Baltic+ Salinity

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

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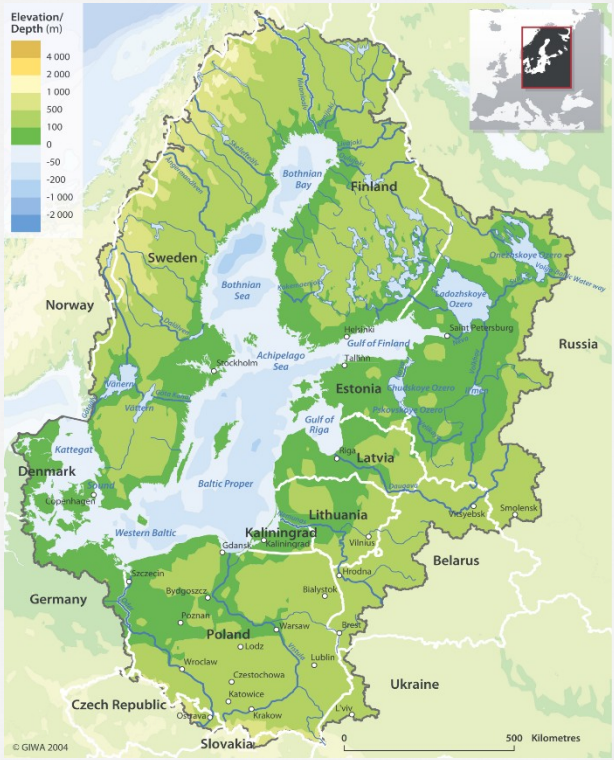
Understanding salinity dynamics through satellite-based measurements

Baltic+ Salinity Dynamics

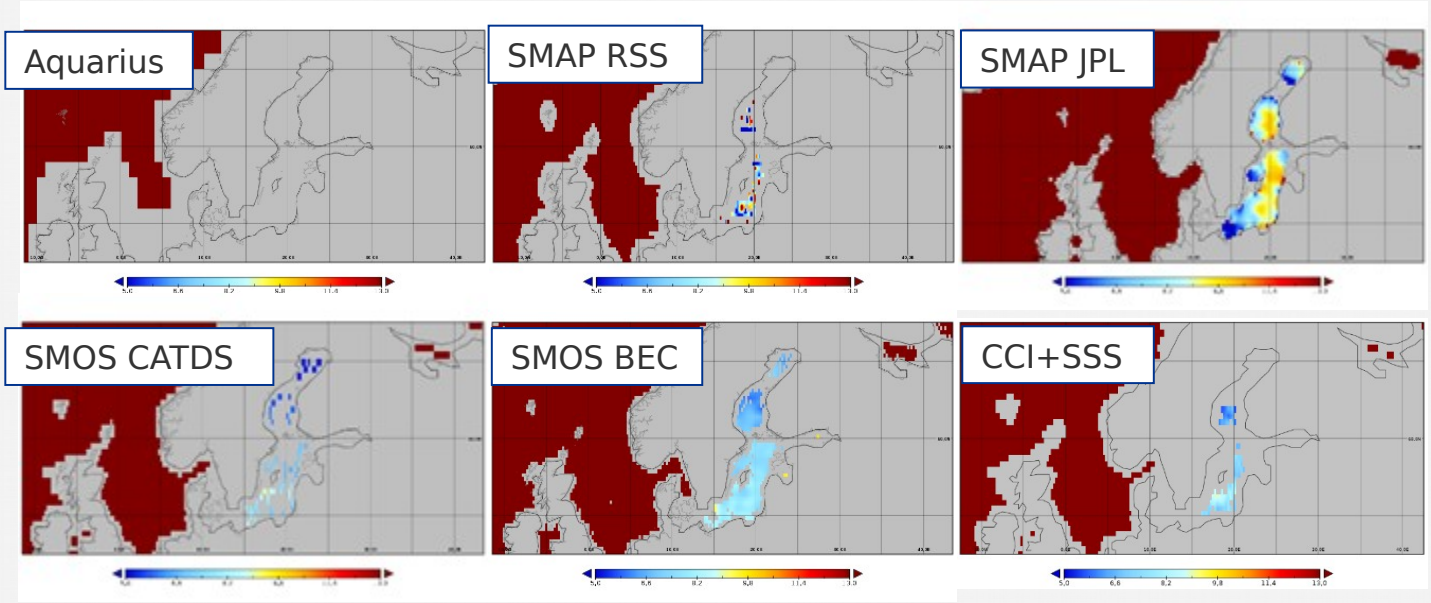
- **Monitorization of long-term SSS changes** in the different sub-basins (determination of salinity annual trends).
- **Detection of frontal areas** where SSS gradients are stronger (river run-offs, ice formation and melting processes, etc.).
- Study of **inflow and outflow dynamics** through the determination of **anomalous salinity periods**.
- Satellite-based SSS measurements can be used as **initial fields and validation data to numerical models**.
- Assessment of the **circulation in the basin according to the observed SSS patterns** (see next presentation *"Synergies between between remote sensing products developed under the framework of ESA Baltic+ initiative: Sea Surface Salinity and Sea Surface Height"*).



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



There is a need for developing regional SSS products over Baltic Sea

Aquarius: version 4.0 CAP
SMOS LOCEAN: L3 debiased version 3

SMAP RSS: version 3.0, 40 km
SMOS BEC: L3 debiased non-Bayesian, version 1

SMAP JPL: version 4.2
CCI+ Salinity product: version 01.7

ITT Baltic+ Salinity Dynamics: Objectives

ESA funded project

https://balticsalinity.argans.co.uk

Partners:

