Pacific Upwelling and Mixing Physics

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 premise is that climate-scale ocean models are ready to exploit realistic vertical exchange processes, but need adequate observational guidance.

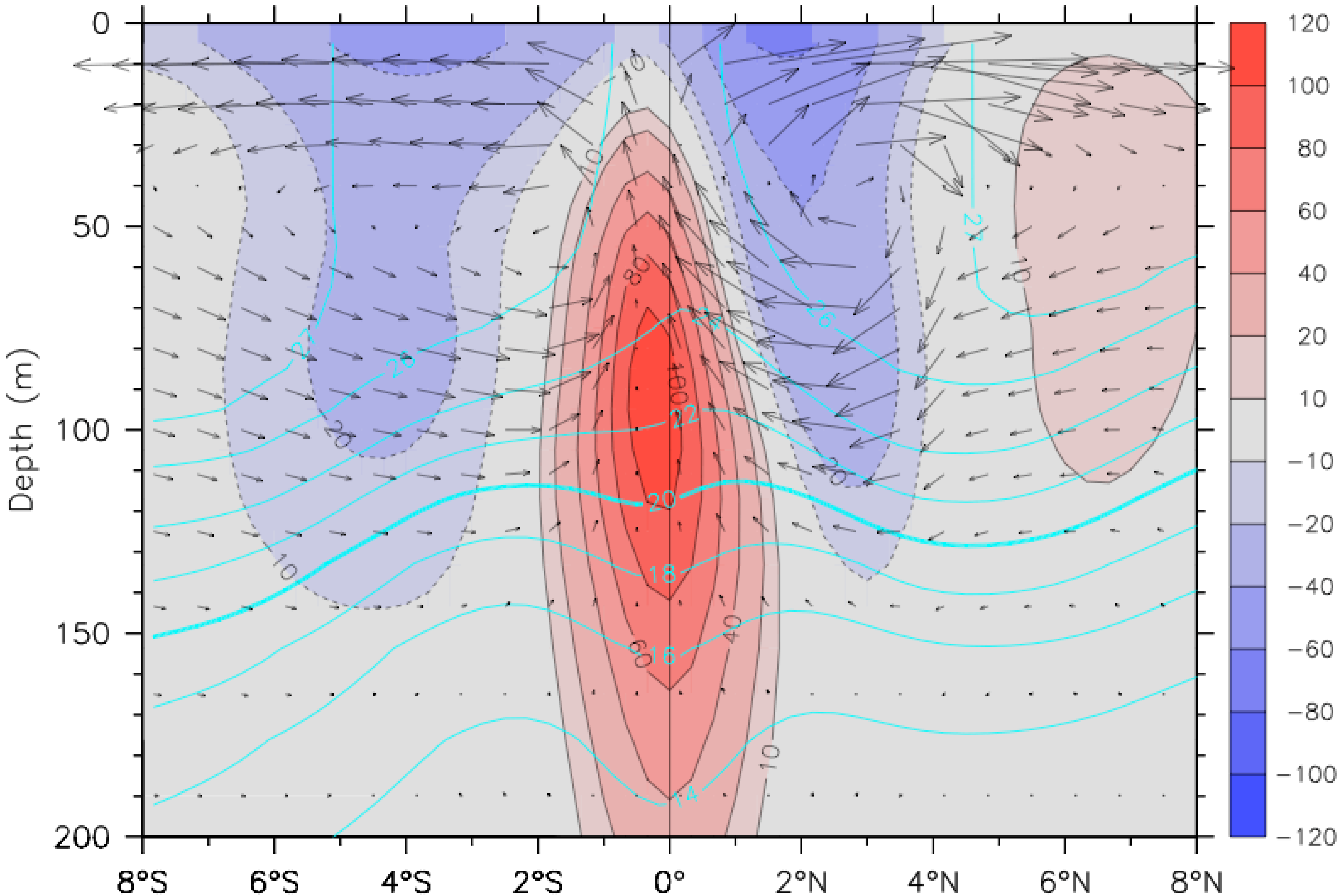
Primary Objectives of PUMP

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

OGCM meridional circulation



MOM2 seasonal run (Vecchi)

140°W

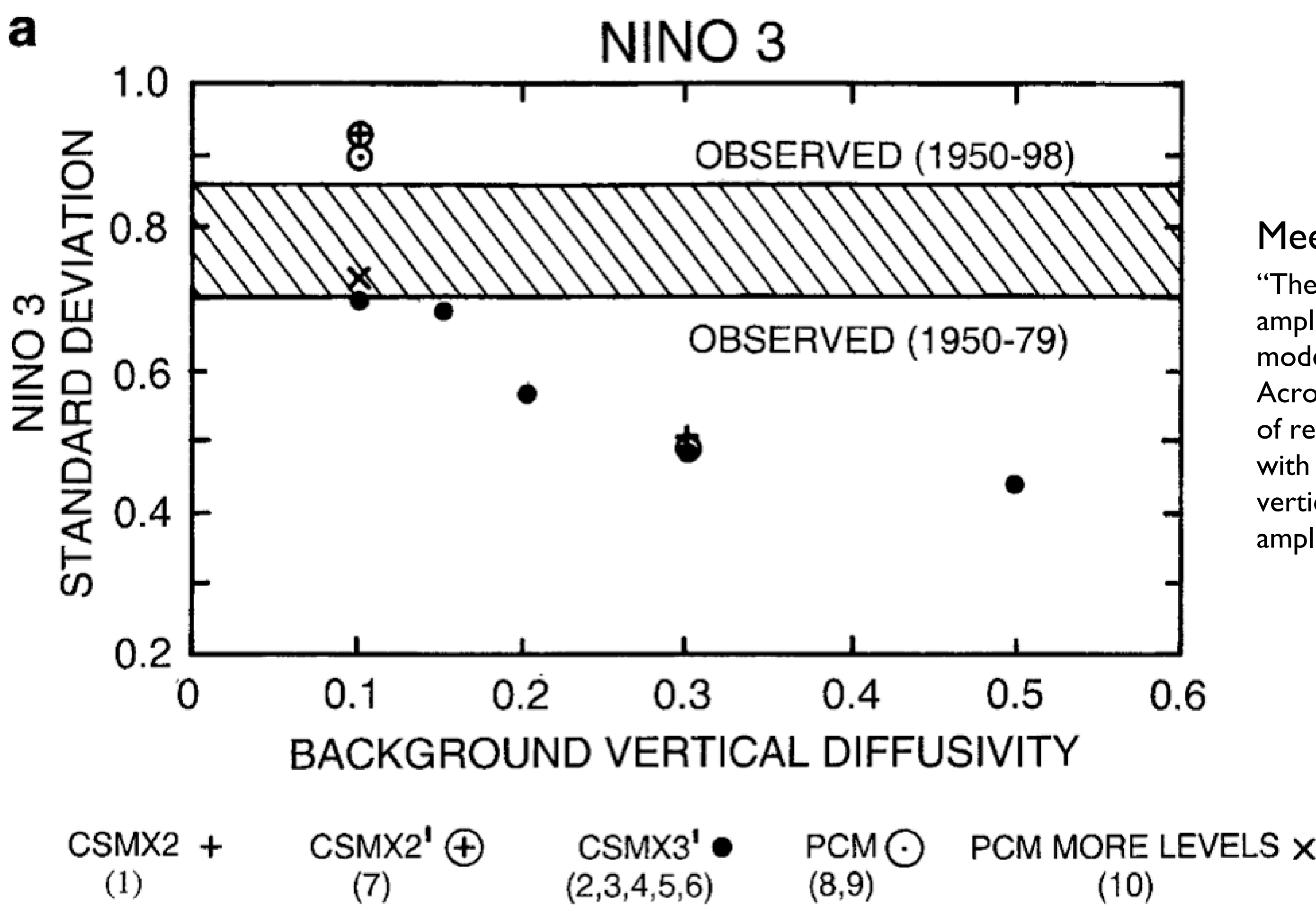
Colors = u
Vectors = (v,w)
Contours = T

ENSO is <u>not</u> 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.

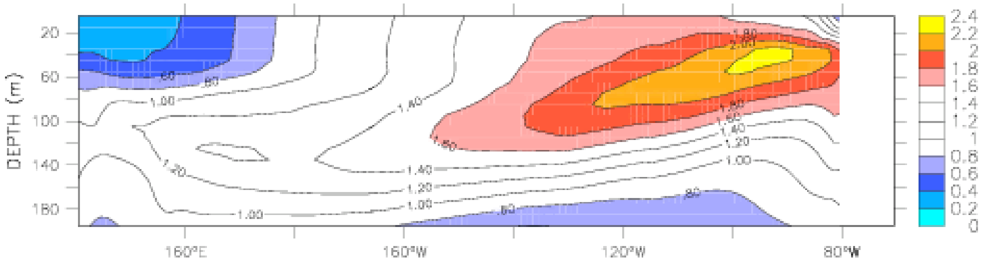
There are few targets the climate community could set for itself that would make more difference to more people than to improve our ability to forecast ENSO and its effects.

