2) TESTING COUPLED OCEAN-ATMOSPHERE-LAND HYPOTHESES

(a) Oceanic mesoscale eddies play a major role in the transport of heat and fresh water from coastally upwelled water to regions further offshore.

→ It is undoubtedly (and almost trivially) true that horizontal advection of cool water is required to balance the mean surface heating. What is at issue is: "What dynamics?" and "What depth?".

→ VOCALS satellite and in situ observations suggest that, if this occurs, it is not primarily in the surface layer. (In the VOCALS region, SST signals of eddies are small, and eddies are relatively weak.) The observations are not well suited for resolving this question, since only ~2-4 mesoscale eddies per year pass a given location.

→ VOCALS modeling activities (and modeling stimulated by VOCALS) suggest eddy heat fluxes are a significant, but nonsystematic, influence in the surface layer (especially Capet et al., 2008; Toniazzo et al., 2009; Zheng et al., 2010). Does this also reflect poor statistics, even in the 20-year model analysis of Toniazzo et al.?

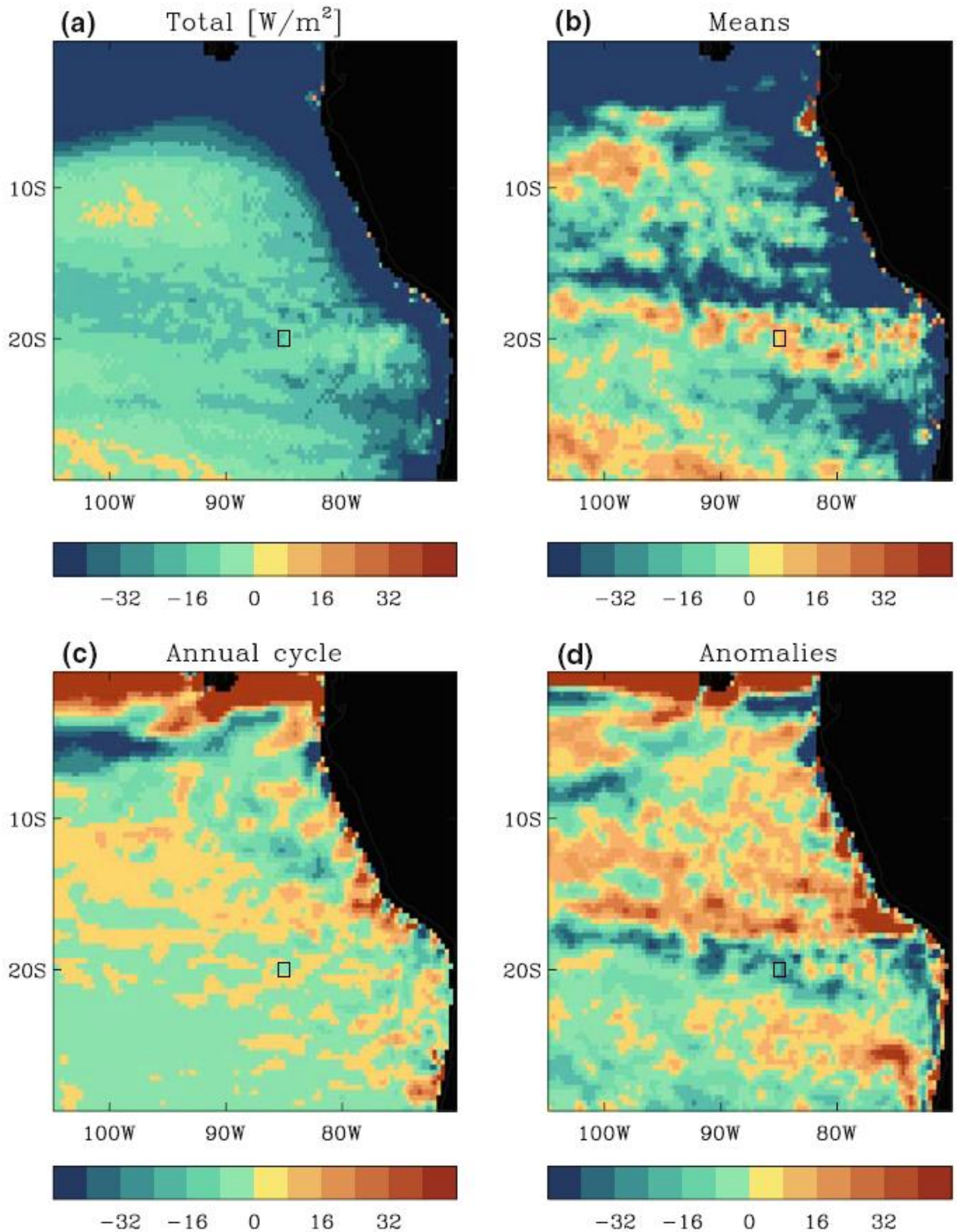

Fig. 6 Maps showing (**a**) the model 20-year mean, total heat advection in the upper ocean (0–500 m), and the partial contributions from (**b**) heat advection by the mean fields, from (**c**) the anomalies, with respect to the long-term mean fields, of the average seasonal cycle, and from (**d**) the remaining anomalies. The *box drawn* in each map represents the location of the IMET buoy (Colbo and Weller 2007)

Capet, X. F. Colas, P. Penven, P. Marchesiello and J.C. McWilliams, 2008: Eastern boundary subtropical upwelling systems. Eddy Resolving ocean modeling*, Geophysical Monograph Series*

