Marine Boundary Layer Cloud-top-height from MODIS, CALIPSO and COSMIC Over Subtropical Eastern Oceans

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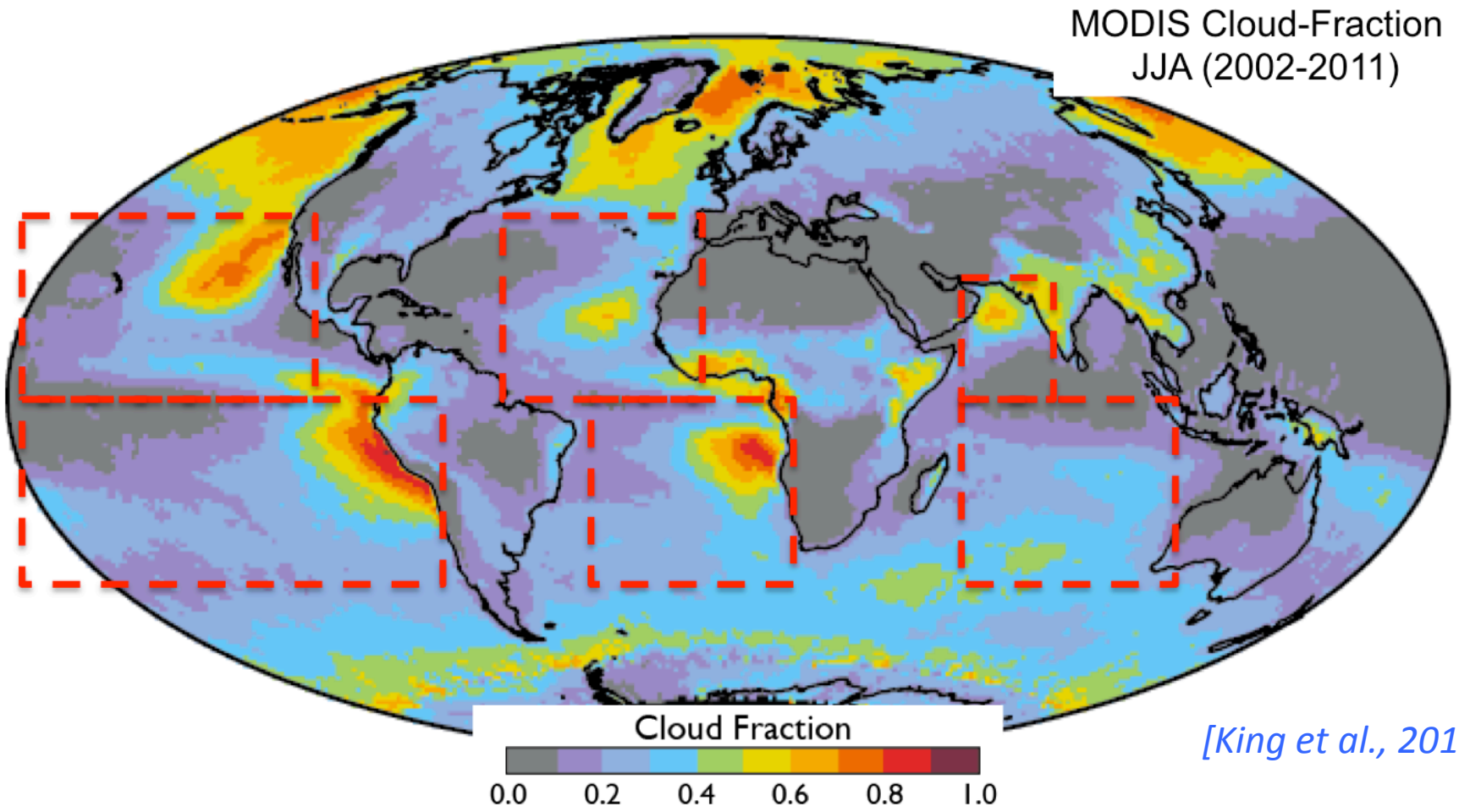
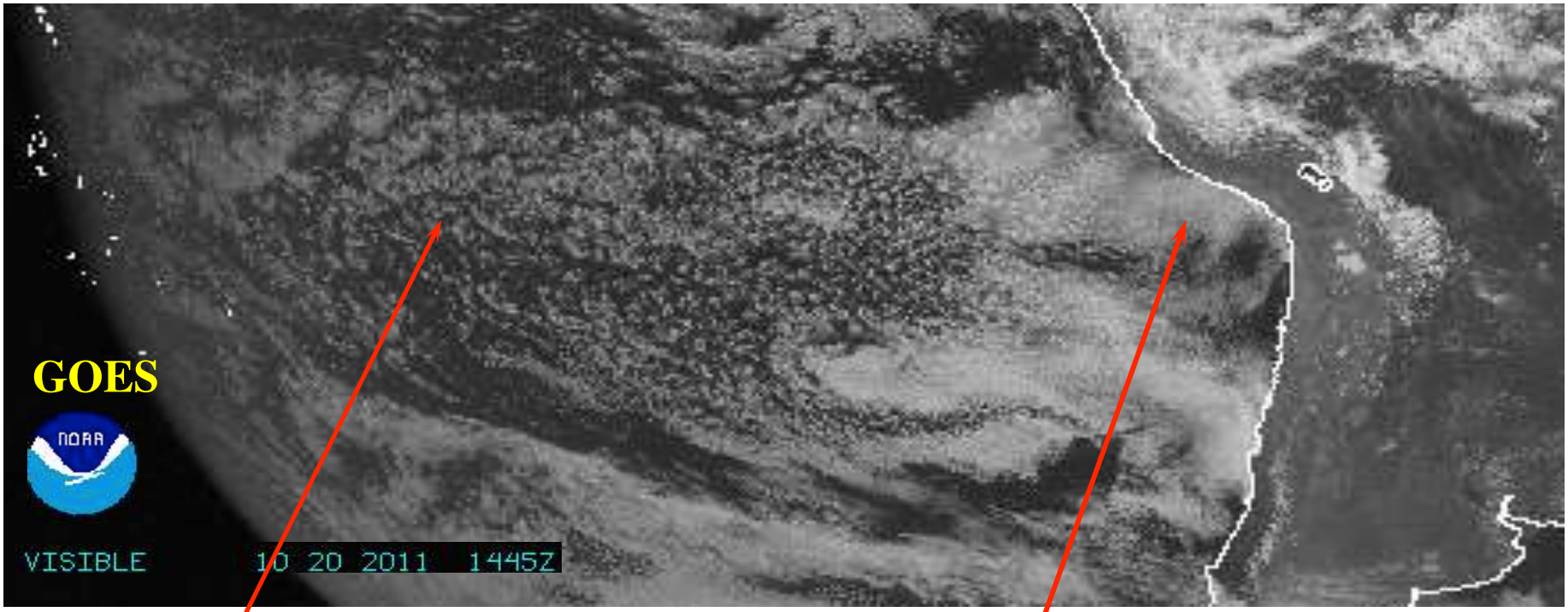
Liquid water cloud fraction – Aqua



[King et al., 2013]

Six selected regions with prevailing boundary layer clouds.

