Tools to support a wider implementation of Real Time Control of urban drainage systems

The wonderful word of online control

- Real Time Control has shown a great potential for reducing CSO volumes

  Plenty of scientific publications showing it

HOWEVER

- Difficult to agree on evaluation criteria with limited dataset

  Long time data series are needed

- Simple approaches are sometimes neglected

  Long time data series are needed

RTC in NOAH

- Evaluation of RTC potential with limited dataseries
- Autocalibration of simple rule-based control strategies

Evaluation of RTC potential with limited data

My control strategy is great

Developer of RTC

(wants to sell the control)

Show me!

Utility Manager

(wants to improve the system performance)

Let's run some simulations!

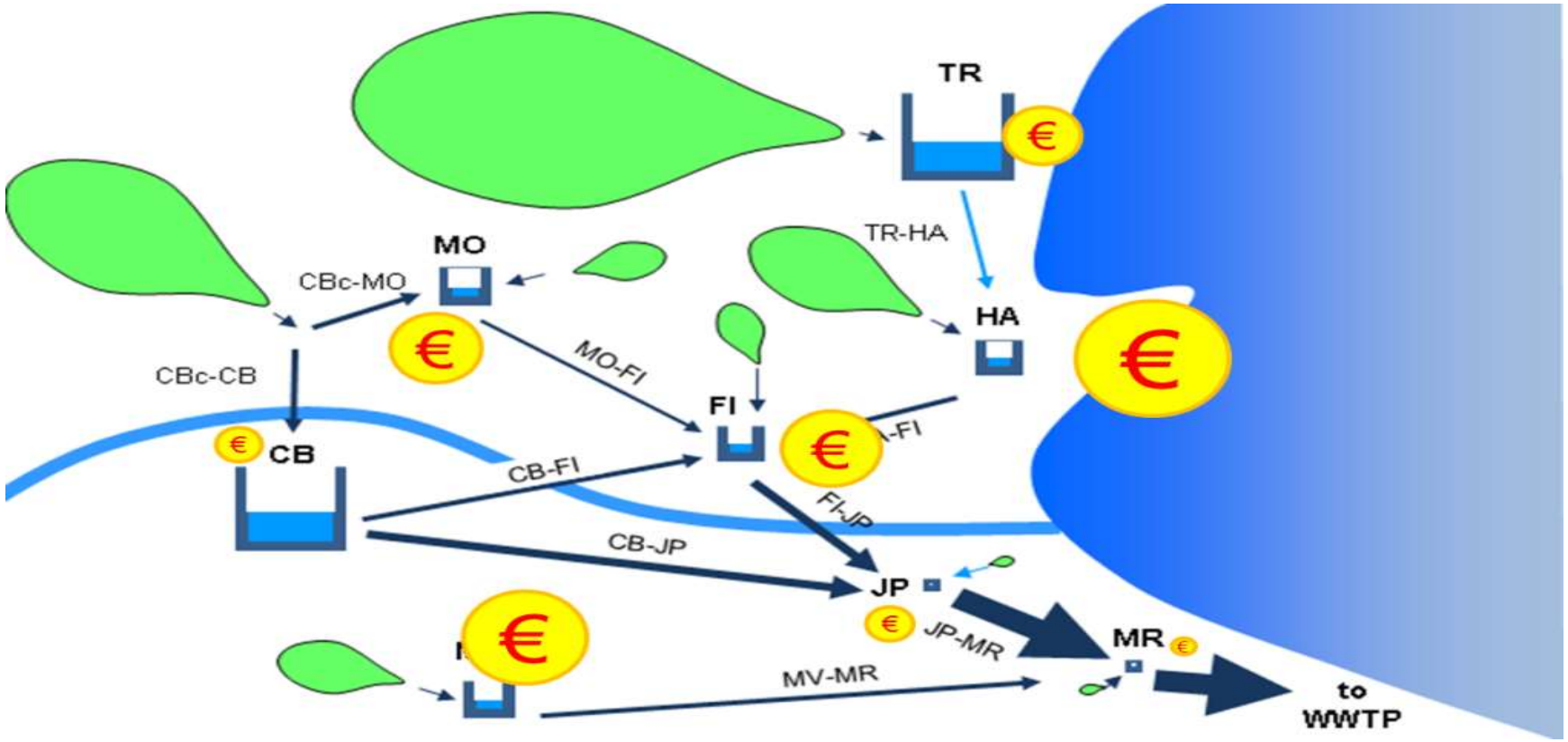
How many?

Which events?