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

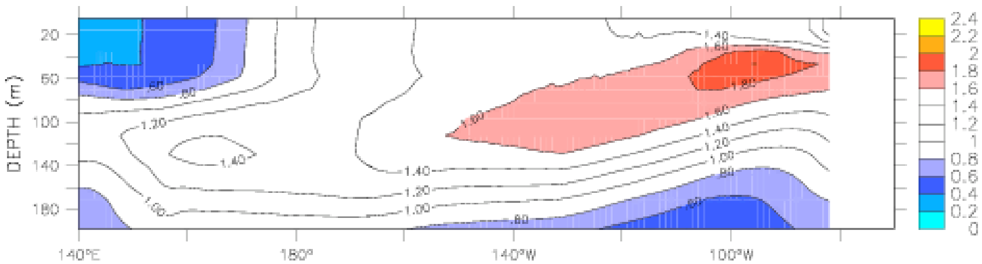


Meehl et al (2001)

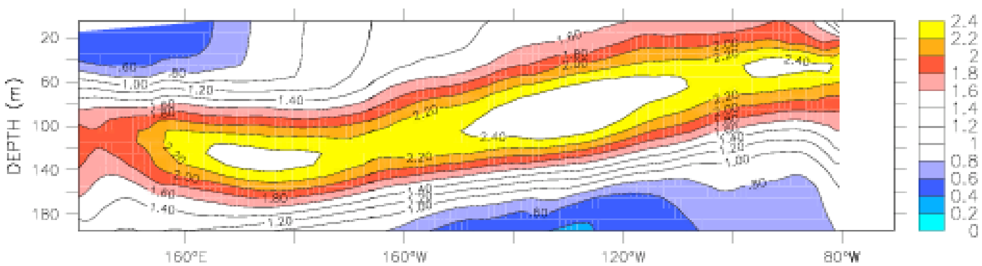
"The dominant influence on El Nino amplitude is the magnitude of the ocean model background vertical diffusivity. Across all model experiments, regardless of resolution of ocean physics, the runs with the lowest values of background vertical diffusivity have the largest Nino3 amplitudes."



GFDL OM-3 anomalies



NCAR gx1v3 anomalies



Assimilation anomalies

Interannual RMS temperature along the Equator

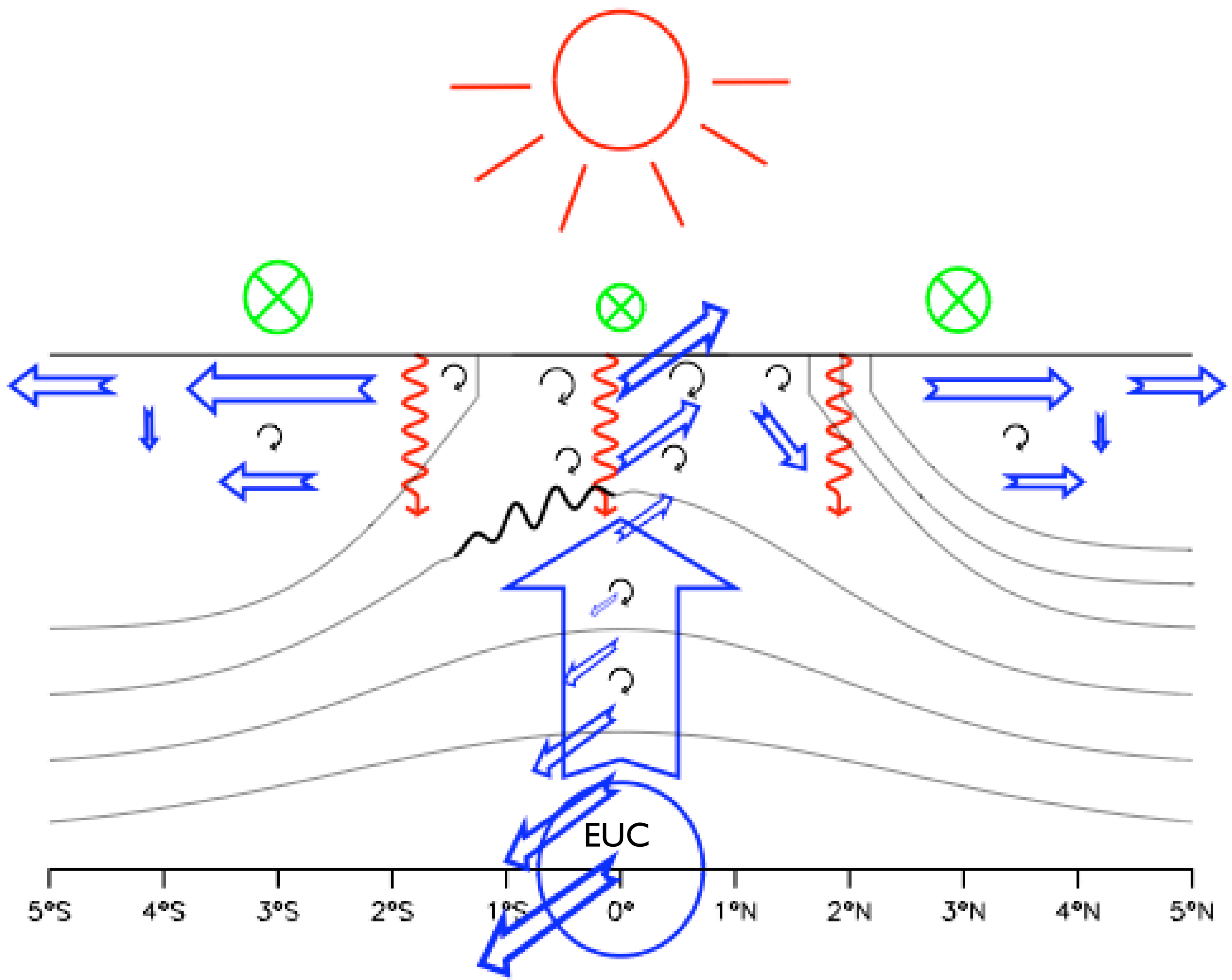
Forced OGCMs:
GFDL OM-3, NCAR gx1v3
Large & Yeager forcing (1958-2000)

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

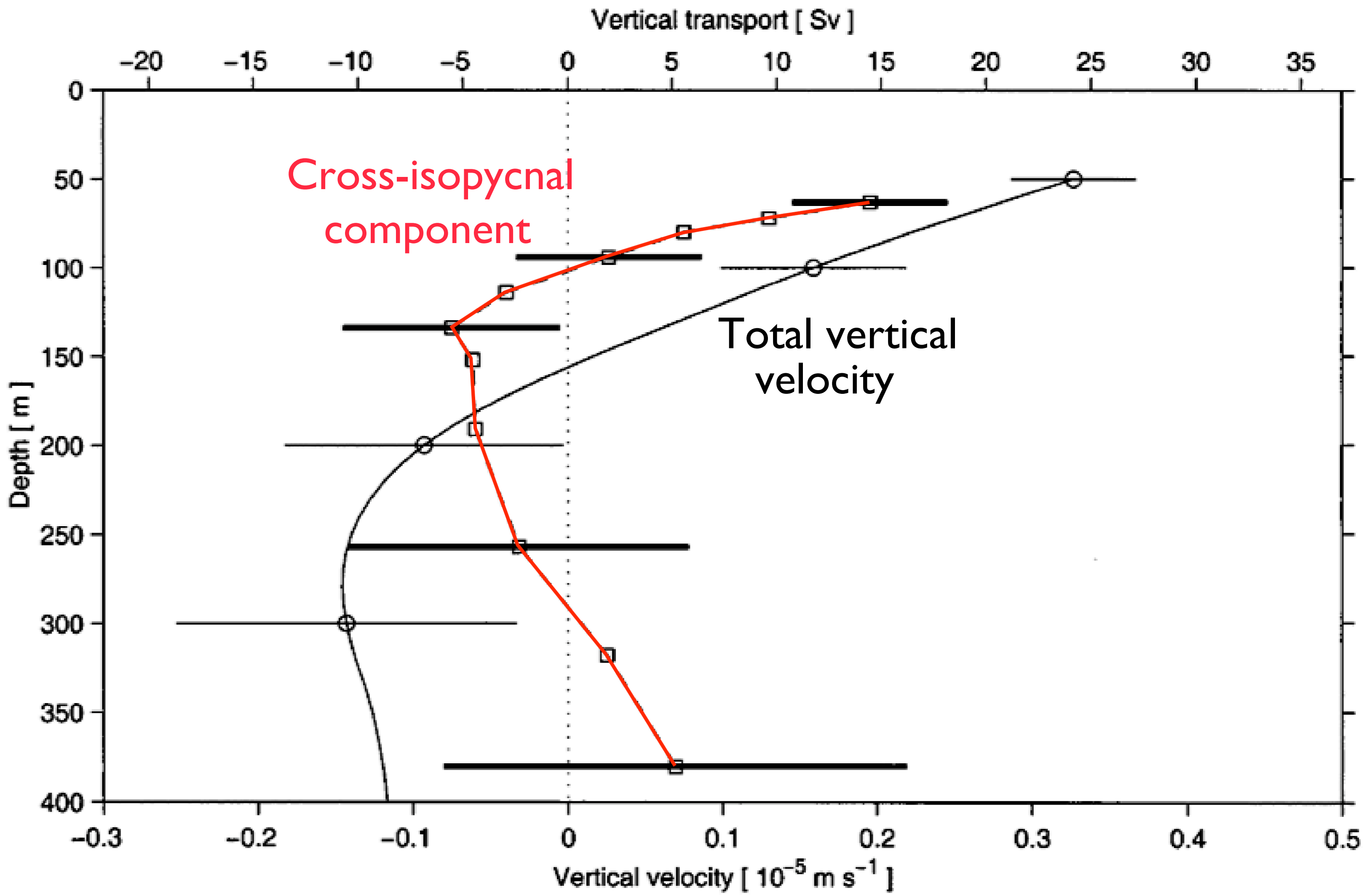
⇨ It is possible to get the right phase of anomalies for the wrong reason.

