International Baltic Earth Secretariat Publication No. 19, September 2020

ESA-Baltic Earth Workshop

Earth Observation in the Baltic Sea region

Online, 21 September 2020

Programme, Abstracts, Participants

Edited by
Silke Köppen and
Marcus Reckermann

esa

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Baltic Earth
Earth System Science for the Baltic Sea Region

Impressum

International Baltic Earth Secretariat Publications
ISSN 2198-4247

International Baltic Earth Secretariat
Helmholtz-Zentrum Geesthacht GmbH
Max-Planck-Str. 1
D-21502 Geesthacht, Germany

baltic.earth
balticearth@hzg.de

Cover photo: Cyanobacteria bloom, Gotland basin, Baltic Sea, 20 July 2019

ESA-Baltic Earth Workshop on Earth Observation in the Baltic Sea region

Online, 21 September 2020

co-organized by

European Space Agency

and the

International Baltic Earth Secretariat
at Helmholtz-Zentrum Geesthacht

This full one-day collocation meeting aims at exposing the results of on-going/recently completed ESA projects conducted in the Baltic Sea region. The objective of the meeting is to define potential synergies and follow-up activities in support to science priorities in the Baltic Sea region.

The following ESA BALTIC+ projects are invited to present their preliminary results and experiences in the project.

List of BALTIC+ projects

BALTIC+ Geodetic SAR for Baltic Height System Unification (SAR-HSU)

BALTIC+ Salinity Dynamics

BALTIC+ Sea-Land biogeochemical linkages (SeaLaBio)

BALTIC+ SEAL – Sea Level

In addition, all scientists from the Baltic Sea region interested in the application of Earth Observation technology to Earth system science in the Baltic Sea region are invited to join the workshop.

Presentations will be given by representatives of the above projects and invited scientists. There will be a large brainstorming and discussion section.

Jérôme Benveniste
Senior Advisor - European Space Agency (ESA-ESRIN)
Directorate of Earth Observation Programmes
EO Science, Applications and Climate Department

Marcus Reckermann
International Baltic Earth Secretariat, Head
Helmholtz-Zentrum Geesthacht, Germany

ESA-Baltic Earth Workshop on Earth Observation in the Baltic Sea region
21 September 2020

Online

Time	*Topic*	*Author*	*Presentation*
09:00	ESA Baltic+ projects	Jérôme Benveniste ESA-ESRIN	**Introduction to ESA Baltic+ projects and the workshop**
09:10	Baltic Earth	Marcus Reckermann Intl. Baltic Earth Secretariat, HZG	**Introduction to Baltic Earth**
09:20	Baltic Earth Salinity	Andreas Lehmann Geomar, Kiel, Germany	**Salinity dynamics in the Baltic Sea**
09:40	Baltic+ Salinity	Verónica González-Gambau Institute of Marine Science ICM/CMIMA/BEC, Barcelona, Spain	**First regional SMOS Sea Surface Salinity products over the Baltic Sea and its oceanographic added-value**
10:00	Baltic+ Salinity	Christina González Haro Institute of Marine Science ICM/CMIMA/BEC, Barcelona, Spain	**Exploring synergies between remote sensing products developed under the framework of ESA Baltic+ initiative: Sea Surface Salinity and Sea Surface Height**
10:20	Baltic+ SAR-HSU	Thomas Grüber Technical University Munich, Germany	**BALTIC+ Geodetic SAR for Baltic Height System Unification (SAR-HSU)**
10:40	Break		
10:50	Baltic+ SEAL	Marcello Passaro Technical University Munich, Germany	**Baltic SEAL: new insights into the mean and variability of the sea level in the Satellite Altimetry era**
11:10	Baltic+ SEAL	Denise Dettmering Technical University Munich, Germany	**Baltic SEAL: Exploiting regional opportunities and a natural laboratory to advance processing algorithms for altimetry-derived Sea Surface Height estimation**
11:30	Baltic+ SeaLaBio	Sampsa Koponen Finnish Environment Institute, Helsinki	**BALTIC+ Sea-Land biogeochemical linkages (SeaLaBio)**
11:50	Baltic+ Applications	Anna Burzykowska ESA-ESRIN	**Baltic Regional Initiative: Way forward for EO Applications**
12:10	Lunch Break		

13:00	Baltic Earth: Water resources	Fernando Jaramillo Stockholm University, Sweden	**Using InSAR observations to understand changes to coastal and inland water resources in the Baltic basin**
13:20	Baltic Earth: Ocean colour	Martin Hieronymi Helmholtz-Zentrum Geesthacht (HZG), Germany	**Efforts towards best Ocean Colour products for the Baltic Sea**
13:40	Baltic Earth: Ocean colour	Miroslaw Darecki Institute of Oceanology PAN Sopot, Poland	**Fusion of satellite data with eco-hydrodynamic model as an effective tool for monitoring and climate research of the Baltic Sea**
14:00	Baltic Earth: Ocean temperature	Rivo Uiboupin TalTech Tallinn, Estonia	**EO data for characterizing wintertime marine heat wave impacts in the Baltic Sea region**
14:20	Baltic Earth: Ocean CO2 exchange	Shuping Zhang Uppsala University,Sweden	**Sea Surface pCO2 in the Baltic Sea with the support of ESA remote sensing missions**
14:40	Baltic Earth: Ocean colour	Kari Kahru Scripps Institution of Oceanography, La Jolla, USA	**The changing seasonality of the Baltic Sea**
15:00	Break		
15:10	ESA Programmes	Diego Fernández Prieto ESA-ESRIN	**The ESA Regional Initiative Programme Element**
15:30	**Discussion**		
17:30	**Wrap-Up and end of meeting**		

