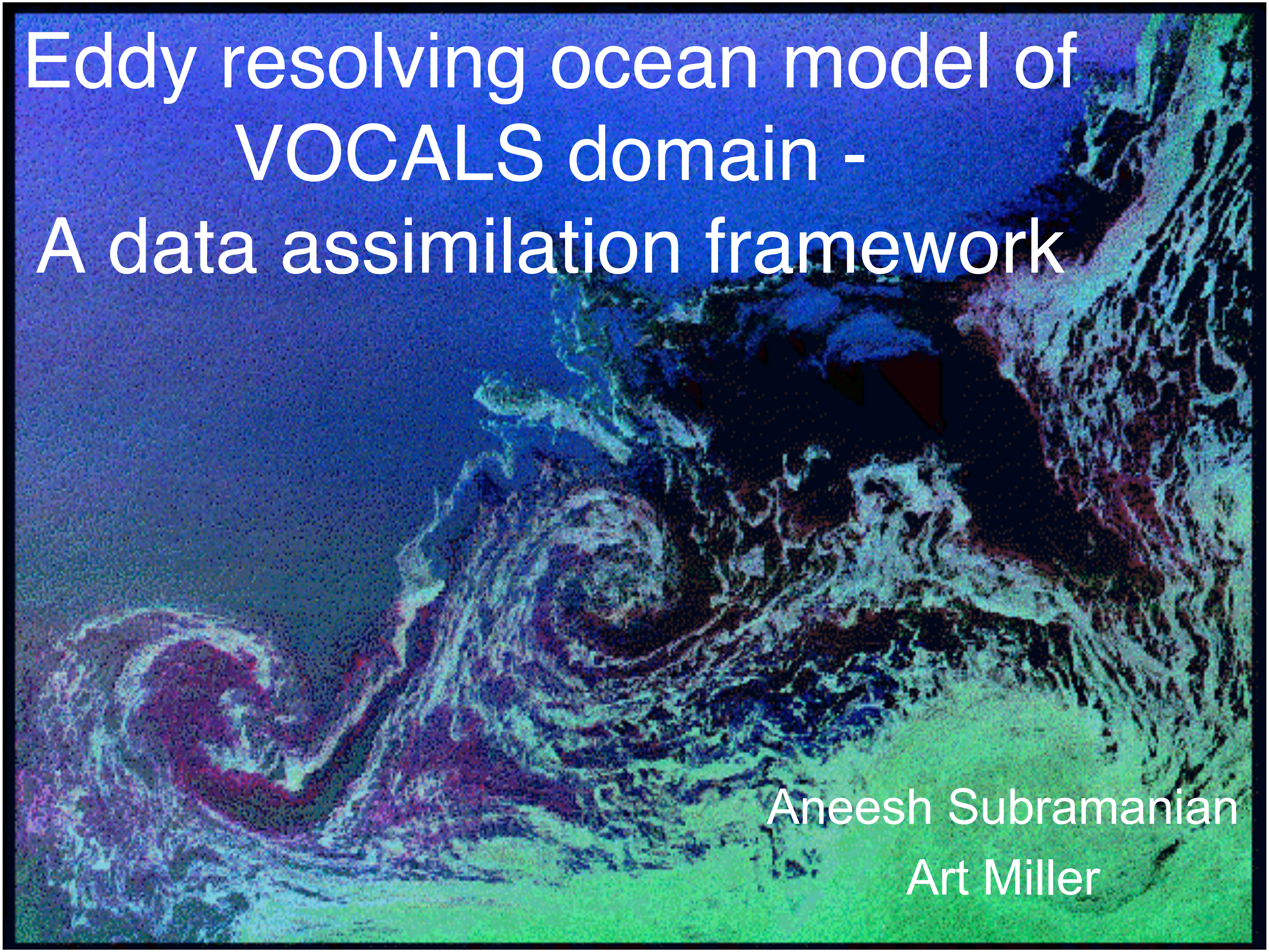

Eddy resolving ocean model of VOCALS domain - A data assimilation framework

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Art Miller

Regional Ocean Modeling of SEP - A data assimilation framework

- Motivation:

  - To diagnose the **physical balances and sensitivities** of the ocean circulation fields.

  - **Data assimilation experiments** with observed mesoscale oceanic surveys of the VOCALS observations and a regional ocean modeling system.

  -This is vital for **understanding** the **biological response**, as well as the **heat transport processes** observed during REx.

Model settings and Observations

• VOCALS-Rex Study Region (13S~27S, 69W~90W)

• Wind forcing – QuikSCAT climatology and QuikSCAT annual wind stress data.

• Heat flux – COADS climatology or NCEP annual data.

