Monitoring Baltic Sea eutrophication from space- from research to applications

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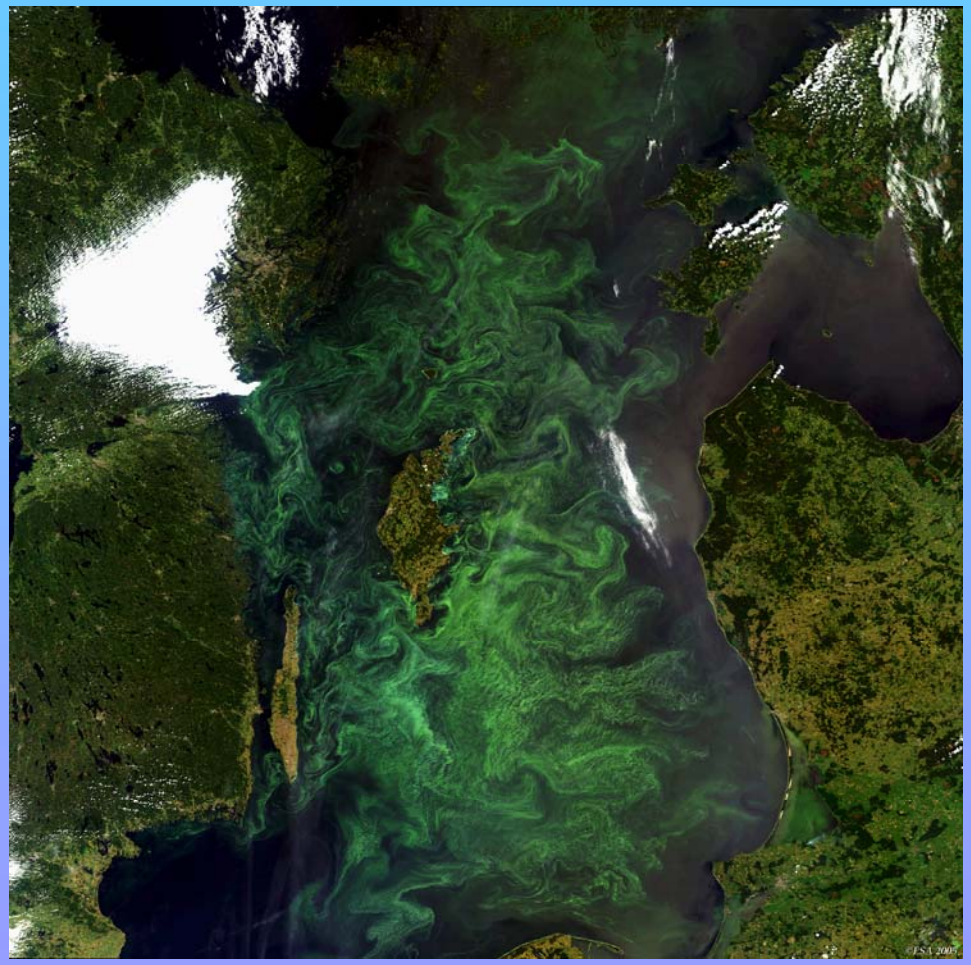
Marine remote sensing and management



Cyanobacteria Bloom in the Baltic Sea,
MERIS FR image Date20050713_Time094518_Orbits17611, ESA

- Covers large areas
- Cost-effective
- Synoptic view
- Visual format easy to understand
- New window into marine ecosystems

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Elements for Ecological Status in the EC Water Framework Directive (WFD):

Biological elements:

Phytoplankton, aquatic flora, benthic invertebrate fauna, fish fauna

Hydro-morphological elements (supporting the biological elements): Morphological conditions, Hydrological and Tidal regime

Chemical and physicochemical elements (supporting the biological elements): **General**: dissolved oxygen, nutrients, transparency, temperature; **Specific:** synthetic and non-synthetic pollutants

***Chl-a* and Secchi depth can be used as indicators for eutrophication**

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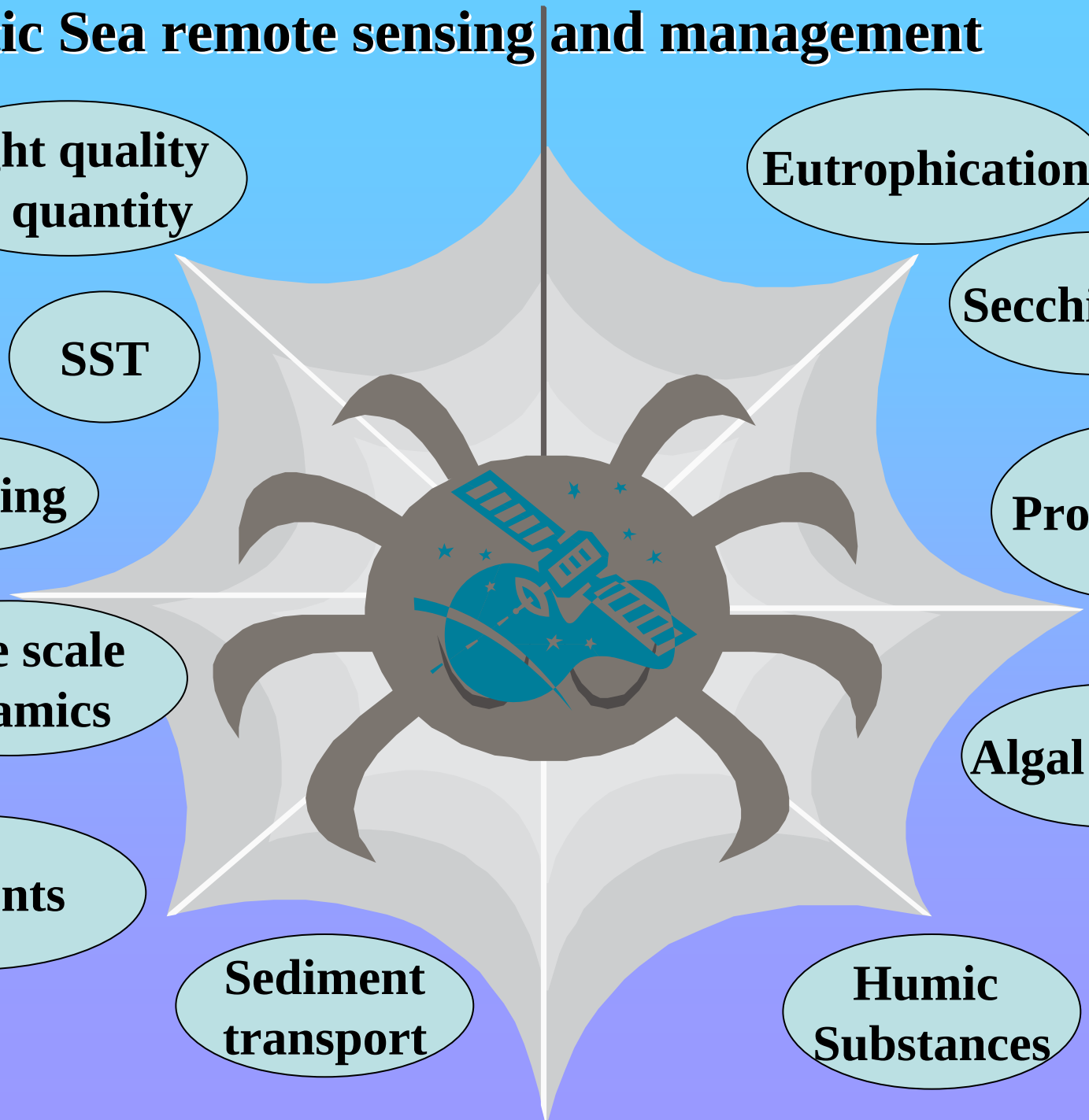
Baltic Sea remote sensing and management



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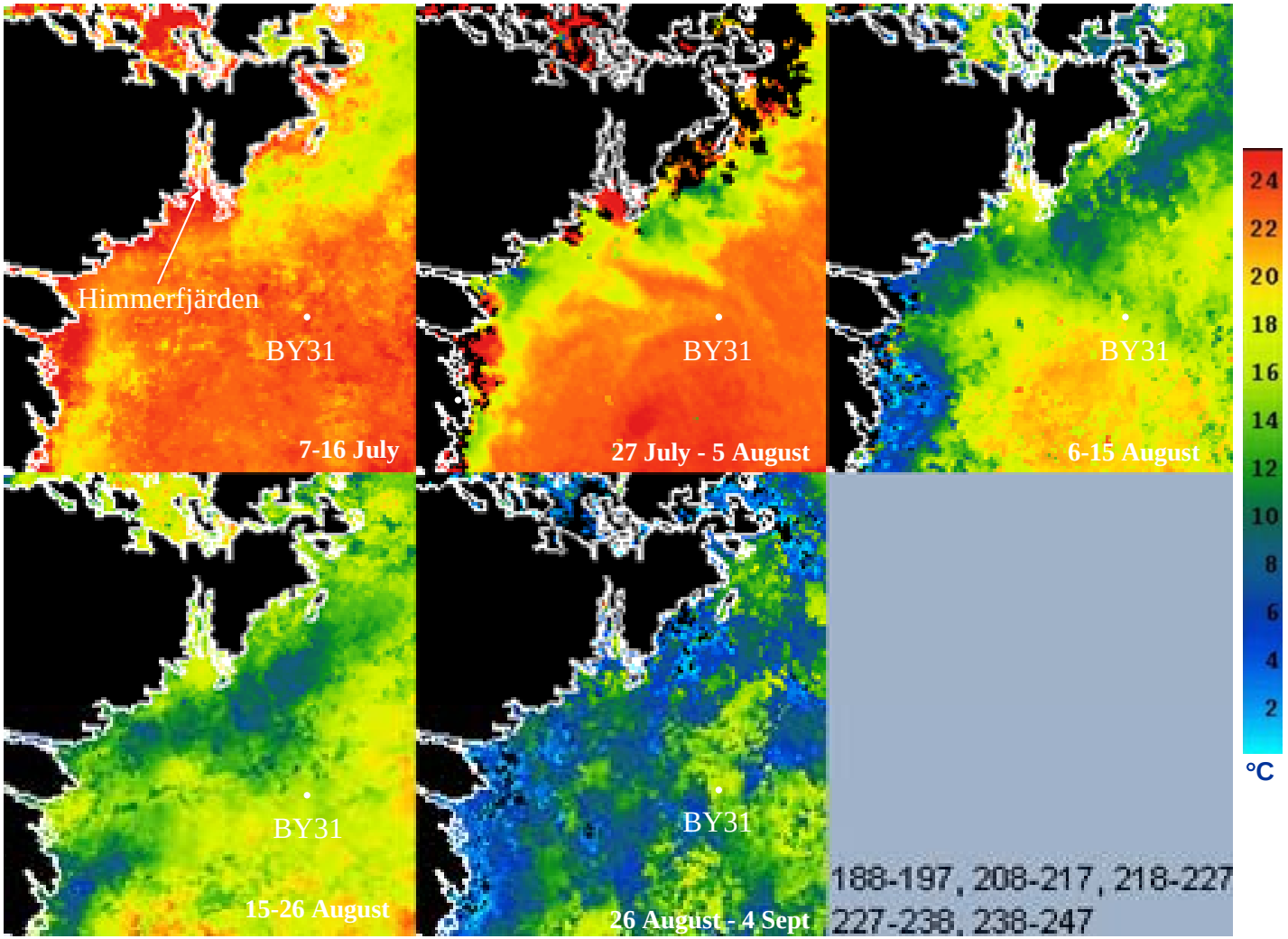
SST in the NW Baltic Sea Derived from AVHRR



Sea Surface Temperature (SST) derived from NOAA/AVHRR data during 7 July-4 September 2001, binned images (10 day composites)

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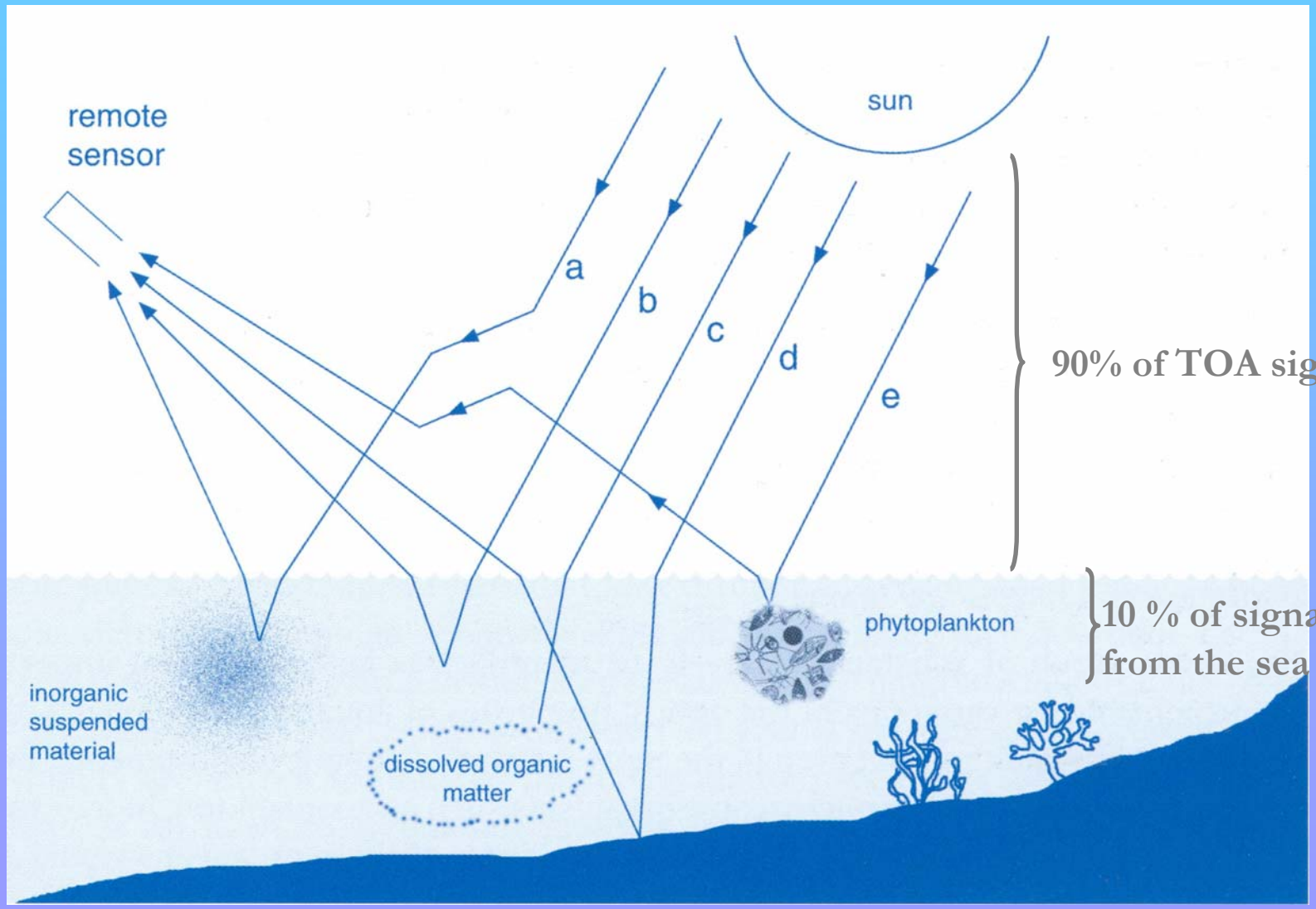
Attenuation of light in the sea



