Progress meeting ISSI team
7-8 December 2020

Comparison of existing radiative transfer models with observations

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Outline

- Results of the comparison with GMI
- Tests with dielectric constants, wave parameters, and at high wind speed
- How to proceed for the next steps?

Comparison with GMI observations : final results

- Collocation with satellite observations and geophysical data to run the different ocean radiative transfer models

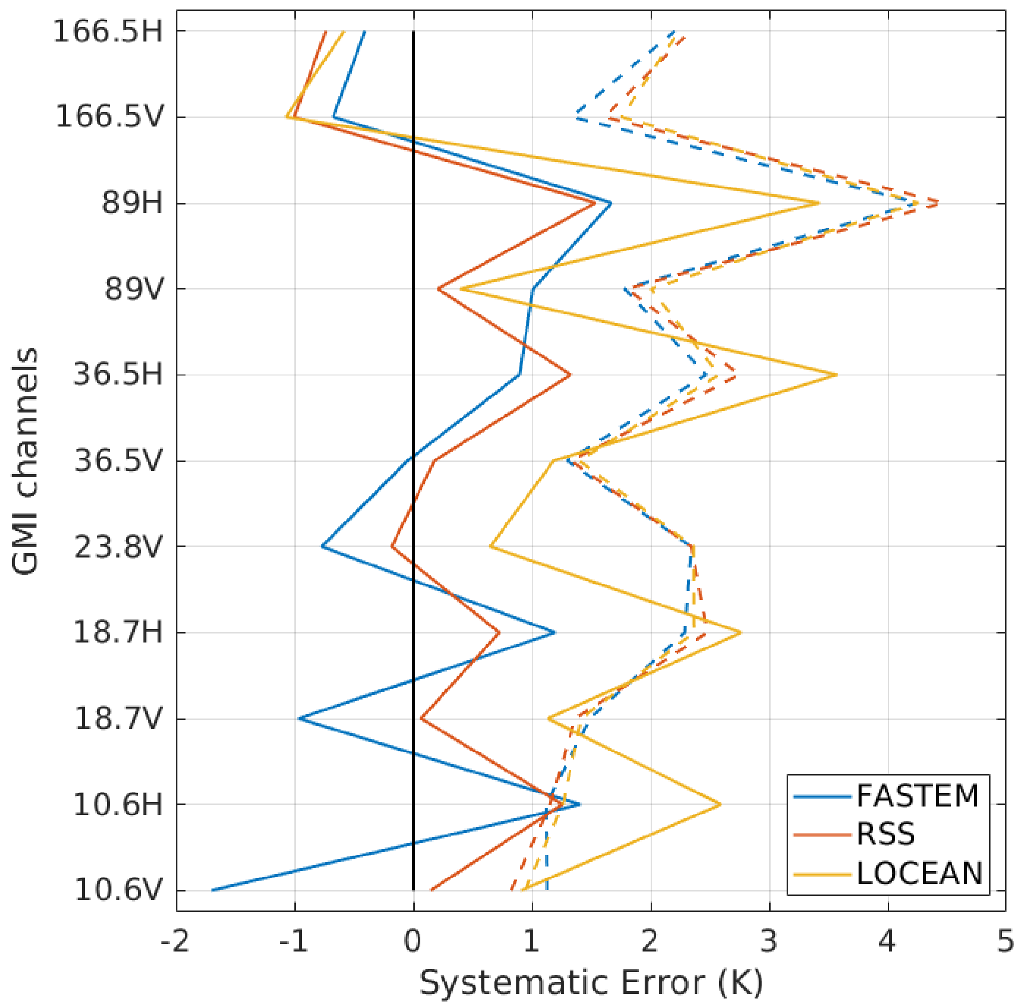
- GMI brightness temperatures (L1R-C) at top of atmosphere provided by NASA
- 10.65 to 166GHz

- ECMWF reanalysis ERA5 data :
  - Ocean Wind Speed
  - Sea Surface Temperature
  - Total Column Water Vapor
  - Total Column Liquid Water
  - Atmospheric profile (temperature, water vapor)

- Mercator ocean reanalysis provided by CMEMS :
  - Sea Surface Salinity

- Filtering of :
  - sea ice with our SIC algorithm,
  - coastal areas,
  - Cloudy pixels using neural network to detect cloud contamination from Favrichon et al.,2019

