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Spatial bias and uncertainty in numerical weather predictions for urban runoff forecasts with long time horizons

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Keywords: Numerical Weather Predictions; urban rainfall; spatial uncertainty; real-time forecasting; ensemble prediction system

Biography:

Jonas Wied Pedersen is a PhD student at the Department of Environmental Engineering at the Technical University of Denmark. His PhD project is about models for real-time warning and control strategies in urban drainage and wastewater systems.

Summary:

Numerical Weather Predictions (NWP) can be used to forecast urban runoff with long lead times. However, NWP exhibit large spatial uncertainties and using forecasted precipitation directly above the catchment might therefore not be an ideal approach in an online setup. We use the Danish Meteorological Institute's NWP ensemble and investigate a large spatial neighborhood around the catchment over a two-year period. When compared against in-sewer observations, runoff forecasts forced with precipitation from north-east of the catchment are most skillful. This highlights spatial biases in the coupled hydro-meteorological setup, which a forecaster should be aware of.

Introduction:

Online forecasts of urban stormwater runoff are often performed by forcing models with precipitation forecasts from radar extrapolation. Such forecasts are skillful up to a few hours ahead. Hereafter forecasts worsen due to non-linearity of atmospheric processes.

Short forecast horizons can be a problem in systems with large storage basins that take many hours to empty. Control strategies could be improved if longer forecast horizons were available and Numerical Weather Predictions (NWP) have the potential to provide these (Thorndahl *et al.*, 2013). In most urban NWP applications evaluation has only been done on a few rain events (e.g. Liguori *et al.*, 2012). Here models were also only forced with forecasted rain directly above the catchments, despite the large spatial uncertainties in NWP.

Courdent *et al.* (2016) examined benefits of including neighboring cells outside the catchment with a combined evaluation of forecasts from cells in a radius of 30 km. We quantify and compare the skill of each individual neighboring cell by propagating its forecasted rain through a runoff model. This evaluation can show appropriate size and shape of a good spatial neighborhood for runoff forecasting and yield information on spatial bias and uncertainty in the hydro-meteorological setup.

Material and Methods:

This study's case area is the northern part of the Damhusåen catchment in Copenhagen, Denmark. The area is 3,000 ha and has combined sewers with overflow structures. The catchment outlet has a capacity of 10,000 m^3/h.

Catchment runoff is simulated with a lumped model consisting of two parallel Nash cascades (fast and slow runoff) and a harmonic function for the dry weather flow (DWF) - see Fig. 1. Evapotranspiration (ET) is based on historical potential ET observations. Calibrated parameters are effective surface areas and time constants for both cascades, and a multiplicative factor on the potential ET. During the calibration period (Sep. 2012 – May 2014) the model is forced with the mean observed intensity at three local rain gauges, and the mean squared error is minimized.

Fig. 1. Setup of the rainfall-runoff model.

The weather forecasts are from the DMI-HIRLAM-S05 model and consists of an ensemble of 25 individual forecasts (Feddersen, 2009). The 25 members are generated by pairing five different atmospheric modeling schemes with five ways of perturbing initial conditions. A new ensemble is produced every six hours. The spatial resolution is 5x5 km and the temporal resolution is one hour. We examine grid cells in a 100x100 km area around Copenhagen.

The focus of this study is stormwater runoff, which is assessed as accumulated hourly volume during the period of June 2014 to July 2016. Forecast skill is evaluated when the observed volume exceeds 2000 m^3/h, which is beyond normal DWF. The ensemble forecasts are evaluated with the Continuous Ranked Probability Score (CRPS) and its related skill score (CRPSS), given in equation (1).

$$CRPSS = 1 - \frac{CRPS_{forecast}}{CRPS_{reference}} \qquad (1)$$

The CRPS is interpretable as a probabilistic generalization of the mean absolute error for point forecasts. The reference is the forecast from the cell directly above the catchment; the CRPSS then gives the skill of all neighboring cells relative to this cell.

Results and Discussions:

Fig. 2 provides an example of a 48-hour forecast of hourly runoff. The individual ensemble members show large variations in the forecasted runoff but encapsulate the observations.

Fig. 2. Example of a forecast with 25 individual members.

