Data Assimilation Techniques for Improving the Accuracy of Model Predictions

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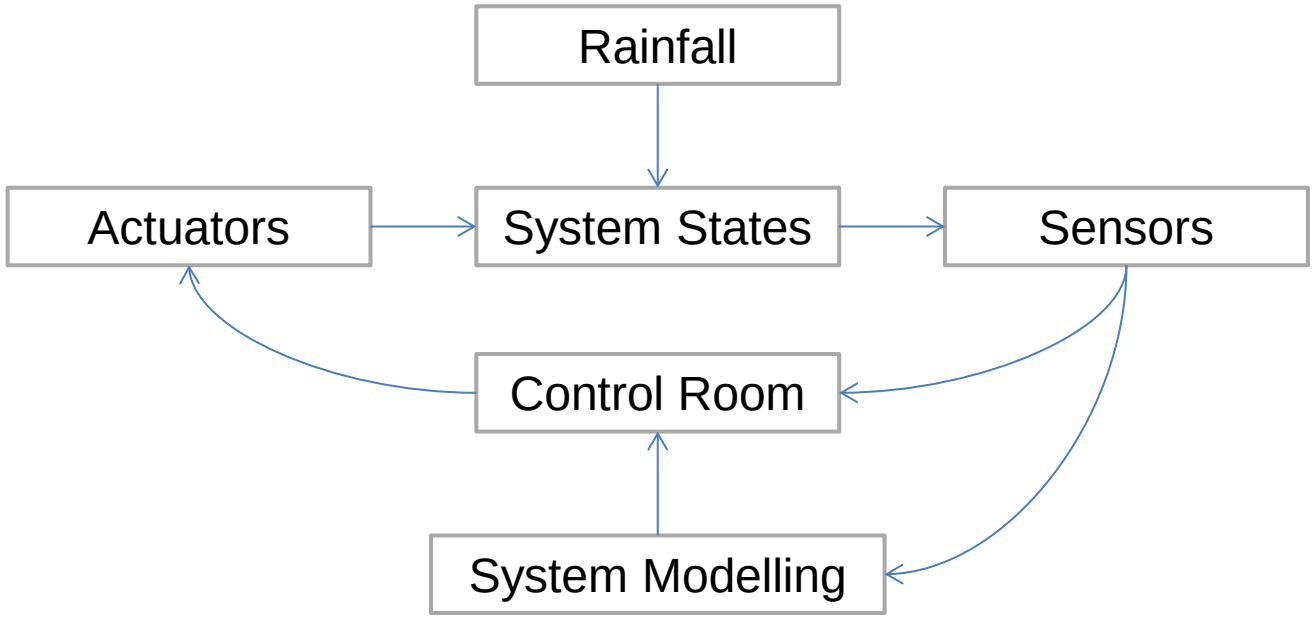
Introduction

- Why Model Urban Wastewater Systems?
- What is Data Assimilation?
- Techniques issues for Data Assimilation in Wastewater Models
- Software
- Conclusions

Why Model Urban Wastewater systems?

Need to control urban rainfall runoff systems:

- Flood risk associated with climatic changes.
- Environmental Regulation (Water Framework Directive).

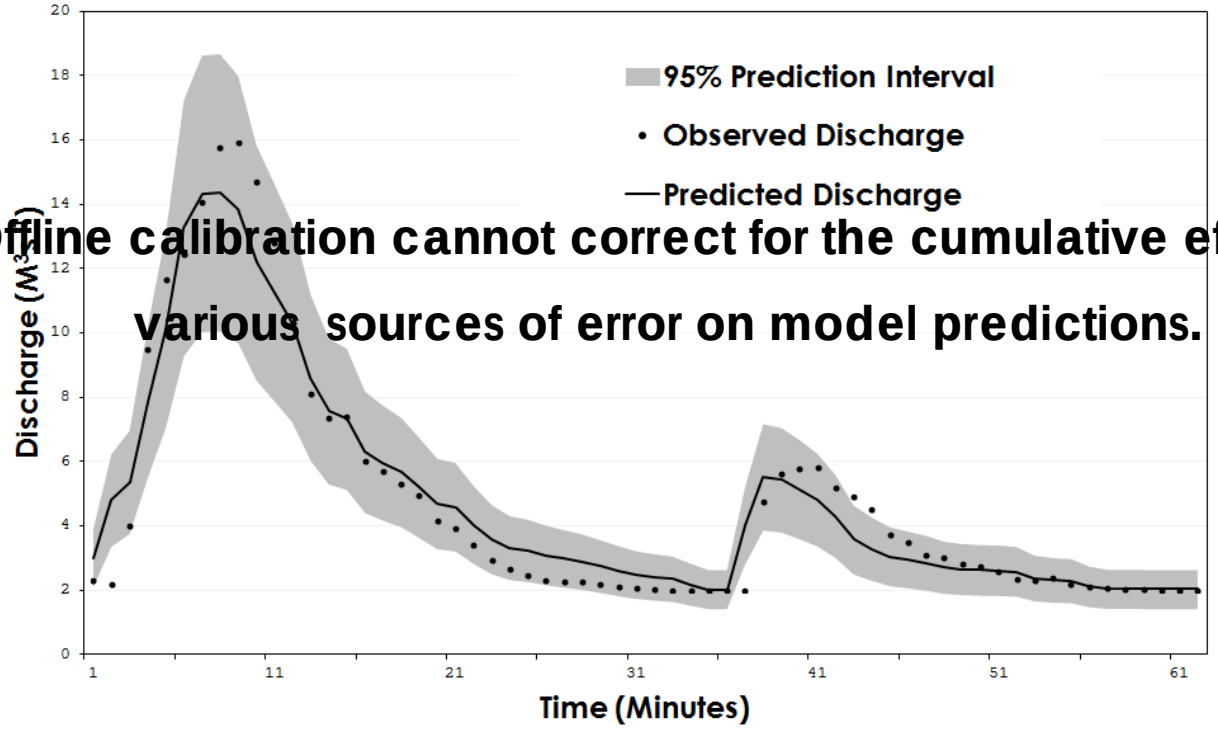


Why Model Urban Wastewater systems?

Models need to provide **reliable**, **robust** predictions.

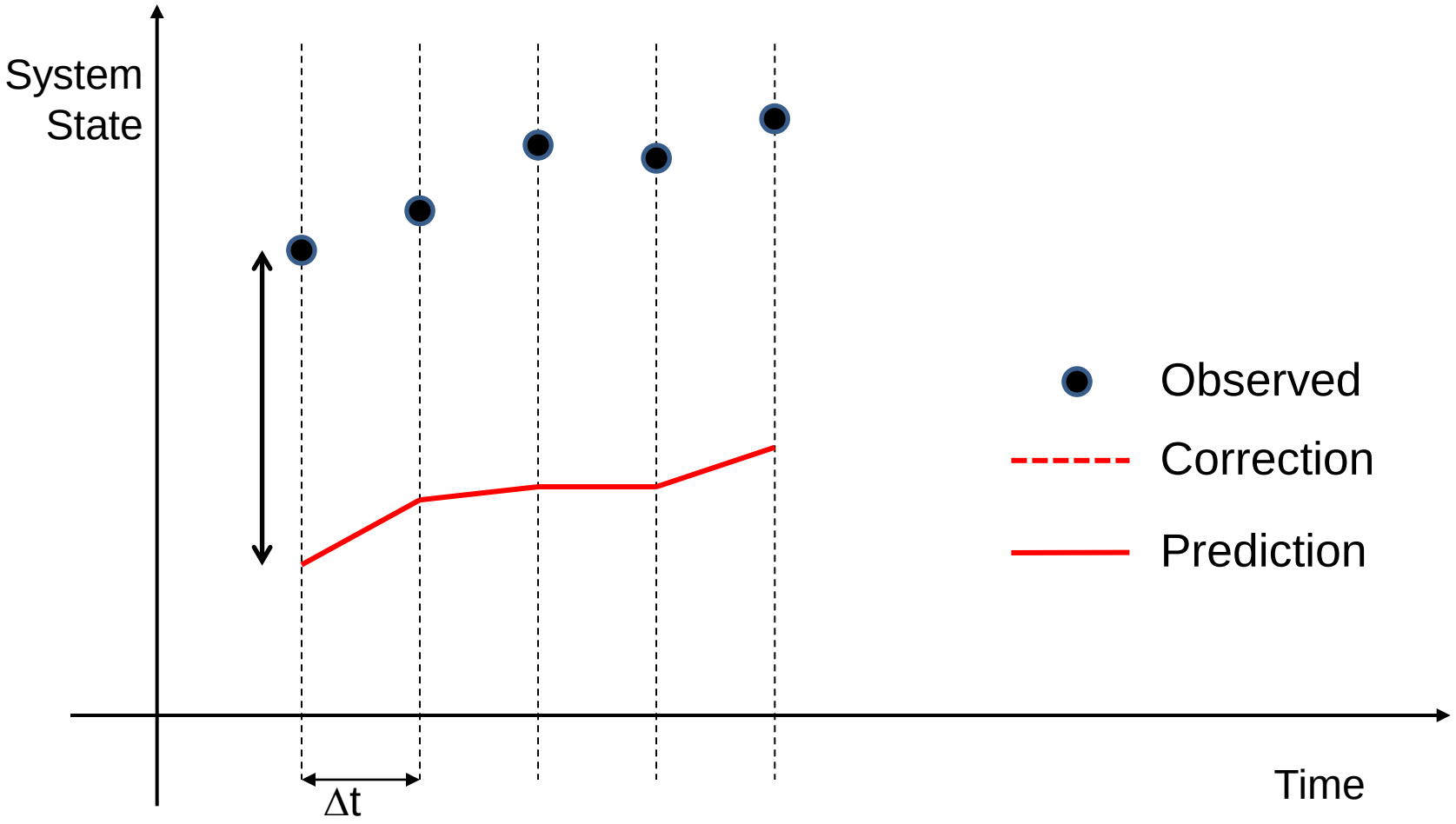
However, **All Models are Wrong**

Off-line calibration may be used to reduce model uncertainty



Offline calibration cannot correct for the cumulative effect of various sources of error on model predictions.

What is Data Assimilation?



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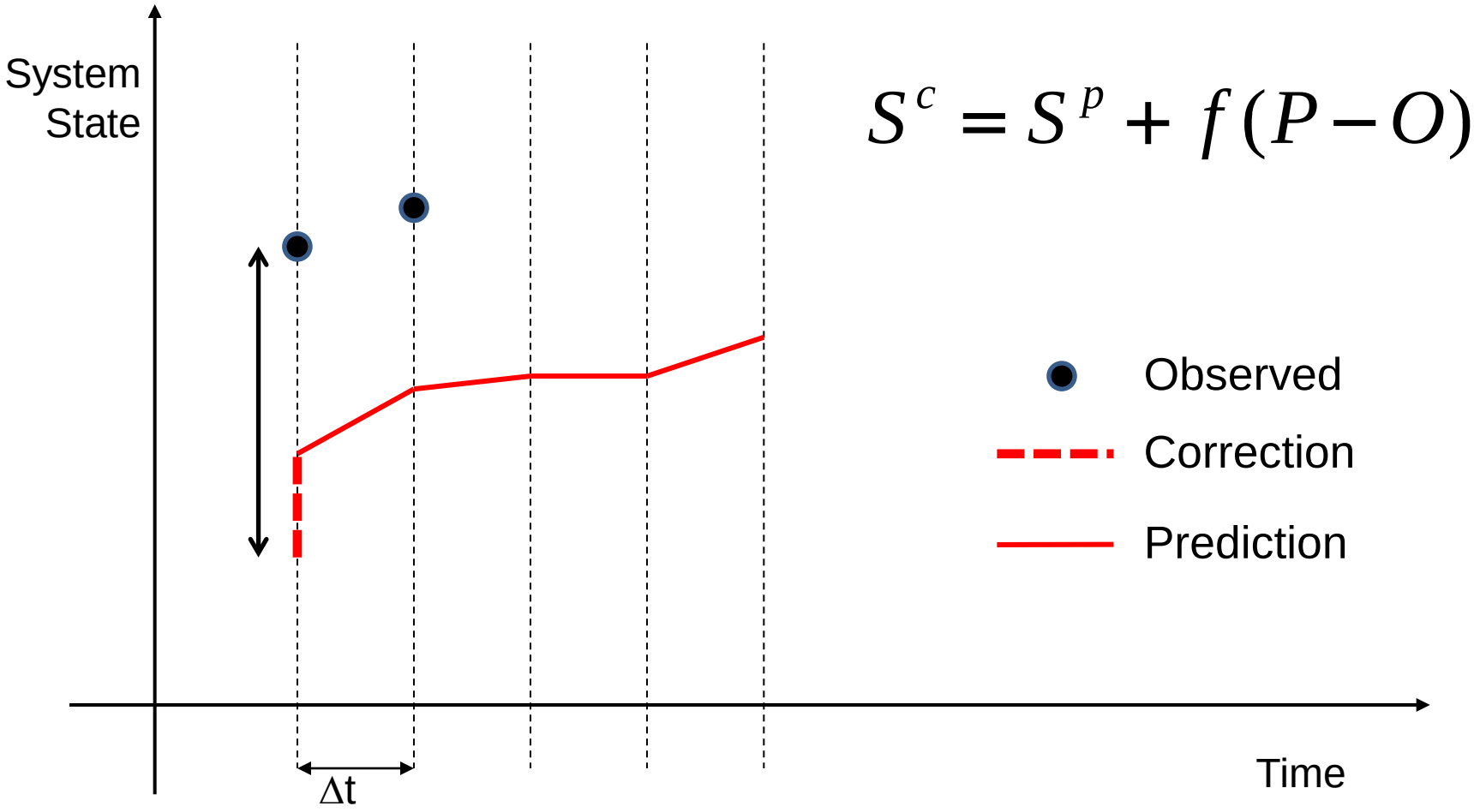

