Correcting sea surface temperature spurious effects in salinity retrieved from spaceborne L-band Radiometer measurements

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(1) LOCEAN (2) ACRI ST (3) NASA (4) LATMOS (5) ARGANS (6) LOPS

See more in Boutin et al. , IEEE TGARSS, 2020

Background (1)

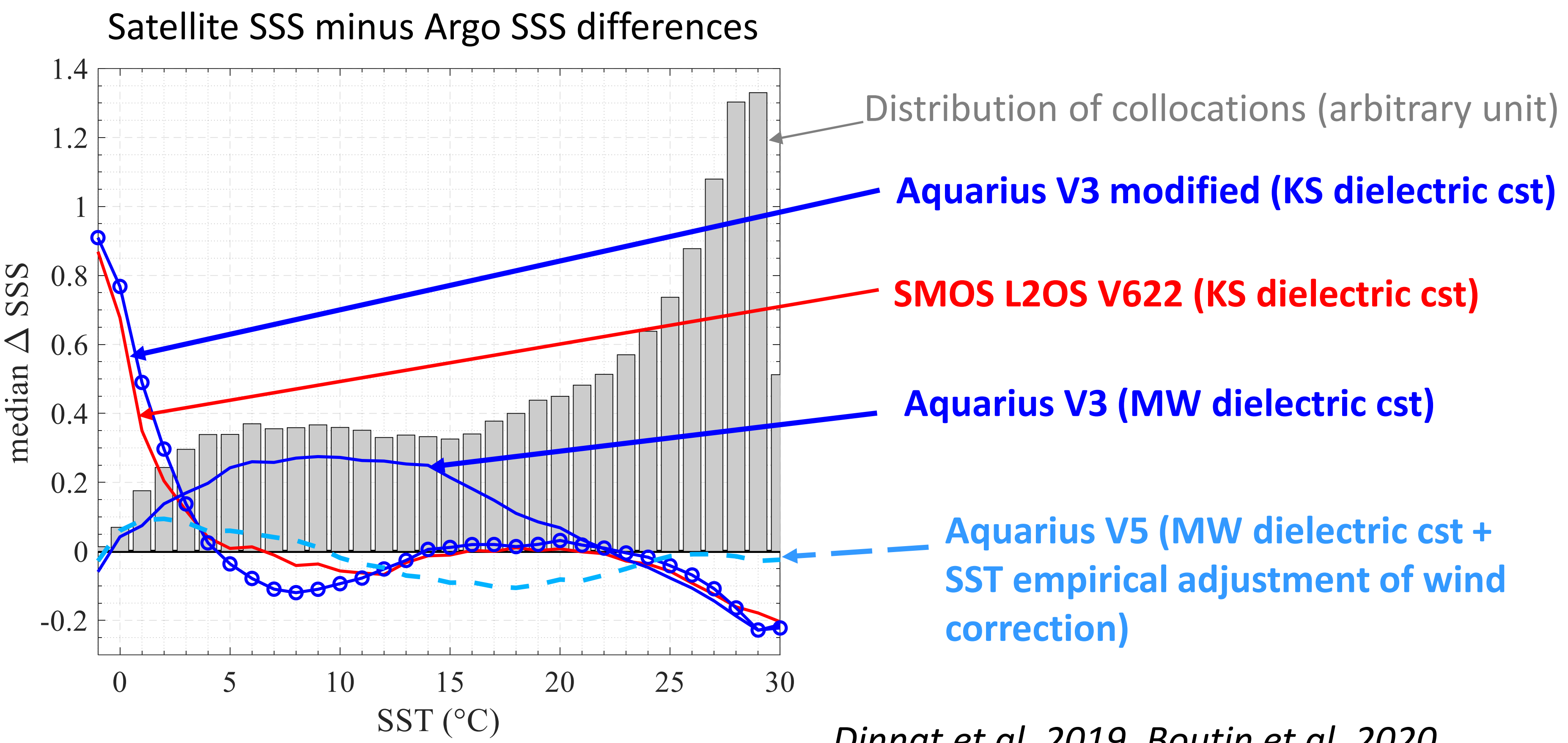
- **Salinity dependency of L-band (1.4GHz) radiometer meas. ⇔ dielectric constant:**

For a flat sea: $\boldsymbol{Tb_{sea} = e\,(SSS, SST).\,SST}$

$$e_v = 1 - \left| \frac{\varepsilon_r \cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\varepsilon_r \cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \right|^2 \qquad e_h = 1 - \left| \frac{\cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \right|^2$$

- |∂Tb/∂SSS| small (1 to 0.2 K/pss)
  => **need very precise $\boldsymbol{\varepsilon_r}$** to retrieve SSS with ~0.1-0.2pss uncertainty
- **Various dielectric constant models used for processing satellite data today:**
  - SMOS ESA : **Klein & Swift (1977) (KS)**: model fitted to laboratory measurements
  - Aquarius/SMAP RSS: **Meissner and Wentz (2004, 2012) (MW):** model fitted to satellite meas. (multiple frequencies)
  - Aquarius/SMAP CAP JPL: intermediate between KS and MW

Background (2): SST residuals between satellite & in situ SSS



Dinnat et al. 2019, Boutin et al. 2020

Both SMOS and Aquarius V3 roughness models depend on SST based on physical considerations (2-scale model for SMOS & geometric optics for Aquarius V3) =>

Could we resolve the SST residuals of satellite SSS without empirical SST adjustment of wind model?

Objective of the study:

- Minimize the SST dependency of residuals between satellite and co-localized in situ salinity while retaining as much as possible physical basis in the modelling of the various components of the radiative transfer model

=> Investigate a revision of dielectric constant model

Method:

- Adjust one parameter of the physical inspired dielectric constant model of Somaraju and Trumpf (2006) by comparing SMOS retrieved pseudo dielectric constant (Acard) with Acard derived from SMOS Tb and ECMWF IFS Temperature & In Situ Salinity

Frequency, Temperature and Salinity Variation of the Permittivity of Seawater

Ram Somaraju and Jochen Trumpf, *Member, IEEE*

Existing models for the permittivity of saline water are ***empirical*** *ones that best fit experimental data. We propose a* ***physically realistic model, similar to the one used in plasma physics, for the variation of the dielectric constant of water with varying frequencies and salinities.***

In addition to using the dielectric model of fresh water Ellison *et al.* [15], Stogryn *et al.* [11] and Meissner *et al.* [12], respectively, use 30, 13 and 12 parameters that are determined from experimental data to predict the variation of all the terms in (5) with temperature and salinity. In contrast, our model is not only physically realistic but also uses only two additional parameters to describe the dielectric behavior of seawater.

