Questioning the importance of the cloud lifetime effect: The relative roles of drizzle and the sun

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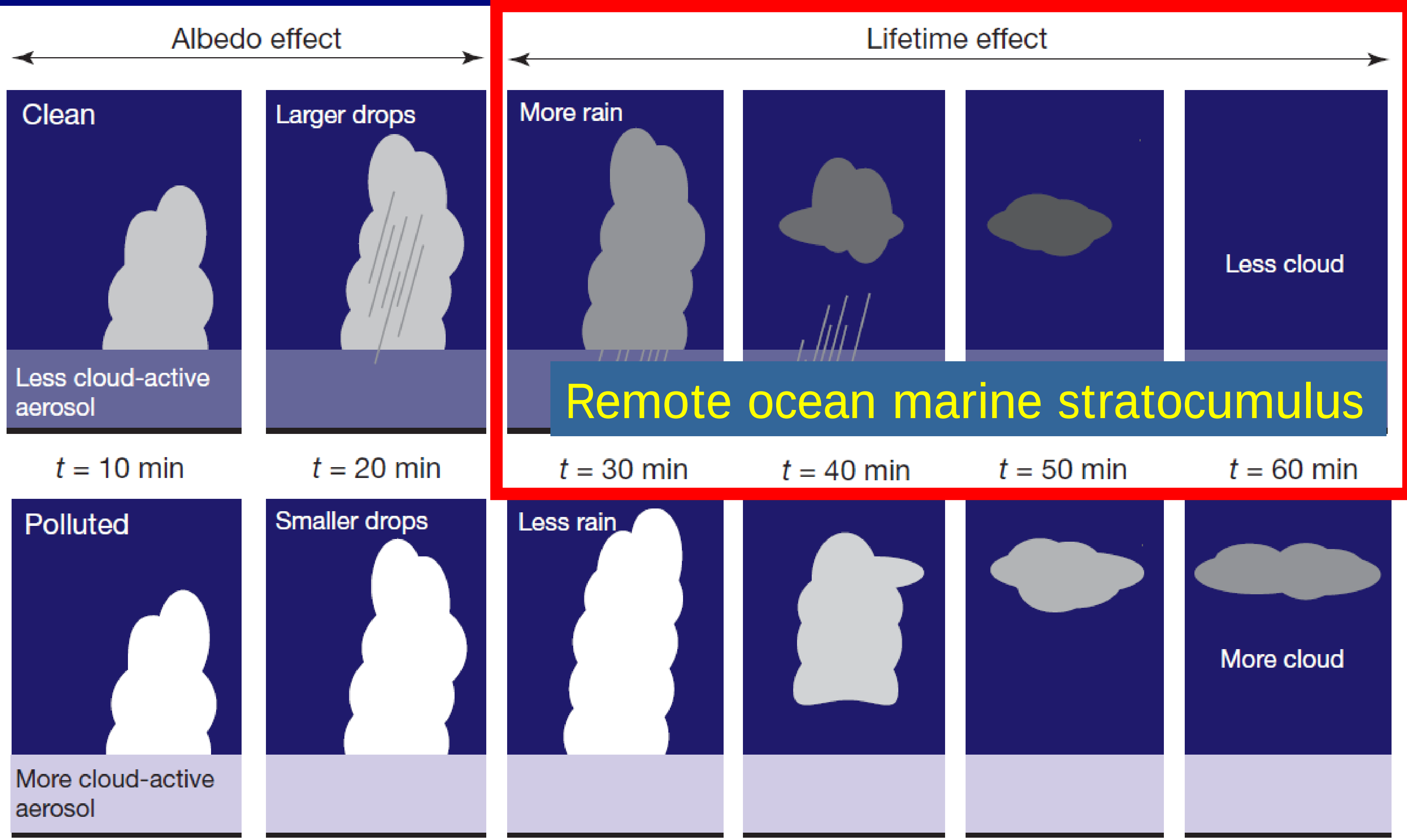
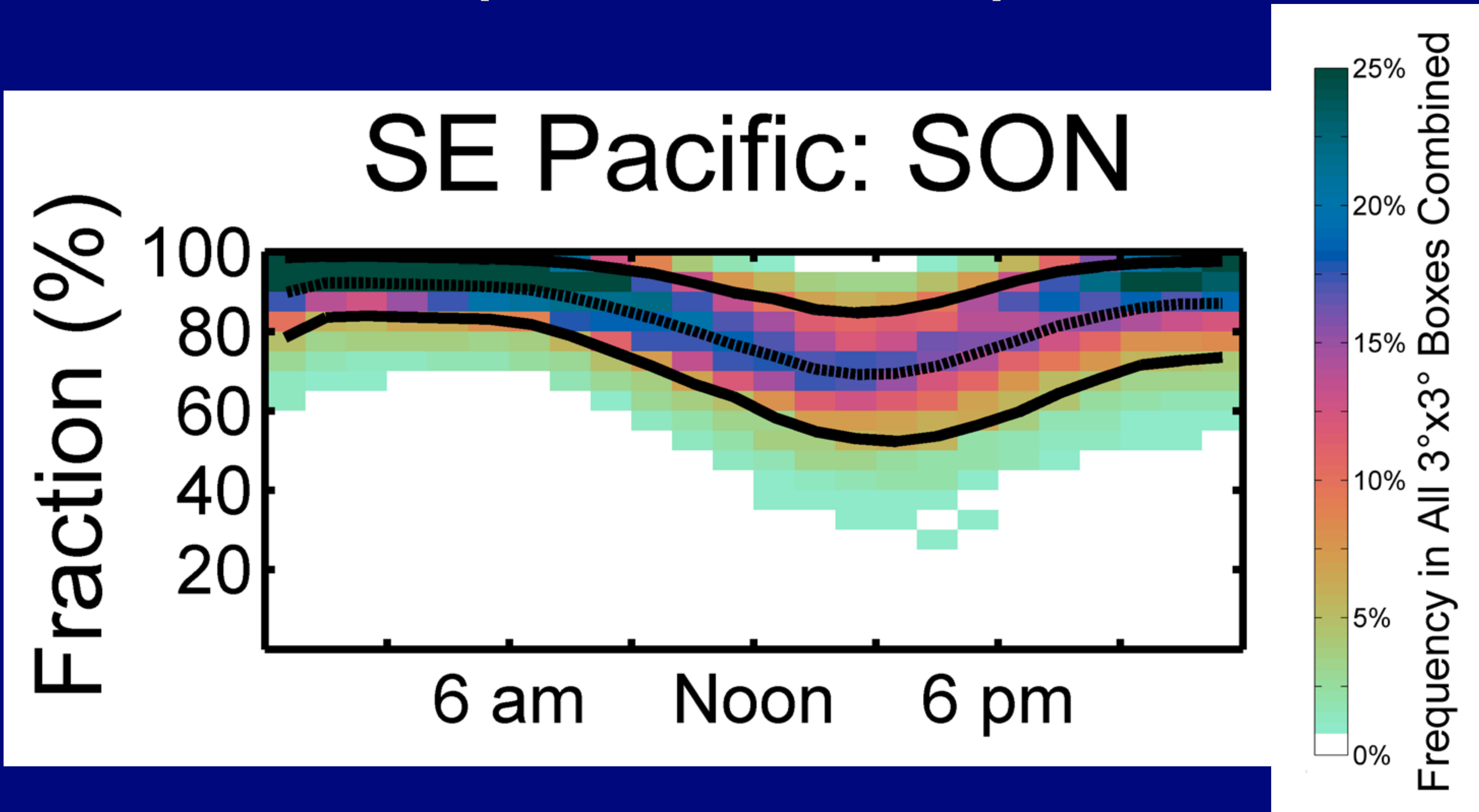
DOE ASR Science Team Meeting



In this figure, a single cloud represents the average response of a field of clouds [Stevens and Feingold (2009) following Albrecht (1989)]

Diurnal cycle of Cloud Fraction (3° x 3° boxes)



Potential Roles of Precipitation in Marine Stratocumulus Cloud Cover Changes

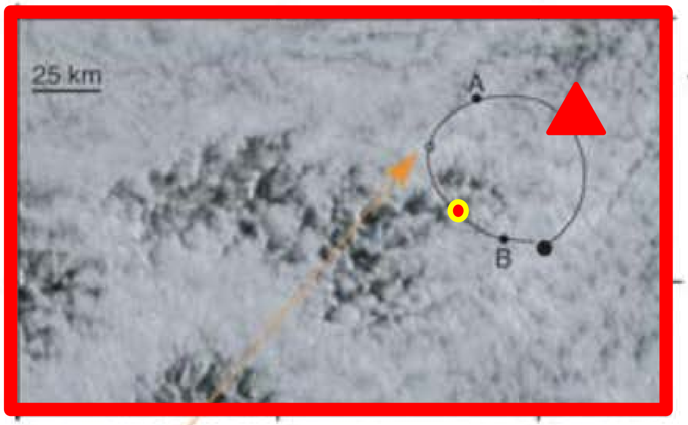
- Strong precipitation has been implicated in regional cloud cover change
  - Depletion of cloud liquid water

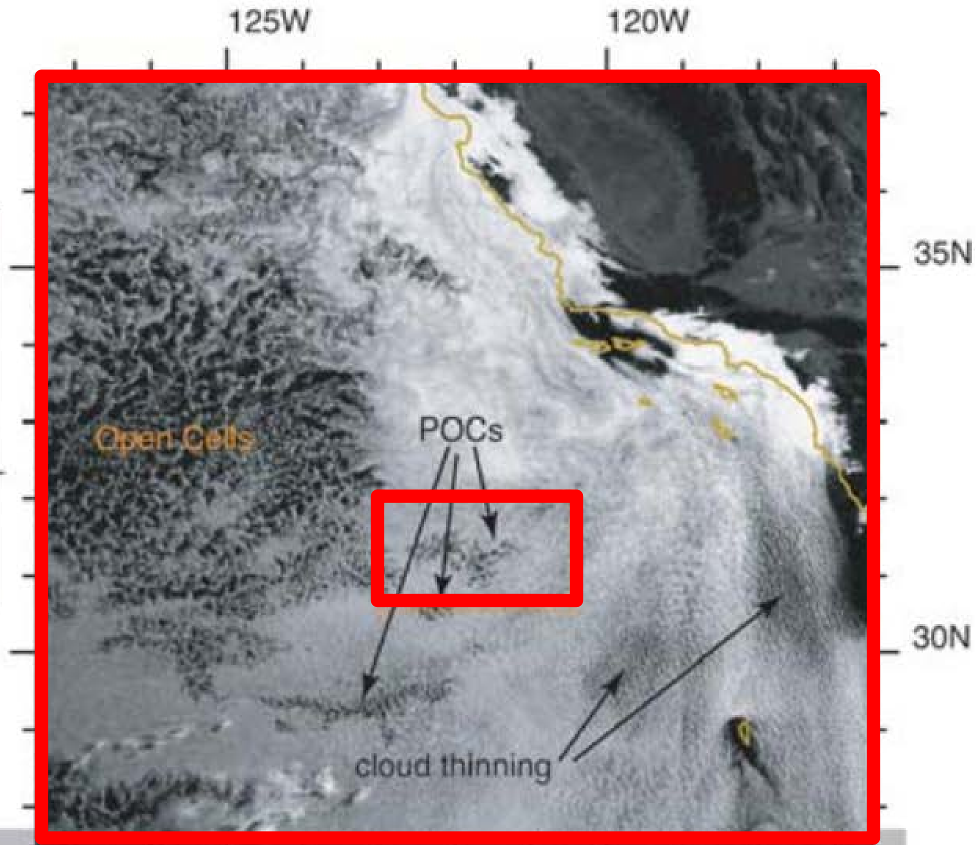
Also occurs during day

  - Reduced moisture transport between ocean surface and cloud
    - Drizzle evaporates below cloud creating stable layer
    - Stable layer decouples the sub-cloud layer from surface and inhibits moisture transport from surface into the cloud layer
  - Oscillating behavior of open cellular clouds related to creation and convergence of cold pools (Feingold/Terai)

