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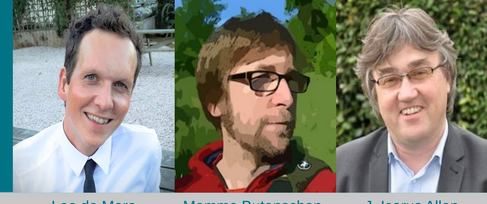


Lee de Mora Momme Butenschon J. Icarus Allen

Evaluating a global marine ecosystem model with emergent properties

Lee de Mora, Momme Butenschön, and J. Icarus Allen

1.

Marine ecosystem models are increasingly being used to inform **policy** and to study **climate change**.

2.

Model validation is crucial, but **data is hard to come by** and direct comparison of model to data are disproportionately vulnerable to mismatches in circulation.

3.

Furthermore, the natural **behaviour** of the ecosystem is **not observable** in standard tools like concentration maps. So, we evaluate models using emergent properties.

4.

Emergent properties are coherent structures, patterns or relationships that are observed in nature and can be reproduced by a sufficiently complex model.

5.

The emergent property must be observed in multiple independent datasets, valid over large spatial and temporal ranges, and is **not explicitly imposed** in the model parameterisation.

6.

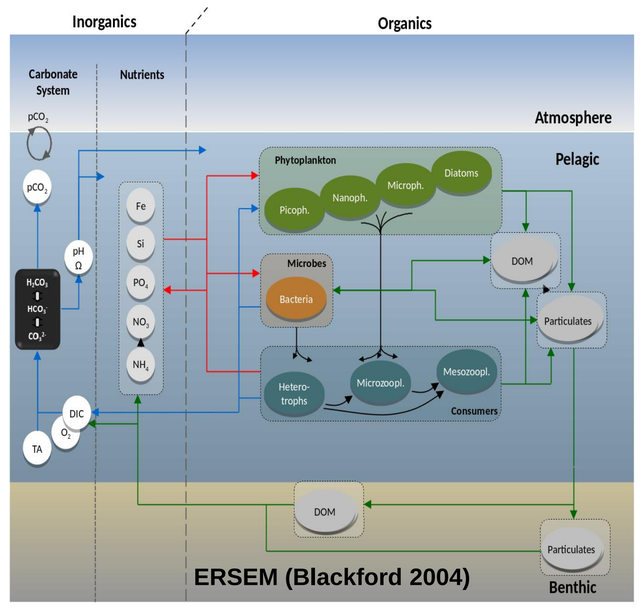
If a model demonstrates emergence, then the model likely has a **good representation** of the **ecosystem functions** that produced the emergent behaviour.

7.

Emergent properties allow model evaluation in the **absence** of **local data** or in the presence of a **less than ideal circulation** model.