Marine Atmospheric Boundary Layer Clouds

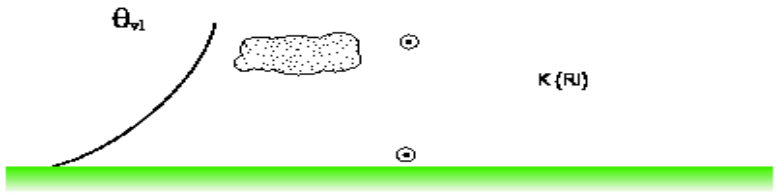


Transition

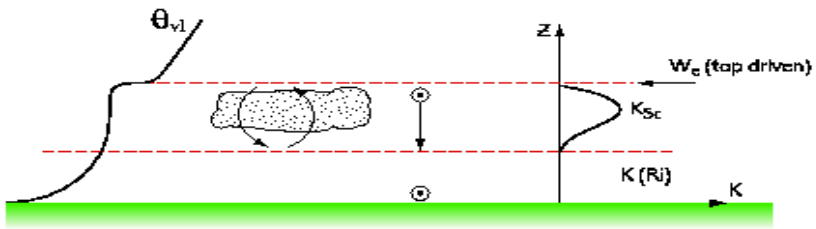
Cloud photos courtesy of Dr. B. Stevens

Different Cloudy Boundary Layer Structure

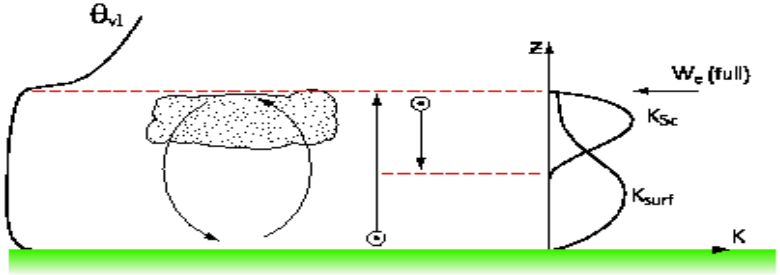
I. Stable boundary layer, possibly with non-turbulent cloud
(no cumulus, no decoupled Sc, stable surface layer)



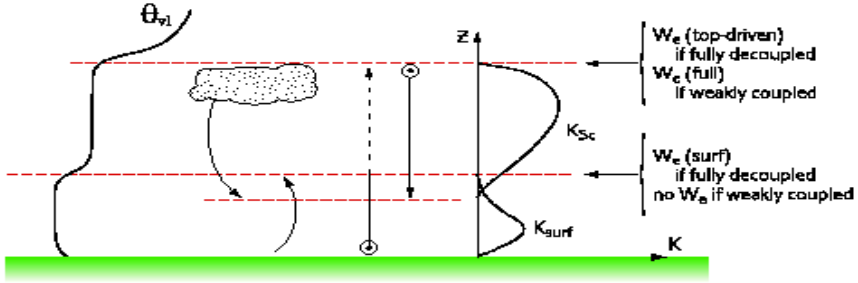
II. Stratocumulus over a stable surface layer
(no cumulus, decoupled Sc, stable surface layer)



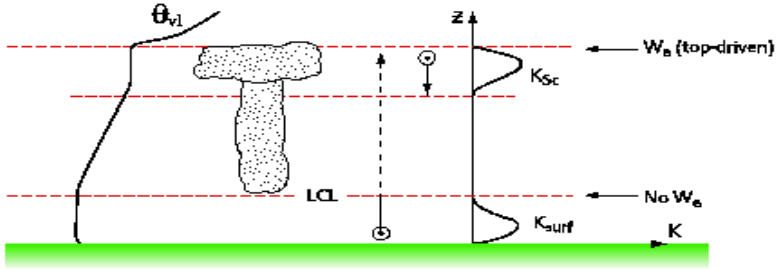
III. Single mixed layer, possibly cloud-topped
(no cumulus, no decoupled Sc, unstable surface layer)



