Evidence of intensification of the water cycle from SMOS SSS maps

BEC (1) Barcelona Expert Center
(2) (3) UPC (4) esa European Space Agency (5) ARGANS

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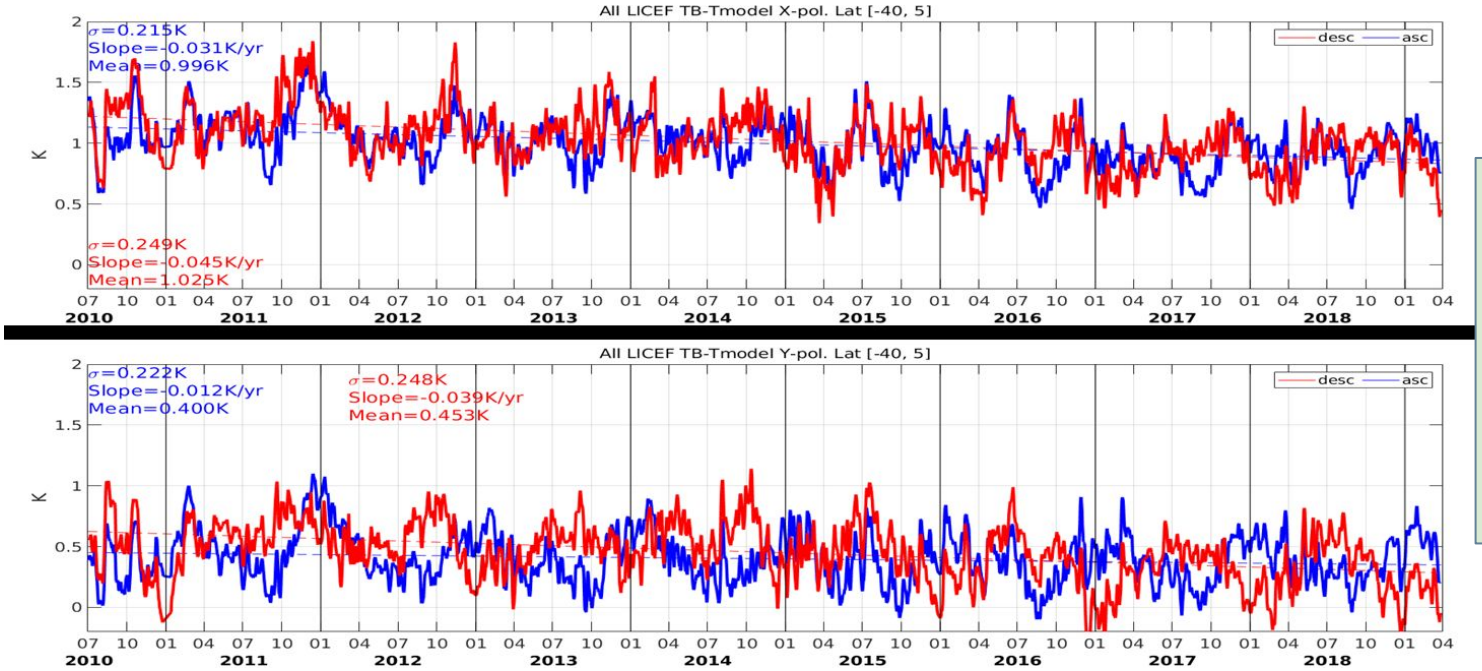
27rd May

SMOS

The beginning of the story

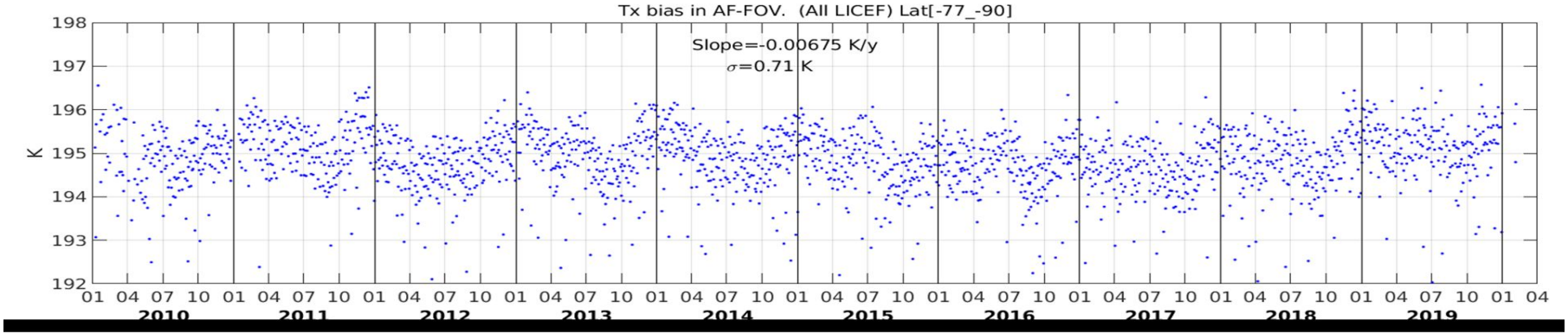
In February 2020, SMOS Level 1 team produced the series of the averaged Brightness Temperatures anomalies in X and Y polarizations and ascending and descending overpasses and **they observed a negative slope**