Biases with GMI observations

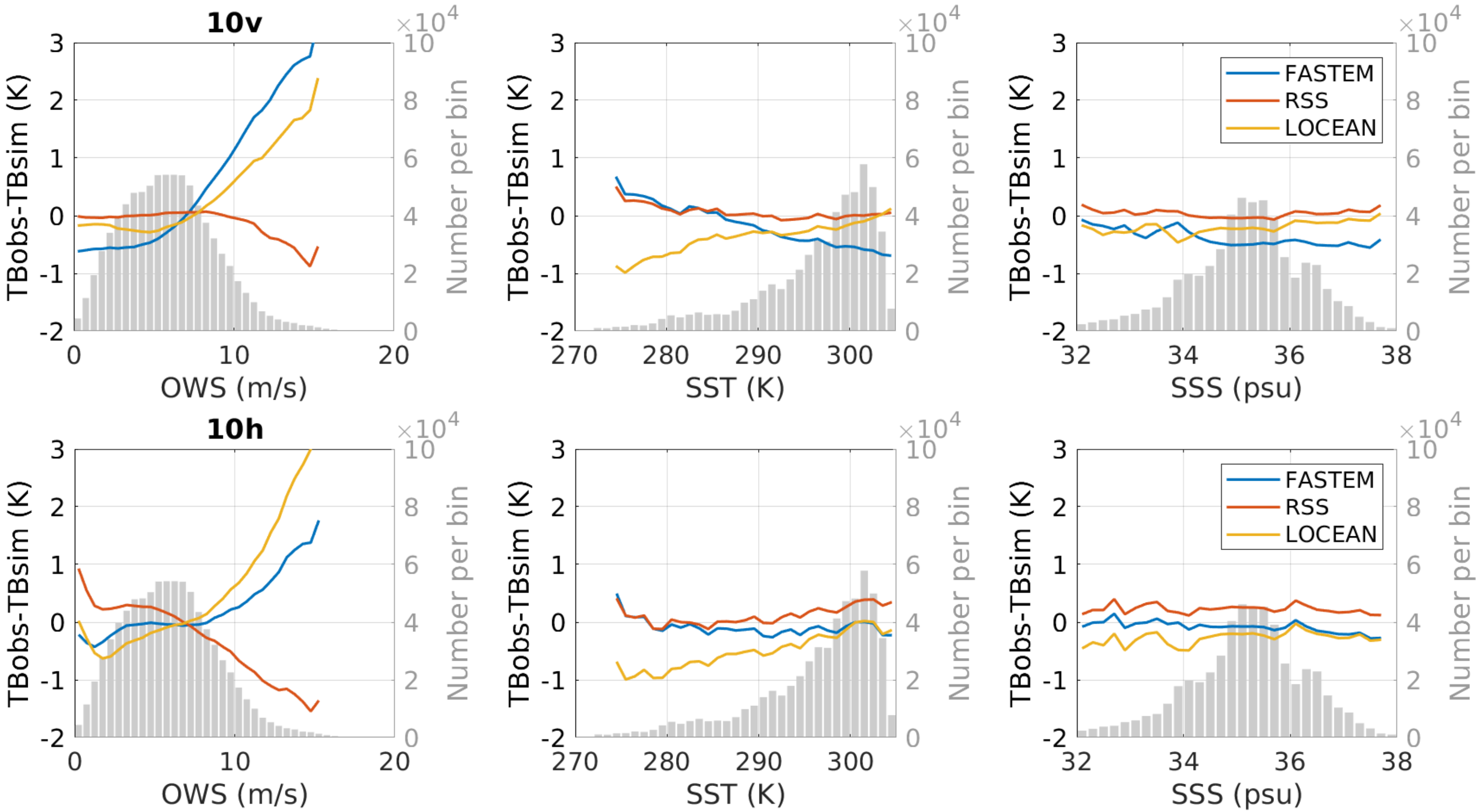


- The systematic errors obtained with GMI are small (<1.5 K with RSS and FASTEM) compared to the systematic errors obtained with AMSR2.
- It confirms the good calibration of GMI.

RTM	Model type	Dielectric constant	Wave spectrum	Foam cover	Foam emissivity
LOCEAN Dinnat et al., 2003	Full physical model adjusted for L-band	Klein and Swift, 1977	Durden and Vesecky, 1985 with $a_0 \times 1.25$	Yin et al. 2016	Anguelova and Gaiser, 2013
FASTEM Liu et al., 2011	Parameterized and fast	Ellison et al., 1998 +Double Debye	Durden and Vesecky, 1985 with $a_0 \times 2$	Monahan and O'Muircheartaigh 1986	Kazumori et al., 2008 with Stogryn,1972
RSS Meissner and Wentz, 2012	Empirically fitted to observations	Meissner and Wentz, 2004 and 2012	Wind induced emissivity fitted to observations Meissner and Wentz, 2012 Meissner et al., 2014		

