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Assimilation of radar data for convective scale NWP at the Met Office

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1 Introduction

The Met Office is developing an NWP based nowcasting system using a 1.5km version of the Unified Model (Davies et al 2005).

Data assimilation is a vital component of that system and exploitation of radar data is essential. The ultimate system would be based on 4D-Var however that is likely not to be affordable for the first system in 2009/2010.

We have been carrying our experiments with nudging and 3D-Var techniques at high resolution and are just starting to run 4D-Var experiments for assimilation of precipitation data in our North Atlantic and European Model. We can currently use latent heat nudging of precipitation rates and have started experiments with 3D-Var assimilation of doppler radar radial winds. Work in collaboration with others in the Met office and Reading University is looking at assimilation of reflectivity and refractivity data. This paper describes the work being undertaken and the importance of specification of errors in the analysis system.

2 Operational systems

A 4km resolution model for the UK was introduced operationally in 2005 and the aim is for a 1.5km resolution system once sufficient computer power is available.

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The 4km model is using a data assimilation system based on that used in the previous 12km resolution model with 3 hourly cycles, see figure 1. Currently surface precipitation rate analyses derived from operational radar data are exploited operationally in the 4km and 12km UK and 12km North Atlantic and European forecast systems via latent heat nudging.

Other data is analysed using incremental 3D-Var (Lorenc et al 2000) and then the analysis increments are nudged into the 4 or 12km resolution forecasts along with the MOPS (Moisture observations Processing System) latent heat increments derived from forecast/analysis precipitation rate differences and humidity increments derived from forecast/analysed cloud cover differences (Jones and Macpherson 1997). Doppler radar radial winds are assimilated via VAD profiles in 3D-VAR. Those available from Europe are used along with the first UK VAD profiles from Cobblecombe Cross in Devon.

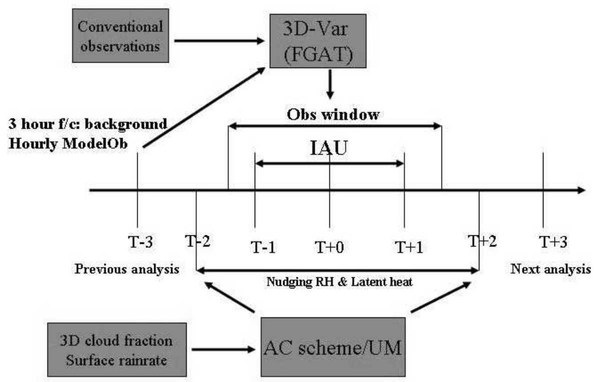

Fig. 1. Schematic diagram of implementation of 3D-Var with initialization via IAU plus MOPS RH and latent heat nudging in the Met Office system at 12 and 4km resolution.

3 Impact of radar rain rates

Experiments and trials have been undertaken to test the impact of the use of the MOPS data on the 4km resolution forecasts and to optimize the system for use at 4km and higher resolution. As forecast resolution increases the assumption in the latent heat nudging scheme that latent heat release occurs in the same column as surface precipitation starts to break down as the structure of convective storms is resolved. However the forecasts show positive benefit in location of precipitation and skill as can be seen in figures 2 and 3. Skill is improved by removing negative latent heat increments due to precipitation evaporation.

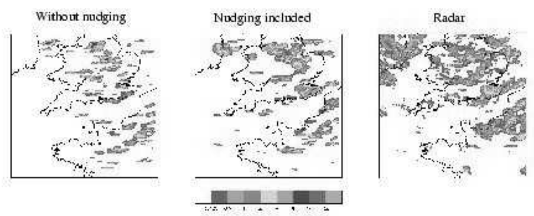

Fig. 2. Comparison of radar derived surface rain accumulation to T+1 to T+2 accumulations from 4km forecasts valid at 13 to 14 UTC 28th August 2005 with and without MOPS nudging

In the basic system hourly radar derived surface rain rates and three hourly cloud analyses are used with data smoothed to 15km resolution and latent heat increments to 20km. There is a slight impact from more frequent observations but more work is needed to check best nudging profiles over time. Significant impact was seen by removing the smoothing of the latent heat increments. Further experiments are required to see the impact of higher spatial resolution cloud and precipitation data. In the Met Office latent nudging schemes the latent heat increments are derived by comparing with the closest model gridpoint with similar precipitation rate rather than idealised profiles. It was important to increase the search radius for suitable profiles at high resolution.

