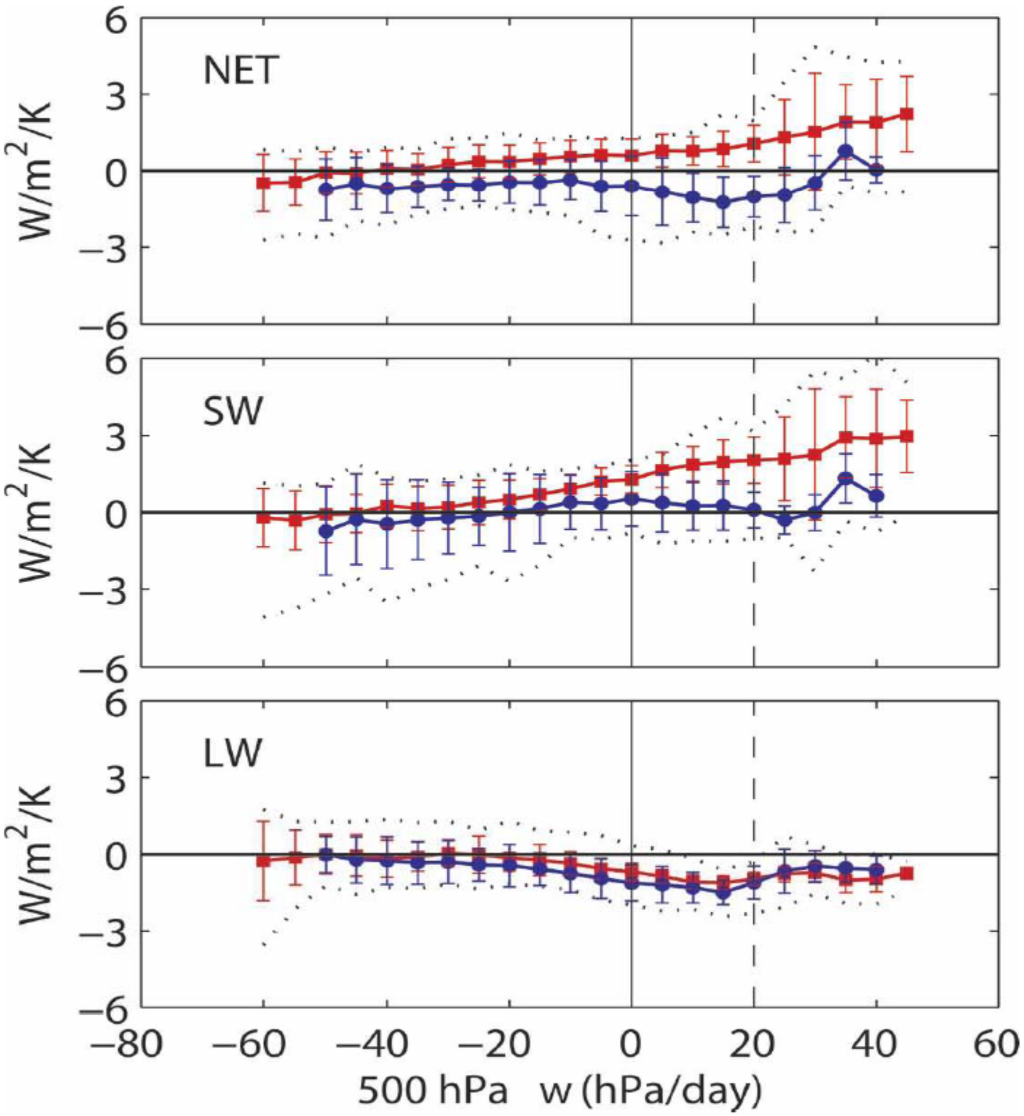
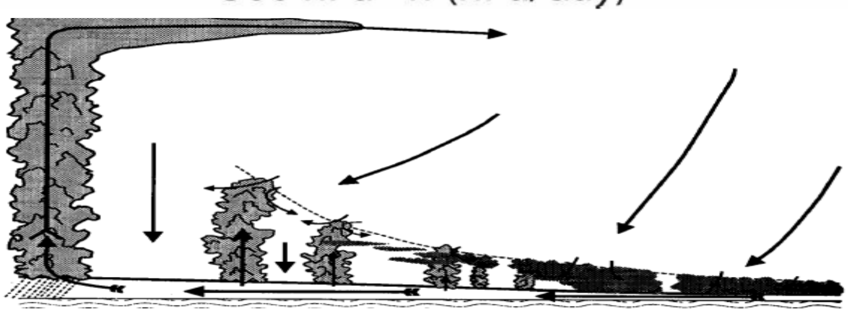
Critical aspects of cloudy boundary layers: what do we need to know?

Robert Wood, University of Washington

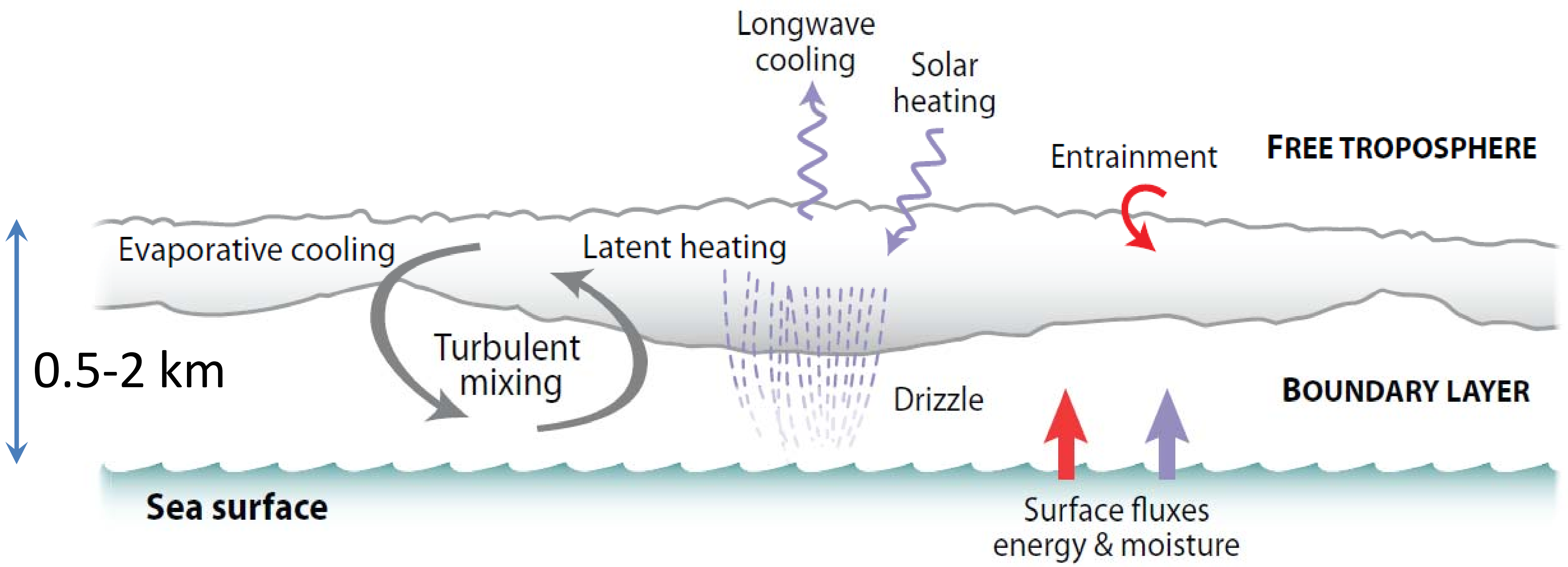




Intermodel SW feedback variability determined by low cloud changes

Bony, S., and J.-L. Dufresne (2005), **Marine boundary layer clouds at the heart of tropical cloud feedback uncertainties in climate models**, *Geophys. Res. Lett.*, 32, L20806, doi:10.1029/2005GL023851.

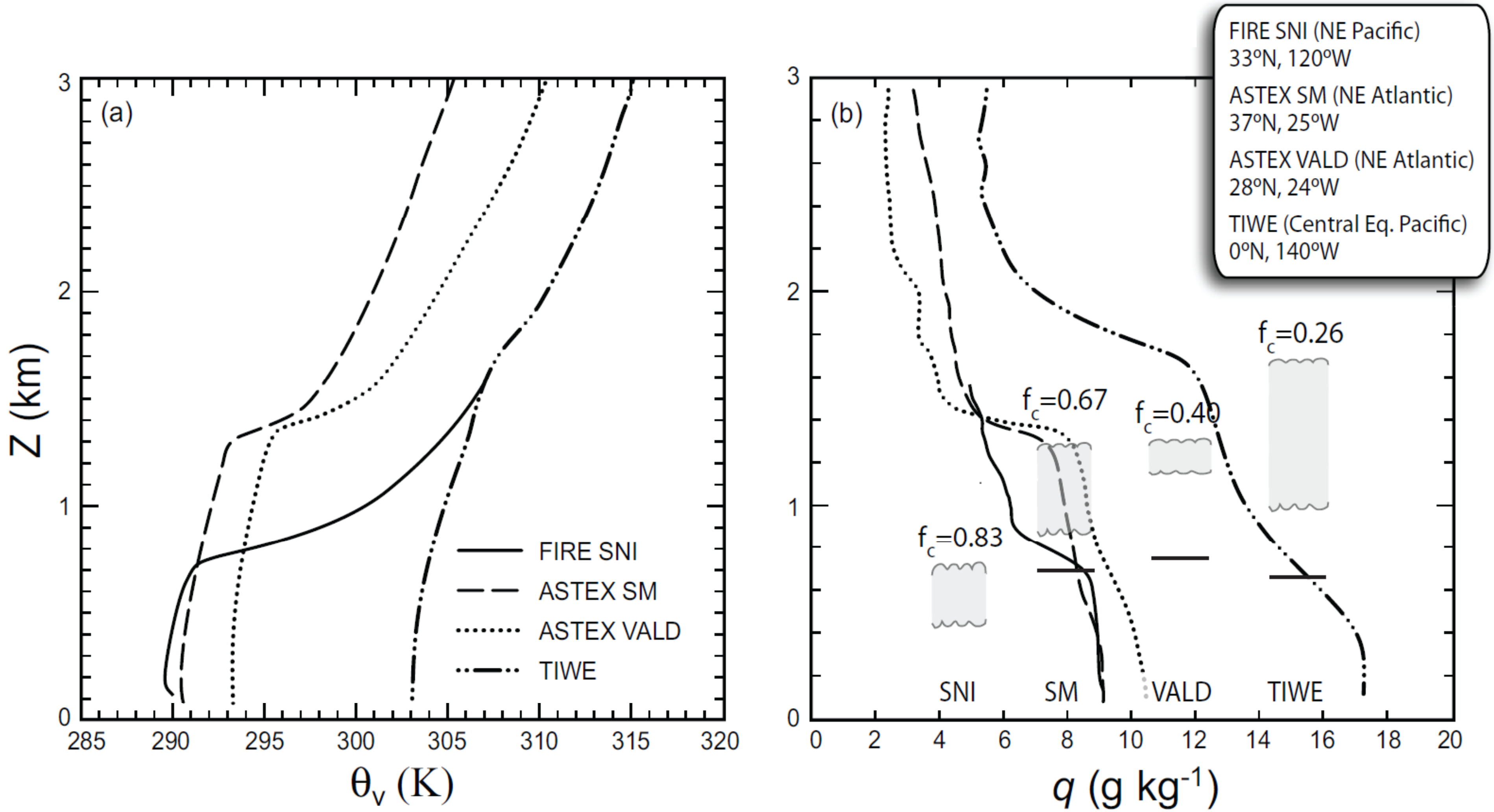
Key physical processes in the cloudy boundary layer



