Ocean Mixed Layer Response to Kinematic Coupling from Currents to Wind Stress over the Gulf Stream Region

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Motivation

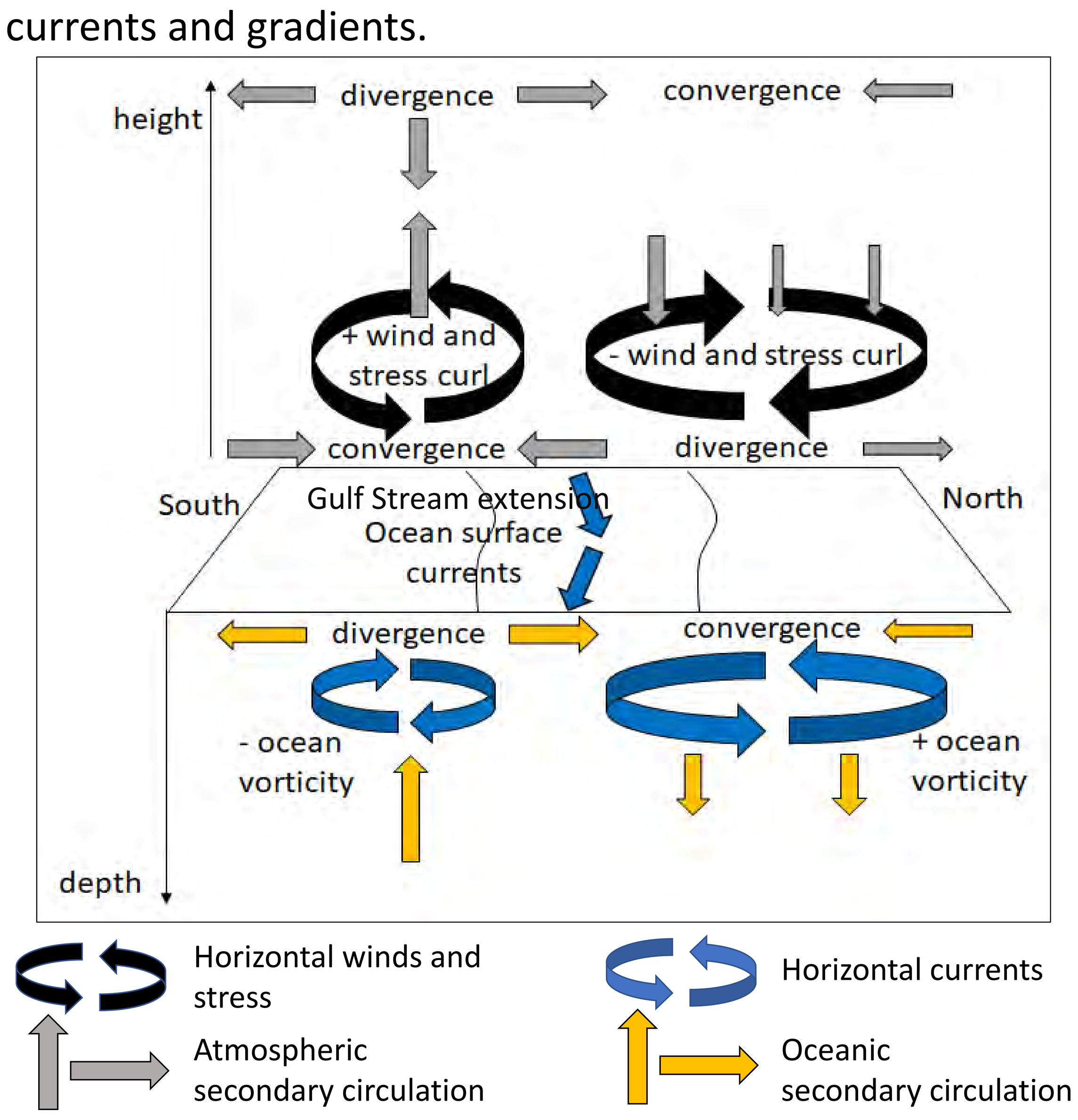
In coupled atmosphere/ocean and atmosphere/ocean/wave models, the kinematic coupling (between currents and winds), atmospheric horizontal resolution, and oceanic horizontal resolution each have a significant impact within the ocean mixed layer, as well as the atmosphere. The response within the upper ocean to changes in these contributions are examined here using two-way coupled atmospheric/ocean models. The first four coupled model simulations are completed with various combinations of 2km (submesoscale resolving) and 6km (submesoscale permitting) atmospheric and ocean grid spacing and without the kinematic coupling. The second four coupled model simulations use the same model resolutions defined in the first set of four simulations, but the kinematic coupling and feedback between the surface currents and wind stress is included.

