Perspectives on the Use of ICA for Integrated Control of Wastewater Systems

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Québec's Global predictive RTC

Pleau et al. (2000)

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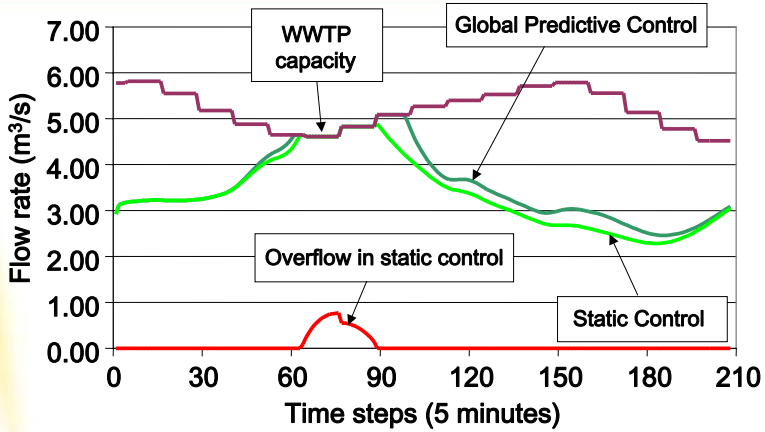
Québec's GP-RTC: Performance



Pleau et al. (2000)

Québec's GP-RTC: Performance

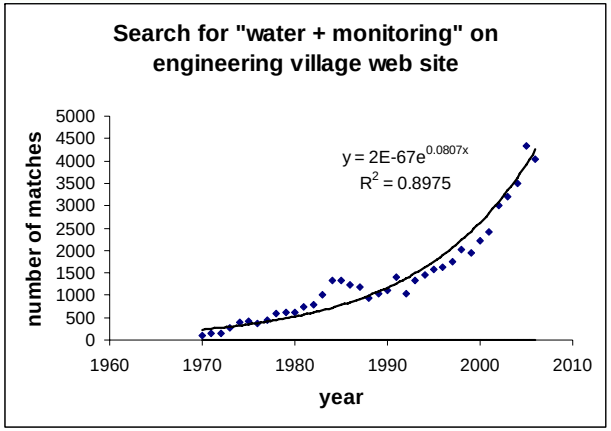
- 4 Retention basins vs. 7 Retention basins
- 22,800 m^3 vs. 37,000 m^3
- 47.4 M$ vs. 61.1 M$

- Main practical experience:
  - System set-up changes continuously (problems/maintenance sensors, telemetry, actuators)
  - Control system needs to adapt continuously
  - Thanks to the GP-RTC approach, it can be done !

Outline

- Motivating example
- Instrumentation and data quality
  - Instrumentation developments
  - Automated monitoring stations
- Immission-based RTC
  - Integrated modelling for RTC development
  - Immission-based integrated RTC – Case study
- Conclusions

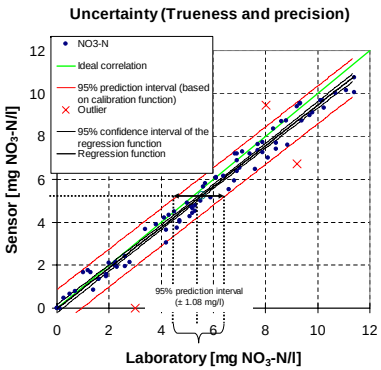
Instrumentation

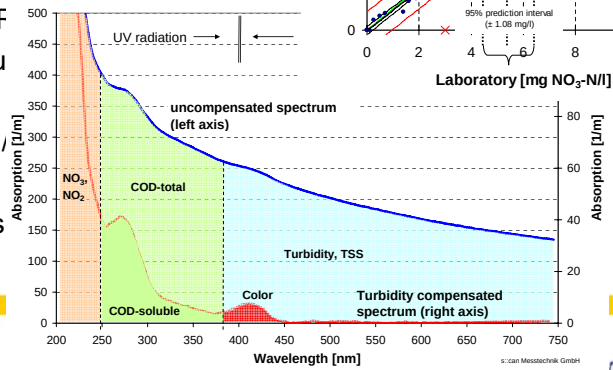


Mathieu Beaupré (2007)

