C03

Assessing bio-physical feedbacks in the shelf areas of Laptev Sea

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Motivation / Introduction

In the context of climate change and of thawing permafrost in Siberia, the freshwater and organic material supplied by rivers to the Arctic Ocean, may increase heavily in the future. Among those rivers, the Lena River in Laptev Sea accounts for the highest annual flux of dissolved organic carbon [1,2]. A fraction of this organic material is coloured (CDOM) and it highly absorbs ultra violet and visible light. The presence of CDOM, in combination with total suspended matter (TSM) and Chlorophyll-a (Chl-a) may significantly limit solar radiation in-water penetration. Here, we investigate the effect of the variability of these optically active water constituents on the heat budget of the Laptev Sea surface waters.

Aim: assess the influence of CDOM, TSM and Chl-a to the radiative heating of the shelf areas of Laptev Sea

Methods

Radiative transfer model (RTM) SCIATRAN [3]:
Spectral RTM simulations for coupled atmosphere-ocean:

- atmosphere: thermal emission, absorption by several trace gases, Rayleigh scattering and scattering by aerosol and cloud particles.
- ocean: scattering by water and TSM, absorption by water, CDOM, Chl-a and TSM.

RTM input: satellite RS retrievals of CDOM absorption (a_{CDOM}) at 443nm, TSM, Chl-a and Sea Surface Temperature (SST) for typical summer conditions (August 04, 2010).

Simulating:

- spectrally net irradiance (E_d, W/m^2, 300 - 1190 nm)
- 2 components: VIS (300 – 800 nm) + NIR (800 - 1190 nm)

Results *(Soppa et al. submitted)*

heat flux components: $\Delta Q_{tot} = \Delta Q_{sw} + \Delta Q_{sensible} + \Delta Q_{latent} + \Delta Q_{longwave}$

- ⬆ CDOM, TSM & Chl-a (snapshot)
- ⬆ Surface absorbed energy
- ⬆ Surface heating rate
- ⬇ Q to the atmosphere

