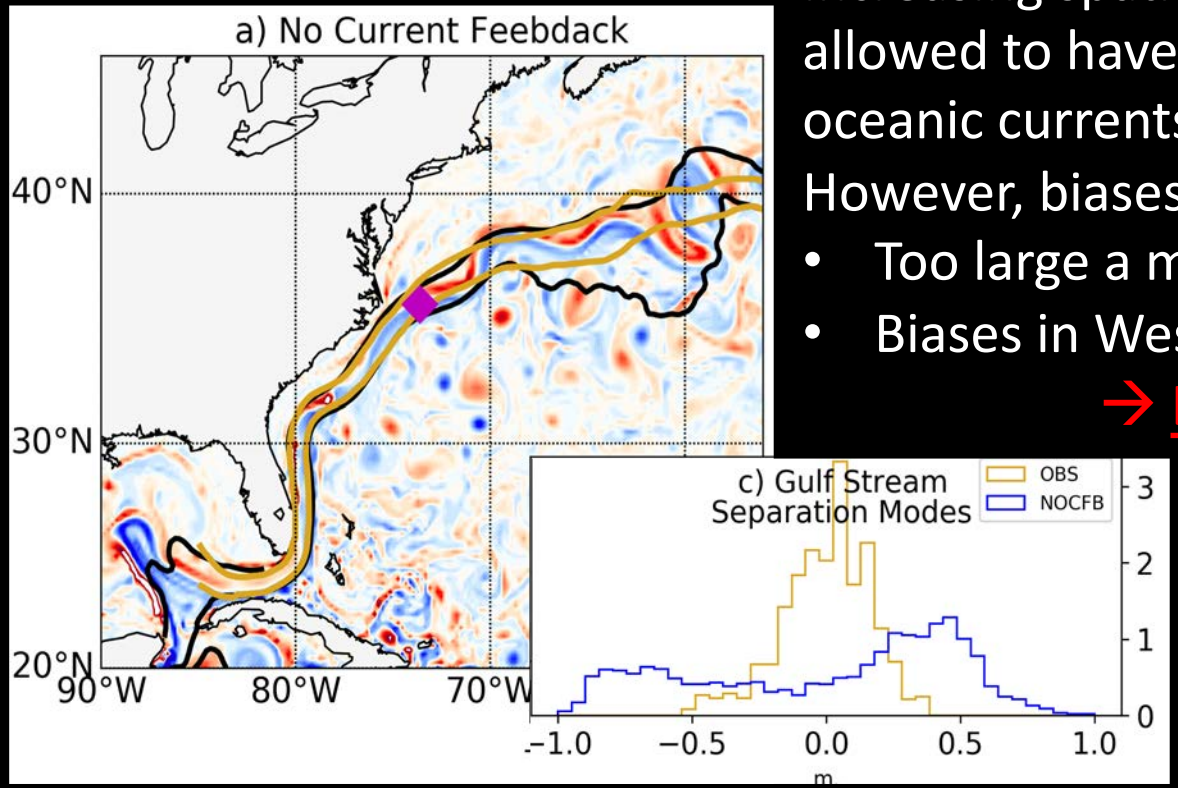
The Current Feedback to the Atmosphere: Implications for the Ocean Dynamics, Air-Sea Interactions, and How to Bes Force an Ocean Model

L. Renault, S. Masson, J.C. McWilliams

Motivations



Increasing spatial resolution of models allowed to have a much representation of oceanic currents.

However, biases persisted or appeared

- Too large a mesoscale activity
- Biases in Western Boundary Currents

→ Lack of sink of energy

- Diffusive advection scheme ?
- Forward cascade and submesoscale missing?
- **Lack of current feedback to the atmosphere (CFB)**

Current Feedback

In a coupled model, when estimating the surface stress:

$$U \equiv U_a - U_o$$

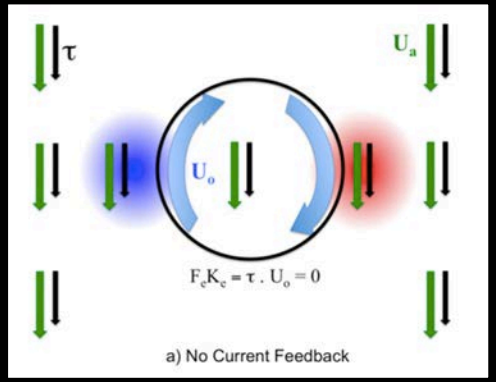
Bye1985,Rooth1992,Duhaut and Straub 2006; Dewar and Flierl 1987; Dawe and Thompson 2006; Hughes and Wilson 2008; Eden and Dietze 2009; Seo et al., 2015; Renault et al., 2016cd; Renault et al., 2017ab

"Mechanical Damping" or "Eddy Killing"

- Not only reduction of F_eK_e but negative F_eK_e (Deflection of energy ocean→ atmosphere)

- Partial re-energization by the atmospheric response

<u>→ need parameterization in a forced ocean model\]</u>



Renault et al., 2016c

Duhaut and Straub 2006; Dewar and Flierl 1987; Dawe and Thompson 2006; Hughes and Wilson 2008; Eden and Dietze 2009; Seo et al., 2016,2018,2019; Renault et al., 2016cd; Renault et al., 2017ab