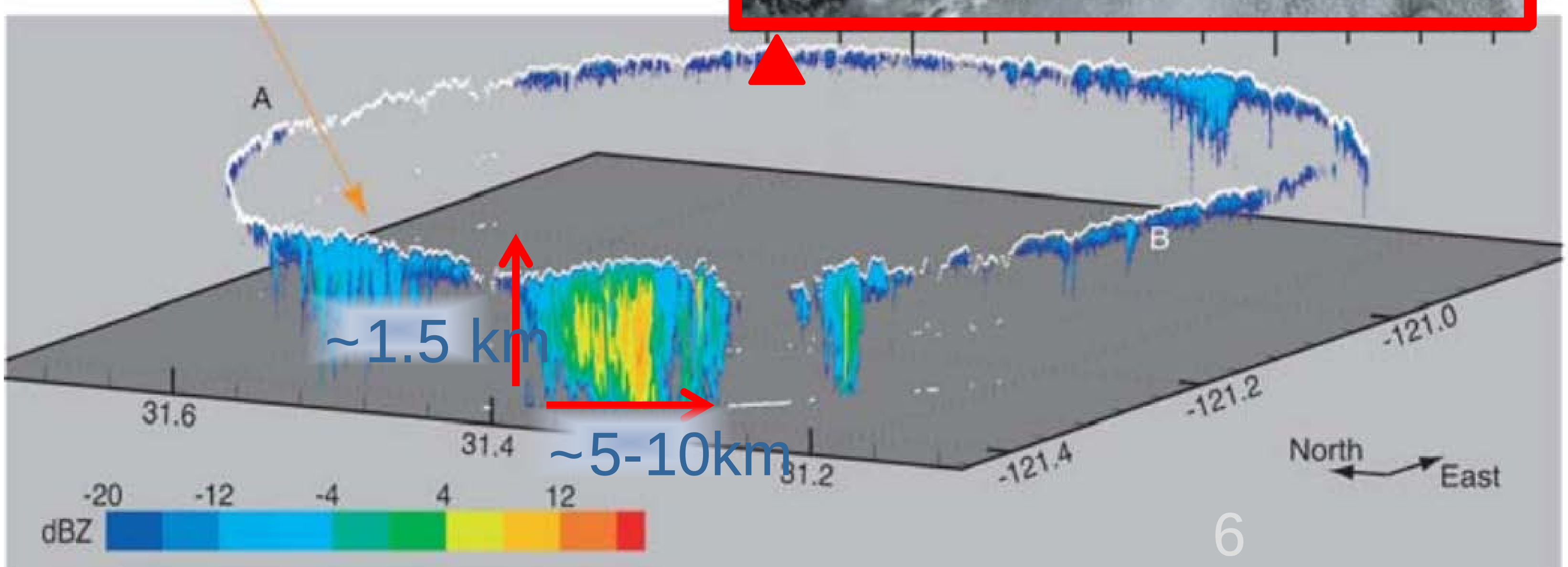
Neglect of Common Cause?

Stevens et al. 2005
example from DYCOMS II

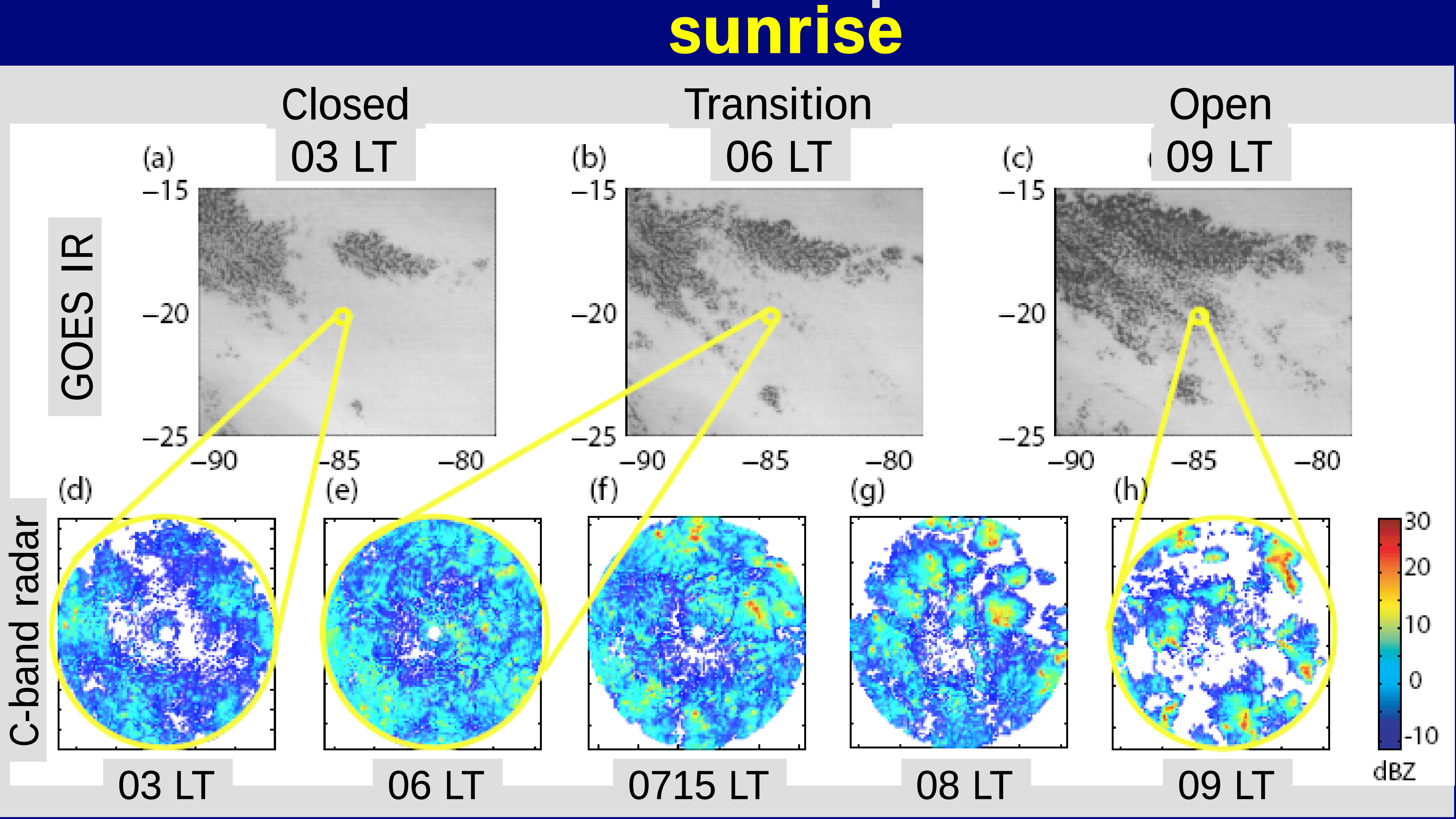




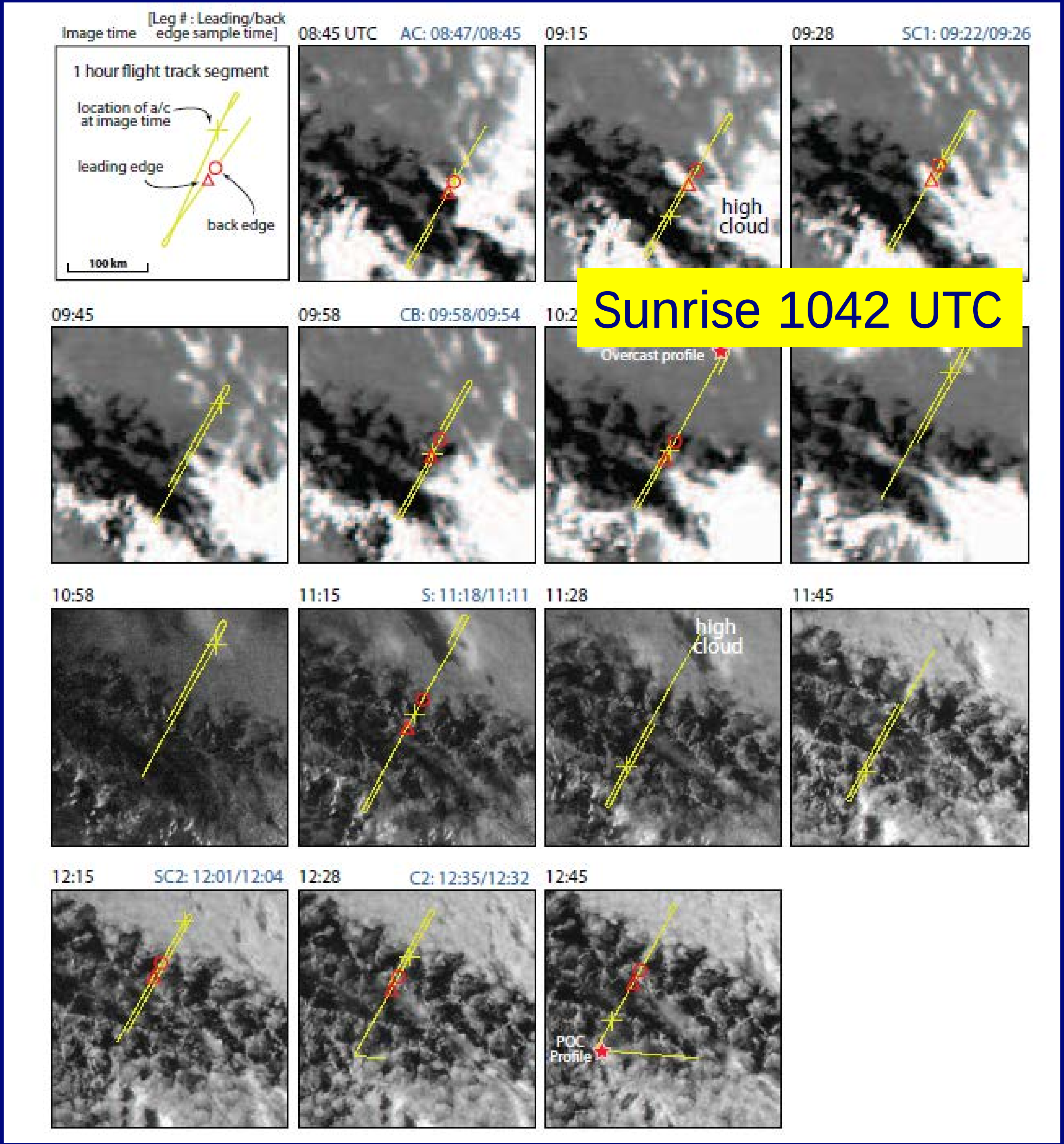
730am local time
(after sunrise)



