Real-time flood forecasting with high-resolution NWP rainfall and dual data assimilation (EGU-2014-7)

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1. Introduction

Numerical Weather Prediction (NWP) models are gaining more and more attention in providing high-resolution rainfall forecasts for real-time flood forecasting. In this study, the Weather Research & Forecasting (WRF) model is integrated with the Probability Distribution Model (PDM) to make real-time flow forecasts in a small catchment. Dual data assimilation is carried out for real-time updating of the forecasting system. The 3-Dimensional Variational (3DVar) system is coupled with the WRF model to assimilate radar reflectivity and meteorological data; meanwhile the Auto-Regressive Moving Average (ARMA) model works with PDM to assimilated real-time flow observations. Four 24h storm events are selected to test the forecasting system with different characteristics of rainfall-runoff responses.

2. The forecasting system: model components and system setup

By coupling WRF and PDM, together with 3DVar and ARMA, a real-time forecasting system is constructed. Data assimilation happens in two places. The first is 3DVar, which helps WRF improve its rainfall forecasts; the second is ARMA, with which the observed flow data are assimilated to obtain more accurate flow forecasts out of PDM.

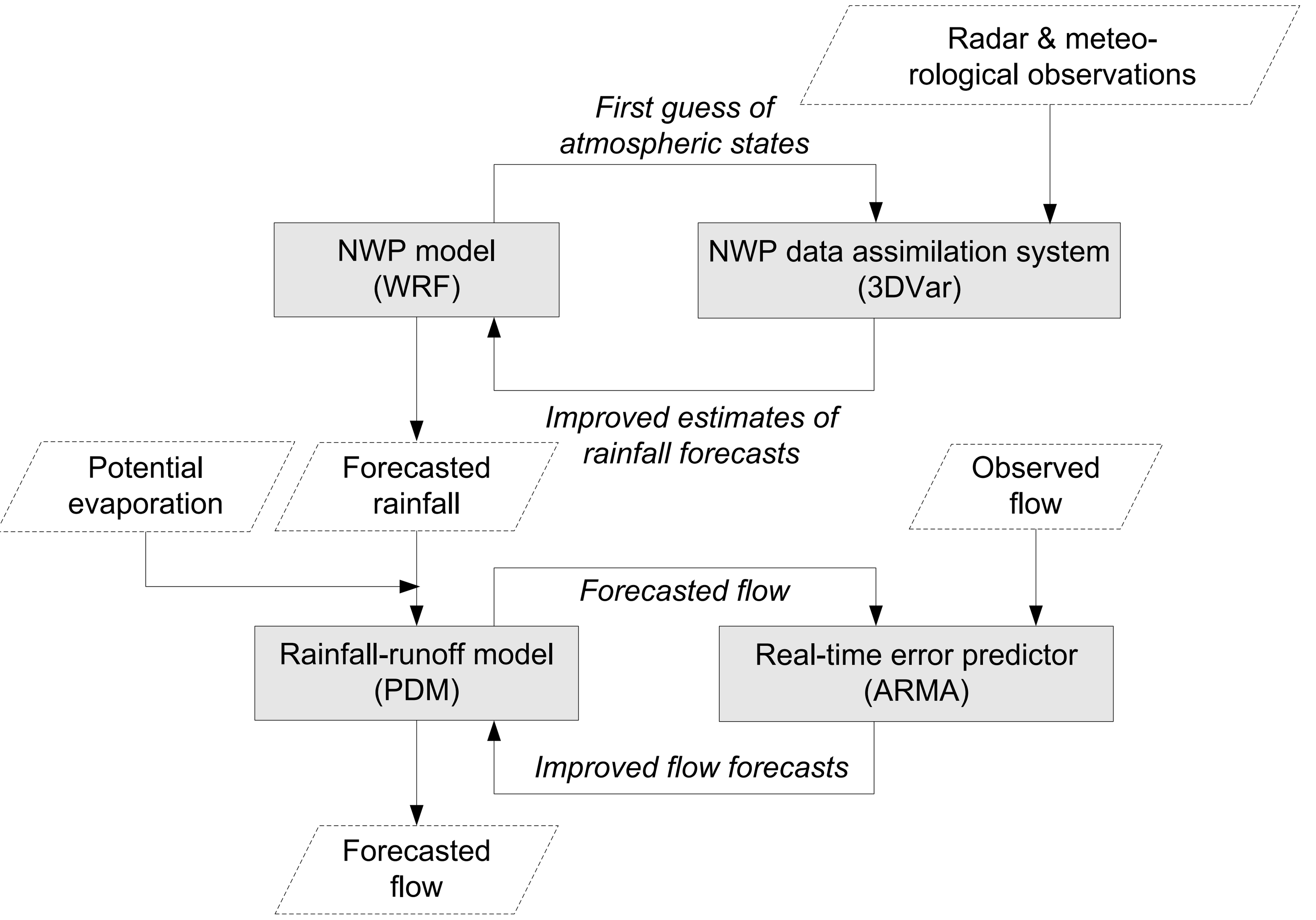
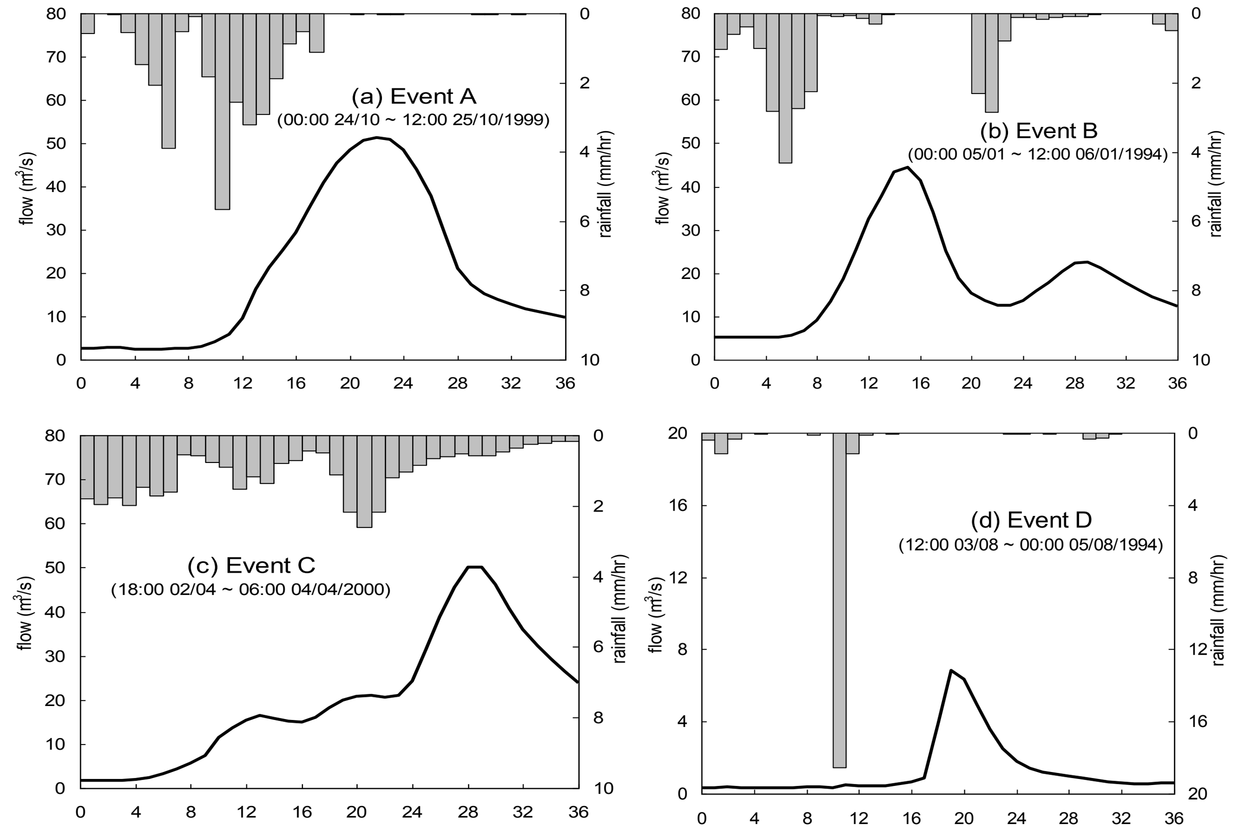


Fig. 1 Components of the real-time flood forecasting system with inputs and outputs framed by dashed lines

3. Study catchment and data sources

3.1 Catchment and storm events



The Brue catchment located in Southwest England with a drainage area of 135.2 km^2 is chosen as the study area. Four 24h storm events are selected from the Brue catchment to test the performance of the constructed forecasting system (see Fig. 2 and Table 1).

Fig. 2 Observed rainfall-runoff responses of the four storm events.

Table 1 Observed and WRF forecasted rainfall accumulations for the 24h durations of the storm events.

	Event A	Event B	Event C	Event D
Start time	24/10/1999 00:00	05/01/1994 00:00	02/04/2000 18:00	03/08/1994 12:00
End time	25/10/1999 12:00	06/01/1994 12:00	04/04/2000 06:00	05/08/1994 00:00
Rain gauge	29.38 mm	21.65 mm	31.12 mm	22.30 mm
Radar	10.36 mm	19.88 mm	12.22* mm	10.30 mm
WRF original	0.15 mm (-99%)	1.28 mm (-94%)	18.68 mm (-40%)	0.06 mm (-100%)
WRF with 3DVar	25.95 mm (-12%)	13.61 mm (-37%)	26.13 mm (-16%)	0.12 mm (-99%)

*Radar accumulation for Event C is only accounted for 10 hours due to the lack of the radar data.

