Baltic+ SeaLaBio
Sea-Land biogeochemical linkages

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  - Satellite data processing
  - Biogeochemical modelling
  - Carbon flux monitoring
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Important terms

- **Water quality EO**
  - Estimation of water quality parameters such as CDOM, Chlorohyll a, and turbidity from optical satellite images
- **CDOM** – Colored Dissolved Organic Matter
  - Contains carbon, terrestrial and marine origins, absorbs light
- **ERGOM –** Ecological ReGional Ocean Model
  - Biogeochemical part of the 3-dimensional ecosystem model of the Baltic Sea developed by IOW (www.ergom.net).
  - Main inputs are meteorological forcing including **river runoff**.
  - Simulates the marine nitrogen, phosphorus, and carbon cycles.

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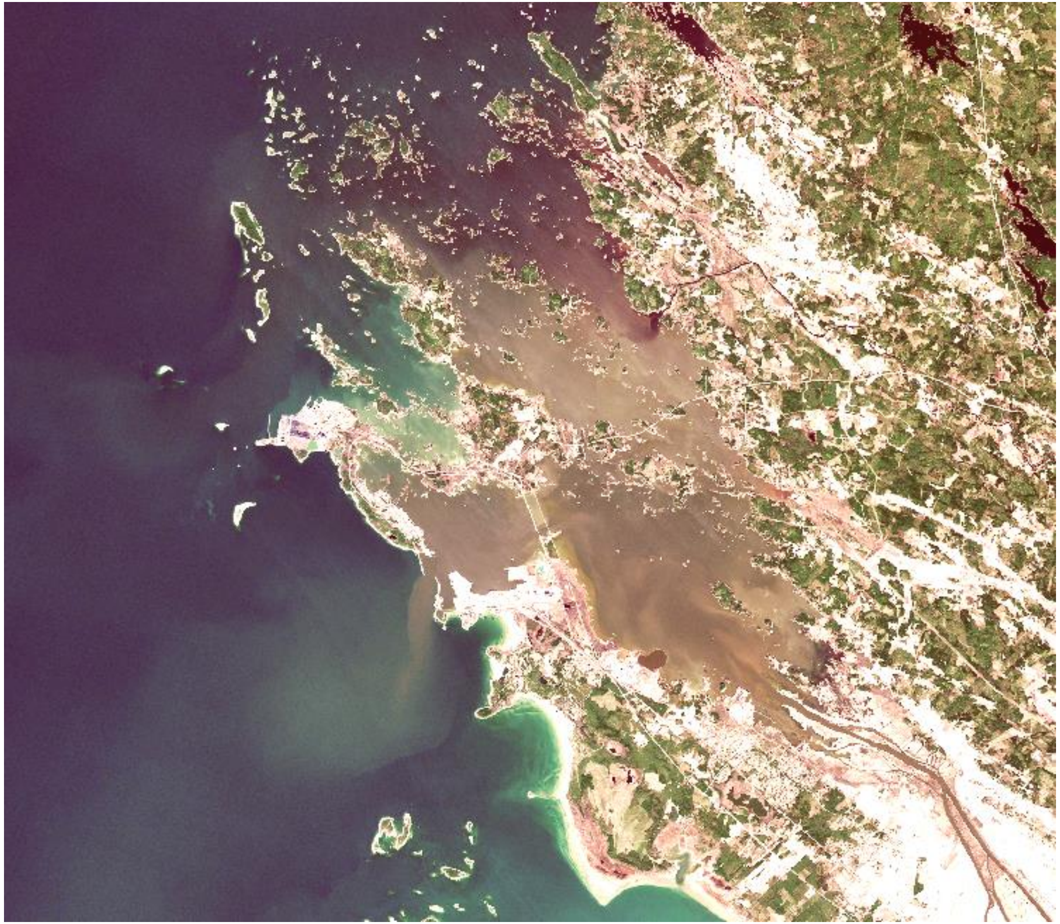
Baltic Sea from space: A river estuary in spring time

S2 MSI RGB 2017-05-04



Highly dynamic coastal areas

Not enough information about fluxes in the Baltic Sea level

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ESA Baltic+ SeaLaBio project (2018-2020)

Goal

The overall goal of the project is to develop methods for assessing carbon dynamics and eutrophication in the Baltic Sea through integrated use of **EO, models, and ground-based data**

Research question:

Can we quantify the carbon flux from land to sea with Sentinel-3 (S3) OLCI and Sentinel-2 (S2) MSI data in the Baltic Sea region? And if not, what are the main obstacles and potential solutions to be addressed in the future?

