How SWOT will improve our understanding of the ocean’s heat absorption capacity ?

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Two topics:

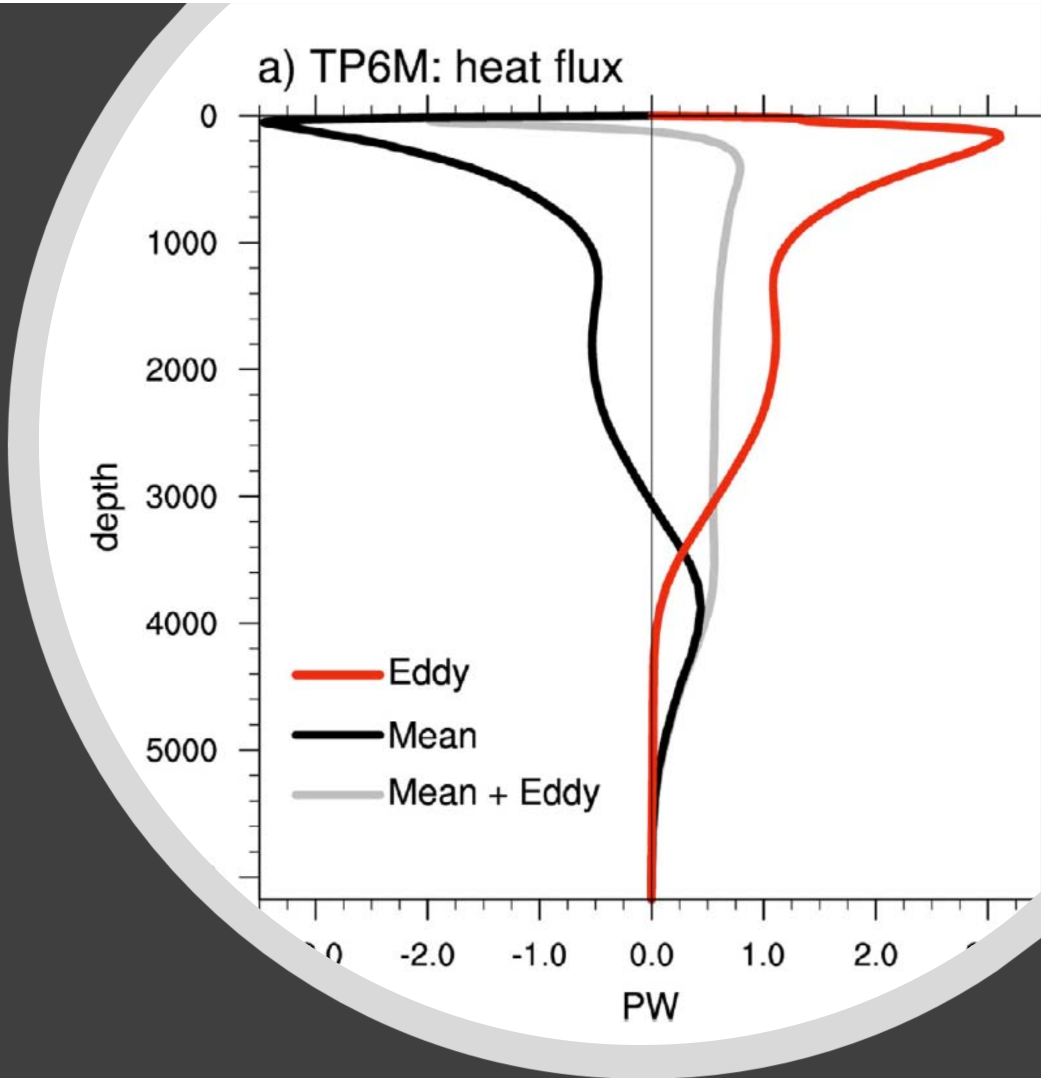
- The Vertical Heat Transport (VHT) associated with mesoscale eddies (50-300 km);
- The impact of mesoscale eddies on air-sea heat fluxes.

- Since the study by Wolfe and Cessi (2008), mesoscale eddies are known as one of the two major contributors to the vertical heat transport [Griffies et al. (2015), Von Storch et al. (2016), Chang et al. (2020)]:

- Wind –driven circulation (~3 PW)

-- Mesoscale eddies (~3 PW)

Errors in the mesoscale eddy heat transport explain much of climate models' temperature drift (Chang et al. 2020).