Errors as a function of parameters after debias

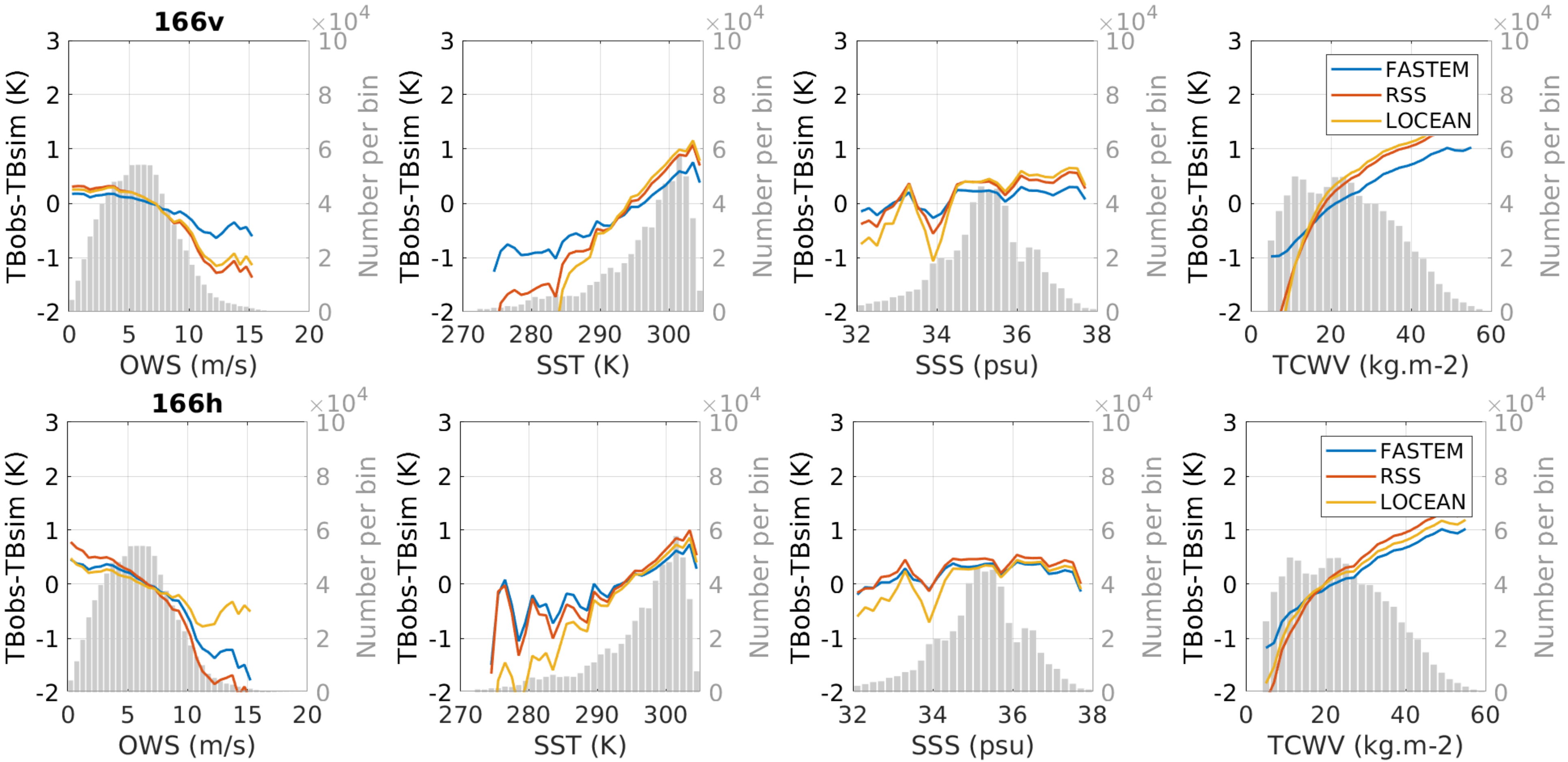
At 10.65 GHz



- The models fit well the GMI observations for « usual » geophysical conditions
- The error is <0.5K for OWS<7m/s and SST>10°C
- The models desagree with observations at OWS > 10 m/s

