PML | Plymouth Marine Laboratory

University of Reading — NERC Science of the Environment — National Centre for Earth Observation, Natural Environment Research Council

Improving Marine Ecosystem Understanding and Predictions through the use of a Novel Data Assimilation Method

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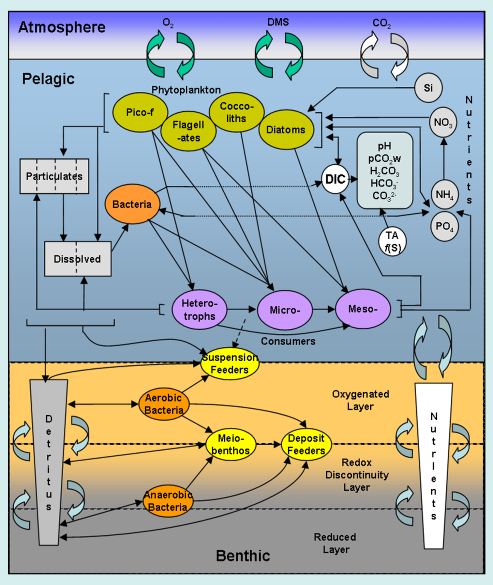
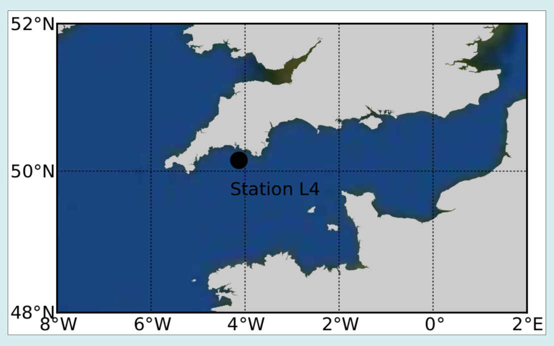
The aim of this research is to improve the model simulation of the surface chlorophyll concentration in the oceans through the use of a novel ensemble-based data assimilation method. The Ensemble Kalman Filter and the Particle Filter have been compared in twin experiments using our model.

1. Model: ERSEM-GOTM

ERSEM[1] (European Regional Seas Ecosystem Model) is a biogeochemical marine ecosystem model. For this research, it has been coupled to GOTM (General Ocean Turbulence Model) to include physical processes in a water column. The outline for ERSEM is shown on the right.



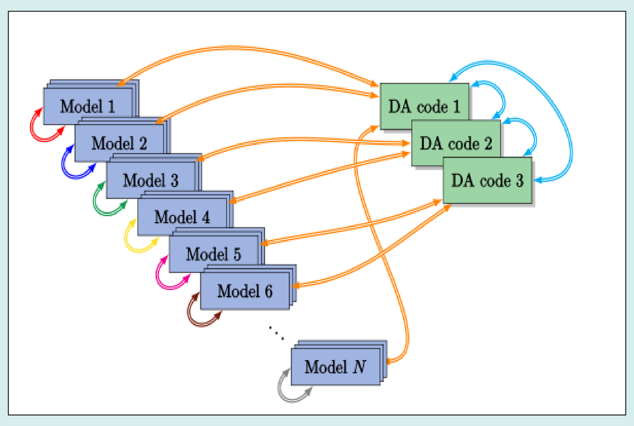
The input data for the forcing functions was retrieved from L4 – a long-term monitoring. Station located in the western English channel.



2. Data Assimilation Framework: EMPIRE

EMPIRE[2] (Employing MPI for Researching Ensembles) is a data assimilation framework developed at the University of Reading along with NCEO. We used EMPIRE to perform twin experiments in which artificial observations were generated. This allowed a comparison between the effectiveness of different data assimilation techniques to be made.

Right: An outline of the interaction between EMPIRE and the chosen model when running an ensemble.



3. Ensemble Methods

Stochastic Ensemble – An ensemble generated from randomly assigned initial conditions. This is not a DA method, but it can be used as a benchmark to see how DA methods can improve the ensemble.

