Seamless observations from satellite

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This presentation

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- Overview of SEAmBOTH bio-optical and remote sensing work
- Joint cruises with Umeå University: intercomparison of methods and dedicated optical measurements
- Development of a novel algorithm to derive inorganic matter from space
- Validation of Sentinel-2 and Sentinel-3 data
- Examples of time series derived from satellite with high measurement frequency
- Summary of results
- Outlook

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SeamBoth Task: Production of new data from satellite images and validation of satellite data (SYKE and BG)

- Remote Sensing of Bothnian Bay (& Bothnian Sea)
- Monitoring of human pressures on water quality
- Provide input data for habitat models/HELCOM HUB classification (SYKE)
- High resolution maps (**Sentinel-2**, 10-60 meter pixels) of all optical parameters/but currently focus of turbidity (SYKE)
- Moderate resolution maps (**Sentinel-3**, 300 meter pixels) of chlorophyll-a, Secchi depth, turbidity, and yellow substances (CDOM); (BG)

Aim of bio-optical research in SEAmBOTH (Stockholm University)

- Characterize the Bothnian Bay and the Bothnian Sea optically
- Set up common standards for optical routine measurements (e.g. for measuring turbidity); harmonization of protocols
- Description of errors in optical *in situ* measurements
- Intercomparison of optical methods between SU and UU
- Evaluate satellite products
- Modelling reflectance from optical measurements (together with SYKE)

Why is optical work in the Bothnian Bay important?

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- Light is one of the limiting factors for primary production.
- CDOM concentrations in the Bothnian Bay & the Bothnian Sea are very high, especially in inner coastal bays/estuaries.
- Here, CDOM has been shown to favour bacterial production (Wikner and Andersson, 2012) whilst the primary production in the upper estuary has shown to be light limited by CDOM (Andersson et al. 2018)
- It is likely that inorganic SPM also plays a strong role in this as inorganic particles fall out very close to the shore (Kratzer and Tett, 2009; Kari et al. 2018).
- There is very little optical data available from the Bothnian Bay; this project contributes to an improved understanding

Background: error statistics for optical key parameters

- Chlorophyll-a (spectrophotometer) in-water measurements: 7-10% standard error of the mean (SEM), dependent on range of values (Kratzer, 2000; Kratzer and Tett, 2009)
- SPM (gravimetric method) (Kratzer, 2000; Kratzer and Tett, 2009): 10-13% SEM
- Turbidity ~ 10-12% SEM (Kari et al., 2017)
- CDOM: 3-6% SEM(Harvey et al. 2015).

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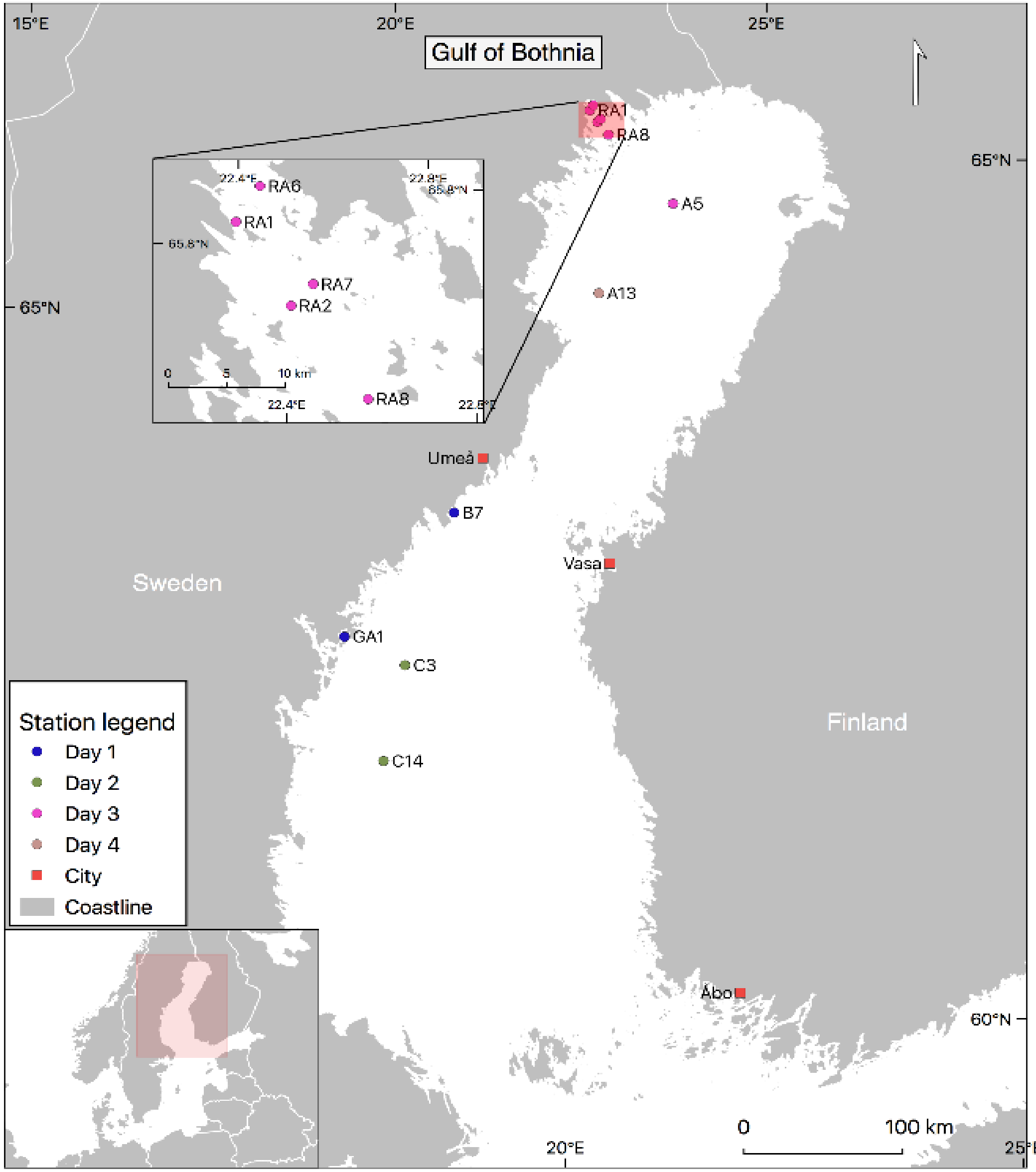
KBV 181
56 m long; 10.2 m width
Speed: 12-15 knots

Research lab + container
CTD rosette,
Winch



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Locations for optical measurements during week 20, 24 and 28 in 2018.
Cruises were organised by UU in collaboration with the Swedish Maritime Administration.