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Advances in the state-of-the-art

- **EO data processing:** A new method for atmospheric correction (AC) of satellite images can now provide more reliable water leaving reflectance values. This is a major step towards the formulation of an optimal AC for the Baltic Sea.
- **Biogeochemical modelling:** The biogeochemical model ERGOM can now utilize EO based aCDOM values as input data and provide more reliable estimates of light attenuation in water, which potentially provides more realistic simulations of several other state variables.
- **Use of EO for monitoring carbon fluxes:** EO based data can e.g. provide information about the Total Organic Carbon loads from rivers.

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Why a dedicated Atmospheric Correction in Baltic+?

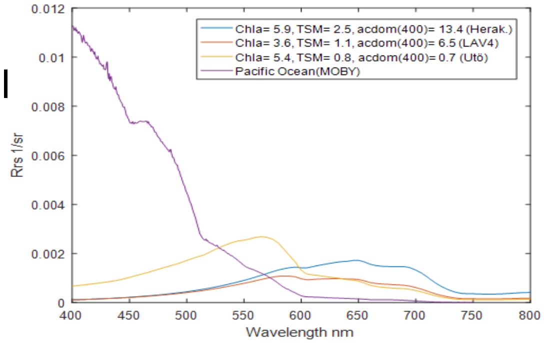
- Satellite data at TOA
- Atmospheric correction
- Marine reflectance
- In-water algorithms
- Geophysical products
- BGC modelling
- Carbon dynamics, eutrophication ...

Role of the AC: decouple the marine and atmospheric signals

$$\rho_t(\lambda) = t_{gas}(\lambda)(t(\lambda)\rho_w(\lambda) + \rho_R(\lambda) + \rho_a(\lambda) + T(\lambda)\rho_G)$$

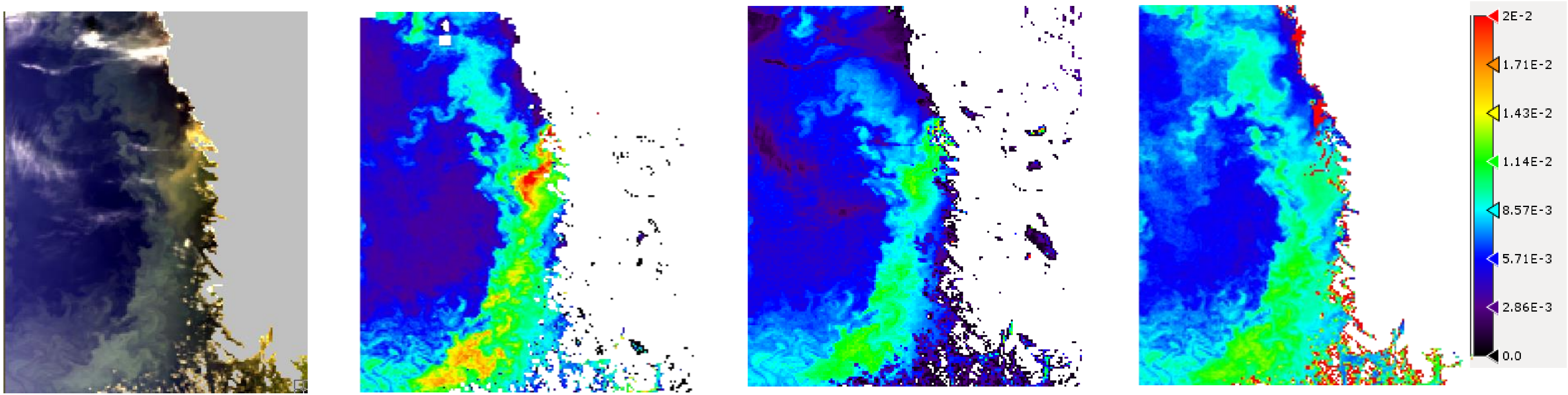
Baltic Sea is a challenging environment:

- CDOM absorption → small marine signal
- Variable aerosol (maritime + urban)
- Enclosed sea → adjacency effects, high resolution at coastline, riverine inputs...