Why one-few events are not enough

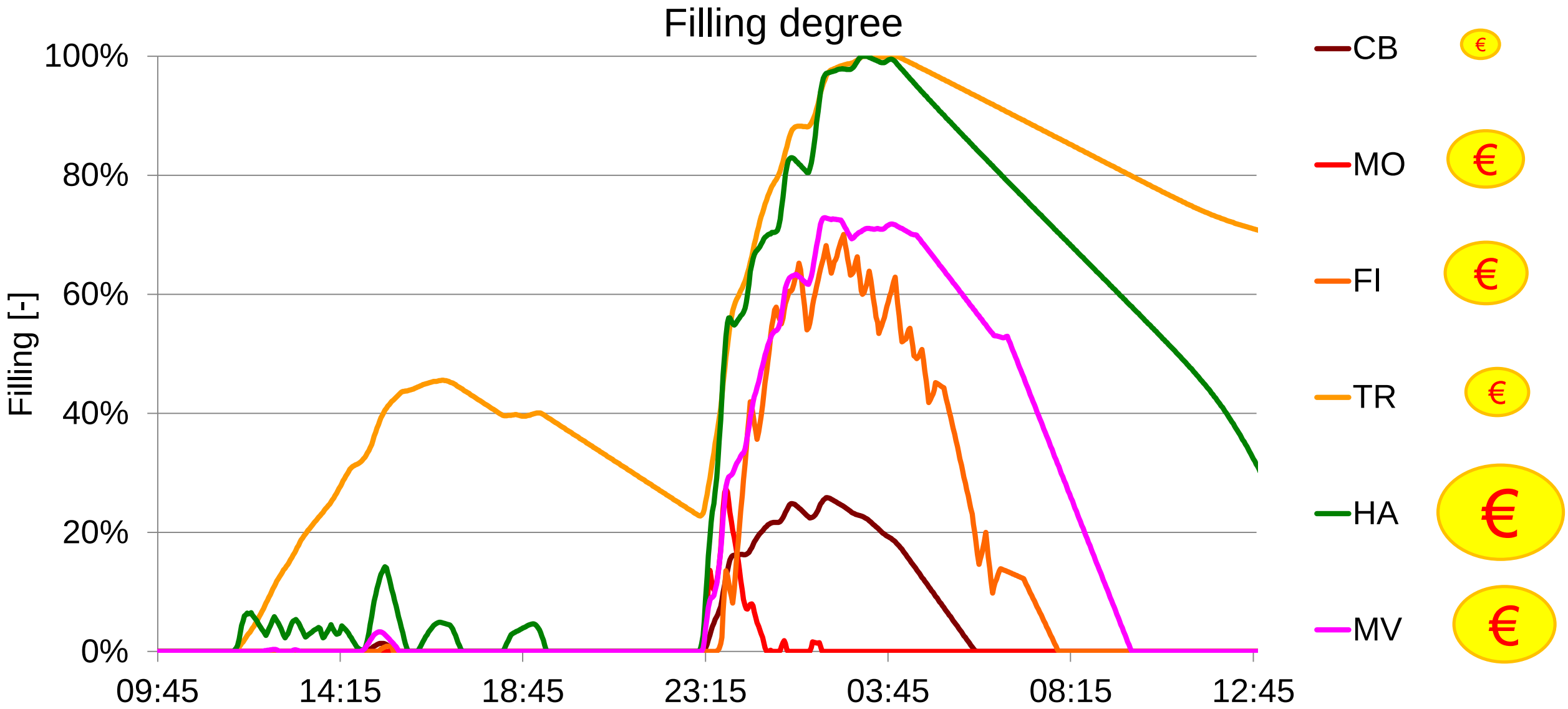
Example from Aarhus integrated control

Aarhus simplified system



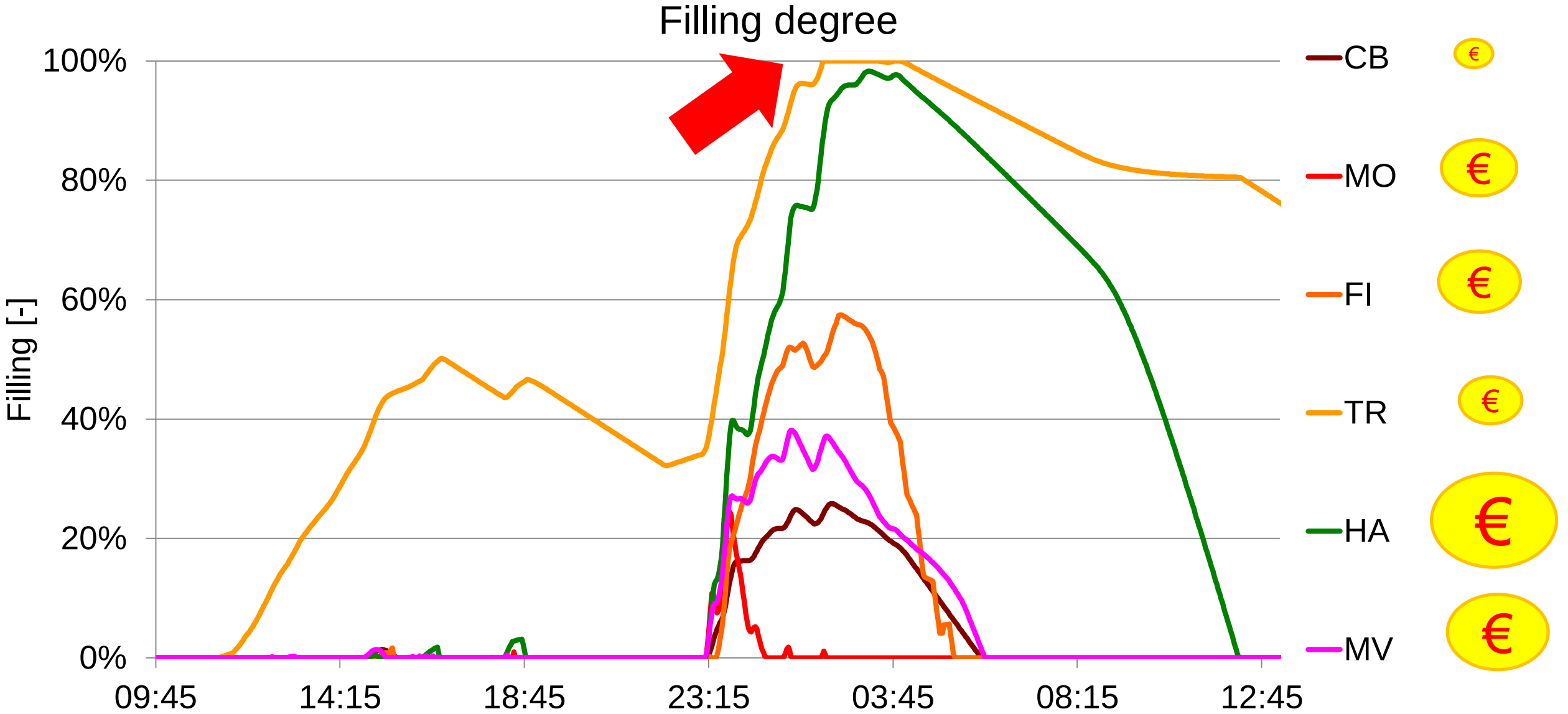
Event 1995-09-03

Without forecasts



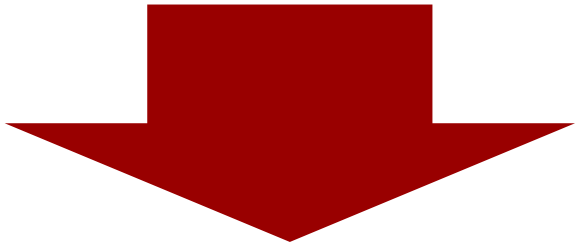
Event 1995-09-03

With forecasts



One (few) events are not enough

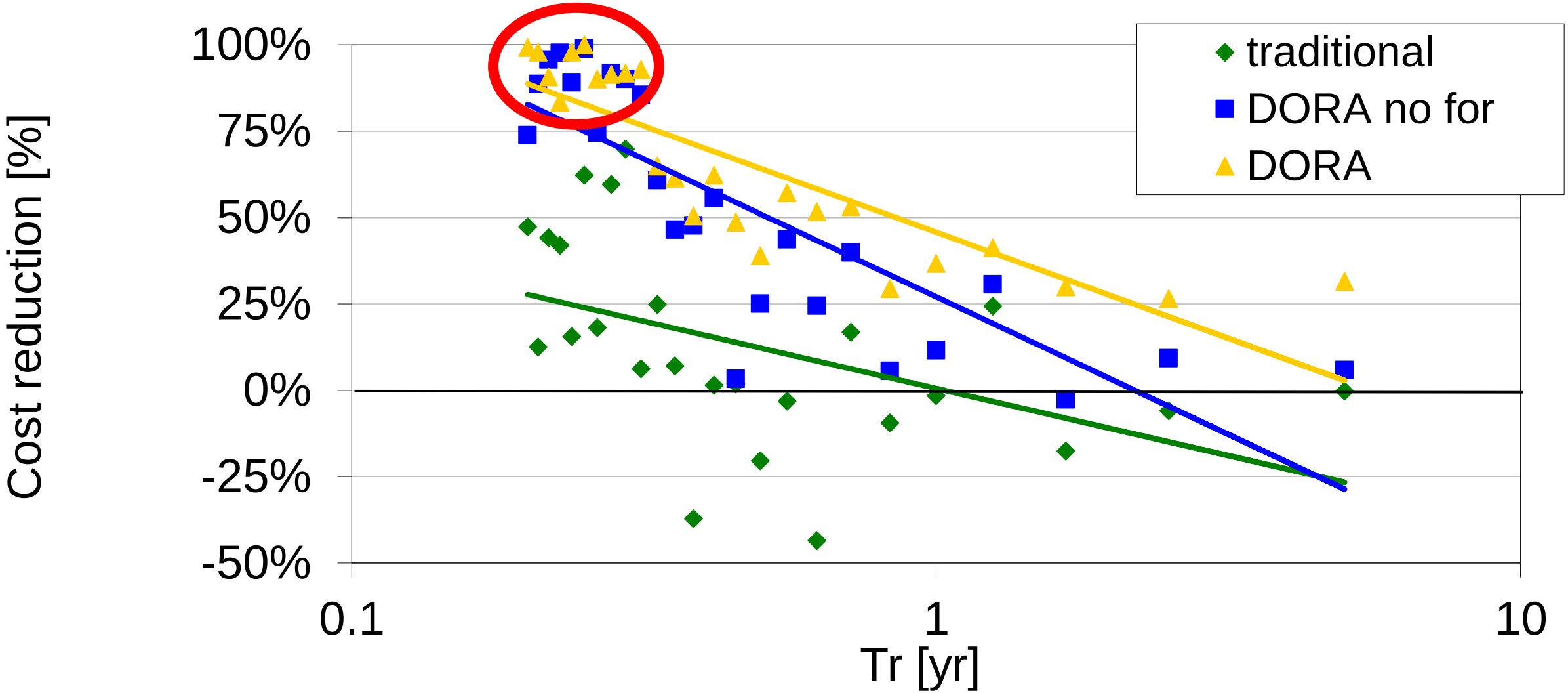
Based on event on 1995-09-03, RTC is worsening the performance of my system



