Environmental Control of Wind Response to Sea Surface Temperature Patterns From Remote Sensing Data

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Session A.08.04

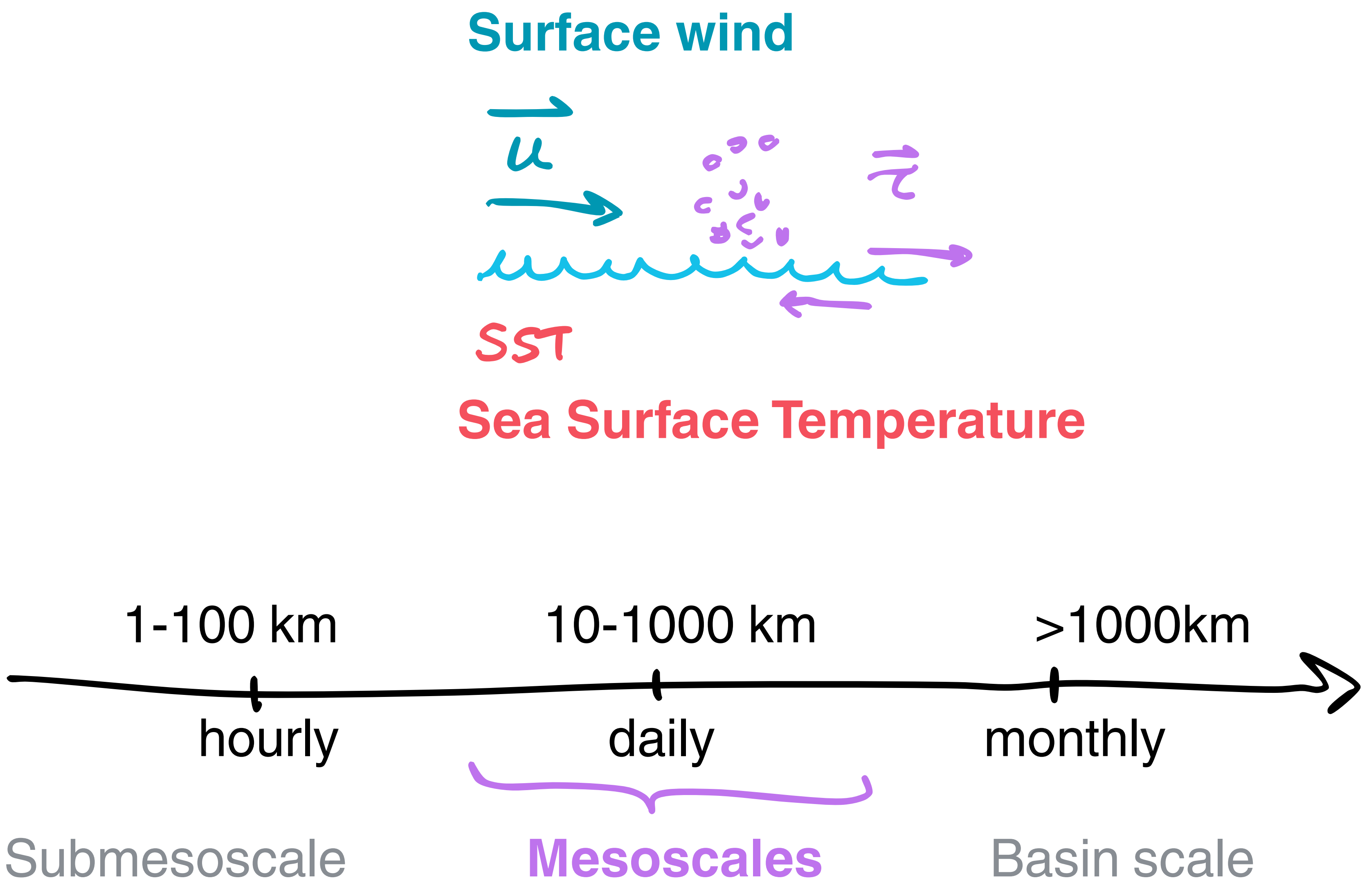
Submesoscale air-sea interactions: understanding, observability and impact

Air-Sea Interactions

... narrowing down

SST-wind coupling

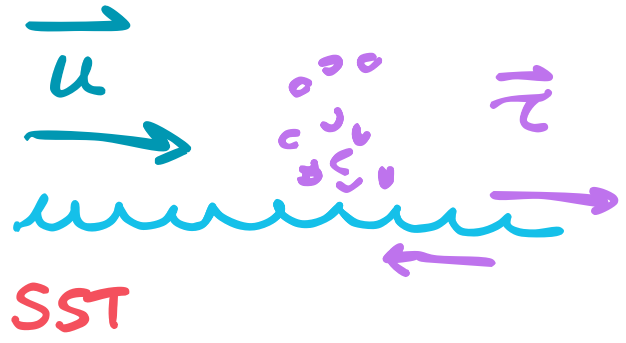
SST features drive Marine Atmospheric Boundary Layer (*MABL*) wind variability



Air-Sea Interactions

... narrowing down

Surface wind



Sea Surface Temperature

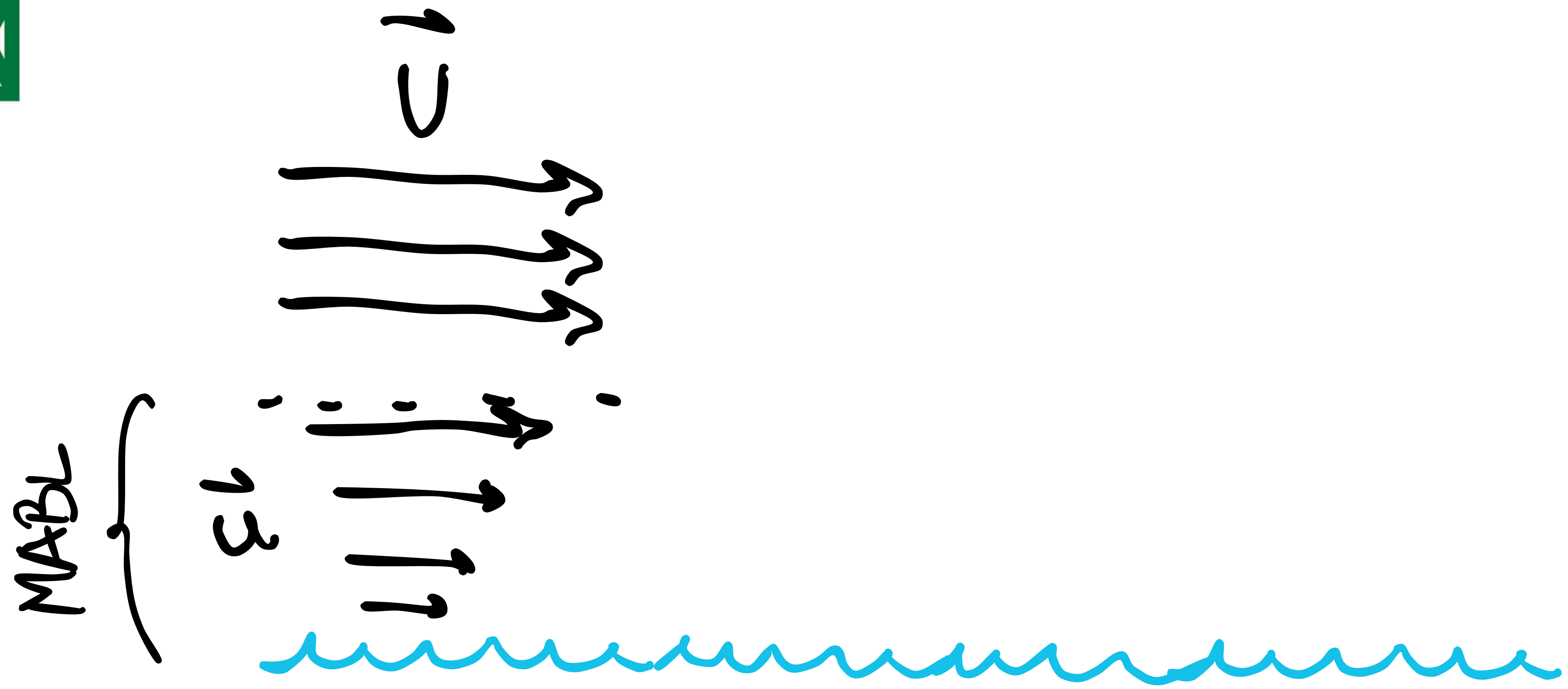
SST-wind coupling

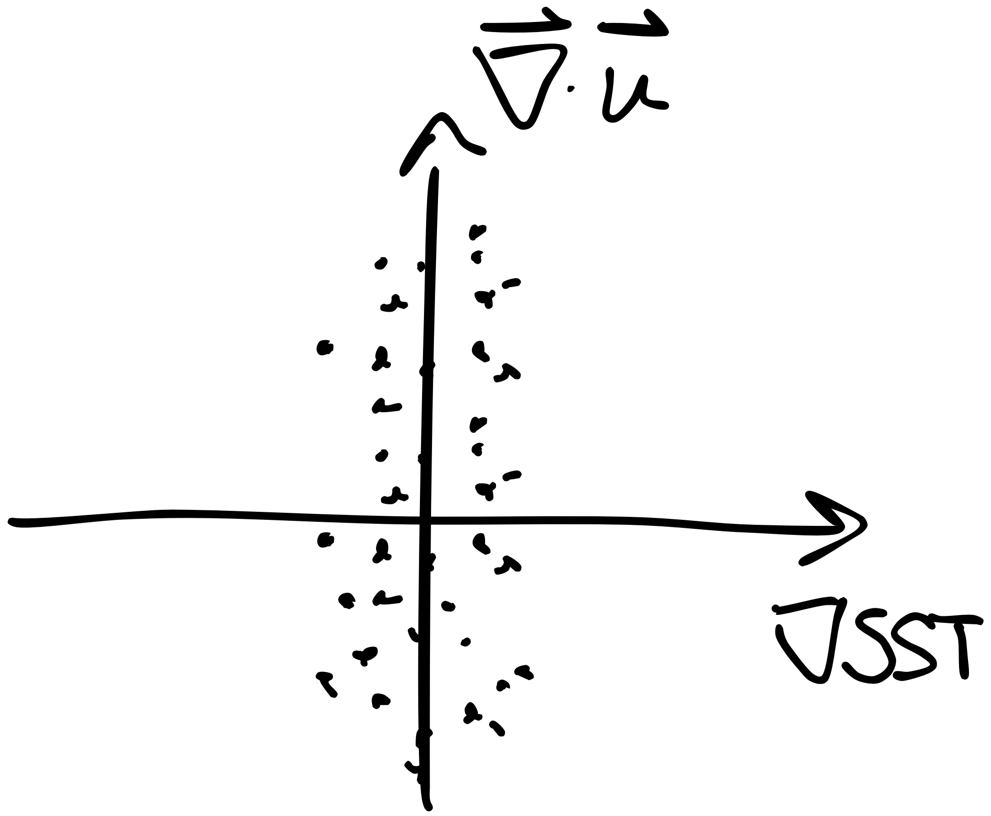
SST features drive Marine Atmospheric Boundary Layer (*MABL*) wind variability

1-100 km	10-1000 km	>1000km
hourly	daily	monthly
Submesoscale	**Mesoscales**	Basin scale

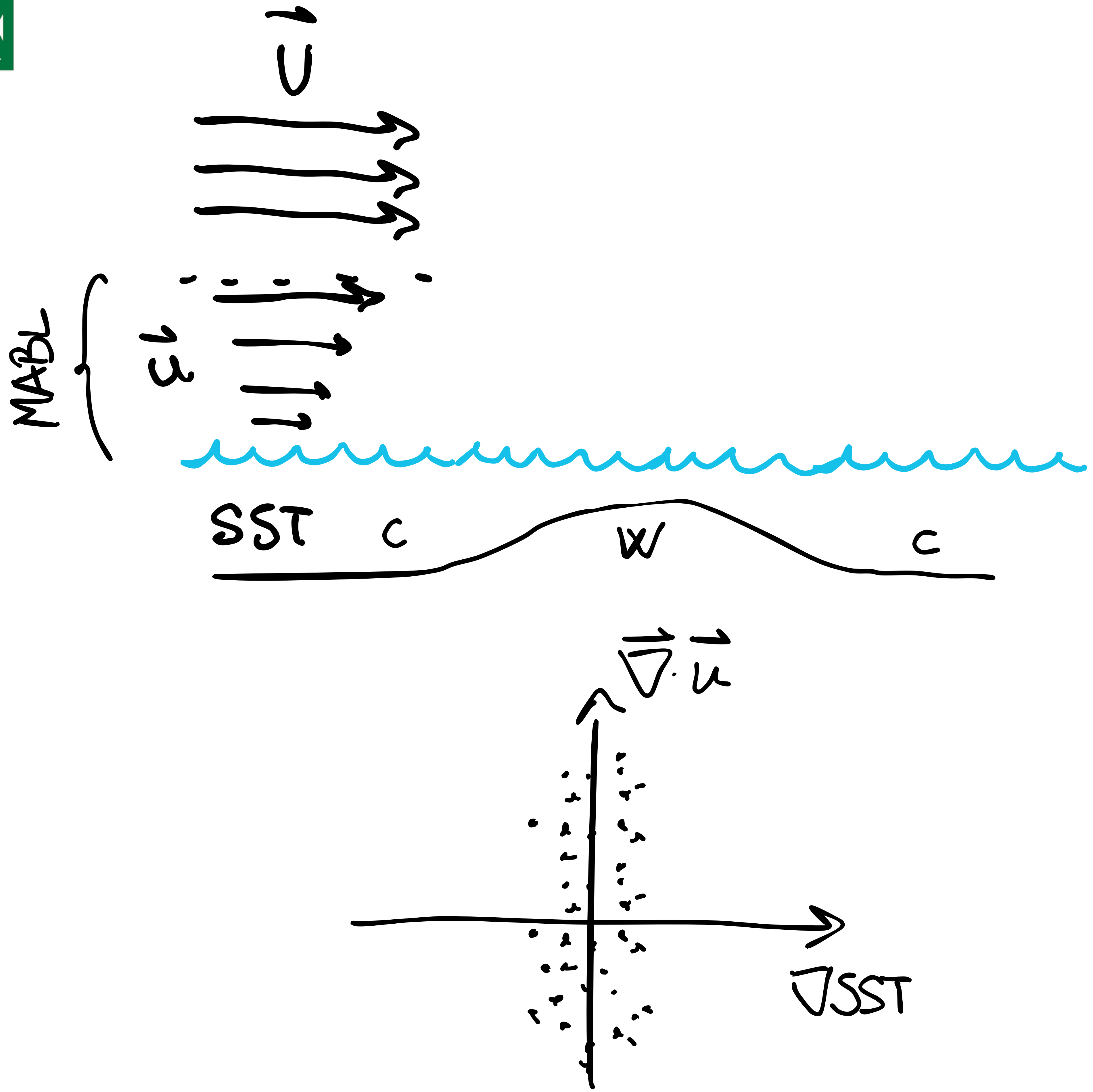
⇒ Downward Momentum Mixing (***DMM***) ⇐

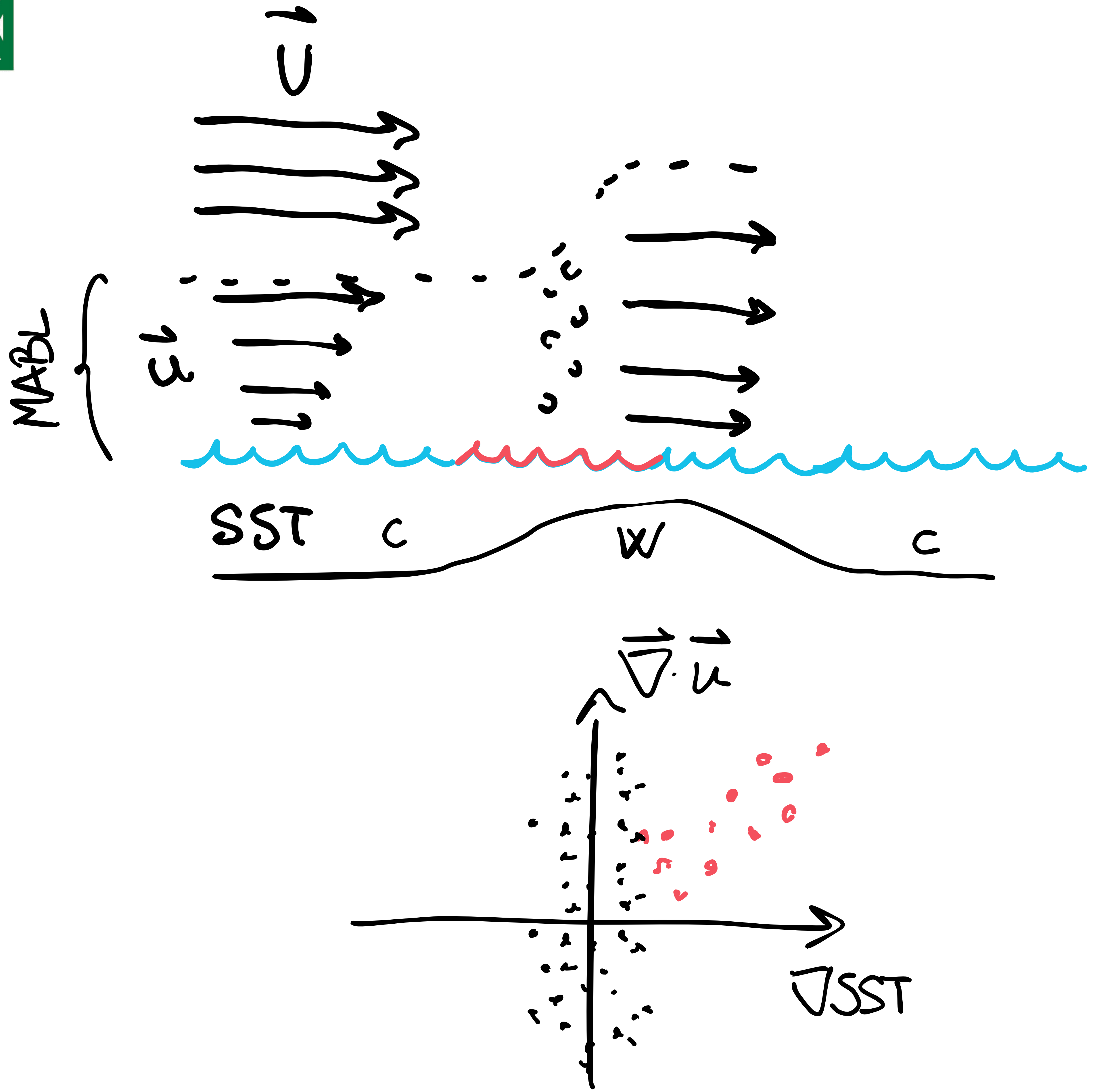
Downward Momentum Mixing (*DMM*)





Downward Momentum Mixing
(*DMM*)





