living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

Oceanographic added-value of the first regional SMOS Sea Surface Salinity products over the Baltic Sea

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23rd May 2022

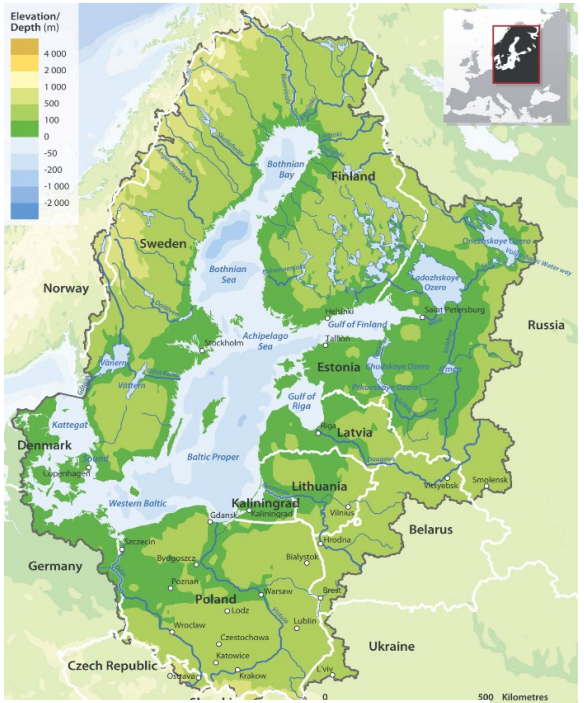
Understanding salinity dynamics through satellite-based measurements

Baltic+ Salinity Dynamics

BEC Barcelona Expert Center

Potential scientific applications identified a-priori, linked to the main challenges of **Baltic Earth** WG on salinity dynamics:

- **Monitorization of long-term SSS changes** in the different sub-basins (determination of salinity inter annual trends).
- **Detection of frontal areas** where SSS gradients are stronger (river run-offs, ice formation and melting processes, etc.).
- Study of **inflow and outflow dynamics** through the determination of **anomalous salinity periods**.
- Using satellite-based SSS measurements as **initial fields and validation data to numerical models**.
- **Complement** temporally and spatially the **sparse in situ measurements** in the region.
- Analysis of the **circulation patterns as derived from salinity** in the basin.



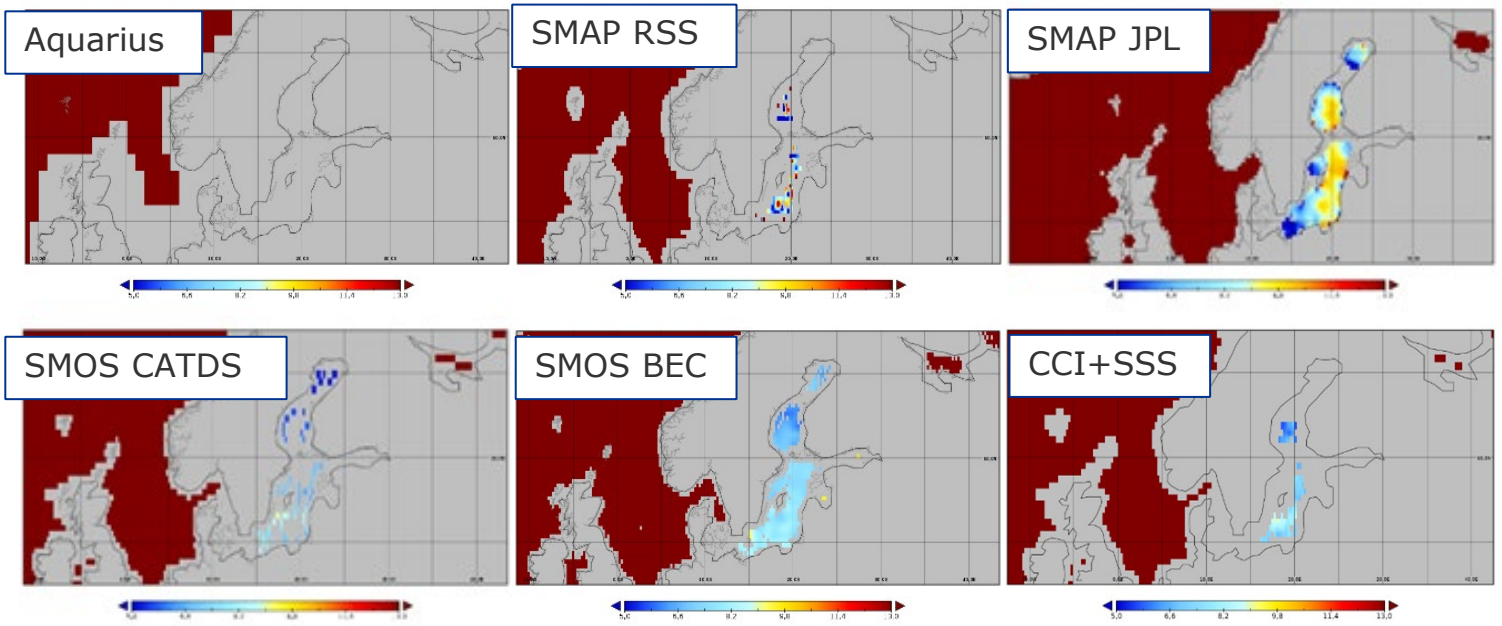
Baltic Earth

Earth System Science for the Baltic Sea Region

L-band satellite SSS before Baltic+ Salinity

Retrieving SSS over this region is a **great challenge** because of several technical issues.

L-band SSS global products provided by 3 missions: Aquarius, SMOS and SMAP



Aquarius: version 4.0 CAP

Need of a dedicated SSS product over the Baltic Sea

SMOS BEC: L3 debiased

non-Bayesian, version 1

CCI+ Salinity product: version 01.7

Challenges in retrieving SMOS SSS over Baltic

Baltic+ Salinity Dynamics

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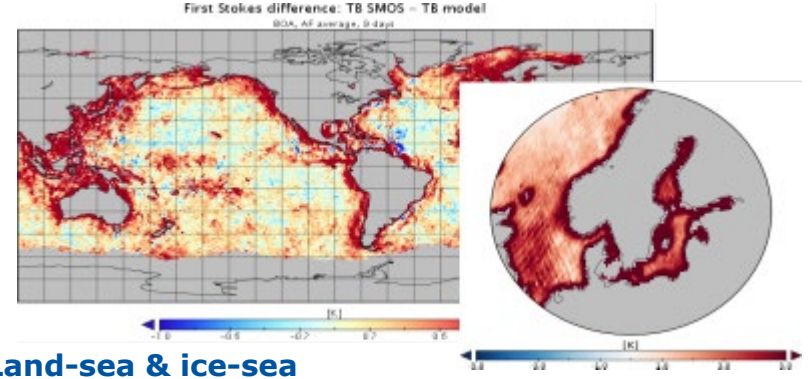
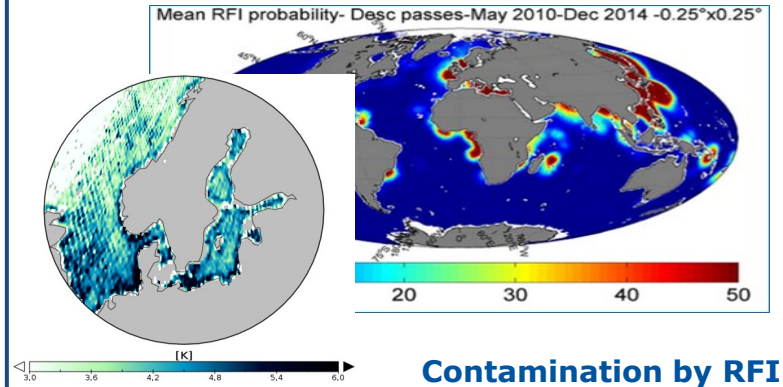


Land-sea & ice-sea contamination

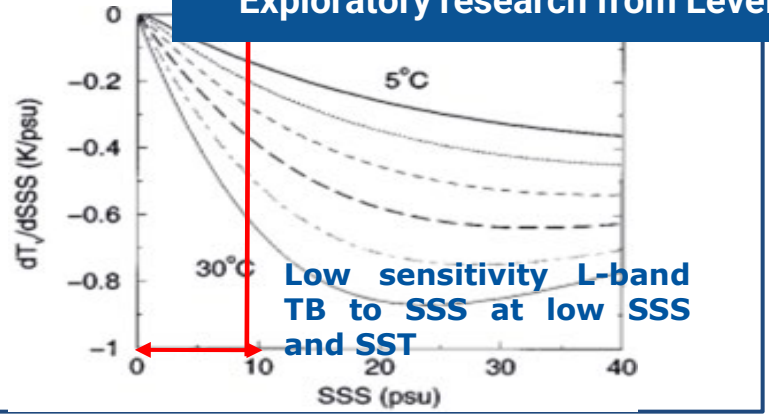
mean(TB_{SMOS}-TB_{mod})



