Theme I: Days to Seasons

Overview of

Recent Progress

Theme I Participants

Co-Investigators

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- Paul Myers (University of Alberta)
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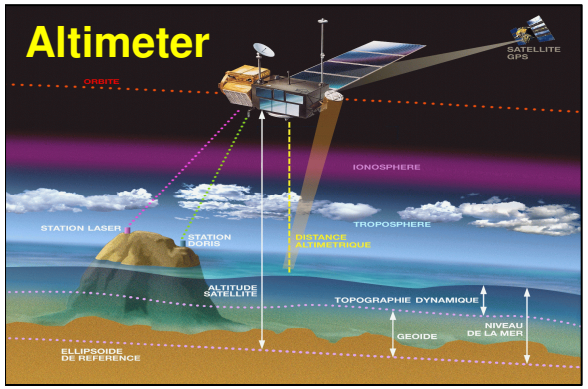
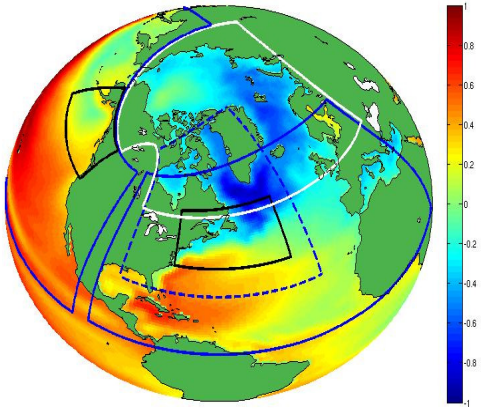
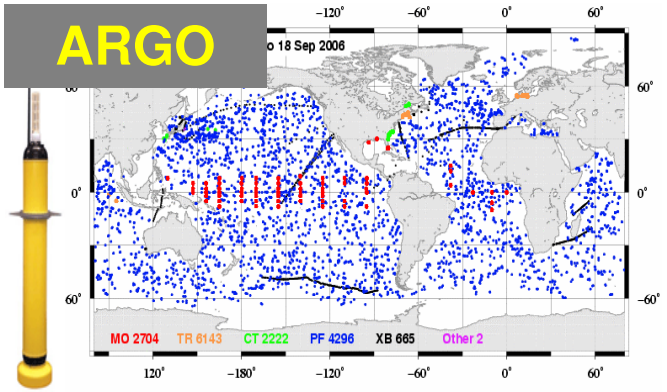
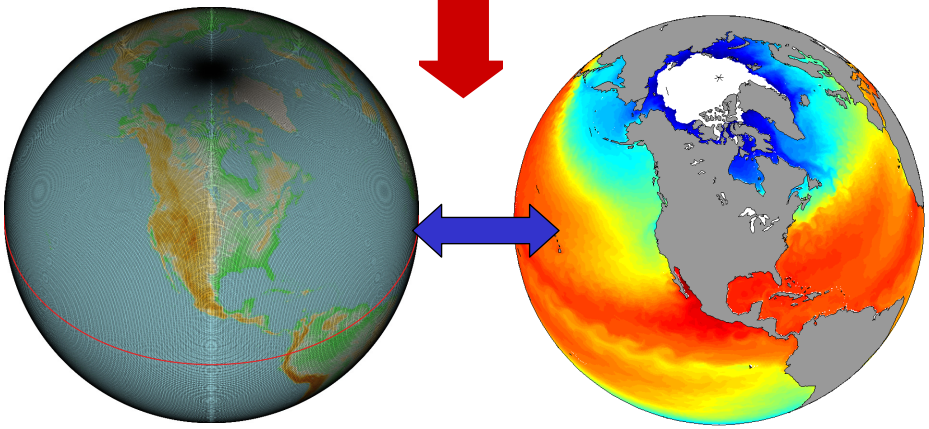
Road Map For Theme I



Ocean modelling & Data Assimilation







Coupled Global NEMO/GEM

Sub-Themes and Projects

Ocean Modelling and Data Assimilation

- ✓ Suppression of bias and drift in ocean models
- ✓ Statistics of variability for model testing and improvement
- ✓ Multivariate assimilation of altimeter and Argo data
- ✓ Ocean reanalysis and forecasting
- Modelling and assimilation of sea ice
- Nested circulation of the eastern Canadian shelf

Coupled Modeling and Assimilation

- ✓ Assimilation into coupled models
- ✓ Studies on joint assimilation into coupled models

Spectral Nudging of Ocean Models

- **Suppresses model drift and bias**
- **Used in some of our models of the North Atlantic, North Pacific and global ocean**
- **Improves hindcasts and forecasts**
- **Implementation of spectral nudging in CCCma's seasonal forecast models underway**
- **Continues to be modified and tested and hopefully eliminated**

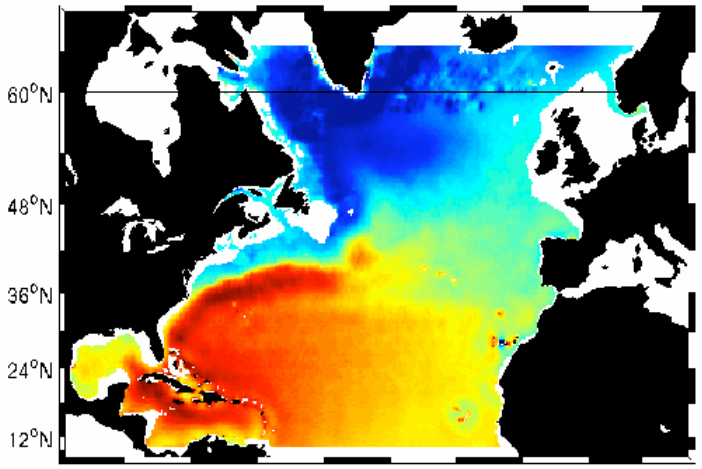
Model Testing and Improvement by Assimilating Moments of Variability

"Use statistics describing mean ocean state and its variability (2nd and 3rd moments) to improve eddy resolving models of North Atlantic, North Pacific and their forcing fields."

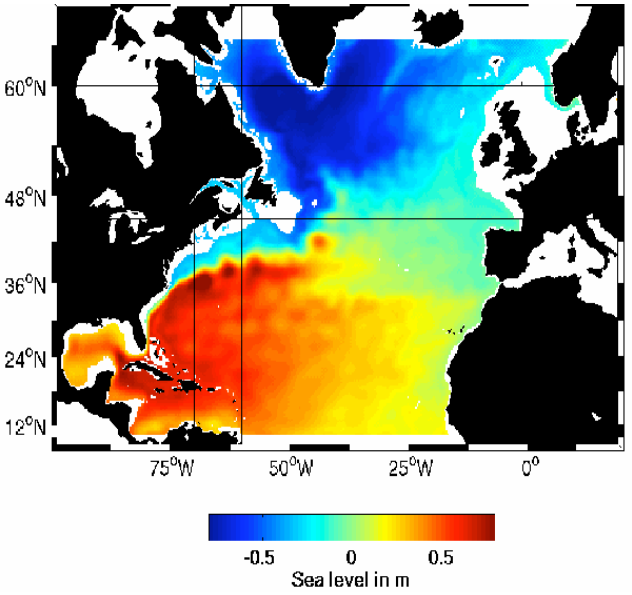
- ***MSST (altimeter+GRACE+terrestrial gravity)***
- ***Variance and skewness of altimeter sea level***
- ***Mean and variance of surface drifter velocities***

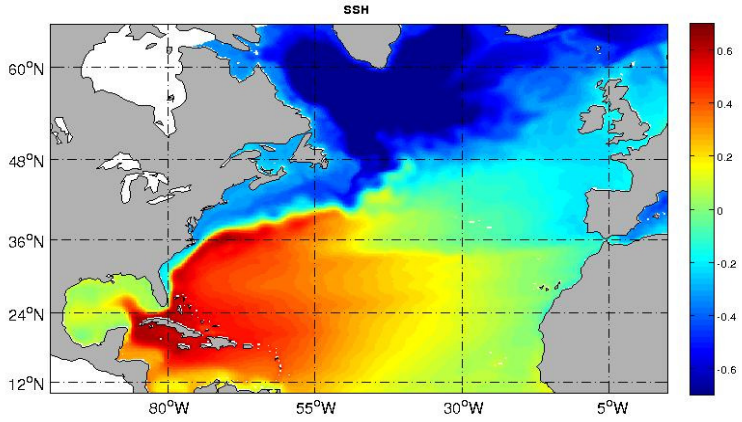
Mean Sea Surface Topography From Space

Satellite-Based Estimate



Previous POP/Yashayaev estimate

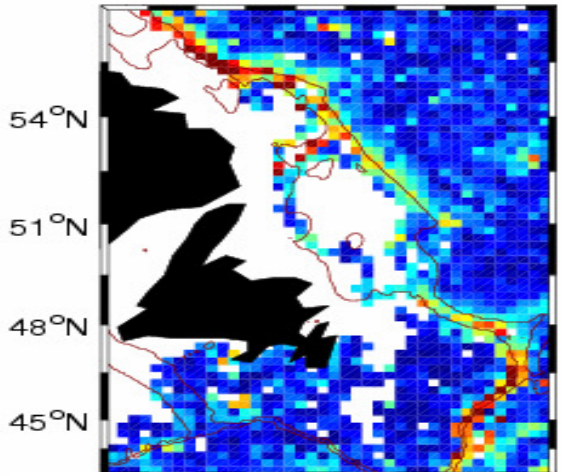




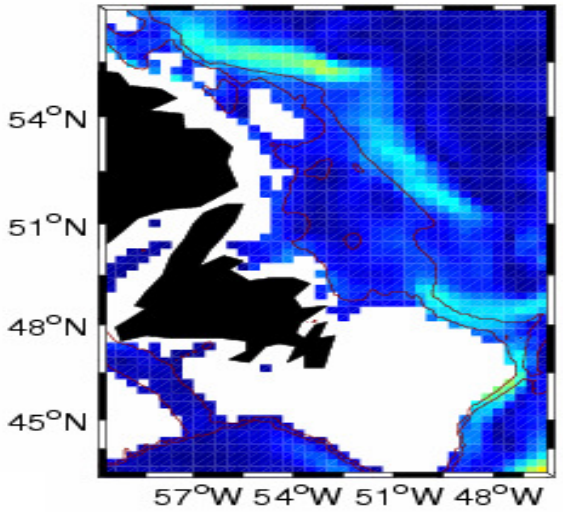
A new spatial smoother has been developed to smooth unrealistic structures in the nudges while still constraining larger scales. Implemented in NEMO.