Precipitation and Cloud Transition EPIC 2001 ship data

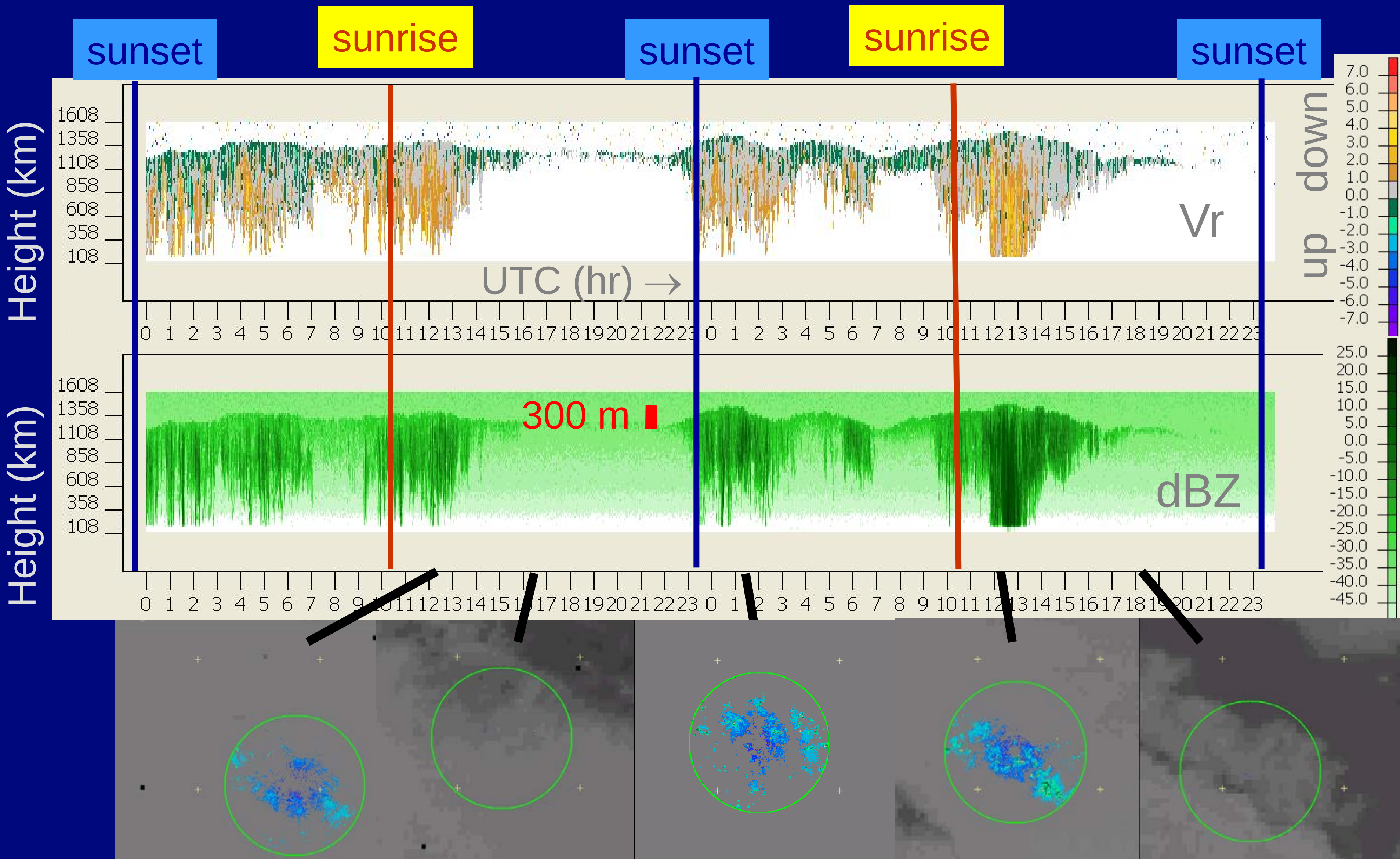


Comstock et al. 2007



VOCALS 2008 C-130 data Wood et al. 2011

NOAA/ESRL vertically-pointing Cloud Radar data
13 -14 Nov 2008, longitude ~76° W



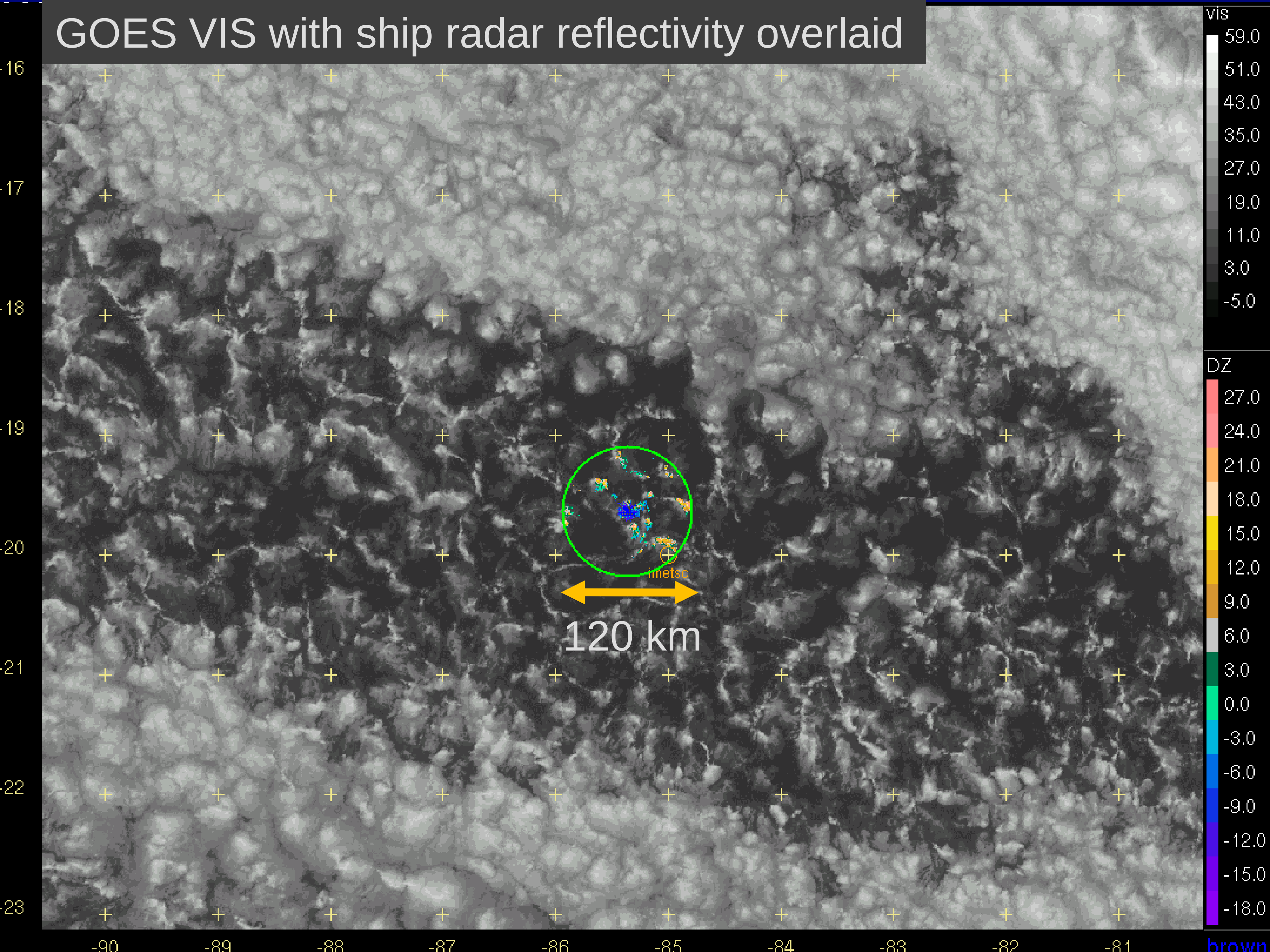
VOCALS REx
(Southeast Pacific, Oct-Nov 2008)

- C-band radar data
  - Precipitation Information
  - Every 3 minutes
  - 60 km radius around ship
  - 250 m resolution