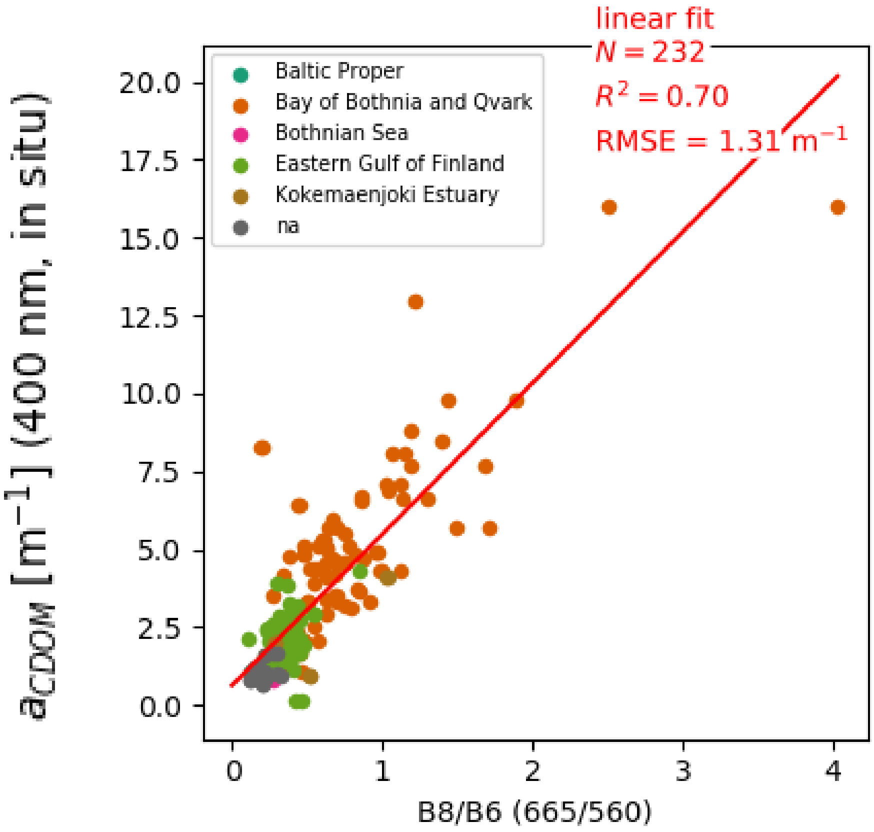
Qualitative results on OLCI scenes

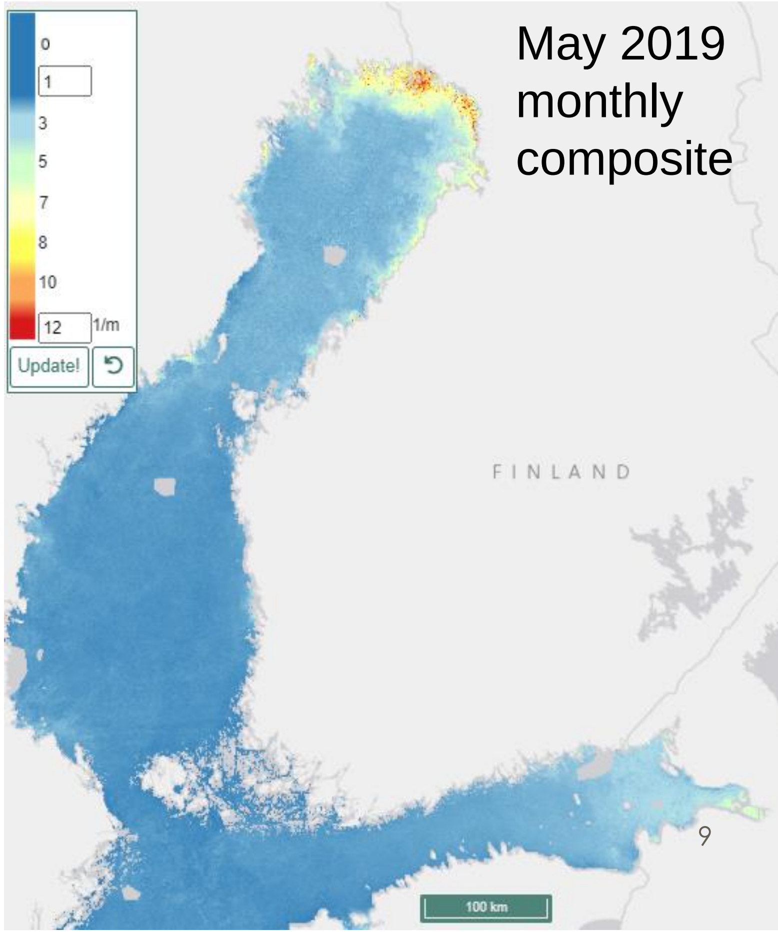
Level-1 **Baltic+** **C2RCC** **POLYMER** $\rho_w(443)$



