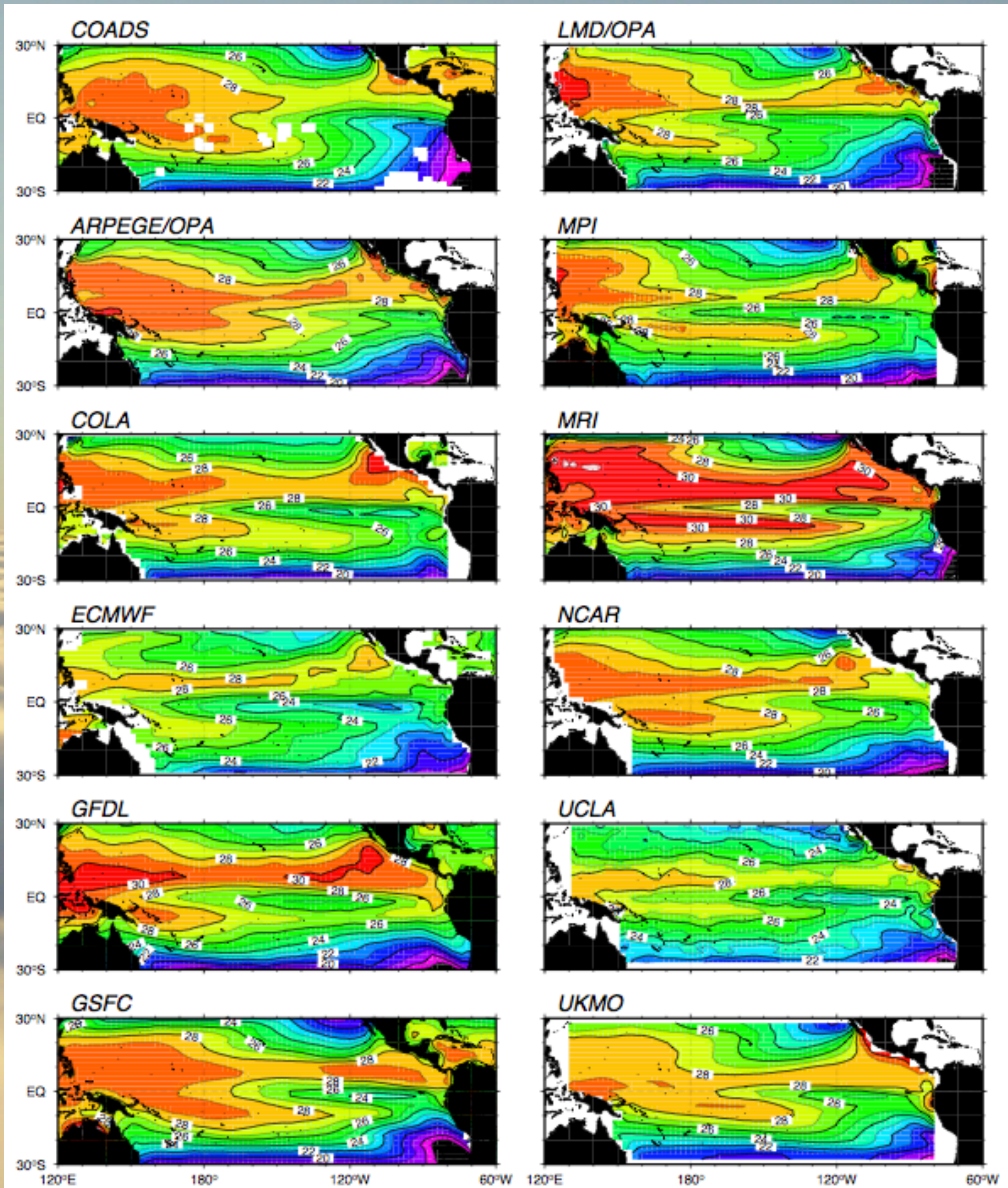
# A Regional Climate with Global Impacts

C. R. Mechoso, AOS UCLA

Research Concerns in Mid 90's

- ENSO, in all its aspects
- CGCM errors in the eastern tropical Pacific region

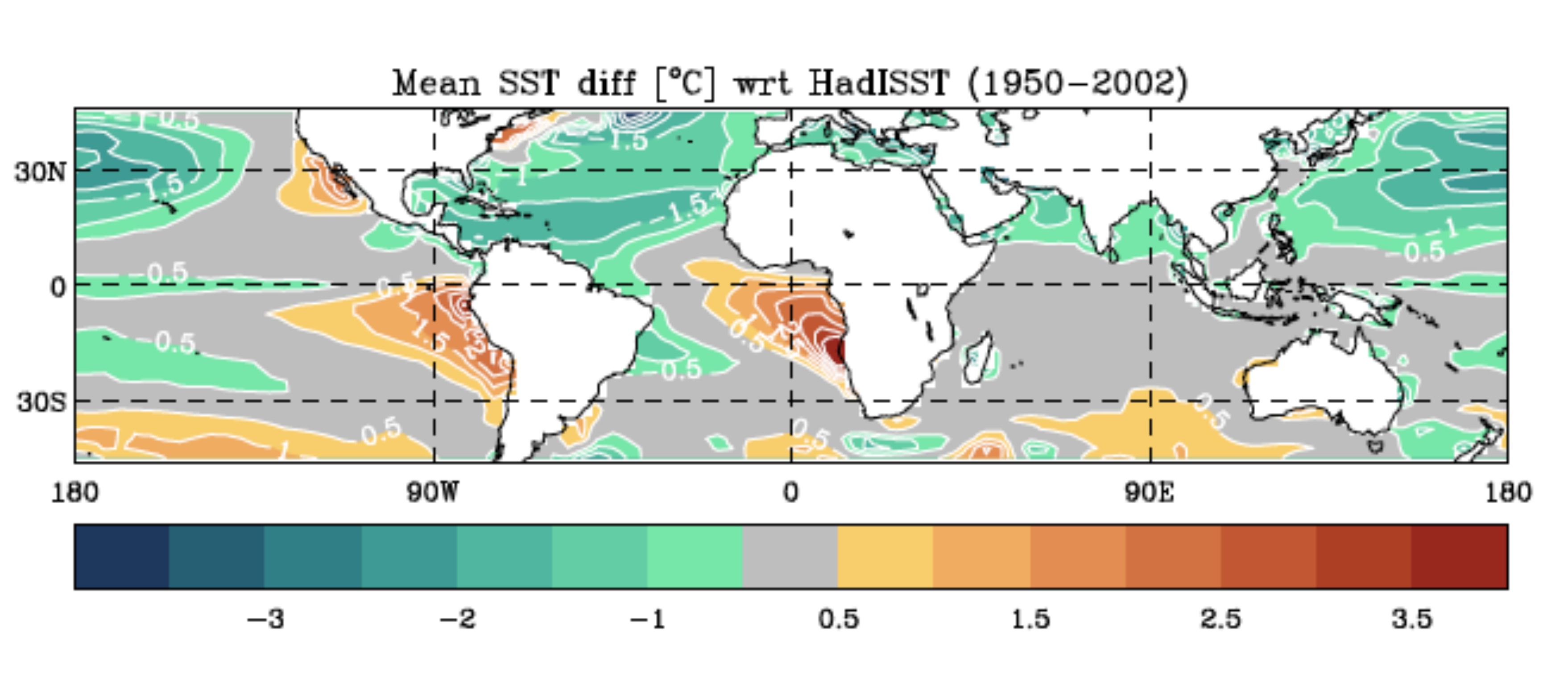



# SST in CGCMs

(October)