$$S^c = S^p + f(P - O)$$

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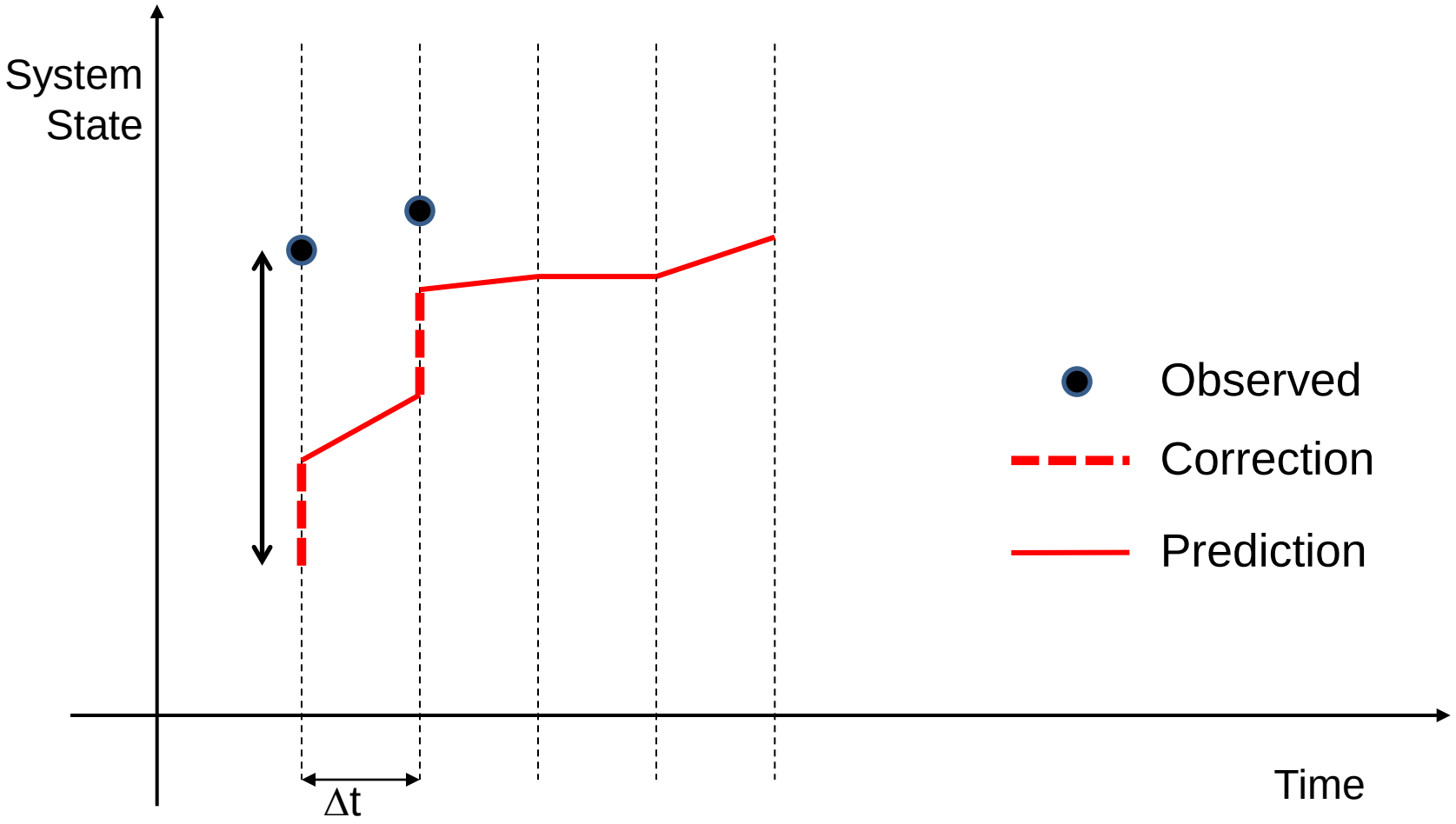

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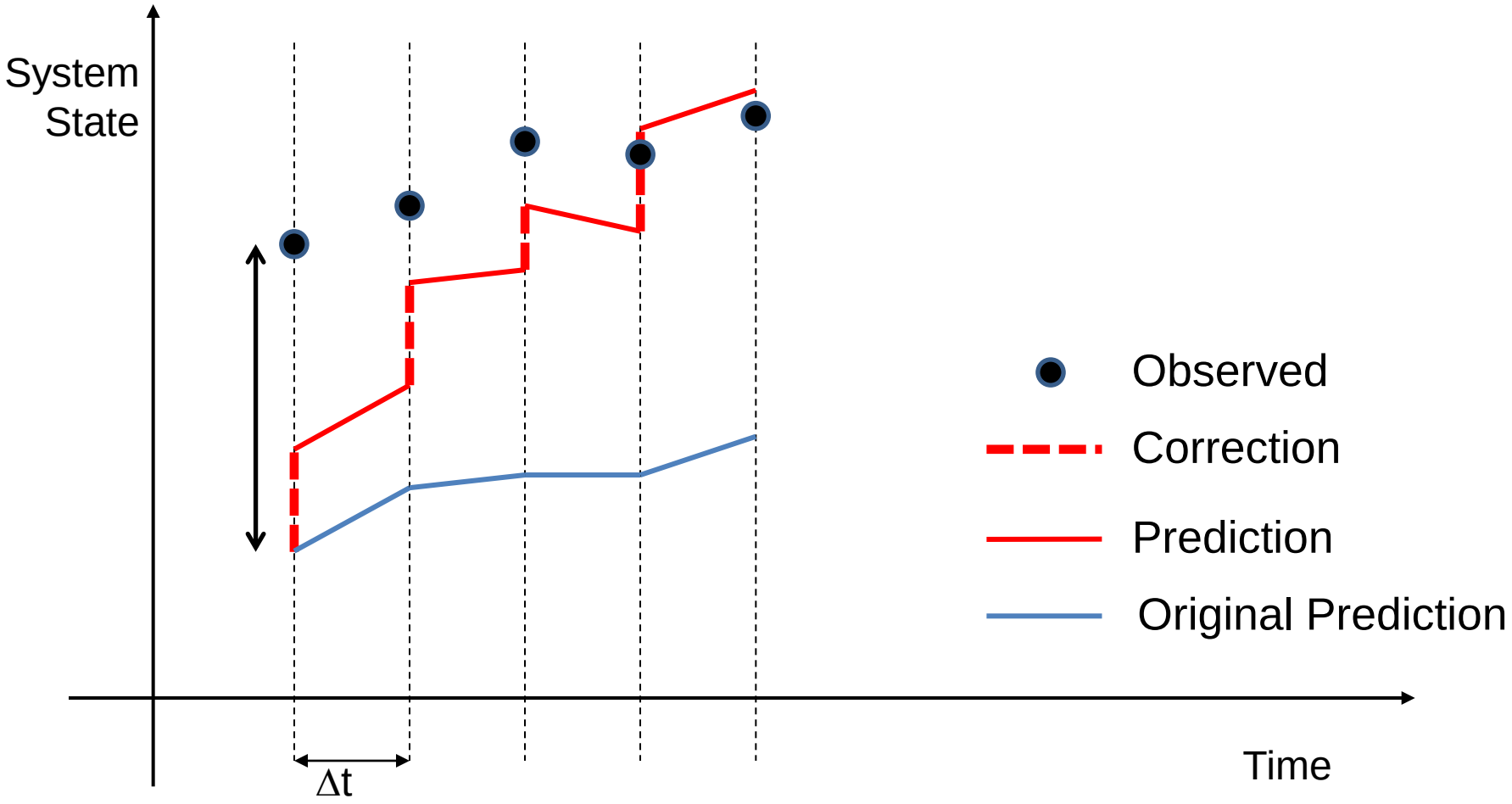


What is Data Assimilation?

Real-time observations are combined with the model prediction to produce a best estimate of the current system state.

Methods to Improve best estimate of current system state:

- Deterministic Correction Procedures (Kalman Filter)
- Ensemble Assimilation Procedures (Ensemble Kalman Filter; Particle Filter).

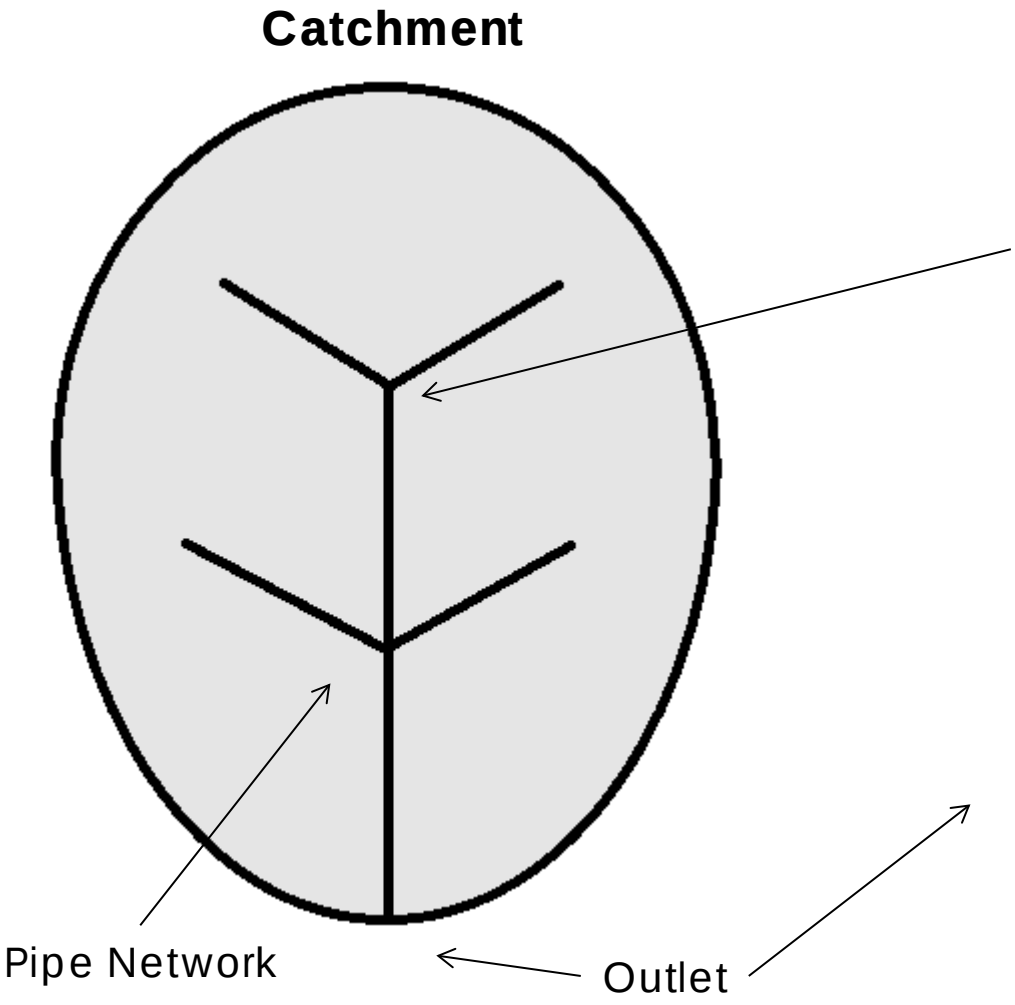
Methods to improve the quality of the model forecast:

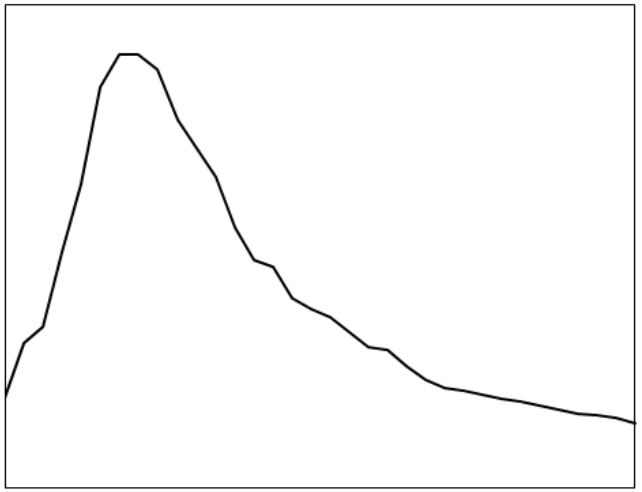
- Data Driven Model for error correction

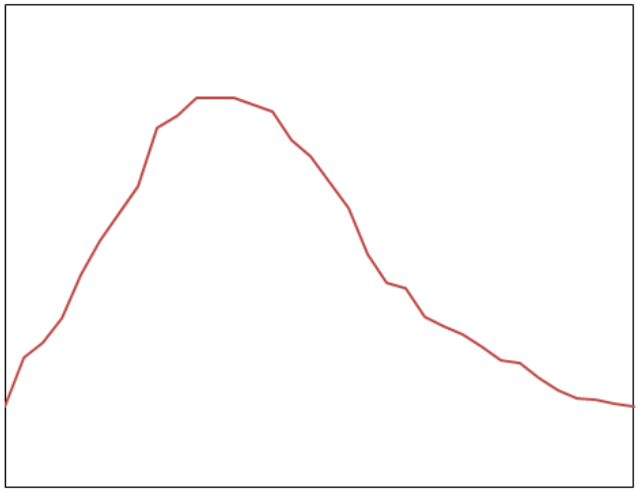
Technical Issues for Data Assimilation

- System Lag time between upstream model states and downstream observations.
- Observation Frequency Relative to System Lag Time.
- Flow Attenuation.
- System Control Structures.
- Measurement Error.

