VAMOS Ocean Cloud Atmosphere Land Study

VOCALS

WCRP/CLIVAR/VAMOS-GEWEX

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 (M. France), S. de Szoeke (NOAA), M. Kohler (ECMWF), T. Toniazzo (U. Reading, UK), and many others...

www.eol.ucar.edu/projects/vocals

Institutions Collaborating in VOCALS

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

Research Institutions

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

Logistic Support:
UCAR JOSS

Operational Centers

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

VOCALS/VAMOS Working Group

Major activities over the past year

- **Second VOCALS General Meeting: 12-14 July 2009, University of Washington, Seattle, WA**
- **Second VOCALS-UK General Meeting: 9 June 2009, Reading University, Reading, UK**
- **Session at AGU Fall Meeting: 14 December 2009, San Francisco, CA**
- **Papers in U.S. CLIVAR Variations: Vol. 7, No.2**
- **Special Issue on VOCALS in Atmospheric Chemistry and Physics, EGU On_line Journals**
- **The VOCALS Chilean Upwelling Experiment (CUpEx) took place in Nov-Dec 2009. (http://www.dgf.uchile.cl/VOCALS CUpEx)**
- **CLIVAR Exchanges, VOCALS Issue: Vol. 15, No. 1 (April 2010)**

VOCALS 20S cloud and boundary-layer structure

C. Bretherton, R. Wood, R. George, D. Leon, G. Allen, X. Zheng, ACPD, 2010

Ten dedicated and 6 partial missions sampled 1500 km offshore along 20S (flight plan at right)

Offshore (80-85 W), typically:
- 1.5-2 km deep PBL
- Decoupled (LCL<cld base)
- Cloud drop conc. <100/cc
- Drizzle cells w. high LWP

Nearshore (70-75 W):
- 1-1.2 km deep PBL
- Well mixed
- Drop conc. 200-250/cc
- Thin clouds, little drizzle

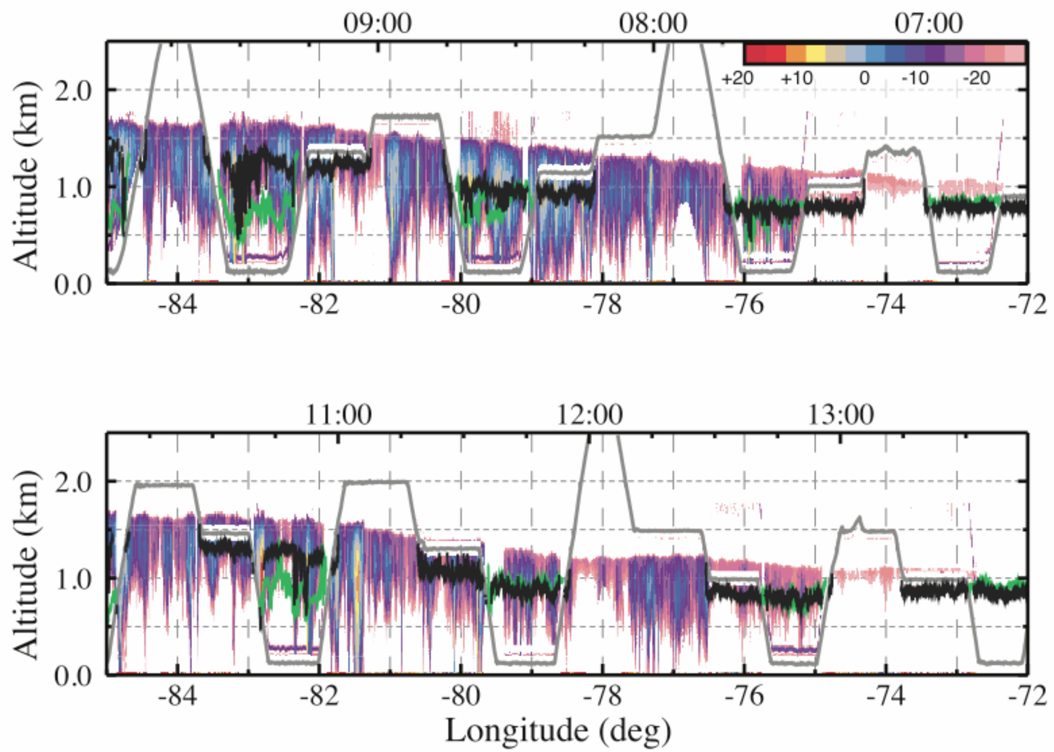
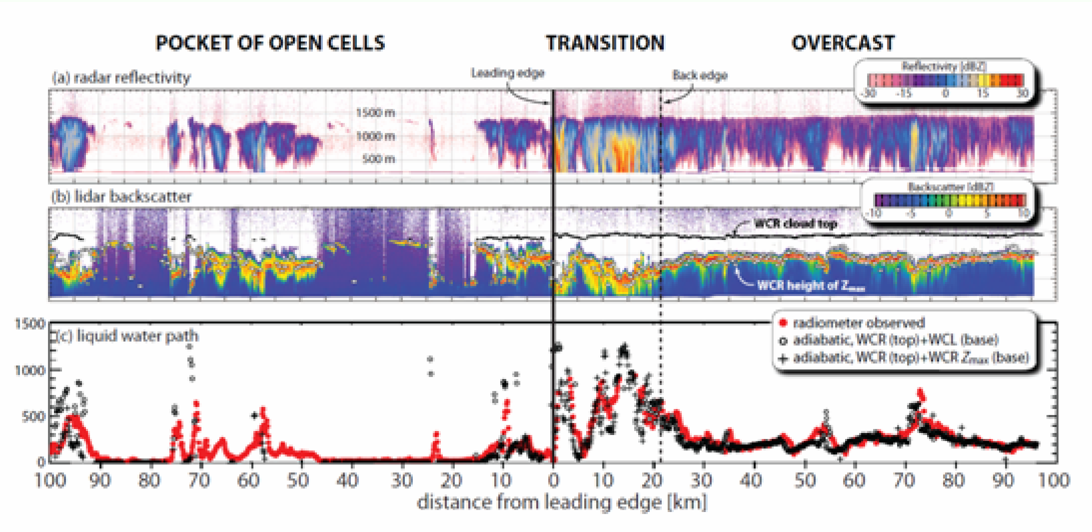


Fig. 2. Longitude-height plot of WCR reflectivity along 20° S for the outbound (top) and return (bottom) portions of C130 RF03. During subcloud legs, the in-situ LCL (green) and the WCL cloud base (black) are superimposed. During cloud legs, the black line shows the cloud base adiabatically derived from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

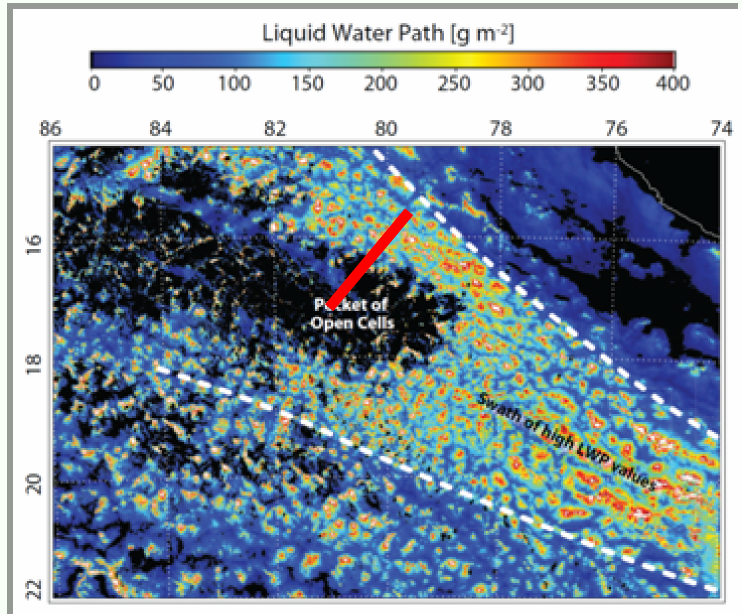
Pockets of open cells (POCs) in marine stratocumulus

