Cooperation in Marine Science around the Baltic Sea and beyond: a view from Tallinn University of Technology, Marine Systems Institute

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Contents

Tallinn University of Technology and some of its marine-related units

Research and cooperation examples:

- Dynamics of algal blooms, nutrients and oxygen
- Long-term ecosystem changes and management
- Safe shipping in winter
- Operational oceanography / Copernicus Marine Service
- Innovative monitoring of harbor effects

Society is interested: headlines of Estonian newspapers

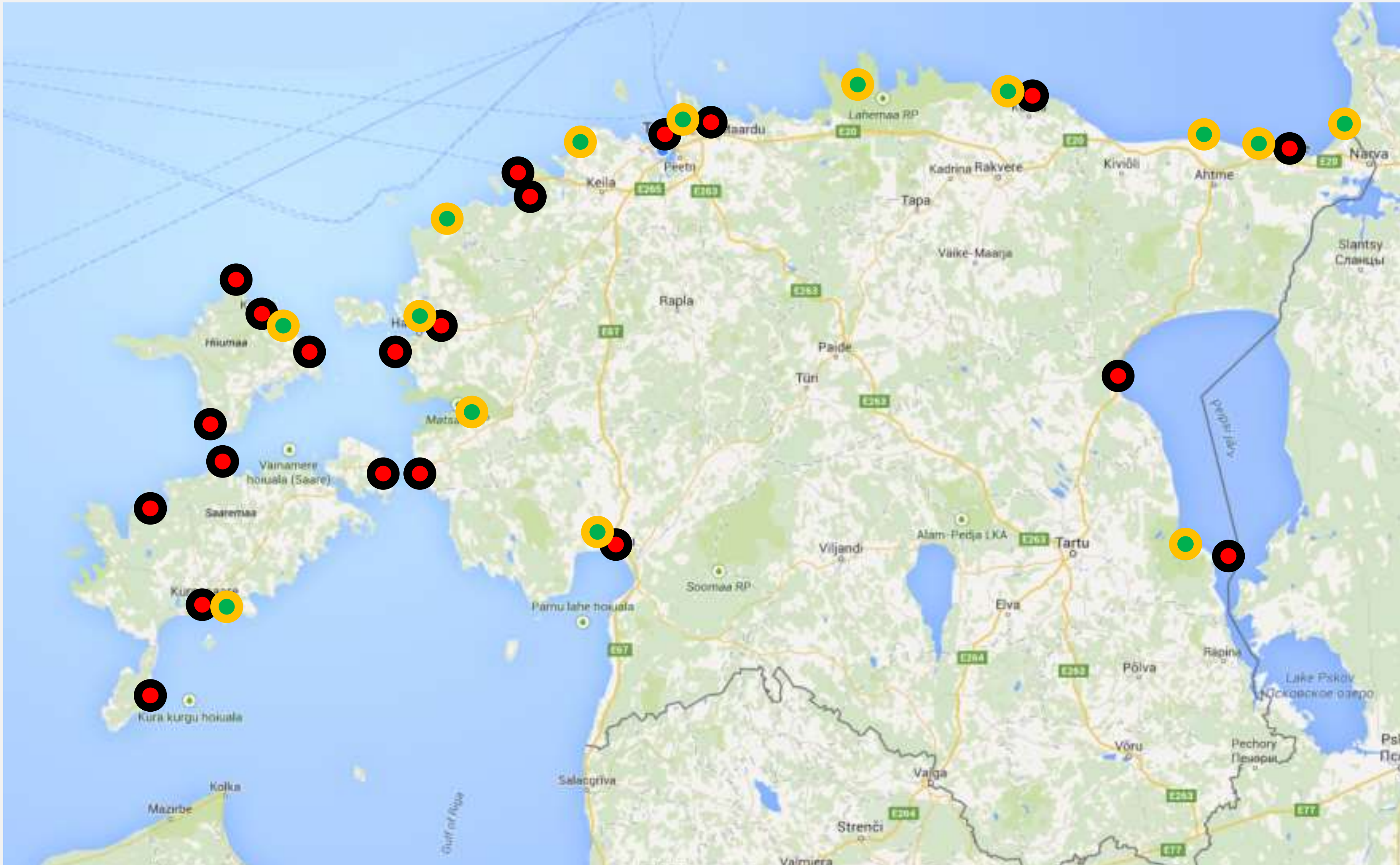
Eventual concerns since 2000

- building **new harbors** in pristine areas
- massive **algal blooms**, eutrophication and/or climate effects?
- **“killing” waves** from high-speed ferries in the Tallinn Bay
- **offshore sand mining** threats storm stability of coasts
- damaging **storm surge FLOOD** in Pärnu and other areas
- several **oil pollution** events in the Gulf of Finland
- **Nord Stream** Gas Link, environmental effects?
- **offshore wind farms**, variety of potential problems
- ships stuck in **heavy ice**

Continuous concerns

- pollution load from land, eutrophication, fishing etc
- threats to biodiversity, invasion of non-native species
- increasing housing, resorts, harbors etc in formerly “closed” coastal areas
- sustainable, ecosystem-based management of marine resources
- development of observation, assessment and forecast technologies

Recent marine-related industry activities in Estonia



Environmental and design studies:

- harbor construction and dredging
- wastewater and pollution

Tallinn University of Technology

People

Students	13 100
Employees	2 100
incl academic	1 200
incl professors	150

Revenue

Total (MEUR)	95.4
Education %	35.6
RTD %	38.7
Other (investments) %	21.1

Ranking

among world top 500

Technical and natural sciences since 1918
+ social and economical sciences

Broad spectrum of marine-related issues

Permanent activities in

- Marine Systems Institute
- Estonian Maritime Academy
- Wave Engineering Lab of Institute of Cybernetics
- Centre for Biorobotics of Information Technology Faculty
- Department of Environmental Engineering of Civil Engineering Faculty

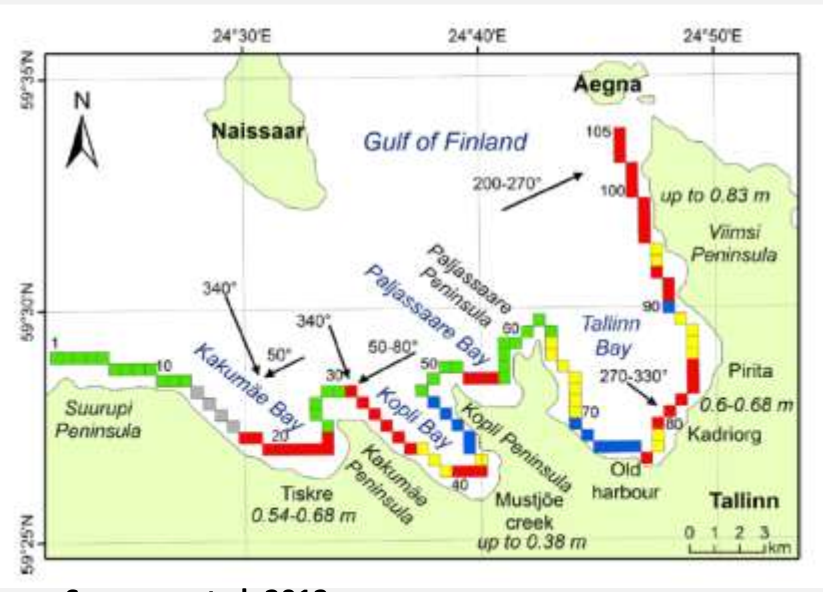
Wave Engineering Laboratory of Institute of Cybernetics

Staff ca 20, Head: Prof. Tarmo Soomere

Focus on complex and nonlinear phenomena in wave dynamics and coastal engineering.

Scope: long wave theory and applications (with emphasize on fast-ferry waves, shallow-water solitons, runup phenomena, tsunami research, and generic aspects of coastal hazards), surface wave modelling, wave climate studies, and wave-driven phenomena in coastal engineering, with application to integrated coastal zone management.

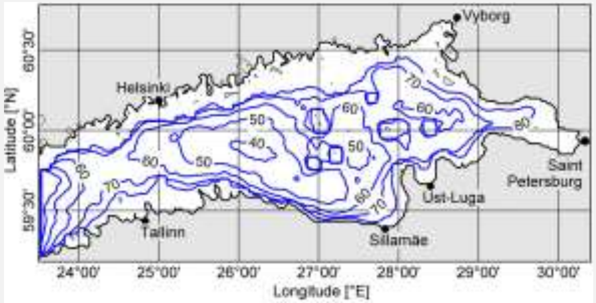
Example: wave set-up of sea level in Tallinn Bay. Red – maximum, green – no set-up.



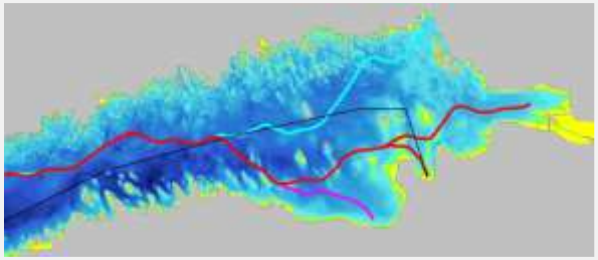
Soomere et al, 2013

BONUS Project BalticWay

probability (%) for a coastal hit within 10 days from the release in the Gulf of Finland



optimal fairways for prevention of coastal pollution from ships

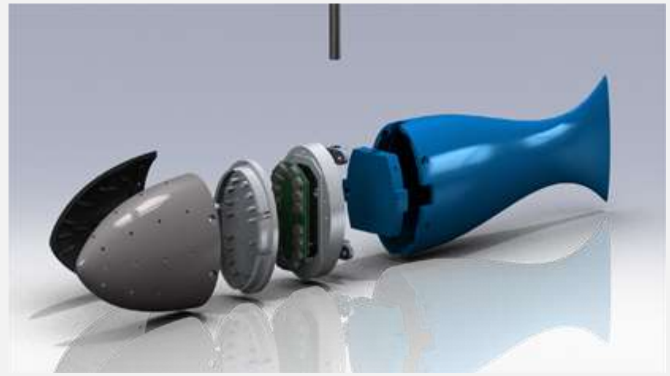


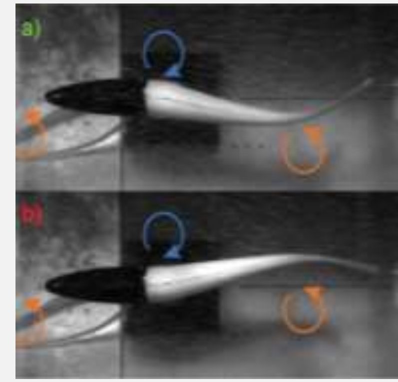
Soomere et al, 2011

Centre for Biorobotics, Faculty of IT

Staff ca 15, Head: Prof. Maarja Kruusmaa

FP7 Project (finished)
FILOSE
(Robotic FIsh LOcomotion and SEnsing)





