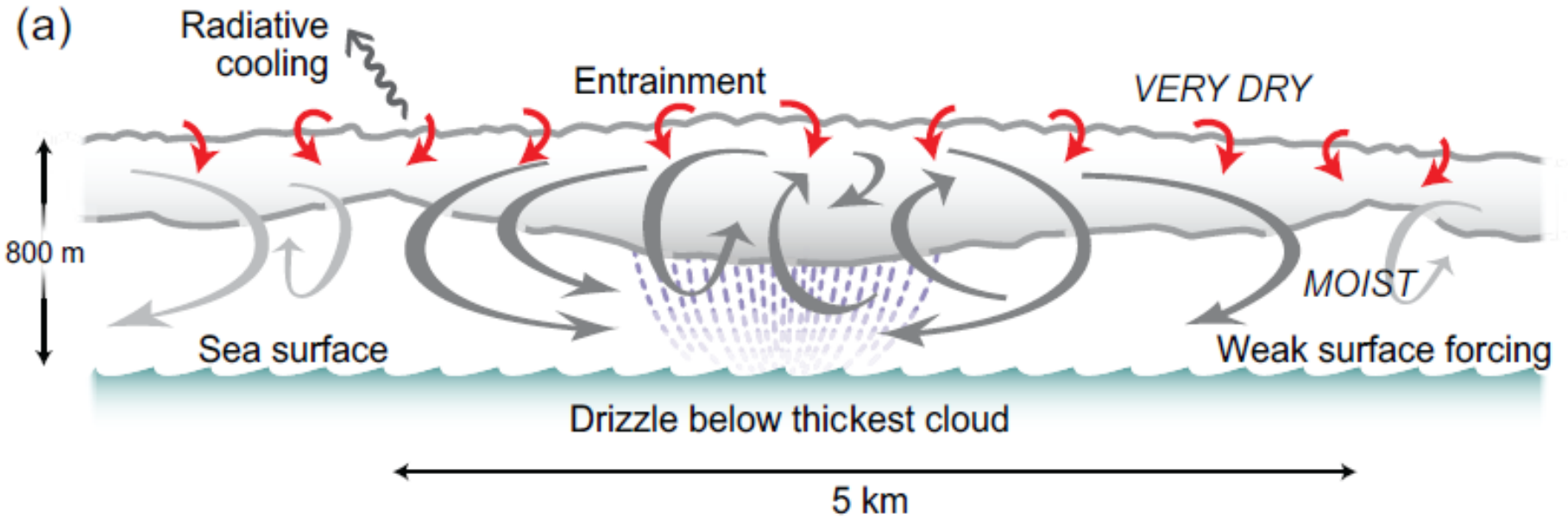
Wood, 2012

Thermodynamic Profiles in Stratocumulus Clouds



Nicholls, 1984

Stratocumulus topped well-mixed BL



Wood, 2012

Fundamental Relationships

$$D_{\uparrow} / I_0 = \frac{(1-g)\tau}{2+(1-g)\tau}$$

Shortwave Albedo

Assume extinction efficiency Qe≈2

$$\tau = \frac{3}{2}\frac{L}{\rho_w r_e}$$

Liquid Water Path (LWP)

How much total liquid in the cloud?

How much surface area does the liquid have?

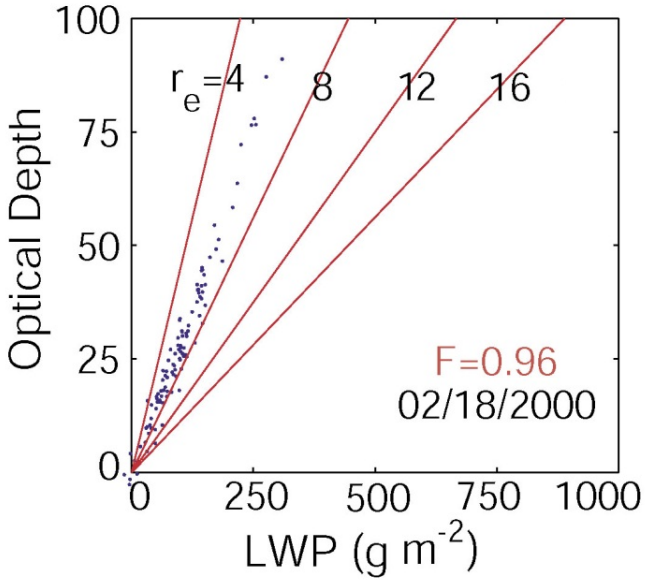
Effective Radius
--Mean radius for scattering

Kim et al. 2003

CLOUD OPTICAL DEPTH VS. LIQUID WATER PATH

North Central Oklahoma, 2000

- Optical Depth as measured by MFRSR
- LWP Measured by Microwave Radiometer
- Observations made every 5 mins



Kim, Schwartz, Miller, and Min, JGR, 2003

Optical depth is highly correlated with and strongly dependent on liquid water path.

Tight cluster of points about a diagonal line through the origin is indicative of constant effective radius over the day.

Slope is inversely proportional to effective radius.

F, fraction of variance accounted for by regression = 96%.

Science Questions

- What are the relationships between optical depth, effective radius and liquid water path under different cloud regimes?
  - Different cloud types
  - Different stages of cloud life cycle

Ship-based data sets from SE Pacific (VOCALS-Rex 2008)

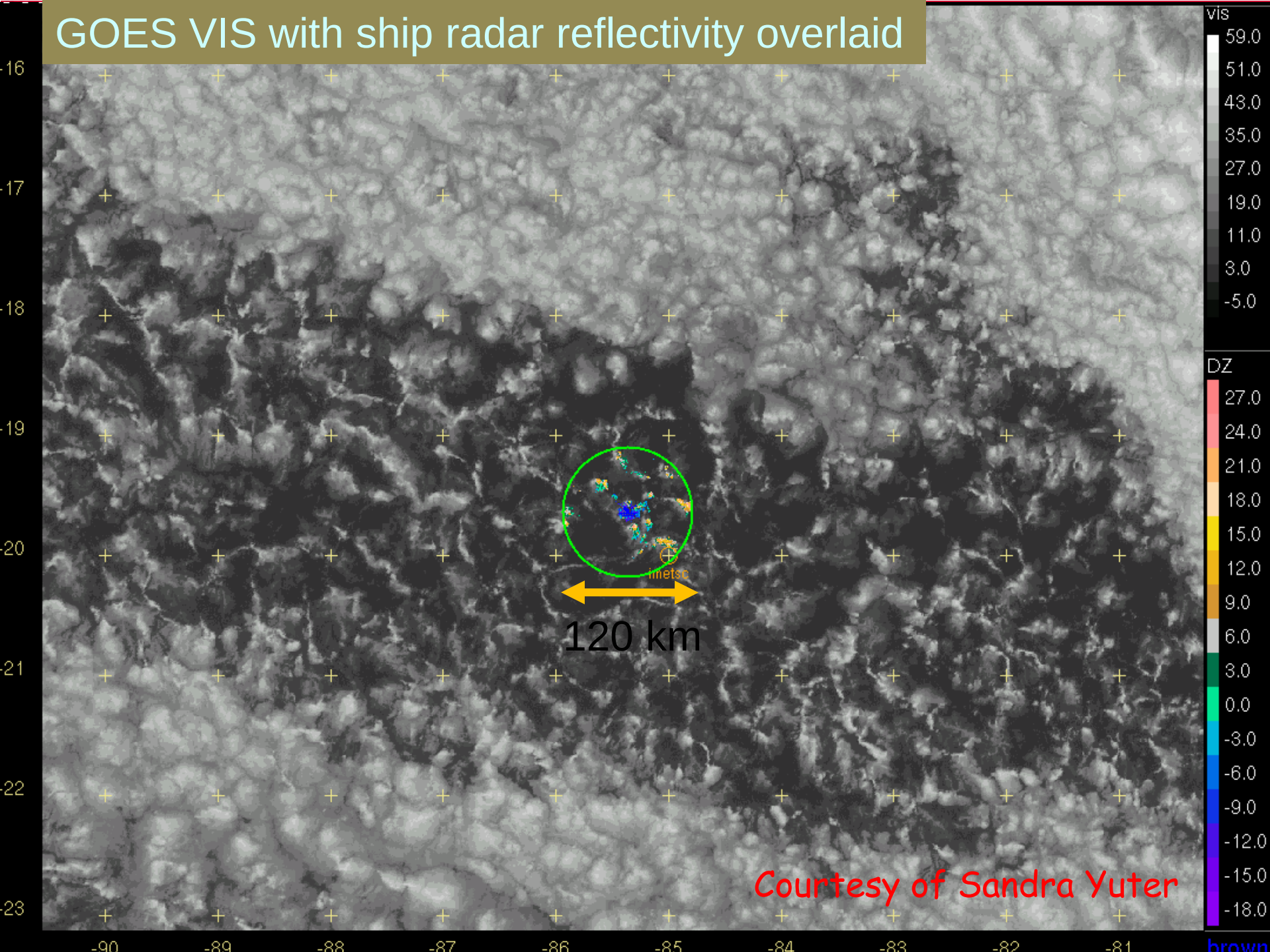
- Radars
  - Scanning C-band
  - Vertically-pointing cloud radar
- Scanning Doppler Lidar
- Soundings
- Microwave radiometer
- Satellite imagery