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

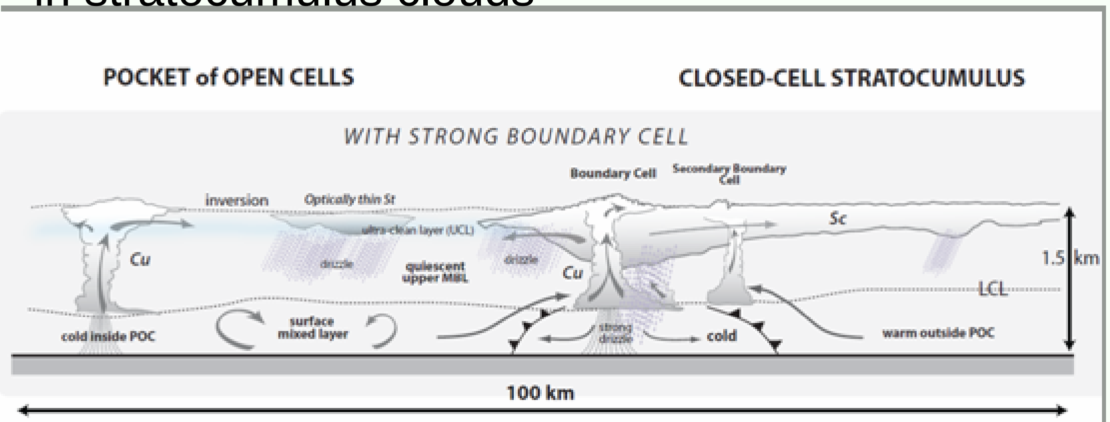


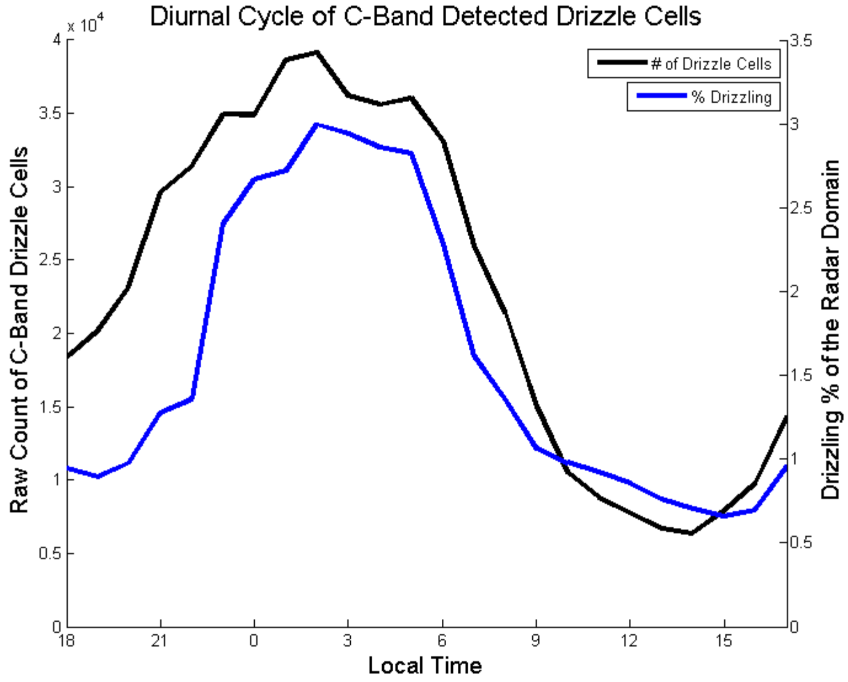
Left: C-130 radar, lidar, and microwave liquid water path obs. during the RF06 POC mission

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



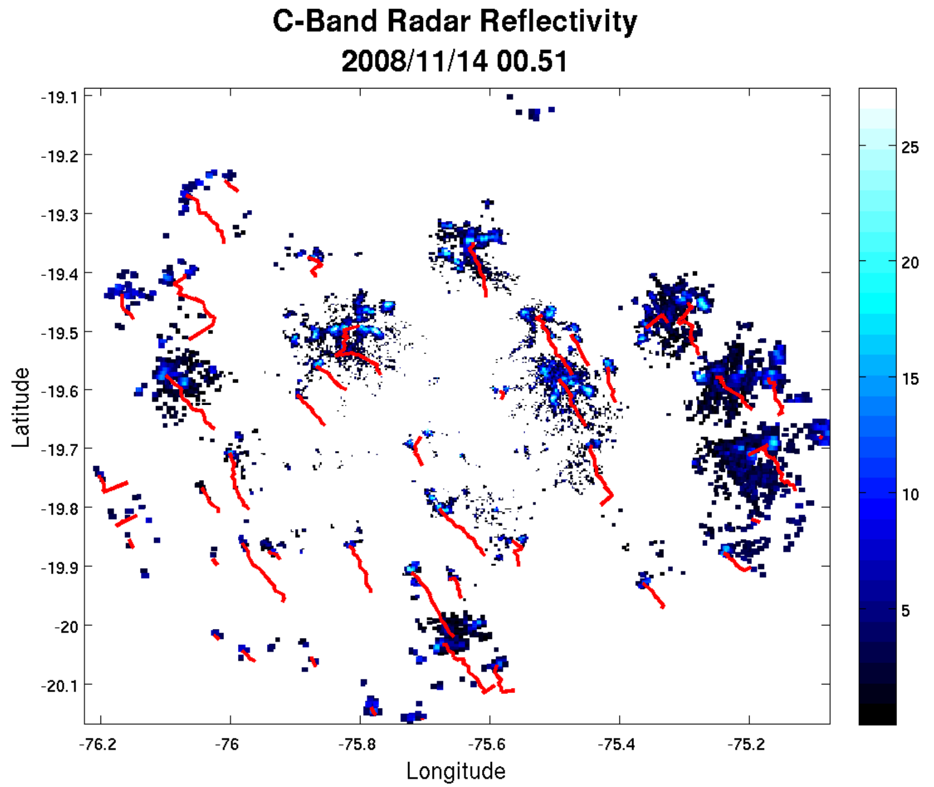


Drizzle Cell Properties

Dr. Sandra Yuter

Our group is investigating the properties of drizzle observed by the scanning C-Band radar aboard the R.H. Brown. An early result (left) is the diurnal cycle of the number of drizzle cells and drizzling area.

One key component of our research is the development of a drizzle cell tracking algorithm (right) that will be used to investigate the life cycle of precipitation within the radar's domain.

