An Optimality-Based Non-Redfield Ecosystem Model for the UVic-ESCM

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Motivation

The canonical Redfield ratio in marine phytoplankton and seawater (carbon(C) : nitrogen (N) : phosphorus (P) =106:16:1) applies to today's ocean as a whole, but strong deviations from this ratio occur in many regions, due to mechanisms such as nitrogen fixation, atmospheric N deposition and denitrification. In order to understand how phytoplankton stoichiometry interacts with these mechanisms, capturing the dynamic stoichiometry of C, N and P for phytoplankton in marine ecosystem models is essential. However, most of the models only use a fixed C:N:P ratio up to the present. We have implemented an optimality-based NPZD model with Nutrients (N, P), non-diazotrophic and diazotrophic Phytoplankton, Zooplankton, and Detritus into the University of Victoria Earth System Climate Model (UVic-ESCM). The new optimality-based phytoplankton compartments utilize ambient nutrients in different C:N:P ratios and thus allows for dynamic stoichiometry of C, N and P in phytoplankton, diazotrophs, and detritus.

Optimality-Based Formulations

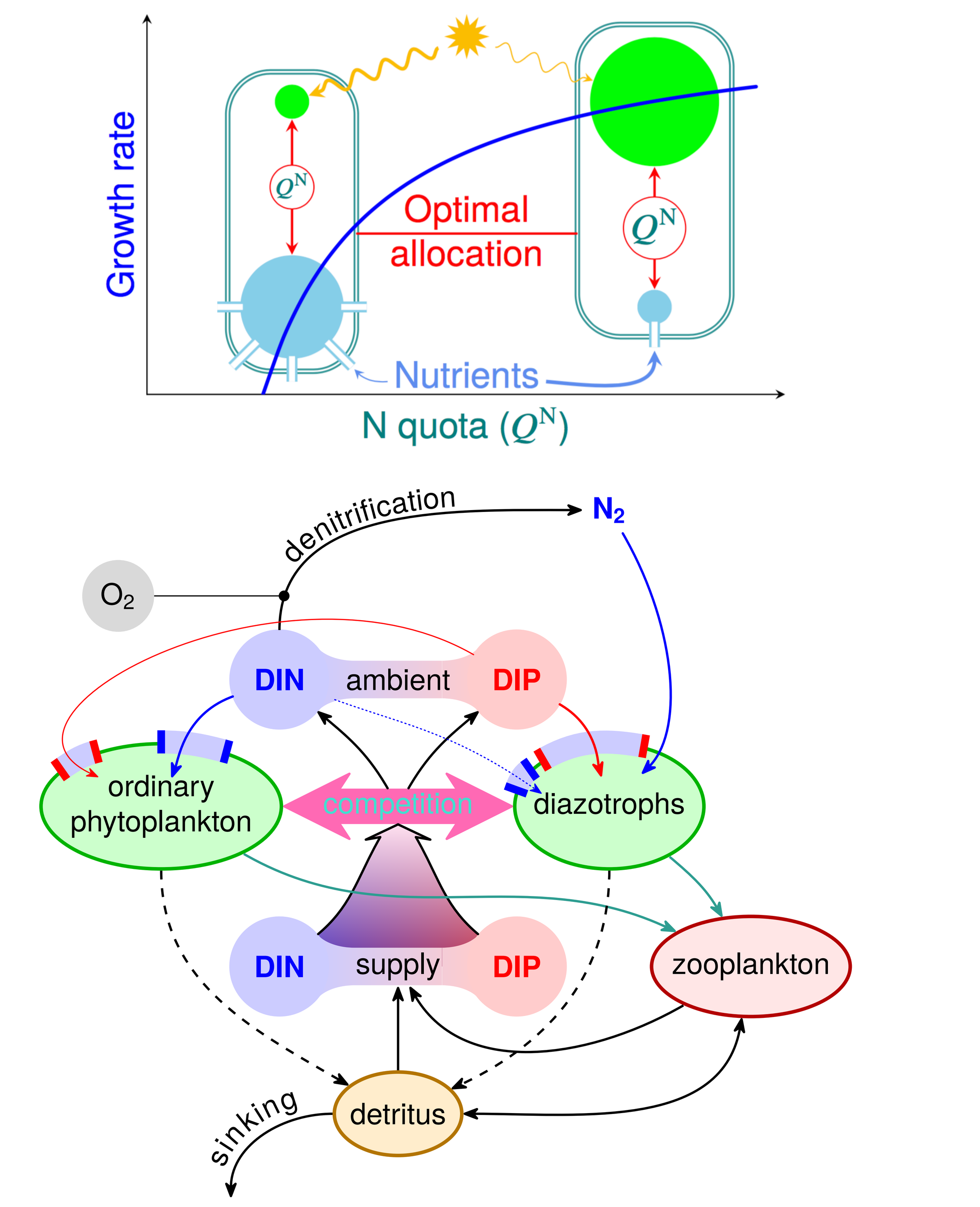

Fig. 1: Optimality-based phytoplankton (top, Pahlow et al., 2013) and the ecosystem scheme in the UVic-ESCM (bottom, modified from Pahlow et al., 2013)

