

MICROWAVE SURFACE EMISSIVITY OVER SNOW AND ICE

T.J.Hewison

UK Meteorological Office

Remote Sensing, Farnborough, UK

Summary: This abstract summarises airborne measurements of the emissivity of snow and ice surfaces. It outlines a model capable of reproducing these observations to the accuracy required to retrieve atmospheric information from microwave satellite instruments.

1. INTRODUCTION

To date, retrieval of atmospheric temperature and humidity from satellite instruments has been restricted to areas of open ocean, where the surface emissivity can be accurately modelled, if the windspeed and temperature are known. It has been shown that it is possible to retrieve as much humidity information over ice and land surfaces where the surface emissivity can be modelled with an error of less than 2% [English, 1999].

Physical modelling of the processes that affect the surface emissivity is not currently practical for operational retrievals from satellite data. A semi-empirical model is presented. Its parameters are fitted to observations, which are based on airborne measurements.

2. OBSERVATIONS

The UK Met Office have conducted a programme to measure the emissivity of various sea ice and land surfaces with microwave radiometers on board the Met Research Flight C-130 aircraft. This allows homogeneous areas to be identified, measured and compared with independent ground truth. Variations on the scale of tens of metres to tens of kilometres can be measured, spanning the gap between ground-based and satellite observations. The results of the Microwave Airborne Campaign over Snow and Ice [Hewison and English, 1999] are summarised in Figure 1.

These results show the spectrum of new ice is similar to that of land surfaces [Hewison, 1999]. The emissivity is relatively high and changes little with frequency, although emissions are more strongly polarised due to their specular nature.

The emissivity of older ice decreases with frequency and can be highly variable. However, this trend is often reversed above 90GHz. Dry snow exhibits similar spectral characteristics, but wet snow appears almost black. Emission and scattering by forestry above the snow masks its signature.

