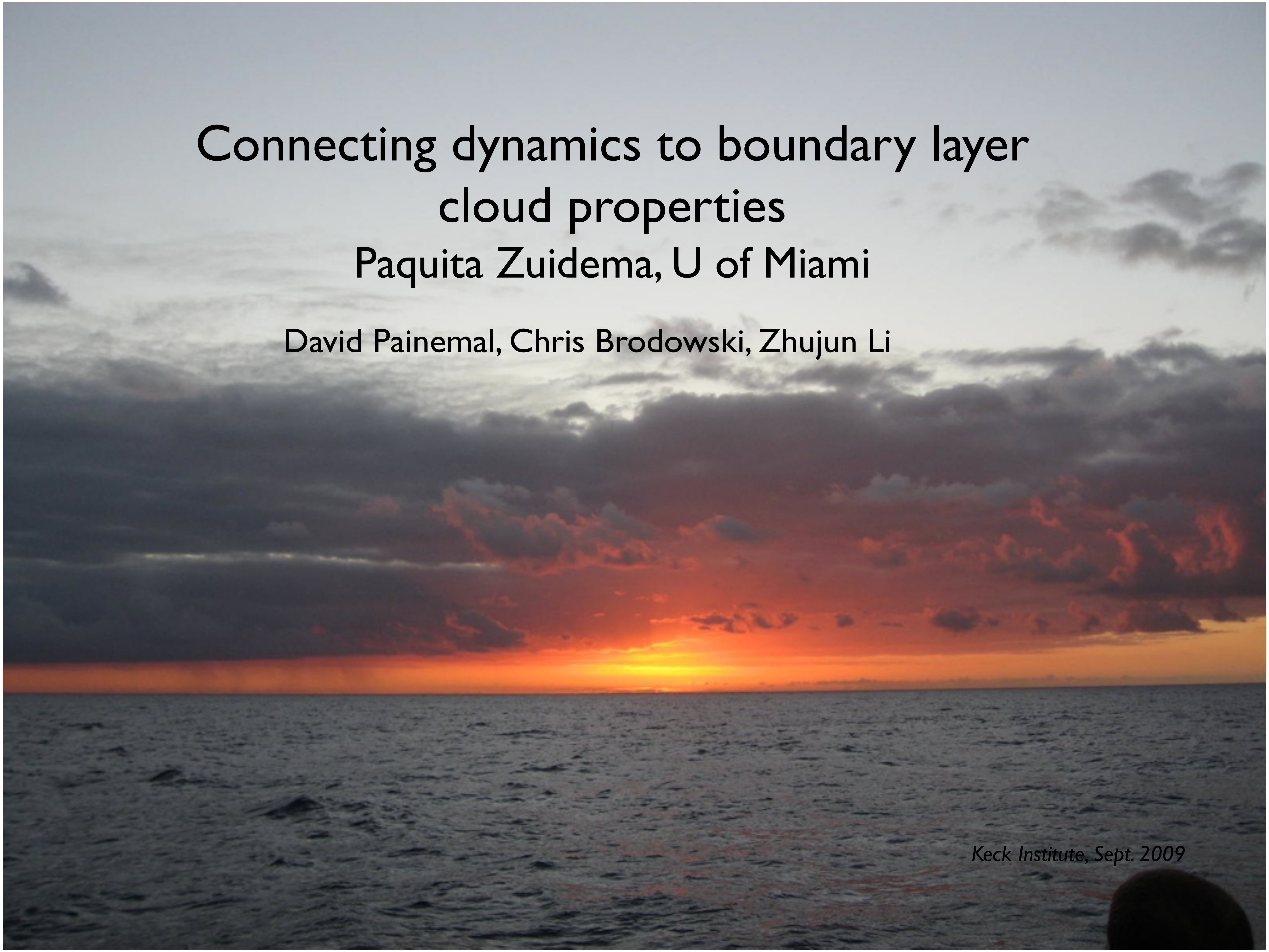
Connecting dynamics to boundary layer cloud properties

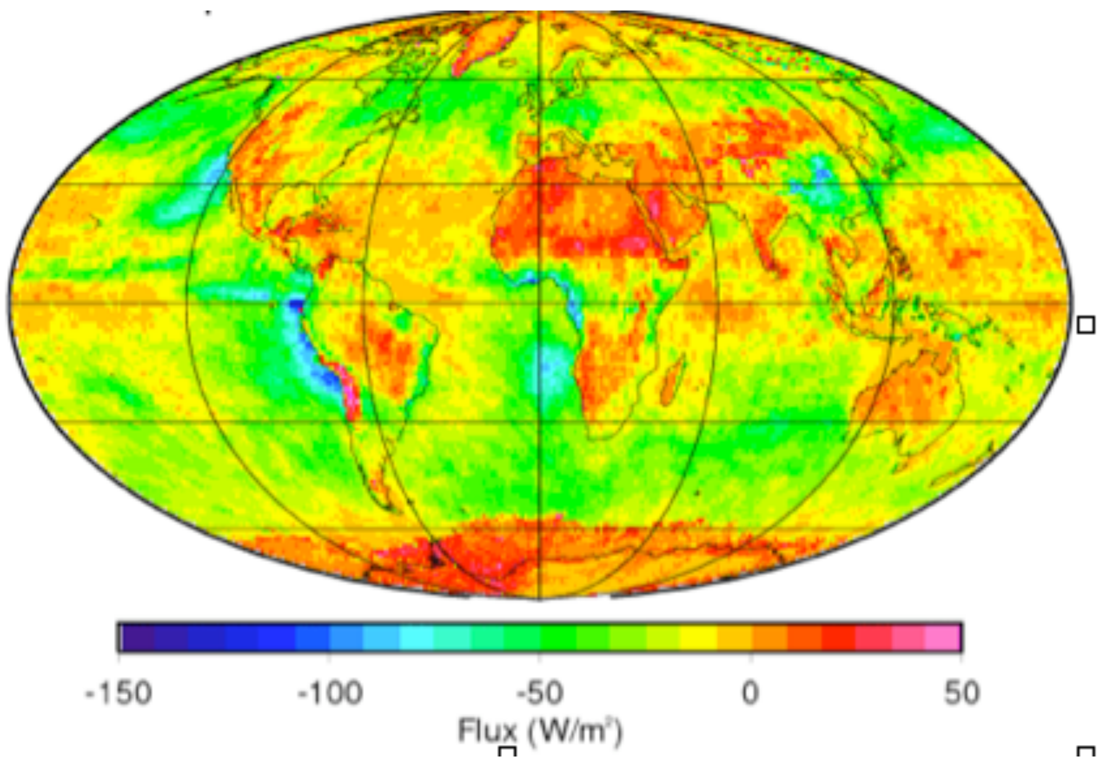
Paquita Zuidema, U of Miami

David Painemal, Chris Brodowski, Zhujun Li



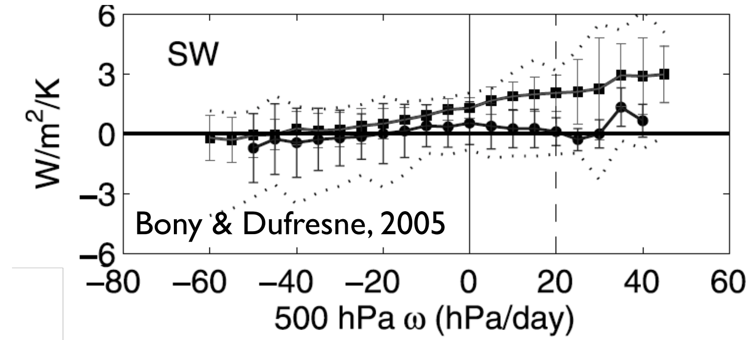
Keck Institute, Sept. 2009

Motivation: marine boundary layer clouds exert a strong radiative impact upon global climate



