SYMPOSIUM OP'24 ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Theme #5: Impact of observations on forecasting systems

Evaluating dynamical quality of ocean prediction modeling and satellite observations

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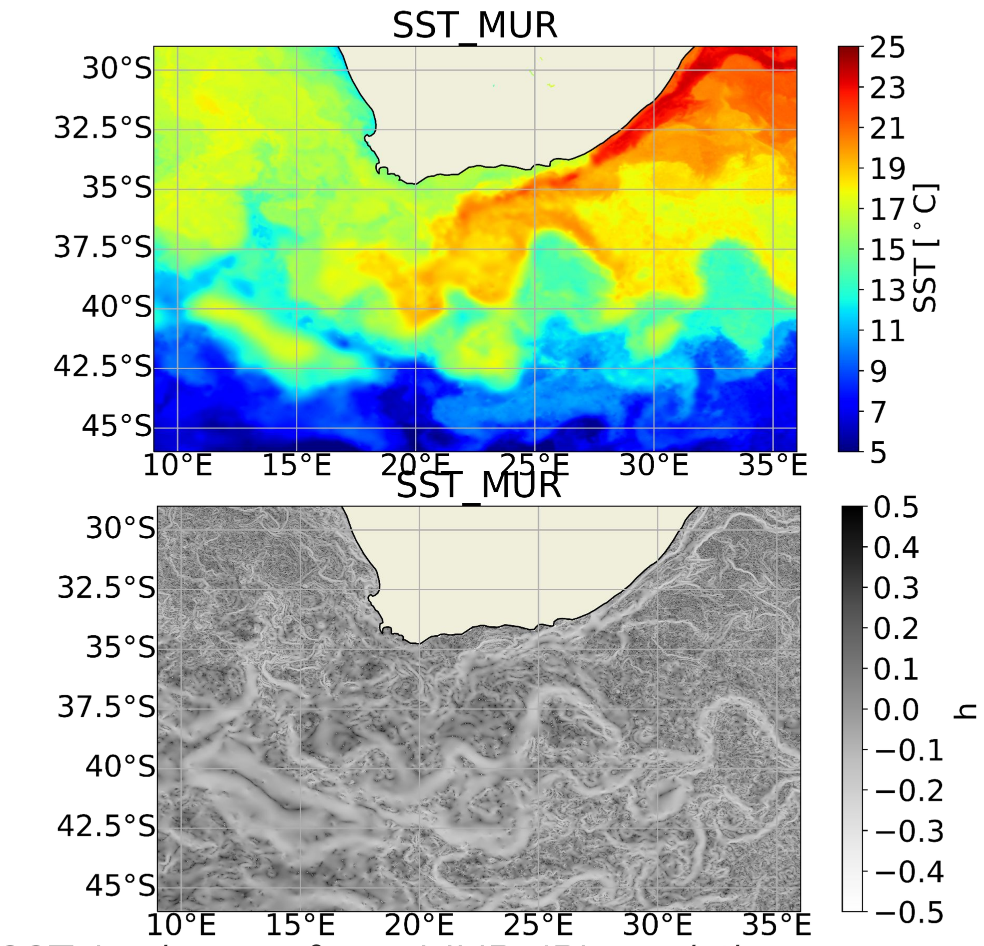
Introduction

The upper ocean is crowded with fronts of varying intensities and extents, which significantly influence the dynamics of the ocean's upper layers and help to determine properties such as the spectral slopes of Sea Surface Temperature (SST), among others.

Here, we show that the upper layers of ocean can be described by the multifractal theory of turbulence. Then, we use this theory to assess the dynamical consistency of:

