Improving mesoscale altimetric data in the Mediterranean Sea: convolutional processing of AVISO products and use of SSH/SST synergy

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ABSTRACT

Multi-satellite measurements of altimeter-derived Sea Surface Height (SSH) have provided a wealth of information on the ocean. Yet, horizontal scales below 100km remain scarcely resolved. Here, we investigate a **novel processing of AVISO products** with a view to resolving the horizontal scales sensed by current along-track altimeter data. The key feature of our framework is the use **of linear convolutional operators** to model the fine-scale Sea Surface Height (SSH) detail as a function of different sea surface fields, especially optimally-interpolated SSH and Sea Surface Temperature (SST). Using an **observing system simulation experiment** with simulated SSH data from model outputs in the Western Mediterranean Sea, we show that the proposed approach has the potential for **improving current optimal interpolations of L4 altimeter-derived SSH fields by about 20% in terms of relative SSH and kinetic energy mean square error**, as well as in terms of spectral signatures for horizontal scales ranging from 30km to 100km.

Keywords— Sea Surface Height, Sea Surface Temperature, convolutional models, super-resolution, OSSE, western Mediterranean Sea

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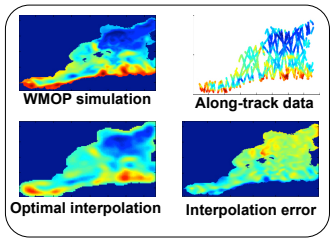
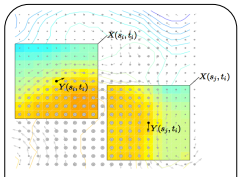
Can we do more than optimal interpolation to recover SSH field from along-track data?

Optimal interpolation cannot reconstruct fine-scale SSH structures, as it acts as a spatio-temporal smoothing of the along-track. Previous works (e.g. [1,2,3]) have explored multi-tracer strategies, such as SQG-related SST-SSH synergies. But, they did not explore the joint use of along-track data with optimally-interpolated SSH field and other geophysical fields such as SST.

Our goal is to investigate such synergies with a view to improving altimetric data in the mesoscale range, with a focus on the western Mediterranean sea.

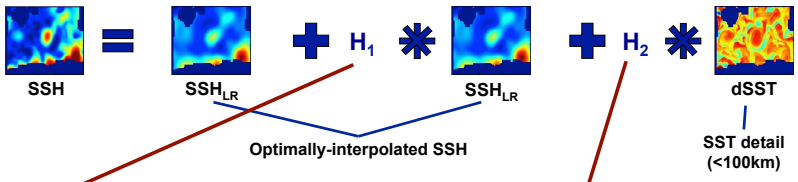




Patch-based representation of a convolution operator, Y=H*X: the size of the patch relates to the mask of the discretized convolution.

A convolutional multi-tracer model

The key feature of our approach is to decompose the SSH field as the combination of three complementary components:

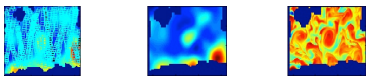


Convolution operator H_1 for the contribution of the optimally-interpolated SSH to the SSH detail

Convolution operator H_2 for the contribution of the SST to the SSH detail

Model parameterization and calibration

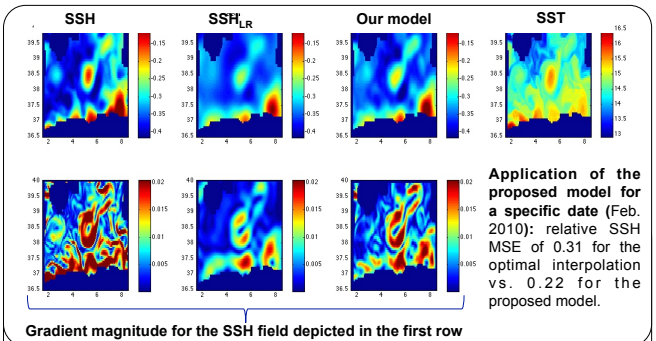
- **Patch-based** representation of convolution operators H_1 and H_2 (3x3 masks)
- Computation of the SST detail as a high-pass filtering of the SST field (<100km)
- **Specific parameterizations for convolutional operators H_1 and H_2:**
  - H_1+H_2: full model
  - H_1+H_2=0: model with no SST contribution
  - H_1=0+H_2: model with no SSH_{LR} contribution
  - H_1+$H_{2,SQG}$: SQG-based parametrization for operator H_2 (fractional Laplacian operator) [1]
  - $H_{1,ISO}$+$H_{2,ISO}$: isotropical parameterization for convolutinal operators H_1 and H_2



Model calibration from the available along-track data regarded as direct observations of the proposed convolution-based model: along-track positions (left), optimally-interpolated SSH (center), SST detial (right).

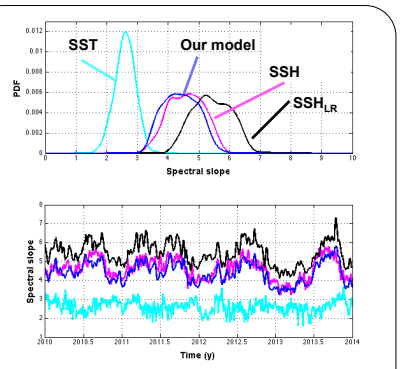
Case-study and numerical experiments

- **Case-study region:** region south of the Balearic Islands in the Western Mediterranean Sea
- **Observation System Simulation Experiment**
  - Use of WMOP ROMS simulations (1/20°, daily, from 2008 to 2013)
  - Simulation of along-track data from real along-track sampling patterns
  - Optimal interpolation scheme with 100km and 7-day space-time correlation length
- Model fit for convolutional operators H_1 and H_2 on a daily basis with a +/-10 time window



Gradient magnitude for the SSH field depicted in the first row

Application of the proposed model for a specific date (Feb. 2010)**:** relative SSH MSE of 0.31 for the optimal interpolation vs. 0.22 for the proposed model.



Spectral characterization of the proposed model for spatials scales between 20km and 100km: distribution of the spectral slopes (top), time series of the spectral slopes (bottom)

MSE statistics over the entire time series for different parameterzations of the proposed model.

	Relative SSH MSE	Relative KE MSE	Relative PSD MSE
OI-derived SSH	0.22	0.95	0.42
$H_1 + H_2$	**0.17**	0.63	**0.31**
$H_1 + H_2$ $DT = \infty$	0.19	0.68	0.34
$H_1 + H_2 = 0$	0.19	0.68	0.31
$H_1 = 0 + H_2$	0.20	0.74	0.42
$H_1 + H_{2,SQG}$	0.18	0.64	0.31
$H_{1,Iso} + H_{2,Iso}$	0.17	**0.62**	**0.30**

Conclusion and Future work

This study points out the potential of the synergistic use of optimally-interpolated SSH, along-track SSH data and SST field with a view to improving current altimetric data for spatial scales below 100km up to 20%.

Our future work will further explore the application of the proposed model to **real data including other geophysical tracers** (e.g., ocean colour, Lagrangian features) as well as to the spatio-temporal sampling of **SWOT mission**. **Non-linear extensions** will also be of interest to address more complex inter-scale and multi-tracer relationships.

References

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More details from:

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