IV. Decoupled stratocumulus not over cumulus
(no cumulus, decoupled Sc, unstable surface layer)



V. Decoupled stratocumulus over cumulus
(cumulus, decoupled Sc, unstable surface layer)



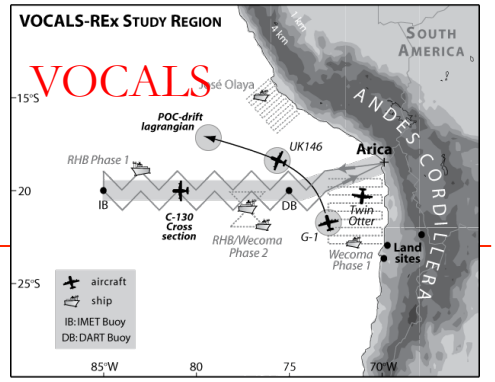
Lock et al., 2000, MWR

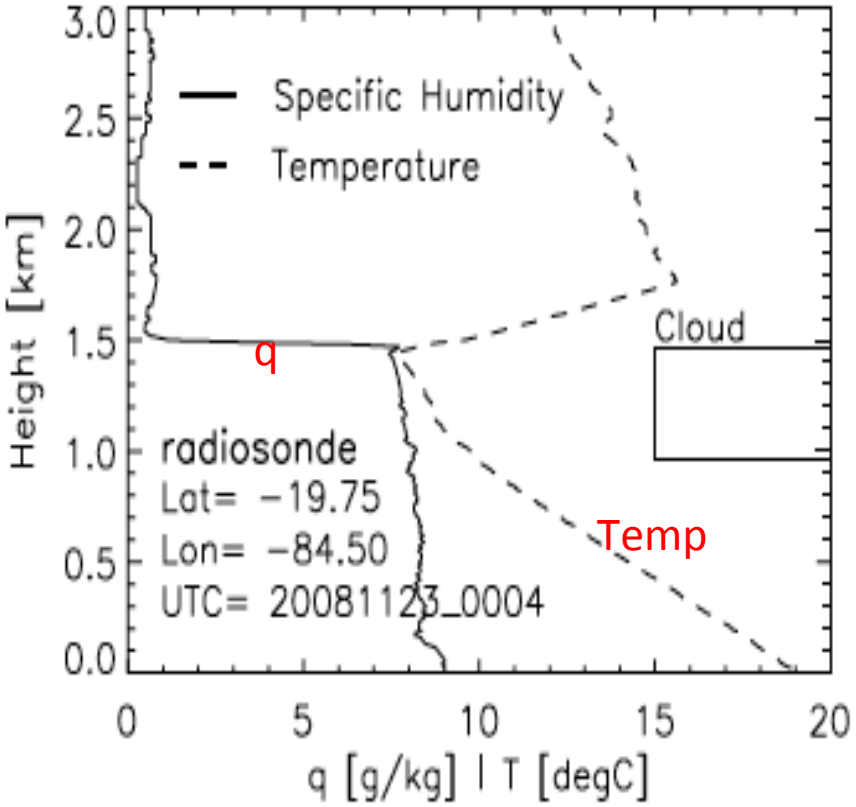
MBL Height Measurement

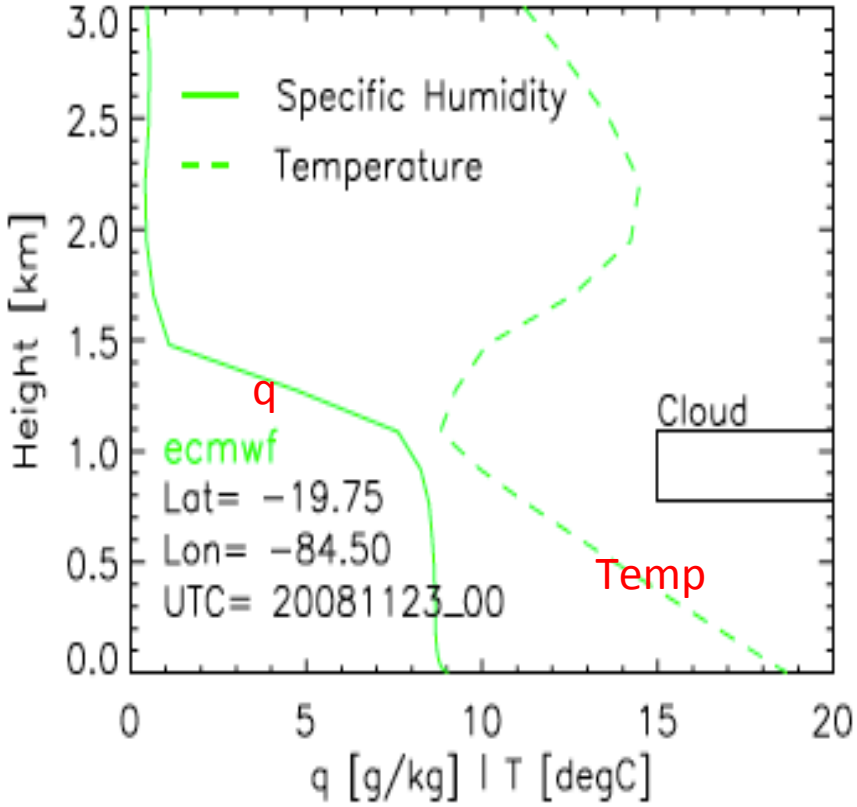
- Vertical profiling
  - Balloon sounding – profiling (T/q)
  - GPS radio occultation (refractivity, bending angle)

- MBL-top tracer tracking
  - CALIPSO lidar, clouds and aerosol backscattering
  - MODIS, cloud-top-temperature, cloud fraction
  - Limitation: only works when tracers are available