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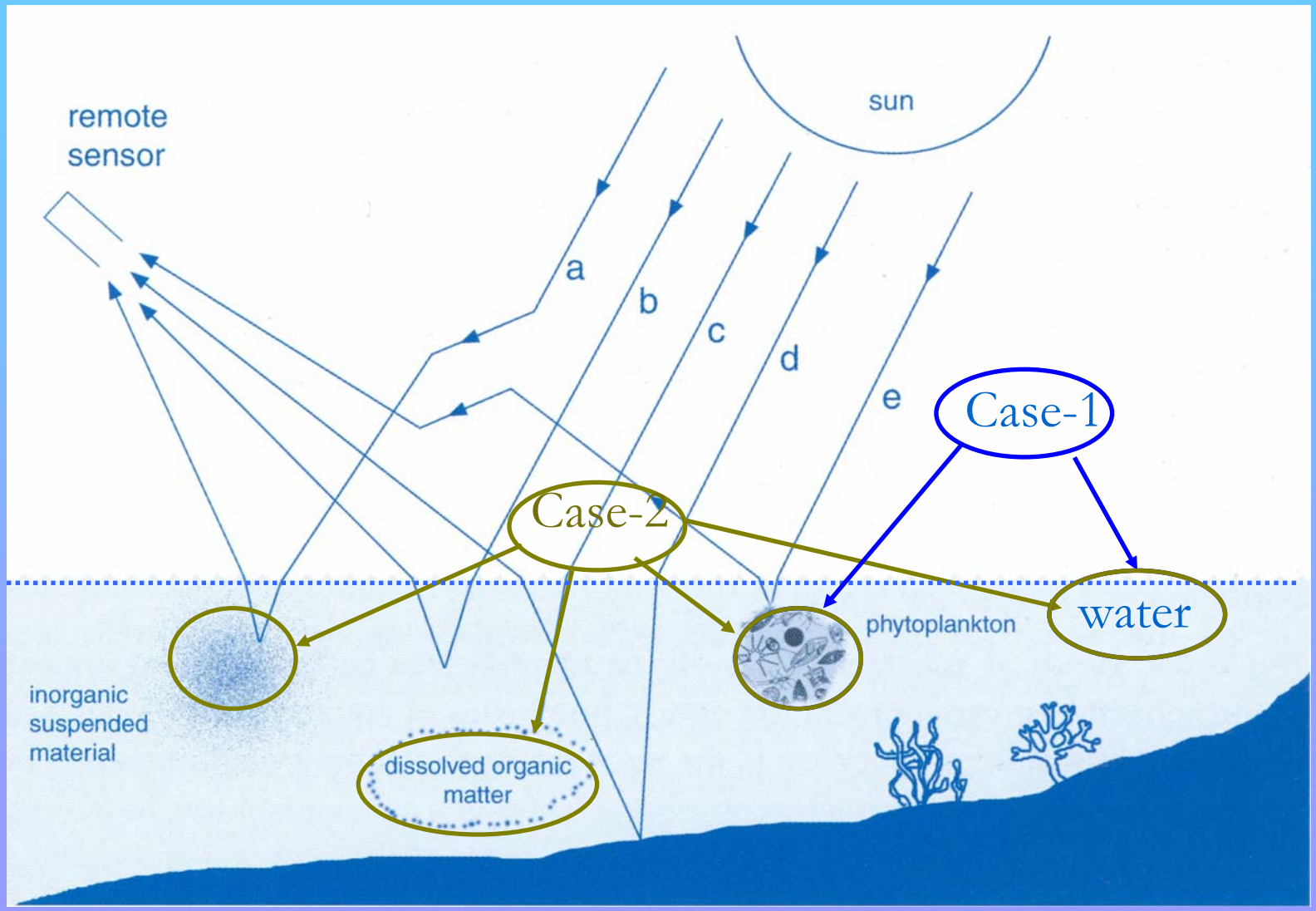
Attenuation of light



Classification: Morel and Prieur, 1977

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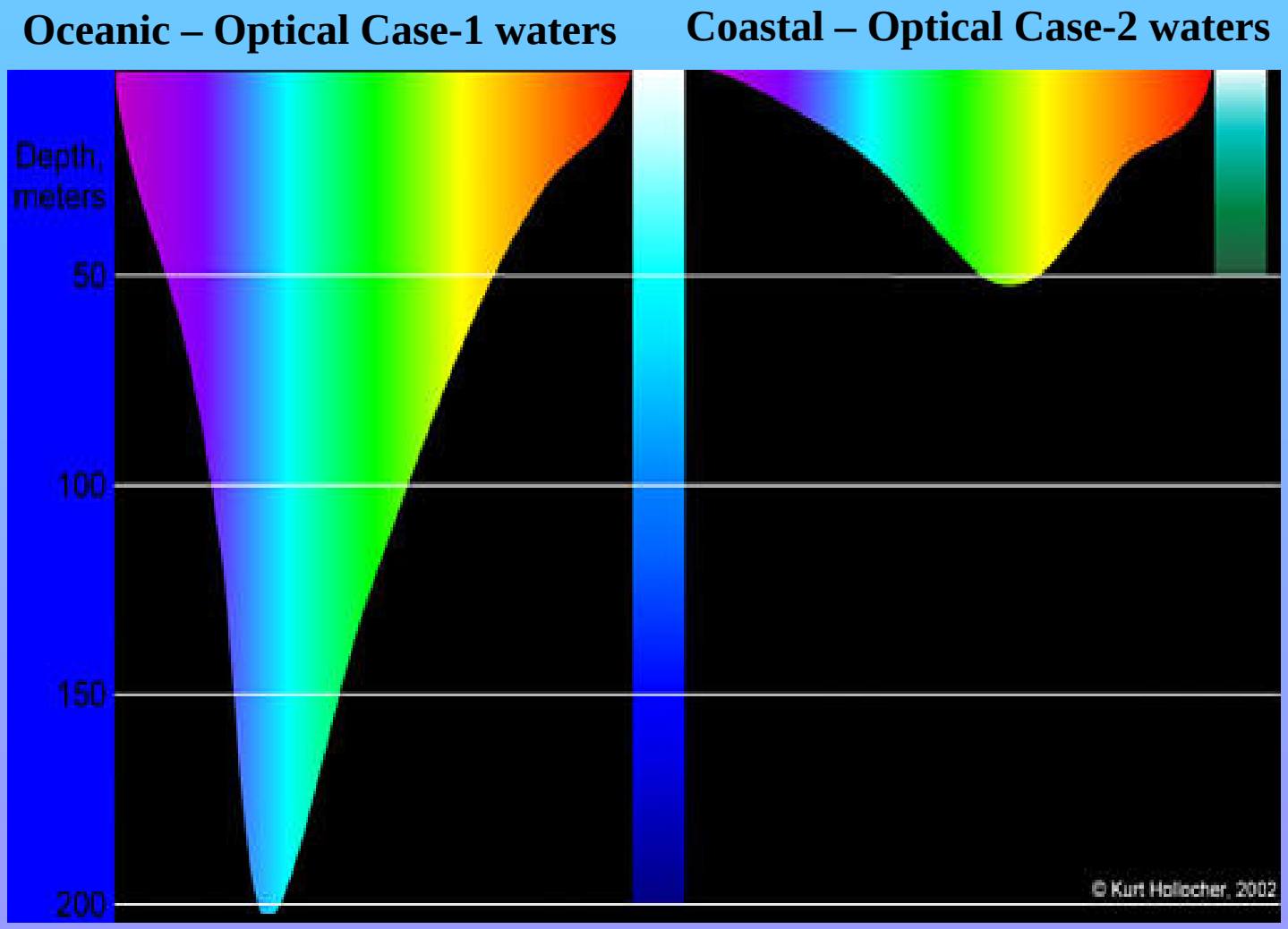
Light penetration in the open sea and in coastal waters



Kurt Holacher, 2002

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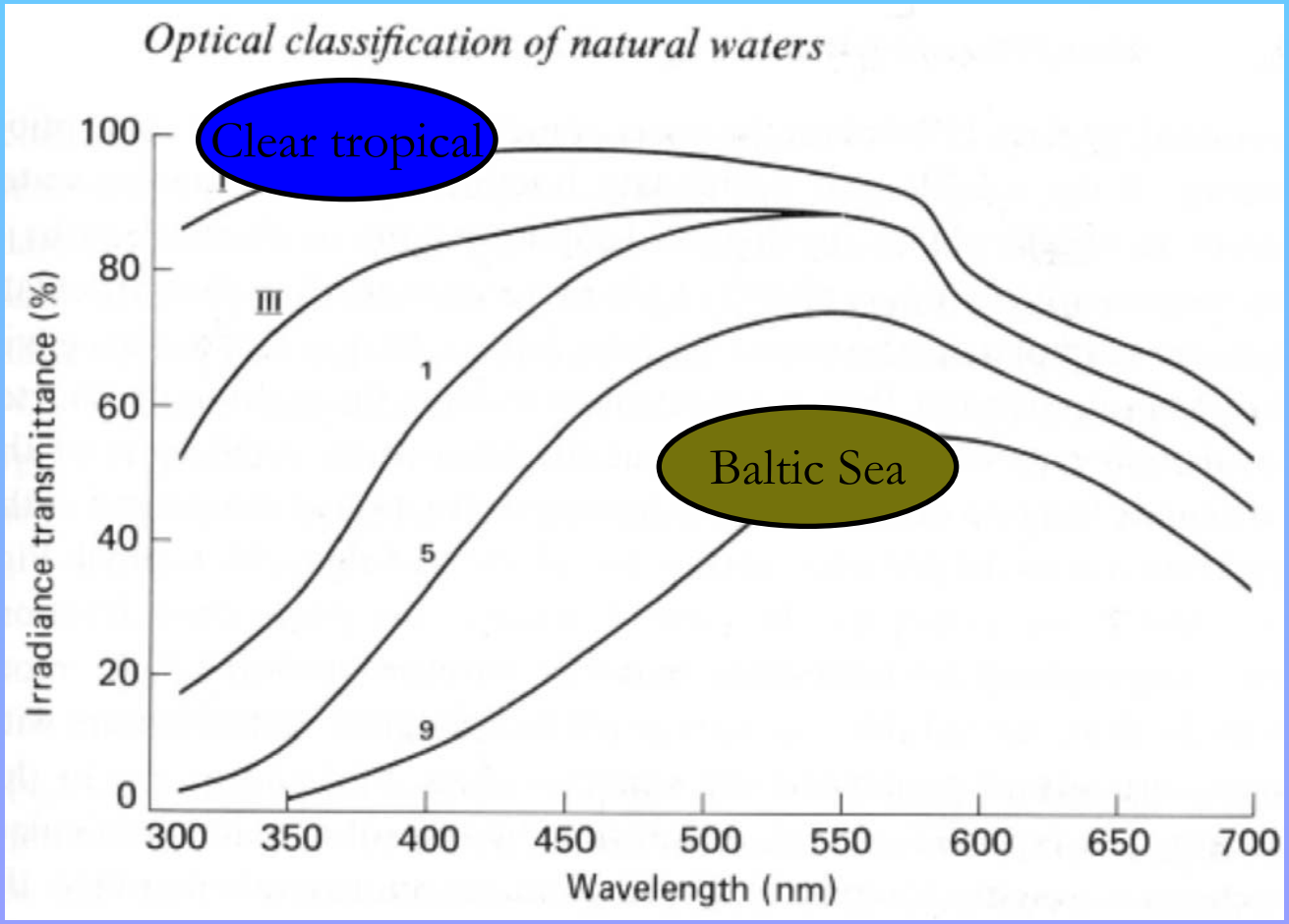
Jerlov's water mass classification



Jerlov's optical classification into the oceanic water types I-III and the coastal water types 1-9 (Jerlov, 1976).

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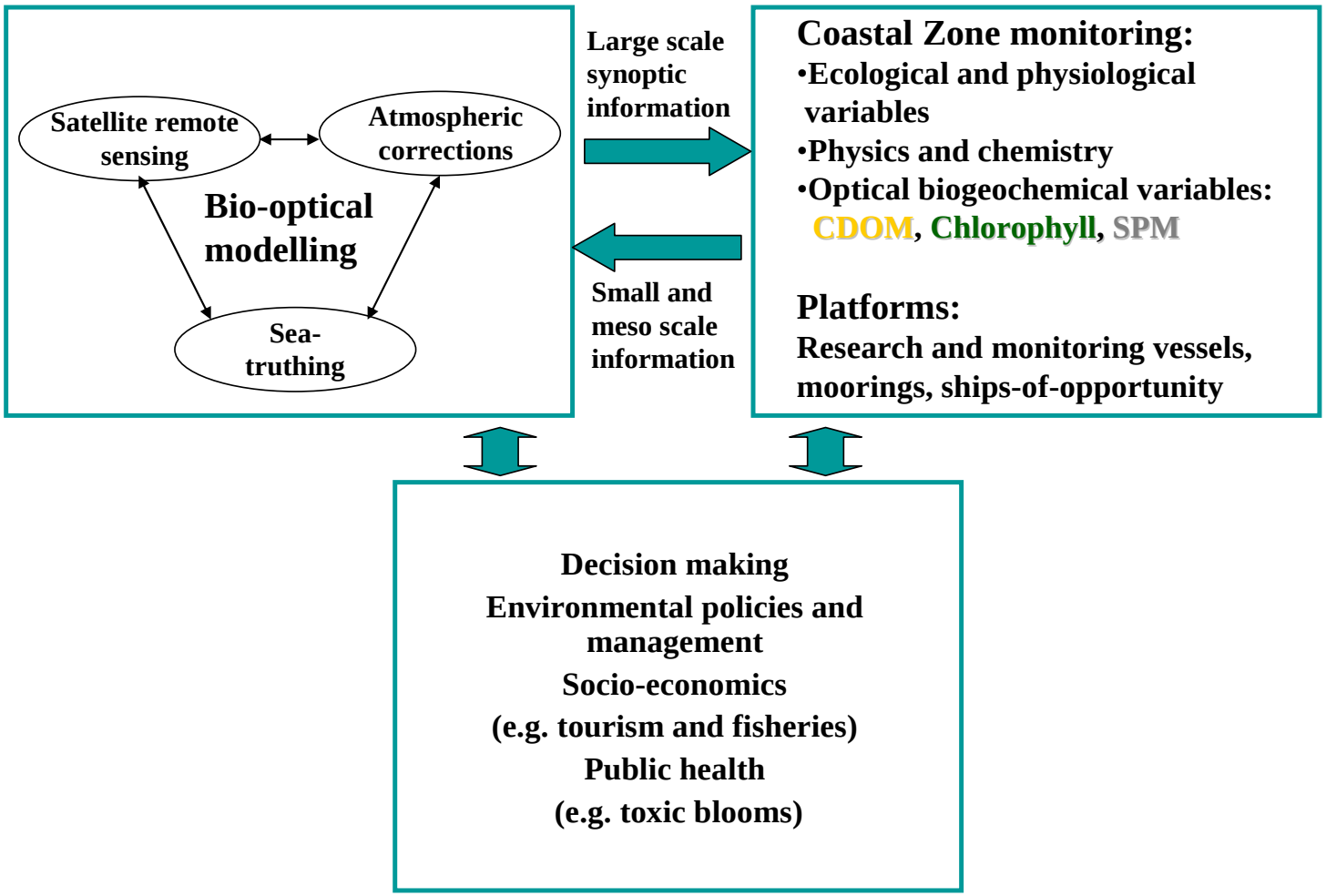
Baltic Sea remote sensing and management



from Kratzer et al, 2003

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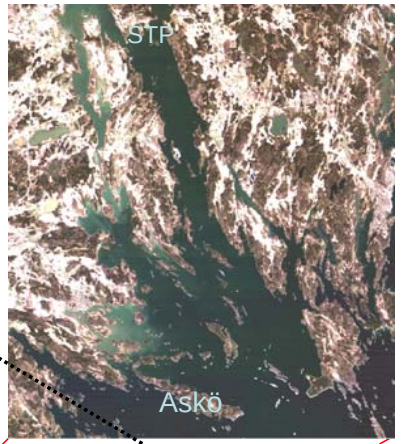
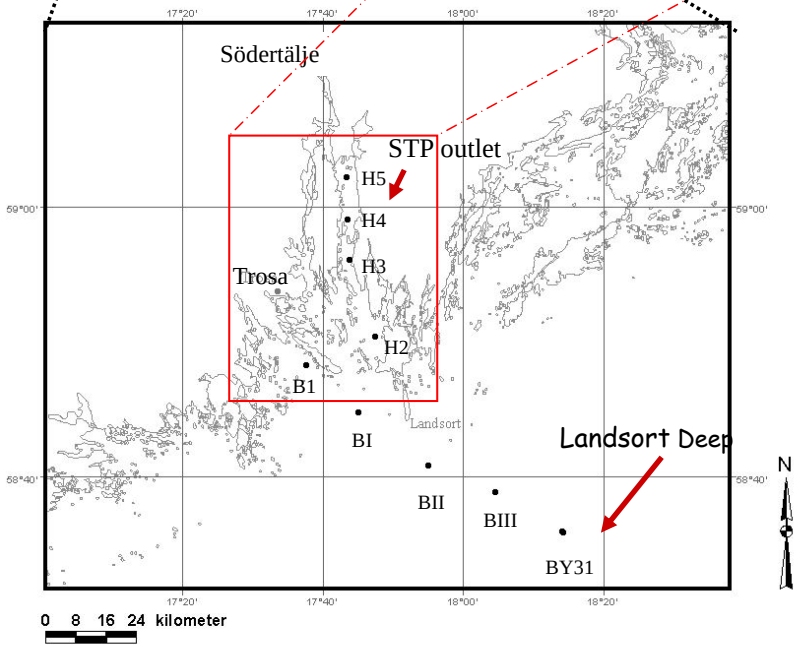
Main area of investigation:

