Plans for the assimilation of cloud-affected infrared soundings at the Met Office

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1. Motivation

Infrared sounding data from AIRS are assimilated operationally at the Met Office, and data from IASI are expected to be brought online soon.

The majority of IR soundings are affected by cloud. Currently, cloudy soundings are rejected by the Met Office data assimilation system.

Cloudy regions are generally meteorologically active, so we expect that the assimilation of cloudy IR soundings should lead to a useful improvement in forecast accuracy (McNally, 2002).

This poster describes a two-stage approach using cloud parameters estimated by 1D-Var analysis. The retrieved cloud parameters are first used to generate a reduced channel selection. The same cloud parameters are then fed into the data assimilation system to act as a fixed constraint on the radiative transfer mode.

The potential of the technique is assessed here by means of a 1D-Var simulation study.

2. Description of the technique

a) Estimation of cloud parameters

One-dimensional variational analysis (1D-Var) is used to retrieve estimates of the cloud top pressure and effective cloud fraction from the cloud-affected radiances (see Eyre, 1989).

The 1D-Var analysis uses the RTTOV forward model. The model assumes single-layer grey cloud. The cloud parameters are retrieved simultaneously with temperature and humidity profiles as part of the operational pre-processing of AIRS data.

The cloud parameters are passed to 4D-Var and used to constrain the radiative transfer model.

b) Channel selection

After the cloud parameter retrieval, channels are selected for assimilation with weighting functions that peak above the retrieved cloud top.

Channels with > 10% of their integrated temperature Jacobian below the retrieved cloud top are rejected.

This channel selection is required to reduce errors caused by cases of multi-layer cloud, which are not realistically modelled by RTTOV (see **Figure 1**).

The channel selection is performed automatically for every individual sounding. **Figure 2** shows example Jacobians before and after channel selection for three sample cases.
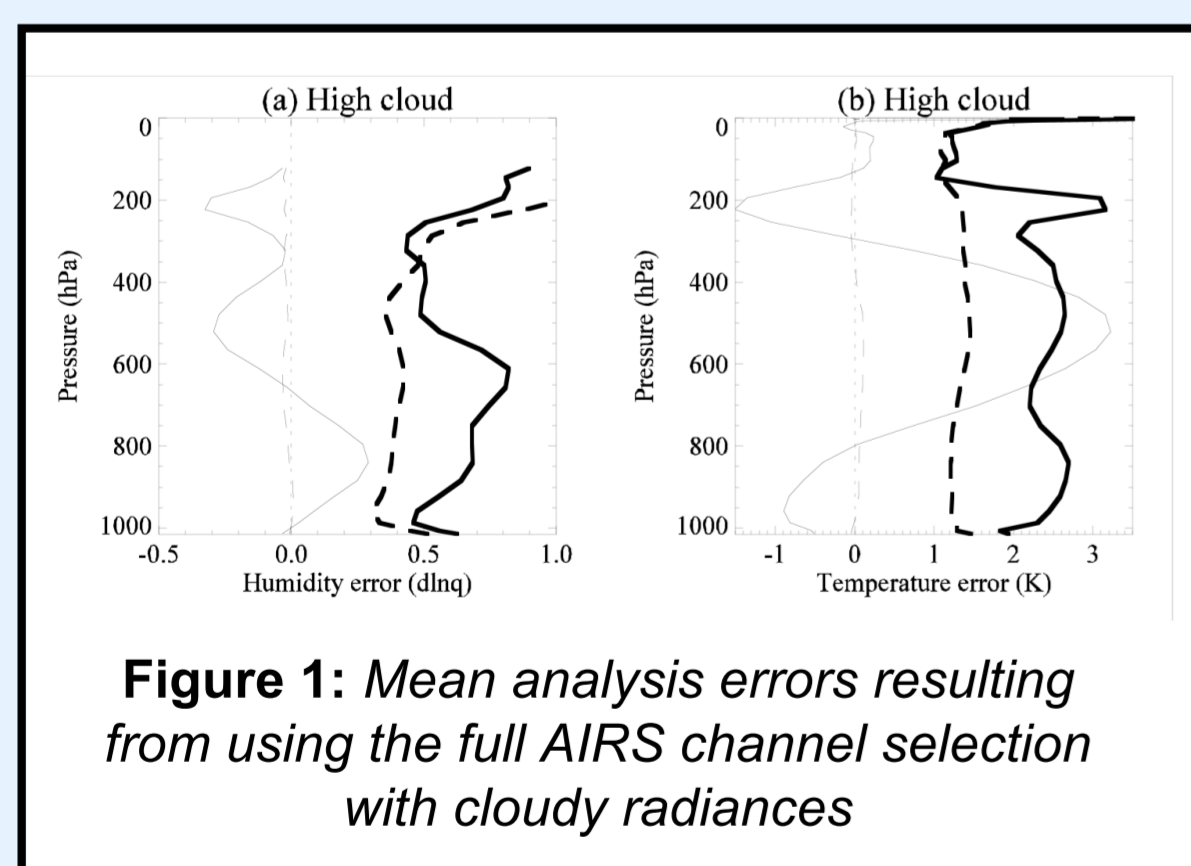