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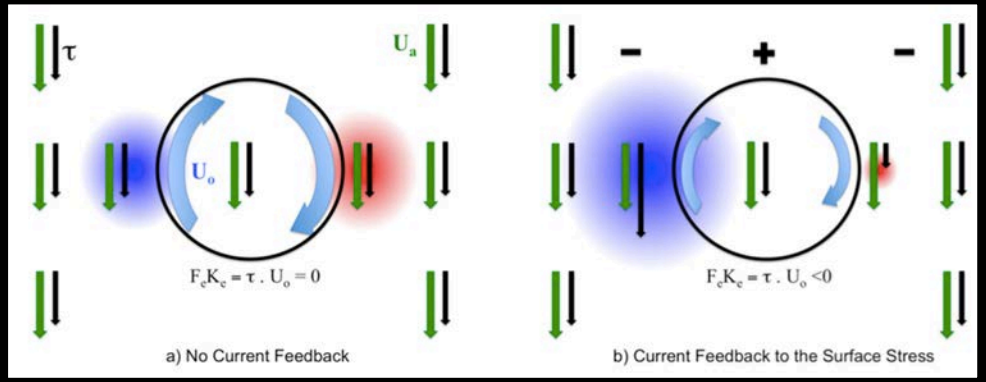

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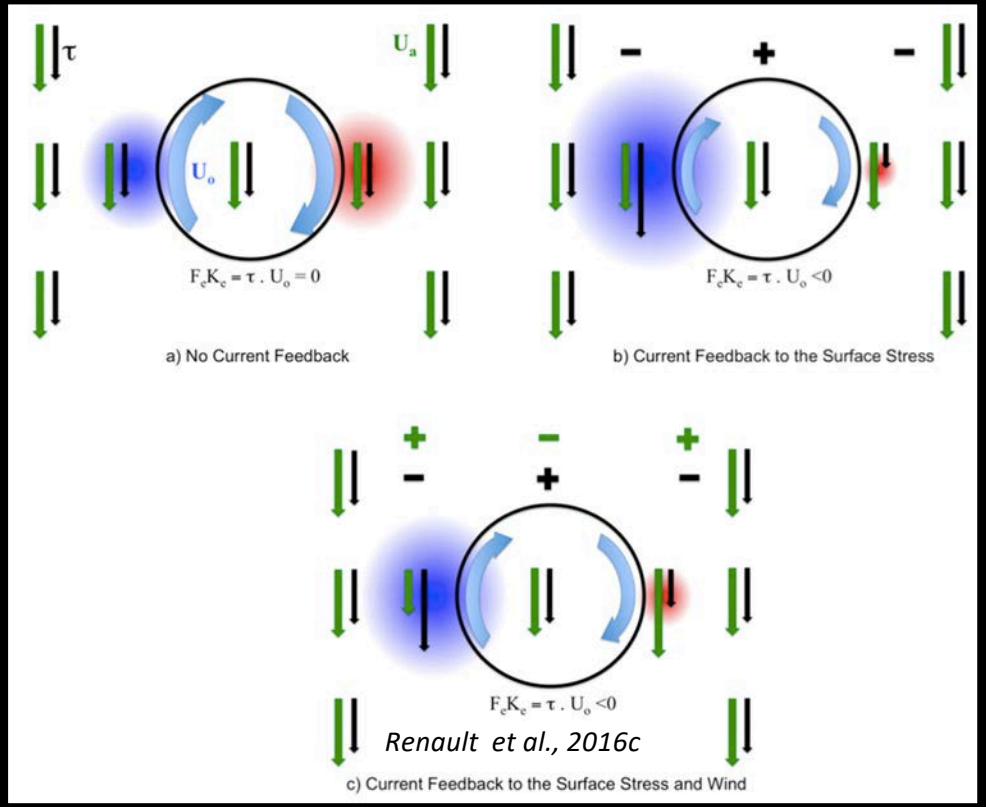

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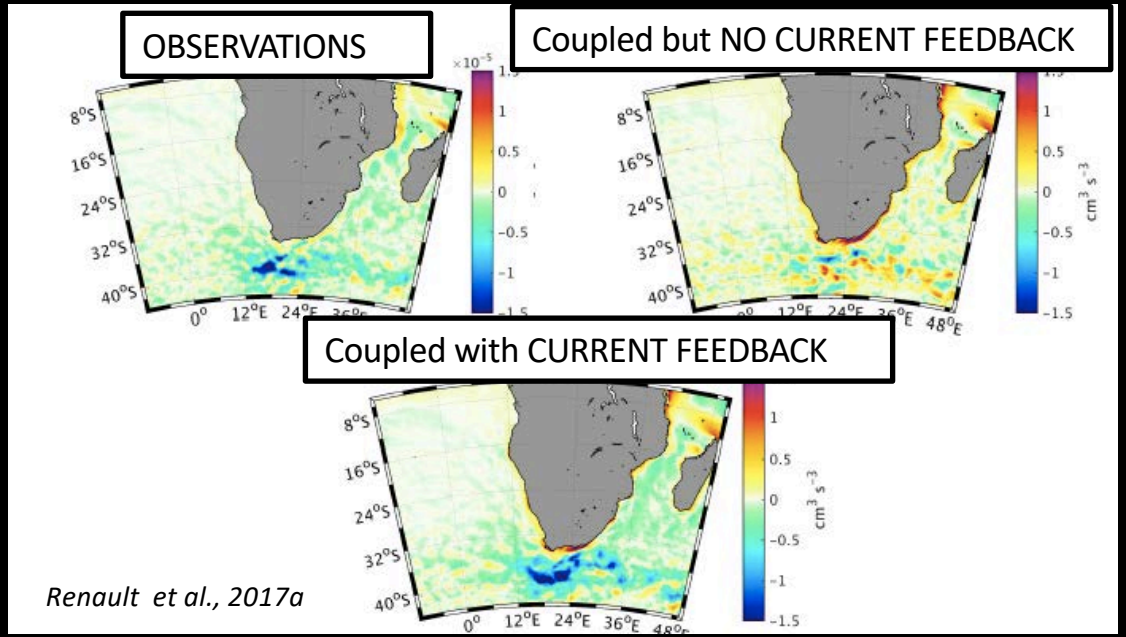
Transfer of Energy from Mesoscale Eddies to the Atmosphere