- satellite observations
- output numerical models



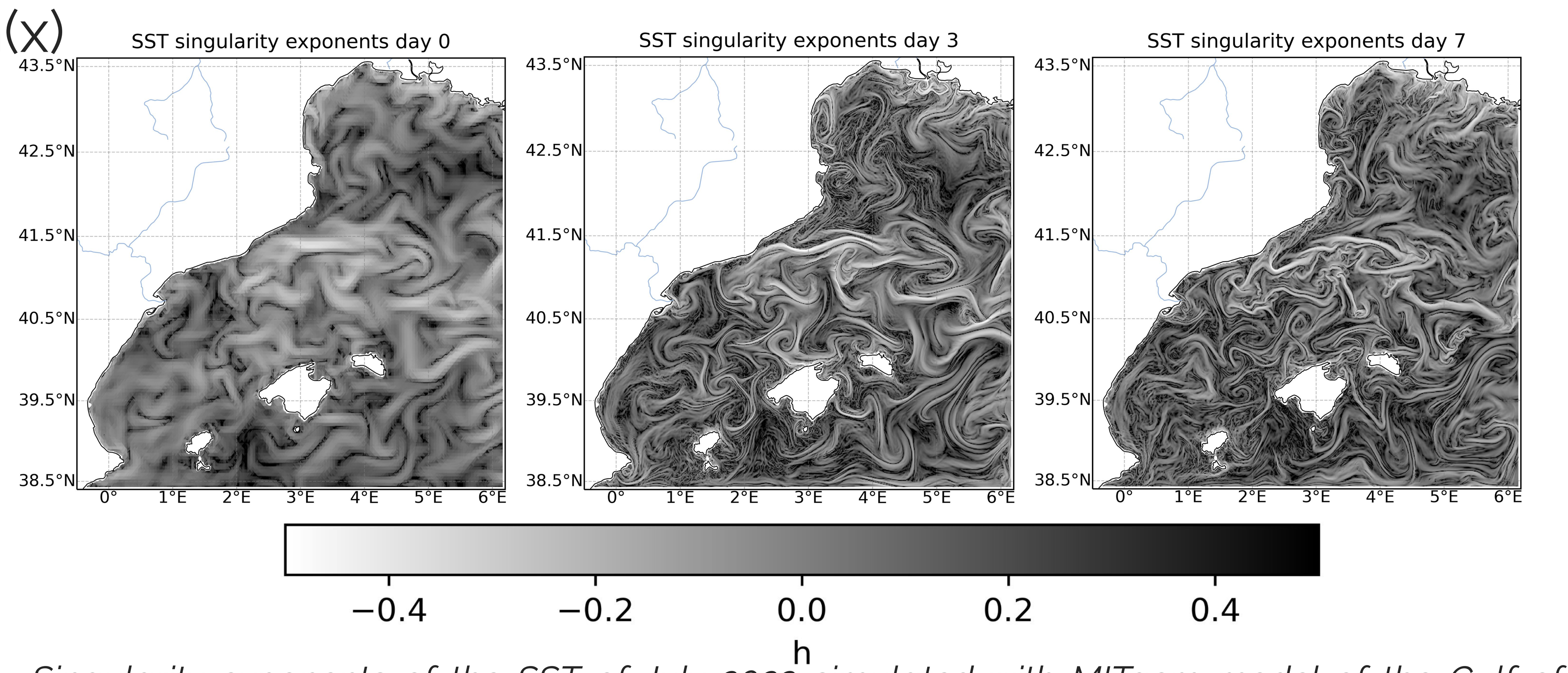
SST L4 image from MUR-JPL and the corresponding singularity exponents for the 29th September 2016 [3].

Theoretical background

- Singularity exponents [1] quantify the degree of continuity of SST. Indeed, if $h(\vec{x}) \in (n, n+1)$ with n being a positive integer, $\overline{|\nabla T|}_{\ell}(\vec{x})$ is derivable n times but not n + 1.
- we use of singularity exponents as measure for the intensity of fronts, being the strongest fronts those with the most marked singularity (brighter in the figure) [2]
- The statistical/geometrical properties of singularity exponents are given by the singularity spectrum
- It can be seen as a transformed PDF of h(x)

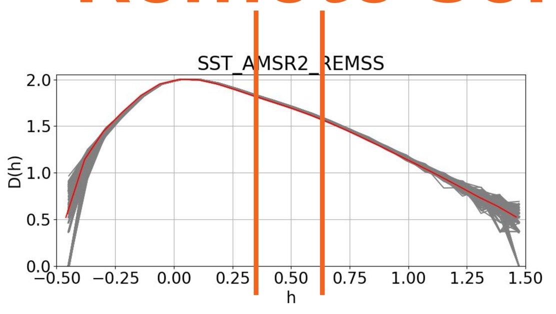
Ocean Prediction Modeling

- Singularity analysis has been used to assess the dynamical downscaling in hydrodynamical modeling.
- Simulations performed for a Gulf of Lions-Balearic sea model using the MITgcm and the CROCO codes and the CMEMS MedSea Physics Analysis and Forecast for initial and boundary conditions