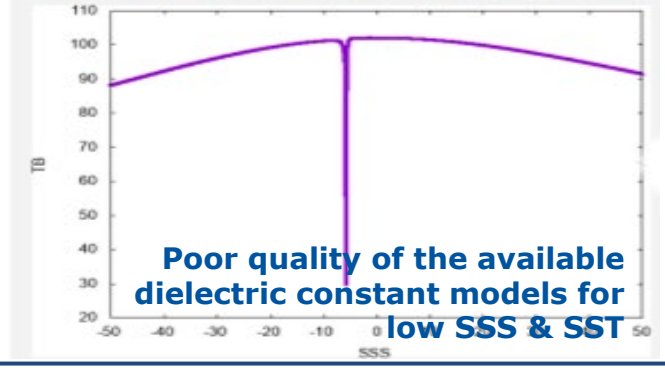
std(TB_{SMOS}-TB_{mod})

Contamination by RFI sources

Exploratory research from Level 0 to Level 4 to develop Baltic SSS

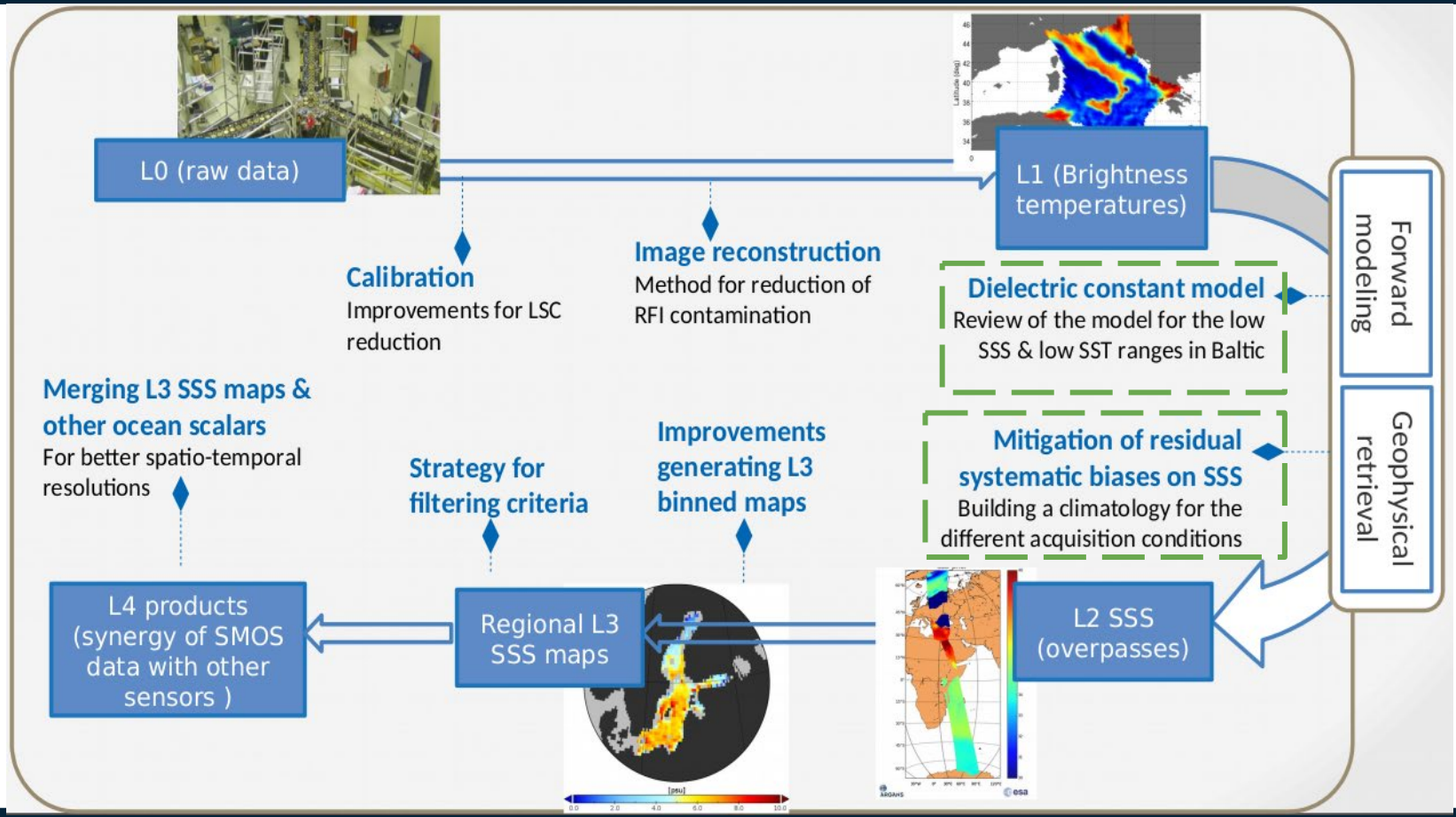


Low sensitivity L-band TB to SSS at low SSS and SST

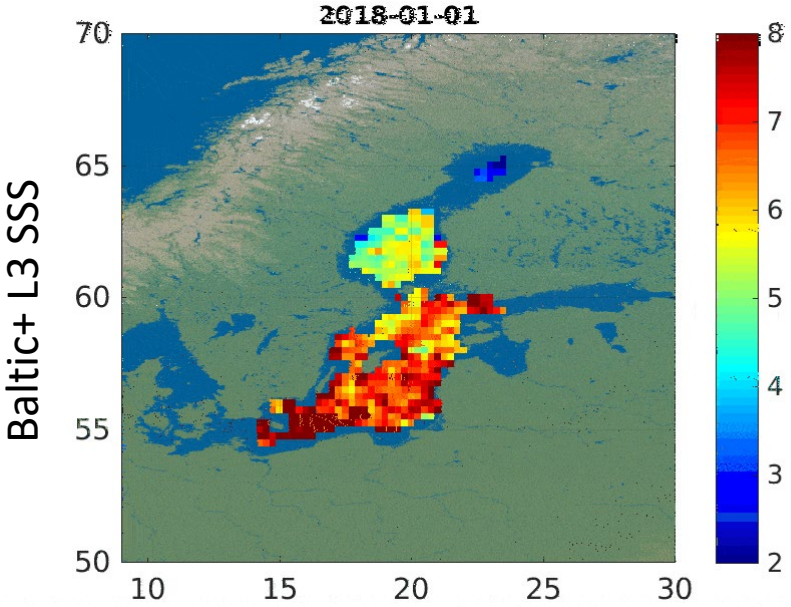


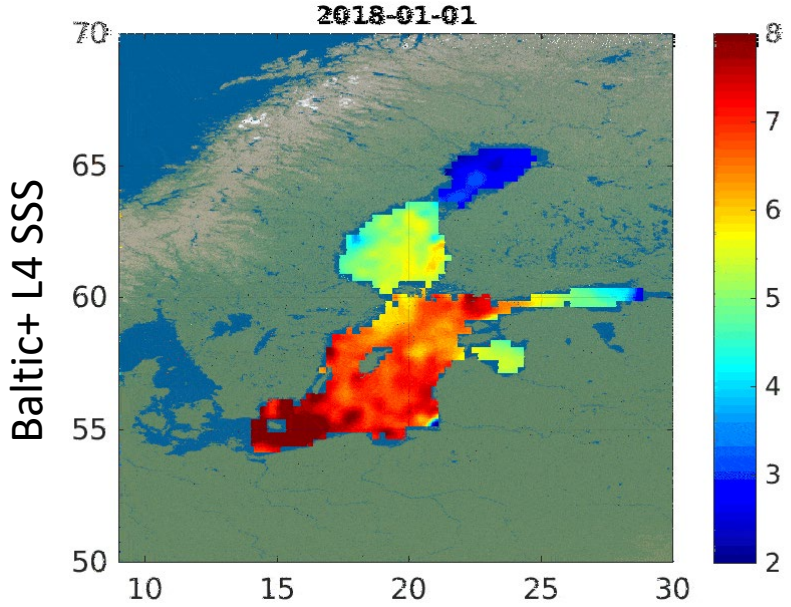
Poor quality of the available dielectric constant models for low SSS & SST

Exploratory research from Level 0 to Level 4



Baltic+ L3 and L4 SSS products





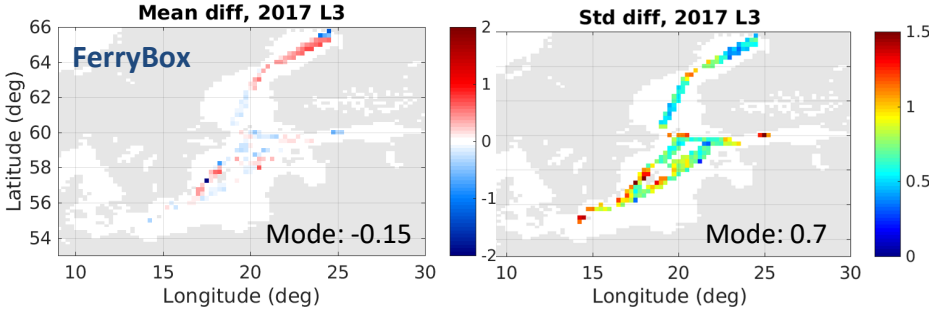
Level	Temporal coverage	Temporal resolution	Spatial resolution	BEC FTP: sftp://becftp.icm.csic.es
L3	Feb. 2011-2019	9 days	0.25 deg.	/becftpdata/OCEAN/SSS/SMOS/Baltic/v1.0/L3/9days
L4	Feb. 2011-2019	daily	0.05 deg.	/becftpdata/OCEAN/SSS/SMOS/Baltic/v1.0/L4/daily

