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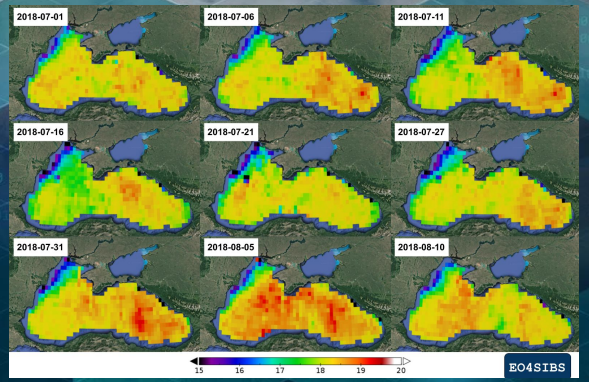



# SMOS Sea Surface Salinity maps in the framework of the regional initiative An Earth Observation Data for Science and Innovation in the Black Sea

**E. Olmedo**[1,2], V. González-Gambau[1,2], A. Turiel[1,2], C. González-Haro[1,2], A. García-Espriu[1,2], A. Alvera-Azcarate[3], M. Grégoire[3], L. Buga[4] and M. H. Rio[5]

(1) Institut de Ciències del Mar (2) BEC Barcelona Expert Center (3) LIÈGE université (4) INCDM (5) esa

23rd May

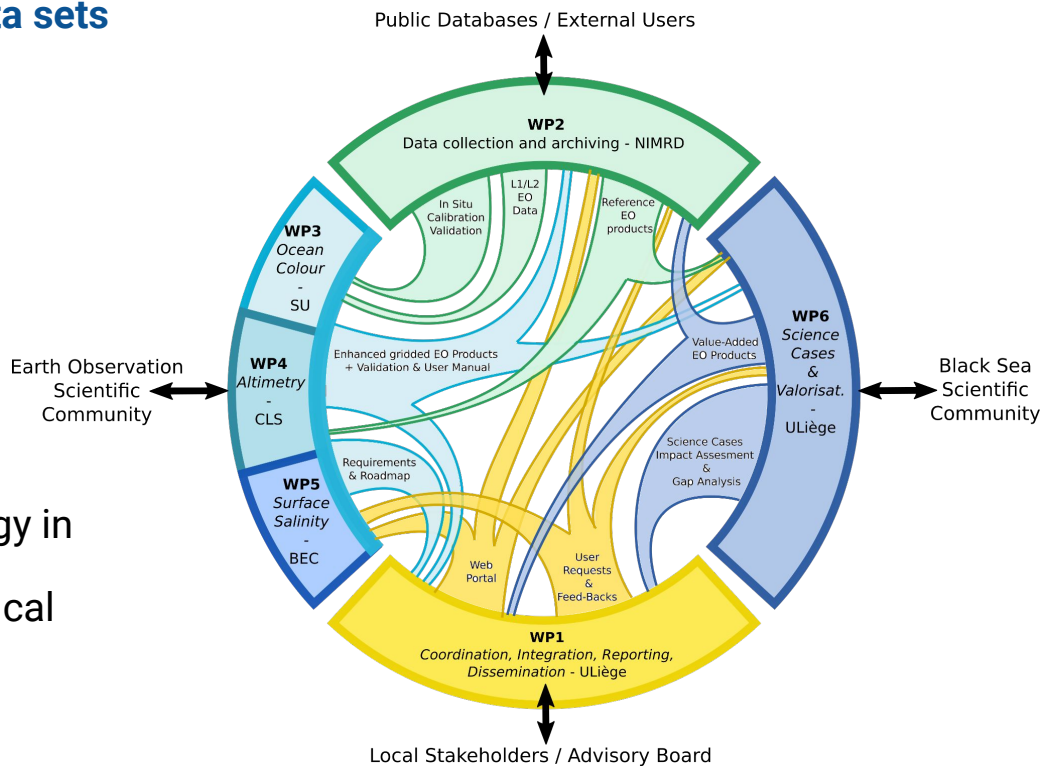
# An Earth Observation Data for Science and Innovation in the Black Sea project

**Novel EO-based products and enhanced data sets dedicated to the Black Sea** as concerns:

- Ocean colour data
- Coastal altimetry
- High resolution salinity
- River plume extent
- Eddy tracking
- Water mass classification
- Stratification Index

To generate new knowledge and methodology in order to better assess:

- Physical oceanography and biochemical ecosystems
- Black Sea level dynamics and trends
- Deoxygenation



# An Earth Observation Data for Science and Innovation in the Black Sea project: Sea Surface Salinity

Novel EO-based products and enhanced data sets dedicated to the Black Sea as concerns:

- Ocean colour data
- Coastal altimetry
- **High resolution salinity**
- **River plume extent**
- Eddy tracking
- Water mass classification
- ***Stratification Index***


To generate new knowledge and methodology in order to better assess:

- Physical oceanography and biochemical ecosystems
- **Black Sea level dynamics and trends**
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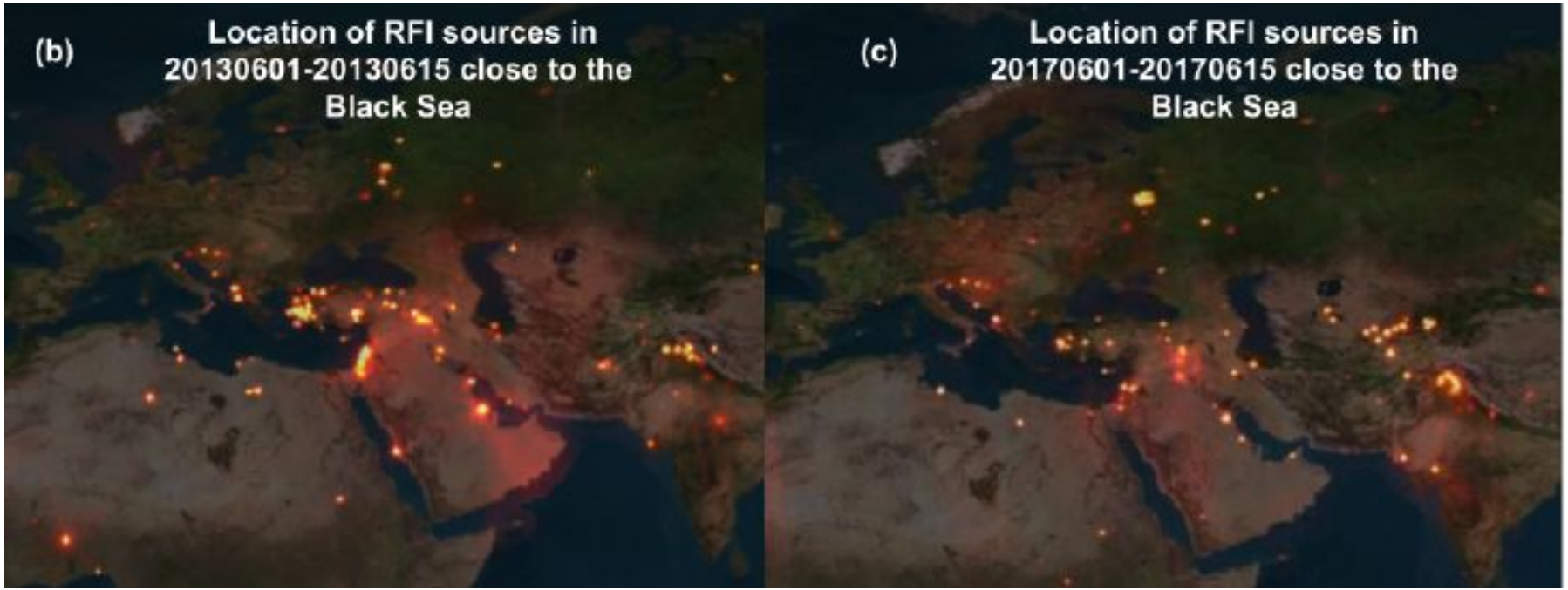
# L-band SSS retrieval in the Black Sea

