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High quality monitoring of water systems using in situ automatic measurement stations that incorporate real-time data quality analysis tools

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Presented by..... John B. Copp, Ph.D.

Overview

- Brief Introduction to Primodal/ULaval
- RSM30 Monitoring Stations/Networks
- Real-Time Data Quality Evaluation
- Discussion for the Future

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www.primodal.com
Monitoring the Future:
Advancing Water Monitoring Network Design

Introducing Primodal / U Laval

- Expertise
  - Process Engineering, Design, Control, Modelling, Monitoring and Data Analysis
    - COMMON THEME → Data Evaluation
      - the need for accurate and representative data

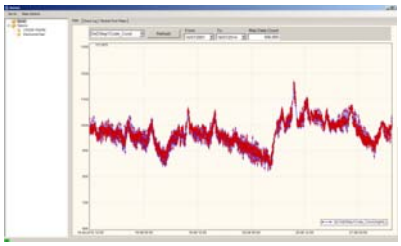
Introducing Primodal / U Laval

- Primodal Inc. / Primodal Systems Inc.
  - Offices in Hamilton, ON.; Quebec, QC; Kalamazoo, MI
  - PI: Water/Wastewater Consulting Firm
  - PSI: Monitoring Equipment
- modelEAU / Université Laval
  - Based in Quebec, QC.
  - Water and Modeling-based Research Group

Primodal / U Laval Cooperation

- **Platform**
  - RSM30™ monitoring station
  - Portable and sensor independent

- **Advanced Data Evaluation Tools**
  - *PrecisionNow* ©
  - Real-time data evaluation methods and data validation algorithms



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Monitoring the Future:
Advancing Water Monitoring Network Design

Monitoring for Process Understanding

- **The Potential**
  - Tracking Impacts
  - Limitless applications for study
  - Whole-system modelling
  - Decision-making

- **The Pitfalls**
  - Data Accuracy
    - system behavior
  - Data Graveyards
  - Communication
  - Data Expertise
  - Data Maintenance
  - Data Quality

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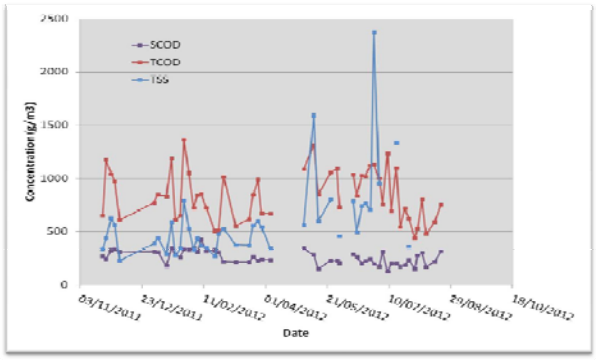
Monitoring the Future:
Advancing Water Monitoring Network Design

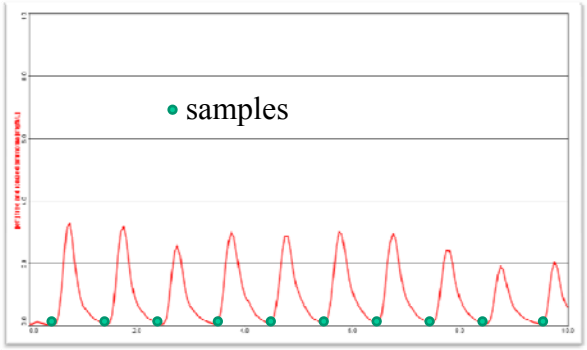
Issues

- Typical Data
  - Grab samples
  - 1-yr time period
  - Variations
    - Time of Day
    - Season
    - Weather
    - Location
    - …