Estuary of the Kokemäenjoki river, OLCI-B, 20190415

CDOM with a band ratio algorithm and S3 OLCI



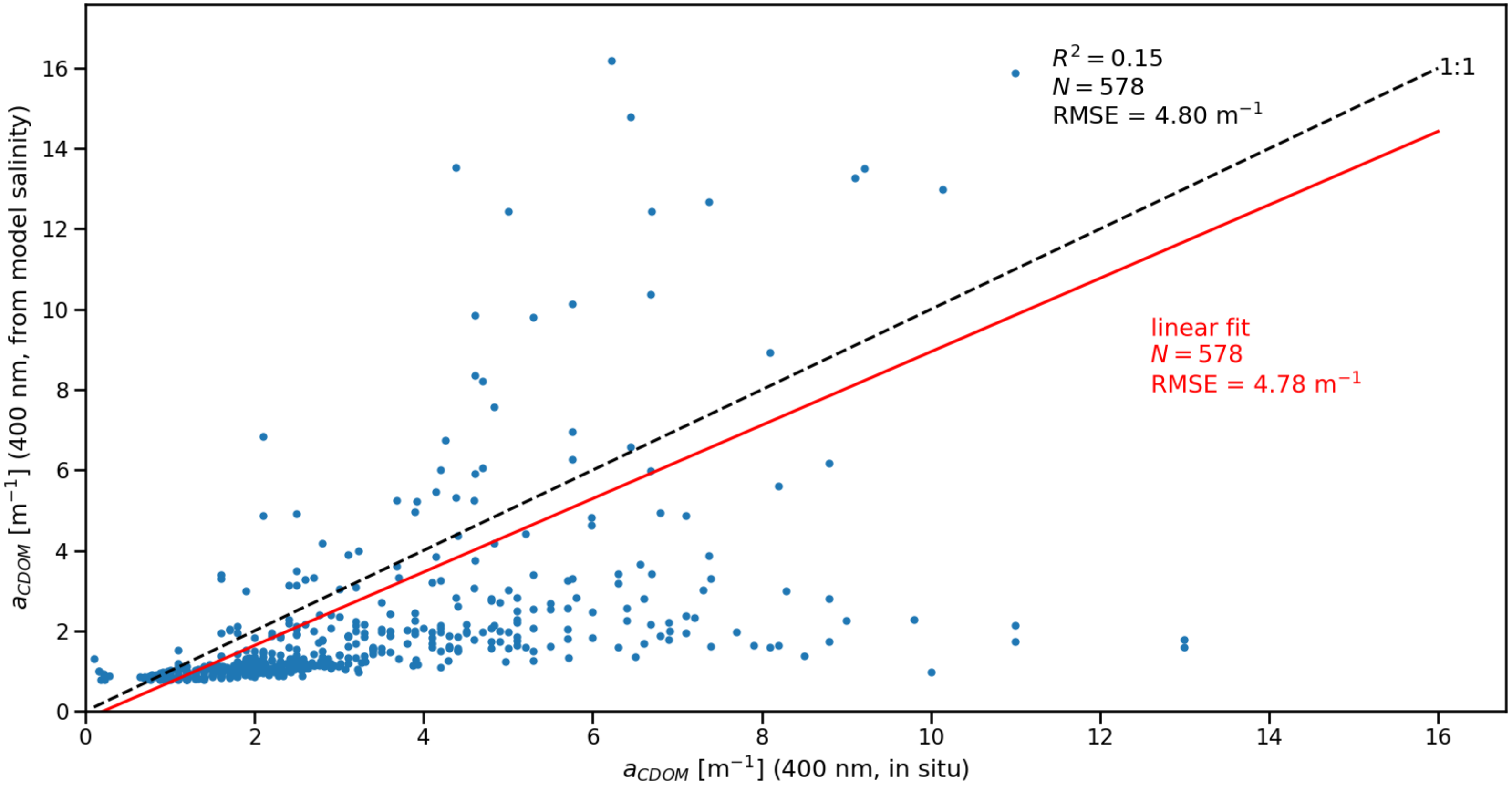


May 2019 monthly composite

EO data processing summary

- New improved method for Atmospheric Correction
- A band ratio algorithm provides CDOM estimations with a good accuracy

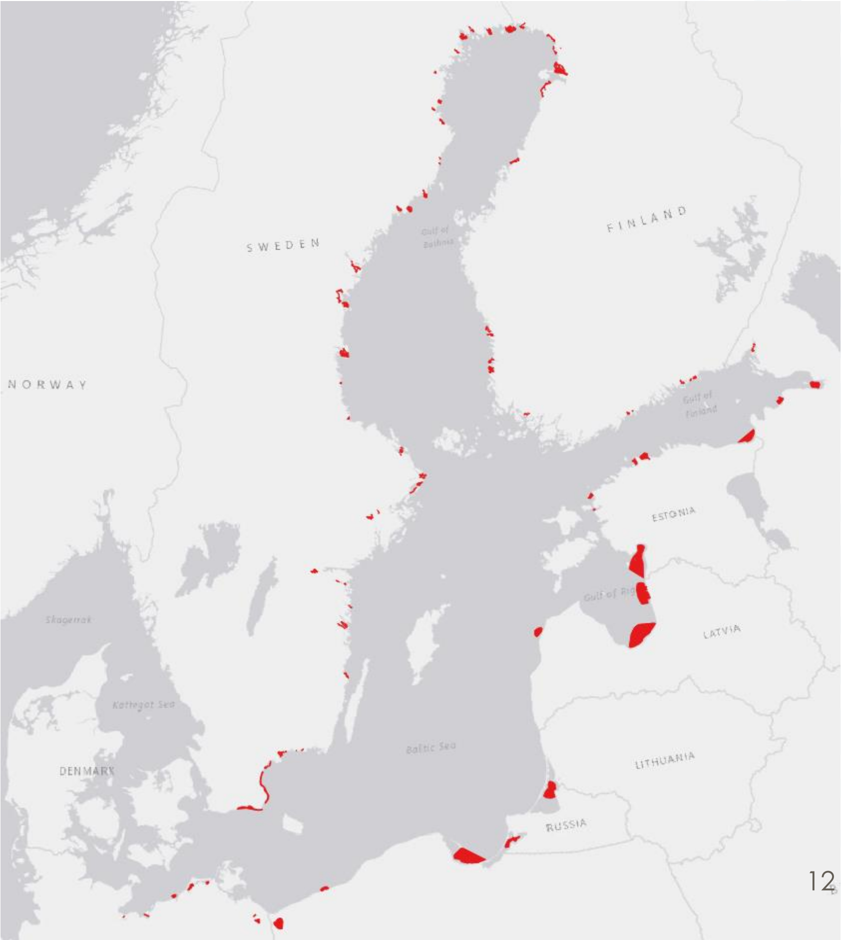
In situ CDOM vs. ERGOM CDOM derived from <u>salinity</u> at monitoring stations in the Northern Baltic