Instrumentation

- New sensors
  - LDO (optical method)
  - UV-VIS spectroscopy
  - (NIR
  - (Flu
  - pH /
  - In-s





Instrumentation

- Terminology

Data quality

Shift from **not enough data,**

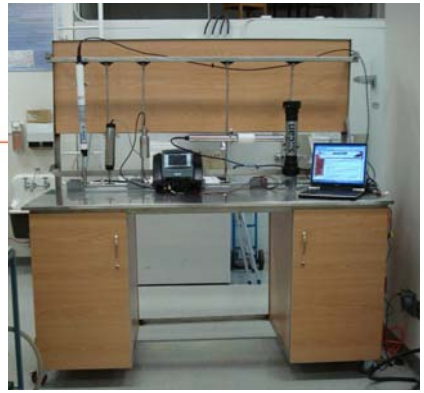
but with typically sufficient accuracy

to

Data graveyards

with unknown accuracy

Data quality



- Sensor characterization
  under field conditions
- Self diagnosis
- Meta-data
  configuration data, calibration parameter, bidirectional information exchange
- Lack of standardized data transmission protocols

PROFIBUS Fieldbus HART HSE High Speed Ethernet 4-20 mA

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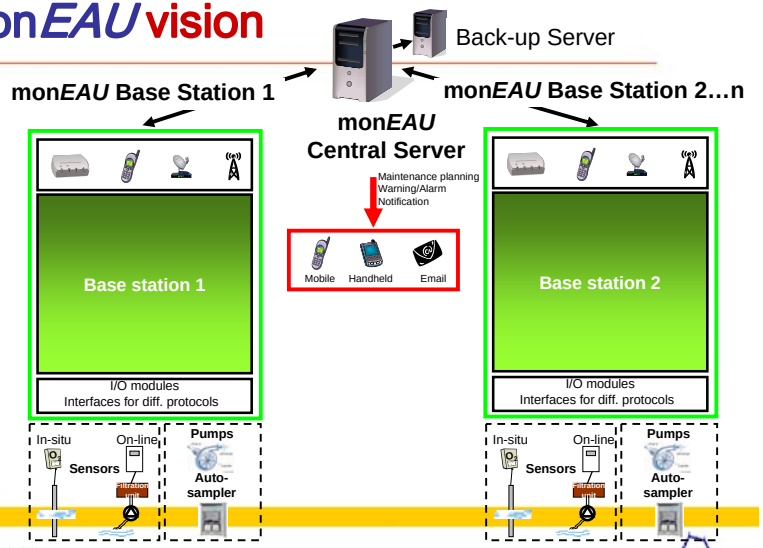
monEAU vision

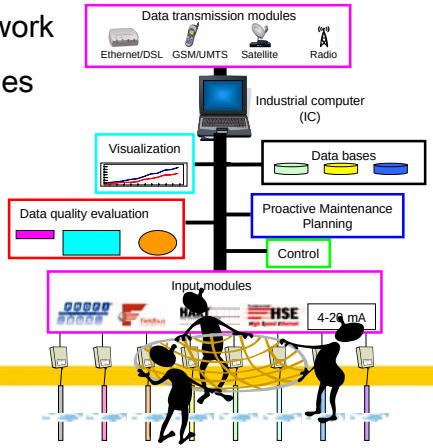
- A flexible system to be used
  - for different monitoring and research needs
  - at different locations (river, WWTP, sewer, …)
  - with all types of sensors and sampling methods (in-situ, on-line, off-line)
  - with all standard communication protocols

monEAU vision



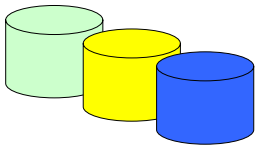
monEAU vision

- An open and modular system
  - robust framework
  - plug-in modules

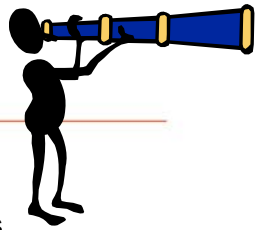


monEAU vision

- A high quality/performance database
  - fast access to large data sets
  - flexible enough for any monitoring task and further developments

