

1 Overview

For prognostic studies of the global carbon cycle it is critical to correctly reproduce primary productivity in different marine environments with the same model. Any given, single model will simulate biogeochemical processes with varying accuracy at different oceanic sites.

In general, we seek for different model formulations that are appropriate for different specific biogeochemical questions. These individual models are required to share a common set of basic parameterisations (the kernel). The efforts put into evaluating and improving a common kernel greatly pay off with a simplified error analysis. Our strategy also helps to determine important processes and those which play only a minor role.

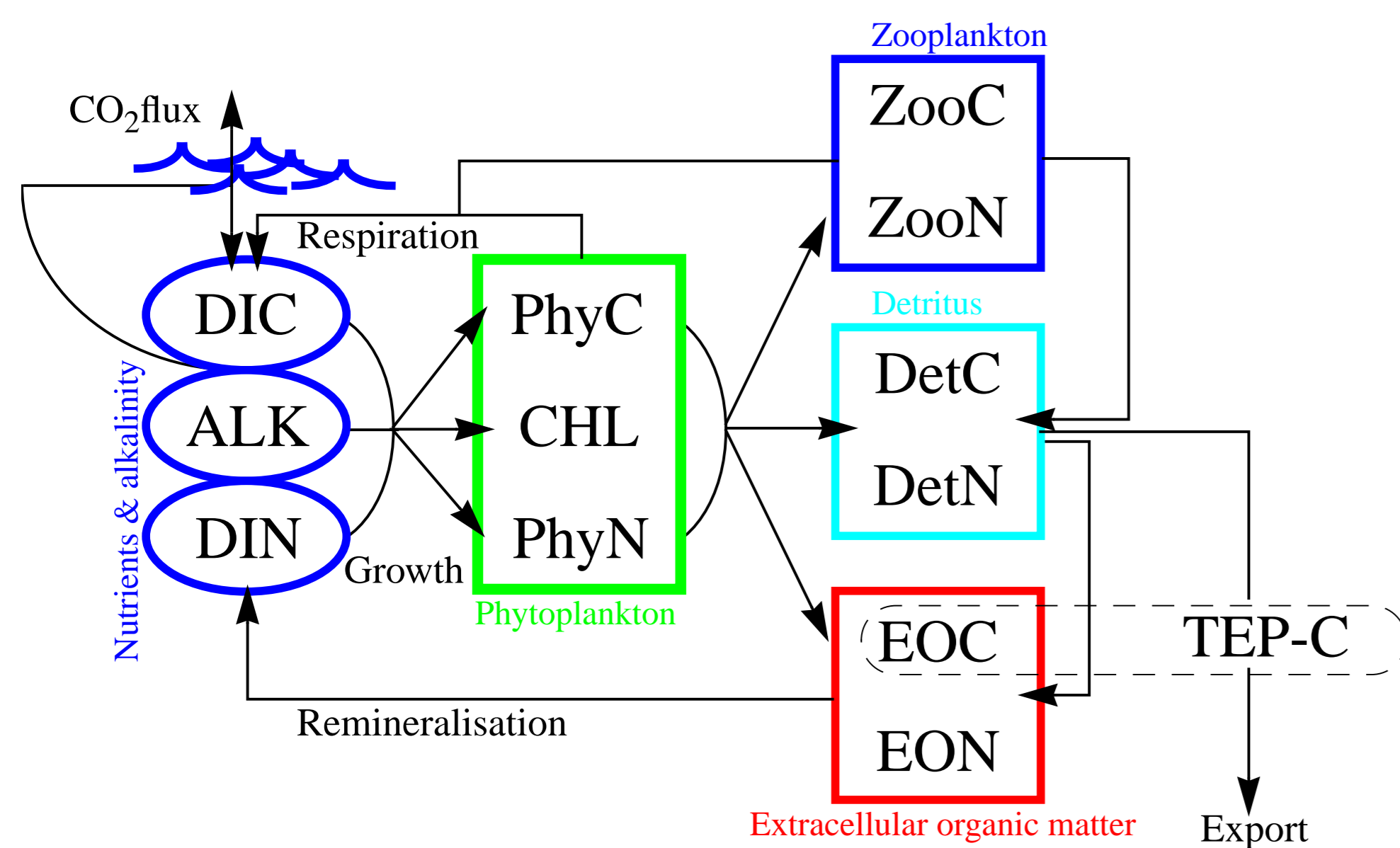


Figure 1: The basic model kernel decouples carbon from nitrogen fluxes. Most parameterisations for phytoplankton growth are adopted from Geider et al. (1998). Mass fluxes within the ecosystem are primarily regulated by the carbon-to-nitrogen (C:N) utilisation ratio of phytoplankton, thus giving it the name C:N-Regulated Ecosystem model (CN-REcoM). As a further new and important feature, the model explicitly resolves the carbon content of transparent exopolymeric particles (TEP-C) and their role for particle formation and export.

4 REcoM & Dia

On a global scale, diatoms contribute some 40% of oceanic primary production and are very efficient exporters of fixed carbon to the abyssal ocean. Diatoms consume silicon and iron, and Fe fertilization has been shown to lead to rapid Si and C drawdown in so-called High-Nutrient-Low-Chlorophyll regions of the ocean such as the Southern Ocean. However, Fe availability and residence time in the euphotic layer also depend on the chemical speciation of iron (Wells, 2003).

Based on CN-REcoM, we have constructed a regulatory model of diatom physiology, that depends on Si and Fe availability. Currently, we are coupling this model to a prognostic model of iron speciation (Weber et al., Modelling the biogeochemistry of iron at the Bermuda Atlantic Timeseries Station. In preparation) to simulate diatom blooms in the Southern Ocean.

