Monitoring for Modelling & Modelling for Monitoring in Water Quality Management

DIPCON'2010

Mont Sainte-Anne
Québec
Canada

14 09 2010

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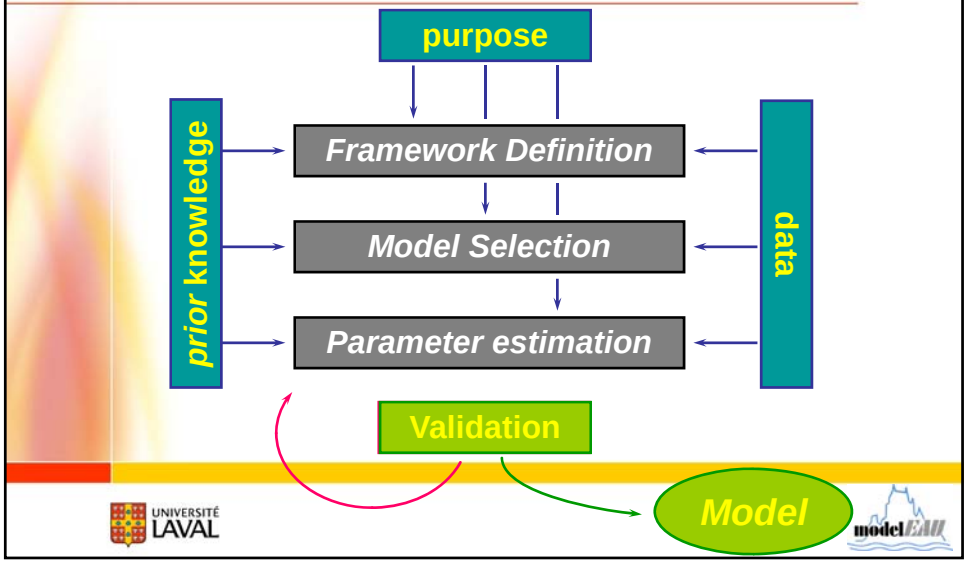
Outline

- Monitoring for modelling
- Modelling for monitoring
- Joint use of modelling and monitoring

The model building exercise



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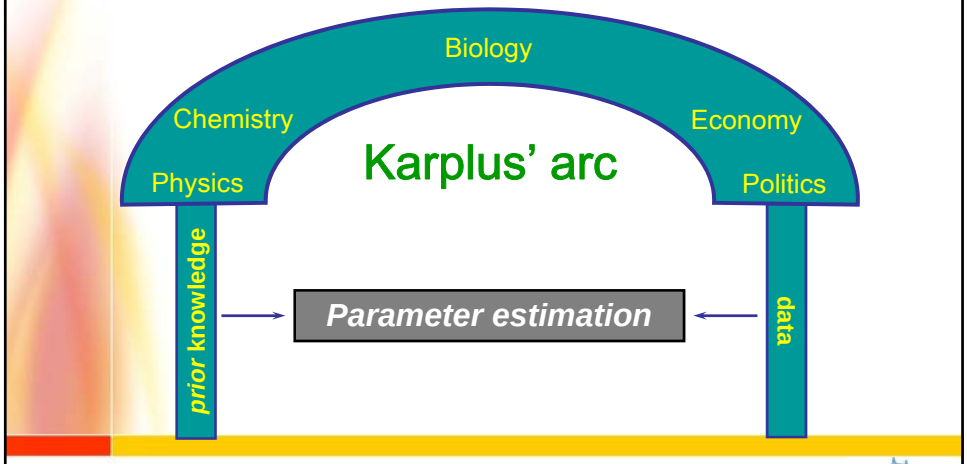
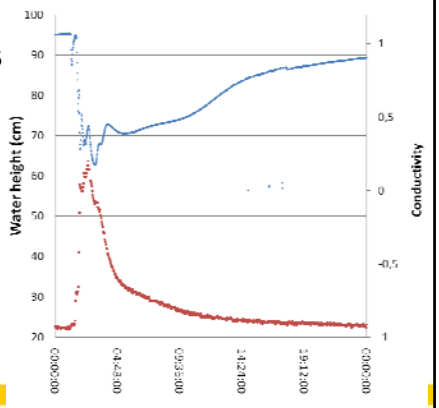


4

Data for modelling: Challenges

- Watershed = Distributed parameter system
- Important phenomena with different dynamics



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Data for modelling: Challenges

- Watershed = Distributed parameter system
- Important phenomena with different dynamics
  - Flow rates change very quickly
  - Dissolved oxygen changes within minutes after rain event (combined sewer overflow)
  - Eutrophication – Ecosystems evolve with seasons

==>

  - Data collection at different locations
  - At minute interval for a number of years...