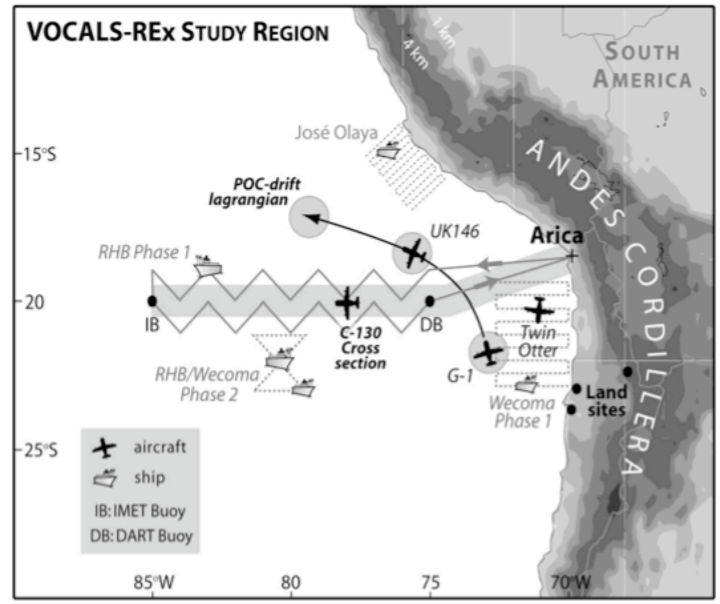
• Freshwater flux – COADS climatology.

• Boundary condition – Radiation condition with 3 degree sponge layer and nudging to the climatology for open boundary.

• 1/15° resolution for zonal and meridional directions (about 7.5 km)

• 32 vertical levels

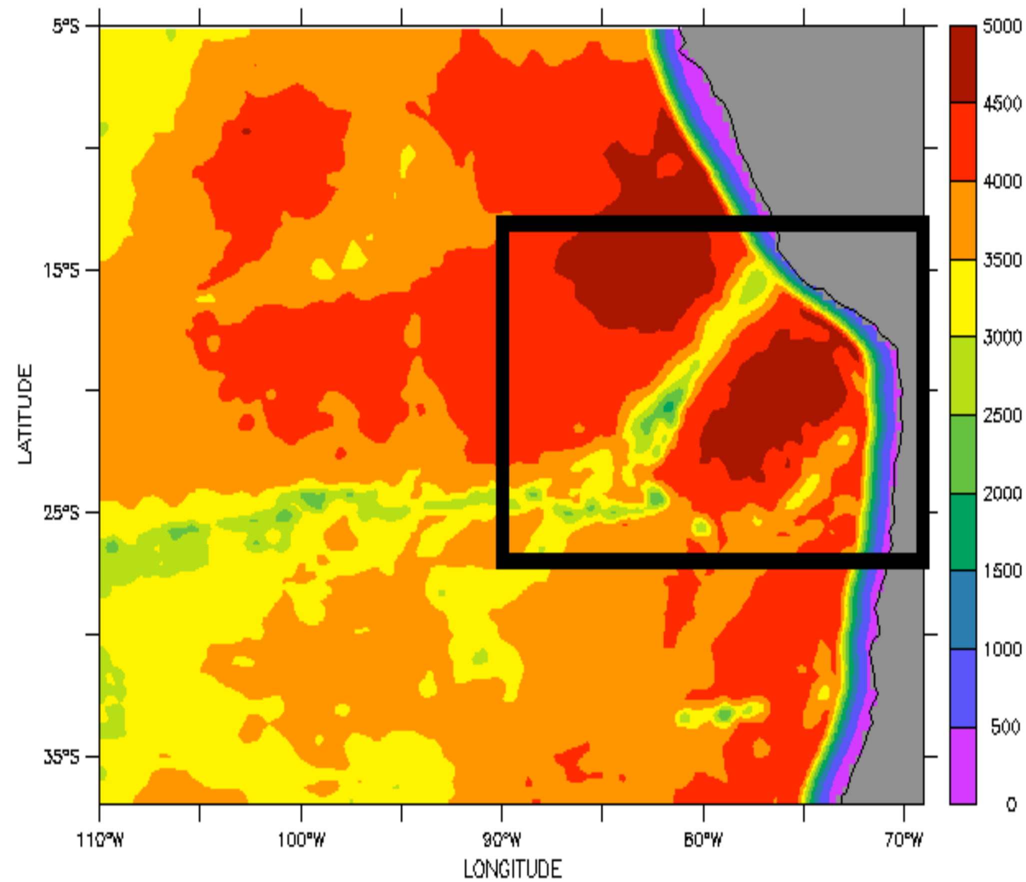
• 7 years climatological spin-up and then annual forcing with 2007-08 winds from QuikSCAT.



