Sea Surface Salinity under rain cells: SMOS satellite and in-situ drifters observations

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We study the signature of rainfall on S_{1cm}, the sea surface salinity retrieved from the Soil Moisture and Ocean Salinity (SMOS) satellite mission. We compare SMOS S_{1cm} with ARGO sea surface salinity measured at about 5m depth in the Intertropical Convergence Zone (ITCZ) and in the Southern Pacific Convergence Zone (SPCZ) (Fig. 1 & Table 1). We also investigate spatial variability of SMOS S_{1cm} related to rainfall (Fig. 2). We estimate that S_{1cm} local decrease associated with rainfall occurring within less than 1hour from salinity measurement is close to -0.2 pss (mm hr^{-1})$^{-1}$. We estimate that rain induced roughness and atmospheric effects are responsible for no more than 20% of this value (Fig. 1). We also study the signature of rainfall on sea surface salinity measured by surface drifters at 45cm depth (Fig. 3 & 4) and find a decrease associated with rainfall of -0.21 (+/-0.14) (Fig. 5), consistent with SMOS observations.

When averaged over one month, this rain associated salinity decrease is at most -0.2 in monthly 100x100km^2 pixels, and at most 40% of the difference between SMOS S_{1cm} and interpolated in situ bulk salinity in pixels near the ITCZ (Fig. 6-7). This suggests that a significant part of this difference is related to the in situ products obtained from optimal interpolation and therefore influenced by smoothing and relaxation to climatology. Finally, further studies on the satellite-derived salinities should pay attention to that as well as to other sources of uncertainties in satellite measurements as variability in SMOS S_{1cm} remains 30% higher than the one in ARGO even after removing short term variability (Fig. 8), and not interpret fully the observed differences between in situ and satellite mapped products, as rain induced SSS variability.

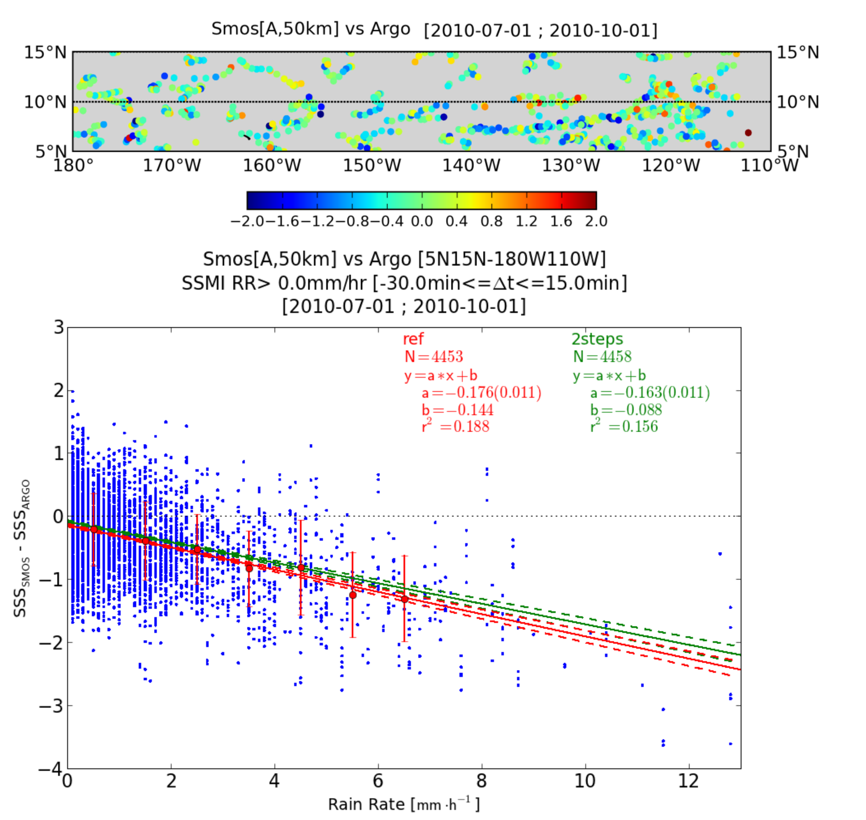


Figure 1 : SMOS minus ARGO S versus SSM/I rain rate colocated within [-30mn;+15mn] in ITCZ region in July-September 2010. The blue points correspond to individual SMOS SSS retrieved with the default algorithm. The corresponding fit (plain line) and its 95% confidence interval (dashed line) is plotted in red. In green, the fit and 95% confidence interval obtained from SMOS SSS retrieved with the two step algorithm (see poster R286 on Tuesday).