Himmerfjärden and Open Baltic Sea

Landsat image of Himmerfjärden
5 May 1986





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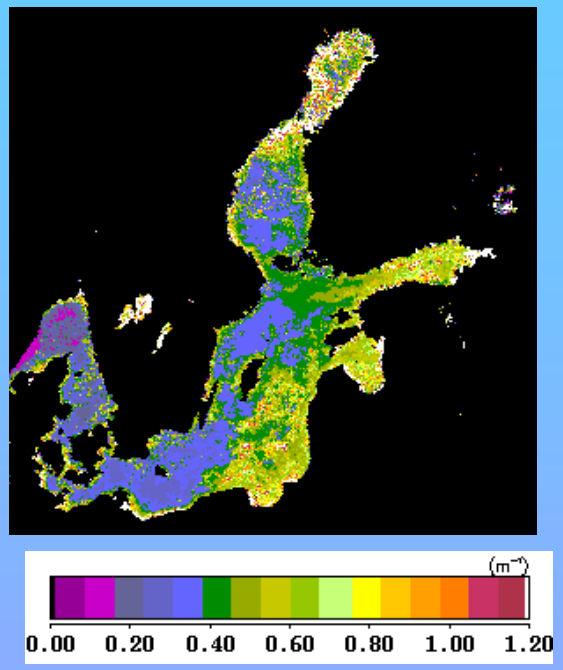
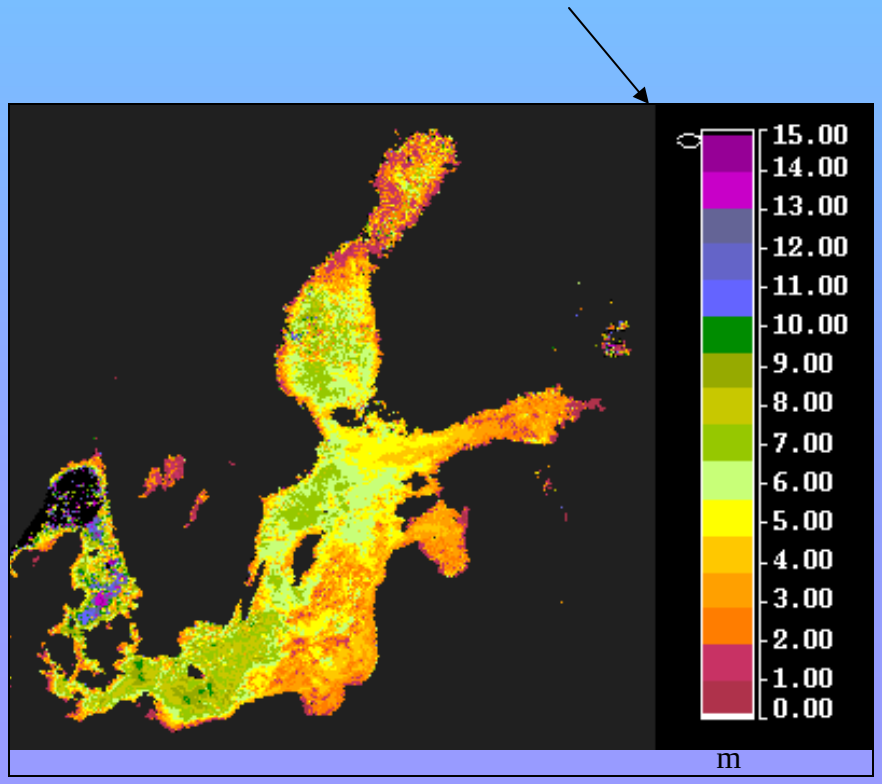
Secchi Depth map of the Baltic Sea derived from SeaWiFS (end of July/beginning of August 1999)

SeaWiFS Kd(490) image



In-water algorithm: $SD = (0.55 * K_d(490) - 0.04)^{-1}$



Kratzer *et al.* , 2003

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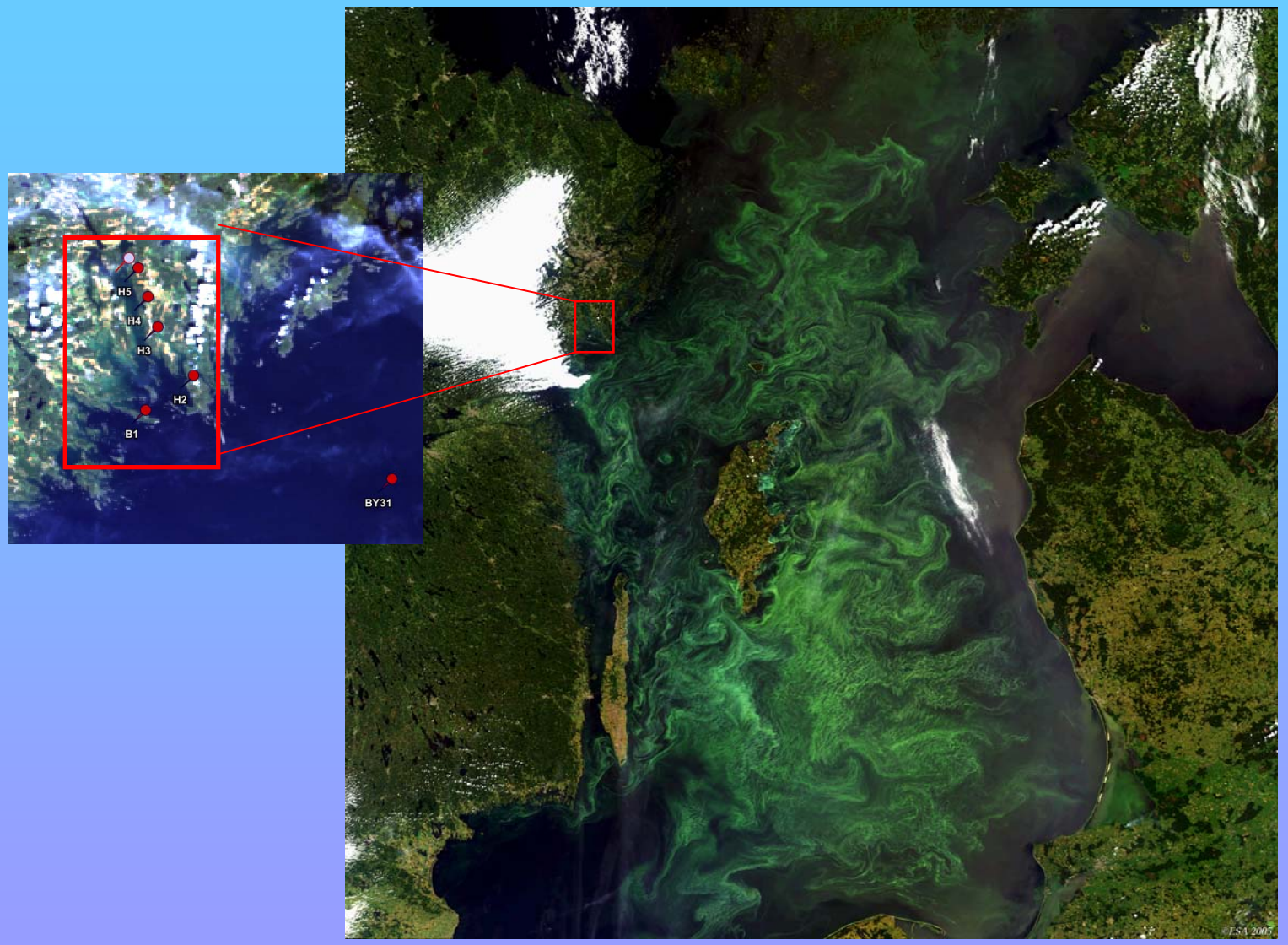

Cyanobacteria Bloom in the Baltic Sea,
MERIS FR image Date20050713_Time094518_Orbits17611, ESA

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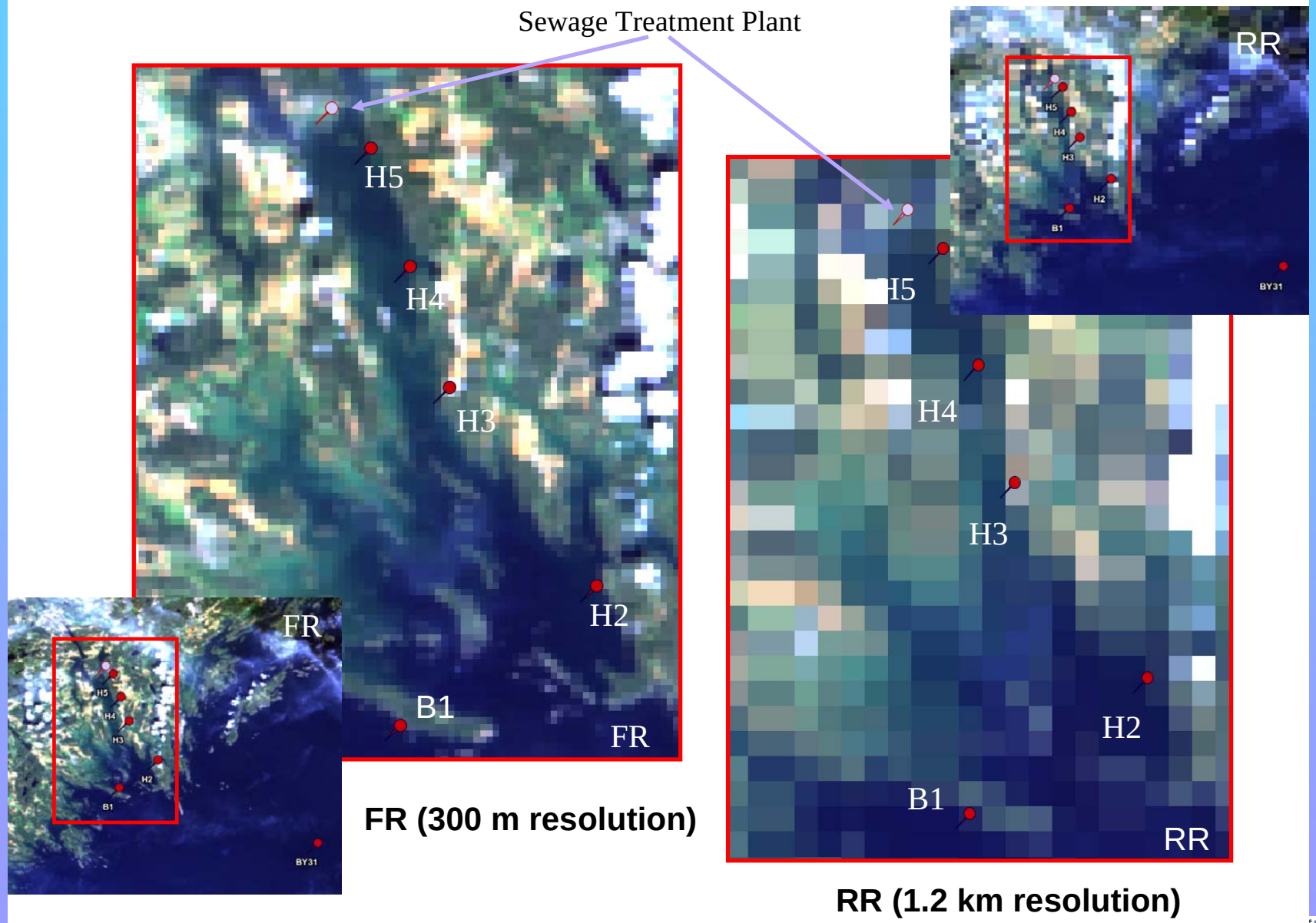

FR (300 m resolution)

RR (1.2 km resolution)

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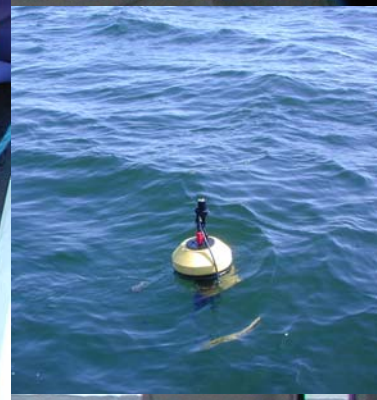
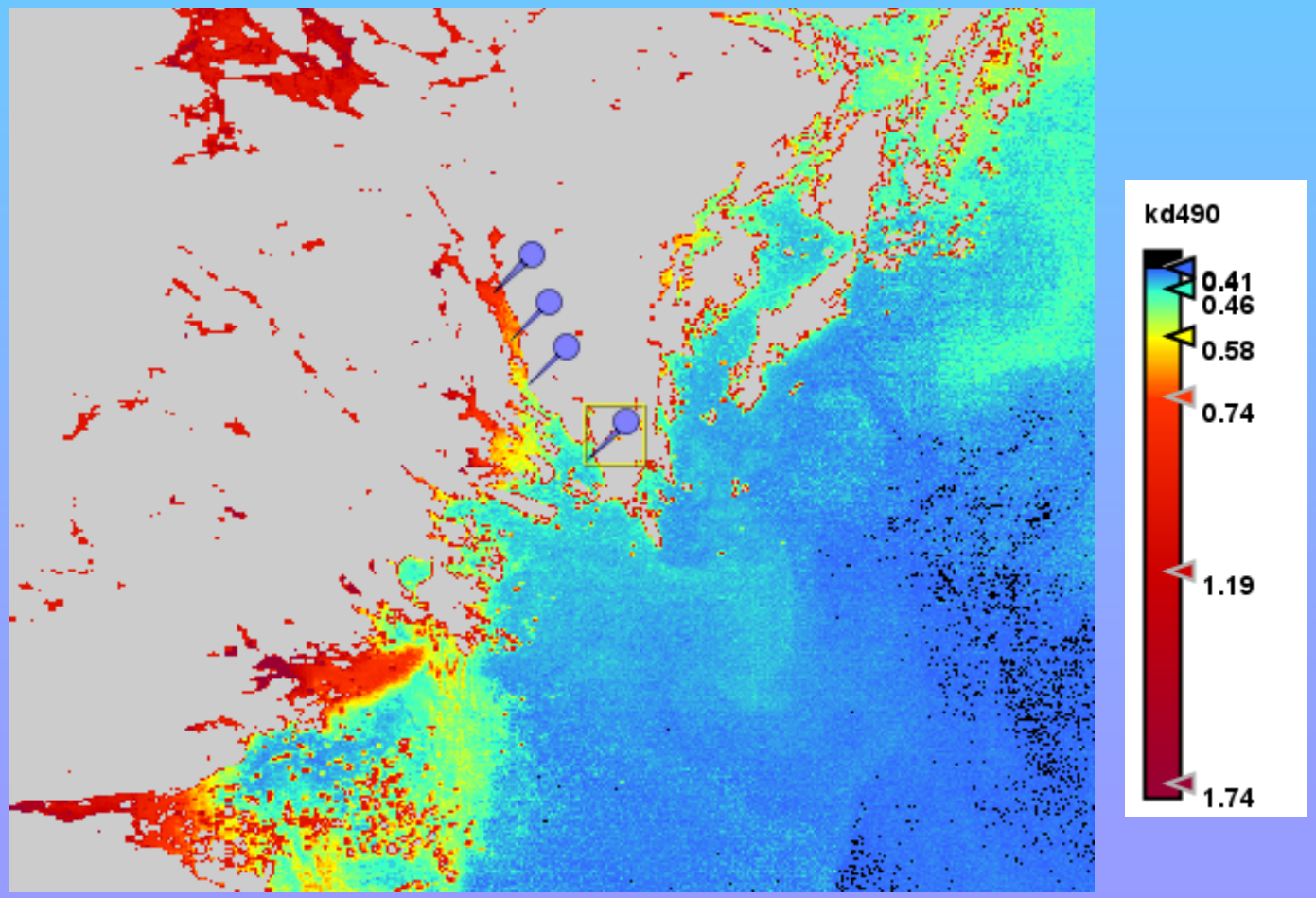
Sea-truthing onboard Limanda





