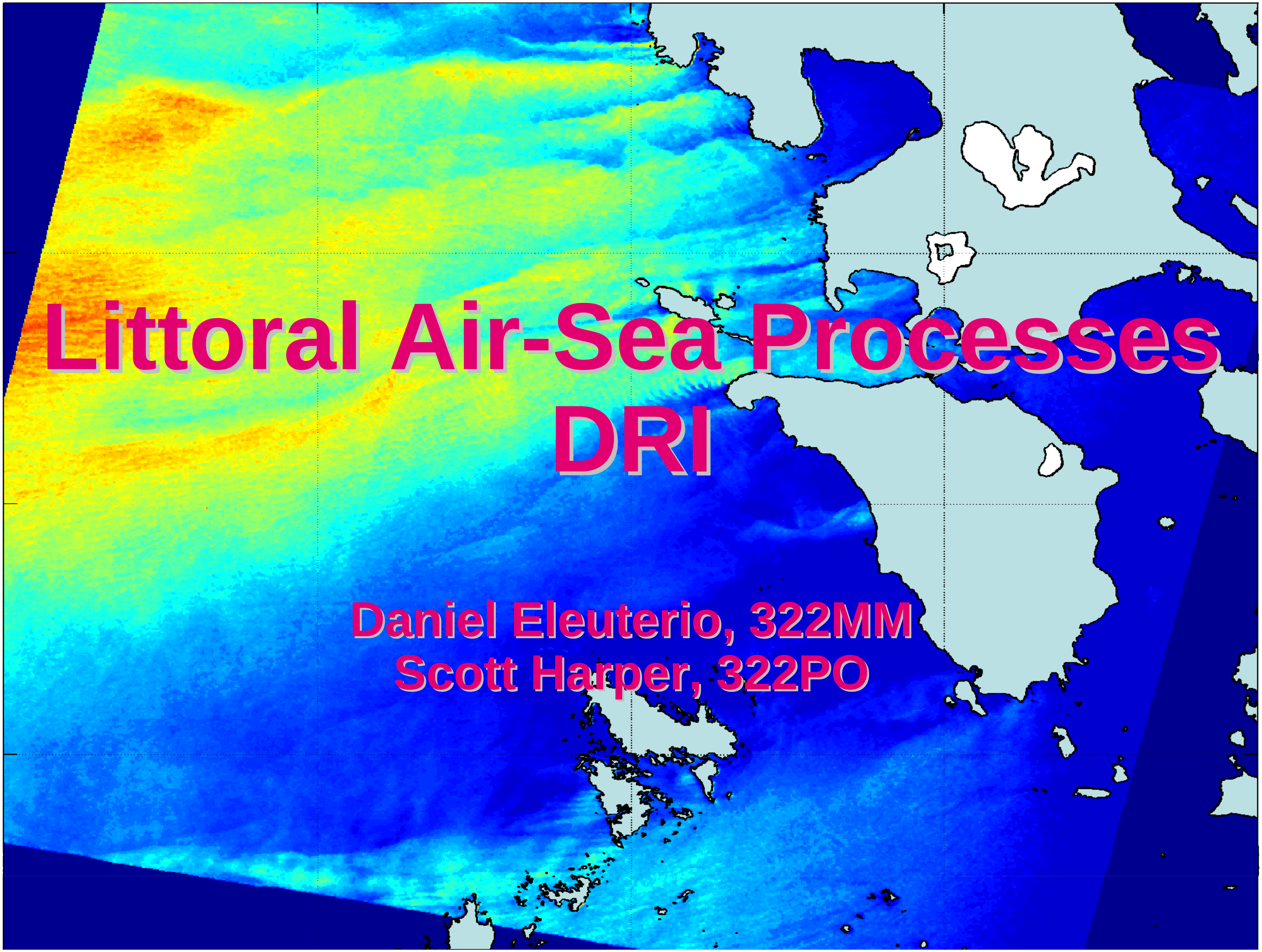
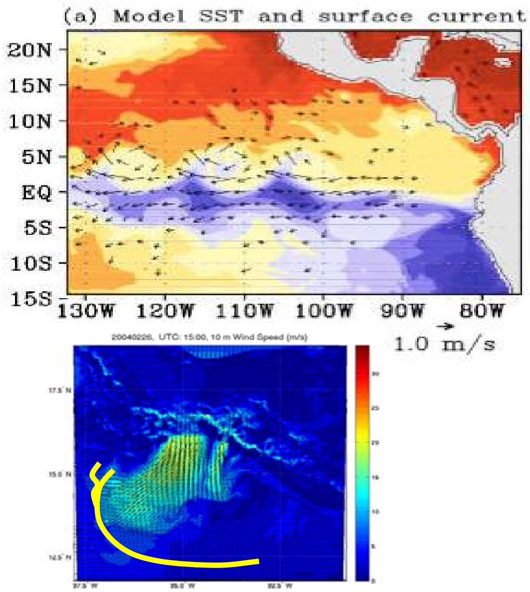


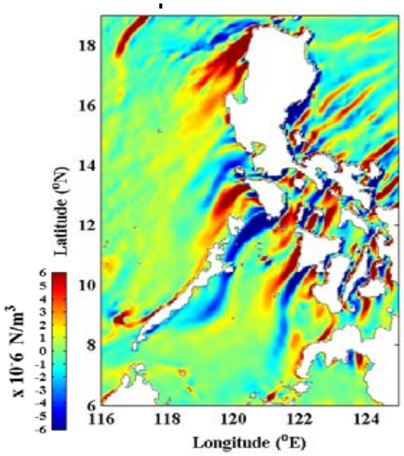
Littoral Air-Sea Processes DRI

Daniel Eleuterio, 322MM
Scott Harper, 322PO

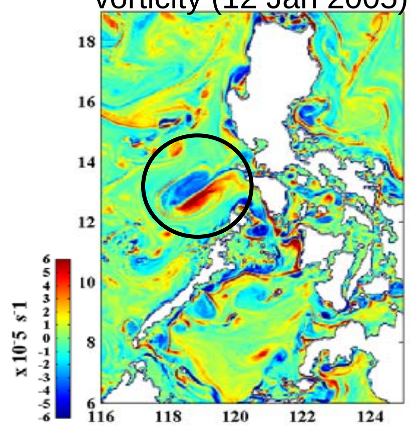
Fully Coupled Air-Wave-Ocean Forecast Models are becoming increasingly available for Operations and Research

