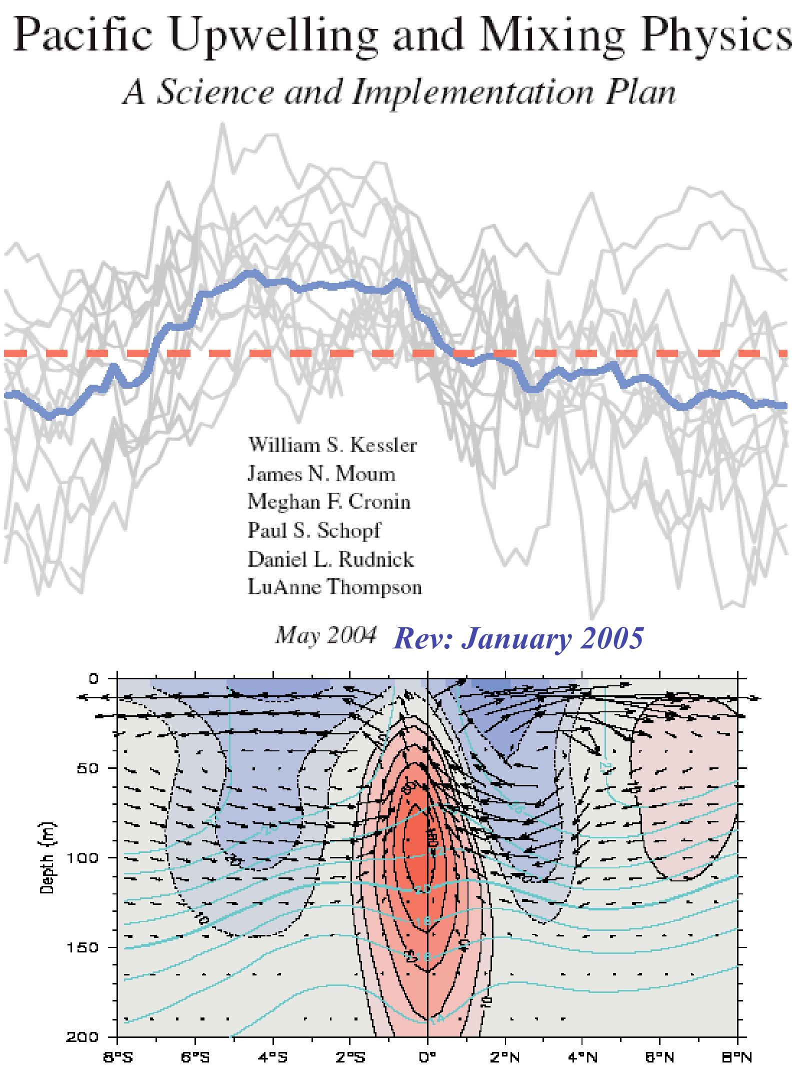


PUMP

PUMP is a process study to observe and model the complex of mechanisms that connect the thermocline to the surface in the equatorial Pacific cold tongue.

Its premises are:

- climate-scale ocean models are ready to exploit realistic vertical exchange processes, but need adequate observational guidance
- historical records now exist upon which we can target process experiments (TAO)
- observational capabilities are superior to what they were 20 years ago
- understanding of mixing now proposes specific hypotheses to be tested

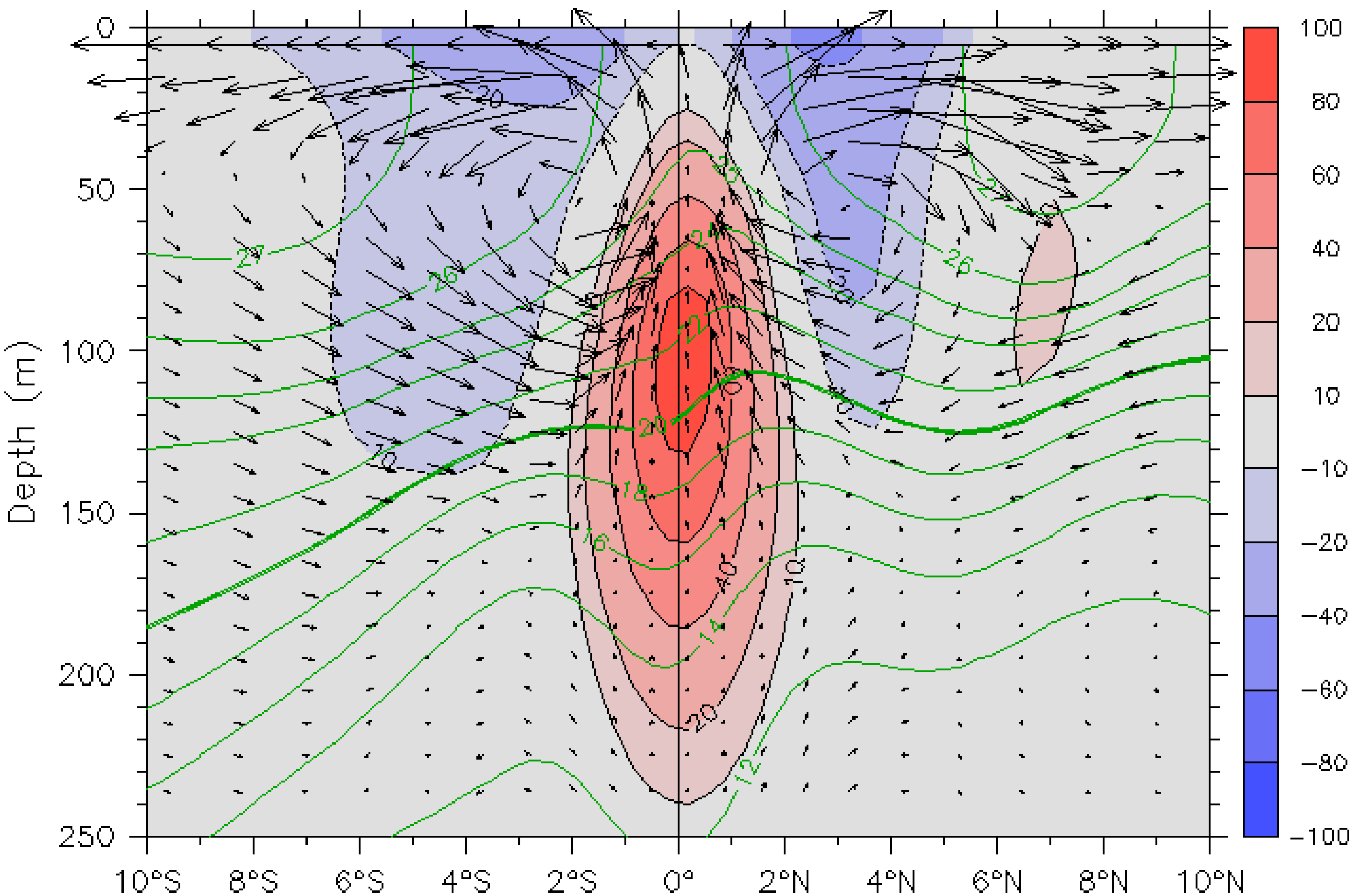
Why PUMP is needed

- ENSO is not a solved problem!
  The past few years have shown that we are a long way from being able to make accurate ENSO forecasts even a few months ahead.

