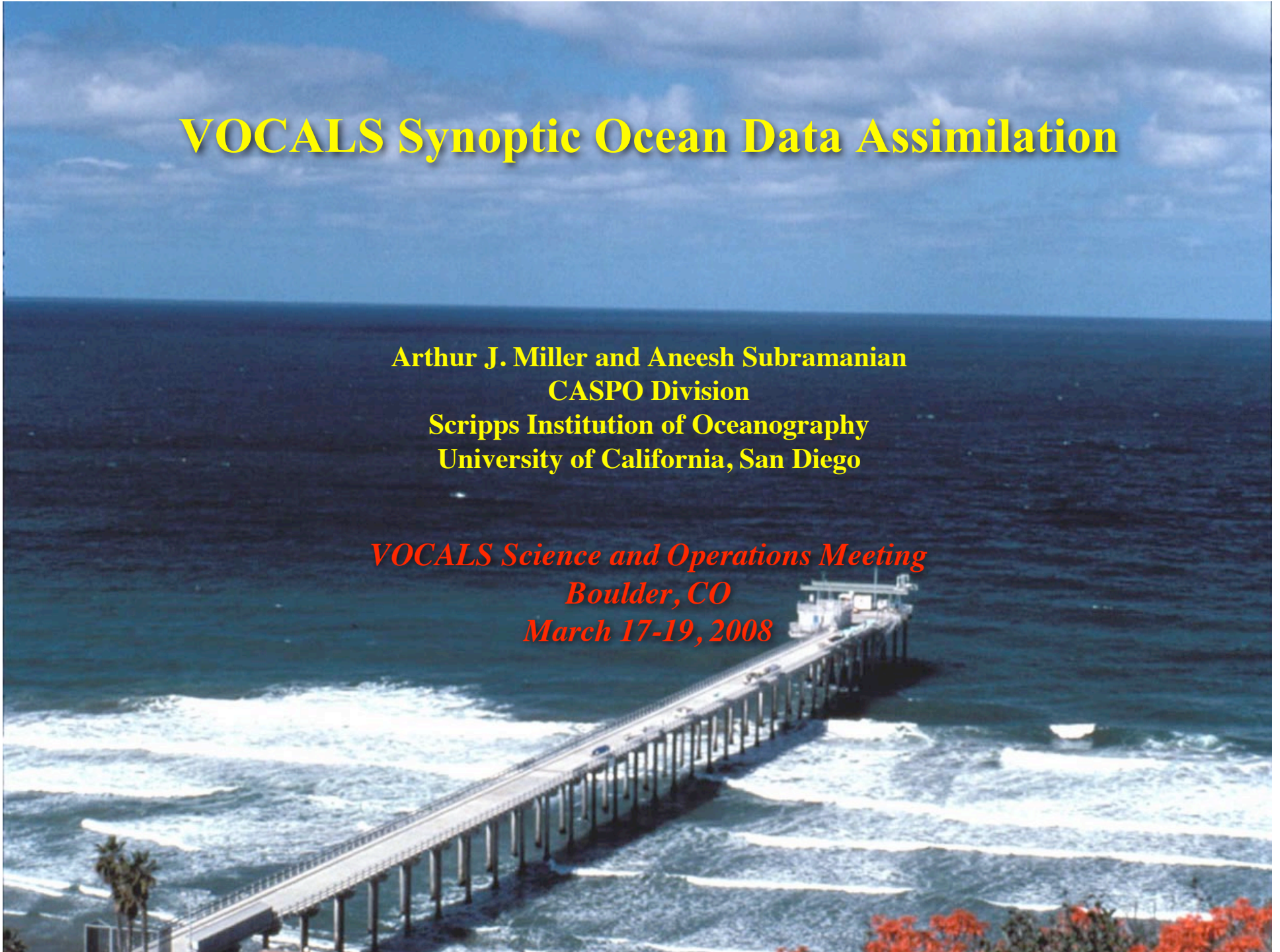


# VOCALS Synoptic Ocean Data Assimilation

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Scripps Institution of Oceanography  
University of California, San Diego

