

Analog Data Assimilation of Along-track Nadir and SWOT Altimetry Observations in the Western Mediterranean Sea

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References

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1. Abstract

The growing availability of ocean data brought forth by recent advancements in remote sensing, in situ measurements and numerical models supports the development of data-driven strategies as a powerful, computationally-efficient alternative to model-based approaches for the interpolation of high-resolution, gap-free, regularly-gridded sea surface geophysical fields from partial satellite-derived observations.

In this work, we investigate such data-driven strategies for the spatio-temporal interpolation of Sea Level Anomaly (SLA) fields in the Western Mediterranean Sea from satellite-derived altimetry data. We develop and evaluate an Analog Data Assimilation (AnDA) framework, which exploits patch-based analog forecasting operators. Two different types of altimetry data are assimilated: along-track nadir data and wide-swath SWOT altimetry data. Using an Observing System Simulation Experiment (OSSE), we demonstrate the relevance of AnDA as an improved interpolation method, particularly for mesoscale features in the 20-100 km horizontal scale range. Results report an SLA reconstruction RMSE (correlation) improvement of 42% (14%) with respect to Optimal Interpolation (OI), and show an additional gain when the joint assimilation of SWOT and along-track nadir observations is considered.

2. Analog Data Assimilation

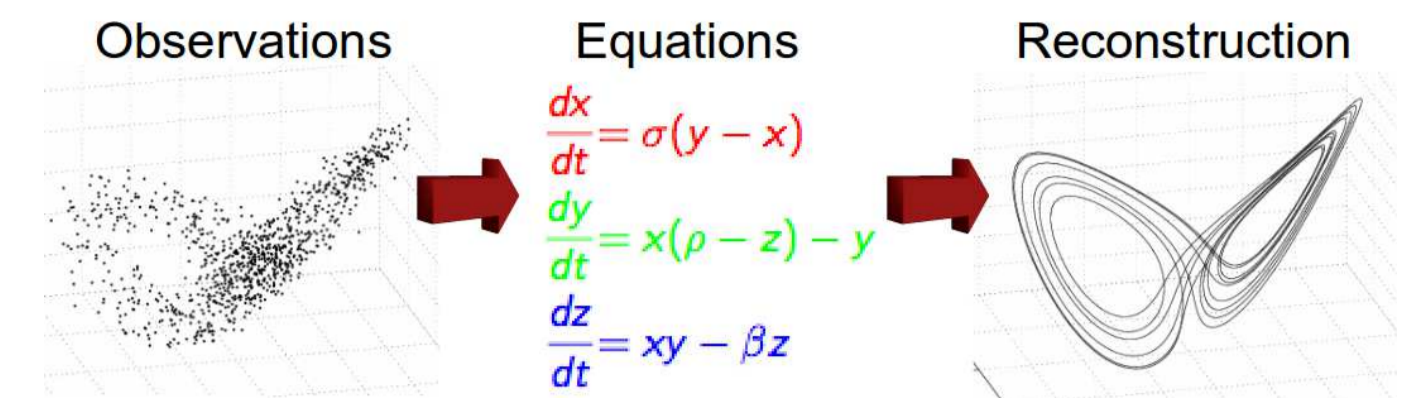
Data Assimilation: Combine a numerical model and observations for reconstruction

- ▶ Observations can be noisy and/or partial
- ▶ Models can be non-consistent with observations, uncertain or even unknown
- ▶ Running models can be computationally expensive

