# Processes Intensifying Air-Sea Mesoscale Interaction

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## 1. Motivation and objectives

### Motivation

A model with two-way coupling between an atmosphere, waves and ocean, produced answers to three questions that are very important to the future of earth systems modeling:

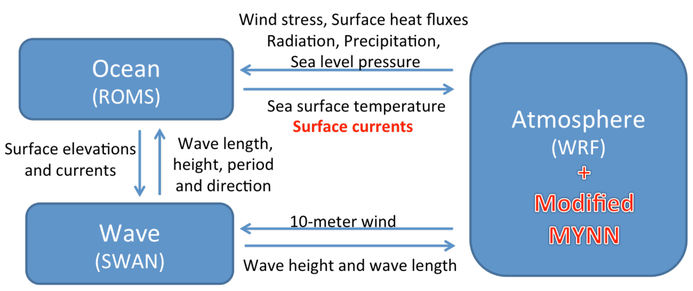
- Does the (modeled) atmosphere respond to small spatial scale ocean surface variability (stratification, waves and currents)? Yes!
- Does the ocean respond to these changes (if any) in the atmosphere? Yes!
- Does resolution matter? Yes!

The model was highly sensitive to the physics considered in the parameterization of surface stress: dependencies on surface current and sea state.

### Objective

- Describe the key physical processes making the coupled model that considers surface currents and waves different from the model with surface fluxes that are independent of surface currents and waves.

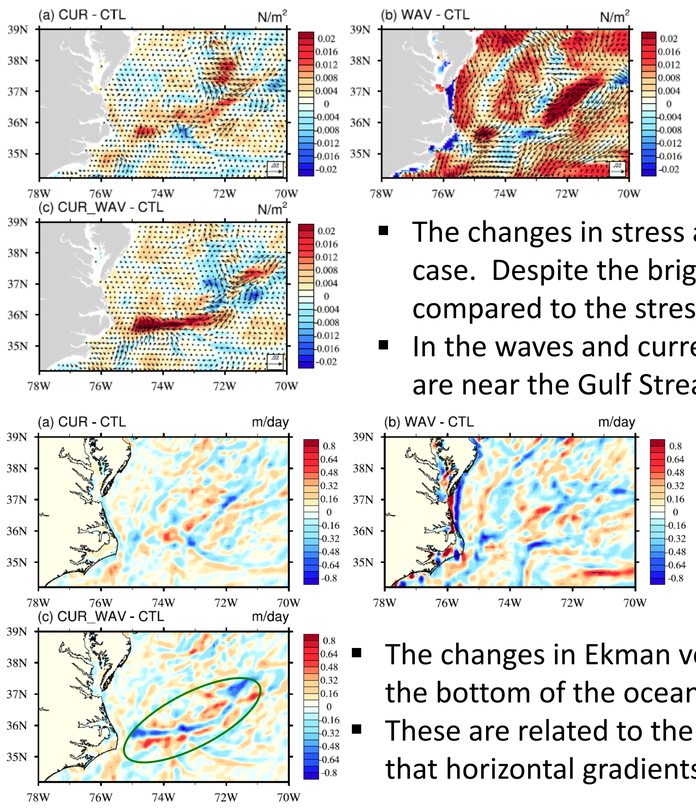
## 2. Experimental Design




| Experiments | Roughness length formula | Wind input |
|---|---|---|
| **CTL** | COARE 3.0 | $\overrightarrow{U_{10}}$ |
| **CUR** | COARE 3.0 | $\overrightarrow{U_{10}} - \overrightarrow{U_{CUR}}$ |
| **WAV** | Taylor and Yelland | $\overrightarrow{U_{10}}$ |
| **CUR_WAV** | Taylor and Yelland | $\overrightarrow{U_{10}} - \overrightarrow{U_{CUR}}$ |

- Atmospheric, ocean and wave models are synchronized every 10 minutes to exchange data fields through the Model Coupling Toolkit (MCT) in the COAWST model.
- Four one-month (October 2012) simulations are performed to investigate the impact of currents and waves on MABL.
- The key changes appear to be tied to the horizontal gradient in stress, rather than the magnitude of stress.

