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Optical model for the Baltic Sea with an explicit CDOM state variable: a case study with Model ERGOM

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ESA Baltic+ SeaLaBio project

ESA Living Planet Symposium 2022, Bonn, Germany

Baltic Sea from space:
A river estuary in spring time

S2 MSI RGB 2017-05-04

Highly dynamic coastal areas

Not enough information about fluxes in the Baltic Sea level

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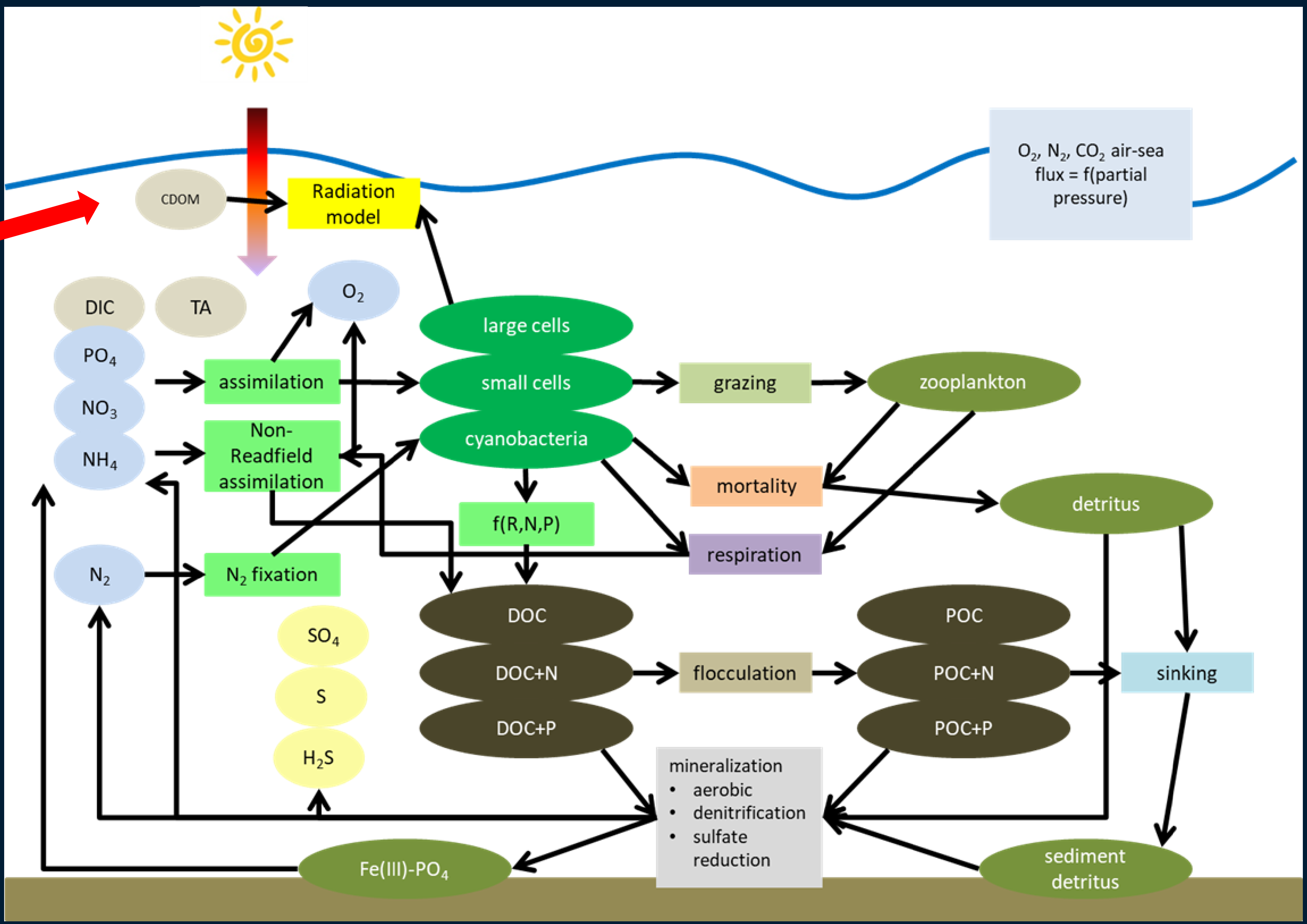
CDOM in Ecosystem Modelling

- Importance of CDOM
  - Impacts primary production due to its absorption effect on PAR
- Sources of CDOM
  - In coastal seas, CDOM originates from terrestrial sources predominantly
  - Causing spatial and temporal changing patterns of light absorption which impacts phytoplankton growth
- Ecosystem Modelling
  - Traditional approach: exploiting the relationship between salinity and CDOM,
  - Often missing the dynamic spatio-temporal pattern of terrestrial inputs
  - ➔ use of EO products to define boundary conditions of CDOM concentrations in an ecosystem model of the Baltic Sea (ERGOM).
- Model adaptation
  - Introduction of an explicit CDOM state variable in the ecosystem model
  - CDOM concentrations in riverine water derived from EO products serve as forcing

ERGOM Model

CDOM salt approximation replaced by explicit state variable



ERGOM radiation model

Radiation model for PAR in ERGOM ($I(z) = I_0 \exp(-Kz)$)

Baltic radiation model:

$K_{PAR} = k_w + k_c \cdot Chl + k_{POM} \cdot POM + k_{DOM} \cdot DOM + K_{CDOM}$

$K_{CDOM} = f(salt)$; lack of data

Baltic radiation model (SeaLaBio):

$K_{CDOM} = k_{CDOM} \cdot CDOM$

$$\frac{dCDOM}{dt} = -pb * CDOM$$

$$pb = PB_0 * I(z)$$

Slow degradation (*pb*) due to light (photobleaching)

Prerequisite: High quality CDOM boundary conditions (river) becomes possible due to SeaLaBio

Utilization of EO based aCDOM values as model forcing data

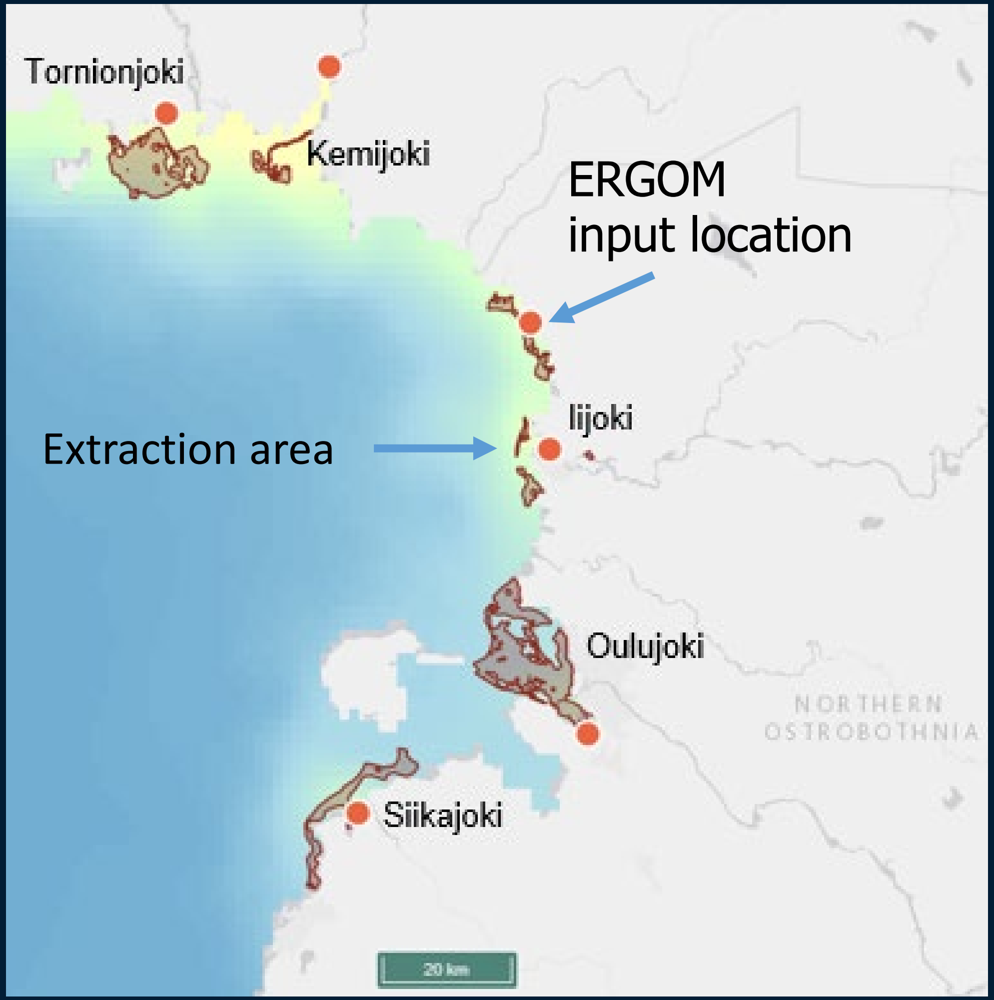
Processing steps

1. Sentinel-2, C2RCC-processor and local calibration (data from Finland)

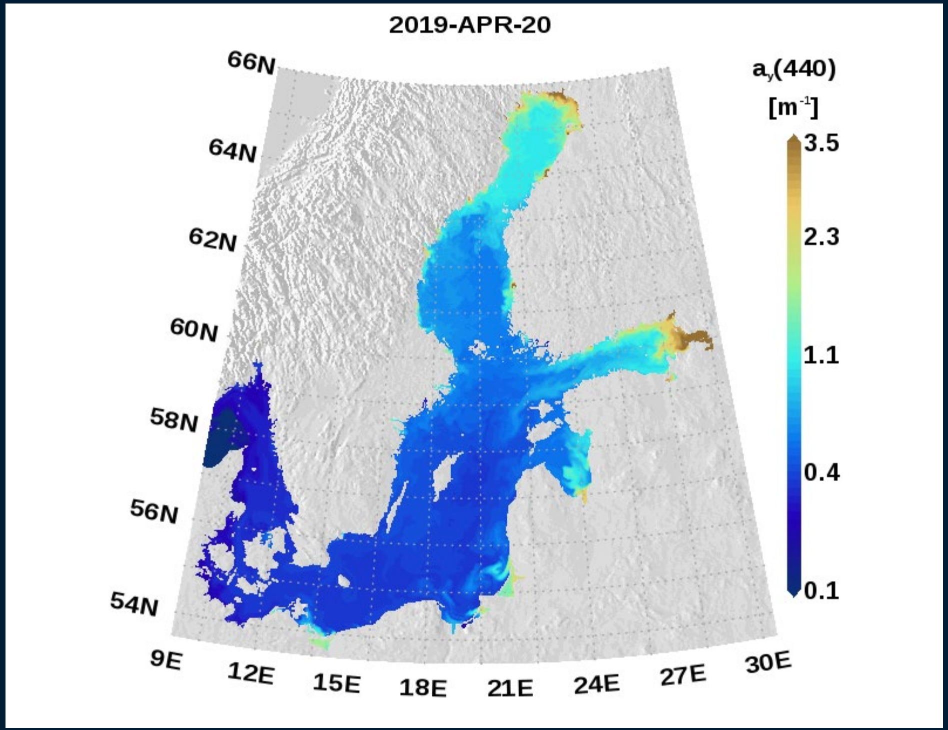
2. CDOM values extracted from 80 estuaries representing ERGOM input locations around the Baltic Sea

