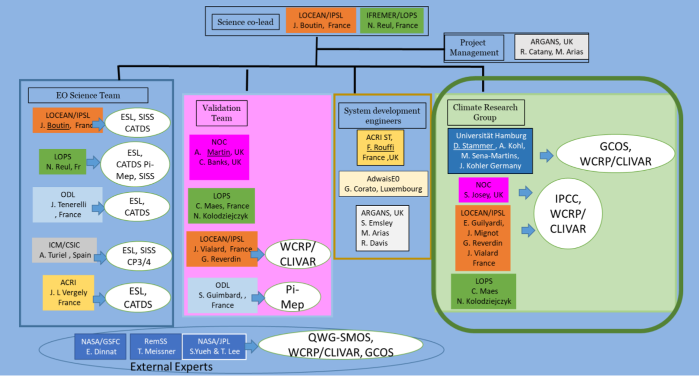
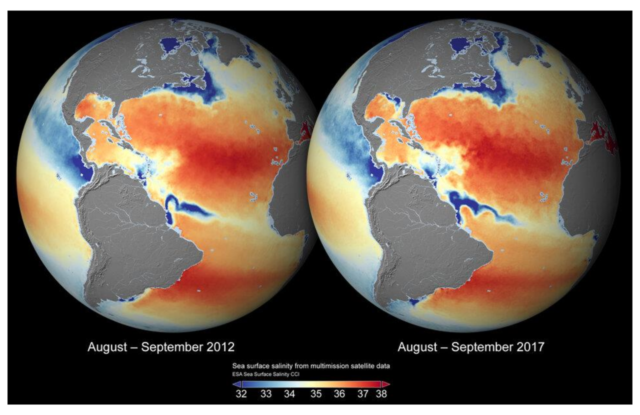
Sea Surface Salinity monitoring from Space: CCI+SSS



Abstract

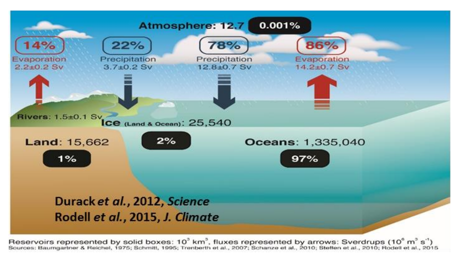
A 10year long Sea Surface Salinity (SSS) times series (2010-2019) has been produced by the CCI+SSS consortium. Following users needs, we retain as much as possible full variability sampled by the satellites at 50km and weekly spatio-temporal scales. The rms difference of these SSS with respect to in situ Argo SSS is 0.16. These products provide new insights into SSS long term variability related to e.g. ENSO events and tropical instability waves.



Why measuring sea surface salinity?

1- A tracer of freshwater fluxes and ocean circulation

- Insights into freshwater fluxes (precipitation, evaporation, runoff, freezing and melting of ice)
  - Global oceans are the engine room of the **water cycle**
- Ocean circulation: advection and mixing



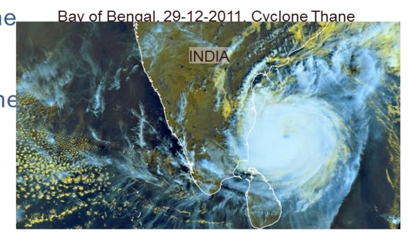
2- A strong influence on sea water density & Air-sea exchanges

Salinity affects sea water density, which in turn governs **ocean circulation & air-sea exchanges:**

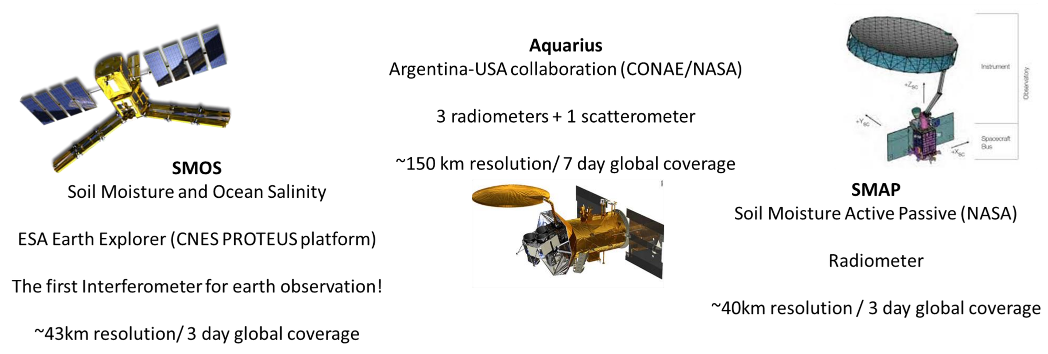
In cold waters (SST=2°C), a **0.1 surface salinity increase** creates the same density change as **a 1°C warming in temperature**