Errors as a function of parameters after debias

At 166 GHz

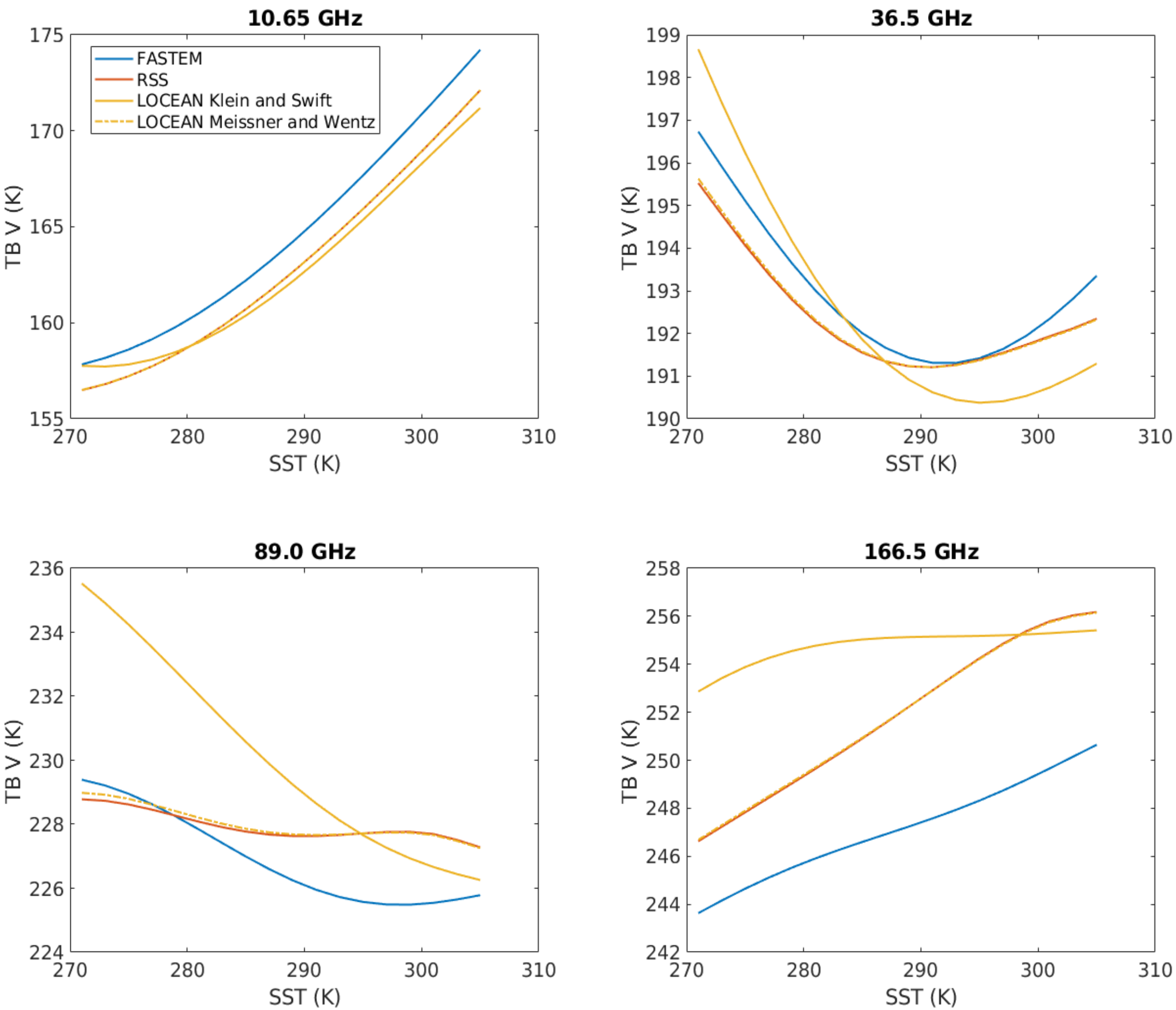


- The models run at higher frequencies
- But with a degraded accuracy when working out of their frequency range

Summary of the comparison with GMI observations

- Conclusions similar to the previous study with AMSR2, with much lower systematic biases.
- The major issues for the ocean RTM simulations are :
  - the low SST
  - The high OWS
- The physical model from LOCEAN (Dinnat et al.,2003) has been chosen to be the basis of the reference emissivity model.
- It is an accurate model adapted for L-band that needs some adjustments to be accurate on a larger range of frequencies to become the reference emissivity model.

