National Oceanographic Partnership Program
Promoting Partnerships for the Future of Oceanography

UCSC California Current System Data Assimilation Activities

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2011 GOV GSOP Workshop

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Santa Cruz, CA
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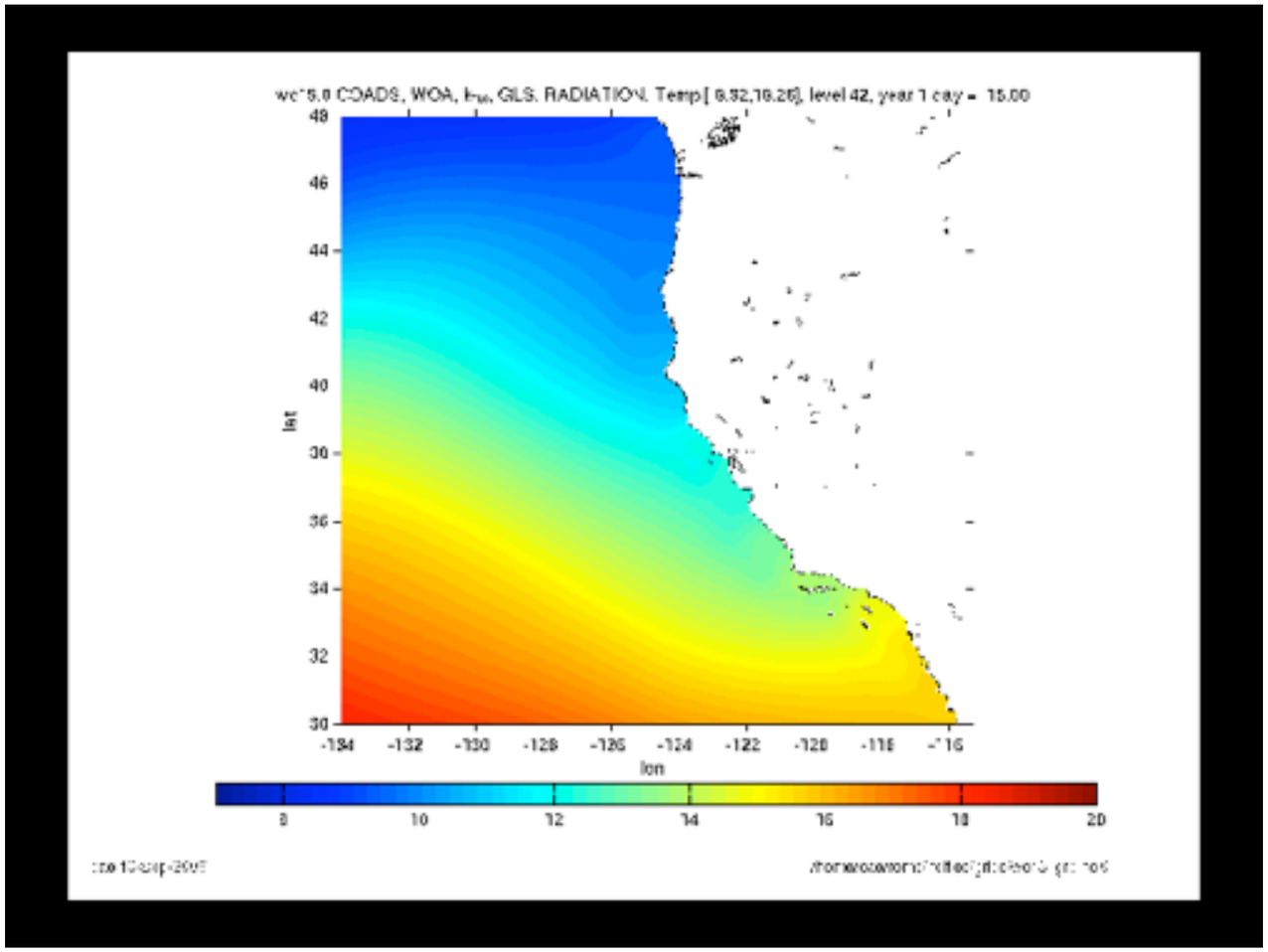
J. Doyle (NRL)

UCSC California Current System model

- Configuration
  - Regional Ocean Modeling System (ROMS)
  - Surface Forcing: COAMPS (NRL-Monterey)
  - Outer Boundary Conditions: ECCO-GODAE (MIT/JPL), SODA, Climatology

- Activities
  - Forward model
  - Data Assimilation
  - Ecosystem/Biogeochemistry
  - Floats/Larval Dispersal

- Various ROMS Grids:
  - 1/3°, 1/10°, 1/30°, 1/90°, 1/270°

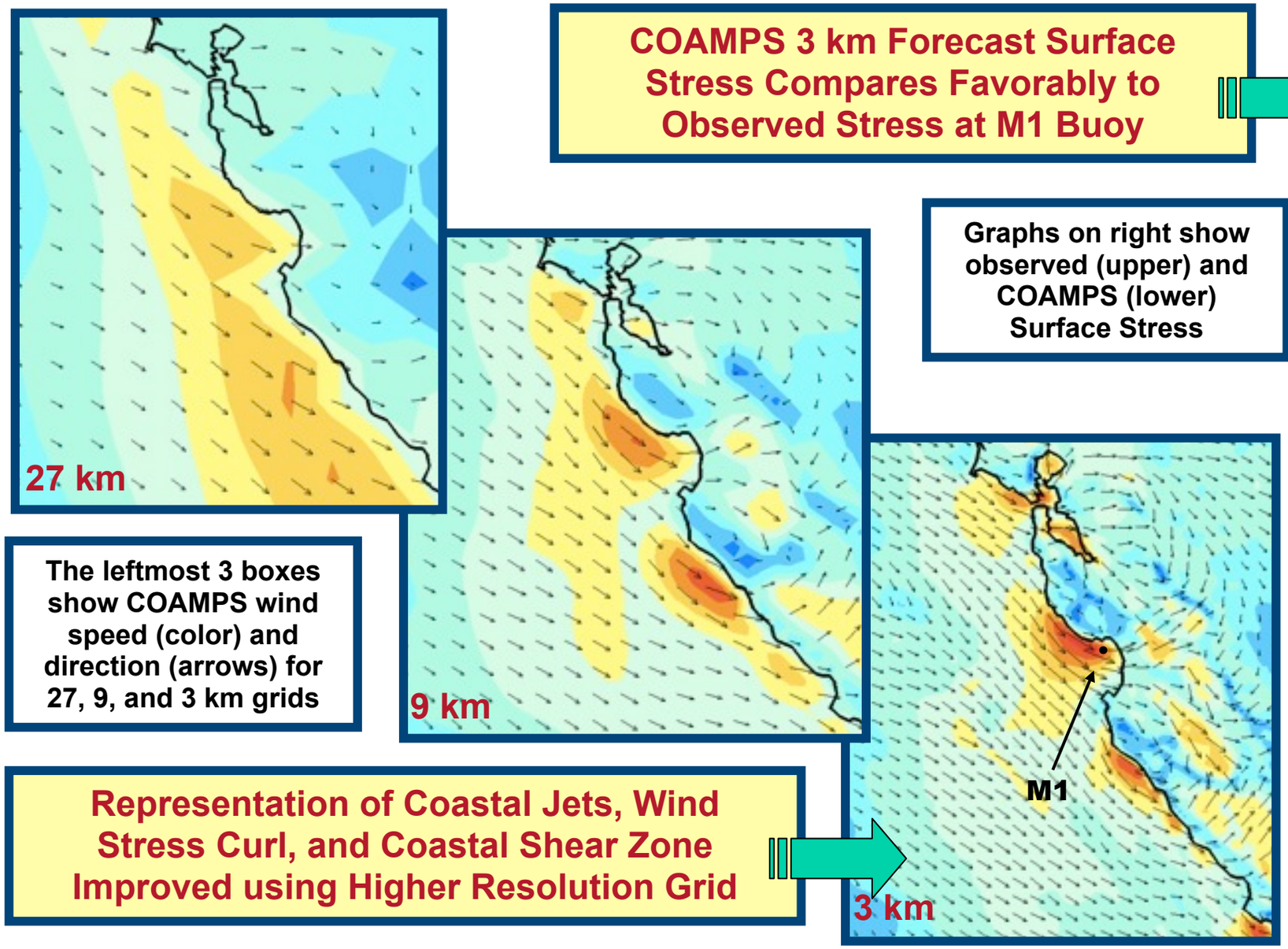


COAMPS Real-Time Forecasts

Products for Atmospheric/Oceanic Forecasting

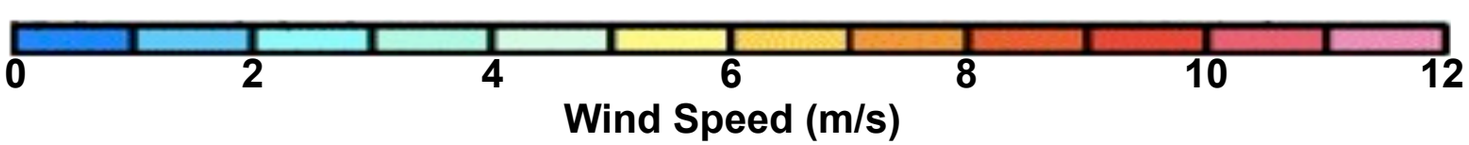
COAMPS 3 km Forecast Surface Stress Compares Favorably to Observed Stress at M1 Buoy

