SMOS-LOCEAN models

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Take home messages

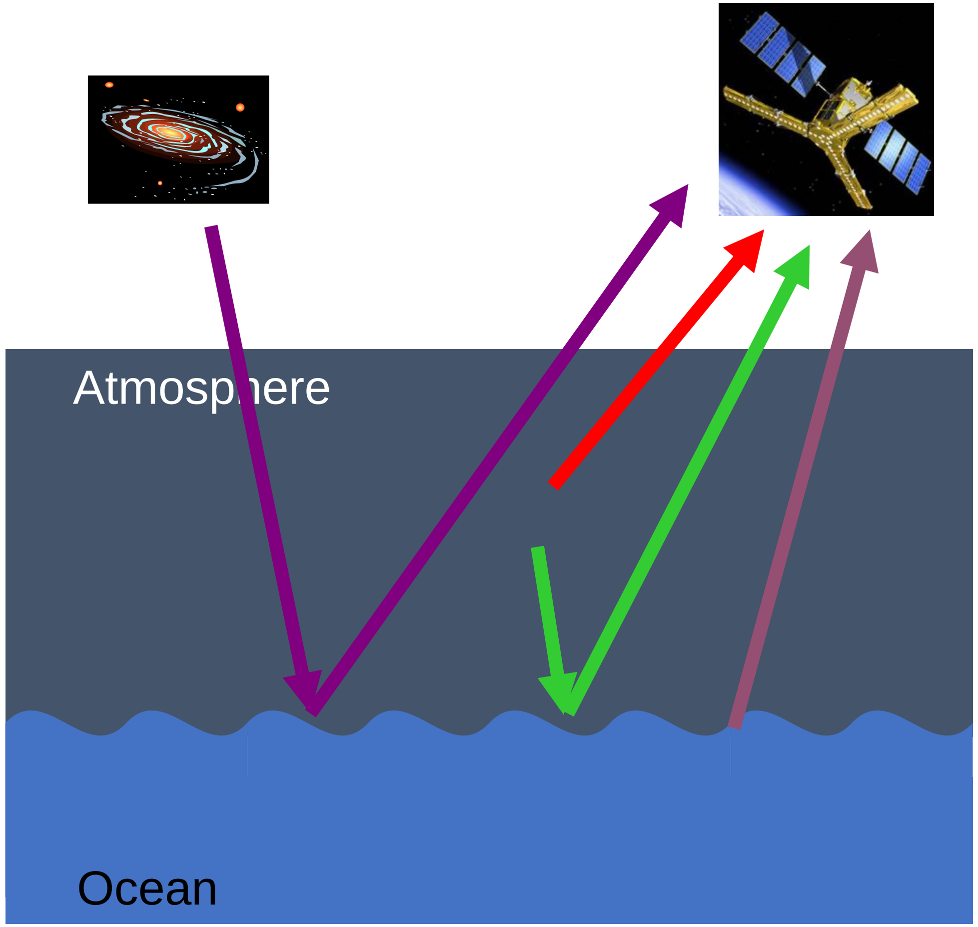
- SMOS-LOCEAN models:
  - Physically based models with parameters empirically fitted to SMOS Tbs
- LOCEAN-wind model :
  - dependent on ECMWF forecast wind speed;
  - foam emissivity and foam coverage wind dependencies strongly coupled
- Adjustment of a simplified permittivity model parameters :
  - adjusting fresh water relaxation time or static dielectric constant are equivalent at L-band: what could other frequencies tell us?
- Effect of noise in auxiliary parameters is a large source of uncertainty for deriving ocean emissivity models from radiometer Tbs:
  - how to better quantify uncertainty on SST ?

Outline

- Introduction: SMOS (1.4GHz) Tb modelling
- SMOS Wind model
- Permittivity model
- Way forward

Modeling of SMOS (1.4GHz) Tbs

- $Tb = Tb_{atm}\uparrow + R_{sea} (Tb_{atm}\downarrow + Tb_{sky}) \exp(-\tau_{atm}) + Tb_{sea} \exp(-\tau_{atm})$



$Tbsea = (Tb_{flat}+Tb_{rough}) (1-F) + F\ Tb_{foam}$

$= Tb_{flat}+Tb_{wind}$

$Tbsea = e_{sea}\ SST$

$e_{sea} = e_{flat} + e_{wind}$

$R_{sea} = 1 - e_{sea}$

e_{wind}: 2-scale roughness + foam models (Yin et al. 2016)