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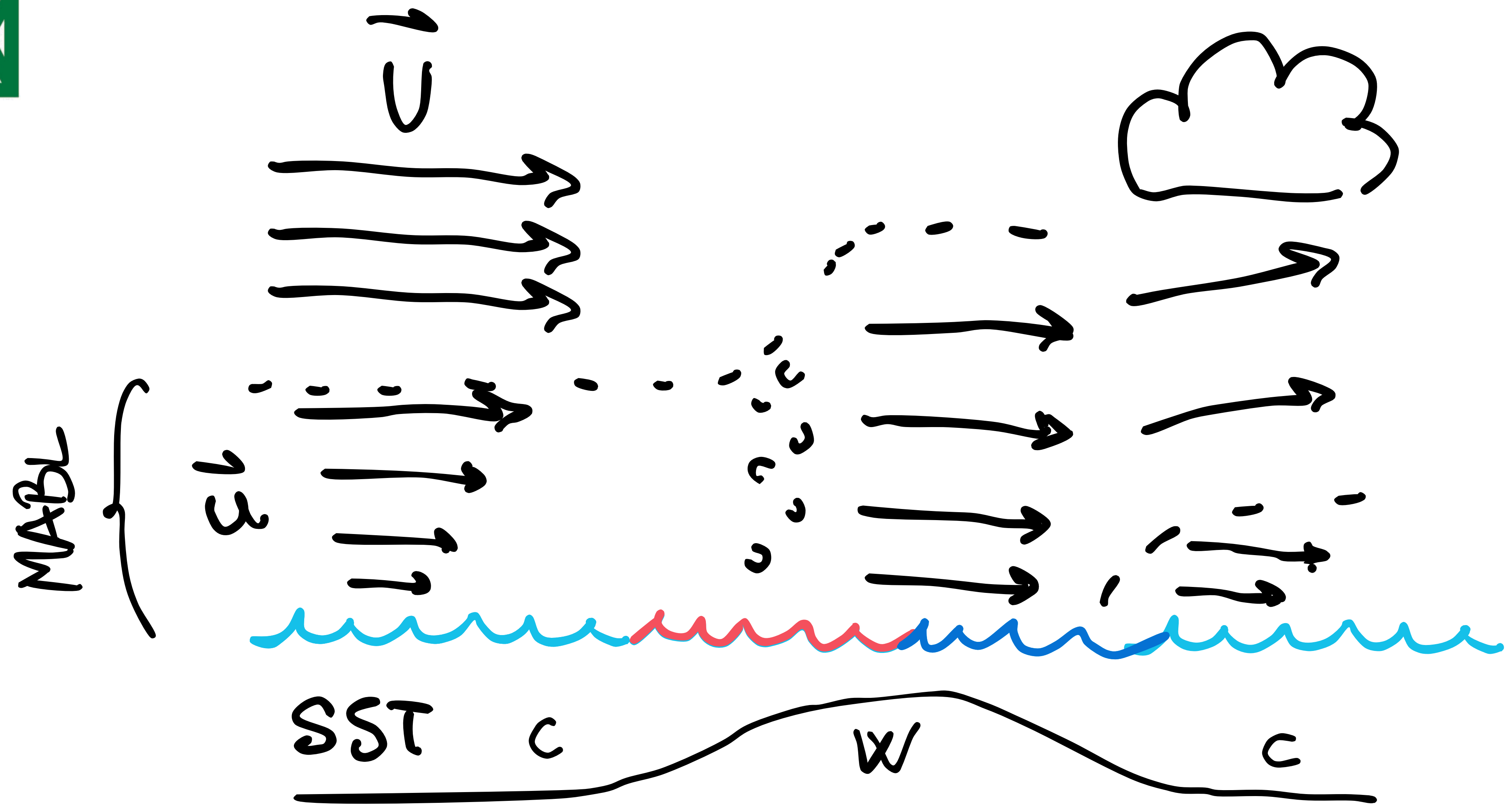
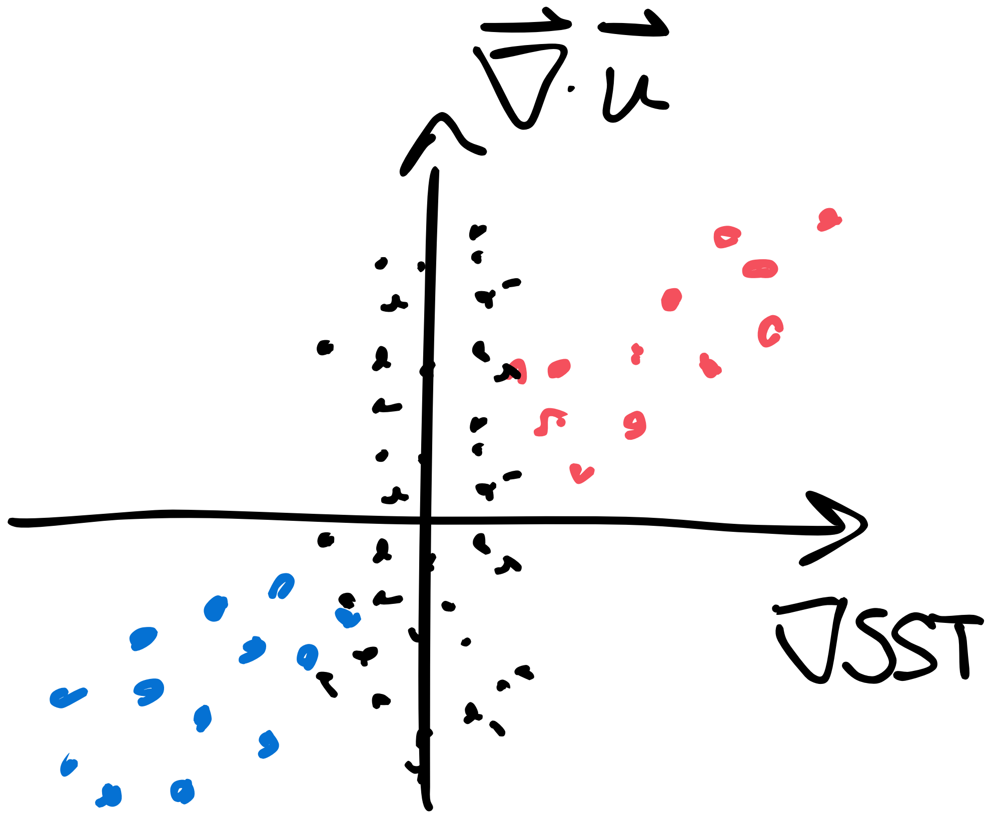
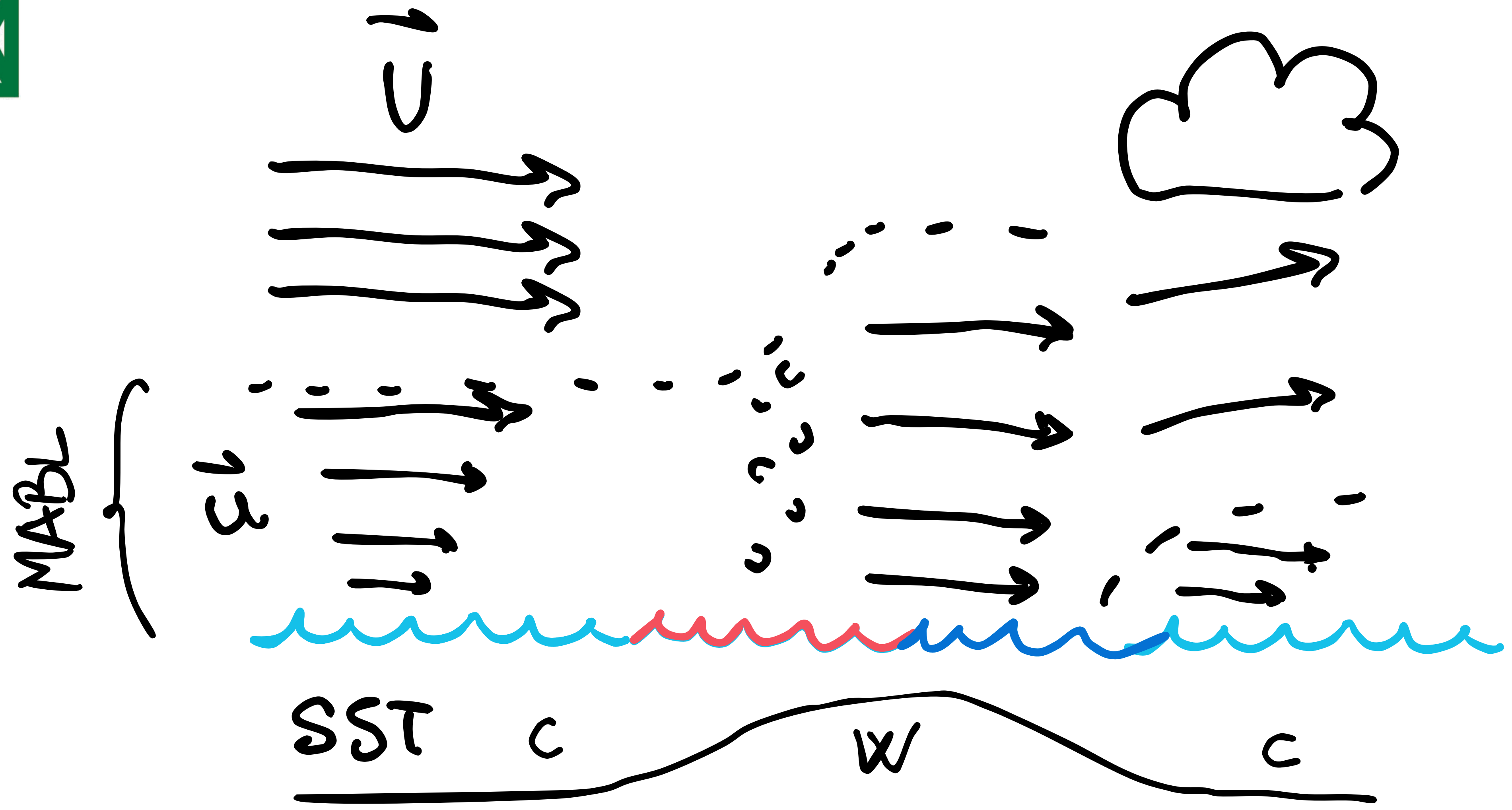
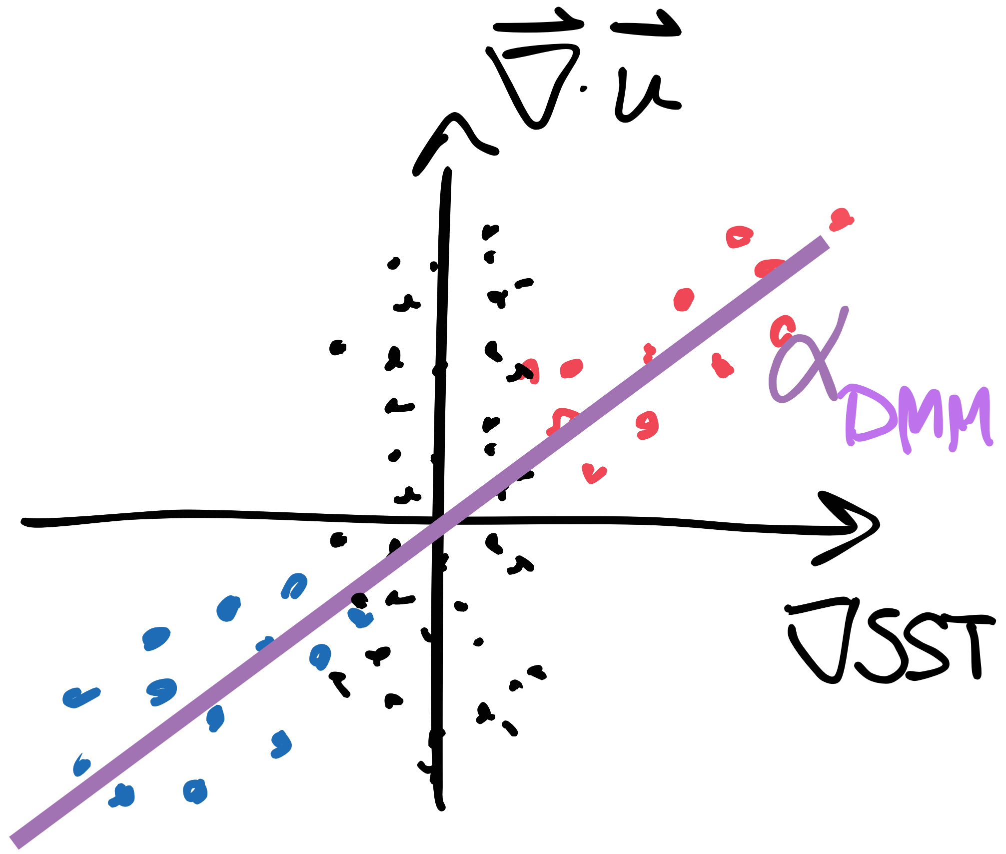




Downward Momentum Mixing (*DMM*)

Increased heat turbulent fluxes, MABL mixing and height, resulting in a vertical transport of momentum toward the surface [Hayes et al., 1989, Wallace et al., 1989]





Downward Momentum Mixing (*DMM*)

Increased heat turbulent fluxes, MABL mixing and height, resulting in a vertical transport of momentum toward the surface [Hayes et al., 1989, Wallace et al., 1989]

Along the large-scale wind direction:

$$\frac{\partial u'_r}{\partial r} = \alpha_{DMM} \cdot \frac{\partial SST}{\partial r}$$

[Meroni et al. 2023]

Mesoscale SST-wind coupling

... environmental control

Observed seasonal and regional variability in coupling intensity
[Chelton et al. 2004, O'Neill et al. 2005]

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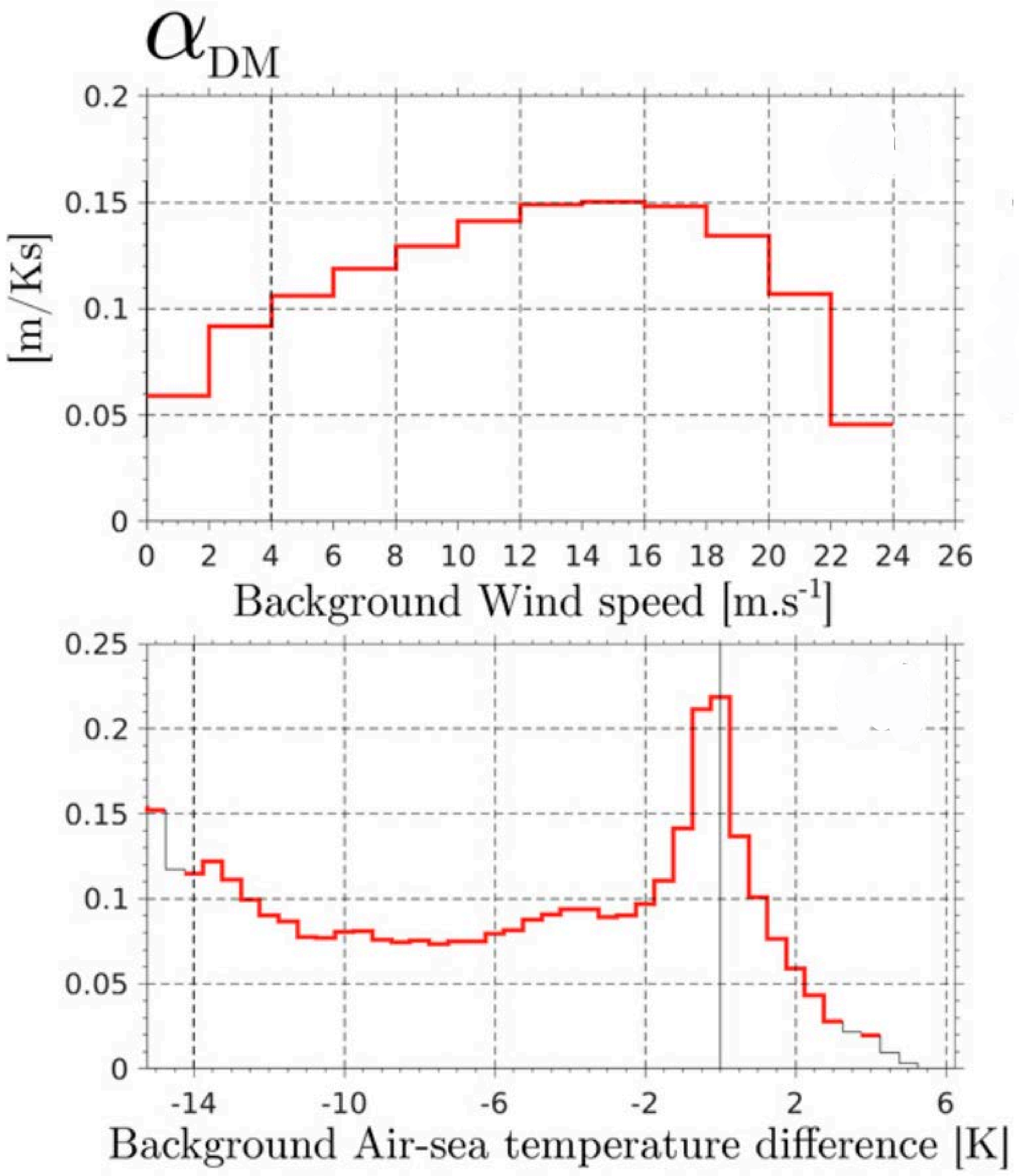
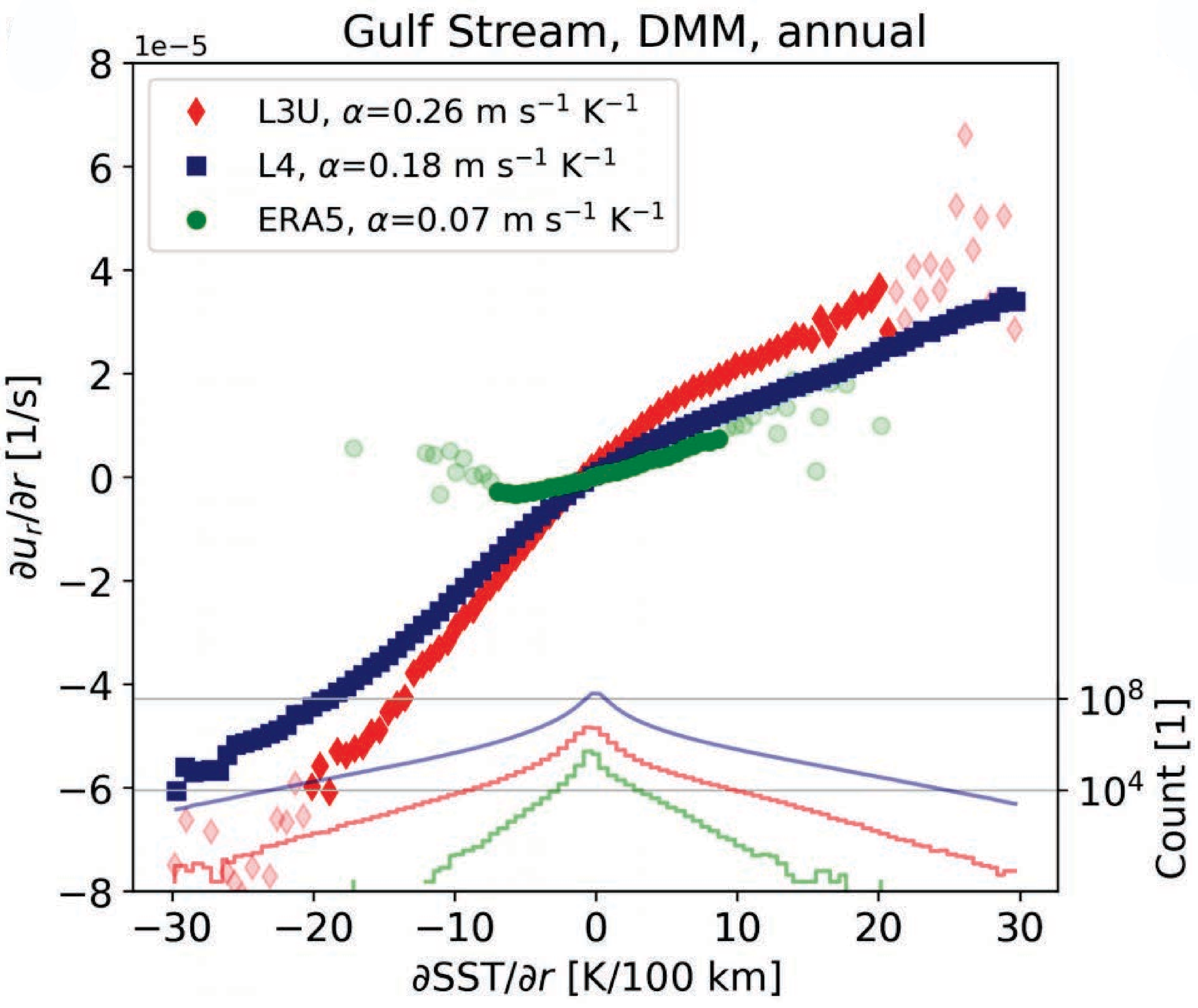
Environmental control on coupling observed in ERA5