Abstracts

In chronological order

Salinity dynamics in the Baltic Sea

Andreas Lehmann

Helmholtz-Zentrum for Ocean Research Kiel (Geomar)

The salinity in the Baltic Sea is not a mere oceanographic variable, but it integrates the complete water and energy cycle which also has Baltic-specific features. There are several salinity frontal areas which separate higher saline Kattegat water from the western Baltic Sea; Baltic Proper water from the sub-basins, and lagoons and river plumes from Baltic Sea water. These highly dynamic frontal areas respond differently to changing climate conditions. Salinity, and especially its low basic value and large variations in the Baltic Sea, is also an elementary factor controlling the ecosystem of the Baltic Sea. The salinity dynamics is governed by several factors: net precipitation, river runoff, surface outflow of brackish Baltic Sea water and the compensating deep inflow of higher saline waters from the Kattegat. The latter is strongly controlled by the prevailing atmospheric forcing conditions. In addition, the salinity dynamics is dictated by the irregular barotropic exchange flows such as MBIs (Major Baltic Inflows) and LVC (Large volume changes) which have a great impact on stratification conditions and oxygen dynamics. Over recent decades, negative salinity trends of about 0.1-0.2 g/kg/decade appear at the surface, 0.4-0.6 °C/decade for temperature and 0.1-0.2 ml/l/decade for oxygen. For the negative trend of surface salinity, it is assumed that runoff and net precipitation play a role. However, in deeper parts the salinity trend (0.2-0.25 g/kg/decade) is reversed, although the frequency of barotropic and major saltwater inflows did not increase. We will present the current status of the Baltic Earth Assessment Report (BEAR) on Salinity Dynamics and will highlight some newly published results.

First regional SMOS Sea Surface Salinity products over the Baltic Sea and its oceanographic added-value

Verónica González-Gambau[1], Estrella Olmedo[1], Cristina González-Haro[1], Antonio Turiel[1], Justino Martínez[1], Carolina Gabarró[1], Pekka Alenius[2], Laura Tuomi[2], Petra Roiha[2], Manuel Arias[3], Rafael Catany[3], Diego Fernández[4] and Roberto Sabia[4]

[1] BEC & Institute of Marine Sciences, CSIC. P. Marítim de la Barceloneta, 37-49, 08003 Barcelona, Spain
[2] Finnish Meteorological Institute (FMI). Erik Palménin aukio 1, FI-00560 Helsinki, Finland
[3]ARGANS Ltd, Davy Road, Plymouth Science Park, Derriford, Plymouth, PL6 8BX
[4]European Space Agency, ESA-ESRIN. Largo Galileo Galilei 1 Casella Postale 64 00044, Frascati, Italy

The Baltic Sea is one of the most challenging regions for the retrieval of SSS from L-band satellite measurements. Nowadays, available EO-based SSS products are quite limited over this region both in terms of spatio-temporal coverage and quality. This is mainly due to several technical limitations that strongly affect the SMOS brightness temperatures (TB) particularly over semi-enclosed seas, such as the high contamination by Radio-Frequency Interference (RFI) sources and the contamination close to land and ice edges. Besides, the sensitivity of TB to SSS changes is very low in cold waters and much larger errors are expected compared to temperate oceans. Salinity and temperature values are very low in this basin, which implies that dielectric constant models are not fully tested in such conditions. In the recent years, the Barcelona Expert Center (BEC) team has been working on the development of innovative algorithms for improving the quality of SMOS TB and SSS retrievals dealing with the main processing issues.

Satellite-based SSS fields as produced by ESA Baltic+ Salinity Dynamics project (https://balticsalinity.argans.co.uk/) can contribute to the monitoring of long-term salinity changes and to the detection of periods with anomalous salinity. These products can also be very useful as initial fields and validation data for improving the existing numerical models. This work aims to present the generation of the first regional SMOS SSS product (2011-2020) that would suit to the needs of the Baltic research community. Very recently, the first version of the Baltic+ SSS product has been produced (2011-2013) and is currently under validation against in-situ measurements. The quality assessment of the SSS product in the Baltic Sea is an issue and its representativeness must be carefully assessed. The basin is strongly stratified and then, the differences between SMOS measurements (first centimetres) and in-situ observations (few meters depth) can be noticeable. Differences are more probable during ice melting and high runoff events in spring where there might be a freshwater layer at the top shallow surface.

We will present at the workshop the Baltic+ SSS v1 product and its added-value with respect to other existing EO-based datasets. The potential scientific impact of this satellite SSS product in advancing on-going regional research initiatives like the Baltic Earth Working Group on Salinity dynamics will be discussed. It is expected to adopt all users feedback (i.e. outcomes from the workshop and user survey available in project website) to improve and systematize SSS validation protocols in the Baltic Sea. These outcomes will be accessible to the public as an going effort to delineate the Science Roadmap document to further improve satellite SSS retrievals in the Baltic Sea.

