A PhD seminar in connection with the Gulf of Finland Scientific Forum

Exchange processes between the Gulf of Finland and other Baltic Sea basins

Tallinn, Estonia, 19 November 2015

Programme, Abstracts, Participants

Impressum

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Impressum

Baltic Earth/Gulf of Finland Scientific Forum

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Co-Organized by

Scope

This seminar is attached to the Gulf of Finland Final Scientific Forum held in Tallinn on 17-18 November 2015. The main idea is to give students working at Gulf of Finland issues the opportunity to present and discuss their work among each other, and also with the senior scientists present. The morning session will be dedicated to four keynote presentations of experienced Baltic Sea and Gulf of Finland researchers. PhD students will present their work in the afternoon session. The scientific intention of the seminar is to describe interactions between the Gulf of Finland with the Baltic Sea, providing new information of the poorly-known exchange processes in between the basins. The interactions include meteorological, oceanographical, hydrological and biogeochemical process descriptions.

Venue

The seminar will take place in the Hotell Euroopa (Paadi 5, 10151 Tallinn), located in front of the Old City Marina, and just 700 m from the medival old city centre.

Organizers

Urmas Lipps, Marine Systems Institute at Tallinn University of Technology, Estonia
Mairi Uiboaed, Marine Systems Institute at Tallinn University of Technology, Estonia
Kai Myrberg, Finnish Environment Institute, Helsinki, Finland
Marcus Reckermann, International Baltic Earth Secretariat, Helmholtz-Zentrum Geesthacht, Germany
Silke Köppen, International Baltic Earth Secretariat, Helmholtz-Zentrum Geesthacht, Germany

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Programme

10:00	**Opening** *Kai Myrberg*, Finnish Environment Institute, Helsinki, Finland *Marcus Reckermann,* International Baltic Earth Secretariat at Helmholtz-Zentrum Geesthacht, Germany
10:10	Keynote 1: **Physical-biogeochemical modelling of the Baltic Sea - Gulf of Finland, fluxes between the basins** *H.E. Markus Meier*, Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany and Swedish Meteorological and Hydrological Institute, Norrköping and Västra Frölunda, Sweden *Kari Eilola*, Swedish Meteorological and Hydrological Institute, Norrköping and Västra Frölunda, Sweden *Kai Myrberg*, Finnish Environment Institute, Helsinki, Finland *Germo Väli*, Marine Systems Institute at Tallinn University of Technology, Tallinn, Estonia
10:40	Keynote 2: **Specific effects of climate change on the Gulf of Finland ecosystem** *Markku Viitasalo*, Finnish Environment Institute, Helsinki, Finland
11:10	**Coffee Break**
11:40	Keynote 3: **Nutrient and oxygen dynamics caused by the Major Baltic Inflow in December 2014** *Günther Nausch*, Baltic Sea Research Institute Warnemünde, Germany
12:10	Keynote 4: **Passive optical remote sensing in the Baltic Sea studies** *Tiit Kutser*, University of Tartu, Estonia
12.40	Discussion
13:00	**Lunch**
14:00	**Exploratory data analysis and biochemical modeling of the Neva Bay and the Eastern Gulf of Finland** *Mark Polyak*, Institute of Computer Systems and Software Development, State University of Aerospace Instrumentation, Saint-Petersburg, Russia
14:20	**Exploring the sensitivity of carbon chemistry to model setup in the Gulf of Finland** *Rocío Castaño-Primo* and *Corinna Schrum*, Geophysical Institute, University of Bergen, Norway *Ute Daewel*, Nansen Environmental and Remote Sensing Center, Bergen, Norway
14:40	**On the accuracy of the modelled wave spectrum in coastal archipelagos** *Jan-Victor Björkqvist, Laura Tuomi, Kimmo Tikka, Carl Fortelius, Heidi Pettersson* and *Kimmo K. Kahma*, Finnish Meteorological Institute, Helsinki, Finland

15:00	**Coffee Break**
15:30	**Spatial variability in the trends in extreme water level components in the Eastern Baltic Sea** *Katri Pindsoo* and *Tarmo Soomene*, Institute of Cybernetics at Tallinn University of Technology, Estonia
15:50	**Examining an upwelling event using satellite data and in-situ surface drifters in the Gulf of Finland** *Toma Mingelaite*, Department of Natural Science, Klaipeda University, Lithuania *Nicole Delpeche-Ellmann* and *Tarmo Soomere*, Institute of Cybernetics at Tallinn University of Technology, Estonia
16:10	**Observing and modelling the Gulf of Finland with high spatial resolution** *Antti Westerlund* and *Pekka Alenius*, Finnish Meteorological Institute, Helsinki, Finland *Roman Vankevich*, Russian State Hydrometeorological Institute, Saint-Petersburg, Russia
16:30	Final Discussion and Wrap-Up
17:00	Closing

Abstracts in first author alphabetically order

On the accuracy of the modelled wave spectrum in coastal archipelagos

Jan-Victor Björkqvist, Laura Tuomi, Kimmo Tikka, Carl Fortelius, Heidi Pettersson and Kimmo K. Kahma

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1. Introduction

Accurate information regarding the wave conditions in the coastal areas of the Gulf of Finland is important for maritime spatial planning and for the safety and efficiency of the heavy marine traffic in this area. The waves also play an important role in the sediment transport (e.g. Bengtsson and Hellström, 1992; Nielsen, 1992). However, the method of quantifying the effect of the waves by simple parameters, such as the significant wave height and the peak period, requires assumptions about the shape of the wave spectrum. Because the typical shape of the wave spectrum in the unique archipelago areas of the northern Baltic Sea is expected to differ remarkably from the general findings of the open sea, these methods might not be directly aplicable to these type of coastlines.

There are very few wave measurements from the archipelago areas. While there has been substantial modelling efforts in archipelago areas (Tuomi et al., 2014), challenges posed by the irregular coastline and complex bathymetry is far from solved. The measurment data-set from the edge of the Helsinki archipelago presented here was planned and collected to fulfill this definite need. To improve wave model physics in order to better model the wave conditions in archipelagos, we analysed and compared these measurements to the results of a third generation spectral wave model WAM. We also aimed to develop methods that would enable us to obtain improved results when modelling the wave spectrum with the current model.

2. Materials and methods

We used the third generation spectral wave model WAM cycle 4.5.1 (WAMDIG, 1988; Komen et al., 1994) to simulate the wave field in the Helsinki archipelago. WAM solves the energy balance equation, which in deep water takes the form:

$$\frac{\partial F(f,\theta)}{\partial t} + c_g \cdot \nabla F(f,\theta) = S_{tot} \qquad (1)$$

The right side term is the sum of the source term functions, which include the wind input and the dissipation caused by white-capping. The weakly non-linear wave-wave interactions were calculated by the discrete interaction method DIA as proposed by Hasselman et al. (1985). In addition, also bottom friction and depth-induced wave breaking source terms are available following Monbaliu et al. (2000). The coastal grid was constructed for WAM with a resolution of 0.185 km. It is mainly based on bathymetric data available in nautical charts. The boundary conditions for the coastal wave model run used a 1.85 km basin scale grid based on freely available data from ETOPO1 and IOW (Amante and Eakins, 2009; Seifert et al., 2001).

