

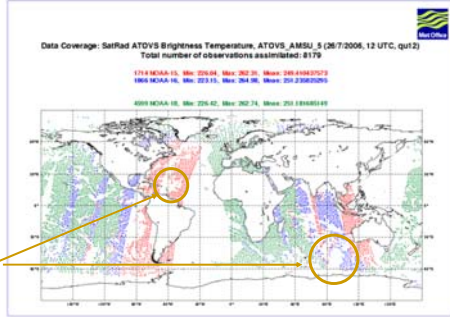
# Assimilation of cloudy AMSU-A microwave radiances



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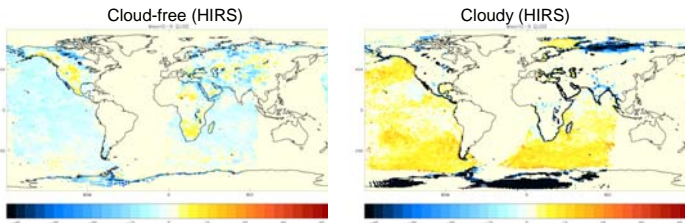
## 1. Motivation

Cloud liquid water has a large impact on microwave radiances. Therefore, if significant liquid water is present, AMSU-A channels peaking in the lower troposphere are not assimilated in 4D-var. This leads to significant gaps in data coverage for AMSU channel 5. An example is given below for 26 July 2006, with some large gaps due to cloud highlighted. Therefore, there is a strong motivation to analyse cloud liquid water in 4D-var to allow closer to "all-weather" sounding.

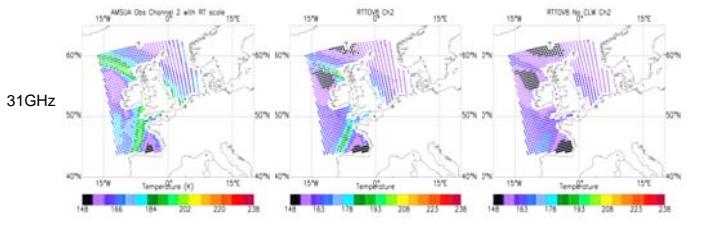


## 2. Comparison of observations and model

AMSU channel 2 has a negative innovation bias (observed brightness temperatures colder than model) in cloud-free conditions and a positive innovation bias (observed brightness temperatures warmer than model) in cloudy conditions. Global maps of the bias based on 4 Weeks AMSU-A from NOAA-16 are shown below using RTTOV-7 and Met Office global model background fields. These biases could be due to data selection i.e. the model has cloud in some cloud-free areas and no cloud in some cloudy areas. It may also be that the model has systematically too little liquid water in clouds.



A specific case study, also for AMSU channel 2, is shown below with radiative effects of liquid water included (middle) and excluded (far right). The observed values from NOAA-16 are shown on the far left.



## 3. Cloud incrementing operator

4D-var uses variable transforms for all variables which relate analysis space to model space. For moisture, a single total moisture analysis variable is used. To allow for cloud we need a cloud incrementing operator which relates cloud liquid water and specific humidity to the total water control variable. This operator uses linear physics which is kept as close as possible to the full physics in the forecast model.

$$C_x^* = C_x + KC_w^*$$

$C_x^*$  is the model state and includes humidity  $q$ , liquid cloud  $q_{cl}$ , ice cloud  $q_{ci}$  and cloud fraction.  $C_w^*$  is the analysis increment and includes  $T$ ,  $p$  and  $q_T$ .  $q_T$  currently considered to be  $q + q_{cl}$

$K$  is an incremental variable transform operator between the control variable space and the model parameter space. In this instance,  $K$  requires linear physics and applies a physically based constraint on the adjustment of cloud, water vapour and temperature.

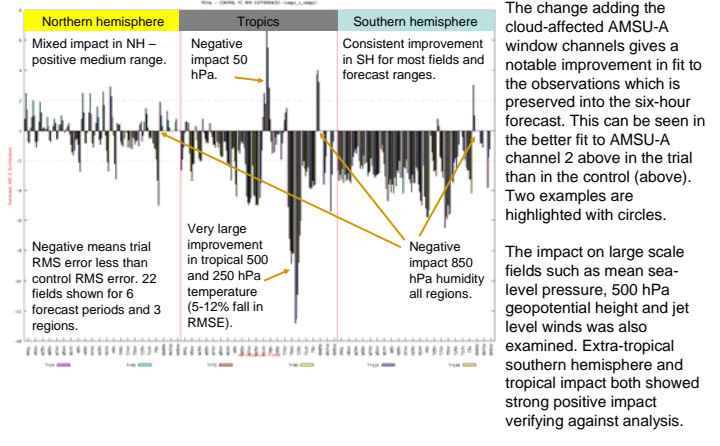
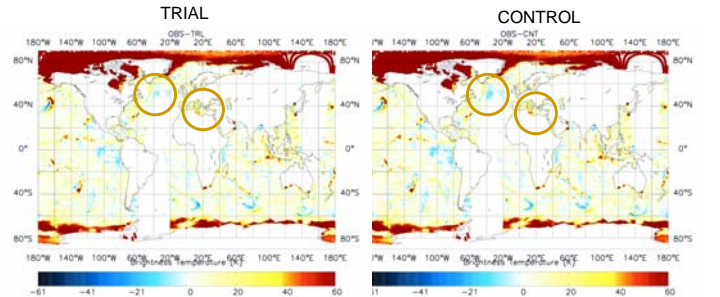
## 4. 1D-var preprocessor

1D-var could be written incrementally and call the same incrementing operator. However, initially the 1D-var is formulated full field total water following Deblonde and English (JAM 42, 1406-1420, 2003). This approach leads to 8% of 1D-var solutions not passing all convergence tests in 1D-var. As data is thinned and satellite passes overlap (in a six-hour window) data volume in 4D-var is not reduced but is **biased away from cloudy areas**. This biased data selection is known to give negative impact (English et al., ITSC-12, 72-78, 2002). A control with the biased data selection was run and used for the incrementing operator assimilation test.

## 5. Assimilation experiment

A four-week assimilation experiment was run using a low cost version of the Met Office operational system (3D-var instead of 4D-var and reduced NWP resolution c.60km and 432 points east to west compared to c.40 km and 640 grid points east to west). **Assimilation changes:** Use AMSU-A channels 1 and 2 in all situations over sea except precipitation as defined using the Bennartz et al. (ITSC-11, 1-8, 2000) scattering index.

	AMSU channels used (sea points no liquid water > 0.1 mm detected)	AMSU channels used (sea points where liquid water > 0.1 mm detected)	AMSU channels used (non-sea points)
Operations (July 2006)	4-14, 18-20	6-14, 18-19	6-14
Control	4-14, 18-20	6-14, 18-19	6-14
Trial	1-2,4-14, 18-20	1-2,6-14, 18-19	6-14



## 6. Conclusions

Assimilating AMSU-A2 cloudy radiances improves cloud fields and provides some benefit to large scale fields from 20N to 90S. The improved cloud analysis should allow more use of AMSU channels 5, 17 and 20. There are still unresolved issues in biases and data selection which need further attention prior to operational use.