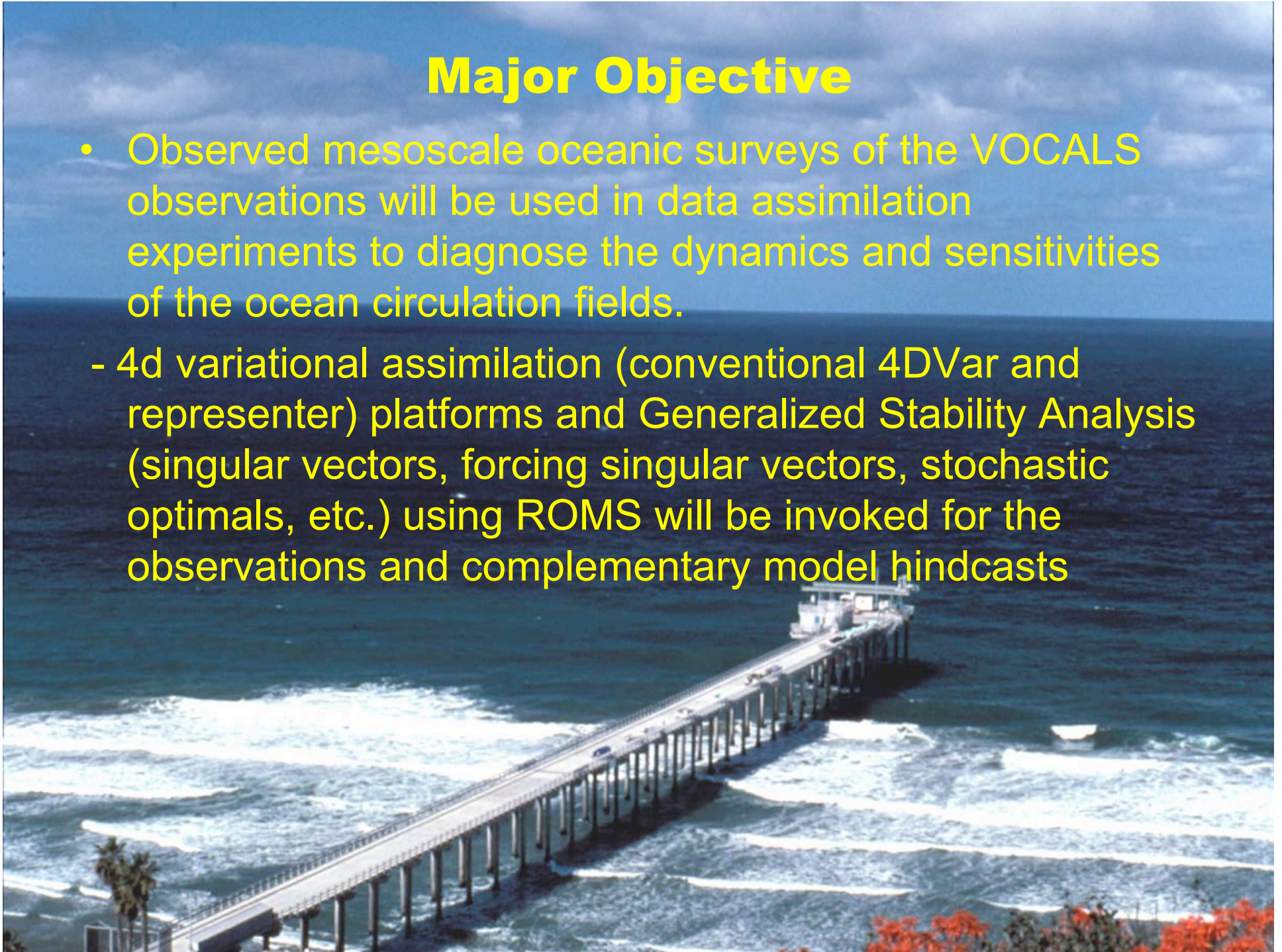
*VOCALS Science and Operations Meeting  
Boulder, CO  
March 17-19, 2008*