Also improving climatology.

Drifters: the benchmark

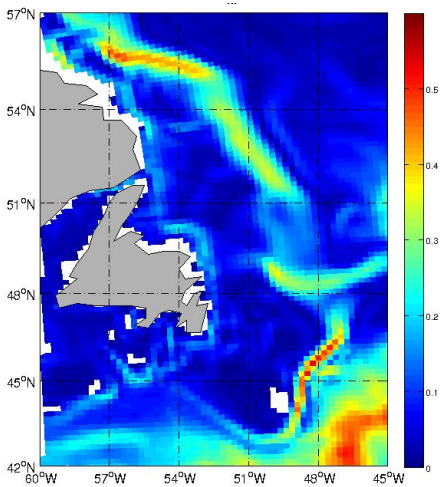


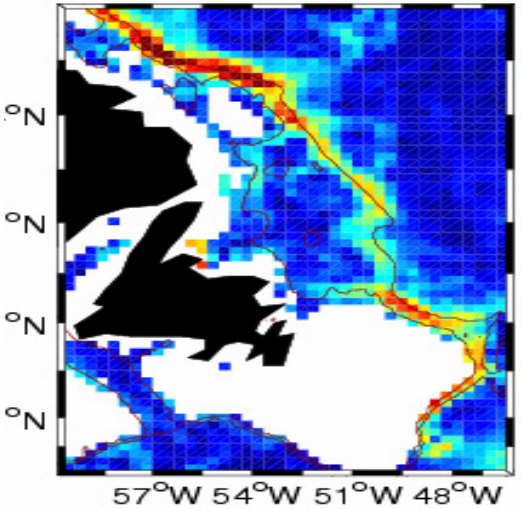
Old nudged model result



$MSST_{G1}$

New nudged model result





Satellite-based result

The old nudged model results have currents significantly too weak in the sub-polar gyre. The new result is significantly improved in spite of greatly reduced nudging.

- ✓ **Systematic sensitivity experiments have also been undertaken to determine "optimal" values of small numbers of parameters (e.g., mixing coefficients) by fitting to sea level moments.**

- ✓ **Adjoint code for earlier version of OPA has been obtained from Anthony Weaver to look at sensitivity to large number of controls (e.g., surface fluxes).**

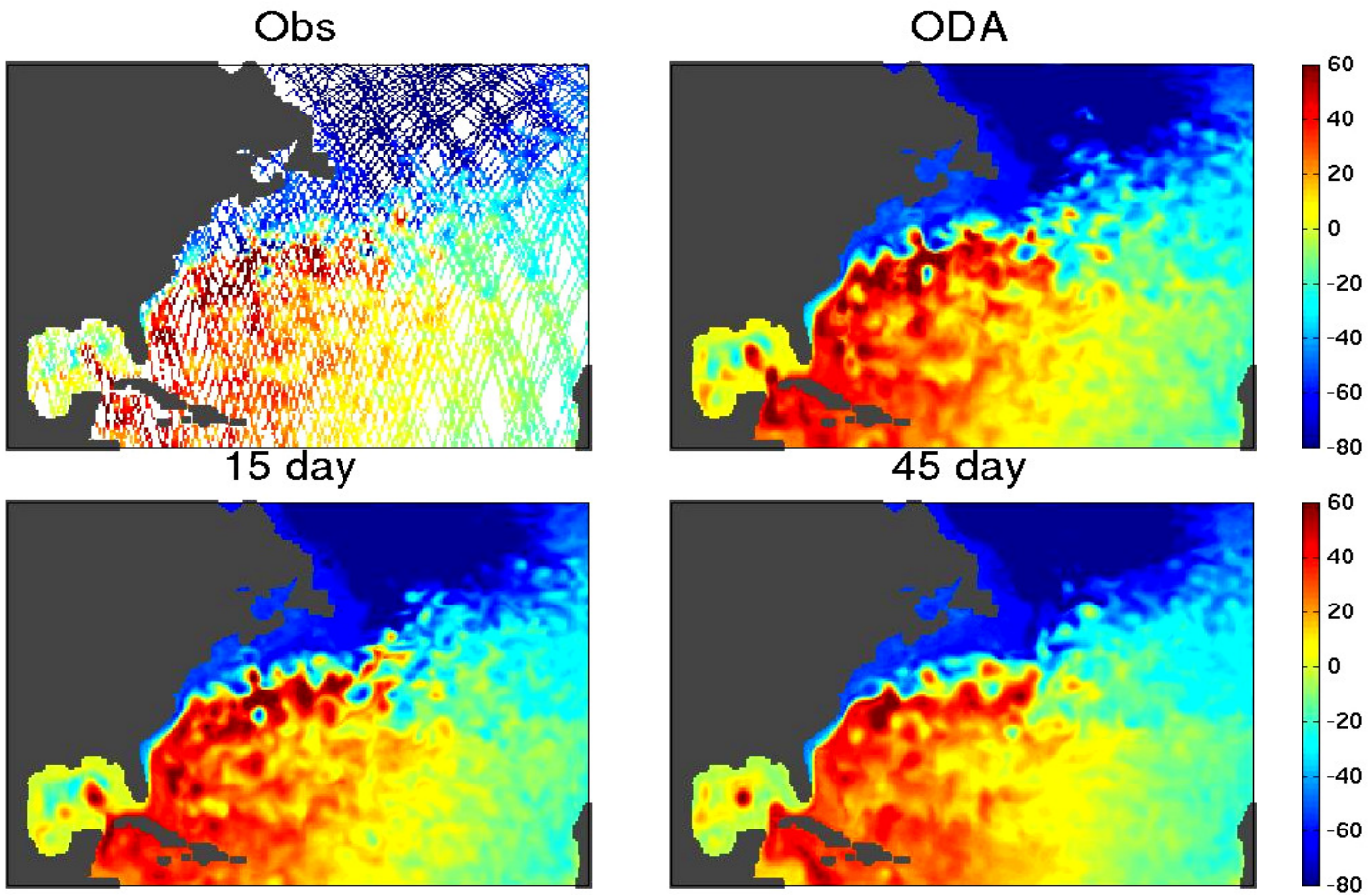
Multivariate Assimilation of Altimeter and Argo Data

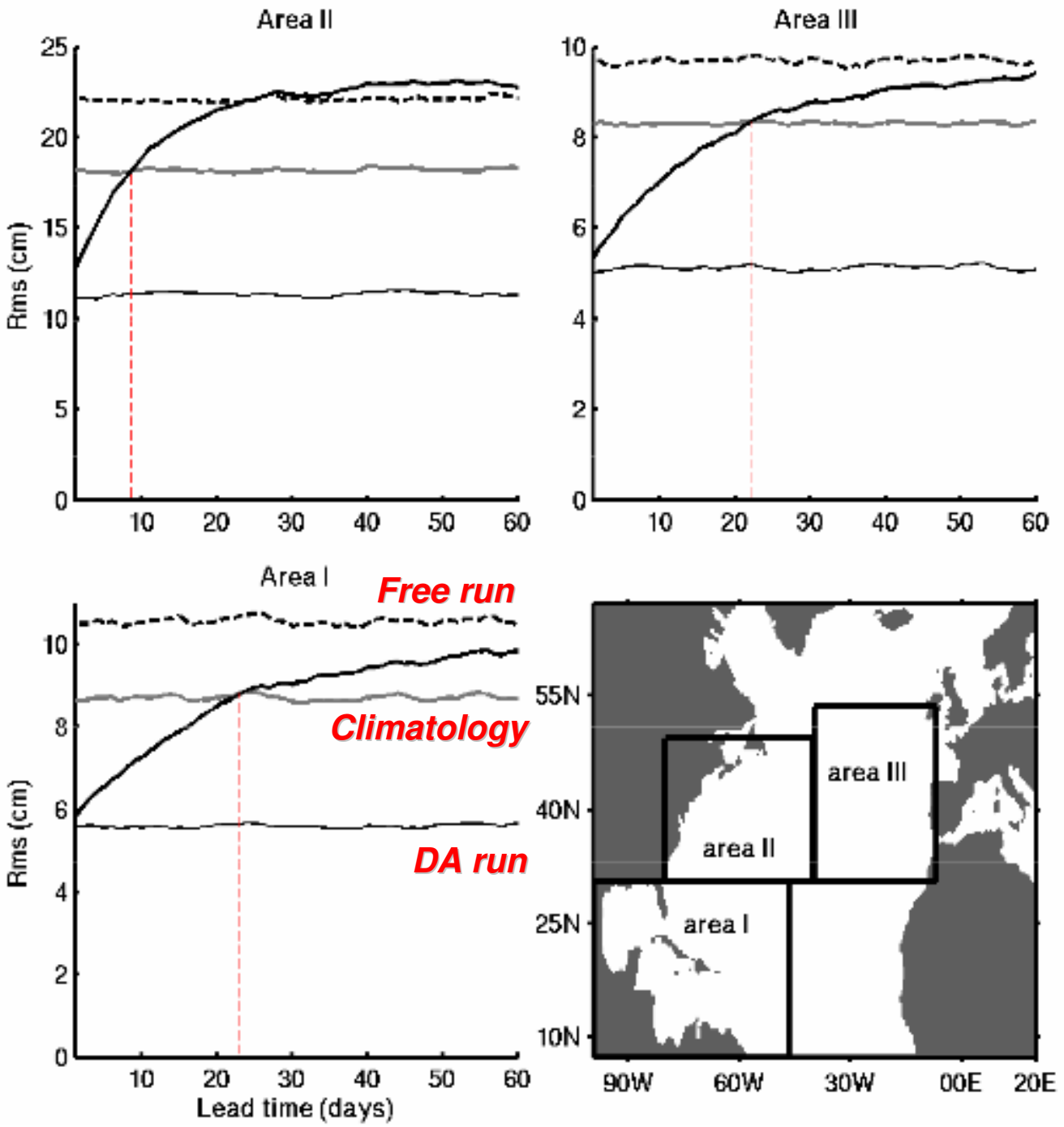
✓ ***Estimate statistics of short-term forecast and observation errors***