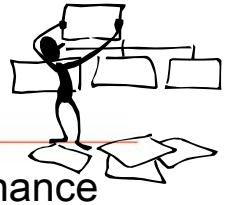


monEAU vision



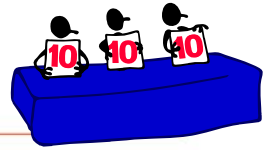
- Remote use
  - reduced maintenance requirements
  - minimized energy demand
  - different power supply options
  - various telemetry options
  - remote access to sensors
  - remote access to monitoring station operation

monEAU vision

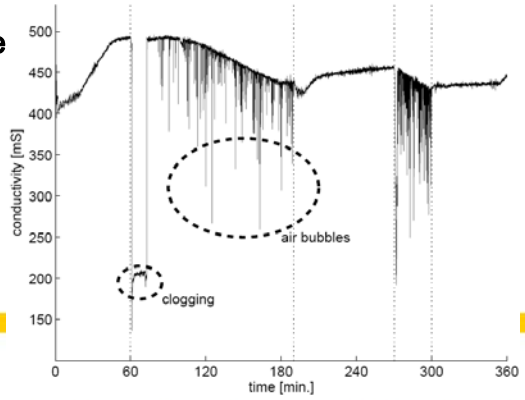


- Proactive and flexible maintenance
  - determination of optimal maintenance schedule
    - sensor self-diagnosis
    - data quality evaluation (at station or server level)
    - company or user experience
  - proactive set of station-triggered experiments

monEAU vision: Data quality assessment

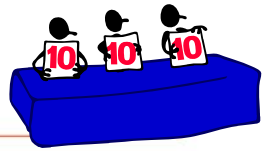


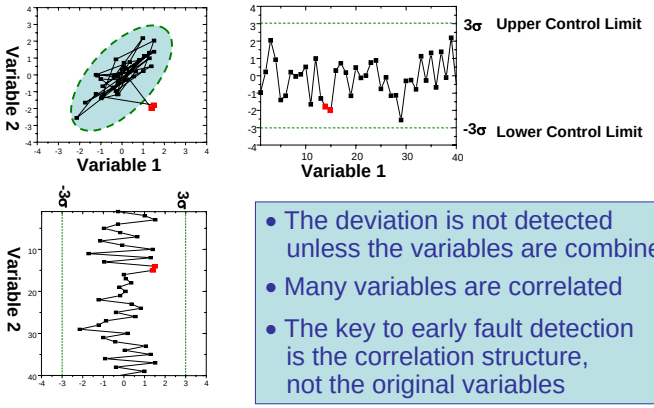
- Three user-selectable assessment levels:
  - **Level 1**: univariate methods
  - **Leve**



Villez (2007)

monEAU vision: Data quality assessment

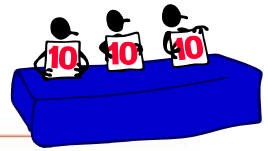




- The deviation is not detected unless the variables are combined
- Many variables are correlated
- The key to early fault detection is the correlation structure, not the original variables

Villez (2007)

monEAU vision: Data quality assessment



- Three user-selectable assessment levels:
  - **Level 1**: univariate methods
  - **Level 2**: multivariate time series analysis
  - **Level 3**: advanced data evaluation including expert and process knowledge

Villez (2007)

