Variability of satellite Sea Surface Salinity under rainfall

Alexandre Supply[1], Jacqueline Boutin[1], Gilles Reverdin[1], Jean-Luc Vergely[2] and Hugo Bellenger[3,4].

[1]LOCEAN/IPSL/SORBONNE UNIVERSITE, Paris, France,
[2]ACRI-st, Guyancourt, France,
[3] LMD/IPSL/SORBONNE UNIVERSITE, Paris, France,
[4] JAMSTEC, Yokosuka, Japan.

Introduction : in-situ observations and models 1/3

- SSS freshening in the top 1cm depends on rain rate and on wind speed (Drushka et al, 2016; Bellenger et al, 2017).

- Maximum of freshening during a rain event is strongly correlated with rain maximum (Drushka et al, 2016).

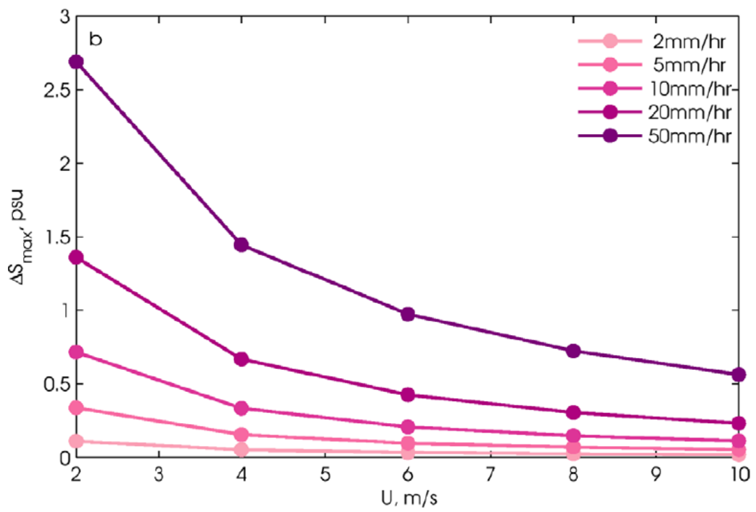
- After a rain event, salinity anomaly relaxing time is variable:

General case :
quickly restored (on the order of a few hours)

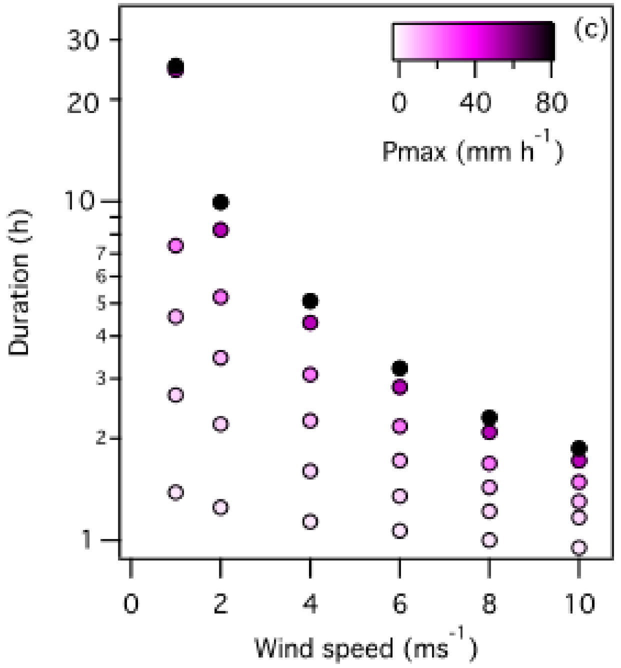
(Wijesekera et al. 1999; Soloviev et al. 2002; Reverdin et al. 2012; Drushka et al. 2016).

Occasionally:
persistence time close to 24h

(Walesby et al. 2015; Dong et al. 2017).