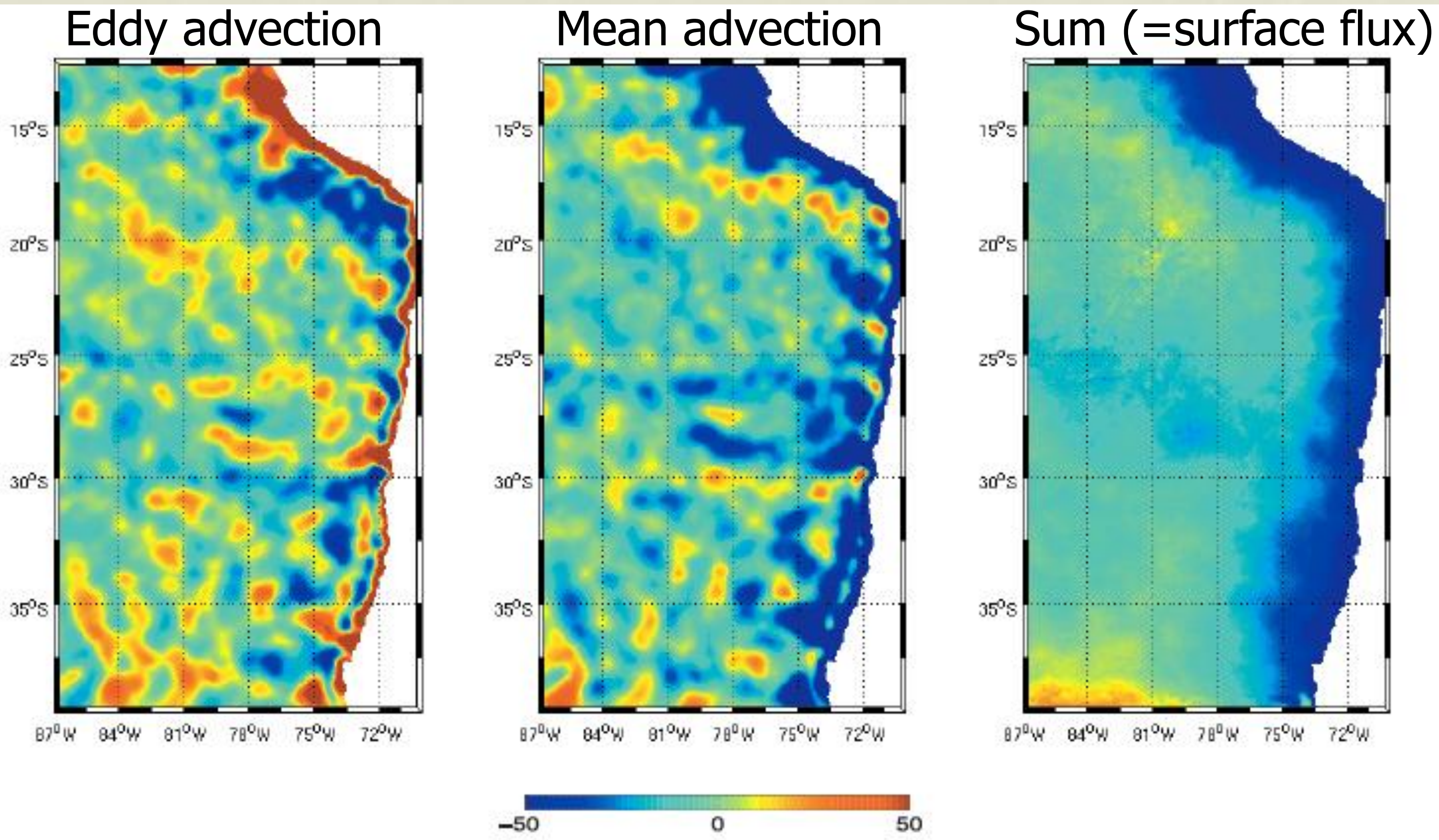

Plate 4. Annual average of vertically integrated (0- to 100-m depth) eddy (left), mean (center), and total (right) heat divergence (W m^{-2}) for a 9-year PCS ROMS solution. Maps of heat flux from the ocean to the atmosphere (i.e., positive upward) are indistinguishable from the panel for total heat flux.

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→ From the work of Toniazzo et al. (2009), it is not clear that the primary source of cool-water eddy advection is the coastal region– they suggest that eddy fluxes from the south in the salinity minimum layer are important.

→ It is perhaps premature, but this hypothesis will probably need to be refined, given what we are learning.

2) TESTING COUPLED OCEAN-ATMOSPHERE-LAND HYPOTHESES

(d) The entrainment of cool fresh intermediate water from below the surface layer during mixing associated with energetic near-inertial oscillations generated by transients in the magnitude of the trade winds is an important process to maintain heat and salt balance of the surface layer of the ocean in the SEP.

→ So far, neither disproven nor substantially supported (but still plausible).

→ Zappa and Farrar et al. find a near-inertial spectral peak in the turbulent kinetic energy dissipation at 8.4-m depth, which is suggestive, but needs more investigation. (This is the first time a dissipation time series this long has been collected away from the equator, so the proper interpretation of the near-inertial spectral peak is not obvious.)

→ Other vertical mixing mechanisms (especially salt fingering) may be important. This may be O(20 W/m^2)– it may be less. The data will allow a more quantitative estimate. This will imply a value of the salt flux, which could be checked against a salt budget. (We may also make independent inferences from T-S relations in historical data and Argo float data.)