- Interannual variability of CO_2 flux out of the equatorial Pacific is 70% of the total oceanic flux variability.

⇨ We must correctly model vertical exchange in the equatorial Pacific (and Atlantic) cold tongues. These are the crucial regions where ocean circulation interacts with the atmosphere.

OGCM meridional circulation

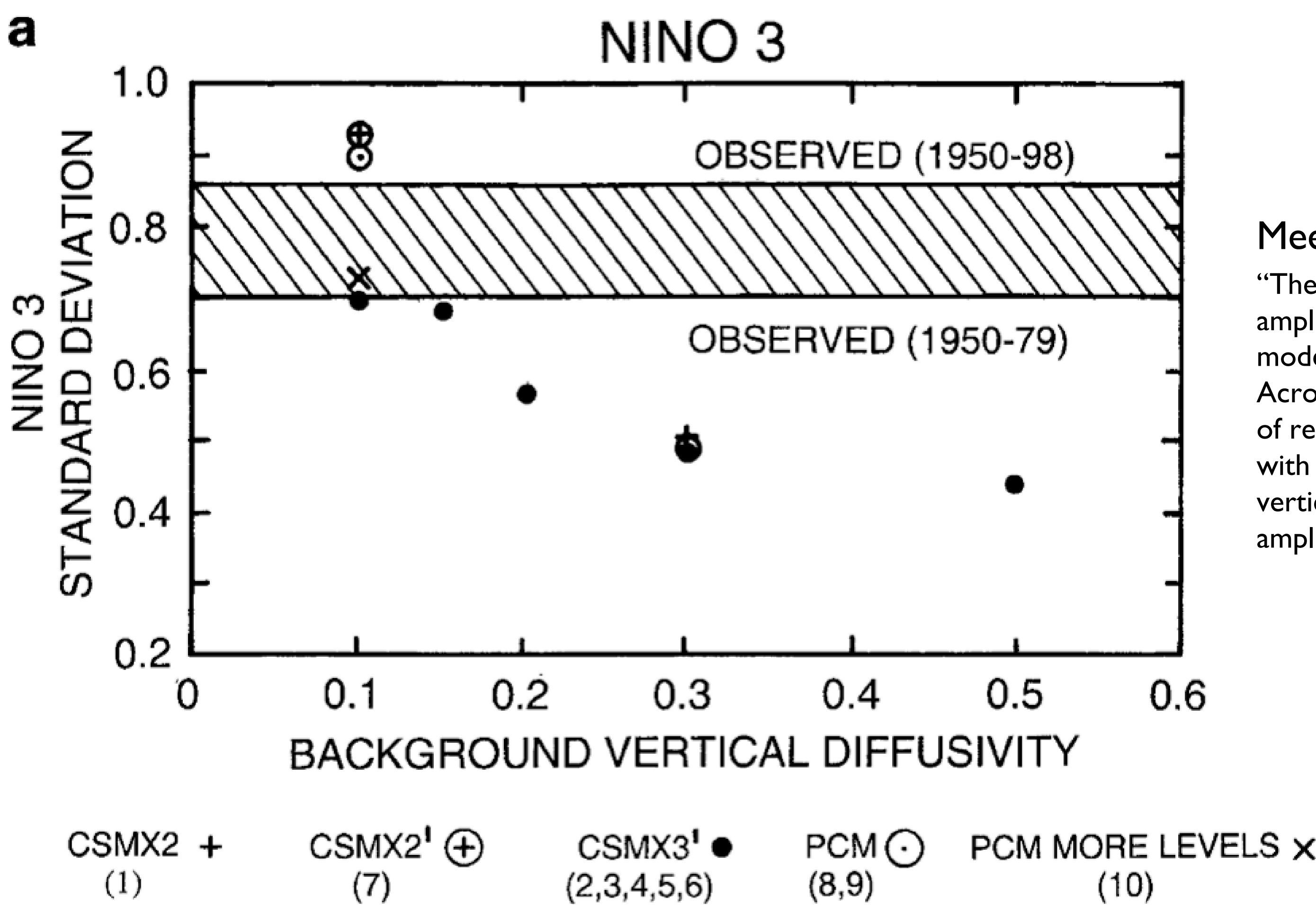


GFDL OM3
IPCC run
(Rosati/Wittenberg)

