Testing Current Feedback in Models

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Outline

- Motivation & Goals
- Methodology
  - Modeling design
  - Stress parameterization differences
- Impacts on the atmospheric boundary-layer (and above)
  - Seasonal Average impacts
  - Interaction with Atmospheric Fronts
- Surface Impacts Centered on the Gulf Stream Extension (without atmospheric fronts)
- Comparison of model surface spectra to observed spectra – lessons learned

Motivation & Goals

- Motivation
  - The impacts of current feedback on the atmosphere, particularly above the surface (10 meters).
    - This is made more complicated because including/excluding current coupling modifies the position of currents and hence modifies thermal gradients and thermal feedback processes.
  - Prior work shows dependence of the surface (10 meter) response to how the stress is parameterized (e.g., dependence on sea state).
    - There is a lot of controversy regarding how sea state influences stress.

- Goals
  - Design a modeling experiment to isolate the response(s) to current feedback.
  - Examine how these model results depend on the parameterization of how stress depends on sea state.
  - Identify the related processes in the atmospheric boundary-layer (work in progress)
  - Make a reality check using observations.

Methodology: Modeling Design

- Our prior work suffered from difficult interpretation because the different stress parameterizations caused currents to be in different locations
  - Modifying thermal feedbacks
- To isolate the impact(s) of current feedback, we decided it was necessary to keep the ocean surface the same when comparing runs with and without current feedback
  - We first run the coupled ocean/atmosphere (and sometimes wave) model with current feedback
  - We then run the atmospheric model without current feedback. The ocean surface output from the coupled run as a boundary condition.
- This approach underestimates some very important impacts of current feedback, but does allow us to isolate the direct impact on the atmosphere.
- We use this approach for each stress parameterization that we consider.
  - Resulting in four pairs of coupled and uncoupled model runs

- Each are run for a winter season.

Methodology: Stress Parameterizations (lite version)

- We use four stress parameterizations, with different dependencies on surface waves.

Default WRF & COAMPS; Smith (1988)

- Sum of roughness lengths from a smooth surface and gravity waves
- ‘Constant’ scalar sea state

Bourassa (2006) / Blair et al. (2023)

- RMS sum of roughness lengths from a smooth surface, capillary waves, and gravity waves
- Directional sea state via changes to wind shear

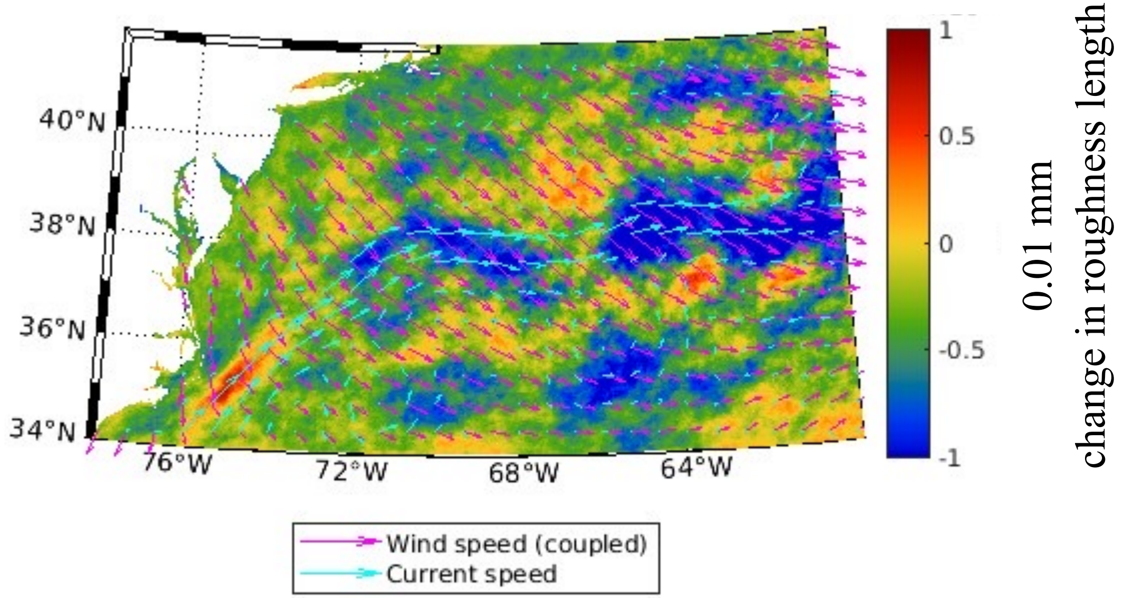
Taylor and Yelland (2001)

