

Digishape Online Technical Sessions

Bed Level Predictions Waal with spatio-temporal networks

29 may 2024





Content

- **Introduction**
- **Model**
- **Challenges**
- **Data processing**
- **Discussion**

Introduction Timeline

Digishape Seedmoney
June 2022

Nieuws
Digishape-project gaat met machine learning waterdiepte van de Waal voorspellen

11 JUN 2022



In het najaar is er via machine learning de waterdiepte van de heler van de Waal te voorspellen. Zoekt u informatie gebaseerd op afmetingen, bodem en andere? Deze vraag gaat HKV samen met 11.000 waterprofielen van Digishape. We spreken projectleider Anilimes Poojith van HKV wat gaan ze precies doen? En wat hopen ze hiermee te bereiken?

Wat ging er aan jullie innovatie vooraf?

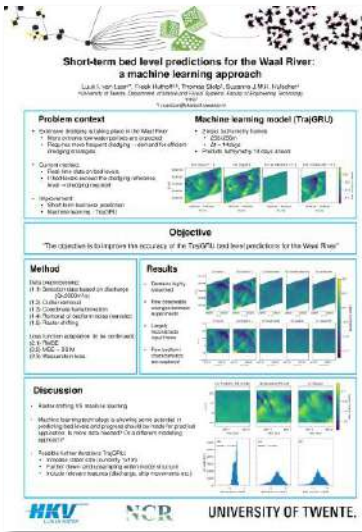
Begin 2023 zijn Martens en Van Oord de aanbesteding van Rijkswaterstaat voor een 5-jarig contract om de vaargebieden van onder meer de Waal te onderhouden. Op de Waal zijn continue bodemwerkzaamheden nodig om de rivier veilig vaarbaar te houden. HKV adviseert en ondersteunt de aannemer bij deze werkzaamheden. Voor de aannemer, maar ook voor Rijkswaterstaat en de onderaannemers, is het belangrijk om te weten hoe de rivier eruit ziet. Dat gebeurt met schepen die de waterdiepte waarvoor meten. In 2021 en in deze data gaan er dus een miljoen en een Digishape van de rivier komen. Maar al is dat een enorme hoeveelheid, een virtuele kopie van de rivier is niet voldoende. De volgende stap is om, naast meten, de waterdiepte enkele dagen tot een week voor uit te kunnen voorspellen.

Wat is daarvan het voordeel?

"Het een voordeel van de bodemmeting en waterdiepte van vaargebieden is dat er meer informatie wordt ingezicht. We kunnen onderhoudsmaatregelen dan concentreren op precies die locaties waar ze het meest nodig zijn. Dat voorkomt overbodige kosten. Het is ook belangrijk om te weten hoe de rivier eruit ziet. Dat gebeurt met schepen die de waterdiepte waarvoor meten. In 2021 en in deze data gaan er dus een miljoen en een Digishape van de rivier komen. Maar al is dat een enorme hoeveelheid, een virtuele kopie van de rivier is niet voldoende. De volgende stap is om, naast meten, de waterdiepte enkele dagen tot een week voor uit te kunnen voorspellen."

TrajGRU model
Jan 2023

NCR poster
Nov 2023



Short-term bed level predictions for the Waal River: a machine learning approach

Luuk I. van Laar*, Freek Huthoff, Thomas Stolp, Suzanne J.M.H. Hulscher
*Universiteit van Twente, Department of Water Engineering, Enschede, The Netherlands

Problem context

- Current bed level predictions in the Waal River
- Highly uncertain and often not used for decision making
- Current method
- Need for more accurate predictions
- Machine learning approach
- Short-term bed level predictions
- Machine learning (TrajGRU)

Machine learning model (TrajGRU)

- Deep learning model
- Input: Time series of water level, discharge, and bed level
- Output: Short-term bed level predictions

Objective

The objective is to improve the accuracy of the TrajGRU bed level predictions for the Waal River.

Method

1. Data collection and preprocessing
2. Model architecture
3. Model training and validation
4. Performance evaluation
5. Model deployment

Results

Deep learning model

High accuracy

Short-term predictions

Machine learning model

Performance evaluation

Discussion

- Machine learning approach is showing great potential in predicting bed level predictions in the Waal River
- Machine learning model (TrajGRU)
- Machine learning model (TrajGRU)
- Machine learning model (TrajGRU)

