Bridging the divide between satellite and shipborne techniques for joint Baltic Sea water quality monitoring

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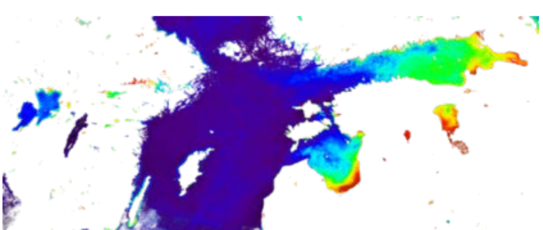
FerryScope

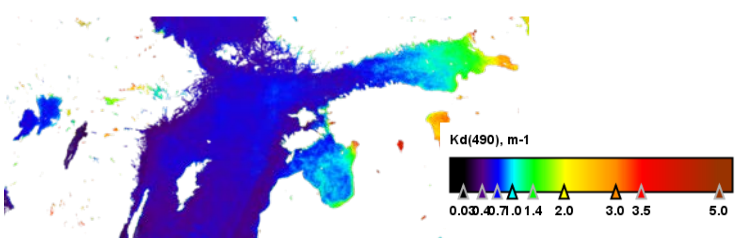
BONUS

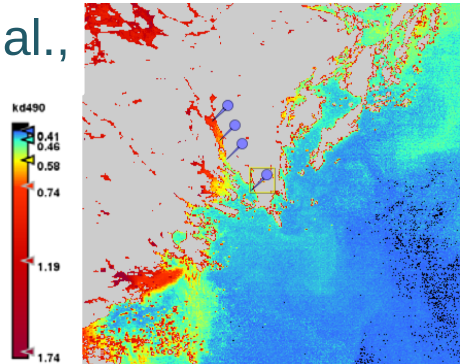
SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

Earth observations (EO)

- Since late 20th century, studies have been made on the use of EO instruments to detect
  - **chlorophyll-a** (e.g. Kratzer et al., 2000, 2008, Kratzer and Vinterhav, 2010, Vepsäläinen et al. 2005, Koponen et al., 2007, Bértran-Abaunza et al., 2013, 2014, Harvey et al., 2015, Attila et al., 2013, 2017, Ligi M. 2017)
  - **cyanobacteria blooms** (e.g. Kahru et al. 2000, 2007, Kahru & Elmgren 2014, Reinart and Kutser, 2006, Kutser et al. 2006, Verlin et al., 2014)
  - **SPM** (Beltrán-Abaunza et al., 2014, Kyryliuk & Kratzer, 2017,sub.), **turbidity** (Attila et al., 2013)
  - **transparency/Secchi depth/Kd490** (Kratzer et al., 2003, Kallio et al., 2006, Kratzer et al., 2008, Alikas et al., 2015, Alikas & Kratzer 2017)

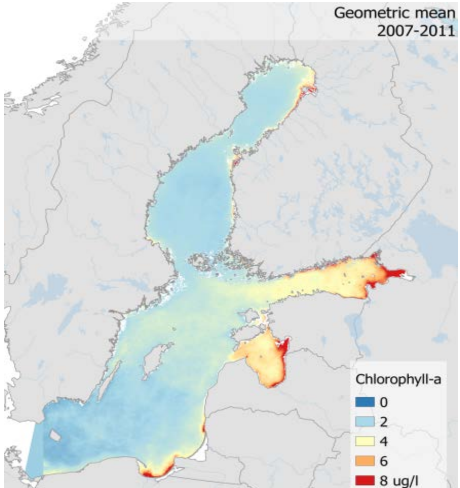


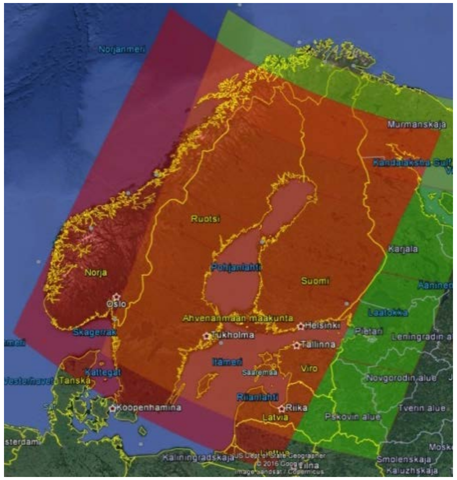




Earth observations (EO)

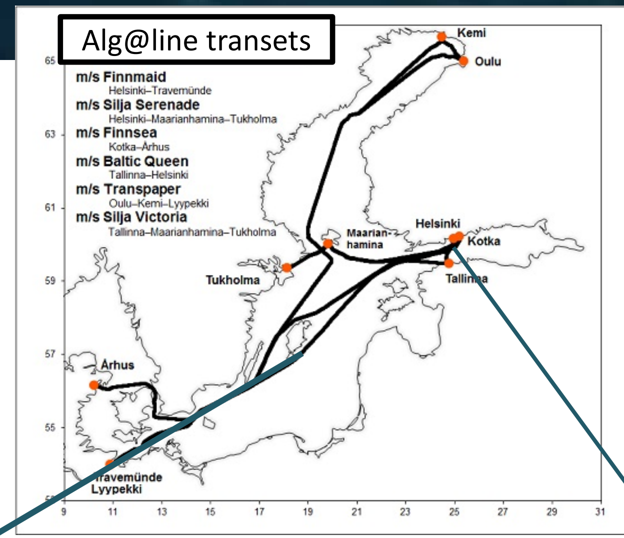
- Before the launch of S3, MERIS has been the frame of reference for algorithm development
- OLCI on-board Sentinel3 can continue reliable water quality estimation
  - Daily overpass
  - Coverage for the whole Baltic Sea at a glance
  - Optimal spectral configuration for developing algorithms for chlorophyll-a
  - 300m resolution

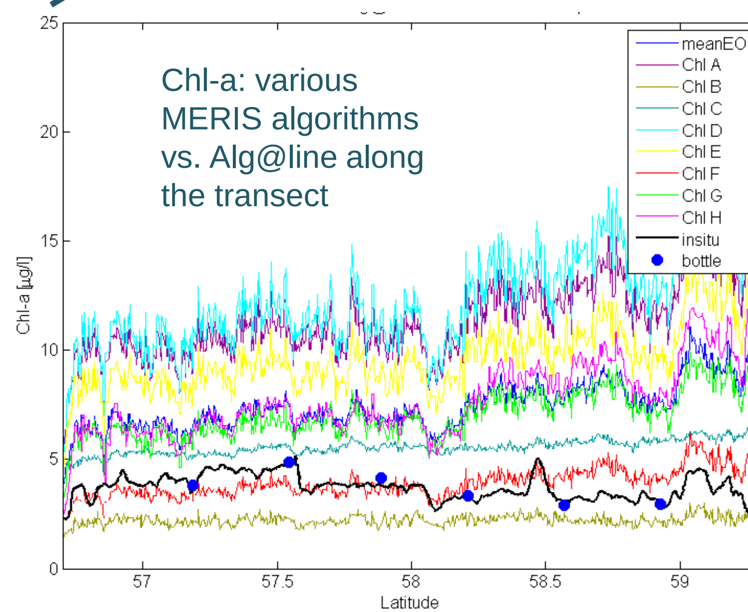




EO-algorithms for the Baltic

- Baltic Sea with its unique optical properties is especially challenging for EO algorithm development.
  - Absorption dominated, CDOM increases towards the northern and easternmost parts of the Baltic Sea (extreme Case II)
  - Finnish coastal aCDOM(400) range from about 0.6 1/m (south) to 5 1/m (river estuaries in north) (Ylöstalo et al., 2016)
  - Bio-optics of the open Baltic Sea (Simis et al., 2017)
- Not all EO water quality algorithms and instruments work properly for the Baltic Sea
- Algorithm development is important
  - using all available data sources
  - accounting the spectral and radiometric characteristics of OLCI