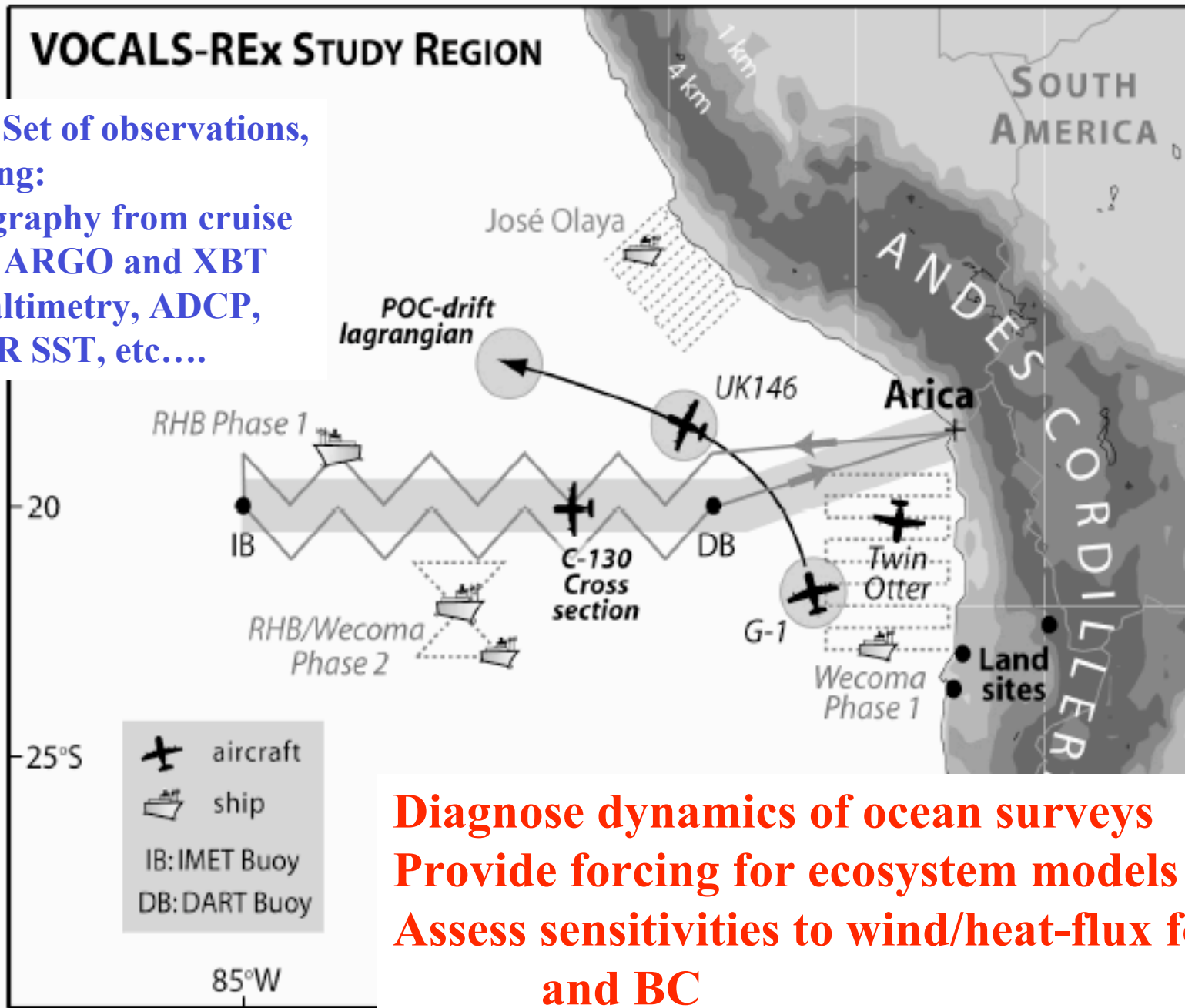
## Major Objective

- Observed mesoscale oceanic surveys of the VOCALS observations will be used in data assimilation experiments to diagnose the dynamics and sensitivities of the ocean circulation fields.
- 4d variational assimilation (conventional 4DVar and representer) platforms and Generalized Stability Analysis (singular vectors, forcing singular vectors, stochastic optimals, etc.) using ROMS will be invoked for the observations and complementary model hindcasts



## VOCALS-REX STUDY REGION

Given: Set of observations, including:  
Hydrography from cruise tracks, ARGO and XBT ships, altimetry, ADCP, AVHRR SST, etc....



**Diagnose dynamics of ocean surveys**  
**Provide forcing for ecosystem models**  
**Assess sensitivities to wind/heat-flux forcings and BC**  
**Determine predictability of mesoscale**