VOCALS-Rex study region and key platforms/components. Ship cruise track of Nov 2008 is shown here.

Model Configuration

- Outer domain (110º W to 69º W and 5º S to 37º S)has a horizontal resolution of 20 km and has 32 vertical levels.
- Inner-domain (90º W - 69º W, 13º S - 27º S) has a horizontal resolution of about 7 km and is the focus of the present study.
- At open boundaries, the inner-domain solution was constrained to match the solution of the outer domain. Radiation conditions were imposed on the free-surface and vertically integrated velocity. No-slip conditions were imposed at all coastal boundaries on velocity, and zero gradient conditions on the free-surface and all tracers.



Contours of the bathymetry used in the ROMS outer and inner- domains for the South East Pacific ocean configuration of the model.

Data assimilation experiments

• Data assimilation of VOCALS cruise time intervals can be achieved using the inverse ROMS, a 4D variational data assimilation system for high-resolution (7 km resolution model) basin-wide and coastal oceanic flows.

•Sensitivity of the South East Pacific ocean circulation is studied using adjoint tracer calculations.

• Sensitivity studies also imply the possible impacts the various datasets will have in data assimilation experiments and also significantly indicate the predictability of the model.

Adjoint Sensitivity

- Consider a model state vector described as $\Phi = (u, v, T, S, \varsigma)^T$
- A cost function $J(\Phi)$ is defined as a function of the state vector Φ.
- Small changes $\delta\Phi$ in Φ will reflect as changes δJ in J.

$$\delta J = \left(\frac{\partial J}{\partial u}\right)\delta u + \left(\frac{\partial J}{\partial v}\right)\delta v + \left(\frac{\partial J}{\partial T}\right)\delta T + \left(\frac{\partial J}{\partial S}\right)\delta S + \left(\frac{\partial J}{\partial \varsigma}\right)\delta\varsigma$$

- Adjoint sensitivity can be defined as:

$$u^{\dagger} = \left(\frac{\partial J}{\partial u}\right),\ v^{\dagger} = \left(\frac{\partial J}{\partial v}\right),\ T^{\dagger} = \left(\frac{\partial J}{\partial T}\right),\ \text{etc}$$

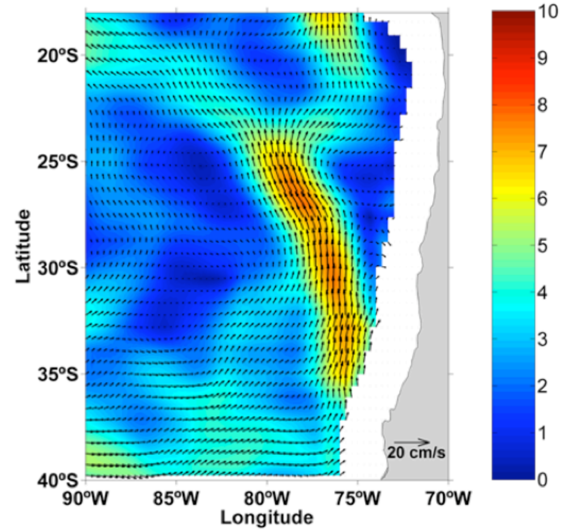
- Hence it can be shown that the solution of the adjoint system also represents the system's sensitivity

$$\Phi^{\dagger} = (u^{\dagger}, v^{\dagger}, T^{\dagger}, S^{\dagger}, \varsigma^{\dagger})^T$$

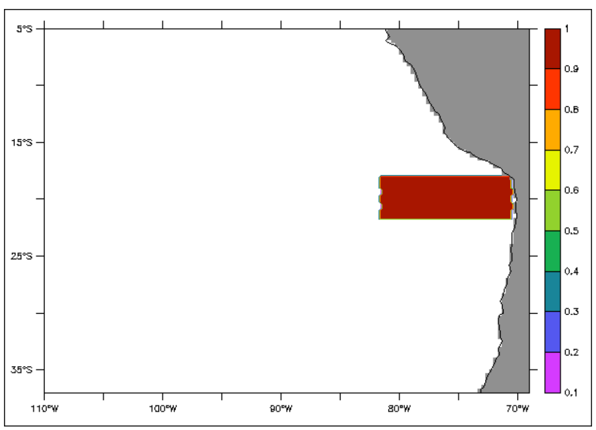
Surface adjoint sensitivity of the South East Pacific ocean domain in an adjoint sensitivity test case was run for 90 days to test the sensitivity of the coastal region to surrounding coastal flows. Sensitivity to strong coastal upwelling and the Humboldt current was evident from the simulations.