R_{sea} : permittivity from Klein and Swift (1977) model

This presentation : Tbsea

SMOS-LOCEAN wind model

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Roughness and foam signature on SMOS-MIRAS brightness temperatures: A semi-theoretical approach

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Method for rough & foam model adjustments

Wind induced component of emissivity from SMOS Tbwind (0-55° in step of 5°)

Tb_{wind} = (1-F) Tbrough + F (Tbfoam-Tbflat)

2-scale roughness model (Dinnat et al. 2004)
wave Spectrum
-proportional to Durden & Vesecky spectrum

$$S(k)=a_0 k^{-3}\left(\frac{1.25 u_*^2}{g_*}\right)^{0.225\log_{10}(k/2)}$$

3m/s<U<7m/s
a_0 (prior=0.004 – 0.008)

a_0 =0.005
(same as Yin et al., 2012)

-Kudryatsev et al. (2003) wave spectrum

Foam

Emissivity adjusted with Tbfoam angular dependency and Anguelova and Gaiser (2013) model

Dependency with U comes from $F = b\ U^c$

7.5m/s<U<22m/s

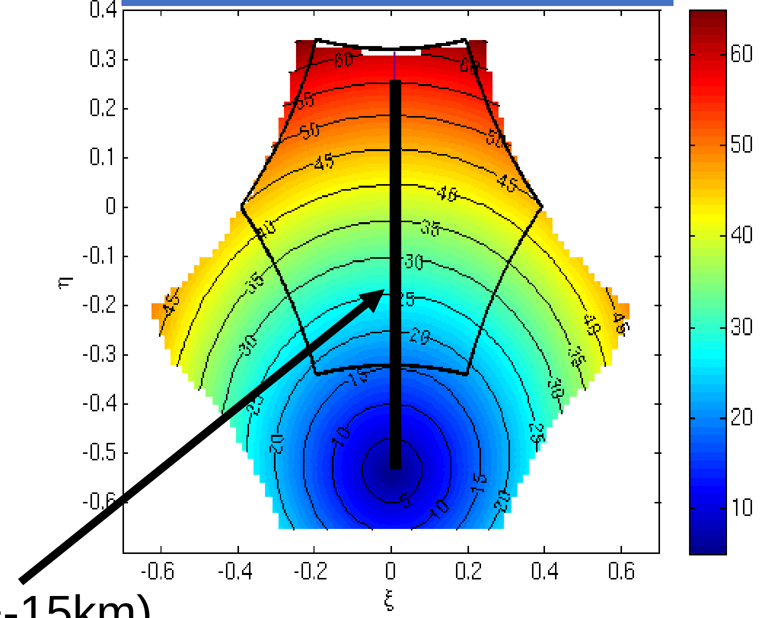
Adjust Coverage F(U) &
Emissivity e_{foam}

SMOS Tb (1.4GHz) used for wind-model devt

Ascending Tbs (L1c V620): Tbs along track (~ no mixing of polarization) with thorough sorting of sun, RFI influence, in the Southern Pacific (far from land) including SMOS calibration region (OTT), July-November in 2010 and 2011.

