# Assimilation of near surface sounding radiances

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1. Motivation

The impact of ATOVS at high level from assimilating data over land and sea separately both give **positive impact** on forecast accuracy in all regions above 400 hPa **except north of 70N**. This is illustrated with zonal cross sections below which show the change in root mean square forecast error for 24 hour geopotential height verified against analysis compared to a control using no ATOVS when (a) ATOVS observations are added over land and sea ice (left hand side) and (b) when ATOVS observations are added over open water sea points (right hand side). The experiment period was 08/01/2006-07/02/2006. The impact over sea ice appears to be negative.


Impact of ATOVS land and sea ice points   Impact of ATOVS sea points
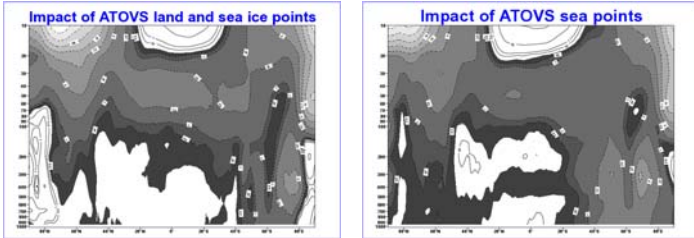
Channel selection	No cloud detected	Cloud detected	Rain detected	Emissivity
Open water	4-14, 18-20	6-14, 18-19	9-14, 18	Fastem vn2.0
Sea ice	5-14	5-14	9-14	F(ice coverage)
Land	6-14	6-14	9-14	0.95

Impact of sea ATOVS   Impact of land and sea ice ATOVS
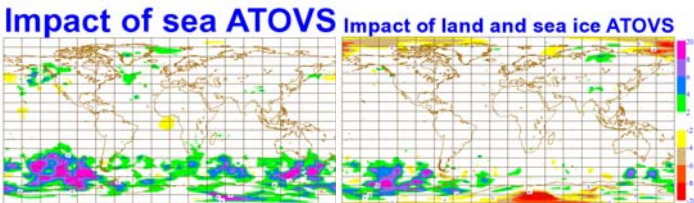
Mercator plots of the impact of ATOVS at 900 hPa (same quantity as zonal plots) show that the main impact of assimilating over land and sea ice is in Siberia, the Arctic and Antarctica. Negative impact over sea ice is clearly visible. Impact of ATOVS over land appears to be neutral or positive.

### 2. Skin temperature accuracy requirement

It is not difficult to determine the accuracy requirements for skin temperature and surface emissivity in order to be able to use satellite data over land. The tangent linear model of the radiative transfer equation for an isothermal atmosphere with specular surface reflection, $I = \varepsilon \tau T_s + (1-\varepsilon) T_c \tau^2 + (1-\varepsilon)T(1-\tau)\tau + T(1-\tau)$, is $dI = \tau\varepsilon\delta T_s + ((T^*-T) \tau + (T-T_c) \tau^2) \delta\varepsilon$. (Emissivity=$\varepsilon$; skin temperature =$T^*$; top of atmosphere brightness temperature=I; atmospheric temperature=T; cosmic temperature =T_c; atmospheric transmittance =τ.) **The interesting property of this equation is that skin temperature errors scale with τ but emissivity errors scale with $a.\tau + b.\tau^2$.** As T_s-T is small compared to T-T_c the impact of emissivity errors becomes small at small τ whereas skin temperature errors remain important at low τ.
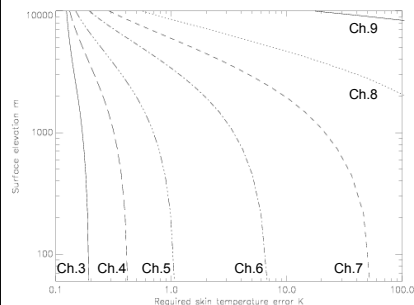
For AMSU six-hour NWP forecast tropospheric atmospheric temperature errors gives rise to 0.1 K top of atmosphere brightness temperature errors. We can calculate how large a skin temperature or emissivity error gives a 0.1 K top of atmosphere brightness temperature error.