Ongoing FP7 Project **ARROWS**
(ARchaeological RObot systems for the World's Seas)

U-CAT developed by the Center for Biorobotics

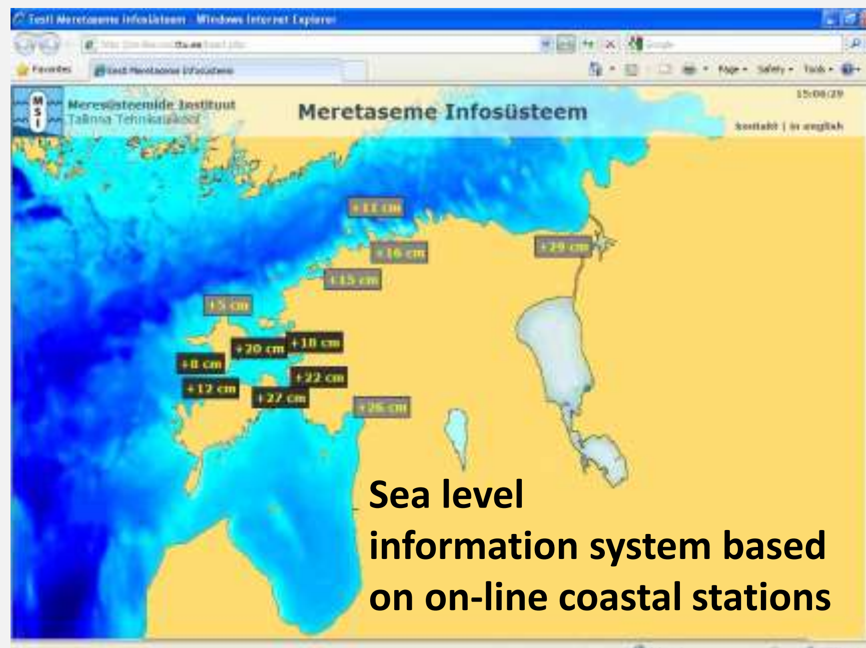
Ongoing BONUS-INNO Project
FISHVIEW (Assessing fish passibility using a robotic fish sensor and hydrodynamic imaging)

Marine Systems Institute

Staff: ca 60, incl ca 25 PhD

Focused on natural science = oceanography, marine meteorology and geology
// but cooperating with engineering and socio-economic scientists

	Administration (Director: Prof. Jüri Elken)
Research Units	**Department of Marine Physics (Head: Prof. Urmas Lips)**
	Department of Modelling and Remote Sensing (Head: Prof. Urmas Raudsepp)
	Laboratory of Marine Ecology (Head: Dr. Inga Lips)
Teaching Unit	**Chair of Oceanography (Head: Prof. Sirje Keevallik)**



Marine Systems Institute: research

Basic research: Multi-scale physical processes controlling the biogeochemical signal dynamics in the stratified Baltic Sea

- near-surface boundary layer;
- thermocline;
- halocline and redoxcline;
- near-bottom layer;
- signal propagation and transformation;
- long-term changes of basin-scale nutrient, oxygen and bloom patterns.

Applied research:

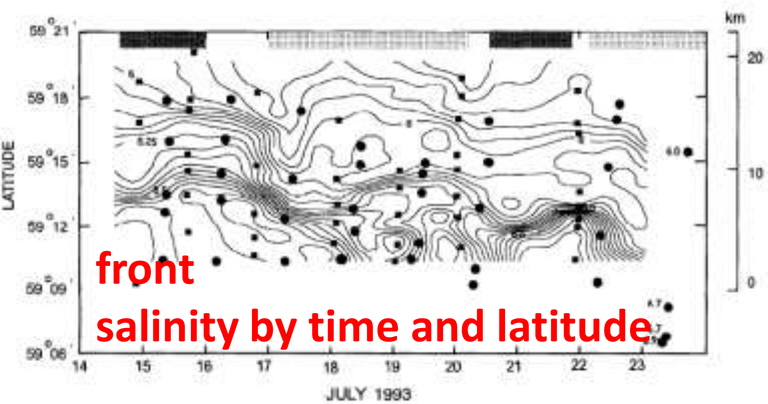
- operational oceanography (high-res observing systems, forecast models) ← GMES, EuroGOOS, BOOS, FerryBox etc
- marine environmental monitoring
- impact studies ← industry
- observation technology

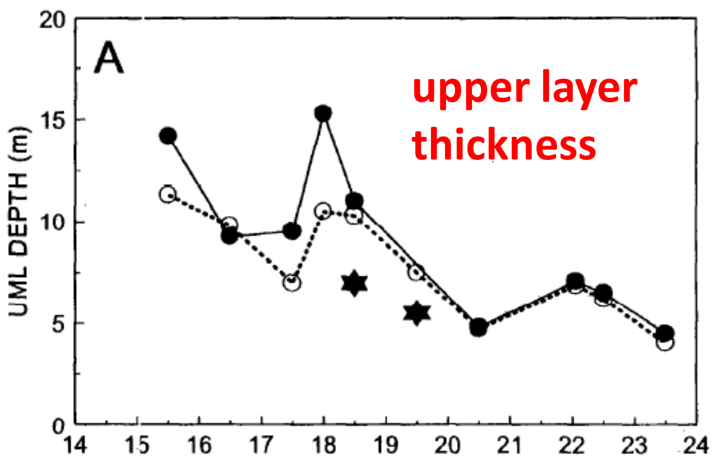
FP projects: HABES, PAPA, SEA-SEARCH, SEADATANET, ECOOP, SAFEICE, SAFEWIN, MyOcean, EuroFLEETS

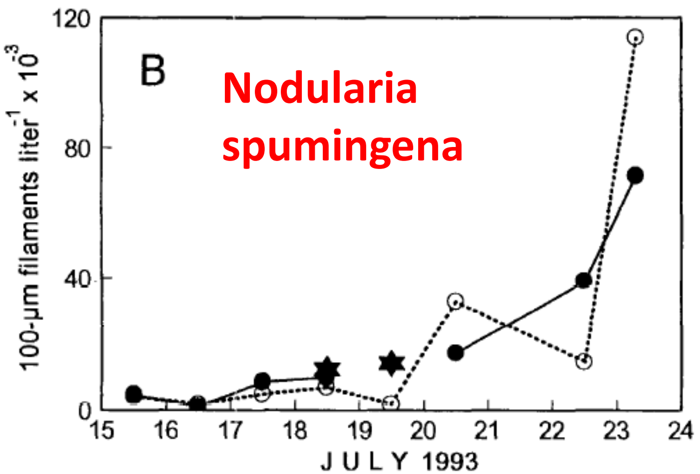
Interreg projects: SNOOP, BalticSeaNow.info, GORWIND, GES-REG

BONUS projects: ECOSUPPORT, GEOILWATCH, HARDCORE, SWERA, SHEBA

Funding Structure:	**Governmental, incl. teaching & grants**	**35 %**
(ca 2 MEUR	**National research contracts**	**30 %**
without investments)	**International**	**35 %**







Dynamics of harmful algal blooms: control by physical processes

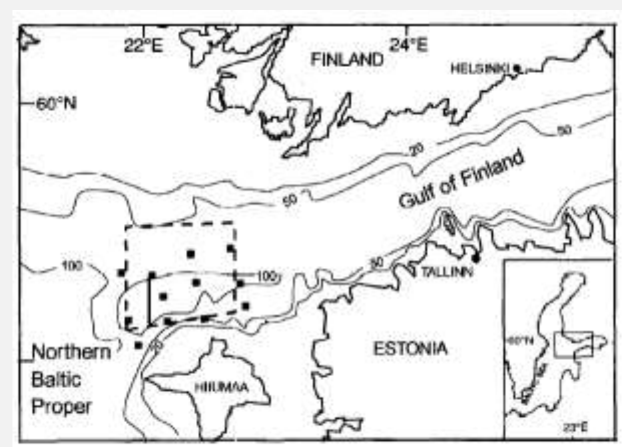
Intense nutrient pulses to the upper layer are needed for cyanobacteria blooms.

Mixing in the area of salinity front forced by stronger winds brought additional nutrients into the upper layer. In the following calmer periood upper layer thickness decreased and temperatuure increased, and intense bloom started.

Finnish-Estonian joint expedition onboard R.V. Aranda 1993.a. at the entrance to the Gulf of Finland

Kononen, K.; Kuparinen, J.; Mäkela, K.; Laanemets, J.; Pavelson, J.; Nõmmann, S. (1996). Initiation of cyanobacterial blooms in a frontal region at the entrance to the Gulf of Finland, Baltic Sea. Limnology and Oceanography, 41, 98 - 112.