140°W

Colors = u
Vectors = (v,w)
Contours = T

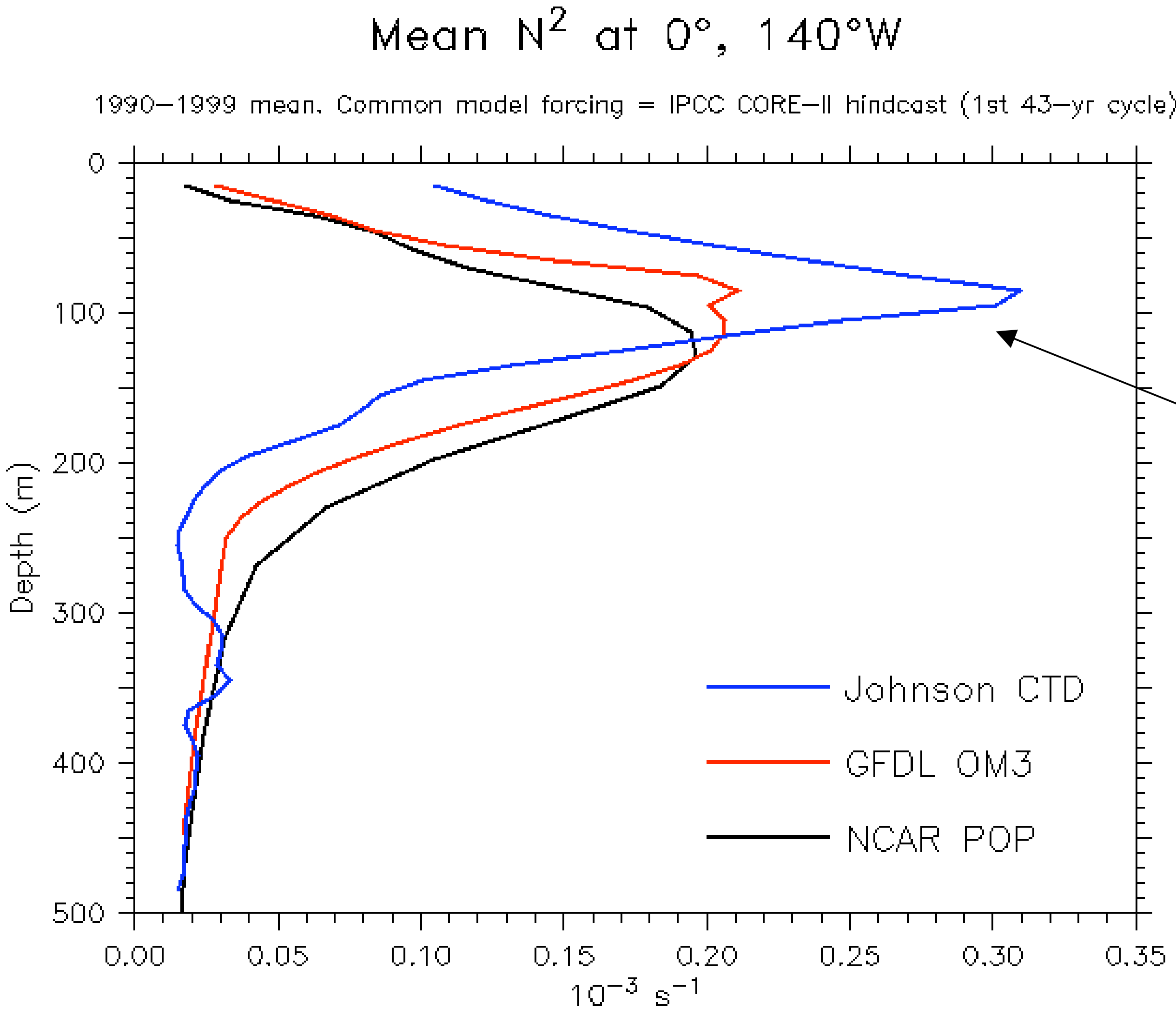
ENSO amplitude is principally controlled by the efficiency of communication between the thermocline and the surface



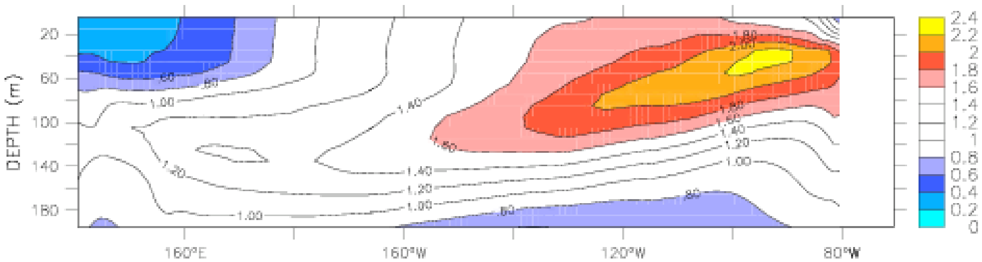
Meehl et al (2001)

"The dominant influence on El Nino amplitude is the magnitude of the ocean model background vertical diffusivity. Across all model experiments, regardless of resolution of ocean physics, the runs with the lowest values of background vertical diffusivity have the largest Nino3 amplitudes."

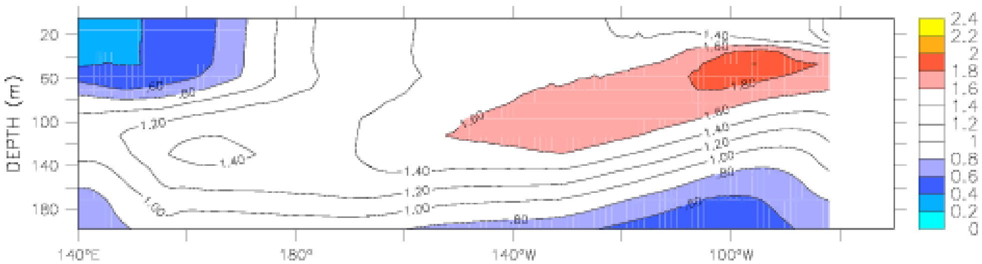
Model thermoclines are still too diffuse



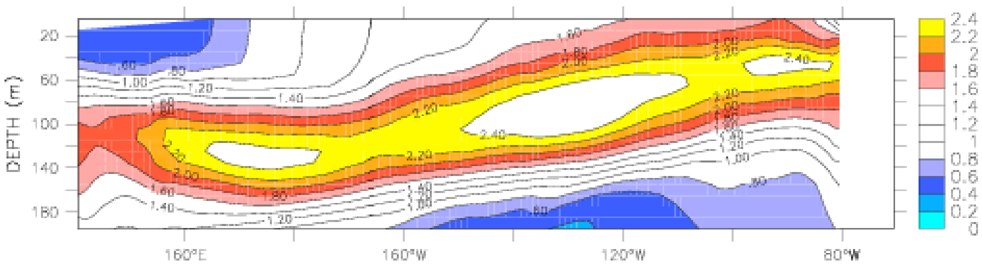
Observed thermocline about 50% sharper than our best models



GFDL OM-3 anomalies



NCAR POP anomalies



Assimilation anomalies

Interannual RMS temperature along the Equator

Forced OGCMs:
GFDL OM-3, NCAR POP (gx1v3)
Large & Yeager forcing (1958-2000)