The wave model was forced with results from two different numerical weather prediction systems: HIRLAM

(HIRLAM-B, 2012) and the AROME-based HARMONIE (Seity et al., 2011). Both are currently in operational use at FMI.

We compared the modelled coastal wave fields to one month of directional wave buoy measurements close to the edge of the archipelago ("Harmaja") and to the measurements of FMI's operational wave buoy. The buoys are located approximately 10 and 30 km from the shore off Helsinki.
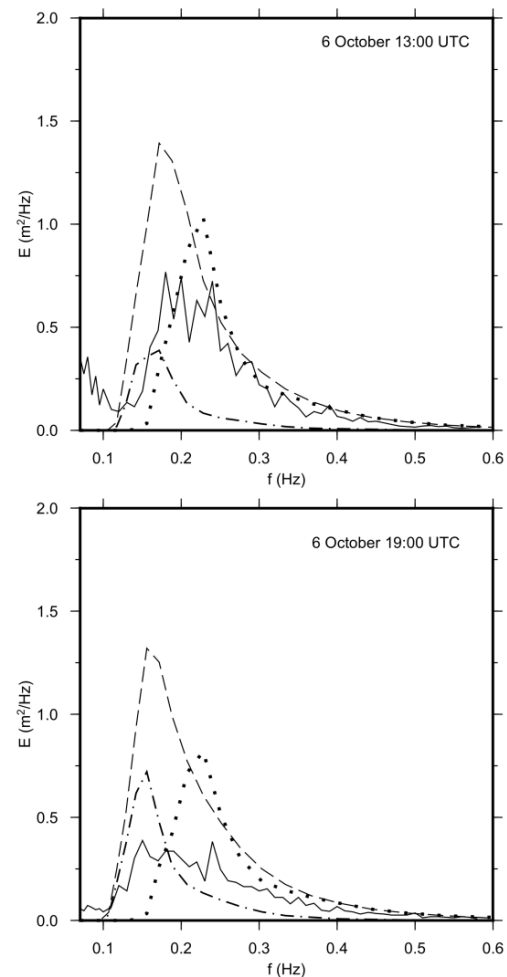

Figure 1. The measured wave spectrum (solid) at Harmaja during steady wind (top) and wave decay (end). The WAM spectrum for the full model run (dashed), the run with no boundary wave field (dotted) and the run with no wind forcing in the coastal grid (dash-dotted) are shown for comparison.

3. Results

We showed that the modelled significant wave height had a direction dependant bias at Harmaja; during south-westerly winds the wave model overestimated the wave

energy at practically all frequencies, even when the boundary wave field was found to be accurate (Fig. 1). The wave field at Harmaja for these situations consisted of waves limited by the fetch to the peninsula of Porkkala in the west combined with longer attenuated waves from the open sea. This finding was confirmed by a simple model relying on a combination of fetch-limited growth curves and the quantification of the low-frequency energy from FMI's operational open sea wave buoy.

The wave model's ability to produce both the propagating longer waves and the locally generated fetch-limited shorter waves was studied with two separate model runs. The longer waves were modelled using only the boundary conditions without any additional wind forcing in the coastal grid. The shorter waves were modelled with a zero-boundary condition using only the wind forcing in the coastal grid to generate the local wave field. The longer waves are predicted well during a steady wind situation during 13 October but overestimated during the wave decay in the evening the same day (Fig. 1). The locally generated shorter waves are overestimated by the model at both times.

Waves travelling from the south-west have to pass a shallow area south-west of Harmaja. As the uncertainties in the bathymetric data may affect the wave model results, we ran the model using several bathymetric configurations and modifications. These had a local impact on the wave field at Harmaja for the full model run, especially for the lower frequencies.

The resolution of the wind forcing might also be a contributing factor to the performance of the wave model (Tisler et al., 2007). However, in this case the higher resolution wind forcing by HARMONIE did not improve the accuracy of the modelled wave field compared to the coarser HIRLAM.

An improvement in the accuracy of the predicted wave spectra at Harmaja was obtained by calculating an attenuation factor for the wind forcing. The factor was determined by scaling the modelled dimensionless spectra to the observed ones for the period of a steady south-westerly wind on 06 October. This was done using the wind dependent ω^{-4} power-law of the observed fetch-limited wave spectra.

4. Discussion and Conclusions

Because the overestimation of the modelled wave energy can't be explained solely by the inaccuracy of any forcing factor (i.e. bathymetric data, wind forcing or boundary wave field), we conclude that there are more fundamental issues connected to the physics of the wave model. Especially, WAM was not able to reproduce the observed fetch-limited.

The energy of the longer waves is clearly overestimated by WAM (Fig. 1). This behaviour might be caused by two reasons. The shape of the wind input source term might be too broad, in which case it would feed too much energy to the longer waves that are travelling quite near the direction of the fetch-limited waves. The other possible reason is a too strong interaction between the two wave systems, which would transfer too much energy from the shorter wave system to the longer waves. To solve these issues the deep water source terms of the wave model needs further rebalancing, ideally in combination with the exact non-linear interactions (van Vledder, 2006).

With the current model, an enhanced accuracy near the Helsinki archipelago can be reached by appropriately attenuating the forcing wind speed. The improved results obtained by this approach can be highly important when determining the impact the wave field has on e.g. bottom sediments. An improved match for the shape of the spectra is especially important in the Baltic Sea, since traditional parametrisations might not be representative for wave conditions in archipelagos.

References

Amante, C., Eakins, B.W. (2009) ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis, NOAA Technical Memorandum NESDIS NGDC-24, 19 pp, March 2009

Bengtsson, L., Hellström, T. (1992) Wind-induced resuspension in a small shallow lake, Hydrobiologia, Vol., 241, pp., 163–172

Hasselmann, S., Hasselman, K., Allender, J., Barnett, T. (1985) Computation and parameterizations of the nonlinear energy transfer in a gravity-wave spectrum. Part ii: Parameterizations of the nonlinear energy transfer for application in wave models, J. Phys. Oceanogr. Vol. 15, pp. 1378-1391

HIRLAM-B, 2012. System documentation. URL: http://hirlam.org

Komen, G.J., Cavaleri, L., Donelan, M., Hasselmann, K., Hasselman, S., Janssen, P.A.E.M. (1994) Dynamics and Modelling of Ocean Waves, Cambridge University press, Cambridge

Monbaliu, J., Padilla-Hernández, P., Hargreaves, J.C.C., Albiach, Luo, W., Sclavo, M., Günther, H. (2000) The spectral wave model, WAM, adapted for applications with high spatial resolution, Coast. Eng., Vol. 41, pp. 41-62

Nielsen, P., (1992) Coastal bottom boundary layer and sediment transport, Advanced Series on Ocean Engineering – volume 4, World Scientific Publishing, Singapore

Seifert, T., Tauber, F., Kayser, B. (2001) A high resolution spherical grid topography of the Baltic Sea – 2nd edition, Baltic Sea Science Congress, Stockholm 25-29. November 2001, Poster #147, www.io-warnemuende.de/iowtopo