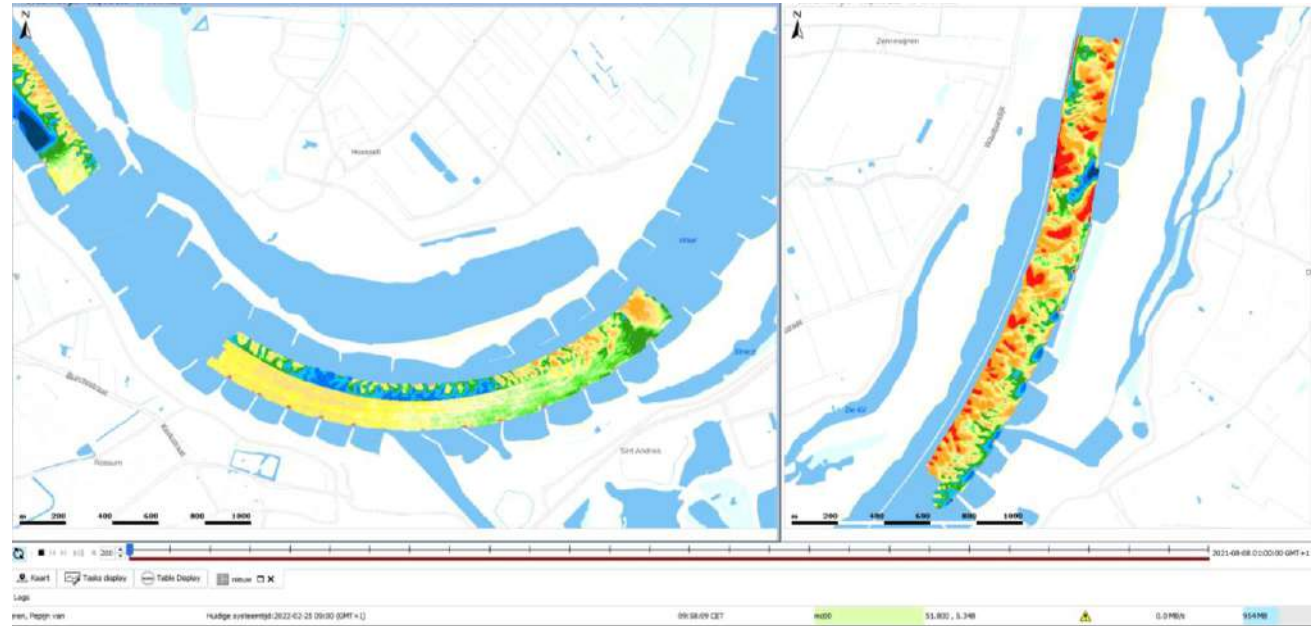
HKV | NCR | UNIVERSITY OF TWENTE

*Luuk I. van Laar, Freek Huthoff,
Thomas Stolp, Suzanne J.M.H.
Hulscher*

Introduction

Bed level in the Waal

- Digital Twin of the Waal river
- Integration of bi-weekly multibeam measurements
- Monitoring of MGD and dredging operations
- Questions around forecasting



Introduction

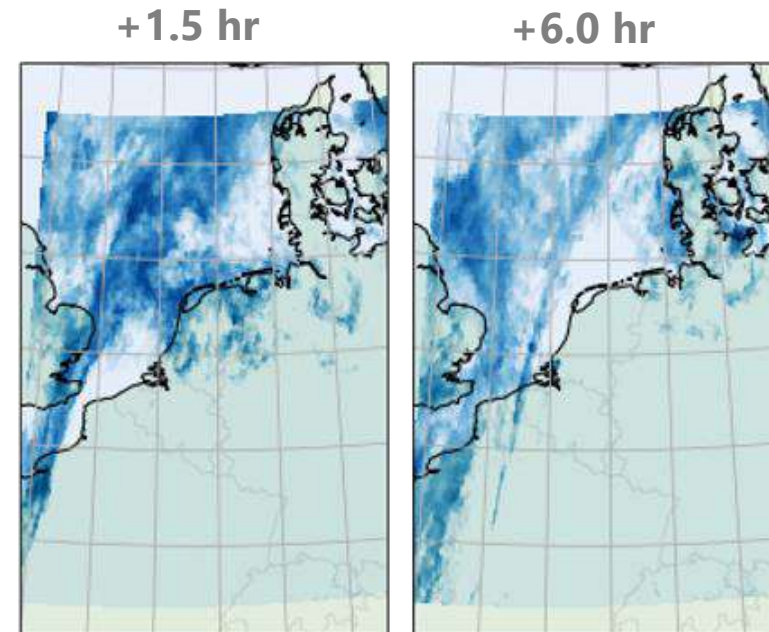
Spatio-temporal networks

- Forecasting algorithms for sequential raster data

Introduction

Spatio-temporal networks

- Forecasting algorithms for sequential raster data
- Use cases:
 - Solar radiation
 - Extreme precipitation