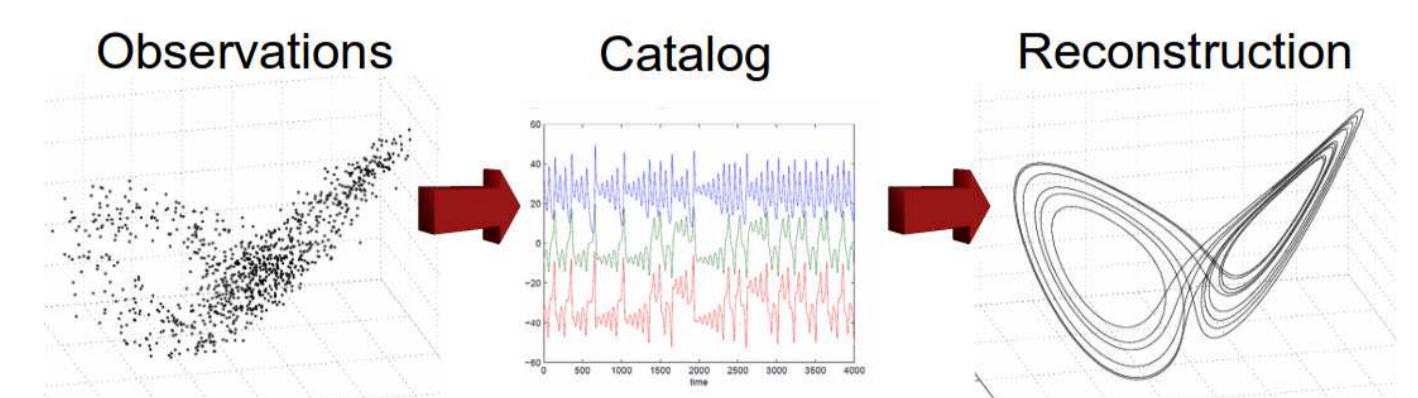
Idea: Replace the model-based forecasting step of data assimilation with a data-driven approach

- ▶ Dynamical models can be built directly from a catalog of realistic simulations of system state dynamics
- ▶ Forecast can be made by exploiting the similarity between the current state and simulated states within the catalog

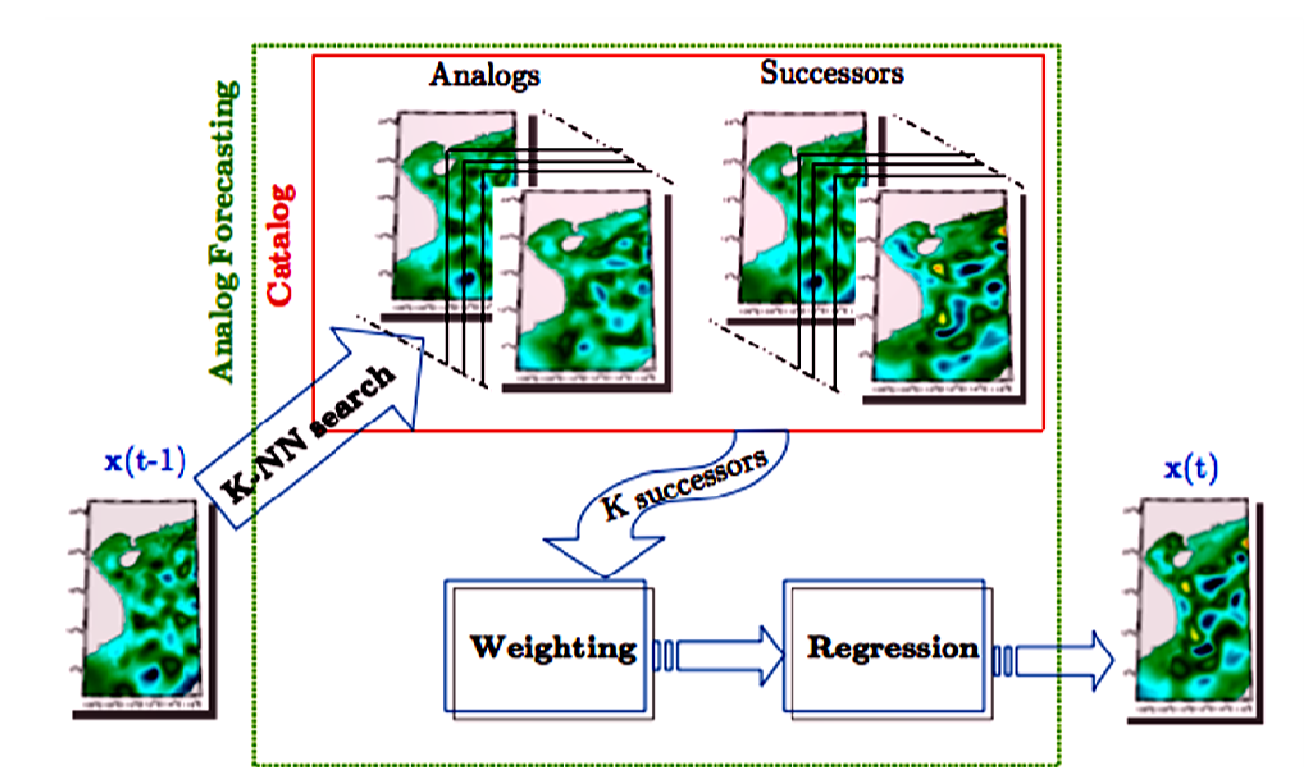
Classic data assimilation [1]