Utilization of EO based aCDOM values as model forcing data

Processing steps

- CDOM values extracted from 69 estuaries representing ERGOM input locations around the Baltic Sea
  - Sentinel-2, C2RCC-processor and local calibration (data from Finland)
- Monthly means derived (years 2016-2019)



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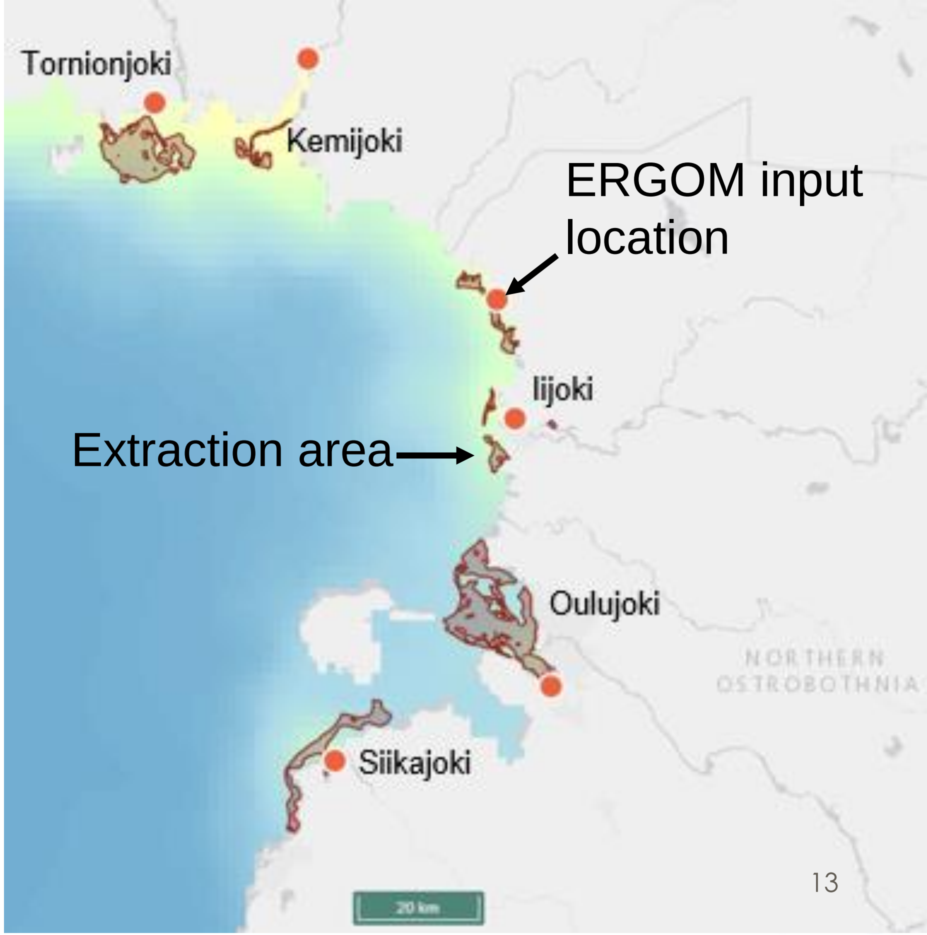