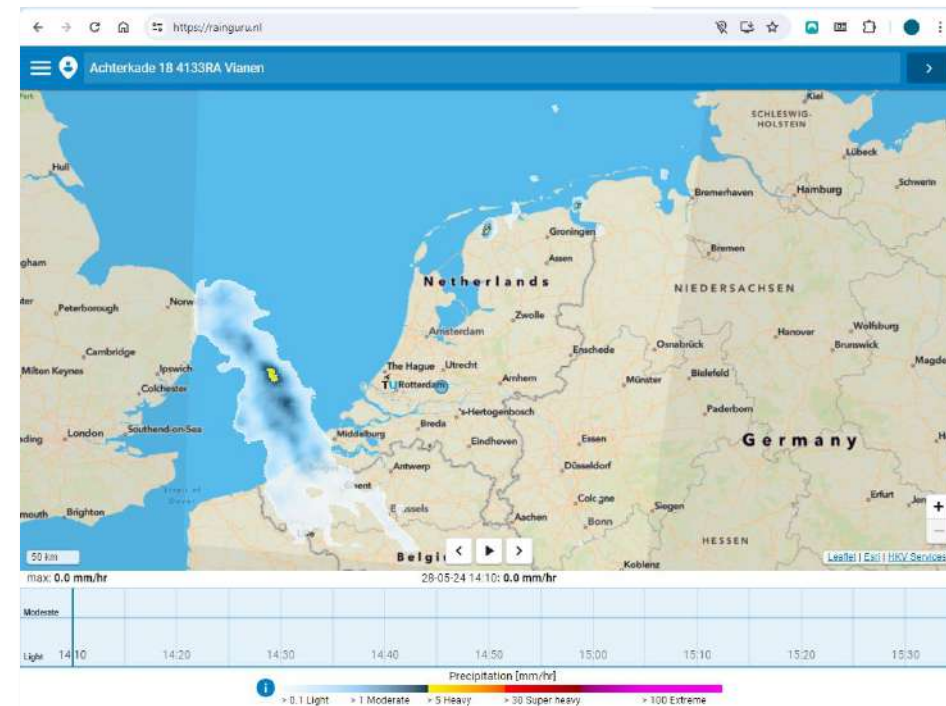


PYTHIA
ENERGY INTELLIGENCE

Introduction

Spatio-temporal networks

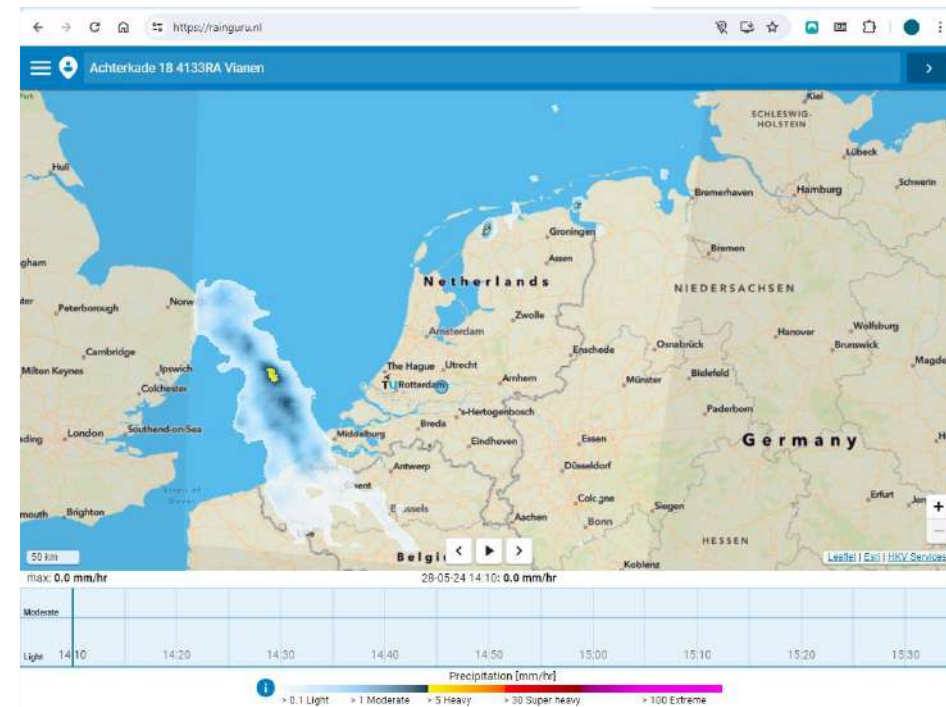
- Forecasting algorithms for sequential raster data
- Use cases:
 - Solar radiation
 - Extreme precipitation



Introduction

Spatio-temporal networks

- Forecasting algorithms for sequential raster data
- Use cases:
 - Solar radiation (**GAN**)
 - Extreme precipitation (**TrajGRU**)



Introduction

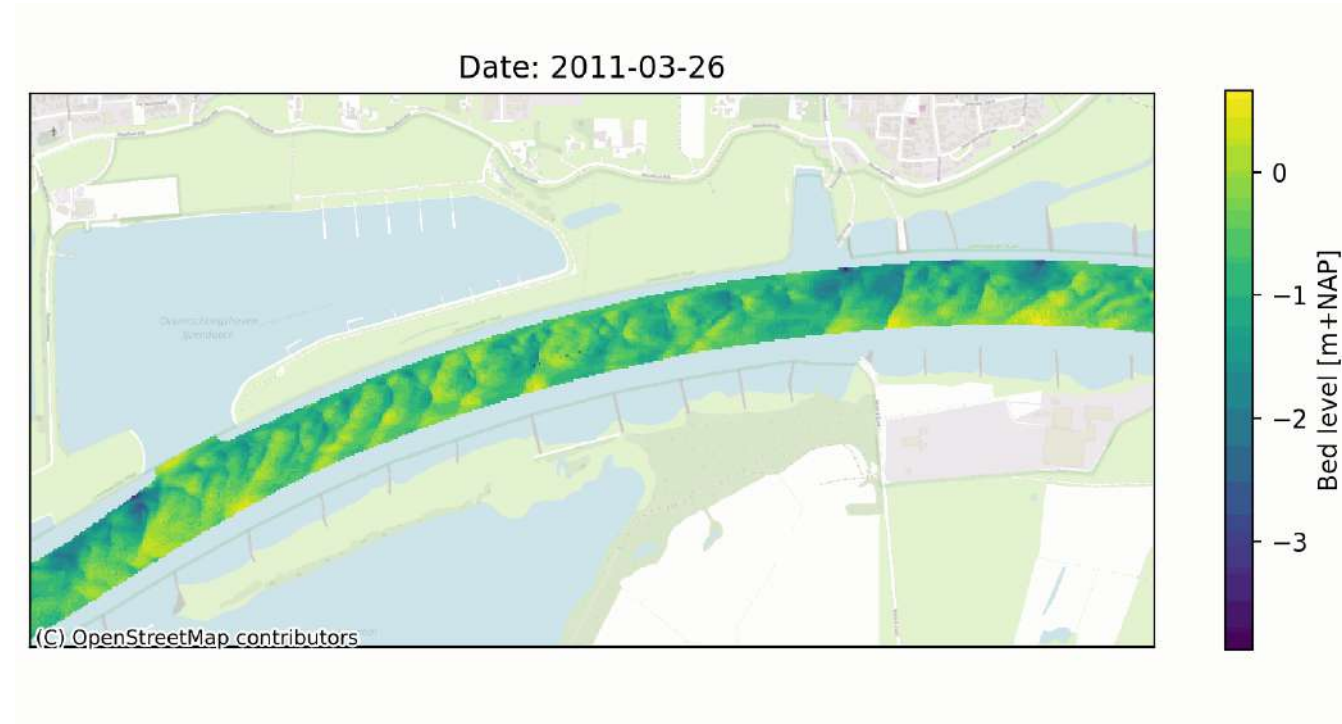
Research question

- *Is it possible to train a spatio-temporal model for forecasting of bed levels in the Waal River?*

