Investigating the Arctic phytoplankton variability and diversity based on modeling and satellite retrievals

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Abstract

In our study we focus on improving our understanding of possible interactions between the open water and sea ice and the surface ocean biogeochemistry under the recently observed sea ice decline in the Arctic. In particular, the analysis of changes in phytoplankton functional types (PFTs) over 2002 to 2012 based on long-term time series of satellite retrievals and supported by a modeling study is presented. The phytoplankton dynamics as well as phytoplankton diversity in response to Arctic Amplification is simulated with the DARWIN biogeochemical model (Follows et al., 2007, Dutkiewicz et al., 2015) coupled to the Massachusetts Institute of Technology general circulation model (MITgcm) with a configuration based on a cubed-sphere grid (Menemenlis et al. 2008). The model results are complemented with information on phytoplankton compositions retrieved with PhytoDOAS (Bracher et al. 2009, Sadeghi et al. 2012) from available hyper-spectral optical satellite measurements (SCIAMACHY and OMI), which are synergistically combined via an optimal interpolation technique with multi-spectral optical satellite data (OC-CCI).

Model

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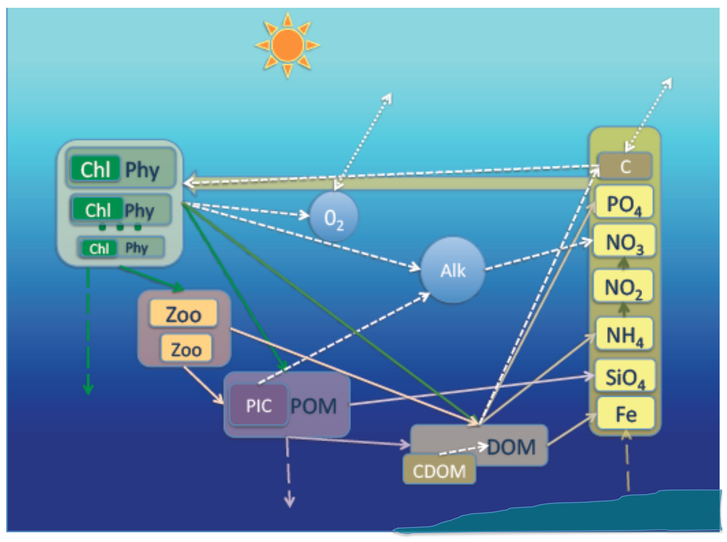
A version of the Darwin ocean biogeochemical model coupled to the MITgcm general circulation model is used to simulate the dynamics of 6 various phytoplankton functional types: Analogues of diatoms, other large eukaryotes, picophytoplankton *Synechococcus,* other picoplankton *Prochlorococcus,* nitrogen fixers, and coccolithophores.



Following Taylor et al. (2013) we use the circulation model configuration based on a cubed-sphere grid (Menemenlis et al. 2008) with mean horizontal spacing of ~18 km and 50 vertical levels with the resolution ranging from 10 m near the surface to ~450 m in the deep ocean. The model is forced by 6-houly atmospheric conditions from the NCEP Climate Forecast System Reanalysis (CFSR).