Stratocumulus,
NE Pacific, July
2001

Trade cumuli,
Antigua, Jan 2005

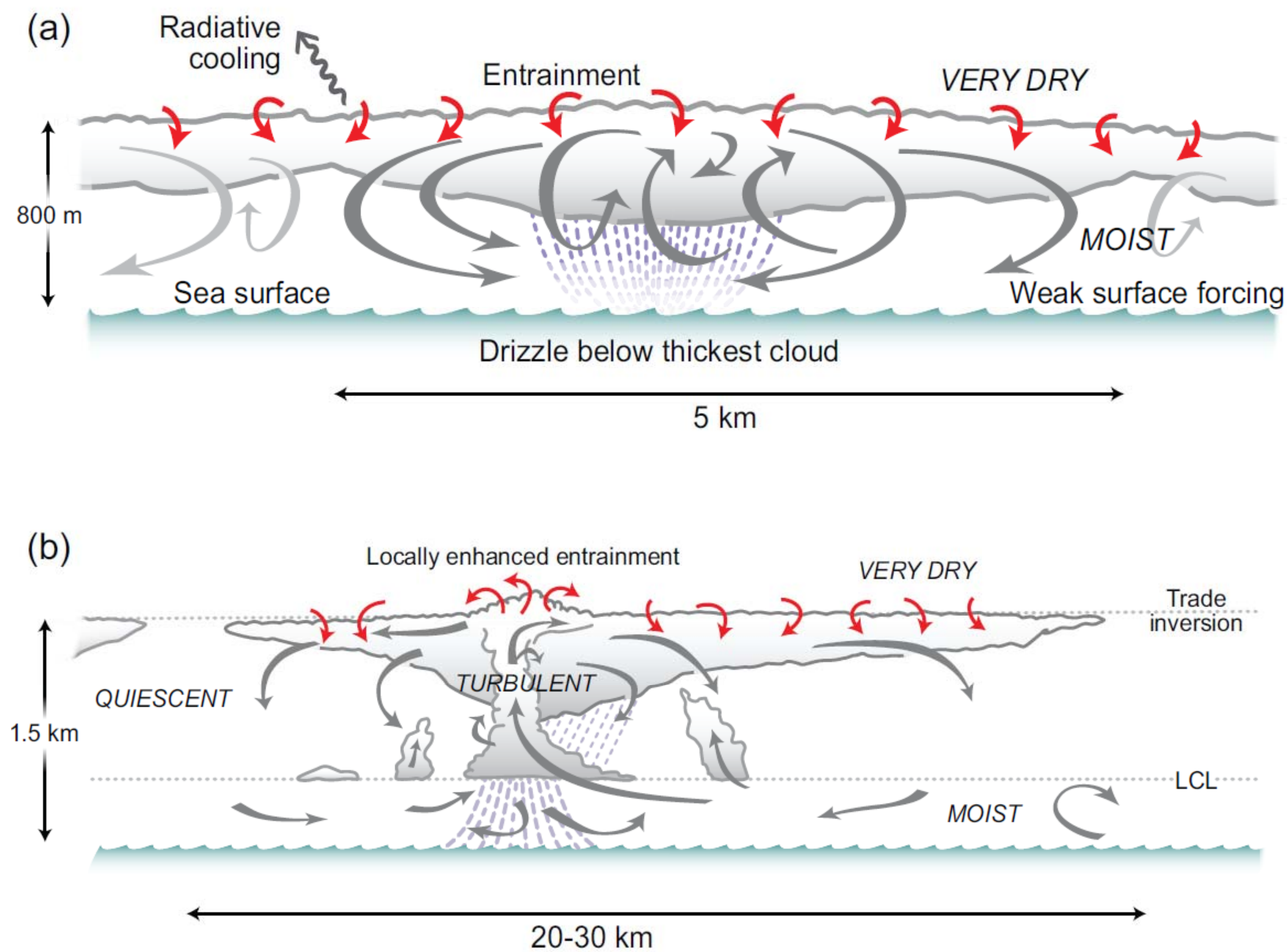
Varying cloudy PBL structure



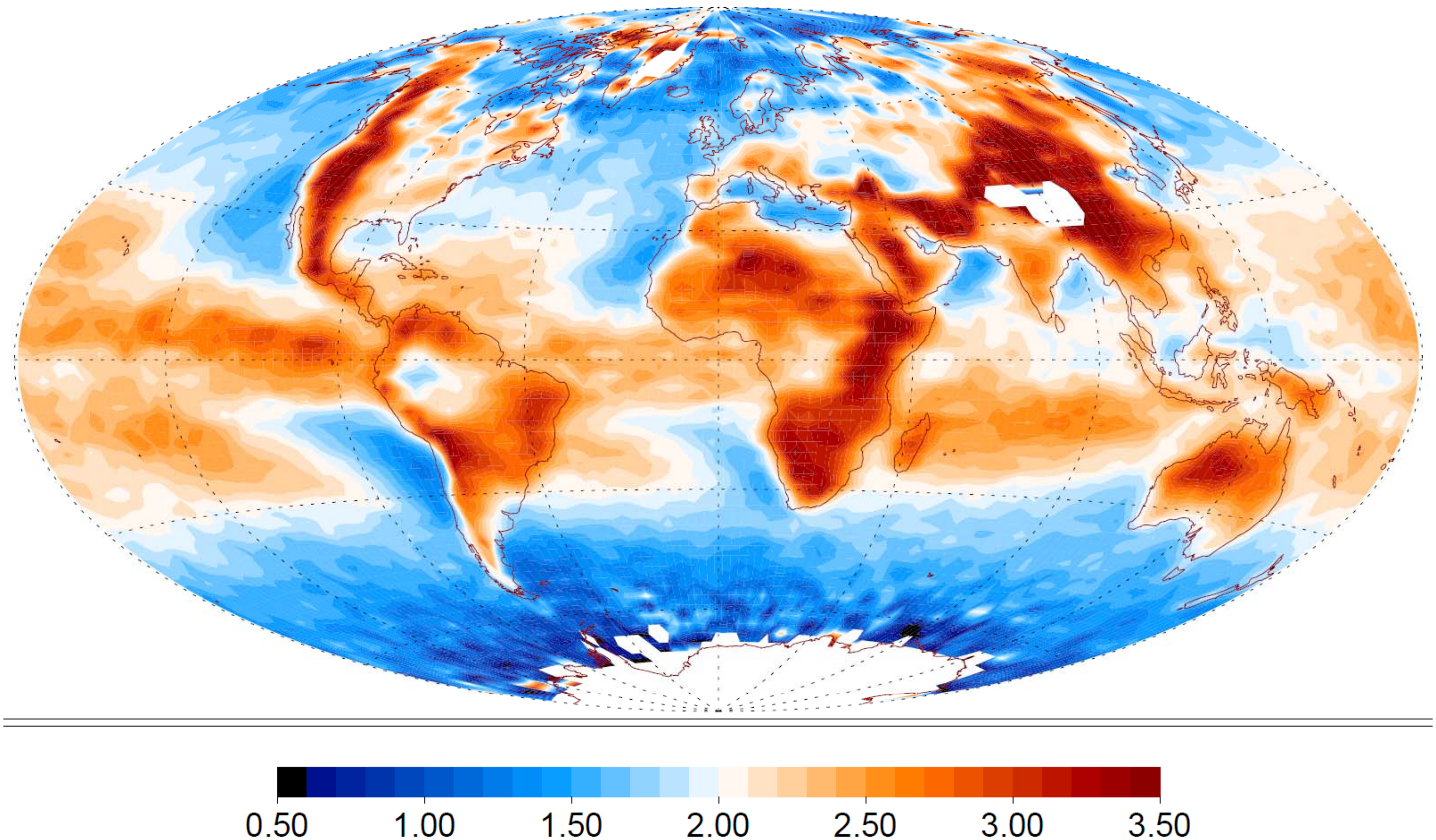
Mesoscale cellular structure

Shallow MBL

Deep MBL

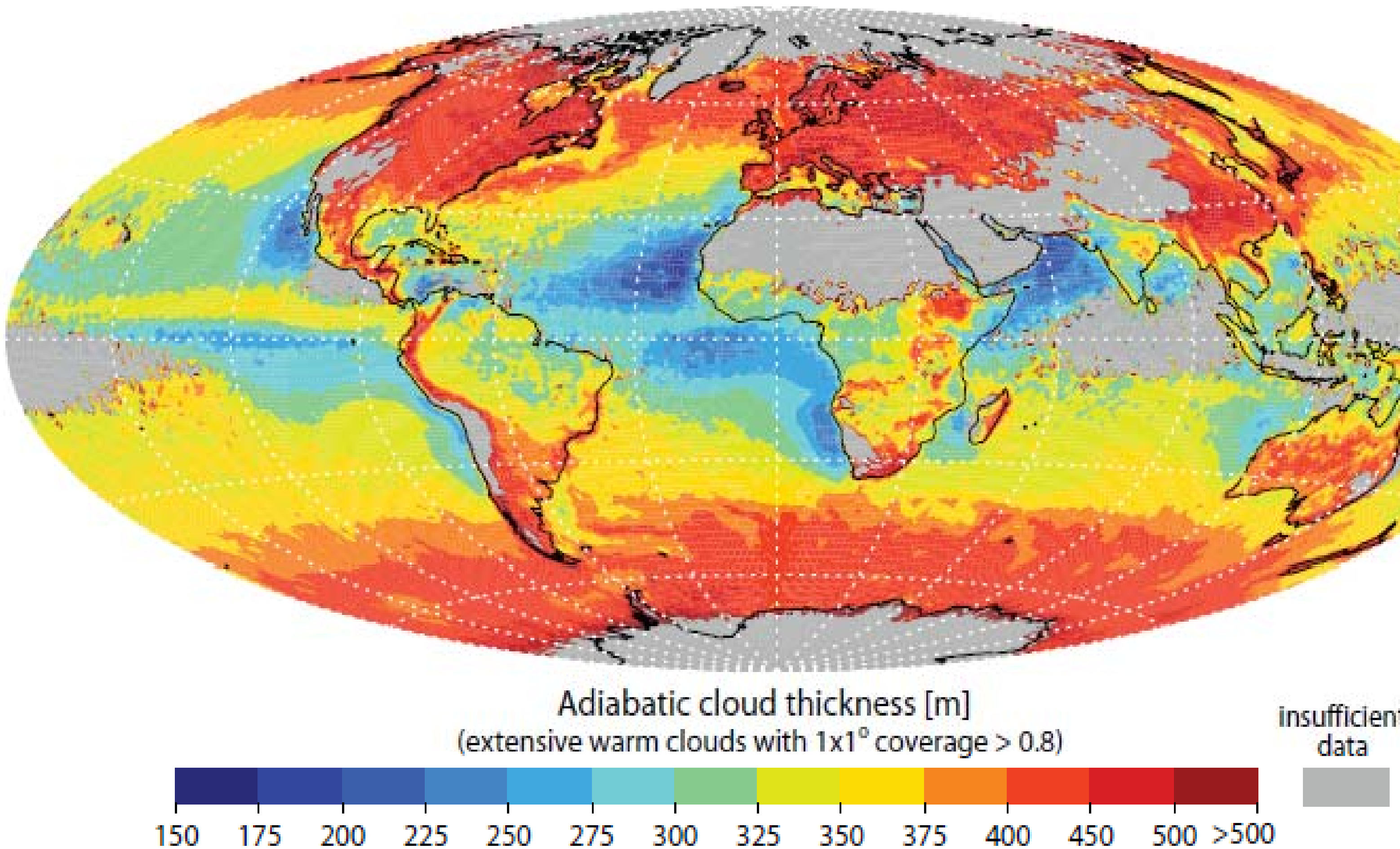


GPS R-O observations of MBL depth



COSMIC (2006-2009), annual mean MBL depth