Introduction

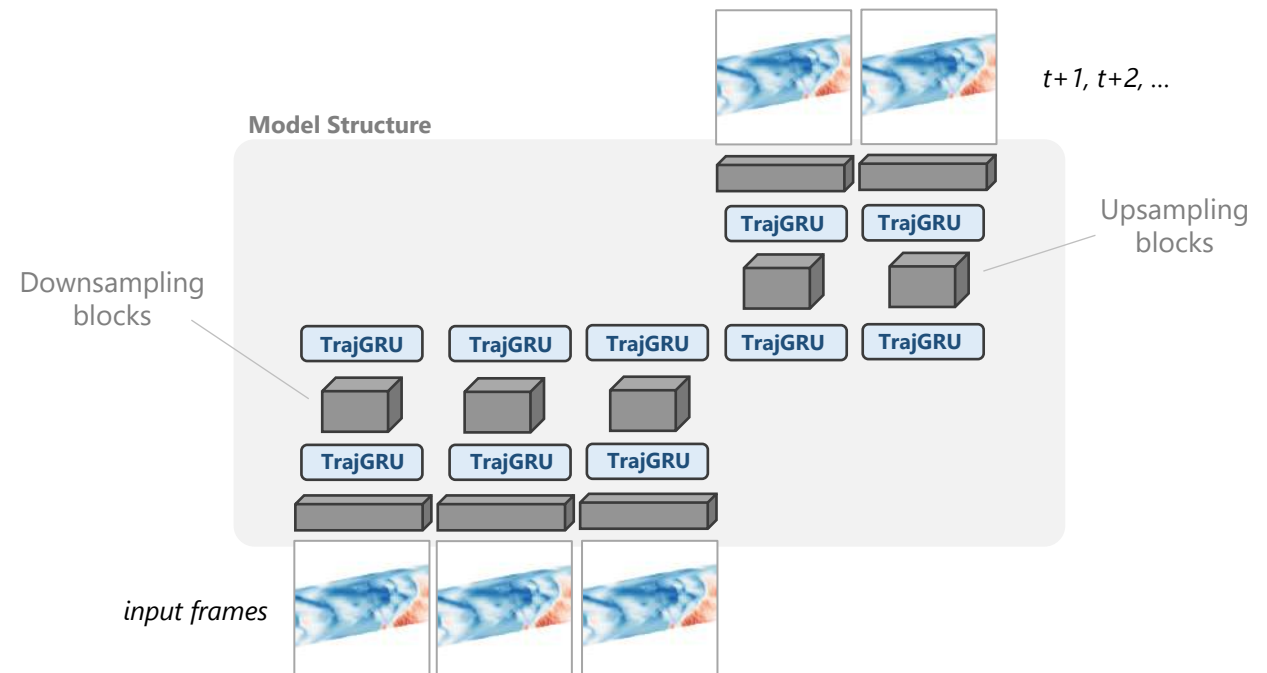
Model selection

- Large dataset, entire length of Waal and collected over many years
- High resolution in temp. dimension (multibeam)



Model TrajGRU

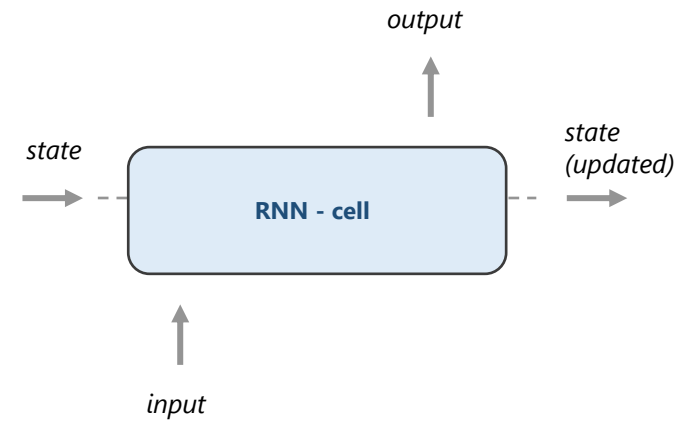
- Encoder-decoder structure
- Extract important features
- Recurrent cells (with convolution), the state or "memory"



Model

TrajGRU

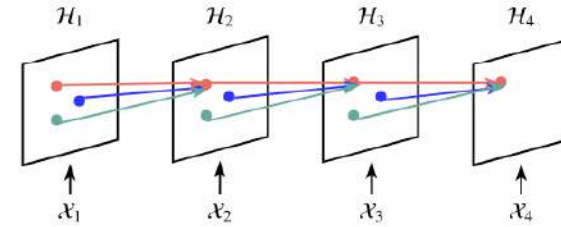
- Input and state interaction
- Gates for updating, resetting
- Extensions with convolution (ConvLSTM)
- TrajGRU uses extra warp function



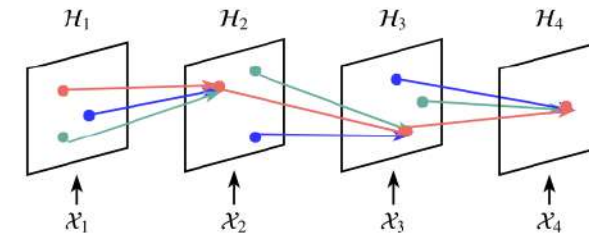
Model

TrajGRU

- Input and state interaction
- Gates for updating, resetting
- Extensions with convolution (ConvLSTM)
- TrajGRU uses extra warp function



(a) For convolutional RNN, the recurrent connections are fixed over time.

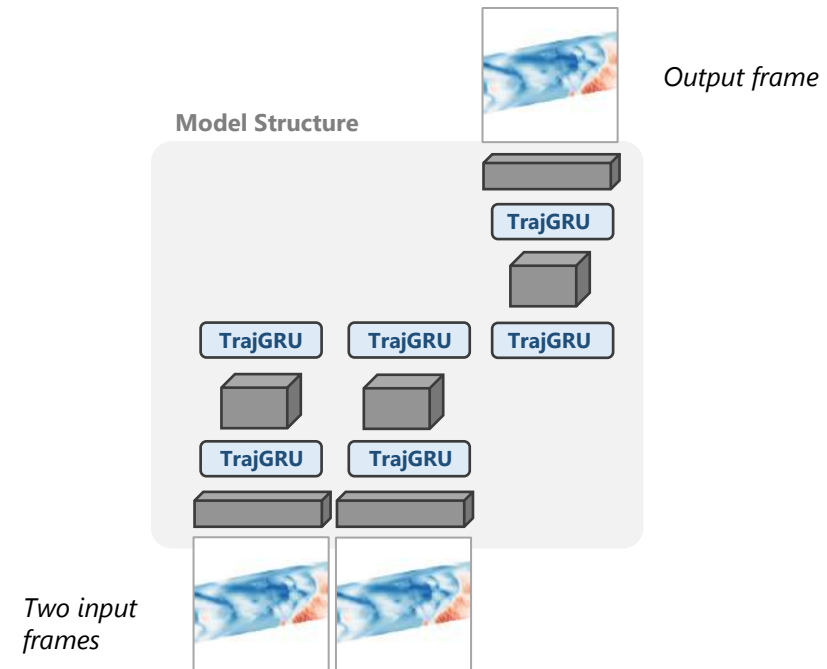


(b) For trajectory RNN, the recurrent connections are dynamically determined.

{1} Shi, X., Gao, Z., Lausen, L., Wang, H., Yeung, D. Y., Wong, W. K., & Woo, W. C. (2017). Deep learning for precipitation nowcasting: A benchmark and a new model. *Advances in neural information processing systems*, 30.