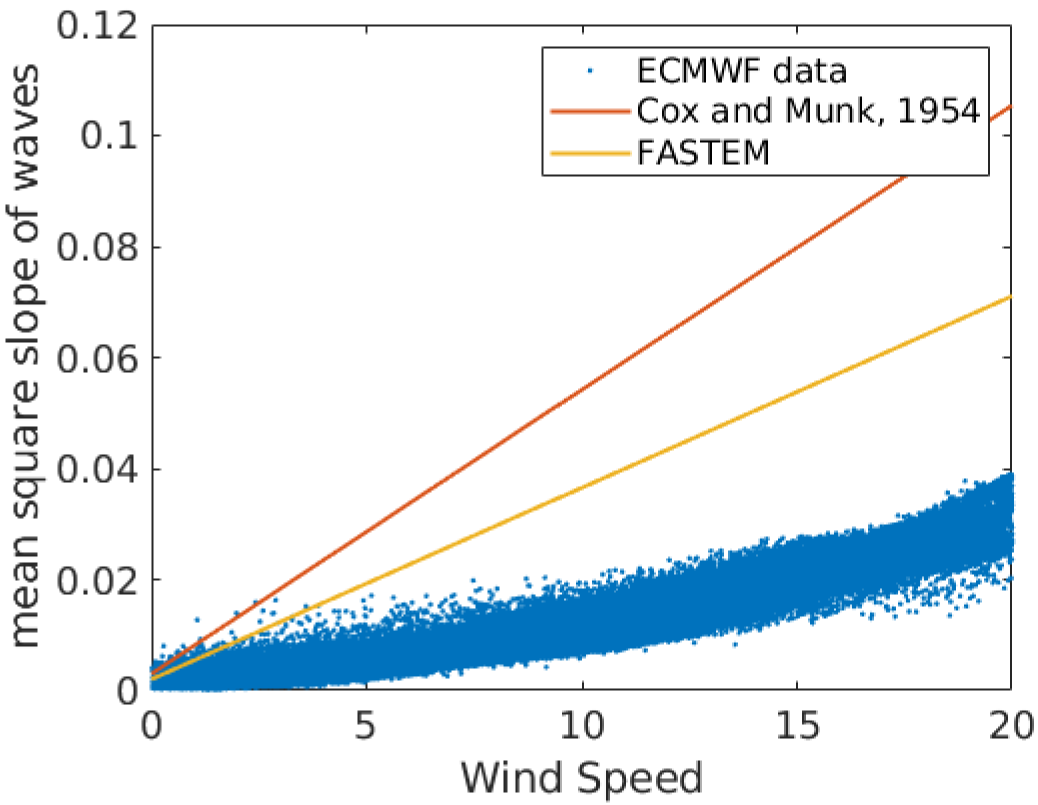
Test with the dielectric constants



- Comparison of the simulated TB with the different models as a function of SST
- LOCEAN model has been run using the Meissner and Wentz, 2012 dielectric constants
- It solves the problem of the SST dependence for frequencies higher than 10 GHz

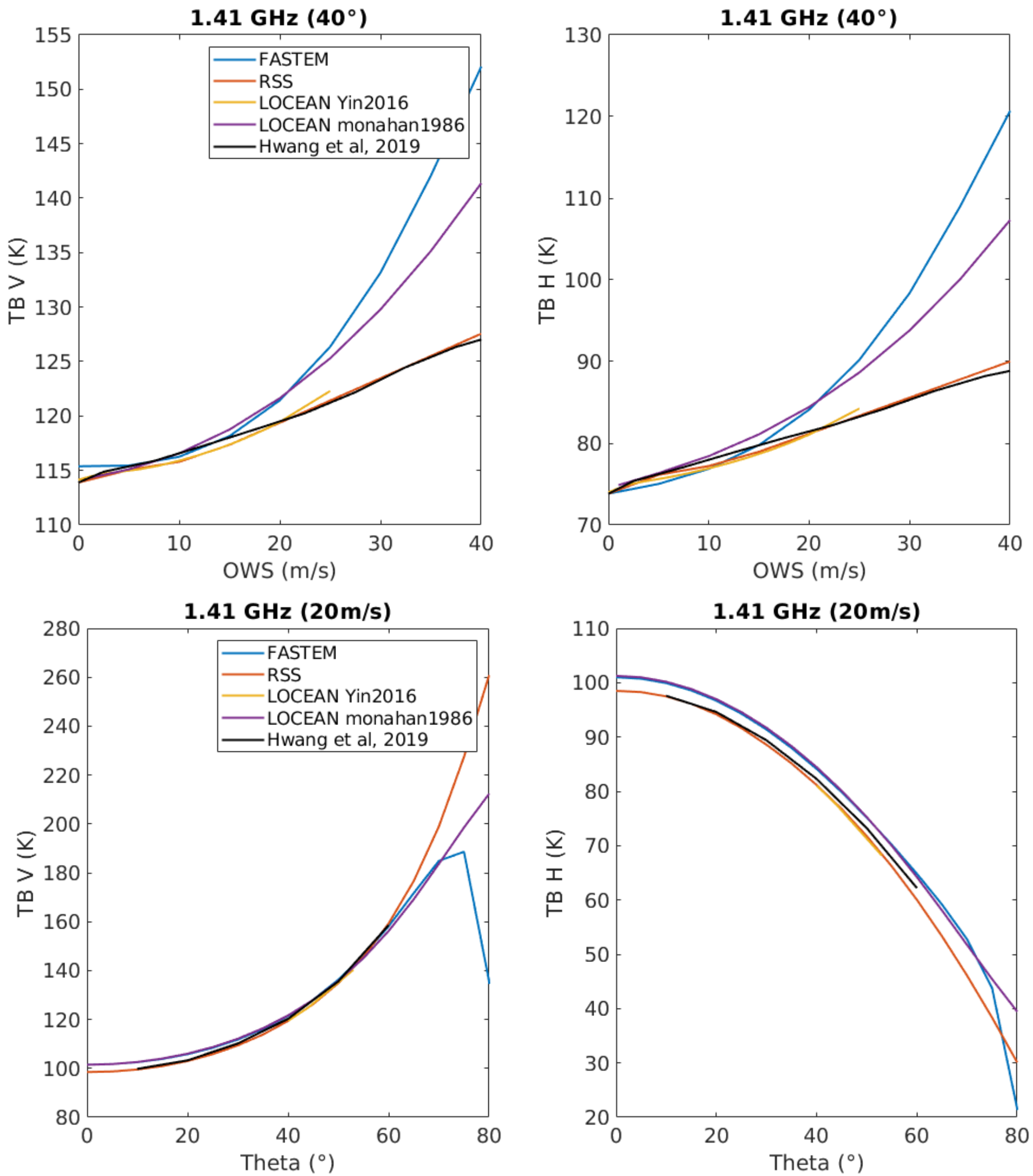
  (as Klein and Swift, 1977 dielectric constant, uses a simple Debye formula, that limits the range of frequencies where the model is accurate from ~1 to 10 GHz)