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- Motivating example
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  - Instrumentation developments
  - monEAU : automated monitoring station concept
- Immission-based RTC
  - Integrated modelling for RTC development
  - Immission-based integrated RTC – Case study
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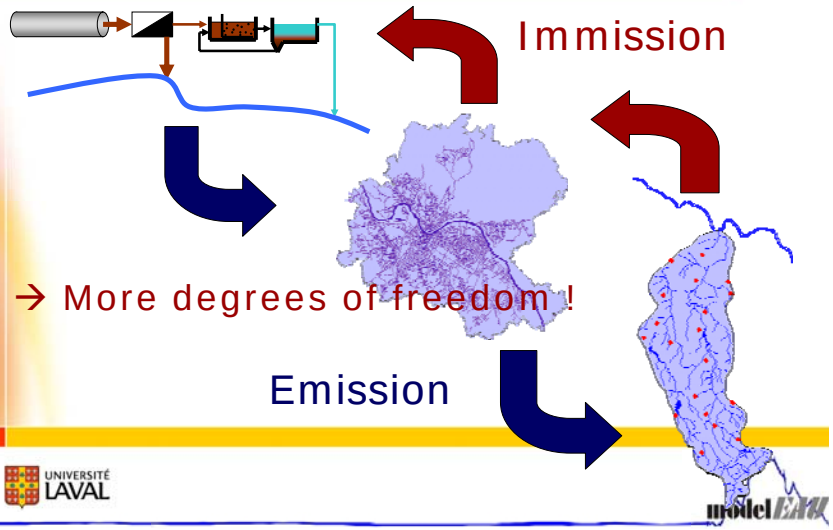
Immission-based RTC of IUWS

- IUWS = Integrated Urban Wastewater System

Immission-based RTC of IUWS



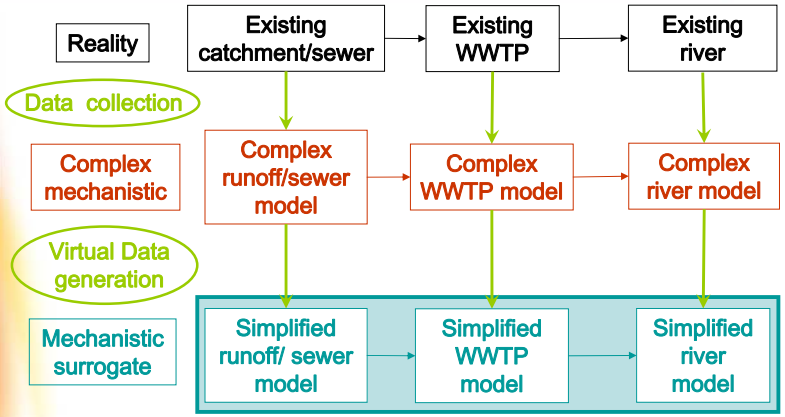
IUWS modelling approach

- Within a single modelling & simulation software
  - Sewer
  - WWTP
  - River → (Immission) Quality !
- Dynamic models
  - solved simultaneously (integrated control)
  - solved fast (NOT event-based analysis)
- RTC strategy evaluation and optimisation