Main Effects:

- *Slow down of the mean circulation*
- *Sinks of Energy from Mesoscale Current to the Atmosphere*

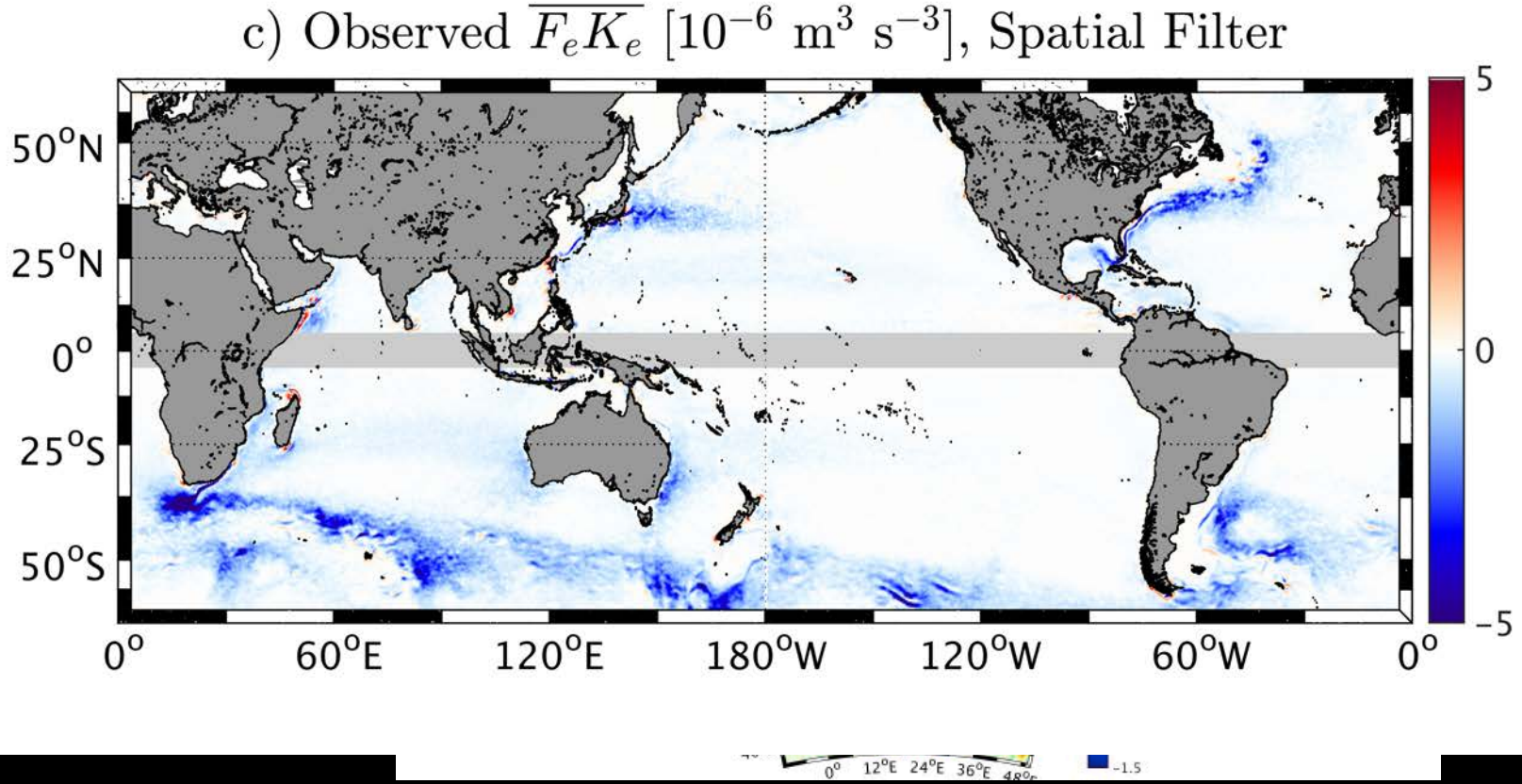
Mean Eddy Wind Work

Blue --> transfer from the ocean to the atmosphere