Seity, Y., Brousseau, P., Malardel, S., Hello, G., B_enard, P., Bouttier, F., Lac, C., Masson, V. (2011) The arome-france convective-scale operational model, Monthly Weather Review Vol. 139, pp. 976-991

Tuomi, L., Pettersson, H., Fortelius, C., Tikka, K., Björkqvist,. J.-V. Kahma, K.K. (2014) Wave modelling in archipelagos, Coast. Eng., Vol. 83, pp. 205-220

Tisler, P., Gregow, E., Niemelä, S., Savijärvi, H. (2007) Wind field prediction in coastal zone: Operational mesoscale model evaluation and simulations with increased horizontal resolution, J. Coastal Res., Vol. 233, pp. 721-730

van Vledder, G.P. (2006) The wrt method for the computation of non-linear four-wave interactions in discrete spectral wave models, Coast. Eng., Vol. 53, pp. 223-242

The WAMDI Group (1988) The WAM Model-A third Generation Ocean Wave Prediction Model, *J. Phys. Oceanog.*, Vol. 18, pp. 1775-1810

Exploring the sensitivity of carbon chemistry to model setup in the Gulf of Finland

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1. Introduction

The increase in atmospheric pCO_2 since the industrial revolution has been accompanied by a general decrease in oceanic pH. This main atmospheric signal is, however, largely modulated by ocean circulation and ecosystem processes. The pH in shelf seas is not only determined by the air-sea exchange and internal processes also present in the open ocean, but additionally by inputs from land and sediment, and lateral exchange with the open ocean or other adjacent seas that may have very different chemical signatures.

Numerical models include a limited set of processes due to computational constrains and/or knowledge of their relevance for the variables considered. In addition, the parameterizations used are usually based on estimates with large uncertainties. Sensitivity tests are important to assess the robustness of the model results to different estimations of key parameters.

2. Materials and Methods

We used the bio-physical model ECOSMO, (Daewel & Schrum, 2013) and integrated an inorganic carbon chemistry module,(Blackford & Gilbert, 2007). We calculate the dissolved inorganic carbon (DIC) and Alkalinity prognostically as a function of riverine inputs, advection, and biological processes such as primary production and remineralization (DIC) and denitrification (Alkalinity). From these two variables, pH and partial pressure of CO_2 (pCO_2) are calculated. The model area comprises the North and Baltic Seas, but for the current presentation we focus on the results from the Gulf of Finland only.

The baseline run uses the dissociation constants from Millero (2006) and the wind speed - CO_2 exchange relationship from Wanninkhof *et al.* (2014). In a set of numerical experiments we explore the model sensitivity to other dissociation constants (Millero, 1995), air-sea exchange parameterizations (Nightingale (2000), Wanninkhof (1992)), doubling and halving of remineralization rates, DOM/detritus ratio and detritus sinking speed and changes (±20%) in phytoplankton growth rate.

3. Preliminary results

According to the model results, at position 54.68 N, 24.27 E, pH decreases with depth, with a difference around 0.8 units of pH between surface and bottom waters (Fig. 1). The model reproduces the distinct characteristics of the surface and bottom layers in the Gulf of Finland: the bottom pH does not replicate the variability of surface pH, and particularly from 2003 it seems to follow a different dynamic.

In general, the calculated pH is quite robust and does not vary substantially between the different formulations. The shape of the time series is essentially kept. This is a positive outcome: seawater is an excellent buffer, and despite the large amounts of CO_2 absorbed by the ocean, pH has decreased by a relatively small amount, 0.1 units since the beginning of the industrial revolution (Feely *et al.* 2009). The model runs for only 10 years, deviations on the scale of 0.1 respect to the baseline run would indicate that the carbonate model is not robust enough.

However, some differences are worth to be noted. In the surface layer, the use of Millero (1995) dissociation constants gives the lowest pH values through the most part of the time series. These dissociation constants were optimized for waters with oceanic salinities; they are less adequate for the brackish waters of the Gulf of Finland than the Millero (2006) constants. The bottom waters, on the other hand, are less sensitive than the surface layer: the different experiments give results very similar to the baseline run.
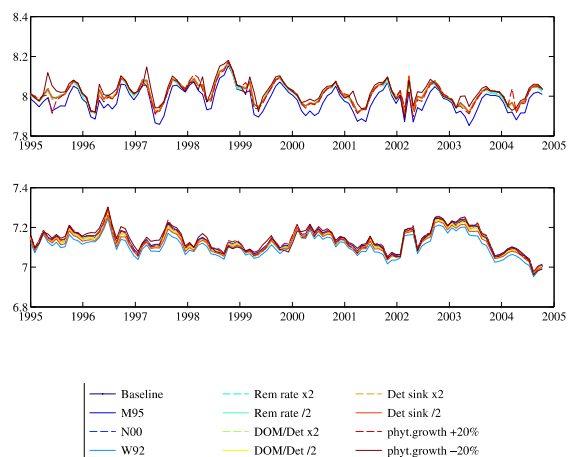
pH from 1995 to 2004 at station F26 for different model runs. M95: Millero (1995) dissociation constants; N00: Nightingale (2000) and W92: Wanninkhof *et al.* (1992) air-sea exchange parametrizations.

References

Blackford, J. C., & Gilbert, F. J. (2007). pH variability and CO_2 induced acidification in the North Sea. Journal of Marine Systems, 64(1-4), 229–241.

Daewel, U., & Schrum, C. (2013). Simulating long-term dynamics of the coupled North Sea and Baltic Sea ecosystem with ECOSMO II: Model description and validation. Journal of Marine Systems, 119-120, 30–49.

Feely R. A., Doney S. C., Cooley S.R. (2009). Ocean acidification: present conditions and future changes in a high-CO_2 world. Oceanography 22: 36–47

Millero, F.J. (1995). The thermodynamics of the carbonic acid system in the oceans. Geochimica et Cosmochimica Acta 59, 661–667

Millero, F. J., Graham, T. B., Huang, F., Bustos-Serrano, H., & Pierrot, D. (2006). Dissociation constants of carbonic acid in seawater as a function of salinity and temperature. Marine Chemistry, 100(1-2), 80–94.

Nightingale, P.D. (2000) In situ evaluation of air-sea gas exchange parameterizations using novel conservative and volatile tracers. Global Biogeochemical Cycles, 14, 373-387.

Wanninkhof, R. (1992). Relationship between wind speed and gas exchange over the ocean. Journal of Geophysical Research, 97(C5), 7373-7382.

Passive optical remote sensing in the Baltic Sea studies

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1. Why passive optical remote sensing?

Carrying out measurements at sea is very time consuming and expensive. Therefore, the number of measurements, spatial coverage and the sampling frequency are low. Moreover, coastal waters are very variable both is space (Figure 1) and time. It means that we may have very detailed information about different water properties in one sampling point, but the situation may be very different just a few tens to hundreds of meters away and the data from the sampling point may not be representative at larger scale.

Figure 1. Variability of water properties in Estonian west coast. A true color image of Advanced Land Imager (30 m spatial resolution).