- GOES IR Satellite
  - Cloud Fraction Info
  - Every 30 min

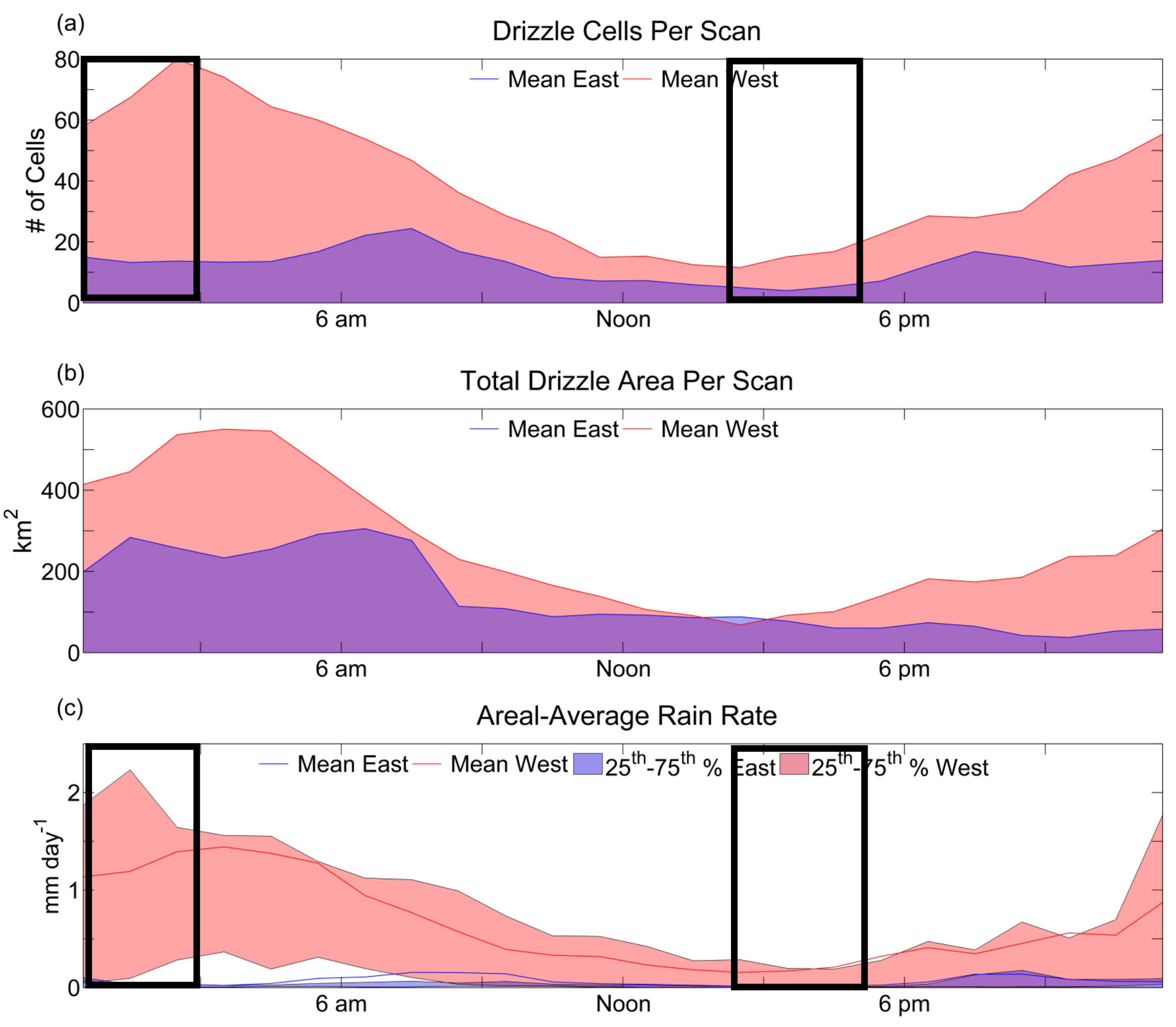
NOAA ship
Ronald H. Brown

GOES VIS with ship radar reflectivity overlaid



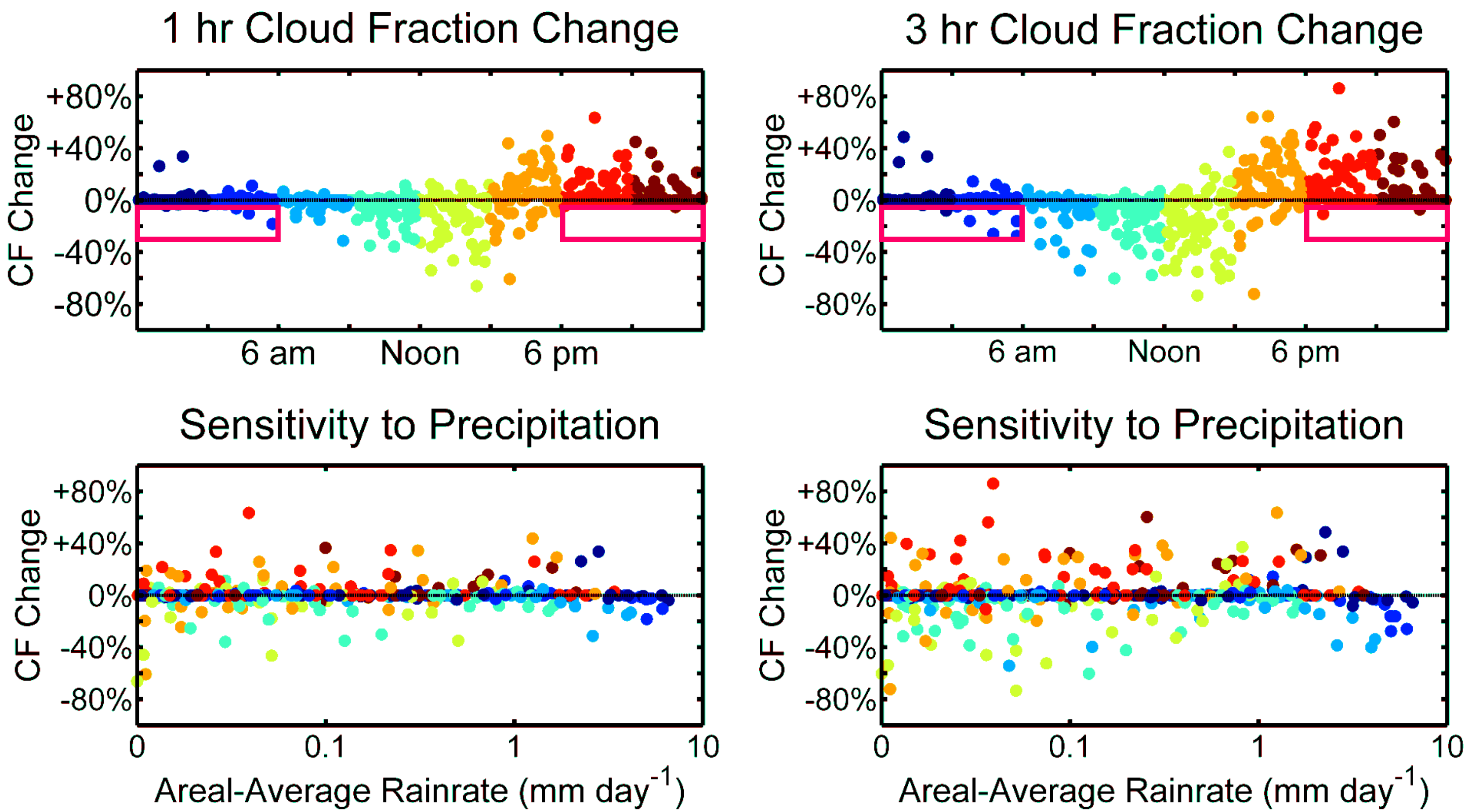
C-band radar- observed drizzle

Areal rain rate and the number of drizzle cells peak between 0-3 am and are at their lowest values between 2-5 pm.



Burleyson et al. (2013)

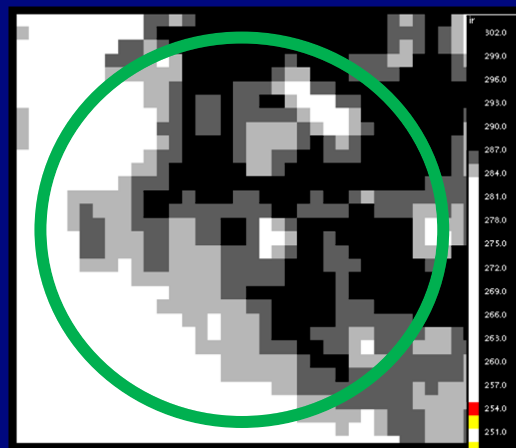
Diurnal cloud amount changes and lack of sensitivity to areal precipitation



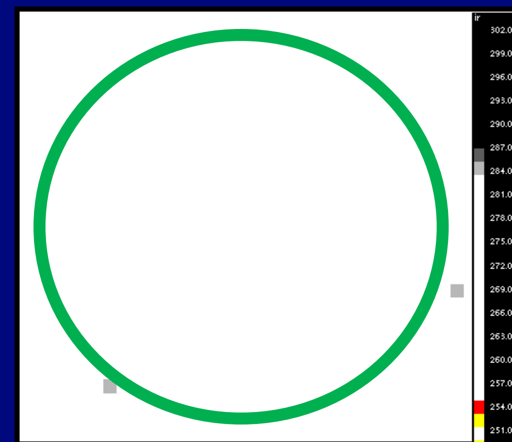
>5% CF decrease overnight (6pm to 6am) in only 4 out of 289 1-hr samples (1%) and 9 out of 306 3-hr samples (3%)