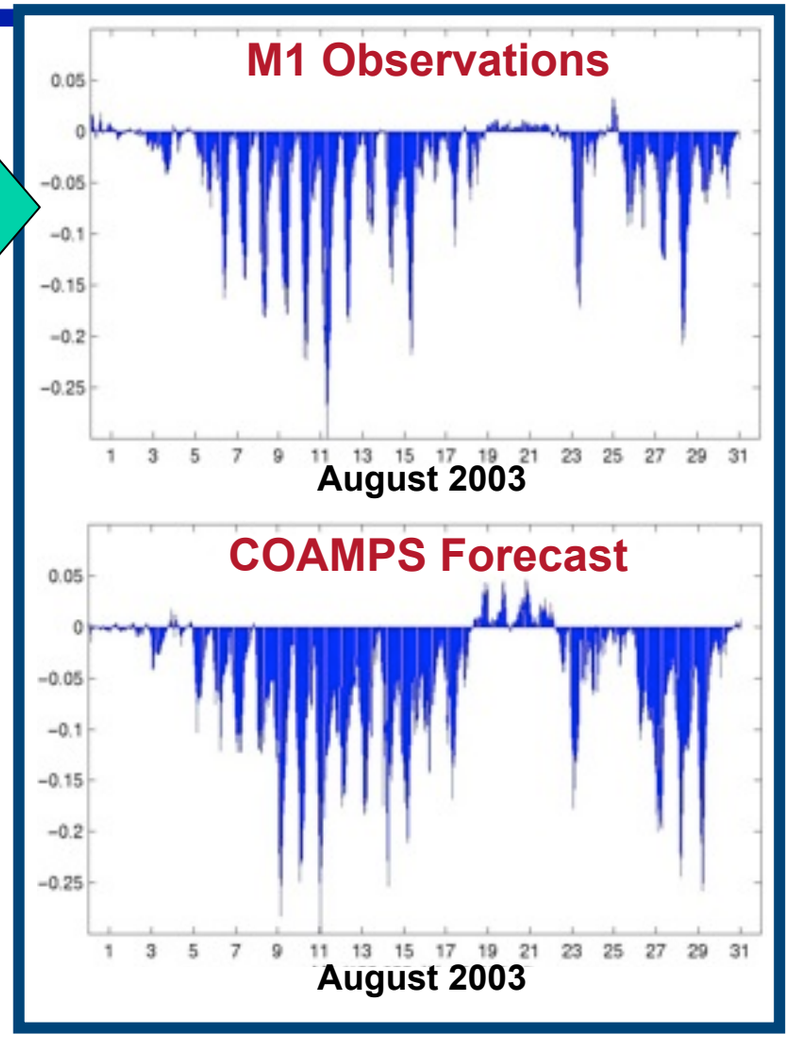
Graphs on right show observed (upper) and COAMPS (lower) Surface Stress



The leftmost 3 boxes show COAMPS wind speed (color) and direction (arrows) for 27, 9, and 3 km grids

Representation of Coastal Jets, Wind Stress Curl, and Coastal Shear Zone Improved using Higher Resolution Grid



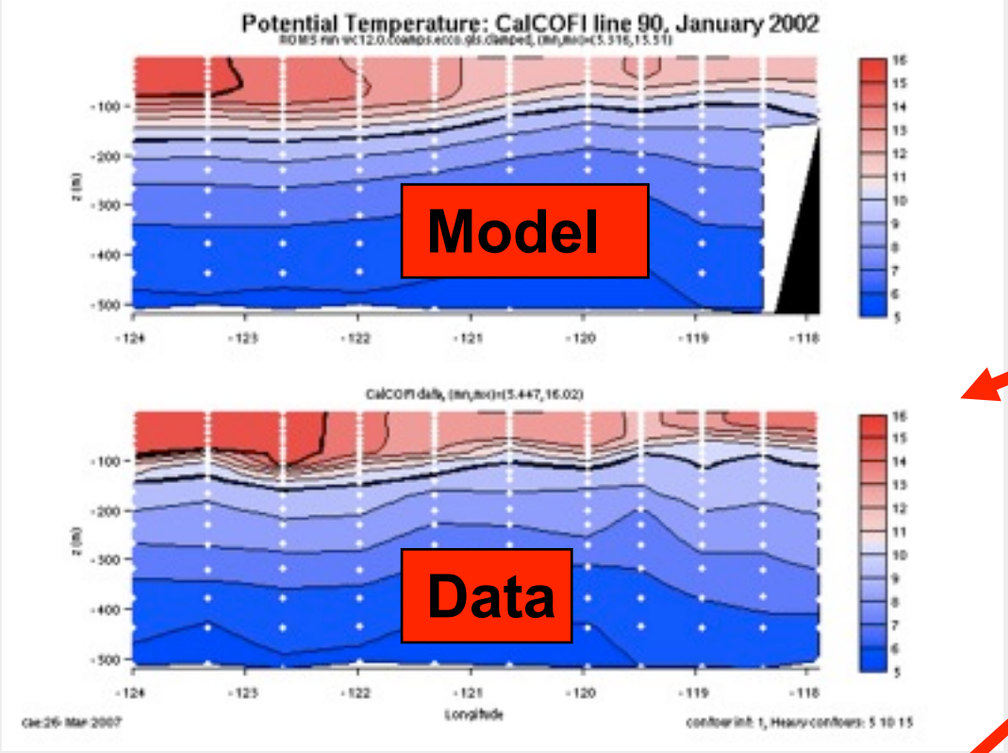


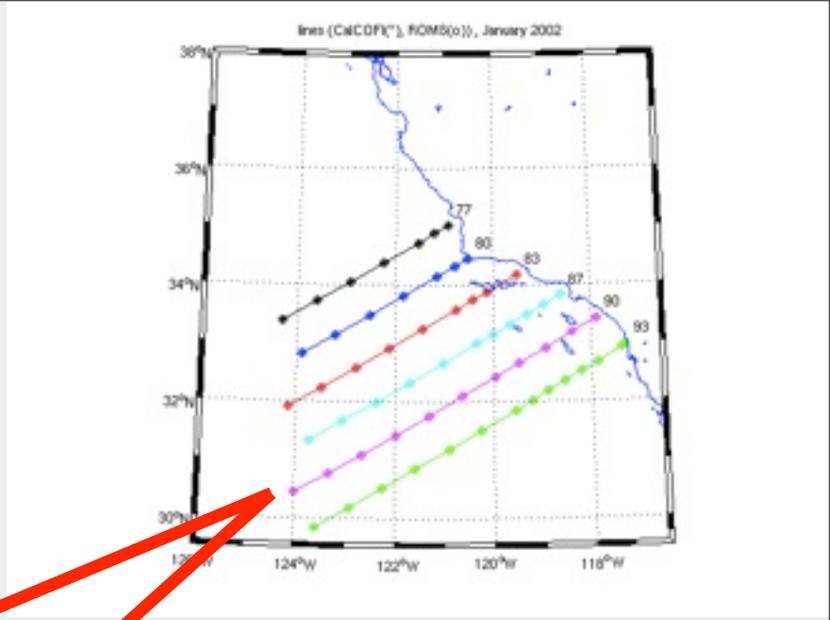
Improved representation of the wind stress curl using the 3 km grid at the coast should drive improved representation of wind-driven processes (e.g., upwelling)

J. Doyle (NRL)

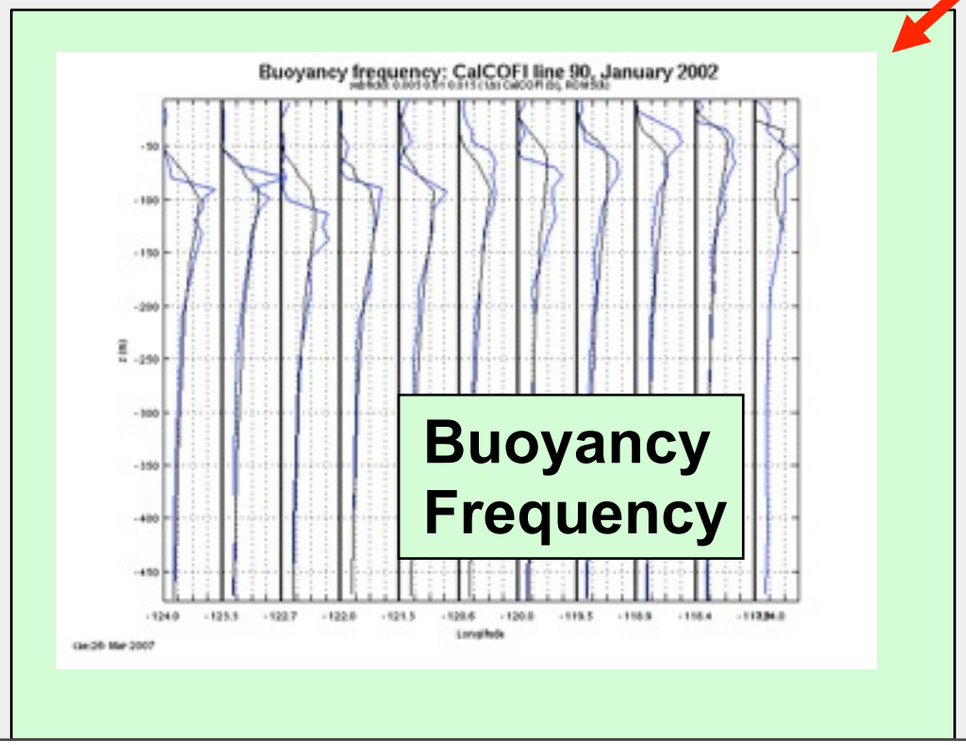
Forward Model (10 km grid) Comparisons to CalCOFI