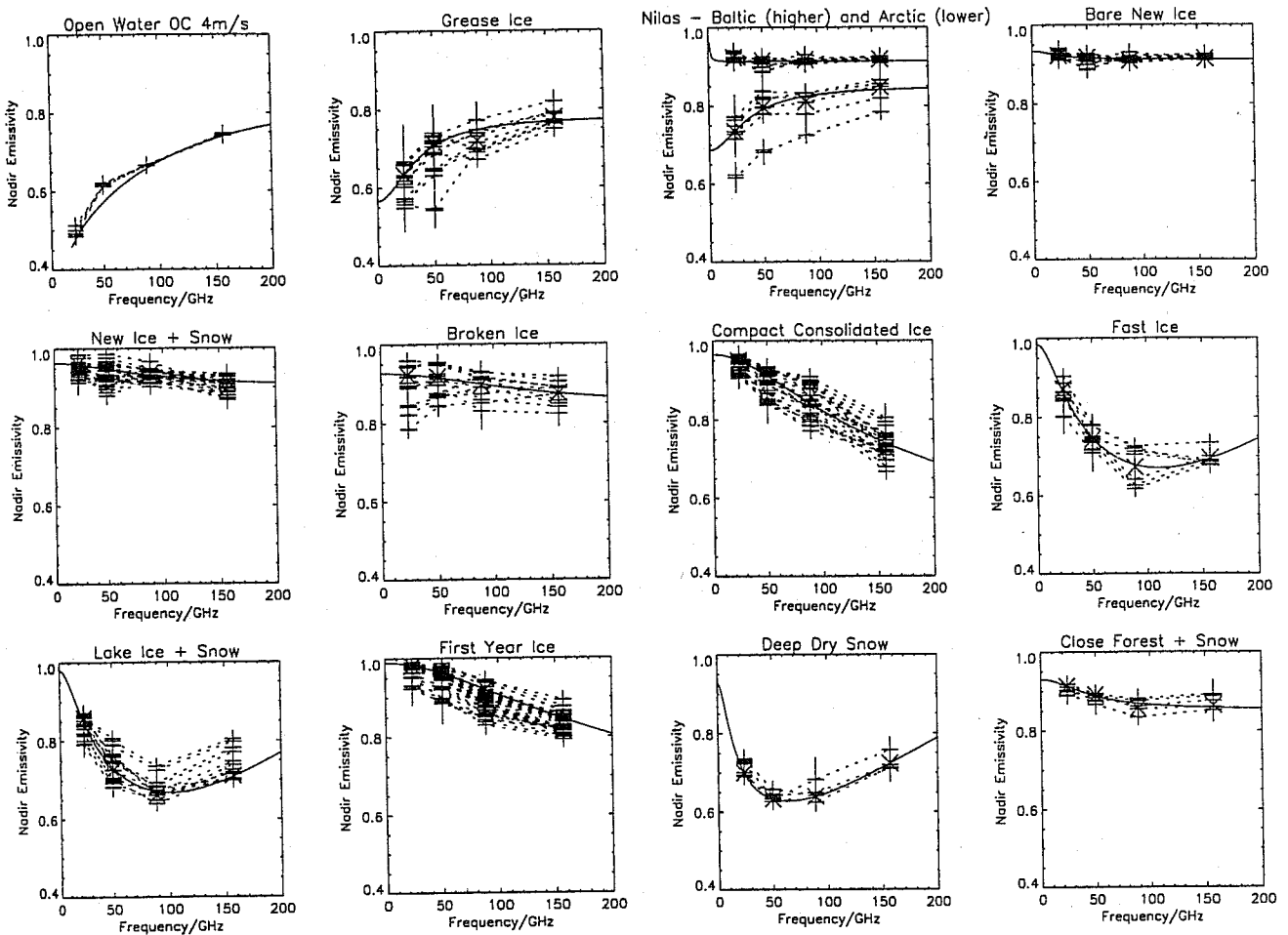


Figure 1 - Nadir emissivity spectra of various surfaces observed from aircraft during MACSI. Crosses show mean and standard error emissivity of each sample, connected by dashed lines. Continuous lines indicate semi-empirical emissivity model (FASTEM) fitted to these data. From [Hewison and English, 1999].

3. A SEMI-EMPIRICAL MODEL

Whilst simple dielectric surfaces, such as new ice can be modelled physically, the observations show the emissivity of dry snow and older forms of sea ice can be very variable in time and space as well as observation frequency, angle and polarisation. This is due to the influence of volume scattering by voids or brine pockets in sea ice and ice crystals in snowpacks. Although physical models of these processes do exist, they are computationally expensive and require input variables that are not readily available on a global scale.

A simple, semi-empirical model has been used by the UK Meteorological Office to describe the emissivity of sea and land surfaces [Hewison and English, 1999]. This has been extended to cover surfaces with snow and ice cover.

The model is based on the Debye formula, describing the variation of the dielectric permittivity with frequency, as a function of 3 parameters. The specular reflectivity is modelled using Fresnel's equations based on this effective permittivity. The resulting reflectivity is then multiplied by a factor representing the influence of small-scale surface roughness. In practice, the roughness must be fitted to the observed emissivity spectra. This parameter also allows the non-monotonic emissivity spectra of dry snow to be represented.

An additional parameter is used to represent depolarisation of radiation by large-scale roughness, and to fit the airborne observations that the specular reflectivities calculated from Fresnel's formula considerably overestimate the difference between polarisations. Extinction by vegetation, volume scattering and surface scattering by large-scale features is not explicitly modelled. Because of this, the estimation of permittivity coefficients will not be equivalent to the actual permittivity of the surface materials.

4. CONCLUSIONS

Aircraft observations show the emissivity of bare soil, dense vegetation, wet snow and new ice are sufficiently uniform on a scale of kilometres to allow retrievals of atmospheric information from satellite microwave instruments. However, dry snow and older ice types have highly variable emissivity, which is very sensitive to the structure of the scatterers within the snow/ice pack.

Physical modelling of these processes is impractical for these purposes at present. A semi-empirical model is presented, which is capable of reproducing observed emissivity spectra of many surface types over the 20-200GHz range of frequencies, 0-50° incidence and any linear polarisation. In the future, integrated models of atmospheric, ice and snowpack evolution may be used. Alternatively, statistical analysis of emissivities retrieved from satellite data may show less variability on larger scales.

5. REFERENCES

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