Kratzer *et al*, 2008

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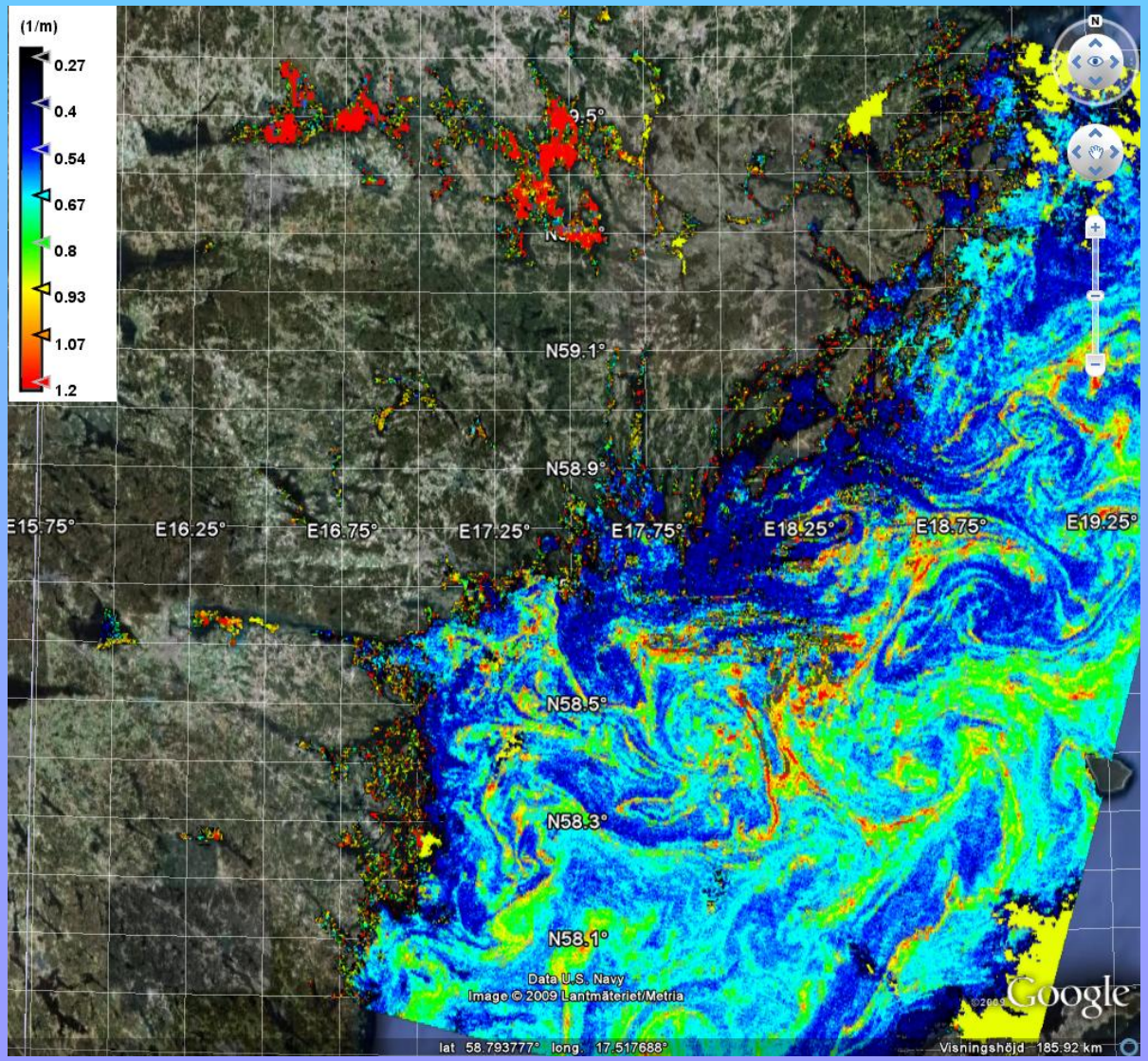
MERIS Kd490 image (300 m resolution) algorithm base on MERIS channels 3 and 6



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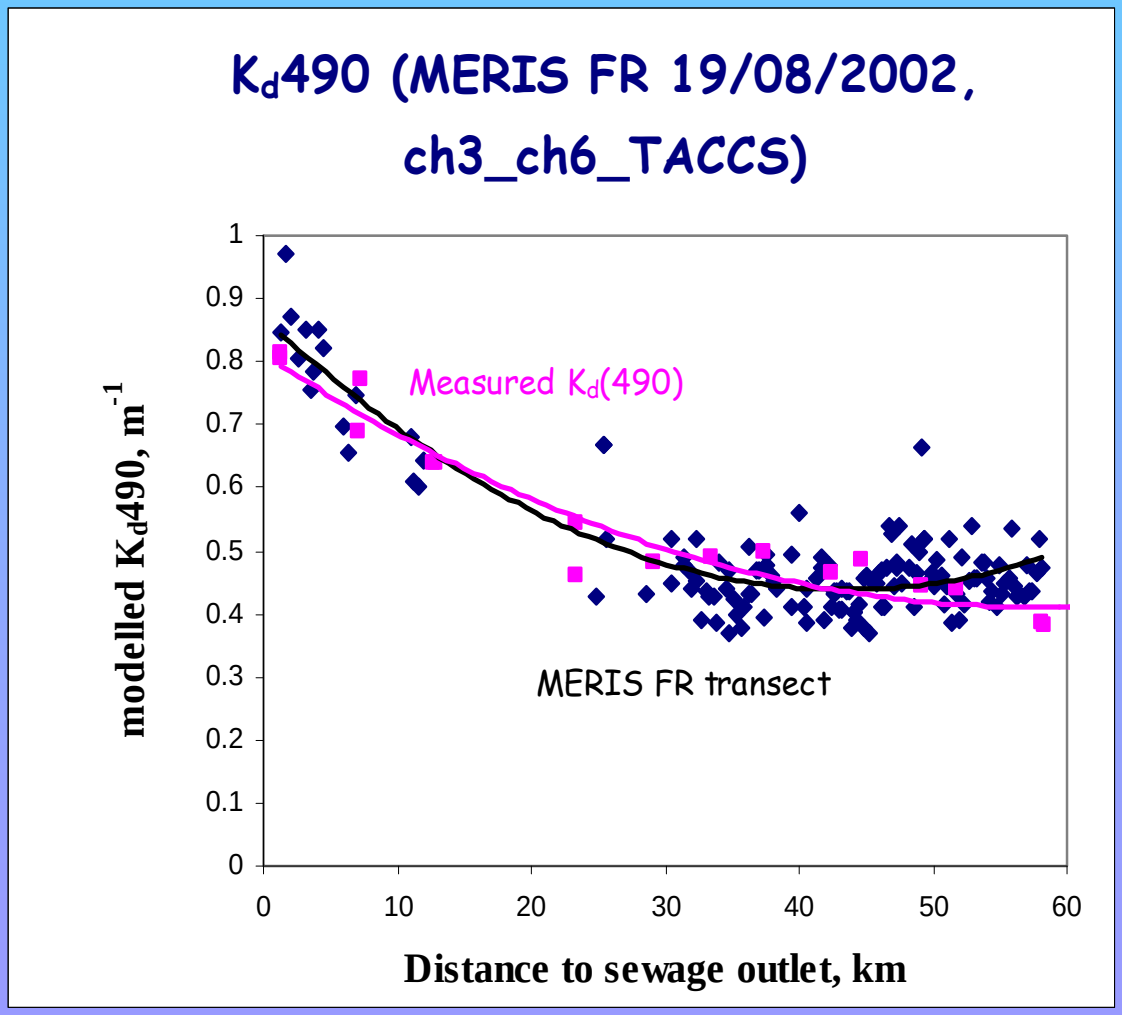
Testing K_d490 algorithm derived from MERIS against sea-truthing data



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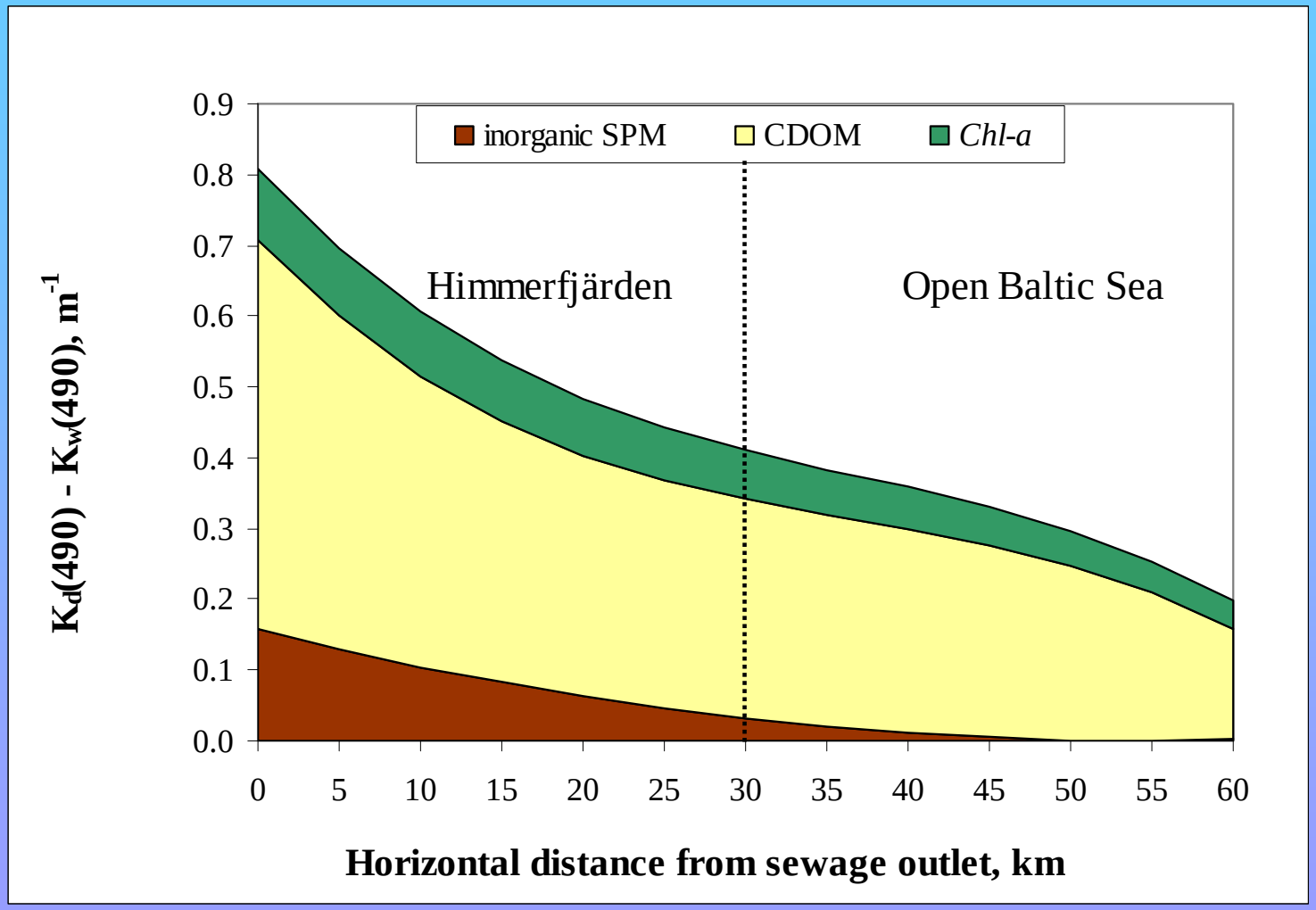
Attenuation model of the coastal zone



Contribution of each optical component to $K_d(490)$ modelled from empirical data; polynomial decline of optical components from source (land) to sink (BY31) from Kratzer and Tett, 2009.

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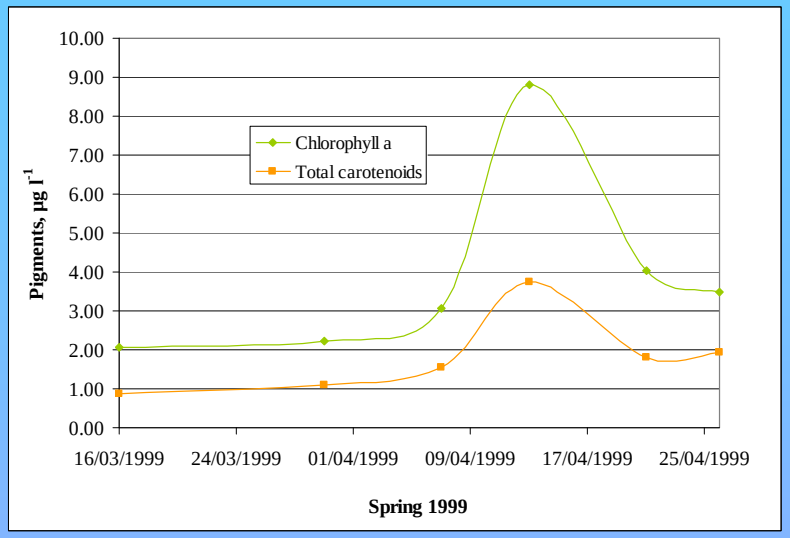
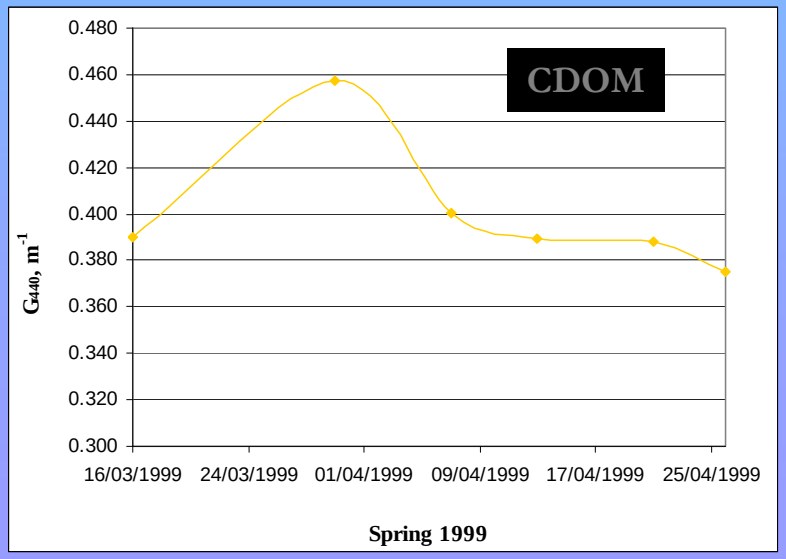
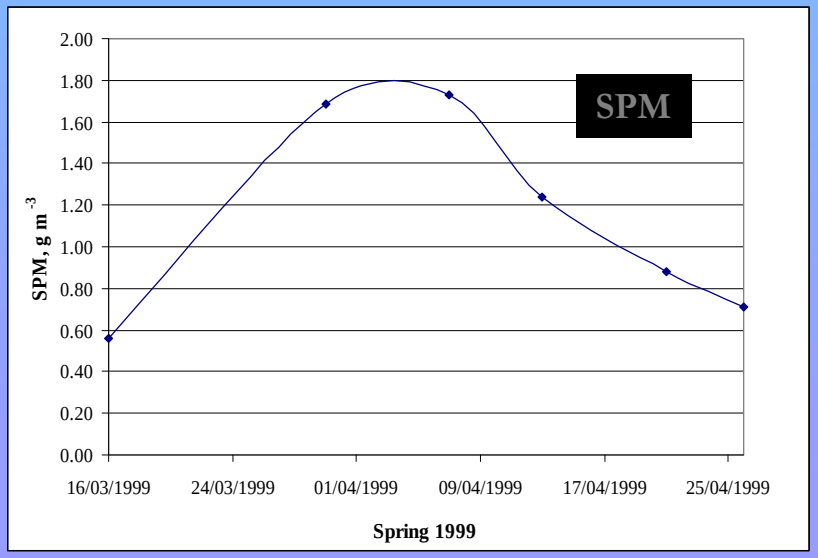
Seasonality of optical constituents- BY31 spring 1999







