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for sustainable **water technology**

Data-driven decision-making for robust drinking water distribution

Developments in Dutch water distribution systems

dr ir Caspar V.C. Geelen

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combining scientific excellence with commercial relevance

Challenges in Drinking Water Distribution

NL#TIMES TOP STORIES HEALTH CRIME POLITICS BUSINESS T

Dripping tap - Credit: AndreyPopov / DepositPhotos - License: DepositPhotos

TECH NATURE DROUGHT WATER SHORTAGE MARK HARBERS
MINISTRY OF INFRASTRUCTURE AND WATER MANAGEMENT » MORE TAGS

WEDNESDAY, 3 AUGUST 2022 - 14:41

SHARE THIS:

Netherlands officially has a water shortage due to ongoing drought

https://nltimes.nl/2022/08/03/netherlands-officially-water-shortage-due-ongoing-drought

NL#TIMES TOP STORIES HEALTH CRIME POLITICS BUSINESS TE

Open water faucet - Credit: gdolgikh / DepositPhotos - License: DepositPhotos

BUSINESS WATER BROKEN WATER PIPE NL ALERT ZEELAND VLISSINGEN
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MONDAY, 25 JULY 2022 - 09:41

SHARE THIS:

No water in parts of Zeeland due to pipe break; Don't shower: NL Alert

https://nltimes.nl/2022/07/25/water-parts-zeeland-due-pipe-break-dont-shower-nl-alert

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Water Distribution

How to **obtain insight** into**,** and **enact control** over the water distribution process?

Reduce water loss (leakages)

Ensure safe & reliable water

Two **Leakage Control** strategies

Reactive

- FDIR: Fault Detection, Isolation, Recovery
  - Burst Detection (FD)
  - Burst Localization (I)
  - Repairs/Replacement (R)
- Minimize disruption to customers

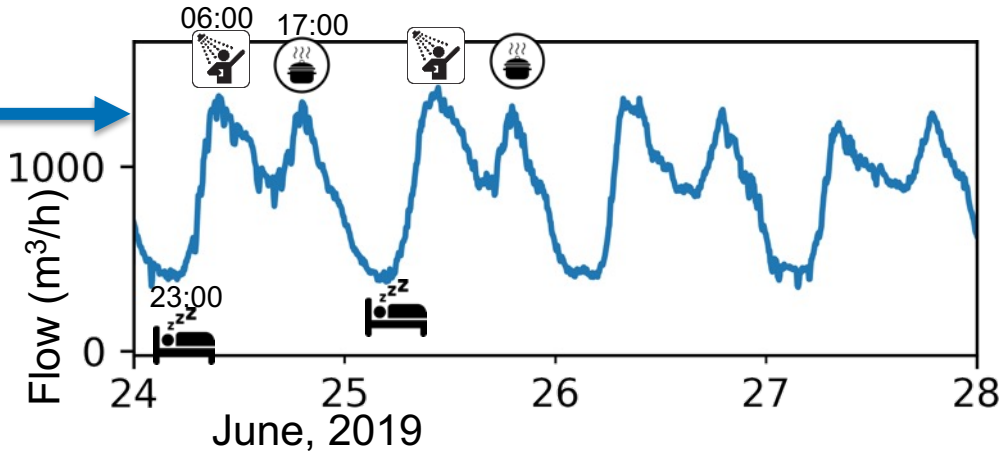
Proactive

- Prevent bursts and other failures
- “Just In Time Replacement”
- Optimize pump regime, valve configurations

How to look inside buried pipes?

Flow & Pressure Sensors

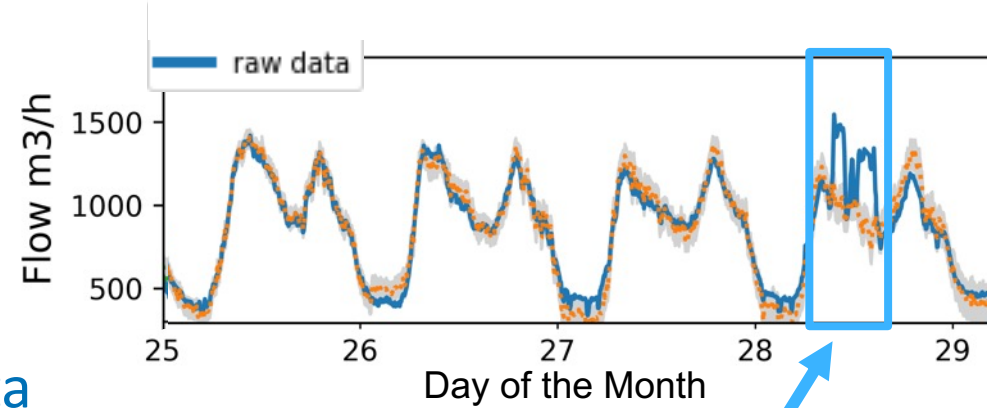
Flow/pressure measurements



Reactive: Demand Forecasting

Flow Sensors

→ Real-Time Data



→ Water Demand Forecast (expectation)

→ Deviations from expectations

→ **Water Loss (Burst) Detection**

Detection ≠ Localization

Detection

- Fault Detection: Did a burst occur?

Localization

- Determining the exact asset that is leaking
  - Customers as surrogate sensors
  - Sensor data + hydraulic models → localization methods

Requires:

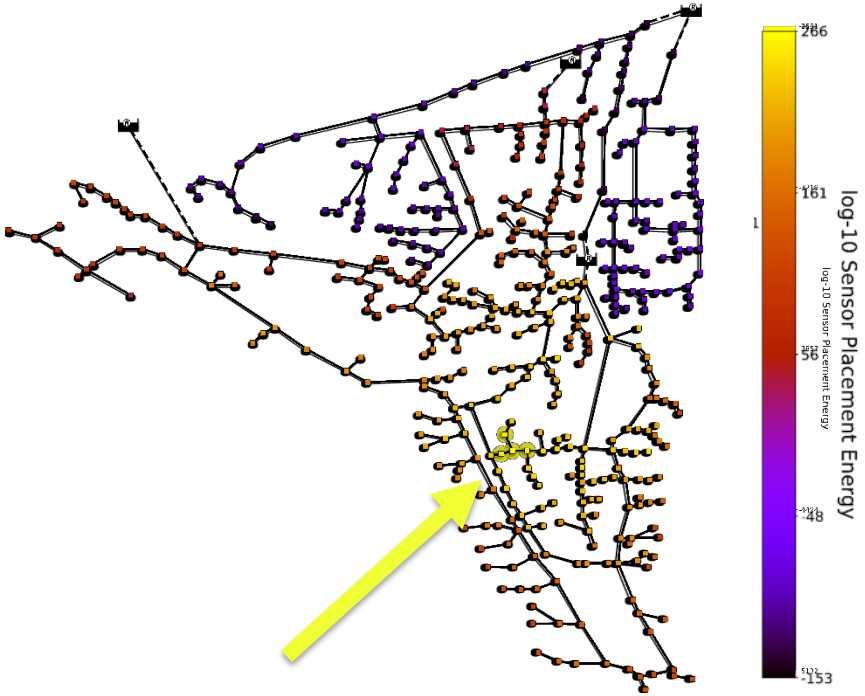
1. Sensors
2. Hydraulic Model

Optimal Sensor Placement

In theory

In practice

Optimal Sensor Placement

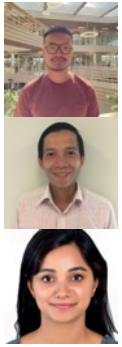


- Pressure sensor placement
- Maximize **Observability:**
  Where to place a sensor for a maximum gain in whole-network conditions?

What Sensors?

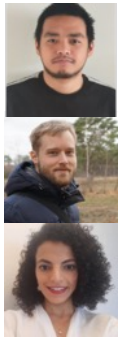
Novel (Bio)Sensors

- Ultrasonic & Smart-pipe sensors
- Transcriptome soft-sensor AI to detect water micro-pollutants (medicine / pesticide residues)



Soft Sensoring

- Indirect measurements via Sensor Fusion
- Use AI to translate (available) sensor measurements big data into estimate of hard-to-measure properties:
  - Oxychlorides in water
  - Oil spill decay in groundwater
  - Micro-pollutants via transcriptome sequencing

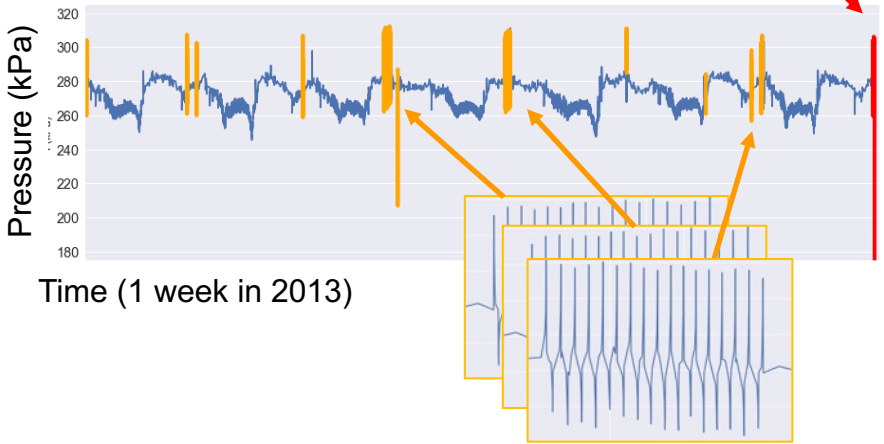


Proactive Leakage Control

Early-Warning Systems

- Detect problems in an early stage before they become a real problem.
  - Leakages
  - Deteriorated pipes
  - Malfunctioning pumps
  - Pollutants/contaminants

Pattern Recognition



Current Challenges & Prospects

- Measuring = knowing
  - Novel Sensors
  - Data = Power
- Reactive → Proactive
  - Data Processing:
    - Early Warning
    - Soft Sensors
- Data Intregration
  - Pipe inspections + computer model
- Ditigal Twin

Digital Twin voor het Waterbeheer

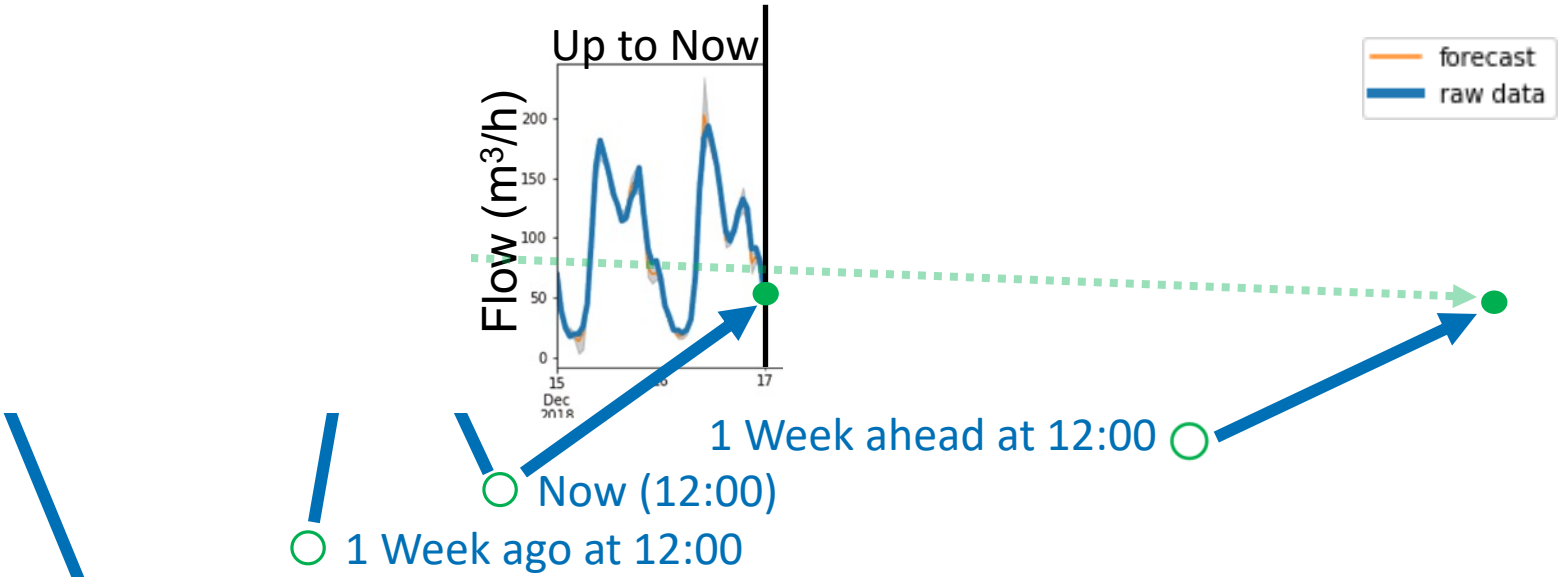
  - Forecasting & Simulation
  - Drought Mitigation + Preparation
  - Water Retention

Data-driven decision-making, robust water systems

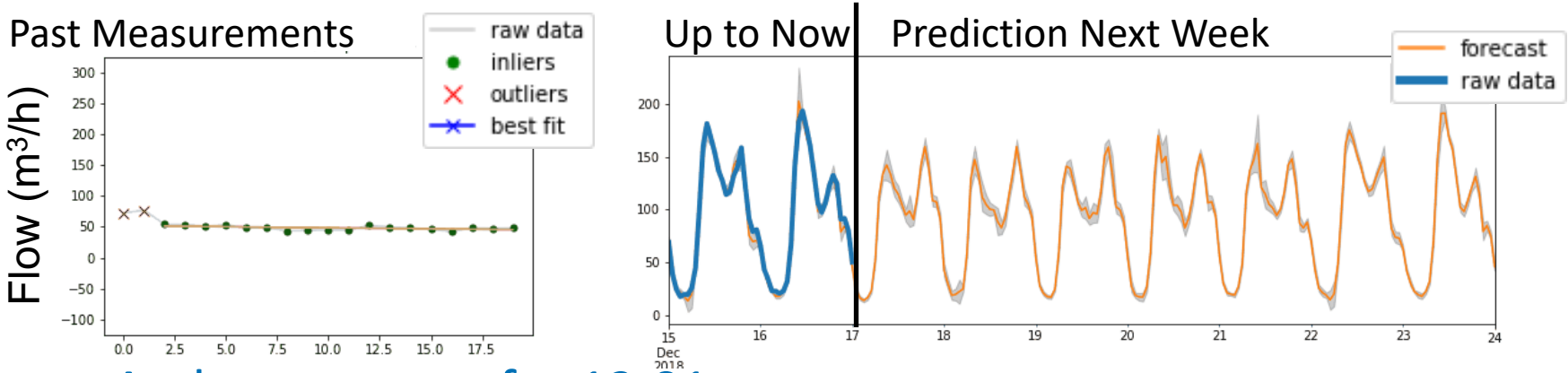
Backup Slides 1

- Example of how forecasting of flow sensor timeseries work (basic, understandable, explainable example)
- Could be placed after slide 6

Water Demand Forecasting
Forecasting of DMA water demand



Water Demand Forecasting
Forecasting of DMA water demand



Advantages:

- Predict regular "seasonal" water demand
- Forecasting (1 week)

And now repeat for 12:01,
Then repeat for 12:02,
And for 12:03,
…

Disadvantages:

- False Positive Burst Detection:
  Bad with "non-seasonal" events
  (e.g. **Christmas**, Pandemics, Maintenace, Events, …)

Christmas is a "Burst"?!

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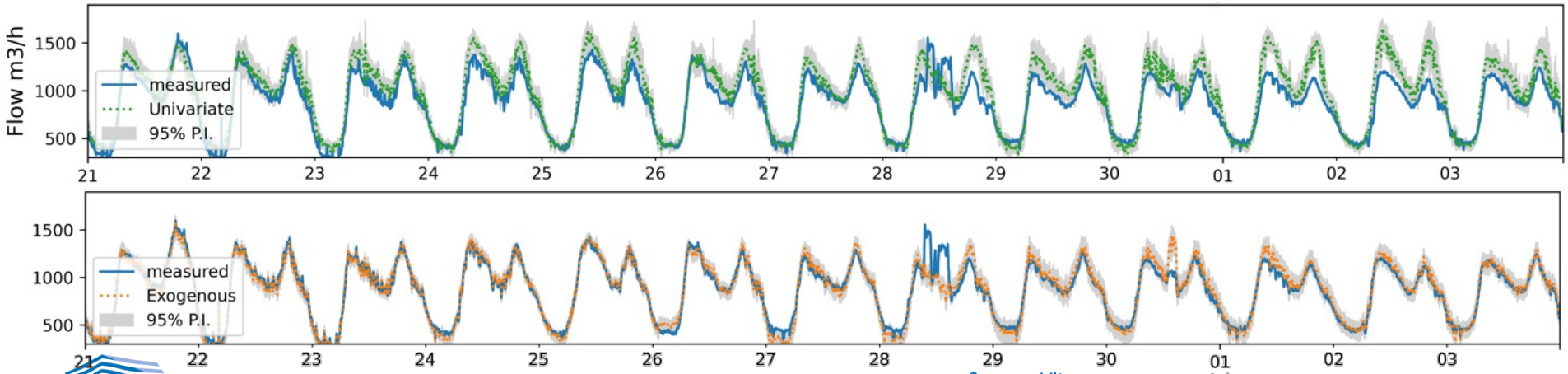
Water Demand Forecasting

Vitens Case Study

Top: measured flow and forecast based on past measurements

Bottom: measured flow and forecast incorporating exogenous sensor signals

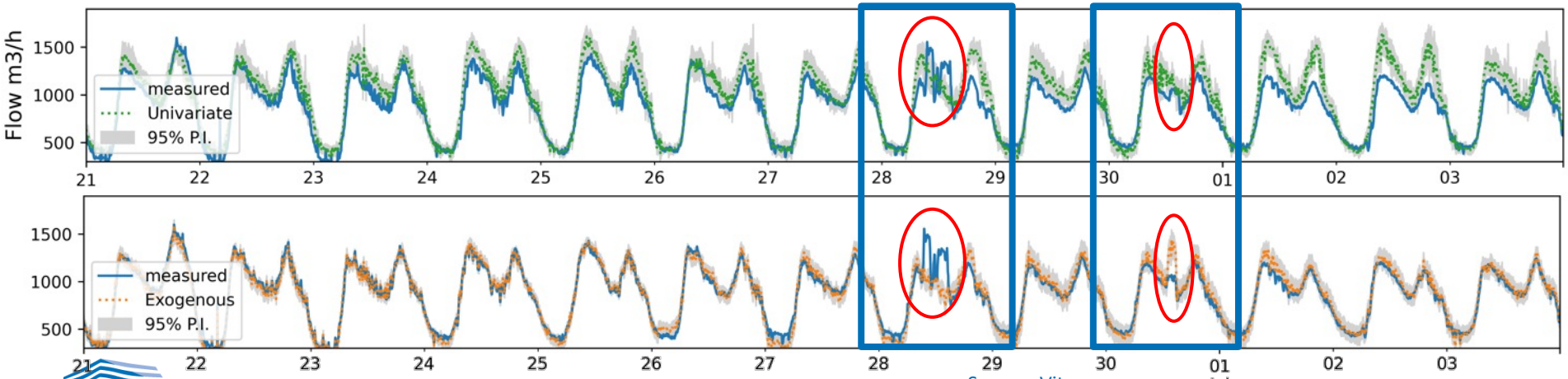


Source: Vitens

Water Demand Forecasting

Vitens Case Study

- 28/06/2017 16:20*
  - lengthwise tear burst
  - 630mm PVC pipe out of 1976
- 30/06/2017 14:20*
  - Water loss, placement of T-junction
  - 3x 400mm PVC pipes (1989 - 1994)

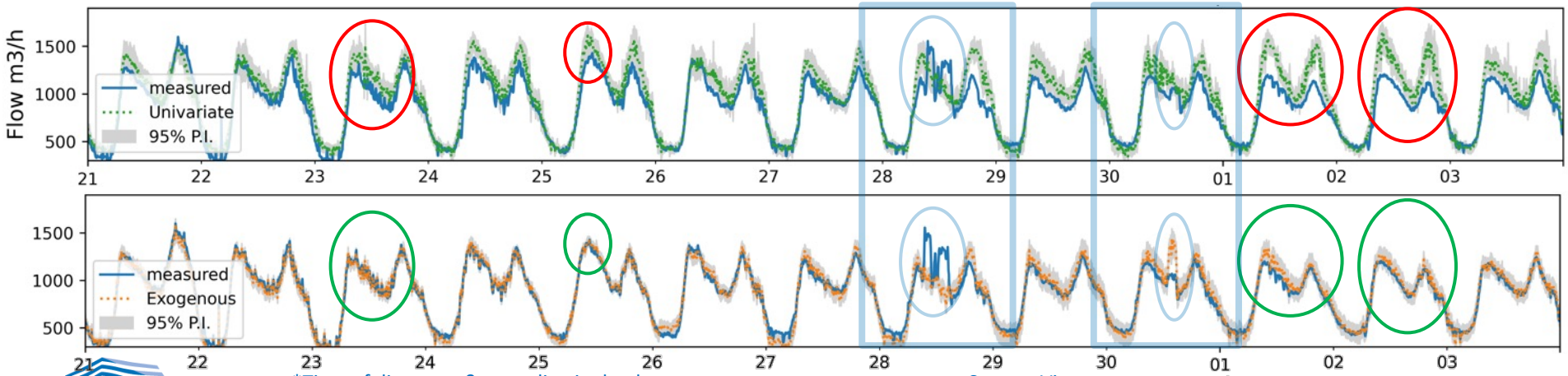


Source: Vitens

Water Demand Forecasting

Vitens Case Study

- False Positives (deviating forecast, but no pipe burst)



*Time of discovery & recording in database

Source: Vitens

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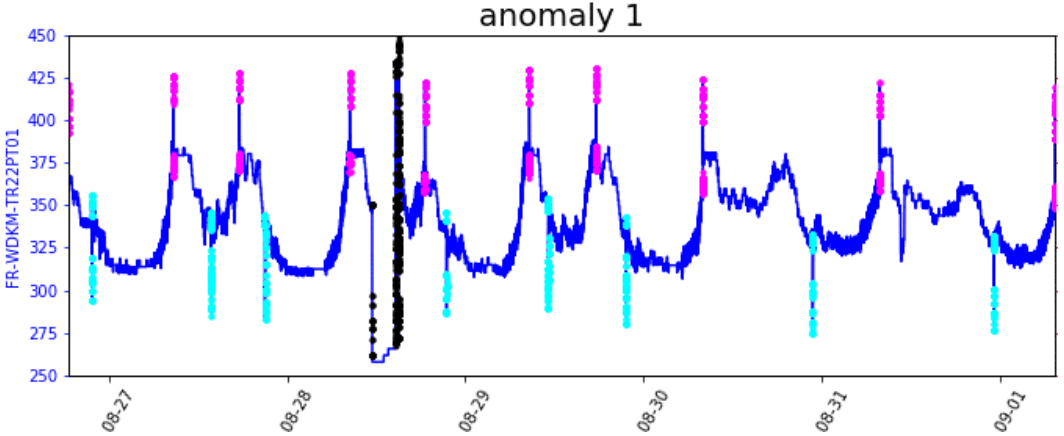
Backup Slides 2

- Proactive leakage control example: track recurring harmful pressure anomalies. If same anomaly keeps occurring, early warning can be issued, cause can be mitigated before further consequences (burst pipes)
  - Detect harmful oscillations (last slide, red cluster, appears in GIF after few seconds) before they cause a leak (as they did in this real example)
  - Cause in this example was to pumps in parallel causing these oscillations due to bad controller.

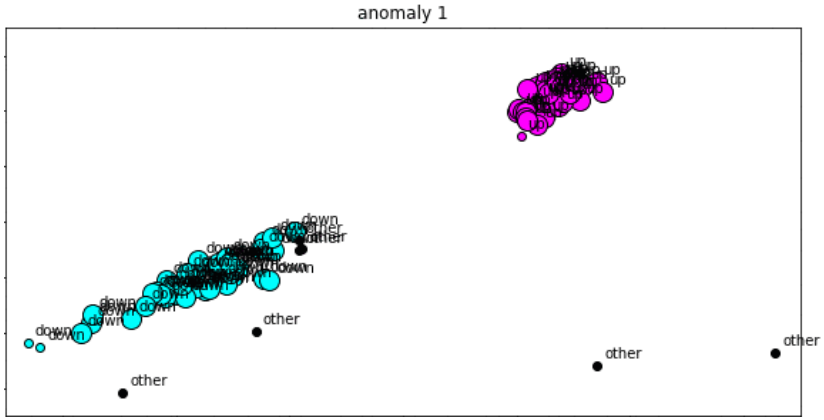
- Could be used to elaborate the idea illustrated on slide 11 right side.

Proactive: Recurring Anomaly Tracking

- Real-time recurring pattern detection & warning system
  - New unexpected patterns are checked for recursion
  - Warning system reports when same damaging pattern keeps occurring



Pressure measurements
Anomalous pressure patterns marked



clustered anomalies
anomaly clusters in different colours