✓ ***Test and evaluate new schemes for assimilating altimeter and Argo profile data into basin and global models.***

Results from New Assimilation Method

Prediction for 7 August, 2004

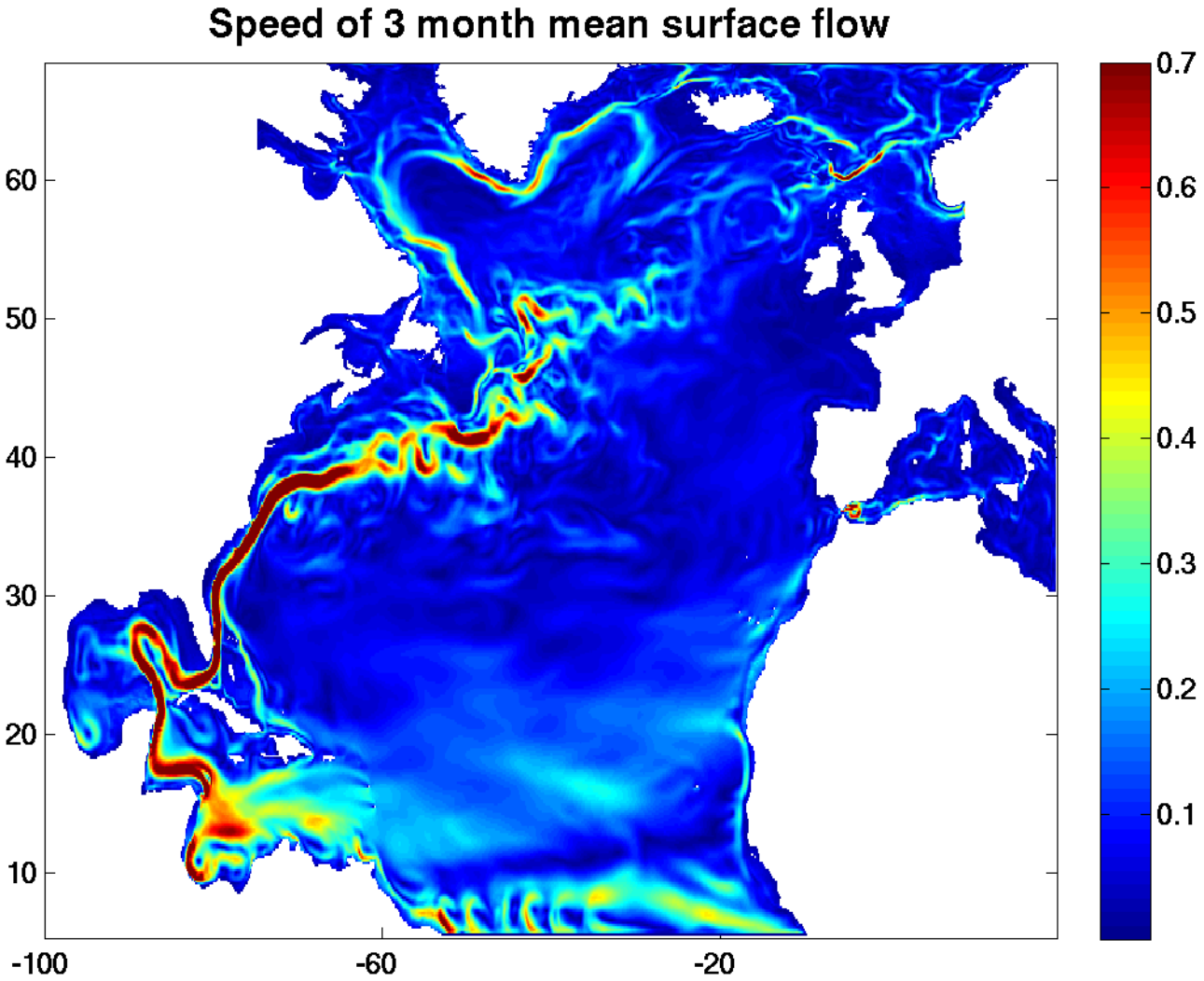




- Rms(η obs-pred) vs lead time
- POP, 2003-4
- 24 monthly forecast runs (each 60d)

Implementing New Scheme in NEMO

Map of Surface Speed (m/s)



- 1/6°, 40 levels
- GEM forcing
- New climatology

Ocean Reanalysis and Forecasting

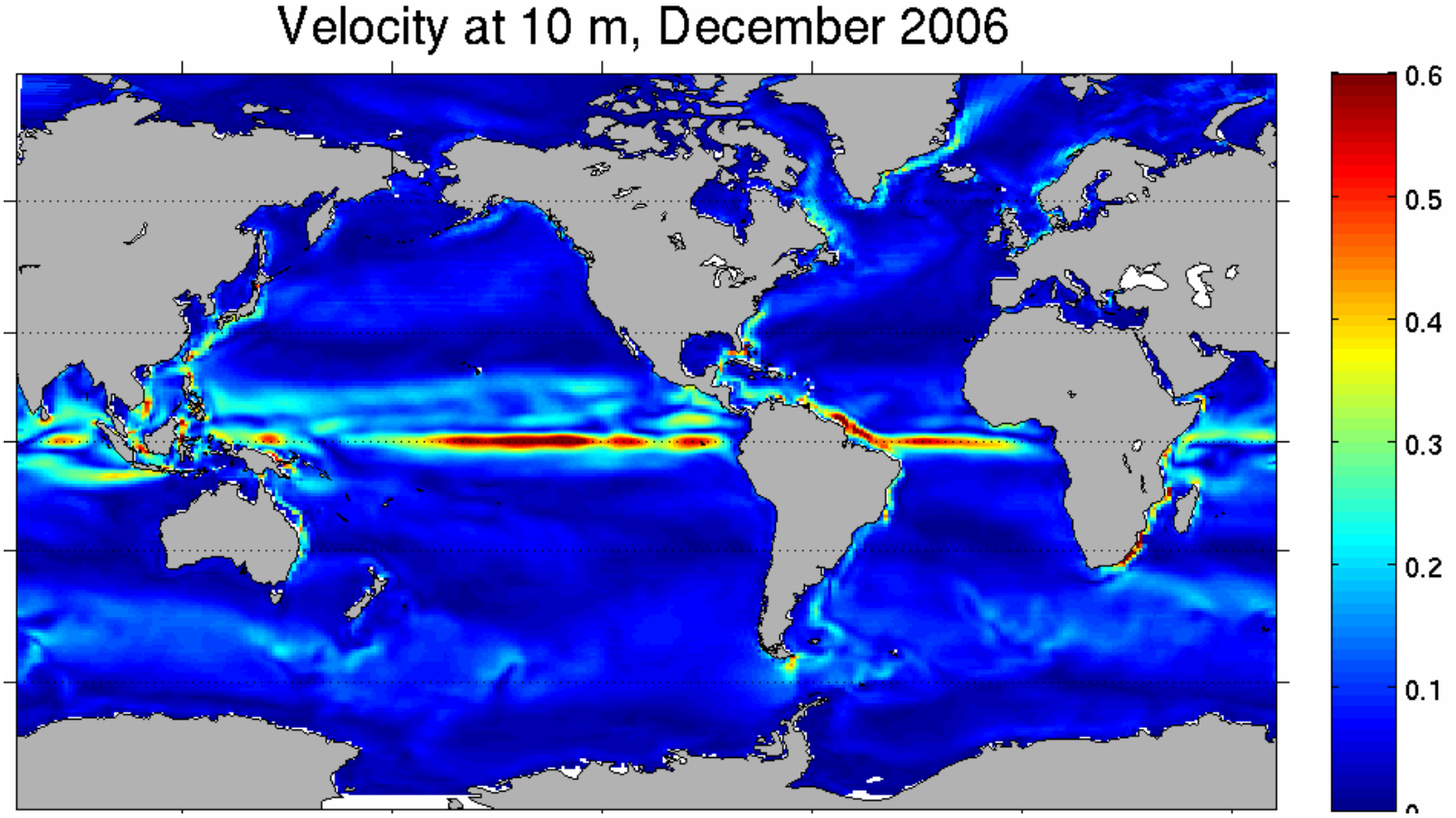
✓ **Assess reanalyses and forecasts using NEMO and new assimilation schemes**