Tb_{wind} derived from SMOS Tbs after correcting for all other effects

SMOS FOV



Along track (+-15km)
Incidence angles from 0° to 55°

Region: from 50S to 0N

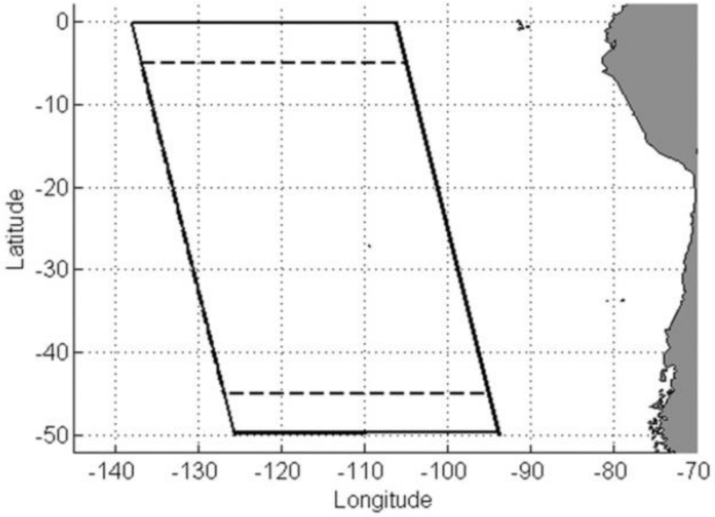
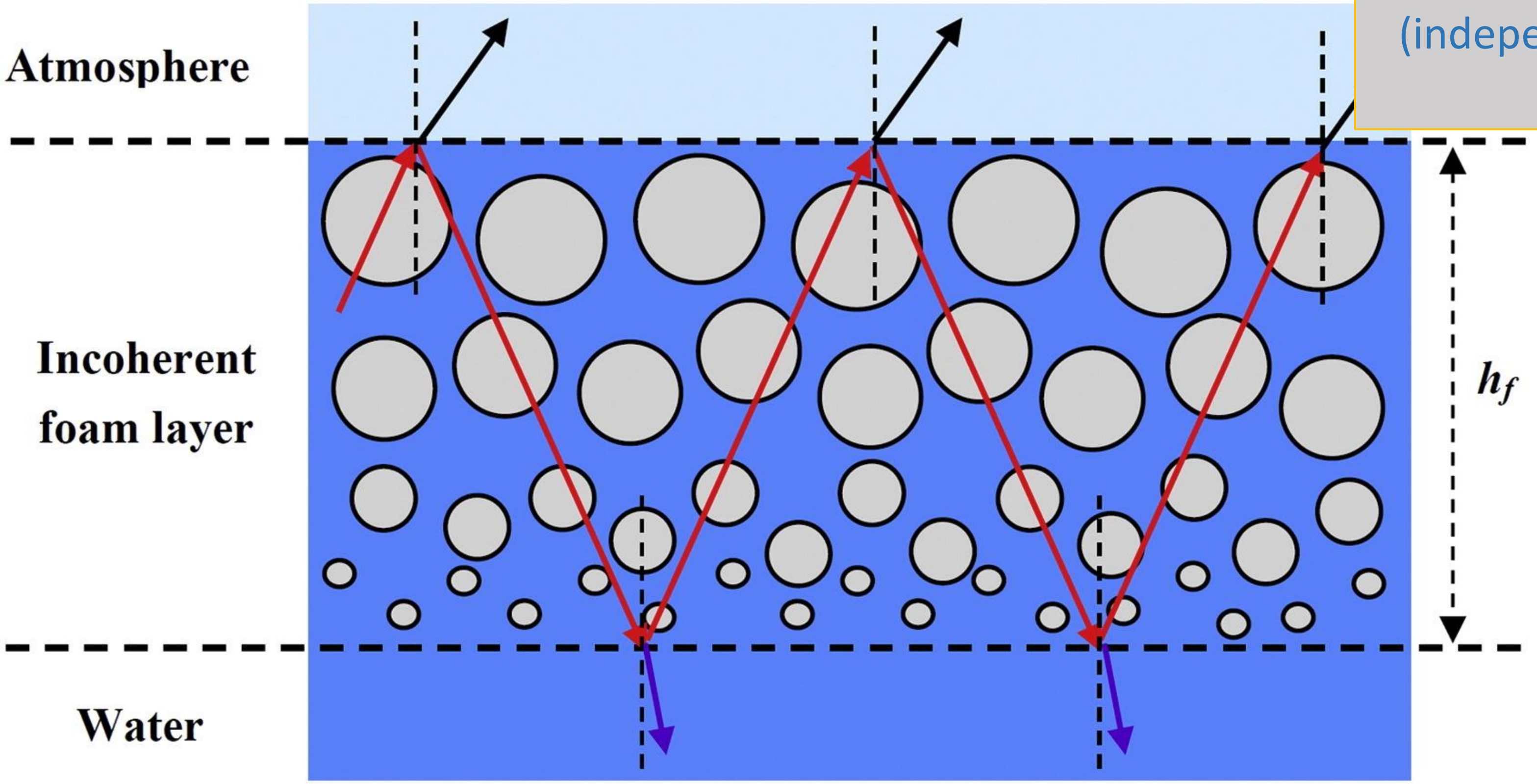


Fig. 1. Regions used in this study. Solid line define the region used for e_w and dashed lines define the region used for OTT.

