Use of SEVIRI data in Met Office convective-scale models

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Abstract

Under certain synoptic conditions the Met Office *UKV* 1.5km-scale and *UK4* 4km-scale NWP systems[1] can reach unrealistically low humidities in the upper troposphere. The causes of these low humidites are related to the observations and data assimilation, and are well understood. A number of different approaches are being taking to address these problems. One approach, described here, is to better-constrain the humidity in the upper troposphere using observed radiances in the water vapour channel of the METEOSAT Second Generation SEVIRI instrument.

Description of the problem

Regular monitoring of observed METEOSAT SEVIRI radiances against simulated radiances from Met Office NWP models revealed occasional dramatic departures of the simulated water-vapour channel radiances from the observations (Figure 2 “control”). These were found to occur during stable atmospheric conditions in cloudy areas (Figure 1 shows the same example case as Figure 2).

The cause of these model departures was traced to the assimilation of cloud information from a Met Office cloud analysis[2] (the UKPP 3D cloud analysis, distinct from the Met Office NWP systems) combined with the assimilation of GPS (GNSS) Integrated Water Vapour (IWV) observations, within the 3D-Var data assimilation system.

Pseudo-observations of cloud were generated from the UKPP 3D cloud analysis, and when assimilated using 3D-Var they helped to improve the horizontal spatial distribution of cloud in the NWP model, but in some instances they had a detrimental effect on the vertical representation or water content of the cloud in the NWP model.

GPS IWV observations also assimilated in the 3D-Var scheme constrain the total integrated water vapour in the NWP model atmospheric column to be close to the truth. As they have no vertical resolution, these observations tend to have most impact on the water content at heights which are least constrained by other observations. After humidity-sensitive radiances from polar satellites were removed from the data assimilation for operational reasons, the upper tropospheric humidity was weakly constrained in cloudy regions and became a “dumping ground” for humidity errors in the model. In clear-sky regions SEVIRI radiances continue to constrain the upper-tropospheric humidity.

Synoptic conditions 2011/10/14

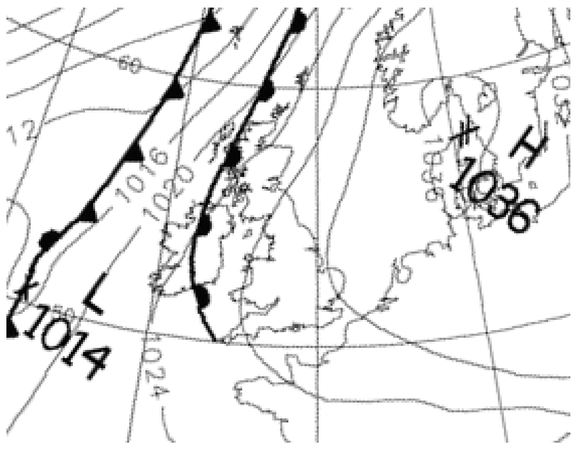


Figure 1: Synoptic conditions at 06Z on 2011/10/14. A stable airmass was situated over Northern Europe and the warm front over Ireland was weakening.

Conclusions and future work

A short trial of the assimilation of SEVIRI channel 5 over low cloud in the UK 4km model shows that it can help constrain the upper-tropospheric humidity and prevent errors in the model humidity fields when cloud prevents assimilation of other satellite radiances. This is now being followed by a longer UK4 trial in 2012 to obtain verification statistics, with the intention of including these observations in the operational UK4 and UKV in future. A second trial is investigating the impact of high spatial resolution AMSU-B and MHS observations (not shown here).

References

1. Experiences with a 1.5km version of the Met Office Unified Model for short range forecasting, H. Lean et al, 91st AMS Annual Meeting, 2011

2. Variational assimilation of cloud fraction in the operational Met Office Unified Model, R. Renshaw, P. Francis, QJRMetS V. 137, PP 1963–1974, 2011

Solutions to the problem

The long-term approach to the problem will be to replace the assimilation of cloud pseudo-observations generated from the UKPP analysis system with direct assimilation of cloud observations into 3D-Var (observations from surface and satellite).

One short-term improvement being tested is the introduction of SEVIRI channel 5 radiances over low cloud (currently SEVIRI radiances are only assimilated in clear-sky regions). Trials of this are discussed here.

Short trials of SEVIRI channel 5 over low cloud

Clouds were characterised in the observations as high (likely to affect SEVIRI ch 5) or low based initially on: a gross O-B check on SEVIRI window ch 9; and a ch 10 O-B vs ch 9 O-B ice-cloud detection test – both using cloud-free simulated radiances for the background. Further observations were then removed in regions where a Met Office cloud-top pressure analysis indicated the presence of high cloud. An example of the resulting cloud characterisation is included at the bottom of Figure 2. The UK4 was used as it is cheaper than the UKV.