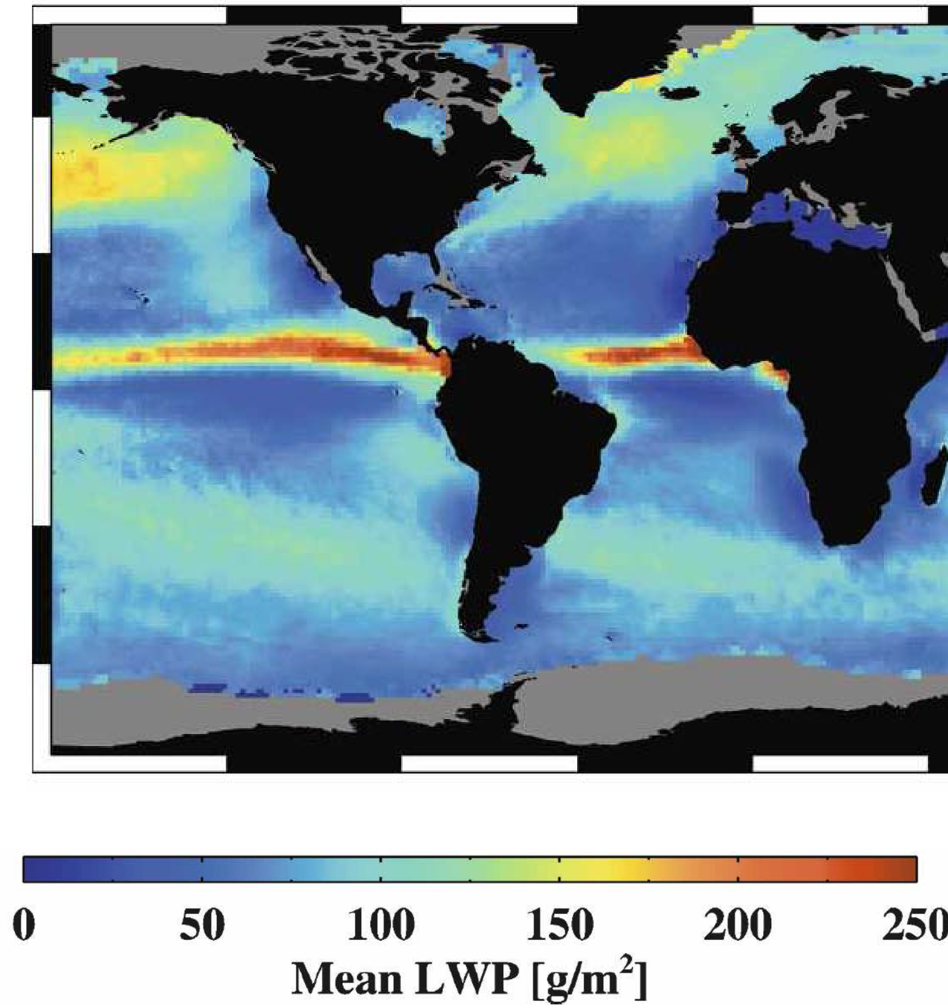
Cloud thickness of stratiform boundary layer clouds

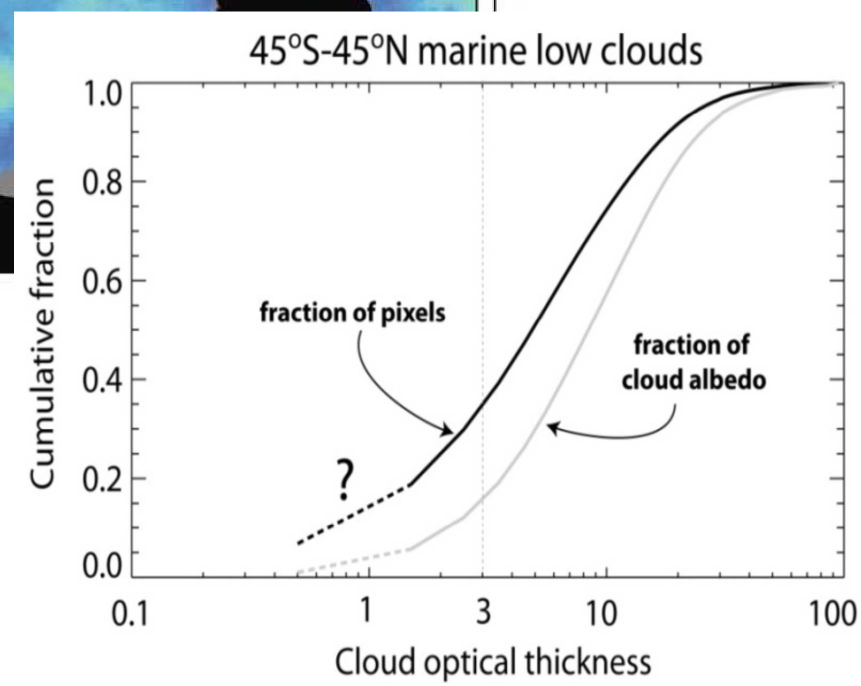


MODIS cloud LWP, and cloud temperature, used to determine adiabatic h

PBL Clouds are thin!

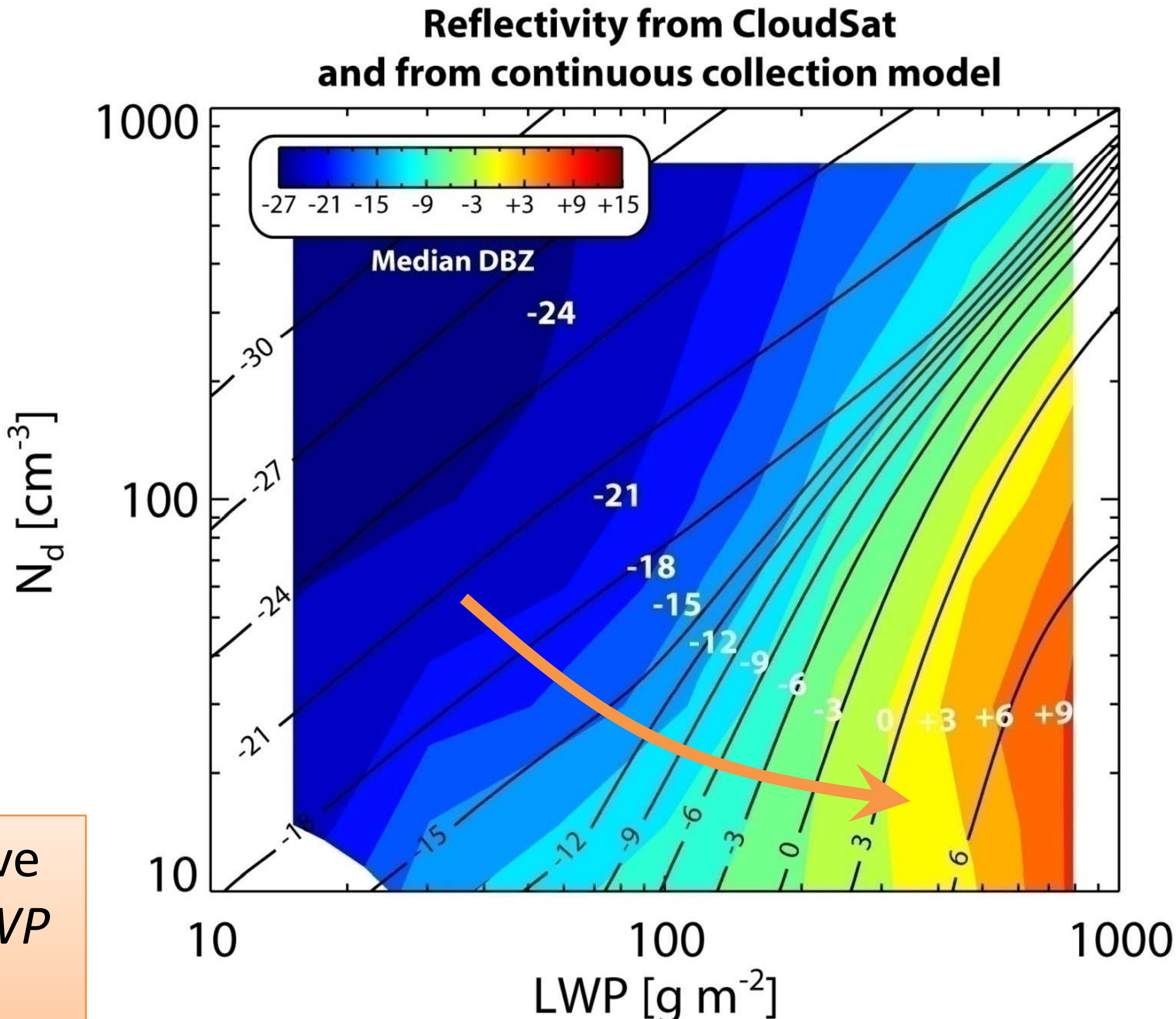
Many MBL clouds have low LWP





Microwave imagers, O'Dell et al (2008, *J. Clim.*)