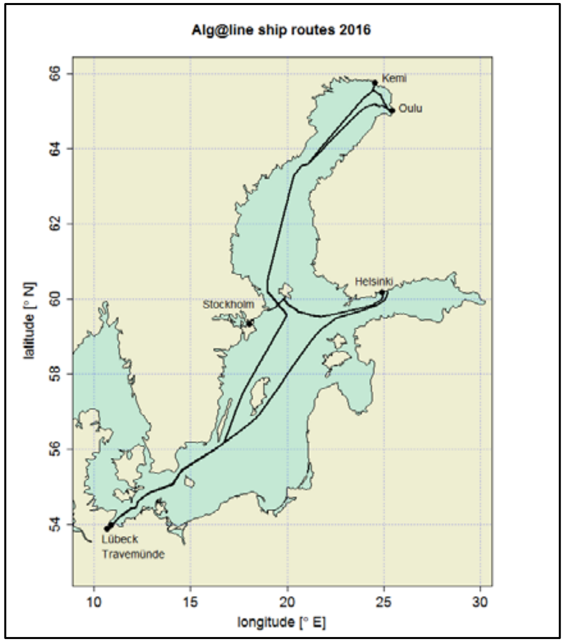


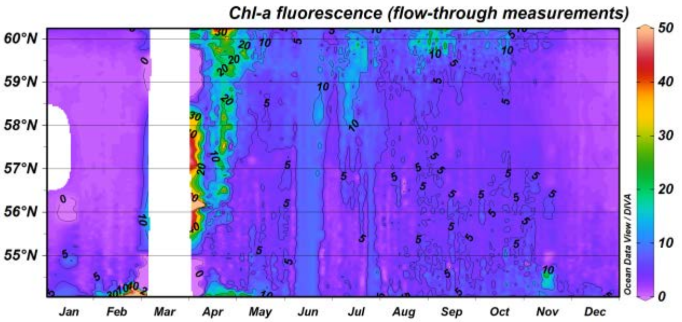


Alg@line

- Ship-of-opportunity (SOOP) for research and monitoring, coordinated by SYKE (seppo.kaitala@ymparisto.fi)
  - Sweden: SMHI, Estonia: EMI, MSI, Germany: IOW
- Automated measurement system onboard merchant ships
  - Flow-through fluorometer measurements and water samples
- **Real-time measurements**
  - Temperature, salinity, turbidity, CDOM fluorescence
  - Chlorophyll *a* and phycocyanin fluorescence
    - photosynthetic pigments present in phytoplankton cells
- **Water samples**
  - Chlorophyll *a,* turbidity, nutrients
  - Phytoplankton species composition
- Data for international marine data infrastructures (e.g. EMODnet, Copernicus Marine Service, ...)

-> EO algorithm development based on water samples and flow-through calibrated with the samples

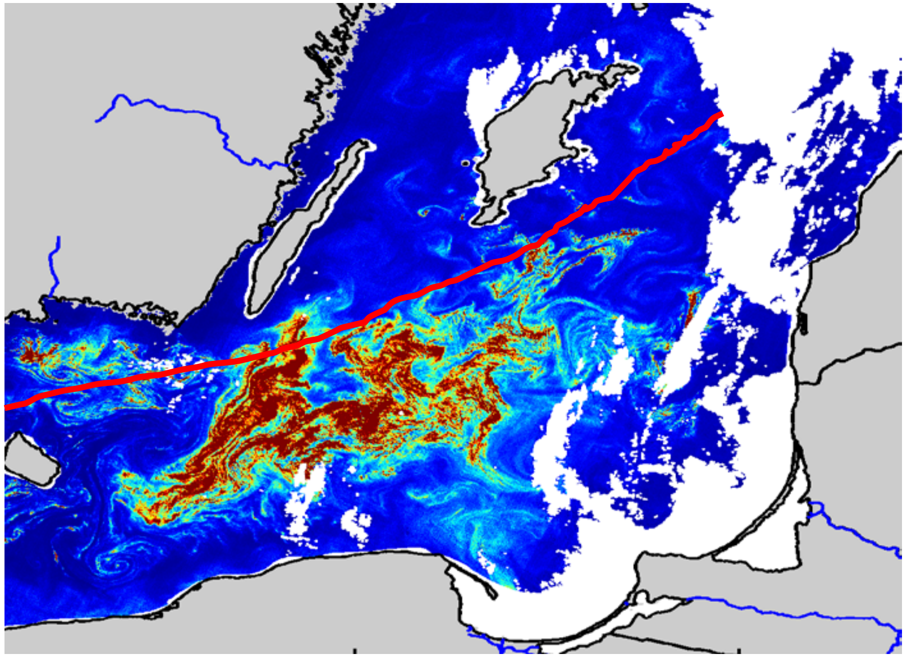


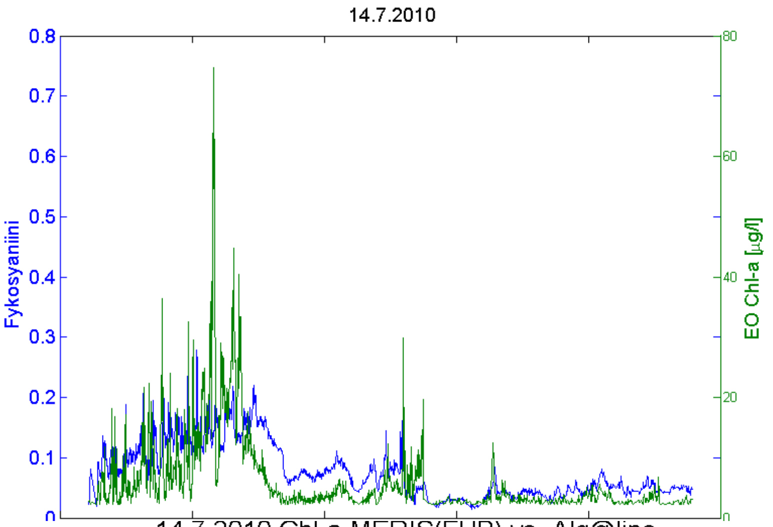


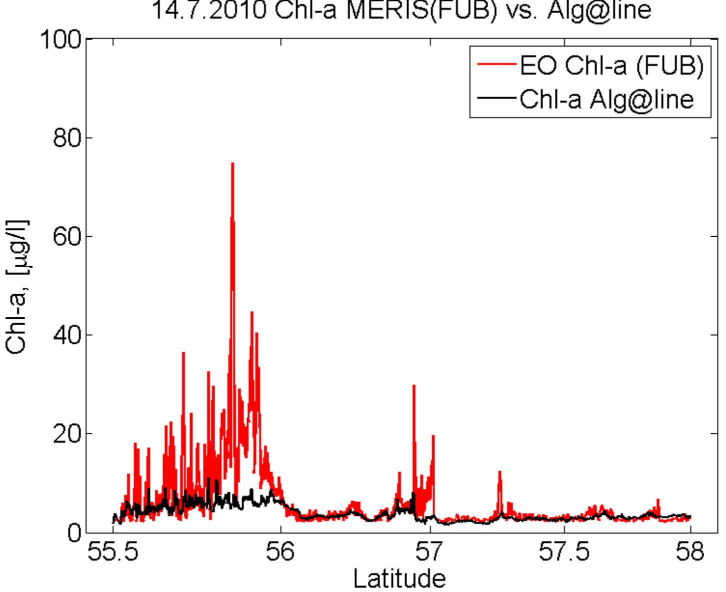
Alg@line and MERIS chl-a during cyanobacteria blooms