September 2001, CERES TOA net crf

Common conclusion to assessment of GCM cloud feedbacks is the need to better elucidate cloudy BL processes



Several approaches I have/am trying:

-Use reanalysis to tell you the synoptic meteorology, satellite data to tell you the cloud properties (SEP)

-Use observed (lidar) vertical velocities, assess model microphysics with cloud radar

Southeast Pacific StCu a poster child for satellite cloud retrievals

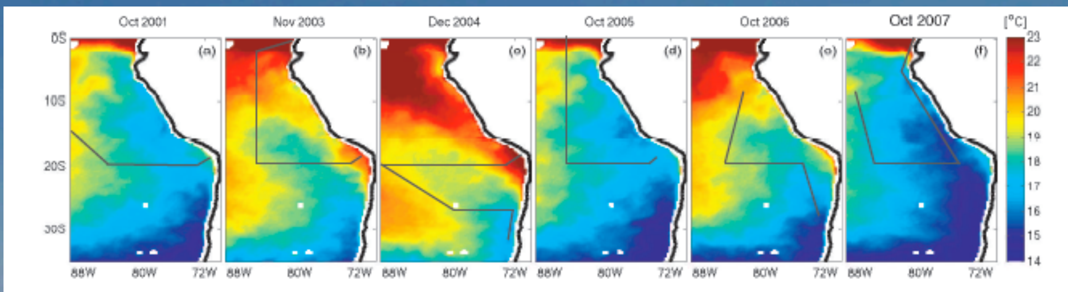
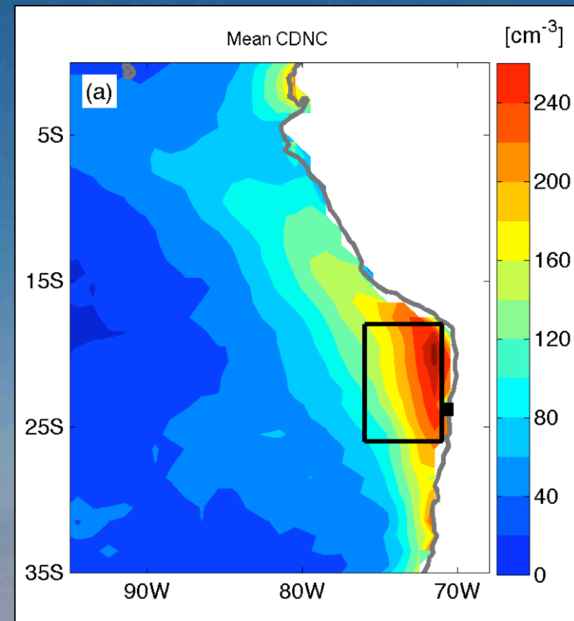
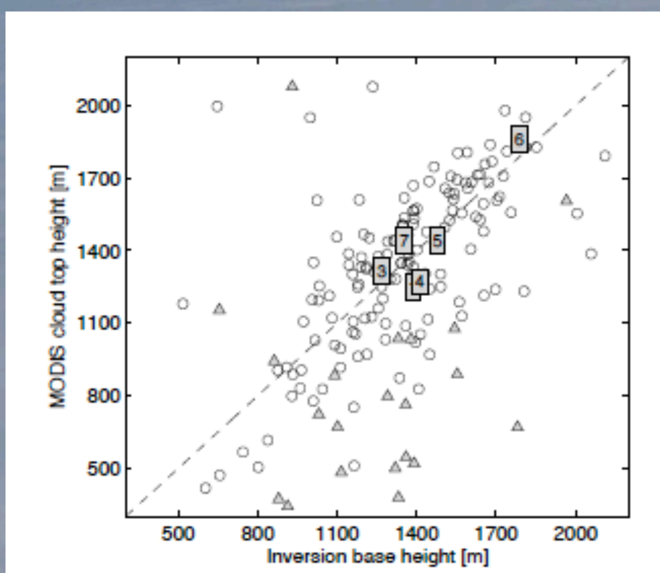


FIG. 1. Monthly-mean TRMM Microwave Imager sea surface temperature with black lines indicating the ship track for the cruise during a) October, 2001, b) November, 2003, c) December, 2004, d) October, 2005, e) October, 2006, and f) October, 2007.





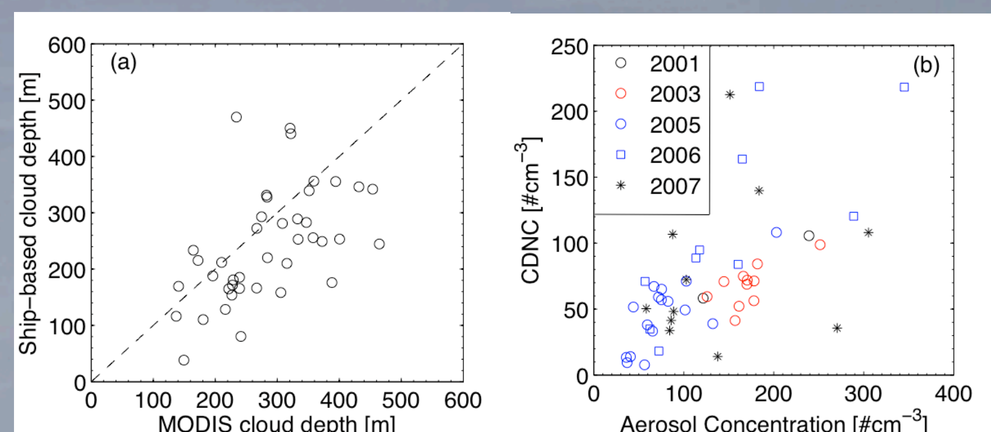
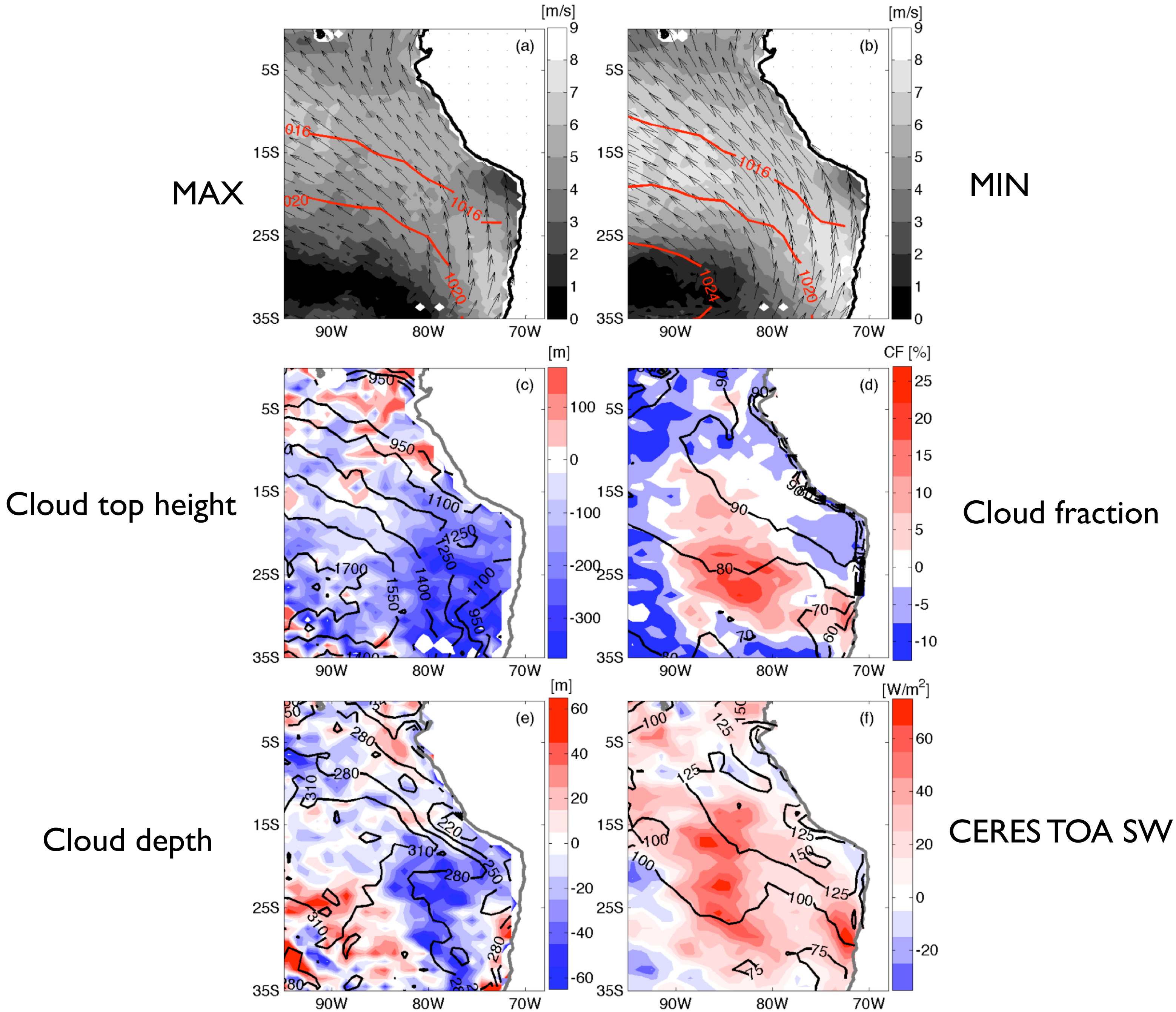