Reflectivity in [*LWP*, N_d] space

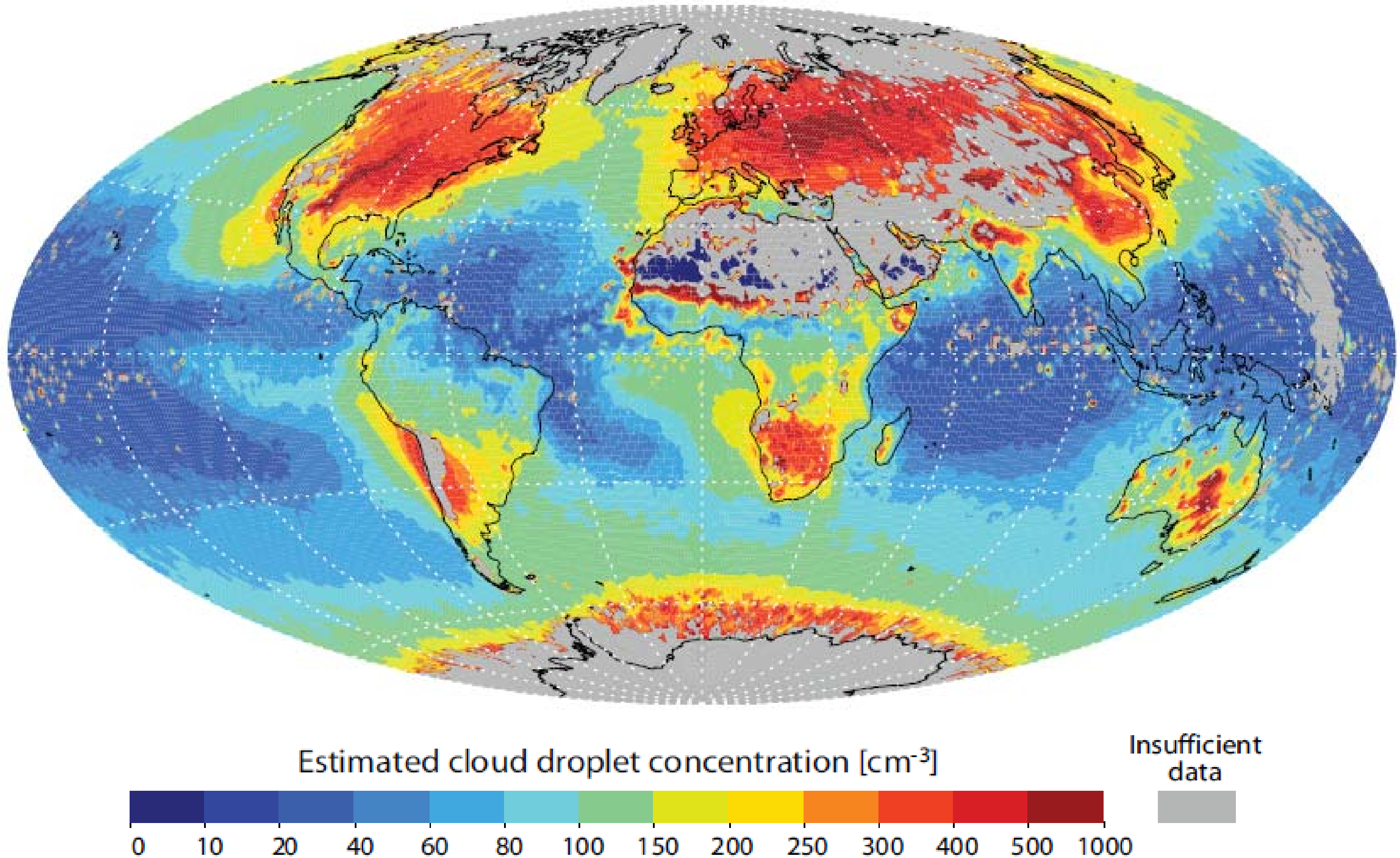


Increasing relative importance of *LWP* over N_d at high rainrates

CloudSat: colors
Model: lines

Wood, Kubar and Hartmann (2009)

Cloud droplet concentration *estimates* from MODIS

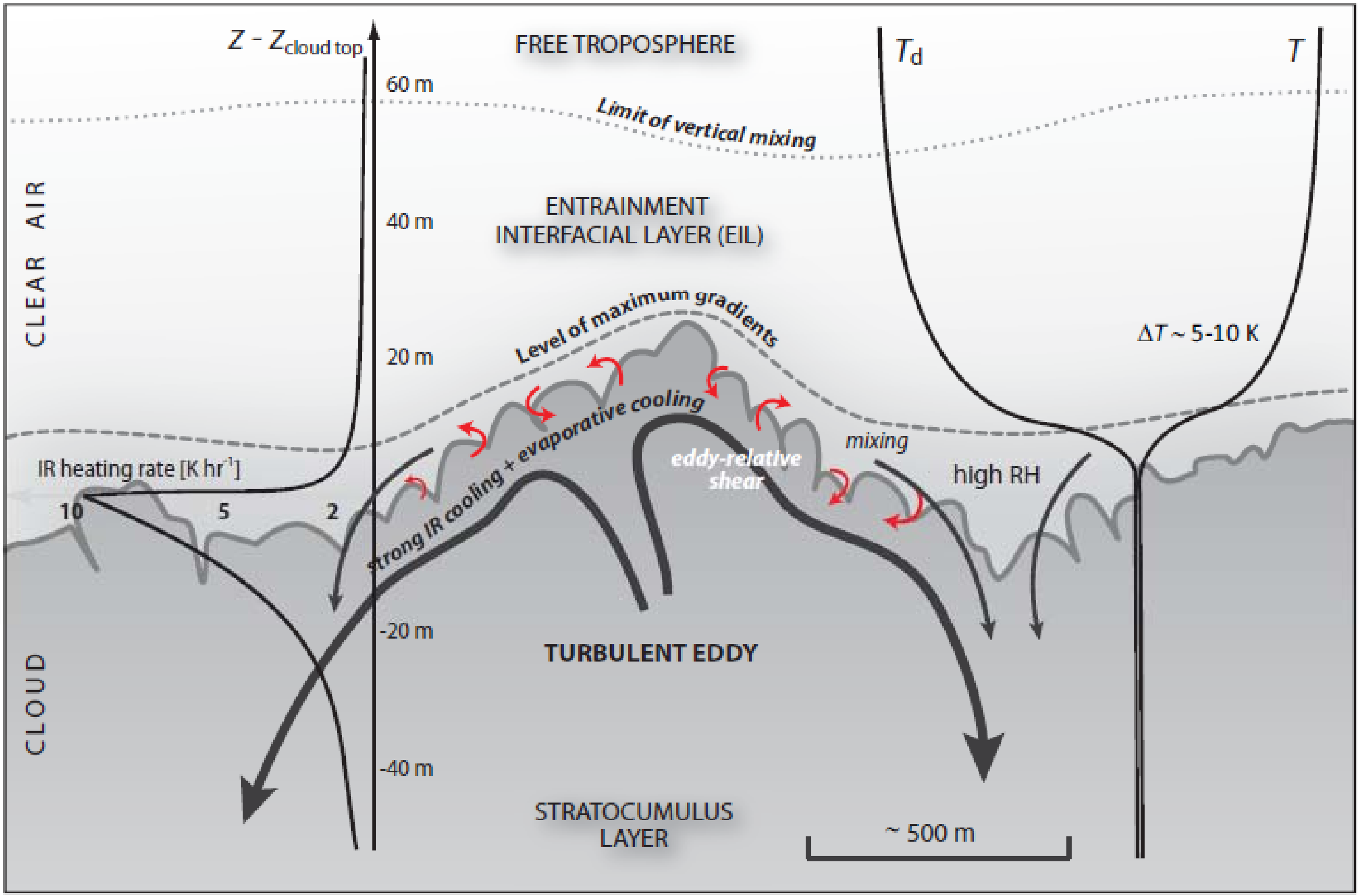


Use MODIS optical depth and effective radius to infer droplet concentration assuming adiabatic clouds

Turbulence and entrainment

Mellado (2010, J. Fluid. Mech.)