- Roughness length from Gravity waves
- Scalar sea state (fit to data)

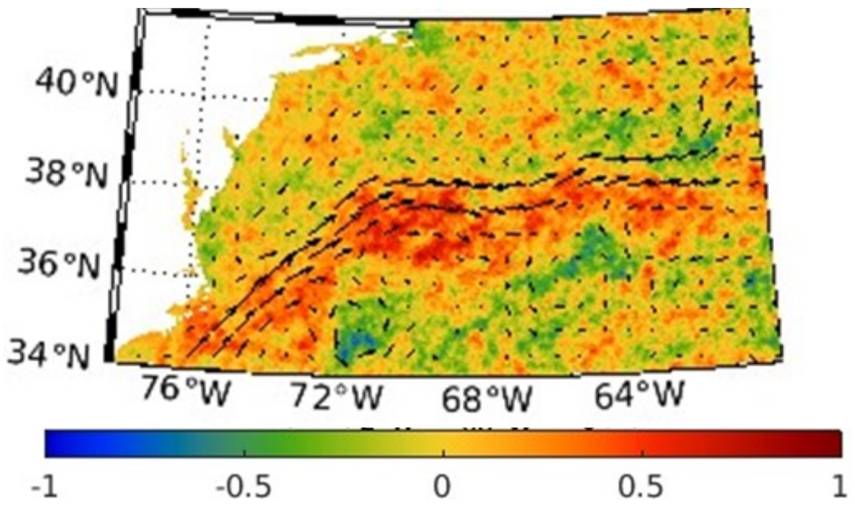
Porchetta et al (2019)

- Roughness length from Gravity waves
- Considers directional sea state (fit to data)

Seasonal Average Impacts for Taylor and Yelland Parameterization



- Average differences in roughness length
  - Taylor and Yelland minus default
- Reduced roughness (and drag) when surface relative winds are reduced by currents
- Larger where wind shear is increased



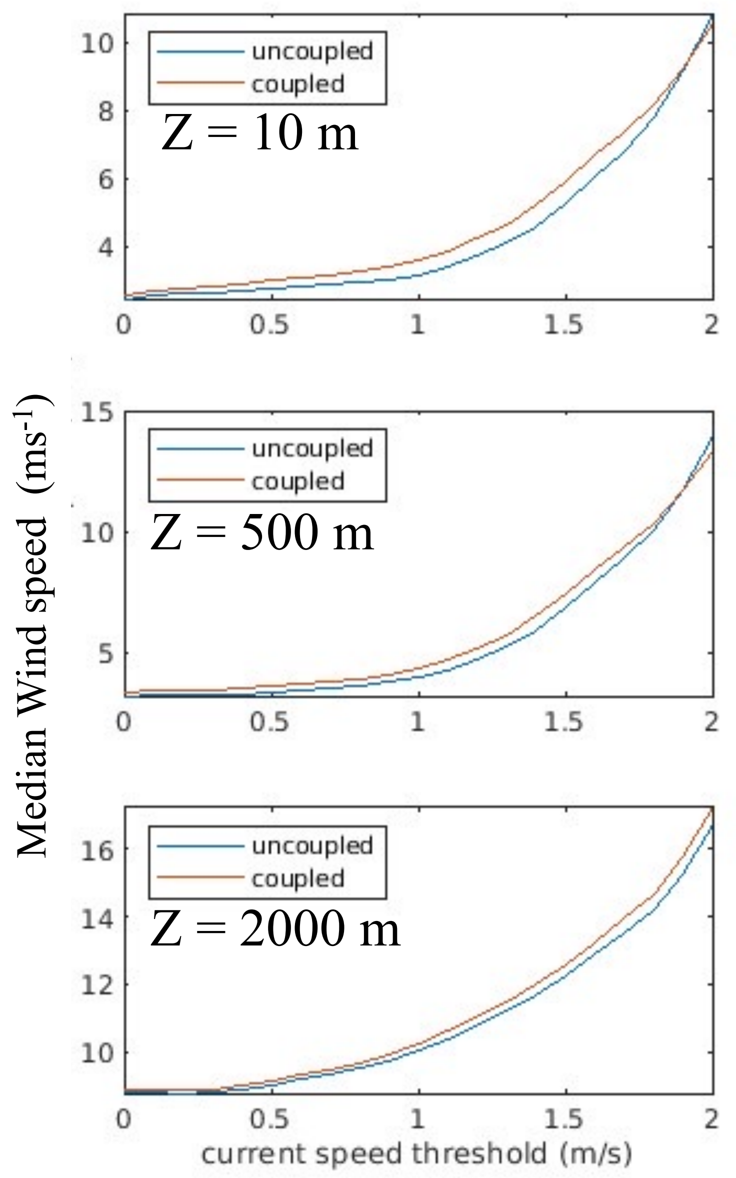
Corresponding Increase in Wind Speed (ms^{-1})