More events

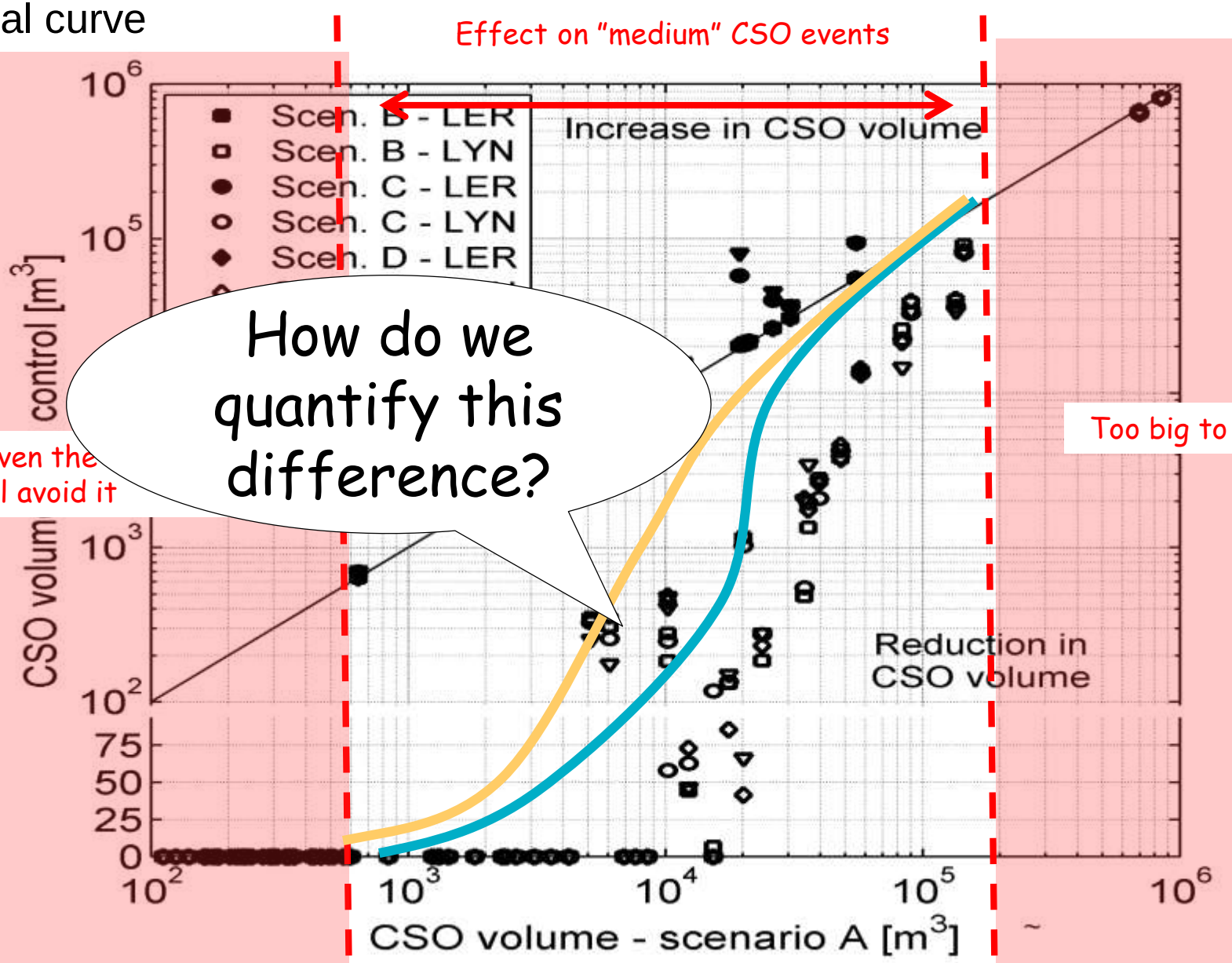
Performance against return period

Cost reduction



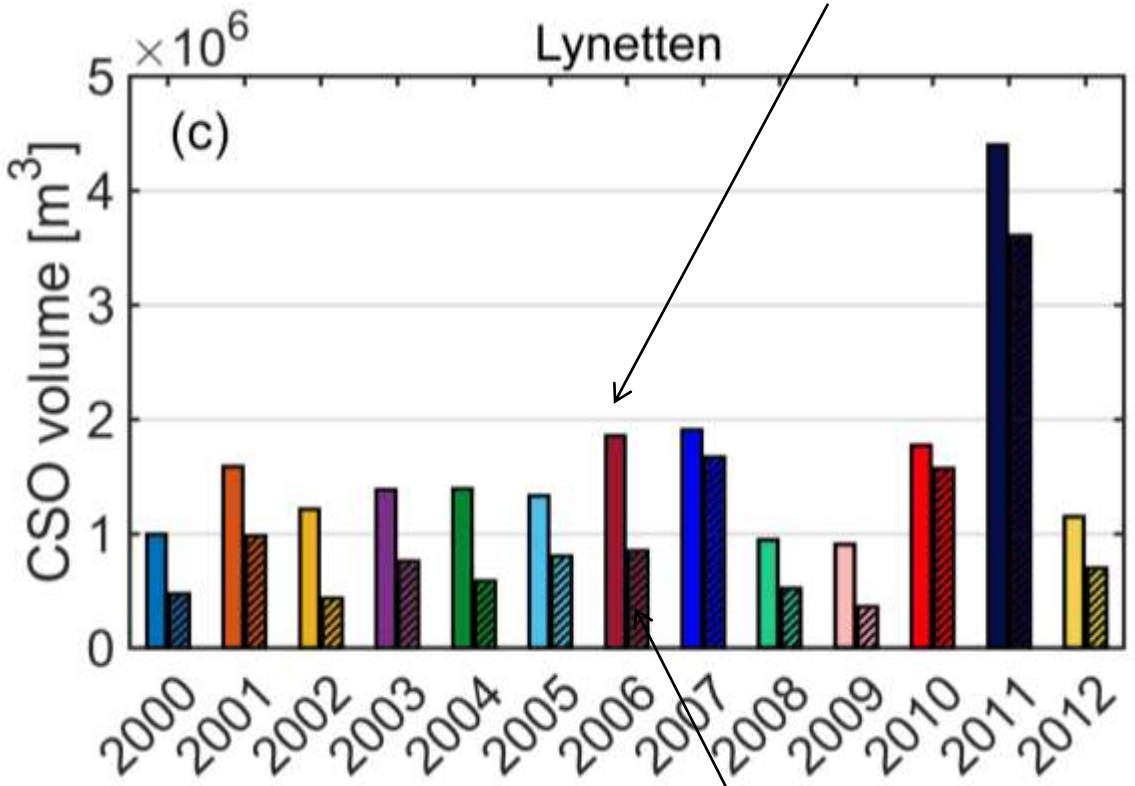
Analysis of CSO events

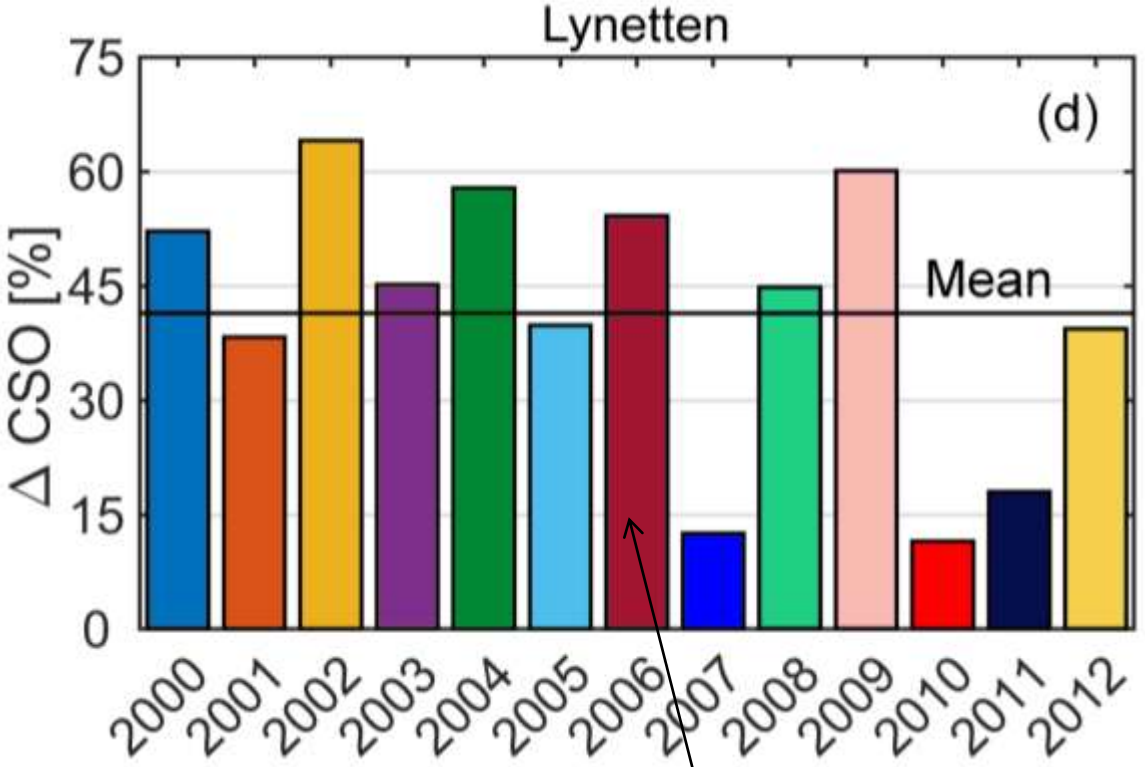
The classical curve



In the ideal world – long time series

Yearly volume without RTC





Yearly volume with RTC

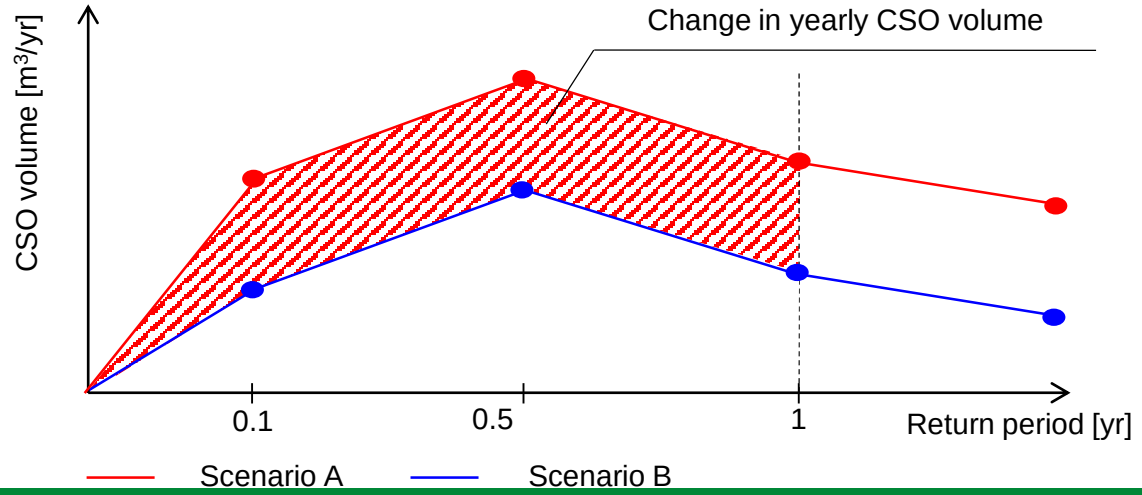
CSO vol reduction for different years

What if I have not enough data/time?

- Sometimes you do not have enough data/time to run long time series?

You can try to extrapolate your results

1. You know the magnitude of your event (as return period)
2. You can weight your result by the magnitude
3. You can extrapolate your yearly performance

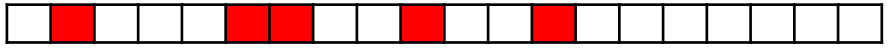


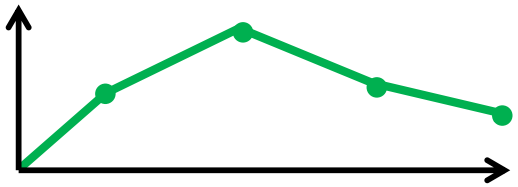
Method testing

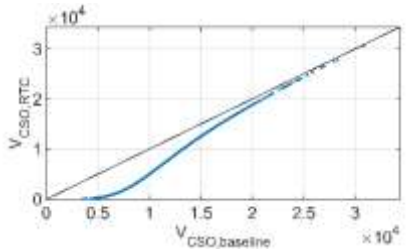
Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10

Results from 13 yrs simulation in Lynetten catchment

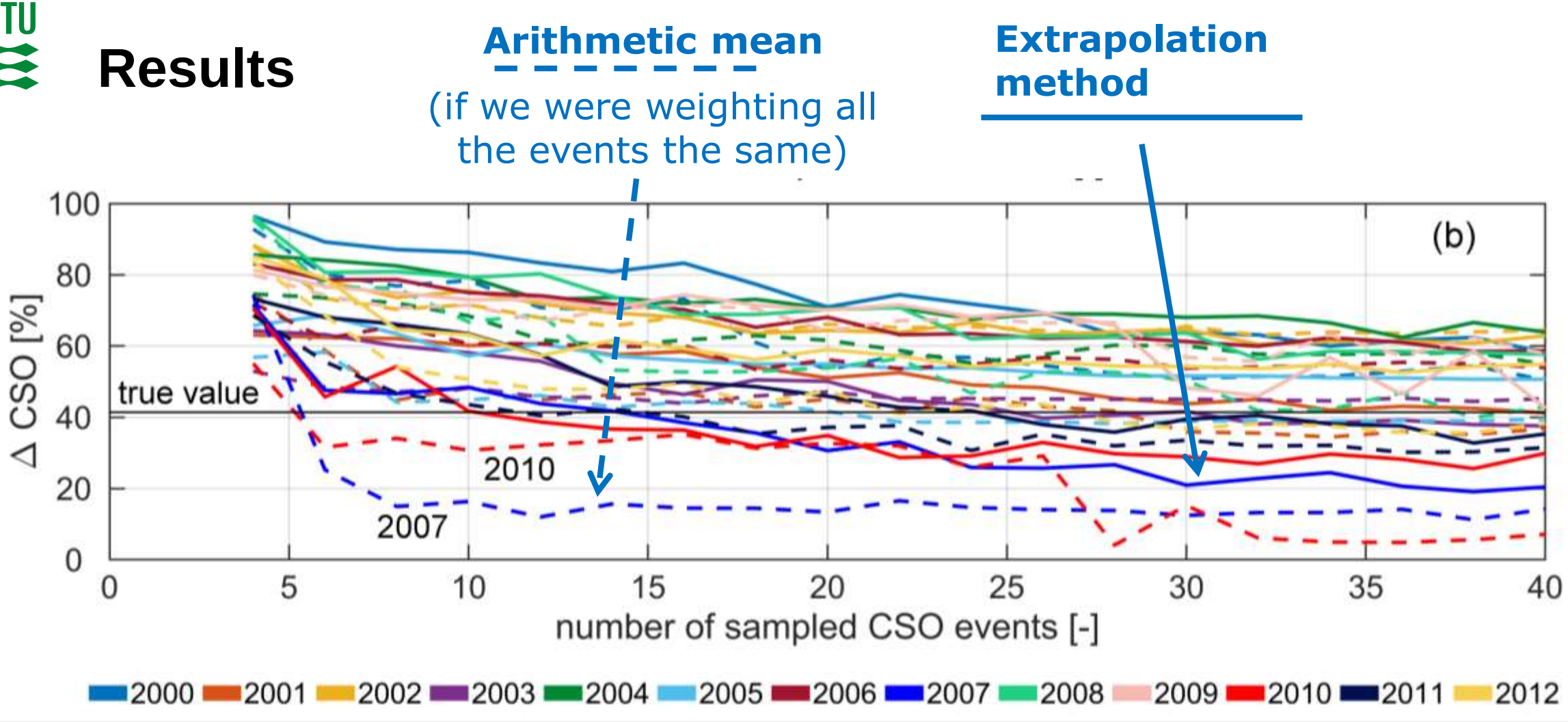
1. *Select a year j in the dataset*
2. *Select n events within the year j*
3. *Calculate the MPC performance based on this event sample*
4. *Compare against the "true" performance*
5. *Repeat 1-4, with increasing n*