Figure 1: (a) MODIS derive cloud depth versus ship-based cloud depth (hourly averaged), (b) MODIS derived CDNC versus in ship-based accumulation-mode aerosol concentrations. Sampling was carried out within 0˚-30˚S, 72˚W-90˚W.

Zuidema et al. 2009 Jclim



MAX
MIN
Cloud top height
Cloud fraction
Cloud depth
CERES TOA SW
(a)
(b)
(c)
(d)
(e)
(f)
[m/s]
[m/s]
[m]
CF [%]
[m]
[W/m2]
5S
15S
25S
35S
90W
80W
70W

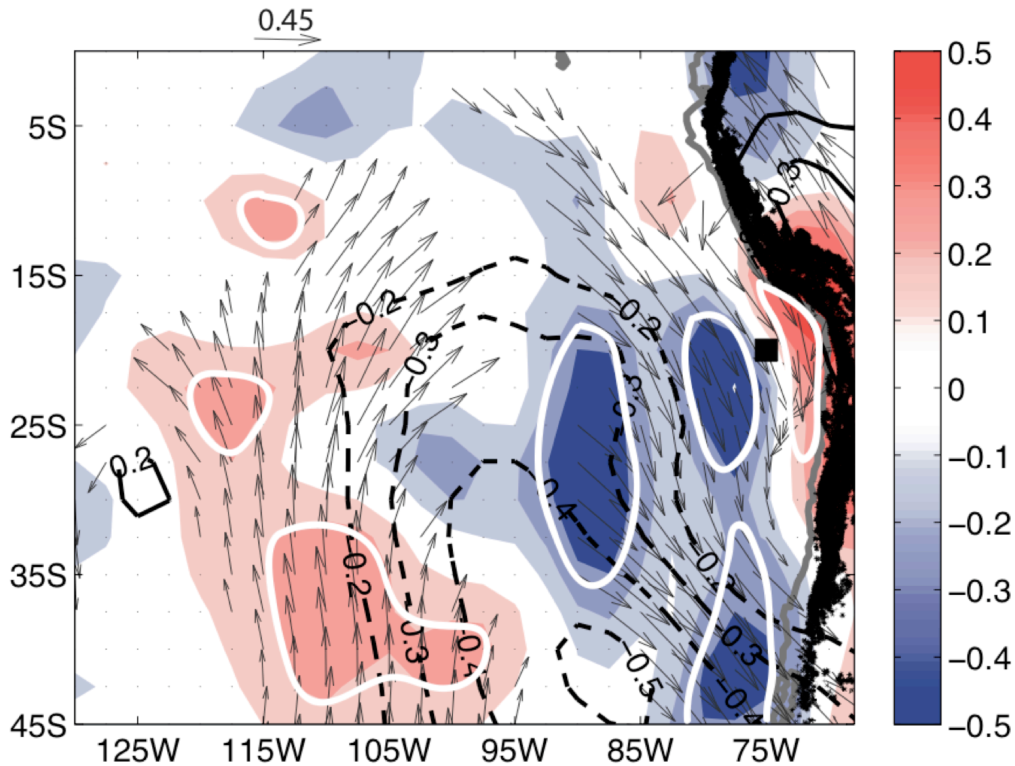


Figure 14: One point correlation at 850 hPa surface between temperature at 20˚S and 75˚W (square) and: subsidence (pressure velocity, dp/dt, colors), geopotential height (contours) and wind (arrows). Values of correlation higher (smaller) than 0.25 (-.25) for geopotential height and white contours for subsidence pass the 99% significa
a Student's t test. The wind-temperature is only shown if the meridional com
statistically significant. Topography highe

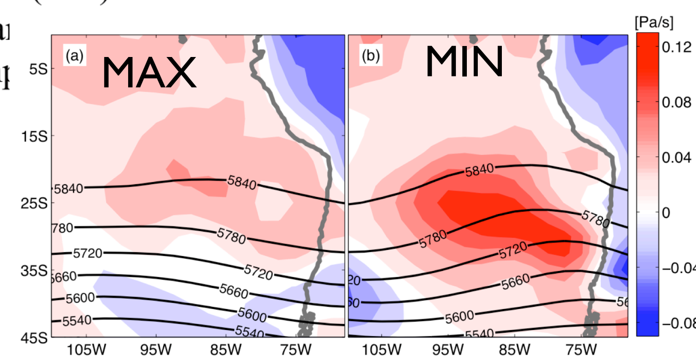


Figure 8: Geopotential heights (contours) at 500 hPa and subsidence at 700 mb (dp/dt, colors) from NCEP/NCAR reanalysis: (a) composit

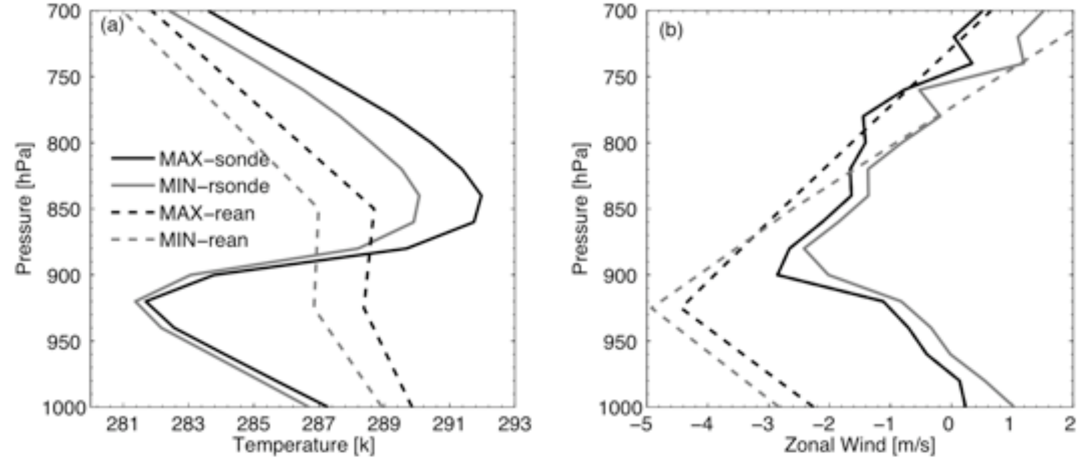


Figure 9: Profile from Antofagasta radiosondes for MAX CDNC (gray line) and MIN CDNC (black line). Dashed lines represent NCEP-NCAR reanalysis data at 22.5°S, 75°W. (a) Temperature and (b) zonal wind.