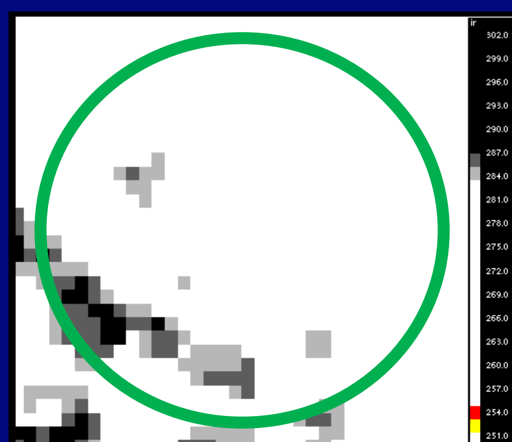
Cloud condition categories

Scattered: < 75% CF



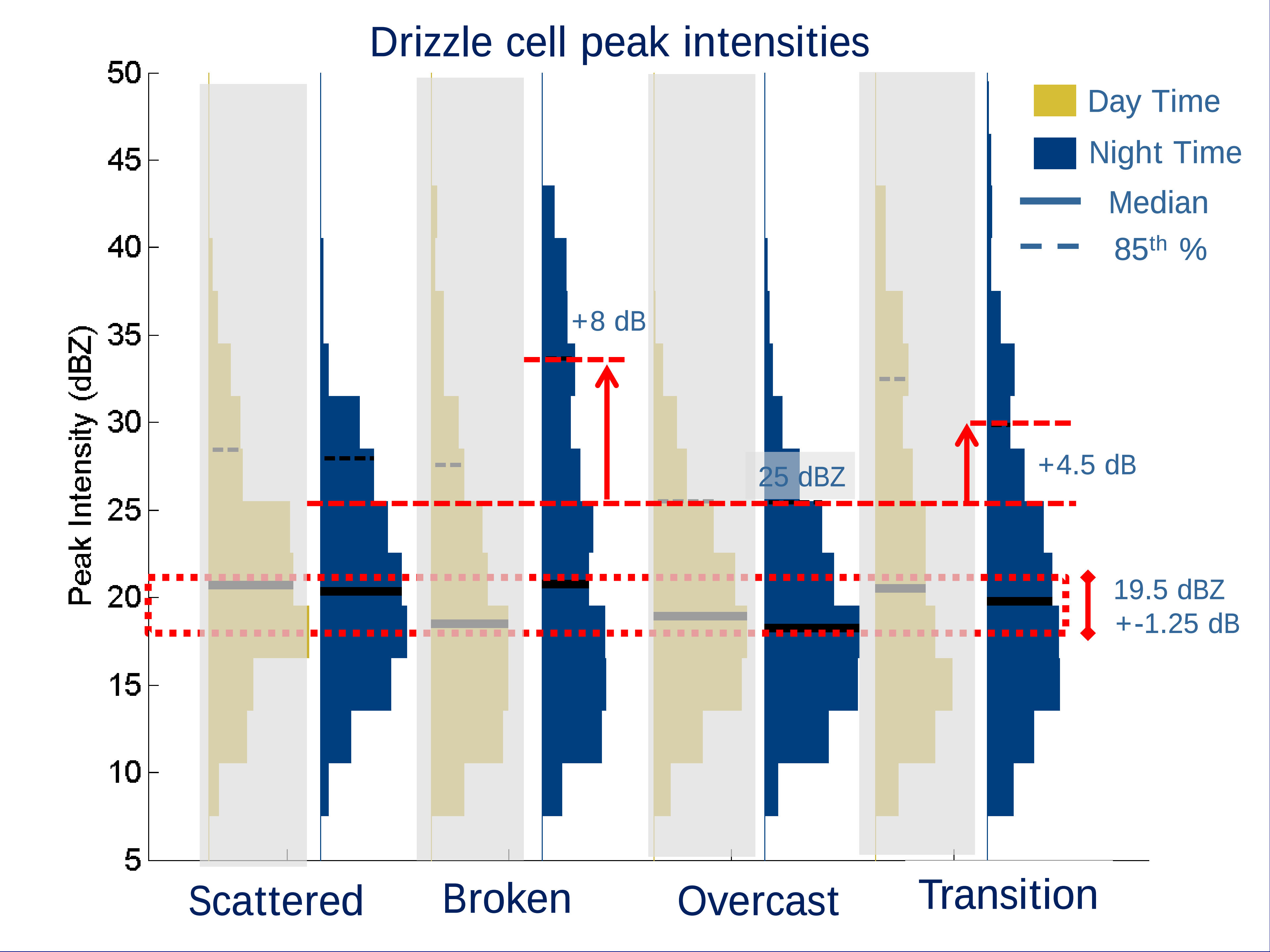
Overcast: CF=100%





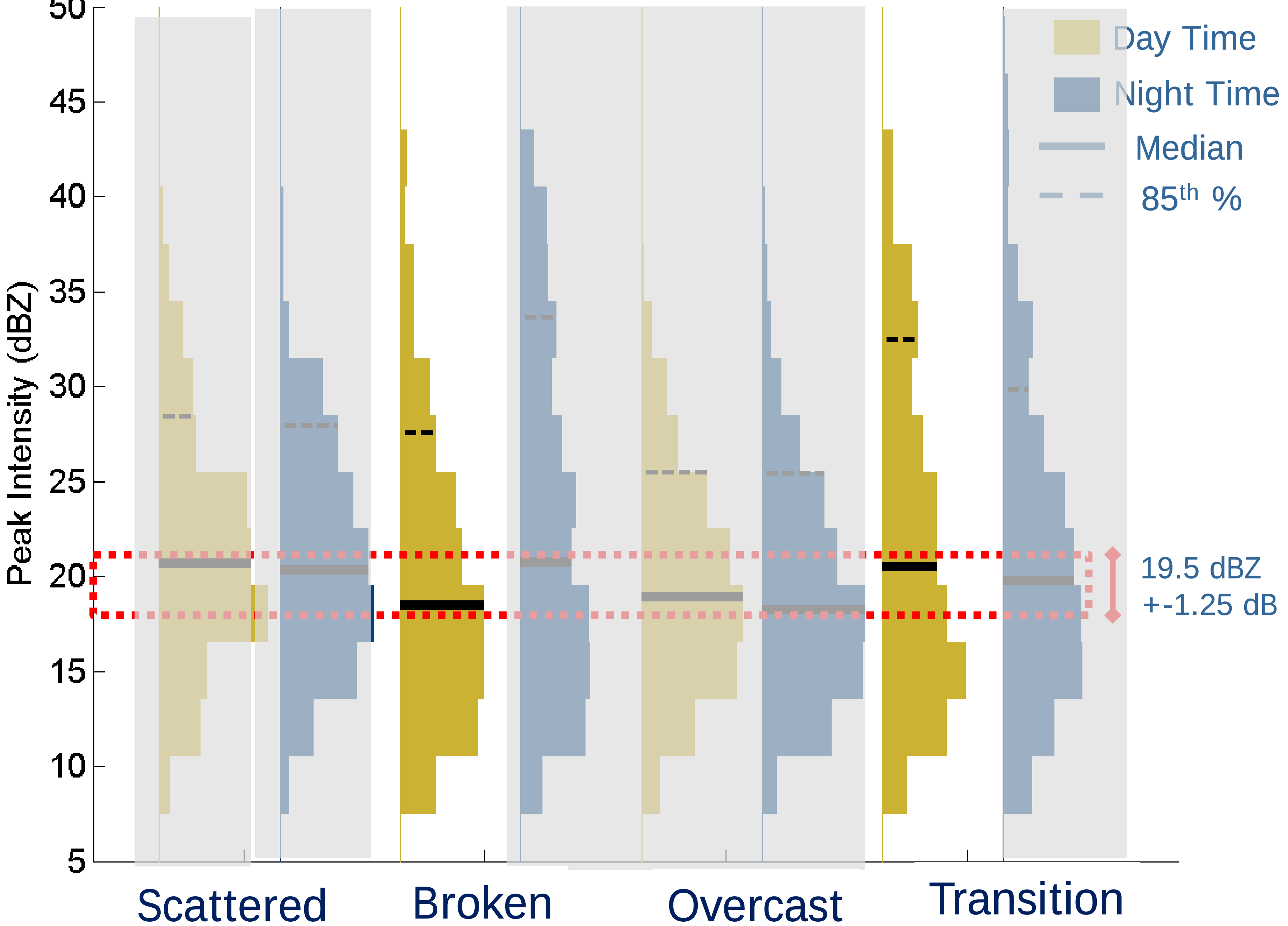
Transition = cloud cover
is changing in time

Broken: 75%<CF<100%

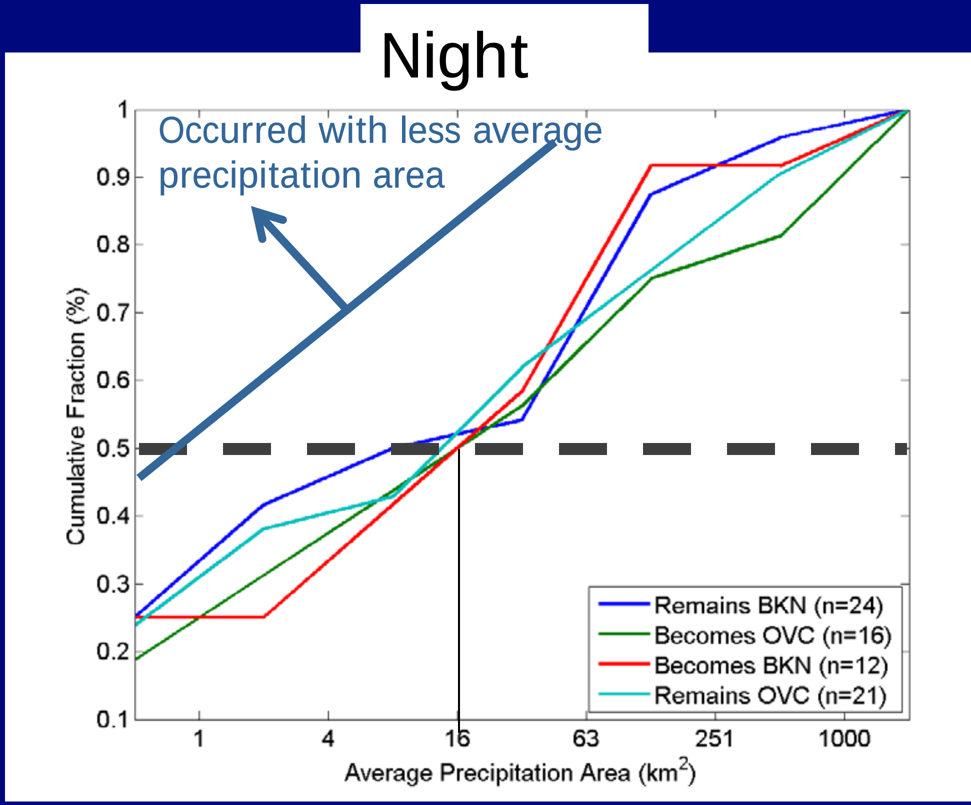


Drizzle cell peak intensities
Peak Intensity (dBZ)
50
45
40
35
30
25
20
15
10
5
Day Time
Night Time
Median
85th %
+8 dB
25 dBZ
+4.5 dB
19.5 dBZ
+-1.25 dB
Scattered
Broken
Overcast
Transition

Drizzle cell peak intensities



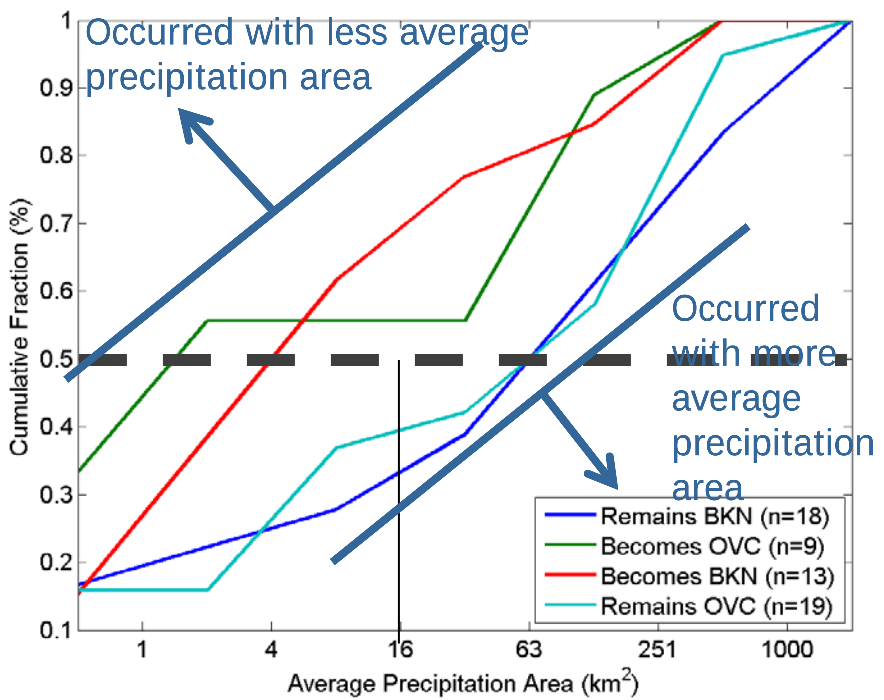
Cumulative Frequency of Precip Area vs Cloud Event (day/night)