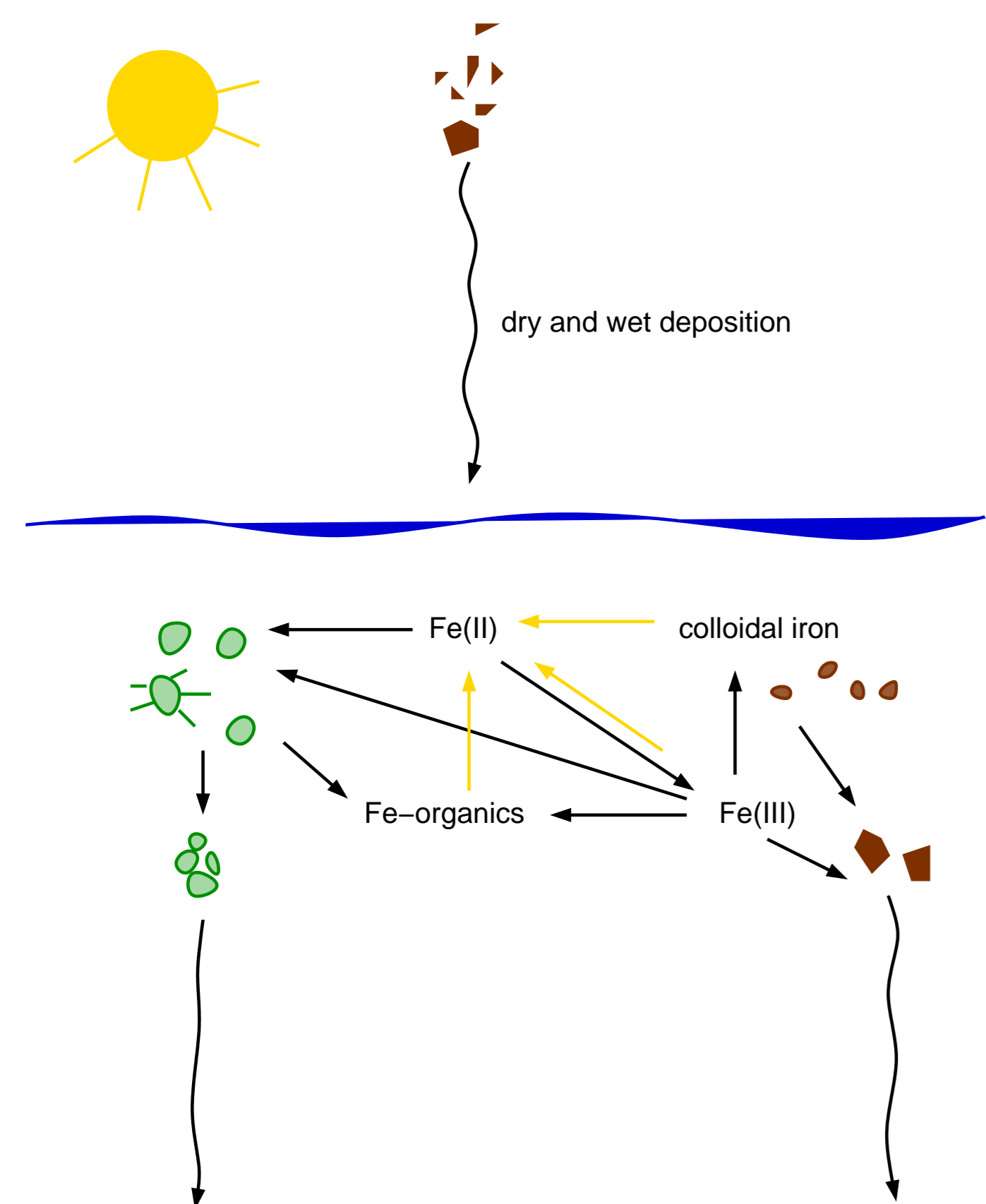


Figure 4: Schematic representation of the iron speciation model: dissolved iron is partitioned into inorganic ferric and ferrous species, truly dissolved organically complexed iron and colloidal iron. Direct or indirect photochemical reactions (yellow) drive a daily cycle in iron speciation. Ultimately iron is either taken up by phytoplankton or adsorbs onto sinking particulate matter.