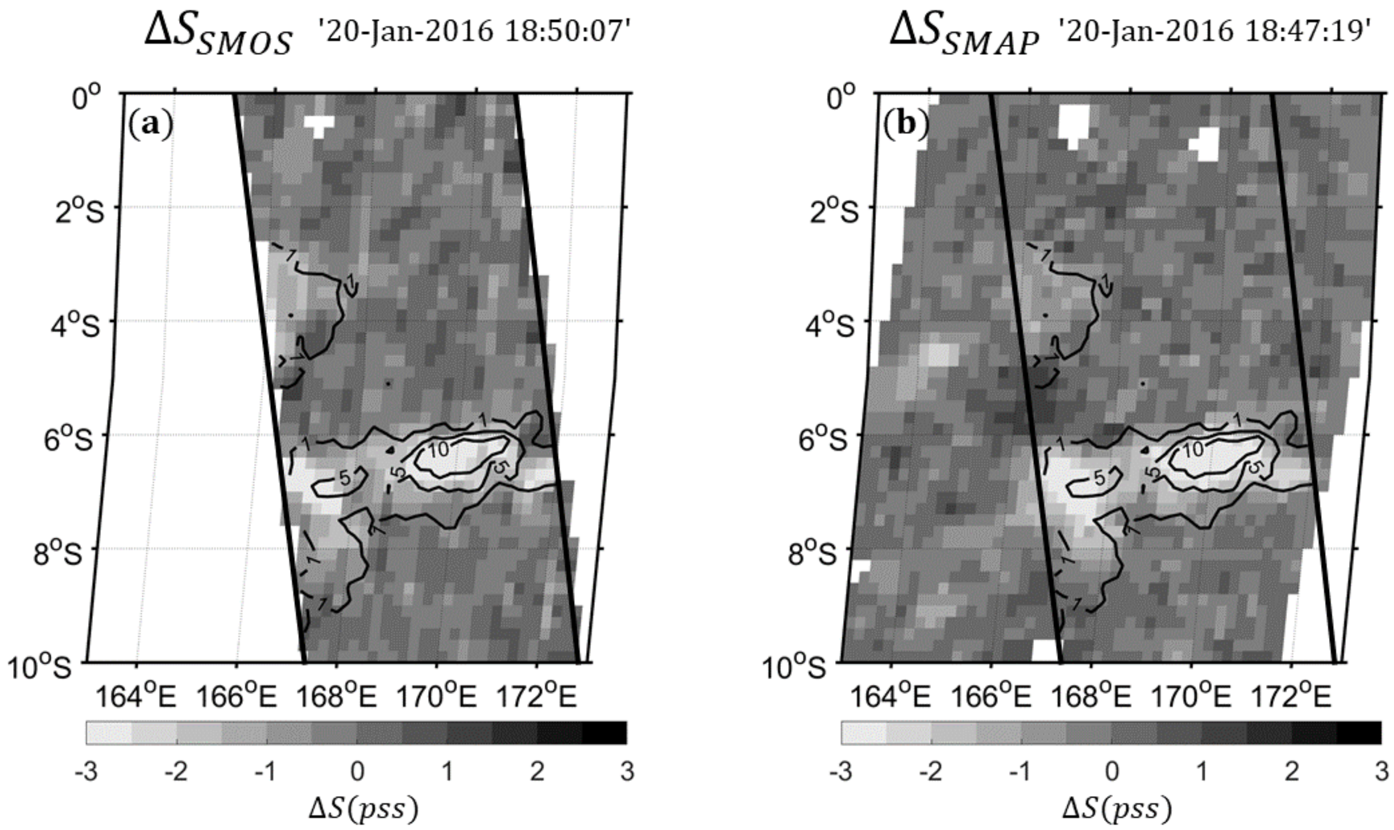
Drushka et al. JGR2016.



Bellenger et al. JGR2017.

Introduction : satellite data 2/3

- SMOS and SMAP satellite salinity (1 cm depth; ~50km resolution) strongly influenced by rainfall. Clear link between instantaneous RR and SSS anomalies (Boutin et al, 2016; Supply et al, 2017).



- Rain Impact Model (RIM; Santos-Garcia et al, 2014) was developed for Aquarius in order to remove rain imprint on SSS retrieved with the satellite using RR history from a morphing rain product (CMORPH).

Introduction : objectives 3/3

What is the imprint of RR history on SSS freshening taking into account RR temporal autocorrelation?

How relationship between SSS freshening and instantaneous RR depend of the RR product ?

What is the influence of WS on relationship between SSS freshening and RR ?

Data & method 1/2

Salinity :

- SMOS/CATDS L2Q SSS (*Boutin et al. 2018*) **~50km**;
- SMAP JPL/CAP L2 V4 SSS (*Fore et al. 2017*) **~60km**;

Rain rate :

- UMORA rain rates (Remote Sensing System - *Wentz and Hilburn, 2012; Wentz and Meissner, 2014*) ;
- GPROF2017 rain rates (NASA's Goddard Space Flight Center - *GPM Science team 2016 and 2017*) ;

RR from various microwaves satellites with different equator crossing times

- IMERG (NASA's Goddard Space Flight Center - *Huffman et al, 2018*) rain rates.

Interpolated RR product using RR from microwaves and IR based on morphing techniques

Wind speed :

- SMAP WS L2 v4 from JPL (*Fore et al, 2017*).

Collocation criteria : same pixel and 30mn radii.

Data & method 2/2

Salinity anomaly :