Potential Temperature

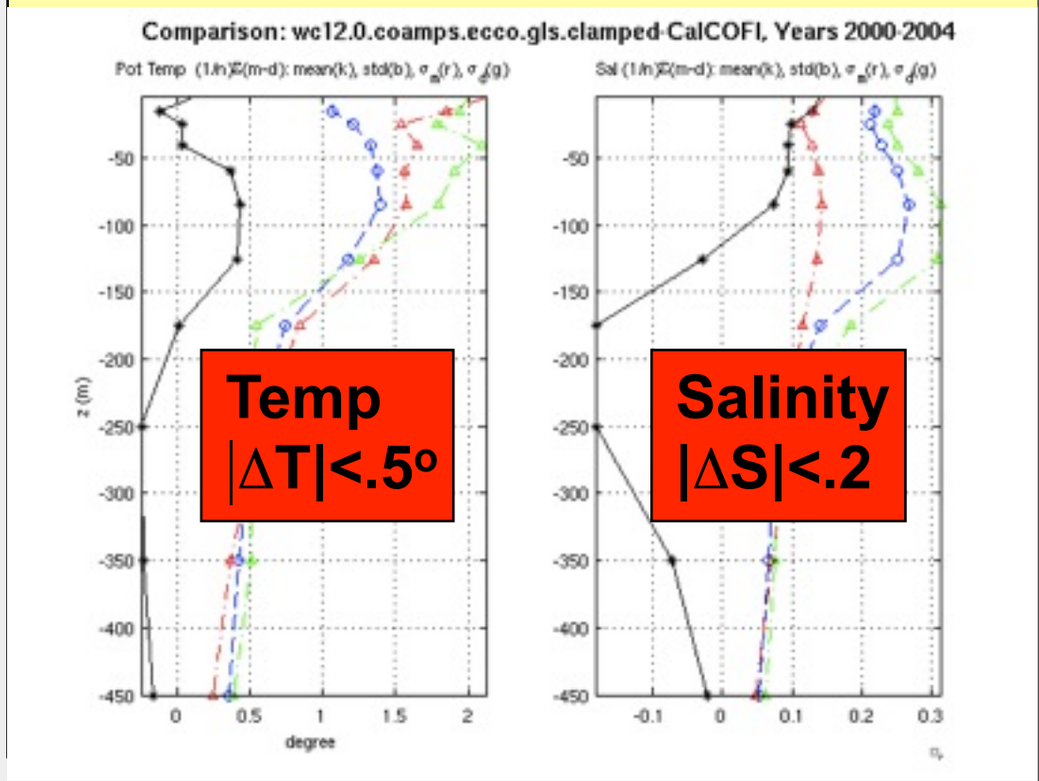




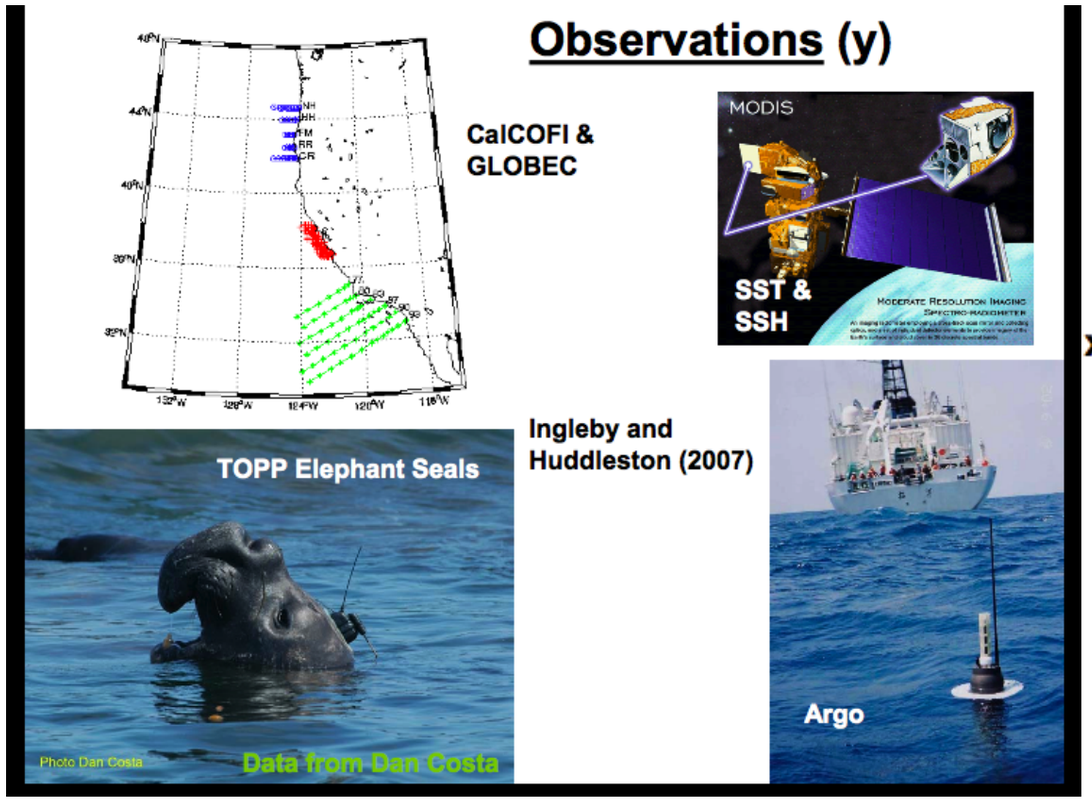
Line 90



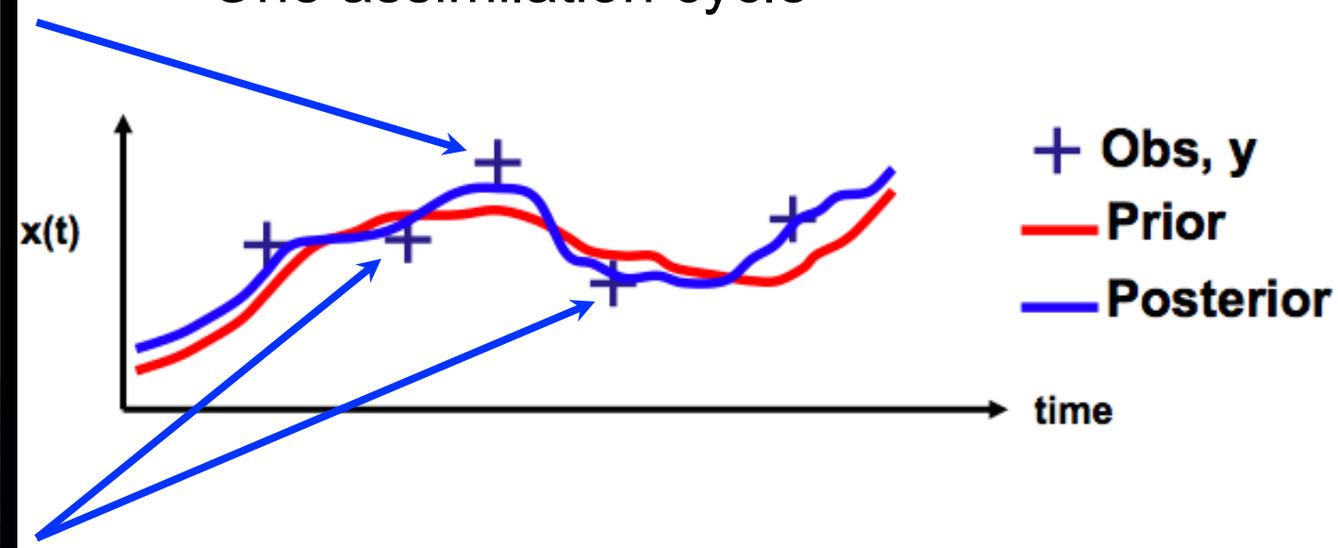
model-data (2000-2004)