- Average differences in Wind Speed
  - Taylor and Yelland minus default
- Faster winds over stronger currents
  - Regardless of the change in roughness (and the drag coefficient)
- This change is driven by the surface boundary match rather than fluxes

Work led by Jiahua Zhou

Average Impact on Fronts

- Isolates the both model runs to conditions with strong atmospheric cold fronts
  - Shows median wind speeds (ms^{-1}) for runs without current feedback (blue, lower line) and with current feedback (red, higher line) for 3 heights:
    - 10 m (top)
    - 500 m (middle)
    - 2000 m (bottom)
  - The changes extend through and above the atmospheric boundary layer.
  - Shown as a function of the underlying surface current
    - The speed of the surface current is important!
- However, these cases are challenging to work with because the fronts are in different places



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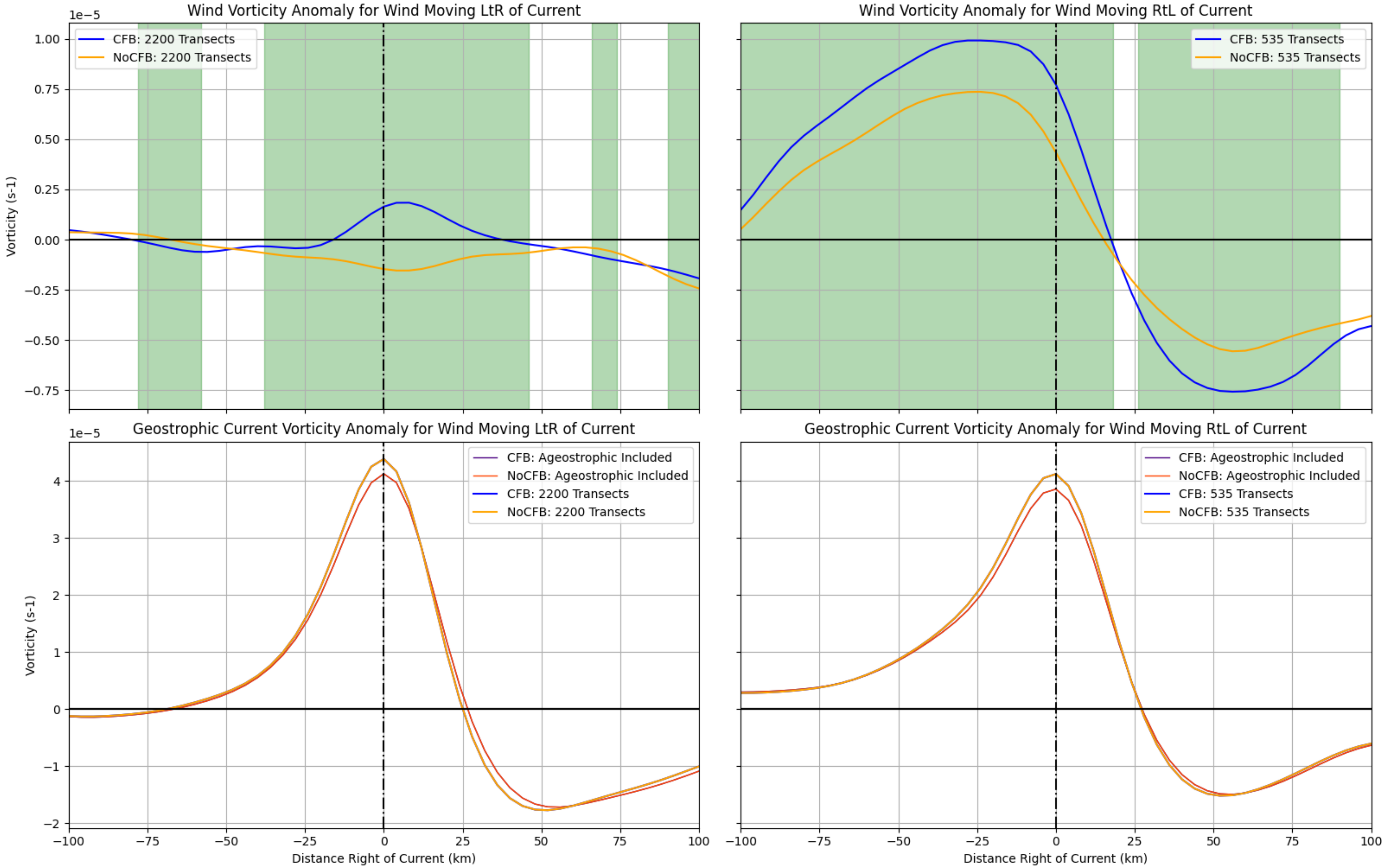
Vorticity on the Gulf Stream Extension (without atmospheric fronts)

