



WP 500: Scientific roadmap

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**FINNISH METEOROLOGICAL
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- Baltic+ interaction with the science community
- Critical review of the Baltic+ Salinity products and further developments
- On-going scientific cases with Baltic+ SSS data
- Potential scientific studies with Baltic+ SSS data
- Baltic+ SSS products distribution
- Plans for catch up and reprocessing
- Additional products based on Baltic+ SSS data
- General conclusions

- The work of Baltic+ Salinity project was presented in **international and regional** conferences/workshops (**8 contributions**, 5 orals, 3 posters):
 - Atlantic from Space
 - EGU General Assembly
 - ESA Living Planet
 - Baltic Sea Science Conference
 - 3rd Baltic Earth Conference Earth system changes and Baltic Sea coasts
 - ESA-Baltic Earth Workshop on Earth Observation in the Baltic Sea region
- **Two new contributions** have been recently submitted to Ocean Salinity Conference 2021:
 - Oceanographic added-value of the First regional SMOS Sea Surface Salinity products over the Baltic Sea
 - Exploring synergies between remote sensing products developed under the framework of ESA Baltic+ initiative: Sea Surface Salinity and Sea Surface Height

The work of Baltic+ Salinity project was presented in:

- The **CCI Salinity Science Seminar** (September 2019):

Outcomes/Feedback: Interest on the techniques used in the generation of Baltic+ products to be also applied to other regional seas.

- The **Baltic+ Sea Level Mid-term review meeting** (January 2020):

- Outcomes/Feedback: Collaboration with C. González-Haro to exploit the synergies between the Baltic+ SSS and Baltic+ SEAL SSH. First analysis of the SSS structures compared to the circulation patterns derived from altimetry observations.

- **L2OS PM45** (June 2021):

- Dielectric constant model in low temperature and salinity regime (analysis in the global ocean).

Contact	Project	Impact on Baltic+	Meetings
Andreas Lehmann (GEOMAR)	Baltic Earth Salinity Dynamics WG (chair)	Definition of scientific requirements, scientific impact assessment of products, provision of BSIOM model	EGU 2019, teleconf, mails. Last contact: June'21
Marcello Passaro Felix Muller (TUM)	Baltic+ SEAL	Provision of monthly DOT product, comparison of SSS structures to the circulation patterns derived from altimetry	Continuous collaboration. Last contact: July'21
Nicole Delpeche- Ellmann (Tallinn University of Technology)		Provision of accurate DOT product, comparison of SSS structures to the circulation patterns derived from altimetry	Recent contact by F. Muller
Antti Westerlund (FMI)		Provision of SSS product to be used in model validation study	Recent FMI internal collaboration

Contact	Project	Impact on Baltic+	Meetings
Jannica Haldin Joni Kaitaranta Kemal Pinarbasi Owen Rowe (Helcom secretariat)		Feasibility of using seasonal averaged Baltic+ L4 SSS maps in their driver indicators. Possibility of serving seasonal & monthly averaged Baltic+ SSS maps in Helcom web map service	Teleconf Dec'20 (Baltic+ SSS v1), Teleconf May'21 (Baltic+ SSS v2)
Oliver Wurl (University of Oldenburg)	Pass-Me	Skin surface salinity data acquired with a Katamaran. Very limited data to be compared to SMOS. Used for understanding differences between skin surface and several meters depth measurements	ELP 2019, Teleconf June 2019

- Baltic+ Salinity team sent a letter to all the members of the **Baltic Earth Science Steering Group (BESSG)** in order to present them the (v1 of the) Baltic+ SSS products. We receive **feedback from 8 members**.
- Their feedback and **interests on Baltic+ SSS products** can be summarized as follows:
 - Importance of new satellite SSS for model verification.
 - This satellite SSS product provides an all-weather whole picture at once that will complement other science studies using in-situ and model-based data sources.
 - Great opportunities of spatially distributed information, not possible with other types of information. Real-time information about salinity is at least as important as similar information about waves, water level, currents or temperature.
 - Application to the tracking of long-term changes in salinity patterns.
 - Concerns about if Baltic+SSS products are expected to be of similar quality than currently available 3D hydrographic model outputs.
- Proposals to perform comparisons to in situ data from cruises.
- Proposal for the announcement of Baltic+ SSS products in the Baltic Earth webpage.

Temporal correction of SSS maps without using external references

Rationale / Current status:

- Time-dependent biases are not corrected in the DNB retrieval. An additional correction is required.
- Several approaches were tested: by calibrating with a in situ subset (very scarce and inhomogeneous distribution), correction with other regions, such as the North Atlantic (too contaminated by RFI).
- Baltic+ SSS v2 products use the CMEMS Baltic reanalysis SSS field for the temporal correction.

Further developments:

- Use the zero anomaly condition: the global mean of salinity does not change with time [Olmedo et al., 2021].
- This requires computing global SMOS SSS maps with the same level 1/level 2 algorithms used for the regional maps. The same temporal correction computed from the global maps can be applied to regional ones.