Adjoint Sensitivity experiments

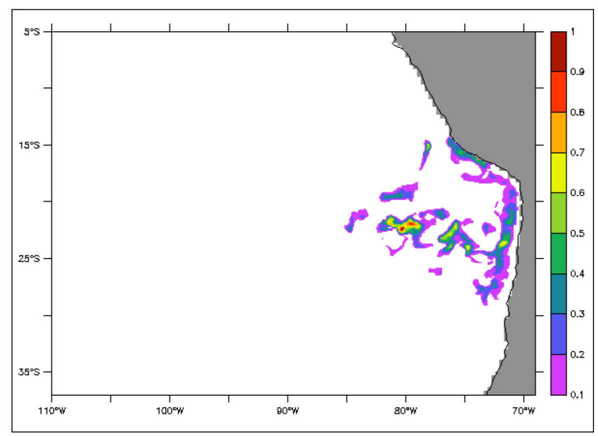
Surface Geostrophic Velocities in austral summer from observations. [Fuenzalida, R., Schneider, W.,Vargas,J. G., and Bravo, L., 2008: Satellite altimetry data reveal jet-like dynamics of the Humboldt Current. *Journal Of Geophysical Research*, Vol. 113]



(a)



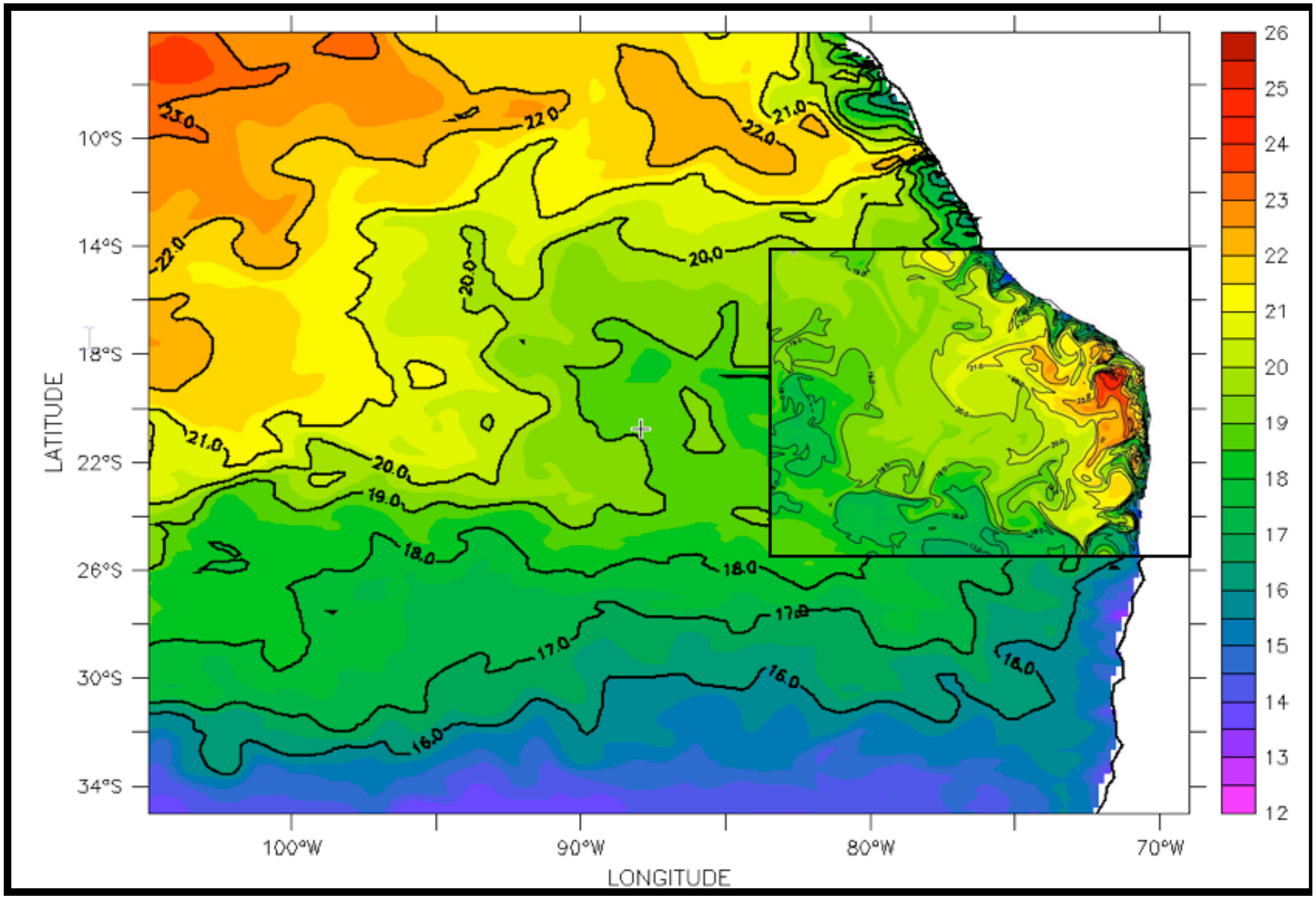
(b)