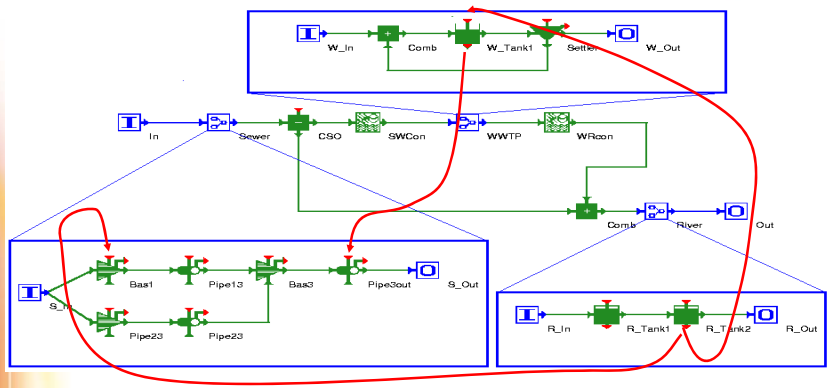
IUWS modelling approach

- Complex system
  - complex models (large, non-linear)
  - long calculation times (long time series, numerically stiff)
- Proposed solutions
  - model simplification (mechanistic surrogate models):
    - Activated Sludge Model Nr. 1: neural networks **unsuccessful**
    - Hydraulics: Saint-Venant equations → Box-models
    - Processes: e.g. two-step nitrification → one-step nitrification
  - model reduction

IUWS modelling approach



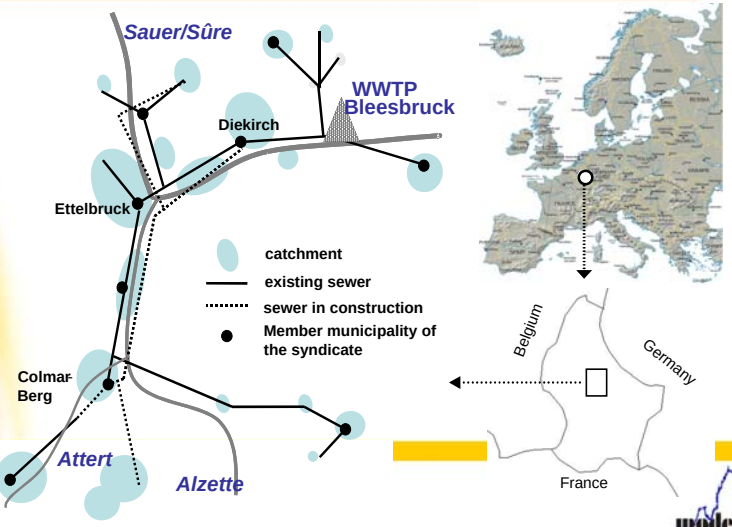
IUWS modelling approach



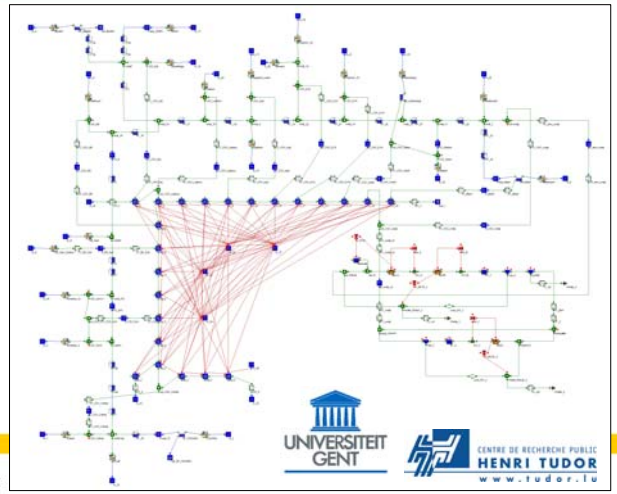
Information flow
from anywhere to anywhere

Meirlaen (2002)

IUWS modelling: Bleesbruck (Lux)



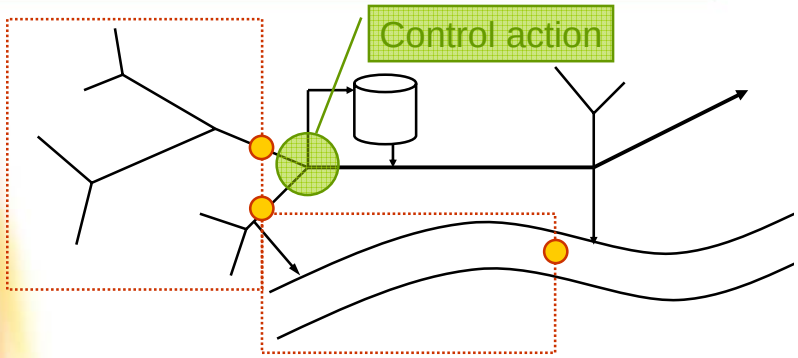
IUWS modelling: Bleesbruck (Lux)