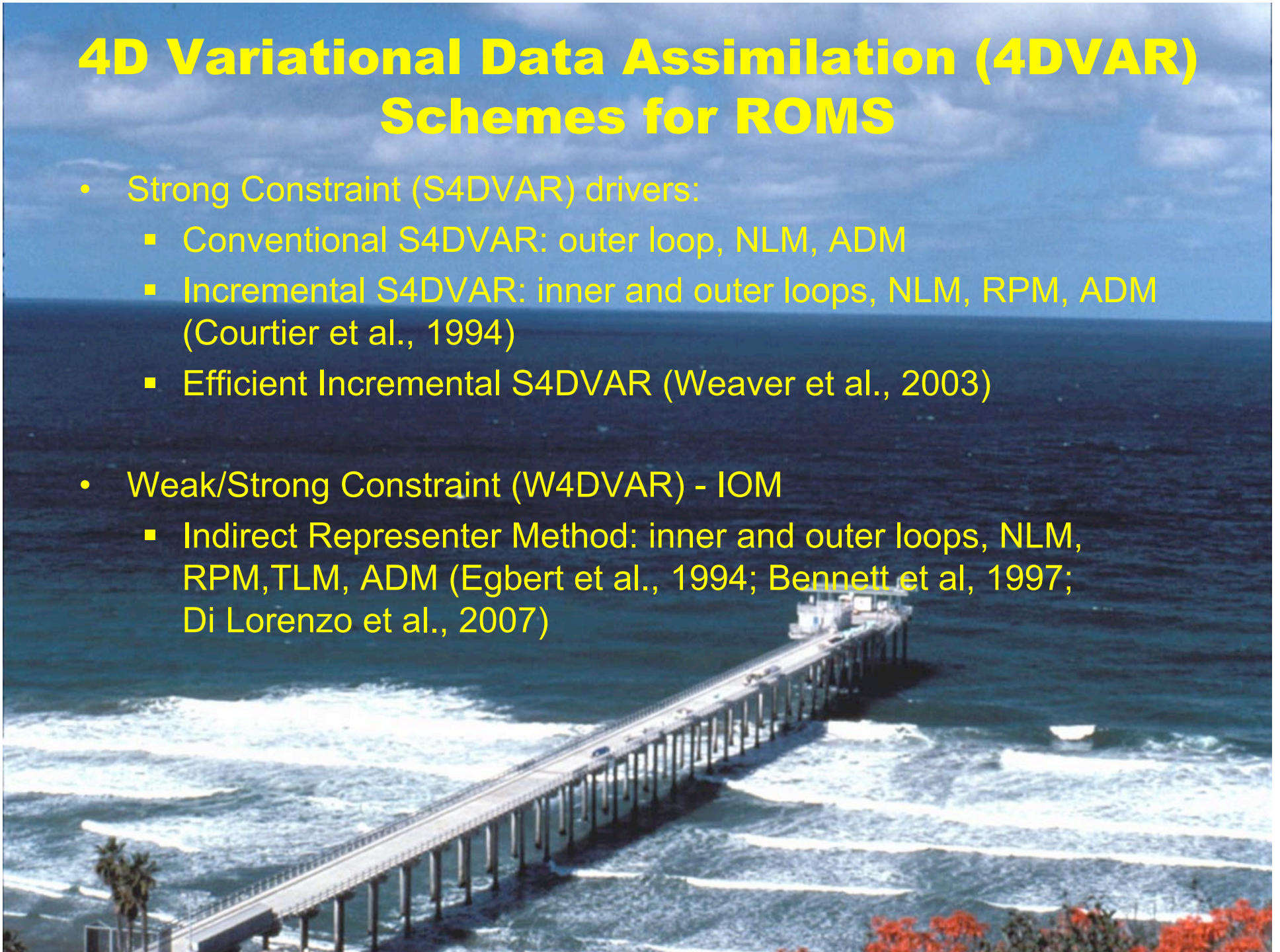
# VARIATIONAL DATA ASSIMILATION





# 4D Variational Data Assimilation (4DVAR) Schemes for ROMS

- Strong Constraint (S4DVAR) drivers:
  - Conventional S4DVAR: outer loop, NLM, ADM
  - Incremental S4DVAR: inner and outer loops, NLM, RPM, ADM (Courtier et al., 1994)
  - Efficient Incremental S4DVAR (Weaver et al., 2003)
- Weak/Strong Constraint (W4DVAR) - IOM
  - Indirect Representer Method: inner and outer loops, NLM, RPM, TLM, ADM (Egbert et al., 1994; Bennett et al., 1997; Di Lorenzo et al., 2007)





# Science Issues with ROMS Tools

## 1. Data Assimilation

- **Adjoint provides cost function gradient information.**
- **Fit model solutions to data by adjusting initial conditions, boundary conditions and parameters.**

## 2. Sensitivity Analysis

- **Sensitivity of a model solution to variations in model parameters evaluated efficiently using adjoint model.**

## 3. Eigenmode Analysis

- **The eigenmodes of the tangent linear equation represent dynamic modes of variability (“normal modes”); adjoint equation yields optimal excitations of corresponding eigenmodes for a chosen norm.**



## **Science issues....**

### **4. Singular Vectors:**

- **Most rapidly growing perturbations that exist (linear limit) for the dynamical system with respect to chosen norm.**
- **Very useful for assessing the stability of the system.**
- **Very useful for perturbing the model initial conditions for generating ensembles of forecasts.**

### **5. Stochastic Optimals (SOs) and Forcing Singular Vectors (FSVs):**

- **The most disruptive patterns of forcing for the TL model (with respect to a chosen norm).**

**Specific VOCALS applications will be developed.....**

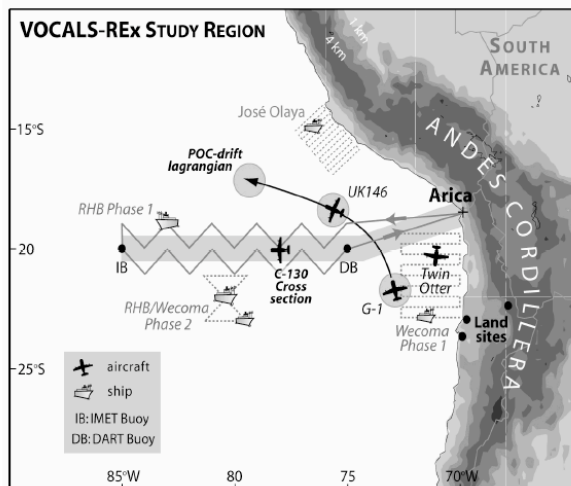


# VOCALS Mesoscale Ocean Dynamical Analysis with Synoptic Data Assimilation and Coupled Ocean-Atmosphere Modeling (NSF)

**Arthur J. Miller, Aneesh Subramanian,** Dian Putrasahan (Scripps Institution of Oceanography)  
Hyodae Seo (UCLA)

## 1. Ocean Data Assimilation

*What processes control oceanic mesoscale variability of the Peru-Humboldt Current System and its consequent influence on the heat transport and SST over the SEP?*