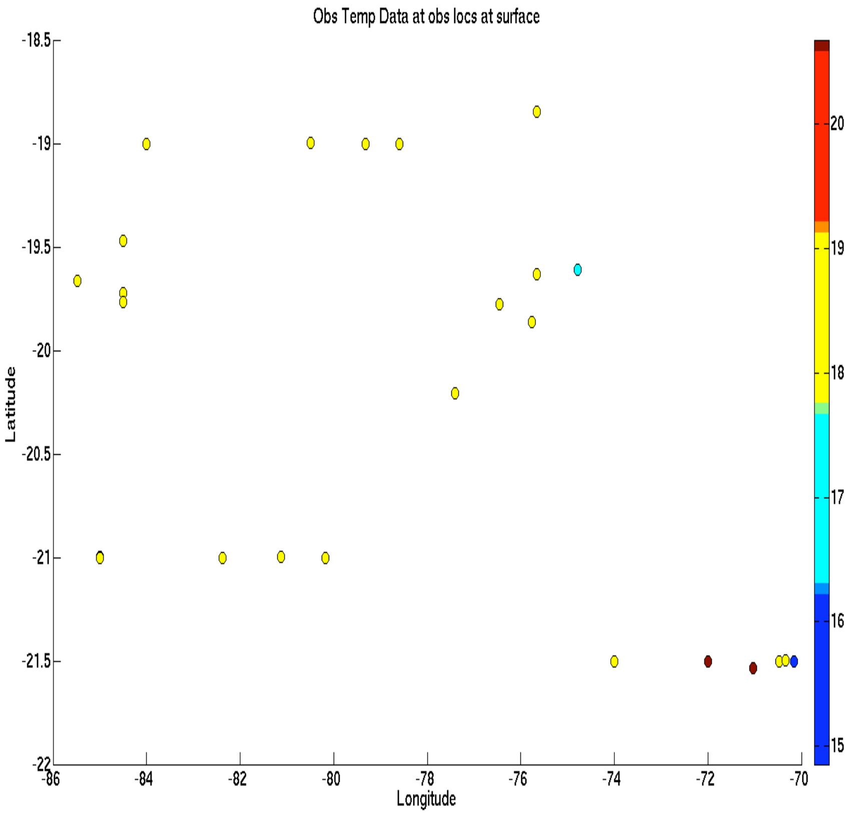
(a) Initial state and (b) 90 day prior to the initial state percent ratio of the passive tracer concentrations close to the surface indicating a bifurcation in the jet-like structure of the Humboldt current.

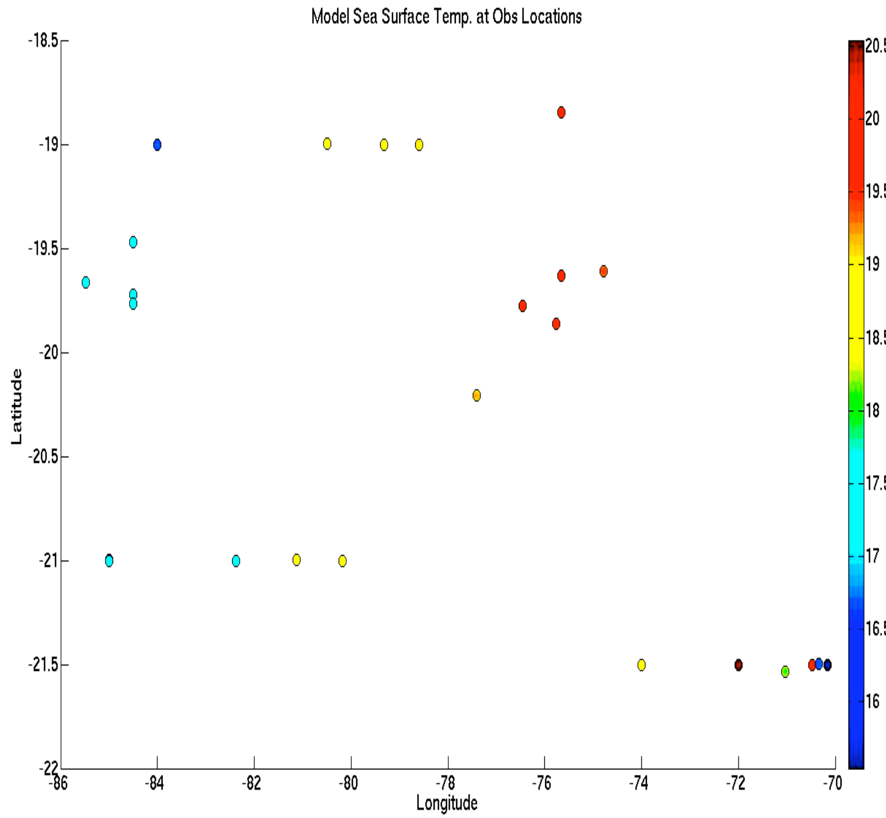
Model SST field - Inner and Outer Domain