Experiments	Simulation Name	Resolution	Wind Input for Surface Stress
Exp 1	a2o2	2 km ocn; 2 km atm	$\vec{U}_{10}$
Exp 2	a2o6	2 km ocn; 6 km atm	$\vec{U}_{10}$
Exp 3	a6o2	6 km ocn; 2 km atm	$\vec{U}_{10}$
Exp 4	a6o6	6 km ocn; 6 km atm	$\vec{U}_{10}$
Exp 5	a2o2-curr2	2 km ocn; 2 km atm	$\vec{U}_{10} - \vec{U}_{cur}$
Exp 6	a2o6-curr2	2 km ocn; 6 km atm	$\vec{U}_{10} - \vec{U}_{cur}$
Exp 7	a6o2-curr2	6 km ocn; 2 km atm	$\vec{U}_{10} - \vec{U}_{cur}$
Exp 8	a6o6-curr2	6 km ocn; 6 km atm	$\vec{U}_{10} - \vec{U}_{cur}$

Conceptual Diagram of Kinematic Coupling

This conceptual diagram depicts the wind vector component moving in the same direction as the current, over the Gulf Stream extension. The ocean circulations will exist regardless of the feedback; however, the atmospheric circulations is determined by the inclusion of the kinematic coupling.

- To the right of the Gulf Stream extension: negative ocean relative vorticity is the primary horizontal circulation, which leads to a secondary circulation in the ocean of ocean surface divergence and corresponding upward motion. The ocean surface divergence acts to compress the Gulf Stream current and subsequently leads to stronger currents and gradients.
- To the left of the Gulf Stream extension: positive ocean relative vorticity is the primary horizontal circulation, which leads to a secondary circulation in the ocean of ocean surface convergence and corresponding downward motion. The ocean surface convergence acts to stretch the Gulf Stream current and subsequently leads to weaker currents and gradients.