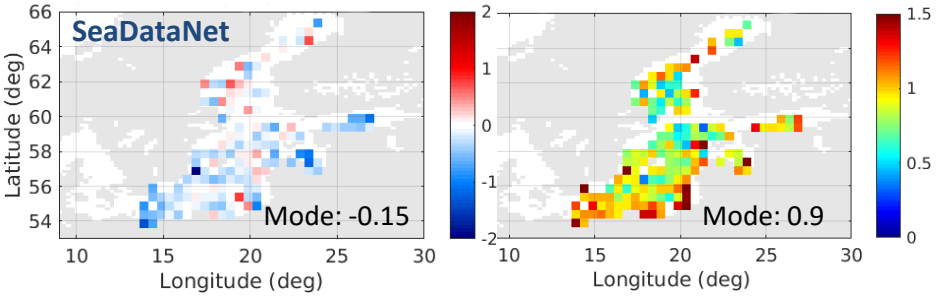
Quality assessment vs in situ data

Baltic+ Salinity Dynamics

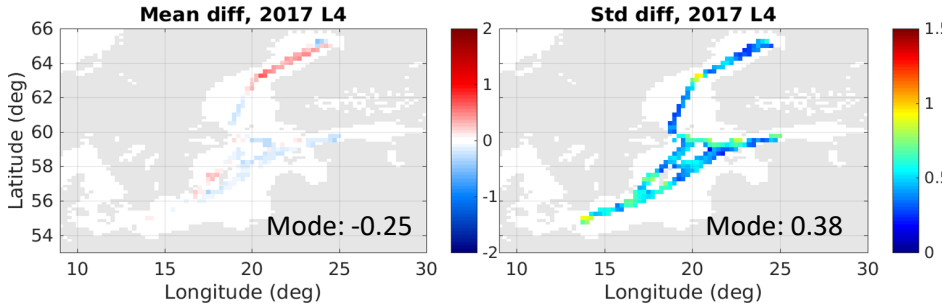
BEC Barcelona Expert Center

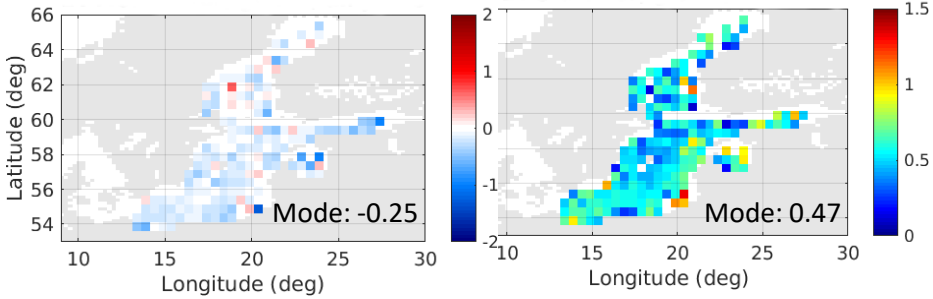
Baltic+ L3 SSS





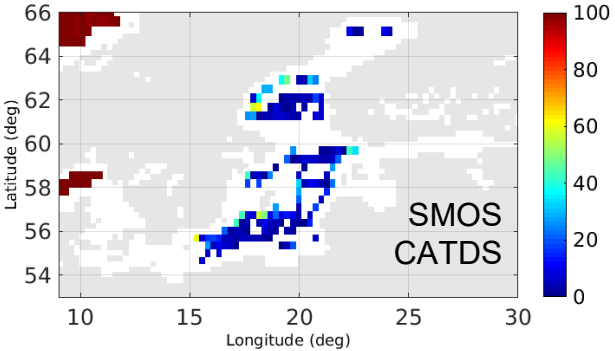
Baltic+ L4 SSS

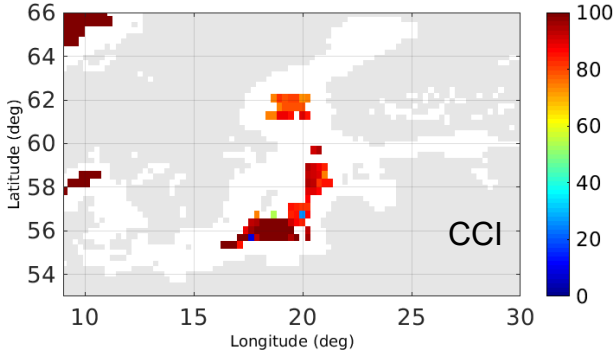


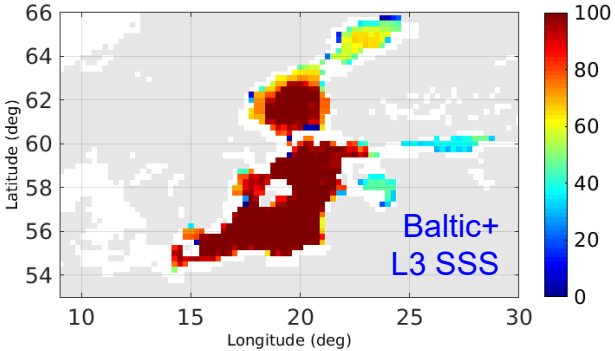


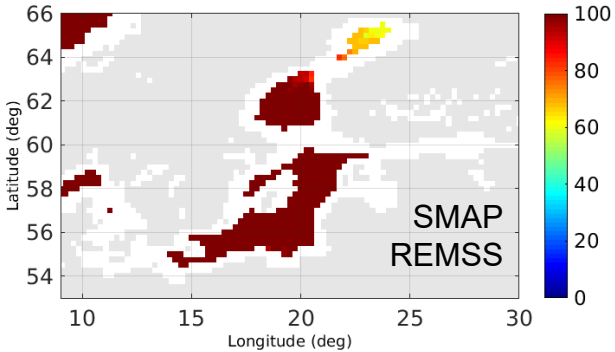
- The accuracy of the L3 SSS is ~[0.7-0.8] psu and for the L4 is ~0.4 psu.
- Standard deviations of L4 SSS are very significantly reduced with respect to the L3 product.
- Higher standard deviation values are located in cells closer to coast/ice edges, Arkona and Bornholm basins.

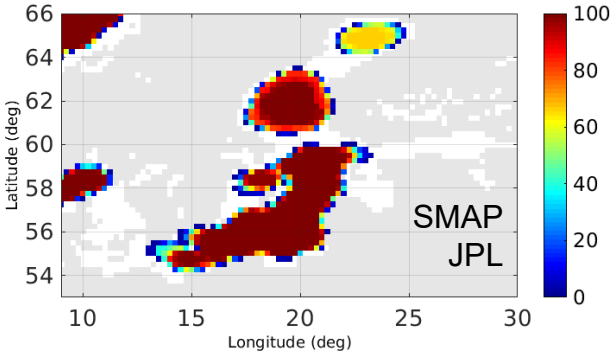
Comparison to other EO SSS datasets: Coverage









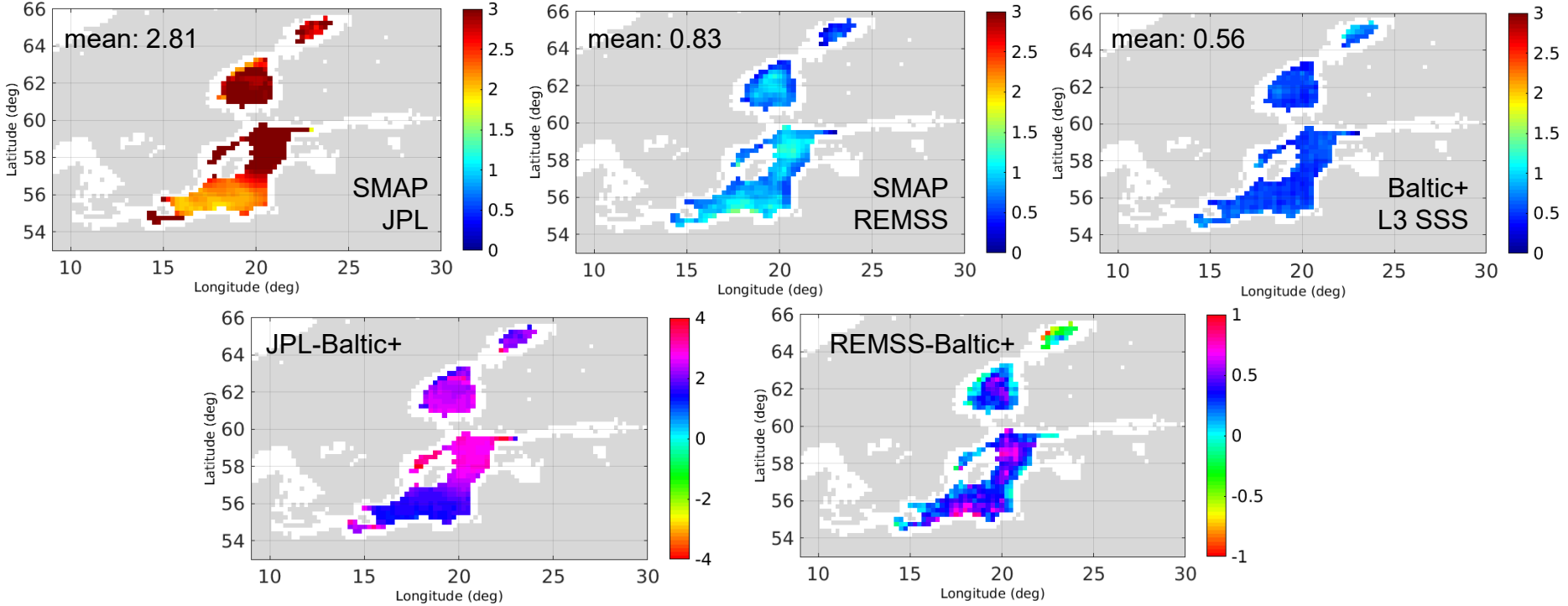


Spatio-temporal coverage 2016

- The three available products with better spatio-temporal coverage are: SMAP REMSS, SMAP JPL and Baltic+ L3.
- The Baltic+ L3 SSS is the EO product with the best performance in terms of coverage.

