Measuring SSS with SMOS since 2010 : Qualities and flaws

J. Boutin[(1)], N. Reul[(2,5)], F. D'Amico[(1)], S. Marchand[(1)], J. Tenerelli [(3)],J.L. Vergely[(4)],

A. Hasson[(1)], N. Kolodziejczyk[(2)], G. Reverdin[(1)], A. Supply[(1)], S. Tarot [(5)], J. Vialard[(1)]

(1) (2) (3) (4) (5)

Collaborations with ESA ESL: M. Arias, P. Spurgeon, R. Davies (ARGANS),

A. Turiel, E. Olmedo (BEC/ICM), R. Sabia, S. Delwart (ESA)

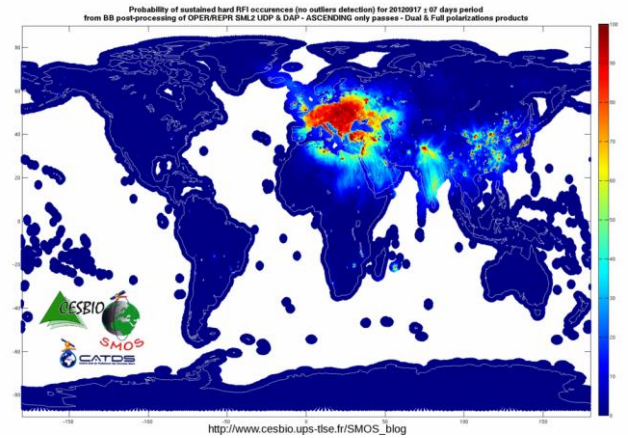
SMOS (Soil Moisture and Ocean Salinity)
An ESA Earth Explorer mission

- The first interferometer for the earth observation from space

⇒ 69 antennas => correlation products => brightness temperatures (Tb)

Image reconstruction ~Fourier transforms
difficult in case of discontinuities in Tbs
(**Land-sea and ice-sea systematic errors**)

17/09/2012



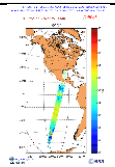
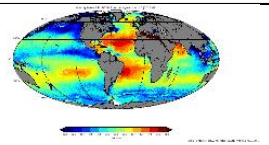
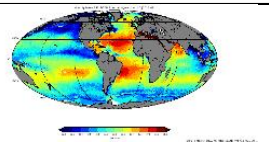
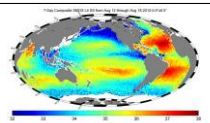
- The first L-band radiometer on satellite

⇒ **Unexpected RFIs**!!! *L-band is a protected band*

SMOS SSS products

Operational centers

Expertise centers

	ESA	CATDS CPDC	CATDS CEC LOCEAN	CATDS CEC IFREMER	BEC
Type of retrieval	Full Pol/Bayesian	Full Pol/Bayesian	Full Pol/Bayesian	ST1	
Level of product	L2	L3 (& L4)	L3	L3 & L4	L3 & L4
					See E. Olmedo's presentation
Products before May 2017	V622	RE04	Debias_v1	**L4** (adjusted to ISAS + other paramers)	
May 2017 products including systematic errors corrections	**V662 NoCorr** **V662 Corr**	**RE05 NoCorr** **RE05 Corr**	**Debias_v2**	L4 (in prep. see N. Kolodziejczyk presentation)	

www.esa.int

catds.ifremer.fr

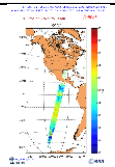
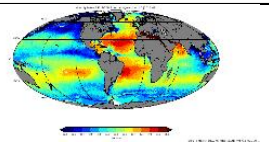
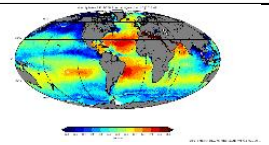
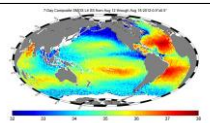
cp34-bec.cmima.csic.es

In bold, publicly available and maintained products

SMOS SSS products

Operational centers

Expertise centers

	ESA	CATDS CPDC	CATDS CEC LOCEAN	CATDS CEC IFREMER	BEC
Type of retrieval	Full Pol/Bayesian	Full Pol/Bayesian	Full Pol/Bayesian	ST1	
Level of product	L2	L3 (& L4)	L3	L3 & L4	L3 & L4
					See E. Olmedo's presentation
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www.esa.int

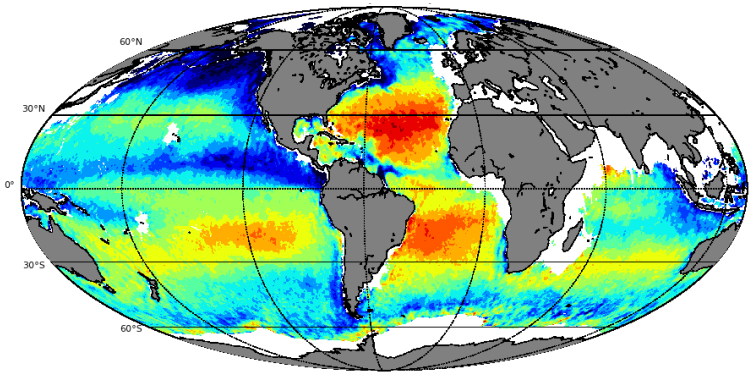
catds.ifremer.fr

cp34-bec.cmima.csic.es

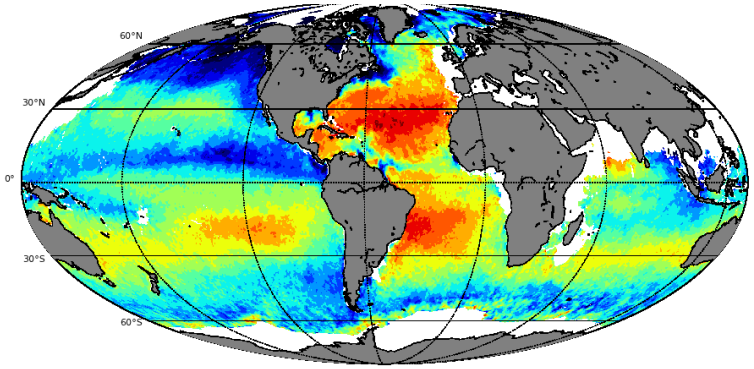
Publicly available and maintained products (in bold)

SSS products used in this presentation

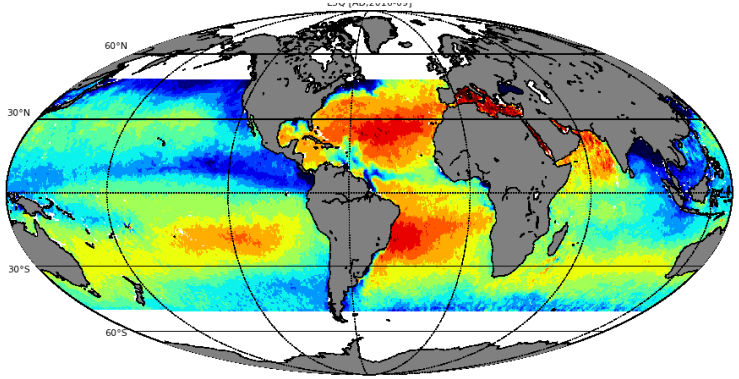
ESA V622 - *Monthly*
(Reference - no correction)



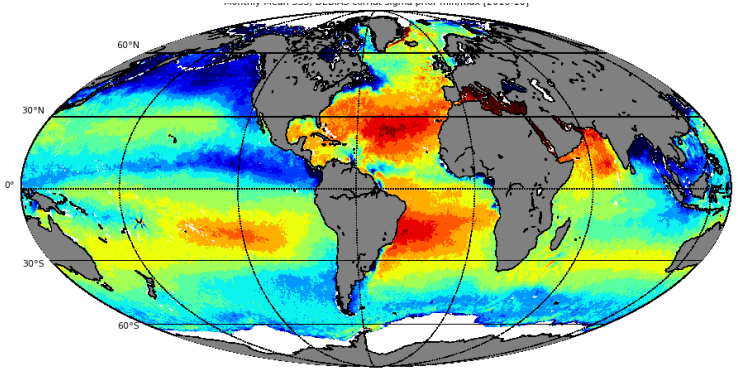
ESA V662
Corrected - *Monthly*



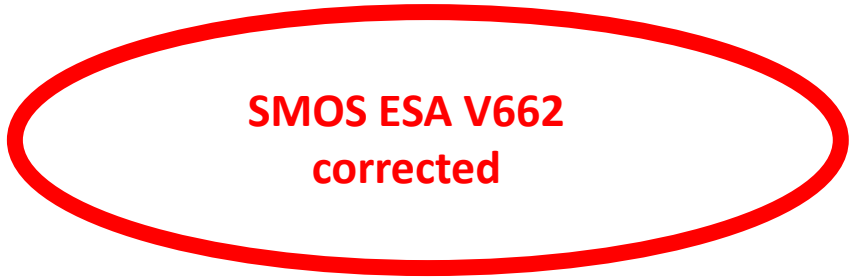
CATDS
CPDC - Corrected - *Monthly*



CEC LOCEAN Corrected – *18 days*



Differences & Pro/Cons of products: http://www.catds.fr/Resources/Documentation



Main changes:

- **Tb bias removal near land**
- **Improved RFI filtering** *(elimination of snapshots with hot Tbs identified from successive snapshots)*

Main changes:

- **SSS bias removal near land**
- **Latitudinal-seasonal bias correction**

See P. Spurgeon's poster and R. Davies talk

smos.argans.co.uk

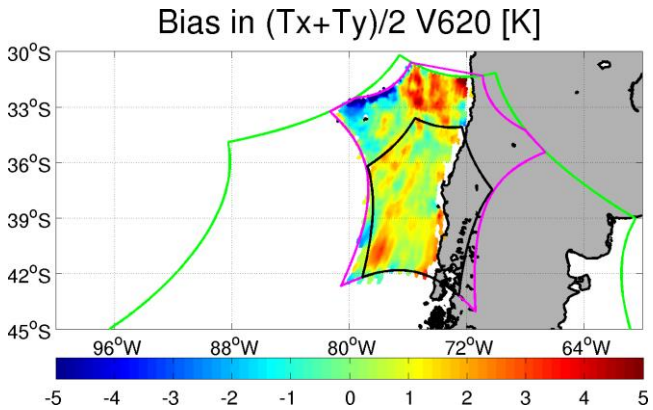
www.catds.fr

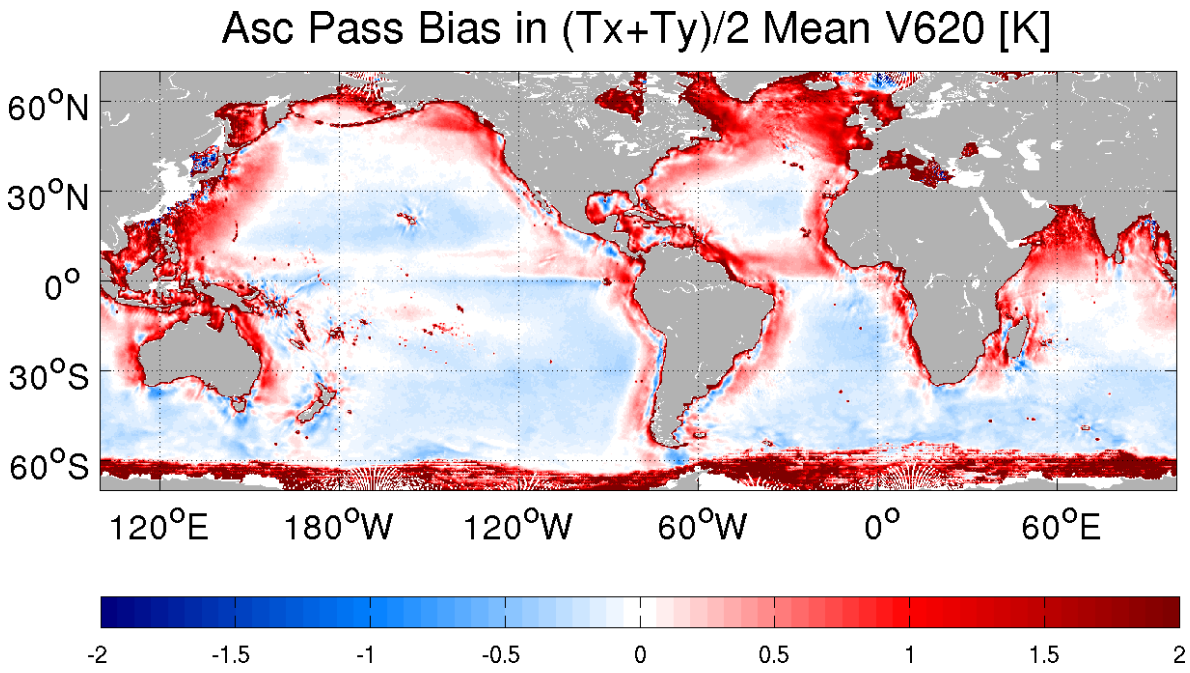
LAND CONTAMINATION CORRECTION IN ESA v662

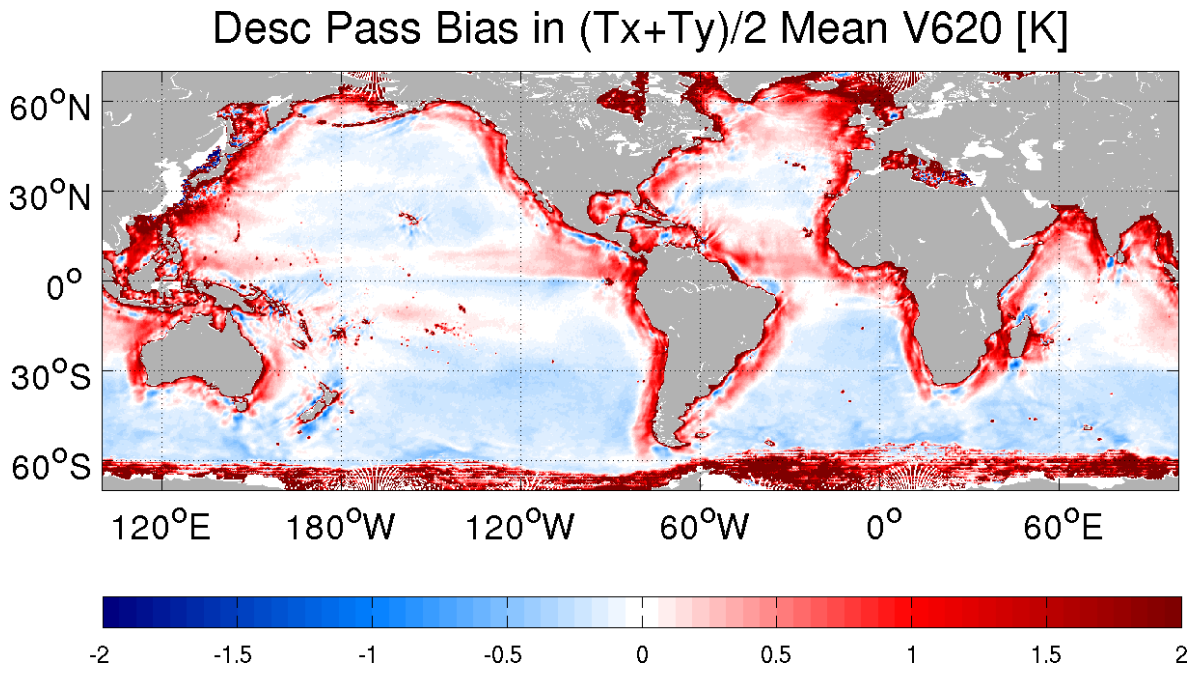
Empirical land contamination correction :

$$\Delta Tb(D,lat,lon,\xi,\eta),$$

where D is the pass direction and (ξ,η) are the director cosine coordinates. Reference SSS is WOA09.