Exploring synergies between remote sensing products developed under the framework of ESA Baltic+ initiative: Sea Surface Salinity and Sea Surface Height

Cristina González-Haro[1], Marcello Passaro[2], Felix L. Müller[2], Verónica González-Gambau[1], Estrella Olmedo[1], Antonio Turiel[1]

[1] BEC & Institute of Marine Sciences, CSIC. P. Marítim de la Barceloneta, 37-49, 08003 Barcelona, Spain
[2] Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM), Arcisstraße 21, 80333 München, Germany

The ESA Baltic+ regional initiative aims at developing research activities to advance the use of ESA and non-ESA Earth observations missions towards the achievement of major scientific challenges identified by Baltic Earth community for the next decade[ ]. This includes, in particular:

- Dedicated products for the Baltic: ocean colour, sea level, coastal altimetry, salinity and new dedicated S2 products.
- Characterization of biochemical exchanges (land-sea and air-sea) including salinity dynamics.
- Characterizing and closing the water cycle of the Baltic.
- 4D reconstruction of Baltic ocean dynamics by integration of EO and modeling.
- Characterizing and predicting major Baltic inflows.

Baltic+ Salinity Dynamics and Baltic+ SEAL projects have contributed to these challenges by developing dedicated products of sea surface salinity (SSS) and sea surface height (SSH), respectively. Here, we will explore the potential synergy between both products with a twofold purpose: to perform an inter-comparison of both products, and to explore the potentiality of both datasets to address some of the scientific challenges identified by ESA and the Baltic Earth community.

We will first explore the detection and monitoring of the Atlantic salinity inflow and its recirculation inside the basin by presenting a preliminary assessment of the consistency between structures detected in Baltic+ Salinity SSS maps and circulation patterns derived from Baltic+ SEAL altimetry observations. As an example of application we will analyze how SSS and SSH reflect the mean flow condition across the Danish strait and how they react by local wind conditions and larger atmospheric circulation patterns. While ideally the characteristics of the full water column would be needed, the combination of SSS and altimetry data can help monitoring the inflow and the distribution of surface waters characterised by different densities.

In a second step, we will explore the synergy of SSS and sea level data to characterise the gradient in sea level trend that is observed in the last decades between S-W and N-E sub-basins and that is likely to be caused by interannual anomalies in the winter westerlies wind forcing, which trap (brackish) water masses in the N-E [Gräwe et al. 2019]

References

Lehmann, A., W. Krauß, and H.-H. Hinrichsen (2002), Effects of remote and local atmospheric forcing on circulation and upwelling in the Baltic Sea, Tellus, Ser. A, 54(3), 299–316.

Gräwe, U., Klingbeil, K., Kelln, J. and Dangendorf, S., 2019. Decomposing mean sea level rise in a semi-enclosed basin, the Baltic Sea. Journal of Climate, 32(11), pp.3089-3108.

https://eo4society.esa.int/regional-initiatives/baltic-regional-initiative/baltic-regional-initiative-science/ (last access 14th July 2020)

Geodetic SAR for Height System Unification and Sea Level Research in the Baltics

Th. Gruber[1], J. Ågren[2], D. Angermann[3], A. Ellmann[4], C. Gisinger[5], J. Nastula[6], X. Oikonomidou[1], M. Poutanen[7] , M. Schlaak[1]

[1] Technical University of Munich, Institute of Astronomical and Physical Geodesy
[2] Lantmäteriet, Swedish Mapping, Cadastral and Land Registration Authority
[3]Technical University of Munich, German Geodetic Research Institute
[4]Tallinn University of Technology, School of Engineering
[5]German Aerospace Center, Remote Sensing Technology Institute
[6]Space Research Centre, Polish Academy of Sciences
[7]Finnish Geospatial Research Institute

Traditionally, sea level is observed at tide gauge stations, which usually also serve as height reference stations for national levelling networks and therefore define a height system of a country. Thus, sea level research across countries is closely linked to height system unification and needs to be regarded jointly. The project aims to make use of a new observation technique, namely SAR positioning, which can help to connect the GNSS basic network of a country to tide gauge stations and as such to link the sea level records of tide gauge stations to the geometric network. By knowing the geoid heights at the tide gauge stations in a global height reference frame with high precision, one can finally obtain absolute sea level heights of the tide gauge stations in a common reference system and can link them together. By this method, on the one hand national height systems can be connected and on the other hand the absolute sea level at the tide gauge stations can be determined. By analyzing time series of absolute sea level heights their changes can be determined in an absolute sense in a global reference frame and the impact of climate change on sea level can be quantified (e.g. by ice sheet and glacier melting, water inflow, global warming). The presentation presents the main scientific questions to be addressed by the project, introduces the idea of using SAR transponders for this application and describes the observation network implemented for this feasibility study.

Baltic SEAL: new insights into the mean and variability of the sea level in the Satellite Altimetry era

Marcello Passaro[1], Felix L. Müller[1], Adili Abulaitijiang[2], Ole B. Andersen[2], Emma Chalençon[5], Denise Dettmering[1], Jacob L. Høyer[3], Milla Johansson[4], Julius Oelsmann[1], Laura Rautiainen[4], Ida M. Ringgaard[3], Eero Rinne[4], Jani Särkkä[4], Rory Scarrott[5], Christian Schwatke[1], Florian Seitz[1], Kristine Skovgaard Madsen[3], Laura Tuomi[4], Americo Ambrozio[6*], Marco Restano[6**], Jérôme Benveniste[6]

[1]Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM), Germany
[2]SPACE National Space Institute, Technical University of Denmark, (DTU), Denmark
[3]Danish Meteorological Institute (DMI), Denmark
[4]Finnish Meteorological Institute (FMI), Finland
[5]MaREI Centre, Department of Geography, Environmental Research Institute, University College Cork (UCC), Ireland
[6]*DEIMOS, c/o ESA-ESRIN, Italy
[6]** SERCO, c/o ESA-ESRIN, Italy 6 ESA-ESRIN, Italy

For sea level studies, coastal adaptation, and planning for future sea level scenarios, regional responses require regionally-tailored sea level information. Global sea level products from satellite altimeters are now available through the European Space Agency's (ESA) Climate Change Initiative. However, these global datasets are not entirely appropriate for supporting regional actions. Particularly for the Baltic Sea region, complications such as coastal complexity and sea-ice restrain our ability to exploit altimetry data opportunities.