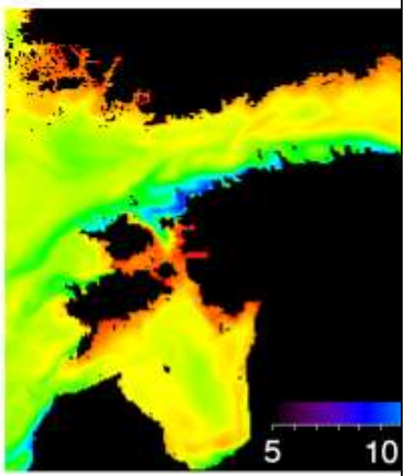
Web of Science gives 126 citations



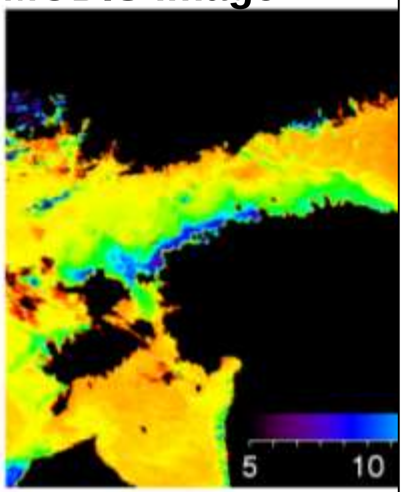
Dynamics of nutrients: upwelling effects

example from 2006: combination of 3 methods in the Gulf of Finland

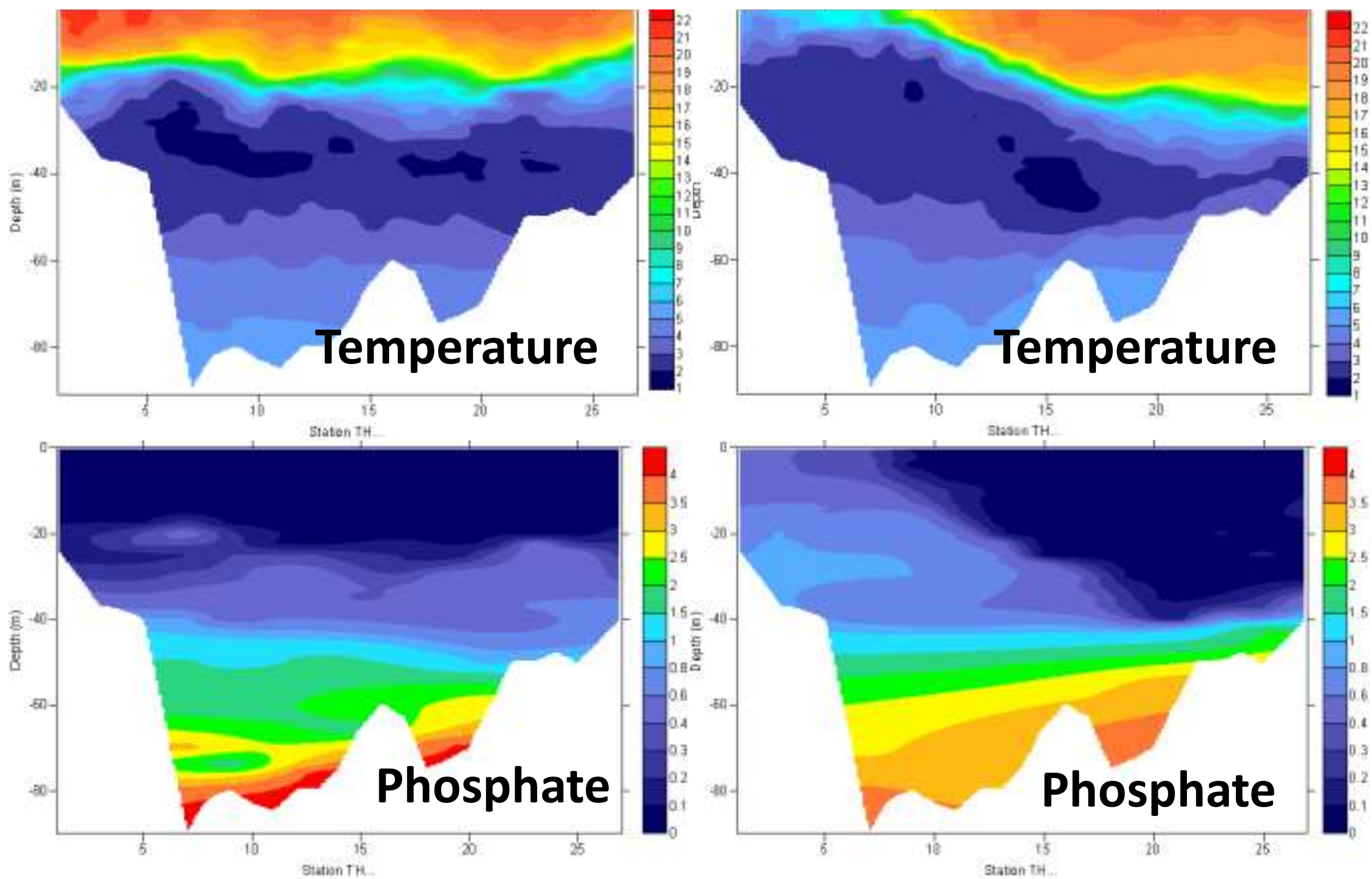
HIROMB model fore



MODIS image



Before upwelling 11.07.2006 **During upwelling 8.08.2006**

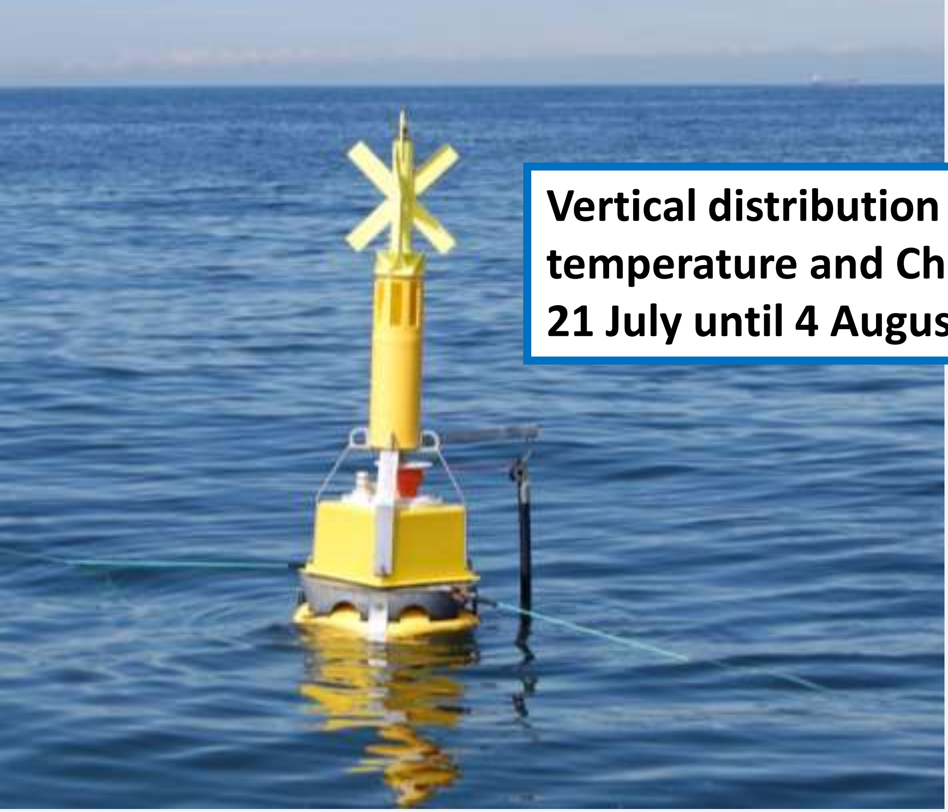


0,3-0,4 µmol/l – 20 m layer – 20 km coastal zone – 100 km long

Vertical flux estimate – 400-600 tons of P, equals to ca 1 month riverine load

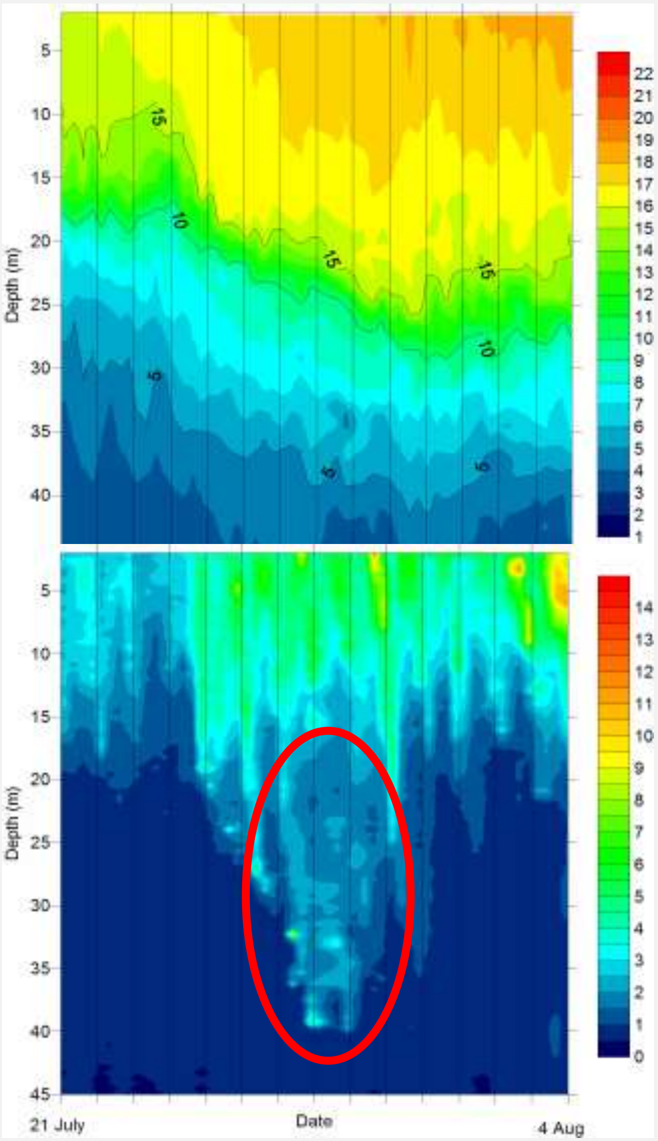
Urmas Lips et al, 2009

Dynamics of phytoplankton: migration effects



Vertical distribution of temperature and Chl *a* from 21 July until 4 August 2009

Data from autonomous profiling station



Nocturnal downward migration of phytoplankton with a swimming speed up to 1.6 mh^{-1}

