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Comparisons of ocean radiative transfer models with satellite observations from 1.4 to 89 GHz

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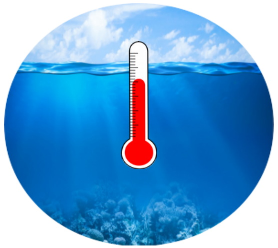
Introduction

- The sea surface temperature (SST), ocean wind speed (OWS) and sea surface salinity (SSS) are fundamental variables for understanding, monitoring and predicting the state of the ocean and atmosphere.

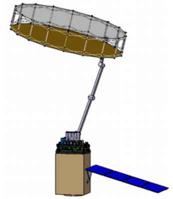
- Passive microwave observations in window channels have a limited sensitivity to the atmosphere and are sensitive to ocean surface parameters.

- The analysis of the ocean parameters from passive microwave satellite brightness temperatures (TBs) requires a radiative transfer model.

- Usually ocean radiative transfer models are developed for a specific application and/or instrument.



Radiative transfer model



Introduction

A new microwave radiometer is currently under study for the expansion of the Copernicus program: **Copernicus Imaging Microwave Radiometer (CIMR)**

- CIMR is designed to observe the Arctic environment
- CIMR will observe at 55° at 5 different frequencies in dual polarizations

Frequency (GHz)	**1.4**	**6.9**	**10.65**	**18.7**	**36.5**
Footprint (km)	<60	15	15	5	<5
NEΔT (K)	0.3	0.2	0.3	0.4	0.7

- For the first time, 1.4 GHz (L-band) observations will be combined with 6, 10, 18 and 36 GHz (C,X, Ku, and Ka-bands) observations to provide coincident SST, SSS, and OWS.
- A **consistent radiative transfer model will be needed** for this new mission
- We compared the existing ocean radiative transfer models working at these frequencies with current passive microwave satellite observations.

Presentation of the selected models

- LOCEAN (Laboratoire d'Océanographie et du Climat)
  A full physical model adjusted to 1.4GHz observations (Dinnat et al., 2003 ; Yin et al., 2016)
- FASTEM (FAST microwave Emissivity Model) version 5
  A fast linear regression fit to the output of a physical two-scale model
  (English and Hewison, 1998 ; Liu et al., 2011)
- RSS (Remote Sensing Systems)
  A semi-empirical model mostly fitted to satellite observations (Meissner and Wentz, 2012)

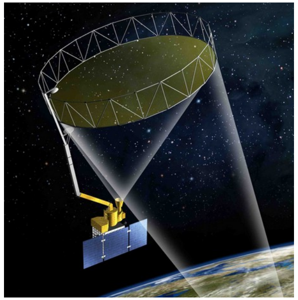
RTM	Model type	Dielectric constant	Wave spectrum	Foam cover	Foam emissivity
LOCEAN Dinnat et al., 2003	Full physical model adjusted for L-band	Klein and Swift, 1977	Durden and Vesecky, 1985 with $a_0 \times 1.25$	Yin et al. 2016	Anguelova and Gaiser, 2013
FASTEM Liu et al., 2011	Parameterized and fast	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		

- Atmospheric contribution simulated with RTTOV version12

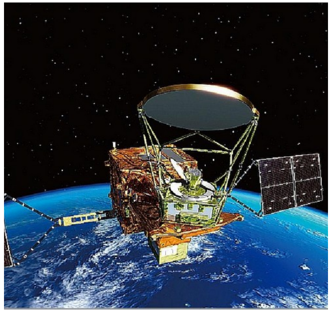
Dataset development

Satellite observations

- SMAP surface brightness temperatures computed by RSS and provided by NASA JPL
- 1.4GHz



- AMSR2 brightness temperatures at top of atmosphere provided by JAXA
- 6.9 to 89GHz



Geophysical data to run the radiative transfer models :

ECMWF

ECMWF reanalysis ERA-Interim data :

- Ocean Wind Speed
- Total Column Water Vapor
- Total Column Liquid Water
- Atmospheric profile (temperature, water vapor)