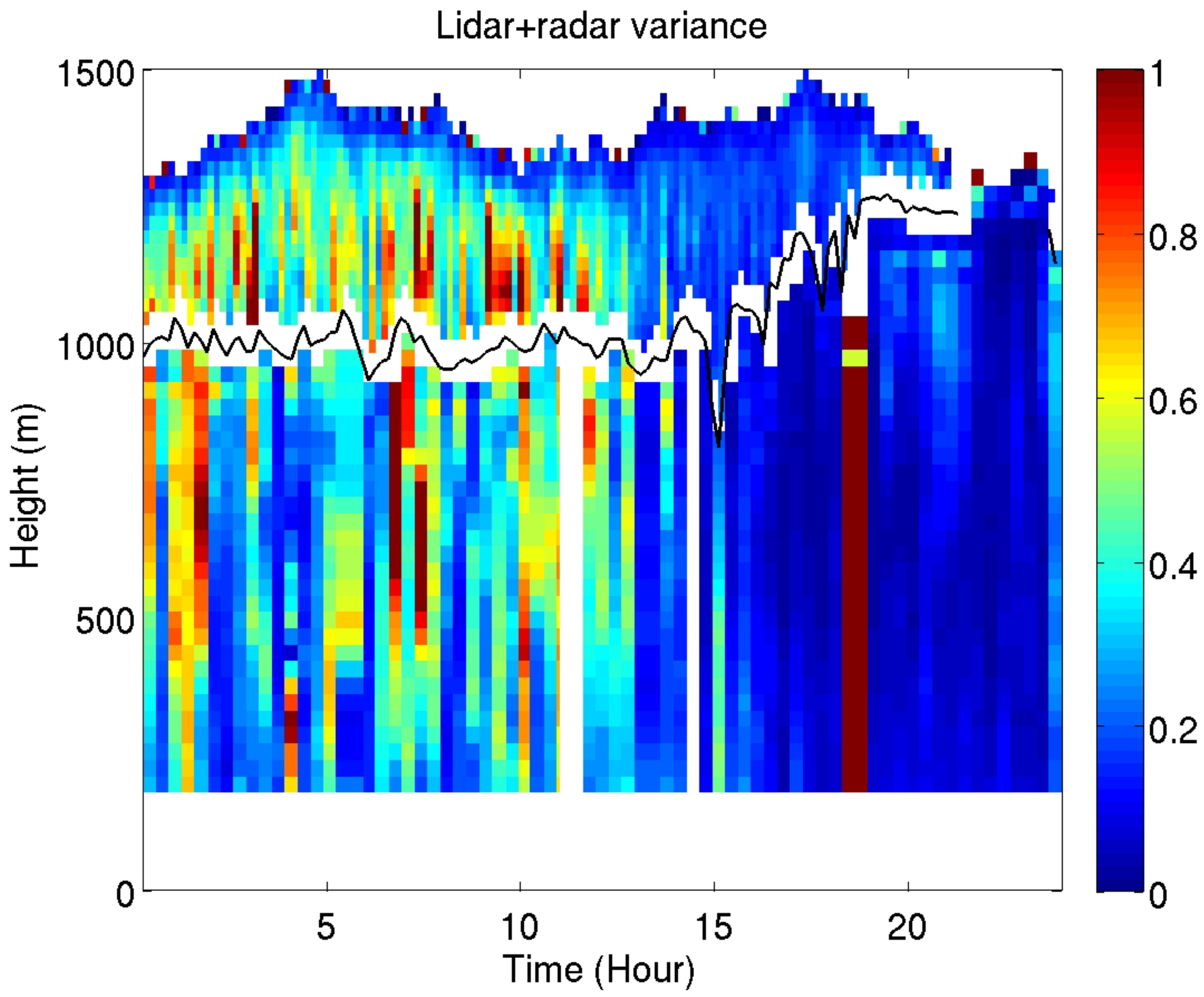


CP[3]g NC STATE UNIVERSITY

Clouds and Precipitation Processes and Patterns Group

Observing Boundary-Layer Turbulence with Combined Lidar and Radar Retrievals

PSD Lidar and Radar: Brewer, Ghate, Fairall



Linking Cloud Microphysics and Liquid Water

PSD Wband Radar: Fairall, DeSzoeke, Pezoa, Moran, Wolfe, Zuidema

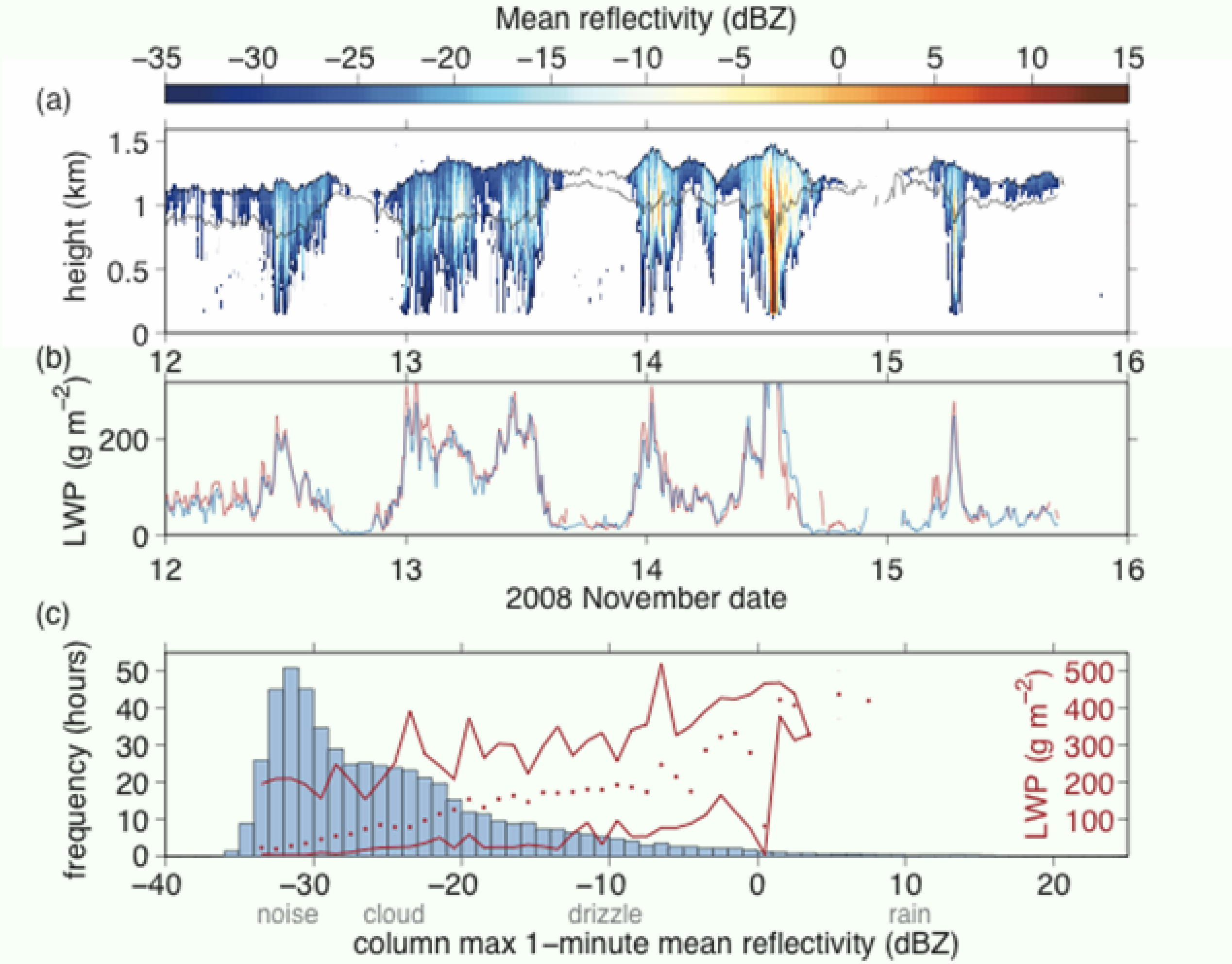
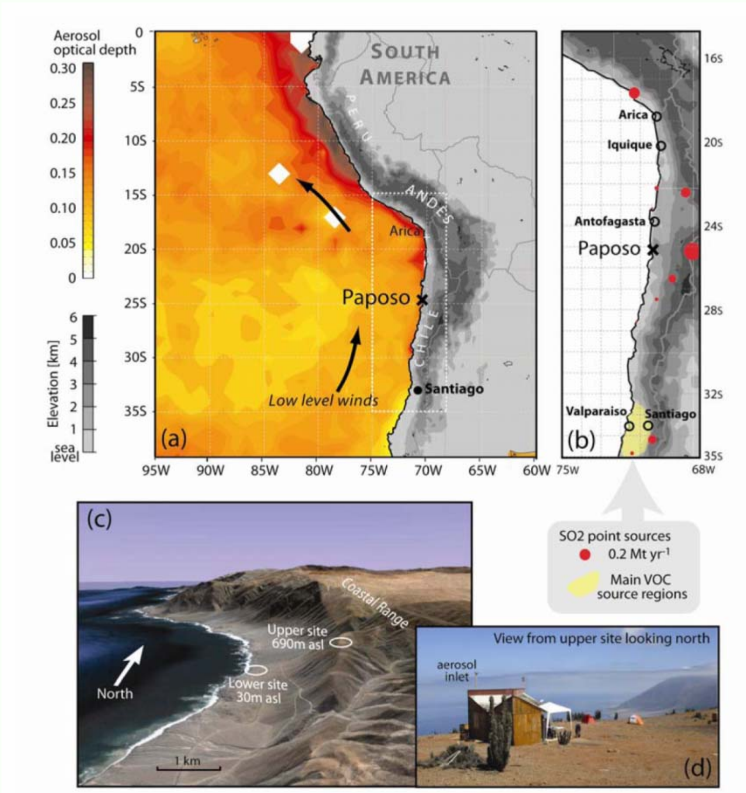


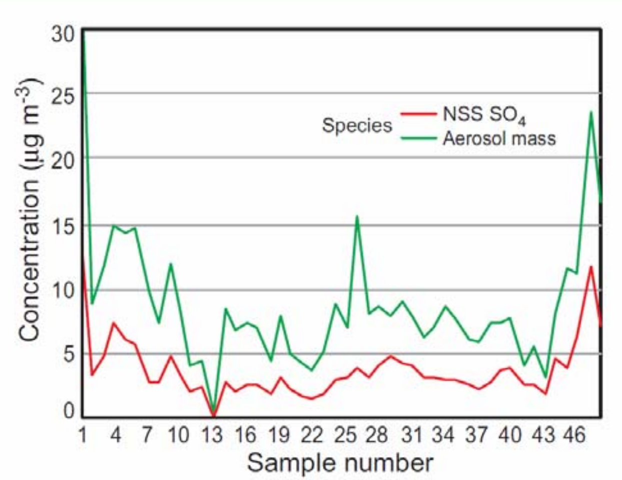
Figure. (a) Mean reflectivity from the W-band cloud radar for November 12-15. Thin lines are cloud top height estimated from the radar and cloud base height from the ceilometer. (b) Liquid water path (LWP) from the microwave radiometer (red) and adiabatic LWP from cloud thickness (blue). Bars in (c) show the frequency of occurrence in hours of column maximum reflectivity (dBZ) of 1-minute samples for *all 538 hours* of the VOCALS cloud radar record. The median and range of 10-minute LWP (g m^{-2}, red dots and lines) are binned by column maximum reflectivity.

Source Attribution of Climatically Important Aerosol Properties measured at Paposo (Chile) during VOCALS-REx

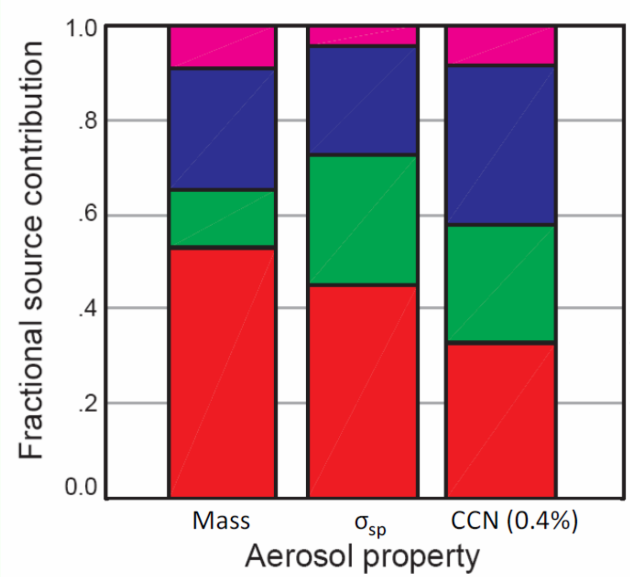
Duli Chand, D.A. Hegg, R. Wood, G.E. Shaw, D. Wallace and D. S. Covert, L. Gallardo