Improvement of the mitigation of land-sea and ice-sea contaminations

Rationale / Current status:

- Mitigation of LSC and ISC is crucial in a semi-enclosed sea such as the Baltic.
- Baltic+ SSS v2 products use the Gkj correction and the DNB to mitigate in a large extent the systematic biases in SSS retrievals.
- The ice-sea contamination is not well corrected by the DNB, since ice edges change over time (a single SMOS-based climatology cannot correct this effect).

Further developments:

- Correction of the PSF of the SMOS antenna (which induces long-range correlation errors in TB). ESL activities.
- The impact of this correction on the LSC & ISC is currently under study.

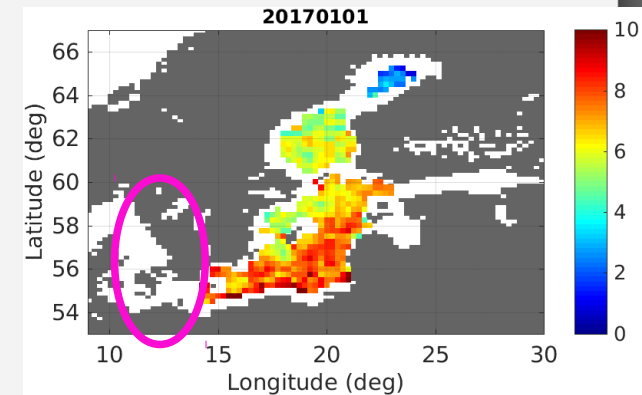
Application of fusion techniques for improving the quality of TB

Rationale / Current status:

- Multifractal fusion was used for generating the Baltic+ L4 SSS.
- L4 SSS error is reduced in the whole basin wrt L3 and leads to approach the spatio-temporal resolutions to the ones required by the users. In some regions, scales resolved may not be high enough for some applications.

Further developments:

- The use of the multifractal fusion at TB level with a template of better spatio-temporal resolution would allow to downscale TB and improve the resolution of SSS maps.
- In ESA EO4SIBS project, this has led to effectively reduce TB errors before the salinity retrieval, with a significant quality improvement of the L3 SSS products.



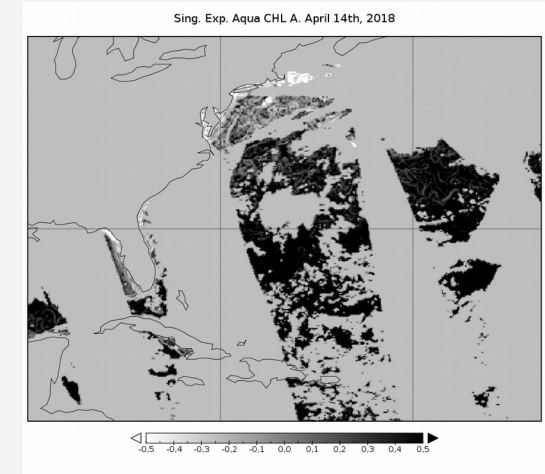
Assessment of the best ocean scalar template for the L4 SSS

Rationale / Current status:

- Higher spatial resolution products are particularly required to monitor the small scale processes with good accuracy.
- The generation of L4 SSS product is based on the assumption that other ocean scalars with higher resolution are available. Due to the frequent presence of clouds, the effective resolution of templates is poor.
- Accuracy of the SST product over Baltic $\sim 0.6-0.7^{\circ}\text{C}$.

Further developments:

- Generating a composite template by combining partial information of independent, very different scalars by using a mutual information approach.
- Applying fusion with this composite template to attain an optimized effective spatial and temporal resolution of the resulting merged maps.



Assessment of ocean surface dynamics from Baltic+ SSS products

- Analysis of the consistency between the structures detected in the Baltic+ SSS products and other variables (SST and DOT) was performed [IAR].
- Good agreement between the structures captured by the Baltic+ SSS, the modeled SSS, the DOT (collaboration with Baltic+ SEAL team) and the SST, at monthly scale.
- Next steps in this study:
 - This analysis is going to be repeated at shorter time scales (9 days).
 - Same analysis by using a more accurate DOT product (developed by Nicole Delpeche-Ellmann, from Tallinn University of Technology) is foreseen.

Study of the tolerance of different species to SSS changes

- Helcom indicators are based on assessments of the state of and pressures on the marine environment as well as the analysis of long-term trends. Salinity is a major driver in Helcom indicators.
- Long time-series of SSS would allow to study the correlation between the SSS variability and the extreme events of different species in the Baltic Sea.
- Baltic+ team has produced seasonal averaged salinity maps from the L4 SSS maps. This data can be helpful for filling gaps in the spatially very sparse in-situ data.
- Next steps in this study:
 - Helcom team to analyze the feasibility of including these seasonal SSS maps for the generation of Helcom driver indicators.
 - If Baltic+ SSS products are proved to be useful in this analysis, a longer time-series would be required.