NOAA ship *Ronald H. Brown*

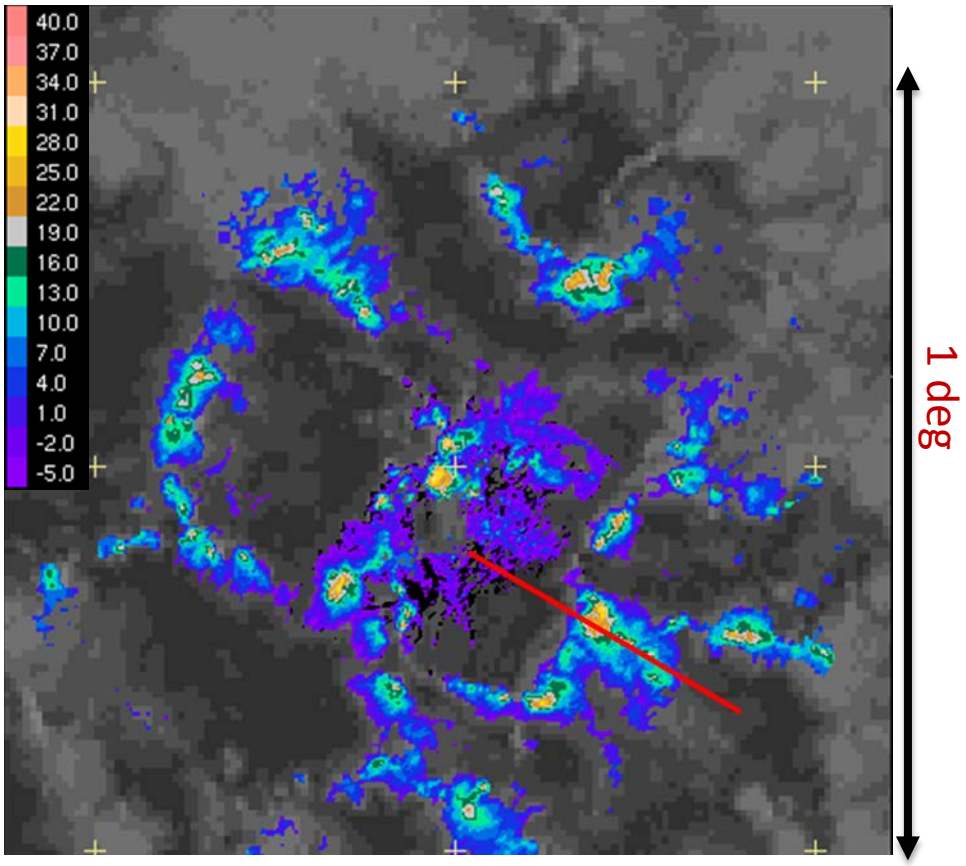
It's like **MAGIC**!

Courtesy of Sandra Yuter

GOES VIS with ship radar reflectivity overlaid



dBZ

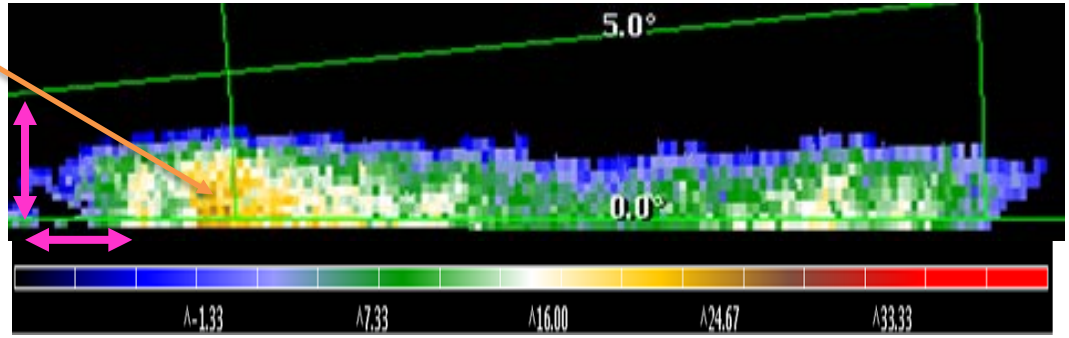


Typical open cells with intermediate drizzle

23 Oct 2008, 12 UTC

Max 27 dBZ

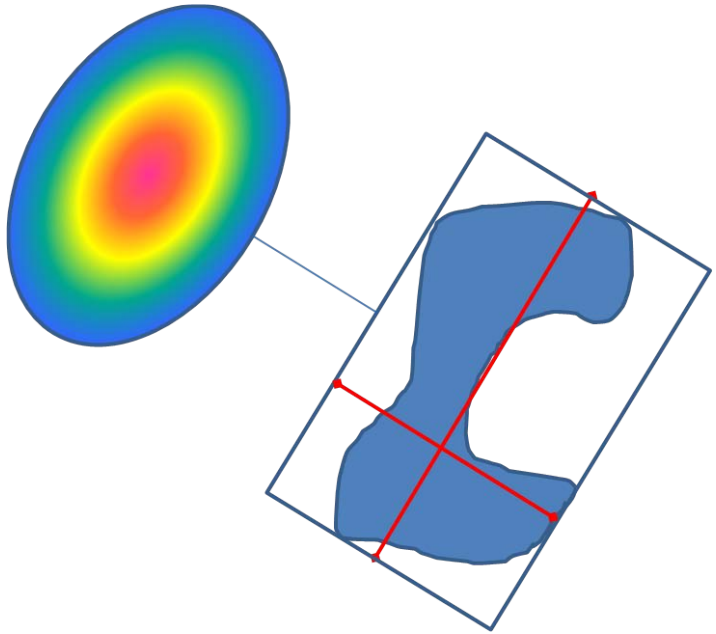
2 km



Courtesy of Sandra Yuter

Automated Cell Tracking (3 min data)

Cells connected to tracks based on proximity and number of pixels of overlap with projected position