Remote sensing is a measurement method where information about a study object is collected with a sensor that is not in contact with the object. In principle, the full spectrum of electromagnetic radiation can be used. However, if we want to collect information about the water properties then the visible part of spectrum has to be used due to optical properties of water as a medium. For example, radar beam cannot penetrate deeper into water than a millimeter or two and can give us information only about the surface roughness (waves, ice, slicks). Thermal infrared radiation provides us information on water temperature, but only on skin temperature. If we are interested in detecting different constituents in the water, map benthic habitat or bathymetry in shallow water areas then optical methods have to be used.

Optical methods can be active (e.g. use LIDAR as a light source) or passive – using the Sun as a light source. Both methods have their advantages and disadvantages. Passive methods cover large areas and are significantly cheaper. Therefore, the passive methods are more commonly used.
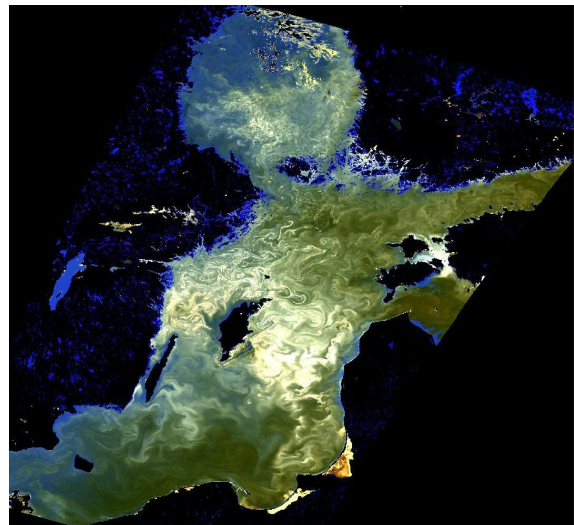

Figure 2. Cyanobacterial bloom in the Baltic Sea on July 25, 2008 imaged by ENVISAT MERIS sensor (predecessor of OLCI on Sentinel 3)

2. Remote sensing applications in the Baltic Sea

Technical achievement will improve significantly our capability to study different processes in the Baltic Sea by means of satellite sensors in the coming months. Launch of Sentinel 3A is planned for the end of 2015. OLCI on board the Sentinel 3 will provide us daily data with 300 m spatial resolution. Recently launched Sentinel 2A and its twin 2B (to be launched in the end of 2016) will provide us data with 10 m spatial resolution every second day at the Gulf of Finland latitude. This will allow us to study

different processes both at the Baltic Sea scale and also on a very local scale (Figure 2-4).
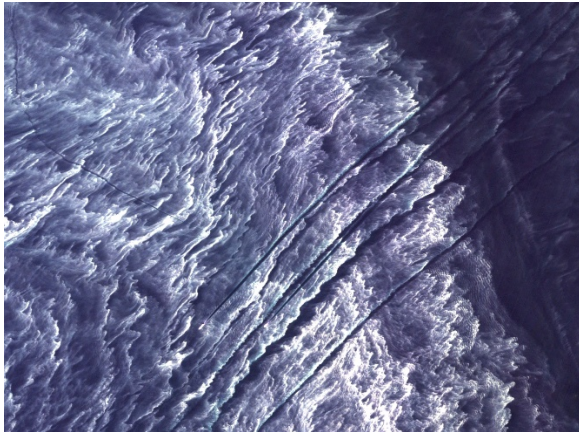

Figure 3. Cyanobacterial bloom in the middle of the Baltic Sea on August 7, 2015 imaged by Sentinel 2 (10 m spatial resolution)

Figure 4. Suspended sediment mixed into the water column by Heltermaa-Rohuküla ferry imaged by Sentinel 2 (10 m spatial resolution)

3. Shallow water remote sensing

High spatial resolution remote sensing is a very useful tool for different shallow water applications. Estonia has very large shallow water areas where mapping of bathymetry and benthic habitats is nearly impossible with conventional methods (from boats). The extent of benthic habitat, its species composition and shifts in it are indicators of ecological state of coastal waters. Moreover, we have shown that spatial heterogeneity of remote sensing imagery collected in shallow water areas is in good correlation with biodiversity in the area.
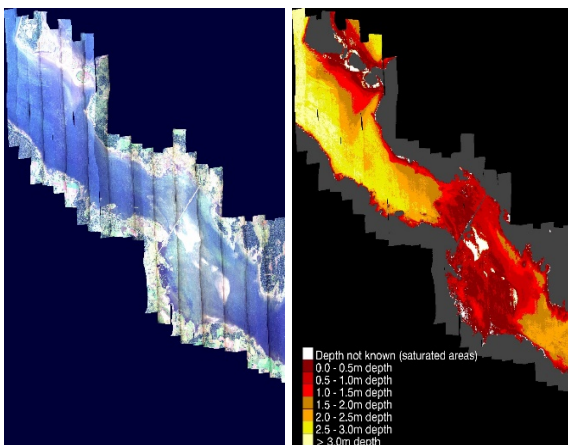

Figure 5. True color image the Small Strait made with HySpex airborne imager (left panel) and a water depth map produced from it.

Figures 5 and 6 illustrate bathymetry mapping using airborne imagery. The image data was collected with HySpex airborne imager. It must be noted that most of the depth information obtained from Estonian Maritime Administration was collected before 1953 not simultaneously with the airborne campaign as this is the latest information available for most of Estonian shallow water areas.
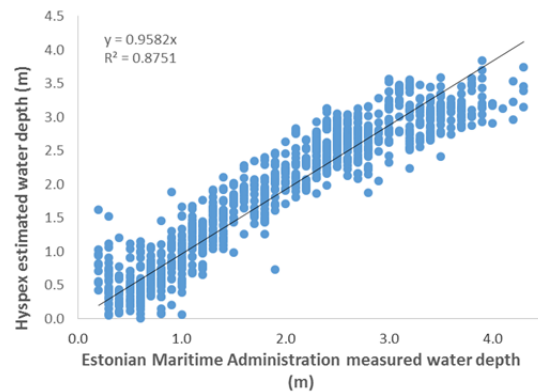

Figure 6. Correlation between the water depths obtained from Estonian Maritime Administration and estimated from HySpex imagery.

4. Combining remote sensing with modelling

Remote sensing provides us information about the surface layer of the waterbody. However, remote sensing products can be combined with hydrodynamic or ecological models in order to get 3D picture of the processes. Remote sensing products can be used both for validation of the model runs and as boundary conditions to run the model.

Combining remote sensing with spatial models can also provide interesting results. Using different remote sensing products (bathymetry, temperature, phytoplankton biomass, benthic habitat type, etc.) as input data we can improve modelling products and get information about topics that remote sensing cannot provide. For example, Figure 7 illustrates a Baltic herring potential spawning area map made with a spatial model and using remote sensing products as input data.
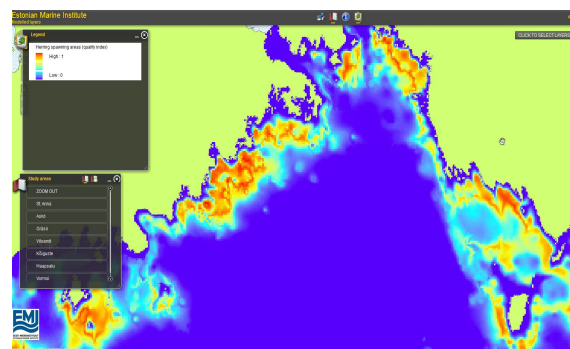
Figure 7. Baltic herring potential spawning area map (reddish colors mean better spawning area) produced with a spatial model that used remote sensing product as input data.