UCSC Ocean Modeling
4D-VAR Data Assimilation

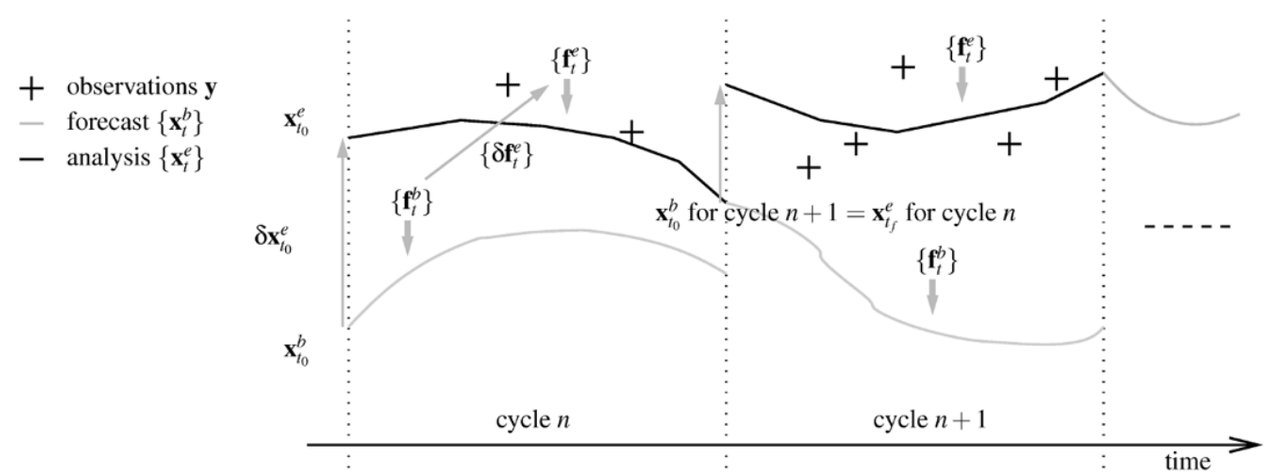


One assimilation cycle



- **Ocean Dynamics** connect temporally separated observations
- Up to14d assimilation cycles
- Controls (ocean initial conditions, surface forcing, boundary conditions)

Sequential assimilation cycles



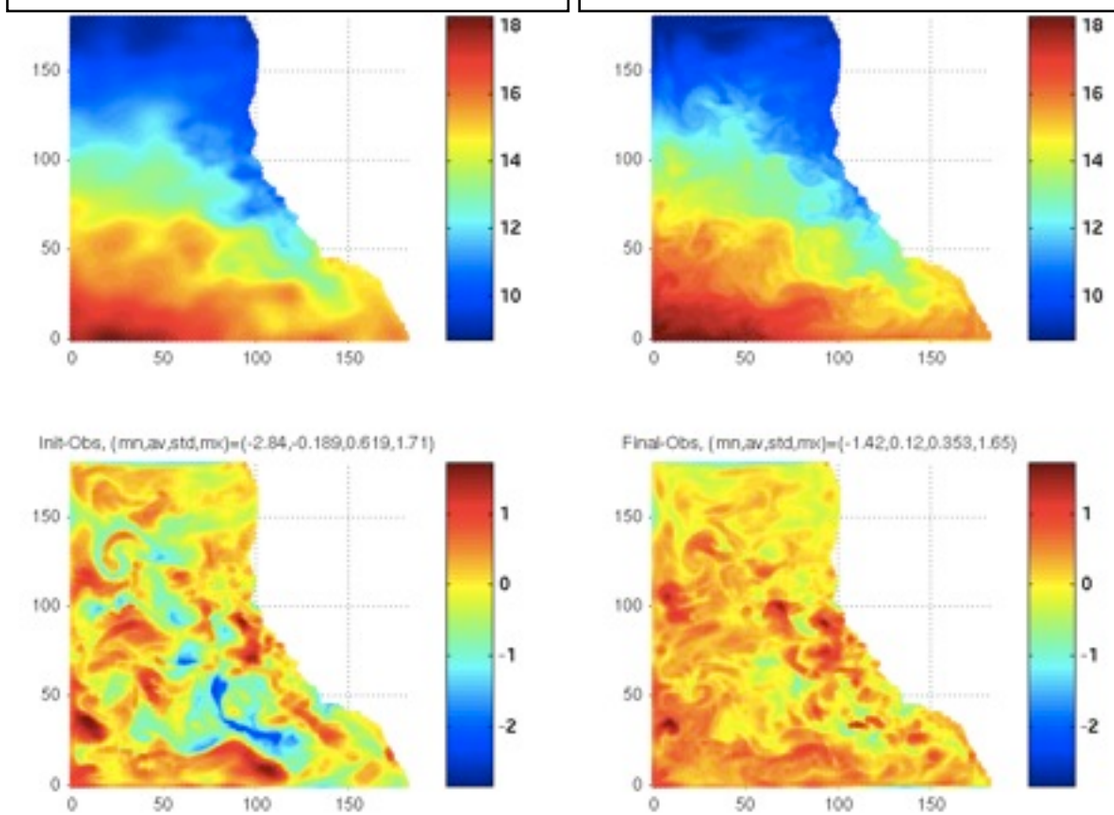
Broquet et al. 2009a,b, 2010
Moore et al. (2011a,b)

Strong Constraint, I4DVAR example

- Minimizes cost function that is weighted sum of squared model-data misfit and squared deviations from background model state.
- Model error variances from nonlinear model
- Univariate background error covariances (Weaver and Courtier, 2001)
- 30km horizontal & 50m vertical length scales
- COAMPS SST (now using OSTIA)
- AVISO Merged SSH
- 7-14 Day Assimilation Window
- Initial Conditions adjusted only