Analog data assimilation [2]



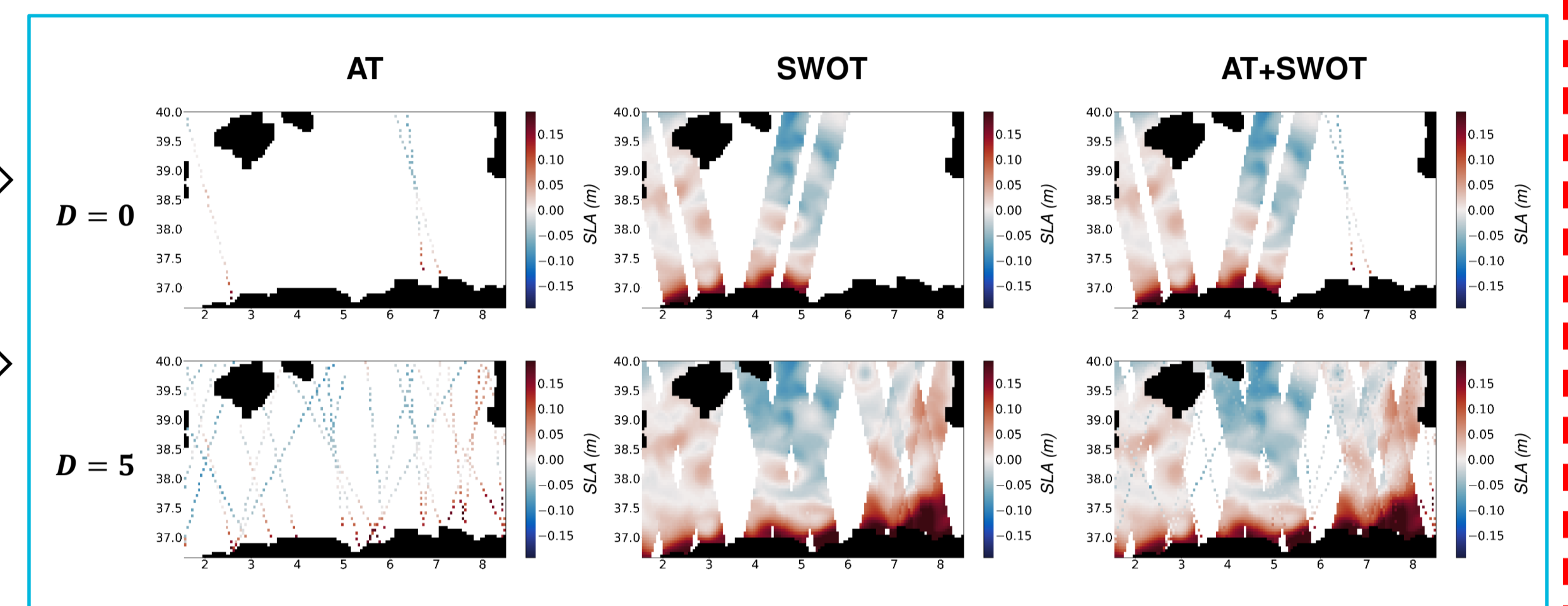