It must be noted that combining of model and remote sensing products is useful also in other ways. For example, it is possible to use model predictions for determining the benthic habitat type at the water depths

where we cannot separate different algae based solely on their optical properties. On the other hand model simulations are usually carried out with relatively large spatial grid (more than 250 m) whereas remote sensing can provide data with much better (below 1 m) resolution.

Combining remote sensing with models and *in situ* data can provides us insight into many processes these methods cannot provide while used alone.

Physical-biogeochemical modelling of the Baltic Sea - Gulf of Finland, fluxes between the basins

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[3] Finnish Environment Institute, Helsinki, Finland
[4] Marine Systems Institute at Tallinn University of Technology, Tallinn, Estonia

The Baltic Sea is a semi-enclosed, marginal sea with freshwater surplus from rivers and limited water exchange with the North Sea. As tidal amplitudes are small and salinity gradients are strong, the Baltic proper consisting of the Arkona, Bornholm and Gotland basins is characterized by a two-layer system with an upper brackish layer and a stratified deeper layer with much higher salinity than in the surface layer. The pronounced vertical stratification prevents the ventilation of the deep water with oxygen from the sea surface. Instead the deep water is only renewed by intrusions of inflowing, high-saline water from the sills located in the entrance.

The elongated Gulf of Finland (GoF) is located next to the northern Gotland Basin without any sills that separate the GoF from the Baltic proper. The central GoF is quite deep (over 60 m) but is getting shallower towards the eastern parts with the large river discharge from the river Neva located at the most eastern tip of the GoF. Hence the whole gulf is a transition zone from fresh water to the more saline waters of the Baltic Sea proper and the physical processes that govern the GoF differ from those in the Baltic proper due to the topographic and hydrographic settings. For instance, during strong wind events a reversal of the dominating estuarine circulation with outflow in the surface and inflow in the deep layer is found. During such events the vertical mixing is strong enough to dissolve the vertical stratification.

In this presentation existing literature on the water exchange between the GoF and the Baltic proper is reviewed. Further, modeling concepts are introduced that enable the calculation of the water and nutrient exchange between the GoF and the Baltic proper.

We use a state-of-the-art coupled physical-biogeochemical model, the Swedish Coastal and Ocean Biogeochemical model (SCOBI) coupled to the Rossby Centre Ocean model (RCO), i.e. RCO-SCOBI (Meier et al., 2003; Eilola et al., 2009). The model domain covers the Baltic Sea including the Kattegat with a 3.6 km horizontal grid resolution and 83 vertical levels with a layer thickness of 3 m. The time step of both the physical and the biogeochemical sub-models amounts to 150 s. The biogeochemical sub-model describes the dynamics of nitrate, ammonium, phosphate, phytoplankton, zooplankton, detritus, and oxygen. Here, phytoplankton consists of three algal groups representing diatoms, flagellates and others, and cyanobacteria. Besides the possibility of assimilating inorganic nutrients, the modelled cyanobacteria also have the ability to fix molecular nitrogen, which may constitute an external nitrogen source for the model system. The sediment contains nutrients in the form of benthic nitrogen and benthic phosphorus, including aggregated process descriptions for oxygen-dependent nutrient regeneration, denitrification and adsorption of ammonium to sediment particles, as well as permanent burial of organic matter. During periods with strong currents, resuspension occurs and sediments may be lifted up into the overlying water and become transported to deeper parts. Anoxic decomposition processes utilize oxygen from nitrate reduction (denitrification) and thereafter from sulphate reduction. Sulphate reduction produces poisonous hydrogen sulphide that is included as negative oxygen in the model. Hydrogen sulphide may be removed when new oxygen is supplied, e.g. by inflowing water.

As the Baltic is a shallow sea with a mean depth of 53 m, nutrient fluxes between bottom water and sediments are important. However, the processes in the sediments are not well understood, and might be regarded as one of the bottlenecks in state-of-the-art biogeochemical modeling. The model calibration has shown that the permanent sink of phosphorus (burial rate in the sediments) has a major effect on Baltic Sea nutrient cycling at longer time scales, i.e. decades. The regulation of phosphorus fluxes by oxygen concentrations is important for phosphorus cycling at seasonal and interannual time scales. However, nitrogen dynamics is selfadjusting through the internal sources (nitrogen fixation) and sinks (denitrification). Consequently, fluxes of the nitrogen cycles have not been calibrated.

The atmospheric forcing of RCO-SCOBI is calculated from multivariate daily meteorological fields (Schenk and Zorita 2012). To reconstruct the daily meteorological forcing (High Resolution Atmospheric Forcing Fields, HiResAFF), a nonlinear statistical method was developed. Long historical station records of daily pressure and monthly temperature since 1850 were used to find multivariate analogous target fields within a shorter 50-year regional climate simulation. The advantage of analog-upscaling (Schenk and Zorita 2012) lays in the physical consistency of the reconstructed fields including their regional topographic and variable specific frequency distributions. As the reconstruction makes use of a limited but relatively constant number of predictor stations, HiResAFF provides a homogeneous longterm reconstruction. Hence, it avoids introducing spurious long-term trends by assimilating different station numbers over time.

From simulation results for the period 1850-2006 horizontal transports between the GoF and the Baltic proper are calculated and analyzed. The method used in this study to calculate nutrient transports and the exchange between the GoF and the Baltic propser follows Eilola et al. (2012).

References

Eilola, K., H.E.M. Meier, and E. Almroth (2009) On the dynamics of oxygen, phosphorus and cyanobacteria in the Baltic Sea: A model study. Journal of Marine Systems 75: 163–184.

Eilola, K., E. Almroth Rosell, C. Dieterich, F. Fransner, A. Höglund, and H.E.M. Meier (2012) Nutrient transports and exchanges of nutrients between shallow regions and the open Baltic Sea: A model study in present and future climate. AMBIO. doi:10.1007/s13280-012-0322-1.

Meier HEM, Döscher R, Faxén T (2003) A multiprocessor coupled ice-ocean model for the Baltic Sea: application to salt inflow. J Geophys Res 108(C8):3273.

Schenk, F., and E. Zorita (2012) Reconstruction of high resolution atmospheric fields for Northern Europe using analog-upscaling. Climate of the Past 8: 1681–1703.

Examining an upwelling event using satellite data and in-situ surface drifters in the Gulf of Finland

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1. Introduction

Wind-induced coastal upwelling is important dynamical feature affecting the circulation and the ecosystem of the Baltic Sea. Since Baltic Sea is a semi- enclosed basin, the winds from all directions can cause upwelling at some part of the coast (Lehmann and Myrberg, 2008). Although the spatial scale of upwelling is small, its high frequency of occurrence is one of the key physical features in the region.