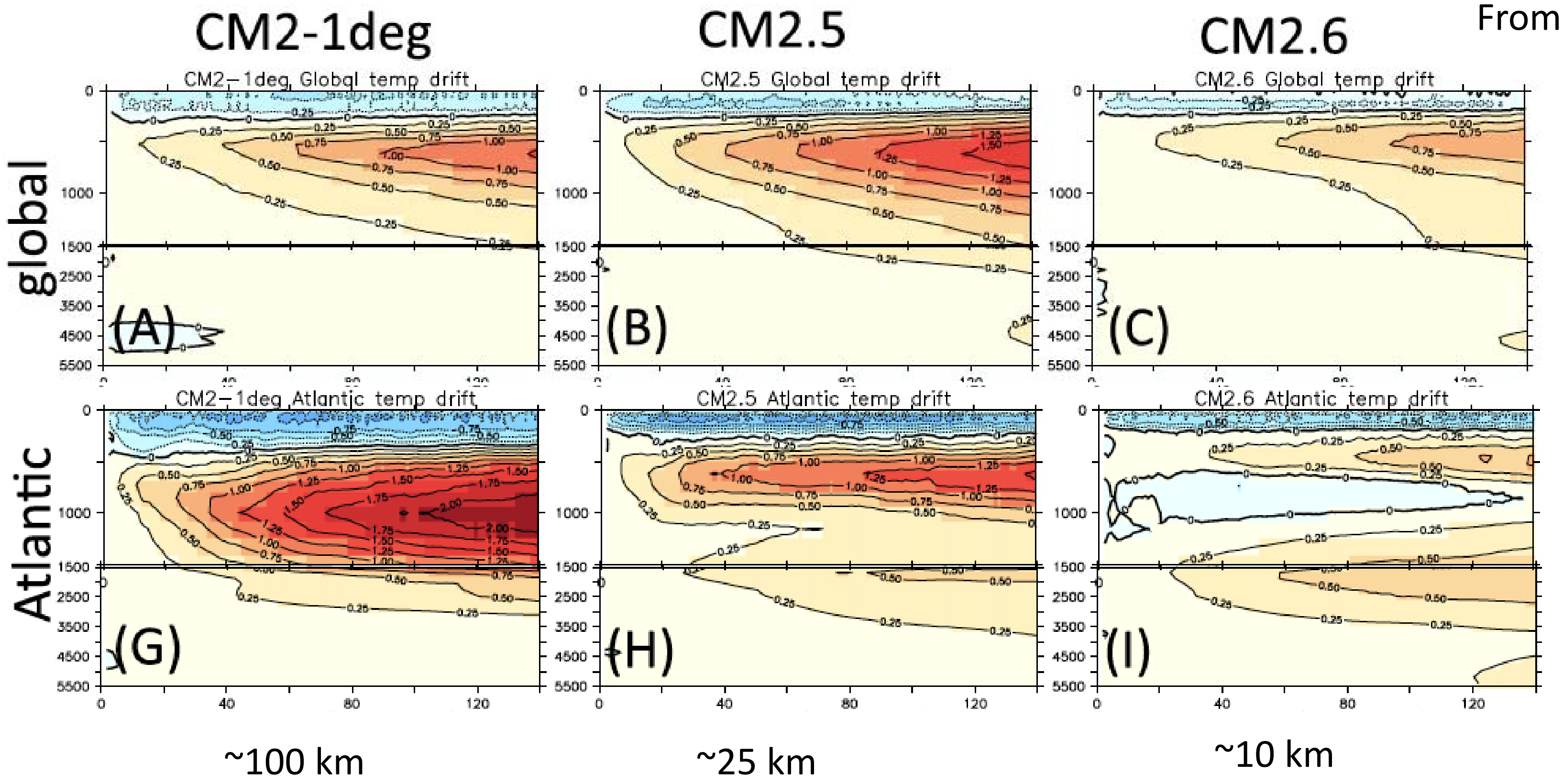


From Von Storch et al. (2006)