In the tropics (SST=28°C), a **0.4 surface salinity increase** creates the same density change as **a 1°C warming in temperature**

=>Large freshwater fluxes (river, rain) => strong haline stratification at the ocean surface => high SST => cyclones



Salinity from space using L-band radiometry

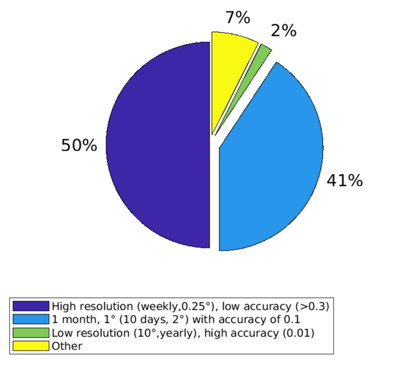


Project first priority (L-band sensors => back to 2010, this poster)

2nd priority (S-band sensors): back to 2002 regionally (in progress)

User Requirements: In brief

- 54 responses in total
- Global spatial coverage, min. 9 years
- Most common requirement: L4 data
- Fully characterized uncertainty information for each SSS grid point
- Quality control checks
- Detailed but also simple documentation



Percentage of preferred SSS product based on the users spatial and temporal resolution needs.

Recommendations for Product Specification

Design a product that meet as many requirements as possible taking into account the available options

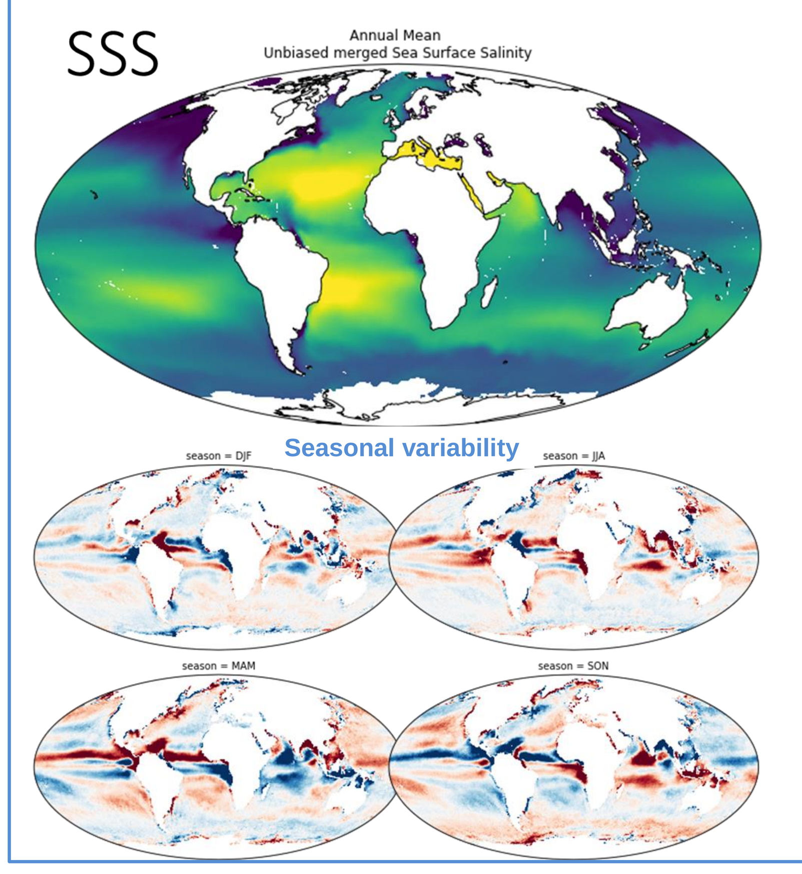
1. **Make high-resolution data available**
2. **Error specification along with error estimation details**
3. **Compatibility with other products (L2, L3 and other CCI)**