3. Monthly means derived (years 2016-2019)

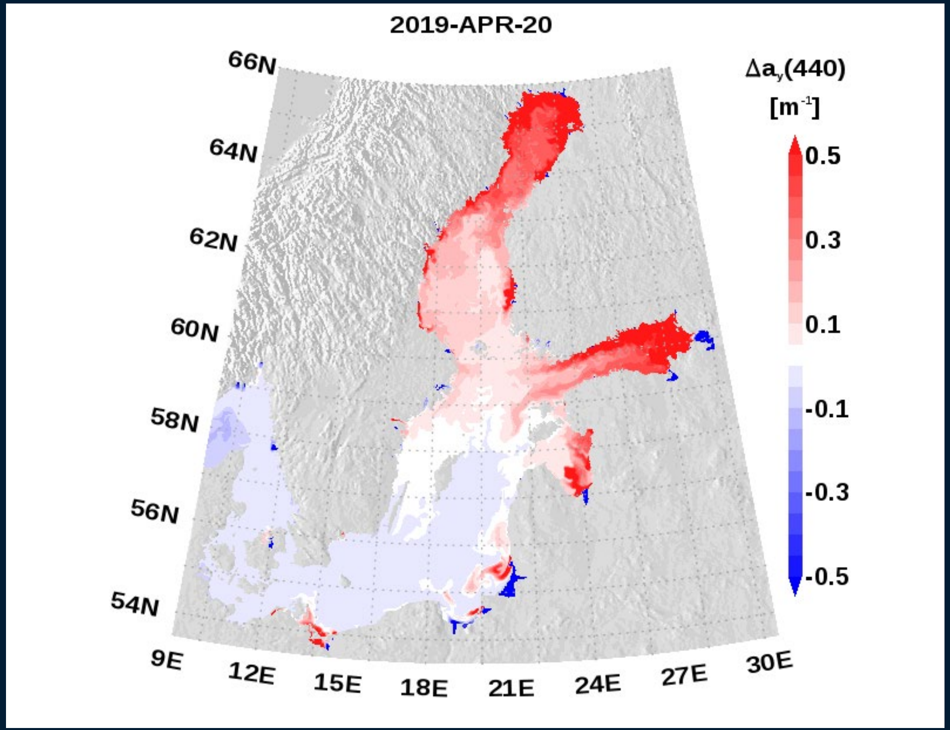
4. Interpolation of time series was used to derive data for winter season