Driven by *U*, MABL instability
[Desbiolles et al. 2023]



Mesoscale SST-wind coupling

... models and observations



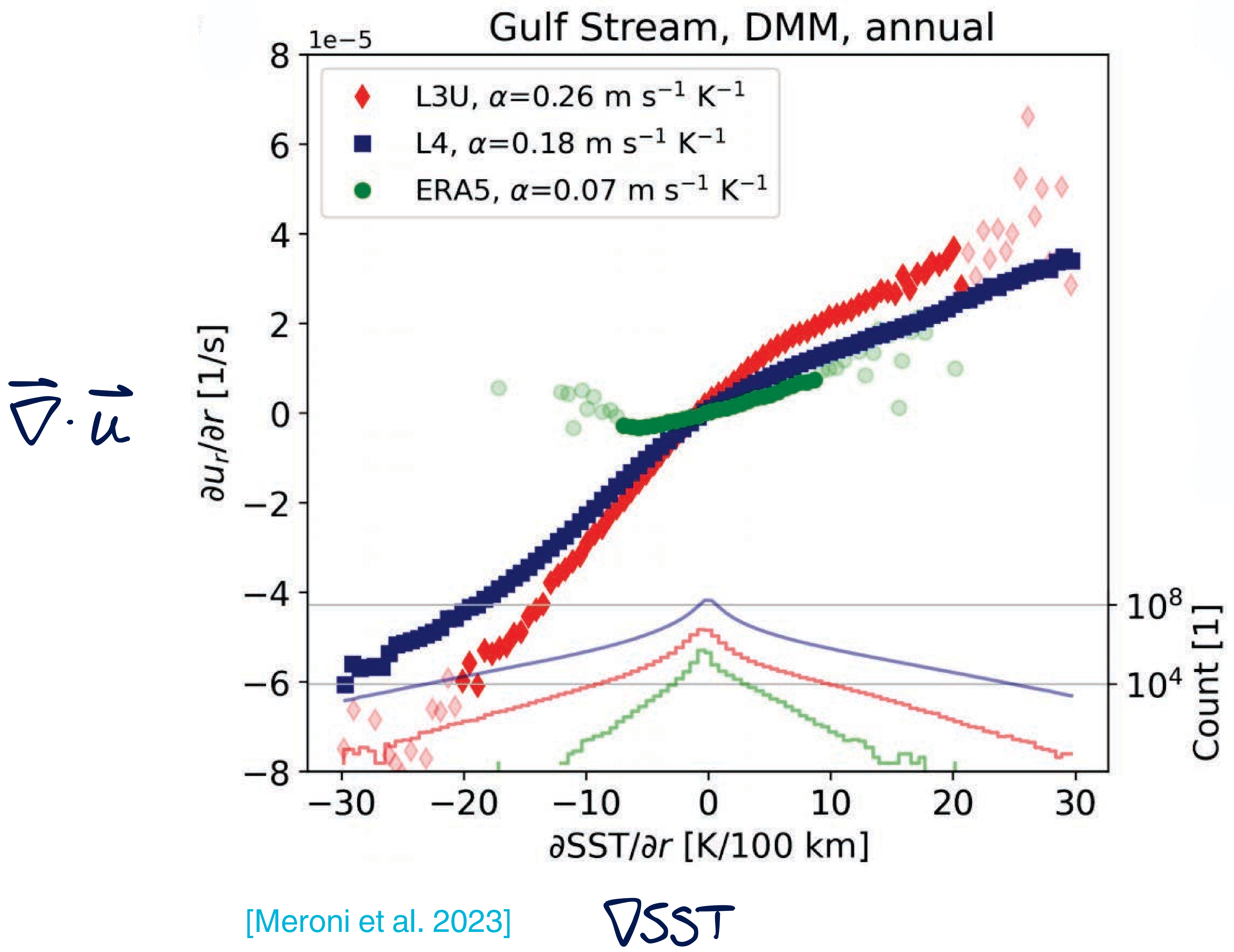
$\vec{\nabla}\cdot\vec{u}$

∇SST

[Meroni et al. 2023]

Variability between different products and models

[Bryan et al. 2010; Meroni et al. 2023]



[Meroni et al. 2023]

Mesoscale SST-wind coupling

... models and observations

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$\Downarrow$

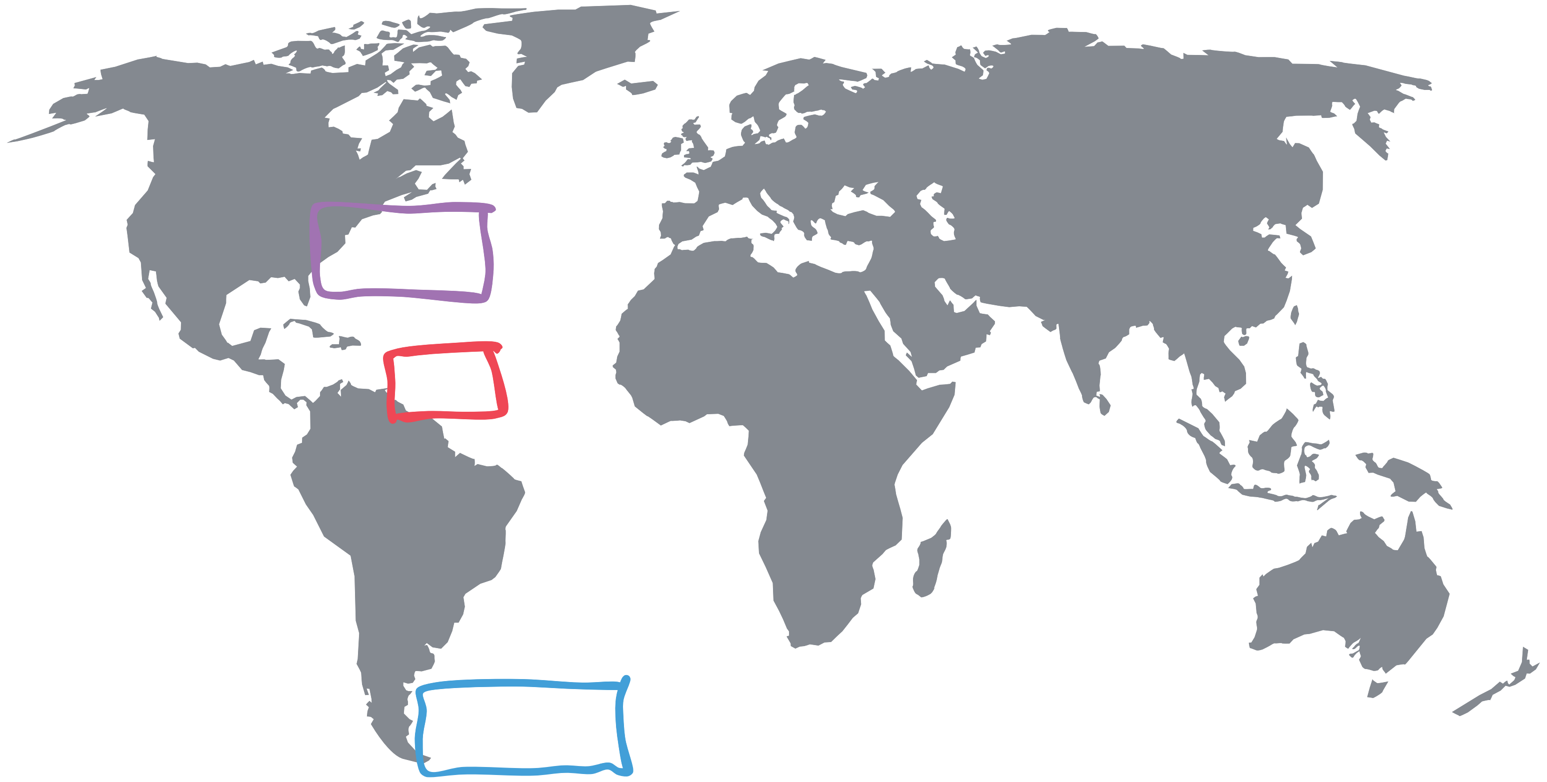
Research question

Is the physical interpretation of environmental control from models matched by observations?

SST, wind and environmental conditions datasets

Regional analyses

Gulf Stream, *Tropical Atlantic*, *Malvinas*



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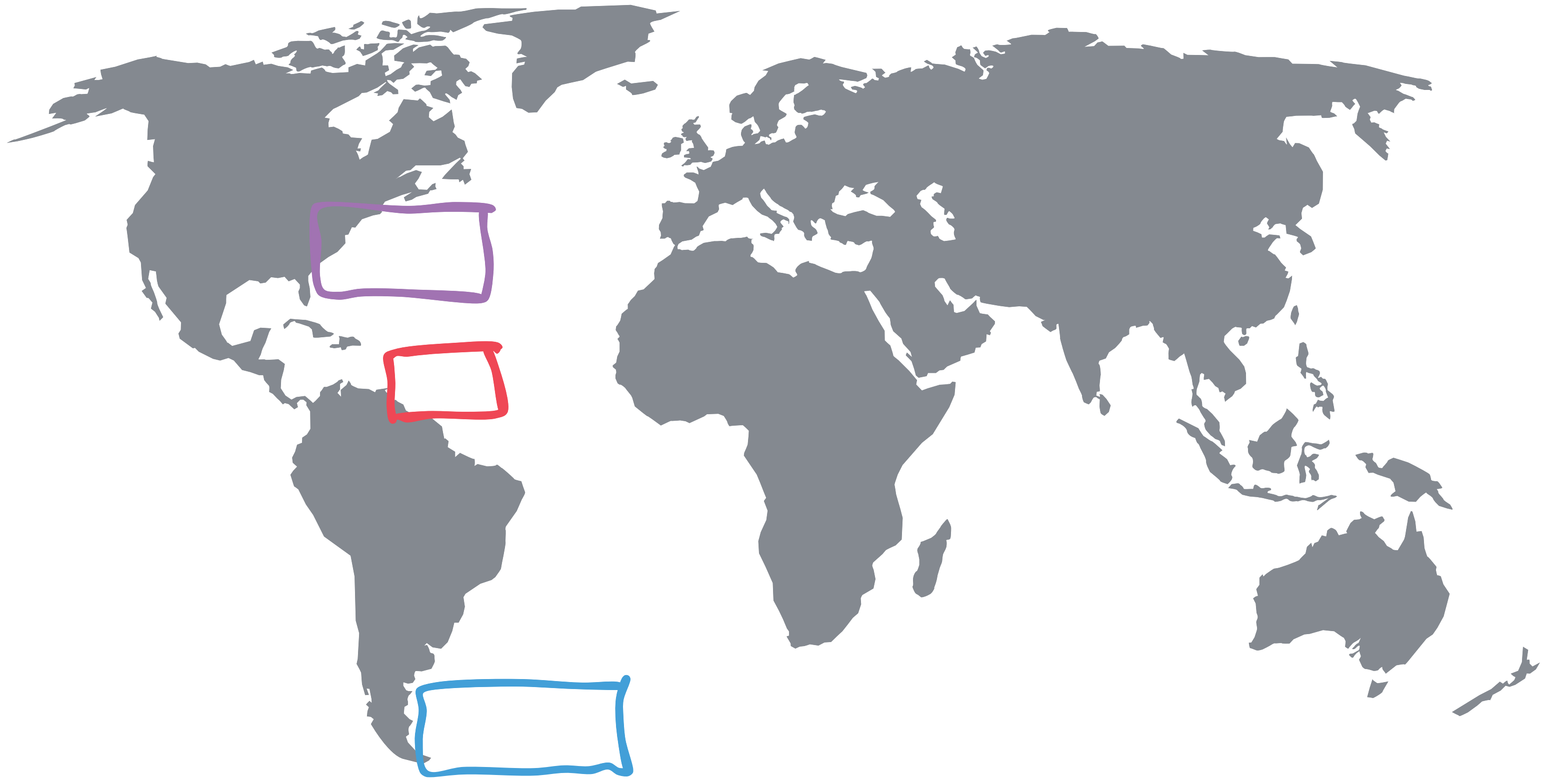

Colocated estimates of wind and SST for coupling computation

MetOp A, 2020-2021

ASCAT wind - 12.5km

AVHRR SST - 5km

ERA5 re-analysis

25km resolution

~ Desbiolles et al. 2023

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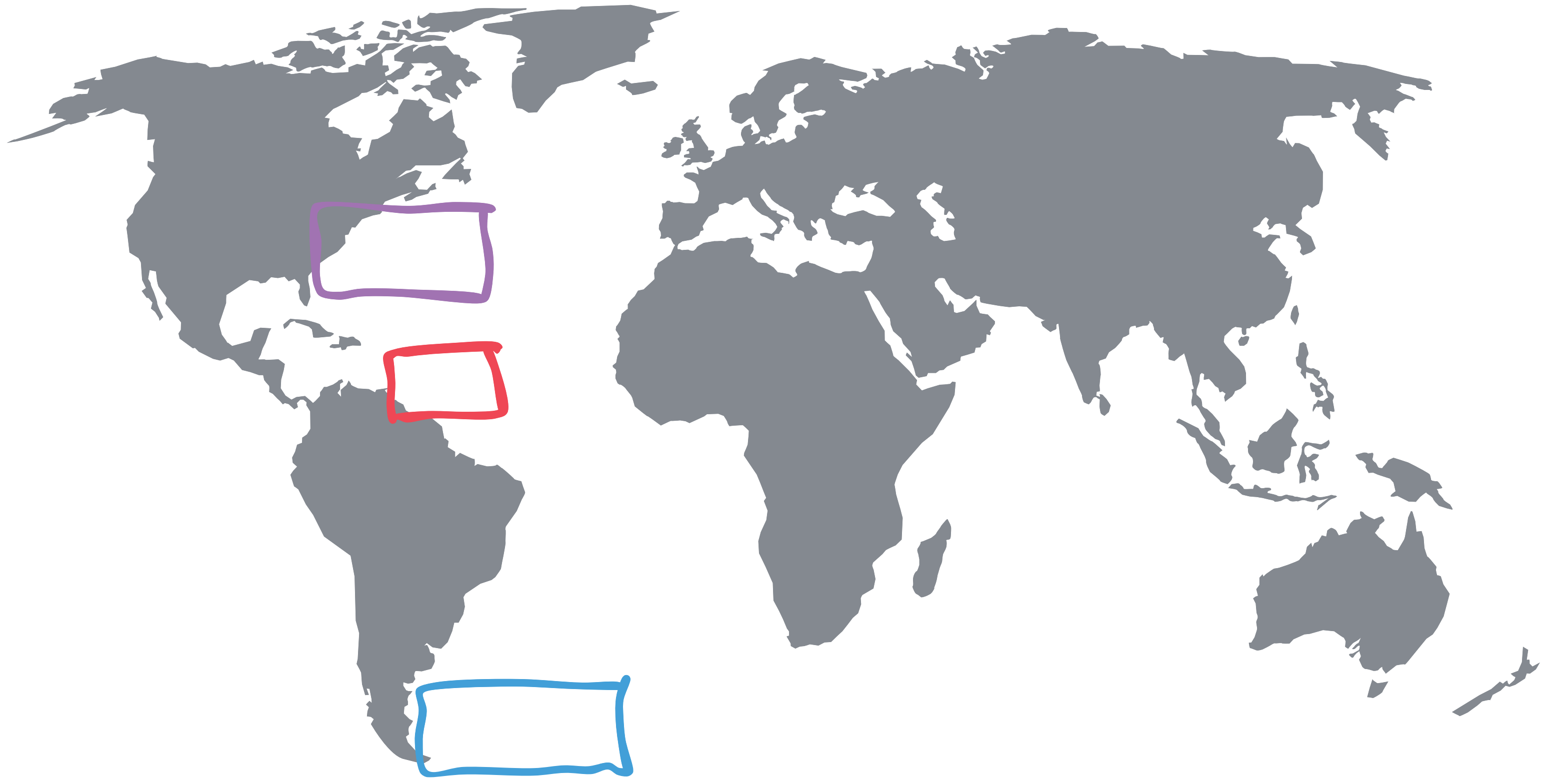

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MABL instability

$T_{air} - SST$

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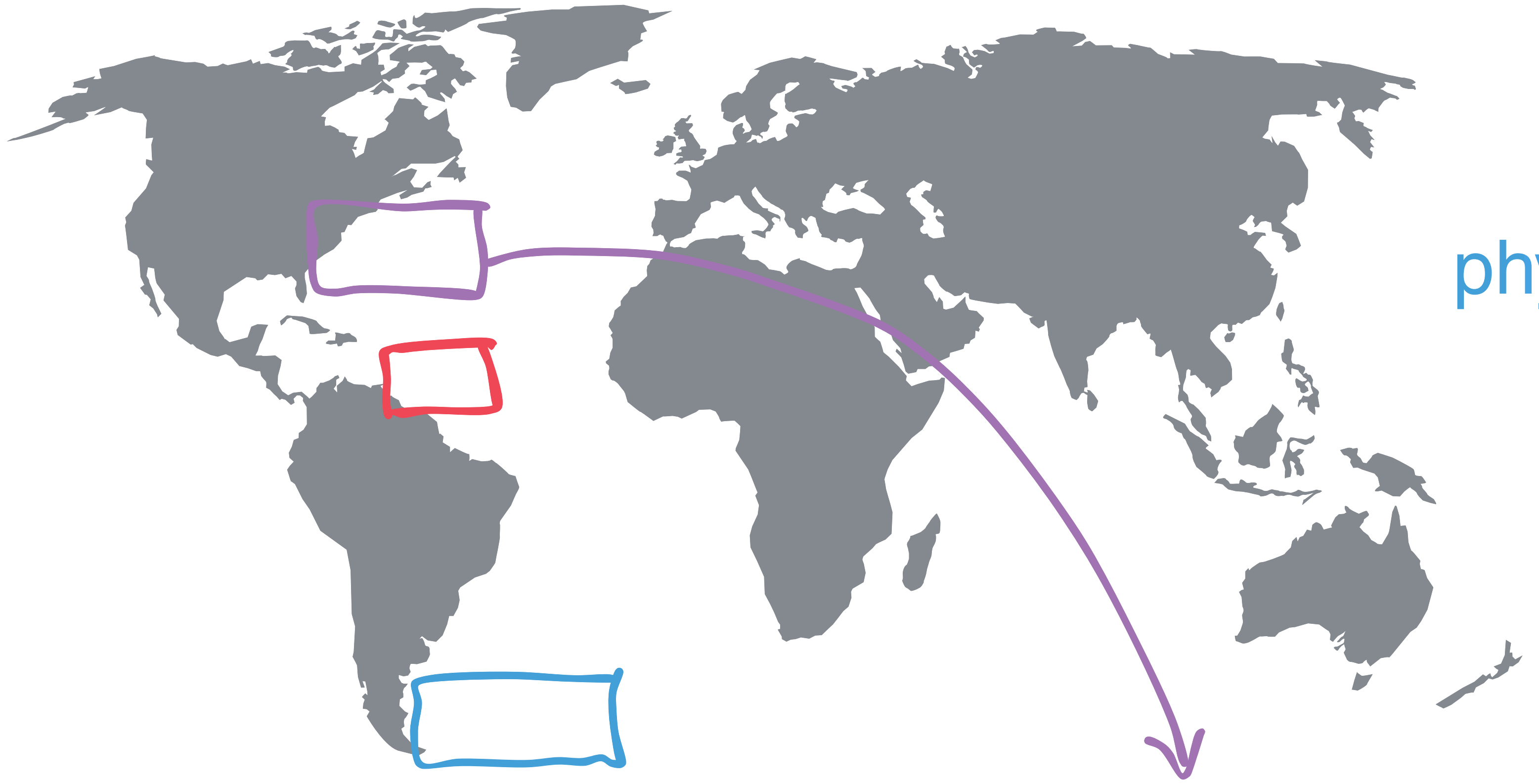

physical interpretation

rather than

coupling values

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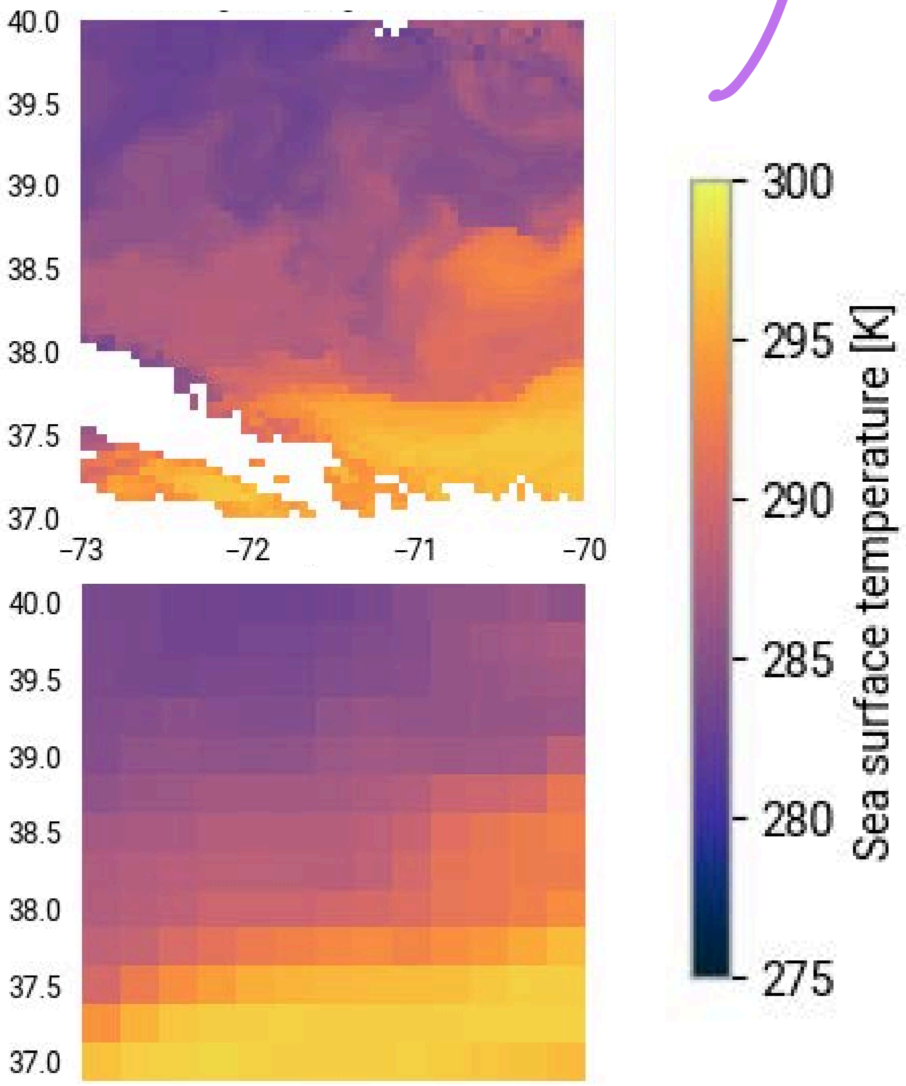