Above: Paposo aerosol measurements were made upwind of offshore VOCALS-REx measurements at an elevated coastal site



Left: Sulfate constitutes roughly half of the submicron aerosol mass



Left: Urban/fossil fuel, biomass burning, soil/smelter, and marine souces all represented in aerosols at Paposo

VOCALS/VAMOS Working Group

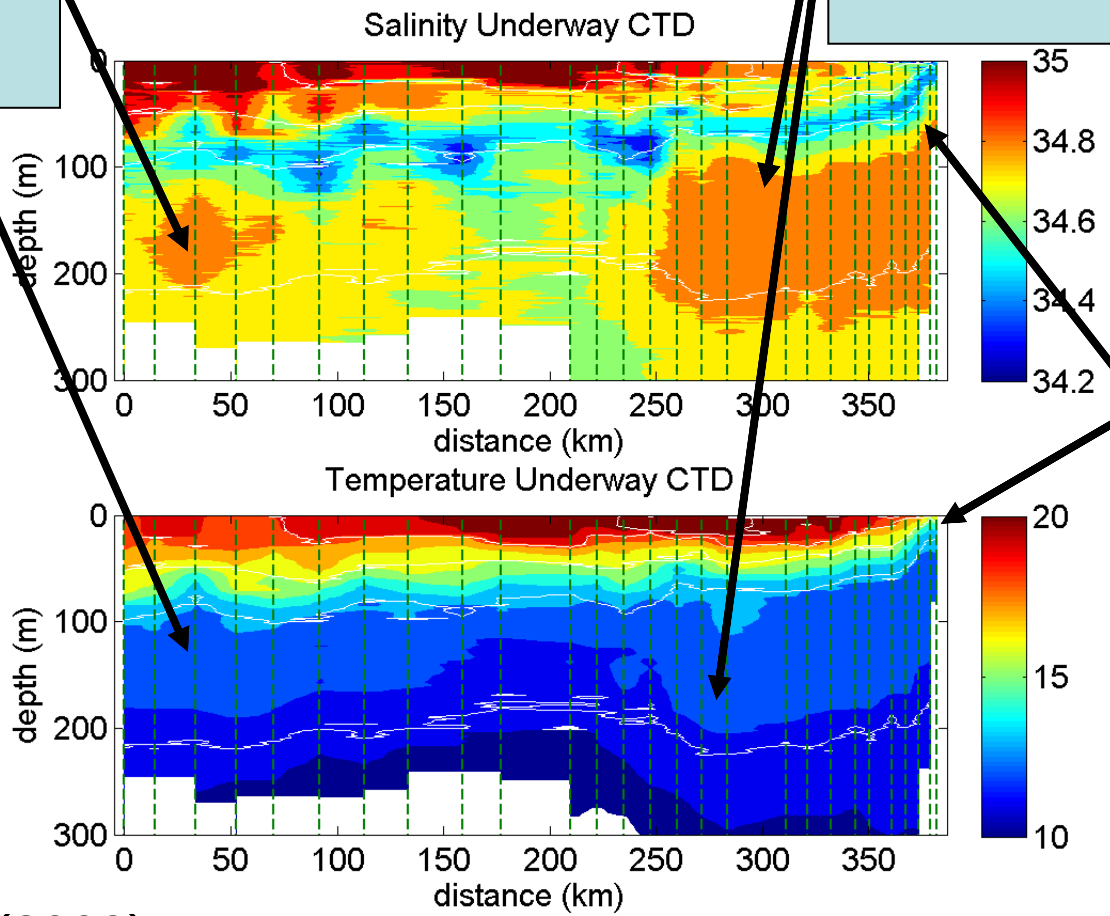
Recent scientific highlights

Ocean Eddies: Ron Brown CTD section up to the coast of Chile

Cyclonic Eddy with a warm salty sub-surface core

Boundary current with same properties as the eddies' core

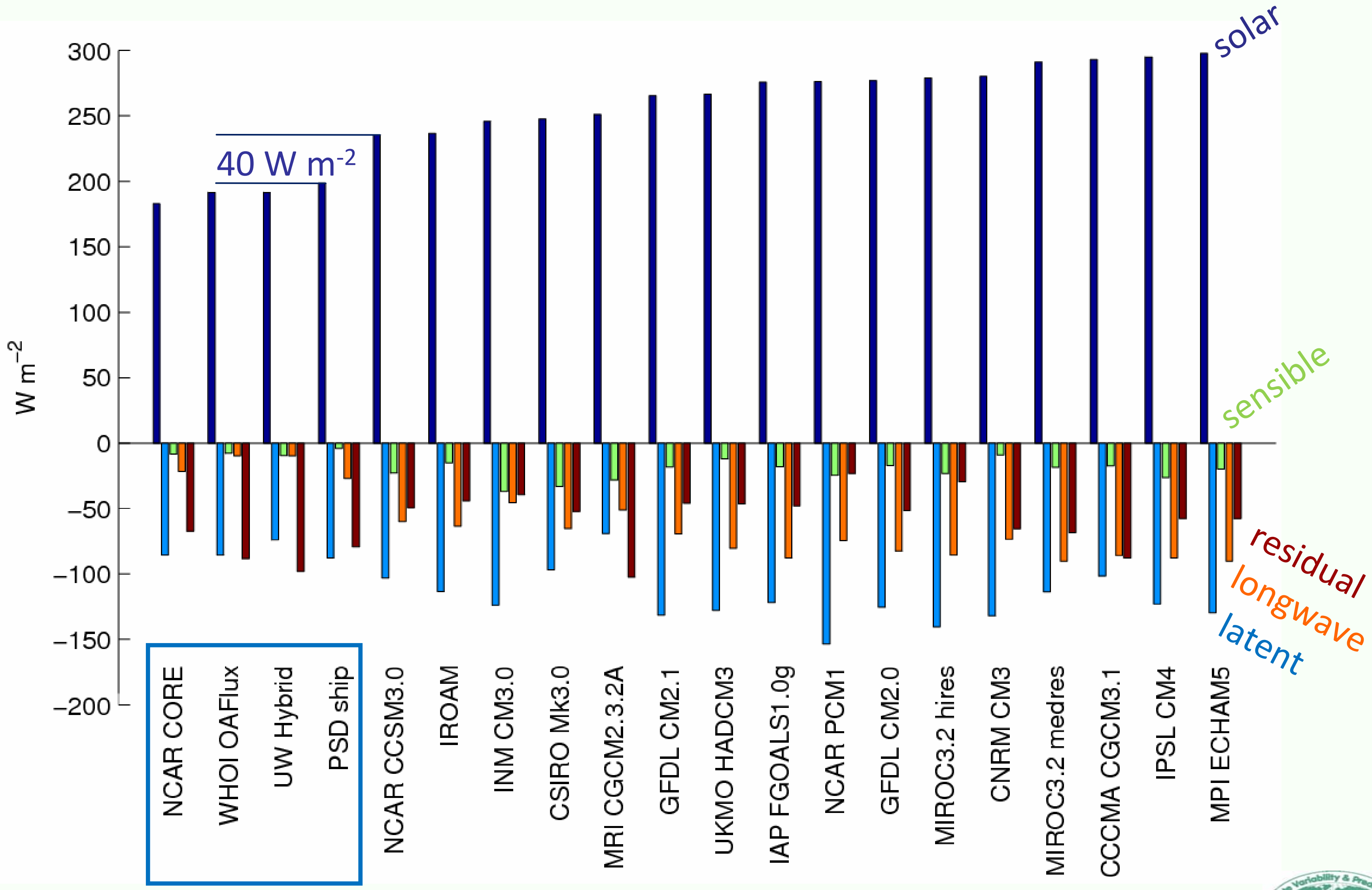
Upwelling of fresh and cold waters of subpolar origin to the surface



F. Straneo (2009)

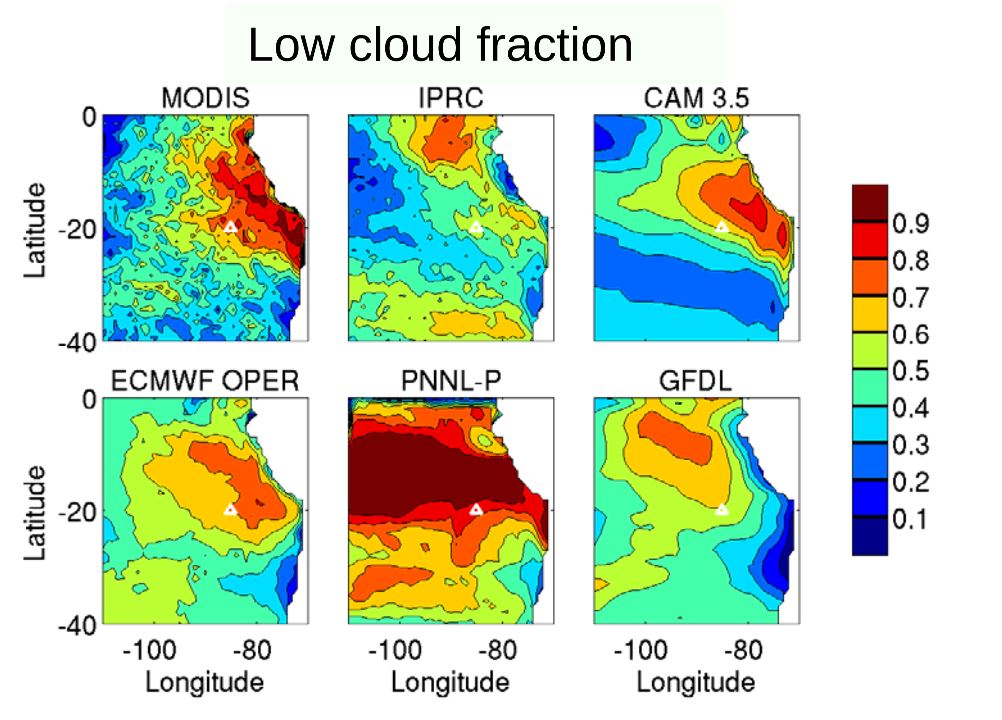
Surface heat balances along 20°S, 75-85°W

