Effect of the spatiotemporal variability of rainfall inputs in water quality integrated catchment modelling for dissolved oxygen concentrations

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1. Introduction

- Integrated catchment modelling (ICM) is used as a tool to evaluate the interactions between urban areas, wastewater treatment plants and receiving natural waters. This integrated evaluation allows to assess the water quality problem accross several scales The use of ICMs is gaining interest in the areas of:

- **Urban water system operations** (Model predictive control applications).

- Alternative **optimization** of water management policies and infrastructural investment.

- Those complex models often present highly uncertain outputs. Scarcity of monitoring data and intensively simplified model structures make difficult to fully represent the pollutant dynamics. Rainfall measurement is often considered a significative source of uncertainty in the model operation process.

Rain gauge networks are usually considered as the most reliable source of rainfall information. However, its low sampling density is often unable to capture in detail the storm processes (specially highly convective) at inter-urban scales. Alternatively rainfall fields can be further characterised with the use of C-Band Radar estimations or secondary rain gauge networks.

This study explores the effect of using rainfall products with different complexity in the performance of a pseudo-distributed ICM for prediction of oxygen depletion in summer conditions. The basic source of information is a single well maintained rain gauge from the KNMI (the National meteorological agency). Additional information from 6 local raingauges, 6 KNMI gauges and weather Radar is used to improve the rainfall field estimation.

2. Methods

2.1 Rainfall Product generation

Rainfall processes present a natural variability in time and space.
Allocation of inputs in a lumped urban catchment model involves making predictions in the **area support of each of the draining areas**.

The following rainfall inputs are produced:

1- BK1: A single rain gauge from the KNMI (Eind370).
2- BKall: Block kriging from a network of 13 rain gauges.
3- UBK: Universal block kriging from the 13 rain gauges using C-Band radar as a covariate.
4- ARadar: Averaged value of C-Band radar (KNMI).

Storm characterisation:
During this study 3 summer periods are considered from 2011 -2013, capturing different rainfall processes. Averaged semivariograms are calculated and used to characterise and predict rainfall intensities at unsampled locations.

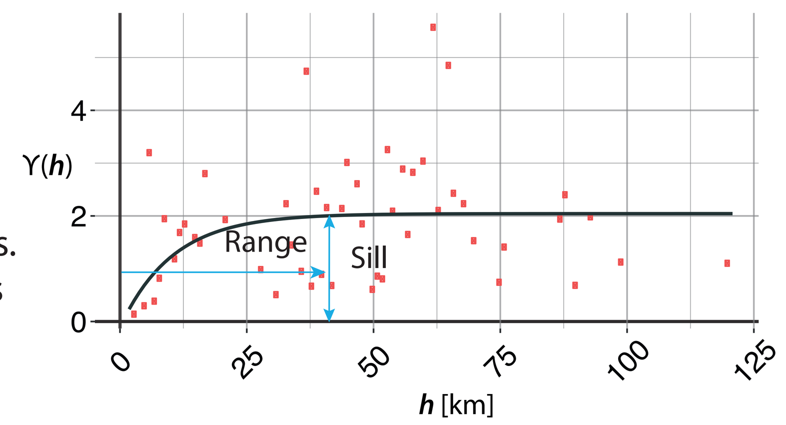

Figure 1. Fitted semivariogram Period 1, 30 min accumulation

Table 1. Sill and range calculated and fitted to an exponential model in each rainfall period.

	Period 1 18/08/2011 - 31/08/2011		Period 2 05/07/2012 - 04/08/2012		Period 3 25/07/2013 - 19/08/2013	
Time step (min)	Sill	Range [km]	Sill	Range [km]	Sill	Range [km]
10	5.10	37.12	2.09	8.61	1.90	59.81
30	2.11	35.39	1.00	15.00	0.82	55.78
60	1.05	38.47	0.61	17.18	0.51	92.88

