SMOS and in situ Sea Surface Salinities (GLOSCAL project)

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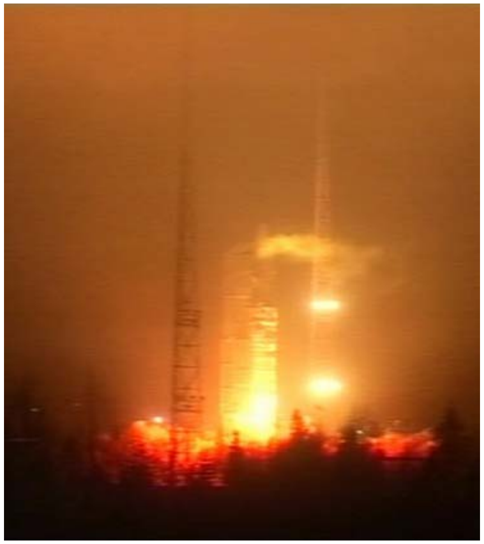
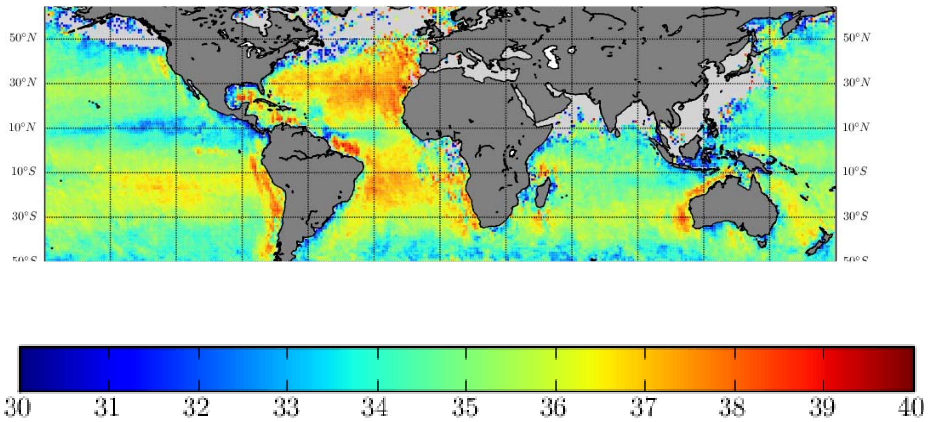
+ collaboration with GLOSCAL team (IFREMER, ACRI-st, LEGOS)
+ Collaboration with ESA Ocean Salinity team:
J. Font et al. (ICM), N. Reul (IFREMER/LOS), J. Tenerelli (CLS),
P. Spurgeon, A. Chuprin (ARGANS), J.L. Vergely (ACRI-st)

SMOS: Artist view
ESA proposal 1999



SMOS: launch
2 Nov. 2009



SMOS: Sea surface salinity
August 2010

Outline

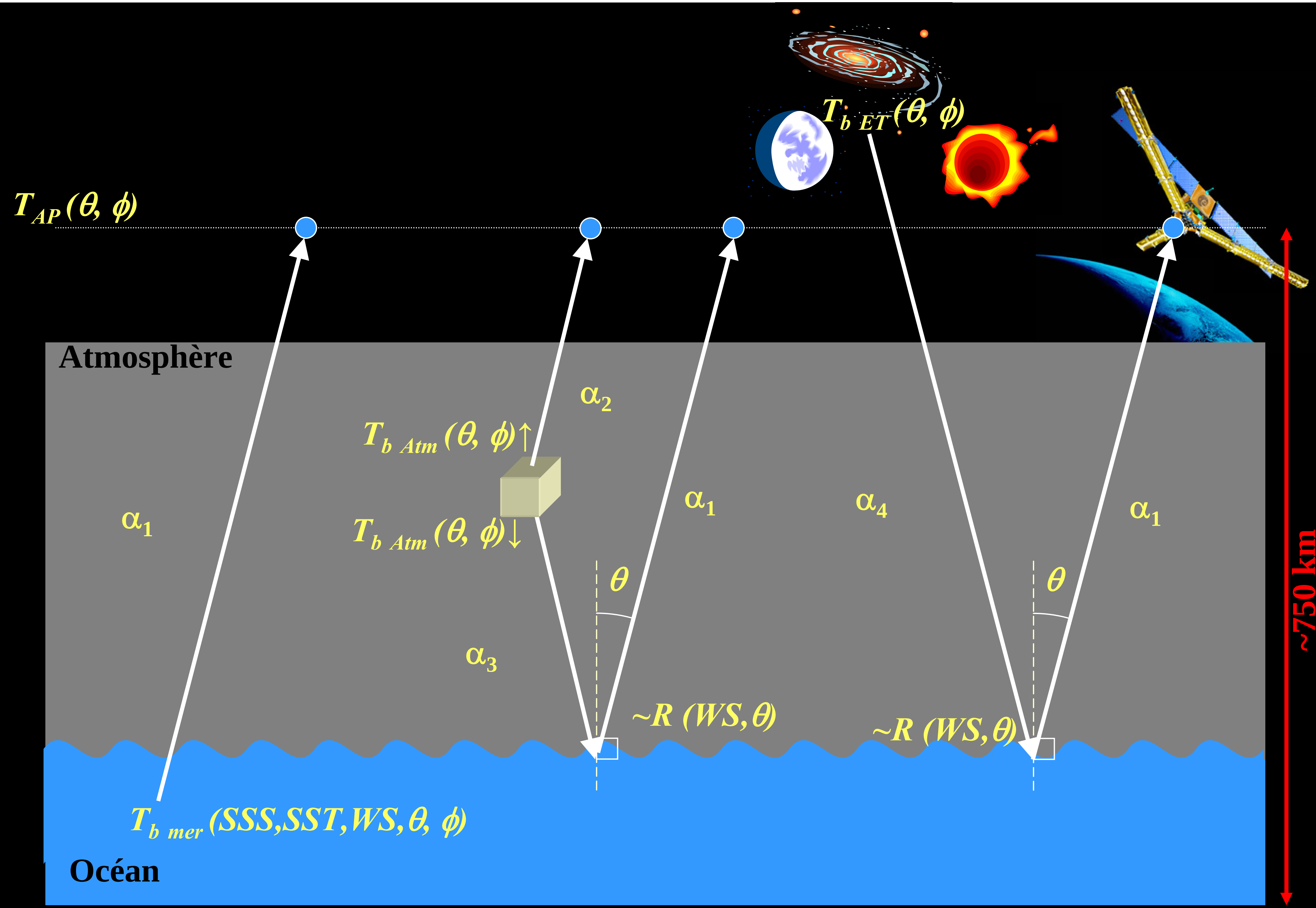
-Overview of radiometer measurements modeling

-Comparison of SMOS retrieved SSS with in situ SSS (ARGO and surface drifters)

-Towards an improvement of roughness model

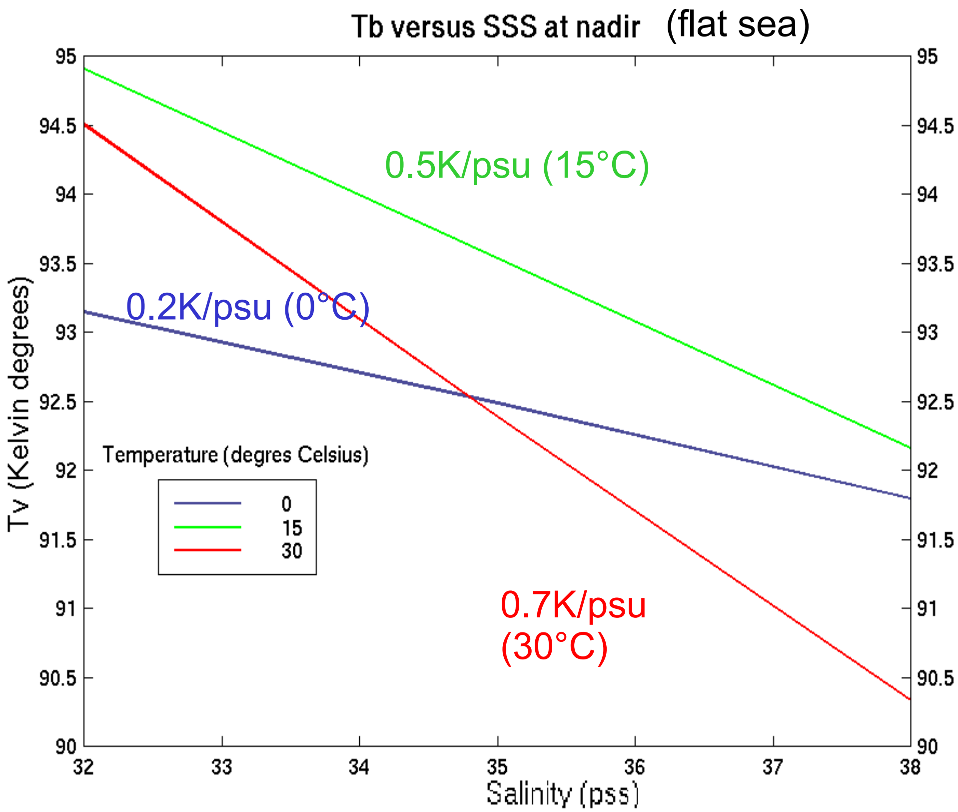
-Conclusions/Perspectives

Overview of radiometer measurements modeling


$T_{AP}(\theta, \phi)$
$T_{b\ ET}(\theta, \phi)$
Atmosphère
α_2
$T_{b\ Atm}(\theta, \phi)\uparrow$
α_1
α_1
α_4
α_1
$T_{b\ Atm}(\theta, \phi)\downarrow$
θ
θ
α_3
~R (WS,θ)
~R (WS,θ)
$T_{b\ mer}(SSS, SST, WS, \theta, \phi)$
Océan
~750 km

Sensitivity of modeled Tb to SSS

Flat sea (*Klein and Swift model)*

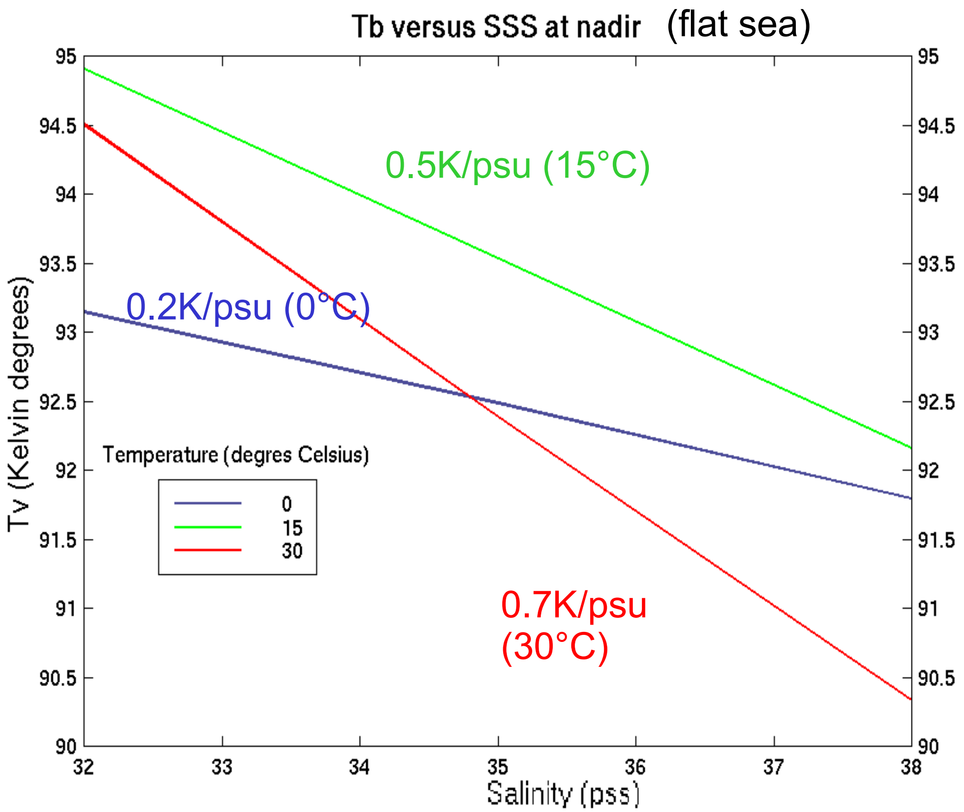


Sensitivity of Tb to SSS is:
-small: always less than 1K/psu
(SMOS radiometric precision of 1 Tb: several K)
-Higher in warm water