Rosati and Wittenberg, 2004

Cold tongue SST is a function of the entire circulation cell

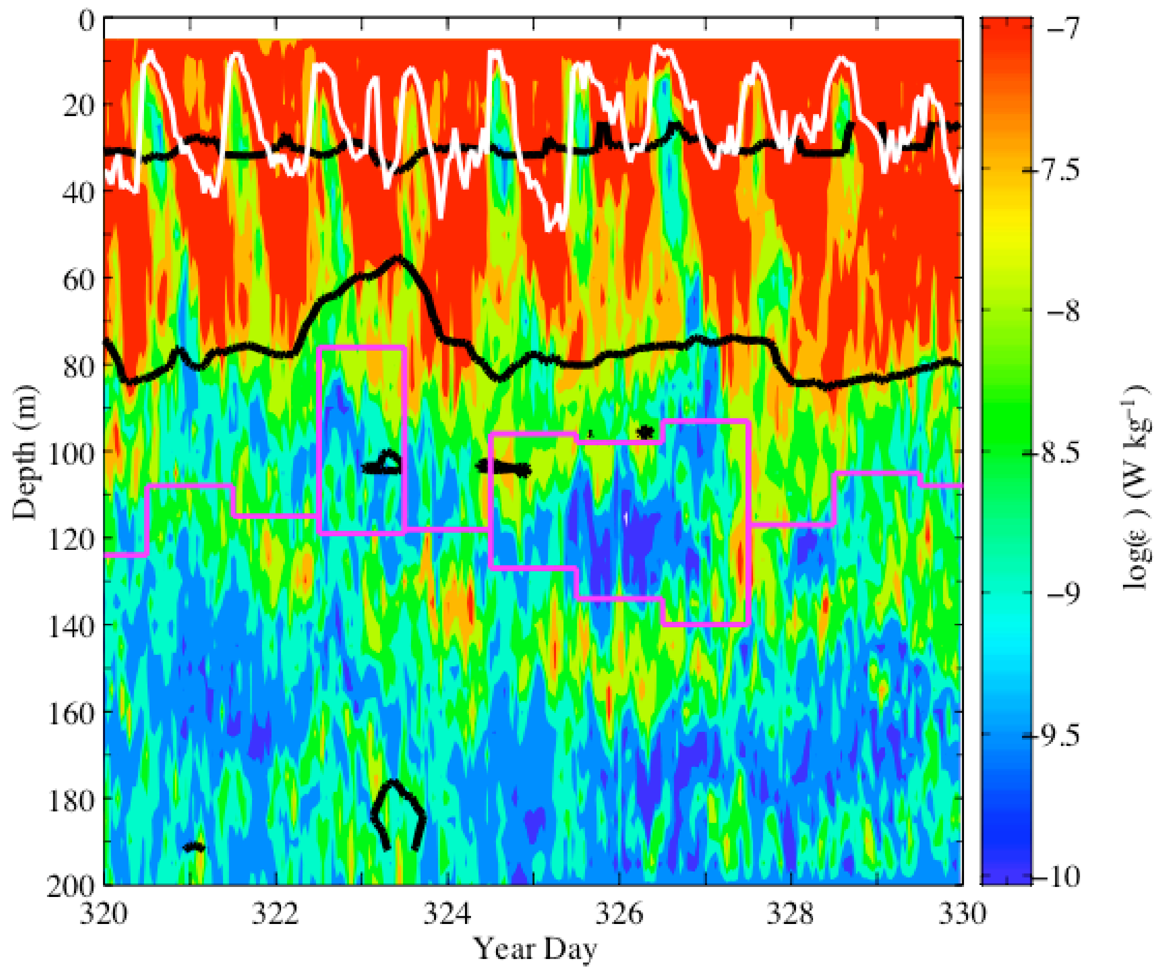


Upwelling requires mixing



Meinen et al (2001)

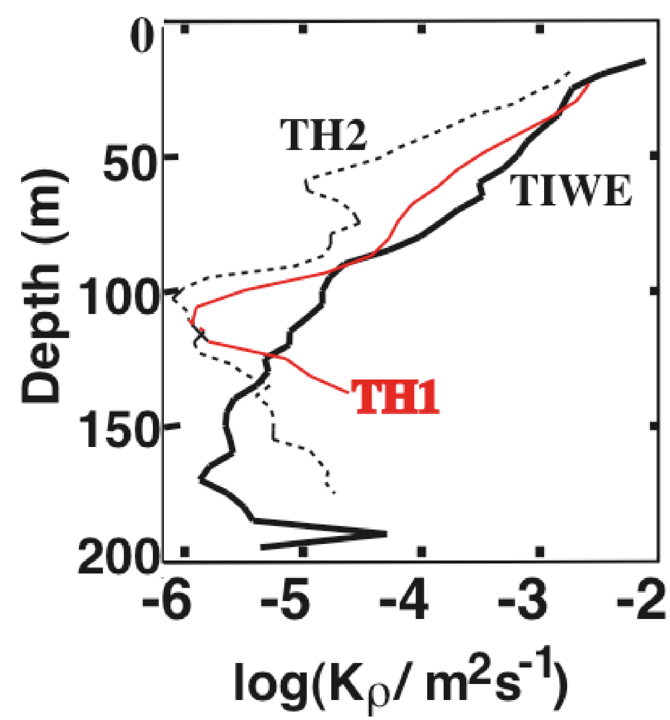
We do not understand the regime-dependence of equatorial mixing