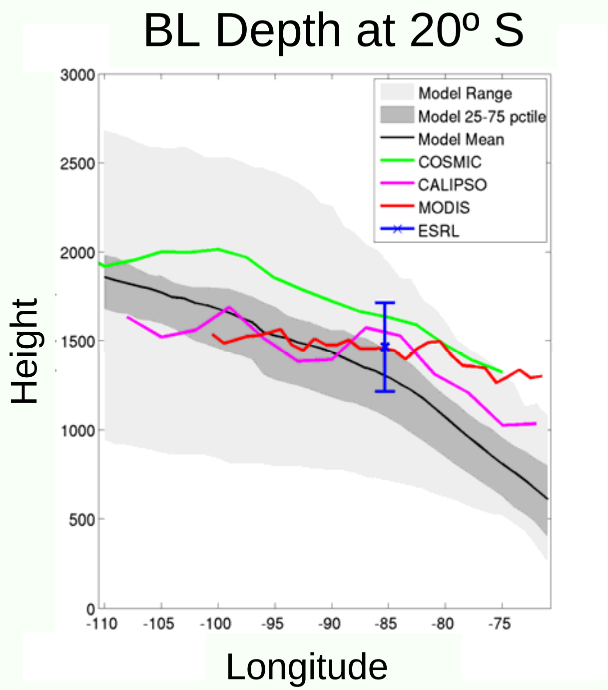
de Szoeke et al. 2009, J. Climate 2010



Pre-VOCA

M. Wyant, R. Wood, C. Bretherton, *Univ. of Washington*
C. R. Mechoso, *UCLA*





- 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 produced a marine BL too shallow near the coast at 20S.
- Most models underestimated LWP at the stratus buoy and to the east of it.

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Recent scientific highlights

Improved Scu Forecasts in SEP (ECMWF)

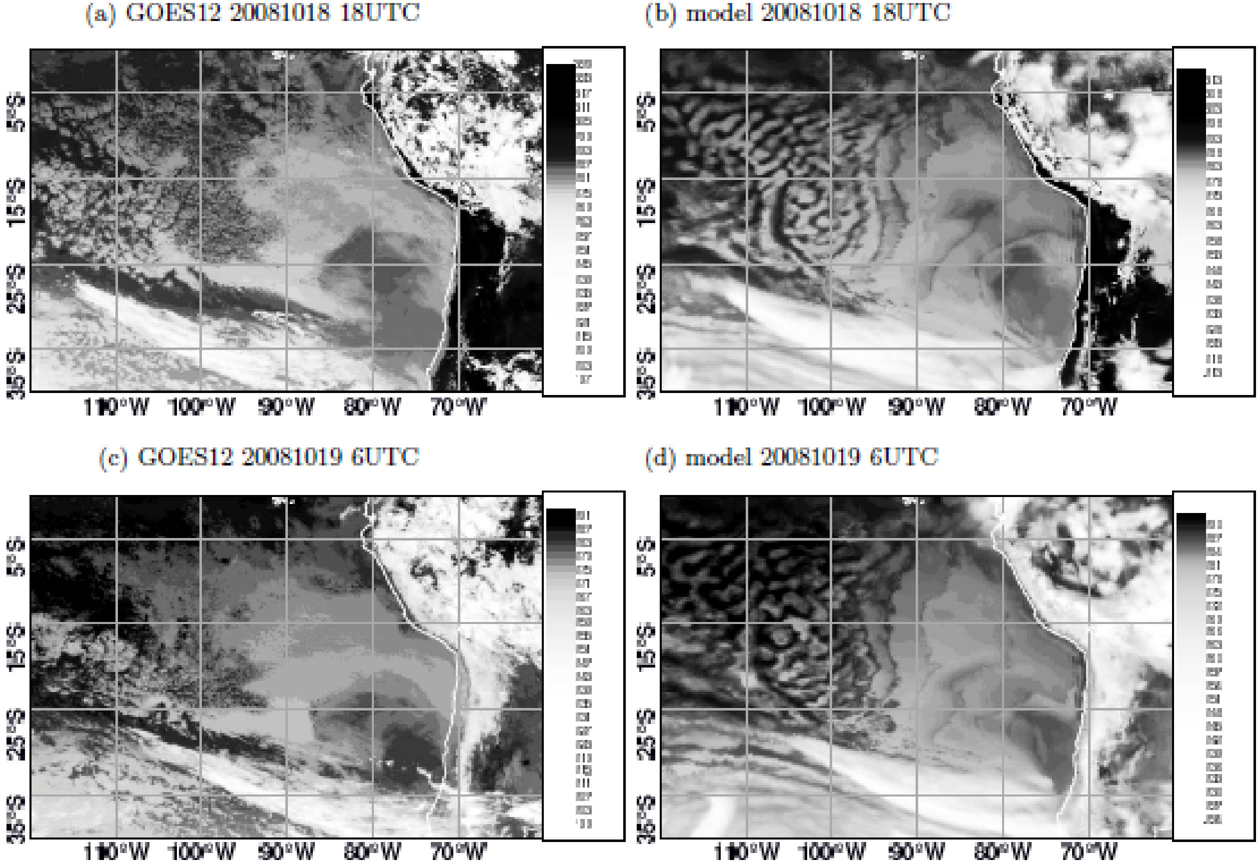


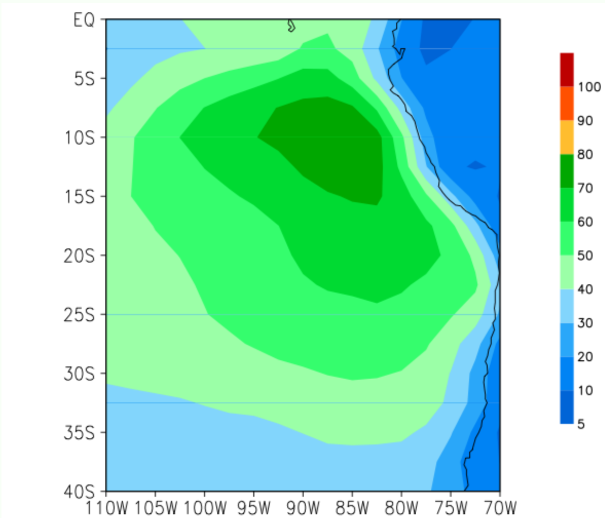
Figure 2. GOES12 satellite 10.8μm infrared band brightness temperature are compared to model generated images. The model was initialized on 20081018 00UTC. Panels (b) and (d) correspond to 18 and 30 hour forecasts representing daytime (10-14LT) and nighttime 22-02LT) respectively.

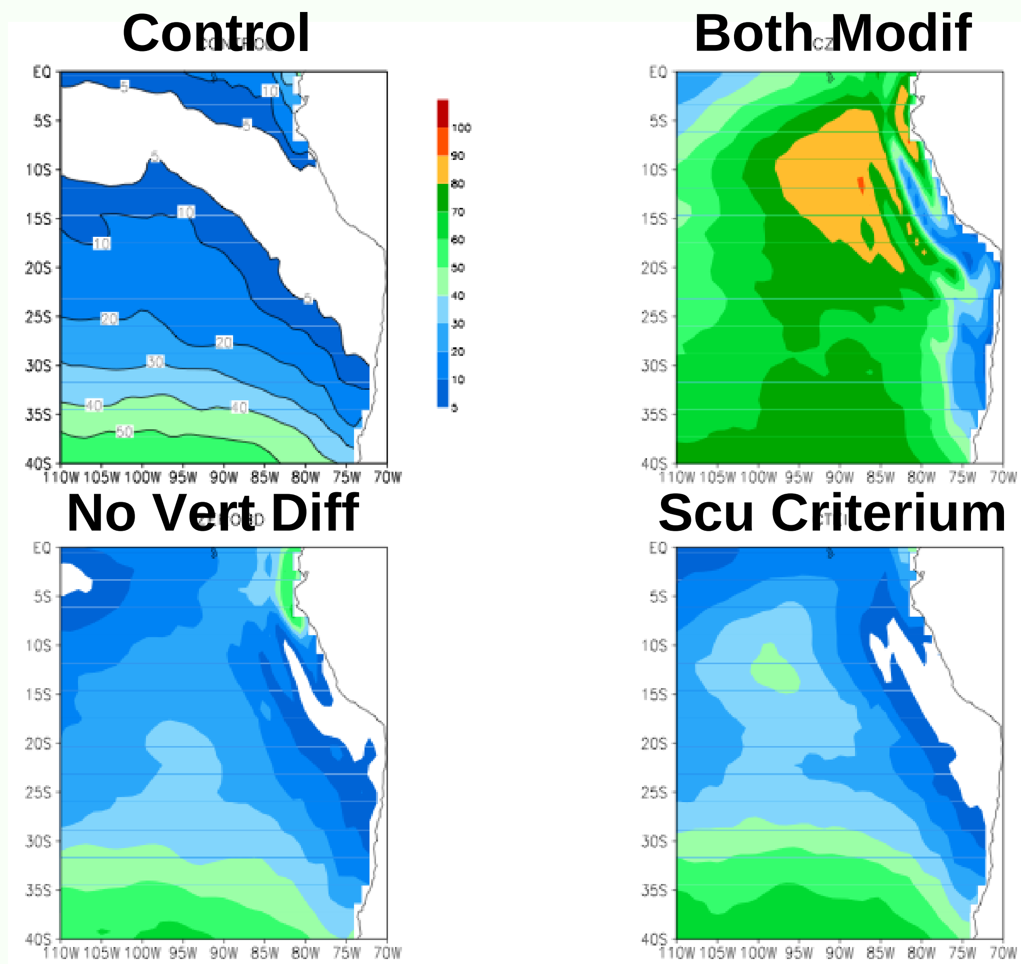
M. Kohler (2009)

