Influence of small-scale ocean structures on surface wind variability over the Western Mediterranean region

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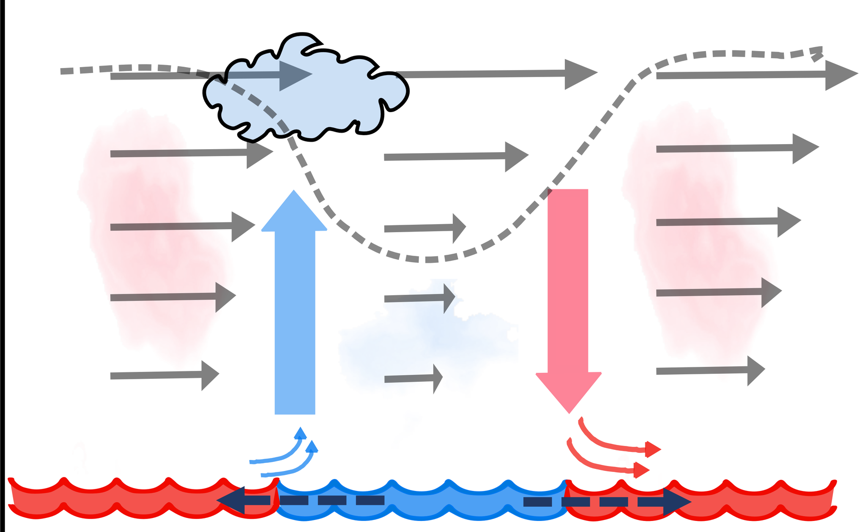
Motivation



Submesoscale SST variability may influence surface winds via a **Downward Momentum Mixing (DMM)** mechanism.

Air blowing from warm (cold) to cold (warm) SST zones generates convergence (divergence) due to increase (decrease) of stability leading to suppression (increase) of vertical mixing that blocks (transfers) momentum from aloft towards the surface.

The analysis of submesoscale SST variability effects on the regional climate of the Mediterranean region has not yet been addressed on climate timescales. To tackle this issue, we analytically evaluate the mechanisms controlling submesoscale air-sea interactions from:

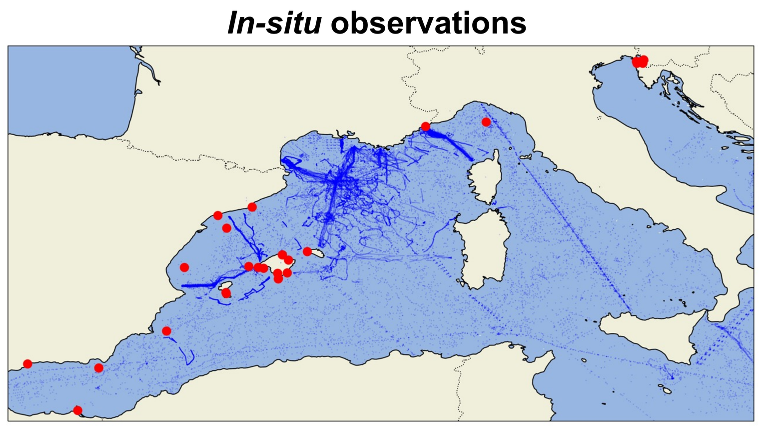
1. High-resolution SST products has been analyzed to characterize the small-scale SST structures and to evaluate associated uncertainties.
2. The influence of small-scale SST structures on **DMM** is analytically explored by comparing its response to different SST and wind resolutions, as well as different HR-SST products.