Temperature drift in a climate simulation for 140 years

The atmosphere is the same but the resolution of the ocean component changes

From Griffies et al. (2015)



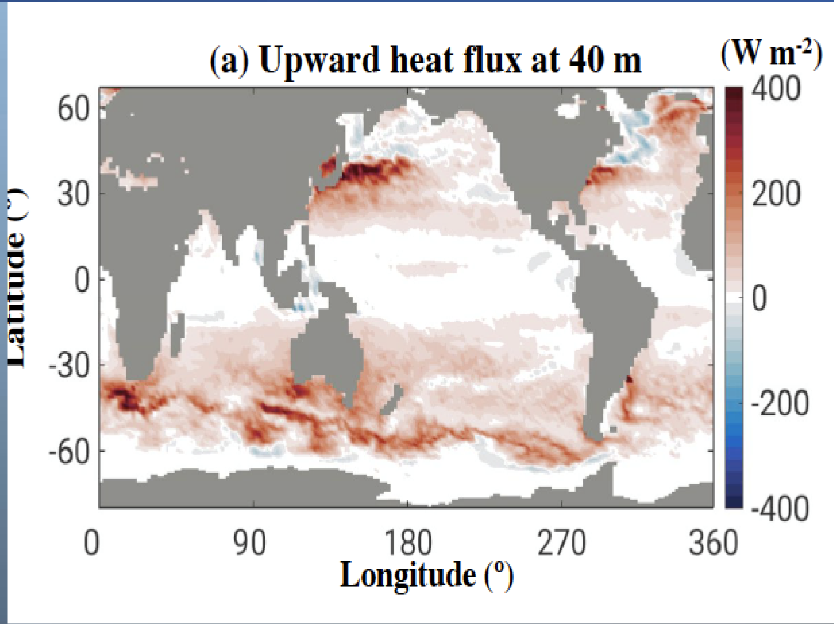
Some mechanisms are missing ?

Recent global MITgcm simulations indicate that using a higher spatial resolution (~2 km) leads to:

- Increase the Vertical Heat Transport (VHT) inside mesoscale eddies
- Take into account the upward VHT associated with submesoscale fronts

Submesoscales (< 50 km): ~3 PW global !!!

[Su et al. (2018, 2020), Yu et al. (2019), Siegelman et al. (2020), Siegelman (2020), …]



Su et al. (2020)

These results are mostly from numerical models. They need to be confirmed with global observations

Can SWOT observations confirm the impact of mesoscale eddies on the VHT?

- The vertical velocity and therefore the VHT strongly depends on the magnitude of the strain field located at the edges of eddies and in-between eddies.

- Magnitude of the strain field principally depends on the detailed geometry of the eddies.

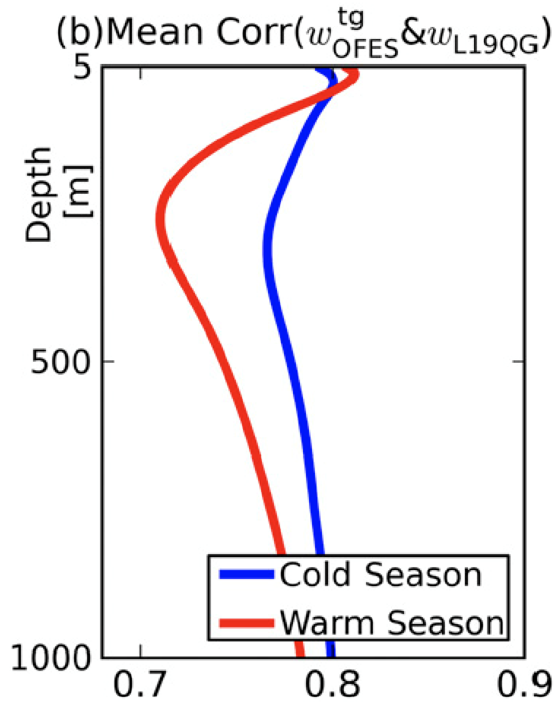
Because of the high spatial resolution and wide-swath characteristics, SWOT observations should give access to the strain field and therefore to the vertical velocity field.

