Effect of spatiotemporal variation of rainfall on dissolved oxygen depletion in integrated catchment studies

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1. Water quality integrated catchment management

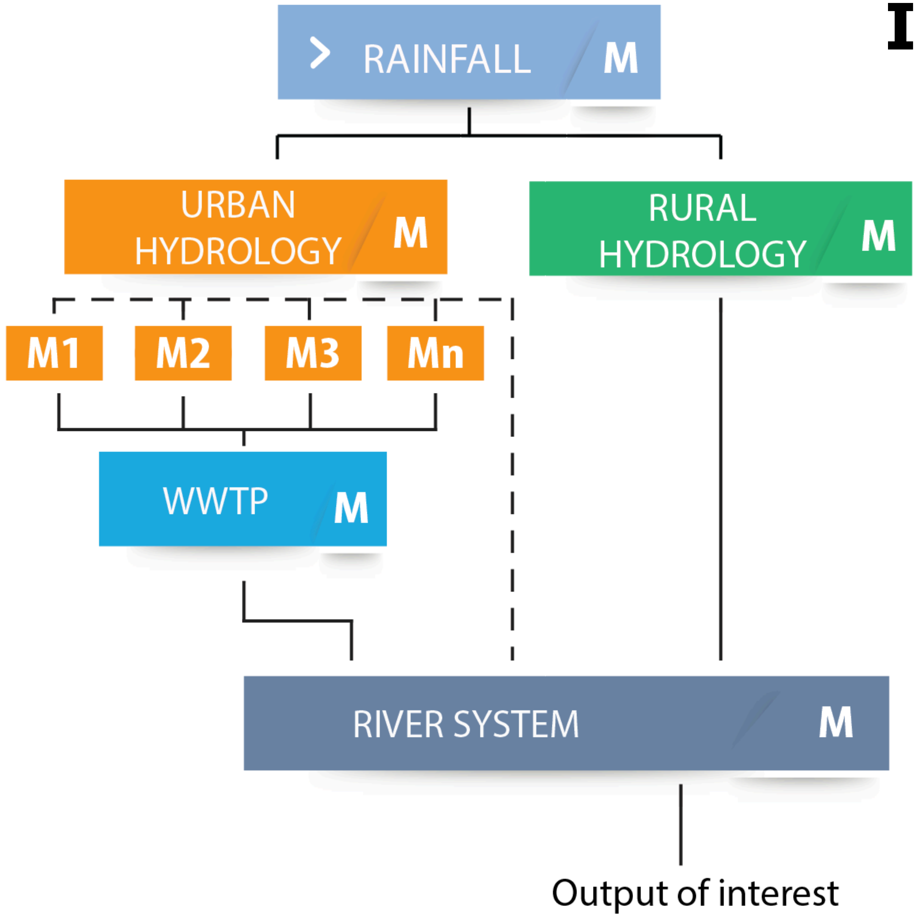
Model based water management practices.
Control of pollution.
Design of water systems

OLD management practices
Attending to pollution input limitation.
Model based design.
Not accounting for natural water characteristics.

WFD

NEW management practices
Ecological and chemical control of water bodies.
Integrated assessment of the interaction between the parts of the water system

1. Water quality integrated catchment management



INTEGRATED CATCHMENT MODELLING

↑

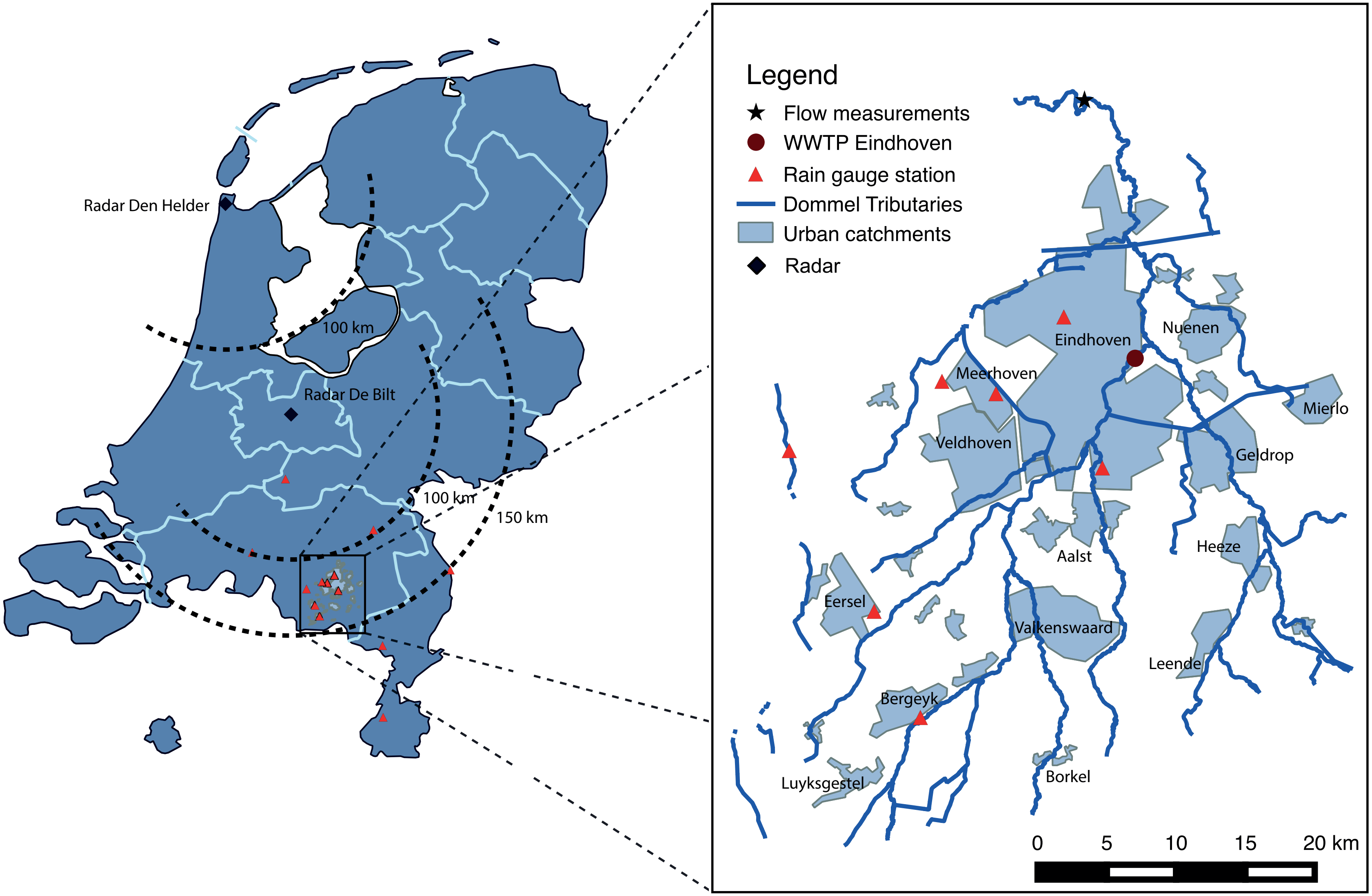
Water Framework Directive

NEW management practices

Ecological and chemical control of water bodies.