1. HR-SST products intercomparison

HR-SST products description

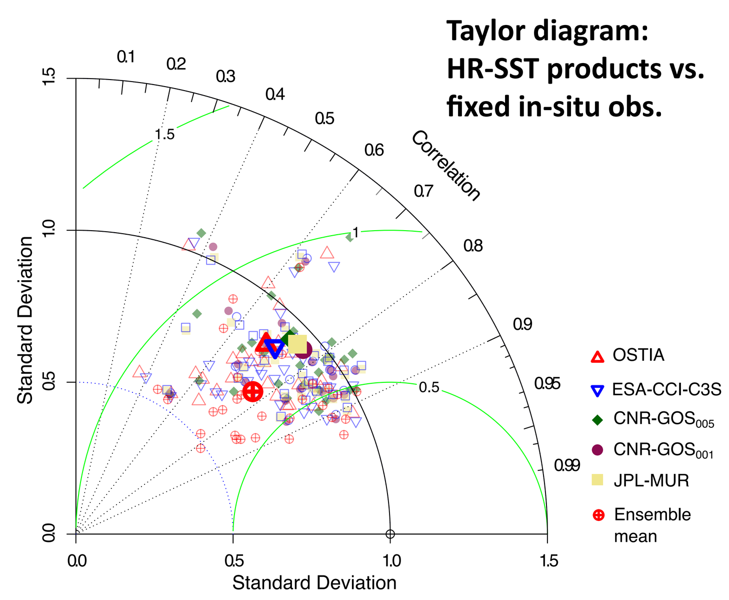
Product	Resolution	SST type	Period	Institution
OSTIA	0.05 X 0.05°	Foundation	1981-present	Met Office, UK
ESA-CCI-C3S	0.05 X 0.05°	20 cm		
$CNR\text{-}GOS_{005}$	0.05 X 0.05°	Foundation	1982-present	CNR, Italy
$CNR\text{-}GOS_{001}$	0.01 X 0.01°	Foundation	2008-present	CNR, Italy
JPL-MUR	0.01 X 0.01°	Foundation	2002-present	JPL, USA

***In-situ* observations**



Summary of statistics (HR-SST vs. In-situ)

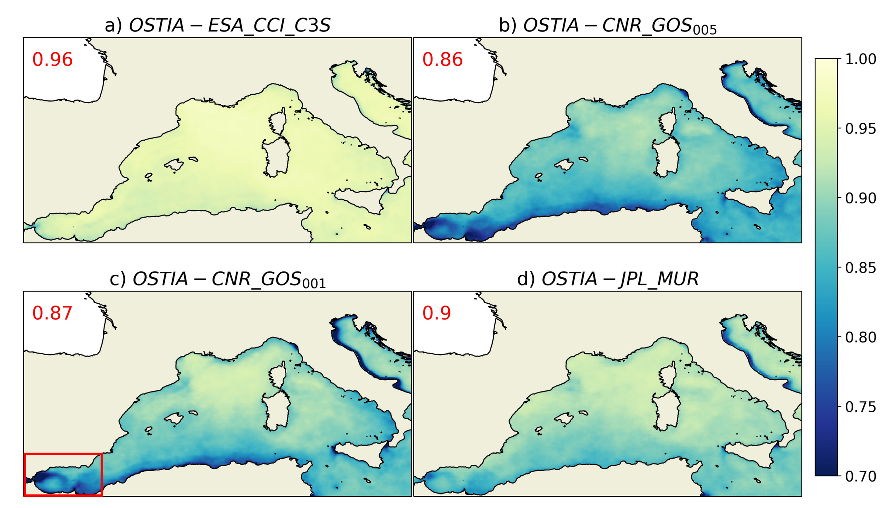
Product	Mean bias (ºK)		RMSE (ºK)		Pearson's r	
	Fixed	Non-fixed	Fixed	Non-fixed	Fixed	Non-fixed
OSTIA	0.07	0.05	0.54	0.54	0.70	0.99
ESA-CCI-C3S	0.01	0.08	0.50	0.52	0.73	0.99
$CNR\text{-}GOS_{005}$	-0.01	0.06	0.48	0.55	0.73	0.99
$CNR\text{-}GOS_{001}$	0.06	0.01	0.48	0.60	0.74	0.99
JPL-MUR	0.04	0.07	0.46	0.53	0.74	0.99
Ensemble mean	0.04	0.07	0.38	0.46	0.78	0.99



The products are compared to *in-situ* observations:

All the products show comparable skills in terms of RMSE and correlation. The ensemble mean shows the lowest RMSE and the higher correlation. Discrepancies between products and in-situ observations could be attributed to a representativity error. i.e., the in-situ observations are pointwise while the satellite products provide the data averaged at the pixel scale. Also, the in-situ observations were obtained at various depths, while satellite data represent the surface layer.

