Spatially varying biogeochemical parameter estimation in a global ocean model

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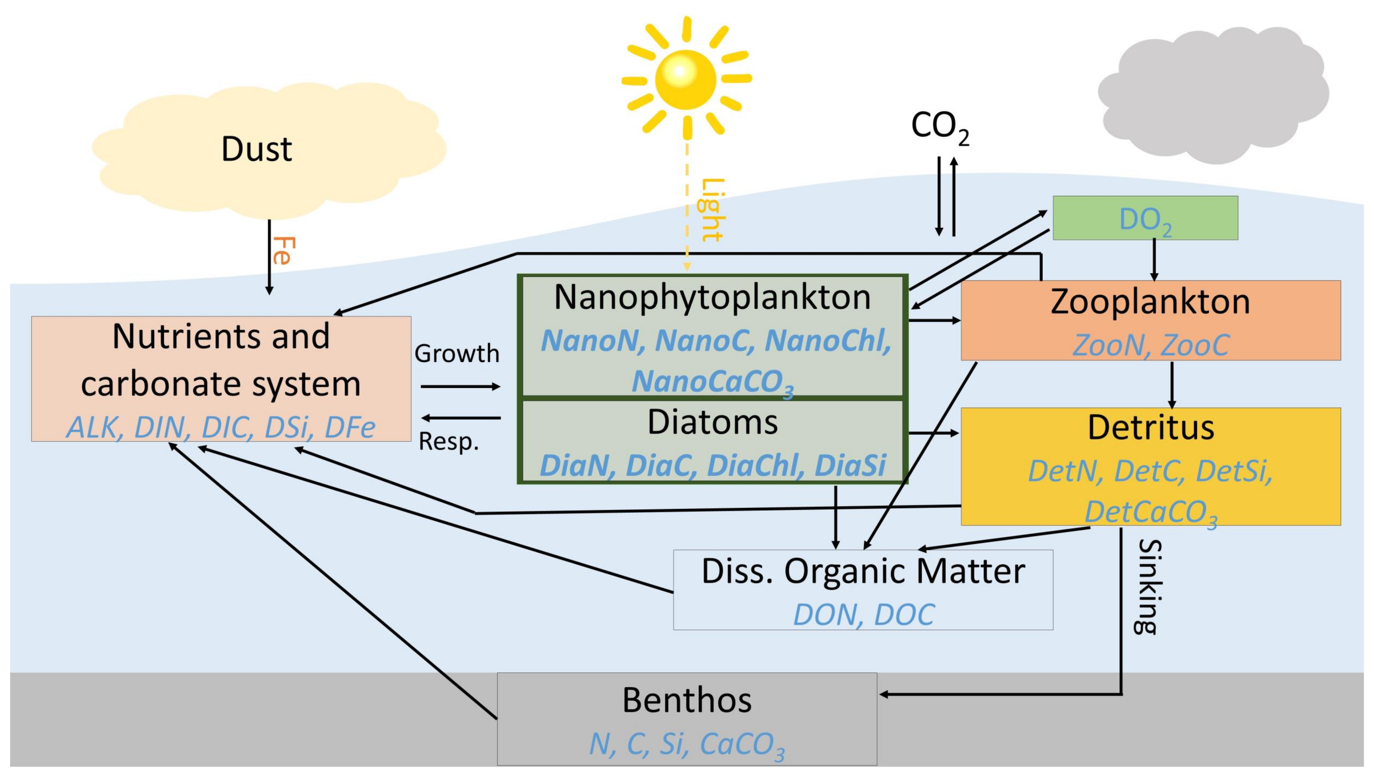
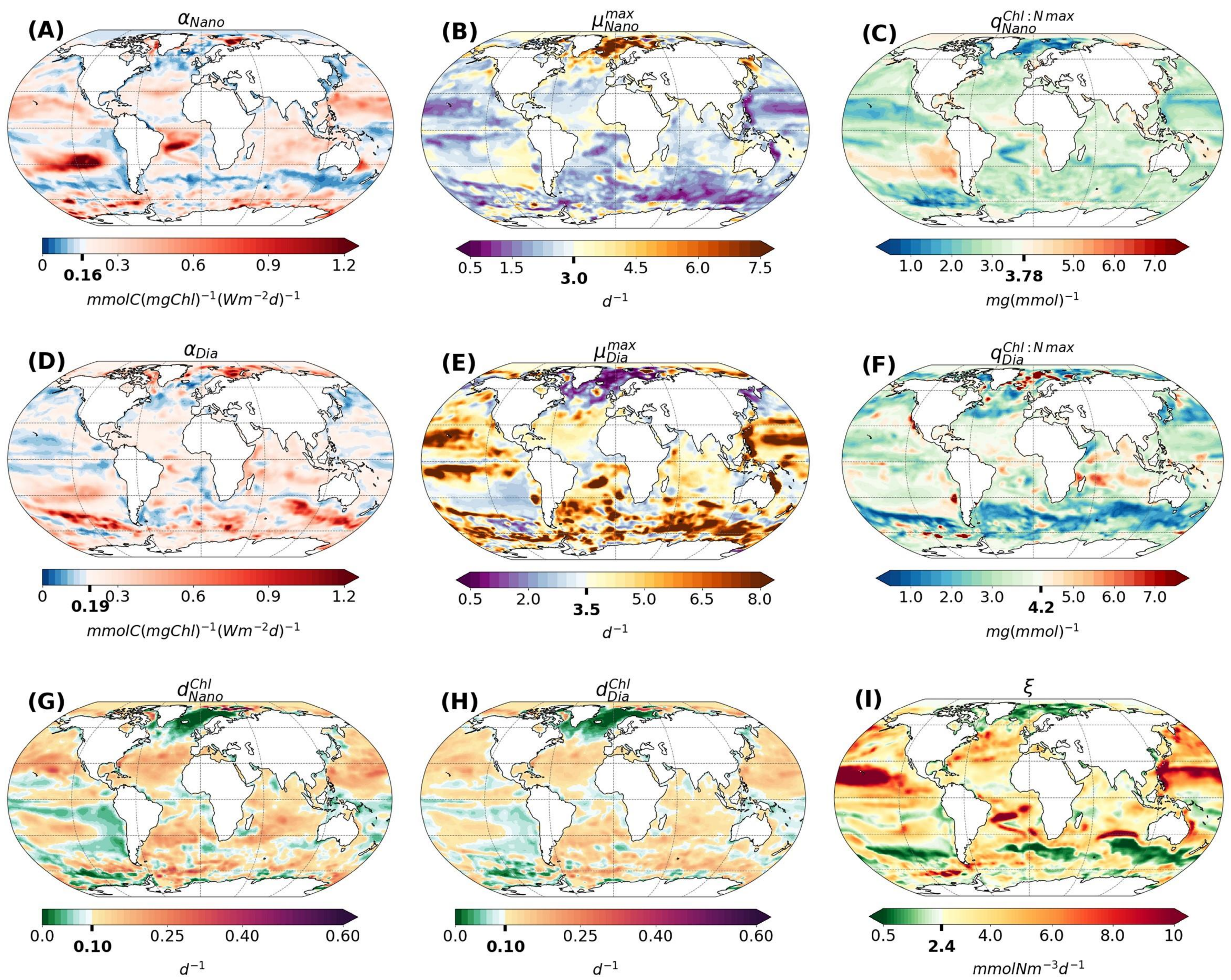
Introduction