Figure 1: *Mean analysis errors resulting from using the full AIRS channel selection with cloudy radiances*
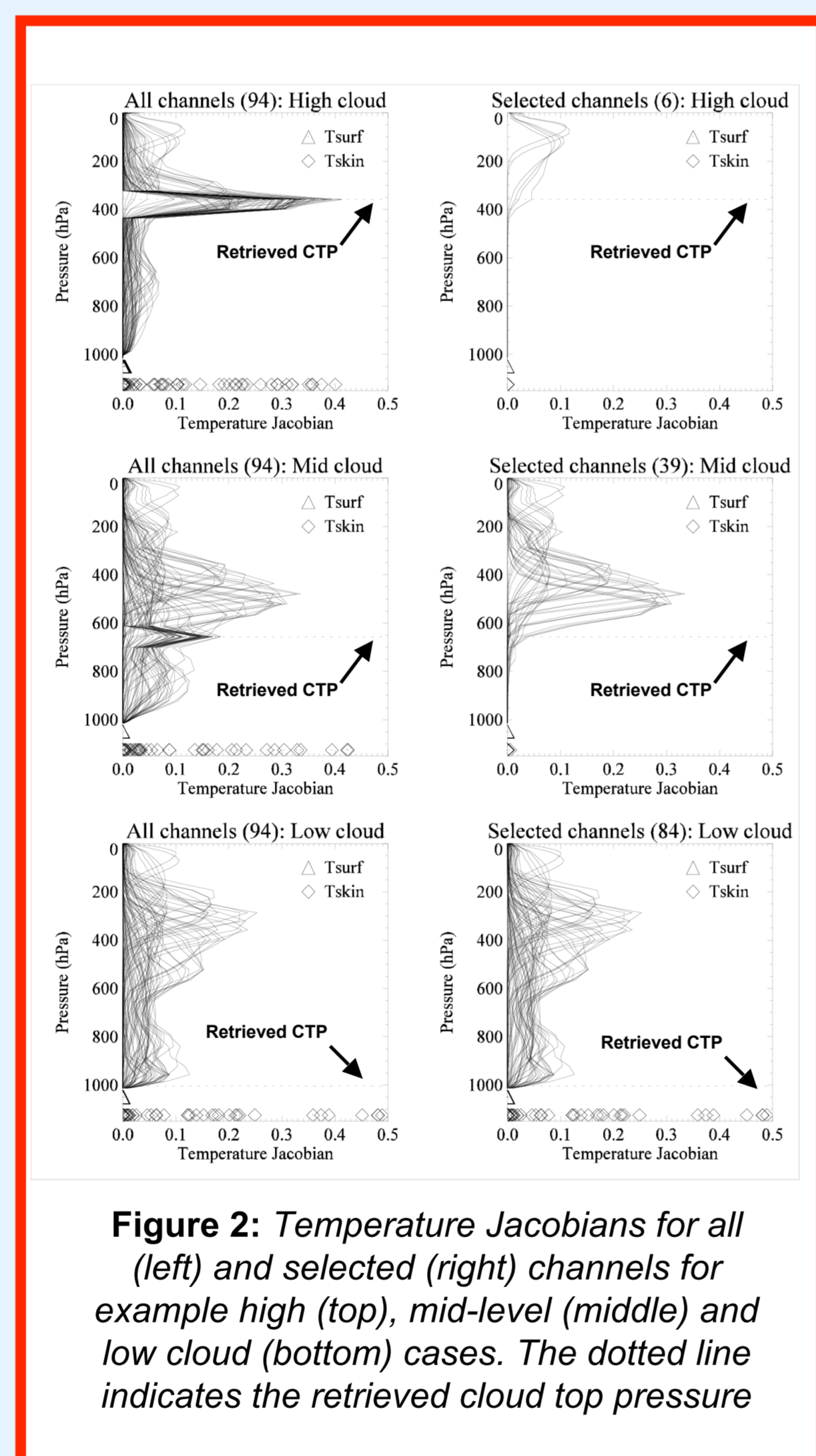