Microwave emissivity of sea foam layers with vertically inhomogeneous dielectric properties

SMOS-adjusted foam emissivity parameters derived from SMOS Tb angular dependency (independent on U: not possible to distinguish between F(U) and e(U))



Void fraction at the air-foam interface

Effective thickness

Anguelova and Gaiser, 2013 model

$$e_f = m_U e_{fU} + m_D e_{fD} + m_w$$

Foam emissivity | upward e | downward e reflected | transmitted water e

Foam emissivity parameters adjusted considering variations of SMOS Tb with incidence angle

Void fraction at the air-foam interface: SMOS-Adjusted 0.97

Effective foam thickness: SMOS-Adjusted ~1.8cm

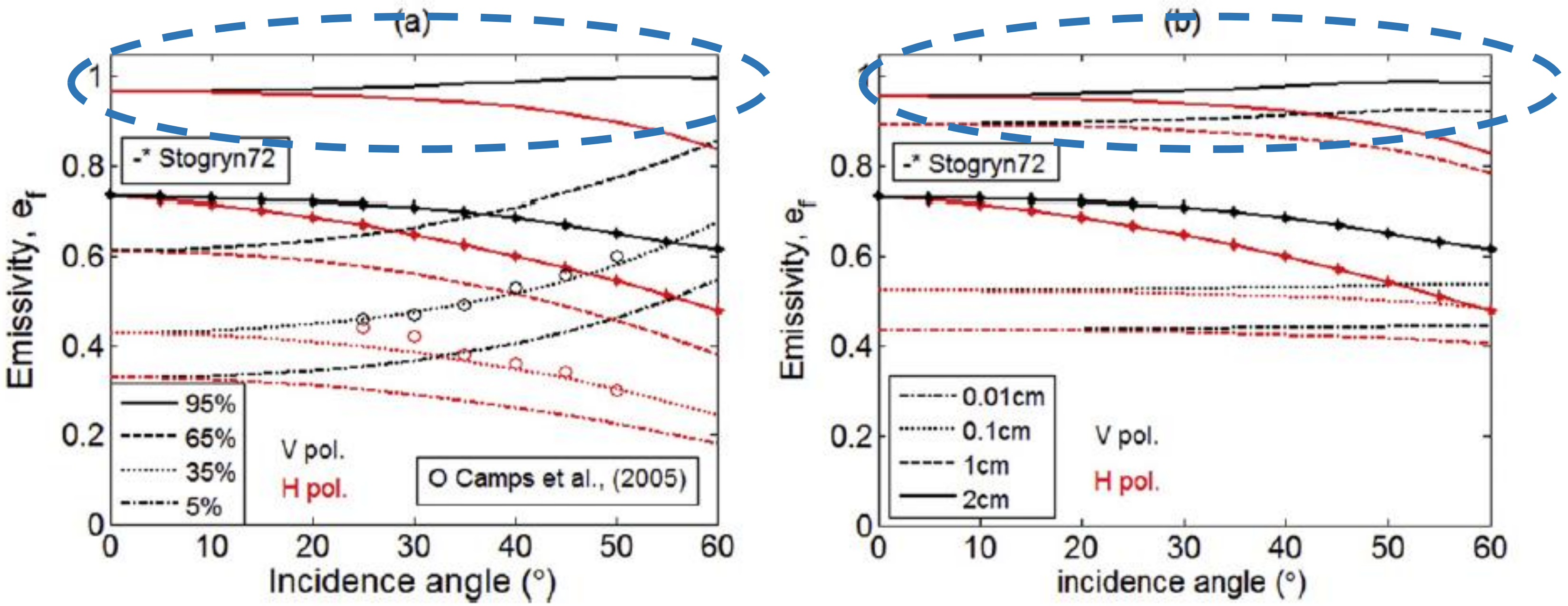
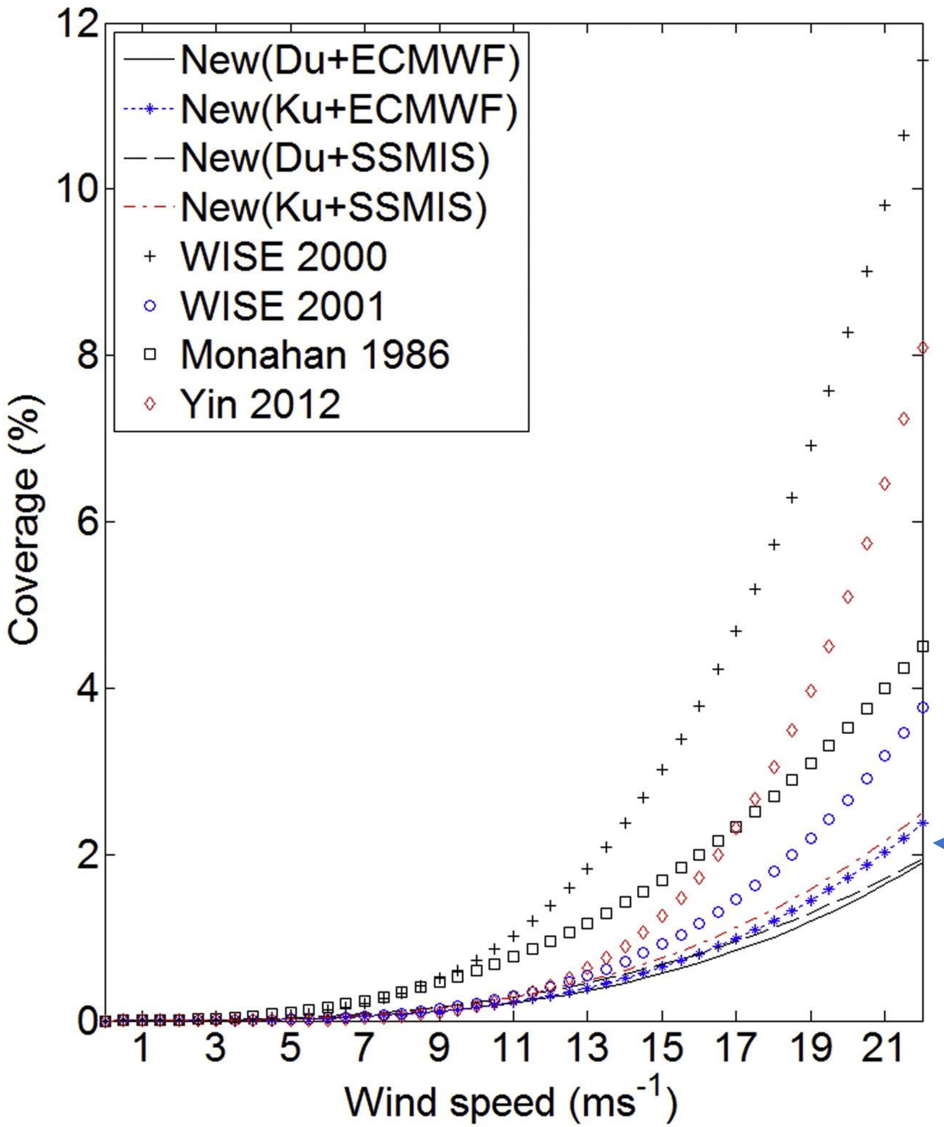