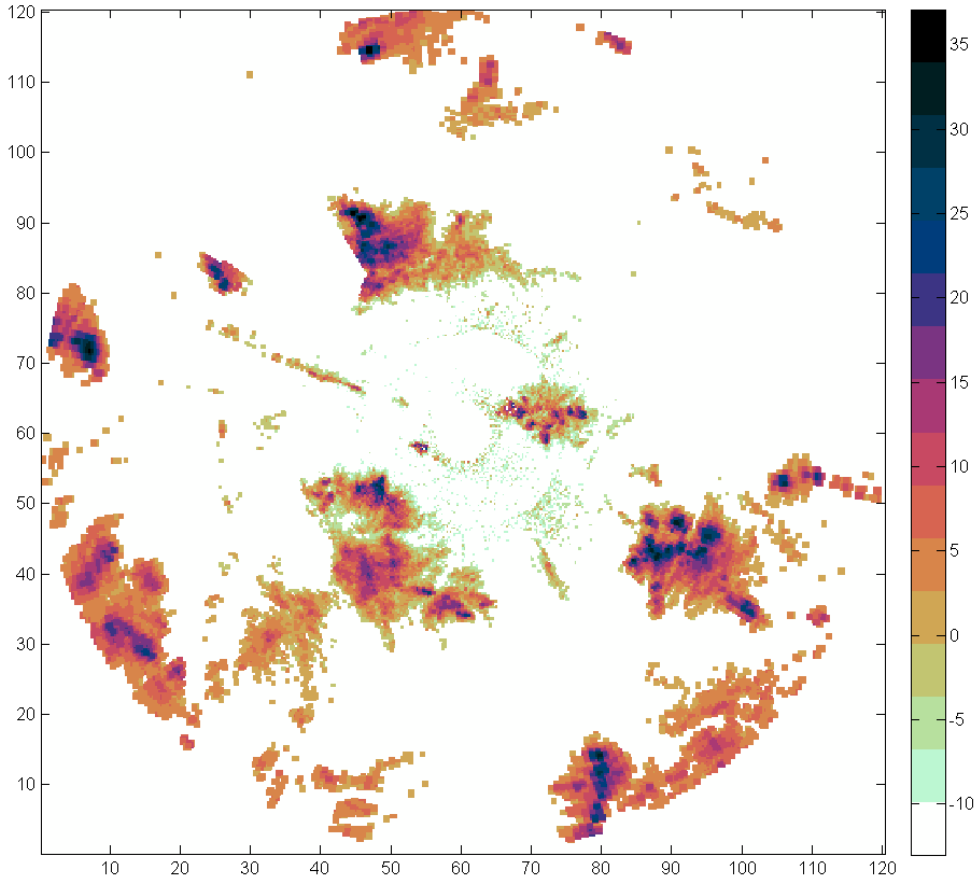


Projected position based on track's established direction and speed

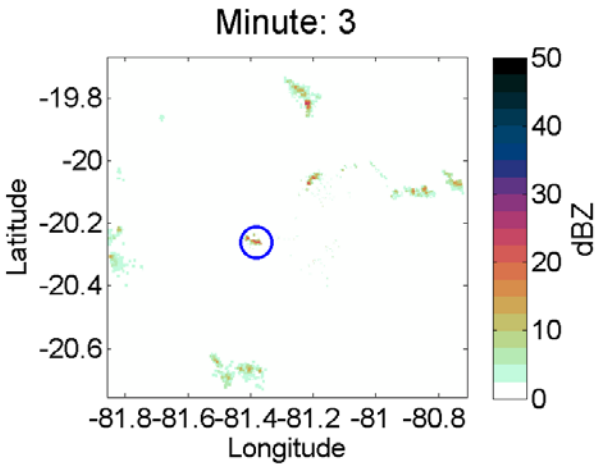
Courtesy of Sandra Yuter

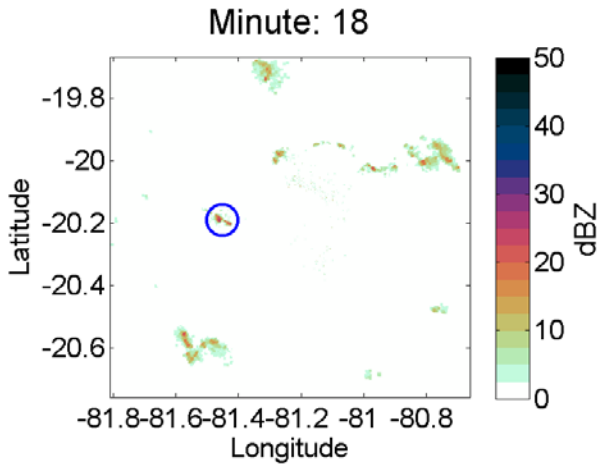
"Cell" = contiguous group of pixels > 6 dBZ and ≥ 0.5 km^2 (8 pixels, each 0.25 km x 0.25 km)
Cell's centroid and area are calculated

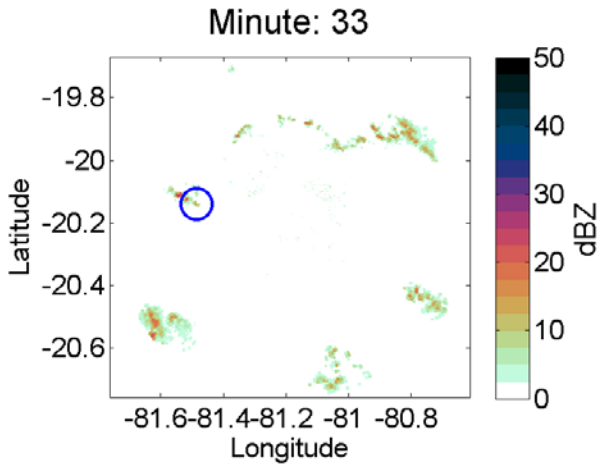
Reflectivity → Filtered/Enhanced → Cells Identified