ARGANS

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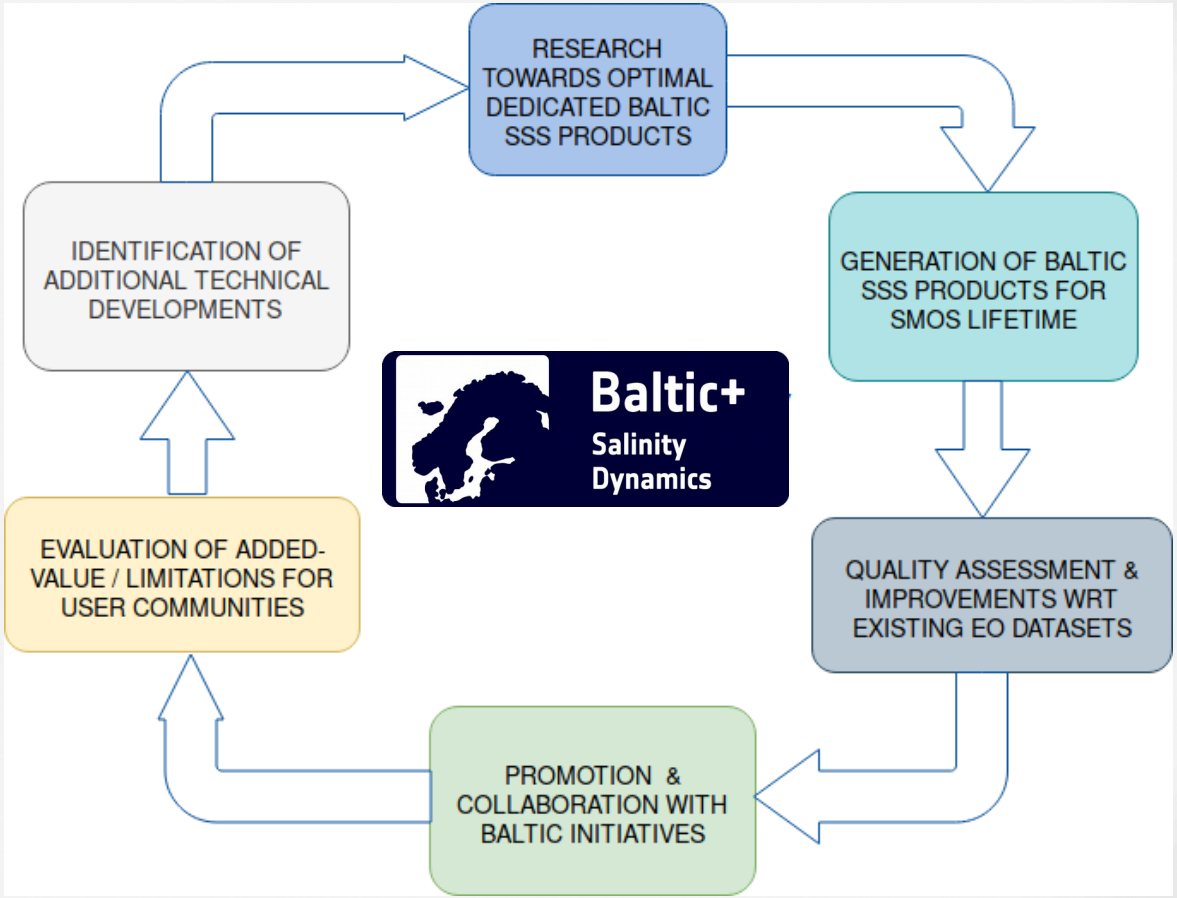
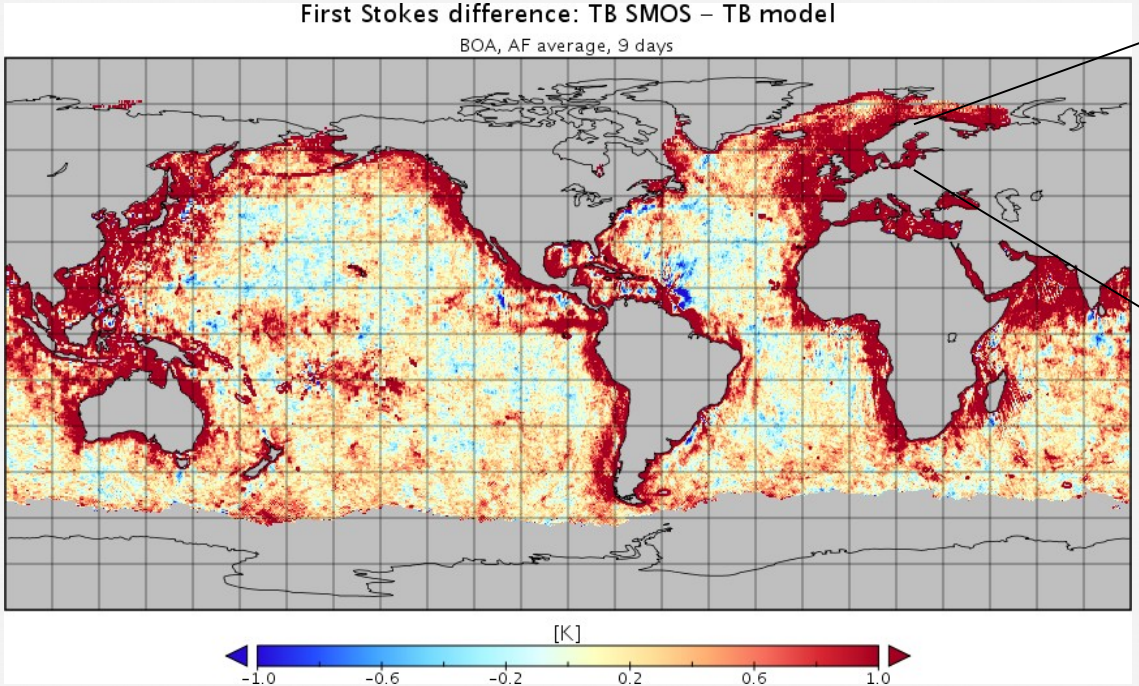
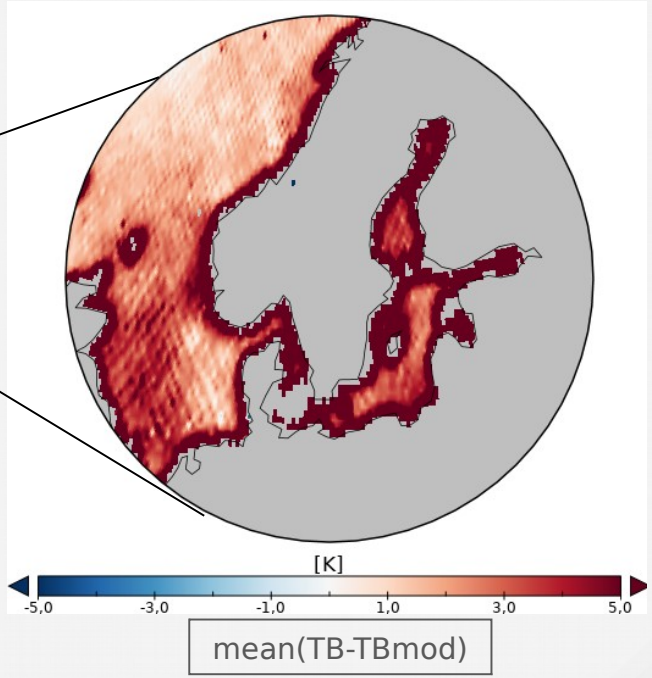


Challenges in retrieving SMOS SSS over Baltic (i)

Land-sea and ice-sea contamination

- Systematic artificial increase of ocean TB close to land and ice edges, particularly crucial in semi-enclosed seas.





[Martin-Neira et al. RSE 2016]
[Corbella et al. GRSL 2015]

Challenges in retrieving SMOS SSS over Baltic (ii)

Contamination by Radio-Frequency Interference sources

- Artefacts corrupt entire TB images when strong RFI sources or the Sun alias are present

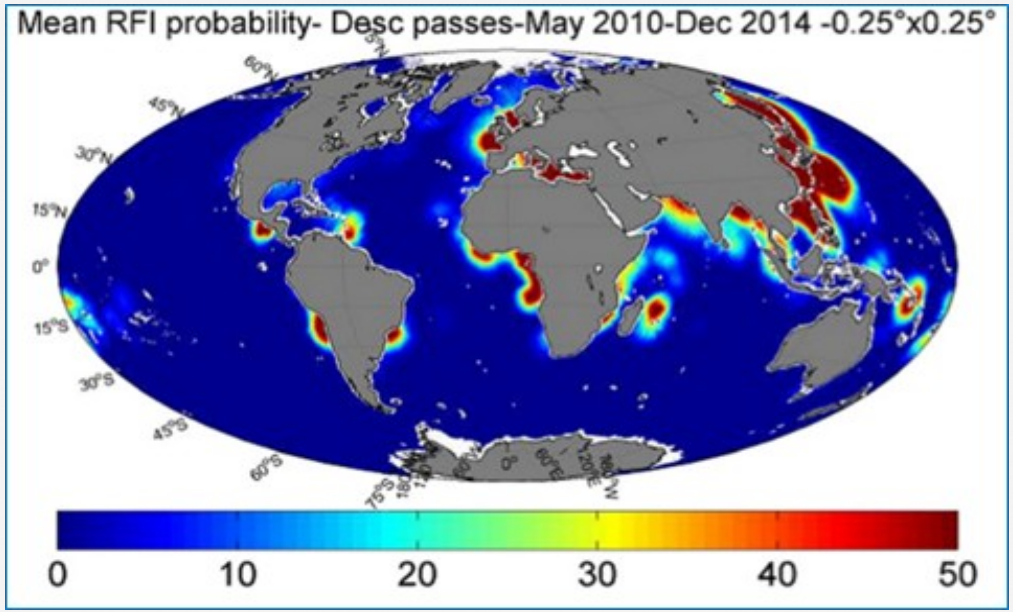
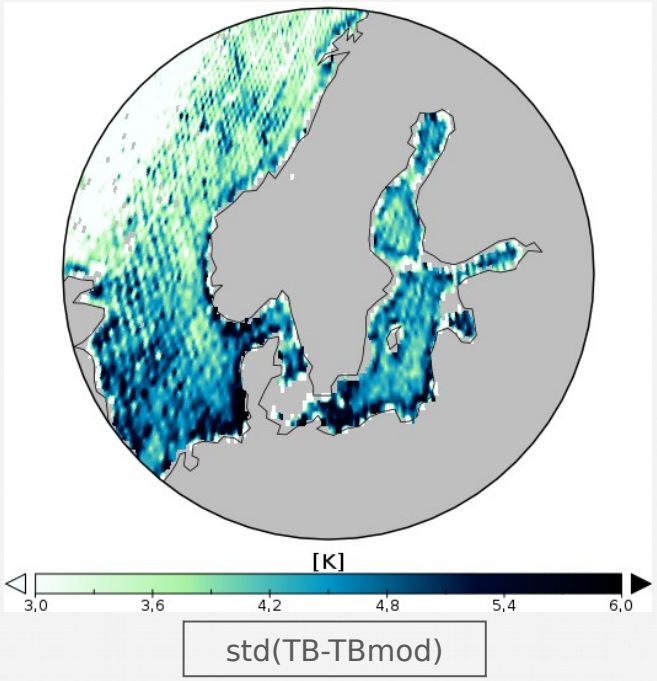