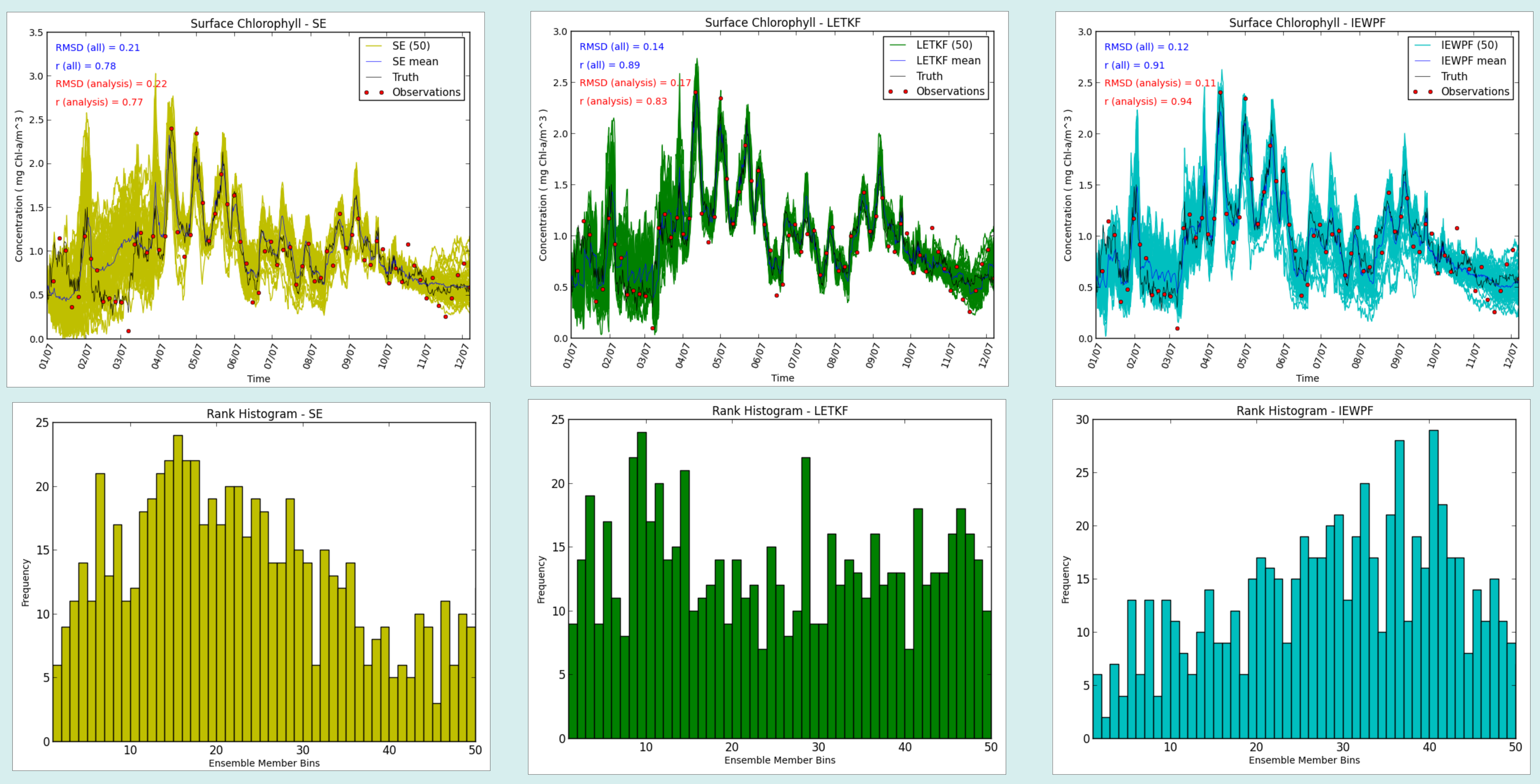
Localised Ensemble Transform Kalman Filter[3] – An efficient DA method that assumes Gaussian distributions for the errors and their covariances at the analysis step. It is non-linear during model propagation.

Implicit Equal-Weights Particle Filter[4] – A fully non-linear DA method that assigns a 'weight' (relative importance) to each particle. Using proposal densities, each particle will have a covariance such that the weights will be equal at the analysis step.

