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Complex Networks to Inform Data Assimilation on the NWES

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Introduction

The current operational 3D-variational data assimilation (DA) system, used by the Met Office, can successfully assimilate the ocean colour derived surface chlorophyll when forecasting the biogeochemistry of the North-West European Shelf (NWES)[1, 2]. However, this DA process cannot directly update the unobservable key variables, such as nutrients, and makes simplifying assumptions about the horizontal correlation lengthscales.

Dataset

- 3-year run (2016-2018) with daily output, of a coupled hydrodynamic-biogeochemical ecosystem model, ERSEM-FABM-NEMO
- 395x297 horizontal grid at 7km resolution (AMM7) , using only surface layer from 51 depth layers of varying depth
- 51+2 ERSEM+NEMO deseasonalised state variables

Lengthscale Analysis

- Correlation radii are found through analysis of deseasonalised model data
- These clearly show that the horizontal lengthscales vary significantly according to each ERSEM variable
- Therefore, any new variables to be included in assimilation will likely need an individual approach, and cannot be deduced from physical scales based on Rossby radii and similar parameters.

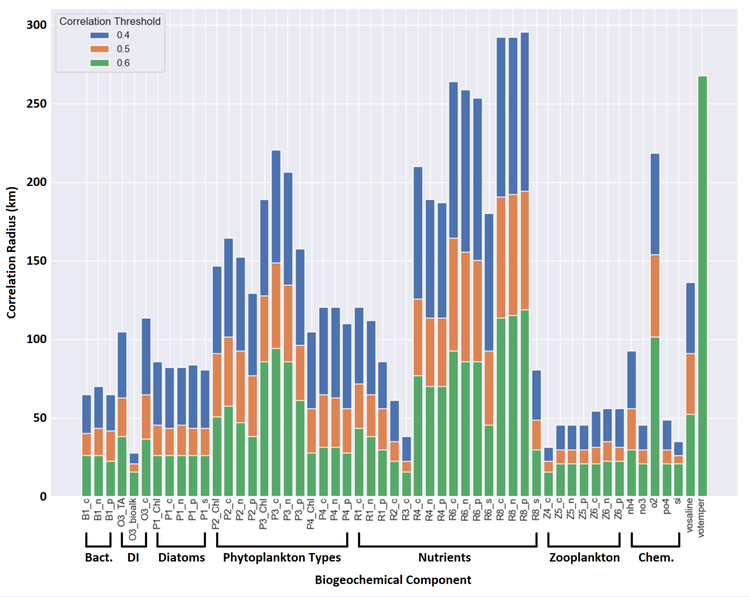

Figure 1. A comparison of the different lengthscales from each variable across correlation thresholds of 0.4, 0.5 and 0.6, with each distance is given in kilometres.

Network Investigation

Creating network structures from correlation analysis provides a natural extension of the lengthscales work shown. Model grid points or variables are treated as nodes, with links determined according to the timeseries correlation of node pairs. This results in an intuitive and human-interpretable representation of connectivity and behaviour, with insights that are easily transferable to applications in ML, DA and ecosystem modelling.