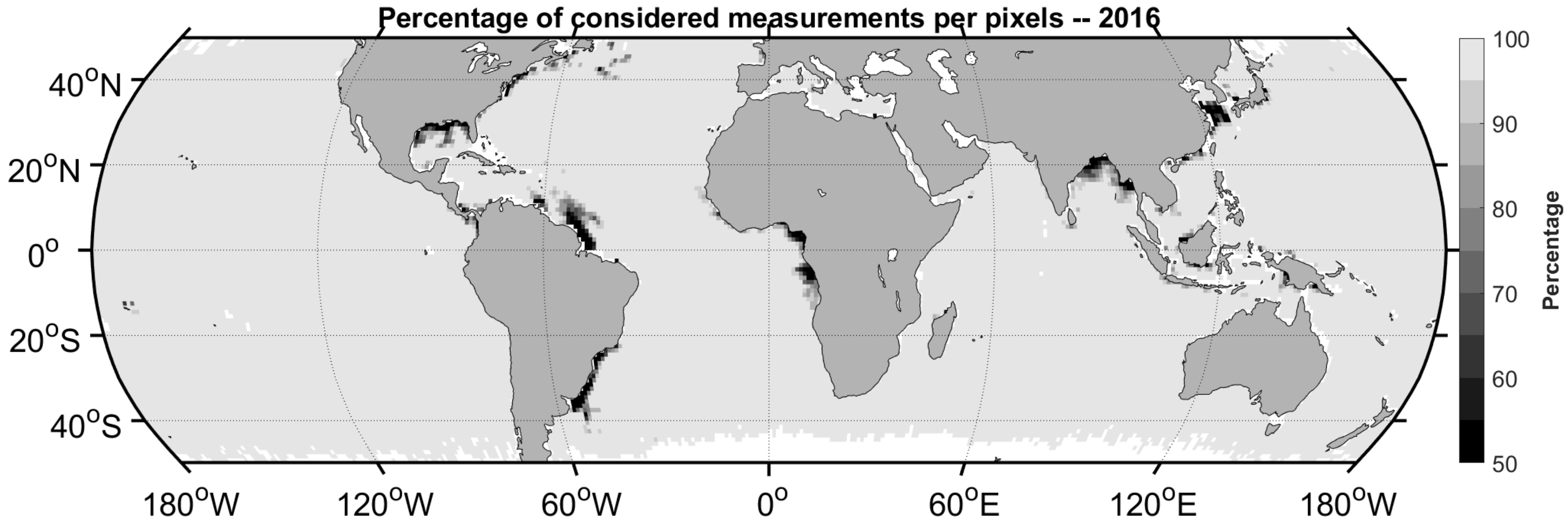
$$\Delta S = S_{sat} - S_{ref}$$

A self consistent satellite reference salinity : reference salinity from quantile 80% in a 3°x3° area.

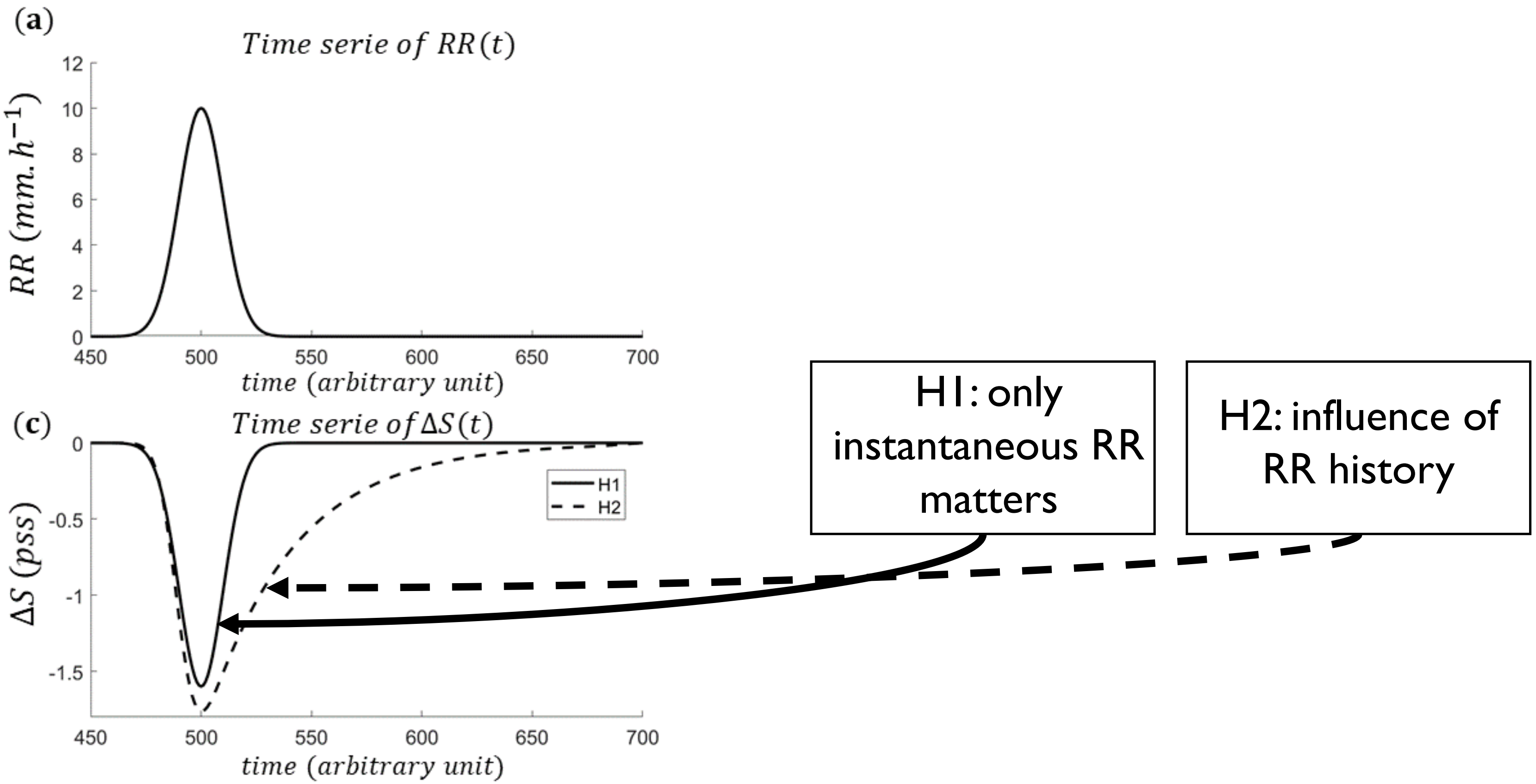
Filtering method :