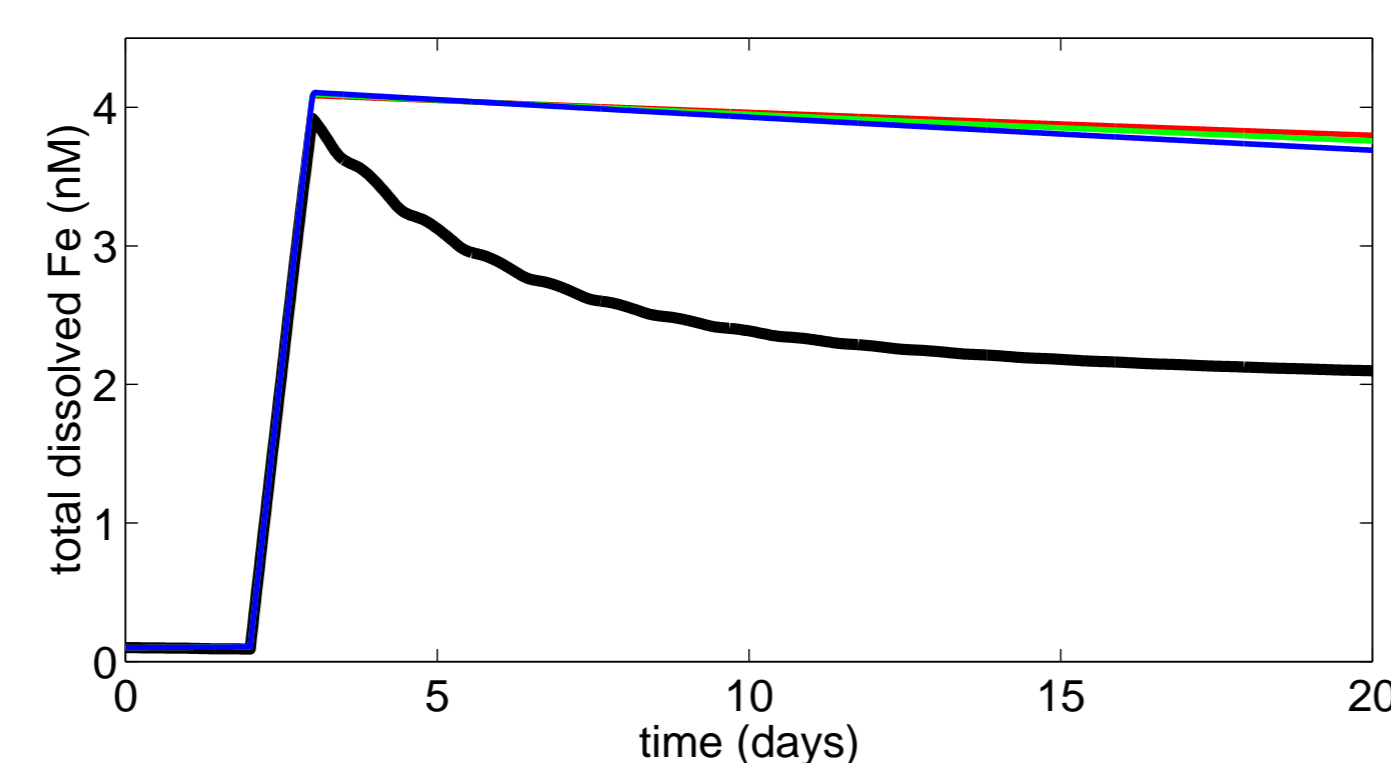


Figure 5: Iron input to the surface ocean with dust deposition is episodic rather than continuous, and the residence time of iron within the surface layer after an iron addition has been observed to be days rather than years, probably due to loss of colloidal iron (Bowie et al., 2001). Such a behaviour cannot be simulated with simple speciation models that are tuned to reproduce the deep ocean Fe distribution with scavenging residence times for iron between years and centuries. Here we compare the temporal evolution of total dissolved iron as modeled by four different models of iron speciation after increasing dissolved iron by four nM over one day. The models are the three models presented in Parekh et al. (2004) that successfully reproduce the interbasin gradients of deep iron concentrations (red, green and blue lines), and our iron speciation model (black line).