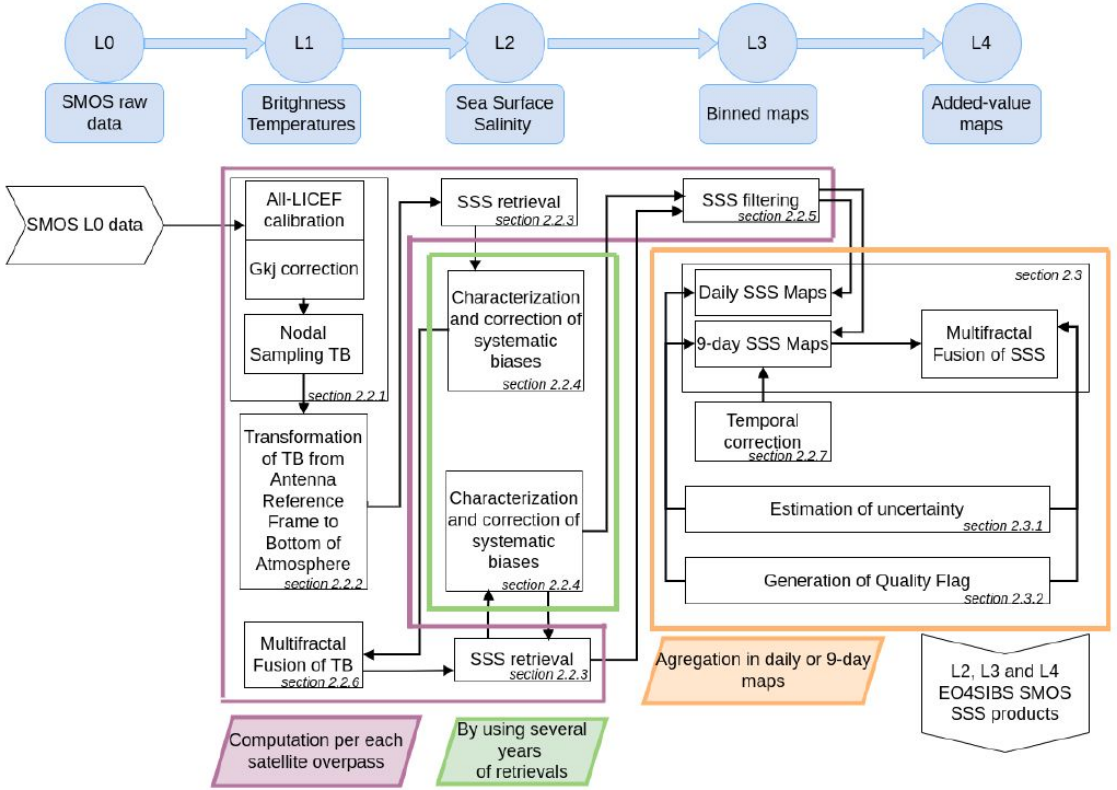
The quality of the Brightness Temperatures in the Black Sea is strongly degraded by the proximity of in land RFI sources



# Novelties in the SMOS SSS data processing

Enhanced algorithms have been introduced to retrieve SMOS SSS under these strong RFI conditions:

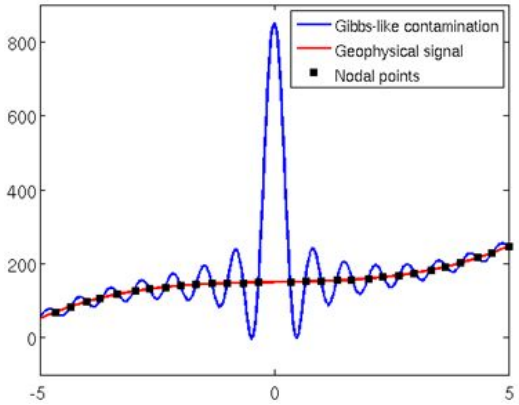
- Nodal Sampling v3
- Multifractal fusion of Brightness Temperatures
- Characterization and correction of systematic biases
- Temporal correction preserving surface dynamics
- Quality Flag of the final product



# Mitigation of RFI contamination: Nodal Sampling

Nodal Sampling is based on oversampling the image to choose sampling points that minimize fast varying distortions.

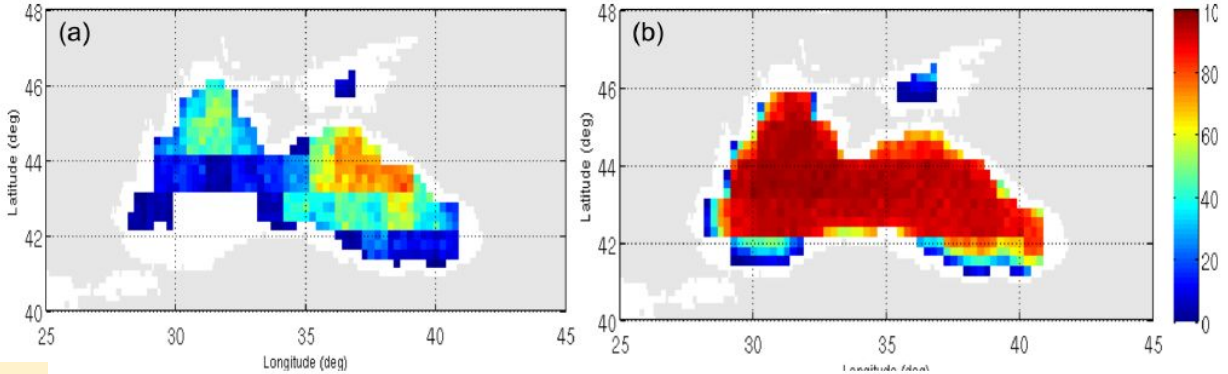
The application of Nodal Sampling in this basin is required because of the strong RFI contamination.