✓ **Embed finer resolution models to improve specific features in critical regions**

✓ **Investigate physical causes of variability where good agreement with observations is found**

✓ **Improve the global coupled system for Theme I and, ultimately, the operational coupled system.**

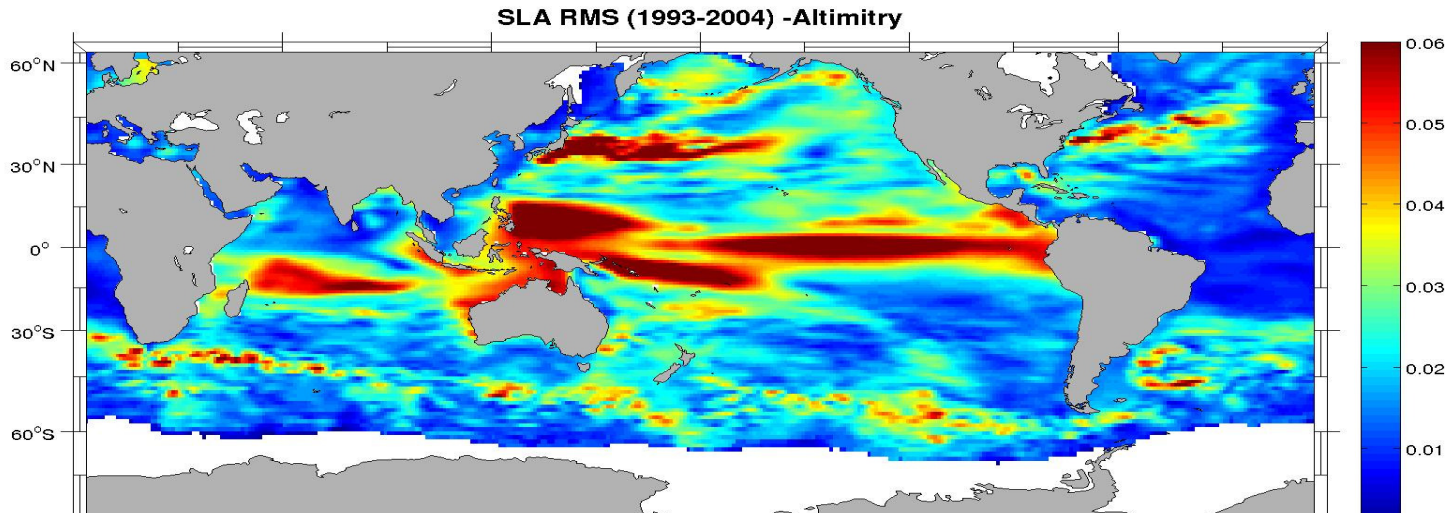
Sub-surface flow from 1° model



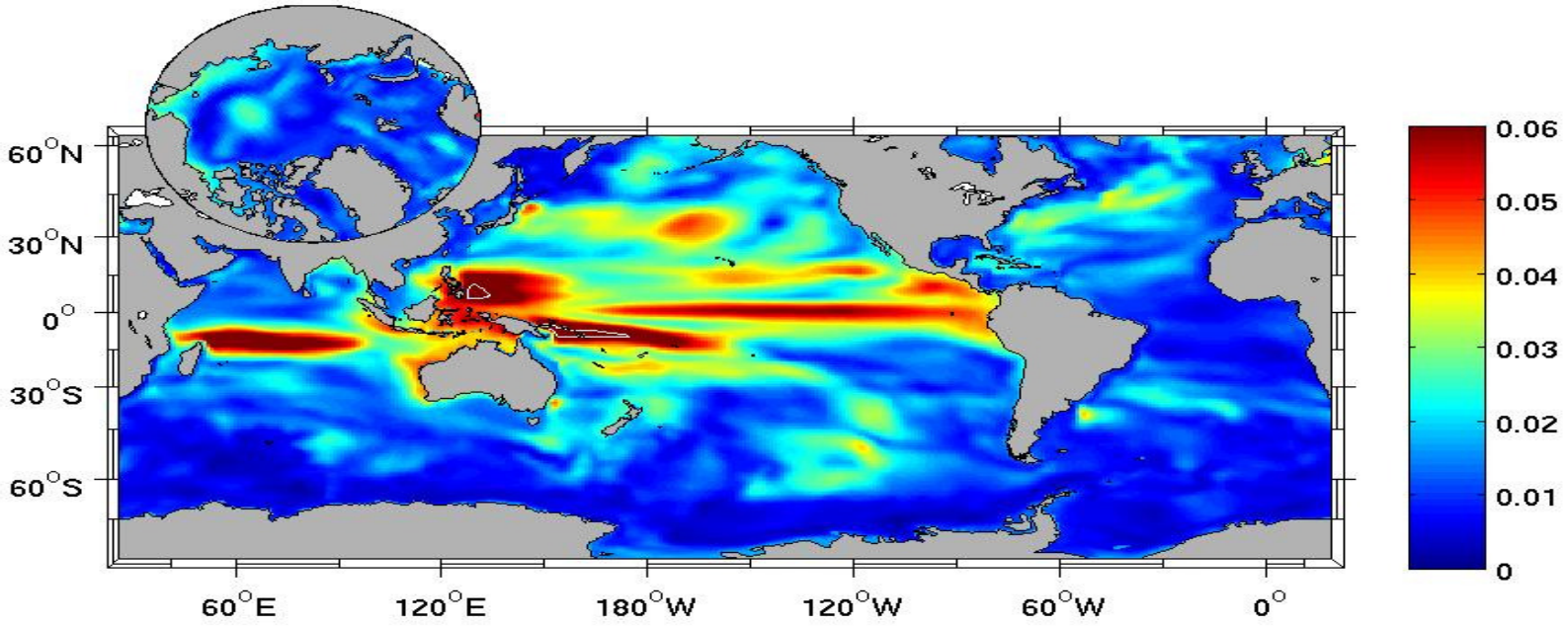
- 1° model, 1/3° in tropics
- Forced by Coordinated Ocean-ice Reference Experiments data