Key results of assessment of optical protocols

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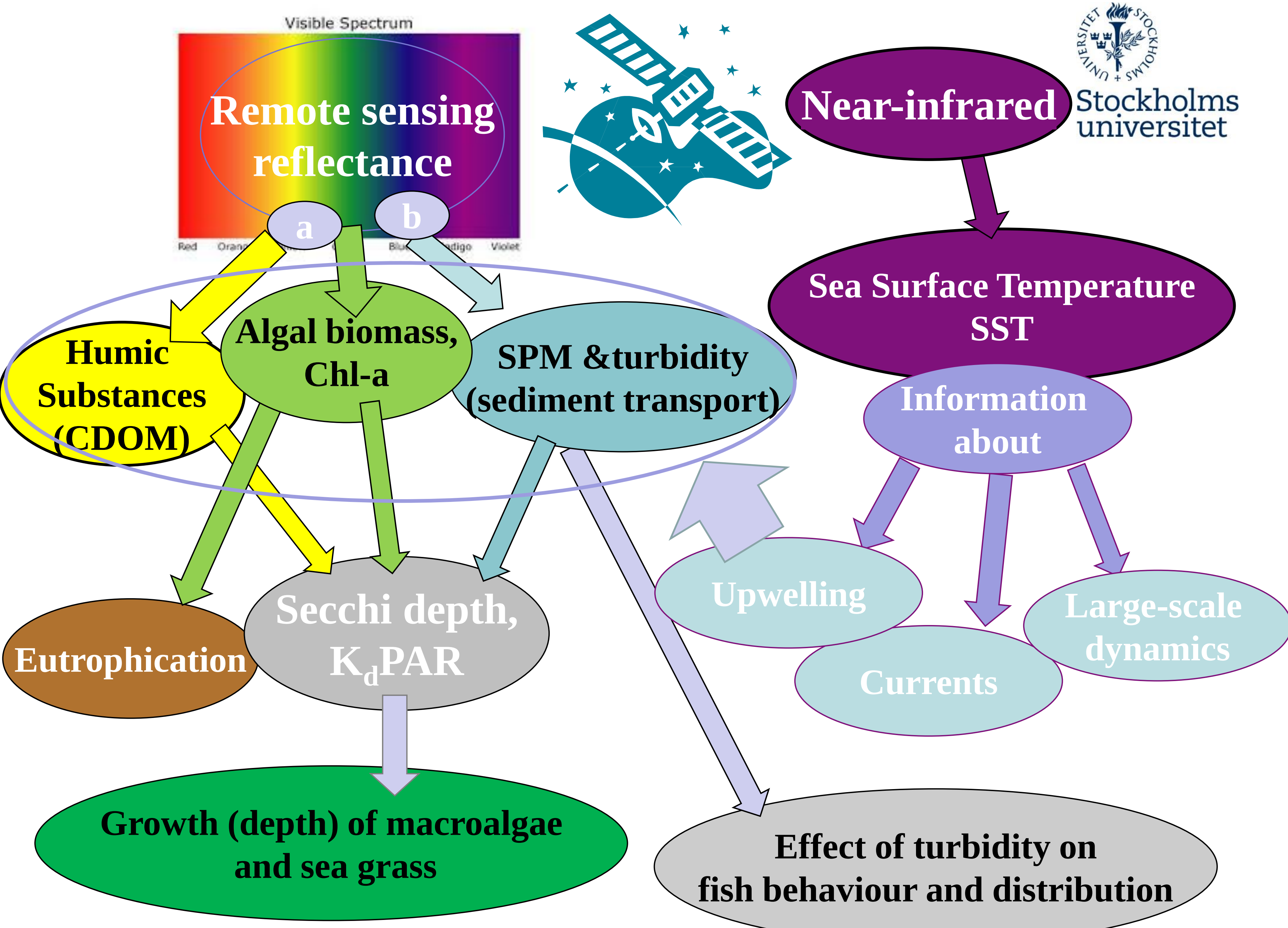
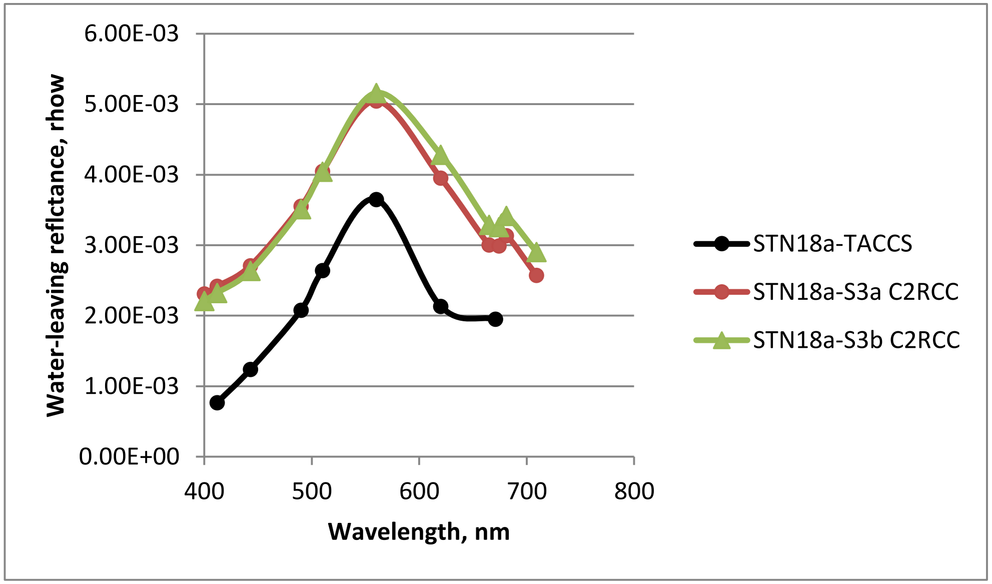
- We found clear differences in turbidity measurements and introduced joint measurement protocols
- Secchi depth measurements did not show a significant difference between 20 cm and 30 cm Secchi discs (in diameter)
- CDOM should be filtered with a glass filtering apparatus and measured with a scanning spectrophotometer (1 nm intervals)
- Chl-a according to HELCOM Combine is different to other international standards; samples should be kept in liquid nitrogen and sonicated during Chl-a extraction (otherwise the Chl-a samples show systematic underestimation)
- Each data provider should evaluate and provide error estimates for each method
- Revised optical protocols have been delivered to SEAmBOTH

