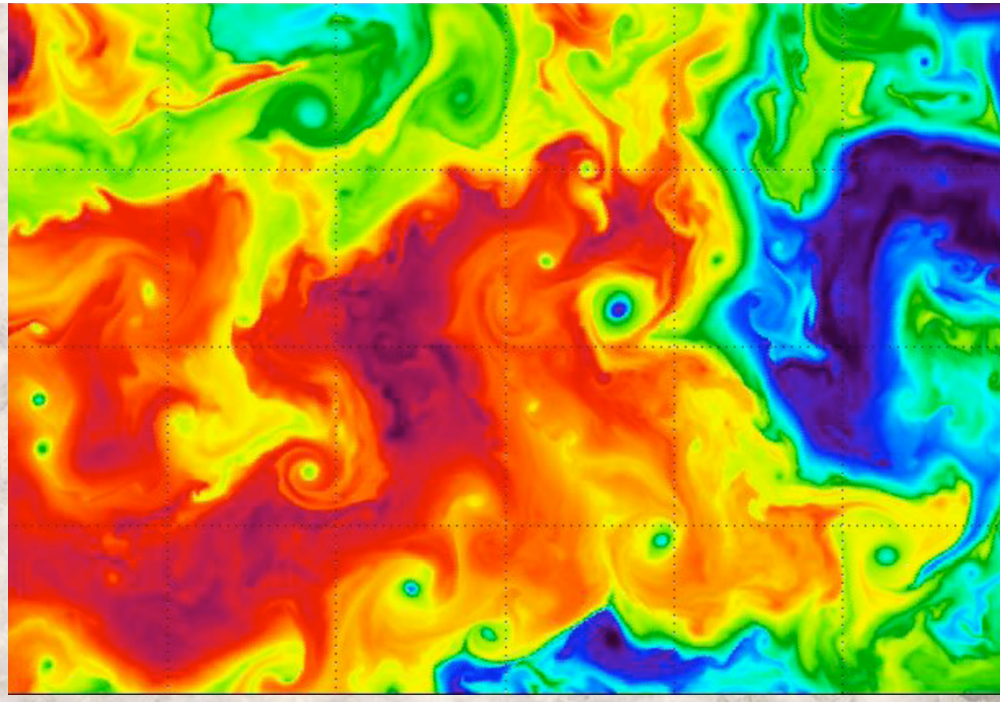
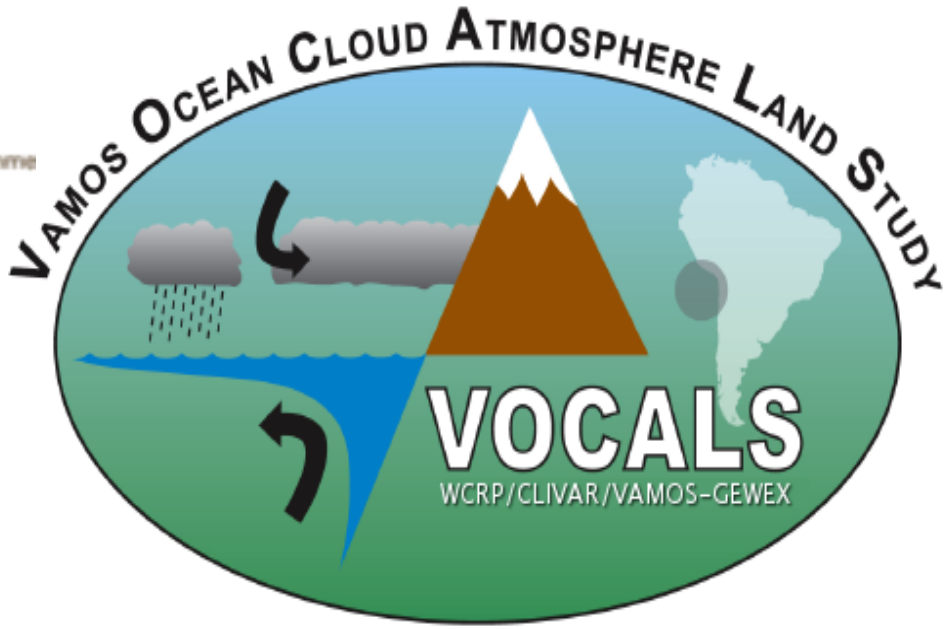
VOCALS Review



Robert Wood, University of Washington

PSMI Panel Meeting, 19 July 2012



Improving understanding, model simulations, and prediction of the Southeast Pacific Climate System

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

VOCALS Goals

Elimination of CGCM systematic errors in the SEP, and improved model simulations of the coupled system in the region and global impacts of its variability.

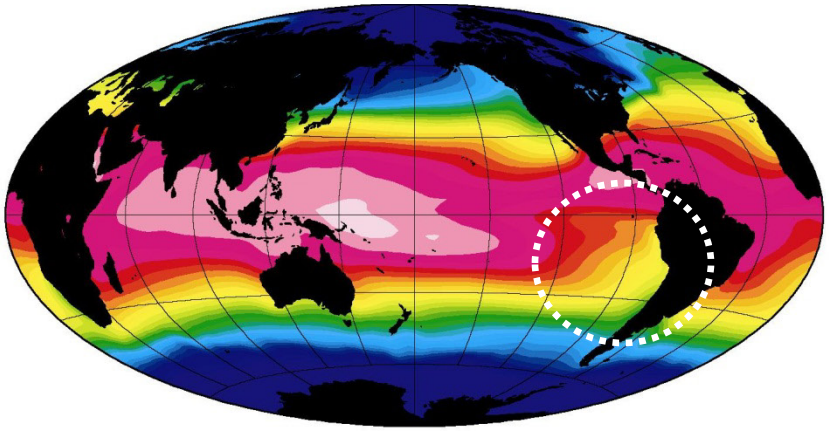
Improved understanding and regional/global model representation of aerosol indirect effects over the SEP.

www.eol.ucar.edu/projects/vocals

Oper. Centers

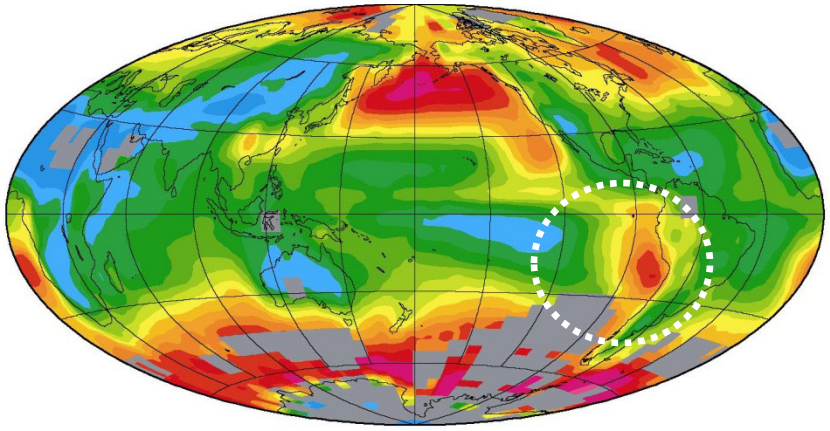
BMRC Australia
CPTEC Brazil
ECMWF Int.
JMA Japan
MetOffice UK
NCEP US

