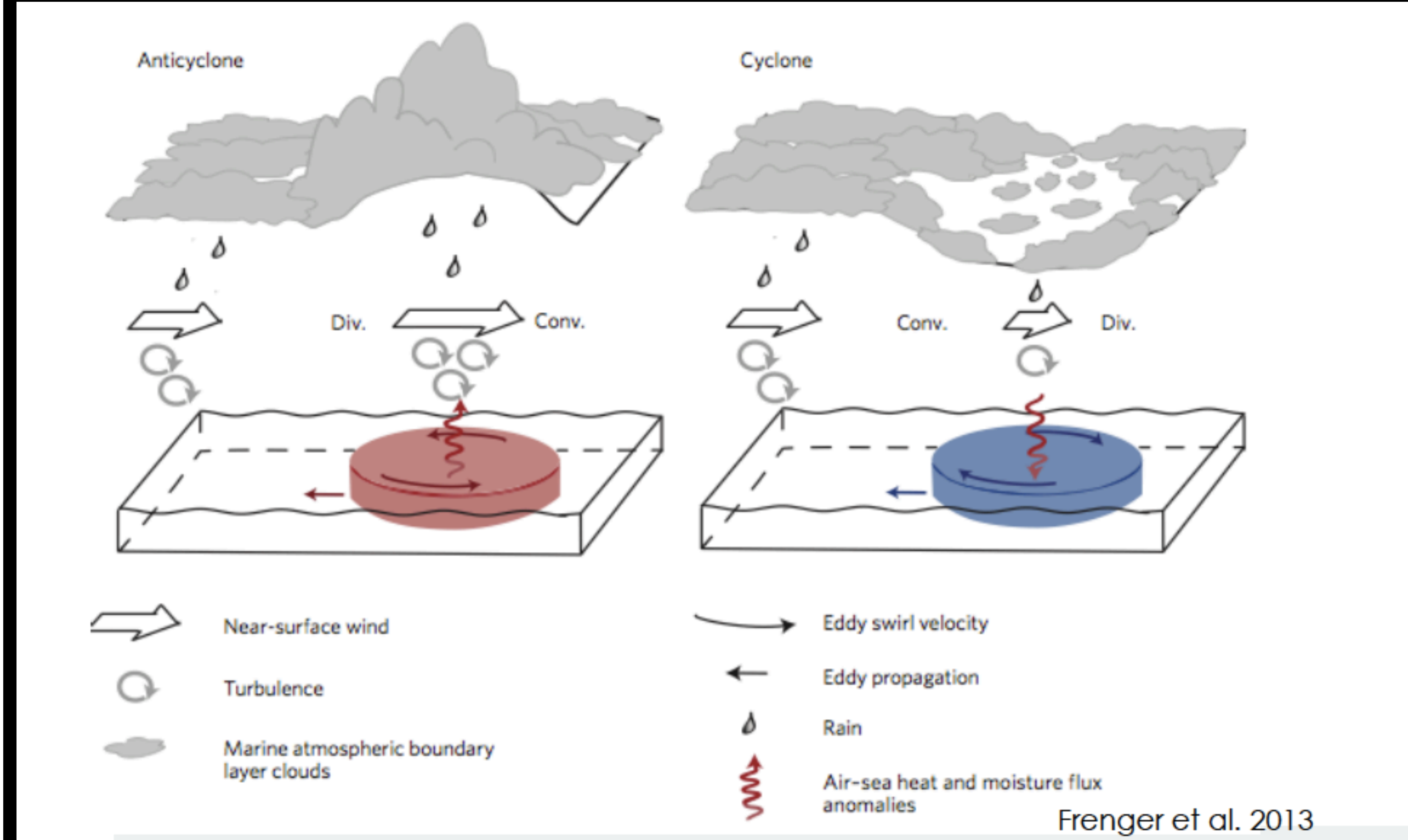
Air-Sea Interactions and Some Coupled Modeling Effort related to the EUREC4/ATOMIC campaign

Lionel Renault, J.C. McWilliams, P. Sullivan, J. Jouanno, and collaborators

Outline

- Importance and characterization of The Thermal Feedback
- Importance and characterization of The Current Feedback
- Some Modeling effort related to EUREC4

Eddy SST signature on the atmosphere



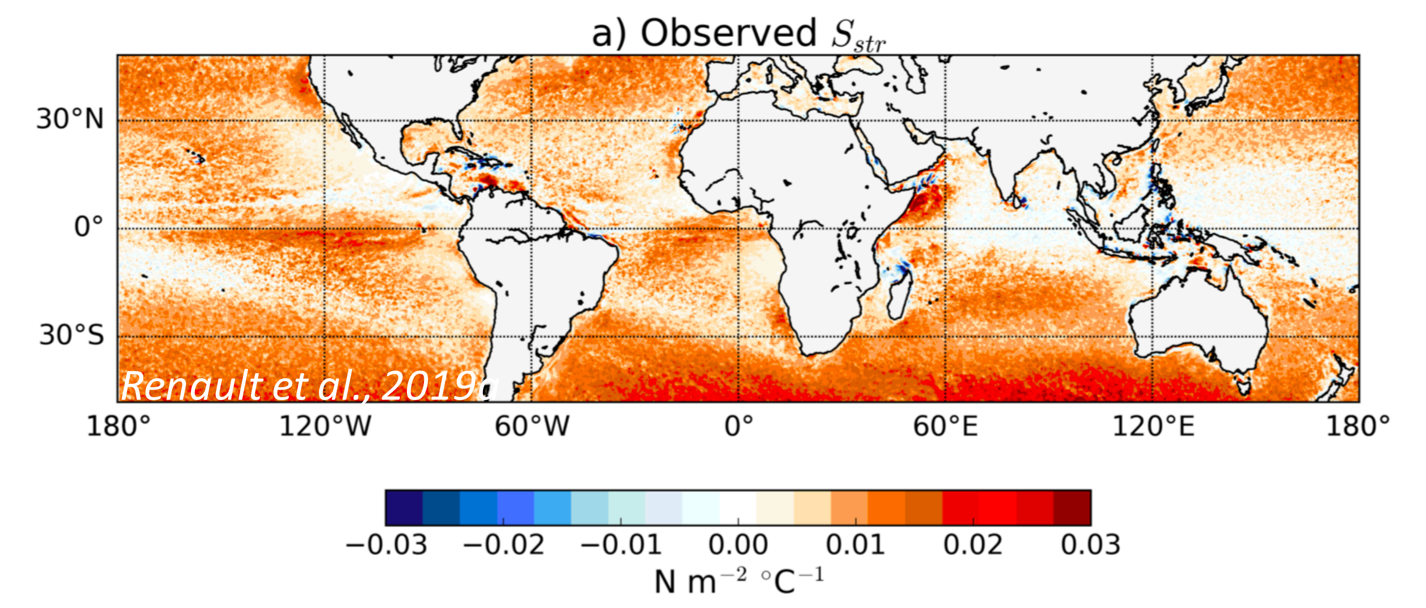
Frenger et al. 2013

Wind Response to SST Feedback

Coupling Coefficient between wind/stress and SST

s_{Cstr}	Cross-wind SST and surface stress curl
s_{Cu}	Cross-wind SST and 10-m wind curl
s_{Dstr}	Down-wind SST and Surface stress divergence
s_{Du}	Down-wind SST and 10-m wind divergence
s_{str}	SST and Surface stress magnitude
s_u	SST and 10-m wind magnitude

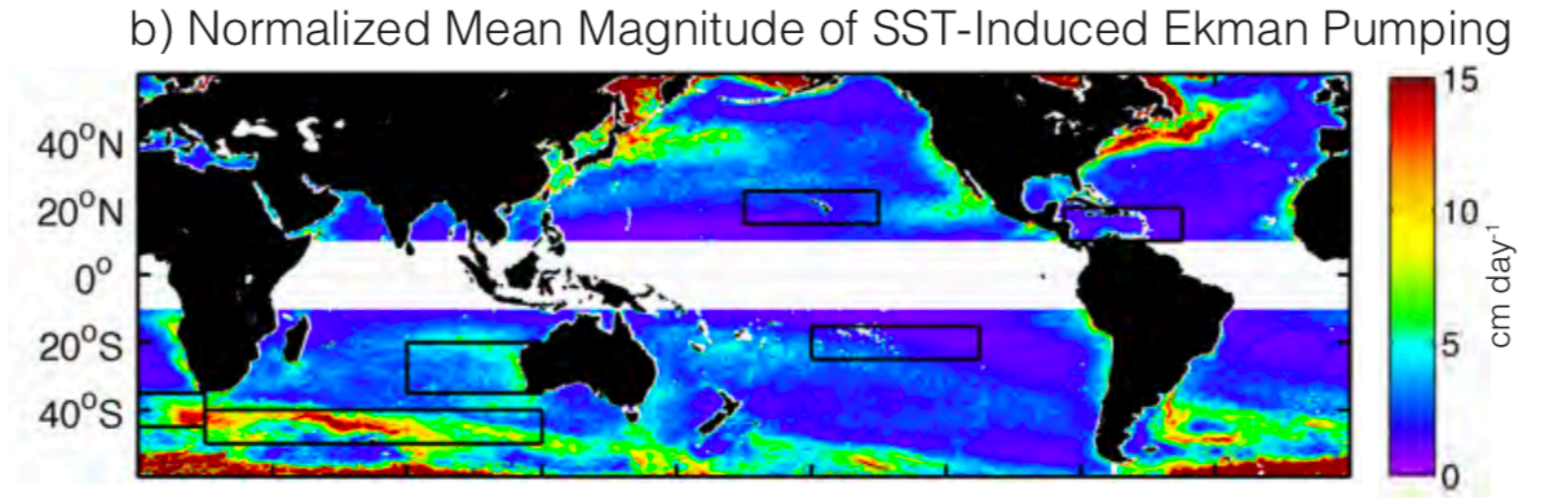
- ✓ Large impact on heat fluxes
- ✓ Can influence the eddies propagation (*e.g.*, Seo et al., 2016)
- ✓ Ekman pumping velocities



Chelton et al., 2001,2002,2007,2011; O'Neill et al., 2003, 2012, O'Neill 2012; Perlin et al., 2014, etc ..