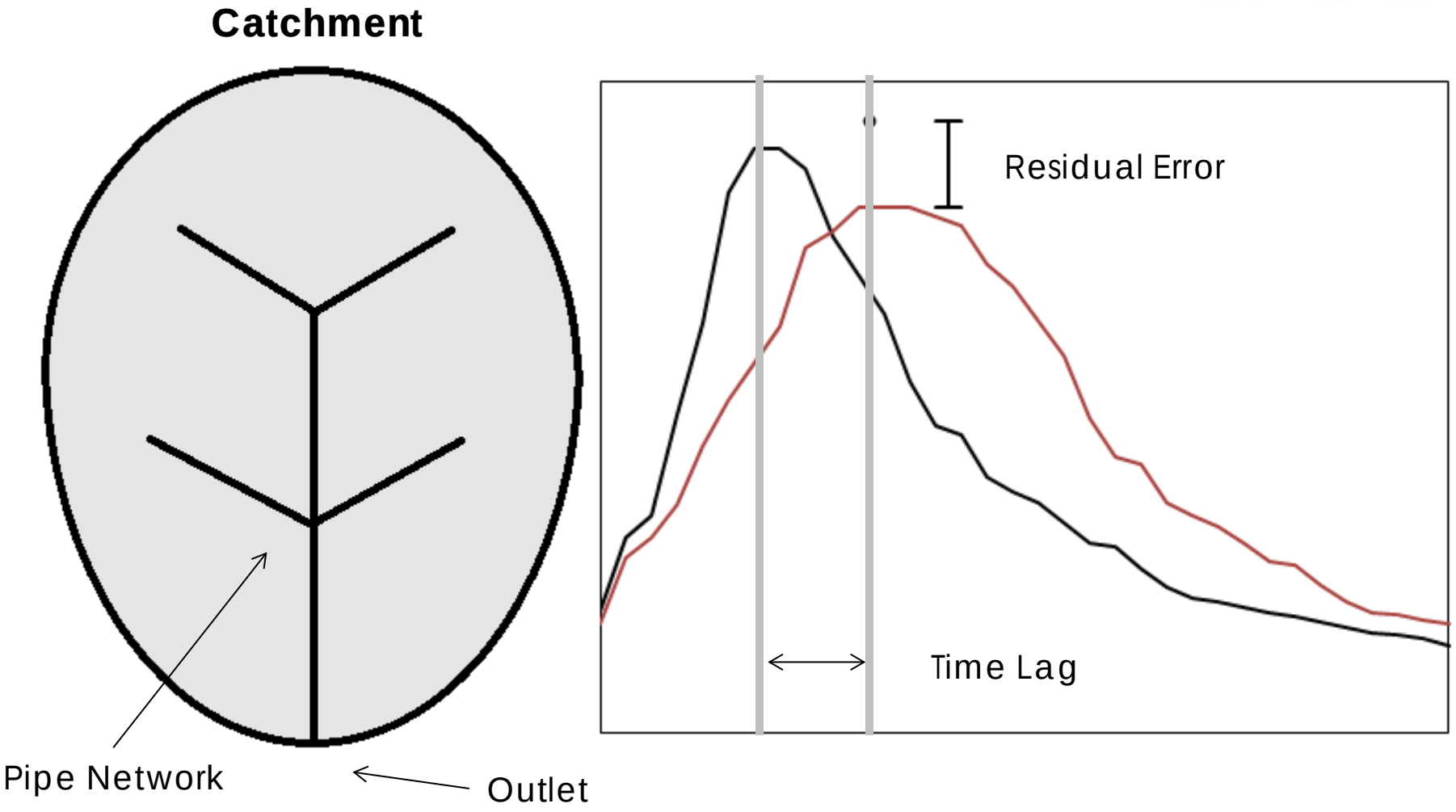
Technical Issues for Data Assimilation







Data Assimilation



Technical Issues for Data Assimilation

$$S^c = S^p + f(P - O)$$

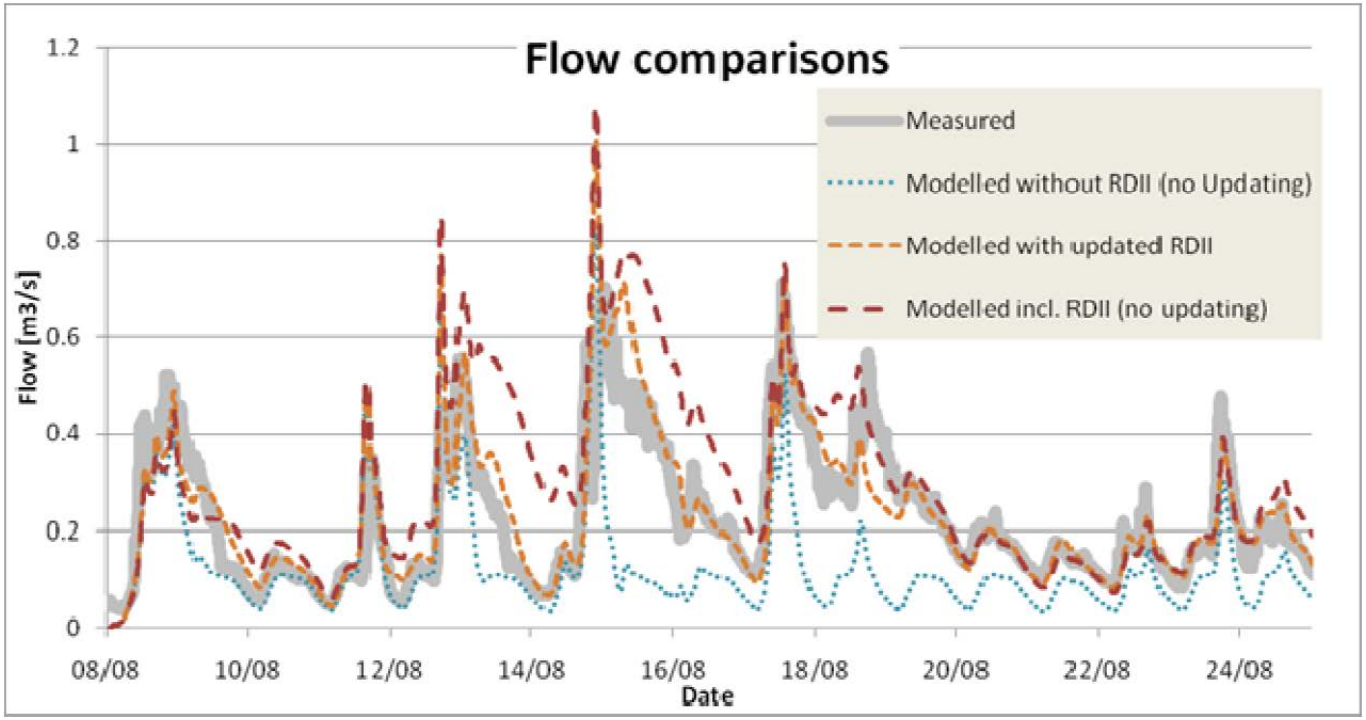
- Lag time between upstream model states and downstream observations.

Depends on the relationship between the lag time in the system and the speed of the processes occurring.

Technical Issues for Data Assimilation

• Slow changing flow components (infiltration process) much greater than the lag time of the system.

$$S^c = S^p + f(P - O)$$



Borup et al (2011)

Technical Issues for Data Assimilation

- Faster changing flow components relative to the time lag in the system.....

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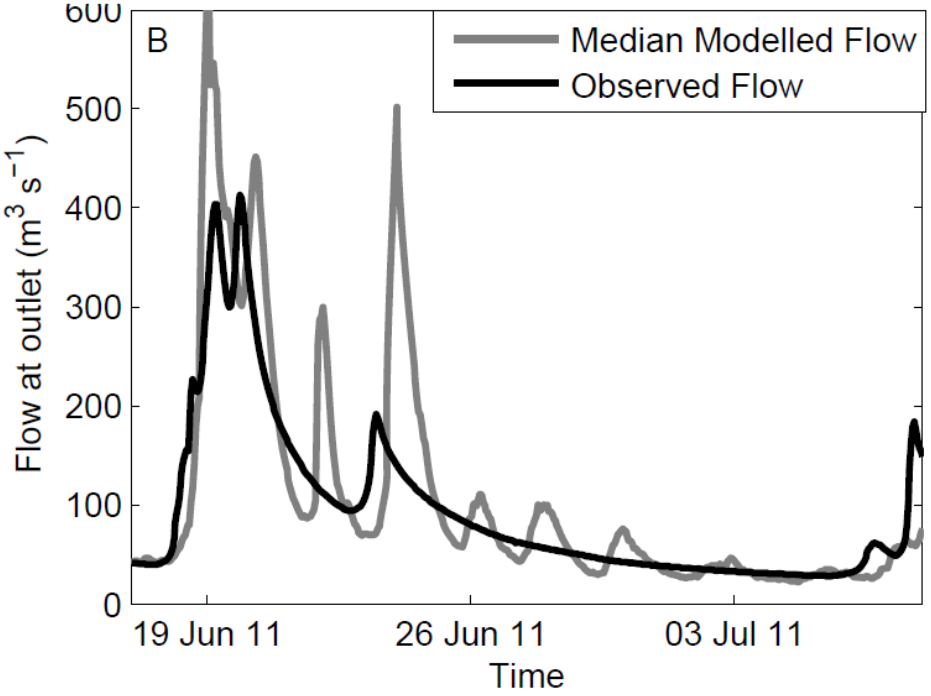
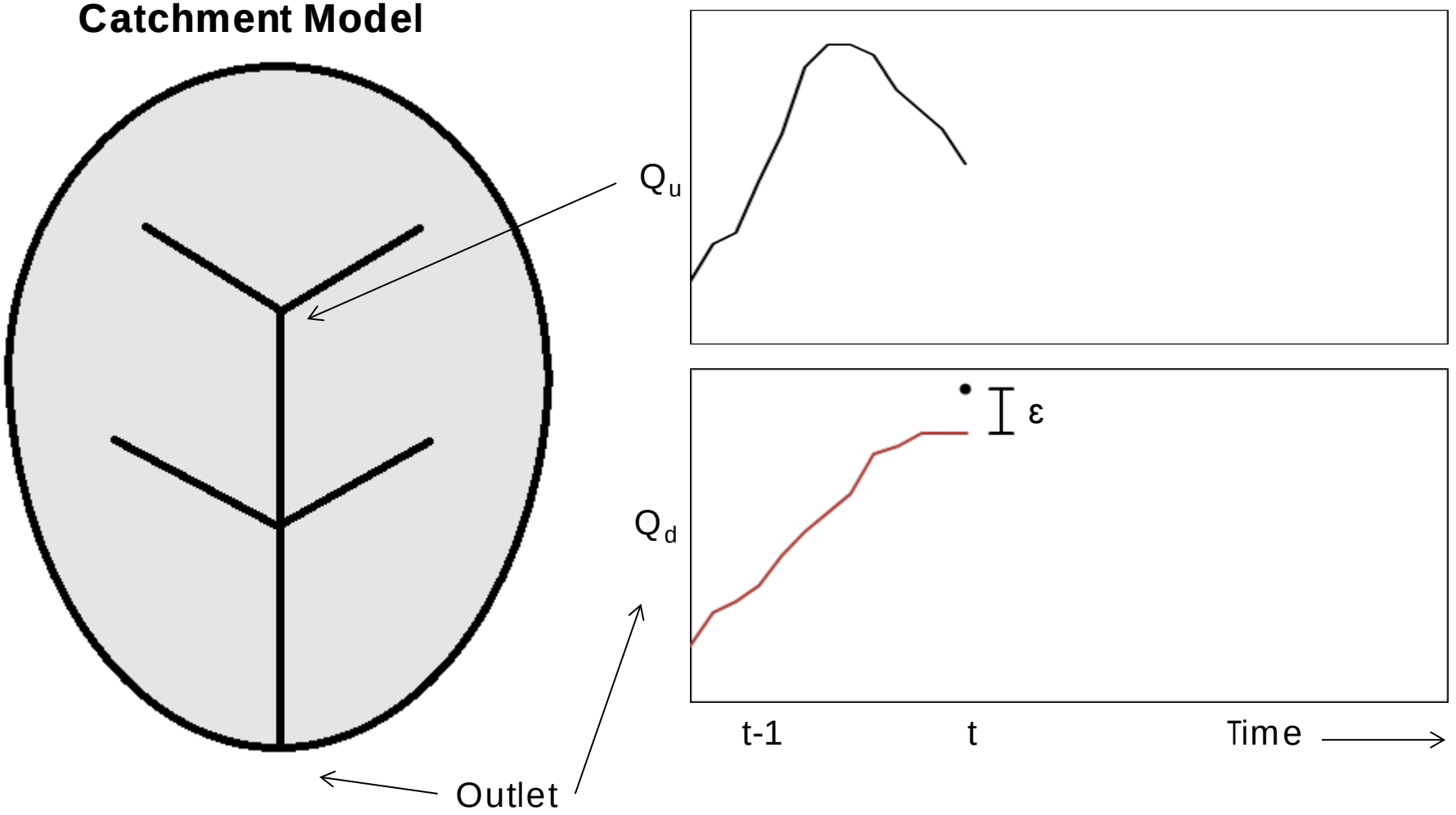


Can be negative if lag is not considered.