During the summer months in the Gulf of Finland westerly or easterly winds are known to trigger intense occurrences of coastal upwellings/downwellings along the northern and southern coast. This is a very important process in the gulf for it restores the surface layer with colder nutrient laden water from the lower layer and also redistributes heat and salt. This uptake of cold water may be followed by mesoscale activity that contributes to its lateral mixing.

2. Data, Methods & Results

In this study we utilize sea surface temperature satellite data obtained from the MODIS Aqua satellite (MODIS Aqua Level 2 imagery covering the study site with spatial resolution of about 1 km were obtained from the NASA OceanColor website (http://oceancolor.gsfc.nasa.gov/)) and from a Lagrangian perspective we employ in-situ surface drifters to examine an upwelling event occurring on the southern coast of the gulf.

To quantify spatially and temporally the lateral mixing characteristics an analysis was made of the daily rate of change of temperature along several transects taken in the upwelled region. The lateral mixing observed was compared with that of the wind data followed by that of the drifter speed and direction.

Results show that lateral mixing is enhanced when wind speed was the weakest and intense mesoscale activity present. Interestingly also that the surface drifters tended to avoid the areas of transverse jet/filaments.

References

Lehmann A., Myrberg K., (2008) Upwelling in the Baltic Sea — A review, Journal of Marine Systems 74, S3–S12.

Nutrient and oxygen dynamics caused by the Major Baltic Inflow in December 2014

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1. Introduction

In December 2014 an exceptional large intrusion of 320 km³ water from the North Sea *o*ccurred in the Baltic Sea and interrupted ten years of wide spread hypoxic conditions in its central deeper basins (Fig.1b). Such intrusions are the only effective mechanism to renew and ventilate the deep water layer of this permanently stratified semi-enclosed sea (Matthäus et al. 2008,) and of superior importance for the Baltic ecosystem (Nausch et al. 2008).

2. The Major Baltic Inflow 2014

Since the early eighties of the last century the frequency of inflow events has dropped drastically from 5 to 7 major inflows per decade to only one inflow per decade. The rare Major Baltic Inflow (MBI) events in 1993 and 2003 could interrupt the anoxic bottom conditions only temporarily. After more than 10 years without a Major Baltic Inflow, in December 2014 a strong MBI brought large amounts of saline and well oxygenated water into the Baltic Sea. The inflow volume and the amount of salt transported were estimated to be 198 km3 and 4 Gt, respectively (Fig. 1). In the list of MBIs since 1880, the 2014 inflow is the third strongest event together with the MBI in 1913 (Mohrholz et al. 2015).
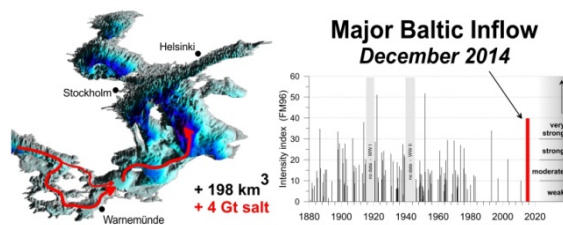

Figure 1. Pathway of the major Baltic Inflow 2014 and inflow statistics since 1880 (Mohrholz et al. 2015)

3. Oxygen and nutrient dynamics

Based on regular monitoring measurements the development of oxygen, phosphate and nitrate are shown for the Bornholm Deep and for the Gotland Deep for the period from January 2014 to July 2015. Soon it became obvious that already during wintertime 2013/14 and spring 2014, a succession of three smaller intrusions interacted positively to a weak to medium sized MBI, that transported in advance to the MBI in December 2014 first smaller volumes of lower oxygen to the eastern Gotland Basin reaching it at the end of May 2014 (Naumann and Nausch 2015). Even this earlier signal was very spectacular and a rare phenomenon in the latest ecological history of the Baltic. It slightly improved the deep-water situation in the central basins and formed precondition of the MBI of late 2014.

The nutrient regime in the deep water reacts to the changes from anoxic to oxic conditions as expected. In the presence of oxygen, phosphate is partly bound in the sediments and onto sedimenting particles in form as an iron-3-hydroxophosphate complex. If the system turns from oxic to anoxic conditions, this complex is reduced phosphate and iron-II ions are liberated. Also the inorganic nitrogen compounds are affected by the interplay of oxygen and hydrogen sulfide. Under anoxic conditions nitrate is denitrified to molecular dinitrogen gas. Ammonium, which is transferred from the sediment into the bottom water or produced by mineralization of organic material, cannot be oxidized and is enriched. In contrast in the presence of oxygen, the inorganic nitrogen pool is almost exclusively in the oxidized form as nitrate.

The actual development of nutrient concentrations is compared with long-term data series reaching back until the sixties of the last century.

References

Matthäus, W.; Nehring, D.; Feistel, R.; Nausch, G.; Mohrholz, V.; Lass, H.-U. (2008): The Inflow of Highly Saline Water into the Baltic Sea. - in: Feistel, R.; Nausch, G.; Wasmund N. (Eds.): State and evolution of the Baltic Sea, 1952-2005, John Wiley & Sons, Inc.Hoboken, New Jersey, pp. 265-309.

Mohrholz, V.; Naumann, M.; Nausch, G.; Krüger, S.; Gräwe, U. (2015): Fresh oxygen for the Baltic Sea – An exceptional saline inflow after a decade of stagnation. – Journal of Marine Systems 148: 152-166.

Naumann, M.; Nausch, G. (2015): Die Ostsee atmet auf – Salzwassereinstrom 2014) (english title: The Baltic Sea is breathing on – Salt Water Inlet 2014). – Chemie in unserer Zeit 49(1): 76-80.

Nausch, G.; Nehring, D.; Nagel, K. (2008): Nutrient Concentrations, Trends and Their Relation to Eotrophication. - in: Feistel, R.; Nausch, G.; Wasmund N. (Eds.): State and evolution of the Baltic Sea, 1952-2005, John Wiley & Sons, Inc.Hoboken, New Jersey, pp. 337-366.

Spatial variability in the trends in extreme water level components in the Eastern Baltic Sea

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Extreme water levels usually reflect a joint impact of several drivers. A specific feature of the Baltic Sea is that sequences of storms may raise the average sea level by almost 1 m for a few weeks. Strong storms occurring during such events may lead to unusually high water levels. We analyse separately the contribution of these two main drivers into the long-term changes in water level extremes. As they act at greatly different scales, it is convenient to separate the overall course of the Baltic Sea water level into a relatively short-term (a few days) reaction to single storms and weekly-scale (or longer) response of the entire sea to sequences of storms.

For the separation we use running average of the local water level time series to single out annual maxima of both components. We employ numerically simulated water levels for 1961-2005 produced by the RCO model and observations in four sites. The trends in the annual maxima of the weekly average are almost constant along the entire eastern Baltic Sea coast for averaging interval longer than 4 days. The trends for maxima of local storm surge heights represent almost entire spatial variability in the water level maxima. Their slopes vary from almost zero for the open Baltic Proper coast up to 5–7 cm/decade in the eastern part of the sea. This pattern suggests that an increase in wind speed in strong storms is unlikely in this area but storm duration may have increased and wind direction may have rotated.