On the Ocean Response to the TFB

- ✓ Large impact on heat fluxes
- ✓ Can influence the eddies propagation (*e.g.*, Seo et al., 2016)
- ✓ Ekman pumping velocities



Gaube et al., 2015

Importance to have a realistic representation and characterization of the Thermal FeedBack

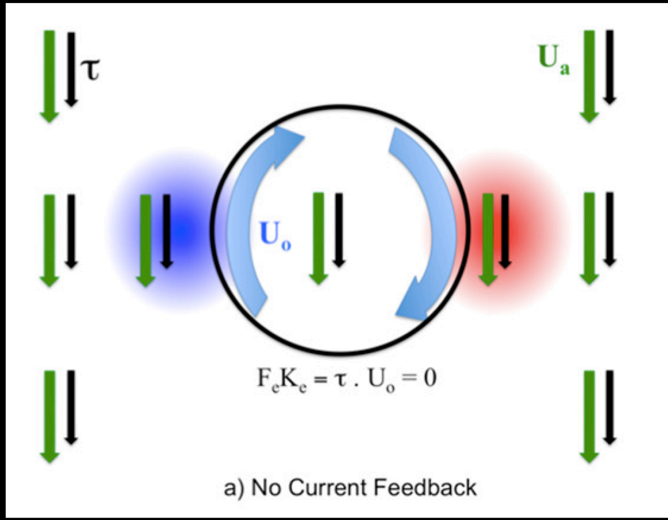
Current Feedback

In a coupled model, when estimating the surface stress:

$$U = U_a - U_o$$

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

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., 2015; Renault et al., 2016cd; Renault et al., 2017ab

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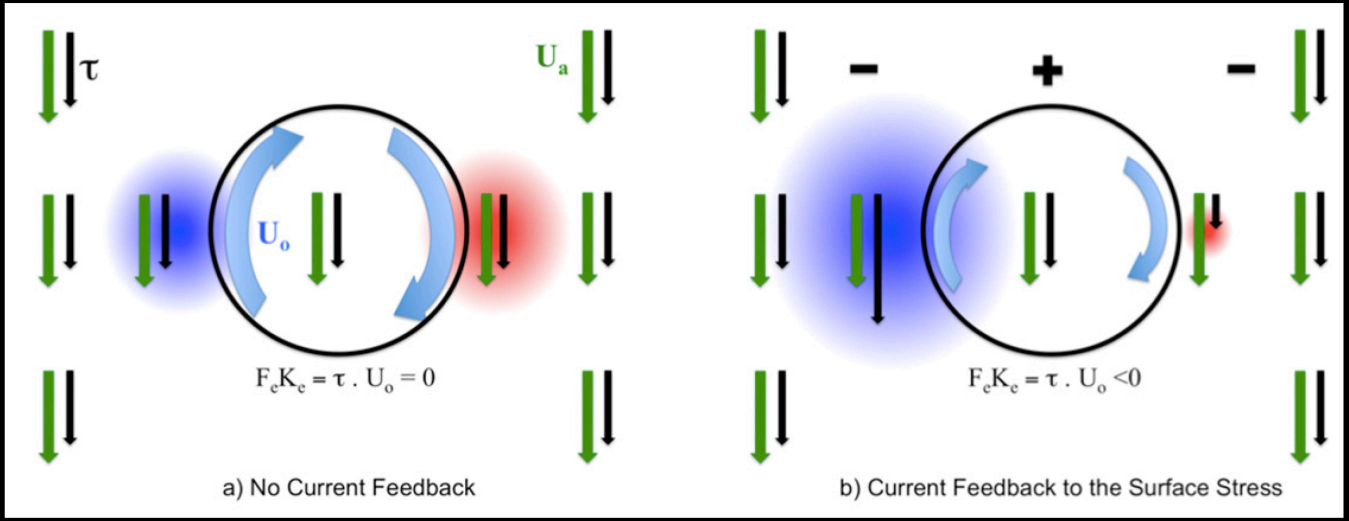

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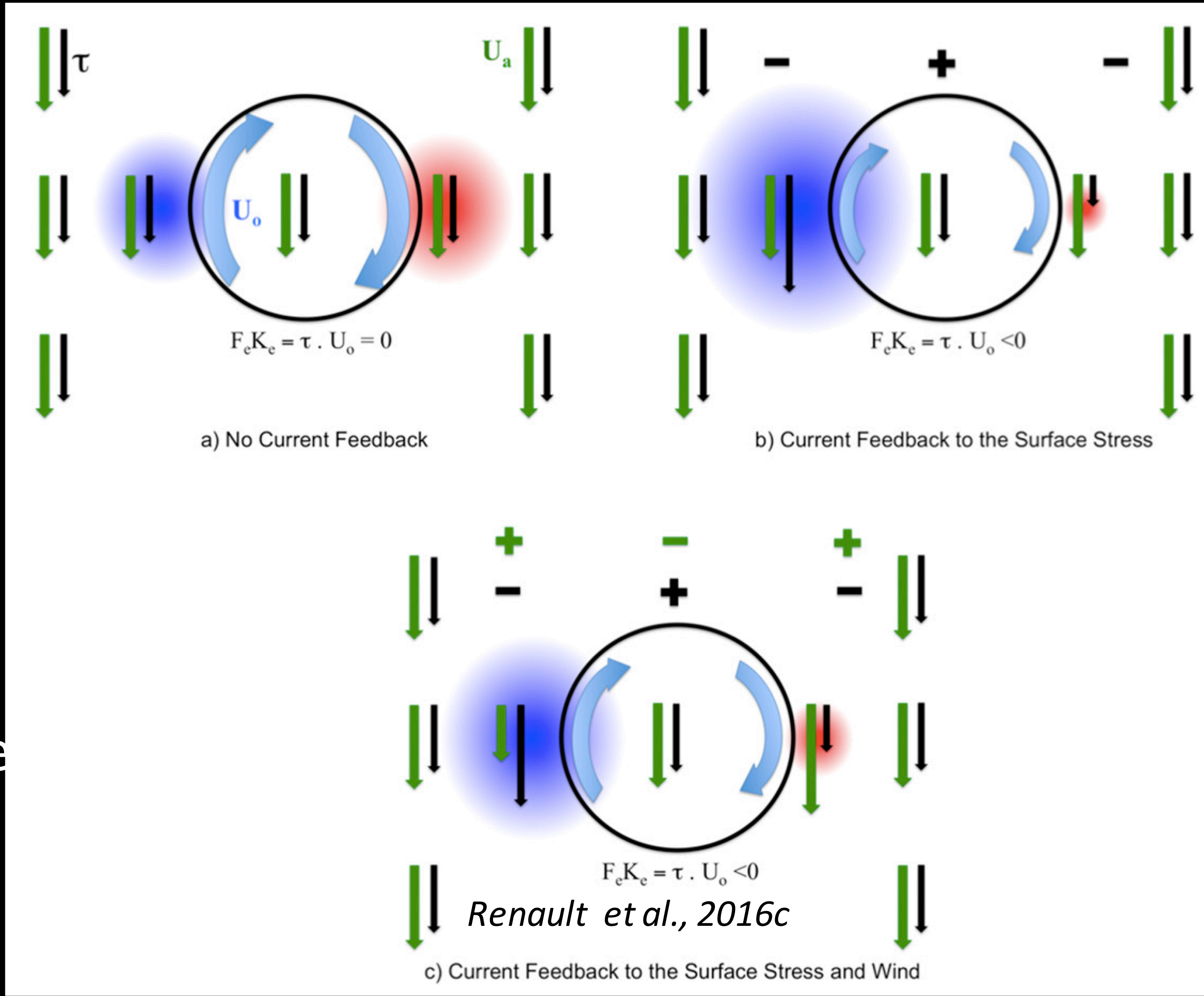