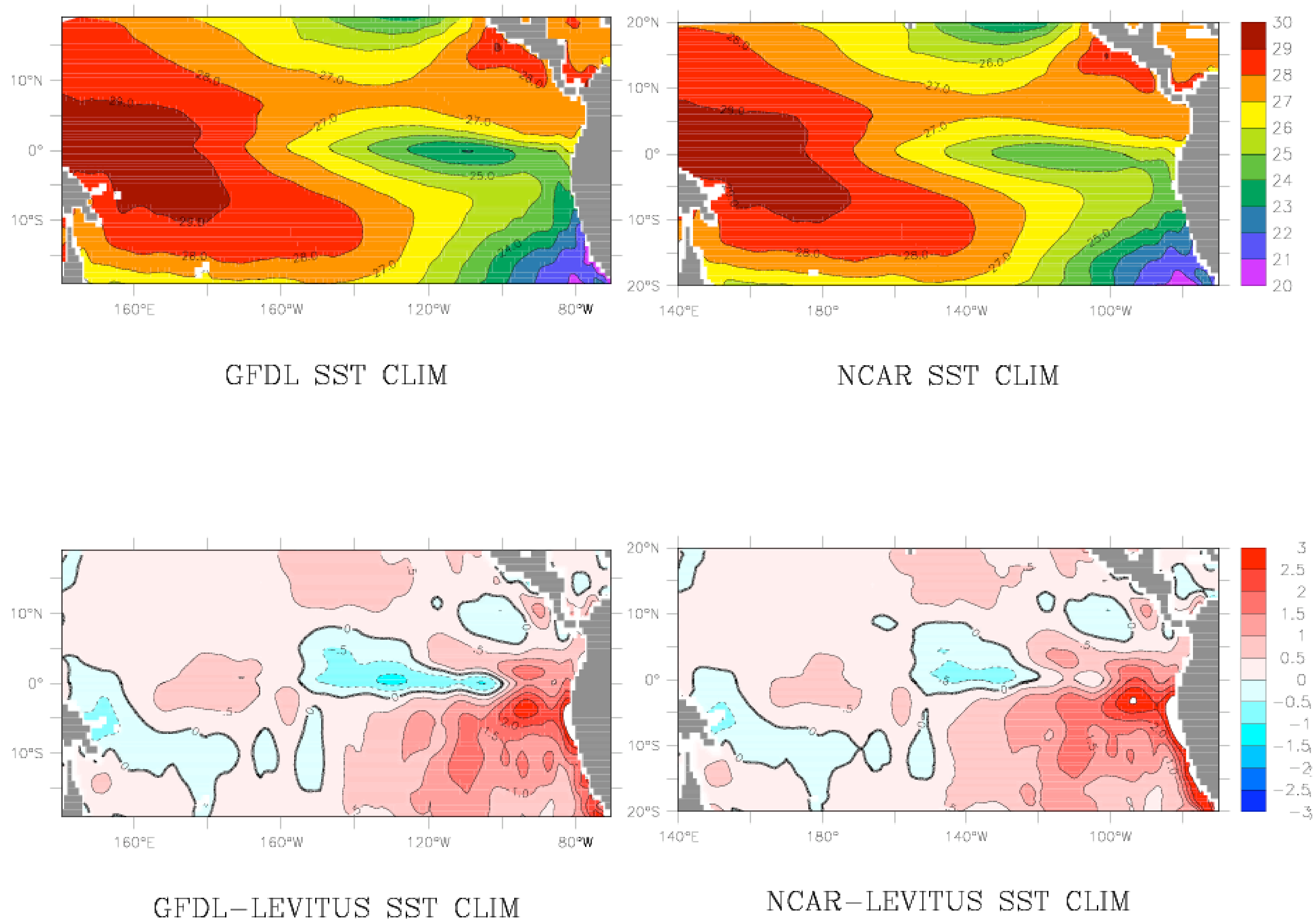
⇨ These models have reasonable ENSO SST (though underestimated and with the maximum too far west), apparently with incomplete physics.

⇨ It is possible to get the right phase of anomalies for the wrong reason.

Rosati and Wittenberg, 2004

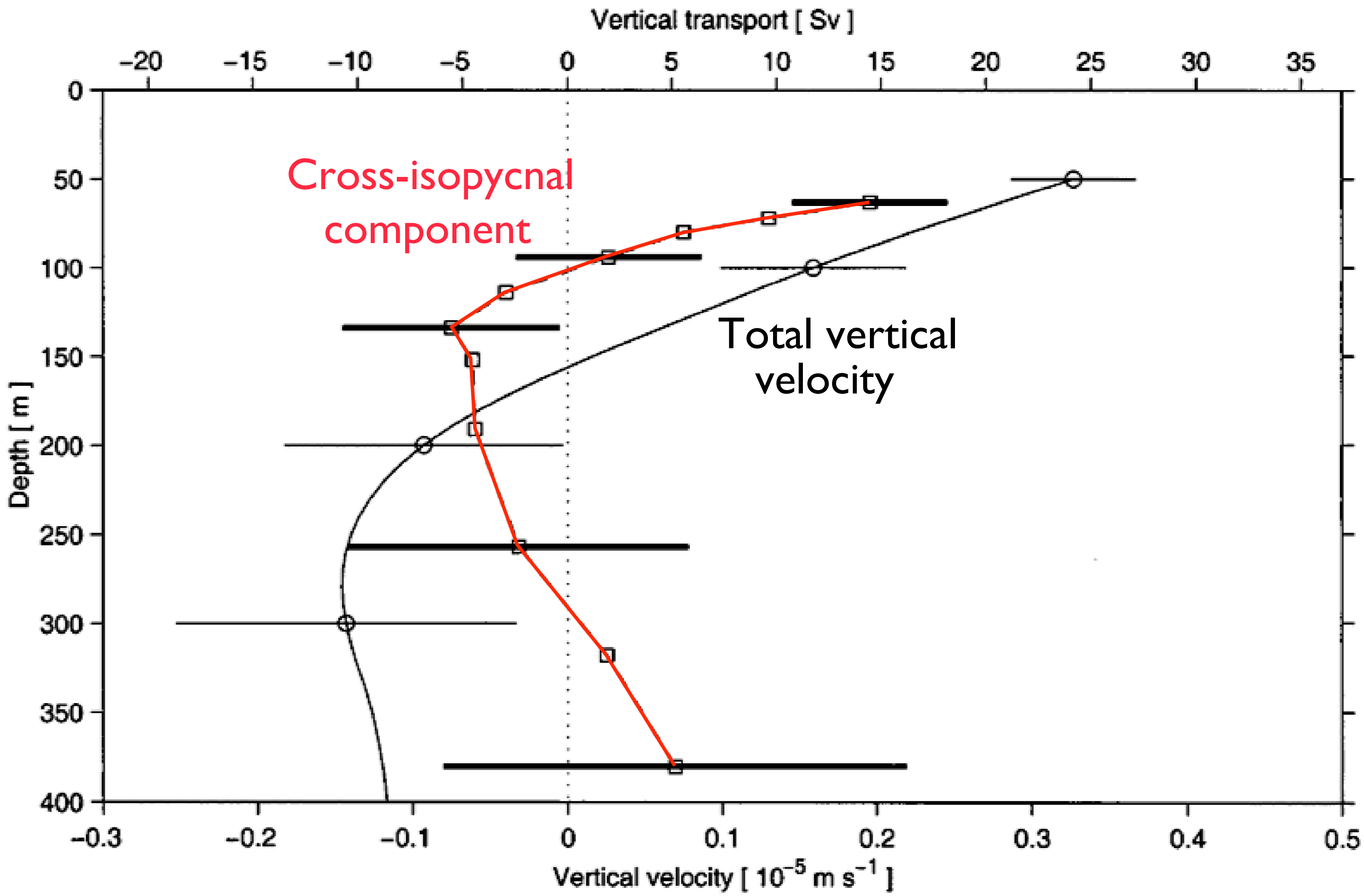
Cold bias occurs in forced OGCMs

Forced OGCMs:
GFDL OM-3, NCAR POP
Large & Yeager forcing (1958-2000)