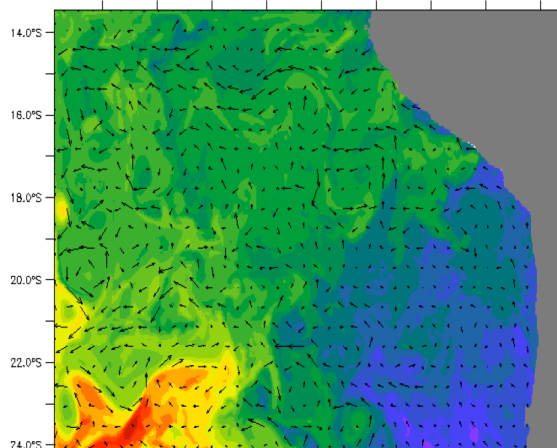


Ocean model (ROMS) hindcasts will assimilate the VOCALS *in situ* and satellite observations to provide a dynamically consistent representations of the physical oceanographic conditions over the region

- diagnose the processes that control the observed physical variability that determines the heat transport, surface flux processes, nutrient transport and mixing properties observed in the surveys.

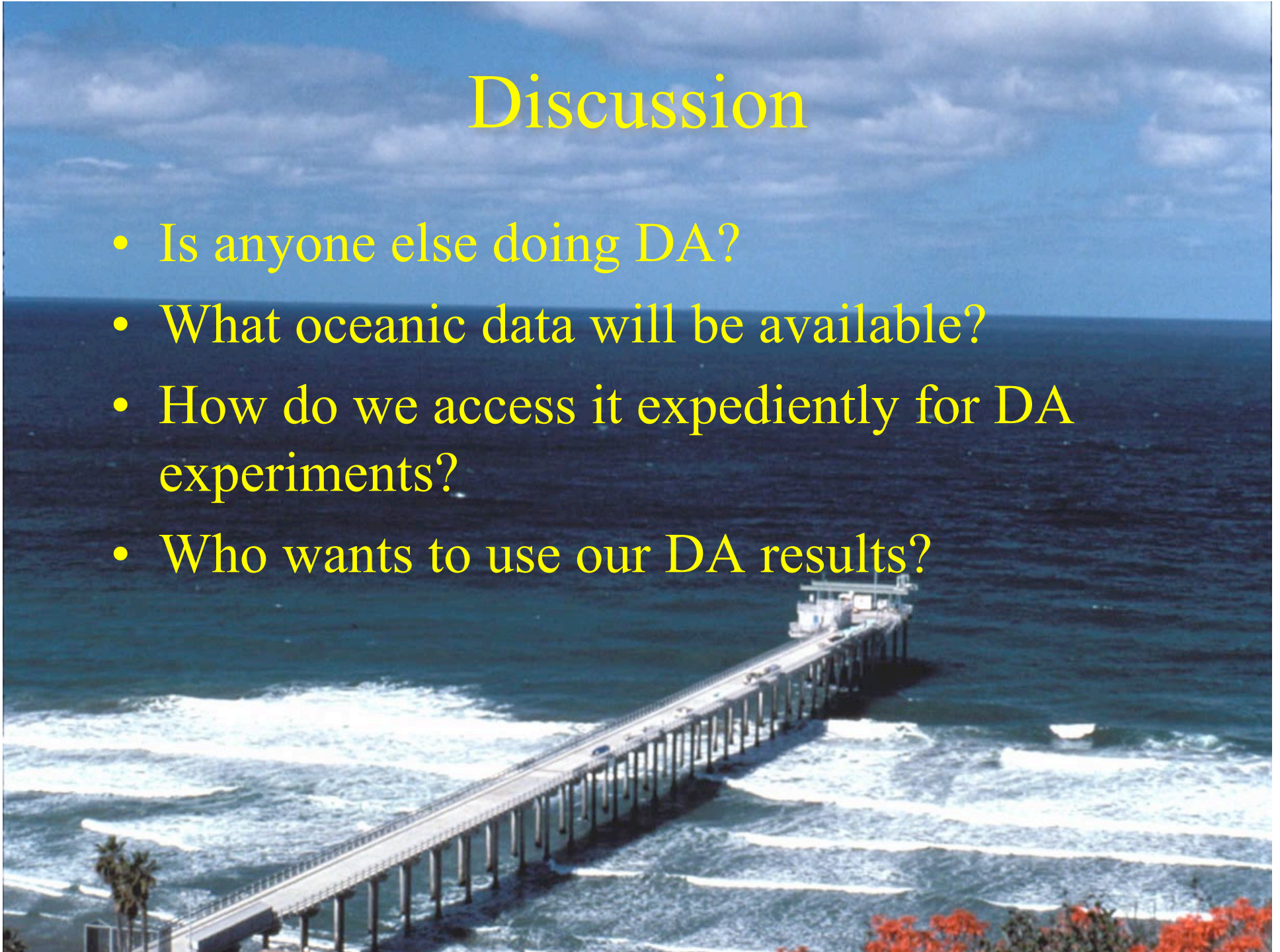
- compute the sensitivities of the oceanic flows in the SEP to atmospheric forcing and remote oceanic forcing with Generalized Stability Analysis tools.

- provide 4D physical forcing for ecosystem models and for observed biological diagnostics.