Test with wave parameters from ERA5



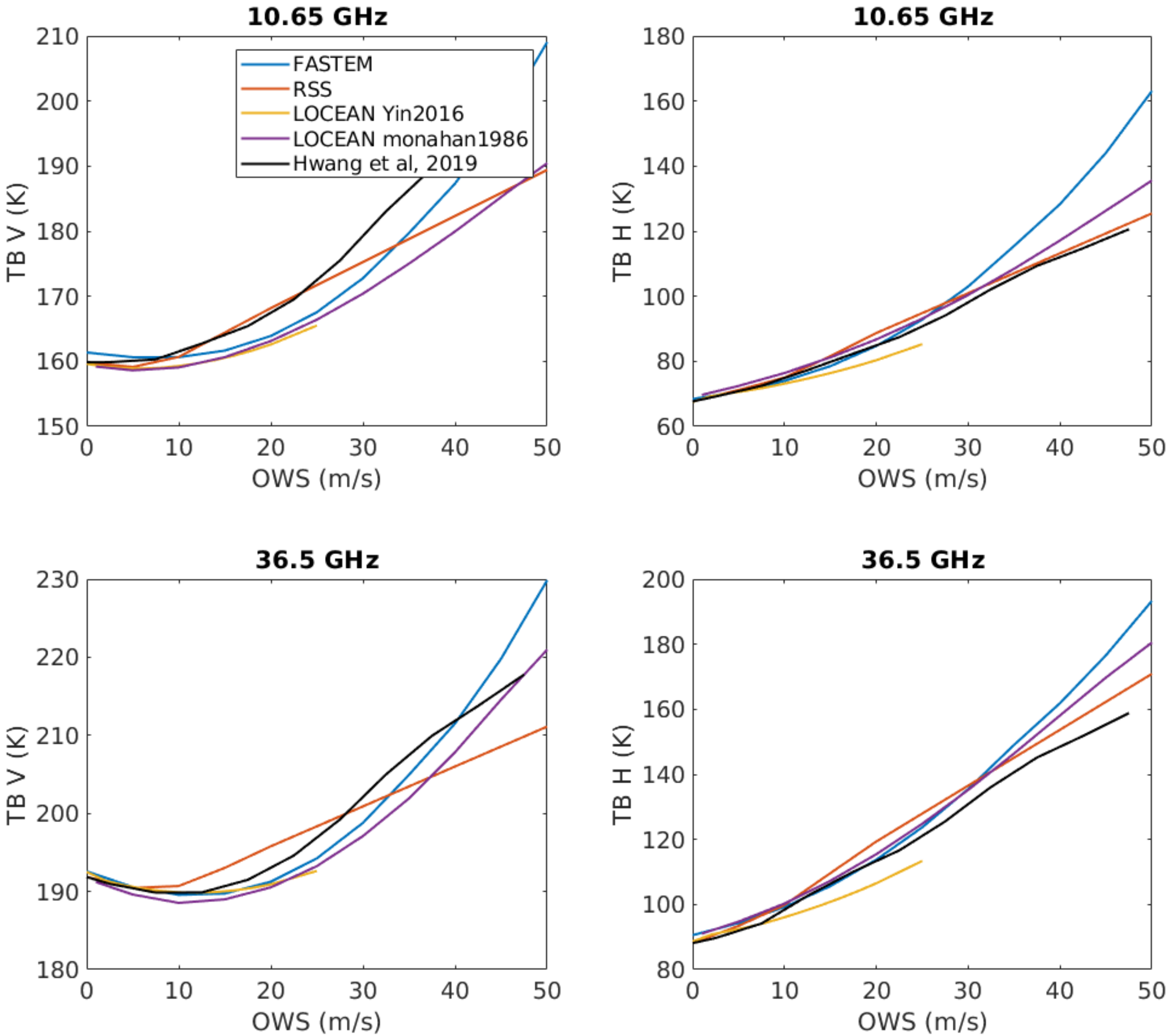
- Some comparison have been done with wave parameters provided by ERA5.
- For example the mean square slopes of the models have been compared with the one from ERA5. The results are very different.
- These analyzes show that it is very difficult to connect the wave parameters from the reanalysis to what it is needed in the radiative transfer model.