Results



- The method tends to overestimate the RTC performance by 10-20%
- Smaller errors compared to arithmetic mean

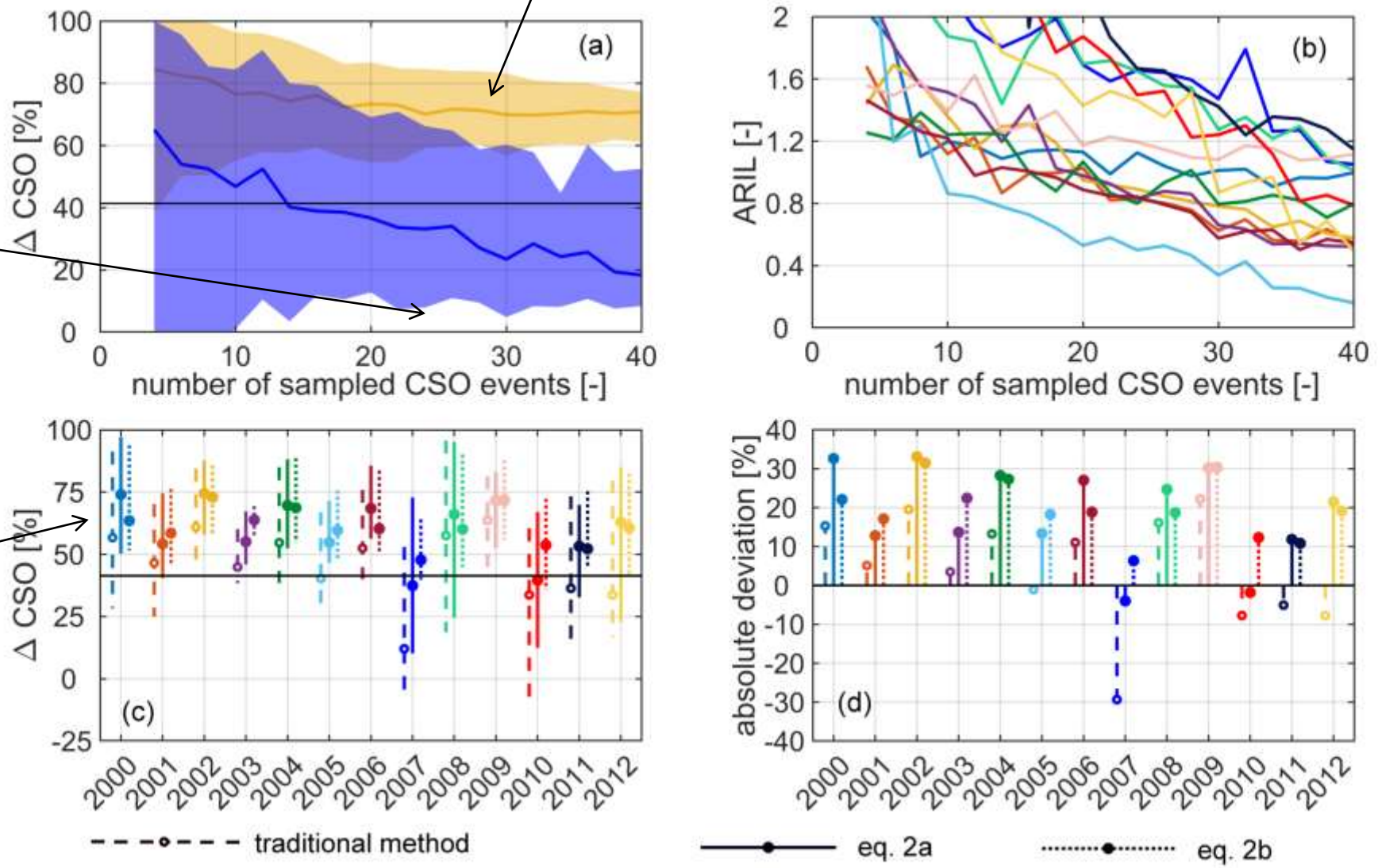
Results

Test of robustness

Convergenge for two years

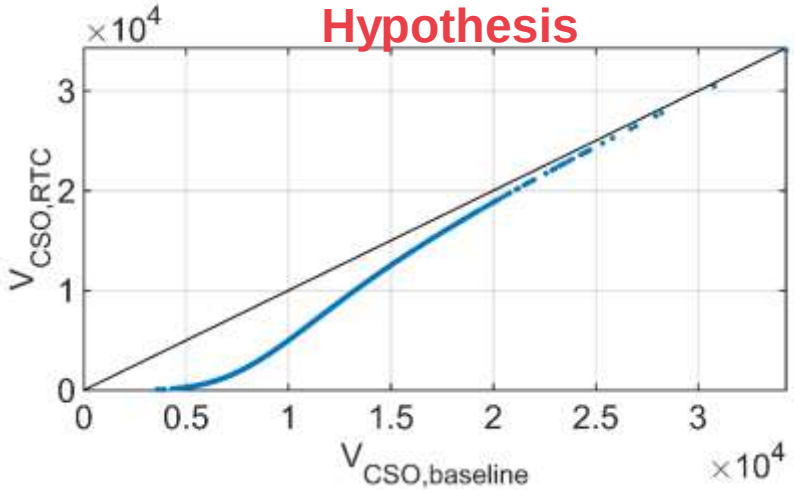
At least 25-30 events to say something

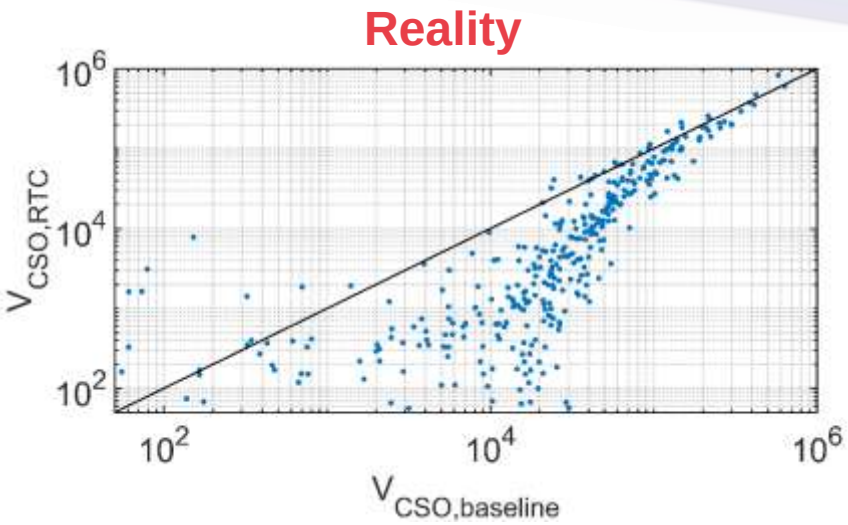
It matters which events you use for the evaluation

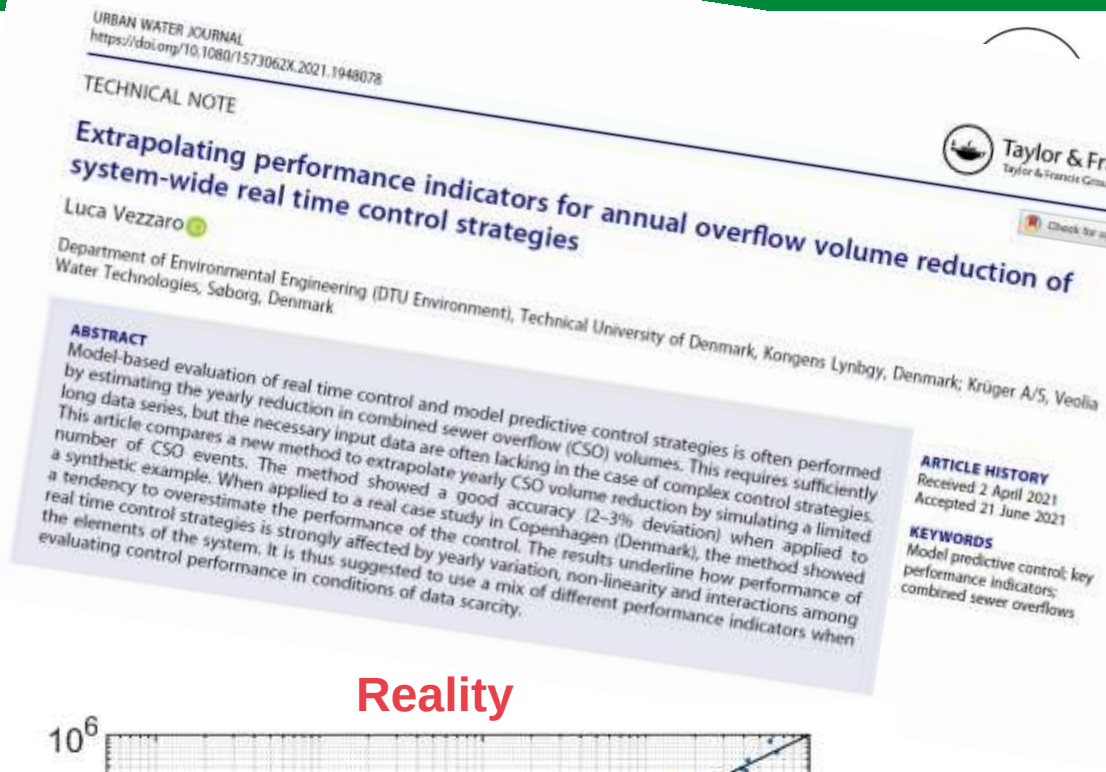


More results...

- Take home message: unfortunately, not a silver bullet
- RTC perfomance are not (always) dependentan on CSO volume/return period



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https://doi.org/10.1080/1573062X.2021.1948078

TECHNICAL NOTE

Taylor & Fr

Extrapolating performance indicators for annual overflow volume reduction of system-wide real time control strategies

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ABSTRACT

Model-based evaluation of real time control and model predictive control strategies is often performed by estimating the yearly reduction in combined sewer overflow (CSO) volumes. This requires sufficiently long data series, but the necessary input data are often lacking in the case of complex control strategies. This article compares a new method to extrapolate yearly CSO volume reduction by simulating a limited number of CSO events. The method showed a good accuracy (2–3% deviation) when applied to a synthetic example. When applied to a real case study in Copenhagen (Denmark), the method showed a tendency to overestimate the performance of the control. The results underline how performance of real time control strategies is strongly affected by yearly variation, non-linearity and interactions among the elements of the system. It is thus suggested to use a mix of different performance indicators when evaluating control performance in conditions of data scarcity.