Inner Domain SST is inside the box superimposed on the Outer Domain SST at the same time for a model time of 10 Oct 2008



Comparing Model SST with Ron Brown CTD SST (RMSE=0.96)





Ron Brown SST

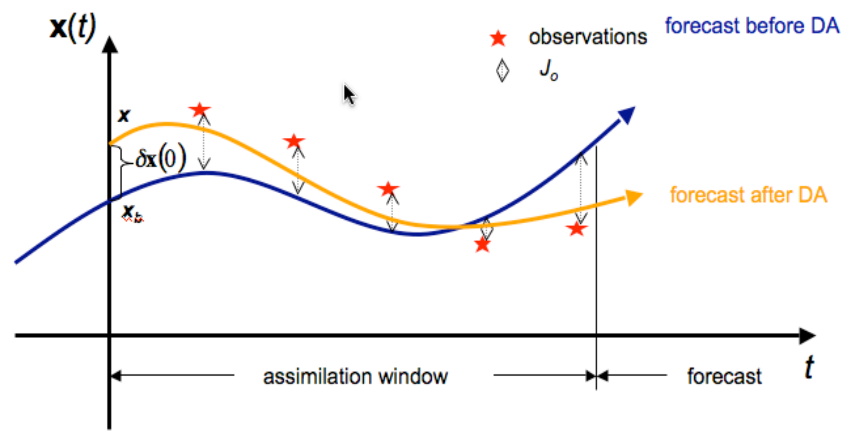
Model SST

List of Data obtained for assimilation

- Data Sets Obtained:
  - Ron Brown CTD data (Temp., Salinity)
  - SST (TMI), SSH (Topex-Poseidon)
  - ARGO Profiles (Validation)
  - Surface drifters (Validation)
- Data Sets Needed:
  - Jose Olaya Data sets, other available data sets.

Incremental Strong Four-Dimensional Variational Analysis (IS4DVAR)

- We want to estimate a new state which is close to the observations, yet dynamically consistent.
- IS4DVAR corrects initial states only. However it is still able to estimate ocean states better.
- We use the cost function a combination of two terms – changes in the initial model states and residuals from observations. It is defined below.



$$J(\delta\mathbf{x}(0)) = \underbrace{\frac{1}{2}\delta\mathbf{x}(0)^T \mathbf{B}^{-1}\delta\mathbf{x}(0)}_{J_b} + \underbrace{\frac{1}{2}\sum_{i=1}^{N}\{\mathbf{H}_i(\mathbf{x}_i+\delta\mathbf{x}_i)-\mathbf{y}_i\}^T \mathbf{O}_i^{-1}\{\mathbf{H}_i(\mathbf{x}_i+\delta\mathbf{x}_i)-\mathbf{y}_i\}}_{J_o}$$

$\mathbf{x}$	Model states	i	Observation time step	N	Total # of obs time steps
$\delta\mathbf{x}$	Perturbation in model states	$\mathbf{y}$	Observations	$\mathbf{O}$	Observation error covariance
$\mathbf{B}$	Background error covariance	$\mathbf{H}$	Observation operator		

- The solution will minimize the cost function. This means that it will make both the residuals and the changes in the initial states small.
- Therefore, the solution for $\delta\mathbf{x}(0)$ satisfies $\nabla_{\delta\mathbf{x}}J = \mathbf{B}^{-1}\delta\mathbf{x}(0) + \sum_{i=1}^{N}\mathbf{H}_i^{\mathbf{T}}\mathbf{O}_i^{-1}(\mathbf{H}_i(\mathbf{x}_i+\delta\mathbf{x}_i)-\mathbf{y}_i) = 0$

Goals and Future Work

- Data assimilation “fits” of the VOCALS hydrographic surveys (and concomitant data) will provide crucial dynamically consistent diagnostics of the circulation for interpreting the relation between physical variables, atmospheric variables and biology.
- Associated with the data assimilation platform of Inverse ROMS is a suite of Generalized Stability Analysis tools which will allow the quantitative assessment of sensitivities of model solutions to various parameters, such as upstream ocean forcing, topography, winds, heat fluxes.