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2 CN-REcoM

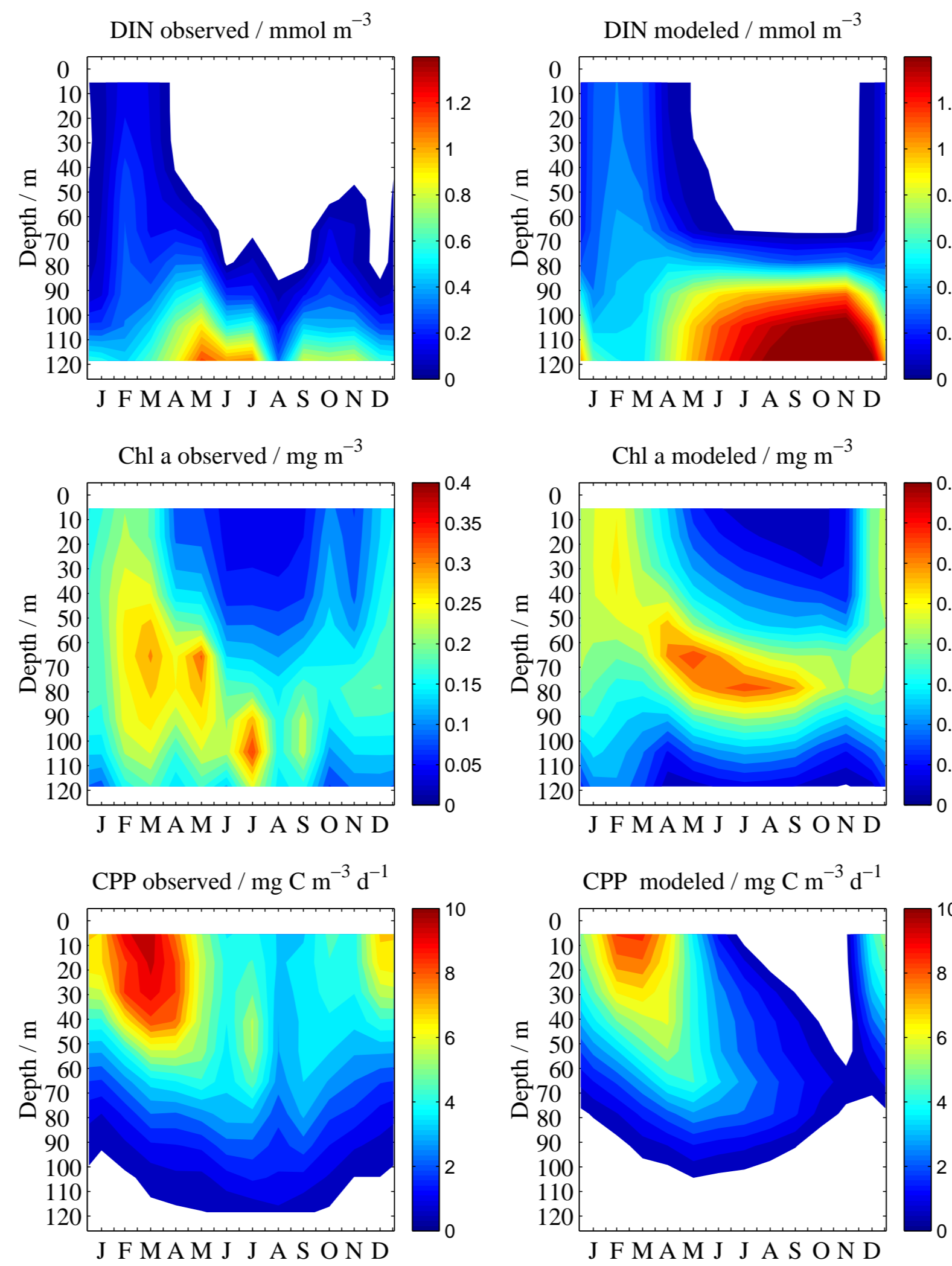


Figure 2: Near Bermuda (BATS site) oligotrophic conditions prevail near the surface except for the short period during the onset of the bloom. When applied to oligotrophic sites, conventional nitrogen or phosphorus based models produce systematic errors in carbon flux estimates (Schartau and Oschlies, 2003). In the monthly averaged values of a CN-REcoM simulation at BATS, that are shown in the figure, the decoupling of nitrate concentration (DIN), chlorophyll a (Chl a), and carbon based primary production (CPP) becomes significant.