This presentation highlights the benefits and opportunities offered by such regionalised advances, through an examination by the ESA-funded Baltic SEAL project (http://balticseal.eu/). We present the challenges faced, and solutions implemented, to develop new dedicated along-track and gridded sea level datasets for Baltic Sea stakeholders, spanning the years 1995-2019. Advances in waveform classification and altimetry echo-fitting, expansion of echo-fitting to a wide range of altimetry missions (including Delay-Doppler altimeters), and Baltic-focused multi-mission cross calibration, enabled all mission data to be integrated into a final gridded product.

This gridded product, and range of altimetry datasets, enabled new insights into the Baltic Sea's mean sea level and its variability to be gathered. A new Mean Sea Surface dataset was developed, in addition to an analysis of sea level trends in the region (using both tide gauge and altimetry data). The Baltic SEAL absolute sea level trend at the coast better aligns with information from the in-situ stations, when compared to current global products. A pronounced sea level trend gradient which increases towards the North-East was found. Furthermore there is a strong observed correspondence between season-specific sea level trends and a decreasing trend in westerly wind forcing. The spatial and temporal density of the data also allows for a robust comparison between the sea level time series and relevant climate indices such as the North Atlantic Oscillation, with implications for regionalising global climate change impacts. These initial investigations highlight the potential of regionalised products for the Baltic Sea region, and beyond. The availability of multi-mission along-track data, gridded monthly data, and an experimental high-rate temporal grid, offers a wide range of opportunities, from supporting local ocean circulation research, to storm surge monitoring. These opportunities are presented to promote further exploitation, and identify synergies with other efforts focused on relevant oceanic variables societal applications.

Baltic SEAL: Exploiting regional opportunities and a natural laboratory to advance processing algorithms for altimetry-derived Sea Surface Height estimation.

Felix L. Müller[1], Marcello Passaro[1], Adili Abulaitijiang[2], Ole B. Andersen[2], Emma Chalençon[5], Denise Dettmering[1], Jacob L. Høyer[3], Milla Johansson[4], Julius Oelsmann[1], Laura Rautiainen[4], Ida M. Ringgaard[3], Eero Rinne[4], Jani Särkkä[4], Rory Scarrott[5], Christian Schwatke[1], Florian Seitz[1], Kristine Skovgaard Madsen[3], Laura Tuomi[4], Americo Ambrozio[6]*, Marco Restano[6]**, Jérôme Benveniste[6]

[1]Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM), Germany
[2]SPACE National Space Institute, Technical University of Denmark, (DTU), Denmark
[3]Danish Meteorological Institute (DMI), Denmark
[4]Finnish Meteorological Institute (FMI), Finland
[5]MaREI Centre, Department of Geography, Environmental Research Institute, University College Cork (UCC), Ireland
[6]*DEIMOS, c/o ESA-ESRIN, Italy
[6]** SERCO, c/o ESA-ESRIN, Italy 6 ESA-ESRIN, Italy

Globally focused datasets are often not entirely appropriate for supporting regional actions. Global sea-level products produced under the European Space Agency's (ESA) Climate Change Initiative have regional limitations, highlighting the need to compliment global products with regionalised datasets. The ESA project Baltic SEAL is an example of one such regionalisation effort. It demonstrates the technical advances needed to realise regional capitalisation of the global satellite altimetry resource.

The Baltic Sea presents a range of opportunities to advance regional altimetry exploitation. Its complex coastlines, with thousands of small islands in the coastal archipelagos, coupled with seasonal sea-ice prevents the direct use of altimetry-derived sea level observations, without the application of dedicated processing steps to address this limitation. Moreover, the Baltic Sea is the perfect playground to test and validate coastal and open ocean dedicated algorithms in the vicinity of a complex topography and an extensive network of tide gauge stations. Meanwhile its low tidal signal allows these factors to be studied more exclusively in comparison to regions with a more influential tidal signal.

The main focus is the development and application of a retracking algorithm, fitting altimetry radar echoes (i.e. waveform) independent of the surface characteristics (e.g. coastal or sea ice conditions) and a waveform classification based on artificial intelligence strategies in order to detect radar echoes reflected by open water areas within the sea ice cover (i.e. leads, polynyas). The retracking algorithm (known as ALES+) enables the homogenous determination of sea surface heights of typical ocean waveforms, but also of complex coastal and very peaky lead reflections. The algorithm is applied to all types of altimetry waveforms, including those acquired using a Delay-Doppler instrument. The unsupervised waveform classification ingests data from all current and past satellite altimetry missions, identifying waveforms returned from narrow cracks within the sea ice domain. Moreover, a relative cross-calibration (i.e. MMXO), referring to the TOPEX/Poseidon mission, was performed to account for radial orbit differences of 13 included altimetry missions, enabling the generation of a regionally-tailored, multi-mission range of along-track datasets. For the first time, the project enables the joint exploitation of a wide cross-calibrated along-track altimetry dataset, a processing step that is usually only performed to generate interpolated grids.

The profiled datasets are used to generate a novel Baltic Sea dedicated mean sea surface. The improved altimetry-derived sea surface heights form the basis of a gridding procedure onto a triangulated surface mesh, featuring a spatial resolution of 7-8 km, to obtain monthly sea level snapshots. The gridding is based on a least-squares approach, fitting an inclined plane to the mesh nodes.

