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Improved understanding of nitrate trends, eutrophication indicators and problem areas using machine learning

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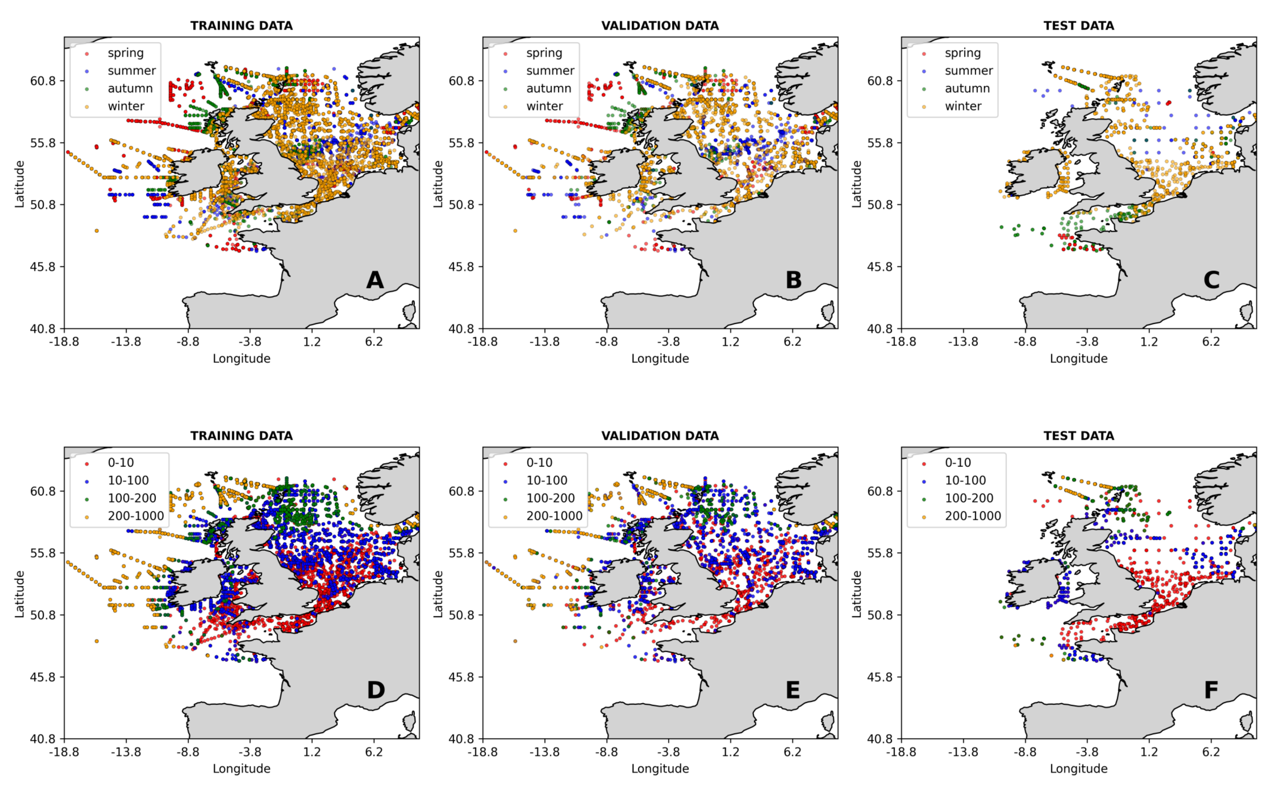
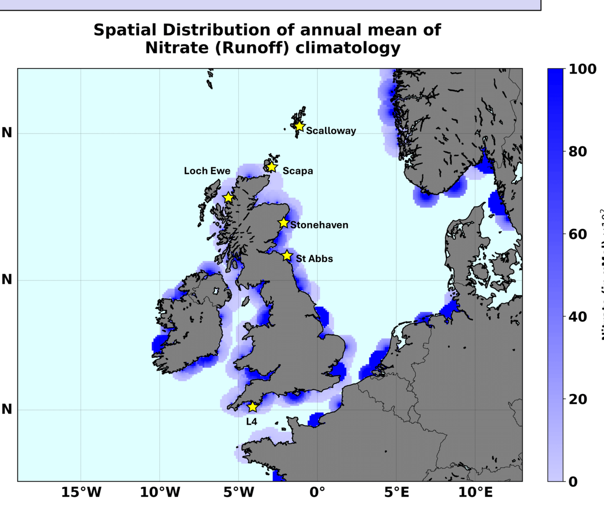
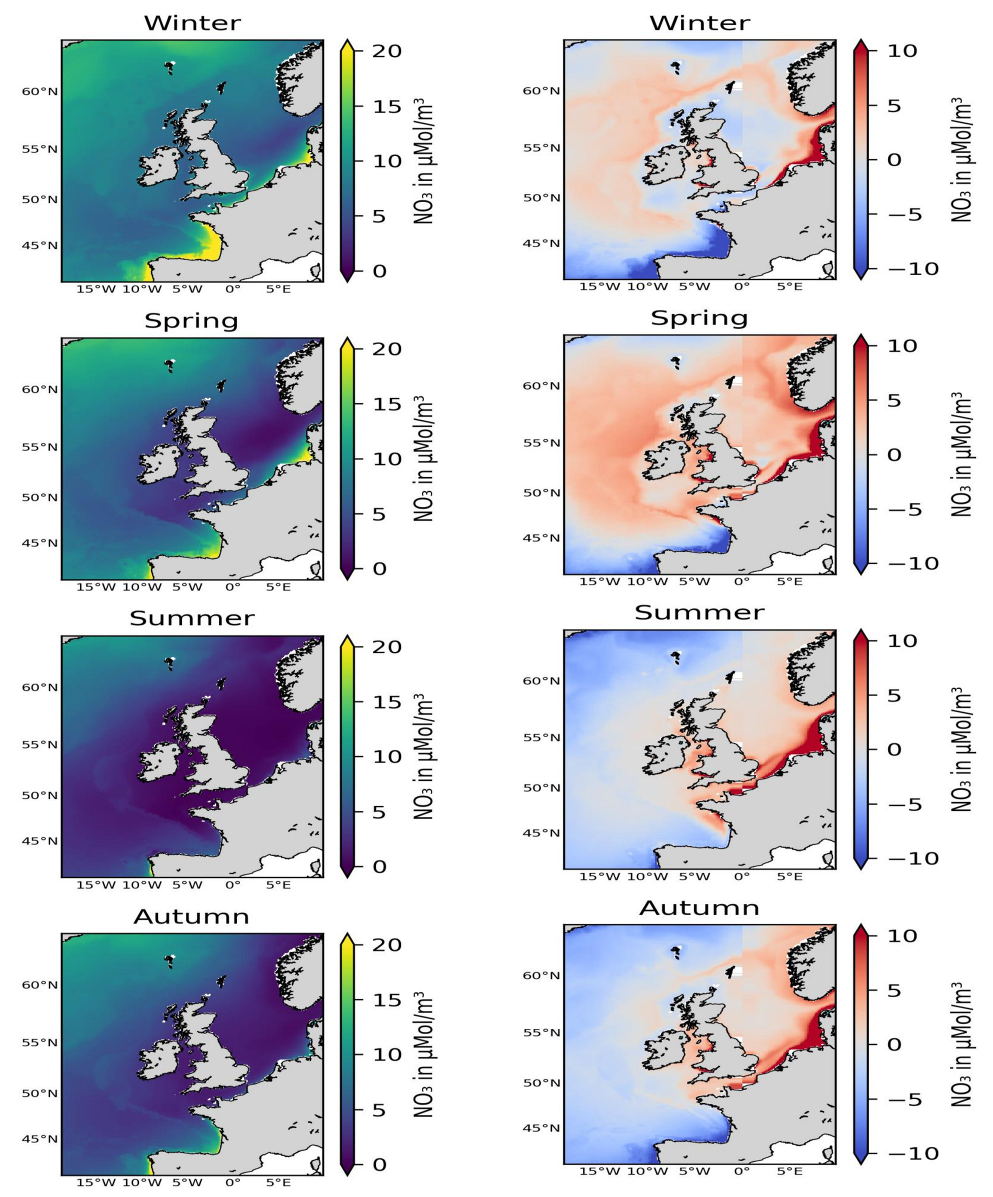
We developed a feed-forward neural network model (using AutoKeras library) to predict nitrate values from observable variables, i.e. atmospheric data, riverine discharge, structural variables and surface variables like SST, chlorophyll. The model was trained for North-West European Shelf (NWES) on ICES nitrate data. The purpose of this work is to produce a gap-free high-quality nitrate dataset for eutrophication studies (trends, variability and problem-areas), as well as to correct NWES operational model biases during the forecast..