$$\epsilon_r(\omega,T,S) = \epsilon_\infty(T,S) + \frac{\epsilon_s(T,S)-\epsilon_1(T,S)}{1+j\omega\tau_1(T,S)} + \frac{\epsilon_1(T,S)-\epsilon_\infty(T,S)}{1+j\omega\tau_2(T,S)} + j\frac{\sigma(T,S)}{\epsilon_o\omega}.$$

Double Debye model used by Stogryn, 1995, Meissner & Wentz 2004, 2012

Total polarization of sea water described as the sum of :

- P_b, the polarization due to the displacement of bound charges in water molecules (i.e. induced and orientation polarization): number of water molecules that orient themselves around the dissolved ions proportional to the number of ions, Ni => ε_s decreases linearly with S.
- P_f, the polarization due to the displacement of ions inside water (i.e. atomic polarization).

$$\epsilon_r(\omega,T,S) = \epsilon_\infty(T) + \frac{\epsilon_s(T)\,(1-\alpha(T)S)-\epsilon_1(T)}{1+j\omega\tau_1(T)} + \frac{\epsilon_1(T)-\epsilon_\infty(T)}{1+j\omega\tau_2(T)} - \sum_i \frac{c_i}{\epsilon_0\omega^2\left(1+j\omega_i^{\text{eff}}/\omega\right)}$$

Somaraju and Trumpf 2006

IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 54, NO. 11, NOVEMBER 2006

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Meissner & Wentz 2004, 2012

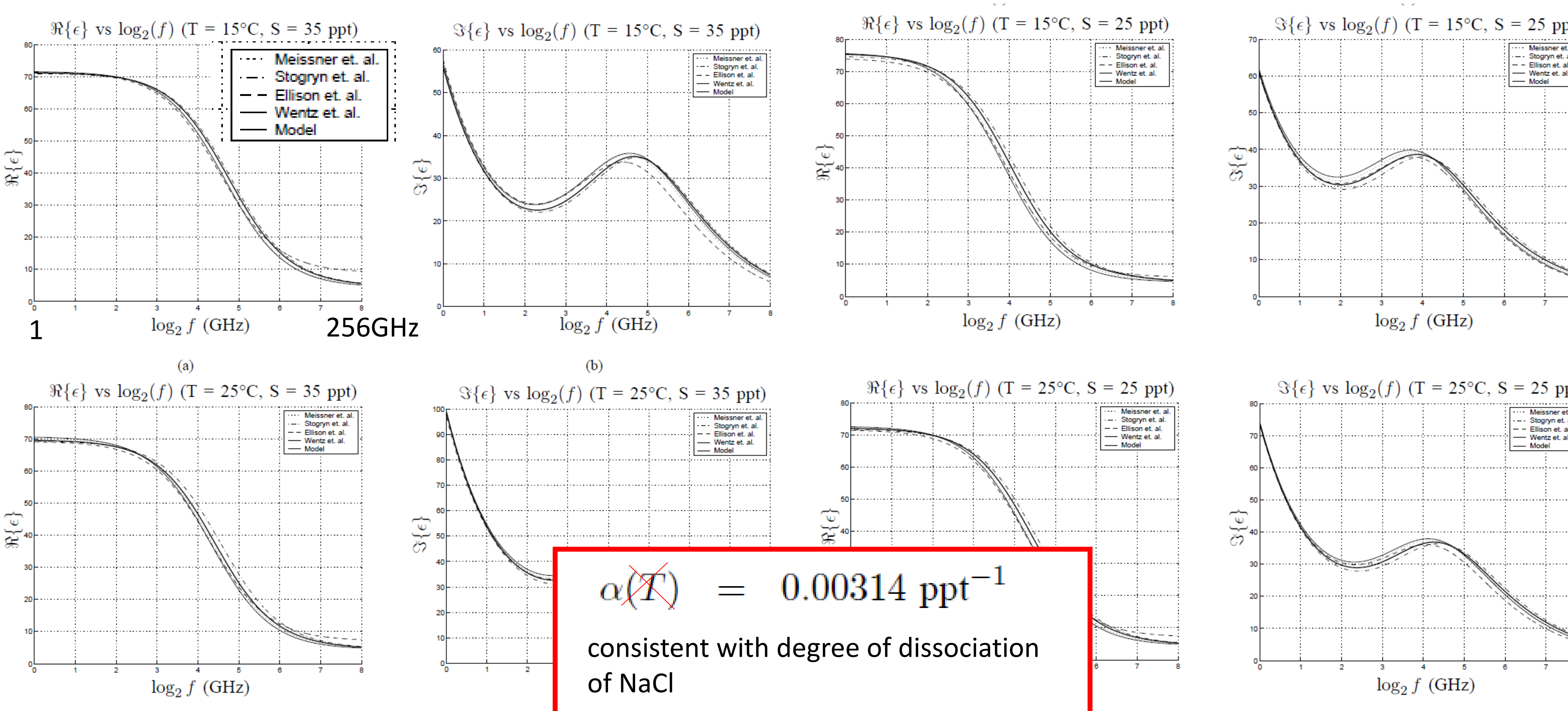
At low frequency, only one unknown parameter in addition to pure water parameters and conductivity

(they use pure water parameters of Stogryn 1995; at L-Band using pure water parameters of MW 2014 gives very similar results)

$$\epsilon_r(\omega, T, S) = \epsilon_1(T) + \frac{\epsilon_s(T)\,(1 - \alpha(T)S) - \epsilon_1(T)}{1 + j\omega\tau_1(T)} + \frac{\epsilon_1(T) - \epsilon_\infty(T)}{1 + j\omega\tau_2(T)} + j\frac{\sigma(T, S)}{\epsilon_o\omega}$$