Allow to perform global analyses:

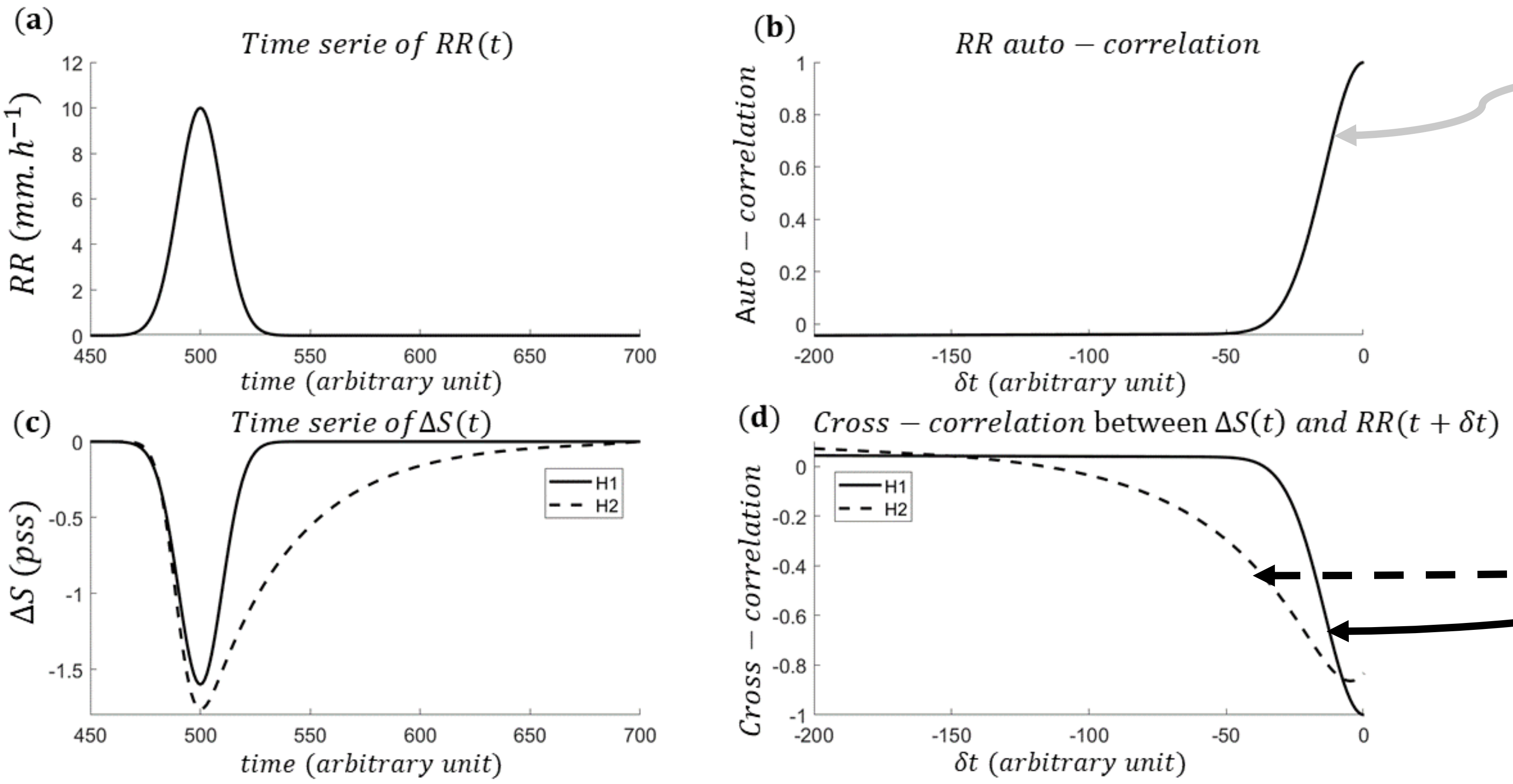
- Rain is intermittent and that monthly variability of SSS is higher in river plumes than in rainy areas. Only pixels that satisfy these monthly statistics are considered:
  - $\overline{\Delta S_{month}} > -0.65$pss ;
  - $\sigma_{S_{month}} < 1.75$pss.