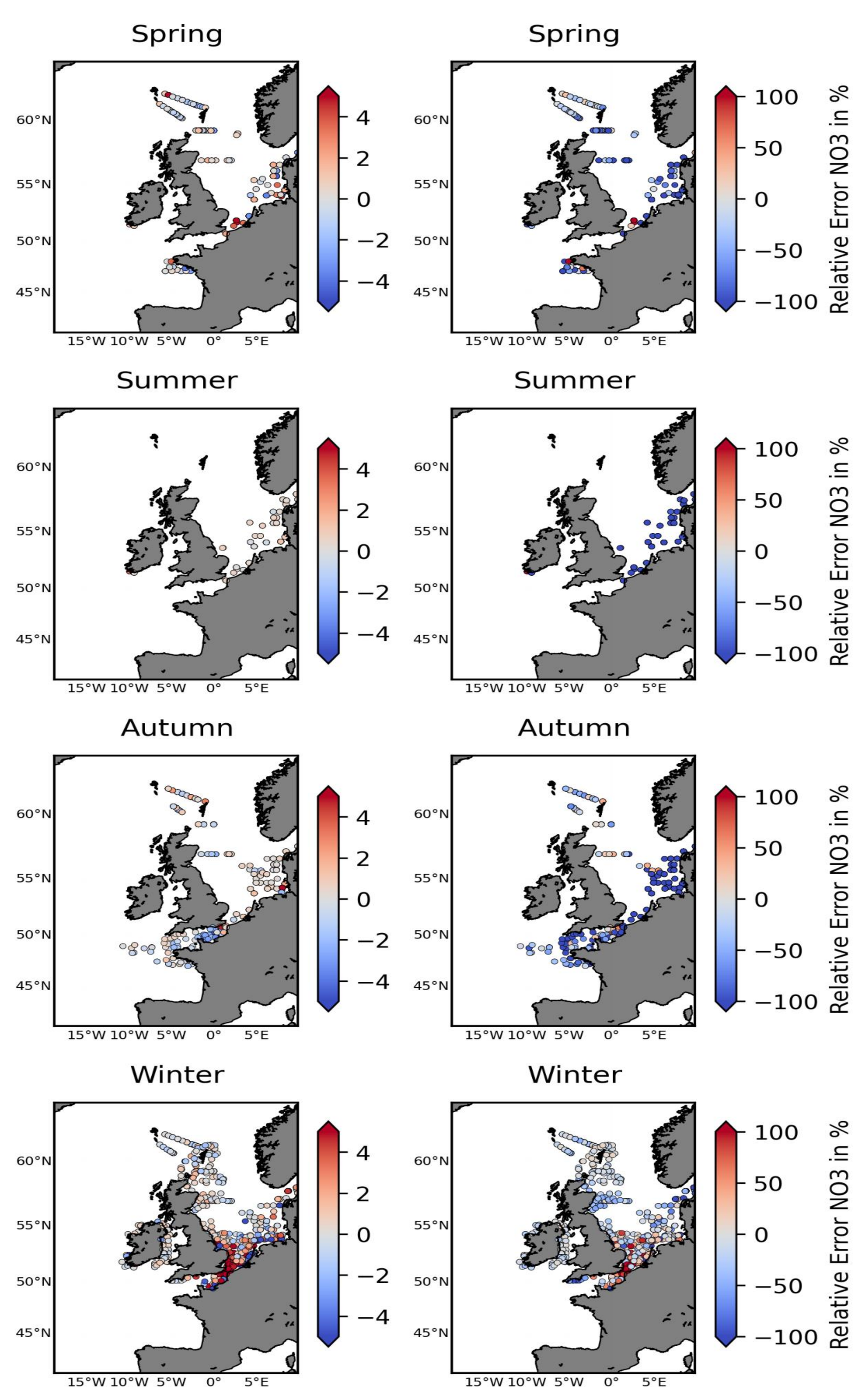


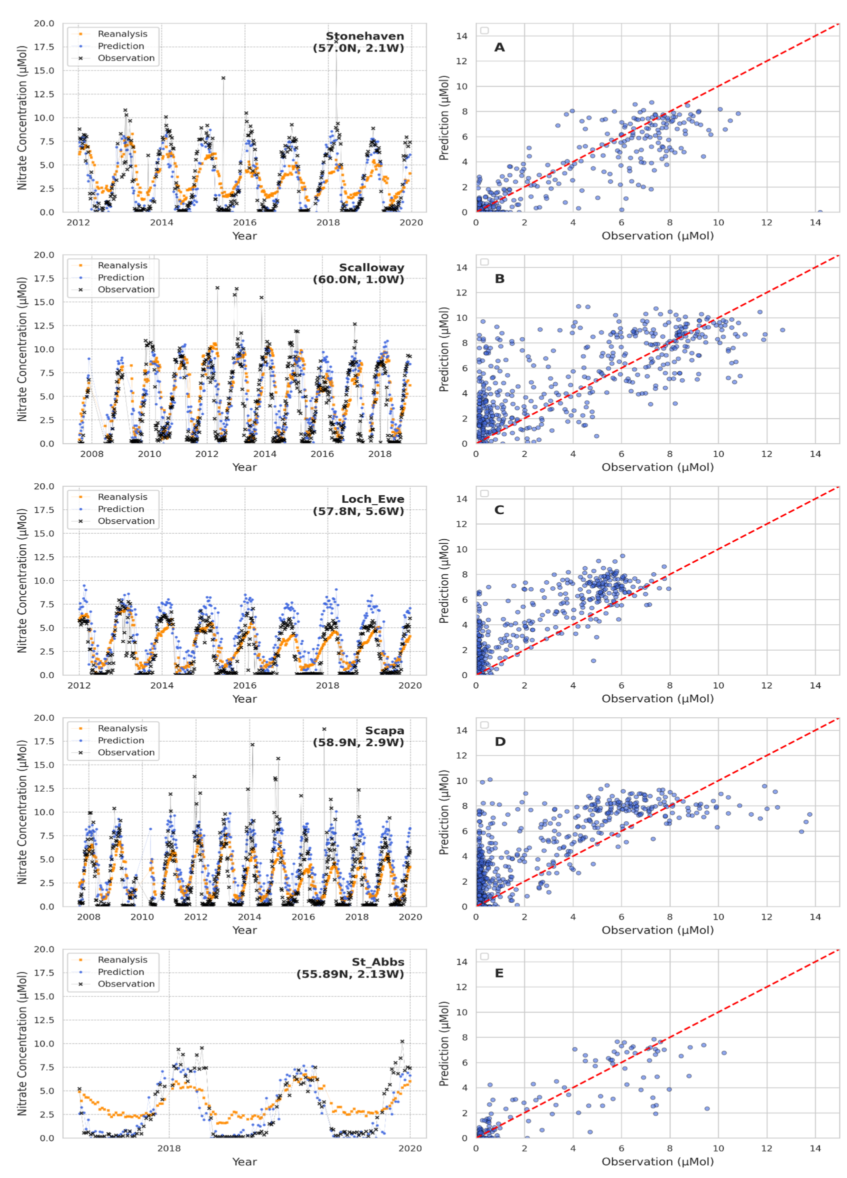
ICES data structure (left) and the river data (top) used to train the neural network model. The top Figure also marks the locations of the observing stations providing test data.