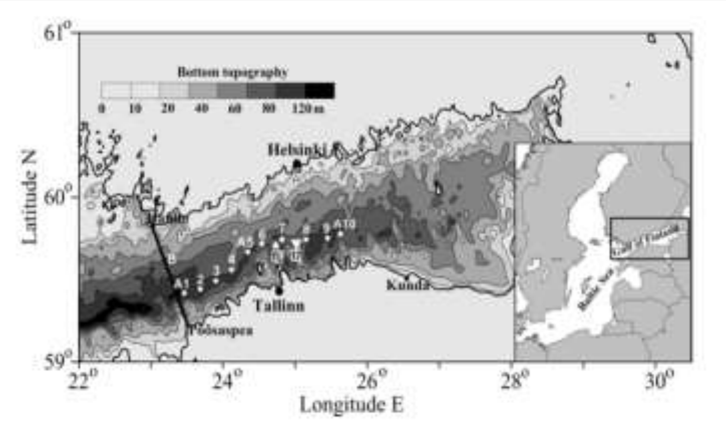
Lips et al, 2011

Flow and oxygen dynamics in the Western Gulf of Finland

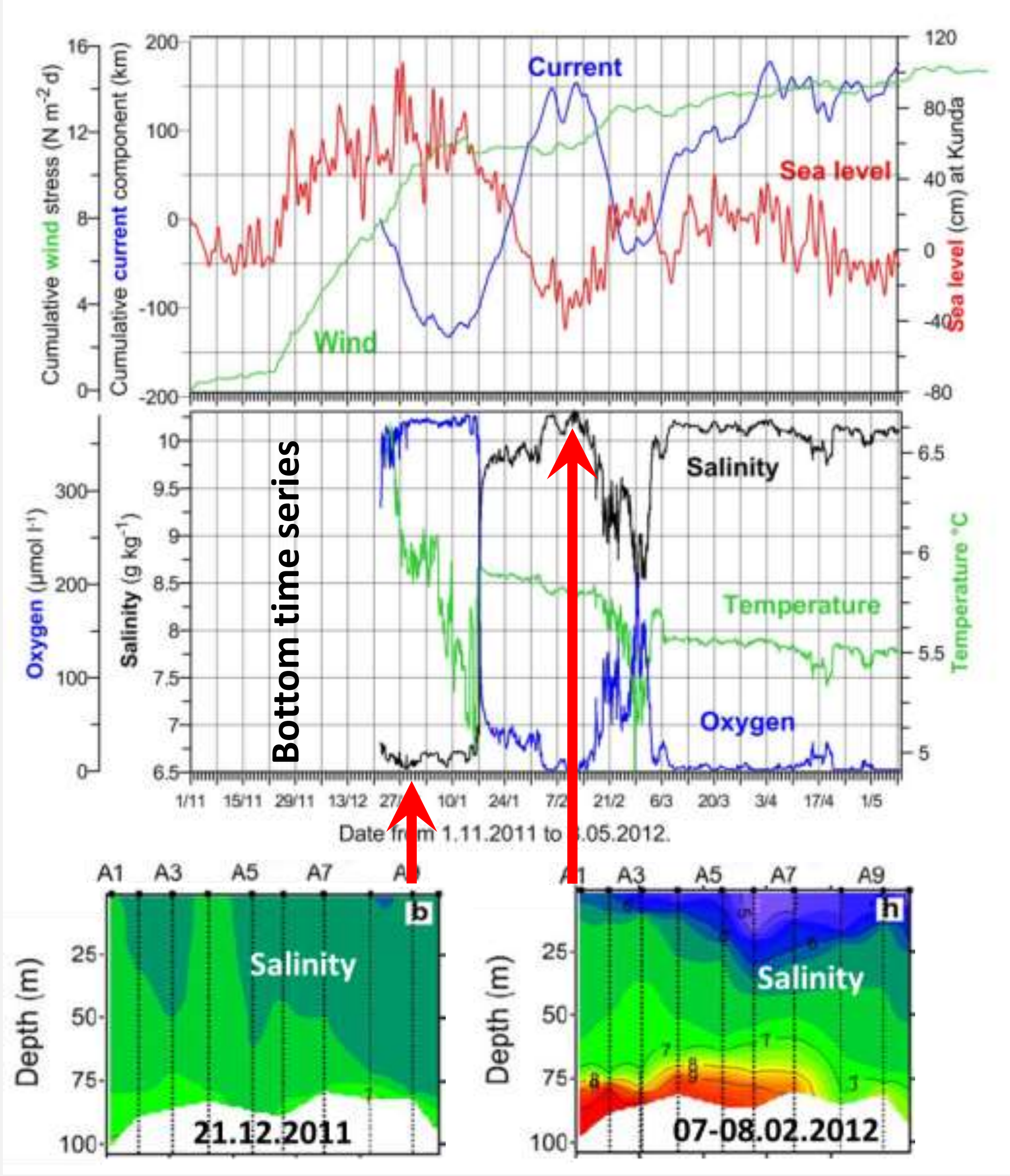
Persistent strong SW winds create during the winter

- anti-estuarine transport
- stratification collapse
- **oxygenation of bottom layers**

By ceasing the SW winds, stratification and hypoxia are rapidly restored



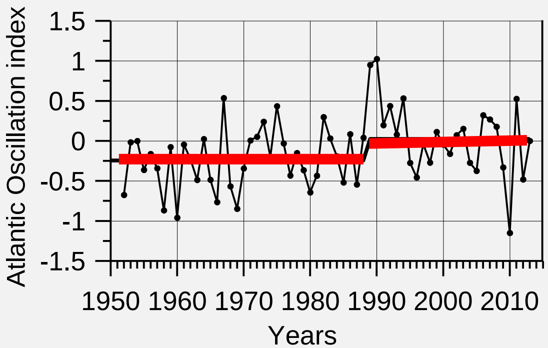
Liblik, T., Laanemets, J., Raudsepp, U., Elken, J., & Suhhova, I. (2013). Estuarine circulation reversals and related rapid changes in winter near-bottom oxygen conditions in the Gulf of Finland, Baltic Sea. Ocean Science Discussions, 10, 727-762.



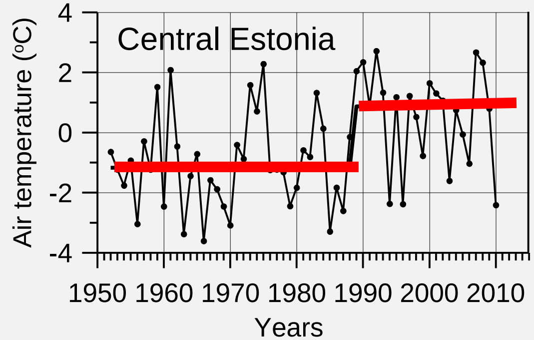
Long-term observed changes: regime shifts

National project **EstKliima** funded by Environmental protection and –technology programme, supported by the European Regional Fund.

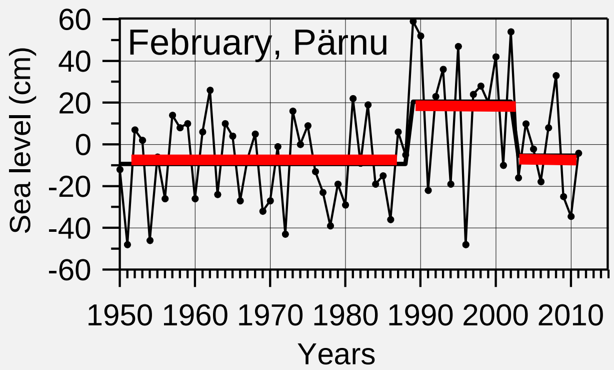
Atlantic Oscillation Index



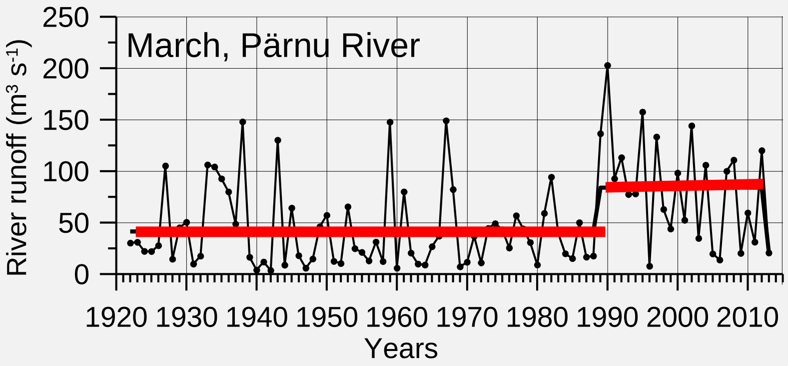
Mean maximum temperature of the cold season