OBSERVATIONS

FINAL MODEL STATE

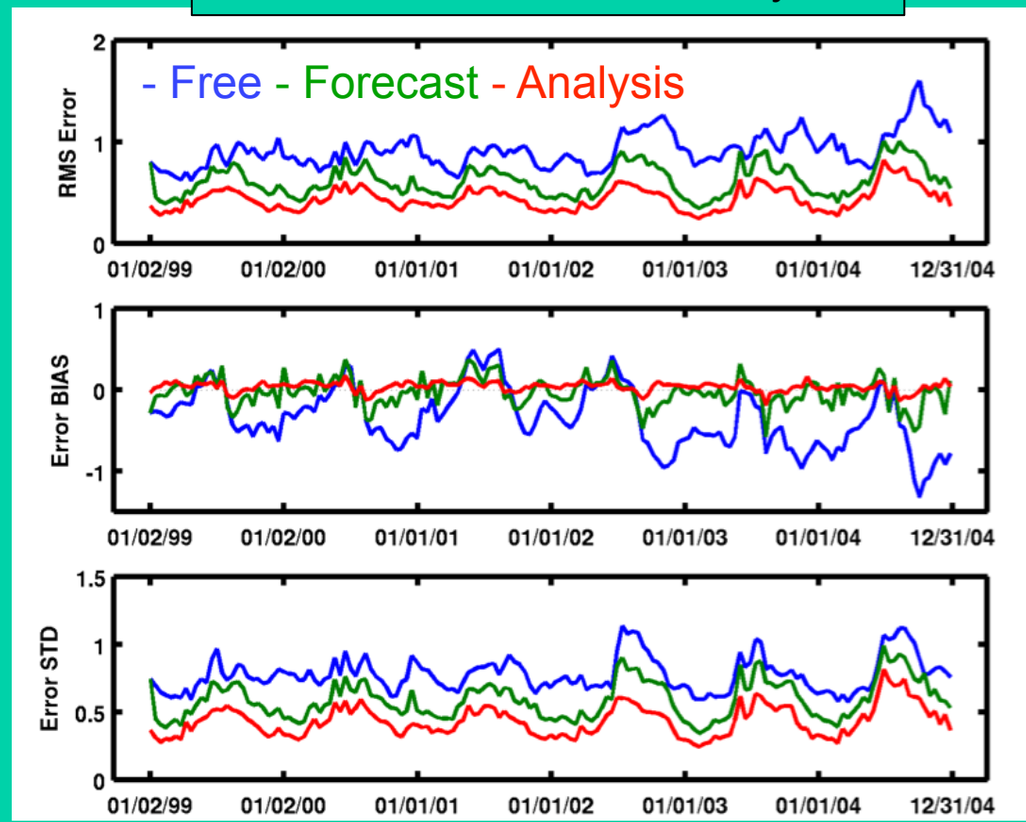


Initial misfit rms=0.62°

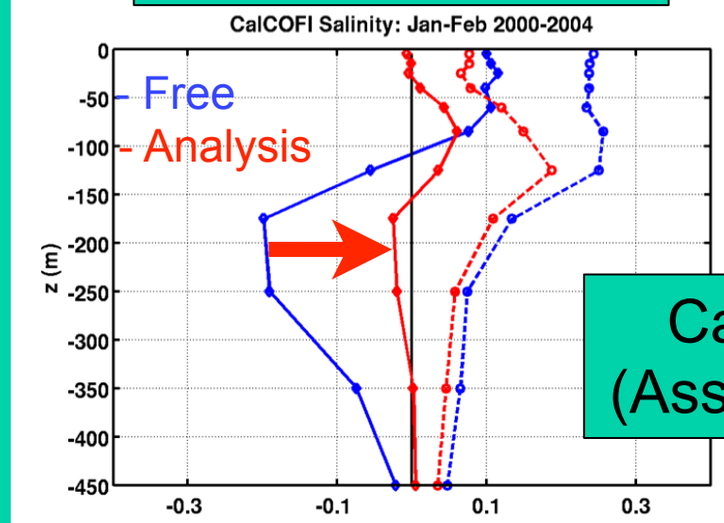
Final misfit rms=0.35°

Strong Constraint I4DVAR Assimilation
Performance, 10km grid

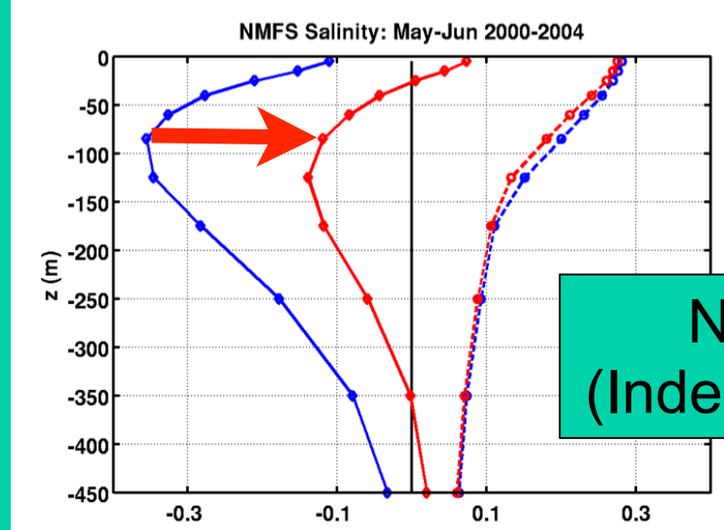
SST
Error statistics for COAMPS SST for each 14d assimilation cycles



Salinity
Error statistics for in situ salinity (2000-2004)



CalCOFI (Assimilated)



NMFS (Independent)

- $(\text{RMS Error})^2 = (\text{Error bias})^2 + (\text{Error STD})^2$
- correction of all components of error
- forecasts still show improvements - sensible corrections on the non observed part of the state

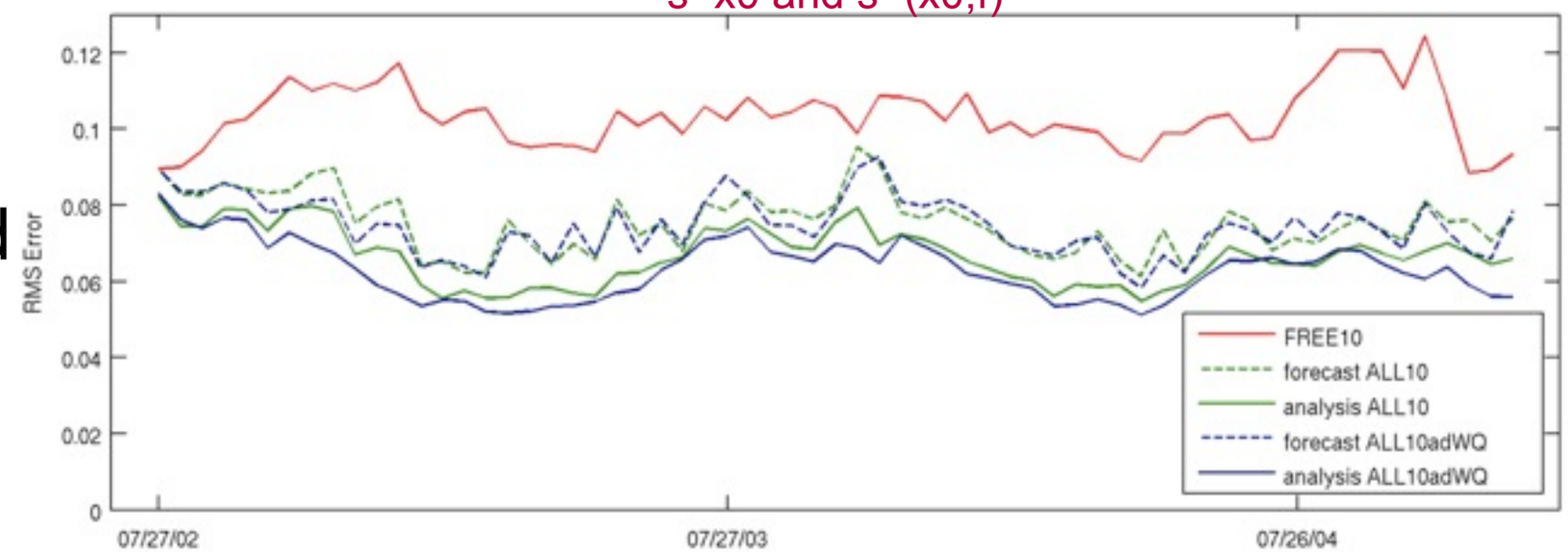
WC10: assimilation of SSH/SST/CalCOFI/GLOBEC

Broquet et al. (2009a)

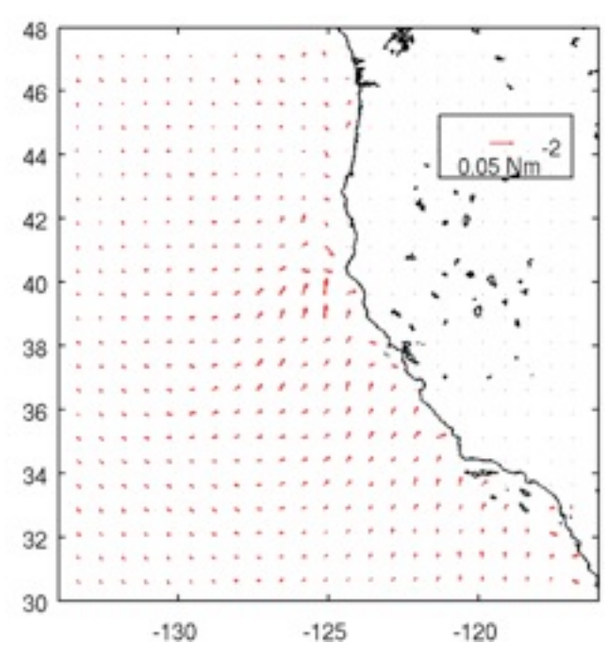
Strong Constraint I4DVAR With Adjustments to Surface Forcing

- RMS Analysis error is reduced
- Forecast shows effectively no sustained improvement
- Surface forcing adjustments at odds with independent observations
- Suggests other source of error

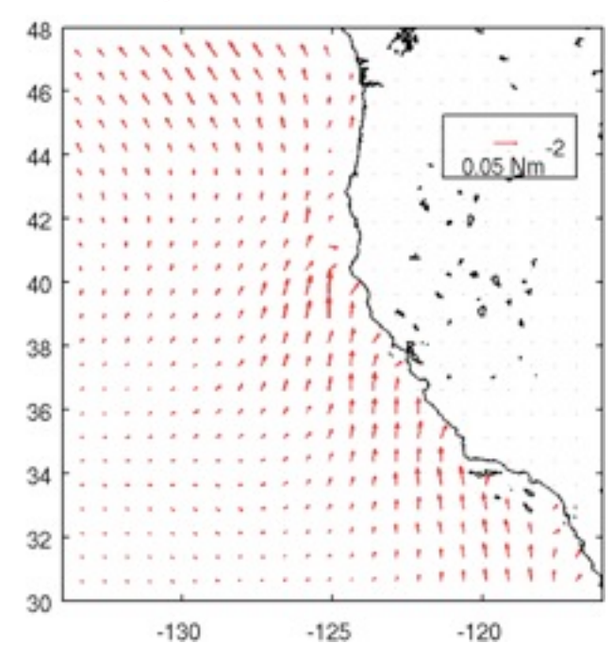
WC10: RMS Errors to SSH data (in m) for each assimilation cycle during free model and analysis with assimilation of SSH/SST/EN3 data using s=x0 and s=(x0,f)