This presentation overviews the current stage of the methodical background of the Baltic SEAL project, providing a deeper insight into the individual processing and data exploitation steps. In doing so, it highlights the technical advances made in regionalizing datasets acquired with a global perspective, and opportunities for knowledge transfer beyond the Baltic Sea to other regions.

ESA Baltic+ Sea-Land biogeochemical linkages (Baltic+ SeaLaBio)

Sampsa Koponen

Finnish Environment Institute and the SeaLaBio team, https://www.syke.fi/projects/BalticSeaLaBio
sampsa.koponen@ymparisto.fi

The overall goal of the Baltic+ SeaLaBio project (Dec 2018 to Oct 2020) is to develop methods for assessing carbon dynamics and eutrophication in the Baltic Sea through integrated use of EO, models, and ground-based data. The developments done in the project have advanced the state-of-the-art in three important fields:

1. **Biogeochemical modelling:** The biogeochemical model ERGOM developed for the Baltic Sea can now utilize EO based aCDOM values as input data and, as a result, provide more reliable estimates of light attenuation in water, which potentially provides more realistic simulations of several other state variables. This has consequences especially in the norther parts of the Baltic Sea where CDOM has a large effect on water transparency.

2. **EO data processing:** A new method for atmospheric correction of satellite images – based on combining the advantages of Polymer & C2RCC – can now provide more reliable water leaving reflectance values. This is a major step towards the formulation of an optimal AC for the Baltic Sea.

3. **Use of EO for monitoring carbon fluxes:** EO based data can e.g. provide information about the Total Organic Carbon loads from rivers.

We will present the main findings of each topic and give an outline of the research required in the future in form of a Scientific Roadmap.

Using InSAR observations to understand effects of climate change on water resources in the Baltic Sea Basin

Fernando Jaramillo[1,2], Mehdi Darvishi[1], Saeed Aminjafari[1], Mohammad Nia[1]

[1] Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, SE–106 91, Stockholm, Sweden
[2] Baltic Sea Centre, Stockholm University, SE–106 91, Stockholm, Sweden

The water resources across the Baltic Sea basin are already experiencing signals of greenhouse-gas-emission climate change. For a country such as Sweden, extending through a long altitudinal gradient, the effects may already be evident in surface and groundwater resources. Important glaciers show reductions in size and thickness in Northern Sweden, seawater ice is decreasing in winter and groundwater levels in Southern Sweden are reaching lower than normal levels during summer. The use of point stations for continuous and large-scale monitoring of these water resources is expensive and requires extended logistics. Cutting edge hydrogeodetical tools, such as Interferometric Synthetic Aperture Radar (InSAR), can now be used to assess large scale changes to water resources. InSAR is a potent tool to study hydrology and water flow of coastal systems, glaciers and groundwater. For instance, recent studies in the tropics have used InSAR to generate displacement maps of the water surface employed to detect water movements in wetland coastal systems. InSAR techniques can also be to understand groundwater level changes through vertical deformations on the ground surface. It is as such that these, spatial geodetic measurements have several superiorities to ground-based approaches. Here we exploit the cost-effective, climate-independent and easy-to-use InSAR technology to unravel the changes to water resources in the Baltic Sea Basin. We calculate phase difference between two or more SAR scenes to deliver information on hydrodynamics, hydrological connectivity and sheet flow in coastal wetlands and sea ice. We also show how InSAR can be used to quantify changes in glacier extent and depth in the mountains between Sweden and Norway, Tarfala region, and groundwater in the island of Gåtland, in the Baltic Sea. The combination of all these studies highlights the potential of InSAR to understand changes in water resources in the Baltic Sea Basin and impacts from human activities.

Acknowledgements
This research was funded by the Swedish Research Council (VR, project 2015-06503) and the Swedish Space Agency (Dnr: 180/18).

Atmospheric correction for the full spectrum of optical water types

Martin Hieronymi[1], Roland Doerffer[1,2], Hajo Krasemann[1] and Eike Schütt[1]

[1] Institute of Coastal Research, Helmholtz-Zentrum Geesthacht (HZG), Geesthacht, Germany
[2] Brockmann Consult, Hamburg, Germany

Ocean colour remote sensing faces the challenges arising from the optical diversity of oceans, coastal and inland waters. In particular, the Baltic Sea has comparable high concentrations of coloured dissolved organic matter (CDOM) from river inputs (highly absorbing and dark waters) and develops regular blooms of cyanobacteria, whose optical properties unqualify usual ocean colour algorithms. Optical Water Type (OWT) classification is increasingly used for the purpose of optimal retrievals of water properties like chlorophyll concentration and CDOM absorption. However, effective exploitation of this method presumes a successful atmospheric correction (AC) over the full spectral range. This leads to the need that the upstream atmospheric correction is suitable for each water type and that it delivers always sufficient total memberships. One ocean colour algorithm that applies OWT classification is the OLCI Neural Network Swarm (ONNS) [Hieronymi et al., 2017], which is utilized in the frame of the Copernicus Marine Environment Monitoring Service (CMEMS) for Baltic Sea near-real time observations of Phytoplankton. ONNS is designed to process fully normalized remote-sensing reflectances at 11 Sentinel-3/OLCI bands from 400 to 865 nm in order to derive different concentrations of water constituents but also several inherent and apparent optical properties of the water body. Existing AC methods, however, do not fulfill all requirements for unlimited usability of ONNS or other OWT-based algorithms. For this reason, we have developed a novel atmospheric correction specifically designed to fulfil the requirements of the ONNS algorithm. Beyond the question of detailed validation, we think that the novel approach provides significant advantages across all optical water types. In particular, for waters with high phytoplankton biomass or floating scum, e.g. during a bloom of cyanobacteria in the Baltic Sea, where all AC methods exhibit serious uncertainties.