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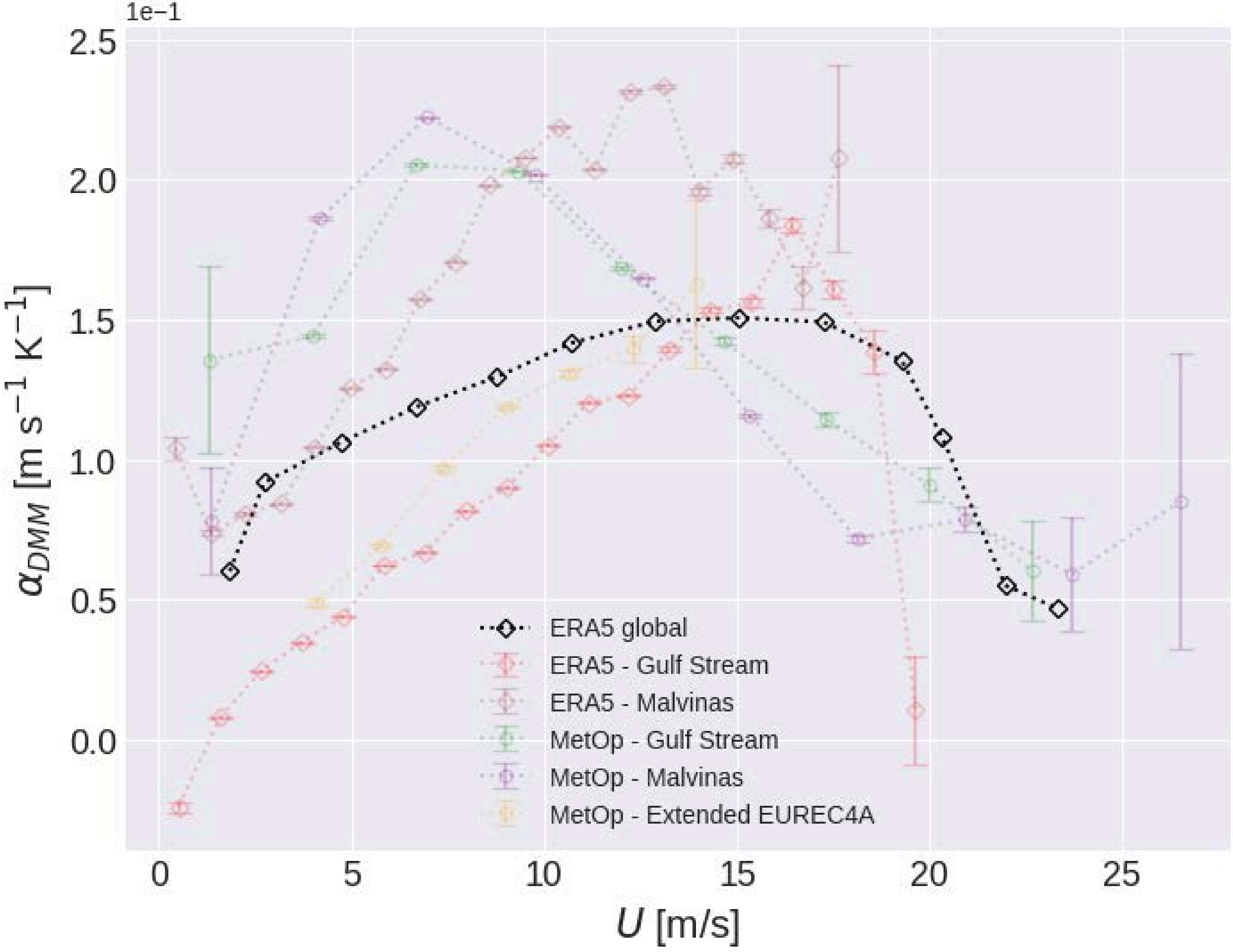
$T_{air} - SST$

Environmental drivers of DMM

... large-scale wind U



Environmental drivers of DMM

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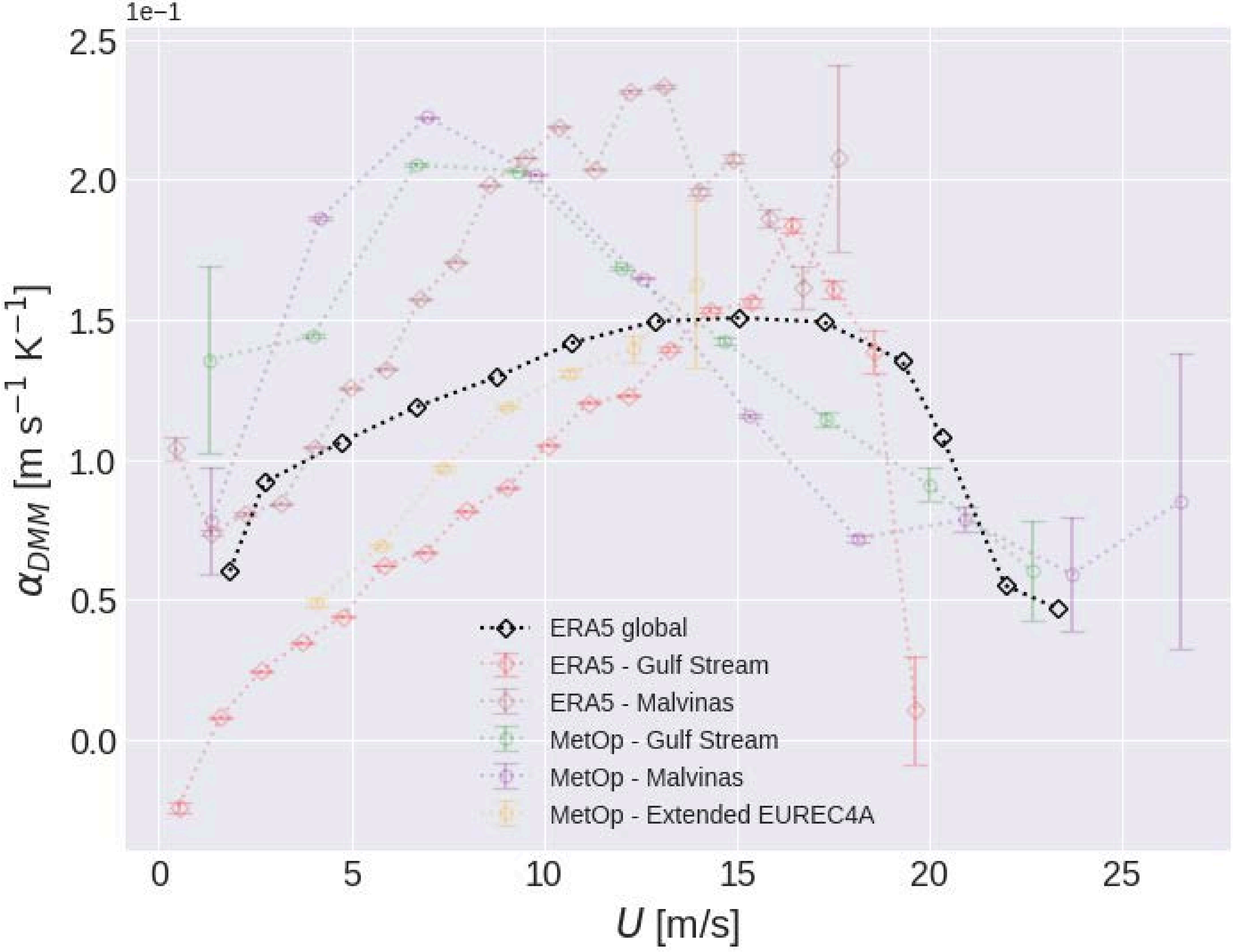
Saturation of the coupling intensity when advective time scales *L/U* become smaller than the MABL response time*



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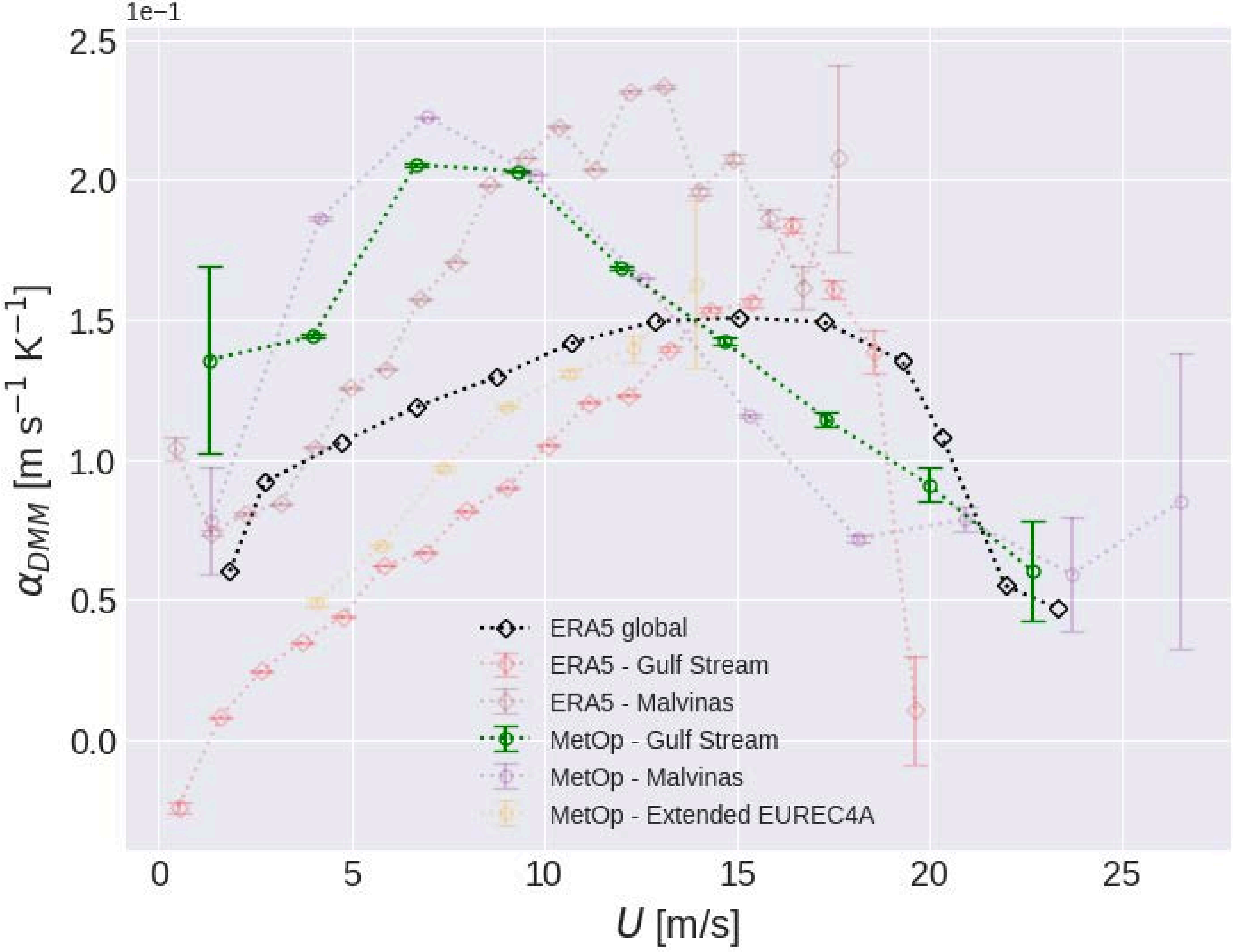

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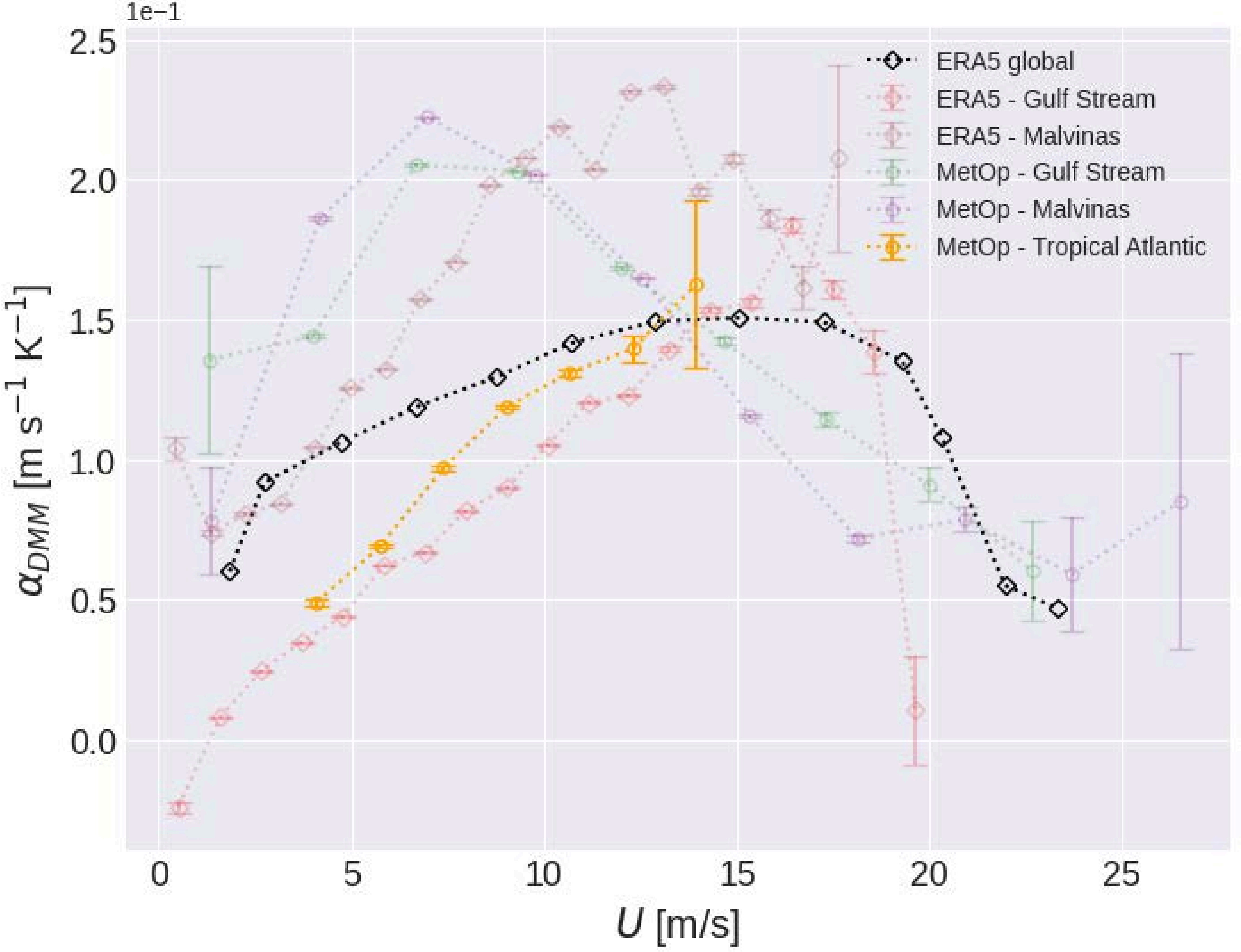

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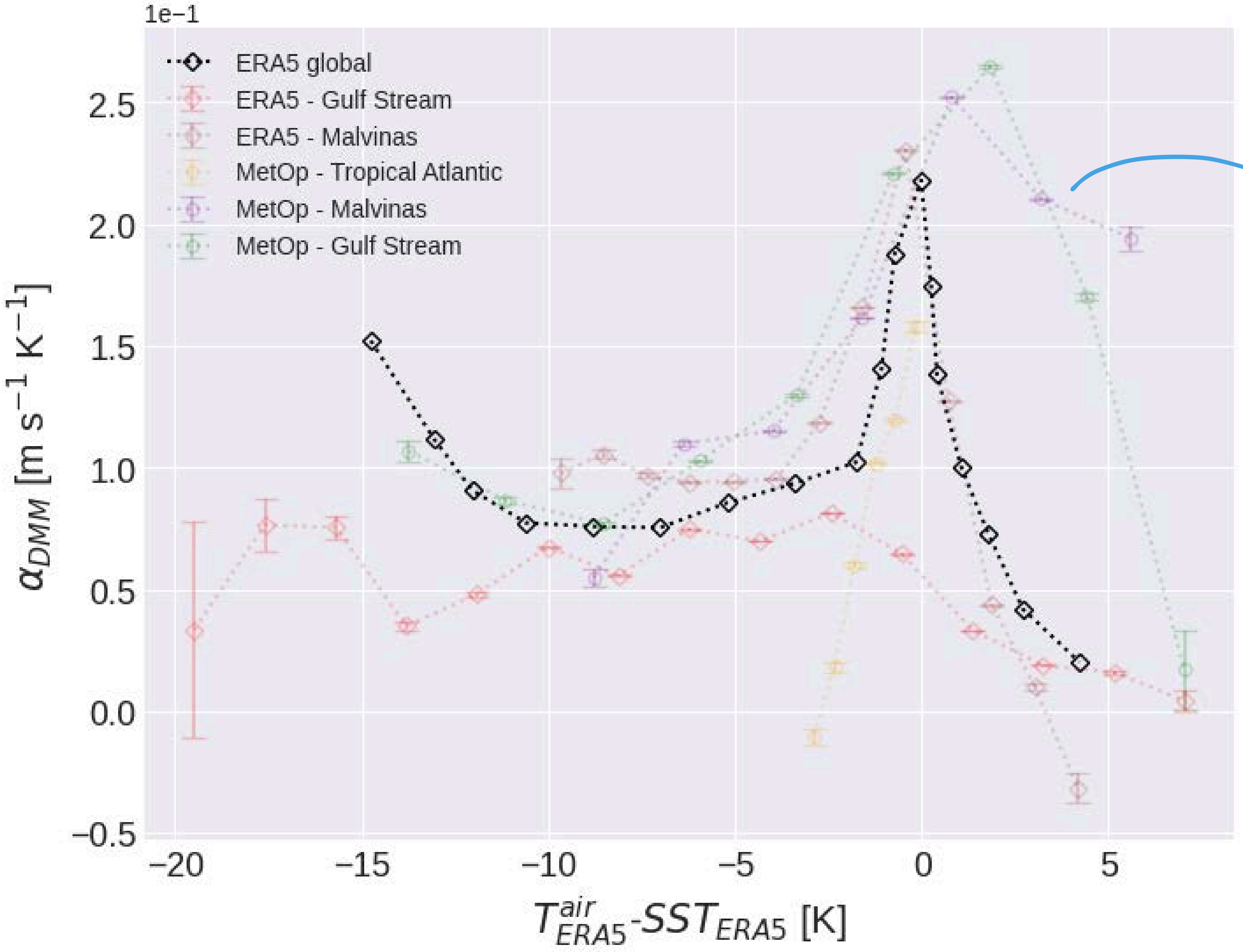