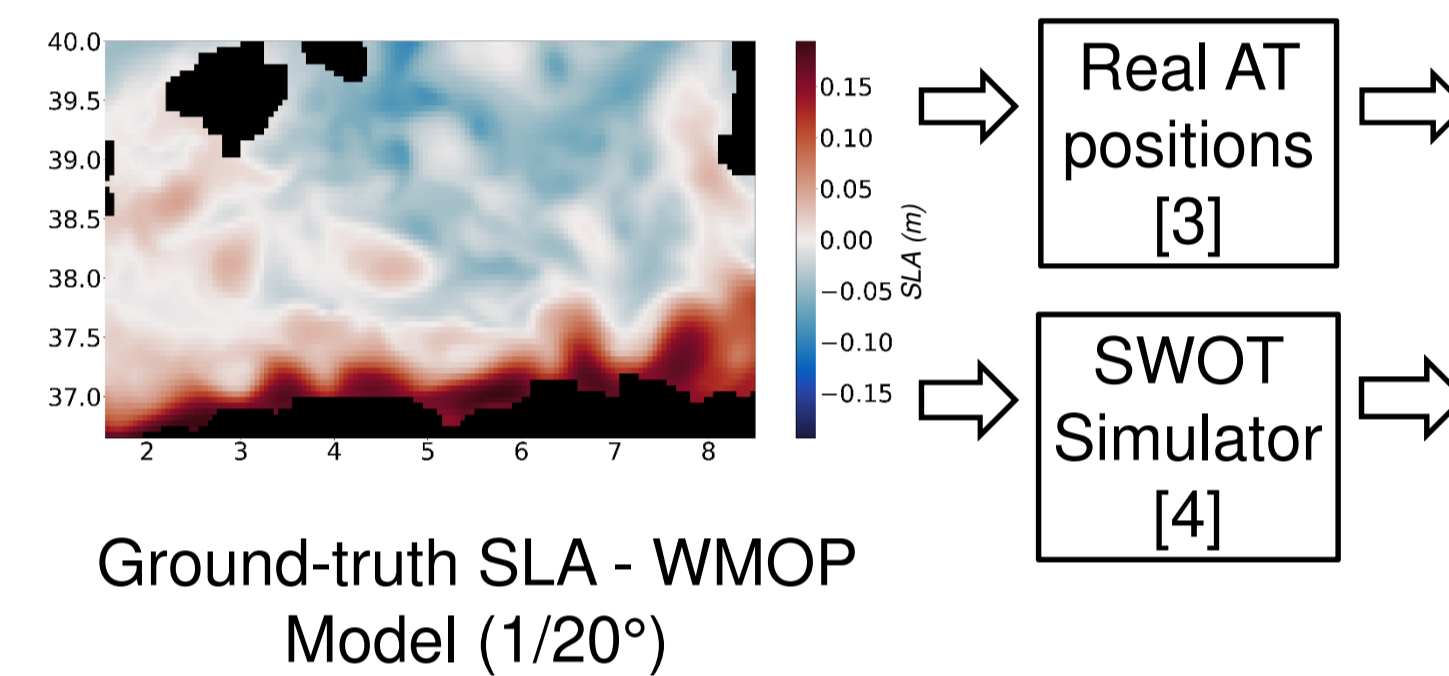
Analog data assimilation for geophysical fields