Percentage of SSS retrievals in years 2011-2013

Percentage of SSS retrievals without Nodal Sampling

Percentage of SSS retrievals with Nodal Sampling



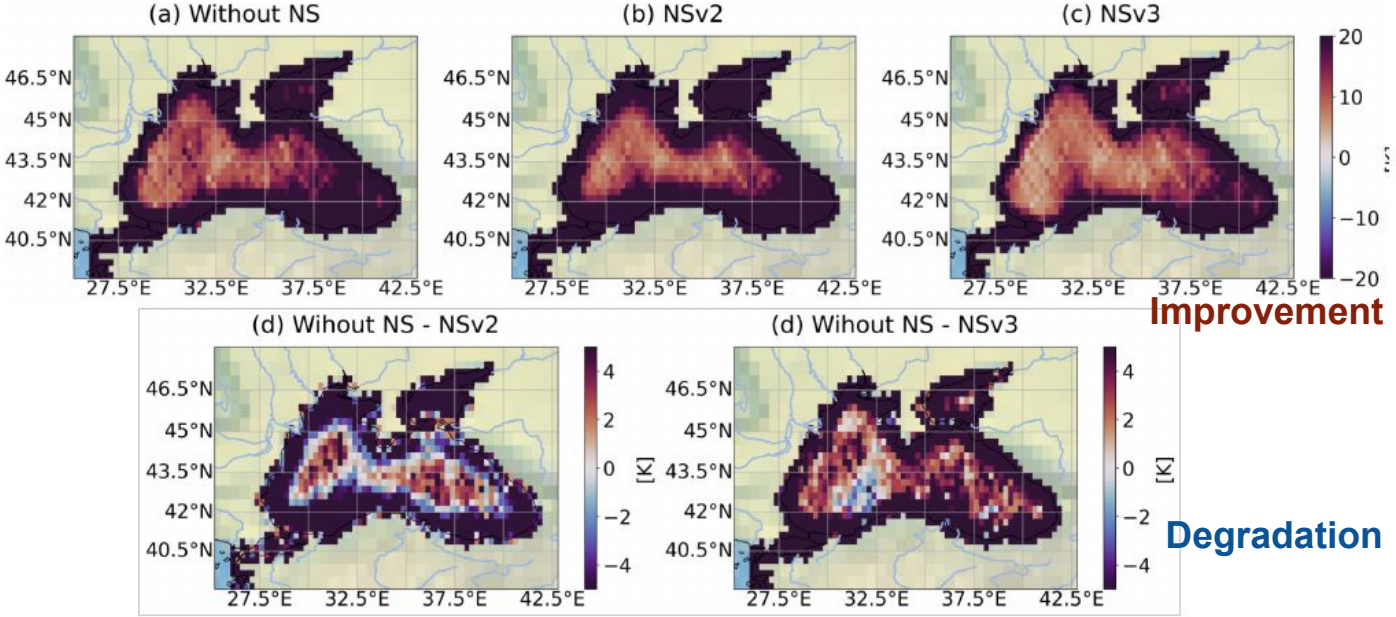

González-Gambau et al., 2016a TGRS, 2016b RSE

# Mitigation of RFI contamination: Nodal Sampling

Nodal Sampling V2 increased the contamination of the coastal pixels

A new version of Nodal Sampling (V3) that integrates a Land-Sea mask in order to separate ocean from land pixels has been used

SMOS Brightness Temperatures




Improvement

Degradation

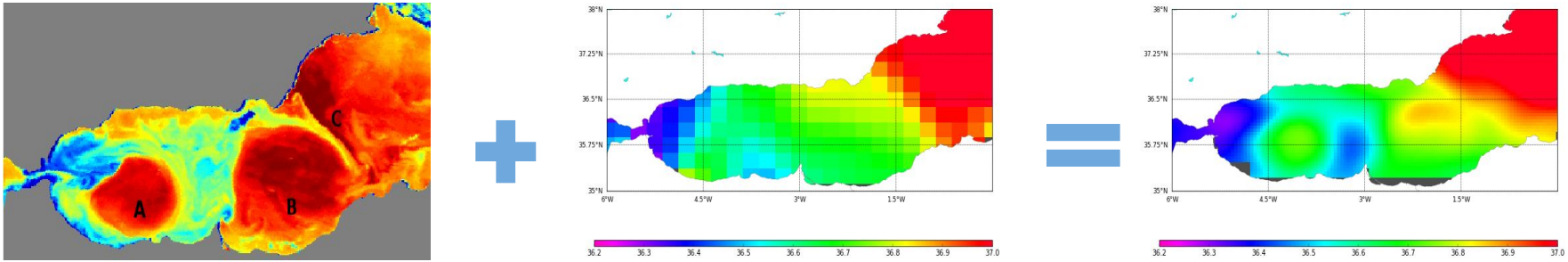
# Reduction of Brightness Temperature Errors: Multi fractal fusion

Even after applying Nodal Sampling the quality of the SMOS TB is still poor in comparison with those in open ocean… additional techniques are required to reduce TB errors!

We have **applied for the first time multifractal fusion over the SMOS TBs**

This technique has been applied before to enhance the quality and the coverage of the Level 3 SMOS SSS maps

Multifractal fusion of Level 3 SMOS SSS and SST in the Alboran Sea (Mediterranean Sea)




Olmedo et al., 2016 RSE, 2018 RS.

# Reduction of Brightness Temperature Errors: Multi fractal fusion

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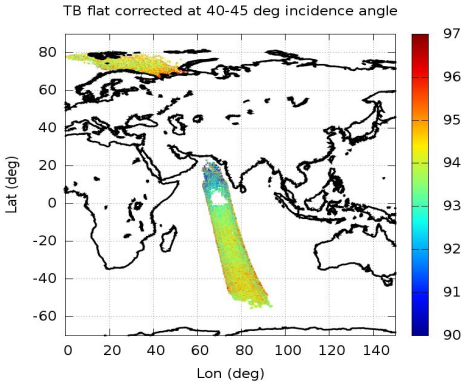
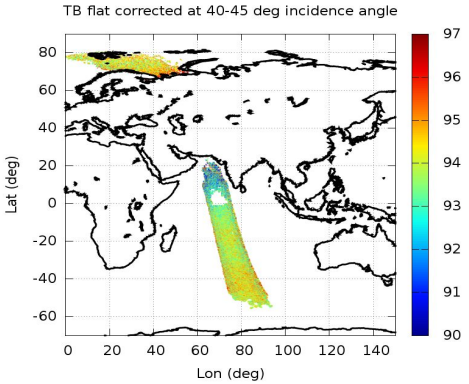
1-Split TB per incidence angle bins