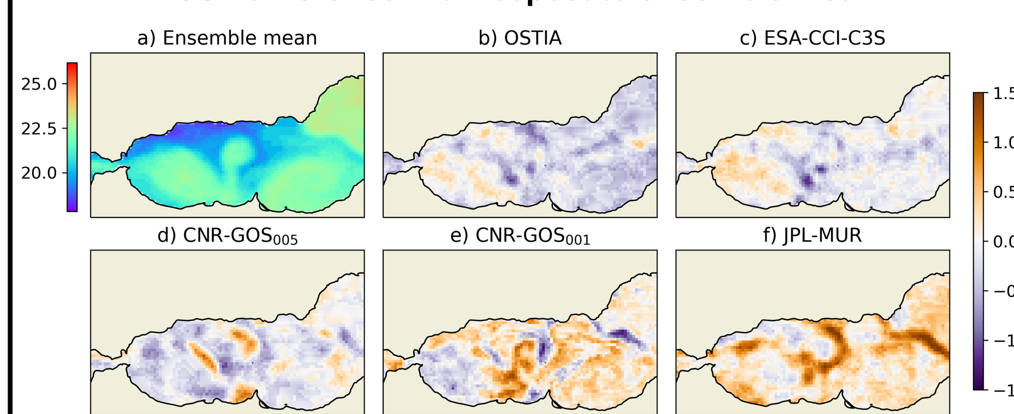
Pearson's correlation of selected HR-SST products



All products highly correlate with each other (r > 0.8). Similar spatial patterns among pairs of products. Lowest in the Alboran Sea and along the African coast.

Apart from OSTIA and ESA-CCI-C3S products (same processing system), $CNR\text{-}GOS_{001}$ and JPL-MUR also shows good agreement (same 0.01° resolution).

SST difference with respect to ensemble mean

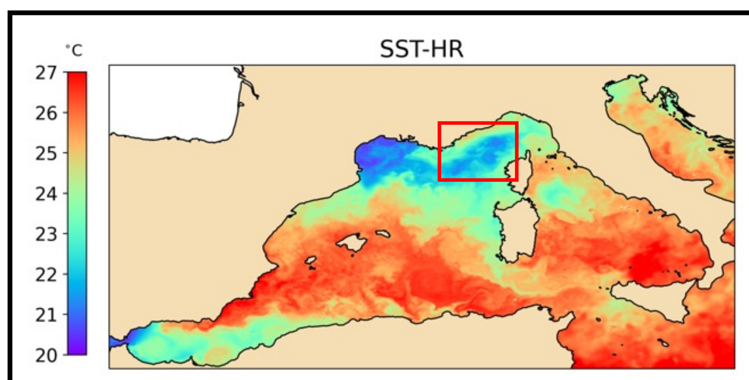


Differences in the representation of small-scale features still exist (Alboran Sea). Discrepancies around the ensemble mean range from -1.5ºC to 1.0ºC. One day as an example.

Analysis error suggests that larger differences in small-scale features arise when error is larger (clouds?)

How important are these differences for the representation of air-sea interactions in a climate modeling framework?

2. Role of submesoscale SST structures on air-sea interactions

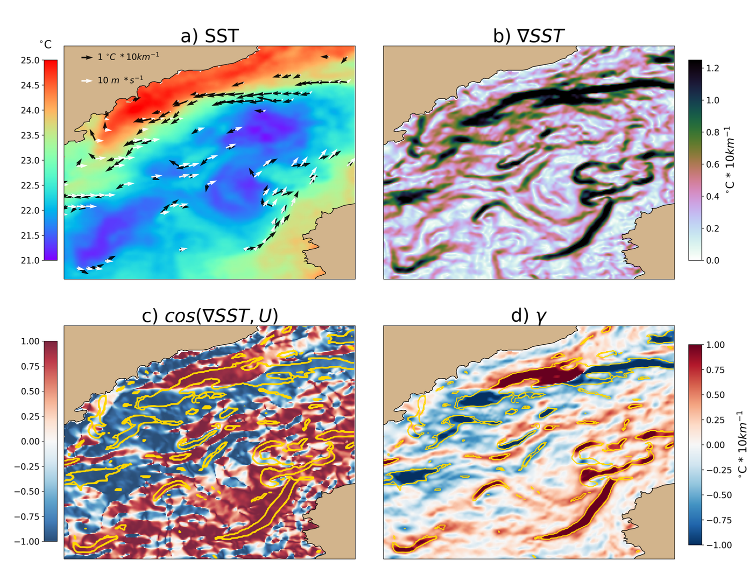


DMM (γ) is given by the dot vector product:

$$\gamma = \nabla SST \cdot \hat{u} = |\nabla SST| \cos\theta$$

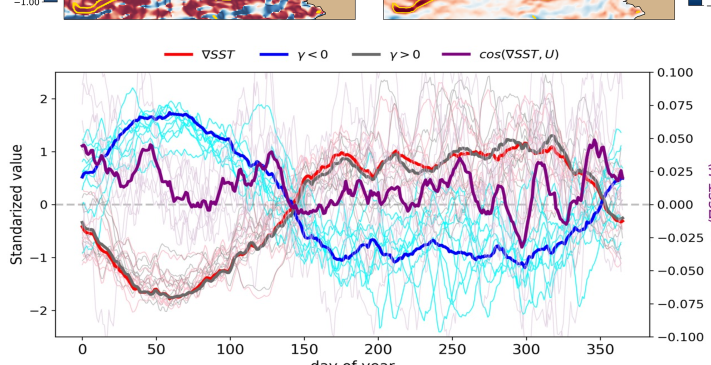
$\hat{u}$ → unit vector in the direction of the wind

θ → counterclockwise angle from ∇SST to $\hat{u}$



Maps: HR-SST (top), and ∇SST, $\cos\theta$ and γ for an enlarged area (a to d). Arrows in a) indicate direction of ∇SST and $\hat{u}$. Contours in c) and d) ∇SST > 0.7 ° C * 10km[-1] Example for one day using **JPL-MUR** dataset. Wind field is obtained from **COSMO-REA6**

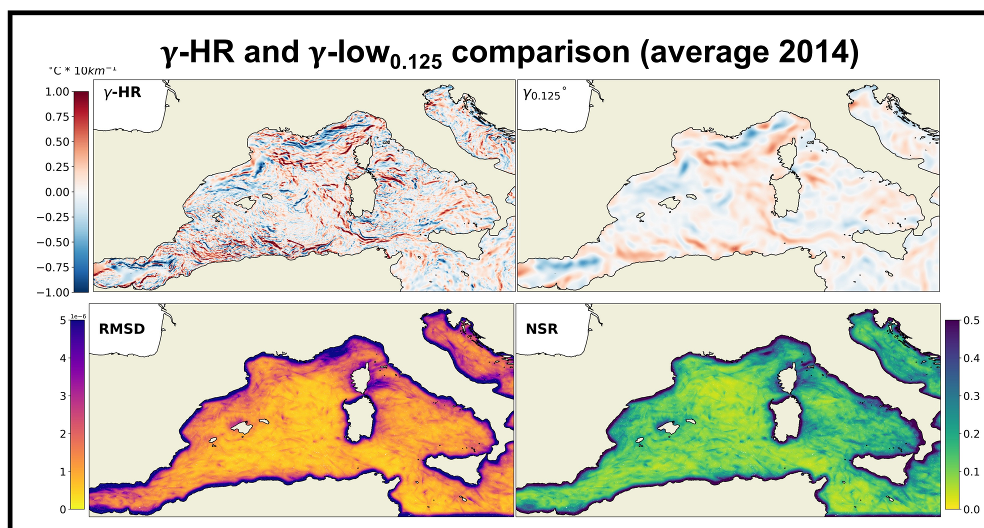
Timeseries: Climatology ∇SST, γ>0; γ<0 and $\cos\theta$ averaged over the region.