Ocean biogeochemical (BGC) models are a primary tool for investigating the global carbon cycle. These models contain many uncertain process parameters. The values of these BGC parameters depend on the local physical and biogeochemical context of the marine environment. However, BGC parameters are typically used as constant values across space and time in the model. This study estimates nine selected BGC parameters using an ensemble data assimilation technique in a global ocean model.

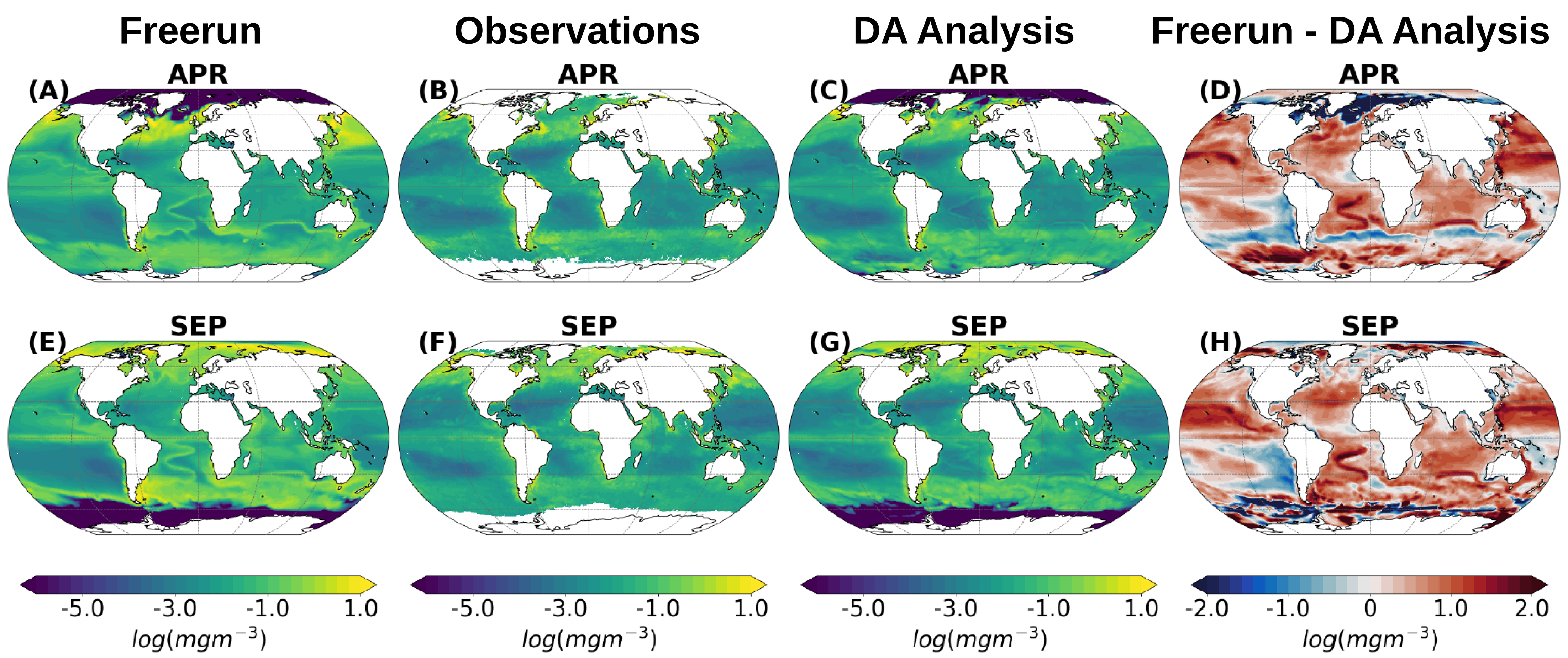
The Regulated Ecosystem Model 2 (REcoM2)



REcoM2 describes two phytoplankton classes, nanophytoplankton and diatoms, a generic heterotrophic zooplankton class and one class of organic sinking particles and simulates 22 passive tracers (blue). Arrows depict source and sink terms. Model parameters regulate the fluxes between these pools.



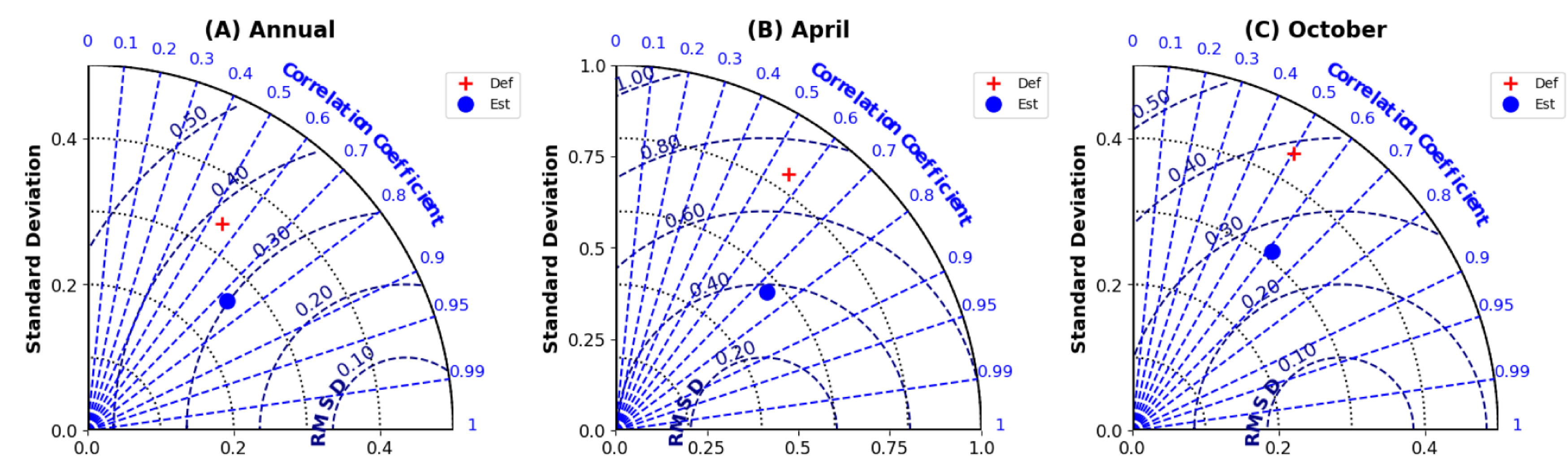
Estimated parameters values for initial slope of the Photosynthesis-irradiance curve of nanophytoplankton (A) and diatoms (D); maximum photosynthesis rate of nanophytoplankton (B) and diatoms (D); maximum chlorophyll to nitrogen ratio of nanophytoplankton (C) diatoms (F); Chl degradation rate nano-phytoplankton (G) and diatoms (H); maximum grazing rate (I). The bold value indicated by the major tick mark on the color bar represents the default value. The values of the BGC parameters vary in regions depending on the physical and BGC conditions naturally.