Figure from [Oliva et al. RSE 2016]
[Martín-Neira et al. RSE 2016]

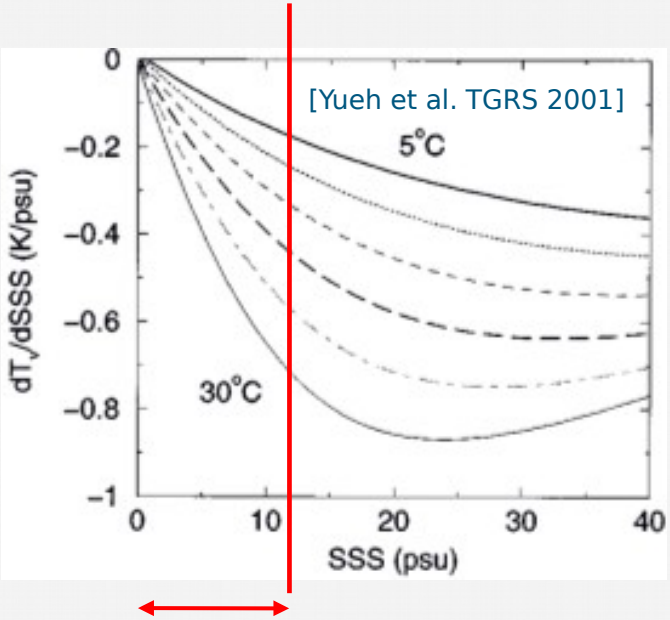


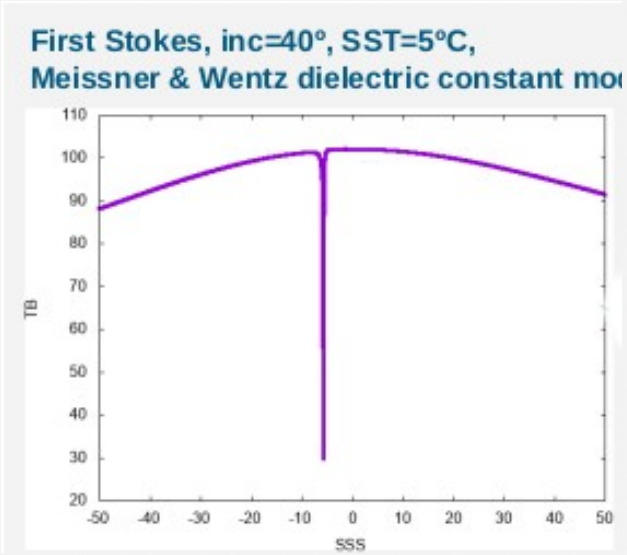
Map: June 2014
More intense RFI activity over Baltic: 2011-2013

Challenges in retrieving SMOS SSS over Baltic (iii)

- Low sensitivity of L-band TB to SSS at low SSS and SST
  - Errors in the determination of SSS values are expected to be much more larger than at temperate oceans
- Assessment of available dielectric constant models for the low SSS & SST

Problems at low SSS, models have been extrapolated with polynomials

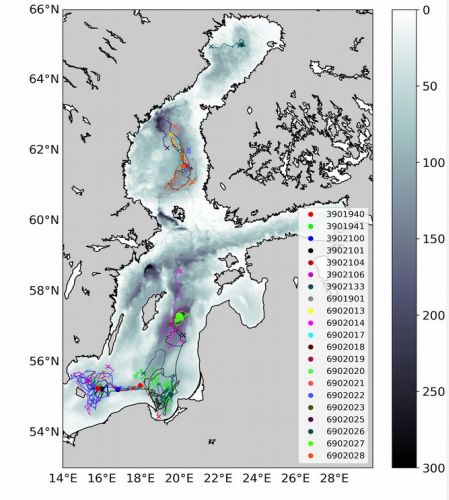




Challenges in validating SMOS SSS over Baltic

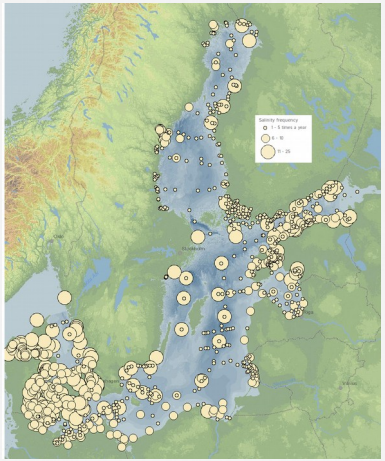
- Scarcity of in-situ SSS measurements
- Inhomogeneous spatial distribution and sampling of in-situ measurements
- Representativeness of satellite SSS vs in-situ measurements

  Significant differences between surface (satellite) and sub-surface (in situ) salinity (seasonal variations in the surface, strong horizontal gradients, etc.)