Table 1 : SMOS minus ARGO SSS versus SSM/I rain rate obtained with 2 time colocation radii ([-60mn;+30mn] and [-30mn;+15mn])

	aRR+b	r	N
Zone ITCZ (Jul-Sep2010)			
Ssmos-Sargo (-60mn;+30mn)	-0.18(0.007)RR-0.16	-0.49	9705
Ssmos-Sargo (-30mn;+15mn)	-0.18(0.011)RR-0.14	-0.43	4453
Ssmos_twostep-Sargo(-60mn;+30mn)	-0.17(0.007)RR-0.11	-0.45	9704
Ssmos_twostep-Sargo(-30mn;+15mn)	-0.16(0.011)RR-0.09	-0.39	4458
Zone SPCZ (Jun10-Feb11)			
Ssmos-Sargo (-60mn ;+30mn)	-0.21 (0.012) RR-0.23	-0.49	3691
Ssmos-Sargo (-30mn;+15mn)	-0.17 (0.019) RR-0.17	-0.38	1697
Zone ITCZ (Jul-Sep2012)			
Ssmos-Sargo (-60mn ;+30mn)	-0.22 (0.007)RR-0.18	-0.56	7915
Ssmos-Sargo (-30mn ;+15mn)	-0.22 (0.008)RR-0.17	-0.58	5694

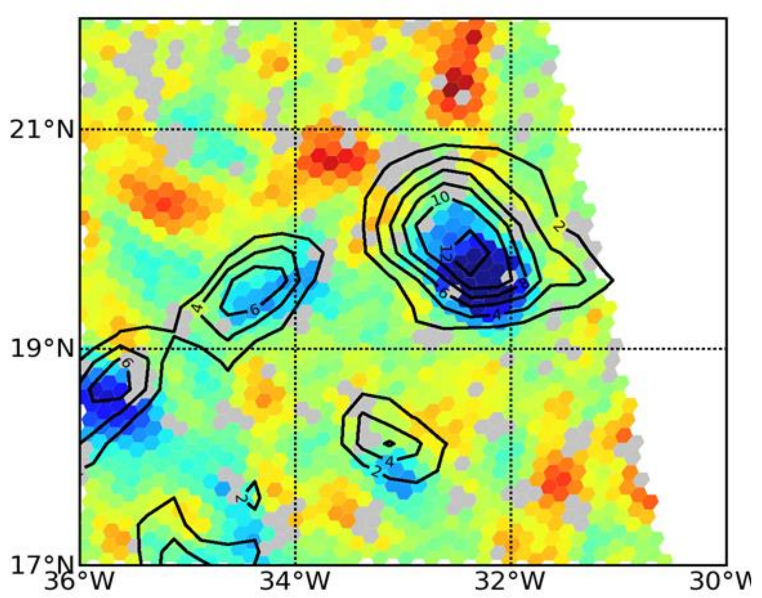
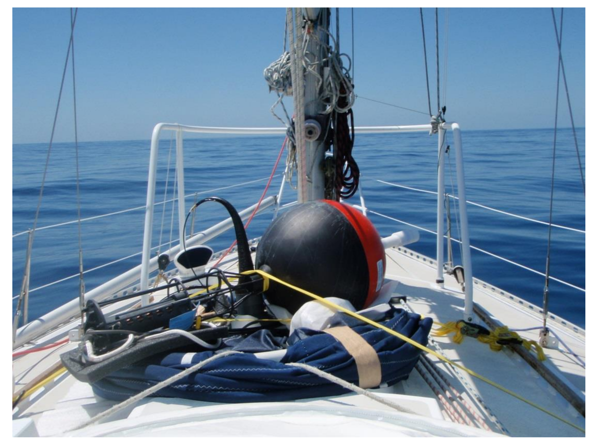


Figure 2: SMOS SSS (color) and satellite rain rate (isolines from 2 to 12mm/hr) on 26 August 2012. SMOS pass was on 8:02 TU and satellite rain rate passes from SSMI F17 on 8:30 TU. The effect of rain on spatial variability of SMOS SSS is -0.18 (+/-0.019) pss (mm hr^{-1})$^{-1}$ (r=-0.67).