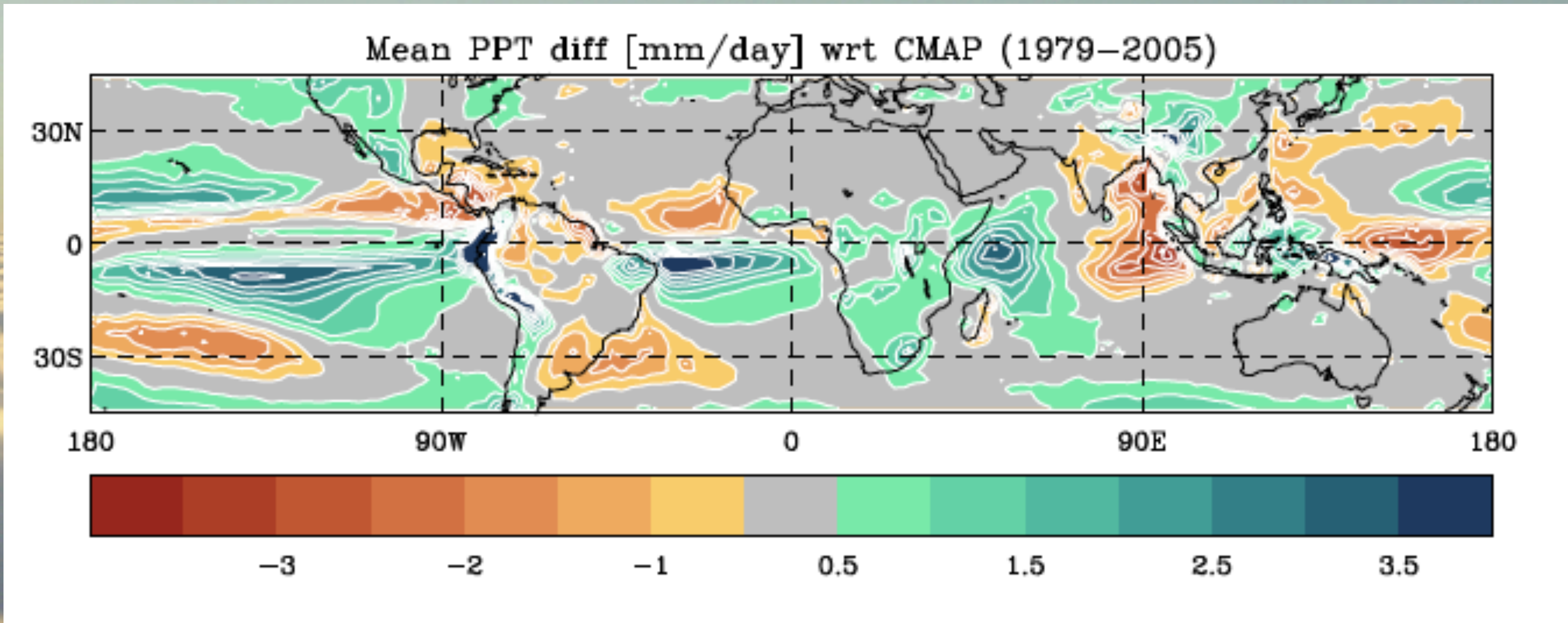
Mechoso et al. (1995)

# SST Errors in CMIP5 CGCMs

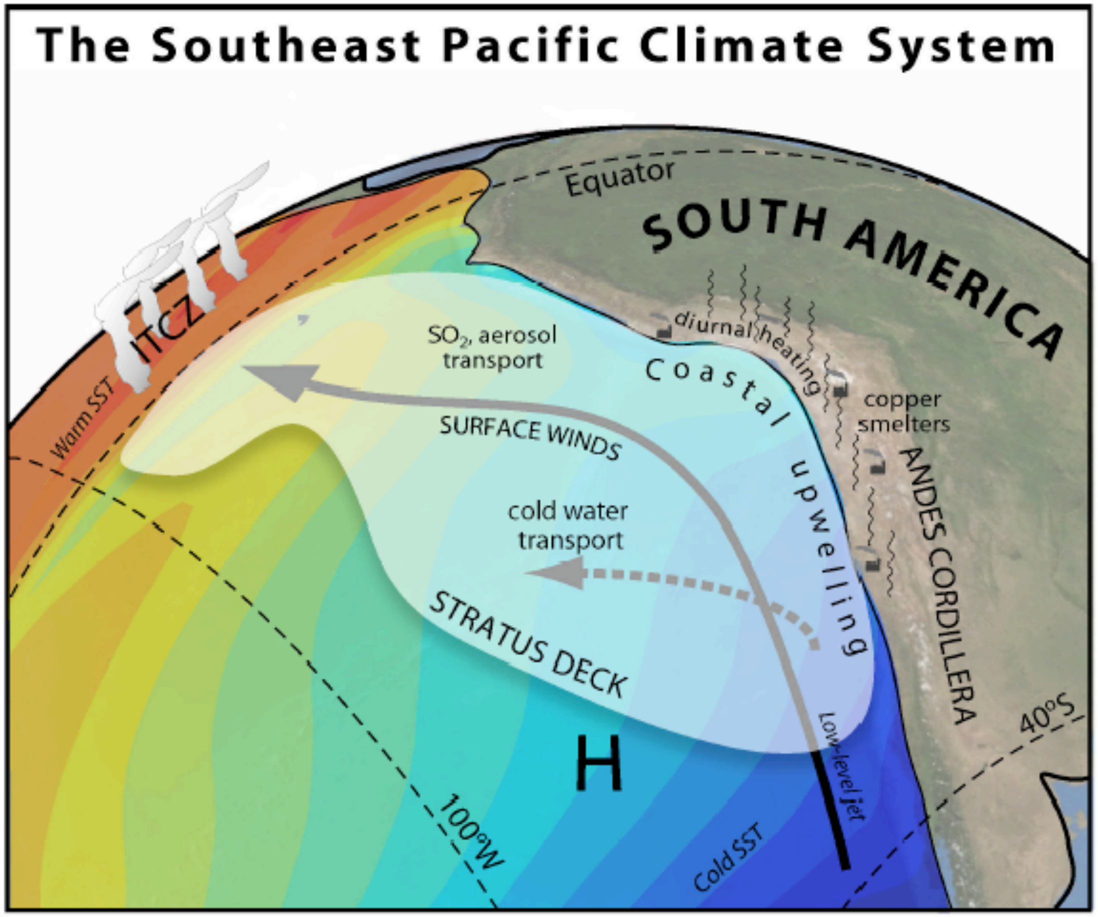



Courtesy T. Toniazzo, C34, #228B

# Precipitation Errors in CMIP5 CGCMs




Courtesy T. Toniazzo, C34, #228B




- Persistent cloudiness, cold SSTs, coastal upwelling
- Influenced by and influential on remote climates (ENSO)
- Poorly simulated by atmosphere-ocean GCMs
- Important aerosol effects
- High ocean productivity

# Consensus and Action

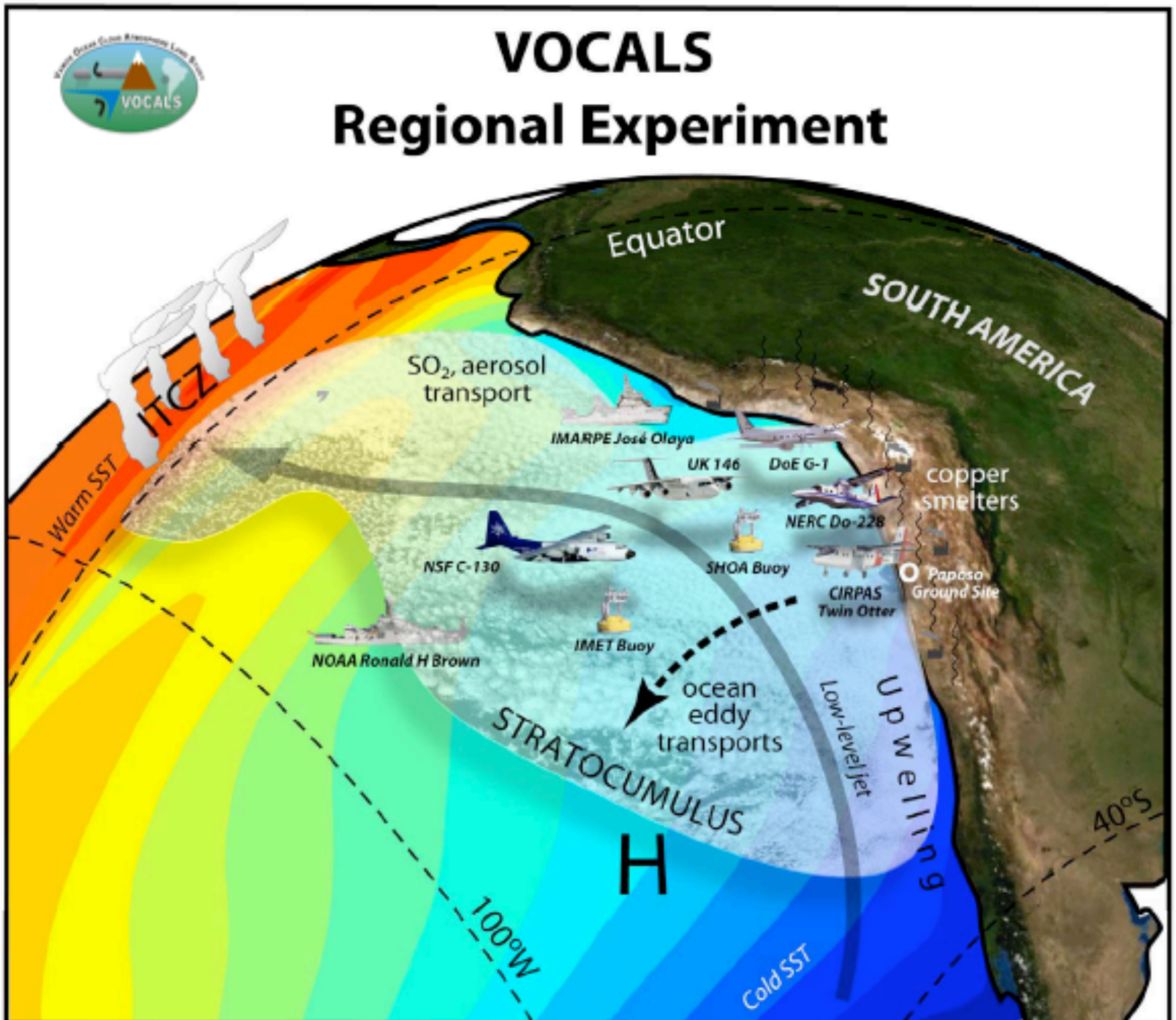
- CGCMs produce too few low level clouds in the tropical oceans
- Totally insufficient local data for model evaluation and parameterization development
- Research programs were started, culminating in VOCALS