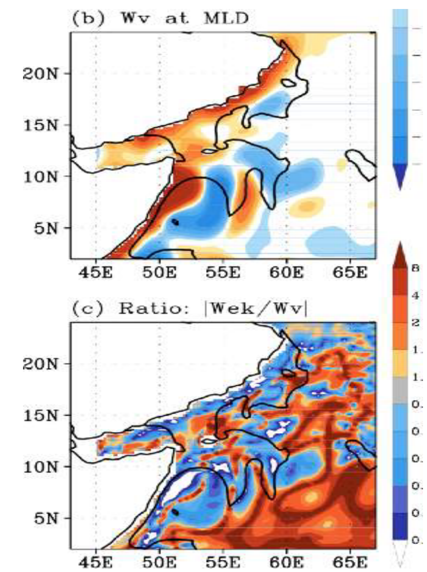


Model wind stress



Model ocean surface vorticity (12 Jan 2005)





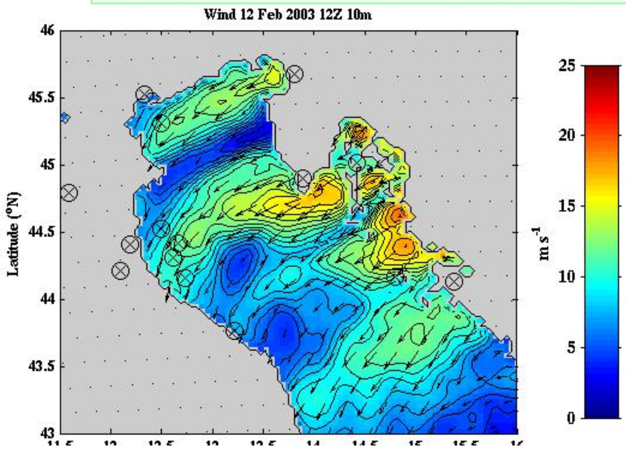
Are the relevant processes adequately represented?

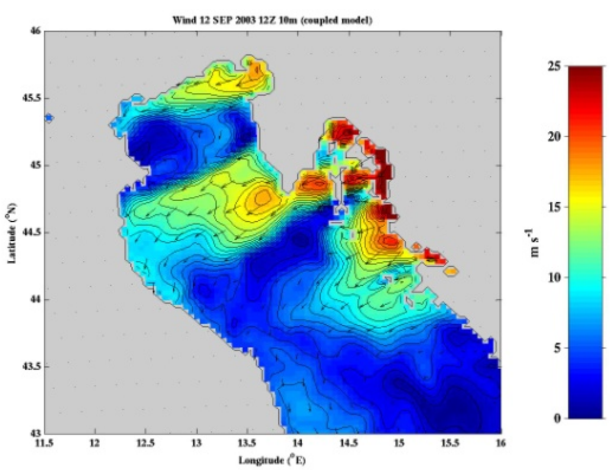
When do (real world) coupled modes cause rapid (model) error growth not captured by Initial Condition error?

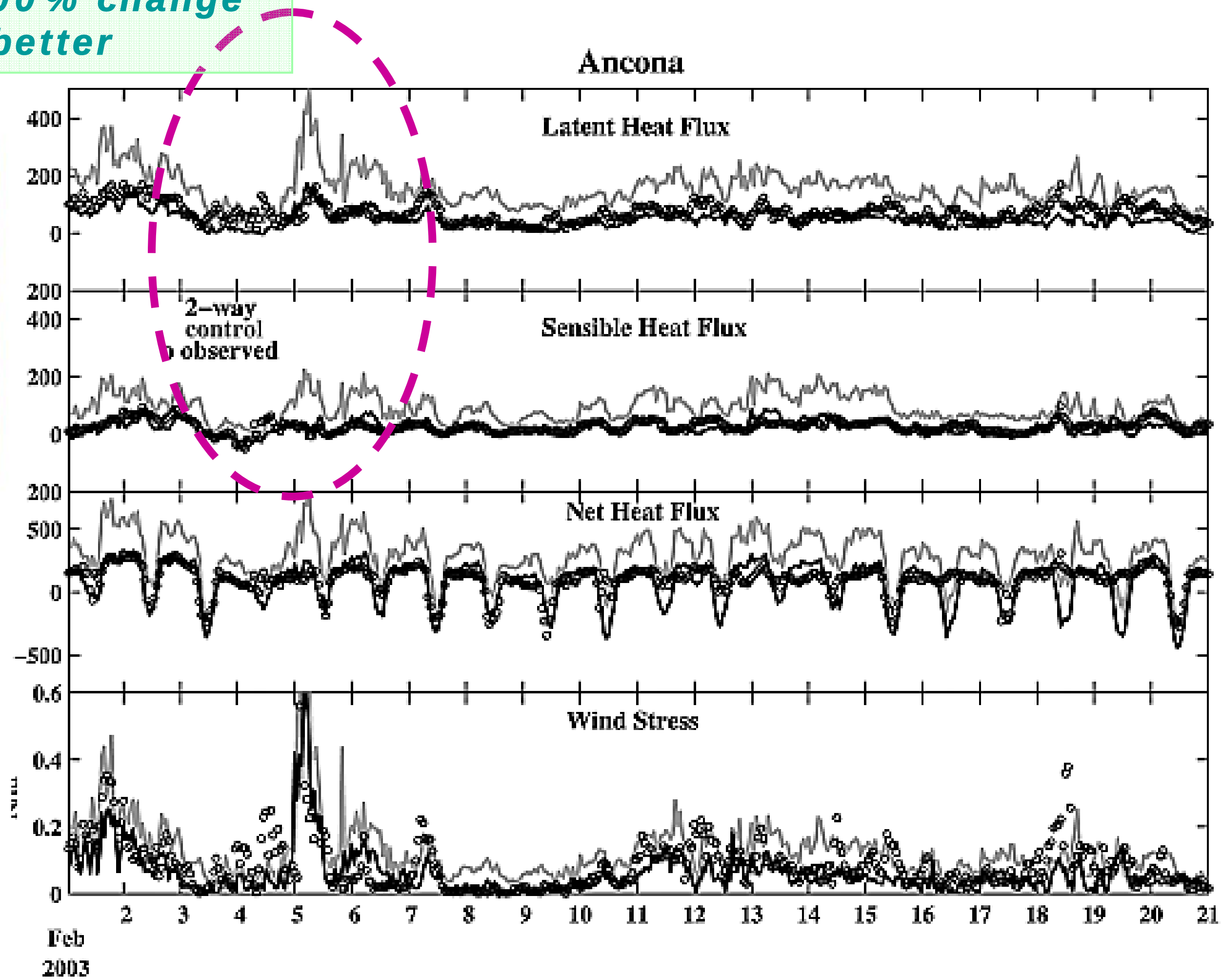
The Challenge

- How well do the models being developed capture the details of coupled modes?