Monthly mean winter sea level



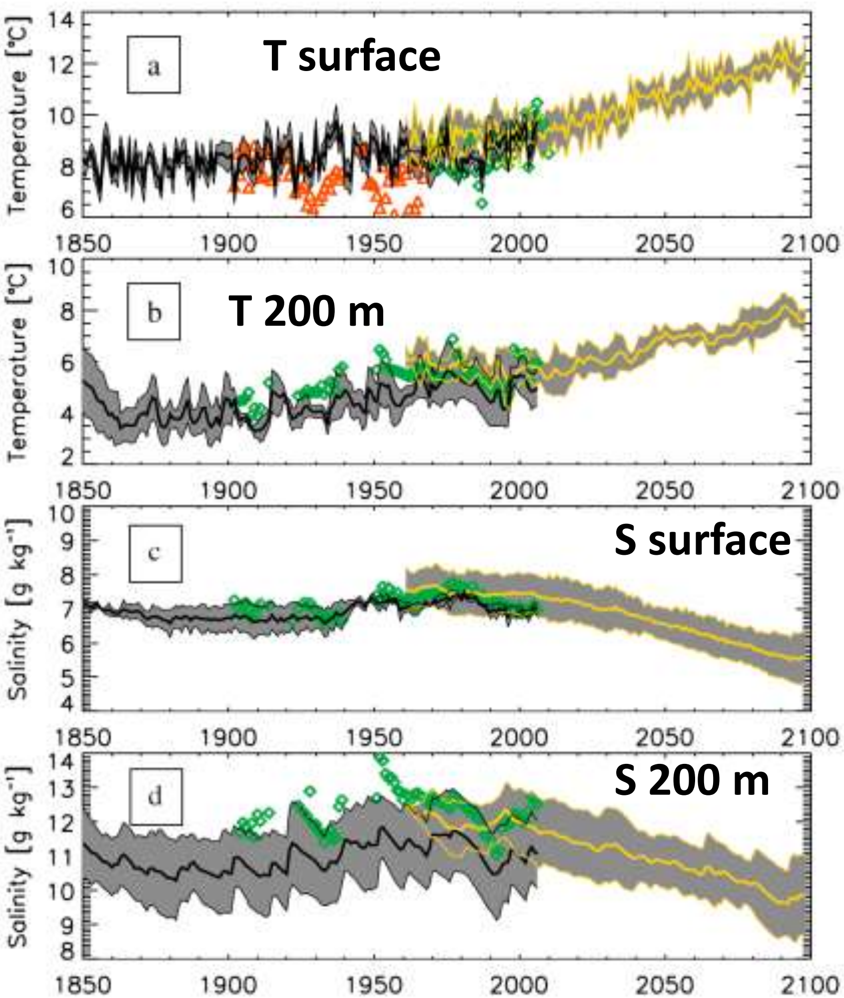
Pärnu River runoff

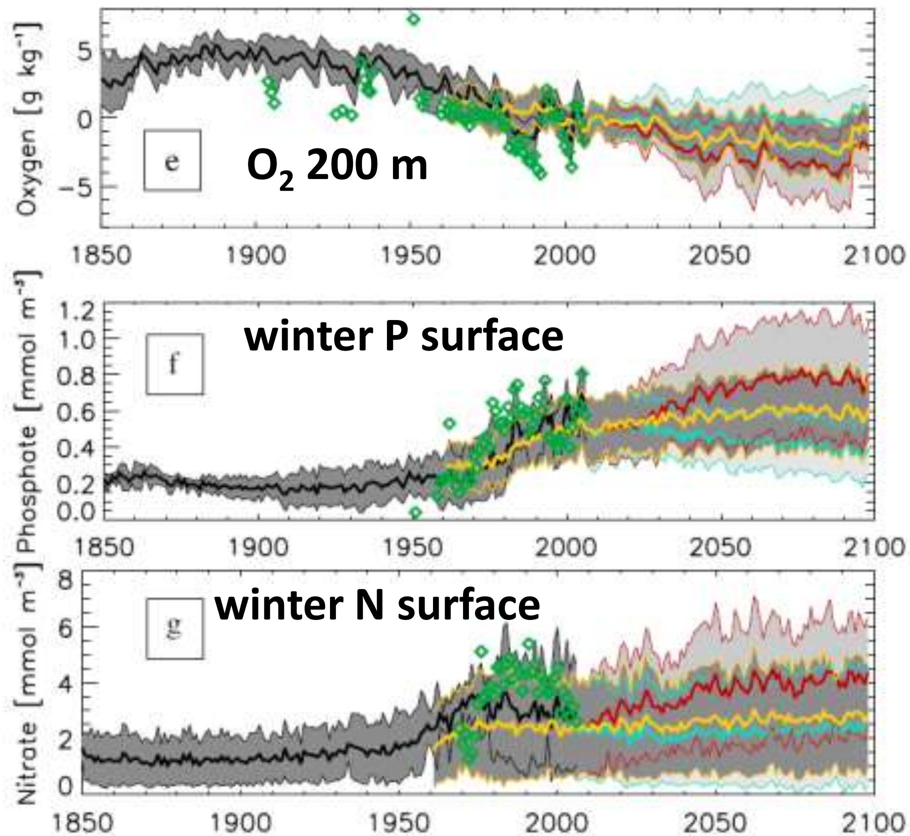


Regime shifts in 1989 detected according to Rodionov test.

Climatic projections: ensemble results

Mean and STDEV (36 cases) of ensemble forecast results. Climate: A1B and A2. Nutrient loads: REF – yellow, BSAP – blue, BAU – red. Points: past observations // Gotland Deep





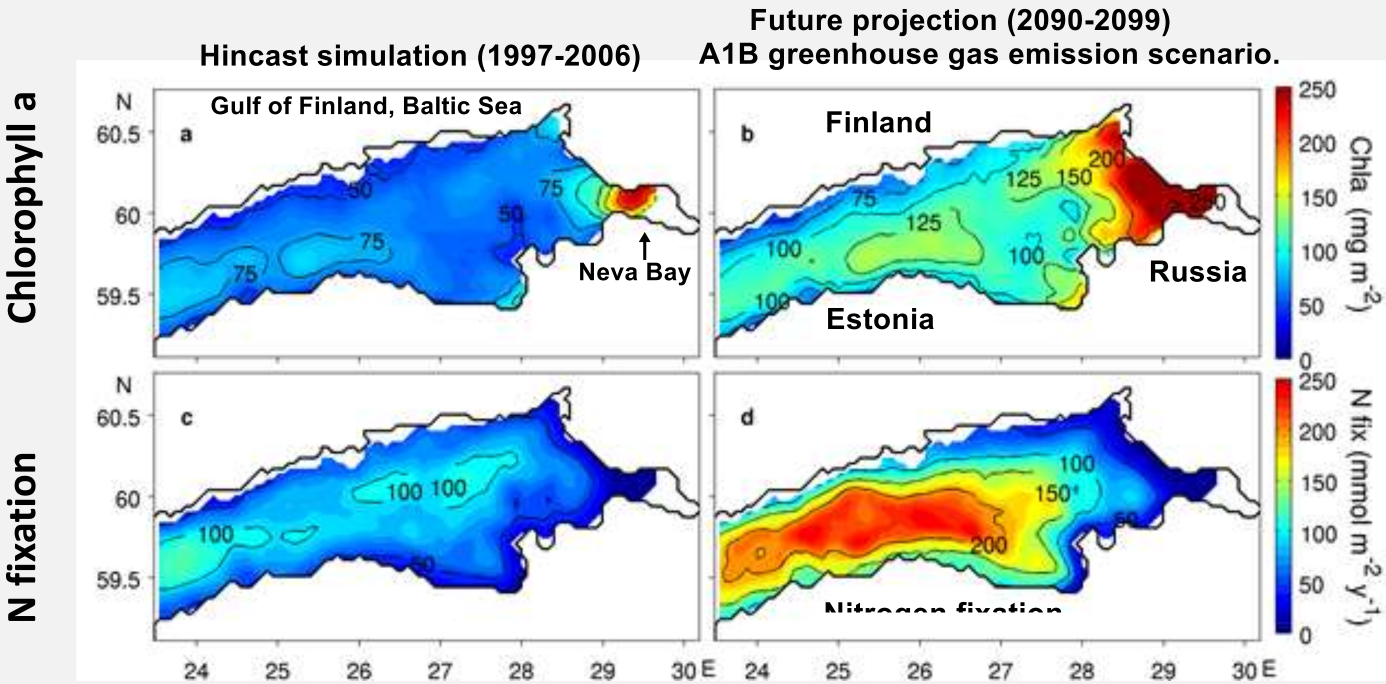
H E Markus Meier[1,2], Helén C Andersson[1], Berit Arheimer[1], Thorsten Blenckner[3], Boris Chubarenko[4], Chantal Donnelly[1], Kari Eilola[1], Bo G Gustafsson[3], Anders Hansson[5], Jonathan Havenhand[6], Anders Höglund[1], Ivan Kuznetsov[1], Brian R MacKenzie[7], Bärbel Müller-Karulis[3], Thomas Neumann[8], Susa Niiranen[3], Joanna Piwowarczyk[9], Urmas Raudsepp[10], Marcus Reckermann[11], Tuija Ruoho-Airola[12], Oleg P Savchuk[3], Frederik Schenk[13], Semjon Schimanke[1], Germo Väli[1], Jan-Marcin Weslawski[9] and Eduardo Zorita[13]

BONUS Project ECOSUPPORT

Env Res Lett 2012

Projection of chlorophyll and N fixation by 2100

from BONUS Project ECOSUPPORT



Management scenario for nutrient loads: BAU / Business as Usual

Then nitrogen fixation will increase, favouring

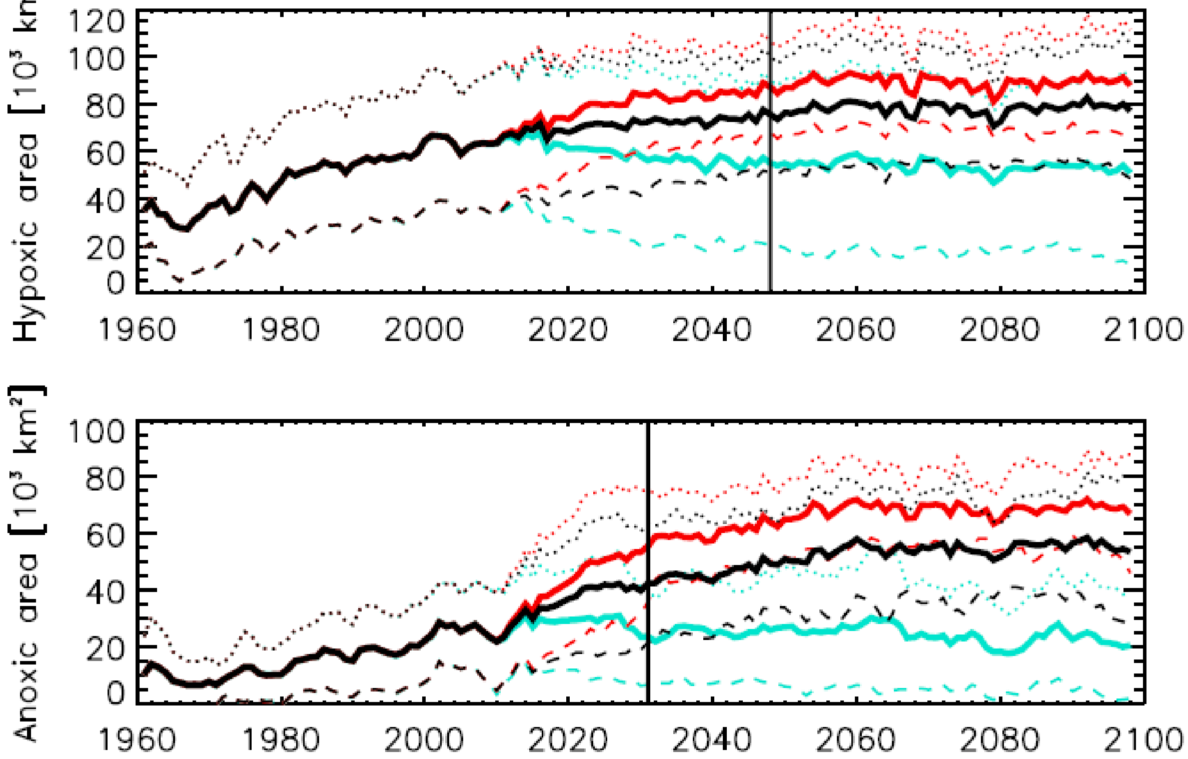
- **more cyanobacteria blooms**
- **more eutrophication as evident by chlorophyll.**

