Submesoscale air-sea interactions as revealed by SWOT

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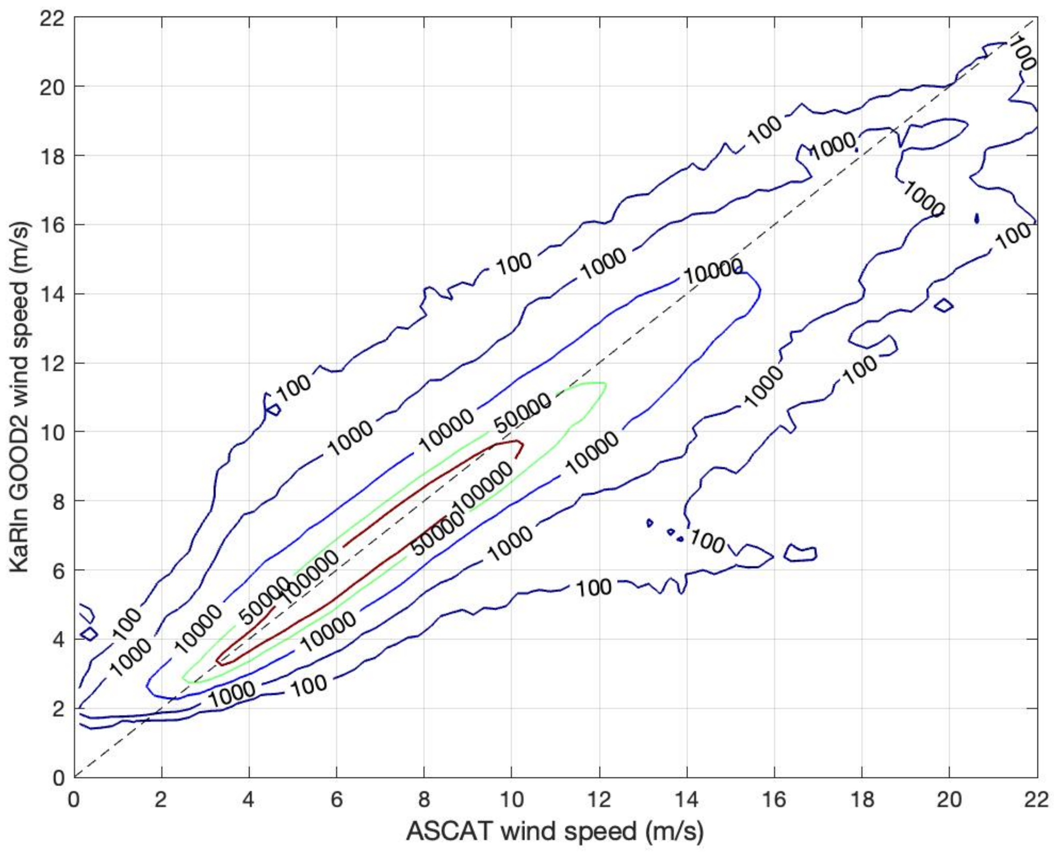
SWOT wind product: a beginners (i.e. myself) guide

SWOT behaves in first approximation as a scatterometer

- measures *backscatter coefficient* (i.e. σ_0), related to surface roughness
- σ_0 is affected by ocean surface winds and significant wave height (SWH)

$\Rightarrow$ **inverse methods to obtain wind speeds from σ_0 and SWH** (Stiles et al. 2024)

