Atmospheric Response to Kinematic Coupling of Wind to Stress and Currents Over the Gulf Stream Region

Mark Bourasa[1] and Jackie May[2]

[1] Center for Ocean-Atmospheric Prediction Studies (COAPS), Florida State University, Tallahassee, FL

[2] Oceanography Division, U.S. Naval Research Laboratory, Stennis Space Center, MS

While local responses to atmospheric responses to SST gradients are now relatively well known, the local wind responses to surface currents gradients remain controversial. The downwind response to these wind perturbations also remains untested and poorly characterized. The current and wind coupling process is based on how winds and stress respond to patterns of currents. This coupling is very different than what we would see over land because land does not move in response to atmospheric forcing.

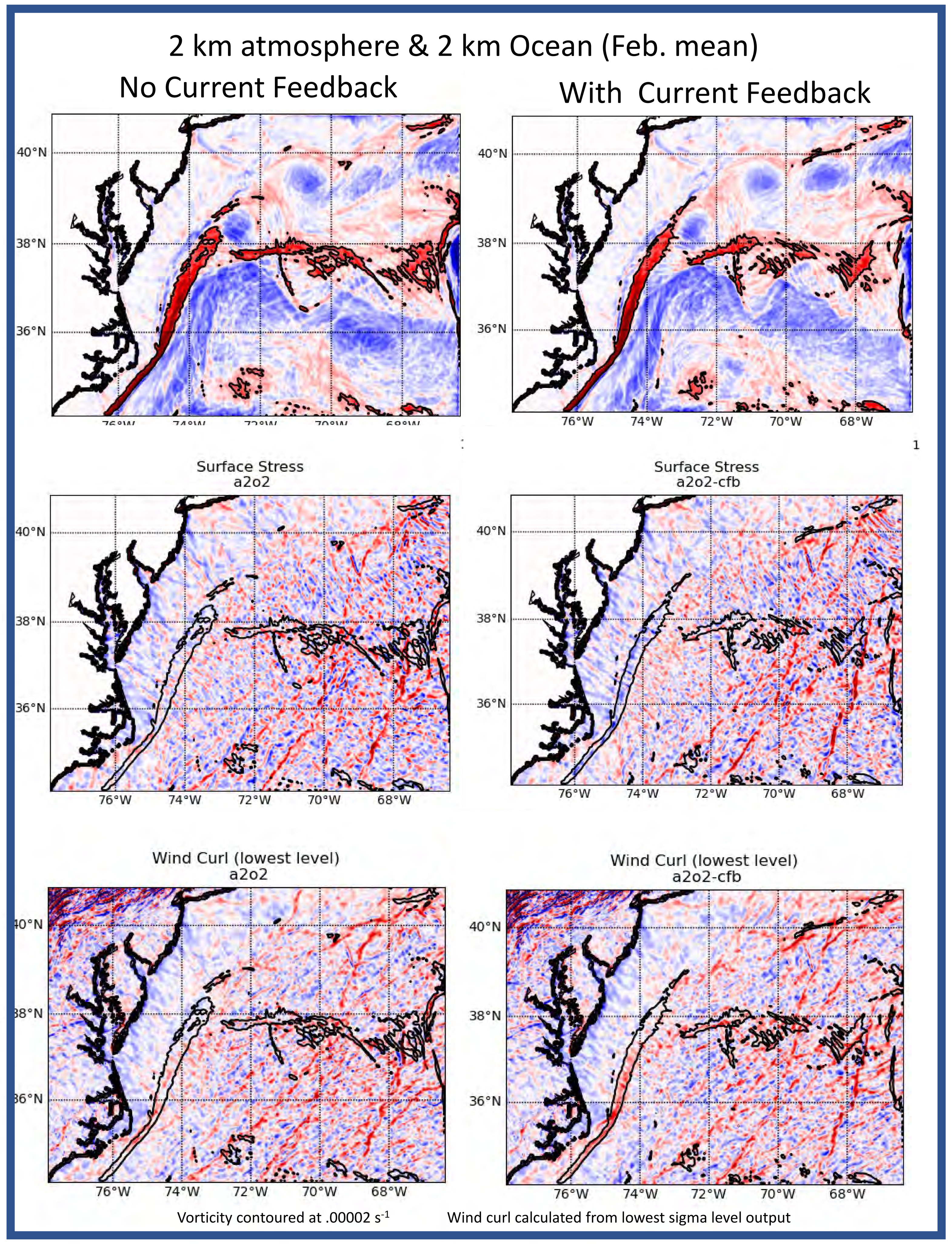
In very high-resolution models (2 km grid spacing) with two fluids that are kinematically linked through surface stress, the two fluids can make physically important changes through feedback processes. Images from this model configuration without and with current feedback are shown in the upper left figure. The changes are much smaller in the same model with 6 km grid spacing, as shown in the upper right collection of images. One finding of our coupled modeling study is that the of stress pattern has minima and maxima at locations matching those of the gradient of the current in the cross-wind direction (as found by Lionel Renault). This suggests that local responses are greater than remote responses (again consistent with Renault's findings). Our prior work found remote responses to be due to high winds, but that remains to be tested with this model configuration.