Eutrophication growth in the Gulf of Finland is larger than in the Baltic Proper

Lessin et al, 2014

Climatic projections, oxygen deficiency

Meier et al 2011 Geophys Res Lett

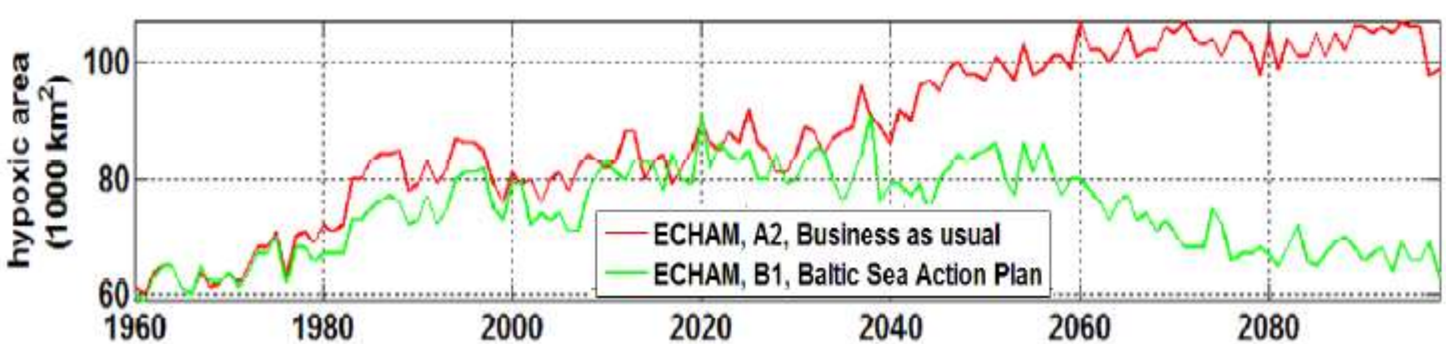


3 models.
Climate: A1B and A2.
Nutrient load: REF – black, BSAP – blue, BAU - red

Hypoxia will decrease only with nutrient load reduction, other options will not give results

BALTEX related BONUS Projects ECOSUPPORT and Baltic-C

Omstedt et al 2012



Implementing Marine Strategy FD

Interreg Project GES-REG

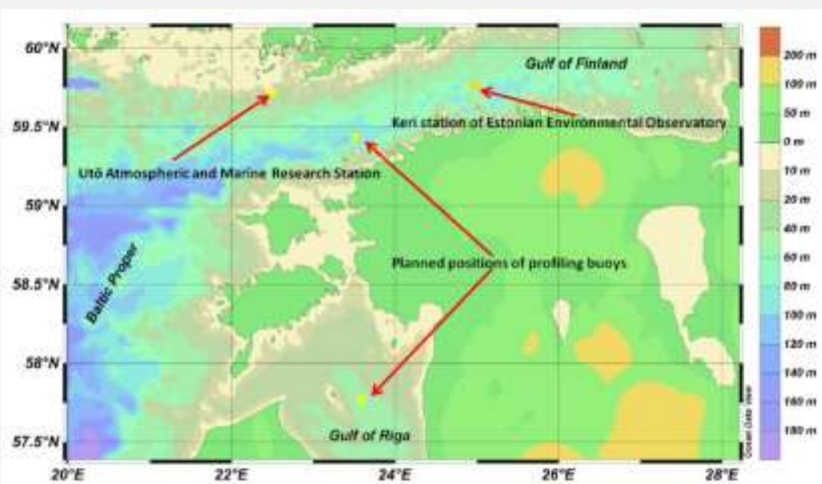
Good Environmental Status Through Regional Coordination and Capacity Building

Activity: propose regionally coherent updated monitoring and assessment programmes to better comply with the requirements of MSFD, other EU Directives and HELCOM BSAP

Example: Major gaps in monitooring of hydrography

- *in situ* current velocities
- wave exposure
- total organic carbon
- near sea-bed oxygen
- pCO2
- high-resolution vertical distribution

Make use of autonomous measurements from the entire water column and real time data delivery



A way forward:

Integrate different monitoring methods in order to produce assessment products with high confidence

Existing shipborne monitoring +

- autonomous buoys, gliders etc
- ferrybox
- numerical models (eg Copernicus Marine Service)
- volunteer’ observations

New sensors/methods for

- underwater acoustic noise
- marine litter
- etc

Safe navigation in winter

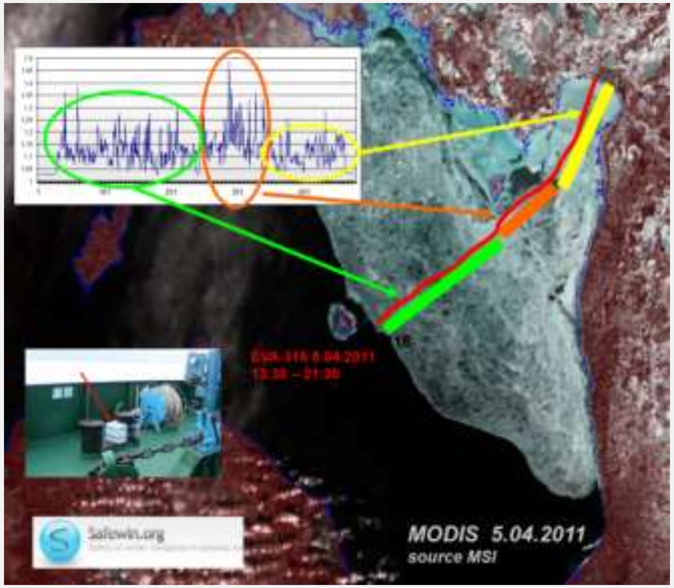
Winter navigation depends strongly on ice conditions. VTS (Vessel Traffic Service) has recently included on-line information on weather and ocean conditions METOC by support from the BSRP Flagship Project **EfficienSea**.

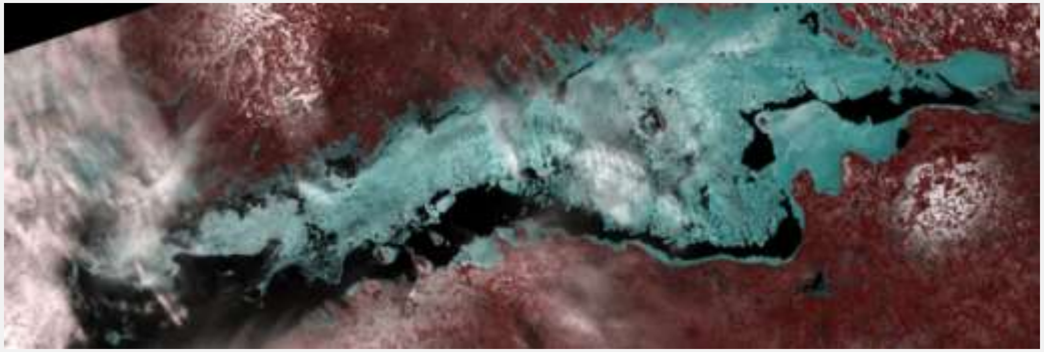
FP6 SAFEICE and FP7 SAFEWIN (MSI coordinator Tarmo Kõuts) has combined

- numerical ice forecast models
- remote sensing data (SAR, visible range, etc)
- ice drifter data
- sensors to measure vibrations of ships

Outcomes:

- better ship design
- good forecast of dangerous ice compressions

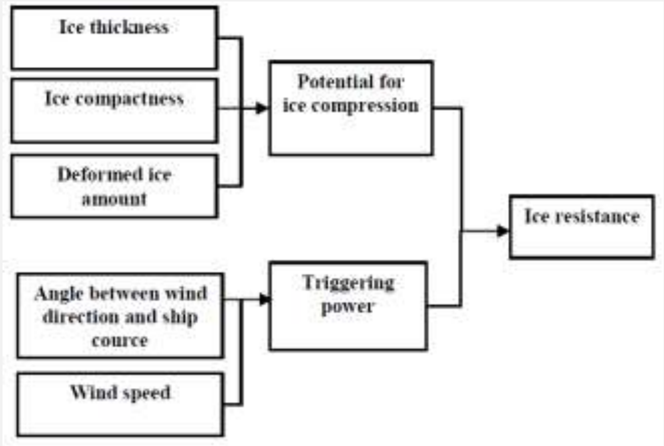




Safe navigation in winter: on-line info system

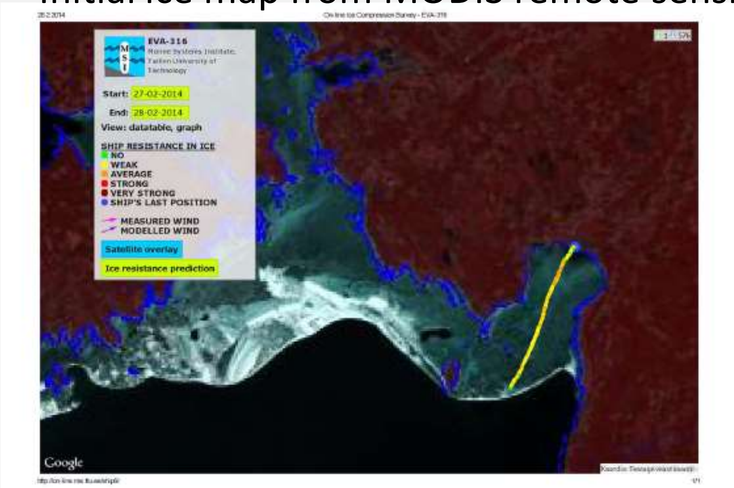
***Fuzzy logic* model for ice resistance**
Input: remote sensing maps of ice, wind forecast