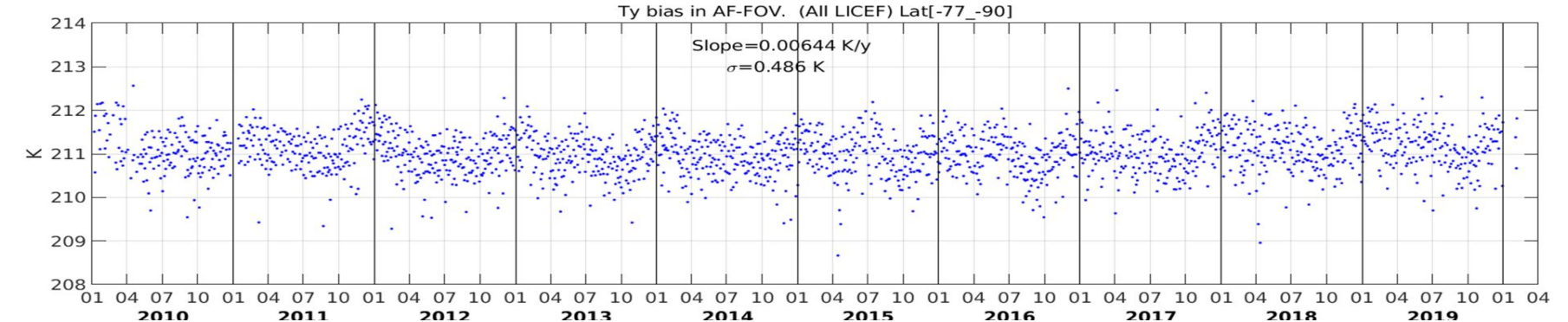


TB anomaly was computed over a stable region in the South Pacific (OTT) with respect to the model evaluated with ISAS SSS

The beginning of the story

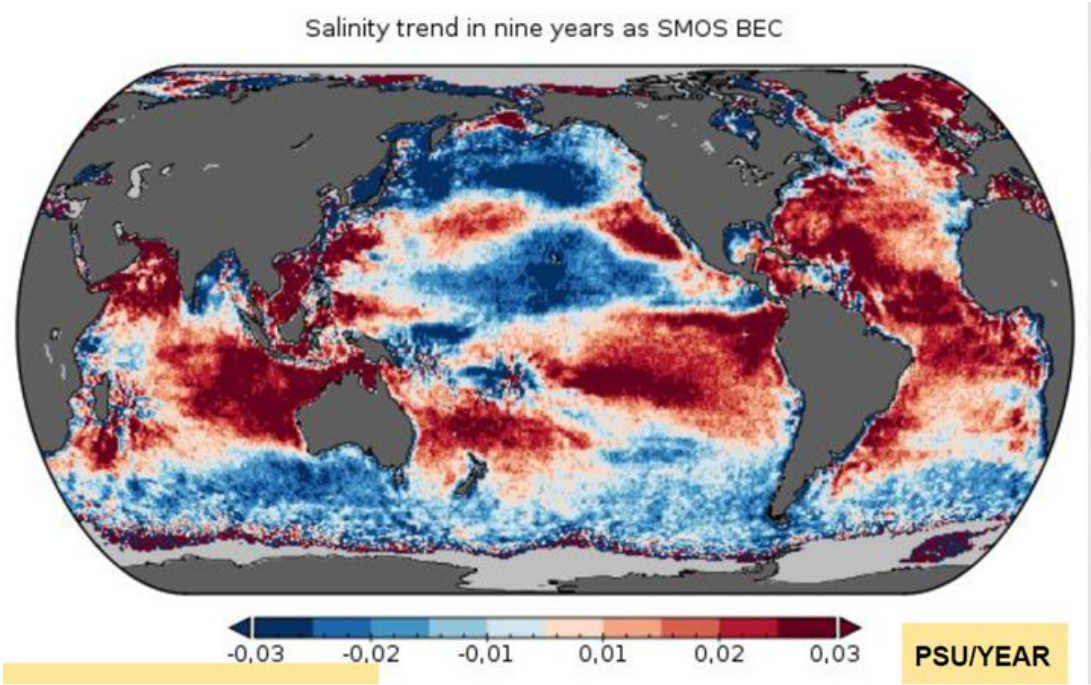
To understand if the negative slope in the OTT regions was from instrumental origin, the Brightness Temperatures were assessed over the Antarctic continent: **no slope was observed**





The beginning of the story

Level 1 team asked to the Level 2 team whether those trends observed on Brightness Temperatures could have a geophysical origin

