The Fastem model

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Stephen English

ECMWF

stephen.English@ecmwf.int

What is Fastem?

Four elements:

1. Permittivity model – can in principle be taken from anywhere, to model ε_0.

2. Linear regression fit using a pre-defined set of predictors to replicate results for ocean from a two-scale "physical" ocean emissivity model,

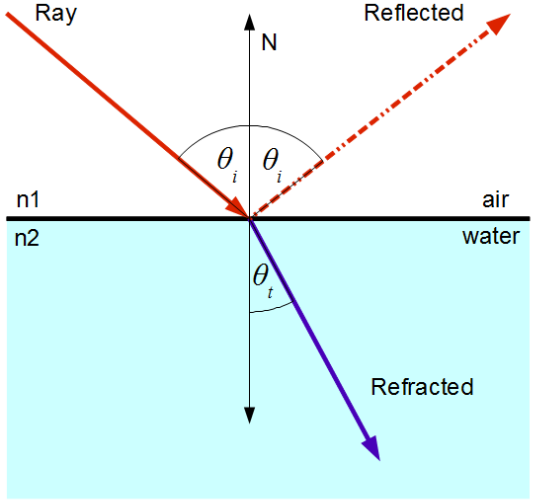
   $\Delta\varepsilon_c = \sum_{k=1}^{n} F_k(W, f, \theta, \varphi)$ where F is a regression fit of ε-ε_0 using functions of W, f, θ and φ,

   $\varepsilon_w(\theta, \varphi) = \varepsilon_0 + \Delta\varepsilon_c$; $r_w(\theta, \varphi) = (1-\varepsilon).\omega(\tau, W, f, \theta)$ ω speeds up RT by enabling specular reflection, which means one pass through atmosphere.

3. Foam model – can in principle be taken from anywhere,

   $\varepsilon = \varepsilon_w(1\text{-}F) + \varepsilon_f F$

4. Azimuthal correction – did use Windrad model, now Kazumori (2015)



Fastem is now maintained by the **NWPSAF**, as part of **RTTOV.**

Fastem has **direct, tangent-linear, adjoint and K** code making it ideal for use in variational data assimilation e.g. **4D-Var**.

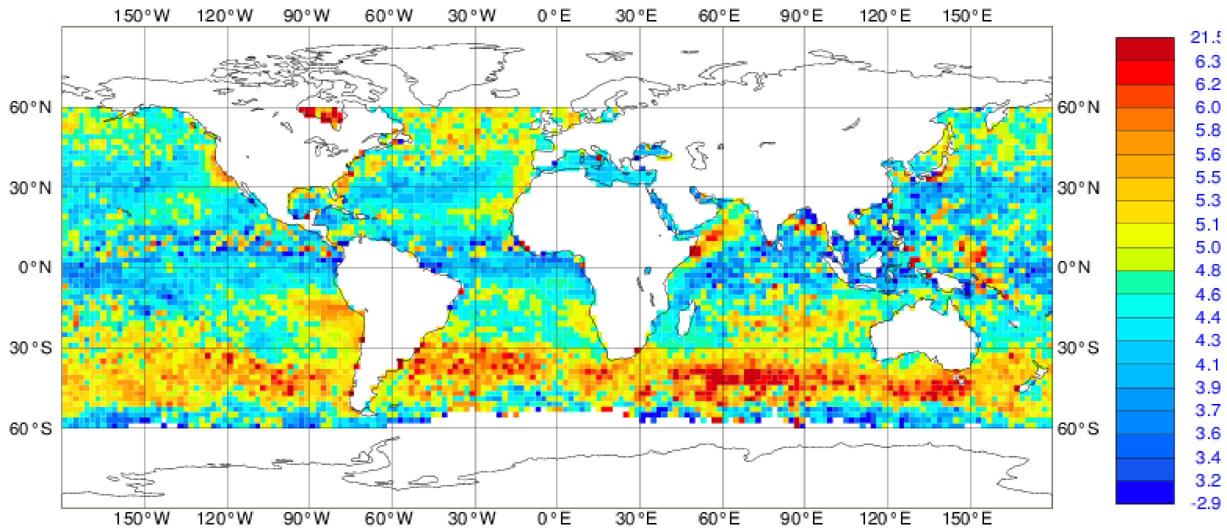
Fastem history

Fastem Version	Permittivity (1 change, poss 2nd)	Roughness (4 changes)	Foam (0 changes, 1 temporary, 1 additional capability tested)
1	Ellison et al 1998	GO / specular Regression fit	Monahan and O'Muircheartaigh (1986)
2	Ellison et al 1998	GO + specular with "omega" term Regression fit	Monahan and O'Muircheartaigh (1986)
3	Ellison et al 1998	GO + omega + WindRad azimuthal term Regression fit	Monahan and O'Muircheartaigh (1986)
4	Liu et al 2011	2-scale + WindRad Regression fit	Tang (1974)
5	Liu et al 2011	2-scale + WindRad Regression fit	Monahan and O'Muircheartaigh (1986)
6	Liu et al 2011	2-scale + Kazumori (2015) azimuthal term Regression fit	Monahan and O'Muircheartaigh (1986) + wave model option
(7)	Lawrence et al. 2019 TBC?	2-scale + Kazumori (2015) Regression fit	Monahan and O'Muircheartaigh (1986) + wave model option