MERIS FUB
Alg@line, 5m depth

14.7.2010







FerryScope project

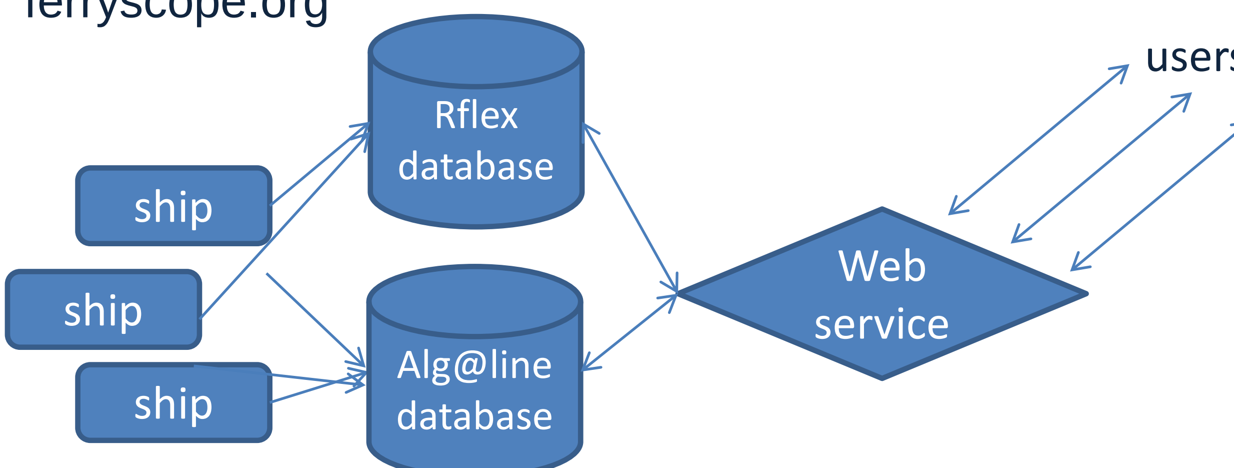
- BONUS/FerryScope strived for improving water quality assessment of the Baltic Sea by combining **satellite data**, **shipborne measurements** and **modelling**.
- Co-operation between companies and research institutes: Brockmann Consult GMBH (GER), Estonian Marine Institute, Finnish Environment Institute (SYKE), Plymouth Marine Laboratory (UK).
- Preparation for the joint use of Sentinels and shipborne data with Baltic specific spectral inversion algorithm SIOCS (The Sensor-Independent Ocean Colour Processor)
- Hydrolight simulations based on a bio-optical database (Simis et al., 2017).

FerryScope Brockmann Consult SYKE Estonian Marine Institute PML Plymouth Marine Laboratory BONUS Science for a better future of the Baltic Sea region

Autonomous measurement system on the deck of the ship

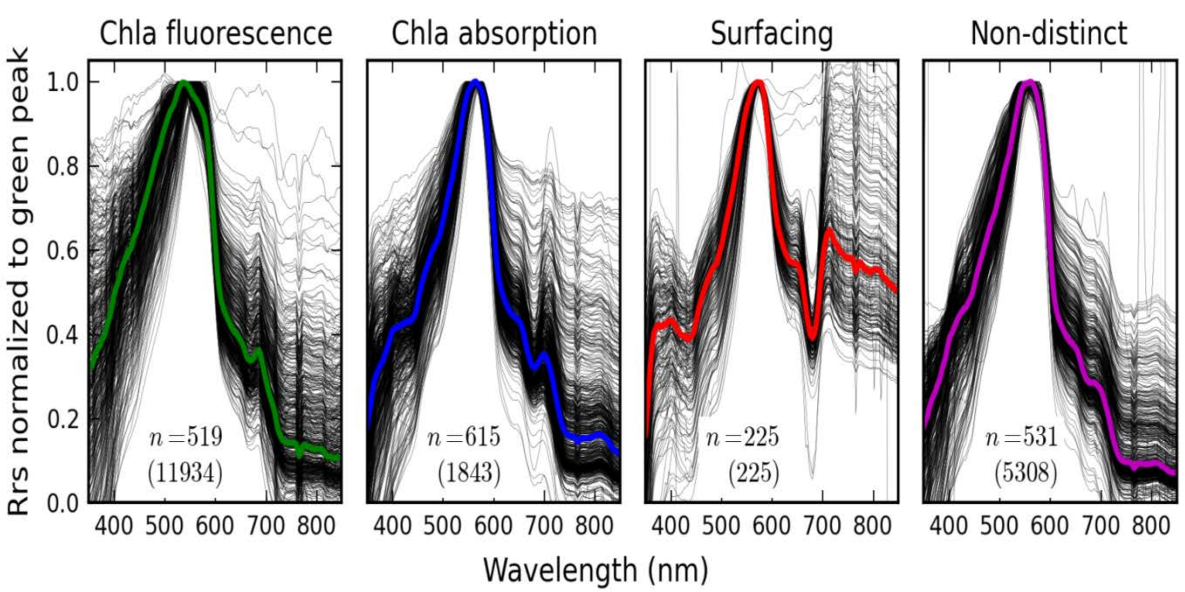
1. Hyperspectral reflectance sensors on Algaline ships
2. Automated data transmission to the database
3. Quality assured reflectance data

4. Access the data in near real-time: ferryscope.org



Reflectance measurements

- Most of the measurements on the ship are discarded - due to weather conditions and ship tilting (Simis and Olsson, 2013)
- After filtering, different types and behavior of algae can be distinguished from ship observations, such as



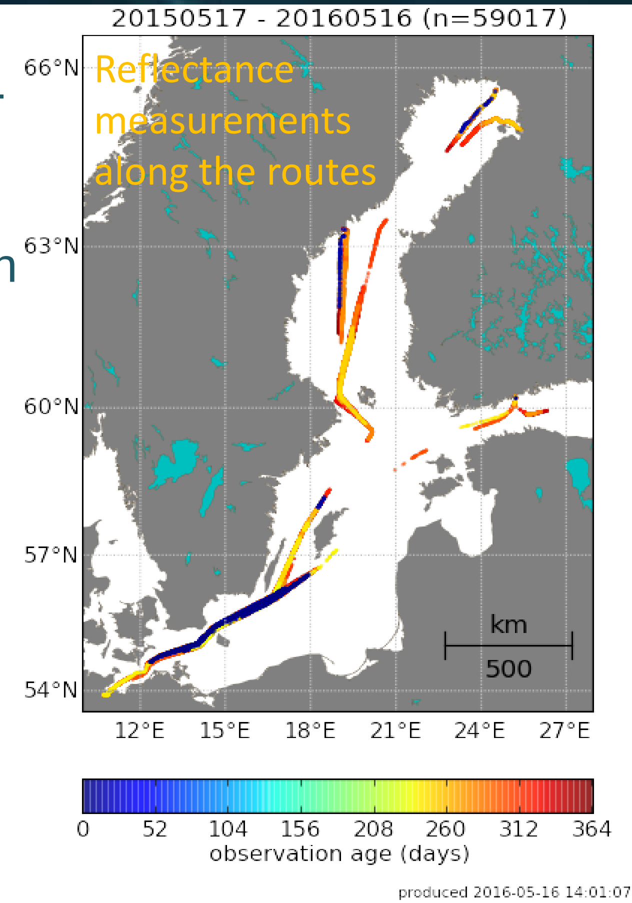
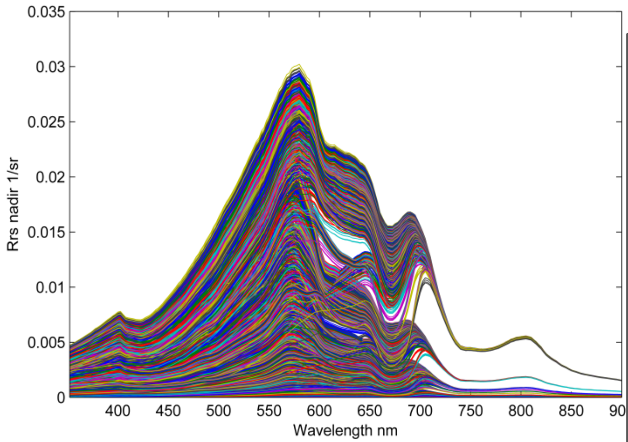
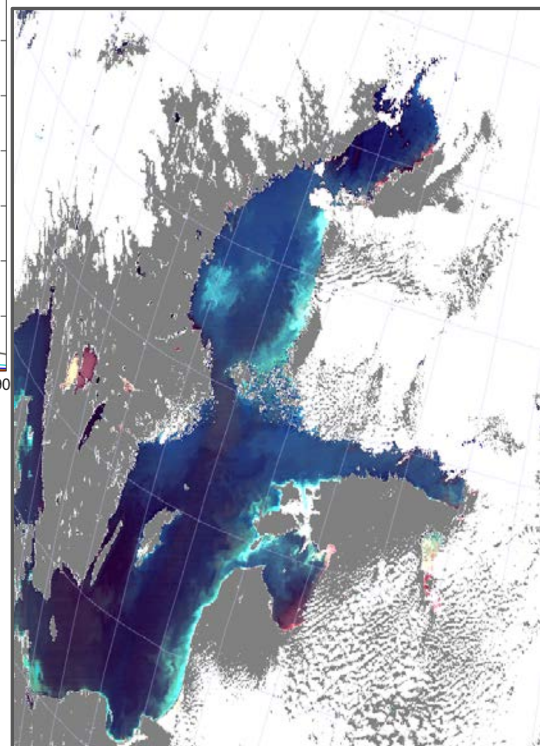