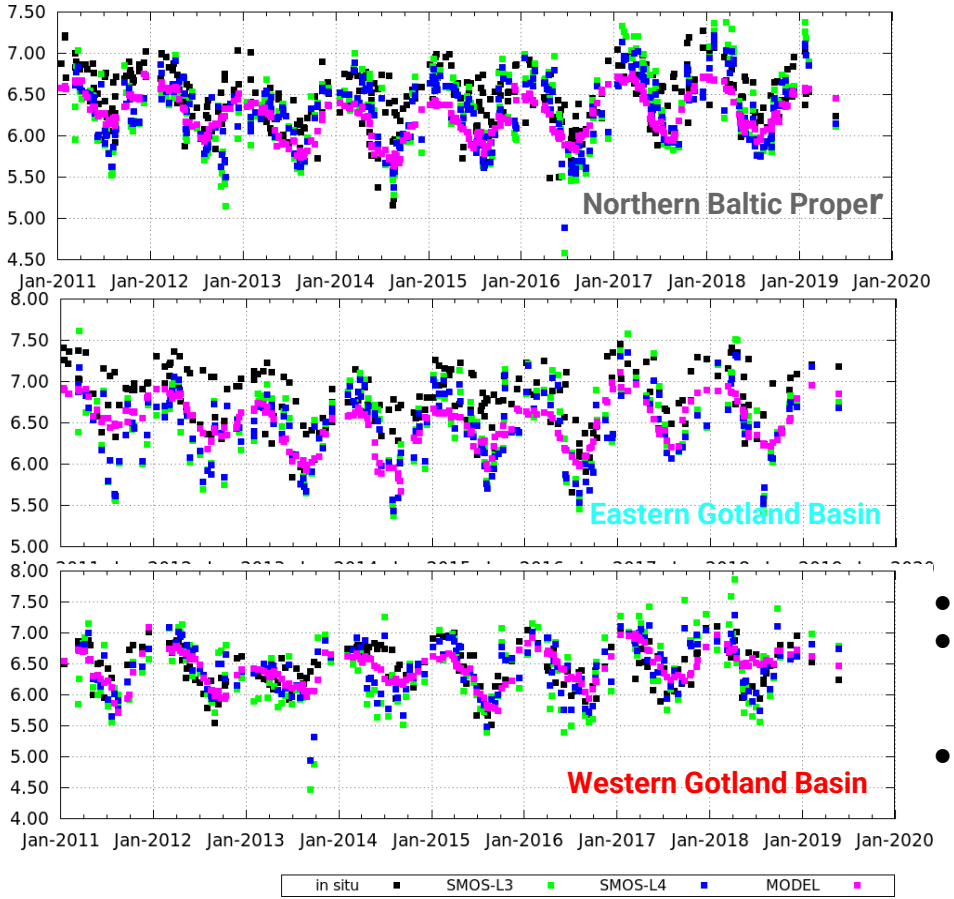
Comparison to other EO SSS datasets: Uncertainty

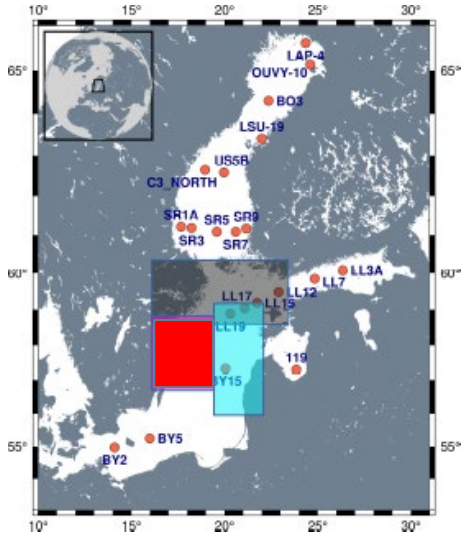
SSS uncertainty estimated by correlated triple collocation (*González-Gambau et al., 2020, Remote Sensing*)



- Estimated errors for the Baltic+ L3 SSS are in agreement with the differences found with respect to in situ.
- The Baltic+ L3 SSS product has the smallest error in the whole basin, except in some grid points of the Bothnian B.

Baltic+ L3 and L4 SSS: Added-value wrt in situ and reanalysis

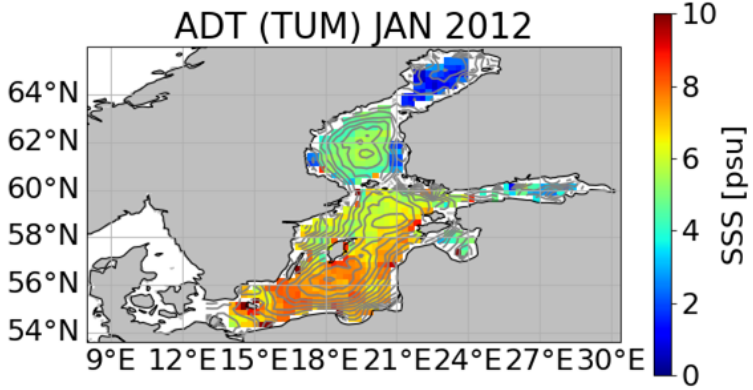




- Overall agreement between satellite, reanalysis and in situ.
- The variability shown by the satellite reflects the variability captured by the in situ measurements better than the reanalysis.
- Baltic+ SSS products can be very useful to validate the models in areas, where in situ data are sparse. Also, the location of gradients is very useful.

Scientific cases with Baltic+ Salinity products (i)

Analysis of the **consistency between** the structures in **Baltic+ SSS** products and the **circulation patterns derived from altimetric** maps.



On-going activities:

First analysis of the alignment between the gradients of DOT and SSS at a monthly scale: oceanic structures present in SSS and DOT are coherent and aligned.

See the poster of this afternoon!

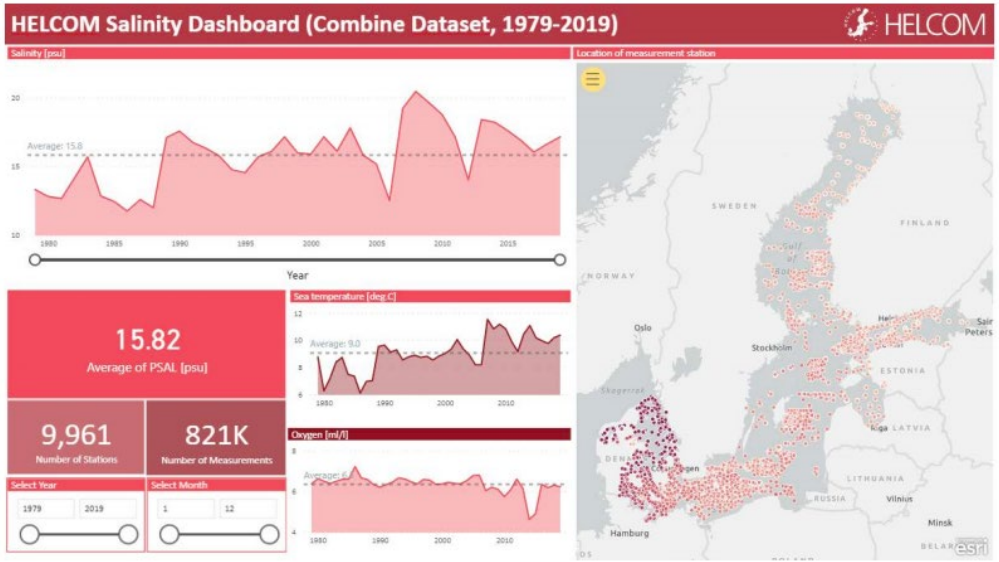
E3.04 **"Exploring synergies between remote sensing products developed under the framework of ESA Baltic+ initiative: Sea Surface Salinity and Sea Level"**, C. González-Haro et al.

Scientific cases with Baltic+ Salinity products (ii)

Study of the **tolerance of different species to SSS changes.** Long time-series of SSS would allow to study the **correlation between the SSS variability and the extreme events** of different species.