Fig. 6. (a) Foam emissivity of horizontal (red curves) and vertical polarization (black curves) as a function of incidence angle for v_{af} to be 5% (dot-dashed lines), 35% (dotted lines), 65% (dashed lines) and 95% (solid lines). The incoherent approach and the refractive model are used. Sea surface temperature is 20 °C, salinity is 34, and foam thickness is the wavelength of L-band (21 cm). Foam emissivity of the Stogryn (1972) model (star-solid lines) and the Camp et al., (2005) data (circles) are also included for comparisons. (b) The same as (a) except for h_f to be 0.01 cm (dot-dashed lines), 0.1 cm (dotted lines), 1 cm (dashed lines) and 2 cm (solid lines) with v_{af} to be 95%.

Foam coverage



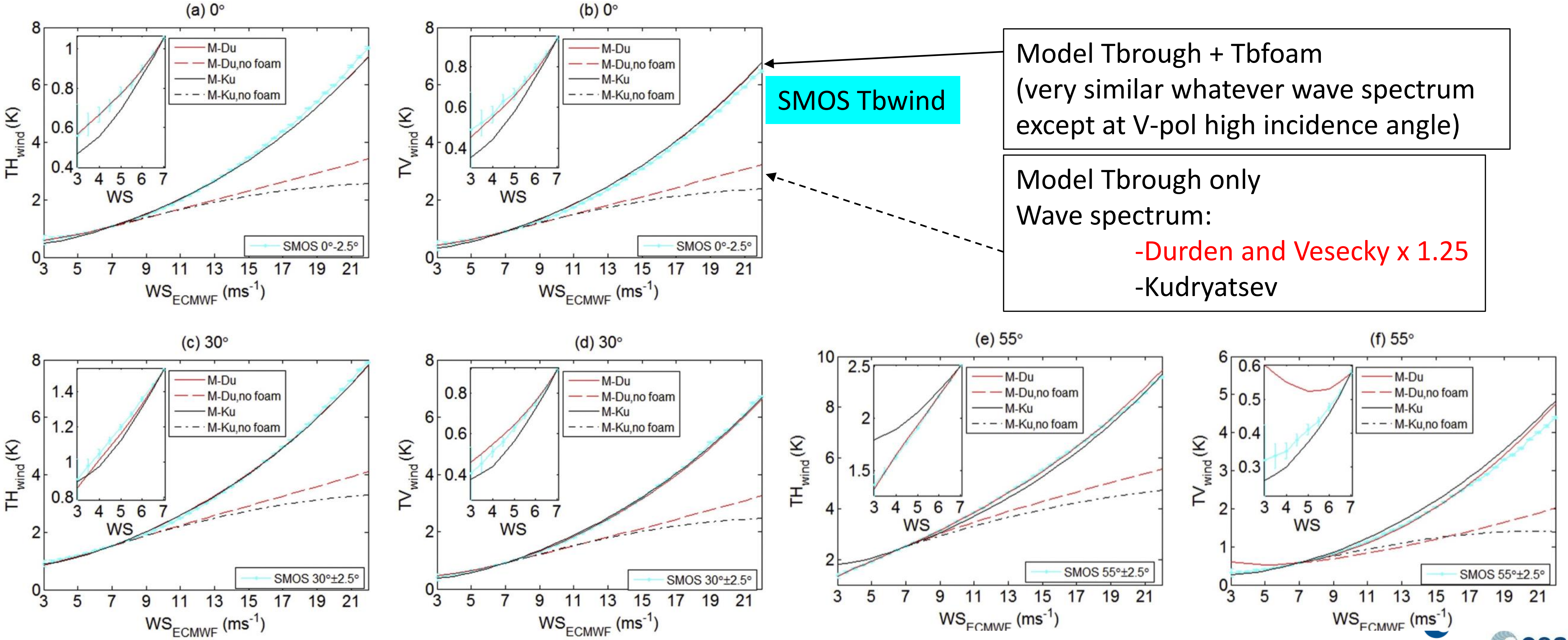
SMOS foam coverage lower than earlier models, likely because the adjusted emissivity is close to 1

Name	Main characteristics of fits	b	c	STD (K)	N
M-Du-E	Durden–Vesecky spectrum, wind induced components collocated with ECMWF WS (e_{wE})	1.12e − 6 ± 0.94e − 7	3.15 ± 0.015	0.06	9
M-Du-E1	Same as M-Du_E except that parameters are optimized from 20°-50° incidence angles	1.29e − 6 ± 1.10e − 7	3.10 ± 0.024	0.05	6
M-Du-S	Durden–Vesecky spectrum, wind induced components collocated with SSMIS WS (e_{wS})	3.83e − 6 ± 2.78e − 7	2.76 ± 0.017	0.05	9
M-Ku-E	Kudryavtsev et al. spectrum, e_{wE}	6.48e − 7 ± 1.05e − 7	3.40 ± 0.019	0.07	9
M-Ku-S	Kudryavtsev et al. spectrum, e_{wS}	1.62e − 6 ± 1.59e − 7	3.12 ± 0.020	0.07	9

