

The Met Office UKV hourly 4D-Var DA system

Robert Tubbs, Dingmin Li, Gareth Dow, Graeme Kelly, Marco Milan,
Bruce Macpherson (all at Met Office)

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1 Abstract

This document gives a brief overview of recent changes to the Met Office UKV NWP system, with particular emphasis given to satellite data assimilation.

2 Introduction – The Met Office UKV 1.5 km NWP system

The UKV uses the Unified Model (ENDGAME) NWP model with a 1.5 km grid resolution over the UK mainland, dropping to 1.5×4 km resolution along the edges and 4×4 km resolution at the corners (see Figure 1). The UKV has 70 vertical levels extending to a height of 40 km. The lateral boundaries are constrained to match forecasts from the 10 km resolution Met Office Global Model. Along the lateral boundaries, the orography in the model is smoothed to match the orography in the Global Model. The UKV model relies on explicit (i.e. not parameterised) convection, and the lower-resolution regions allow explicit convection to spin up before air is advected into the inner full-resolution region (region with lightest sea colour in Figure 1).

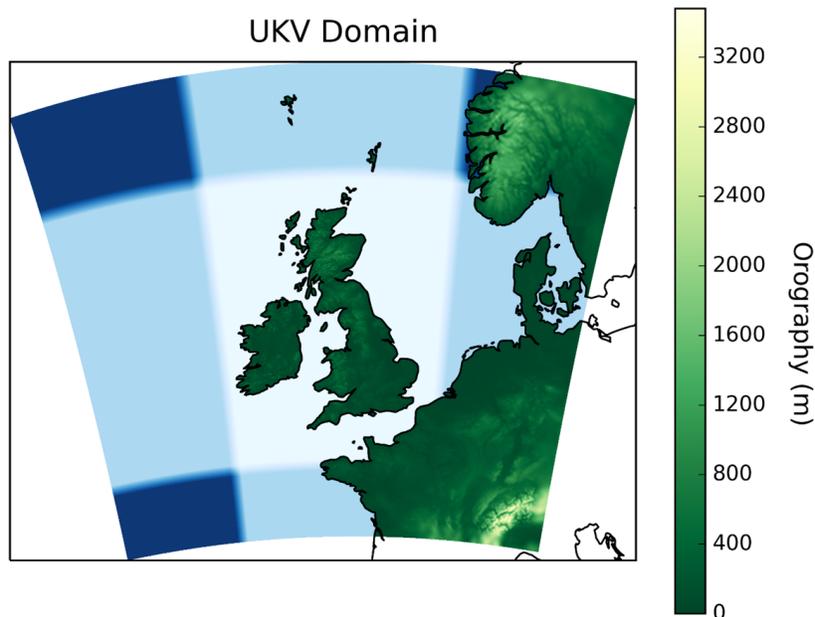


Figure 1: UKV domain. Orography is shown over land (scale at right). The sea is coloured according to grid box area to highlight the 1.5 km resolution region of the model (lightest blue) and lower grid resolutions (darker blues).

The UKV uses hourly 4D-Variational Data Assimilation (4D-Var DA) with a wide range of satellite, surface and airborne observations. The 4D-Var DA is performed on a 4.5 km grid which extends to within a few grid points of the lateral boundaries. For the analysis at hour hh:00Z, observations are assimilated if they are taken between (hh-1):30Z and hh:29Z, and arrive at the Met Office before hh:45Z. This allows in most surface observations (including remote-sensing data such as radar Doppler winds), aircraft observations, geostationary satellite observations and polar-orbiter satellite observations locally-received in Exeter. The surface observations used include a dense network of road-side sensors in the UK. Radar-derived rain rates are assimilated into the model separately using the Latent-Heat Nudging scheme.

3 Hourly 4D-Var Obs Usage

At Parallel Suite 39 (PS39) the Met Office replaced 3-hourly 3D-Var in the UKV with hourly-cycling 4D-Var. On average the PS39 analysis is 2 hours newer than for the old OS38 set-up. Figure 2 shows the time since the observations were taken for the latest analyses in the OS38 and PS39 systems.