Stratocumulus-topped MBL

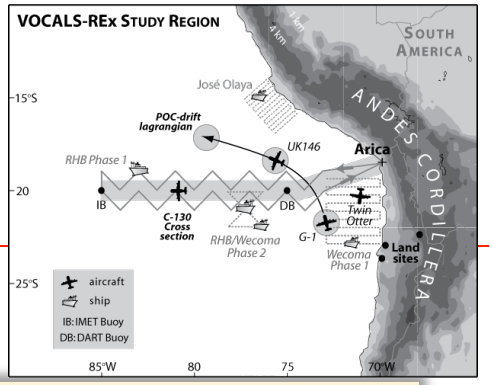


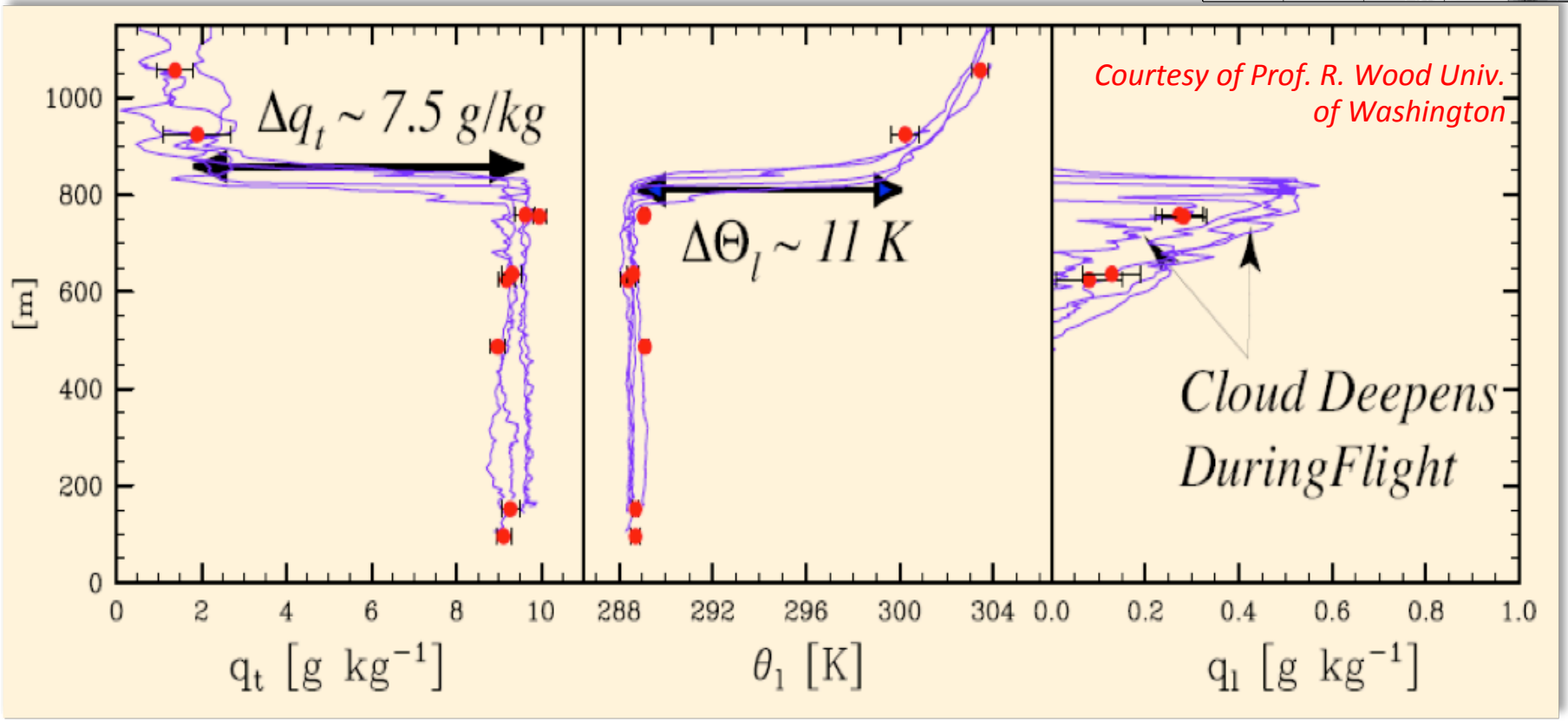




VAMOS Ocean-Cloud-Atmosphere-Land Study (2008-Oct-Nov)

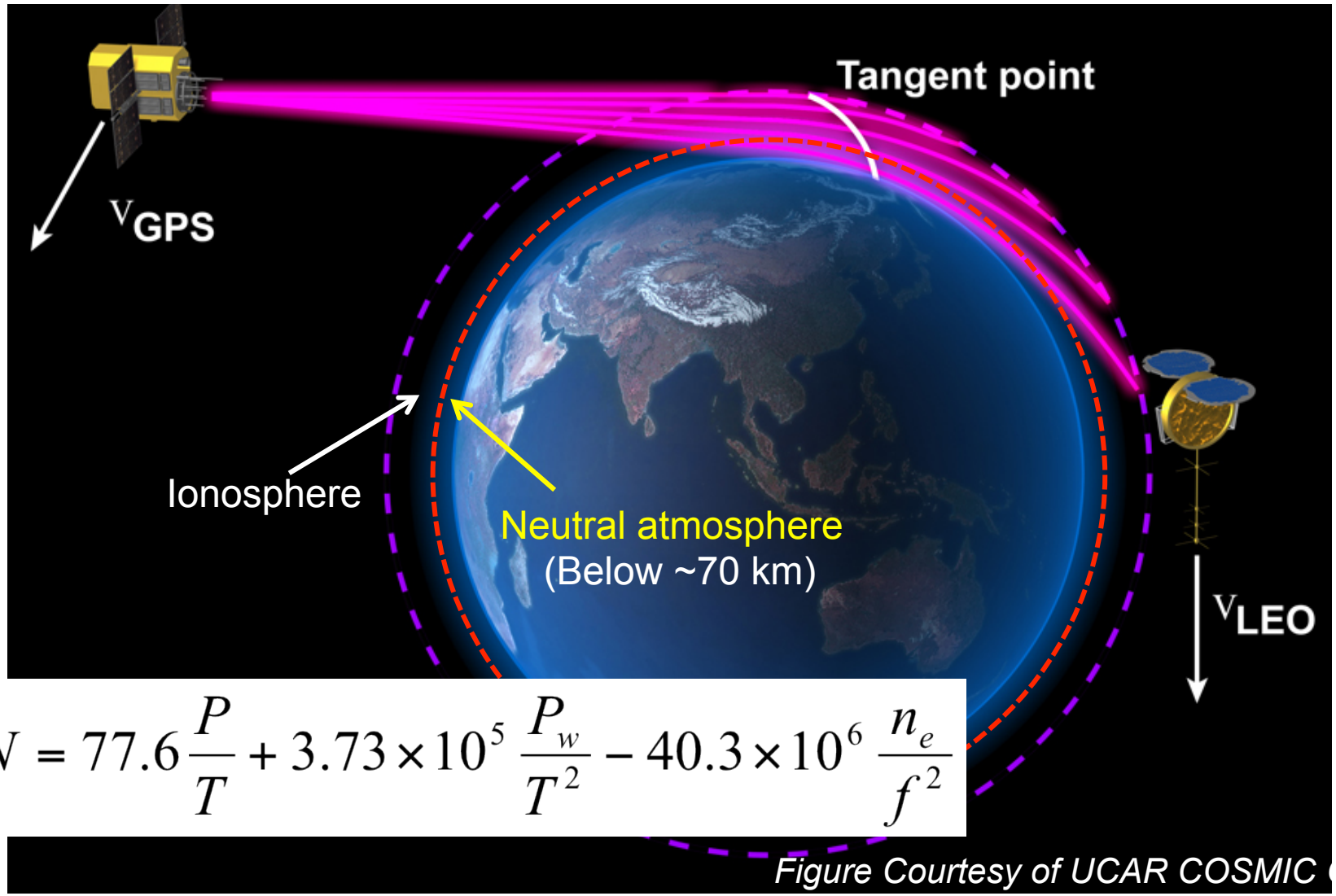
VOCALS MBL Structure





The inversion-base height is consistent with Cloud-top-height
Lower boundary layer height → lower clouds