Which is the imprint of rain history on salinity anomalies? 1/3



Which is the imprint of rain history on salinity anomalies? 1/3



Temporal auto-correlation of the RR :
$R_{RR}(\delta t)=r(RR(t),RR(t+\delta t))$

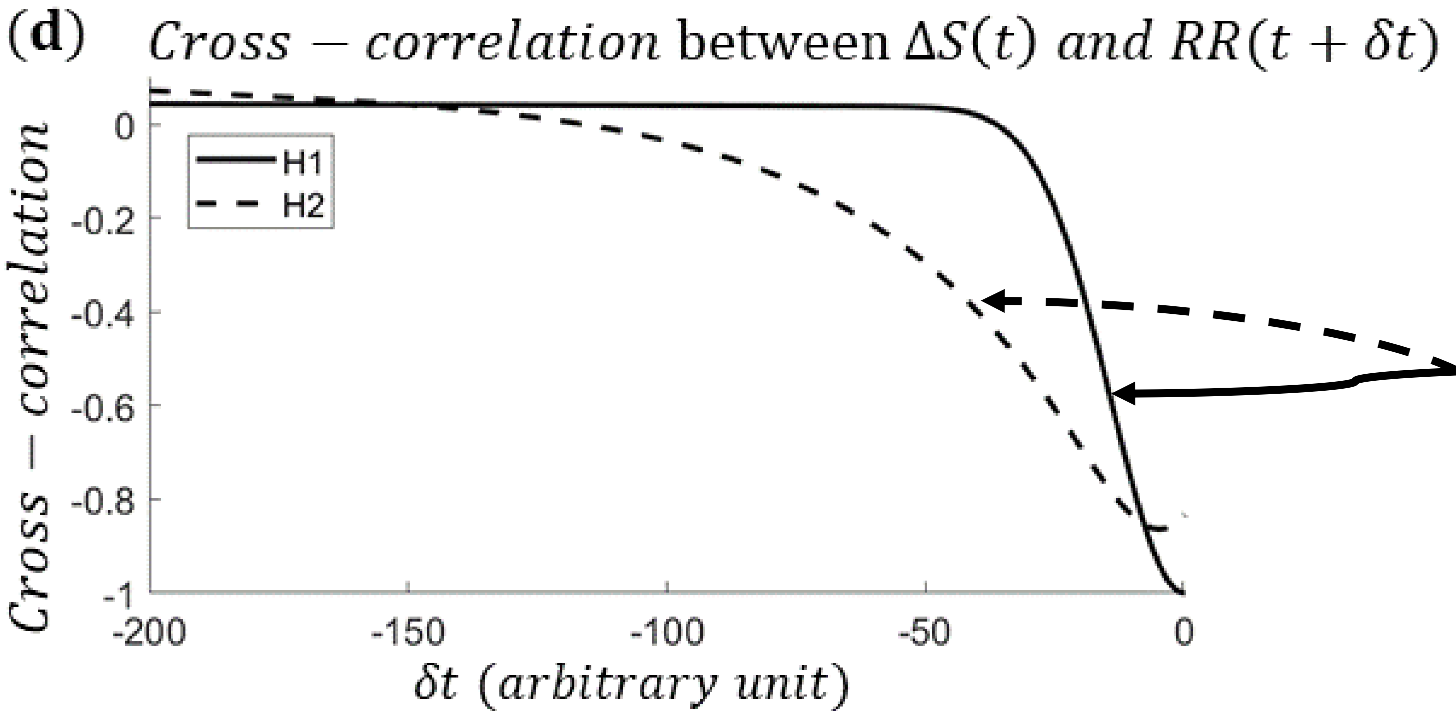
Observed temporal cross-correlation function between ΔS and RR :
$\Gamma_{\Delta S;RR}(\delta t)=r(\Delta S(t),RR(t+\delta t))$

H1: only instantaneous RR matters

H2: influence of RR history

r(X,Y) correspond to the Pearson correlation between X and Y.

Which is the imprint of rain history on salinity anomalies? 1/3



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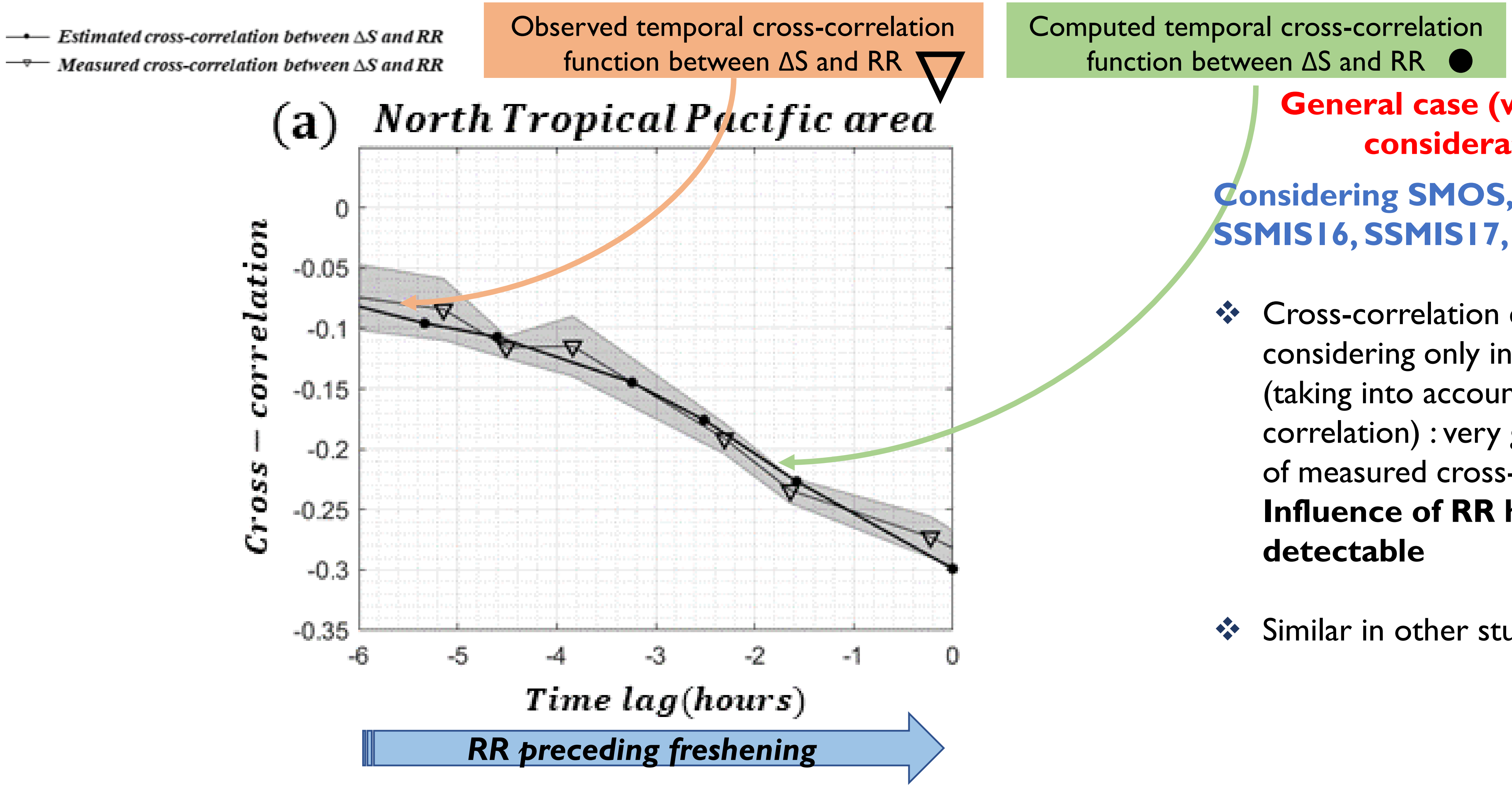
H1: only instantaneous RR matters

H2: influence of RR history

$$\Gamma_{\Delta S;RR}(\delta t)=\Gamma_{\Delta S;RR}(\delta t=0)\times R_{RR}(\delta t)$$

Which is the imprint of rain history on salinity anomalies? 2/3



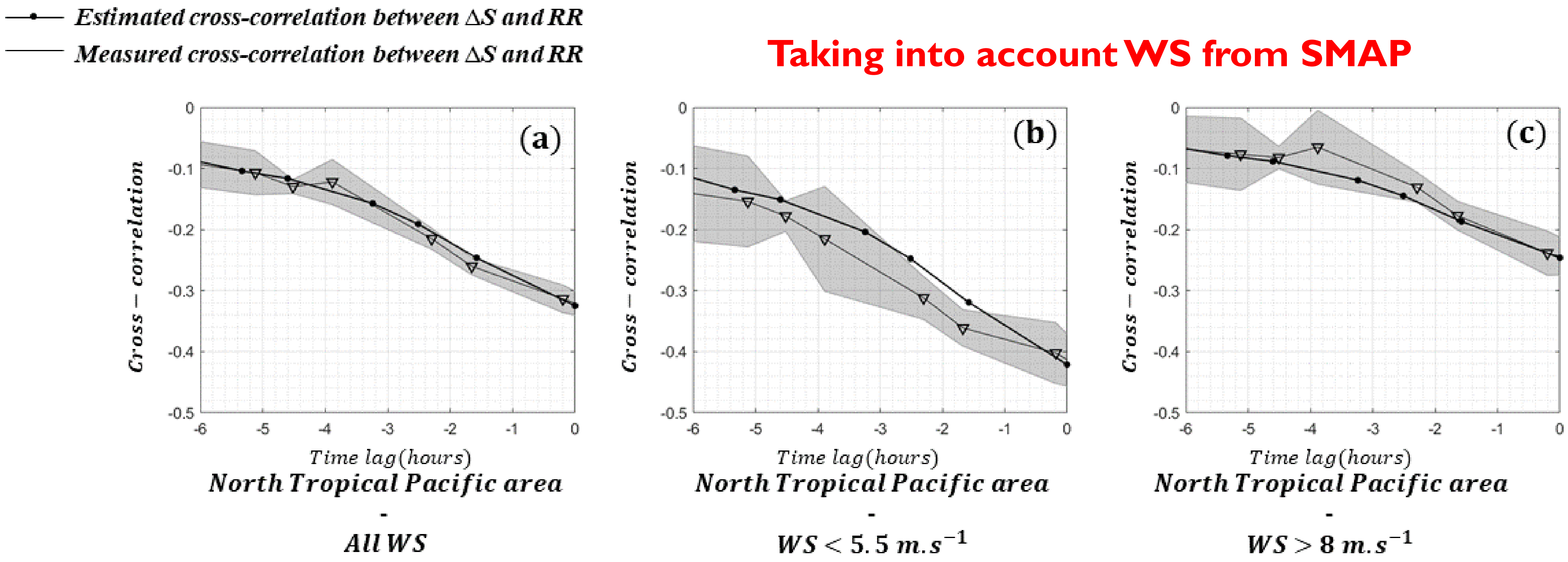
General case (without WS considerations)

Considering SMOS, SMAP, SSMIS16, SSMIS17, and AMSR2:

- Cross-correlation computed considering only instantaneous RR (taking into account RR auto-correlation) : very good estimation of measured cross-correlation. **Influence of RR history is not detectable**
- Similar in other study areas.

Which is the imprint of rain history on salinity anomalies? 3/3

Taking into account WS from SMAP



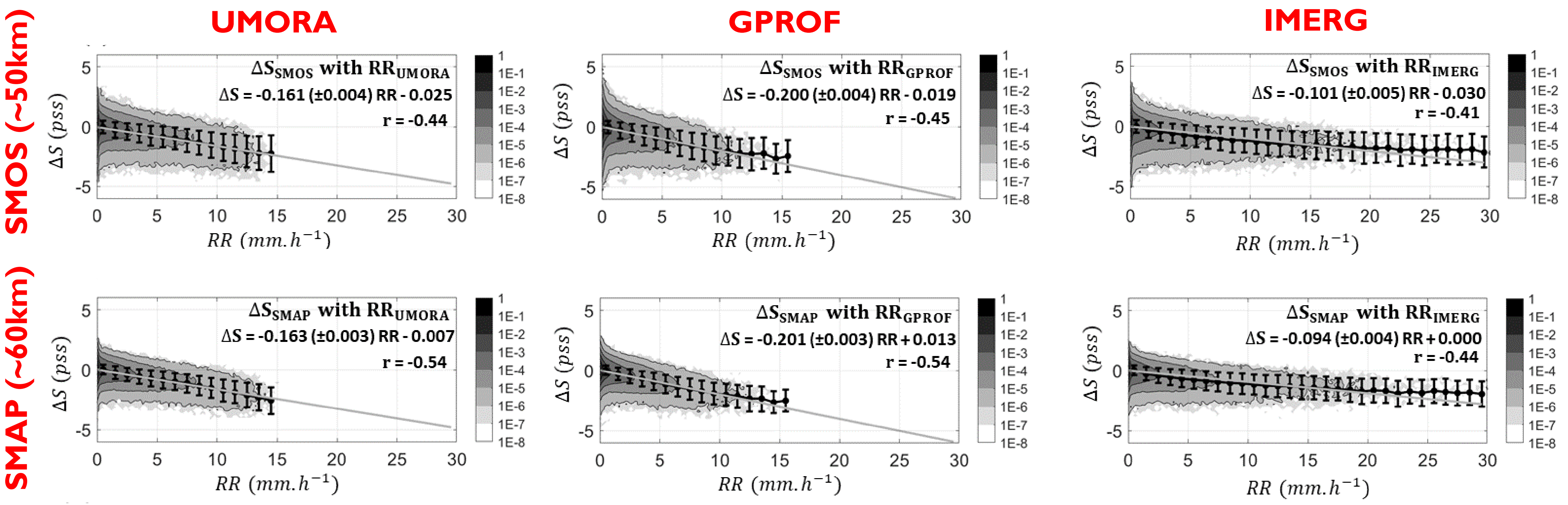
Computed temporal cross-correlation function between ΔS and RR ●

Observed temporal cross-correlation function between ΔS and RR ▽

Considering ~~SMOS~~, SMAP, SSMIS16, SSMIS17, and AMSR2:

- **For low WS :** measured cross-correlation between ΔS and RR **>** cross-correlation computed considering only instantaneous RR : slight effect of RR history.
- Limits :
  - WS considered at time of salinity measurement (no information about WS history) ;
  - Extreme WS conditions : limit number of measurements and increase the uncertainty.