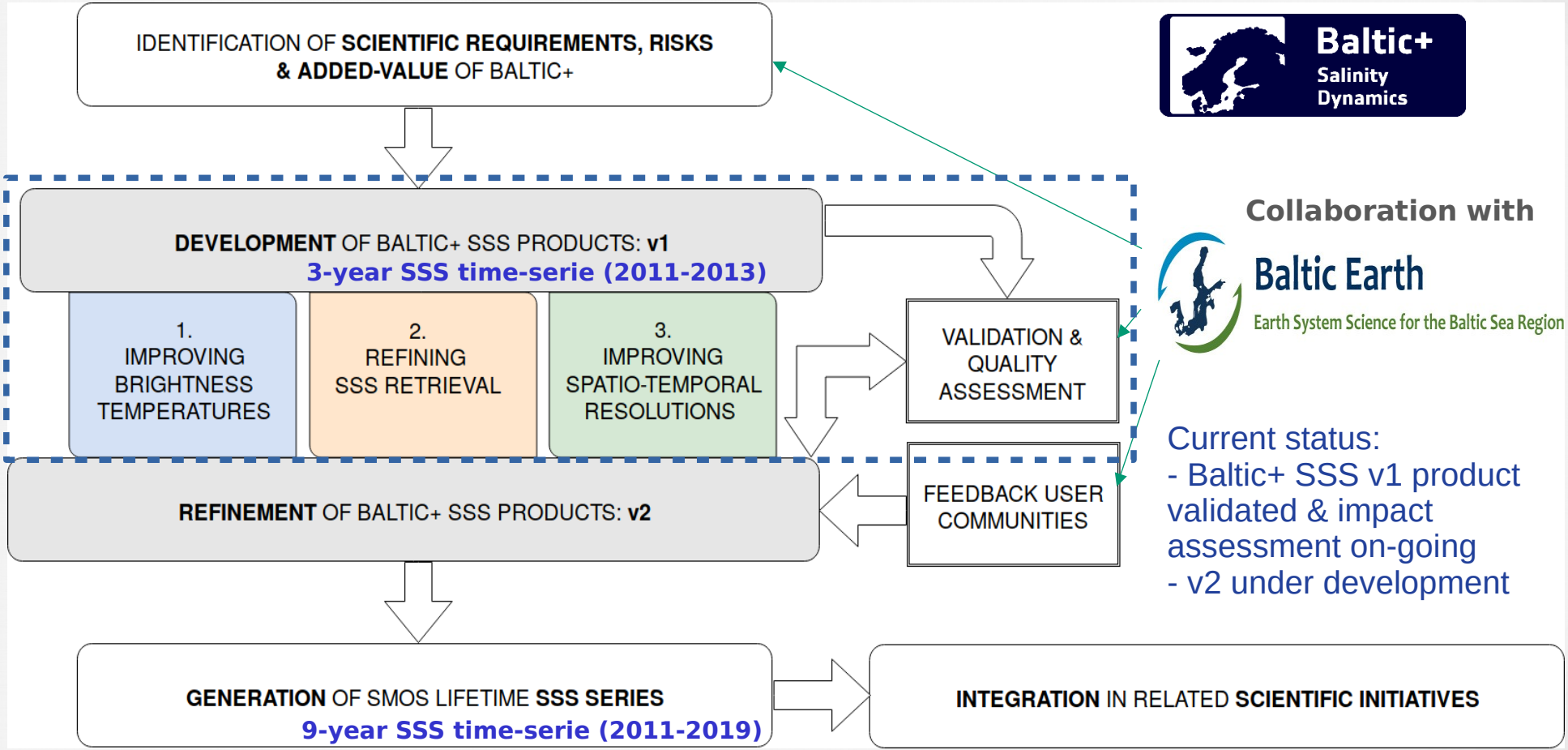
Argo floats

FerryBox lines



Monitoring stations Helcom

ITT Baltic+ Salinity Dynamics: Scientific approach



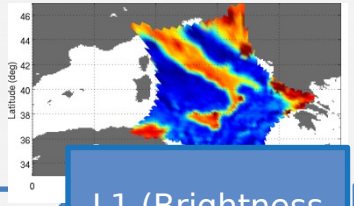
Algorithm development: Exploratory research L0-L4

Baltic+ Salinity Dynamics

L0 (raw data)

Calibration
Improvements for LSC reduction

Image reconstruction
Method for reduction of RFI contamination



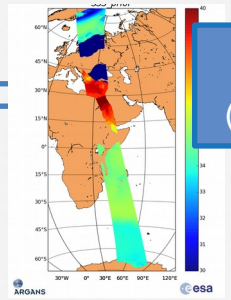
L1 (Brightness temperatures)

Dielectric constant model
Review of the model for the low SSS & low SST ranges in Baltic

Forward modeling

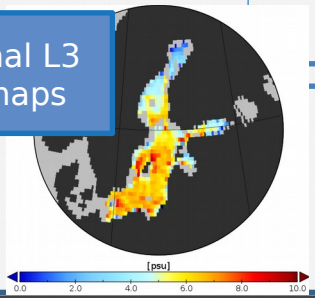
Geophysical retrieval

Mitigation of residual systematic biases on SSS
Building a climatology for the different acquisition conditions



L2 SSS (overpasses)

Improvements generating L3 binned maps



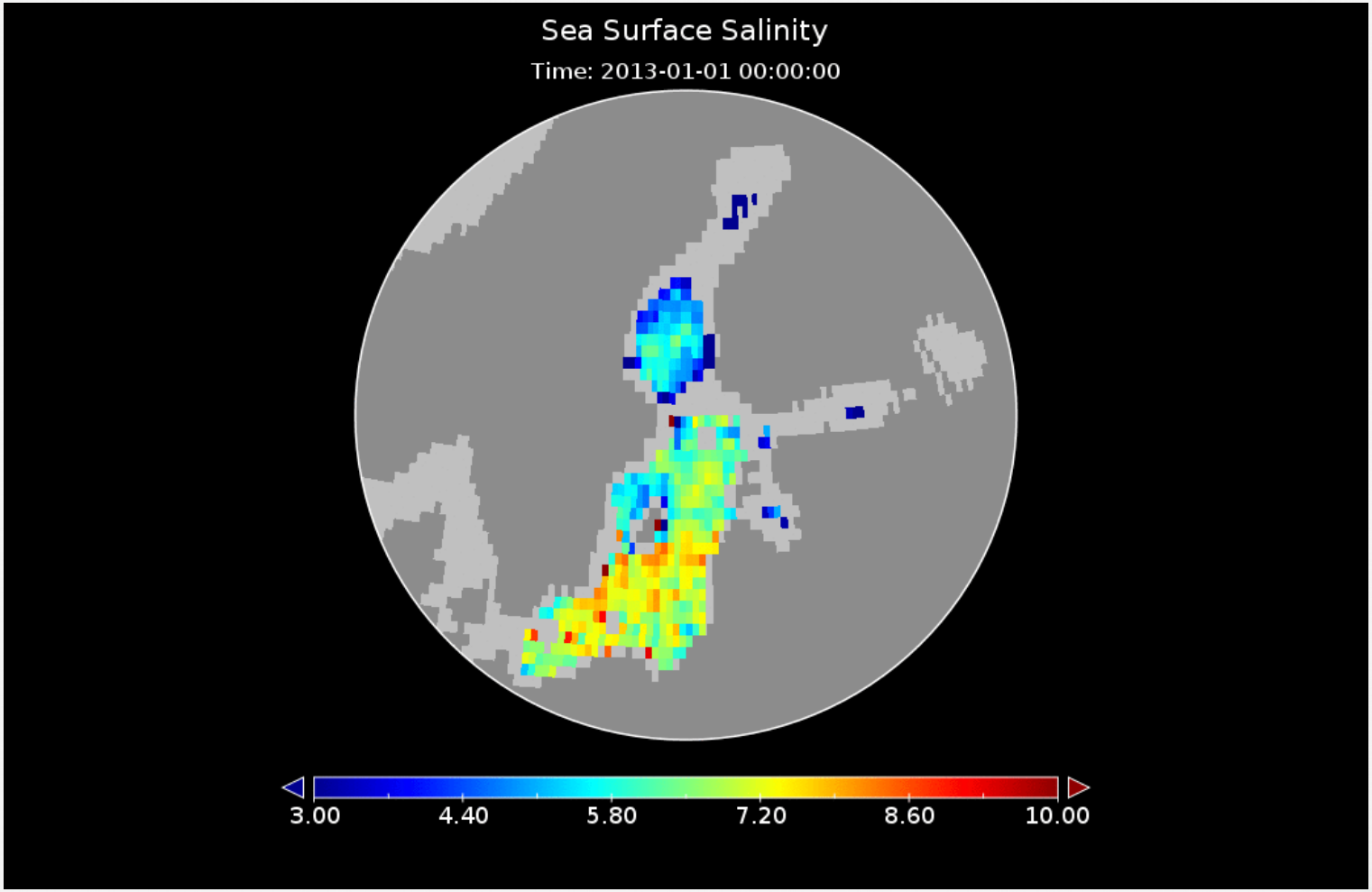
Regional L3 SSS maps

Strategy for filtering criteria

L4 products (synergy of SMOS data with other sensors)