Trends are similar, however 2-way coupling results in 50-100% change in fluxes, matching obs better



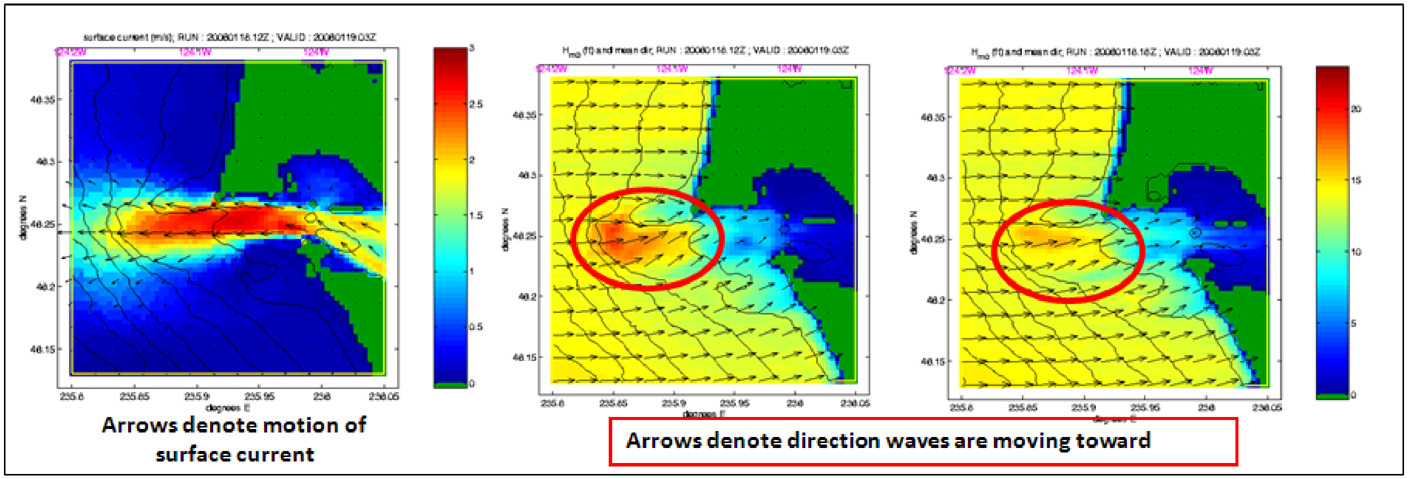




Coupled Processes: Wave/Current Interaction

CIRCULATION MODEL

WAVE MODEL



Ocean currents can be "read" by SWAN or WaveWatchIII; ESMF-based air-ocean-wave modeling system already ingesting SWAN currents. New version of WW3 (curvilinear grid capability added by Rogers & Campbell) will become ESMF compliant in FY09 and will also be able to ingest ocean currents.

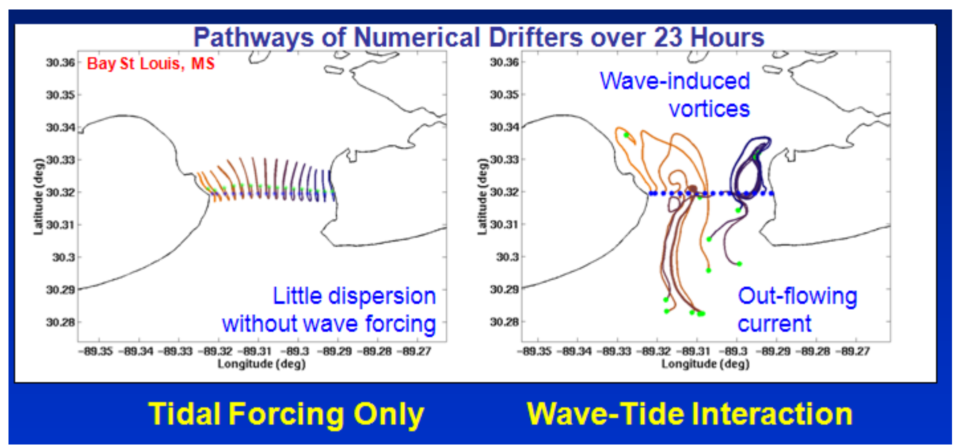
Surface currents and water levels from ocean circulation model

Wave heights are steeper due to circulation from Columbia river

Lower wave heights when currents not included in simulation

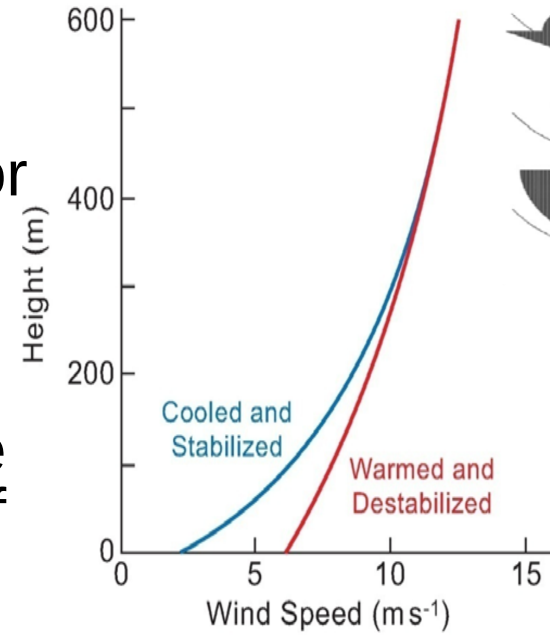
The importance of wave-current interaction is demonstrated by this study in the Bay of Saint Louis (MS).

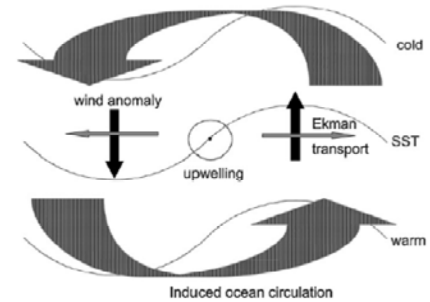
Wave-induced circulation can significantly alter the transport of sediments, pollutants and biological organisms (Cobb & Blain, 2002)



Coupled Processes: Small-scale variations in SST field – MABL and OML momentum transport

- Most observations are not <u>*coupled*</u>; either in routine in-situ and remotely sensed datasets or in field studies.
- Many field studies focus on one medium (air or ocean) and have limited or bulk measurements of the other.
- A few studies from CBLAST and other efforts indicate that “to get the fluxes right” for one media the forcing is not correct in the other media by a factor of at least 2-3.