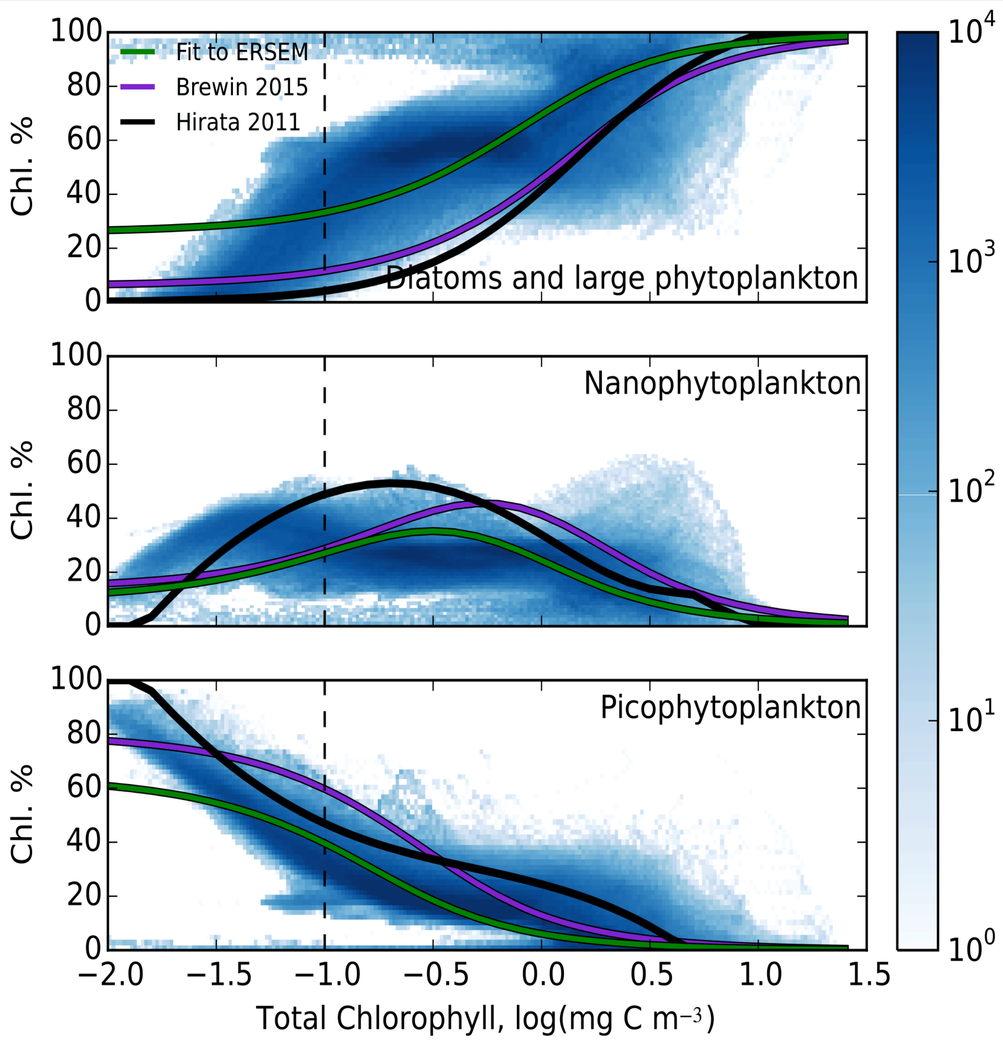
8.

ERSEM is successful at reproducing the natural relationships observed in the following emergent properties.



Phytoplankton Community Structure

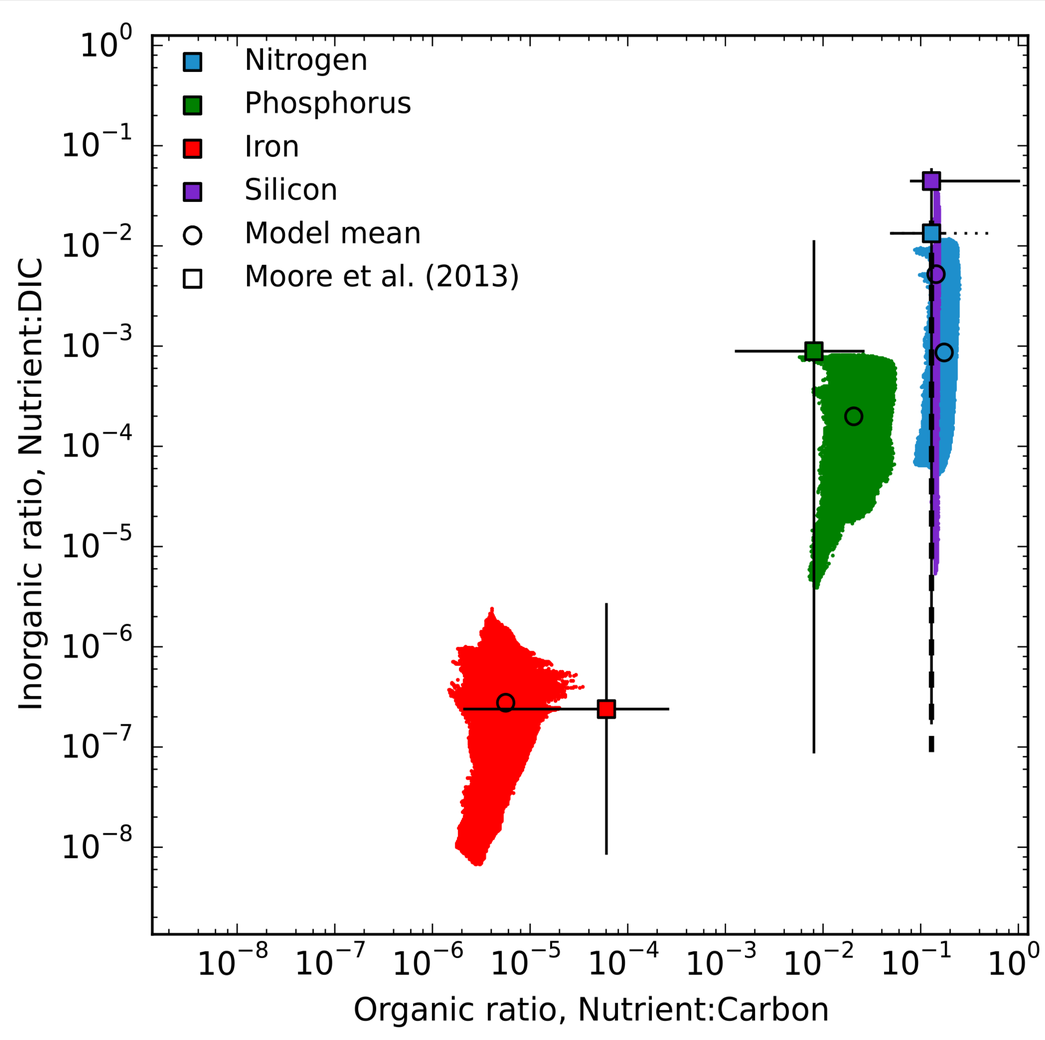
The relative abundance of each phytoplankton class