Somaraju and Trumpf 2006

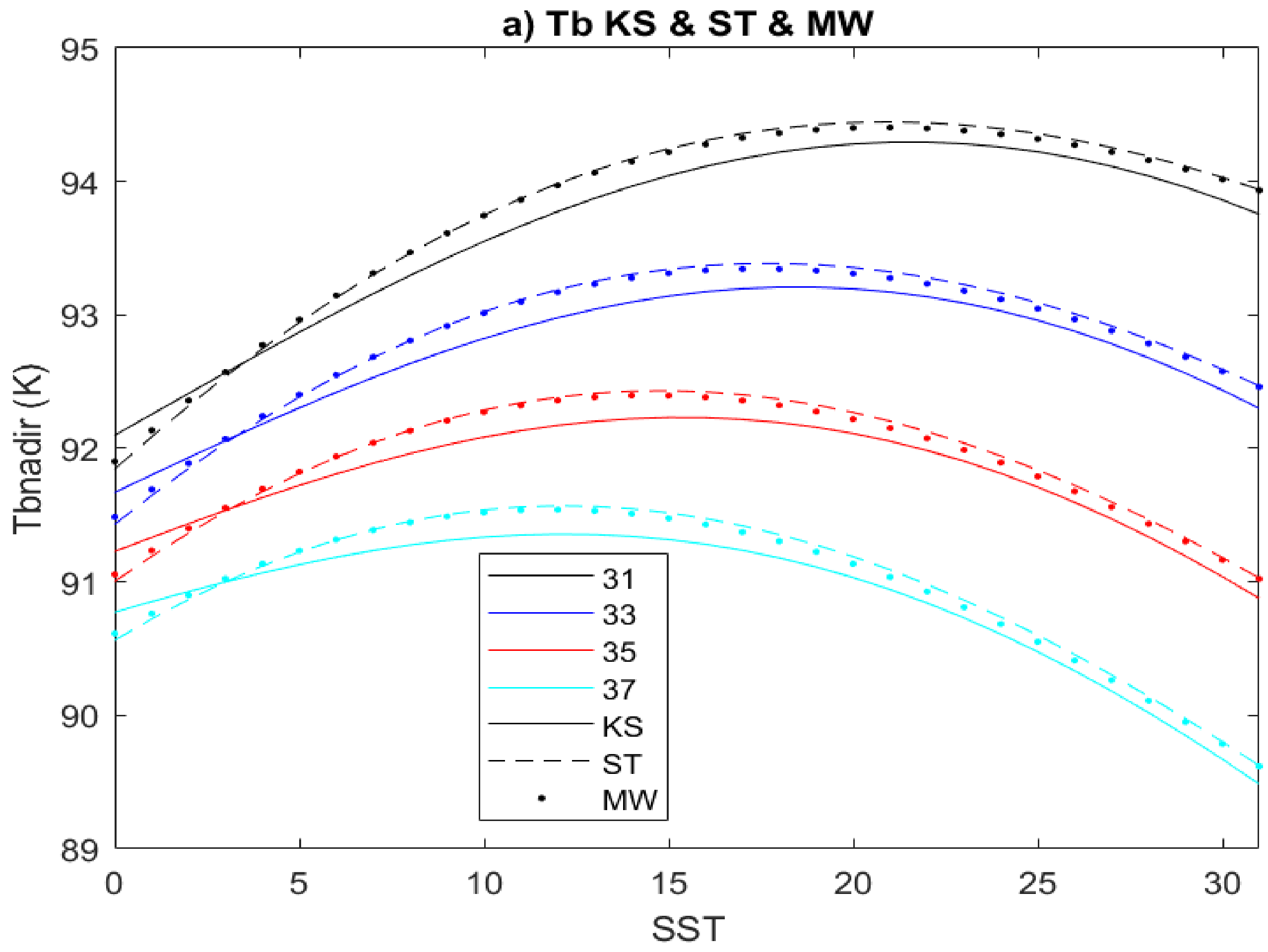
Somaraju’s fits of Re(ε) and Im(ε) to various dielectric constant models, at various S, T as function of frequencies (1-256GHz)



$$\alpha(\cancel{T}) = 0.00314 \text{ ppt}^{-1}$$

consistent with degree of dissociation of NaCl

Tb (SSS, SST) at L-band



KS: Klein and Swift (1977)

MW: Meissner and Wentz (2004, 2012)

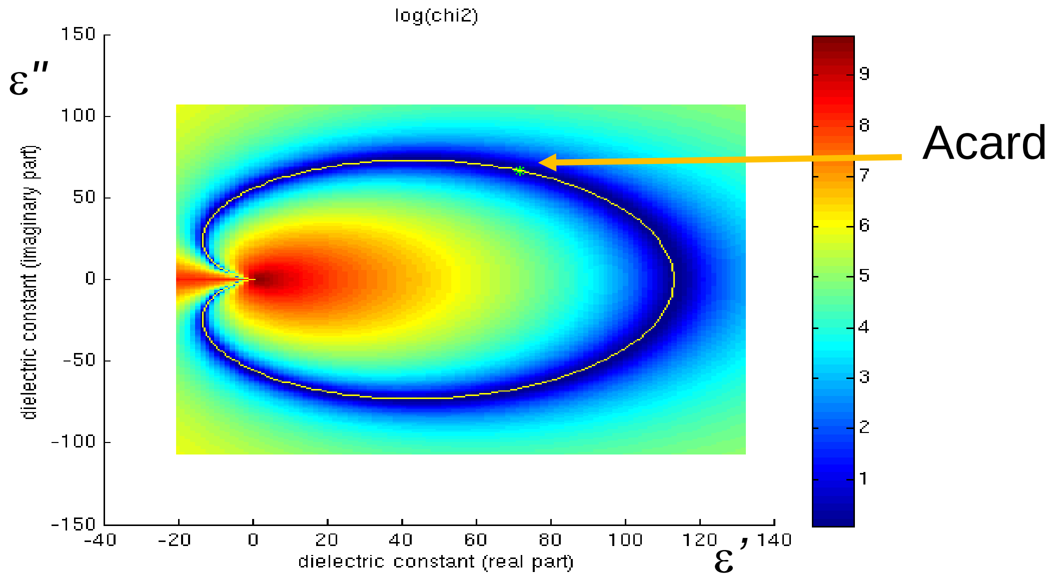
ST: Somaraju and Trumpf (2006)

Data and methods

- SMOS ESA v662 retrieved pseudo dielectric constant (Acard) compared the one derived with *in situ* (Argo and ship) SSS measurements and ECMWF IFS SST
- Period: 2012- 2015
- Thorough SMOS data sorting:
  - within +/-400 km away from the track, in order to avoid SMOS swath edges with fewer and noisier Tb measurements than in the central part of the swath,
  - further than 1000 km away from the coasts, in order to avoid land-sea contamination
  - wind speeds between 5 and 9m s^{-1}, to minimize uncertainties in wind corrections
  - latitudes south of 40°N in order to avoid high northern latitudes possibly contaminated by remaining RFI, ice vicinity and solar contamination during the eclipse period [19],
  - latitudes north of 60°S and 50°S for descending and ascending orbits, respectively => minimize ice-sea contamination