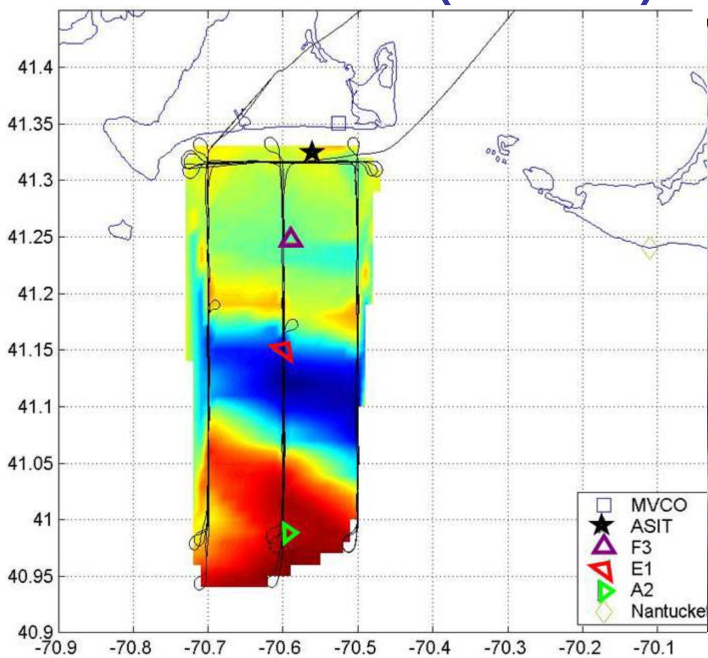




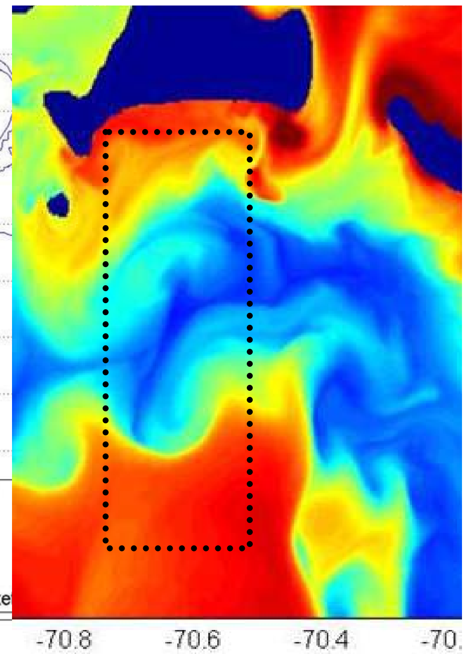
Over cool water increased stability decouples the surface winds, collapses the MABL, and increases vertical shear. Surface wind differences are then amplified by the resulting PGF normal to the SST gradient, which results in changes in sfc stress to the OML and changes the ocean vertical mixing.

Simulation of SST Variability and Its Impacts on Wind in CBLAST-Low

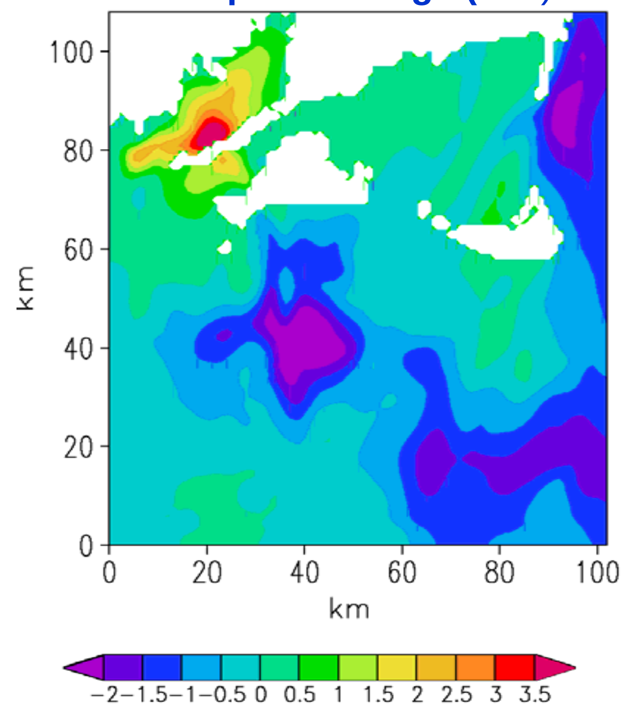
Pelican SST (20030818)



NCOM Simulation

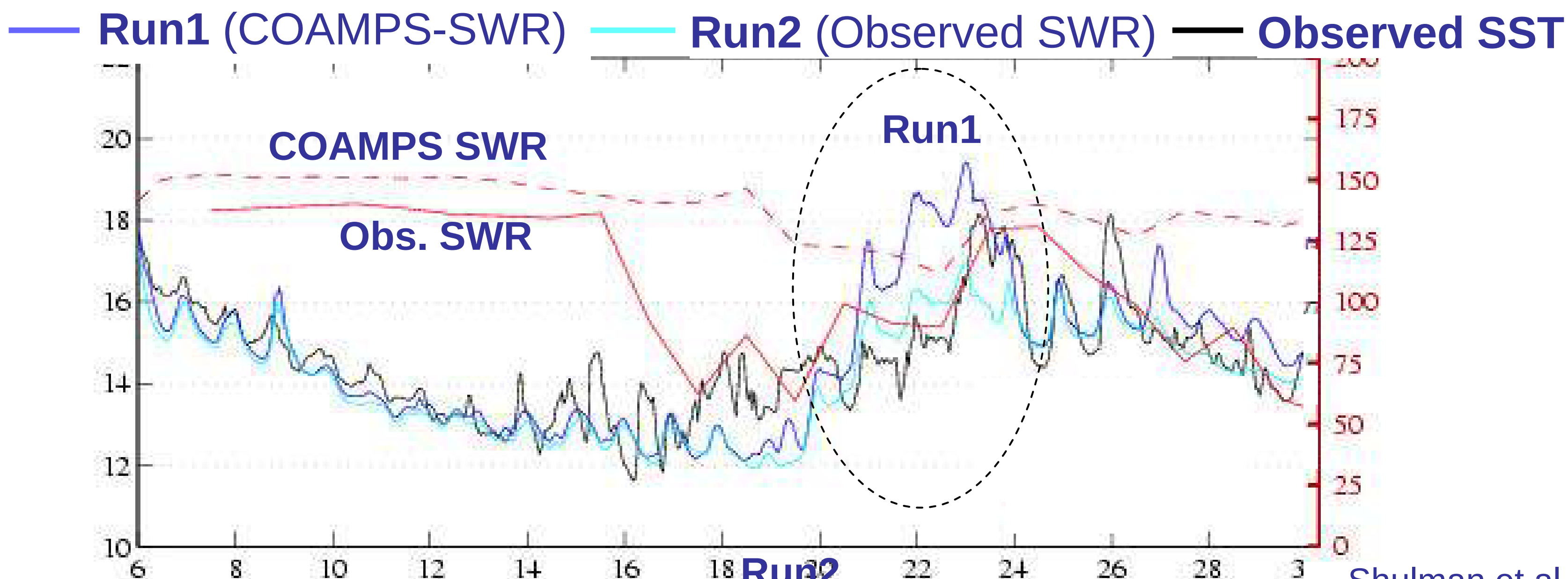


Wind speed change (m/s)