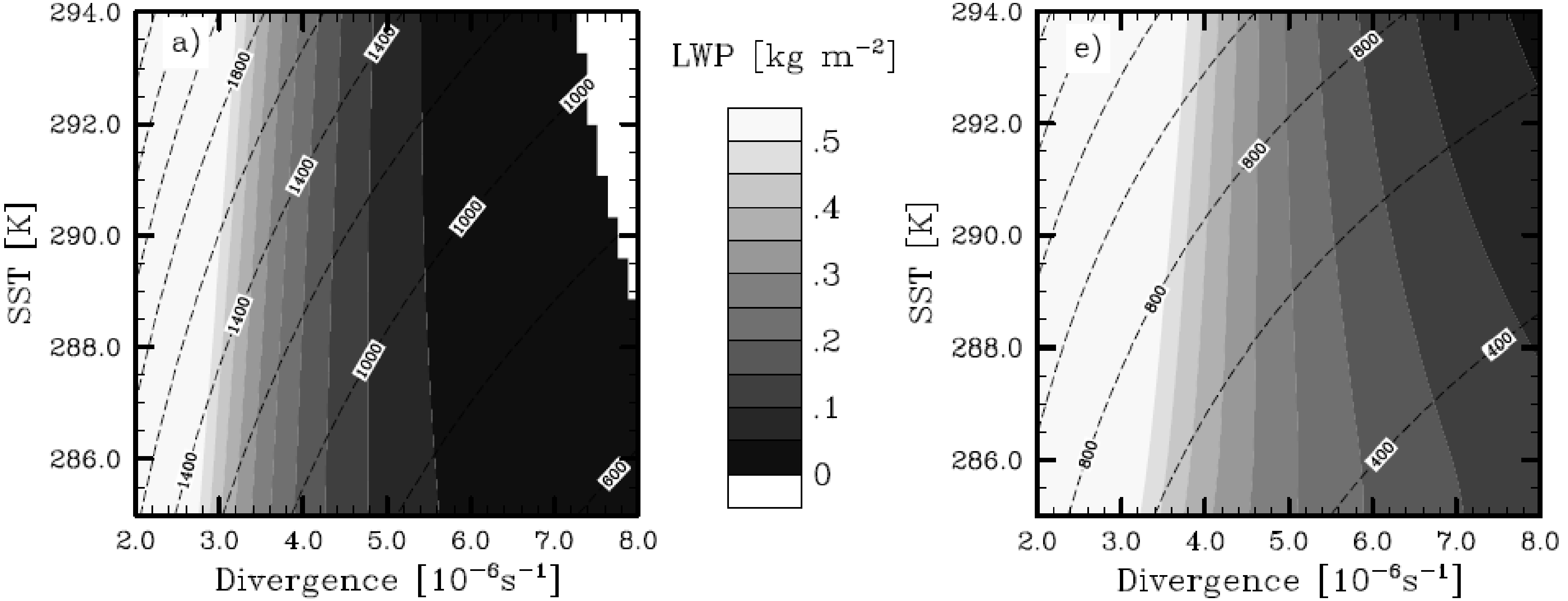
Cloud top and entrainment



Effect of changing entrainment efficiency

E = 1

E = 0.5



Entrainment critical for correct prediction of cloud LWP and therefore optical thickness

Stevens (2002)

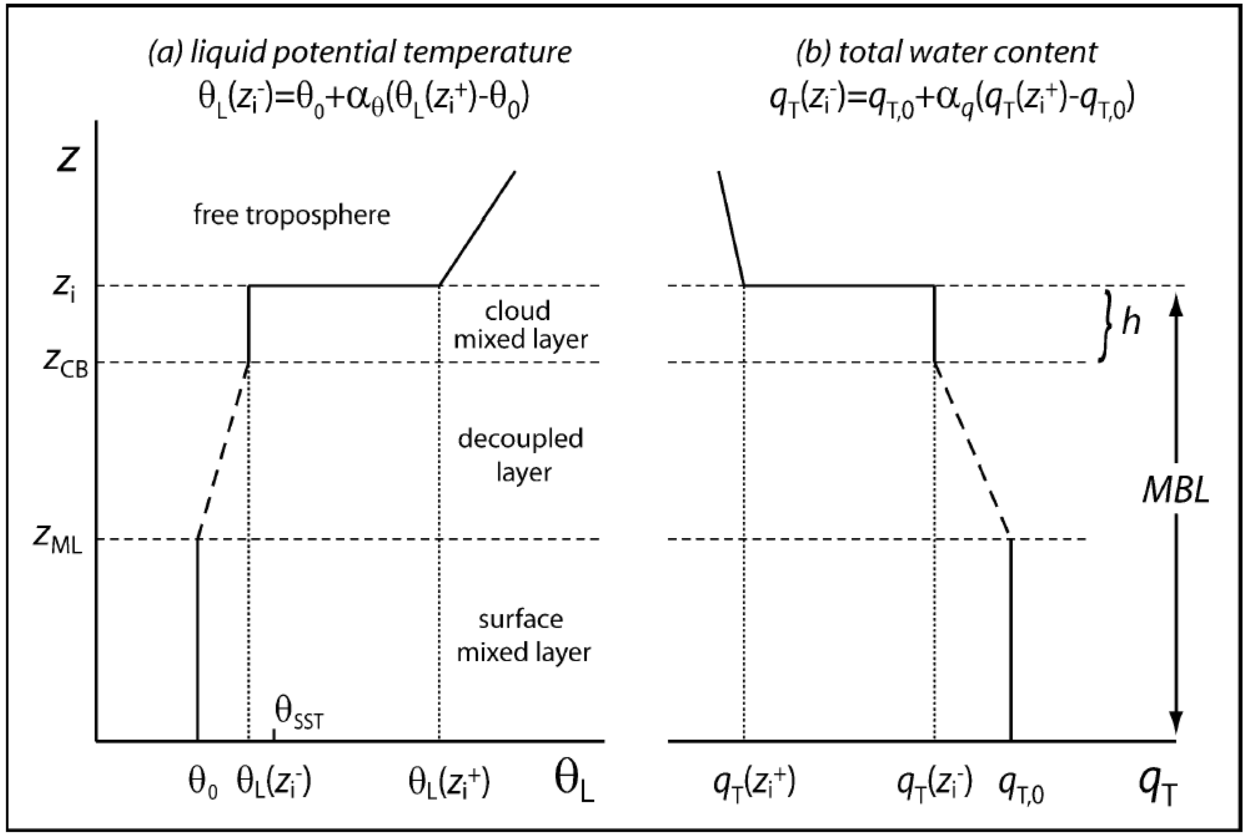
Key considerations for spaceborne observations of PBL cloud structure

- Cloudy boundary layer almost everywhere **shallower than 2 km**, often as shallow as few hundred meters
- PBL clouds typically **200-500 m thick**
- Drizzle **very sensitive to small changes in LWP**/cloud thickness, and to **cloud droplet concentration**
- **Low liquid water path**, scant/no information from space on vertical profile of LWP
- Need information on turbulence structure and **entrainment**

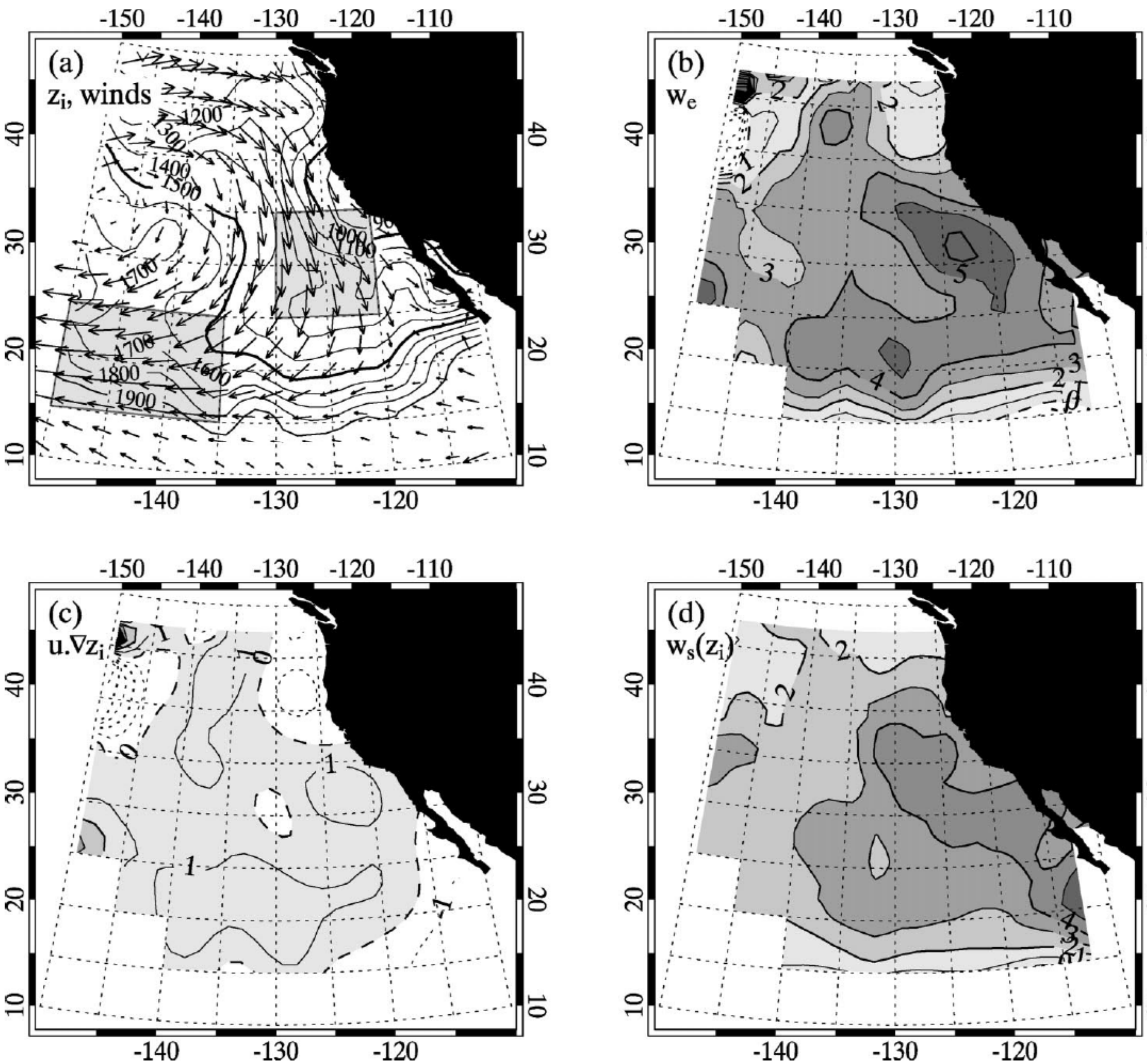
Sensor synergy – MBL profile reconstruction

Inputs:
MODIS LWP => cloud thickness, cloud top temperature pdf
AMSR => SST, column WVP
GPS => FT moisture, MBL depth
AMSR-GPS => MBL moisture path

Outputs:
MBL moisture/temp stratification
Inversion structure (trade wind MBL)
Lapse rate (static stability in the MBL)



