Modeling the Arctic coloured dissolved organic matter (CDOM) and phytoplankton diversity in/with support to/from satellite retrievals

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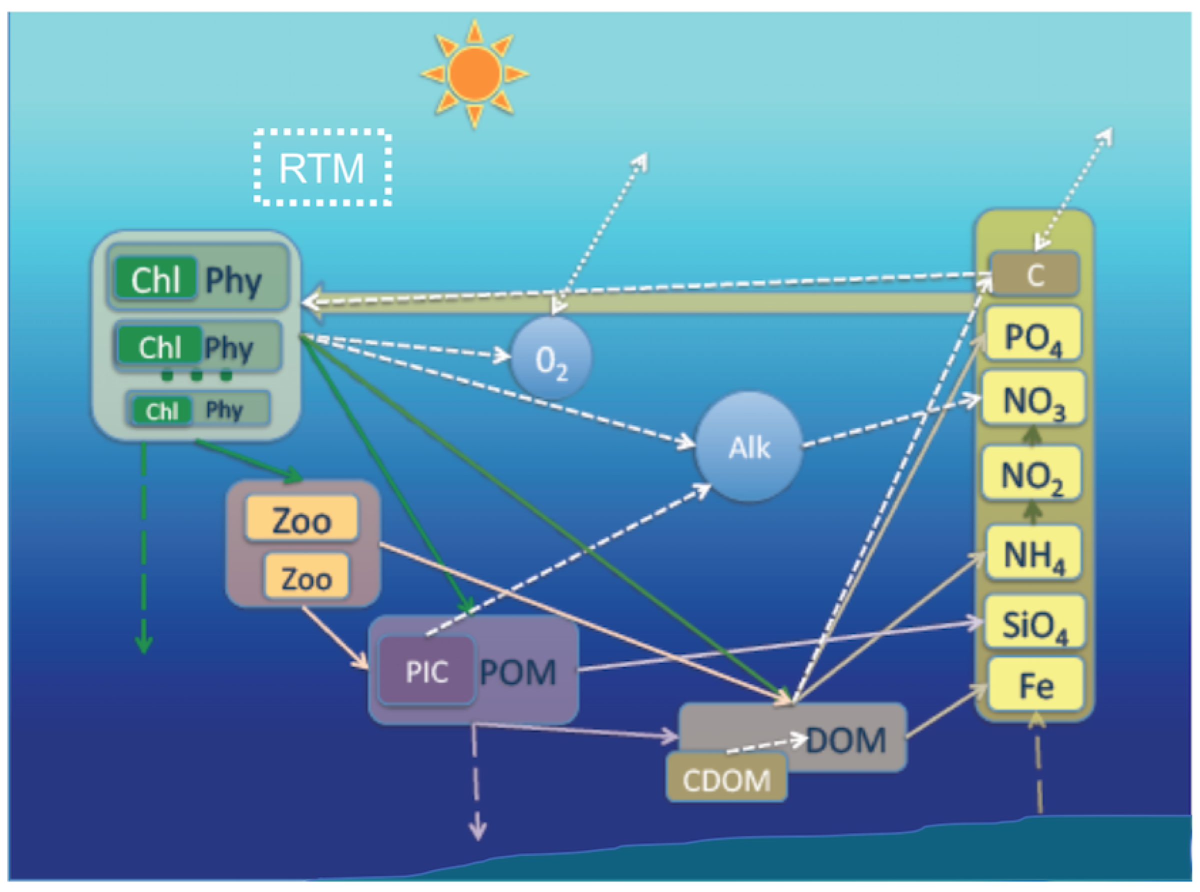
Abstract

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) 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 biogeochemocal module is coupled to an optical/radiative transfer model (RTM) that allows to consider explicitly phytoplankton and CDOM as oceanic optical constituents and, therefore, to investigate possible feedbacks between ocean – oceanic biota – sea ice – atmosphere and evaluate satellite ocean colour (phytoplankton chlorophyll *"a"* and CDOM) data products.