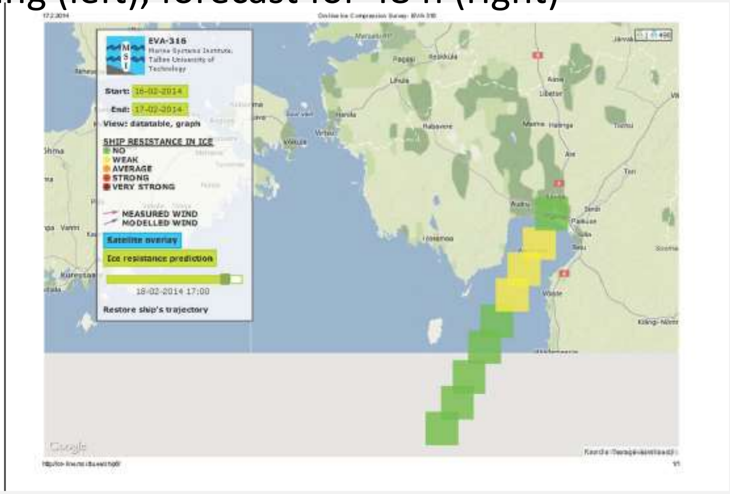
from FP7 Project SAFEICE



Validation measurements with vibration sensor

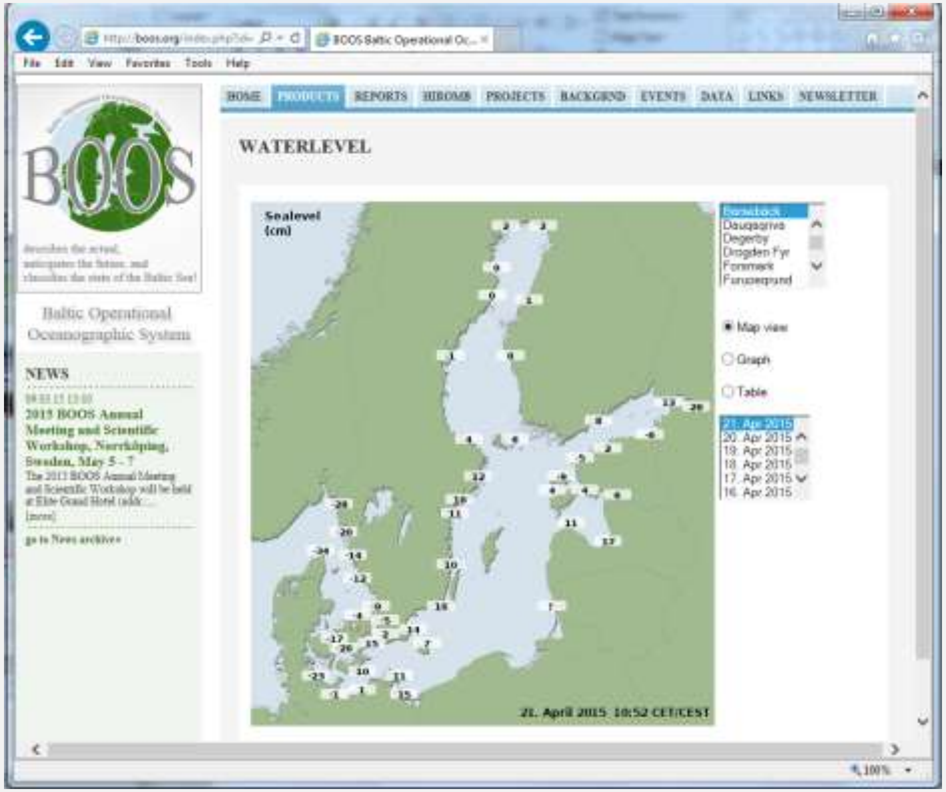
Screenshots of web user interface
Initial ice map from MODIS remote sensing (left), forecast for 48 h (right)





Lilover & Kõuts, 2012; Kõuts et al, 2014

BOOS: Baltic Operational Oceanographic System



Organizes Baltic-wide coherent

- real-time in-situ observations
- model forecasts
- data products

Partner to EuroGOOS
Supports Copernicus Marine Service

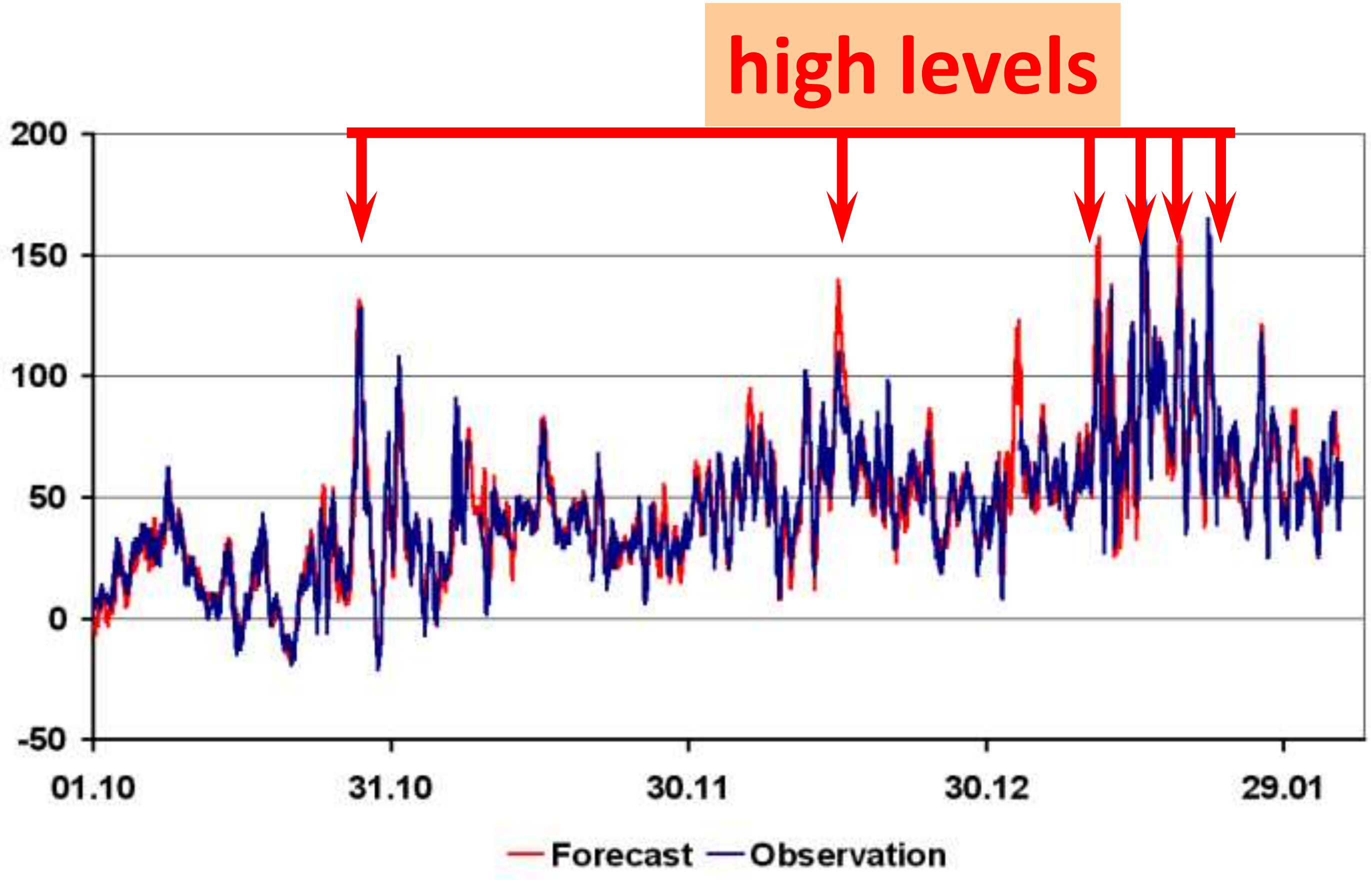
BOOS Steering Group
Urmas Lips - MSI - Tallinn (Chair)
Ole Krarup Leth - DMI - Copenhagen
Pekka Alenius- FMI - Helsinki
Jan Reissmann - BSH - Hamburg
Marcin Wichorowski - IOPAS - Gdansk

To provide integrated marine services to the marine users and policy makers. The objectives are to:

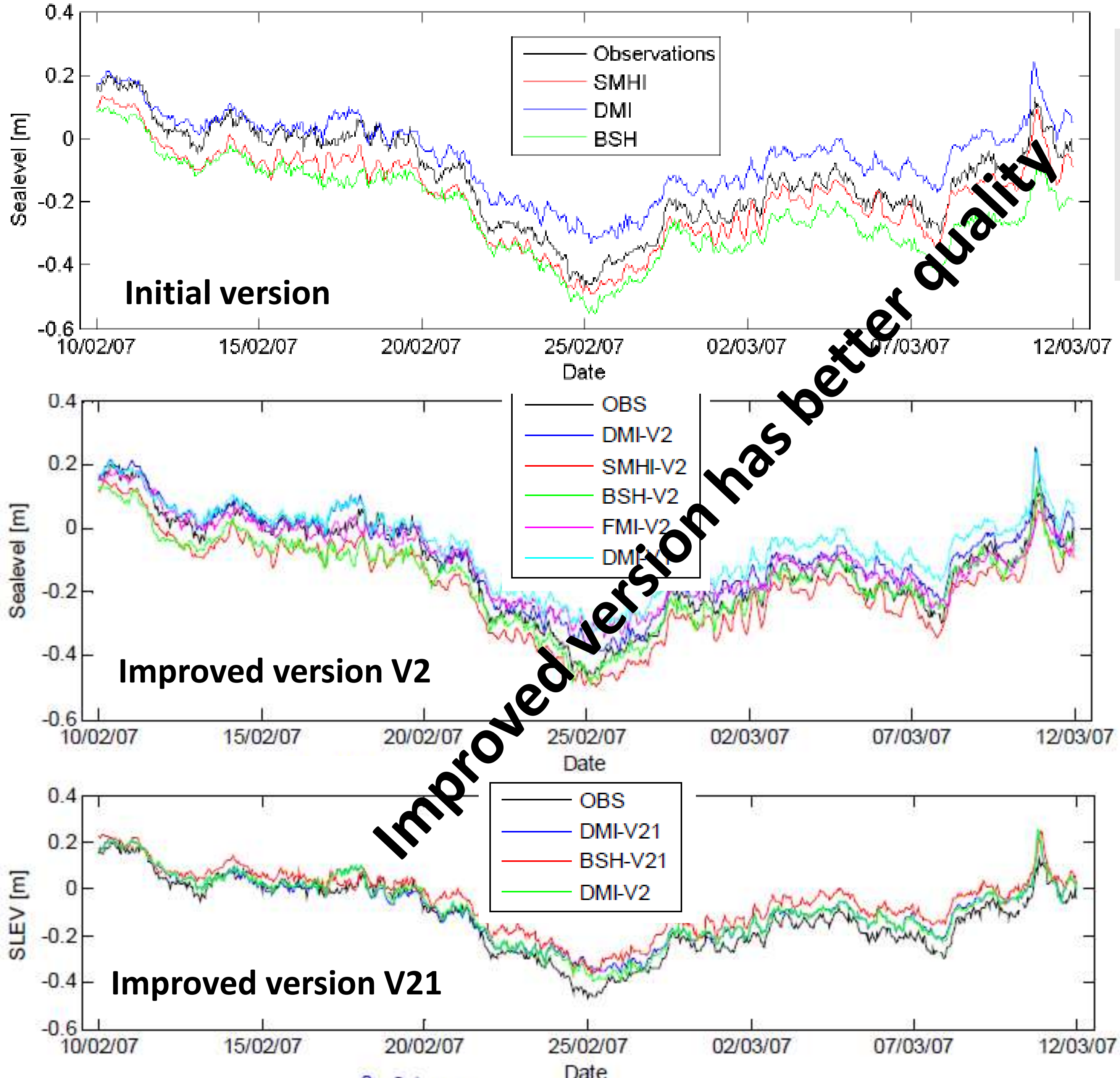
- **Improve the safety and efficiency of maritime transport and marine operations.**
- **Enable the sustainable exploitation and management of Baltic Sea resources (fisheries).**
- **Support safe and efficient offshore energy activities.**
- **Mitigate the effects of environmental hazards and pollution crisis.**
- **Contribute to ocean climate variability studies and seasonal climate prediction.**
- **Federate the resources and expertise of diverse institutes, agencies, and companies in the public and private sector.**