Sea surface temperature



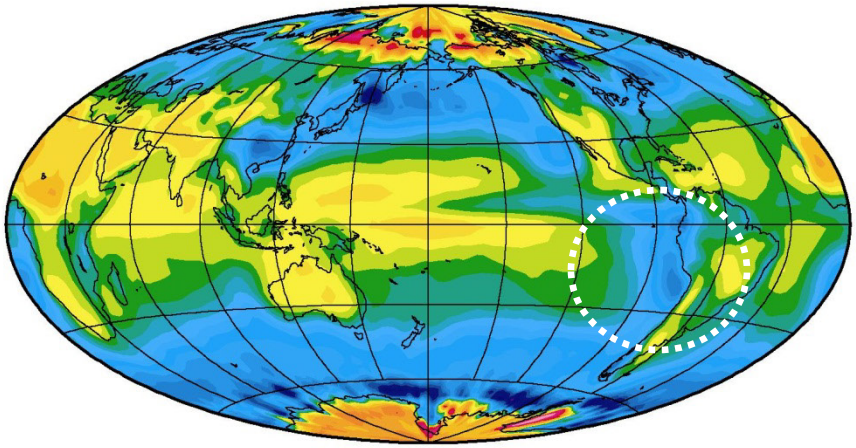
NO DAT 0 4 8 12 16 20 24 28 °C

Low cloud amount



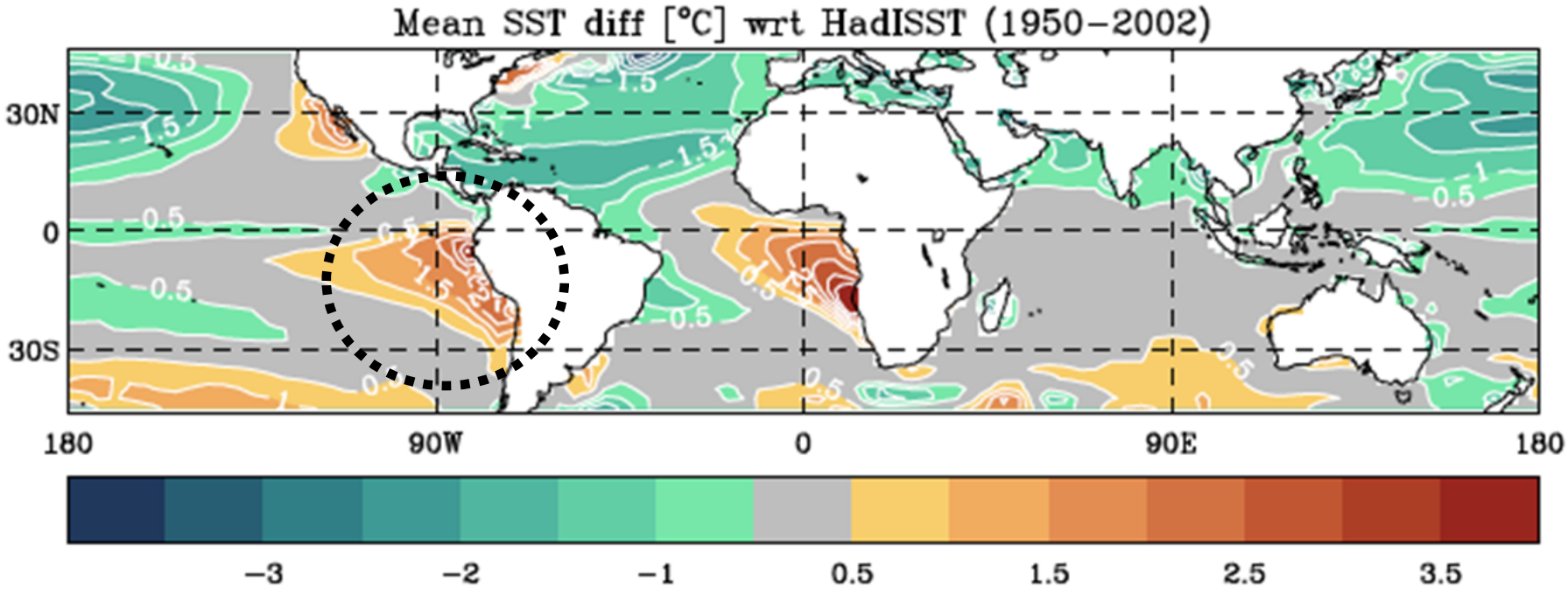
NO DATA 0 10 20 30 40 50 60 70 80 %

Net Cloud Radiative Forcing



NO DATA -120 -80 -40 0 40 W m^{-2}

Motivation: major biases in Eastern Tropical Ocean climate in models

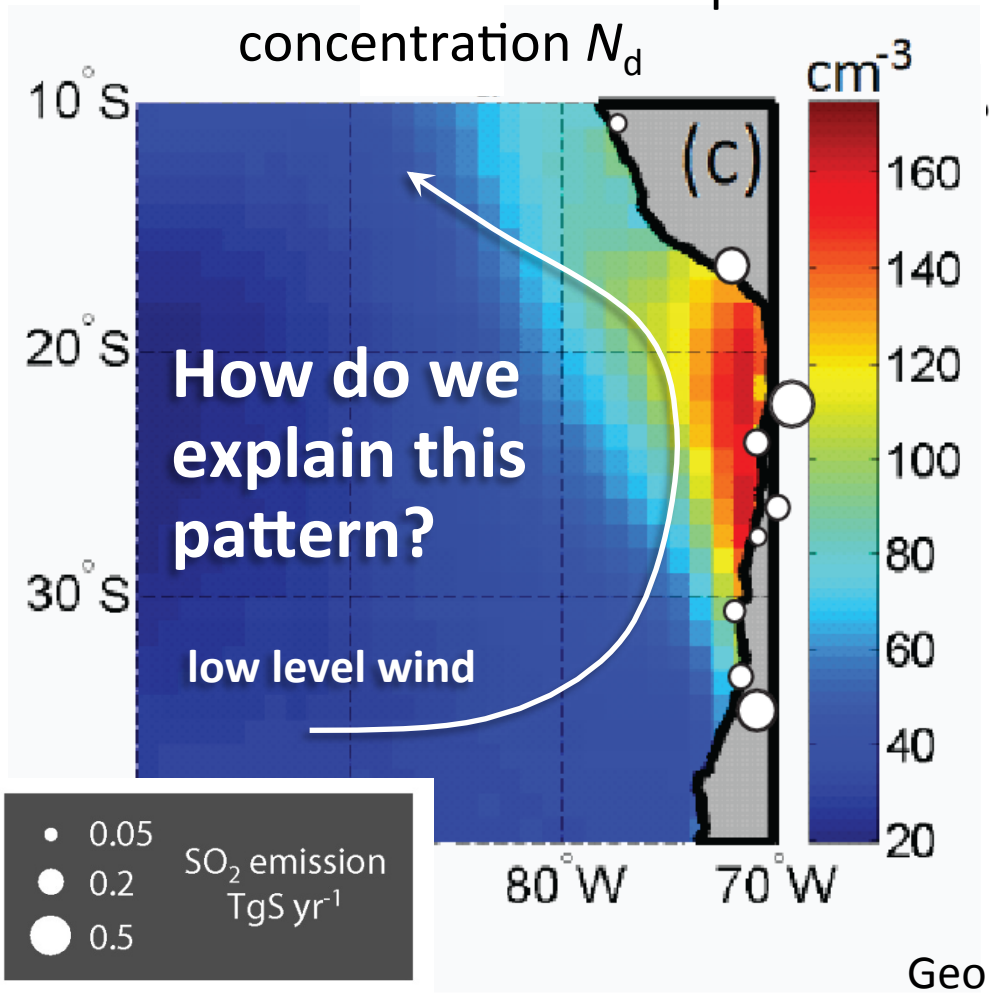


SST Errors in CMIP5 CGCMs

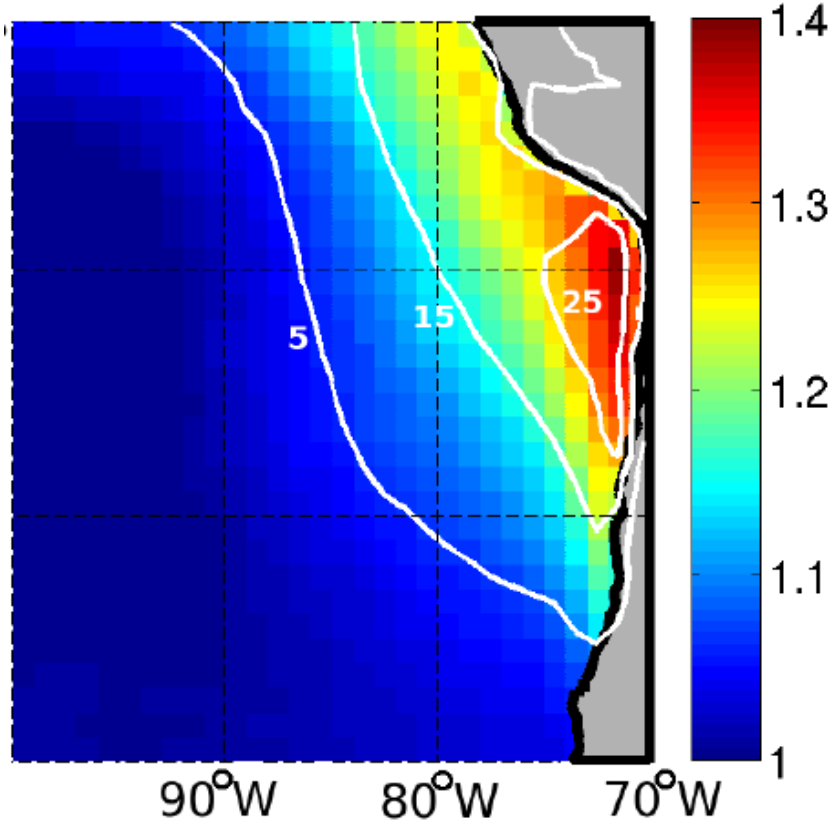
Courtesy T. Toniazzo, University of Reading

Motivation: strong aerosol indirect effects in a clean background

Satellite-derived cloud droplet concentration N_d



Albedo enhancement (fractional)