SMOS Foam coverage

$F=b\,U^c$

SMOS and models Tbwind versus wind speed



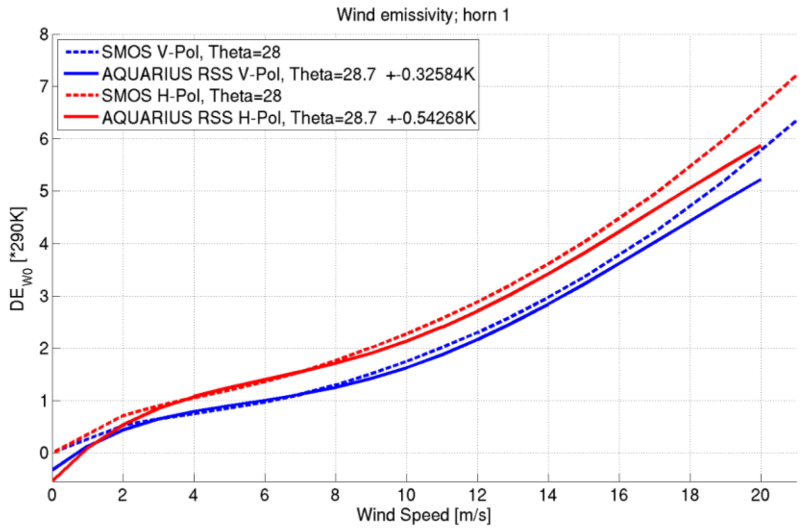
Comparison with Aquarius and SMAP wind models

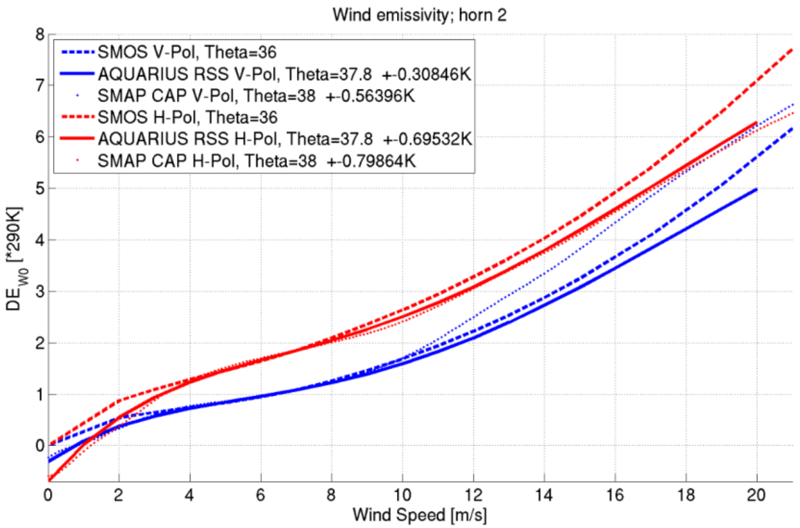
- SMOS roughness model ESA v662 (2-scale roughness model + foam adjusted to ECMWF wind speed (Yin et al 2016))
- SMAP JPL/CAP (LUT from the CAP processor – - Nov 2018 - WS only model– adjusted to NCEP wind speeds?)
- Aquarius RSS version 5 (Meissner and Wentz RSE 2018 – adjusted to NCEP wind speeds)

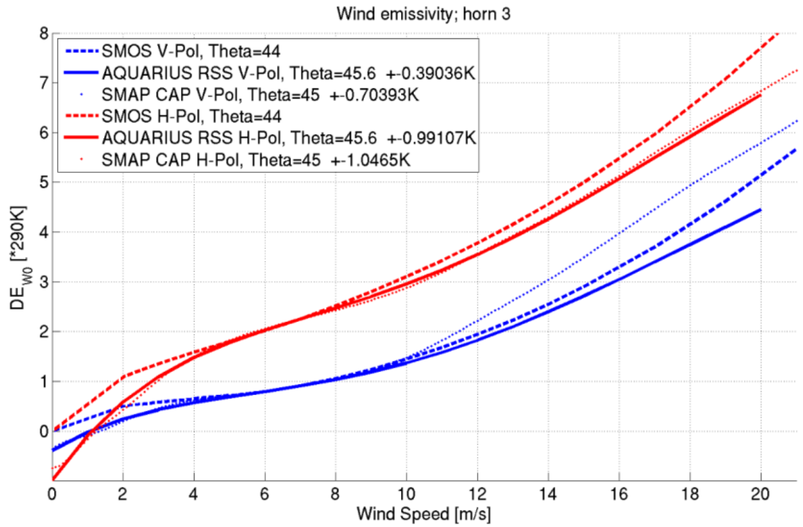
- Study at the 3 Aquarius incidence angles

SMOS, Aquarius and SMAP Tbwind

(all curves adjusted to SMOS Tb at 7m/s)







SMOS Tb-wind dependency higher than Aquarius at high WS, lower at low WS: an effect of ECMWF versus NCEP WS differences?
Or an artefact of permittivity model uncertainties?