On-going activities:

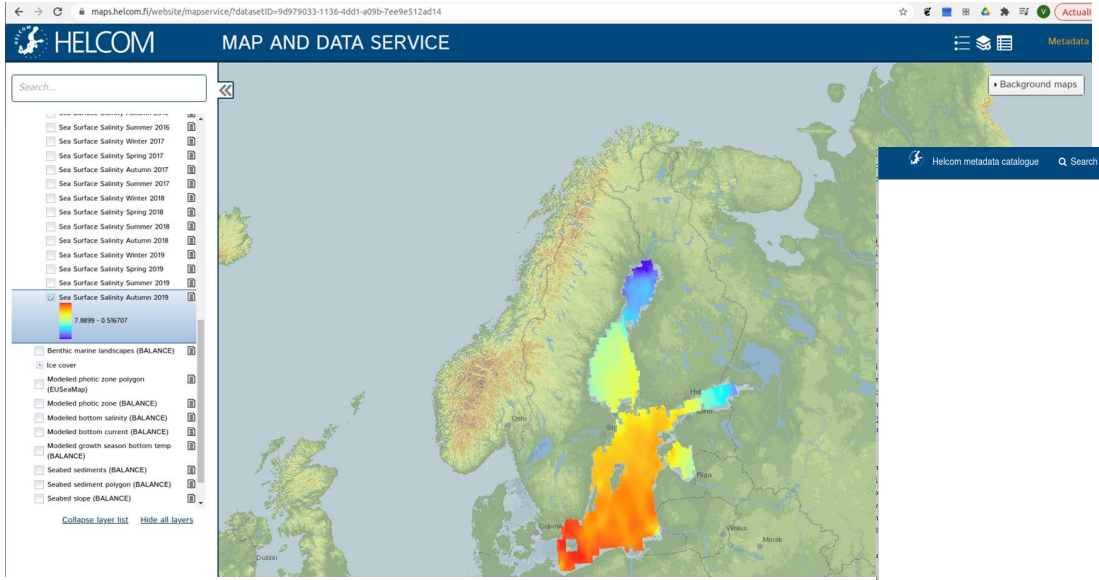
HELCOM is analyzing the feasibility of including **seasonal averaged Baltic+ L4 SSS maps (complementing their in situ measurements)** for the generation of Helcom driver indicators.

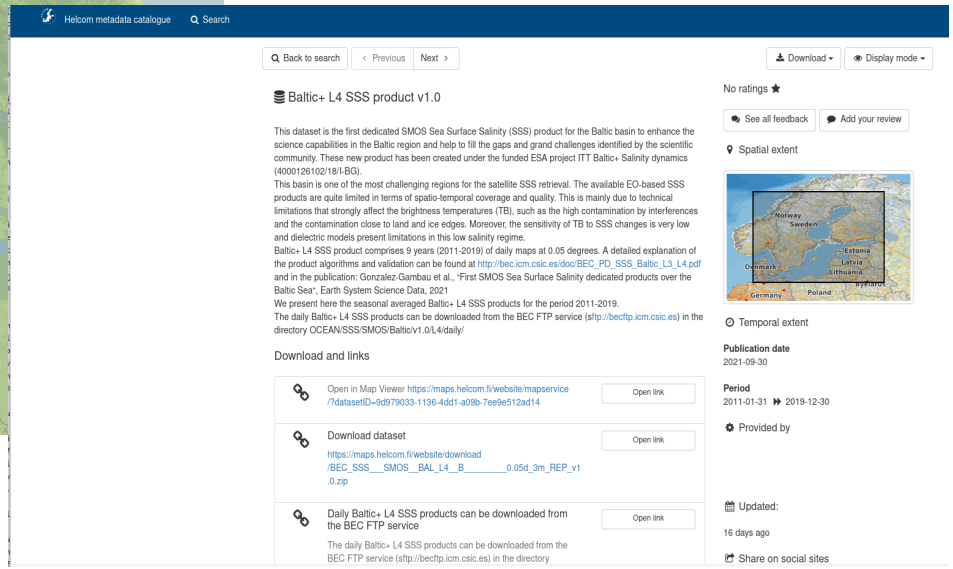


https://portal.helcom.fi/meetings/GEAR%2024-2021-876/Documents/Presentation%206%20-%20Driver%20Indicators.pdf

Baltic+ SSS ingested at HELCOM

Regional data provider





Baltic+ L4 seasonal averaged SSS maps

https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/9d979033-1136-4dd1-a09b-7ee9e512ad14

Conclusions

- Several **technical improvements** required for Baltic+ SSS products have a **significant impact on** other **regional initiatives** (such as EO4SIBS, in the Black Sea).
- Baltic+ SSS products have a **good spatio-temporal coverage with an accuracy of 0.7-0.8 psu** for the **L3 product** (9-day, 0.25º) and **0.4 psu for the L4 product** (daily, 0.05º). Regions with higher errors and limited coverage: Arkona and Bornholm basins and gulfs of Finland and Riga.
- They provide valuable information about the changes in the **salinity gradients** and show **geophysically consistent seasonal variability in surface salinity** from the melting of sea ice in spring and increased run-off from land when snow cover melts.
- Baltic+ SSS data **complement the temporally and spatially very sparse in situ** measurements and can be **useful for the validation of numerical models,** particularly where in situ are sparse. Also the **location of the gradients** and their variability are valuable in evaluating models performance and provide possibility to assimilate SSS fields.
- **Several scientific studies** are in progress. Interactions with the scientific community have allowed to identify **potential applications that would benefit from further technical developments** (*e.g.* determination of annual trends, monitoring the salinity in the straits connecting the Baltic Sea with the North Sea)**.**
- All these **applications would benefit of Baltic+ SSS time-series as long as possible.**

Reference (10.5194/essd-14-2343-2022)

Earth Syst. Sci. Data, 14, 2343–2368, 2022
https://doi.org/10.5194/essd-14-2343-2022

Open Access Earth System Science Data

First SMOS Sea Surface Salinity dedicated products over the Baltic Sea

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EUMETSAT ECMWF EUSPA

Thank you for your attention!

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BACK-UP SLIDES

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Mitigation of errors in SMOS TB

ALL-LICEF calibration approach and the **G_{kj}** correction are crucial to **reduce the LSC/ISC** close to coasts and ice edges.

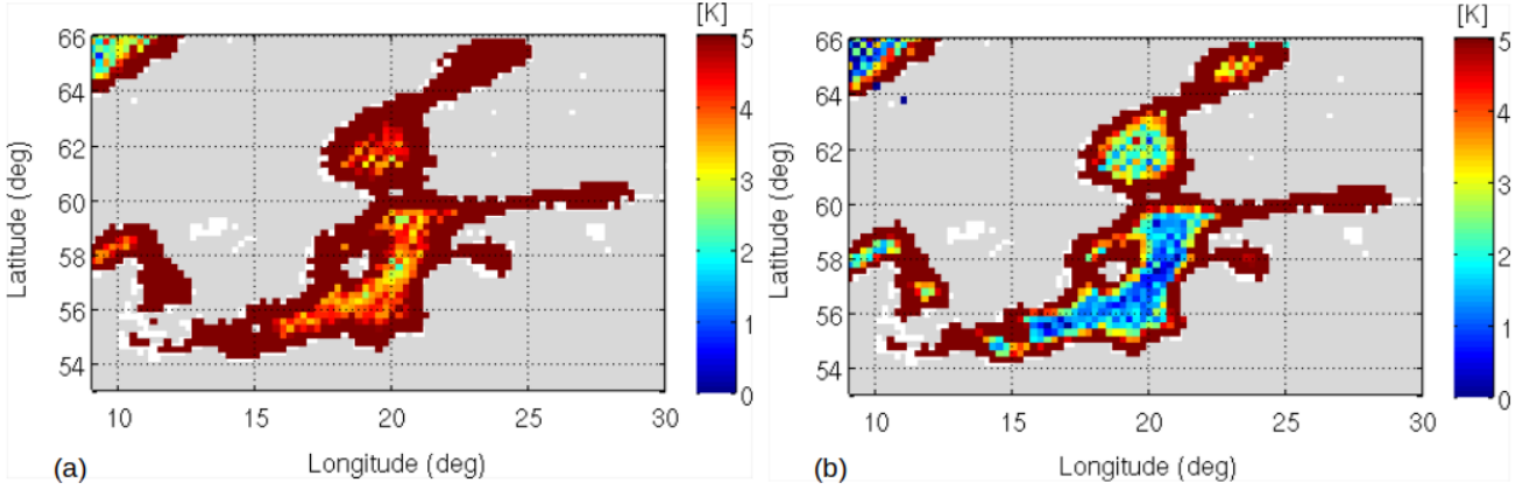


Figure 2. 9-day 0.25° map (June 2014) of the mean anomaly ($TB_{SMOS} - TB_{mod}$) of the first Stokes parameter divided by two (($T_H + T_V$)/2), that is, the average between the horizontal and vertical polarizations of the TB (($TB_H + TB_V$)/2) [K]. (a) TB without the G_{kj} correction, (b) TB after applying the G_{kj} correction.

Empirical correction of dielectric constant model

Dielectric constant models that relate the TB and the SSS were derived from measurements in the range of the global ocean (32-38 psu) and they are **not fully tested in the low SSS and low SST regimes of the Baltic Sea**.