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Setting up a measurement campaign

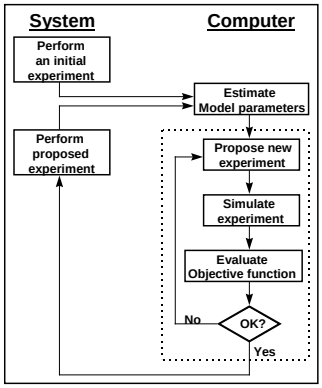
- Collecting such data sets is really expensive
- Good design of measuring campaign answers the following questions:
  - What variables should be measured ?
  - What is the required accuracy ?
  - How long must we measure ?
  - At what frequency must we measure ?
  - Where are the measurements to be made ?

Setting up a measurement campaign

- How to design a good measuring campaign?
  - Use your common sense – experience
  - Use available data – insights
  - Use a prior run of an approximate model

Setting up a measurement campaign

- Model-based design of measuring campaigns
- Optimal experimental design theory



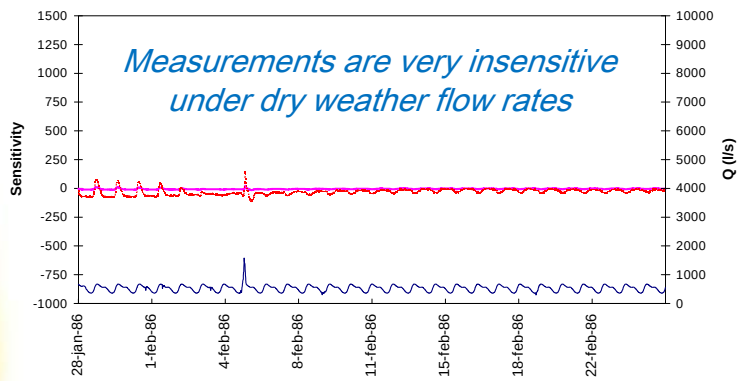
- Try out the experiment in the modelled world before you actually do it!
- Iterate!

Setting up a measurement campaign

- Model-based design of measuring campaigns
- <u>Sensitivity analysis:</u>
  How much a modelled variable depends on:
  - Inputs (rainfall/run-off, overflows, discharges, ...)
  - Model parameters (aeration, settling, degradation, ...)
- Tells us:
  - What is important in the model
  - Where we should focus attention on
  - Where the uncertainty will come from

Setting up a measurement campaign

- Sensitivity of turbidity on settling properties



Setting up a measurement campaign

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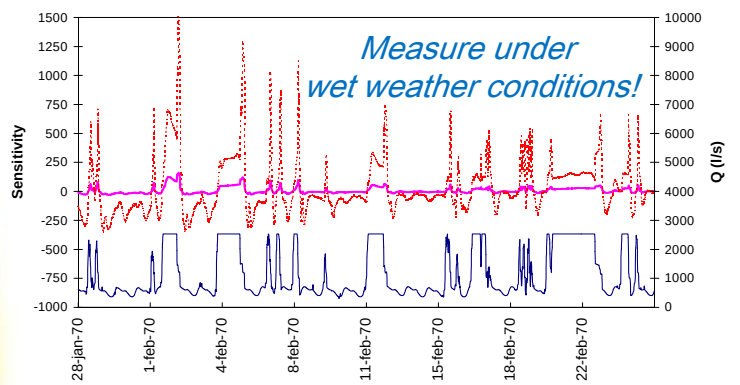
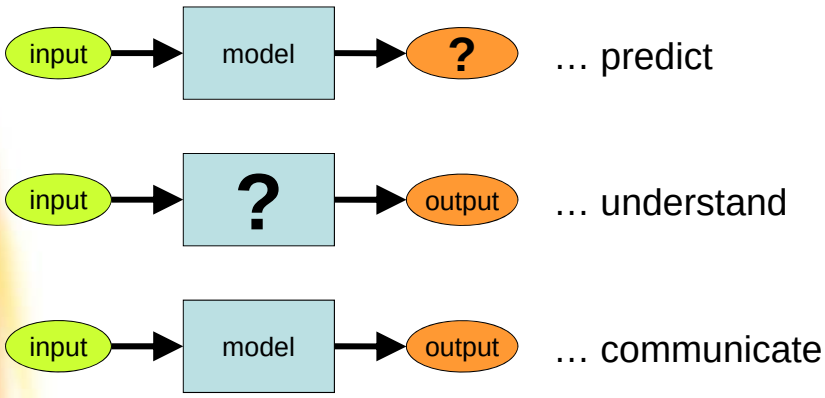
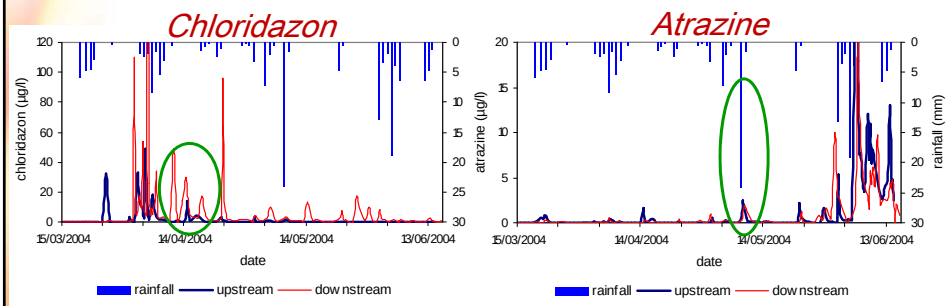


