Impact of Horizontal Model Resolution and Current Coupling on Upper Ocean in a Coupled Model over the Gulf Stream Region

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Motivation

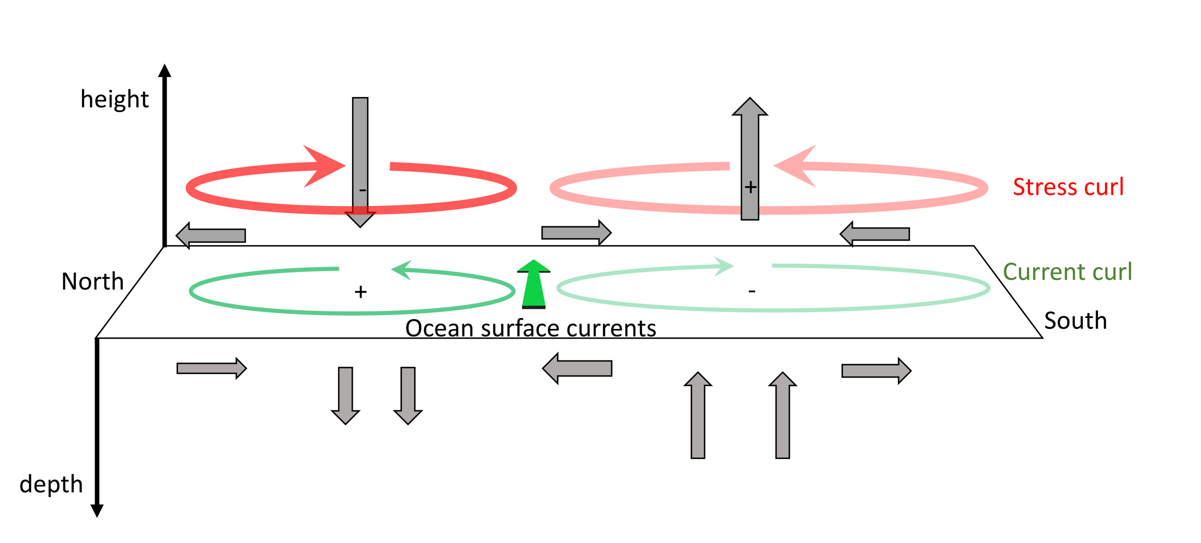
The coupling and feedback between the ocean surface currents and the atmospheric wind stress has primary and secondary impacts on the circulations within both the upper ocean and throughout the atmosphere. With high resolution coupled model simulations over the Gulf Stream region, we are able to examine these impacts with respect to the Gulf Stream current. The primary circulation in the ocean is related to the ocean surface relative vorticity. The secondary circulation in the ocean consists of ocean surface convergence / divergence and corresponding downward / upward vertical motion. Including the current feedback in coupled model simulations results in a reduction of both the mean and eddy kinetic energy from the atmosphere to the ocean, which acts to control the Gulf Stream path. Additionally, when the current feedback is included, the ocean submesoscale vertical heat flux (which is representative of part of the ocean secondary circulation) has enhanced upward motion to the right the Gulf Stream extension and enhanced downward motion to the left of the Gulf Stream extension. The magnitude of the submesoscale vertical heat flux daily average is shown to be comparable to the magnitude of the latent heat flux daily average. These results will have further implications on vertical mixing and weather.

Experiments	Simulation Name	Resolution	Wind Input for Surface Stress
Exp 1	a2o2	2 km ocn; 2 km atm	$\vec{U}_{10}$
Exp 2	a6o6	6 km ocn; 6 km atm	$\vec{U}_{10}$
Exp 3	a2o2-cfb	2 km ocn; 2 km atm	$\vec{U}_{10} - \vec{U}_{curr}$
Exp 4	a6o6-cfb	6 km ocn; 6 km atm	$\vec{U}_{10} - \vec{U}_{curr}$