Integrated assessment of the interaction between the parts of the water system

2. The Dommel river



3. Sources of uncertainty

- Input data measurement uncertainty
- Model structure
- Aleatoric uncertainty (non-deterministic/chaotic behavior)
- Parameter calibration
- Code/numerical implementation errors

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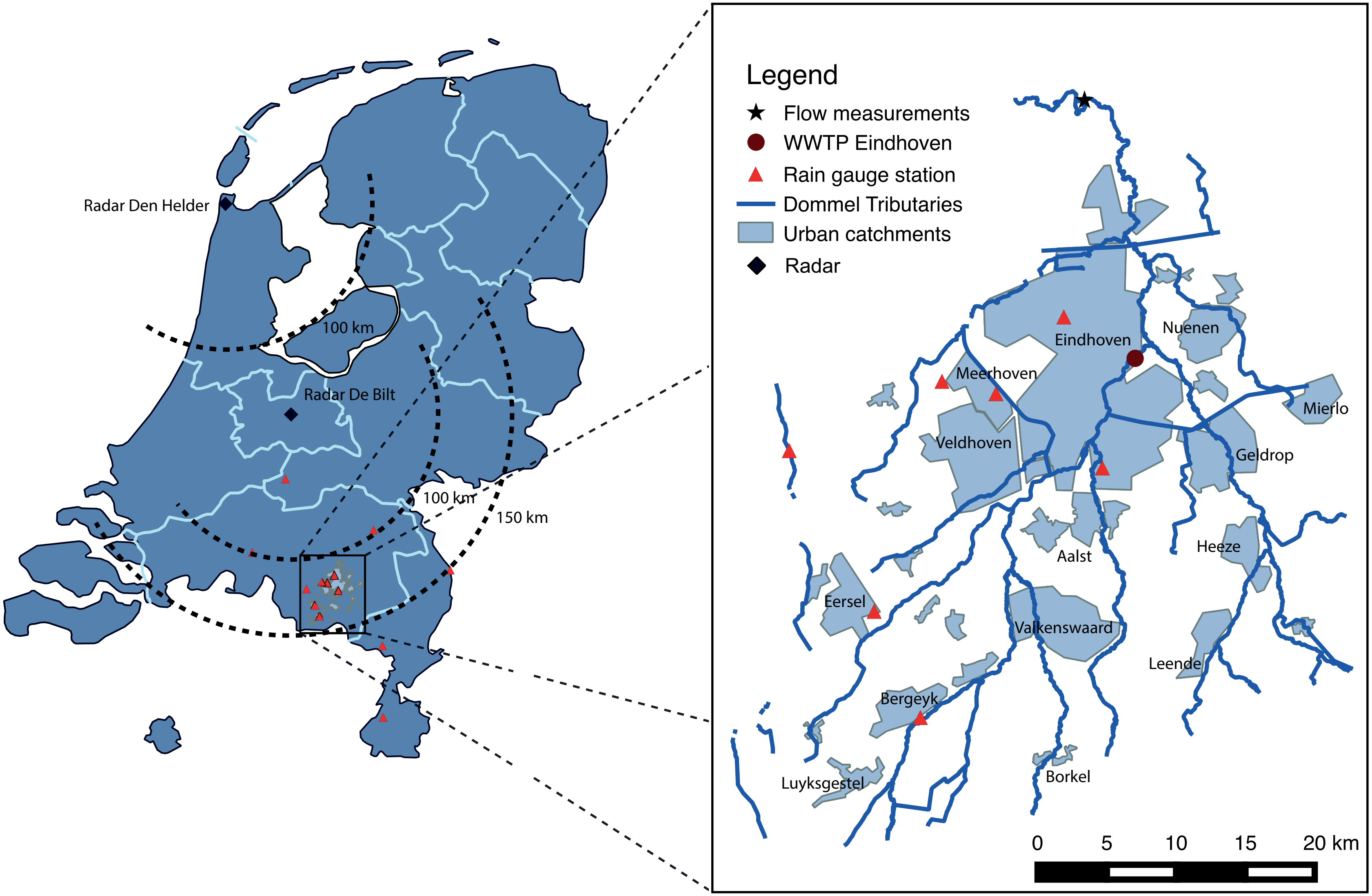
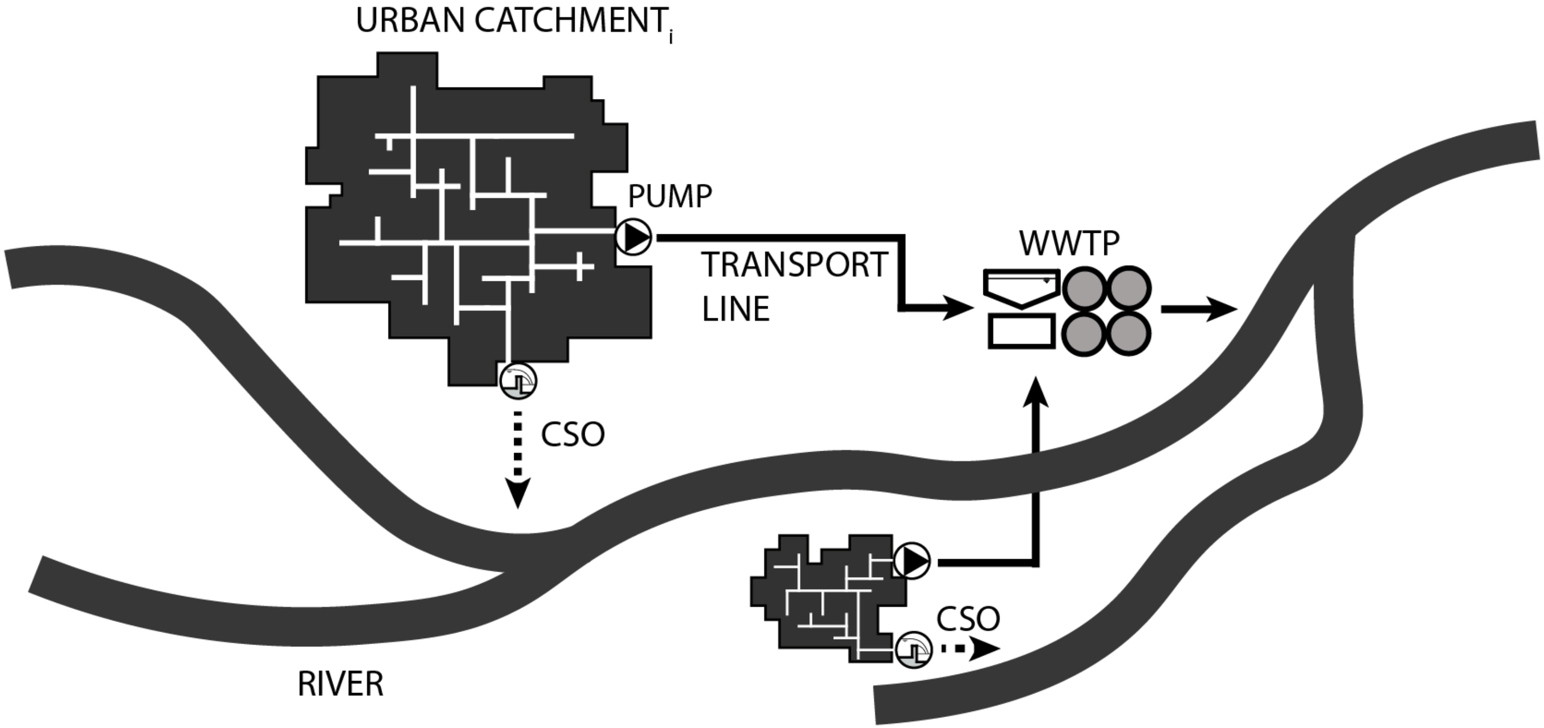