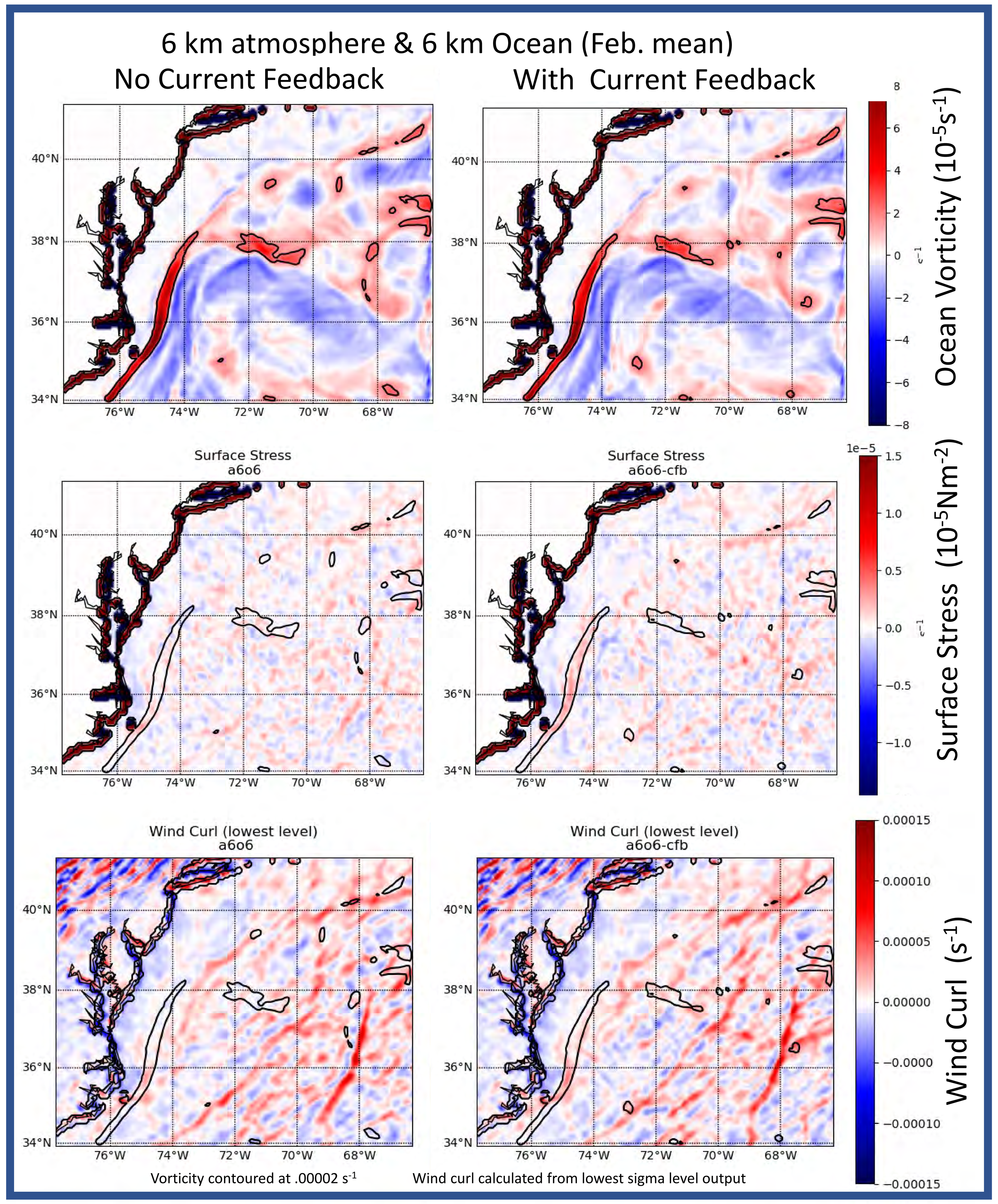
For both local and remote wind responses the model has organized changes in winds and currents that lead to curl and divergences of surface winds and currents that contribute to mixing in the boundary-layer and impact the free atmosphere (bottom figures), where the differences between runs with and without current feedback are greatest where there are strong current gradients (zero distance corresponds to the maximum gradient in the cross section through the Gulf Stream extension at 70°W). The green lines outline the area around these maxima.