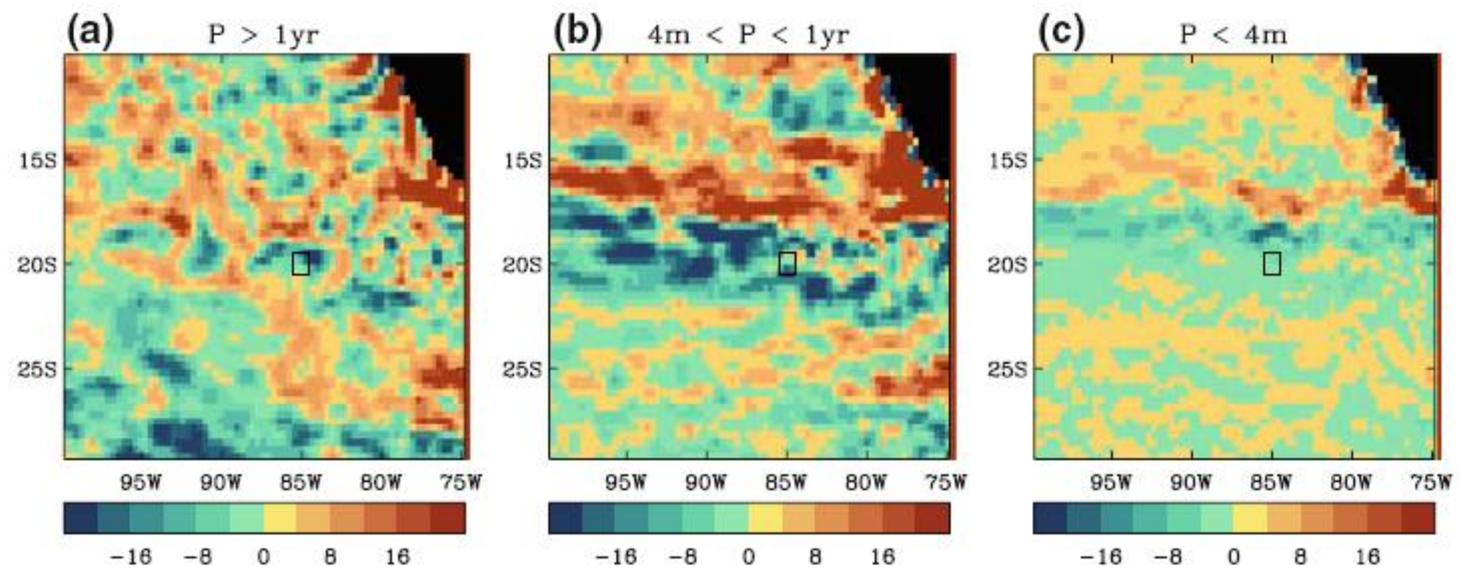


Fig. 7 Similar to Fig. 6, further decomposition of ocean heat advection from anomalies into contributions from anomalies low-, band-, and high-pass filtered in time, in panels (**a**), (**b**) and (**c**) respectively. The residual from the cross-terms of the Fourier components is non-vanishing due to FFT aliasing of the finite time-series, but it is very small

