VOCALS Regional Experiment (REx)
Goals and Hypotheses

Robert Wood, University of Washington
many contributors
THE VOCALS STRATEGY
VOCALS Regional Experiment (REx)

- Joint NOAA/NSF funded field program in October/November 2008. Additional support from ONR and DoE and international agencies

- REx will provide observations of poorly understood aspects of the SEP climate system

- Main platforms: NSF C-130, NOAA Ronald H Brown, CIRPAS and Chilean Twin Otter, DoE G-1, FAAM BAe-146, Chilean land site, Peruvian ship, second (UNOLS) ship.
VOCALS-REx Platforms and Sampling

Oct-Nov 2008

**Aircraft:**
NSF C-130
CIRPAS Twin Otter
DoE G-1
UK BAe-146

**Ships:**
NOAA Ronald H Brown
UNOLS Wecoma
Jose Olaya

**Land sites**
Meteorological context

SST (Reynolds)

Surface winds (Quikscat)

Sep-Nov climatology
MBL depth

Open cell frequency
E-W transect 20°S
VOCALS-REx Science Goals

1. AEROSOL-CLOUD-DRIZZLE GOALS

Factors controlling the stratocumulus cloud thickness, cover, and optical properties over the SE Pacific

2. COUPLED OCEAN-ATMOSPHERE-LAND GOALS

Physical and chemical links between the topography, coastal oceanic upwelling and the marine boundary layer
SEP stratocumulus in GCMs

Poor representation of the vertical structure of stratocumulus-topped boundary layers – improved parameterization central to improved global models

Bretherton et al. 2004, BAMS
**AEROSOL-CLOUD-PRECIPITATION HYPOTHESES**

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Precipitation is a necessary condition for the formation and maintenance of pockets of open cells (POCs) within stratocumulus clouds.

- Cloud albedo strongly dependent upon open/closed cells.
- Strong precipitation associated with open cell structure.
- In-situ aircraft measurements of the mesoscale dynamics needed.

Sandra Yuter, NCSU
POC formation

Kim Comstock
Flight-plan for C-130

POC-Drift missions
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.
Cloud Microphysical Variability

- Chile is world’s largest copper producer
- Copper smelting SO₂ emissions from Chile (1.5 TgS yr⁻¹) comparable to total SO₂ emissions in Germany
- 90% of Chilean SO2 emissions from seven smelters!
- Andes mountains prevent eastward transport
VOCALS-REx Cross-Section Sampling

Combined NOAA Ronald H Brown and NSF C-130 Missions

- direct evaluation of GCM lower tropospheric structure
Depletion of aerosols by coalescence scavenging is necessary for the maintenance of POCs.
Loss rate of CCN due to drizzle

- Accurate precipitation rate observations and microphysical measurements required (C-130)
- Cloud droplet concentration budget estimates
- Microphysical modeling
- Captured in GCMs?
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Ocean surface heat budget

Reanalysis surface fluxes are not accurate, for example, NCEP has a longer, cooler winter and little net heating of the ocean.

- Buoy obs show more surface net heat gain than models; NCEP shows a loss
- NCEP stress 30% stronger
- Models: rain (0.07 to 0.3 m yr\(^{-1}\)) Buoy: no rain to 0.03 m yr\(^{-1}\)
Surface forcing from buoy driving a one-dimensional ocean model (PWP) produces a surface layer that is too warm and too salty.

Bob Weller
Mesoscale ocean eddies form in coastal upwelling regions and propagate westward.

Their impact on the heat, nutrient, and freshwater budgets is poorly known.

They are not resolved in coupled GCMS.

Art Miller, Scripps
S-P. Xie

(From J. McWilliams)
SST at IMET Buoy (20°S, 85°W)

- Strong diurnal signature
- Simultaneous submonthly warming events
VOCALS-REx: Ship sampling

- **Phase 1 (3 wks):** RHB sits for 6 days at each buoy (20°S, 85°W to 75°W) and concertina transit between the buoys; Wecoma carries out a survey of the eddy-genesis region.