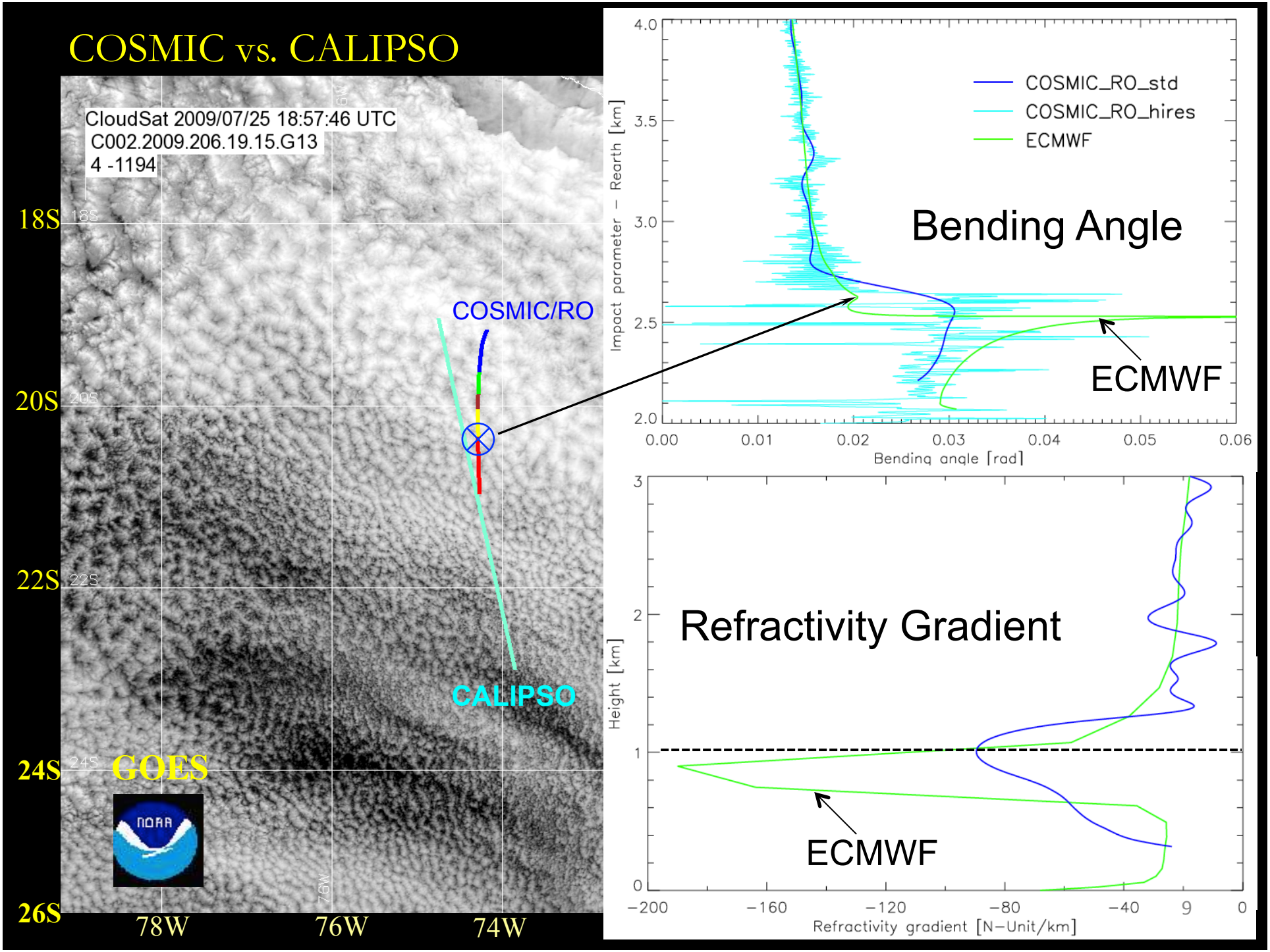
GPS Radio Occultation

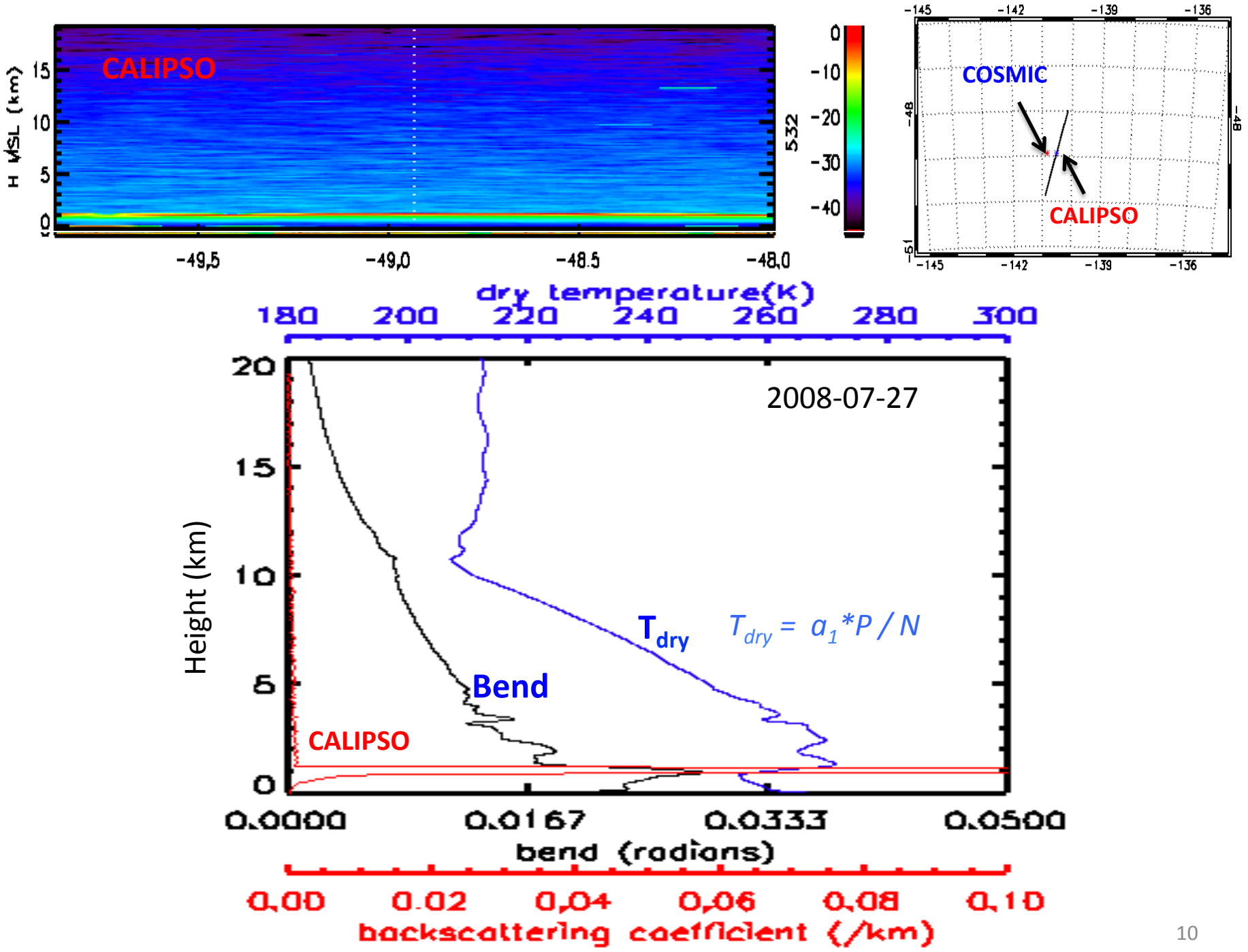


$$N = 77.6\frac{P}{T} + 3.73\times10^{5}\frac{P_w}{T^2} - 40.3\times10^{6}\frac{n_e}{f^2}$$