One of the key differences is that there is clearly a response in wind curl in the 2 km model run, whereas this wind curl changes in the 6 km run are quite small, the currents impacting stress rather than wind. This change in wind patterns in the 2 km run complicates modeling current feedback, but also contributes to a much greater impact on vertical winds (not shown). Changes in winds imply changes in drag coefficients, which adds two terms to the elegant parameterization in Renault et al. (2016). These other dependencies are apparent a reduced fraction of variability explained directly by currents (not shown).

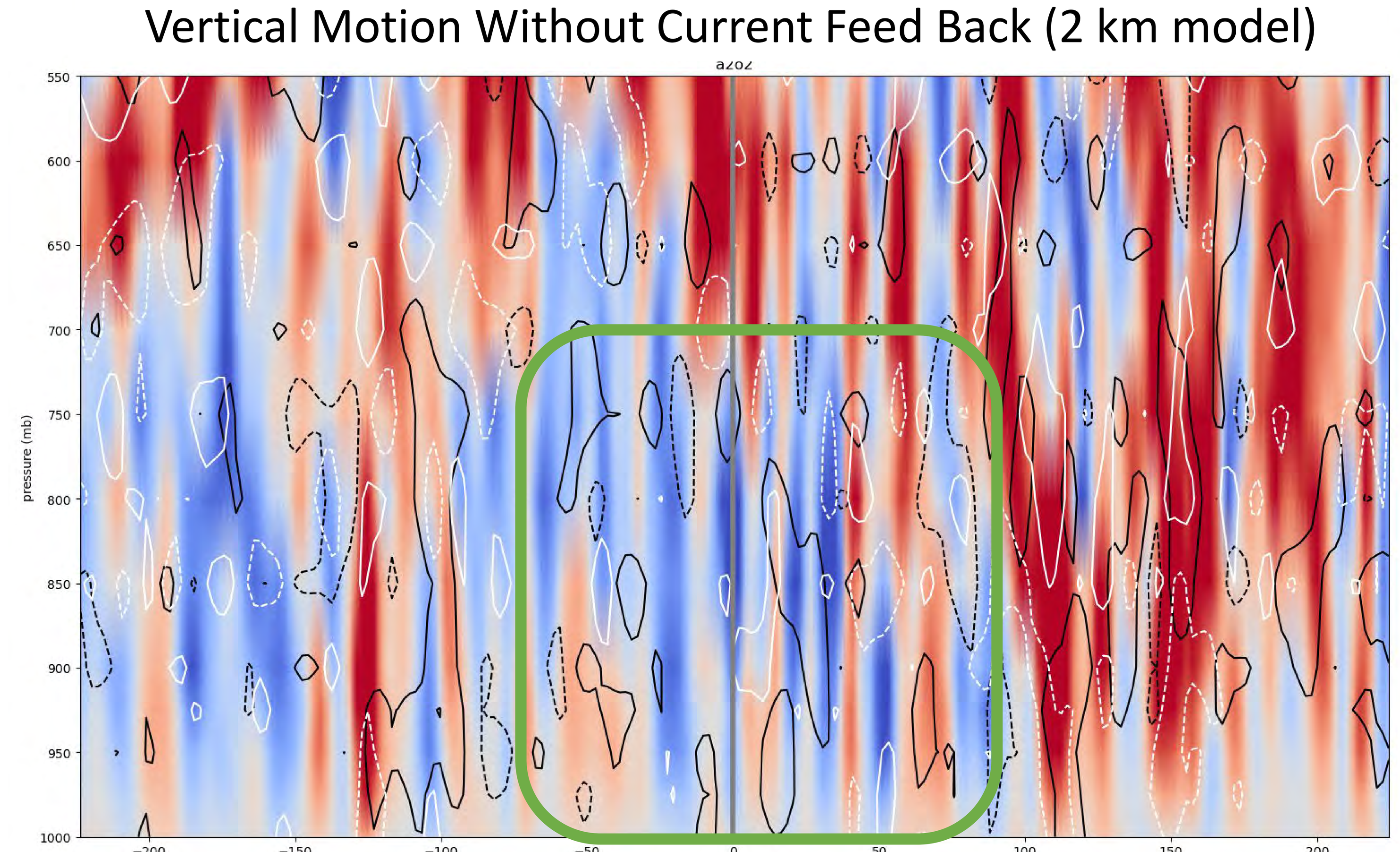
This modeling work (and that or Renault) suggests that we need observations of both wind and currents (and ideally temperatures) that can resolve the local impacts (e.g., wind curl on a 15 km scale). Following the Lindzen and Nigam model extended to high wind speeds, we might expect a length scale of responses scaling with wind speed divided by the Coriolis parameter, which mean at mid latitude that distant effects will only occur with high wind speeds. For such conditions, as well as in the tropics where the Coriolis parameter is much smaller, the decay of the remote response with distance from the front could also be evaluated with wind and stress curl measurements at on a 15 km scale). The ODYSEA mission, with 5 km currents and neutral equivalent winds, and sufficient coverage to capture higher wind speed events would be well suited investigate questions related to this coupling. Similarly, the Butterfly mission (measuring variables need to calculate turbulent heat fluxes) would be well suited to examine latent and sensible fluxes associated with current feedbacks.