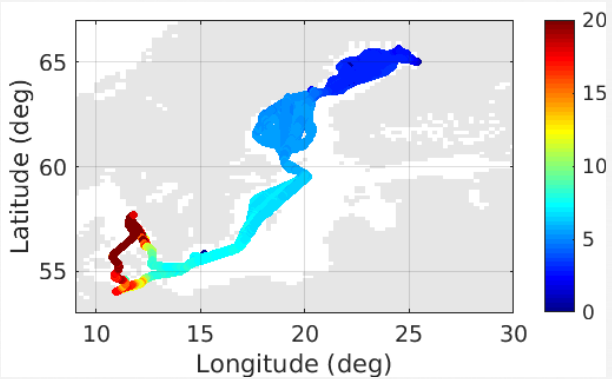
Merging L3 SSS maps & other ocean scalars
For improving the SSS error budget and spatio-temporal resolutions

Baltic+ SSS product v1: first regional maps



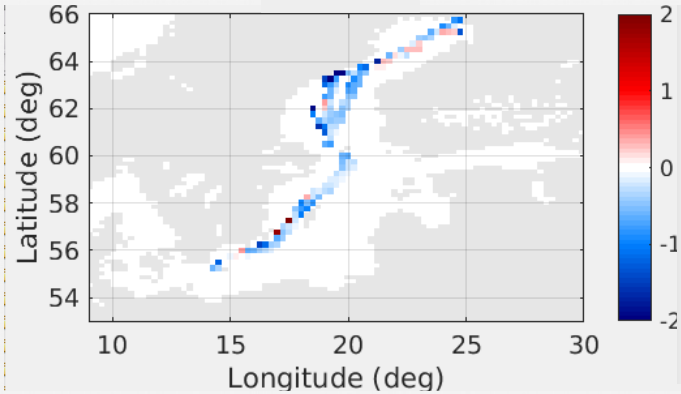
Quality assessment of Baltic+ SSS v1 product (i)

Ferrybox line: Transpaper
Collocations in 2011-2013

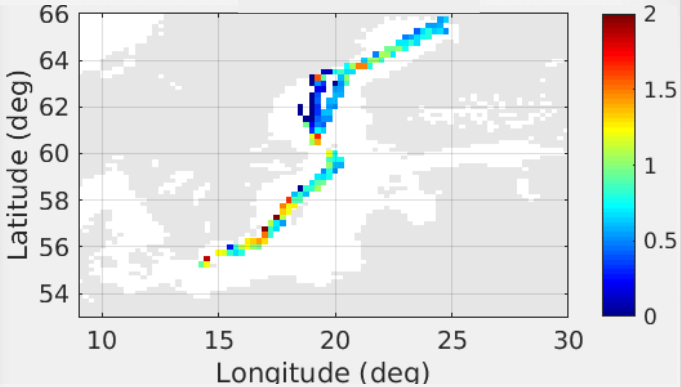


Spatial error patterns 2013

Mean



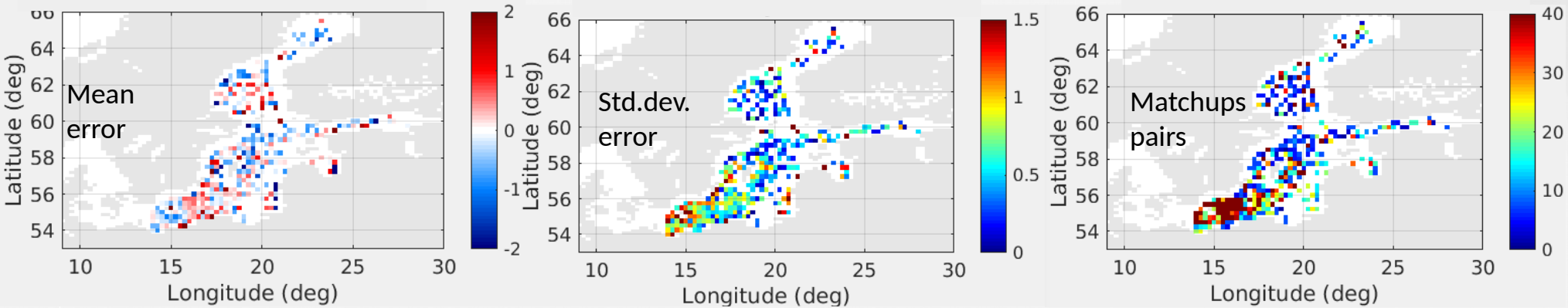
Std.dev.



SMOS - TRANSPAPER	Matchups	Mean	Median	R	Std
2013	4906	-0.34	-0.36	0.8	1.01
2012	4948	-0.01	-0.03	0.75	1.16
2011	3166	-0.17	-0.16	0.84	0.99

- Higher biases for cold season (Nov-May) and for latitudes above 60ºN due to ice-sea contamination.

Quality assessment of Baltic+ SSS v1 product (ii)



- Arkona basin, gulfs of Finland & Riga, gridpoints closest to land are the regions with largest errors.

SMOS - SeaDataNet	Matchups	Mean	Median	R	Std
All matchups	9723	-0.16	-0.18	0.74	1.15
Distance to coast > 25 km	7374	-0.09	-0.1	0.78	0.96

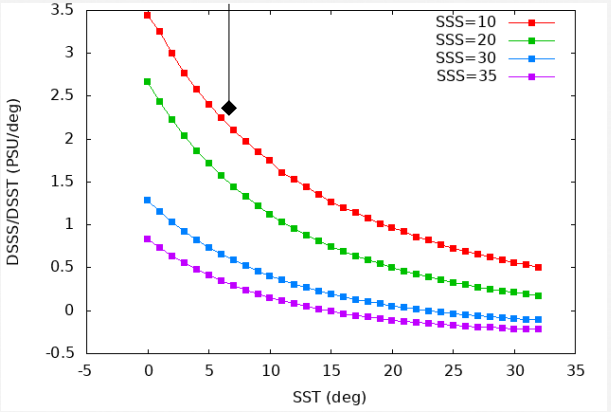
- Improved bias & std when considering gridpoints 25 km far away from coast.

Quality assessment of Baltic+ SSS v1 product (iii)

Stats collocations auxiliary SST vs SDN insitu:

Matchups	9723
Mean	-0.17
Median	-0.14
Std	1.06
R	0.98

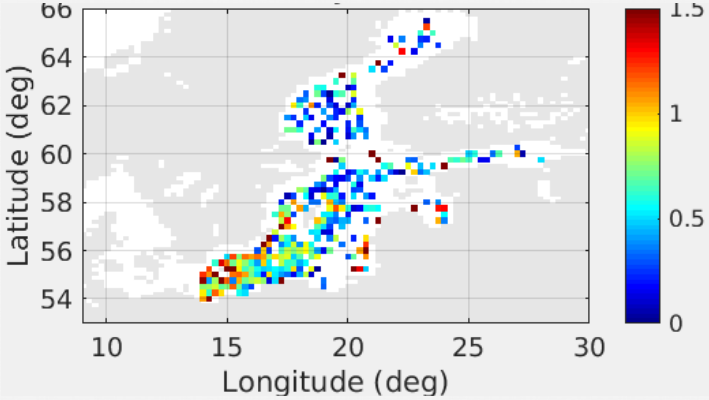
Sensitivity of SSS to SST
(increases with low SSS)