Exploratory data analysis and biochemical modeling of the Neva Bay and the Eastern Gulf of Finland

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1. Preface

Consistent biological monitoring of the Neva Bay and the Eastern Gulf of Finland started in 1981 and continued till the 1990. The data collected during that period included phytoplankton, zooplankton and zoobenthos, photosynthetic pigments such as chlorophyll *a*, *b* and *c*, bacterioplankton and hydrological data with local weather conditions and some other information. The majority of that data has not been digitized until recently and was stored in yearly paper-reports on library shelves.

In 1990s biological data in the Neva Bay was collected irregularly mainly due to lack of financial support from the government. Starting from 2000s and nowadays in 2010s the amount of collected data is increasing each year. Large amounts of data bring forth the problem of building a computer-based information system (IS) to store, manipulate and research that data. Combining together in one database all available biological data of Neva Bay and Russian part of GoF for the last 30 years is important for solving data mining tasks, analysis of human impact and of Neva Bay ecosystem's dynamics.

The main goal of this work is to bring all the data sources of biochemical monitoring of the Neva Bay in one place and build a regional geographic information system (GIS). Such system would implement data analysis algorithms and mathematical models to evaluate and predict ecosystem health, pollution risks, eutrophication, etc.. For the current work we have investigated phytoplankton and chlorophyll models only.

2. Data description and database design

A network of water quality monitoring stations in the Neva Bay that were used to collect the data is shown on figure 1.
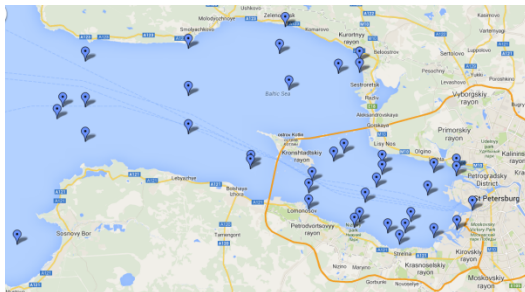

Figure 1. Location of ground monitoring stations in the Neva Bay and Eastern Gulf of Finland.

Database schema of IS consists of more than 40 tables designed to store hydrobiological and hydrological data, weather conditions and water chemistry data. Currently more than 1000 samples from about 90 monitoring stations from the period 1981-1990 have been digitized. These are mainly samples of phytoplankton and photosynthetic pigments.

The list of dominant phytoplankton species in samples collected during this period consists of more than 12000 entries. Total number of unique phytoplankton species exceeds 500. Chlorophyll concentrations are described by 800 samples and more are expected to be digitized soon.

At this moment the data of the 1990s period is not yet found. The data from 1999 to 2003 is scheduled to be digitized in the near future. Starting from 2004 the data is present in the digital form, but it requires additional preprocessing to bring it in consistence with the GIS database schema.

3. Mathematical models

Using the data described above we have built a regression model that is able to predict chlorophyll *a* concentrations based on such factors as water temperature, nutrients concentration, water transparency and others, Box (1976), Rozenberg (1994). The accuracy of the original model was poor so other models were investigated. Nevertheless a more accurate regression model was built recently when new data was digitized and fuzzy-logic factor decomposition was applied before fitting the model.

We have used a two-dimensional statistical model to approximate parameter values in locations outside of a network of land monitoring stations. Distribution of a biochemical parameter can be modeled as a random field with X- and Y-axis denoting coordinates and Z-axis showing the value of that parameter, see Tikhonov (1987). The modeled parameter can represent chlorophyll *a* concentration, sea surface temperature, pixel intensity of the remotely sensed image data, etc. An example of such random field is shown on figure 2.
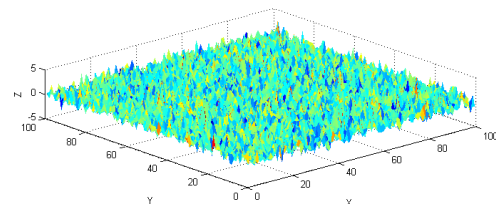

Figure 2. Random field with Gaussian distribution of Z-axis values.

We have also investigated a phytoplankton population dynamics model based on evolutionary predator-prey model with stochastic disturbance, which is described in Krestin (2004) and Polyak (2013).

4. Conclusion

It is too early to talk about the quality of the models while the process of gathering missing data is not finished. But preliminary results suggest that reasonably accurate models can be built to predict chlorophyll concentrations and algal blooms.

The dataset being digitized is unique as it describes the biological diversity of the Neva Bay before, during and after the Saint-Petersburg Dam has been built. Statistical methods could be used to analyze the impact of the Dam on the Neva Estuary once the GIS and its database are completed.

References

Box, G. E. P., Jenkins, G. M. (1976). Time series analysis: Forecasting and control. San Fransisco, CA.

Rozenberg, G.S., Shitikov, V.K., Brusilovskiy, P.M. (1994) Forecasting in ecology: functional predictors and time-series, Tolyatti (in Russian)

Tikhonov, V. I., Khimenko, V.I. (1987) Excursions of the Trajectories of Random Processes, Moscow, Nauka (in Russian)

Krestin, S. V. (2004) Mathematical modeling of spatially-distributed ecosystems – evidence from freshwater algal blooms, Ph.D. thesis (in Russian)

Polyak, M. (2013) Evolutionary Predator-Prey Model with Stochastic Disturbance, XIV International Forum «Modern information society formation — problems, perspectives, innovation approaches»: Proceedings of the Forum. St. Petersburg, SUAI, pp. 59-63

Specific effects of climate change on the Gulf of Finland ecosystem

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1. Indirect and direct effects

The Gulf of Finland ecosystem responds to natural climatologic variations in the North Atlantic region, characterized by the North Atlantic Oscillation (NAO), as well as the human-induced global climate change, that has been projected to affect various oceanographical and biogeochemical parameters in the Gulf in the coming decades. The complexity of the interactions and feedbacks between the atmosphere, watershed and the marine ecosystem make it difficult to distinguish anthropogenic effects, such as eutrophication, from those caused by changes in climate. Temperature drives biological processes, life-history traits, population growth, and ecosystem processes. Salinity is also a fundamental factor in the Gulf of Finland, because many organisms here live at the edge of their salinity tolerance levels. Other environmental factors that are also affected by climate are the oxygen concentration and pH of the seawater. Climate also indirectly affects species and populations by affecting water stratification, mixing depth and availability of nutrients from deep water, thus influencing the primary producers as well the animals feeding on them. Below two specific processes, namely climate effects on species biogeography, and climate effects on the eutrophication of Gulf of Finland are discussed.