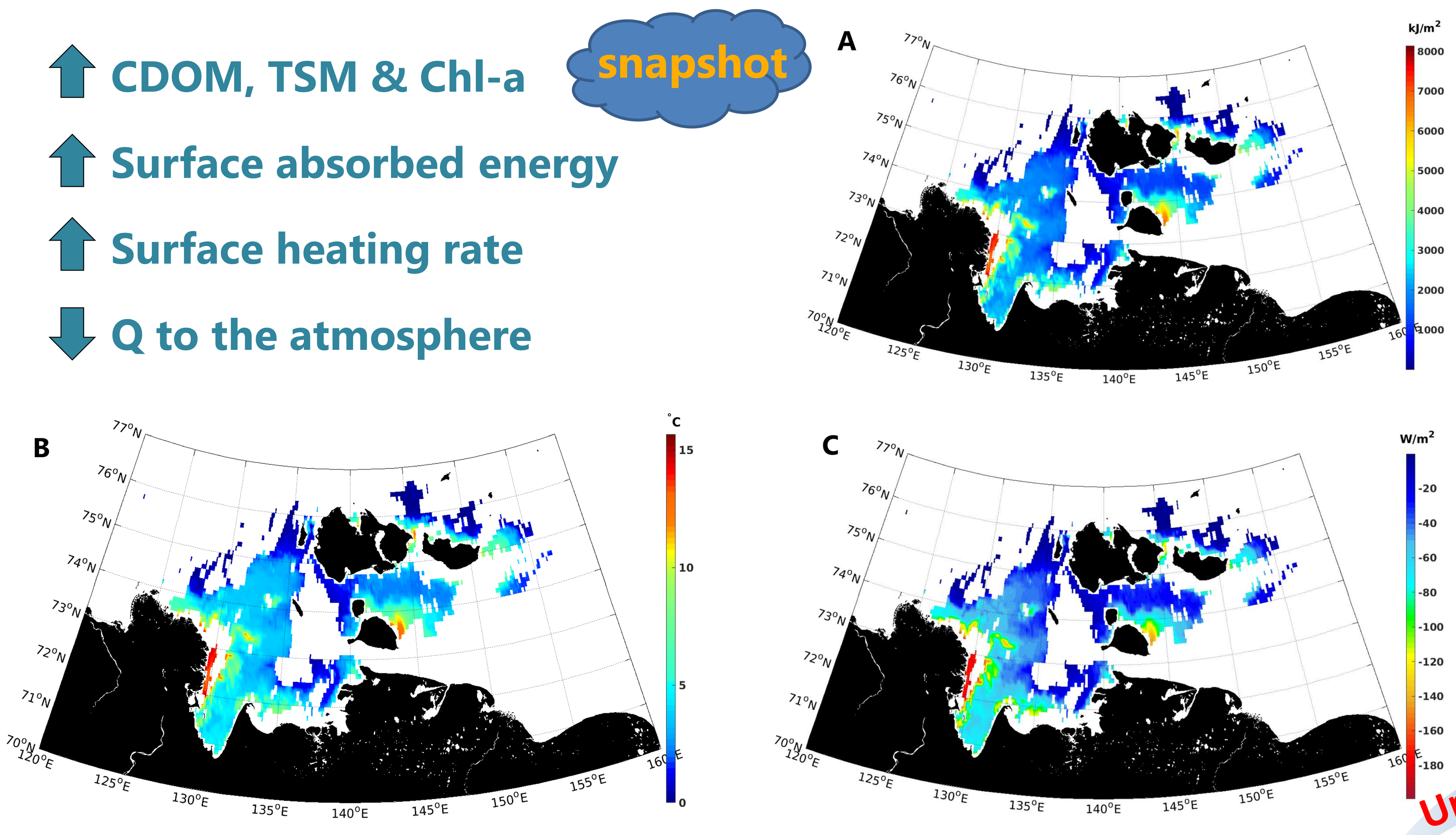

Fig. 1: Spatial distribution of A) absorbed energy at 2m ($E_n abs_{2m}$, KJ/m^2) B) radiant heating difference at the surface (ΔRH, °C) and C) total heat flux difference (ΔQ_{tot}, W/m^2) on August 04, 2010.

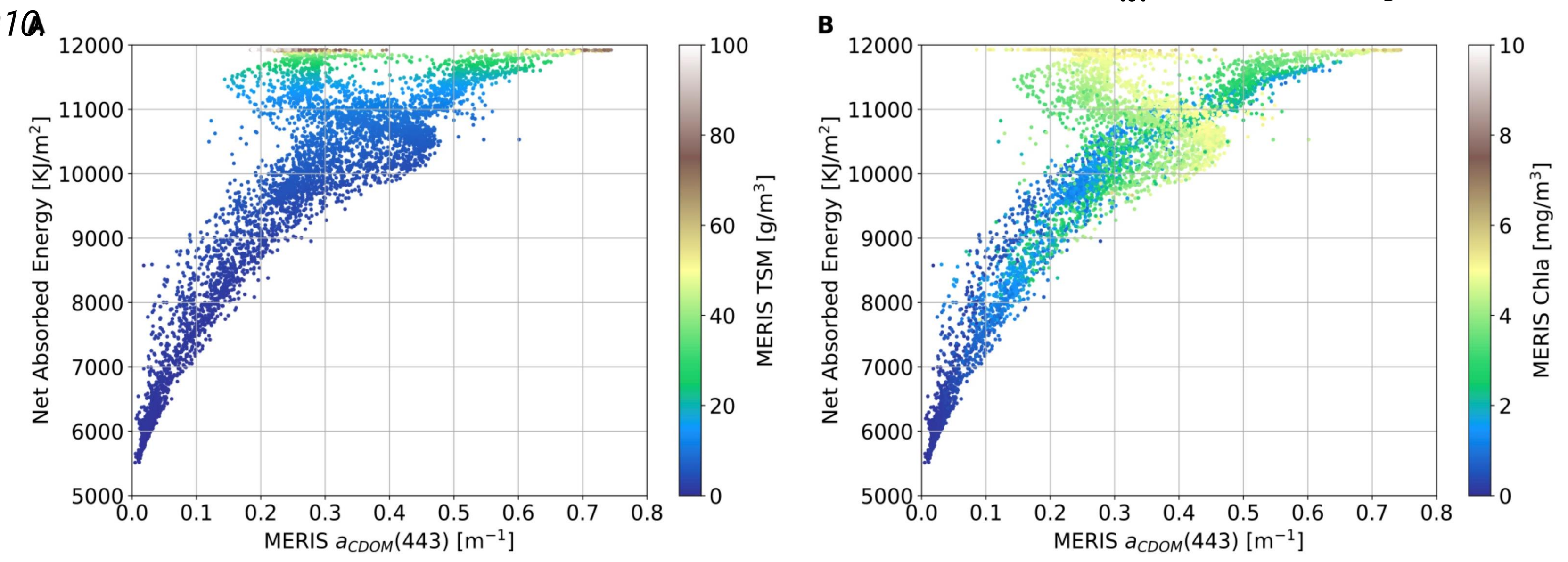

Fig. 2: Scatterplot of A) $E_n abs$, $a_{CDOM}(443)$ and TSM B) of $E_n abs$, $a_{CDOM}(443)$ and Chl-a [4].

