J1.7 APPLYING COTREC-DERIVED RAINFALL FORECASTS TO THE RAINFALL-RUNOFF MODEL PDM - ESTIMATING ERROR SOURCES

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1. INTRODUCTION

This contribution focuses on estimating the sensitivity of flood forecasts on the quality of the position and intensity rainfall forecasts. To investigate the importance of refined intensity forecasts a comparison between rainfall forecasts derived from the tracking algorithm COTREC and the Met Office GANDOLF system will be carried out for selected convective storms.

2. RAINFALL FORECAST: COTREC

Method: The tracking algorithm COTREC (COntinuity of TREC vectors) originates from the pattern recognition technique TREC (Tracking Radar Echoes by Correlation; Rinehart and Garvey, 1978, Fig. 1) and extrapolates radar images in space and time. To overcome inconsistencies of the displacement vectors caused by clutter, shielding, rapid changes in the radar pattern or divergent components of the motion field, a variational technique is applied (Li et al., 1995).

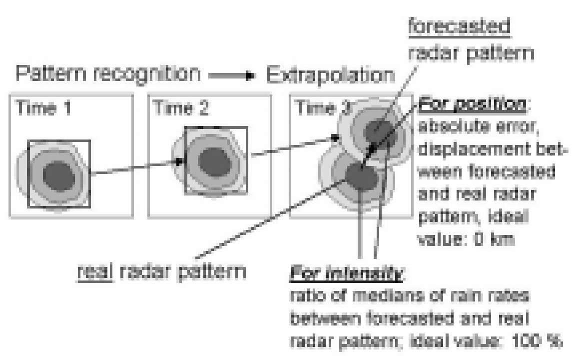

Fig.1. *The forecast consists of two steps: 1) the change in position (displacement vectors) and the change in intensity (growth areas) are determined using pattern recognition, and 2) both values are extrapolated linearly starting from time 2.*

Quality assessment: To estimate the forecast quality and potential error sources a parameter scheme able to distinguish between errors in the position and the intensity of the predicted precipitation is applied (Mecklenburg et al., 2000). Two parameters will be used in this contribution (Fig. 1): 1) the absolute error (mean value of the displacement vectors between the real and the forecasted radar image) to estimate the quality of the forecasted position, and 2) the ratio of the medians between the real and the forecasted radar image to evaluate the forecasted intensity.

3. RAINFALL-RUNOFF MODEL: PDM

Method: The conceptual rainfall-runoff model PDM (Probability Distributed Model; Moore, 1999) transforms rainfall and evaporation into flow at the catchment outlet. Catchment rainfall is partitioned into direct runoff (passing through the surface storage before contributing to the basin runoff) and subsurface runoff by using a probability-distributed soil moisture storage. Rainfall entering the soil storage is depleted by evaporation and recharge to groundwater (contributing to the basin runoff after passing through the groundwater storage).

Quality assessment: To assess the performance of the flood forecast the statistic $R^2 = 1 - \frac{\sum(Q_t - q_t)^2}{\sum(Q_t - \bar{Q})^2}$, has been used, where Q_t is the observed flow, q_t is the forecasted flow and $\bar{Q}$ is the mean of the observed flows over n time steps. The R^2 statistic quantifies the proportion of the variability in the observations accounted for by the model forecasts. The optimum value for R^2 is 1.0, but note that it can take negative values for forecasts worse than the unknown mean flow.

4. ESTIMATING ERROR SOURCES FOR THE FLOOD FORECAST

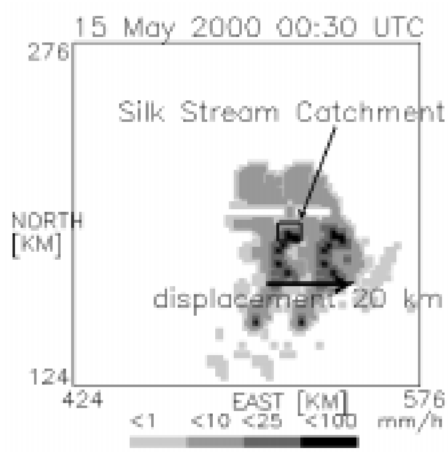

Fig.2.*Real and displaced (20 km to the east) radar pattern for 15 May 2000 00:30 UTC for the Chenies radar.*

To estimate the influence of rainfall forecast errors in the forecasted position and intensity separately, two approaches are investigated as follows.

a) Simulated rainfall forecast errors: In the first approach the absolute error and the ratio of the medians are