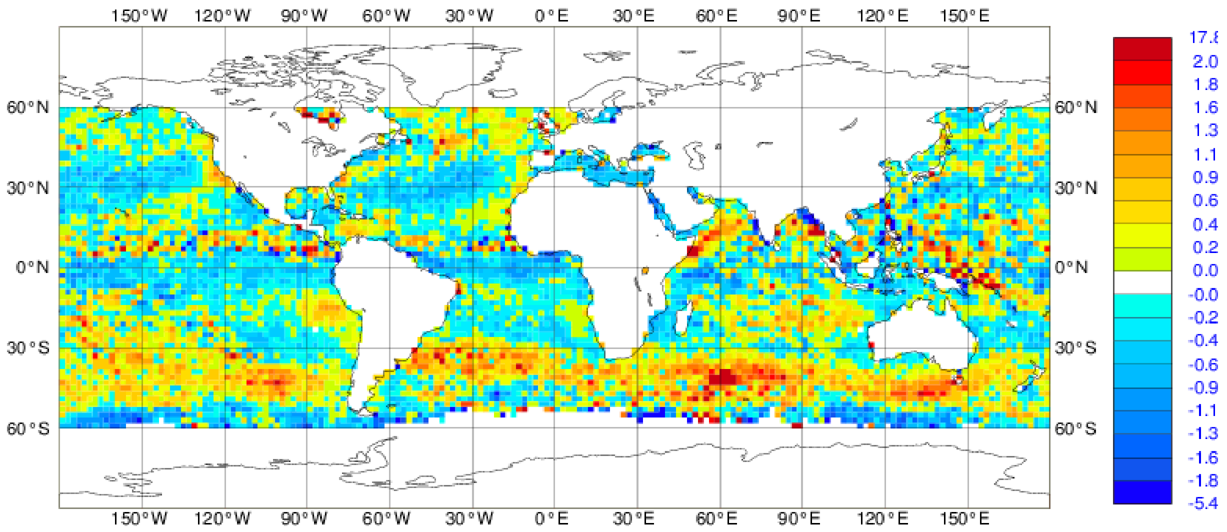
How good is Fastem?

- Comparisons are misleading
- Big biases v AMSR2 (and SSMIS) but bias-free against GMI, e.g. 18.7 GHz V-pol for July 2019

AMSR-2: Mean +4.7 K (range 3.2-6.3 K)



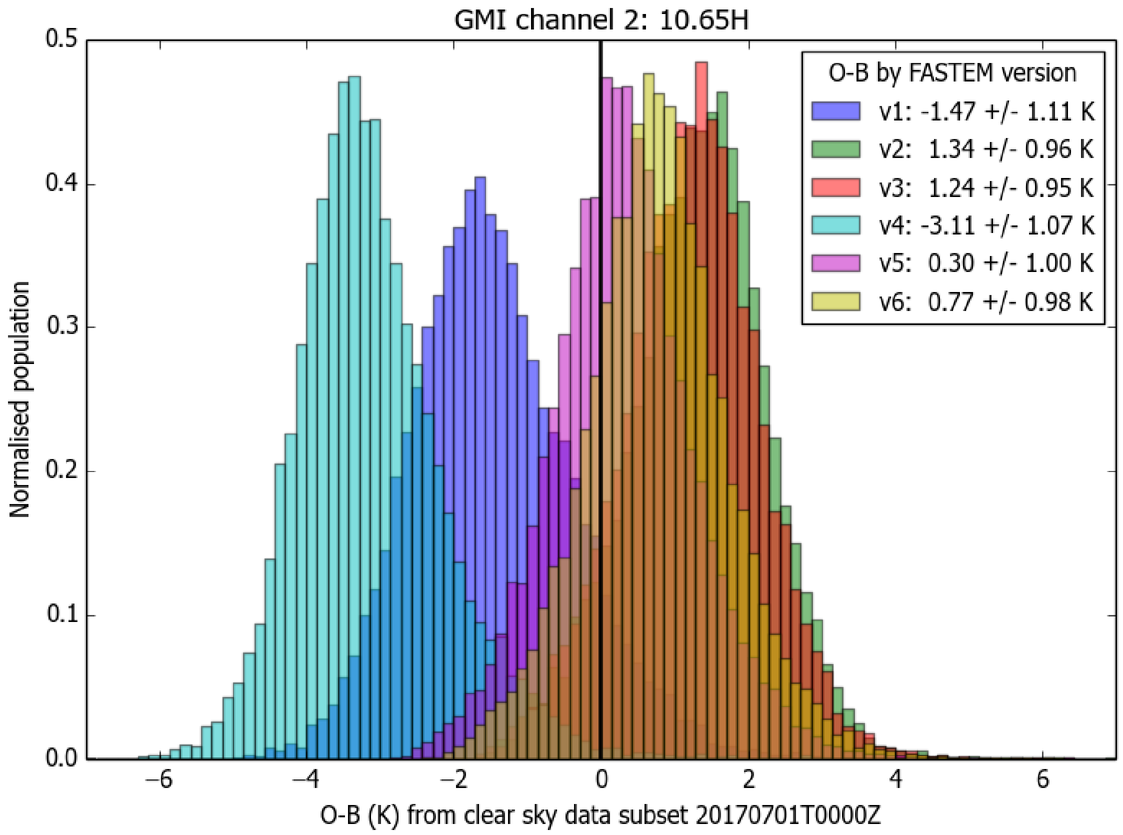
GMI: Mean +0.0 K (range -1.8-2.0 K)