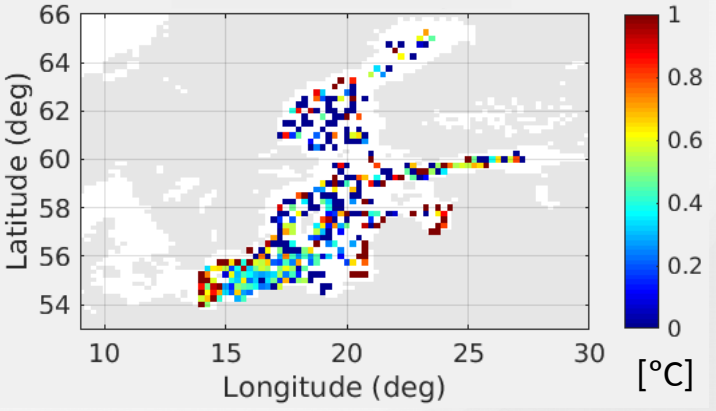
Higher SSS errors located in the Arkona basin and gulfs of Bothnia, Riga and Finland

Higher errors also in SST→ Errors in SST seem to be the main contributor to SSS error

Std (SSS_{SMOS}-SSS_{SDN})



Std (SST_{SMOS}-SST_{SDN})



Lessons from v1 → Developments towards Baltic+ SSS v2

- Baltic+ SSS v1 time-series covers the period 2011-2013, particularly affected by strong RFI contamination.
  - Baltic+ SSS v2 time-series will cover 2011-2019
- RFI contamination affects the SMOS-climatology used for the correction of residual systematic errors on SSS
  - Computing the SMOS-based climatology considering the cleanest period (2013-2019)
- High SSS errors detected in ice-covered regions
  - Introduction of a sea-ice mask to discard the SSS retrievals in ice-covered regions.
- Limited spatial coverage over specific regions, such as at the entrance of the Skagerrak & Kattegat straits and gulfs
  - Assessment of the spatial coverage, particularly to evaluate improvements/limitations over those regions with the debiased SSS v2
  - Review of the filtering criteria
- One of the main sources contributing to SSS errors is the errors in the auxiliary SST data
  - Study the impact of using other auxiliary SST on SSS errors

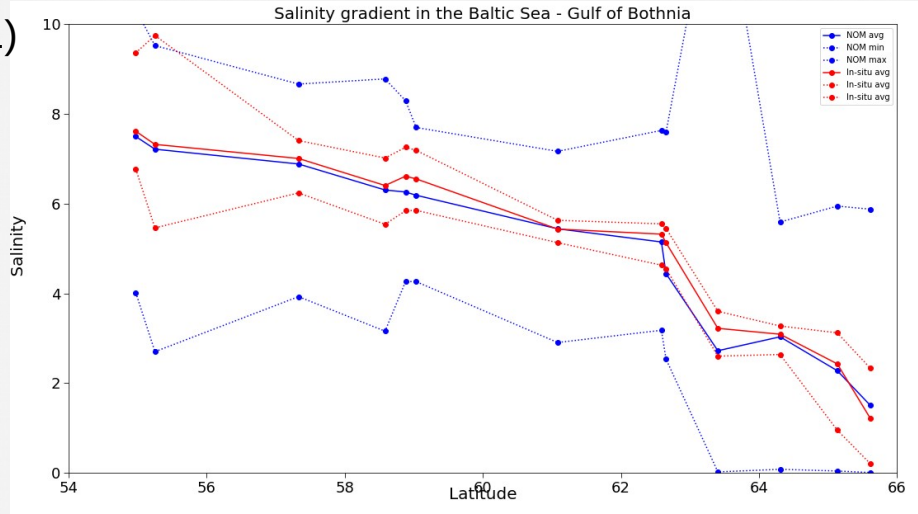
Baltic+ SSS v1: Preliminary impact assessment

First time we have a satellite SSS-product for the Baltic Sea that is worth assessing:

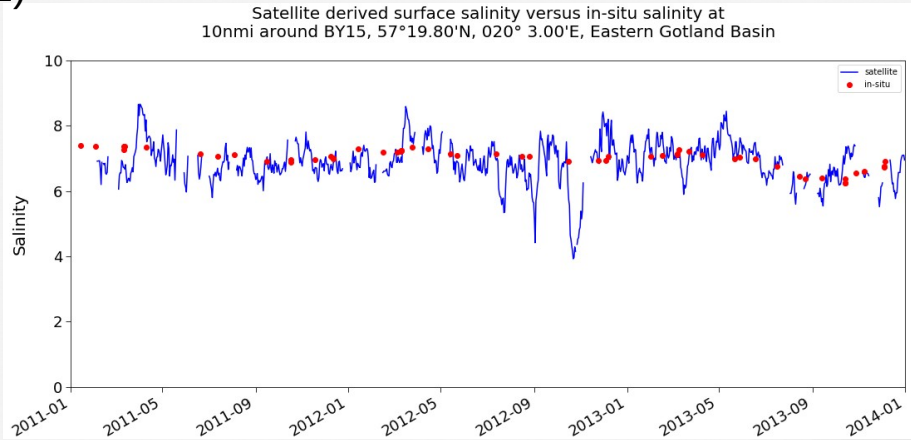
(1) In the open sea the mean values and large scale gradients seem to be reproduced rather well.

(2) Satellite SSS variability between consecutive days is larger than expected, partly due to noise (still very large) and partly due to actual geophysical variability.

(1)



(2)



Baltic+Salinity Dynamics and other Baltic innitiatives

- **Baltic+ SSS v1 product** is **available** for the users. Users feedback is crucial for improving its quality.
- You can **contact** us to **access to the data** at: **baltic@icm.csic.es**
- **Additional technical developments will be included in** the development of **Baltic+ SSS v2 product** to meet **users feedback** (project schedule permitting).
- The quality of the Baltic+SSS v1 product indicates is best fit for **applications at sub-basin and monthly scales**. First assessments of the product show its good performance **in the detection of gradients** and **a good coherence in the SSS structures.**
- The close **collaboration** with **Baltic Earth** and user communities will foster:

  - The identification of the **limitations/added-value** of Baltic+ SSS products.
  - The **potential exploitation of Baltic+ SSS products** by the communities involved in the study of Baltic processes.

- Potential synergies with Baltic+ SEAL have been already identified.

Baltic+ Salinity

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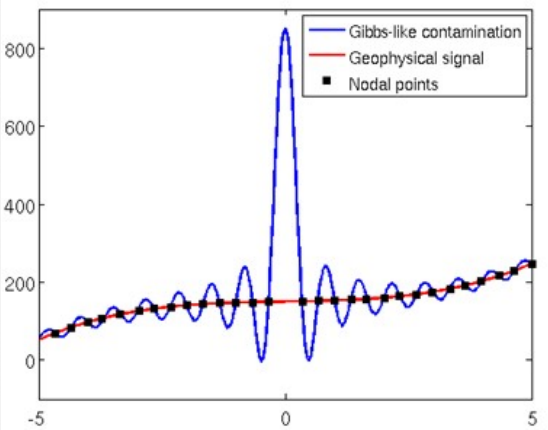
Baltic+
Salinity
Dynamics