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*Corresponding author address: Susanne Mecklenburg, Atmospheric Science, ETH, CH-8093 Zürich, Switzerland, e-mail: susanne@atmos.umnw.ethz.ch. from April 2001: CEH, Wallingford, Oxon, OX10 8BB, U.K., e-mail: smme@ceh.ac.uk varied separately and the effect on the flood forecast is investigated. Figure 3 shows flood forecasts starting from a fixed origin and a one day lead time for the flood forecast for varied error sources. A convective rainfall event passed the Silk stream catchment (29 km^2, urban) on 14-15 May 2000 between 23:45 and 3:15 UTC. The maximum average catchment rainfall (radar over a 15 minute interval) amounted to 17.6 mm h^{-1}, causing river flow to rise from 0.1 to 14 $m^3 s^{-1}$. The input to the PDM is provided by real and displaced radar data used as a 'simulated rainfall forecast' up to one hour ahead with a 15 minute resolution. Real radar images are displaced to the north, east, south and west for 4, 8, 12, 16 and 20 km (Fig. 2), thus assuming constant absolute errors over time. Absolute errors are usually progressively growing over the forecast time (Mecklenburg et al., 2000). Therefore, the impact of simulated rainfall position errors on the flood forecast shown in this contribution might be exceeded by real forecast errors. Furthermore, the displacement implicitly causes errors in the predicted intensity.

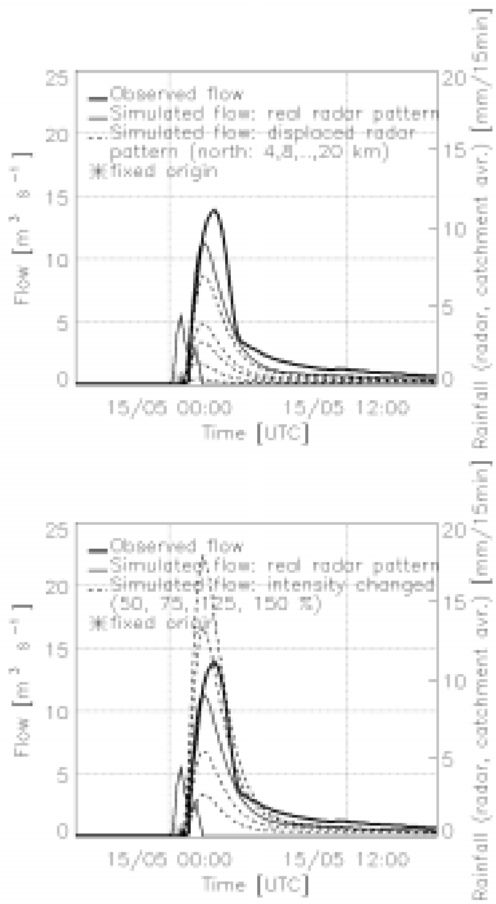


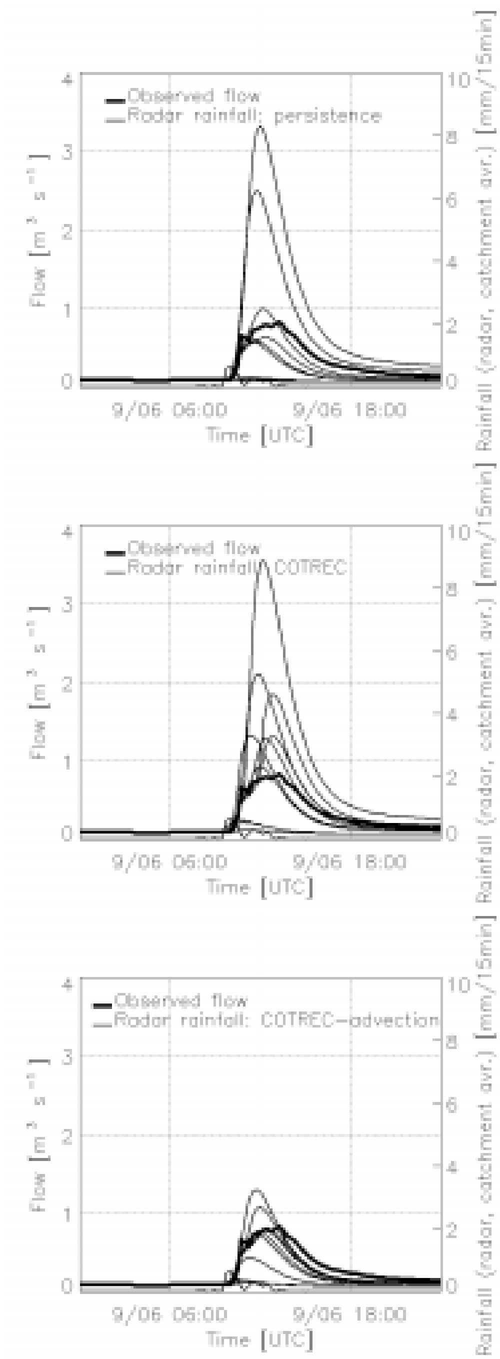
Fig.3.*Fixed origin flood forecast for 15 May 2000 00:15 UTC using real and* **displaced radar data** *(top) and using real and* **intensity changed radar data** *(bottom).*