2. Effects on species biogeography

Climate change may affect biogeography of species via their salinity and temperature tolerance effects. Recent spatial modelling shows that, e.g., the distribution areas habitat-forming species like bladderwrack (Fucus vesiculosus) and blue-mussel (Mytilus trossulus) will be significantly reduced, and that eelgrass (Zostera marina) will probably completely disappear from the Finnish coasts, if the salinity in the Gulf of Finland and the Gulf of Bothnia decreases by 1.0-1.5 permilles, as predicted by the models used. In the case of eelgrass, however, the species seems to be able to remain in small refugia, where near-optimal conditions occur despite less than optimal salinity. Also, the analysis predicts changes in the living conditions of non-indigenous species that have invaded the Baltic Sea: some species, such as the zebra mussel, which has caused economic losses in the areas it has invaded by fouling boat hulls and water intake pipes, will benefit from the expected lowering of salinity and increase of temperature. Such geographical and population changes need to be taken into account when deciding upon spatial allocation of sea uses, including the need and management of marine protected areas.
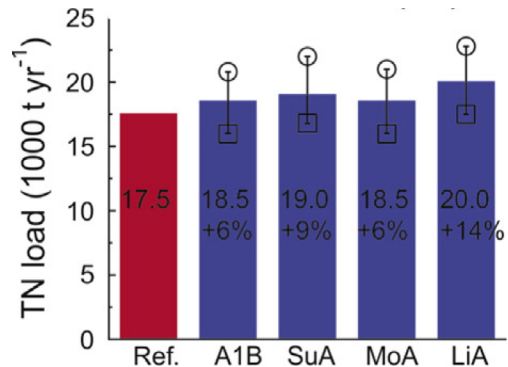

Figure 1.Total nitrogen riverine loading from Finland into the Gulf of Finland in 2001-2010 (Ref.) and in different climate change scenarios (Mean A1B IPCC scenario) combined with three agricultural adaptation scenarios (successful adaptation, moderate adaptation, little adaptation). Source: Huttunen et al. (2015)

3. Effects on eutrophication

Climate change has often been predicted to worsen eutrophication, because of increasing nutrient runoff into the sea, when rainfall and freshwater discharge to the sea will increase. It is notable, however, that the amount of nutrients reaching the sea is also dependent on agricultural adaptation to the climate change. Recent results show how climate change affects agricultural practises (crops, cultivars, land use), how climate affects the hydrological cycle, and how soils and lakes retain nutrients under a changing climate. The results show that climate change increases nitrogen loading into the sea, that economic factors (e.g. crop and fertilizer prizes) affect the outcome significantly, and that by adapting to the climate change (farm level changes in cultivars and land use) a significant reduction in the nutrient loading into the sea can be achieved (Fig. 1).

References

Huttunen, I., Lehtonen, H., Huttunen, M., Piirainen, V., Korppoo, M., Veijalainen, N., ... & Vehviläinen, B. (2015). Effects of climate change and agricultural adaptation on nutrient loading from Finnish catchments to the Baltic Sea. *Science of The Total Environment*, *529*, 168-181.

Observing and modelling the Gulf of Finland with high spatial resolution

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The Gulf of Finland is a highly dynamic sea area with large horizontal and vertical gradients and small hydrodynamic scales. To understand the physics of the gulf, we need both horizontally dense high quality observations and numerical modelling. This is especially so when we want to study sub-mesoscale processes. The Gulf of Finland Year 2014 offered an excellent possibility to increase our understanding of the gulf.

Regular monitoring has for decades used a relatively sparse set of stations in the Gulf of Finland. To improve the observational knowledge base of the gulf, FMI conducted three research cruises to the western Gulf of Finland in 2013 - 2014 using a much denser grid than is usually possible in monitoring cruises. The 84-point grid was a compromise between available ship time and needed resolution of the observations. However, the CTD-profiles from this grid form the best dataset for model development and validation yet.
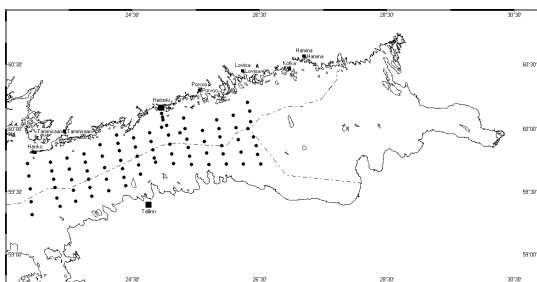
Figure 1. Special 84-point grid used during 2013-2014 physical oceanography cruises to the Gulf of Finland by R/V Aranda.

Preliminary comparisons between data and the results of FMI's implementation of the NEMO circulation model for the Baltic Sea show the necessity of having high-resolution spatial data in evaluating the models ability to simulate the 3D structure of the temperature and salinity. The model simulated surface salinity fairly accurately at most of the comparison points, but it had some difficulties in producing the salinity gradients. For example the more saline surface water in the Estonian coast extended further to the east than was simulated in the model.

FMI and RSHU are now taking steps together to improve our modelling of the hydrodynamics of the gulf. There are ongoing efforts to jointly develop a community based high-resolution eddy-resolving 3D hydrodynamic modelling configuration. The dense grid CTD data sets are valuable assets also in this development. Already now the results show the need to continue observations with high spatial resolution in the area in the future, too.

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No. 2   Conference Proceedings of the 2nd International Conference on Climate Change - The environmental and socio-economic response in the Southern Baltic region. Szczecin, Poland, 12-15 May 2014. International Baltic Earth Secretariat Publication No. 2, 110 pp, May 2014.

No. 3   Workshop Proceedings of the 3rd International Lund Regional-Scale Climate Modelling Workshop "21st Century Challenges in Regional Climate Modelling". Lund, Sweden, 16-19 June 2014. International Baltic Earth Secretariat Publication No. 3, 391 pp, June 2014.

No. 4   Programme, Abstracts, Participants. Baltic Earth - Gulf of Finland Year 2014 Modelling Workshop "Modelling as a tool to ensure sustainable development of the Gulf of Finland-Baltic Sea ecosystem". Finnish Environment Institute SYKE, Helsinki, 24-25 November 2014. International Baltic Earth Secretariat Publication No. 4, 27 pp, November 2014.

No. 5   Programme, Abstracts, Participants. A Doctoral Students Conference Challenges for Earth system science in the Baltic Sea region: From measurements to models. University of Tartu and Vilsandi Island, Estonia, 10 - 14 August 2015. International Baltic Earth Secretariat Publication No. 5, 66 pp, August 2015.

No. 6   Programme, Abstracts, Participants. International advanced PhD course on Impact of climate change on the marine environment with special focus on the role of changing extremes. Askö Laboratory, Trosa, Sweden, 24 - 30 August 2015 International Baltic Earth Secretariat Publication No. 6, 61 pp, August 2015.

No. 7   Programme, Abstracts, Participants. A joint HyMex-Baltic Earth Workshop Joint regional climate system modelling for the European sea regions. ENEA Headquarters, Rome, Italy 5 - 6 November 2015. International Baltic Earth Secretariat Publication No. 7, 103 pp, November 2015.

No. 8   Programme, Abstracts, Participants. Baltic Earth/Gulf of Finland Seminar: Exchange processes between the Gulf of Finland and other Baltic Sea basins International Baltic Earth Secretariat Publication No. 8, 27 pp, November 2015.

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