RMS of InterAnnual Sea-Level, 1993-2004

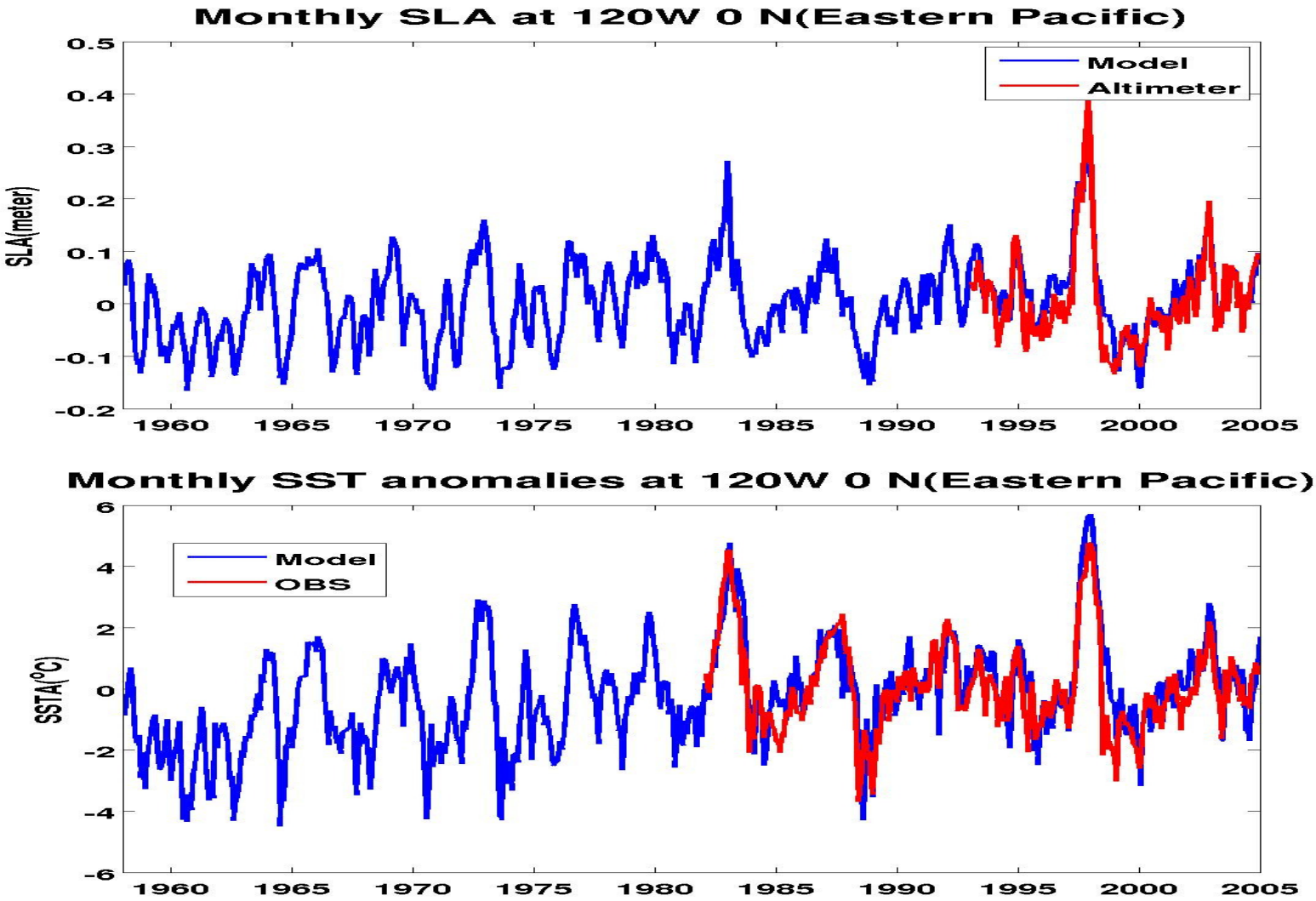
Obs



Model

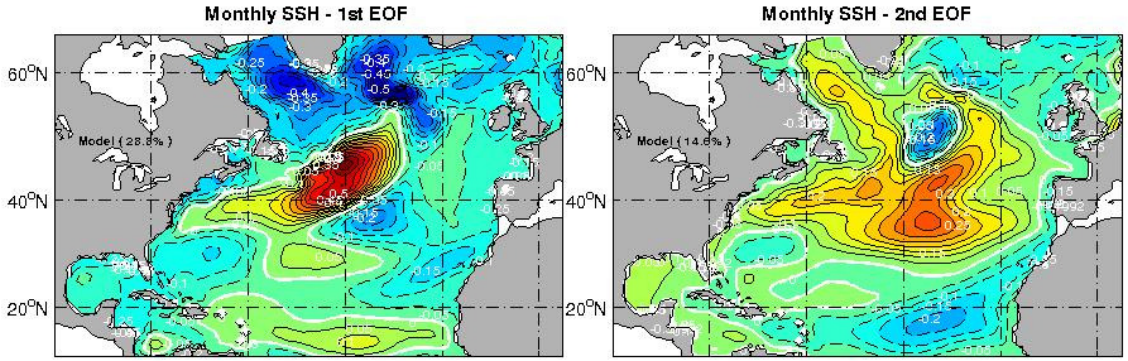


Tropical Pacific Variability

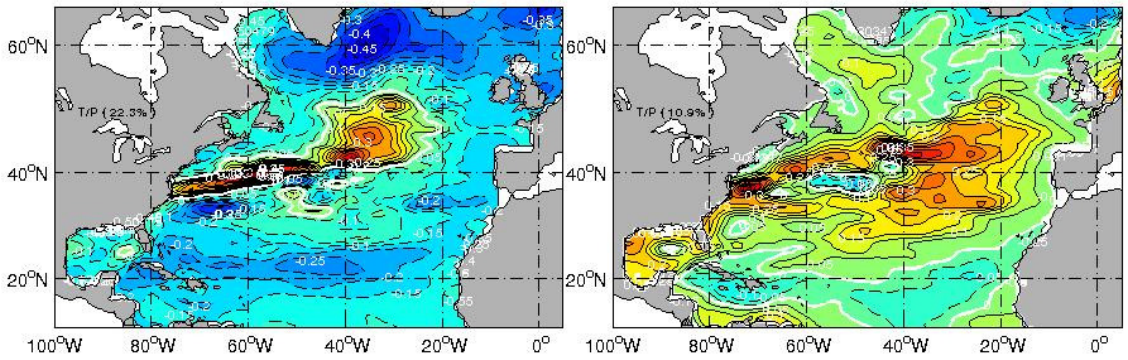


Also reproduces changes associated with MJO

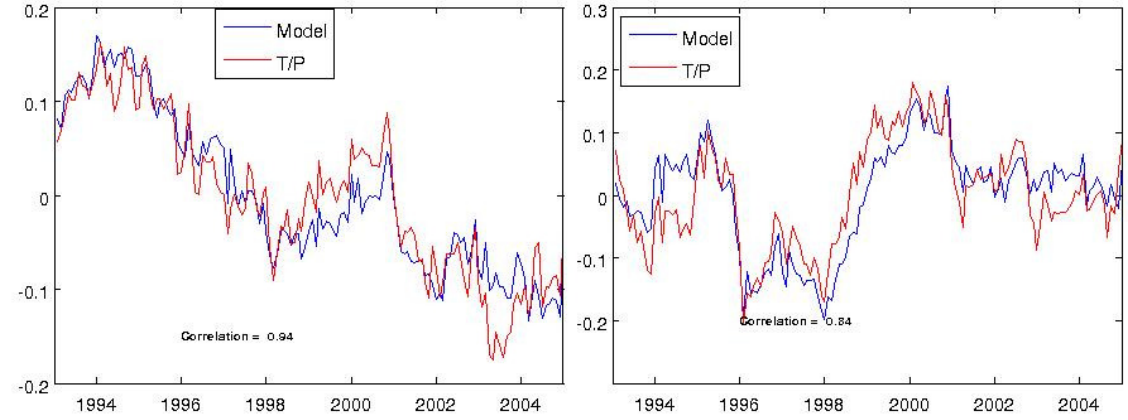
EOFs of North Atlantic Sea Level Variability: Observed and Simulated



First two EOF of simulated variability. (42% of variance.)



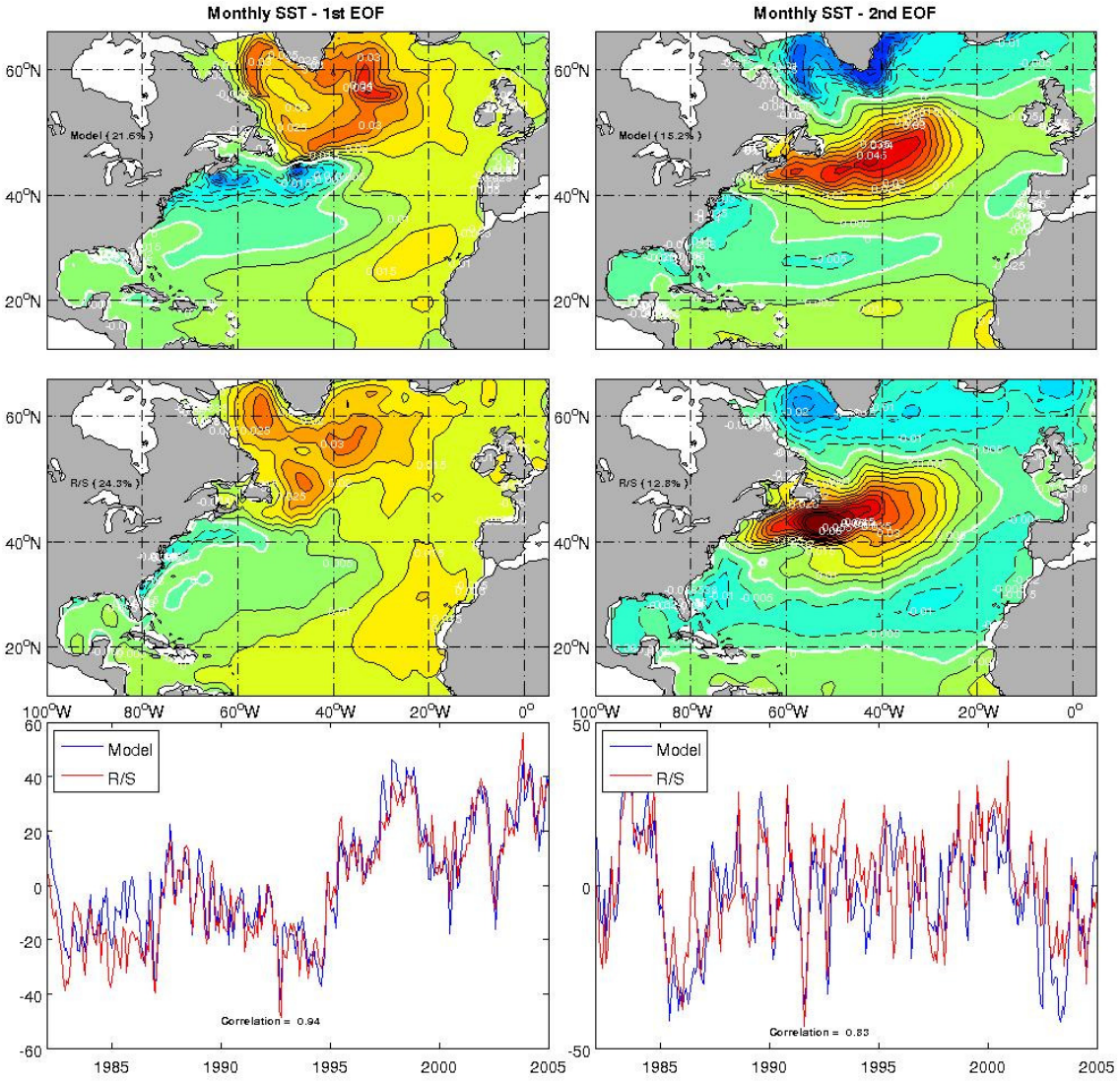
First two EOF of observed variability. (33% of variance.)



Observed and simulated amplitudes highly correlated.