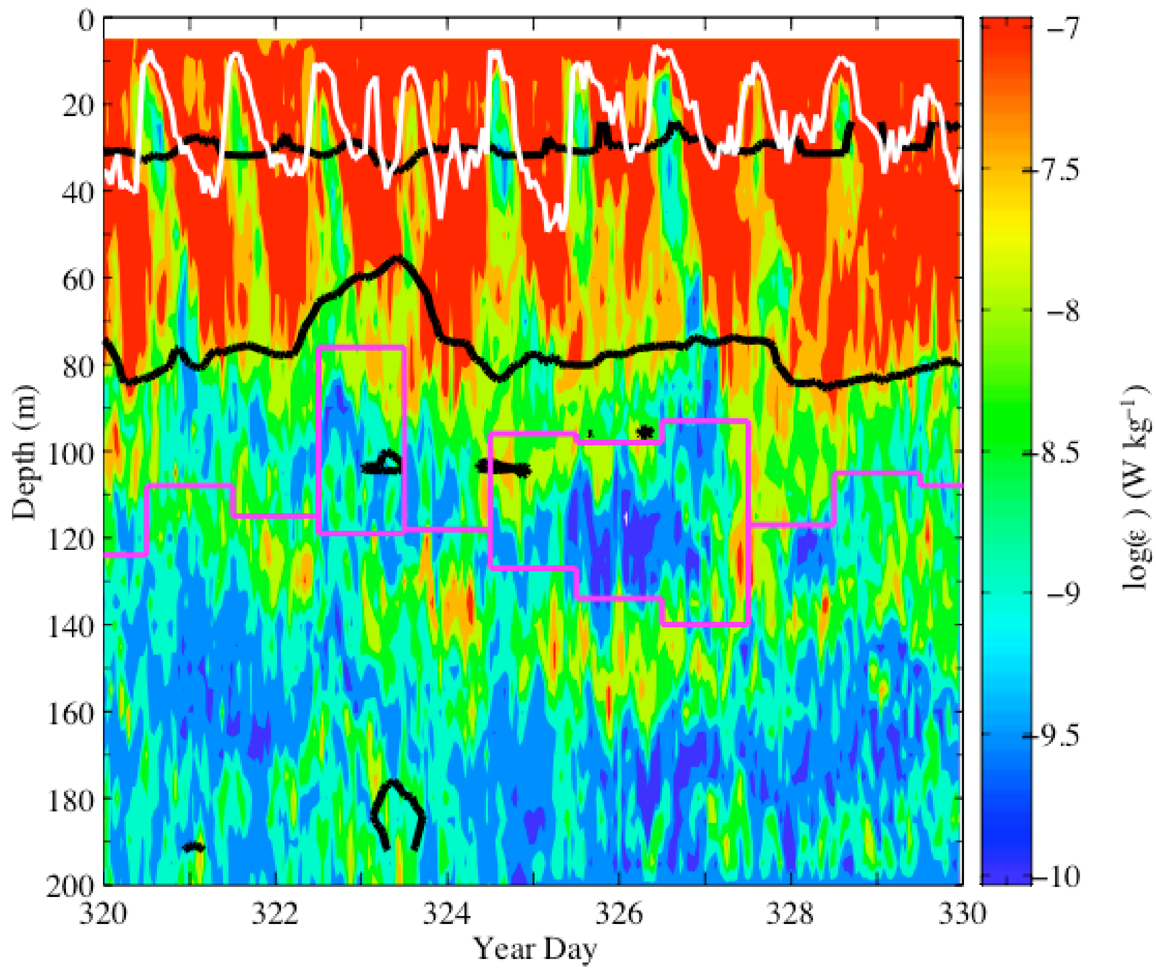
Rosati and Wittenberg, 2004

Upwelling requires mixing



Meinen et al (2001)

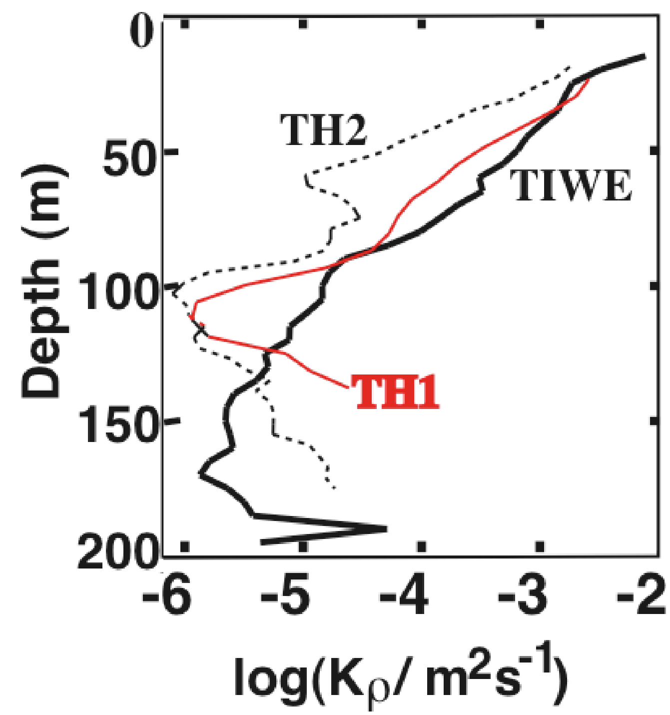
We do not understand the regime-dependence of equatorial mixing



Dissipation rate during 10 days of TIWE

Lien and D'Asaro

All existing eddy diffusivity profiles in the cold tongue



Gregg (1998)

Primary Objectives of PUMP

To observe and understand:

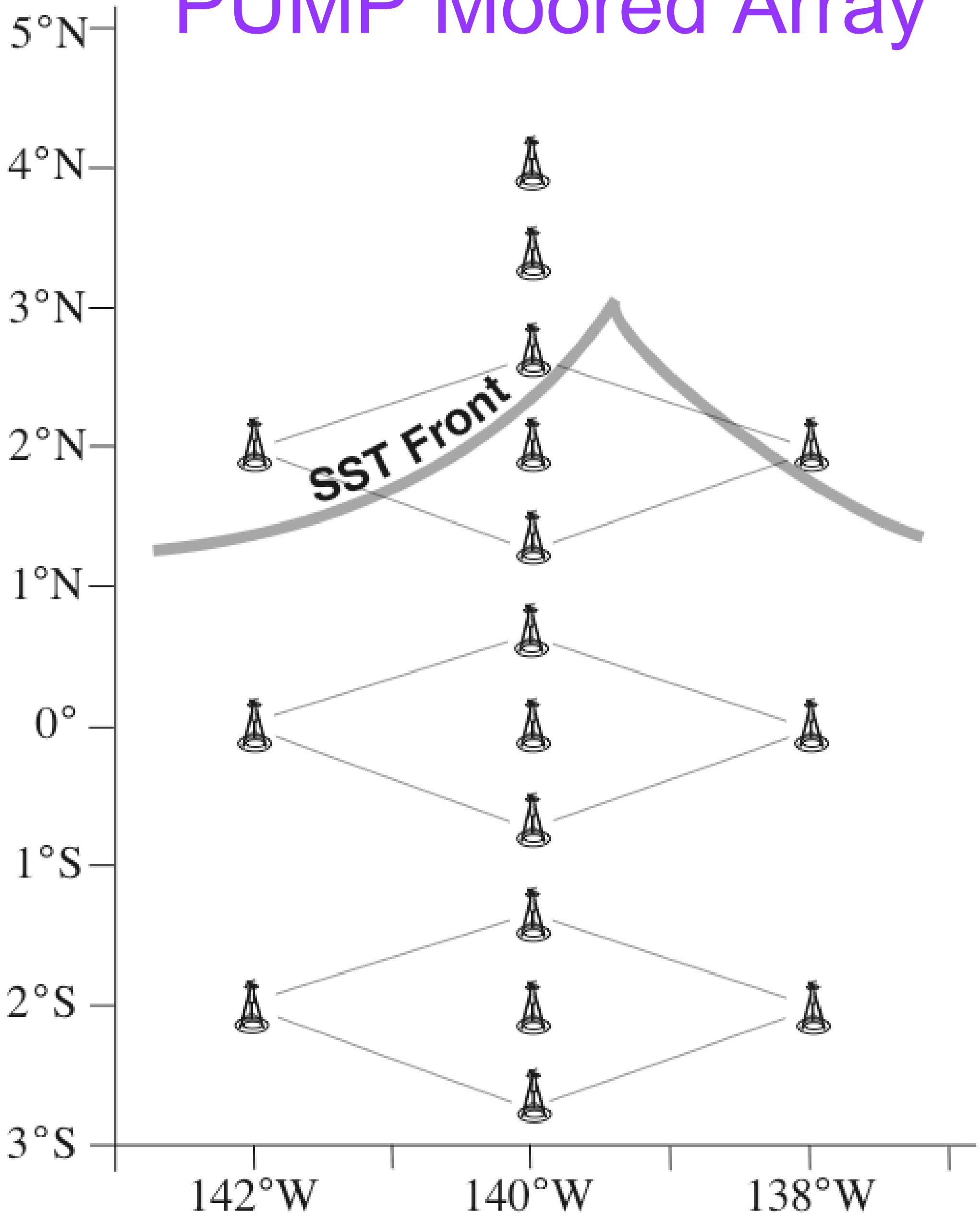
1) The evolution of the equatorial cell under varying winds
2) The mixing mechanisms that determine
   (a) the depth of wind-input momentum
   (b) the transmission of surface heat fluxes into the upper thermocline
3) The processes that allow and control exchange across the sharp SST front north of the cold tongue

PUMP will put mixing observations in their regime context

Components of PUMP

- Reanalysis of historical data
- Multi-scale modeling effort
- 2-3 year moored array along 140°W, to establish the scales and variability of equatorial upwelling
- Two IOPs, both on and just north of the equator at 140°W, to quantify the relative effects of upwelling and mixing

PUMP Moored Array



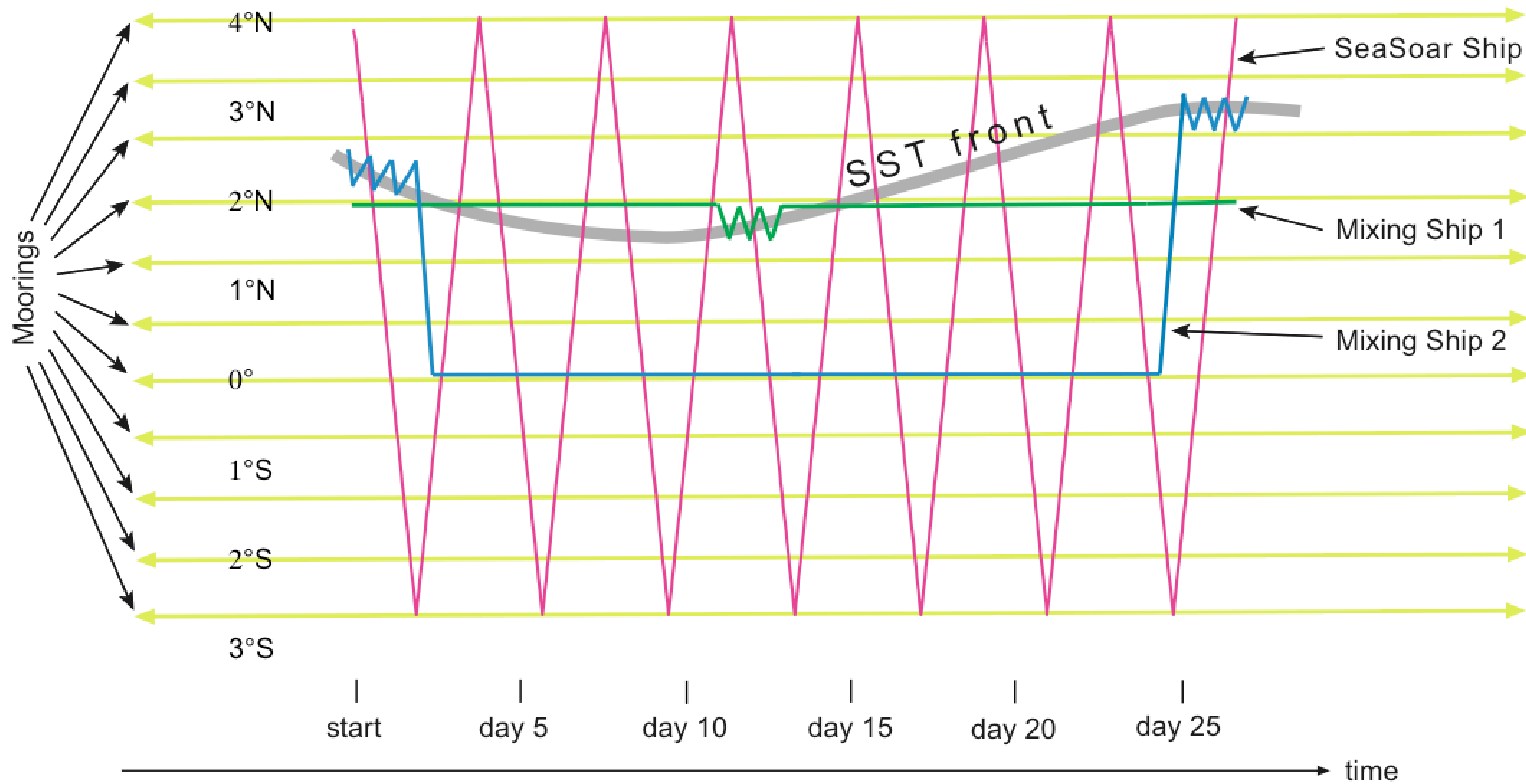
Each mooring is a pair:
Surface buoy + ADCP