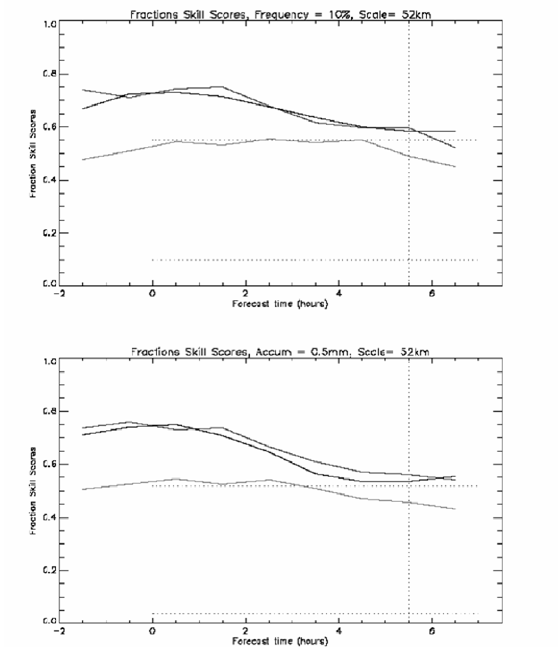

Fig. 3. Comparison of skill score for 5 CSIP cases, 4 forecasts per case. Bottom red line is no MOPS nudging, top blue line is with MOPS nudging and removal of negative, sub cloud latent heating increments and middle black line is standard MOPS. Top figure is top 10% of rain rates and bottom is greater than 0.5mm/hr.

4 Assimilation of radial Doppler winds

Code to assimilate Doppler Radar radial winds directly has been incorporated into the Met Office Variational Data Assimilation system. The code has been tested using data derived from a PPI scan by the Chilbolton Advanced Meteorological Radar. The very high resolution raw data from Chilbolton is averaged (or "superobbed") to model resolution before assimilation. The project with the Chilbolton data was carried out as a collaboration between the Met Office and a team at the Telford Institue of Environmental Science, Salford University (Dr. F. Rihan and Prof. C. Collier). Work is underway to ingest the operational radar data when it is available and to develop quality control and monitoring systems as well as operational systems to specify observation error and perform superobbing.

In order to run the 4km model with assimilation the background errors are the same as those for the 12km model. Potentially improvements can be made by altering the correlation lengths and variances of the background errors. This is particularly important when exploiting high resolution data such as the radial Doppler winds.

Figure 4 shows that there is more impact from observed radial winds on the analysis if the lengthscale is halved and the background weights reduced. The important impact on resulting forecast has yet to be studied. This would show the importance of the specification of observation and background errors on forecasts of wind and subsequently surface precipitation.

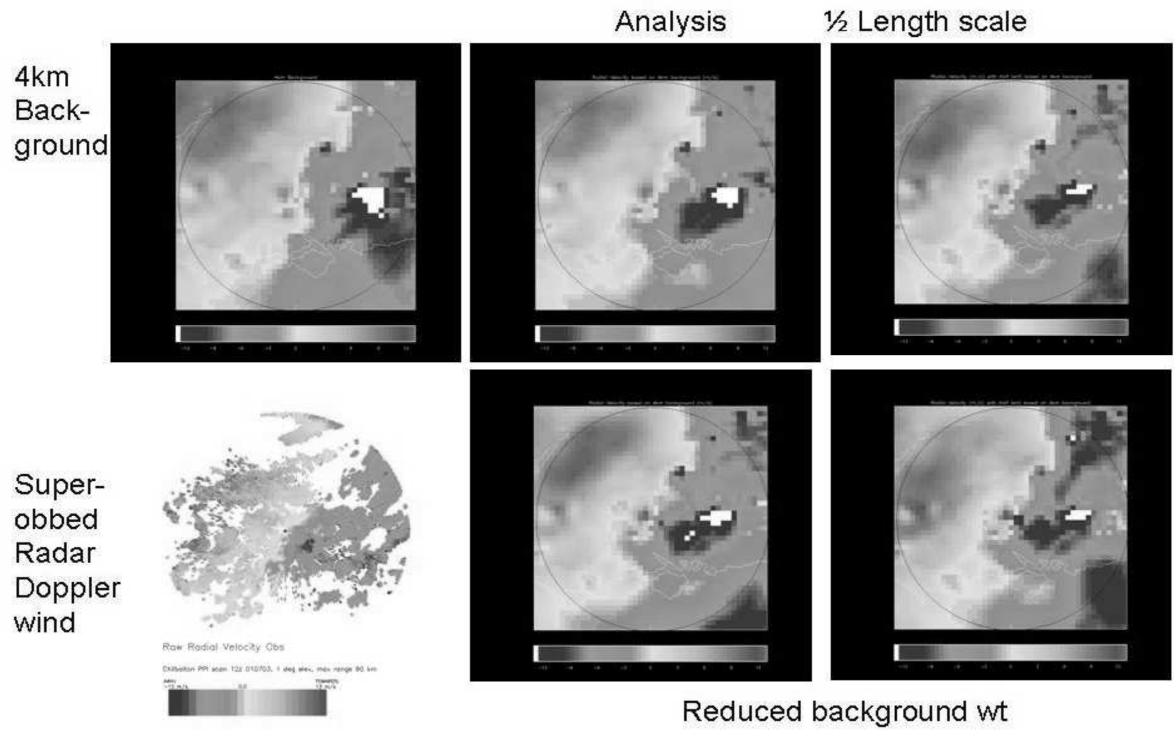

Fig. 4. Impact of radial Doppler winds on analysis of radial wind on 1deg scan elevation

5 Assimilation at 1.5km resolution

Preliminary experiments have started with 3D-Var and MOPS nudging at 1.5km resolution. The aim is to have hourly assimilation cycles but initial experiments have used 3 hourly cycles and performed the analysis on 38 rather than the full 76 model levels. There is amazing detail in these forecasts as can be seen from figure 5 which challenges the resolution of the satellite imagery.