Plan to use the model time series with observed EOF to hindcast pre-satellite variability

EOF of North Atlantic SST Variability: Observed and Simulated

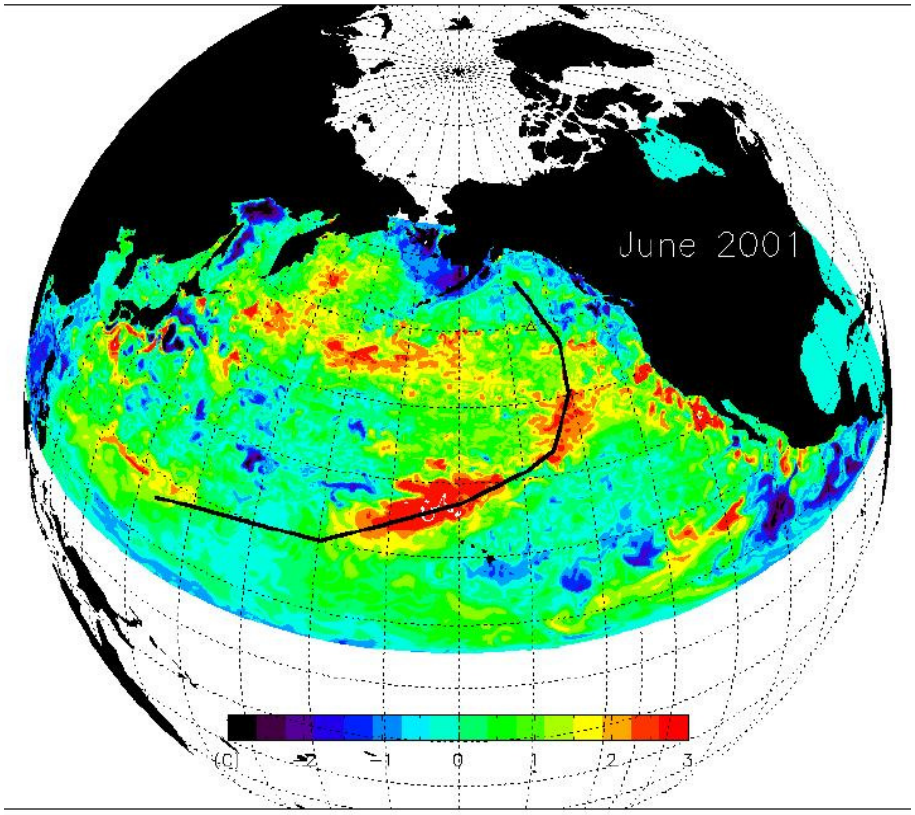


First two EOF of simulated Variability.(38% of variance)

First two EOF of observed variability. (37% of variance).

Times series again correlated suggesting hindcasting over full 50y worthwhile.

Predicting North Pacific SST

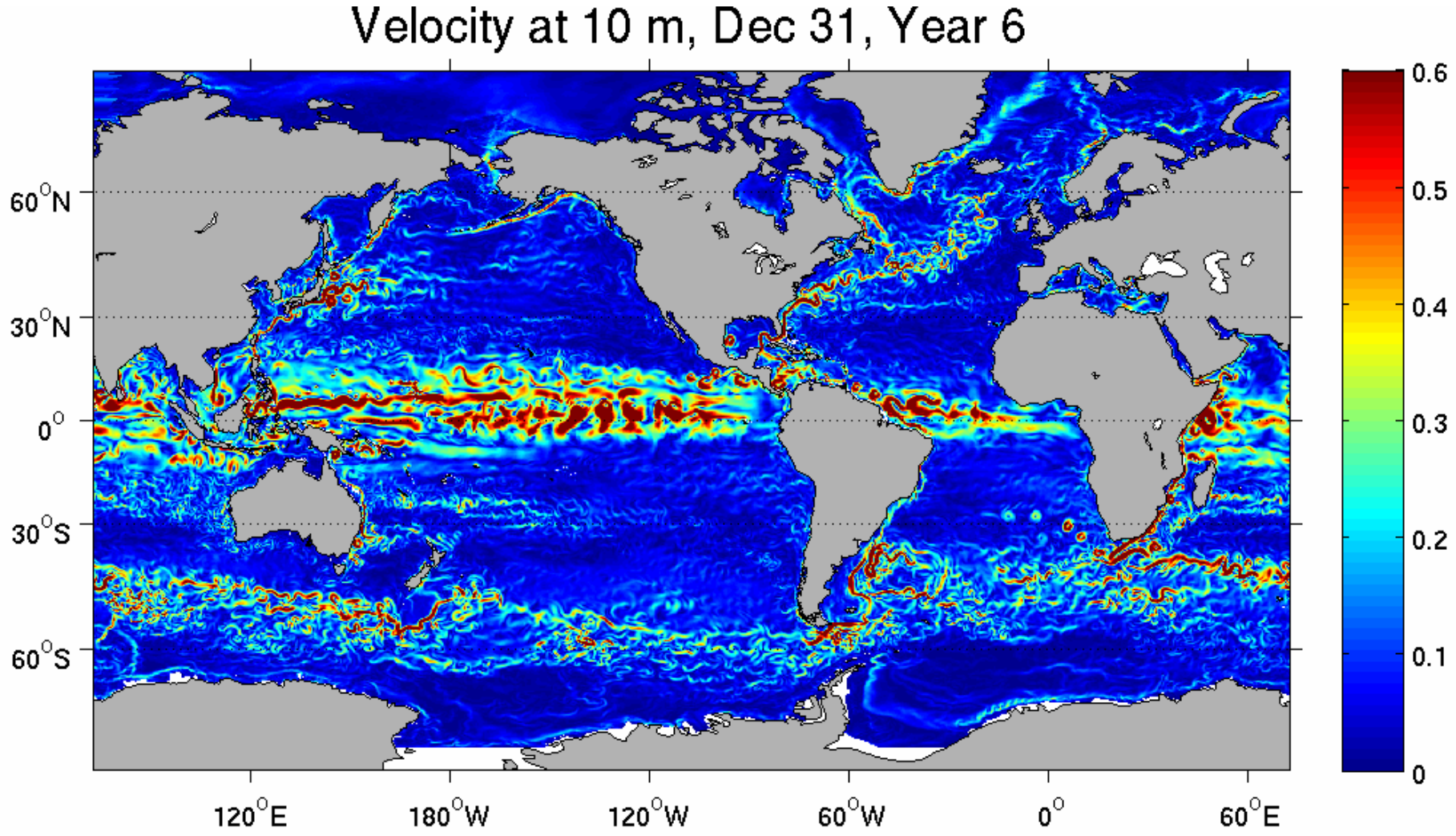


Black line shows theoretical position of Rossby wave front, generated at the coast 3y earlier by ENSO event.

Note correspondence of the black line with maxima in the predicted SST anomaly.

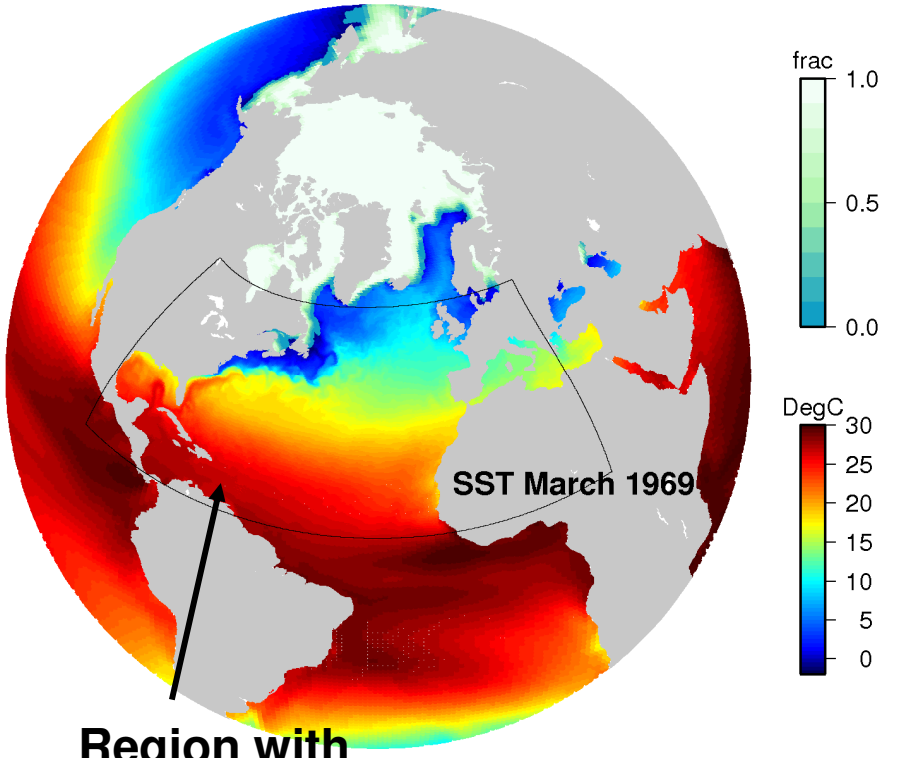
Rossby waves takes 3-5y to propagate from coast to OWSP for example, implying predictability in the northeast Pacific.

