

Improving Sea Level Height warnings in Venice and Alexandria with hybrid sub-seasonal forecasts

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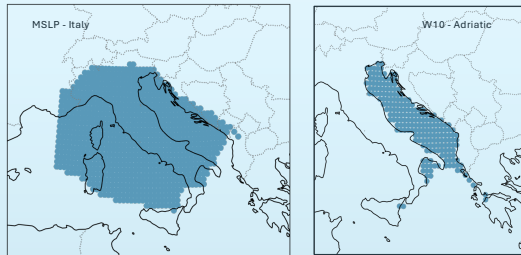


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The cities of Venice (Italy) and Alexandria (Egypt) are highly vulnerable to **coastal floods**. Early warnings of these events help increase the preparedness of involved stakeholders. The increased frequency and intensity of High Water events is linked to the rise in average global Sea Level Height (SLH) and to the combination of astronomical tide and weather-driven SLH surge. The project MedEWSa aims to improve the calculation of the meteorological contribution with the use of AI algorithms, extending the time horizon of the current **Early Warning System** to the sub-seasonal scale. In the case of Venice, we employed the Probabilistic Coral Reef with Substrate Layers (PCRO-SL) to detect the relevant lagged drivers of SLH anomaly. These drivers were used to train multiple fine-tuned Neural Networks and Tree-Based algorithms. After evaluating the performances, the best model was **operationally implemented**, providing Venice Municipality with an extended prediction of Sea Level Height. For the case of Alexandria, a Random Forest was trained using local meteorological drivers and developing a similar module for the sub-seasonal forecast of SLH.

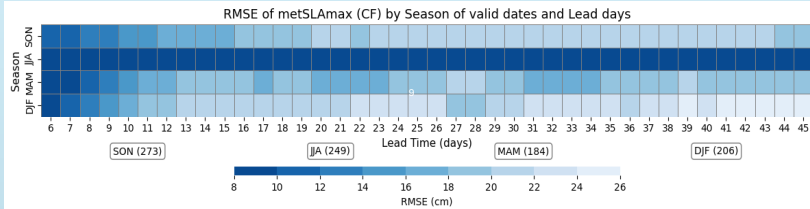
1. Drivers of SLH meteorological component in Venice

The drivers were selected among a list of clustered meteorological variables (e.g.: MSLP, wind, wind stress) in the Euro-Med domain. The PCRO-SL, using obs as target, detected the most influential ones together with their lags.



Variable	Area	Min. lag [days]	Max. lag [days]
MSLP	Italy	0	6
MSLP	Mediterranean + Tunisia	0	6
Geop. H. 500hPa	Central Atl. + N. Africa	3	6
Zonal wind 10 m	Italian Ionian Sea	1	5
Meridional wind 10 m	Greek Ionian Sea	5	6
Meridional wind 10 m	Adriatic Sea	0	0
EW wind stress 10m	Adriatic Sea	0	0
EW wind stress 10m	Italian Ionian Sea	0	1
NS wind stress	Adriatic Sea	0	1
Pressure difference	Venice – Otranto St.	0	5
Precipitation	Po Valley	0	1
Precipitation	Northern Adriatic	1	4

3. Model verification

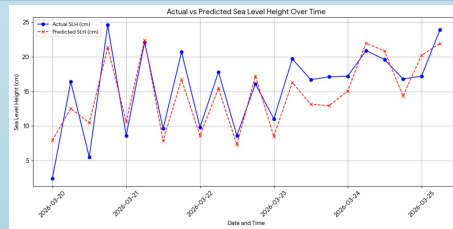


4. Operationalization

Every day the ECMWF-S2S runs are processed with the trained MLP, allowing to produce forecasts of SLH for the next 46 days. These are transferred to the Venice Control Room, that consults them to issue early warnings.

5. SLH sub-seasonal forecasts in Alexandria

The city of Alexandria, affected by frequent coastal floods, lacked a structured EWS. Thanks to the cooperation with CMCC and Venice Municipality, EMA developed a SLH sub-seasonal forecast based on a Random Forest model. This has been trained using ERA5 reanalysis of local variables like MSLP, wind and wave height as predictors and in-situ observations as target. The Egyptian Authority is now able to foresee the eventuality of these events with larger advice and to prepare the response of local institutions and general public.



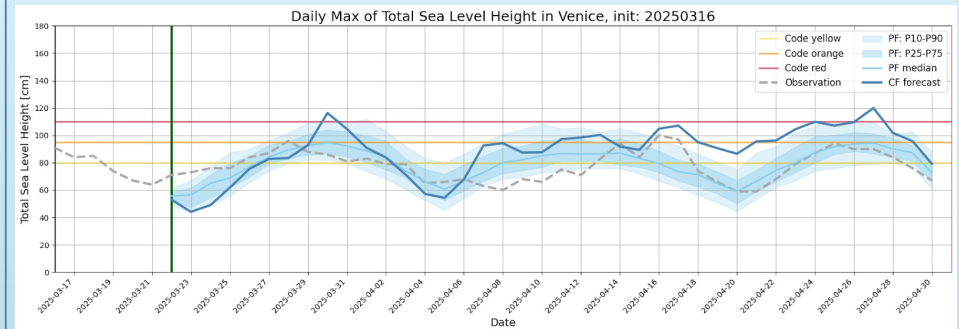
2. Selection of prediction model and its application

Using the selected predictors, 8 models were fine tuned and trained (ERA5 vs obs., 2004-2019) and tested (ERA5 vs obs., 2019-2024). Predictions of **daily maximum component of SLH** and **total SLH** are evaluated in order to detect the best model.

The **MLP** is then applied to the the historical archive of sub-seasonal (S2S) ECMWF (control and perturbed) forecasts. Predictions of the anomalies of the clustered variables are used as input, accounting for their lags.

Model	Correlation	RMSE
Linear Regression (LR)	0.88	7.83
MultiLayer Perceptron (MLP)	0.90	7.27
Keras/TensorFlow Sequential (Seq)	0.90	7.28
pyTorch MLP (pyTorch)	0.89	7.61
Random Forest (RF)	0.88	7.84
Adaptive Boosting (AdaBoost)	0.87	8.21
Gradient Boosting Regressor (GBR)	0.89	7.65
Extreme Gradient Boosting (XGB)	0.89	7.56

TOTAL SEA LEVEL HEIGHT =
METEOROLOGICAL COMPONENT ANOMALY (with MLP) + ASTRONOMICAL TIDE (harmonic constituents) + SEASONAL CYCLE (form observations 2004-2024) + LONG TERM SIGNAL (from observations 2004-2024)



6. Conclusions and next steps

Thanks to the use of a fine tuned MultiLayer Perceptron we are able to construct daily series of predicted maximum sea level in Venice for the next 46 days by using forecasts of clustered meteorological variables. This product is operationally transferred to the Tide Prediction Center of the Venice Municipality, increasing its preparedness to extreme events. By applying the module (and its verification procedure) to perturbed forecasts we plan to investigate which features in the variables bring to better scores, aiming to develop an AI-based member subsampling. In Alexandria, with a similar process, a trained Random Forest module is operationally used by the Egyptian Meteorological Authority for the prediction of coastal floods.