# VOCALS is a component of the Variability of American Monsoon Systems (VAMOS), a panel of WCRP/CLIVAR

*www.eol.ucar.edu/projects/vocals*

# VOCALS Goals

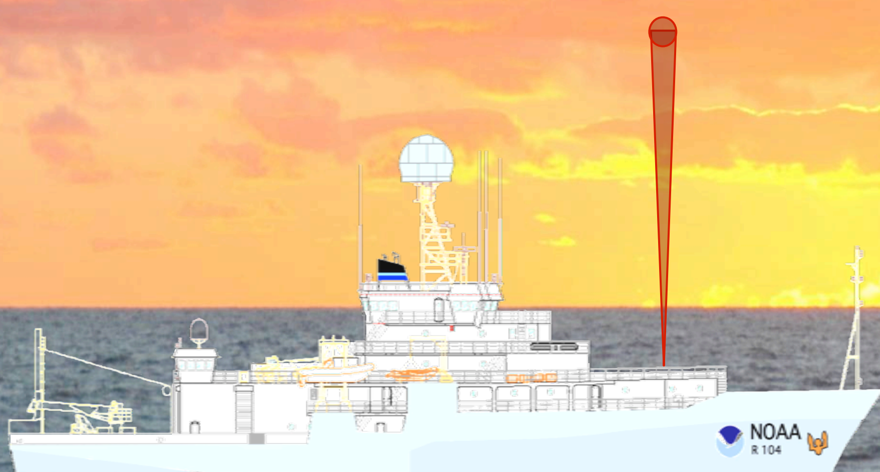
- Elimination of CGCM systematic errors in the Southeastern Pacific, and improved model simulations of the regional climate system and global impacts of its variability
- Improved understanding and regional/ global model representation of aerosol indirect effects over the region

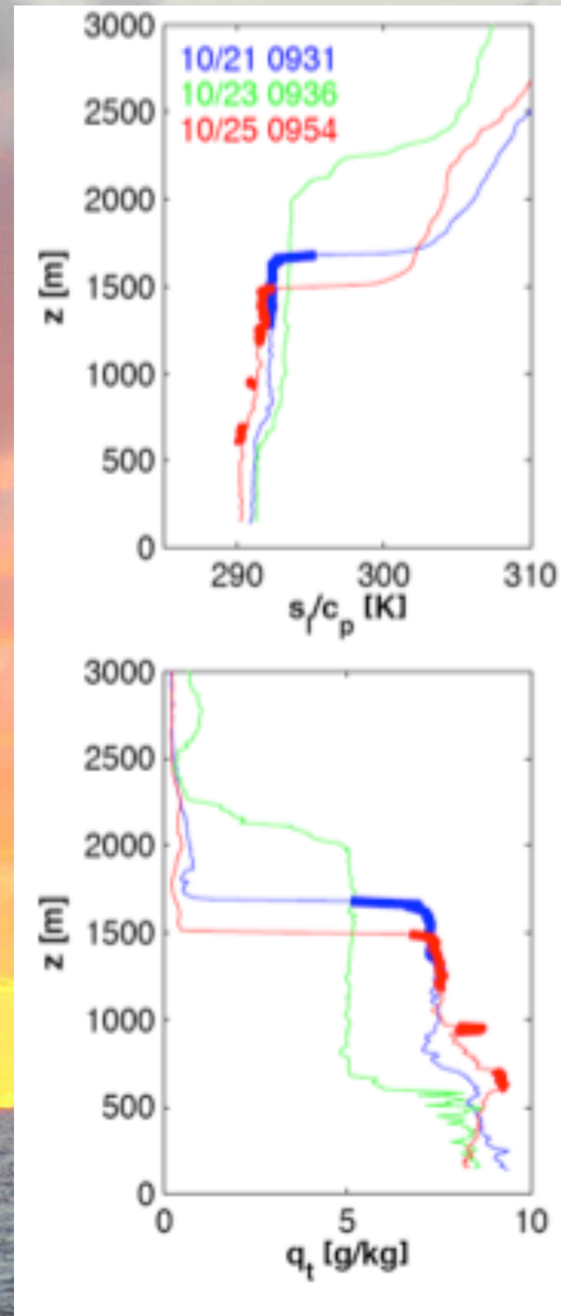



October-November 2008

## Ship Campaign

Potential Temperature and Specific Humidity Profiles (20S, 85W)



# VOCALS 20S cloud and boundary-layer structure

## Aircraft Campaign

Ten dedicated and six partial missions sampled 1500 km offshore along 20S (flight plan at right)

<u>Offshore (80-85 W):</u>

1.5-2 km deep PBL

Decoupled (LCL<cld base);