5. Modelling structure (Dissolved oxygen)



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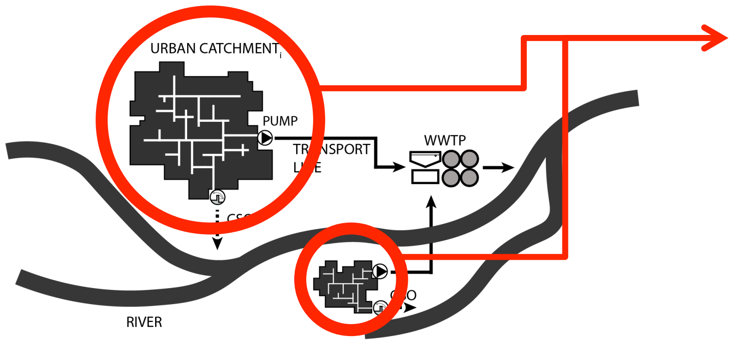
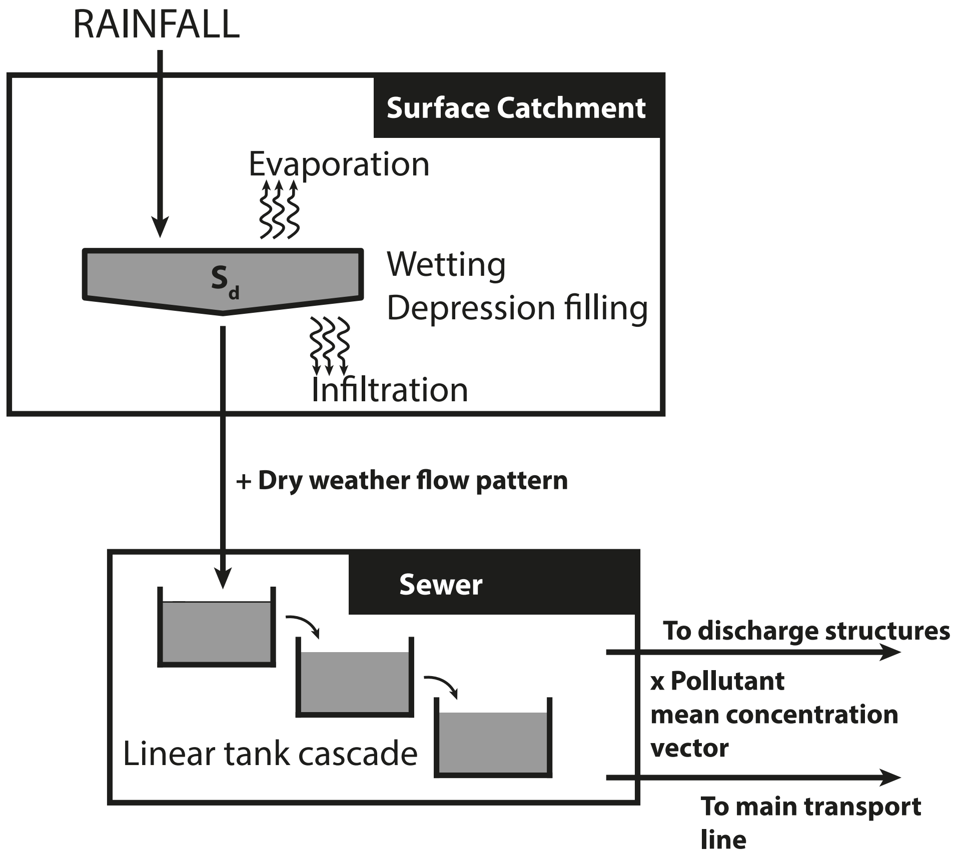


Urban catchment



- Spatially lumped
- Rainfall-runoff
  - Evaporation
  - Wetting losses, depressions
- Sewer routing
  - Tank in series routing
  - DWF daily pattern
  - DWF mean pollutant concentration vector

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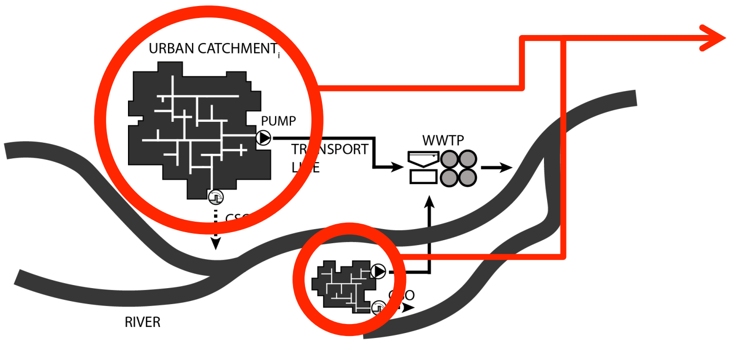
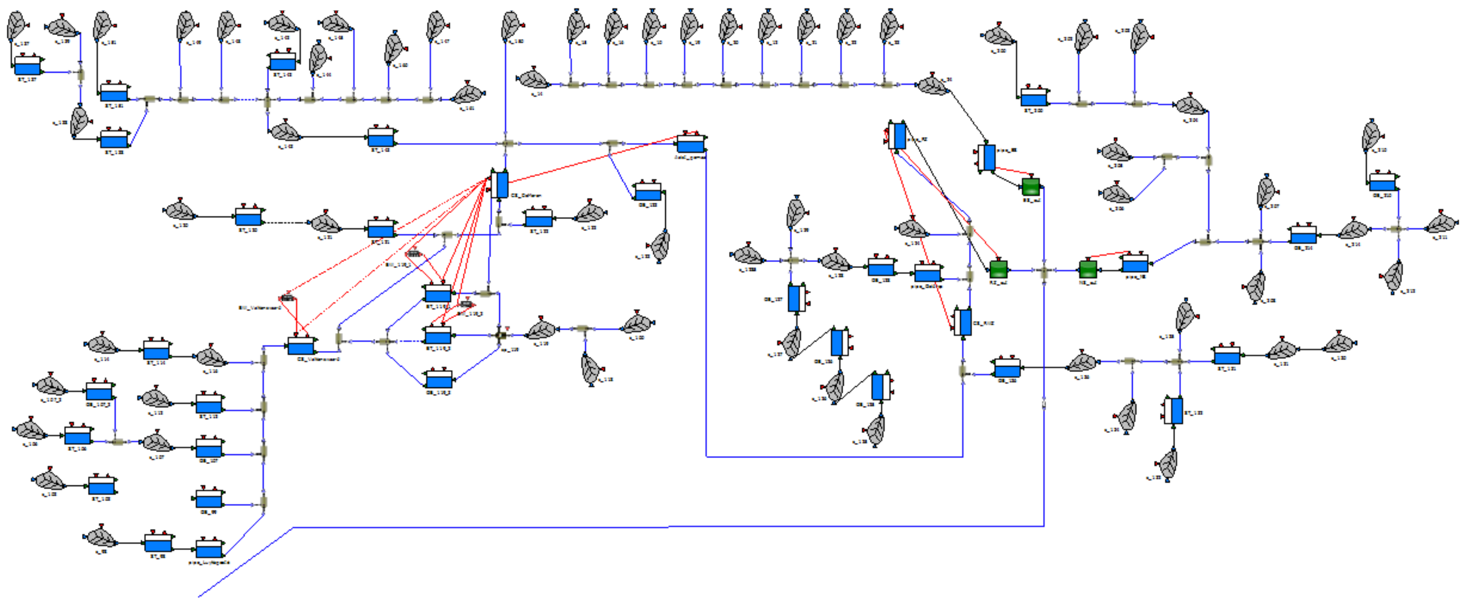