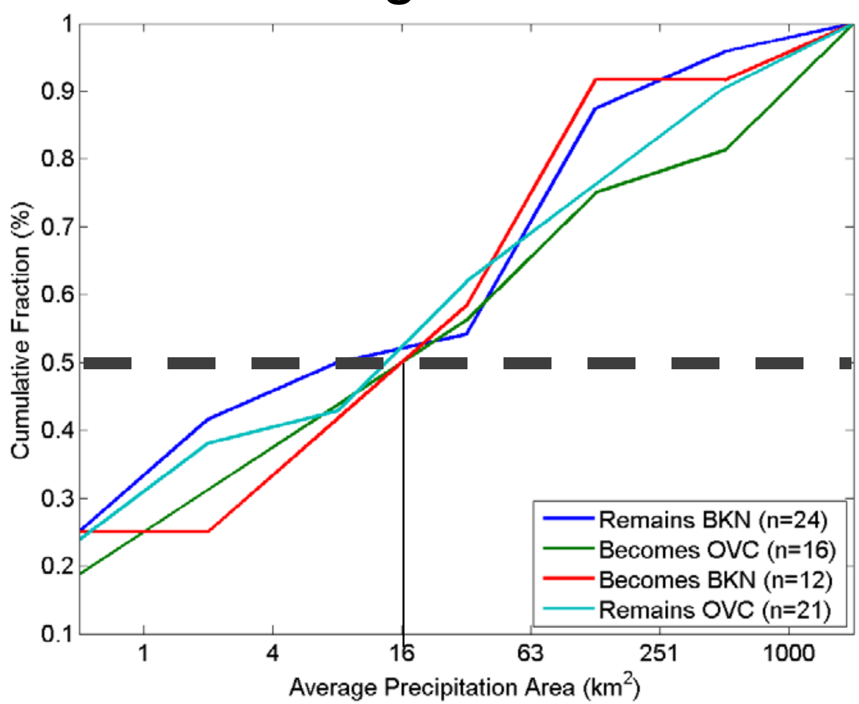
Becomes Overcast, Remains Broken
Remains Overcast, Becomes Broken

Cumulative Frequency of Precip Area vs Cloud Event (day/night)