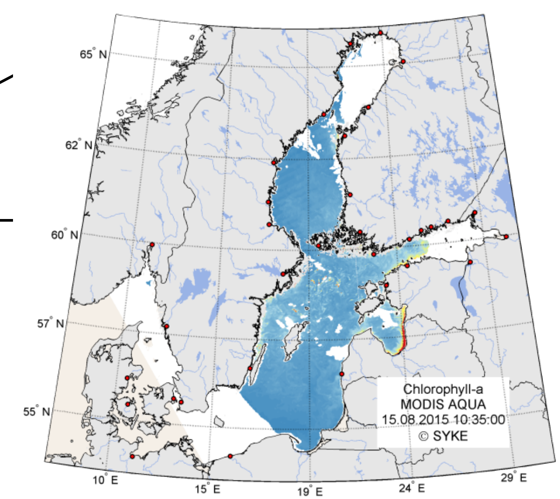
Image by S. Simis, unpublished data

Modelling chain:
Combination of data sources with Baltic SIOCS model

Pre-modelled data & satellite & on-line ship observations







Modified for different satellite constellations

MODIS

OLCI

Rflex reflectances

Alg@line

Matchups

Baltic model SIOCS

Estimated water quality

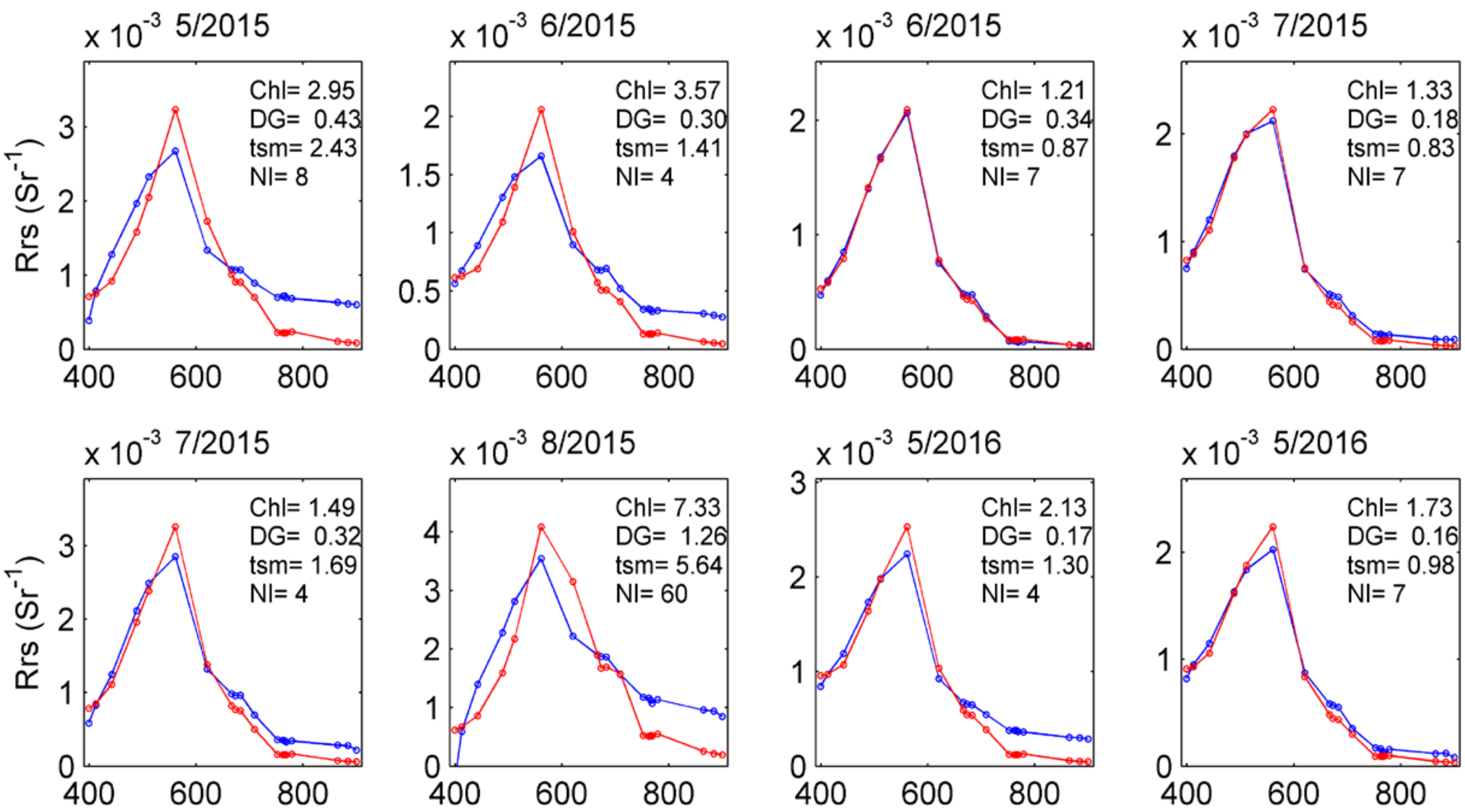
image data

transect data

Look-up tables

Rflex reflectance data for algorithm development

- Baltic Sea specific SIOCS model using shipborne reflectance data with OLCI spectral configuration.



FerryScope

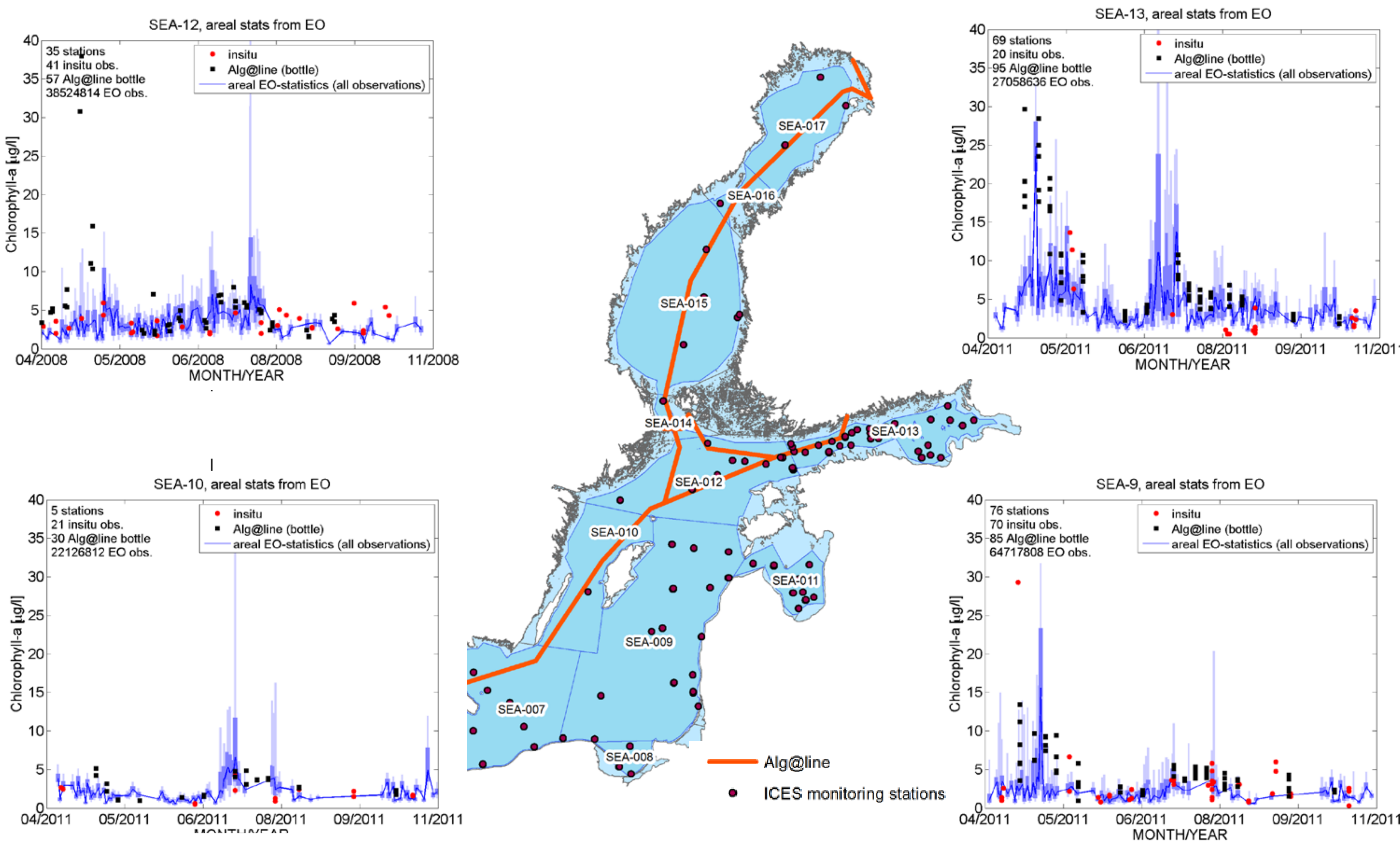
Accurate estimation of chl-a using MERIS and OLCI?