## 3. Impacts on the wind stress and Its curl



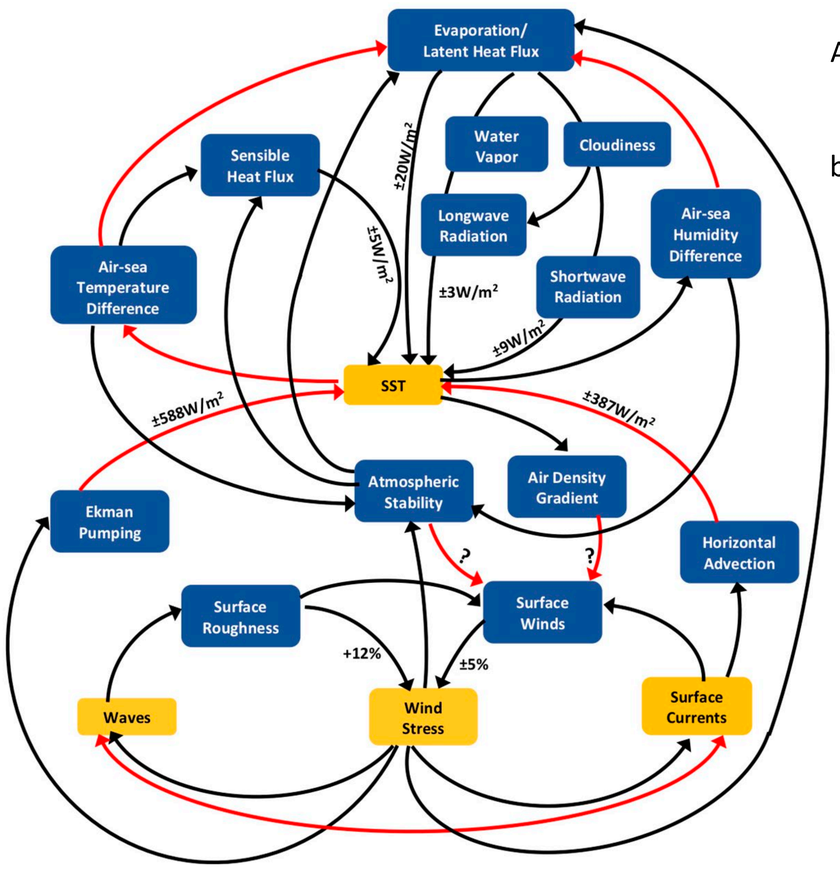

### Wind Stress

- The changes in stress are shown relative to the control case. Despite the bright colors, these are small compared to the stresses in the control case
- In the waves and currents case, larger changes in stress are near the Gulf Stream

### Ekman pumping vertical velocity

- The changes in Ekman vertical velocity, the speed at the bottom of the ocean's mixed layer are substantial.
- These are related to the curl of the stress, indicating that horizontal gradients are important.

## 4. Feedback Mechanism

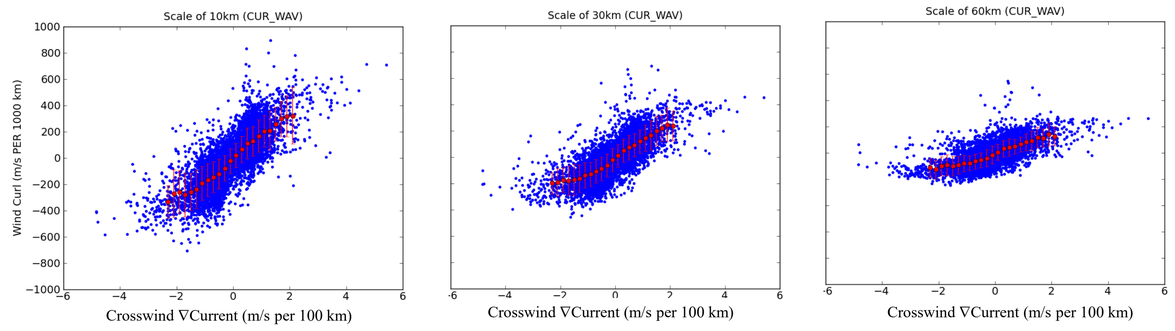



All numbers are median values of 30-day averaged differences between CUR_WAV and CTL simulations over the Gulf Stream

- These changes over the Gulf Stream are quite substantial in both the atmosphere and the ocean. But they are very different from WAVE or CURRENT models runs.
- The changes in wind, temperatures, and air-sea fluxes seem to be closely linked to the curl of the stress, which is highly dependent on how stress is parameterized.
- Therefore it is important be better understand this parameterization and the related impacts on the ocean and atmosphere

## 5. Processes That Intensify Air-Sea Interaction

- Since the results appear to be sensitive to the **curl of the stress**, this seems like an obvious choice for validation. However, this led us to the conclusion related to the third bullet point under motivation.




- We calculated the curl from model data for three resolutions using a Greens function (line integral) approach: 10 km (three grid cell width), 30 km and 60km.
  - The resulting sensitivities to the gradient in the surface current were dramatically altered by this resolution.
  - At these high resolutions, Ekman motion (horizontal and vertical is greatly enhanced across current gradients, changing the depth of the mixed layer and the temperature budget for that layer, changing the SST gradients and atmospheric stratification.
  - For this case study, the changed pattern of surface stress and currents partially compensated for the current-based reduction in eddy kinetic energy.
- The atmospheric changes in wind speed energy fluxes (radiative and turbulent) are also influenced by the change in wind and moisture content of the boundary-layer.




- These probability distribution functions of six-hourly differences in $U_{10}$ due to currents (black), boundary-layer stability (red), and surface roughness (blue), for the CUR_WAV minus WAV experiments.
  - The statistics are for strong-current (>1m/s) regions
  - Wind changes associated with negative changes in current are indicated as dashed lines.
  - Wind changes associated with positive changes in current are indicated as solid lines.
- Currents and stability largely counter each other for changes in wind, but not changes in turbulent fluxes.
- The atmospheric changes in wind speed energy fluxes (radiative and turbulent) are also influenced by the change in wind and moisture content of the boundary-layer.
  - Changes in SST and winds change the turbulent fluxes of heat and moisture, changing the stratification of the boundary-layer, and the water vapor content in this layer.
  - Increases in the water vapor content are linked to decreases in the shortwave radiation that are not compensated by changes to the long-wave radiation.
  - The longer-term impacts on weather and climate remain to be determined.

## 6. Conclusions

Ocean surface currents have a much greater effect on the coupled ocean, wave and atmosphere system when resolved at fine mesoscales than at larger mesoscales. These impacts substantially alter the surface fluxes, gradients of many variables, and the surface energy budget.

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