How good are the new reanalyses ?

YOTC, MERRA, CFSRR, ERA-Interim


cloud processes at smaller scales…..

modeling studies suggest differing impacts from drizzle on BL thermodynamic/turbulence structure

Stevens et al., 1998: drizzle suppresses turbulence

Feingold et al., 2003; cloud base drizzle enhances buoyancy

Comstock et al., 2005; drizzle associated w/ mesoscale circs.

Ackerman et al., 2009: large range of LES drizzle rates

Large-Eddy Simulations of a Drizzling, Stratocumulus-Topped Marine Boundary Layer

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MARAT KHAIROUTDINOV,[h] STEVEN K. KRUEGER,[i] DAVID C. LEWELLEN,[j] ADRIAN LOCK,[k]
CHIN-HOH MOENG,[l] KOZO NAKAMURA,[m] MARKUS D. PETTERS,[n] JEFFERSON R. SNIDER,[o]
SONJA WEINBRECHT,[p] AND MIKE ZULAUF[i]

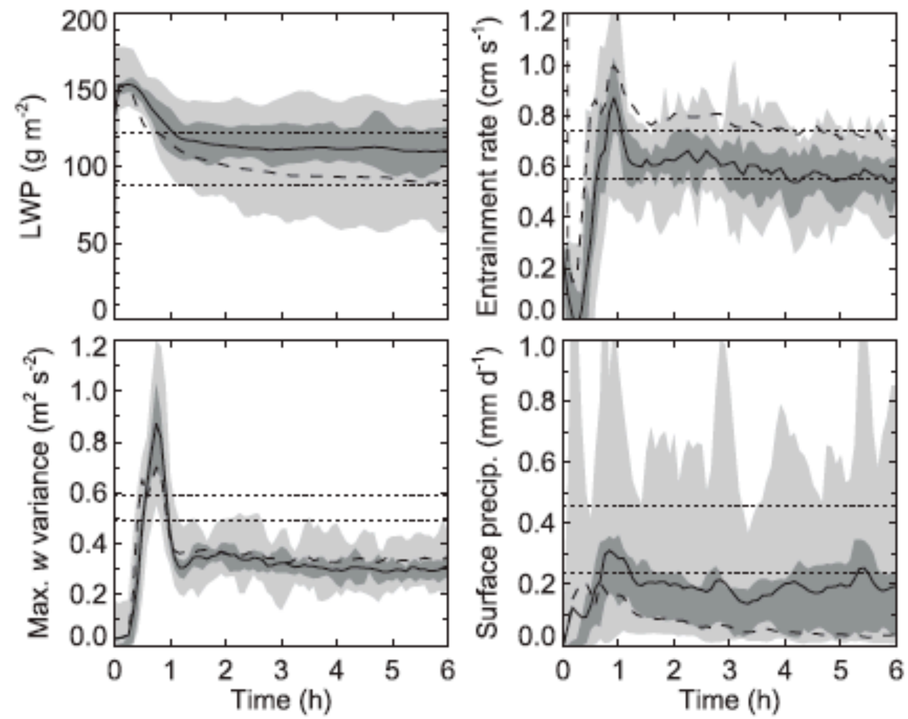

FIG. 1. Evolution of domain average LWP, entrainment rate (defined in text), maximum $\overline{w'^2}$ (peak value in the $\overline{w'^2}$ profile), and surface precipitation for simulations that include cloud water sedimentation and drizzle. Ensemble range, middle two quartiles, and mean denoted by light and dark shading and solid lines, respectively. Ensemble mean from simulations that include drizzle but not cloud water sedimentation denoted by dashed lines. Approximate ranges of measurements (averaged over closed and open cells) denoted by dotted lines, with upper and lower LWP values estimated from Stevens et al. (2003a) and aircraft soundings, respectively; entrainment rates from Faloona et al. (2005); maximum $\overline{w'^2}$ from vanZanten and Stevens (2005); and precipitation from vanZanten et al. (2005).

A single-column model intercomparison of a heavily drizzling stratocumulus-topped boundary layer

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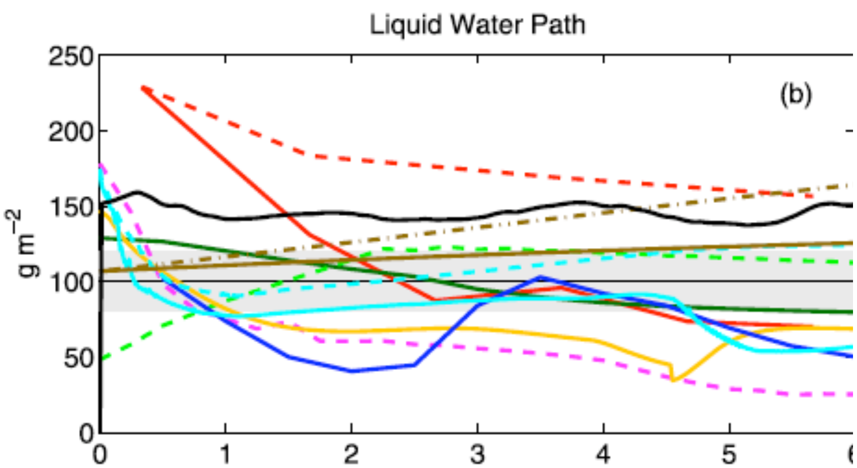
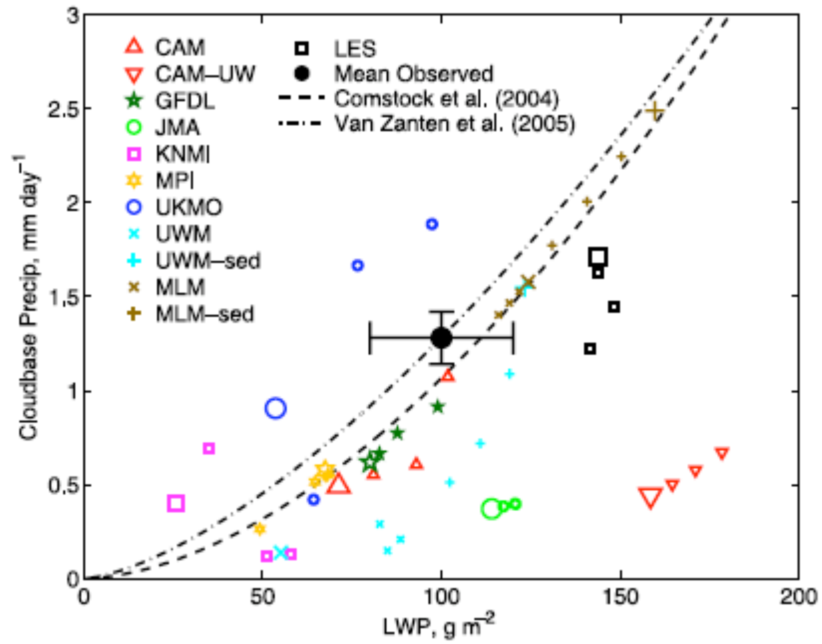




cloud processes at smaller scales…..

Radiative flux closure in Arctic
but not in Stcu !