Fusion of satellite data with eco-hydrodynamic model as an effective tool for monitoring and climate research of the Baltic Sea.

Miroslaw Darecki

Institute of Oceanology , Polish Academy of Sciences, Sopot, Poland

Occurrence of cloud cover over the Baltic Sea is a significant or even critical limitation in the ocean color and infra-red remote sensing applications, especially when operational use of such a data is considered. An effective method for the reconstruction of missing data in satellite images with the corresponding information from the adapted ecohydrodynamic model has been developed and tested.

Unlike in other similar methods, emphasis has been put on retaining remotely sensed information to a high degree and preserving local mesoscale phenomena that are usually difficult to capture by other methods than satellite remote sensing.

Selected water parameters estimated from satellite data, hydrodynamic model and merged product were compared with in situ data and the method has been validated. The results show that the proposed method well utilizes advantages of both satellite data and numerical simulation, at the same time reducing the errors of estimation of merged parameters compared to similar errors for both primary sources.

Examples of multiyear variability of chla concentration at the Baltic sea, retrieved from the merged product and from the satellite data itself have been presented and discussed.

EO data for characterizing wintertime marine heat wave impacts in the Baltic Sea region

Rivo Uiboupin

Department of Marine Systems, Tallinn University of Technology
rivo.uiboupin@taltech.ee

Considering the relatively warm winters during 2016-2020 (incl. extremely warm winter of 2020) the wintertime marine heat waves (MHW) are phenomena that need further investigation using EO data. The routine Copernicus Marine Environment Monitoring Service (CMEMS) provides valuable and useful data to detect and quantify large scale climate change trends – e.g. sea surface temperature, ice cover and water level trends - that are related to wintertime MHW's in the Baltic Sea region. However, the characterization of the fine scale and regional impact of the MHWs on hydrological regime (e.g. changing nature of flooding events) and marine biology is limited and requires novel purpose-oriented synergistic EO products. Various wintertime MHW impacts can be assessed in a fine scale from EO data: flood mapping from Sentinel-1 and Sentinel-2 data; rapid water level variations from synergistic use of altimetry and in situ data; characterization of the impact of elevated sea surface temperature and high sea state on phytoplankton and benthos of shallow waters using Sentinel-1, -2 and -3 data etc

Sea Surface pCO2 in the Baltic Sea with the support of ESA remote sensing missions

Shuping Zhang[1], Anna Rutgersson[1], Petra Philipson[2], Marcus B. Wallin[1], Bernd Schneider[3], Matti Perttilä[4]

[1]Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM), Germany
[2]Brockmann Geomatics Sweden AB, Kista, Sweden
[3]Leibniz-Institut für Ostseeforschung Warnemünde, Rostock, Germany
[4]Finish Meteorological institute, Helsinki, Finland

Oceans uptake a significant share (~25%) of the anthropogenic CO2 emitted to the atmosphere and thus play a fundamental role in the global CO2 cycle. As a semi-closed brackish sea receiving substantial complex terrestrial input, the Baltic Sea present unique characteristics in global CO2 air-sea exchange and yet insufficiently investigated or understood. Remote Sensing has shown great potentials in assisting understanding the oceanic processing in a large scale.

In this study we retrieved the sea surface pCO2 in the Baltic Sea from remote sensing data including those ESA remote sensing mission. For the period of 2002 -2012 the sea surface pCO2 in the Baltic Sea were estimated with the support of Chlorophyll (Chl-a) concentration and absorption of CDOM (aCDOM) product derived from MERIS. The variable relevance analysis showed that, in addition to Photosynthetically Available Radiation (PAR) and Sea Surface Temperature (SST), aCDOM, which has been neglected by previous study, played an important role for pCO2 estimate in the Baltic Sea, particularly in the Gulf of Finland. This study also showed the spatiotemporal distribution of sea surface pCO2 in the Baltic Sea. In further step, we also investigated the potential of ESA Sentinel-3 OLCI products in estimating sea surface pCO2 in the Baltic Sea. The output of this study has greatly improved the understanding of the air-sea CO2 exchange and the oceanic processes in the complex Baltic Sea.

Changing seasonality of the Baltic Sea

Mati Kahru

Scripps Institution of Oceanography, UCSD, USA

Satellite data are suitable for detecting global and regional change as they have large-scale coverage, regular frequency and are usually free to the user. However, remote estimates of biological and chemical variables in the oceans are almost always indirect and with large uncertainties. For example, we can detect changes in near-surface Chlorophyll-a (Chla) concentration in the Baltic but due to interference by other substances, the trend estimates are uncertain. In addition to remote estimates of absolute values of various variables we suggest adding timing (phenology) variables. Following Kahru et al. (Biogeosciences, 13, 1009-1018, 2016) we have detected significant and sometimes drastic trends in the timing of many physical, chemical and biological variables such as surface incoming shortwave irradiance (SIS), sea-surface temperature (SST), light attenuation (Ked490), Chla, cyanobacteria blooms and surface accumulations. Combined, they show a complicated pattern of drastic changes in the seasonality of the Baltic Sea during the last few decades. For several ecologically important variables (Ked490, Chla, cyanobacteria accumulations) the length of the annual period of high values has increased by a factor of 2 or more.