CDOM Model Difference

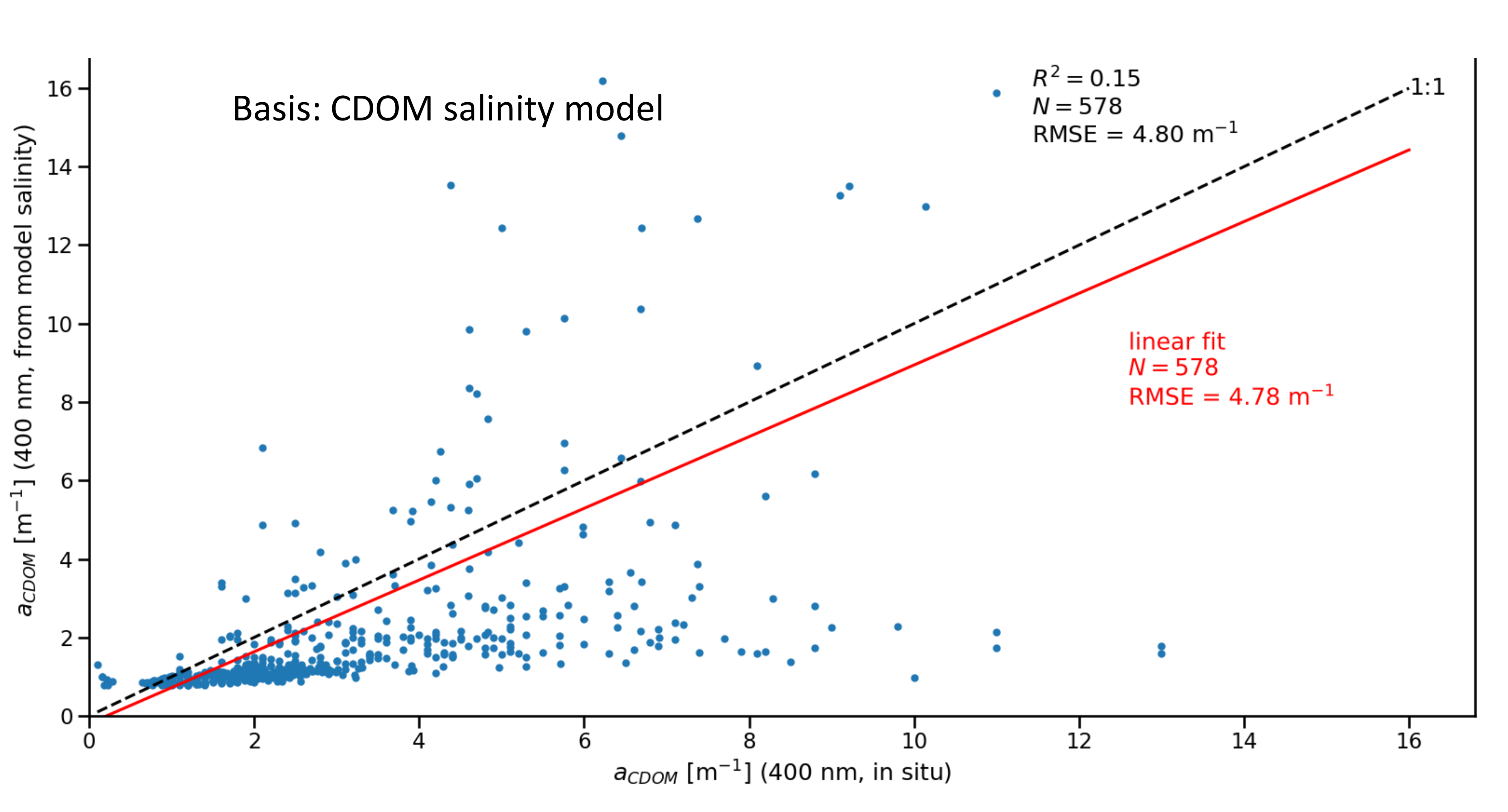


New ERGOM simulated CDOM absorption map, using satellite based CDOM as a new input state variable.



Difference to salinity approximation for CDOM. Large impact in northern Baltic Sea and river estuaries

In situ CDOM vs. ERGOM CDOM derived from salinity at monitoring stations in the Northern Baltic