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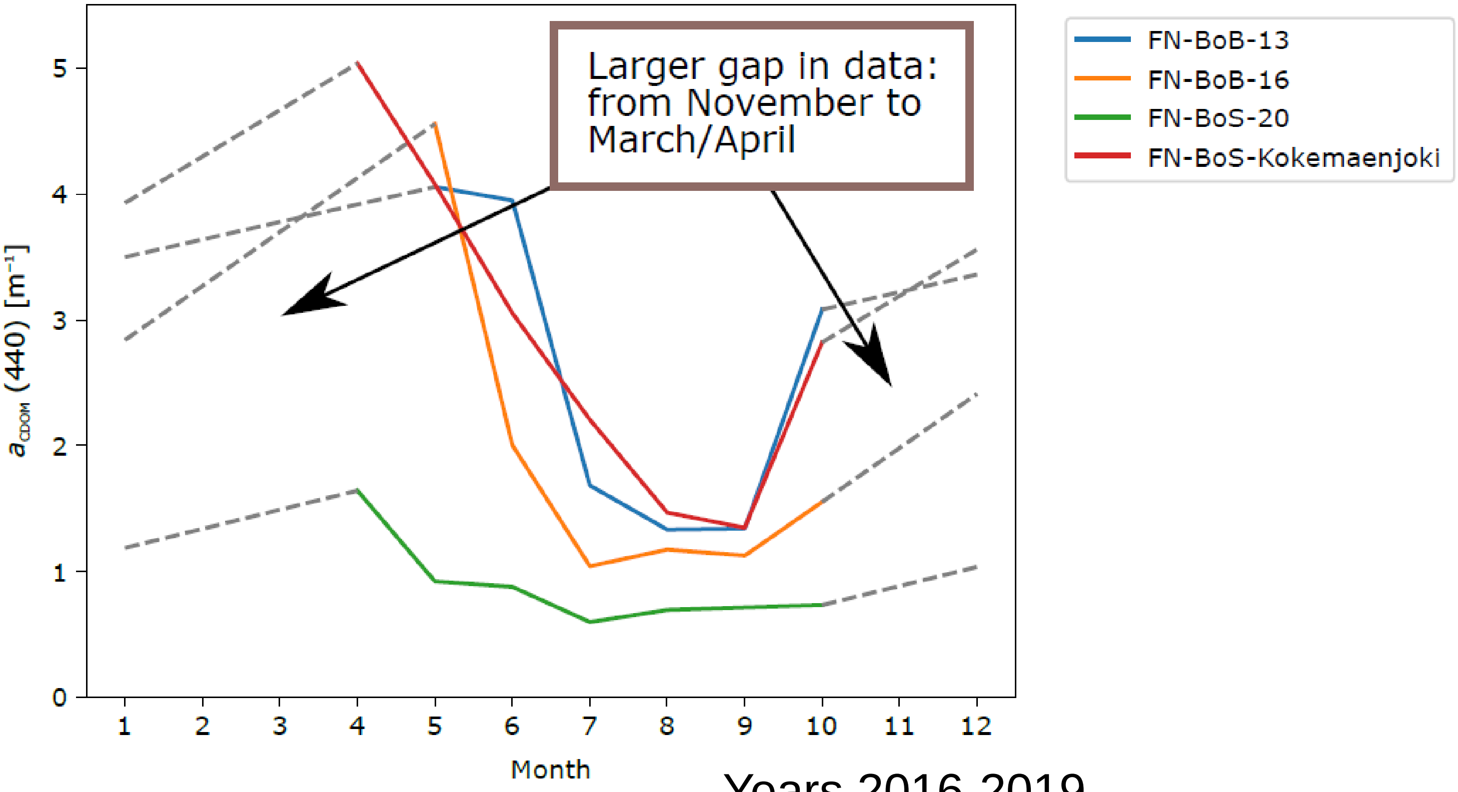
