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Antarctic phytoplankton in response to environmental change studied by a synergistic approach using multi- and hyper-spectral satellite data (PhySyn)

Project description

The project focuses on the assessment of the impact of environmental change in the Southern Ocean on phytoplankton. Phytoplankton is the key organism determining the functioning of the marine ecosystem and biogeochemical cycle and it can be detected from space. In this study analytical bio-optical retrieval techniques are to be used to develop generic methods, which extract unique global long-term information on phytoplankton composition. The methods will be based on using all available high-resolution optical satellite data which are complemented by in-situ and multi-spectral satellite data. Combined with modeling studies, this information will be used to attribute the relative importance of anthropogenic activity and natural phenomena on the marine ecosystem and biogeochemical cycling of the Southern Oceans during the last decades.

Satellite Observations

Extracting the biomass of important phytoplankton groups in the Southern Ocean using differential optical absorption spectroscopy (DOAS) on hyperspectral satellite data.

PhytoDOAS Retrieval Method (Vountas et al. 2007, Bracher et al. 2009, Sadeghi et al. 2012, Dinter 2015)
The method is based on the Beer-Lambert law:

$$I(\lambda) = I_0(\lambda) \cdot \exp(-\tau(\lambda)) \Rightarrow \tau(\lambda) = \ln \frac{I_0(\lambda)}{I(\lambda)}$$

Here $I(\lambda)$ is backscattered spectrum from earth measured by satellite sensor;
$I_0(\lambda)$ is sun spectrum measured by satellite sensor.

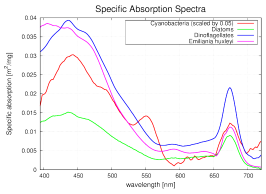
DOAS (Differential Optical Absorption Spectroscopy) equation is a minimization problem. Including phytoplankton absorption → PhytoDOAS equation:

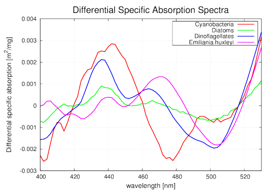
$$\left[\begin{matrix} S_k, S_j \\ x_i \end{matrix}\right] = Arg\min \left\| \tau(\lambda) - \boxed{\sum_{k=1}^{K} S_k \sigma_k(\lambda)} - \boxed{\sum_{j=1}^{J} S_j a_j(\lambda)} - \boxed{\sum_{i=0}^{I} x_i \lambda^i} \right\|$$

Atmospheric effects Oceanic effects Polynomial

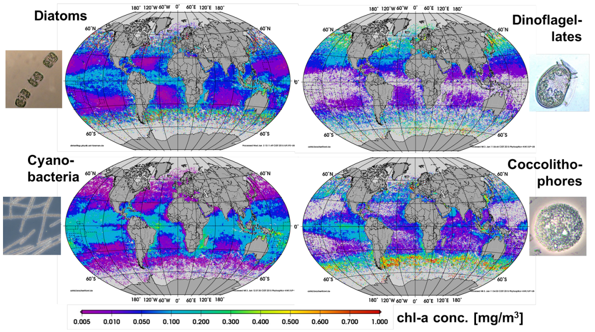
Subject to relevant trace gas absorption, ring effect, phytoplankton and liquid water absorption, vibrational Raman scattering (VRS), lower frequency structures such as Rayleigh and Mie scattering.

S_k, S_j are fit factors of the atmospheric and oceanic effects; a_j, σ_k are atmospheric and oceanic absorption cross sections.





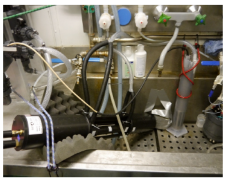
Global Biomass of Phytoplankton Groups (Bracher et al. 2009, Sadeghi et al. 2012)



In-situ Validation Data

HPLC pigment data + ac-s spectrophotometer continuous absorption and attenuation measurements of sea water.

ac-s In-Situ Spectrophotometer:
Flow-through system
Wavelength range: 400 nm to 730 nm
4 nm resolution



Modeling

A version of the Darwin ocean biogeochemical model coupled to the MITgcm general circulation model (Follows et al., 2007, Prowe et al., 2014, Dutkiewicz et al., 2015) is used to simulate the dynamics of 9 various phytoplankton functional types: Analogues of diatoms, other larger eukaryotes (Lg Euk), *Synechococcus* (Syn), high and low light *Prochlorococcus* (HL Pro and LL Pro), nitrogen fixing *Trichodesmium* (Tricho), unicellular diazotrophs (UniDiaz), small eukoryotes (Sm Euk) and cocolithophores (Coccol).

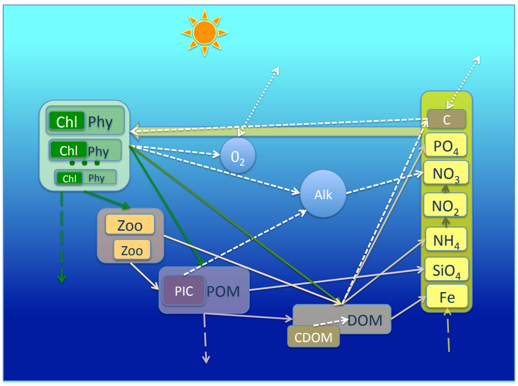


Figure: The schematic diagram of the DARWIN biogeochemical model.

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).

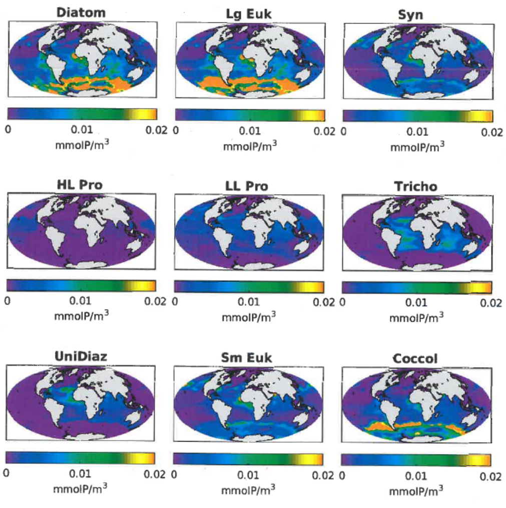


Figure: Spatial distribution of the model PFTs after 1 hour of Darwin-based model integration started from the same initial condition based on a coarse resolution MITgcm setup.

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mit vergleichenden Untersuchungen in arktischen Eisgebieten

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