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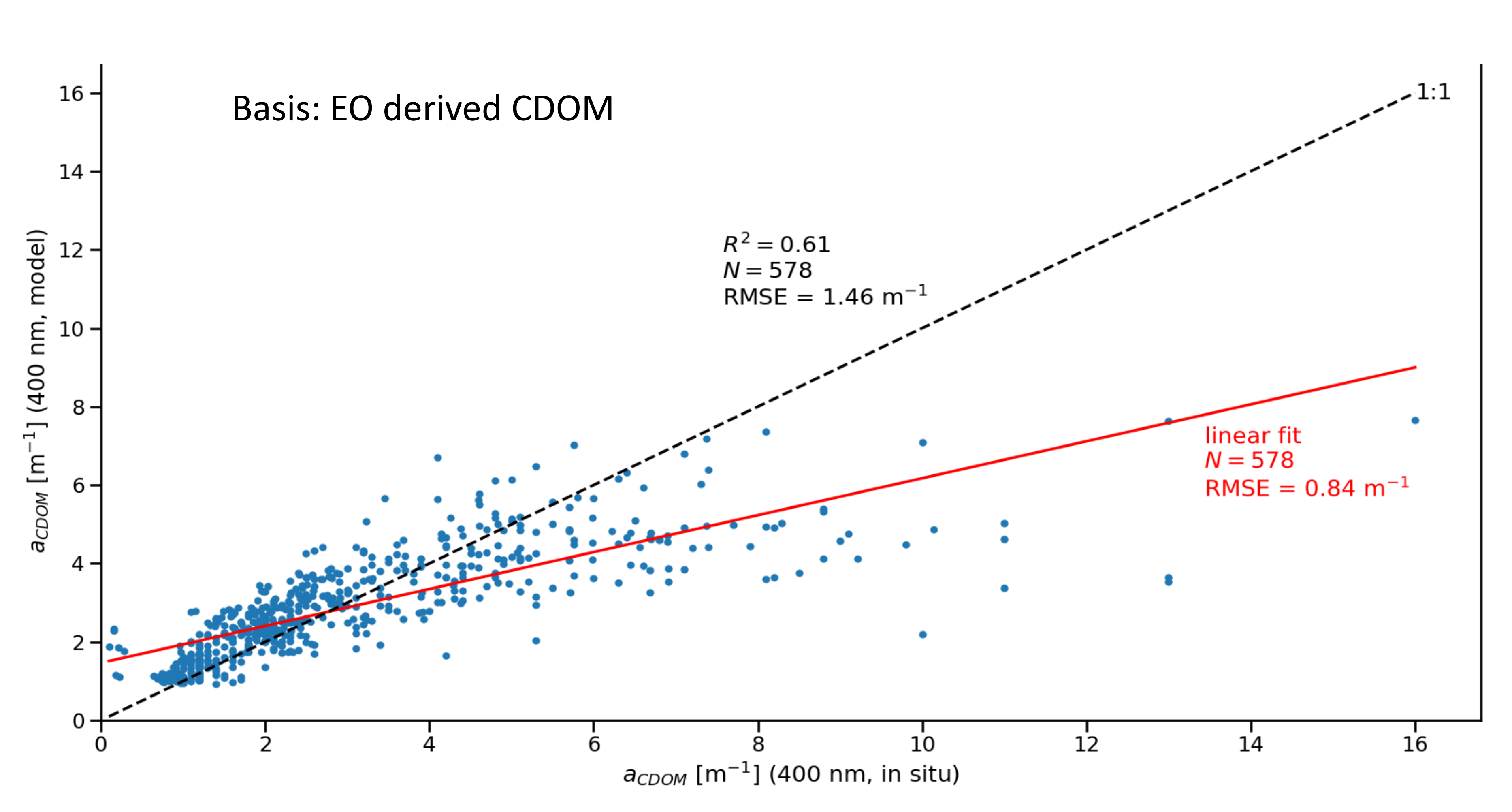
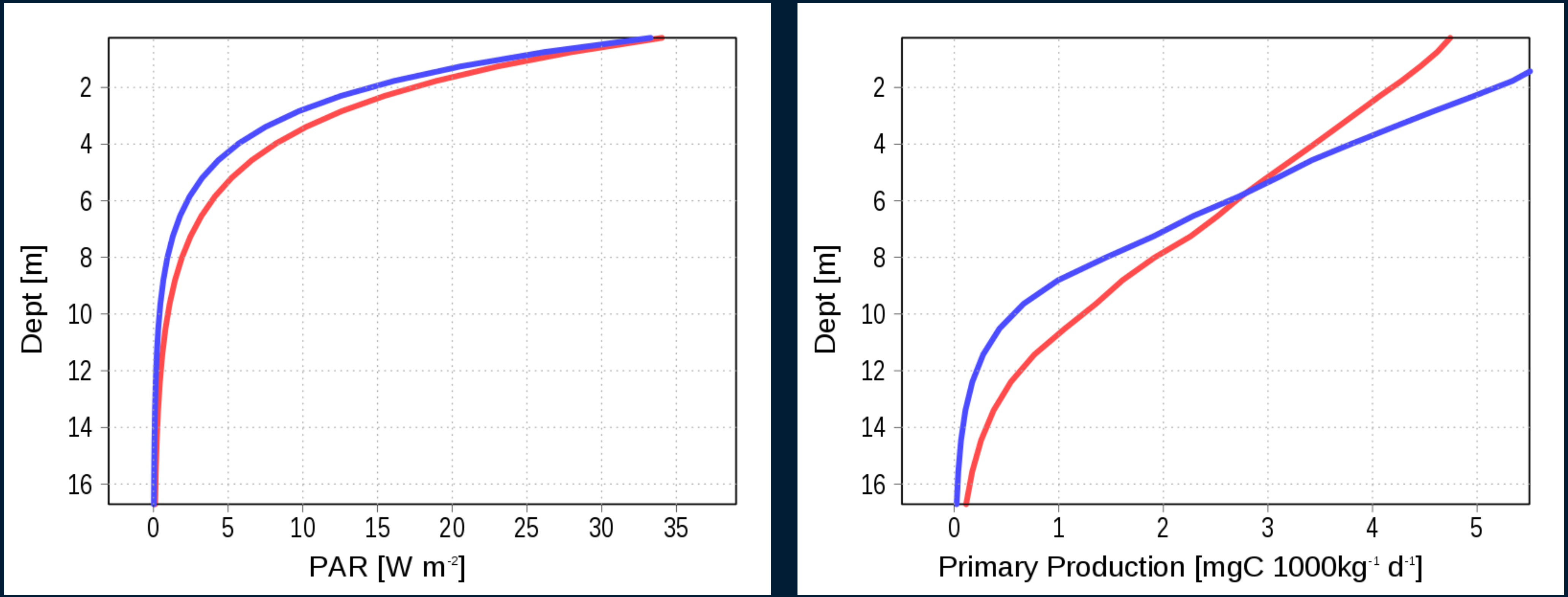
In situ CDOM vs. ERGOM CDOM derived from salinity at monitoring stations in the Northern Baltic