Benefit of Increased Resolution: Sub-surface Flow from ¼° model

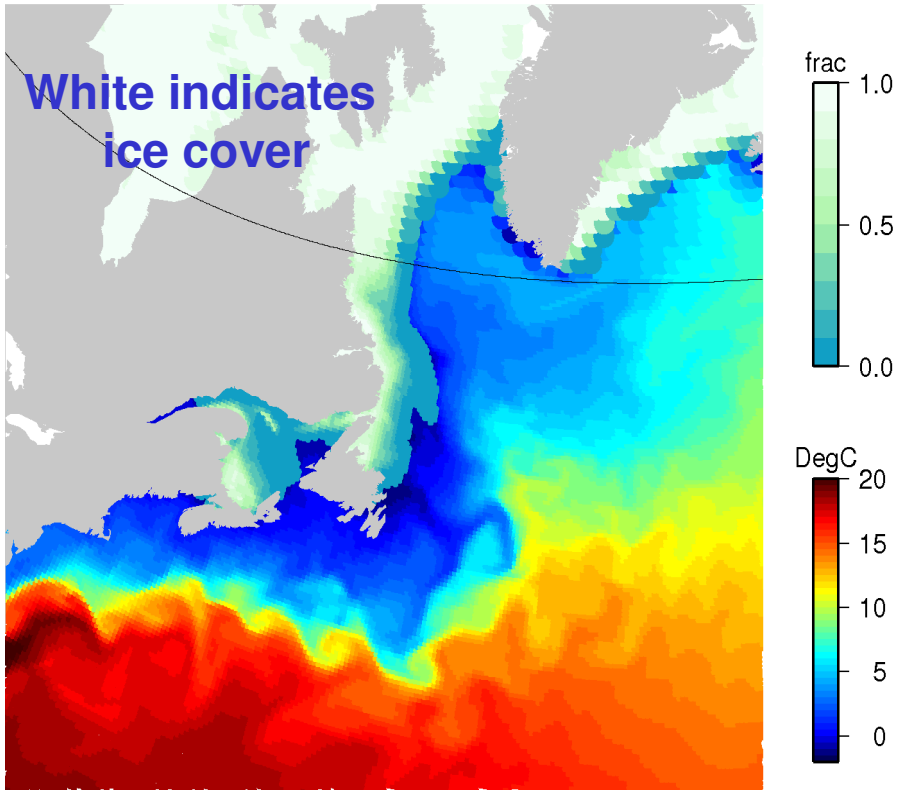


Increasing Resolution Regionally: Example of SST and Sea Ice Prediction Based on Local Grid Refinement

Results from a 1 degree global model with a NA zoom to ¼ degree



Region with ¼ degree resolution

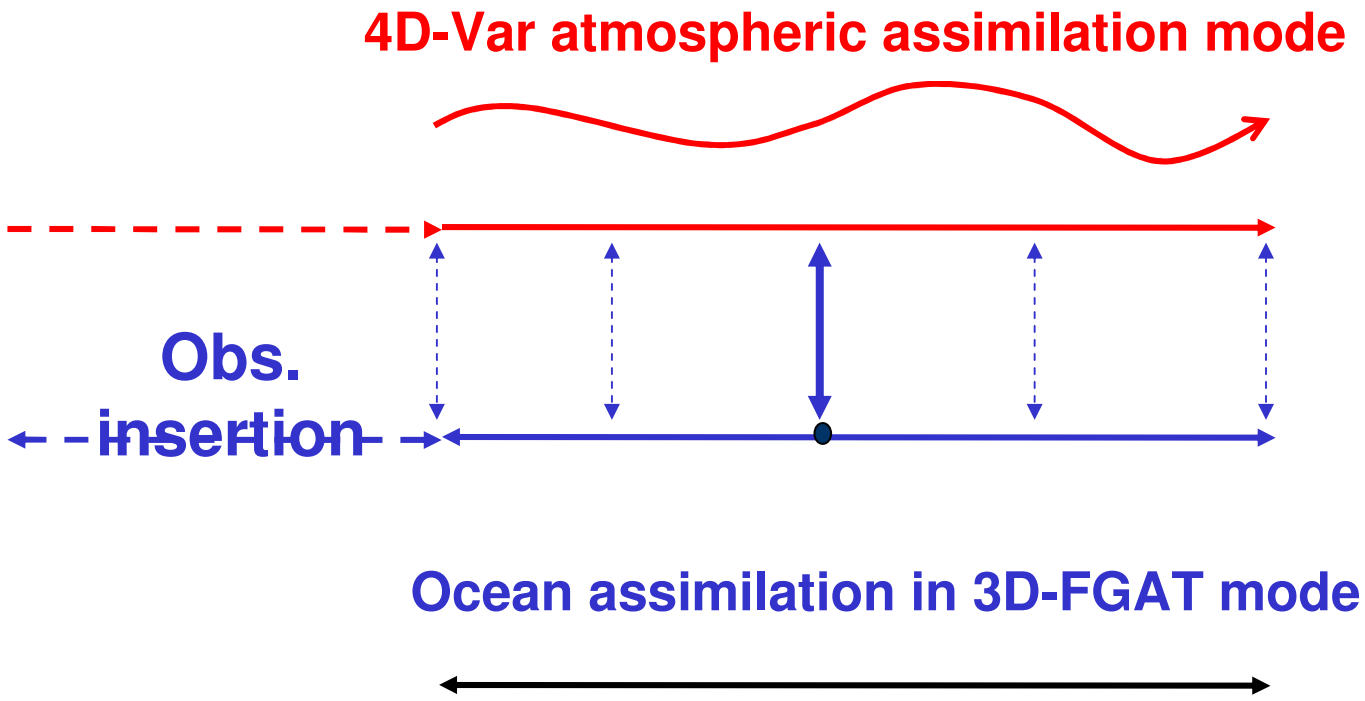


Results from enhanced resolution region illustrating new ability to use AGRIF in ice infested regions

Independent Assimilation into Coupled Atmosphere Ocean Models

- ✓ **EC is coupling GEM to Mercator's NEMO ocean system.**
- ✓ **Data assimilation into a coupled model raises new issues.**
- ✓ **Incremental formulation: independent assimilation for ocean and atmosphere in an "inner loop" but full coupled model integrated.**
- ✓ **Recent work focused on parameter estimation to improve heat, momentum and moisture exchange between atmosphere and the ocean. Anticipate significant improvements in quality of the analyses.**
- ✓ **Project carried out in collaboration with EC and DFO (CONCEPTS).**

Schematic of Independent Coupled Atmosphere-Ocean Data Assimilation



- Coupled model produces a 9h forecast.
- Atmospheric assimilation in incremental mode.
- Ocean assimilation using 3D-FGAT (first guess at appropriate time).
- First experiments focus on obs near interface, and estimation of turbulent bulk exchange coefficients

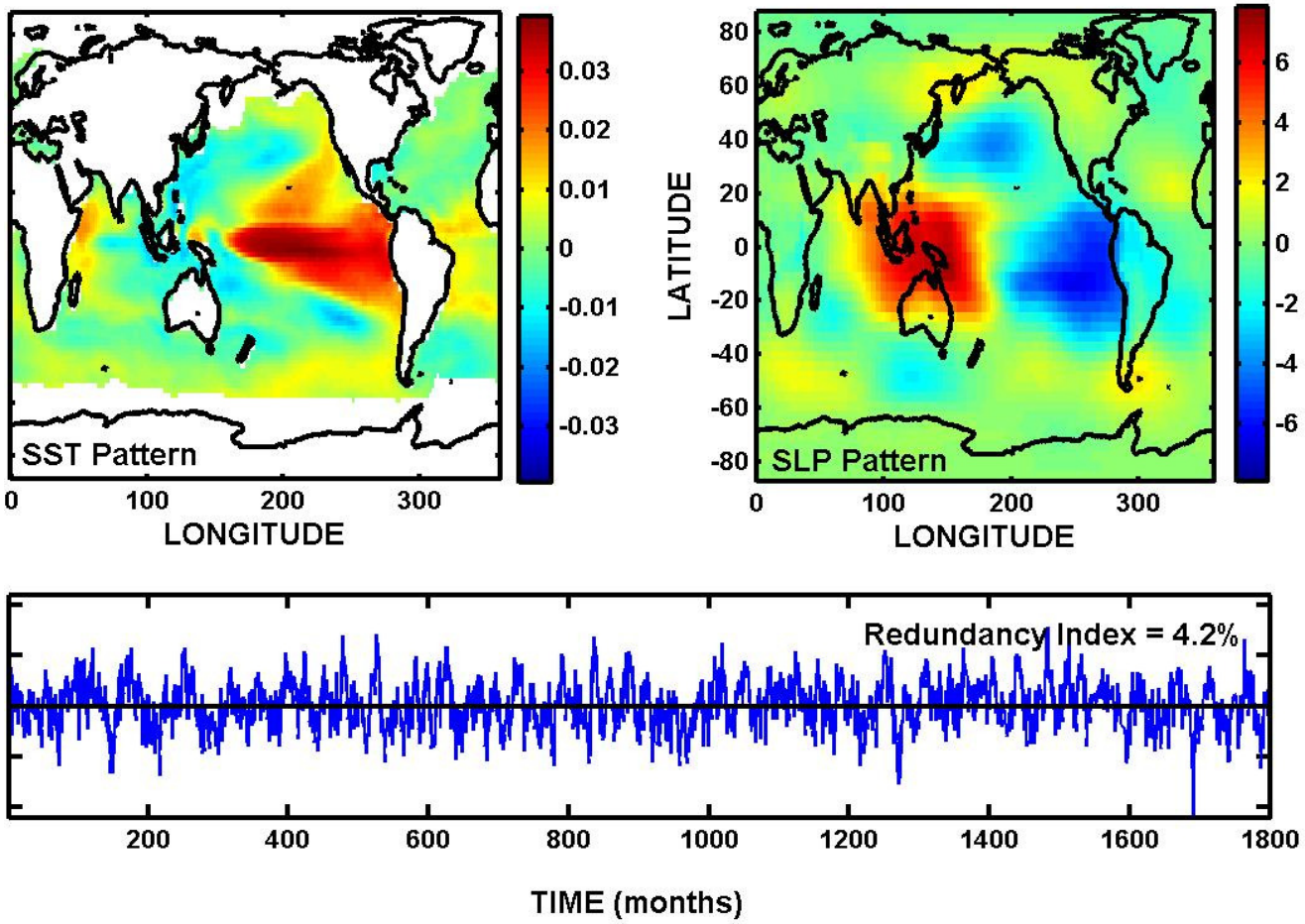
Joint Assimilation into Coupled Atmosphere Ocean Models

Initially focused on covariance between atmospheric and ocean state variables.