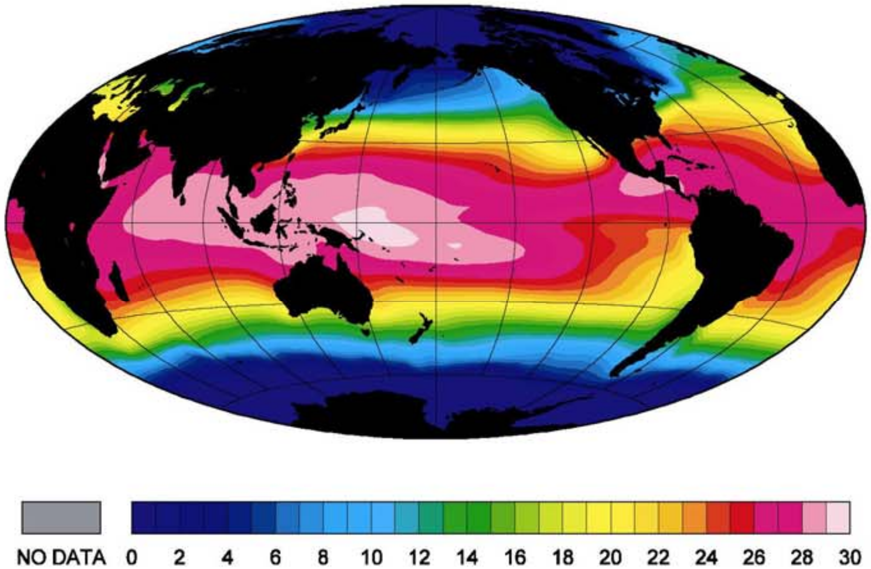
Entrainment rate estimates



Wood and Bretherton et al. (J Climate, 2004)