Light penetration

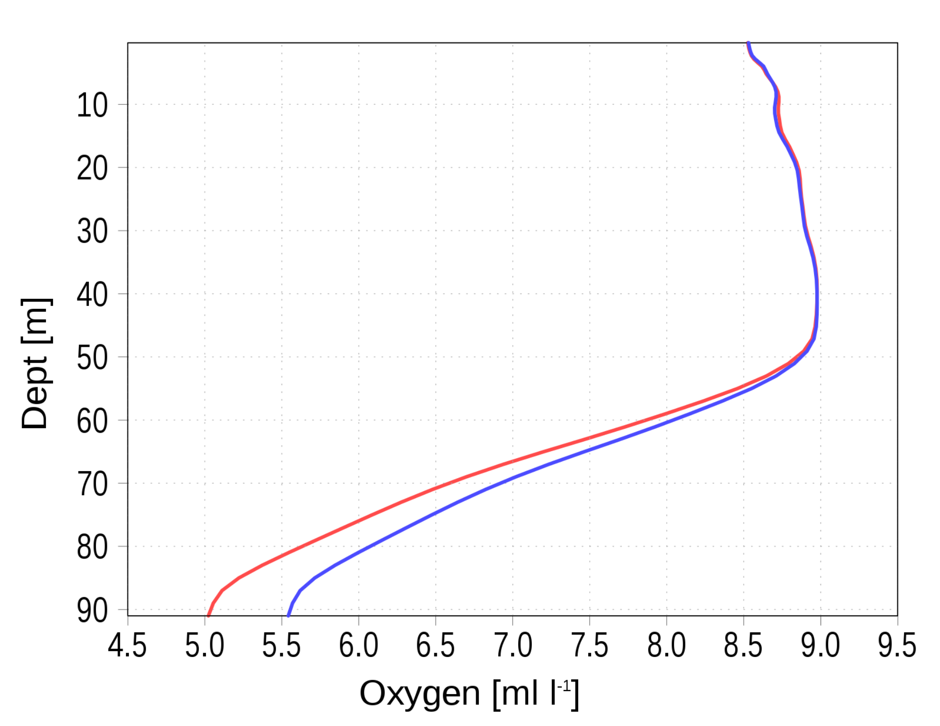
Station in the Bay of Bothnia, annual mean 2018
Blue: explicit CDOM; Red: Salt parametrization



Consequence: Primary production reduced in deeper water layers

Bottom oxygen

Blue: explicit CDOM; Red: Salt parametrization



Modified biogeochemical cycles result in increased bottom oxygen

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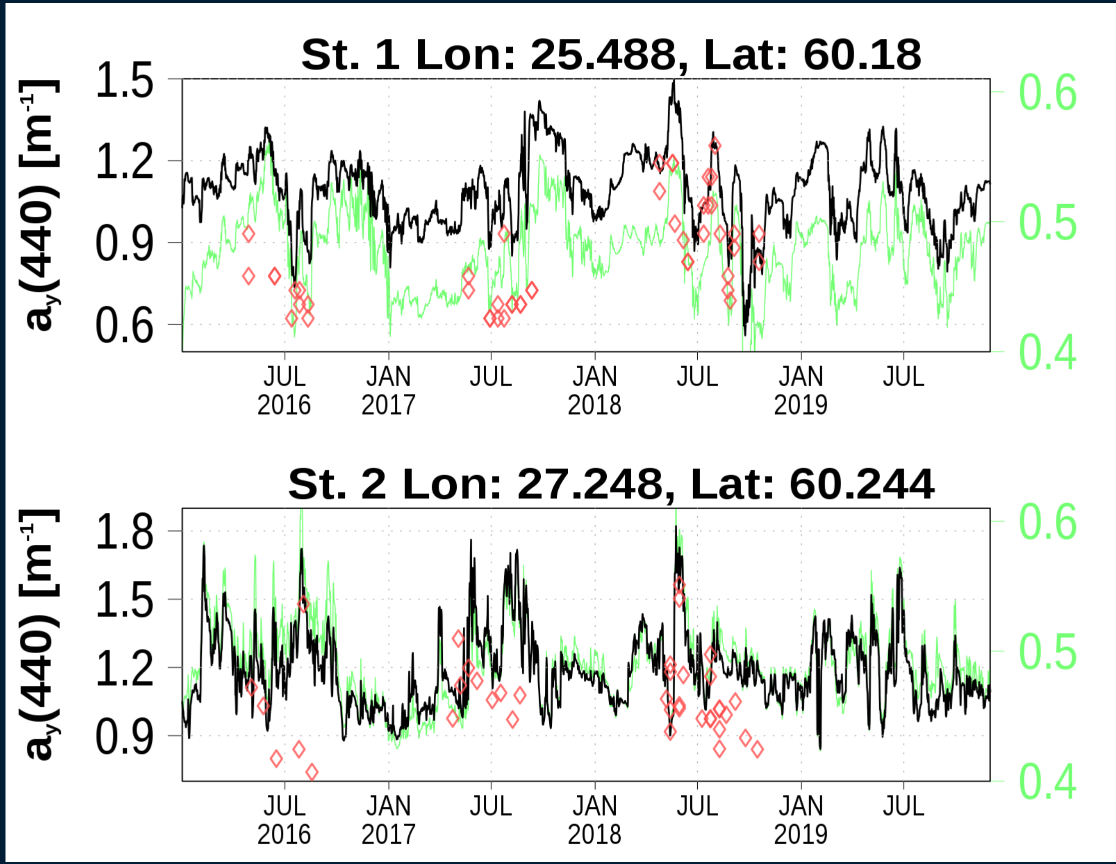
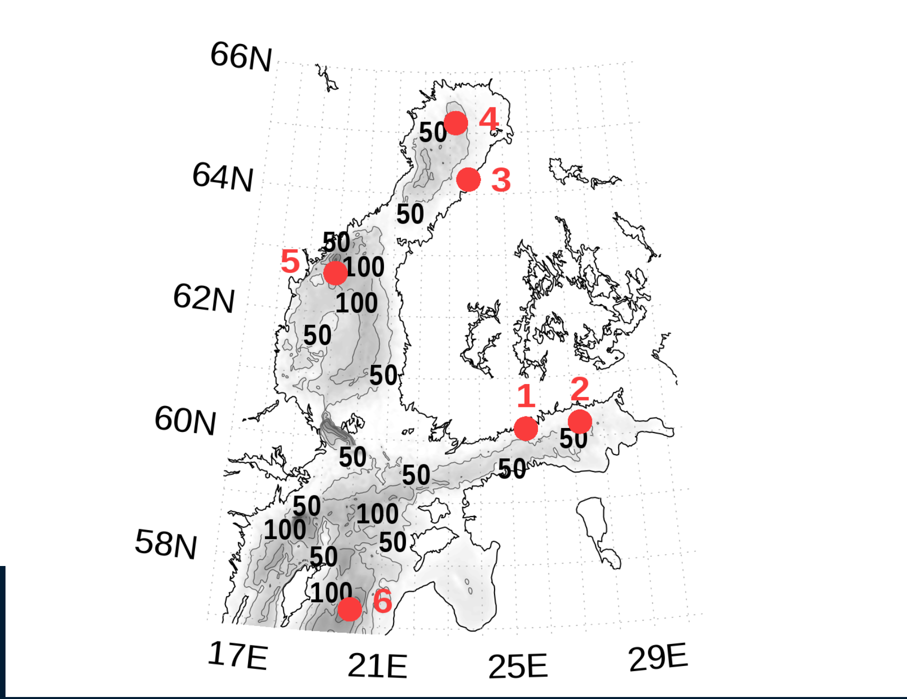
Model Performance