✓ For TSM > 10 g/m^3 & Chl-a > 4 mg/m^3 → less direct relationship between $E_n abs$ and a_{CDOM}

Ongoing work

Coupled 3D modelling:
Darwin ocean biogeochemical model [5] coupled to the MITgcm ocean circulation model [6]

- In total, 42 tracers included
- 6 phytoplankton functional types (PFT)
- 2 zooplankton types
- CDOM
- 18km resolution (global)

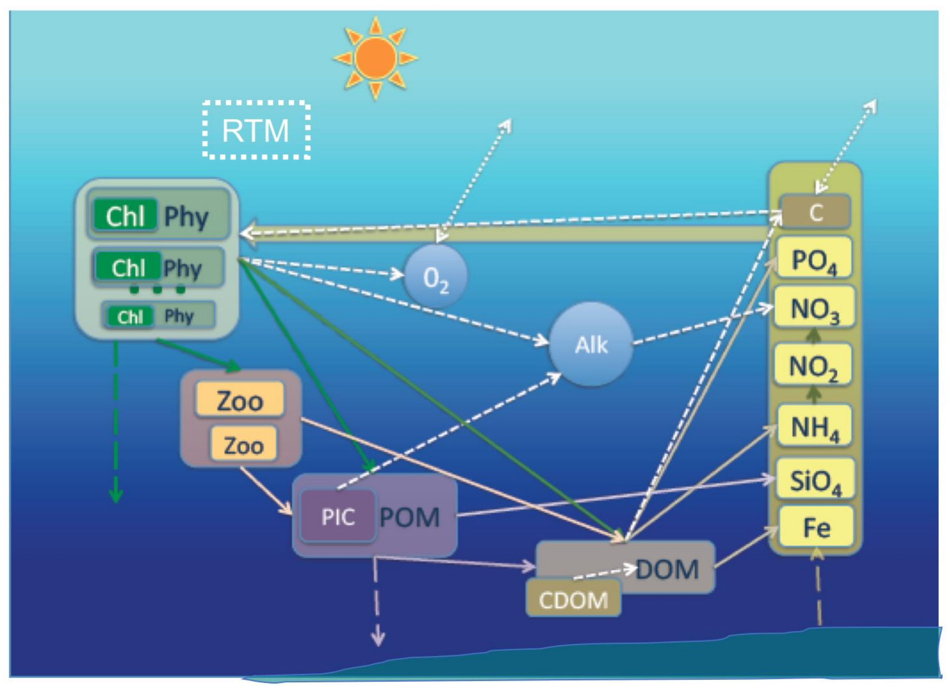

Fig. 3: Schematic representation of the Darwin biogeochemical cycling [5].

Upscale

✓ Implement feedback of biogeochemistry to the physical model

✓ Construct time series of major biogeochemical and physical parameters *(Fig. 5)*

✓ Investigate their feedback on heating rate and sea ice melting

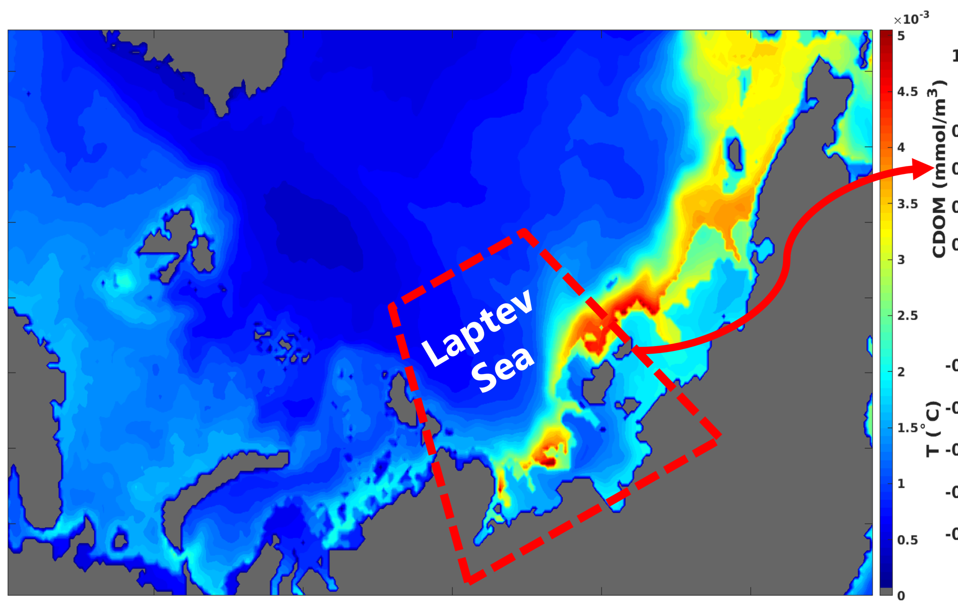

Fig. 4: Simulated average CDOM concentration (mmolP/m^3) in the Arctic Ocean (1999-2010).