VHT can be diagnosed from SWOT

Recent studies using hi-res realistic simulations

[Qiu et al. (2020), Yang et al. (2021), Liu et al. (2021)]

confirm that SSH from SWOT (+ SST) can be used to diagnose the order of magnitude of the VHT in the global ocean



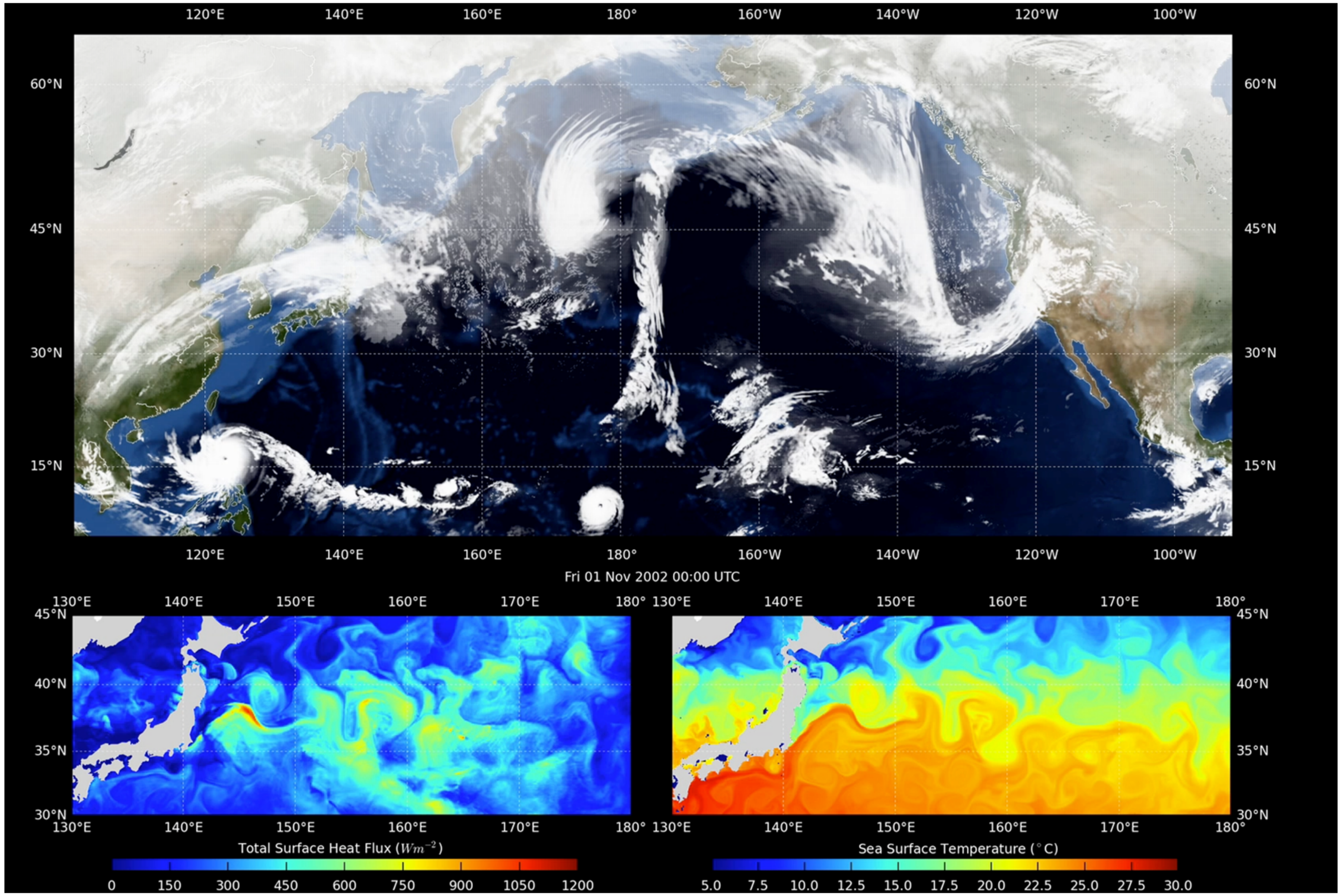
From Liu et al. (2021)

Ocean eddies are associated with an upward VHT from the ocean interior up to the surface.