Model TrajGRU

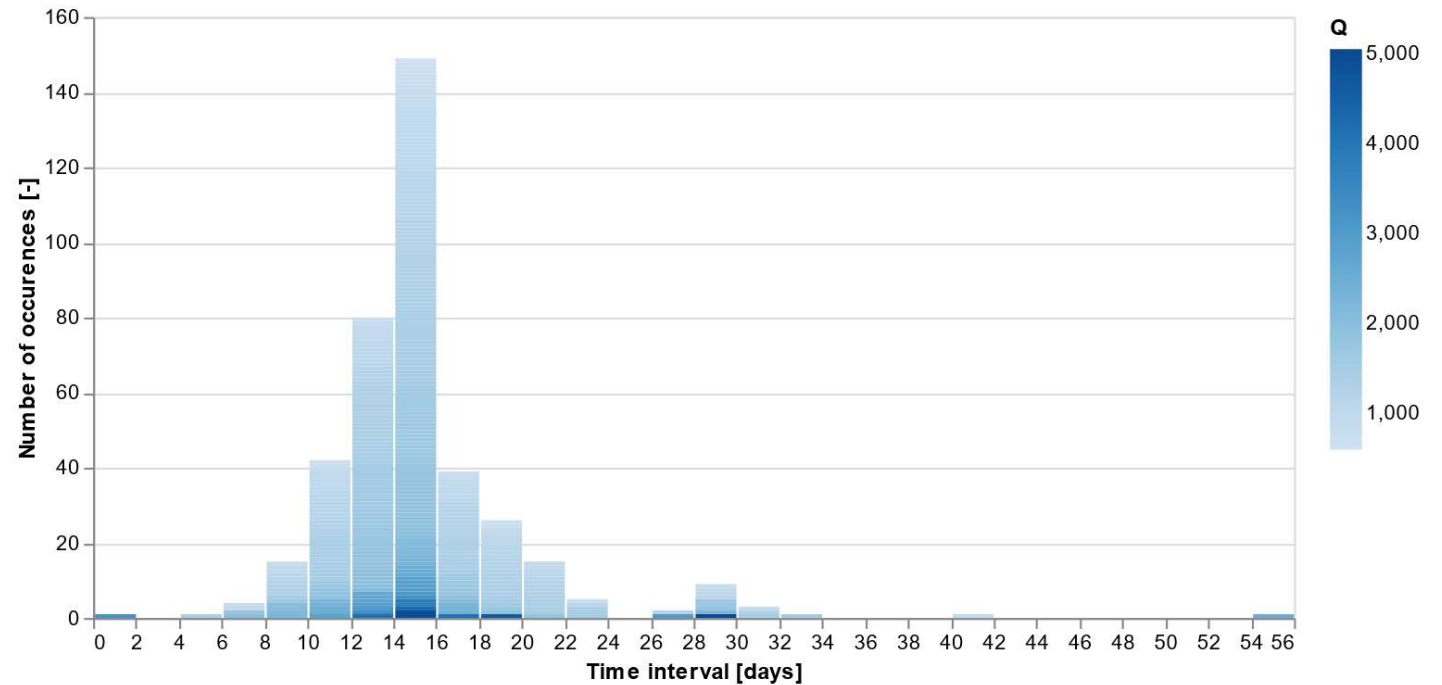
- Modified architecture, reduced size
- Two input frames, one output



Challenges

Irregular time intervals

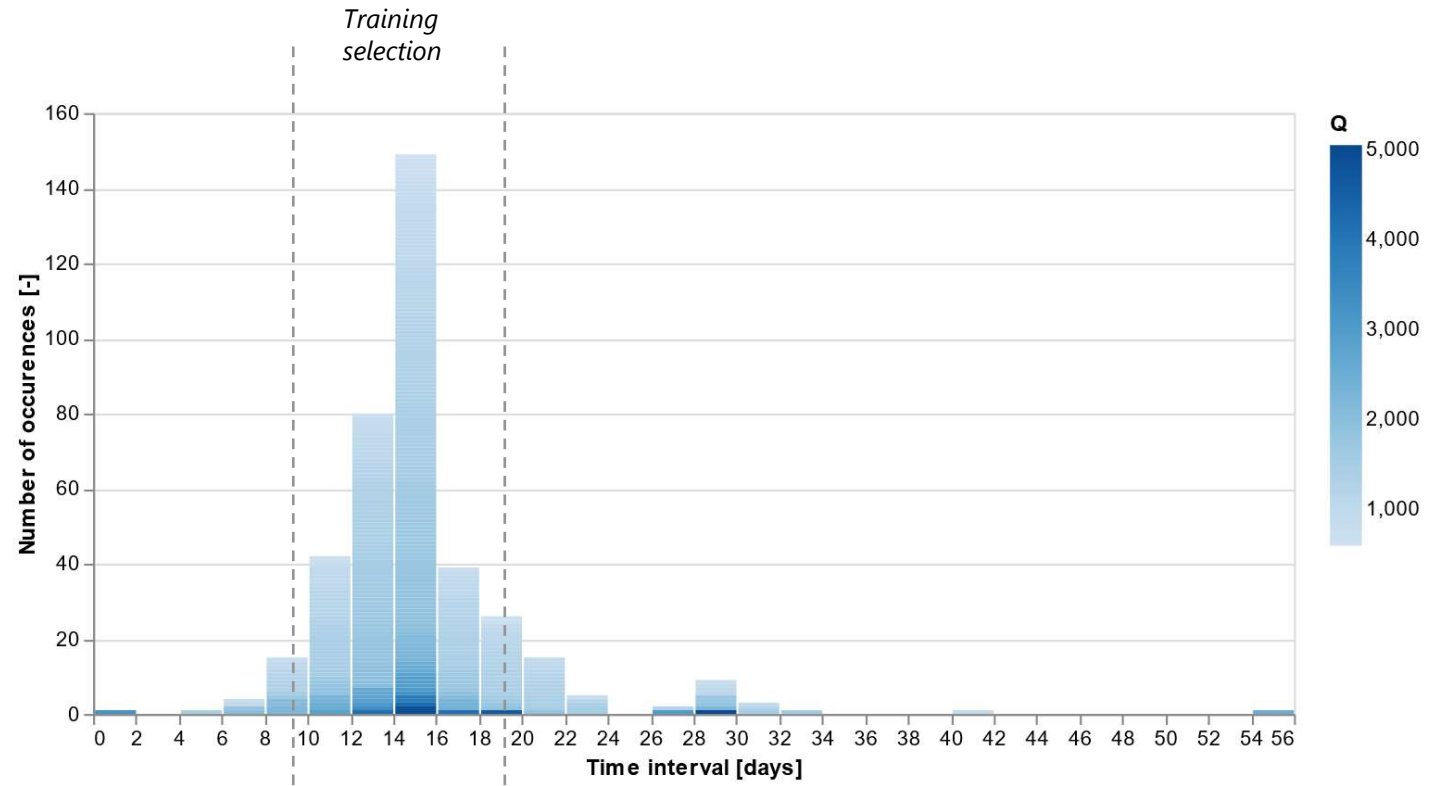
- Time between two measurements varies
- Increased complexity in training