Summary

ROMS eddy resolving high resolution coastal ocean model in the Peruvian Current system was setup forced by satellite derived winds and estimated heat fluxes. This high resolution ROMS coastal model is nested in a coarser resolution model to have a more consistent boundary condition. Further tests in adjoint sensitivity of this region needs to be performed to understand the regional dynamics better of the VOCALS region, before data assimilation is embarked upon.

Acknowledgements

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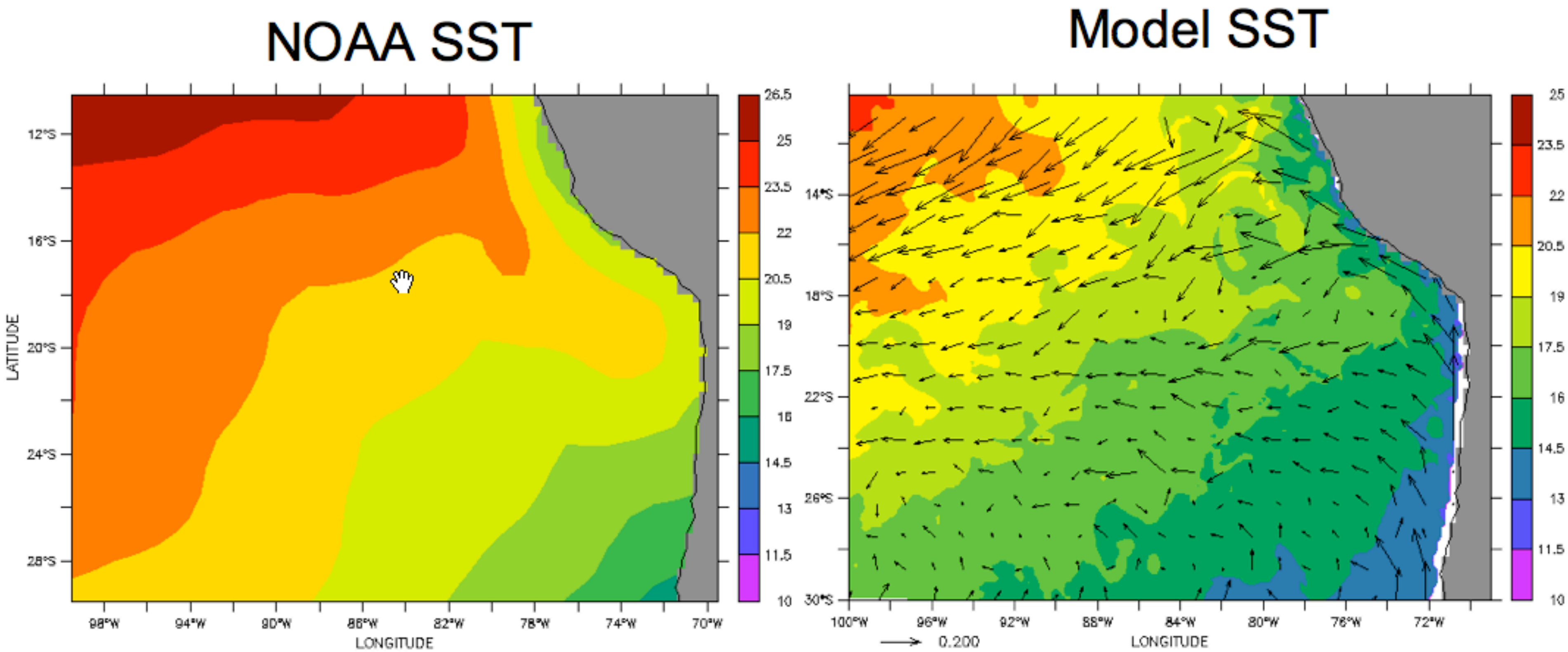
Thank You


TURING TEST EXTRA CREDIT:
CONVINCE THE EXAMINER THAT HE'S A COMPUTER.
YOU KNOW, YOU MAKE SOME REALLY GOOD POINTS.
I'M ... NOT EVEN SURE WHO I AM ANYMORE.