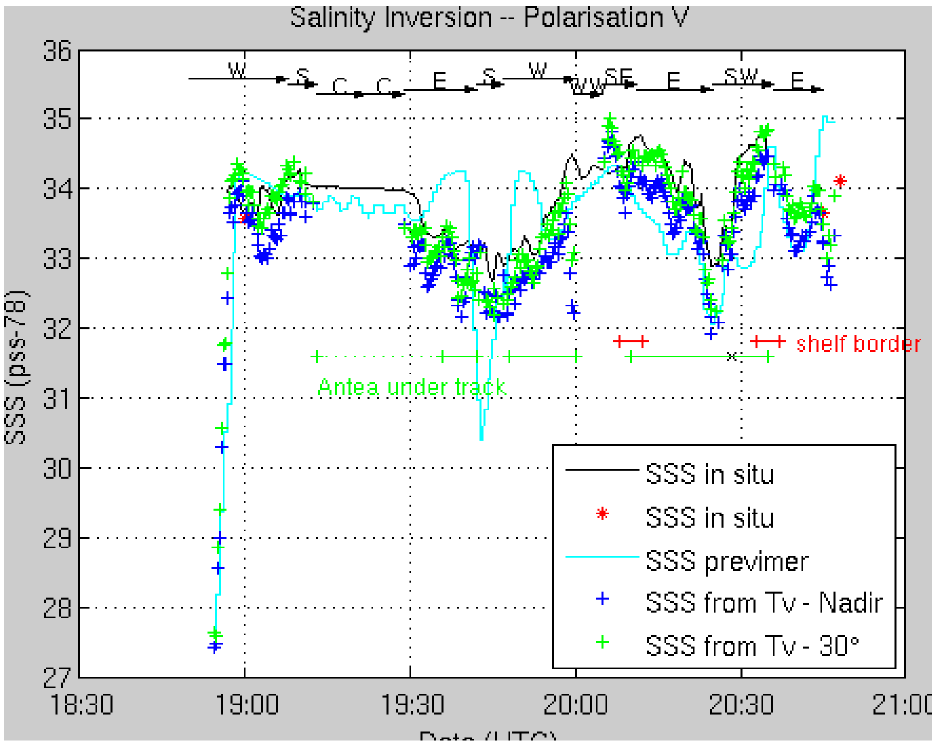
NB: L-band radiometer measurements are representative of top 1cm surface ocean

Sensitivity of modeled Tb to SSS

Flat sea (*Klein and Swift model)*



Validated using in situ/airborne data:
CAROLS flights in the Gulf of Biscay
(see Adrien Martin' poster)



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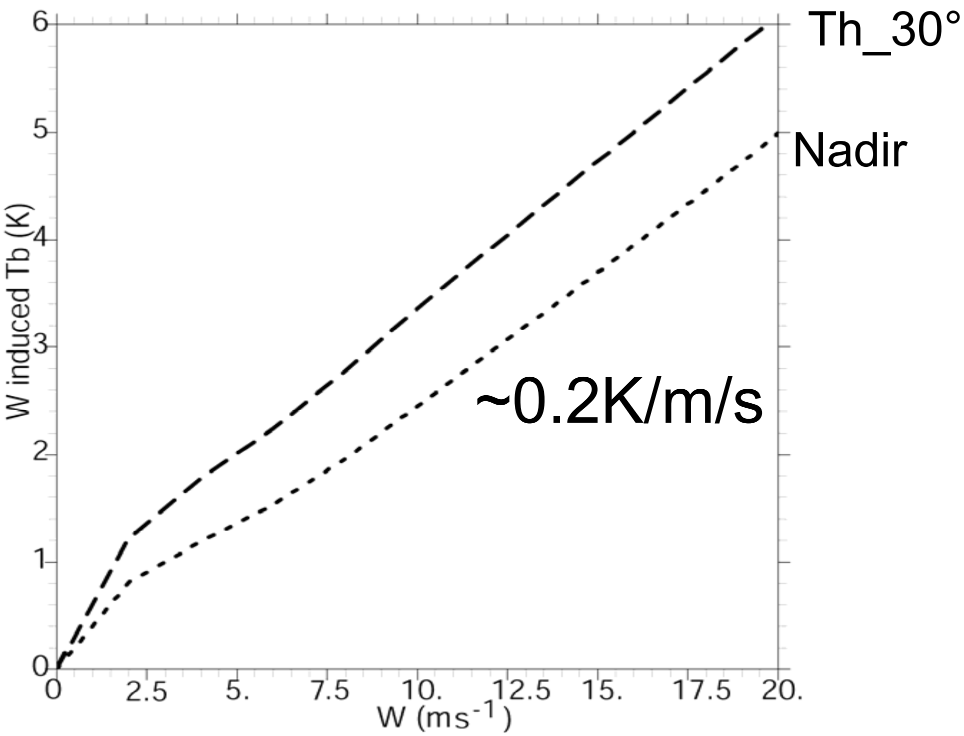
Sensitivity of modeled Tb to roughness (2-scale-DV2 model (Dinnat et al.): SMOS model 1)

2 scale emissivity model: small waves superimposed on large tilted waves
Wave spectrum from Durden and Vesecki multiplied by an arbitrary factor 2 (to fit data)

Rough sea (without foam)



10m equivalent neutral wind speed (m/s)

At 15°C, a 0.1K Tb variation can be generated by :
-0.2psu SSS variation
or
- 0.5m/s wind speed variation

Dinnat et al., IJRS, 2002, Radio Science, 2003

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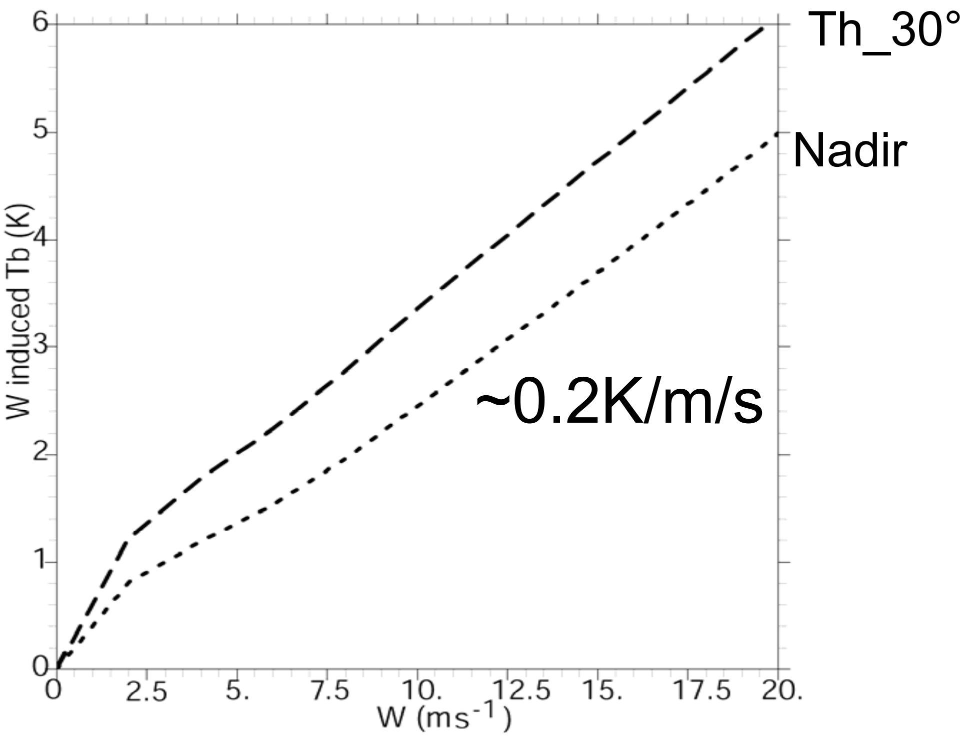

10m equivalent neutral wind speed (m/s)

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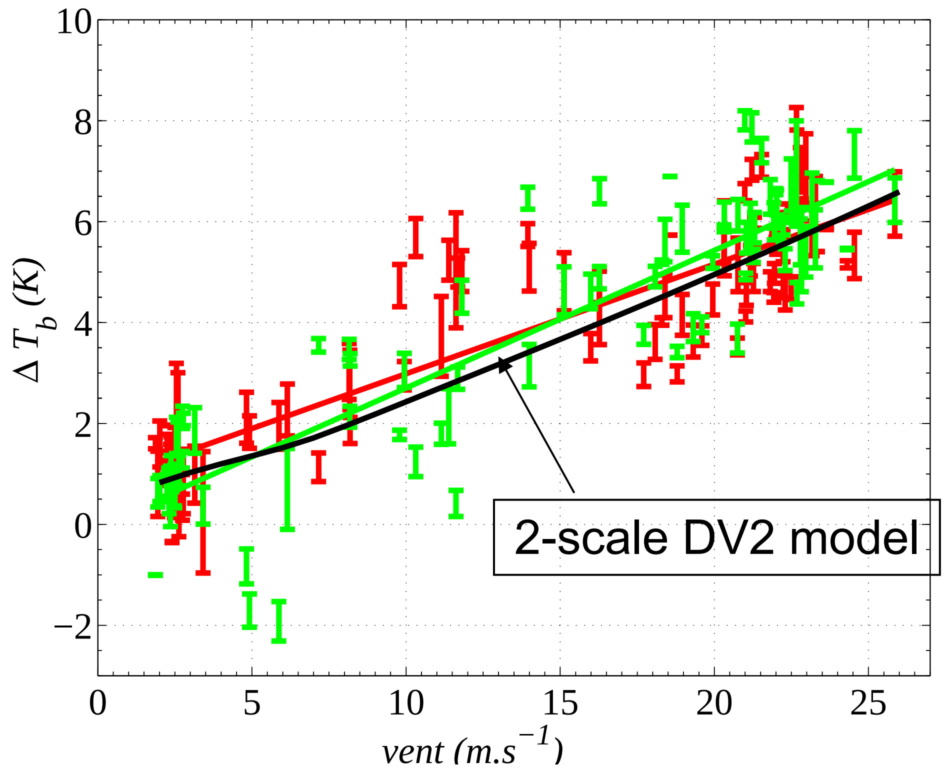
Comparison ofTb simulated with 2-scale DV2 roughness model (SMOS model 1) with EuroStarrs data (Etcheto et al., 2004)



Good general agreement but large scatter!

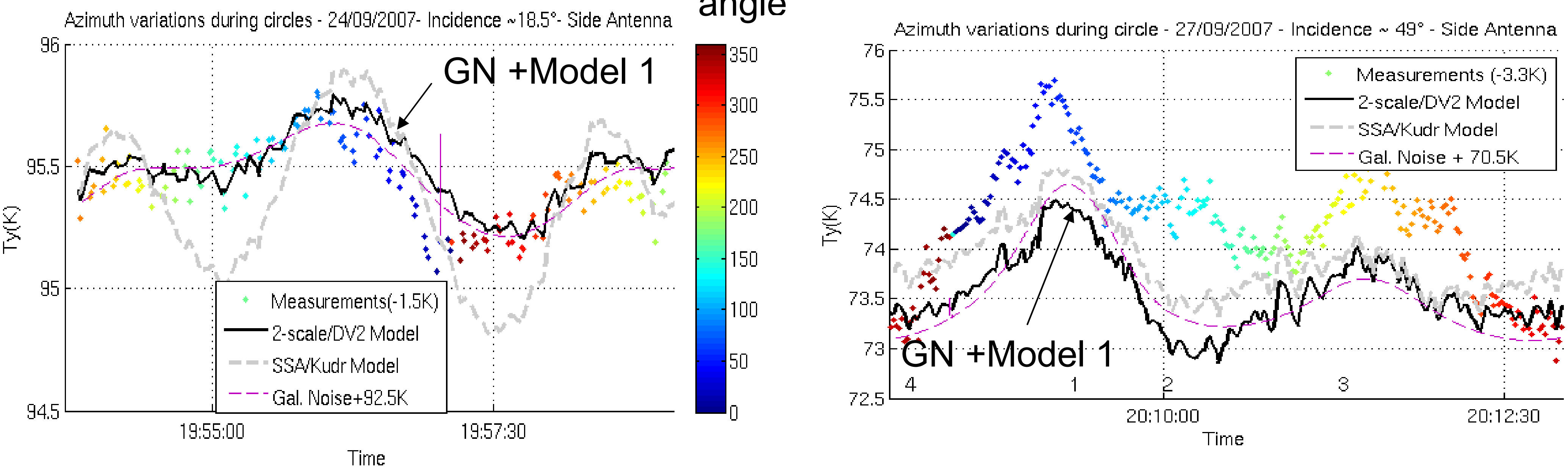
Dinnat et al., IJRS, 2002, Radio Science, 2003

Galactic noise scattering modeled using an azimutal modelling of the bistatic coefficients (Tenerelli et al., 2008)

Moderate galactic signal

Azimuth angle

Strong galactic signal



Very good agreement between modeled and airborne CAROLS azimutal variations in case of moderate galactic signal but imprecise in case of strong Milky Way signal

(Boutin et al., submitted to PIERS proceedings, 2010)

Validation of SMOS SSS

SMOS SSS retrieval method

SMOS SSS is retrieved through a least square minimisation of the difference between SMOS and modeled Tb.