Improvement of low clouds simulation in the Southeast Pacific in the NCEP GFS

R. Sun, S. Moorthi, H. Xiao, and C. R. Mechoso

ISCCO low couds





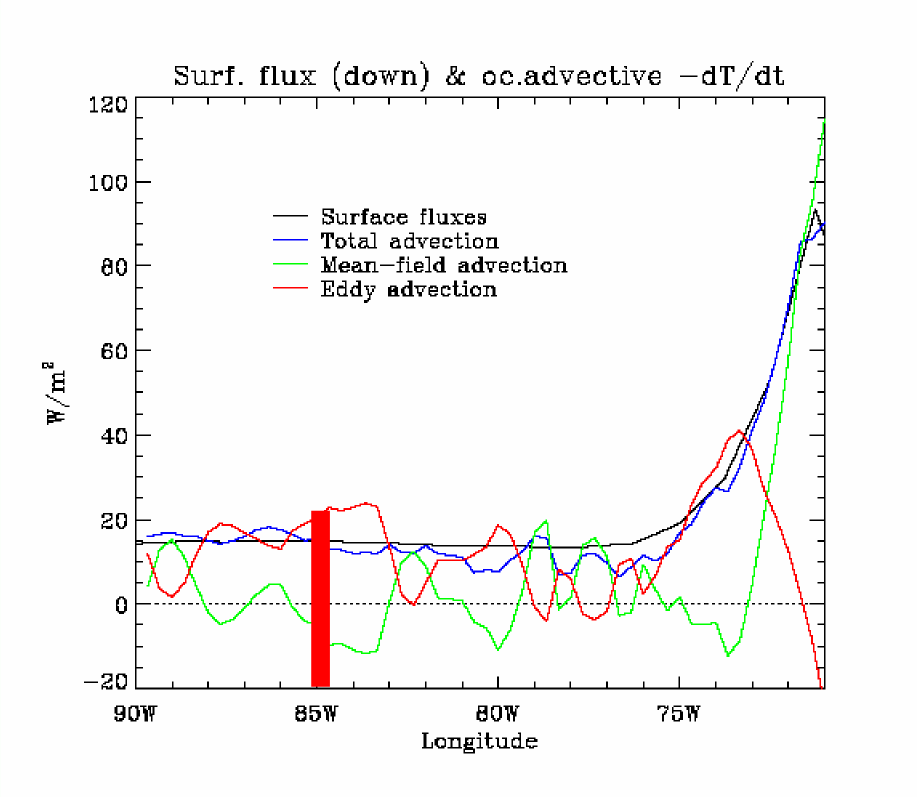
Heat transport by mesoscale ocean eddies

$$u\cdot\nabla T = u\cdot\nabla T + u'\cdot\nabla T' + u'\cdot\nabla T + u\cdot\nabla T'$$

rectifying non-rectifying

$u' = u'_1 + u'_2$ etc.; spatially or temporally filtered components

Toniazzo et al. (2009) found that geostrophic transients with 4 month < Period < 1 yr are dominant, and organised in large-scale pattern in simulation by HiGEM



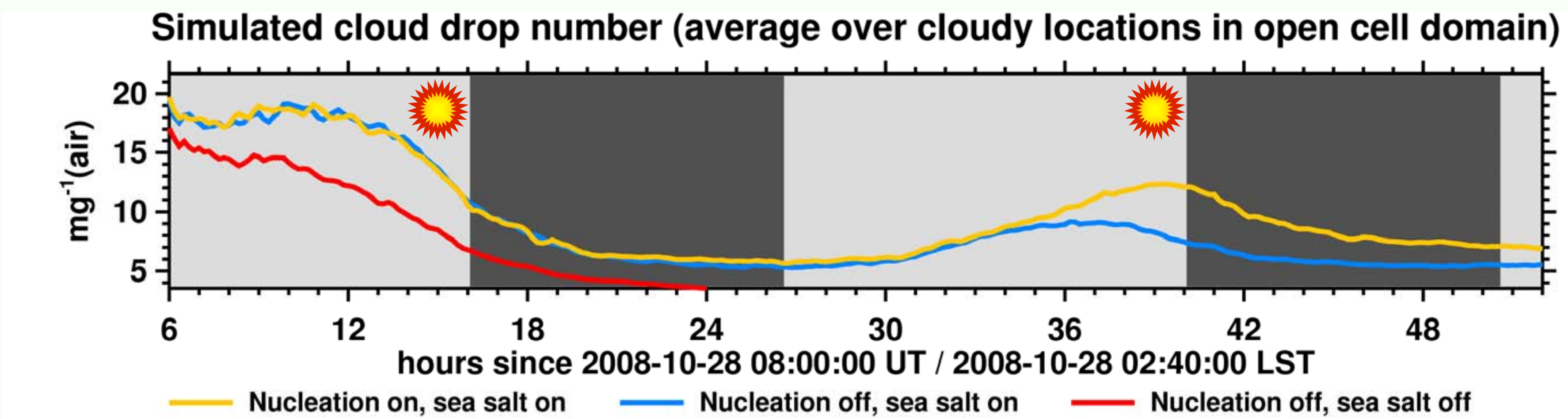
Toniazzo et al. (2009))

Large eddy simulations with detailed coupling of the aerosol-cloud-radiation-chemistry-dynamical system in the marine boundary layer

Jan Kazil[1], Hailong Wang[2], Graham Feingold[1]

1) Cooperative Institute for Research in Environmental Sciences, U.Colorado / NOAA
2) Atmospheric Sciences and Global Change Division, Pacific Northwest National Laboratory

- Selected results of open cell simulations initialized from VOCALS-REx observations:
  - The model reproduces chemical, aerosol, and cloud properties in open cells observed during VOCALS-REx
  - Ocean emissions of sea salt aerosol can compensate the loss of CCN by cloud processes, and thereby maintain the open cell dynamic structure and cloudiness
  - Ocean emissions of DMS, and transport as well as chemical and cloud processes in open cells result in the formation of new aerosol particles from the gas phase, which contribute to the CCN population and bear upon cloud properties