Model

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

Schematic representation of the Darwin biogeochemical cycling (produced in accordance with the model description by Dutkiewicz et al., 2015)



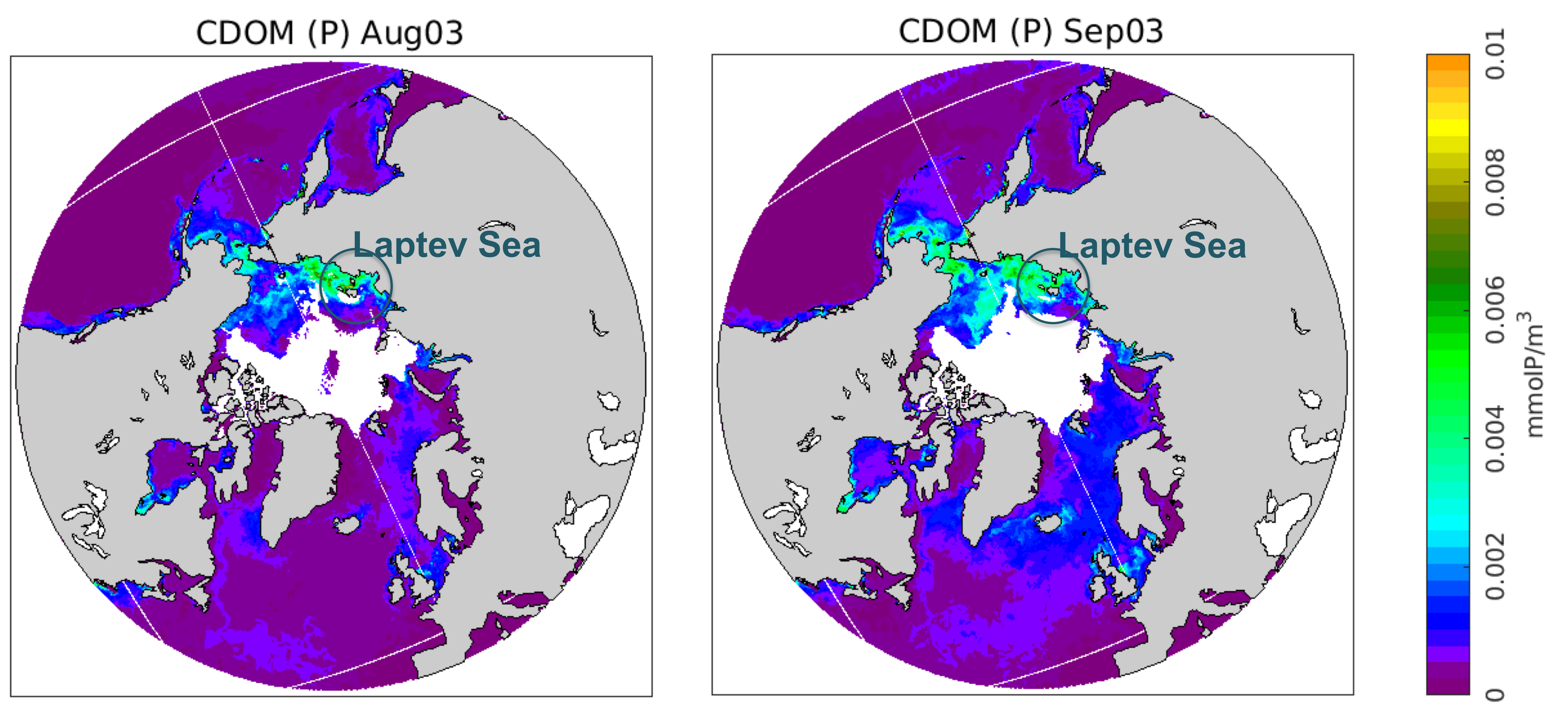


Figure: Spatial distribution of the Arctic CDOM for August and September 2003.