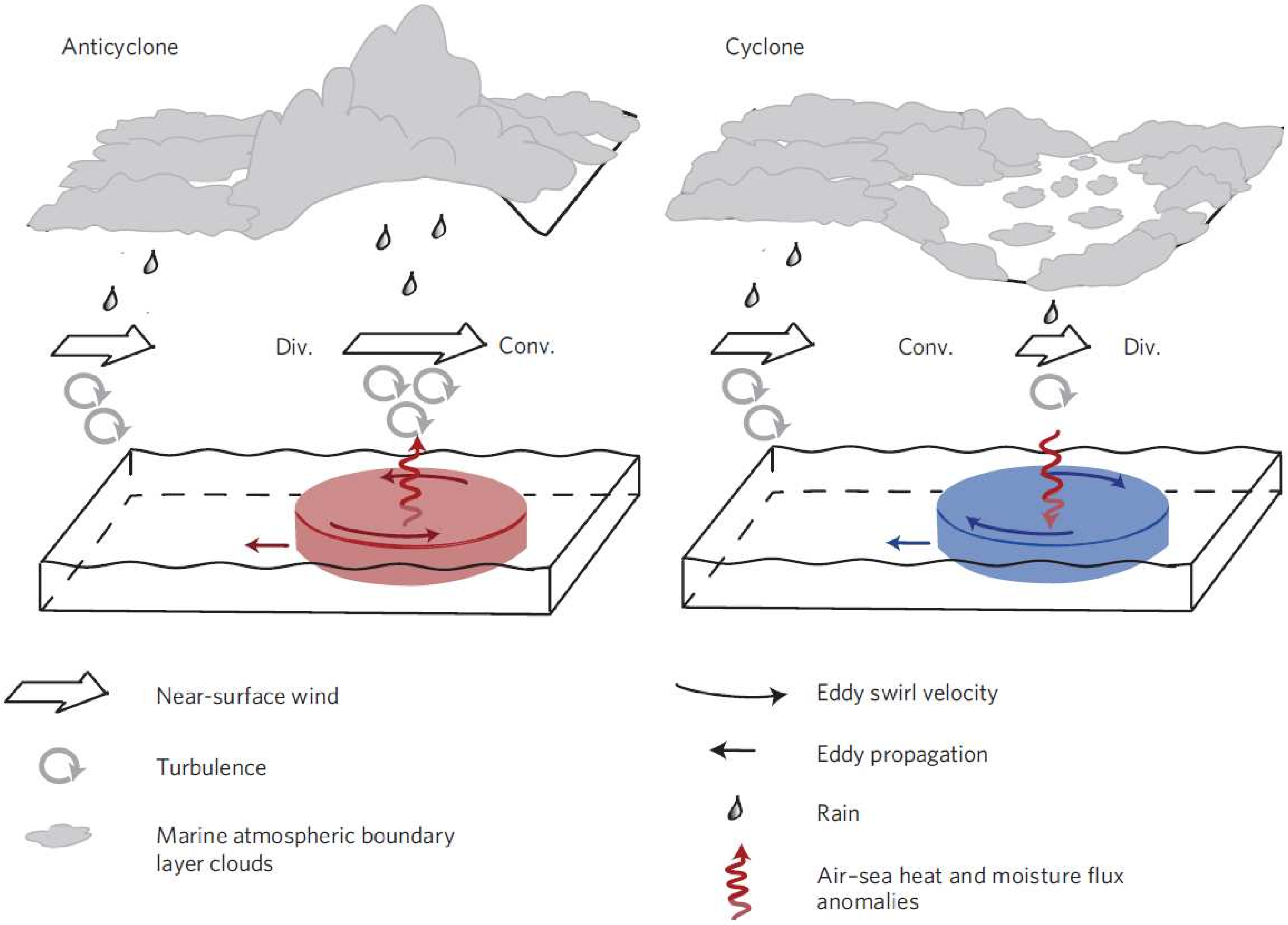
- Consistent with ASCAT and ECMWF wind speeds and buoy data in the tropical region (Stiles et al. 2024, Dong et al. 2025)
- std error ≈ 1 m s^{-1}



Differences from a scatterometer:

- No wind direction, only wind speed
- SSH and wind speed at 2 km resolution

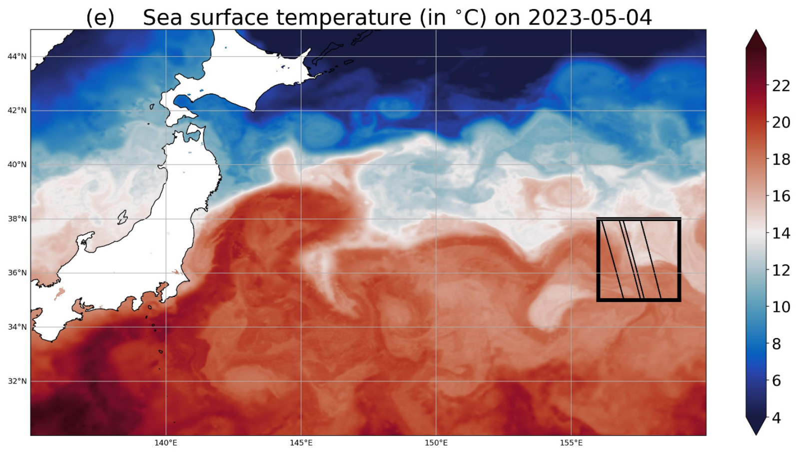
Mesoscale air-sea interactions: an expert (i.e. myself) guide