- The SST cold tongue is produced both by the advection of cold water generated by tidal mixing (Active Ocean model) and the strong upward heat flux during the time period (Active Atmospheric model).
- The COAMPS forecast used the operational SST field which has no SST change during the forecast.
- The wind speeds were (50%) too large in this region in the uncoupled model.

Coupled Processes: Cloud modulated solar forcing



Shulman et al., 2006

- SST prediction and OML surface layer stability is sensitive to the short wave (SW) and freshwater fluxes at the surface, especially in low winds/ sea states
- SW flux is sensitive to stratocumulus cloud prediction
- Current mesoscale models have difficulties in predicting these clouds, feeding back to both the OML and MABL evolution

Coupled Processes

- Coupled modes have been shown to be important in several theoretical, modeling, and process studies.
- Loosely coupled models show improved predictability in these regimes, although the causal mechanism is not always apparent.
- Models and simulations represent these effects in a variety of bulk or explicit ways, and not always in a consistent manner.
- Field studies often observe the turbulent or bulk properties in all three media, again not usually in an integrated coincident manner.

The time is now for a focused effort.

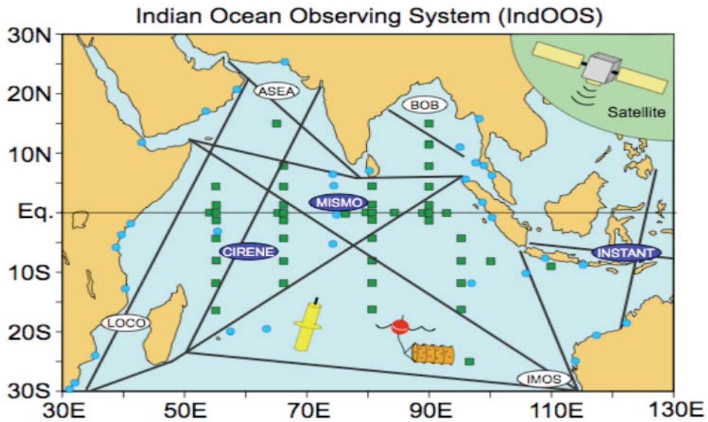
Approach

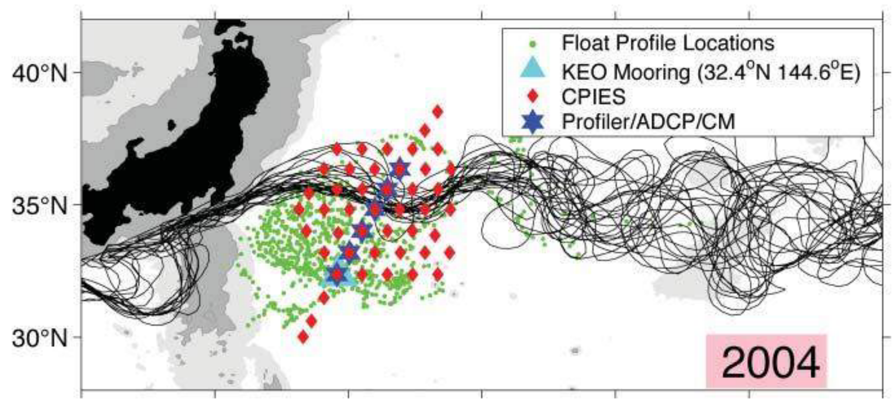
Split research efforts into three thrusts:

- Observations
  - Intensive Observational Period (field study) – focusing on a relevant phenomena of interest.
- Techniques and Assessment
  - Assess Ocean, Wave and Atmosphere coupling physics, parameterizations, resolution dependencies, and software protocols.
  - Assess current state-of-the-art forecast systems with available datasets from previous efforts.
- Improved Ocean, Wave and Atmosphere Predictions and Data Assimilation
  - Use results of observational efforts and model assessment/ development to improve global and basin scale prediction

Modeling Approach (Year 1-3)

- Evaluate the current coupled models with datasets from recent field studies where coupled modes likely exist and some measurements in both media are available.
- LASIE'07, GOTEX, VOCALS, AOSN II, ASAP, TCS-08, PHIL-EX, KESS, MISMO





Observational Approach (Year 1-3)

- Enhance existing sites to enable long term *<u>directly measured</u>* air-sea-wave flux and bulk observations to assess model performance in these coastal coupled regimes.

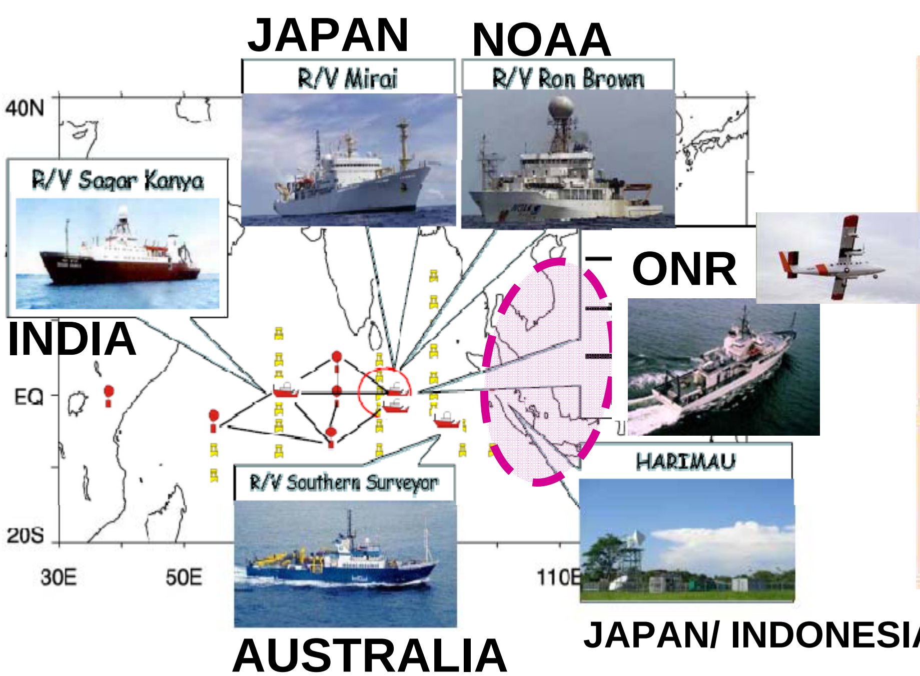
- Possible collaborations with current systems by marine science consortiums (e.g. MBARI, NPS, JAMSTEC, NTU, Rutgers, etc.)