McMillan et al (2013)

Methodology

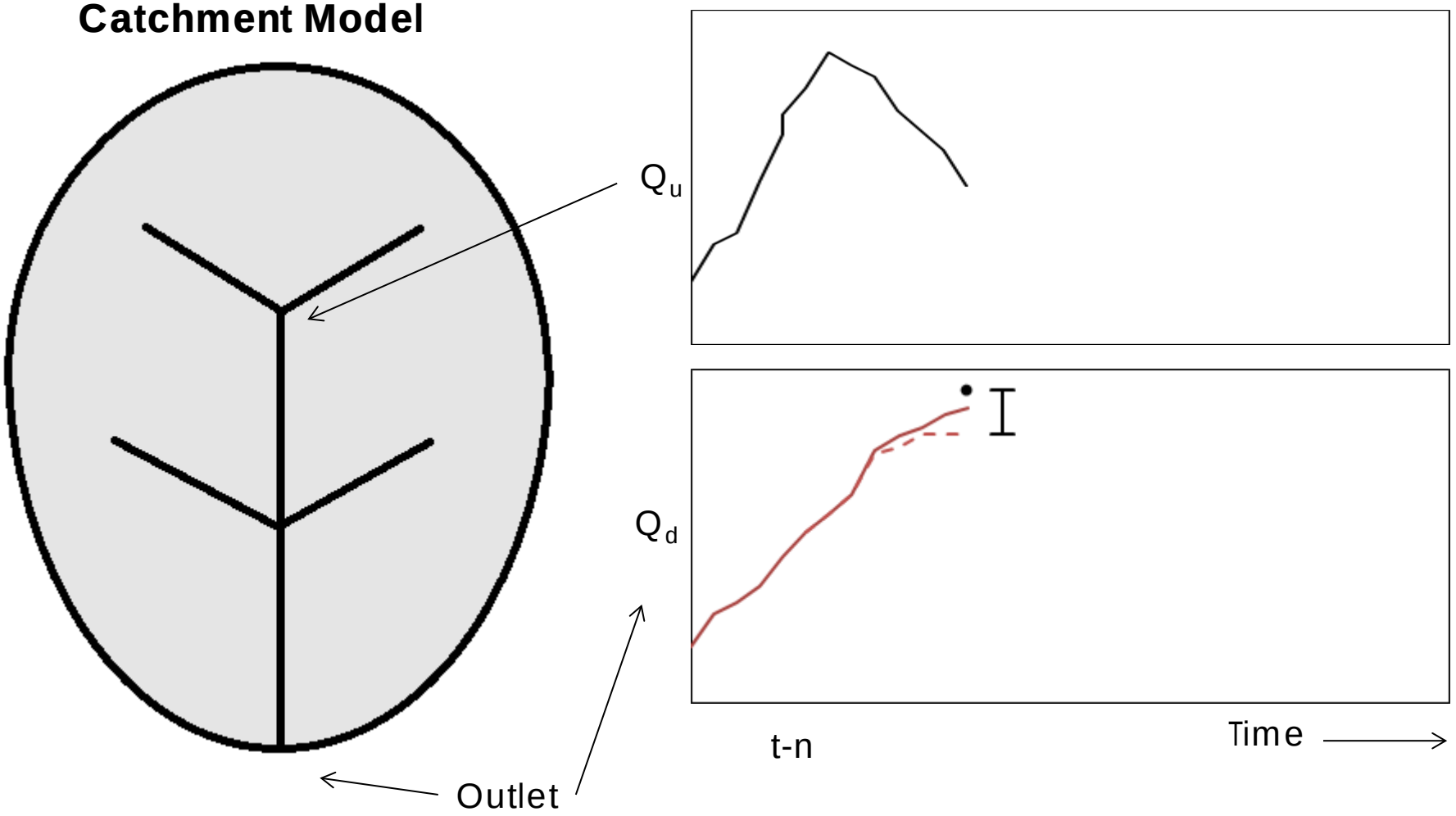
Catchment Model



Methodology

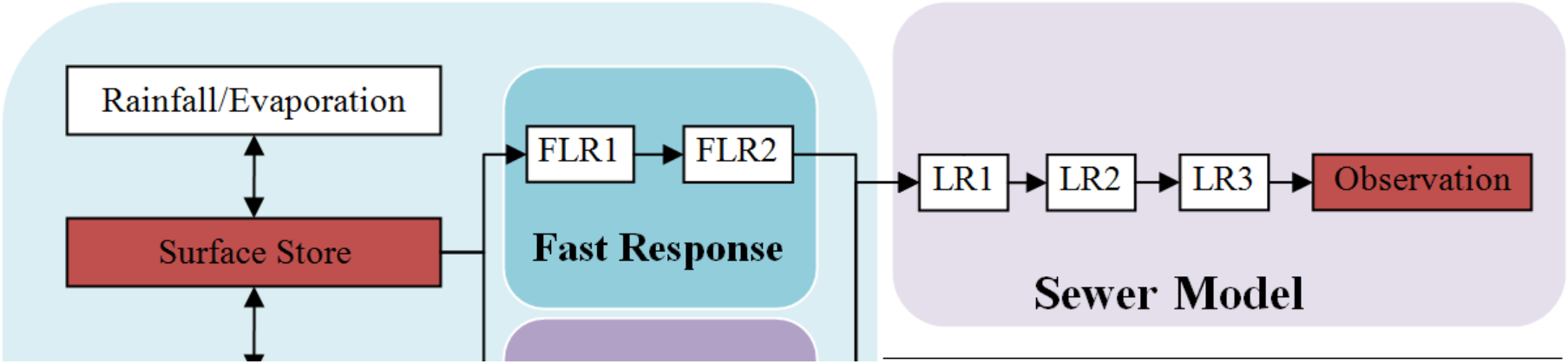
Prepared enabling change

Catchment Model



Prepared enabling change

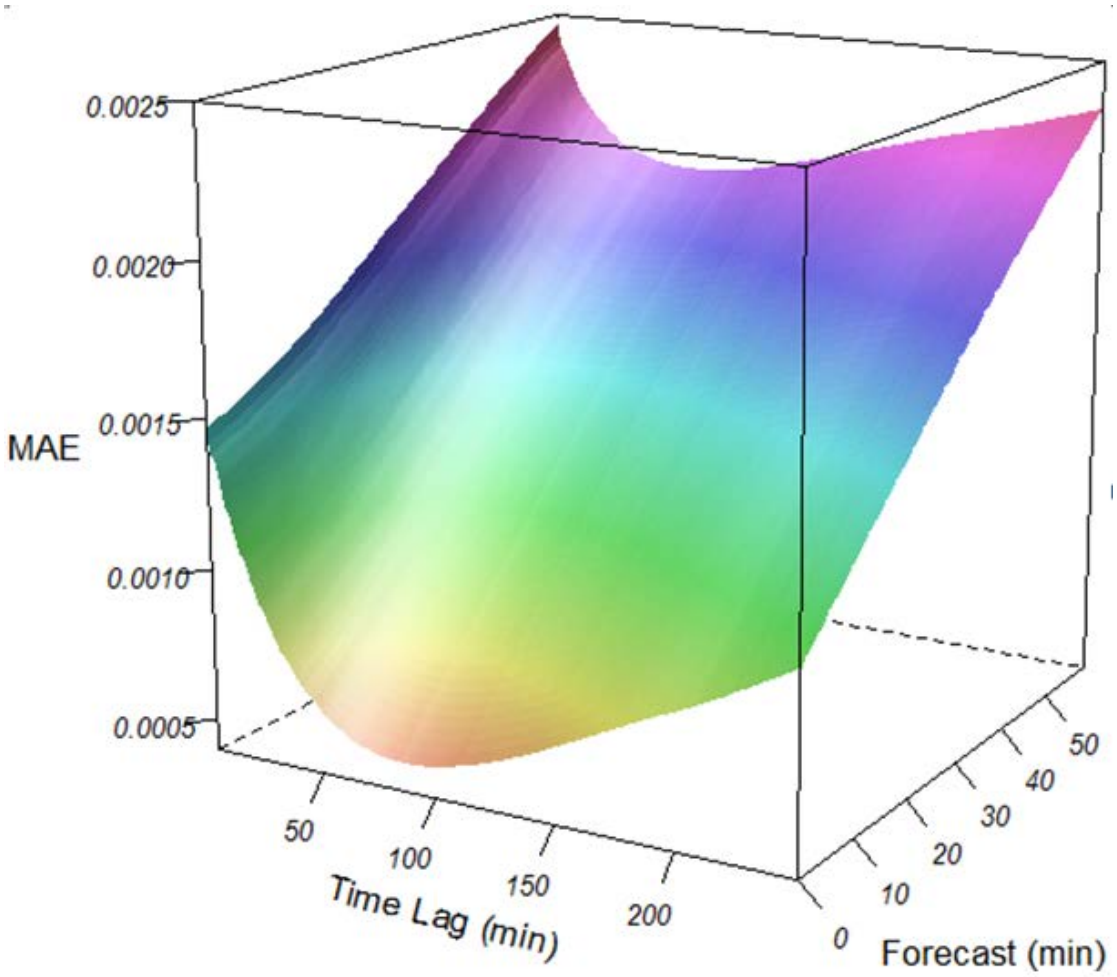
Conceptual Rainfall-Runoff Model



$$ss_c = ss_f + \frac{\partial ss_{t\text{-}n}}{\partial q}(q_o - q_p)$$

Prepared enabling change

Sensitivity Analysis:



Technical Issues for Data Assimilation

- System Lag time between upstream model states and downstream observations.
- **Observation Frequency Relative to System Lag Time.**
- Flow Attenuation.
- System Control Structures.
- Measurement Error.