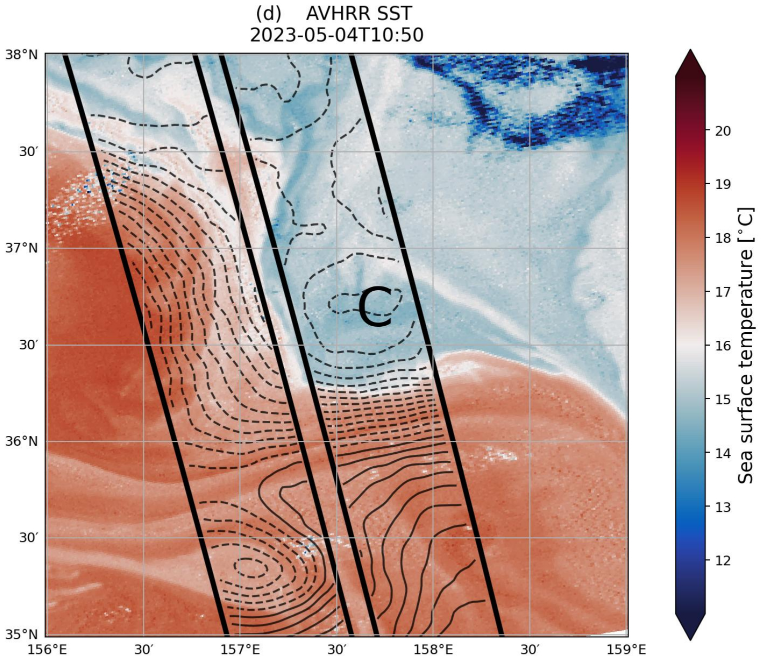


(Frenger et al. 2013, composites over 600k eddies)

also visible in instananeous winds?

Impact of SST in the Kuroshio Extension region