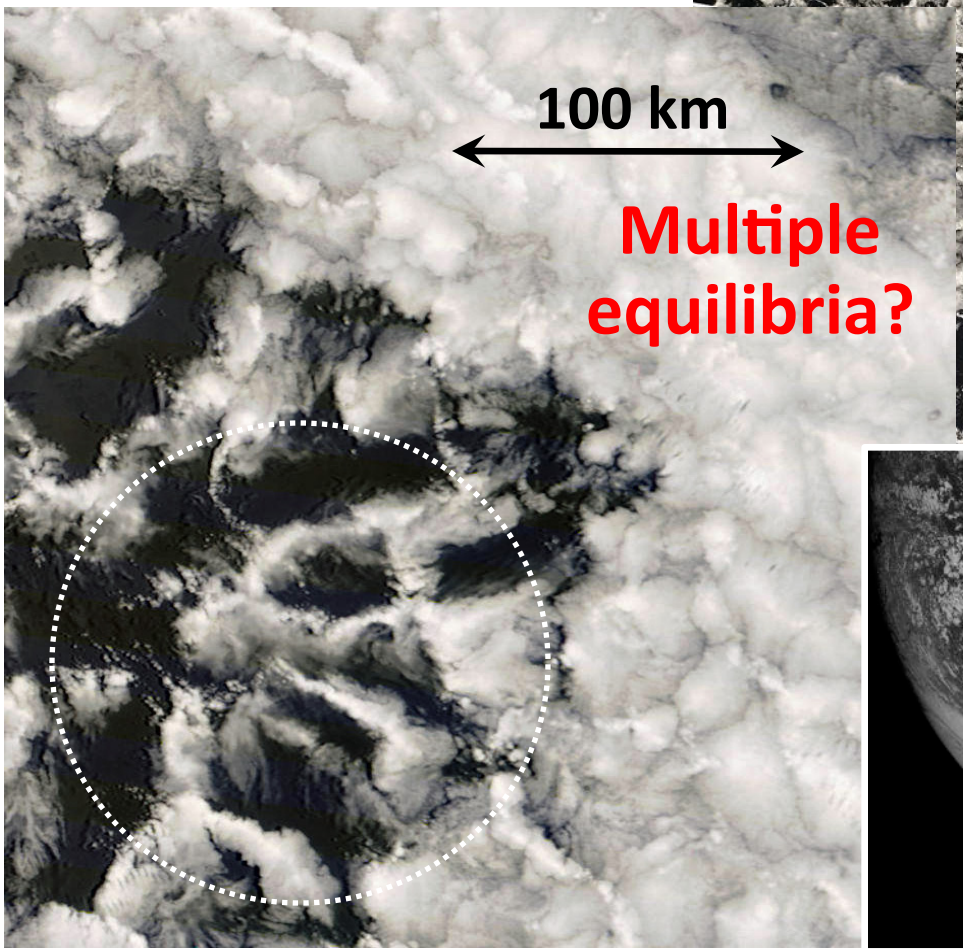


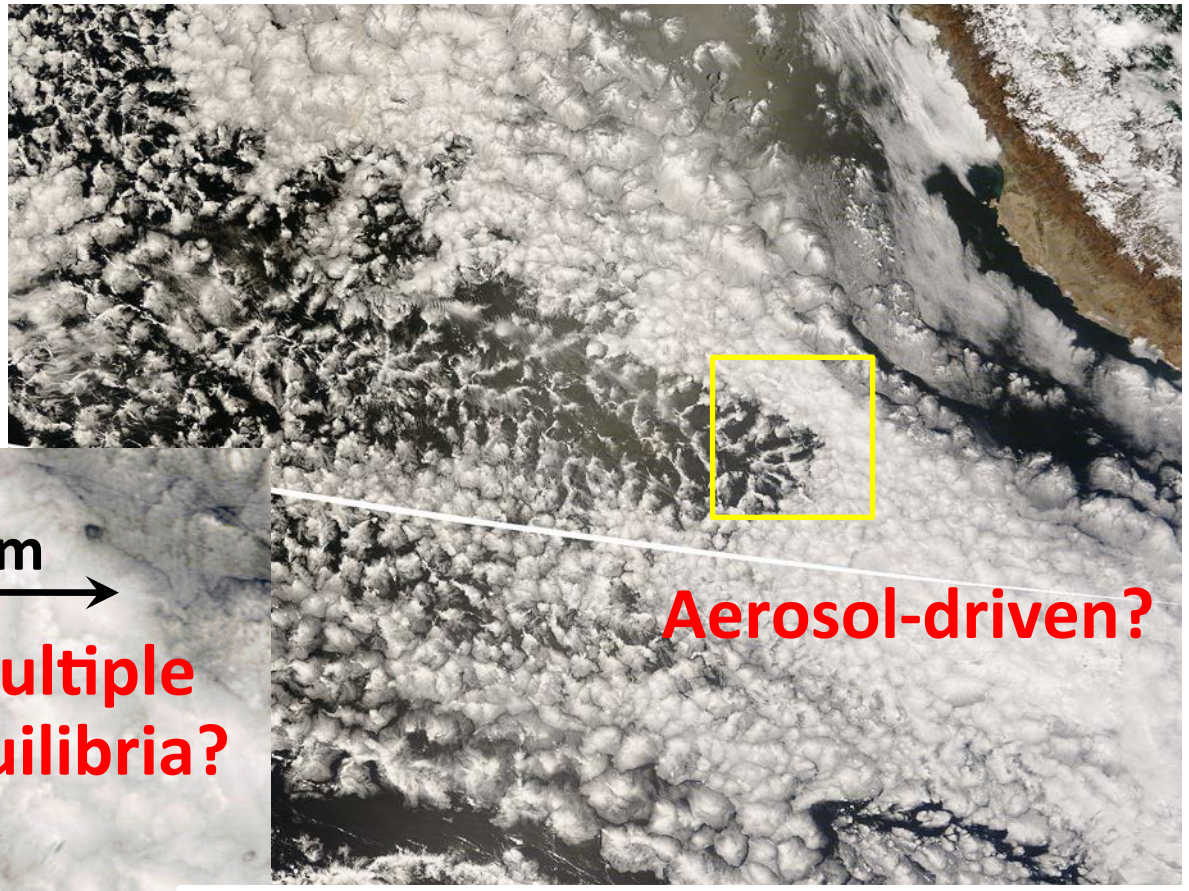
George and Wood, *Atmos. Chem. Phys.*, 2010

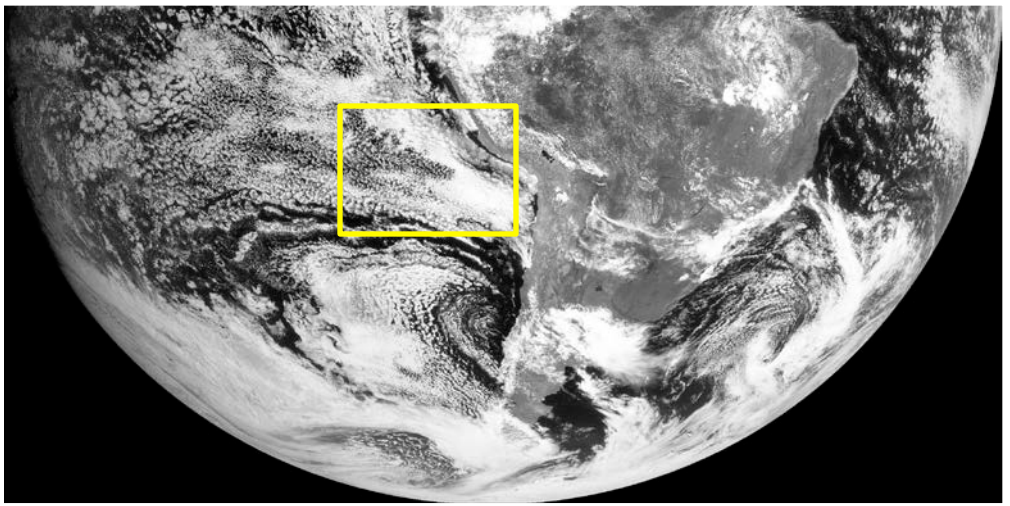
Pockets of Open Cells (POCs)

October 27/28th 2008

POC Lagrangian - BAe-146 & NSF C-130



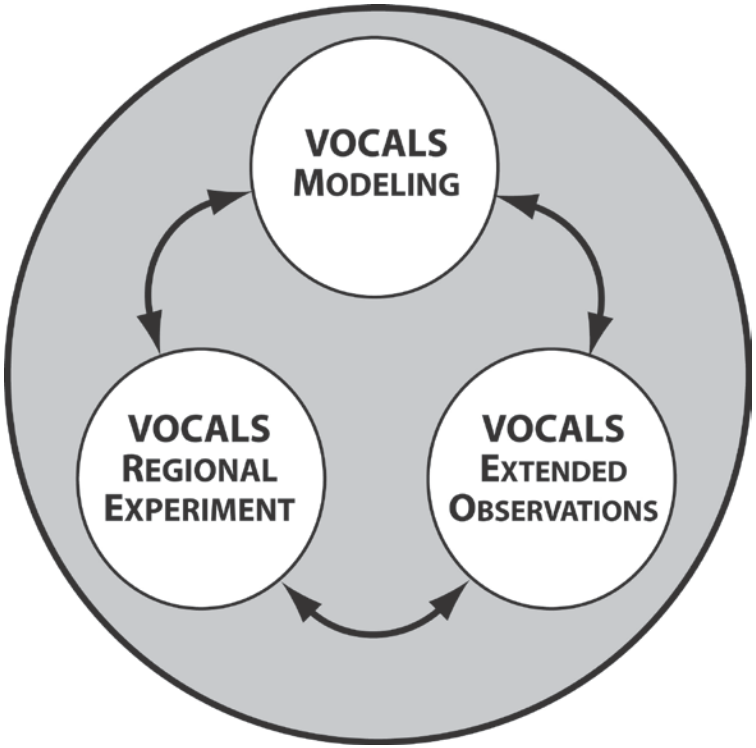


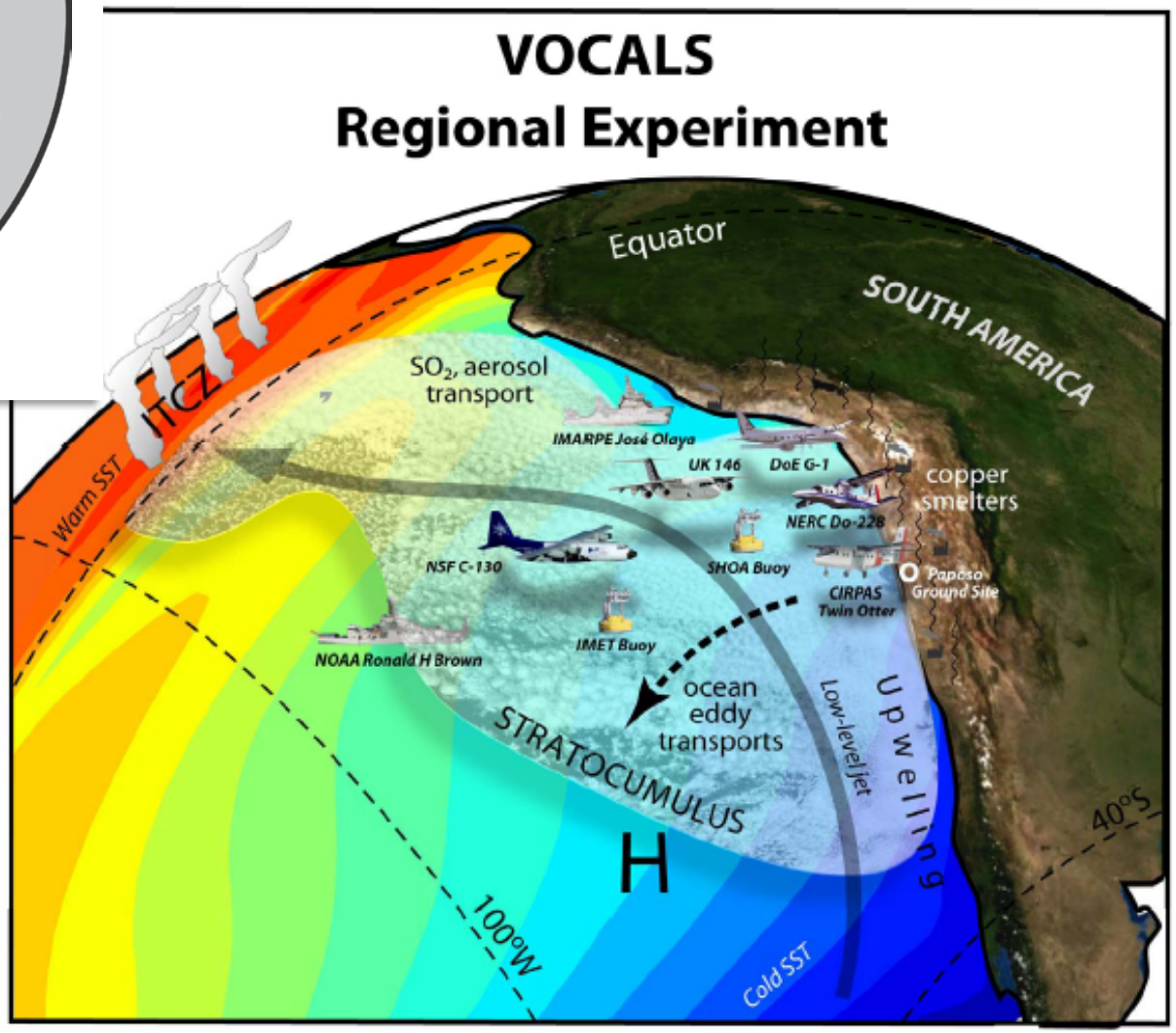


VOCALS Objectives

- **The elimination of coupled GCM systematic errors in the SEP, and improved model simulations of the coupled system in the region and global impacts of its variability**