# Discussion

- Is anyone else doing DA?
- What oceanic data will be available?
- How do we access it expediently for DA experiments?
- Who wants to use our DA results?







**Art Miller and Aneesh Subramanian**  
**CASPO Division**  
**SIO-UCSD**

*VOCALS Science and Operations Meeting*

**Thanks!**

# VOCALS Mesoscale Ocean Dynamical Analysis with Synoptic Data Assimilation and Coupled Ocean-Atmosphere Modeling (NSF)

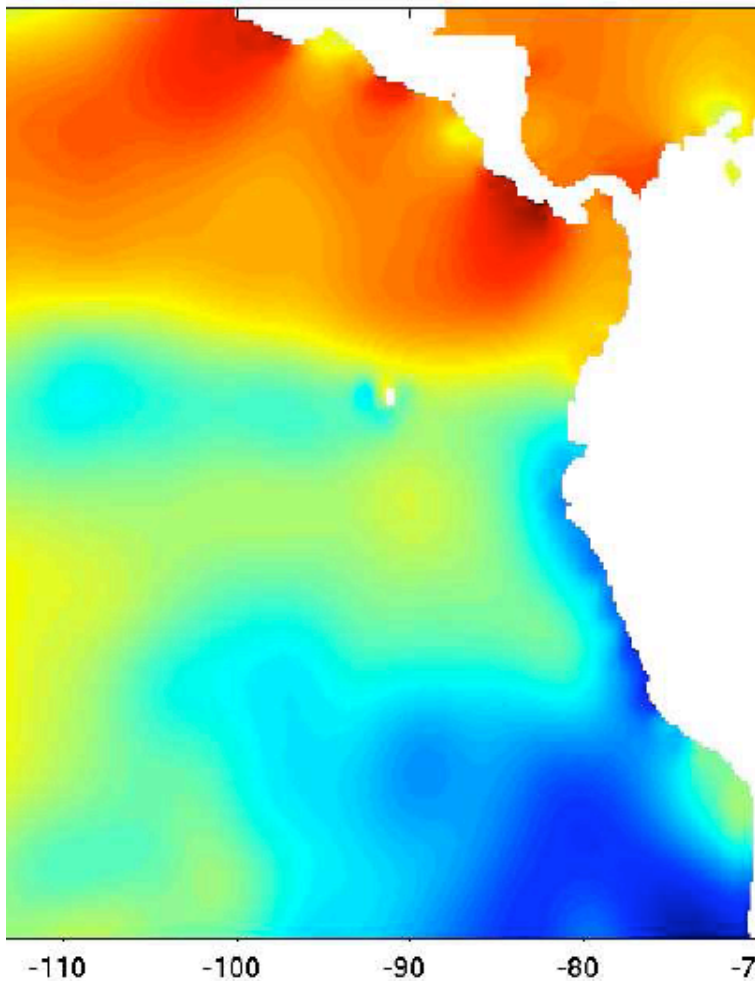
**Arthur J. Miller**, Aneesh Subramanian, **Dian Putrasahan** (Scripps Institution of Oceanography)  
**Hyodae Seo** (UCLA)

## 2. Coupled O-A Modeling

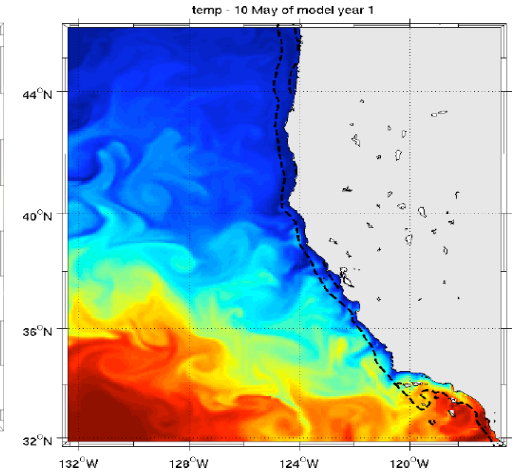
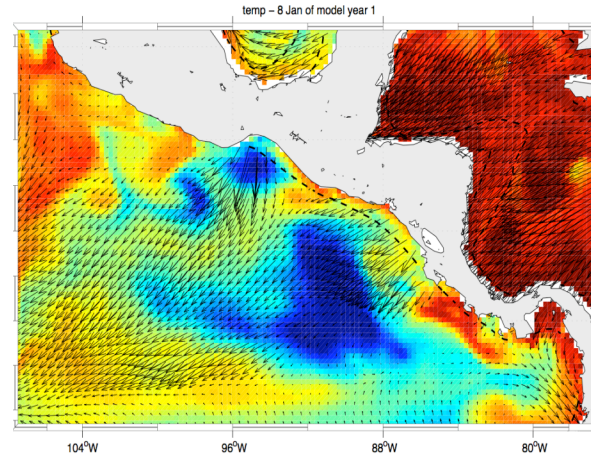
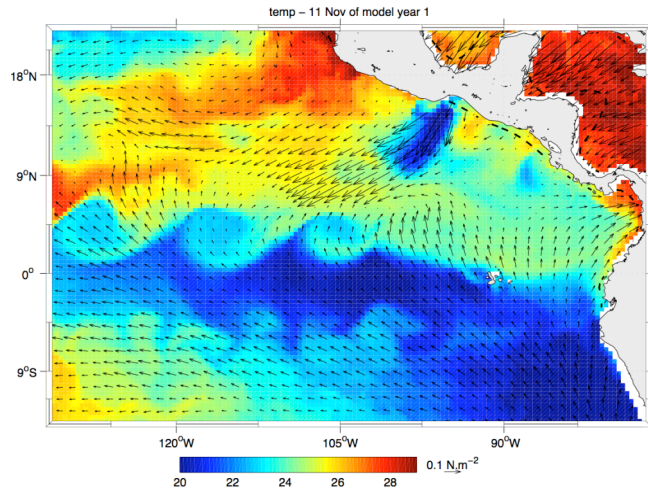
*What is the effect of mesoscale ocean-atmosphere coupling on the distribution of SST, mesoscale eddy statistics, cloud variability and regional-scale oceanic and atmospheric mean circulation?*