Retrieval of SSS (σ=100psu), SST (σ=1°C), WS(σ=2m/s) through the minimisation of:

$$\chi^2 = \sum_{i=0}^{Nm-1} \frac{\left[T_{bi}^{meas} - T_{bi}^{\mathrm{mod}}(\theta, P)\right]^2}{\sigma_{T_{bi}}^2} + \sum_{j=0}^{Np-1} \frac{\left[P_j - P_{j,\,prior}\right]^2}{\sigma_{P_j}^2}$$

=> estimate of SSS error

(Levenberg & Marquard algorithm)

Use of :

-SMOS Tbs in AFFOV and EAFFOV after removal of a systematic bias estimated over an ascending orbit in the south east Pacific (50S-10N ascending orbit on 5th August)

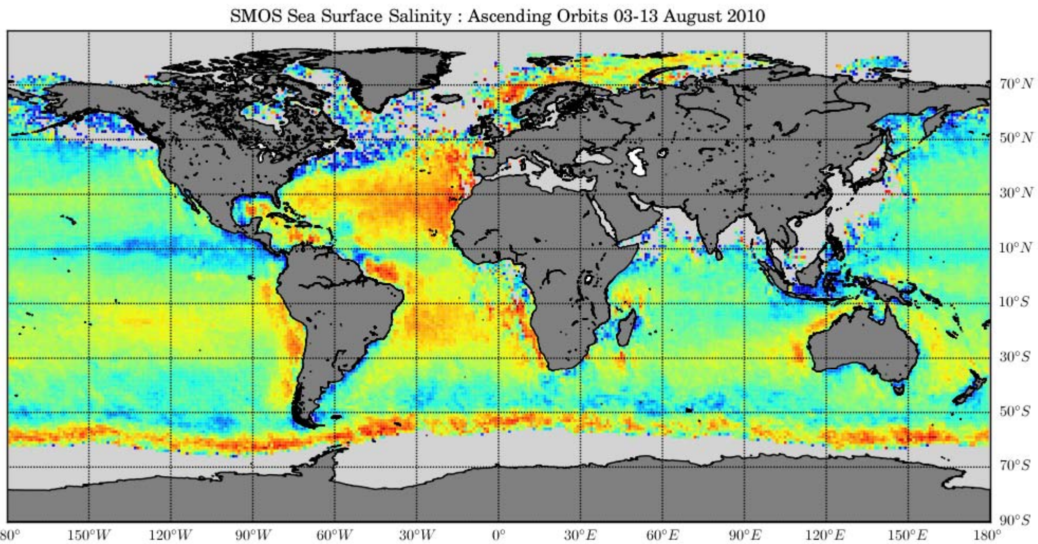
-Roughness model 1 (SSS1 in SMOS L2 product)

-ECMWF wind and SST fields as prior

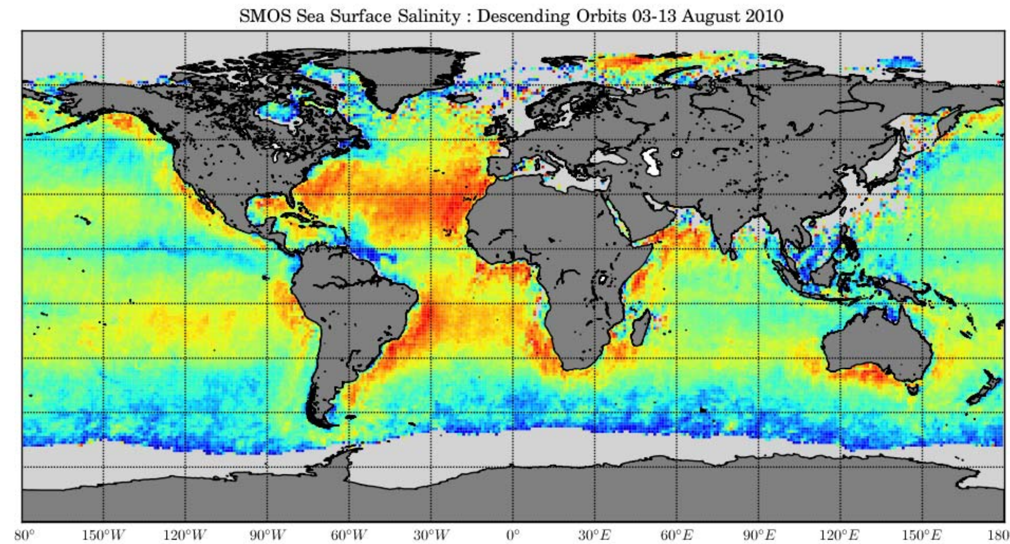
10days-100km SSS maps computed from averages of SMOS SSS weighted by their spatial resolution and error (derived by the retrieval)

Maps of retrieved SSS 10days (3-13 August) -100km

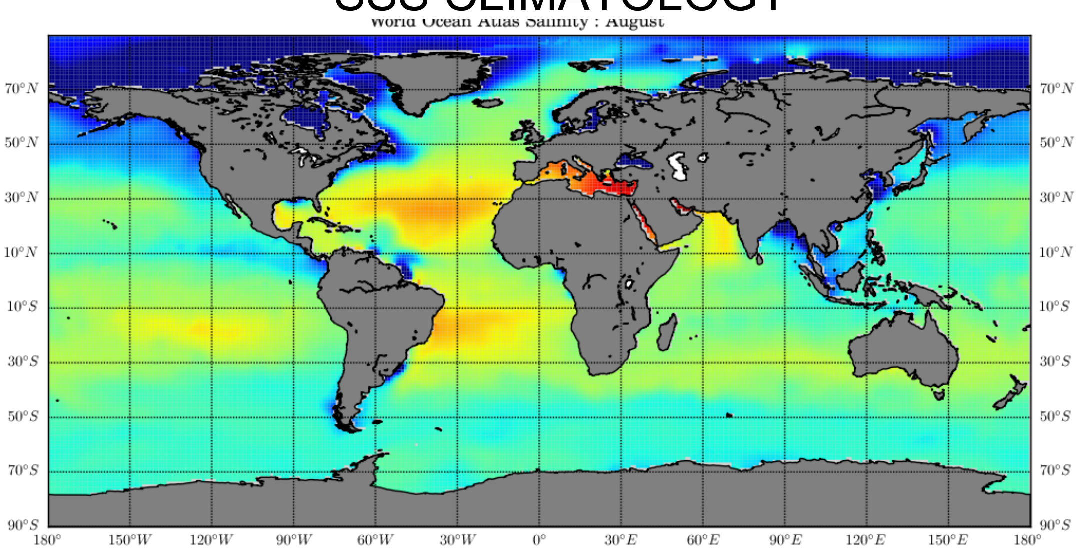
SMOS Ascending orbits

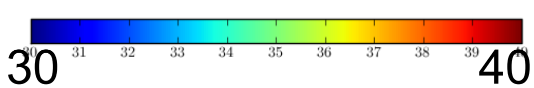


SMOS Descending orbits



SSS CLIMATOLOGY



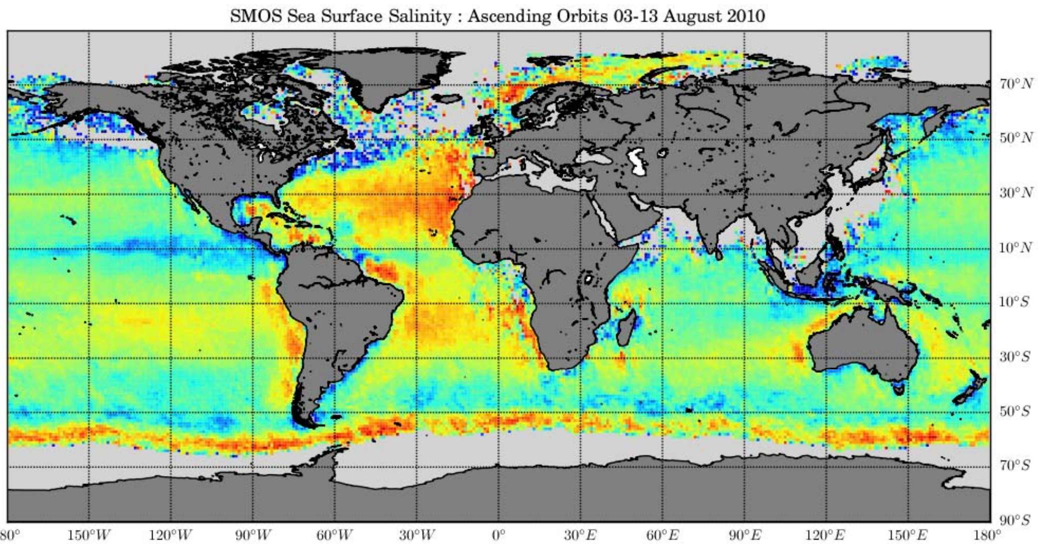


🙂 At first order, spatial features of SSS well reproduced:
- -Salty Atlantic & Subtropics
- -fresh convergence zones & high latitudes, Amazone plume)

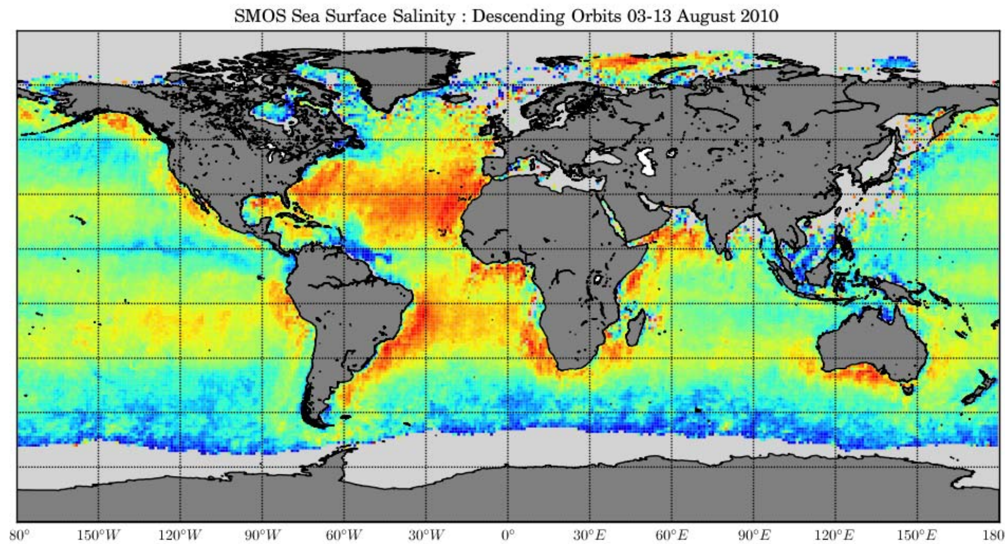
🙁 -Large biases close to land and ice *(Pb in image reconstruction under study)*
- -Spots of low SSS in the Southern Ocean => *Pb in wind correction*
- -Ascending SSS ≠Descending SSS *(pb of antenna heating & Galactic noise under study)*
- -RFI