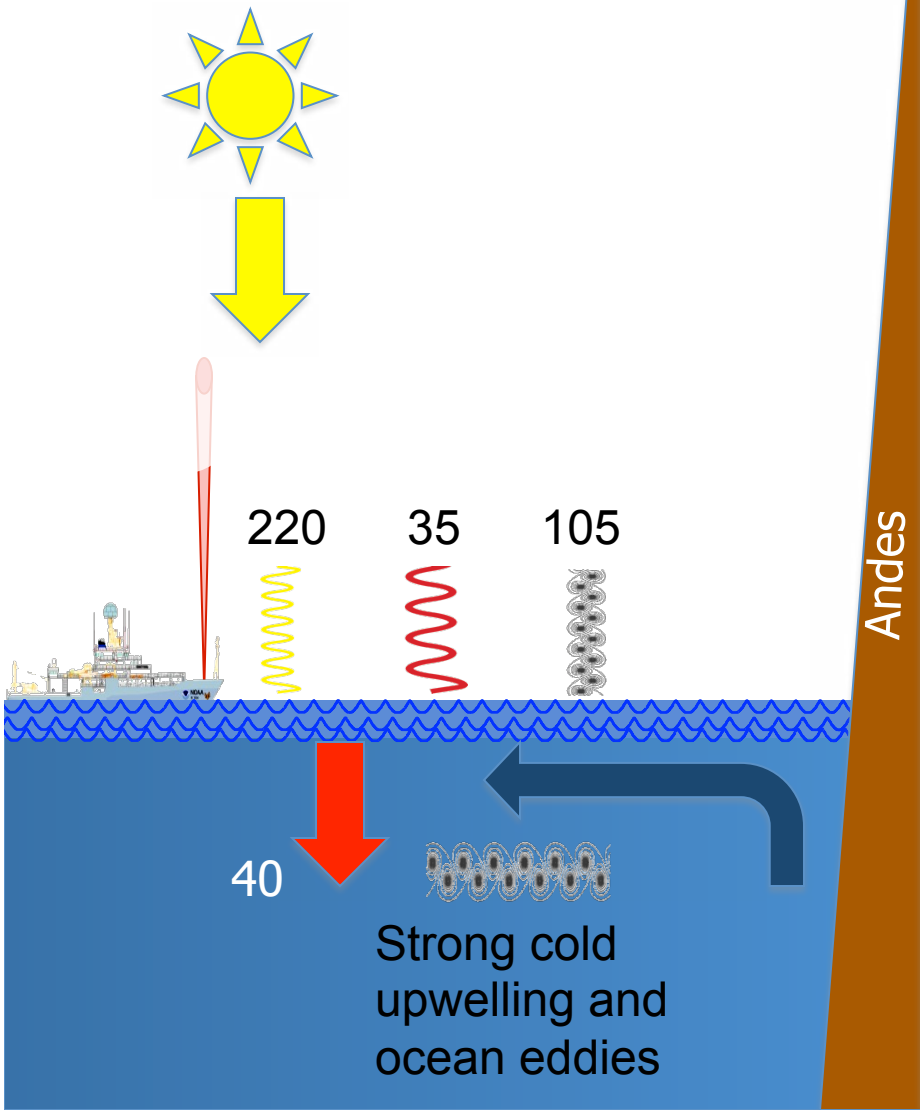
- **Improved understanding and regional/global model representation of aerosol indirect effects over the SEP**


VOCALS
MODELING
VOCALS
REGIONAL
EXPERIMENT
VOCALS
EXTENDED
OBSERVATIONS


VOCALS
Regional Experiment
Equator
SOUTH AMERICA
SO_2, aerosol
transport
ITCZ
Warm SST
IMARPE José Olaya
UK 146
DoE G-1
copper
smelters
NERC Do-228
NSF C-130
SHOA Buoy
Paposo
Ground Site
CIRPAS
Twin Otter
IMET Buoy
NOAA Ronald H Brown
ocean
eddy
transports
STRATOCUMULUS
Low-level jet
Upwelling
H
100°W
40°S
Cold SST

Nature

Cloudy skies above cold oceans



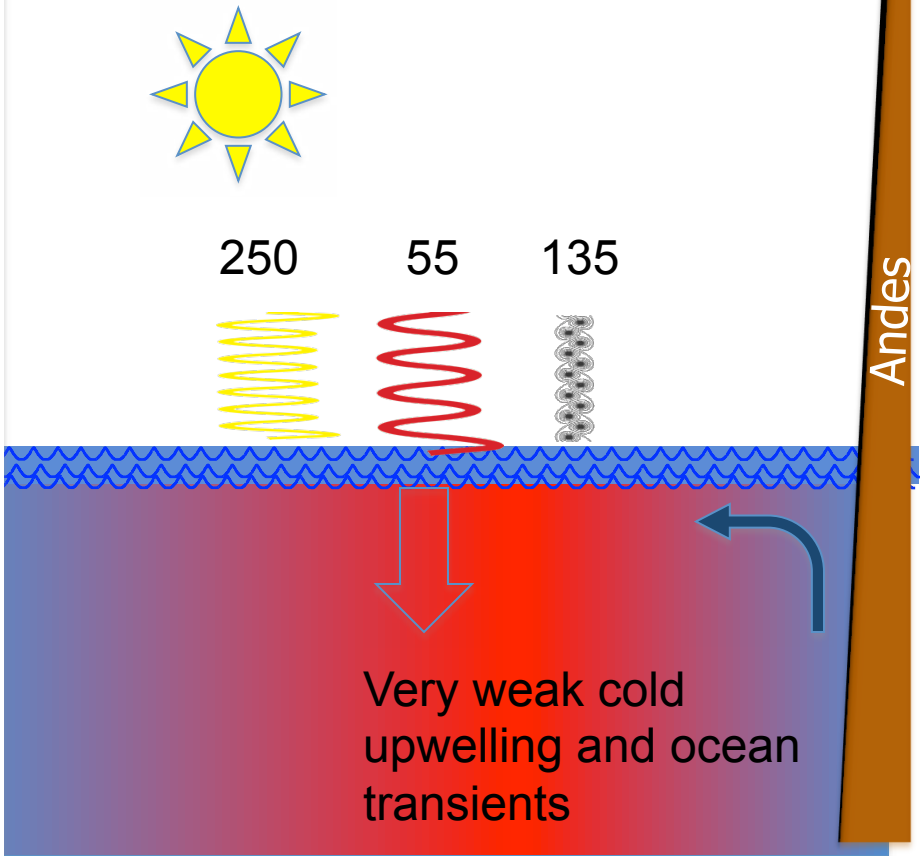
VOCALS Modeling and Field data

CGCMs

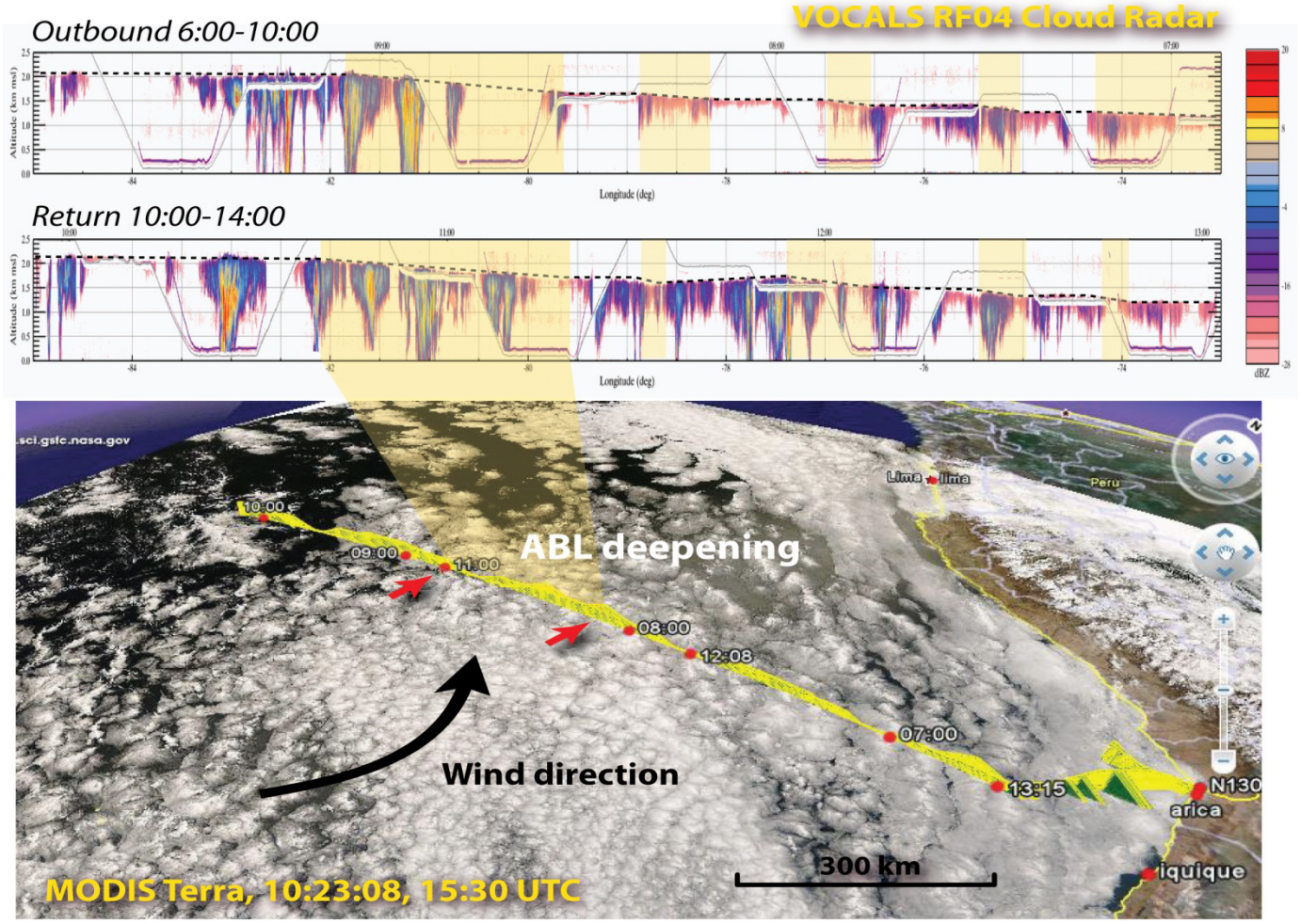
(deSzoeke et al 2011)