Dissipation rate during 10 days of TIWE

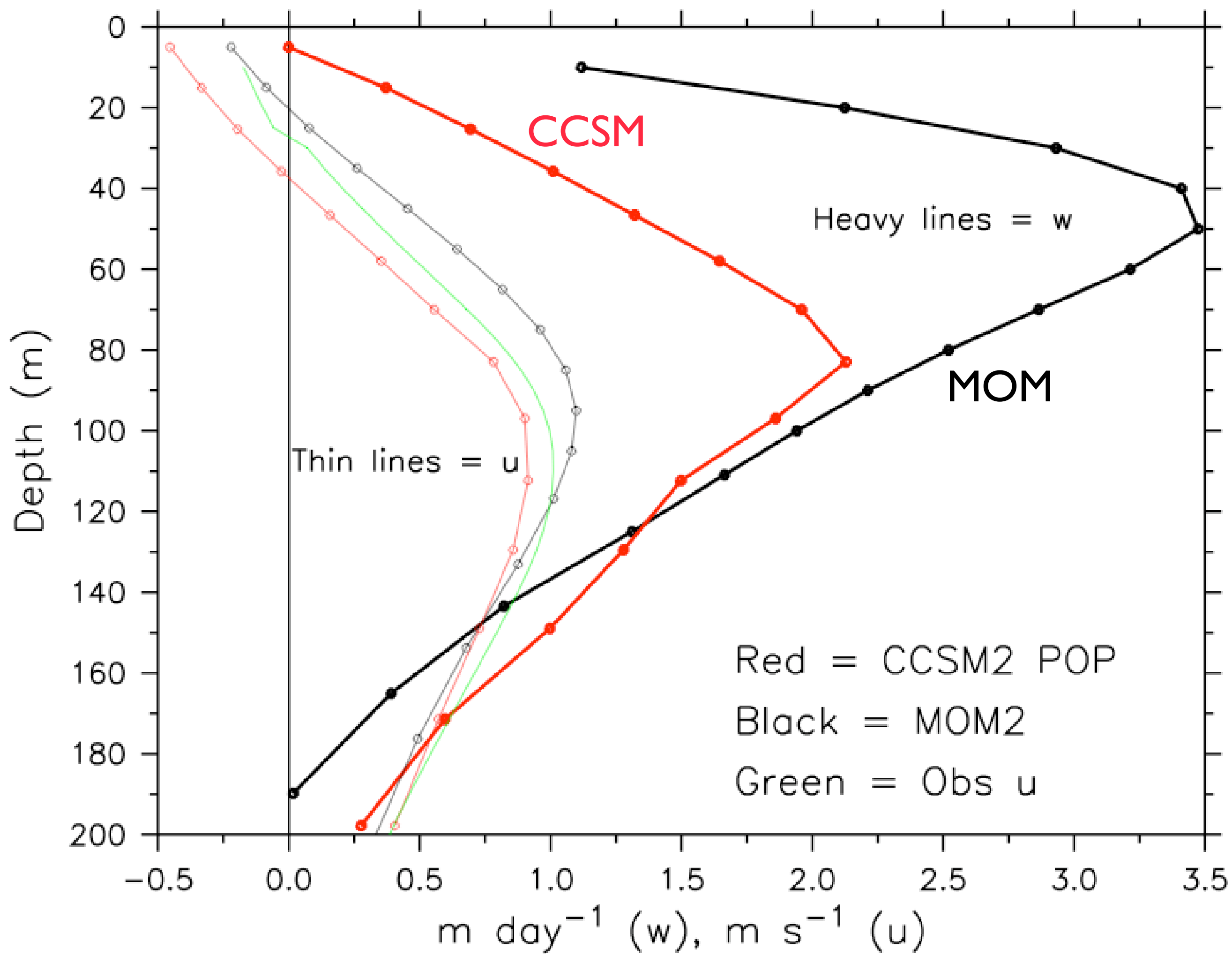
Lien and D'Asaro

All existing eddy diffusivity profiles in the cold tongue



Gregg (1998)

OGCM meridional circulations are very different



CCSM (Bryan), MOM (Vecchi)

Mean u and w at 0°, 140°W

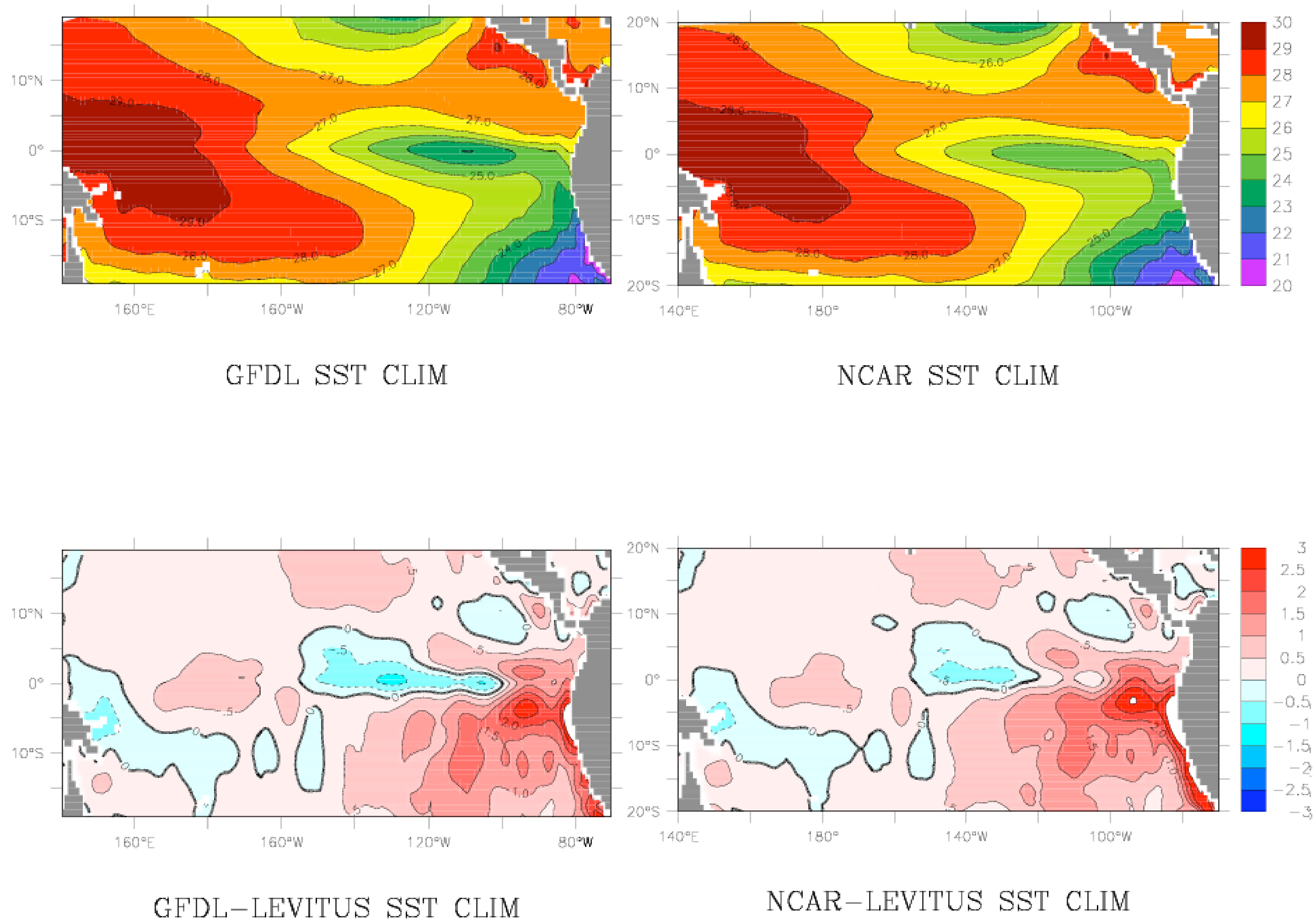
Compare two forced OGCMs: MOM2 (1/3°) vs CCSM2 (1/10°)