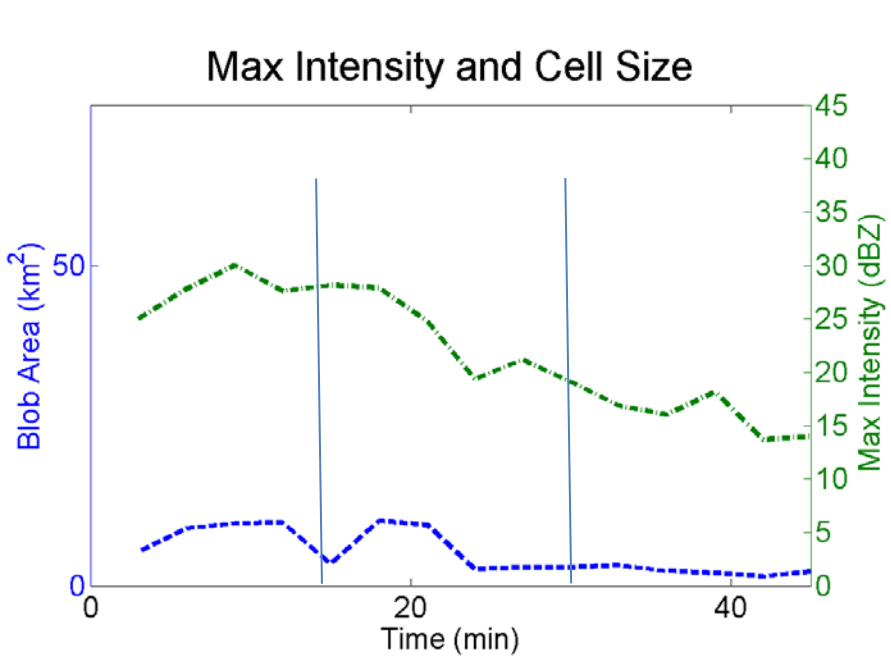


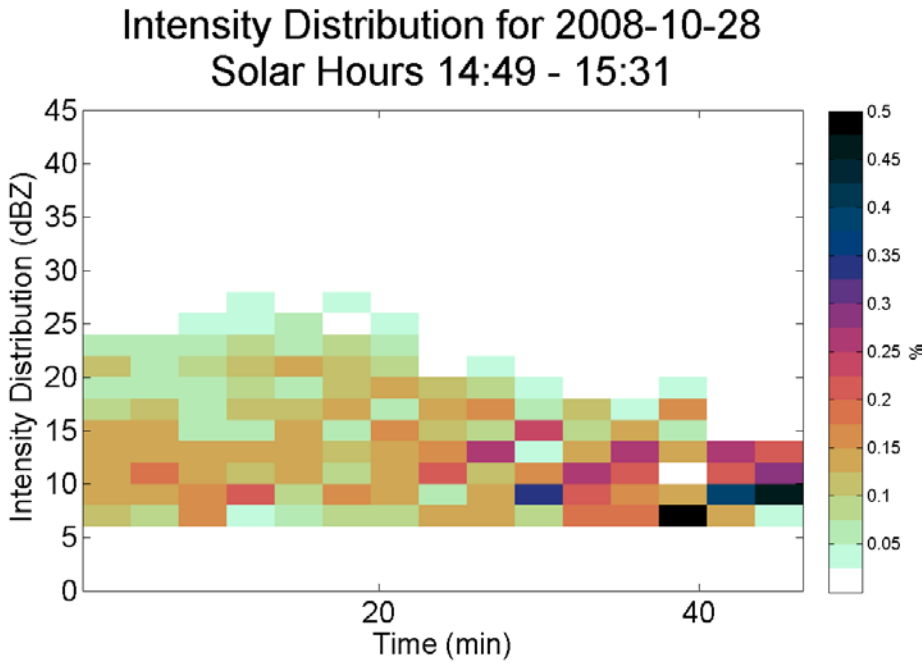
Courtesy of
Sandra Yuter

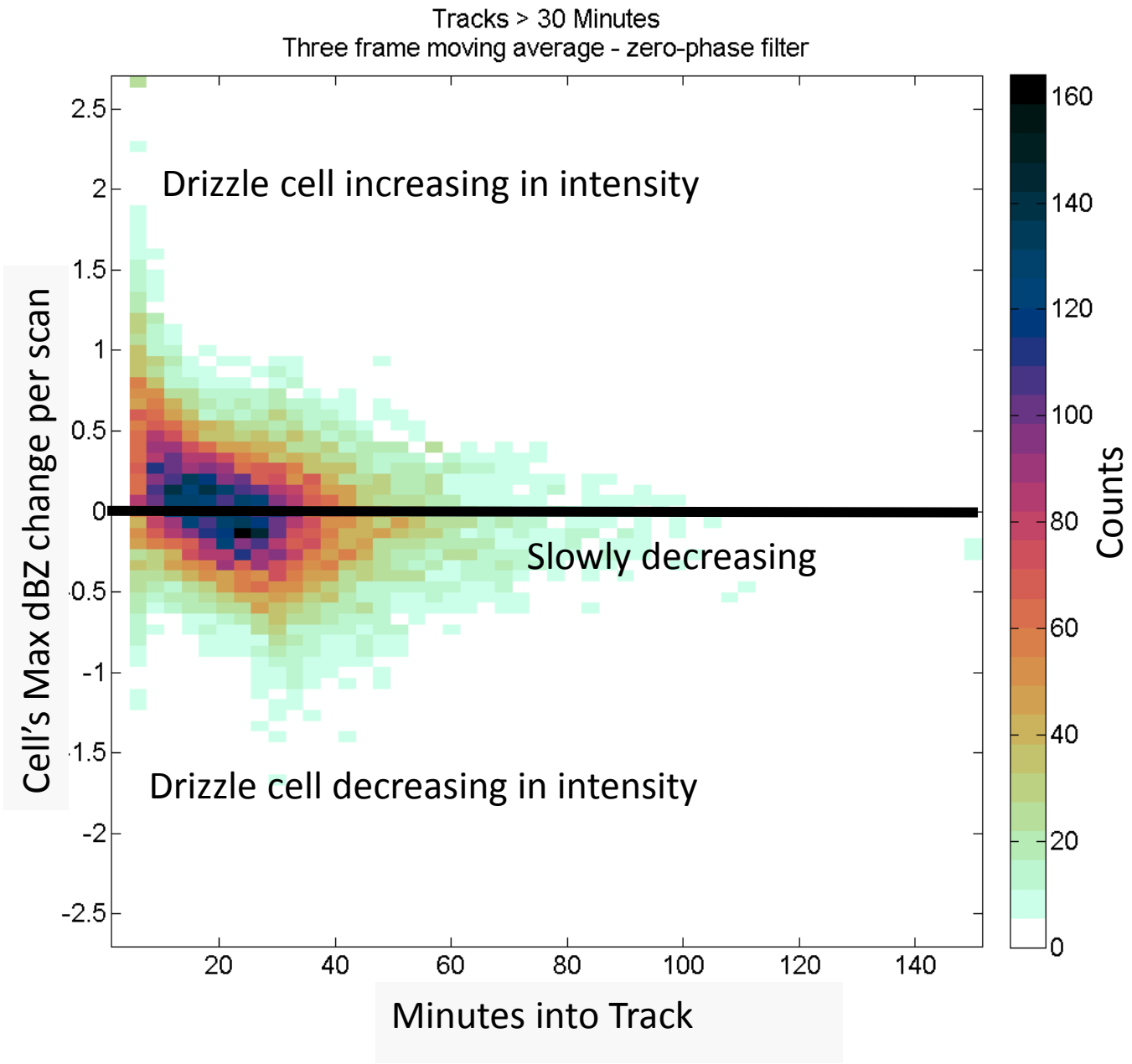

Minute: 3
Latitude
-19.8
-20
-20.2
-20.4
-20.6
-81.8 -81.6 -81.4 -81.2 -81 -80.8
Longitude
50
40
30
20
10
0
dBZ


Minute: 18
Latitude
-19.8
-20
-20.2
-20.4
-20.6
-81.8 -81.6 -81.4 -81.2 -81 -80.8
Longitude
50
40
30
20
10
0
dBZ


Minute: 33
Latitude
-19.8
-20
-20.2
-20.4
-20.6
-81.6 -81.4 -81.2 -81 -80.8
Longitude
50
40
30
20
10
0
dBZ


Max Intensity and Cell Size
Blob Area (km2)
50
0
0
20
40
Time (min)
45
40
35
30
25
20
15
10
5
0
Max Intensity (dBZ)


Intensity Distribution for 2008-10-28
Solar Hours 14:49 - 15:31
Intensity Distribution (dBZ)
45
40
35
30
25
20
15
10
5
0
20
40
Time (min)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
%


Tracks > 30 Minutes
Three frame moving average - zero-phase filter
Drizzle cell increasing in intensity
Slowly decreasing
Drizzle cell decreasing in intensity
Cell's Max dBZ change per scan
Minutes into Track
Counts
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
20
40
60
80
100
120
140
160
140
120
100
80
60
40
20
0