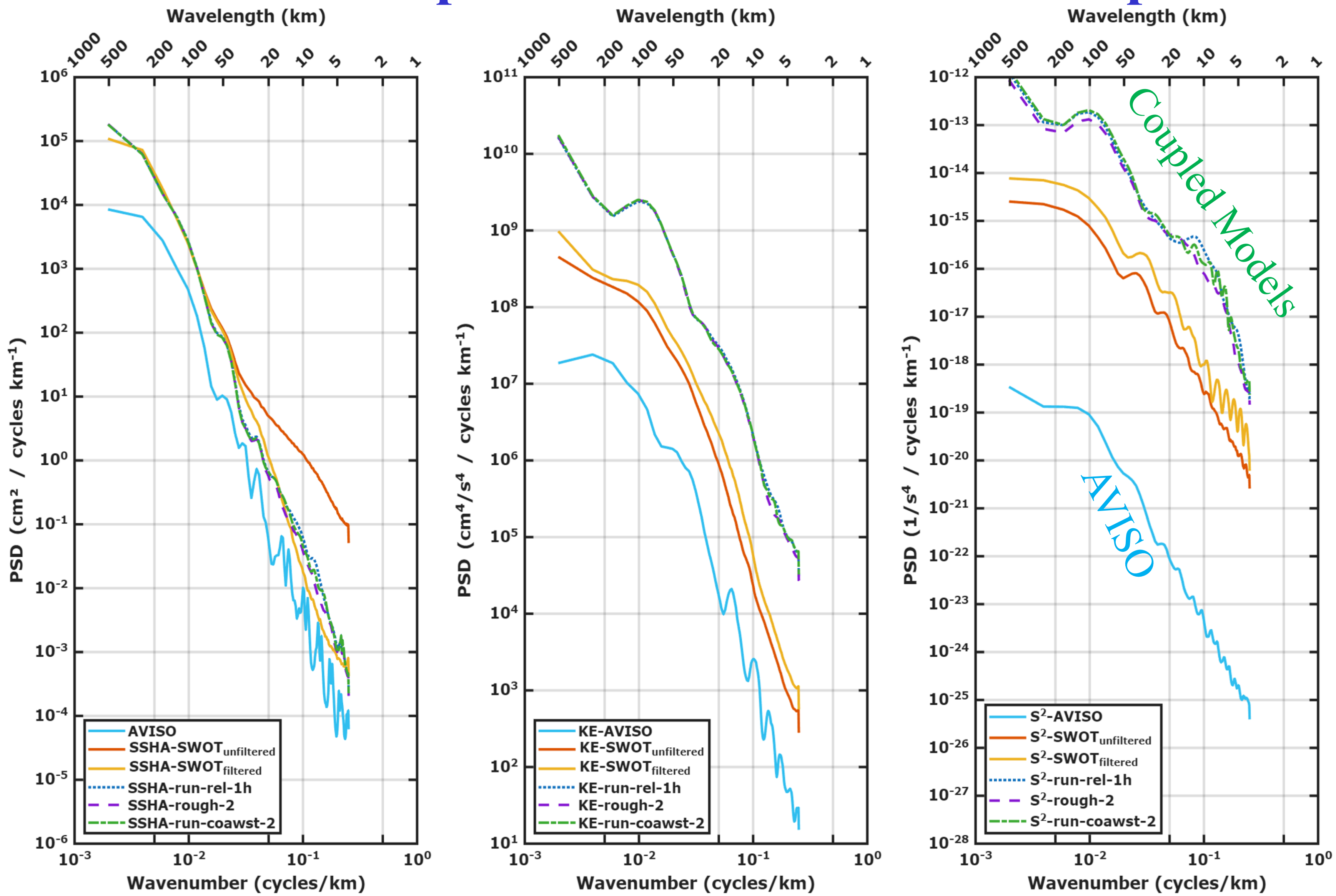
- Bottom: Current vorticity.
- There is little dependence on CFB and stress parameterization.
  - The vertical dashed line indicates the vorticity maximum
- Top: atmospheric vorticity with and without CFB
  - Left: winds move from the right of the currents to the left
  - Right: winds move from the left of the currents to the right