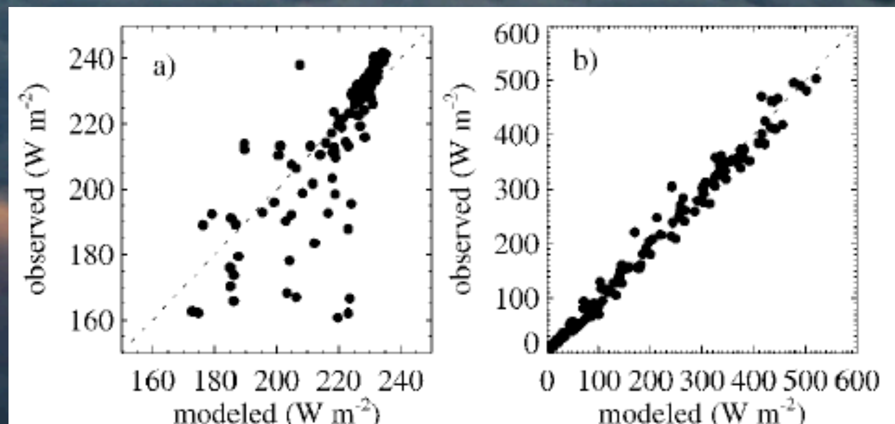


FIG. 13. Modeled and observed broadband downwelling surface (a) infrared fluxes and (b) shortwave fluxes from 1 to 7 May (8

Optical depth also depends on absorption model

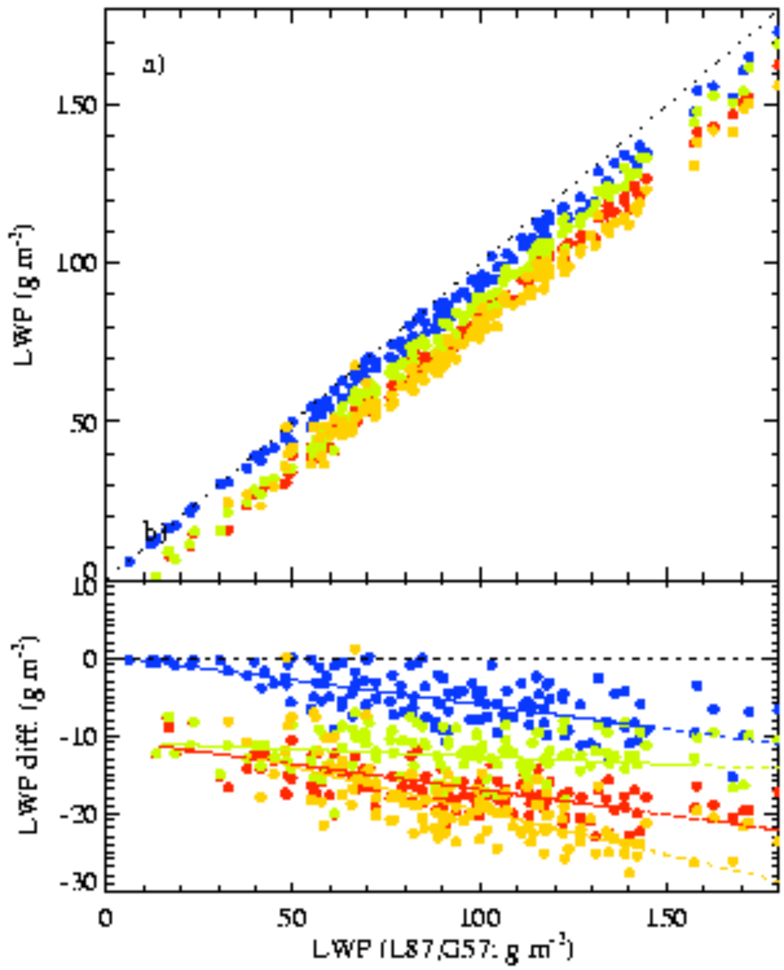


Figure 4. (a) Liquid water paths retrieved for 15 October from Hughes MWR data using the (Lieb87, L91), (R98, L91), (R98, G57), and (Lilj05, L91) models (grey and black pluses, grey and black circles, respectively) versus LWPs retrieved using (Lieb87, G57) model. (b) Similar to Figure 4a but showing the difference between the LWPs retrieved with each model and the (Lieb87, G57) model.

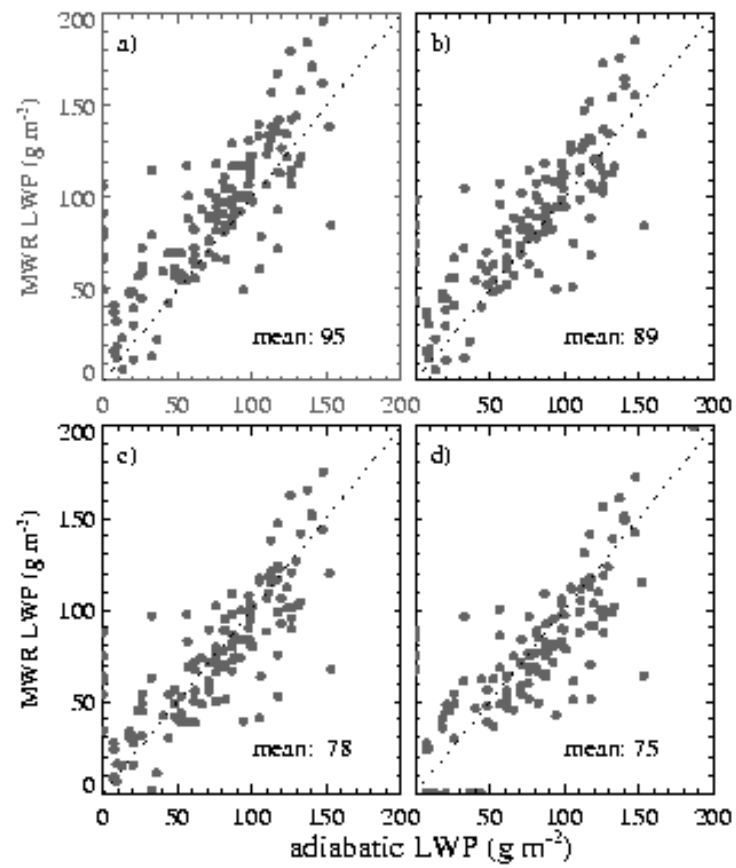


Figure 5. (a) Liquid water paths retrieved using the (Lieb87, G57) models, (b) (Lieb87, L91) models, (c) (R98, L91) models, and (d) (Lilj05, L91) models versus adiabatically calculated LWPs. The mean retrieved LWP for each model combination is indicated in Figures 5a–5d. Data are from the Hughes MWR on 15 October.

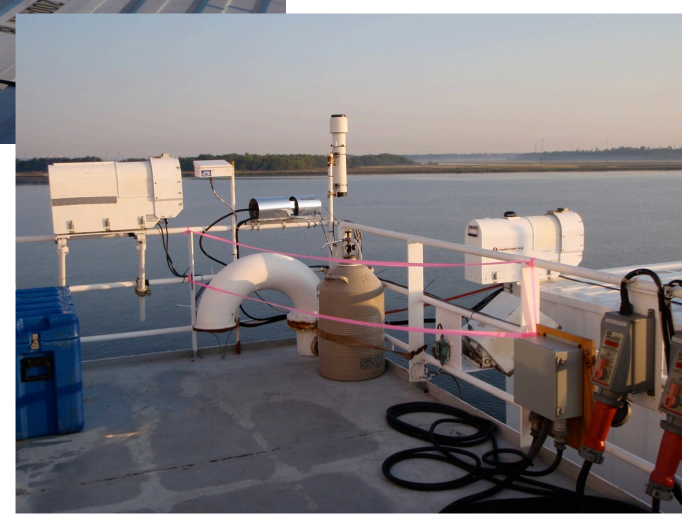
GVR (G-band Vapor Radiometer)

prototype instruments intended for dry,cold (Arctic) conditions, first use in stratus

