Oceanic Eddies in the VOCALS Region of the Southeast Pacific Ocean

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Outline:

• Overview of VOCALS
• Overview of the oceanographic component of VOCALS
• Preliminary analysis of satellite altimeter observations of oceanic eddies in the VOCALS region

Photo courtesy of Bob Weller
SST is cold over a broad region of the southeast Pacific
Persistent Stratus Cloud Cover

- The cold SST in combination with warm, dry air aloft and large-scale subsidence results in a persistent stratocumulus cloud deck over the southeast Pacific.

- The enhanced albedo from the clouds results in a positive feedback that helps maintain the cold SST

From Klein and Hartmann (1993)
CGCMs exhibit systematic errors in the eastern tropical Pacific.

In the NCEP CFS Model, for example:

- The ITCZ is shifted equatorward.
- SST in the southeast Pacific is 1°-3°C too warm.
- Cloud cover in the southeast Pacific is 25-50% too high.

Errors are similar in other CGCMs

These errors in the CGCMs have a negative effect on the structure of the equatorial cold tongue, on precipitation patterns throughout the tropics, and on ENSO prediction.
Global cloud droplet concentration (MODIS, annual mean 2001-2004)
Cloud Microphysical Processes

Cloud Droplet Concentration from MODIS

Clouds and Sulfer Emissions from Copper Smelters
In the SEP near the coast Pockets of Open Cells (POCS) rarely develop, but away from the coast they are more frequent and extended than in other Scu regions.

Are these behaviors evidence of strong links between aerosol and cloud macrophysical structure? What is the role of drizzle?
Mesoscale stratocumulus structure

- Cloud albedo strongly dependent upon open/closed cells
- Strong precipitation associated with open cell structure
- Open cells form in clear marine environment – potential anthropogenic impacts

Ship Radar

Low albedo

Satellite

Closed Cells

High albedo

100 km

Open Cells

Strong drizzle

Weak drizzle
VAMOS: Variability of the American MONsoon Systems
A CLIVAR-sponsored program to study the American monsoons in the context of global climate variability.
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VOCALS

The overall goal of VOCALS is to develop and promote scientific activities leading to improved understanding, model simulations, and predictions of the southeastern Pacific (SEP) coupled ocean-atmosphere-land system, on diurnal to interannual timescales.

The focus of VOCALS in the SEP includes:

- Interactions with remote climates.
- Systematic biases of atmosphere-ocean GCMs.
- Ocean budgets of heat, salinity, and nutrients.
- Aerosol-cloud-drizzle interactions in the marine PBL.
VOCALS is interdisciplinary:
The climate in the VOCALS region involves poorly understood interactions between:

- clouds
- aerosols
- marine atmospheric boundary layer processes
- upper-ocean dynamics and thermodynamics
- coastal currents and upwelling
- large-scale subsidence in the atmosphere
- regional diurnal circulations
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The VOCALS program includes modeling, in situ observations of the atmosphere and ocean, and satellite observations
Modeling
CGCM Biases
Numerical Predictions

AIRBORNE
NCAR C-130 (and others)
Stratocumulus, aerosol

SHIP
Ron Brown (and others)
Ocean eddies, DMS fluxes

Monitoring
Satellites, Buoys, Maintenance cruises

VOCALS-REX
The VOCALS Regional Experiment (REx)
October - November 2008
VOCALS Timeline

Planning Phase

Modeling and REx Workshops

Field site surveys

VOCALS REx
Oct - Nov 2008

VOCALS Conference

2003 - 2006

2007

2008

2009

2010

Field and modeling synthesis/analysis

PI Proposal submission
July 2007
Oceanographic Component of VOCALS

Motivated largely by estimates of the imbalance of heat budget estimates at the IMET mooring ~1500 km offshore at 20°S, 85°W:

The annual mean heat flux is ~30 W/m² into the ocean under persistent stratocumulus cloud cover.

How is this air-sea heat flux maintained?
Hypothesis: *Cold water is transported offshore by oceanic eddies*

- Mesoscale eddies form in the coastal upwelling region of cold water and propagate westward.
- Their impacts on the heat, nutrient, and freshwater budgets in the VOCALS region are not yet known.
- *Note that these oceanic eddies are not resolved in Coupled GCMs, which may contribute to the biases in the coupled models.*
Satellite Altimeter Observations of Oceanic Eddies
14 October 1992 - 3 January 2007, lifetimes ≥12 weeks
Satellite Altimeter Observations of VOCALS Eddies
14 October 1992 - 3 January 2007, lifetimes ≥12 weeks
Animation of VOCAL Eddies with Lifetimes $\geq 12$ weeks
Genesis and Census of VOCALS Eddies
14 October 1992 - 3 January 2007, lifetimes ≥4 weeks

Genesis Locations

14-Year Census
Characteristics of VOCALS Eddies
Lifetimes ≥12 weeks
Time Series of VOCALS Eddy Characteristics
Lifetimes ≥8 weeks
Meridional Deflection of VOCALS Eddies that propagate ≥10° of longitude

Number of Cyclonic Eddies = 137

Number of Anticyclonic Eddies = 91
Time-Longitude Propagation along $20^\circ$S
Time-Depth Variations of Temperature at the IMET Mooring (20°S, 85°W)

Depth variations of isotherms can be 50-100 m for large eddies
Summary and Conclusions

• The Climate in the VOCALS region is complex and interdisciplinary, involving coupling between the ocean, atmosphere and land.

• The VOCALS region is poorly represented in CGCMs. Systematic errors in CGCMs are attributable to:
  - inadequate representation of MABL processes (turbulence, drizzle, mesoscale organization, etc.).
  - poor representation of cloud microphysical processes (i.e., aerosol processes, including transport from continents and oceanic biological sources, and removal by drizzle).
  - inadequate resolution of coastal upwelling and mesoscale oceanic eddies.

• Oceanic eddies are prolific in the VOCALS region.
  - Though their surface expressions are weak, their subsurface signatures can be large.

• Surface and subsurface observations, as well as ocean models, are needed to determine whether oceanic eddies can account for the heat flux of ~30 W/m² into the ocean observed at the IMET mooring at 20°S, 85°W.