ARTICLE HISTORY
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KEYWORDS
Model predictive control; key performance indicators; combined sewer overflows

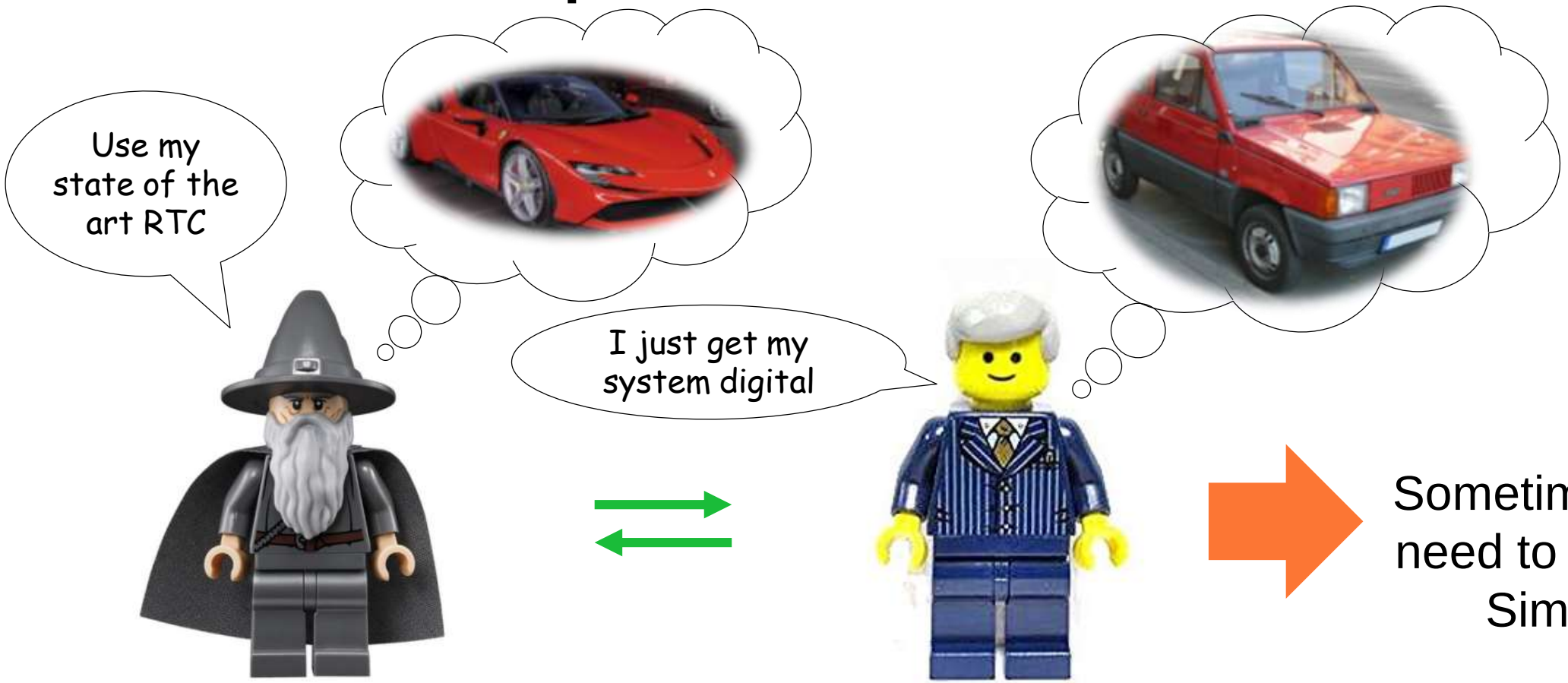
- In case of limited data, better to use multilple different indicators

RTC in NOAH

- Evaluation of RTC potential with limited dataseries

- Autocalibration of simple rule-based control strategies

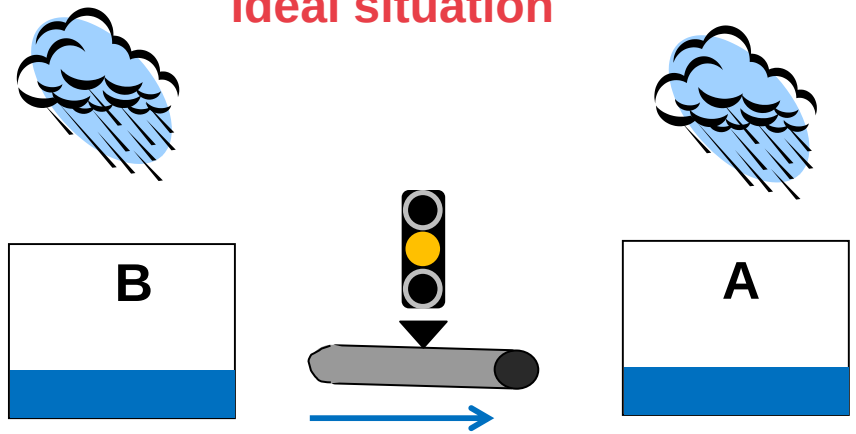
Evaluation of RTC potential with limited data