Summary and Future Work

- We have implemented an optimality-based NPZD model into the UVic Earth System Climate Model. Preliminary results show some ability in reproducing global patterns in the C:N:P ratios of marine particles, as well as the distribution of global primary production and nitrogen fixation.
- Many parameters (14 for phytoplankton, 5 for zooplankton) and long spin-up times (>5000 model years to reach steady state, which takes more than two weeks) make parameter estimation difficult.
- Currently we are working on parameter estimation with a Latin Hypercube sampling method. Model simulations are evaluated by comparison with observations.
- Further new components, e.g., nitrogen deposition, may be needed for model improvement in the future.

Behavior of the UVic-ESCM with the Optimality-Based Non-Redfield Ecosystem model

The most important feature is the decoupled C, N and P stoichiometry in our ecosystem model. It allows us to study the behavior of phytoplankton elemental stoichiometry in response to different ambient conditions.

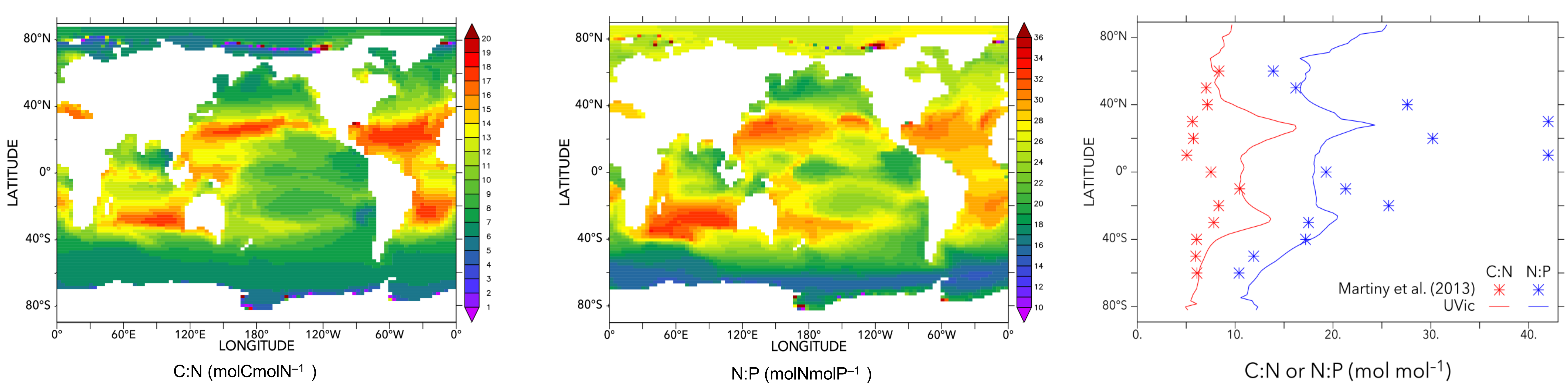

Fig. 2: Global patterns of phytoplankton (ordinary phytoplankton and diazotrophs) C:N (left) and N:P (middle). Right, UVic simulations compared to zonally average particulate matters C:N and N:P form Martiny et al. (2013).