Use of Models



Data for improved understanding

- Study on pesticide dynamics (Holvoet, 2006)



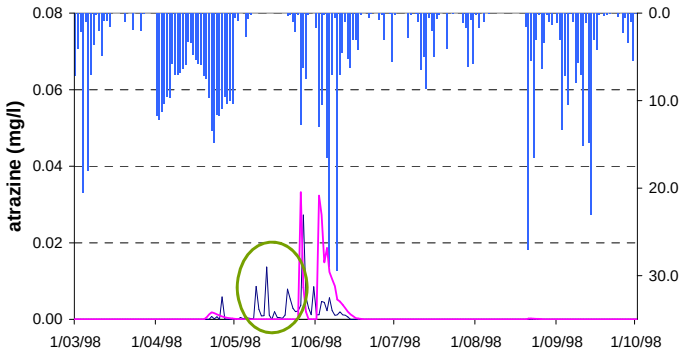
→ highly dynamic system with hourly variations

→ due to runoff

Data for improved understanding

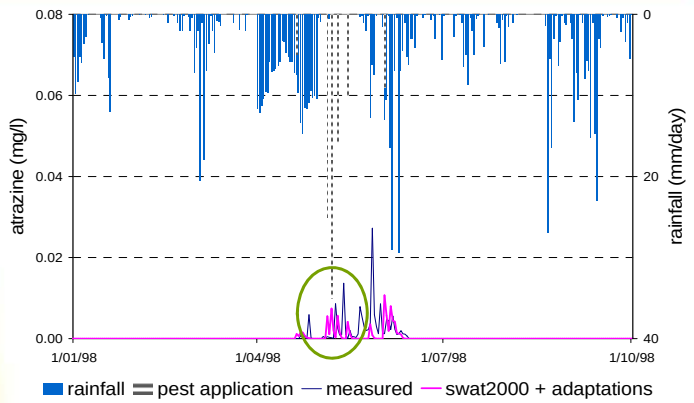
- Direct losses …

Data for improved modelling: SWAT



⇒ adjustments to SWAT code necessary

Data for improved modelling: SWAT



Outline

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- Modelling for monitoring
- Joint use of modelling and monitoring

Monitoring data: Objectives

- Assessing the current situation
- Identifying hot spots
- Evaluating progress-success-failure of management actions
- Supporting model development in view of decision-making

Monitoring in the Water Framework Directive

- Surveillance monitoring:
  - Determine the status - Assess slow changes
  - Assist in designing future monitoring programmes
- Operational monitoring:
  - Water bodies at risk – Evaluate actions
- Investigative monitoring (surface waters)
  - To understand reasons for water quality violation
- Water level monitoring (only groundwater)
  - Evaluate effect of abstractions

Modelling for monitoring

- Data quality assurance
- Interpolation and extrapolation
  - in time
  - In space
- Make a mathematical model to:
  - Support decision-making
  - Identify errors in data and our system understanding
- Assess the effects of anthropogenic activities
- Monitoring programme design

Modelling for data validation

- Environmental agencies: huge amounts of data

Modelling for data validation

- Environmental agencies: huge amounts of data
- For example: Flemish EPA (13,522 km^2):
  - > 1300 sampling locations over 10 catchments
  - > 10 variables to evaluate 12-26 times per year
- Important to detect anomalies (surveillance): e.g. potential water quality loss
- Hard for human experts to validate all data
- Need for semi-automatic data validation

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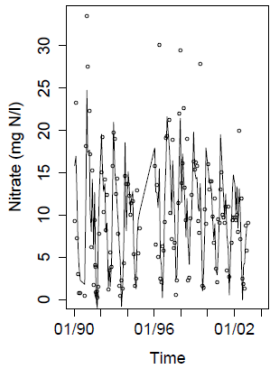
Modelling for data validation



- Fit model with historical data t=1..n
- Construct prediction & prediction interval at t=n+1
- Evaluate whether new measurement value is covered by prediction interval