CCI+SSS v2 SSS (2010-2019) and associated error

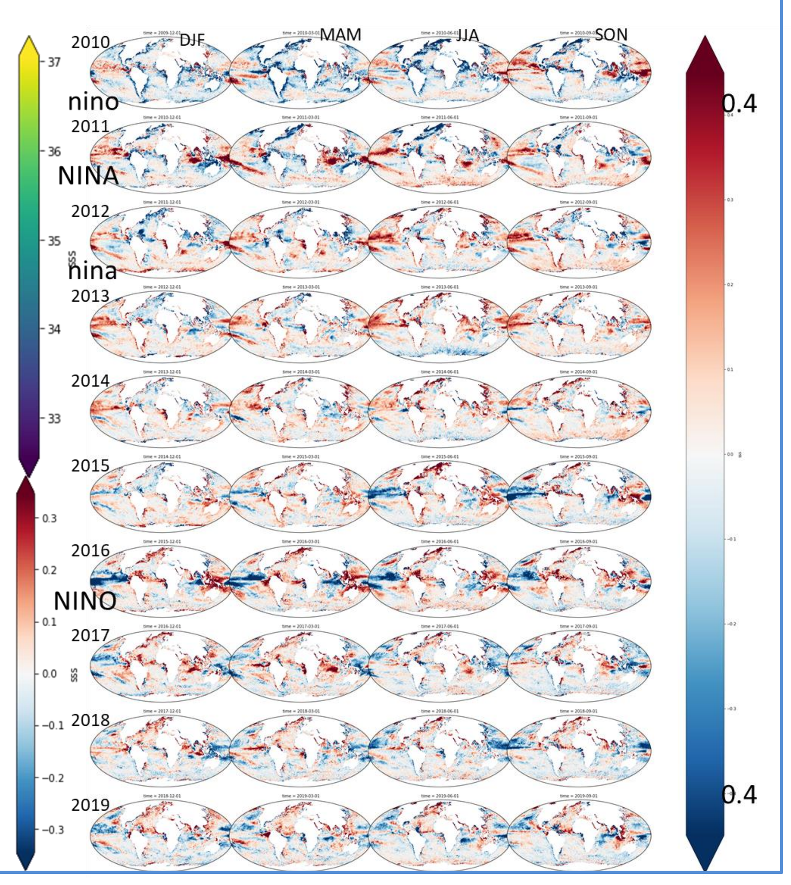
Level	Decorrellation timescales	Spatial smoothing scale	Temporal timesteps	Spatial grid size	Coverage
L4	weekly	50 km	Daily (based on 7-day running means)	25 km	Global 2010-2019
L4	30 days	50 km	Centred on 1st and 15th day of the month	25 km	Global 2010-2019

Citable as: Boutin, J.; Vergely, J.-L.; Reul, N.; Catany, R.; Koehler, J.; Martin, A.; Rouffi, F.; Arias, M.; Chakroun, M.; Corato, G.; Estella-Perez, V.; Guimbard, S.; Hasson, A.; Josey, S.; Khvorostyanov, D.; Kolodziejczyk, N.; Mignot, J.; Olivier, L.; Reverdin, G.; Stammer, D.; Supply, A.; Thouvenin-Masson, C.; Turiel, A.; Vialard, J.; Cipollini, P.; Donlon, C. (2020): ESA Sea Surface Salinity Climate Change Initiative (Sea_Surface_Salinity_cci): weekly and monthly sea surface salinity products, v2.31, for 2010 to 2019. Centre for Environmental Data Analysis, 07 September 2020. doi:10.5285/4ce685bff631459fb2a30faa699f3fc5.

CCI+SSS v2



SSS quarter anomalies over 2010-2019



CCI+SSS L4 algorithm

Strategy

•Merge existing SSS from different satellite sensors

•Limit as much as possible external information other than satellite signal to preserve full variability.

•Systematic errors corrected using satellite SSS self-consistency analysis.

Main changes from CCI+SSS V1 to CCI+SSS V2:

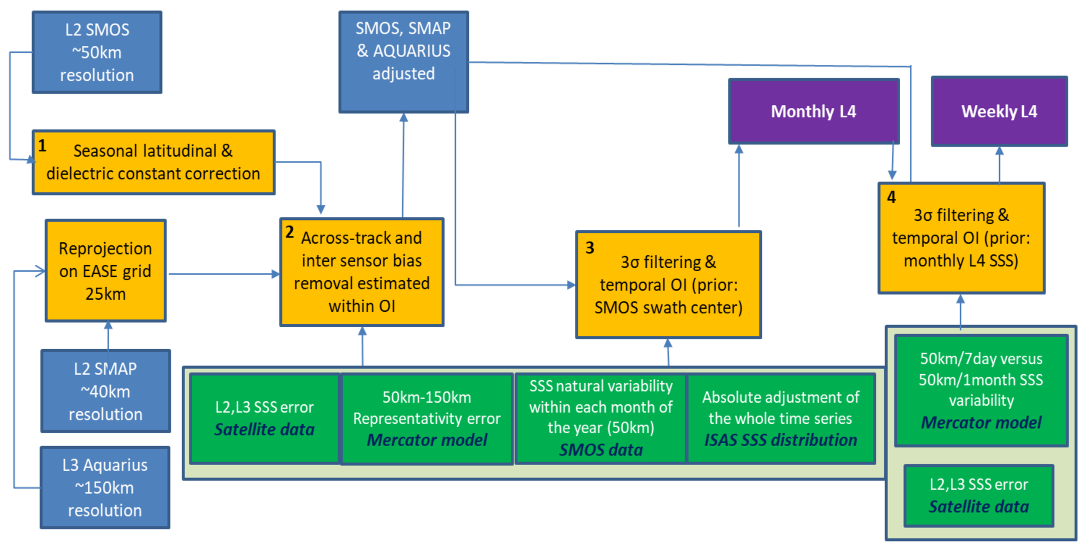
•Extend the time period: Jan 2010 – Dec 2019

•Improved error estimate (in weekly fields & in the vicinity to land)

•Dielectric constant in cold water updated (change in SST correction)

•Improved filterings

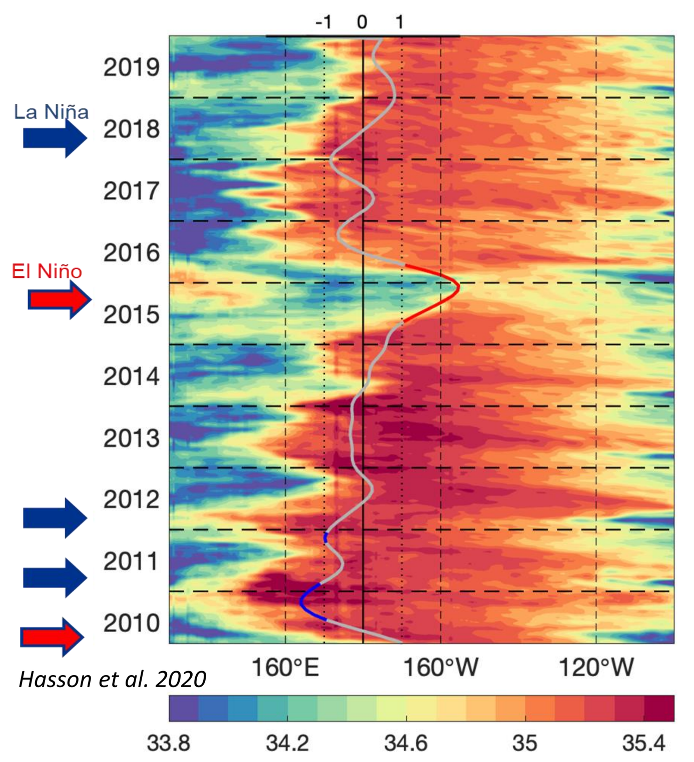
•Updated SMAP and Aquarius SSS products



External information (other than satellite SSS):
In CCI OI:
- Monthly climatology of representativity errors from Mercator model
- In each pixel, adjustment of absolute SSS value using upper quantile(s) of 8 year Argo OI SSS distribution

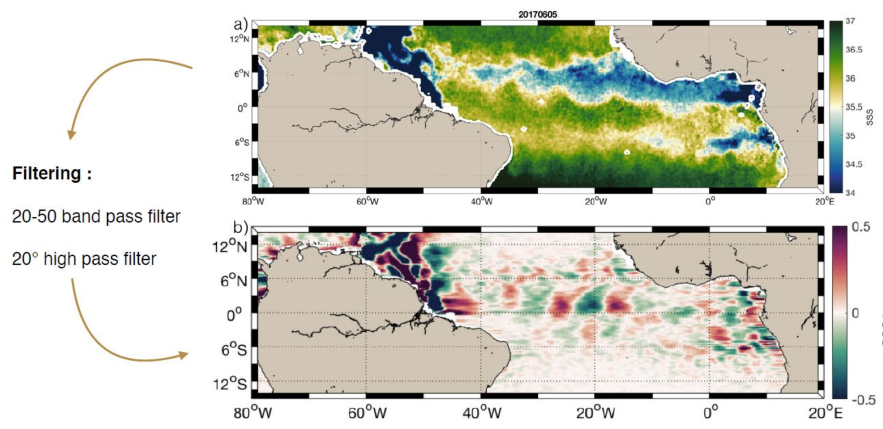
Individual sensor calibration at L2:
- SMOS : mean Tb in a SE Pacific Ocean (45S-5S) adjusted with a SSS climatology (WOA) over ~10days
- Aquarius: Mean global Ta adjusted every 7day to mean global Ta derived from Argo salinity
- SMAP : weekly latitudinal correction based on Argo salinity.