Figure Courtesy of UCAR COSMIC

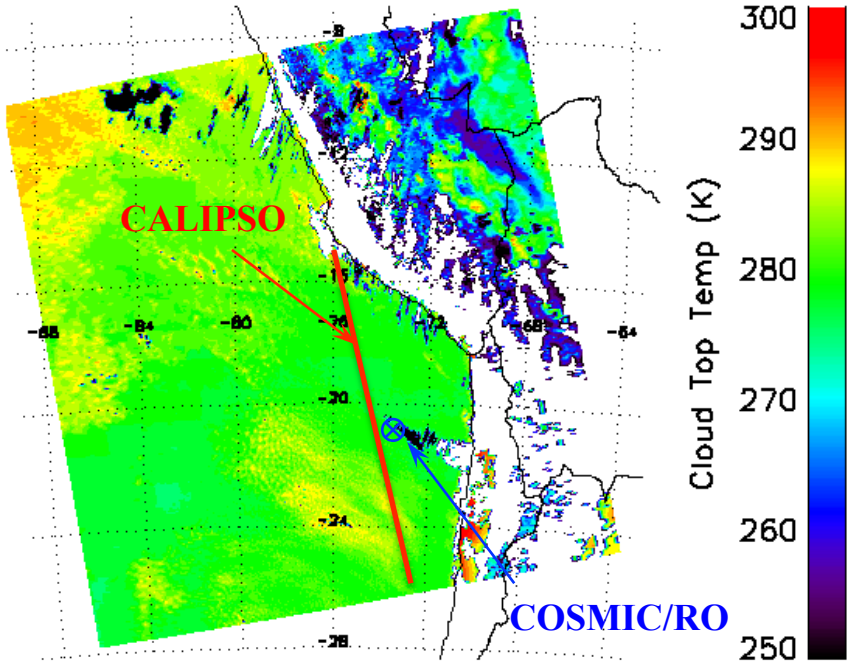
COSMIC vs. CALIPSO



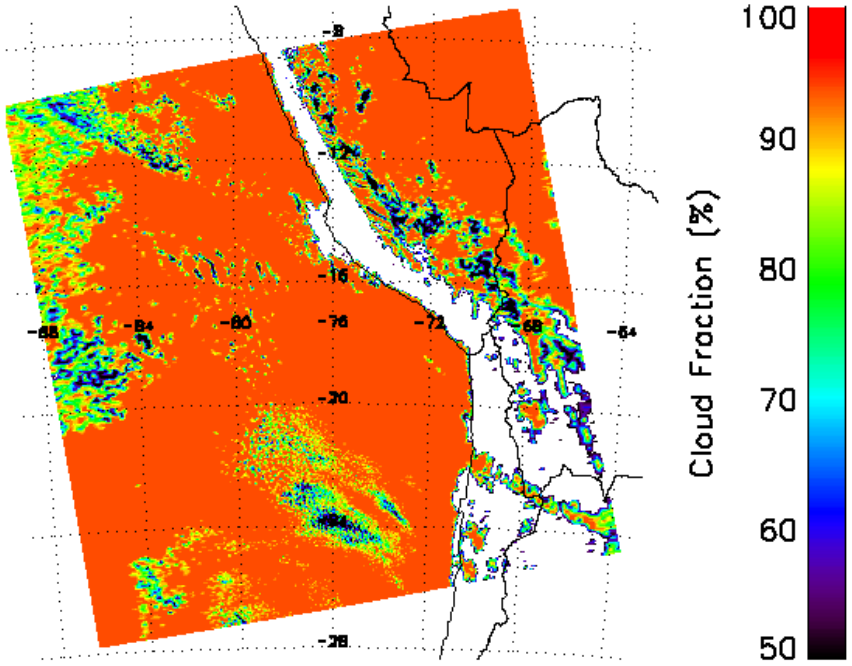

CALIPSO
H MSL (km)
532
COSMIC
CALIPSO
dry temperature(K)
2008-07-27
Height (km)
T_{dry}
$T_{dry} = a_1 * P / N$
Bend
CALIPSO
bend (radians)
backscattering coefficient (/km)

MODIS Cloud Measurement

Cloud-top-temperature (K)

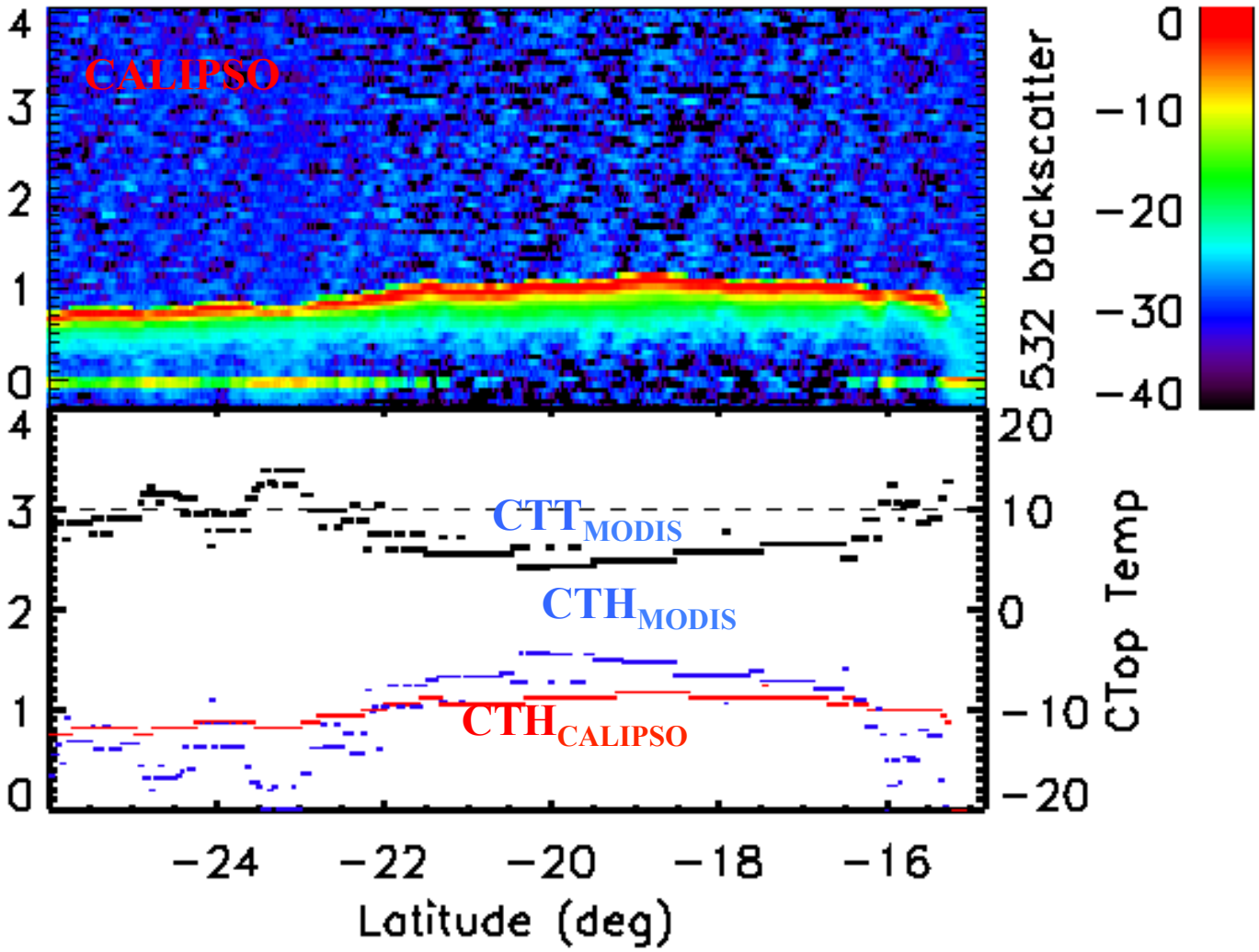


Cloud Fraction (%)