Equation for the vertically-averaged temperature in the mixed layer:

$$\frac{\partial \bar{T}}{\partial t} = -\bar{u}\cdot\nabla\bar{T} + \frac{Q_{surf} - Q_{pen}}{\rho_0 c_p h} + R$$

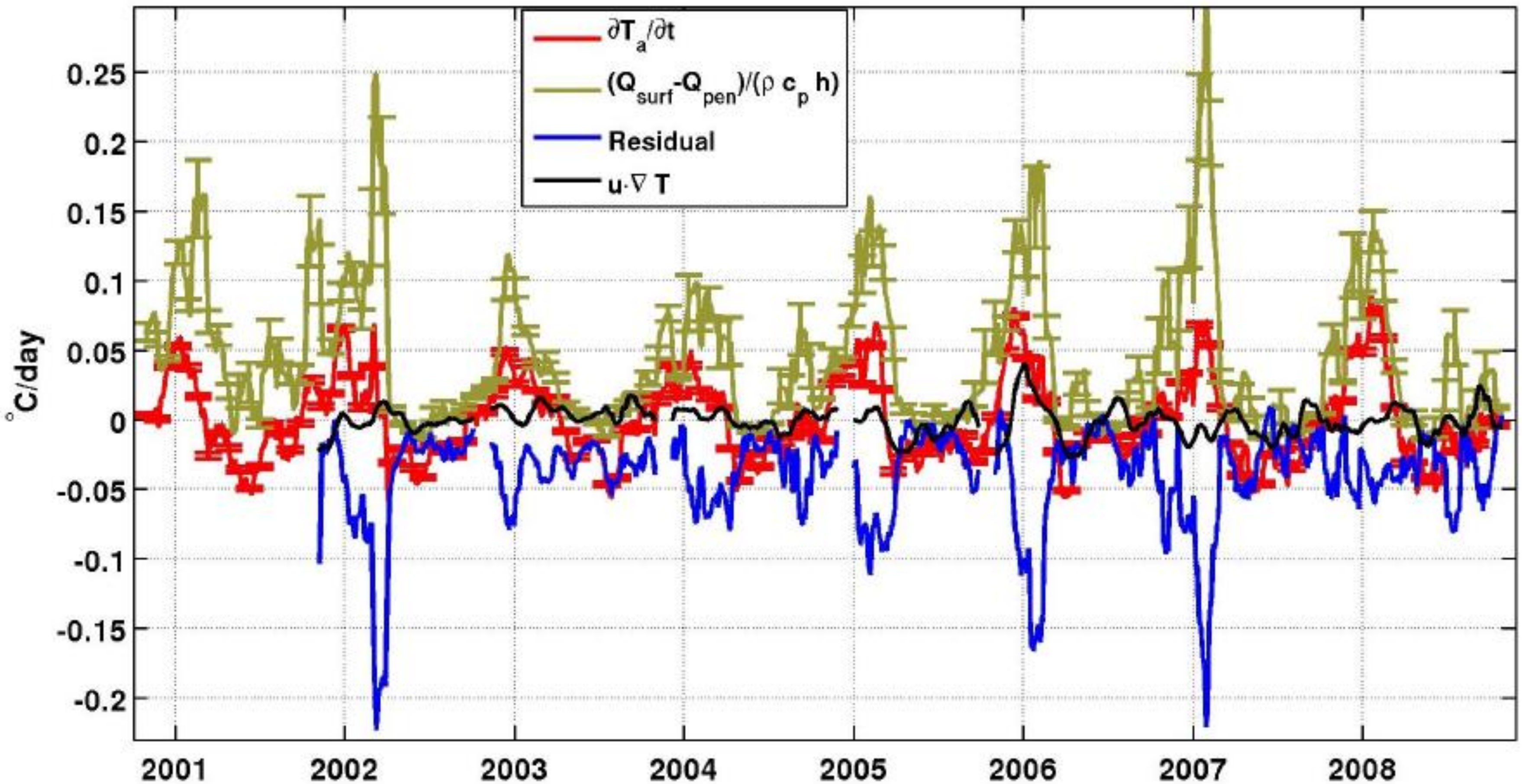
$$R = \hat{T}_{-h}\left(\frac{\partial h}{\partial t} + w_{-h} + u_{-h}\cdot\nabla h\right) - \frac{Q_{-h}}{h} - \frac{1}{h}\nabla\cdot\int_{-h}^{0}\hat{u}\,\hat{T}\,dz$$