Prior wind stress error



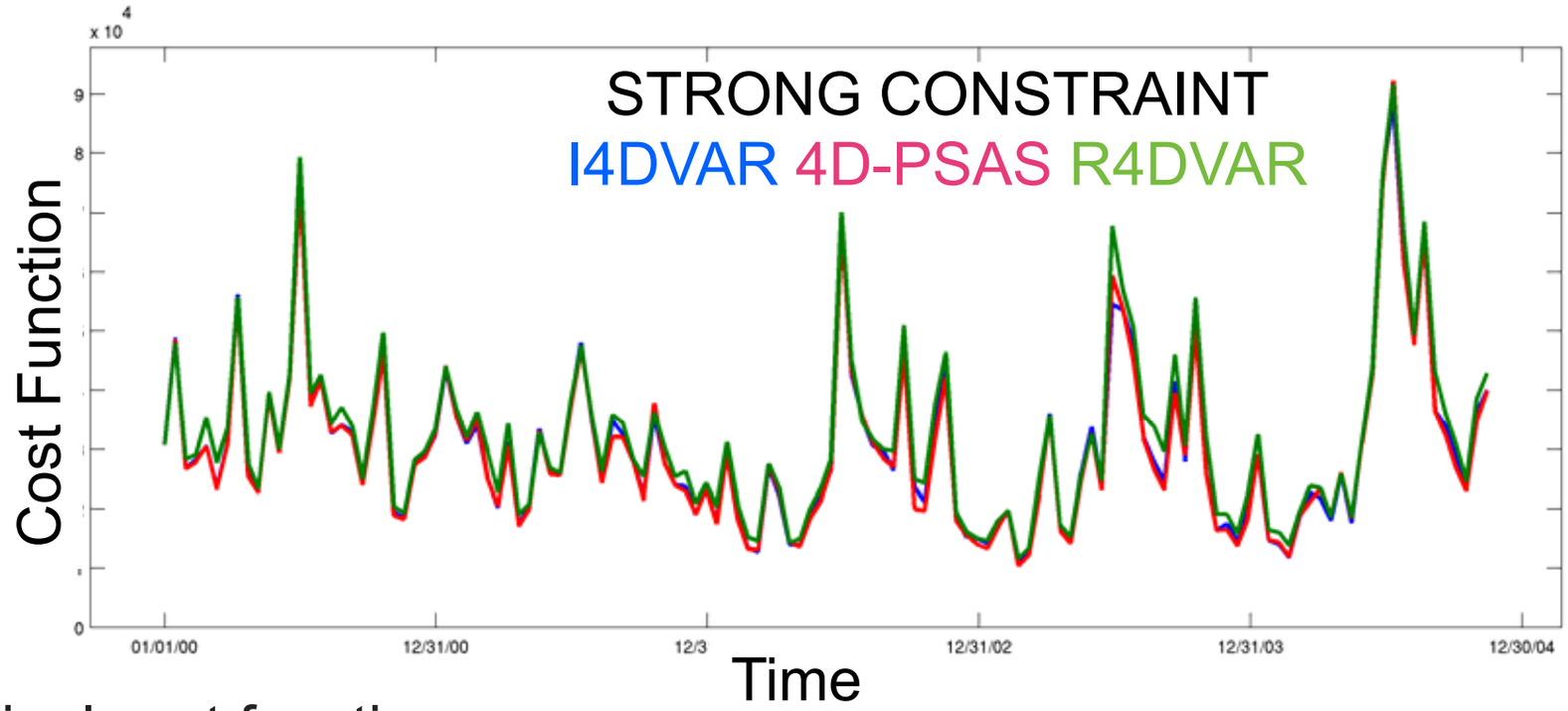
Analysis wind stress error



Summer bias in τ relative to QuikSCAT data (in Nm^{-2}) for 2003-2004

Broquet et al. (2010)

Investigating Weak Constraint Assimilation



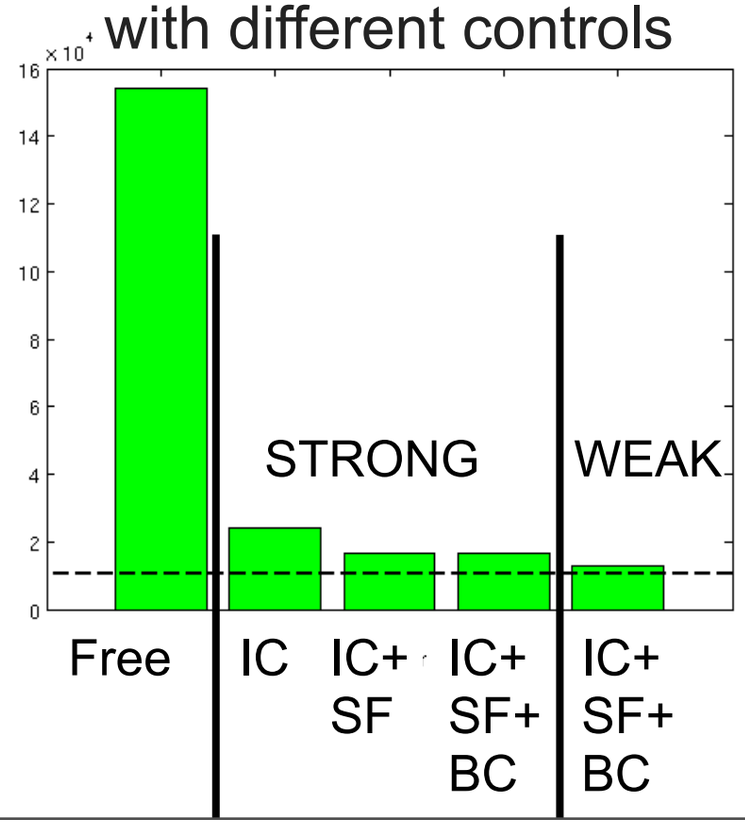
3 different 4DVAR approaches within ROMS:

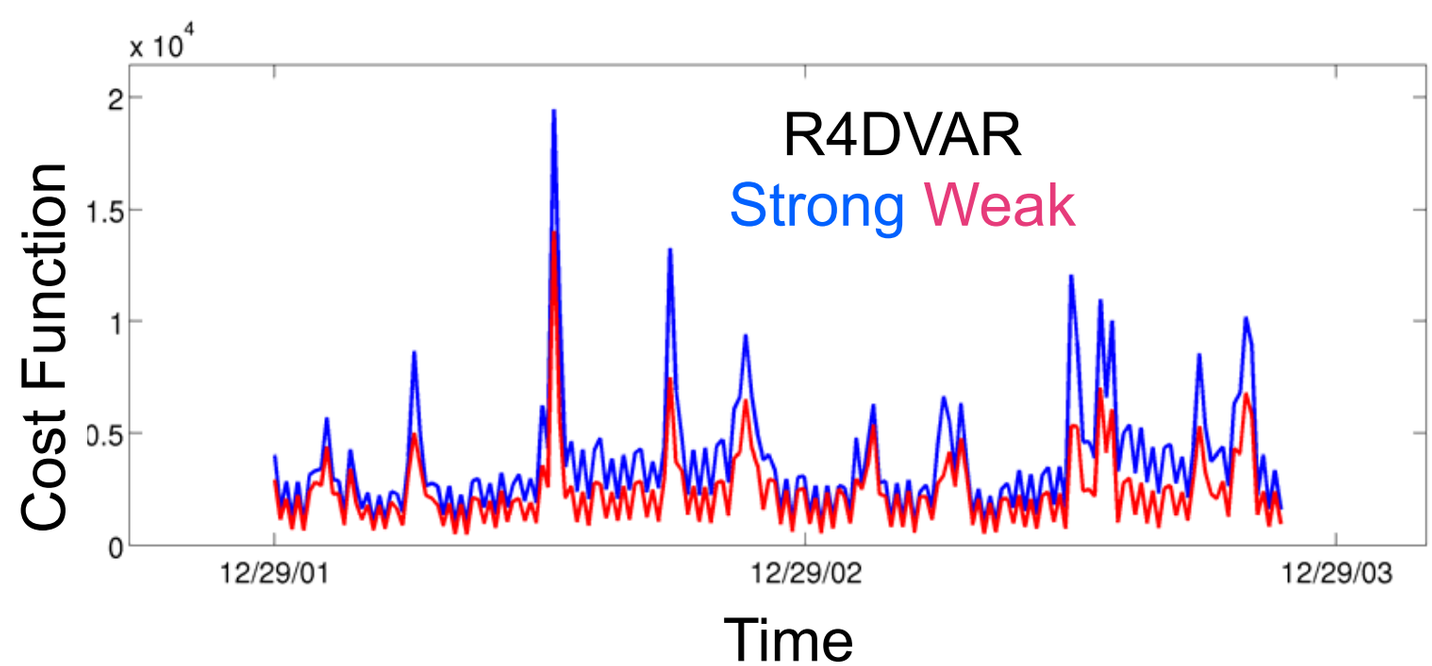
1) Incremental

2) Physical-space Statistical Analysis System (PSAS)

3) Indirect Representer

Final cost function with different controls





Summary

- High resolution, regional modeling requires high quality, high resolution atmospheric forcing products.
- CCS implementation using ROMS.
- Incremental 4DVAR approach yields improved state estimate.
  - Over time, adjustment extends to non-observed portions of the domain.
  - Skill remains in forecast mode, beyond 14-day limit suggested by linearity assumptions.
- Surface forcing adjustments can further reduce model-data misfit.
  - Adjustments inconsistent with independent observations
  - Forcing uncertainty likely too large.
  - Suggest another source of error.
- Impact of model error can be investigated through weak constraint 4DVAR
  - Both PSAS and indirect Representer method are coded within ROMS.
  - Cost function systematically reduced through weak constraint approach.