Marine remote sensing and ecology



Use of TACCS reflectance measurements to evaluate Sentinel-3 reflectance



- The results show that S3A and S3B have a similar reflectance (S3a is somewhat lower)
- Overall, S3 data is brighter than the data measured *in situ*
- However, the spectral signature is correct
- This is important because the products are mostly based on the spectral shape (various spectral slopes in different parts of the spectrum)
- Turbidity and suspended material increase the reflectance

Bio-optical modelling using inherent optical properties, IOPs (i.e. absorption and scattering) measured *in situ*

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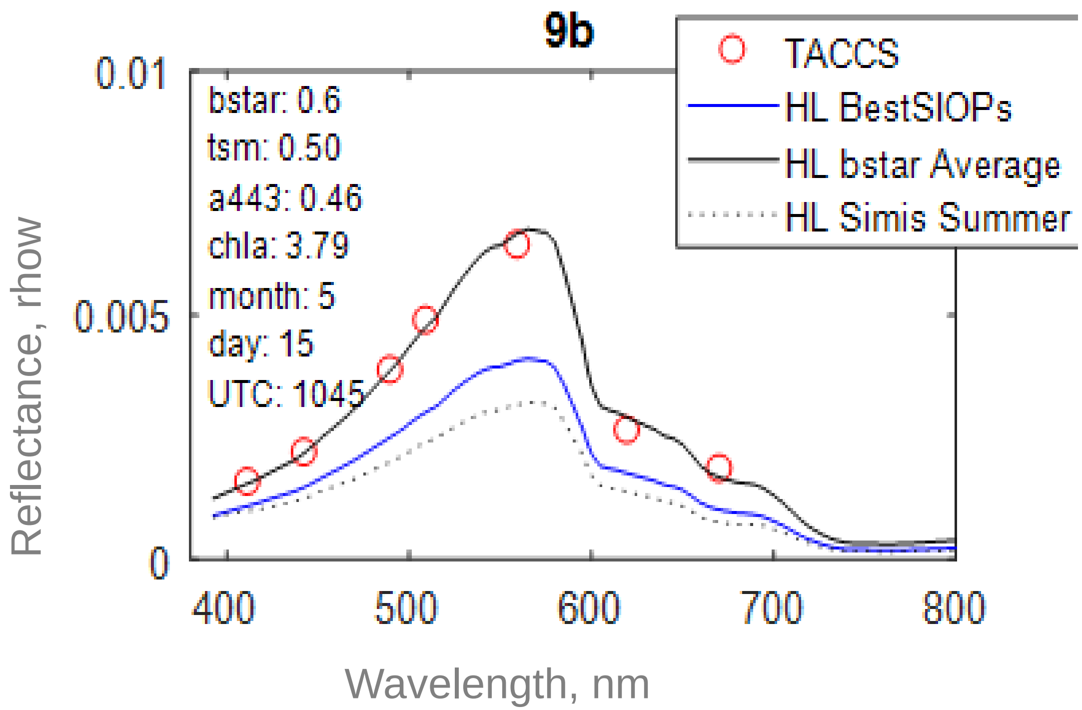

Example of reflectance simulations using Hydrolight and different specific inherent optical properties (SIOPs) parameterisations. The work helps to develop a dedicated optical model for high CDOM waters.

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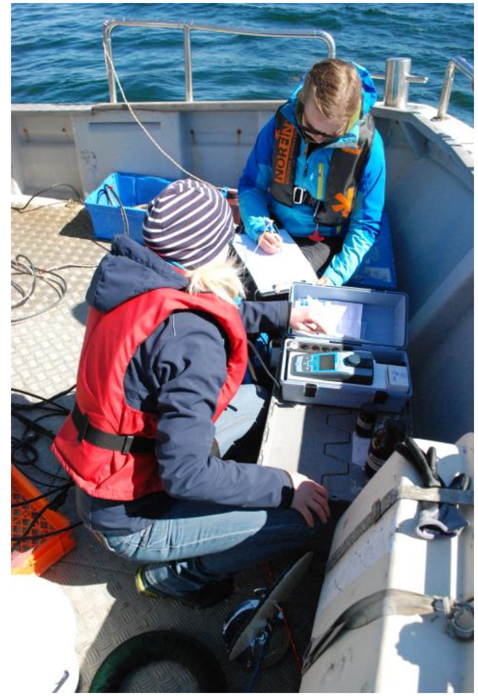
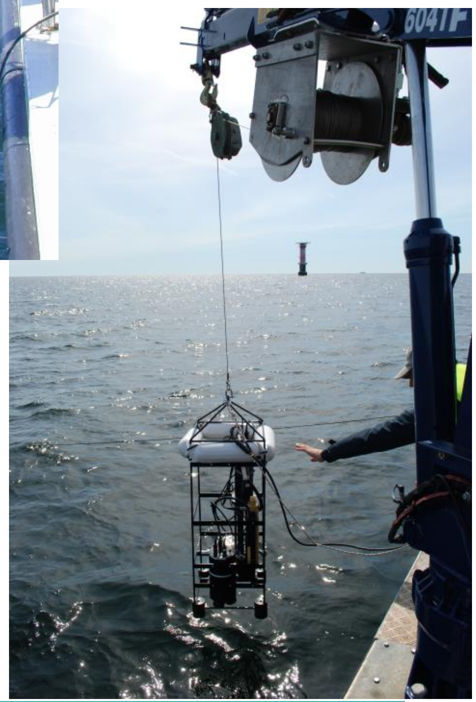
AC9 measurements:
Absorption (a) and beam attenuation (c)
at 9 wavelengths
c = a + b