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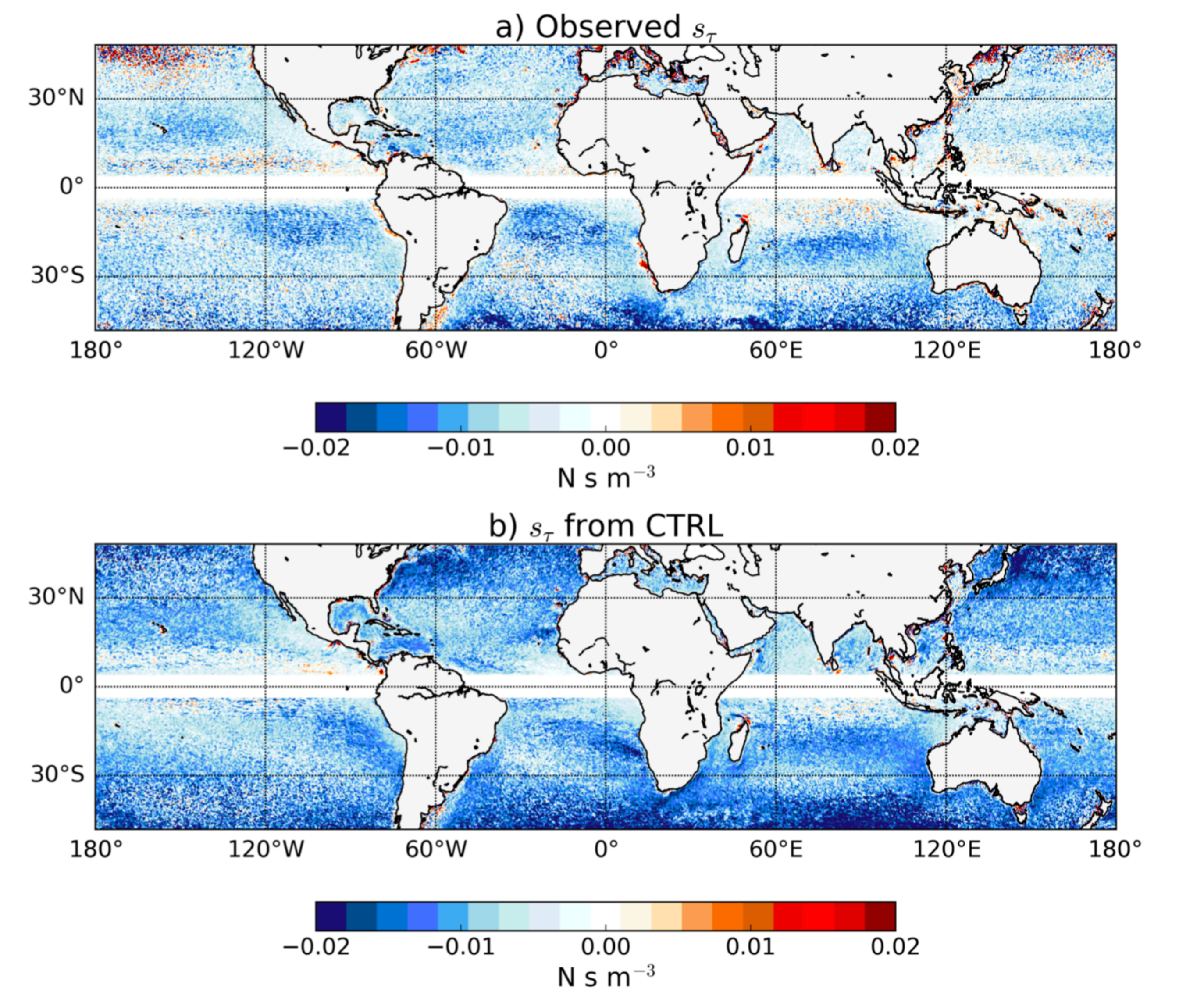
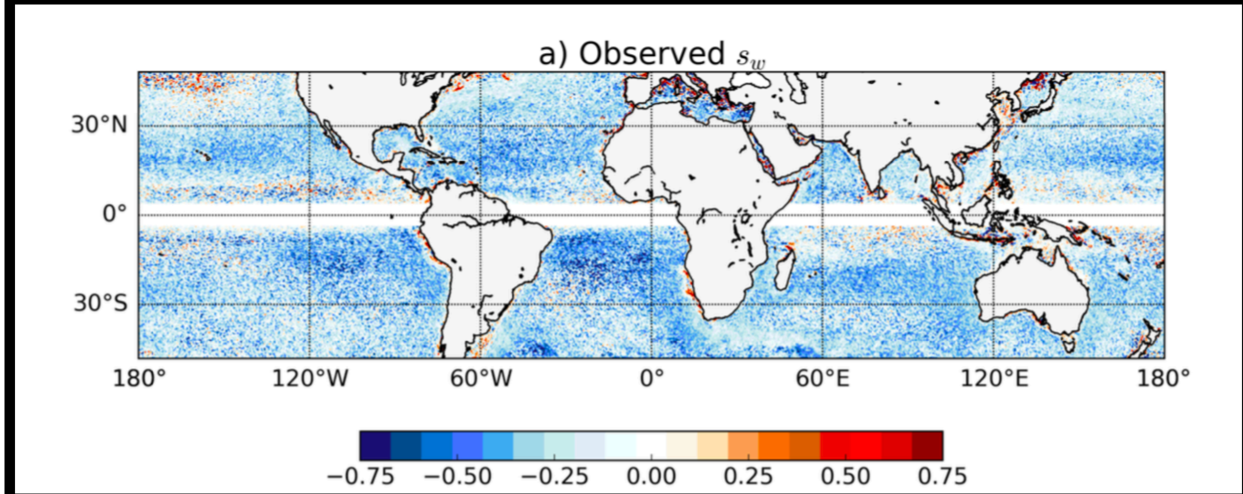
CFB Coupling Coefficients: Current and Stress

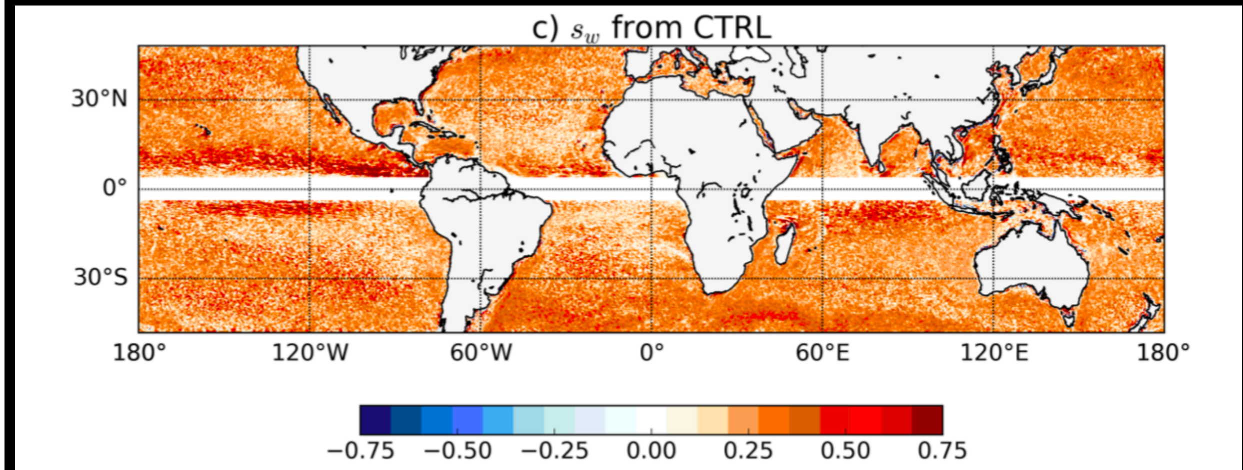


Renault et al., 2019a

- ✓ Discrepancies between model and satellite
- ✓ Large uncertainties in observations