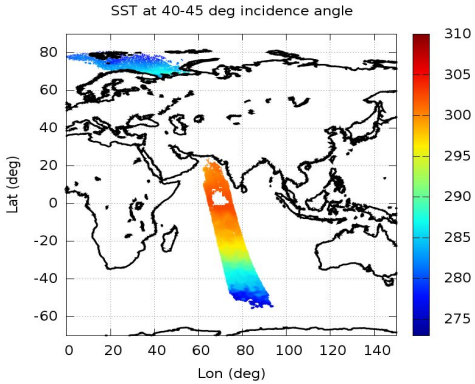


# Reduction of Brightness Temperature Errors: Multi fractal fusion

1-Split TB per incidence angle bins

2-We collocate TBs with SST



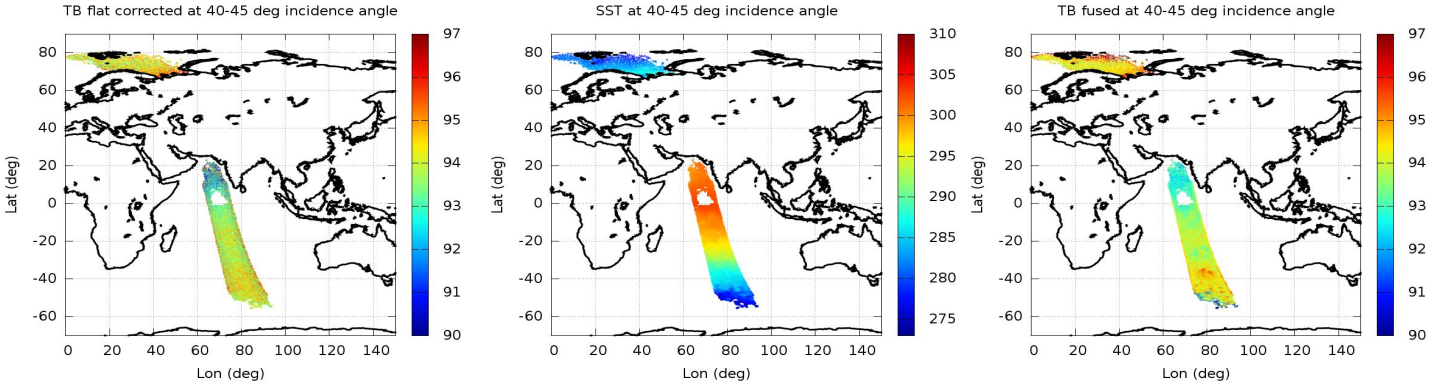
# Reduction of Brightness Temperature Errors: Multi fractal fusion

BEC
Barcelona Expert Center

1-Split TB per incidence angle bins

2-We collocate TBs with SST

3-We apply scalar fusion



# Reduction of Brightness Temperature Errors: Multi fractal fusion

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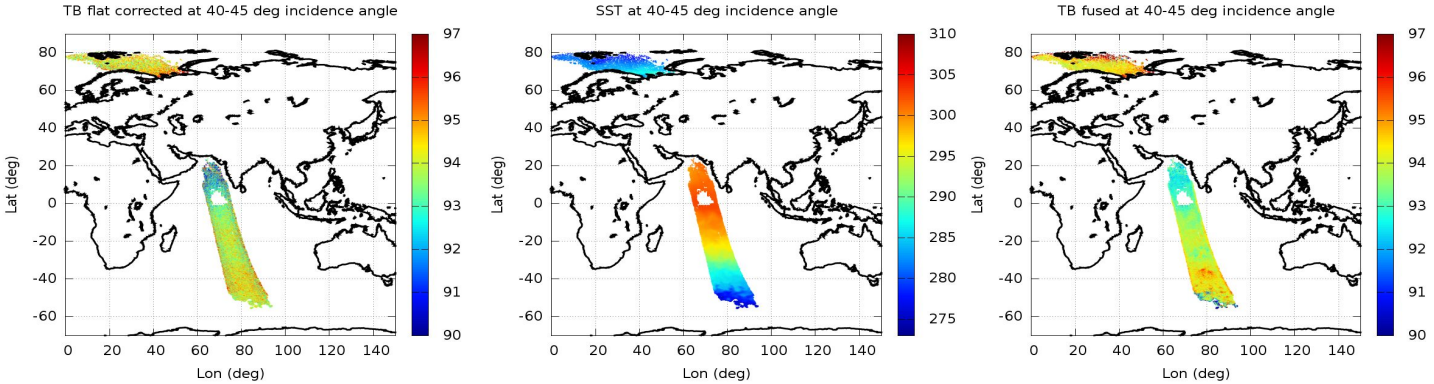


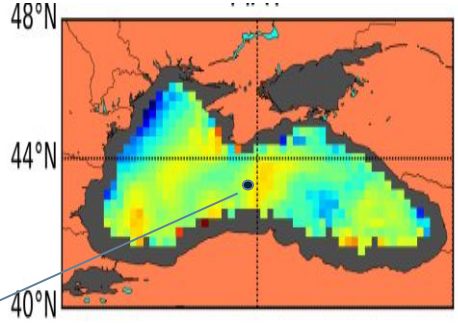

We observe a reduction of the standard deviation of the difference between SMOS SSS and Argo larger than 60%

| 2014 | | | |
|---|---|---|---|
| Nominal | | Fusion | |
| MD | SD | MD | SD |
| 0.68 | 1.48 | 0.60 | 0.92 |
| **2017** | | | |
| Nominal | | Fusion | |
| MD | SD | MD | SD |
| 0.54 | 1.06 | -0.02 | 0.65 |

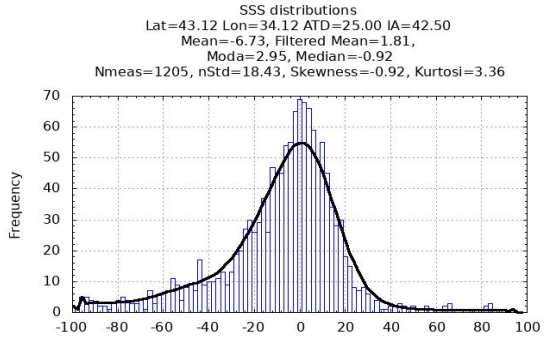
# Characterization of systematic errors: Debiased Non Bayesian approach

Debiased non Bayesian (DNB) approach empirically characterizes and mitigates those systematic errors that depend on the geographical location and acquisition conditions.

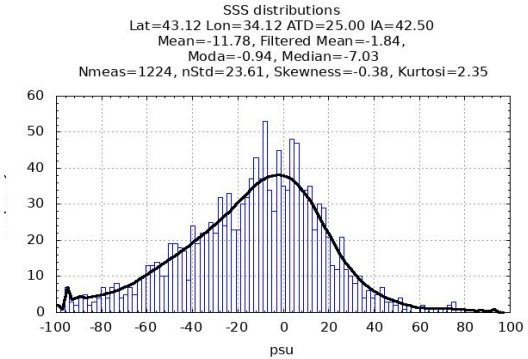
Filtering criteria are defined as a function of the statistical properties of large temporal series of SSS retrievals under the same geographical location and acquisition conditions.