Model reduction

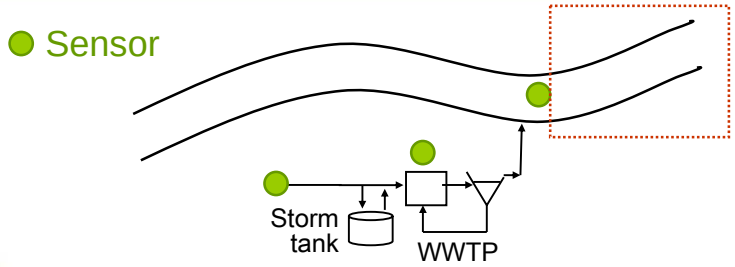
- Simulations are never fast enough…
- Leave out parts of the model
  - with minimal loss of accuracy
    !! AIM !! → Evaluate performance of RTC strategies
- Three approaches
  - Relocate upstream boundaries
  - Relocate downstream boundaries
  - Relocate time boundaries

Upstream boundary relocation



- RTC strategy doesn't influence some upstream parts
- Simulate these parts once and use that then as input

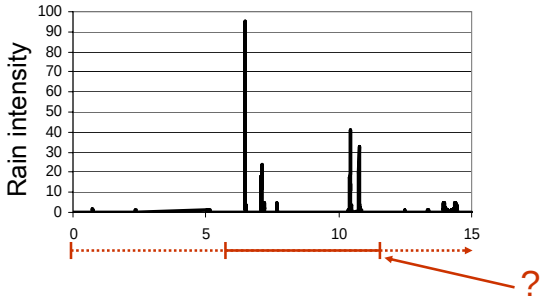
Downstream boundary relocation



- RTC is not influenced by part downstream of the last sensor
- Downstream river part may be left out of model

Time boundary relocation

If the RTC strategy is only active during wet weather:
Leave out dry period at the start / end for its evaluation



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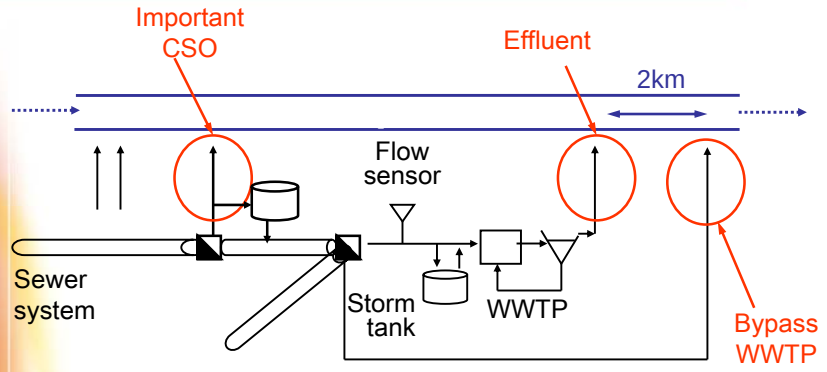
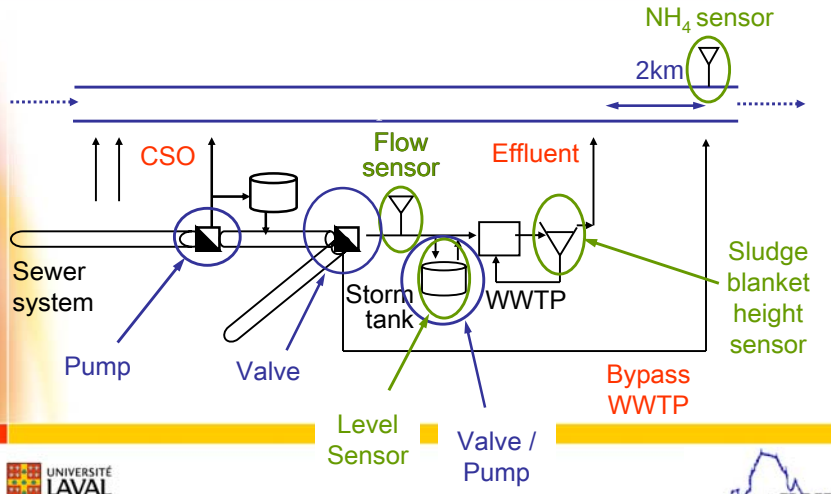
Tielt case study: Site description