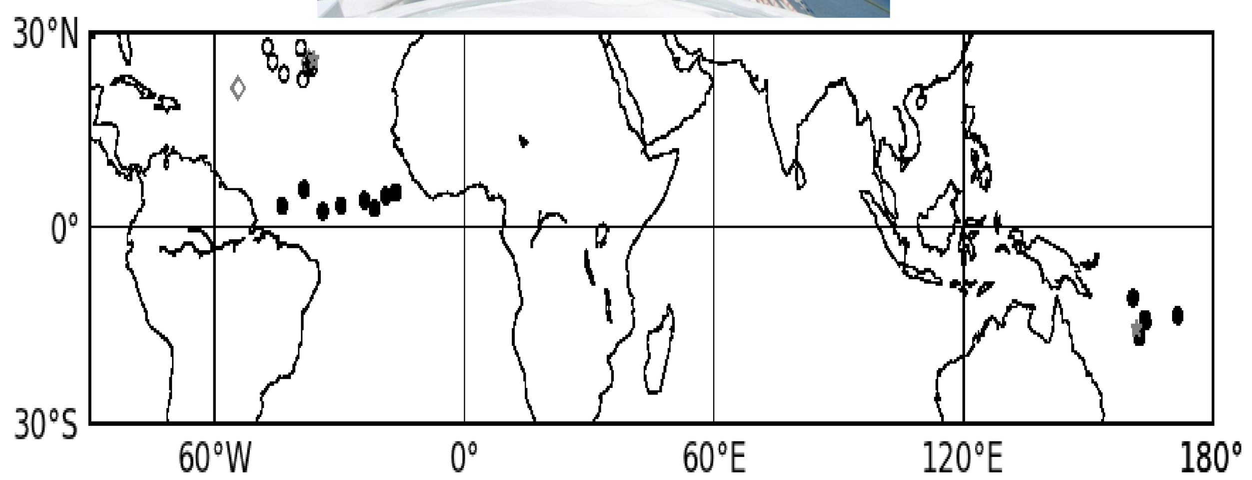


Figure 3 : Locations of S_{45cm} large decreases measured by drifters and colocated with RR. The black filled and open circles are for moderate (3-12m s^{-1}) wind speed conditions in respectively tropical and subtropical regions; the grey losanges are for low wind speed (<3m s^{-1}), the grey stars are for high wind speeds (>15m s^{-1}).

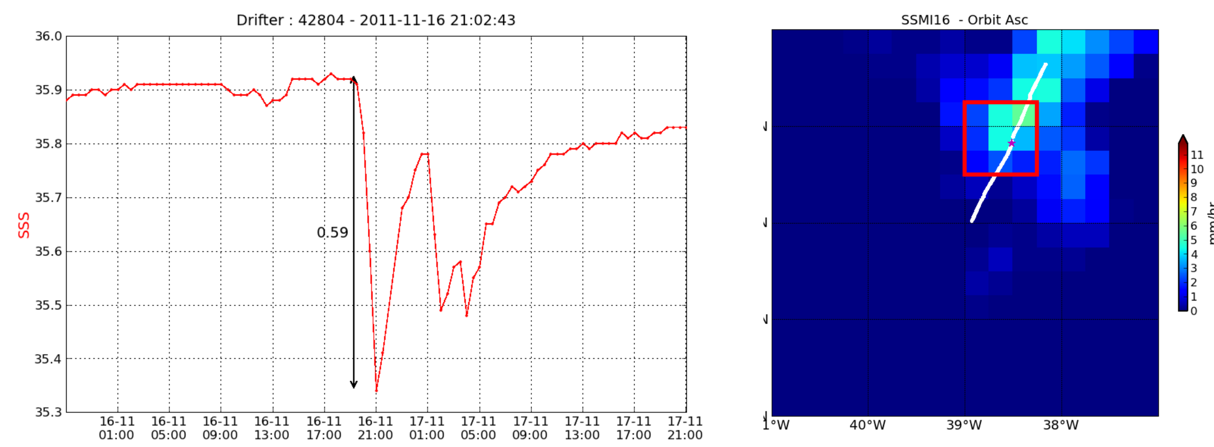


Figure 4 :Time series of drifter SSS just before and after SSSmin (left) and associated maps of RR with superimposed drifter trajectory (white; +/-24h around the SSS minimum); violet point corresponds to drifter position when SSS is minimum (right).