- Chl-a results achieved with MERIS have been validated throughout the Baltic Sea in comparison to various data sources
  - Coastal comparisons (e.g. Kratzer et al., 2008, Bértran-Abaunza et al., 2014, Harvey et al., 2015, Attila et al., 2013, 2017)
  - HELCOM open water assessment areas & ICES dataset (EUTRO-OPER, 2015)
  - Gulf of Finland: trilateral GoF-dataset (Kauppila et al., 2016)

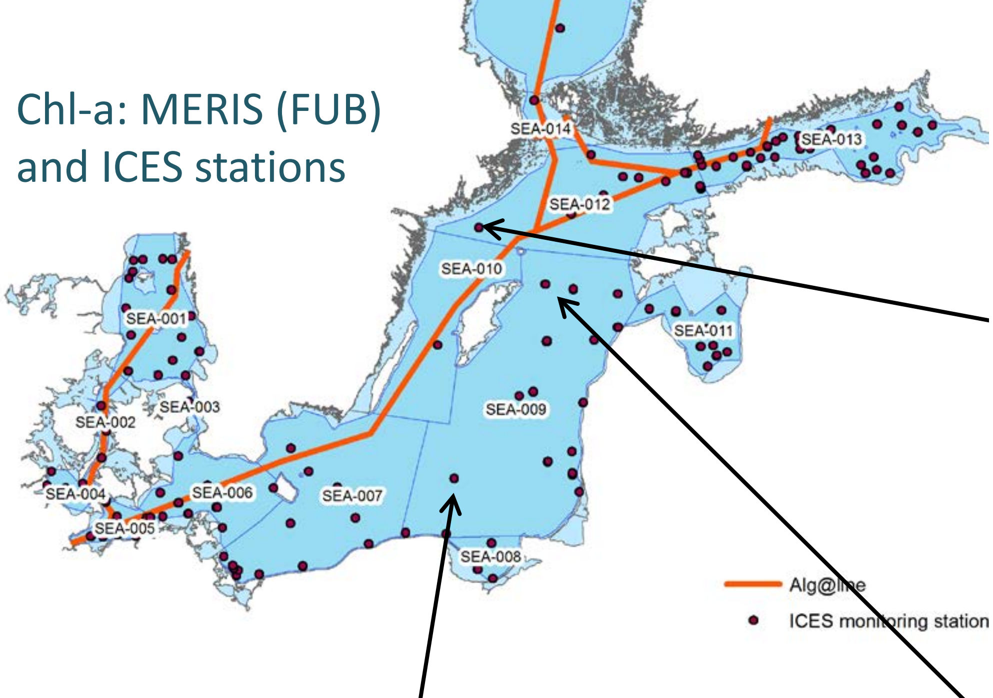
- The differences in time, depth, number and spatial extent of observations account for much of the discrepancy between various monitoring methods.
- We look forward to using OLCI with improved spectral configuration in comparison to MERIS.
- Part of OLCI data is in commissioning phase, the improvement of the calibration is ongoing.

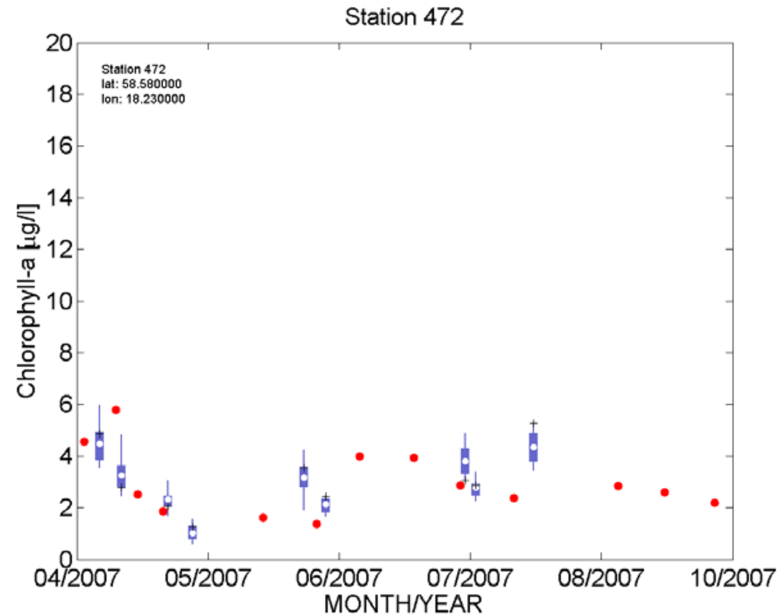
HELCOM assessment areas, EO (MERIS) (▮) ICES MS (●), Alg@line (■), (EUTRO-OPER, HELCOM, 2015)