Cloud drop conc. <100/cc

Drizzle cells, with high LWP

<u>Nearshore (70-75 W):</u>

1-1.2 km deep PBL

Well mixed; Cloud drop conc. 200-250/cc

Thin clouds, little drizzle

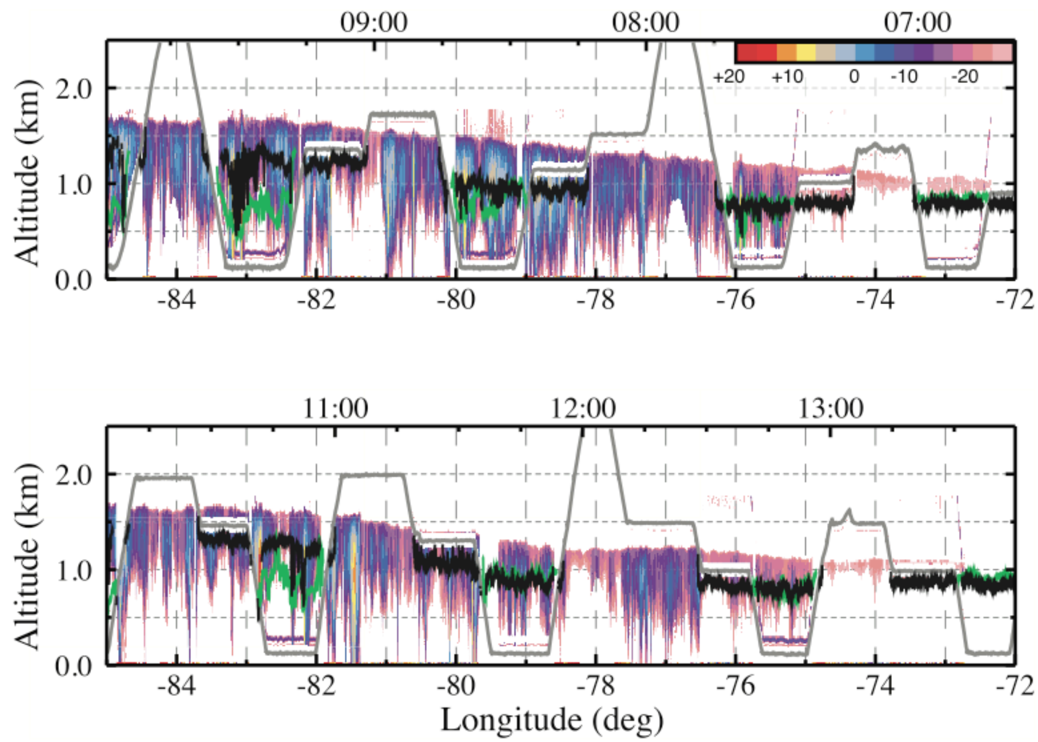
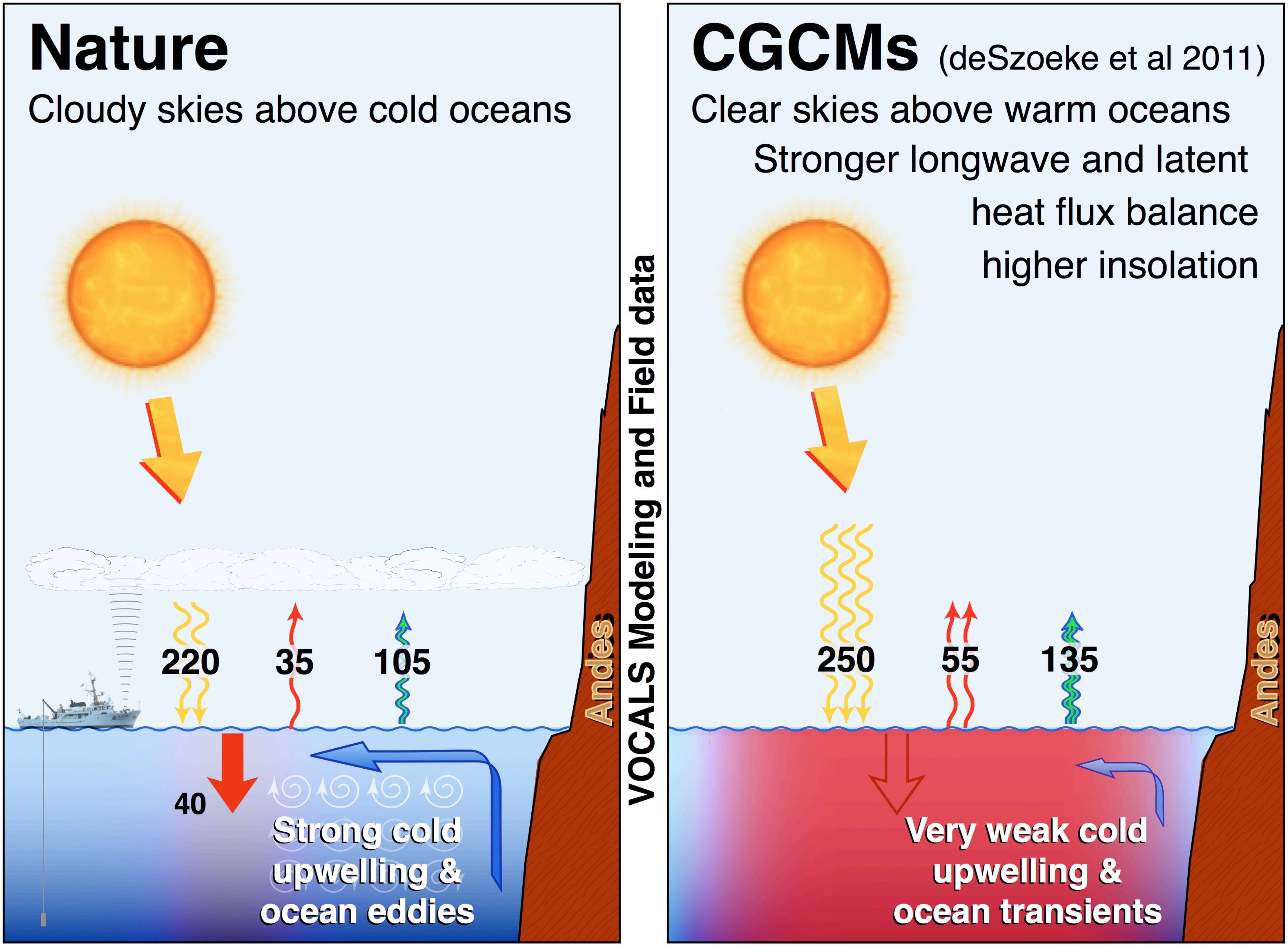
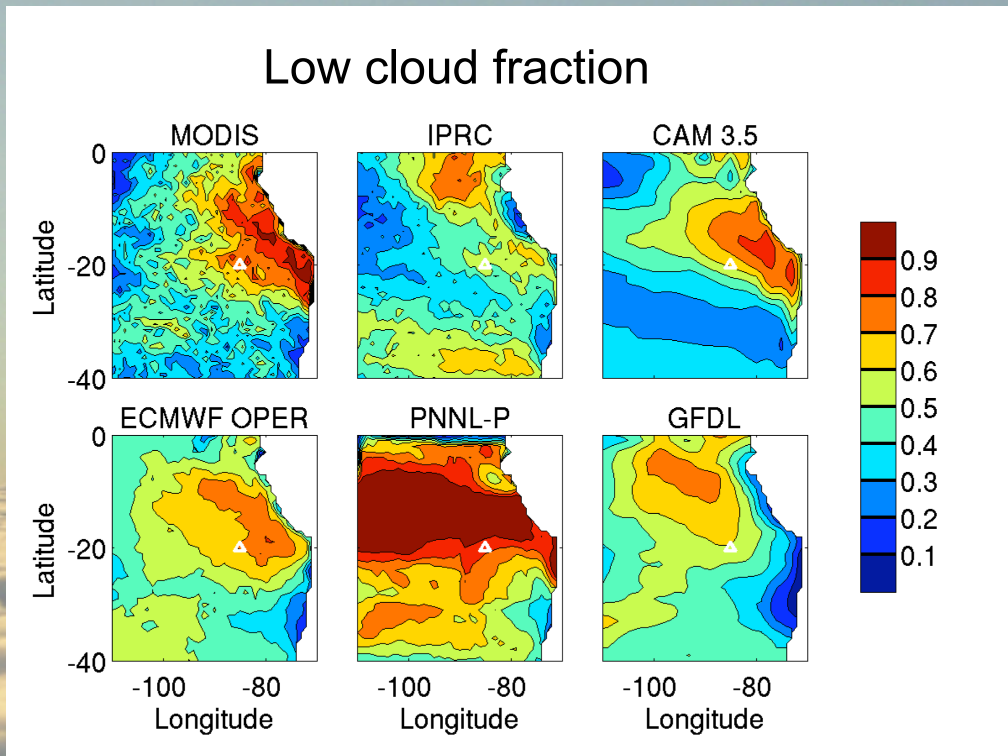


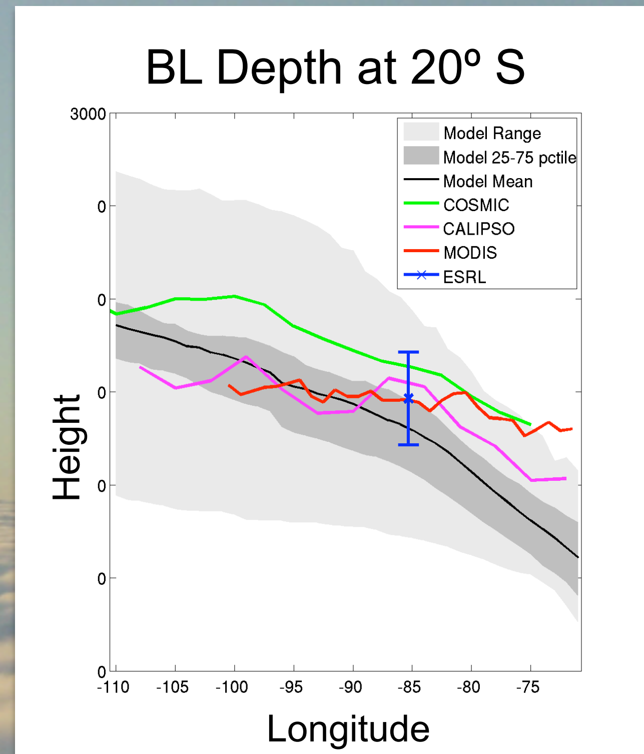

**Fig. 2.** Longitude-height plot of WCR reflectivity along 20° S for the outbound (top) and return (bottom) portions of C130 RF03. During subcloud legs, the in-situ LCL (green) and the WCL cloud base (black) are superimposed. During cloud legs, the black line shows the cloud base adiabatically derived from in-situ LWC. The grey line traces the aircraft flight track; the top axis labels show UTC time.