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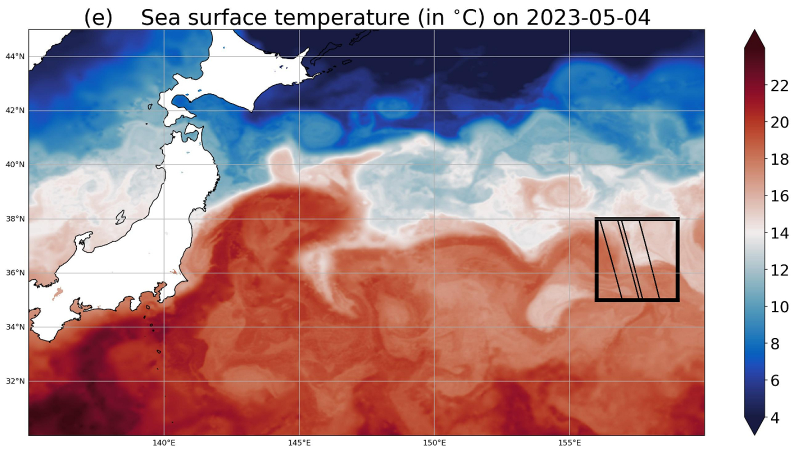
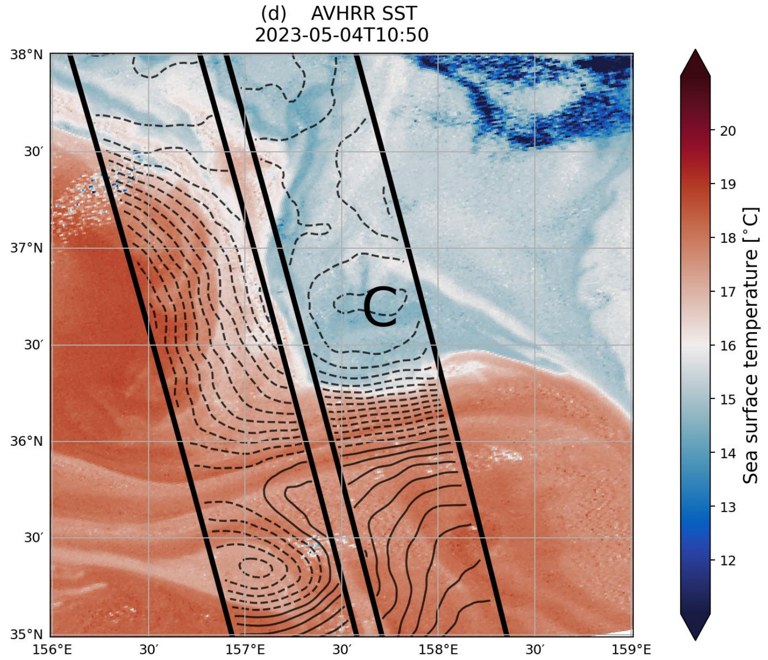
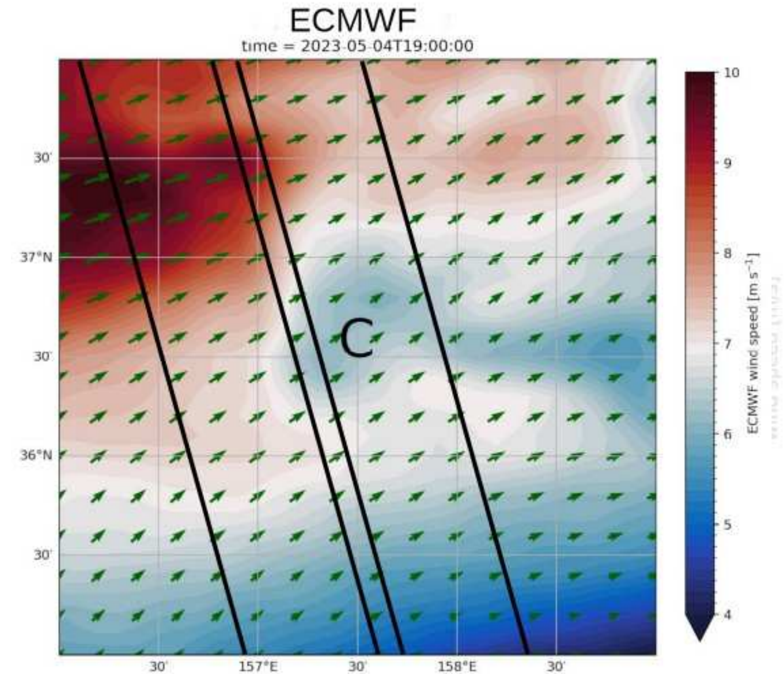
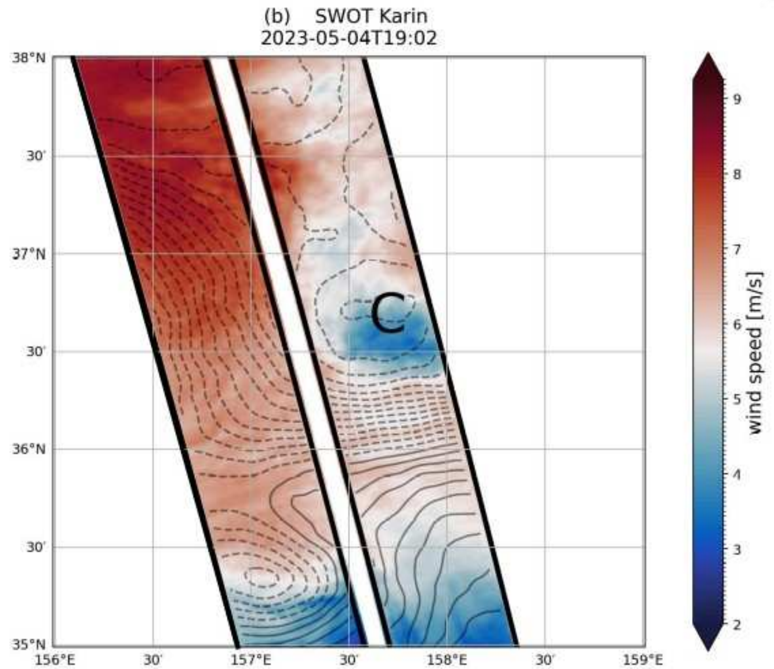