CFB Coupling Coefficients: Current and Stress



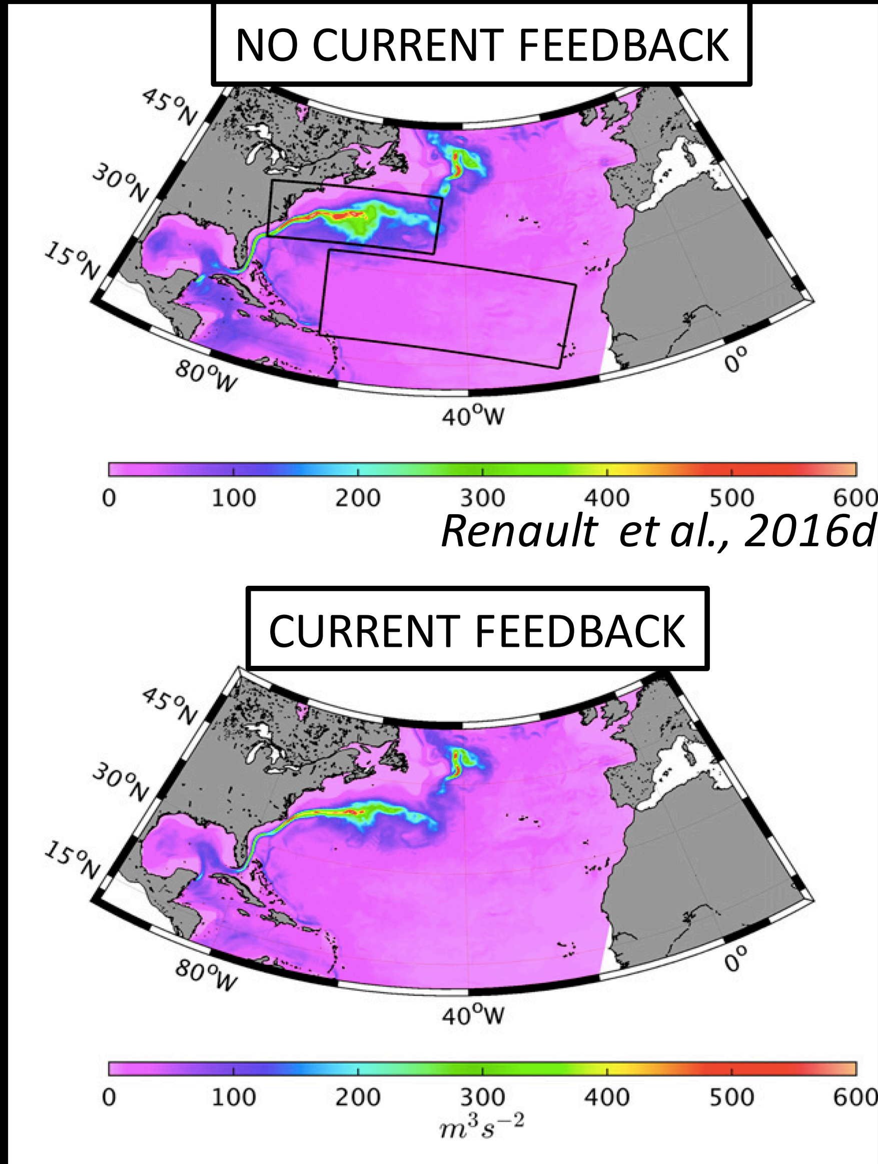


Renault et al., 2019a

- ✓ Scatterometers monitor relative wind (ENW) response to the CFB rather than absolute wind → Opposite sign
- ✓ Need more observations to characterize wind response and validate model simulations

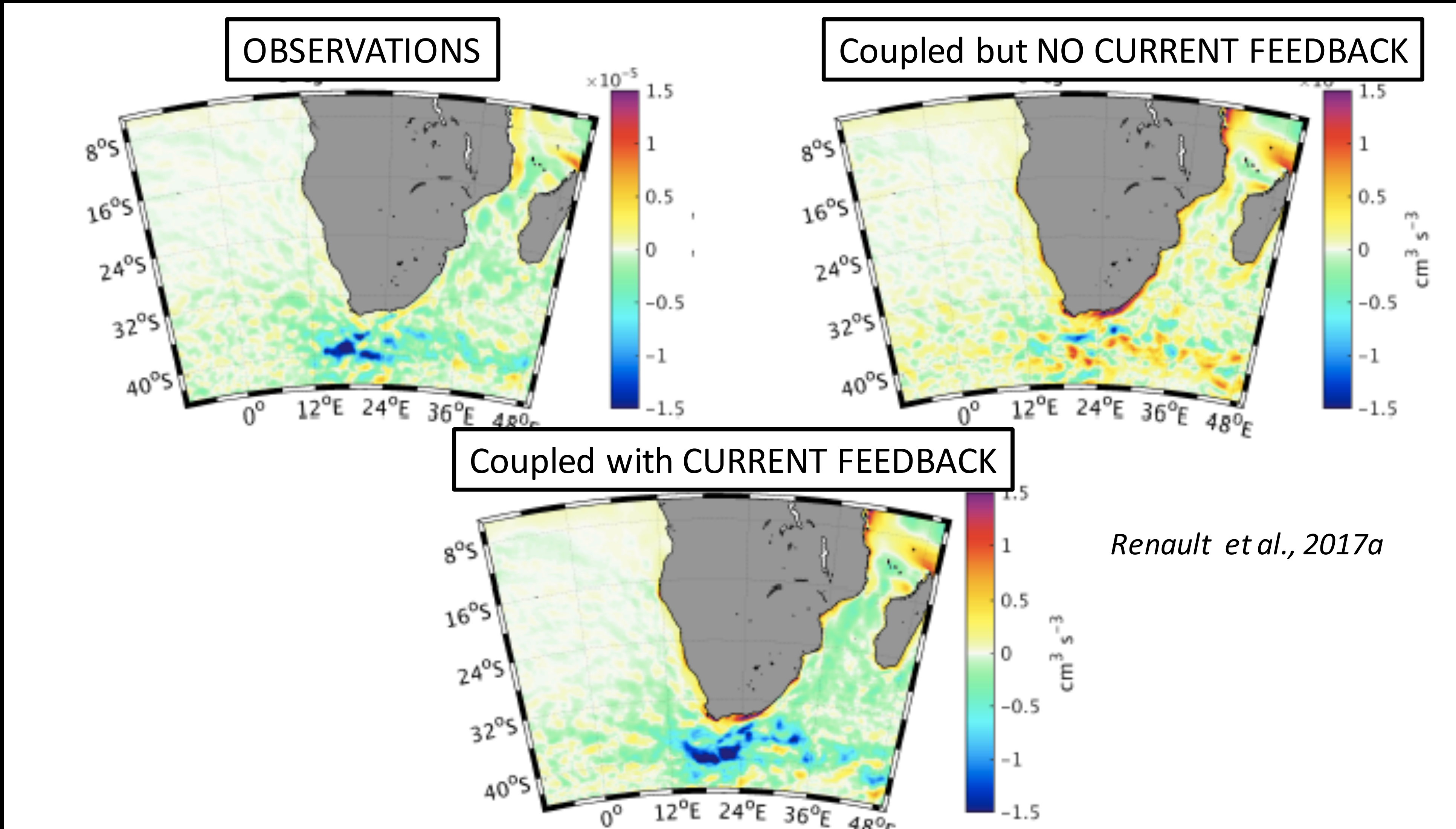
Importance of CFB coupling coefficient: A Large Scale Effect

- Reduction of integrated KE by 27% (NATL), 15% global …
- Better dynamic (GS separation, Agulhas Retroflection)



Luo et al. 2005; Eden and Dietze 2009; Renault et al., 2016bc

A Mesoscale Effect: "Mechanical Damping" or "Eddy Killing"