SSS signatures of ENSO Equatorial Pacific Ocean (2°N-2°S)



CCI+SSS longitude variability related warm pool and equatorial upwelling spatio-temporal variations – Very complementary to SST, SLA, Chla time series (Popp et al. 2020)

Tropical Instability waves (TIW) in the Atlantic Ocean



The horizontal density gradient generated by the equatorial upwelling is subject to undulations called TIWs which influence air-sea exchanges and ocean dynamics. The scarcity of salinity observations has often be a limiting factor in the study of the importance of density on TIWs. CCI+SSS allows a better characterization of the seasonal and interannual variations and energetics of TIWs. We find that TIWs salinity seasonal cycle leads the temperature one by one month. This impacts the energetics of the waves, salinity being responsible for most of the potential energy generated by the density gradient in May-June. *Olivier et al., 2020, submitted to JGR-Oceans*

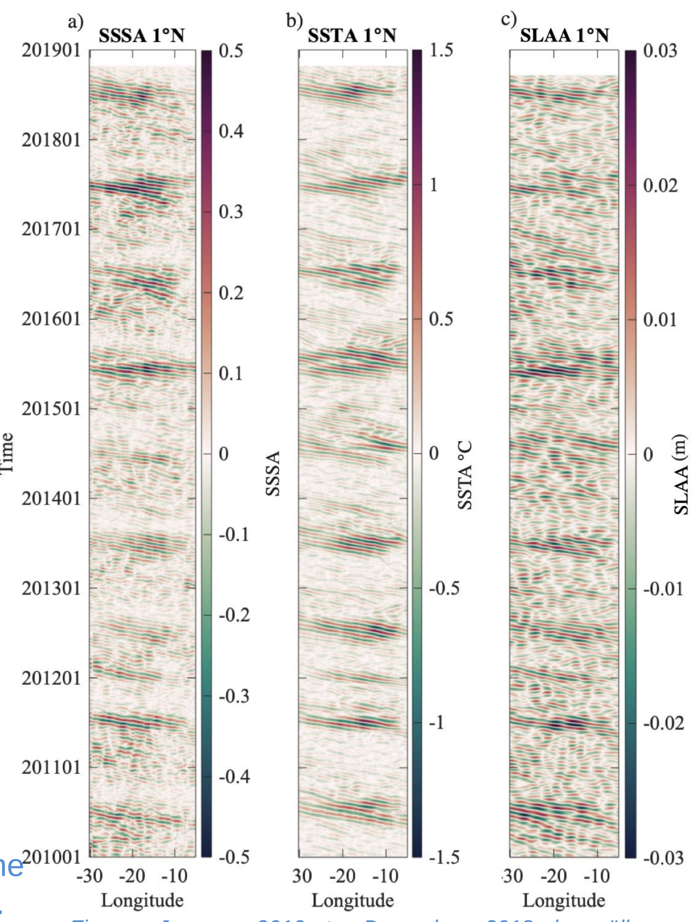


Figure: January 2010 to December 2018 hovmöller diagrams at 1°N of a) sea surface salinity anomaly, b) sea surface temperature anomaly, c) sea surface height anomaly