Patterns comparable, mean bias very different. Can we say anything about absolute calibration of the RTM and the satellite instruments?

How good is Fastem (2)?

Compare all Fastem versions v GMI (Stu Newman, Met Office)
Bias changes between -3.11 and +1.34 (best Fastem V5 v GMI)
SD only changes between 0.95 and 1.11 K



V4 biased low poor due to use of Tang (1974) foam model: note this gives a better fit to AMSR-2!

V1 poor due to poor handling of non-specular reflection.

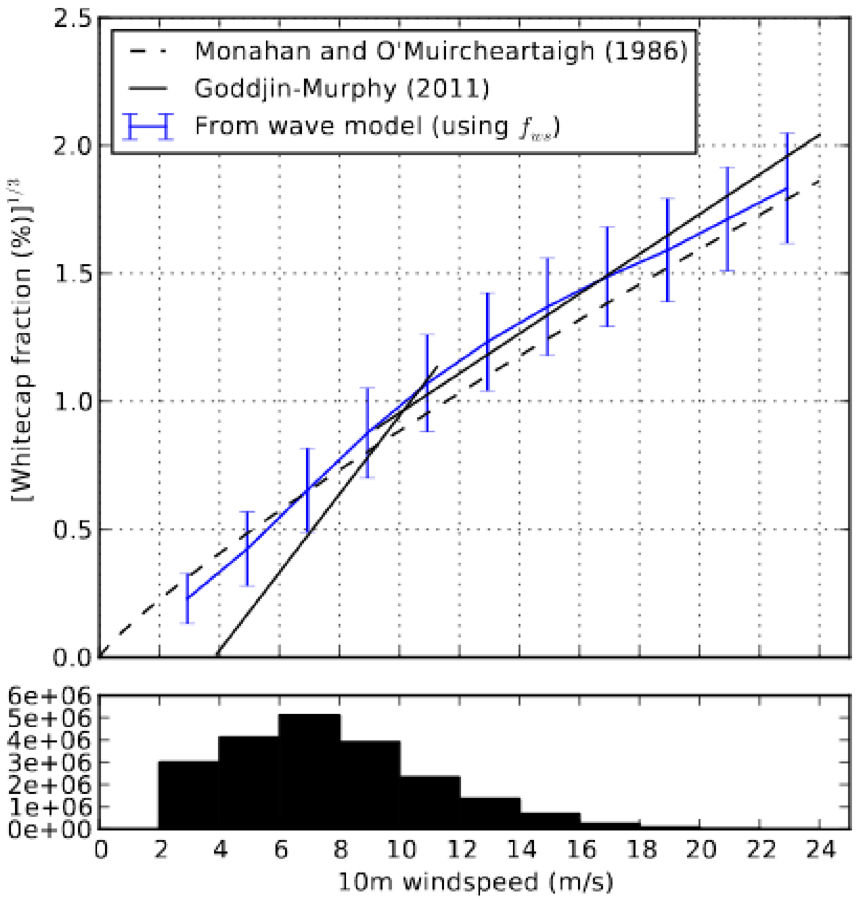
V2, 3, 5, 6 similar performance.

Similar story at other frequencies.

From Stu Newman, Met Office

Taking foam coverage from a wave model

- Foam can be diagnosed from the dissipative wave energy predicted by a wave model
- Meunier, Anguelova and Bettenhausen, working with the NWPSAF, explored this.
- Handling roughness, from swell, waves, ripples and foam should be done in a flexible way, that can allow inputs from models like a wave model, where appropriate
- To date Fastem is hard-wired to windspeed for roughness, and ignores swell, except:
  - Research versions for foam
  - Non-zero roughness at zero windspeed
  - Biggest problem for Fastem is its inflexibility, it's a fast-fit, it can't easily be updated with better science, new frequencies



Conclusions

- A model like Fastem supports **operational data assimilation.**
- It is only as good as the model it attempts to replicate.
- We could develop a new generation of fast models, using AI, but care is needed that gradient code is both robust and consistent with direct code, as is the case with Fastem.
- We also need one model for VIS-IR-MW, like Fastem.
- We want a fast model, but we also want flexibility, to take inputs from ocean and wave models, not just atmospheric 10m wind speed.

- Validation exercises (e.g. Bormann, Kilic, Newman, Kilic….) give conflicting messages, largely because **uncertainty on satellite observations is not well known**.