3. Ocean Observing System Simulation Experiment

Observing System Simulation Experiment

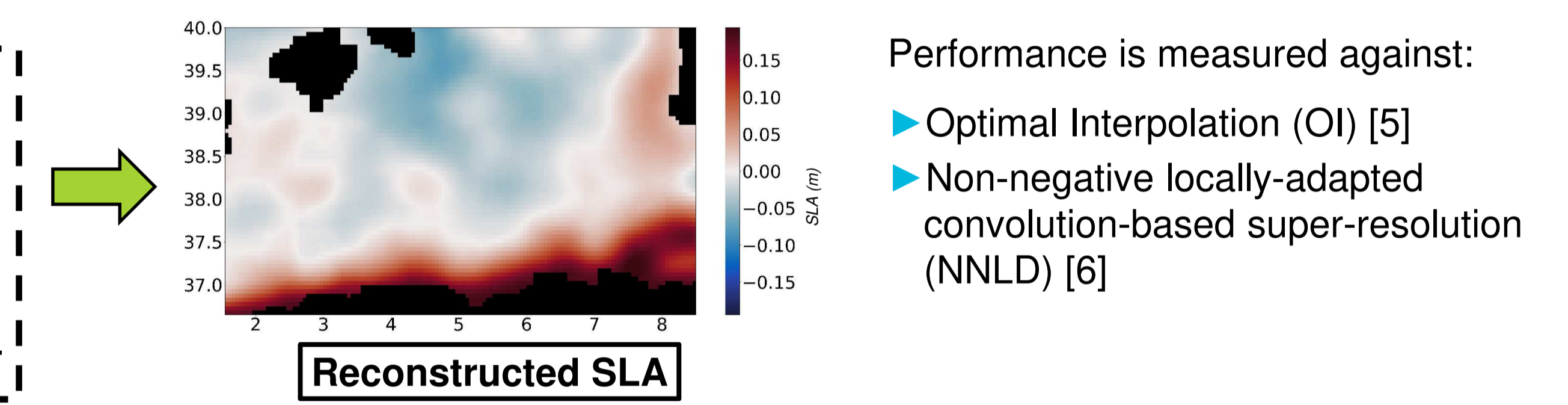
- ▶ Case study in the Western Mediterranean Sea, from 2010 to 2013
- ▶ Daily synthetic SLA fields computed using the WMOP model
- ▶ Real satellite along-track positions [3] used to simulate nadir along-track observations
- ▶ Pseudo-SWOT observations generated using the SWOT Simulator [4]



Pseudo-observations: Observations accumulated on a time window $t_0 \pm D$

Analog Data Assimilation

- ▶ Data from 2010-2012 is used to create a catalog.
- ▶ AnDA is evaluated on data from 2013.
- ▶ Pseudo-observations are assimilated every $dt = 1$ days.