Determination of SSS annual trends in the Baltic Sea

- One of the major applications of Baltic+ SSS products for the Baltic Earth Salinity Dynamics Group.
- Surface salinity trends of about -0.2 [psu/decade] has been computed from observational data over the recent 30 years.
- Baltic+ SSS products are helpful to determine the changes over the last decade (analysis of shorter term changes).
- We propose to address first the temporal correction of the SSS products without using external references

Study of the inflow and outflow dynamics

- Interactions with Baltic Earth group strengthened the need of monitoring the salinity in the straits connecting the Baltic Sea with the North Sea.
- Baltic+ SSS maps could help in the determination of periods with anomalous SSS.
- The study of the feasibility of applying multifractal fusion at brightness temperature level and the study of the better ocean template are required previous to this analysis.

Exploiting the synergies between Baltic+ SSS and Baltic+ SEAL SSH

- The detection and monitoring of the Atlantic salinity inflow and its recirculation can be done by assessing the consistency between Baltic+ SSS structures and circulation patterns derived from Baltic+ SEAL altimetry observations.
- The mean flow condition across the Danish strait can be altered by local wind conditions. The combination of SSS and altimetry data can help monitoring the inflow and the distribution of surface waters characterised by different densities.
- The synergy of SSS and sea level data can be explored to characterise the gradient in sea level trend that is observed in the last decades between S-W and N-E sub-basins.

Study of the ocean dynamics combining SSS and SST

- According SQG theory, it is possible to reconstruct the full velocity field up to a certain depth from the anomalies of the buoyancy just at the surface layer.
- Anomalies of the buoyancy follow those of the density, thus, there is a simple proportionality between the gradient of SSD and the velocity field.
- Determining the appropriate conditions to reconstruct the velocity field from sea surface density requires extensive analysis. But we could obtain high-resolution fields of Sea Surface Currents.

Baltic+ Salinity dynamics webpage
<https://balticsalinity.org.uk/#dataaccess>

- 9-year series (2011-2019)
 - L3 SSS maps (9-day, 0.25 deg)
 - L4 SSS maps (daily, 0.05 deg)

BEC FTP server
<sftp://becftp.icm.csic.es>

Helcom web map service

<https://maps.helcom.fi/website/mapservice/>

- Regional data provider
- Seasonal and monthly averaged L4 SSS maps
- Link to BEC FTP server

Baltic Earth webpage

<https://baltic.earth>

- Link to the project webpage
- Link to BEC FTP server

Catch up:

- Extension of Baltic+ L3 and L4 salinity series up to date.
- Running a catch-up campaign every 6 months until the end of SMOS mission (depending on resources availability).

Reprocessing:

- From SMOS raw data through the BEC internal processing chain.
- Considered if some of the outputs of the SMOS ESL can lead to a clear improvement in the quality of the SSS over Baltic or if some of the proposed additional developments are addressed.

Sea Surface Density product:

SSD products can be generated from the combination of SSS and SST satellite maps. We will intend to develop, produce and distribute SSD for the convenience of the final users.

Sea Surface Current product:

- The development of SSC products requires an extensive study.
- If the study phase is successful, we would produce experimental datasets of SSC derived from SSD for research purposes.

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- The main outcomes of the Baltic+ Salinity project are the first regional satellite SSS maps over the Baltic Sea.
- Several technical improvements developed in Baltic+ (dielectric constant models for low temperatures and low salinity regimes, characterization of SMOS SSS systematic errors depending also on the SST) have a clear impact on other regional initiatives (EO4SIBS and SO-Fresh projects) and in other SMOS projects (ESL contract).
- These products have a good spatio-temporal coverage with an accuracy of 0.7-0.8 psu for the L3 product (9-day, 0.25deg) and around 0.4 psu for the L4 product (daily, 0.05 deg).
- Baltic+ SSS products provide valuable information about the changes in the salinity gradients and about the temporal variability in the surface salinity.
- They show geophysically consistent seasonal variability in surface salinity which results from the melting of sea ice in spring and increased run-off from land when snow cover melts after the winter.

- This EO SSS data can complement the temporally and spatially very sparse in situ measurements, covering data gaps in the region.
- They can also be useful for the validation of numerical models in areas where in situ data are sparse. Also the location of the gradients and their variability is valuable in evaluating model performance.
- Interactions with the scientific communities working in the Baltic has allowed to better understand the science applications of Baltic+ SSS beyond to the scientific studies addressed along this project.
- Potential scientific applications have been identified (additional developments needed): (i) study of the inflow and outflow dynamics at the entrance of the North Sea, (ii) determination of the SSS annual trends in the basin, (iii) study of the ocean dynamics combining SSS and SST.
- Many of the scientific applications would benefit of a time-series as long as possible.