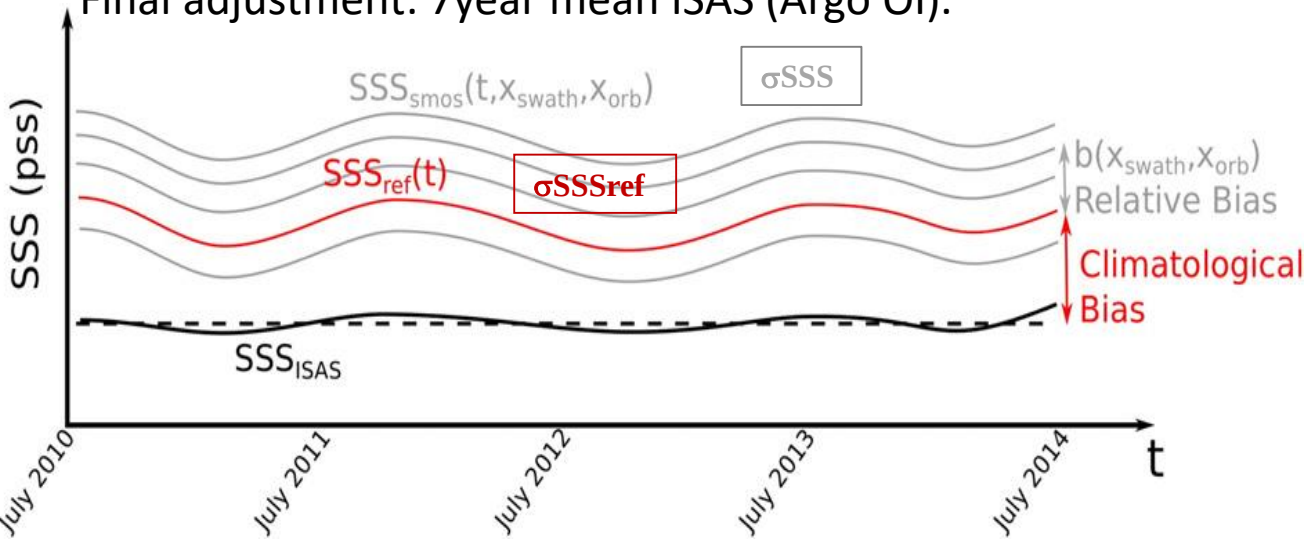


LAND CONTAMINATION CORRECTION IN CATDS RE05

Empirical land contamination correction :

ΔSSS(D,Xswath,lat,lon)

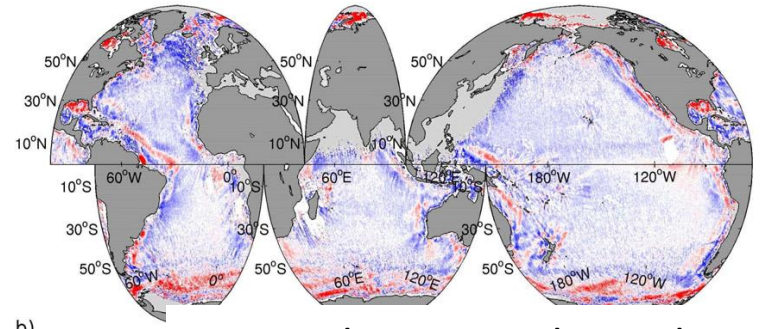
- D is the pass direction. Self consistency criteria on SMOS SSS low frequency ariability in different across track locations. Final adjustment: 7year mean ISAS (Argo OI).



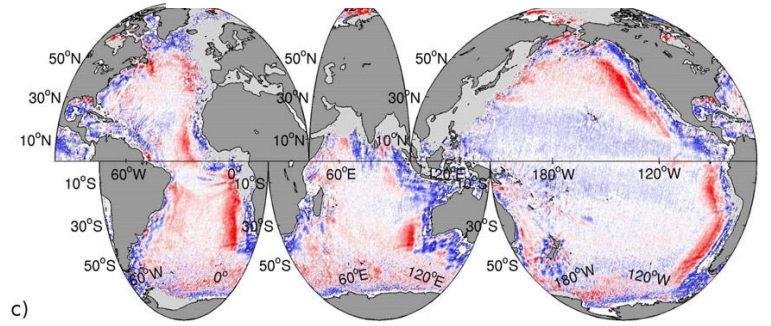
Kolodziejczyk et al. RSE 2016.
& CEC-LOCEAN debias v0

Median SSS bias

Ascending, Xswath=0



Descending, Xswath=225km

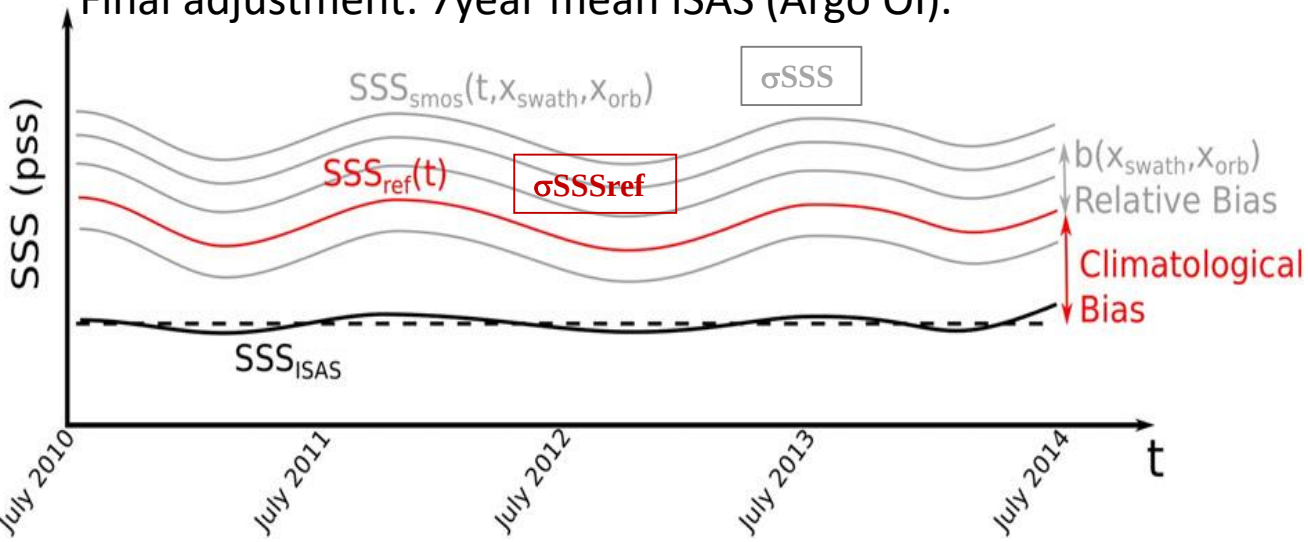


LAND CONTAMINATION CORRECTION IN CATDS RE05

Empirical land contamination correction :

$$\Delta SSS(D, Xswath, lat, lon)$$

- D is the pass direction. Self consistency criteria on SMOS SSS low frequency ariability in different across track locations. Final adjustment: 7year mean ISAS (Argo OI).



Kolodziejczyk et al. RSE 2016.
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Median SSS bias

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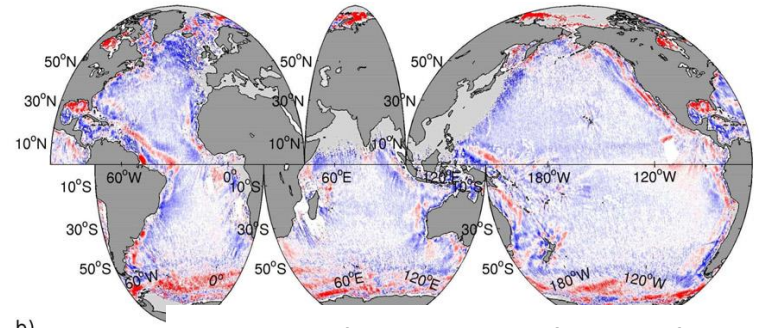
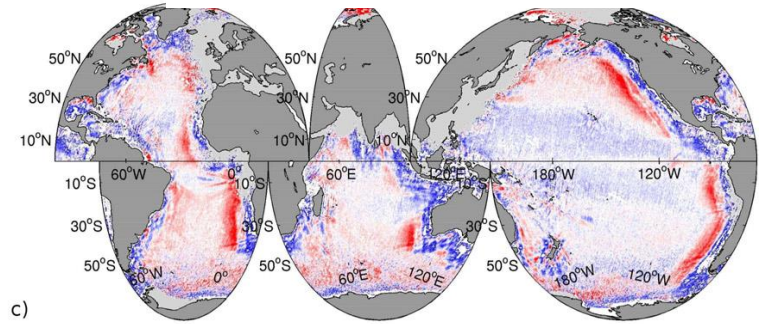


Descending, Xswath=225km

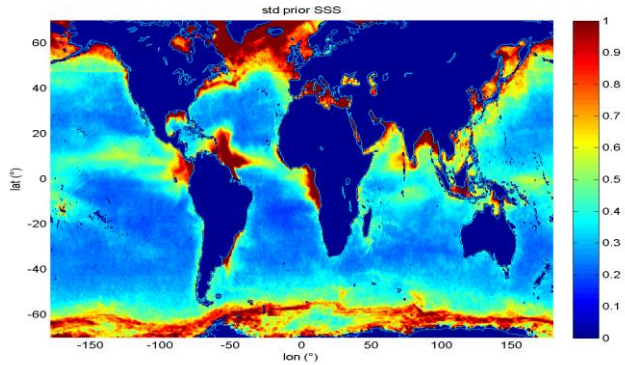


With respect to Kolodziejczyk et al. RSE 2016, RE05 versions:

Seasonal latitudinal bias correction **(reference: the less biased Xswath)**

Bias computed over 7 years

Improved filtering taking into account SMOS derived SSS natural variability



Method of validation

- SMOS SSS ascending + descending orbits 2010-2017 compared with:

- Argo OI (ISAS fields (Gaillard et al. 2016)) :
  - Difference between monthly means, std(difference), frequency of significant differences and of significant improvements

- Ship data
  - Ships of opportunity transects (from ORE SSS (Alory et al. 2016) and Ute Schüster (pers. Comm.)
  - 100km ship averages

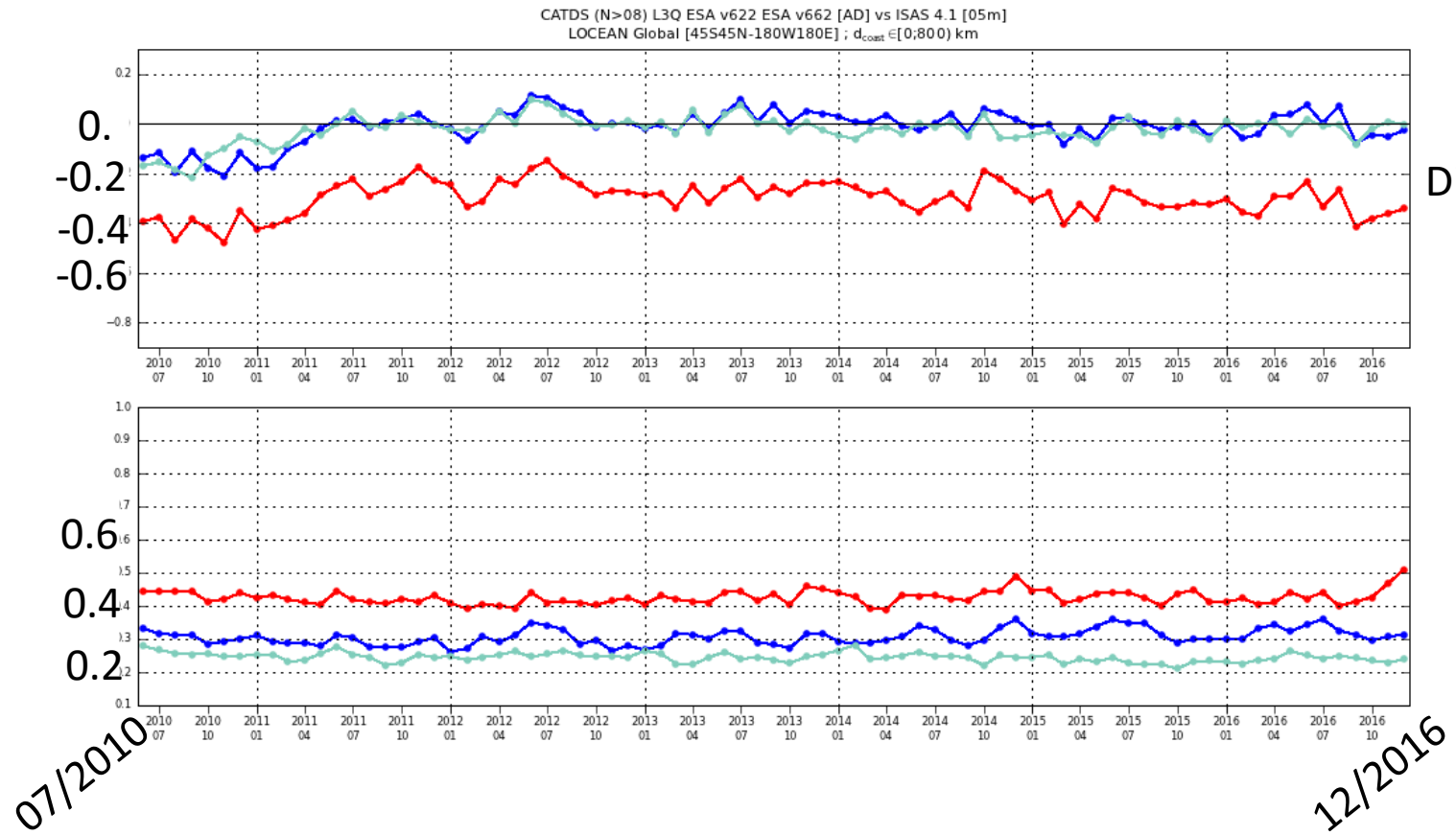
- SMAP SSS
  - JPL CAP v3
  - Weekly products