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3 REcoM & Co

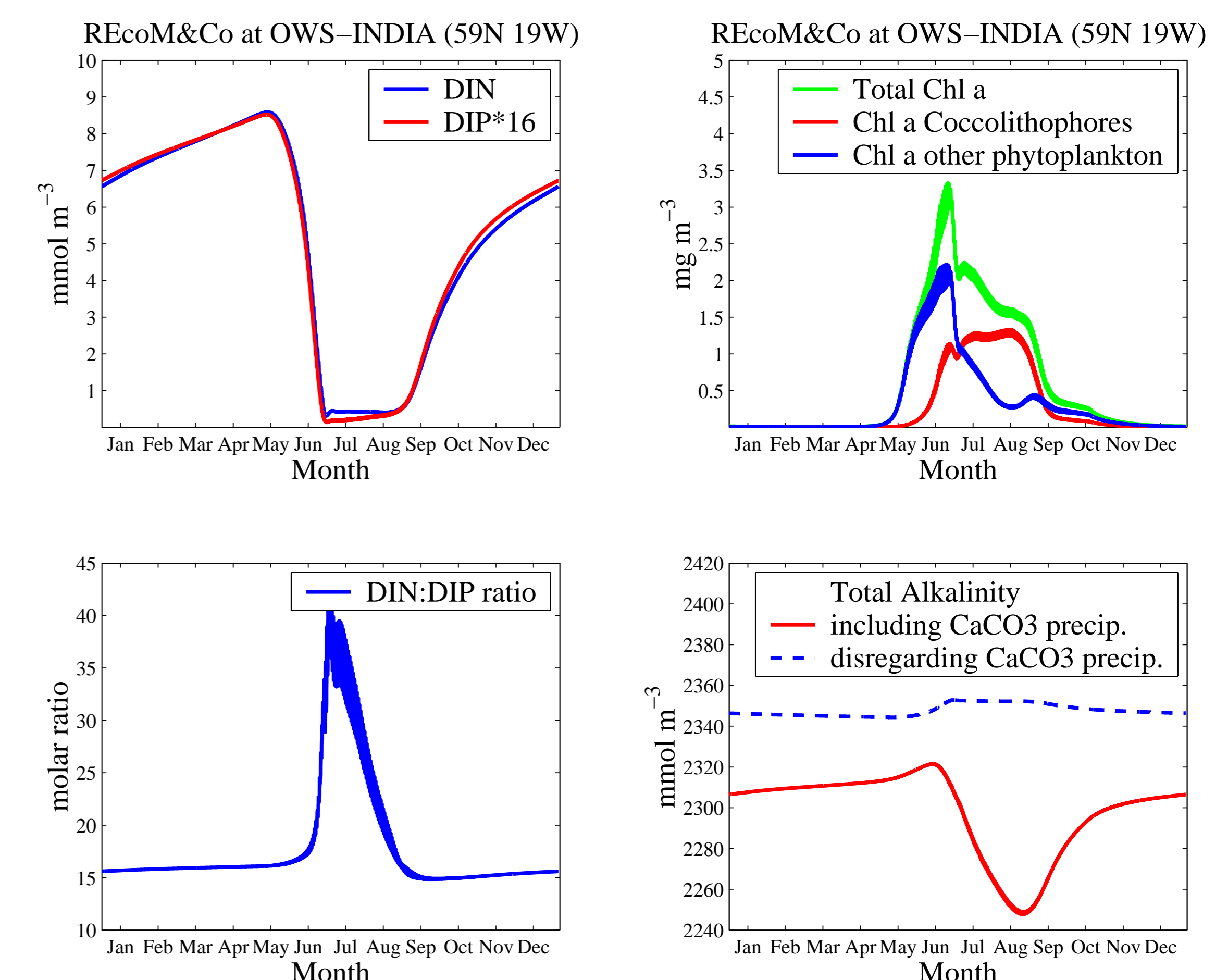


Figure 3: For carbon cycling it is of particular interest to determine the amount of calcification by phytoplankton. Here, we seek for a mechanistic model that can simulate coccolithophorid blooms. We postulate that the success of the calcifying algae (*Emiliania Huxleyi*) is strongly regulated by the nitrogen-to-phosphorus (DIN:DIP or N:P) utilisation ratio of phytoplankton. The figure shows the success of coccolithophores over other phytoplankton (e.g., diatoms) under high N:P conditions at the site of Ocean Weather Ship India (OWS-INDIA).

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5 An Ocean General Circulation Model with REcoM & Dia

REcoM&Dia has been coupled to the general circulation model MITgcm (Marshall et al., 1997). Research activities include assessing the impact of physical processes, for example advection, mixing, mixed layer depth, on biological productivity and export fluxes into the deep ocean. For this purpose the modelling system is configured in a zonally periodic channel (Fig. 6 and Fig. 7), but it is also possible to design an experiment which simulates production and export of the global oceans.