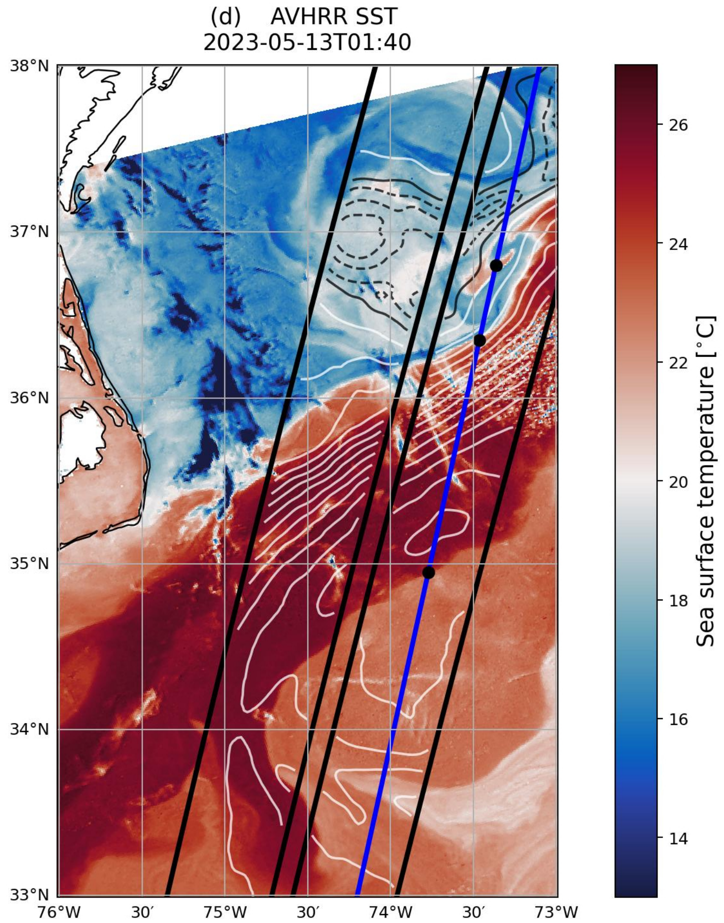


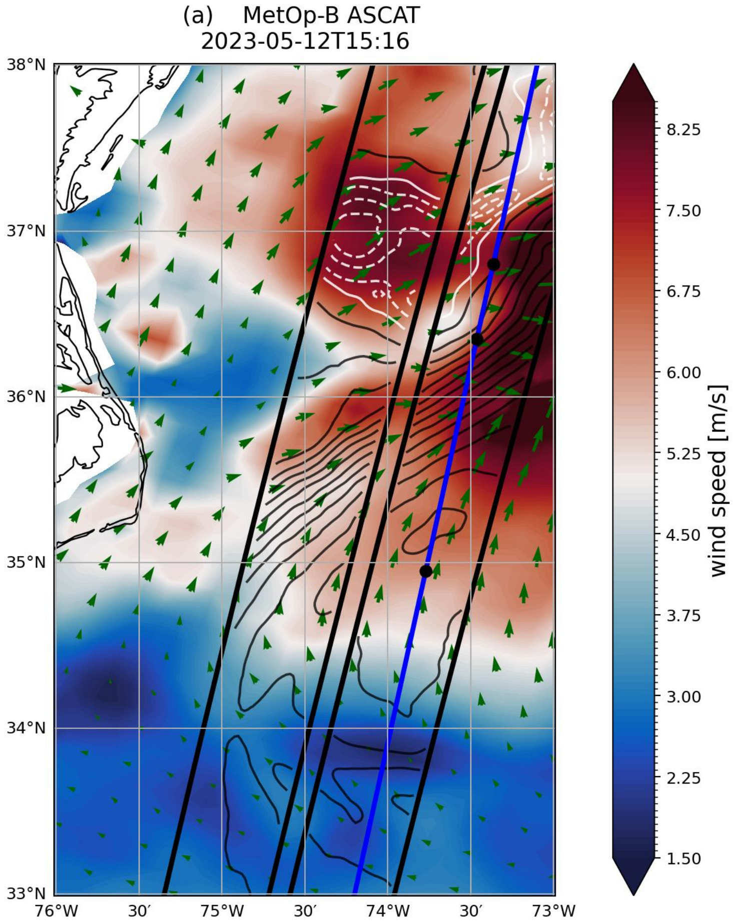
- SWOT and ECMWF qualitatively agree
- Wind anomaly over cold eddy (50 km diameter)