Challenges

Irregular time intervals

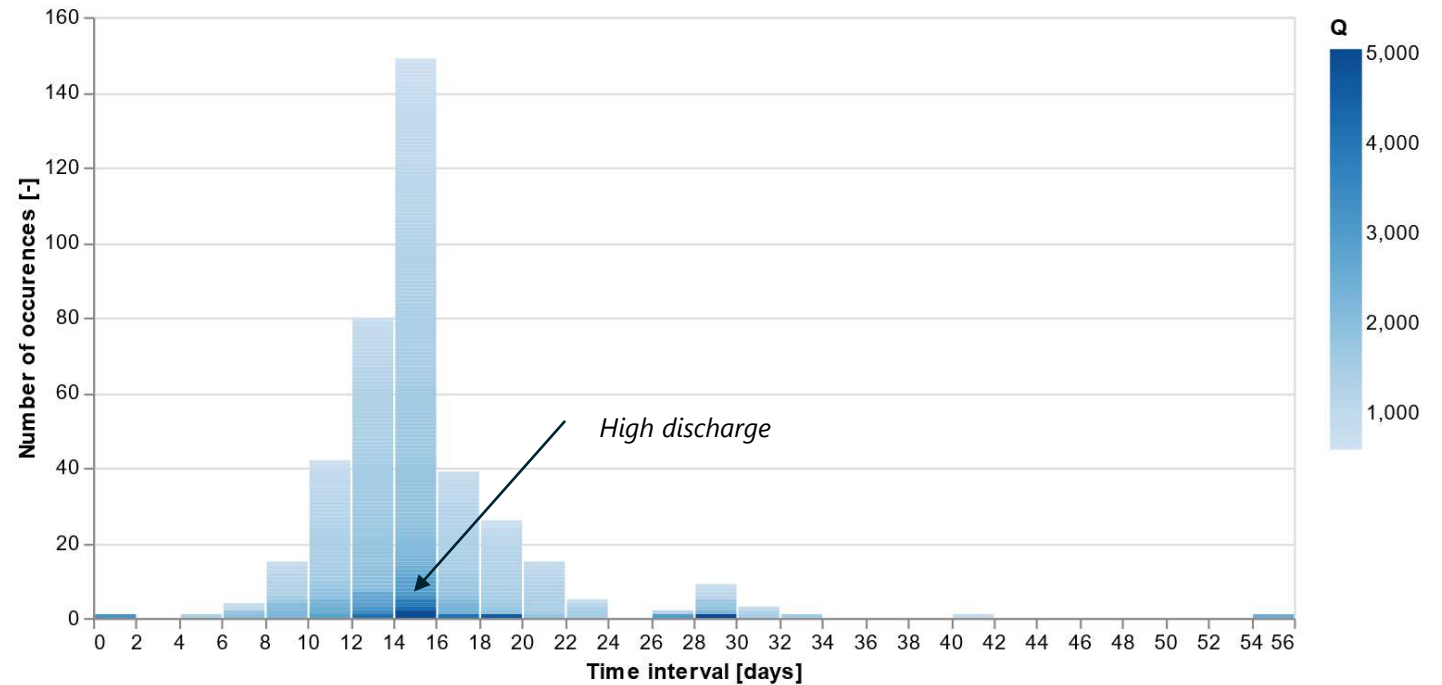
- Regularization of time series



Challenges

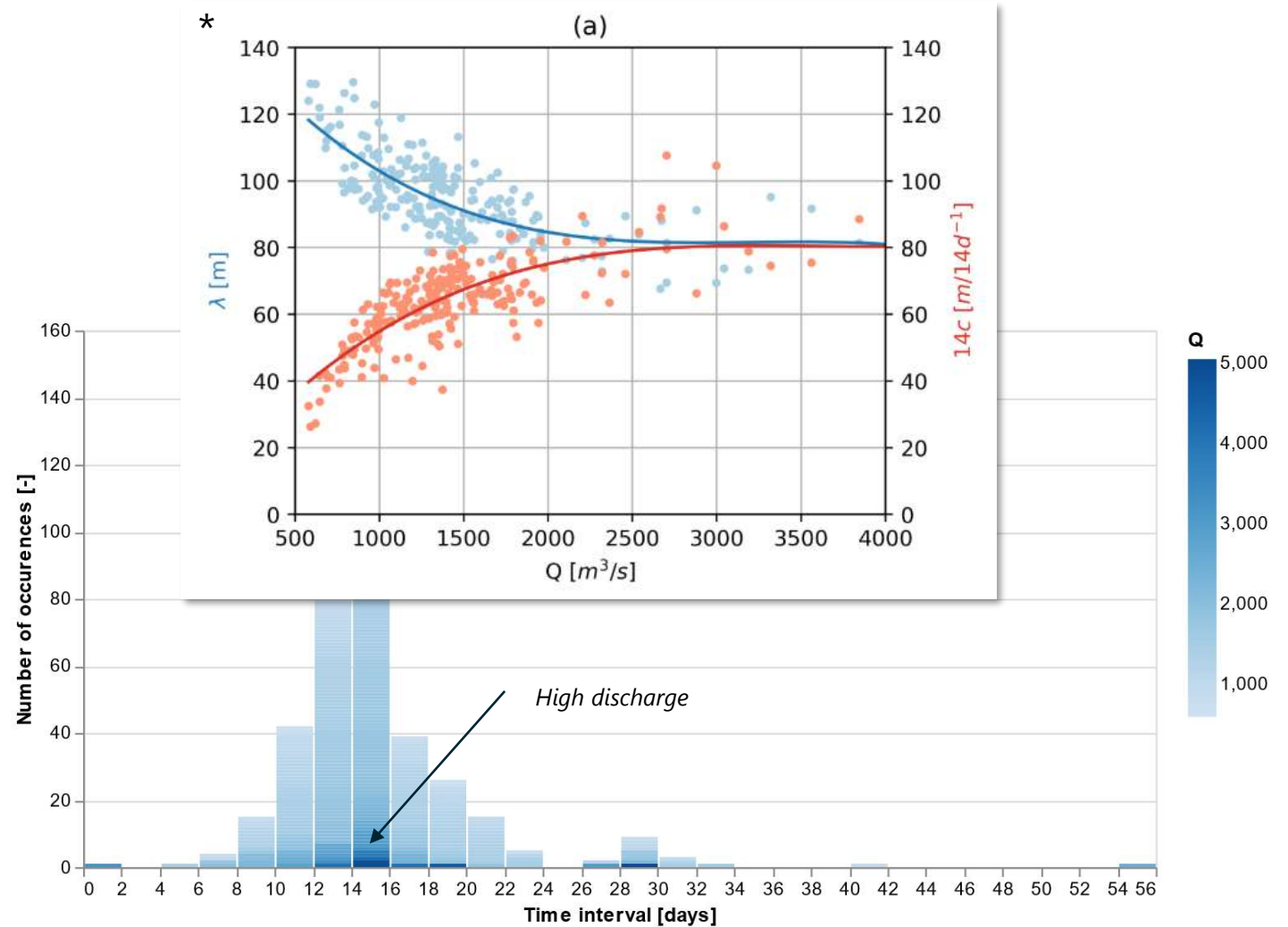
Flow regimes

- Discharge regimes
- The dune length λ , and 14-day dune celerity $14c$.
- Exclude high discharge regime ($>2000\text{m}^3/\text{s}$)



Challenges Flow regimes