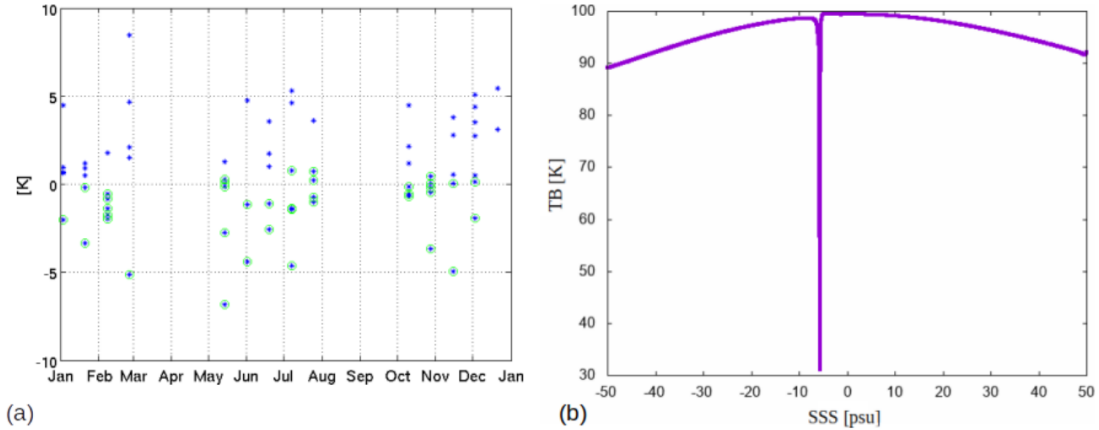


Figure 3. (a) Difference of SMOS and modeled TB (blue stars) for ascending orbits in 2013 for the following acquisition conditions: ($\varphi = 56°, \lambda = 19°, Ascending, x = 0km, \theta = 42.5°$). Green circles indicate those measurements for which a valid SSS is retrieved. (b) Half first Stokes modeled TB (MW model) versus raw SSS for $\theta = 40°$ and $T_s = 0°C$. Note that negative SSS values do not have any physical meaning. They only reflect the presence of instrumental biases that need to be corrected.

Linear extension of M&W dielectric constant model for SSS lower than 20 psu.

Exploratory research from L0 to L4

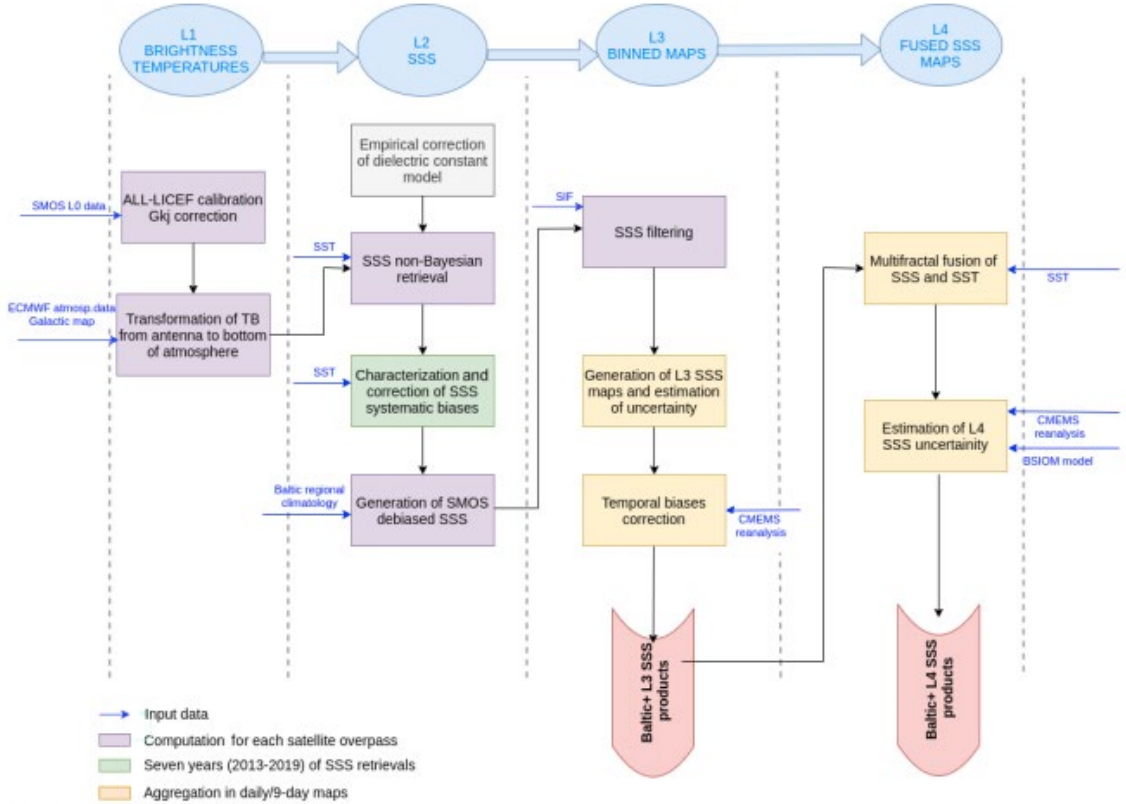
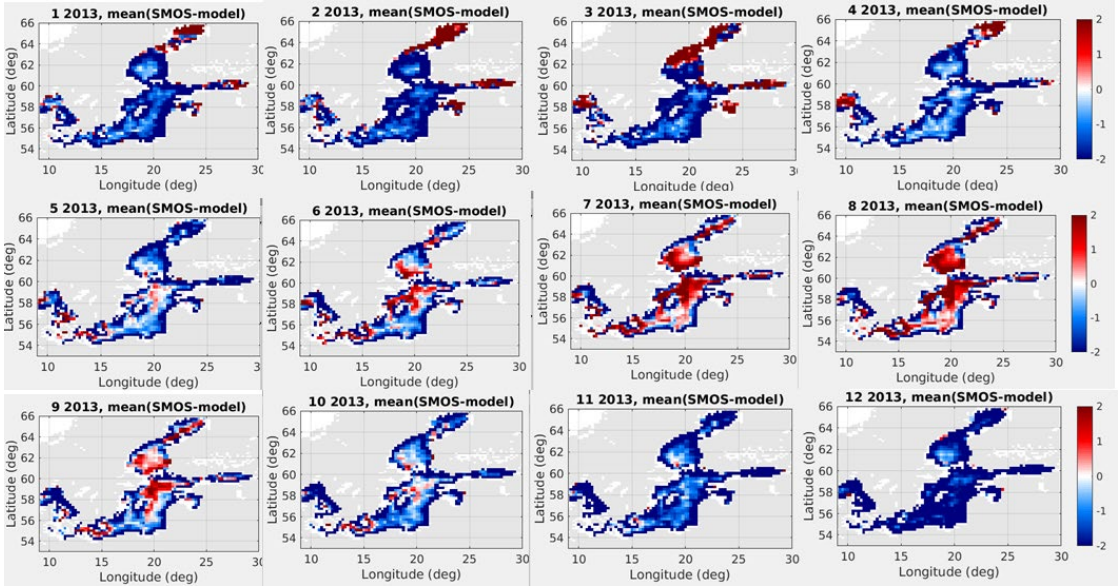
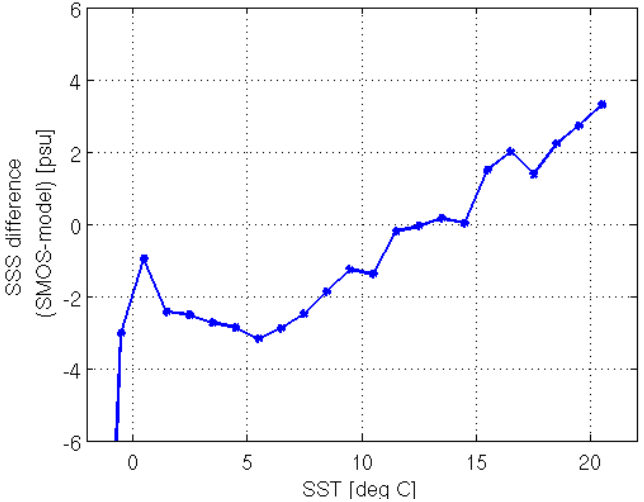


Figure 1. Block diagram of the Baltic+ SSS processor.