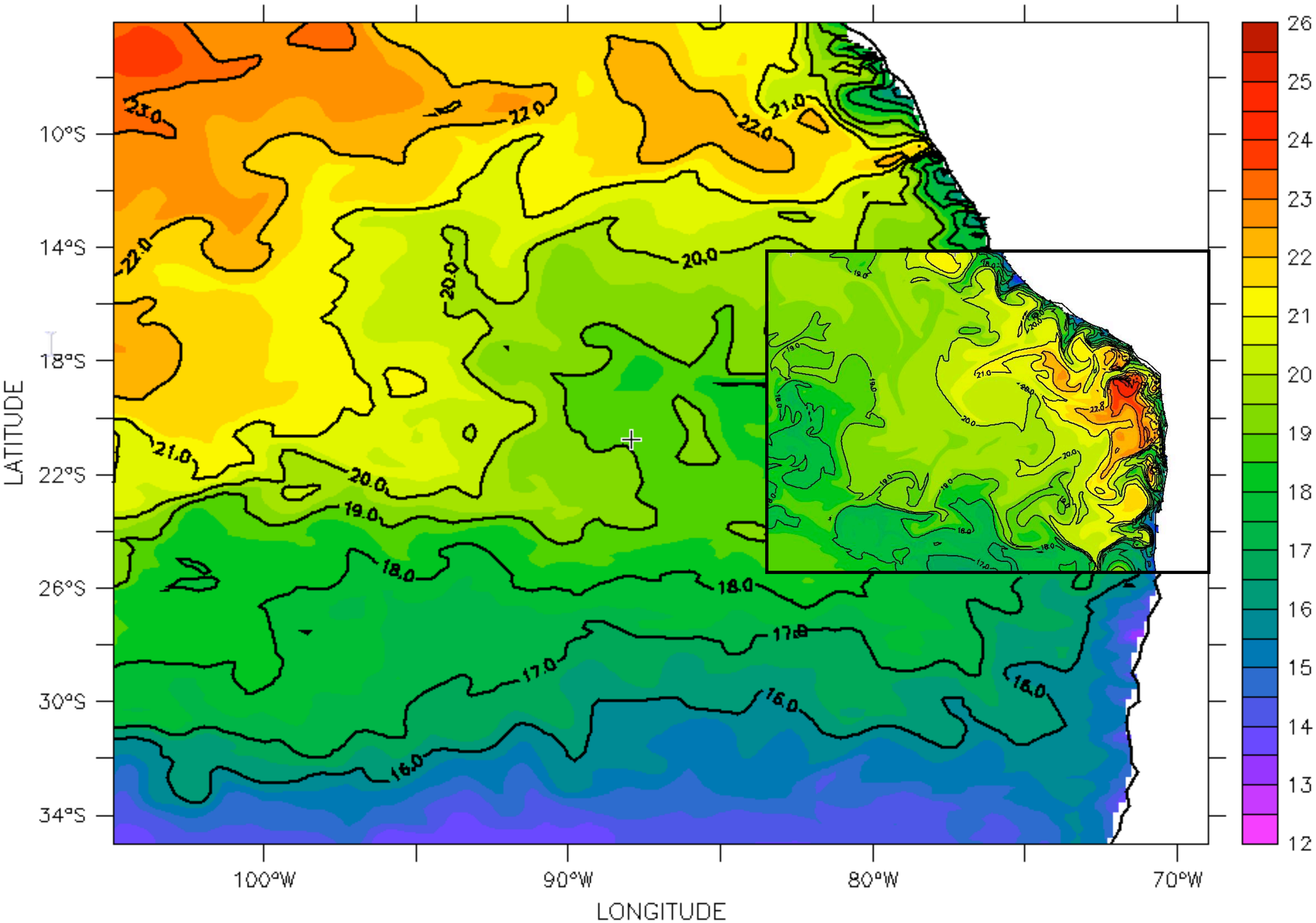
Regional Ocean Modeling of SEP - A data assimilation framework

- Model
  - A one-way nested configuration of ROMS (Regional Ocean Modeling System) was setup.
  - Radiation conditions were imposed on the free- surface and vertically integrated velocity. No-slip conditions were imposed at all coastal boundaries on velocity, and zero gradient conditions on the free-surface and all tracers.
  - Both the inner and outer-domains employ the same physical parameterizations and numerical algorithms.

Comparison of NOAA OI SST V2 with the Model derived SST for May 2006



- After model spin up forced by climatological surface winds and heat and freshwater fluxes, the model was forced with winds from QuikSCAT data and heat and freshwater fluxes from NCEP Reanalysis of 2006. The geostrophic velocities are also plotted for the model fields. The Model has a cold bias of about 1 - 1.5 o C.



10°S
14°S
18°S
22°S
26°S
30°S
34°S
LATITUDE
100°W
90°W
80°W
70°W
LONGITUDE
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