Figure 2: *Temperature Jacobians for all (left) and selected (right) channels for example high (top), mid-level (middle) and low cloud (bottom) cases. The dotted line indicates the retrieved cloud top pressure*

c) Cloudy radiance assimilation

The retrieved cloud parameters are passed to the data assimilation system as a fixed constraint on the radiative transfer. This improves the forward modelling of the channels with weighting function tails below the cloud top.

References

Chevallier, F. (2001): 'Sampled databases of 60-level atmospheric profiles from the ECMWF analyses'. Eumetsat/ECMWF SAF Programme, Research Report No. 4.

Eyre, J. (1989): Inversion of cloudy satellite sounding radiances by nonlinear optimal estimation I: Theory and simulation for TOVS. *Q. J. R. Meteorol. Soc.*, **115**, 1001-1026.

McNally, A. (2002): A note on the occurrence of cloud in meteorologically sensitive areas and the implications for advanced infrared sounders. *Q. J. R. Meteorol. Soc.*, **128**, 2551-2556.

3. A simulation study

a) Study framework

A set of 13495 NWP profiles from the ECMWF ERA-40 reanalysis was used (Chevallier, 2001) as the basis of a simulation study.

The NWP profiles were used to simulate cloudy AIRS brightness temperatures and 6-hour forecast background profiles. The brightness temperatures were simulated using a cloudy RTM, RTTOV_CLD.