Science Questions

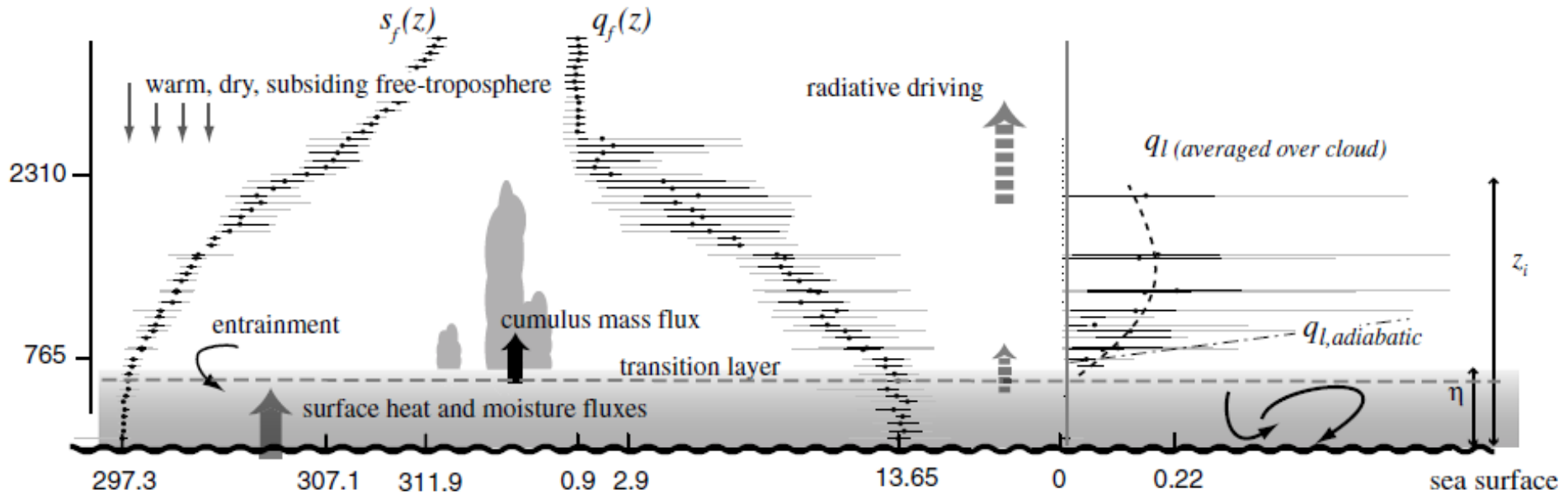
- How does drizzle influences the cloud field and affects the life-cycle of stratocumulus clouds?

- How does drizzle influences the formation of open/closed cells?

Xiquan's Talk:
Focus on statistics of Azores/SGP Clouds

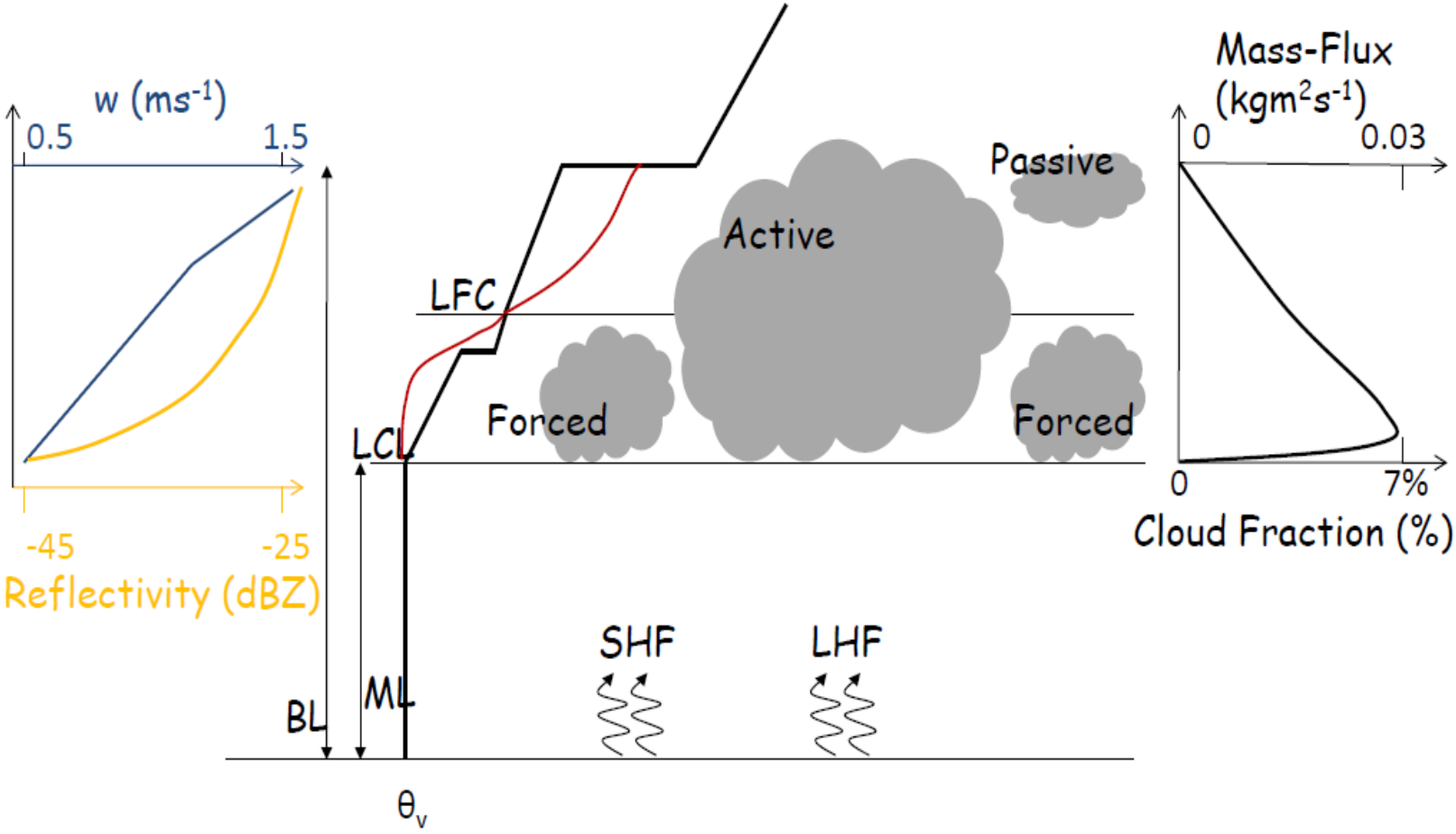
FAIR WEATHER CUMULUS

Cumulus topped BL



Stevens, 2006

Marine Trade Cumulus



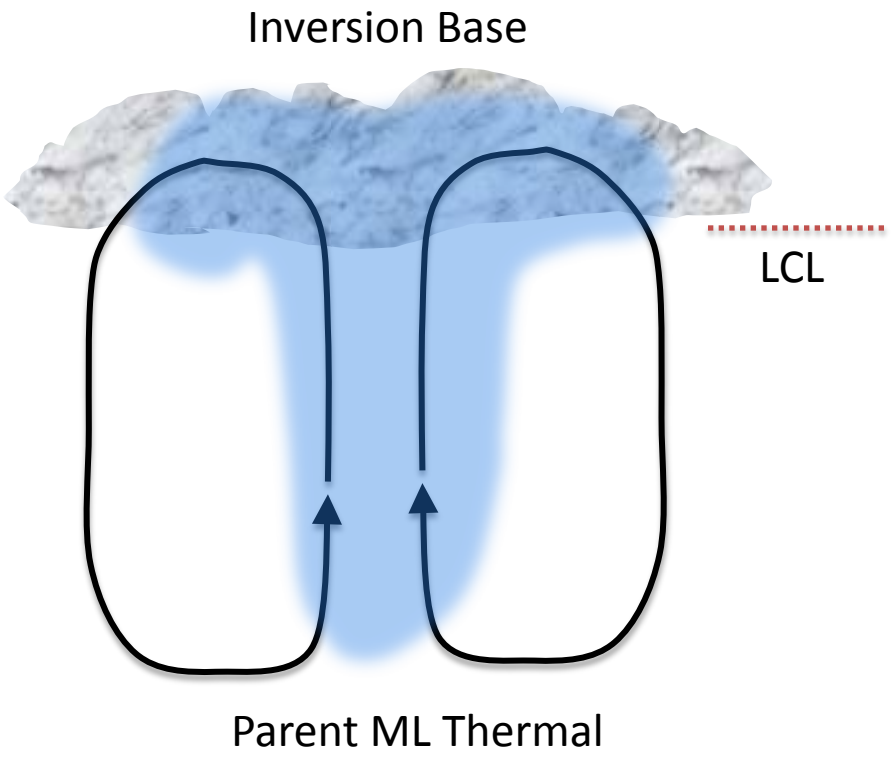
General conditions associated with a fair weather boundary layer