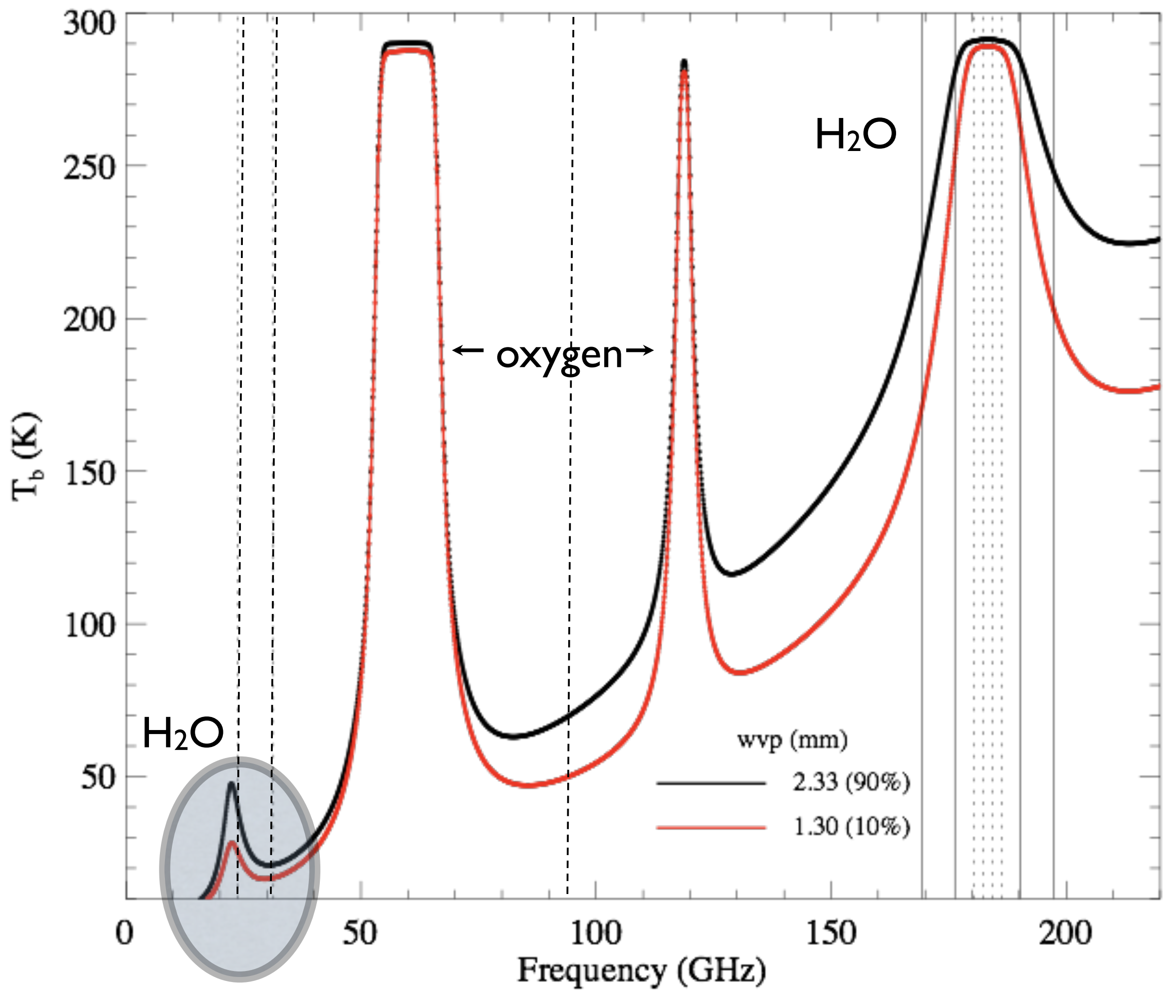
C-130

upward-looking, small

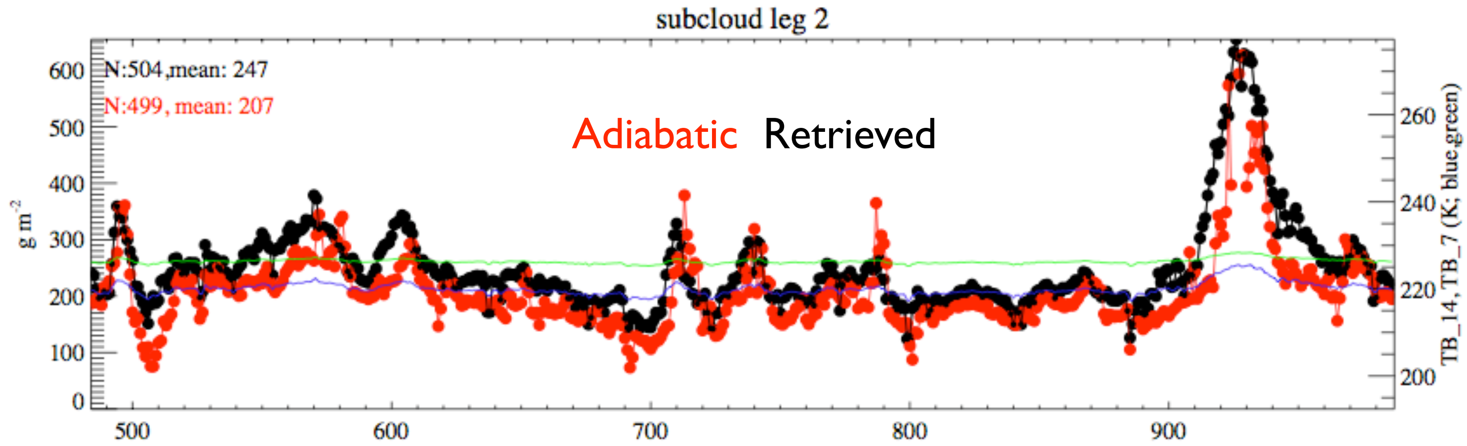
Ron Brown, MP183 + standard 2-channel



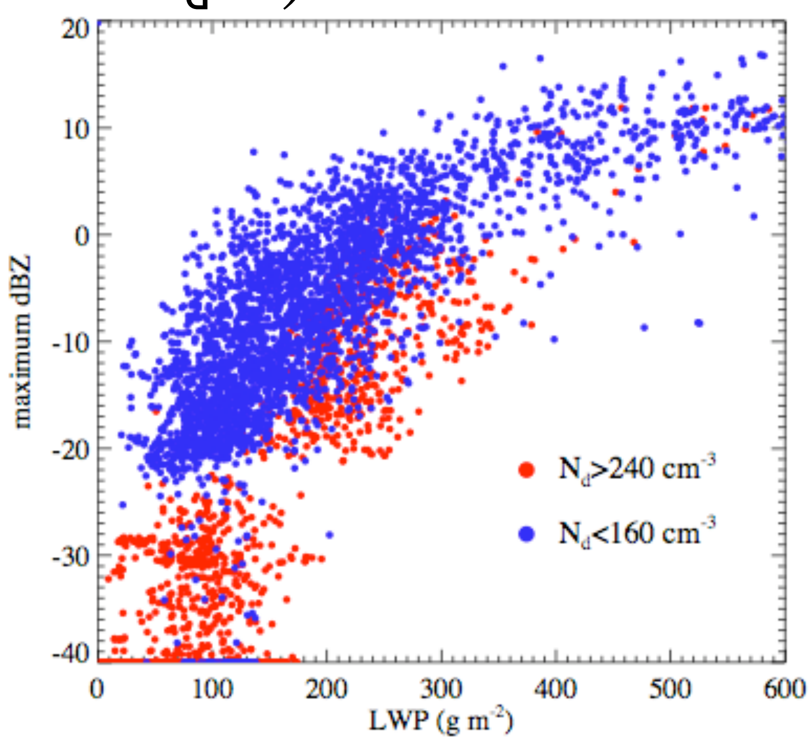
clear-sky spectra of 10th and 90th percentile VOCALS-REx domain soundings