Pseudo dielectric constant retrieved from SMOS Tb: Acard

Cost function obtained when retrieving (ε', ε") from SMOS Tbs



Waldteufel et al. 2004

While it is not possible to retrieve real and imaginary part of dielectric constant separately,
It is possible to derive a combination of them: Acard

Multiangular (θ ~ 0°- 60°) SMOS Tbs corrected from roughness, atmosphere, and galactic noise => Acard

$$Acard = m\_card^2 / (m\_card + \varepsilon' - B\_card)$$

with: $m\_card = ((\varepsilon'-B\_card)^2 + \varepsilon''^2)^{1/2}$

with B_card = 0.8

Order of magnitudes:

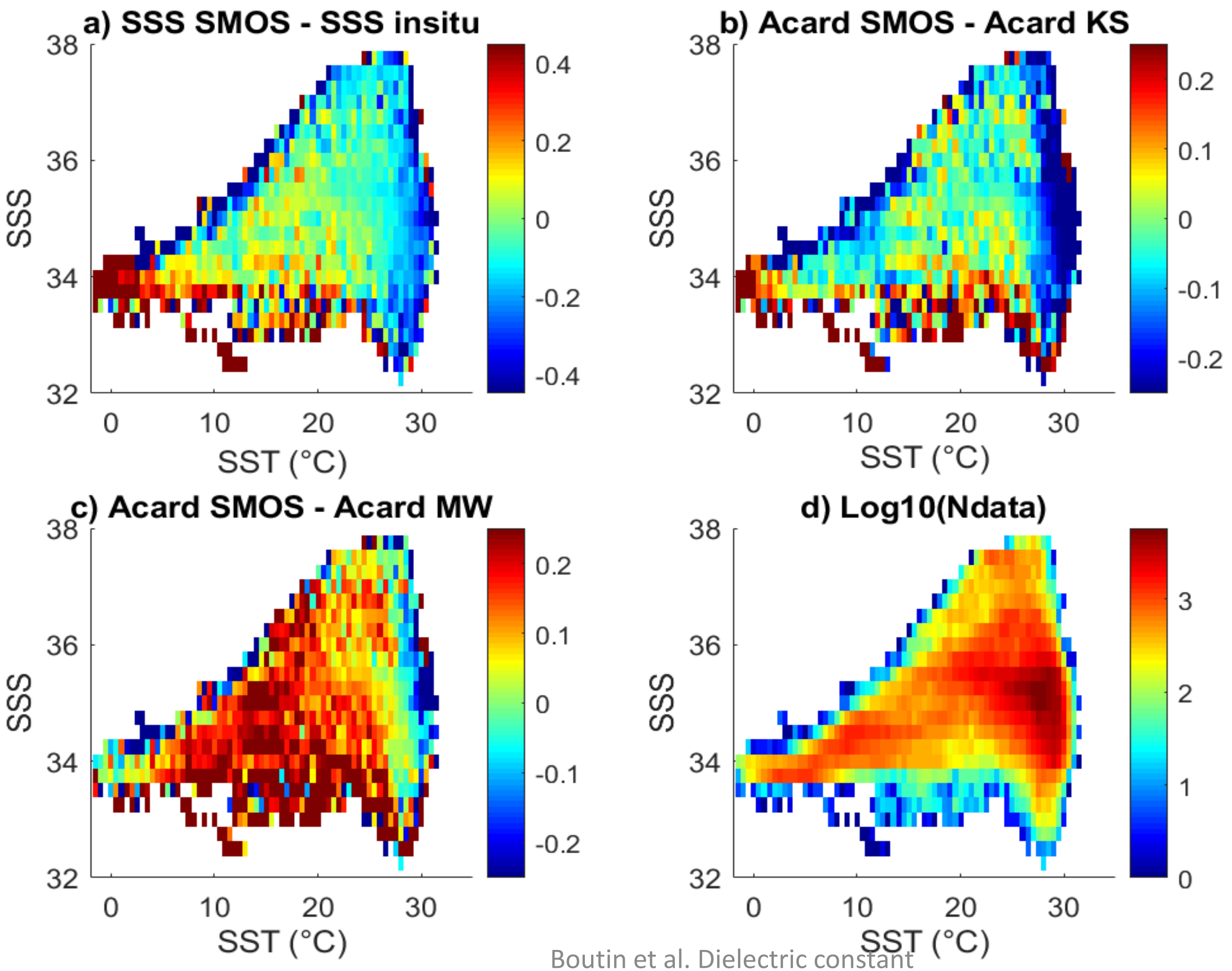
dAcard/dSSS=1.1/pss @ 30°C

dAcard/dSSS=0.3/pss @ 0°C

SMOS SSS and Acard compared to in situ values

2012- 2015 period

Wind Speed 5-9m/s



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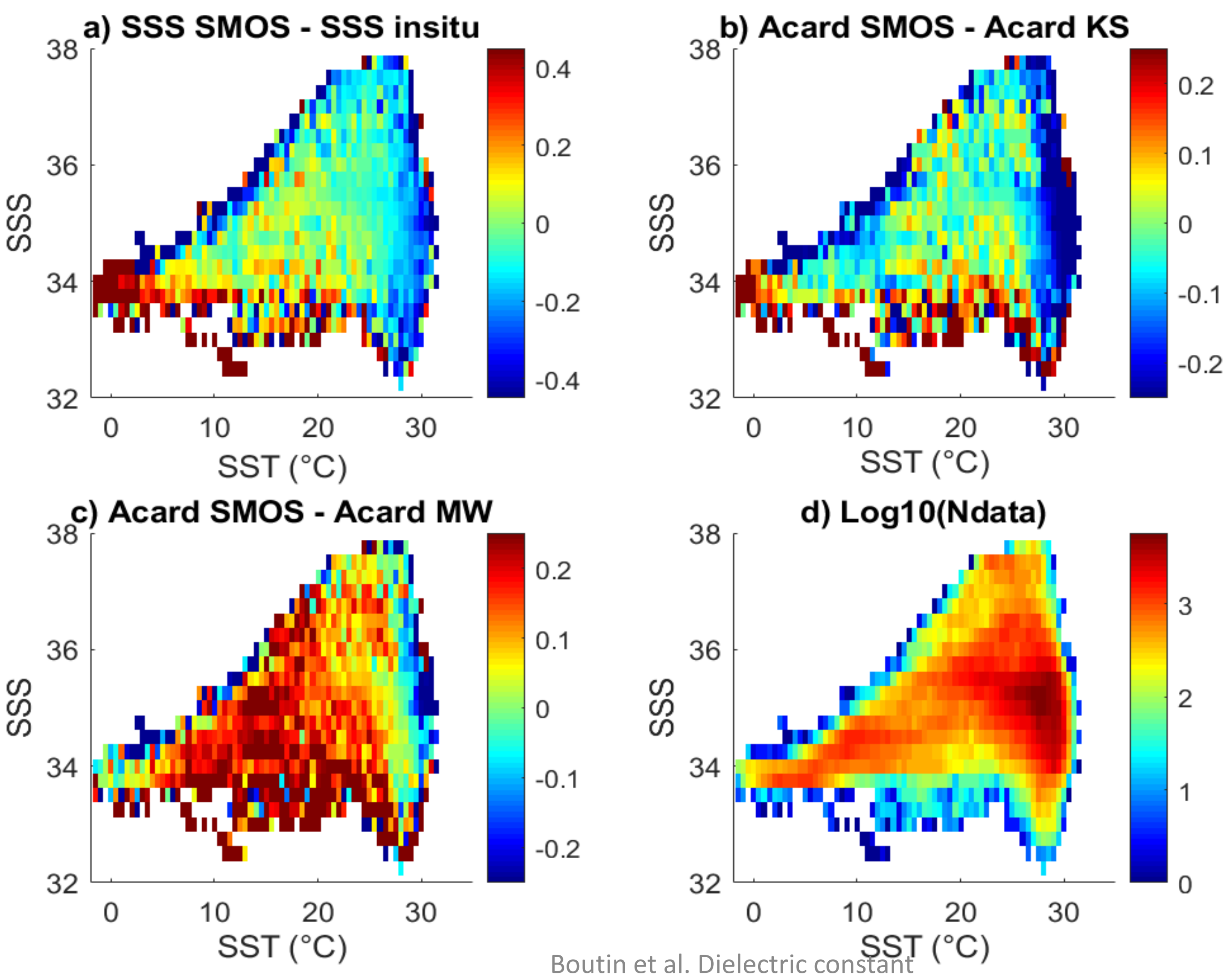
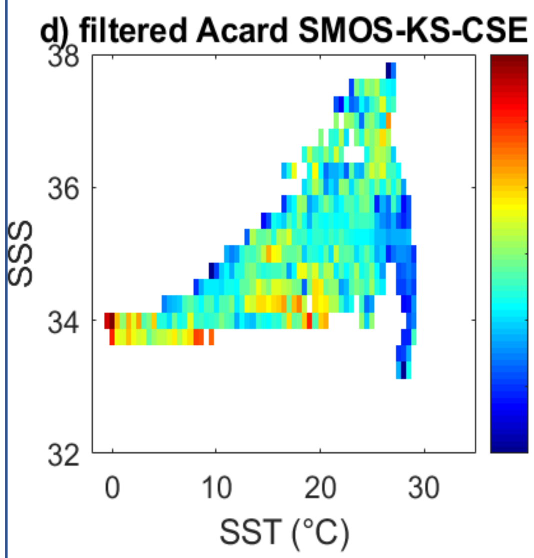
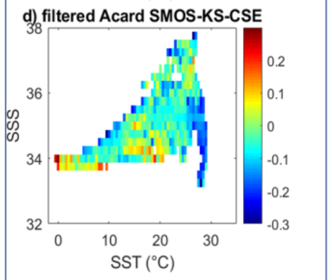