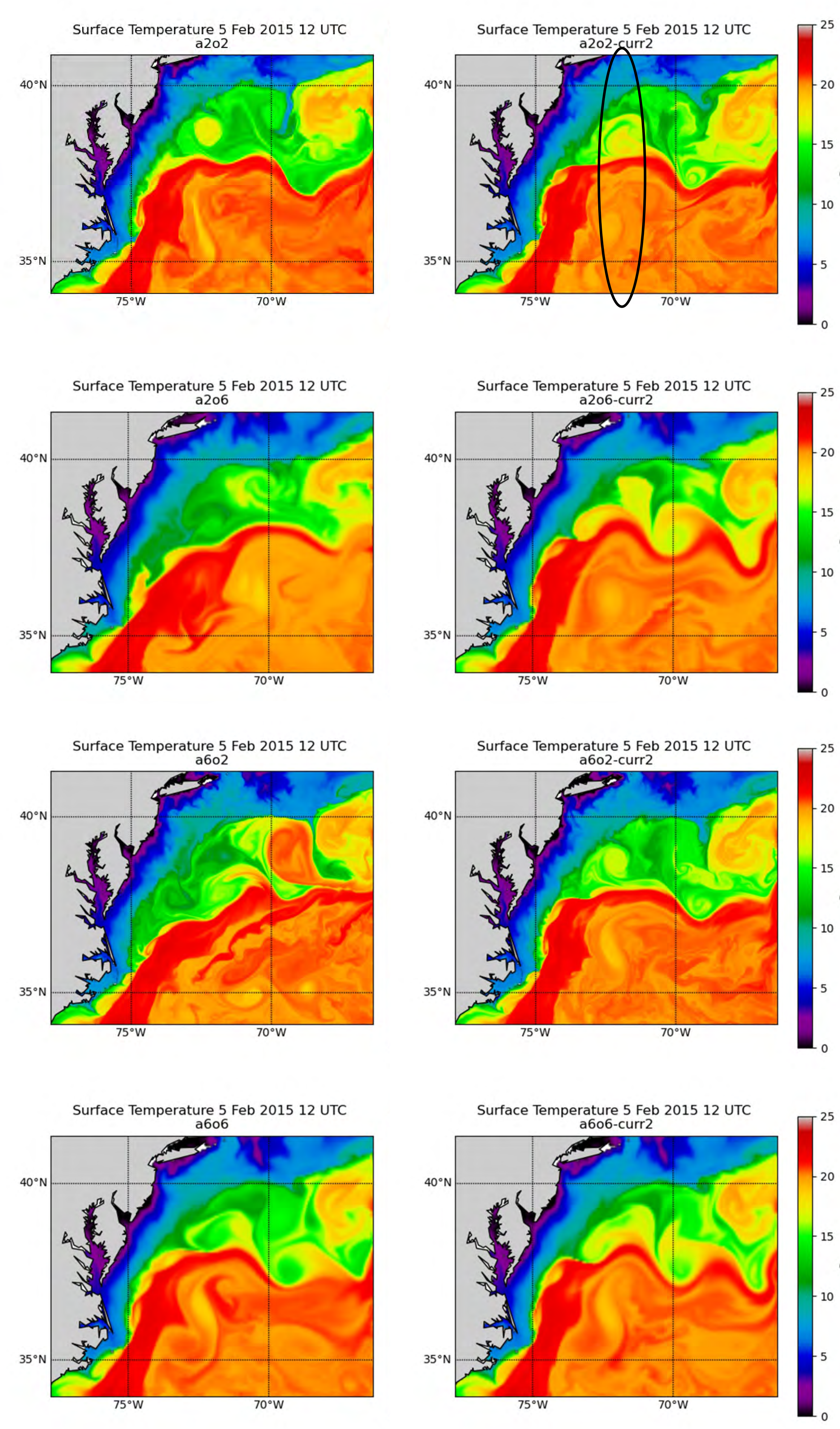
Acknowledgements

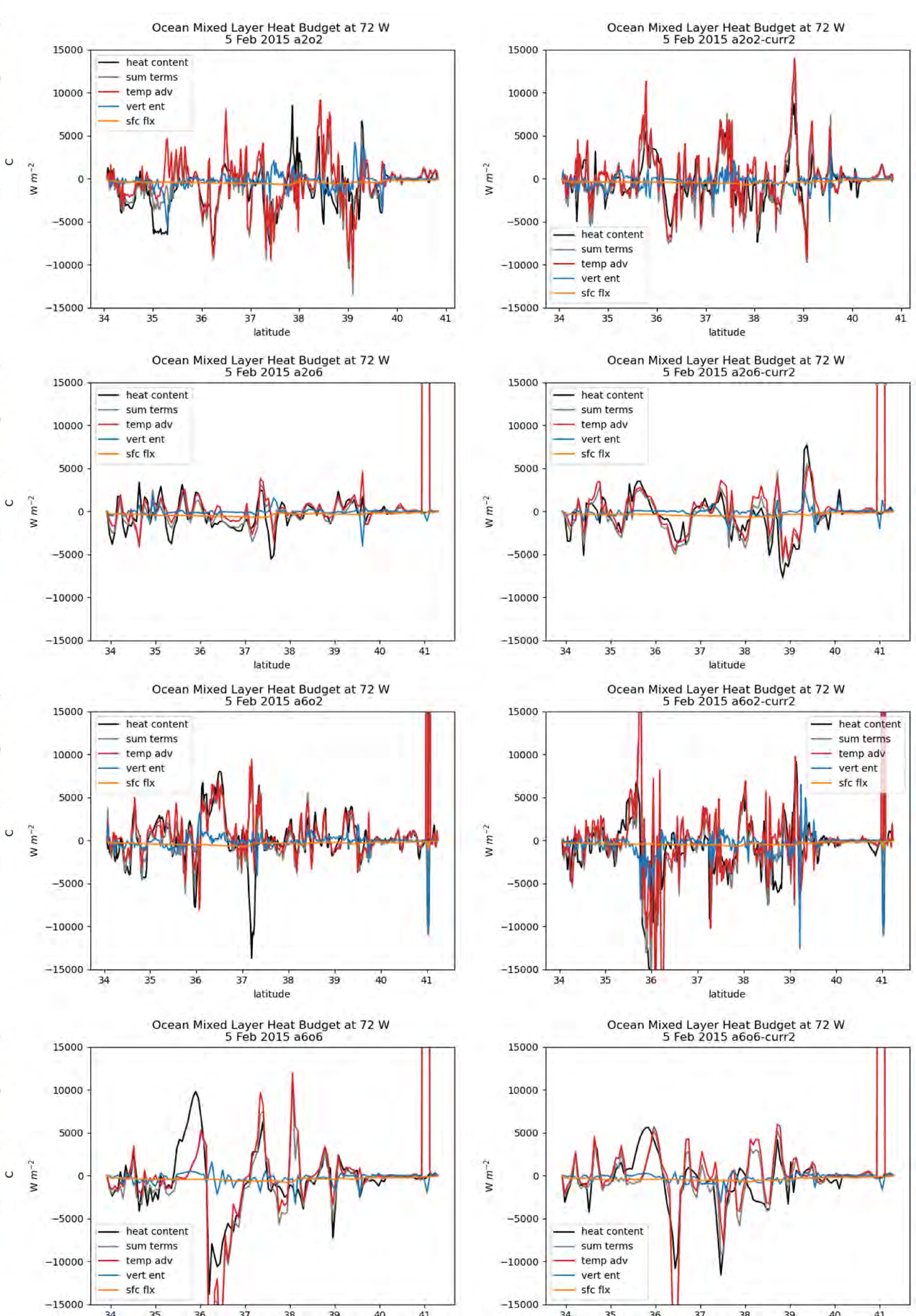
- Some of this work described here is built upon prior research by Zhan Su et al., Peter Gaube et al., Hyodae Seo et al., Lionel Renault et al., and much earlier work in the atmosphere and ocean related to Ekman transport.
- We thank ONR for largely funding this work, and support for MAB from NASA and NOAA.