Work led by Kamran Choudhury

Comparison of Means of Modelled Spectra to Means of SWOT Spectra

- Comparisons of spectra for
  - SSH anomalies (left)
  - Geostrophic Current (middle)
  - Strain (right)
- The colors represent
  - AVISO
  - SWOT unfiltered
  - SWOT filtered
  - Coupled Models
- The results are similar for each model with CFB



Work led by Sthitapragya Ray

Comparison of Medians of Modelled Spectra to Medians of SWOT Spectra

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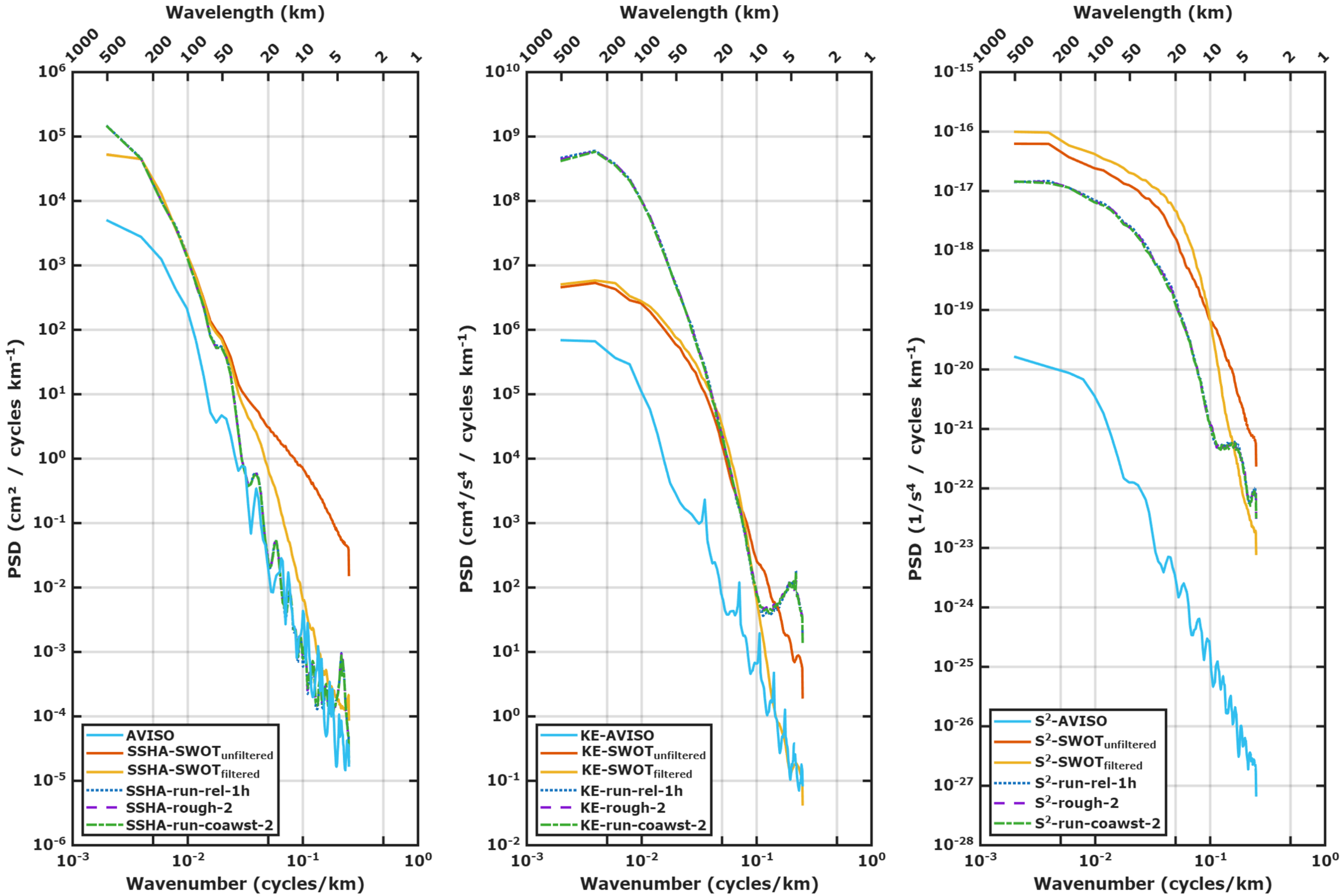