Kratzer, unpublished

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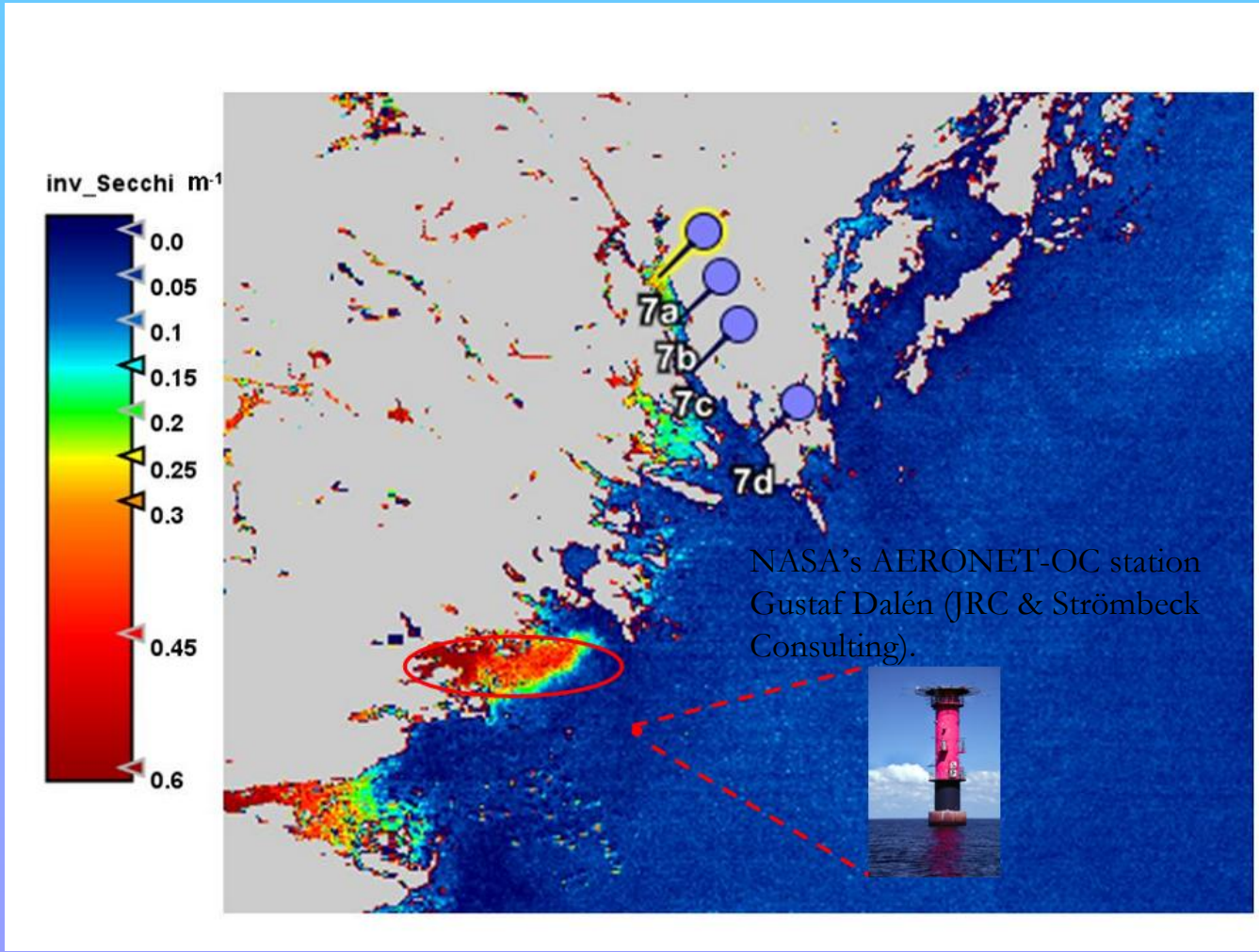
Inverted Secchi depth derived from MERIS data 19 August 2002 using a new algorithm (Kratzer *et al*., 2008)



Inverse Secchi depth (m^{-1}) map as derived from the MERIS scene from 22 August 2002, using a Secchi depth algorithm derived from sea-truthing data. Station 7a-7d in Himmerfjärden are the same as H5-H2 in the national monitoring program.

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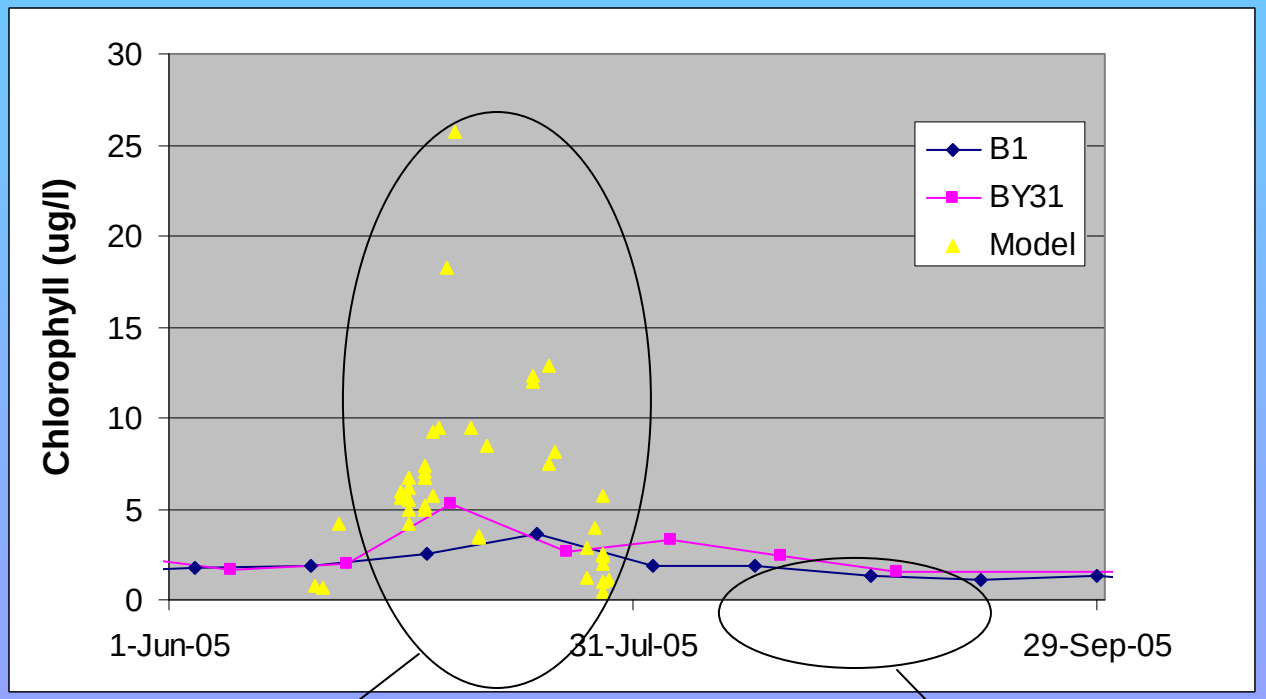
Aeronet-OC Gustav Dalén – algal bloom 2005



Experimental monitoring
(reflectance measurements
on Gustav Dalén)

Regular monitoring data
(point sampling, monthly means)

Courtesy Niklas Strömbeck

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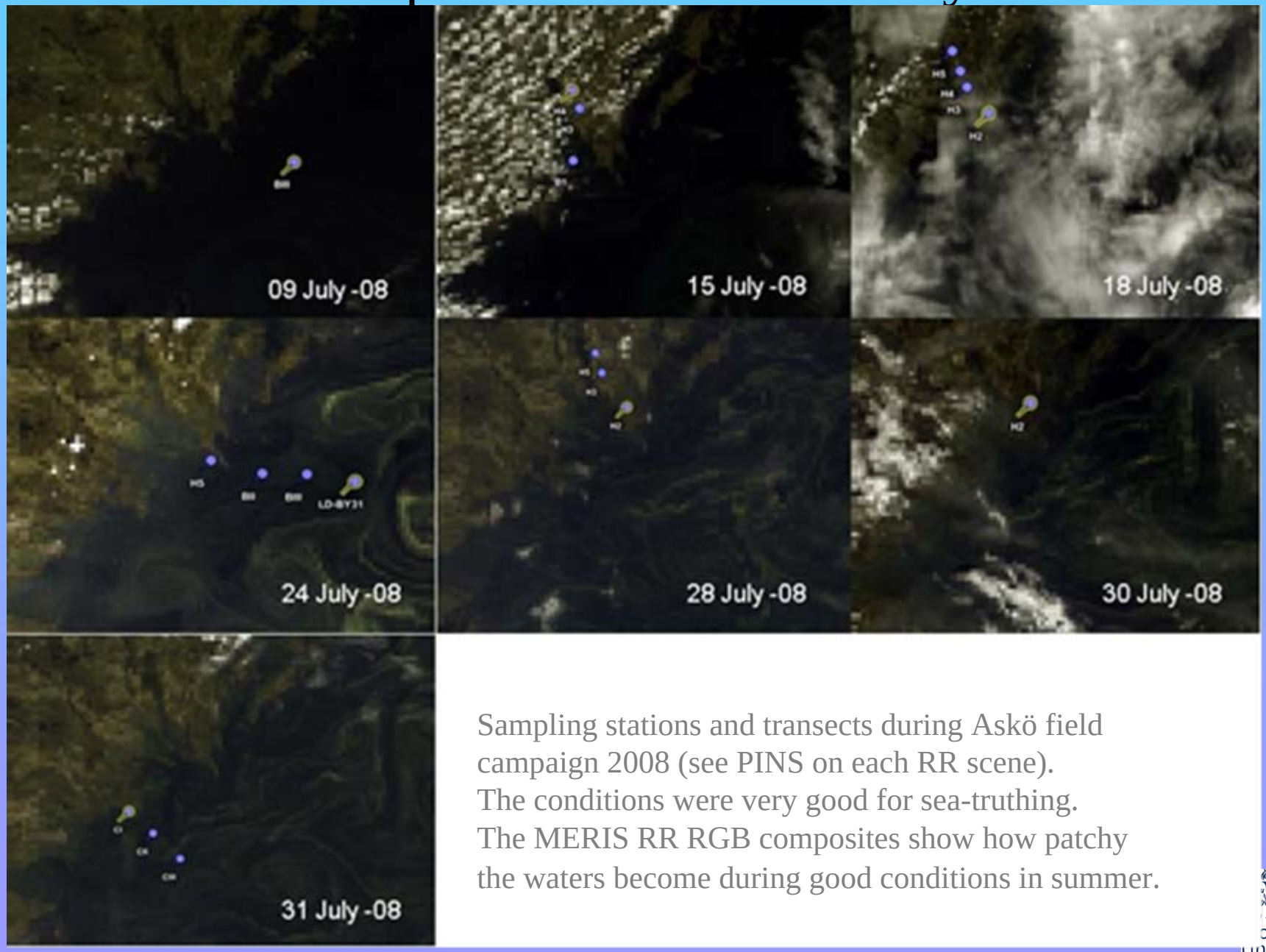
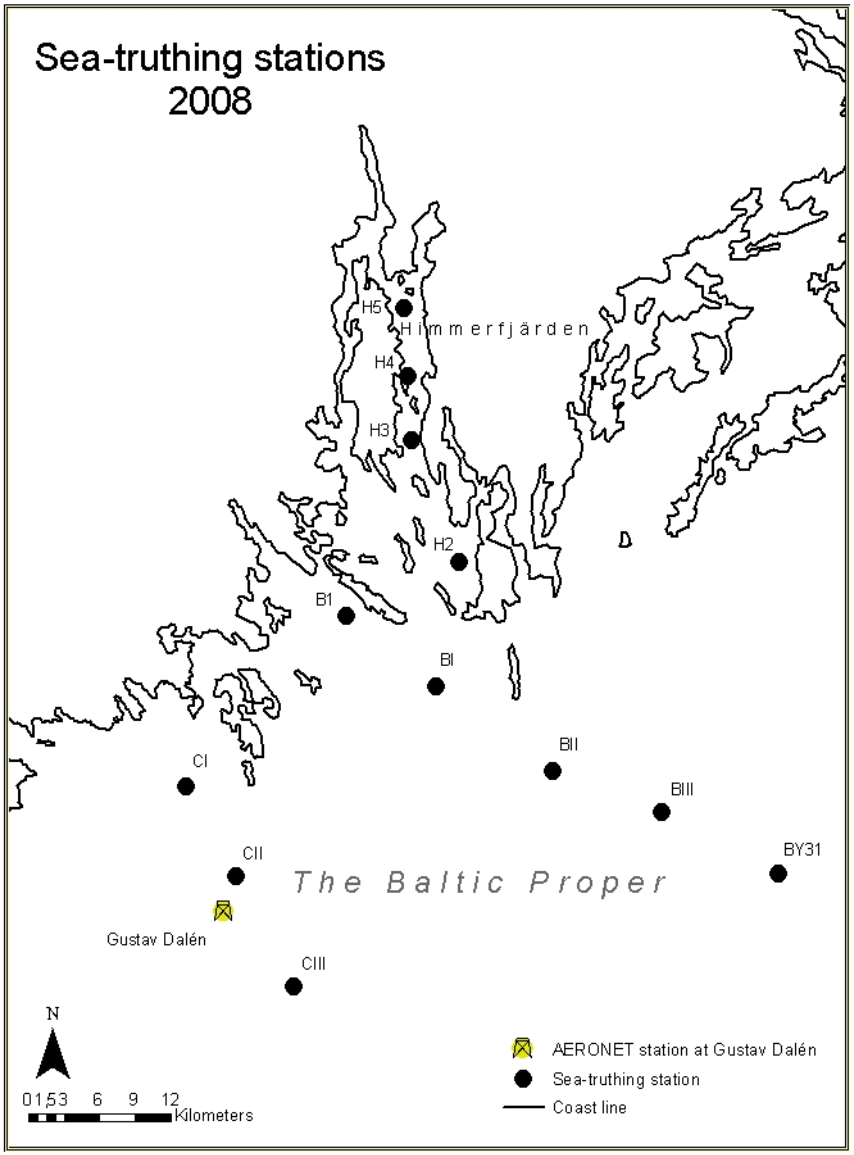
Match-ups NW Baltic Sea July 2008



Sampling stations and transects during Askö field campaign 2008 (see PINS on each RR scene).
The conditions were very good for sea-truthing.
The MERIS RR RGB composites show how patchy the waters become during good conditions in summer.



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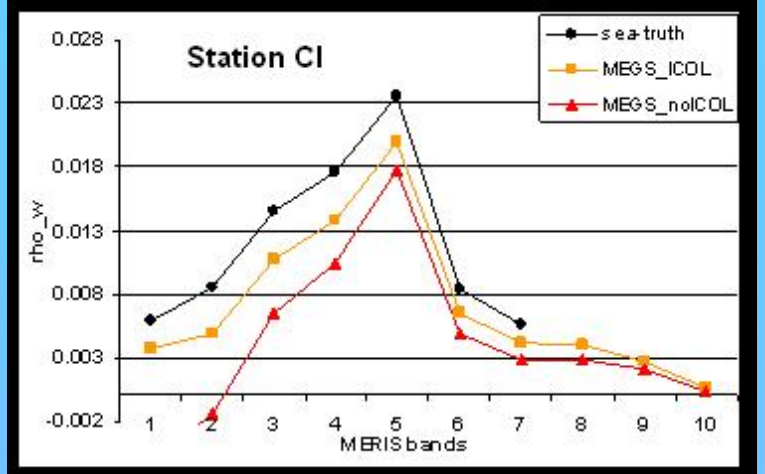
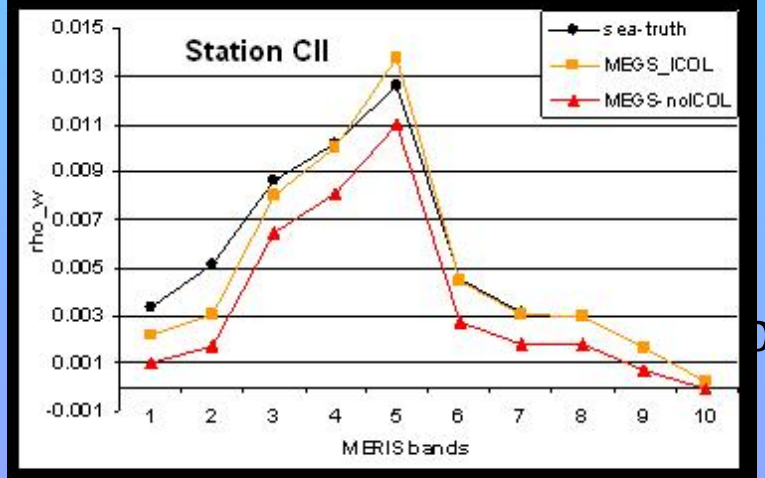
MERIS FR image 31 July 2008

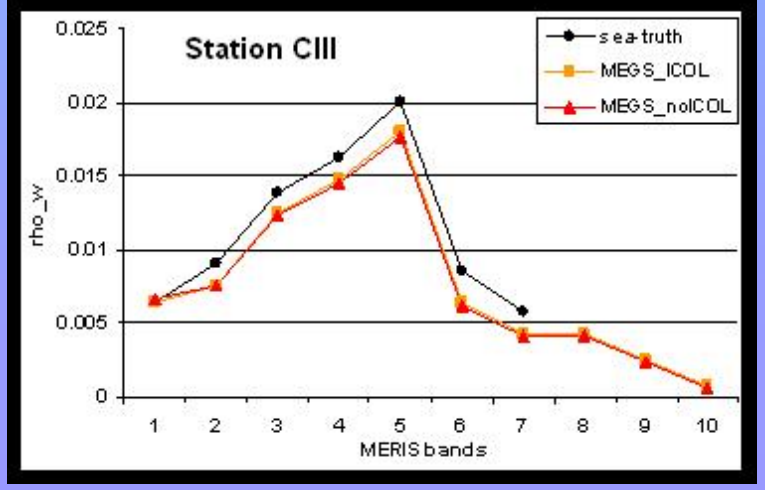
Sea-truthing @ STN CI-CII-CIII

(30 km long transect)

Gustav Dalén light house close to CII







Testing ICOL processor

MERIS RR data,
transect on 31 July 2008
near Gustaf Dahlén light house

both ICOL and non-ICOL processed and compared
to the sea-truthing data.