SSS variability as modelled and observed

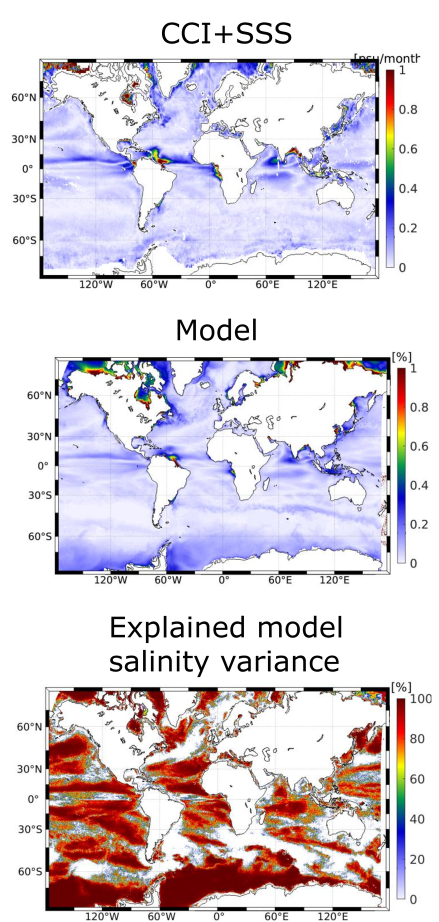
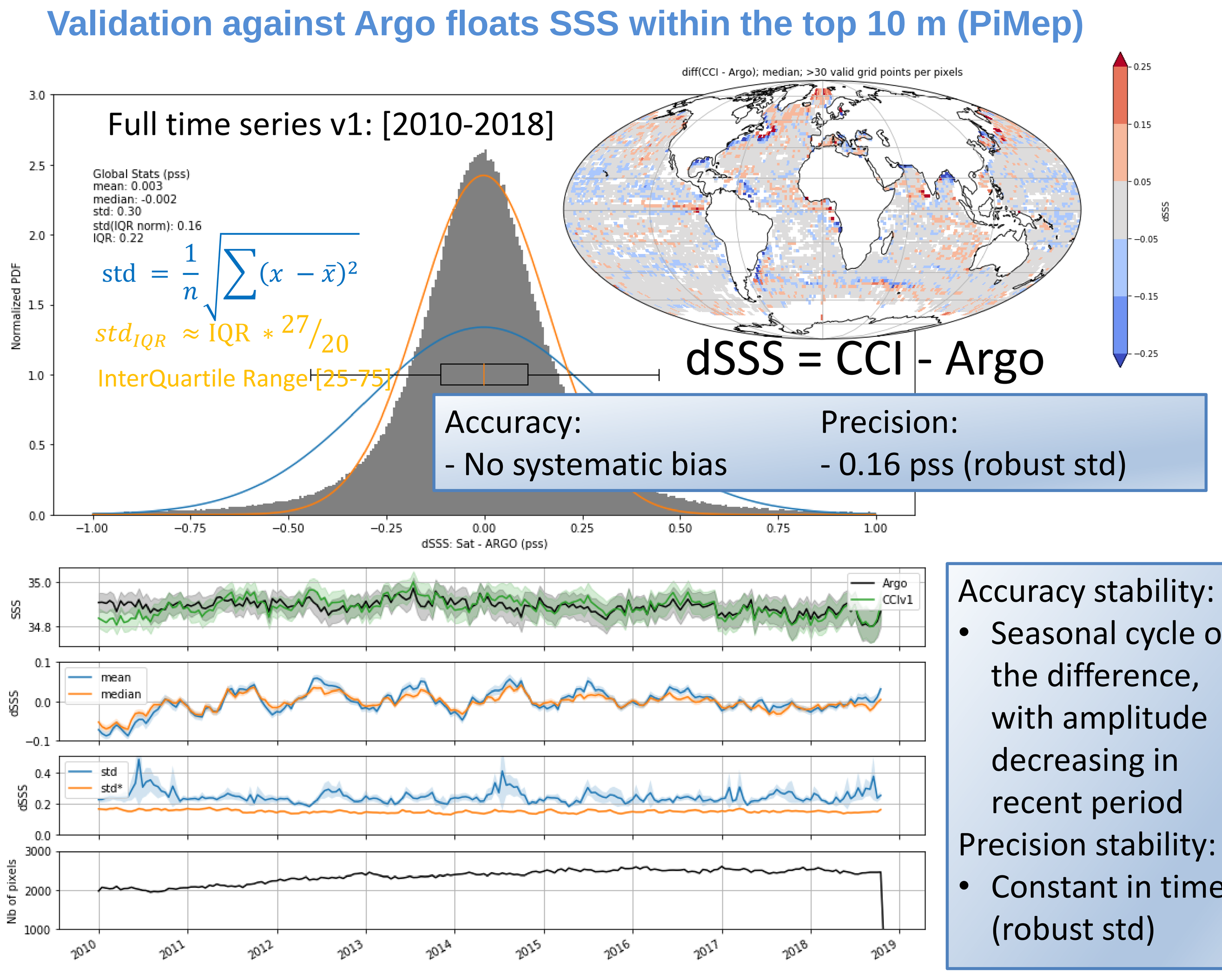


Figure: Amplitude of the annual salinity tendency cycle of (top) CCI+SSS data and (middle) high-resolution model output (in pss/month)(Bottom) Explained annual model salinity variance by the sum of the terms which can be calculated using observations (SUM= Surface external forces + mean horizontal advection + vertical diffusion and entrainment).