Test at high OWS



- A parametric model has been published in Hwang et al., 2019 to describe the ocean emissivity OWS dependence up to 100 m/s.
- The results of this model have been compared with FASTEM, RSS, LOCEAN *(yin2016)* and the LOCEAN *(monahan1986)* github which is the code provided by E. Dinnat on github run in ‘default mode’ so foam coverage from Monahan,1986 and foam emiss Stogryn, 1972.

Test at high OWS



- All the models can provide results within the large errorbars for very high OWS.
- Hwang et al., 2019 follow the other models.
- It is hard to say wich model is the best at this range of OWS (hardly or impossible to compare with satellite observations).

How to proceed for the reference quality emissivity model?

- The reference quality emissivity model should :
  - Be decomposed as follows :
    - $e_{tot} = (1-Fc)(e_0 + e_{wind\ roughness} + e_{wind\ direction}) + Fc*e_{foam}$
  - Be as physical as possible.
  - Stay simple and straighforward to understand.
  - Consistent and continuous over a large range of frequencies
- What about the diffusion of the downwelling atmosphere ? $e_{tot} + e_{scatt\ atmo}$?
- NWP SAF expectation within the next 12 months: agreement on the ingredients for the reference model to develop a method to derive a first version of the fast emissivity code.

Fc:Foam cover ; e_0 emissivity of a flat sea (no wind)

How to proceed for the reference quality emissivity model?

For e_0

- The Meissner and Wentz model reasonable over the full frequency range
- Jacqueline and Thomas to explore the possibility to use the Somaraju and Trumpf model over the full frequency range
- Compatibility with the IR? Stuart Newman talk.

How to proceed for the reference quality emissivity model?