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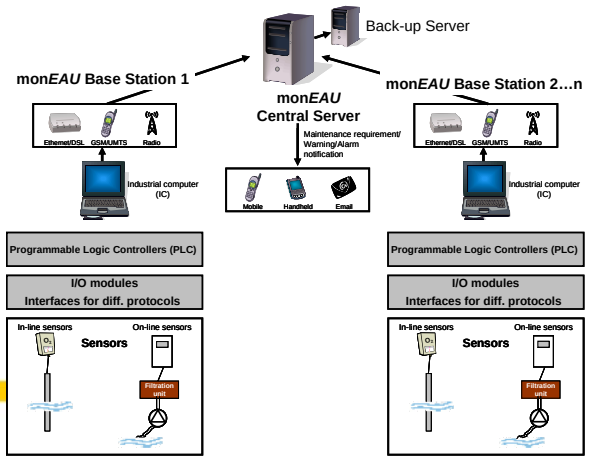
Robust monitoring stations

- mon*EAU* monitoring station



Robust monitoring stations

- mon*EAU* station installed at Notre-Dame creek

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Robust monitoring stations

IMW-project – www.imw.ac.at

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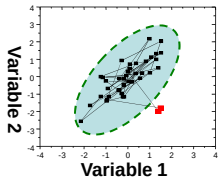
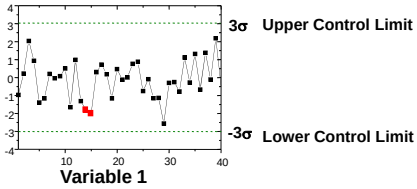
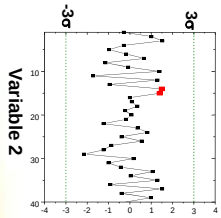
Multivariate fault detection







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

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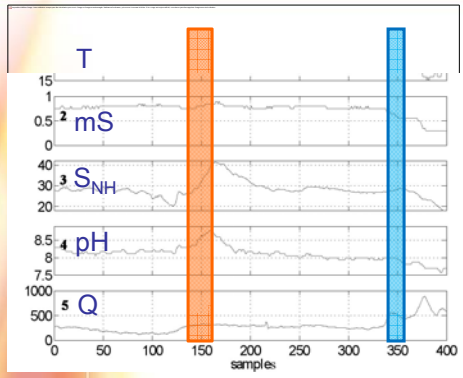
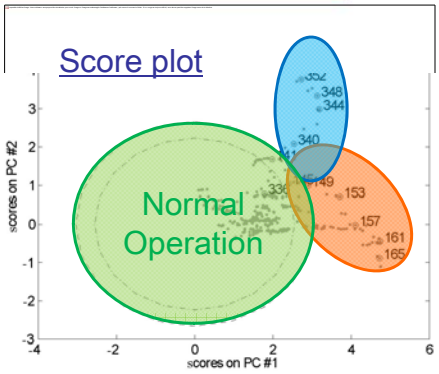
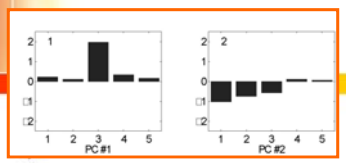
Multivariate fault detection: PCA







Fault diagnosis: Contribution of measured variables to deviating PC's

Outline

- Monitoring for modelling
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Joint use of monitoring/modelling

- Models must be adjusted using data to describe the site-specific conditions
- Without data:
  - Models cannot provide insight in the system of interest
  - They remain limited to provide some generalities on the system behaviour
  - Predicting the response to management actions is just guesswork

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Joint use of monitoring/modelling

- Data on their own only provide information on:
  - The current state of the system
  - Obvious trends
- They do not allow:
  - Explaining the cause of such trend
  - Discovering more hidden trends
  - Thinking about impacts of management actions
  - Using our insights at best (knowledge injection)

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Joint use of monitoring/modelling

- Obstacles to joint use:
  - Lack of awareness of the power of models
  - Low confidence in models (decide under uncertainty)
  - Technical background (no collaboration)
  - State of mind (they camp on different sides)
  - Conflict of interest (competition for limited resources)
  - Time frame (fast decisions, long modelling exercises)
  - Lack of data (never enough, not designed for model)
  - Incompatibility of time scales (long time series to detect possible problems – problem driven model)

Joint use of monitoring/modelling

- Currently, joint use is limited to
  - Calibration – validation
  - Evaluating uncertainty on the model (residuals)
- We could be benefiting from joint use for:
  - Interpolation/extrapolation
  - Trend detection and explanation
  - Data quality assessment and data validation
  - Knowledge gap identification and model extension
  - Model-based design of monitoring networks

Take home

- Models
  can be used to improve monitoring
- Monitoring
  is essential for good modelling
- We should strive for joint use

Acknowledgement

NSERC CRSNG

Canada Research Chair in Water Quality Modeling

Strategic Research Project on Ecohydraulics management

Neptune FP6 Project