Processing: Christian Vinterhav;
MEGS processing by Gerald Moore

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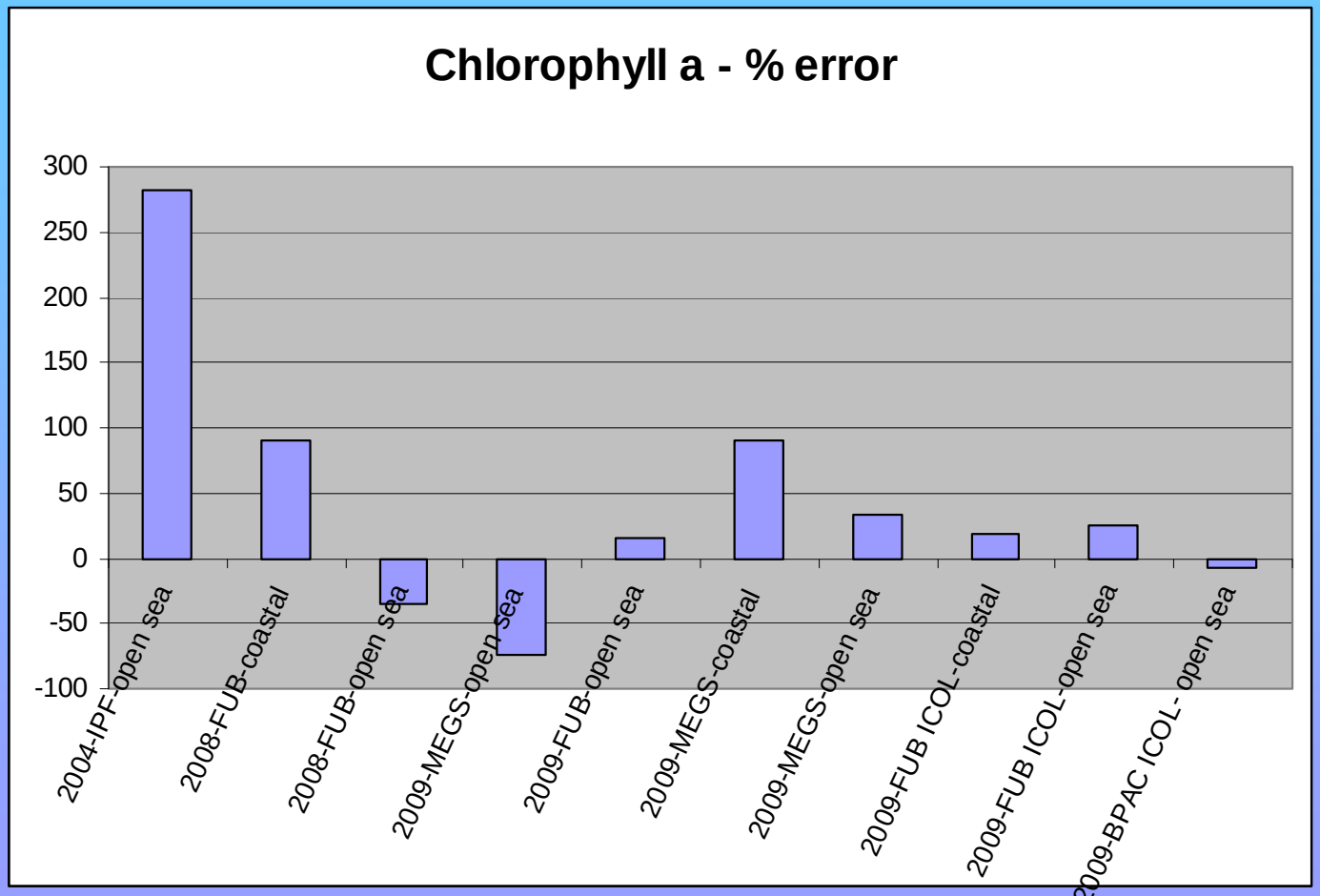
Improvement of MERIS processors 2004-2009



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Optical variables as indicators of ecosystem state

- Humic substances (CDOM): terrestrial inputs of freshwater,
- suspended particulate inorganic matter (SPIM): land drainage and wind-stirring in shallow waters,
- and phytoplankton pigments: productive status of the pelagic ecosystem, influenced by anthropogenic nutrients from land

(Kratzer and Tett, 2009)

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From research to applications -Development and quality assurance of an operational monitoring system

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Vattenkvalitet.se

...från forskning till fungerande tillämpning

Petra Philipson – Vattenfall Power Consultant AB

VATTENFALL

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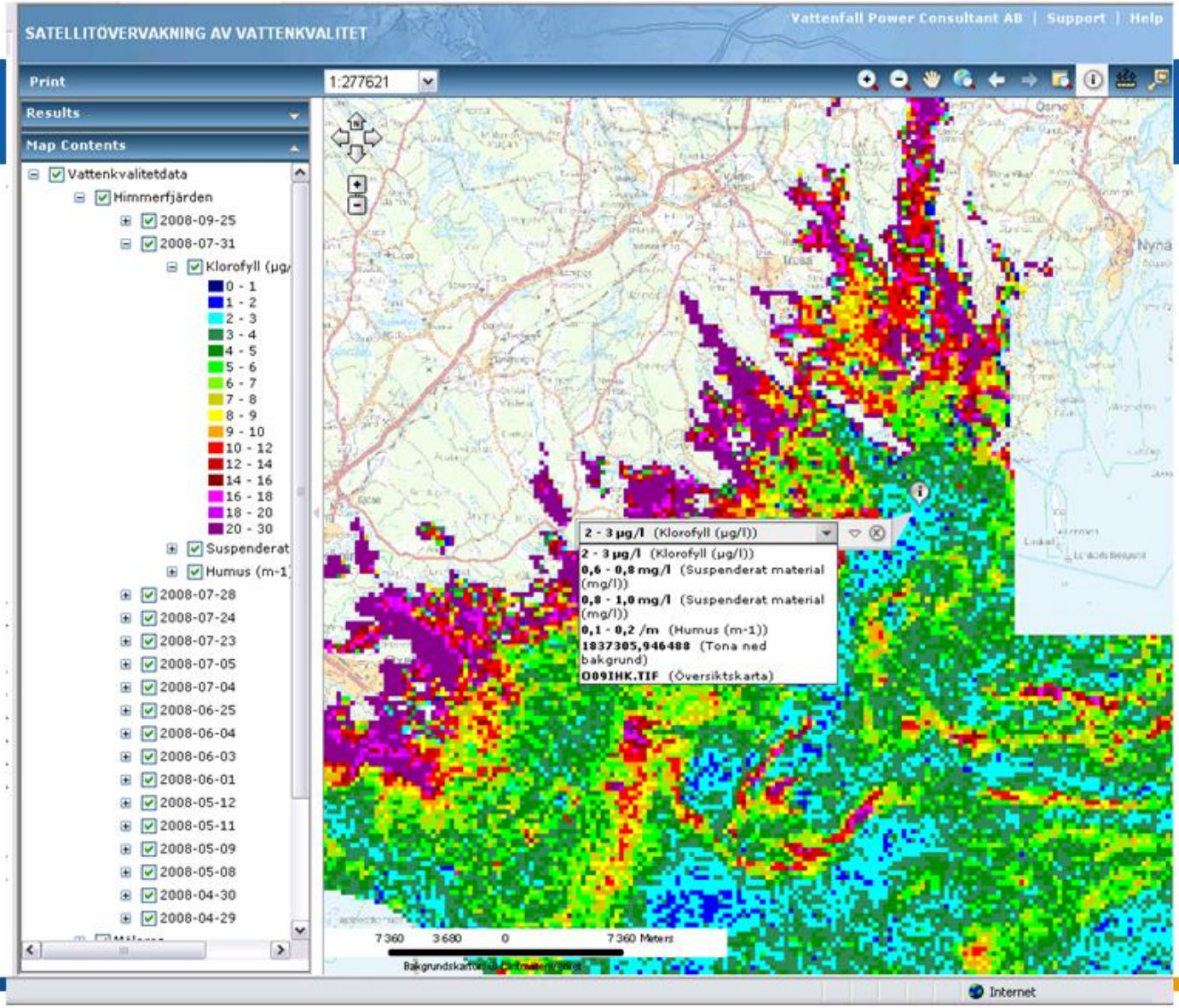

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User consultation meetings

- Vattenfall Power Consultant's user group
- EU FP6 SPICOSA stakeholder group
- Himmerfjärden nitrogen study reference group

- Direct contact to user, feed-back on what can be improved; need to develop user friendly products
- Problem: many users are not familiar with the method- many perceive the topic as 'too technical'

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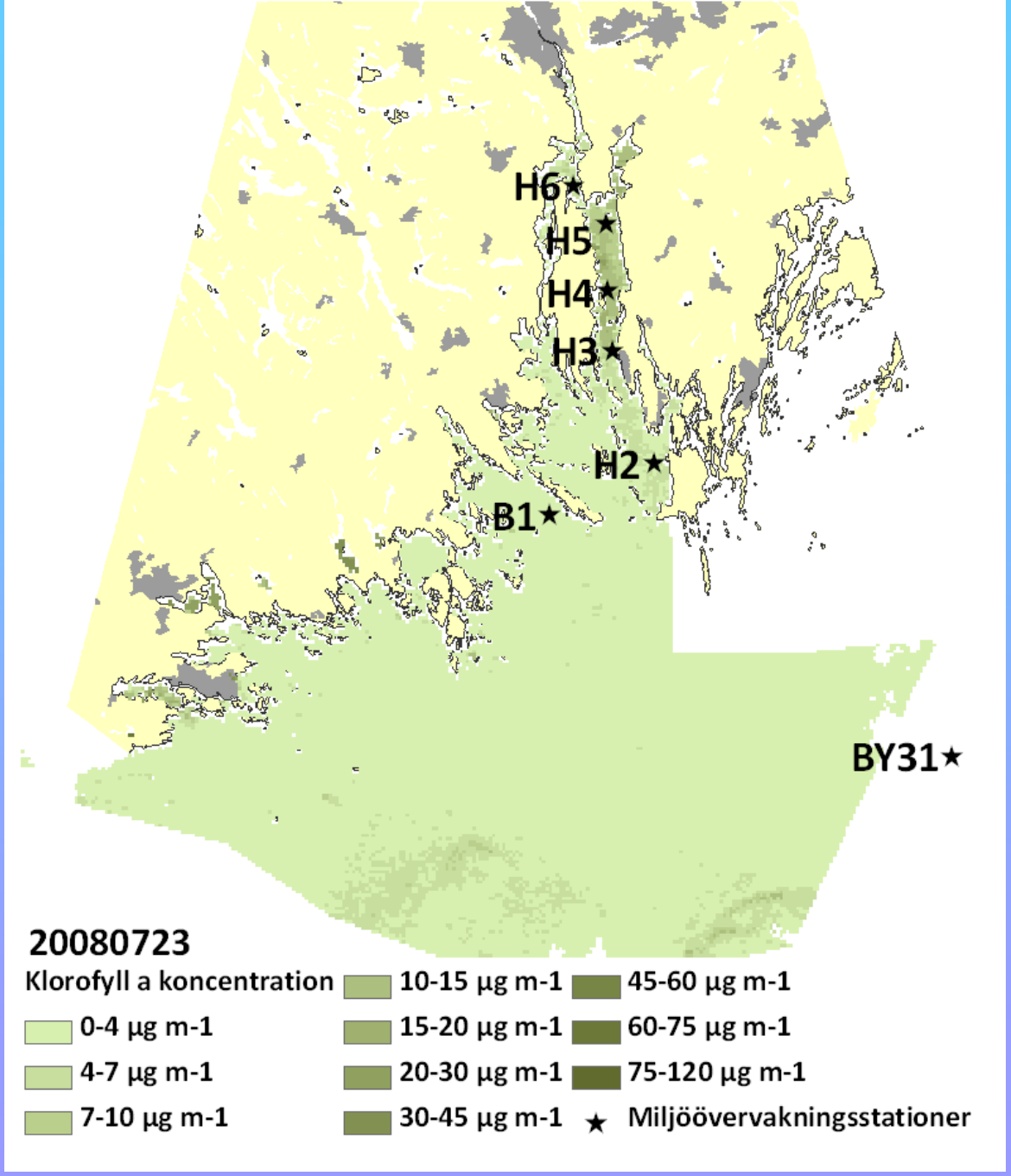

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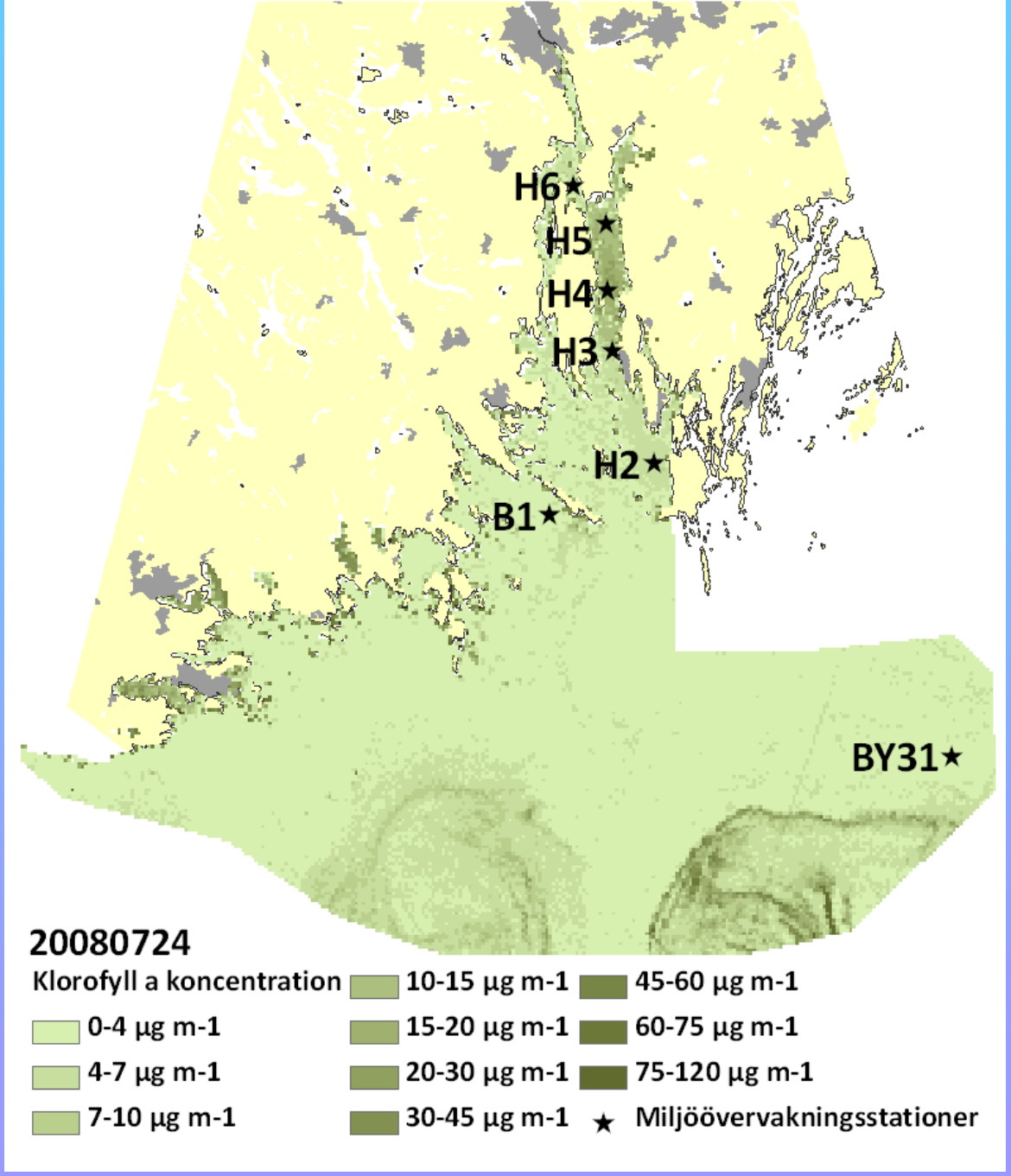