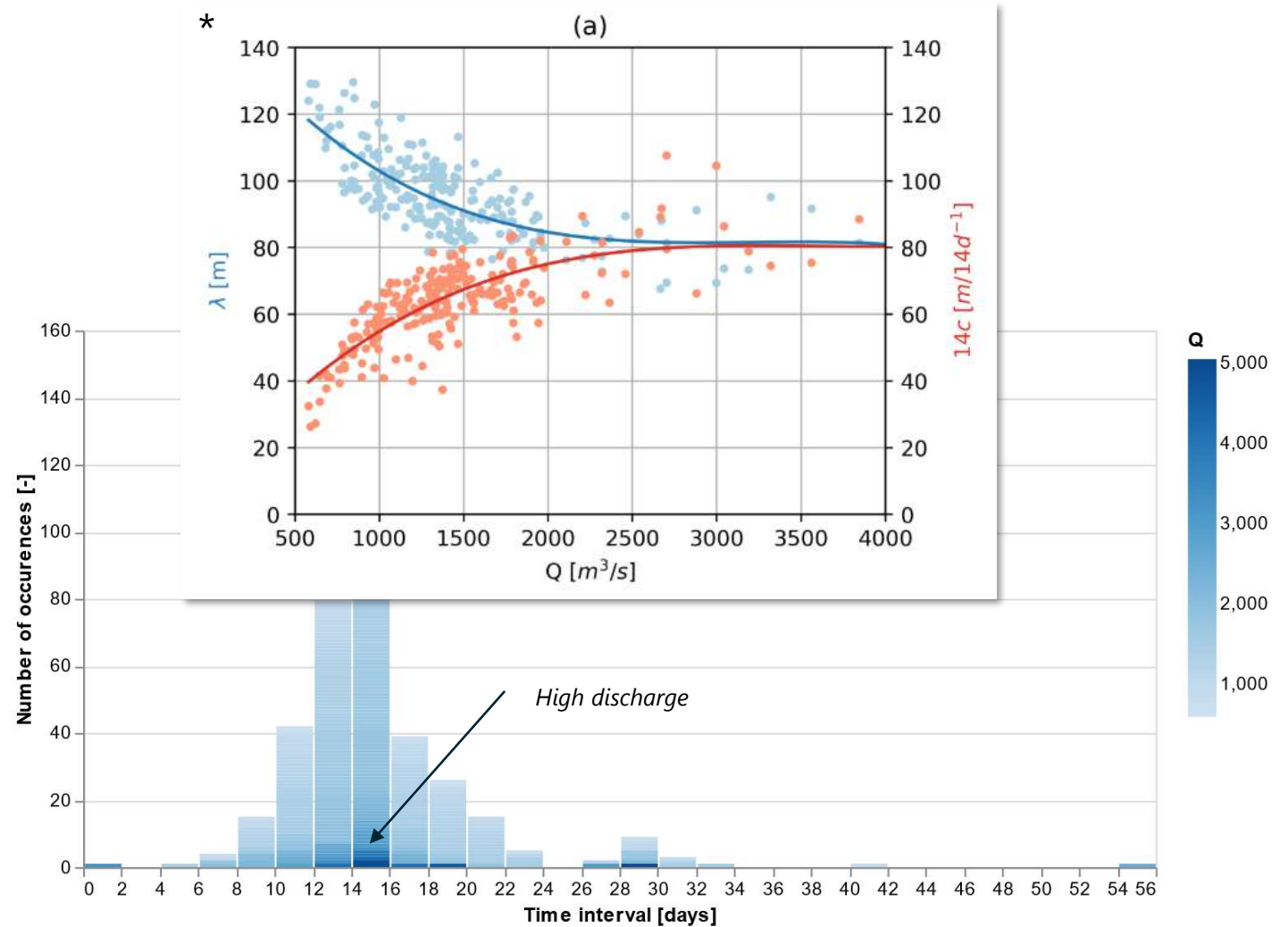
- Discharge regimes
- The dune length λ , and 14-day dune celerity $14c$.
- Exclude high discharge regime ($>2000\text{m}^3/\text{s}$)



* Laar, L. I. (2024). *Two data-driven approaches for predicting bed levels in 3D for the Waal River* (Master's thesis, University of Twente).