Maximum response of surface wind to SST gradients for near-neutral conditions, as in ERA5

Environmental drivers of DMM

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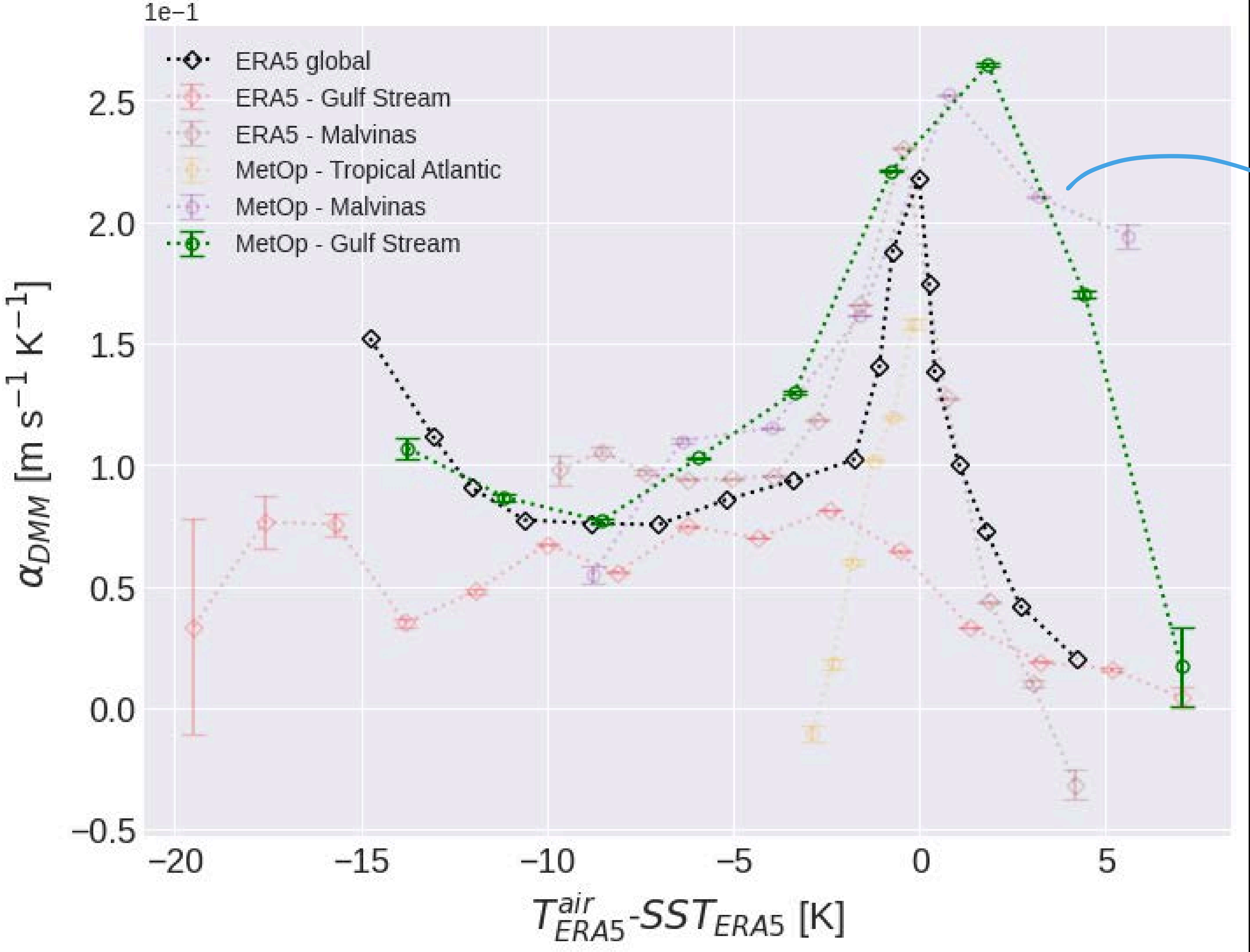

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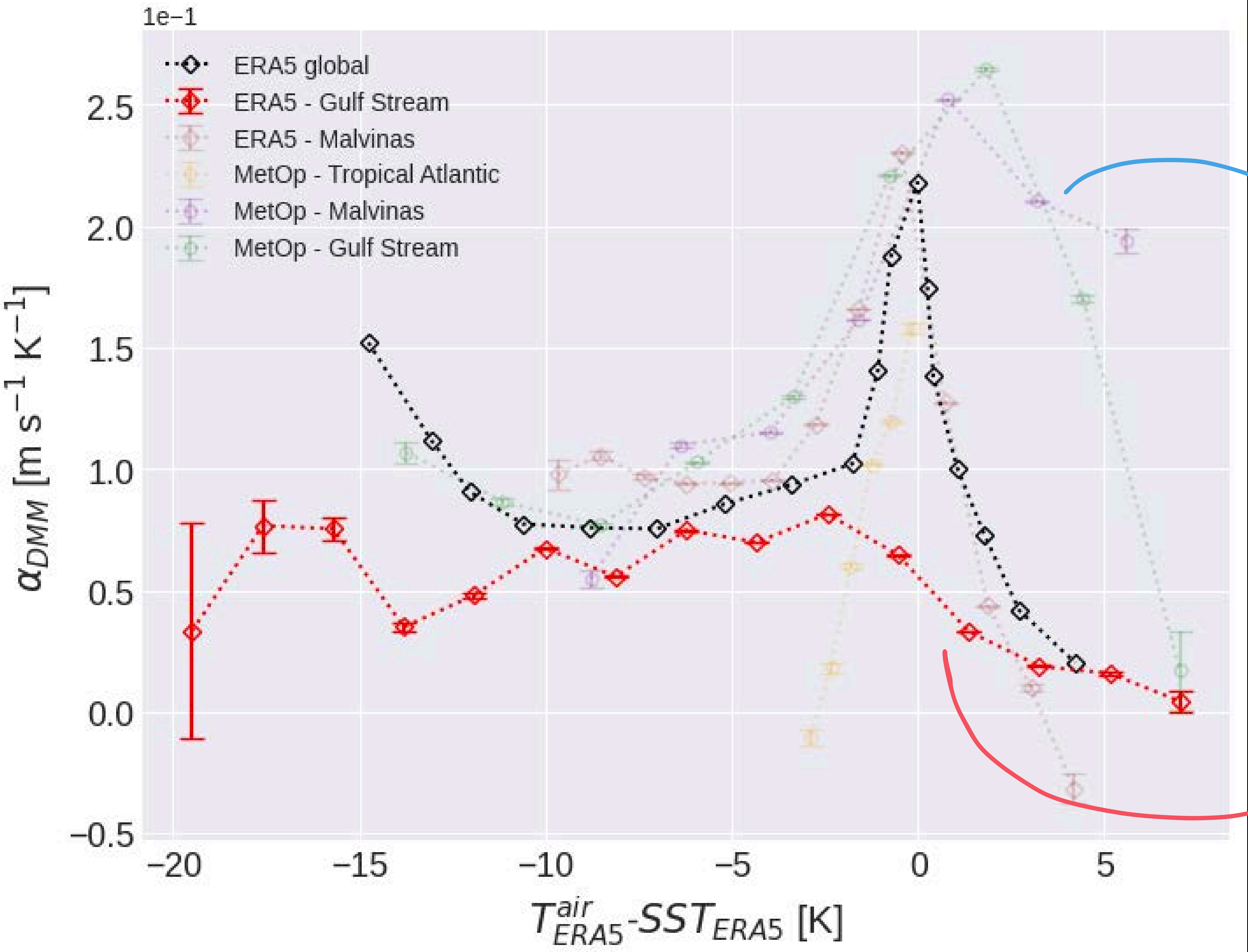


Environmental drivers of DMM

... MABL instability

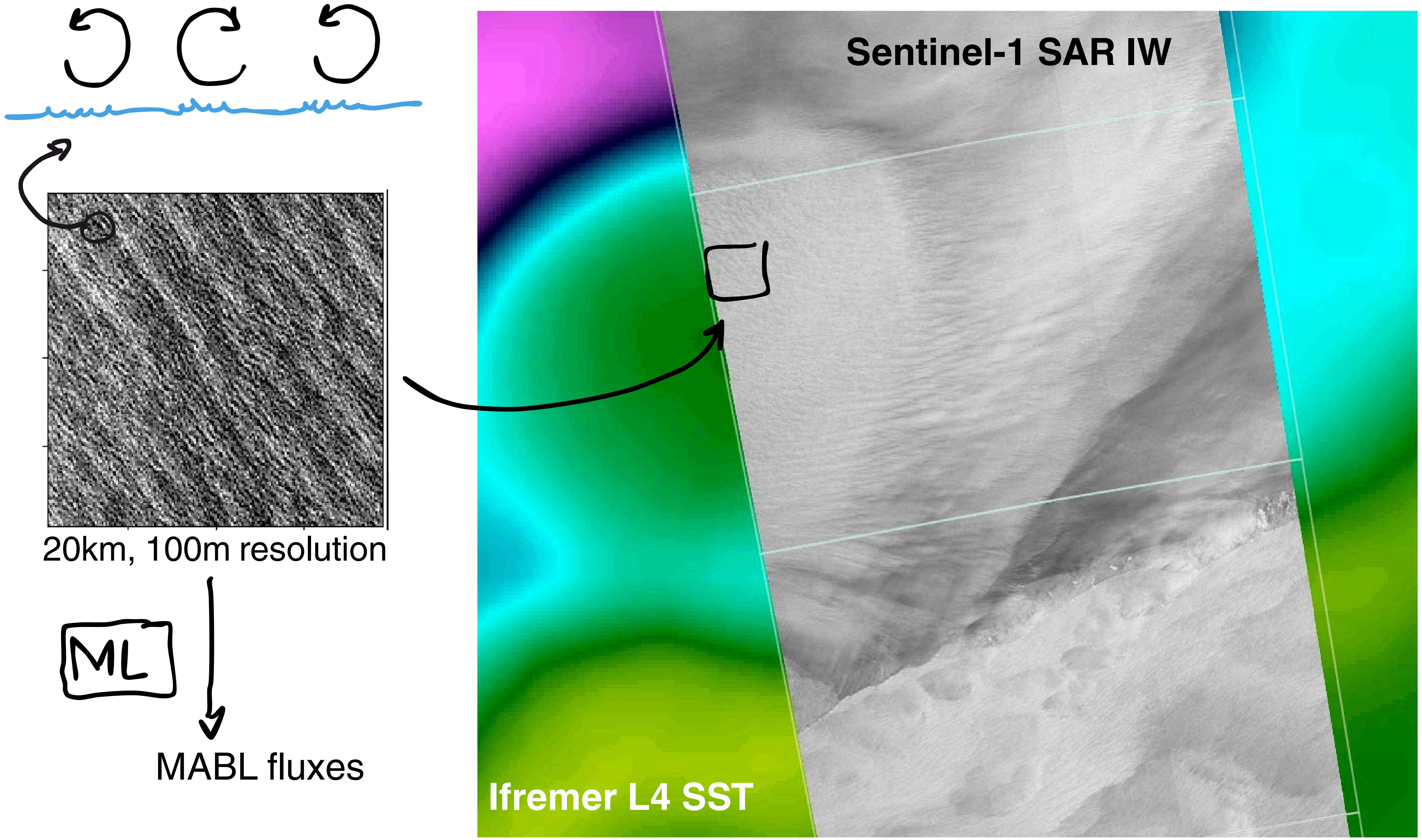
Maximum response of surface wind to SST gradients for near-neutral conditions, as in ERA5

Regional discrepancy in ERA5 (under investigation)

MABL instability from Sentinel-1 SAR IW images

... a path to MABL (submesoscale) observation

Estimate MABL fluxes from the imprints of atmospheric dynamics on the sea surface [O'Driscoll et al. 2023]



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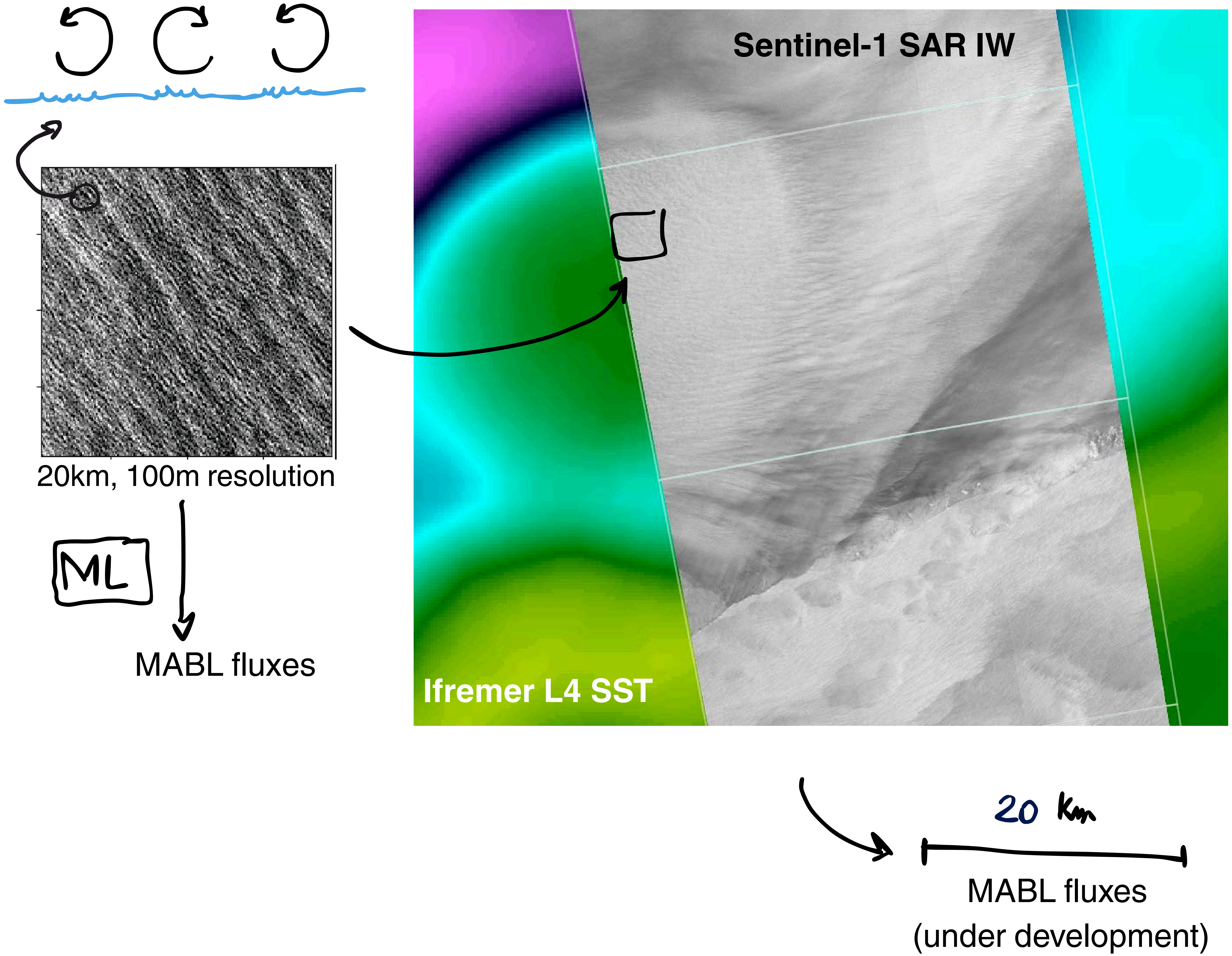

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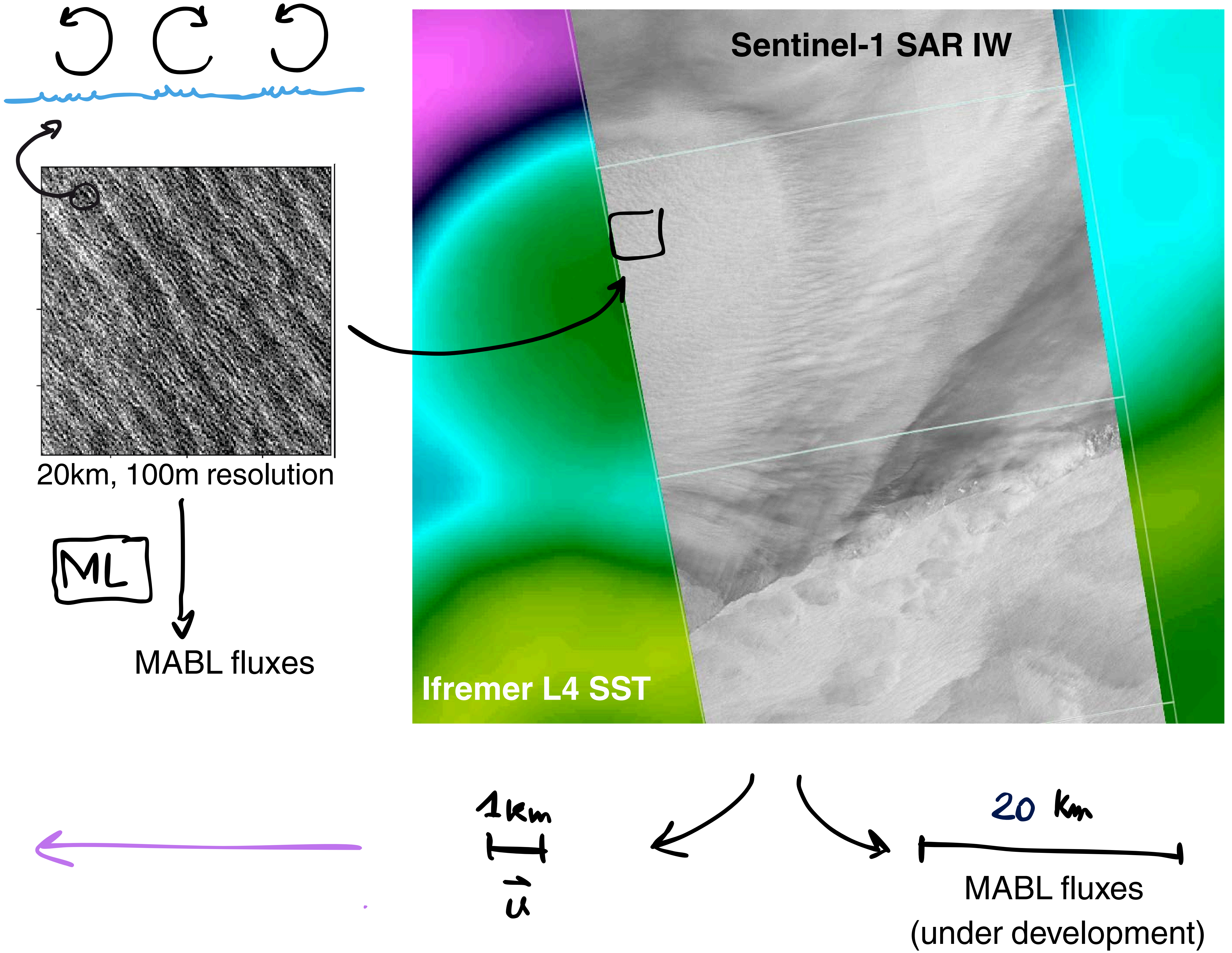

Potential for **km-scale** wind and MABL observations for **sub-mesoscale air-sea interactions**

Conclusions

Satellite observations confirm the environmental control of wind response to sea surface temperature patterns depending on large-scale wind and MABL instability.