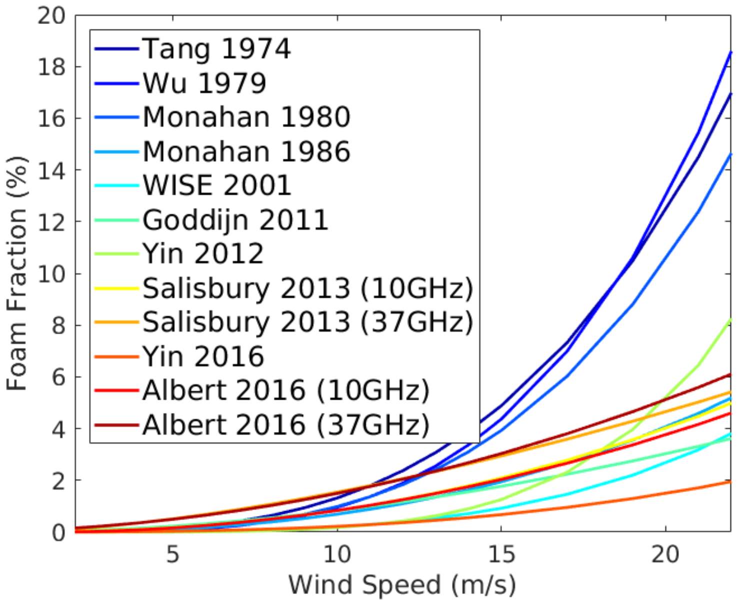
For $e_{wind\ roughness}$

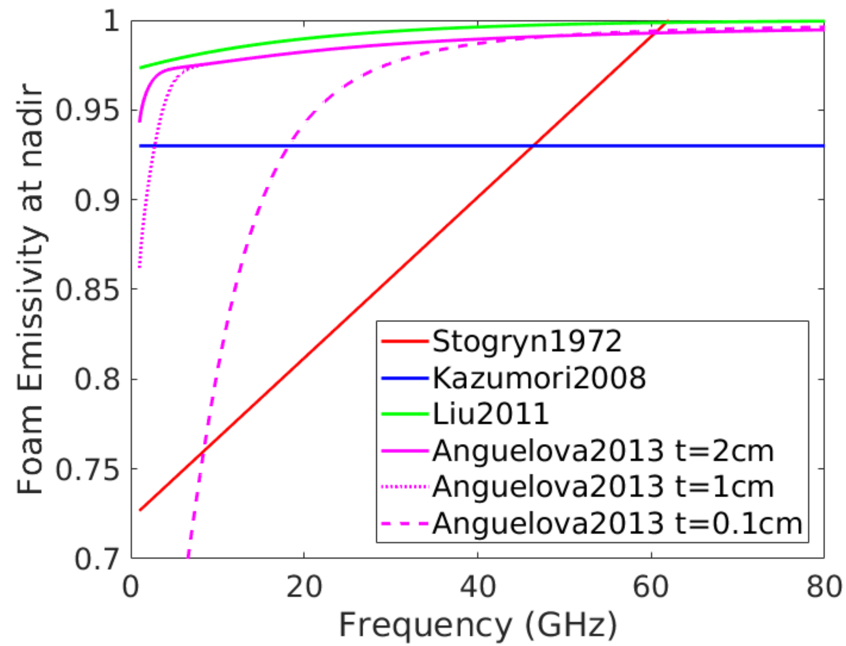
- $e_{wind\ roughness}$ includes wave spectrum (small and large scales with a cut-off between the two scales).
- Wave spectrum: the wave spectrum used in LOCEAN model (Durden and Vesecky, 1977) shows good results even at 166GHz for OWS <10m/s. So we would like to keep it.
- Wave parameters from reanalysis are far from what it is used in the model (e.g. mean square slope) so difficult at that stage to use them.
- Is this wave spectrum ok with radar ? Are the cut-off frequencies suitable? The wind speed as inputs or the wind stress?
- Is this wave spectrum OK for the IR? Cut-off frequencies? Stuart Newman talk

How to proceed for the reference quality emissivity model?

For Fc

- Foam coverage Fc: we would like to keep it as physical as possible. E.g., as suggested by S. English Fc = a*OWS^3
- Fc should not depend on frequency (as the frequency dependency will be in e_{foam}).
- How to determine the value of a?





How to proceed for the reference quality emissivity model?

For e_{foam}

- e_{foam} from Anguelova et 2013 has been chosen for the reference model. Its translation in FORTRAN will be soon avalaible in the code on github.

- Up to now, this e_{foam} model has been used only at L-band in LOCEAN model with Yin2016 foam cover (isn't it?).

- How to determine the physical inputs in Anguelova 2013 to be consistent in frequency ? In Yin2016 the values have been fix to fit L-band measurements :
  - foam–air interface=0.95 ; foam–water interface=0.01 ; thickness=2cm ; shape factor m=1, void fraction…

- Quick tests have been done in Kilic 2019 to show that it is possible to adapt the foam emissivity as a function of frequency by changing the foam thickness.

How to proceed for the reference quality emissivity model?

For $e_{\text{wind direction}}$

- $e_{\text{wind direction}}$ component is important if we want to reach a good precision, and to provide the emissivity for each stokes polarizations.
- The RSS and LOCEAN model accounts for the wind direction for V, H, and the 3rd and 4th Stokes parameters. Discussions at the first meeting tend to show that the reference model should reproduce this wind direction dependence. Tests to be done to verify it.

Plan for the next months

- Discussion with Emmanuel about the model model details, especially about the radar simulations.
- Discussion about the diffusion of the downwelling atmosphere with Emmanuel, Thomas and Steve.
- Discussion with Magdalena about the foam model.
- Discussion with radar expert / wave modelers about the suitable wind inputs and about the best satellite data / GMF model for comparison (Steve to provide the contacts)
- Show comparisons between radiative transfer models and ATMS observations.
- Estimate uncertainties on the major model parameters and propagate them in the model.
- Test with radar data / GMF
- Coordination with the tests in the IR