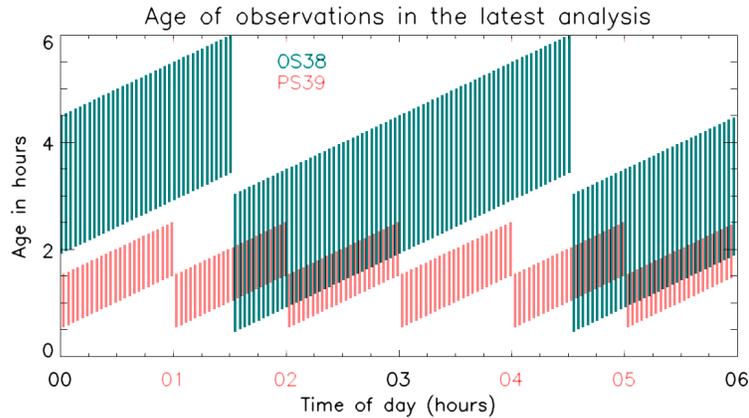


Figure 2: Impact of hourly cycling on observation age. Shown is how old the observations currently are (the observations which were used for the latest analysis). This is plotted against current time – the step changes occur whenever a new analysis becomes available at the Met Office (using a new set of observations). Key shown in Table 1.

The use of 4D-Var also allows PS39 to find a better analysis fit to the observations and previous model forecast over the whole DA time window (and extract dynamical information from temporal variations in the observations). This allows PS39 to better-exploit observation sources with high temporal resolution, such as radar winds and SEVIRI. In PS39, SEVIRI radiance data was changed from one image every 3 hours to 4 images per hour giving a big increase in the number of assimilated observations (Figure 3). However, the lowest 4 km of UKV radiosonde ascents is usually missed, as the observations take place before 11:30Z (or 23:30Z) but are received at the Met Office after the cut-off time of 11:45Z (or 23:45Z). Small changes were seen in the usage of polar orbiter data (Figure 4), with reductions in the usage of MetOp-A data (data arrive late due to the limitations on local reception of MetOp-A). Timeliness of MetOp-A ascending overpasses was improved in November 2017 through the usage of the Svalbard EARS fast dump (not shown). Most observations taken in the last 30 minutes of the DA time window were missed at OS38. Many of these observations are assimilated in PS39, leading to a small net increase in observation usage for satellite instruments such as MHS and ATMS. In both OS38 and PS39, SEVIRI observations were combined with the latest UKV model backgrounds to provide estimates of cloud-top pressure. These are then converted into pseudo-observations of cloud (or of cloud-free volume) and assimilated into the UKV. With the increased cycling frequency at PS39 these observations had to be thinned in order to prevent columns of cloud-free pseudo-observations

from suppressing convective towers in the model.

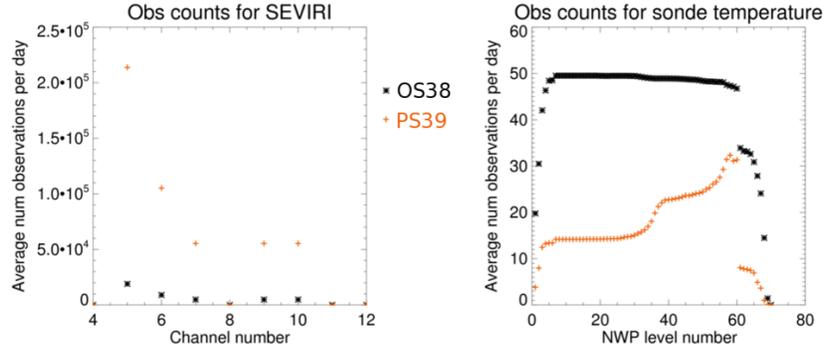


Figure 3: Average number of observations assimilated into the UKV per day for SEVIRI and for radiosondes. Key shown in Table 1.