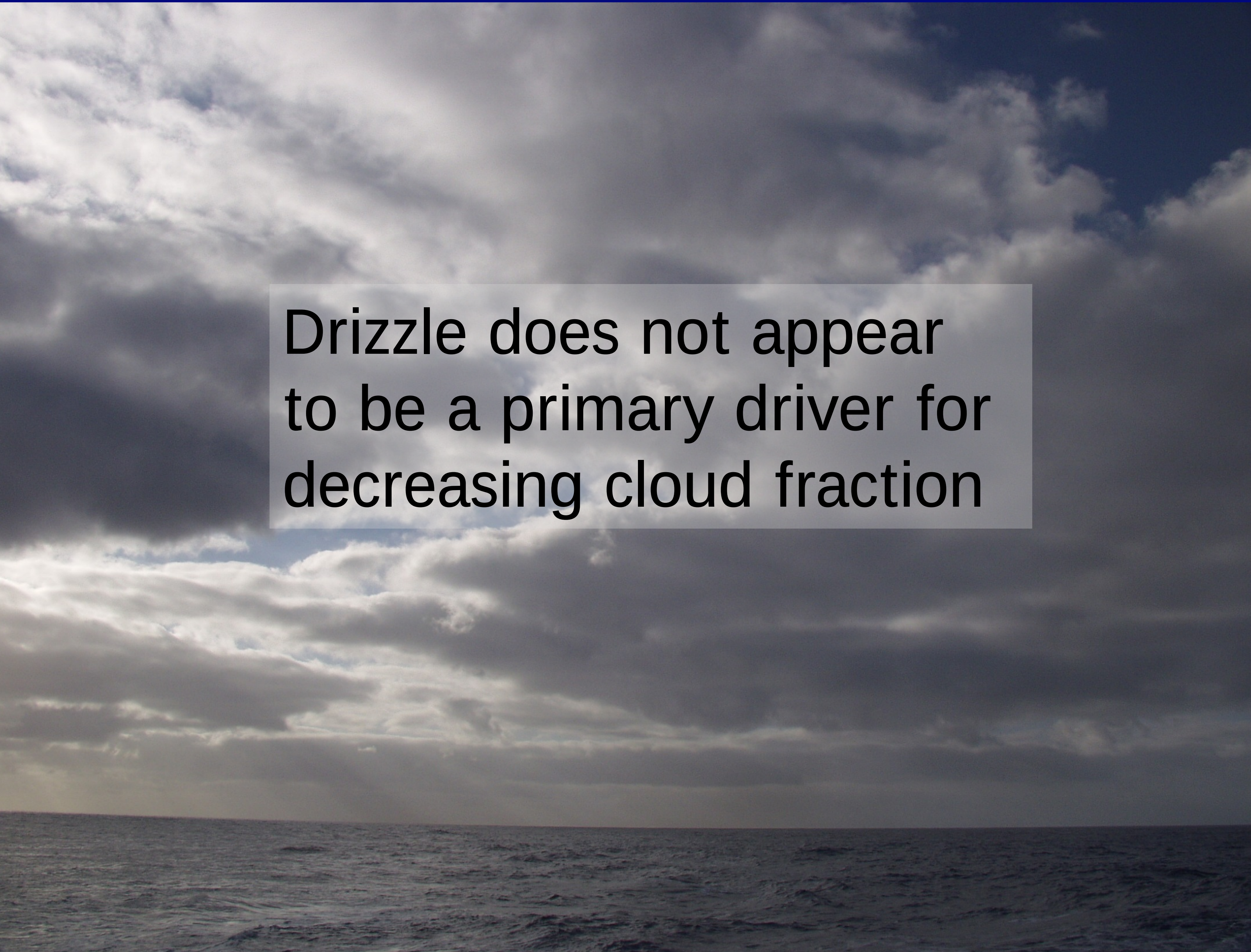
Day



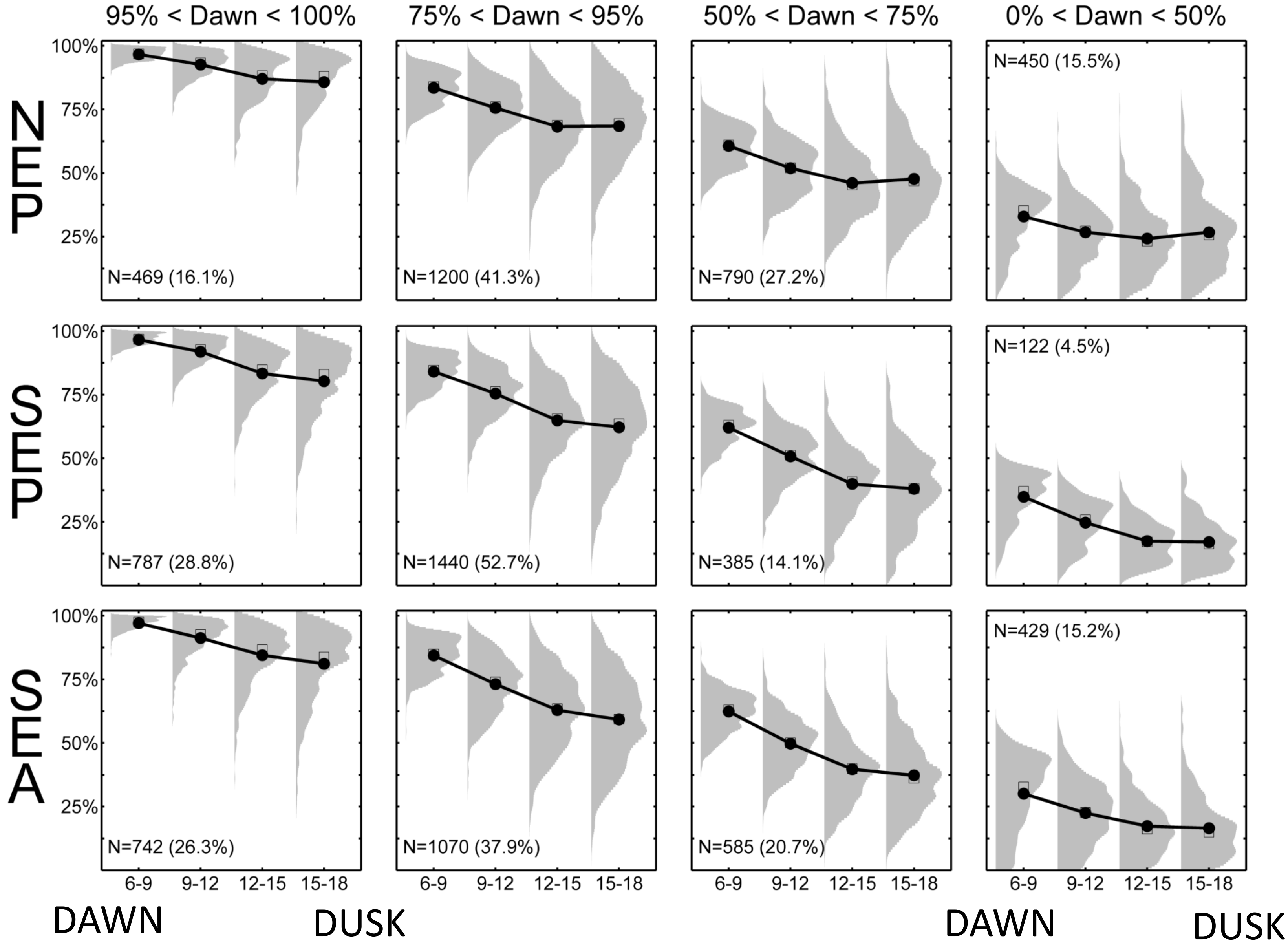
Night



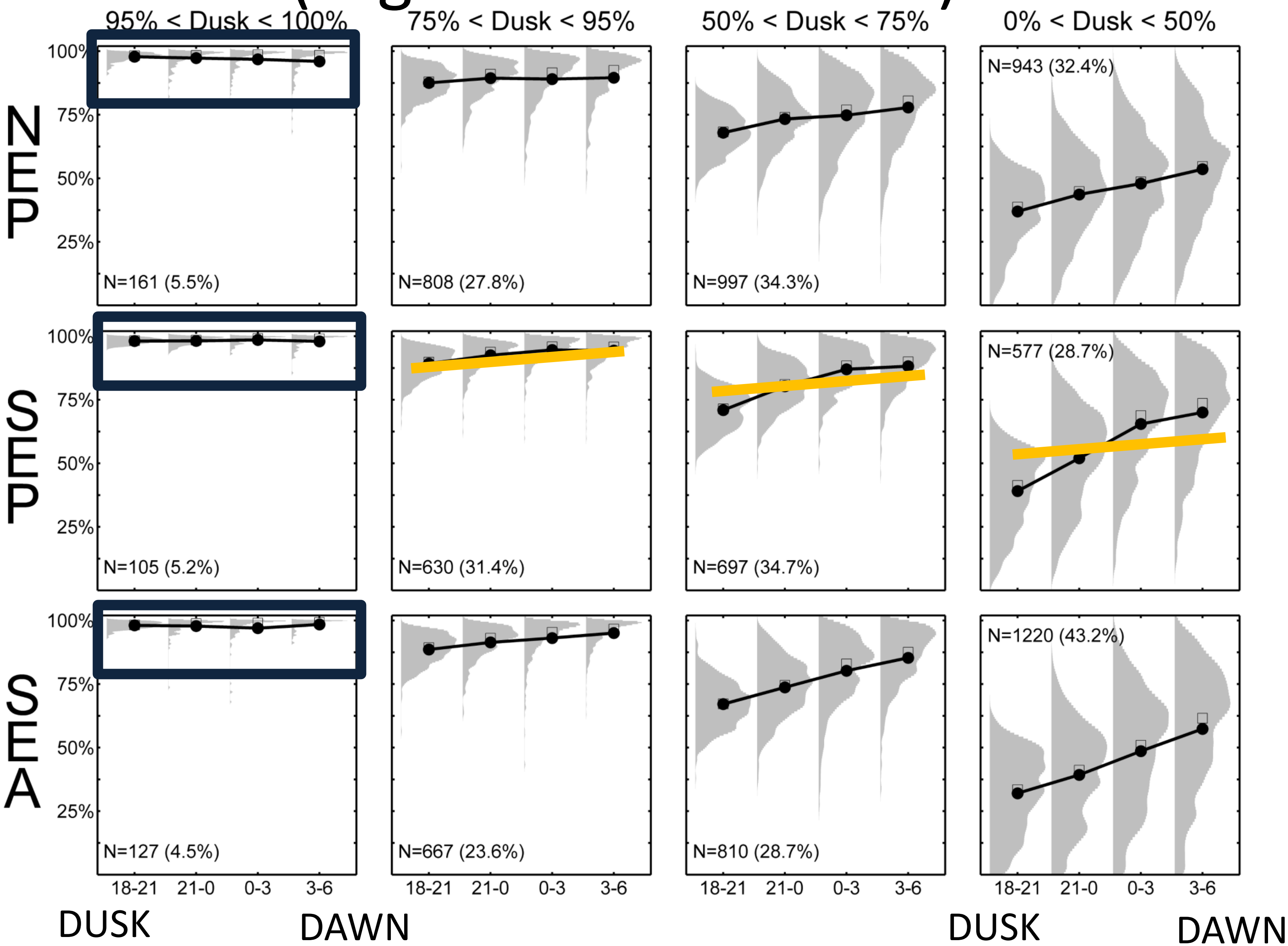
Becomes Overcast, Remains Broken
Remains Overcast, Becomes Broken


Drizzle does not appear to be a primary driver for decreasing cloud fraction

Importance of Starting Cloud Fractions (Day: Dawn to Dusk)



Importance of Starting Cloud Fractions (Night: Dusk to Dawn)



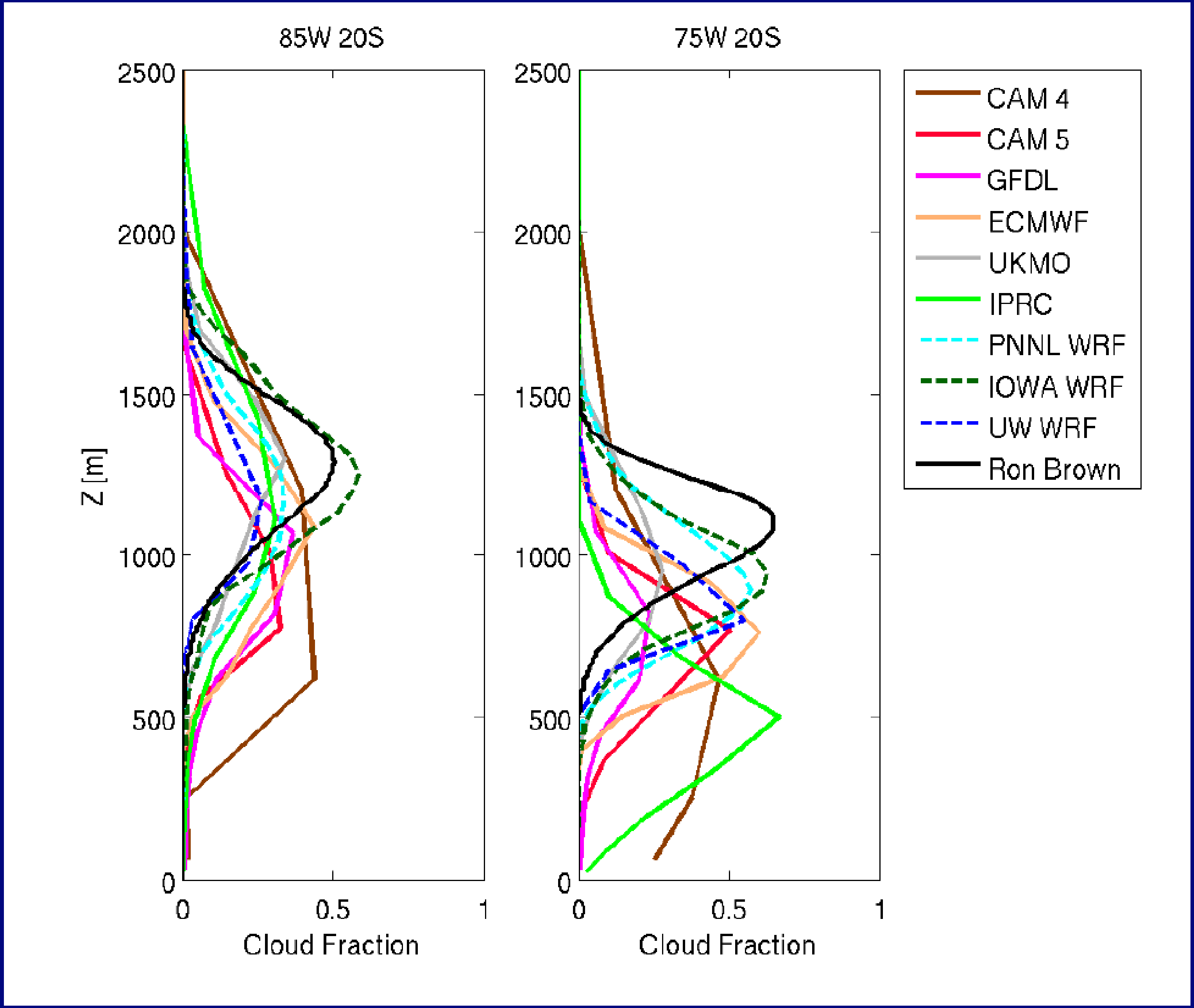
Conclusions

- Anecdotal examples can be found for a variety of cloud fraction and precipitation area conditions
  - Cloud fraction increasing with/without precipitation
  - Cloud fraction decreasing with/without precipitation
  - Cloud fraction persisting with/without precipitation
- At night:
  - Overcast conditions with/without precipitation usually do not break up
  - Overcast cloud breakup can occur without precipitation
- During the day:
  - Clouds with larger precipitation areas tend to maintain their existing cloud fraction (likely thicker clouds)
  - Clouds that change cloud fraction have less precipitation area (likely thinner clouds)

Conclusions

- At 100-300 km and < 5 hour scales:
  - Drizzle and cloud fraction co-varying with diurnal cycle of solar radiation
  - Drizzle is neither necessary nor sufficient for reducing cloud fraction overnight
  - Impact of overnight drizzle reducing cloud fraction is very small (< 3% occurrence)