- **Phase 2 (3 wks):** Wecoma surveys oceanic mesoscale variability around the RHB (using SeaSoar)
Chaigneau and Pizarro

- Second ship coastal sampling
- Capture eddies in genesis region
SeaSoar TUV (towed undulating vehicle)

- Upper ocean horizontal and vertical structure
- Oxygen, nitrate, chlorophyll, salinity
- Radiative properties
- Mesoscale ocean eddy structure

Examples from EPIC, Wijisekera, OSU
Upwelling, by changing the physical and chemical properties of the upper ocean, has a systematic and noticeable effect on aerosol precursor gases and the aerosol size distribution.
The diurnal subsidence wave ("upsidence wave") originating in northern Chile/southern Peru has an impact upon the diurnal cycle of clouds and provides a useful framework for analysis of numerical model performance on diurnal time scales.

- Strong diurnal cycle in lower tropospheric subsidence in MM5
- Strong diurnal cycle in MBL and clouds observed during EPIC (+satellites)
- RHB, Chilean land site will make measurements of the free-troposphere at different distances from the coast

Garreaud and Muñoz
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 an important process to maintain heat and salt balance of the ocean surface layer.

Northward current velocity at IMET Buoy April-May 2005

Note strong (30 cm/s), subsurface velocities, strong shears.
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VOCALS Timeline

Planning Phase

REx and Modeling Workshops

Field site surveys

2000 - 2006

IUGG Perugia

2007

Field and modeling synthesis/analysis

2008

VOCALS Conference

2009

VOCALS REx

2010

Second REx Prep. Workshop

PI Proposal submission
ADDITIONAL SLIDES
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## REx - GCM Evaluation Hypotheses

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<td>3A</td>
<td>Poor representation of the vertical structure and depth of the stratocumulus-topped MBL contributes significantly to systematic GCM model errors in cloud cover, precipitation, and aerosol indirect effects over the SEP.</td>
<td>C-130 Cross Sections RHB vertical structure Chilean land site IMET buoy long term data</td>
<td>McWilliams/Hall/Gruber/Large Mechoso/Pan Kohler Garreaud Wang/Xie/deSzoeke Bretherton Donner/Golaz S. Wang</td>
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<td>Errors in near-coastal winds contribute to errors in upwelling intensity in coupled ocean-atmosphere GCMs</td>
<td>Second Ship coastal data IMET/SHOA buoy Quikscat</td>
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Sophisticated models

Single column models
Aerosol indirect effects in climate models

Strength of second indirect effect (drizzle suppression) is strongly dependent upon the depth of the cloud base.
VOCALS Coastal Program
CCN = f(Biology)
Biology = f(CCN)

Cloud properties in remote regions are controlled in part by marine algae.

SOLAS scientists seek to quantify that linkage, so that models of changed climates will be realistic.

The controls on gas exchange rates are poorly understood.

VOCALS Extended Observations

**IMET Buoy (WHOI):**
Instrumented mooring (WHOI) – 6 years continuous dataset (meteorology/oceanography/radiation) at 20°S, 85°W

**EPIC/PACS Fall Cruises (NOAA ESRL):**
Ship measurements: 2001 (EPIC), then annually 2003-2006, remote sensing, meteorology, oceanography, aerosols

**San Felix (Universidad de Chile):**
Meteorological station on remote oceanic location under Sc deck

**Satellite Measurements:**
GOES/MODIS/JASIN/AMSR/Quikscat, now Cloudsat and Calipso
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Field site surveys

PI Proposal Target Date

July 15

VOCALS

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VOCALS Conference
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OUTLINE

• Background on REx

• The REx hypotheses
  – Aerosol-Cloud-Precipitation Hypotheses
  – Coupled Ocean-Atmosphere-Land Hypotheses

• REx and Modeling
VOCALS Goal

To develop and promote scientific activities leading to improved understanding of the Southeast Pacific (SEP) coupled ocean-atmosphere-land system on diurnal to inter-annual timescales.
Cold SSTs, coastal upwelling
Cloud-topped ABLs
Influenced by and influential on remote climates (ENSO)
Unresolved issues in heat and nutrient budgets
Important links between clouds and aerosol
Poorly simulated by atmosphere-ocean GCMs
Precipitation is a necessary condition for the formation and maintenance of pockets of open cells (POCs) within stratocumulus clouds.

Wood et al. (2007)
Conceptual model of POC formation

1. CCN removal by coalescence exceeds primary production

2. Reduced cloud drop conc. favors increased coalescence and heavier drizzle

3. Evaporative cooling drives mesoscale circulations that lead to greater heterogeneity

4. Finally, clouds break, leading to open cell structure
Strong diurnal cycle over SEP
TMI data, Wood et al. (2002)
“UPSIDENCE WAVE”

MM5, Garreaud and Muñoz (2004)