Work led by Sthitapragya Ray

Comparison of 90th percentile of Modelled Spectra to 90th p of SWOT Spectra

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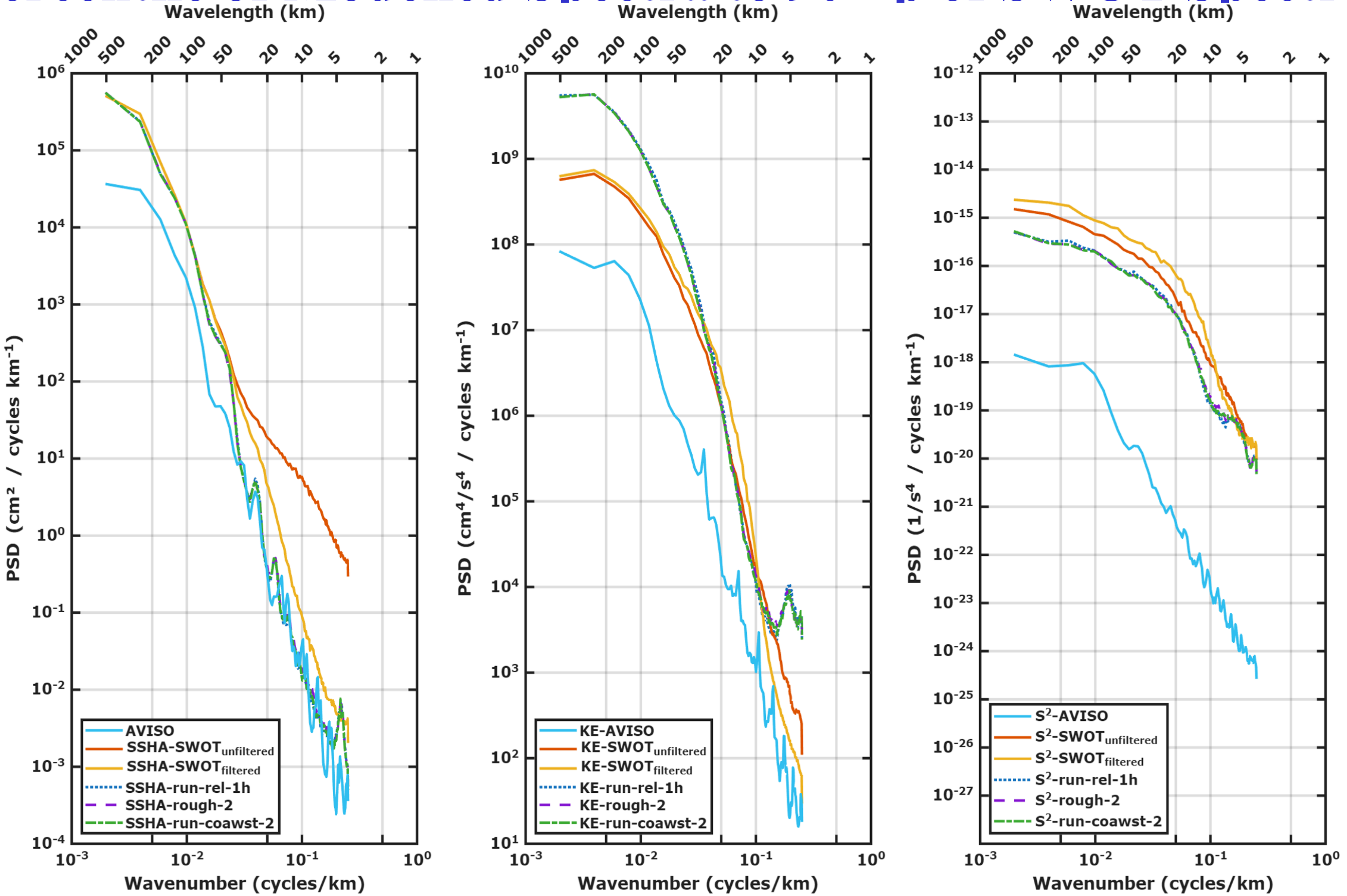
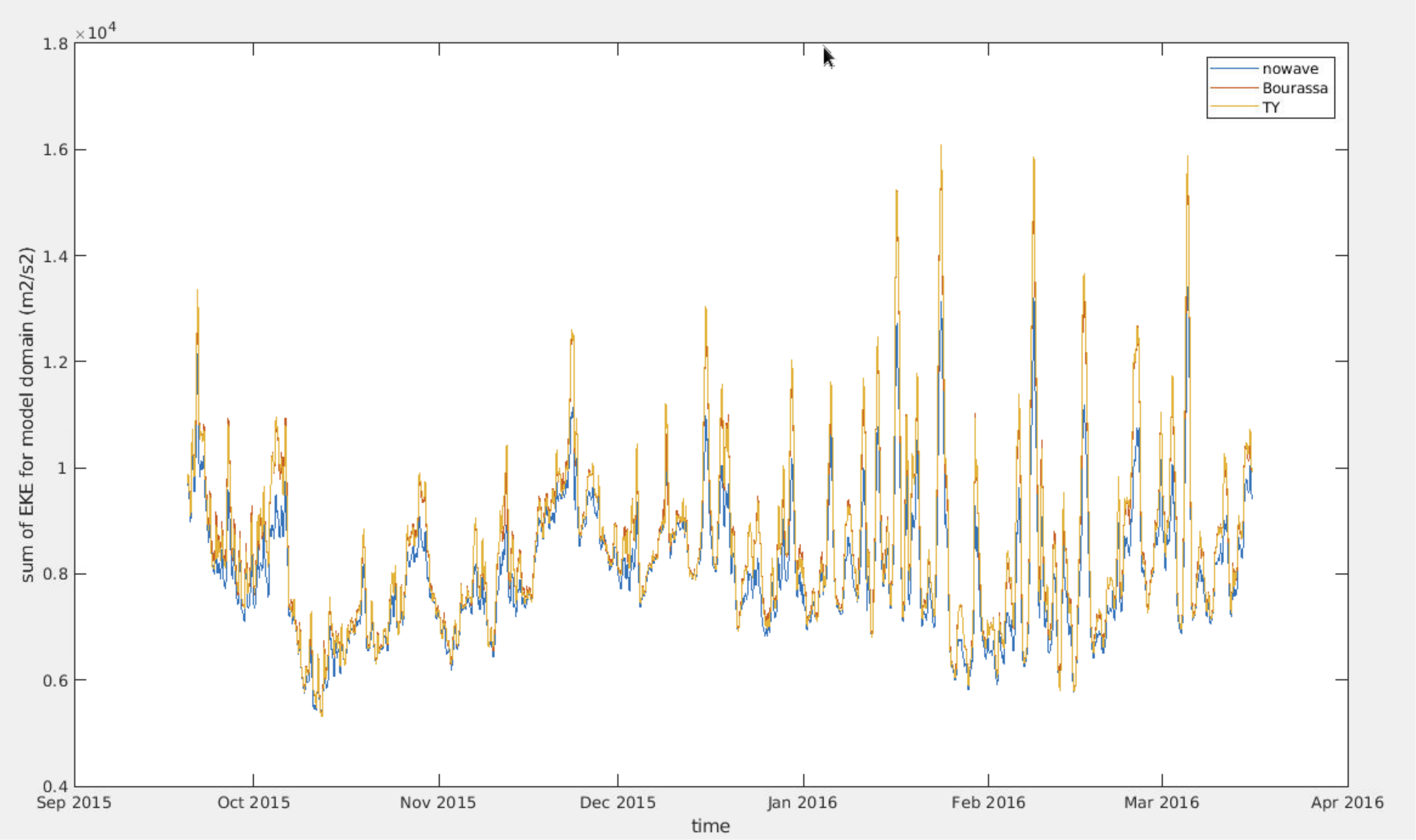