Biases correction in ESA and CATDS processings: major improvements

Comparisons of SMOS with Argo OI (ISAS) SSS

45S-45N - 0 to 800km from land

ESA v622 Corrected ESA v662 Corrected CATDS RE05

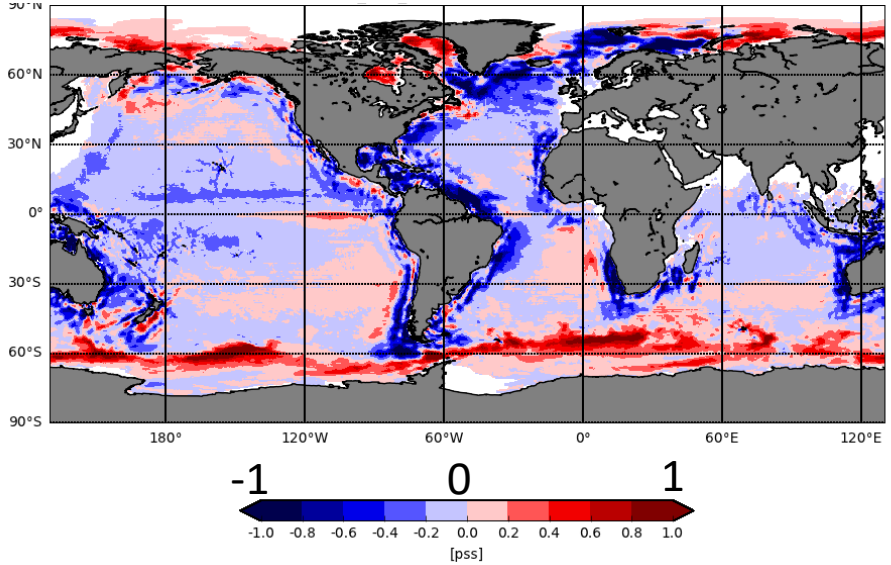


Further than 800km from land std(SMOS-ISAS) =0.2

SMOS averages 100x100km^2-1month

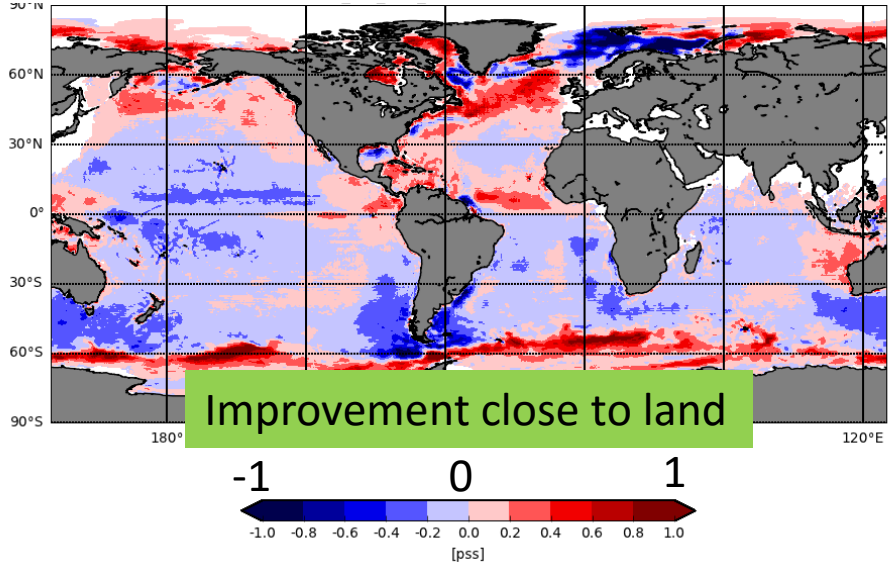
(SMOS SSS – ISAS SSS) 2010-2017

ESA V622

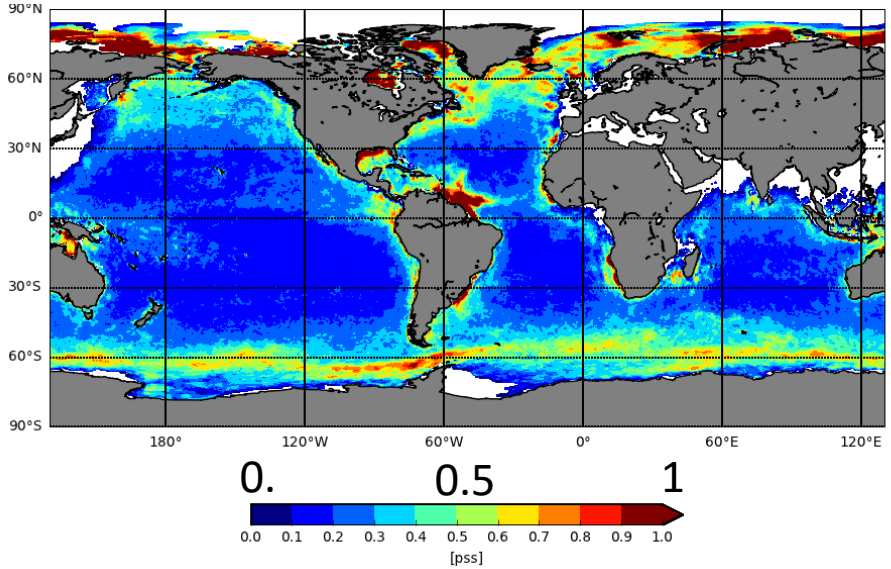


Mean difference

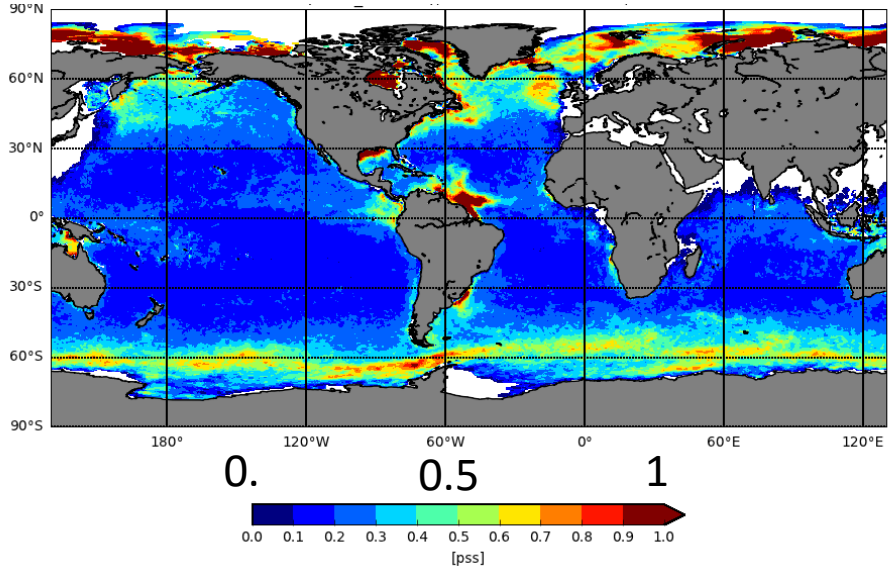
ESA V662corr



Improvement close to land

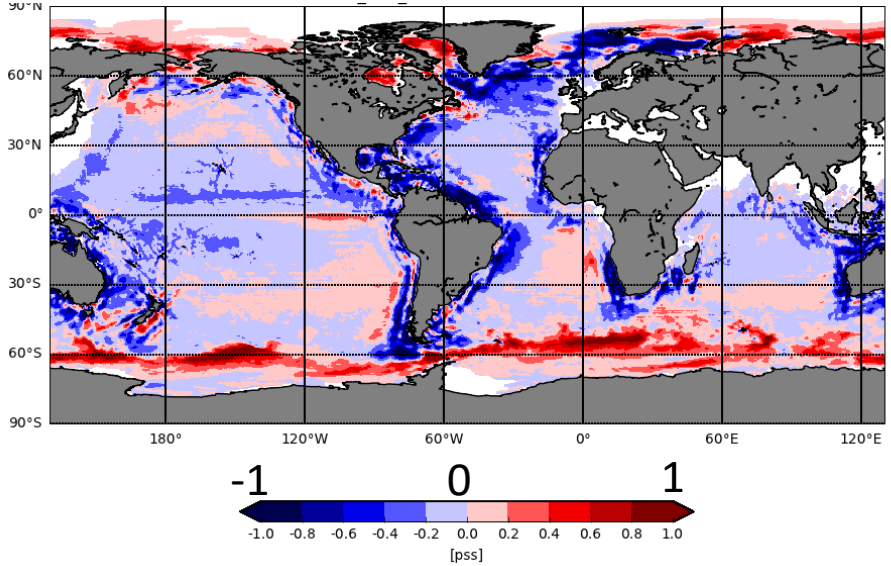


Std (difference)



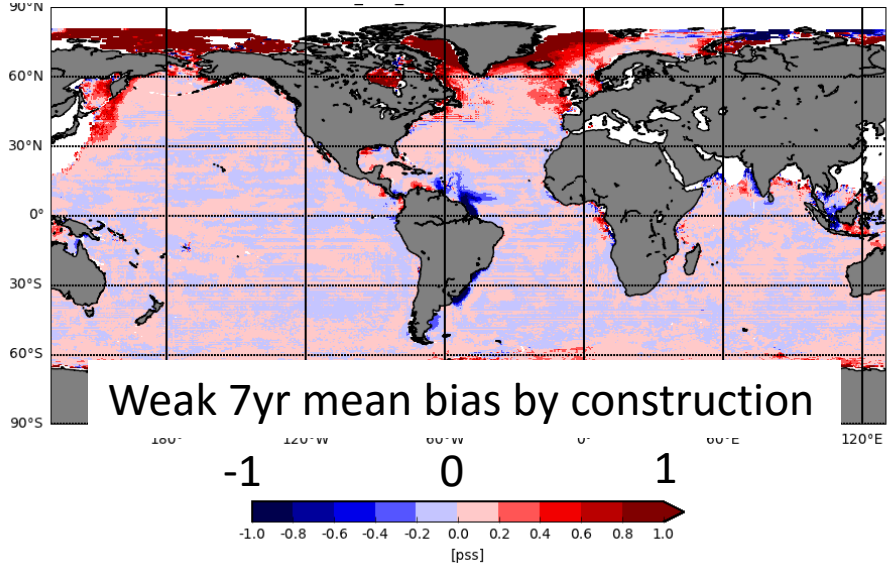
(SMOS SSS – ISAS SSS) 2010-2017

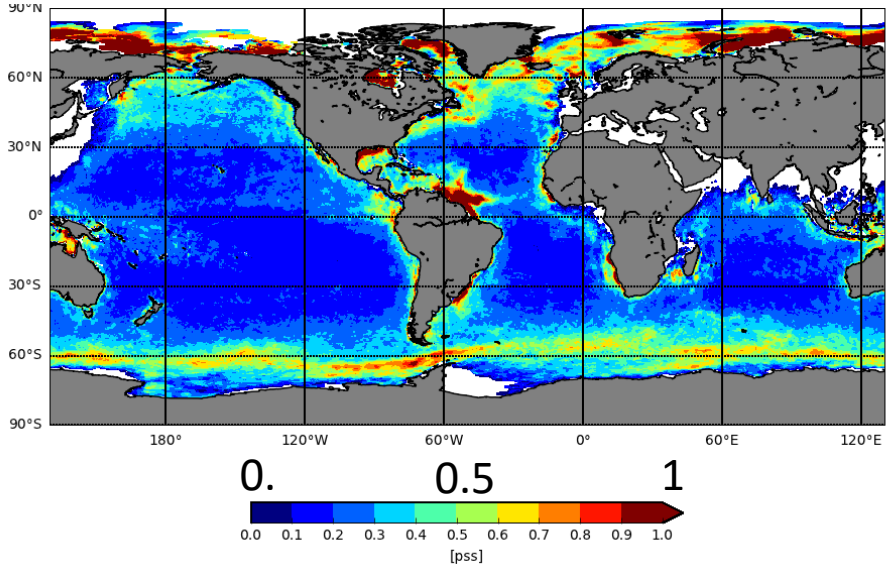
ESA V622



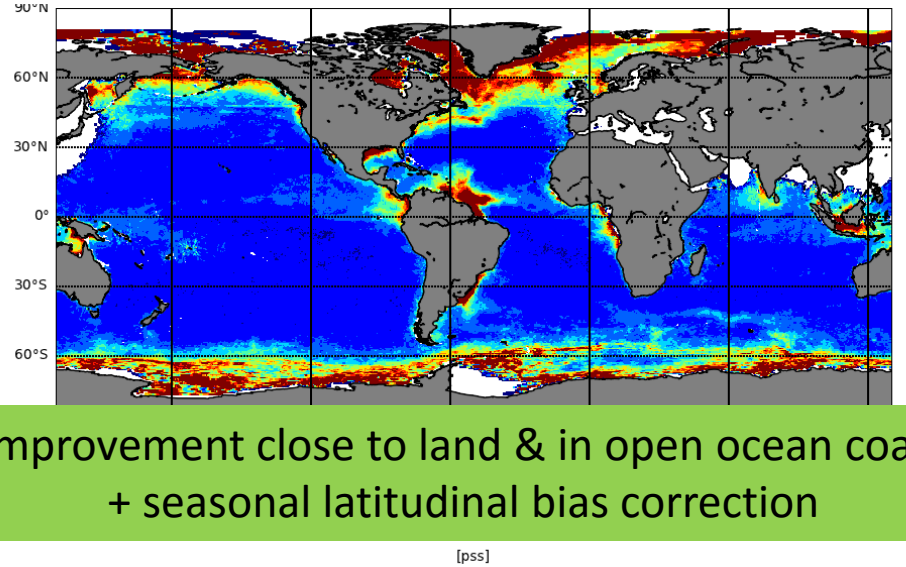
Mean difference

CATDS RE05 corr





Std (difference)

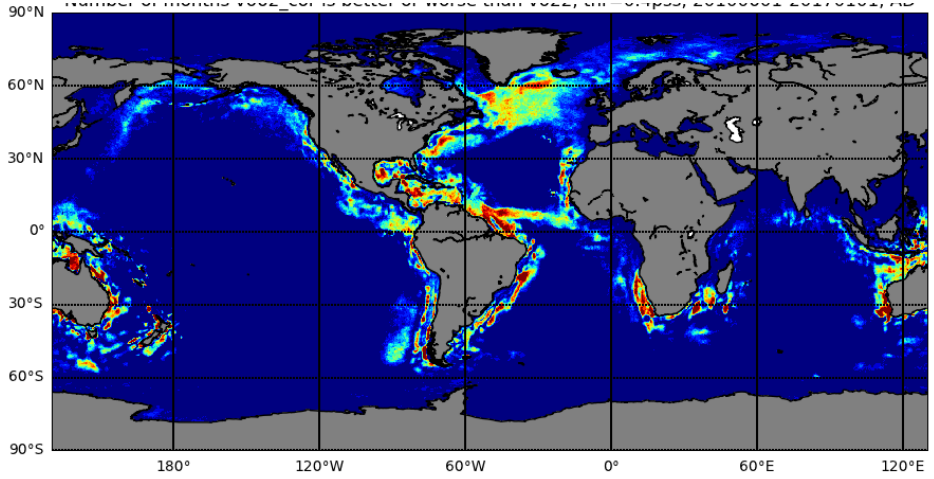


Improvement close to land & in open ocean coast
+ seasonal latitudinal bias correction