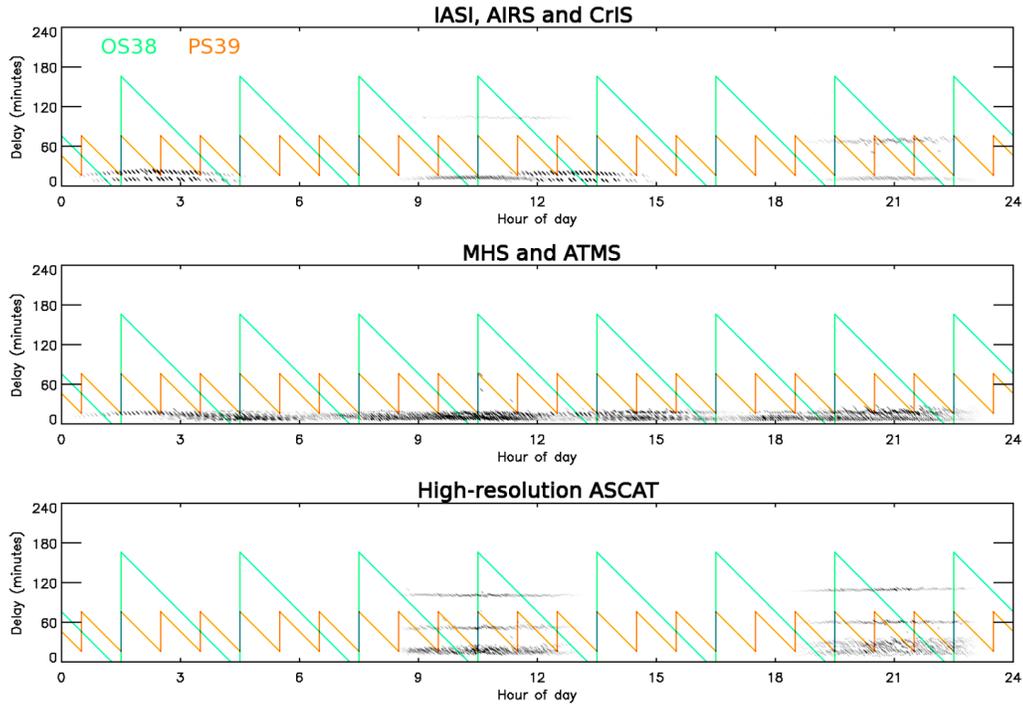


Figure 4: Impact of PS39 changes on the fraction of observations which arrive before the DA cut-off. The horizontal axis is time of day that the observations were taken, and the vertical axis is delay before the observations reach the Met Office. Greyscale shows observation density, with any points below the coloured lines meeting the relevant DA cut-off. Key shown in Table 1.

OS38 (green/black) Older 3-hourly cycling 3D-Var system
 PS39 (red) Newer 1-hourly cycling 4D-Var system

Table 1: Key to labels in Figures 2 to 4. The data used came from June 2017.

4 Variational Bias Correction

Variational Bias Correction (VarBC) was also introduced into the UKV at PS39. This gave a small improvement to forecast performance (+0.8% index change over one month) in the UKV, but also greatly reduces the technical maintenance costs of the NWP system. Further details are in Graeme Kelly's talk from the 2017 EUMETSAT Conference.

5 Verification

As well as providing earlier and more frequent analyses and forecasts, the changes in PS39 also gave a small but significant improvement (+1.0% index change over 3 months) to the UK Index verification score (compared with the previous OS38 system), as shown in Table 2.

Verification parameter	OS38 Data Mean ETS	PS39 Data Mean ETS	PS39 - OS38 ETS Dif- ference
Surface Visibility	0.076	0.084	0.158
6 hr Precip Accum	0.328	0.332	0.075
Total Cloud Amount	0.266	0.270	0.040
Cloud Base Height (3/8)	0.291	0.290	-0.009

	OS38 Data Mean Skill	PS39 Data Mean Skill	PS39 - OS38 Weighted Difference
Surface Temp	0.751	0.762	0.216
Surface Wind	0.792	0.790	-0.051

Total Weighted Score % change (Test - Control) = 1.0 % change

Table 2: UK Index verification for the period 2017/04/04 - 2017/07/11 using forecast from cycles at 00Z 06Z 12Z and 18Z over verification area code: 2103. Positive values indicate that PS39 is performing better than OS38.

6 Conclusion

The upgrade of the UKV system from OS38 to PS39 gave two types of benefits:

- Improved forecast timeliness (forecast data was available sooner)
- Improved forecast accuracy as judged by the UK Index verification

PS39 went operational at the Met Office as OS39 on 11th July 2017.