Current Feedback

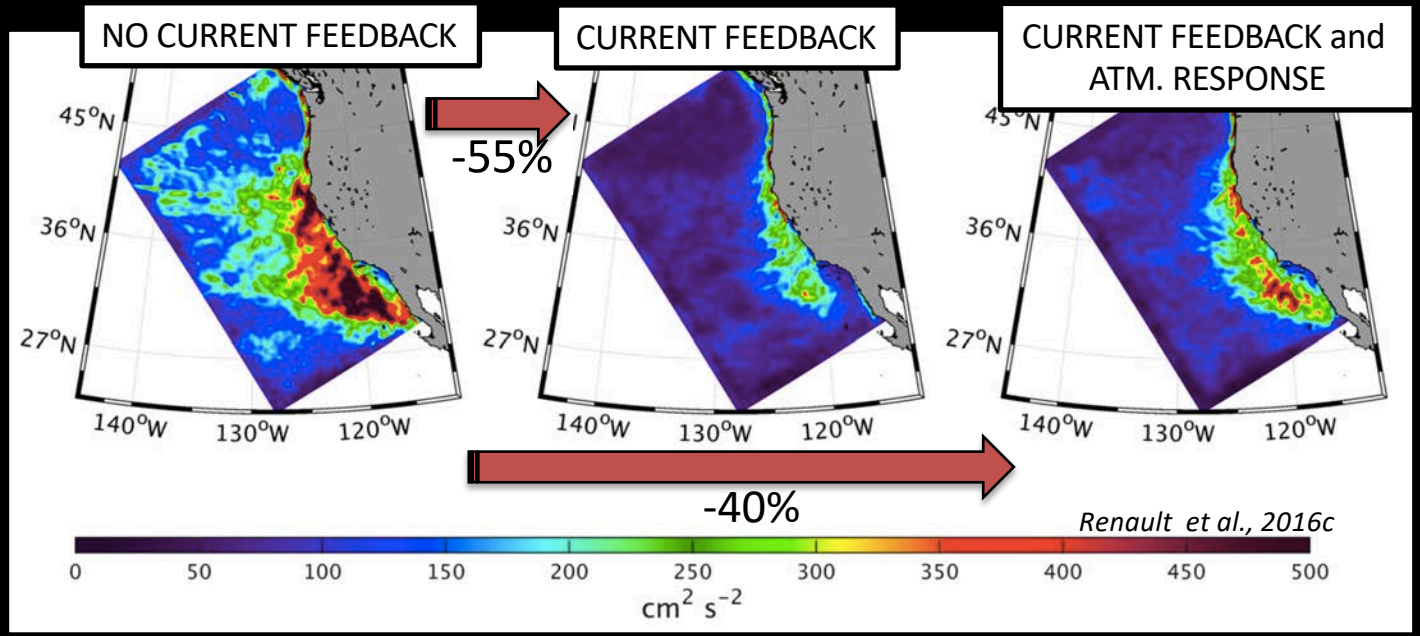
Sinks of Energy can be observed everywhere



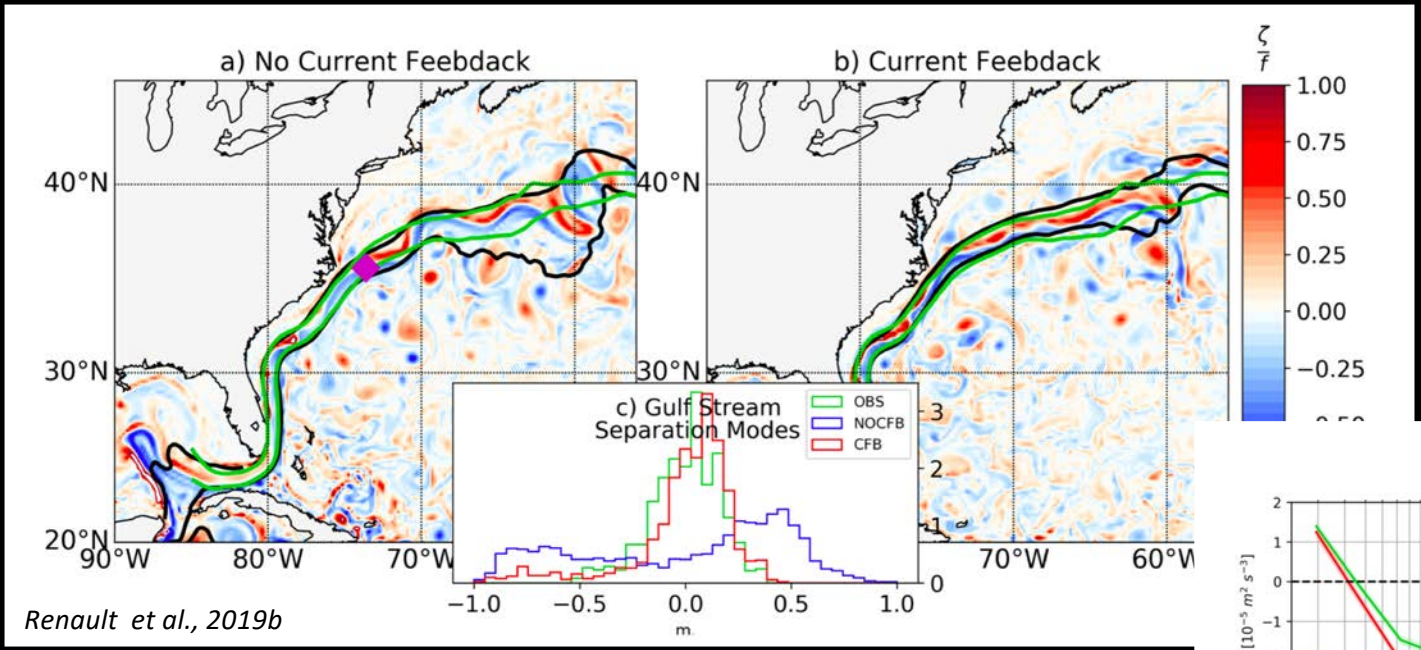
Current Feedback

Main Effects:

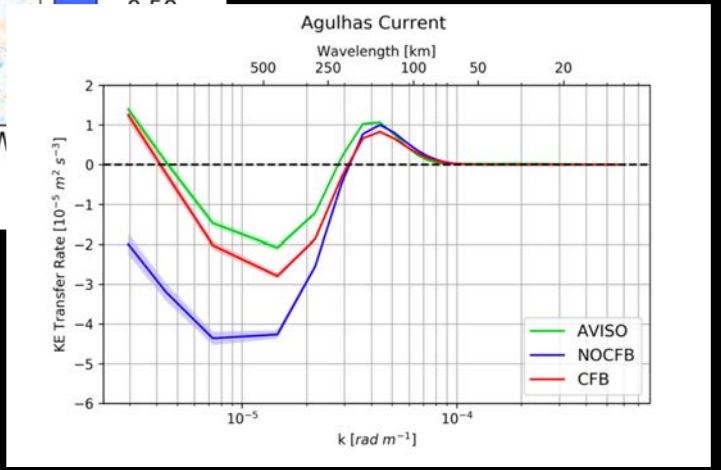
- *Slow down of the mean circulation*
- *Sinks of Energy from Mesoscale Current to the Atmosphere*
- *Dampening of the EKE*
- ***Wind Response induces a partial re-energization of the ocean !***



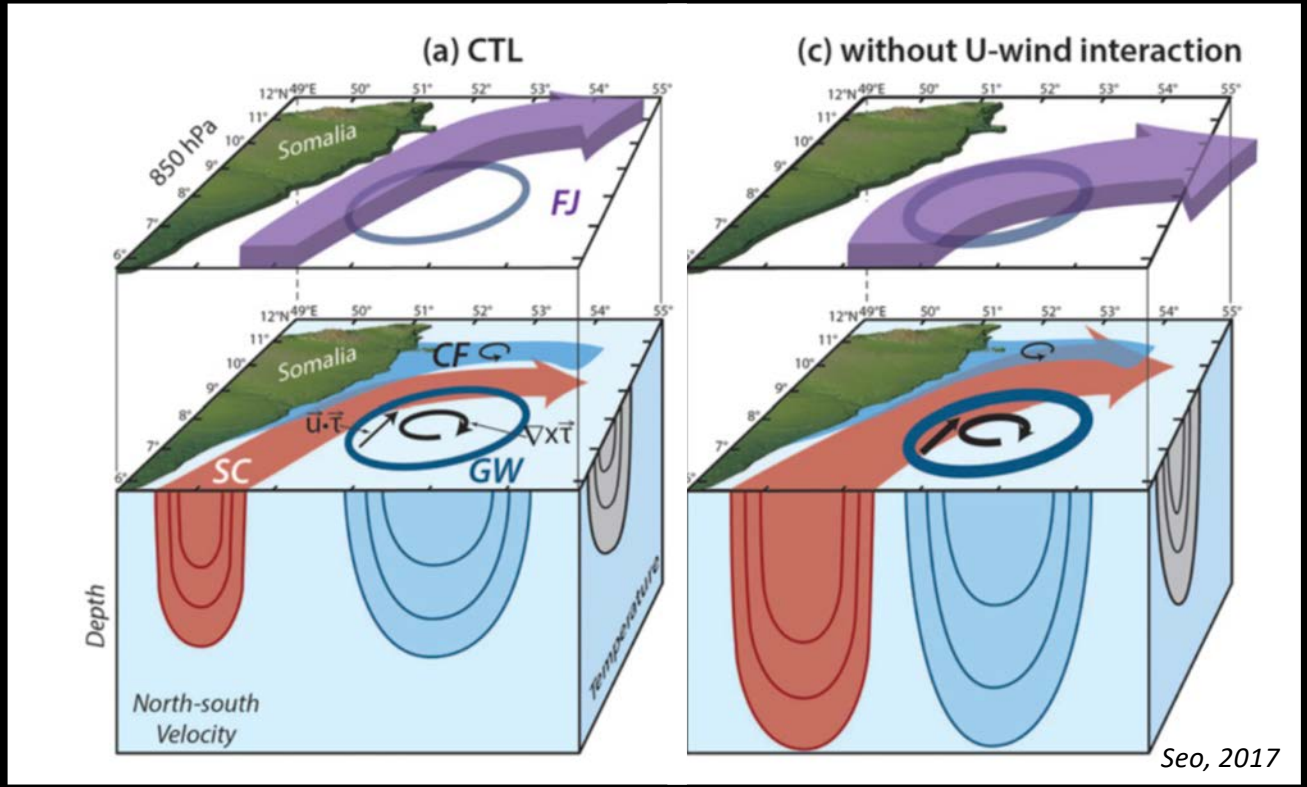
Partial Control of Western Boundary Current through a reduction of the inverse cascade of energy



Renault et al., 2019b



Large Impact on Arabian Sea



Seo, 2017

Uncoupled modeling approach is no longer suitable unless new formulations that better account for air-sea interactions are used.