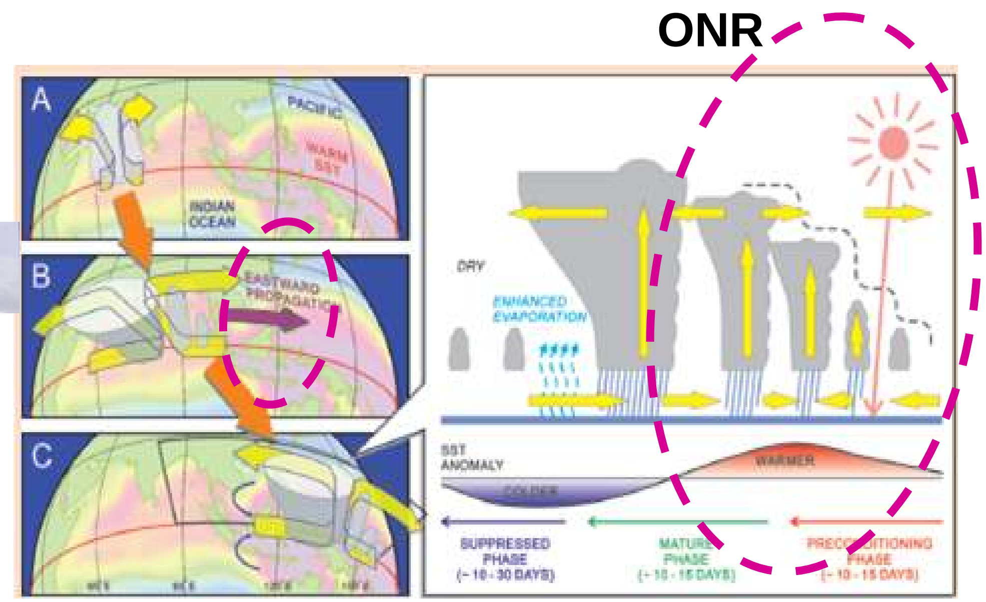
Observational Approach (Year 2-4)

- Design an Intensive Observation Period/ field study to validate and improve the explicit and parameterized coupled turbulent processes in these modeling systems for a specific regime of interest.
- Possible leverage: CINDY2011 (JAMSTEC) / DYNAMO (NOAA/NSF) studying the Madden Julian Oscillation (MJO) in the Indian Ocean. Many recent papers have established air-sea coupling is critical to the phase/speed/strength of MJO.
- NOAA climate focus planned in winter 2011 (FY12) is focused on bulk measurements, large scale convective interactions, and convective mid-atmospheric moistening needed for monsoon onset but would provide large-scale B.C. and forcing needed for mesoscale process studies.

Observational Approach (Year 2-4)

- Combined ship/aircraft measurements of direct fluxes and process studies on ONR topics such as mixed layer response to mesoscale forcing and land-air-sea interaction in the Maritime Continent would leverage these efforts extensively and advance fundamental understanding of Naval relevant processes.