Copernicus Marine Service

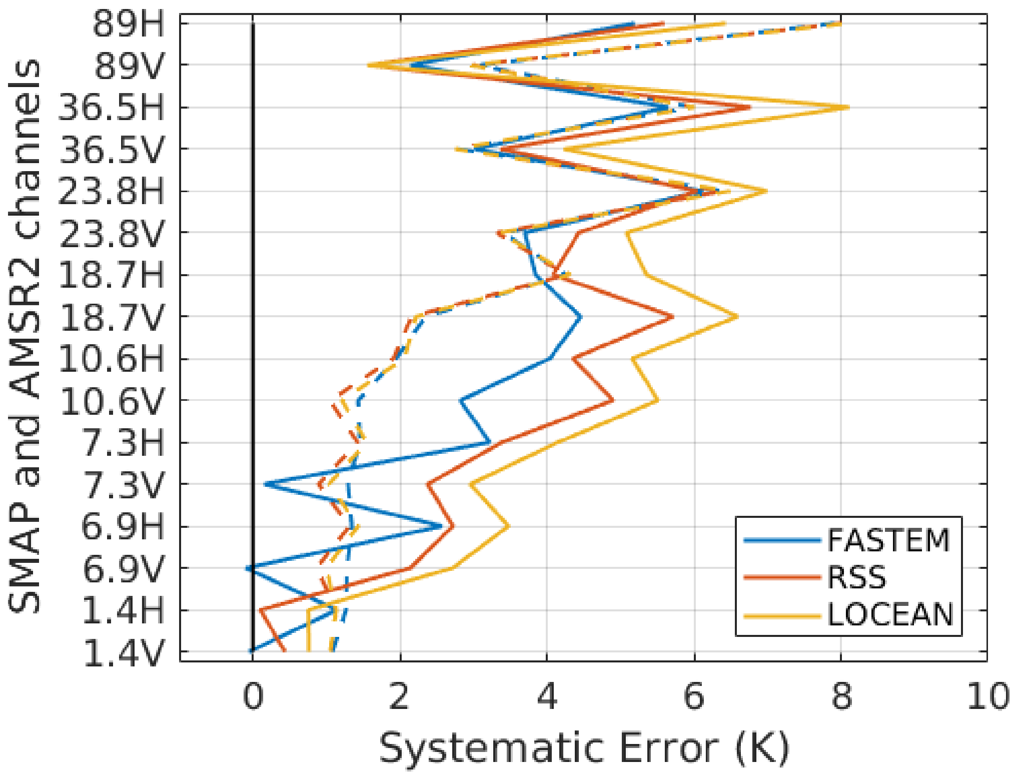
MERCATOR OCEAN

Mercator ocean reanalysis provided by CMEMS :

- Sea Surface Temperature
- Sea Surface Salinity
- Sea Ice Concentration

- Collocation with satellite observations and geophysical data
- Filtering of sea ice, coastal areas, and pixels with more than 0.01kg/m2 of liquid water content