Wyant et al. 2014 Model Intercomparison



Wyant et al. 2014

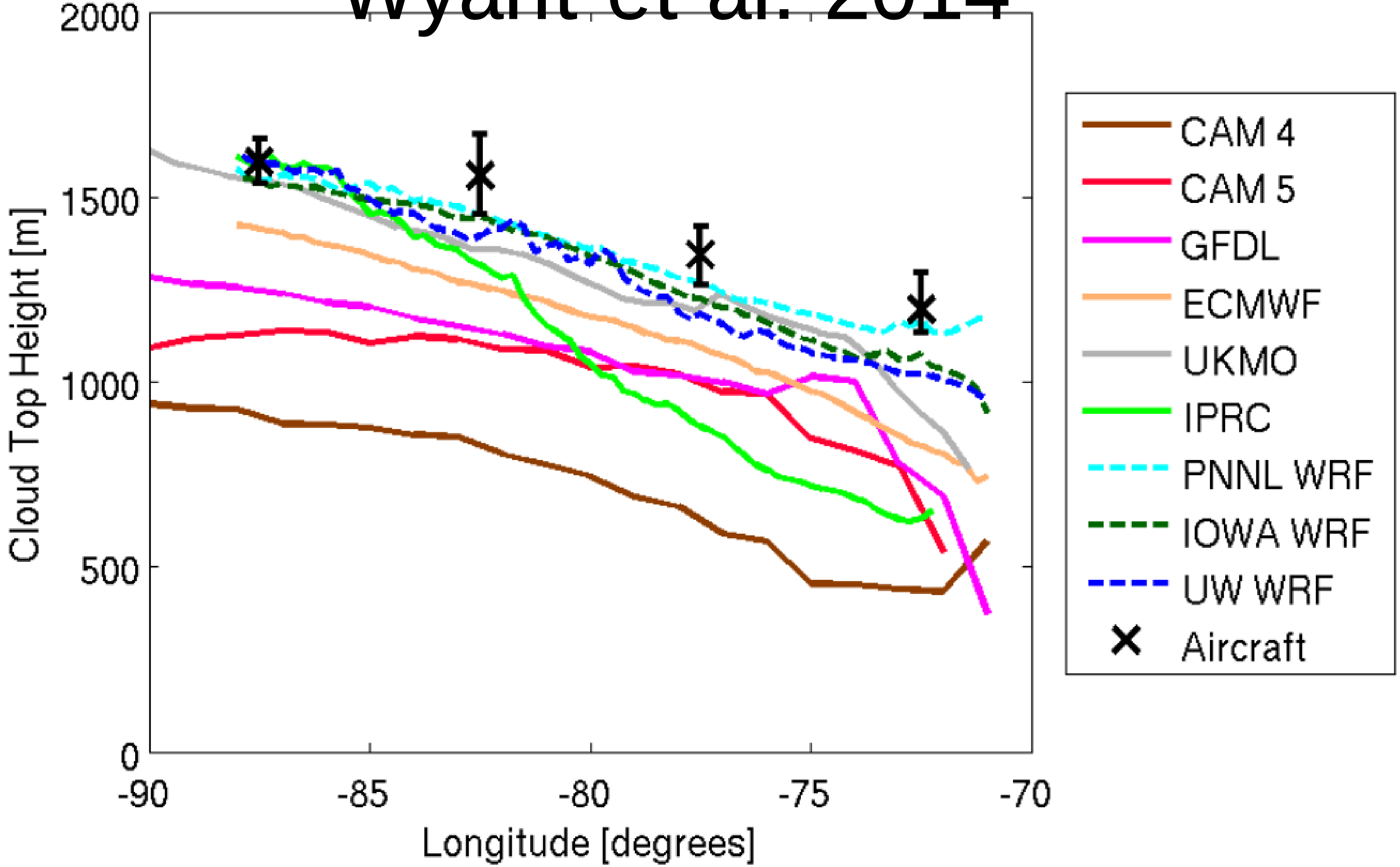
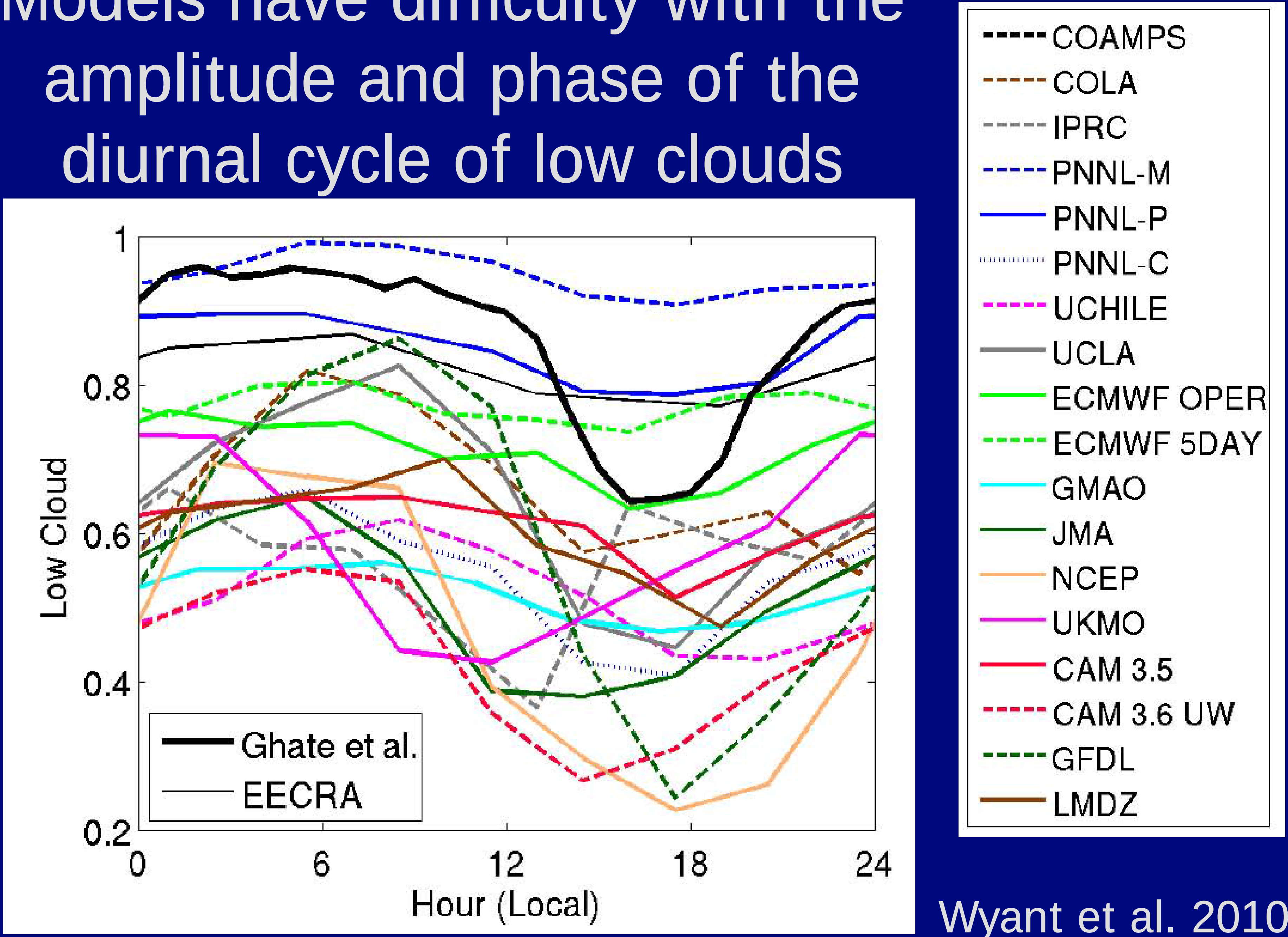


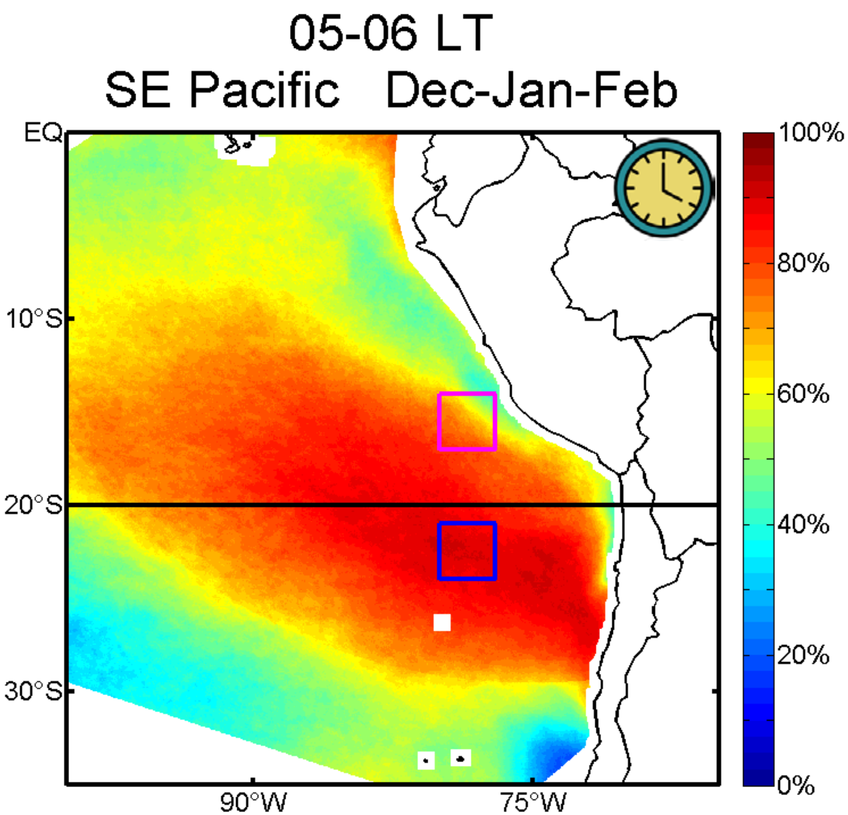
Fig. 4. Model-mean cloud-top height along 20º S compared with mean cloud-top measured using cloud radar from C-130 flights (Bretherton et al 2010).

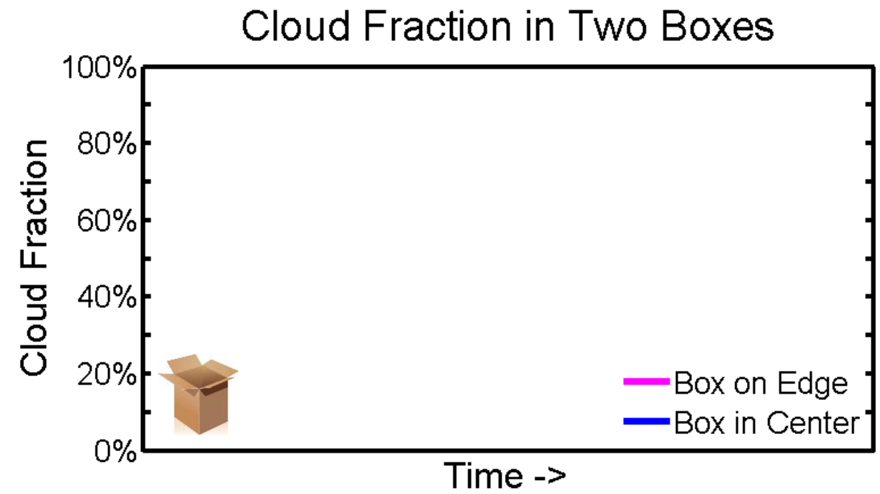
Models have difficulty with the amplitude and phase of the diurnal cycle of low clouds

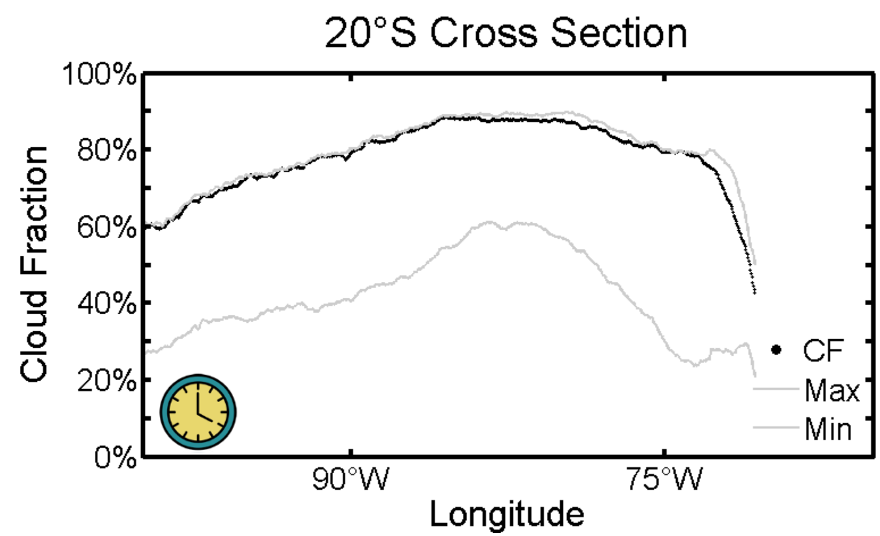


Wyant et al. 2010

Results – Diurnal Cycle of Cloud Fraction







Earlier breakup of the cloud and larger amplitude diurnal cycles are observed in low cloud fraction regions and in deeper boundary layers.

Burleyson (2013)

Observed to vary with diurnal cycle in marine Sc

- Long Wave and Short Wave radiation fluxes
- Cloud fraction
- Subcloud turbulent moisture transport
  - Profiles of vertical velocity variance, potential temperature, water vapor mixing ratio, horizontal wind, dew point temp
  - Wind direction
- Cloud top height, cloud base height, cloud depth, Liquid Water Path
- Number of drizzle cells, drizzle area, areal average rain rate

Not observed to vary with diurnal cycle in southeast Pacific marine Sc

- Near surface aerosol concentration
- Near surface wind speed
- Conditional rain rate
- Proximity of drizzle cells