Differences in re-analysis and satellite observations emerge at a regional level, mainly due to the different SST features length scale.
The overall physical interpretation remains unaffected.

The observational gap in MABL instability poses a serious challenge to the study of air-sea interactions at meso- and submesoscales.
High-resolution SAR imagery potential in providing a solution to this gap is currently under investigation.

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Thank you for your attention!

LinkedIn

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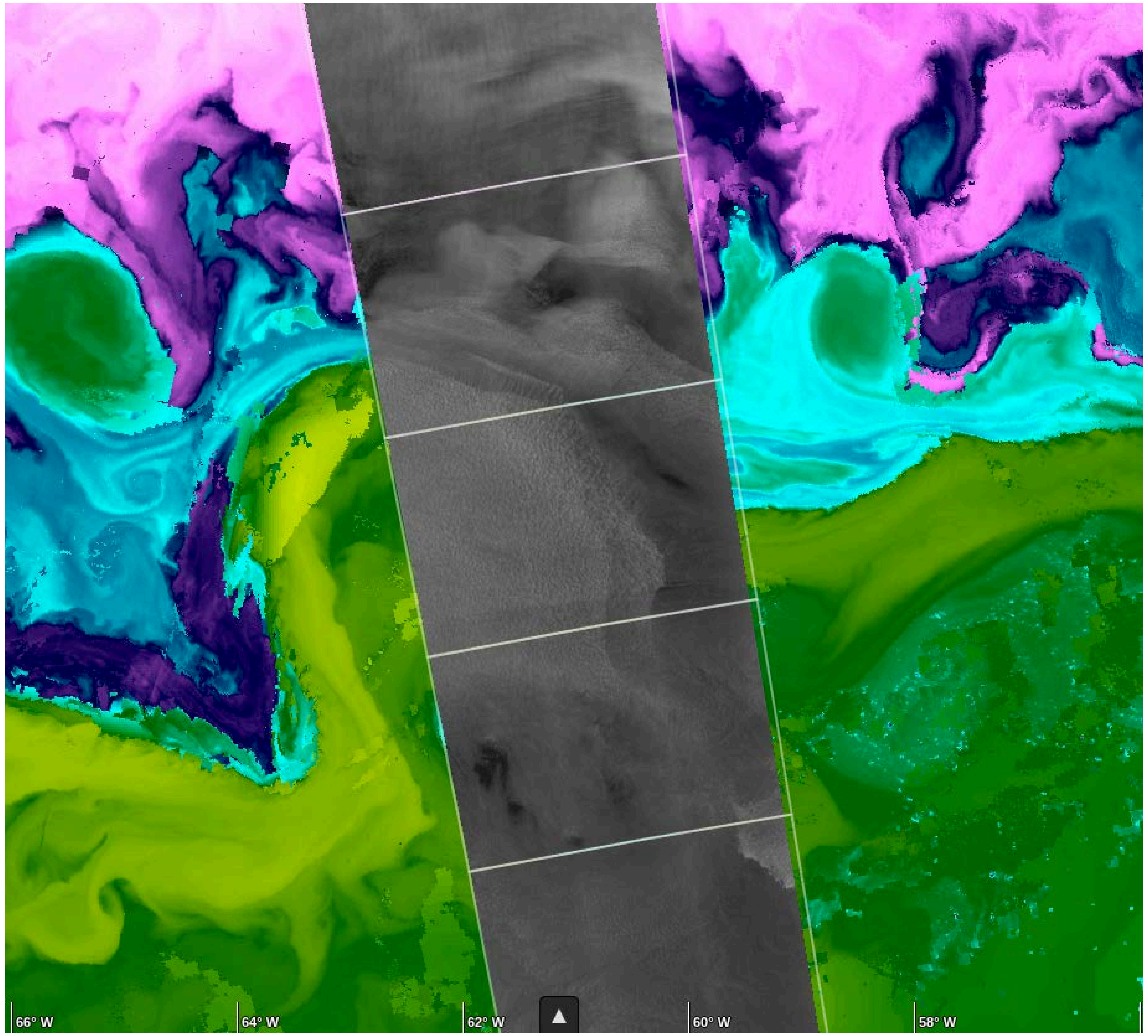
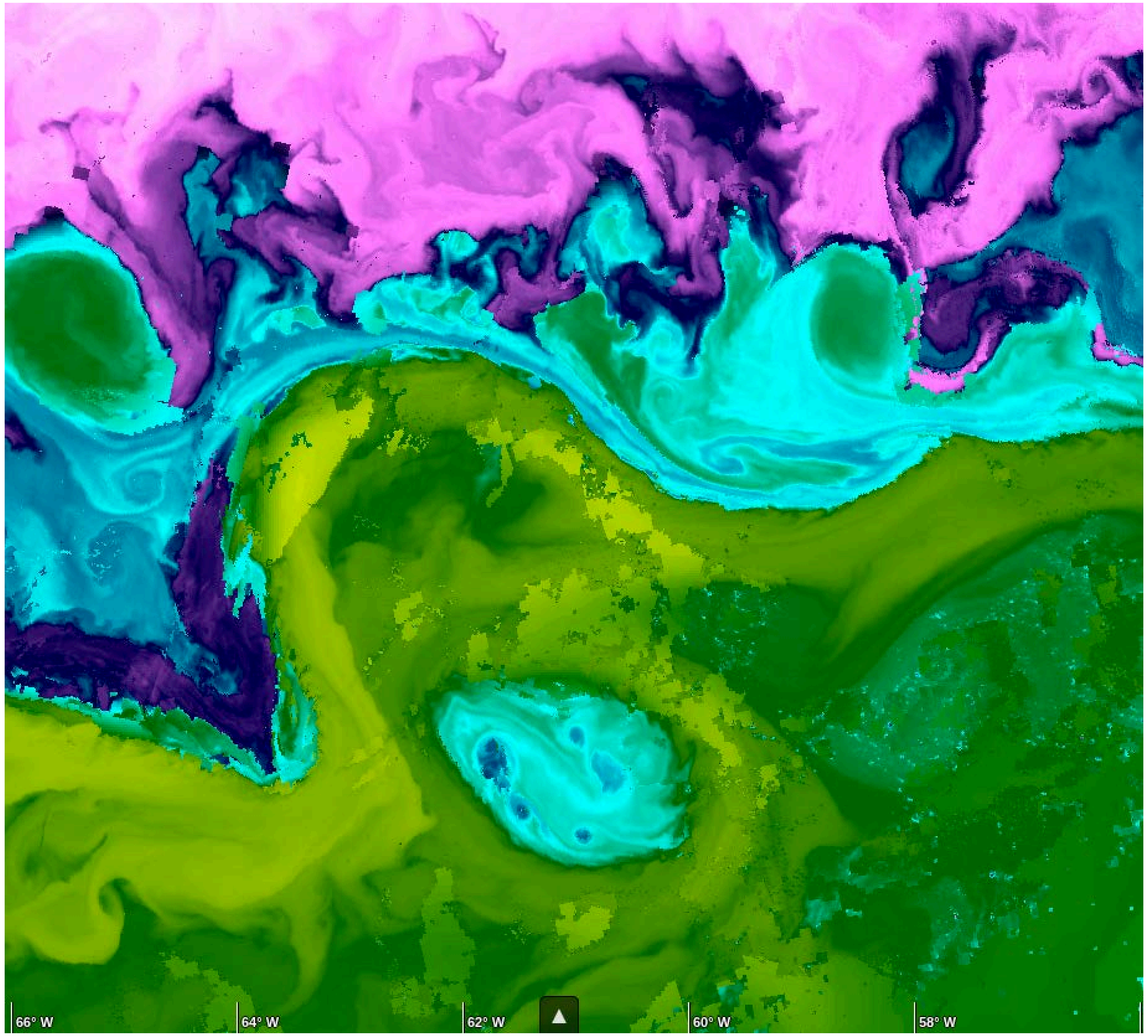
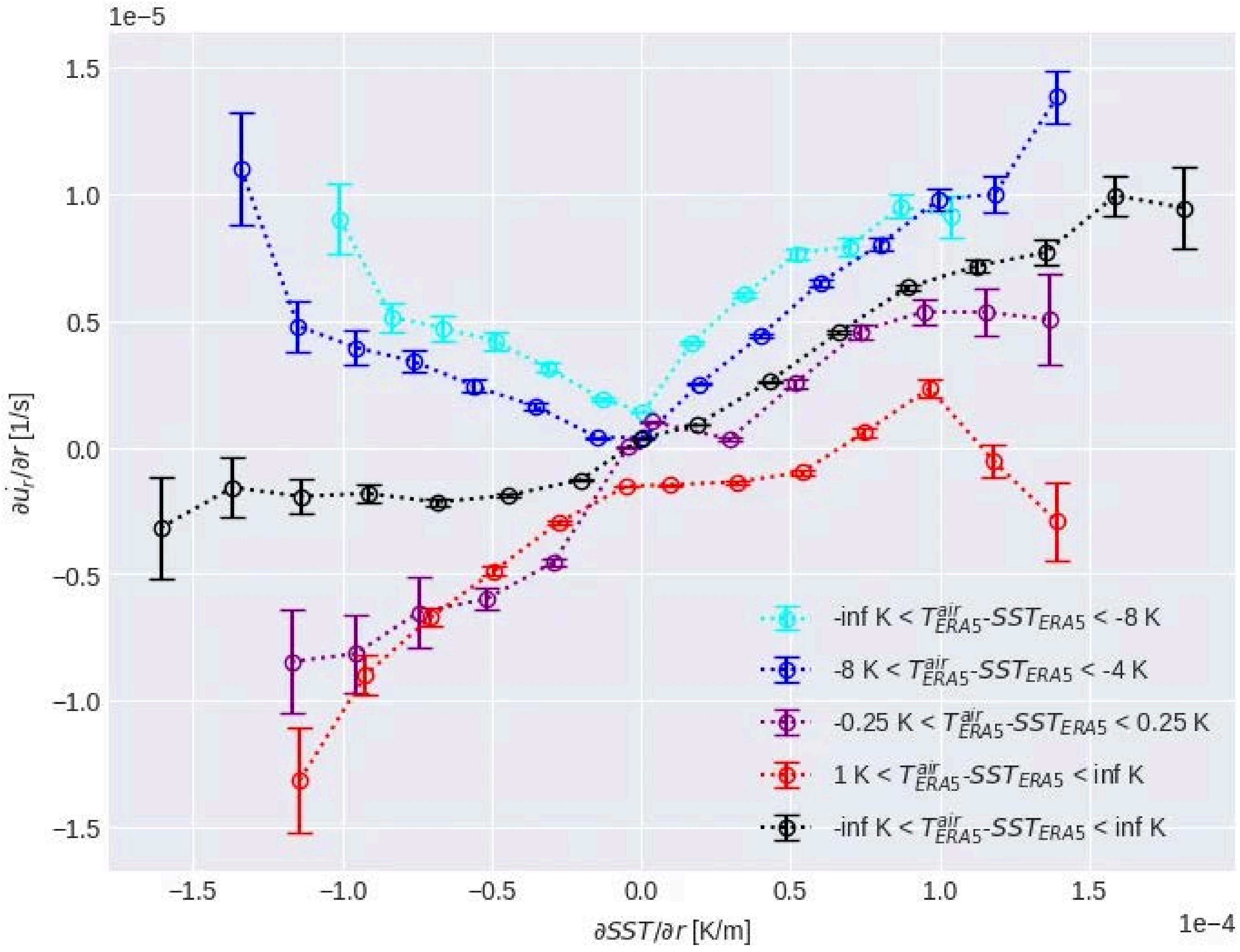
Appendix