The sum of these terms explains more than 90% of annual salinity tendency parts in most of the ocean regions. Interestingly, these terms don't explain the variance in frontal regions (Gulf Stream, Southern Ocean frontal region etc.) and major river outlet region, indicating that also small scale high frequency terms are of importance and/or the contribution of the terms is time lagged. (NCAR model)

Validation against Argo floats SSS within the top 10 m (PiMep)



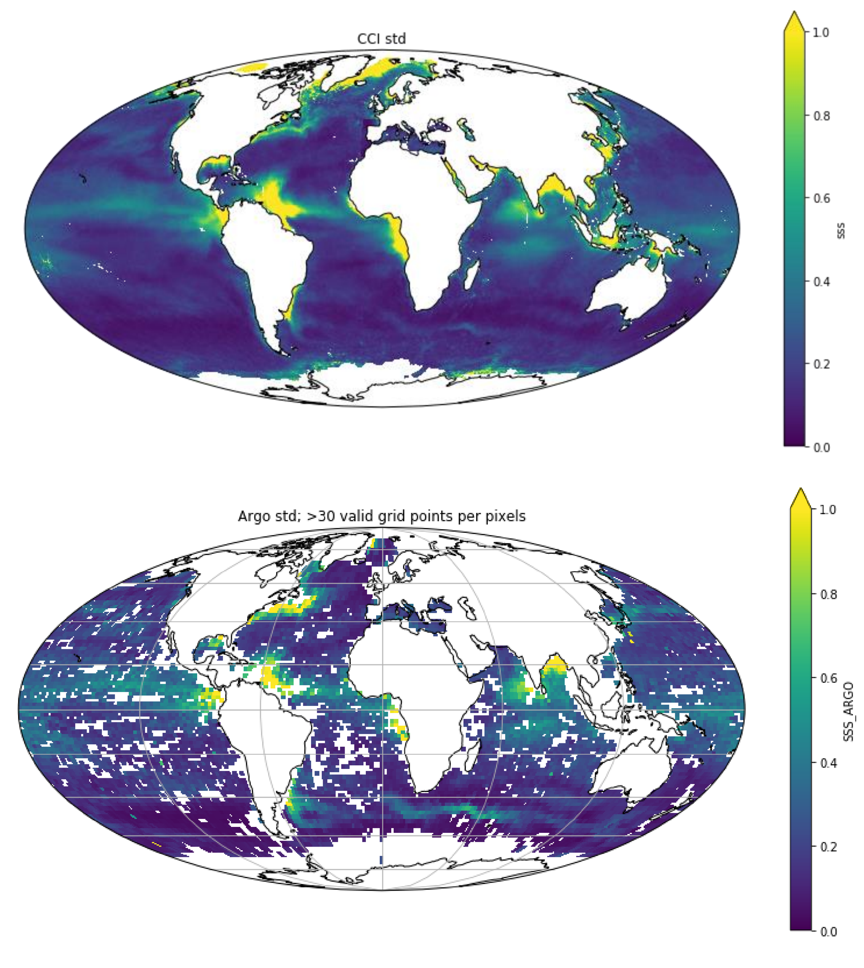
$$\text{std} = \sqrt{\frac{1}{n}\sum (x-\bar{x})^2}$$