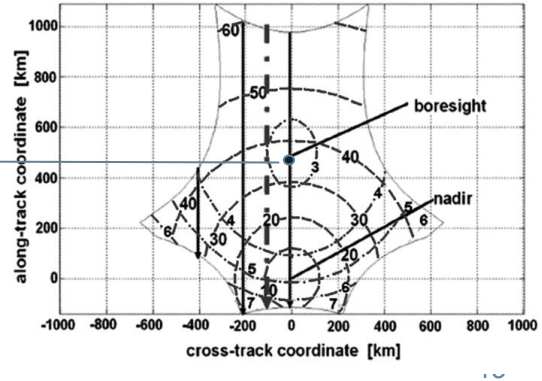



**ASC**




**DES**



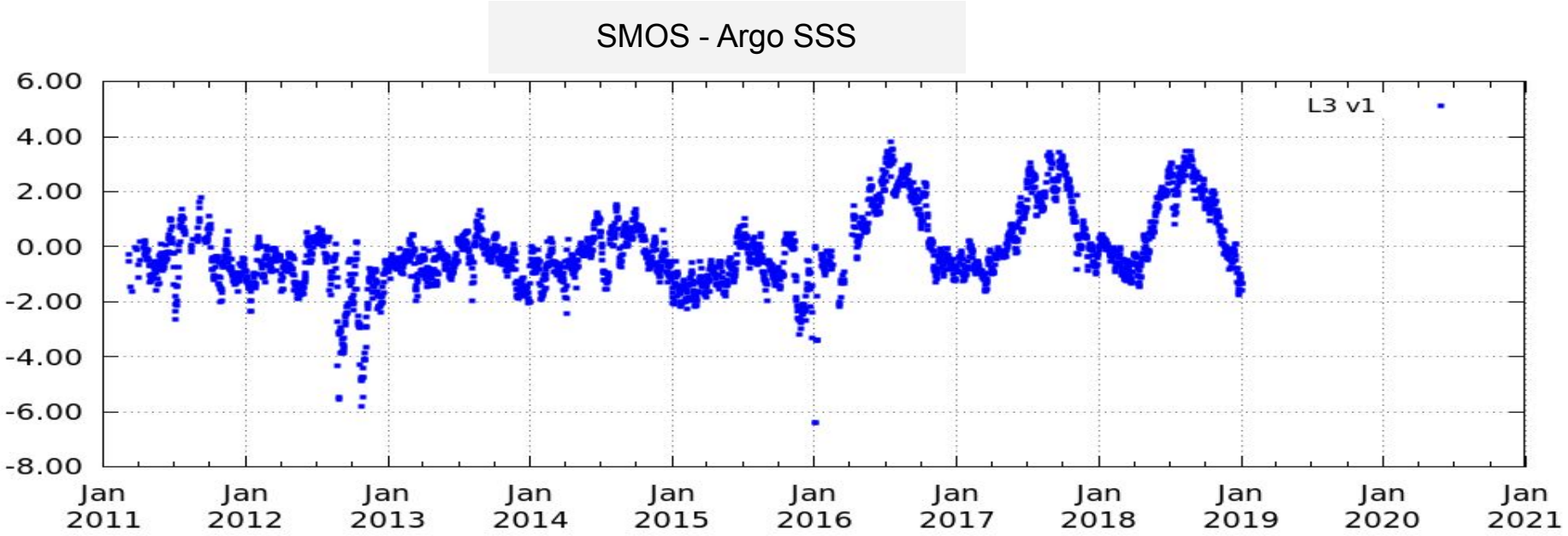




b)

Olmedo et al., 2017 RSE

# Characterization of systematic errors: Debiased Non Bayesian approach

The application of the original DNB approach leads to two different SSS signatures: before and after 2016

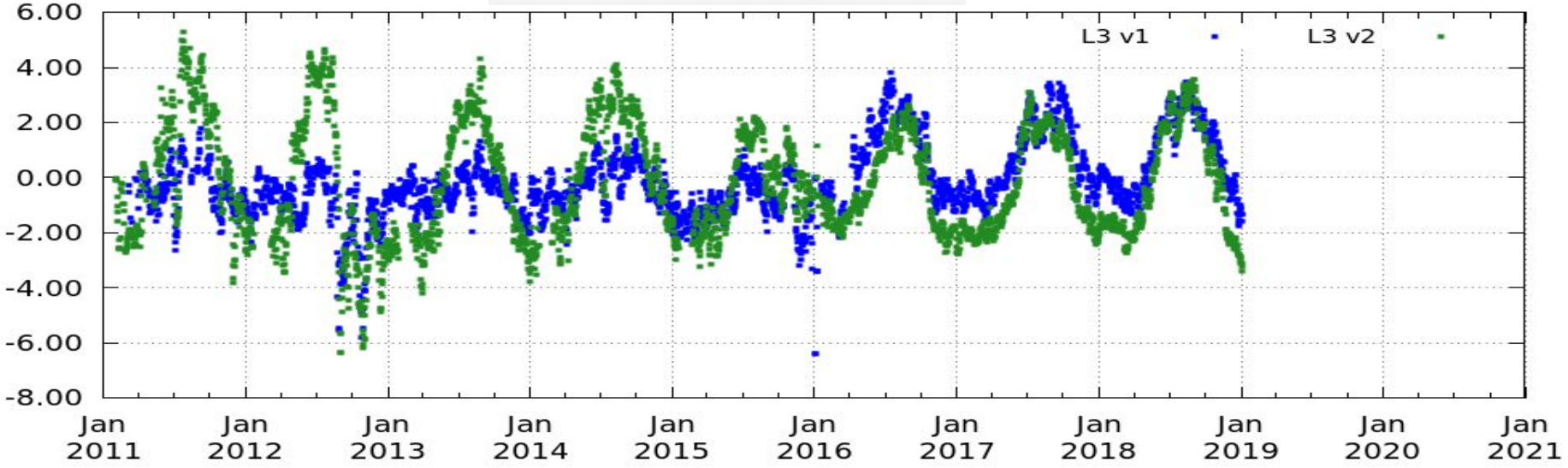


# Characterization of systematic errors: Debiased Non Bayesian approach

The reason is that the **RFI affectation before 2016 is different to the one after 2016**. Therefore, for the proper characterization and mitigation of systematic errors these two periods should be separated.