Related Activities

- Quasi-near-real-time system (nearly implemented)
  - Weekly hindcast cycles with 1-2 day forecast
  - AVISO SSH, NOAA tidal SSH, OSTIA SST, glider TS
  - Strong Constraint Incremental (I4DVAR) approach
  - Web accessible

- 10-year, 30-year Reanalysis Effort (next few years)

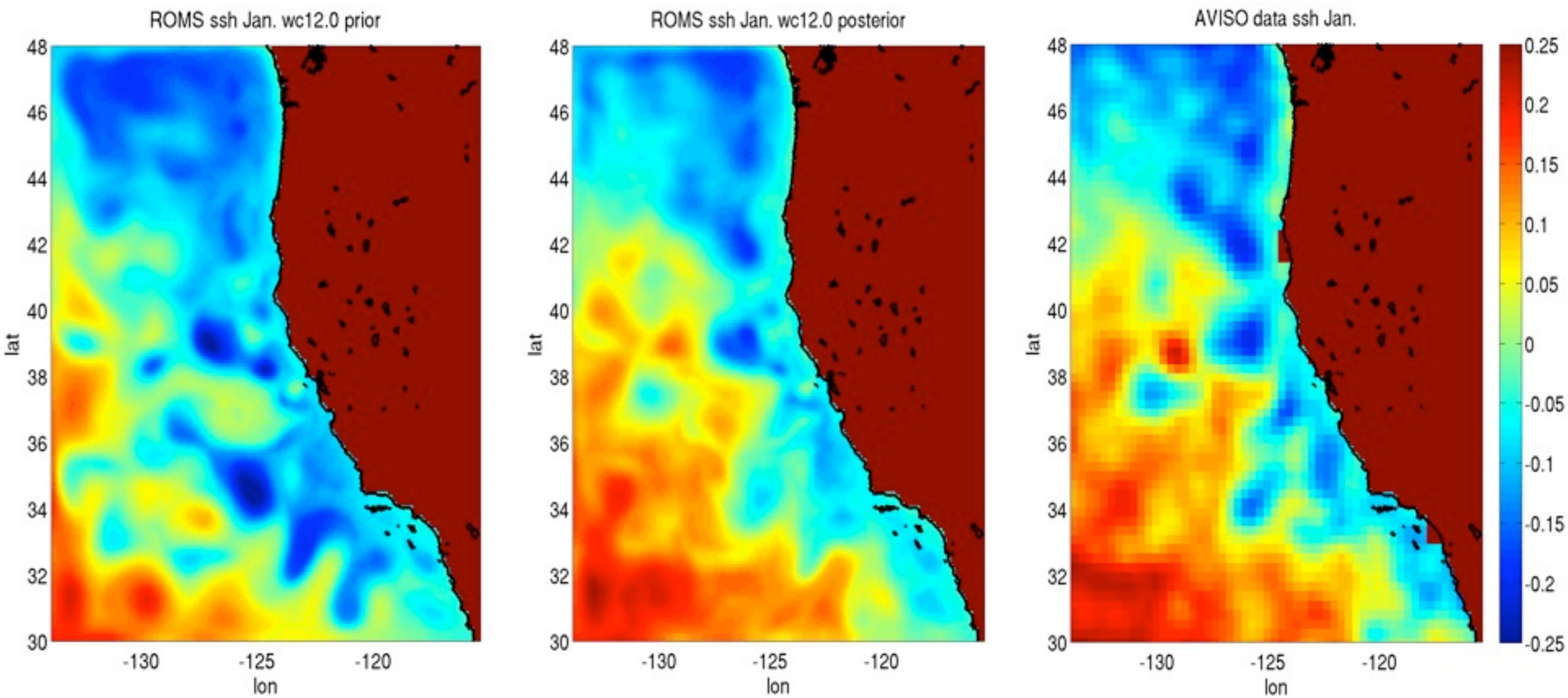
- Biogeochemical Modeling (in progress)