C. Bretherton et al., 2010


Nature
Cloudy skies above cold oceans
220
35
105
40
Strong cold upwelling & ocean eddies
Andes
VOCALS Modeling and Field data
CGCMs (deSzoeke et al 2011)
Clear skies above warm oceans
Stronger longwave and latent heat flux balance higher insolation
250
55
135
Very weak cold upwelling & ocean transients
Andes

# Pre-VOCA Experiment

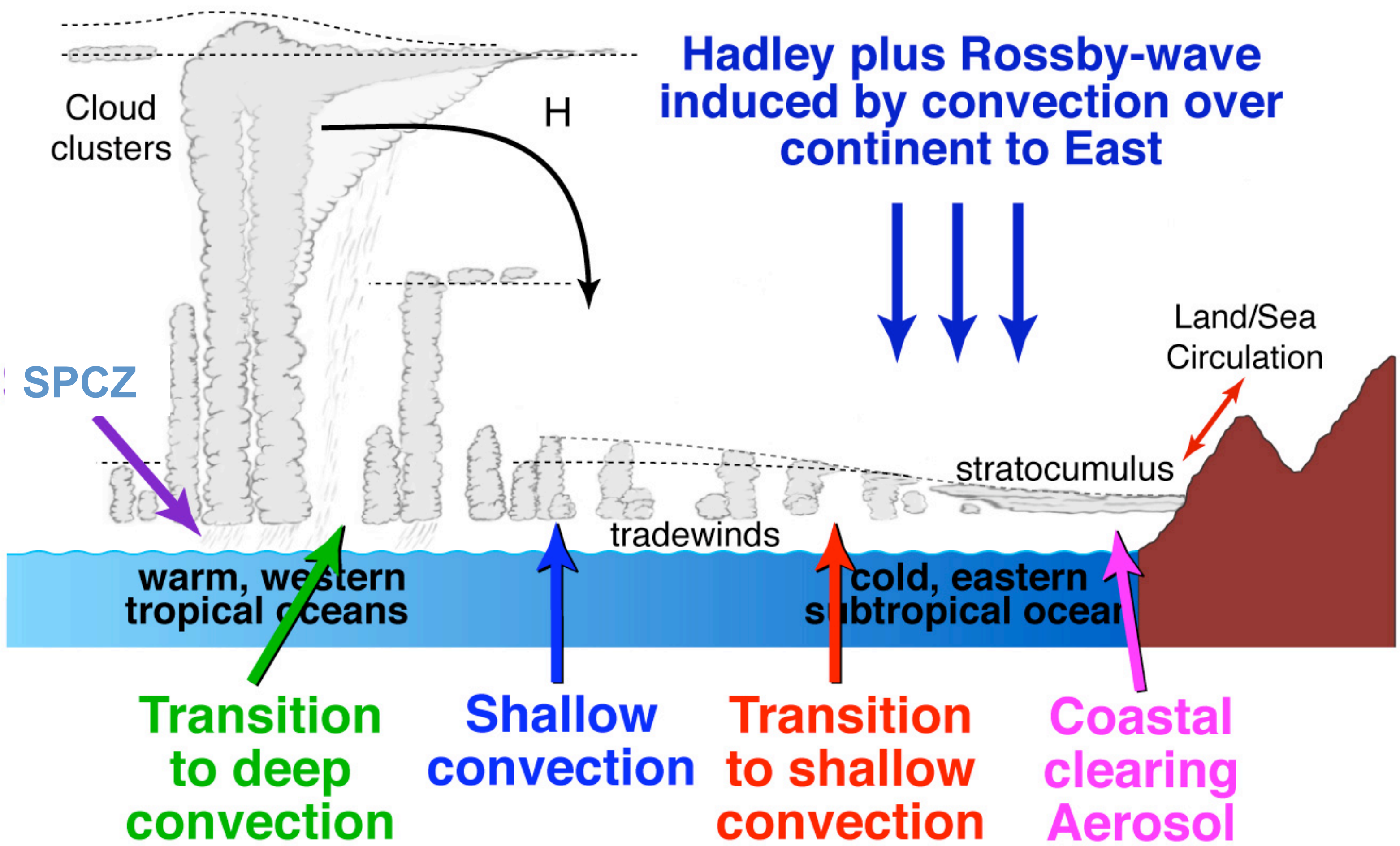



- PreVOCA compared 15 regional, forecast, and climate models for October 2006 in the VOCALS region.
- Many models had large errors in distribution of low cloud cover.
- Most models qualitatively captured diurnal and day-to-day variability of the cloud and BL despite mean biases.
- Global models outperformed most regional models.

M. Wyant et al. 2010, ACP

# The Southern Tropical Pacific (10-20S)

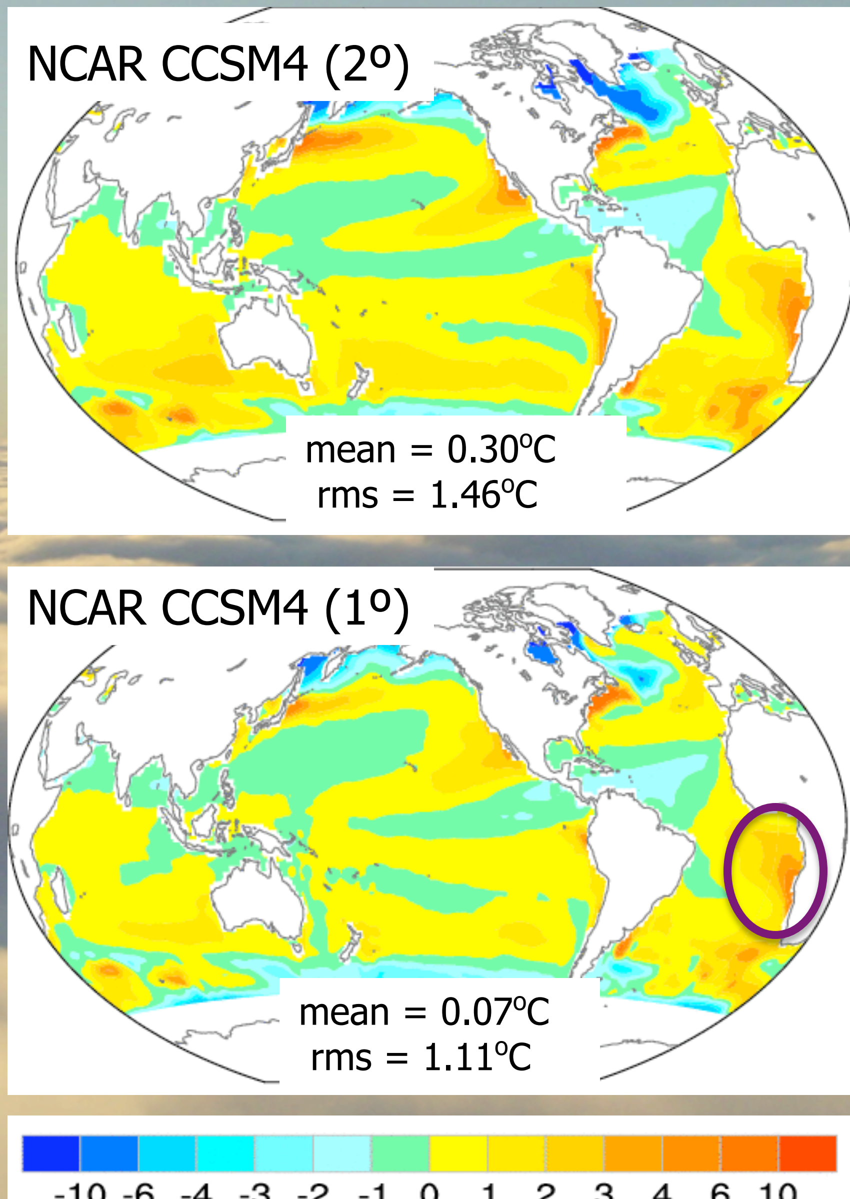



The successful simulation of these cloud regimes is the major target of specialized research groups, such as the Climate Process Teams (CPTs), championed by US CLIVAR