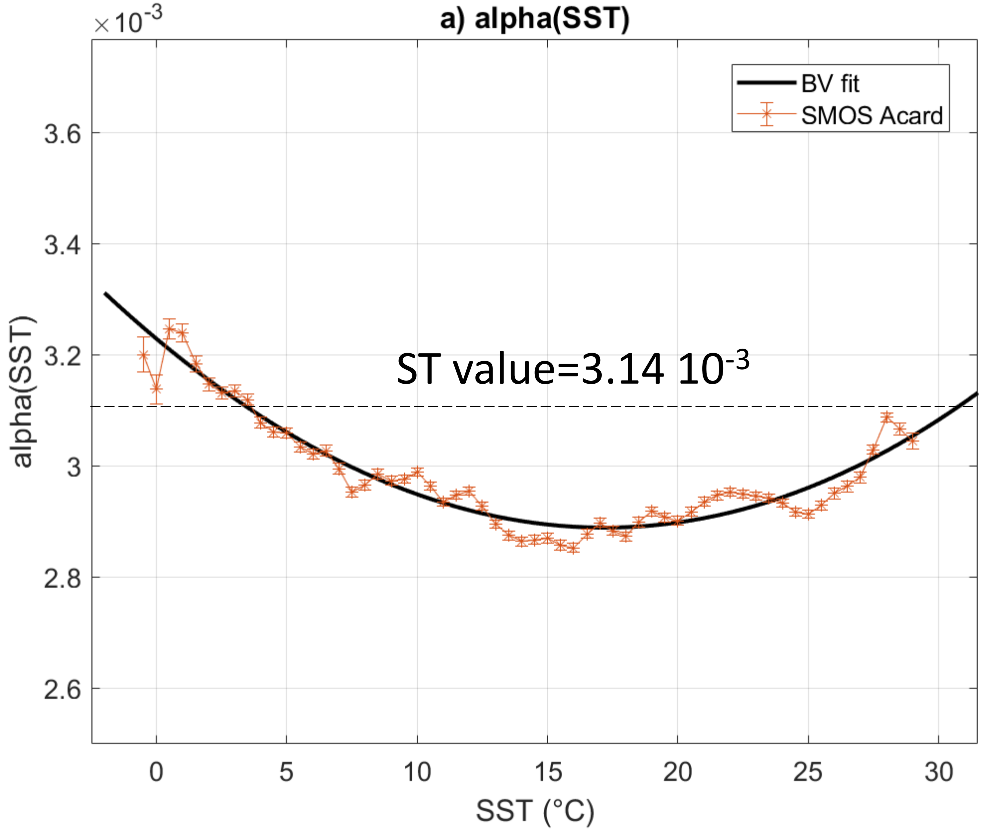


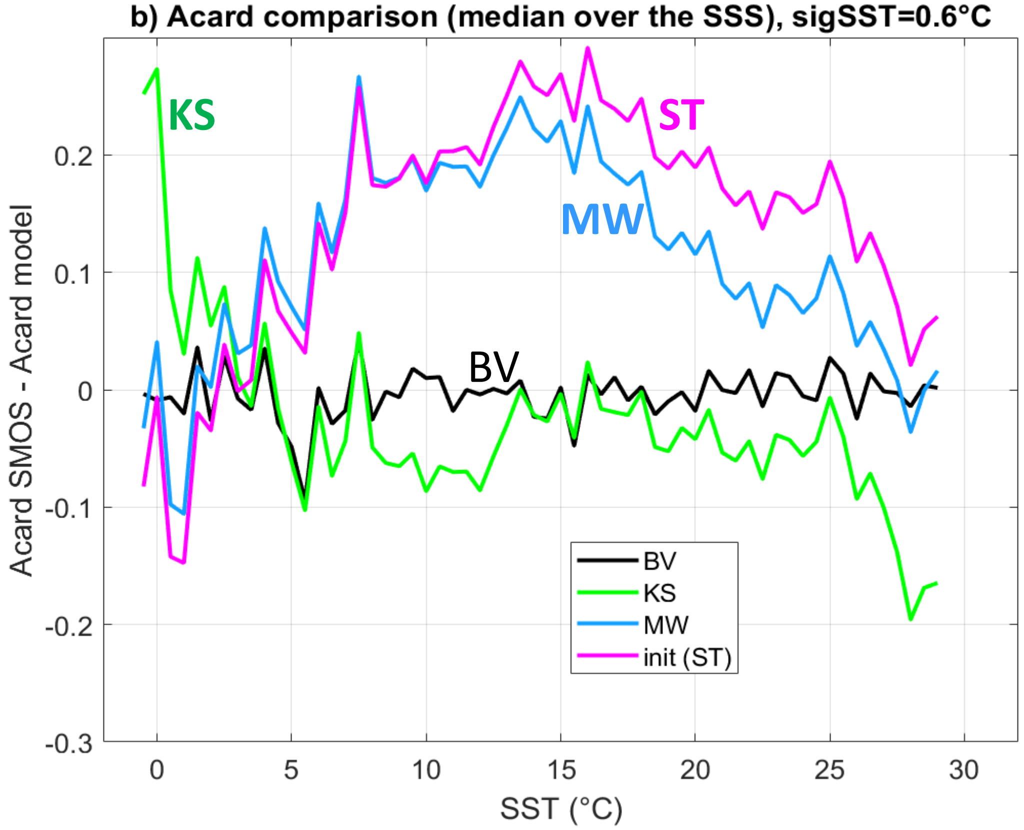
After filtering and correction for conditional sampling effect

Revision of α(T) => New ε parametrisation (BV)



After filtering and correction for conditional sampling effect





Validation (1):
SMOS SSS compared to Argo OI SSS

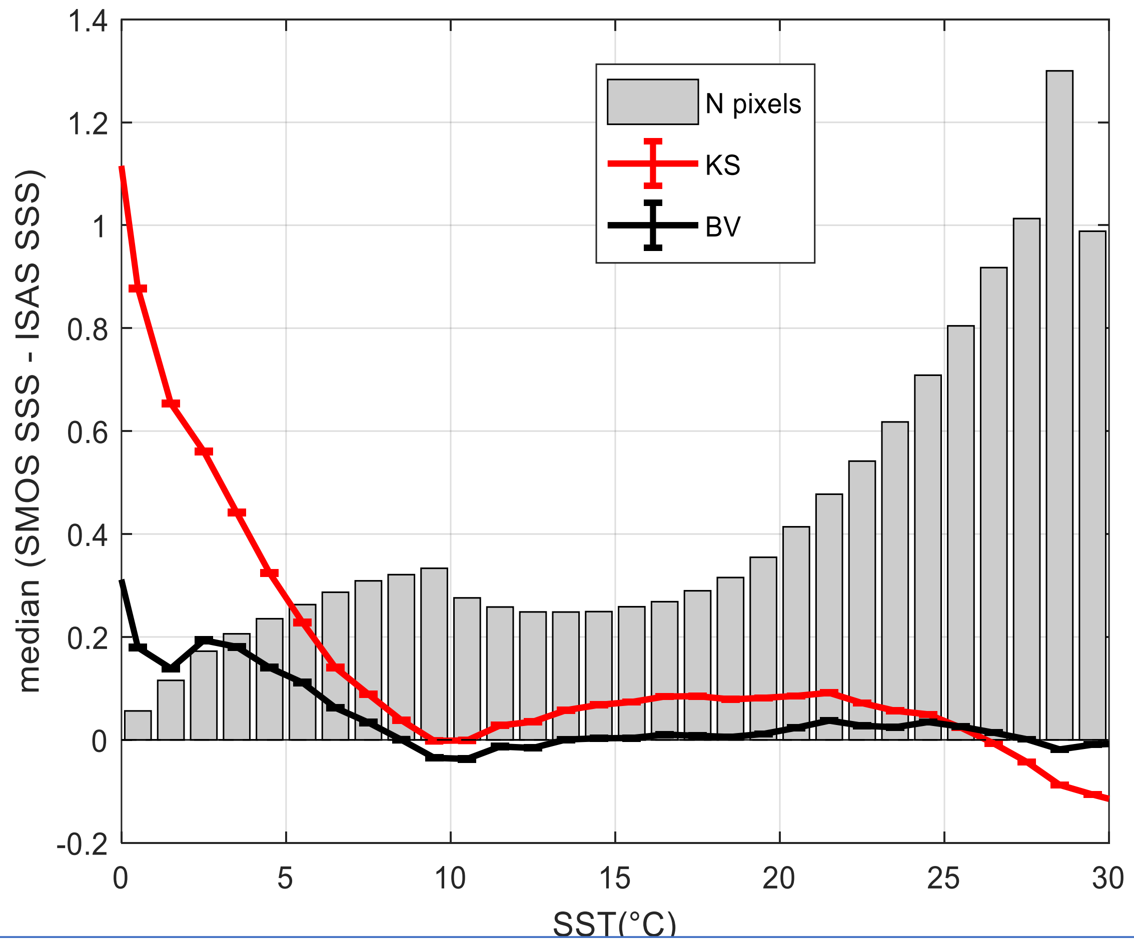
SMOS Tb obtained with v721 experimental reprocessing