- Tielt catchment (Belgium, Aquafin)
  - 30.000 P.E.
  - Combined sewer system
  - Bio-P treatment plant (Bio-denipho)
  - Poekebeek: small creek
  - Integrated modelling study done (EU-project)
    - Data available
    - Complex models available for sewer system and Poekebeek
    - Simplified model for the sewer system and WWTP

Tielt case study: Site description

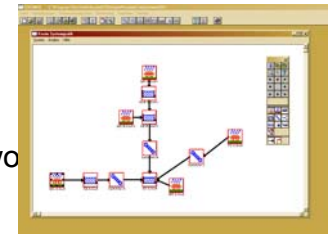


Tielt case study: RTC description



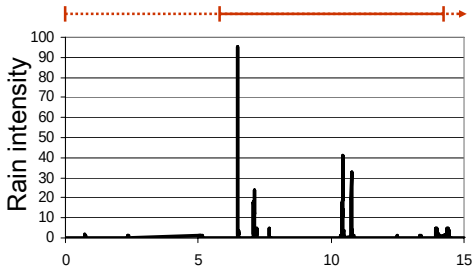
Model simplification and reduction

- Run-off and Sewer system
  - Simplification: Hydroworks to Kosim
  - Reduction: 68 to 4 elements
- Treatment Plant
  - 1D settler models
  - Other simplifications didn't wo
- River
  - Hydraulics: Box model (Tanks-in-series)
  - Reduction: from 18 to 6 tanks