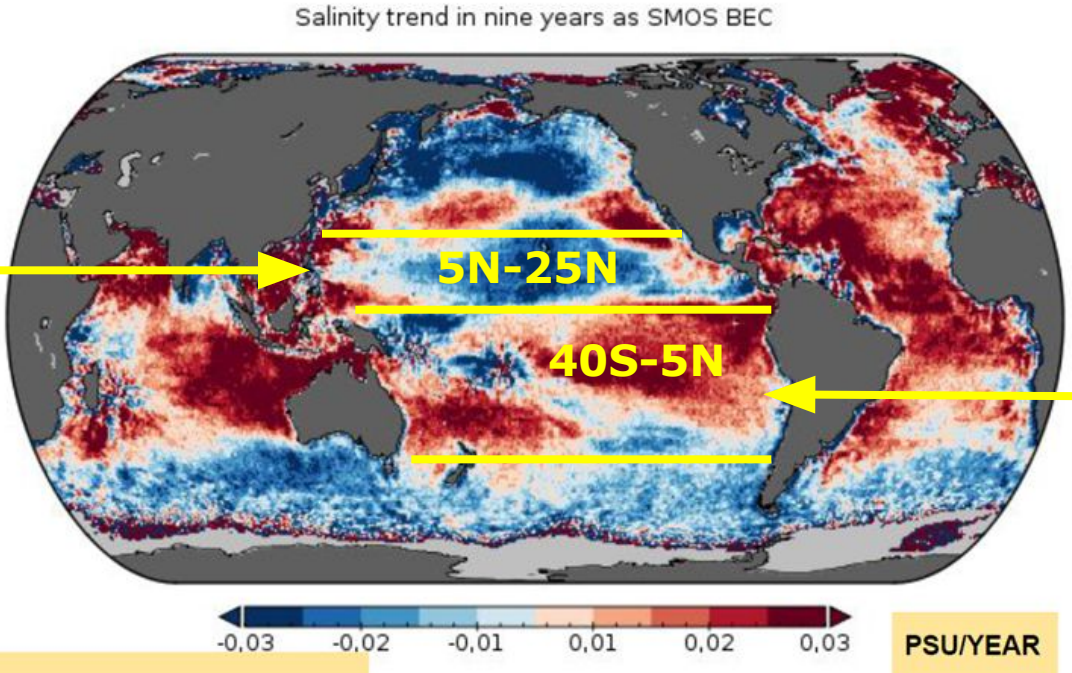


The beginning of the story

Two regions were considered, one with positive SSS trend and another with negative SSS trend:

- Both corresponded to negative trends in TB.-> There was an inconsistency between trends observed in TB and the ones observed in SSS

Freshening trend



Salty trend

The beginning of the story

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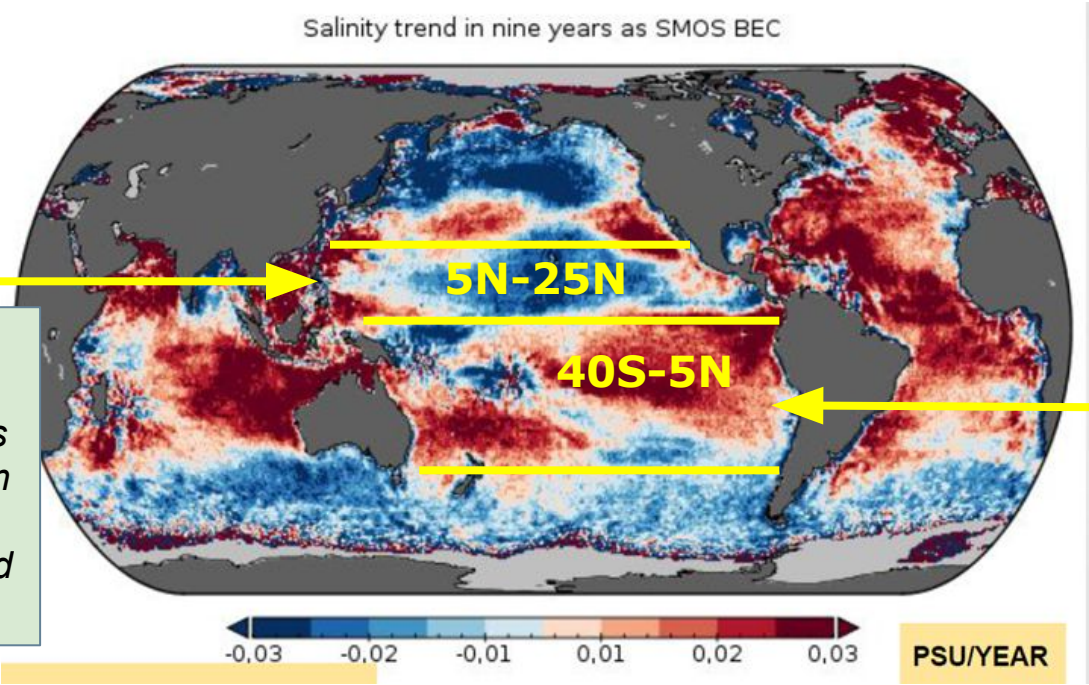

Freshening trend

Salty trend

TB anomaly trends are calculated with respect to Argo-derived modeled TB: Is there any difference between surface (measured by satellite) and near (measured by Argo) surface salinity?

Trying to answer this question….

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Increasing stratification as observed by satellite sea surface salinity measurements