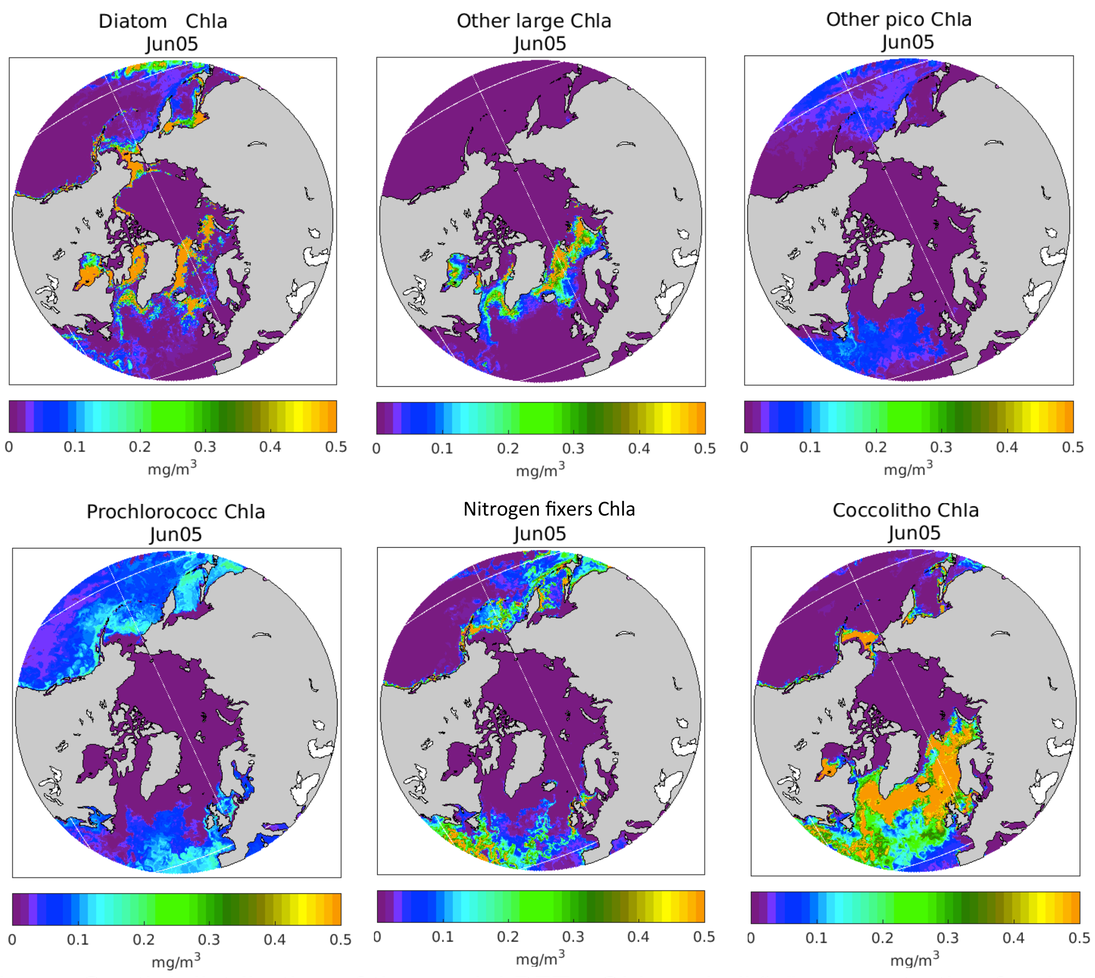


Figure: Spatial distribution of the model PFTs Chlorophyll "a" concentration for June 2005. The solution is sensitive to a large extend to the model parameters specified.

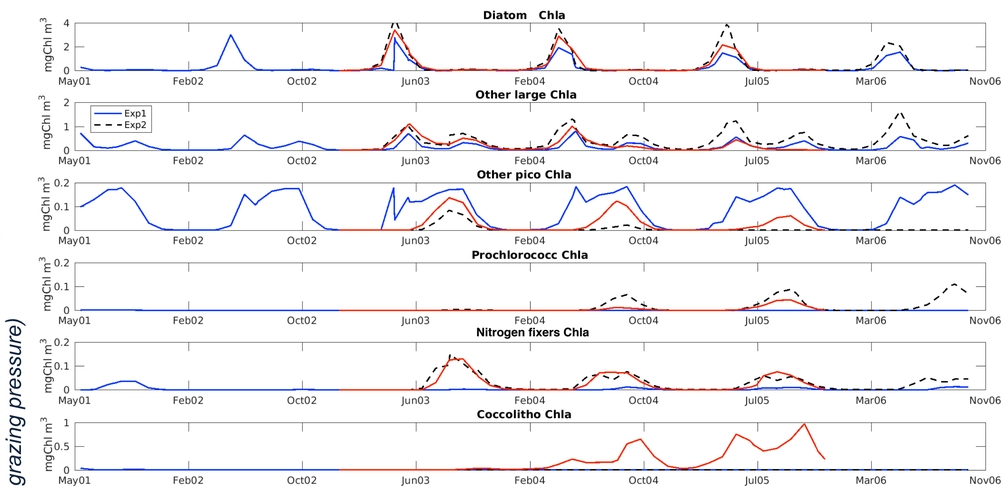


Figure: Temporal evolution of the model various PFT Chla (mg/m³) for the ARCT biogeochemical province for experiments with different physyological parameter sets (red: cocco is treated as nonoplankton with slower growth and lower grazing pressure)