3.2 Data sources for dual data assimilation

A C-band weather radar was located 30 km to the south (at Wardon Hill in Fig. 3), which gave a complete coverage of the catchment. Radar reflectivity taken from the lowest scan on the 2 km Cartesian grid (a 76 × 76 grid of 2 km square pixels covering a radius of 76 km) is assimilated by 3DVar in the system. Besides, two types of NCAR archived data (SYNOP and SOUND, see http://dss.ucar.edu) are also assimilated, which provide real-time surface and upper-level observations of pressure, temperature, humidity and wind from fixed and mobile stations. Both radar reflectivity and NCAR data are assimilated by 3DVar at a time interval of 6 hours.

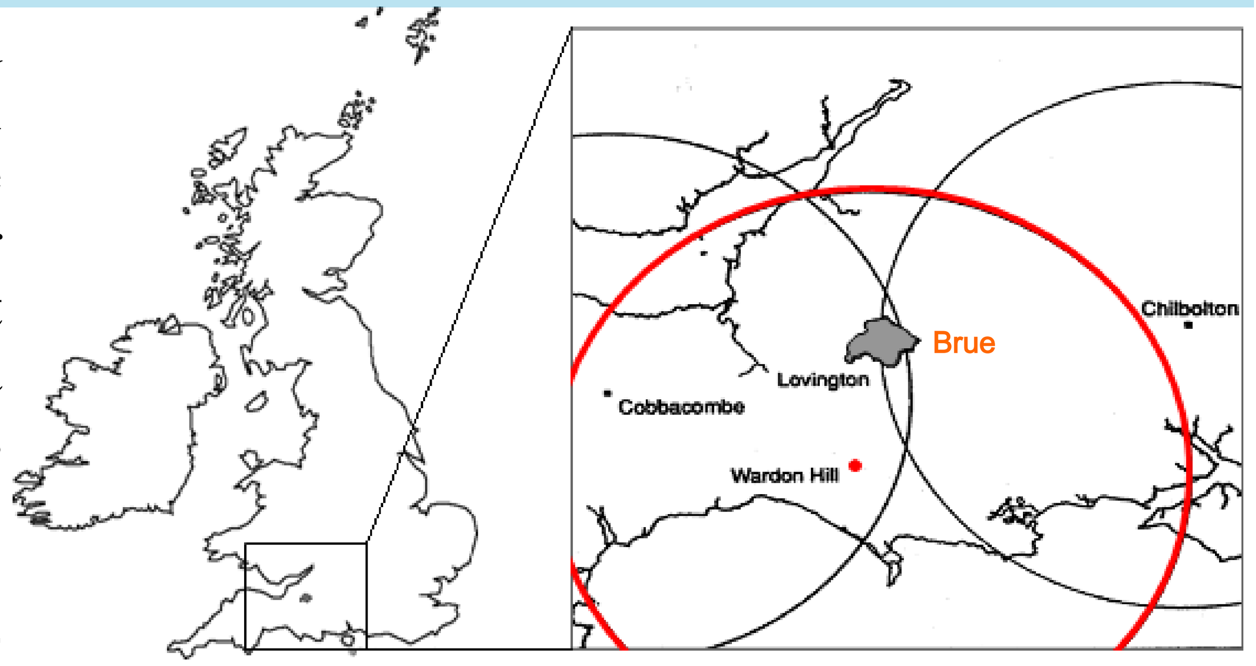


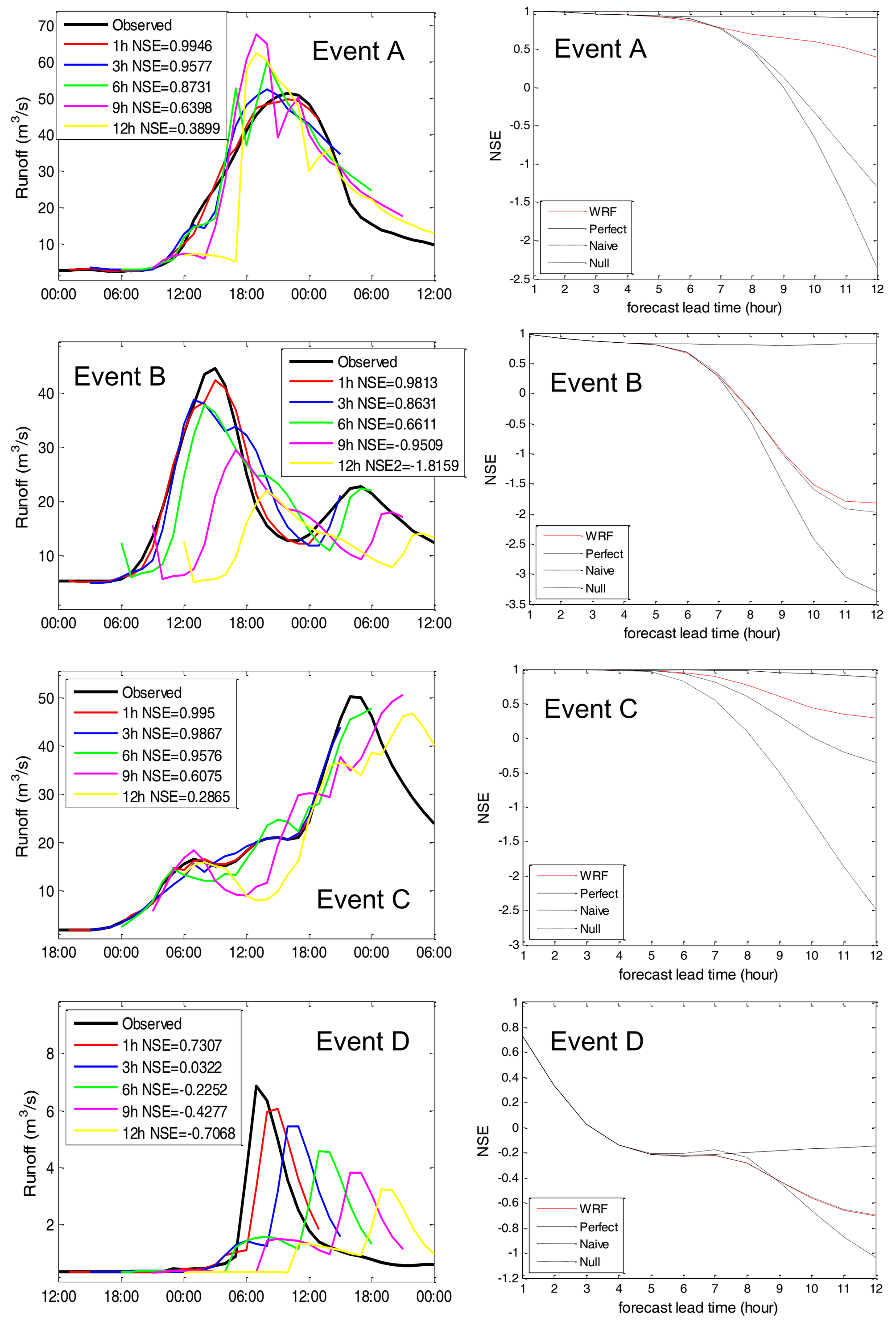
Fig. 3 Location of the Brue catchment and the Wardon Hill radar

4. Results and discussion

1) Rainfall forecasts from the NWP model

The accumulative amounts of the observed and WRF forecasted rainfall for the four storm events are also shown in Table 1. After data assimilation, errors of the first three events are decreased to -12%, -37%, -16%. However, the improvement for Event D is negligible. It can be found in Fig. 2d that nearly 83% of rain fell in one hour during Event D with very large intensity. Such heavy convective storms develop very quickly without preceding rainfall being previously detected in the surrounding regions. To improve this in the future, a shortened assimilation time interval together with satellite data which contain cloud development information may help precede the storm formation.

2) Performance of the real-time flood forecasting system



The flow forecasting results for the four storm events are shown in the left figures.

In the left column, hydrographs in different colours are made by connecting together *x*-h-ahead forecasts from all different forecast origins, for *x* equalling to 1, 3, 6, 9 and 12 hours.

In the right column, 3 modes of synthetic rainfall are adopted to enable comparative analyses: (i) **Perfect Mode**: using gauge observed rainfall after the forecast origin; (ii) **Naïve Mode**: using a constant rate to describe the future rainfall, which is defined as the average observations of the previous 12 hours before the forecast origin; and (iii) **Null Mode**: no input of rainfall after the forecast origin.

Although using the WRF forecasted rainfall is not as good as the Perfect Mode, but much better than the Naïve Mode and the Null Mode. Beyond the catchment concentration time, as the increase of the forecast lead time, the differences caused by the four modes of rainfall inputs become more and more obvious.

5. Conclusions

The forecasting accuracy is found to be largely improved by incorporating WRF forecasted rainfall when the lead time is beyond the catchment concentration time. The assimilation of real-time radar and meteorological data also show great advantage in improving the NWP rainfall forecasts. More significant advantage is expected to be found with shorter assimilation time intervals and more efficient data assimilation techniques.