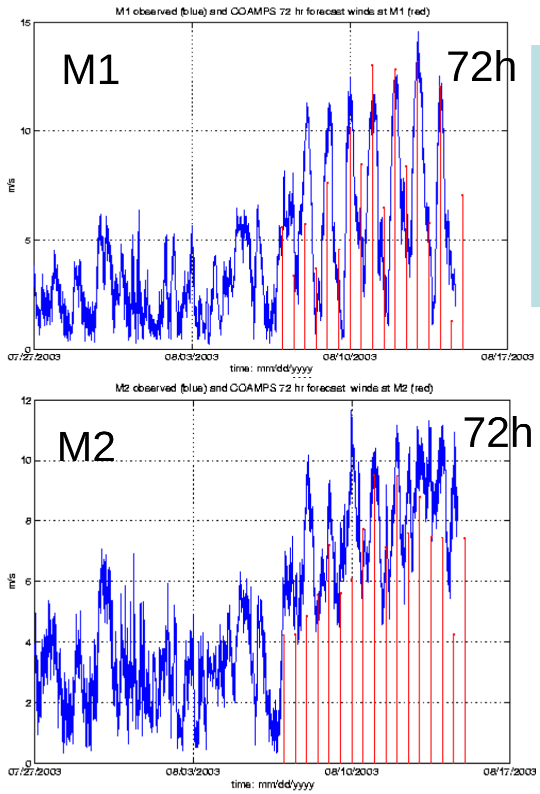




MJO Conceptual model
Zhang, 2005

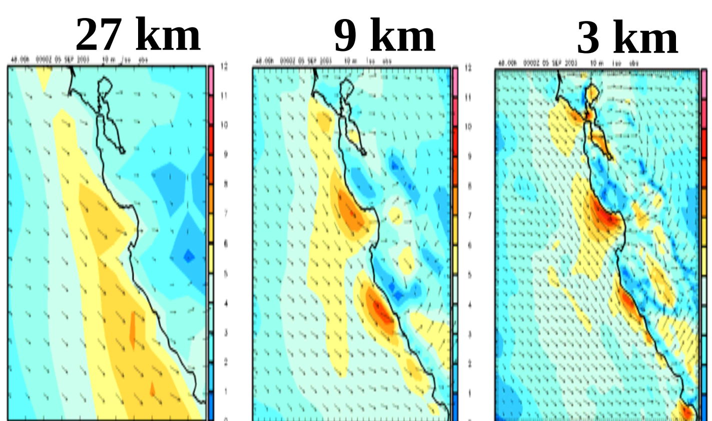
Modeling Opportunities

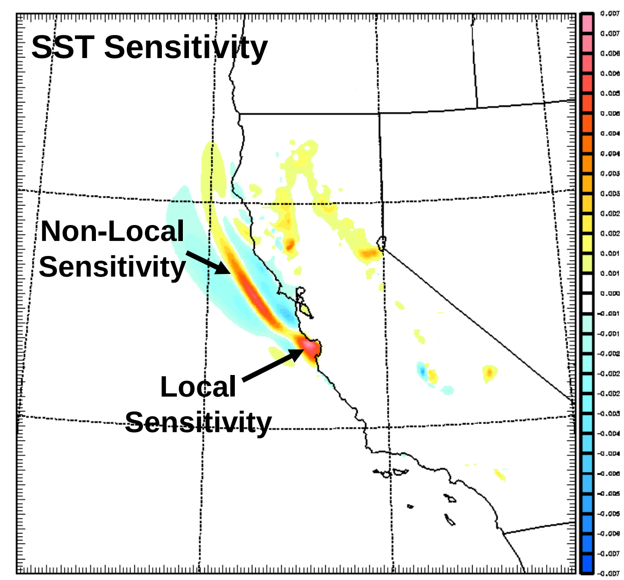
- Further develop results from CBLAST-Low, ASAP, AOSN-II in mesoscale models and ongoing work in global models on dynamics of the MJO



Sensitivity of the cost function (***J***) at time ***t_n*** to the state at time ***t_0***

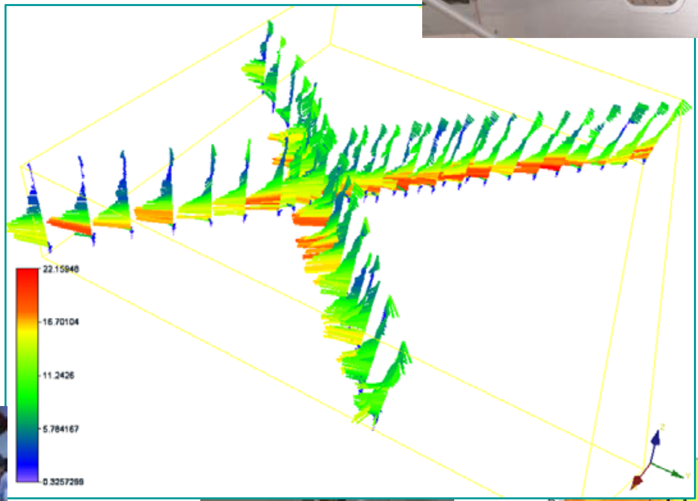
$$\frac{\partial J}{\partial \mathbf{x}(t_0)} = \mathbf{M}^T \frac{\partial J}{\partial \mathbf{x}(t_n)}$$

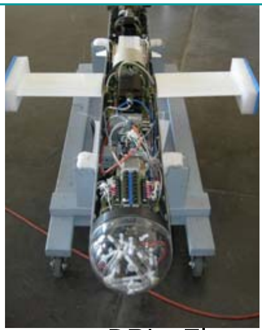


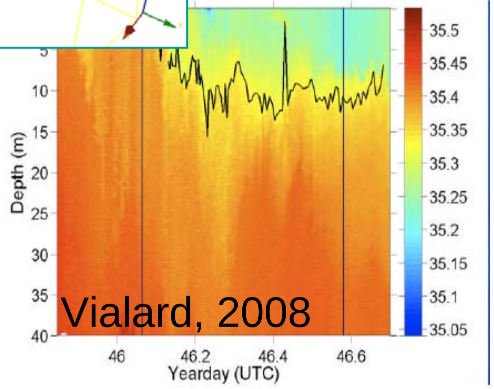


New Sensing Technologies

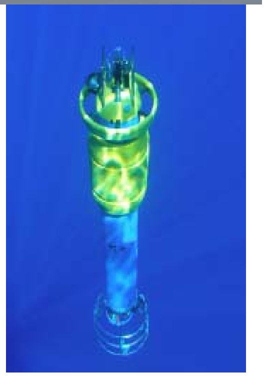
- New observational technologies can directly measure coincident air-wave-sea bulk and turbulent properties.