We thank ONR and NASA PO (OVWST) for funding this study.

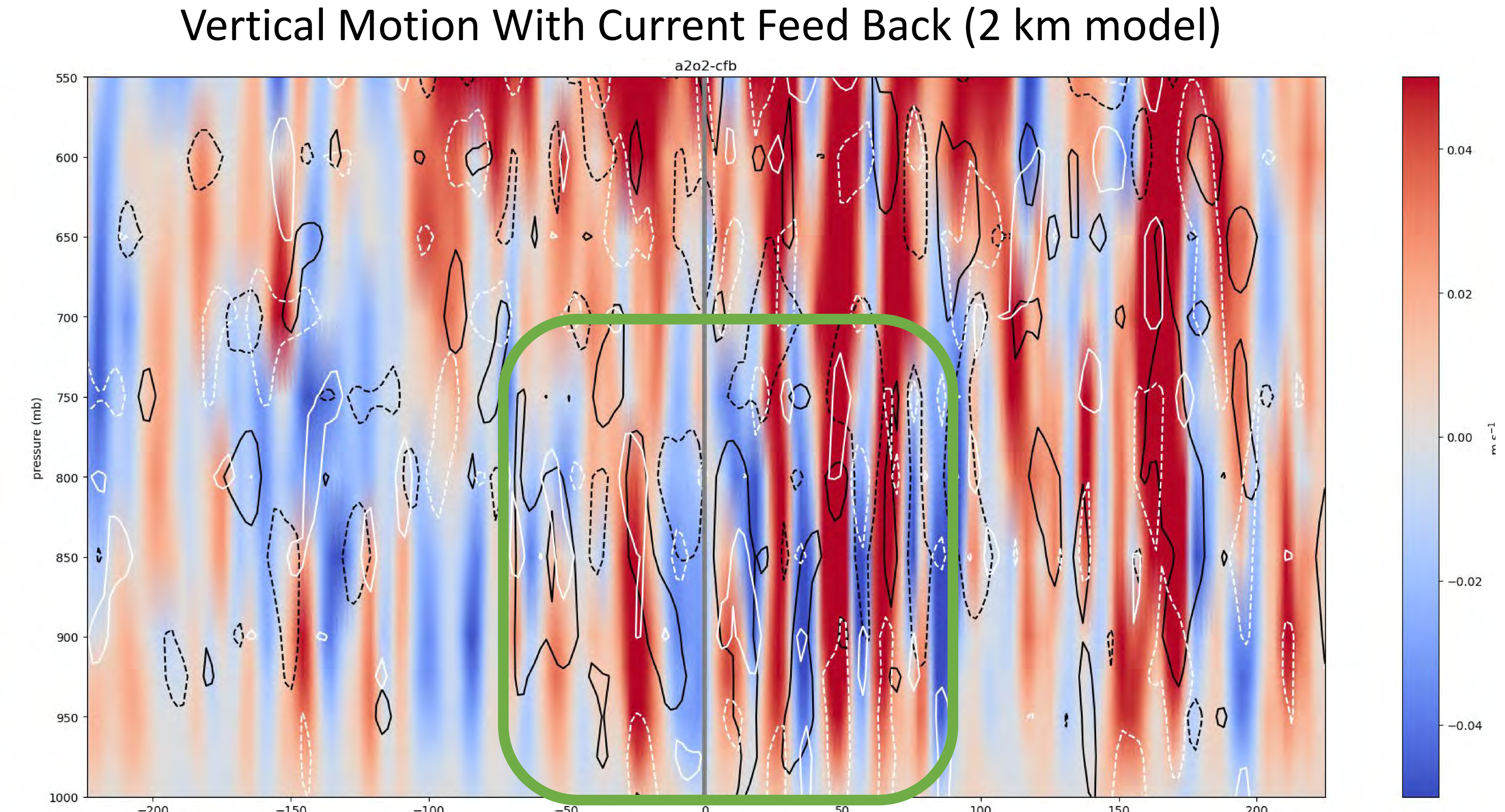




Vertical Motion Without Current Feed Back (2 km model)



Vertical Motion With Current Feed Back (2 km model)



Contours at +/- .00006
positive = solid contour; negative = dashed contour

Enhanced Red areas = rising motion
Corresponding to enhanced convergence (dashed white)
and positive vorticity (solid black)

Enhanced Blue areas = sinking motion
Corresponding to enhanced divergence (solid white)
and negative vorticity (dashed black)