2.2 Model set up

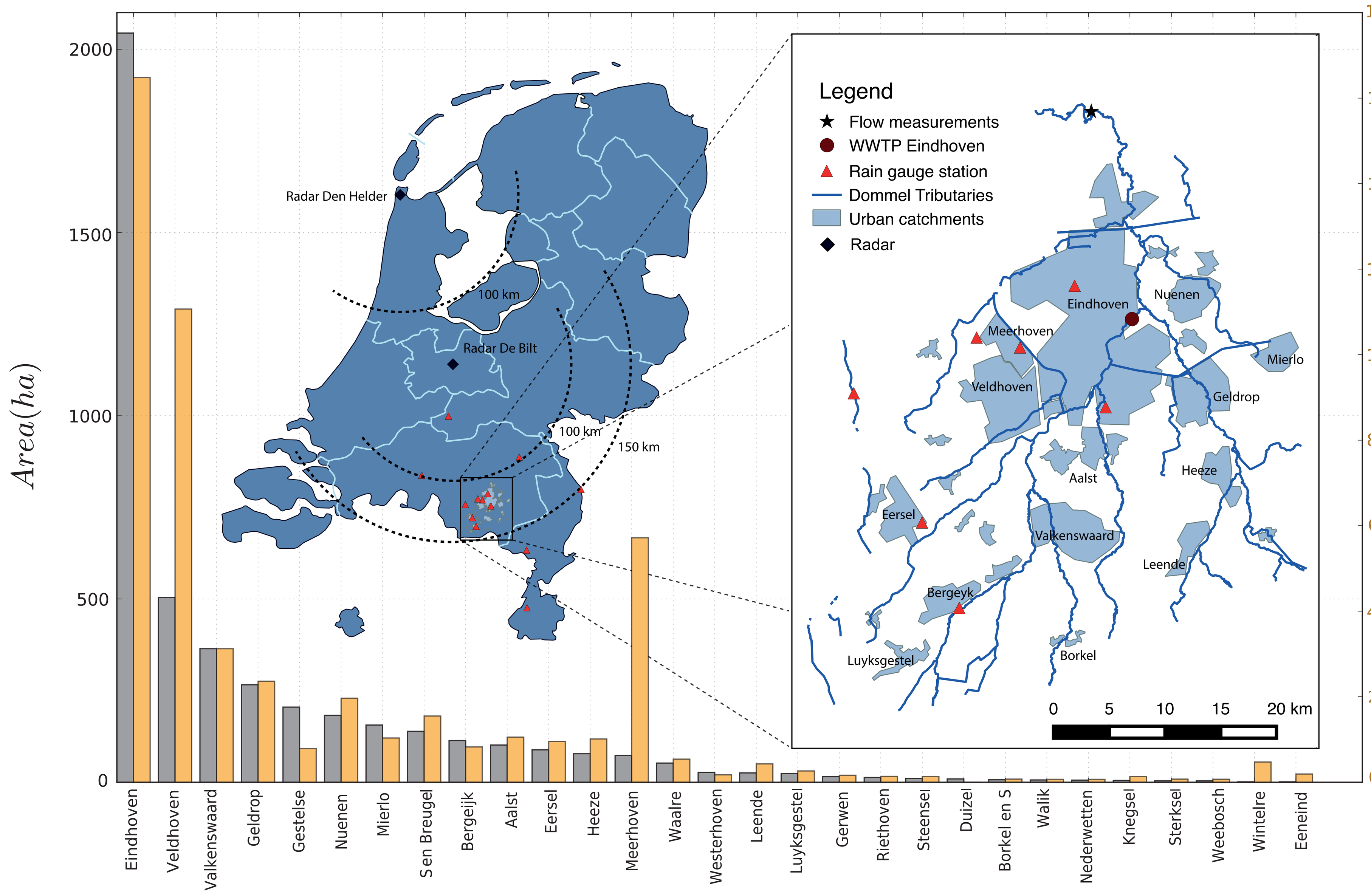

Figure 2. Location of the Eindhoven catchment, raingauge network and Radar, distribution of municipal areas and inhabitants.

The Dommel is a sensitive small river located in the south of The Netherlands. A WWTP of ~750,000 i.e. discharges to this river along with near 200 combined sewer overflow structures from the city of Eindhoven and its surrounding municipalities. Heavy storms and high temperatures often render oxygen drops in the river, which deteriorates its ecological water quality.

A pseudo-distributed simplified integrated water quality model is proposed for this system. Using the software WEST (mikedhi.com) 3 different submodels are linked:

1- **Urban water** rainfall-runoff and sewer networks:
34 Individual urban catchments hydraulically modelled as a tank-in-series structure.

2- **WWTP**:
Three parallel biological lines (26,000 m^3/h) consisting in a primary clarifier, a biological tank and four secondary clarifiers. Modelled as an ASM2d biokinetic and calibrated through the BIOMATH calibration protocol.

3- **River Dommel**:
A tank-in-series structure discretises the river.. A DO/NH_4 model is set-up with differenciation of BOD decay (fast and low), reaeration, algae production and respiration, nitrification and settling of particulate matter.