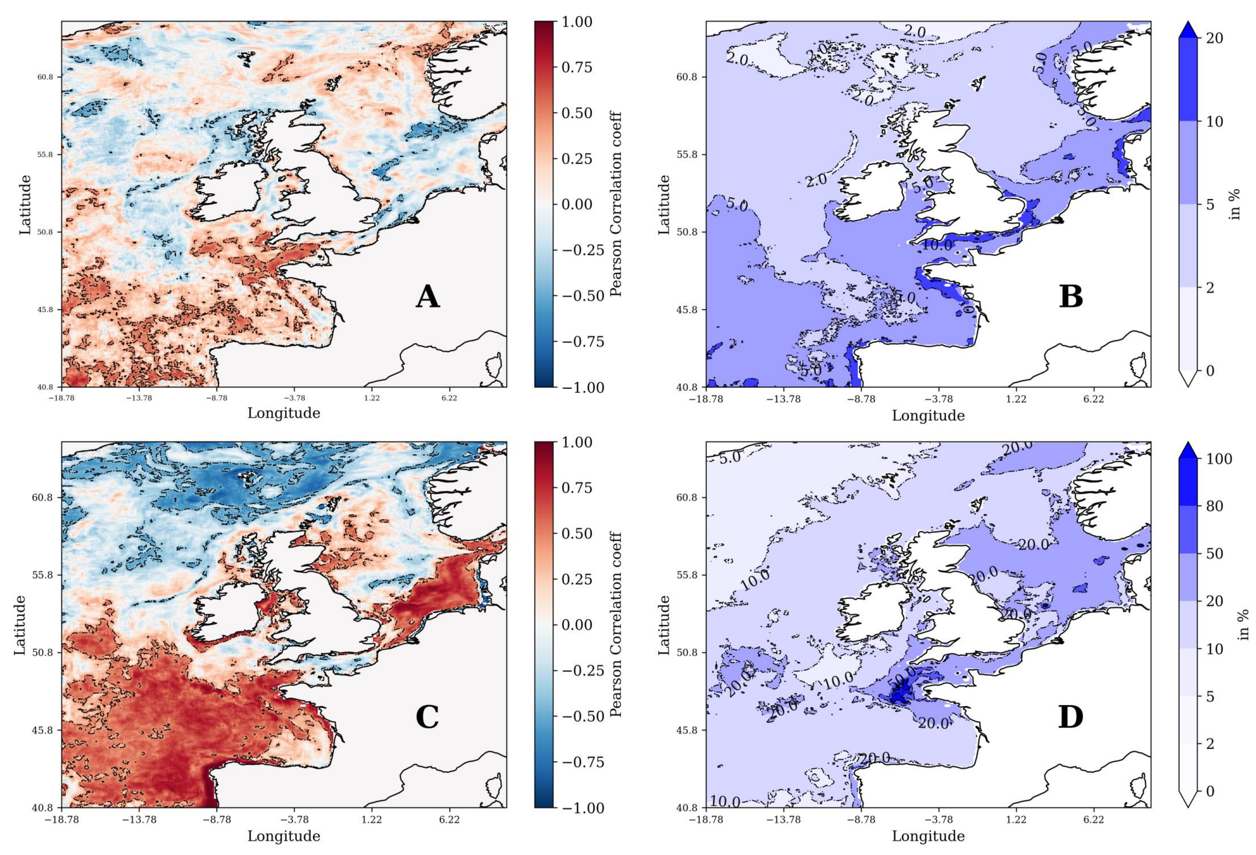
The left-hand panels show nitrate seasonal climatology from the ML model and the right-hand panels show the difference in climatology between UKMO reanalysis and the ML model. The Figure shows that UKMO surface nitrate reanalysis has significant geographic and seasonal biases.

The ML model has been validated on independent test data from ICES and coastal stations (L4 and Scottish), substantially outperforming the existing UK Met Office (UKMO) nitrate reanalysis: e.g. 80% reduction of bias and 60% reduction of bias-corrected RMSE compared to the UKMO reanalysis (when validated against ICES test data). We have used the ML model to produce 1998-2020 bi-decadal surface nitrate data-set for the NWES.