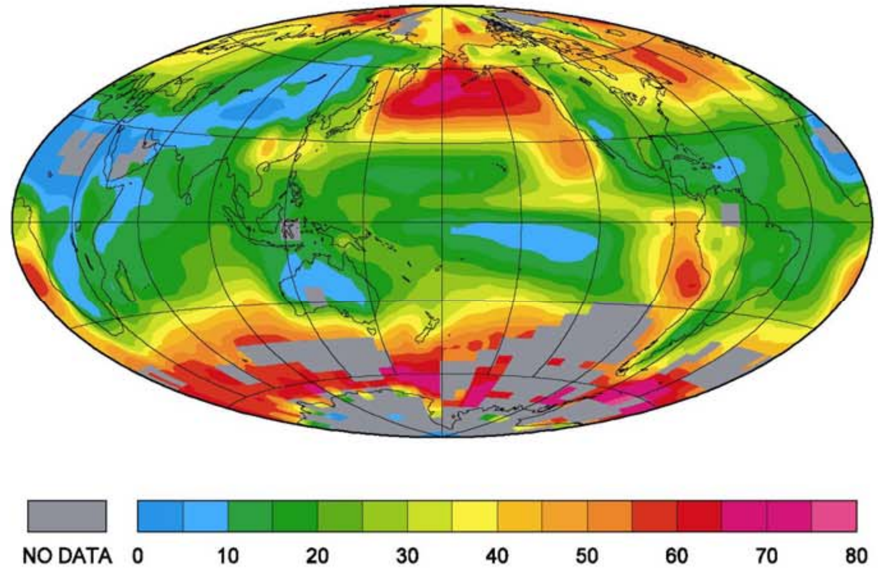
Supplementary slides

Sea Surface Temperature



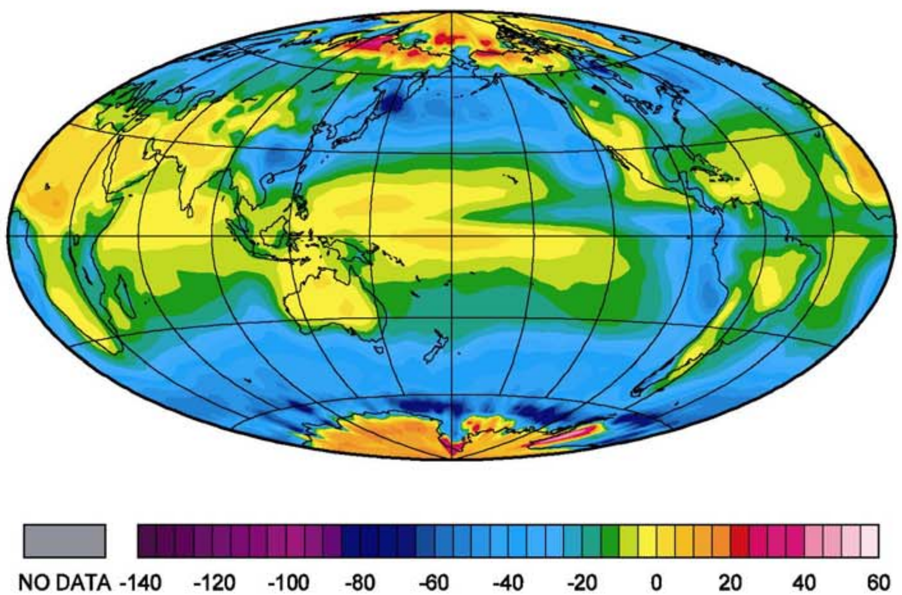
deg C

Annual Warren Stratus Cloud Amount



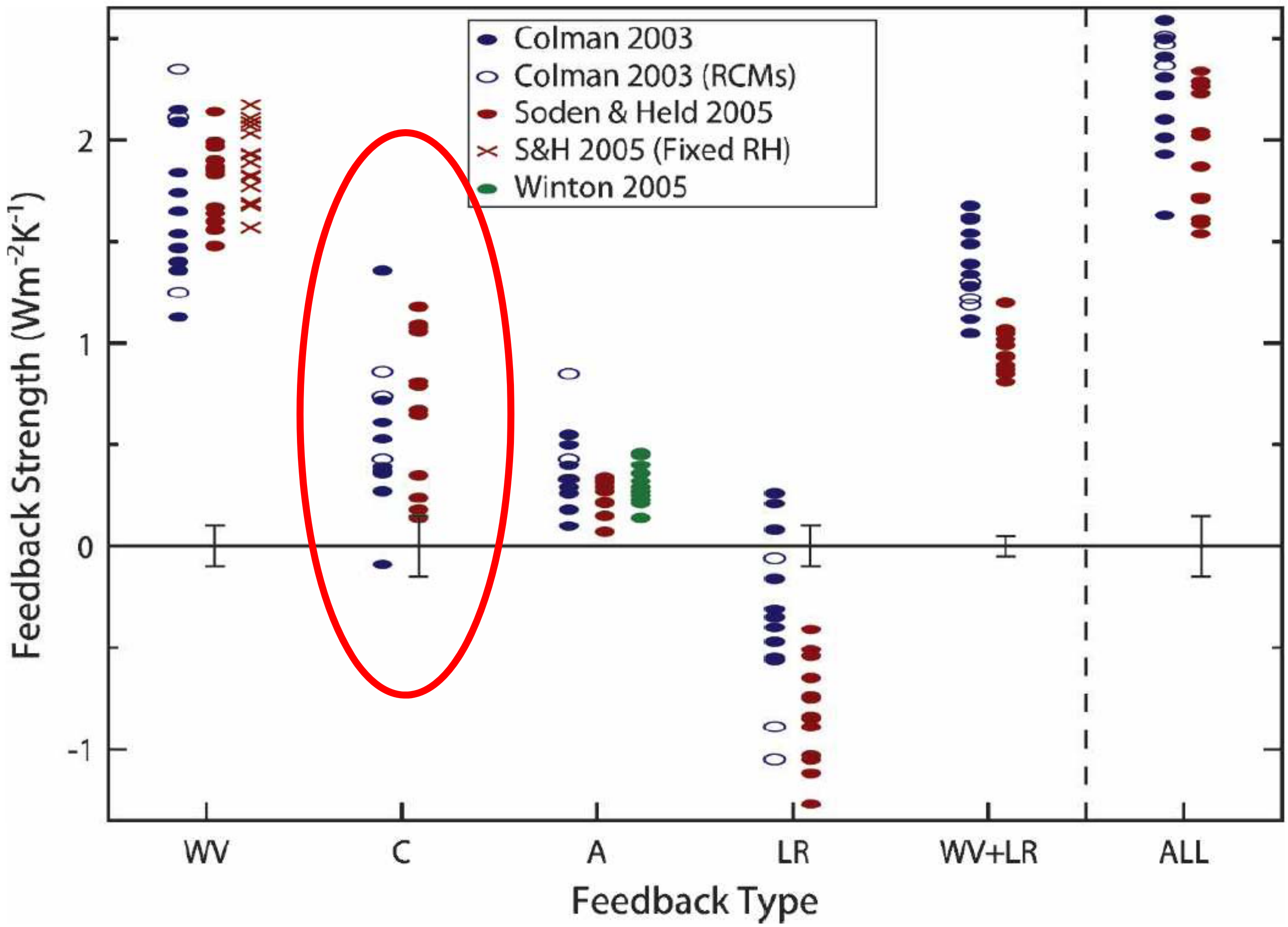
Percent

Net Radiative Cloud Forcing
1985-1986



W/m**2

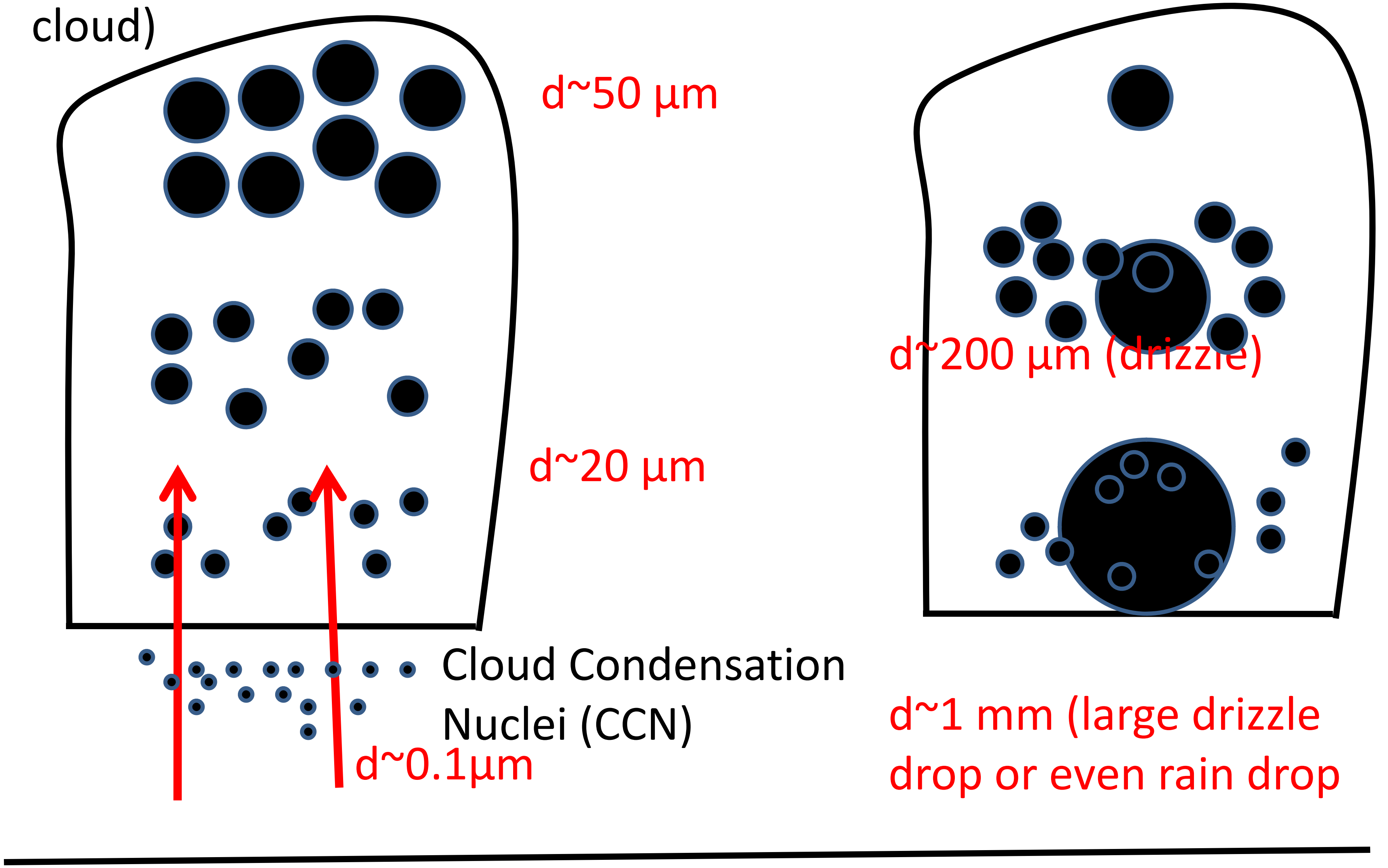
Cloud feedbacks remain the leading source of uncertainty in future climate prediction



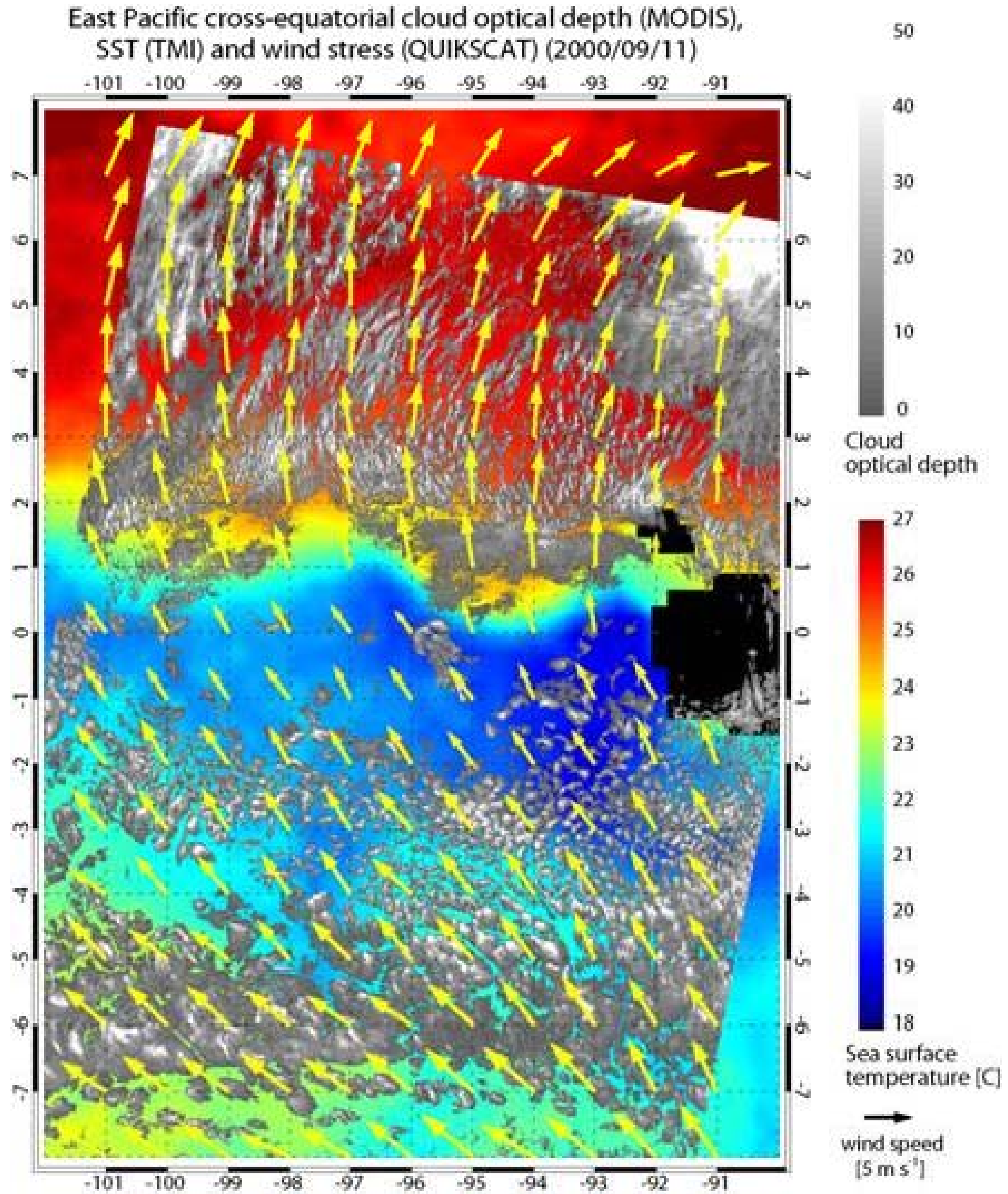
From Bony et al. (2006)

Condensational Growth to grow cloud droplets (Nonprecipitating cloud)

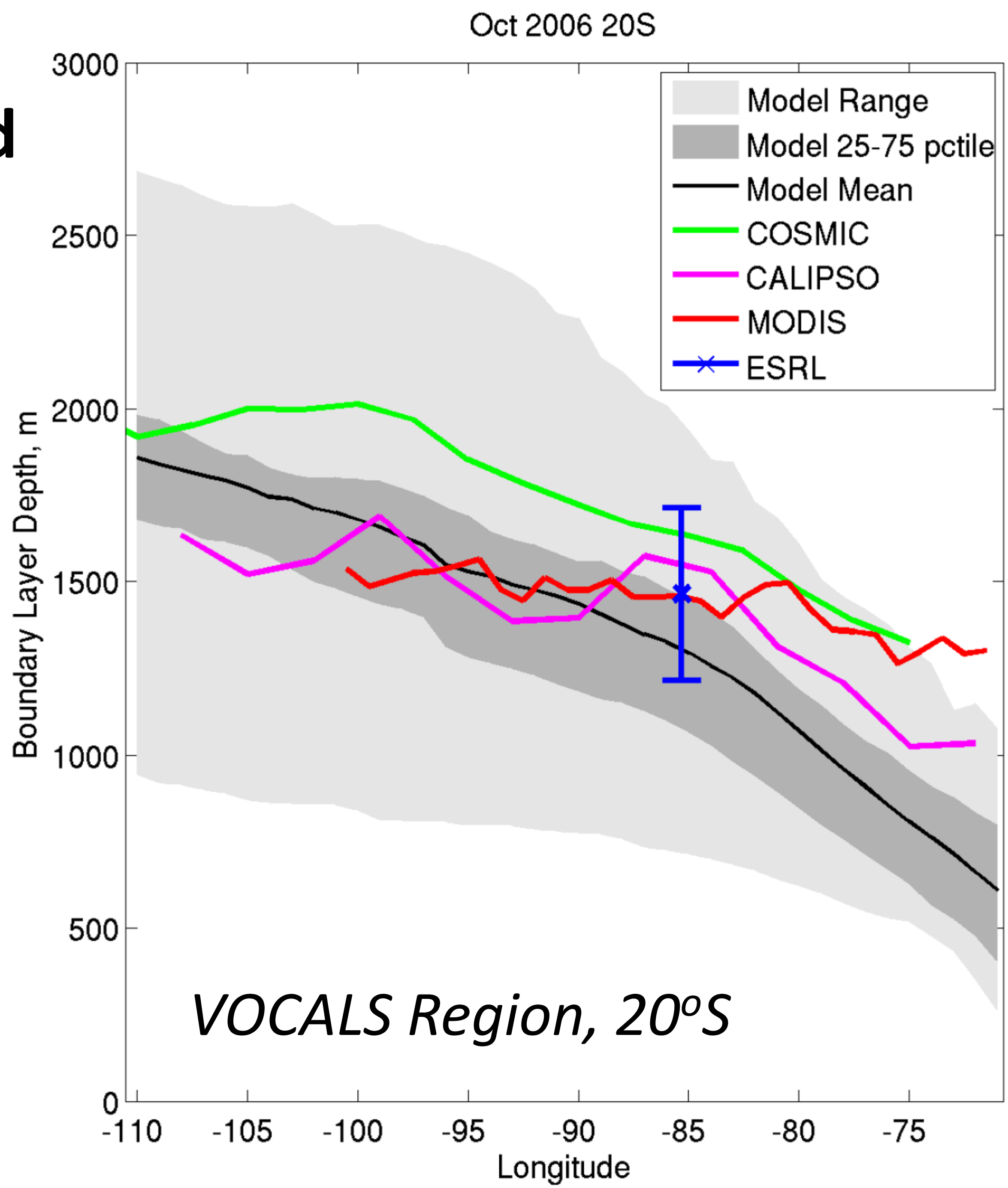
Collision and Coalescence to grow into drizzle and rain drops