Intercomparison of RR and SSS products



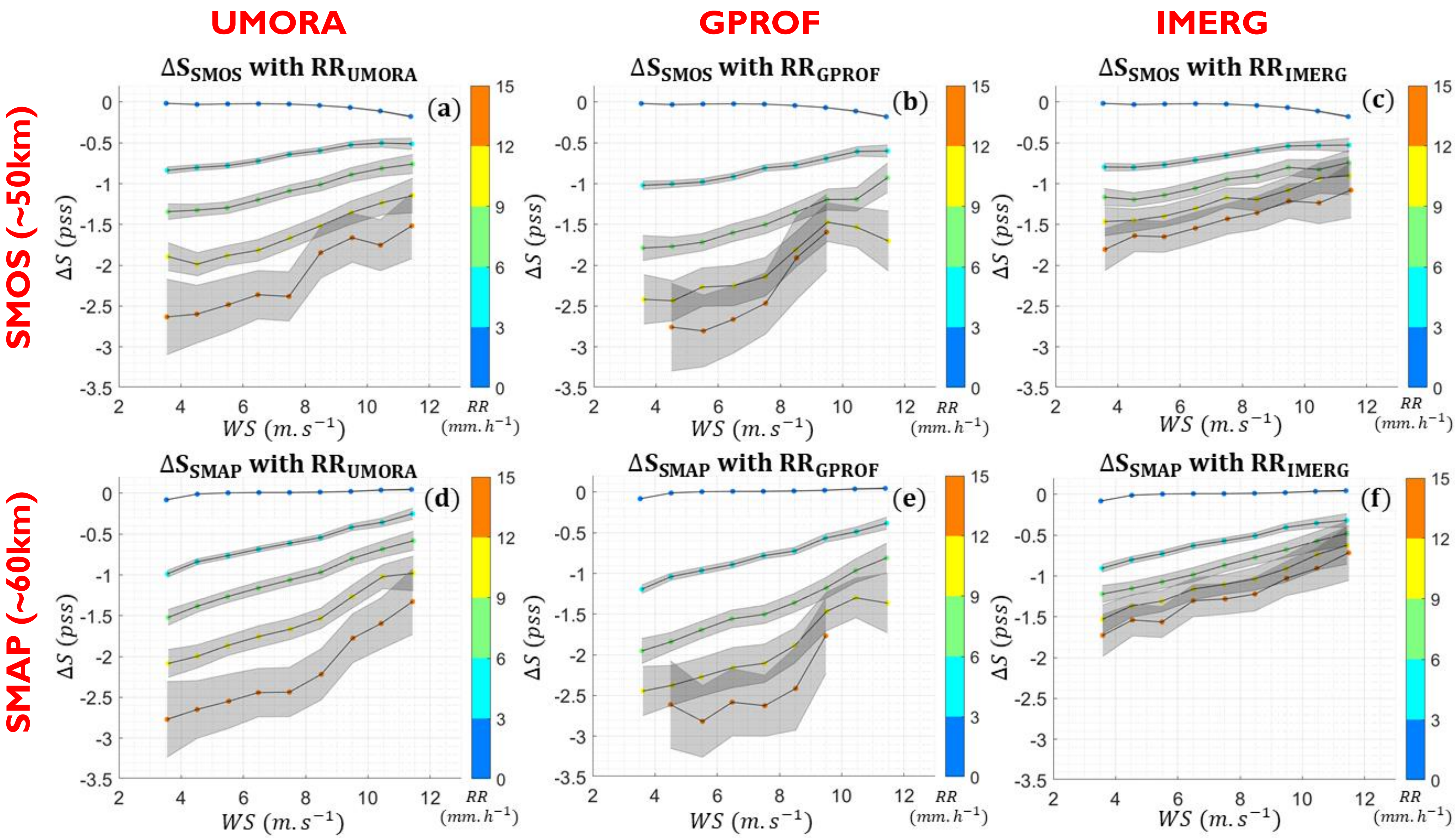
For a given RR product:

- SMOS and SMAP very consistent
- Same slope (RR versus ΔS relationship)
- Similar noise (given the difference of resolution)

Differences between ΔS versus RR relationships:

- UMORA and GPROF : linear but different slopes
- IMERG : flattening at high RR and higher RR.

WS dependency of instantaneous RR influence on SSS freshening 1/2



Averaged ΔS as function of WS and RR:

- Results show a strong WS dependency of freshening with all RR products.
- SMOS and SMAP give very close results.

WS dependency of instantaneous RR influence on SSS freshening 2/2

Drushka et al. (2016) present a relationship between ΔS_{max} ,RR_{max} and WS during a local freshening event:

$$\Delta S_{max} = a\ \mathrm{RR}_{max}\ WS^{-b}$$

with a = 0.11 pss.(mm.h^{-1}*)*$^{-1}$ *and b = 1.1.*

	a	b
UMORA	$0.37\ \mathrm{pss.}(\mathrm{mm.h}^{-1})^{-1}$	0.68
GPROF	$0.90\ \mathrm{pss.}(\mathrm{mm.h}^{-1})^{-1}$	0.80
IMERG	$0.35\ \mathrm{pss.}(\mathrm{mm.h}^{-1})^{-1}$	0.77

With satellite data:

- Different a and b coefficient for different RR algorithms.
- Different coefficients comparing with Drushka et al. (2016) but not the same spatial scales are considered.

Conclusion

- **SMOS and SMAP SSS anomalies : very consistent** over global ocean under rainfall.

- **Rain history produces a non-detectable effect on freshening** at satellite pixel.

- These results provide a methodology for **removing rainfall imprint on SMOS or SMAP SSS by using instantaneous RR (**30-mn IMERG RR) (cf. Boutin presentation).

- We observe a decreasing freshening with increasing WS but some unexpected behavior (freshening remaining at very high WS, different amplitudes comparing to models and in-situ,…).

- Detailed process studies needed to reconcile satellites and in-situ measurements : how heterogeneity and cross-correlation of WS, RR and SSS at local scale could influence satellite observations ?


Thank you.