A UK4 control was run using the standard observation set (including clear-sky SEVIRI observations), along with a trial which, in addition, assimilated SEVIRI ch 5 over the low cloud regions. This short trial showed a significant reduction in the model volume with zero humidity. The O-B values in SEVIRI channels 5 and 6 are significantly better than for the control for all time steps. Figures 2 and 4 show a snapshot of the control and trial at 09Z on 2011/10/14. The simulated radiances in channels 5 and 7 are much closer to observations for the trial (Figure 2). Clear-sky regions in the South and East of England allow SEVIRI observations to improve the humidities in both analyses. Less of the upper troposphere has zero humidity in the trial (Figures 3 and 4).

Comparing observations with simulated imagery at 09Z 2011/10/14

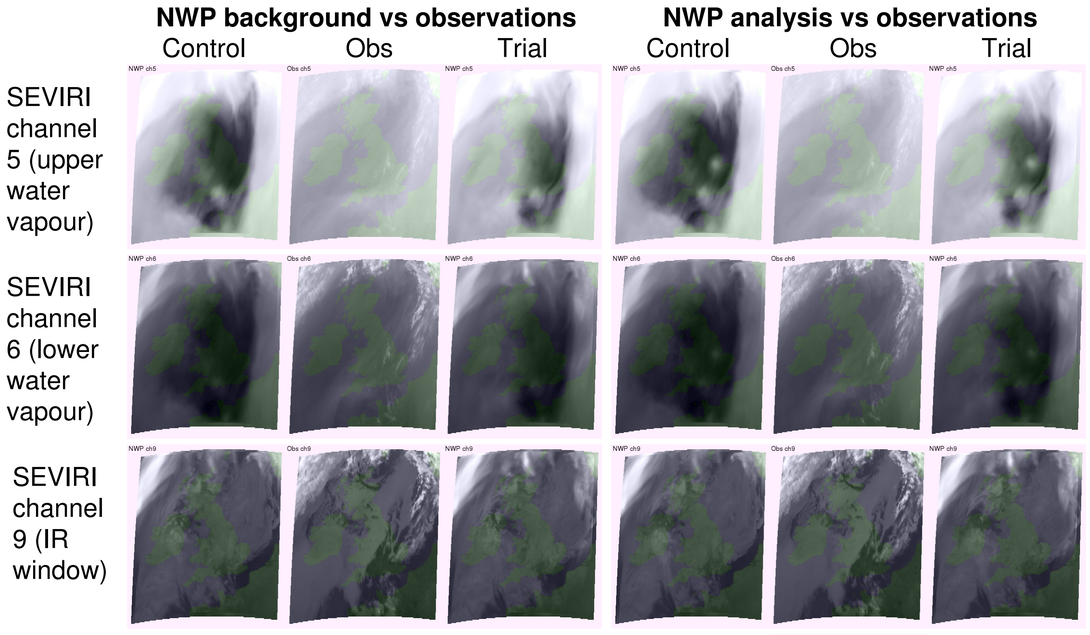
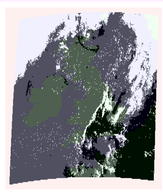


Figure 2: Comparison of SEVIRI observations at 09Z on 2011/10/14 with simulated radiances from RTTOV v9. The overly dry (dark) regions are more extended in the analysis than in the background. The cloud mask at the lower-right, diagnosed from the observations, shows low clouds (below the SEVIRI channel 5 weighting function) and high clouds.