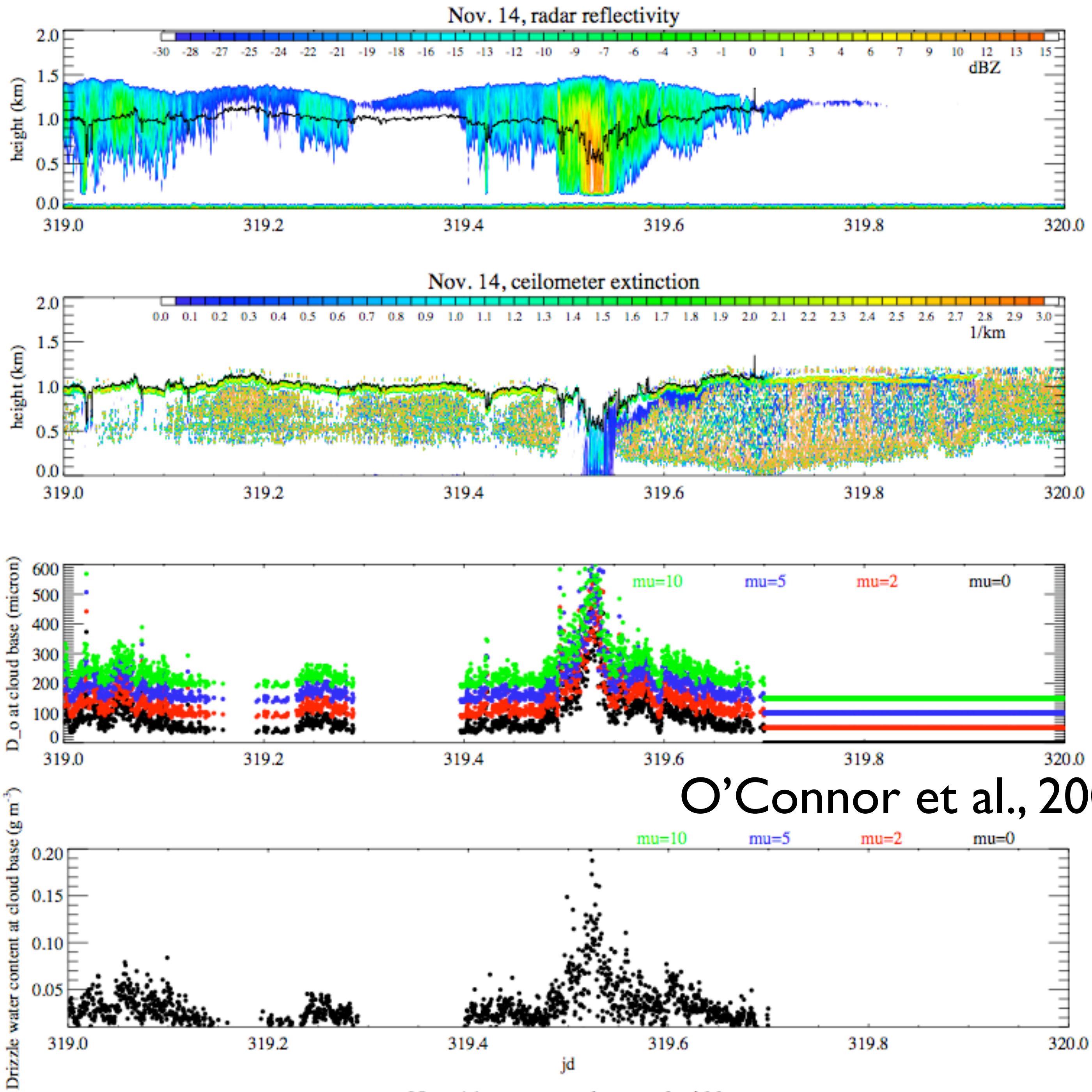
2channel



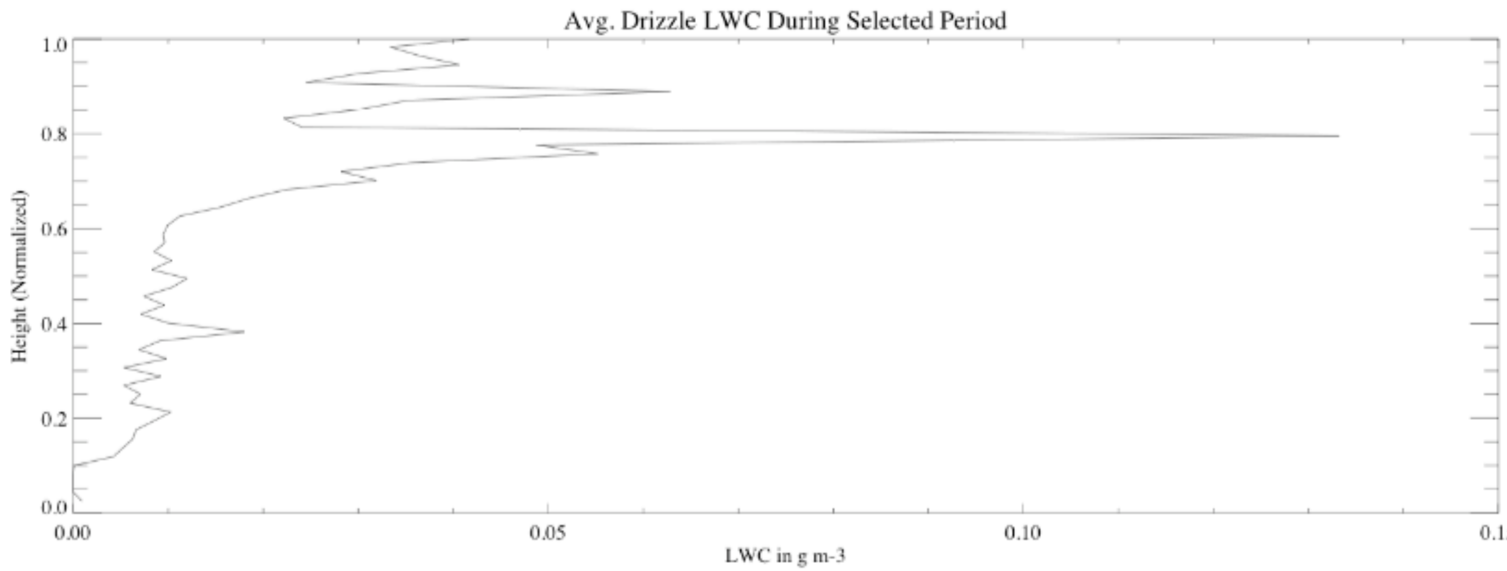
$$\text{drizzle} = f(\text{LWP}^{\alpha}\ N_d^{-\beta})$$



rf3



O’Connor et al., 2005,2006

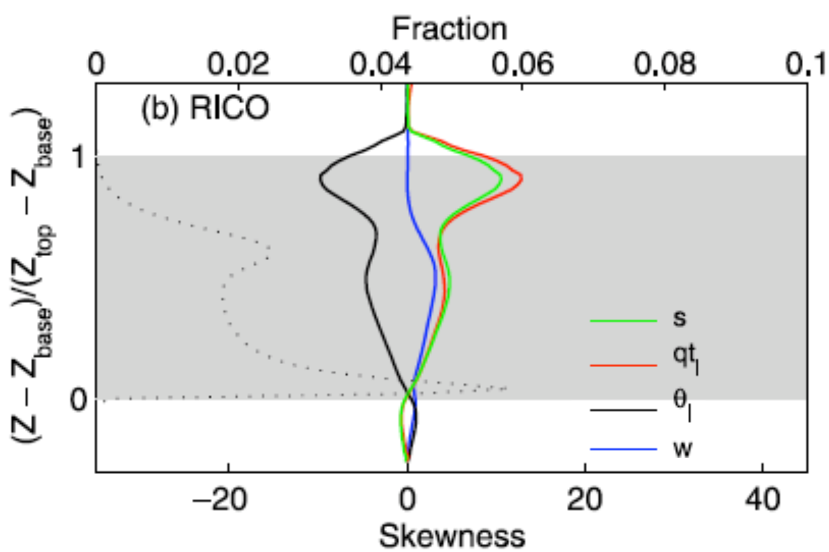


While drizzle frequently observed on ship,
SEP drizzle water paths typically small (<10 g/m2)