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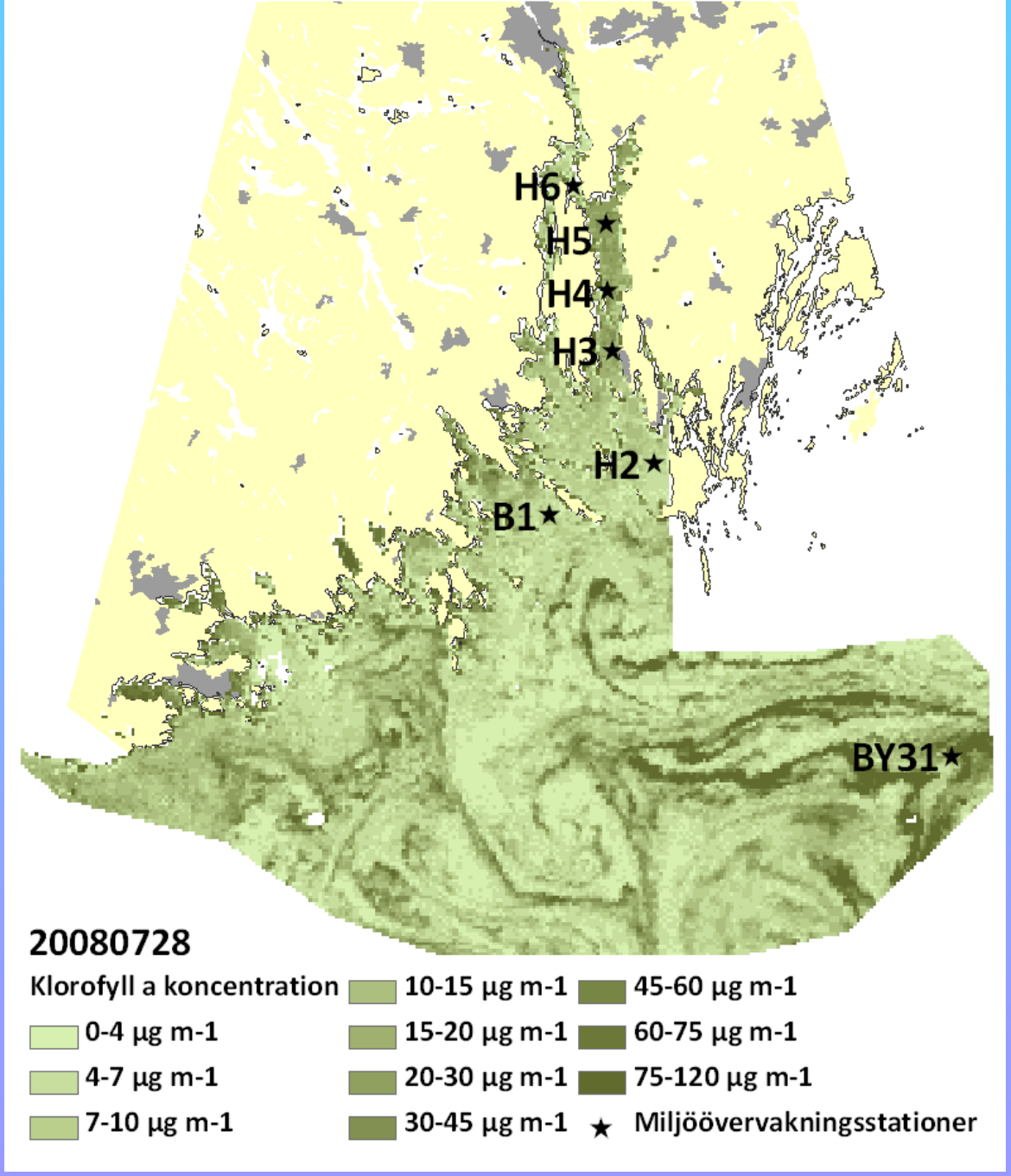

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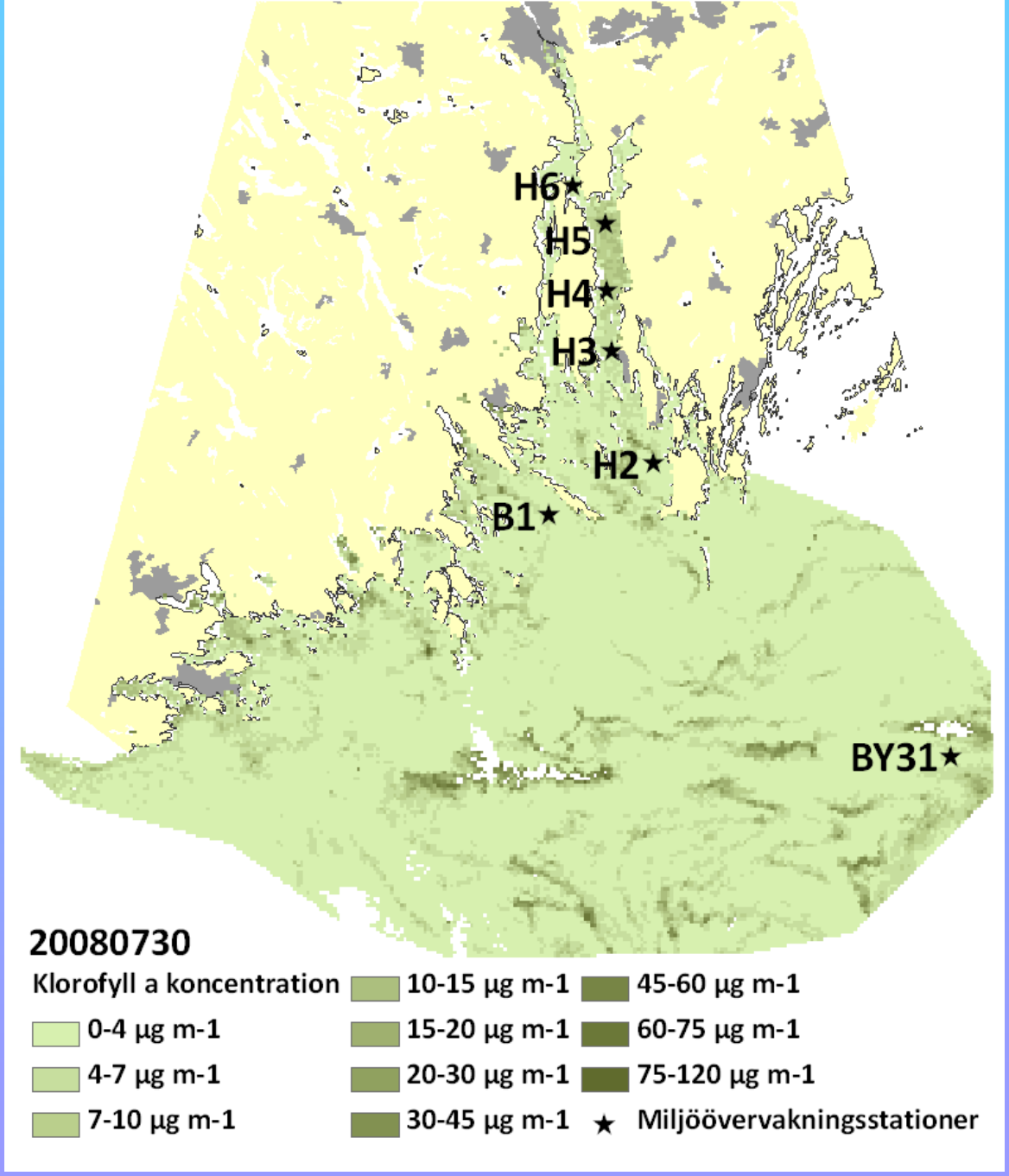

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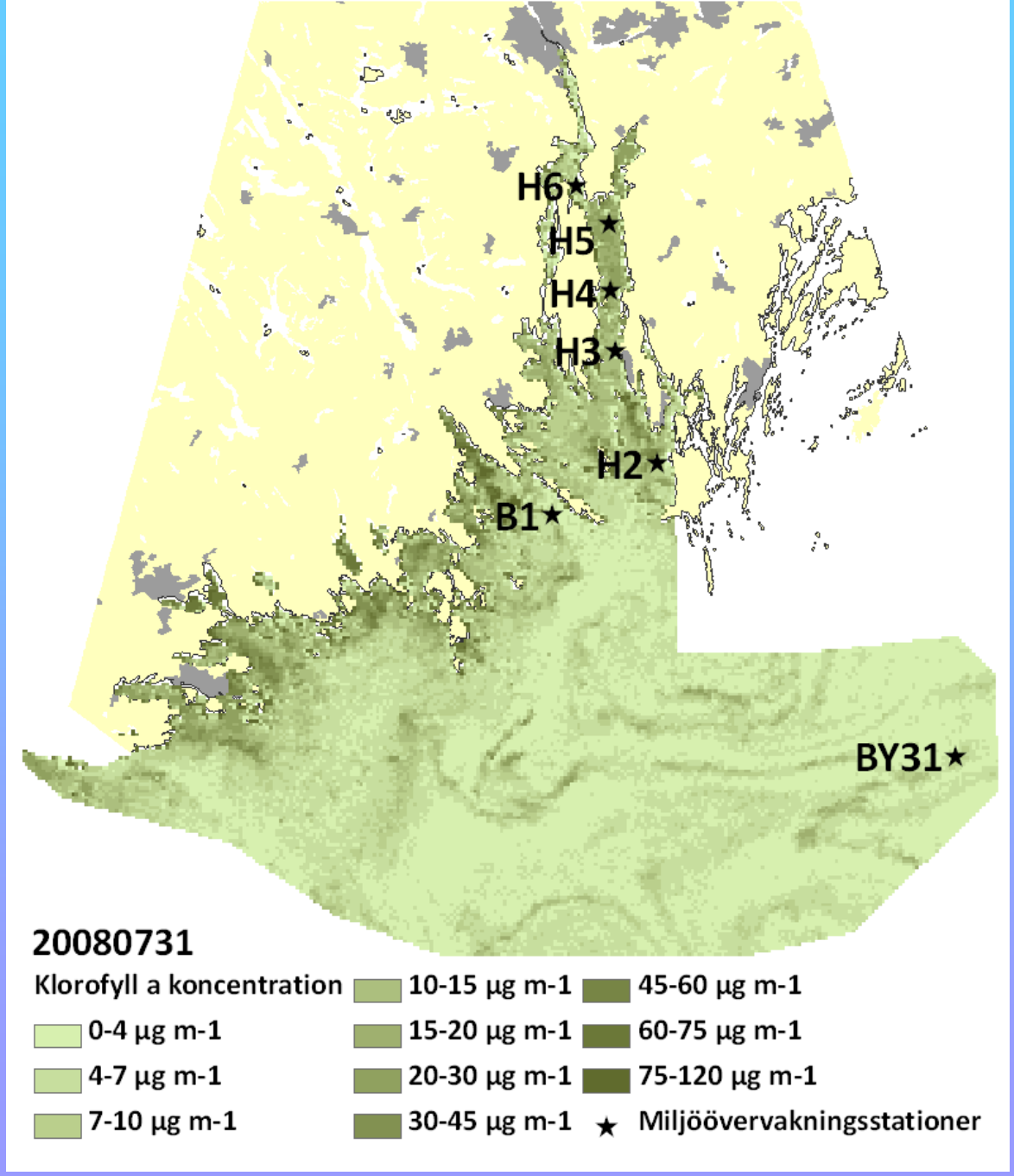

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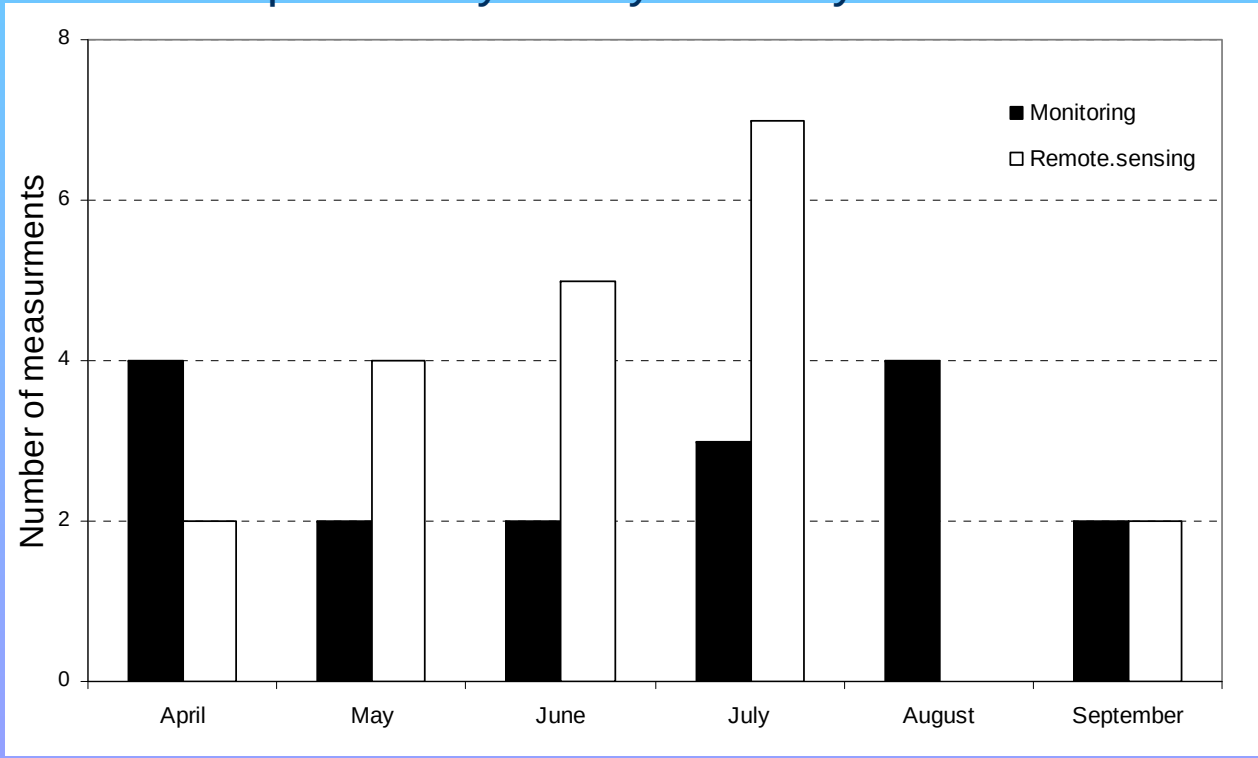
Temporal resolution in Hf area 2008

Measurements between April and September
MERIS passes by every 2-3 day



Regular cruises by monitoring vessels: 17
Remote sensing by MERIS: 20
Total set of chlorophyll a measurements: 37

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How representative is the satellite-derived chlorophyll-*a* product?

- In the inner fjord chlorophyll *a* concentrations are overestimated by 91 %.
- In open Sea and the outer basin of Himmerfjärden the Chlorophyll *a* concentrations is overestimated by 25 %.