4. Results

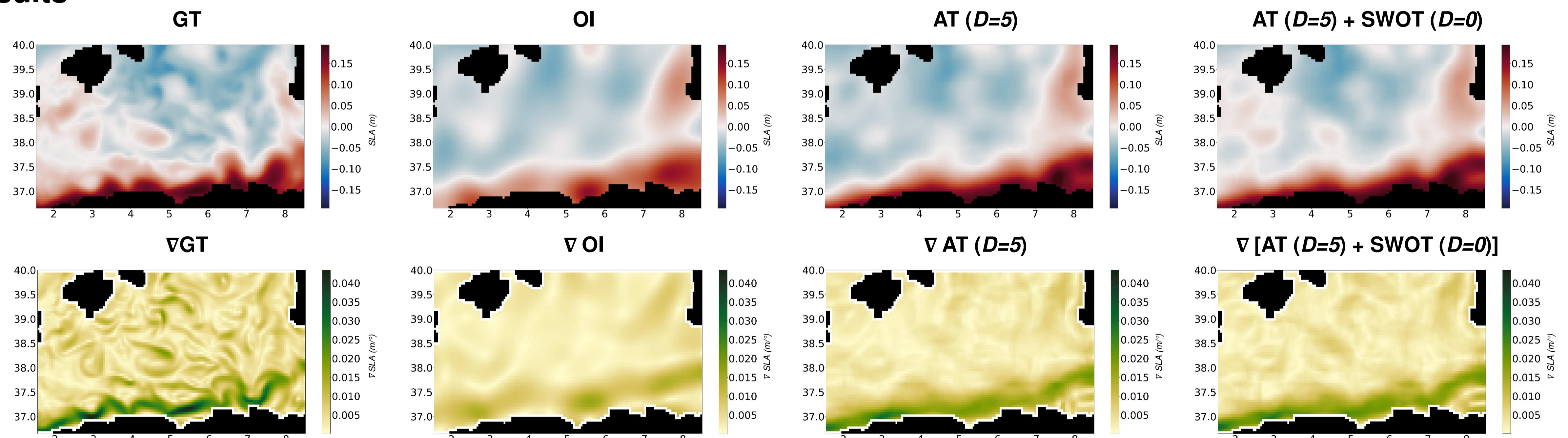


Table 1: RMSE (Correlation) for AnDA using SWOT observations with different noise settings. Best results in bold. Result for OI [5] and NNLD [6] given as reference.

Setting	SLA	∇ SLA
No noise	0.01802 (0.9548)	0.004410 (0.7894)
KaRIN noise	0.01809 (0.9543)	0.004427 (0.7873)
All noise sources	0.03761 (0.8104)	0.005775 (0.5869)
OI	0.02927 (0.8451)	0.006655 (0.6052)
NNLD	0.02115 (0.6965)	0.004506 (0.5893)

Table 2: RMSE (Correlation) for AnDA using different combinations of SWOT and AT observations. Best results in bold. Result for OI [5] and NNLD [6] given as reference.

Setting	SLA	∇ SLA
AT (D = 0)	0.02381 (0.9202)	0.005484 (0.7019)
AT (D = 5)	0.01980 (0.9459)	0.004702 (0.7676)
SWOT (D = 0)	0.01802 (0.9548)	0.004410 (0.7894)
SWOT (D = 5)	0.01919 (0.9502)	0.004339 (0.7918)
AT (D = 0) + SWOT (D = 0)	0.01738 (0.9577)	0.004382 (0.7928)
AT (D = 5) + SWOT (D = 5)	0.01871 (0.9526)	0.004317 (0.7953)
AT (D = 5) + SWOT (D = 0)	0.01688 (0.9608)	0.004299 (0.8044)
OI	0.02927 (0.8451)	0.006655 (0.6052)
NNLD	0.02115 (0.6965)	0.004506 (0.5893)

▶ Correlated noise in SWOT significantly degrades performance of AnDA.

▶ 32% (12%) improvement in SLA RMSE (correlation) with respect to OI when considering AT data.

▶ 29% (27%) improvement in SLA gradient RMSE (correlation) with respect to OI when considering AT data.

▶ Additional improvement from the joint assimilation of SWOT and along-track nadir observations, with a total gain of 42% (14%) in terms of SLA RMSE (correlation) and 35% (33%) in terms of SLA gradient RMSE (correlation).

5. Conclusion

We developed an application of the Analog Data Assimilation (AnDA) to the reconstruction of SLA fields in the Western Mediterranean Sea from satellite altimetry data, namely satellite along-track nadir data and wide-swath SWOT data. The AnDA framework can be regarded as a means to exploit high-resolution numerical simulation datasets for the reconstruction of SLA fields from partial satellite observations. The reported OSSE support the relevance of AnDA with respect to state-of-the-art approaches (OI and NNLD). For instance, we report a clear improvement of 32% (12%) in terms of SLA RMSE (correlation) and 29% (27%) in terms of SLA gradient RMSE (correlation) with respect to OI when considering along-track nadir data. Our experiments also report an additional improvement from the joint assimilation of SWOT and along-track nadir observations, with a total gain of 42% (14%) in terms of SLA RMSE (correlation) and 35% (33%) in terms of SLA gradient RMSE (correlation) with respect to OI. However, additional preprocessing should be carried out to filter out the correlated noise in SWOT data. Future work will focus on combining such preprocessing strategies with the AnDA framework in order to develop useful tools to process real observations from the future SWOT altimetry mission. Other interesting research avenues include the combination of different sources of altimetry data as well as considering additional ocean dynamical tracers (e.g. sea surface temperature, sea surface salinity, ocean color, etc.). The exploitation of structural information present in wide-swath observations, for example by means of numerically resolved SLA gradients and/or finite size Liapunov exponents (FSLE), is also an appealing research direction.