black: a_y from CDOM
green: a_y from salt
red: observations



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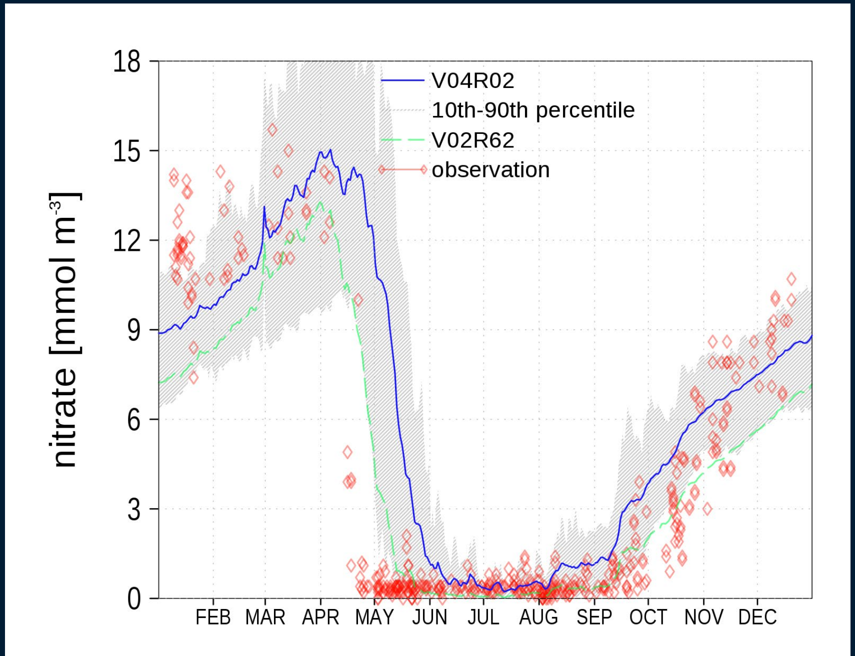
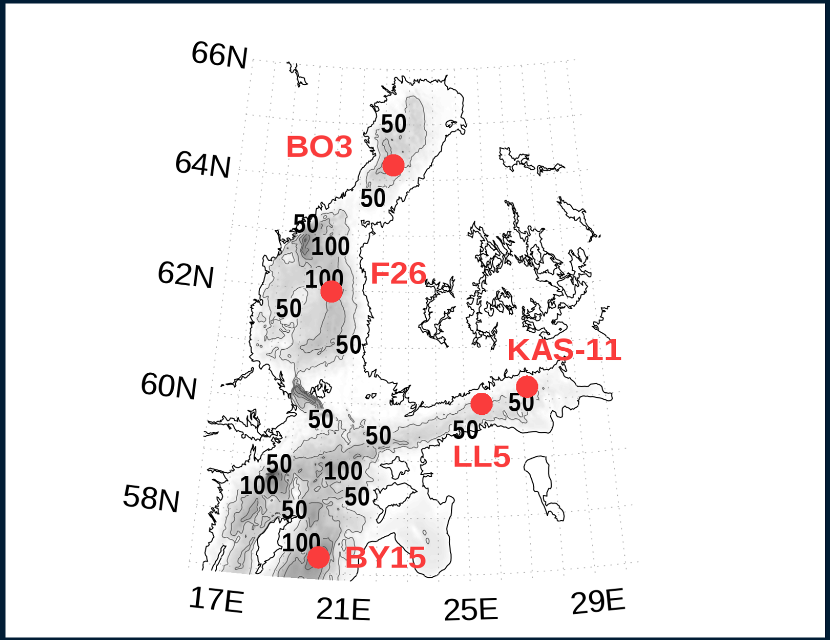
Impact on biogeochemistry

