Altimetric Derived Estimates of the North Atlantic Upper Ocean Heat Budget: Consequences for Climate Prediction and Ocean Modeling

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Planned Activities

Abstract: We will be using the JASON and TOPEX/POSEIDON altimeter data to study the upper ocean heat budget, circulation changes, heat storage, and their implications for climate variations and predictability in the North Atlantic Ocean. We will estimate heat budget terms directly from observations and using a thermodynamic model (geostrophic currents specified by the altimeter). These estimates will be compared with the heat budget constructed from a high-resolution numerical ocean general circulation model. The analyses will extend previous research in the Gulf Stream to include its interaction with the North Atlantic Current and the subpolar gyre. The heat budget estimates will help us understand both fluxes of heat across the current systems and the nature of atmosphere-ocean interaction in the North Atlantic. In comparison with previous work, these analyses will show the improvement in the heat budget with twice the altimeter resolution, particularly the accuracy of eddy heat fluxes, and facilitate the comparison with the ocean circulation model.

The hypotheses to be tested in this study include:

- Heat content anomalies are predictable and result from wind-forced changes in heat transport
- Local heat storage in the Gulf Stream affects the meridional heat transport
- Heat transport variations are more important in the upper ocean heat budget than eddy heat fluxes.

We are particularly interested in how well the models reproduce variations in the zonal penetration of the western boundary currents, anomalies of heat content, and the upper ocean heat budget. Ocean circulation models have the advantages of subsurface fields and higher spatial and temporal resolution. Comparisons between the Hybrid Coordinate Ocean Model (HYCOM) fields and altimeter data for the western North Pacific shown here.

Model successes:

- seasonal cycle of heat content
- large advection contribution to heat budget

Model weaknesses:

- systematic path differences
- lack of decadal variations

Section 1: Previous Western Boundary Current Results

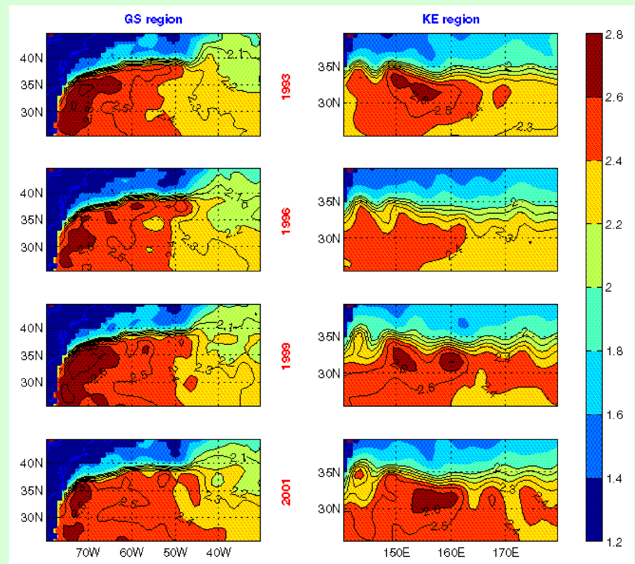

Figure 1. Sea surface height maps from TOPEX/POSEIDON. (left) Gulf Stream region in the North Atlantic and (right) Kuroshio Extension (KE) region in the North Pacific for years 1993, 1996, 1999, and 2001. Units are meters. More positive SSH indicates more heat stored in the ocean. [Kelly and Dong, 2004]