Goal is to determine:

- The structure of $\tilde{\mathbf{u}}(x,y,z,t)$ over 2 annual cycles.
- The spinup of the poleward limb of the meridional circulation under varying winds. Δ
- The (y,z) structure of horizontal divergence and upwelling.
- The downwelling at the SST front, and its relation to TIW.
- The rate of diapycnal conversion, accounting for heat fluxes.

OSSEs will refine the array

PUMP Intensive Observing Periods



Goal is to determine:

- The mechanisms by which internal waves are modulated, on and off the Eq
- The spatial structure of mixing across the equatorial region
- The variability of mixing and air-sea forcing across the SST front
- The turbulent heat flux integral on a scale to be compared to upwelling
- The nature of mixing during the rapid and reduced cooling periods

Perfecting OGCMs for climate forecasting

Four elements:

1) Improve the forcing fields
2) Provide benchmark data sets to compare model circulations across the upwelling cell
3) Improve mixing parameterizations
4) Learn to use sparse sustained observations (ENSO OS), assimilated into models, to infer equatorial mixing

What is already happening?

1) Test measurement of near-surface shear.
   Point doppler current meters deployed at 5-25m on a test mooring at 2°N,140°W.

2) Post-doc studying array design (OSSEs).
   Arrived at PMEL last fall.

3) Test moored mixing sensors (fast-response thermistors). Deployed at 0°,140°W late last year.

Budget

NOAA

Hardware (17 double moorings for 2 yr)	$3.9m
Personnel (design, purchase, prepare, deploy, recover, display)	$2.6
Shipping/travel/computer	$0.5
Total cost of moored array (over 5 yr) …………………………..	$7.0

Mixed NOAA / NSF

Science/analysis proposals to be expected: (3 groups of 3 PIs @ 3 mon/yr = 27 mon/yr) Start yr 3, continue for 5 yr …………………………………….	$2.2
Modeling: (3 groups of 3 PIs @ 3 mon/yr = 27 mon/yr) Start yr 1, continue for 7 yr ……………………………………….	$3.1

NSF

Cost of 2 IOPs (3 ships for two 30-day cruises each) ………	$5.1

Total cost of PUMP over 7 yr ………………………………….. $17.4m

Summary rationale for PUMP:

1. The processes of mixing and upwelling that control equatorial SST are poorly understood and modeled.
2. Present-generation OGCM representations of the upwelling cell are not adequately constrained by observed reality.
3. This deficiency contributes to the fundamental problems of coupled models of the tropical climate.
4. The tools both to observe these phenomena and to improve the models are at hand.

➪ PUMP will spur a leap in our ability to diagnose and model the tropical Pacific (and Atlantic) and to predict its variability.

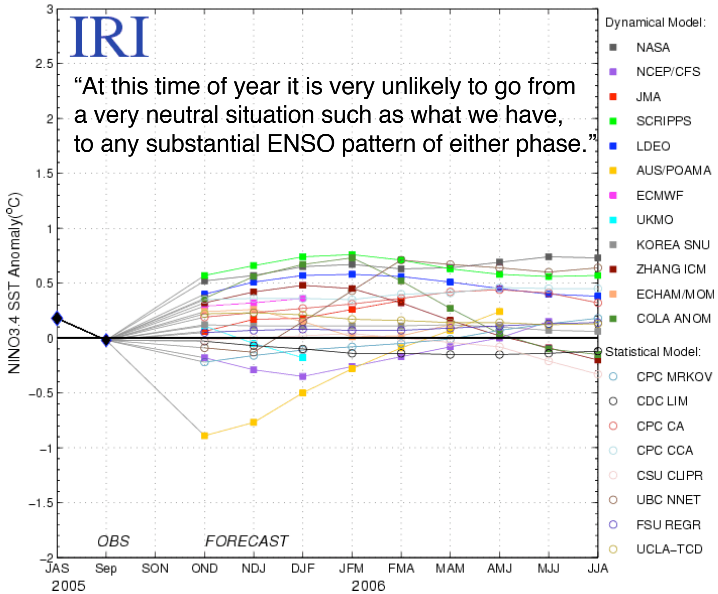
Extra

Figures

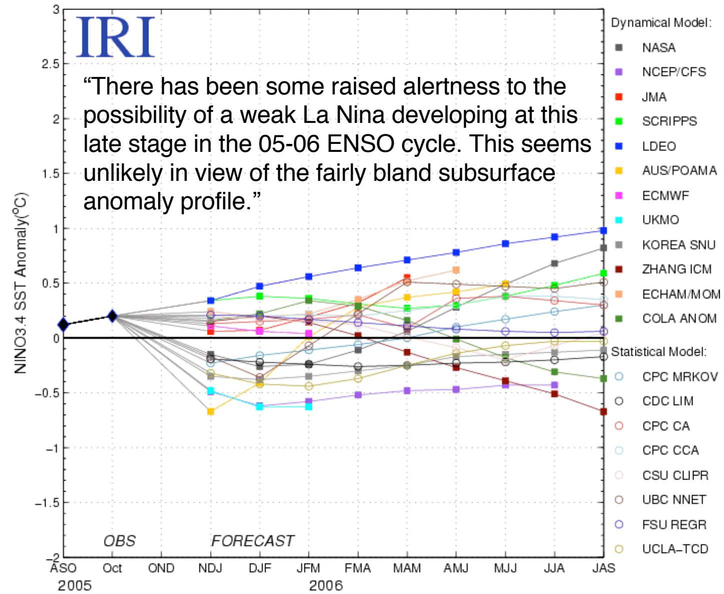
Follow ….