Participants

Alenius	Pekka	Finnish Meteorological Institute	Finland	pekka.alenius@fmi.fi
Alikas	Krista	University of Tartu, Institute of Physics	Estonia	krista.alikas@ut.ee
Arias Ballesteros	Manuel	ARGANS Limited	UK	MArias@argans.co.uk
Attila	Jenni	Finnish Environment Institute SYKE, Helsinki	Finland	Jenni.Attila@ymparisto.fi
Benveniste	Jérôme	European Space Agency ESA	Italy	Jerome.Benveniste@esa.int
Burzykowska	Anna	European Space Agency ESA	Italy	Anna.Burzykowska@esa.int
Catany	Rafael	ARGANS Limited	UK	RCatany@argans.co.uk
Čepienė	Erika	Klaipėda University	Lithuania	erikacepiene@gmail.com
Dailidiene	Inga	Klaipėda University	Lithuania	dailidiene.ku@gmail.com
Darecki	Miroslaw	Institute of Oceanology, Polish Academy of Sciences, Sopot	Poland	darecki@iopan.pl
Darvishi	Mehdi	Physical geography department, Stockholm University	Sweden	mehdi.darvishi@natgeo.su.se
Dettmering	Denise	Technische Universität München	Germany	denise.dettmering@tum.de
Elken	Jüri	Tallinn University of Technology TalTech	Estonia	juri.elken@taltech.ee
Fernández Prieto	Diego	European Space Agency ESA	Italy	diego.fernandez@esa.int
González Haro	Cristina	Institute of Marine Science (ICM/CMIMA/BEC)	Spain	cgharo@icm.csic.es

González-Gambau	Verónica	Institute of Marine Science (ICM/CMIMA/BEC)	Spain	vgonzalez@icm.csic.es
Grüber	Thomas	Technische Universität München	Germany	Thomas.Gruber@tum.de
Hieronymi	Martin	Helmholtz-Zentrum Geesthacht, Institute of Coastal Research	Germany	martin.hieronymi@hzg.de
Jakovels	Dainis	Institute for Environmental Solutions	Latvia	dainis.jakovels@videsinstituts.lv
Jaramillo	Fernando	Physical geography department, Stockholm University, Stockholm	Sweden	fernando.jaramillo@natgeo.su.se
Kahru	Mati	Scripps Institution of Oceanography, UCSD, La Jolla, CA	USA	mkahru@ucsd.edu
Kallio	Kari	Finnish Environment Institute SYKE	Finland	kari.y.kallio@ymparisto.fi
Koponen	Sampsa	Finnish Environment Institute SYKE	Finland	Sampsa.Koponen@ymparisto.fi
Kratzer	Susanne	Stockholm University	Sweden	susanne.kratzer@su.se
Kulinski	Karol	Institute of Oceanology, Polish Academy of Sciences, Sopot	Poland	kroll@iopan.pl
Kutser	Tiit	University of Tartu, Estonian Marine Institute	Estonia	tiit.kutser@ut.ee
Labuce	Astra	Latvian Institute of Aquatic Ecology, Riga	Latvia	astra.labuce@lhei.lv astra.labuce@gmail.com
Labucis	Atis	Latvian Institute of Aquatic Ecology, Riga	Latvia	atis.labucis@lhei.lv
Lehmann	Andreas	Helmholtz-Zentrum für Ozeanforschung Kiel Geomar, Kiel	Germany	alehmann@geomar.de
Liblik	Taavi	Tallinn University of Technology TalTech	Estonia	taavi.liblik@taltech.ee

Ligi	Martin	University of Tartu, Institute of Physics	Estonia	martin.ligi@ut.ee
Mäkynen	Marko	Finnish Meteorological Institute	Finland	marko.makynen@fmi.fi
Martinez Prentice	Ricardo	Estonian University of Life Sciences	Estonia	ricardo.martinez@student.emu.ee
Mazeran	Constant	Solvo	France	constant.mazeran@solvo.fr
Meier	Markus	Leibniz-Institute for Baltic Sea Research IOW	Germany	markus.meier@io-warnemuende.de
Müller	Felix	Technische Universität München	Germany	felix-lucian.mueller@tum.de
Müller	Dagmar	Brockmann Consult GmbH	Germany	dagmar.mueller@brockmann-consult.de
Neumann	Thomas	Leibniz-Institute for Baltic Sea Research IOW	Germany	thomas.neumann@io-warnemuende.de
Oikonomidou	Xanthi	Technische Universität München	Germany	xanthi.oikonomidou@tum.de
Olmedo Casal	Estrella	Institute of Marine Science (ICM/CMIMA/BEC)	Spain	olmedo@icm.csic.es
Papirtis	Miks	Latvian Institute of Aquatic Ecology, Riga	Latvia	miks.papirtis@lhei.lv
Passaro	Marcello	Technische Universität München	Germany	marcello.passaro@tum.de
Philipson	Petra	Brockmann Geomatics Sweden AB	Sweden	petra.philipson@brockmann-geomatics.se
Reckermann	Marcus	Helmholtz-Zentrum Geesthacht, International Baltic Earth Secretariat	Germany	marcus.reckermann@hzg.de
Schlaak	Marius	Technische Universität München	Germany	Marius.Schlaak@tum.de
Schöne	Tilo	Helmholtz-Zentrum Potsdam GFZ	Germany	tschoene@gfz-potsdam.de