$$std_{IQR} \approx \text{IQR} * {}^{27}/_{20}$$

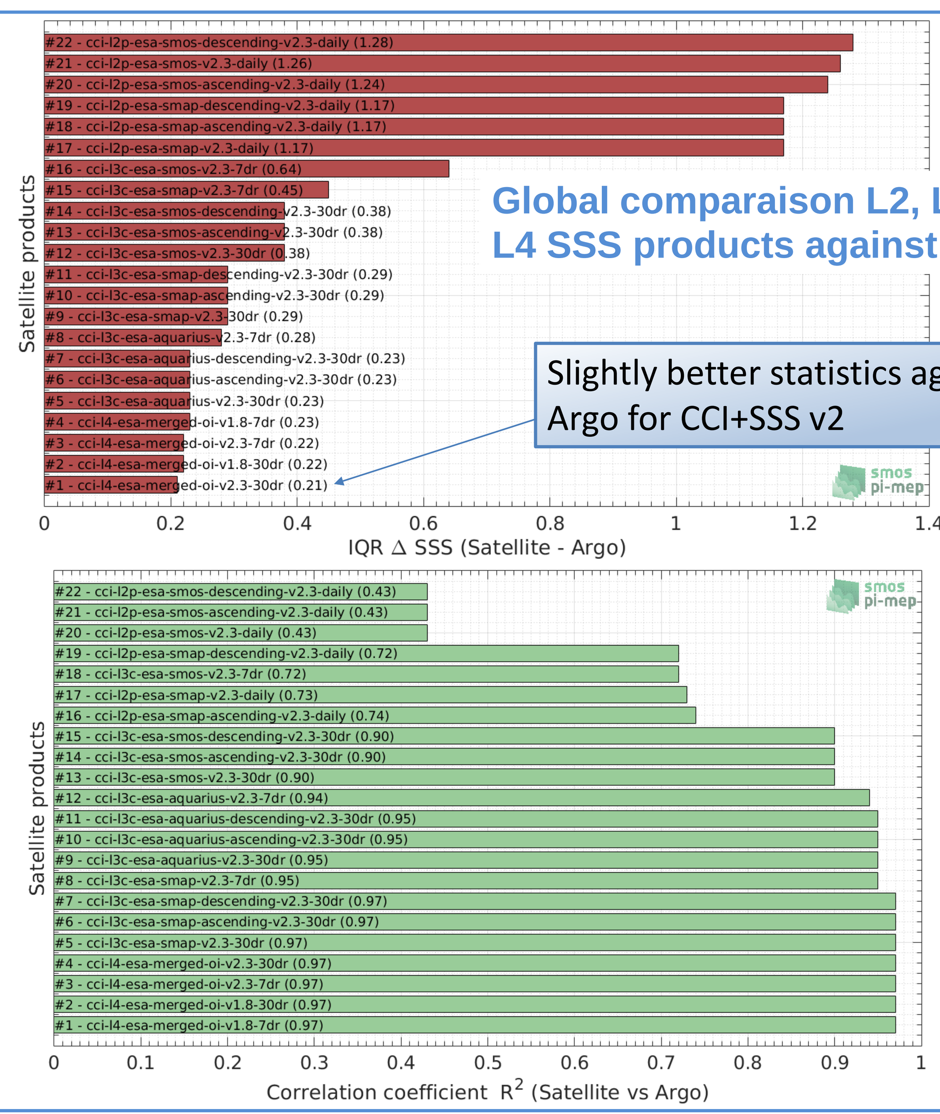
Accuracy stability:
- Seasonal cycle of the difference, with amplitude decreasing in recent period

Precision stability:
- Constant in time (robust std)

CCI SSSv2 vs Argo observed variability



Good agreement in the observed variability where there is enough Argo data



Global comparaison L2, L3 and L4 SSS products against Argo

Slightly better statistics against Argo for CCI+SSS v2

References: Documentation available on http://cci.esa.int/salinity#CCI SSS Documentation

•V. P. Akhil, J. Vialard *et al.* (2020), "Bay of Bengal Sea surface salinity variability using a decade of improved SMOS re-processing," *Remote Sensing of Environment*, vol. 248, p. 111964, 2020, doi: https://doi.org/10.1016/j.rse.2020.111964

•Popp, T., et al. (2020), Consistency of satellite climate data records for Earth system monitoring, , *Bull. Amer. Meteor. Soc.*, https://doi.org/10.1175/BAMS-D-19-0127.1.

•Reul, N. et al. (2020), Sea Surface Salinity estimates from Spaceborne L-band radiometers: an overview of the first decade of observation (2010-2019), *RSE*, vol. 242, 2020, doi: https://doi.org/10.1016/j.rse.2020.111769.

•Boutin, J., J.L. Vergely, *E. Dinnat*, et al., Correcting sea surface temperature spurious effects in salinity retrieved from spaceborne L-band Radiometer measurements, in revision for IEEE TGARSS.

•Olivier, L., et al., *Tropical Instability Waves in the Atlantic Ocean: investigating the relative role of sea surface salinity and temperature from 2010 to 2018, submitted to JGR-Ocean, 2020.*

In preparation:

•Stammer, D., M. Sena Martins, J. Köhler , A. Köhl, How good do we know ocean salinity and its changes, to be submitted to JGR-Ocean, 2020

•Boutin, J., J. Koehler, A. Martin, N. Reul, et al., *Satellite-based time-series of sea surface salinity designed for ocean and climate studies, in preparation for JGR-Ocean.*