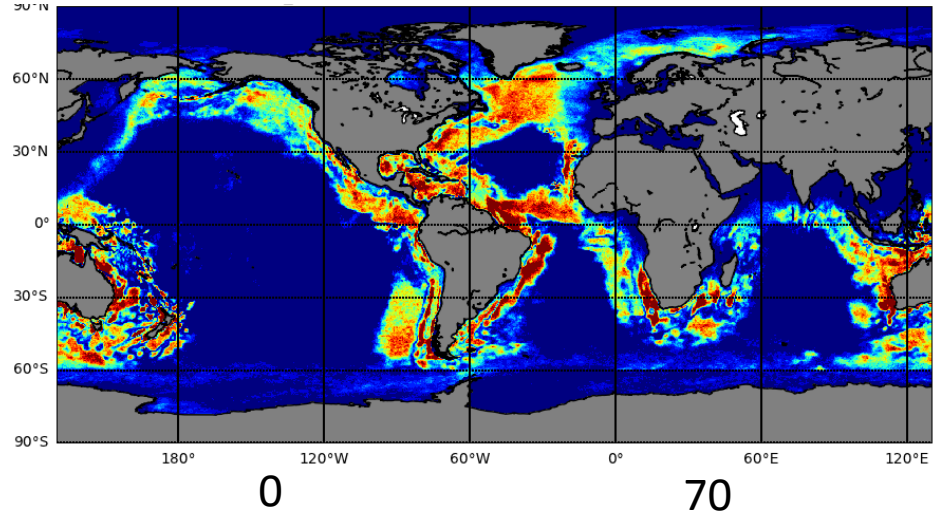
Nb of months with significant changes wrt v622

ESA

|**SSSv662corr**-SSSv622| > 0.4pss



|**SSSv662corr**-SSSv622| > 0.2pss

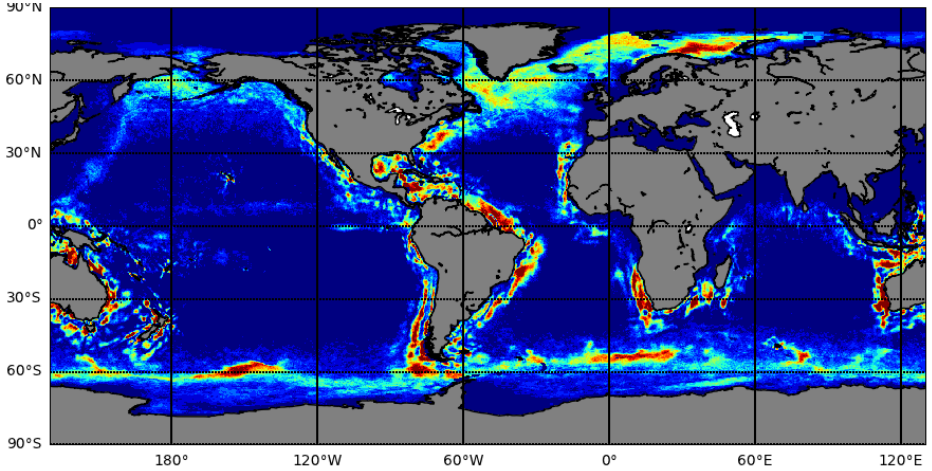


|difference|>0.4

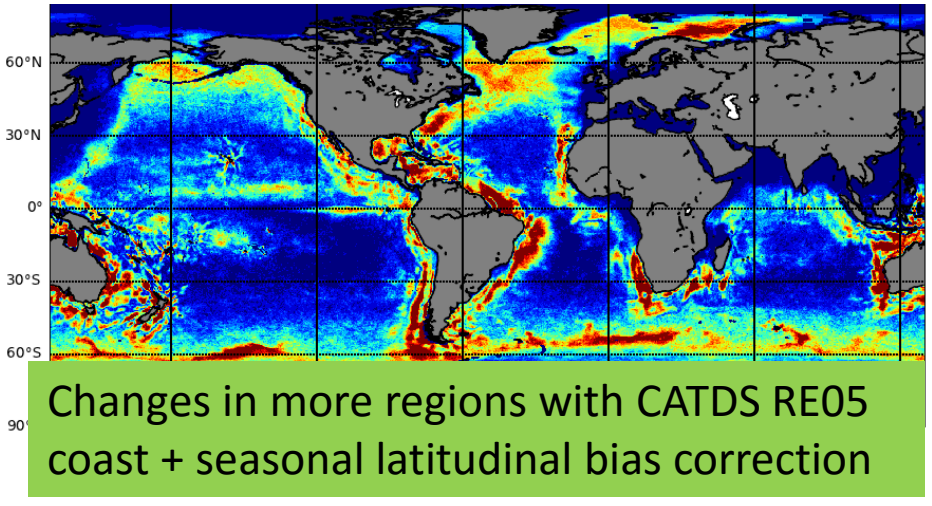
|difference|>0.2

CATDS

|**SSSRE05corr**-SSSv622| > 0.4pss



|**SSSRE05corr**-SSSv622| > 0.2pss



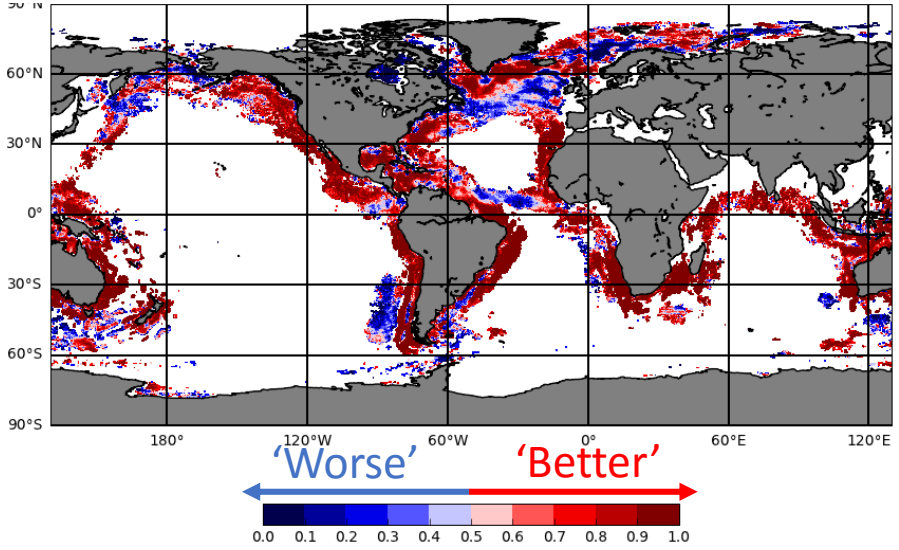
Changes in more regions with CATDS RE05 coast + seasonal latitudinal bias correction

% of months with SMOS SSS closer to ISAS (‘better’)

ESA

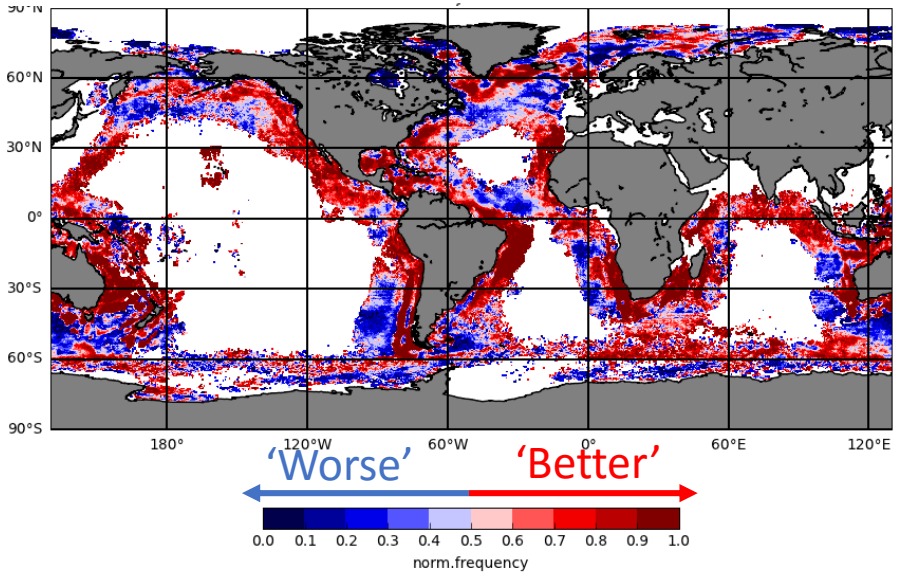
‘Better’ if:

|**SSSv662corr** – SSSisas|< |SSSv622 – SSSisas)|



|difference|>0.4

‘Better’ close to coast

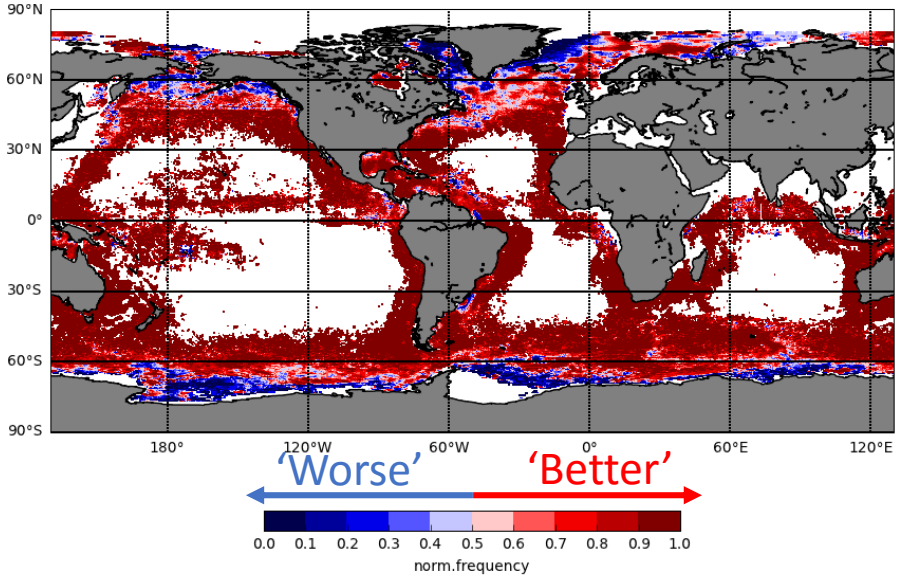


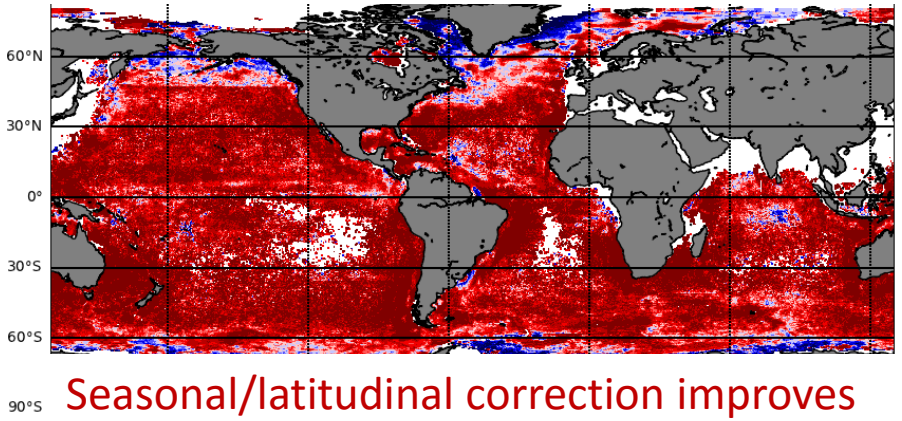
|difference|>0.2

CATDS

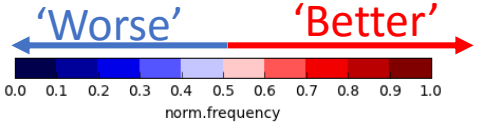
‘Better’ if:

|**SSSRE05corr** – SSSisas|< |SSSv622 – SSSisas)|





Seasonal/latitudinal correction improves

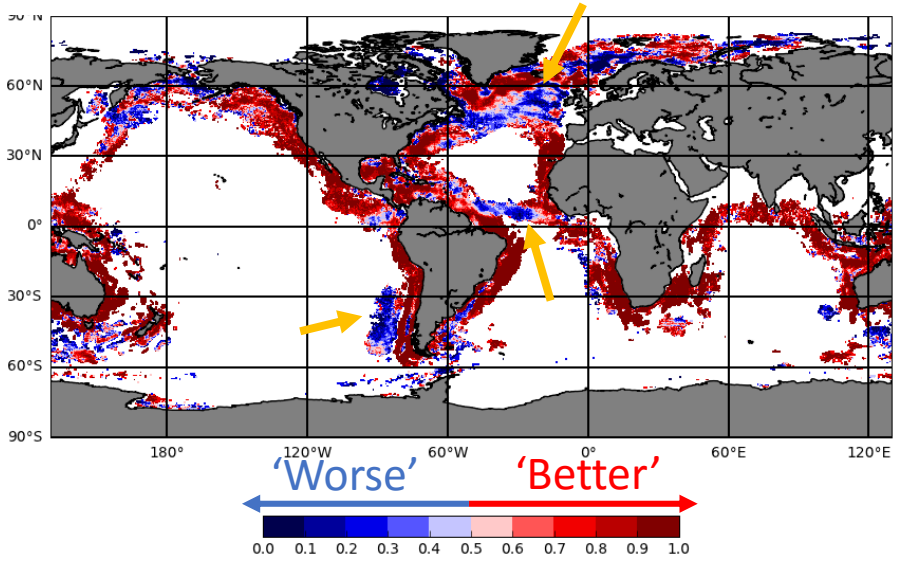


% of months with SMOS SSS closer to ISAS (‘better’)

ESA

‘Better’ if:

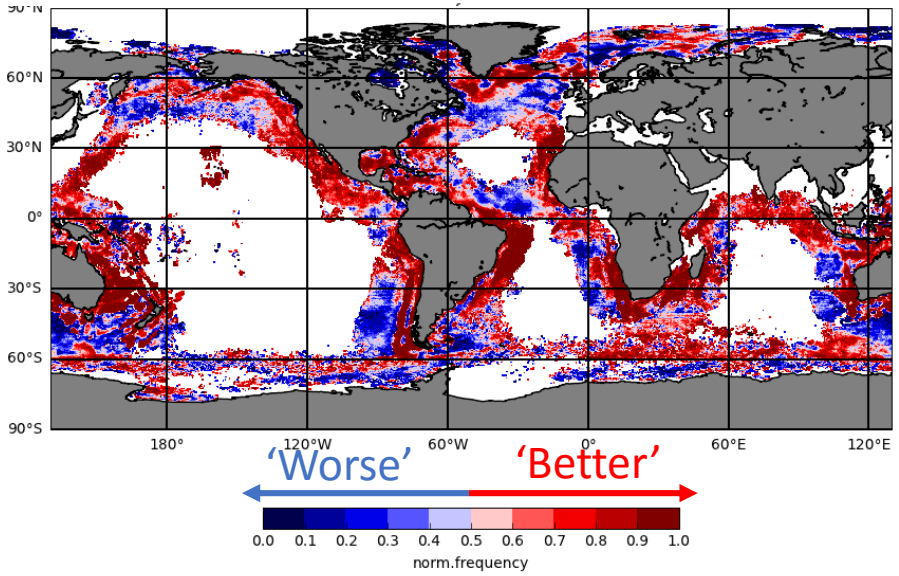
|**SSSv662corr** – SSSisas|< |SSSv622 – SSSisas)|



|difference|>0.4

‘Better’ close to coast

Some degradation (e.g. high latitudes (RFI, ice))