The usual comparisons of u(Eq,z) can be misleading

Δ_1, Δ_2

Cold bias occurs in forced OGCMs

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



Rosati and Wittenberg, 2004

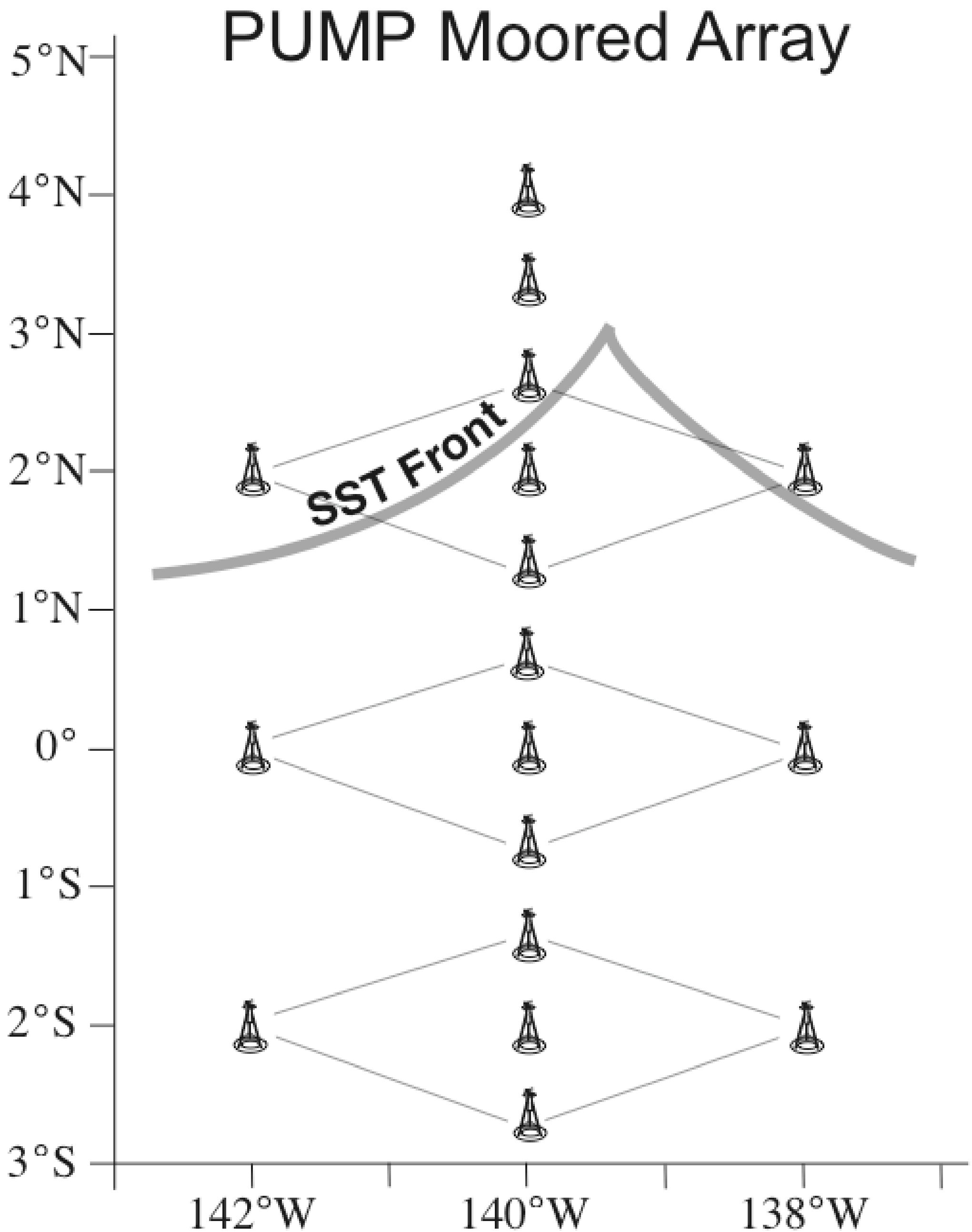
Components of PUMP

- 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

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



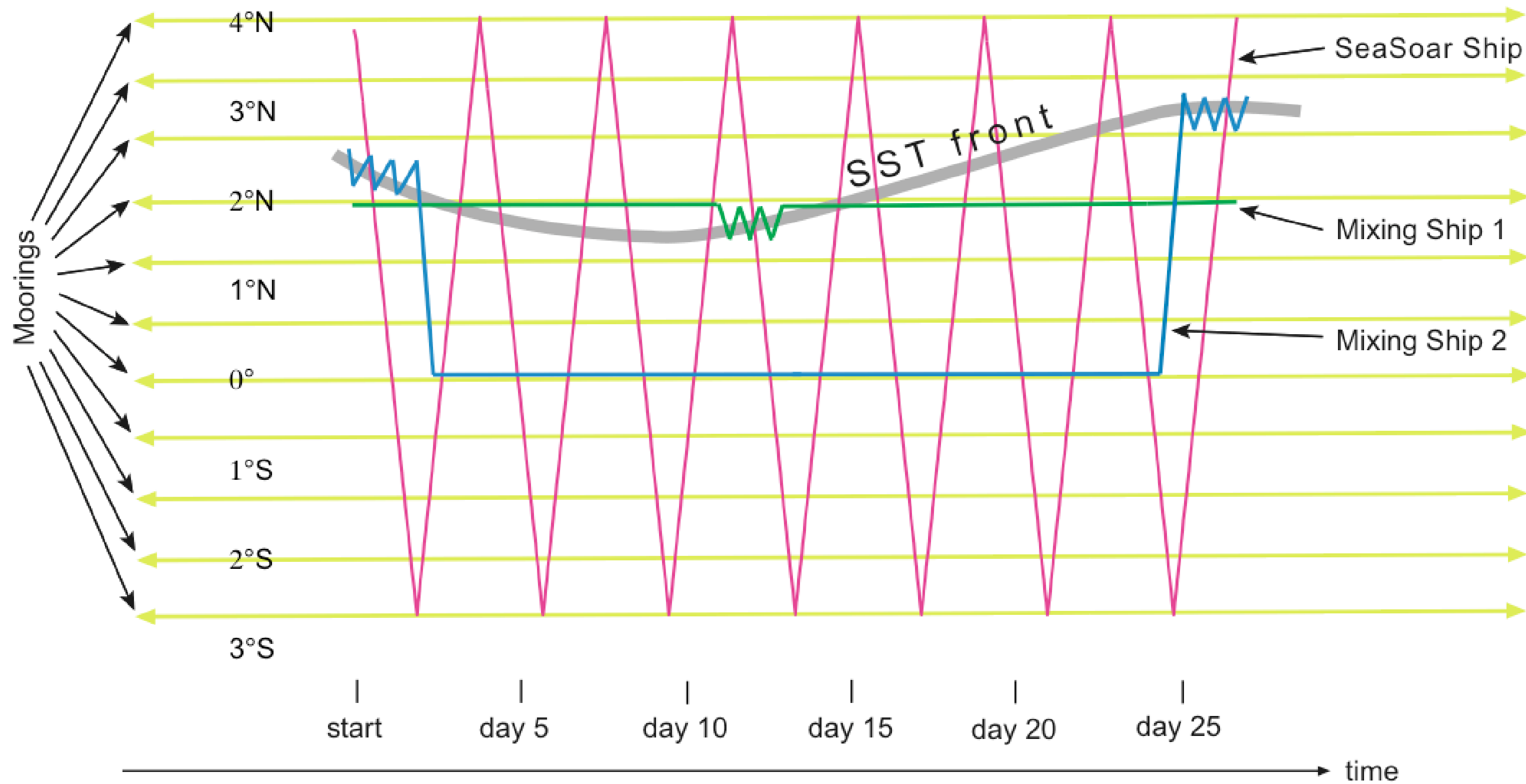
Each mooring is a pair: Surface buoy + ADCP

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

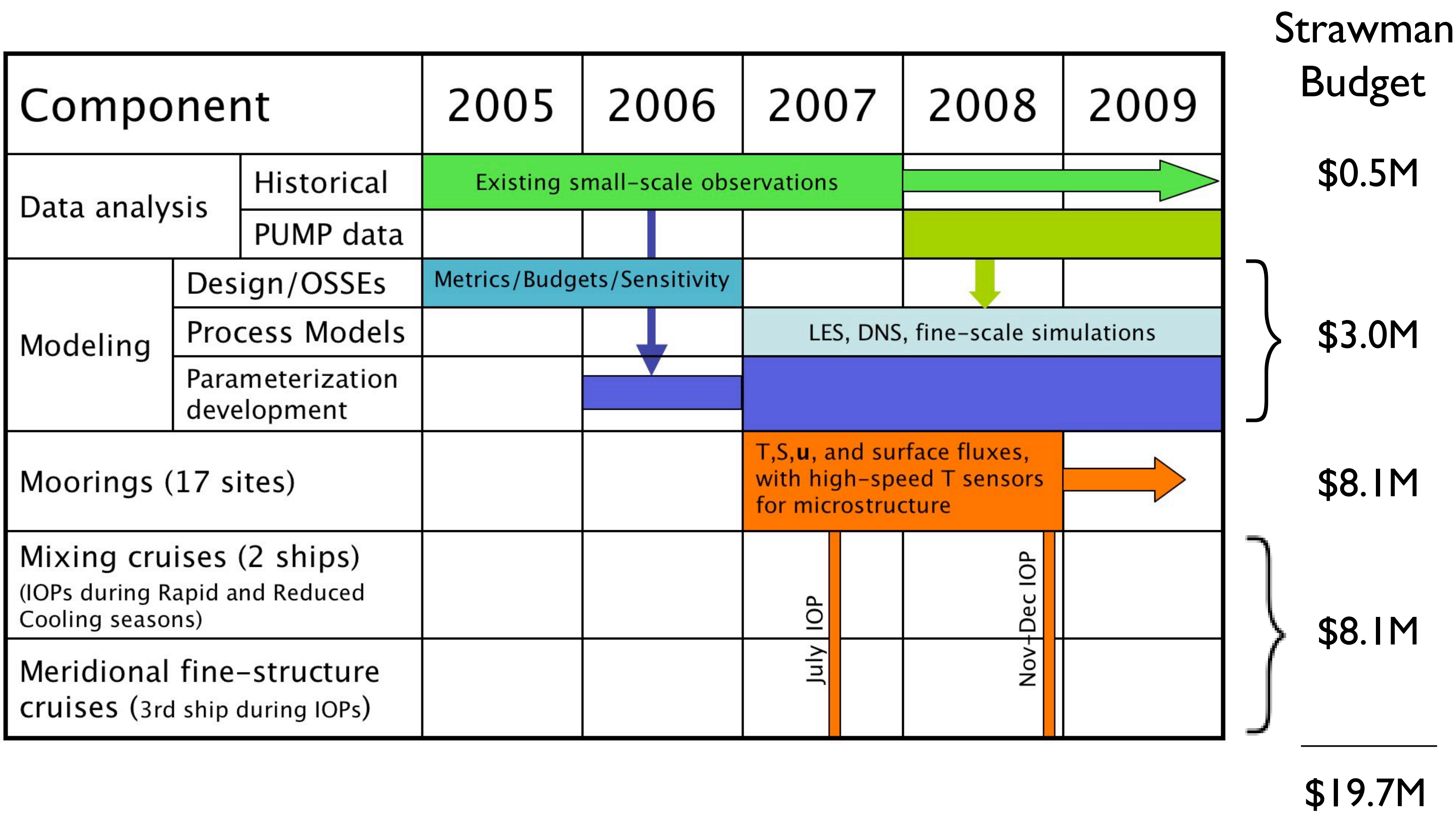
PUMP Intensive Observing Periods



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

PUMP timeline:



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 and differ widely among models.
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 ....