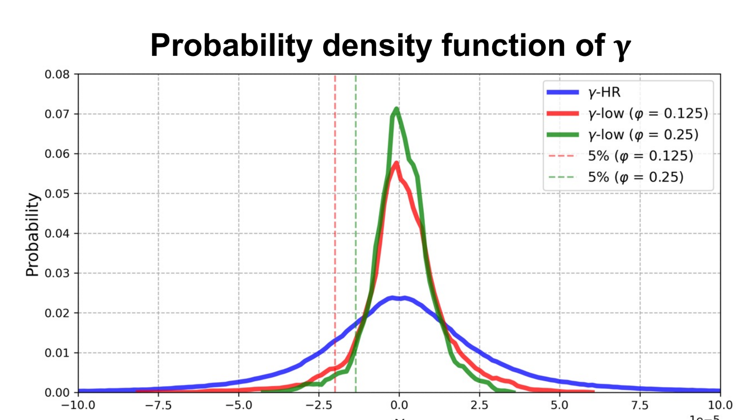


γ>0 (γ<0) when ∇SST and $\hat{u}$ are aligned (opposed); **$\cos\theta$ >0 ($\cos\theta$ <0)**

Large values of γ are obtained for large ∇SST. $\cos\theta$ plays a minor role in the magnitude of γ

γ-HR and γ-low$_{0.125}$ comparison (average 2014)



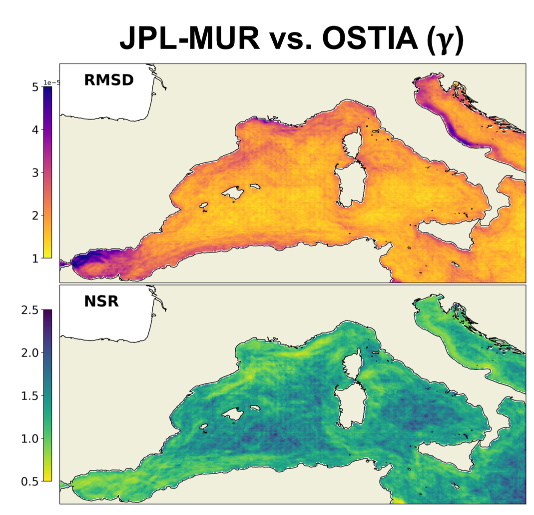


How sensitive is γ to the spatial resolution of the SST field?

We compute γ with the same COSMO-REA6 winds but smoothed (i.e. 0.125°, 0.25°, 0.50°) versions of the SST. **Small-scale structure of γ evident in HR are filtered out. The magnitude of γ is clearly reduced**. The RMSD ($\sqrt{\sum_{t=1}^{T}(\gamma_{HR,t} - \gamma_{low,t})^2/T}$) and the NSR ($RMSD/\sigma_{\gamma_{HR}}$) show significant differences.

The pdfs of γ show a reduction in the tails of the distribution as the horizontal resolution decreases. This may be relevant for the representation of submesoscale air—sea interactions in climate model simulations, as large values of γ can have an influence on precipitation. Previous works (e.g., Desbiolles et al. 2021) showed that the 5% strongest warm-to-cold fronts may lead to a ~35% more chance of having rainfall in ERA5 data.

JPL-MUR vs. OSTIA (γ)



How sensitive is γ to the HR-SST product?

We compare the γ values obtained from the JPL-MUR and OSTIA datasets. **Even if both HR-SST products show a reasonable degree of accuracy, the results in terms of γ are significantly different (NSR > 1).**

This should be taken into account when HR—SST products are used as SST forcing in convection permitting regional model simulation.

Conclusions and Future steps

The results show that an HR-SST field leads to a stronger representation of the DMM (γ) mechanism, which may be important for the representation of air—sea interactions in convection permitting model regional climate model (CP-RCM) simulations, as stronger warm-to-cold fronts may promote convection and precipitation. Also, it is important to be aware that different available HR-SST satellite products may produce differences in the representation of γ due to uncertainties in the representation of small-scale features.

Current CP-RCM simulations do not allow representing such processes due to a relatively coarse SST forcing field. A joint study between **MedCORDEX** FPS is being conducted to assess the sensitivity of the regional climate to a HR-SST forcing configuration by means of an ensemble of CP-RCM simulations.

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