Clear skies above warm oceans

Stronger latent heat flux balances higher insolation



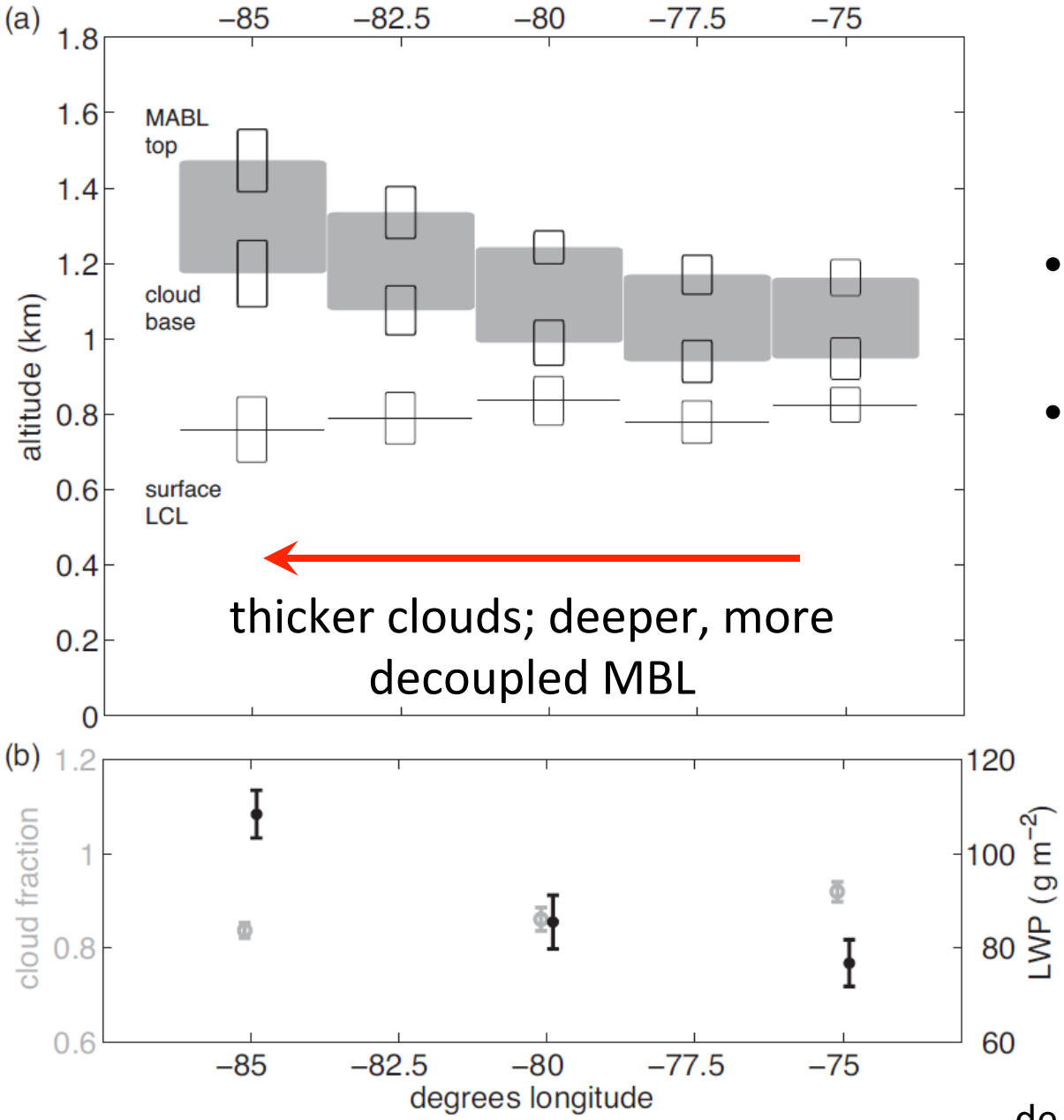
20°S Cross Section sampling (with ships, planes, buoy, satellites)



Offshore

Coast

NOAA VOCALS Cruises

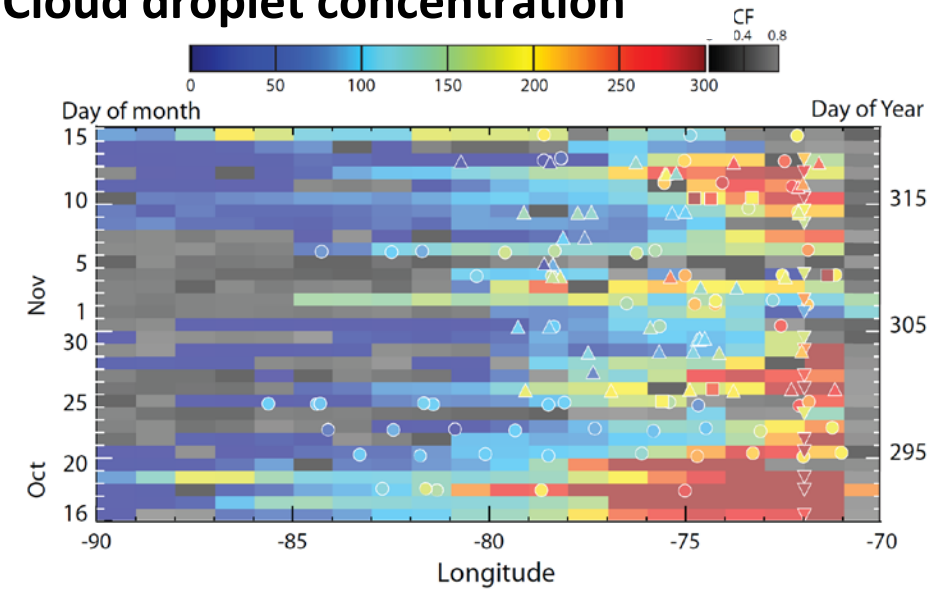


- 2000-2008 during Sept-Dec
- repeated sampling of Sc deck

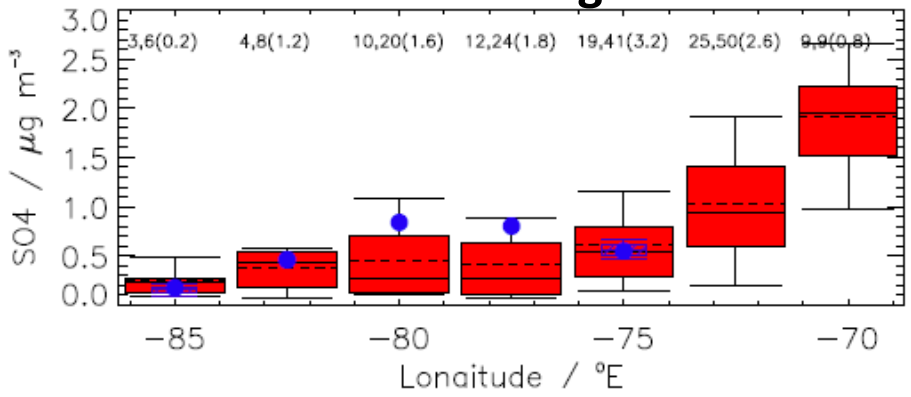
de Szoeke et al. (2011)