Operational oceanography in practice in Estonia

Observed and 24h forecasted sea levels (cm) in Pärnu
during the stormy period from 1 October 2006 to 3 February 2007



FP7 MyOcean: Calibration of sea level forecast



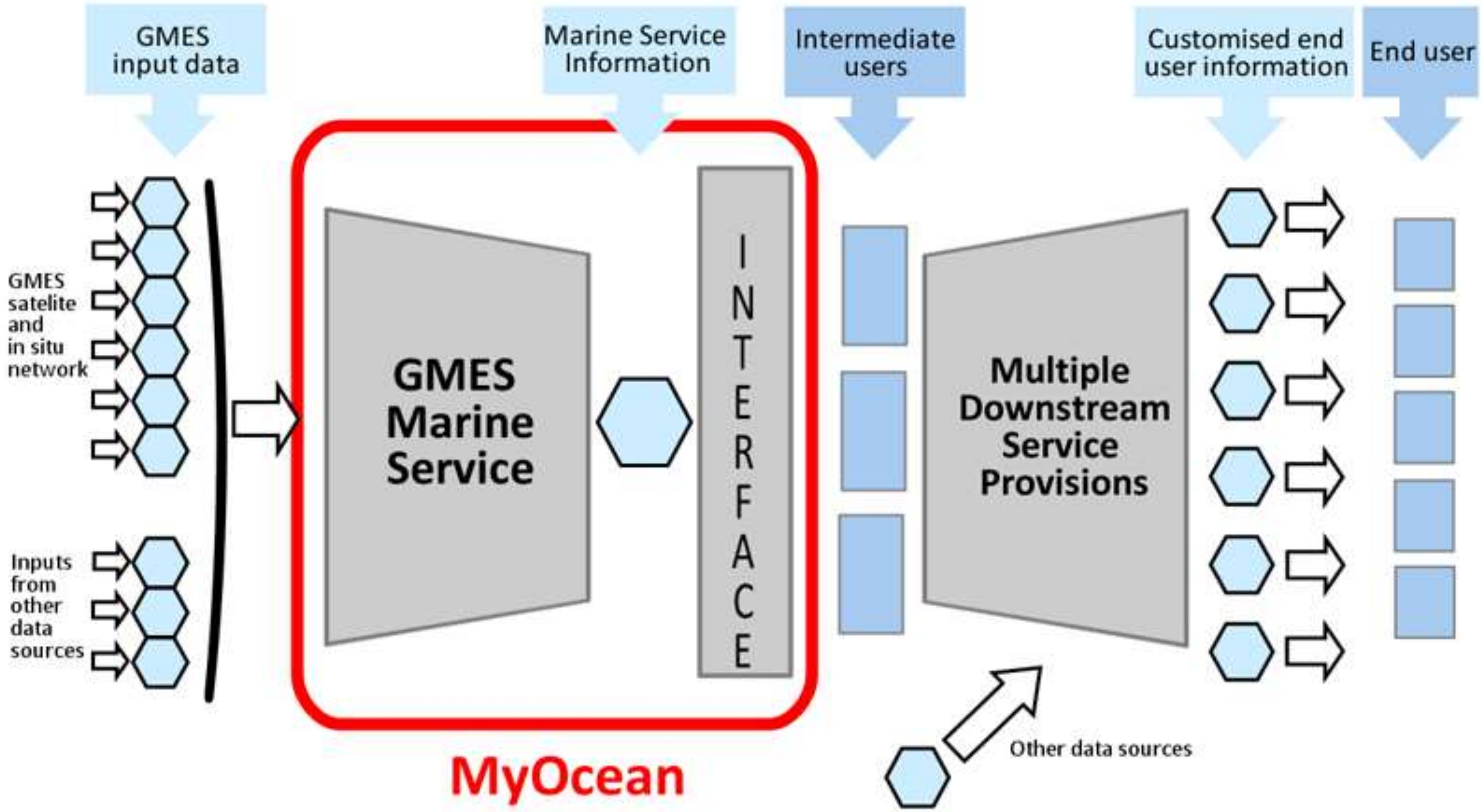
Different producers and system versions, compared with observations

Low sea levels in Sõru 2007

FINNISH METEOROLOGICAL INSTITUTE
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

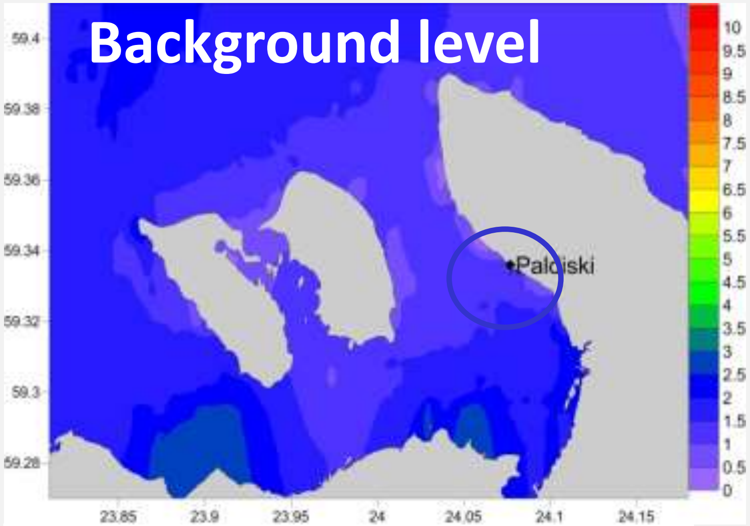
Lagemaa & Väli

Copernicus Marine Service Today

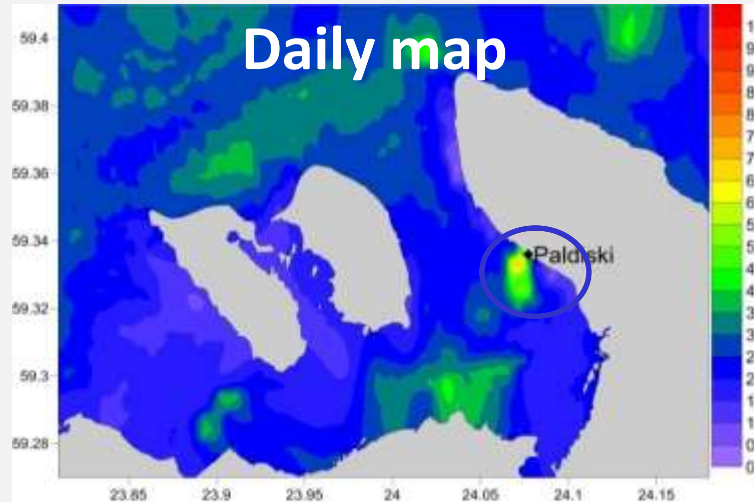


MSI provides service within the Baltic monitoring and forecasting centre

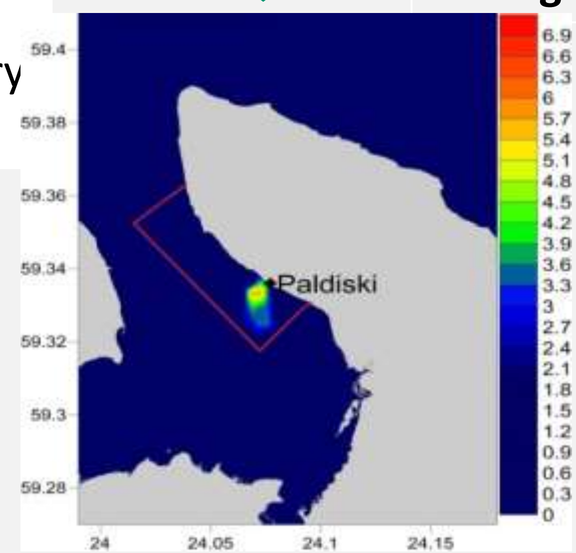
Dredging impact monitoring from satellite imagery



Monthly mean total suspended mater concentration in July calculated from satellite imagery (2003-2010)



Total suspended matter concentration **during dredging operations** (27 July 2008)



Difference from background indicating the area influenced by dredging operations

- Amount of dredged material on that month was 5250 m^3
- Total suspended matter concentration increased in an area of 1 km^2

Innovative ESA Project „Environmental monitoring of harbour dredging“, in cooperation with enterprises Port of Tallinn, AS Regio

Outlook

- Sustainable exploitation of marine goods and services needs **decisions based on robust knowledge** of the present marine situation as well as good predictions of its changes; earlier intuitive approaches do not necessarilry work in changing natural conditions and alterating human pressures // **why the sea does not behave like we assumed?**
- New challenges for marine knowledge are provided by **revolutionary observation and modelling techniques, especially for biogeochemical variables**
- Dealing with **practical sea use problems**, quite often causing conflict of interests, requires coopereation between **natural and technical scientists**, supported by social scientists and economists