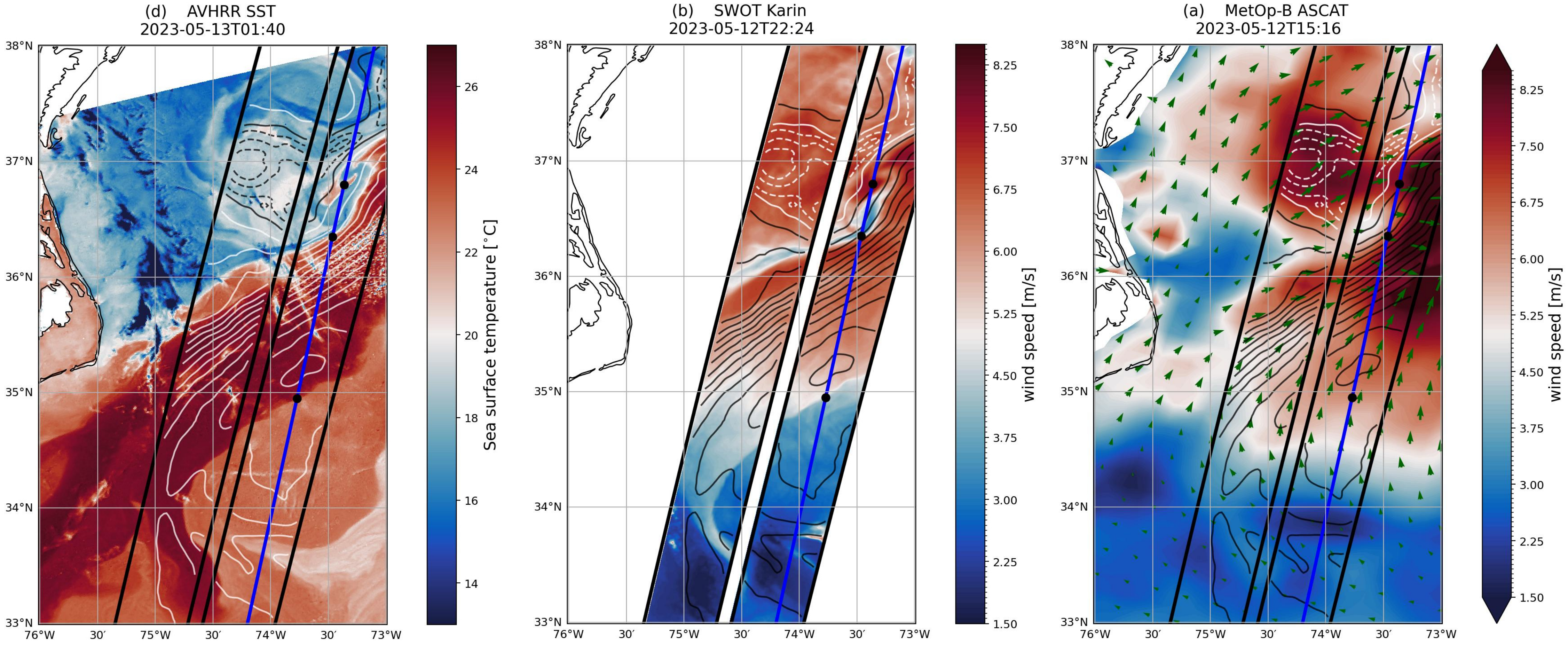
Impact of SST in the Gulf Stream region





- AVHRR SST at 1 km resolution; SWOT at 2 km; ASCAT at 30 km
- The cold filament of ≈ 50 km width seen in ASCAT

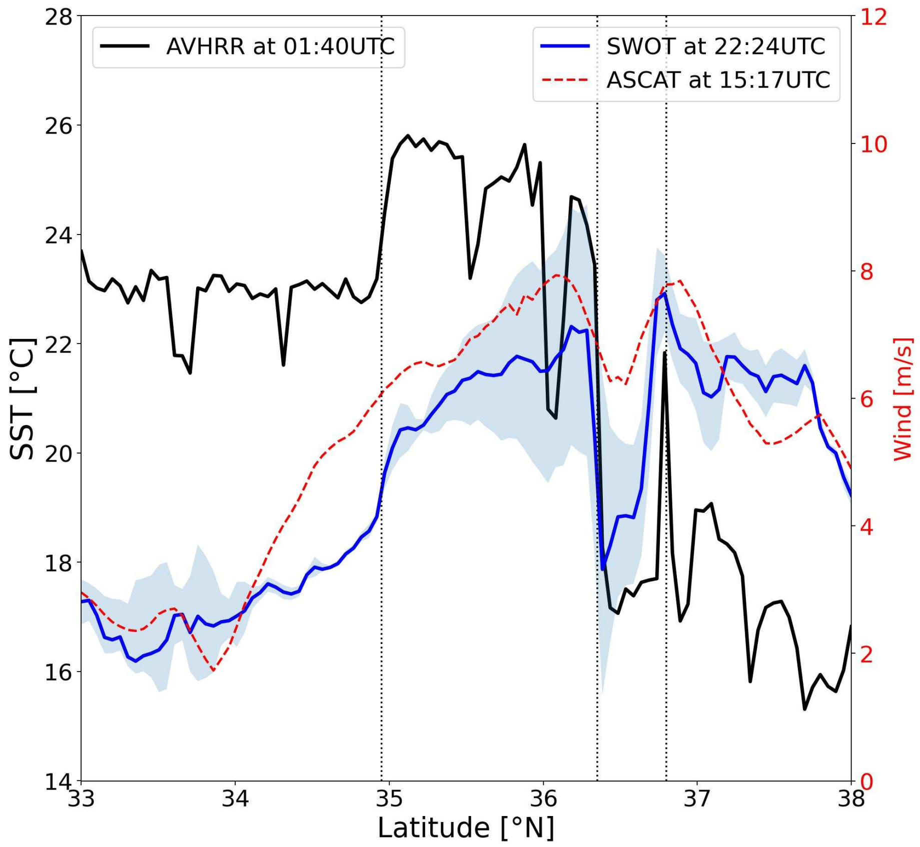
Impact of SST in the Gulf Stream region



- The cold filament of ≈ 50 km width seen in ASCAT and 15 km in SWOT
- SWOT and ASCAT qualitatively agree
- Submesoscale frontal structures visible in SWOT
  - Strong correspondence with SST anomalies (correlation coefficient 0.44 at submesoscales)

Section across the submesoscale filament

- Wind decrease much larger for SWOT
  - change of 3 m s^{-1} for $6°$C over 15 km