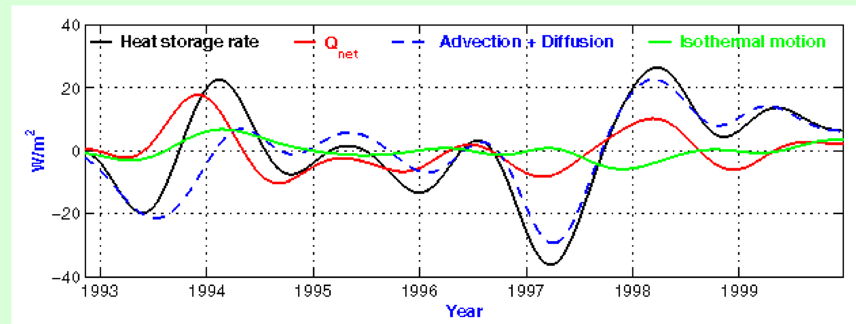

Figure 2. Heat budget for the Gulf Stream region. The heat storage rate (black) is the sum of surface heating (red), advection and diffusion (blue dashed), and vertical motion of isotherms (green). Advection plus diffusion account for 70% of heat storage variance. After Dong and Kelly [2004].

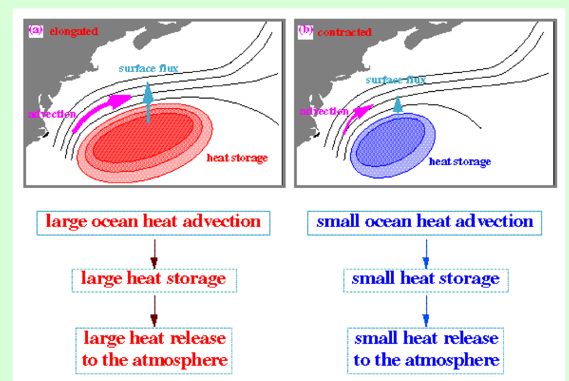

Figure 3. Schematic illustrating different Gulf Steam states. (left) "Elongated" state: Gulf Stream transports more heat to the region, which is stored locally, causing an anomalous heat loss to the atmosphere. (right) "Contracted" state: less heat transport, storage and heat loss.

Bibliography:

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Dong, S. and K.A. Kelly, 2004: Heat budget in the Gulf Stream region: the importance of heat advection and storage, J. Phys. Oceanogr., 34, 1214-1231.

Qiu, B., 2000: Interannual variability of the Kuroshio Extension system and its impact on the wintertime SST field, J. Phys. Oceanogr., 30, 1486-1502.

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Section 2. HYCOM Model/Altimeter Comparisons in the Pacific

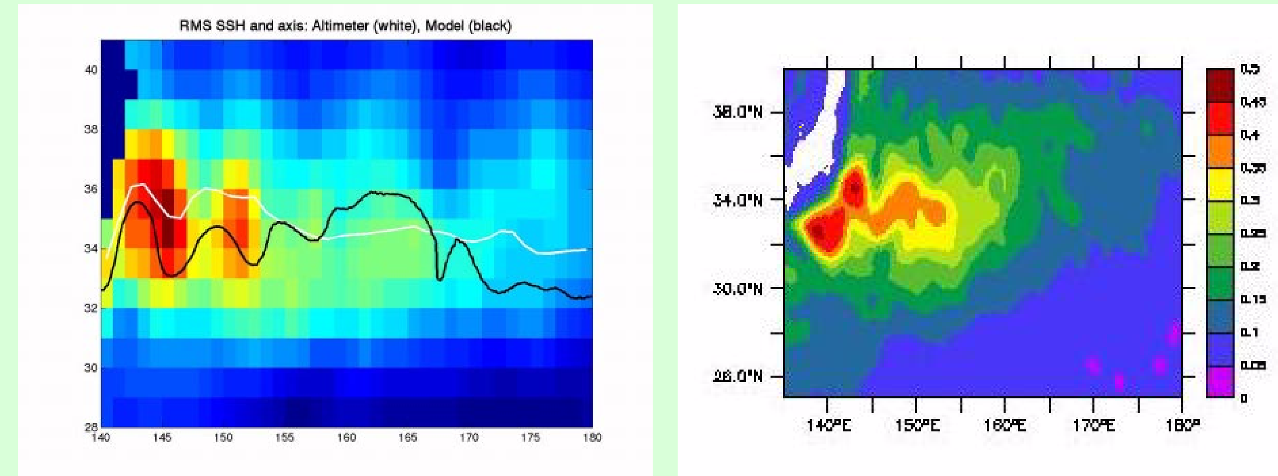

Figure 4. Sea surface height variance for TOPEX/Poseidon (left) and model (right). The maximum variance is located closer to the western boundary in the model. The axis of the Kuroshio Extension (KE) from the model (black) is too far south, upstream of 150˚E and too far north, downstream. The axis from the altimeter (white) overlies the variance maximum.