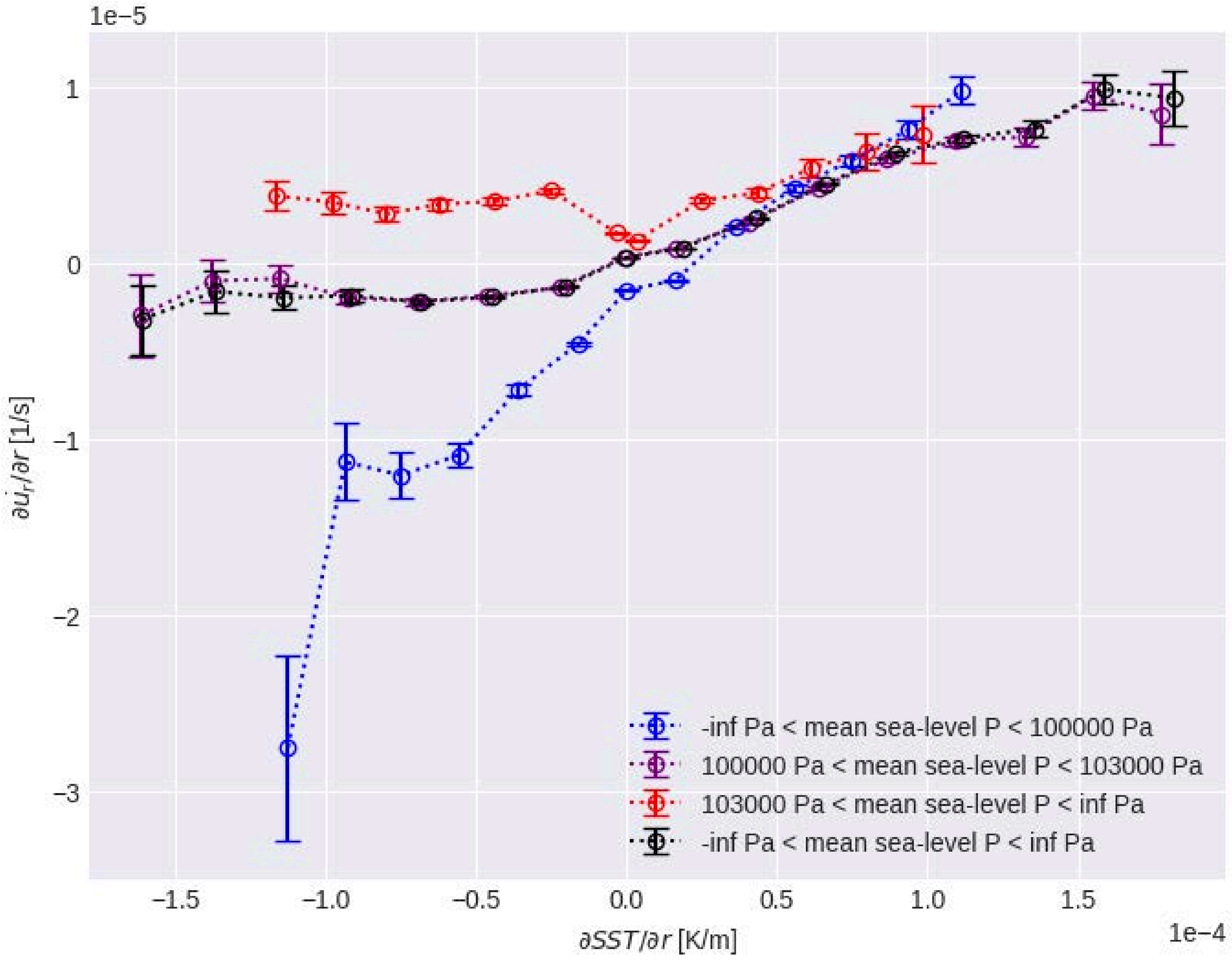
Quick ABL response time to SST patterns



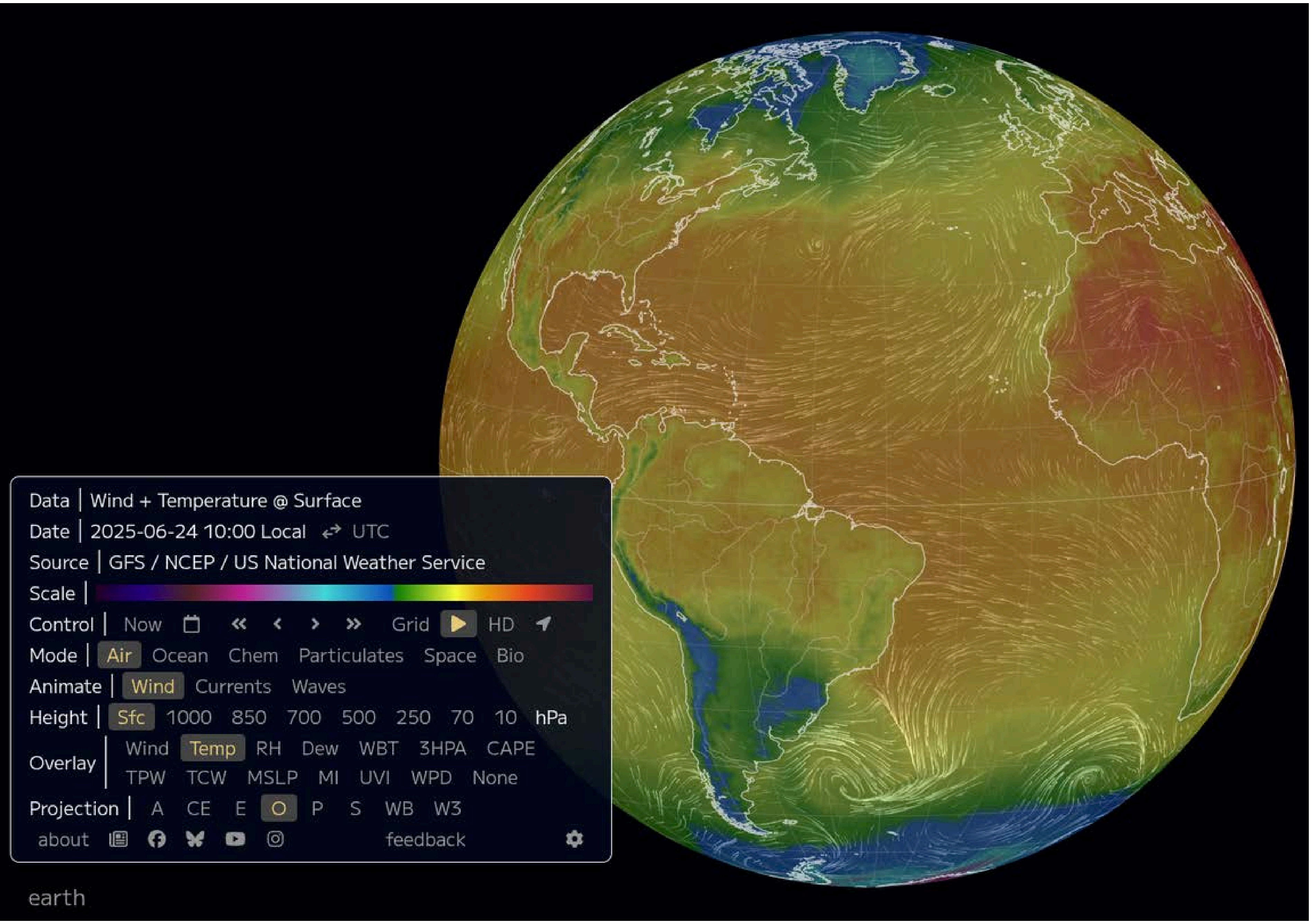


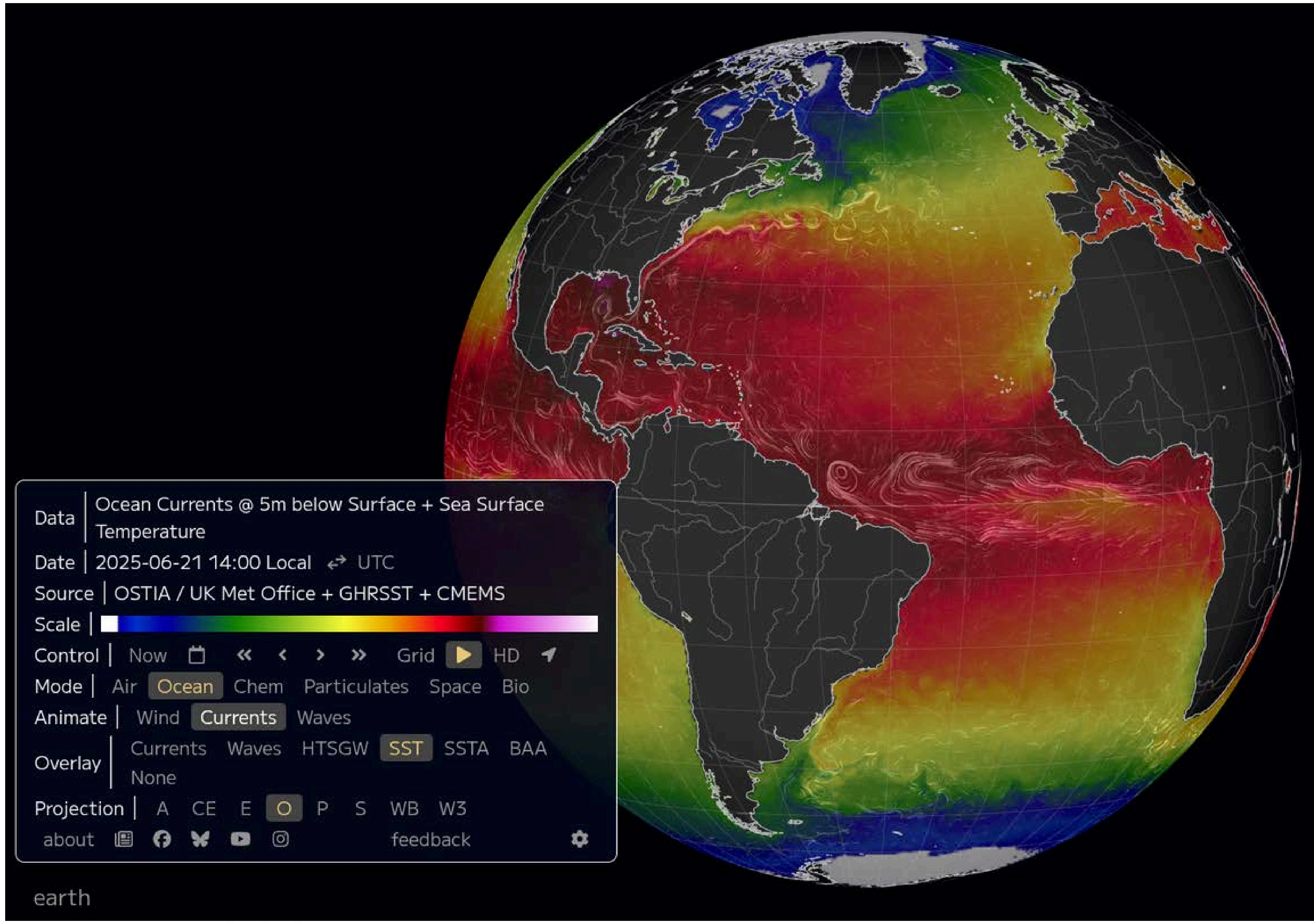
Regional ERA5 anomaly





Air temperature and SST

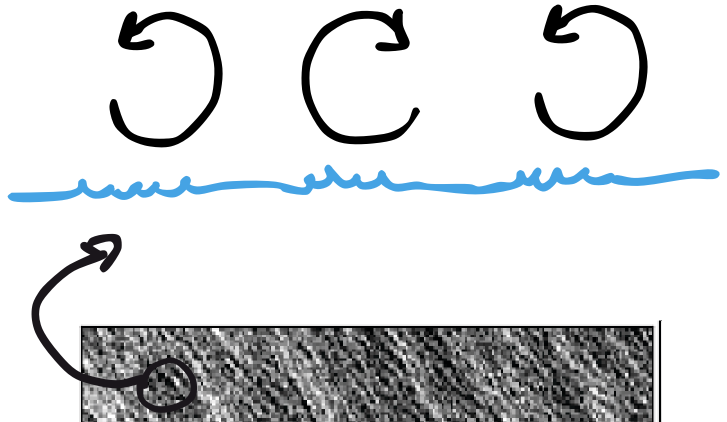


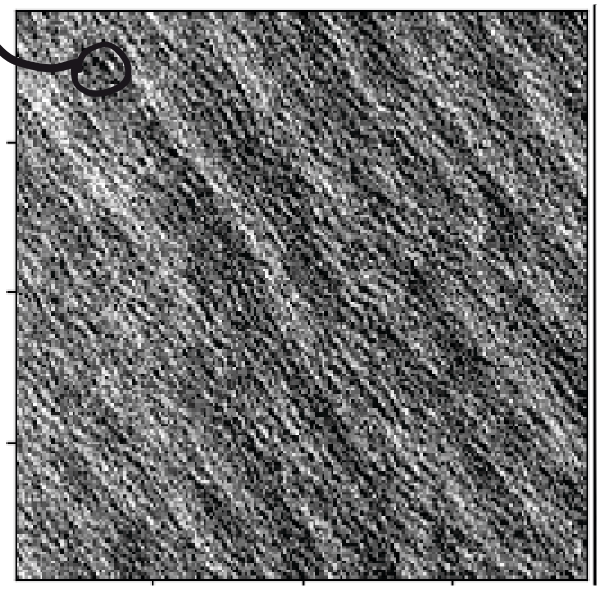


MABL instability from Sentinel-1 SAR IW images

... IW implementation

Estimate Obukhov length from the imprints of atmospheric convective dynamics on the sea surface [O'Driscoll et al. 2023]



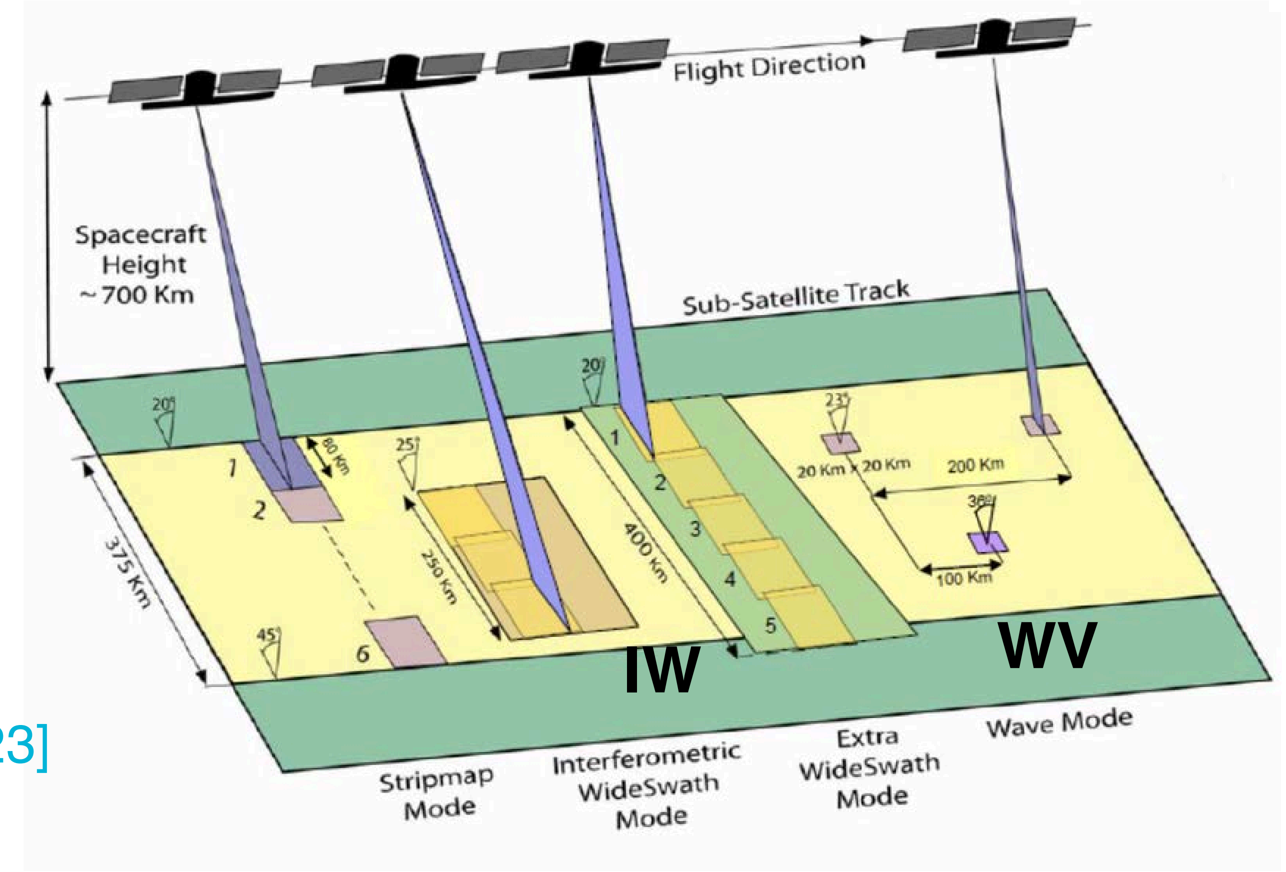


20km, 100m resolution

ML

$\longrightarrow L$

[O'Driscoll et al. 2023]

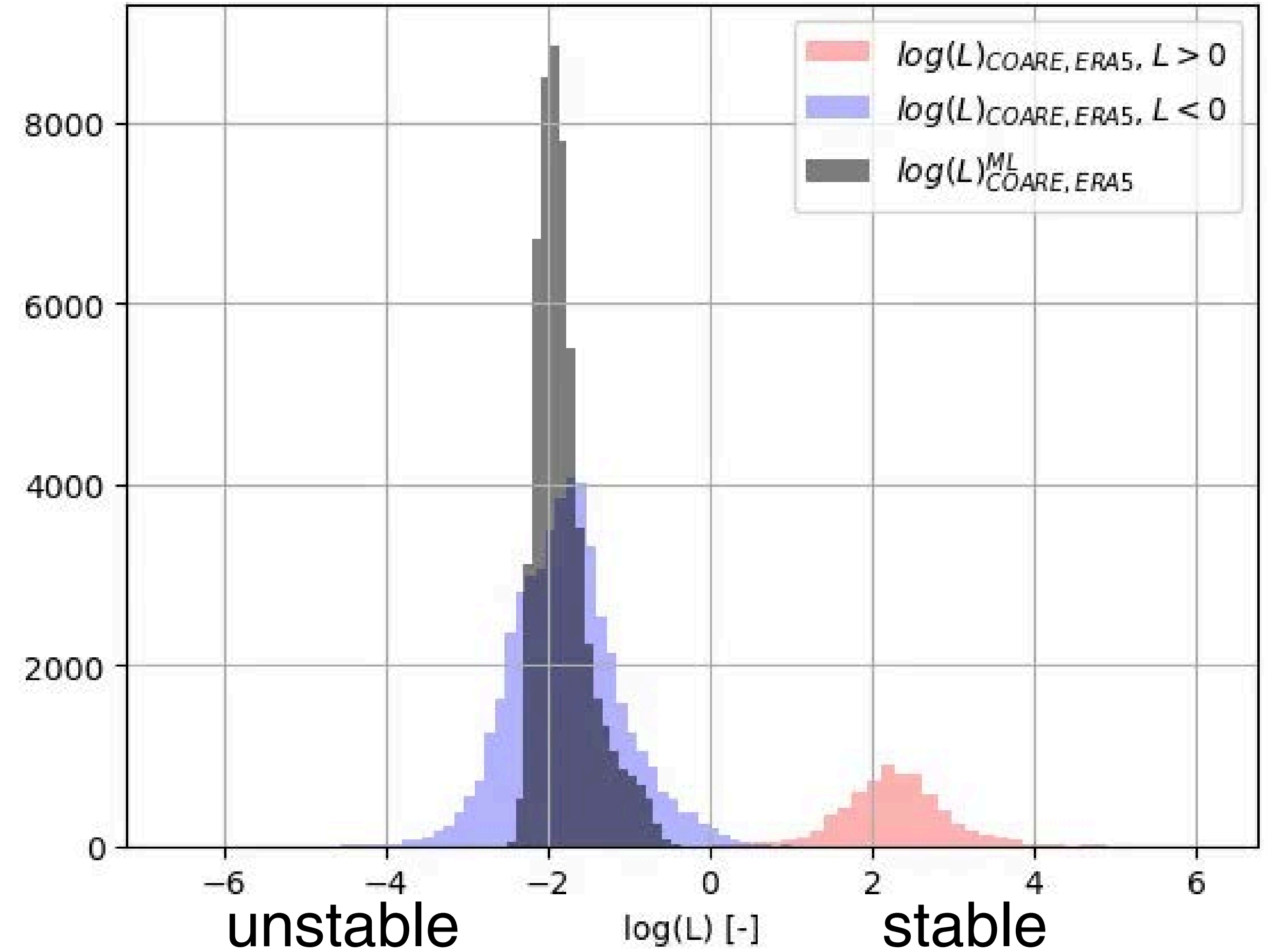


training:
only convective
scenes

WV mode:
limited coverage,
open ocean

⇓

IW mode



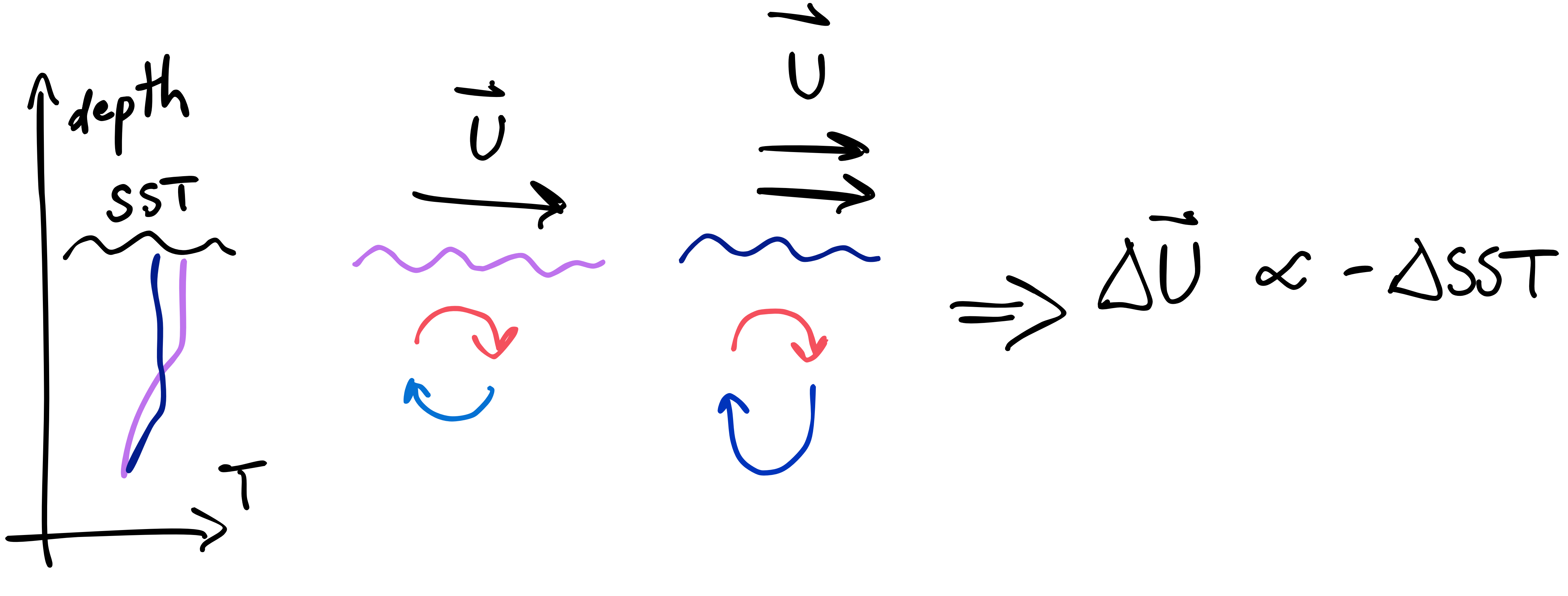
Feasible application to IW, but we need to re-train the algorithm to include a wider spectrum of atmospheric conditions

Air-Sea Interactions

... SST-wind coupling scale dependence

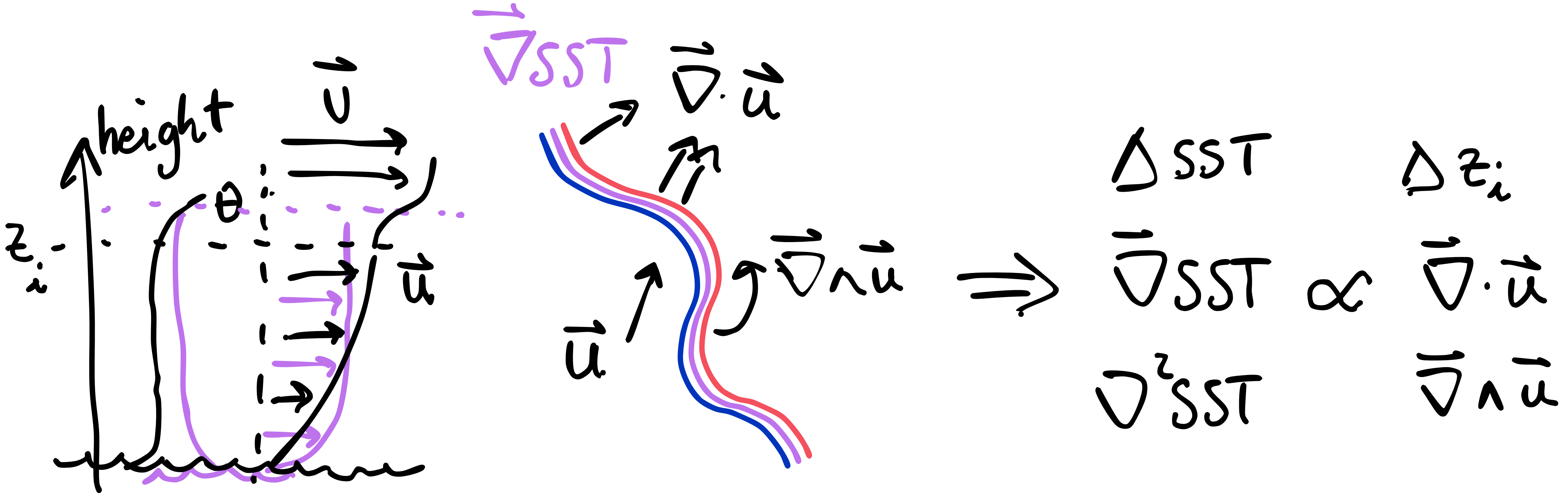
Basin scale (>1000km)

Increased large-scale surface wind (*U*) induces negative Sea Surface Temperature (*SST*) anomaly through deeper mixing in the ocean



Mesoscale (1000km to 10km)