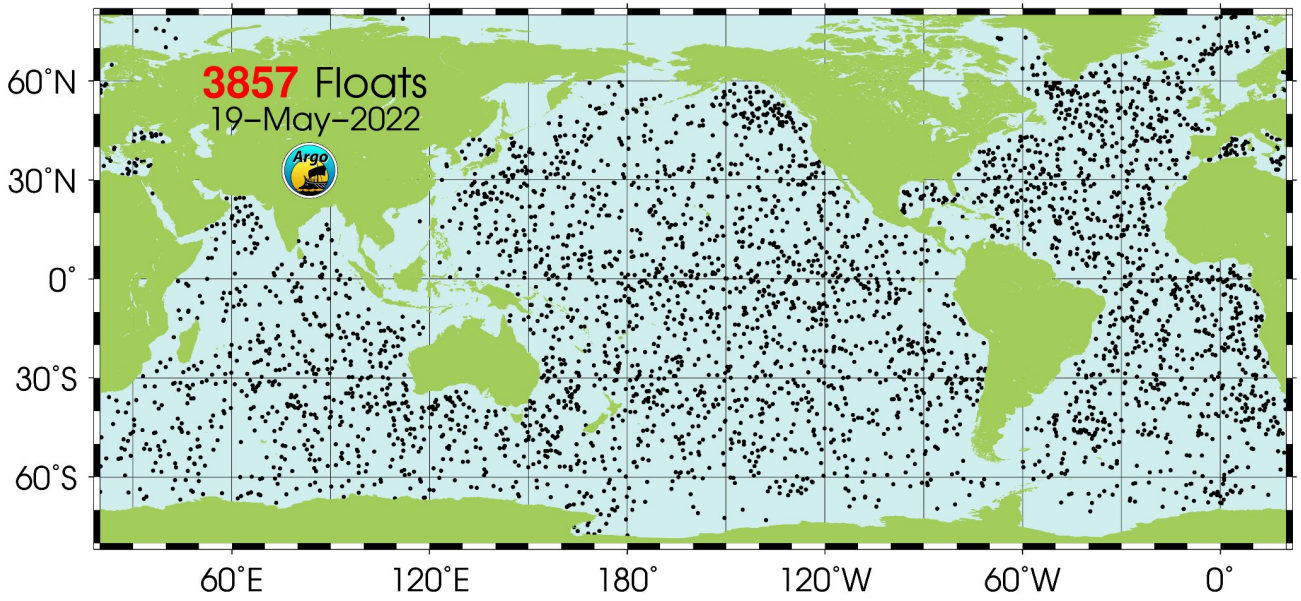
Estrella Olmedo[1]✉, Antonio Turiel[1], Verónica González-Gambau[1], Cristina González-Haro[1], Aina García-Espriu[1], Carolina Gabarró[1], Marcos Portabella[1], Ignasi Corbella[2], Manuel Martín-Neira[3], Manuel Arias[1], Rafael Catany[4], Roberto Sabia[5], Roger Oliva[6] & Klaus Scipal[3]

Satellite vs in situ measurements

BEC
Barcelona Expert Center

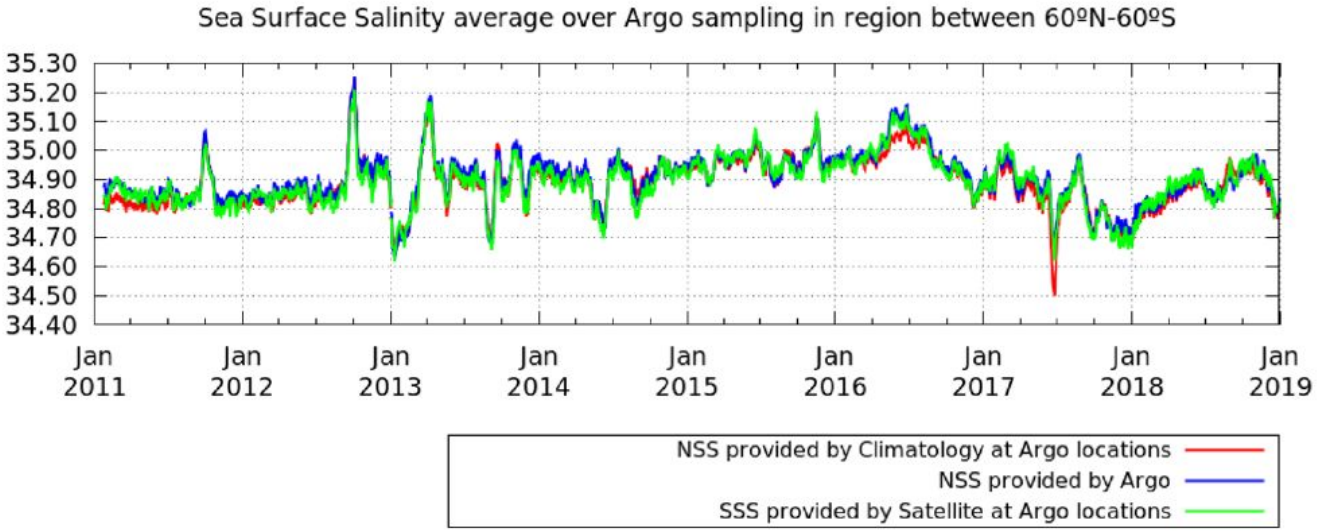
Argo float system:

- Capability of monitoring salinity dynamics
- Main source of validation of satellite salinity measurements
- Very valuable input for models



Satellite vs in situ measurements

Argo float system:



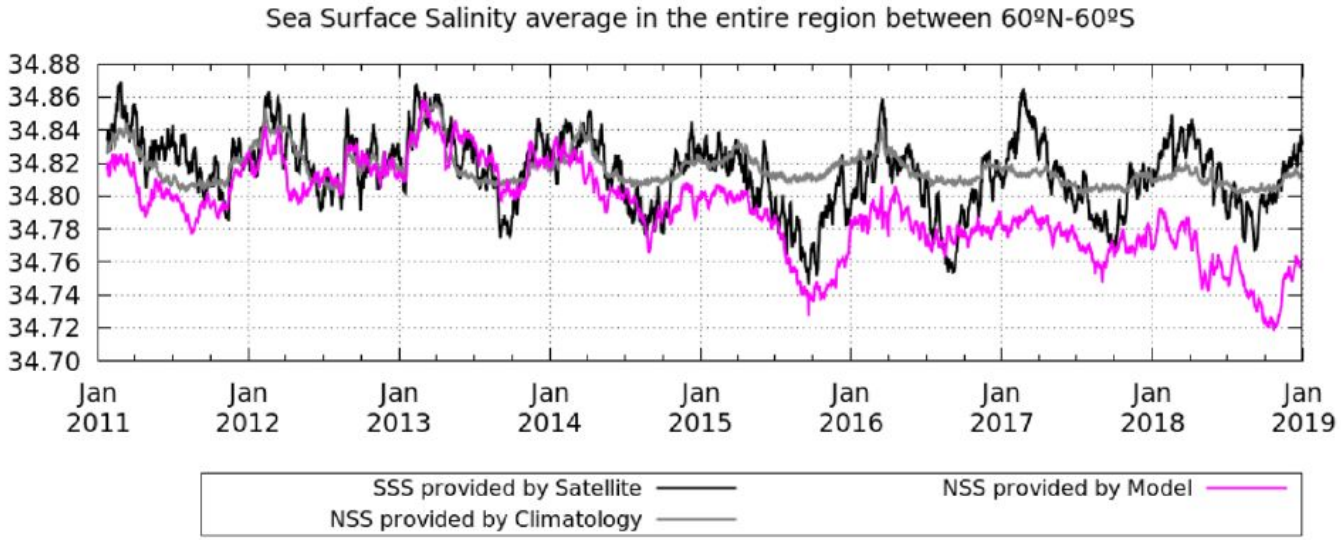
… but:

- Coastal and polar regions are undersampled
- Ocean currents drive the locations of Argo

Satellite vs in situ measurements

When ***we look at the entire region*** **(independently on the sampling)**:

- Seasonal variations
- Significant differences between satellite and model… why?



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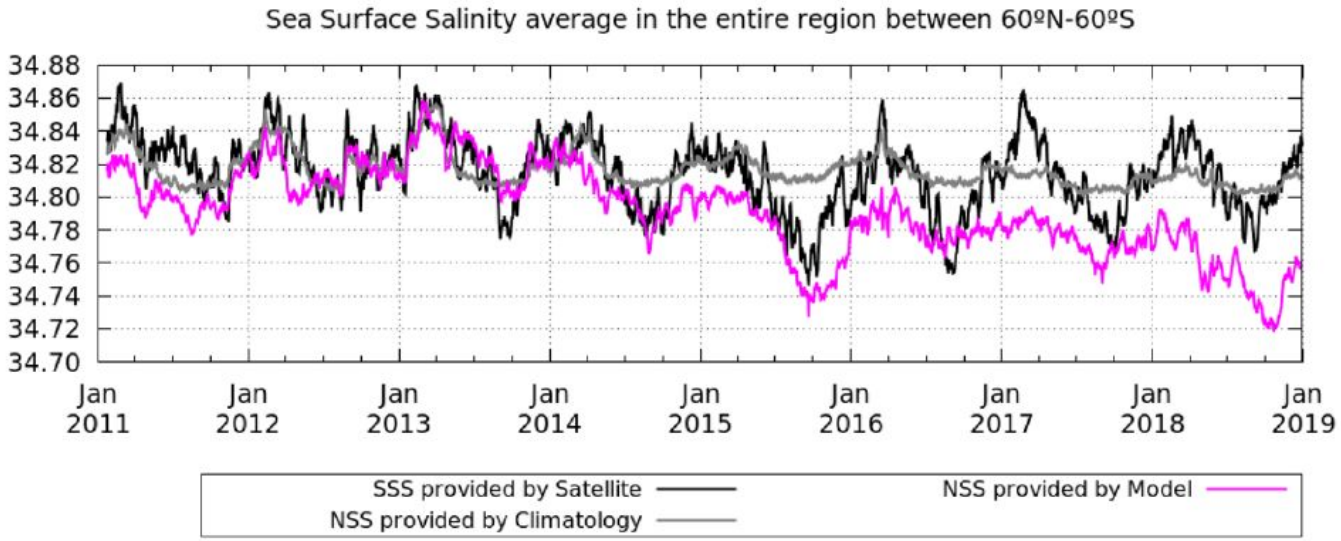


Part of these differences come from the in situ undersampled regions, because in those regions the model performance may be degraded.

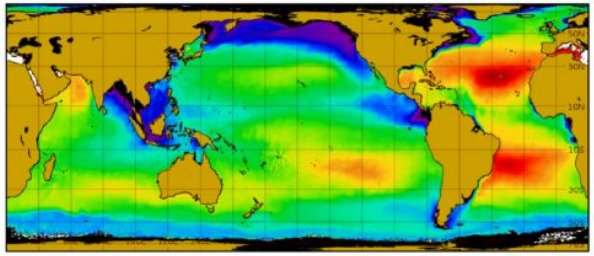
Part of these differences come from the different dynamics between Surface Sea Salinity (SSS) and the Near Surface Salinity (NSS).

Salinity trends in global ocean (2011-2018)