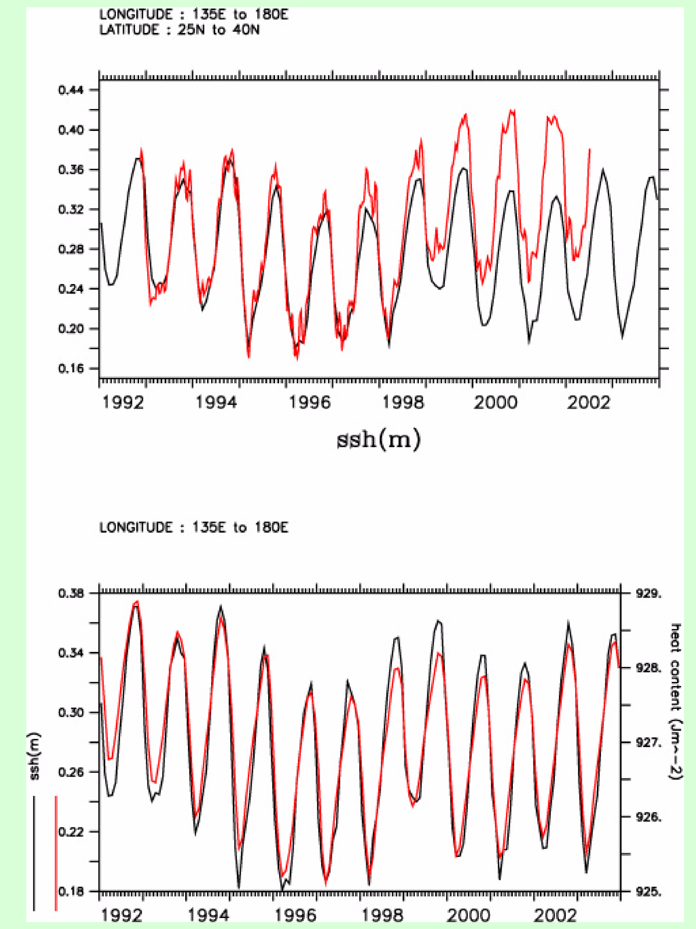

Figure 5. Sea surface height and heat content averaged over the KE region. (upper panel) The model reproduces well the seasonal cycle of the SSH, but not the long time scales of the SSH anomalies. SSH is a good proxy for heat content, as seen in the model comparisons (lower panel).