Turbidity measurements

AC9 WET Labs



Bench turbidity meter
Hach Lange 2100 Qis

Measure absorption and beam attenuation

Turbidity measurement

Susanne Kratzer, Department of Ecology, Environment and Plant Sciences

SPM- Suspended Particulate Matter

Gravimetrical determination of SPM according to Strickland and Parsons, 1972

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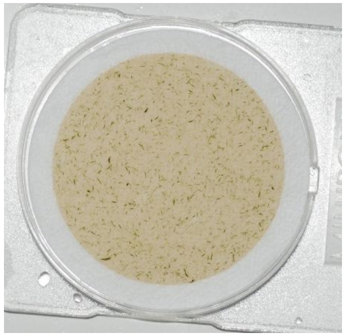
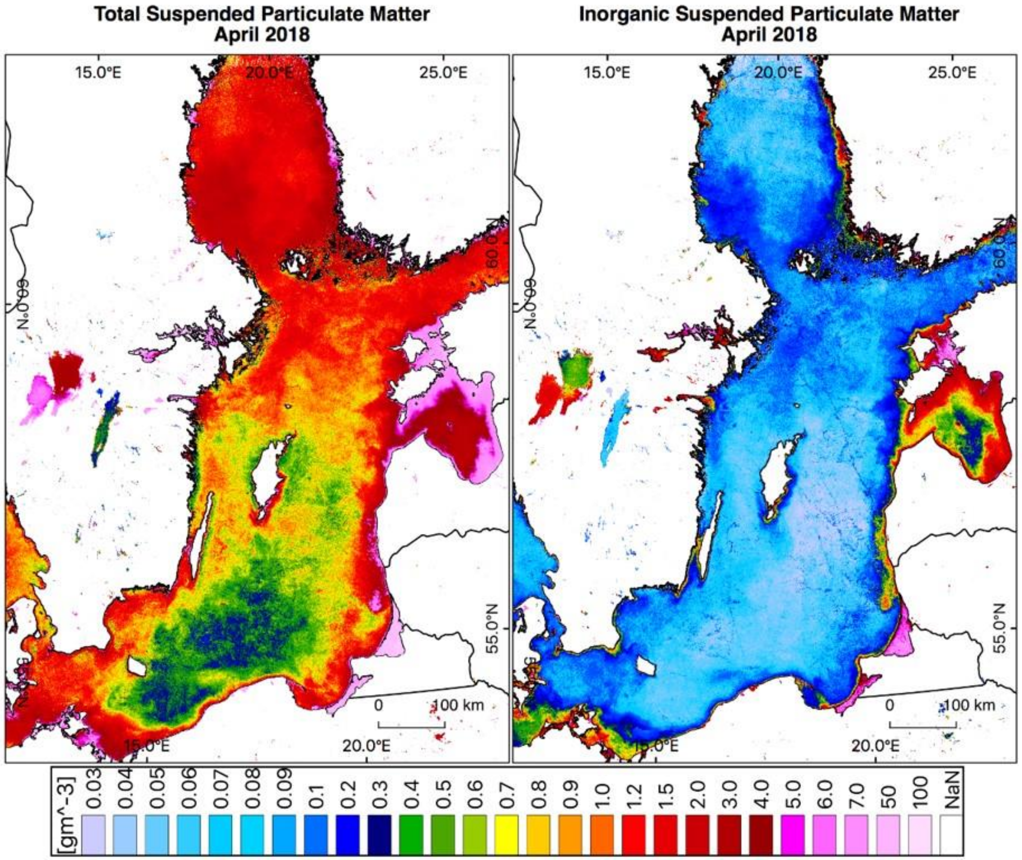
Filter 1-2 l of sea water through GF/F filters

- Measure dry weight and combusted weight of particulate matter
- The difference between the combusted filters and the tare weight equals the inorganic fraction.
- The organic fraction is calculated by taking the difference between the dry weight and the inorganic fraction.



Sediment on GF/F filters

Development of a new algorithm to derive inorganic matter from space



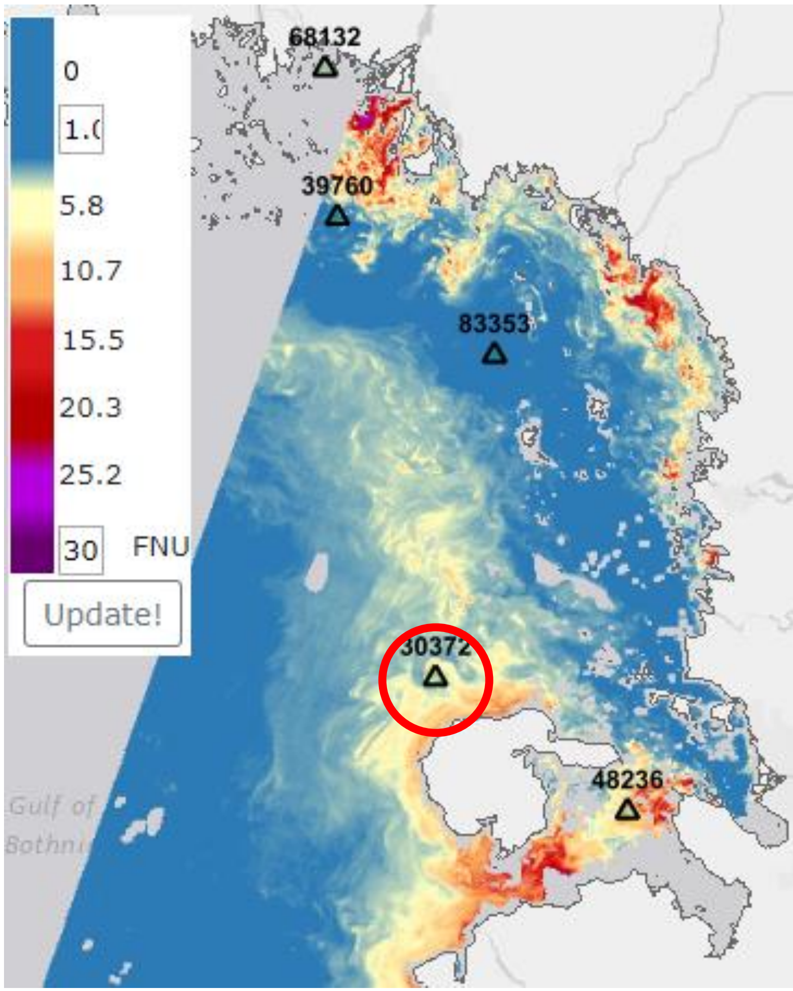
- The ISPM algorithm is based on the relationship between scatter and inorganic matter measured *in situ*
- This relationship was applied to Sentinel-3 data.
- The map (right panel) shows the influence of coastal processes (run-off from land and wind-wave stirring in coastal waterbodies)
- The study was published in *Remote Sensing Environment* and in *Havsutsikt* (popular science journal).
- We would like to evaluate the method in the Bothnian Bay (on an independent dataset)

Monitoring stations used for satellite validation

Location of sampling stations from the different monitoring programs in Sweden and Finland used for satellite validation