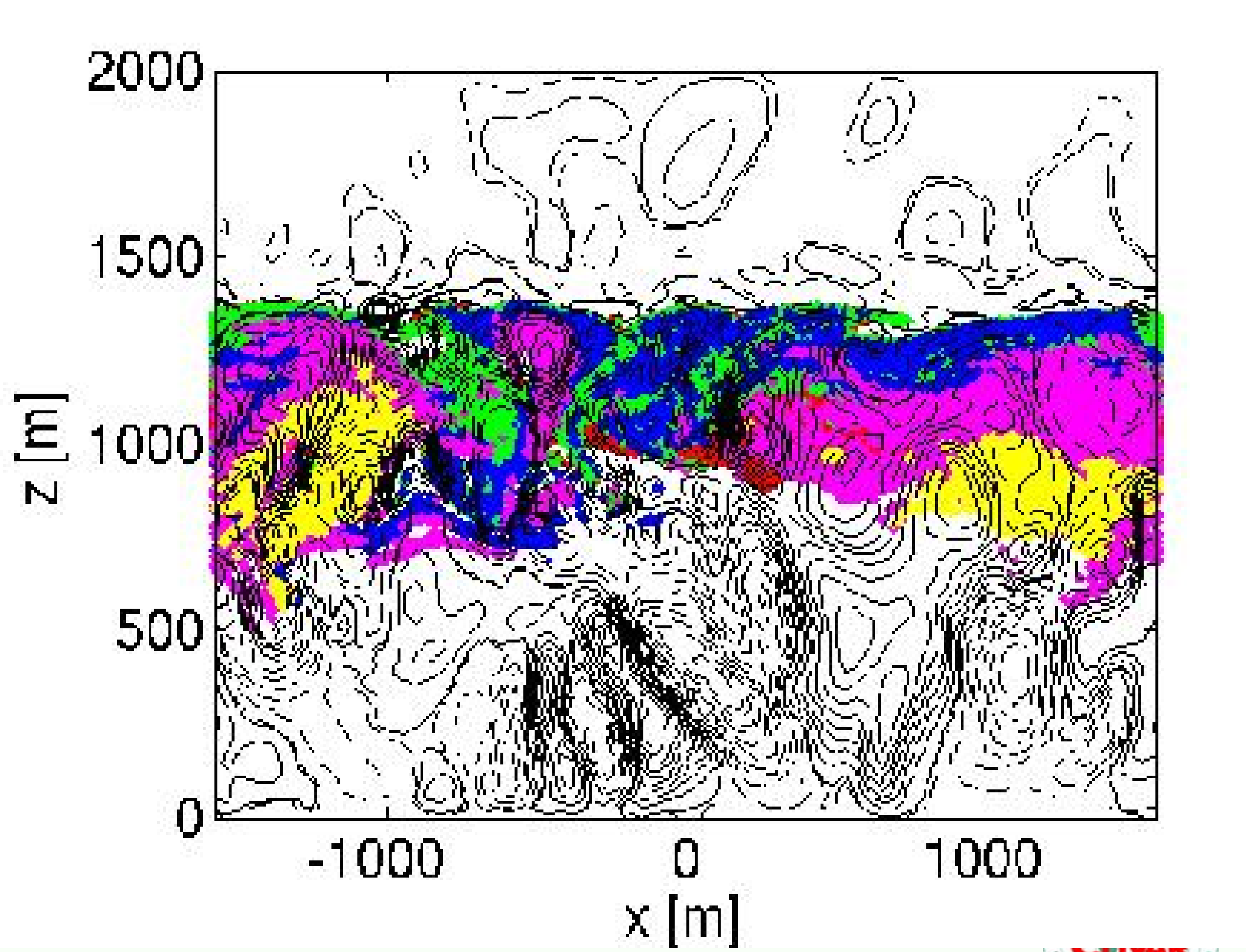


The affect of aerosols on Stratocumulus clouds; some current results from the VOCALS experiment and proposed further research studies.

Miroslaw Andrejczuk

(Part of the Leeds VOCALS group, M. Andrejczuk, M. Bart, A. Blyth, B. Brooks,, A. Gadian, P. Krecl and Jim McQuaid)

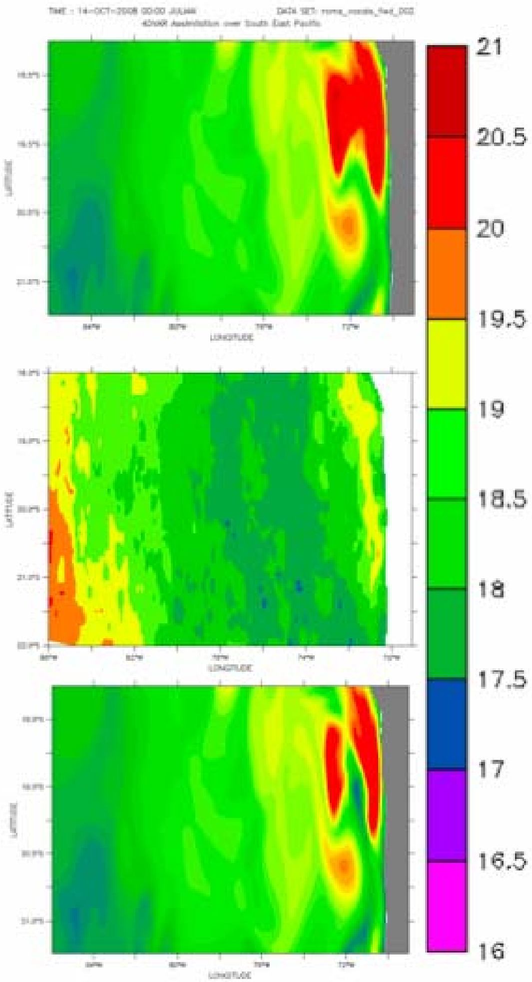
A model solution, showing parcel location, size and flow velocity. With red locations of parcels with radius < 10 um are shown, with green parcels with sizes 10 - 20 um, with blue 20 - 50, with purple 50–100 and with yellow bigger than 100 um.



Regional Ocean Data Assimilation During VOCALS REx

Aneesh Subramanian and Arthur J. Miller
Scripps Institution of Oceanography, UCSD

SST (°C)



Before Data Assimilation

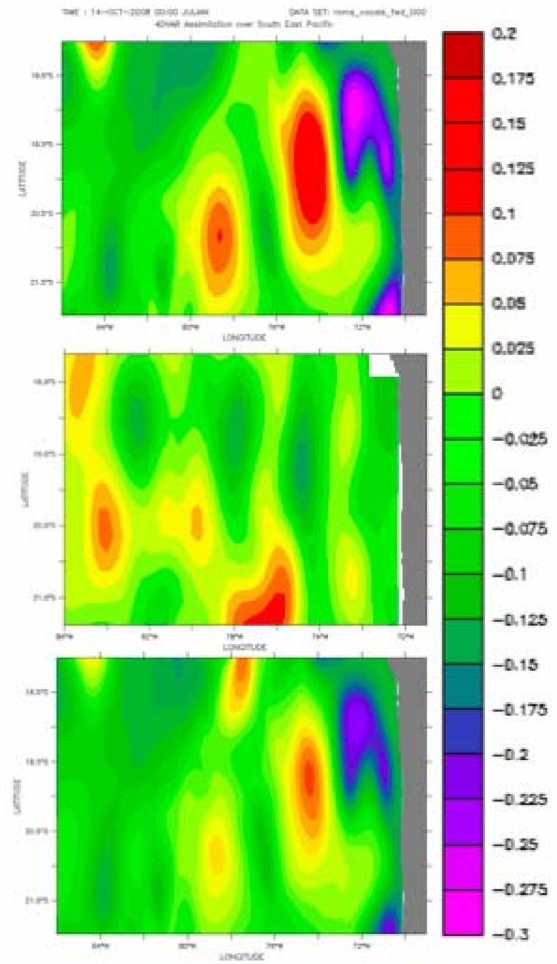
(ROMS; QuikSCAT winds, COADS fluxes)

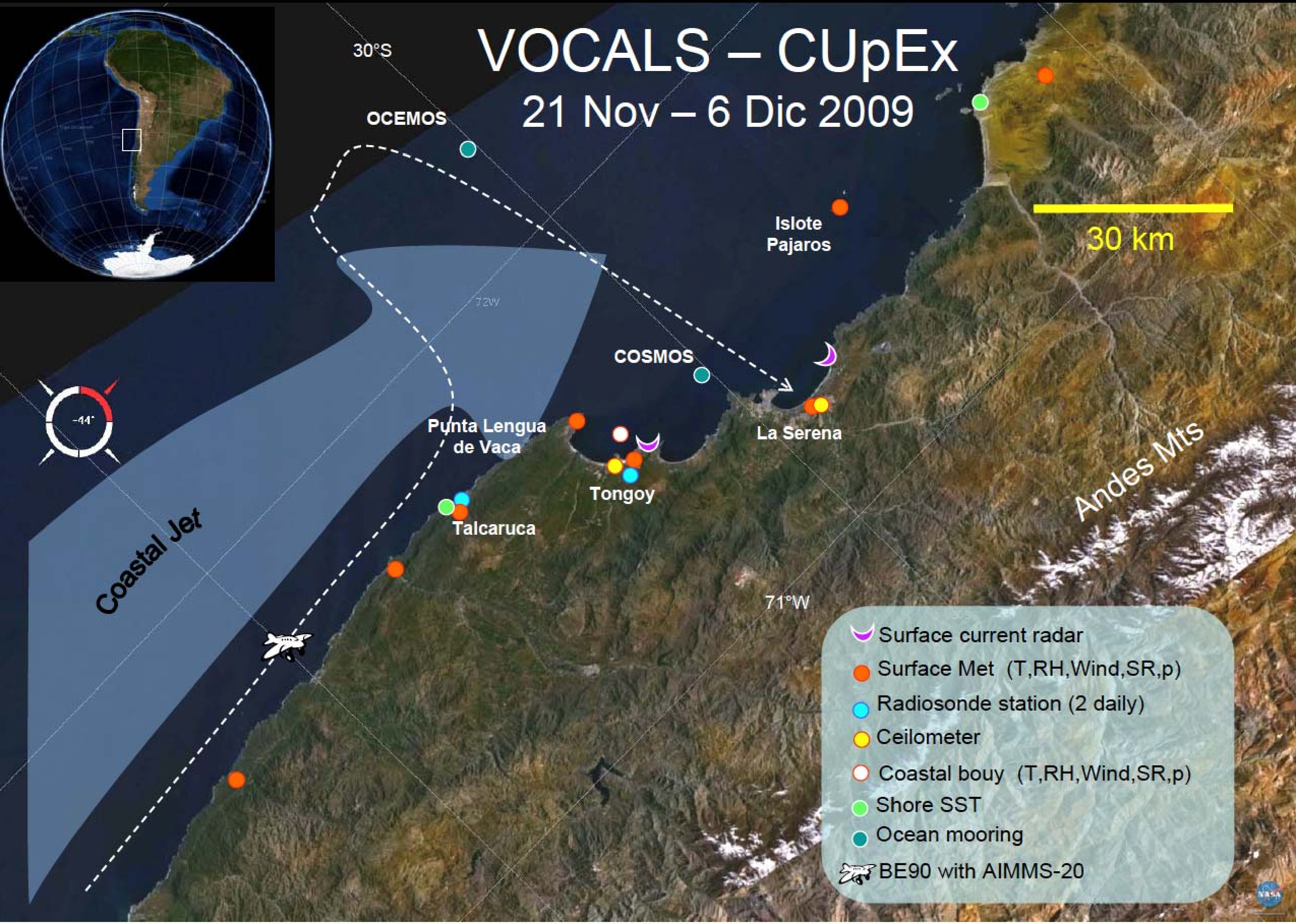
Observations
(Merged OI SST AMSR-E, TMI)
(AVISO SSH Anomaly)