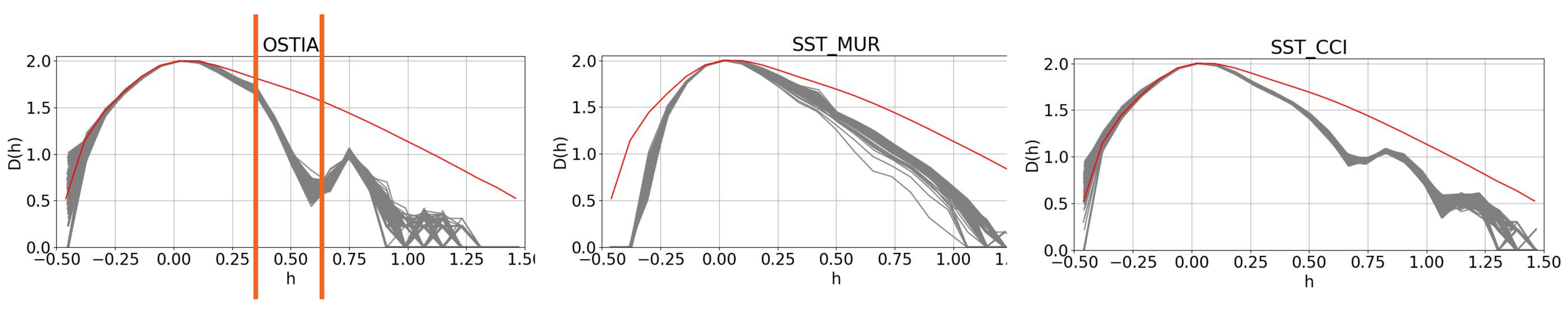


Singularity exponents of the SST of July 2022 simulated with MITgcm model of the Gulf of Lions-Balearics sea region. From left to right: At time 0 of the simulation (from MedSea, 1st of July 2022), after 3 days , after 7 days.

Remote Sensing



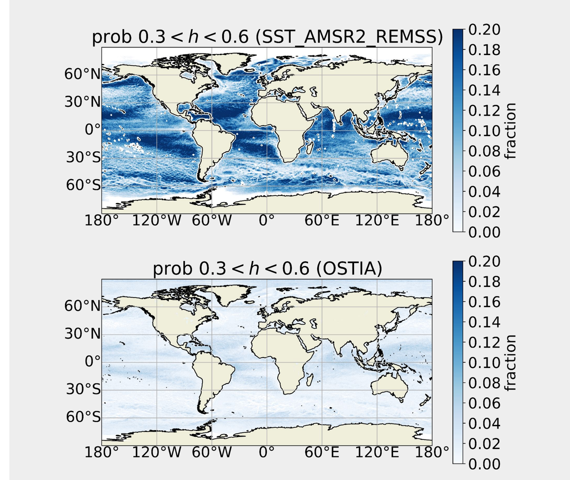
- The singularity spectrum, which is scale invariant, is computed from daily h(x) at the original grid resolution.
- The large dips in h(x) (h=0.6 in OSTIA) indicate an unexpected loss of energy.



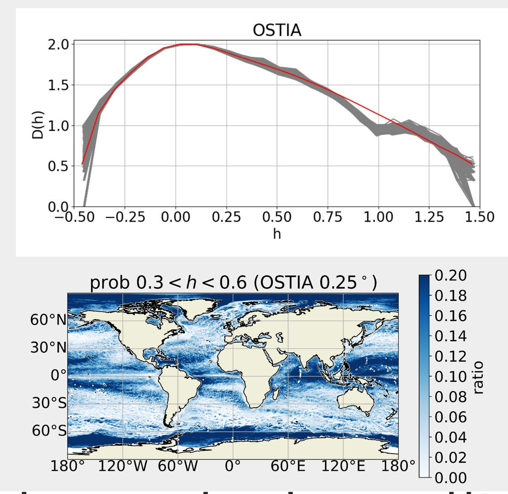
AMSR2_REMSS presents a more realistic D(h)

Daily Singularity spectra D(h) for the year 2016 (gray lines). Median of AMSR2_REMSS singularity spectra (red line) [3]

To better understand the loss of energy, we compute the fraction of days for which the singularity spectrum D(h) is in the 0.3 to 0.6 range



To investigate whether the loss of energy is caused by the L4 algorithms, we reinterpolated the OSTIA product to a 0.25° and repeated the analysis.



Conclusions

- Multifractal theory of turbulence constitutes a valuable tool to assess the structural and dynamical quality of remote sensing product and ocean model outputs.
- Our results reveal that the different schemes used to produce the L4 SST products generate different singularity spectra, which are then used to identify a potential loss of dynamical information or structural coherence [3]

References

[1] Turiel, A., Yahia, H., & Pérez-Vicente, C. J. (2008). Microcanonical multifractal formalism—A geometrical approach to multifractal systems:Part I. Singularity analysis. Journal of Physics A: Mathematical and Theoretical, 41(1), 015501
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[3] González-Haro, C., Isern-Fontanet, J.,Turiel, A., Merchant, C. J., & Cornillon, P.(2024). Structural and dynamical quality assessment of gap-filled sea surface temperature products. Earth and Space Science, 11, e2023EA003088.

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