  (Kratzer and Vinterhav, 2010)
- Correct for this in the *chl-a* estimates

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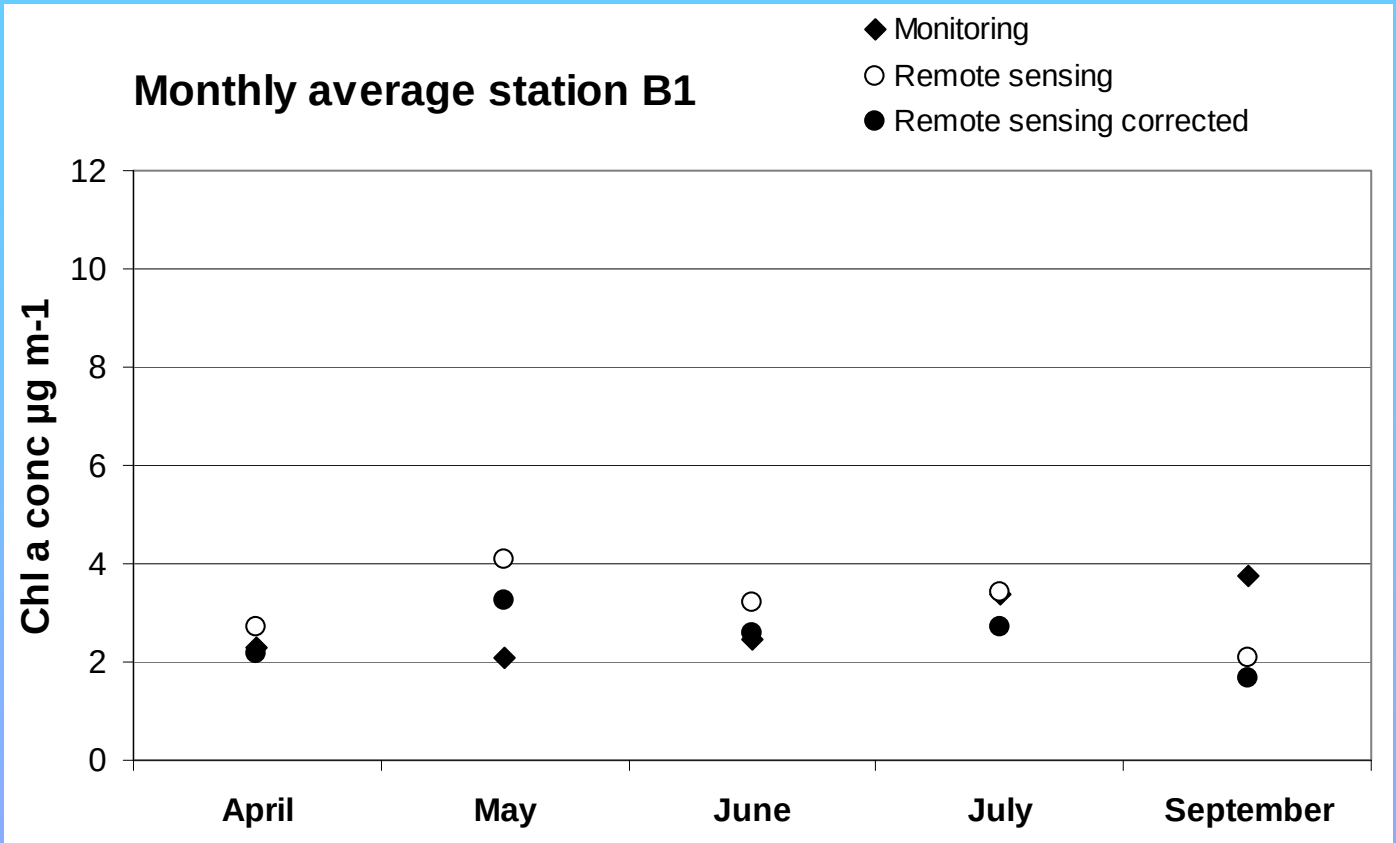
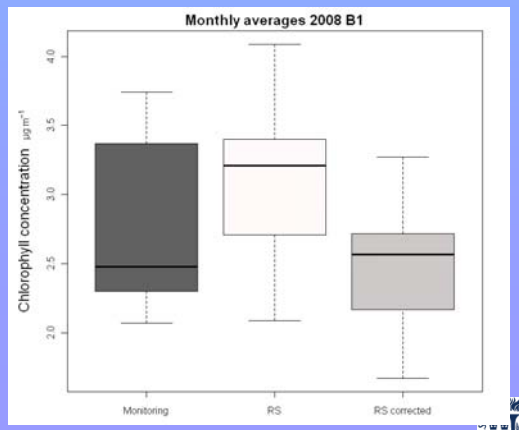


Paired t-test	Monitoring	Df	p-value
Remote sensing at B1	n.s	4	0.63
Remote sensing at B1 corrected	n.s	4	0.59



Therese Arredal Harvey, PhD student

Stockholm University

Summary

- MERIS provides us with a new tool to assess coastal systems from space
- Indicators for eutrophication, e.g. *chl-a* and Secchi depth, can be derived from space reliably (if data is validated)
- *Chl-a* concentrations from remote sensing not significantly different from conventional monitoring data
- Remote sensing data provides improve spatial and temporal resolution
- Together with Vattenfall Power Consultant we have developed a user-friendly operational system
- Continuation of operational system by joining GMES MarCoast downstream services for 2010-2012
- Aeronet-OC stations both for validation of satellite data and for providing local continuous time series
- Continuation of MERIS mission through Sentinel-3 (ocean colour sensor OLCI and SST / (A)ATSR) through 2023

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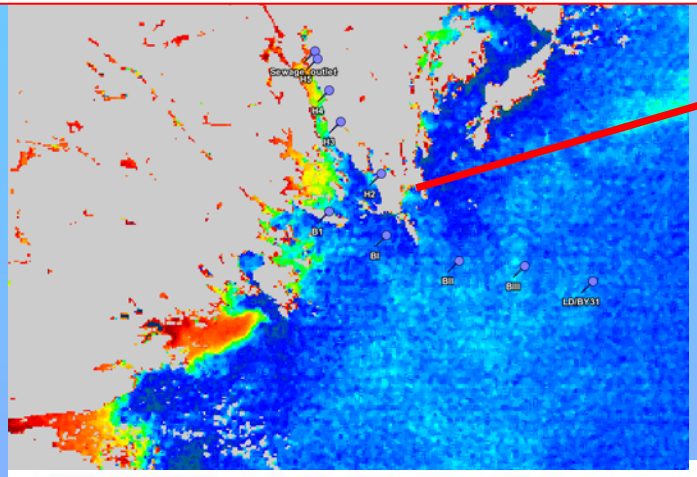
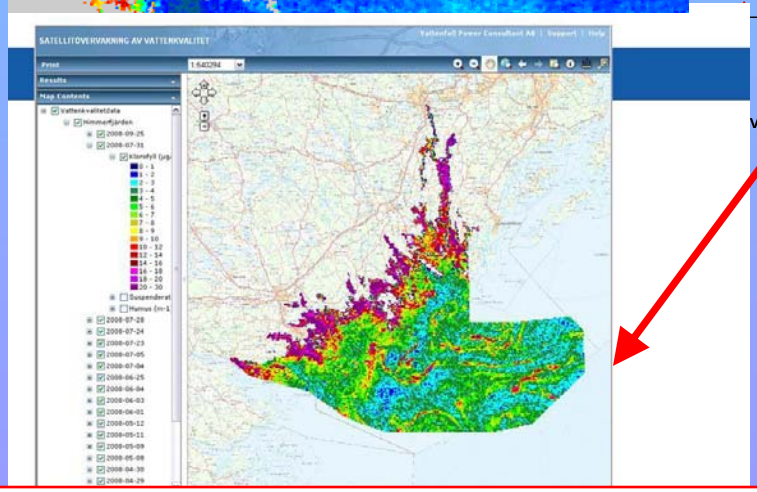
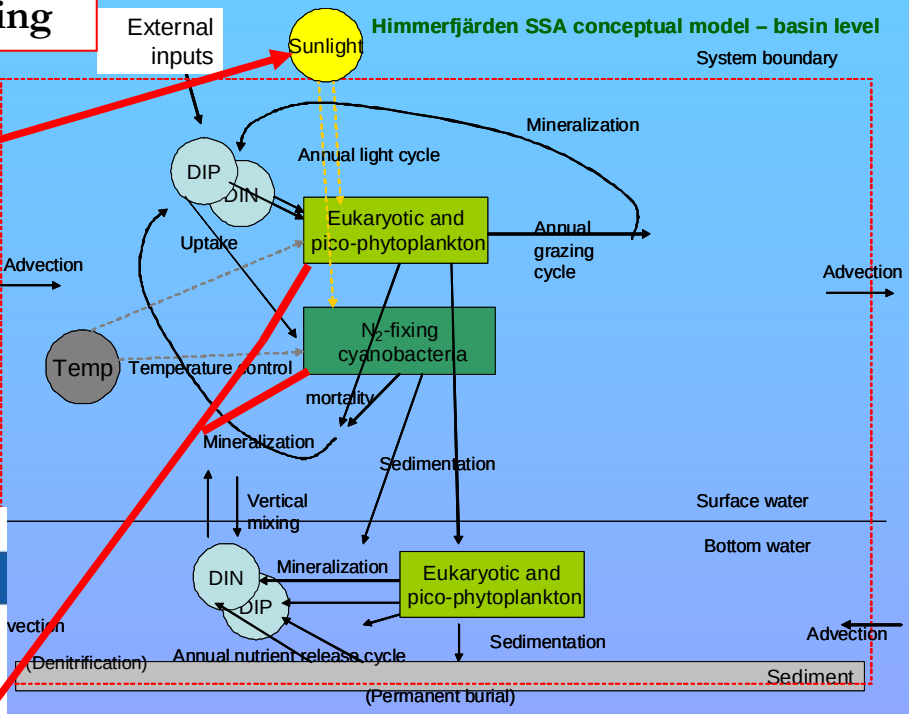
Possible future application – using MERIS data to test biogeochemical model

Model input: Kd490 as proxy for light forcing







SPICOSA Conceptual model 2

Courtesy: Jakob Walve

Model output: *chl-a* as proxy for phytoplankton biomass

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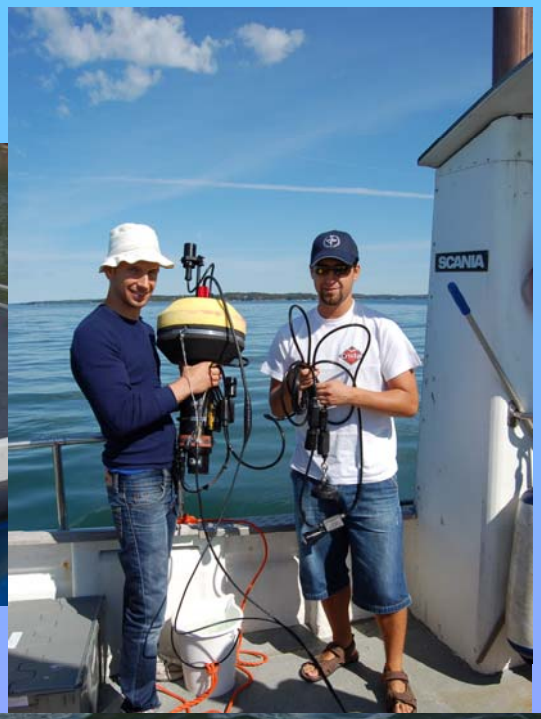
MVT intercalibration work-shop July 2008, Askö



COASTCOLOUR Project from ESA

- Stockholm University and SYKE are champion users of the COASTCOLOUR project
- Round Robin of different algorithms for Baltic Sea remote sensing products

  (Sept 2010- Feb 2011)
- Validation of coast colour algorithm in the Baltic Sea

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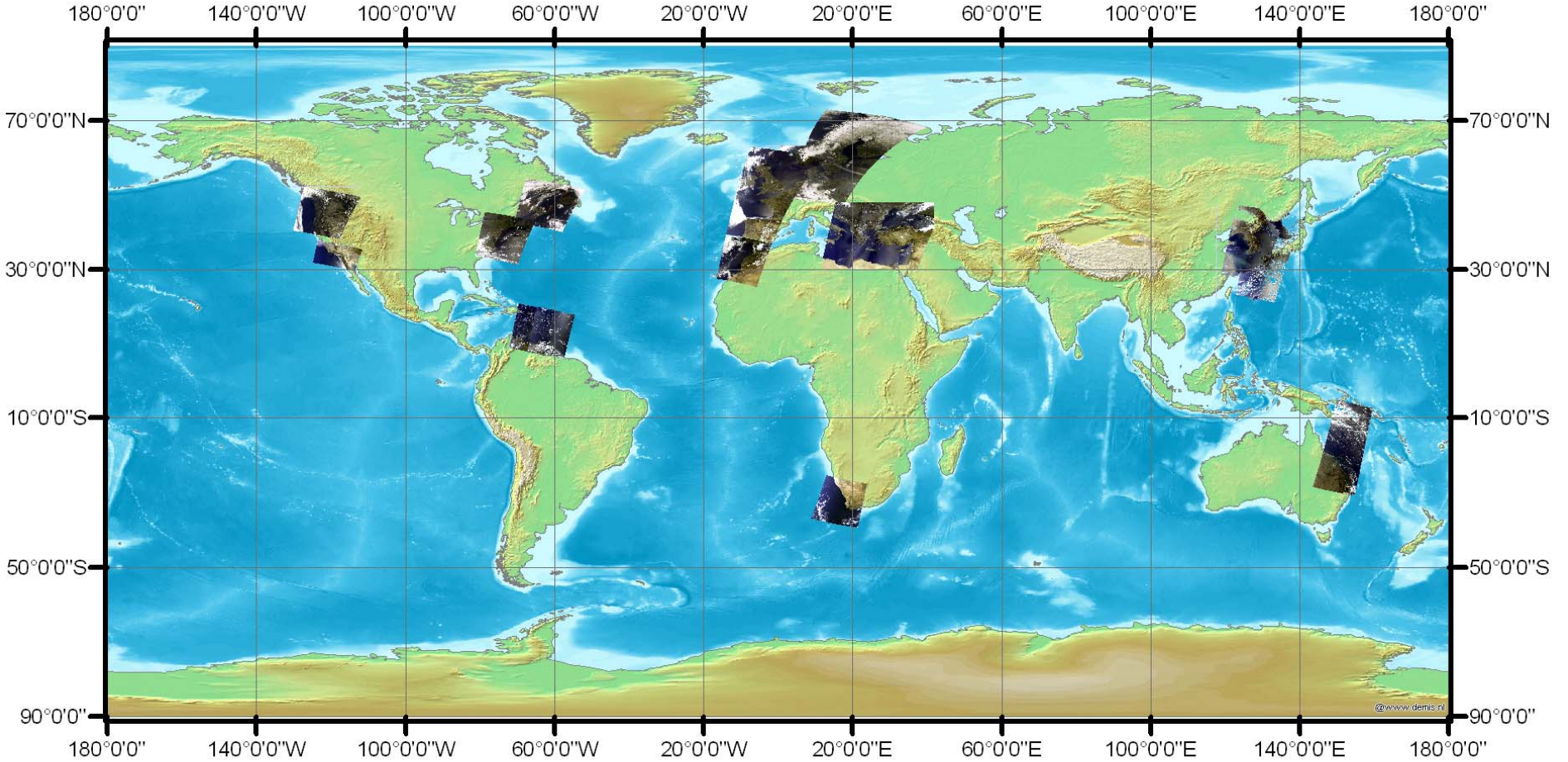
COASTCOLOUR sites



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Thanks for listening!

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Acknowledgements

- Swedish National Space Board (SNSB): ‘Algorithm development and validation of MERIS data over optically complex waters’, 2008-2010. Focus: Fundamental research.
- ESA/ESRIN: Technical Assistance for the validation of MERIS products in lake Vänern and coastal waters of the north-western Baltic Sea (Sweden), mid 2008- mid 2011. Focus: Validation of MERIS data and intercalibration of radiometers.
- Swedish Environmental Protection Agency (SEPA) and SYVAB, 2008-2009. Focus: Applications.
- NordForsk: NORDic network for AQUAtic REMote Sensing (NordAquaRemS), Sept 2008-Sept 2010; coordinator: S.Kratzer. Focus: Networking and PhD training.
- Participation in SPICOSA, and EU FP6 project on integrated coastal zone management (PI: Ragnar Elmgren): Focus: Academic training & developing remote sensing as diagnostic tool for integrated coastal zone management.

Close collaborations

- Petra Philipsson, Vattenfall Power Consultant AB, www.vattenkvalitet.nu
- Niklas Strömbeck, Strömbeck Consultant, Aeronet-OC Stations

  http://aeronet.gsfc.nasa.gov/new_web/ocean_color.html, (in collaboration with Giuseppe Zebordi, JRC, Ispra, Italy and NASA and ESA)
- Anu Reinart, Tartu Observatory, Estonia
- Gerald Moore, Bio-Optika, UK
- Carsten Brockmann, Brockmann Consult, Germany
- Roland Doerffer, GKSS, Germany
- Paul Tett, Napier University, UK

Stockholm University

NORDic network for AQUAtic REMote Sensing (NordAquaRemS)

Coordinator:
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Organizing committee:
Prof. Matti Leppäranta, Helsinki University, Finland
Dr. Anu Reinart, Tartu Observatory, Estonia
Dr. Piotr Kowalczuk, IOPAS, Poland
Dr. Are Folkstad, NIVA, Norway

Main Communication:
E-mail & Skype conferences

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Aims and Objectives- NordAquaRemS

(1) Advanced education for PhD students and young researchers, increased mobility and international experience

(2) Organize PhD and research training courses and seminars /workshops for students & researchers.

(3) Share expertise and define the most relevant common problems when applying remote sensing methods in Nordic conditions.

(4) Stimulate the application of new algorithms for the atmospheric correction for satellite images of Nordic water bodies (Baltic Sea and Nordic lakes)

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Aims and Objectives- NordAquaRemS

(5) Share experience, data and instruments according to agreed conditions and rules.

(6) Improve exchange between scientists, users and service providers, including small/medium enterprises.

(7) Span the research and education across the whole seasonal cycle in Nordic waters, including the winter season.

(8) Create a Virtual Nordic Institute in Aquatic Remote Sensing.

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