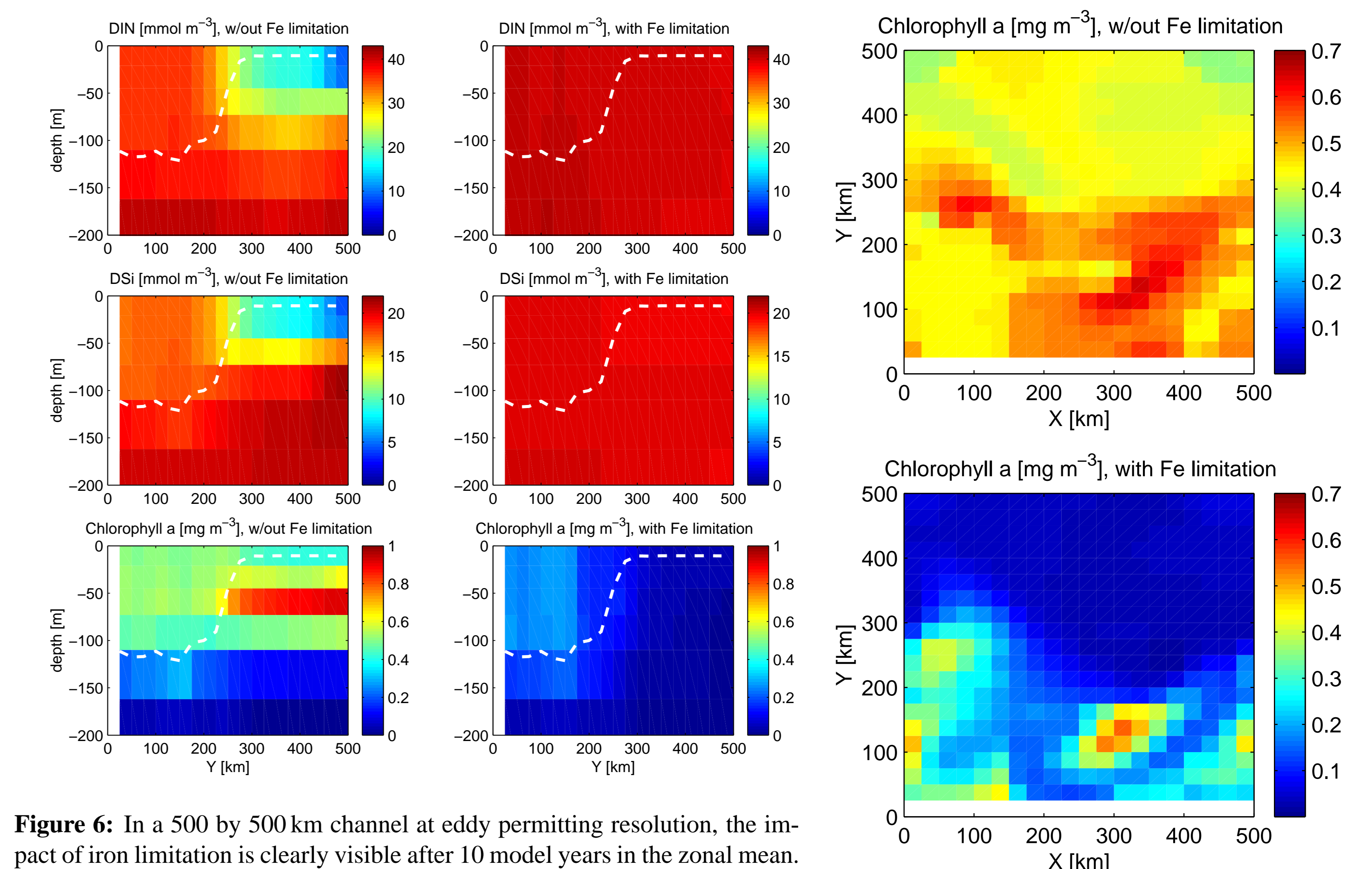


Figure 6: In a 500 by 500 km channel at eddy permitting resolution, the impact of iron limitation is clearly visible after 10 model years in the zonal mean. The white dashed line marks the mixed layer depth. On the left hand side, without iron limitation, mixing provides high nutrient concentrations (DIN and DSi, nitrogen and silica respectively). The choice of wind forcing causes an Ekman drift to the right where nutrients are depleted. On the right hand side, with iron limitation, chlorophyll concentrations are generally smaller and limited to the region where mixing recharges surface concentrations of iron.

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Figure 7: Top view of the same channel as in Fig. 6. With iron limitation (bottom figure), production is limited to regions where suitable mixing recharges surface concentrations of iron from below. Without iron limitation (top figure) production occurs over the entire surface area.

References

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