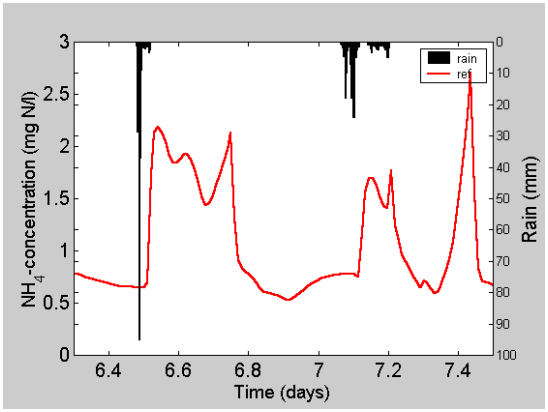


Model simplification and reduction

- Time boundary

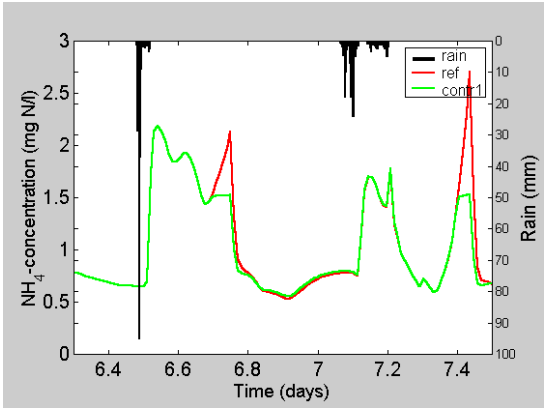


Immission-based control: NH_4



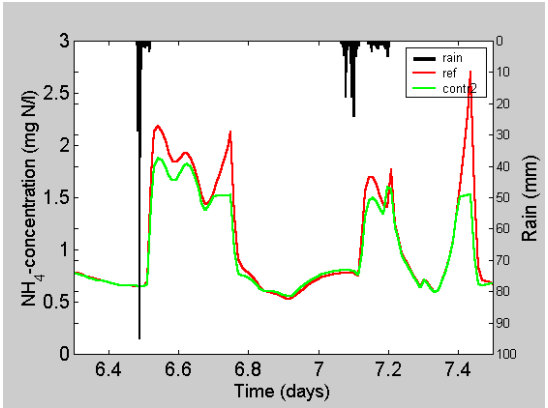
Base case

Immission-based control: NH_4



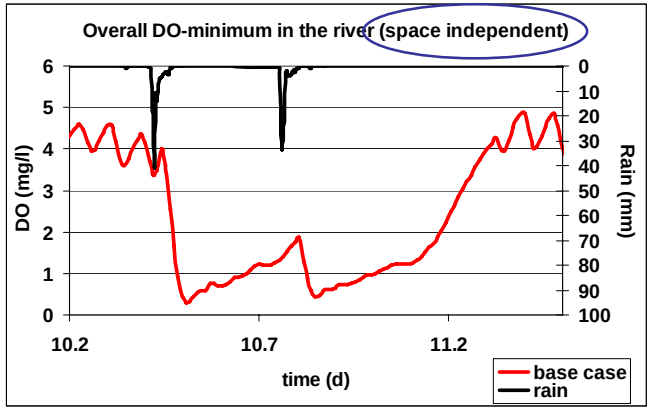
Control of the WWTP bypass

Immission-based control: NH_4

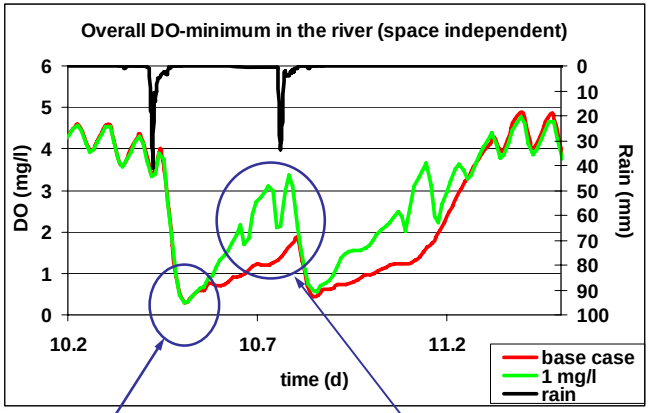


+ Control of pump at storage tank

Immission-based control: DO_{min}



Immission-based control: DO_{min}



Absolute minimum does not improve

Quicker recovery

Immission-based control: Summary

- NH_3 criterion
  - Peak shaving can be done ←→ acute toxicity
  - Both at CSO and at WWTP level
- Oxygen criterion
  - Overall minimum oxygen concentration is not improved
  - Average oxygen concentration is improved
  - Time under a critical limit (3 mg/l) is reduced

Take home messages

- New sensor principles (optical !) have reached maturity
- Every data value should have its uncertainty label so that we don't and up with data graveyards
- mon*EAU* concept

Take home messages

- Integrated control from the on-line assessed river's state is already in place (Québec's GP-RTC)

Another Example

- Sacramento river Freeport, California
- Tidal influence
  - During low flow, no WWTP discharge
  - Huge storage needed
- No river data used…
- Model-based design

Paulsen et al. (2007)

Take home messages

- Integrated control from the on-line assessed river's state is already in place (Québec's GP-RTC)

- Integrated modelling is under strong development and can now be applied for RTC development
- Immission-based RTC has been prototyped, but as far as known, no actual application yet with on-line river water quality measurements …

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