Example assimilation, automated NRT System

SSH Before Assimilation

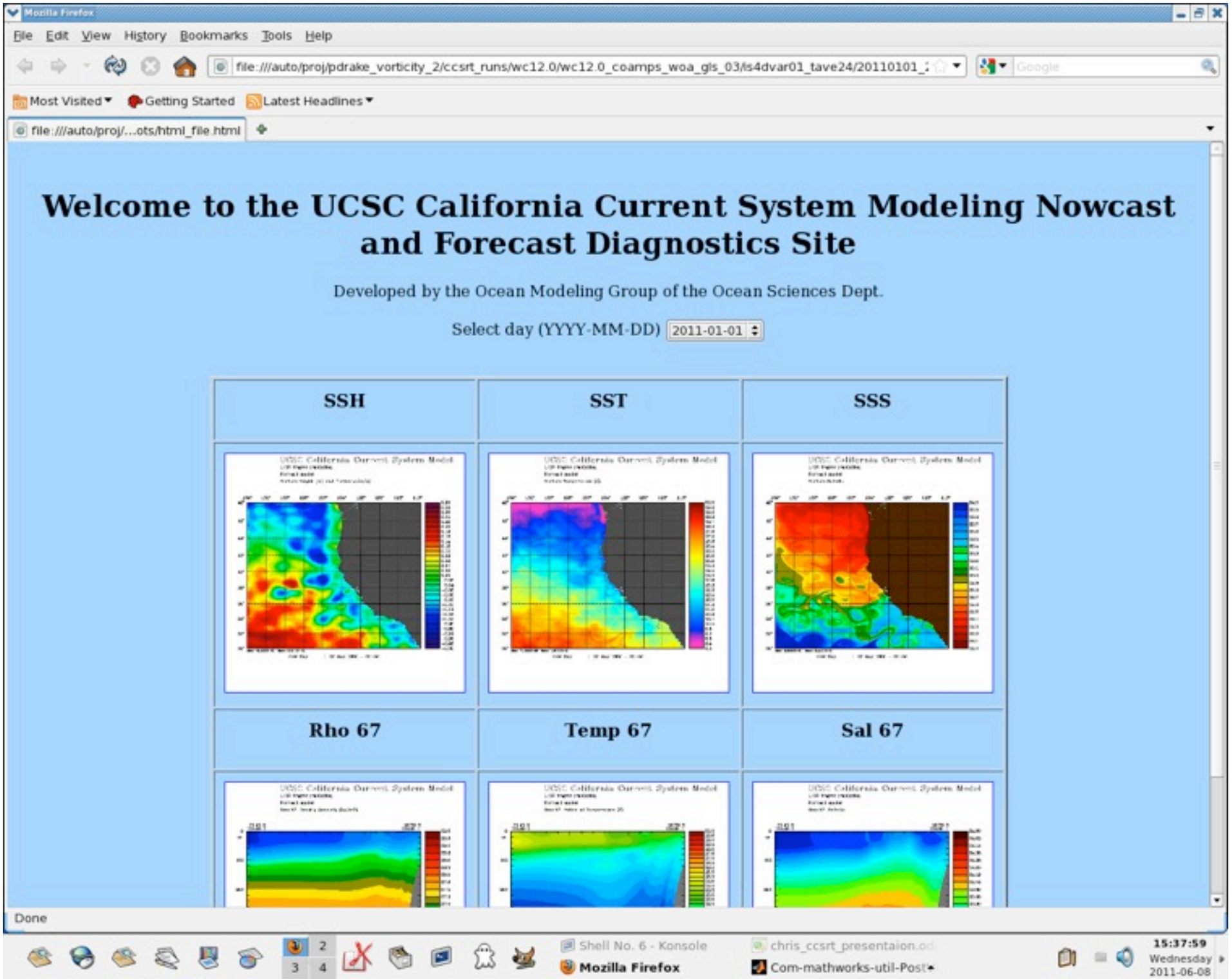
SSH After Assimilation

SSH Satellite



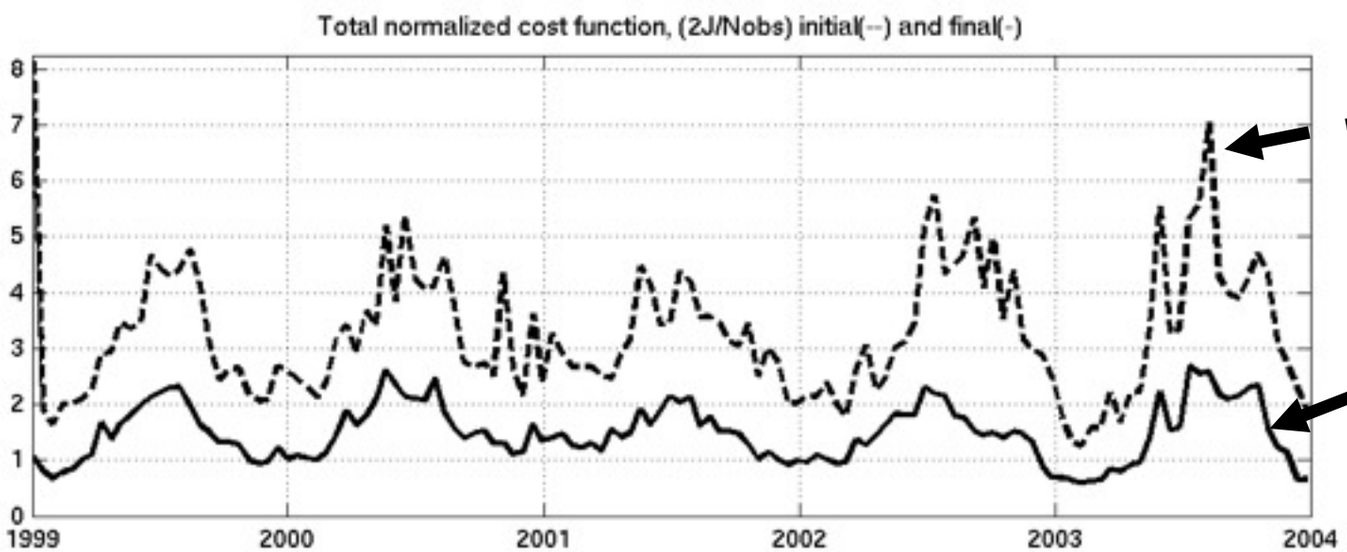
time-average of 1-week cycle, Jan. 2011

Example screenshot: NRT output



Analysis of sensitivities

5-year run, 30 km grid, 14 day window



Initial Cost function

Final Cost function

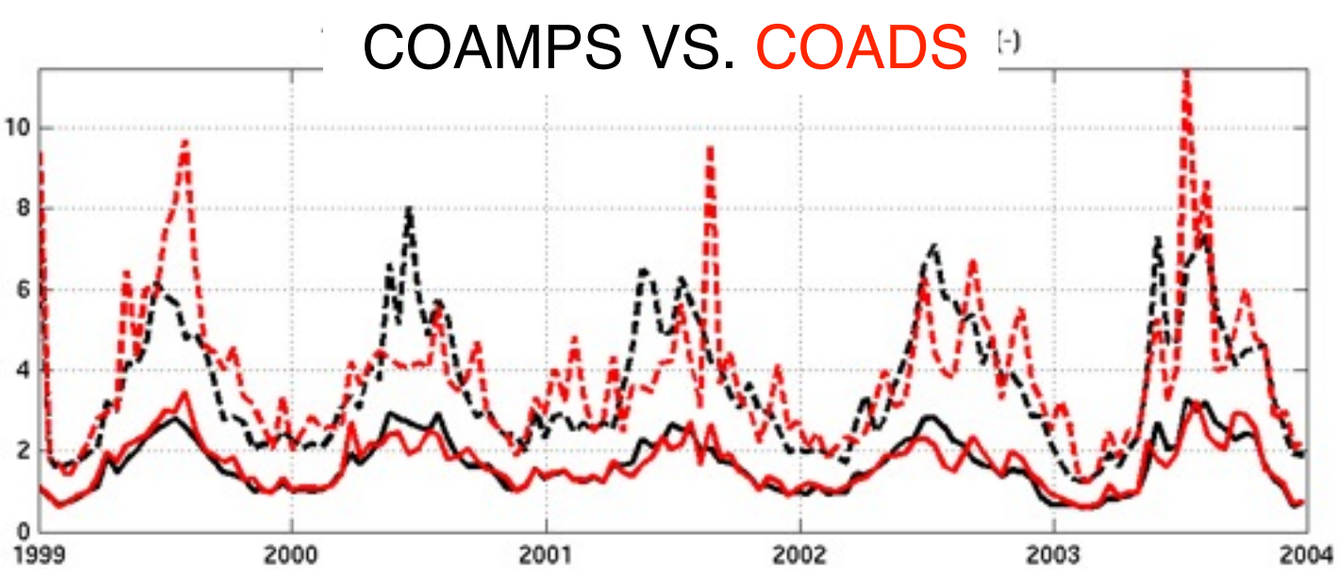
ADJUSTMENTS
to Initial Temperature

$rms(\overline{\Delta T})=0.04^o$

$\overline{\sigma_T} = 0.28^o$

$rms(\overline{\Delta T})=0.07^o$

$\overline{\sigma_T} = 0.31^o$

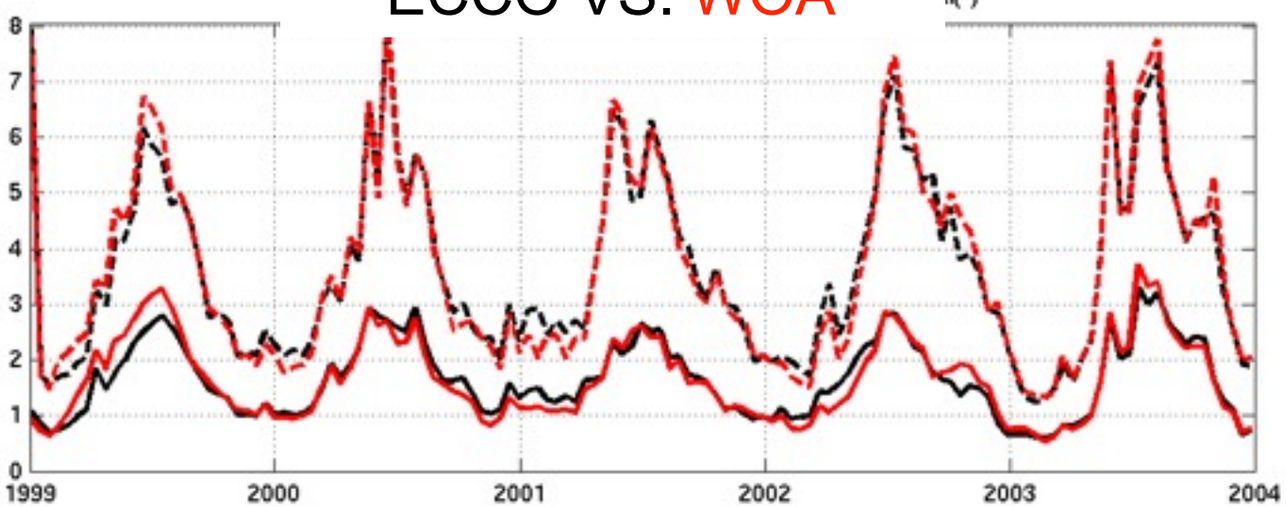


Analysis of sensitivities

5-year run, 30 km grid, 14 day window

ADJUSTMENTS
to Initial Temperature

ECCO VS. WOA



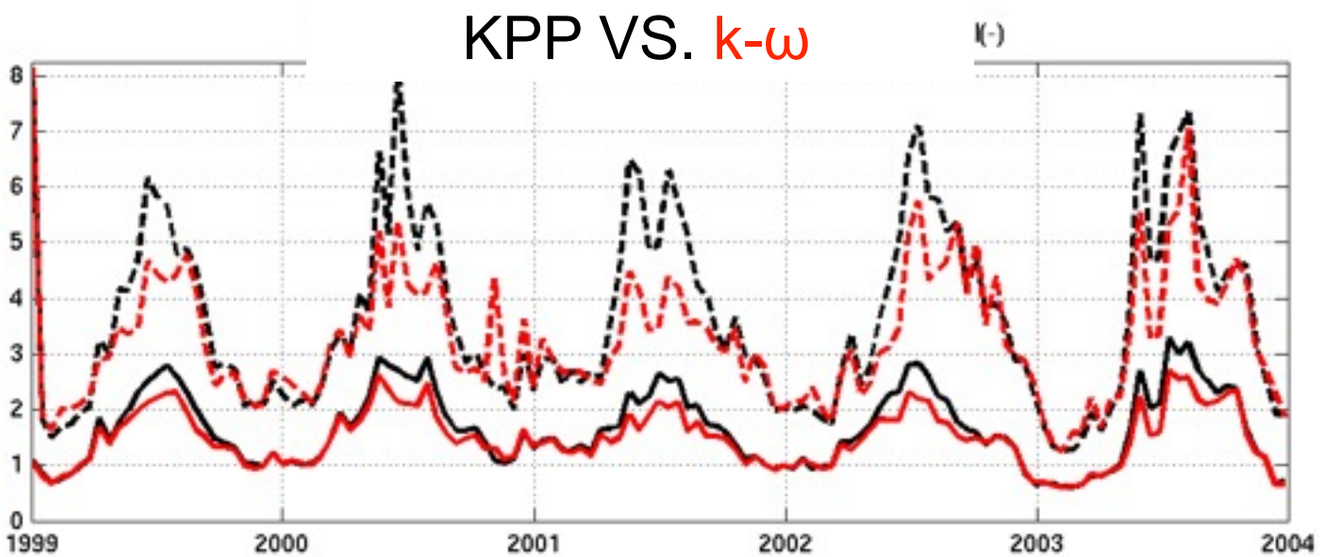
$rms(\overline{\Delta T})=0.04^o$

$\overline{\sigma_T} = 0.28^o$

$rms(\overline{\Delta T})=0.04^o$

$\overline{\sigma_T} = 0.29^o$

KPP VS. k-ω



$rms(\overline{\Delta T})=0.04^o$

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