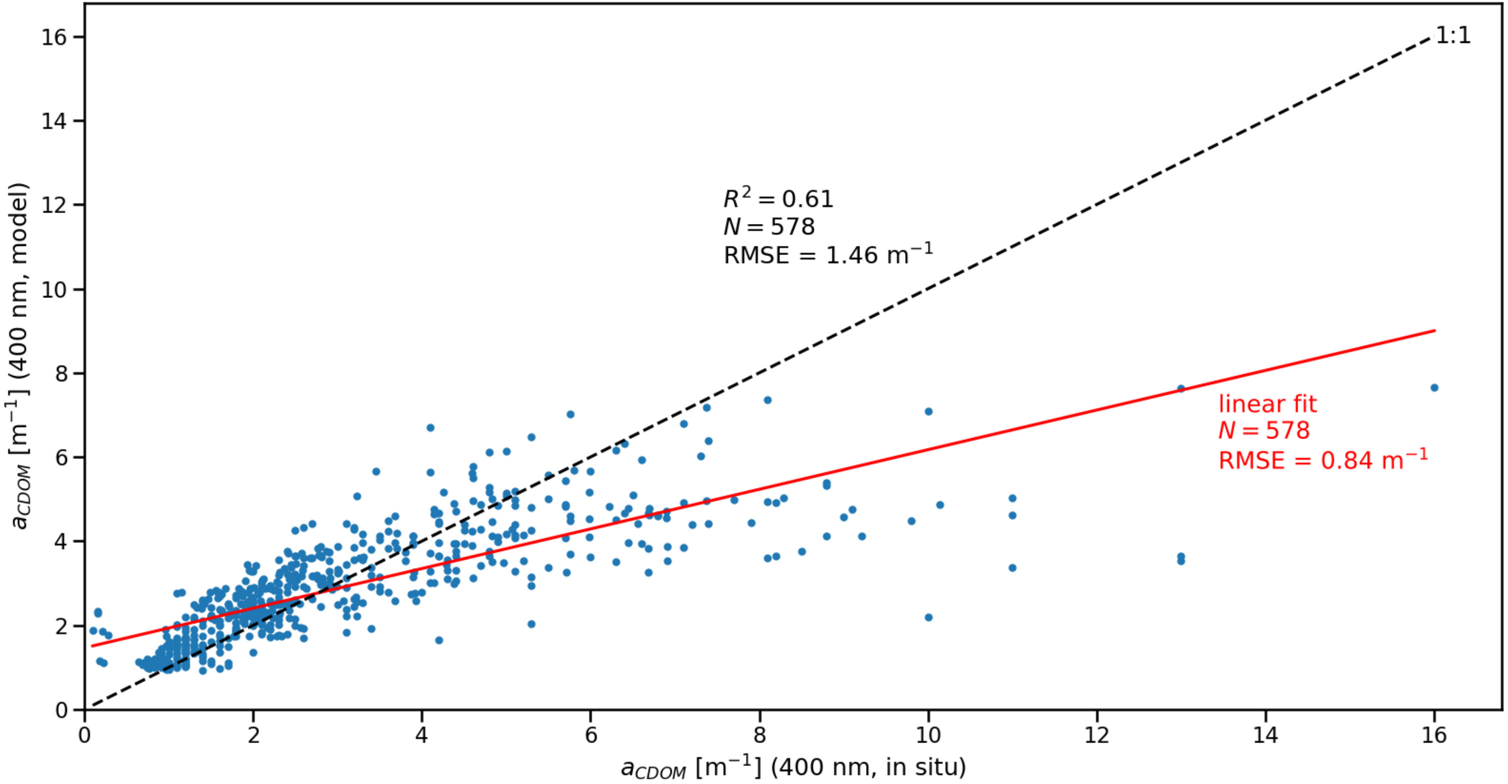
Monthly CDOM means of four extraction areas based on EO observations