Urban catchment

29 locally lumped catchments
Pseudo-distributed



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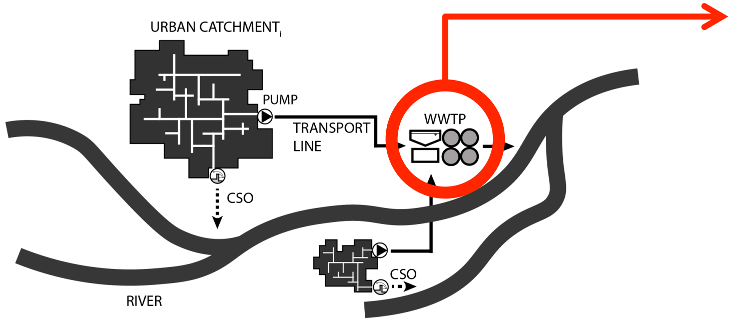
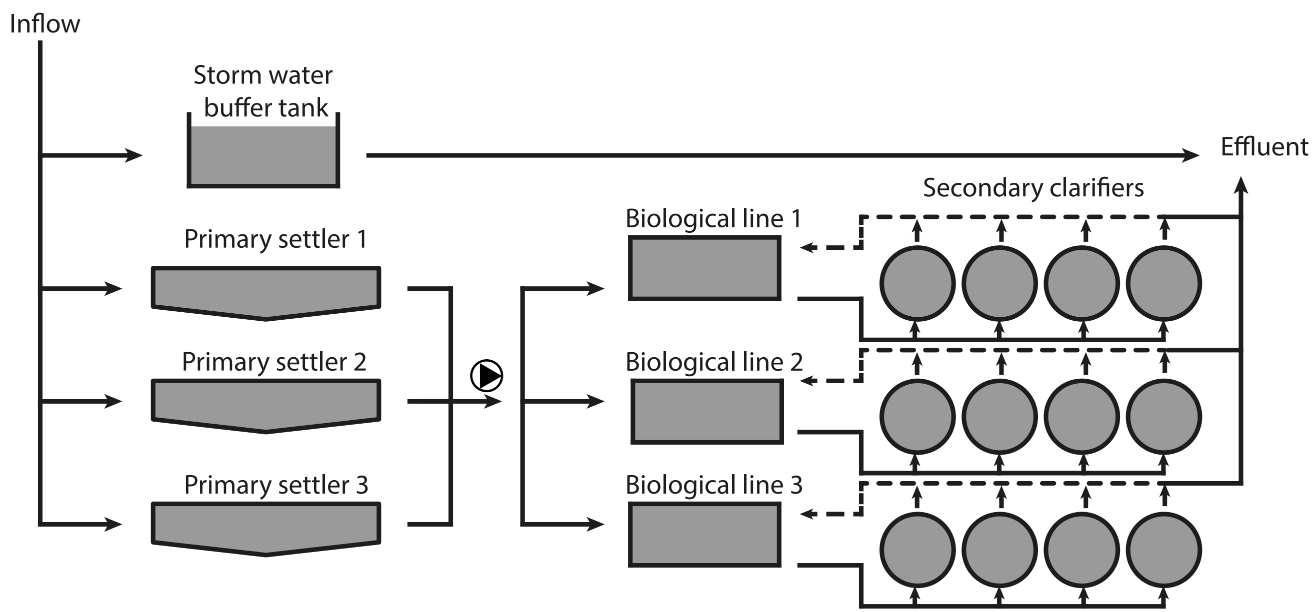


WWTP

- ASM2d Biokinetic model
  Gernaeay and Jøgensen (2004)
- BIOMATH calibration protocol



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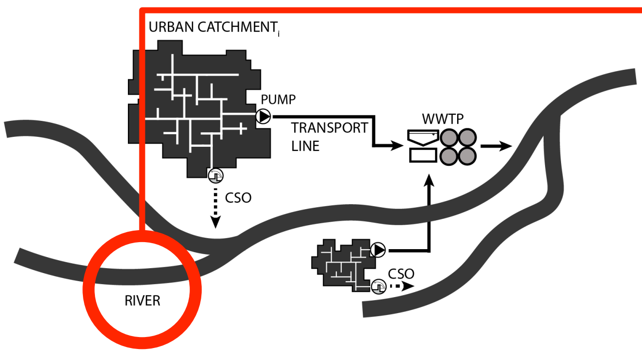
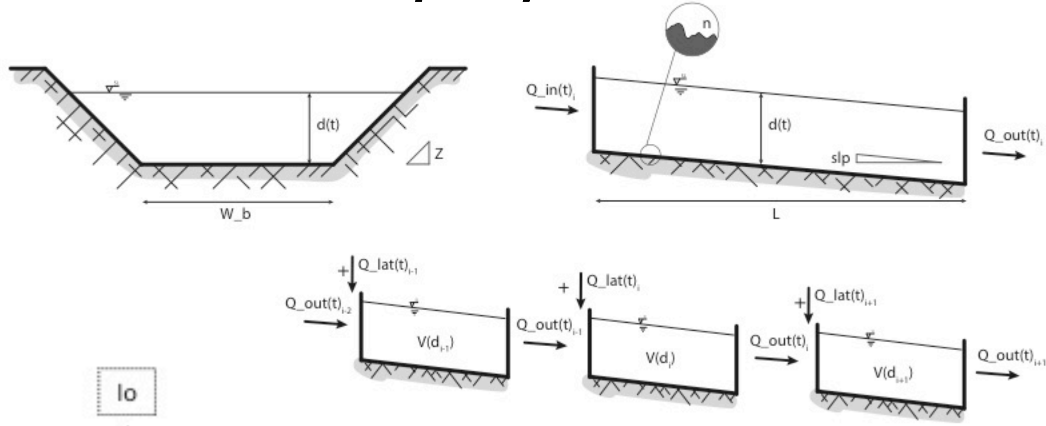
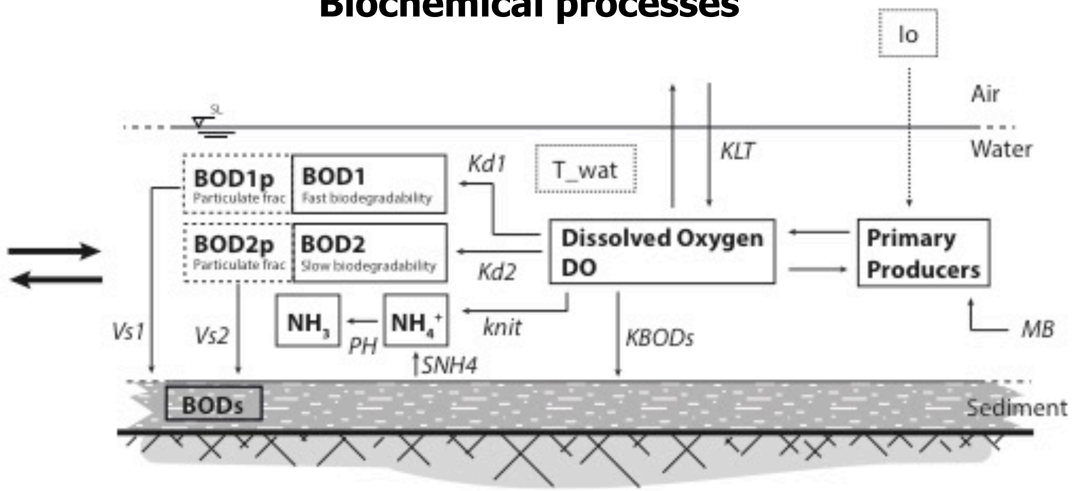