Section across the submesoscale filament

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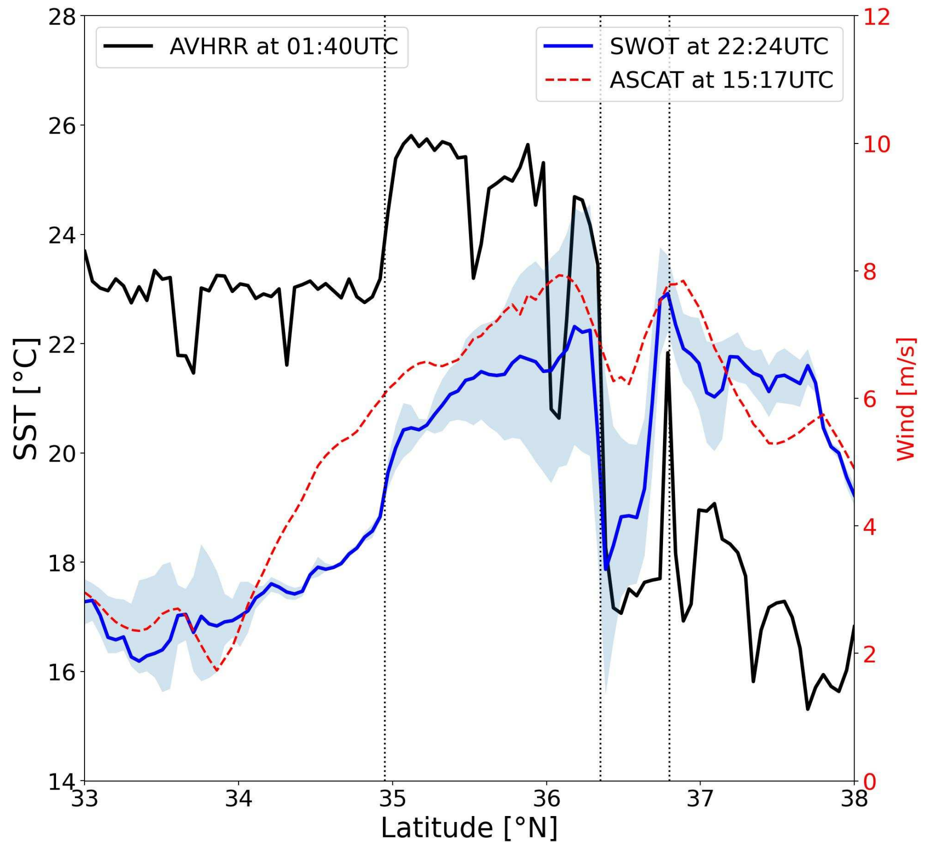
Why?

- Effect of SST on the instrument?
  - < 0.3ms^{-1} (Stiles et al.)
    $\Rightarrow$ not instrumental effect



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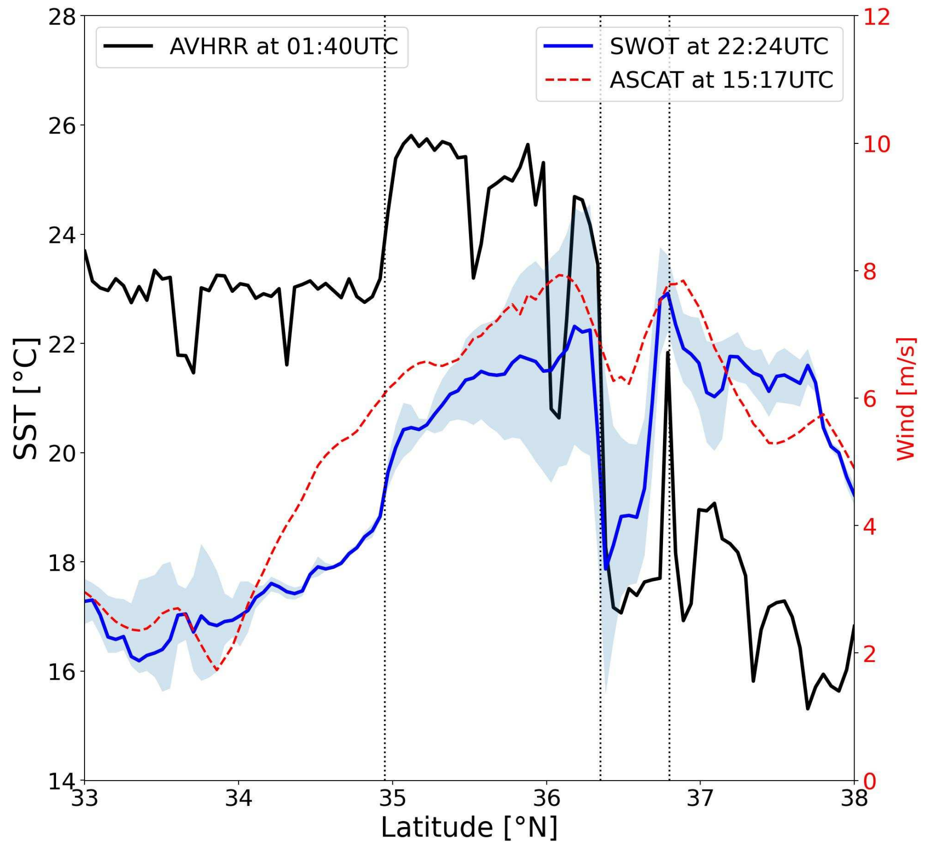
Why?