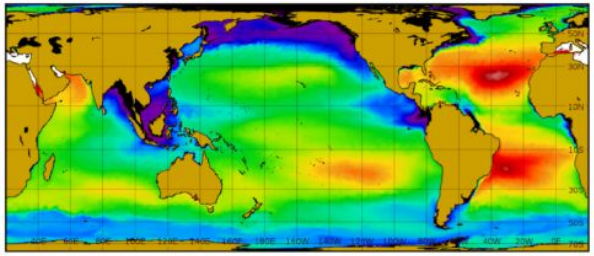
SSS from satellite

NSS from model

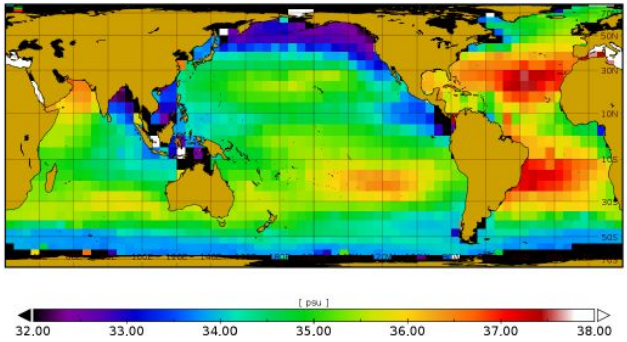
NSS from Argo



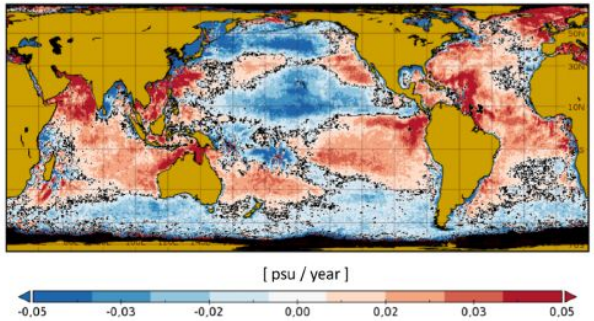
Sea Surface Salinity Trends in 2011-2018

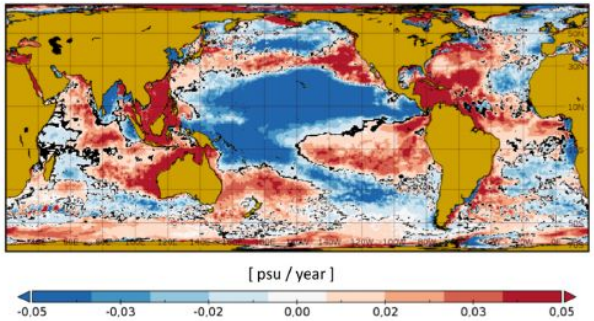


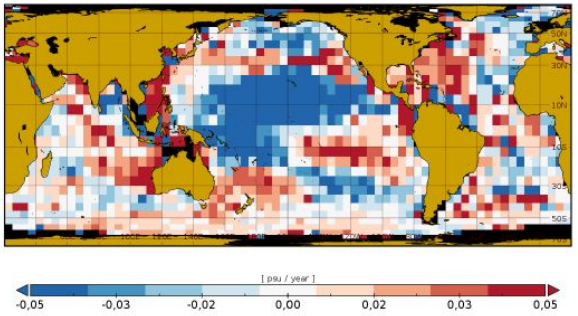
Near Surface Salinity Trends in 2011-2018



Near Surface Salinity Trends in 2011-2018 as observed by Argo floats

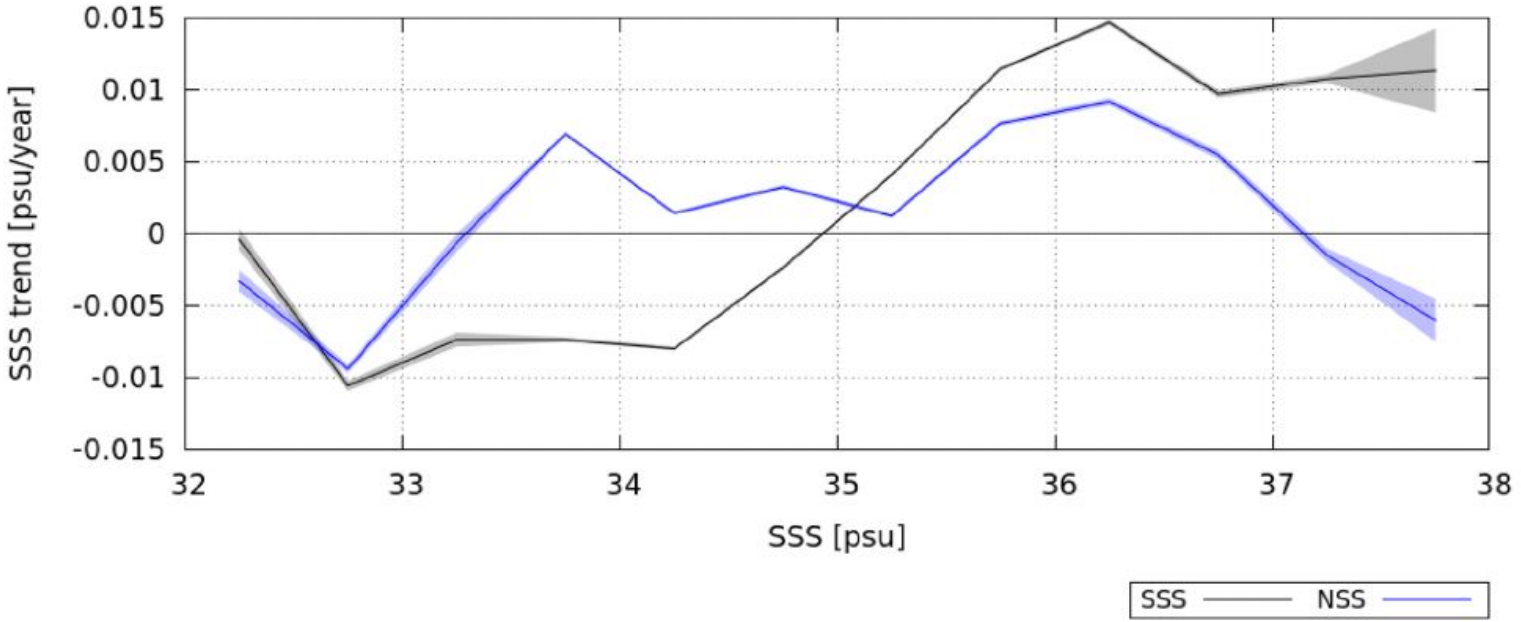






- Satellite, model and Argo present similar salinity patterns
- Argo and model present similar salinity trends: model (Glorys12v1) assimilates Argo
- Significant differences in SSS and NSS trends: Southern Ocean, Atlantic Ocean, …