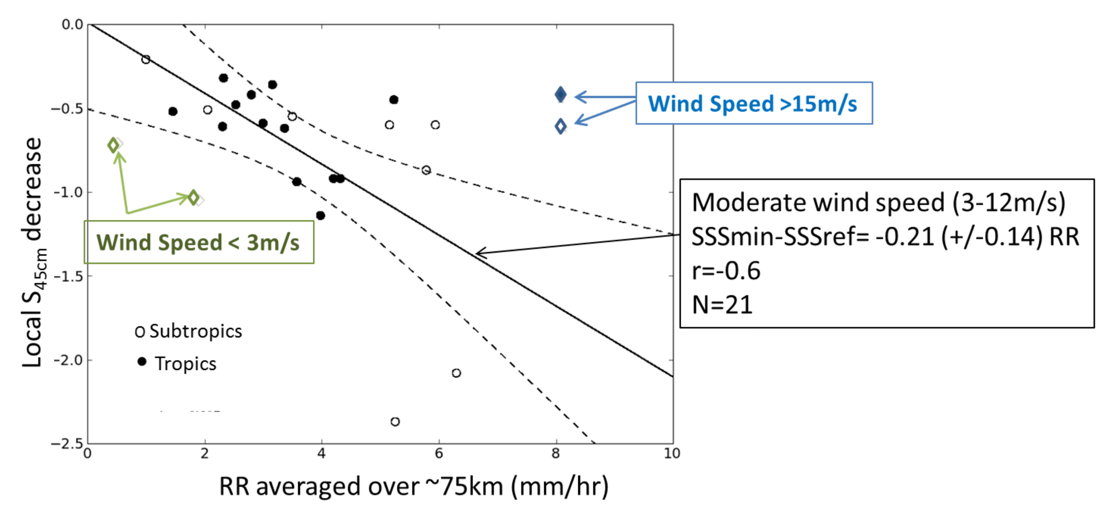


Figure 5 : DSSS versus RR. Filled dots : tropical region ; Open dots: subtropical region. The black filled and open circles correspond to moderate wind speed (3-12m/s); the grey losanges correspond to low wind speed (<3m/s), the grey stars correspond to high wind speeds (>15m/s).

Conclusions

Local variability in salinity at 1cm depth and at 45cm depth induced by rain events as observed by SMOS and by drifters is on same order. When this effect is removed, a large variability remains at monthly time scale in rainy regions probably associated with the remaining fresh signal after the rain event. The variability observed by SMOS is about 30% larger than the ARGO one. Given the data set available it is not possible to detect whether this is a vertical stratification effect or an additional flaw in satellite measurements.