The resulting mesoscale SST anomalies impact the atmospheric weather through air-sea interactions (Chang et al. 2020)!

Eddies in the Kuroshio, through latent heat fluxes, can impact the rainfall over the West coast of the U.S. (Ma et al. 2015, 2017, Chang et al. 2020).

We need to improve the representation of the eddy impacts on air-sea interactions, in particular to take into account the submesoscale SST fronts (Small et al. 2014, Wenegrat et al. 2018, Sullivan et al. 2020).

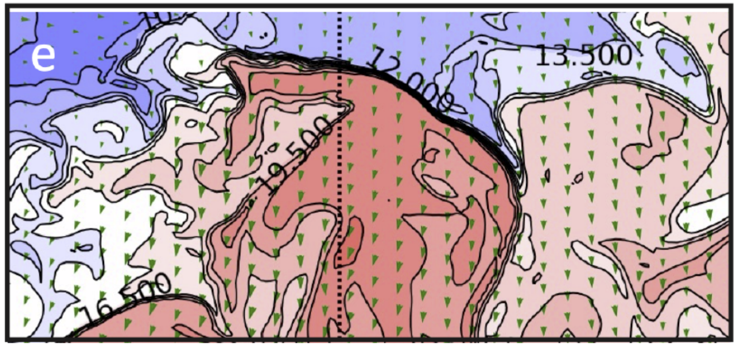


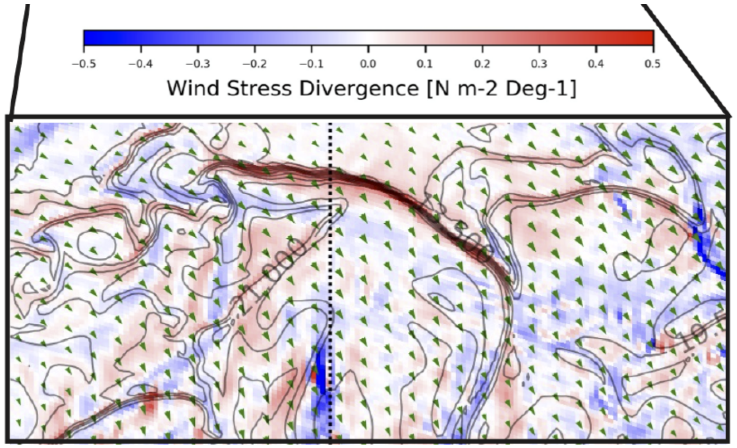
Courtesy of Saravanan

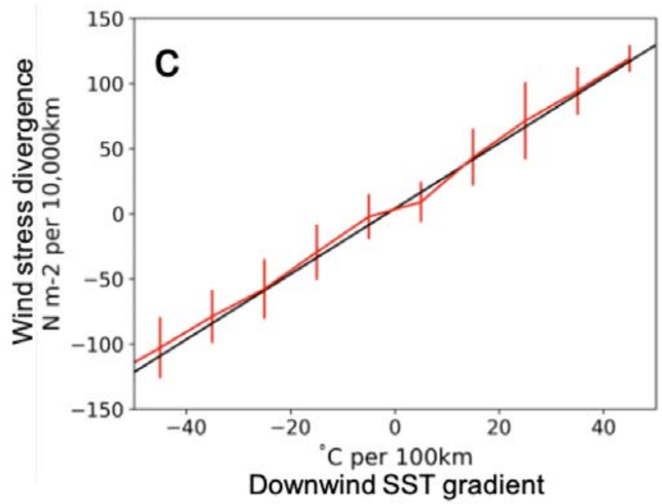
JPL/GSFC global coupled ocean-atmosphere model (2-4 km in the ocean and 6 km in the atmosphere)

Strobach et al. (2021)

SST anomalies in the GS







Windstress divergence is two orders of magnitude larger than found 15 years ago!

Latent heat fluxes are increased by 20-30% because of SST fronts through wind stress divergence !

How SWOT observations can help to better diagnose the eddy impacts on air-sea interactions?

We can infer SST fronts at small-scale from SWOT observations and low-res microwave SST (AMSR-2,3). This requires to use Lagrangian methods such as those developed by Berti and Lapeyre (2014). But we do need other satellite observations (ASCAT1,2, WaCM).