The **Model Data** distribution of the relationship between each Plankton Functional Type's chlorophyll concentration and the total chlorophyll. The **fit of ERSEM to the three population model**, and the **Hirata 2011** and **Brewin 2015** fits to data are also shown.

Stoichiometric Balance

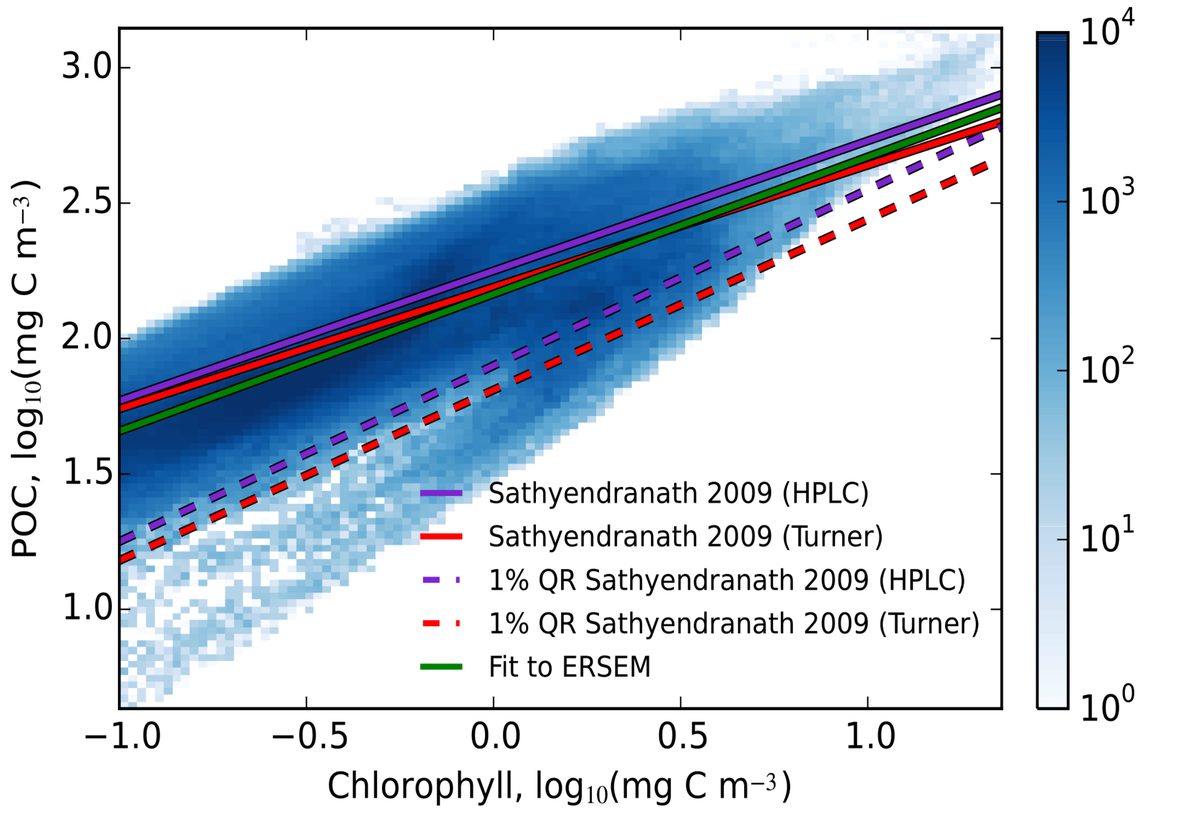
The balance of each element in organisms and in the ecosystem