Redundancy Analysis used to explore "cause-effect" relationships between fluids using low dimensional representations. Complements EOF analysis.

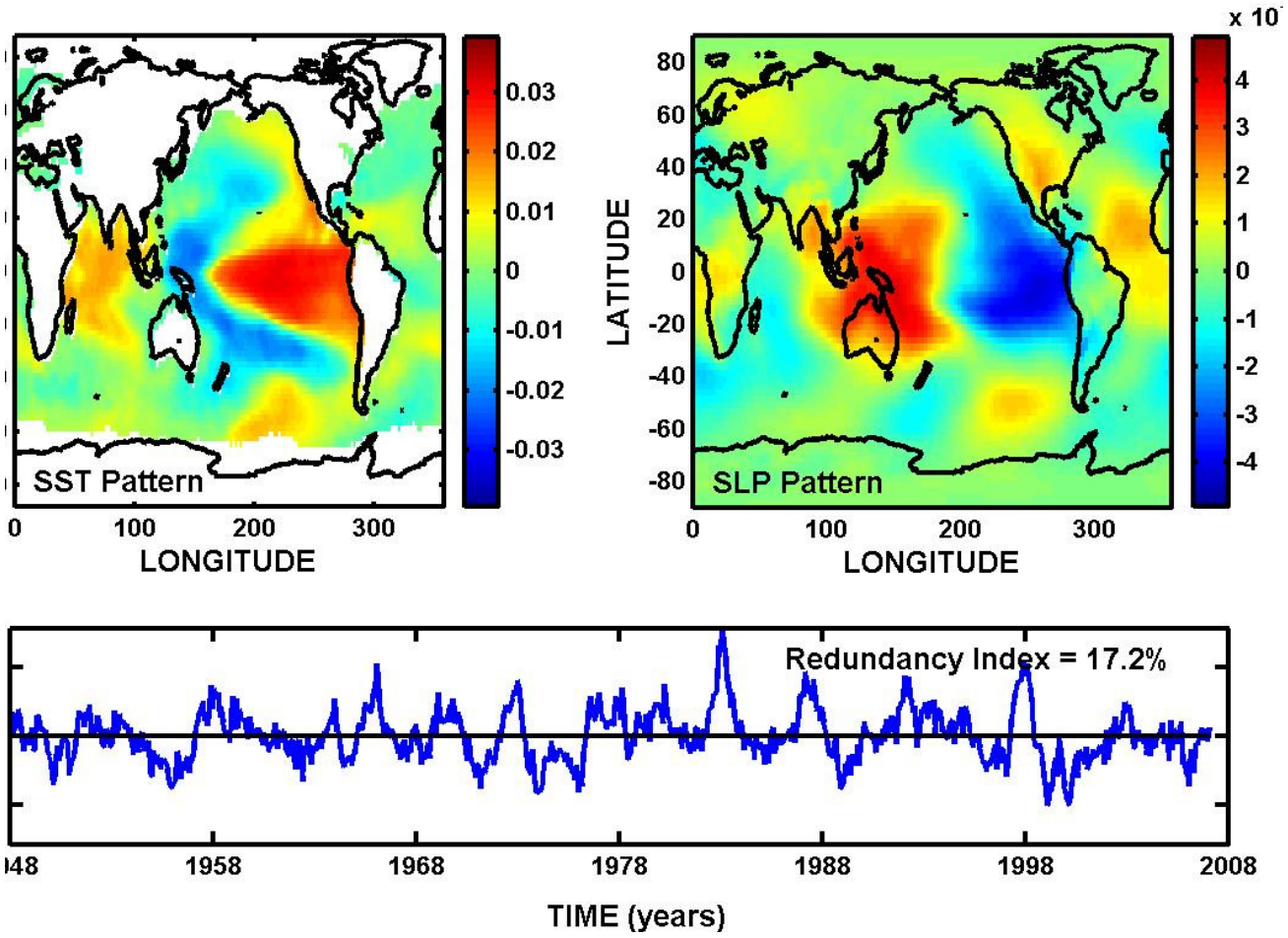
Time-Lagged Redundancy Index may be useful as a predictive tool.

Redundancy Analysis of Monthly Air Pressure and SST From Long CCCMa Coupled Model Run



- First RA mode
- Pa is driver
- 4% SST variance
- ENSO pattern
- Differs from EOF

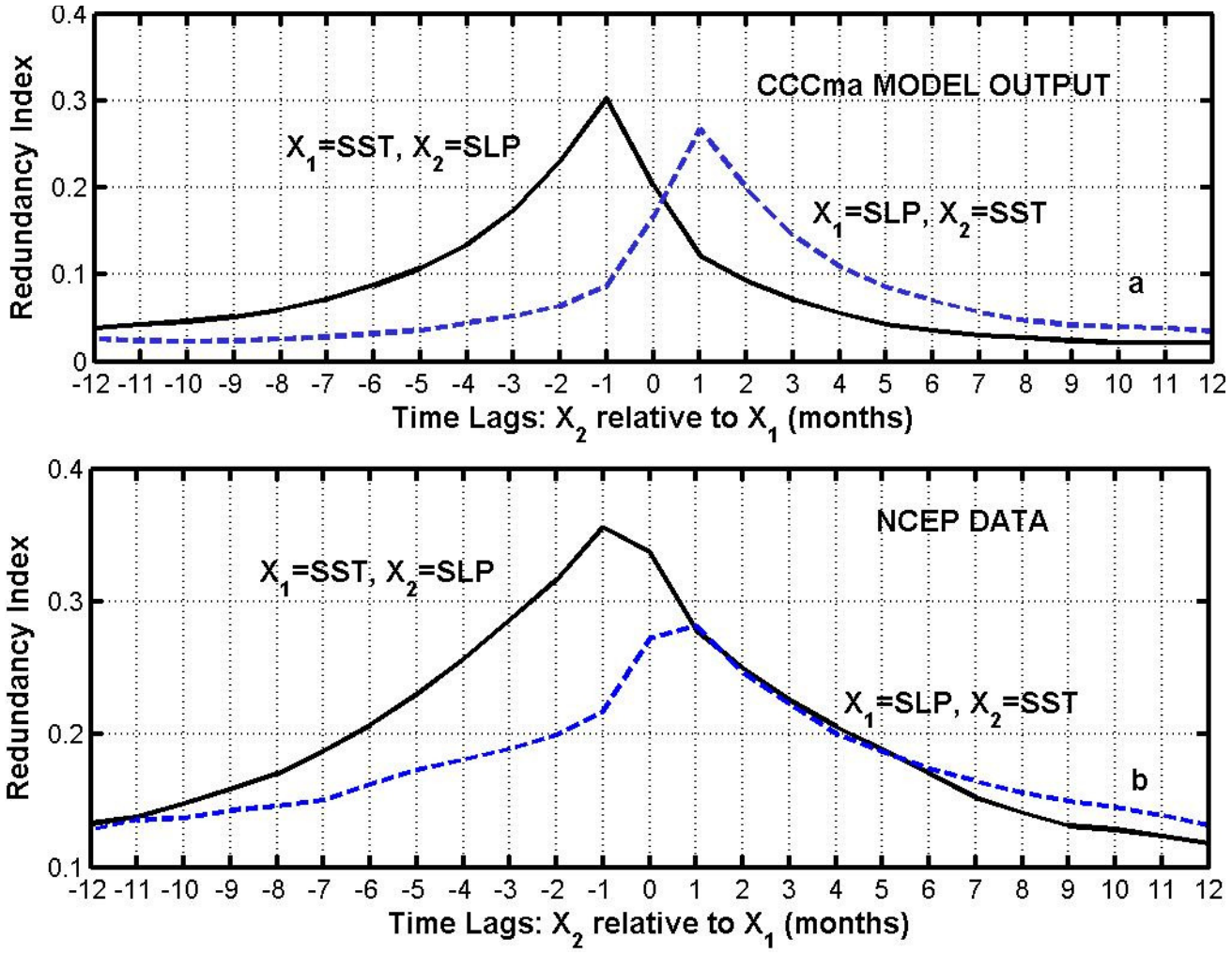
Redundancy Analysis of Monthly Air Pressure and SST From NCEP Reanalysis



- First RA mode
- Pa is driver
- 17% SST variance
- Same as CCCMa
- Note 97-8 ENSO

RA provides more consistent analysis of obs and pred than EOF analysis.

Time-Lagged Redundancy Index



- **Solid line: Pa driver, SST response**
- **Y-axis: proportion of SST variance accounted for by first 20 RA modes**
- **Peak at -1 means SST lags Pa by 1 month**

Same lag relationship for CCCMa and NCEP even though ENSO too weak in model.

Summary

- Progress in ocean, ice and coupled modelling and data assimilation has accelerated over the last year.
- Building on the NEMO code, now have realistic models of North Atlantic, North Pacific and global ocean with demonstrated predictive capability. Coupled models and assimilation schemes being evaluated.
- Useful schemes have been developed to assimilate climatologies, Argo and altimeter data and downscale.
- Exploring physical reasons for variability (e.g., Rossby waves, wind versus buoyancy forcing).
- Collaborations building with Mercator and other international groups (e.g., University of Reading).