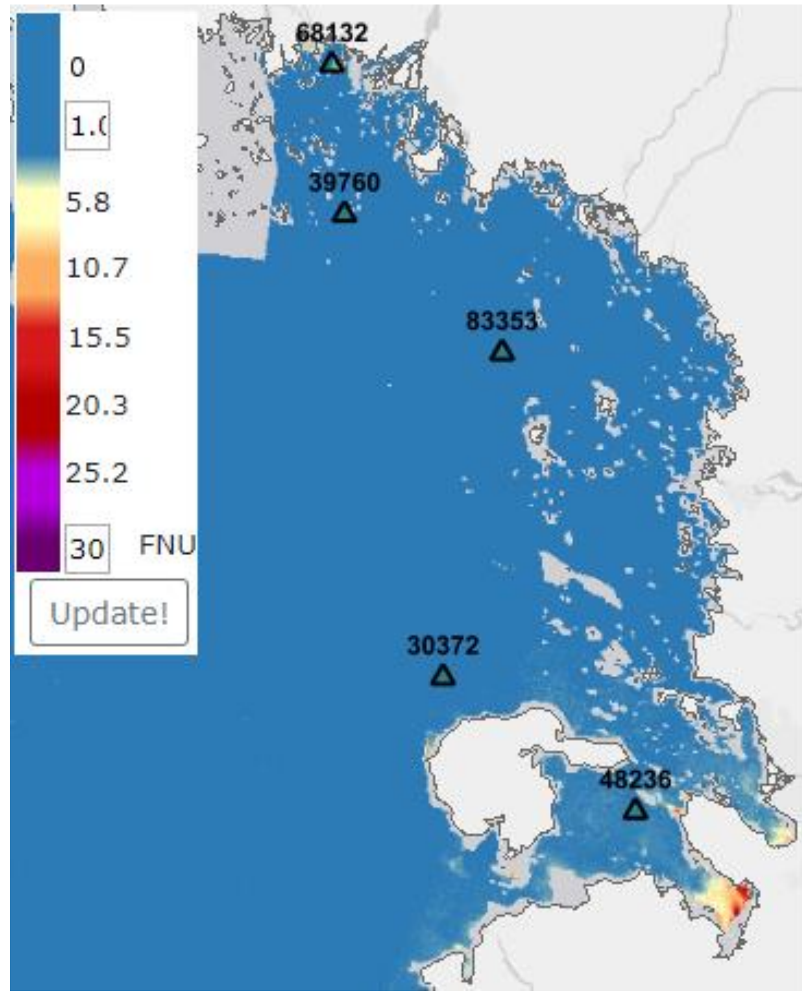
Turbidity maps estimated with EO - Monitoring of various events

Aug 19, 2018



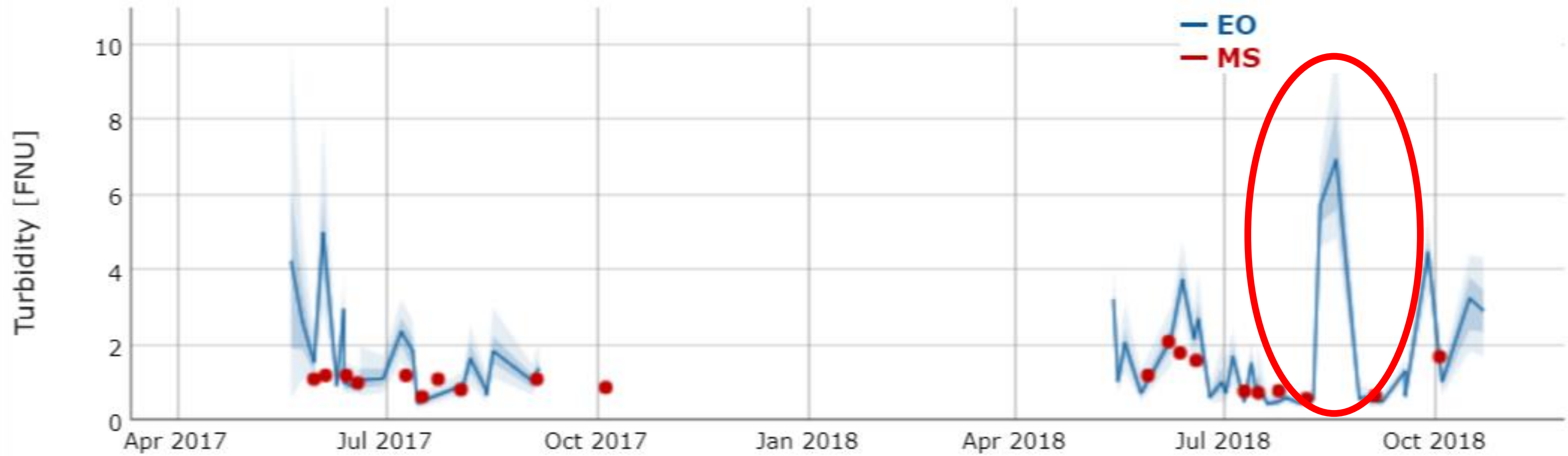
Resuspension (strong winds)