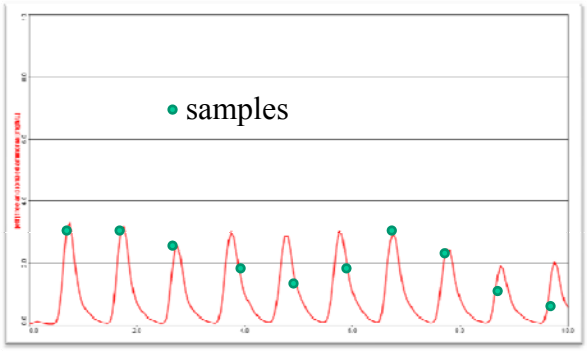
Issues

- Grab Sample Issues
  - Behavior missed
  - Trends missed
  - Events missed
  - Average case missed



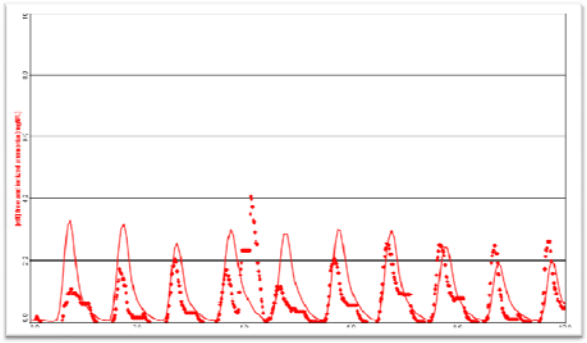
Issues

- Grab Sample Issues
  - Concentrations unrepresentative
  - Trends incorrect
  - Impacts incorrectly inferred



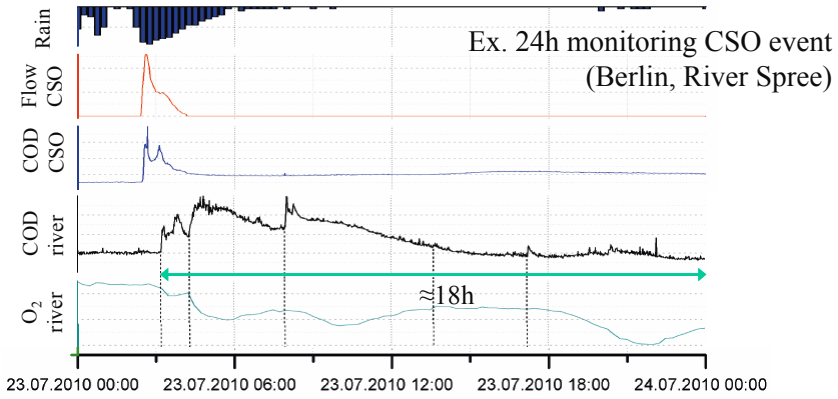
Issues

- High Frequency Monitoring
  - Essentially continuous
  - Trends
  - Event detection



Problem Definition

➢ Need for advanced data quality evaluation



Problem Definition

➢ Need for advanced data quality evaluation

Effective management of water systems

↓

Monitoring and assessment strategy

↓

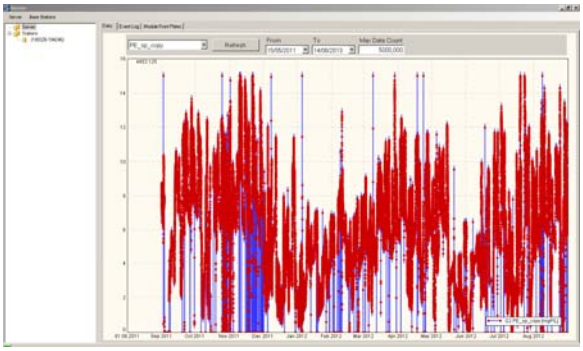
Reliable water quality information

↓

Modelling, forecasting, control...

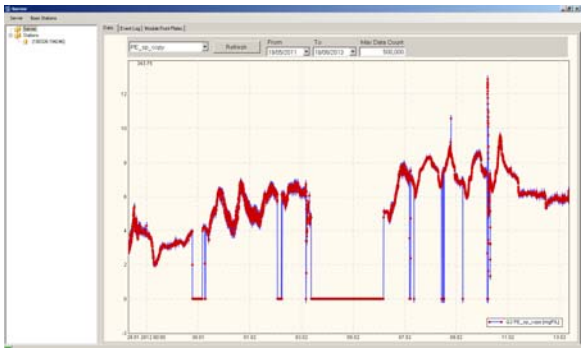
Issues

- Typical Real-Time Data
  - Outliers
  - Sensor Faults
    - Noise
    - Malfunction
    - Calibration



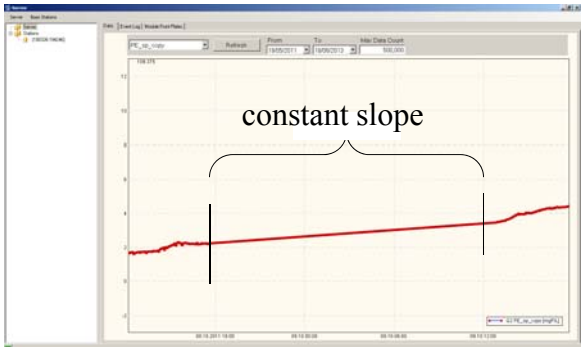
Issues

- Typical Real-Time Data
  - Malfunction
    - zero



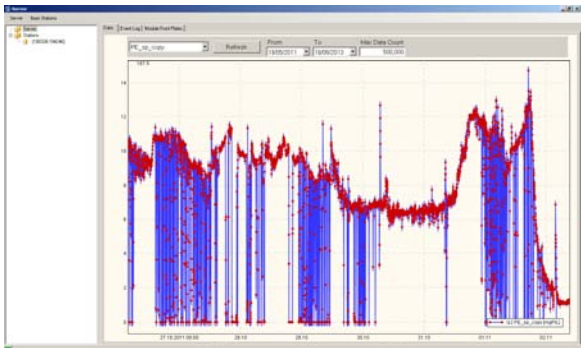
Issues

- Typical Real-Time Data
  - Malfunction
    - Odd Behaviour



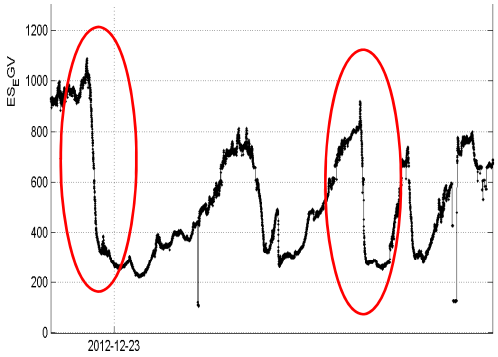
Issues

- Typical Real-Time Data
  - Malfunction
    - Noise



Issues

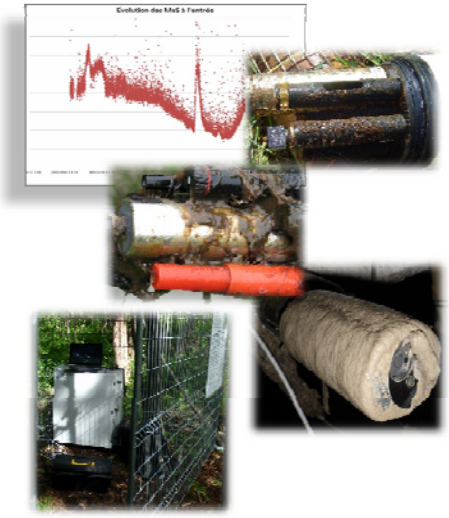
- Typical Real-Time Data
  - More complicated
    - Detecting the difference between real events and problems



Identified Needs In Water Monitoring

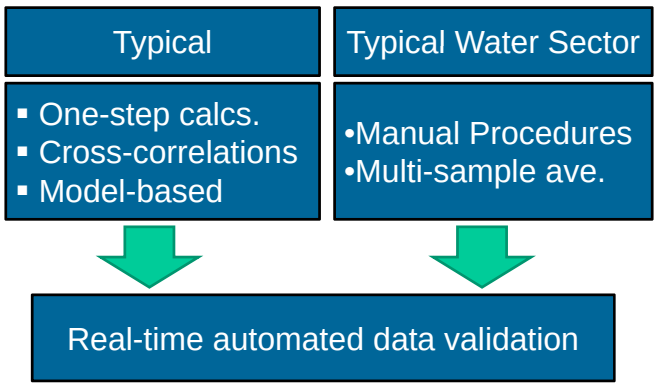
- Identified Issues:
  - complex data graveyards too common
  - too much post-processing effort
  - data from faulty sensors too common

Challenge:
Automated Data Validation



Methods for Data Validation

- PrecisionNow Practical Implementation



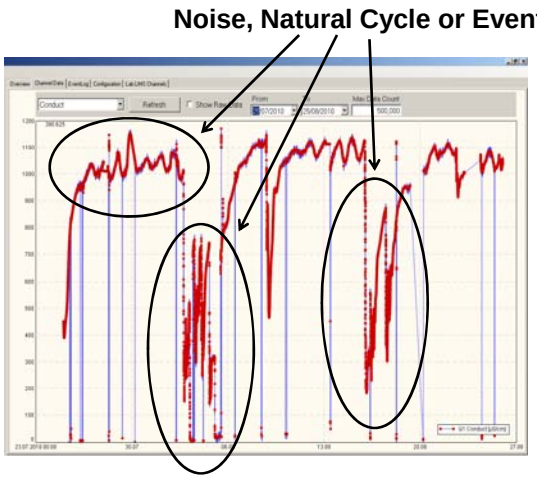
Classic Methods for Data Validation

- Single data validation: **one-step**

Method	Description
Manual evaluation	Comparison with grab samples
Constant value (TCV)	Constant value in allowed period
Range	[min, max] allowed values
Rate of change	[min, max] allowed rate of change over time
Running variance	[min, max] allowed StD

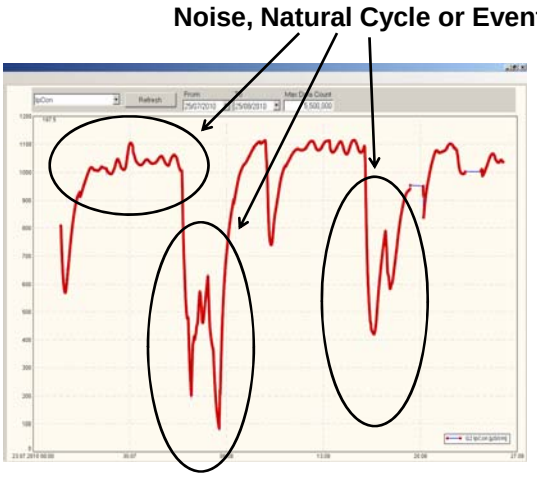
Univariate

- Data from Quebec City: St Charles River
  - Conductivity raw data



Univariate

- Data from Quebec City: St Charles River
  - Outlier detection followed by a LowPass Filter

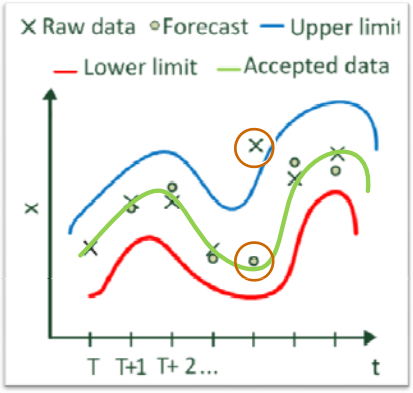


Model-Based Method for Outlier Detection

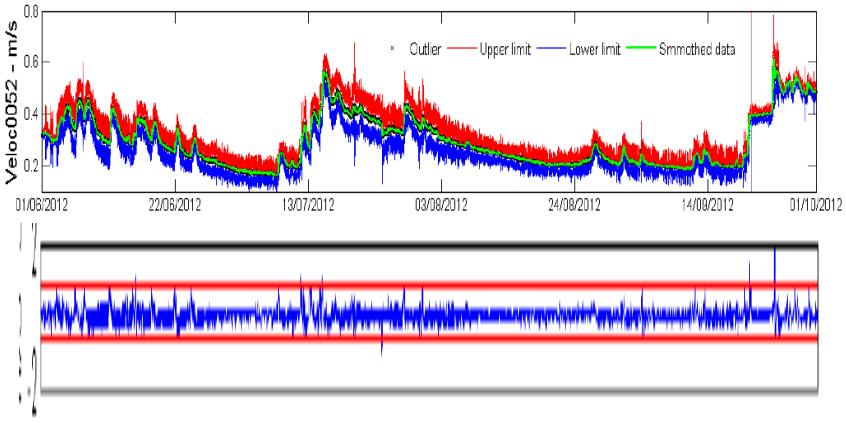
- Univariate time series analysis
  - Outlier detection

- Model-based forecast of expected data $\hat{x}$
- Prediction interval

$$x_{\lim} = \hat{x} \pm K \cdot \hat{\sigma}_e$$

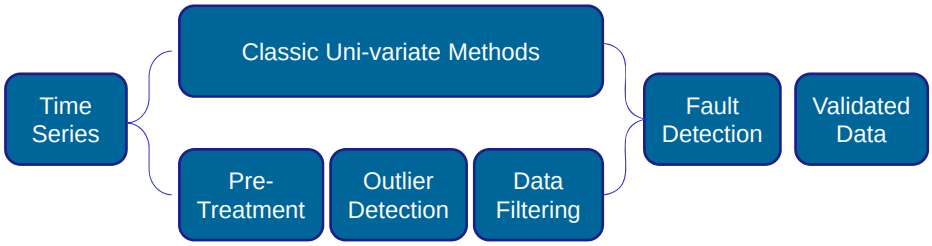


Model-Based Method for Outlier Detection



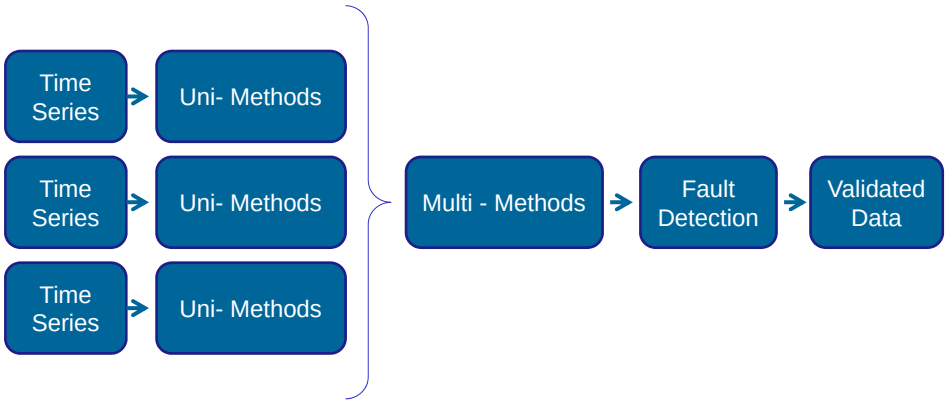
Combination of Methods

- PrecisionNow univariate analysis
  - Multi-step method combination



Combination of Methods

- Multivariate time series analysis

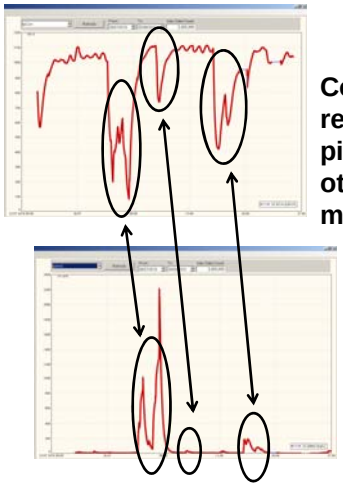


Multivariate – Simple Case

- Data from Quebec City: St Charles River

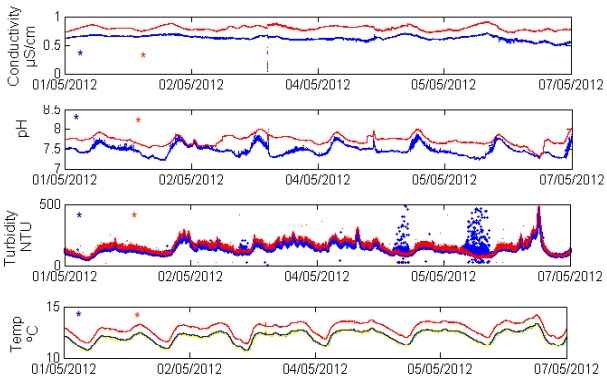
  – Conductivity vs TSS (data after LowPass Filter)

  - no alarm



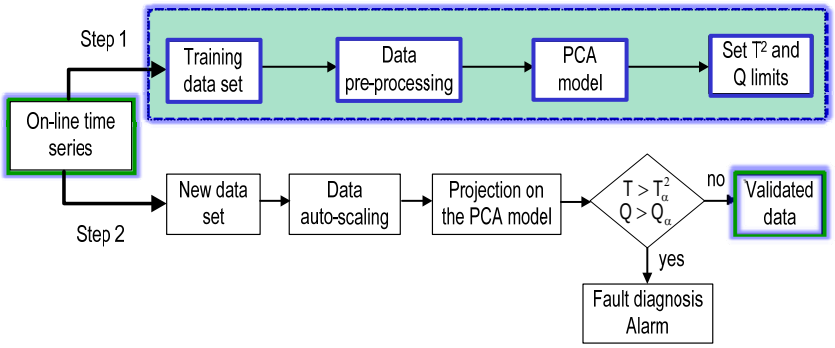
Confirmation of real events as picked up by other measurements

Multivariate – PCA Approach



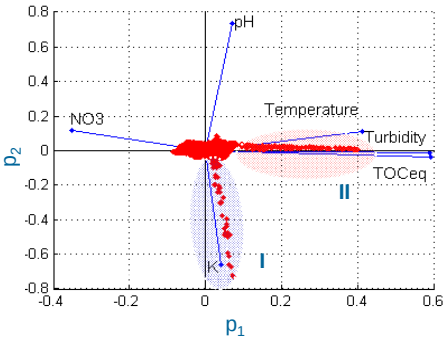
- Variable 20% bias ($Cond_1$,$Cond_2$)
- Variable bias (pH_1, pH_2), ($Turb_1$, $Turb_2$)
- Const. 5% bias ($Temp_1$,$Temp_2$)

Multivariate – PCA Approach

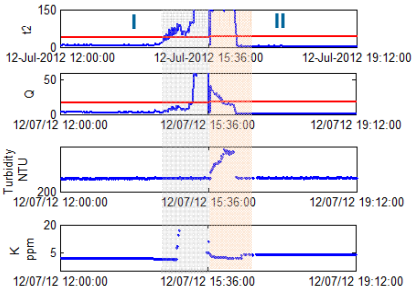


Real-Time Data Modules – PCA

Data in the new space – 2 Components



Statistics period I and II



Conclusions

- Dealing with faulty sensors represents a challenge for effective WQ monitoring
- Real-time fault detection minimizes post-processing effort, and maximizes response times
- Uni- and Multi-variate methods allow for the detection of multiple faults in real-time

Conclusions

- RSM30
  - Easily shipped and deployed in various environments (WWTP, river,…)
- *PrecisionNow* provides
  - Data logging
  - Customizable, real-time data evaluation capability
  - Sensor independent
  - Can be used as a stand-alone package (office) or in conjunction with an RSM30 (water's edge)

Acknowledgements

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