Aalborg Universitet

Radar Based Flow and Water Level Forecasting in Sewer Systems

a danish case study

Thorndahl, Søren Liedtke; Rasmussen, Michael R.; Grum, M.; Neve, S. L.

Publication date:
2010

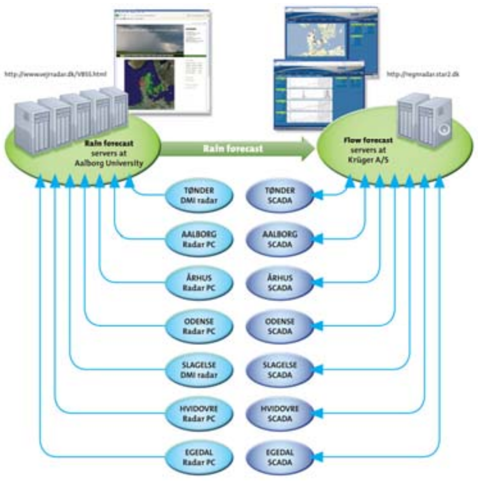
Document Version
Også kaldet Forlagets PDF

RADAR BASED FLOW AND WATER LEVEL FORECASTING IN SEWER SYSTEMS – A DANISH CASE STUDY

Introduction

Climate changes and increased urbanization are causing flooding and increased pollution due to discharge of untreated storm and waste water during heavy rainfall. This environmental problem will most likely increase in the future and can be solved in two ways; either by reconstruction of sewer systems, by expanding basin volumes, pipe dimensions, and treatment facilities or by optimizing the existing infrastructure. The present is an approach of the latter.

By the use of weather radars, it is possible to measure and forecast the spatially distributed rainfall over an urban catchment. Applying the forecasted rain as input to a runoff model, it is possible to forecast flow at key points within the sewer system, thereby improve the real time operation of the sewer and wastewater treatment system, and thus reduce the discharged combined sewer overflow volumes.



Data infrastructure.

Ranges of C-band radars (large circles) and X-band radars (small circles).

Cases

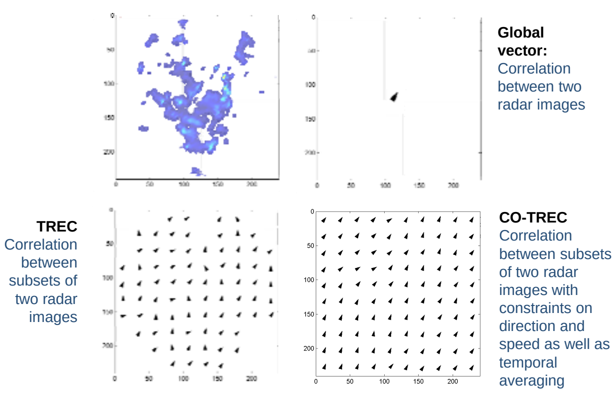
This project is a collaboration between Aalborg University, Denmark, Krüger Veolia Water, Denmark, and the seven Danish municipalities: Aalborg, Egedal, Hvidovre, Odense, Slagelse, Toender, and Aarhus. Some of the municipalities possess their own X-band radar while some use online C-band data from the Danish Meteorological Institute (DMI). Each municipality has chosen an urban catchment in which different types of observations are recorded and transmitted online to a server, e.g., flow, water level, pump discharge, overflow registration, etc.

Aalborg University is in charge of radar data and rain gauge data collection, calibration, and rain forecast and Krüger, Veolia Water is in charge of the collection of in-sewer measurements and the flow/water level forecasting.

Radar calibration and forecast

The X-band radars apply an empirical relationship between reflectivity and rain intensity, and thus have to be calibrated against rain gauges. In this project the X-band radars are calibrated statically over a period of time ranging from 1-12 months applying from 5 to 40 rain gauges (hindcast). The C-band radars are calibrated using a standard Marshall-Palmer relationship. Moreover, in order to gain the most reliable levels of rain intensity, the radar data is adjusted continuously (dynamically calibrated) using 2-5 on-line rain gauges for each radar.