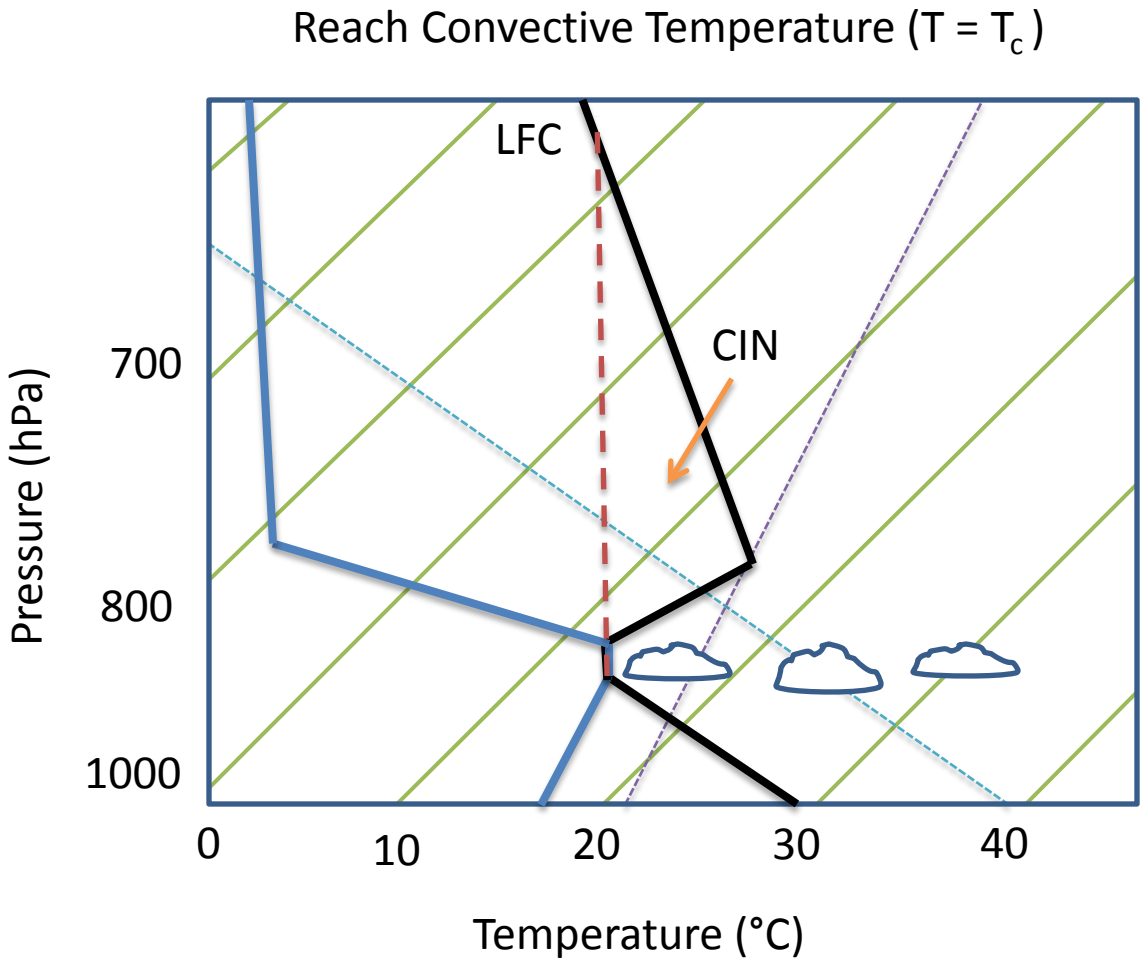
Ghate et al., 2011

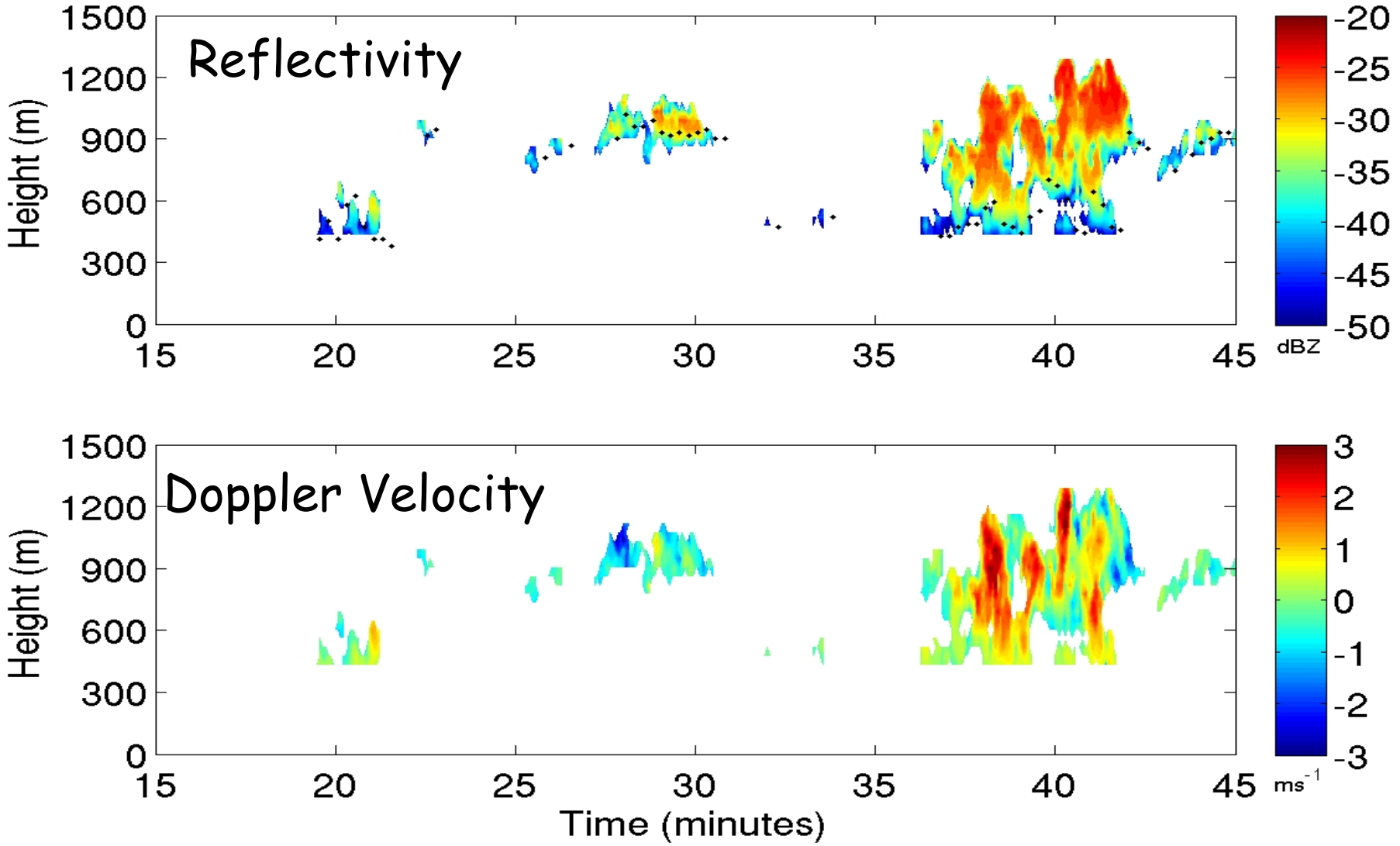
Forced Cumulus Clouds

Forced Cumulus Clouds

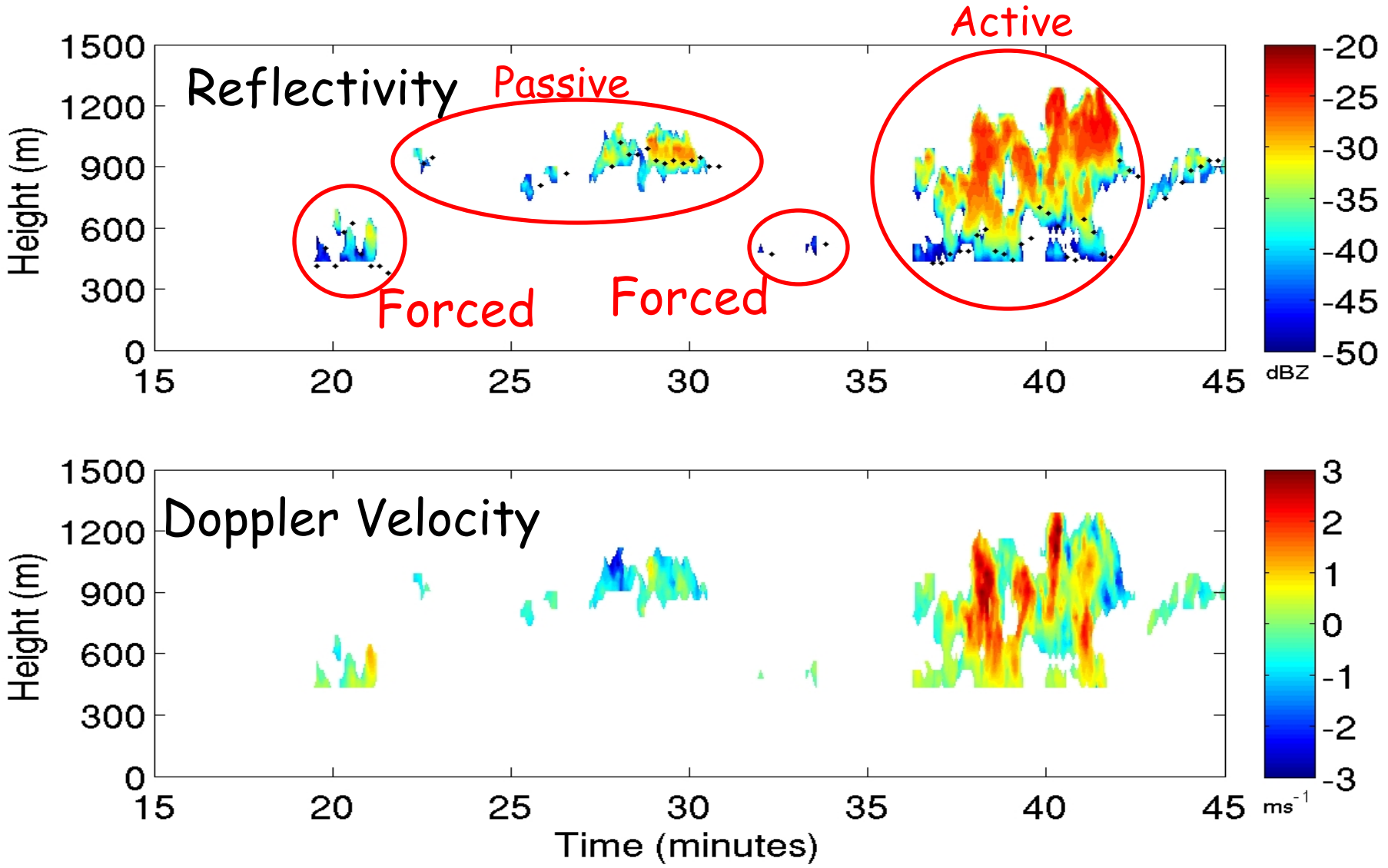
- exists only while there is forcing from the ML thermal
- lifespan of several minutes as long as updraft is sustained
- air entering cloud base is quickly deflected back into ML by inversion
- no venting of ML air into free atmosphere above
  - vapor and pollutants trapped