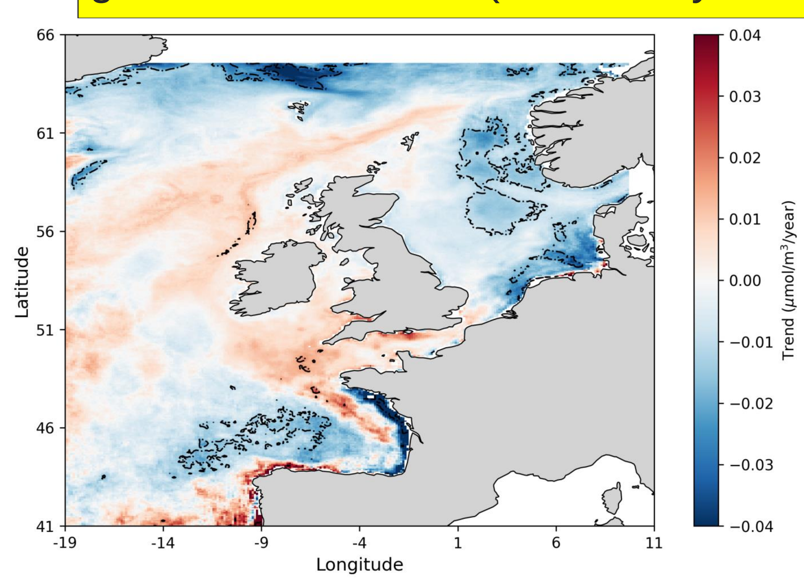




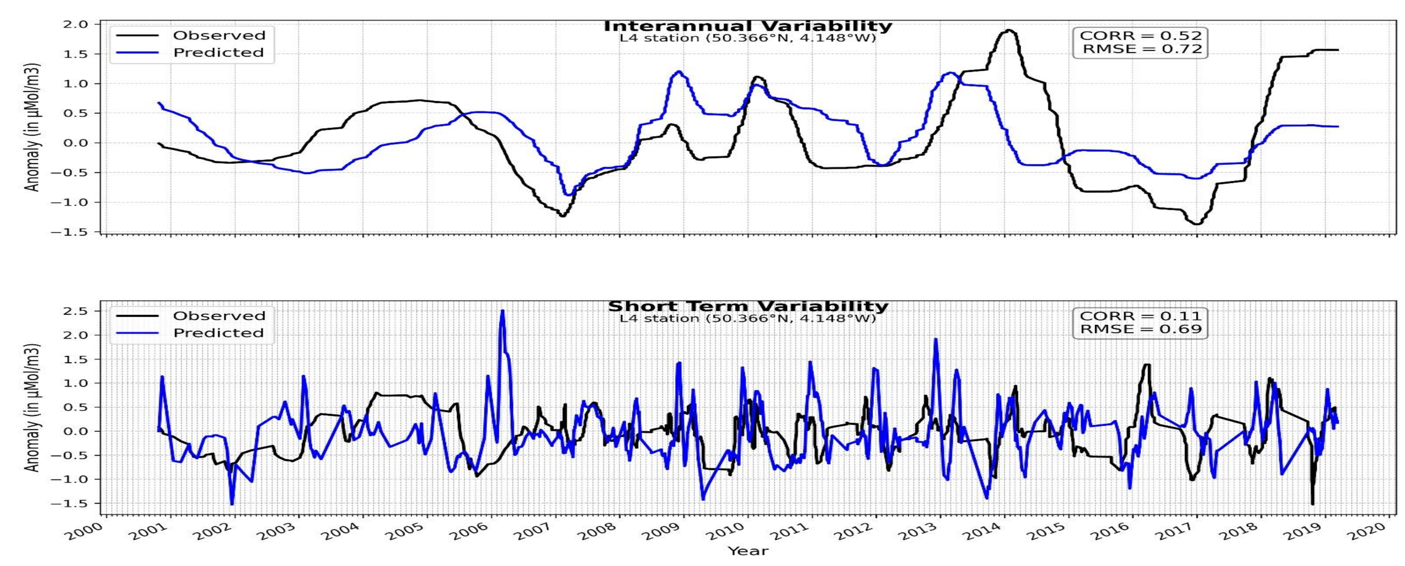
The left-hand Figure shows validation against the ICES data and the top Figure against the data provided by 5 Scottish coastal stations.



In the bottom left panel, using Pearson correlation between summer nitrate and chlorophyll, we identify parts of coastal NWES that are strongly nutrient-limited and especially vulnerable to eutrophication, subject to river discharges. Apart from known problem areas (south-west North Sea, Bay of Biscay) this includes also some areas such as south coast of Ireland, Irish Sea, east coast of Scotland. In the top right panel we also show, through correlation between winter nitrate and spring chlorophyll, that winter nitrate might not be the best indicator for growth next season (as used by OSPAR).



The nitrate NWES 1998-2020 trends are not very significant, with exception in the Bay of Biscay, where some more substantial decrease of nitrate values can be observed.



Comparison with L4 data across different time-scales. The predicted nitrate data have an effective resolution on the scale of weeks.

Conclusions:

Gap-free ML generated skilled nitrate data-set can become essential tool to help studying trends, variability, drivers and problem areas of eutrophication. Future plan is to improve forecasts run on NWES by assimilating these nitrate data into the NWES model.

Paper: *Banerjee and Skakala (2024), doi: 10.22541/essoar.171405637.-76928549*

Acknowledgements:

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