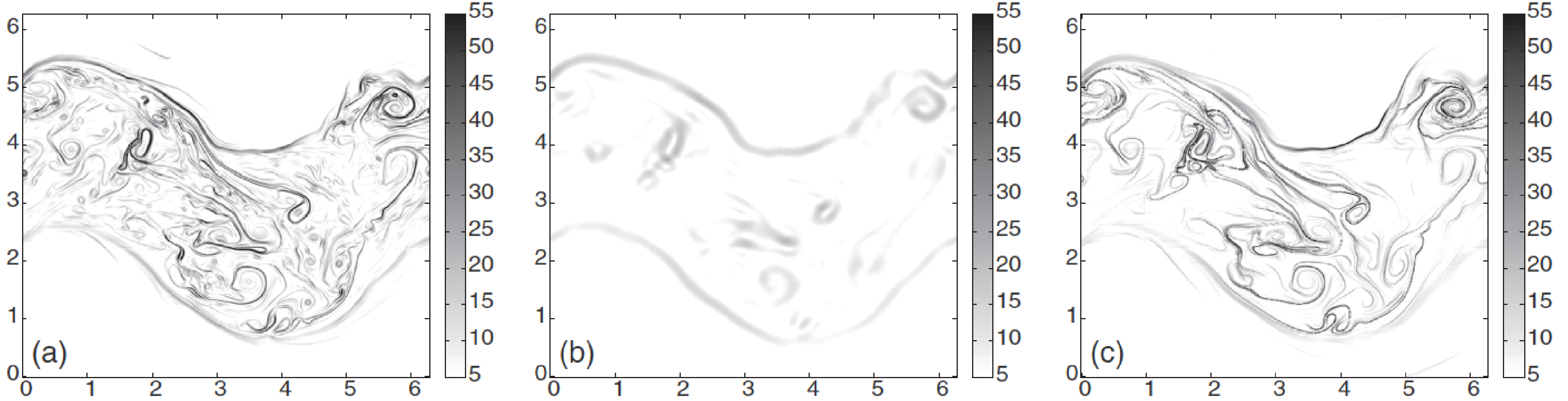


Fig. 5. Intensity of temperature gradients $|\nabla\theta'|$: original field at time t_0 (a), low-resolution field at the same time (b), reconstructed field at t_0 for $\tau_a = 8\tau_{lr}$ (c).

Berti & Lapeyre 2014

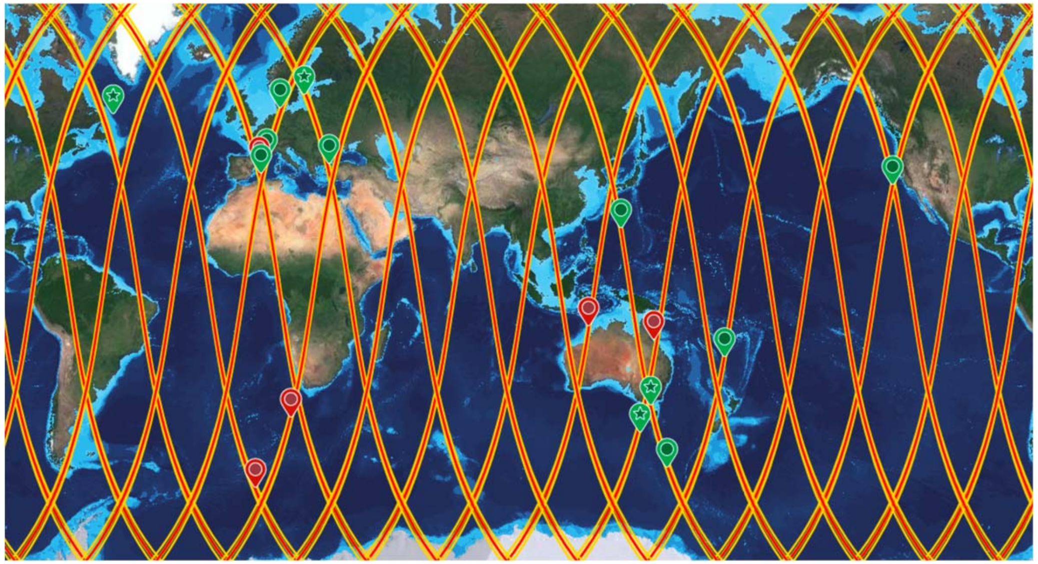
- **Mesoscale eddies** heat the atmosphere.
- Models (Chang et al. 2020) indicate that, although localized in the WBCs and the ACC, these eddies **affect the global atmosphere**, which leads to increase the ocean's heat absorption capacity.