Wind speed [3 12] m/s

Descending orbits 45°N - 60°S

Distance to coast > 1000 km

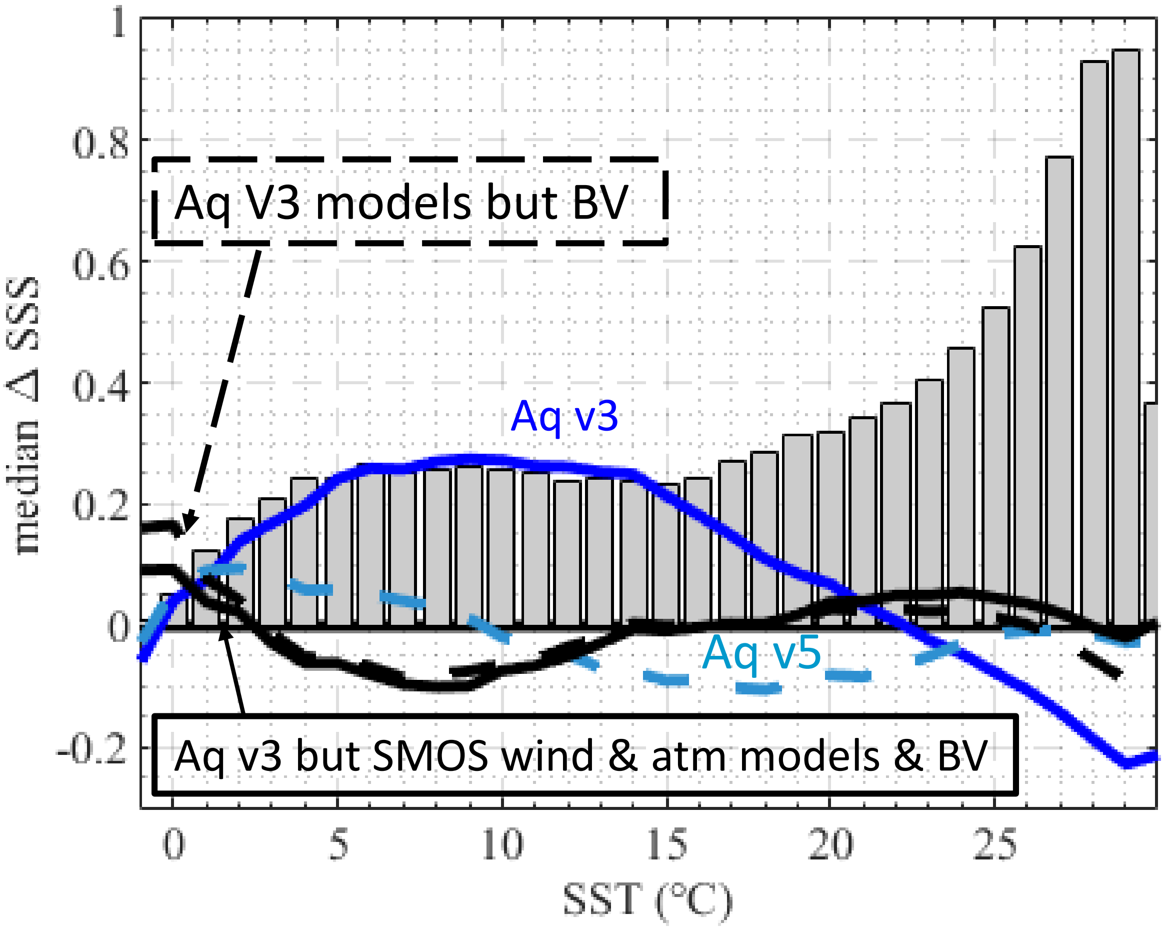
March to October 2016.



With ε BV, SMOS SSS - Argo SSS: within +/-0.05 for SST > 7°C; [0.05 0.2] for SST< 7°C

(N.B. SMOS v7 Tb slightly different from SMOS v6 Tb used to adjust ε BV parametrisation)

Validation (2): Aquarius SSS compared to Argo SSS



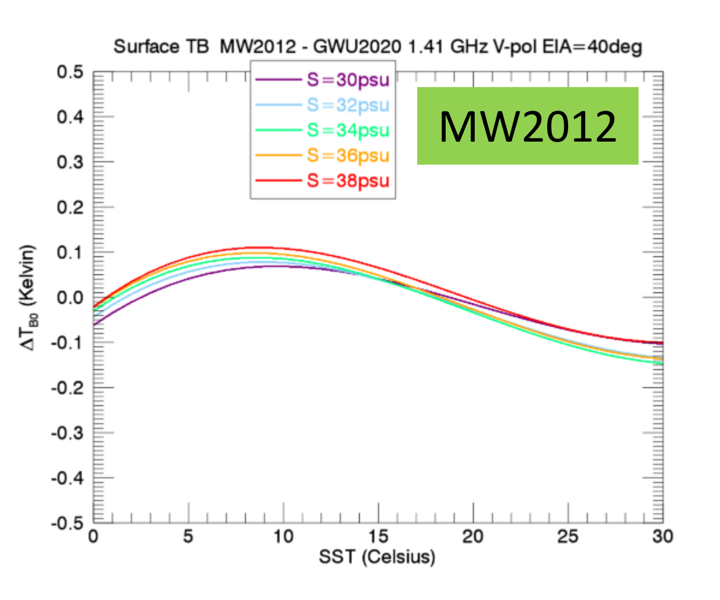
With ε BV, Aquarius V3 SSS- Argo SSS +/-0.1pss for SST>2°C
(Aquarius V3 without adjustment of SST-wind induced emissivity)