The rain forecast is based on the CO-TREC algorithm in which a vector field of the movement of the rain is obtained. X-band radar data is forecasted with a lead time of 1 hour and the C-band radar data is forecasted 2 hours.



Concept of the CO-TREC forecasting method.

On-line applications

Radar data and rain forecast:

http://www.vejrradar.dk/VBSS.html

Flow and water level data and forecast:

http://www.regnradar.star2.dk

Bandwidth	C-band	X-band
Range	240 km	60 km
Spatial resolution	2000 x 2000 m	500 x 500 m
Temporal resolution	10 min.	5 min.
Frequency	5.6 GHz	9.4 Ghz
Wave length	5.0 cm	3.2 cm
Scanning strategy	Multiple layers	Continuous in one layer
Owner/developer	DMI	Municipalities/DHI

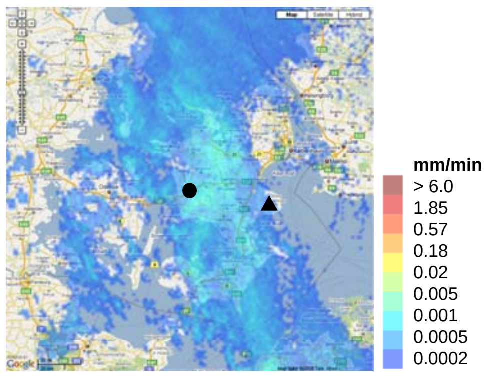
Radar specifications.

Runoff forecast

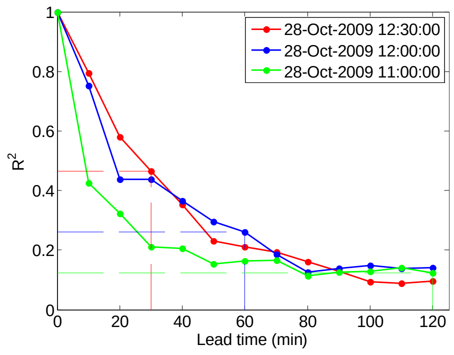
The runoff model applied in the study is the simple and non-physically based flow routing model, WaterAspects. Using the overall structure of the sewer system, a simple model are set up and interrelated timeseries of rain and observations in the drainage system is then used to calibrate the model. In order to make the most reliable forecast the model is continuously adjusted against real time measurements in the drainage system using a Bayesian update algorithm.

Result example

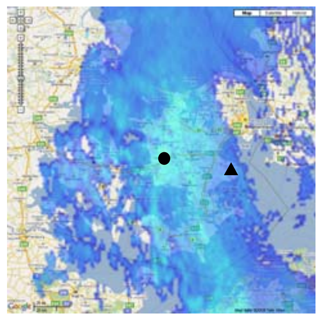
The following figures present the observed and forecasted radar data from the City of Slagelse on Oct. 28, 2009 at 13:00. The applied radar is located on Stevns approx. 50 km from Slagelse.



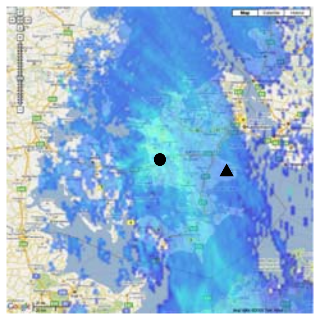
Observed rain Oct. 28, 2009, 13:00. Black dot marks Slagelse City and the triangle marks the location of the Stevns (DMI) C-band Radar.



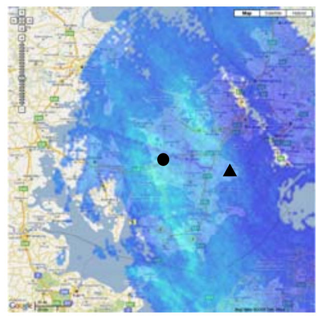
Validation of the rain forecast.



Forecasted rain, Oct. 28, 2009, 12:30 + 30 min.