Systematic error evaluation



Solid lines : Systematic errors
Dashed lines : Standard deviations

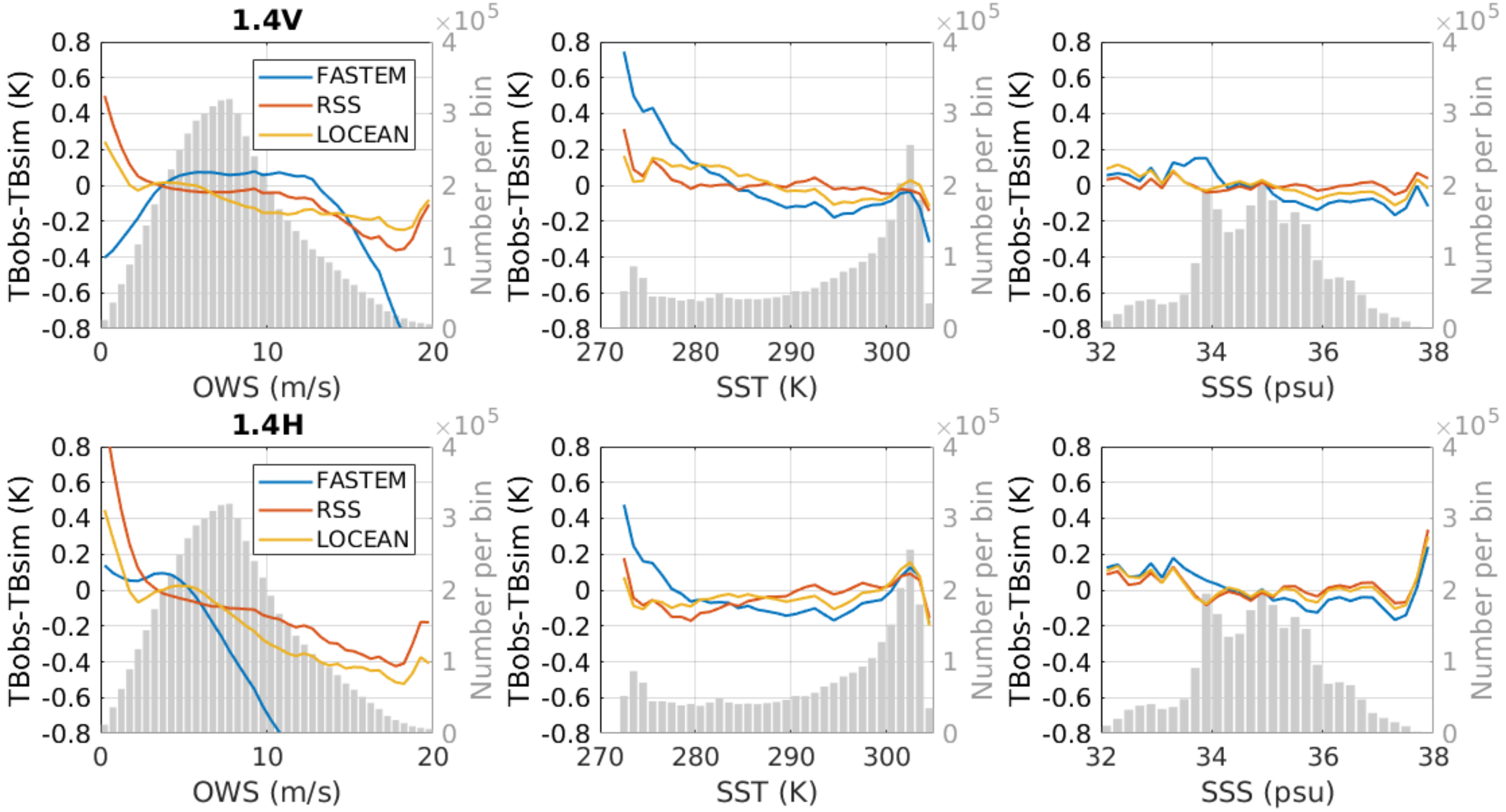
Systematic errors can come from :

- Instrument calibration issues
- Ocean radiative transfer models
- Ancillary data used to run the models

AMSR2 is known to have calibration issues, it explains a part of the large systematic errors