Prepared enabling change

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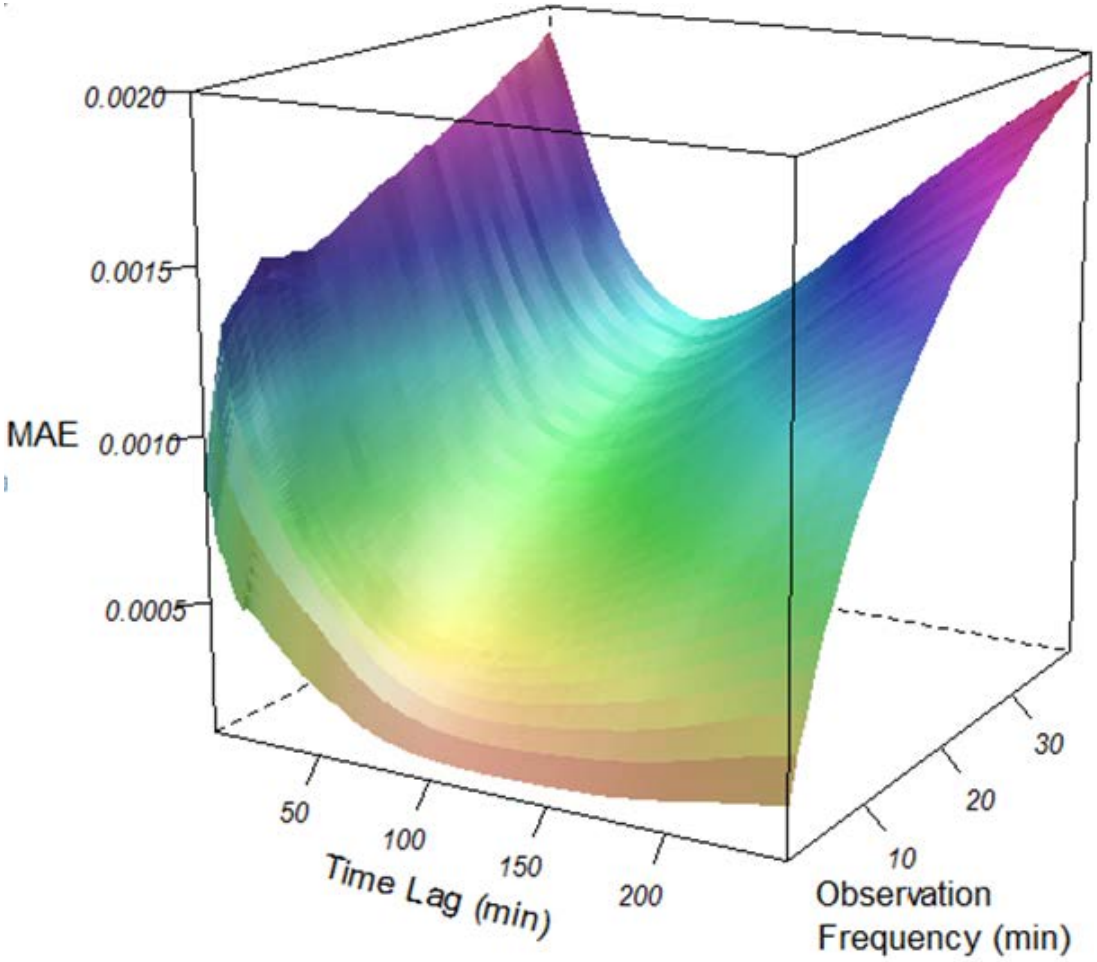
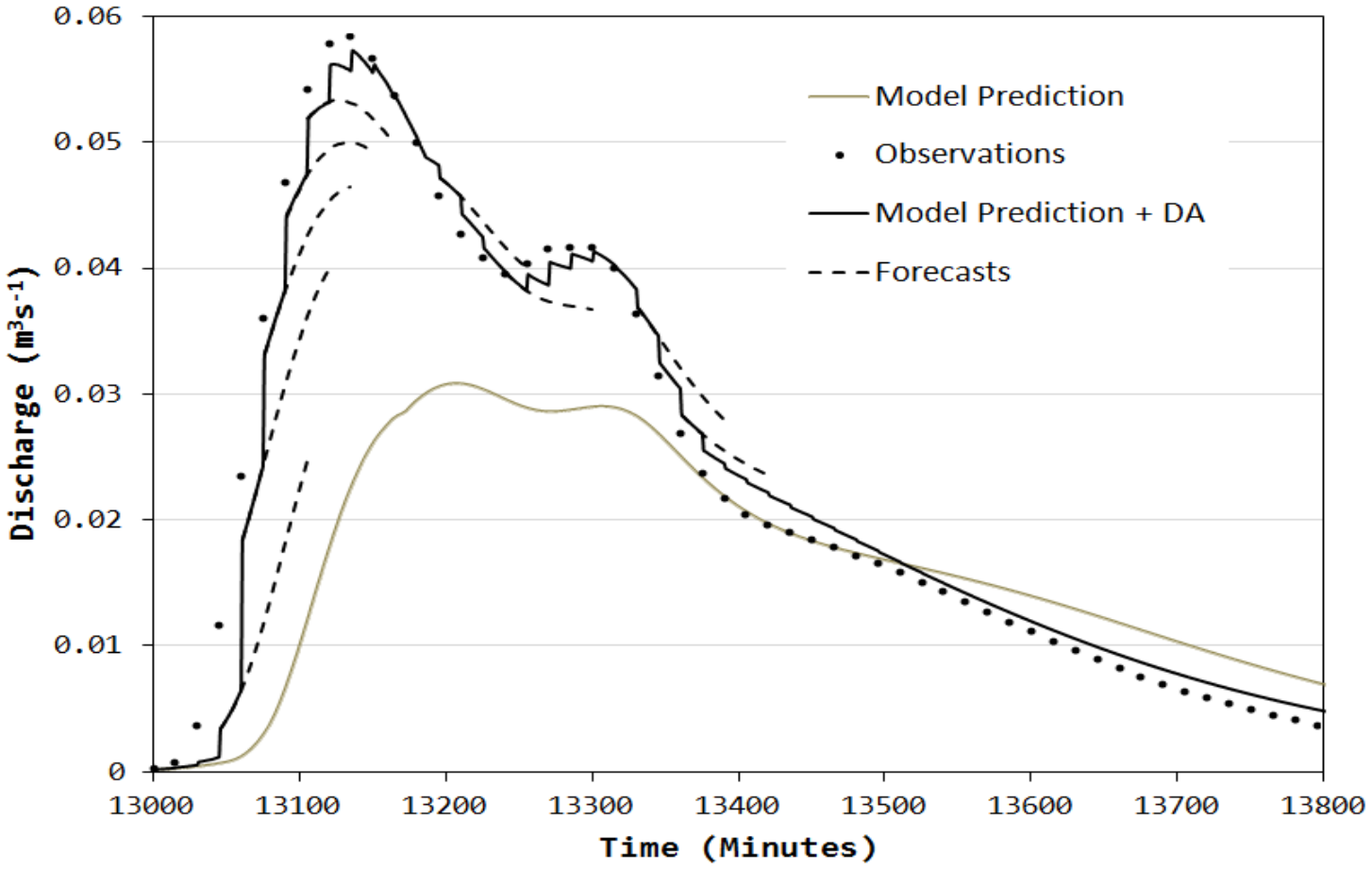


Case Study

- Observation Frequency: 15 min
- Time-Lag: 100 minutes



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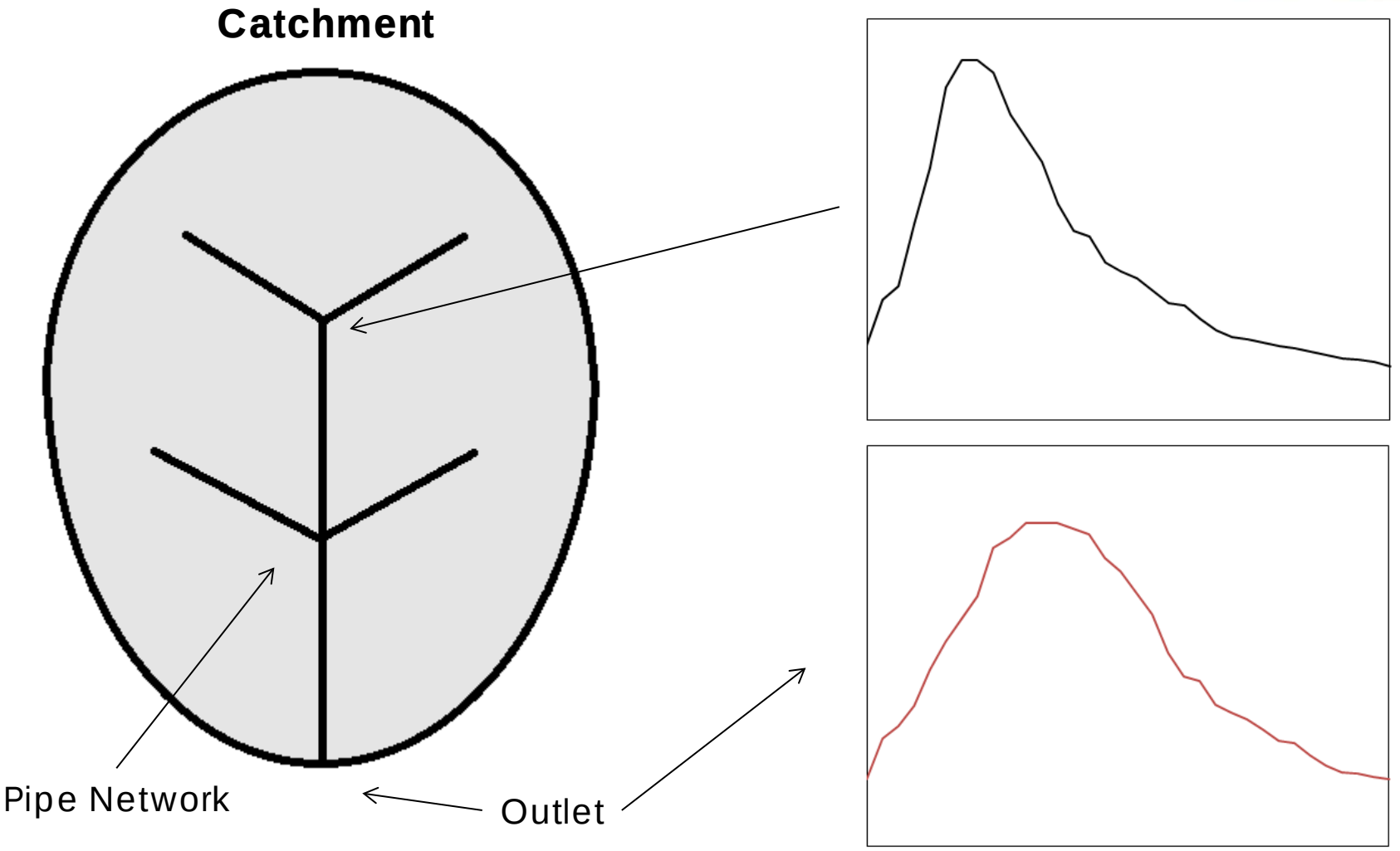
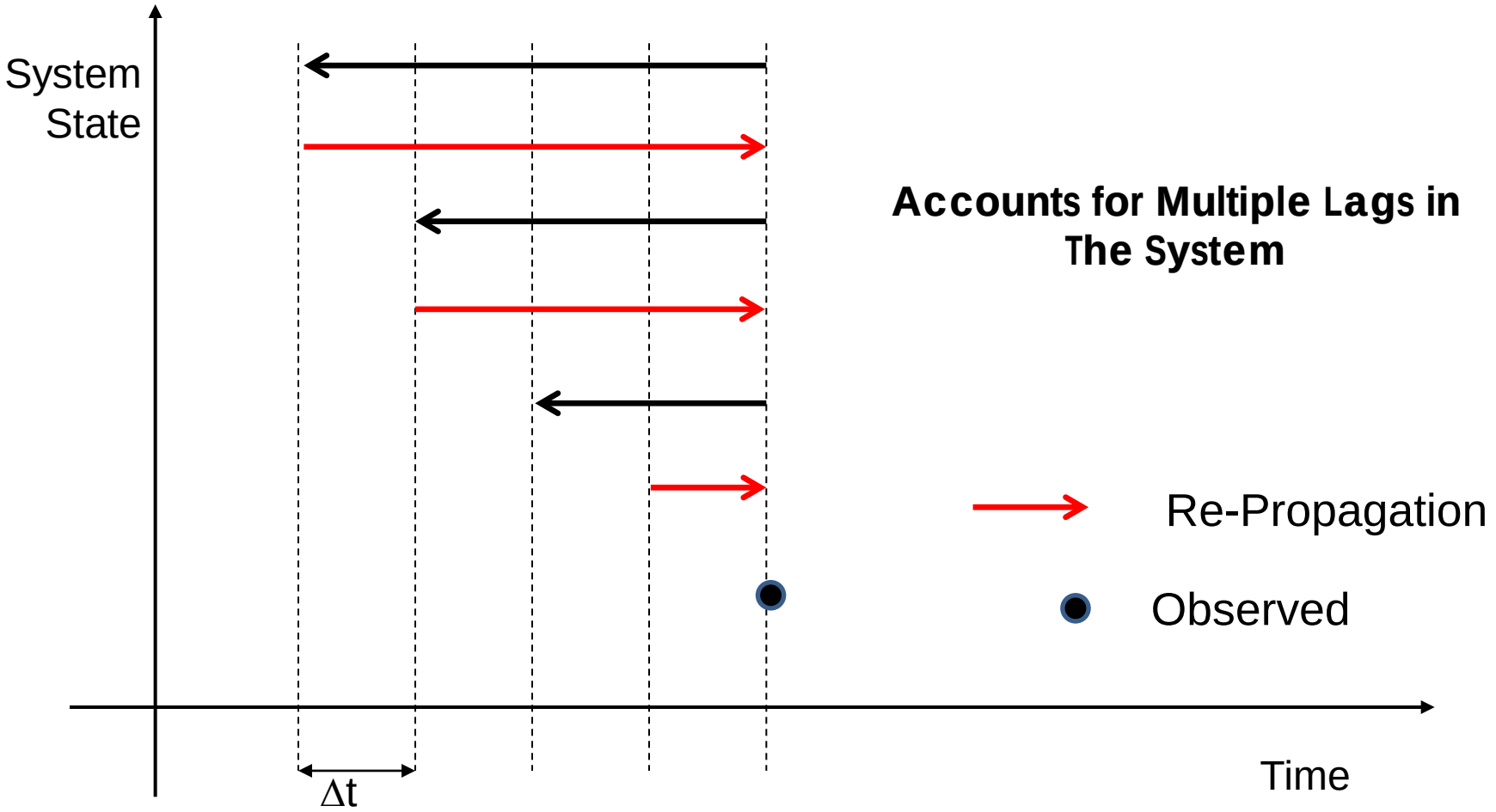


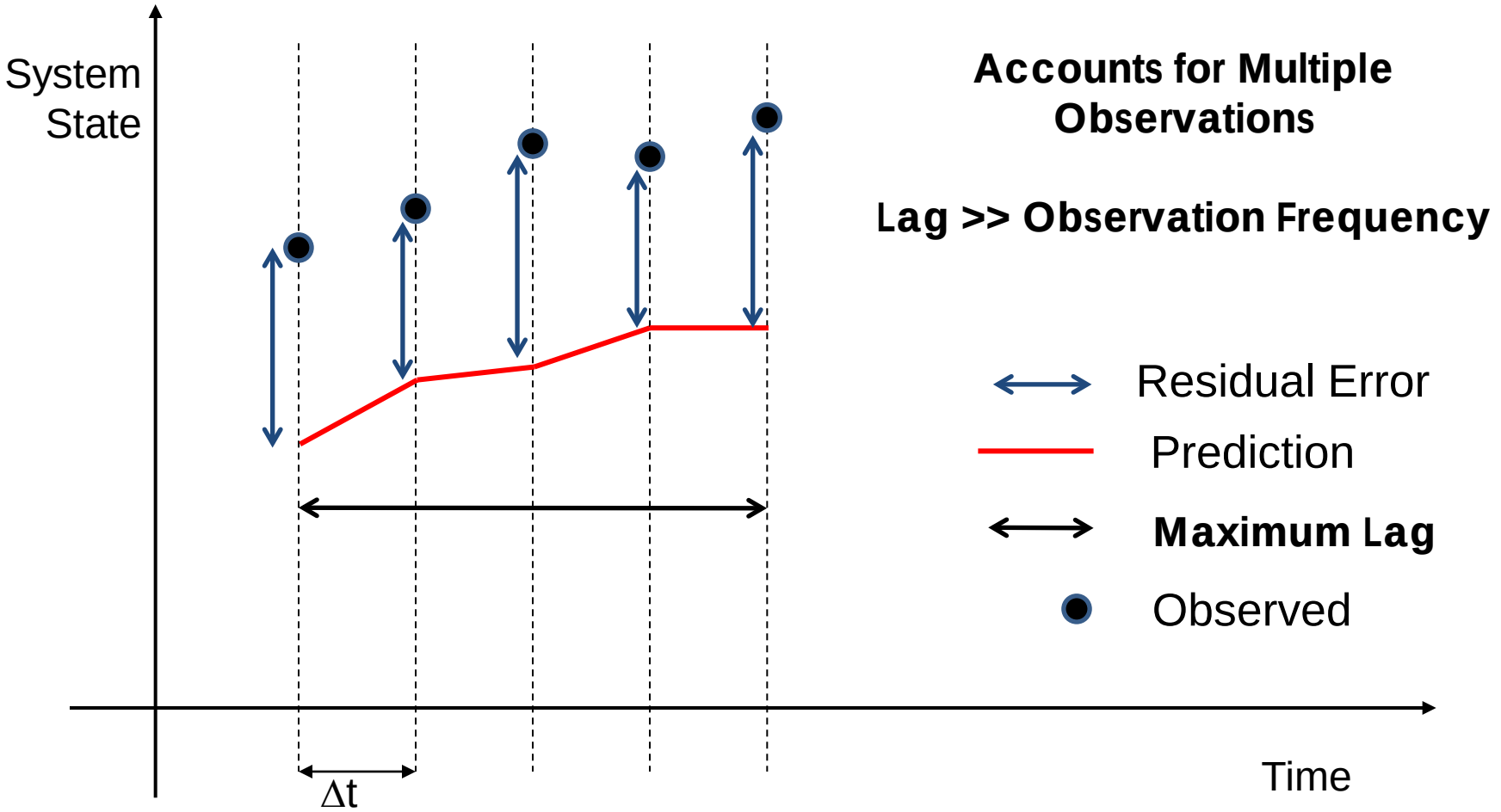
Technical Issues for Data Assimilation

McMillan et al 2013: Recursive Ensemble Kalman Filter



Technical Issues for Data Assimilation

Noh et al 2011: Lagged Particle Filter



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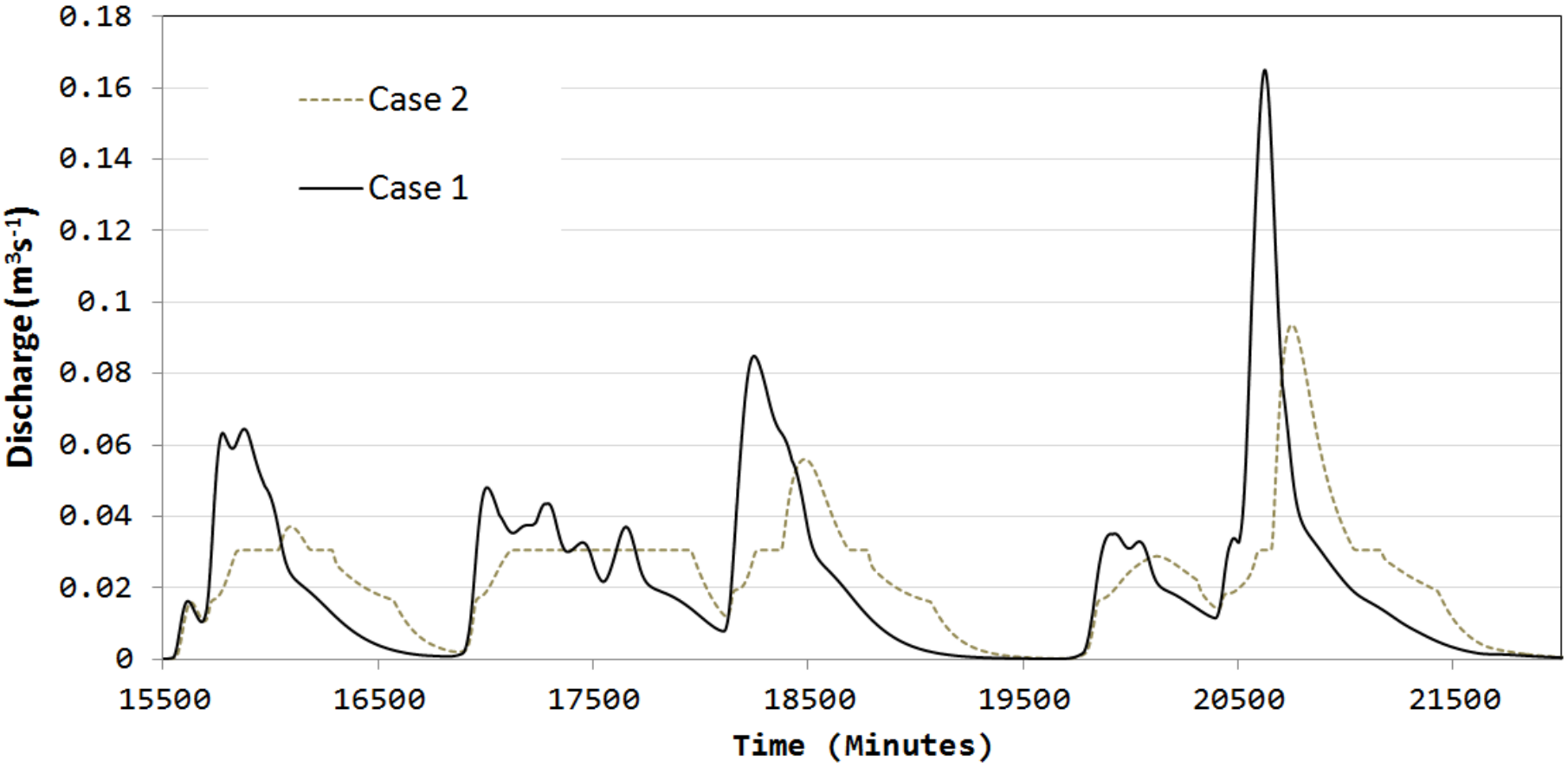
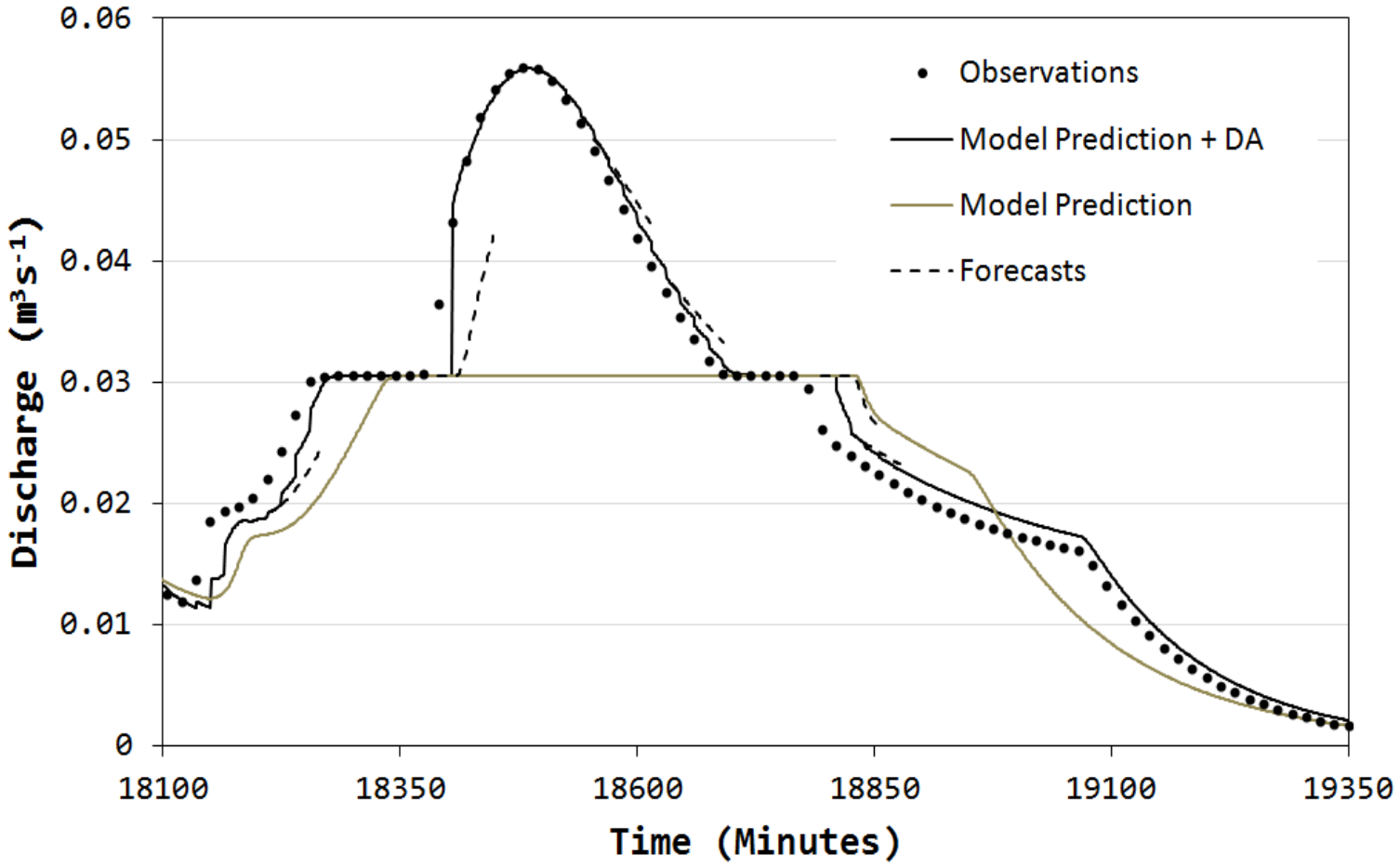


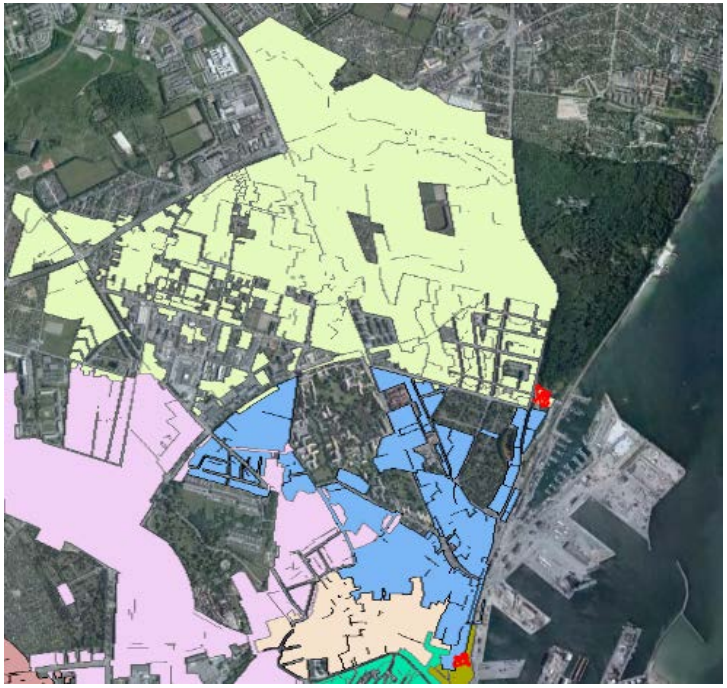
Technical Issues for Data Assimilation

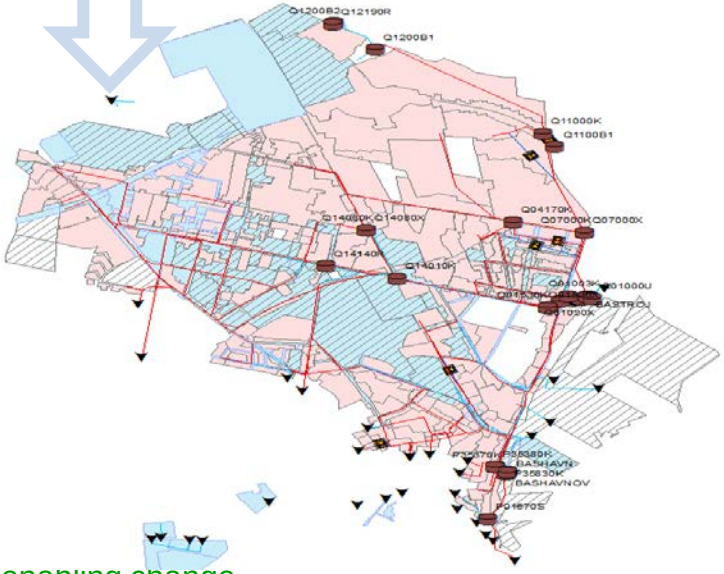
- Observation Frequency: 15 min
- Time-Lag: 323 minutes



Aarhus - Conceptual model

- Two sub-catchments
  - TB – yellow green
  - HB – blue
- Source of data – MIKE URBAN model



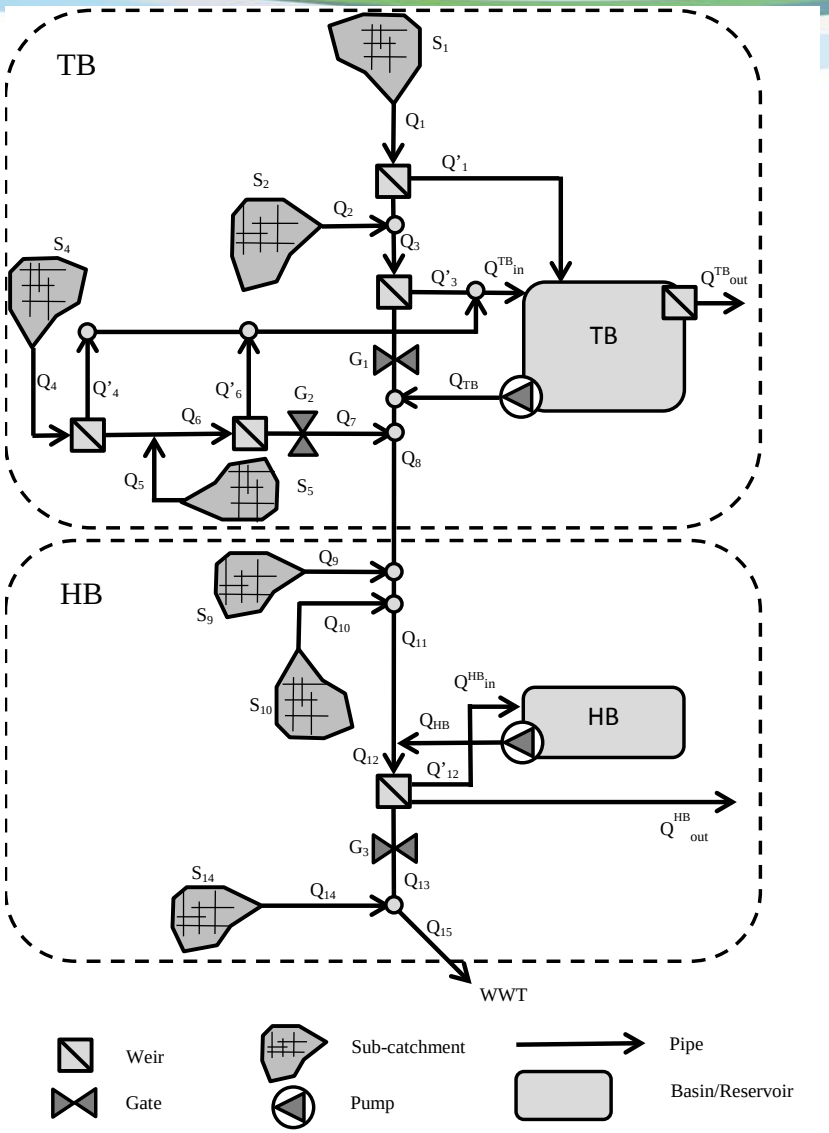


Aarhus - Conceptual model

- Seven sub-catchments
- Two basins
- Three static weirs
- Three weirs with control gates

Input variables:

- Rain
- Control states
- Pump states

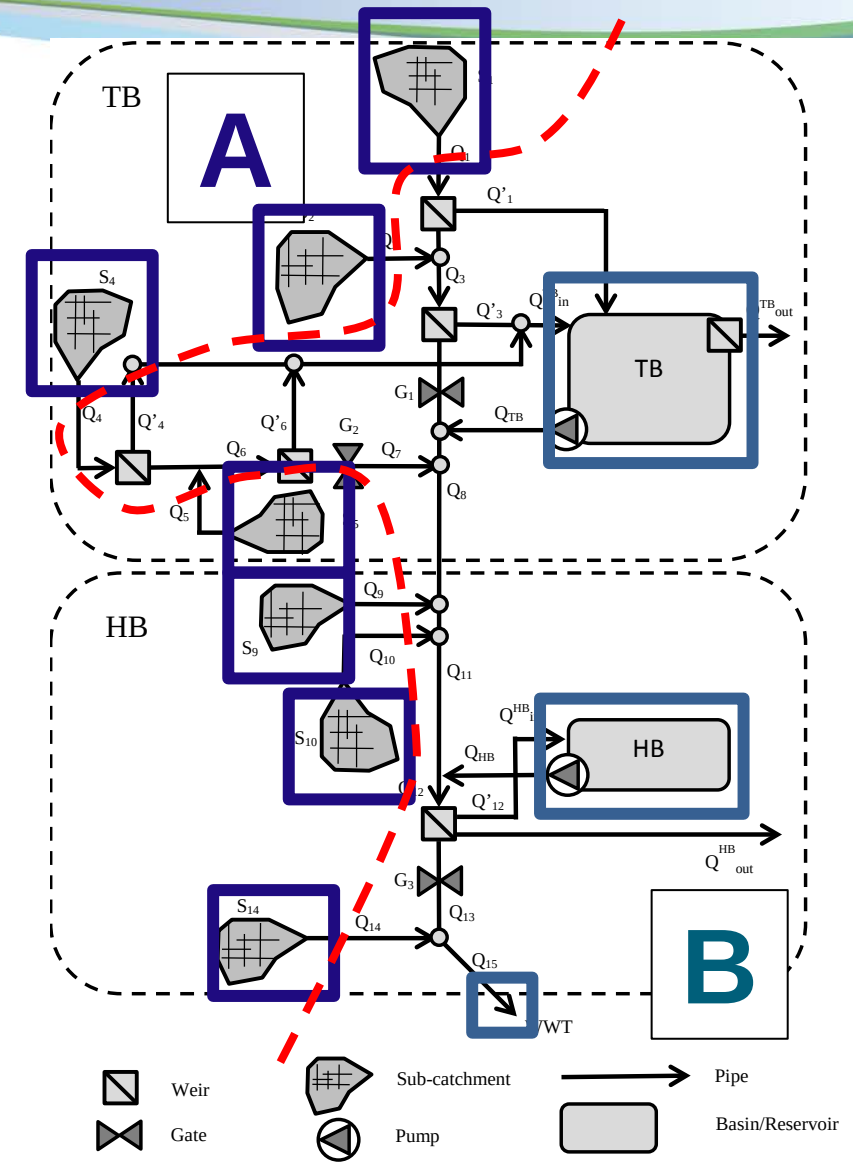


DA example – model

Model divided into two modules:

A. State estimate results – volumes in linear reservoir

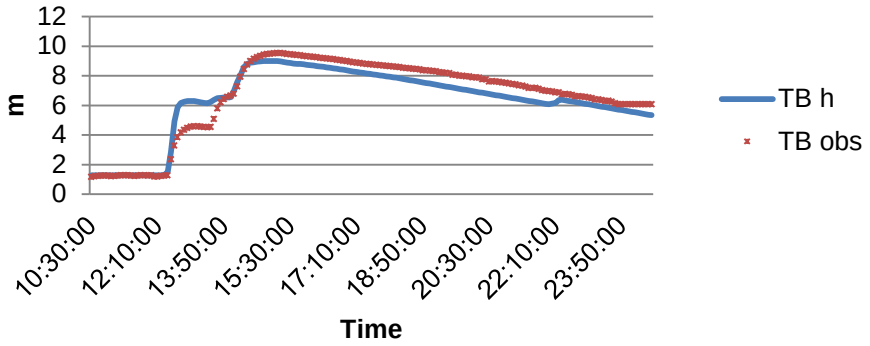
B. Observation estimate results– levels in basins and downstream flow



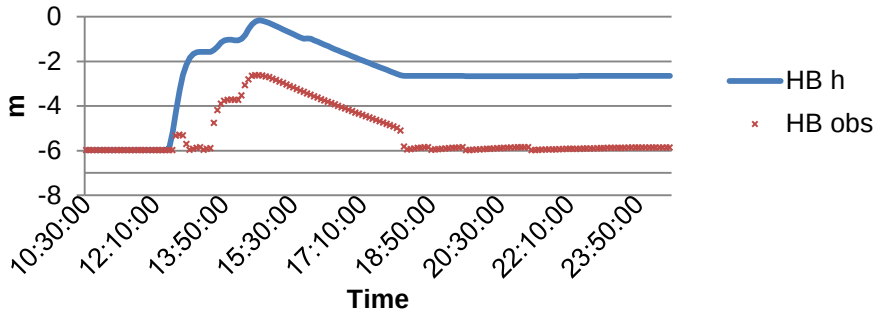
Aarhus – Extended Kalman Filter

No Data Assimilation

TB basin level

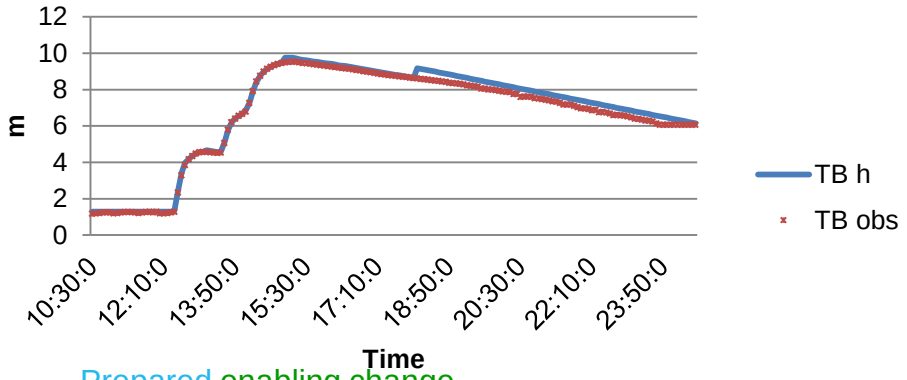


HB basin level



With Data Assimilation

TB basin level



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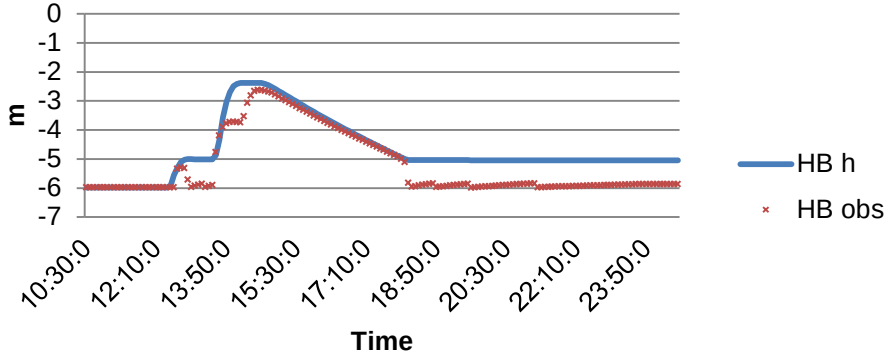

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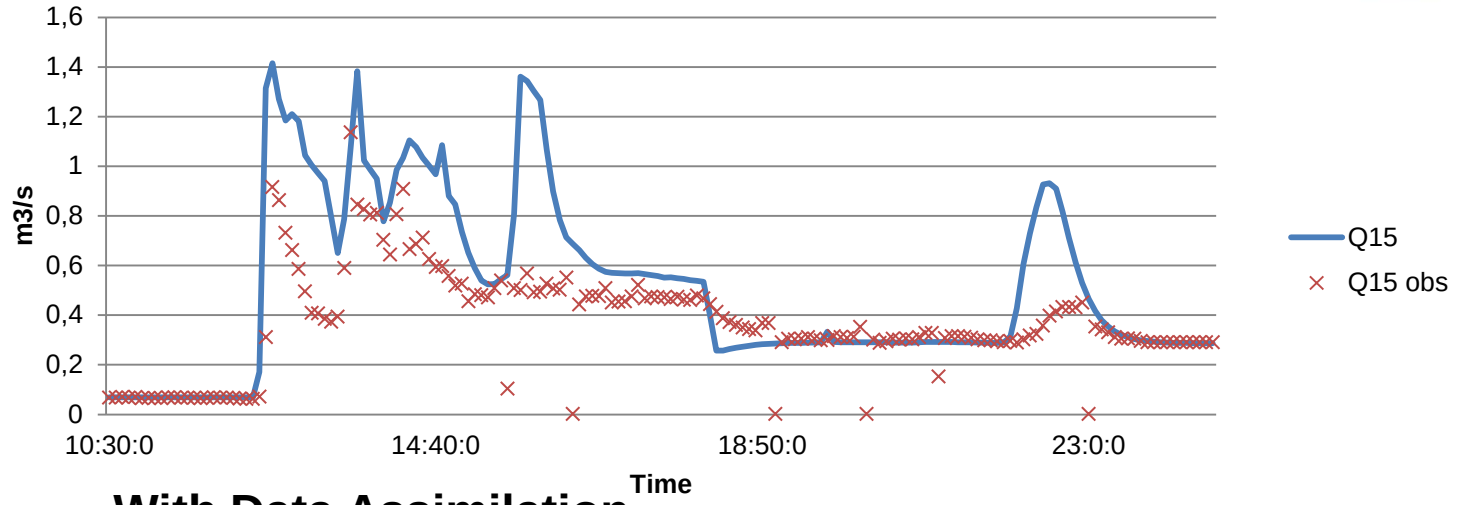

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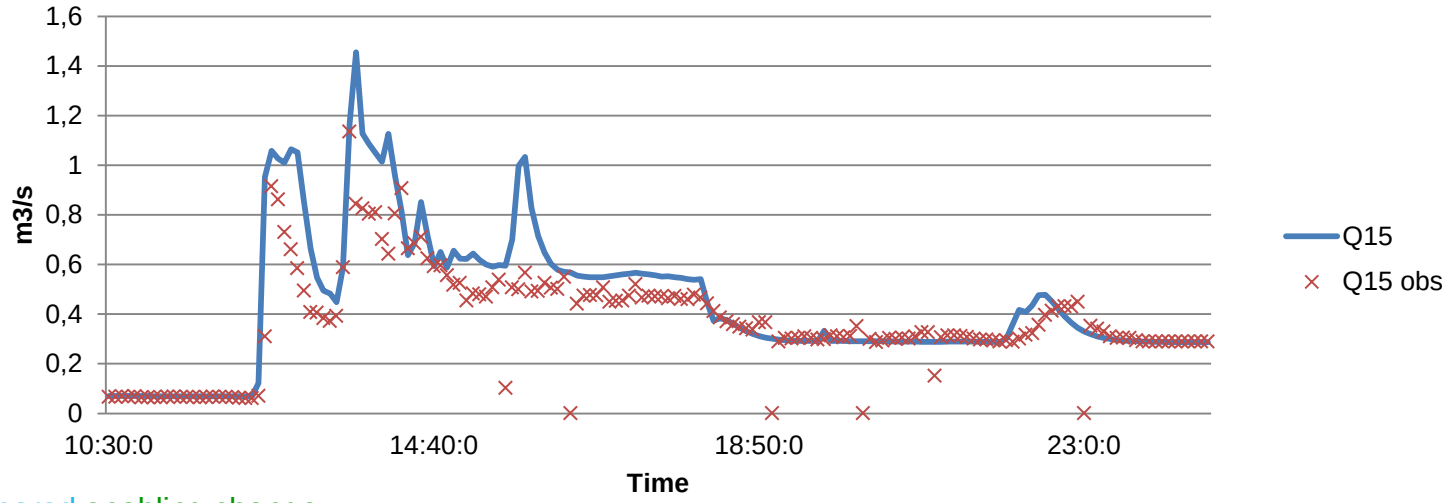

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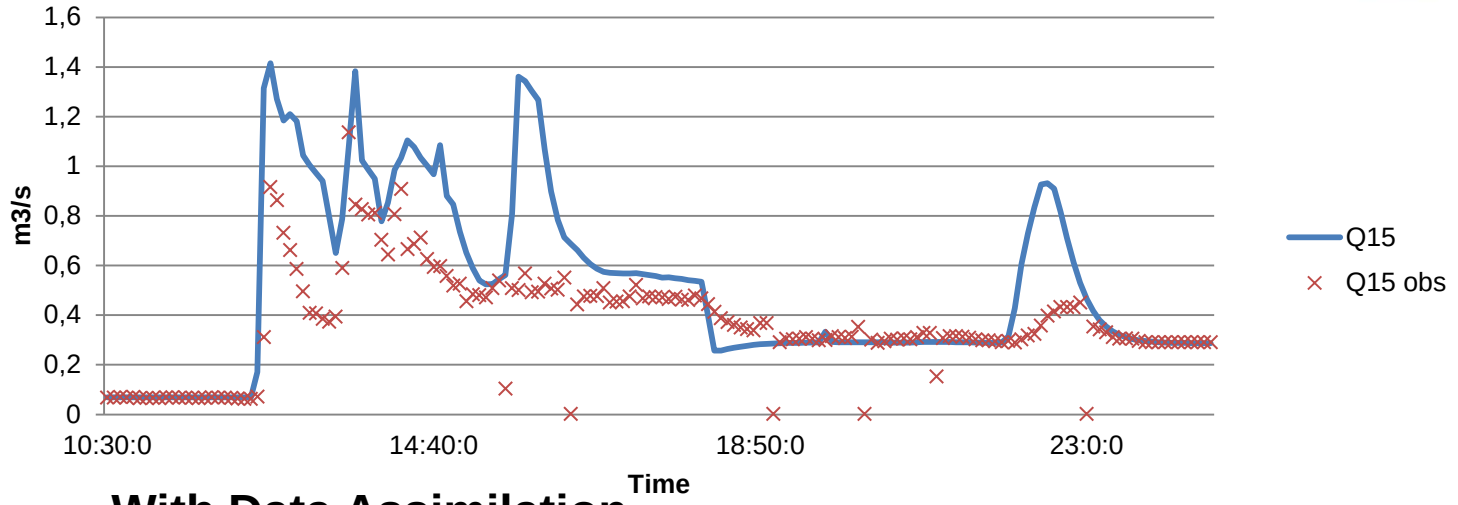

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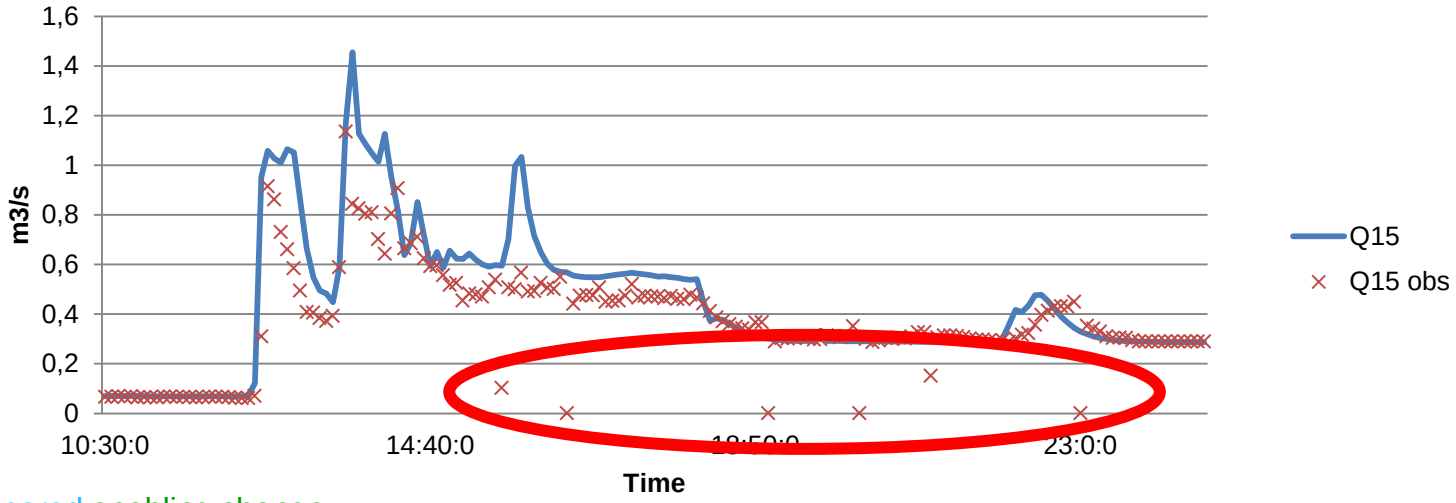


Introduction

- Why Model Urban Wastewater Systems?
- What is Data Assimilation?
- Techniques issues for Data Assimilation in Wastewater Models
- **Software**
- Conclusions and Research Challenges

Data Assimilation Software

- General DA toolbox developed for DIMS.CORE
- Three DA algorithms:
  - Extended Kalman filter
  - Ensemble Kalman filter
  - Particle filter
- Ready to implement with other models (DHI software)
- Ready to implement the real time mode
- The DA components are independent from the model

Software architecture – big picture

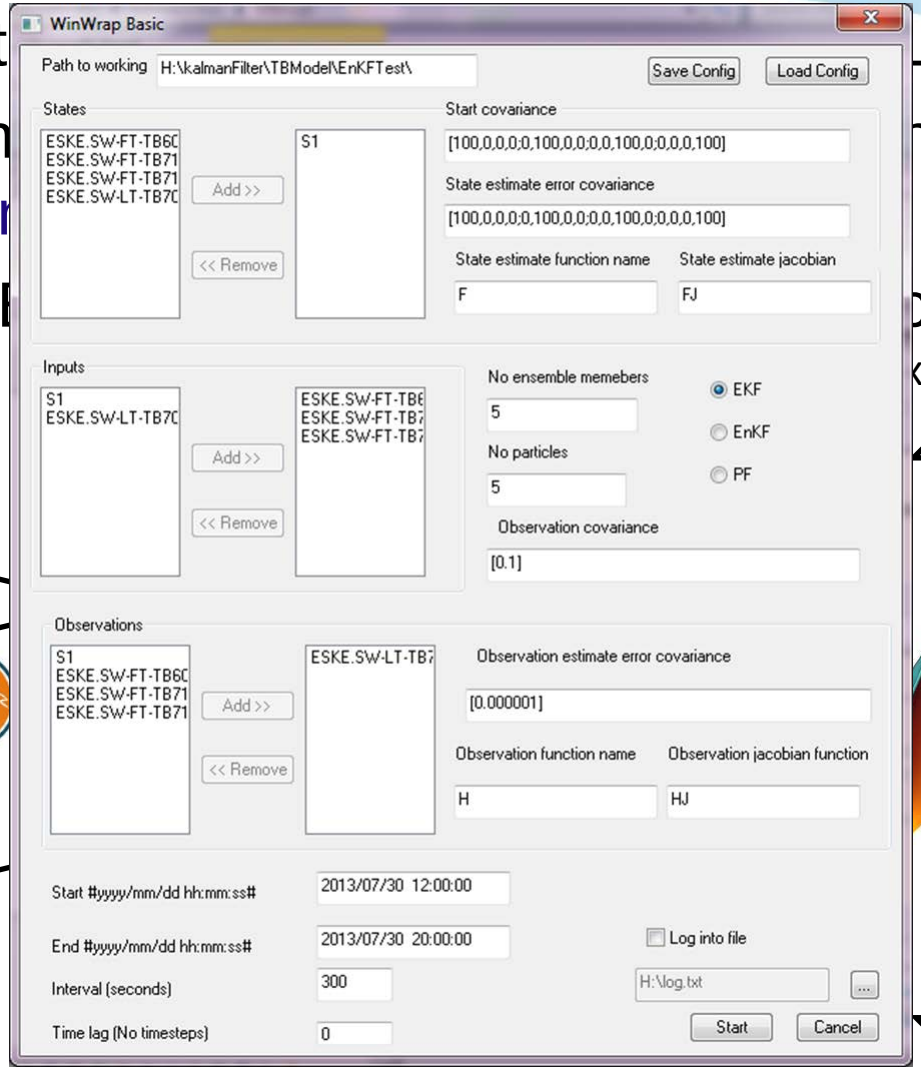
- Component
- Independen
- DIMS.CORE

Lab

nd data

coded in it

xecutables



Database

Services

Toolboxes

Conclusions

- Data Assimilation Methods can Lead to Improved System Forecasts

- Technical Issues affect implementation in Wastewater systems (More information in Technical Guidelines)

- DA Software developed in DIMS.CORE (More information in Manual)