NWP skin temperatures (T^*) errors are large. A 4 K skin temperature error would imply we can use
•Ch.7 only if surface elevation < 3000m
•Ch.6 only if surface elevation < 800m
•Ch.5 requires T^* error < 1.3 K
•Ch.4 requires T^* error < 0.4 K
•Ch.3 requires T^* error < 0.2 K

3. Emissivity accuracy requirement
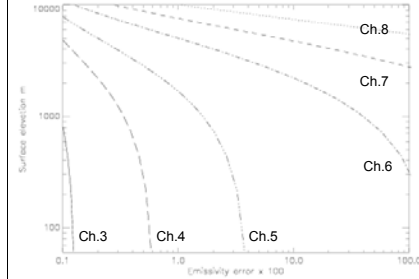
Prigent (JGR, 1997) showed emissivity atlases may provide prior emissivity estimates with an error of about 2%. An accuracy of 2% implies we can use
•Ch.7 always
•Ch.6 only if surface elevation < 4000m
•Ch.5 only if surface elevation < 800m
•Ch.4 requires ε error < 0.5%
•Ch.3 requires ε error < 0.2%

This is a much less demanding requirement than the skin temperature requirement.

It is the analysis of skin temperature which is critical to atmospheric sounding and which drives the accuracy requirement for emissivity. If we have a sufficiently accurate prior skin temperature estimate we do not need accurate emissivity for sounding applications.

4. Estimation of emissivity and skin temperature errors from innovations
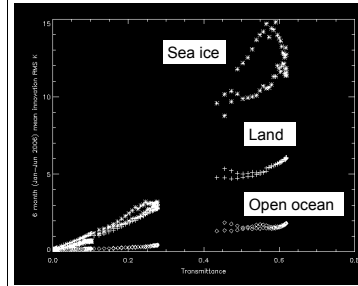

For sea level surface	δTs K	δε x 100	Lowest channel (nadir)	Lowest channel (scan edge)
Land	6-9	0.8-1.2	7	6
Sea ice	5-9	7-9	7	6
Sea	0.2-0.5	1.0-1.5	5	4

Innovations over sea ice, land and open water show us the actual errors in skin temperature and emissivity. These can be inferred from the curvature of the dependence on surface to space transmittance. We can determine the lowest altitude channel which will give us useful information without any additional skin temperature analysis and whether there is sufficient emissivity information to analyse skin temperature.

5. Data denial of AMSU Ch.5 over sea ice

An experiment was run which excluded AMSU channel 5 over sea ice. The impact is shown (right) – coloured shaded areas are where the 24-hour geopotential height forecast is more accurate verified against analysis without AMSU channel 5 for the period 8 June to 7 July 2006. Solid unshaded contours are where the forecast is less accurate in the test. The forecast is generally improved by a very small amount in most regions with a more substantial improvement over the arctic itself. However, there is very little impact over the southern hemisphere sea ice. This was sufficient evidence to lead to a Met Office decision to exclude AMSU channel 5 over sea ice.

Impact of AMSU channel 5 over sea ice
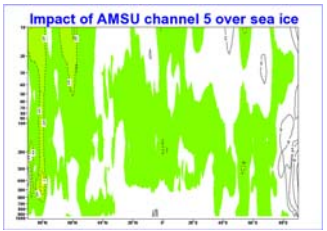
6. Surface temperature analysis from AMSU

Using simulated data and a 1D-var system we can calculate skin temperature errors for realistic emissivity errors and error correlations for AMSU channels. If we assume prior knowledge of skin temperature of 9 K (equivalent to the worse case over land and sea ice) and then assume emissivity error of 0.01 (land) and 0.07 (sea ice) the analysed skin temperature errors (ignoring any cloud detection issues) are 2.7 K and 6.5 K respectively. Thus for sea ice the analysed skin temperature error is not good enough for atmospheric sounding using AMSU channel 5.

7. Conclusions

It has been shown that innovations as a function of scan position can provide insight into errors in skin temperature and emissivity. This has shown that skin temperature errors are very high over land and sea ice. It has also been shown that it is skin temperature errors which are most important for sounding applications. Over land, emissivity estimates may be good enough to analyse skin temperature accurately enough from AMSU window channels to assimilate AMSU channels 6 and above and under some circumstances AMSU channel 5. However, over sea ice, substantially more accurate emissivities are required to allow any use of AMSU channel 5. AMSU channel 5 was being used over land at the Met Office and removing it improves forecast accuracy, especially in the summer hemisphere (Arctic in June-July, Antarctic in December-February).

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