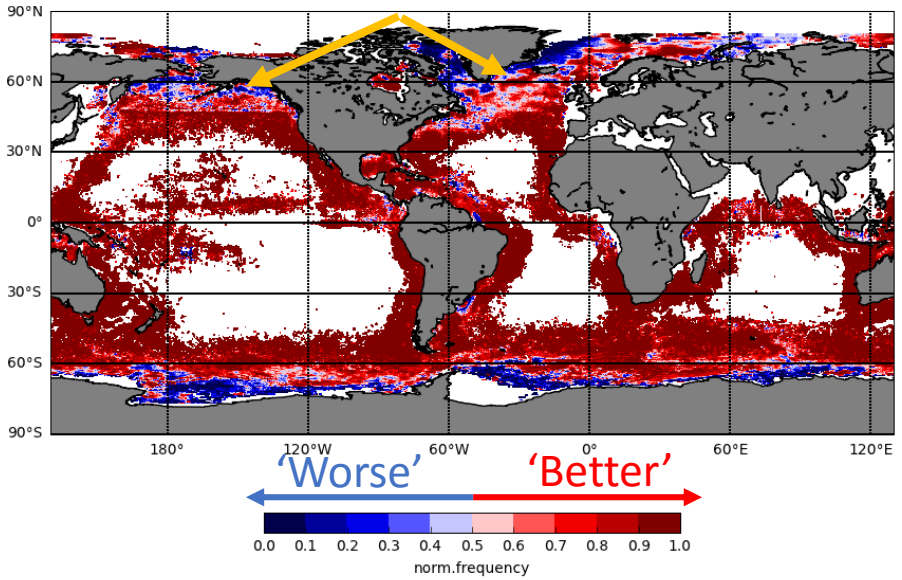


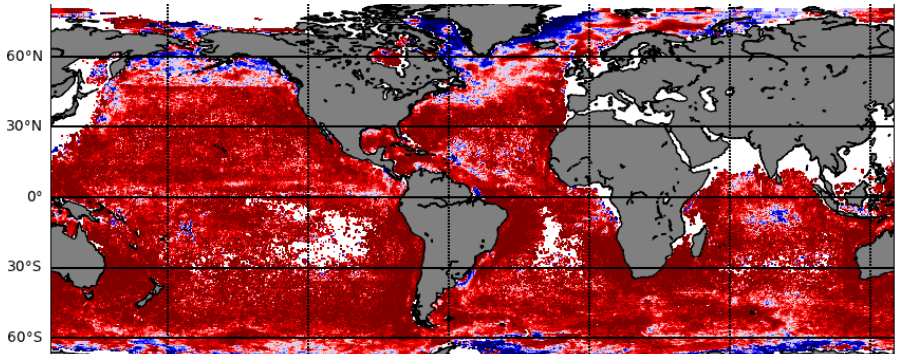
|difference|>0.2

CATDS

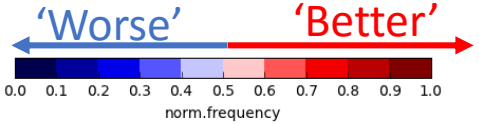
‘Better’ if:

|**SSSRE05corr** – SSSisas|< |SSSv622 – SSSisas)|

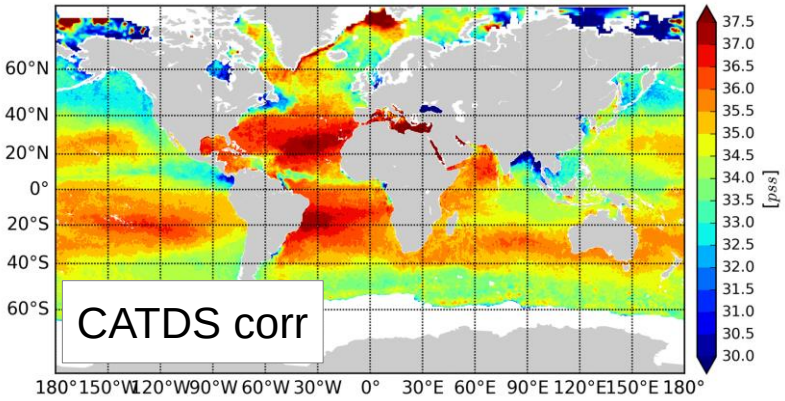


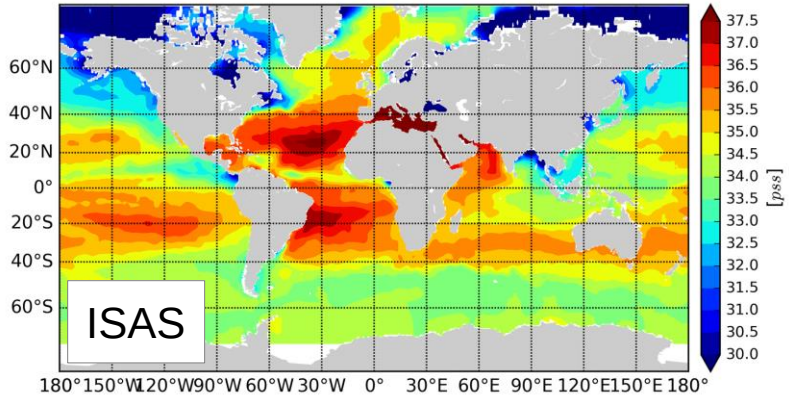


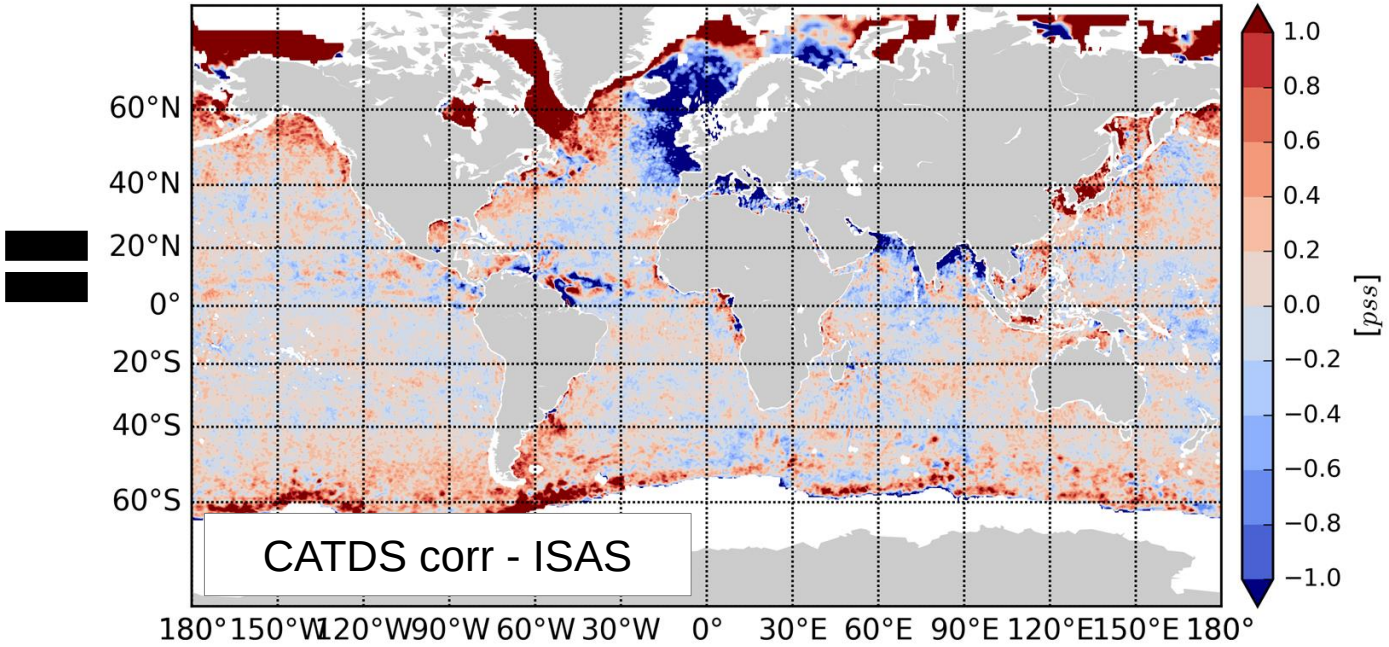
Seasonal/latitudinal correction improves



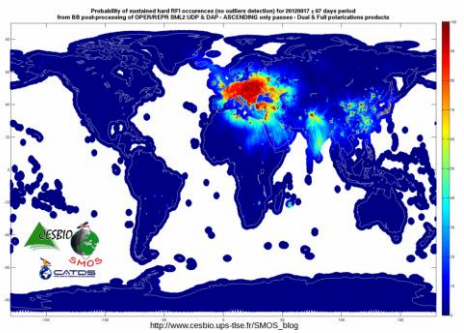
SMOS CATDS corr (5 October 2012)