Maps of retrieved SSS 10days (3-13 August) -100km

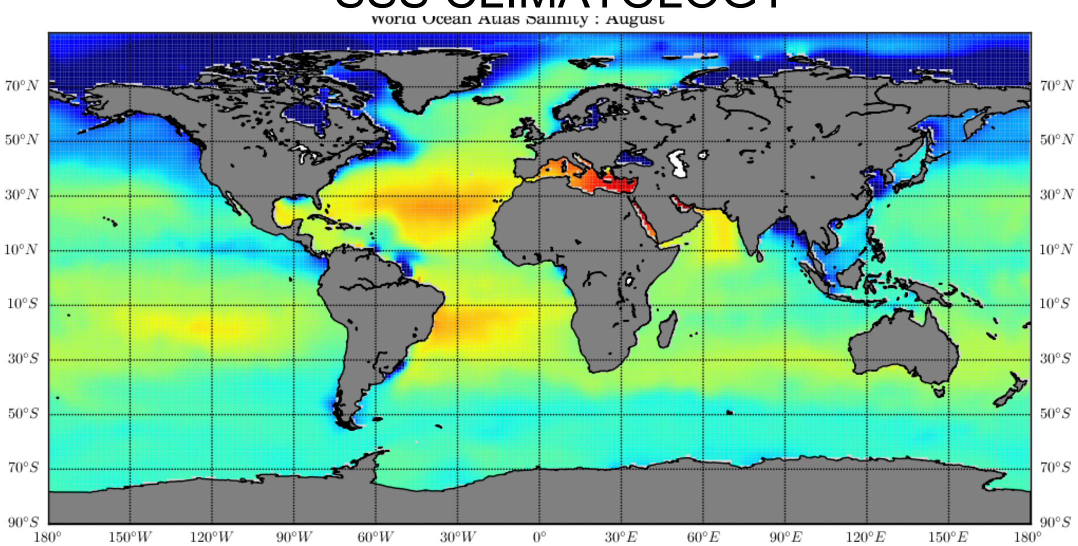
SMOS Ascending orbits

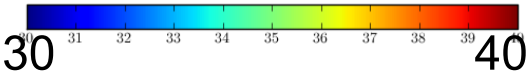


SMOS Descending orbits



SSS CLIMATOLOGY





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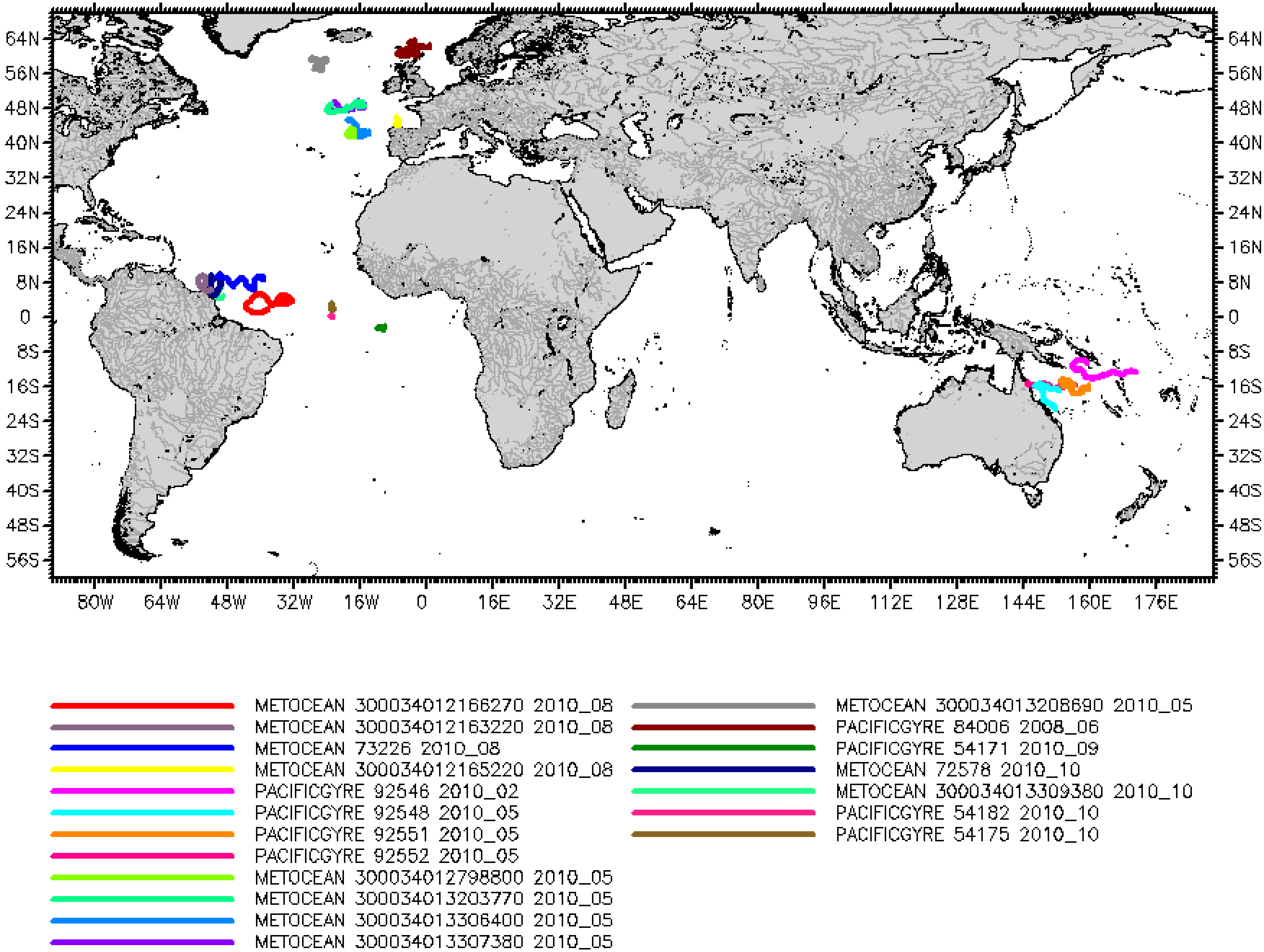
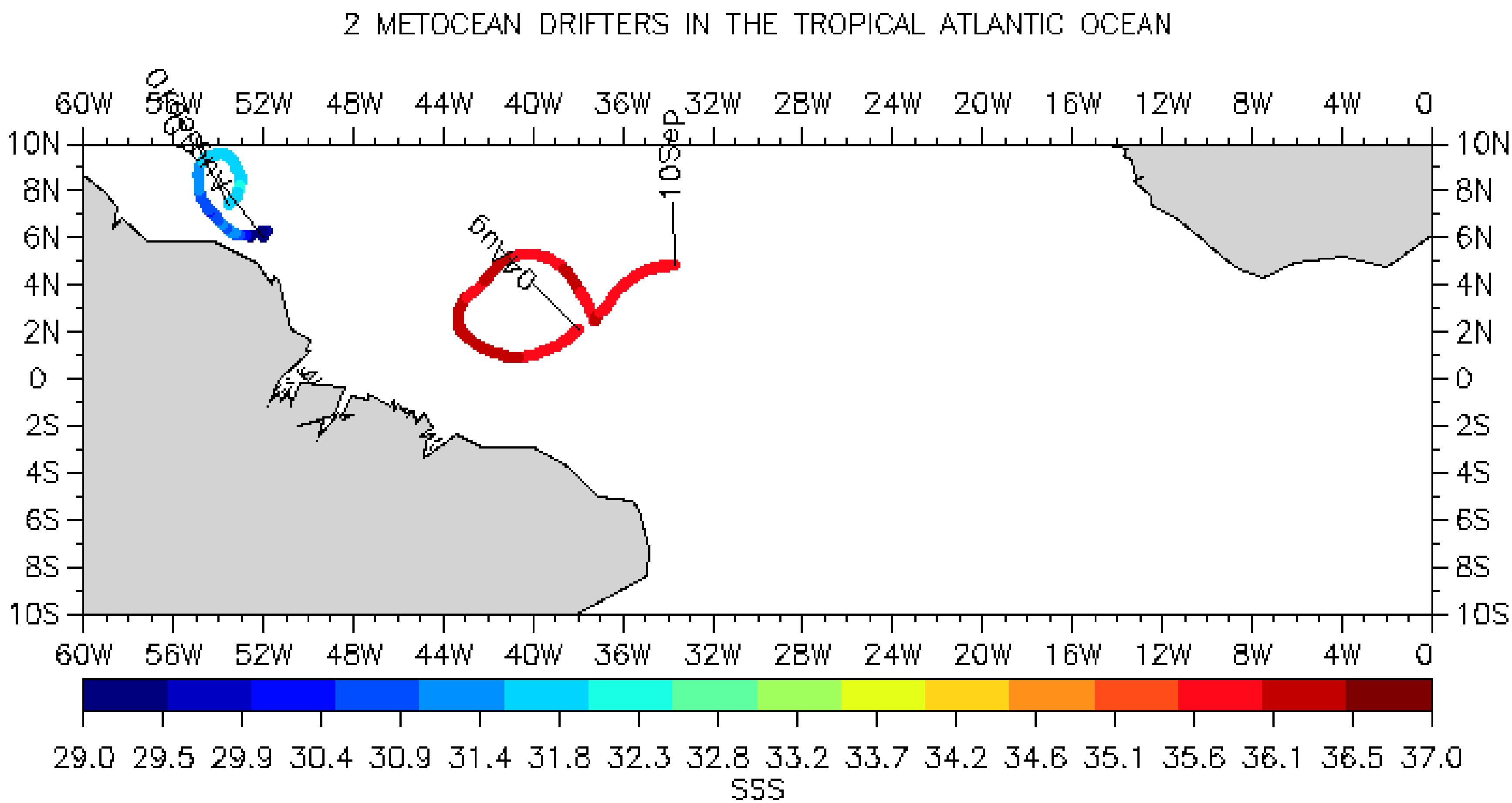
19 Sea Surface Salinity drifters (Aug.-Oct. 2010) in the frame of GLOSCAL project (measurements at 40cm depth) http://www.locean-ipsl.upmc.fr/smos/drifters/

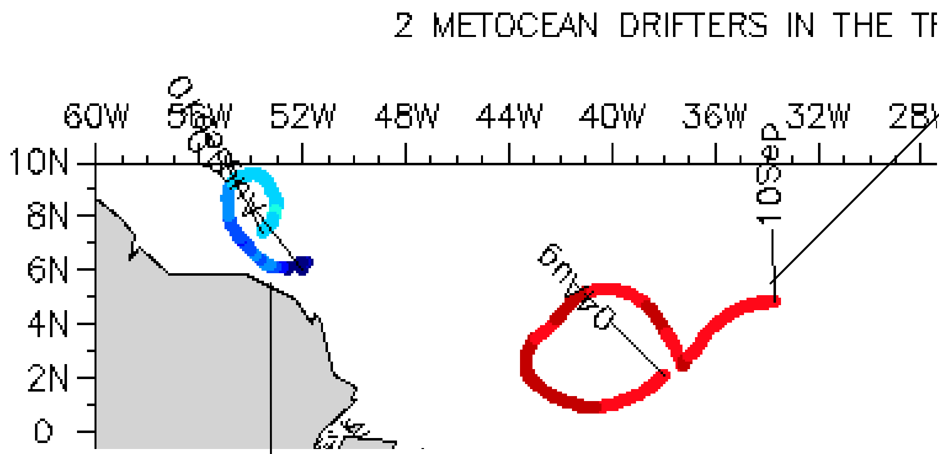


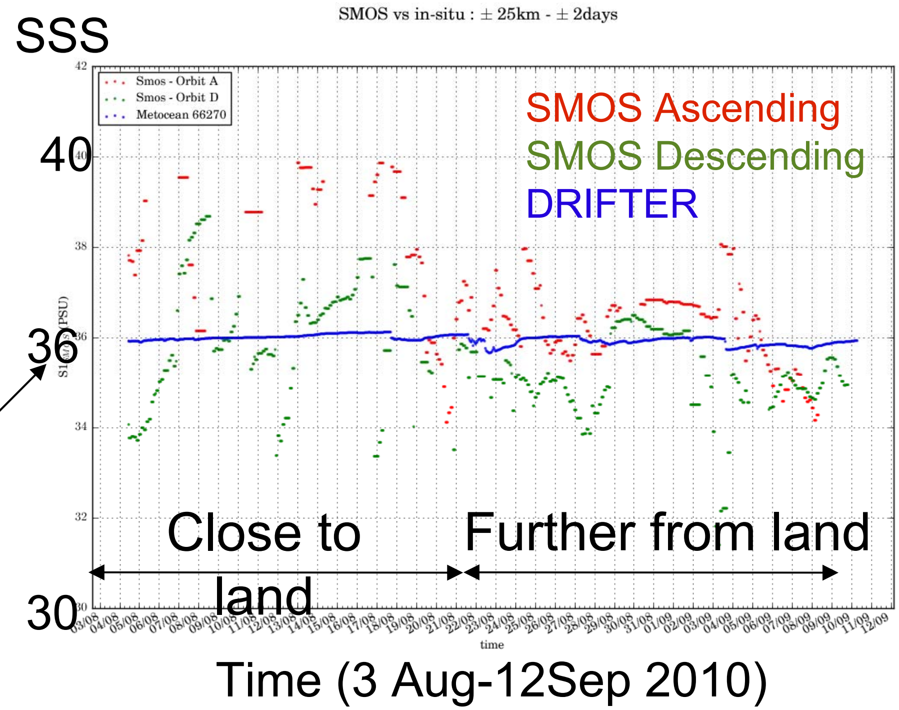
SSS from in situ drifters close to the Amazone Plume – Colocation with SSS from L2 OS OP