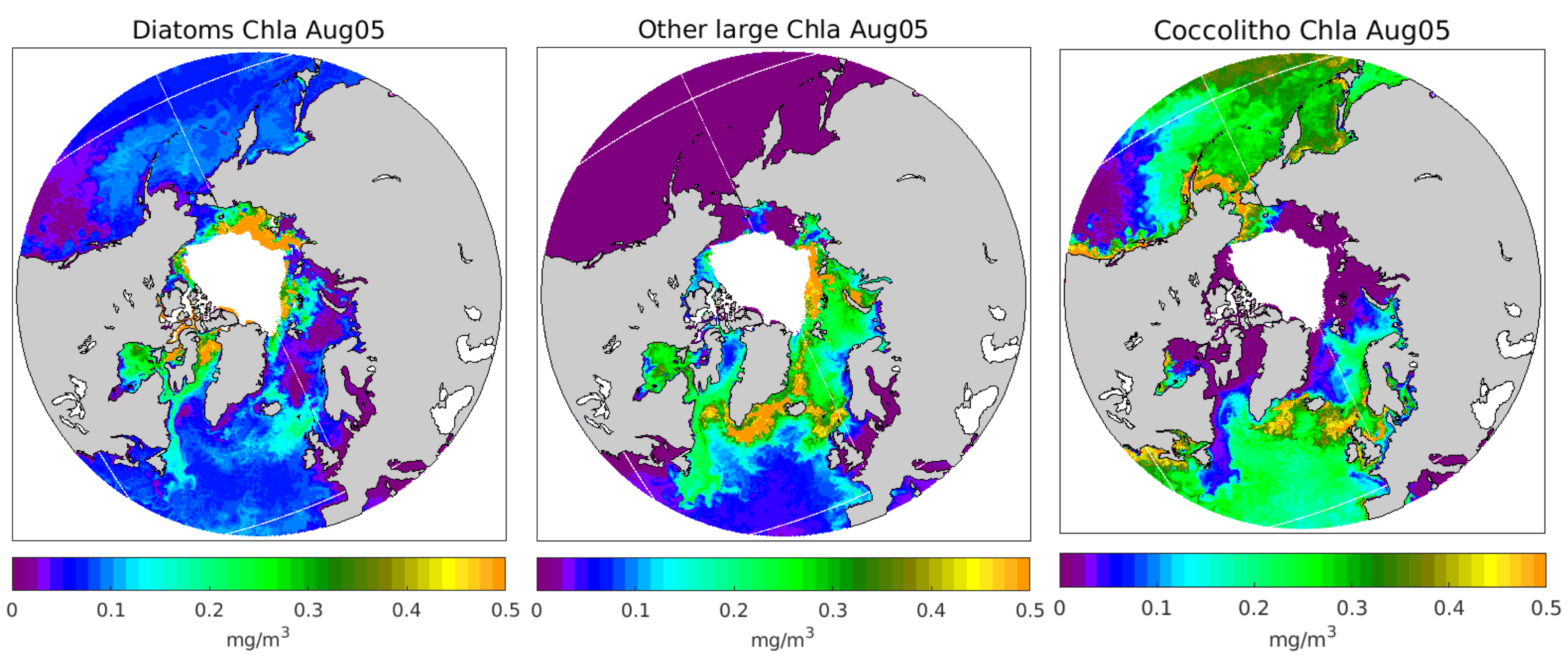


Figure: Spatial distribution of the model simulated Arctic chlorophyll "a" for diatoms, other large phytoplankton) and coccolithophores in August 2005.

Ccccolithophores are considered with corrected physiology to account for high affinity for nutrients and ability to escape grazing control (Losa et al. 2006). Diatoms represent two different size classes, other large include two distinct life stages of *Phaeocystis* (Popova et al. 2007).

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References: 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. Losa, S. N., Soppa, M. A., Dinter, T., Wolanin, A., Brewin, R. J. W., Bricaud, A., Oelker, J., Peeken, I., Gentili, B., Rozanov, V. and Bracher, A. (2017). Synergistic exploitation of hyper- and multispectral precursor Sentinel measurements to determine Phytoplankton Functional Types (SynSenPFT). *Frontiers in Marine Science,* 4, 203, doi: 10.3389/fmars.2017.00203. 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. 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.

Satellite retrievals

Two algorithms based on the Neural Networks – Case 2 Regional Coast Colour (C2RCC) and Extreme Case 2 Waters (C2X, trained for extreme ranges of scattering and absorption) – are considered for retrieving CDOM absorption and total chlorophyll *"a"* (Chla), the evaluation has been done for the Laptev Sea.

MERIS CDOM absorption $a_{CDOM}(443)$ (04.08.2010)