- We need global observations to confirm the impact of ocean eddies on the physical climate system and to improve models.

- SWOT will be a determinant component in a global observing system. But **to better infer the impact of smaller scales,** we will need to exploit the synergy of using SWOT with existing satellite observations such as AMSR-E, SMOS, ASCAT, SAR images, … , and also future satellite observations such as WaCM (Winds and Currents Mission).

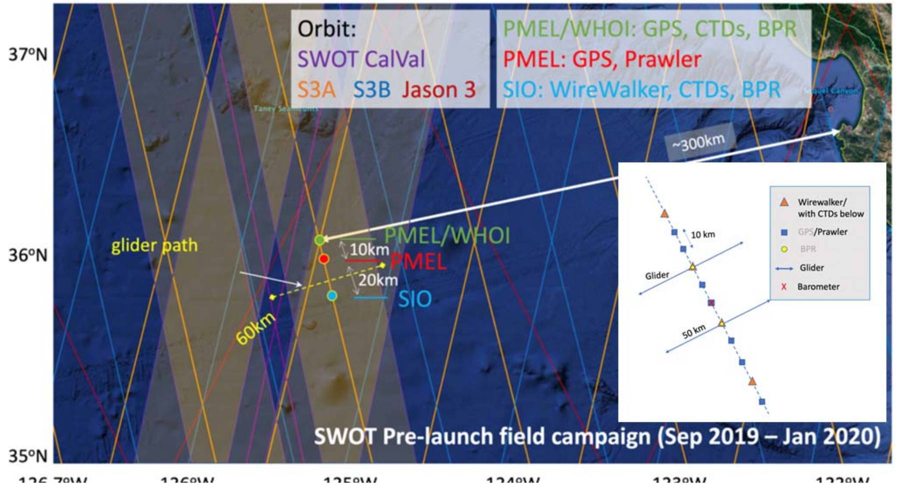
- In addition, …

Opportunities to connect SWOT SSH with these vertical fluxes during the Cal/Val phase and beyond



Adopt-A-Crossover
https://www.swot-adac.org/

California Xover (11 moorings, 2 gliders)



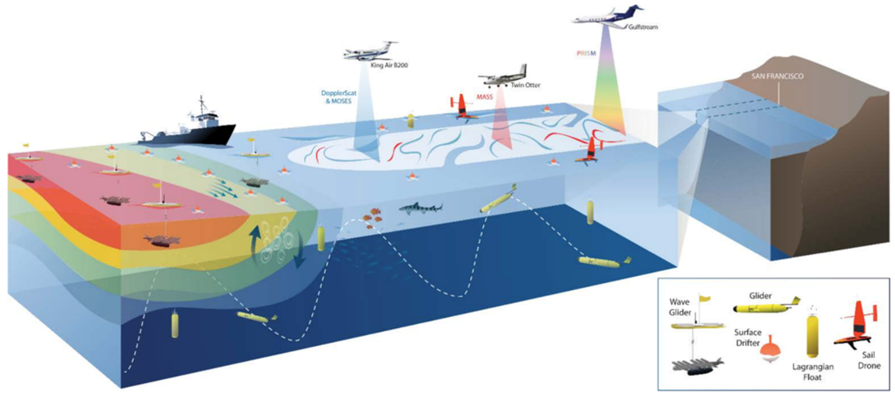


Figure 2: Schematic depiction of the S-MODE investigation. (Illustration by Jennifer Matthews, SIO.)