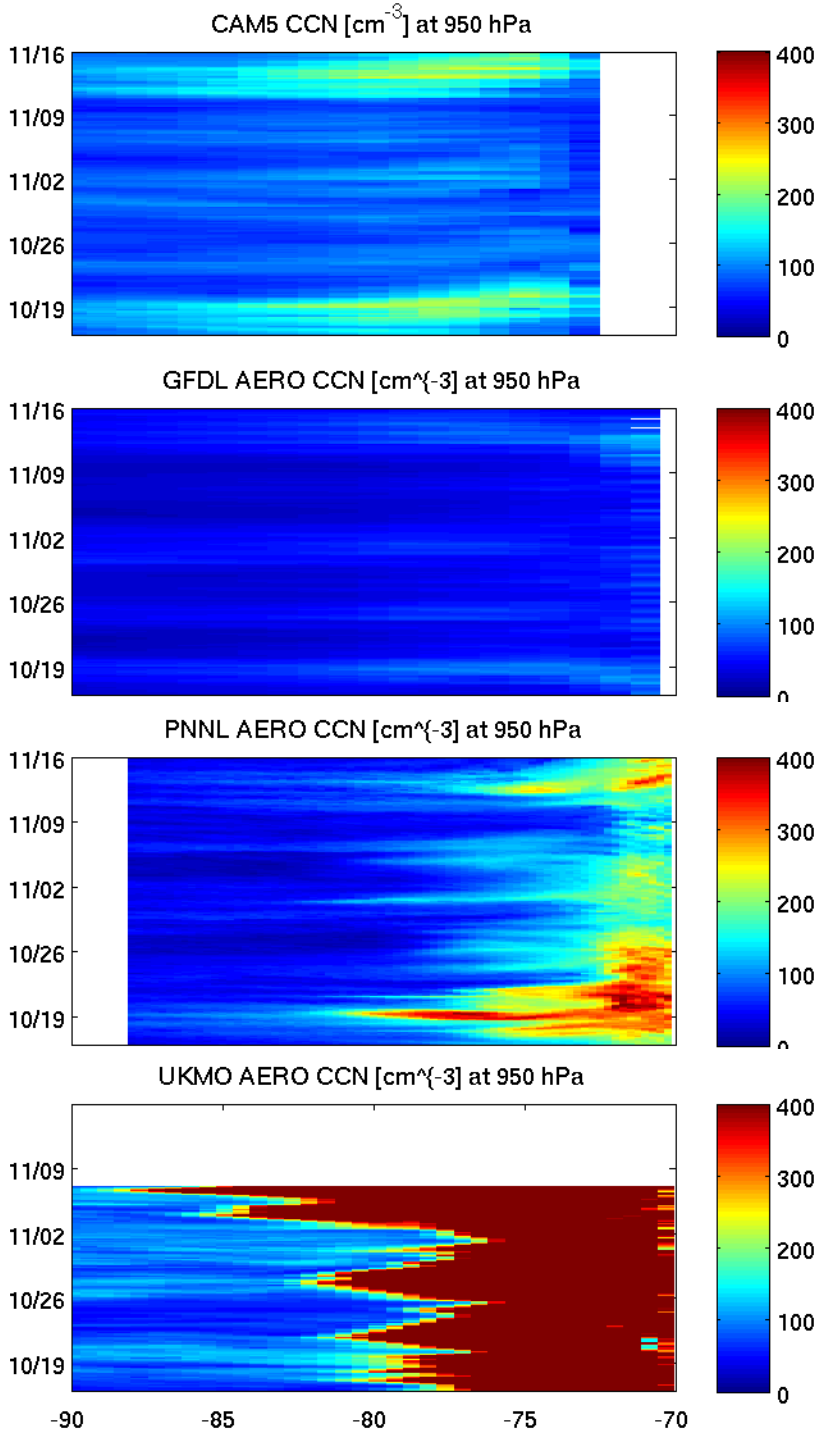
Confronting models with VOCALS observations

Cloud droplet concentration

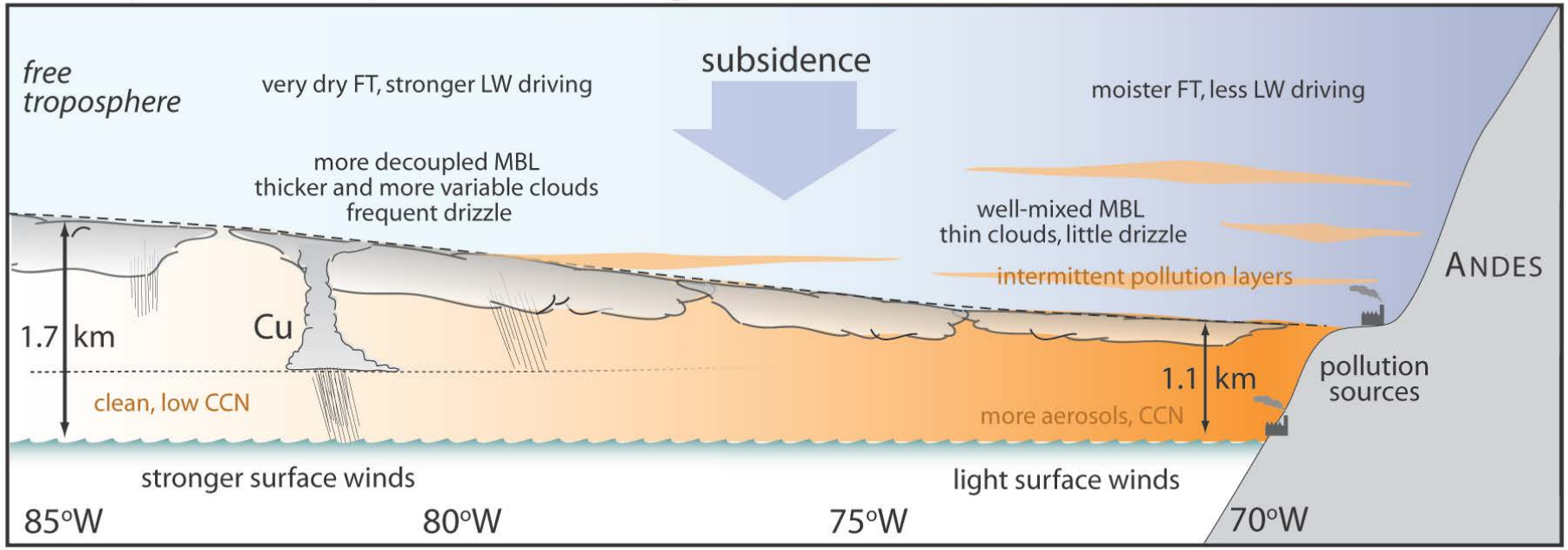


Sulfate aerosol mass loading





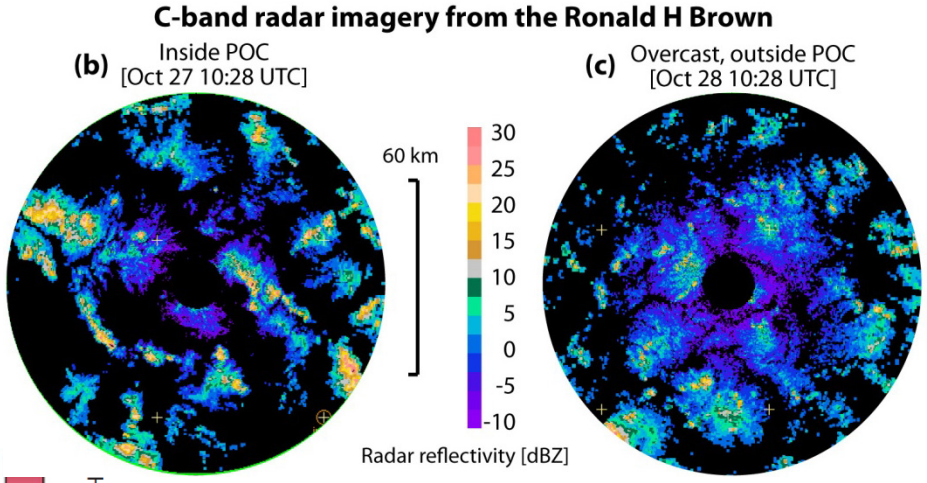
Clouds, MBL structure, and aerosols along 20°S

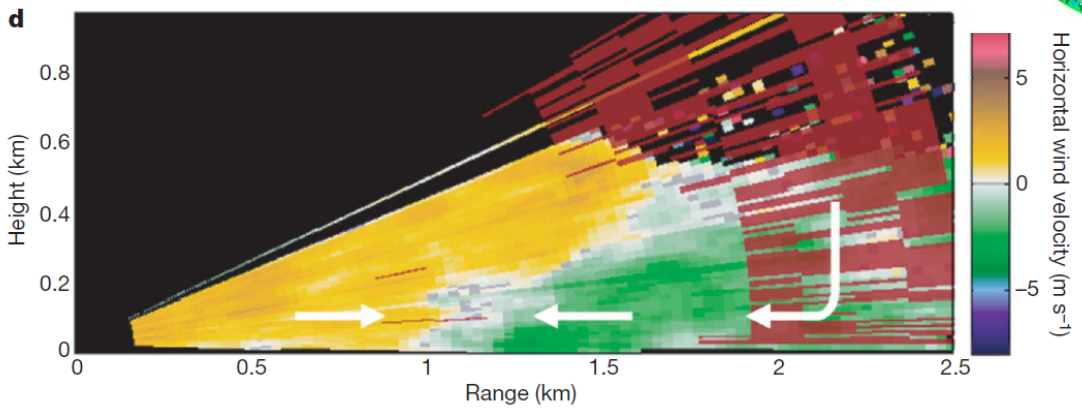


Precipitation and pockets of open cells

Strikingly different precipitation structure in POCs compared with overcast stratocumulus

Sandra Yuter, NCSU



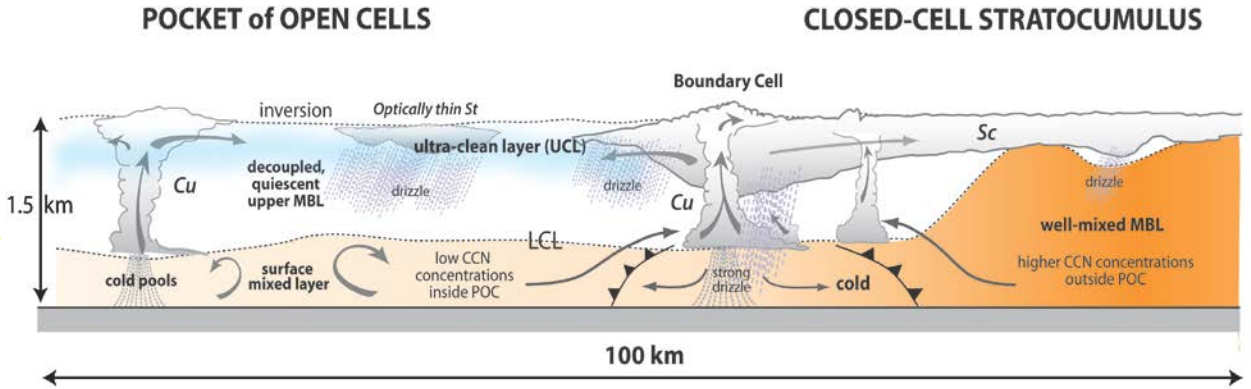


Precipitation generates cold outflows and local convergence that maintains open cell structure

Feingold et al., *Nature*, 2010

New conceptual models of macrophysical-microphysical interaction across POC boundary