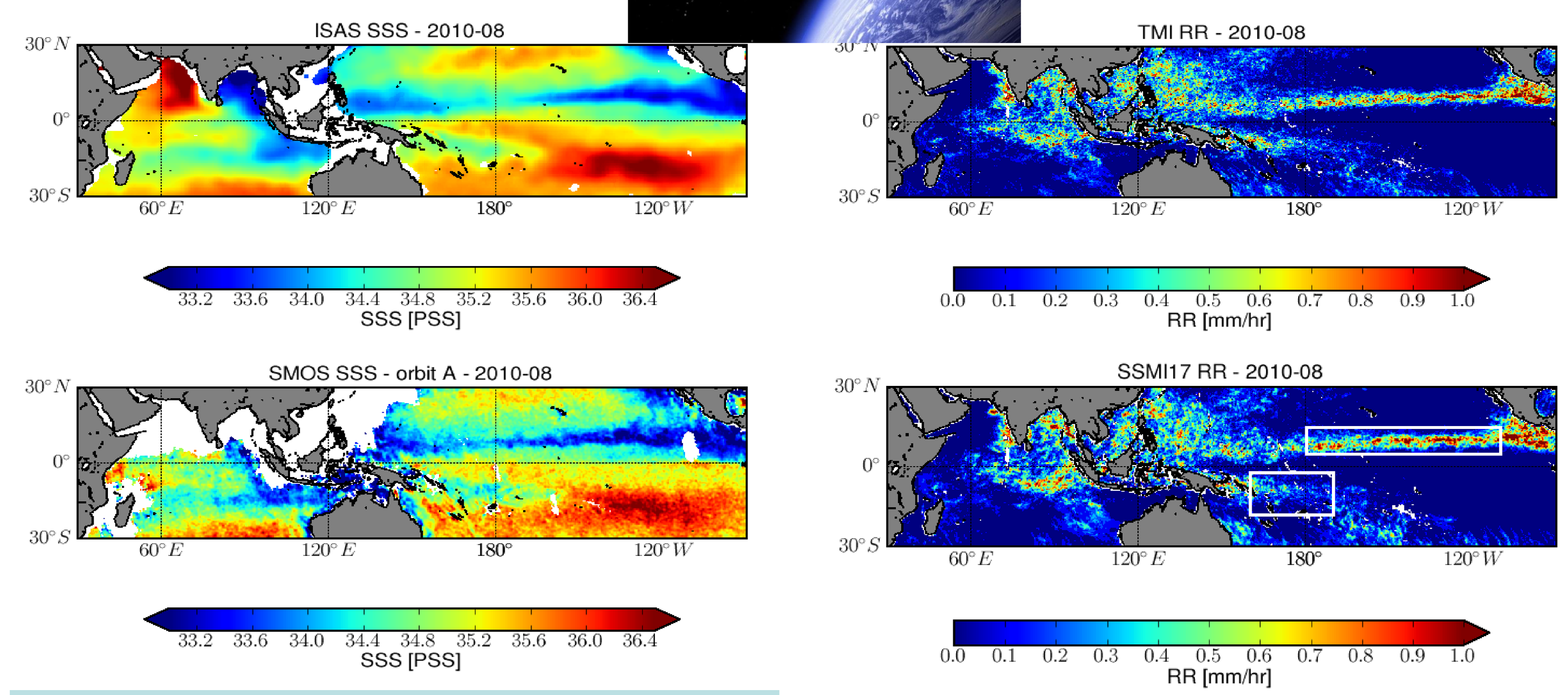


Figure 6 : Left) SSS maps in August 2010 derived from (top) ARGO measurements using the ISAS version 6 D7CA2S0 optimal interpolation at 5m depth [*Gaillard*, 2012]; (bottom) SMOS measurements during ascending orbits (6AM) (LOCEAN CEC CATDS 2013 product); Right) Rain rates derived from (top) monthly TMI measurements; (bottom) monthly SSMI F16 measurements with superimposed white boxes that indicate the regions in which we study SMOS-ARGO SSS differences.

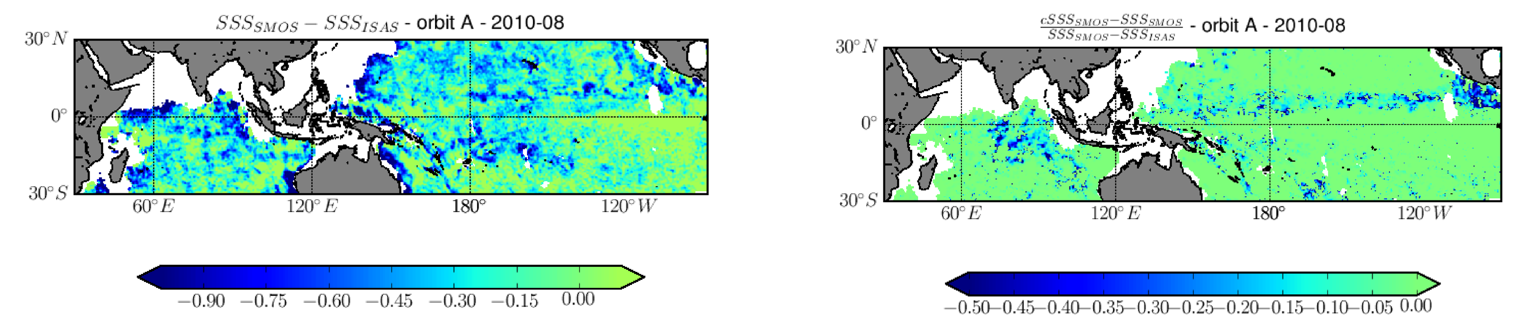


Figure 7 : Left: SMOS minus ARGO interpolated salinities shown on Figure 1; Right: ratio between the rain induced salinity local decrease (-0.2pss (mm hr^{-1})$^{-1}$) and the SMOS minus ARGO interpolated salinities. The rain induced local variability is at most 40% of the difference.