h = mixed layer depth (SST - 0.5° C)

$\overline{T} = T(z)$ averagedto depth h

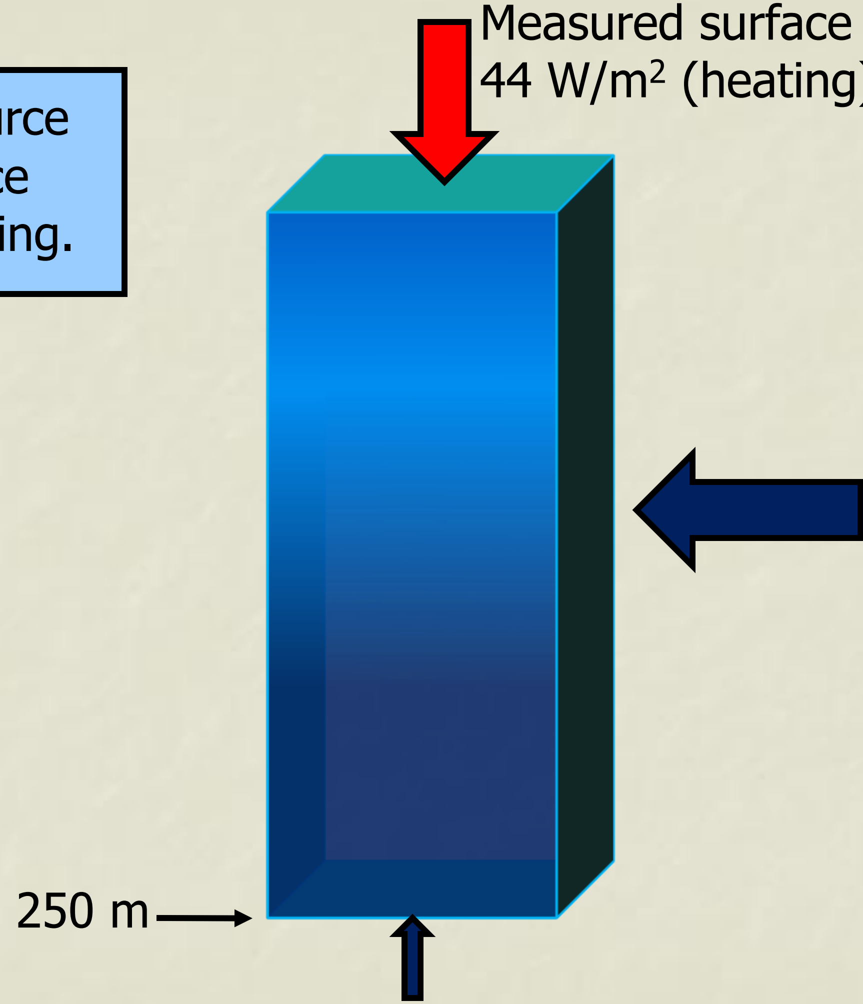
$\hat{T}(z)$ = deviation of T from $\overline{T}$

Mixed layer heat budget



Colbo and Weller (2007, *J. Mar. Res.*): Time-mean heat budget

→There must be a source of cool water to balance the mean surface heating.



Colbo and Weller (2007, *J. Mar. Res.*): Time-mean heat budget

→Their budget was for the upper 250 m, but for SST, the depth of this horizontal flux matters.