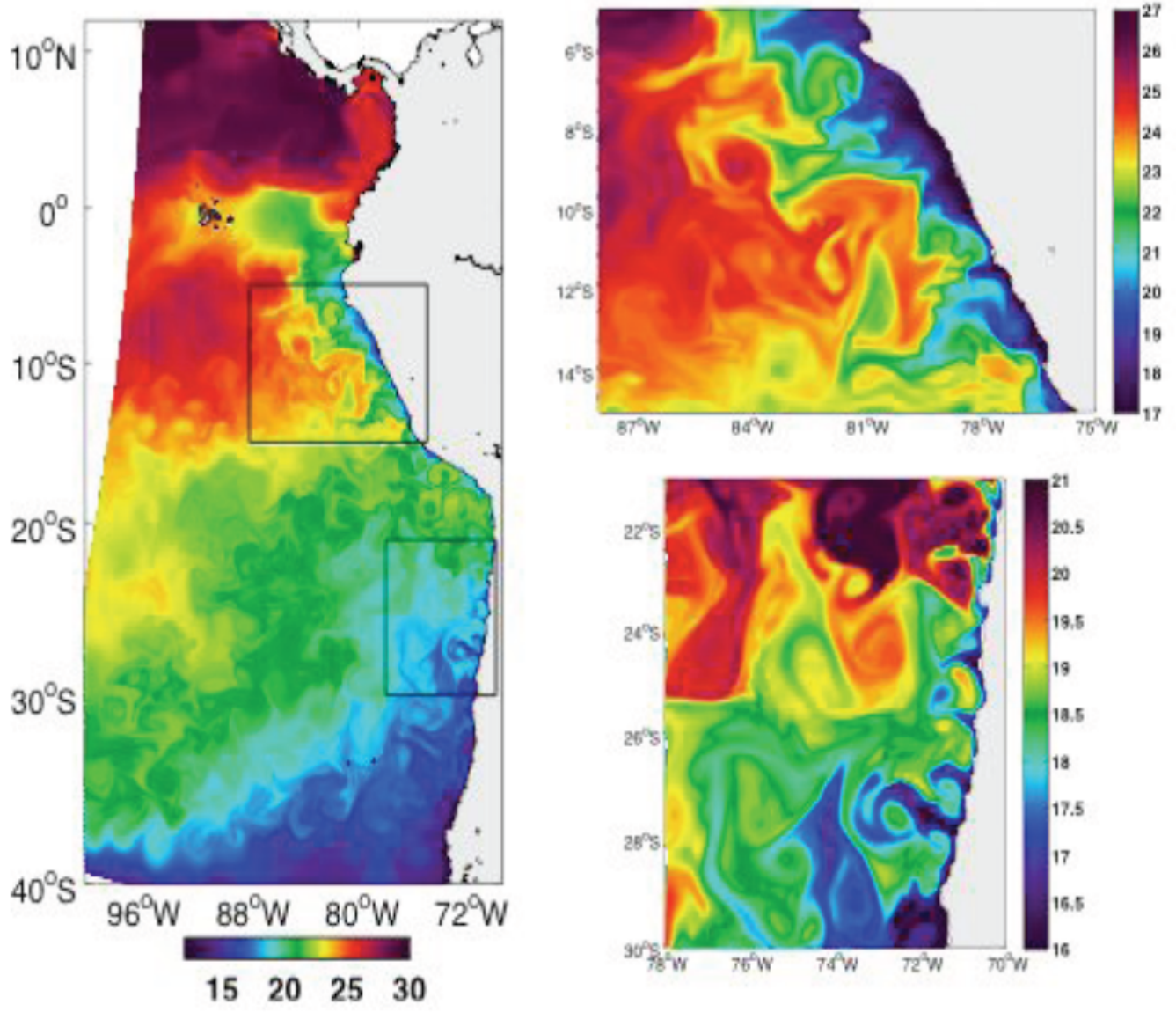
Wood et al. *ACP*, 2010



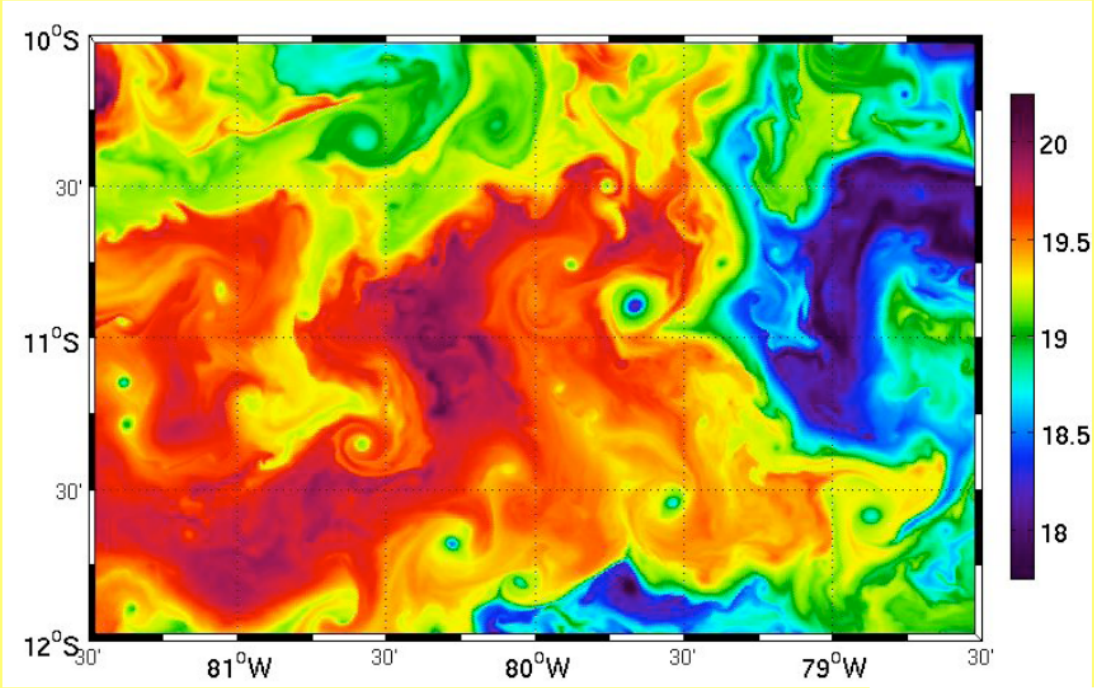
Mesoscale Eddies in an Ocean Model

ROMS: 7.5 km x 7.5 km x 32 levels (Colas et al., J. Climate 2010)

SST



Submesoscale Eddies

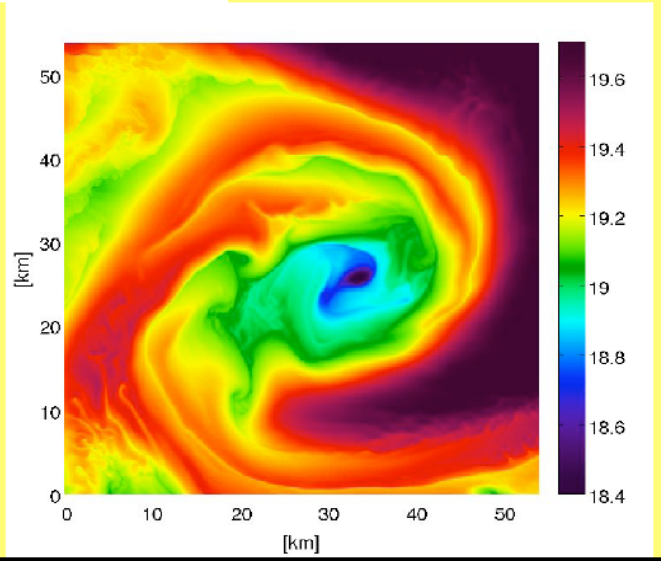


Snapshots of SST [C] at high-resolution numerical simulation (**dx = 500 m**, from a set of embedded domains, dx = 7.5 km and dx = 2 km) of the Peru-Chile coast.

Submesoscale coherent vortices, fronts and filaments are seen between the mesoscale eddies

SST snapshot of one eddy (at resolution **dx = 180 m)**. Note the cold eddy core, and cold filaments (the spiral arms).

Colas et al. (2010)



What has been gained from VOCALS?

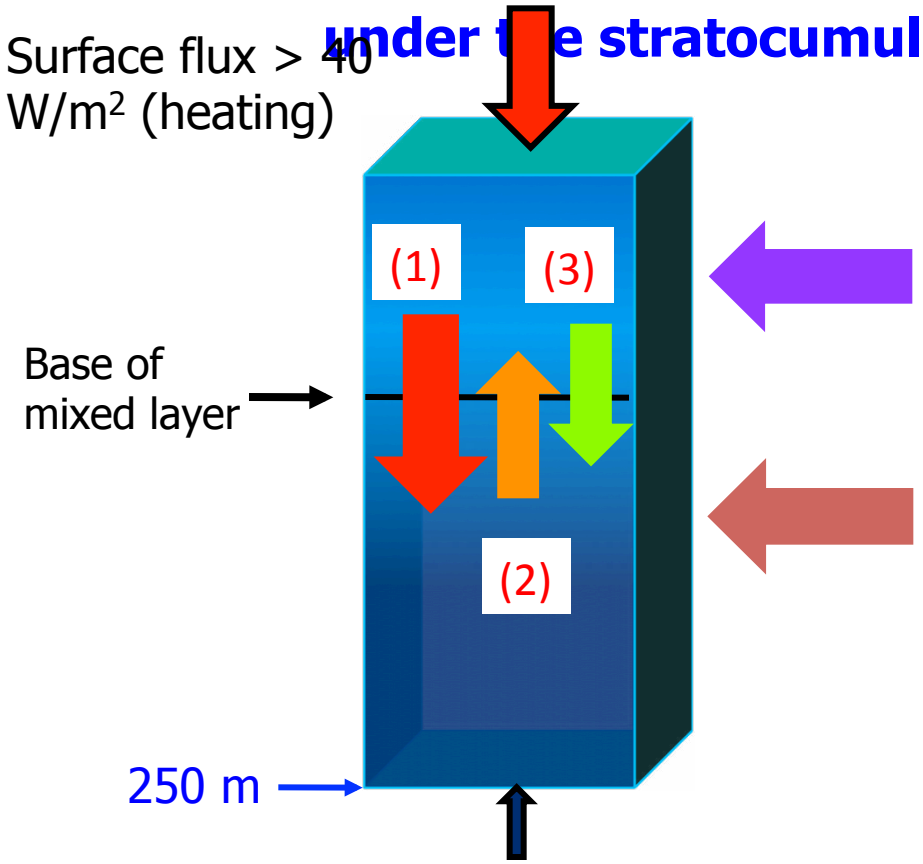
- First detailed sampling of a cross-section through a tropical low cloud region and associated transitions
  - Major modeling centers currently engaged in the use of field data (e.g. two CPT projects are using VOCALS data)
  - New mechanisms for pollution transport to cloud decks
- Characterization of the major terms in the surface heat budget over the eastern tropical Pacific
  - Residual term associated with mixing and transport by small-scale processes
  - Direct heat transport in ocean eddies not a primary influence on SST
- An understanding of the near-ubiquity and importance of precipitation in marine boundary layer clouds
  - Precipitation plays a leading role in driving offshore transitions in cloudiness and aerosol
  - Major implications for aerosol indirect effects

Lessons learned

- Good examples of synthesis dataset creation but no common format and no dedicated funding to create protocols
  - Could NCAR EOL be better used to catalyze activties?
- Difficult to characterize the role played by eddies given short observational campaigns
- Very high resolution global modeling work to examine upper ocean heat budget and controlling factors has not occurred
- Ron Brown arrived in VOCALS-REx 10 days later than planned, and so shortened available time for comparison with aircraft by almost 50%.