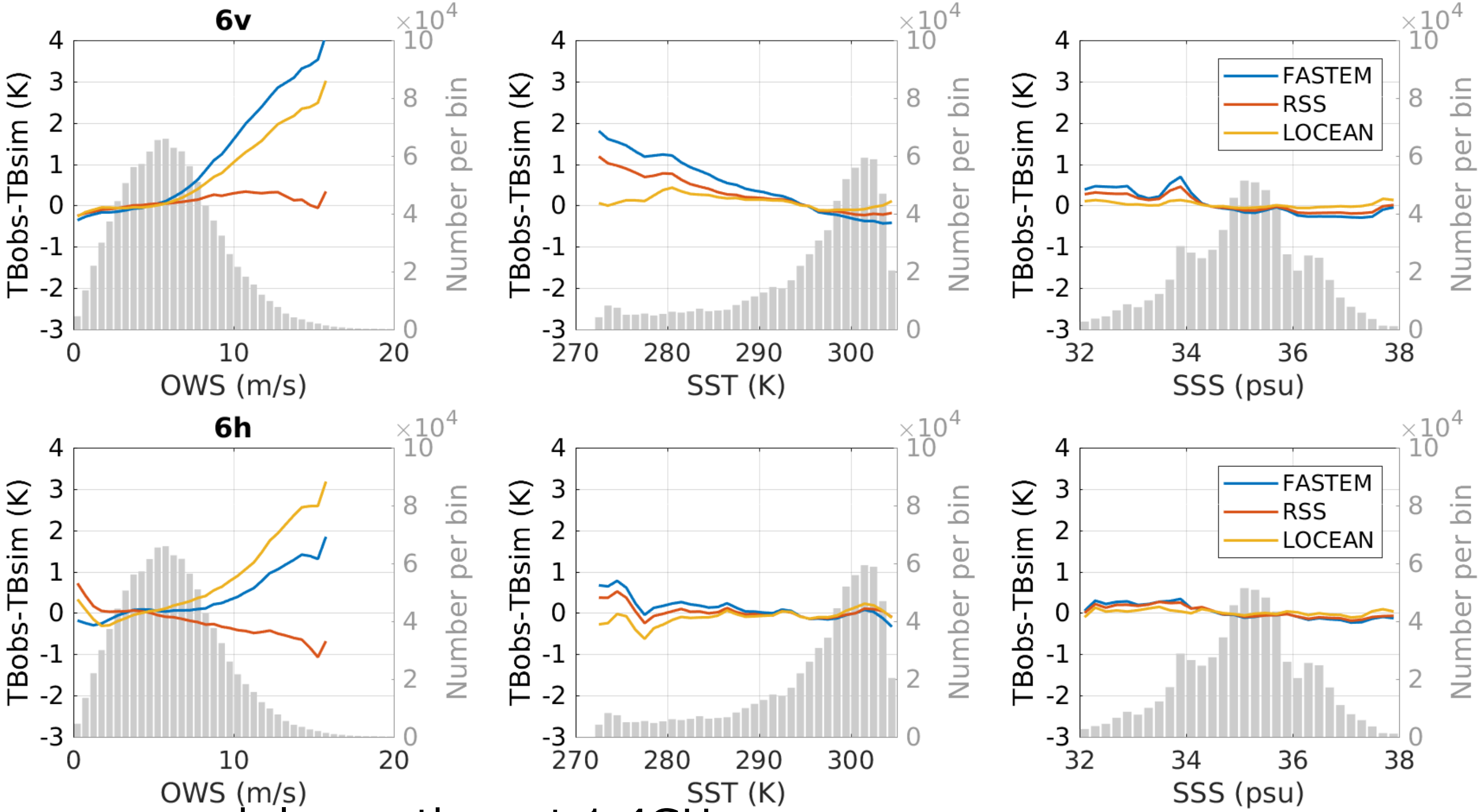
These systematic errors are substracted for the rest of the study