July 10, 2018



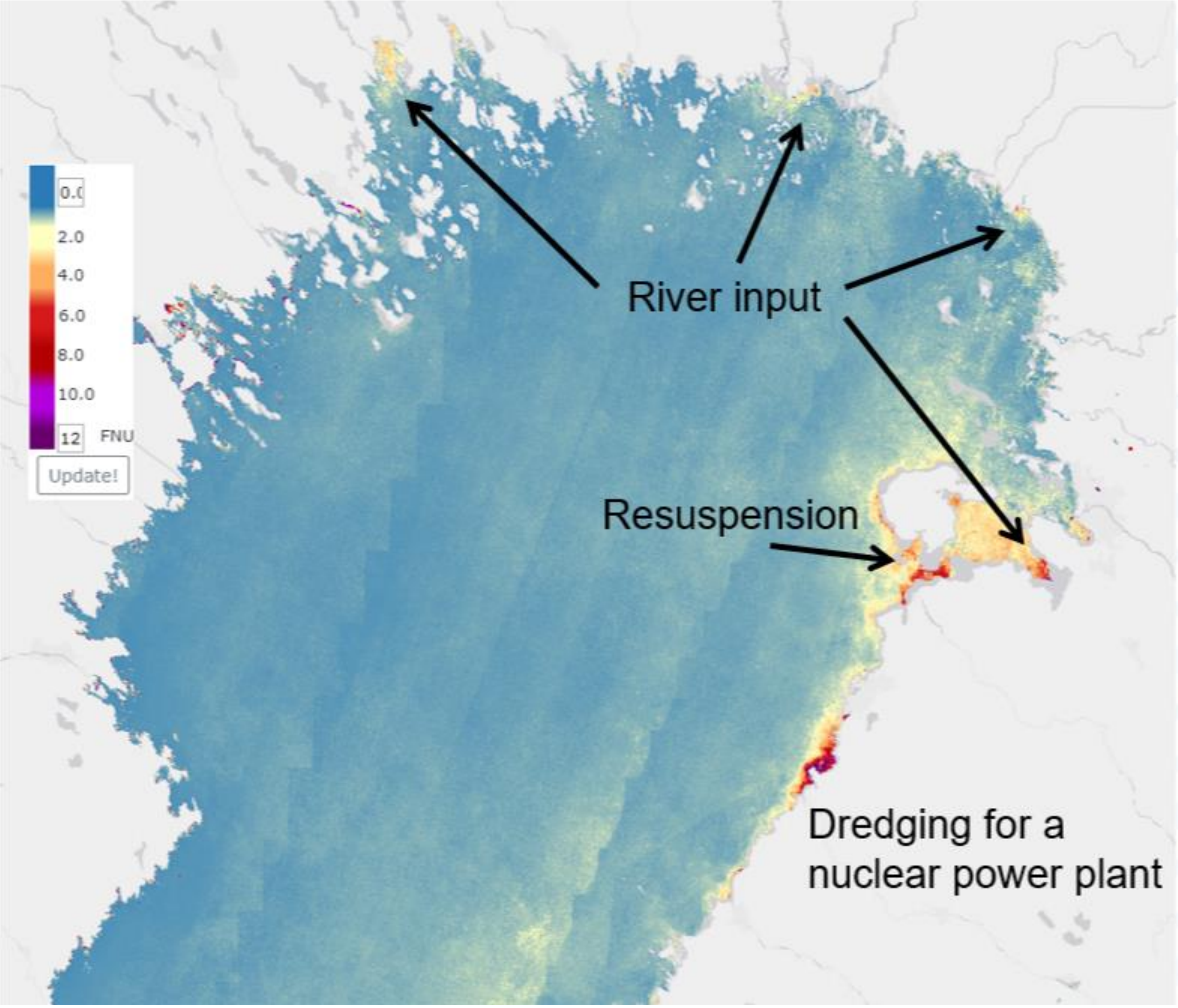
Normal scenario (indicates coastal run-off)

Turbidity time series at Hailuoto intensive station - in situ samples (MS) and EO (S2 data with SYKE algorithm)



Validation: EO data follows the behavior of MS data. The resuspension event is not detected with MS data.

Turbidity EO composites for modeling Summer 2017 (1.7-7.9)



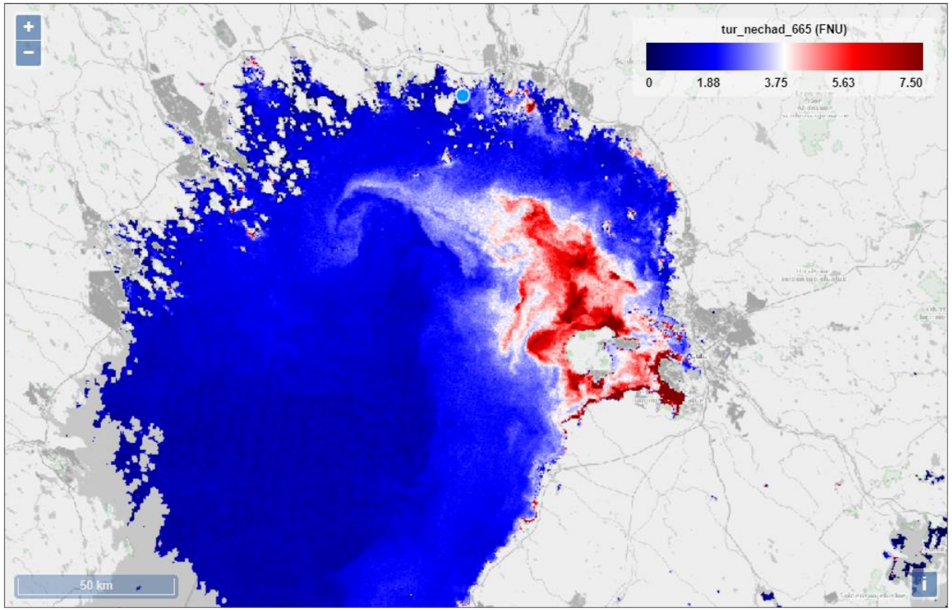
Data access

- Browsing and visualization through SYKE's TARKKA service www.syke.fi/tarkka/en
- Files from sampsa.Koponen@ymparisto.fi
- More info www.syke.fi/EOstorymap

Water quality estimated with EO Sentinel-3A and 3B (300 m)

BROCKMANN GEOMATICS SWEDEN AB

- **Turbidity (FNU)**
- Chl a (ug/l)
- Transparency - Secchi Depth (m)
- CDOM absorption (443 nm) (m^{-1})



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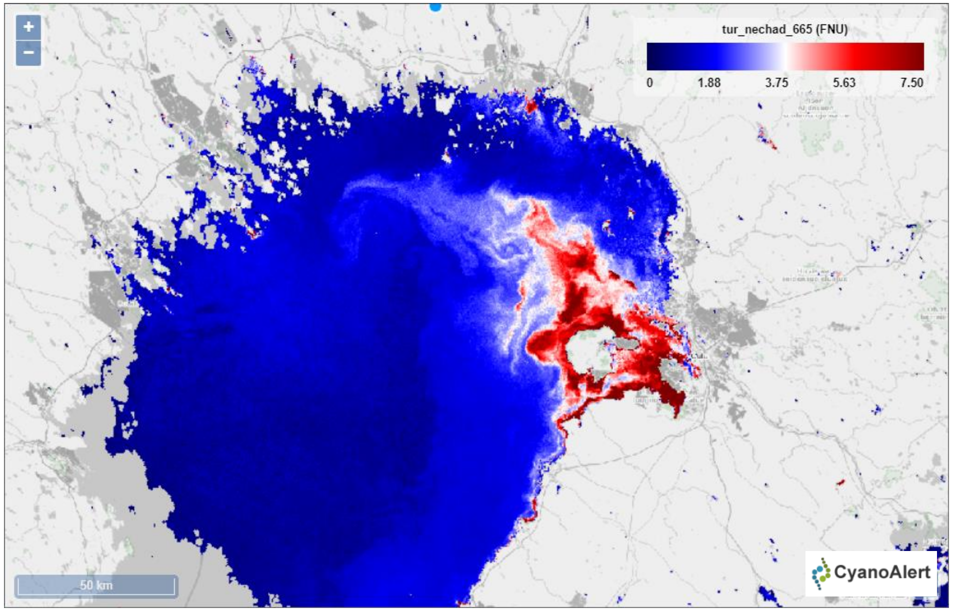