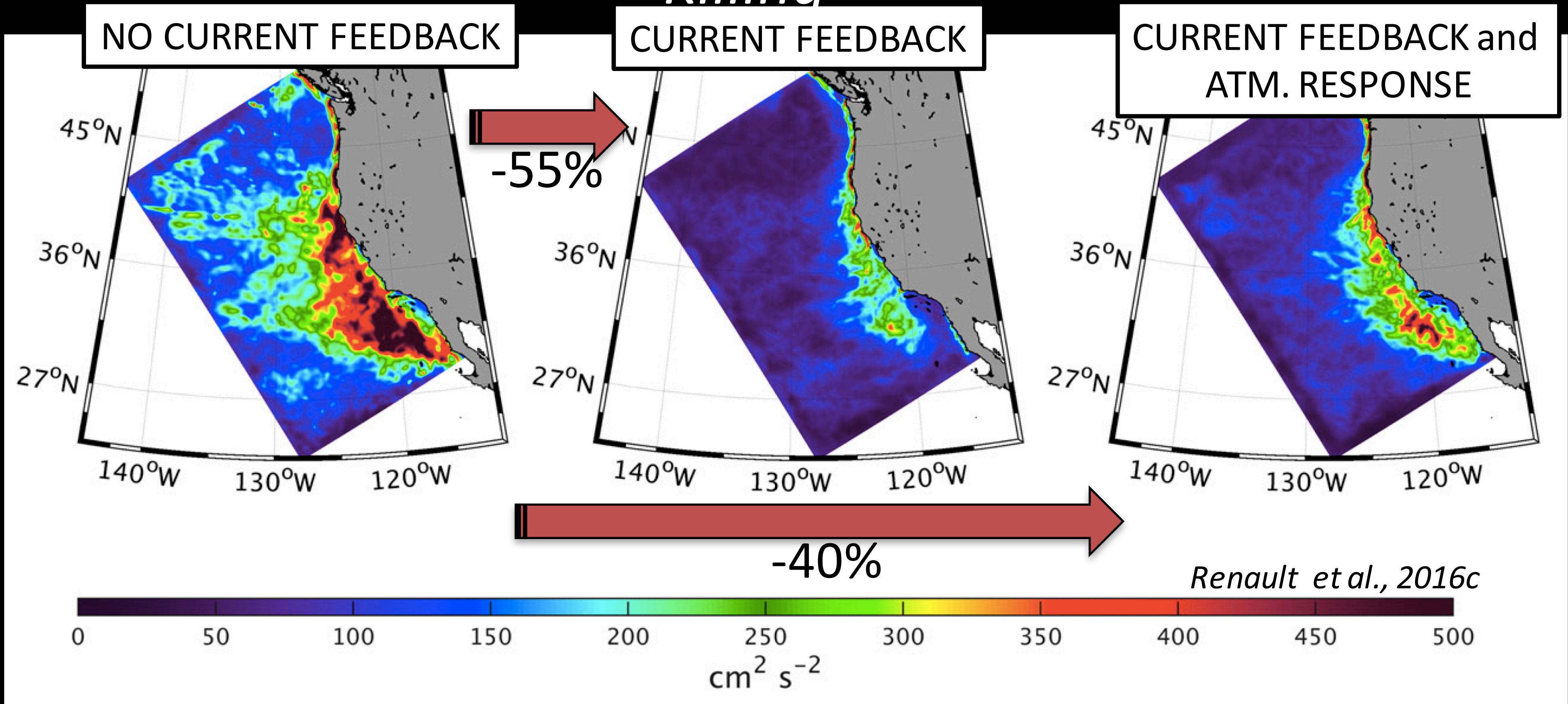


Deflection of energy from the Ocean to the Atmosphere

But partial re-energization of the Ocean by the Atmosphere

Xu et Scott 2008, Scott et Xu 2008, Hugues et Wilson 2016

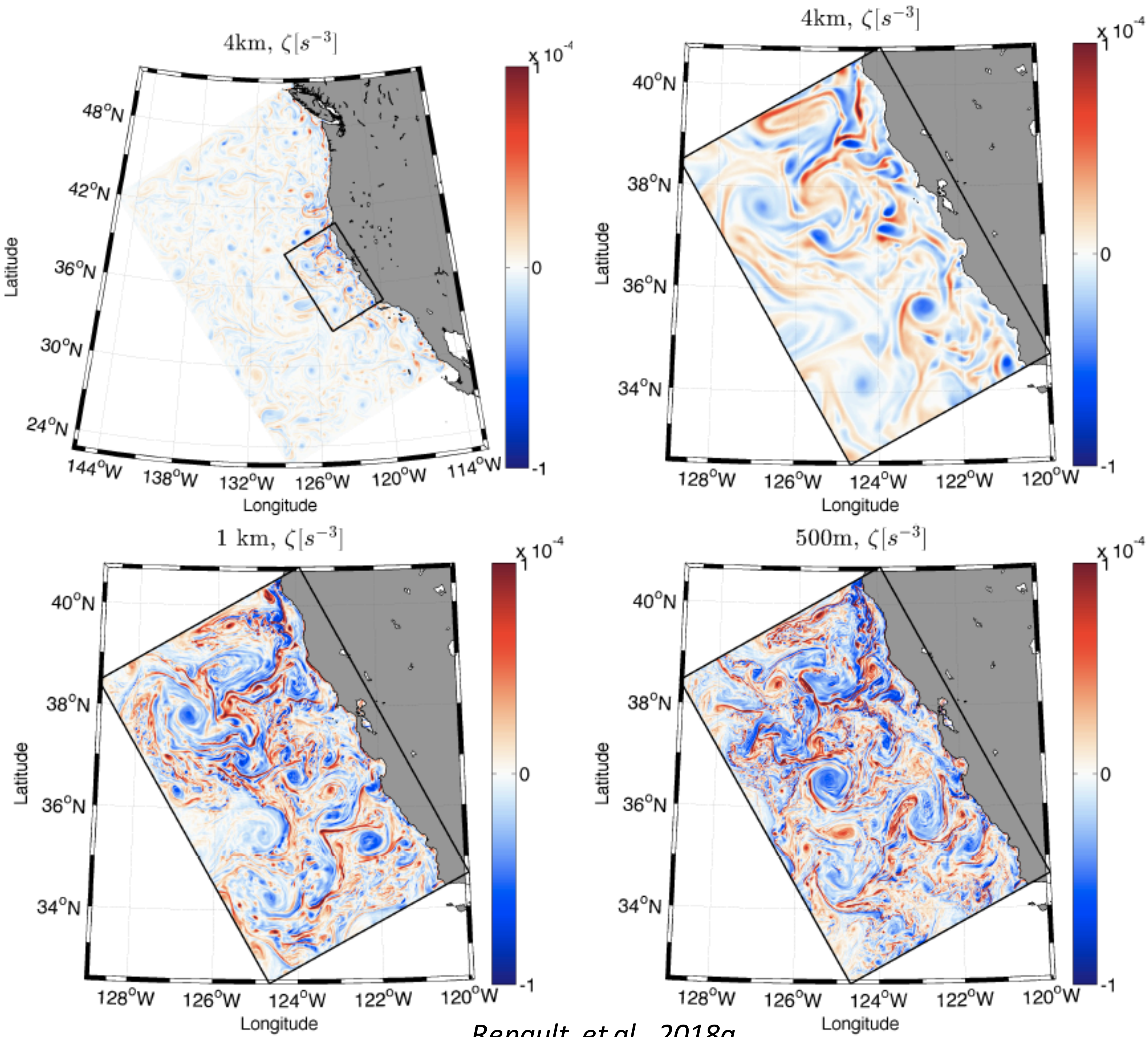
A Mesoscale Effect: "Mechanical Damping" or "Eddy Killing"



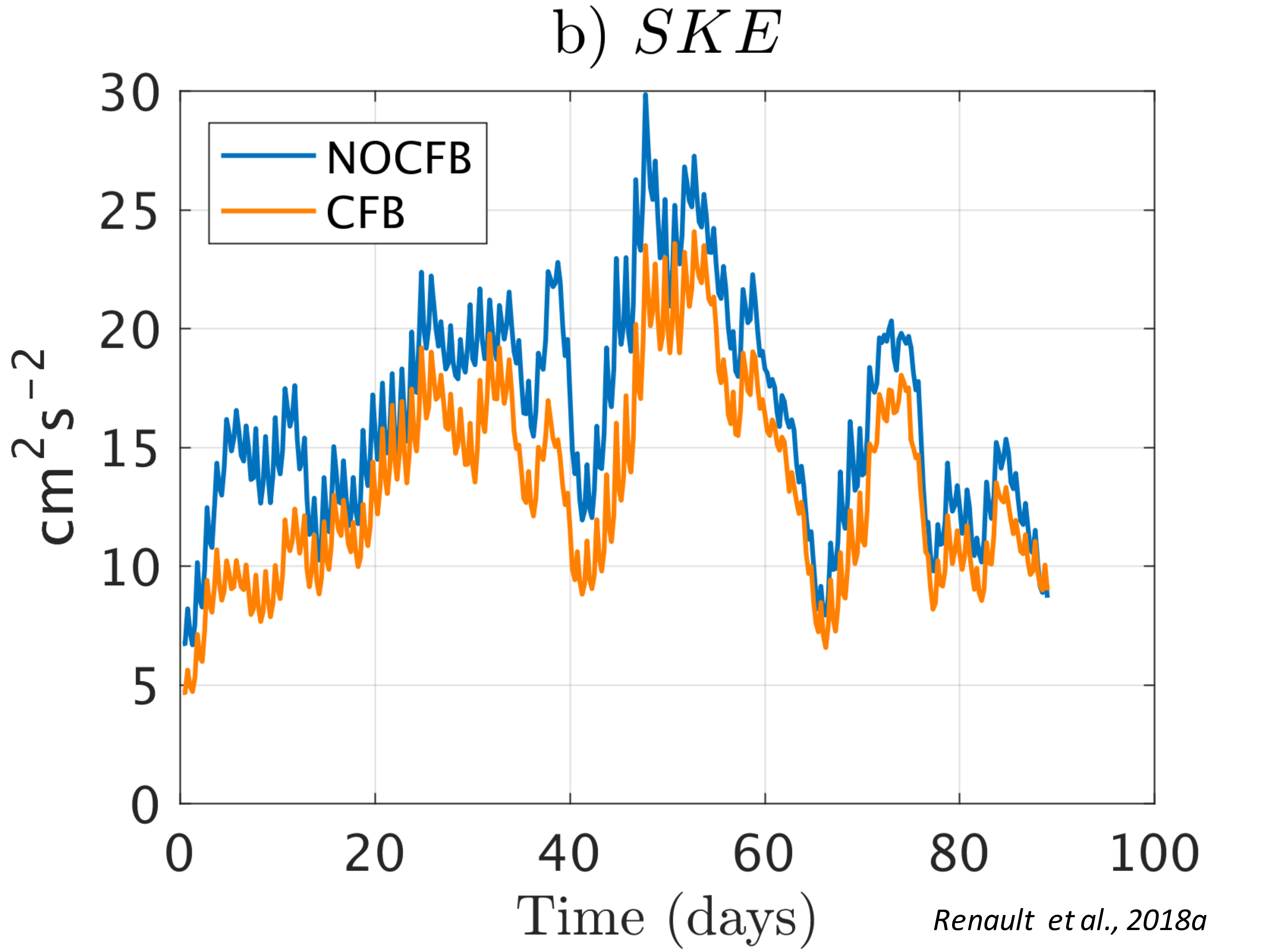
EKE reduction because of deflection of energy Ocean → Atmosphere:

- 44% US West Coast *(Renault et al., 2016a)*
- 27% North Atlantic *(Renault et al., 2016b)*
- 25% Agulhas Current *(Renault et al., 2017a)*
- 40% South East Pacific *(Oerder et al. 2017)*
- 35% global *(Jullien et al., to be submitted)*