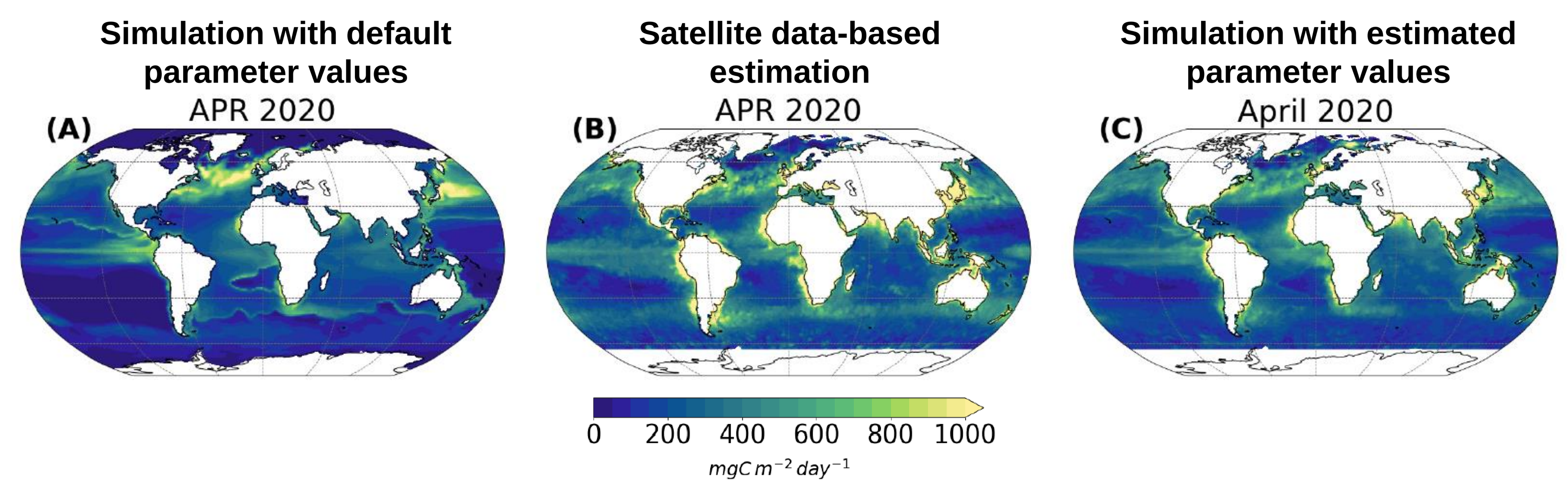
Monthly mean log-transformed surface chlorophyll-a concentrations for April 2020 (A-D) and September 2020 (E-H). From left to right: Freerun; ESA OC-CCI data; DA analysis and difference of DA analysis from Freerun. DA analysis shows a better field with spatial pattern closer to the observations than the Freerun. However, in September, the model still overestimates the chlorophyll-a concentration compared to the observations.

Conclusion

We estimated 9 spatially and temporally varying parameters of a global ocean BGC model applying ensemble data assimilation. Estimated parameters point to variations similar to in situ measurements. Data assimilation can lead to unrealistic parameter values in regions of model deficits. Including spatially variable parameters improved the simulation of surface chlorophyll-a concentrations across space.



Taylor diagrams illustrating the comparison of surface chlorophyll-a concentration from model simulations with default parameters and estimated parameters against satellite observations for the period 2019-2021. The diagrams represent: (A) Annual mean, (B) Monthly mean for April, and (C) Monthly mean for October.



Monthly mean vertically Integrated NPP for April 2020. A) The reference simulation with default parameter values; B) Satellite estimation with updated carbon-based productivity model; and C) simulation with estimated parameter values. Over large parts of the global ocean, the vertically integrated NPP simulations agree reasonably with the observations.

Data Assimilation Method

- Assimilate 5-day satellite chlorophyll-a concentration from ESA OC-CCI
- Apply Error-Subspace Transform Kalman Filter
- Implement with Parallel Data Assimilation Framework – PDAF (https://pdaf.awi.de/)
- Use ensemble size 36
- Perturb 9 biogeochemical parameters
- Update 8 state variables (bold) + 9 parameters related to phytoplankton growth and loss
- DA experiment for the full year 2020
- Log transformed concentrations and parameters