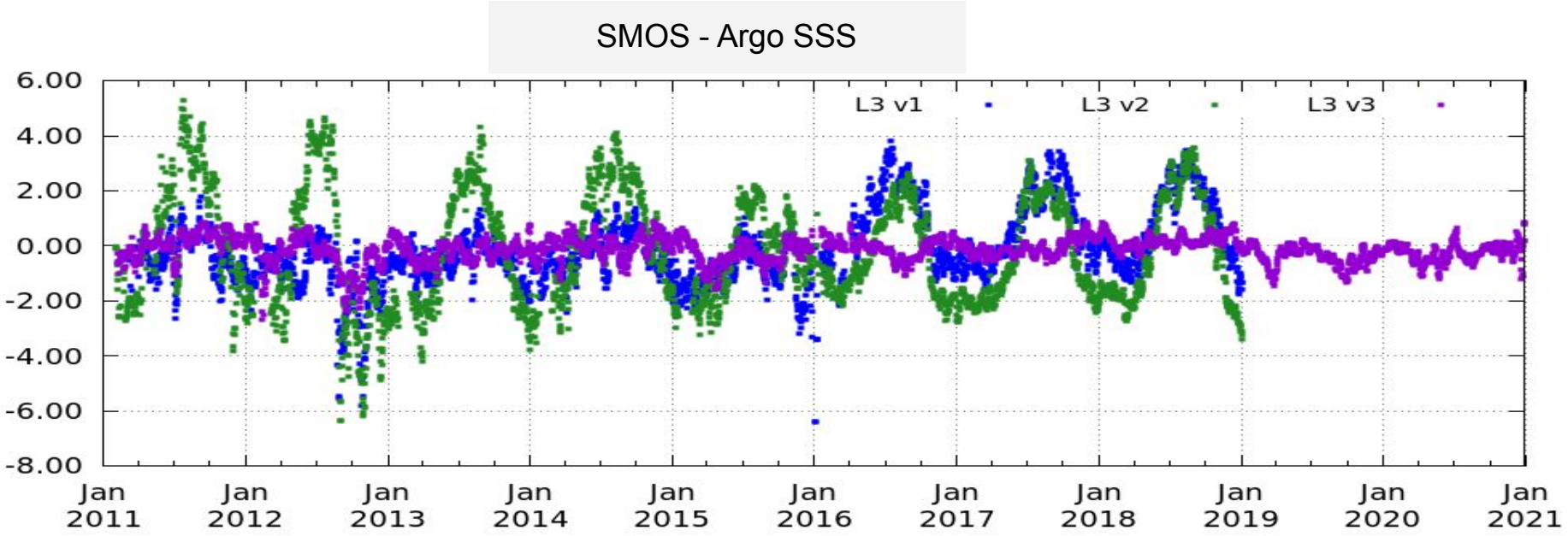
After correcting errors separately in the two RFI affected periods, we observe a too large seasonal error.

SMOS - Argo SSS



# Characterization of systematic errors: Debiased Non Bayesian approach

We characterize and mitigate systematic errors as function of the geographical location, acquisition conditions and **Sea Surface Temperature**



# Temporal corrections

Olmedo et al. 2022 shows that SSS dynamics is actually different from Near Surface Salinity dynamics. **Black Sea is prone to stratification episodes**.

*Temporal correction should be done carefully if we want to preserve the surface dynamics*

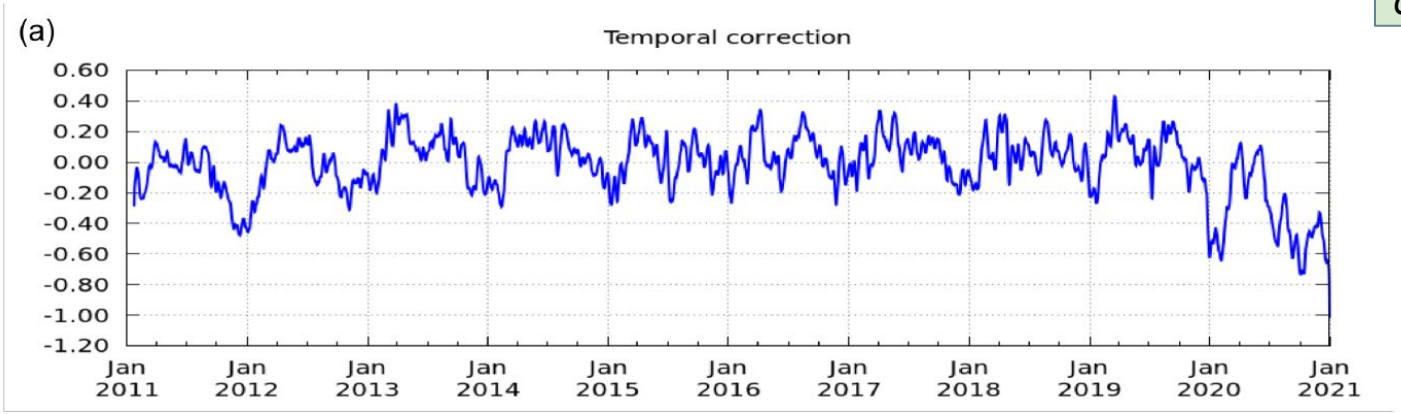
*See presentation on Friday: Evidence of intensification of the water cycle from SMOS SSS maps*

***How to do it?***

Global product: Assuming the global average of SSS does not change with time.

Regional products: Apply the same correction as in the global.

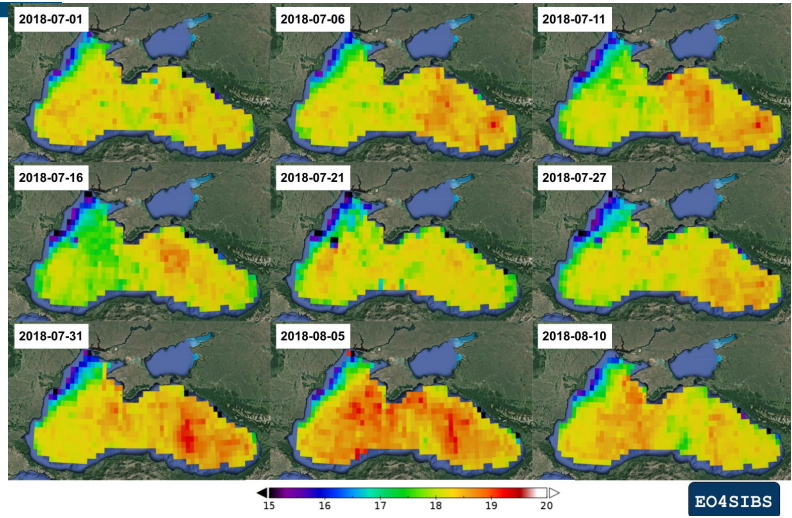
*This implies computing global maps..huge computation effort!*



# EO4SIBS SMOS SSS products

| | Level 2 A | Level 2 D | Level 3 | Level 4 |
|---|---|---|---|---|
| Type of orbit | Ascending | Descending | Both | Both |
| Spatial resolution | 0.25x0.25º | 0.25x0.25º | 0.25x0.25º | 0.05x0.05º |
| Temporal resolution | Daily | Daily | 9-day | Daily |