Submesoscale Reduction but also re-energization

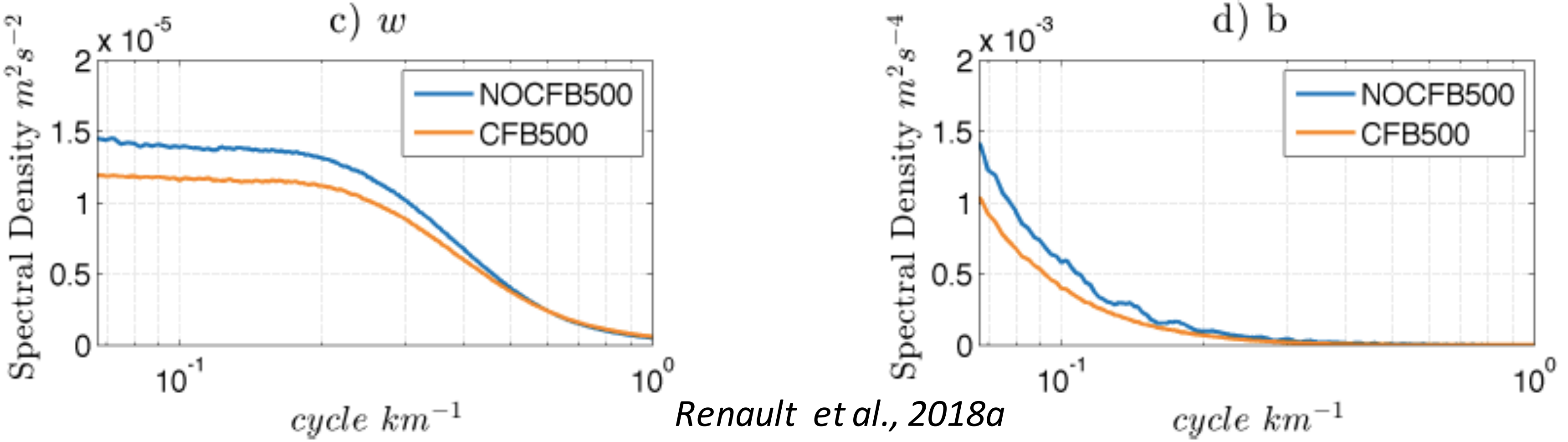


Renault et al., 2018a



b) SKE
NOCFB
CFB
cm^2 s^-2
30
25
20
15
10
5
0
0
20
40
60
80
100
Time (days)
Renault et al., 2018a

[redacted]



Renault et al., 2018a

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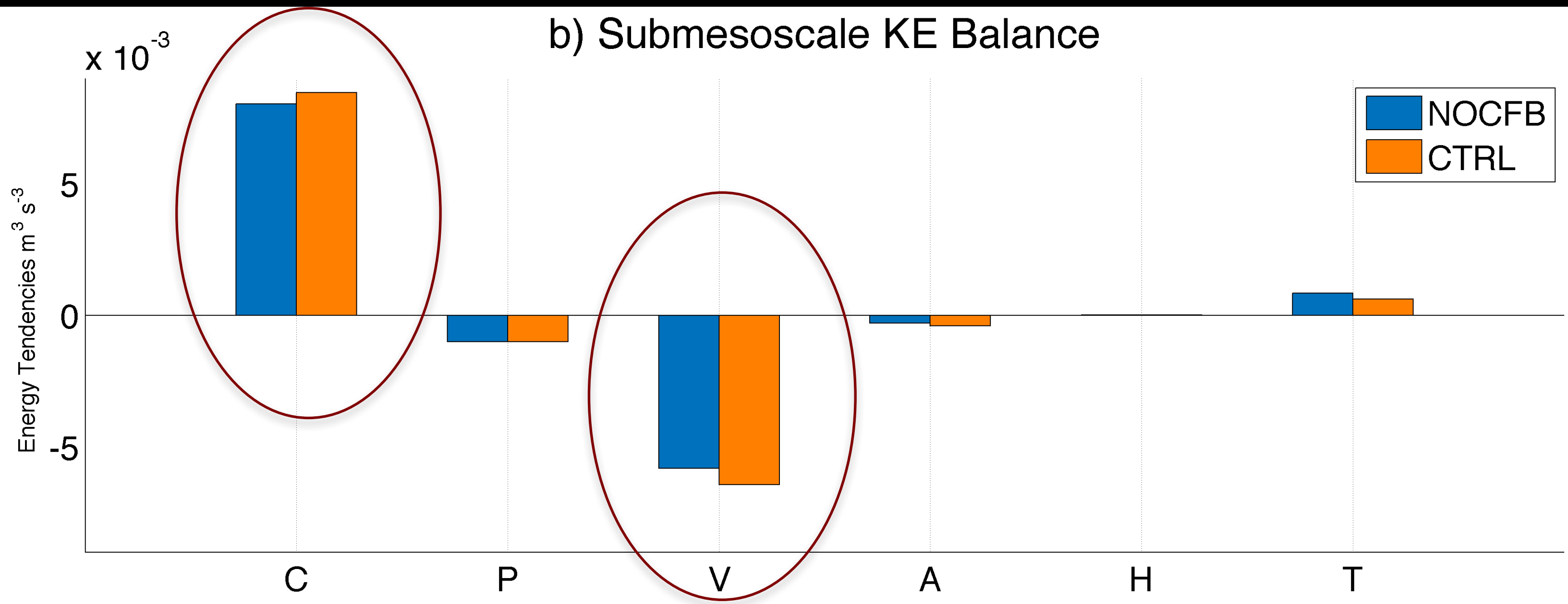

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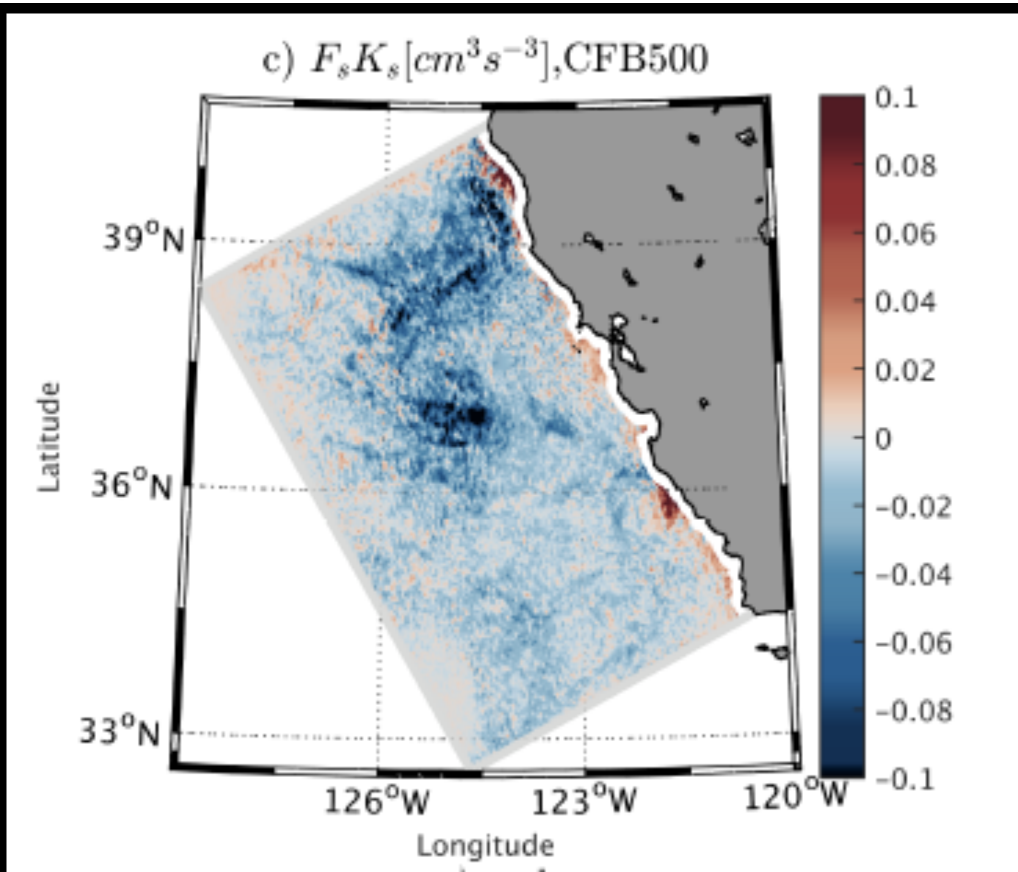
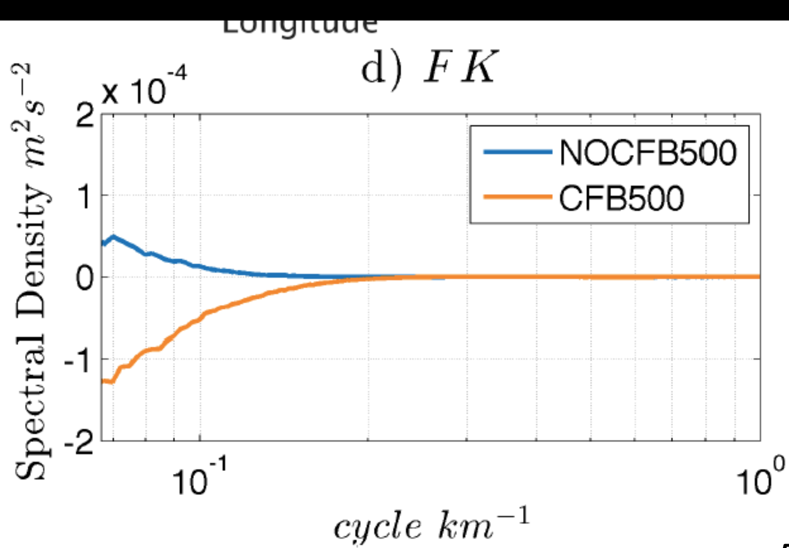
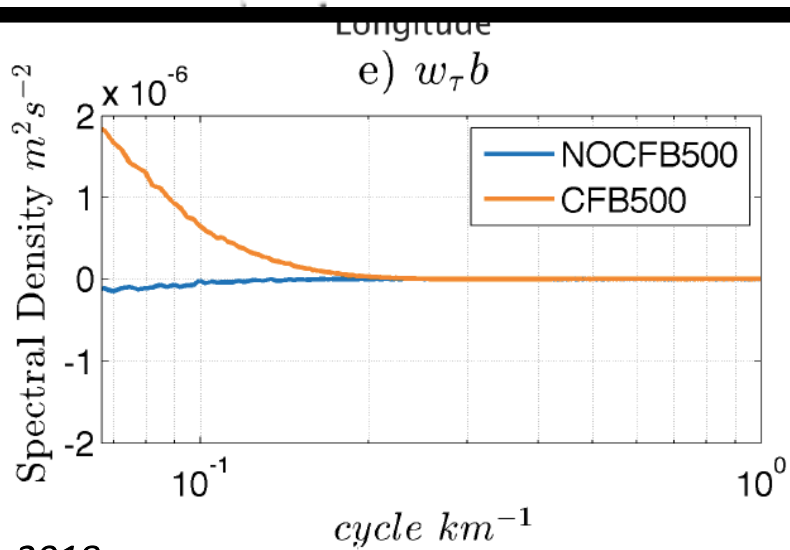
- Sink of energy
- Less APE should induce less submesoscale