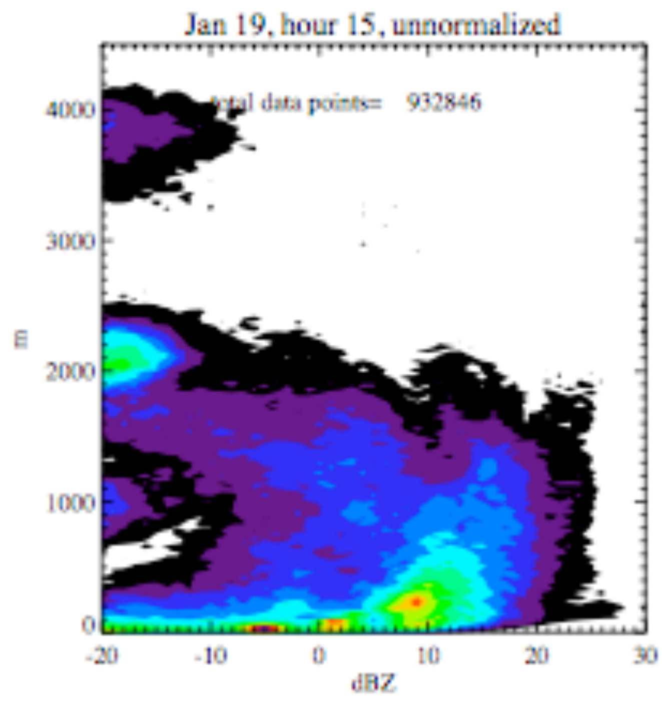
RICO
using lidar-derived vertical velocities, testing microphysical representations (Ben Shipway's 1D model) comparing to scanning cloud radar reflectivities

Zhujun Li

Complements modeling by Ping Zhu



Zhu and Zuidema, 09

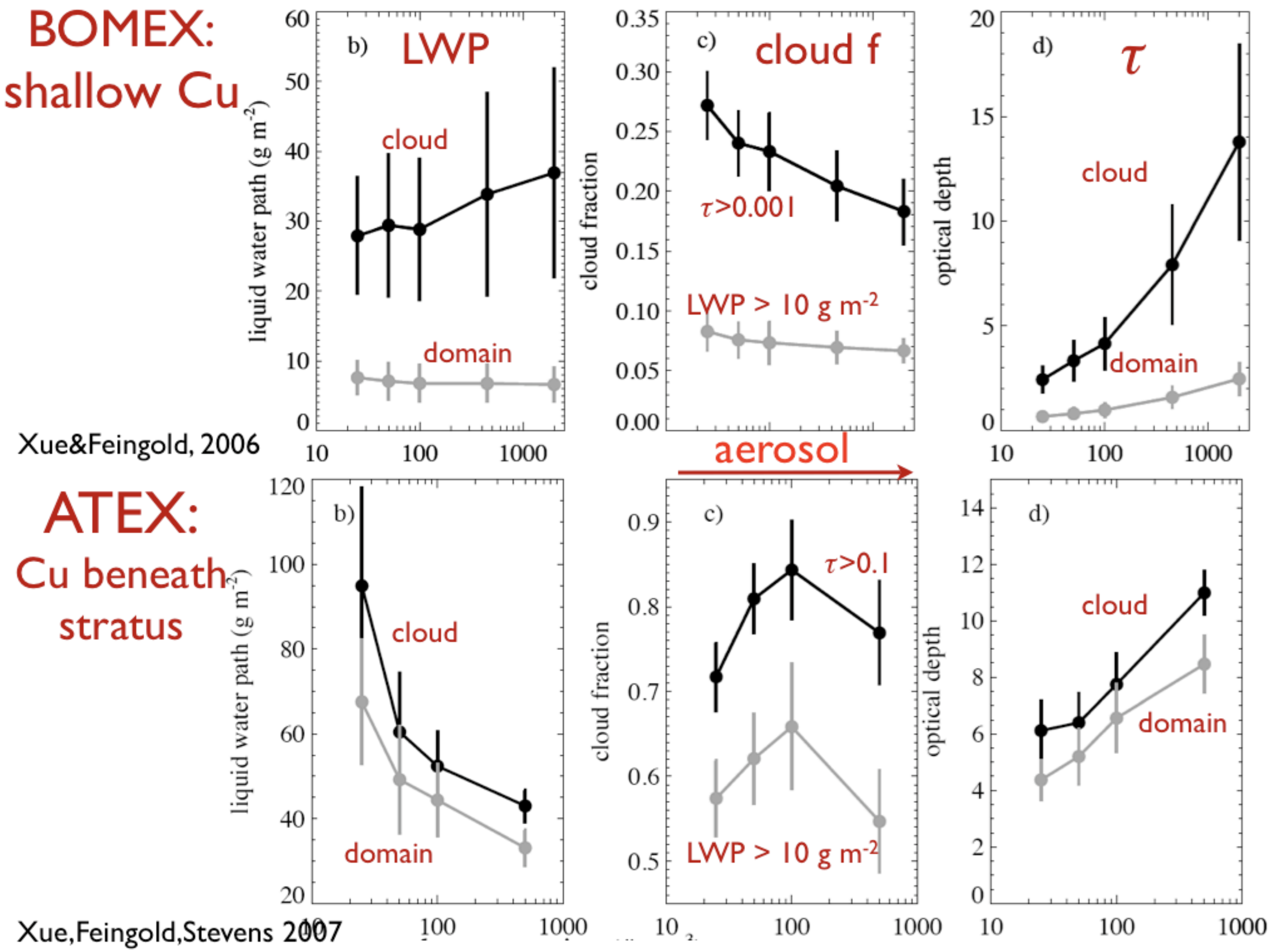


These individual assessments contribute to broader views but statistics ultimately better for GCMs

Umiami recently funded to establish a Cloud-Aerosol-Rain OBserving (CAROB) system

Zuidema,Albrecht,Voss,Prospero

BSRN,AERONET,MPLNET

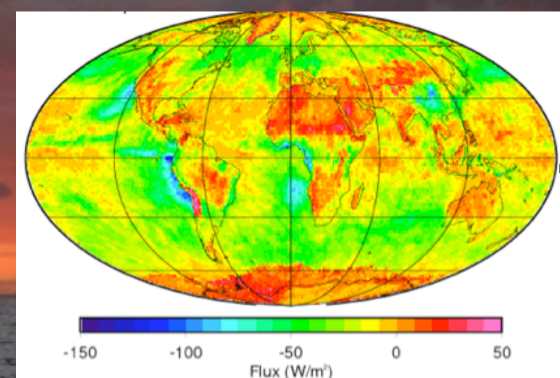


Cloud fraction reductions partially compensate for optical depth increases in net SW CRF

Zuidema,Xue,Feingold,08

In summary:

Data/process observations necessary;
consider what observations are worth investing in



September 2001, CERES TOA net crf