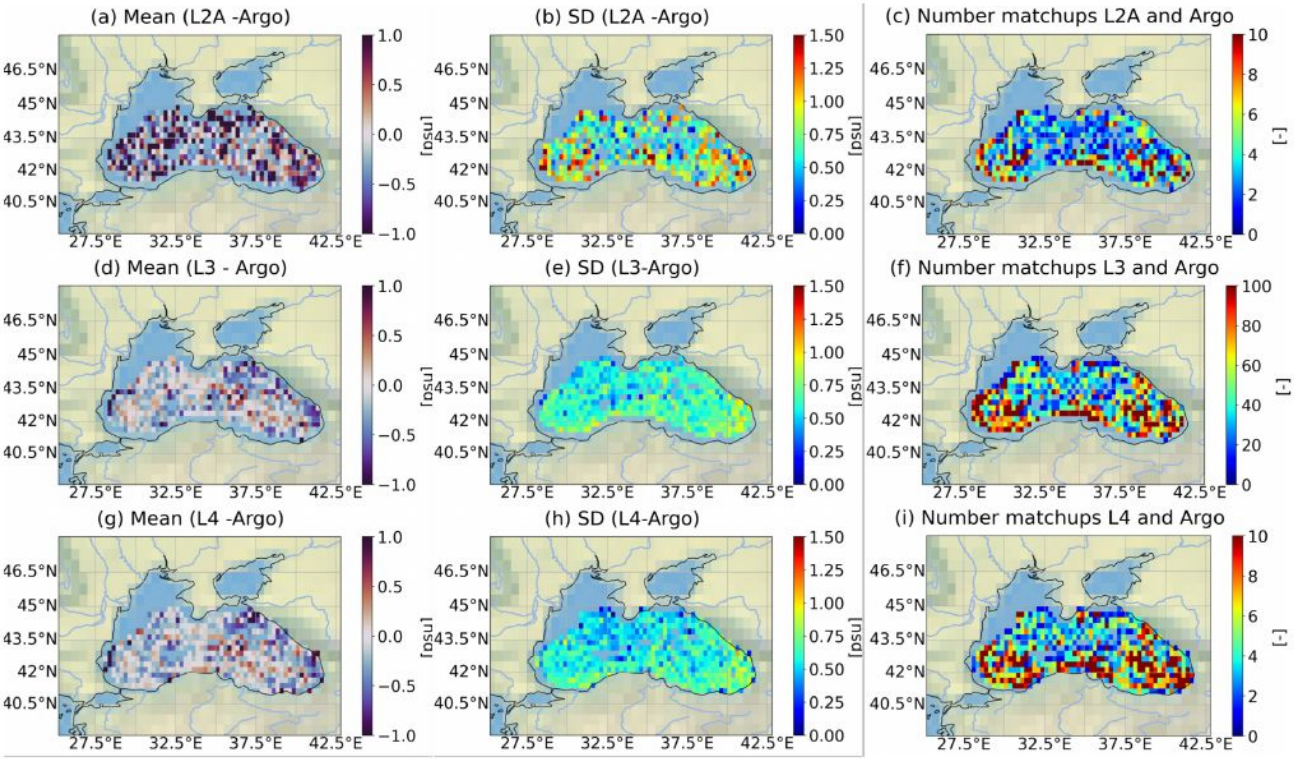
*Each product includes sss, estimated uncertainty and quality flag and it is freely distributed in netcdf files in our website:*
**ftp://becftp.icm.csic.es**

# Comparison with Argo floats

| | 2011-2015 | | |
|---|---|---|---|
| | NM | MD | SD |
| L2A | 733 | -0.18 | 1.80 |
| L2D | 424 | -0,17 | 2,74 |
| L3 | 11393 | -0.17 | 0.71 |
| L4 | 1556 | -0.17 | 0.61 |

| | 2016-2020 | | |
|---|---|---|---|
| | NM | MD | SD |
| L2A | 1366 | -0.18 | 1.49 |
| L2D | 1192 | -0,32 | 1,94 |
| L3 | 19729 | -0.16 | 0.56 |
| L4 | 1912 | -0.14 | 0.48 |

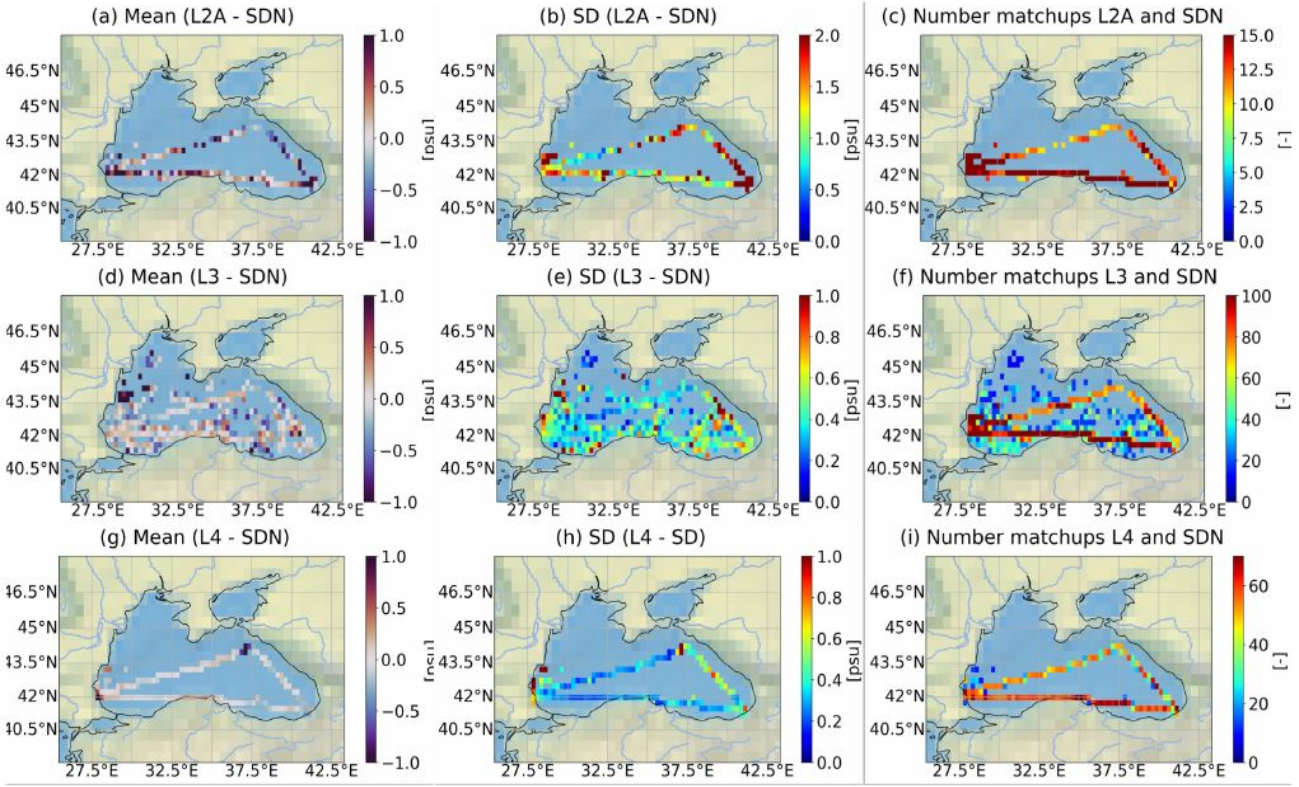


# Comparison with SeaDataNet in situ measurements

BEC Barcelona Expert Center

| | 2011-2015 | | |
|---|---|---|---|
| | NM | MD | SD |
| L2A | 962 | 0.12 | 1.8 |
| L3 | 7115 | 0.14 | 0.71 |
| L4 | 986 | 0.10 | 0.68 |

| | 2016-2019 | | |
|---|---|---|---|
| | NM | MD | SD |
| L2A | 1820 | -0.21 | 1.8 |
| L3 | 11801 | -0.04 | 0.59 |
| L4 | 7308 | -0.00 | 0.50 |