- But also Ekman pumping induced by the Current Feeback → More efficient



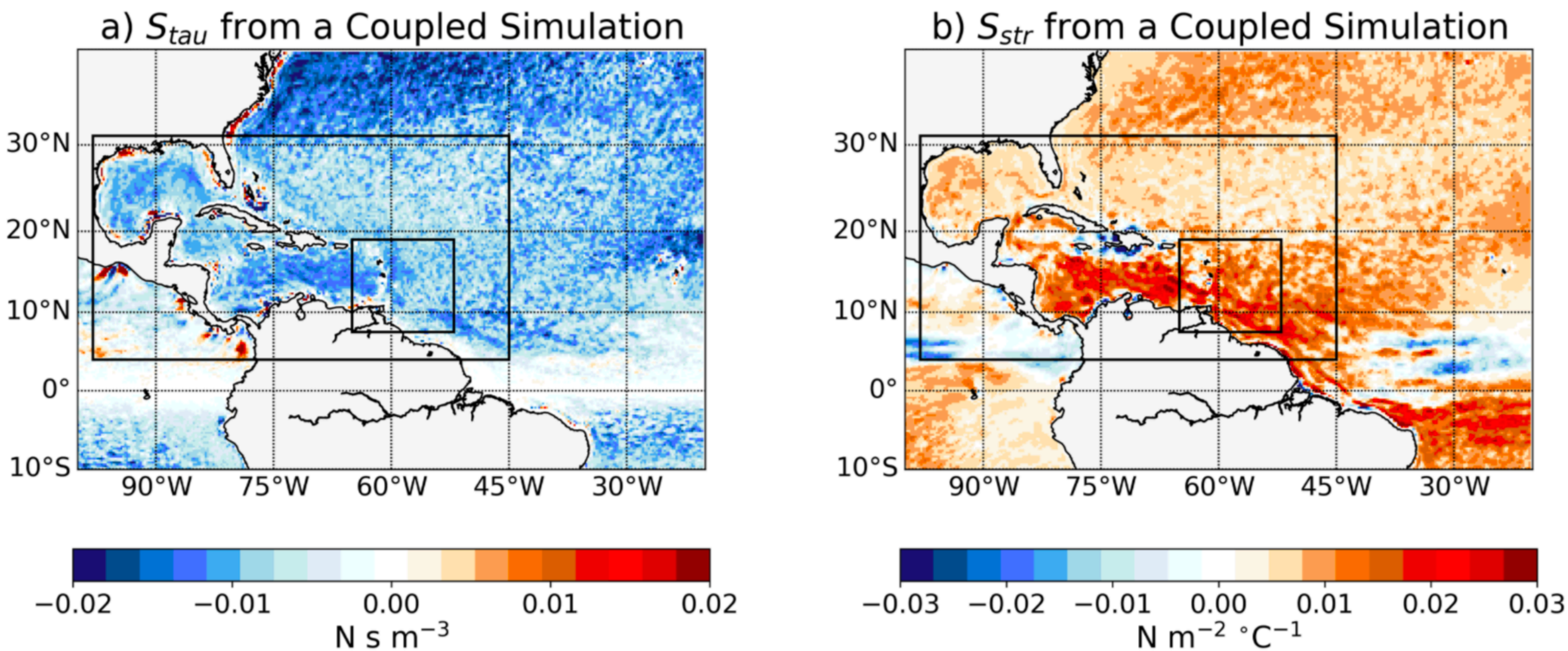




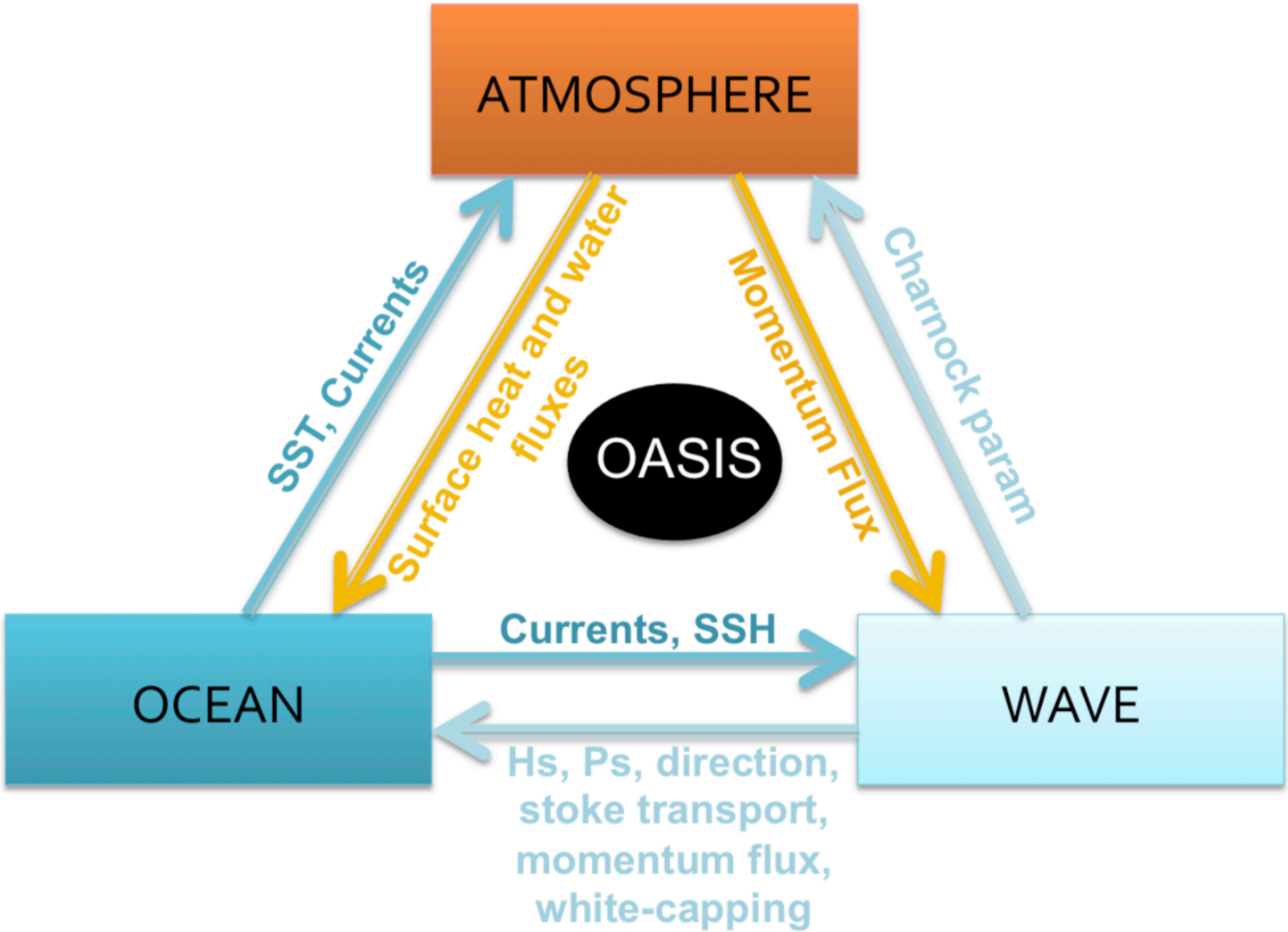
Renault et al., 2018a

Some Modeling effort related to EUREC4

Domain of Interest illustrated with Coupling Coefficients



- From Mesoscale to Submesoscale Coupling (See after)
- Large Coupling Coefficients (both CFB and TFB) → Expect important impact on Ocean Dynamic and Heat fluxes
- Need *in situ* Observations to better understand OA coupling (see after)