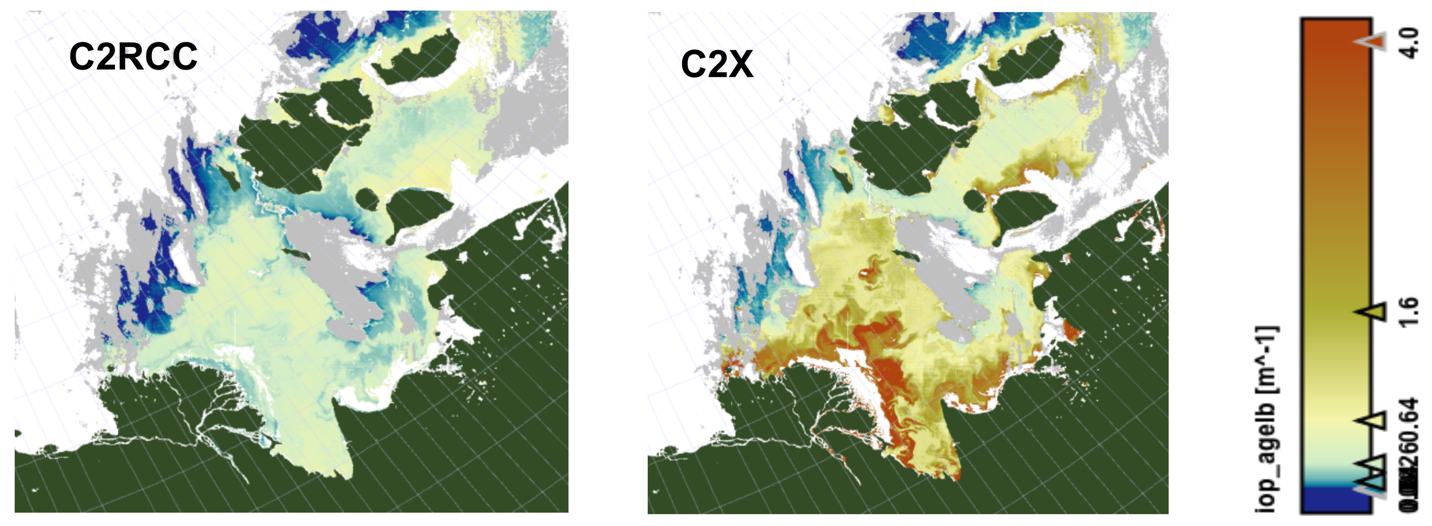


Figure: Spatial distribution of the CDOM absorption in the Laptev Sea retrieved with C2RCC and C2X on 4 August 2010.

MERIS Chlorophyll *"a"* Chla (04.08.2010)

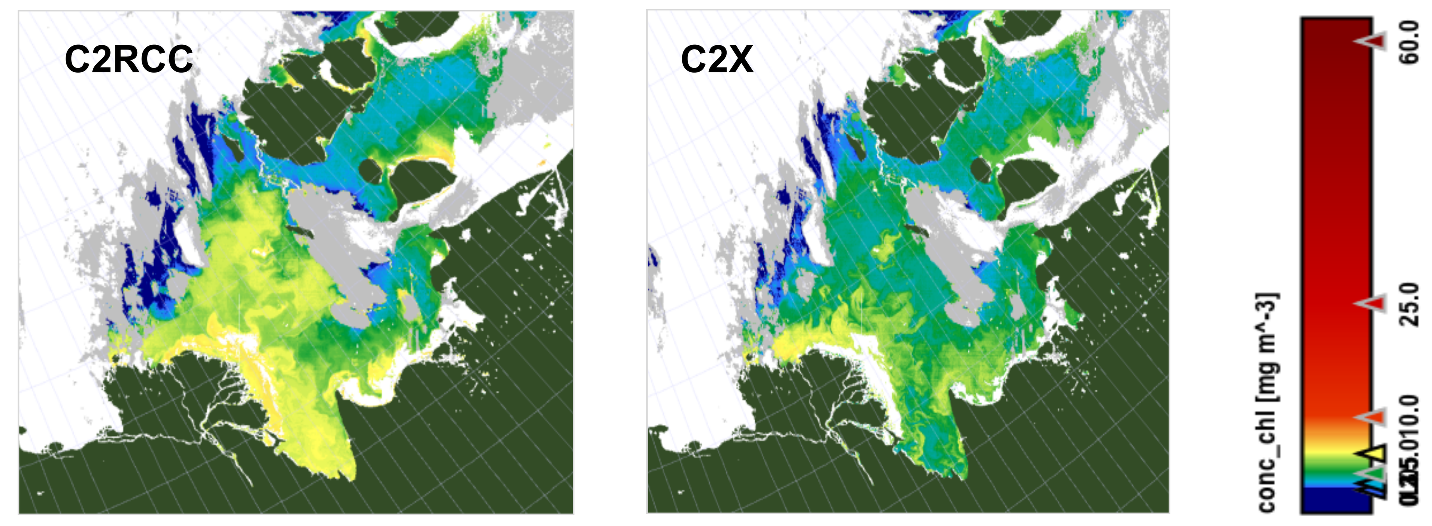


Figure: Spatial distribution of the total chlorophyll "a" concentration in the Laptev Sea retrieved with C2RCC and C2X on 4 August 2010.