The ratio of each nutrient to carbon in organic matter against the dissolved inorganic nutrient to carbon ratios. This figure shows the model mean ○ and distribution of the **Nitrogen**, **Phosphorus**, **Iron** and **Silicon** to carbon ratios and the observed range, □.

Carbon to Chlorophyll Ratio

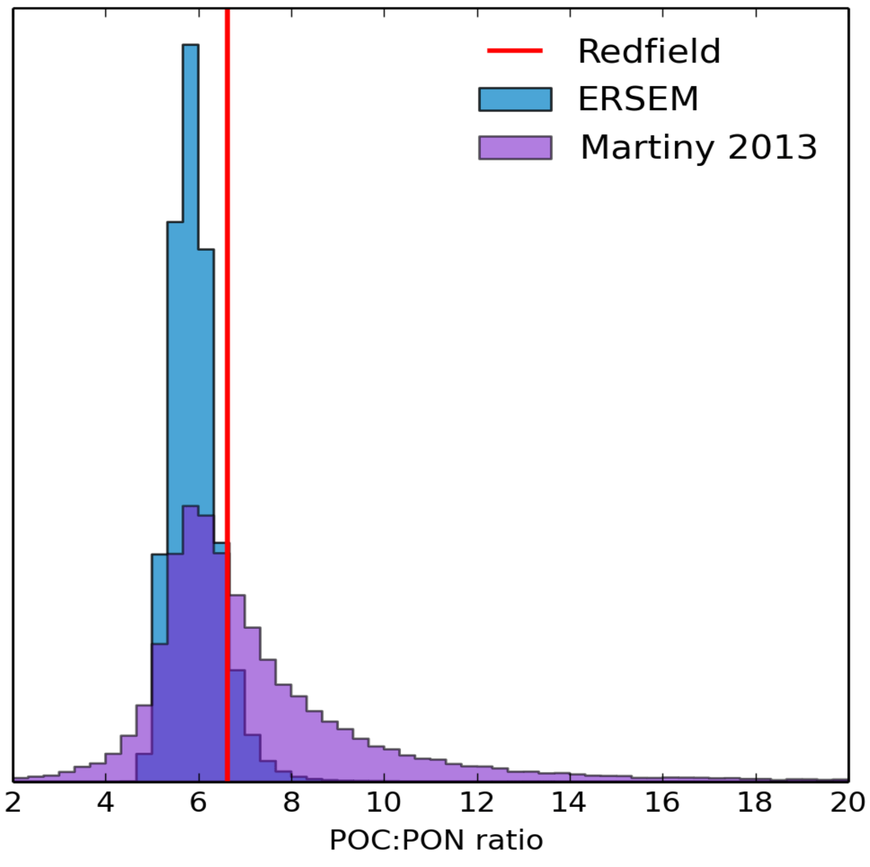
The relationship between particulate organic carbon and total chlorophyll



The POC against total Chlorophyll in the **Model Data**, a **fit to the model**, and in two fits to data (**HPLC** and **Turner**) from Sathyendranath 2009. The dashed lines show the 1% quantile regression fits to the data (**HPLC** and **Turner**). They indicate a theoretical lower bound for the modelled POC:Chl.

Ratio of POC to PON

The Redfield ratio



The ratio of particulate organic carbon (POC) to particulate organic nitrogen (PON) in the **Martiny 2013 in situ Data**, in the **Model Data**, and the **Redfield ratio**.

More details: de Mora, L., Butenschön, M., and Allen, J. I.: The assessment of a global marine ecosystem model on the basis of emergent properties and ecosystem function: a case study with ERSEM, Geoscientific Model Development, 9, 59-76, doi:10.5194/gmd-9-59-2016, 2016.

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