Satellite retrievals

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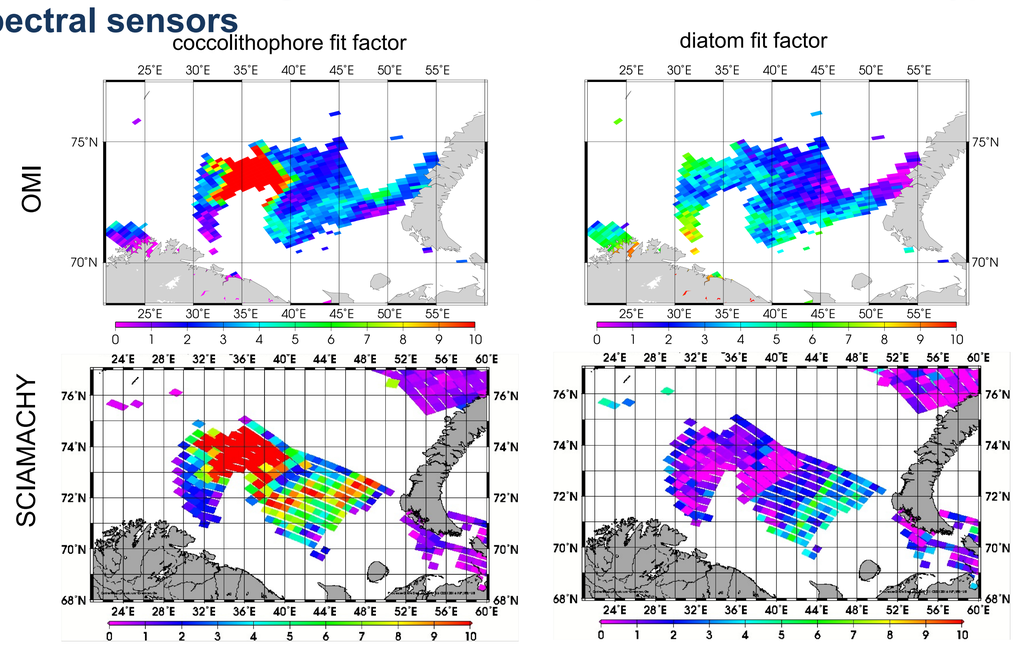
The biomass of important phytoplankton groups are extracted using differential optical absorption spectroscopy (PhytoDOAS) on hyperspectral satellite data. Combining the PFT products from two hyper-spectral sensors provides better spatial sampling of the Southern Ocean and extension of observed time period (2002 until present). Current status of PFT products from the still operating OMI sensor is presented.