Analyses were then carried out using a stand-alone 1D-Var code (the NWP SAF Met Office 1D-Var).
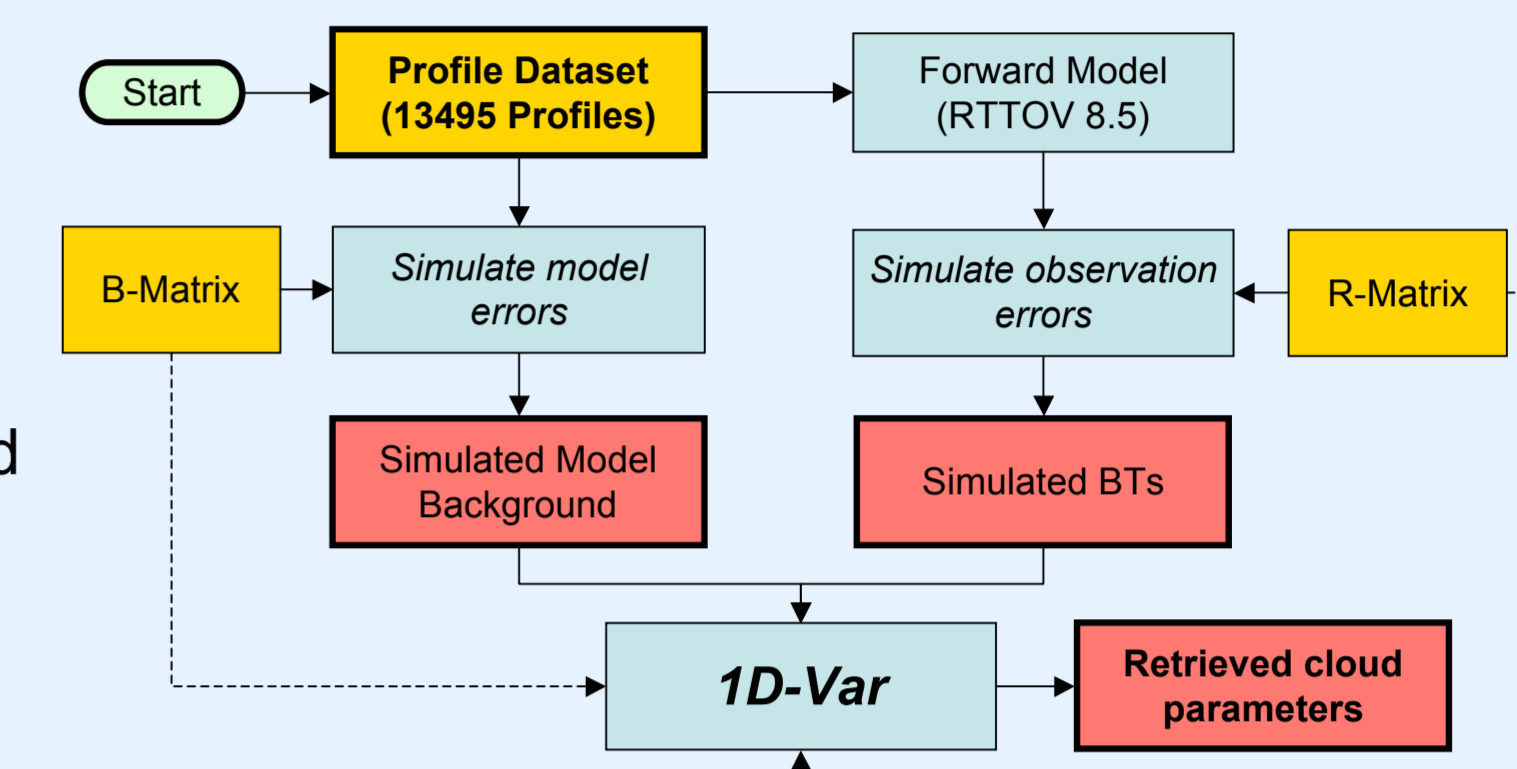
b) 1D-Var assimilation results

Figure 4 shows the results of the 1D-Var assimilation of all cloudy profiles over sea.

Error profiles are shown for high cloud, mid-level cloud and low cloud.

RMS errors for low cloud cases are comparable to the cloud-free case (see **Figure 3**).

Mid-level cloud cases show a useful improvement over the background.

High cloud cases are well-behaved, but contribute little information to the analysis.