Cloud mask

Dark=no cloud

Mid=low cloud

Light=high cloud

Volume of model with zero specific humidity

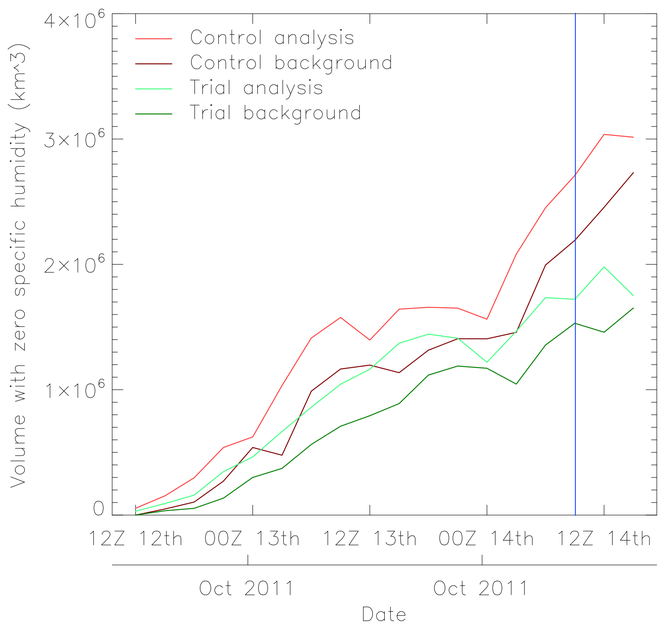


Figure 3: Volume of the NWP model where the humidity has reached the numerical limit of zero specific humidity. Diffusive processes help reduce this volume during the forecast, whilst errors in the cloud pseudo-observations and assimilation process cause an increase in the analysis. The time step used for Figures 2 and 4 is shown with a blue line.

Specific humidity plots for regions of very low humidity in the NWP model at 09Z 2011/10/14

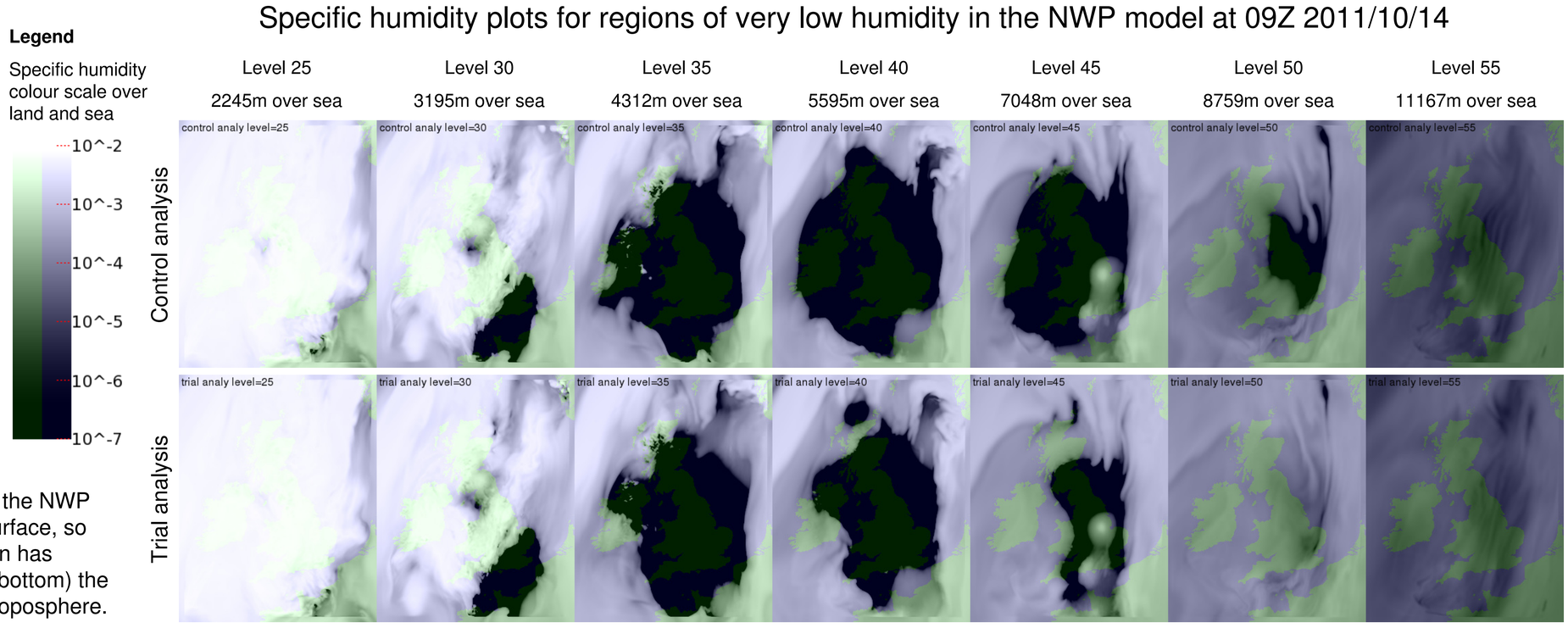


Figure 4: Specific humidity at selected height levels in the NWP model. The hybrid levels are terrain-following at the surface, so height quoted is that above sea points. The dark region has reached the zero-humidity numerical limit. In the trial (bottom) the zero-humidity region has been reduced in the upper troposphere.

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