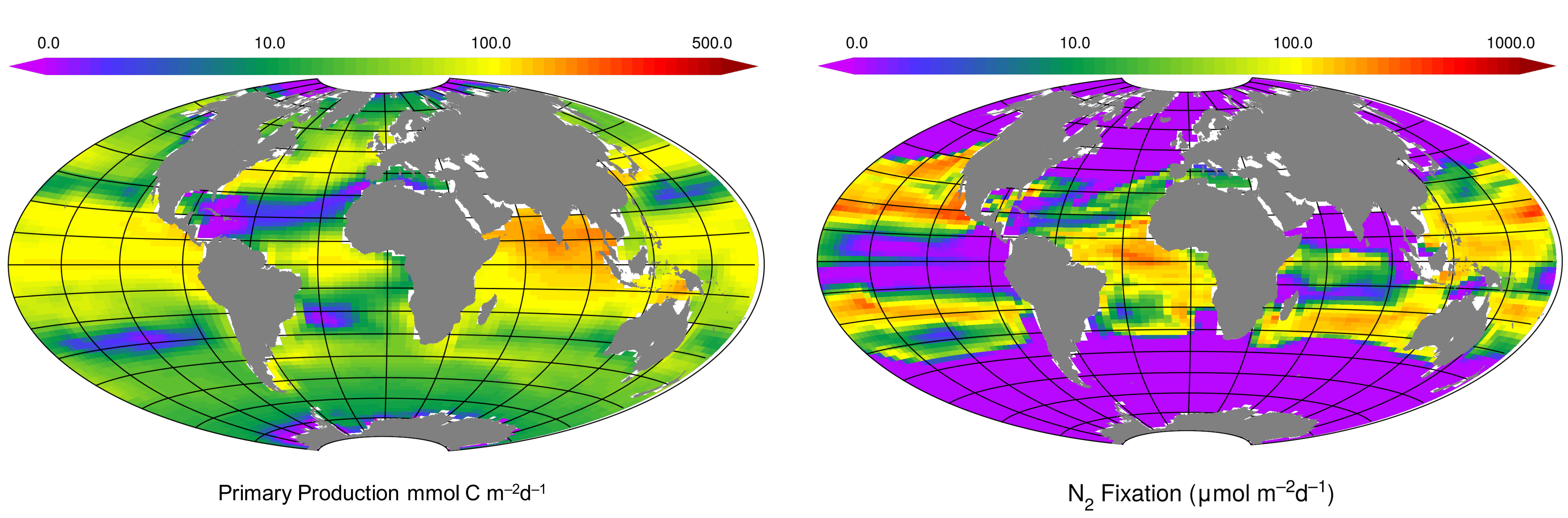

Fig. 3: Primary production (left) and nitrogen fixation (right) predicted by the UVic-ESCM with our optimality-based ecosystem model.

What else do we need?

Atmospheric nitrogen deposition is one of the most important N sources to the ocean. Since we want to study interactions between phytoplankton and nutrient conditions, we will incorporate this component for future model improvement .

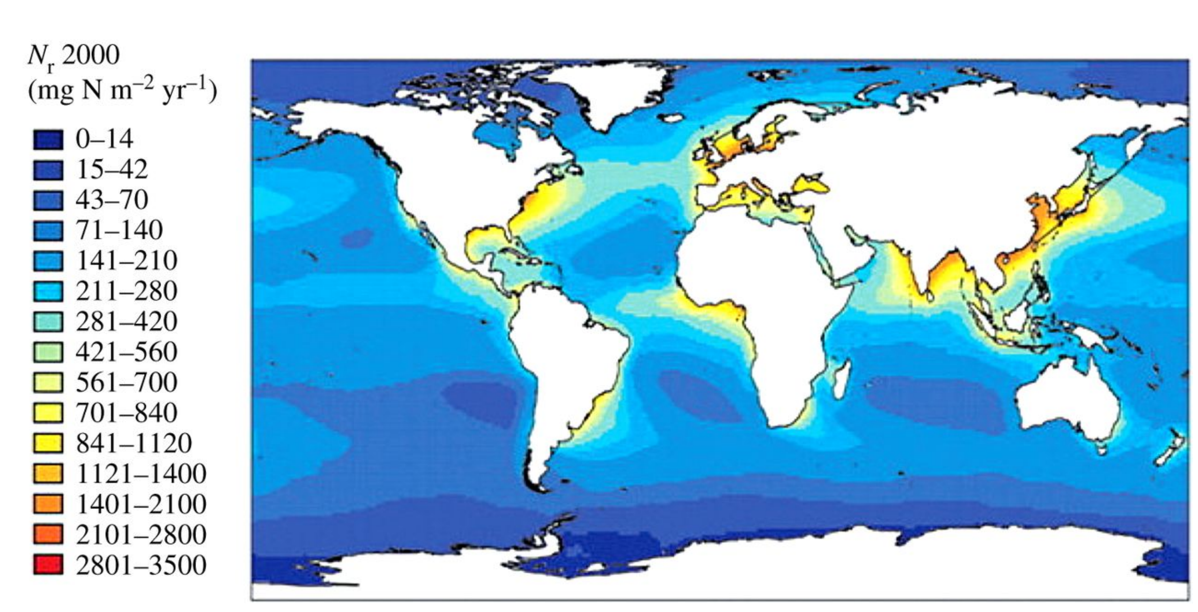

Fig. 4: Total atmospheric reactive nitrogen (N_r) deposition in 2000, (Duce et al. 2008)

References

Keller, D. P. et al. (2012). Geosci. Model Dve. 5: 1195.
Martiny, A. C. et al. (2013). Nature Geosci. 6:279.
Duce, R. A. et al. (2008). Science 320:893.
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