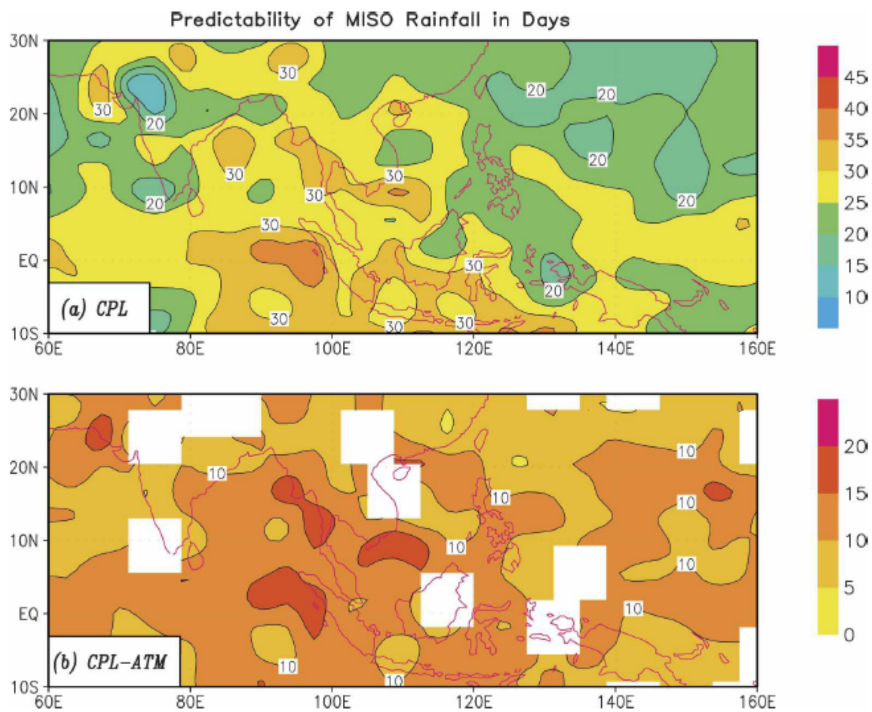


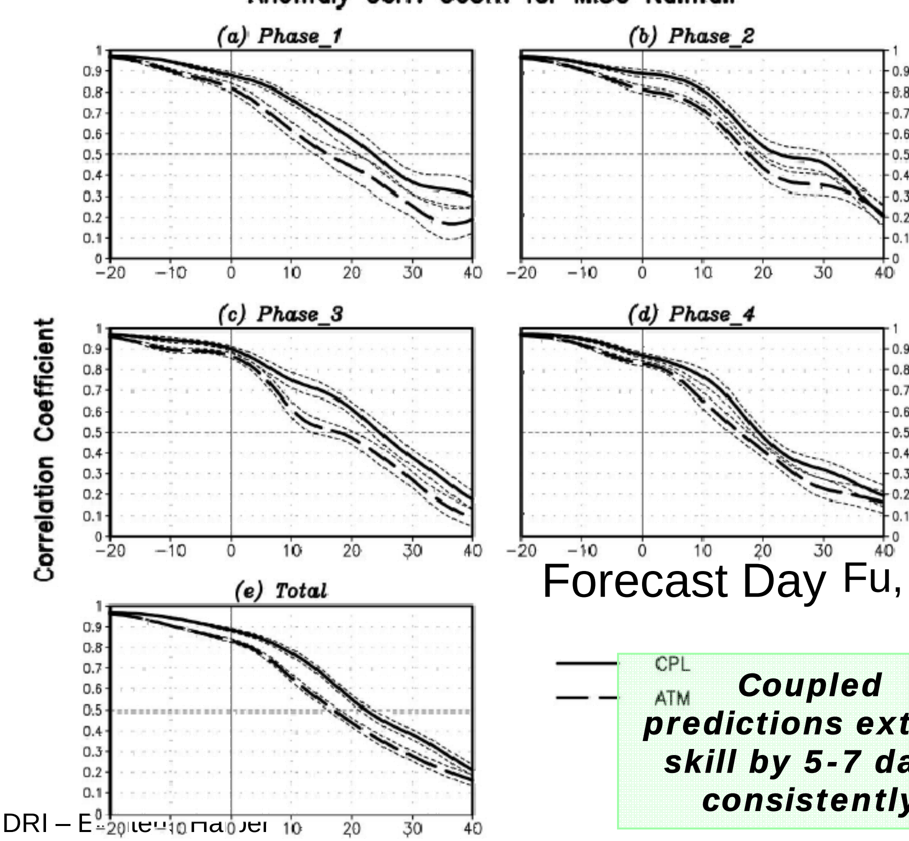
Vialard, 2008



Goal: Improved Basin-Scale Predictability

- Coupled synoptic forecast models shows a 5-7 day improvement in skill for certain phenomena such as MJO, depending on region and inherent predictability (IO better than WNP)





Fu, 2008

Coupled predictions extend skill by 5-7 days consistently

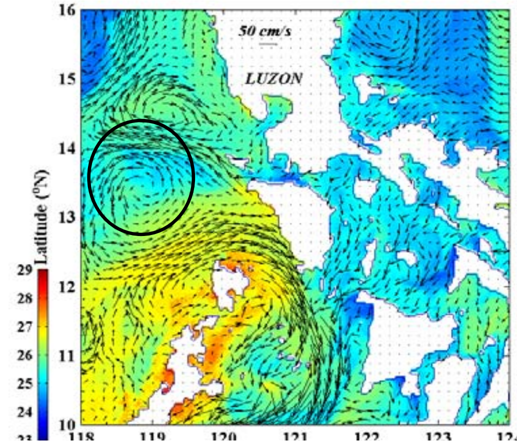
Why Now

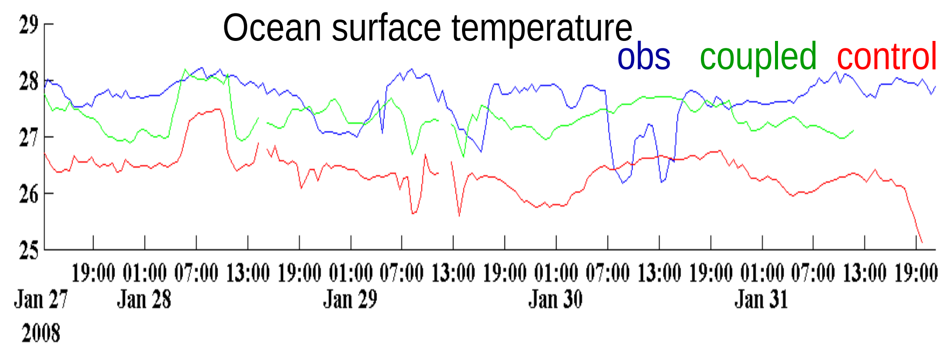
- A-W-O Forecast Models are operational or coming on line with operational transitions planned over the FYDP
  - TC-COAMPS, ECMWF, UKMO UM, HWRF, etc.

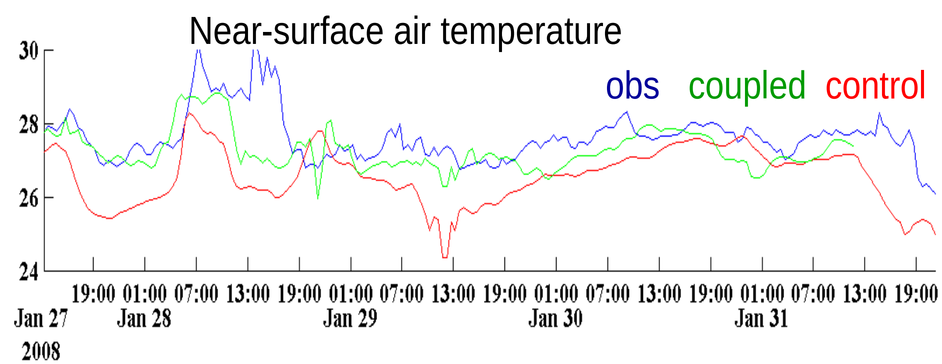
- Coupled datasets are needed for verification & validation

- Process studies are needed for forecast improvement

Model SST & Surface Current (27 January 2005)







Coupled high-resolution run reduced the SST & air temperature bias

Summary

1. The coupling problem must be examined in a 3-way wave-ocean-atmosphere mode in order to improve predictability (more reliability) and to properly address higher resolution simulations needed in littoral regions (coastal, island, and shallow marginal seas).

2. There are already convincing cases demonstrating the need to include coupling in both global and regional scales, with emphasis on the littoral environment.

3. There is a need to obtain dedicated coupled data sets; both intensively for phenomena of interest such as the MJO and in a sustained manner for model validation; and develop new observation tools to validate and calibrate methodologies and guide new research efforts.

4. There are already available modeling tools (e.g. flux couplers, protocols etc.) that can be adapted and tuned to be used by the scientific community to address this challenge.

This DRI Will Produce

- ***A better understanding of physical processes and numerical representation of coupled modes.***
- ***Better operational prediction in the maritime tropics and subtropics.***

<u>Under real, strongly coupled conditions</u>

Questions/ Discussion