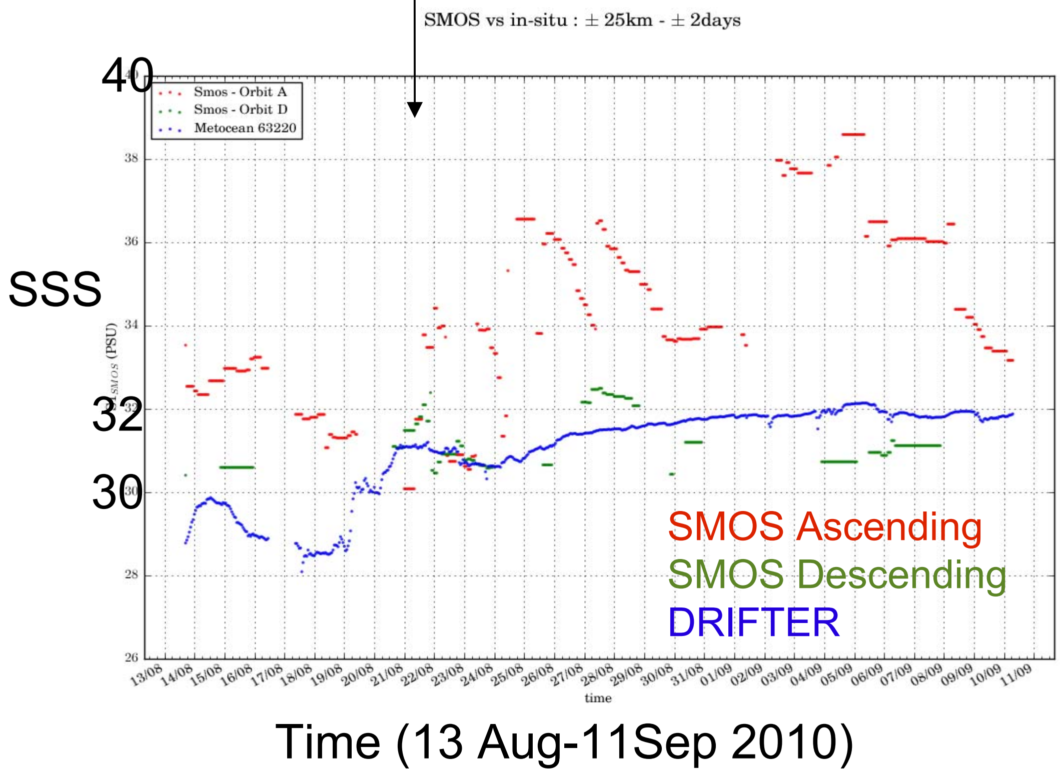


http://www.locean-ipsl.upmc.fr/smos/drifters/

SMOS SSS colocated within +/- 25km and 2days







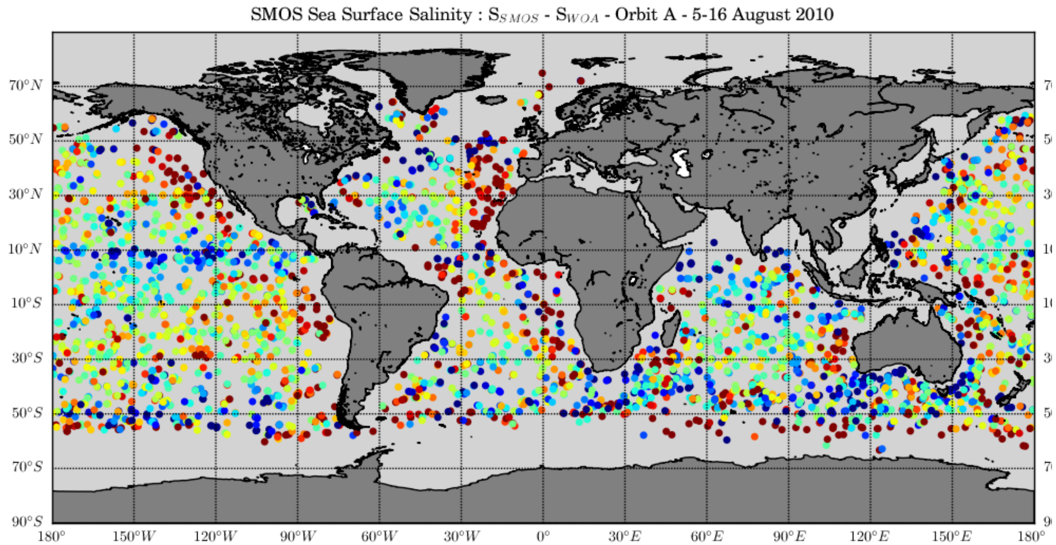
SSS retrieved on descending orbits senses the SSS contrast between the two drifters

SSS retrieved on ascending orbits are highly biased close to land

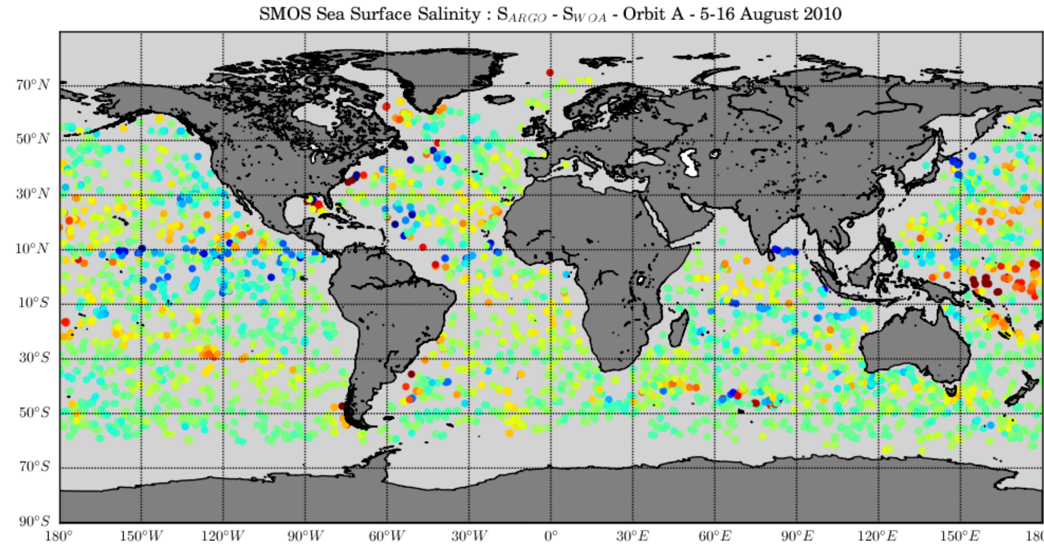
SMOS, ARGO (August 2010) & CLIMATOLOGICAL SSS

Colocation +/- 5 days, +/-50km, center swath +/-300km, Ascending orbits

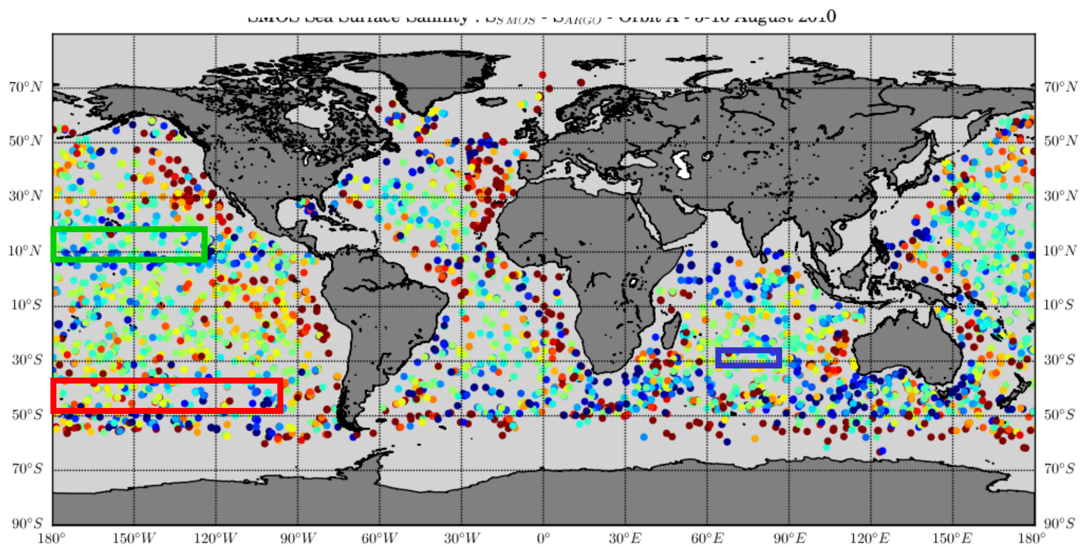
SSS SMOS – SSS CLIMATO

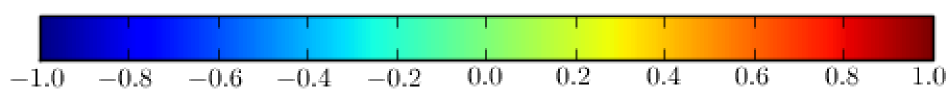


SSS ARGO – SSS CLIMATO



SSS SMOS – SSS ARGO



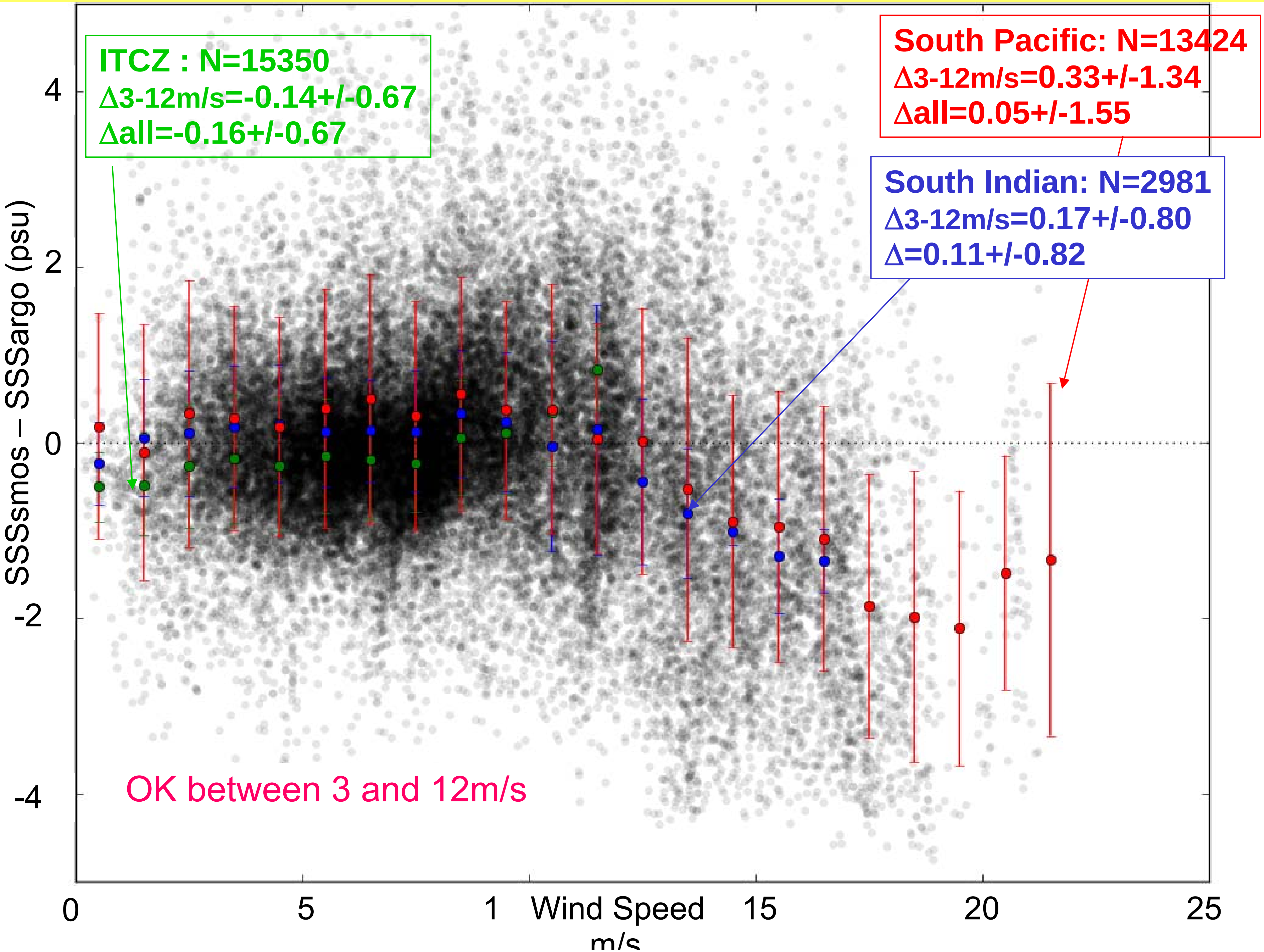


-Negative anomalies around 10°N seen by SMOS and ARGO (but smos fresher by 0.3psu): effect of smos algorithm or vertical stratification?