RIVER

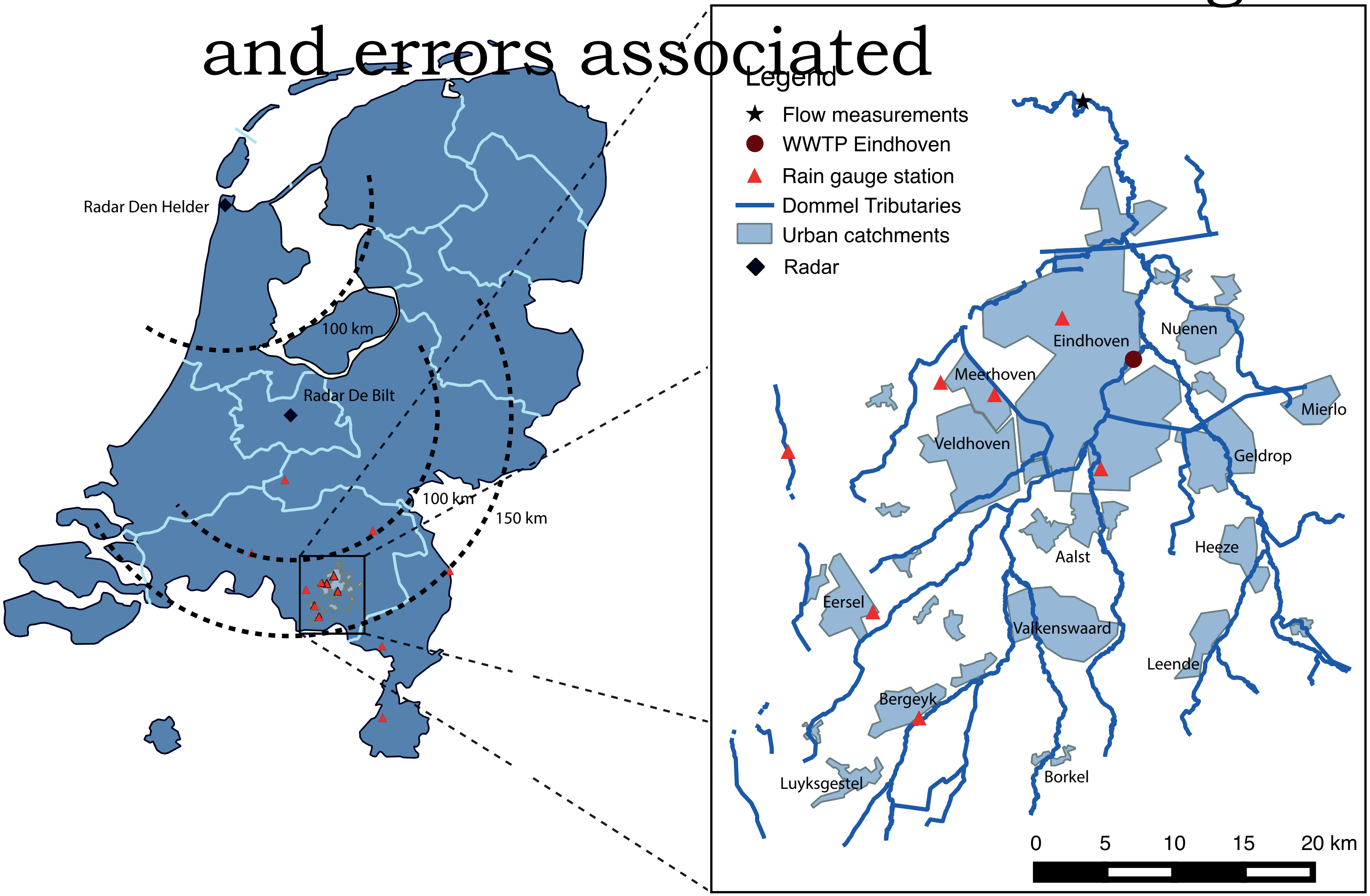
hydrodynamics



Biochemical processes



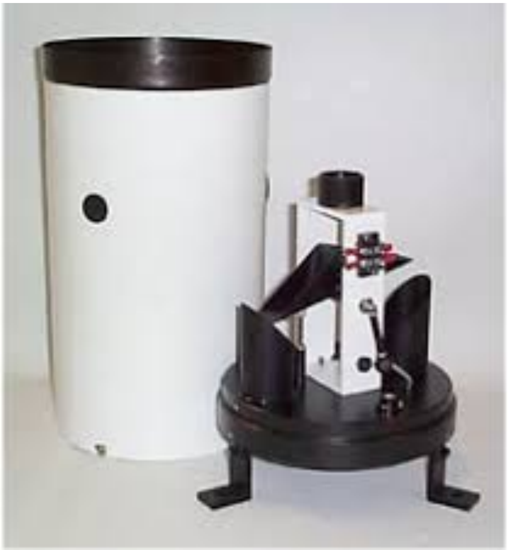
6. Rainfall measurement technologies and errors associated



6. Rainfall measurement technologies and errors associated

Rainfall measurements at the inter-urban scale

Rain gauge:



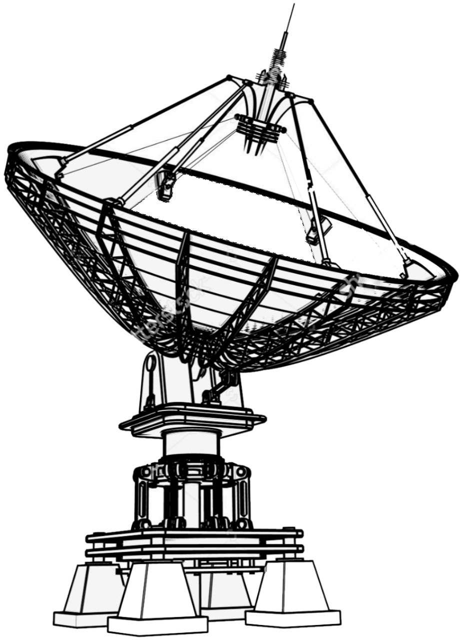
Characteristics:
- Punctual measurement
- Low spatial density
- Accurate

Error sources:
- Wetting loses
- Blockages (leaves, snow)
- Poor maintenance
- Tipping-bucket and high intensity

6. Rainfall measurement technologies and errors associated

Rainfall measurements at the inter-urban scale

C-Band radar:



Characteristics:

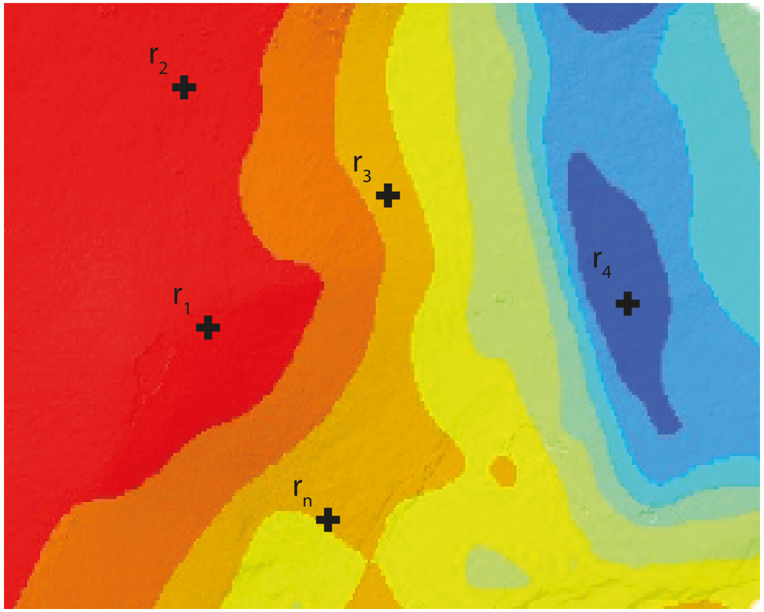
- High spatial density sampling
- Volume/area integration (resolution)
- Indirect estimation (from reflectivity)

Error sources:

- Ground-clutter
- Erroneous Z-R relation
- Bright band
- Attenuation
- Many more

7. Rainfall as a spatial stochastic process

Rainfall variability in time and space.
Convective – Stratiform storm nature.