SYKE
Finnish Environment Institute

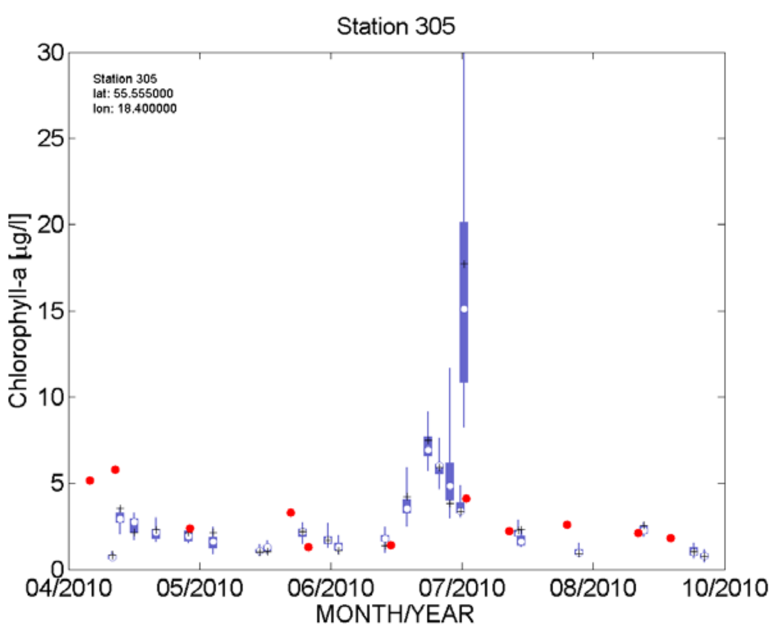


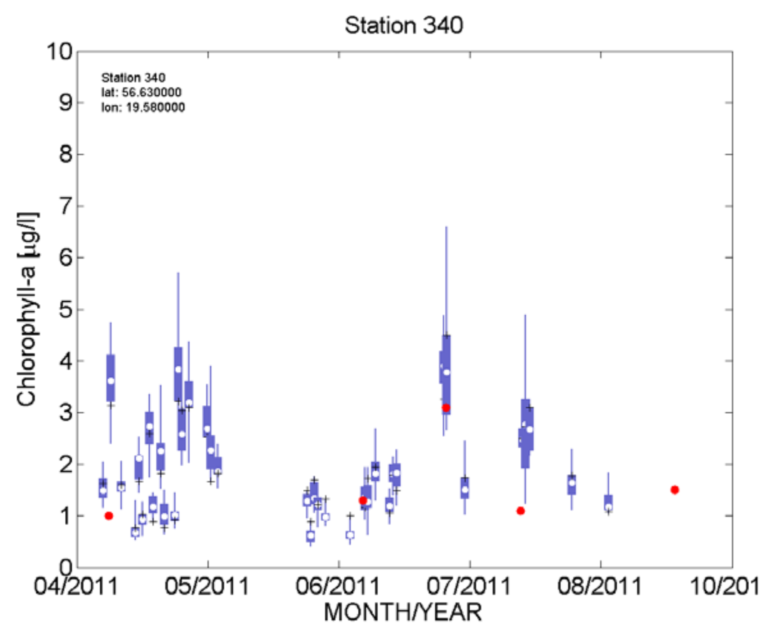
Chl-a: MERIS (FUB) and ICES stations





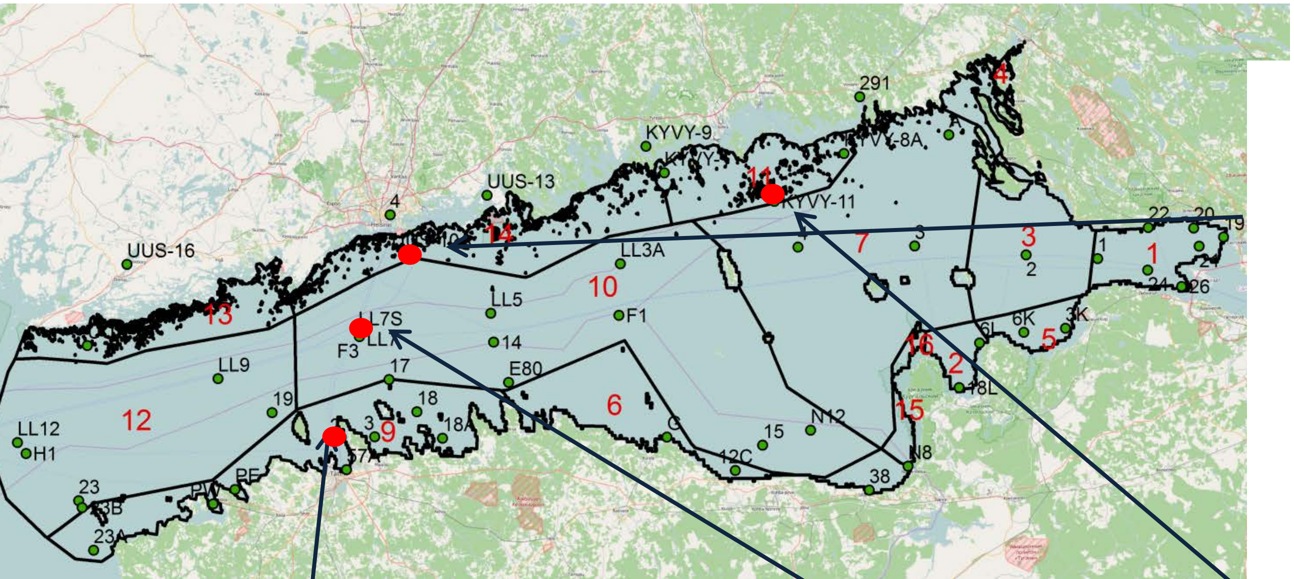
EUTRO-OPER (HELCOM, 2015)

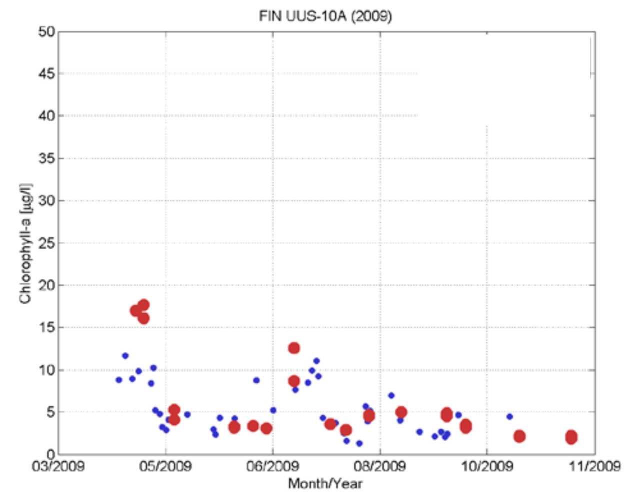


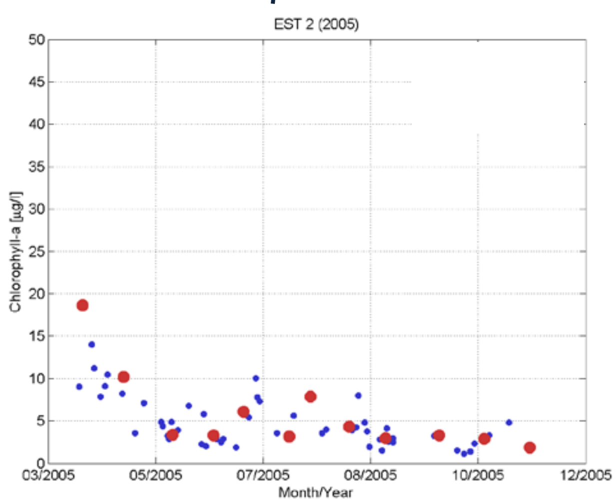


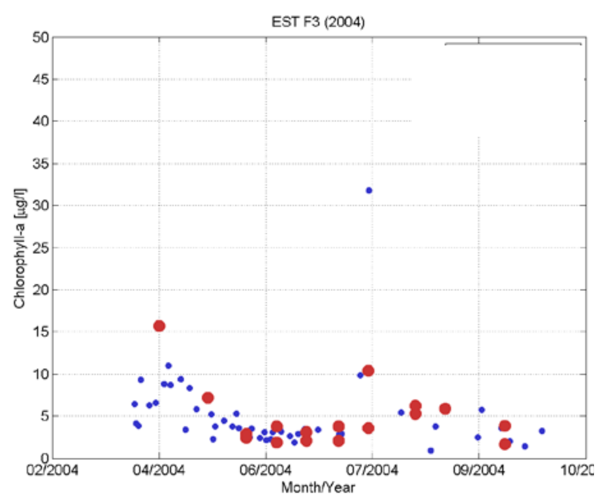
Comparison of EO and GoF trilateral dataset

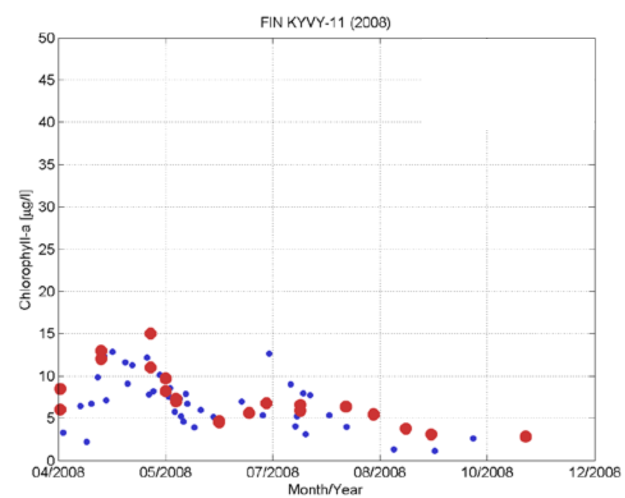
Kauppila et al. (2016)