Objectives

→ *How to best force an Ocean Model ?*

→ *Parameterize properly the Current Feedback in a Forced Ocean Model*

→ *Determine what variables are needed*

→ *Can we disentangle the Current Feedback from the Thermal Feedback ?*

The stress correction

$$\boldsymbol{\tau} = \boldsymbol{\tau}_a + s_\tau \boldsymbol{U_O}$$

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RESEARCH ARTICLE
10.1029/2019MS001715

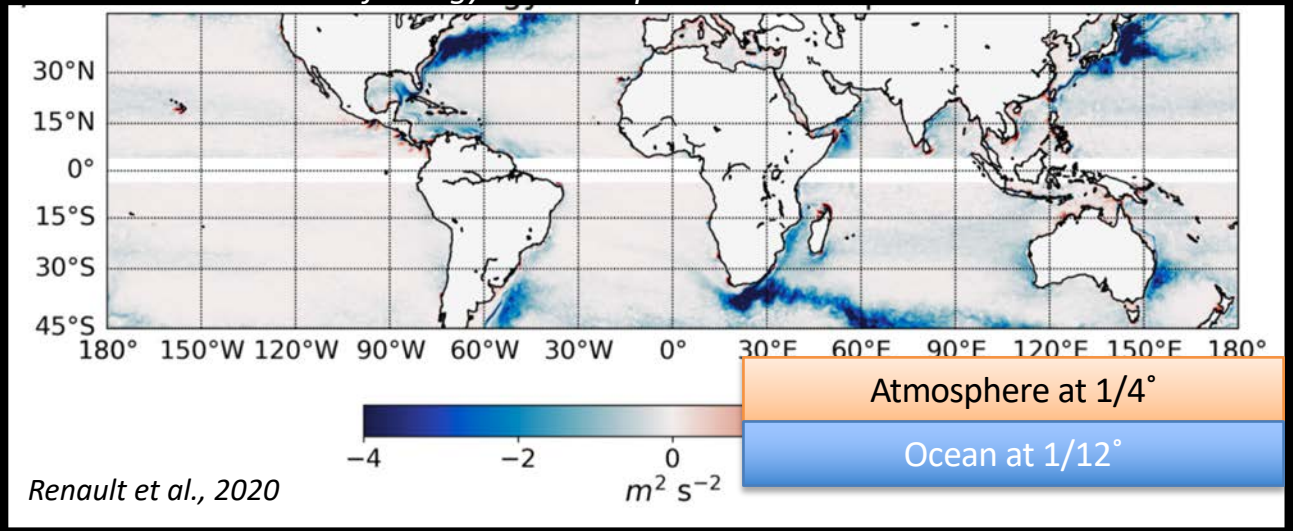
Recipes for How to Force Oceanic Model Dynamics

Lionel Renault[1,2], S. Masson[3], T. Arsouze[4], Gurvan Madec[3], and James C. McWilliams[2]

Coupled and Forced Simulations

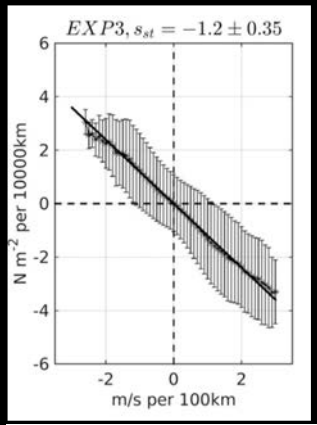
- Two coupled simulation **with CFB** (“True”) and **without CFB**
- ~15 forced oceanic simulations that mimic the different forcing strategies
- Here focus on forced oceanic simulation forced by a reanalysis-like
    - That previously did not feel the CFB

Sinks of Energy in the coupled simulation with CFB

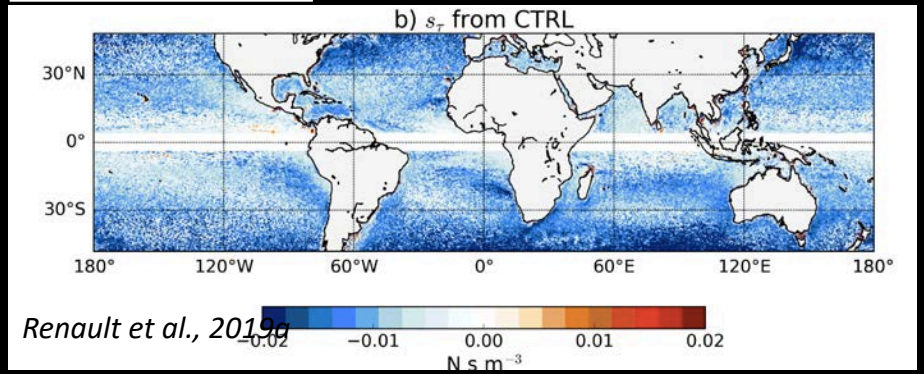


Renault et al., 2020

The Stress Correction



- ✓The more negative the s_τ, the more efficient the sink of energy
- ✓s_τ can be used to force an ocean model **as it does not mix up TFB and CFB.**
- ✓Can be estimated from a coupled simulation or predicted from wind magnitude