**Regional ocean-atmosphere (SCOAR: ROMS-RSM) model downscaled hindcasts of large-scale observed atmospheric flows will allow full ocean-atmosphere coupling, orography and land-sea distribution**

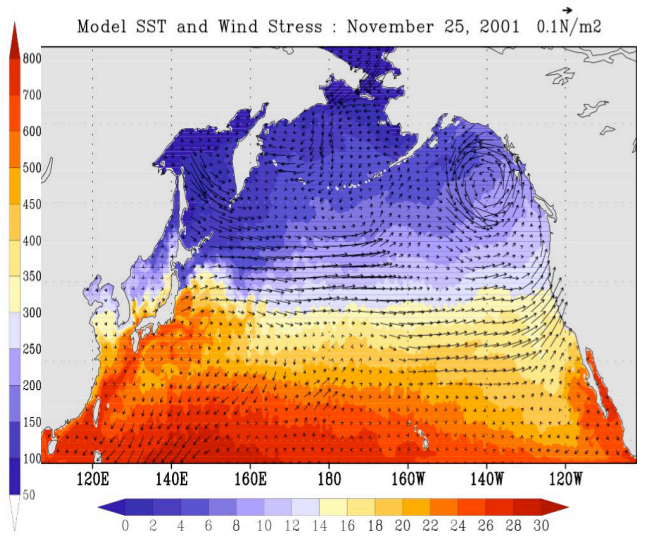
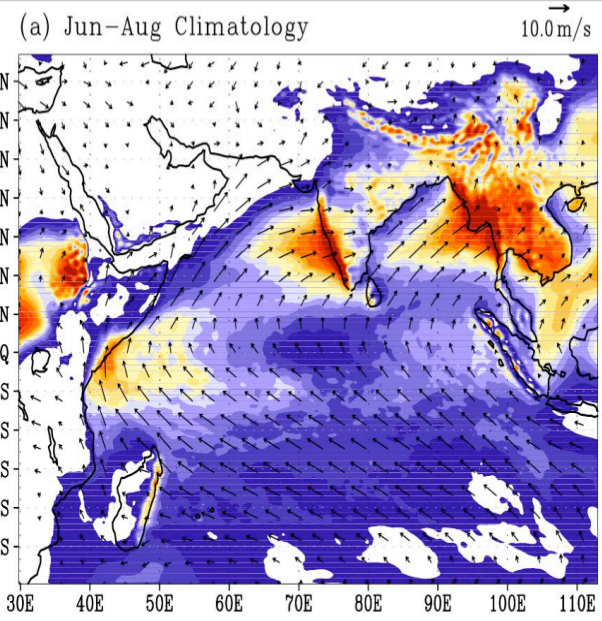
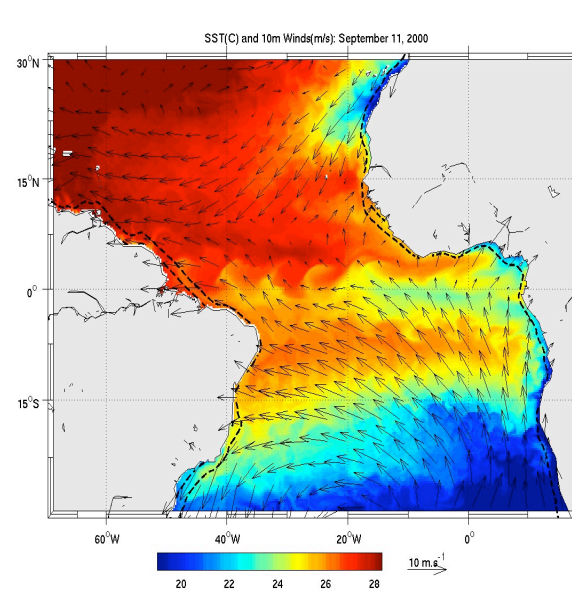
- compare coupled O-A runs to uncoupled atmosphere and uncoupled ocean model runs during VOCALS and other longer time periods
- compute statistics of intraseasonal through interannual variability of ocean mesoscale and local atmosphere
- determine mechanisms that control mesoscale eddy characteristics and distribution in the SEP and links between large-scale climate-scale forcing and variability of the SEP.