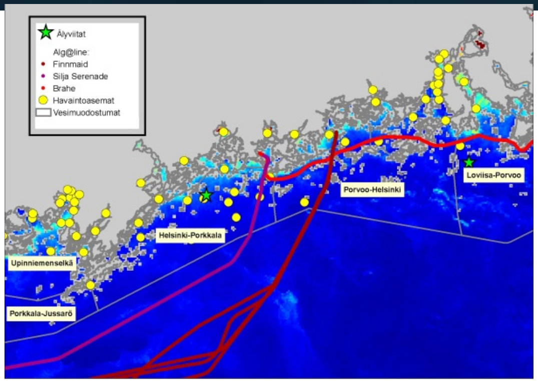








OLCI C2RCC comparison against various field data



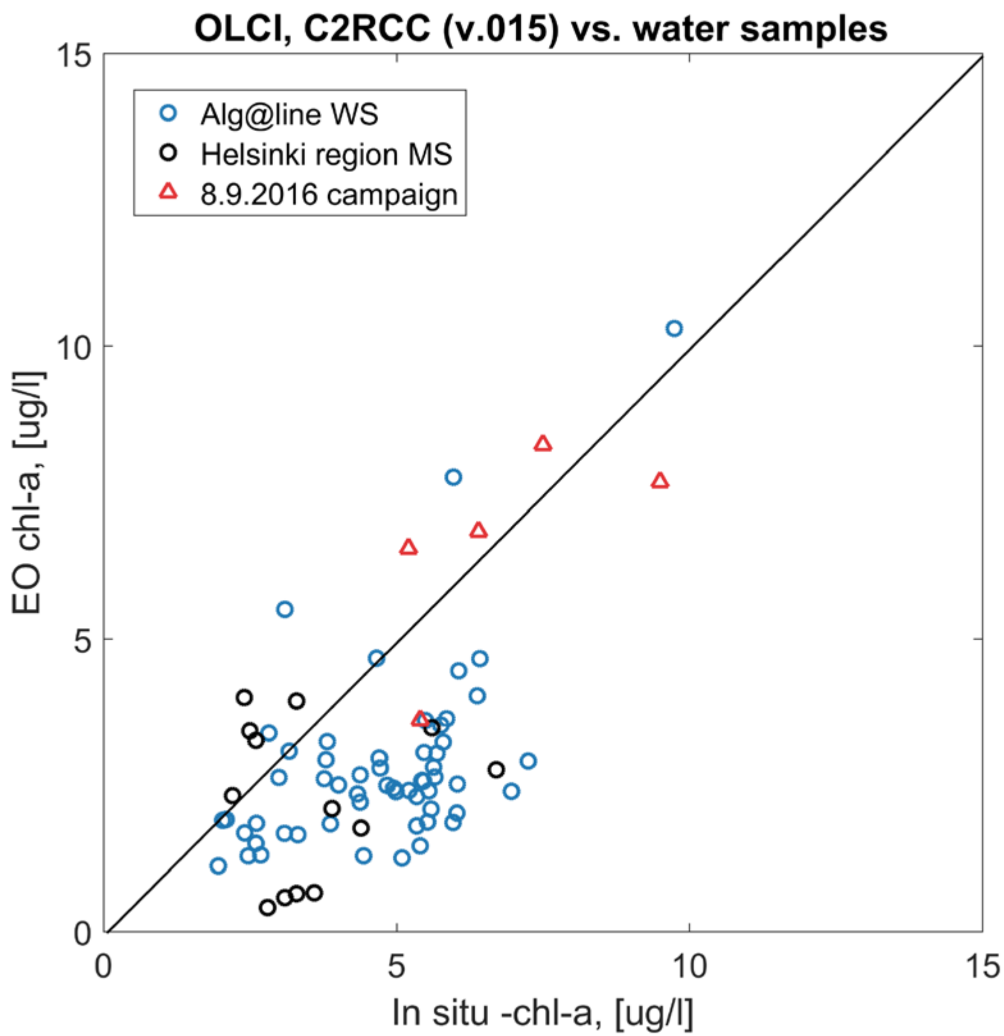
Validation data 2016 (analysed so far):

Alg@line water samples

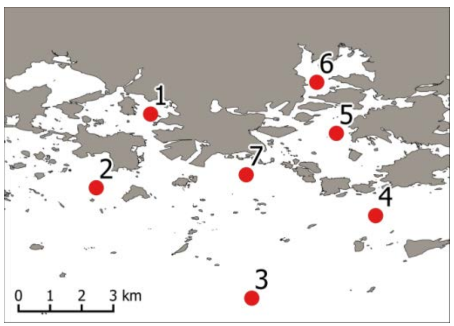
- From mid May to August
- Area: Gulf of Finland

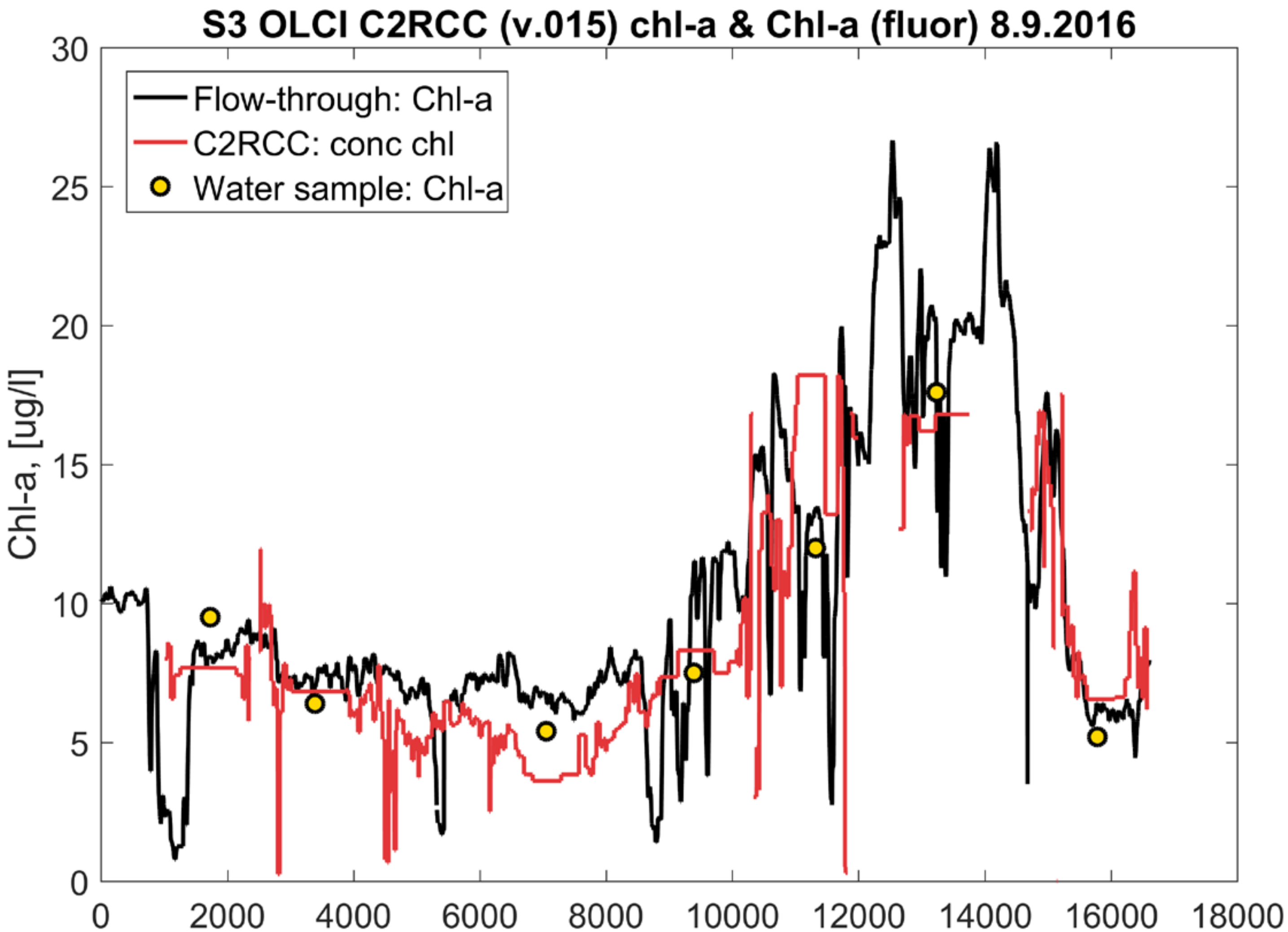
Coastal monitoring stations near Helsinki