# VOCALS Impact

- Comprehensive, organized, and accessible datasets for the Southeastern Pacific
- Different models confronted to datasets
- Framework for improvement of tropical low level clouds
- Demonstration that large international community efforts under WCRP, based on sound scientific hypotheses, can be successful

# Progress has been achieved, but...




**Tropical Atlantic warm bias still strong!**

**Next Target for WCRP?**

Courtesy J. Hurrell

## Universities

Arizona
Arizona State
California Los Angeles
California Irvine
California San Diego
California Santa Cruz
Chile, Chile
Concepción, Chile
Colorado Boulder
Colorado State
Drexel
Hawaii
Iowa
Leeds, UK
Manchester, UK
Miami
N. Andres Bello, Chile
Naval Post. School
North Carolina State
Oregon State
Purdue
Reading, UK
Washington
Wyoming

*Logistic Support: UCAR JOSS*

## Research Institutions

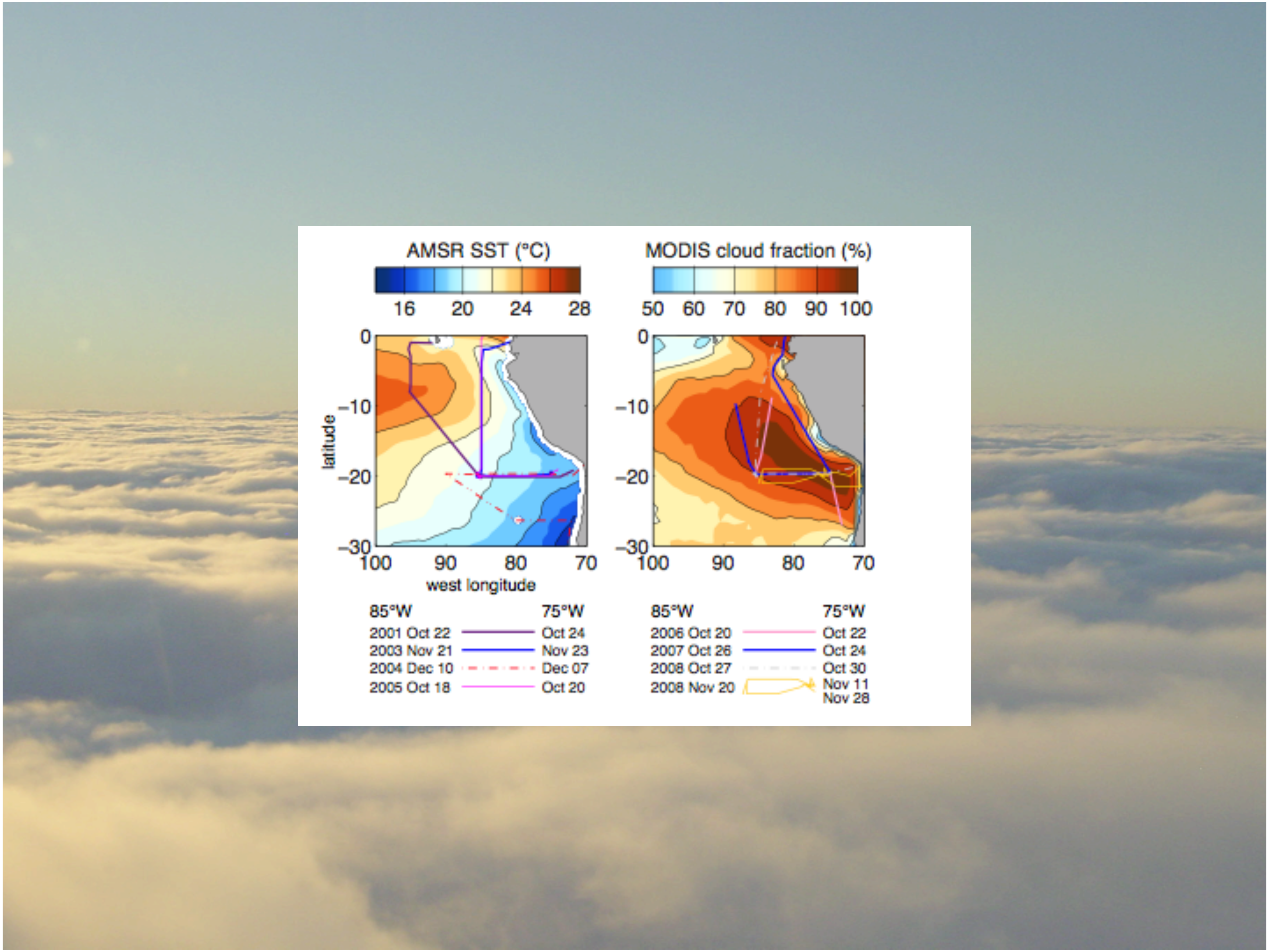
Brookhaven Nat.
COLA
CNRM/GAME France
CNRS/LMD France
IMARPE Peru
Inst. Geofísico del Peru
IPRC
JISAO
LEGOS
LOCEAN France
NASA/GSFC
NCAR
NCAS, UK
NOAA/ESRL
NOAA/GFDL
NOAA PMEL
NRL
Pacific Northwest
Scripps
Woods Hole

## Participants

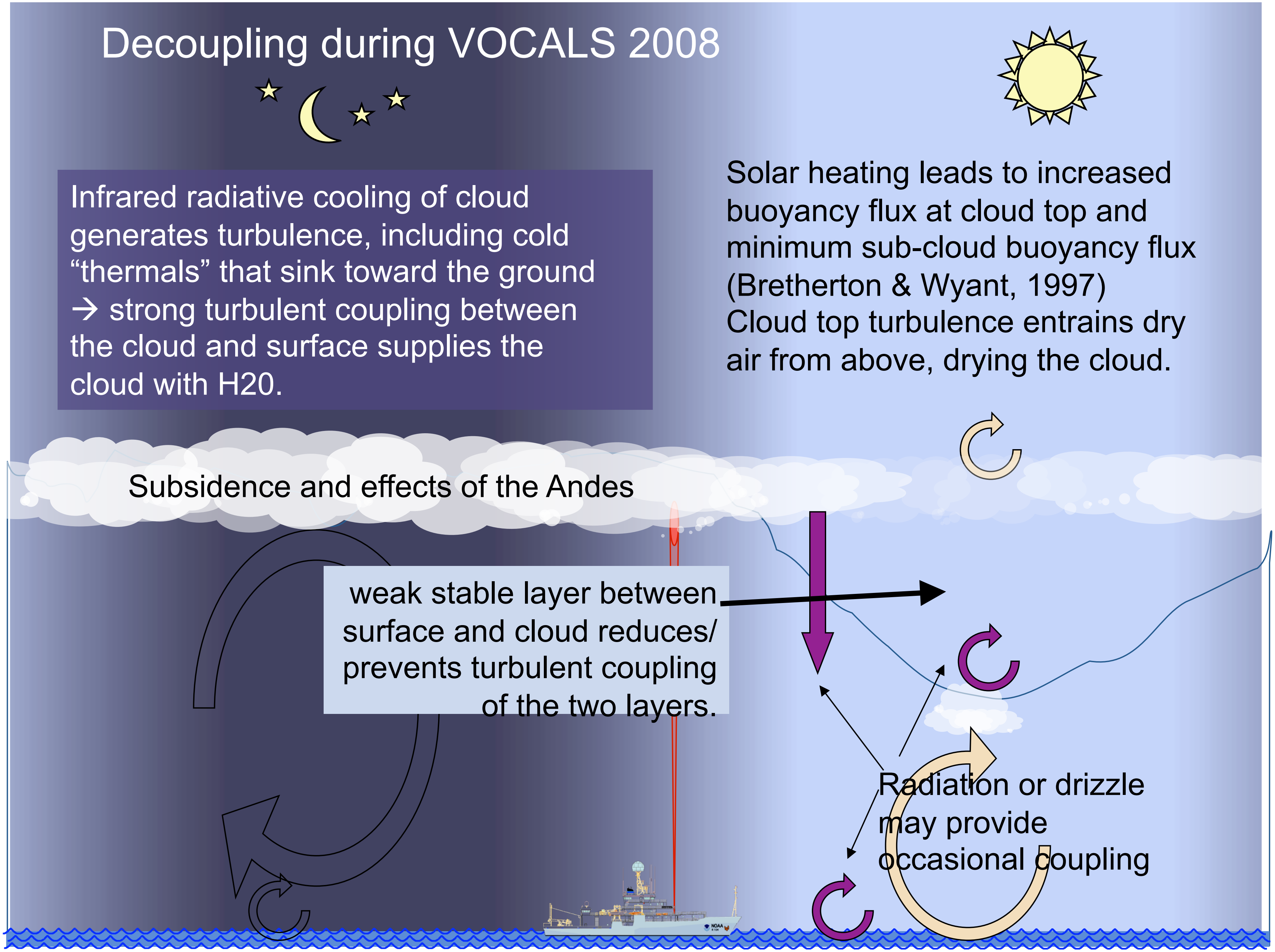
R. Wood (U. Wash., REx-PI), C. R. Mechoso (UCLA, Chair), C. Bretherton (U. Wash.), R. Weller (WHOI), C. Fairall (NOAA), H. Coe (Manchester U., UK), F. Straneo (WHOI), C. Grados (IMARPE, Peru), R. Garreaud (U. Chile), G. Feingold (NOAA), B. Huebert (U. Hawaii), J. L. Brenguier (Met. France), S. de Szoeke (NOAA), T. Toniazzo (U. Reading, UK), M. Kohler (ECMWF), and many others…