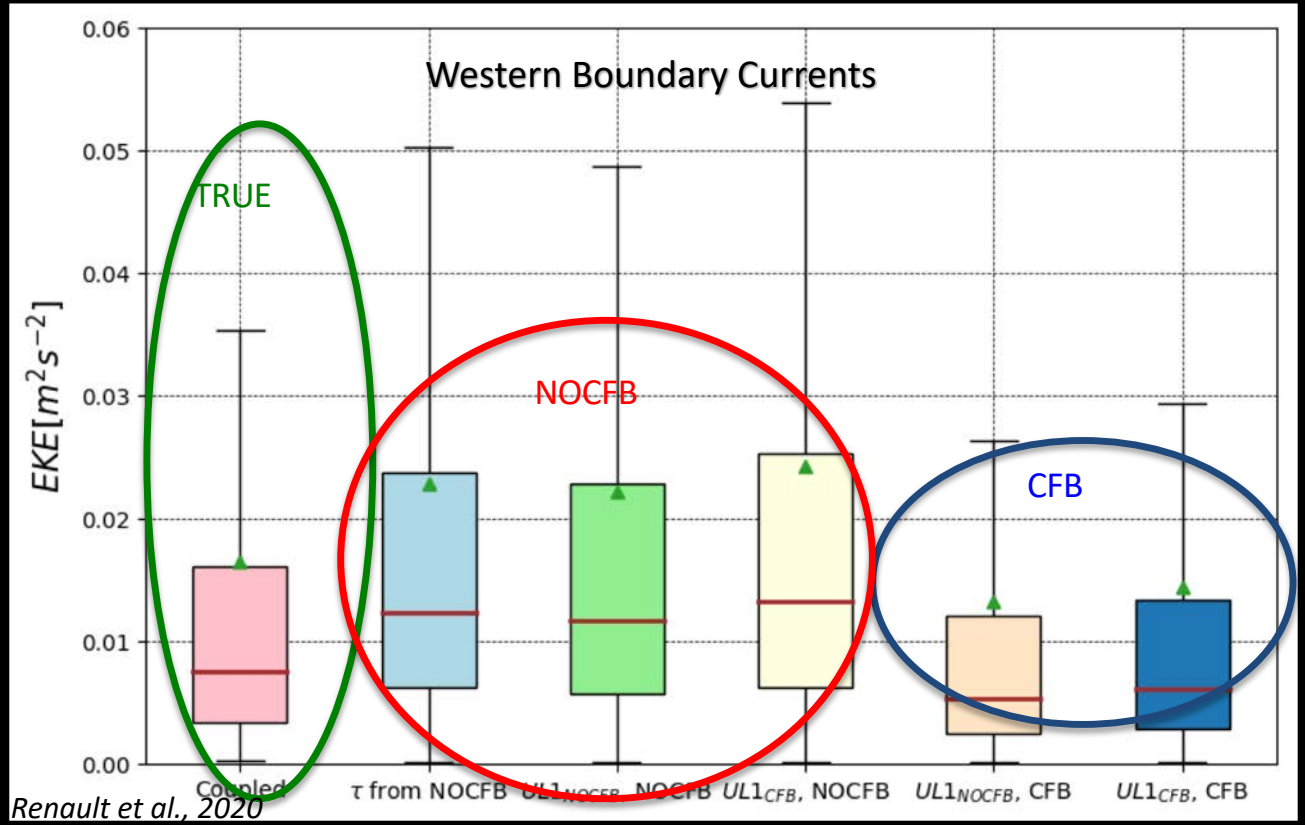
Renault et al., 2019a

$$\boldsymbol{\tau} = \boldsymbol{\tau_0} + \boldsymbol{\tau'},$$

$$\boldsymbol{\tau'} = s_\tau \boldsymbol{U_o}.$$

$$s_\tau = -2.9\ 10^{-3}|U_a| + 0.008\ N\ m^{-3}$$

Eddy Killing and EKE

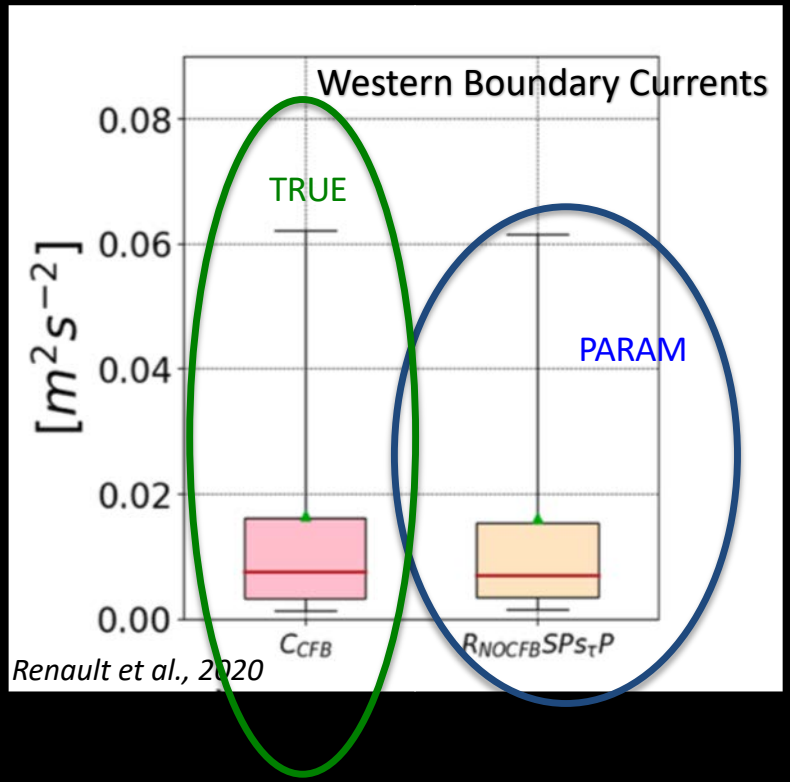


Renault et al., 2020

- Too large an EKE without CFB
- Overestimation of the eddy killing with CFB, too low EKE