Field campaign (8.9.2016)



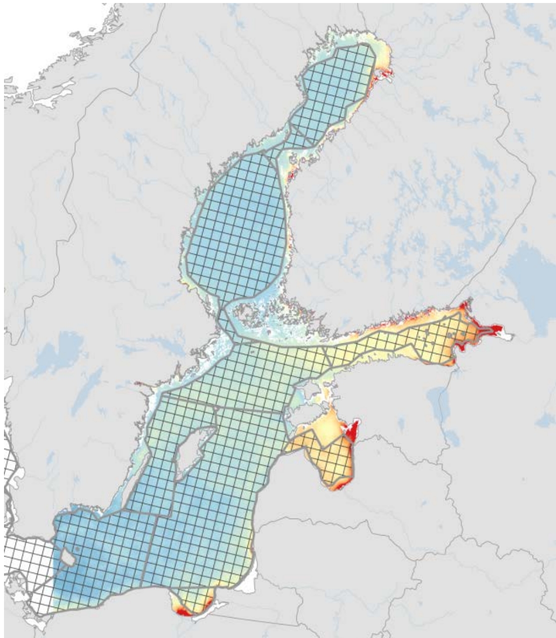
Coastal vessel flow-through, water samples & OLCI





Outlook and future aspects

- A lot of autonomous data is being collected for the Baltic Sea by instruments onboard ships.
- Combining data from different sources overcomes the shortcomings of individual systems – via modelling in the future.
  - EO: clouds, inaccuracies caused by atmosphere
  - Rflex: measurement errors by weather, movements of the ship, bubbles in water, spatially and temporally limited to the shipping routes
- Algorithm evolution in parallel to product development for users is important.
- Cost-effective and reliable methods for monitoring and assessment are needed
  - National and regional assessment requirements (EU MSFD & WFD).
  - Important for defining actions and measures for protecting the Baltic Sea.
  - Regional and independent validation with in-situ data could help to enlarge the acceptance of EO data for reporting to EU.

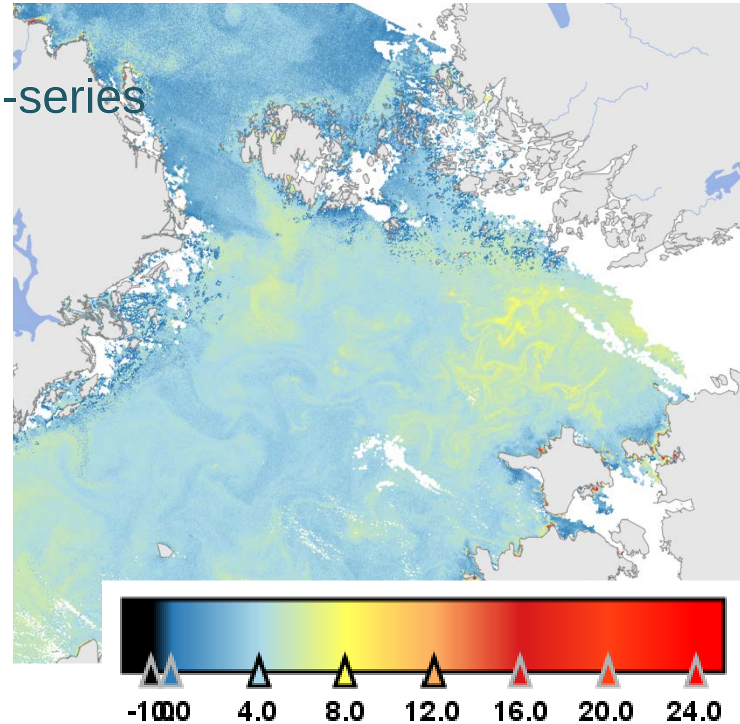


Future considerations

- ESA Copernicus Sentinel-series instruments are ensured and we can exploit them at least until 2030.
- Baltic Sea specific EO algorithms are needed to fully exploit
  - the automated instrumentation on ships
  - new spectral configurations by the Sentinel-series instruments

How can we benefit further from the already established systems and knowledge by institutes and companies in the Baltic countries?

OLCI 4.7.2016



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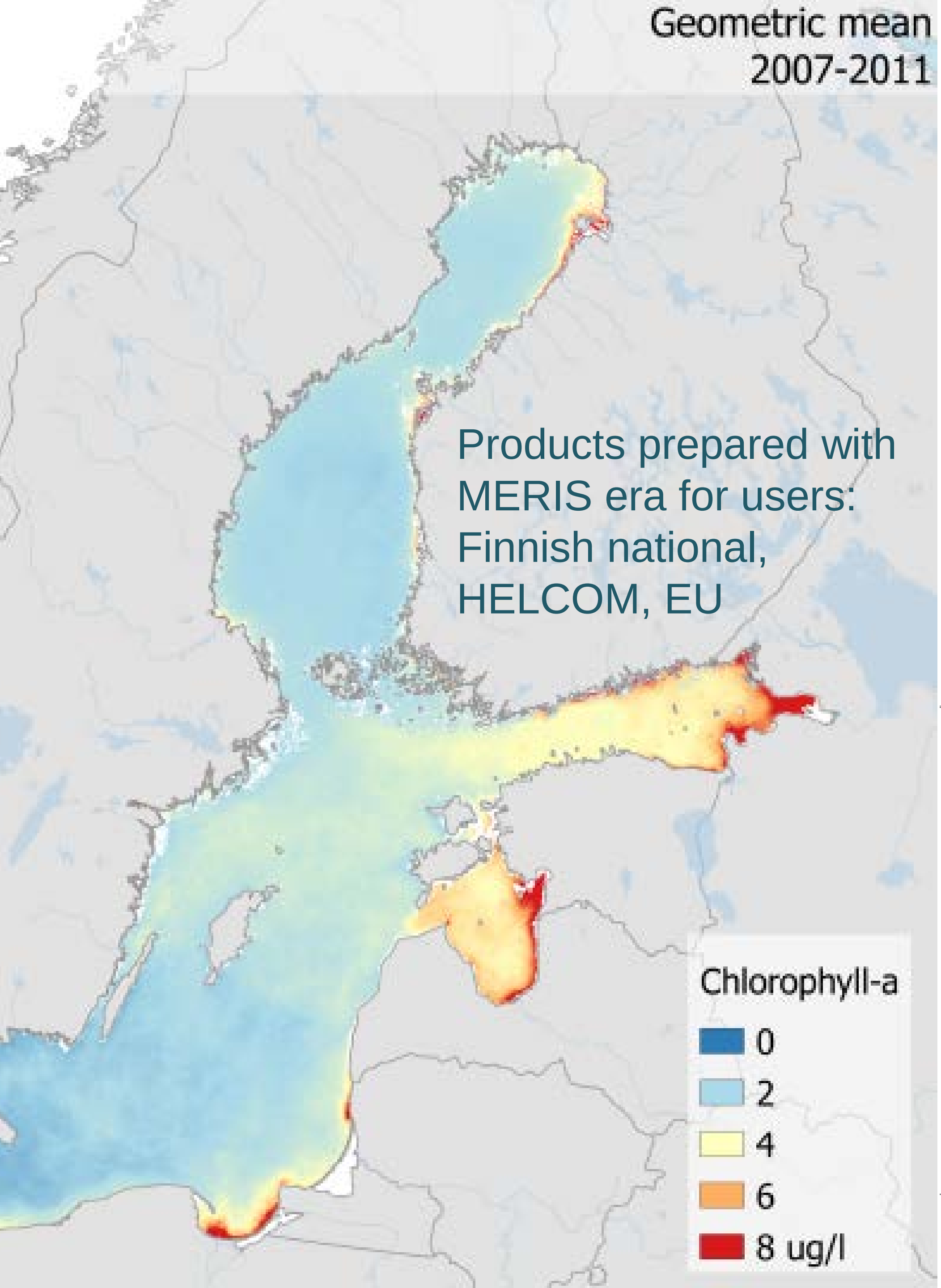

Products prepared with MERIS era for users: Finnish national, HELCOM, EU

S3/OLCI: Continuation of accurate assessment information on the state of the Baltic Sea

EUTRO-OPER (HELCOM, 2015)