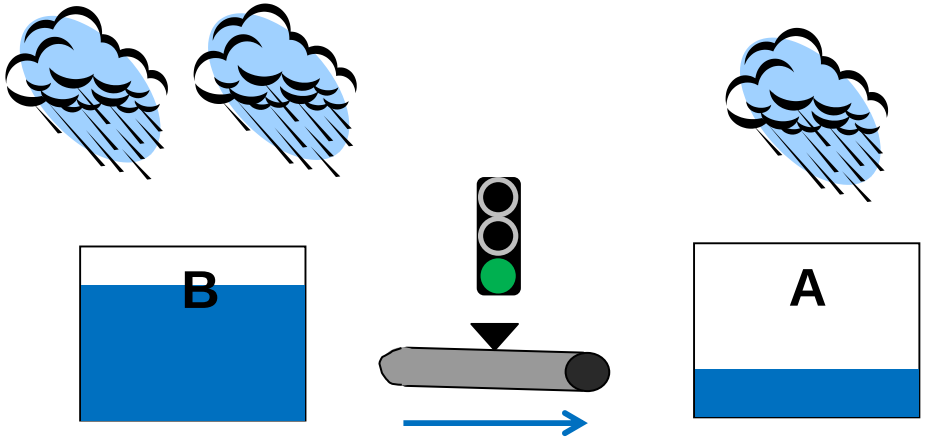


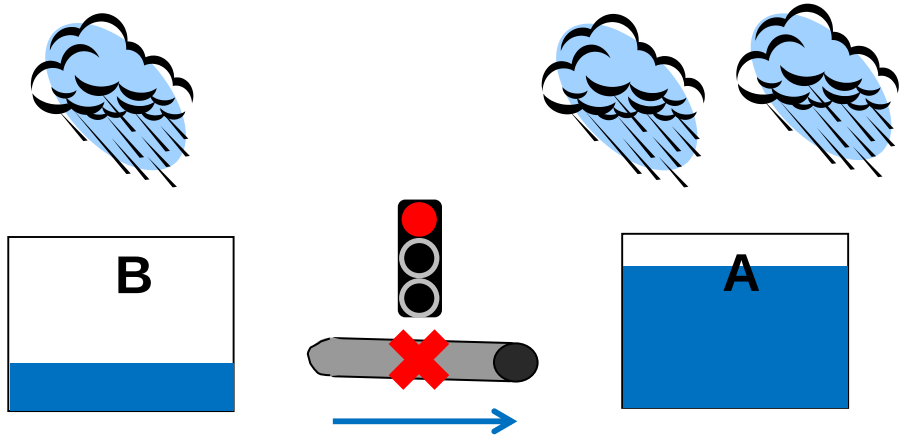
Basic control

Equal filling

Ideal situation

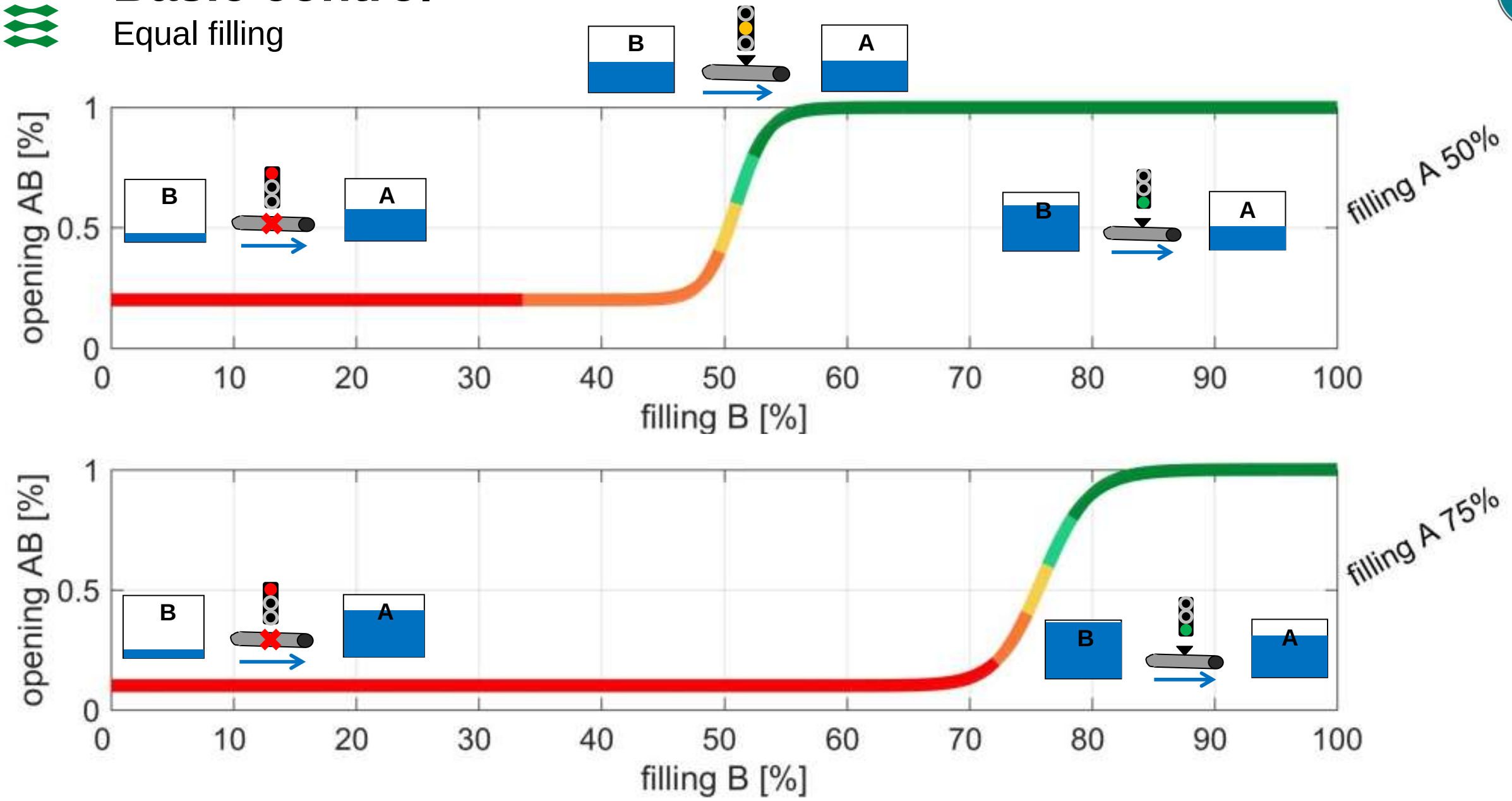






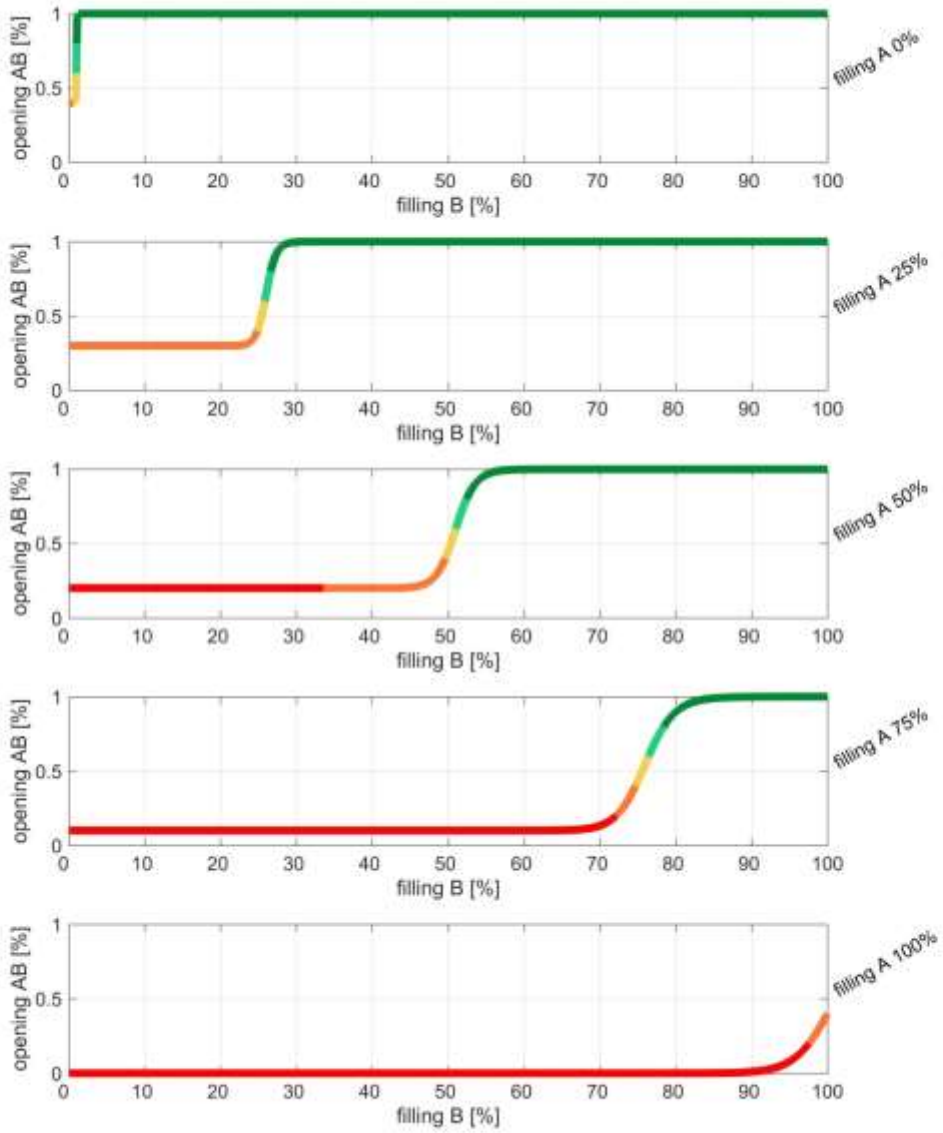
Basic control

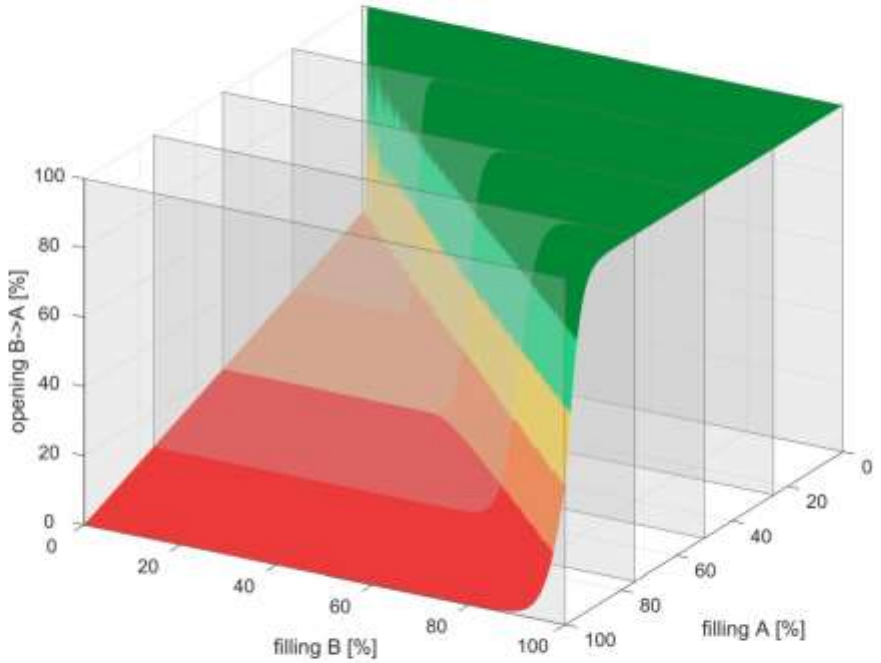
Equal filling



Basic control

Equal filling





Basic control

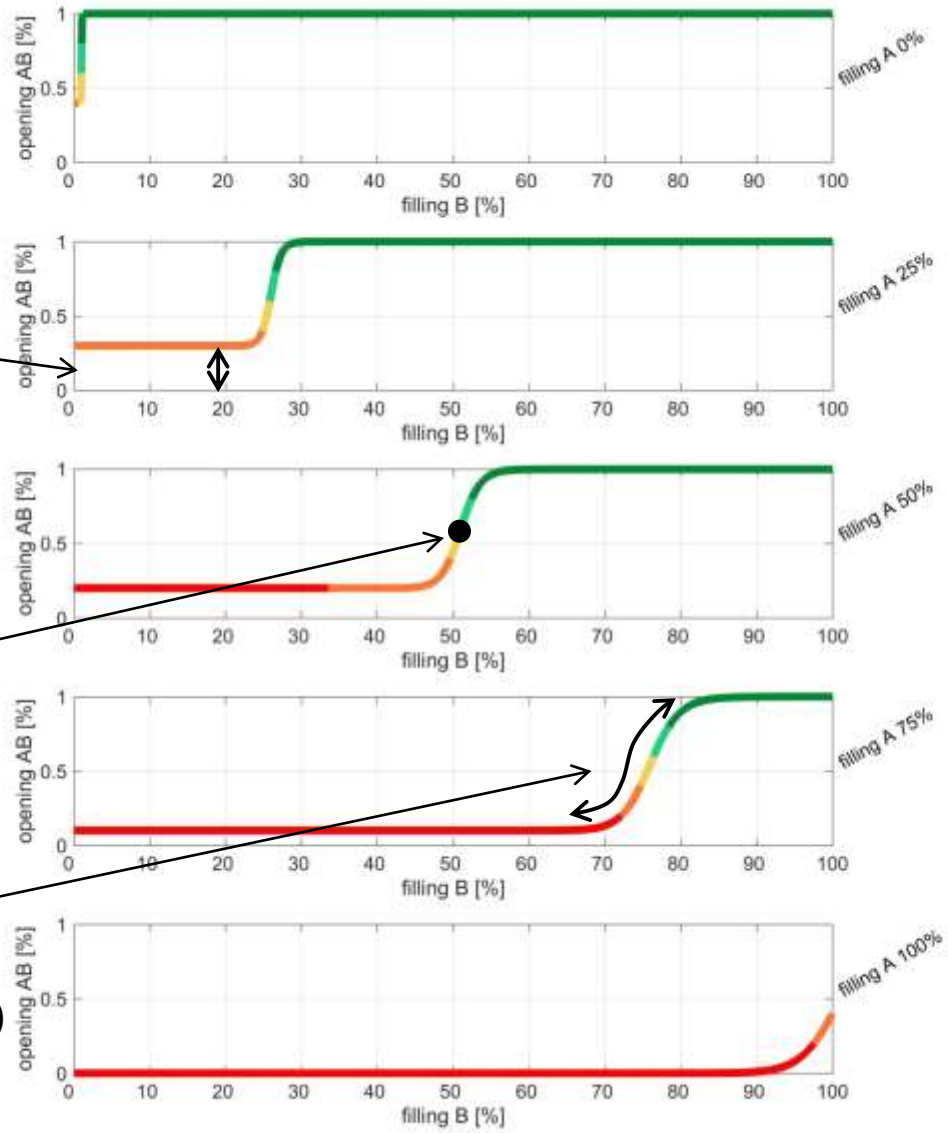
Equal filling

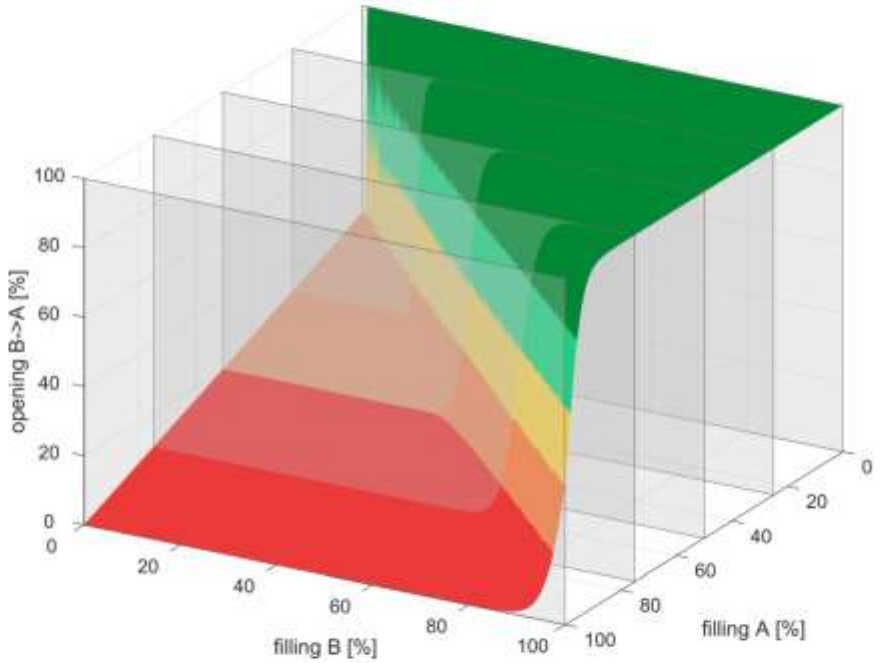
$$\theta_{BA} = \left(1 - \beta(1 - \varphi_B)\right) \frac{{\varphi^n}_A}{(\varphi_B + \alpha)^n + {\varphi^n}_A} + \beta(1 - \varphi_B)$$