Salinity trends in global ocean (2011-2018)

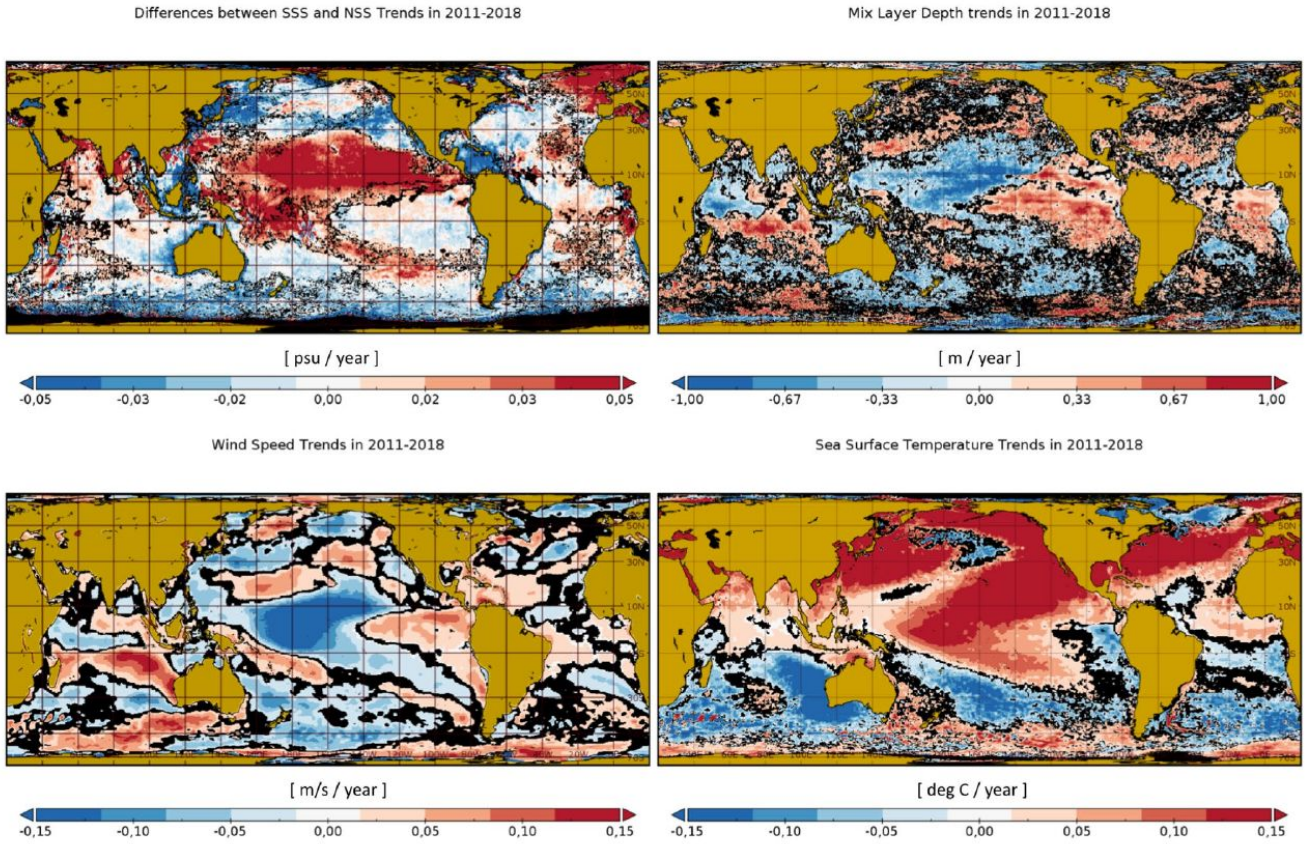


SSS reveals that fresher regions are getting fresher while saltier regions are getting saltier:

- SSS values larger than 34.7 psu present positive trends reaching 0.015 psu/year
- SSS values lower than 34.7 psu present negative trends reaching -0.01 psu/year

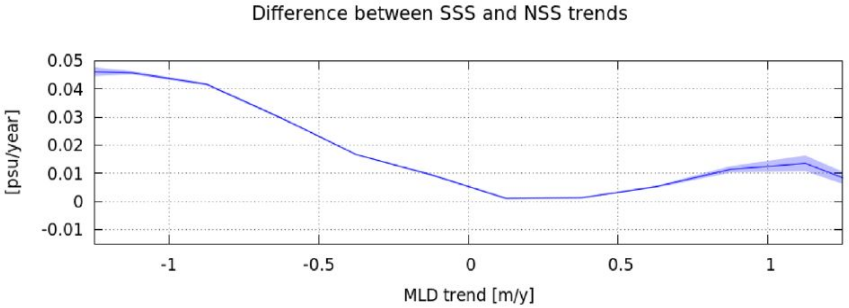
This intensification of fresher and saltier regions is not so clearly present in NSS