This result is very encouraging, and we hope that we will see similar benefits when extended to the 4D-Var case.
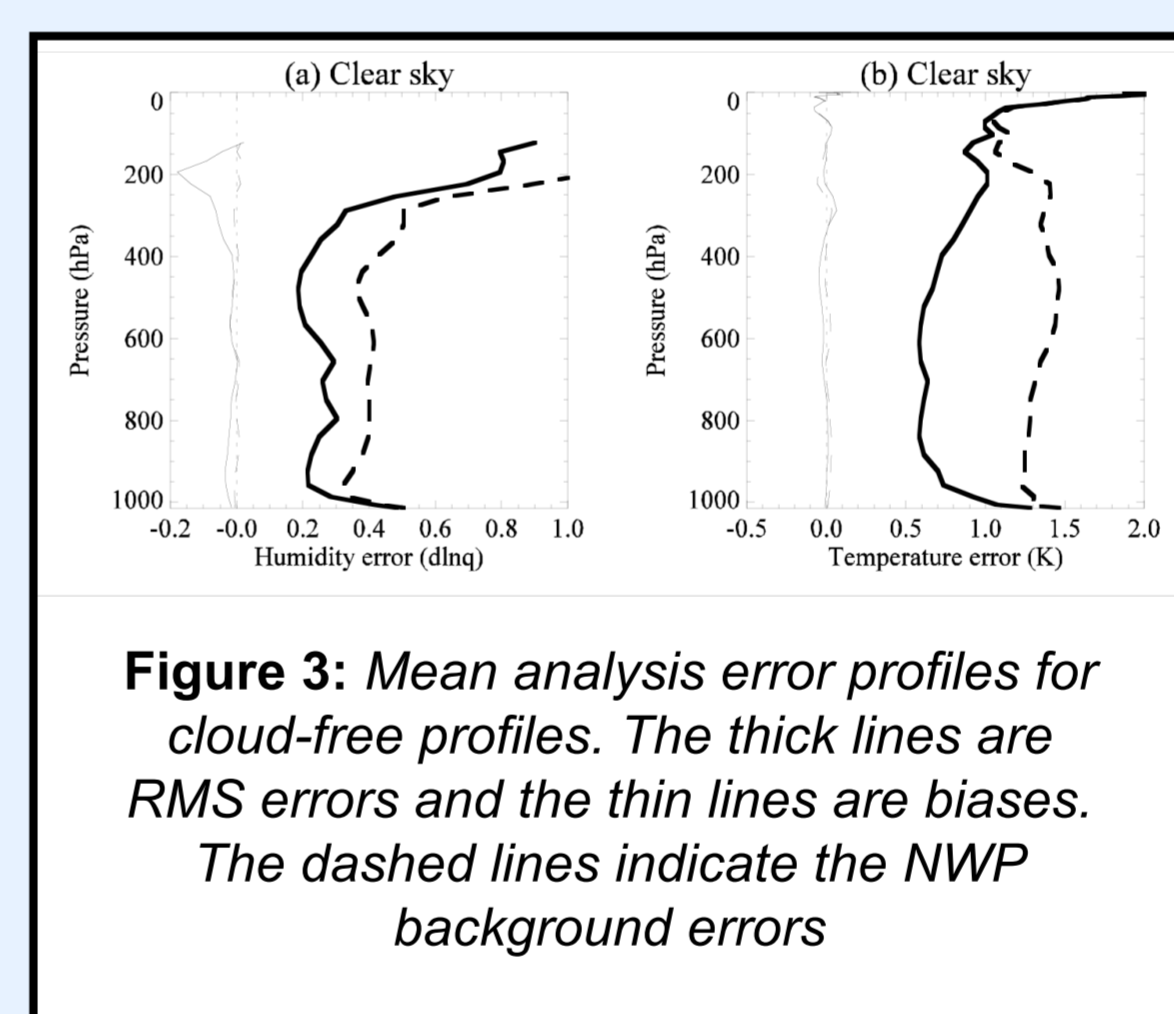