3. Results

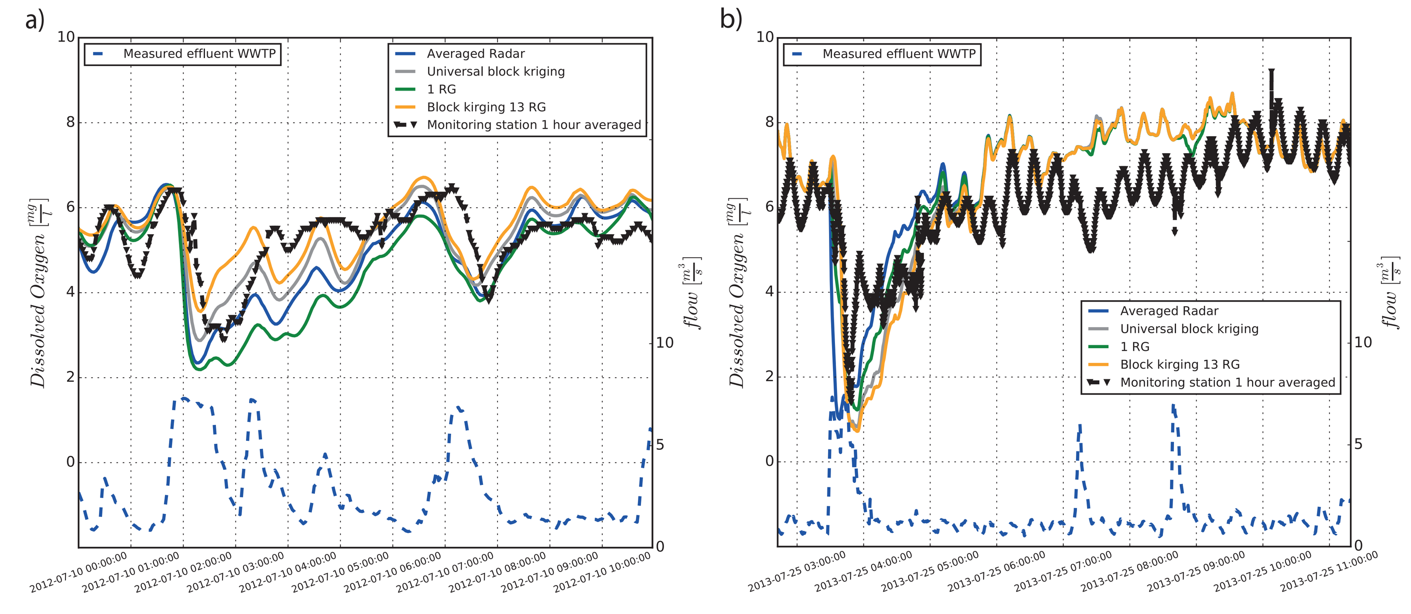

Figure 3. Dissolved oxygen concentrations in the river, modelled and observed. In a) a series of storm events from July 2012 modelled at the end of the catchment (flow measurement location). In b) it is shown the section located just upstream the WWTP during July 2013.

Figure 3.a presents the dissolved oxygen dynamics induced by each of the rainfall products, the magnitude of the oxygen drop is dependent on the rainfall characterization. In this particular case the single rain gauge and averaged radar are overestimating the process whereas by merging all available information (UBK) a closer match is achieved.

Figure 3.b shows an event where the averaged radar product renders a shift on time, which is not present in the rain gauges. This is a common phenomena in the radar-rain gauge comparison and shows the benefits of correcting the radar estimation with rain gauge data.

4. Conclusions and further work

1- **Model structural uncertainties** can easily dominate the rainfall measurement errors.

2- The use of a single rain gauge is not recomended even in such highly simplified model structures. Additional information, specially the use of merged radar (**UBK**) can improve the timing and location of peak flows, which can affect the DO dynamics.

3- The added benefit of the use of rainfall spatial information depends on the **system areal distribution and the local climatology** a wider range of storm processes will be assessed to prove this initial findings.

5. References

Benedetti, L. et al (2013). Cost-effective solutions for water quality improvement in the Dommel River supported by sewer-WWTP-river integrated modelling. Water Science & Technology, 68(5).
Haberlandt, U. (2007). Geostatistical interpolation of hourly precipitation from rain gauges and radar for a large-scale extreme rainfall event. Journal of Hydrology.
Bruni, G. et al (2015). On the sensitivity of urban hydrodynamic modelling to rainfall spatial and temporal resolution. Hydrology and Earth System Sciences.

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