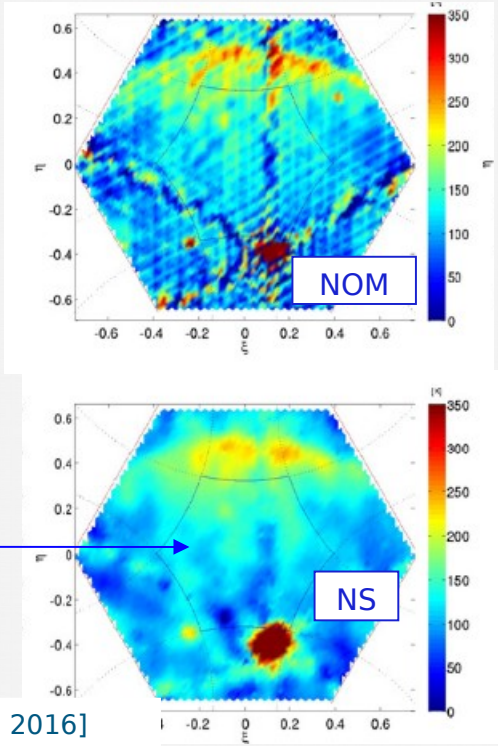
BACKUP SLIDES

1. Improvement of brightness temperatures

Nodal Sampling (NS): Mitigation of RFI contamination

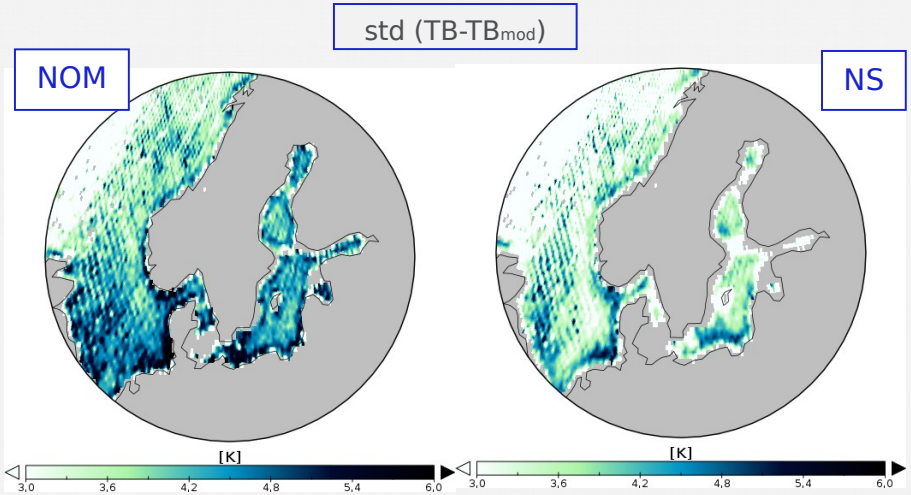
Based on sampling TB at nodal points (perturbations vanish, minimum impact on geophysical signal)





Reduction of RFI tails and general ripples

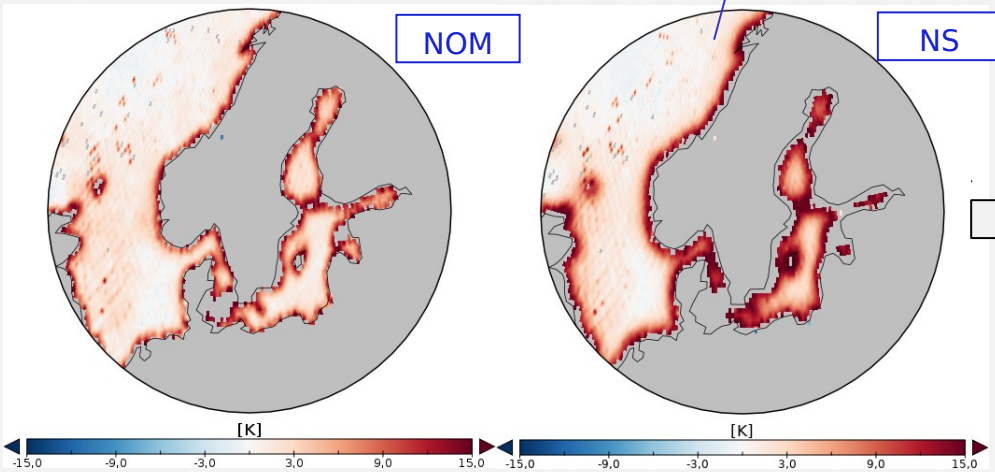
[Gonzalez-Gambau et al. TGRS 2016, RSE 2016]



Significant reduction of RFI contamination over Baltic Sea → better-quality SSS retrievals are expected

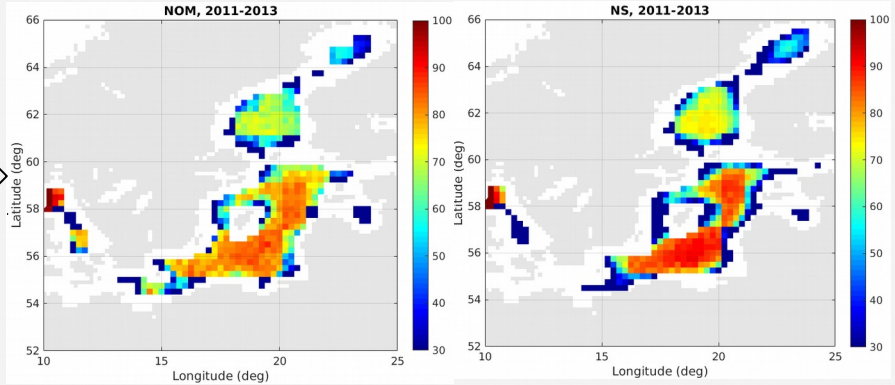
1. Improvement of brightness temperatures

Nodal Sampling (NS): Mitigation of RFI contamination



Mean (TB-TBmod)

Percentage of SSS retrievals



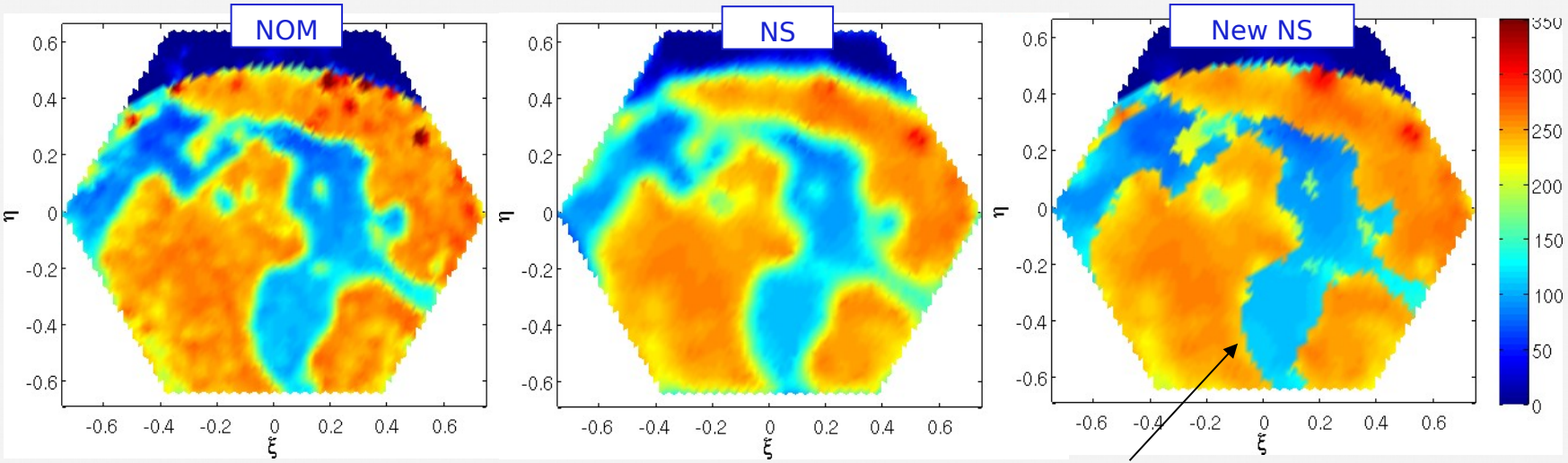
NOM NS

Artificial increase of ocean TB wrt NOM very close to coasts & ice edges.

Overall increase in the percentage of valid SSS retrievals in NS SSS, except close to coasts & ice edges.