SST and Mixed Layer Heat Budget

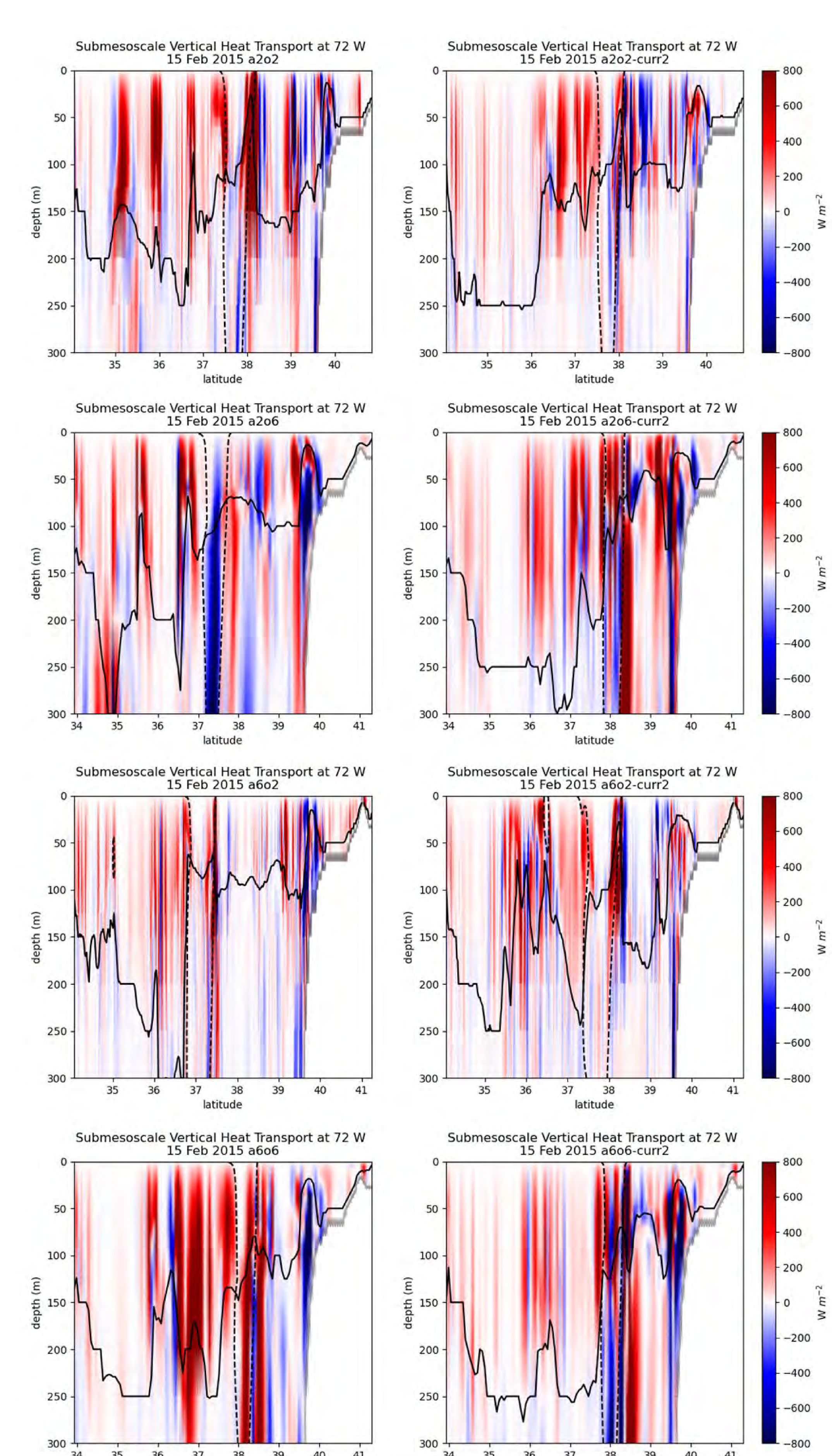
Including kinematic coupling leads to more consistent model results when the atmospheric model is changed. This implies the kinematic coupling (and current feedback) is important in controlling the Gulf Stream path.

The dominant term in the ocean heat content variability is the temperature advection. Including kinematic coupling leads to more consistent model results when the atmospheric model is changed. These results imply that ocean processes, rather than atmospheric thermodynamic forcing, control the SST variability on short time scales.





Submesoscale Vertical Heat Flux



- The submesoscale vertical heat flux has a significant heat transport that is largely constrained to the mixed with a high resolution ocean model, when averaged over a day or longer.
- Having both a high resolution atmosphere and ocean, as well as including the kinematic coupling, leads to enhanced:
  - Upward motion to the right of the Gulf Stream extension.
  - Downward motion to the left of the Gulf Stream extension.
- Submesoscale vertical heat flux energy spectra:
  - Increased north (compared to south) of the Gulf Stream extension due to a more dynamically active ocean region.
  - Reduced as ocean model resolution increases due to increasing the horizontal advection magnitude.
  - Increased as atmospheric model resolution increases - given a high resolution ocean and including the kinematic coupling.