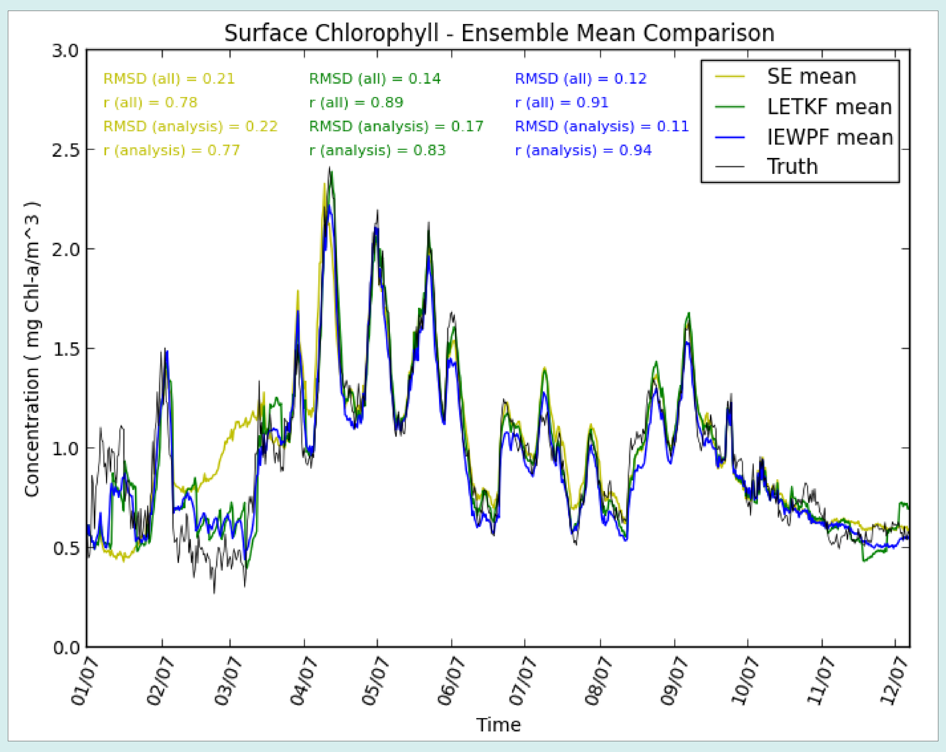
4. Twin Experiment Setup

- Ensemble Members: 50
- Timescale: 1 Year (2007-2008)
- Timestep: 600 seconds (10 minutes)
- Observations: Surface chl-*a* concentration, generated every 5 days
- Observation Error: 30%
- Q matrix from seasonal correlations between variables.
- RMSD between ensemble mean and truth at all timesteps / analysis steps.
- r: Spearman correlation between mean and truth.
- **(PF)** Nudging factor: 0.75, Keep: 1.0

5. Results



Stochastic Ensemble | **Localised Ensemble Transform Kalman Filter** | **Implicit Equal-Weights Particle Filter**



Above: A comparison between the mean of each ensemble and the truth.

'All' - RMSD and correlation calculated using every timestep.

'Analysis' - RMSD and correlation calculated using analysis steps.

Conclusion: While particle filtering is designed to be effective in non-linear systems (like ERSEM), previous marine models have used the Ensemble Kalman Filter due to its ease of use and reliability. However, these results indicate that the IEWPF may be able to compete due to its comparable results in a twin experiment designed to emulate a real system. Beyond this experiment, the performance of these methods with real data will be explored.

[1] Blackford, J., Allen, J., Gilbert, F., J. J. Mar. Syst., **52**, 191-215, (2004).

[2] Browne, P. A., Wilson, S., Environmental Modelling & Software, **68**, 122-128, (2015).

[3] Hunt, B. R., Kostelich, E. J., Szunyogh, I., Physica D: Nonlinear Phenomena, **1-2**, 112-126, (2007).

[4] Zhu, M. et al., van Leeuwen, P. J., Amezcua, J., Q. J. R. Meteorol. Soc, (2016).

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