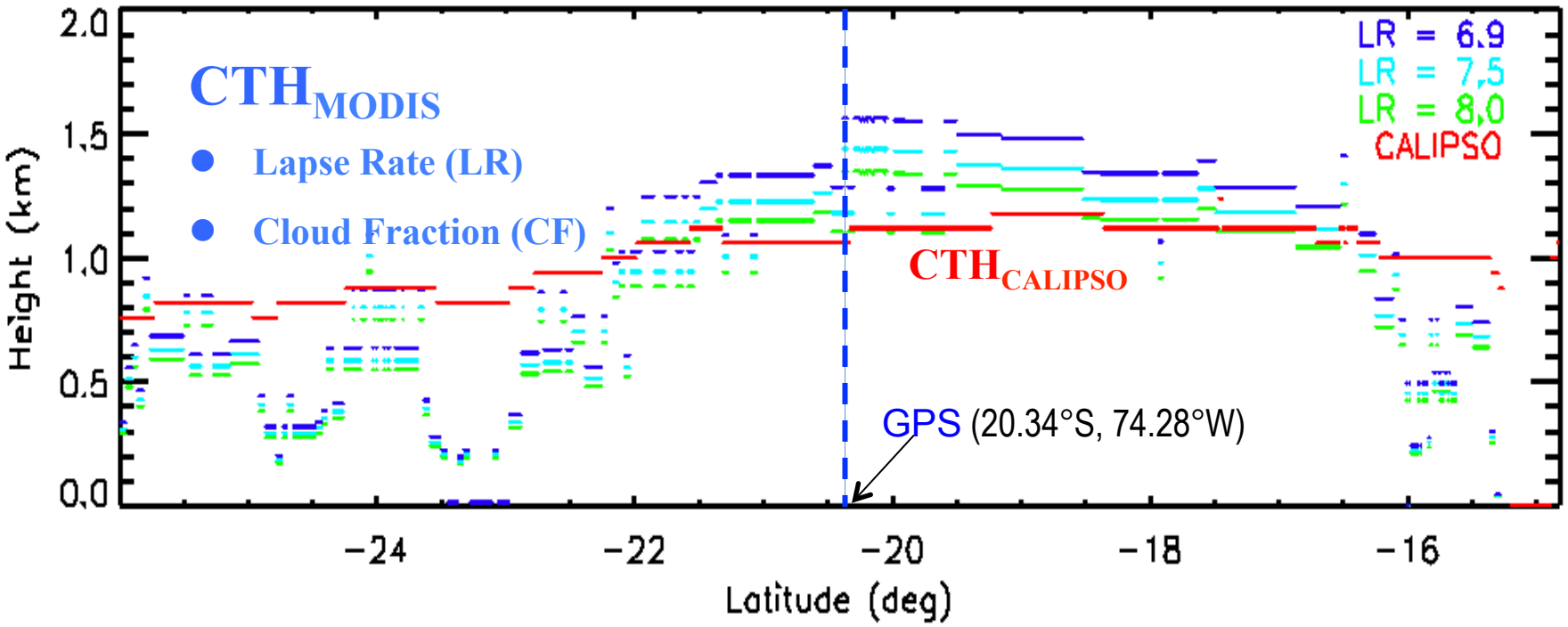


$$CTH = \frac{(SST - CTT) - \delta T}{\Gamma_T}$$

MODIS Cloud-top-height

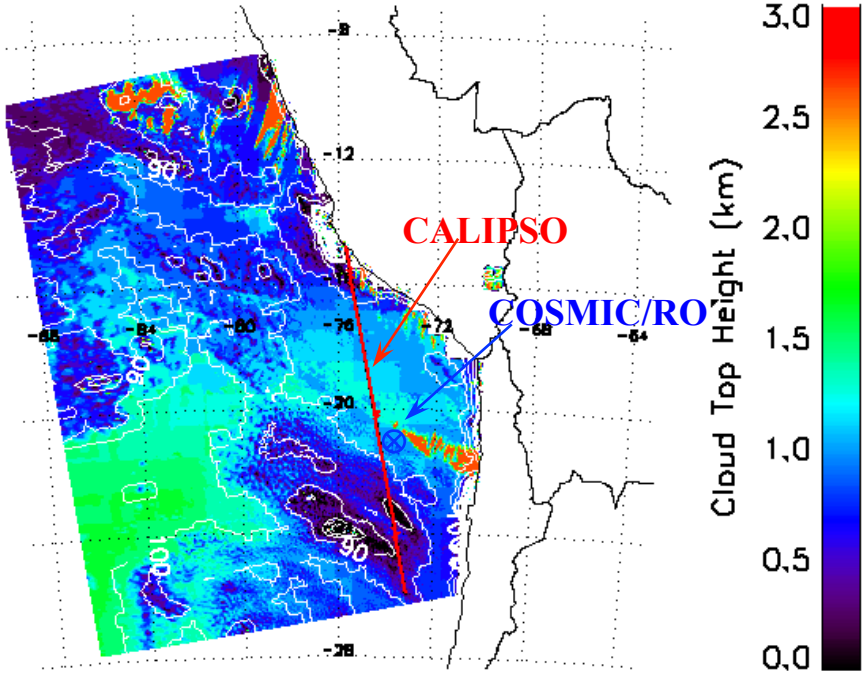


MODIS-CTH - Lapse rate

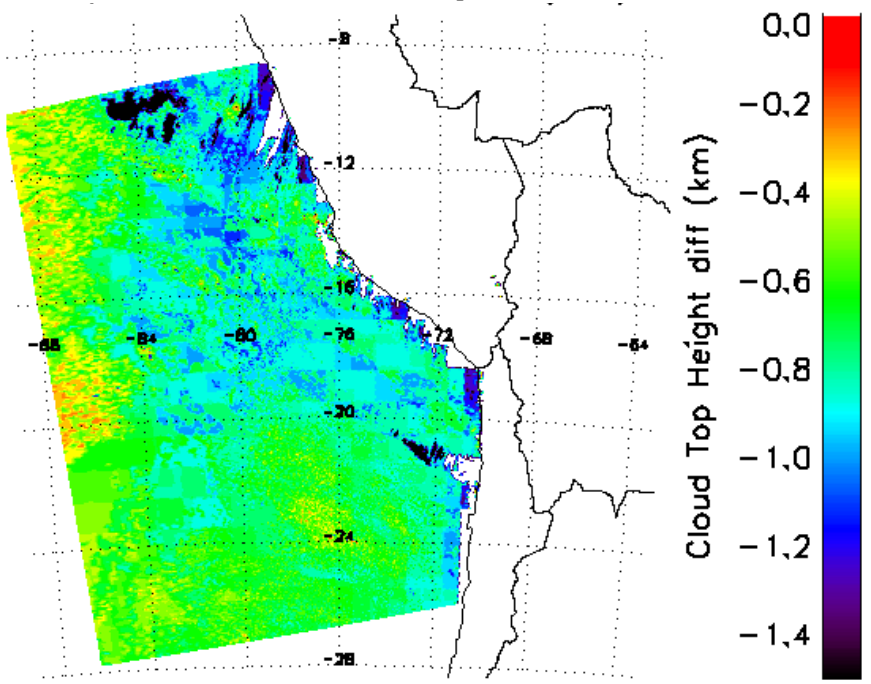


MODIS Cloud-top-height

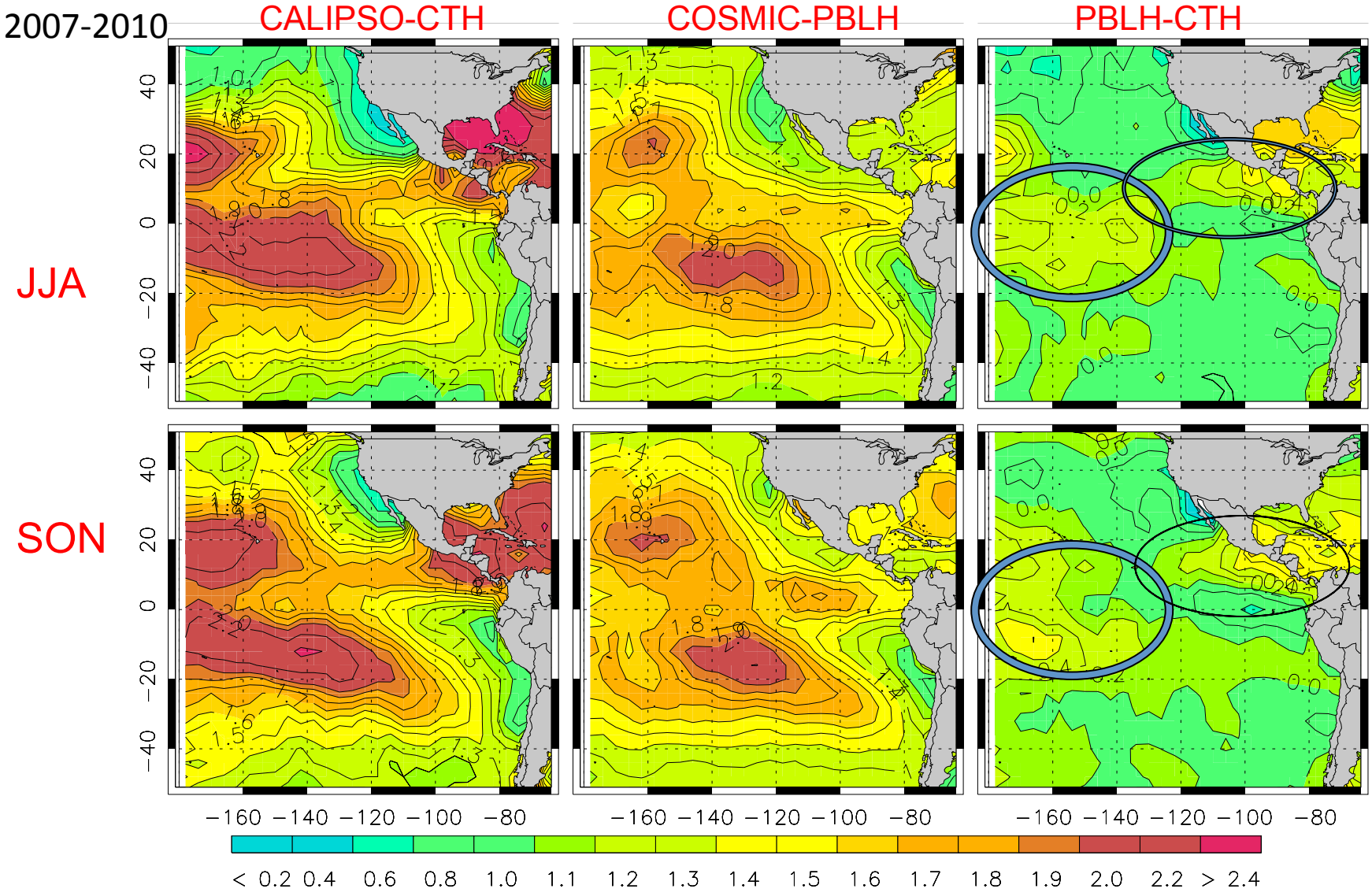
MODIS Lapse Rate CTH & Cloud Fraction



CTH Difference: $CTH_{LapseRate} - CTH_{MODIS\text{-}V6}$



Cloud-Top-Height vs. MBL Height



Conclusions and Future Works

- MODIS cloud-top-temperature (CTT) along with SST can be used to derive the cloud-top-height (CTH) based on the lapse rate method.
- CALIPSO Cloud-top-height climatology compares well with COSMIC GPS RO with best agreement over stratocumulus region (<200 m) near the coast of subtropical eastern Pacific ocean.
- Significant discrepancy is found over tropical and trade wind region, where broken clouds and weaker boundary layer inversion and moisture gradient complicate the detection of CTH from CALIPSO lidar and GPS RO measurements, respectively.
- The lapse rate method is sensitive to the lapse rate and the cloud fraction. More robust retrieval algorithm need to be developed to offer best quality CTH retrieval.
- CALIPSO and GPS RO offer independent CTH measurements and will be used to verify and improve the MODIS CTH retrieval, which will be used to derive cloud top entrainment rate given the cloud top wind and large-scale subsidence rate estimation.

Acknowledgement

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- UCAR COSMIC Group for UCAR COSMIC retrievals
- ECMWF/ERA-interim data
- CALIPSO data These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center.