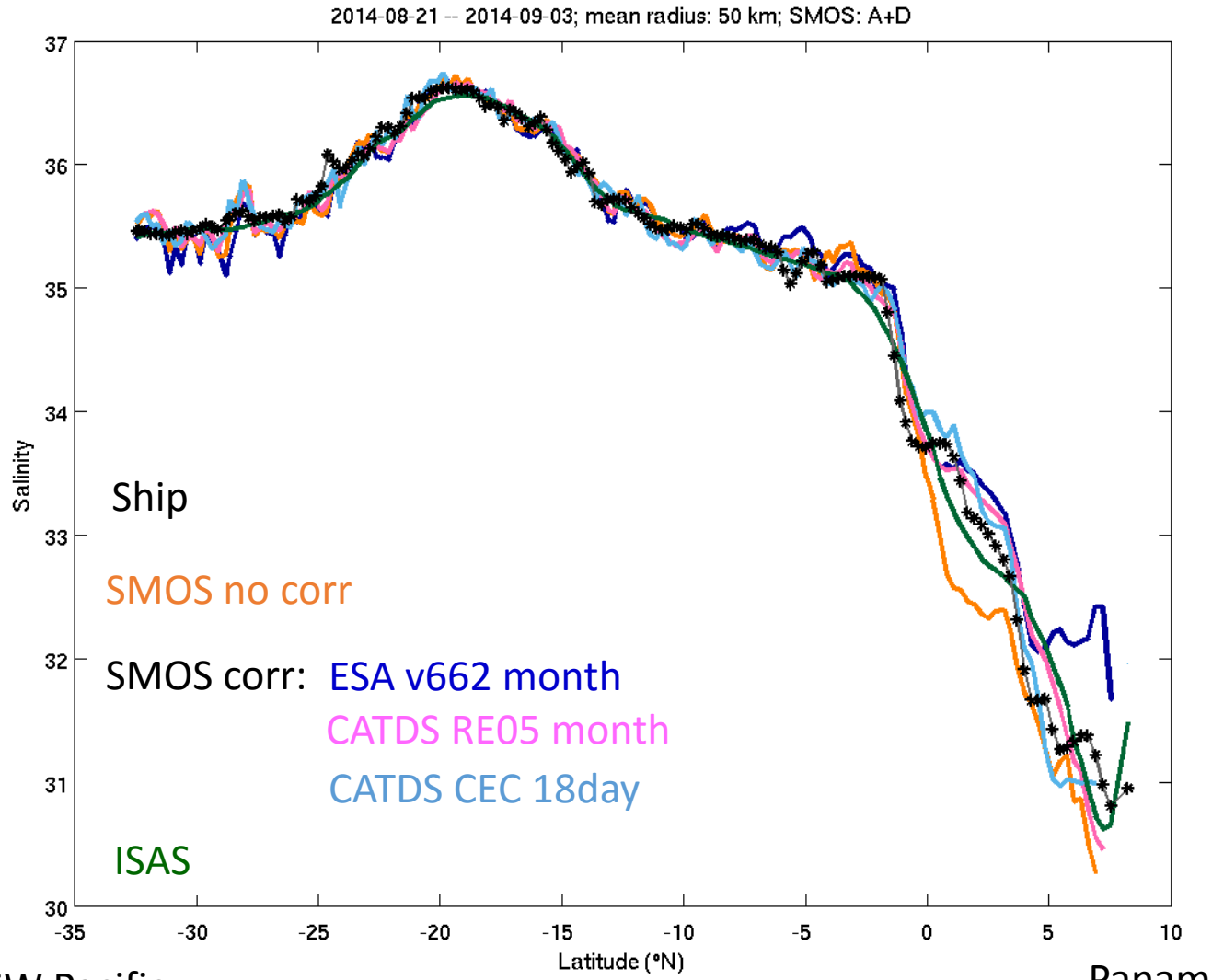


Fall 2012

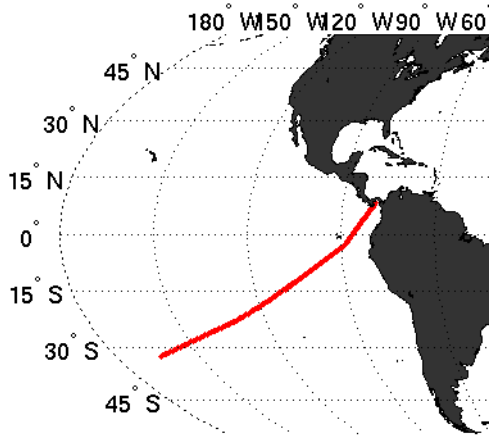


Comparison with ship data

South Pacific Ocean transect



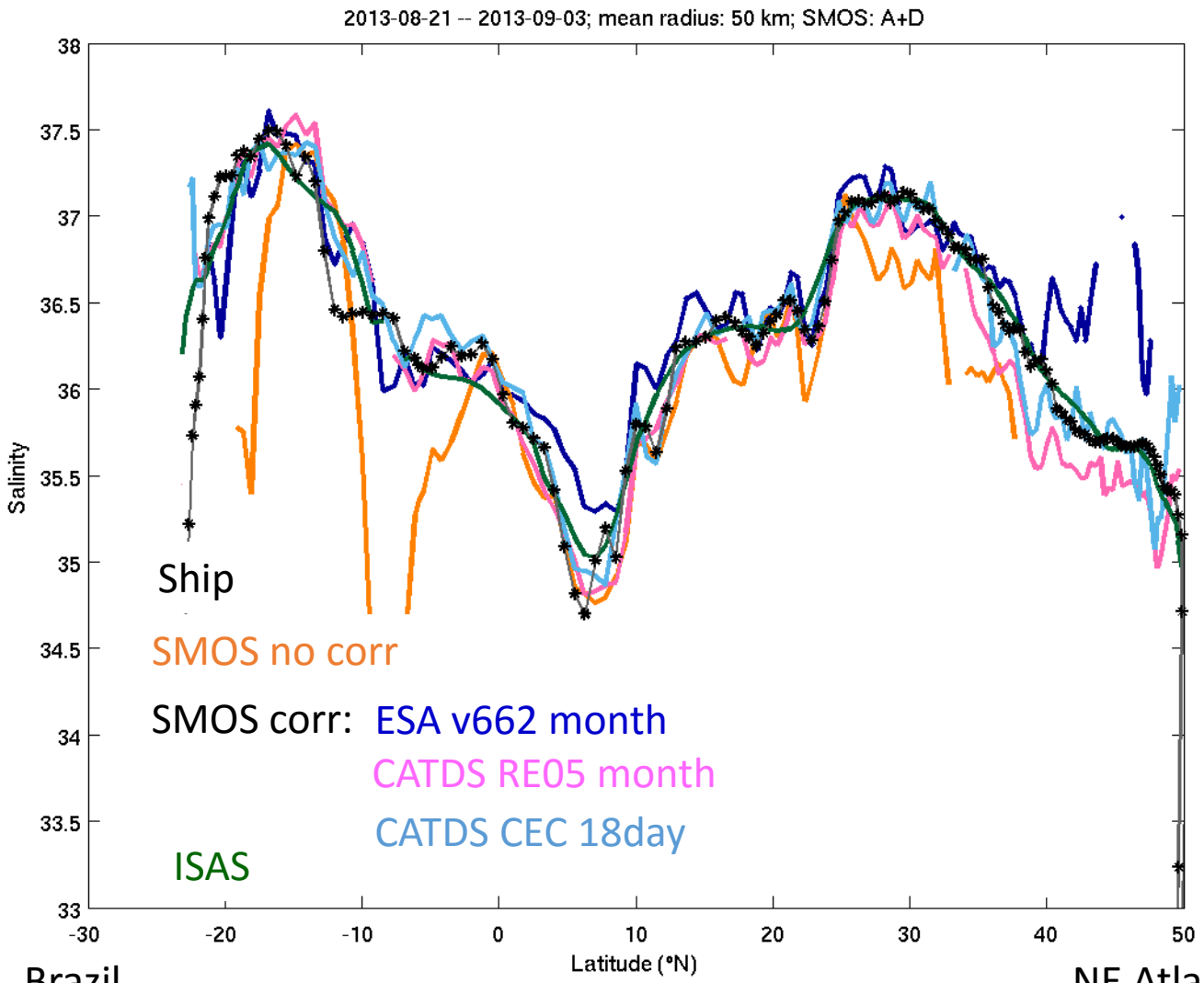
SW Pacific



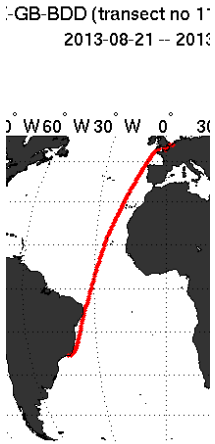
Panama

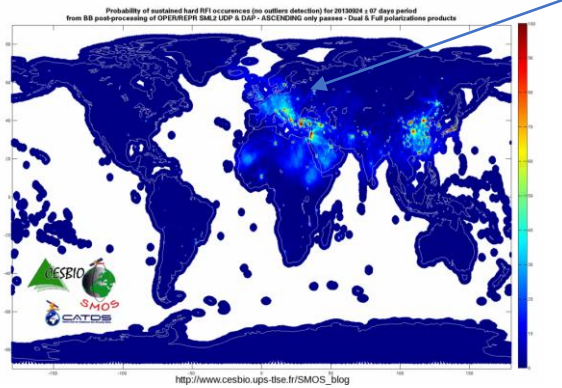
Corrected versions better than non corrected

Atlantic Ocean transect in 2013



Brazil

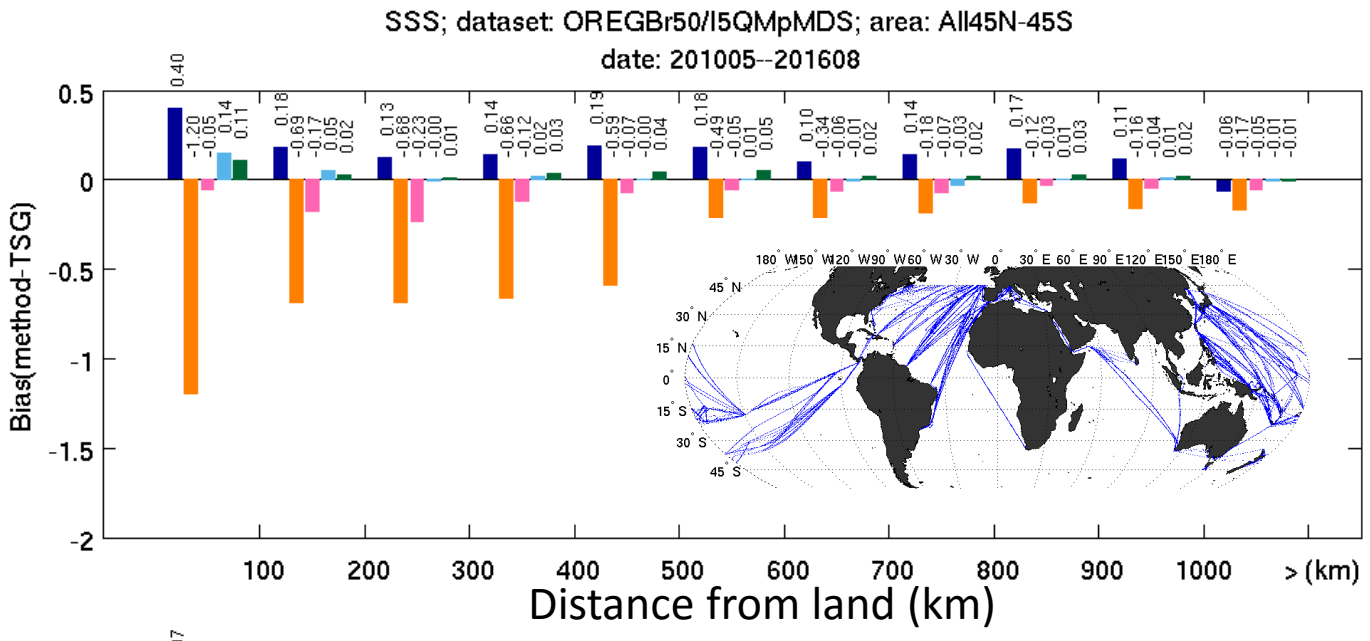


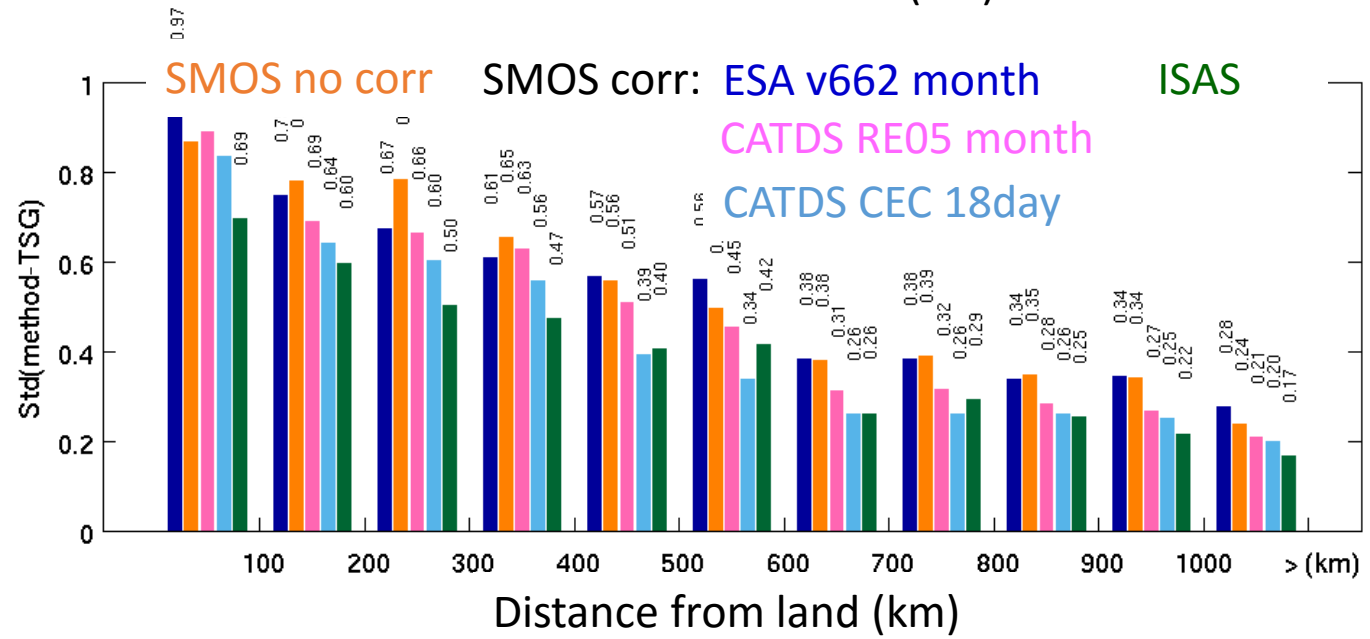


A moderate RFI period in N. Atl

NE Atlantic (often RFI polluted)

Ship comparisons - 100km averages – 45N-45S



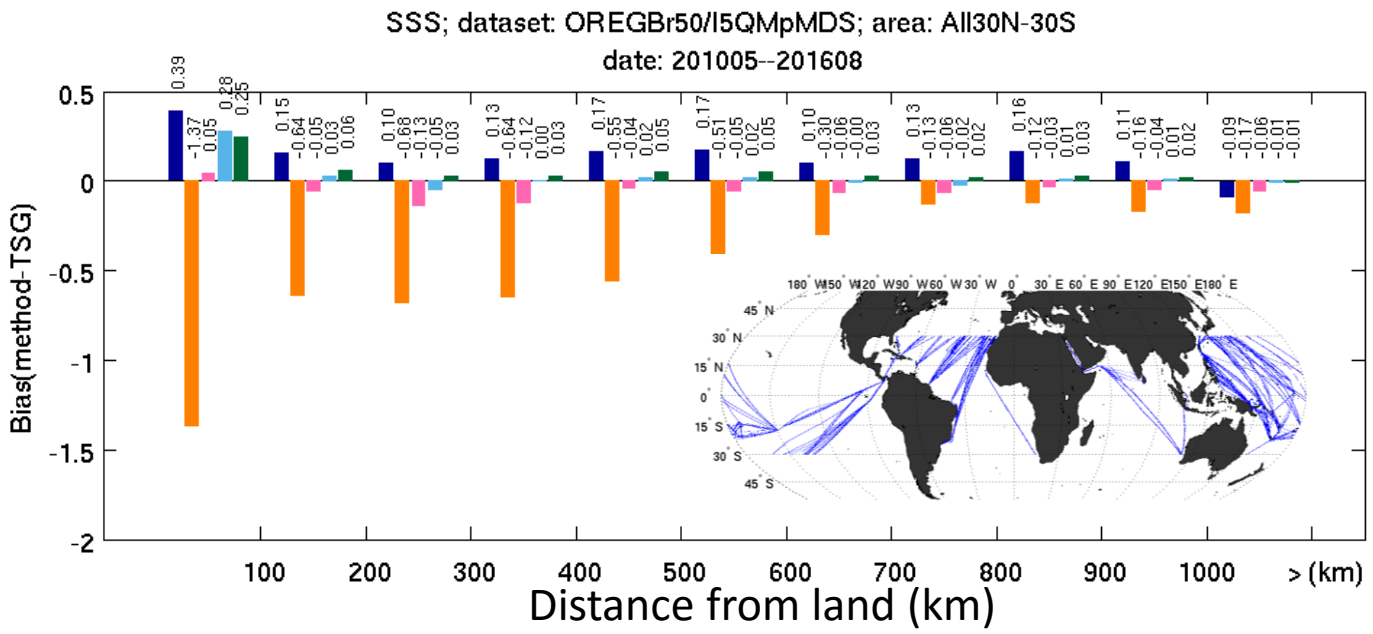


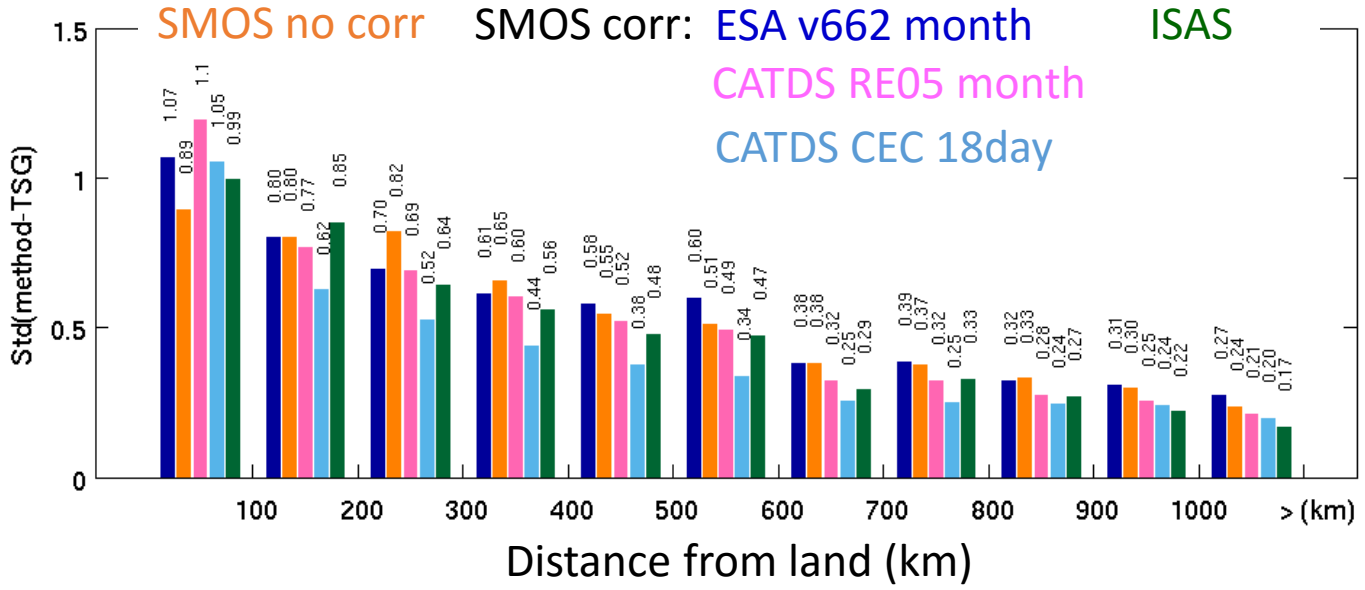
Biases & std reduced with corrected versions

Better statistics when considering 18day averages

In open ocean std~0.2pss

Ship comparisons - 100km averages – 30N-30S





Biases & std reduced with corrected versions

Better statistics when considering 18day averages

Std with CATDS 18day between 100km and 800km from land (0.6-0.2pss) is less than std with ISAS