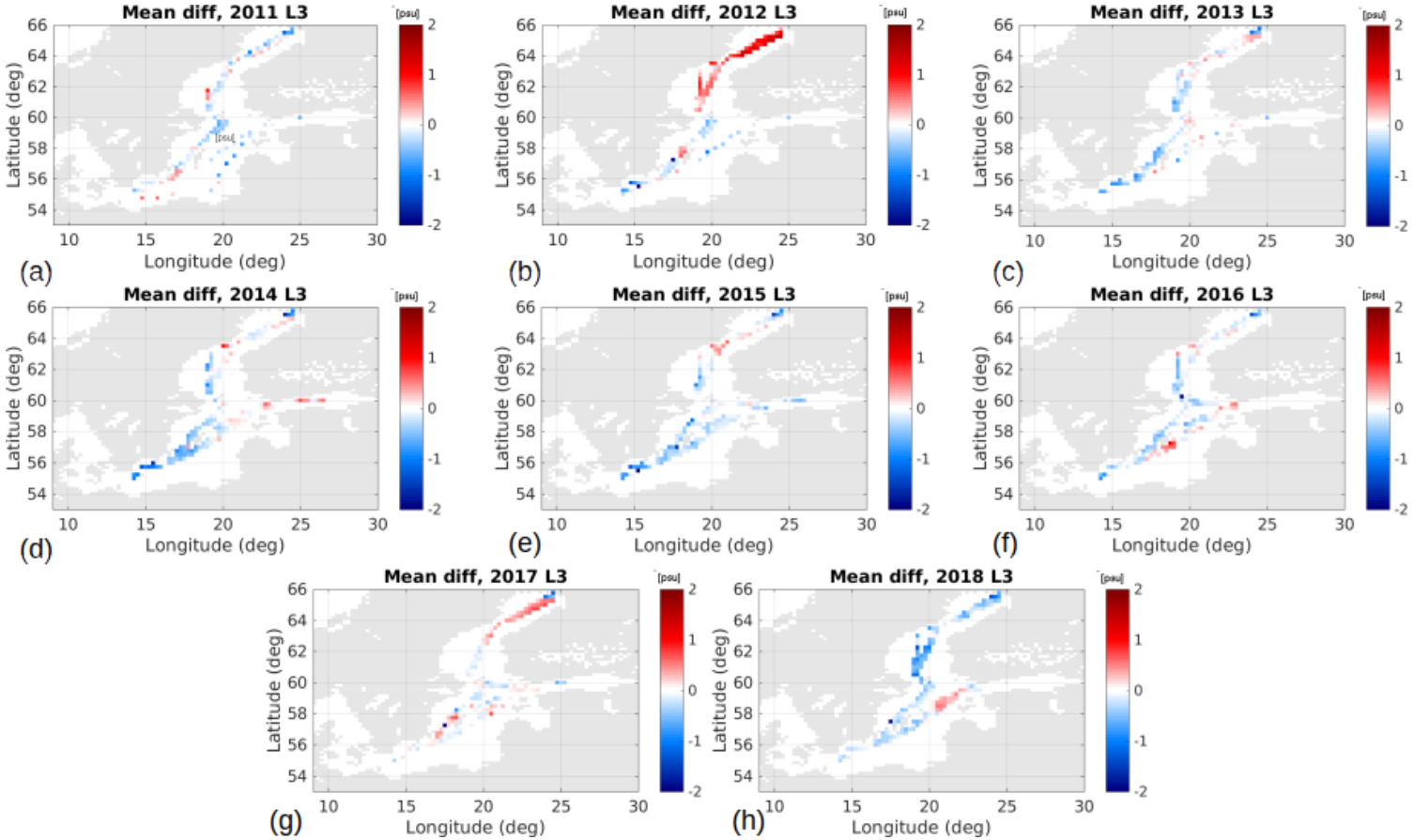
Empirical correction of dielectric constant model



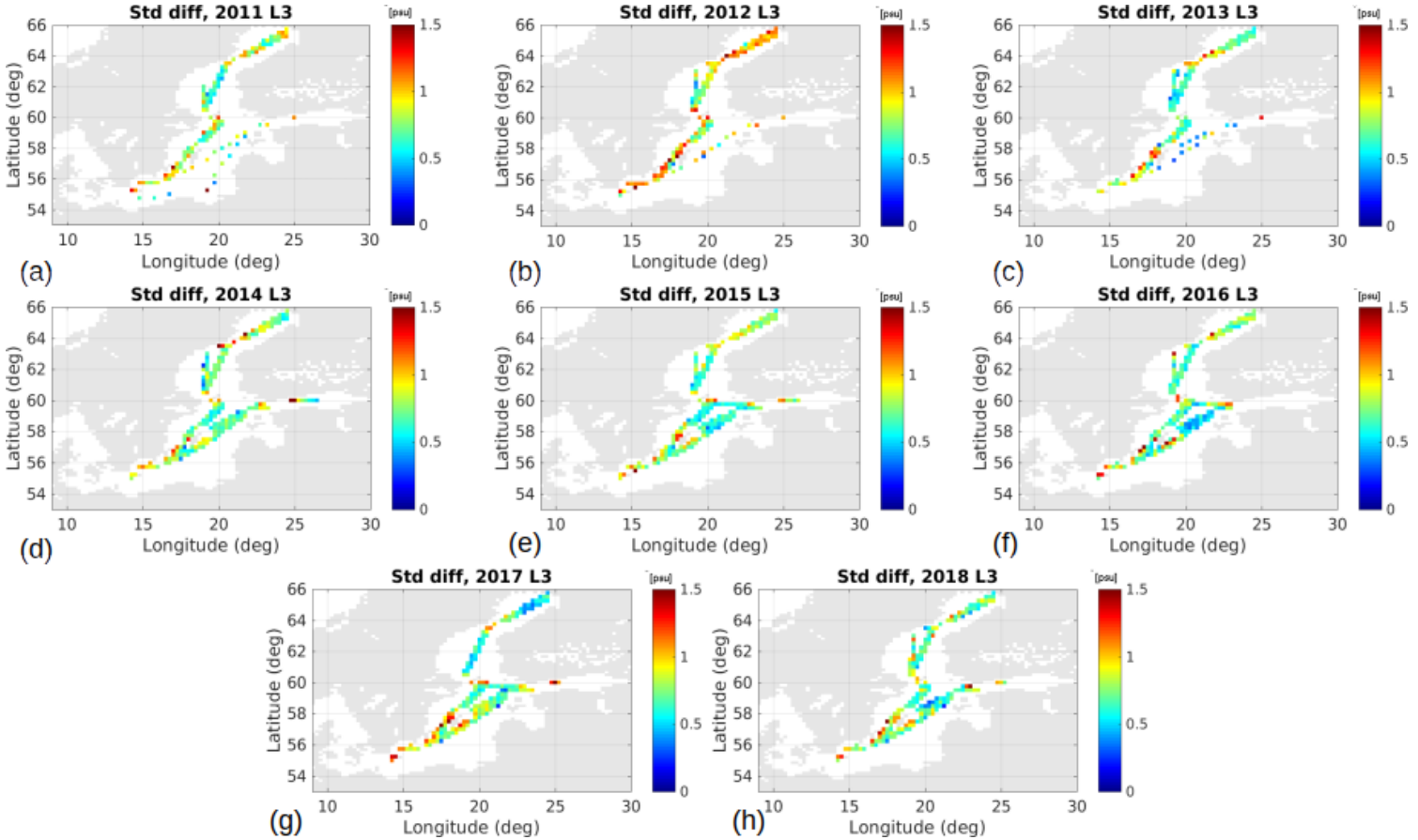


The characterization/**correction of SSS systematic errors, depending** not only on the acquisition conditions, but **also on the SST**.

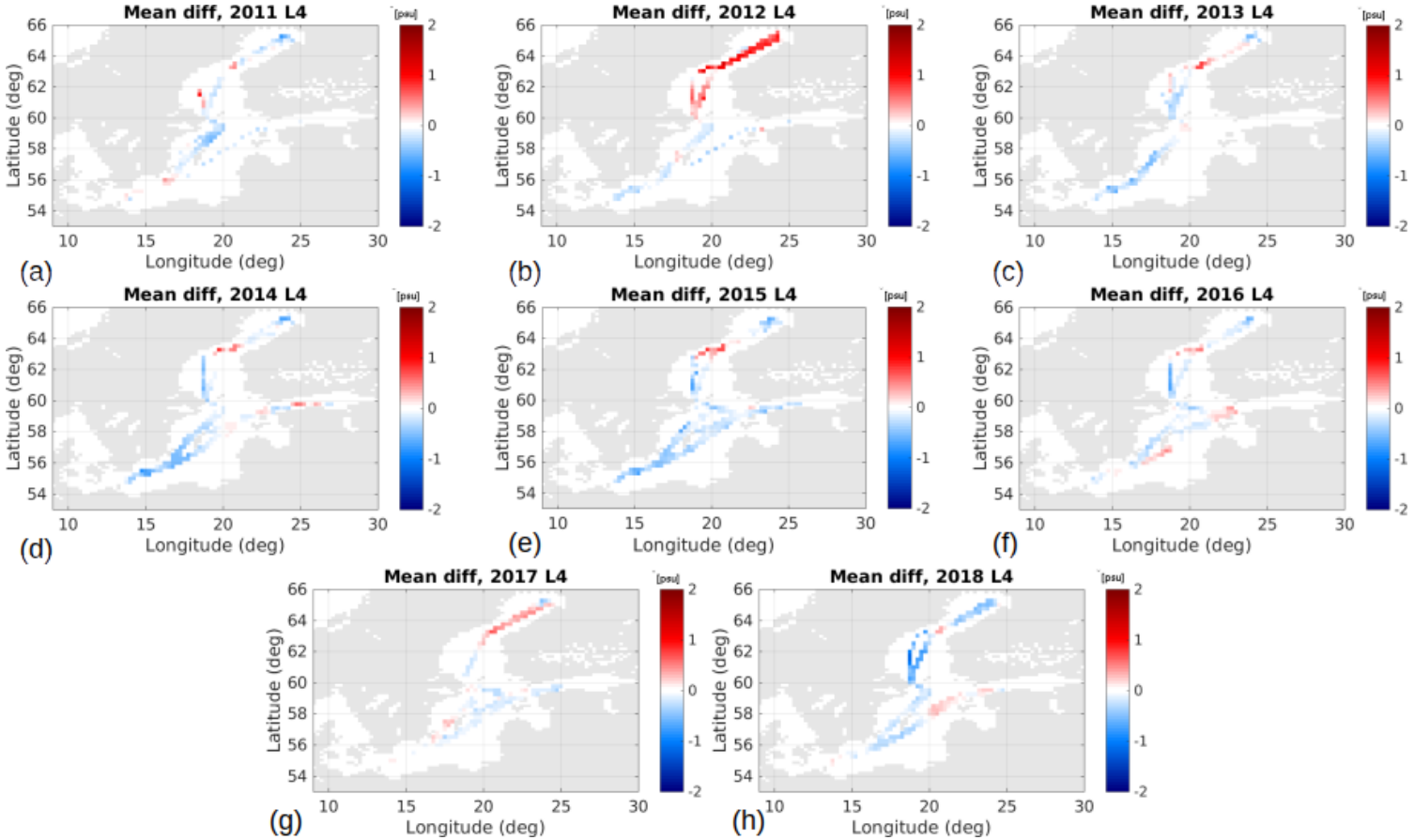
Baltic+ L3 SSS and FerryBox (Mean of delta SSS)