The result of using the forecasted precipitation in the runoff model is shown on Fig. 3, where the overall CRPSS for the two-year period is illustrated at four lead times. For lead times up to 24 hours it is seen that cells north and east of Copenhagen perform better than those to the south and west. At 48 hours cells that are located south-east of Copenhagen perform best. These structural differences show that a simple circular neighborhood centered over the catchment might not be an optimal NWP post-processing setup for forecasting.

Fig. 3. CRPSS values for grid cells in the considered area. The grid cell above the catchment is highlighted by a black square. Green indicate better and red worse skill relative to the cell in the black square.

Future research will consider how a forecaster can choose a spatial neighborhood that yields the most skillful runoff forecast. This requires analysis of different types of rain, seasonal variations, and error correlations between cells and ensemble members.

Conclusions:

NWP contain large spatial uncertainties which affect the quality of urban runoff forecasts. This uncertainty is shown by considering how well forecasted rain in grid cells outside the catchment perform when used in a runoff model. The results show there are spatial biases in the forecasts and that simply using precipitation from the cell directly above the catchment does not yield the best runoff forecasts.

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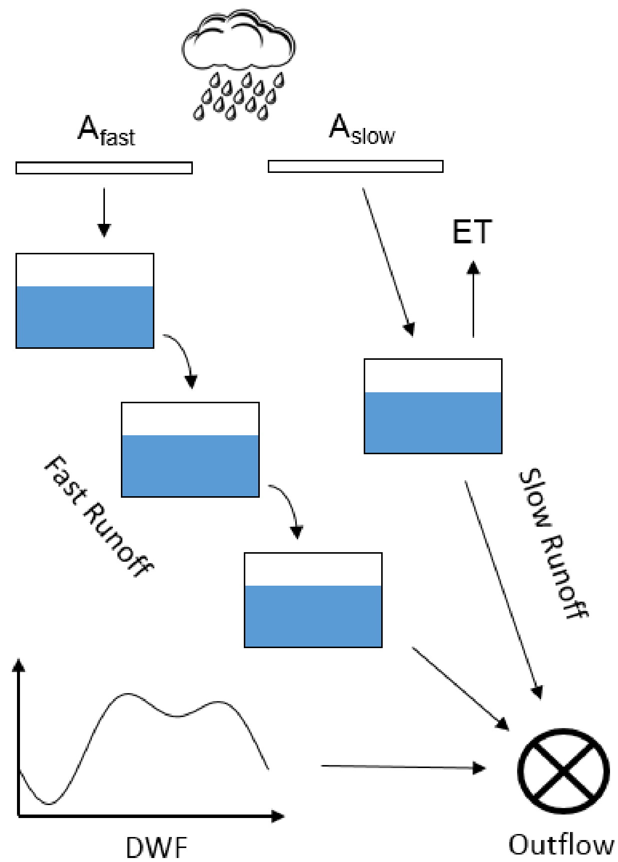