β
(minimum allowed flow)

α(inflection point)

n
(how quick the opening should be)

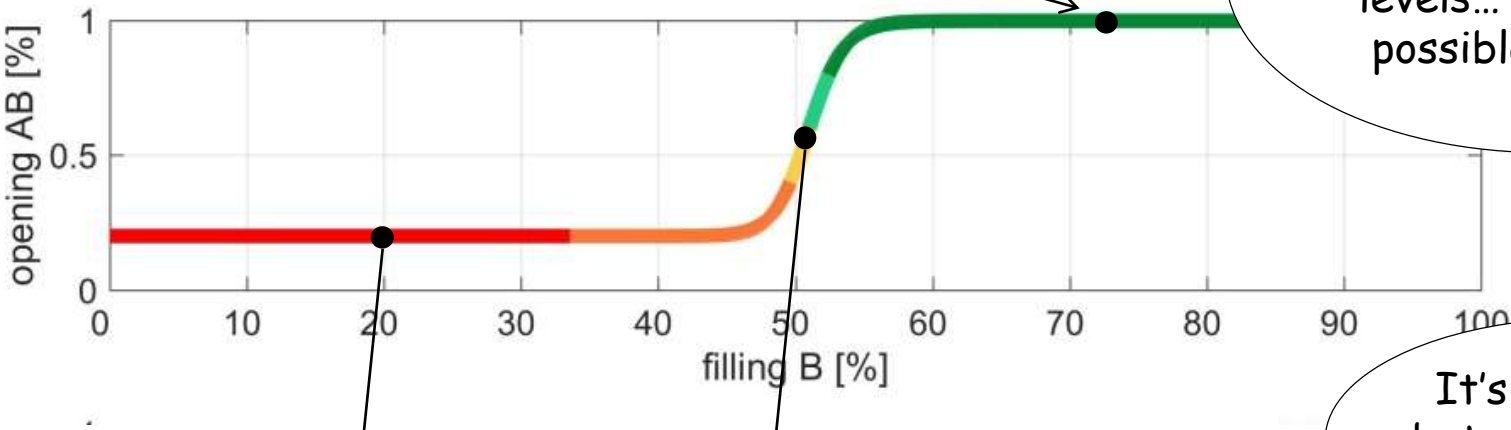




Basic control

from theory to if-then rules

If filling A=50% and filling B=75%, then θ_{BA}=100%



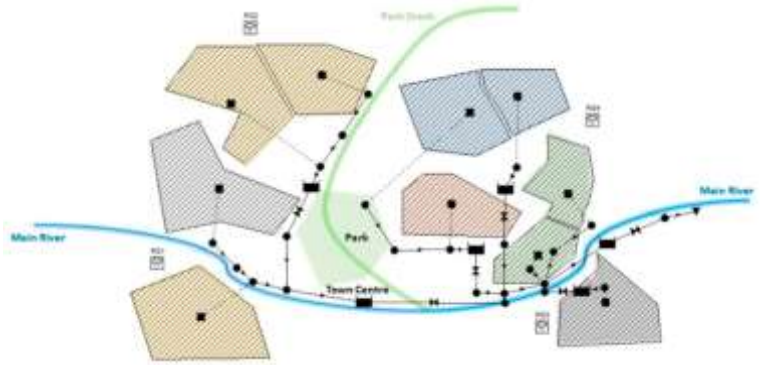
Three parameters, several discretization levels… it's a lot of possible settings!

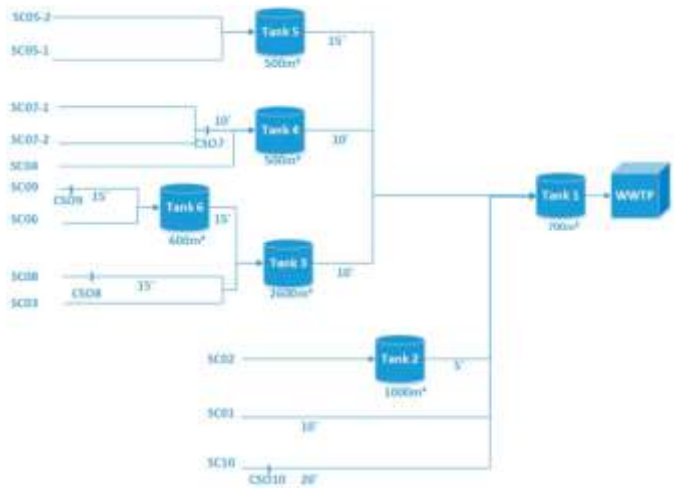
It's a dirty job, but somebody has to do it

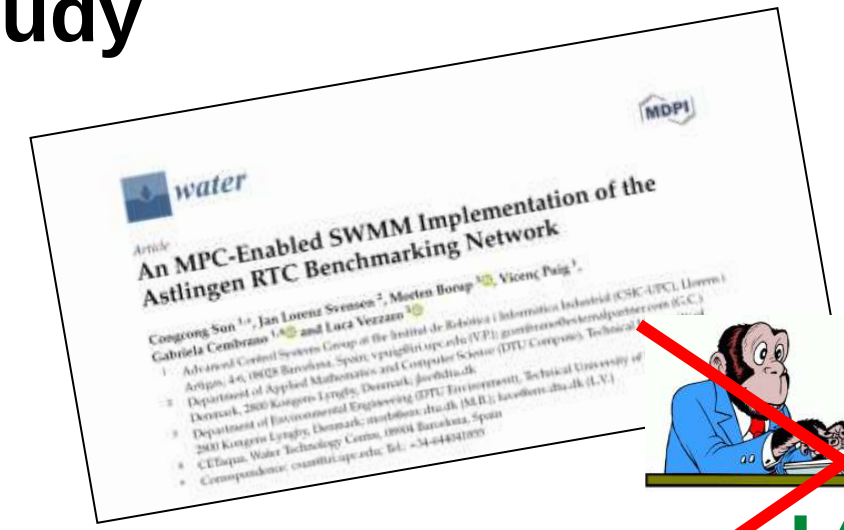
If filling A=50% and filling B=50%, then θ_{BA}=50%

If filling A=50% and filling B=20%, then θ_{BA}=20%

Astlingen case study

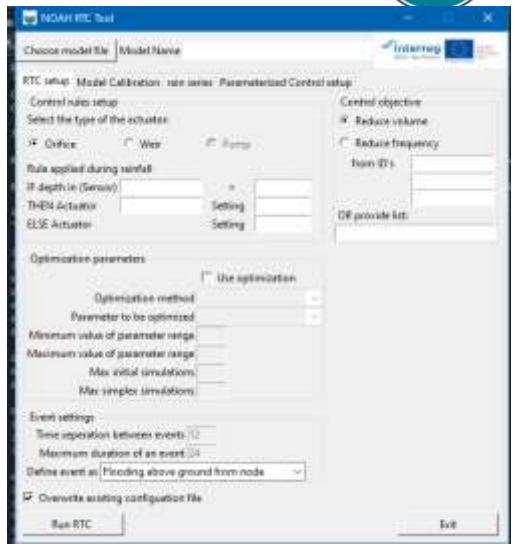





water

Article

An MPC-Enabled SWMM Implementation of the Astlingen RTC Benchmarking Network



Trial and error

SWMM model

results

Set-point (if-then rules

python

RTC settings (actuators/ sensors)