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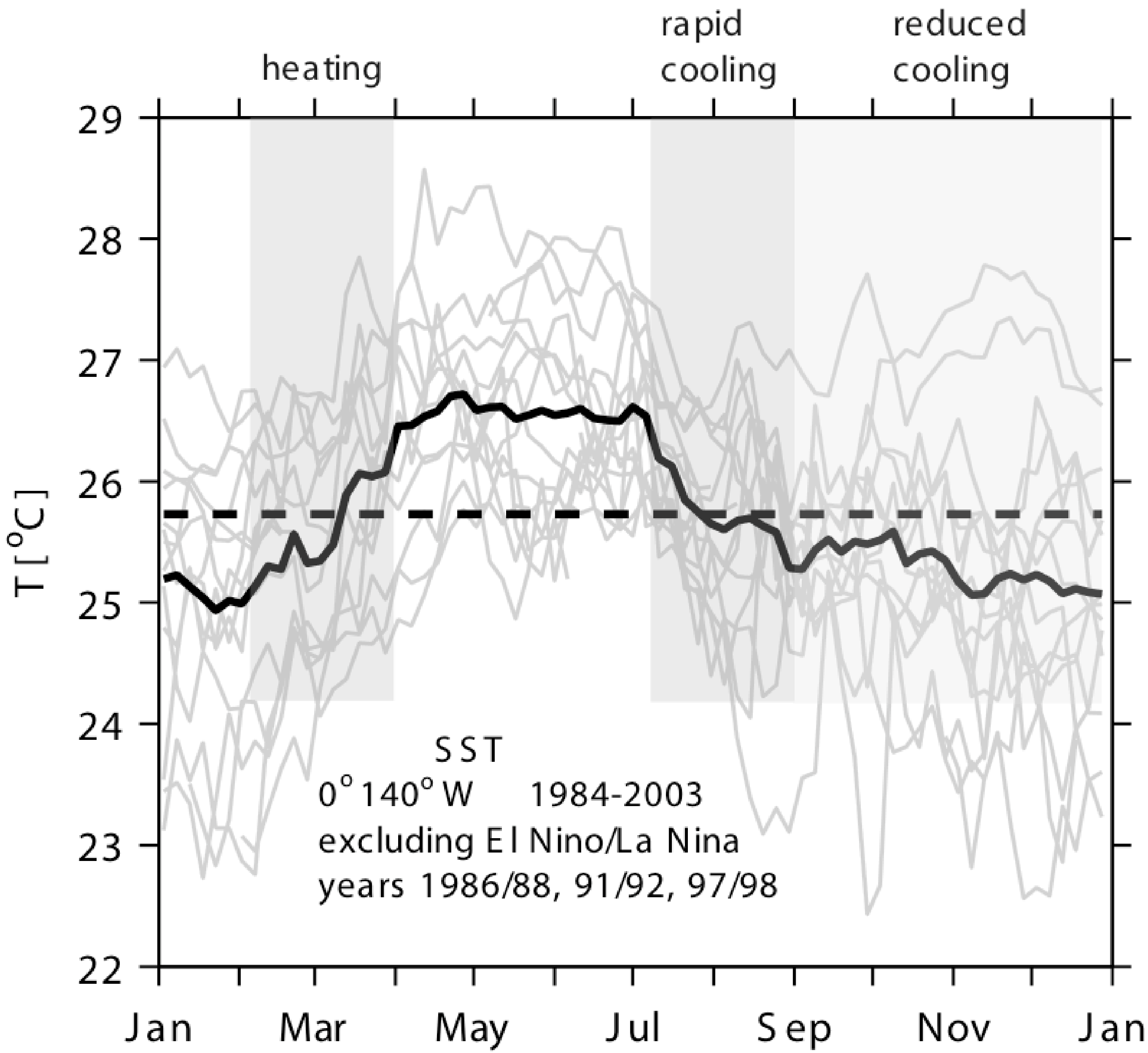
SST at 0°,140°W: Rapid and reduced cooling periods



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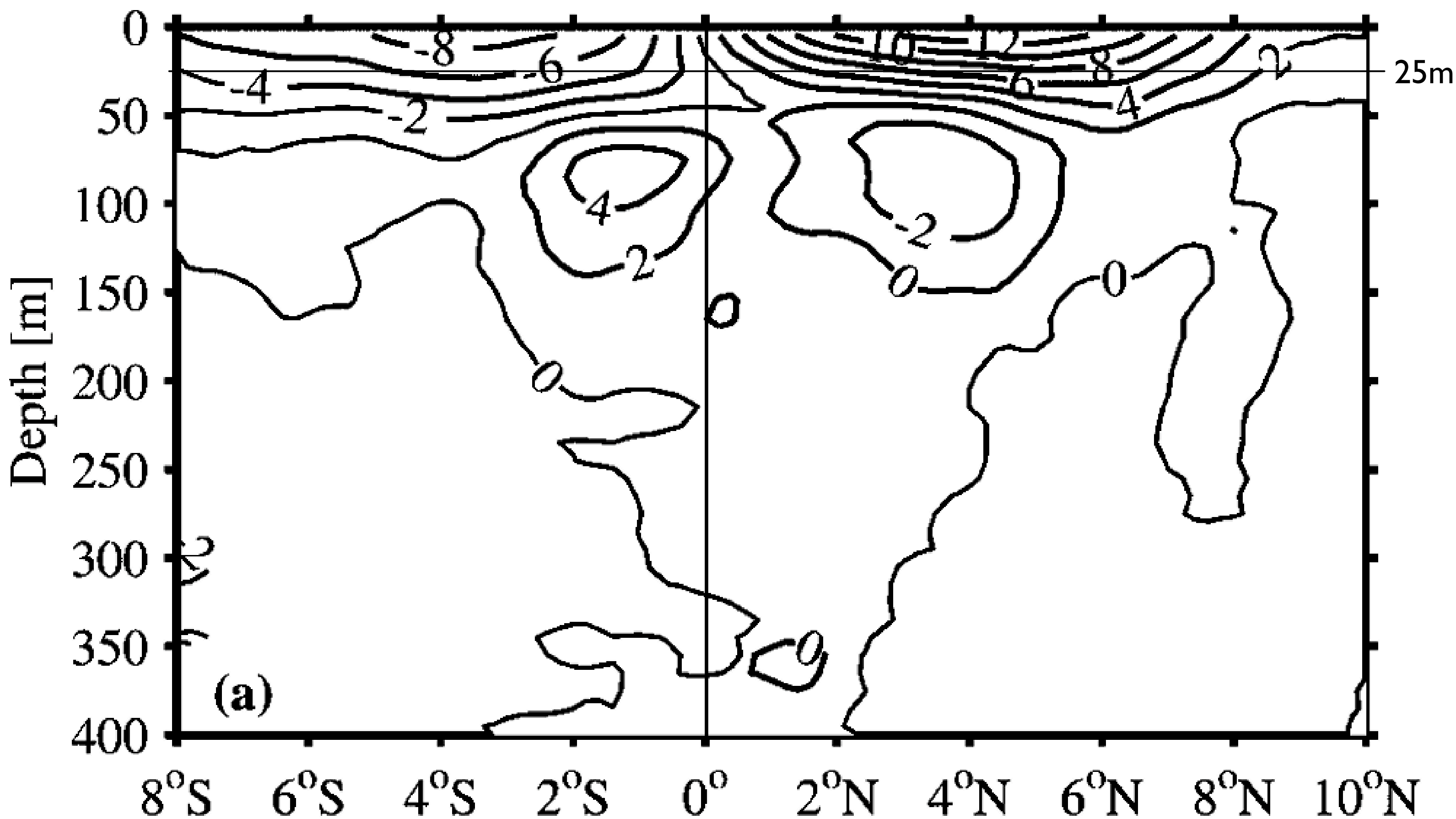
Divergence must be sampled very near the surface



Johnson (2001)