Work led by Sthitapragya Ray

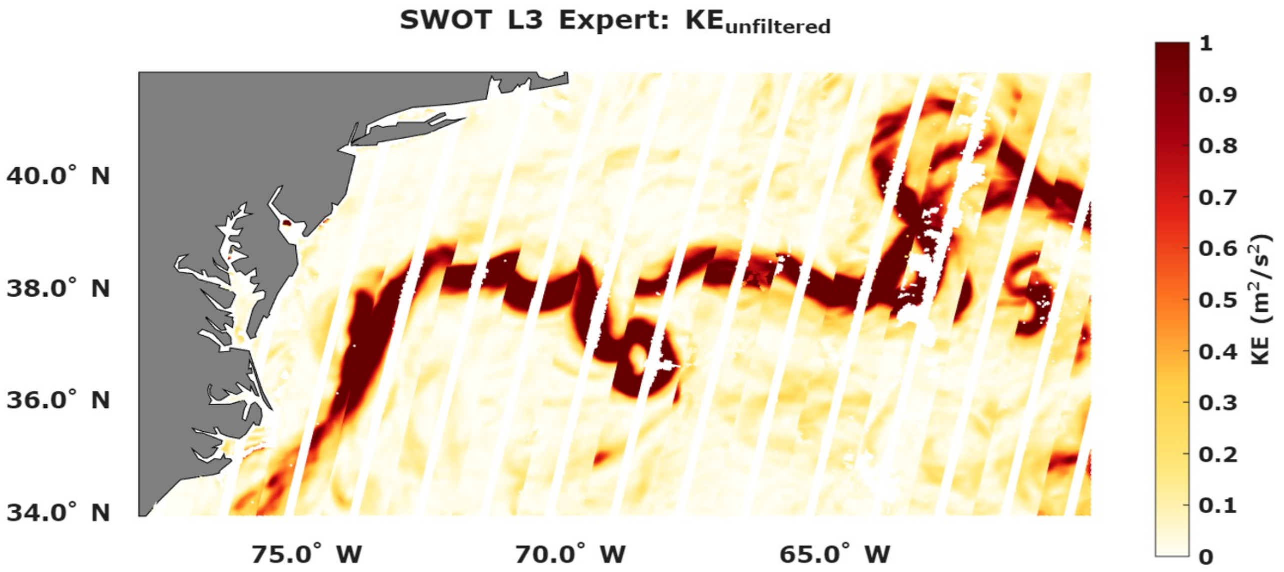
What to do next?

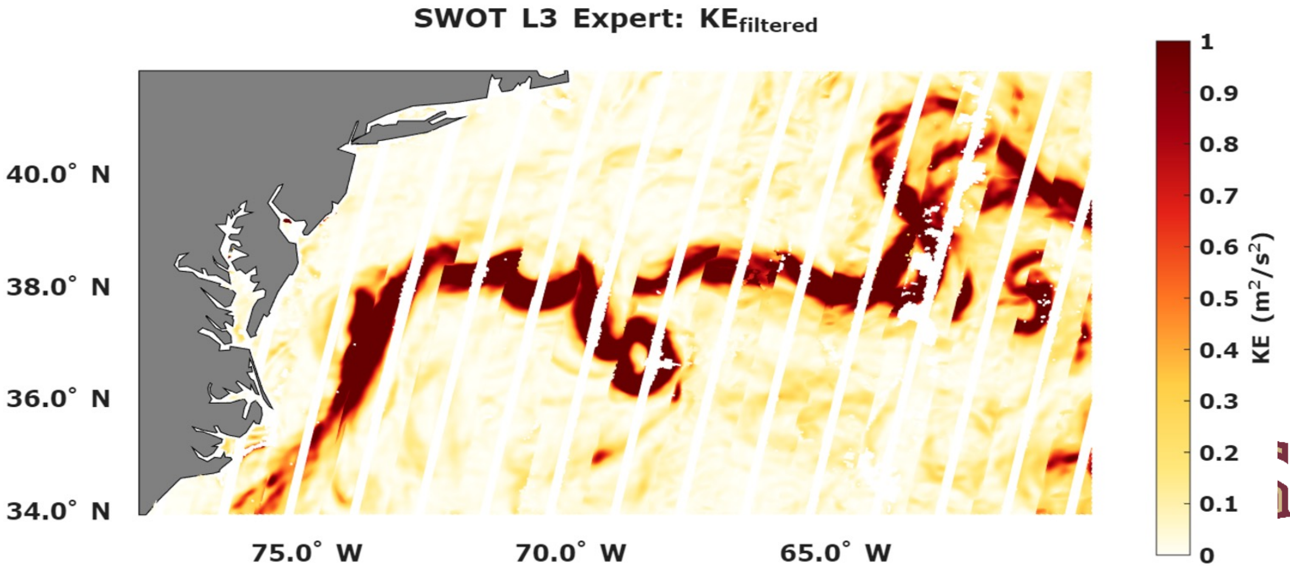
- We need a better diagnostic variable to assess the importance of the coupled models and stress parameterizations
- The Time Series of EKE is Clearly Different
- Something focused more on the spatial scale of interest should work better.



Questions?

•21-day SWOT Composite (Up pass only)





•21-day Composite of Synthetic SWOT