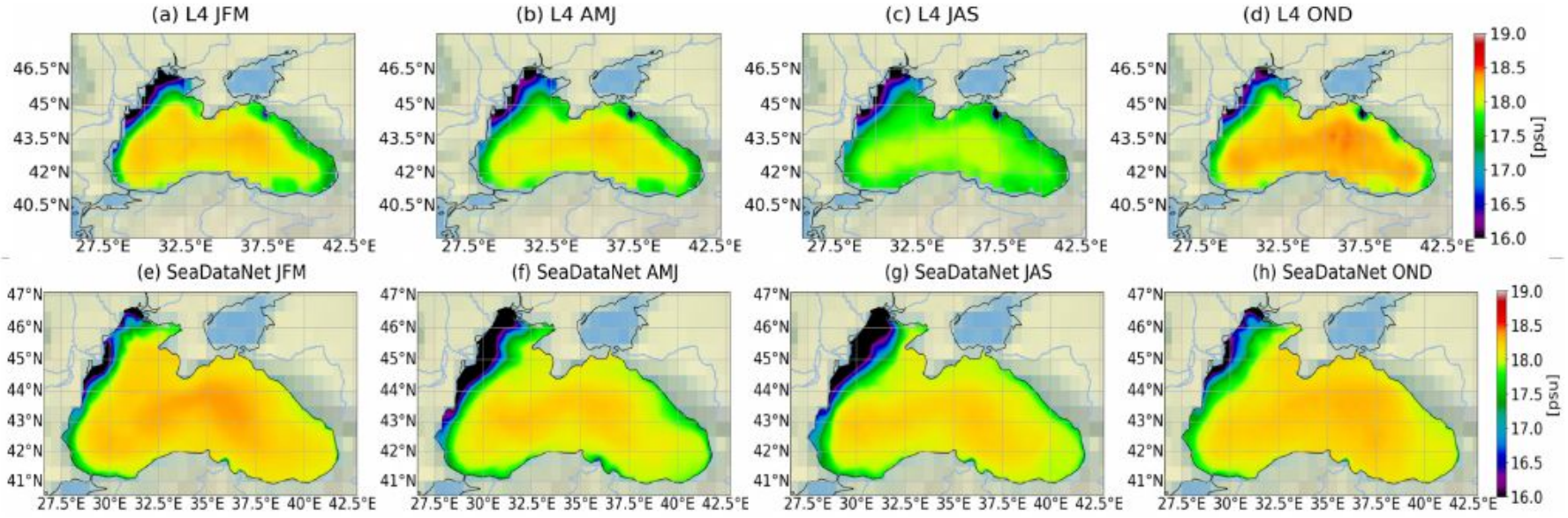


# Comparison with SeaDataNet climatology

Seasonal behaviour consistent with the one presented by the SeaDataNet climatology:

- In summer the satellite presents fresher waters than climatology
- In autumn the satellite presents saltier waters than climatology

*Is the satellite really capturing the surface salinity dynamics?*

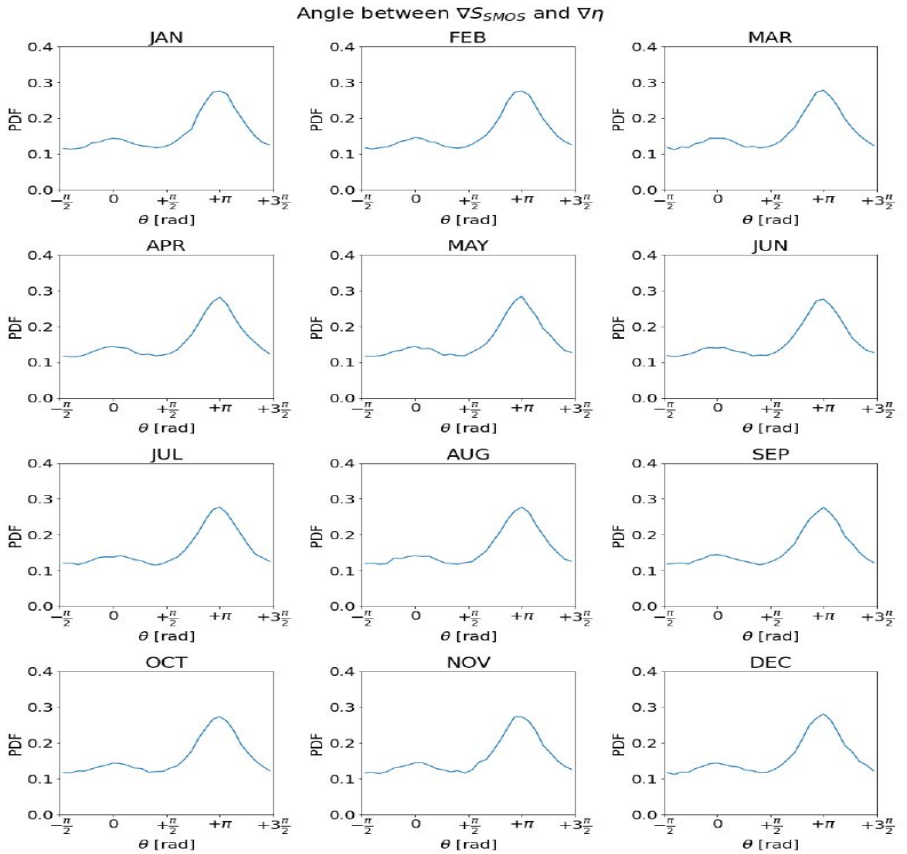


# Alignment between SSS and ADT gradients

Angle between ADT and SSS gradients tends to be in counter phase independently on the analysed month.

This is consistent with the thermohaline alignment and density compensation that dominates the large scale and mesoscale.

**This suggests that spatial structures of the product are consistent with the streamlines.**



# Conclusions

We have generated the first SMOS SSS regional products in the Black Sea.

For this, enhanced algorithms aiming at the mitigation of the RFI contamination have been developed and successfully applied:

- Nodal Sampling V3 that includes a Land-Sea mask to diminish the coastal contamination
- Multifractal fusion of the Brightness Temperatures to reduce TB errors
- Characterization of the systematic biases in two separate periods depending on the RFI affectation

These algorithms are applicable to other strong contaminated ocean regions such that the Chinese Sea and the East Mediterranean Sea.

Temporal corrections have been applied trying to preserve the surface salinity dynamics.

# Conclusions

We have generated 10 years of level 2, level 3 and level 4 products:

- Level 2 descending overpasses have a very poor accuracy, which makes unlikely its use for scientific purposes.
- Level 2 ascending overpasses have an overall accuracy of 1.85 in 2011-2015 and 1.5 in 2016-2020. The quality of this product depends on the way that the satellite crosses the basin.
- Level 3 has an accuracy of 0.7 in 2011-2015 and  0.56 in 2016-2020.
- Level 4 has an accuracy of 0.6 in 2011-2015 and 0.4 in 2016-2020.

The seasonal climatology derived from the EO4SIBS SMOS SSS presents consistent behaviour with the one provided by SeaDataNet.

The comparison with altimetry observations shows that the EO4SIBS products are consistent in describing the dynamics of the basin, i.e SSS gradients are aligned with the streamlines.

***The product is ready to address scientific studies in the basin!***

DLR

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*Enjoy the product!*

esa


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