ADDITIONAL SLIDES

Conjecture on the heat budget of the ocean column in SEP under the stratocumulus



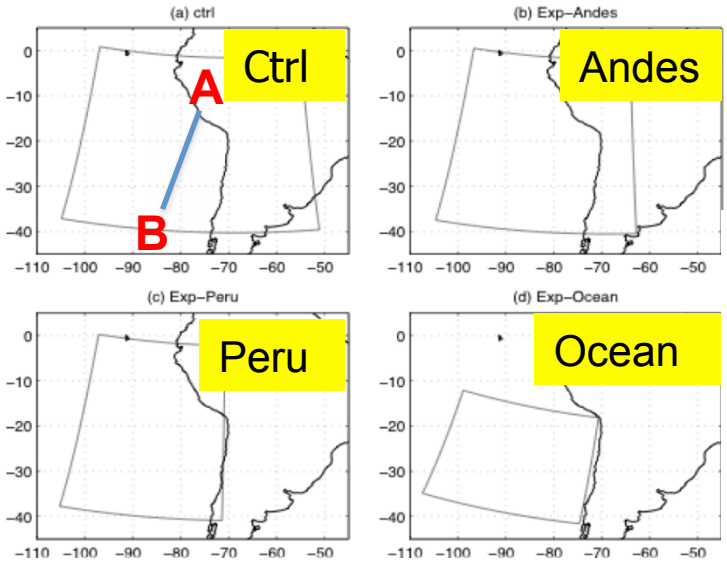
Weak horizontal cooling above the thermocline (~ 0-10 W/m² from current meters and satellite SSTs).

Horizontal advection at and below the thermocline (cooling) due to processes that vary with region; it is partly by transient eddies.

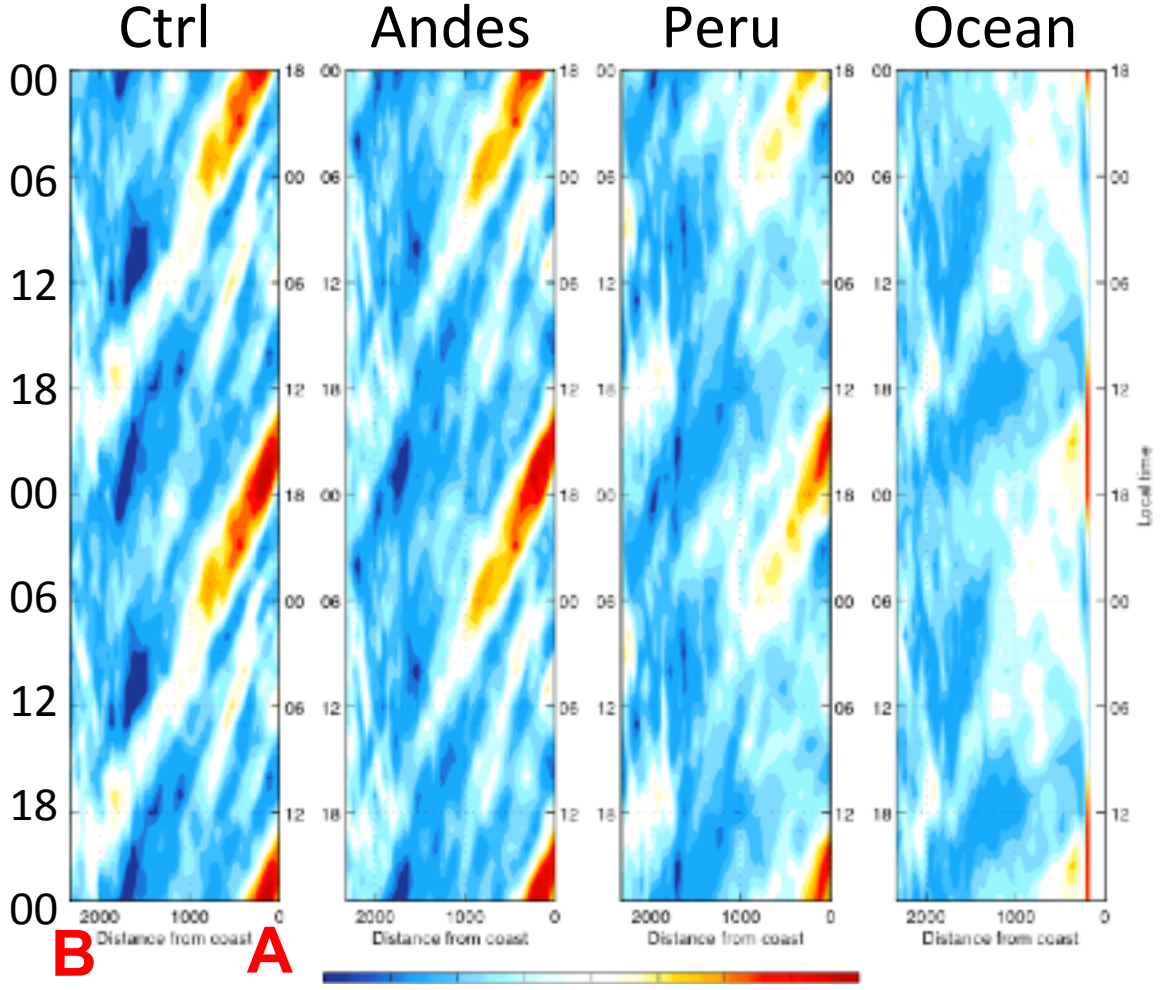
(1) Heat transport by turbulence processes
(2) Heat transport by submesoscale eddies
(3) Heat transport by processes such as mixing associated with near-inertial oscillations, with a possible contribution by others such as salt fingering.

Mechoso and McWilliams, 2010

Contribution of different Andes sectors to diurnal cycle



- Small impact of low-lying land east of Andes
- Chilean Andes contribute significantly to the signal
- Very weak diurnal cycle in ocean domain, even though lateral BC's are prescribed every 6 hours from NCEP FNL.



Vertical wind -0.02 -0.01 0.0 0.01 0.02 [Pa/s]

Toniazzo, Sun, Mechoso, and Hall, ACP 2012

VOCALS – Achievements 2011/2012

- **PUBLICATIONS**: ***Atmospheric Chemistry and Physics*** **(EGU Journal) VOCALS Special Issue set up, currently ~40 papers in ACP special issue; 70-80 total. VOCALS-REx operations overview paper published (Wood et al. 2011).**

- **MEETINGS: Special VOCALS sessions at AMS Cloud Physics Conference (June 2010), and AGU Fall Meeting (Dec 2010); VOCALS 3rd Science Meeting Miami (March 2011); poster cluster planned for WCRP Open Science Conf. (Oct 2011). Special session requested for AGU Fall Mtg (Dec 2011).**

VOCALS – Achievements 2010/2011

- **VOCALS OBSERVATIONAL SYNTHESES: The 20°S latitude line captures a wide range of boundary-layer/cloud processes, lending itself well to model-observational comparisons**

- **Synthesis papers published documenting SE Pacific clouds and atmospheric structure, composition and variability sampled along 20°S during VOCALS-REx, Allen et al. (2011) and Bretherton et al. (2010)**

- **Seven years of VOCALS cruise data compiled along 20°S and described in deSzoeke et al. (2012)**

VOCALS – Achievements 2010/2011

- **MODEL ASSESSMENT: Completion of PreVOCA Model Assessment: Modeling the lower troposphere in Southeast Pacific for Oct. 2006 period pre-VOCALS-REx. Paper published, Wyant et al. (2010).**
  - **Large scale dynamics well-represented but representation of clouds is poor in general, and coastal model boundary layers are too shallow**
- **Second phase of VOCALS Model Asessment (VOCA) began fall 2010, ongoing. Focus is upon aerosol-cloud-climate interactions. Participation from most major modeling centers.**
- **MODEL DEVELOPMENT: Two Climate Process Teams (CPT) supported by NOAA and NSF will use VOCALS observations and process modeling of VOCALS case studies.**
- **Climate model improvement of PBL representations assessment (e.g. NCAR CCSM)**

VOCALS – Plans for 2011/2012

- **Groups submitting proposals for funding to support continuted analysis of VOCALS data and modeling activities.**
- **Complete VOCALS Model Assessment Phase 2**
- **Complete science overview paper for submission to BAMS, expected end of 2011**
- **Second year of CPTs using VOCALS data and process modeling experience**
- **AGU Fall Meeting Session. Encourage strong presence at ICCP Clouds and Precipitation Conference, Leipzig, July/ Aug 2012.**

VOCALS – Plans beyond 2012

- **Further VOCALS meetings? Contingent on funding decisions for follow-on modeling and observational analyses. Agency support for meetings would be extremely helpful to prevent fruit "wilting on the vine"**
- **Integrated 'model ready' datasets**
  - **Difficult to produce useful datasets of this type within 3 years because teams need to understand and quality-control their data, and modelers need to work with observationalists to determine the optimal content and formatting**