**Scripps Coupled Ocean-Atmosphere Regional (SCOAR) Model:**  
 to study effects of ocean-atmosphere coupled feedback on the regional climate.





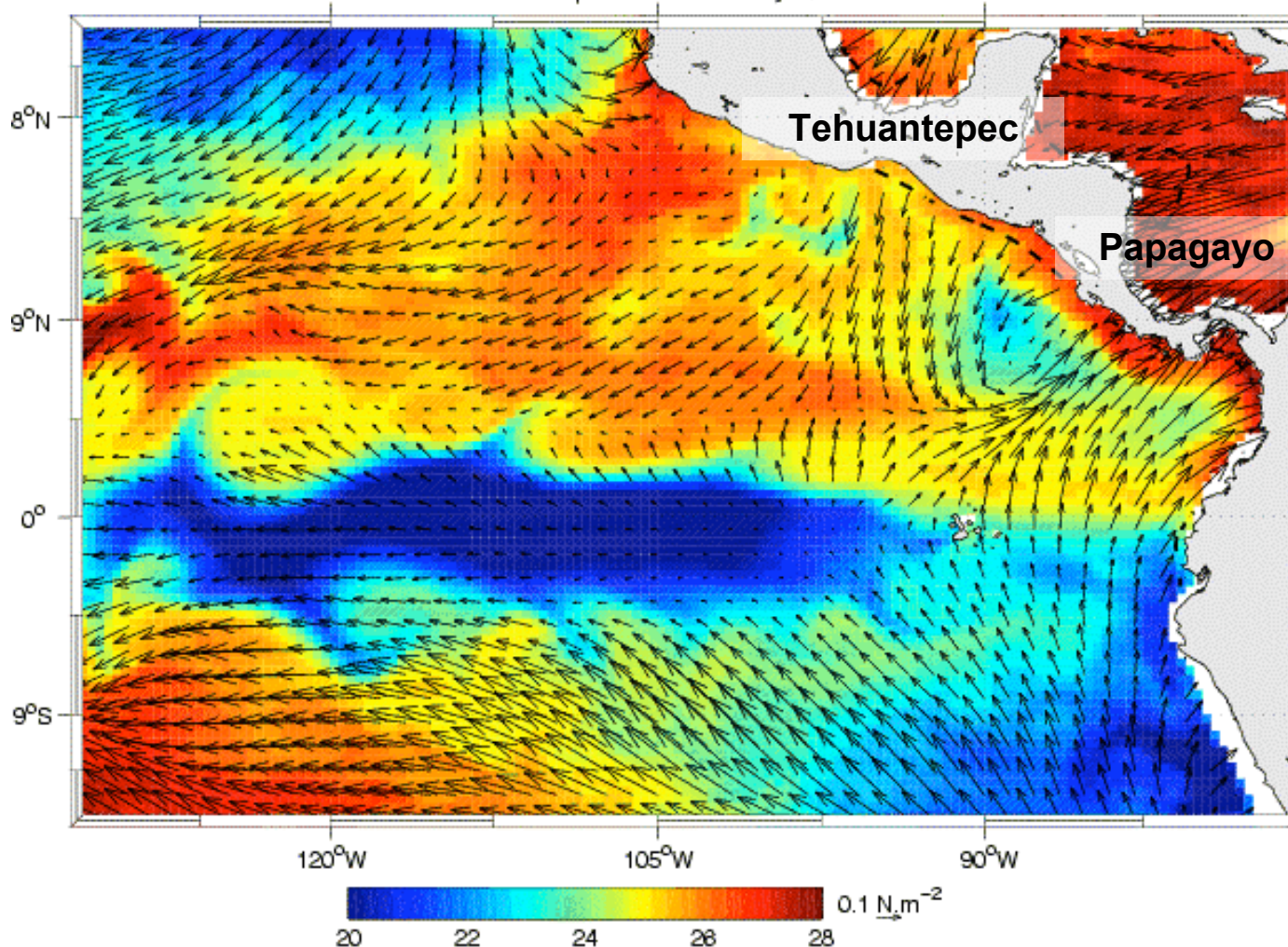
# Eastern equatorial Pacific domain example

Evolving SST and wind-stress vector in 1999-2000

45 km ROMS + 50 km RSM

Hyodae Seo, Art Miller and John Roads (*J. Climate*, 2006)

temp - 3 Jan of model year 1



- **Coupled system**

- ITCZ / Eastern Pacific Warm Pool
- Cross-equatorial trade winds
- *Gap Winds*
- Tropical Depressions and Hurricanes
- Equatorial and Coastal Upwelling
- Tropical Instability Waves

*VOCALS Domain* now being tested by Dian Putrasahan and Hyodae Seo