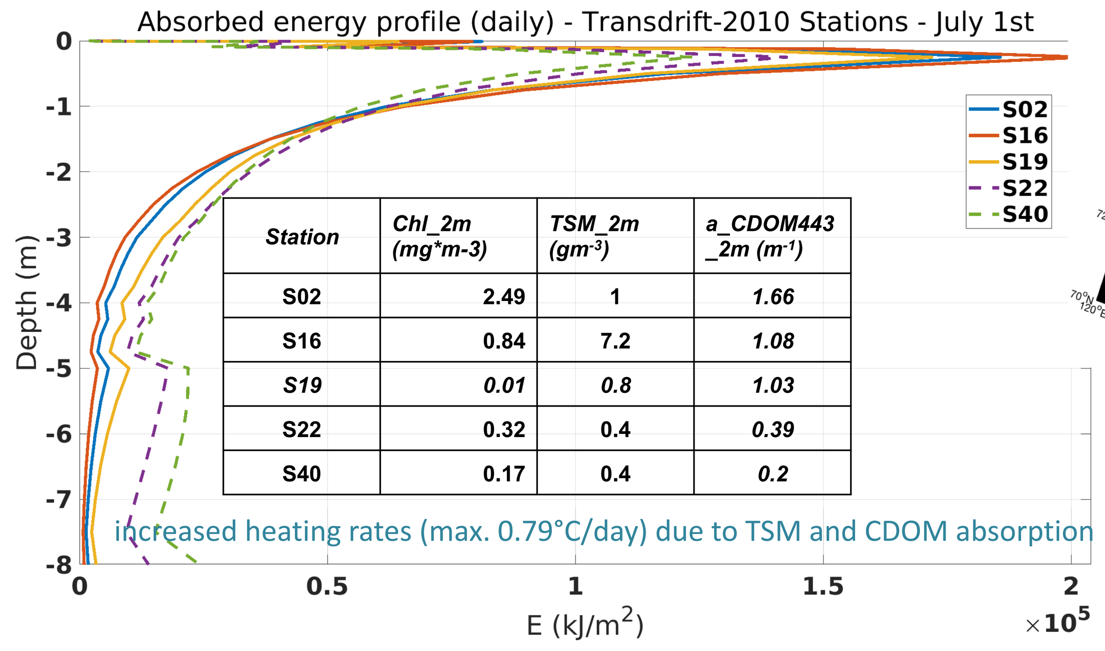
Additionally, SynSenPFT (Losa et al. 2017) Chla product for diatoms, cyanobacteria and coccolithophores is used for evaluating the coupled sea-ice – ocean – biogeochemical simulations and obtaining long-term time series on the Arctic phytoplankton diversity (based on combined information).

Comments/Outlook

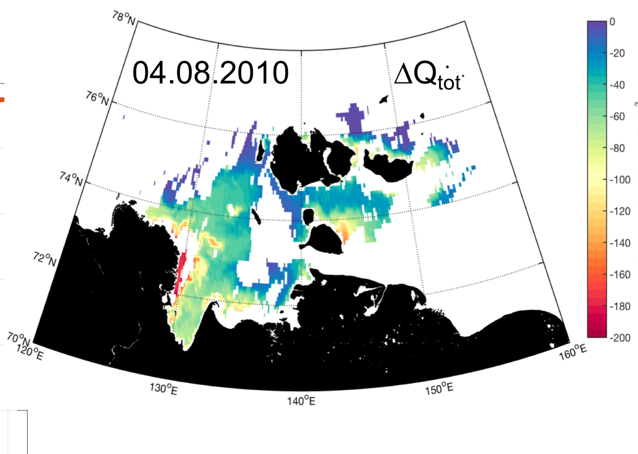
The model simulations show that CDOM alters remineralisation processes affecting the nutrients distribution and therefore the spatial and temporal distribution of PFTs competing for the available resources. Amount and distribution of CDOM impacts PFTs dynamics as well by impacting strongly the light penetration and availability for the photosynthesis.

More Darwin-based numerical simulations (with increased model resolution) are to be performed to complement satellite retrievals and *in situ* measurements when understanding the role of CDOM (phytoplankton/Chla) in the radiative heating in the shelf waters (the Laptev Sea).

CDOM & radiative budget in the Laptev Sea



Station	Chl_2m (mg*m-3)	TSM_2m (gm^{-3})	a_CDOM443 _2m (m^{-1})
S02	2.49	1	1.66
S16	0.84	7.2	1.08
S19	0.01	0.8	1.03
S22	0.32	0.4	0.39
S40	0.17	0.4	0.2



SCIATRAN 1D RTM – based estimates of the energy absorbed by CDOM&TSM / total heat flux differences

In collaboration with Jens Hölemann, Sebastian Hellmann, Fedor Martynov, Markus Janout

REKLIM Helmholtz-Verbund Regionale Klimaänderungen

PHYTOOPTICS Helmholtz Young Investigators Group

TRANSREGIO TR 172