Years 2016-2019

In situ CDOM vs. CDOM simulated with ERGOM at monitoring stations in the Northern Baltic with EO based method



Impacts on the modelling

- Much more reliable CDOM values in ERGOM
- Improved knowledge about the light climate especially in coastal areas
  - Photosynthetically Active Radiation (PAR) - Main driver for all biogeochemical processes in marine ecosystems
- ERGOM has to be re-calibrated after these changes
- More input rivers are needed

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Use of EO for monitoring carbon fluxes

- Reporting of river loads to HELCOM
  - Countries should report annual loads of TN (and dissolved N), TP (and dissolved P), hazardous substances and organic matter (Total organic carbon (TOC) or Chemical oxygen demand (COD)) to **Pollution Load Compilation (PLC)**
  - In practice only Sweden, Finland and Estonia report organic matter loads regularly
- Growing interest of TOC load in the PLC project due to climate change

→ **Analyse how EO can provide a solution**

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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)

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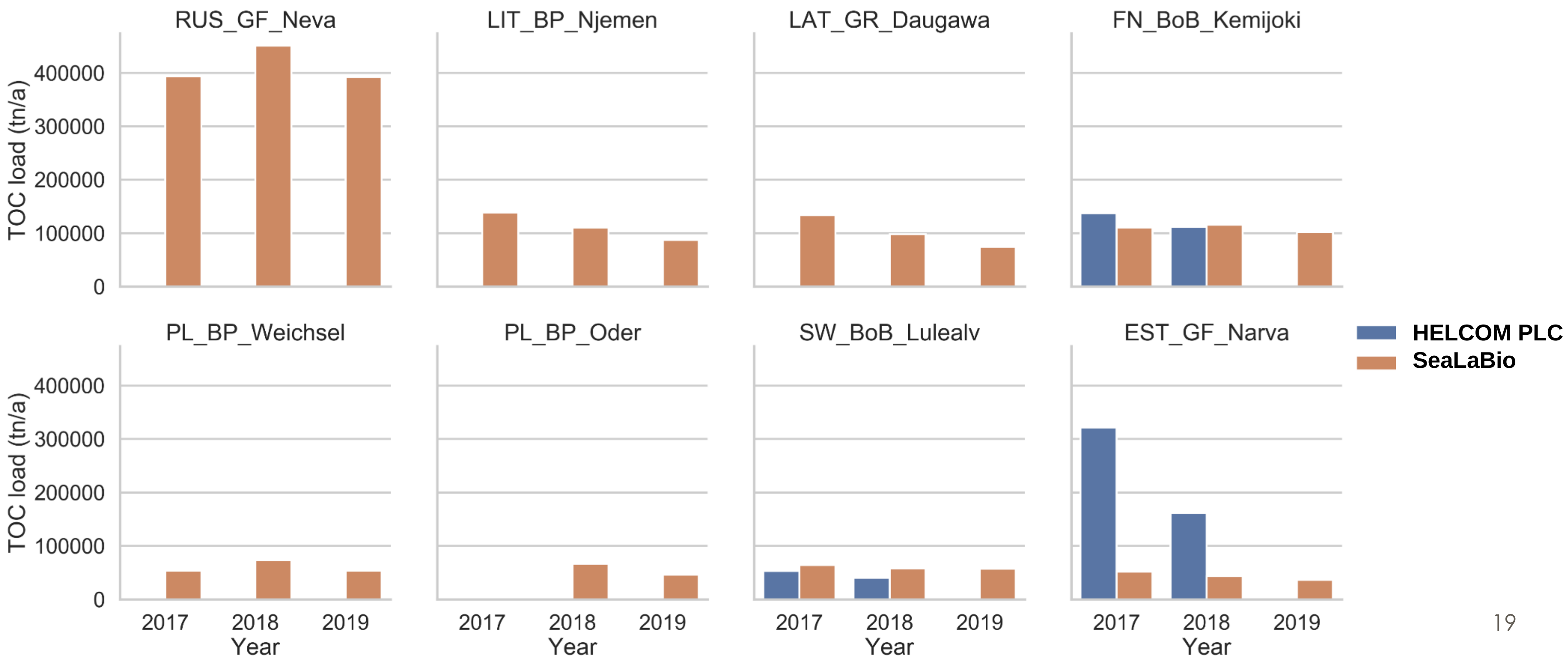
Annual TOC loading according to the SeaLaBio method and PLC - the eight biggest rivers* in 2017-2019



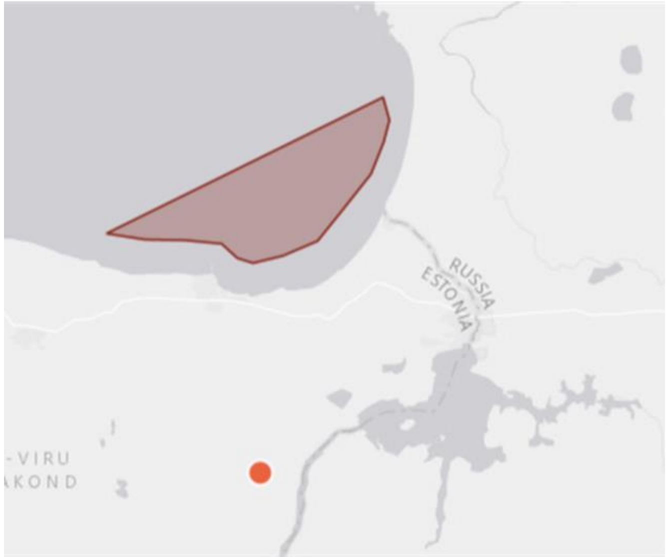
* https://www.worldatlas.com/articles/the-major-rivers-draining-into-the-baltic-sea.html

EO extraction areas (red shading) in three rivers

River Lulealv

River Kemijoki

River Narva



Improvements needed

- Selection of **extraction areas** could be improved
- Own extraction areas/loading points for **smaller rivers**

- More in situ measurements of **a_{CDOM} and TOC(DOC)** in different river types (estuaries and river beds)
  - EO validation
  - Conversion factors

Scientific roadmap

Good progress but more can be done:

- Technical improvements for AC, in-water, ERGOM etc…
- Define Baltic-wide relationships CDOM-TOC, CDOM-DOC, CDOM-POC in river outlets (terrestrial sources)
- Derive EO based data sets for terrestrial loads of TOC, DOC, POC
- Analyse dynamics of terrestrial organic carbon in marine environment

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Thank you

- sampsa.koponen@ymparisto.fi
- https://www.syke.fi/projects/BalticSeaLaBio
- TARKKA map application (www.syke.fi/tarkka/en)
  - https://wwwi4.ymparisto.fi/i4/eng/tarkka/index.html?type=BP_CDOM&date=2018-05-01&lang=en&zoom=6&lat=63.23467&lon=25.50462&valuerange=1:12

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