After Data Assimilation

(Data along R. V. Brown track)

SSHA (m)



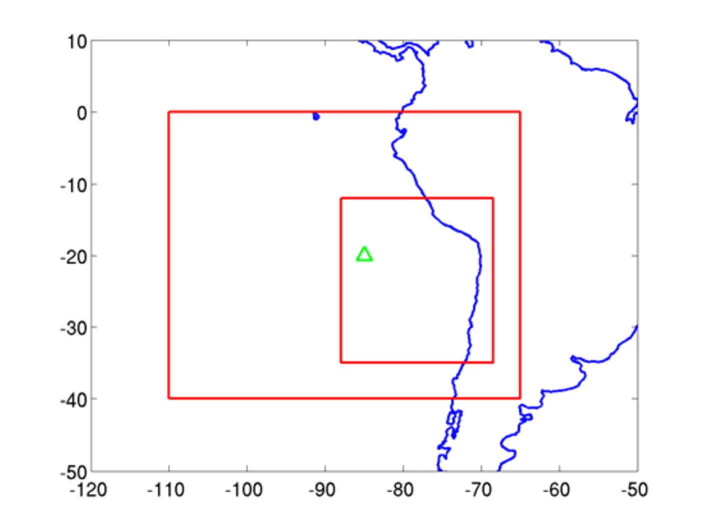

VOCALS – CUpEx
21 Nov – 6 Dic 2009
30°S
OCEMOS
Islote
Pajaros
30 km
72W
COSMOS
Punta Lengua
de Vaca
La Serena
Tongoy
Talcaruca
Andes Mts
Coastal Jet
71°W
-44°
Surface current radar
Surface Met (T,RH,Wind,SR,p)
Radiosonde station (2 daily)
Ceilometer
Coastal bouy (T,RH,Wind,SR,p)
Shore SST
Ocean mooring
BE90 with AIMMS-20

VOCA

M. Wyant, R. Wood, C. Bretherton, *Univ. of Wash.*

S. Spak, *Univ. of Iowa*

J. Fast, *PNNL*



- VOCA will compare and evaluate models during the period of VOCALS REx, October 15 – November 15, 2008.
- 15 modeling groups are planning to participate so far.
- VOCA will further explore aerosol-cloud interactions and try to address the following questions:
  1. Do models simulate the variation of droplet concentration, N_d, along 20S?
  2. Is anthropogenic sulfate the main contributor to N_d?
  3. What controls N_d in remote ocean regions?
  4. What is the simulated indirect effect of anthropogenic aerosol on clouds and radiative fluxes?

Results are due September 30, 2010. See http://www.atmos.washington.edu/~mwyant/vocals/model/VOCA_Model_Specs.htm

VOCALS/VAMOS Working Group
Major future plans/activities

- **Session at AGU Meeting of the Americas, 8-13 August, 2010, Foz do Iguacu, Brazil. (Rene Garreaud and Bob Weller, Convenors)**
- **Session at AGU Fall Meeting, December 2010 (P. Zuidema, Convener)**
- **Third VOCALS Science General Meeting, March 2011, RSMAS, Miami, Florida.**

VOCALS
Issues and challenges

- Analysis of VOCALS datasets is under way with great enthusiasm and promise of major scientific contributions: Funding should be available to complete the work.
- Similarly, monitoring of the VOCALS region should be continued to obtain longer time series.

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Science highlight slides

- **VOCALS Science is organized around a set of hypothesis.**

- **These can be broadly divided in two sets:**

  1) Aerosol-Cloud-Drizzle Hypothesis

  2) Coupled-Atmosphere-Land Hypothesis

- **The following slides are a synthesis of how preliminary findings from VOCALS are being used to confront the hypothesis.**

- **Supporting data comes from modeling work as well as from radars, lidars, microwave radiometers, and in-situ aerosol and cloud instruments on board the airborne and ship platforms during the VOCALS field campaign (REx)**

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Science highlight slides

- **Aerosol-Cloud-Drizzle Hypothesis #1**: *Variability in the physico-chemical properties of aerosols has a measurable impact upon the formation of drizzle in stratocumulus clouds over the southeastern Pacific (SEP)*

  Preliminary analysis supports the hypothesis. In the SEP, however, the liquid water path (LWP) of the clouds may be as important at promoting drizzle as variations in aerosols.

- **Aerosol-Cloud-Drizzle Hypothesis #2**: *Precipitation is a necessary condition for the formation and maintenance of pockets of open cells (POCs) within stratocumulus clouds*

  Data from REx suggests that drizzle is not sufficient to cause transition of closed-cell convection into a POC. Large eddy simulation results indicate that increased precipitation due to meteorological variability may also be effective at driving POC formation.

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Science highlight slides

- **Aerosol-Cloud-Drizzle Hypothesis #3**: *The small effective radii measured from space over the SEP are primarily controlled by anthropogenic, rather than natural, aerosol production, and entrainment of polluted air from the lower free troposphere is an important source of cloud condensation nuclei (CCN).*

  Support was found for the first part of the hypothesis. No evidence was yet found that biogenic DMS production close to the coast controls the observed geographic gradient of cloud droplet number. DMS appears to be the most important source for new sulfate further offshore.

- **Aerosol-Cloud-Drizzle Hypothesis #4**: *Depletion of aerosols by coalescence scavenging is necessary for the maintenance of POCs.*

  All POCs sampled in REx showed an *ultra clean layer* close to the top of the boundary layer within the POC. To fully address this issue, REx case studies are being used to initialize and evaluate high-resolution models.

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Science highlight slides

- **Coupled Ocean-Atmosphere-Land Hypothesis #1:** *Improvement of CGCMs performance in the SEP is key to the successful simulation of the ITCZ/SPCZ, complex, which will also benefit simulation of other regions. A significant improvement can be achieved through better representing the effects of stratocumulus clouds on the underlying surface fluxes and those of oceanic mesoscale eddies in the transport of heat.*

  VOCALS has emphasized and promoted work on the parameterization and simulation of marine stratocumulus, Major progress has been achieved, which has alleviated the systematic errors with the ITCZ/SPCZ transition, transition to other cloud regimes, and SST errors in the eastern tropical oceans. Analysis of a high resolution CGCM simulation has produced a heat flux by ocean eddies with a magnitude comparable to the observational estimates at the IMET WHOI buoy site.

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Science highlight slides

- **Coupled Ocean-Atmosphere-Land Hypothesis #2**: *Oceanic mesoscale eddies play a major role in the transport of fresh water from the coastal upwelling region and in the production of sea-water and atmospheric DMS in the coastal and offshore regions. By changing the physical and chemical properties of the upper ocean, upwelling has a systematic and noticeable effect on aerosol precursor gases and the aerosol size distribution over the SEP.*

  Several cyclonic eddies were found and surveyed during REx . The results suggest that the eddies originate from instabilities of the boundary current in the upwelling region and that contribute to the cooling of the offshore upper ocean. The ocean mesoscale and sub-mesoscale structures appear to modulate the production of DMS in the offshore region and hence determine its role in producing aerosol.

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Science highlight slides

- **Coupled Ocean-Atmosphere-Land Hypothesis #3**: *The diurnal subsidence wave (upsidence wave) originating in northern Chile/southern Peru has an impact upon the diurnal cycle of clouds that is well represented in numerical models.*

  There is strong evidence from modeling and observational studies that a such a diurnal subsidence wave propagates offshore at a speed of 25-30 m s^{-1}. Work in progress aims to isolate the effect on clouds of the subsidence wave compared with variations in solar warming.

- **Coupled Ocean-Atmosphere-Land Hypothesis #4**: *The entrainment of cool fresh intermediate water from below the surface layer during mixing associated with energetic near-inertial oscillations generated by transients in the magnitude of the trade winds is important to maintain heat and salt balance of the surface layer of the ocean in the SEP.*

  Analyses are been made of vertical microstructure data collected both in the coastal and offshore regions, inside and outside of eddies and fronts.

More realistic annual mean precipitation with enhanced representation of land surface processes

S. -Y. Ma, C. R. Mechoso, H. Xiao, and Y. Xue