Barents Sea, 28 August 2006: Comparison of two different hyper-spectral sensors



Synergistic Product: Combining hyper- and multi-spectral satellite data

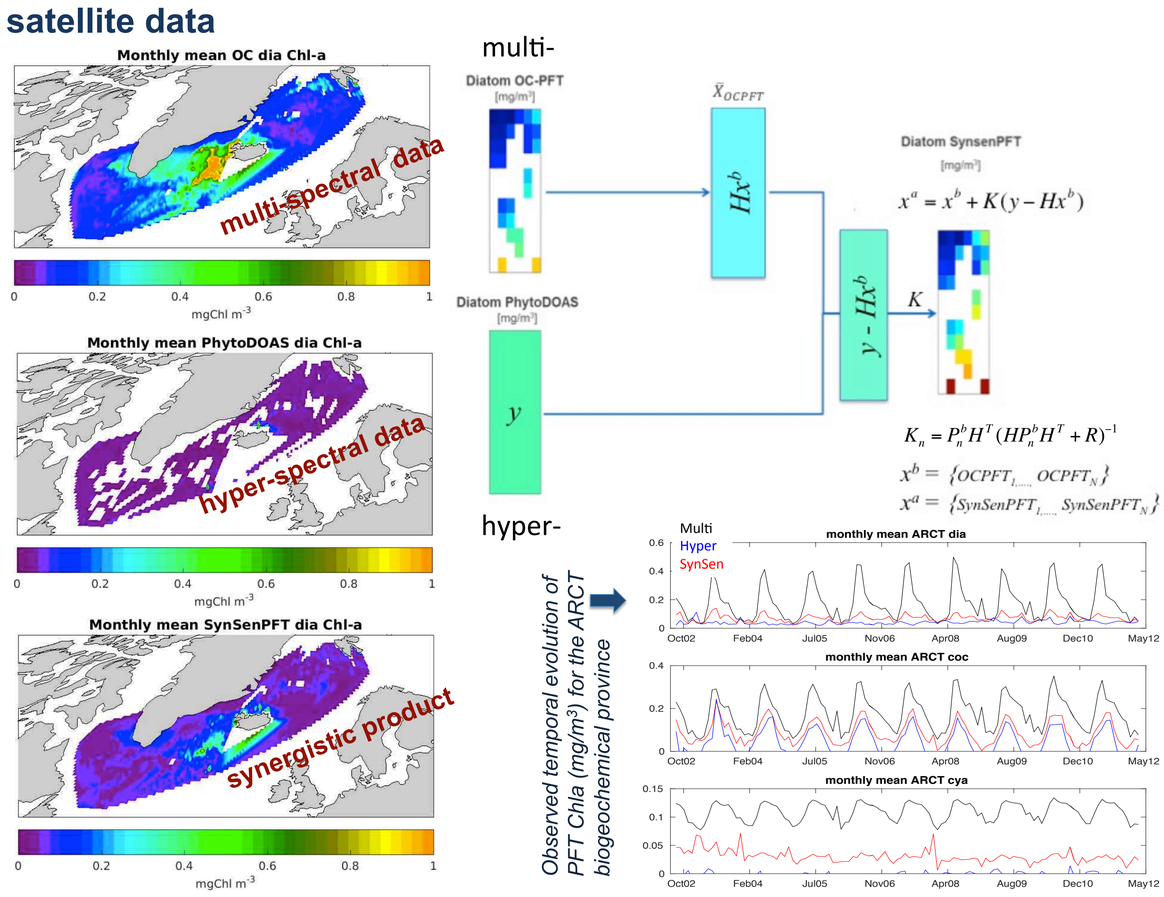


Figure: Spatial distribution of monthly mean diatom Chlorophyll "a" concentration (Chla) over the ARCT biogeochemical province (Longharst, 1998) for June 2010.

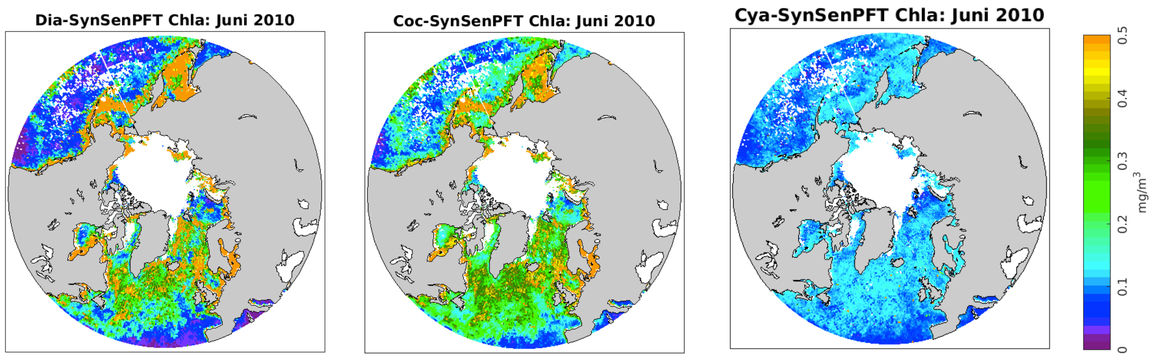


Figure: Spatial distribution of the synergistic (SynSenPFT) Chlorophyll "a" concentration for diatom, coccolithophore and cyanobacteria averaged over June 2010.

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References: Bracher A, Dinter, T., Vountas, M., Burrows, J. P. , R.ttgers, R., Peeken, I. (2009) Quantitative observation of cyanobacteria and diatoms from space using PhytoDOAS on SCIAMACHY data. Biogeosciences, 6, 751–764. Dinter T, Rozanov, V. V., Burrows, J. P., Bracher, A. (2015) Retrieving the availability of light in the ocean utilising spectral signatures of vibrational Raman scattering in hyper-spectral satellite measurements. Ocean Science, 11, 373-389. Dutkiewicz, S., Hickman, A. E., Jahn, O., Gregg, W. W., C. B. Mouw, C. B., and M. J. Follows (2015) Capturing optically important constituent and properties in a marine biogeochemical and ecosystem model, Biogeosciences, 12, 4447-4481. Follows, M. J., Dutkiewicz, S., Grant, S., and Chisholm, S. W. (2007) Emergent Biogeography Of Microbial Communities In A Model Ocean, Science, 315, 1843–1846. Longhurst. A. (1998) Ecological Geography of the Sea, Academic press. Menemenlis, D., Campin, J.-M., Heimbach, P., Hill, C., Lee, T., Nguyen, A., Schodlock, M., and H. Zhang (2008). High resolution global ocean and sea ice data synthesis (2008) Mercator Ocean Quartely Newsletter, 31, 13–21. Sadeghi, A., Dinter, T., Vountas, M., Taylor, B. B., Altenburg-Soppa, M., Peeken, I., Bracher, A. (2012) Improvement to the PhytoDOAS method for identification of coccolithophores using hyper-spectral satellite data. Ocean Science, 8, 1055–1070.Taylor, M. H., Losch, M., Bracher, A. (2013) On the drivers of phytoplankton blooms in the Antarctic seasonal ice zone: a modelling approach. J. Geophys. Res.–Oceans 188: 63-75. Vountas M, Dinter, T., Bracher, A., Burrows, J. P., Sierk, B. (2007) Spectral studies of ocean water with space-borne sensor SCIAMACHY using Differential Optical Absorption Spectroscope (DOAS). Ocean Science, European Geosciences Union, 3, 429-440.