1. Improvement of brightness temperatures

Nodal Sampling: Improvements for Baltic (new version of NS)



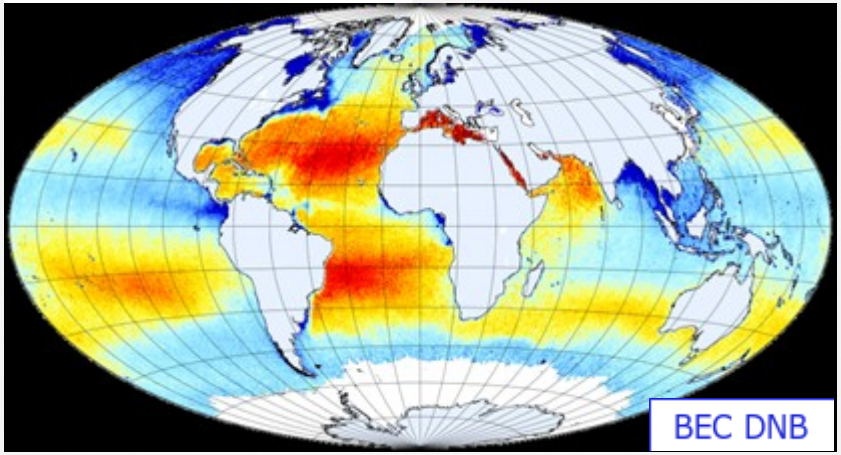
Introduction of a land/sea/(dynamic)ice/sky mask for refining the selection of nodal points

- Reduction of overall biases in new NS -> more SSS retrievals expected.
- Errors in new NS significantly reduced wrt nominal TB and even wrt previous NS -> better quality SSS retrievals are expected.

2. Refinement of the SSS retrieval

Debiased non-Bayesian retrieval (DNB): Mitigation of residual systematic biases on SSS

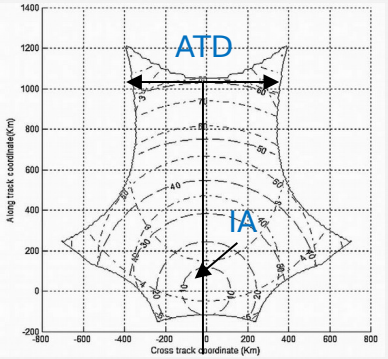
[Olmedo et al. RSE 2017]

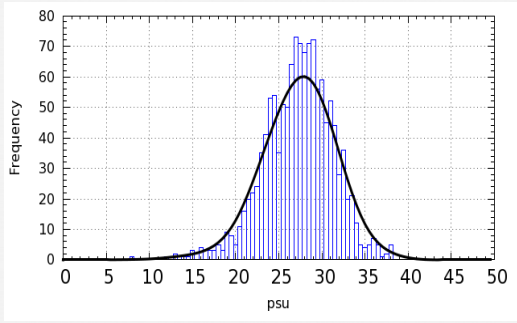


- One SSS retrieval per each TB measurement.
- Characterization/correction of systematic errors:

SMOS-based climatologies (min. 3 years) depending on:

- Acquisition geometry, geographical location and overpass direction.





Used in **BEC Arctic and Mediterranean dedicated SSS products**

[Olmedo et al. RS 2018]

[Olmedo et al. RS 2018b]

- Debiased SMOS SSS = SMOS SSS anomalies + annual reference
- Improved statistical filtering criteria based on the statistical properties of SSS distributions.

2. Refinement of the SSS retrieval (ii)

Baltic+ Salinity Dynamics

Debiased non-Bayesian retrieval (DNB): Improvements for Baltic Sea

- Review of the dielectric constant model -> Meissner and Wentz, analysis at the low SST and SSS ranges of Baltic Sea.

- Computation of SMOS-based climatologies -> SSS errors much more larger than in global ocean. Mitigation of the impact of SSS outliers in the climatologies is needed.

- Generation of debiased SMOS SSS -> Use of a regional climatology (SeaDataNet) as annual reference field.

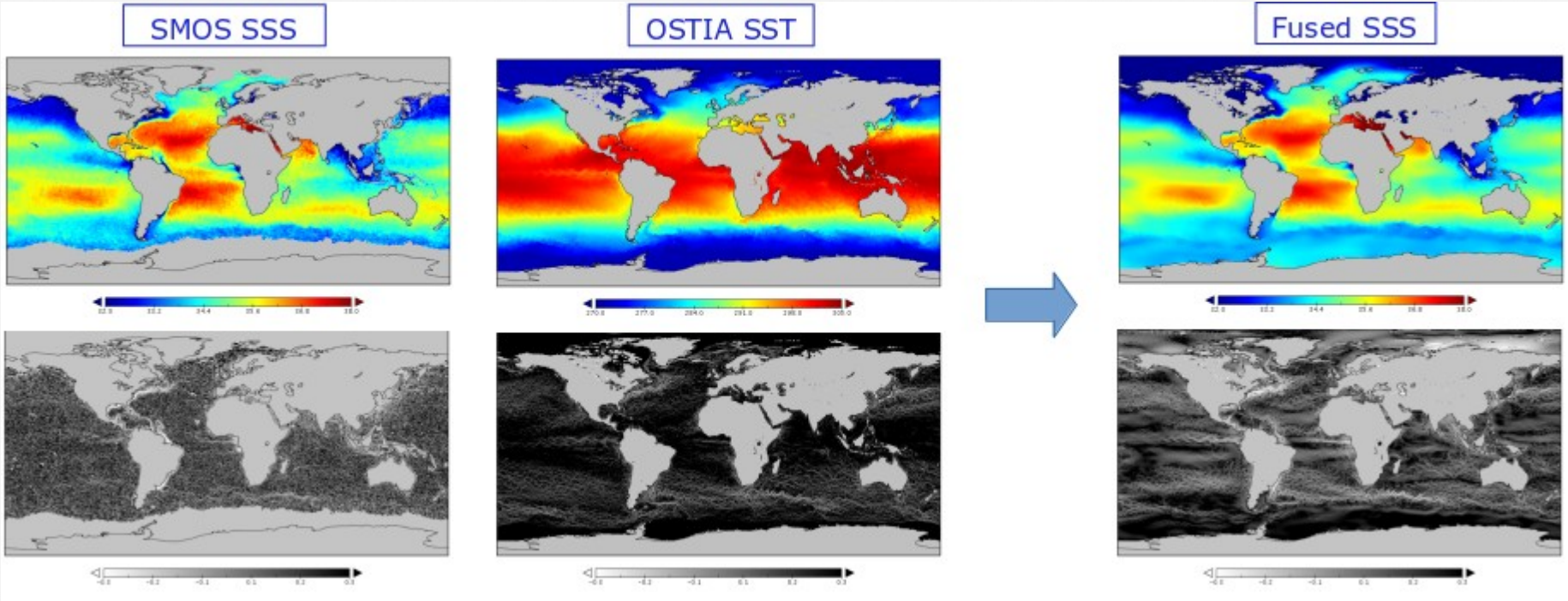
- Review of filtering criteria -> The statistical properties of the SSS distributions in the Baltic are very different that in open ocean.

- Characterization/correction temporal biases -> The hypothesis for the global product (zero global spatial average of SSS anomalies) is not suitable for regional products. In-situ measurements/model outputs used for fixing the average SSS in v1 product.

- Generation of L3 binned SSS -> Objective analysis smoothens salinity gradients. Binned fields are generated.

3. Improvement of spatio-temporal resolutions

Multifractal fusion: SMOS SSS maps merged with other ocean surface scalars to meet end-users requirements of spatio-temporal resolutions.



Further developments **for Baltic+ SSS product v2**

- Study of different templates: SST, surface chlorophyll concentration and reflectance.
- Assessment of the effective spatial resolutions of the different templates.