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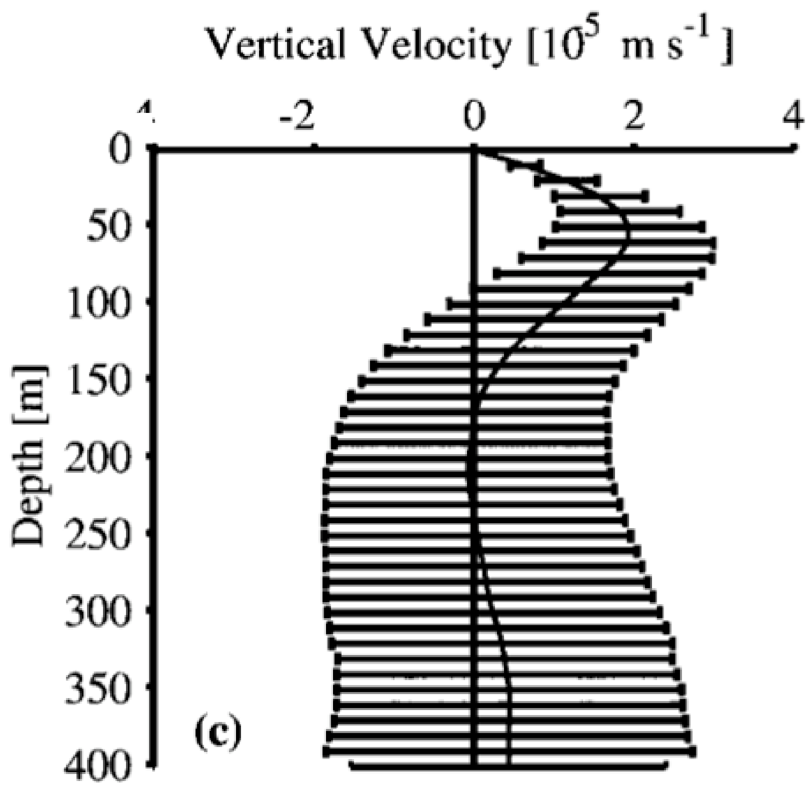
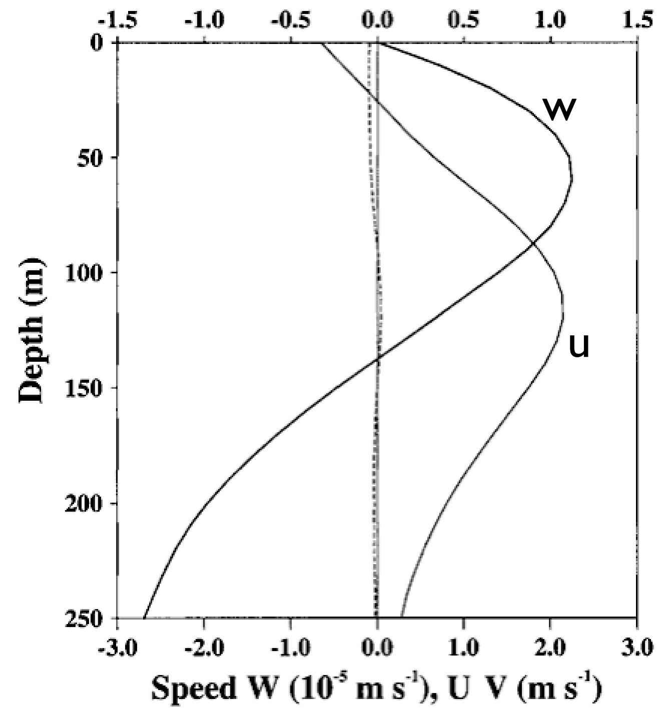
Observed estimates of w

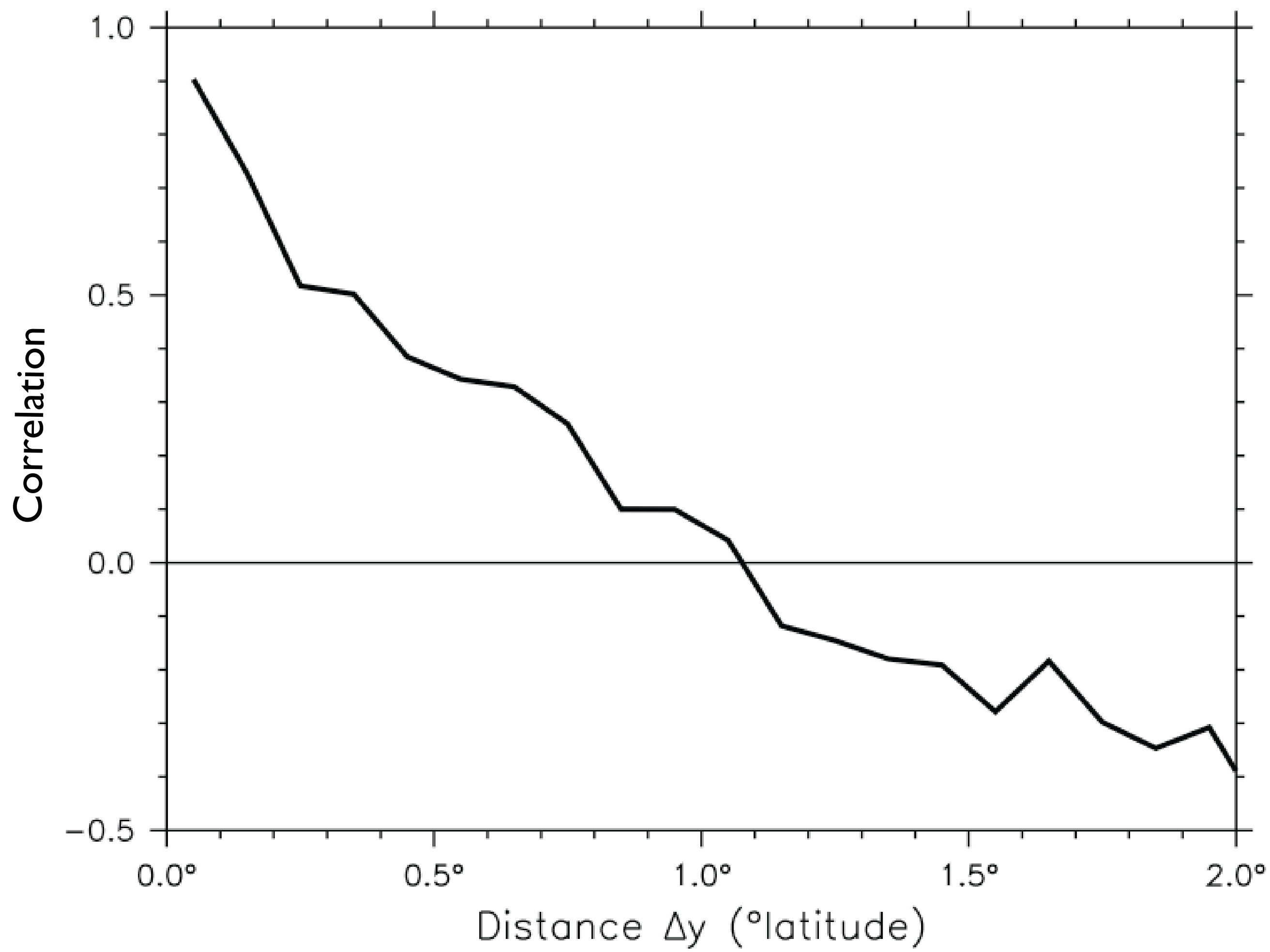


Johnson et al (2001)
Mean over shipboard ADCP



Weisberg and Qiao (2000)
Moorings at 0°, 140°W

Estimate of meridional scale of v



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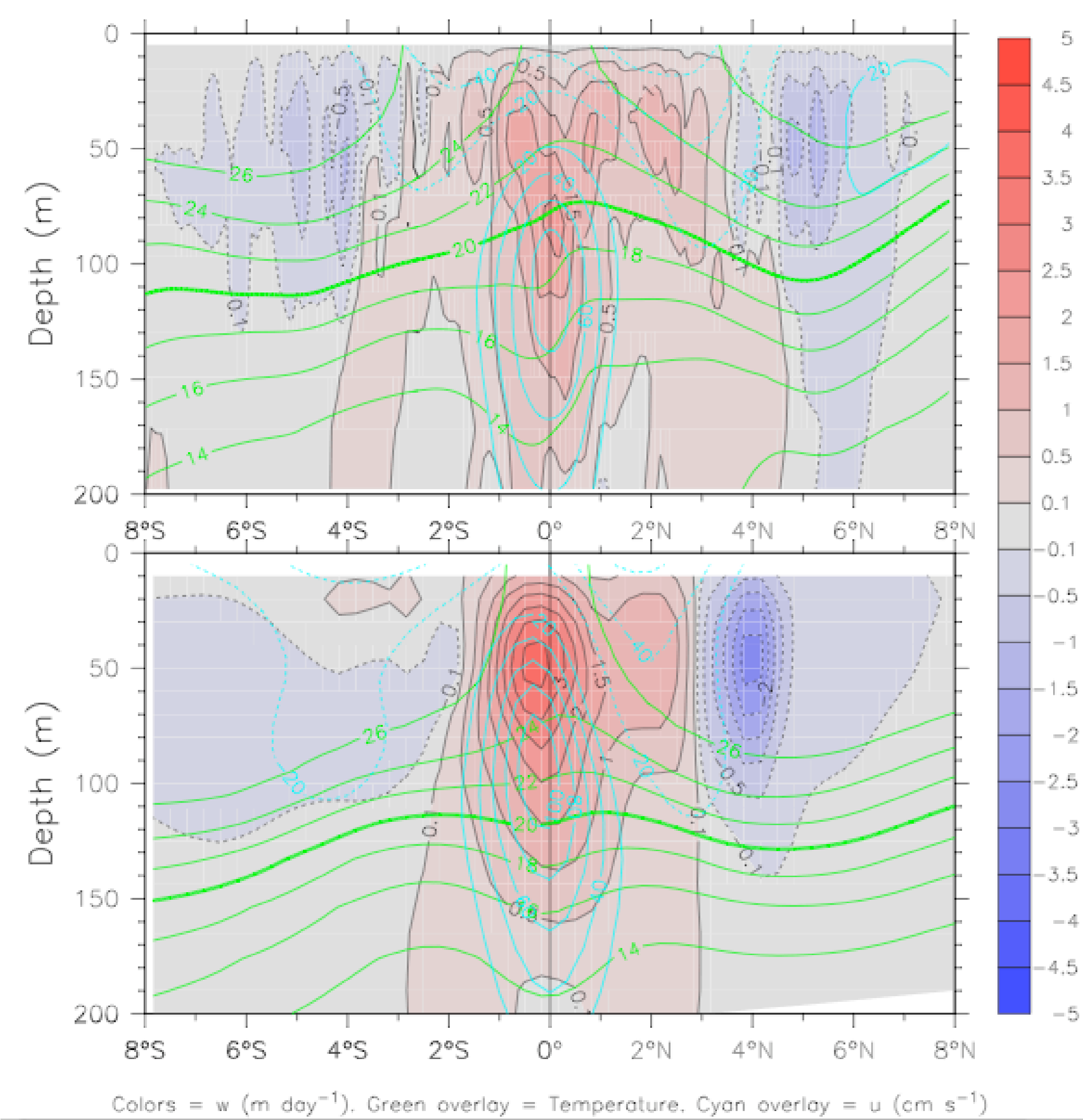
OGCM w,u,T(y,z)