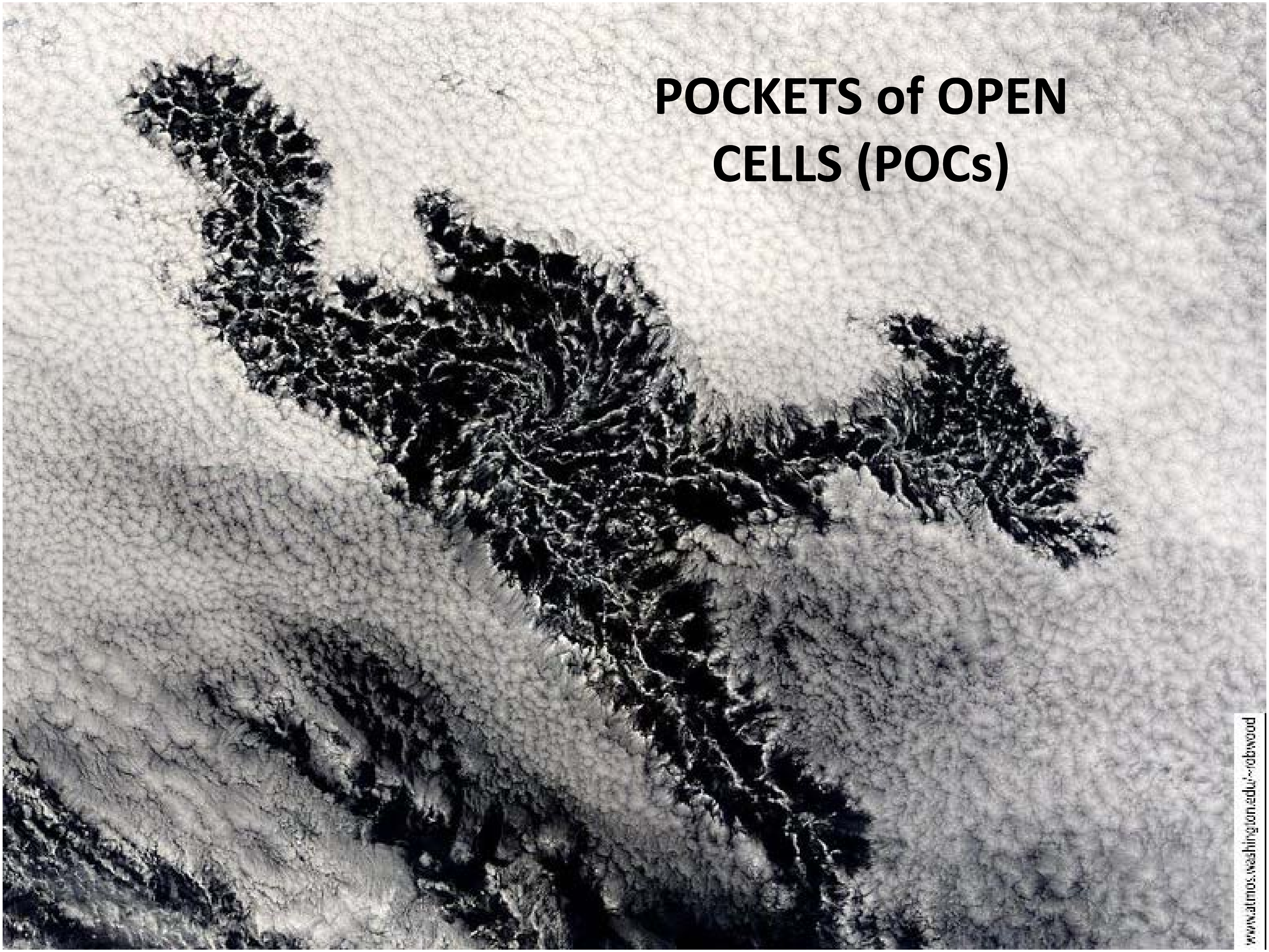


Tight couplings between SST, winds, and clouds

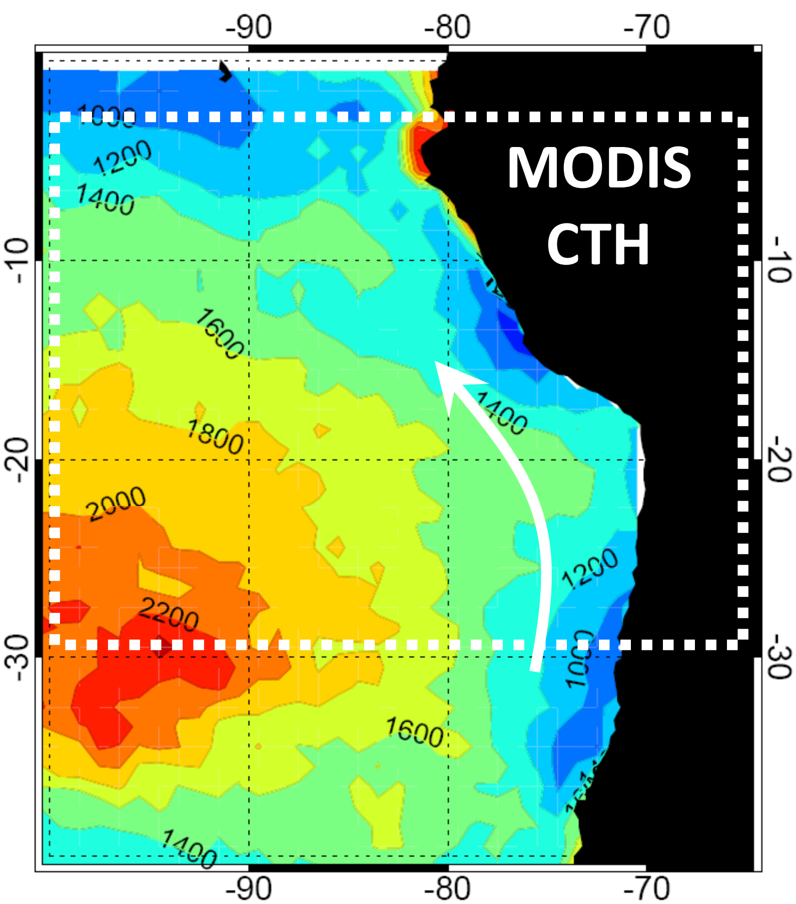


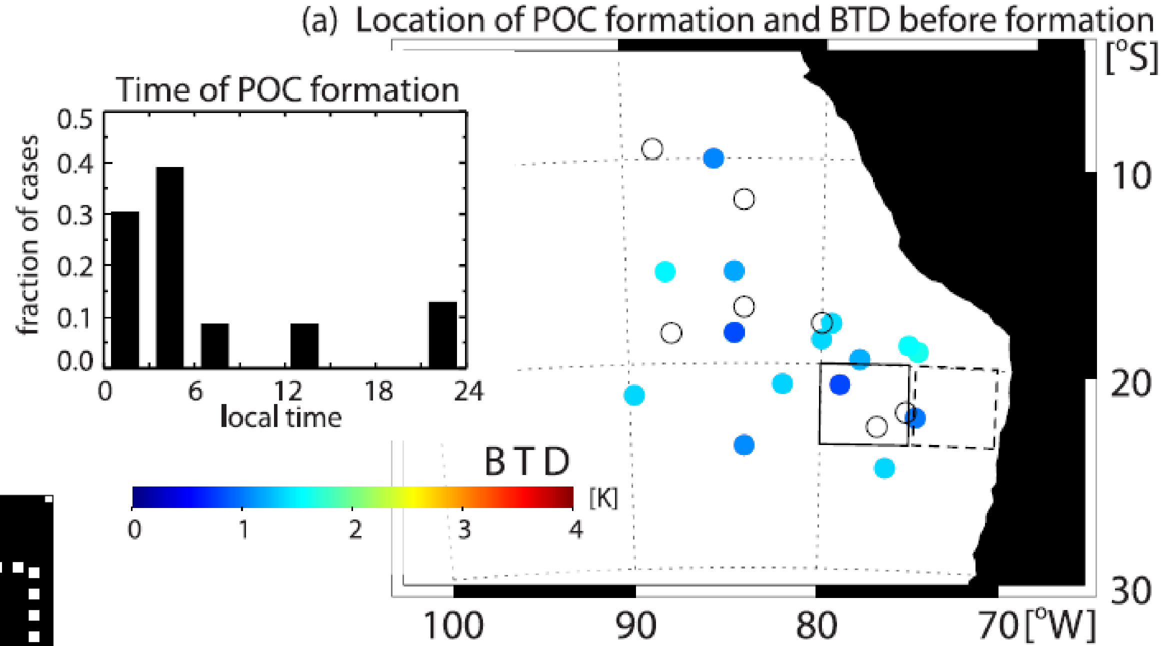
MBL depth/cloud top height estimates

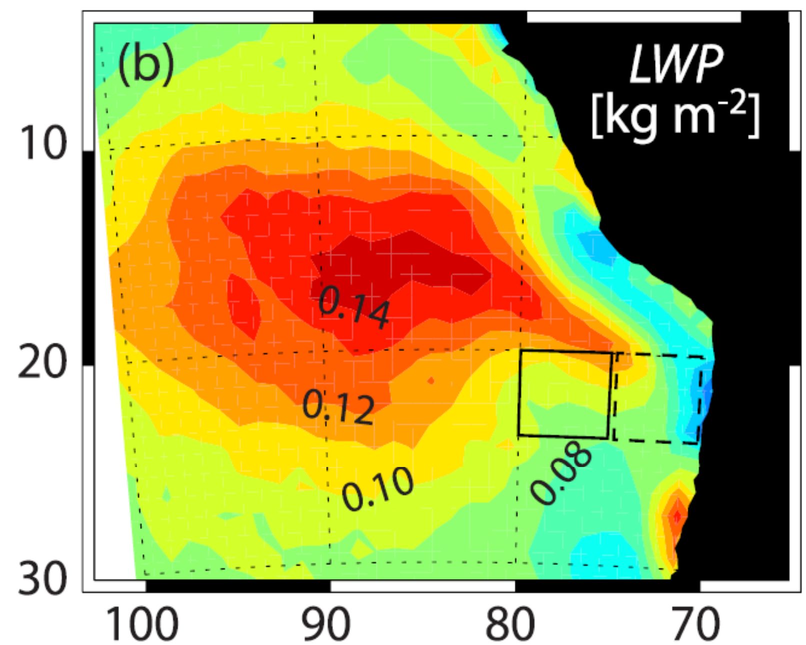



POCKETS of OPEN CELLS (POCs)
www.atmos.washington.edu/~robwood

MBL depth, LWP, and POC formation







With independent cloud top height or MBL depth information

- Lapse rate (MODIS CTT, CALIPSO CTH, SST)

Wu et al. (GRSL, 2008)