SST features drive Marine Atmospheric Boundary Layer (*MABL*) wind variability

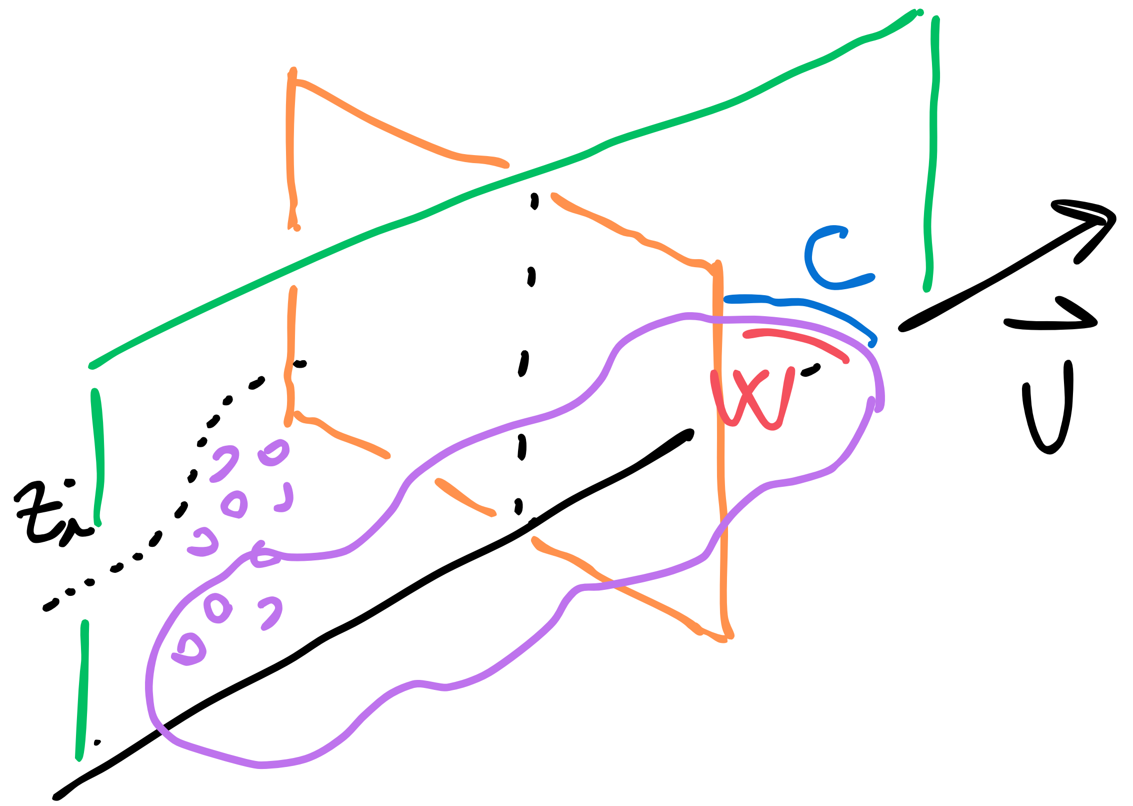


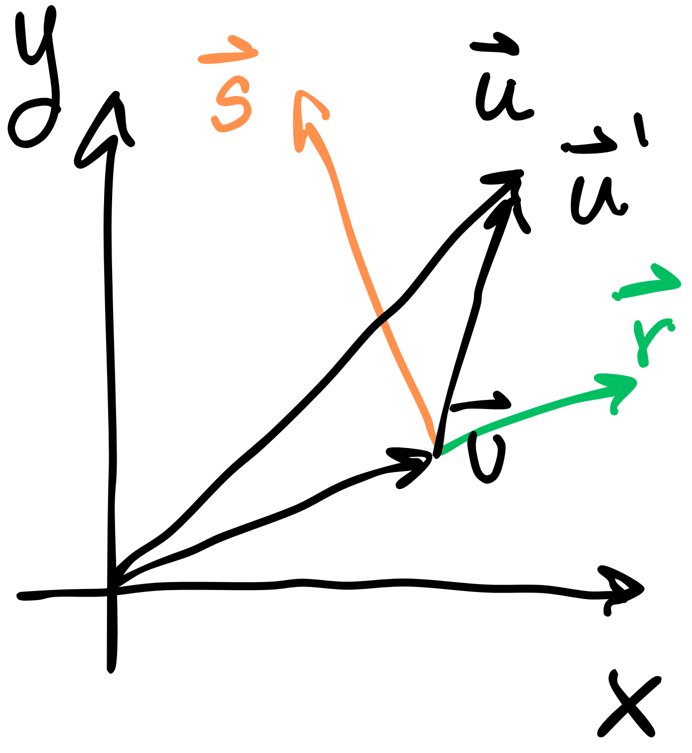
Submesoscale (100km to 1km)

Largely unexplored, mainly due to the lack of high-resolution observations

Mesoscale SST-wind coupling

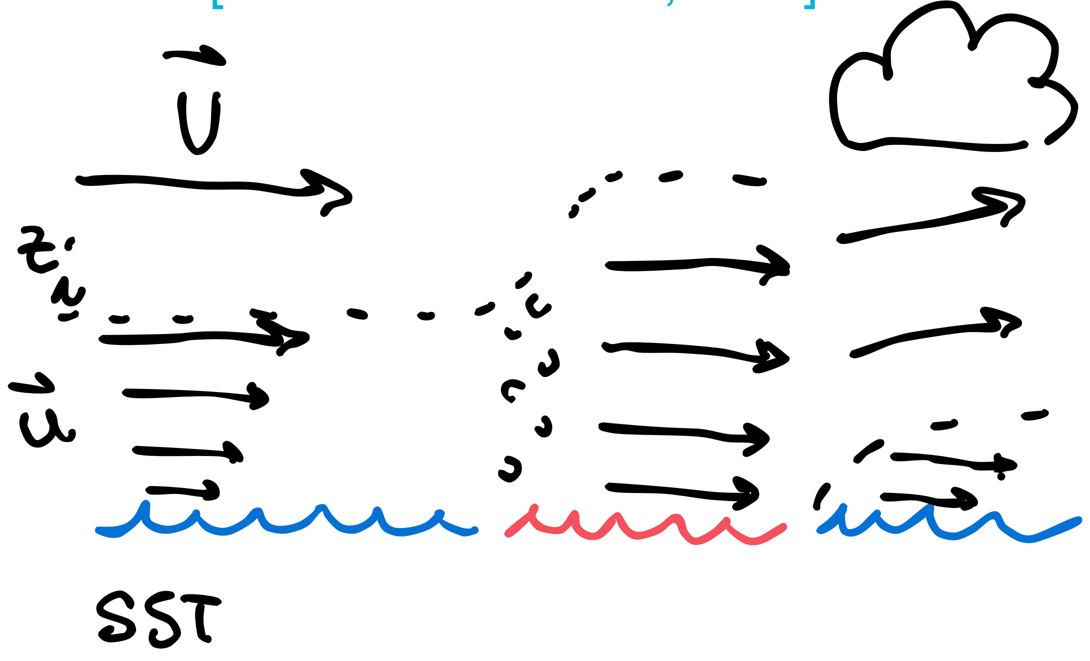
... main mechanisms



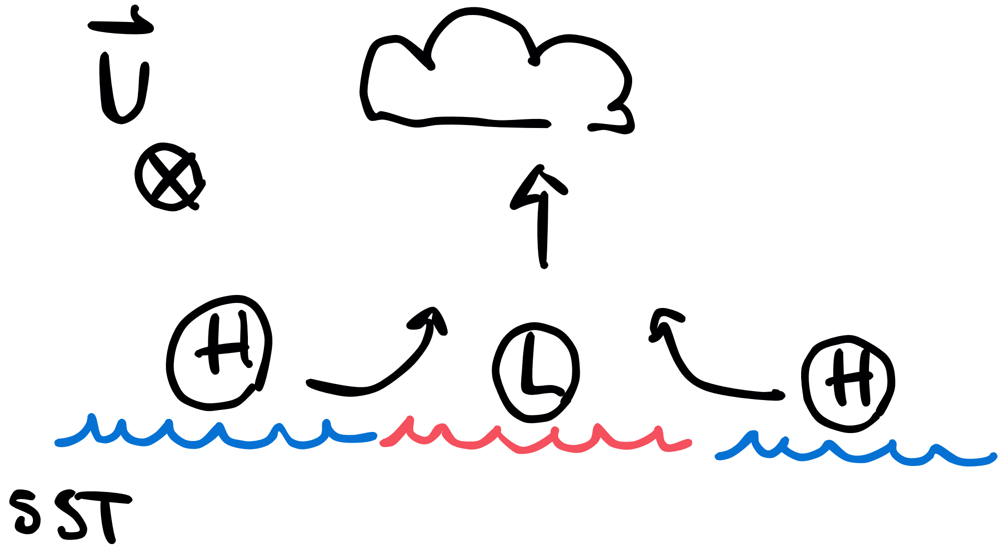


$$\vec{u} = \vec{U} + \vec{u}'$$

[Meroni et al. 2022,2023]



$$\frac{\partial u'_r}{\partial r} = \alpha_{DMM} \cdot \frac{\partial SST}{\partial r}$$



$$\frac{\partial u'_s}{\partial s} = \alpha_{PA} \cdot \frac{\partial^2 SST}{\partial s^2}$$

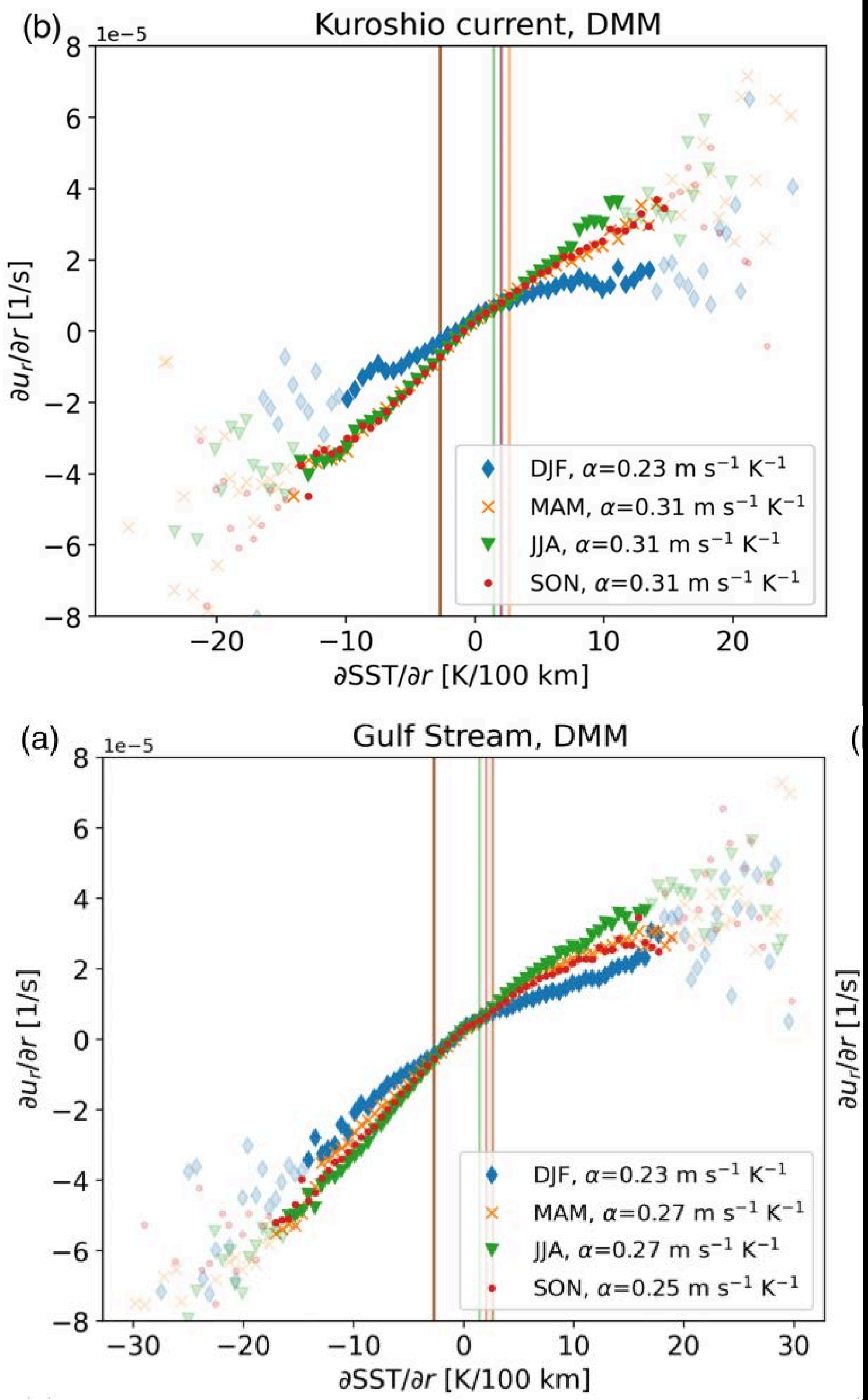
Downward Momentum Mixing (*DMM*)

Increased heat turbulent fluxes, MABL mixing and height, resulting in a vertical transport of momentum toward the surface [Hayes et al., 1989]

Pressure Adjustment (*PA*)

SST-induced pressure gradient generates convergence in surface wind [Lindzen and Nigam, 1987]

[Meroni et al. 2023]

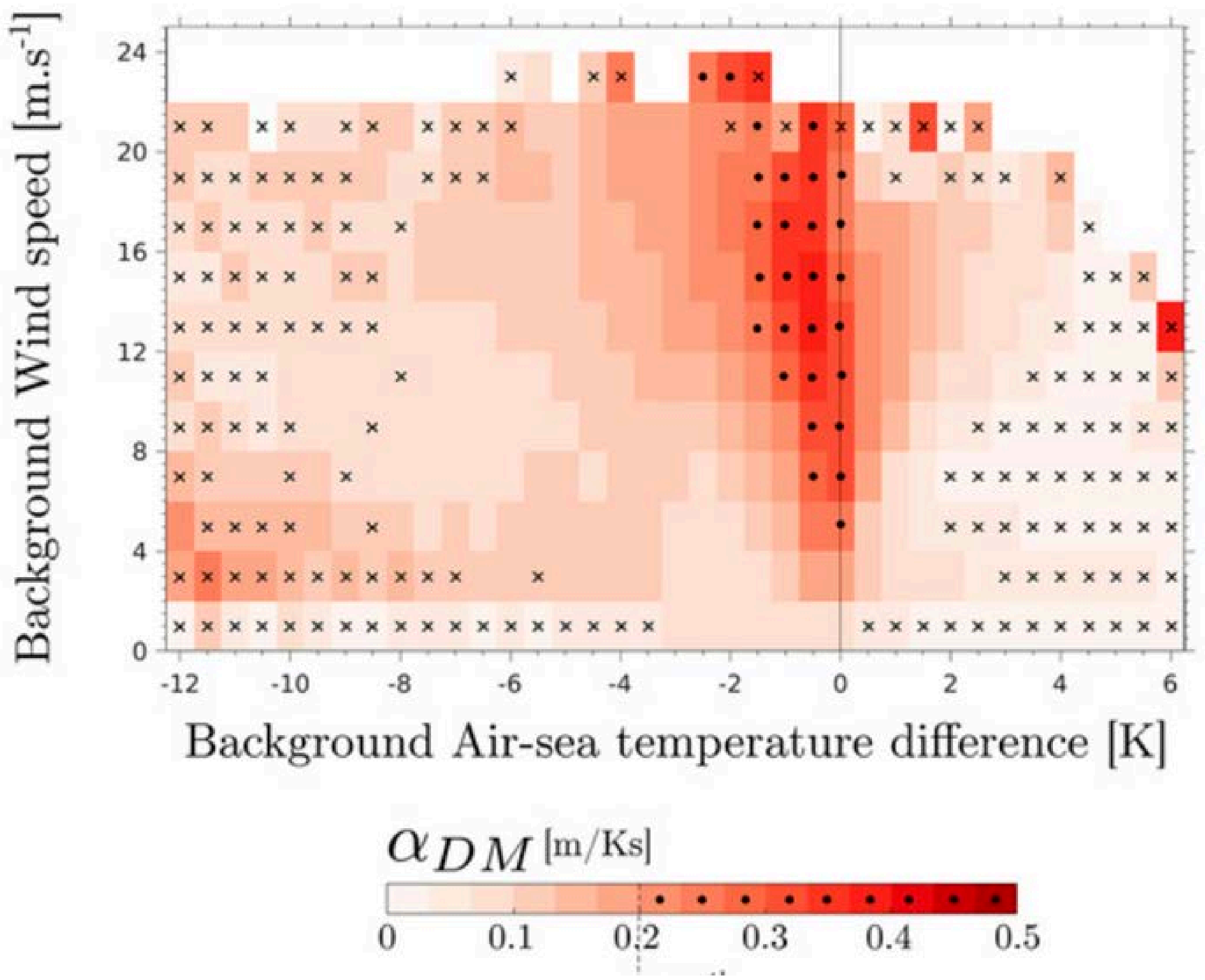


Mesoscale SST-wind coupling

... observed variability

Seasonal and regional variability in coupling intensity
[Chelton et al. 2004, O'Neill et al. 2005]

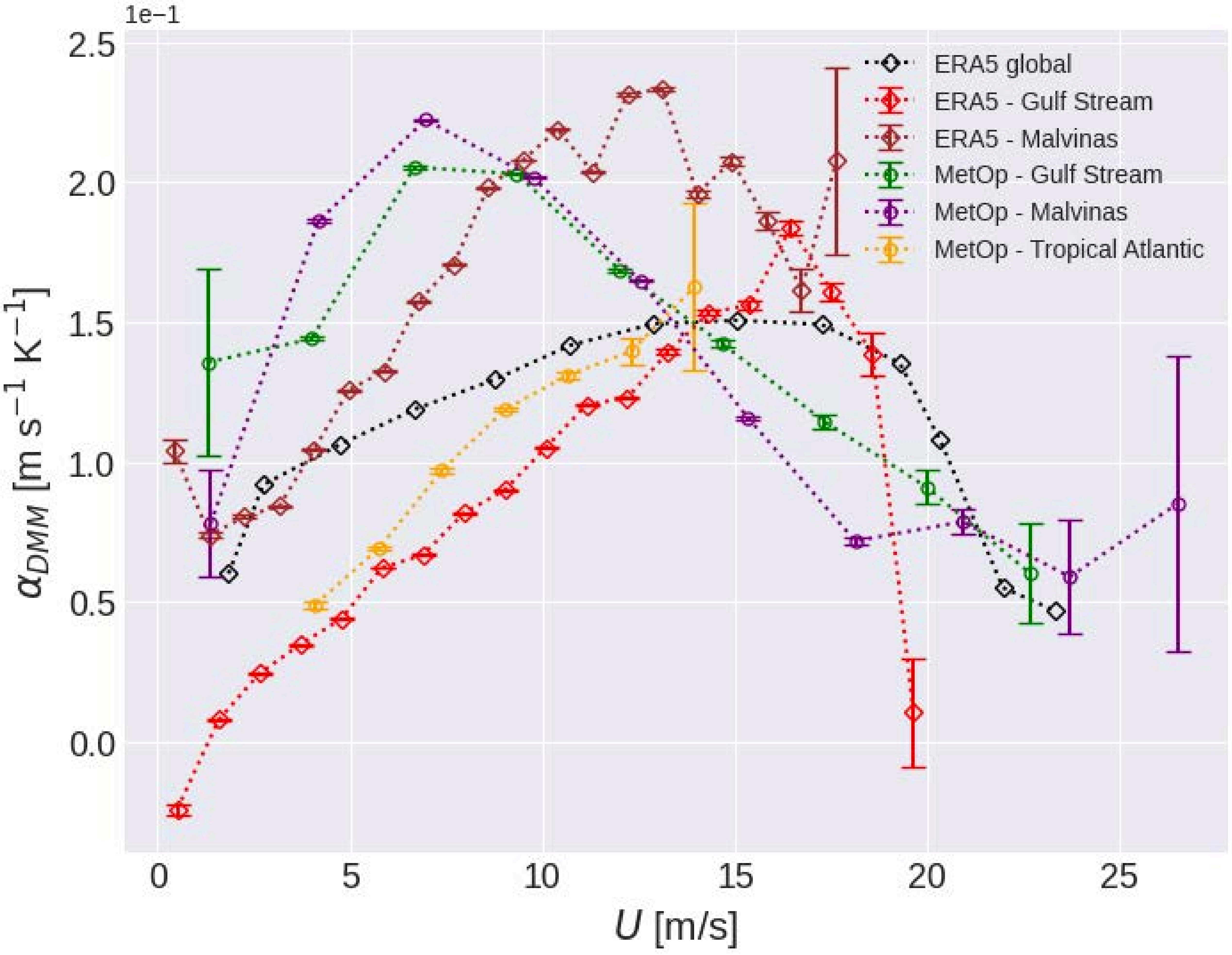
Driven by U and MABL instability
[Desbiolles et al. 2023]



[Desbiolles et al. 2023]

Environmental drivers of DMM

... large-scale wind U



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