Comparison as a function of ocean parameters at 1.4GHz



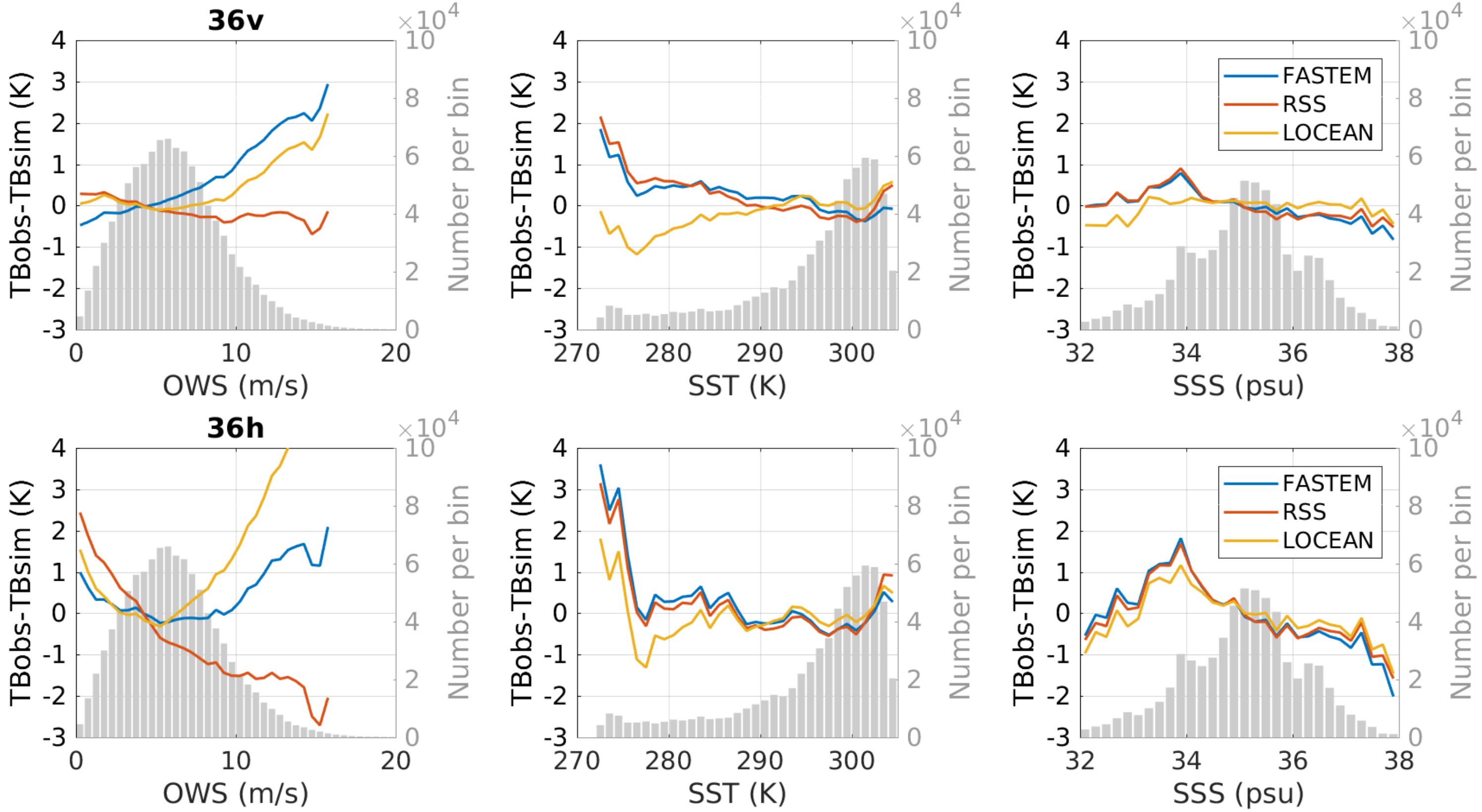
- Discrepancies with the observation at high wind speed and low temperature
- For the estimation of salinity with 1.4GHz, a very good precision is needed because of the low sensitivity to salinity
- The errors are lower than 0.2K as a function of salinity

Comparison as a function of ocean parameters at 6.9GHz



- The errors are much larger than at 1.4GHz
- RSS model shows good results as a function of wind speed whereas LOCEAN and FASTEM models do not simulate correctly the wind speed dependence
- LOCEAN model shows good results as a function of temperature and RSS and FASTEM models show larger errors for low temperature

