# Establishing a microwave land surface emissivity scheme in the Met Office 1D-Var

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Several strategies for establishing a land surface emissivity scheme for AMSU have been tested at the Met Office in recent years. The initial approach used an atlas to give a first guess estimate of emissivity[1]. These estimates proved to have little effect on the distributions of observed minus background (O-B) brightness temperatures.

A second scheme converted the atlas into a set of parameters to be used in FASTEM[2], the microwave emissivity parameterization in the RTTOV[3] forward model. The parameters were used to calculate channel-dependent emissivities as part of a 1D-Var retrieval. This approach was hampered by poor convergence rates and a lack of significant improvement in the observed minus analysis (O-A) brightness temperatures.

A new approach is under development to use Weng and Yan's (2003)[4] microwave snow emissivity model to provide a first guess emissivity where appropriate and to retrieve emissivities directly in the 1D-Var. The reduced O-B values from this scheme are a promising step.

## 1. The Met Office operational land surface microwave emissivity scheme

The land surface emissivity scheme has been the same throughout the history of direct radiance assimilation at the Met Office. A value of 0.95 is used across the spectrum over all land points regardless of surface type.

This value is unreasonable for many surfaces such as desert, snow and observations which contain significant water fraction, such as lakes or rivers (**Figure 1**).

The uncertainty in the appropriateness of the emissivity values used means that we reject the lower sounding channels AMSU 4 and 5 over land and also channel 6 over high land.

A more accurate emissivity will allow inclusion of more channels, hopefully improving forecasts.

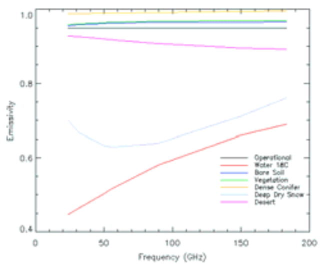


**Figure 1:** *Nadir emissivity spectra from FASTEM2. Parameters for the model are taken from Hewison and English (2000)[5] and correspond to classes from Hewison's airborne campaign, except Desert for which the parameters are based on Prigent's SSM/I atlas*

## 2. Initial studies with an emissivity atlas

Poulsen (2001)[1] used FASTEM2 to estimate emissivity for AMSU observations. The FASTEM parameters were derived from Prigent's emissivity atlas at SSM/I frequencies[6].

AMSU observations were compared with forward modeled calculations (RTTOV67 with Met Office NWP analyses). The approach did not greatly reduce the observed minus forward-modeled background (O-B) values.

**Figure 2** shows that areas around lake edges and deserts were poorly modeled. The FASTEM parameter atlas has large areas of missing data (mostly over snow) where parameters could not be derived from the Prigent dataset. This limits its use over data-sparse regions such as Siberia and Antarctica (**Figure 3**).

**Figure 4** shows that in the case of vegetated classes there was very little change in the O-B distribution.

Poulsen also tried a scheme where the emissivity was calculated as:

*Emissivity = land fraction * 0.95 + water fraction * water emissivity*

(water emissivity calculated by FASTEM using the surface windspeed).

This scheme was found to produce much better results for coasts and inland water areas (**Figure 4**) but the convolution of a surface-type atlas with the ATOVS observations was found to be prohibitively expensive. Nor would the method benefit the snowy areas.

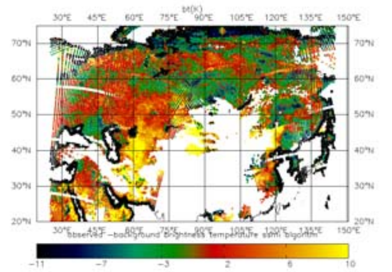


**Figure 2:** *O-B values for the parameterized SSM/I emissivity atlas method*

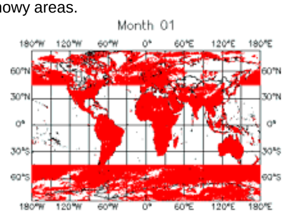


**Figure 3:** *Location of points in the SSM/I emissivity atlas for January. Note gaps over Canada and Siberia*

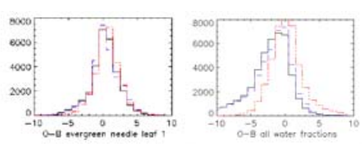


**Figure 4:** *O-B distrubutions for three emissivity schemes: black=operational, blue=SSM/I atlas, red=water fraction. a) Evergreen needle forest b) water fraction >0*

## 3. A 1D-Var approach using the emissivity atlas as first guess

Poulsen's study concluded we should retrieve FASTEM parameters (using Prigent's emissivity atlas as background) in 1D-Var. This approach was attempted by the author using operational data assimilation code. The intention was to use the lower sounding and window channels in the 1D-Var to analyse emissivity, and then use channels 4 and 5 in the 3D-Var assimilation for cloud-free observations.