Stratification observations in the global ocean

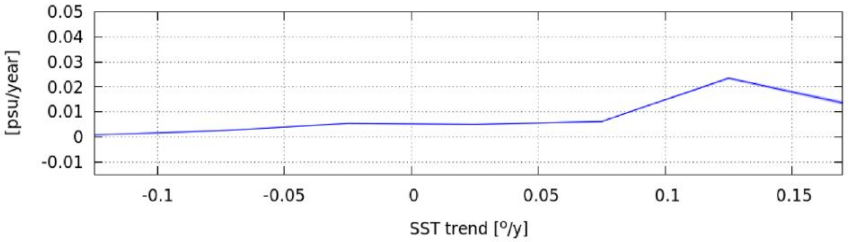


Stratification observations in the region comprised between 40ºS-40ºN

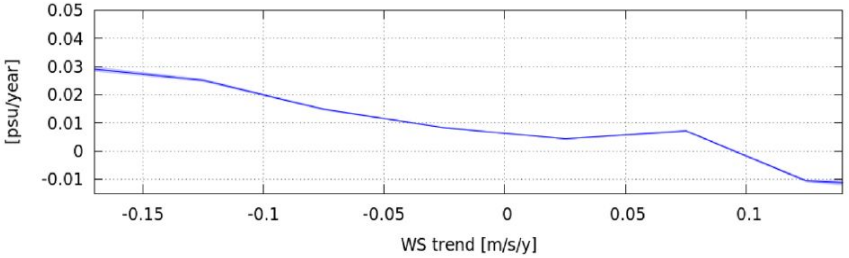
The largest positive differences between SSS and NSS trends occur when the Mix Layer depth presents the largest negative trends (~ -1 m/year)



Regions with larger positive differences between SSS and NSS trends are characterized by large Sea Surface Temperature trends trends (~ 0.1 - 0.15 º/year)



The largest positive differences between SSS and NSS trends correspond to the largest negative Wind Speed trend (~ -0.15 m/s /year)



Discussion (I)

- Satellite salinity measurements are providing a unique source of information of the ocean mesoscale processes in the upper-layers of the ocean:
  - Routine and global maps: reaching coastal and polar regions
  - Provide measurements of the surface that are different from the near surface

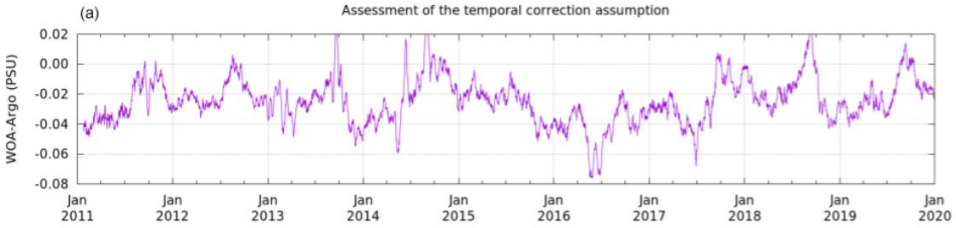
- **Satellite measurements are complementary to those of the in situ**.

- **Water cycle is expected to be intensified according to Clausius-Clapeyron relation**:
  - “Saturation of water vapor pressure increases a rate of 7% per degree of warming”
  - The same rate of increase is expected in the Evaporation minus Precipitation (E-P) (Yu. et al. 2020)
  - This leads to a paradigm of “dry gets drier and wet gets wetter” (DDWW) under conditions of climate warming
  - Our results show that positive trends of SSS dominate in regions with SSS larger than 34.7 psu, while the opposite is true in regions with SSS lower than 34.7 psu.
  - This is consistent with the DDWW paradigm
  - NSS does not show this amplification
  - This reinforces the idea of **using SSS and not NSS as a proxy of E-P**.

Yu, L., Josey, S. A., Bingham, F. M. & Lee, T. Intensification of the global water cycle and evidence from ocean salinity: Synthesis review. Ann. N. Y. Acad. Sci. 1472, 76–94 (2020).

Discussion (II)

- In tropical and mid-latitude regions we observe significant differences between SSS and NSS trends:
  - This is probably originated by a **net stratification effect induced by surface warming**
  - Persistent increase of SST under low wind conditions is forming a warm layer in the upper ocean layer
  - Since these conditions persist over time, the evaporation from the ocean surface is favoured
- In this study we use a SMOS SSS product that mitigates the temporal biases without NSS external reference:
  - We use BEC SMOS SSS global product v2 (Olmedo et al. 2021)
  - The global average of SSS does not change with time
  - SSS variations are only expected due to the sea-ice extension



E. Olmedo, C. González-Haro, N. Hoareau, M. Umbert, V. González-Gambau, J. Martínez, A. Turiel Nine years of SMOS sea surface salinity global maps at the Barcelona Expert Center, Earth System Science Data, 13, 857-888 (2021)

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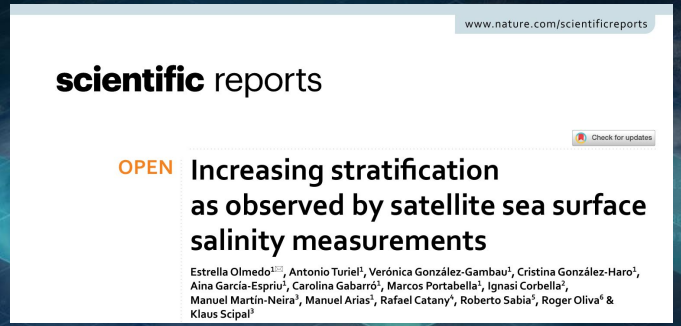
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THANK YOU FOR YOUR ATTENTION!

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