Climatology 1990-2019

KAS-11

blue: a_y from CDOM
green: a_y from salt
red: observations





Spring bloom delay by 14 days

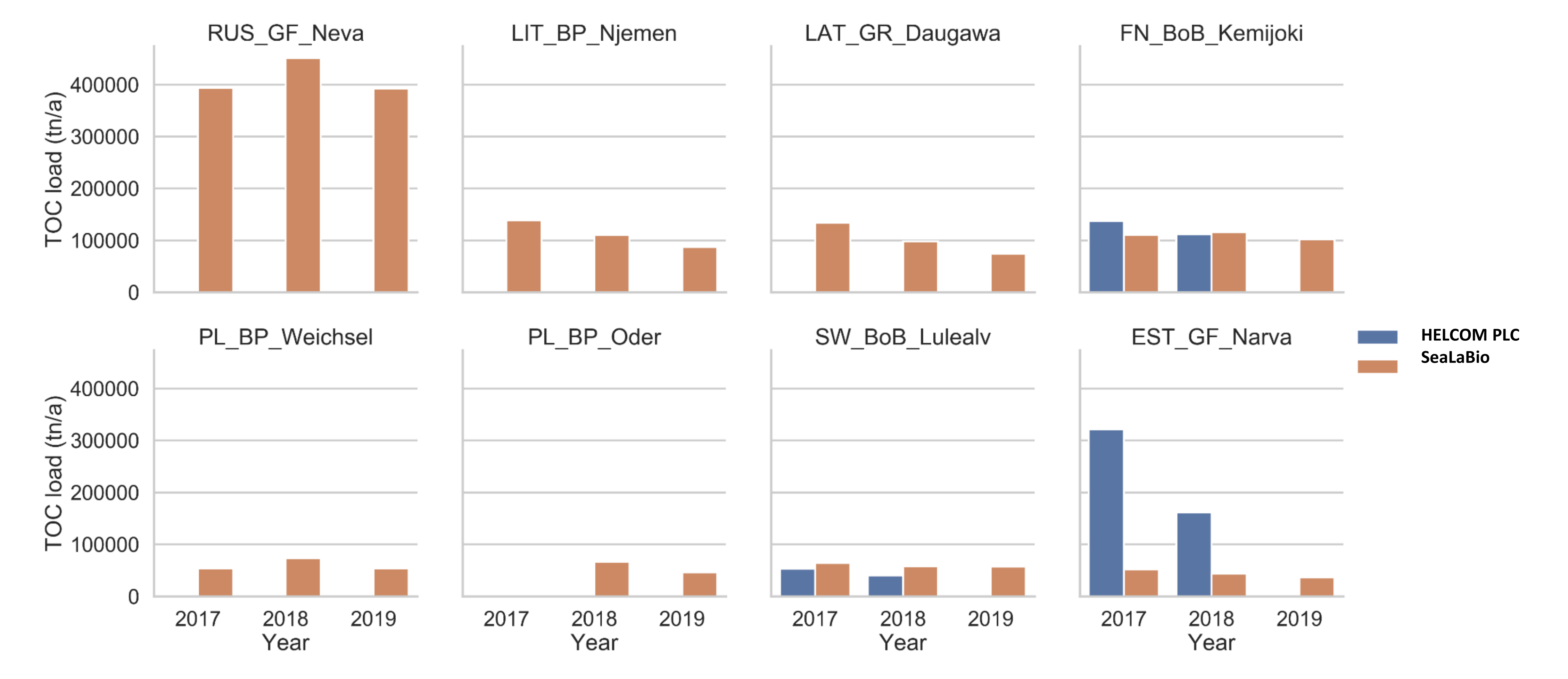
Use of EO for monitoring carbon fluxes

- CDOM absorption improved in the northern Baltic
- Impact of CDOM on the ecosystem is via PAR
- CDOM changes light penetration depth and in turn primary production
- Owing to complex and non-linear relationships, a quantitative response of the ecosystem hardly can be predicted
  - Less PAR -> less PP -> more nutrients left -> more PP (upper layer)
  - New equilibrium?
- A careful validation of **all** model variables is needed
  - E.g., the altered light climate may require a re-calibration of phytoplankton assimilation parameters

EO based method for TOC load estimation

- River runoff from ERGOM
- Monthly aCDOM values for rivers from EO
- Empirical relationship between aCDOM and TOC (based on Finnish data)

Annual TOC loading



Annual TOC loading according to the SeaLaBio method and PLC - the eight biggest rivers* in 2017-2019

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Summary

CDOM absorption improved in the northern Baltic

- + CDOM absorption independent on model salt uncertainties
- + Differences of individual catchments
- + Annual cycle
- + Realistic CDOM -> improved light climate
- \- Model complexity increased
- \- Sophisticated data base necessary

CDOM changes light penetration depth and in turn primary production

A thorough validation of all model variables is needed

E.g., the altered light climate may require a re-calibration of phytoplankton assimilation parameters

Available info, data and sofware

New water quality information and EO methods available

- Monthly CDOM maps (2016-19) are available for public use on TARKKA: www.syke.fi/tarkka/en
- Geoscientific Model Development 14, 5049–5062, 2021, https://doi.org/10.5194/gmd-14-5049-2021
- Baltic+ AC satellite data processor available in GITHUB

Optical model for the Baltic Sea with an explicit CDOM state variable: a case study with Model ERGOM (version 1.2)

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For more information

- Visit: https://www.syke.fi/projects/BalticSeaLaBio
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