Schröder	Ludwig	German Federal Agency for Cartography and Geodesy	Germany	ludwig.schroeder@bkg.bund.de
Thulin	Susanne	Brockmann Geomatics Sweden AB	Sweden	susanne.thulin@brockmann-geomatics.se
Toll	Velle	University of Tartu, Institute of Physics	Estonia	velle.toll@ut.ee
Tuomi	Laura	Finnish Meteorological Institute	Finland	laura.tuomi@fmi.fi
Turiel	Antonio	Physical & Technological Oceanography Department // Barcelona Expert Center	Spain	turiel@icm.csic.es
Uiboupin	Rivo	Tallinn University of Technology TalTech	Estonia	rivo.uiboupin@taltech.ee
Uusõue	Mirjam	Tartu Observatory	Estonia	mirjam.uusoue@ut.ee
Virsilaite	Kristina	Institute of Geosciences, Vilnius University	Lithuania	kristina.virsilaite@chgf.stud.vu.lt
Volynets	Eugenia	Institute of Earth Sciences, Saint Petersburg University	Russia	evgenia59-007@mail.ru
Waver	Rafal	The Institute of Soil Science and Plant Cultivation - State Research Institute	Poland	huwer@iung.pulawy.pl
Weisse	Ralf	Helmholtz-Zentrum Geesthacht, Institute of Coastal Research	Germany	ralf.weisse@hzg.de
Zhang	Shuping	Department of Geosciences, Uppsala University, Uppsala	Sweden	shuping.zhang@geo.uu.se

International Baltic Earth Secretariat Publications

ISSN 2198-4247

No. 1 Programme, Abstracts, Participants. Baltic Earth Workshop on "Natural hazards and extreme events in the Baltic Sea region". Finnish Meteorological Institute, Dynamicum, Helsinki, 30-31 January 2014. International Baltic Earth Secretariat Publication No. 1, 33 pp, January 2014.

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. HyMex-Baltic Earth Workshop "Joint regional climate system modelling for the European sea regions", ENEA, Rome, Italy, 5- 6 November 2015. International advanced PhD course on Impact of climate change on the marine International Baltic Earth Secretariat Publication No. 7, 103 pp, October 2015.

No. 8 Programme, Abstracts, Participants. A PhD seminar in connection with the Gulf of Finland Scientific Forum: "Exchange process between the Gulf of Finland and other Baltic Sea basins". Tallinn, Estonia, 19 November 2015. International Baltic Earth Secretariat Publication No. 8, 27 pp, November 2015

No. 9 Conference Proceedings. 1st Baltic Earth Conference. Multiple drivers for Earth system changes in the Baltic Sea region. Nida, Curonian Spit, Lithuania, 13 - 17 June 2016. International Baltic Earth Secretariat Publication No. 9, 222 pp, June 2016

No. 10 Programme, Abstracts, Participants. Baltic Earth Workshop on ”Coupled atmosphere-ocean modeling for the Baltic Sea and North Sea”, Leibniz Institute for Baltic Sea Research Warnemünde, Germany, 7- 8 February 2017. International Baltic Earth Secretariat Publication No. 10, 24 pp, February 2017

No. 11 Baltic Earth Science Plan 2017. International Baltic Earth Secretariat Publication No. 11, 28 pp, February 2017

No. 12 Programme, Abstracts, Participants. MedCORDEX-Baltic Earth-COST Workshop ”Regional Climate System Modelling for the European Sea Regions”. Universitat de les Illes Baleares, Palma de Mallorca, Spain, 14 - 16 March 2018, International Baltic Earth Secretariat Publication No. 12, 96 pp, March 2018

No. 13 Conference Proceedings. 2nd Baltic Earth Conference. The Baltic Sea in Transition. Helsingør, Denmark, 11 - 15 June 2018. International Baltic Earth Secretariat Publication No. 13, 216 pp, June 2018

No. 14 Programme, Abstracts, Participants. Baltic Earth Workshop "Multiple drivers for Earth system changes in the Baltic Sea region". Tallinn, Estonia, 26-27 November 2018. International Baltic Earth Secretariat Publication No. 14, 58 pp, March 2018

No. 15 Programme, Abstracts, Participants. Baltic Earth Workshop "Hydrology of the Baltic Sea Basin: Observations, Modelling, Forecasting". St. Petersburg, Russia, 8-9 October 2019. International Baltic Earth Secretariat Publication No. 15, 44 pp, October 2019

No. 16 Programme, Abstracts, Participants. Baltic Earth Workshop "Climate projections and uncertainties in the northerb Baltic Sea Region". Helsinki, Finland, 19-20 November 2019, International Baltic Earth Secretariat Publication No. 16, 38 pp, November 2019

No. 17 Anders Omstedt: 45 years of wandering - from processes to systems, through outer and inner seas. An interview by Hans von Storch and Marcus Reckermann with foreword by Jüri Elken, 63 pp. International Baltic Earth Secretariat Publication No. 17, 63 pp, February 2020

No. 18 Conference Proceedings. 3rd Baltic Earth Conference. Earth system changes and Baltic Sea coasts. To be held in Jastarnia, Hel Peninsula, Poland, 1 - 5 June 2020. Held online 2-3 June 2020. International Baltic Earth Secretariat Publication No. 18, 209 pp, June 2020

No. 19 Programme, Abstracts, Participants. ESA-Baltic Earth Workshop on Earth Observation in the Baltic Sea Region. Online, 21. September 2020. International Baltic Earth Secretariat Publication No. 19, 26 pp, September 2020

For a list of International BALTEX Secretariat Publications (ISSN 1681-6471), see www.baltex-research.eu/publications

International Baltic Earth Secretariat Publications
ISSN 2198-4247