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 are 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
  - secondary circulation in the ocean of ocean surface divergence and corresponding upward motion
  - 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
  - secondary circulation in the ocean of ocean surface convergence and corresponding downward motion
  - 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.
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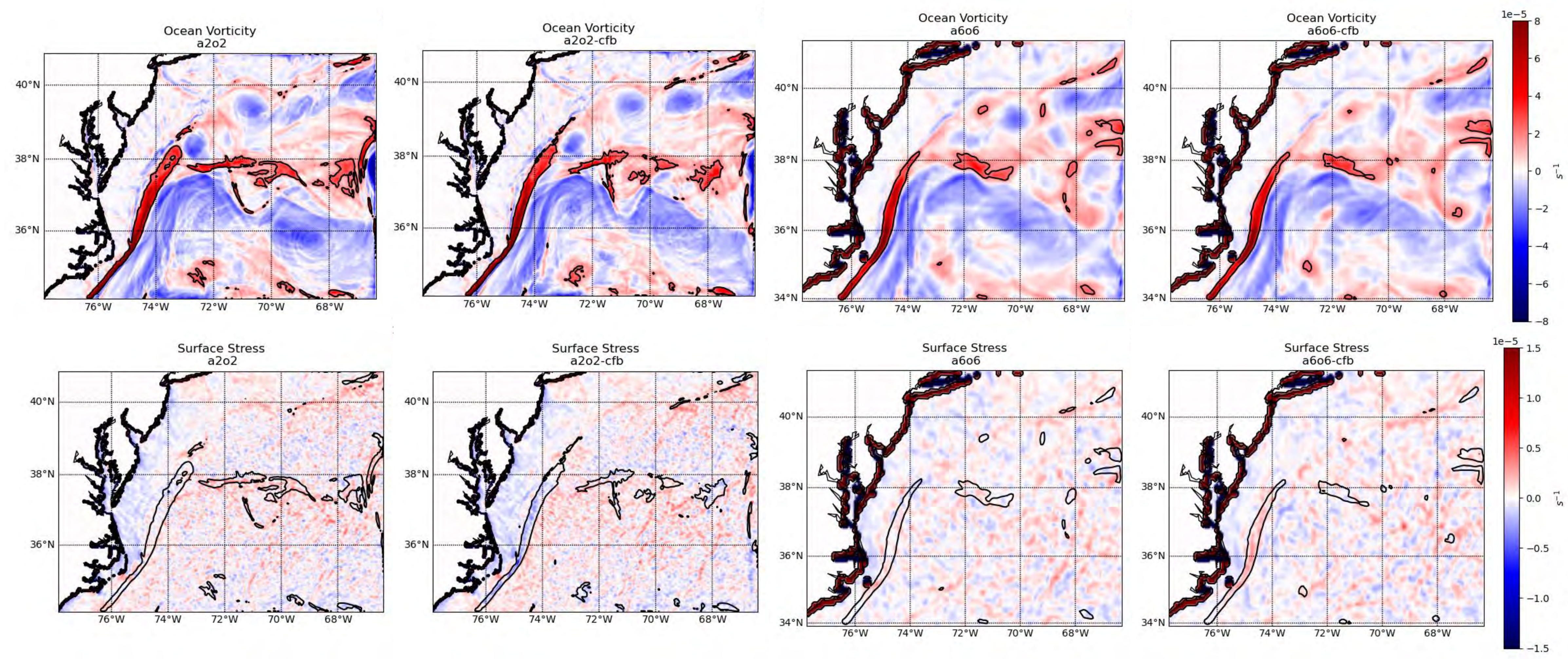
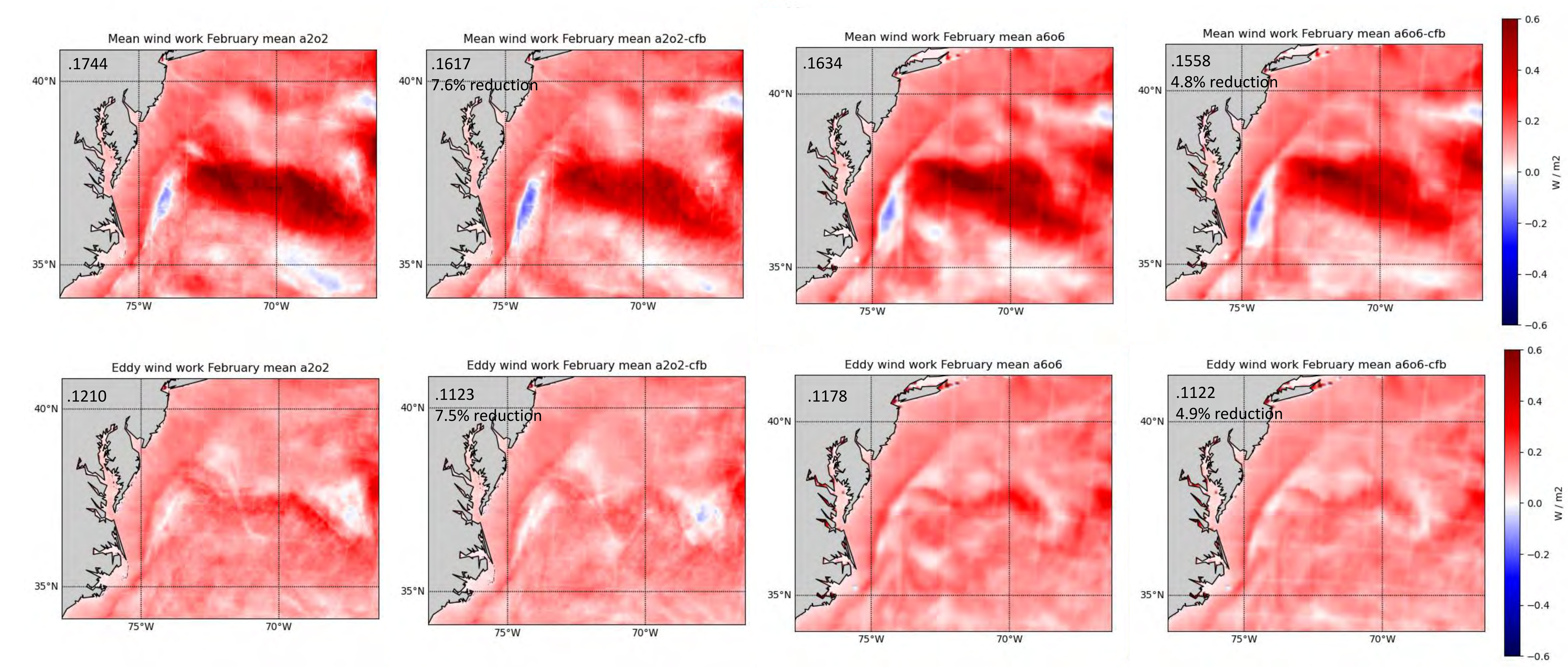
Primary circulations and wind work