- Role of ocean currents?
  - SWOT and scatterometers measure winds relative to ocean currents

$$U_{SWOT} = |\boldsymbol{U}_{wind} - \boldsymbol{U}_{current}| \approx |\boldsymbol{U}_{wind}| \pm |\boldsymbol{U}_{current}|$$



Shading: $U_{SWOT} \pm U_{current}$

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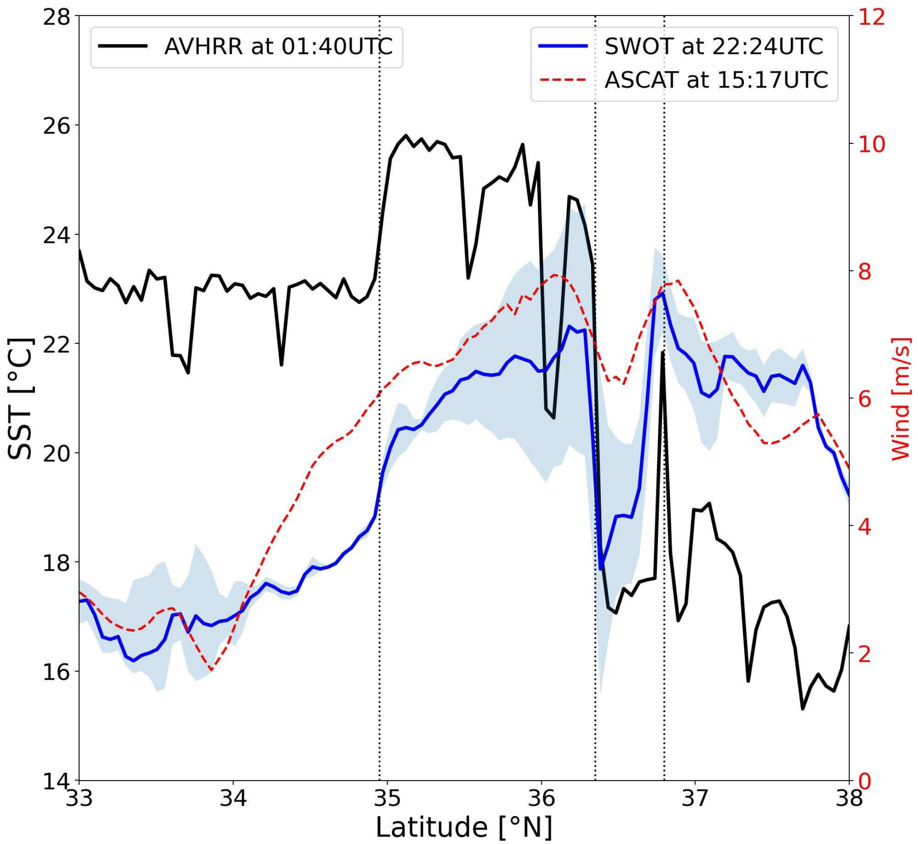
- not here $\Rightarrow$ variations of winds at submesoscales essentially driven by SST variations
- related to physical processes:
  - stability of atmospheric boundary layer



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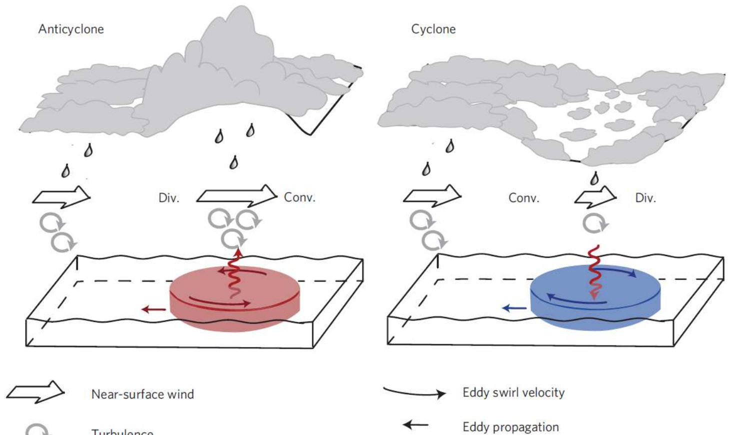

Conclusions

- SWOT measures SSH but also wind speed at the same resolution and same time
- In specific regions,
  - clear signature of submesoscale SST anomalies on instantaneous winds
  - coupling coefficients (wind vs. SST, 0.2 m s^{-1} °C^{-1})
    similar to numerical coupled simulations and in situ campaigns

Perspectives

- Needs a more general assessment on global scales
- Situations such as wind rolls, rail cells, others... can dominate the signal
- Confrontation with coupled simulations at high resolution still needed

Kaouah et al. (Geophysical Research Letters, 2025, in press)

Zoom on the Gulf Stream region