- thin clouds with -diameters roughly equal ML depth




Reach Convective Temperature (T = T_c)
LFC
CIN
700
800
1000
Pressure (hPa)
0
10
20
30
40
Temperature (°C)



Ghate et al., 2011



Ghate et al., 2011

Science Needs

- Routine observations of forced clouds at the ARM sites.

- Observations of associated liquid water path and radiation.

Measurement of LWC

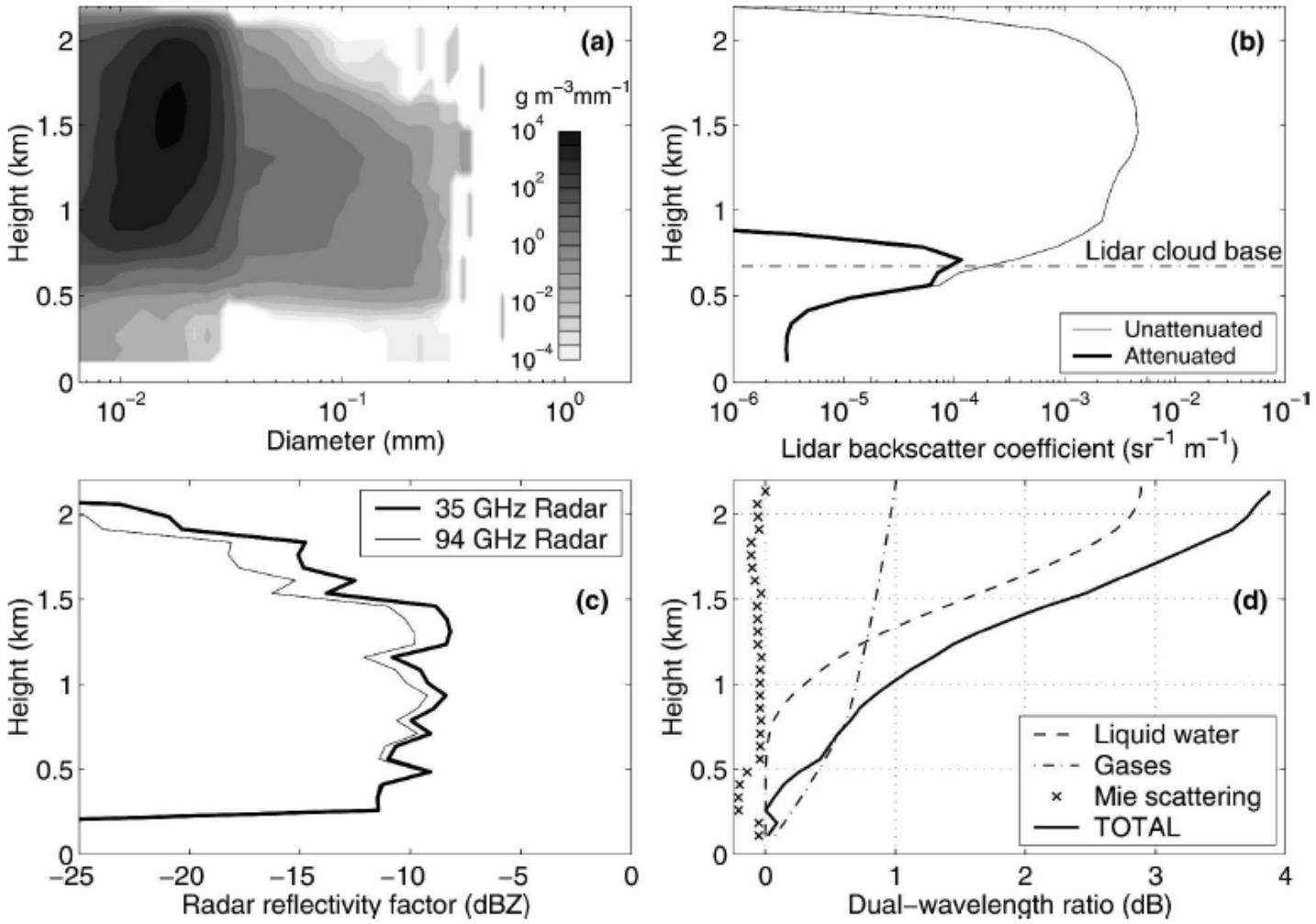
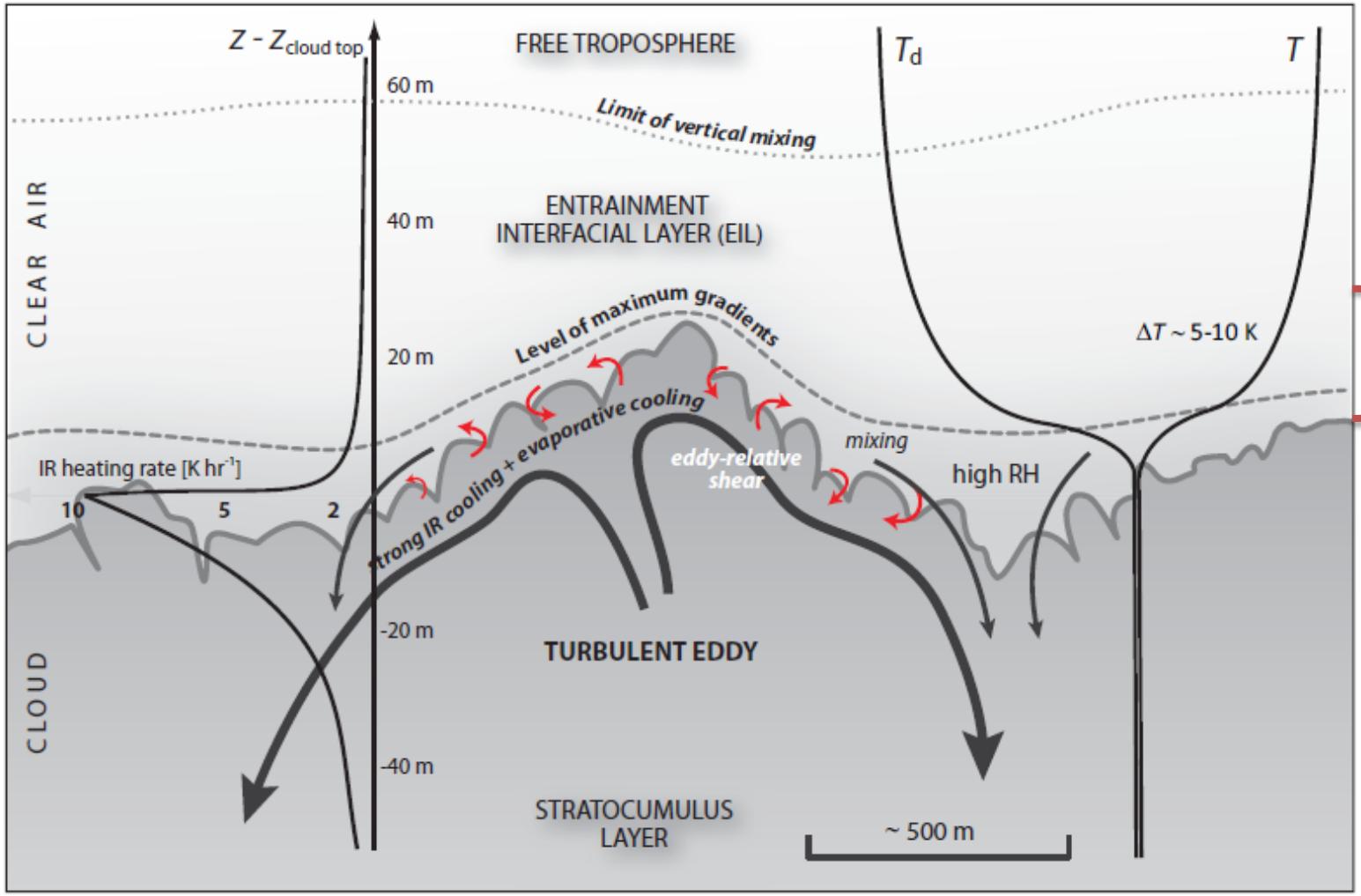