In open ocean std~0.2pss

SMOS CATDS RE05 SSS and SMAP SSS

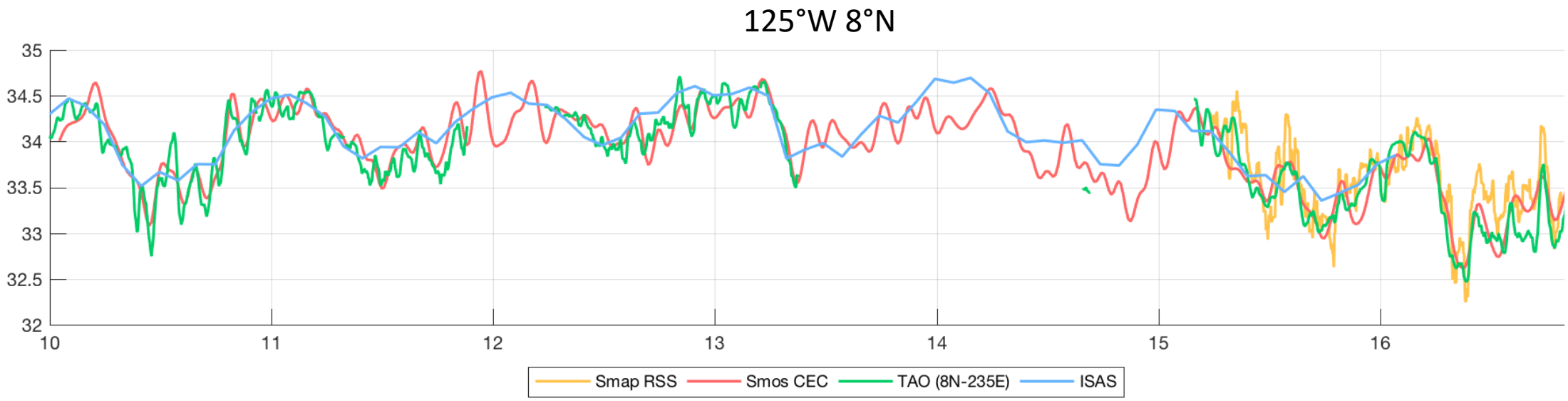
-Comparison with TAO
-Regions with large natural variability

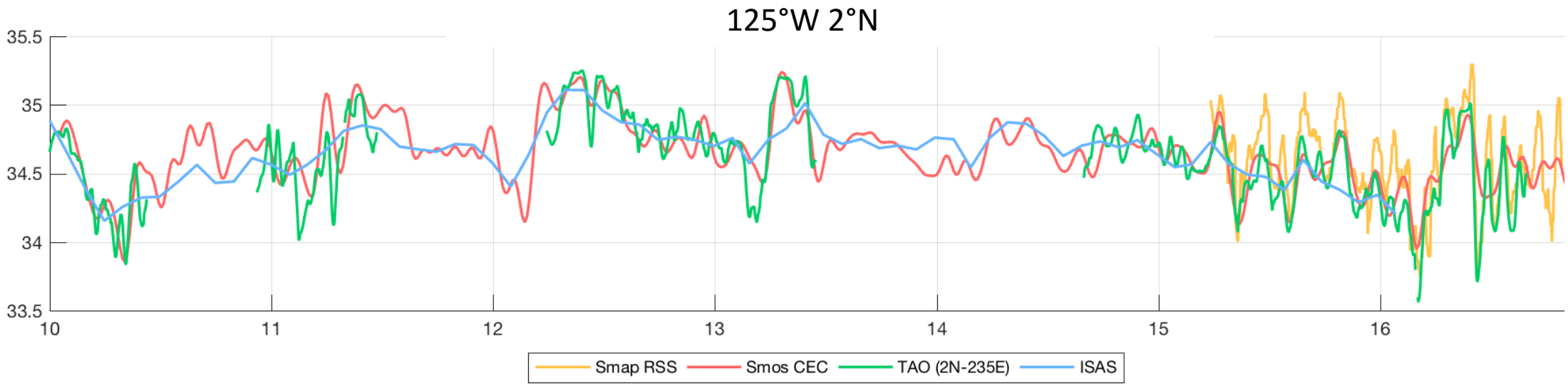
SMOS CATDS RE05 SSS and SMAP SSS

-Comparison with TAO

-Regions with large natural variability

Examples of TAO-SMOS-SMAP-ISAS comparison





SMOS CATDS RE05 SSS and SMAP SSS

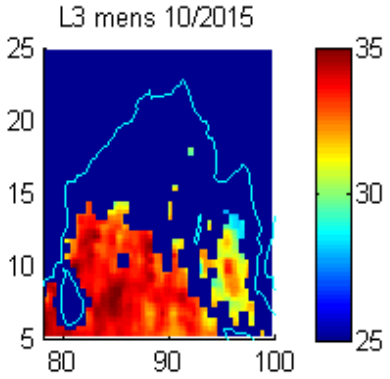
-Comparison with TAO

-Regions with large natural variability

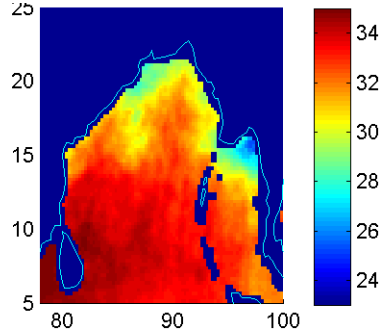
Evolution of bias correction at CATDS:

The different steps

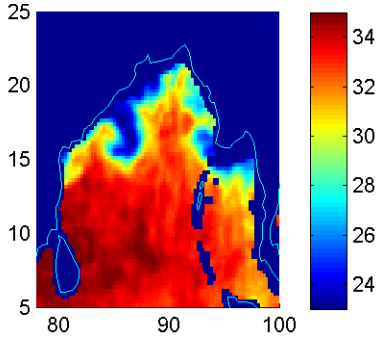
No debiasing, RE04



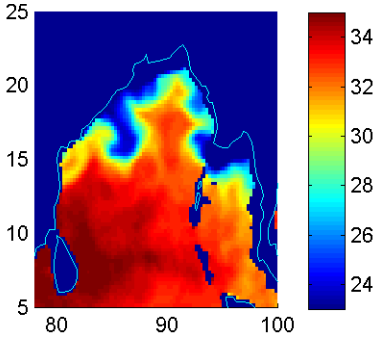
CEC LOCEAN Debias v1



CEC LOCEAN Debias v2



SMAP



Bias correction + data filtering

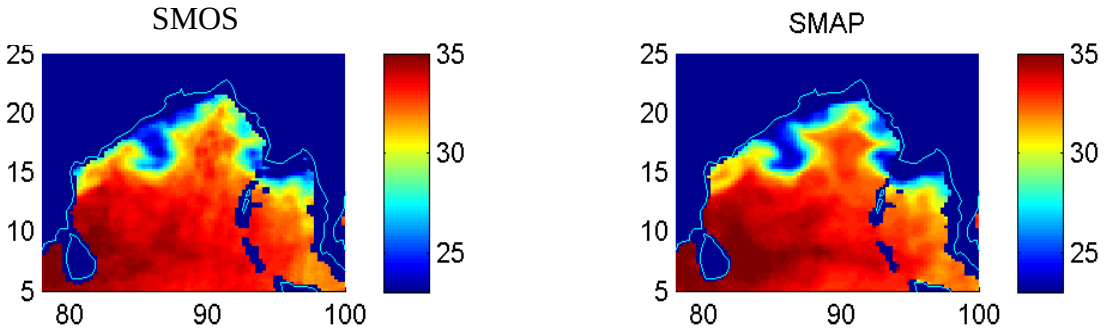
Data filtering taking into account natural variability

Validation with respect to SMAP

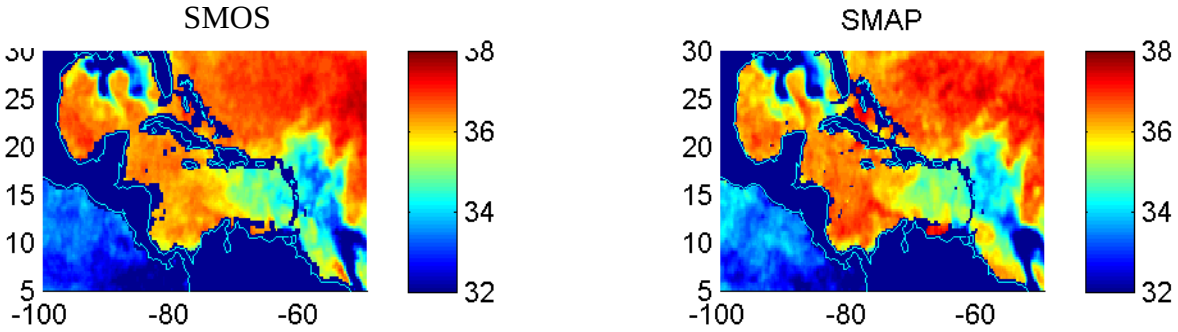
CATDS CPDC RE05 corrected (CSQ3 product)

Freshwater river plumes from SMOS and SMAP
=> monitoring at ~50km resolution

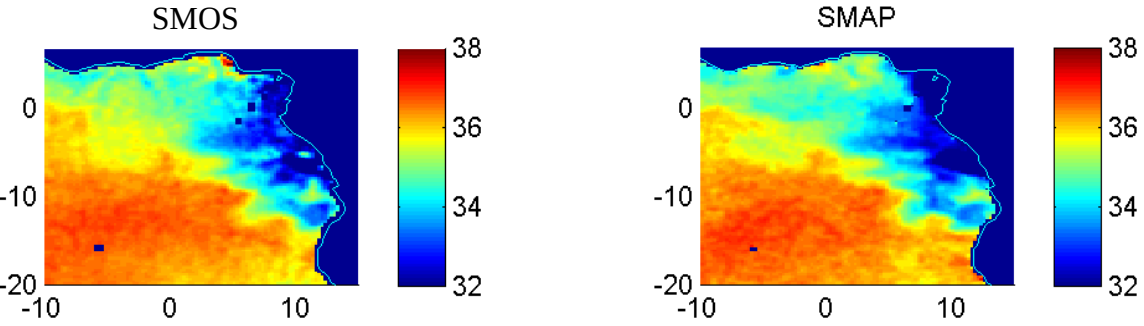
Bay of Bengal



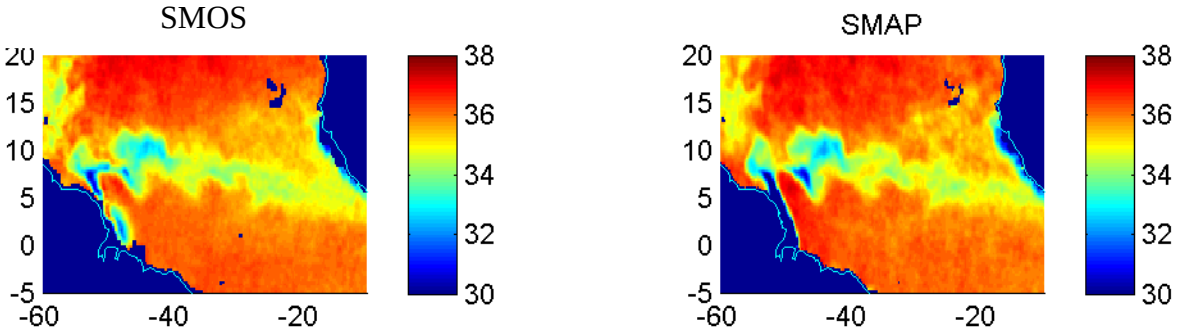
Gulf of Mexico



Eastern tropical Atlantic

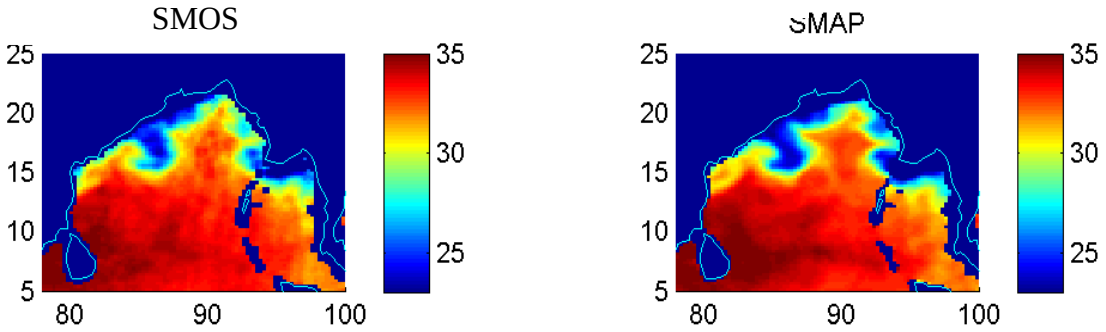


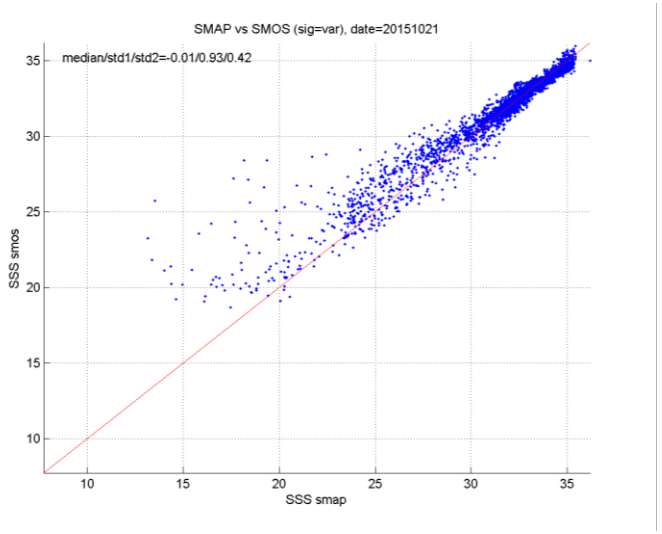
Amazone plume

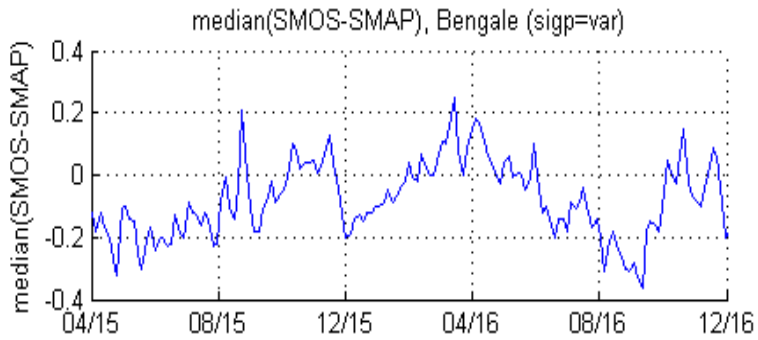


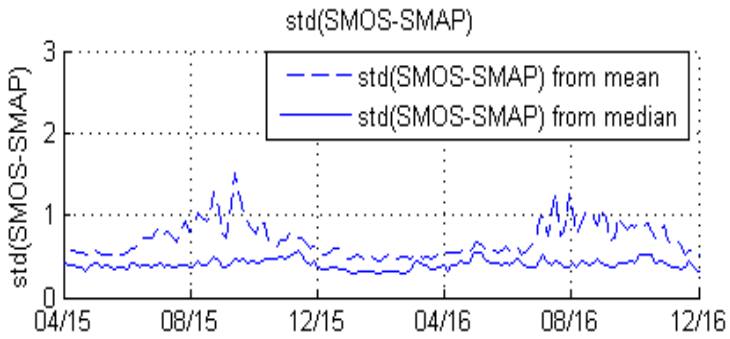
Freshwater river plumes from SMOS and SMAP => monitoring at ~50km resolution