Spatial Networks

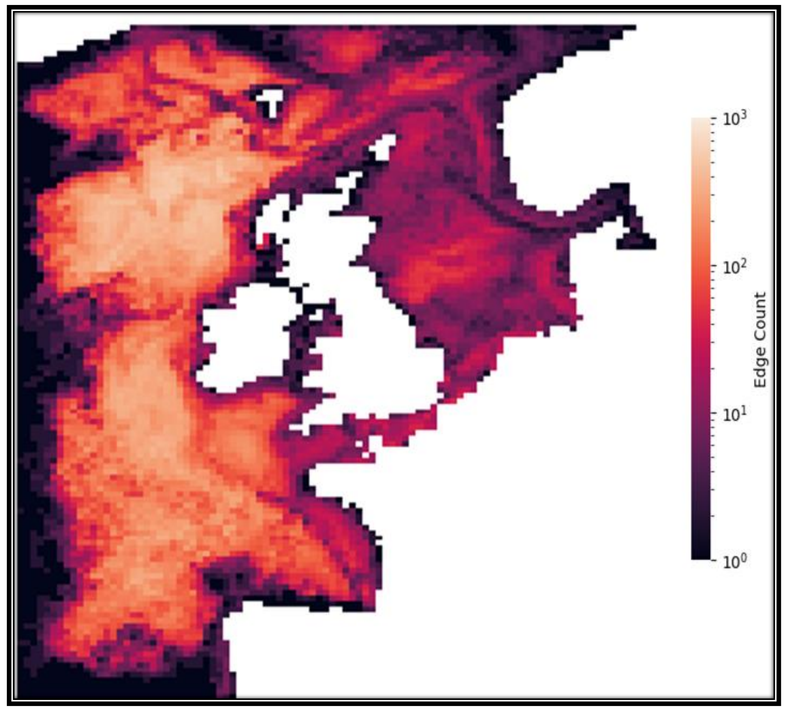

Figure 2. A visualisation of the node degree (number of connections or edge count) across the ERSEM NWES domain at the surface for Heterotrophic Bacteria Nitrogen (B1_n)

- Spatial networks provide a more detailed insight into the distribution of connections across the spatial domain
- To generate them, we correlate the pre-processed timeseries of each location with every other location for a single variable
- A dynamic threshold is applied to the network of each variable so that each spatial network has comparable nodes and links –most differences should be found in the 'wiring'
- These structures can then be compared directly, or even used to detect distinct communities of connectivity within the NWES – regions of locally consistent behavior

Intervariable Networks

- An intervariable network is generated by correlating the pre-processed timeseries of each variable at a single spatial point with each other variable
- This generates a correlation matrix which can be understood as a network adjacency matrix
- Performing clustering algorithms on this data can help us to easily identify functional groups of similarly behaving variables
- These networks, and any simplifications that can be made to their structure provide us with an approach that can be used to reduce the number of input features passed into an ML model

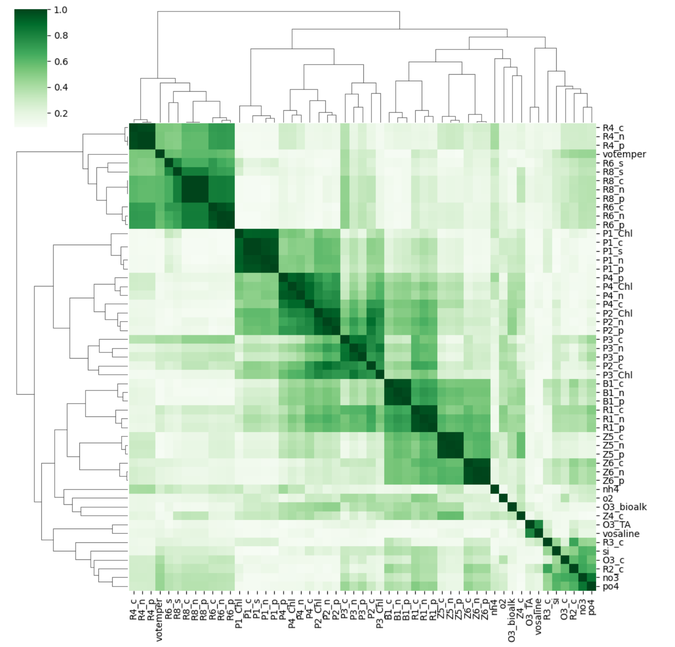

Figure 3. A weighted adjacency matrix representation of the intervariable relationships found at reference location (56.1N, 3.2E) on the NWES. A hierarchical clustering algorithm has been applied to the data, sorting the variables into groups.

References

1. Skákala, Jozef, et al. "The assimilation of phytoplankton functional types for operational forecasting in the northwest European shelf." Journal of Geophysical Research: Oceans 123.8 (2018): 5230-5247.
2. Skákala, Jozef, et al. "Towards a multi-platform assimilative system for North Sea biogeochemistry." Journal of Geophysical Research: Oceans 126.4 (2021): e2020JC016649.

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