Up to the fixed origin radar observations will be used, beyond the fixed origin 'simulated rainfall forecasts' and subsequently (beyond the extrapolation time of the rainfall forecast) zero rainfall provide the input for the PDM. The simulated flood using real (the best estimate at this particular time) and displaced radar patterns are compared in terms of the previously mentioned R^2 statistics and the volume of catchment runoff integrated over time. The ratio of medians is varied between 50, 75, 125 and 150 % of the average catchment rainfall. An absolute error of 4 km corresponds to the mean displacement of the rainfall pattern within 15 minutes (approximately 3.7 km). For an absolute error of 4 km (displaced to the north) only 79.8 % of the actually predictable total catchment runoff volume is forecasted (Tab. 1). The larger the absolute error for the forecasted position of the rainfall pattern the more significant the error in the flood forecast becomes. The percentage of the forecasted runoff volume is based on the drained runoff volume applying real radar data would cause. The flood forecast errors increase (R^2 diminishes) significantly for an absolute error of 16 km, being beyond the approximate length of the catchment (covered by 5x4 radar pixels for a 2 km resolution). The effect of the position error is probably most recognizable if the absolute error exceeds the catchment size. Decreasing the average catchment rainfall to 50 % of the real value or applying an absolute error of 8 km (twice the mean displacement of the rainfall pattern within 15 min) leads to equivalent flood forecast errors for this particular event.

Displacement to the north for 4, 8, 12, 16, 20 km	
R^2	0.93, 0.36, 0.58, 0.04, -0.22
Runoff volume [m^3] Percentage [%]	122.2, 54.4, 75.0, 30.1, 10.9 79.8, 35.6, 48.9, 19.7, 7.1
Change in intensity, 50, 75, 125, 150 %	
R^2	0.35, 0.80, 0.73, -0.16
Runoff volume [m^3] Percentage [%]	53.5, 100.1, 209.1, 266.4 35.0, 65.4, 136.6, 174.0

Tab.1. *To what extent do errors in the forecasted position and intensity within a rainfall forecast influence the subsequent flood forecast ? The percentage of the catchment runoff volume is based on the water volume resulting from a forecast using the real radar data (153.1 m^3).*

b) Comparison to GANDOLF: To estimate the performances of different intensity forecasts COTREC and GANDOLF rainfall forecasts have been applied as input to the PDM. The rainfall inputs used are: 1) Persistence: assuming the present radar rainfall to be the best estimate for the future, 2) COTREC: applying a linear extrapolation of COTREC-derived displacement vectors and growth areas, 3) COTREC-advection: radar patterns are moved according to the COTREC-derived displacement vectors but the intensities remain unchanged, and 4) GANDOLF rainfall forecasts. GANDOLF (Generating Advanced Nowcasts for Deployment in Operational Land-surface Flood forecasts, Pierce et al., 2000) is the Met Office system to provide rainfall forecasts for convective events. It combines the object-oriented approach for cell identification with a conceptual life cycle model, using radar data and mesoscale numerical model outputs to predict movement and development up to 3 hours ahead. Figure 4 shows 11 fixed origin flood forecasts between 8:30 and 11:00 UTC for a small convective event on 9 June 2000 passing the Silk stream catchment. The maximum average catchment rainfall (radar) of 2.7 mm h^{-1} led to a small rise in the river flow from 0.1 to 0.9 m^3s^{-1}. Comparing the hydrographs shows that GANDOLF and COTREC-advection forecasts lead to more precise flood forecasts compared to persistence and COTREC, the latter extrapolating growth areas linearly. COTREC-advection forecasts result in slightly overestimated flood forecast. This emphasises the value of refined rainfall forecast for this particular event.



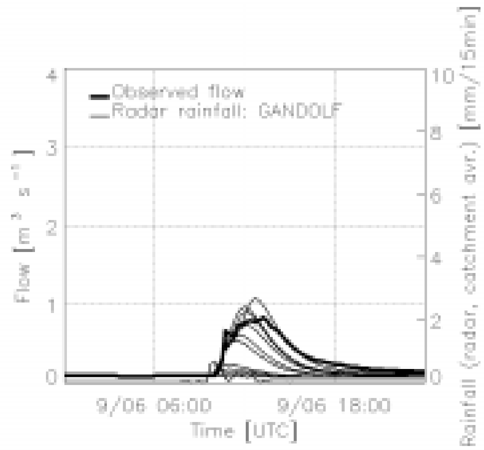


Fig.4. *11 fixed origin forecasts for 9 June 2000 between 8:30 and 11:00 UTC, rainfall input to the PDM (from top to bottom): persistence, COTREC, COTREC-advection, GANDOLF.*

5 OUTLOOK

The case studies presented illustrate the intended method to investigate the sensitivity of flood forecasts to errors in the predicted position and intensity of a rainfall pattern. The relative importance of various error sources still has to be investigated for a larger number of cases and catchments. First results of a comparison between COTREC and GANDOLF imply that refined intensity forecasts lead to more precise flood forecasts.

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