-positive SSS anomaly in westerm tropical Pacific seen by SMOS and ARGO

Look at wind effect in 2 zones in the Southern Ocean far from land and in ITCZ

SMOS Model 1 - ARGO SSS (3-31 August 2010; asc orbits) versus wind speed (center of orbit)



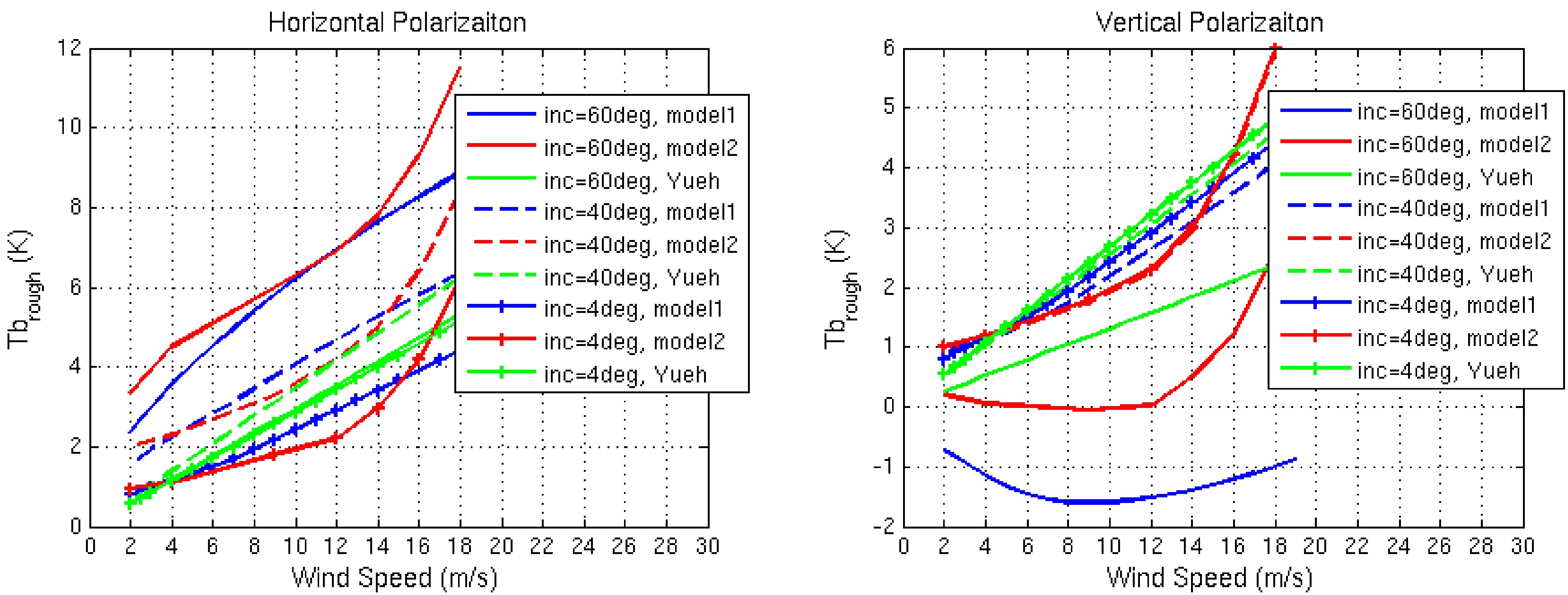
Comparison with SSS retrieved using other roughness models

Given the numerous correlations between geophysical parameters (e.g. cold SST, high wind speed) and the unknowns about the instrument behavior, instead of deriving an empirical algorithm, we prefer first to test algorithms independent of SMOS measurements (physically based or airborne data based algorithms)

-Model 2 (SSA from IFREMER, SSS2 in DPGS L2)

-Yueh et al (2010) empirical model from PALS airborne data: *(after removal of a systematic bias computed according to that model – Asc. Orbit 5 August 50S-10N)*

Tbrough from **model 1**, **model 2** and **Yueh (2010)**



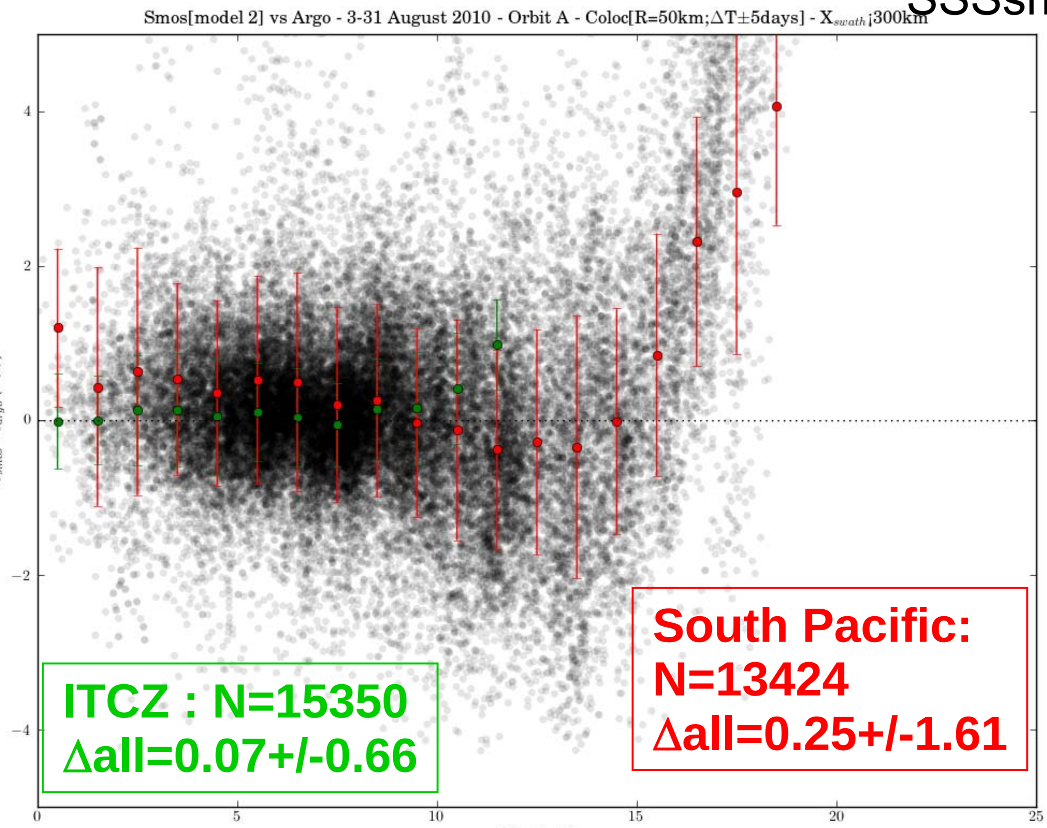
Model 2 is highly non linear with WS due to the inclusion of foam effect

Yueh (2010) model:
-linear with WS
-smaller dependence with WS than model 1 & 2 at low wind speed, stronger dependence at high wind speed than model 1
-dependence of Tbrough with incidence angle smaller than in models 1 and 2

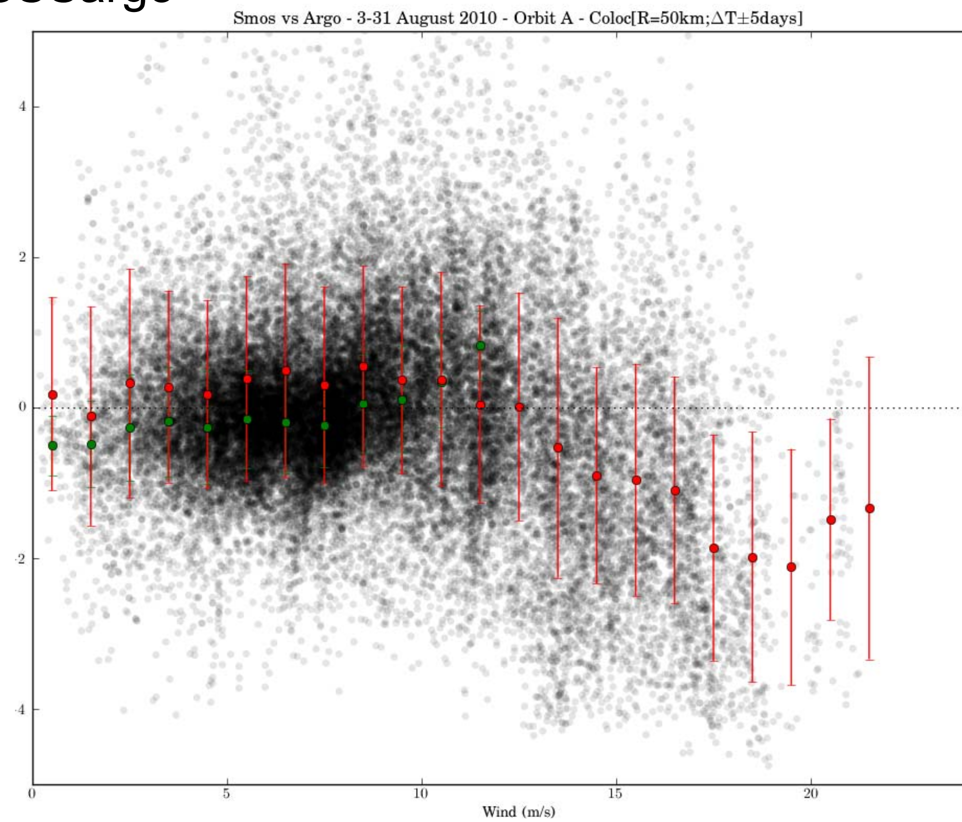
MODEL 2 WITH FOAM

MODEL 1

SSSsmos-SSSargo



4
0
-4



Model 2 overestimates Tbrough at WS>14m/s

Yueh 2010 (derived from aircraft measurements)

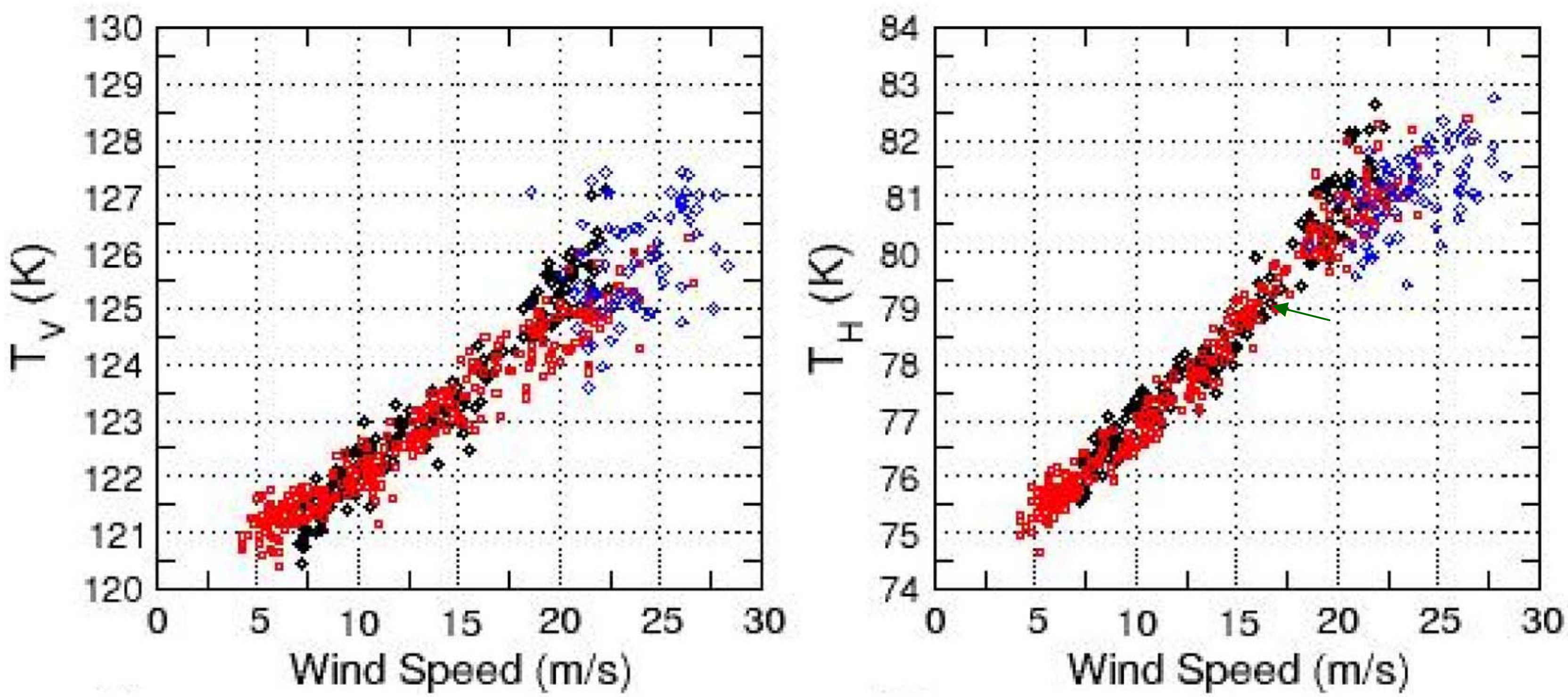


Fig. 13. V and H brightness temperatures taken at a 45◦ incidence angle from the star pattern (blue), inbound (red), and outbound (black) tracks on March 2, 2009, are plotted versus the wind speed derived from the POLSCAT measurements. All brightness temperature measurements have been translated to a 45◦ incidence angle and corrected for galactic radiation.