S-MODE final campaign overlaps with mission Cal/Val

Thank you

- Ocean eddies impact the global atmospheric circulation

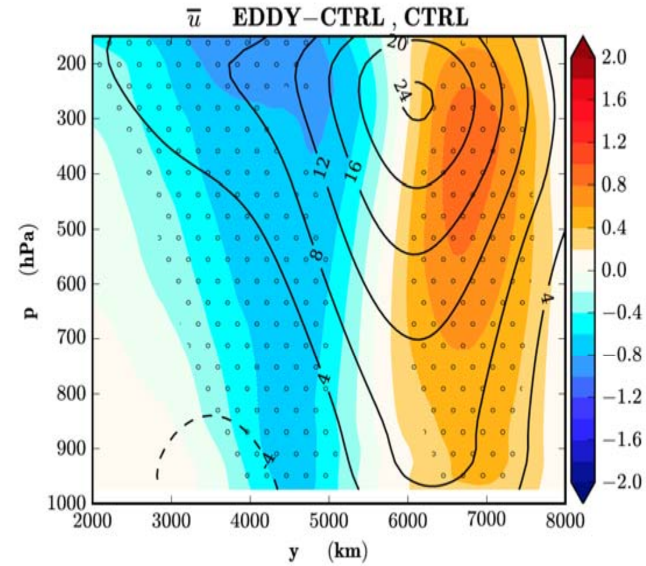
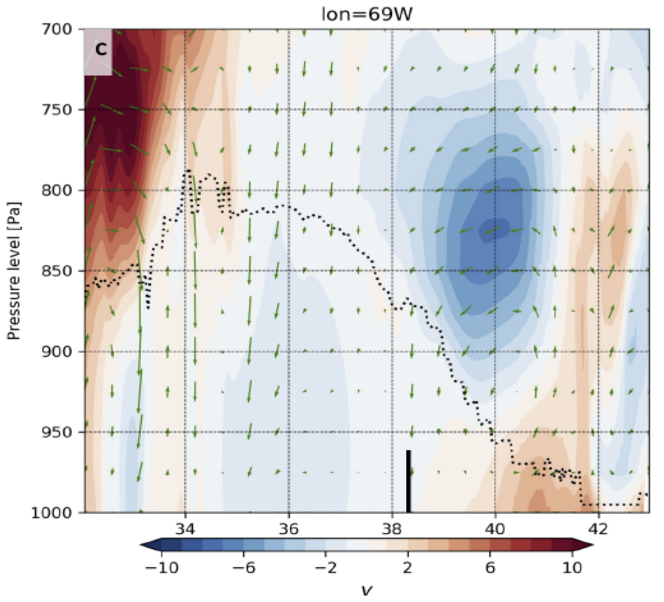
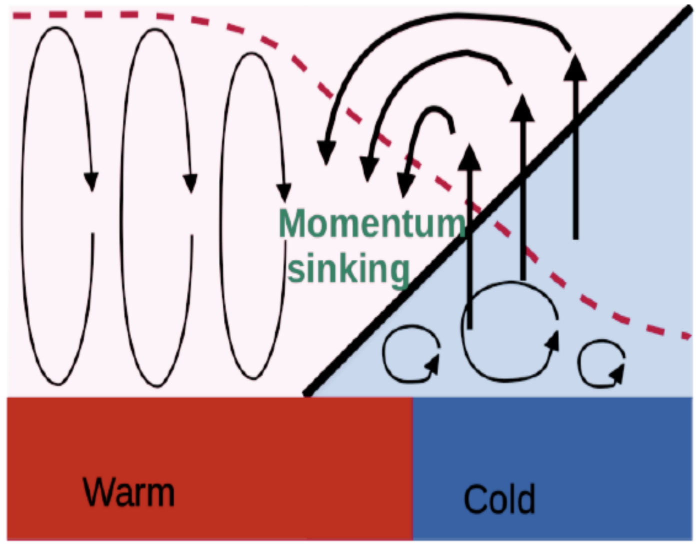


FIG. 5. Zonal and time average of zonal wind (m s^{-1}) showing the CTRL experiment (contours) and differences between EDDY and CTRL (shading). Zonal wind differences that are significant at the 95% level are stippled with black dots.

From Foussard et al. (2019)

Latent heat fluxes are increased by 30% because of SST fronts





Strobach et al. (2021)

This increase is due to the secondary circulation driven by the windstress divergence.

Impact of ocean eddies on air-sea interactions depends on the SST fronts
that border ocean eddies