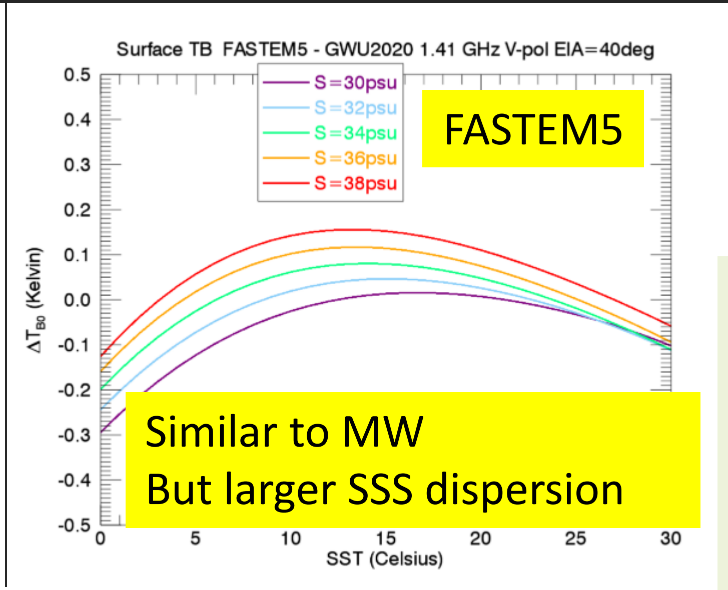
Conclusions and perspectives

- A temperature dependent parametrisation of α parameter in the Somaraju and Trumpf (2006) ε_r model allows to deal with SST dependency of residuals between satellite and in situ salinity measurements while retaining much physical basis in the modelling of the other components of the radiative transfer model (RTM).
- When considering BV parametrisation, remaining SST-dependency of the satellite SSS residuals is:
  - SMOS : +/-0.05 for SST > 7°C; between 0.05 and 0.2 for SST< 7°C
  - Aquarius: +/-0.1pss for SST>2°C and with Aquarius V3 RTM or with SMOS RTM
- To go further :
  - Laboratory measurements of ε_r are needed to validate ε_r model independently of any assumption on other components of the RTM. A wide range of SSS and SST would be suitable to get more rigorous adjustments of ε_r model parameters.
  - Study Somaraju and Trumpf (2006) model at higher frequency
- BV parametrisation implemented in ESA & CATDS SMOS L2OS processors; it will be used in SMOS v7 reprocessing (beginning 2021)
- Matlab code available on : https://owncloud.locean-ipsl.upmc.fr/index.php/s/ovhgqNazmMsEdna

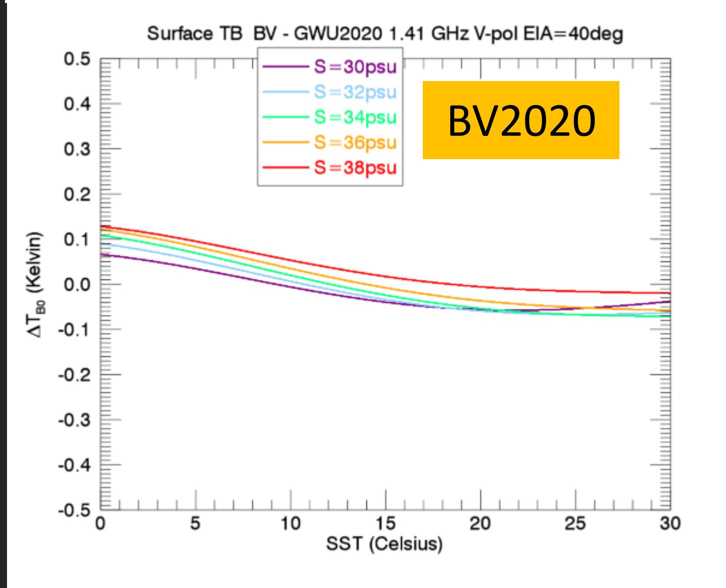
Comparison with GWU 2020

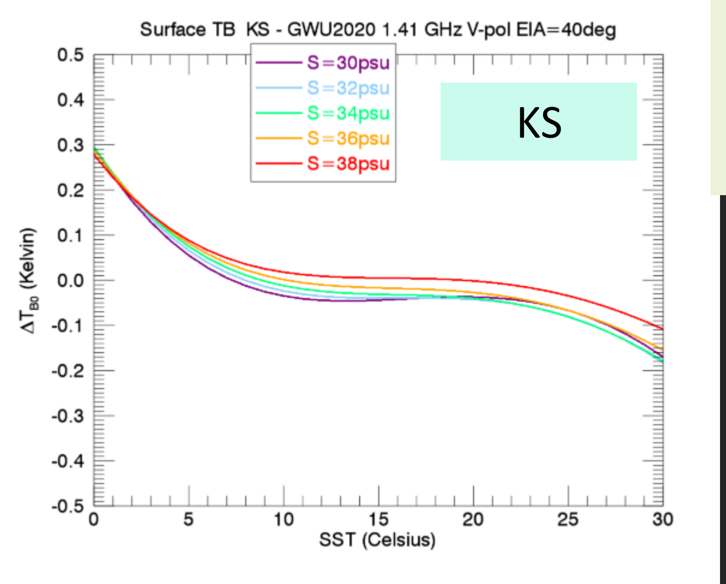
FREQ=1.41GHz, EIA=40°, V-pol





Similar to MW
But larger SSS dispersion





- SST from 0°C to 30°C in steps of 1°C.
- SSS from 30 psu to 38 psu in steps of 1 psu.
- ΔTB surface = ΔEmissivity ·SST (Kelvin).

Meissner ISSI meeting 7 Dec. 2020

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

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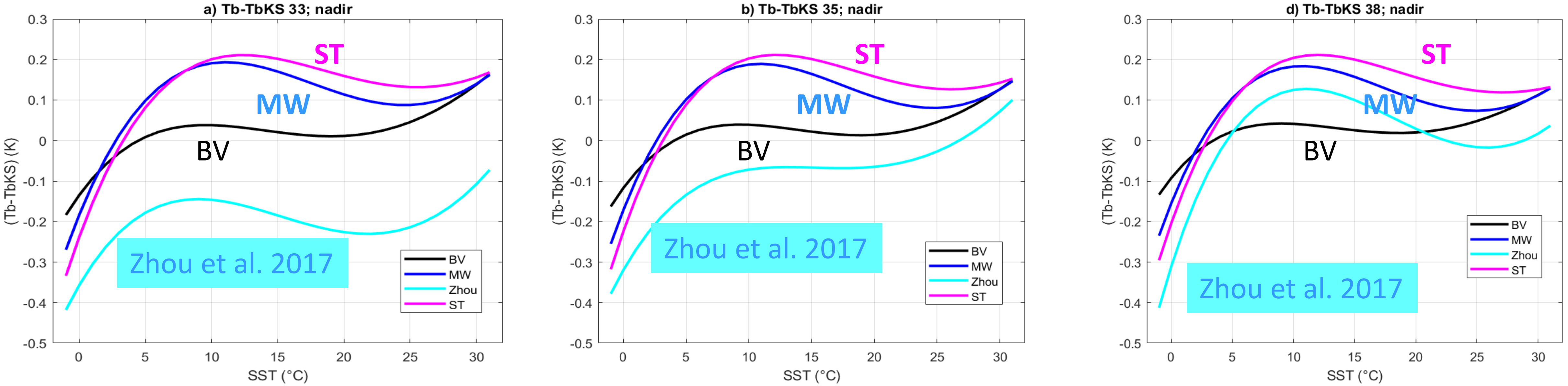
Tbmodel - TbKS



BV parametrisation leads to Tb intermediate between KS and MW

Tb with MW, BV, Zhou17 is lower than Tb with KS at low SST

ΔTb between 25°C and 30°C higher with MW, BV, Zhou than with KS

BV closer to KS between 5 and 25°C than MW, BV, Zhou