Permittivity model: background

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

  For a flat sea and Fresnel equation:

$$Tb_{sea} = e\,(SSS, SST).SST$$

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

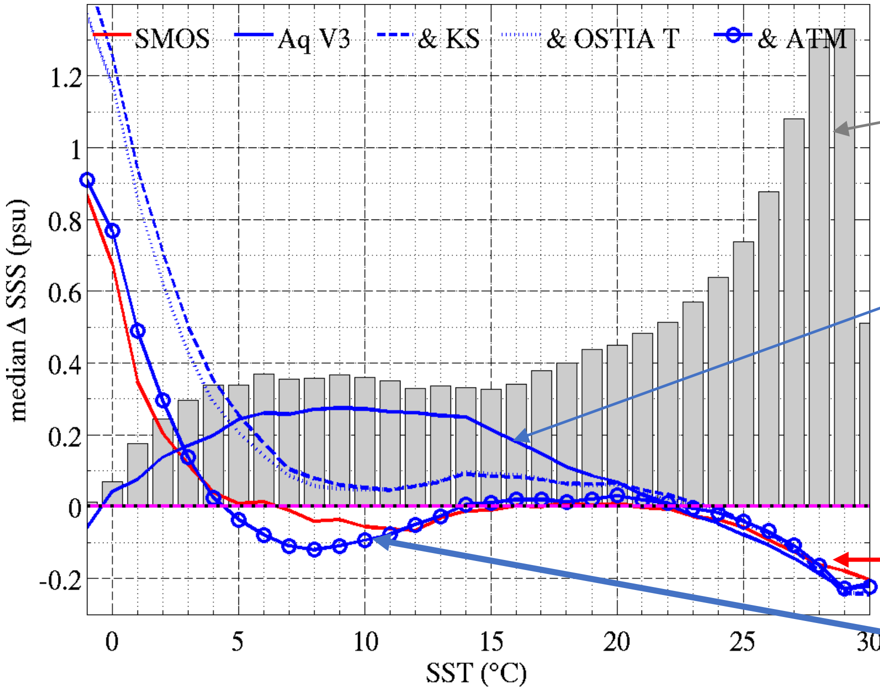
- **Various dielectric constant models used for processing satellite data today:**
  - SMOS ESA : **Klein & Swift (1977) (KS)**: model fitted to laboratory measurements
  - Aquarius/SMAP RSS: **Meissner and Wentz (2004, 2012) (MW):** model fitted to satellite meas. (multiple frequencies)
- At L-band (21cm), the dielectric constant can be modelled with a single Debye relaxation law:

$$\varepsilon = \varepsilon_\infty + \frac{\varepsilon_S - \varepsilon_\infty}{(1 + i\tau)} - \frac{i\sigma}{2\pi\varepsilon_0\gamma}$$

SMOS and Aquarius SSS compared to Argo:

KS => large bias at low SST

MW => smaller but not negligible bias dependency with SST



Distribution of collocations (arbitrary unit)

Aquarius V3 processed with MW (next versions have been empirically SST fitted to HYCOM or Argo)

SMOS L2OS V622

Aquarius processed with KS and Liebe atmospheric model

Fig. 1 SST dependence of SSS bias for (red) SMOS and (blue) Aquarius V3. Aquarius uses the (plain) nominal algorithm to which are successively introduced (dashed) the KS dielectric constant model, (dotted) the OSTIA SST product, and (circles) the revised atmospheric model (see text). Bias is computed as differences between satellite SSS and Argo in situ measurements over the Aquarius era.

Dinnat et al. 2019

Origin of the observed systematic differences with respect to Klein and Swift model?

- Conditional sampling effect
- Pseudo dielectric constant derived from SMOS ACARD parameter (Waldteufel et al. 2004) allows to revise Klein and Swift parametrization by either adjusting the static dielectric constant or the fresh water relaxation time: analysis of higher frequency measurements would allow to distinguish between the two parametrizations!

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