## Oper. Centers

BMRC Australia
CPTEC Brazil
ECMWF Int.
JMA Japan
MetOffice UK
NCEP US

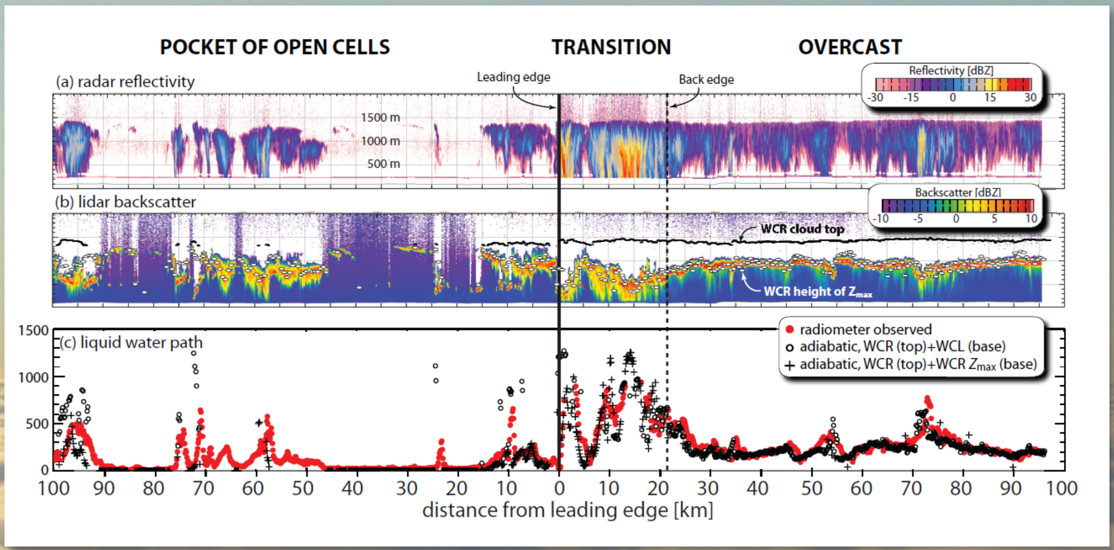


AMSR SST (°C)
16 20 24 28
MODIS cloud fraction (%)
50 60 70 80 90 100
latitude
0
−10
−20
−30
100 90 80 70
west longitude
85°W
75°W
2001 Oct 22
Oct 24
2003 Nov 21
Nov 23
2004 Dec 10
Dec 07
2005 Oct 18
Oct 20
2006 Oct 20
Oct 22
2007 Oct 26
Oct 24
2008 Oct 27
Oct 30
2008 Nov 20
Nov 11
Nov 28


Decoupling during VOCALS 2008
Infrared radiative cooling of cloud generates turbulence, including cold “thermals” that sink toward the ground → strong turbulent coupling between the cloud and surface supplies the cloud with H20.
Solar heating leads to increased buoyancy flux at cloud top and minimum sub-cloud buoyancy flux (Bretherton & Wyant, 1997) Cloud top turbulence entrains dry air from above, drying the cloud.
Subsidence and effects of the Andes
weak stable layer between surface and cloud reduces/ prevents turbulent coupling of the two layers.
Radiation or drizzle may provide occasional coupling

# Pockets of open cells (POCs) in marine stratocumulus

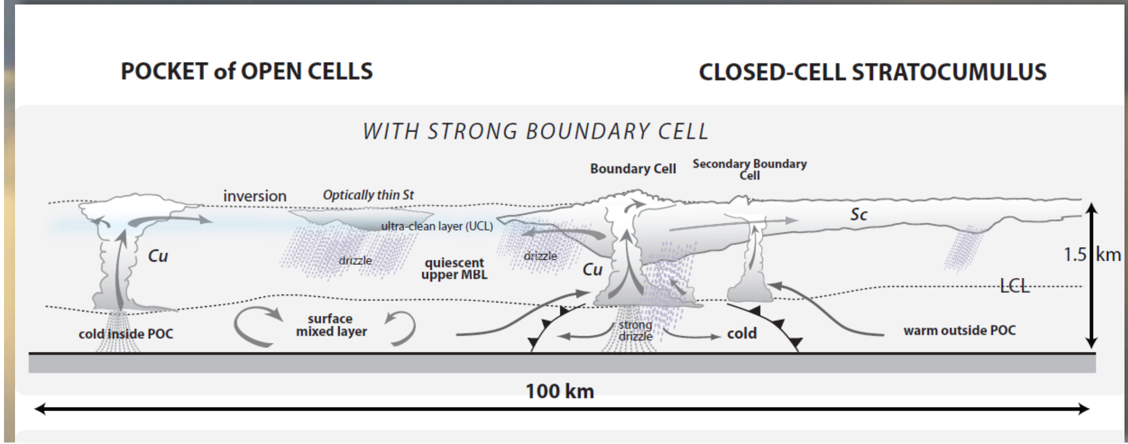
R. Wood, C. S. Bretherton, D. Leon, A. D. Clarke, P. Zuidema, G. Allen, and H. Coe