FIG. 3. Aircraft profile through stratocumulus on 12 Jun 1992 of the (a) spectral density of liquid water content vs diameter; (b) simulated attenuated and unattenuated lidar backscatter coefficient; (c) simulated reflectivity factor at 35 and 94 GHz; and (d) simulated DWR, both for the individual components and the total.

Hogan



Bragg Scatter Amplified

Dual Wavelength LWC

FIG. 13. Schematic of the entrainment interfacial layer (EIL) atop a layer of marine stratocumulus.

Stevens 1999

Science Needs

- More frequent measurements/retrievals of temperature and humidity in both clear and cloudy conditions.

MWRP Thermodynamic Profiles

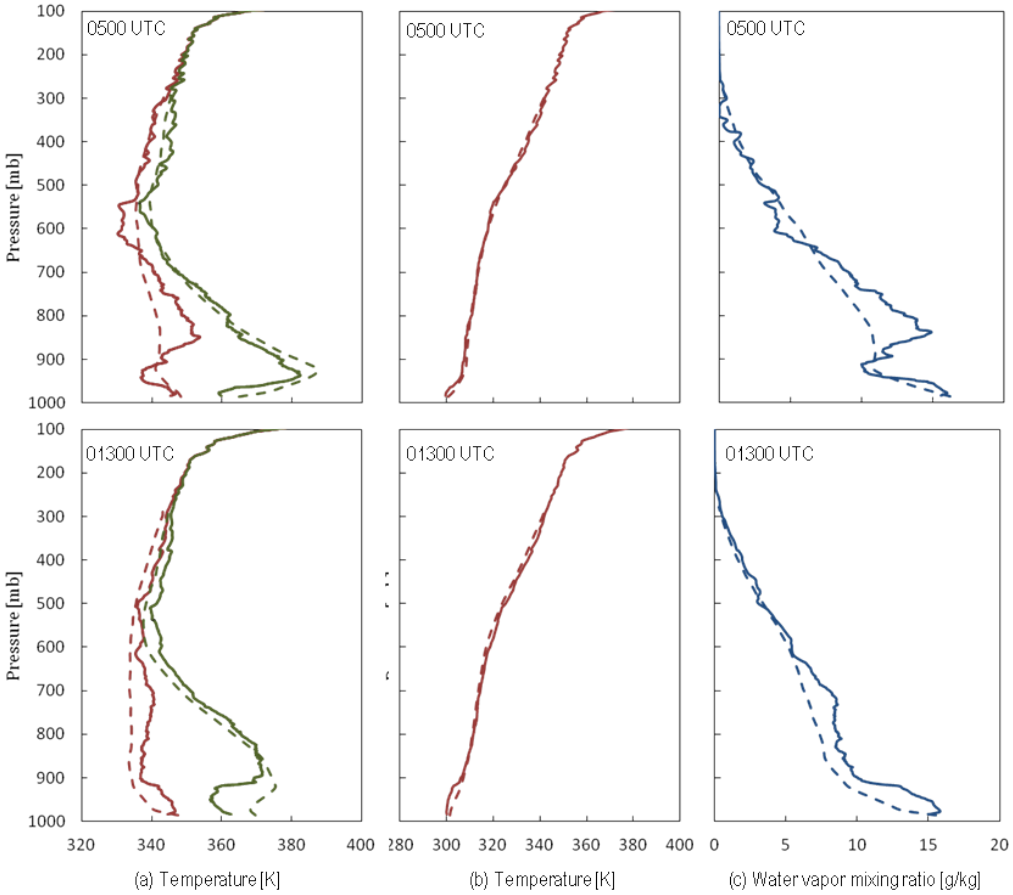


Figure 5. Pre-storm (0500 UTC) and post-storm (1300 UTC) thermodynamic environments on June 9, 2006 described in terms of: (a) equivalent potential temperature (red lines) and saturation equivalent potential temperature (green lines); (b) potential temperature; and (c) water vapor mixing ratio from the Merged Sounding VAP (solid lines), as in Kollias et al. (2009), and from the MWRP (dashed lines).

Courtesy of
Lynne DiPretore