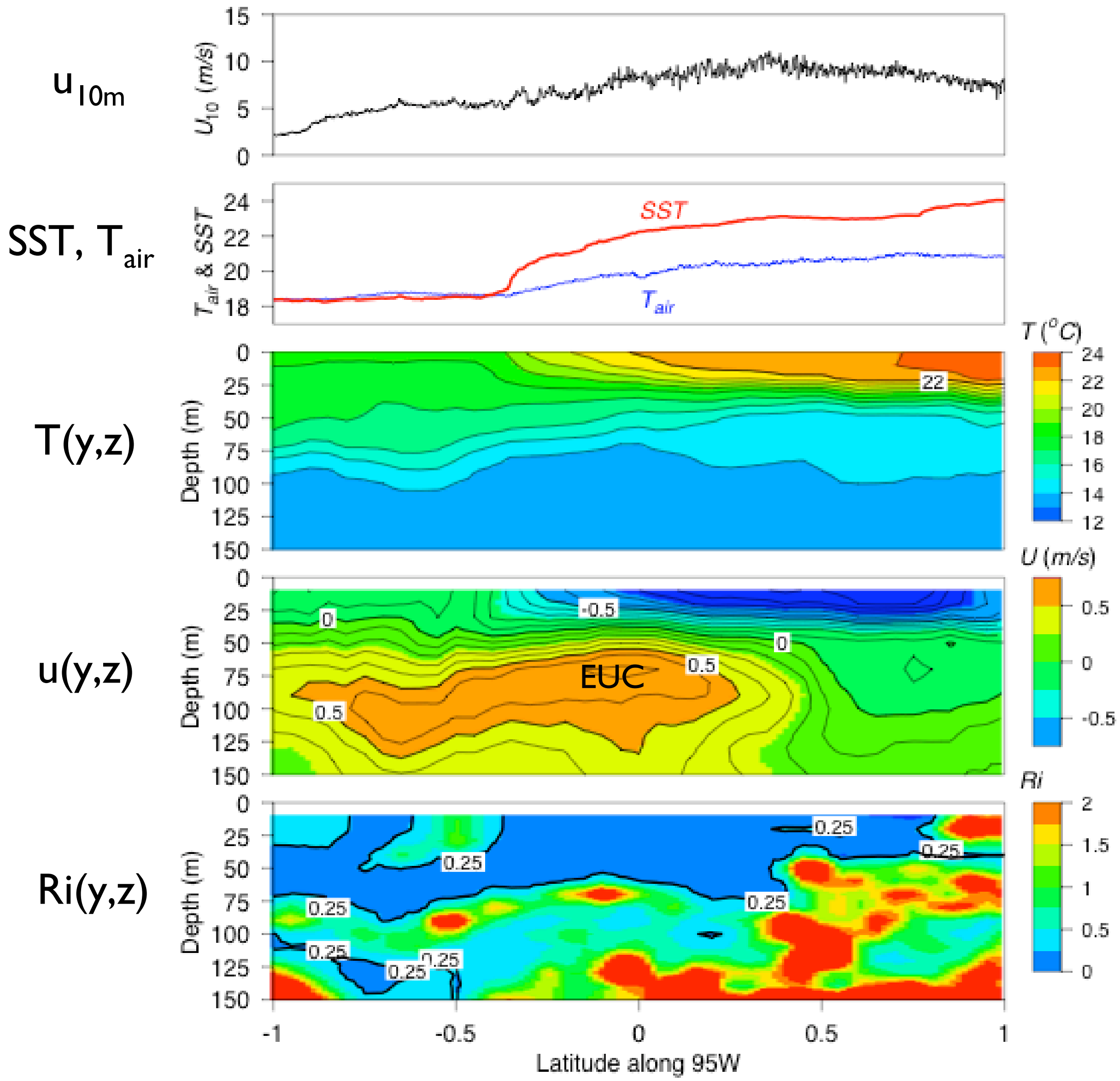


Compare
CCSM2 (top)
vs
MOM2 (bottom)

Colors = w (m/day)
Green = Temperature
Cyan = u (cm/s)

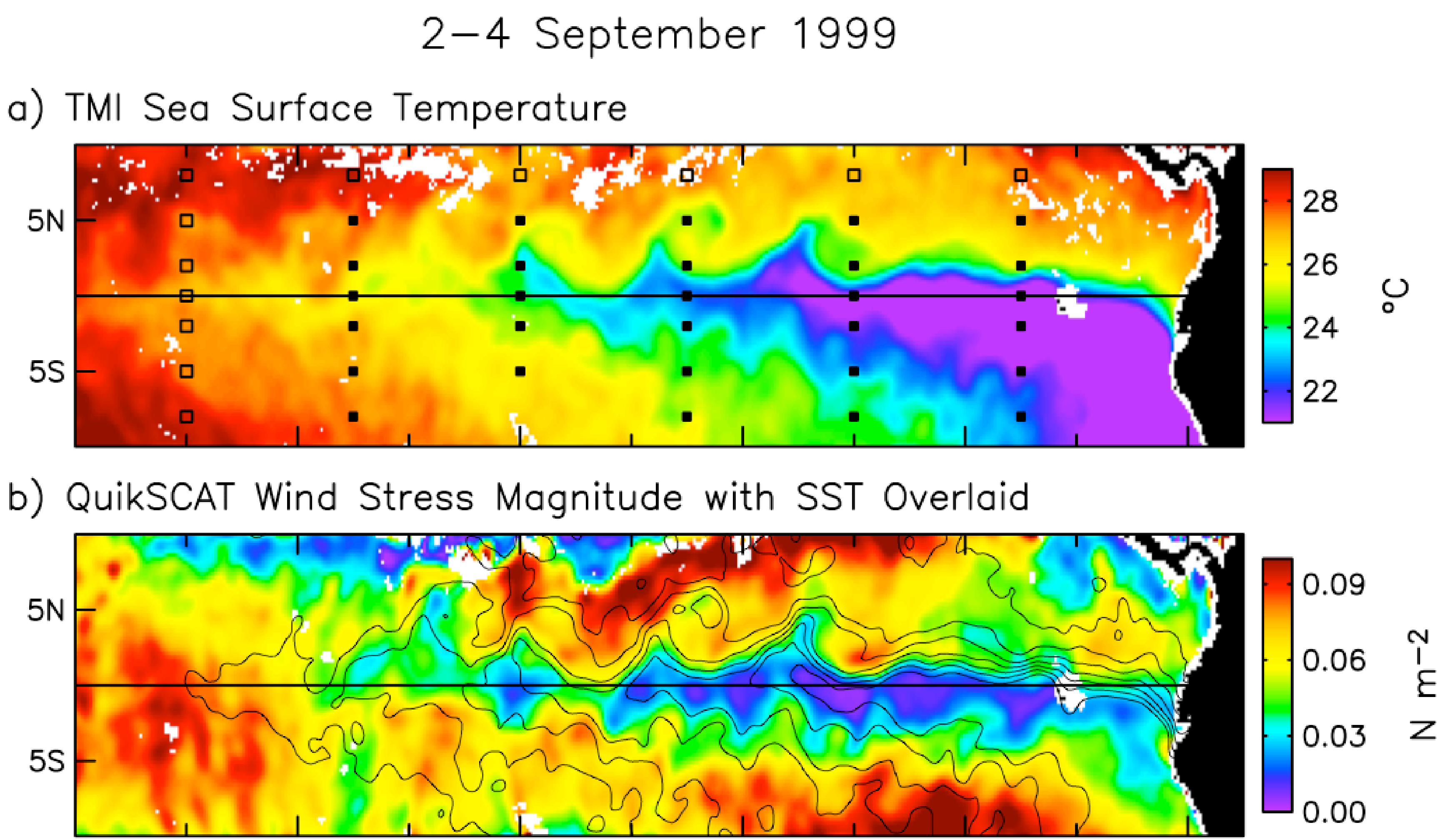
CCSM2 (Bryan)
MOM2 (Vecchi)

The front north of the Equator



Section along 95°W during EPIC 2001. (Wijsekera, Paulson, Rudnick)

Sensitivity of winds to SST



Chelton et al (2001)