Passive and Active L-Band Microwave Observations and Modeling of Ocean Surface Winds, TGARSS, 2010

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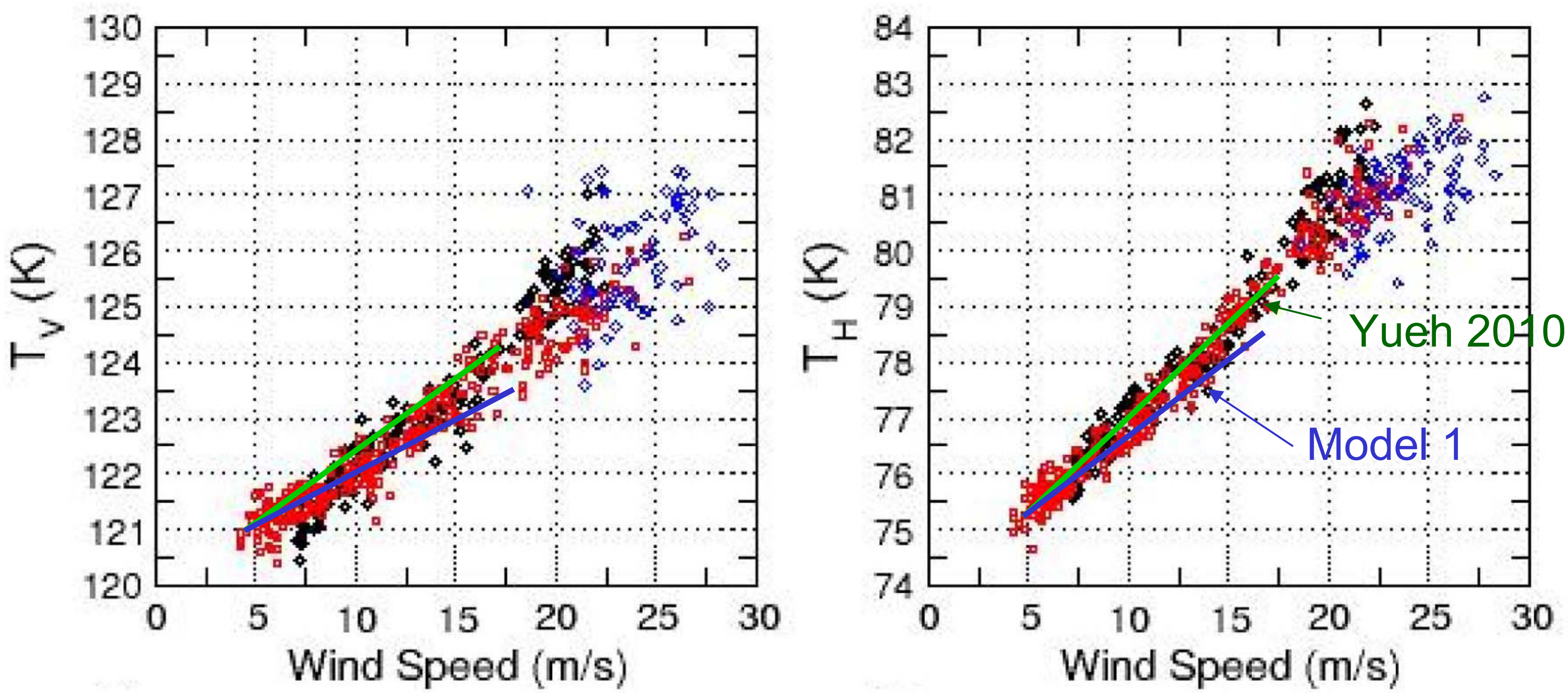

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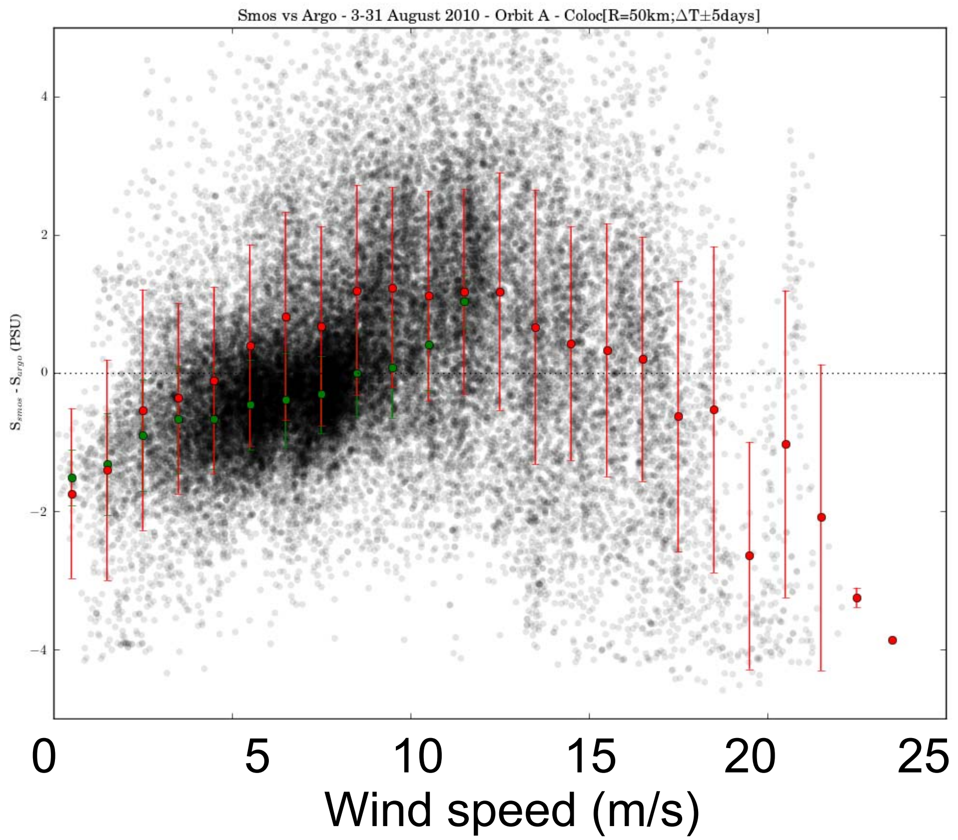
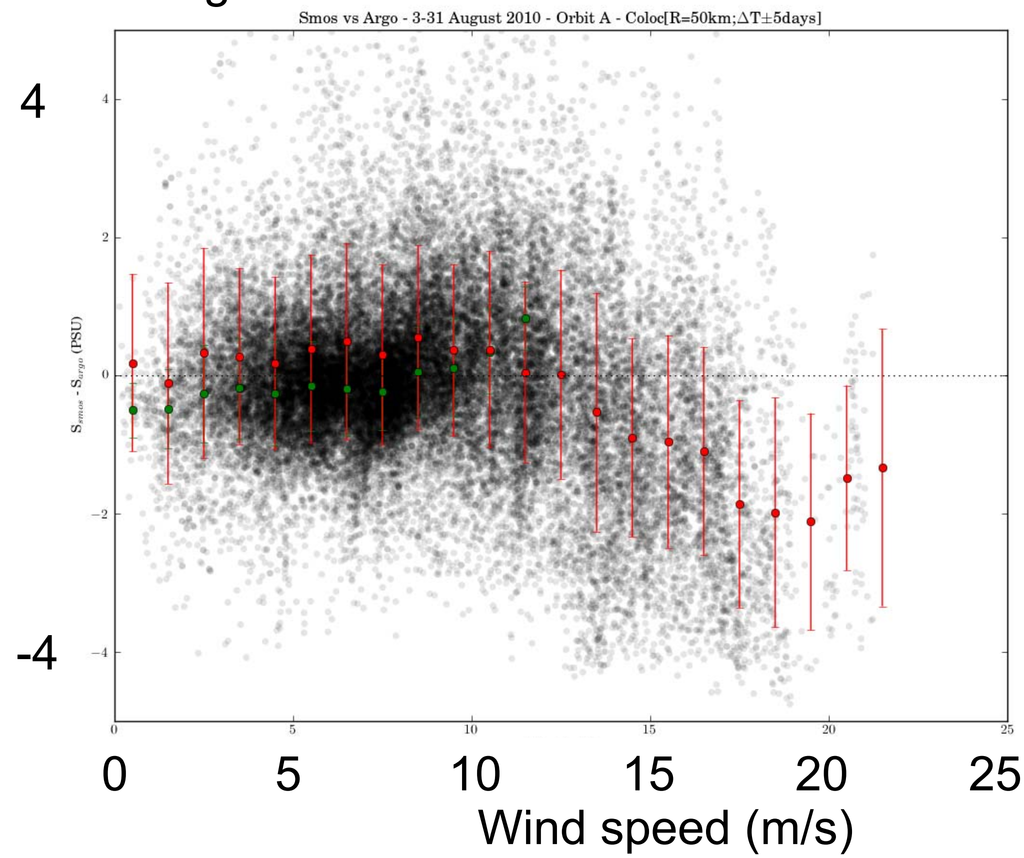
Yueh (2010)

Model 1

SSSsmos-SSSargo





-With Yueh (2010) model, for wind speed lower than 10m/s, bias depends on the wind speed ; model 1 or model 2 are better

-Yueh (2010) model slightly better between 13 & 18m/s but negative bias at higher wind,

=> **Need for a non linear dependence with WS**

-No dependence of Tbrough to SST in Yueh empirical model (contrary to model 1 & 2)=> difference between northern tropical and S. Pac zones varies with WS

Towards theoretical improvement

SMOS data =>L-band Tb depend in a **non linear way** to wind speed =>

Modify model 1 to include a foam dependency and reduce roughness impact to compensate foam impact at moderate wind speed:

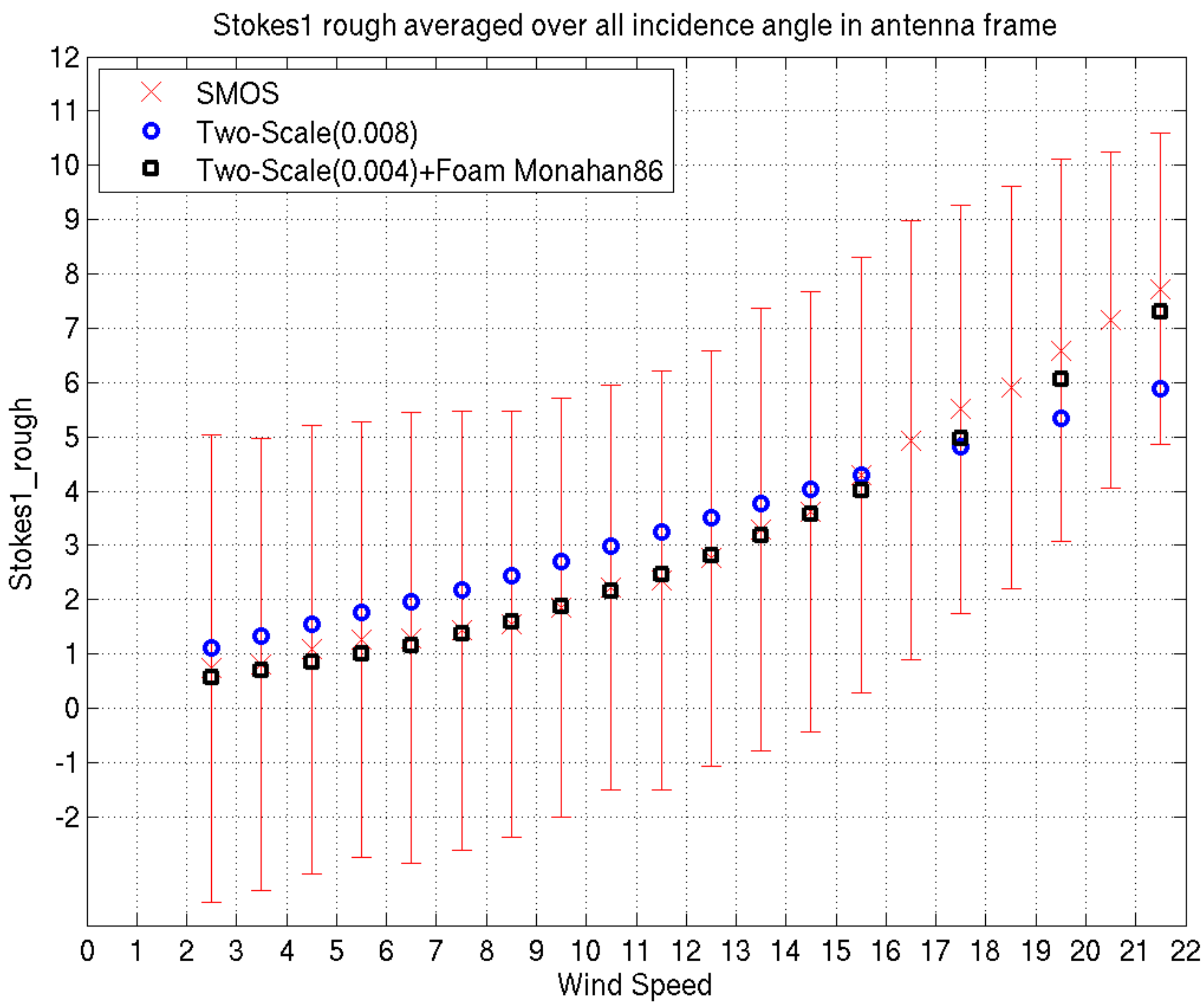
New version of model 1 to be included in next version of L2 processor:

Roughness: 2-scale model using wave spectrum from Durden and Vesecki *1 (instead of *2)

Foam coverage: Monahan and Muircheataigh (1986)

Foam emissivity: Stogryn (1972)