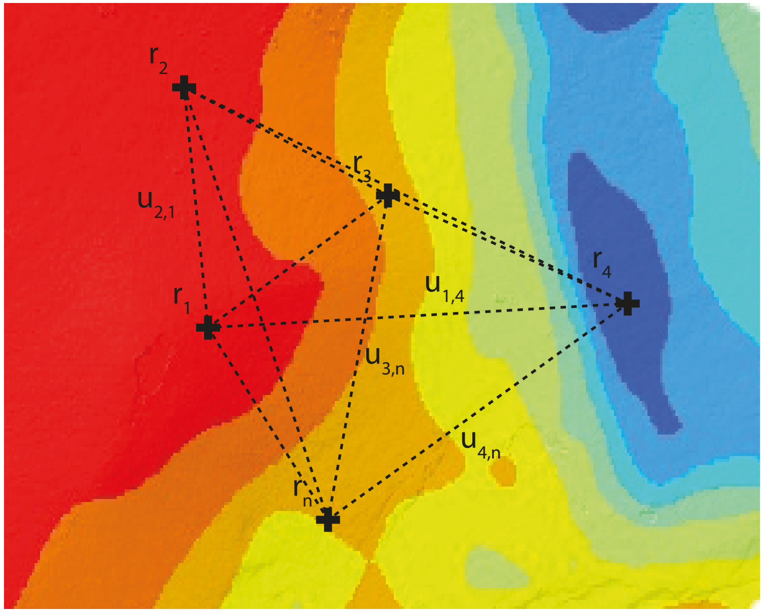
Spatial gaussian process

Conditional probability to known measurements.

Predictions which minimize the variance: (krige) BLUE.

7. Rainfall as a spatial stochastic process

Evaluation of the correlation structure of given measuring points (Rain gauge network).



Semivariogram.

Assumptions:

- Stationarity of the process
- Isotropy

e.g Exponential experimental semivariogam

$$\gamma(d) = \begin{cases} 0 & for\ d = 0 \\ c\left(1 - \exp\left(-\frac{3d}{r}\right)\right) & for\ d > 0 \end{cases}$$

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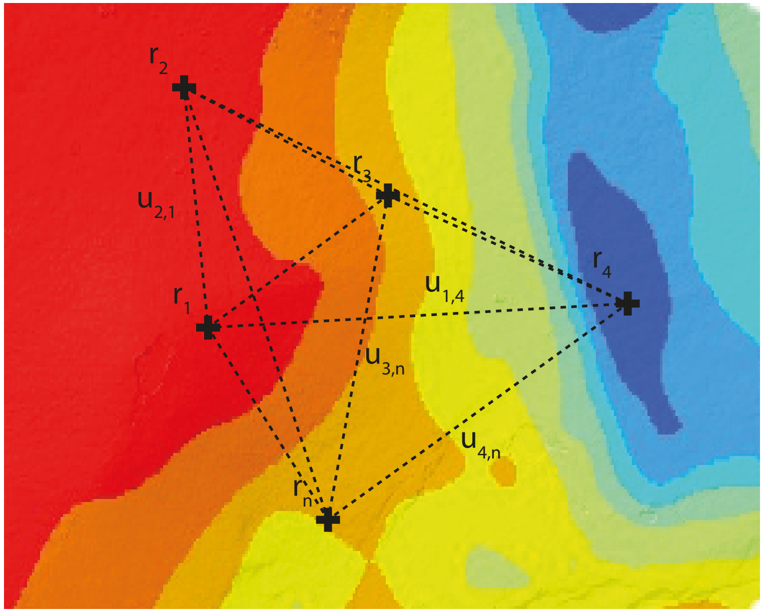

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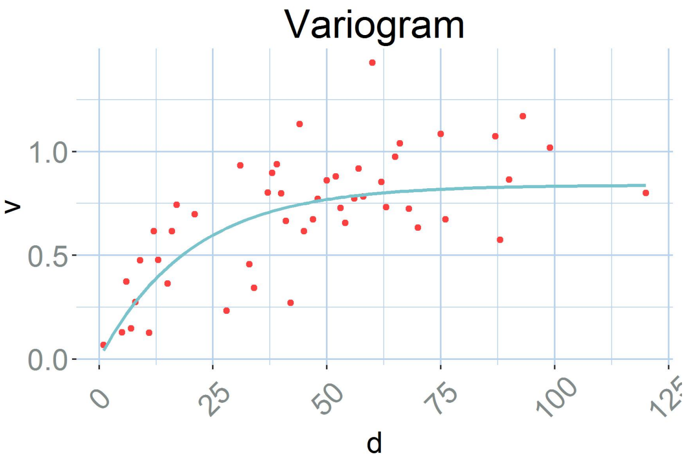
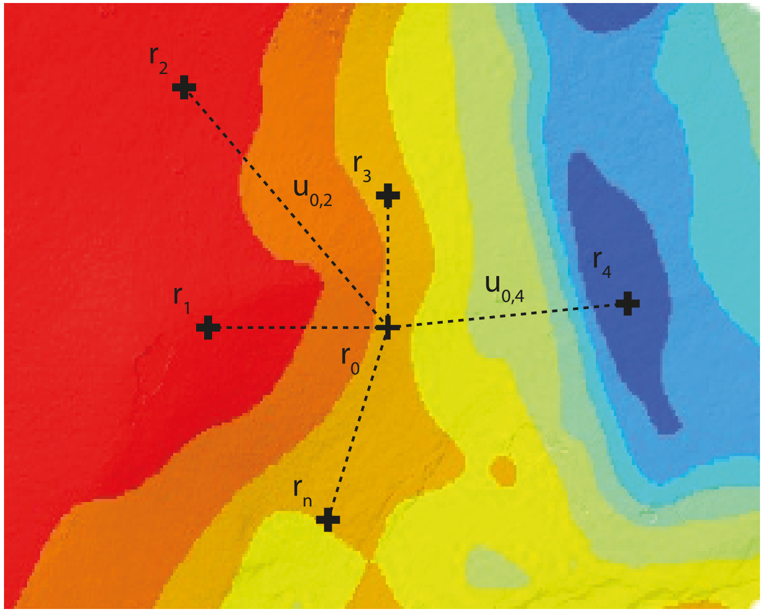


7. Rainfall as a spatial stochastic process

Conditional probability to known measurements.

$$\hat{r}(x_0) = \sum_{i=1}^{n} w_i(x_0) r(x_i)$$

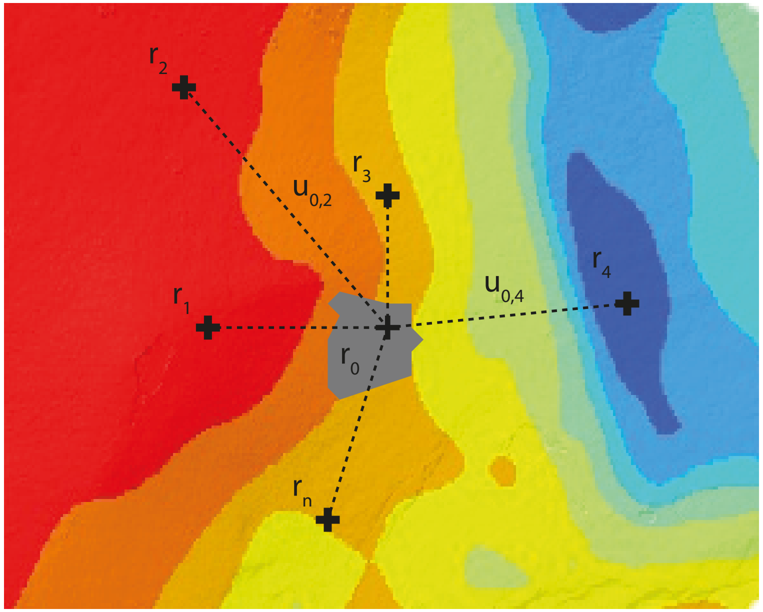


Weighted linear interpolation from the known points to every unsampled location.