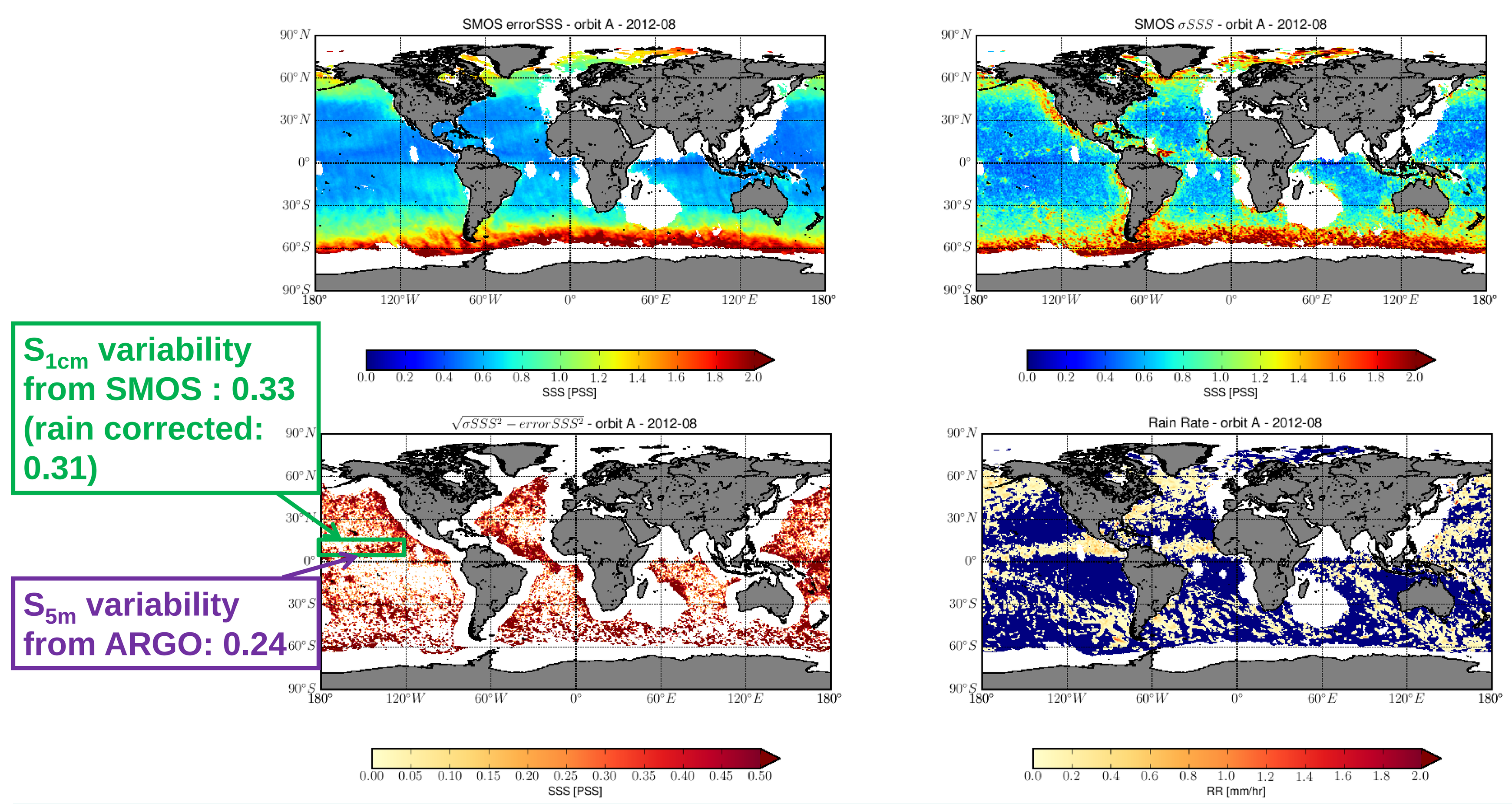


Figure 8 : August 2010 - Top: left) Mean theoretical error derived from radiometric noise; Top, right) monthly SMOS S_{1cm} standard deviation; Bottom left : S_{1cm} variability observed by SMOS when mean theoretical error has been removed (pixels at less than 800km from large land masses in which SMOS image reconstruction is imperfect have been removed); Bottom right: Satellite rain rate.
In the ITCZ, SMOS S_{1cm} variability remains 30% higher as the one of ARGO S_{bulk} even when the rain induced variability is removed by our fits.

Reference:
Boutin, J., N. Martin, G. Reverdin, S. Morisset, X. Yin, L. Centurioni, and N. Reul (2014), Sea surface salinity under rain cells: SMOS satellite and in situ drifters observations, Journal of Geophysical Research: Oceans, 119(8), 5533–5545, doi:10.1002/2014JC010070.

Acknowledgements:
This work is part of the SMOS GLOSCAL Cal/Val project supported by CNES-TOSCA and of the SMOS+SOS STSE study supported by ESA. We thank Jean-Luc Vergely for very helpful discussions about SMOS theoretical error. The US drifters were funded by the NOAA Global Drifter Program grant number NA10OAR4320156. L. Centurioni was supported by NOAA grant number NA10OAR4320156 and NASA grant number NNX12AI67G.