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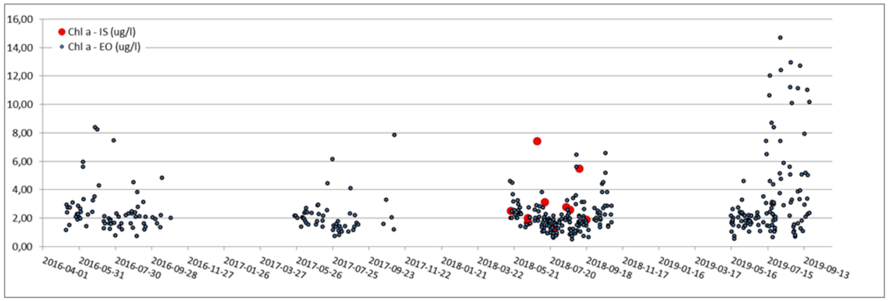
Water quality estimated with EO Sentinel-3A and 3B (300 m)

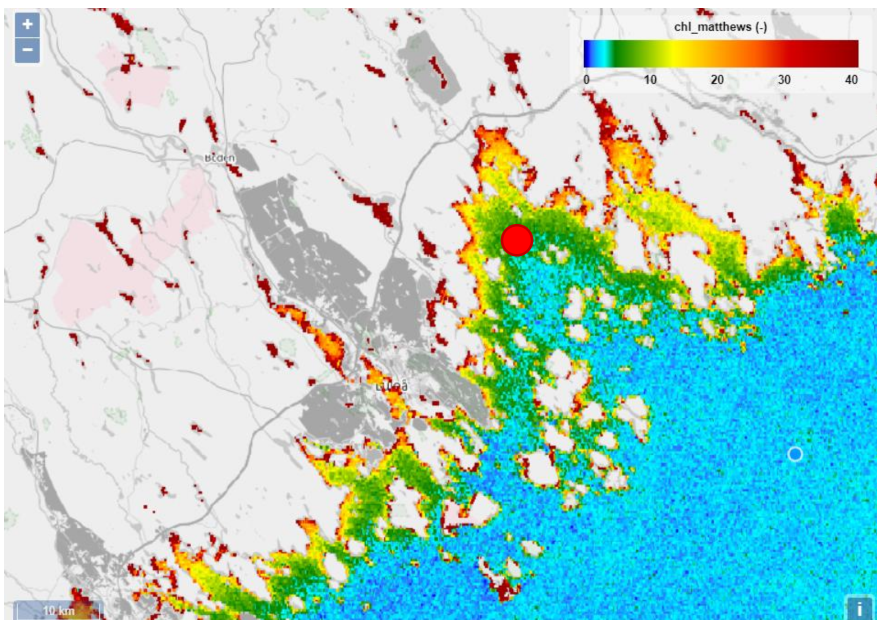
Brockmann Geomatics Sweden AB

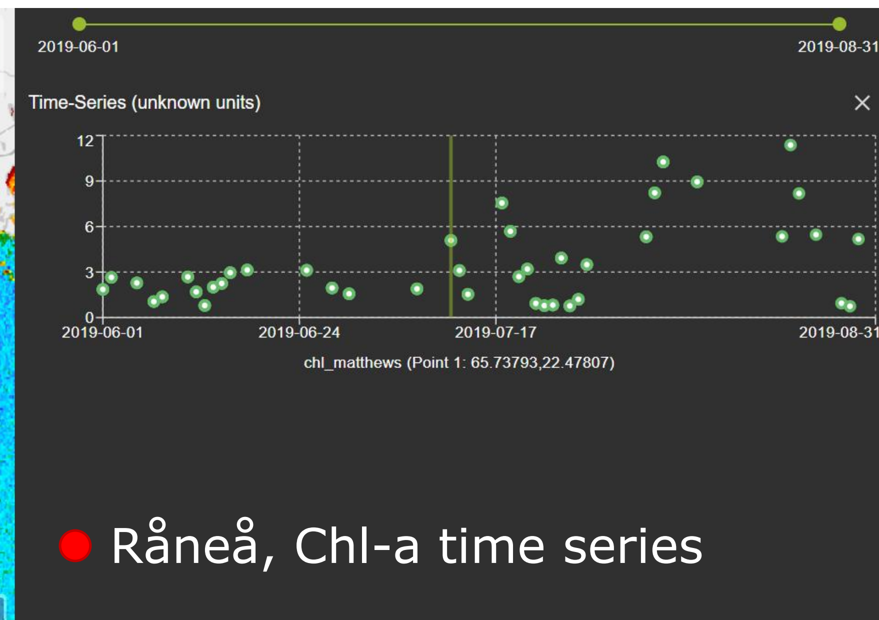
Chl-a (ug/l)



Validated Chl-a products not suitable for all areas or noisy.
Good correspondance between field and EO data in several areas, e.g. SEAmBOTH station "Råneå 2R".

EO data in blue and field data (0.5 m depth) in red.





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Water quality estimated with EO Sentinel-3A and 3B (300 m)