Punctual Prediction

7. Rainfall as a spatial stochastic process

Our interest goes on estimating an **averaged rainfall intensity at the urban catchment scale**.

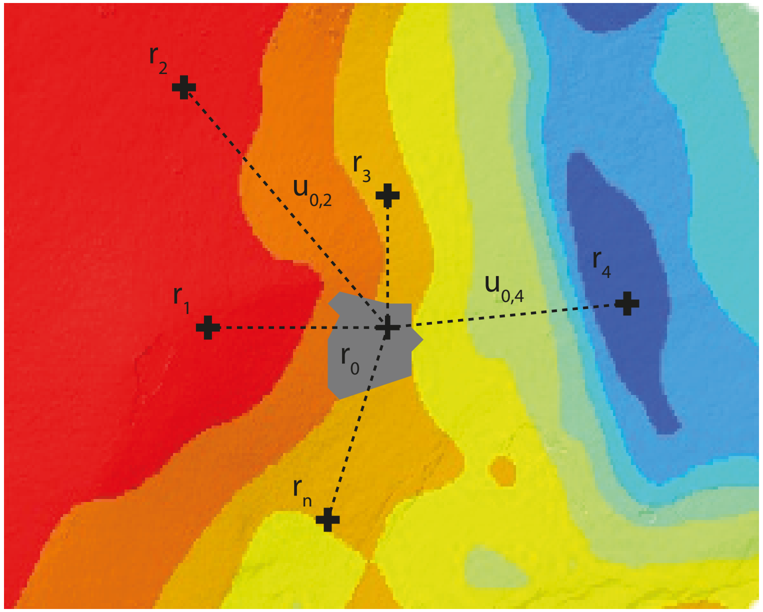


Block kriging. Change of spatial Support for the predictions.

- **Reduction of the prediction variance**

7. Rainfall as a spatial stochastic process

Presence of a covariate: e.g. RADAR



Kriging with external drift.

The average of the regionalized variable is a linear regression of extra variables.

But in our case we still search for the prediction at the block support: **Universal Block kriging**

8. Methods

1. Definition of the block support.

   Georeference of the urban catchment drainage area

2. Measured rainfall intensities:

   How many stations? Rain gauges

   Covariates? Radar

3. Estimation of the event-averaged correlation structures

4. Selection of rainfall accumulation times-spatial density

5. Rainfall estimation at each lumped pseudo-distributed catchment.

6. Comparison of model results with river Dissolved Oxygen monitoring data.

8. Methods

Rainfall Products

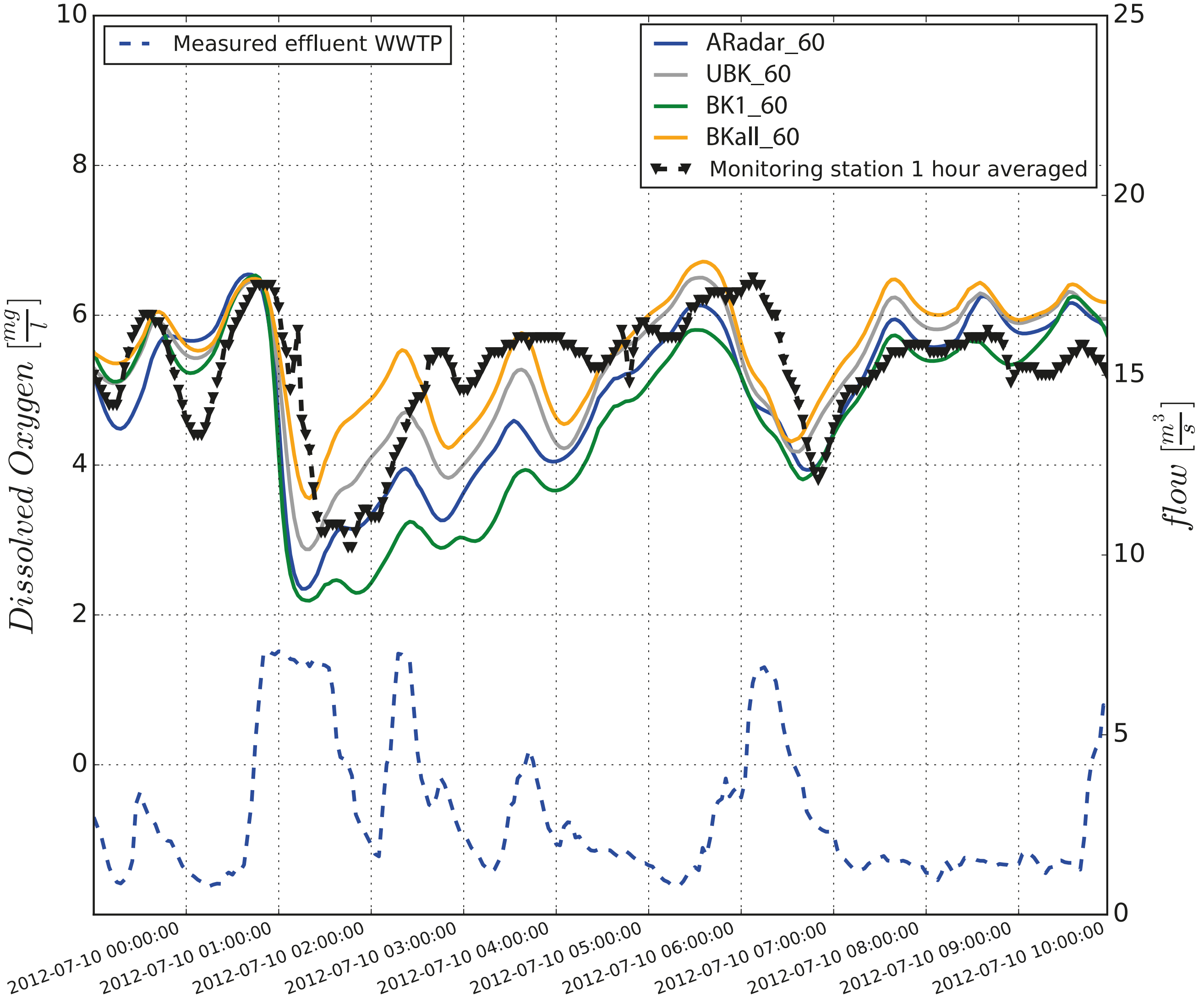
	Spatial information			
Temporal accumulation	**1 RG**	**13 RG**	**13 RG + Radar**	**Averaged Radar**
60'	BK1_60	BKall_60	UBK_60	Aradar_60
30'	BK1_30	Bkall_30	UBK_30	Aradar_30
10'	BK1_10	Bkall_10	UBK_10	Aradar_10

Period	2011-08-18_2011-08-31	2012-07-05_2012-08-04	2013-07-25_2013-08-19
Duration	13 days	30 days	25 days