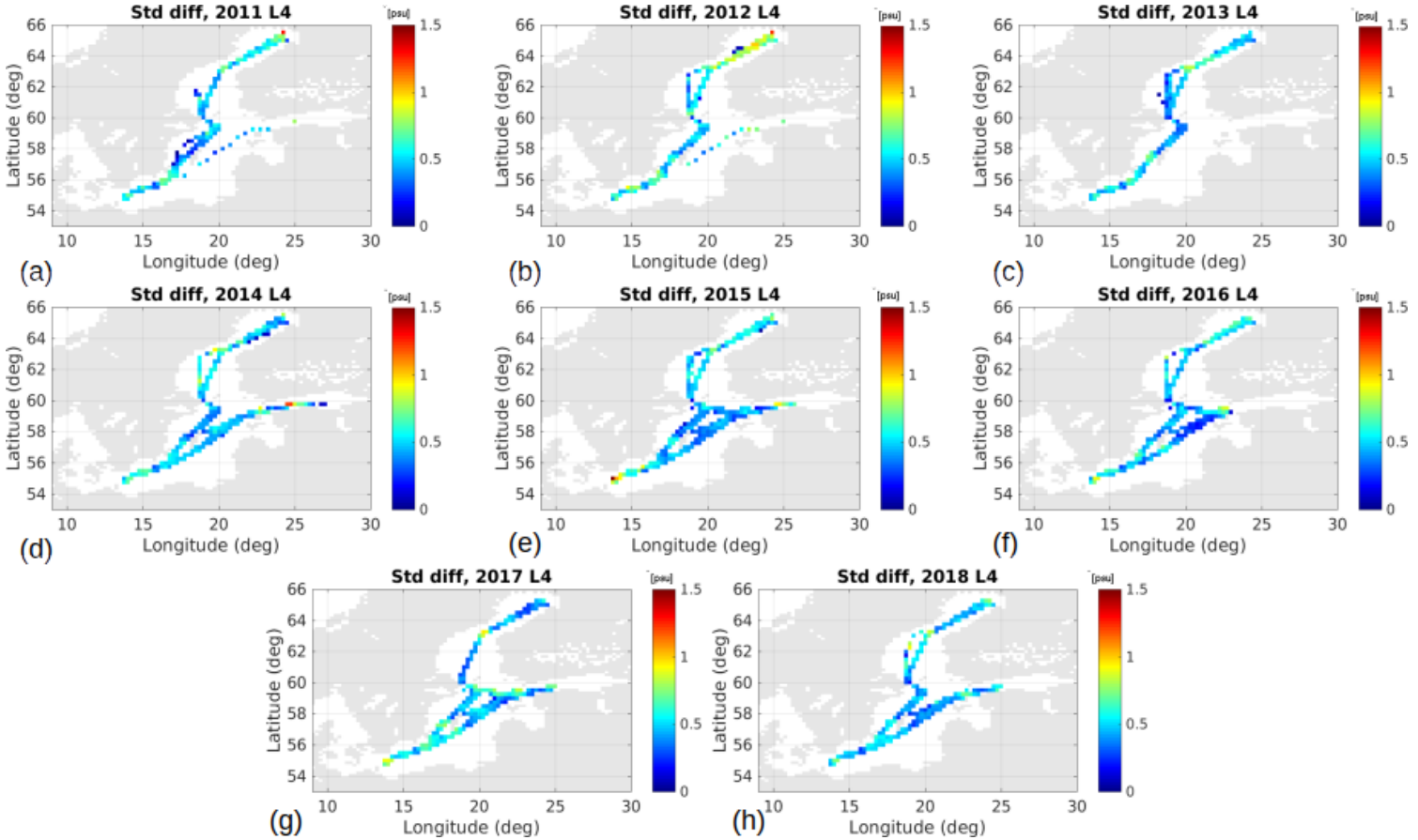
Baltic+ L3 SSS and FerryBox (STD of delta SSS)



Baltic+ L4 SSS and FerryBox (Mean of delta SSS)



Baltic+ L4 SSS and FerryBox (STD of delta SSS)



Baltic+ L3/L4 SSS and FerryBox (Statistics)

		2011	2012	2013	2014	2015	2016	2017	2018	Full period
L3	Mean	-0.16	0.21	-0.19	-0.23	-0.21	-0.16	0.03	-0.19	-0.11
	Median	-0.2	0.16	-0.18	-0.23	-0.22	-0.17	0.02	-0.16	-0.13
	STDD	0.88	1.12	0.84	0.86	0.81	0.83	0.87	0.85	0.89
	R	0.87	0.73	0.85	0.83	0.83	0.87	0.81	0.88	0.83
	Match-ups	3827327	6240087	6835592	10026054	12565303	7089550	13384262	8951692	68919867
L4	Mean	-0.11	0.15	-0.15	-0.2	-0.21	-0.08	-0.05	-0.1	-0.11
	Median	-0.12	0.07	-0.14	-0.19	-0.25	-0.1	-0.08	-0.08	-0.13
	STDD	0.55	0.73	0.55	0.56	0.57	0.53	0.56	0.52	0.58
	R	0.94	0.89	0.93	0.92	0.91	0.94	0.87	0.92	0.91
	Match-ups	481038	781871	854449	1254285	1585228	890838	1678201	1119688	8645598
L4 filtered	Mean	-0.14	0.2	-0.16	-0.21	-0.22	-0.1	-0.04	-0.14	-0.11
	Median	-0.17	0.13	-0.17	-0.21	-0.25	-0.12	-0.08	-0.12	-0.14
	STDD	0.57	0.76	0.58	0.58	0.58	0.55	0.59	0.54	0.6
	R	0.94	0.87	0.93	0.9	0.9	0.93	0.86	0.91	0.9
	Match-ups	362726	594404	633280	933735	1187949	727614	1143172	773918	5287648

Table 3. Global statistics Baltic+ L3, L4 and filtered L4 (not considering extrapolated measurements from reanalysis) SSS products against FerryBox in situ data. Note the high variability in the number of match-ups is due to the different cruises operated each year.

Baltic+ L3/L4 SSS and SeaDataNet (Statistics)

		2011	2012	2013	2014	2015	2016	2017	2018	2019	Full period
L3	Mean	-0.2	-0.15	-0.2	-0.32	-0.4	-0.35	-0.26	-0.22	-0.17	-0.26
	Median	-0.19	-0.09	-0.21	-0.31	-0.36	-0.37	-0.3	-0.19	-0.12	-0.25
	STDD	1.06	1.36	0.94	0.97	0.95	1.05	1.03	0.91	1.06	1.04
	R	0.73	0.46	0.68	0.7	0.6	0.74	0.73	0.73	0.75	0.69
	Match-ups	4526	8352	9695	5689	11619	7871	7701	10009	8742	74204
L4	Mean	-0.16	-0.15	-0.16	-0.25	-0.32	-0.3	-0.23	-0.16	-0.11	-0.2
	Median	-0.09	-0.14	-0.14	-0.22	-0.31	-0.31	-0.25	-0.16	-0.1	-0.19
	STDD	0.63	0.79	0.58	0.56	0.59	0.71	0.61	0.58	0.73	0.65
	R	0.87	0.73	0.84	0.9	0.83	0.88	0.87	0.89	0.87	0.86
	Match-ups	917	1459	1603	987	1780	1242	1349	1629	1510	12476
L4 filtered	Mean	-0.2	-0.14	-0.18	-0.29	-0.33	-0.32	-0.23	-0.18	-0.09	-0.22
	Median	-0.16	-0.14	-0.22	-0.28	-0.32	-0.33	-0.28	-0.18	-0.09	-0.23
	STDD	0.69	0.86	0.61	0.59	0.61	0.74	0.59	0.55	0.75	0.67
	R	0.85	0.66	0.82	0.88	0.78	0.85	0.87	0.87	0.85	0.83
	Match-ups	570	1019	1185	692	1418	953	938	1200	1078	9053

Table 4. Global statistics Baltic+ L3, L4 and filtered L4 (not considering extrapolated measurements from reanalysis) SSS products against SeaDataNet in situ data.