Figure 3: *Mean analysis error profiles for cloud-free profiles. The thick lines are RMS errors and the thin lines are biases. The dashed lines indicate the NWP background errors*
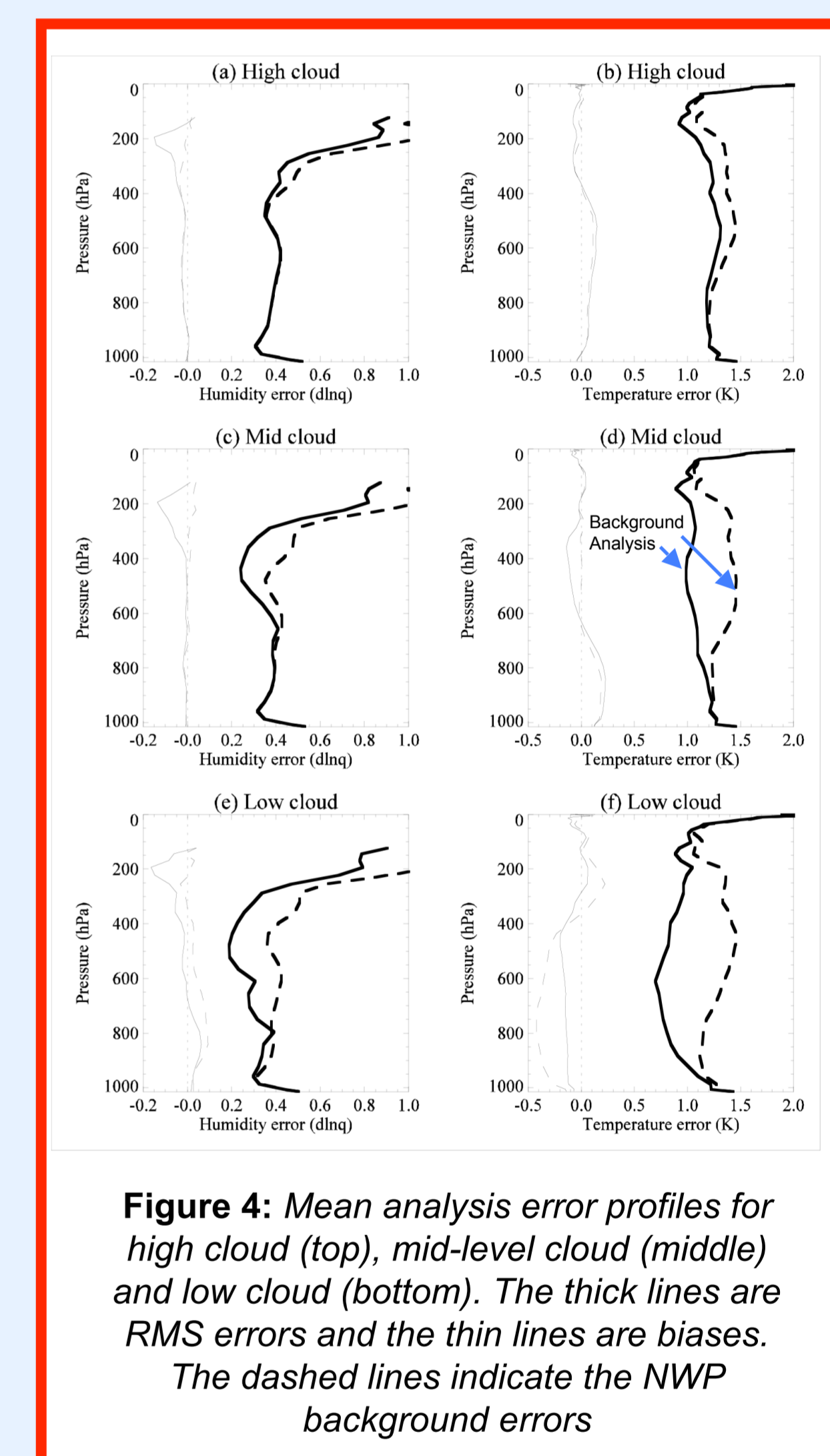

Figure 4: *Mean analysis error profiles for high cloud (top), mid-level cloud (middle) and low cloud (bottom). The thick lines are RMS errors and the thin lines are biases. The dashed lines indicate the NWP background errors*

4. Next steps

The implementation of cloud processing for AIRS in the Met Office 4D-Var assimilation system is underway in preparation for forecast impact trials.

Depending on the outcome of AIRS trials, implementation for IASI will follow.

The use of cloudy radiances will also lead us to revisit the issue of infrared cloud detection. Is a simple binary cloud mask still adequate, or can we develop a cloud test to identify cloud types best suited to the 1D-Var analysis?

5. Summary

- Cloudy IR soundings are not currently assimilated at the Met Office. The assimilation of cloudy radiances should lead to a large increase in data volume from AIRS and IASI, and useful improvements in NWP skill.
- A new technique for handling cloudy radiances is being tested:
  - cloud top height and cloud fraction are estimated by 1D-Var;
  - assuming grey, single-level cloud;
  - channels selected for assimilation which peak above retrieved cloud top;
  - 1D-Var simulation study shows good performance for low and mid-level cloud compared to cloud-free cases.
- The new technique is currently being tested in the Met Office 4D-Var system for AIRS.