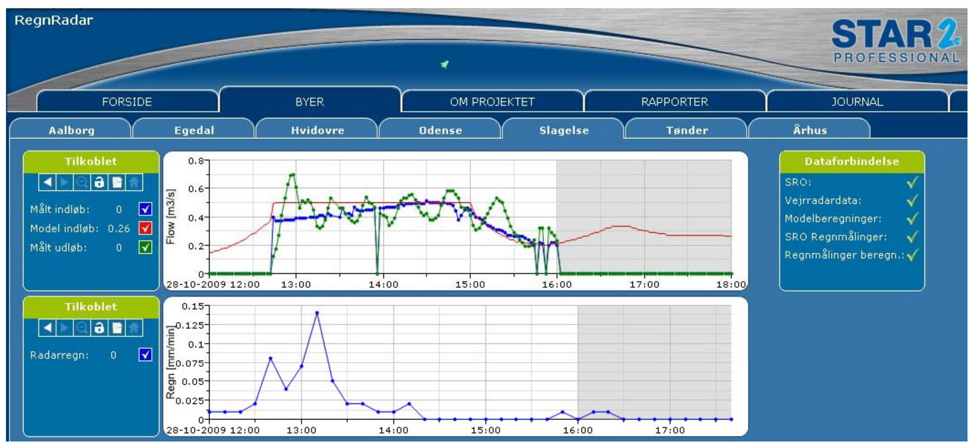


Forecasted rain, Oct. 28, 2009, 12:00 + 60 min.



Forecasted rain, Oct. 28, 2009, 11:00 + 120 min.

The presented figures shows a statiform rain event with moderate rain intensties. The correlation coeffeceints (R^2) on the forecast (of the whole radar extent) are quite high on the short lead times, but obviously lower on the longer forecast. Convective storms are more difficult to forecast with satisfactory results, which is why a new generation of the forecast algorithm is currently under developement. The observed and simulated inlet flow to Slagelse Waste Water Treatment Plant (WWTP) are shown in the following figure on the same date as presented above. The divergence between model and observations is quite low.



Example of the web user interface for the Slagelse Municipality on Oct. 28, 2009. Gray areas mark the forecast. Top: Time series of observed intet flow to Slagelse WWTP (blue), modelled flow (red), and observed outlet flow (green). Bottom: time series of rain intensity (observed by the Stevns, C-band radar) in the catchment of the WWTP.

Conclusion

A radar based forecast of flow and/or water level is implemented on seven urban catchments in Denmark. It is demonstrated that rain can be forecasted successfully with a lead time of 1-2 hours depending on the type of radar, and furthermore the total lead time can be extended to 1.5-3.5 hours due to the transportation time in the drainage system. Radar data is calibrated statically using historical data dynamically applying on-line rain gauges in real time. The simple flow routing model, WaterAspects, is calibrated against historical data, and continuously updated using online in-sewer measurements. Hereby, it is emplified to forecast flow and water levels in specific points of the drainage system, e.g. inlets to large detention basins or inlets to wastewater treatment plants.

The system shows a large potential, e.g. in retaining water in detention basins in order to minimize combined sewer overflow and loads on wastewater treatment plants, to switch between dry and wet weather operation in wastewater treatment plants, economical operation of pumps, etc. The system is currently running online and is tested for a year, until the spring of 2010.

S.Thorndahl[1], M.R. Rasmussen[2], M. Grum[3], and S.L. Neve[4]

[1] Aalborg University, Department of Civil Engineering, Sohngaardsholmsvej 57, 9000 Aalborg, Denmark (st@civil.aau.dk)
[2] Aalborg University, Department of Civil Engineering, Sohngaardsholmsvej 57, 9000 Aalborg, Denmark (mr@civil.aau.dk)
[3] Krüger, Veolia Water, Gladsaxevej 363, 2860 Søborg, Denmark (mg@kruger.dk)
[4] Krüger, Veolia Water, Indkildevej 6 C, 9210 Aalborg SØ, Denmark (snl@kruger.dk)

KRÜGER AALBORG UNIVERSITY