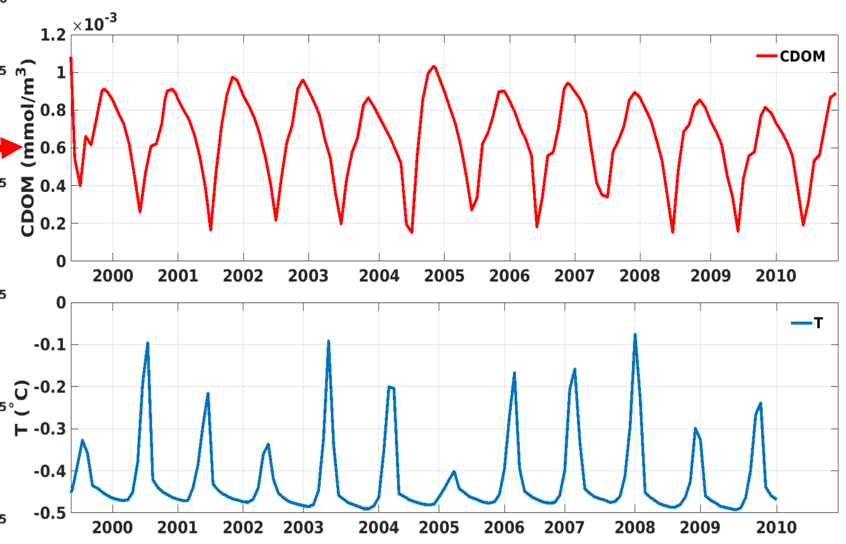

Fig. 5: Time series of average CDOM concentration (mmolP/m^3) and temperature in Laptev Sea (upper 40m).

Conclusions / Outlook

The presence of high a_{CDOM} and TSM concentration leads to more energy absorption in the surface layer of Laptev Sea shelf waters *(Fig. 1A)*. This excess of energy corresponds to increased heating rates comparing to low concentration open sea regions *(Fig. 1B)*. During summer, induced surface heating results to less ocean heat loss to the atmosphere *(Fig. 1C),* in means of sensible and latent heat flux. However, water constituents effect on net longwave flux is almost negligible. CDOM and TSM seem to be the dominant factors in the surface heating of Laptev Sea, as long as Chl-a concentrations are not very high *(Fig. 2)*.

With the use of an ocean biogeochemical model (Fig. 3) coupled to a general circulation model it is possible to simulate the dynamics of various constituents *(Fig. 4)* and their feedback on physical processes. The ongoing investigation aims in identifying how varying CDOM, TSM and Chl-a concentrations in Arctic waters affect heating rates at the surface of the ocean in response to Arctic Amplification. Additionally, to what extent this induced surface heating can result to higher ice melting rates and potential implications to upper ocean stratification and primary production. For this, Darwin-MITgcm will be configured with a local high resolution setup (1 or 2km) for the Arctic Ocean.

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References

[1] Stedmon, C. et al. 2011. The supply and characteristics of colored dissolved organic matter (CDOM) in the Arctic Ocean: Pan Arctic trends and differences. Marine Chemistry 2011, 124, 108–118.
[2] Holmes, R.M. et al. 2012. Seasonal and annual fluxes of nutrients and organic matter from large rivers to the Arctic Ocean and surrounding seas. Estuaries and Coasts 2012, 35, 369–382.
[3] Rozanov, V. et al. 2017. Radiative transfer modeling through terrestrial atmosphere and ocean accounting for inelastic processes: Software package SCIATRAN. Journal of Quantitative Spectroscopy and Radiative Transfer, 2017.
[4] Soppa, M.A. et al. Assessing the influence of water constituents on the radiative heating of Laptev Sea shelf waters. Frontiers in Marine Science. Submitted.
[5] Dutkiewicz, S. et al. 2015. Capturing optically important constituent and properties in a marine biogeochemical and ecosystem model. Biogeosciences, 12, 4447-4481.
[6] MITgcm user guide. MITgcm group 2012.