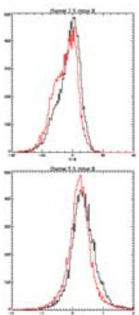

**Figure 5:** *Histograms of O-B for AMSU2 and 5 for the emissivity parameter retrieval. Red=atlas, black=operations*

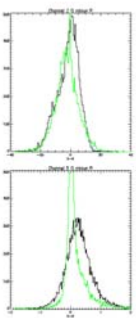

**Figure 6:** *Histograms of O-R for AMSU2 and 5 for the emissivity parameter retrieval. Green=atlas, black=operations*

This approach proved disappointing in several respects. **Figure 5** shows little difference in O-B distributions between the control run and the new scheme. The O-R distributions (**Figure 6**) are slightly improved, but this has come at a cost.

With existing quality control checks, the new scheme caused ~2.5 times more cloud-free observations to be rejected. This was mostly a result of convergence failure. Even those observations which were accepted took more iterations to converge increasing computational cost. The convergence problem was partly due to attempts to retrieve emissivity where the window channels had been rejected by quality control. However, the background error covariance matrix which was difficult to define was an influence.

Again, gaps in the FASTEM parameter atlas (**Figure 3**) were problematic. In these areas, the first guess remained 0.95 for all frequencies and this contributed to the rejection rate.

## 4. Weng and Yan's snow emissivity model[4]

A flat 0.95 emissivity is a particularly bad approximation for snow covered surfaces but is a reasonable first guess for other surface types (**Figure 1**). Since snow often covers large areas with few conventional observations (e.g. Siberia), Weng and Yan's empirical snow emissivity model is being tested as a first guess emissivity in snowy areas. We will then use a 1D-Var to retrieve an emissivity for all data points, as in **Section 3**. The Weng and Yan model fits AMSU window channel brightness temperatures to one of a series of reference emissivity profiles for different snow types.

At this stage, only the O-B values have been studied, as more work is required to make the retrieval code function properly. **Figure 7** shows that these are much improved for Weng and Yan's scheme. However, the snow classification results suggest that perhaps this model is more complicated than we need: more than 80% of observations fail to be classified with a snow type and end up with the default emissivity profile of 'Thick Crust Snow' (**Figure 8**).

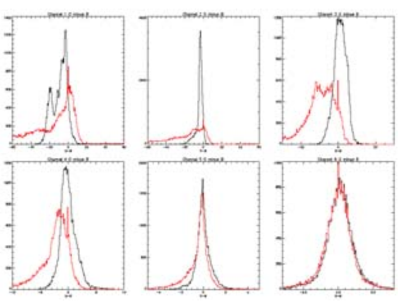

**Figure 7:** *Histograms of O-B for AMSU1-6 for snow points. Red=operations black=Weng and Yan*

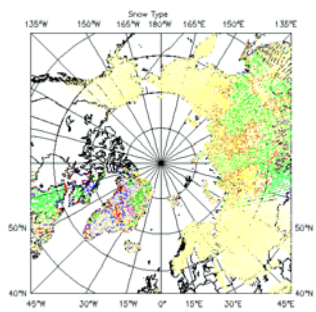


**Figure 8:** *Snowtype classification of AMSU observations. Yellow='Thick Crust Snow'*

## References

[1] Poulsen, C. (2001): A quick evaluation of whether knowledge of the land surface will lead to better retrievals over land using AMSU. *Unpublished Internal Met Office Short Working Paper*

[2] Hewison, T.J. and English, S. (1999): Airborne retrievals of snow and ice surface emissivity at millimeter wavelengths. *IEEE Transactions in Geoscience and Remote Sensing, v.37, p.1871–1879*

[3] RTTOV web page: http://www.metoffice.com/research/interproj/nwpsaf/rtm/index.html

[4] Weng, F. and Yan, B. (2003): A microwave snow emissivity model. *ITSC XIII Proceedings Sainte Adele, Canada, 29 October 2003 – 4 November 2003*

[5] Hewison, T. and English, S. (2000): Fast models for land surface emissivity. In: *Cost Action 712 — Radiative transfer models for microwave radiometry Final Report of Project 1, ed. Matzler, C, p117–127*

[6] Prigent C., Rossow, W.B. and Matthews, E. (1997): Microwave land surface emissivities estimated from SSM/I observations. *Journal of Geophysical Research, v.102, p.21867–21890*

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