Performance comparison: 2 Metrics

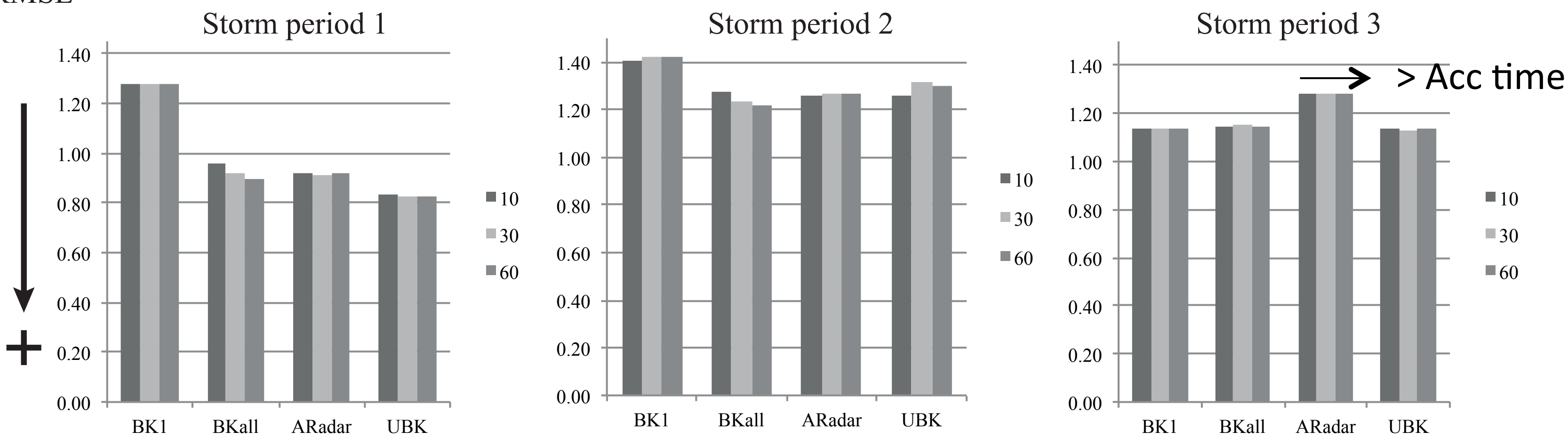
- RMSE at the DO modelled-monitored
- Max oxygen drop difference

9. Simulation

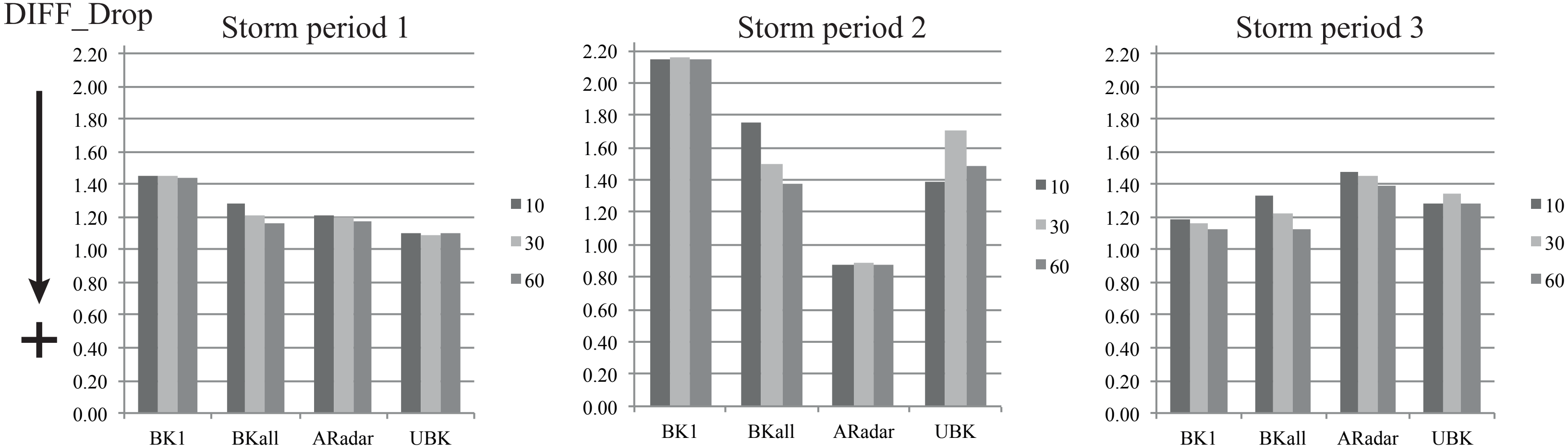


10. Preliminary results

RMSE



DIFF_Drop

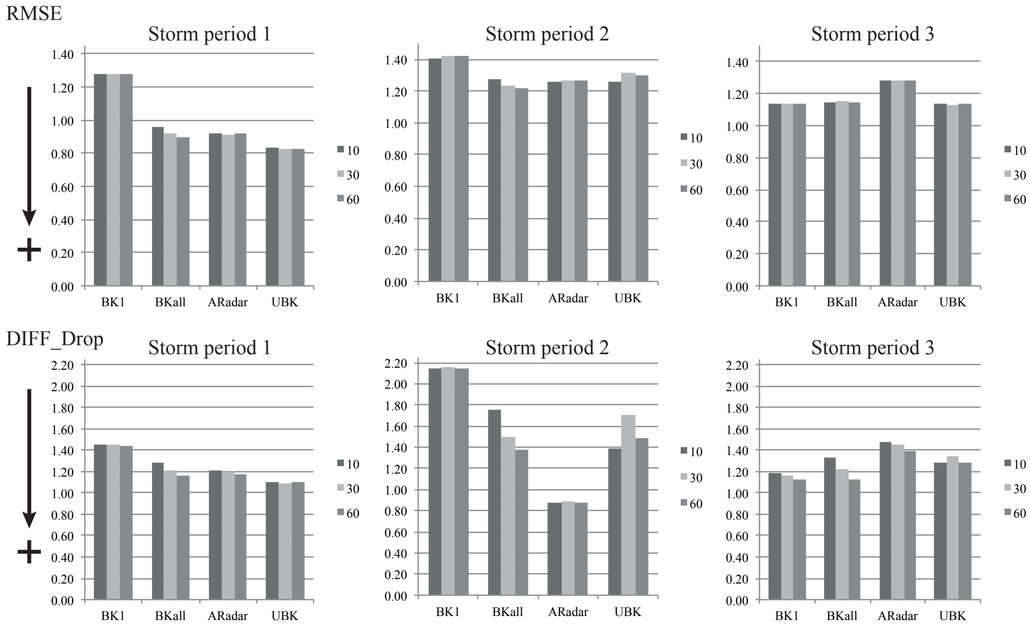


10. Preliminary results

Averaged spatial correlation structure:

	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

11. Conclusions-Discussion



- Low sensitivity of the results to the temporal resolution used.
- Effect of spatial resolution. Especially single rain gauge vs spatially distributed rainfall.

11. Conclusions-Discussion

What can we say about these preliminary conclusions?

Dependency on:

1- Rainfall event selected. Highly spatially variable?

2- Selection of the rainfall prediction methods.

- Non-gaussianity.
- OK sensitivity to high time resolutions (possible instabilities).
- Correlation anisotropy.
- Averaged correlation structure

3- Real system's characteristics vs **Model structure**

Are the urban drainage/river dynamics correctly represented?

Need of CSO's flow estimations/data to check local-model performance.

THANKS FOR YOUR ATTENTION

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 607000.