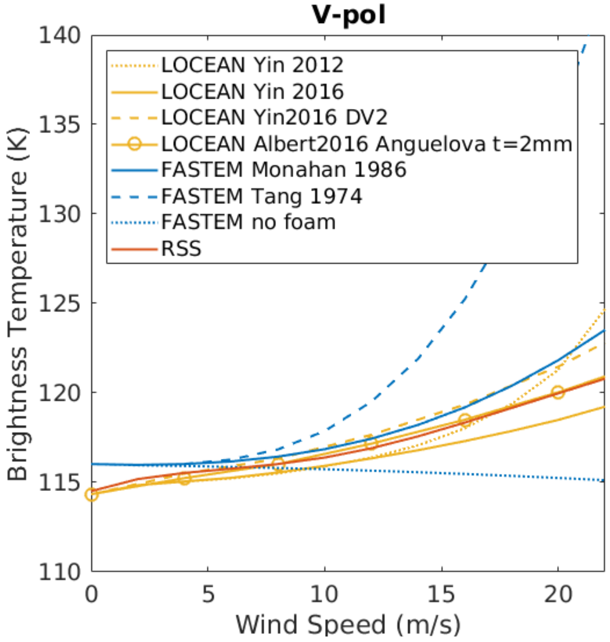
Comparison as a function of ocean parameters at 36.5GHz



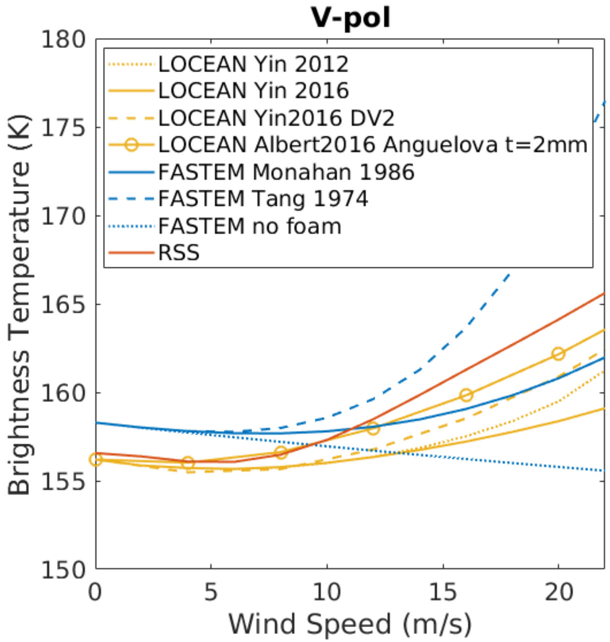
- At 36.GHz the errors due to the atmosphere are not negligeable. The data with a liquid water content > 0.01kg/m² are filter out, but we still have noise.
- LOCEAN model shows more bias for the low temperatures with increasing frequency.
- The largest errors are at high wind speed and low temperatures

Preliminary tests to adapt the models

1.4 GHz



6.9 GHz



- New simulations have been done testing different foam models
- By changing the foam parameterization of the LOCEAN model, it is possible to better fit the wind speed dependence at higher frequencies

- To improve the dependence to the temperature at low temperature in the models, it is necessary to change the dielectric constant.
- For this purpose precise measurements are required over different parameters (frequency, temperature, salinity).

Conclusion

Major issues :

- TBs at low SST are underestimated by the models
  - Modify the dielectric constant.
- TBs for high OWS are underestimated by the models
  - The problem can come from the modelisation of foam

- Efforts have to be done, to develop a precise radiative transfer model continuous in frequency from very low (1 GHz) to very high frequencies (700 GHz).

- The precision of the radiative transfer model is very important for the assimilation of surface sensitive channels in NWP models as well as for the estimation of ocean parameters

See paper recently accepted in JGR oceans

Comparisons of Ocean Radiative Transfer Models with SMAP and AMSR2 Observations, by Lise Kilic, Catherine Prigent, Jacqueline Boutin, Thomas Meissner, Stephen English, and Simon Yueh.

Perspectives

- Work is underway to reproduce this study with different instruments such as :
    - GMI because of its good calibration
    - AMSU to describe the angle dependence in the models
    - We will also use the ERA-5 reanalysis

- These studies will be used as a basis to improve the current radiative transfer models


Thank you for your attention !