Test over 3 orbits in the east southern Pacific



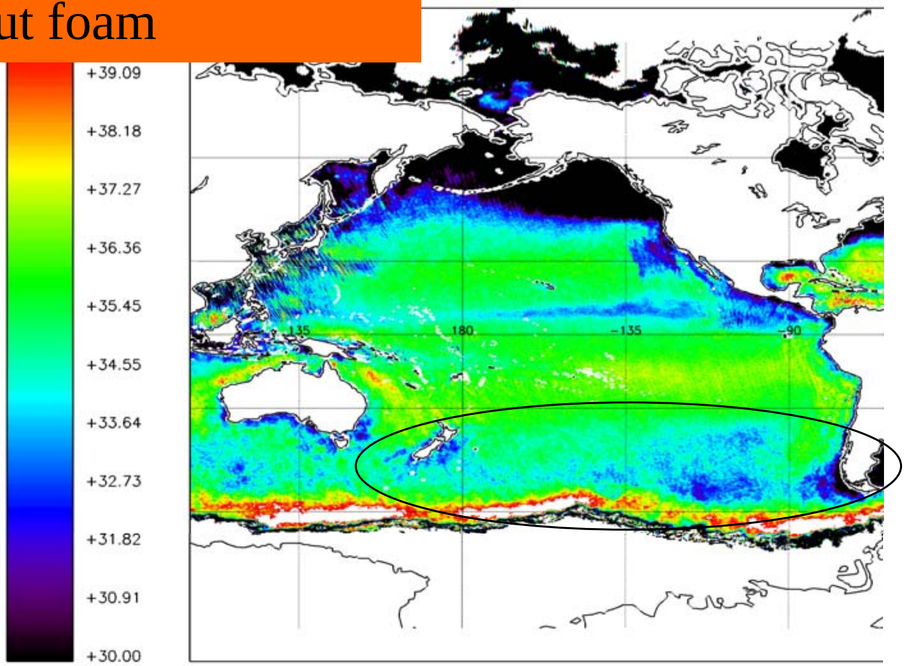
X SMOS Stokes 1 corrected for all effects except roughness (OTT computed with new model)

O Old model (2-scale-DV2)

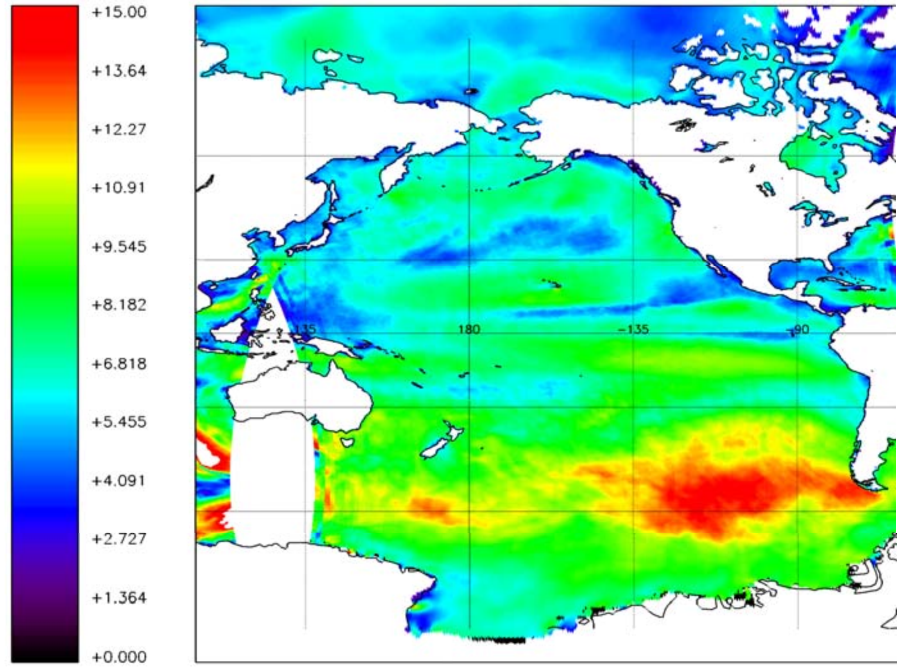
O New model (DV1 + Foam)

Model 1: Two-Scale without foam

SMOS SSS

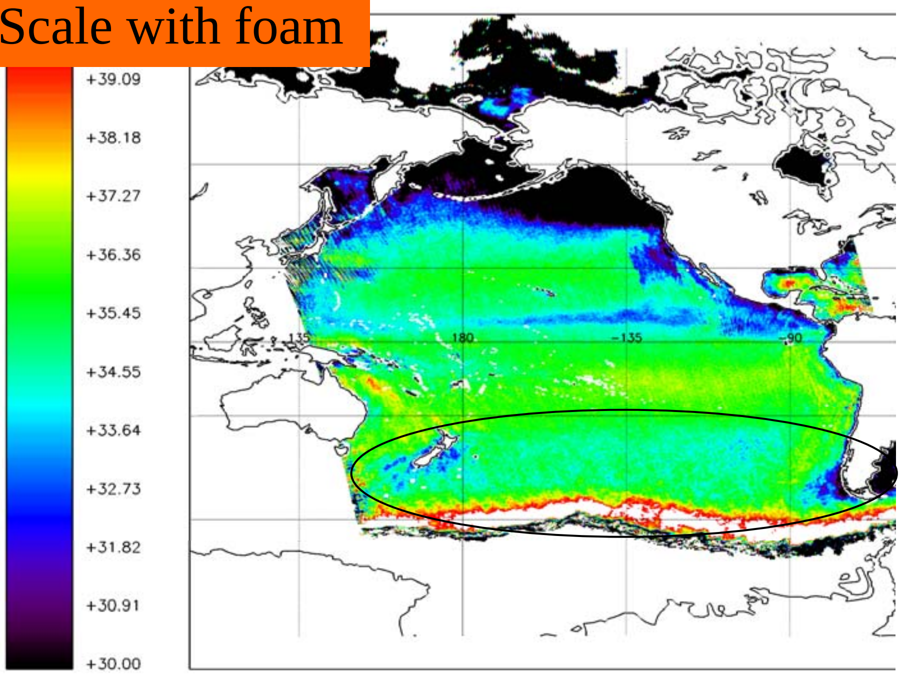


ECMWF WS



Model 1 modified: Two-Scale with foam

SMOS SSS



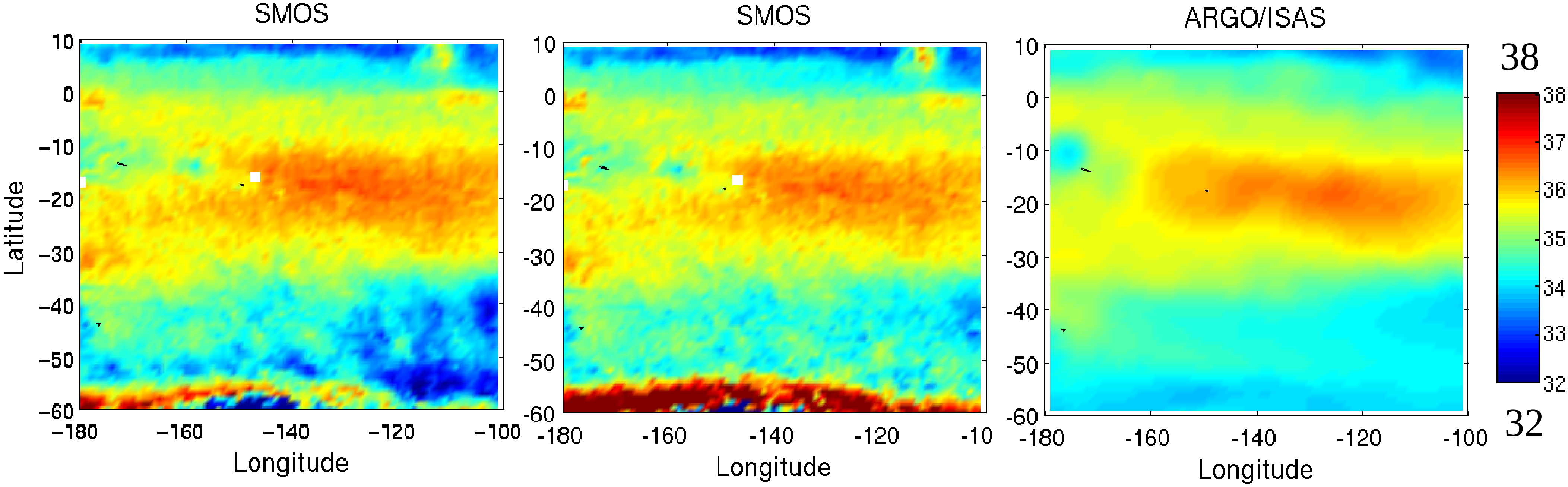
Low SSS associated with large wind speed diseappeared

SSS comparisons

Model 1: Two-Scale without foam

Modified model 1: Two-Scale with foam

ISAS: objective analysis of ARGO SSS (F. Gaillard, IFREMER)



Summary

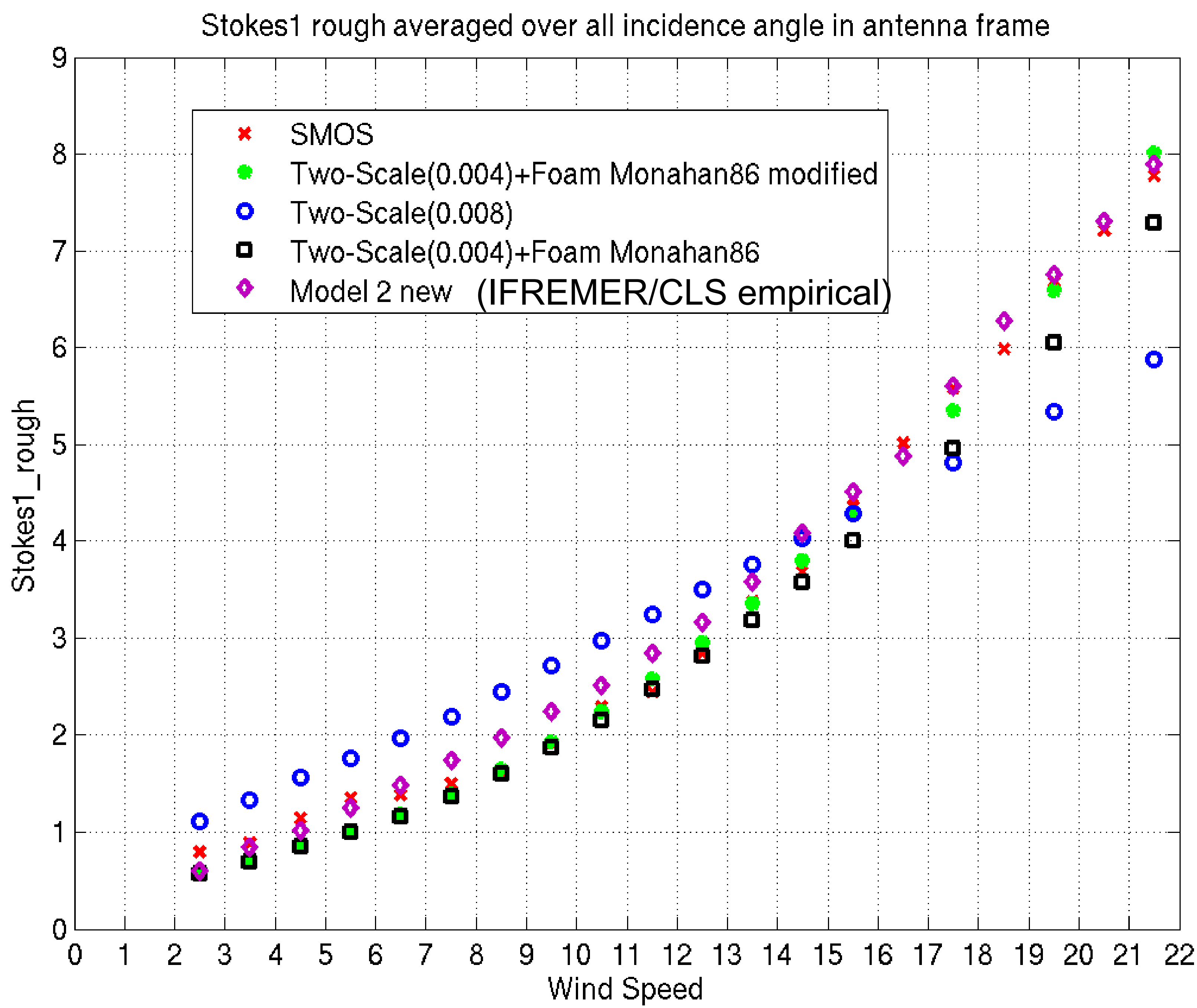
After systematic bias correction, far from ice and land, **SMOS** senses **geographical variations of SSS** (using algorithm defined before launch)

Improvements (ice & land biases, Ascending/Descending orbits biases,wind speed biases) are anticipated from:
-image reconstruction,
-instrument calibration
-L-band sea surface emissivity model (roughness+foam; modified model under study)

Need to refine validation:

-In regions with strong precipitations: are SMOS SSS anomalies around 10°N in the Pacific realistic? Need to measure SSS in the few cm close to the sea surface (e.g. drifters)

-lower accuracy on SSS retrieved in August during descending orbits in case of strong galactic signal scattered by the sea surface


Stokes1 rough averaged over all incidence angle in antenna frame
SMOS
Two-Scale(0.004)+Foam Monahan86 modified
Two-Scale(0.008)
Two-Scale(0.004)+Foam Monahan86
Model 2 new
(IFREMER/CLS empirical)
Stokes1_rough
Wind Speed
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22