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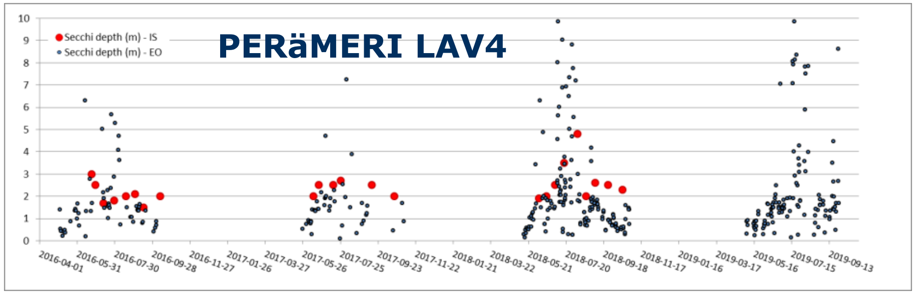
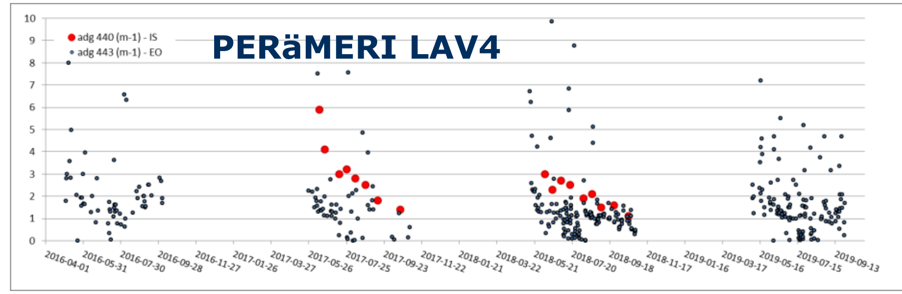
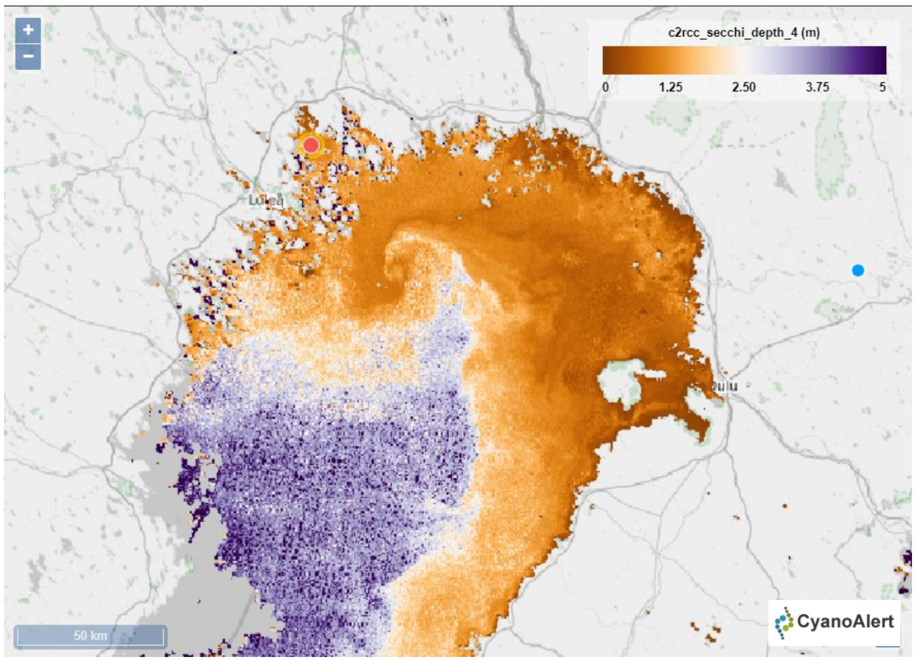
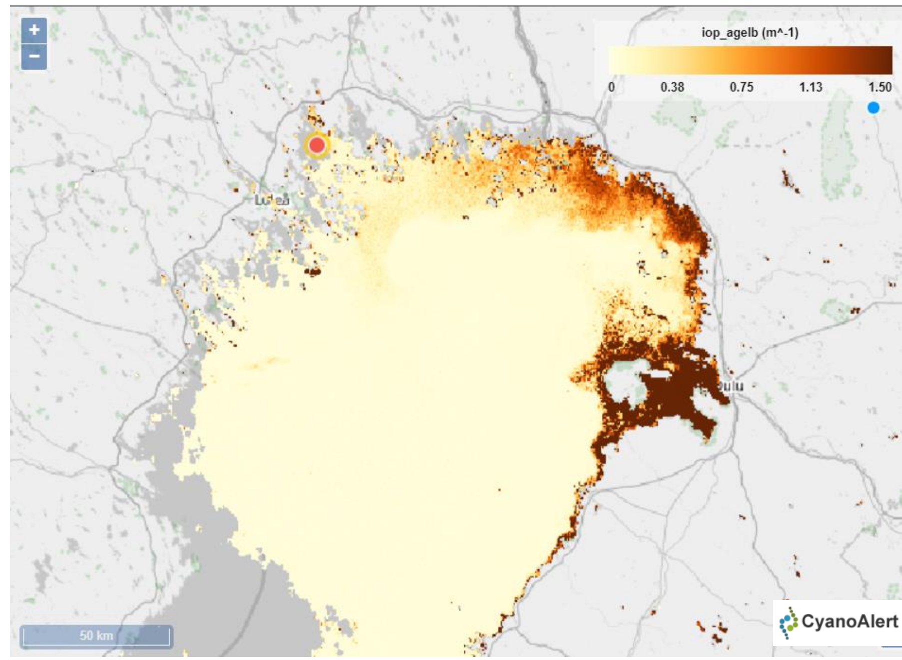
Secchi depth (m)

a_{CDOM} 443 nm (m^{-1})









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Key results - bio-optics

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- Great need to inter-compare optical *in situ* measurements between different groups
- Error characterisation required to secure reliable measuring standards
- Joint measurement campaigns have led to improved data quality
- SwAM is supporting SU to give additional bio-optical training to the Swedish monitoring groups during 2020
- The same support could be offered to Finnish groups during 2021/22 (SeaRECON?)

Key results – Remote Sensing

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- Satellite data can derive time series with much better temporal resolution
- The spatial resolution and coverage is also superior
- Many features are missed by standard monitoring data (e.g. upwelling events, algal bloom events)
- We got rather good results for measuring Chl-a, Secchi depth, CDOM and turbidity using Sentinel-3 data (300 m resolution)
- Turbidity can also be derived reliably from Sentinel-2 data (10-60 m resolution); the data has been delivered to SYKE's modellers
- We produced a novel algorithm to derive inorganic matter from space; can be used as indicator for coastal processes (erosion and resuspension of sediments) and as proxy for light in inner coastal areas

Challenges and future plans - Optics

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- Optical protocols should be followed by data providers (use of international standards)
- More data quality control of *in situ* measurements needed; intercomparisons of protocols and measurements at sea
- Description of measurement uncertainties is required (both for *in situ* and RS data)
- More IOP data (absorption and scattering properties) required to develop a dedicated remote sensing processor for high CDOM/low turbidity waters (i.e. dark waters)

Challenges and future plans- Remote Sensing

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- The EU Copernicus mission is still at an early stage; products and algorithms are continuously improved by ESA & validation teams
- There is a continues need for more validation data, especially in the Bothnian Bay with very high background CDOM (dark waters)
- Further work needed on integration of satellite data into oceanographic models
- For example, turbidity can be used as an input into models e.g. as a proxy for light limitation in inner coastal areas, or as proxy for wind-wave stirring
- Secchi depth can be used as an input for light in production models
- Chl-a can also be used to test the output of bio-geochemical models (see Kratzer, Harvey and Philipson, 2014; *Marine Policy*)


Thanks!