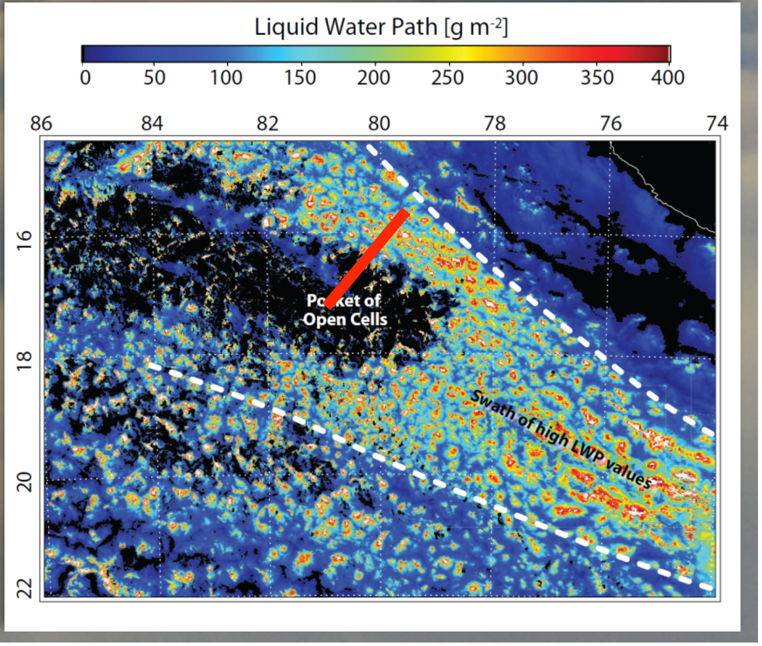


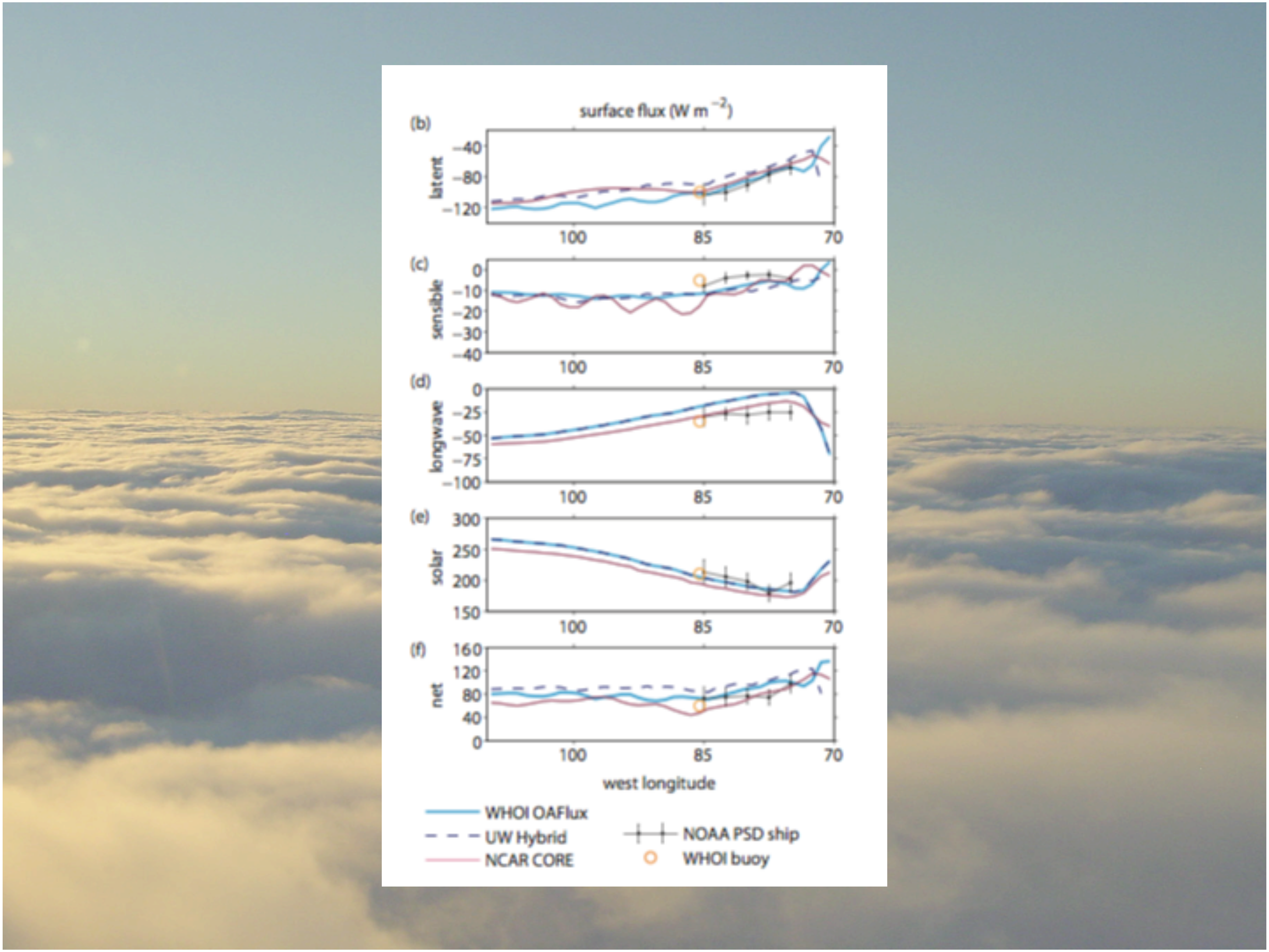

Left: C-130 radar, lidar, and microwave liquid water path obs. during the RF06 POC mission

Below: Satellite and in-situ data show that POCs tend to form in regions with abundant liquid water

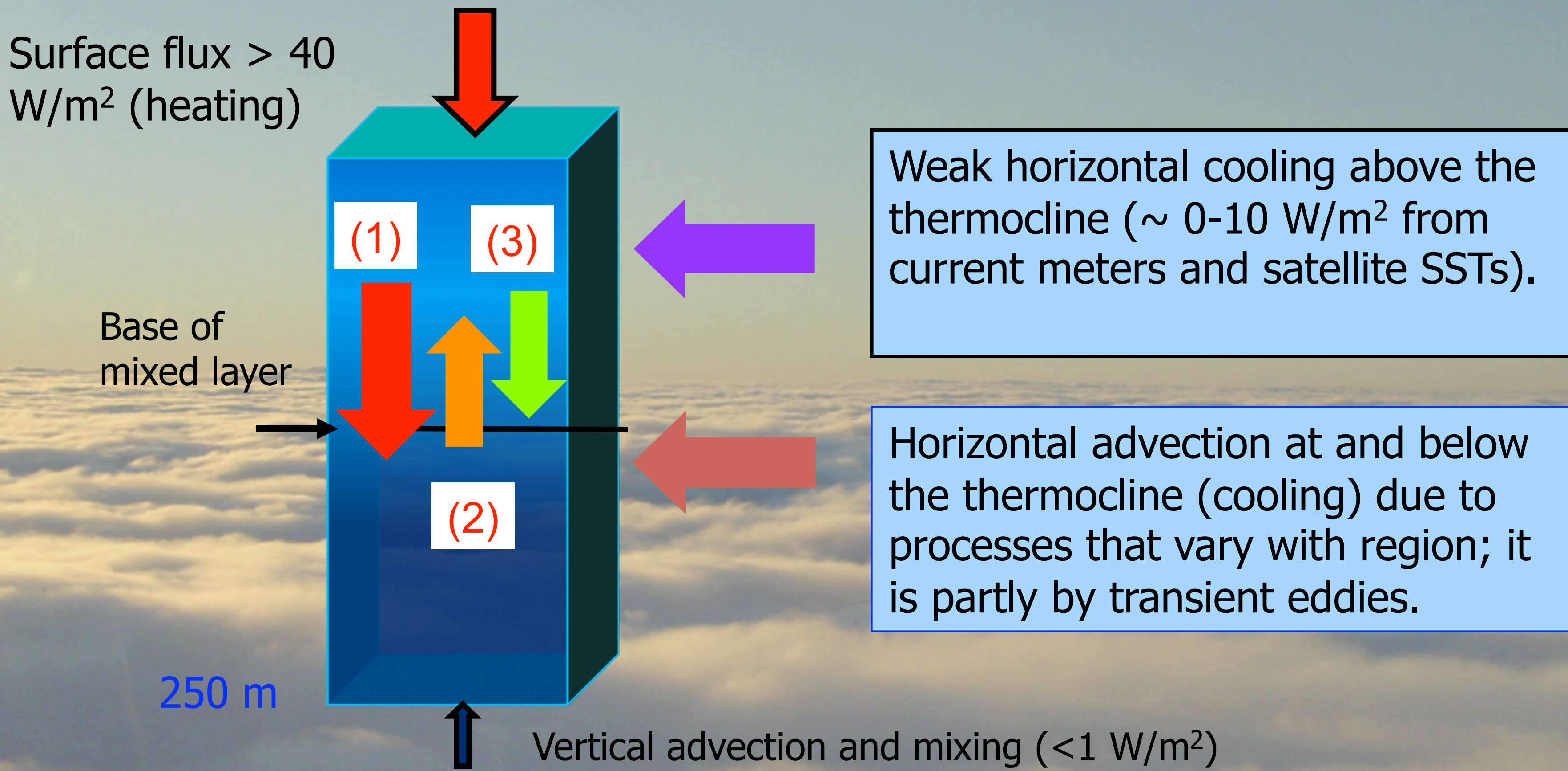
Below: POC missions are aiding the development of conceptual models of transitions in stratocumulus clouds




surface flux (W m⁻²)
(b)
latent
-40
-80
-120
100
85
70
(c)
sensible
0
-10
-20
-30
-40
(d)
longwave
0
-25
-50
-75
-100
(e)
solar
300
250
200
150
(f)
net
160
120
80
40
0
west longitude
WHOI OAFlux
UW Hybrid
NCAR CORE
NOAA PSD ship
WHOI buoy

# Hypothesis on the heat budget of the ocean column




(1) Heat transport by turbulence processes
(2) Heat transport by submesoscale eddies
(3) Heat transport by processes such as mixing associated with near-inertial oscillations, with a possible contribution by others such as salt fingering.

# Annual Mean Precipitation - IPCC Models: The Double ITCZ Syndrome