Bay of Bengal

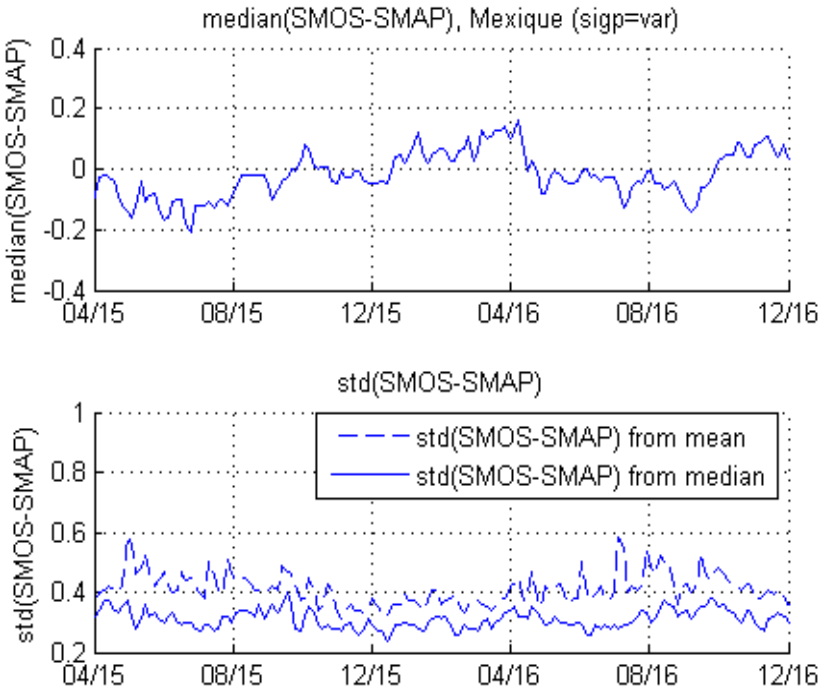




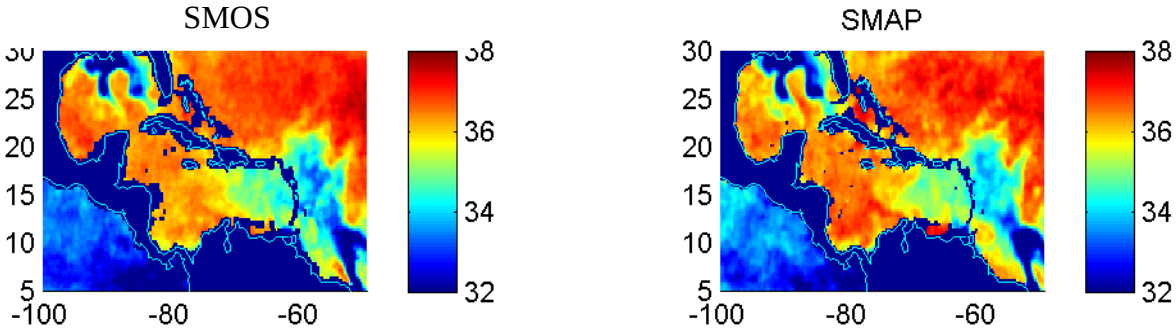


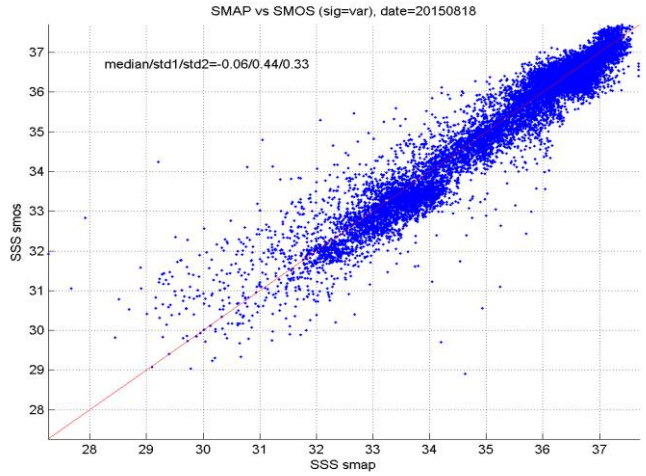


Freshwater river plumes from SMOS and SMAP => monitoring at ~50km resolution

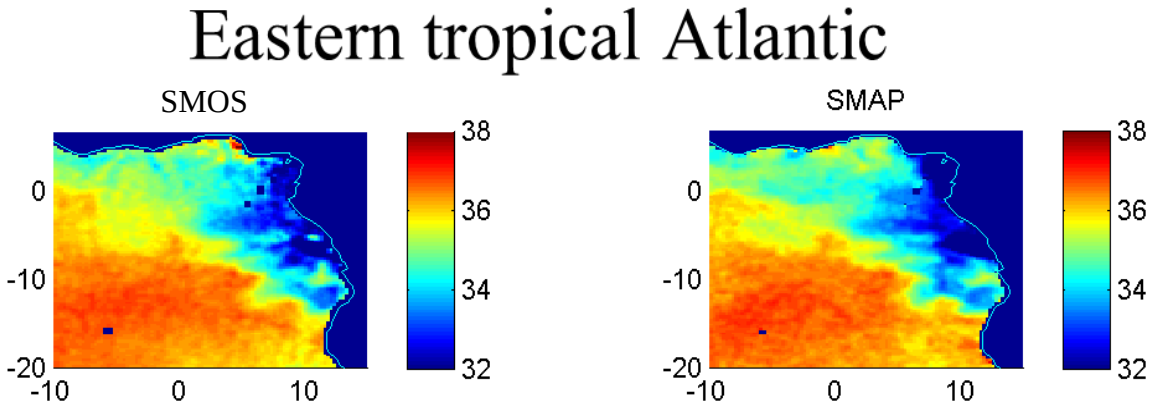


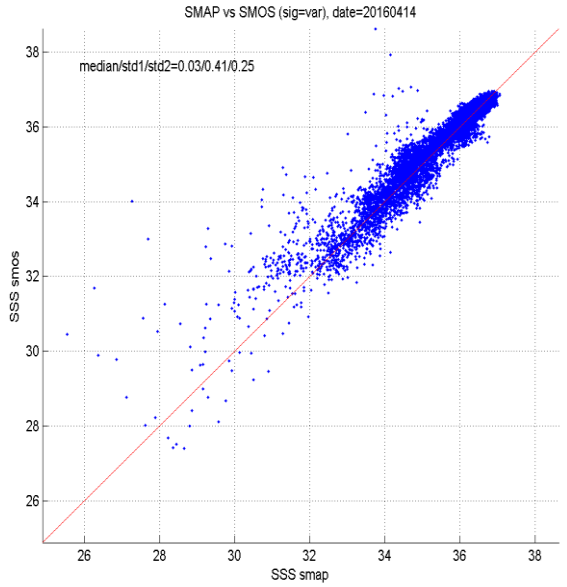
Gulf of Mexico

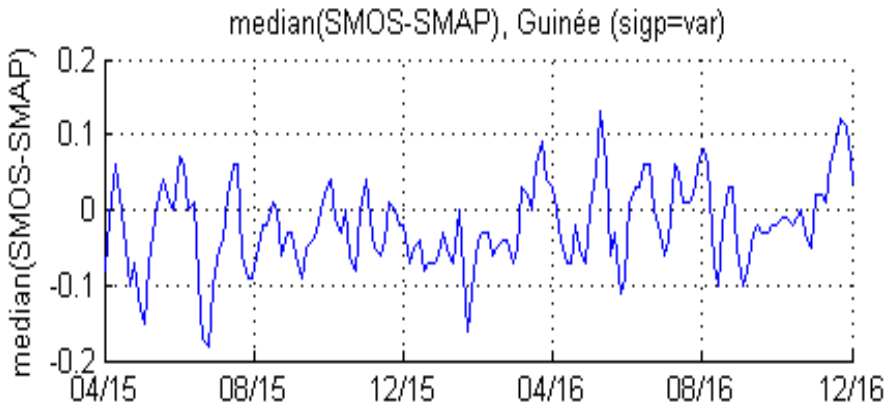


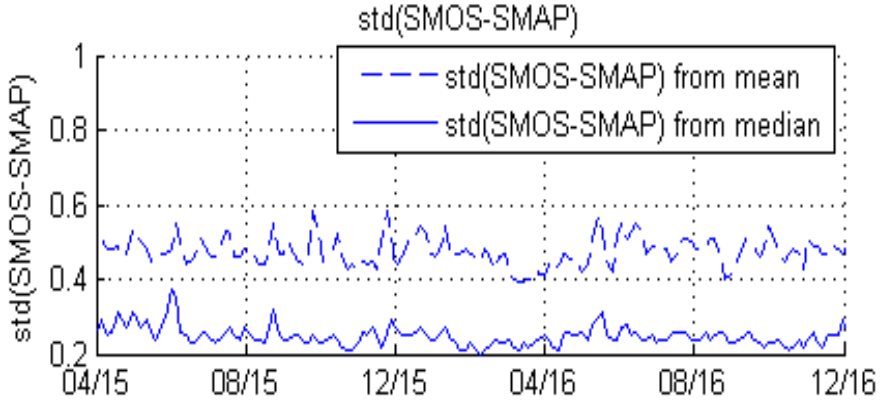


Freshwater river plumes from SMOS and SMAP
=> monitoring at ~50km resolution

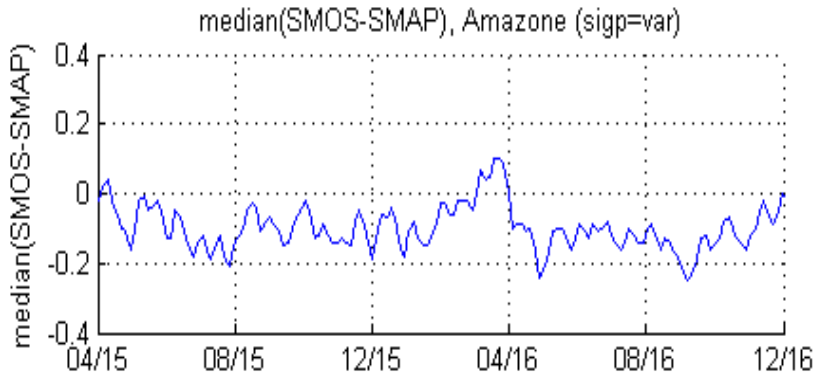


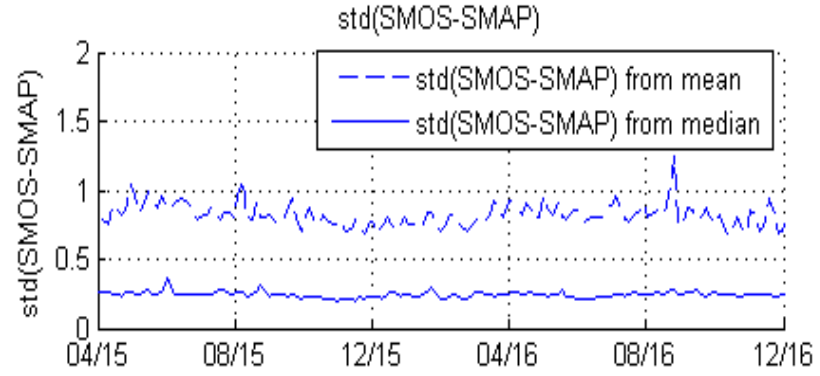




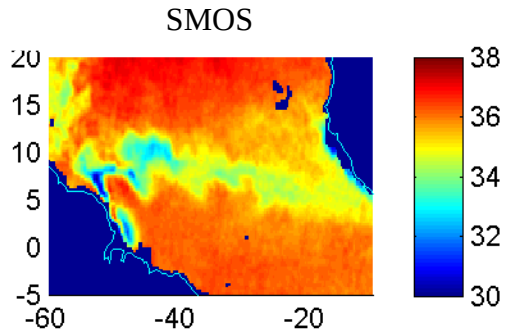


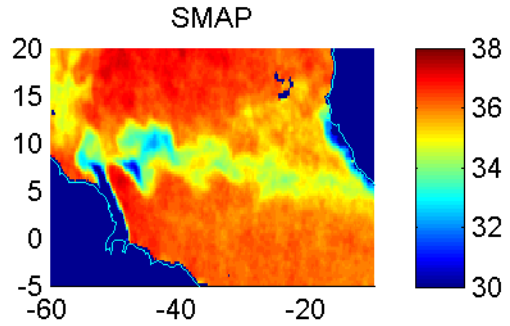
Freshwater river plumes from SMOS and SMAP => monitoring at ~50km resolution

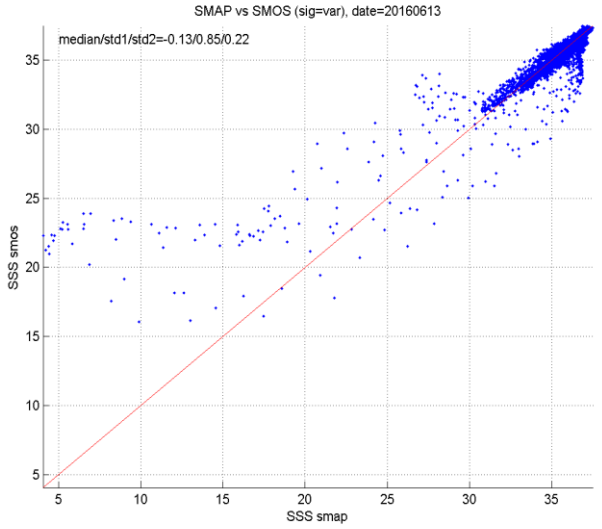




Amazone plume







SUMMARY

- Empirical corrections for systematic biases bring improvements in SMOS SSS up to 800km from land

- In tropical and subtropical regions, CATDS corrected SSS peforms much better than non corrected SSS, big improvement in very variable regions (river plumes), very close to SMAP SSS

- New RFI filtering in ESA v662 improves; RFI filtering is tricky: tradeoff between removing RFI corrupted measurements and keeping natural variability

PERSPECTIVES

- Correcting SMOS SSS biases at high latitudes remains tricky (especially the North Atlantic before 2013) because of ice, land and RFI contaminations

=> L4 OI (N. Kolodziejczyk talk)

=> Future SMOS reprocessing (ESA v7, 2018):

- Land-sea and ice-sea contaminations corrected in the SMOS image reconstruction (less empirical corrections?)
- SSS anomalies estimated using similar methodology as in CATDS RE05 correction
- Refined filtering (see Estrella's talk)
- Roughness correction (higher frequency (hourly) ECMWF wind speed)
- Dielectric constant (see poster)