ATMOSPHERE
SST, Currents
Surface heat and water fluxes
Momentum Flux
Charnock param
OASIS
OCEAN
Currents, SSH
WAVE
Hs, Ps, direction, stoke transport, momentum flux, white-capping

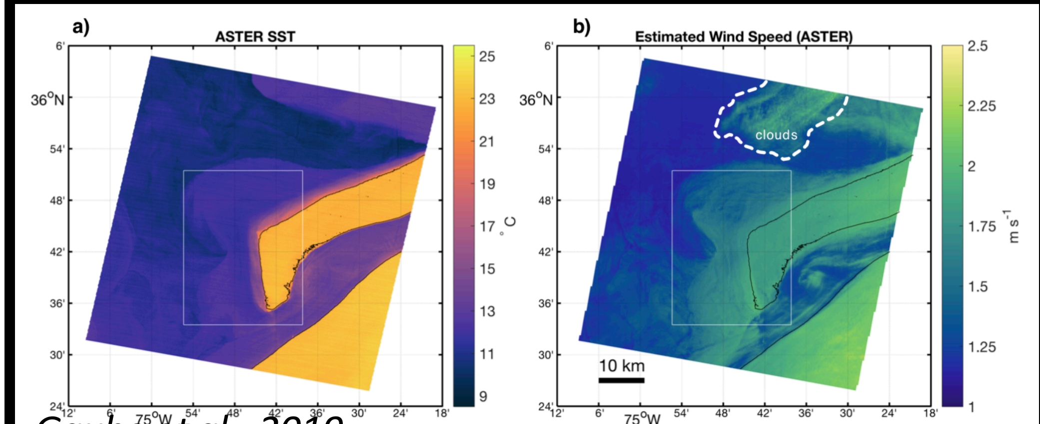
From Mesoscale to SubMesoscale

- Large domain: Ocean at 1/24˚ and Atmosphere at 1/12˚:
    - Thermal Coupling
    - Mechanical Coupling
    - But also Wave Coupling (need wave observations too)
    - Set of WRF parameterizations already tested
    - Links with SKIM and WaCM

- Submesoscale Domains up to 500m resolution for the Ocean, 2km for the atmosphere:
    - Thermal Coupling
    - Mechanical Coupling

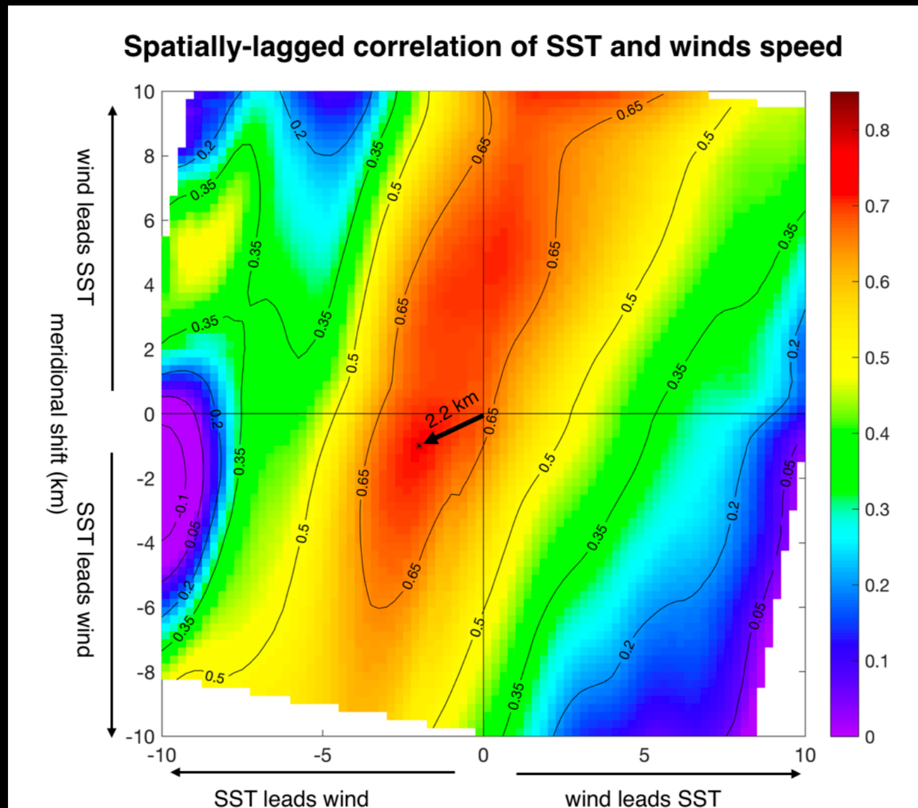
Some "SubMesoscale" Objectives …

- Submesoscale coupling: TFB and CFB impacts on
  - Stress and wind: so far very few observations or modeling studies (*e.g.*, Renault et al., 2018, Gaube et al., 2019).



Gaube et al., 2019

- Determination of TFB and CFB coupling coefficients
- Spatial Lag of a few km (at both mesoscale and submesoscale) ?



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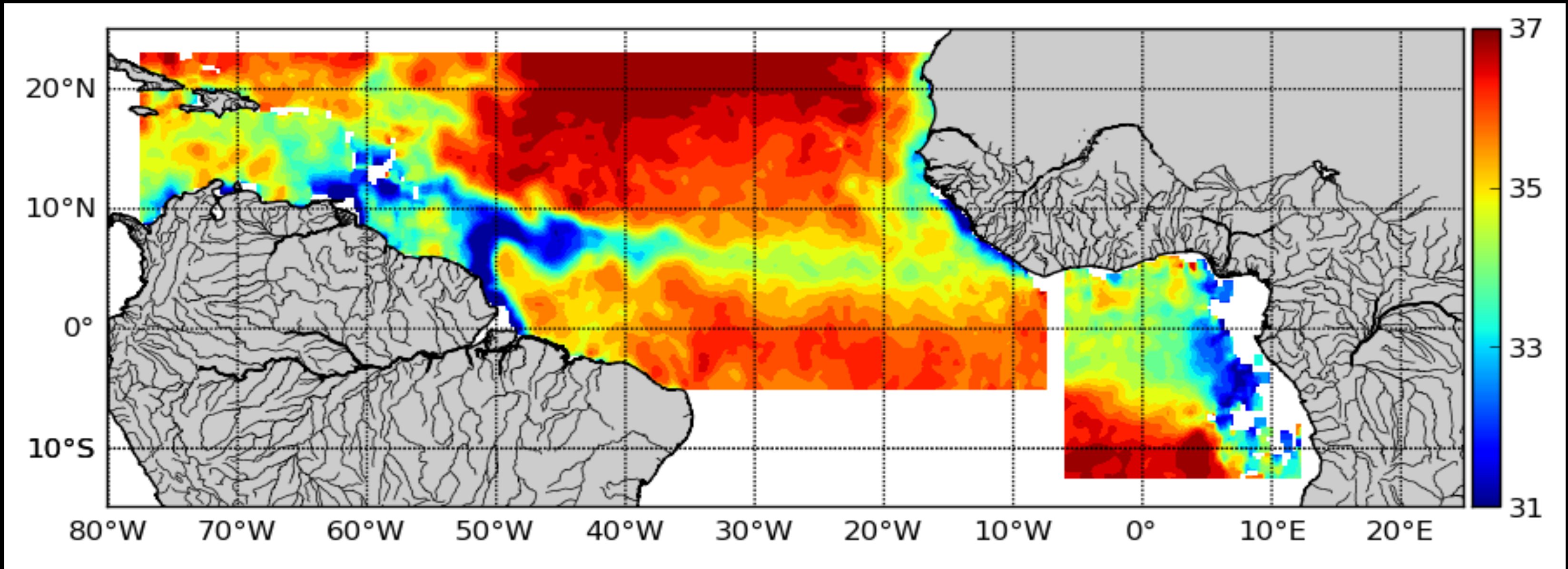
    - Stress and wind: so far very few observations or modeling studies (*e.g.*, Renault et al., 2018, Gaube et al., 2019).
    - Characterization of the clouds response
    - Characterization of the oceanic response: vertical velocities, submesoscale dynamic (generation and dampening)

Some " Mesoscale" Objectives …

- Mesoscale coupling: TFB, CFB and WFB impacts on
    - Stress and wind coupling coefficients to be compared to satellite and *in situ* data.
    - Modulation of wind, stress, currents, and TFB and CFB by WFB
    - Characterization of the clouds response
    - Characterization of the oceanic response
    - Role of stratification in modulating the TFB (run-off)

Sea Surface Salinity from SMOS, September 2011 (West Atlantic) and June 2011 (East)



Jouanno, personal communication

Need of in situ observations to better understand air-sea interactions, satellite observations and to validate coupled model

Thanks for your attention

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