Eddy Killing and EKE

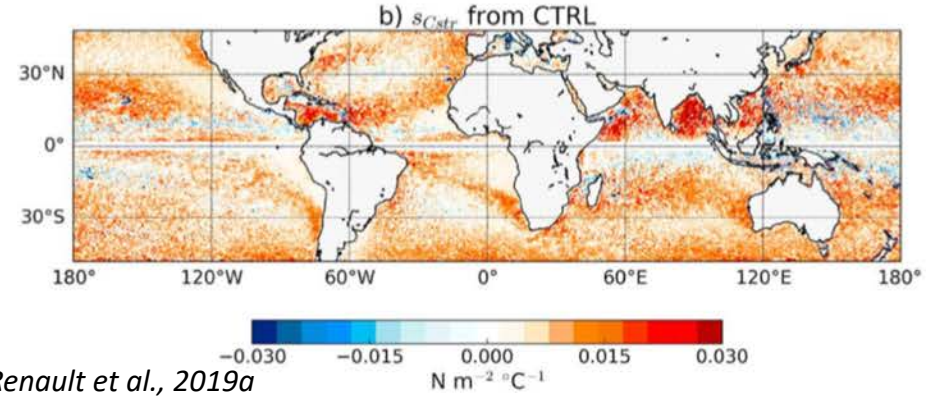
- EKE characteristics well reproduced with both approaches.
- Better over Western Boundary Currents with stress correction
- Same results are found for transfer of energy and large scale circulation

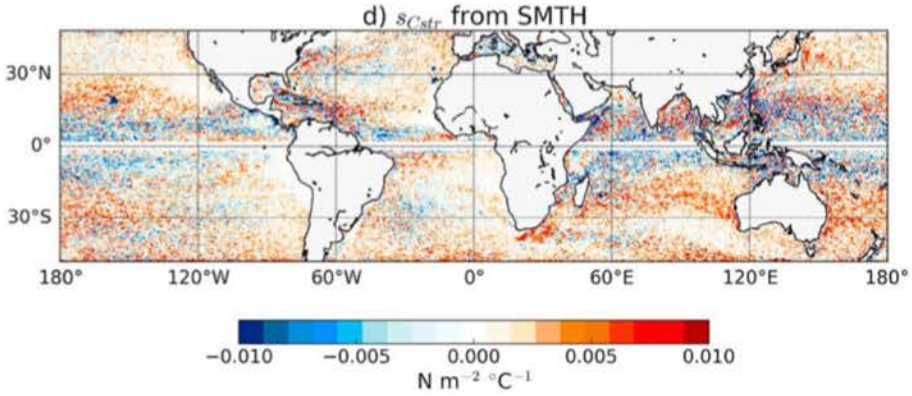


One word on Thermal Coupling Coefficient (cross-wind)

Simulation with both Thermal and Current Feedbacks feedback

Simulation without Mesoscale Thermal Feedback





Renault et al., 2019a

- Blue is driven by the atmosphere, Red by the SST
- → still positive values that are induced by the surface currents

The coupling coefficient between the surface stress curl and the cross-wind SST (s_{Cstr}) does not properly isolate the thermal feedback from the current feedback: the current feedback can cause surface stress mesoscale features that are correlated with the cross-wind SST.

Conclusion

- Current feedback to the Atmosphere has a crucial role in determining the energy exchange and oceanic circulation
- Stress and wind approaches are able to mimic a coupled model for a marginal computational cost
- Stress approach: flexibility and can reproduce temporal and spatial variabilities
- Wind approach: heat fluxes can be corrected too
- Observations-based products should be corrected to remove CFB effect
- Current Feedback has a direct influence on some Thermal Coupling coefficients
- **Need more observations !**
- In a coupled reanalysis s_τ can still be used **if and only if the oceanic currents are provided**

Thanks for your attention

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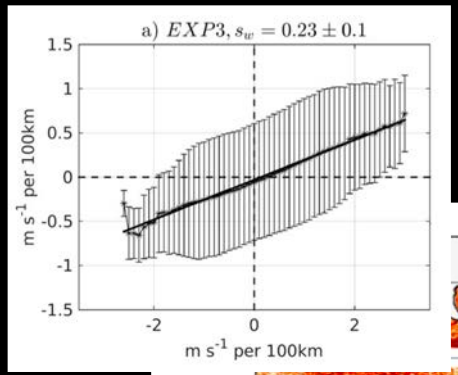
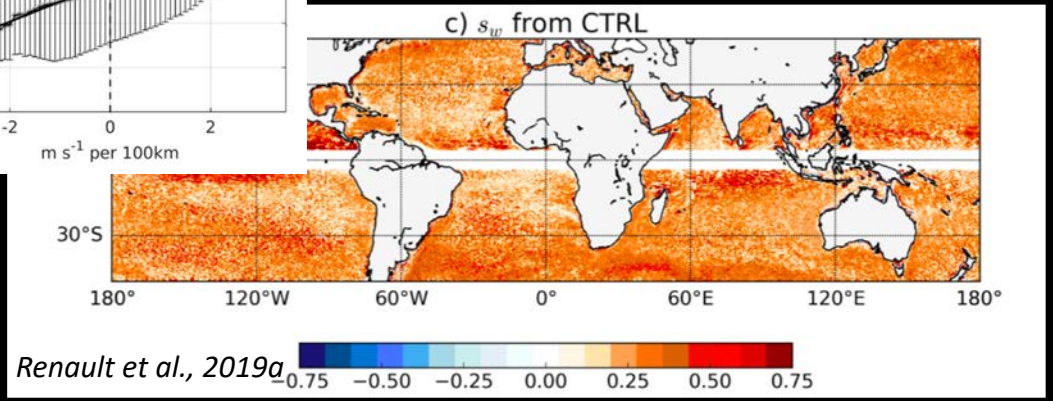
Two Approaches: a) The Wind Correction





Renault et al., 2019a

- ✓ 1 means a full re-energization
- ✓ 0 no re-energization (forced case)
- ✓ Can not be estimated from observations (so far)

$$U'_a = s_w U_o$$

When estimating the surface stress, we use:

$$U_{10abs} - (1 - s_w) U_o$$