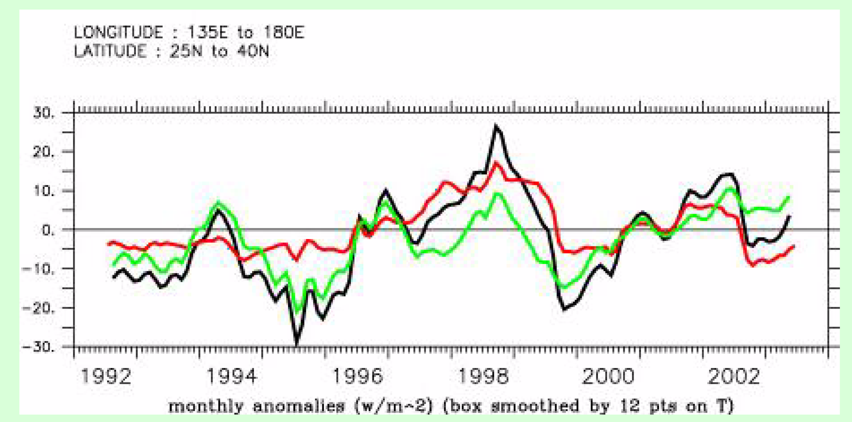

Figure 6. Model heat budget for the KE region. Heat storage rate in the upper 800m (black), surface heating (red) and residual (green) show that ocean advection plays a large role in the upper ocean heat balance. Similar conclusions were found by Qiu (2000) and Vivier et al. (2002) for the KE and by Dong and Kelly (2004) for the GS (Figure 2).

(a) (b)

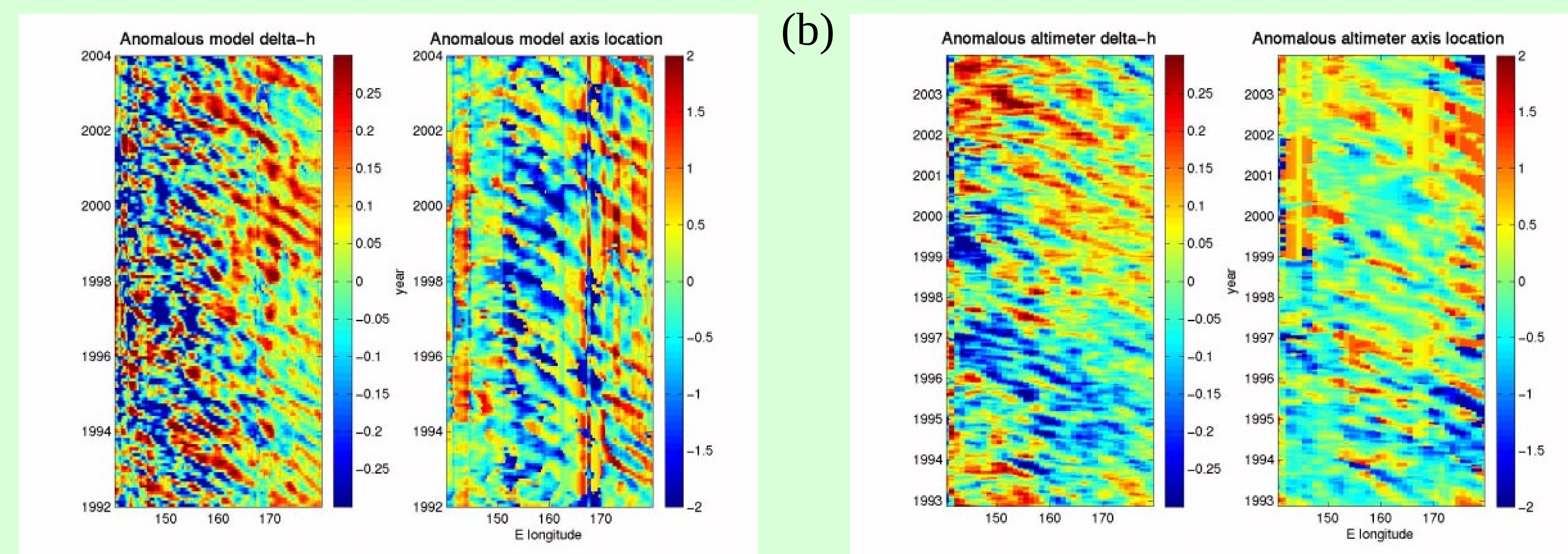

Figure 7. Comparison of nonseasonal anomalies of SSH difference and axis latitude for the KE. SSH difference across the jet and axis latitude are determined by fitting an error function to the SSH at each longitude. Both (a) ocean model and (b) altimeter observations show clear westward propagation of delta-h anomalies. However, observed negative anomalies in 1994-1997, followed by positive anomalies in 1999-2004, are not seen in the model.