Figure 1

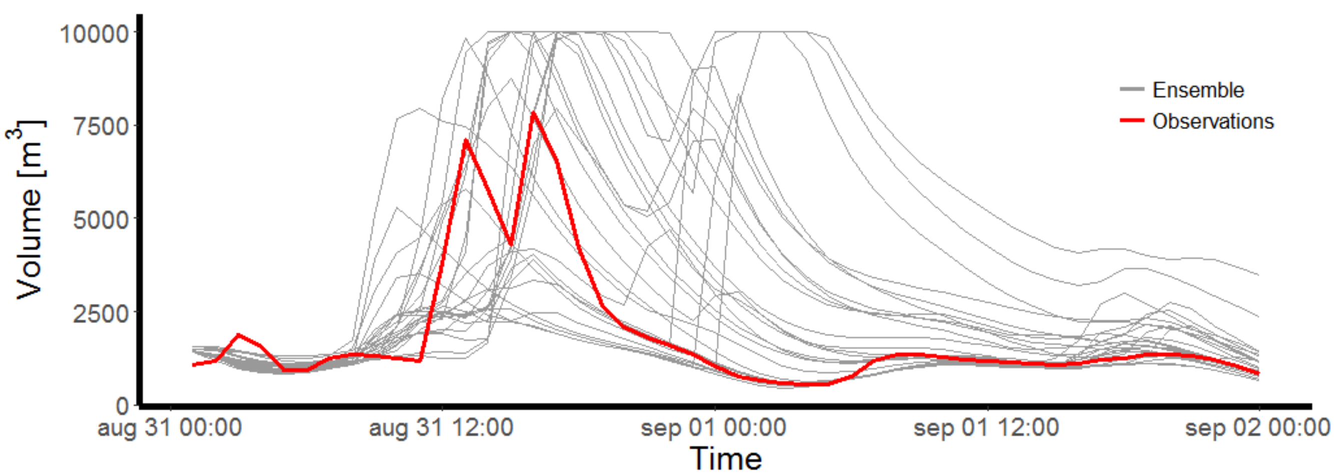
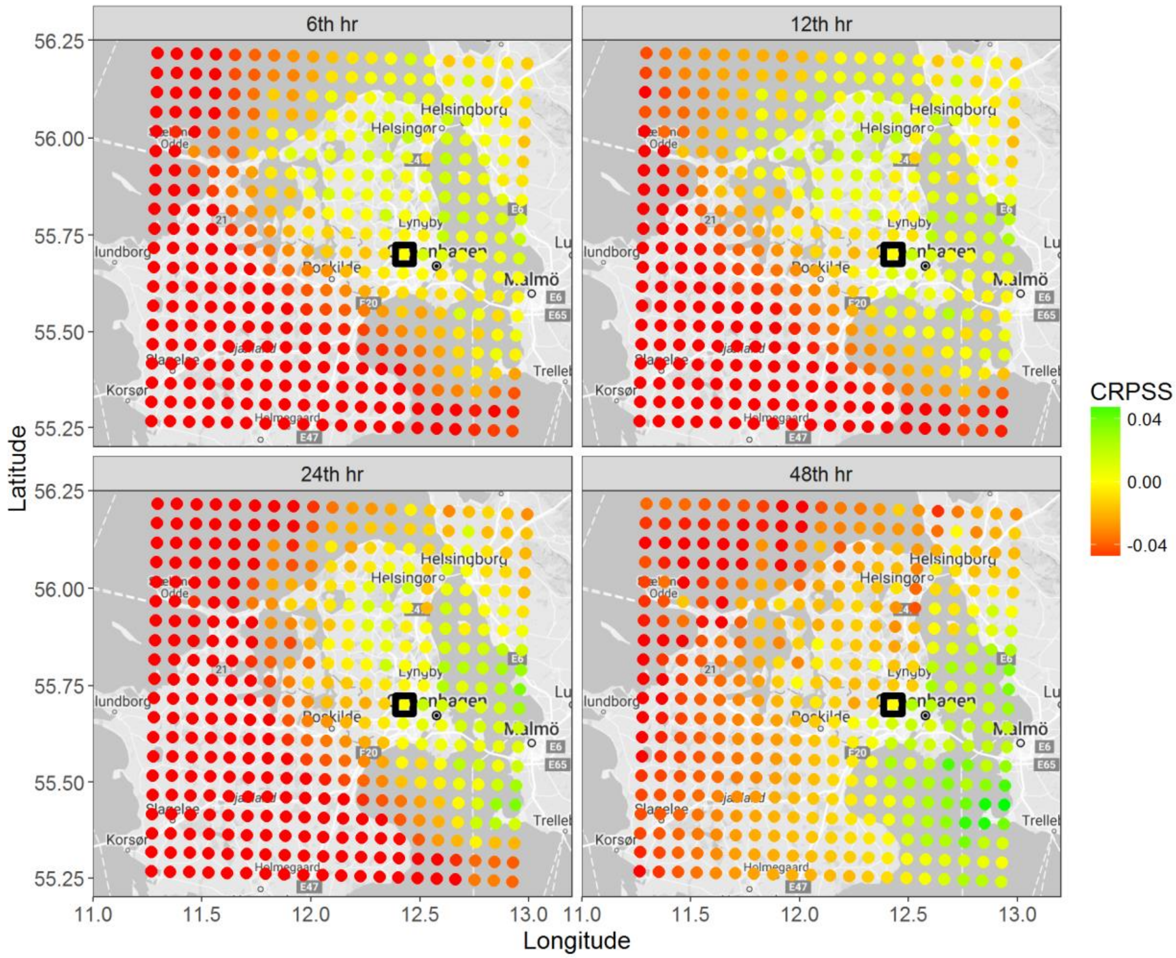


Figure 2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11.0
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13.0

Figure 3