NOAH RTC Tool

optimizer

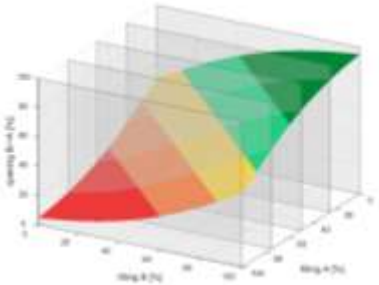
Finds the best set up

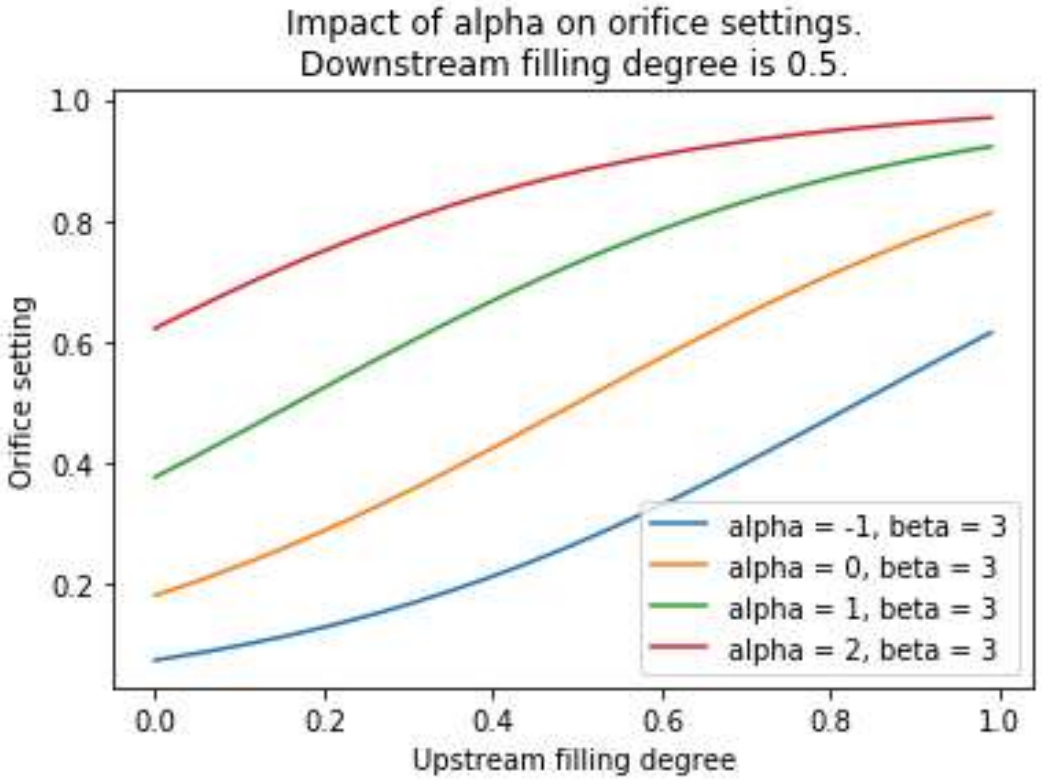
Test on Astlingen system

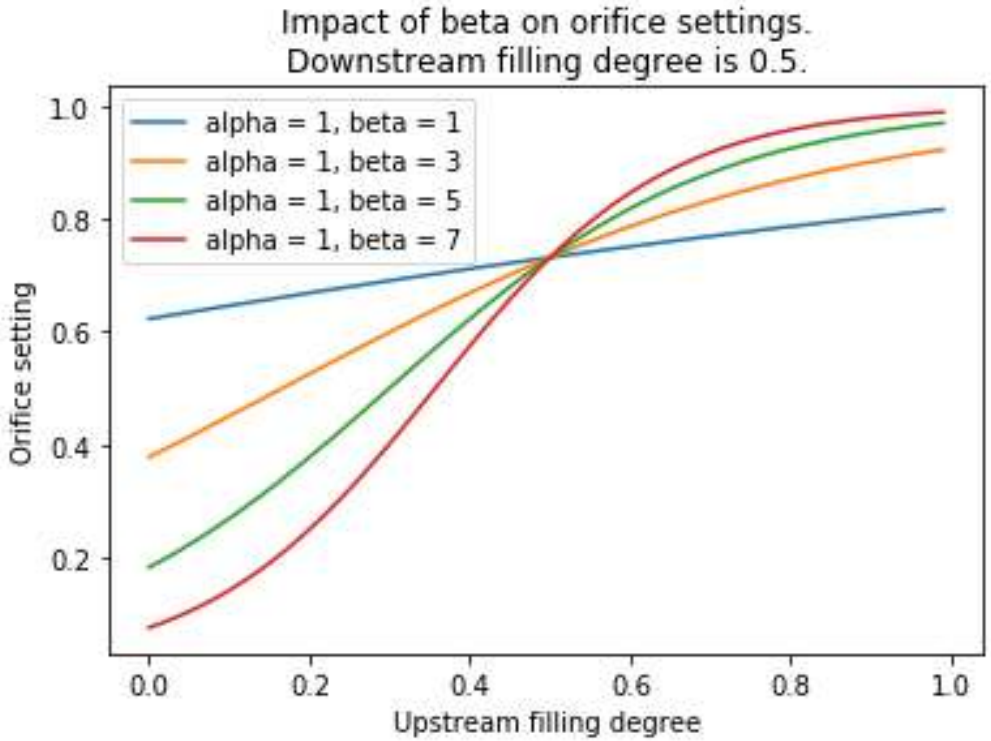
Parameter sensitivity

Mathematically slightly different formula

$$\theta_{BA} = \frac{1}{1 + e^{-beta(\varphi_B - \varphi_A) - alpha}}$$







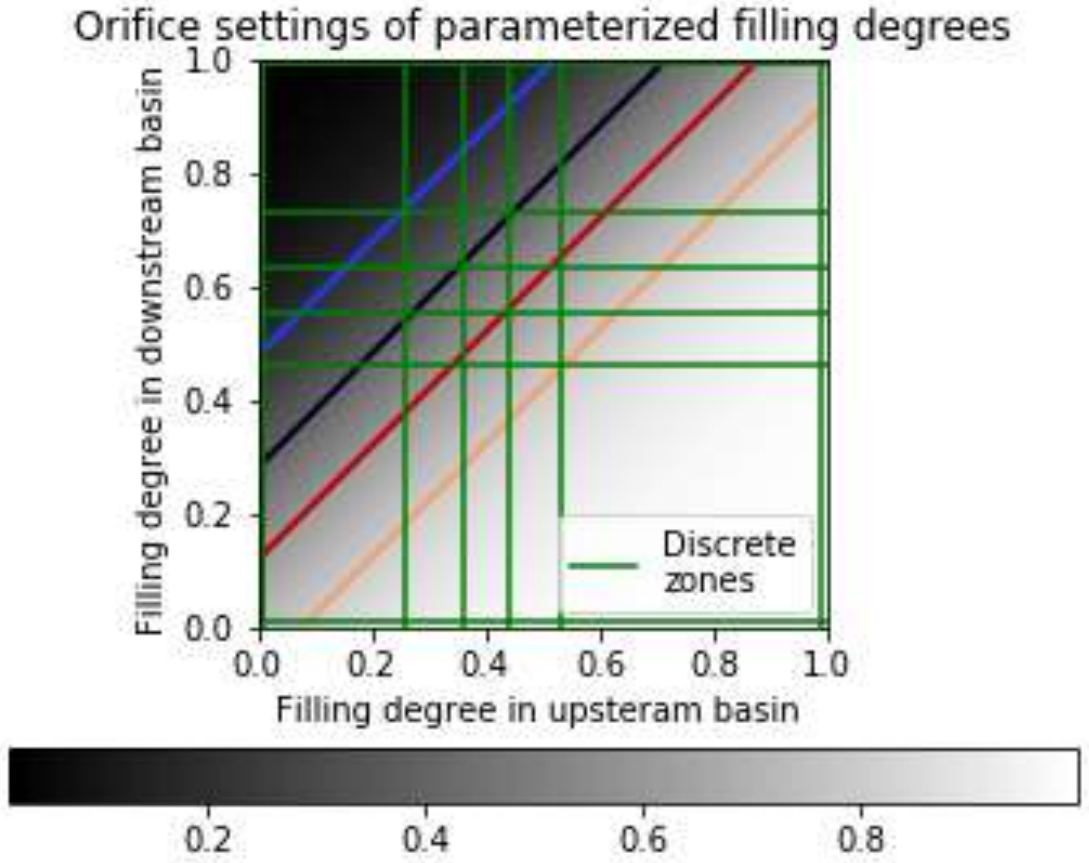
Test on Astlingen system

Discretization in if-then rules

$$\theta_{BA} = \frac{1}{1 + e^{-beta(\varphi_B - \varphi_A) - alpha}}$$

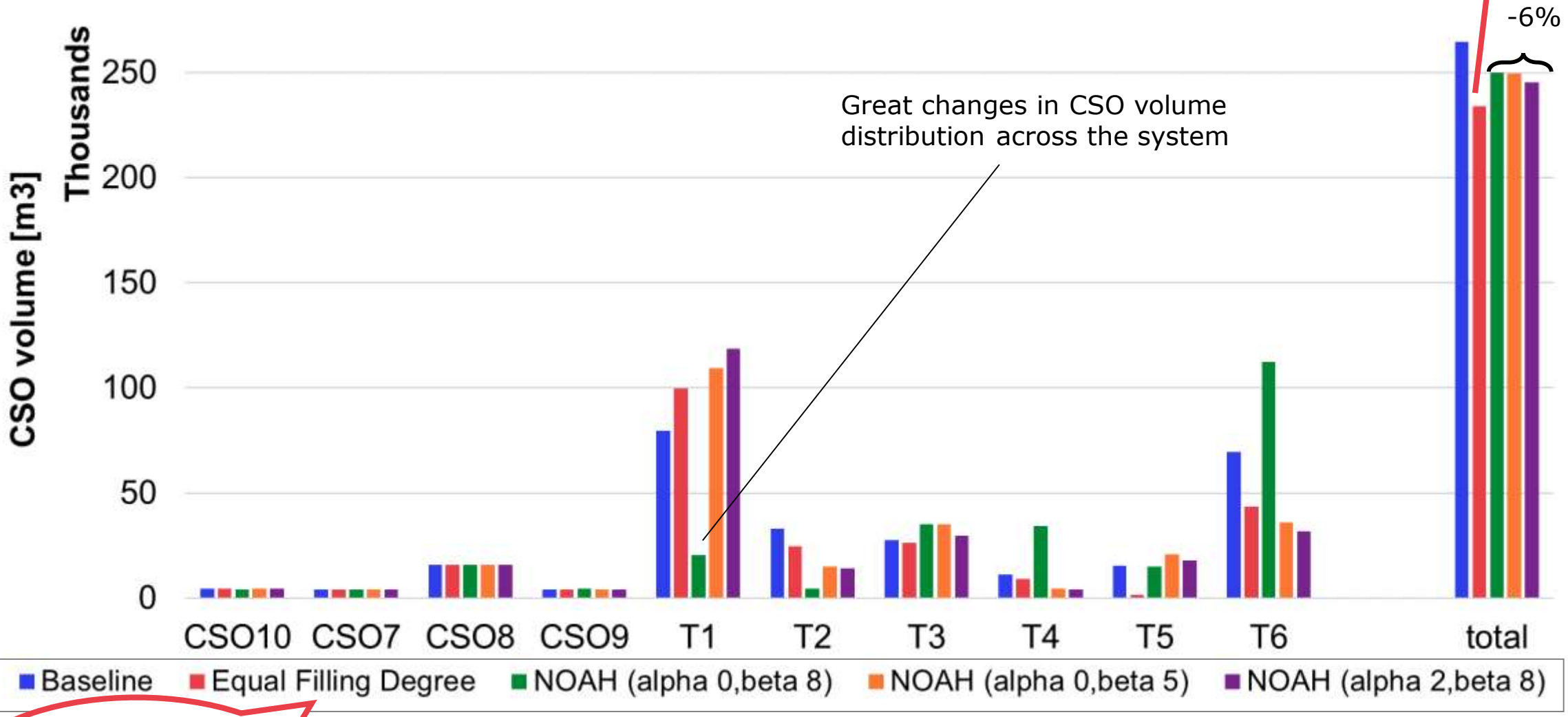
alpha=1

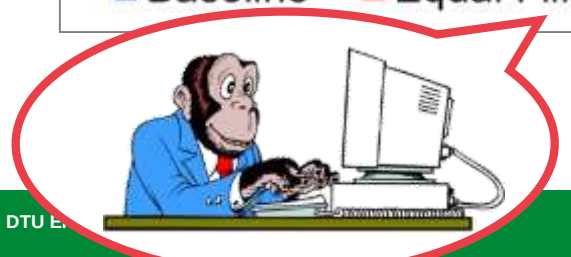
beta=5



Preliminary results

Total CSO volume





NOAH tool (not optimized)

Tools to support a wider implementation of Real Time Control of urban drainage systems

- Evaluation of RTC potential with limited dataseries
  - *the number of events matters*
  - *methods to evaluate long term performance available, but..*
  - *… not silver bullet: long simulations still needed*

- Autocalibration of simple rule-based control strategies
  - *automatic estimation of simple if-then rules*
  - *based on hydrodynamic models (SWMM)*
  - *Enable quick implementation of RTC in simple systems*