ENSO forecast uncertainty

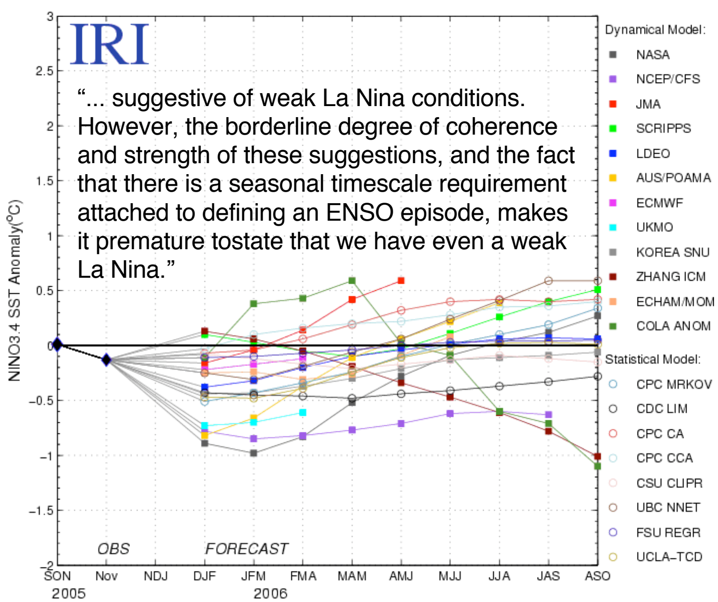
Model Forecasts of ENSO from *Oct 2005*



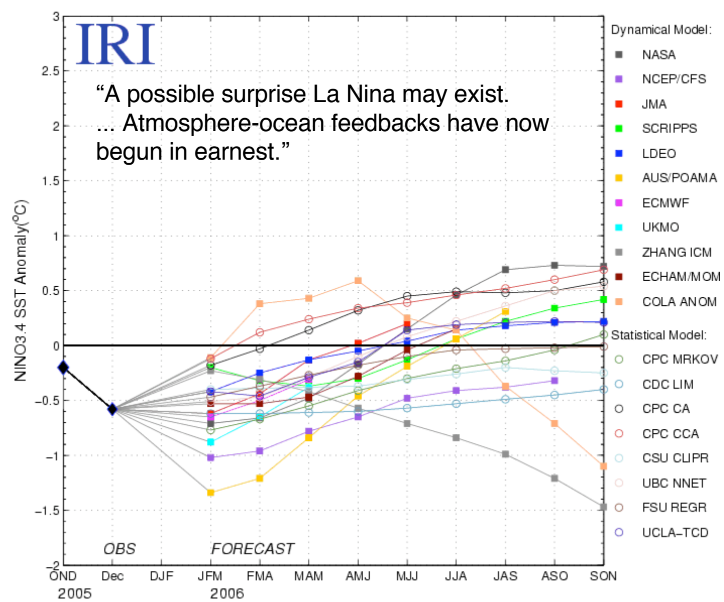
Model Forecasts of ENSO from *Nov 2005*



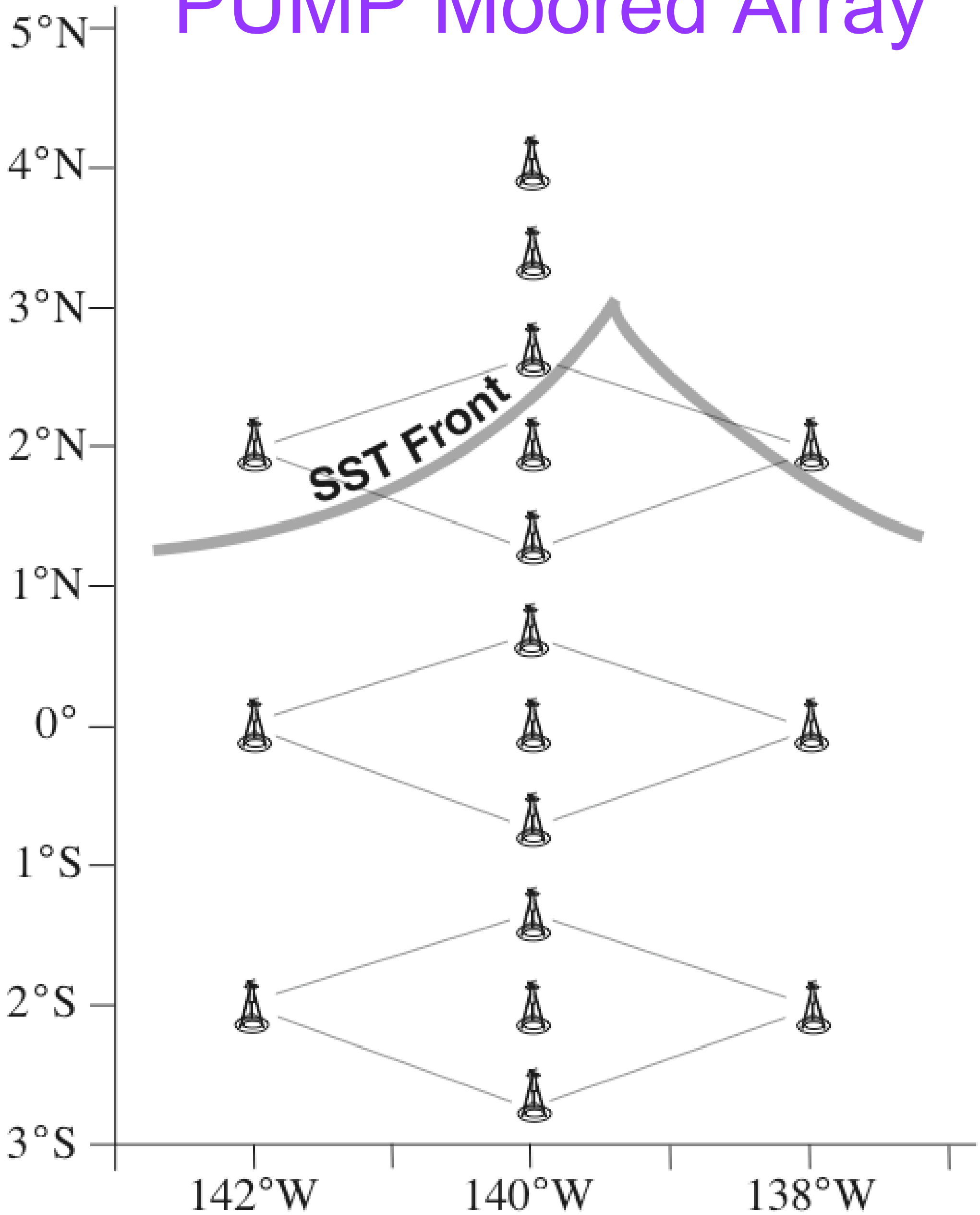
Model Forecasts of ENSO from *Dec 2005*



Model Forecasts of ENSO from *Jan 2006*



PUMP Moored Array



PUMP timeline: