Groundwater Modeling with Machine Learning Techniques: Ljubljana polje Aquifer

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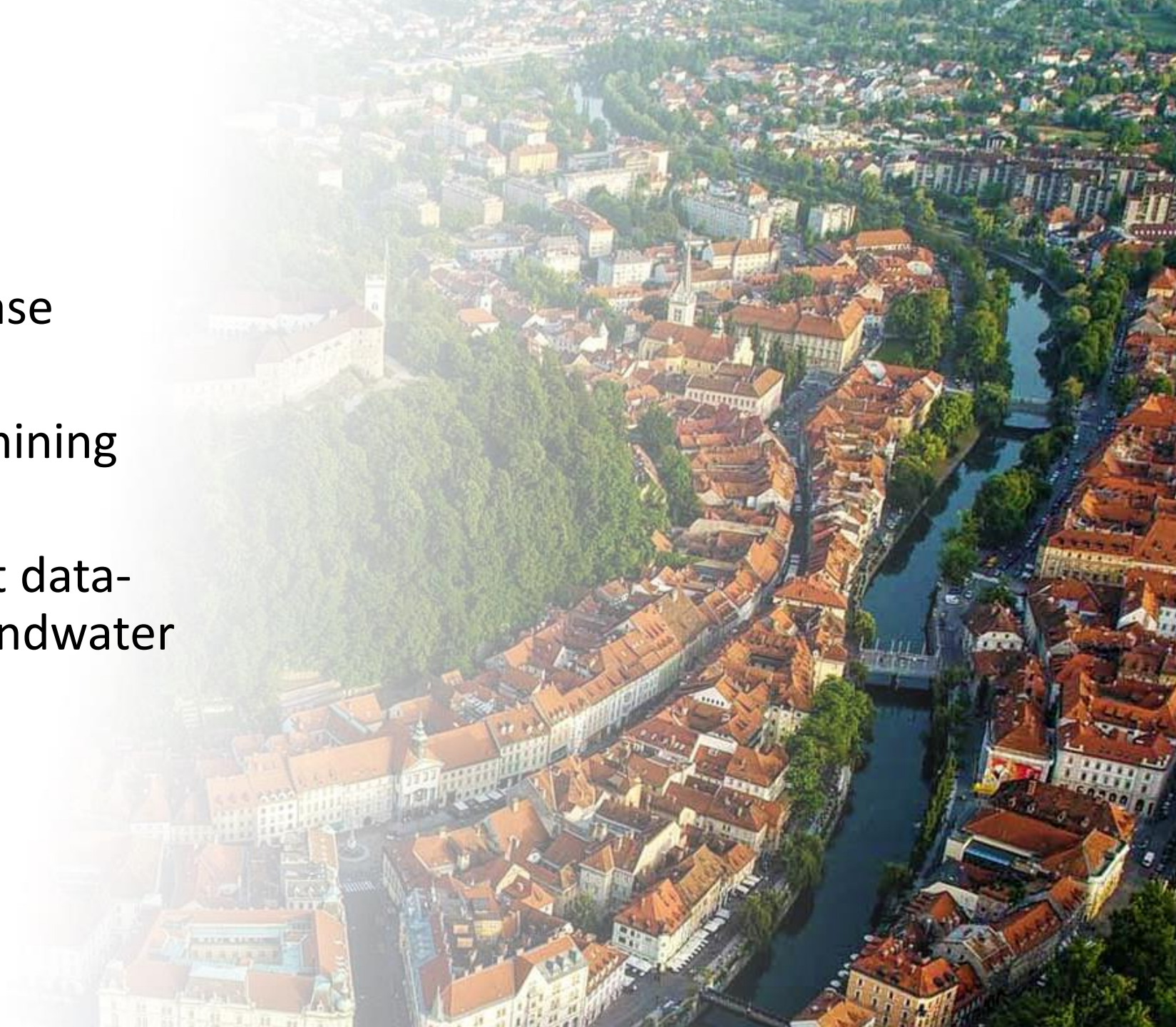
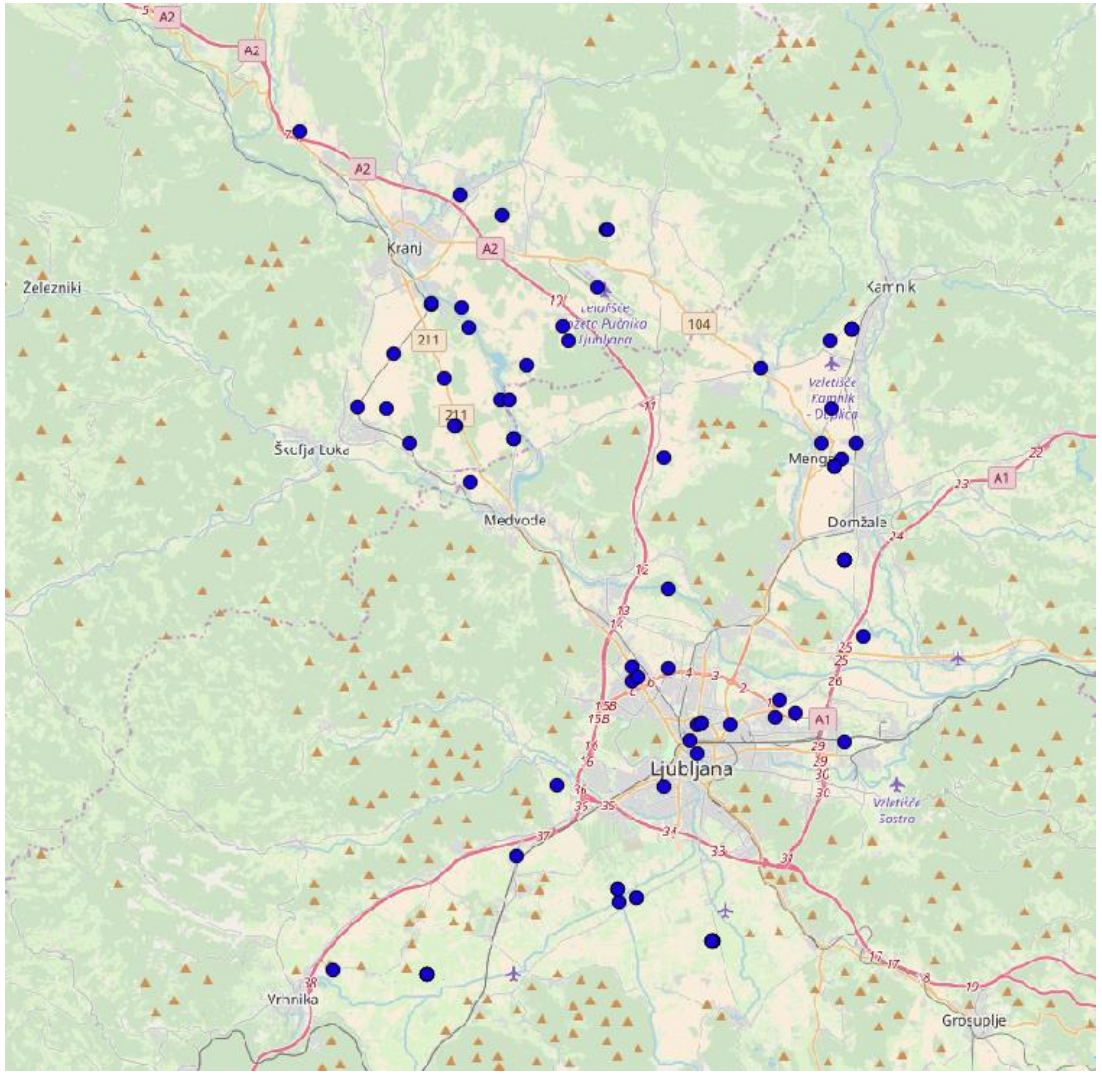
Outline

- Motivation and use-case presentation
- Introduction to data mining and machine learning
- The Quest for the best data-driven model for groundwater level
- Results



Motivation

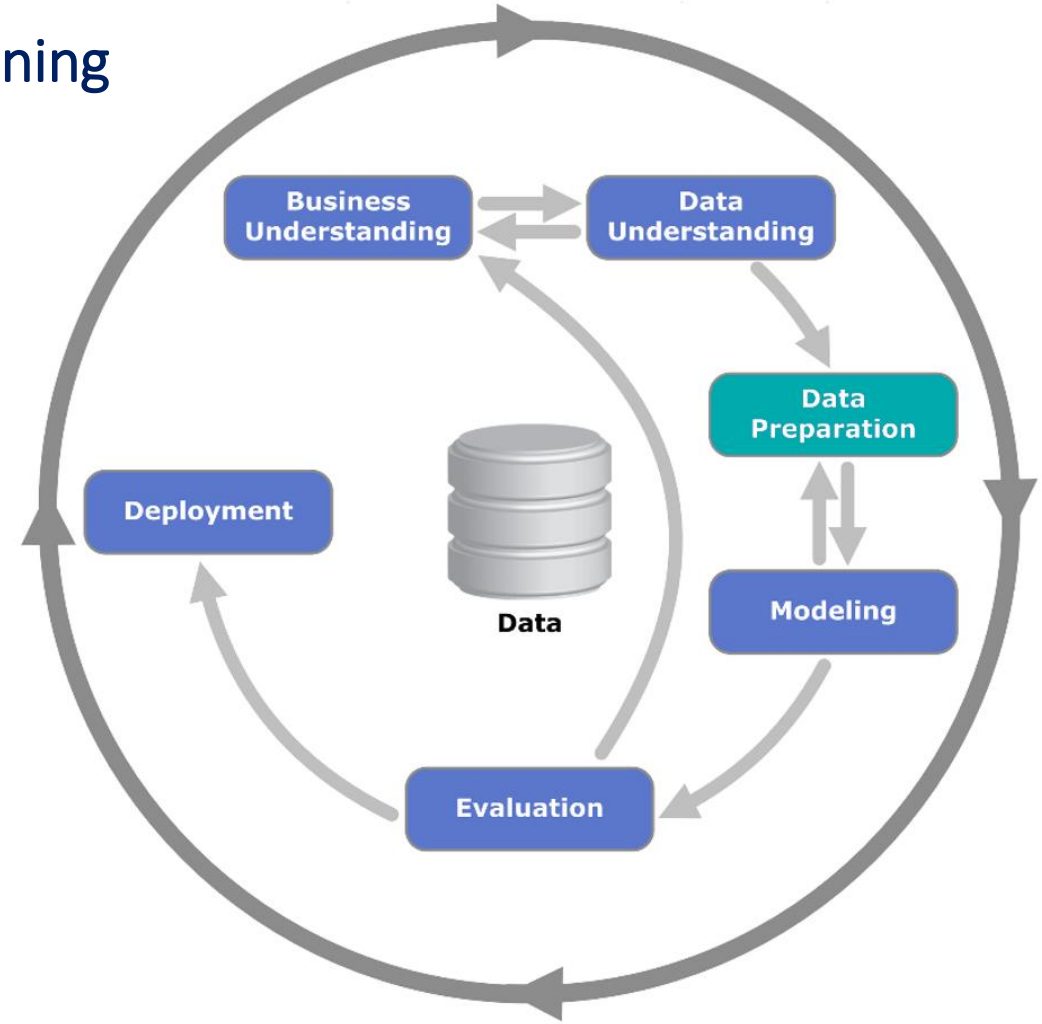
- groundwater levels are the principal source of information about hydrologic stress
- integrate groundwater into urban design
- can we contribute or improve previous results from process models



Data Mining Process

Data Mining / Machine Learning / Stream Mining

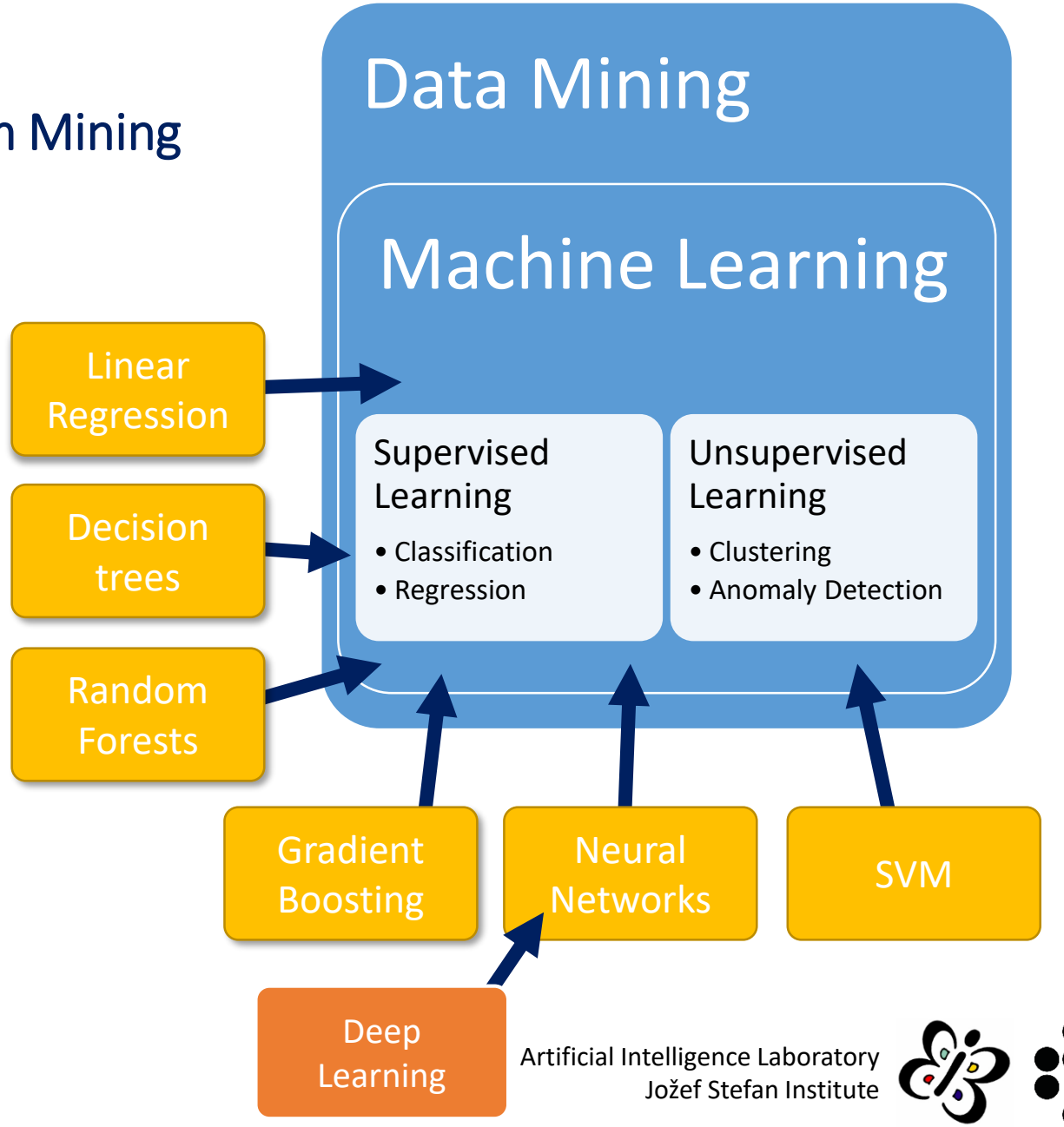
- Cross Industry Standard Process for Data Mining
- Holistic approach to data-driven modeling – useful for real-world applications
- From understanding of needs to deployment of models
- Data Preparation is the most time-consuming step



Definitions

Data Mining / Machine Learning / Stream Mining

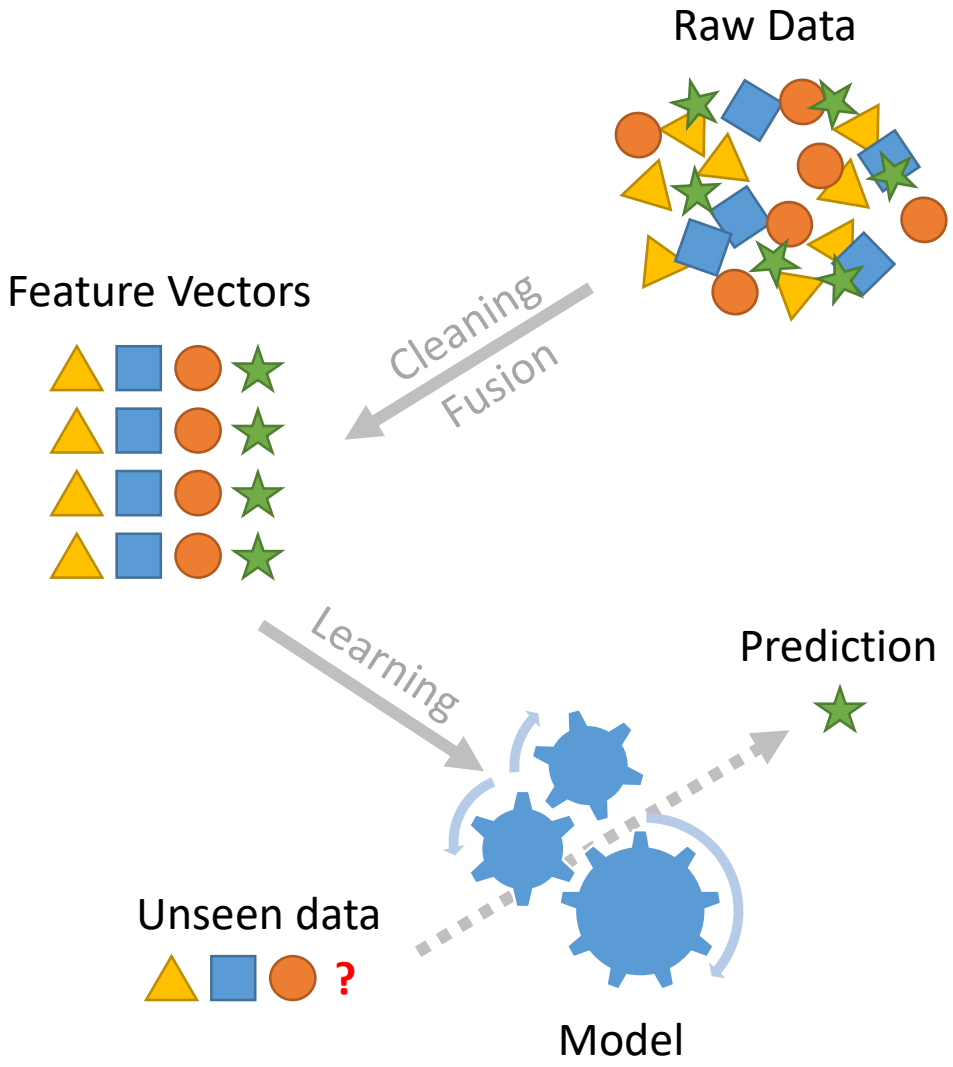
- Data Mining: Extraction of useful information from data
- Data Mining is application of Machine Learnig techniques to solve real-life data analysis problems



Supervised Learning

Data Mining / Machine Learning / Stream Mining

- **Model** that can predict continuous or nominal attributes
- Different than process-based models (!); underlying mechanisms are **not** important
- Based only on data
- Domain knowledge introduced through feature engineering
- Stream Mining



Data – 1 /4

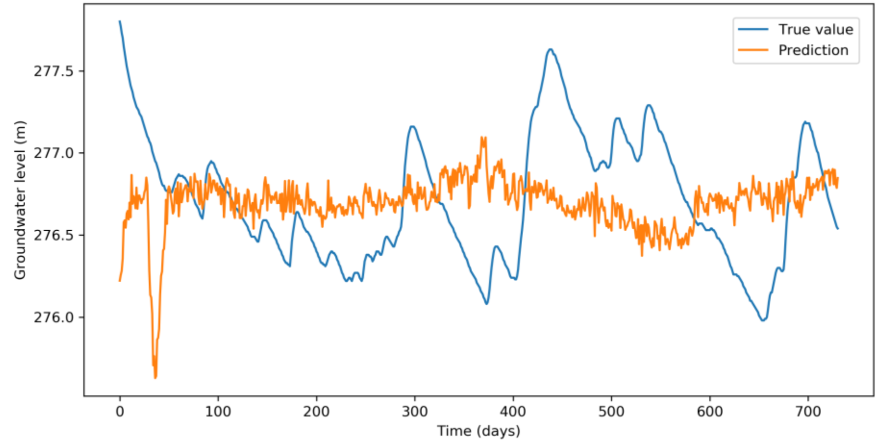
Input Data (features)

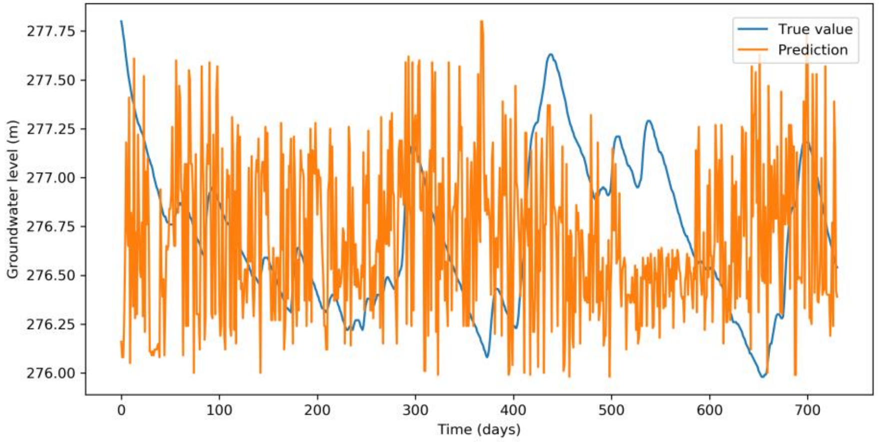
- Daily aggregates of weather data
  - Temperature avg / min / max
  - Precipitation
  - Snow
  - Sun duration
  - Cloud cover

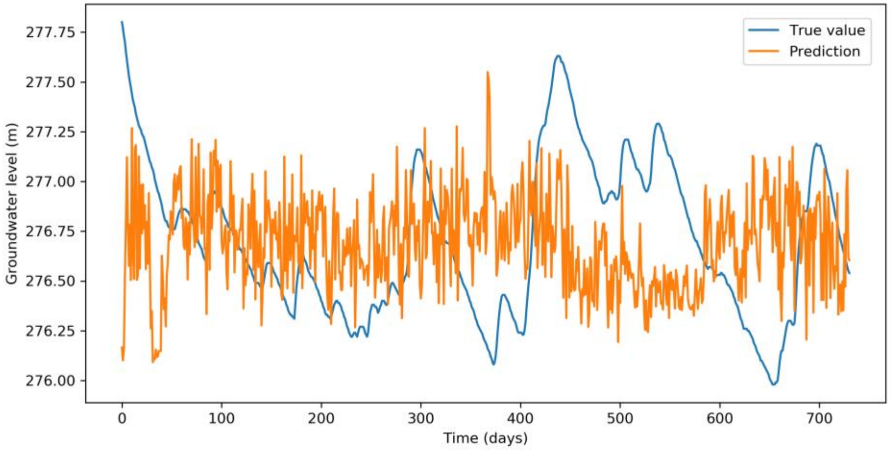
Label

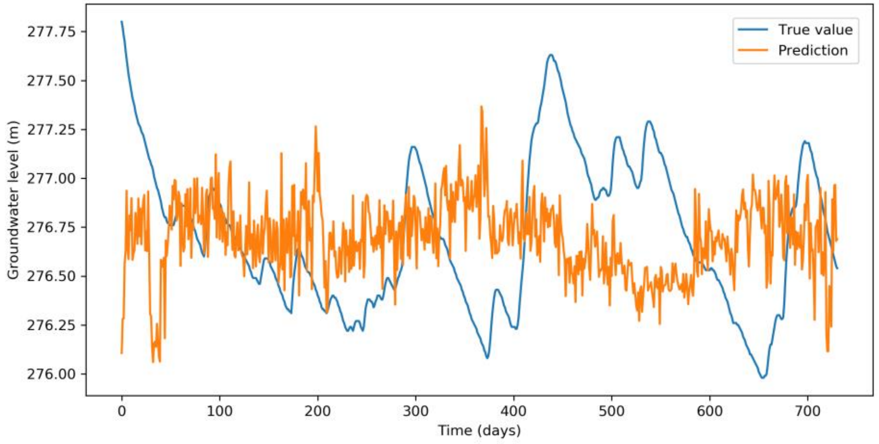
- groundwater levels
  for 5 sensors in Ljubljana polje aquifer
  (1 measurement / day)

The Quest – 1/4 (direct approach)









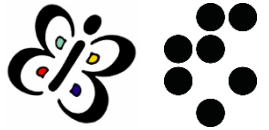
Data – 2/4

Input Data (features)

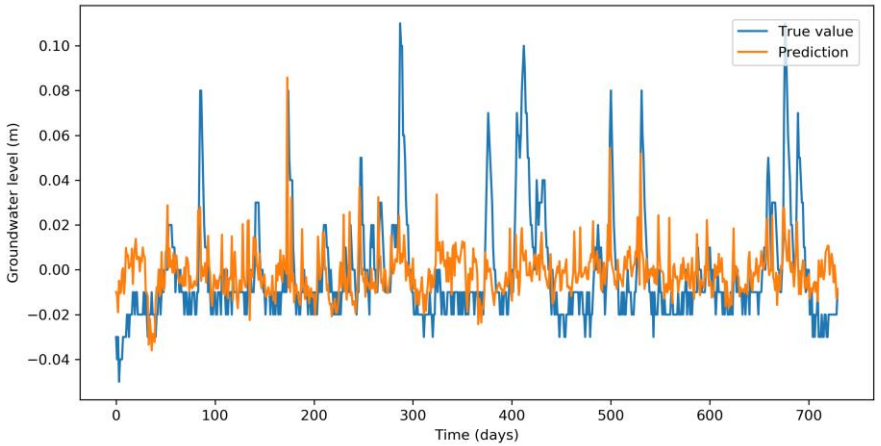
- Daily aggregates of weather data
  - Temperature avg / min / max
  - Precipitation
  - Snow
  - Sun duration
  - Cloud cover

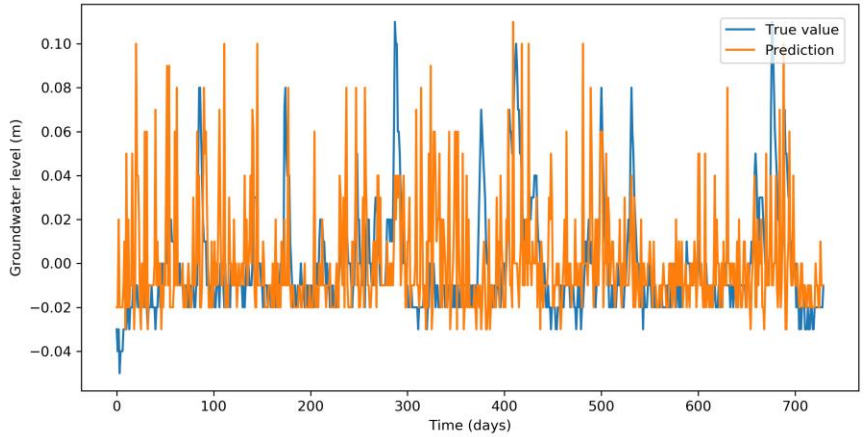
Label

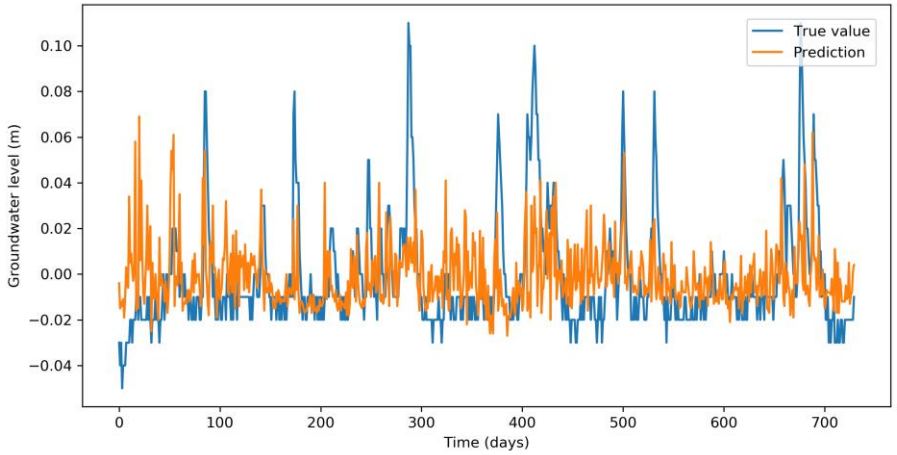
- groundwater level changes for 5 sensors in Ljubljana polje aquifer (1 measurement / day)

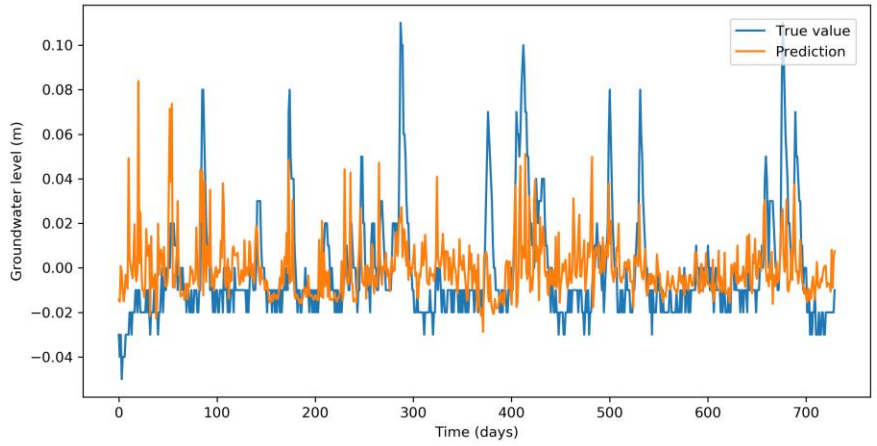


The Quest – 2/4 (differential approach)



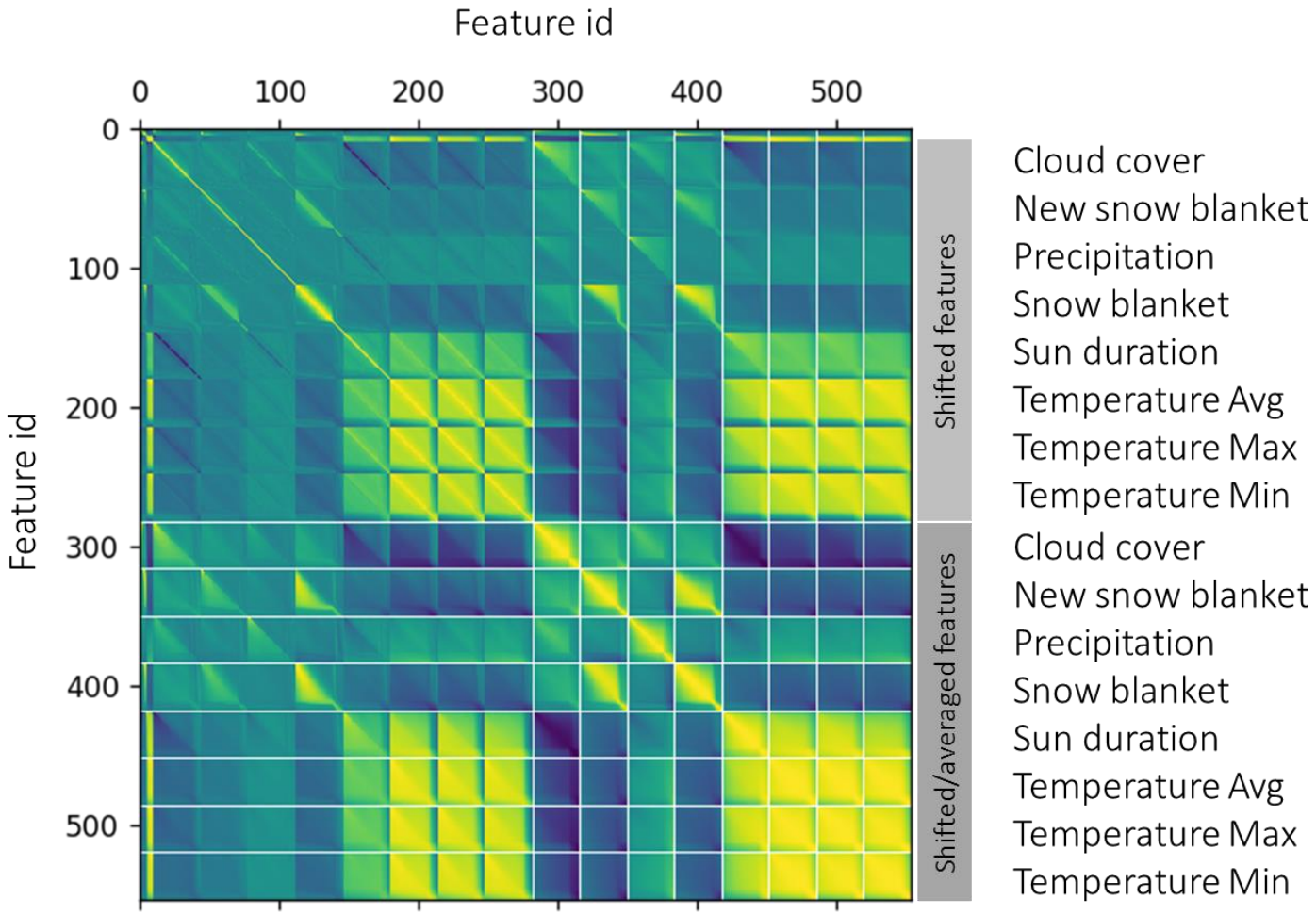




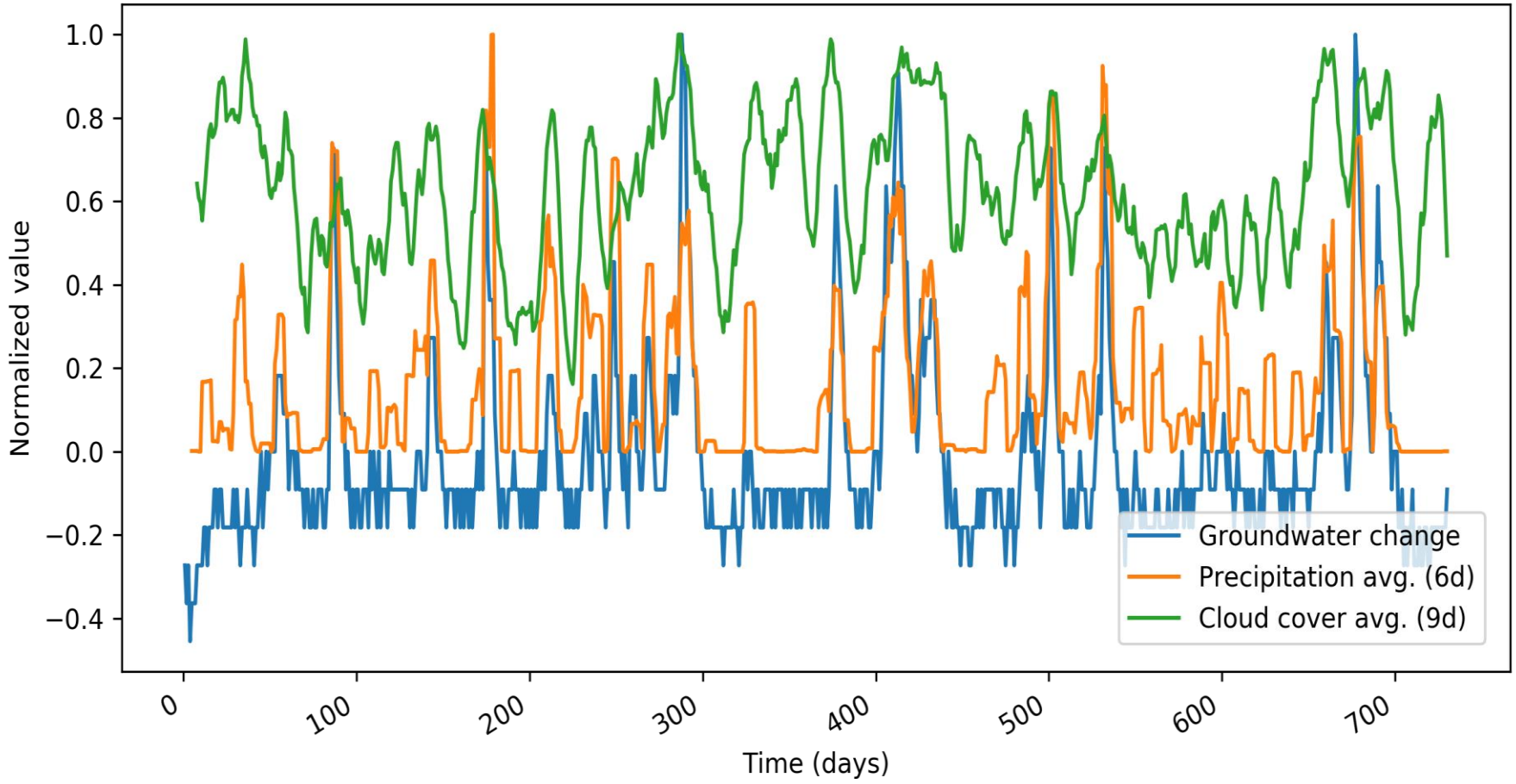


Feature engineering

- process of deriving new relevant features for modeling
- different moving aggregates (mean, min, max, variance)



Correlated features



Data – 3/4

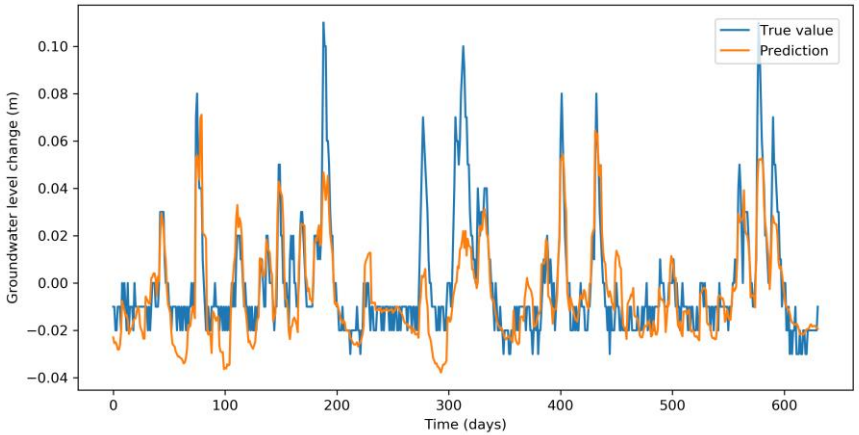
Input Data (features)

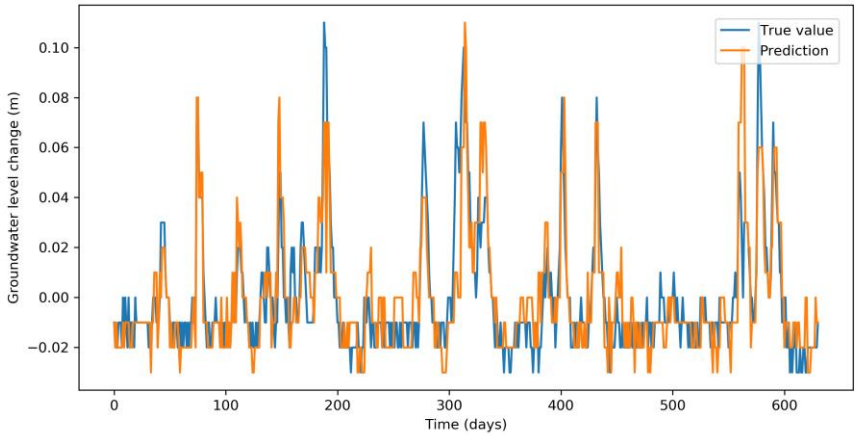
- Daily aggregates of weather data
  - Temperature avg / min / max
  - Precipitation
  - Snow
  - Sun duration
  - Cloud cover
- Shifted over 1 – 100 days
- Averaged over 1 – 100 days

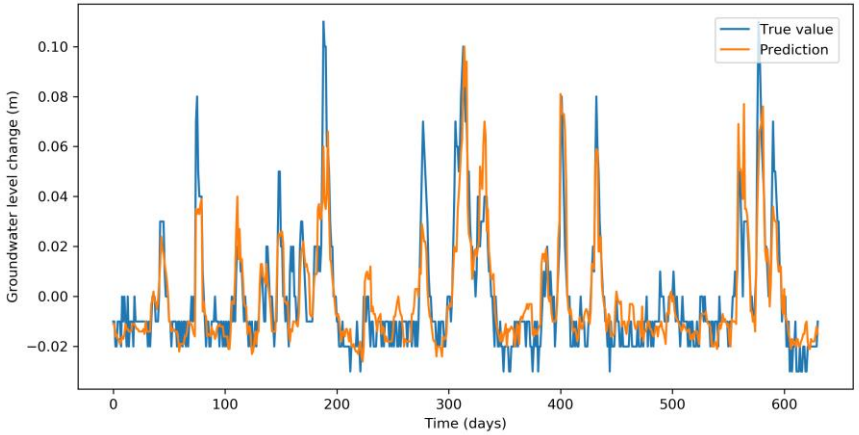
Label

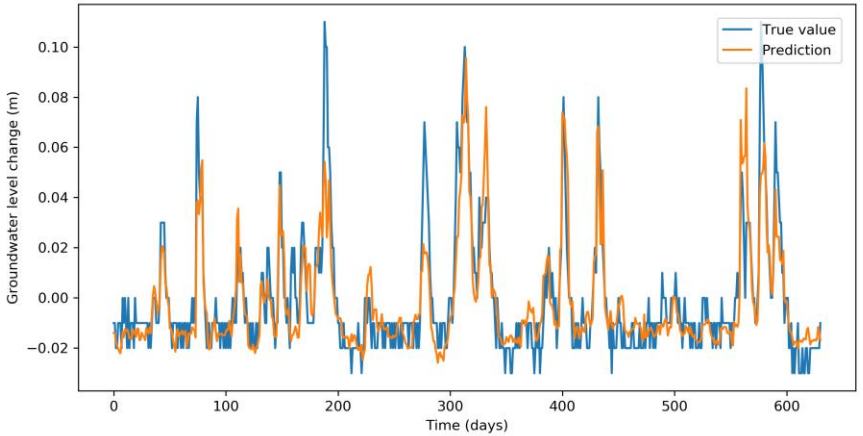
- groundwater level changes for 5 sensors in Ljubljana polje aquifer (1 measurement / day)

The Quest – 3/4 (with feature engineering)









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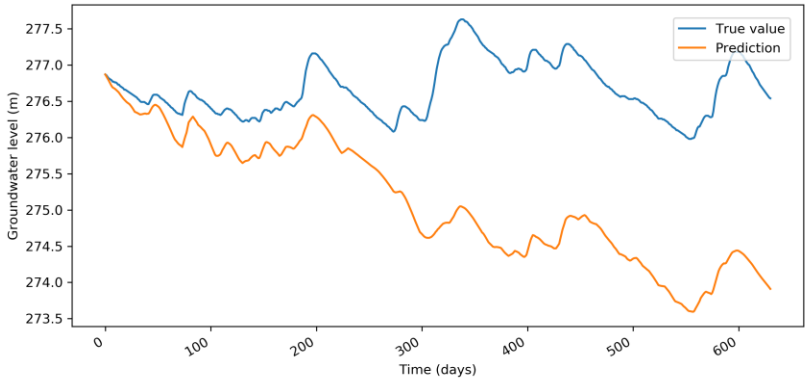
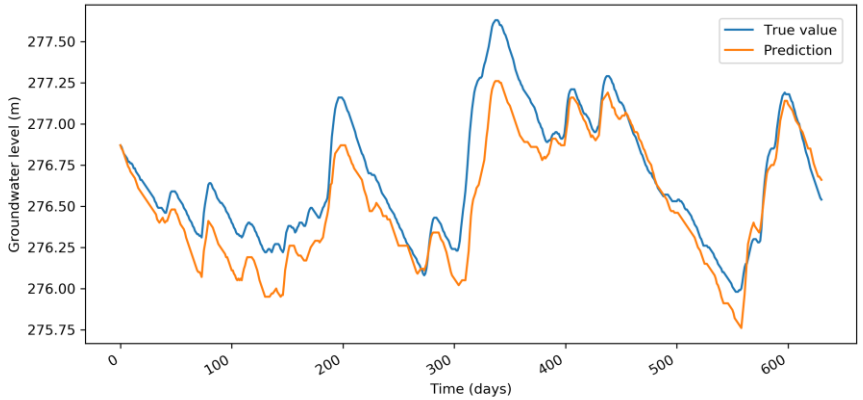
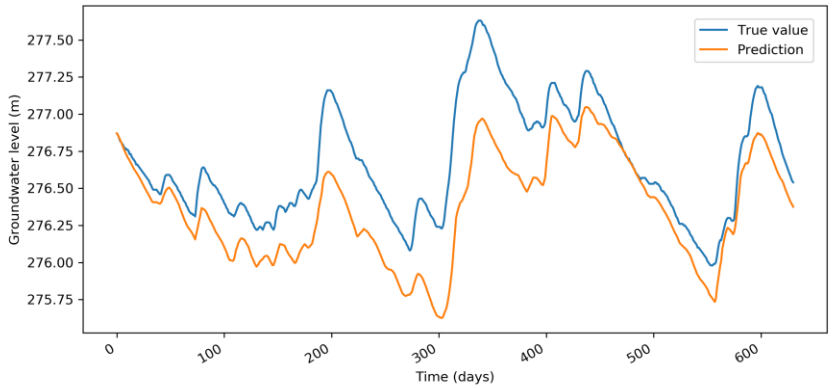
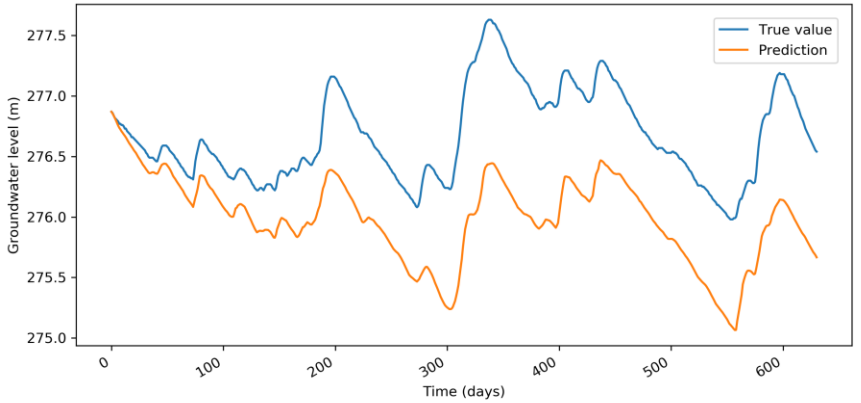
The Quest – 4/4 (final results)









Final results

Algorithm	R^2	RMSE
Linear regression	0.624	$2.23 \cdot 10^{-4}$
Decision trees	0.415	$3.46 \cdot 10^{-4}$
Random forest	0.609	$2.31 \cdot 10^{-4}$
Gradient boosting	**0.644**	$\mathbf{2.11 \cdot 10^{-4}}$

* Only weather in Ljubljana has been used as input

Conclusions & Future Work

Model improvement

- Additional feature engineering
  weather, nearby weather, different derivatives, land use, anthropogenic features
- Better definition of use cases include also groundwater level as a feature
- Try other methods
  Deep learning, SVM
- Generalization of the models

Other directions

- Explore stream mining approach
  Big Data ready
- Opposite way
  what do the models tell us? drought?
- Implementation of the real-time platform
- Compare with process-based models
  find synergy, improvement

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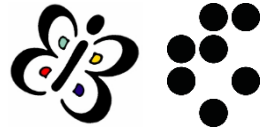

Support slides

Data-driven modeling of groundwater

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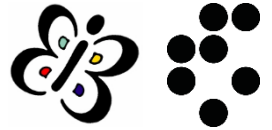
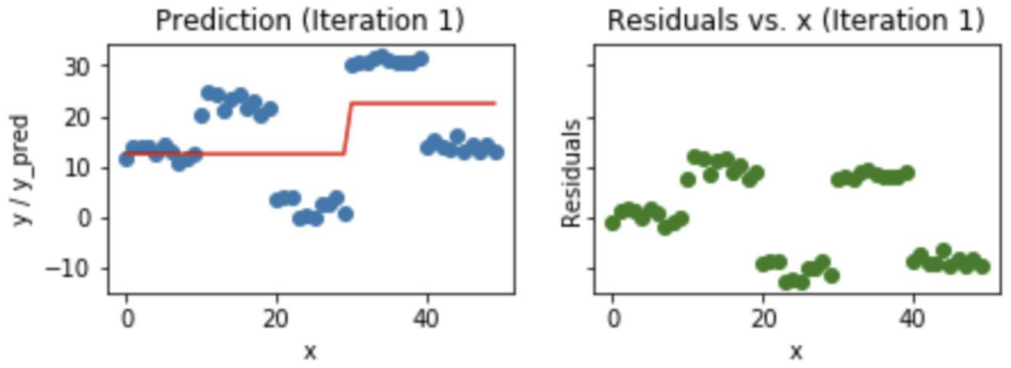


Gradient Boosting

1. learn the model (usually regression trees)
2. calculate residuals
3. learn the model on the residuals
4. repeat step 2 until residuals are small enough



Introducing non-linear relations!