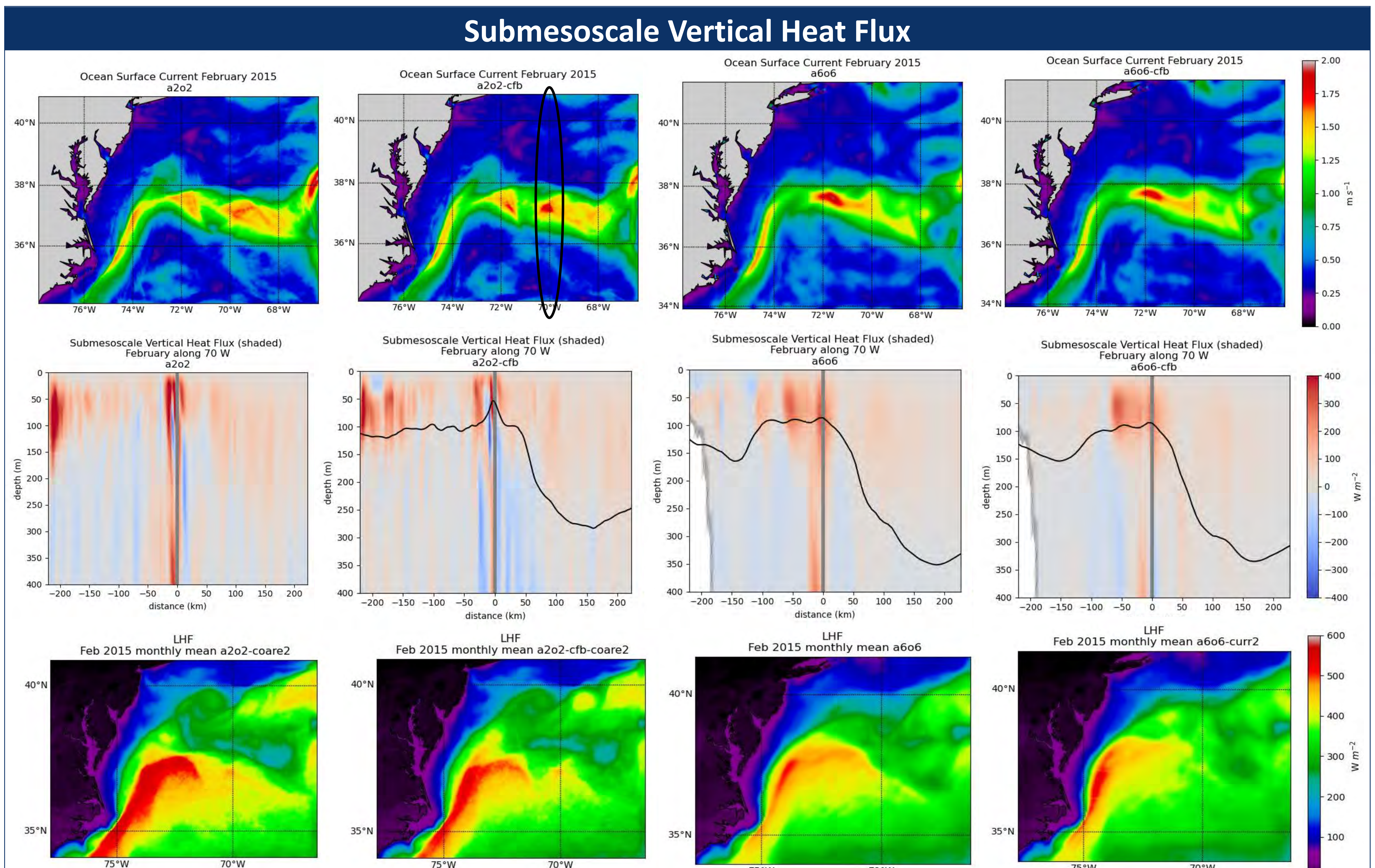


- Including the current feedback leads to
  - negative relationship between the ocean relative vorticity and the atmospheric surface stress curl



- Including the current feedback leads to
  - Overall reduction in both the mean (~8%) and eddy (~5%) kinetic energy
  - More enhanced reduction over strong currents

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 current feedback, leads to enhanced:
  - Upward motion to the right of the Gulf Stream extension.
  - Downward motion to the left of the Gulf Stream extension.

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