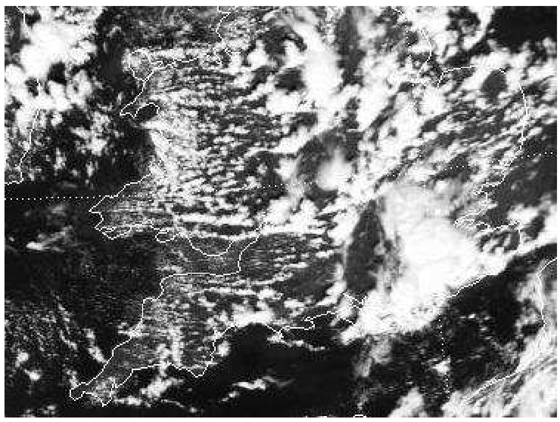

Fig. 5. MODIS AQUA at 1310 28th August 2005

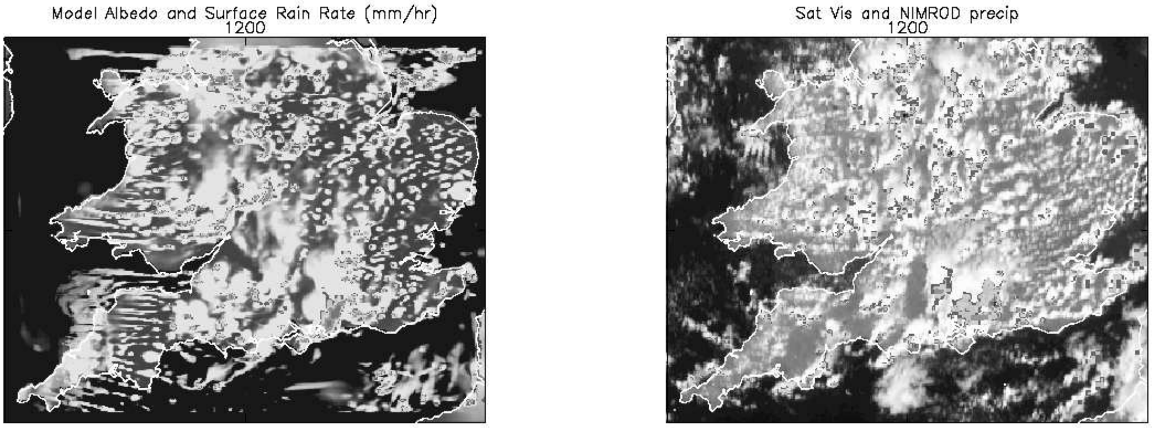

Fig. 6. left 1.5km forecast model albedo and rain rate and right MSG visible and radar rain rate at 1200 28th August 2005.

6 Conclusions and future work

Initial trials of data assimilation for 4 and 1.5km versions of the unified model show the benefit of continuous assimilation over spinning up from coarser resolution forecasts for prediction of the location of precipitation in the early hours of the forecast. They also show some benefit from latent heat and moisture nudging in correcting the location of precipitation.

Ideally we would like to move away from 3D-Var and nudging for cloud and preciptation data and use 4D-VAR to exploit the information in the time history of the observations and to provide a link to the full dynamics of the generation of the precipitating systems. This is unlikely to be affordable for a first operational system but work is underway to implement the physics required to enable assimilation of cloud and precipitation data within the Met Office 4D-Var system. A limited area 4D-Var capability is now available and we are just starting experiments with assimilation of surface rain rates. We hope to test it at high resolution in the future.

Radar data provide a good source of high resolution information for use in convective scale numerical weather prediction. We have started work to exploit higher resolution observations starting with radar radial doppler winds. It is clear that work may be required related to interaction with other high resolution sources of data such as AMDAR aircraft take off and landing data and the need to allow finer scale structure to be analysed by use of reduced lengthscales in the background error covariances. Work is also starting in the Met Office unit at Reading to enable use of high resolution geostationary imagery data and radar reflectivity data. Reading University are looking at the feasibility of extracting refractivity information as a source of low level humidity information from the UK operational radar network. Additional sources of data are higher time resolution surface observations and GPS data.

References

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