Challenges Flow regimes

- Discharge regimes
- The dune length λ , and 14-day dune celerity $14c$.
- Exclude high discharge regime ($>2000\text{m}^3/\text{s}$)

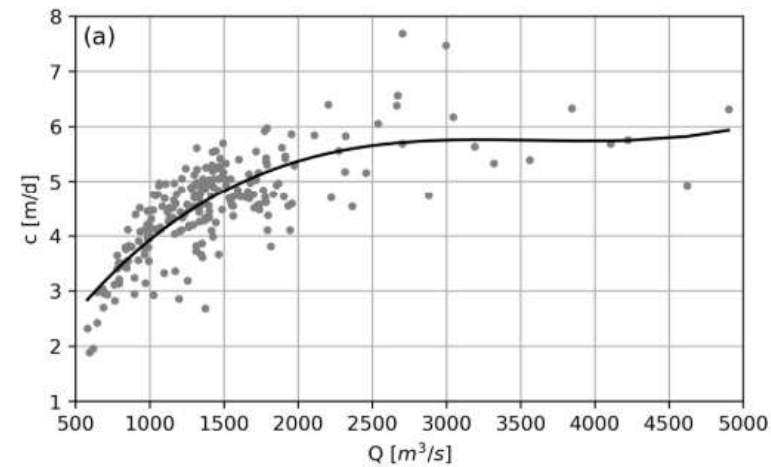
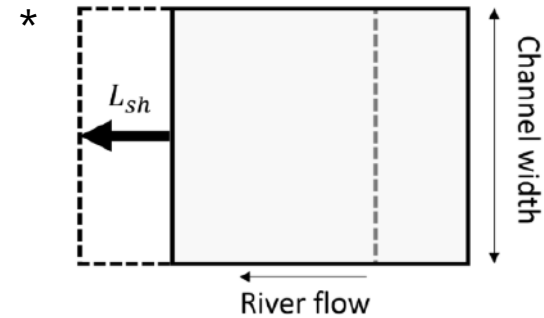


* Laar, L. I. (2024). *Two data-driven approaches for predicting bed levels in 3D for the Waal River* (Master's thesis, University of Twente).

Challenges

Irregular time intervals

- Feature engineering with dune celerity
- Make time intervals more consistent (14 days)



[Lokin, L. R., Warmink, J. J., Bomers, A., & Hulscher, S. J. M. H. \(2022\). River Dune Dynamics During Low Flows. Geophysical Research Letters, 49 \(8\)](#)

* Laar, L. I. (2024). *Two data-driven approaches for predicting bed levels in 3D for the Waal River* (Master's thesis, University of Twente).

Data preprocessing

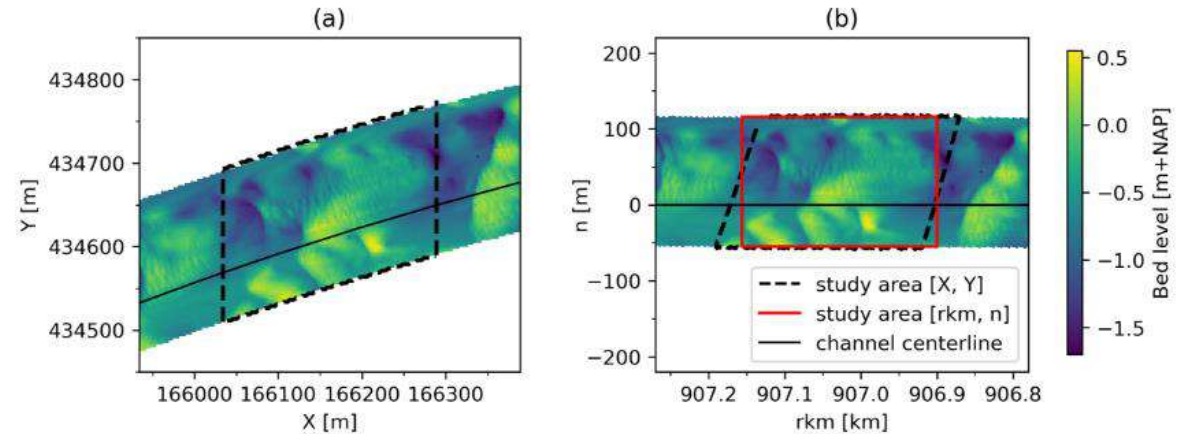
Three techniques

- Improved the removing of outliers in training data
- Stream coordinate transformation
- Wavelet reconstruction

Data preprocessing

Three techniques

- Improved the removing of outliers in training data
- Stream coordinate transformation
- Wavelet reconstruction

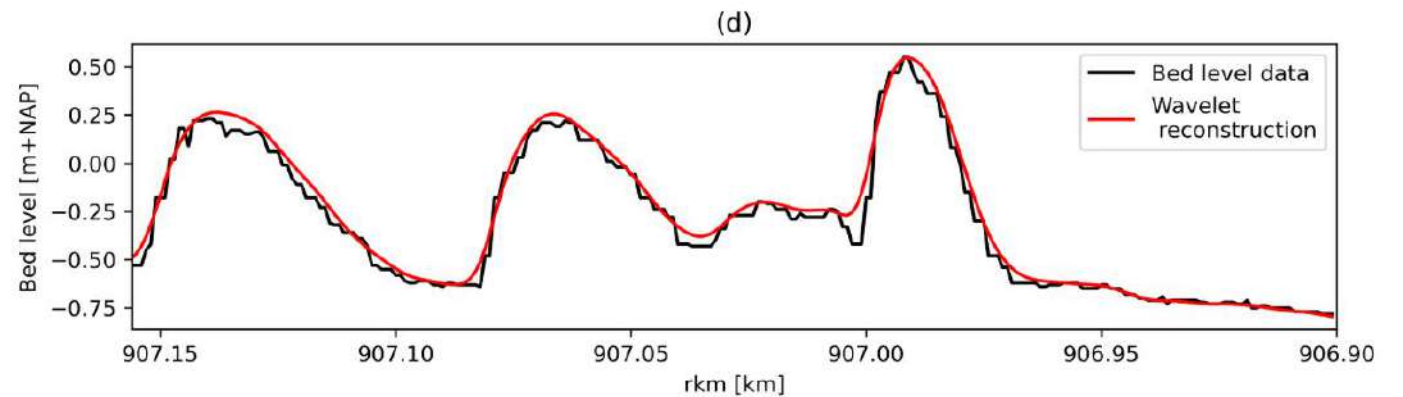


* Laar, L. I. (2024). *Two data-driven approaches for predicting bed levels in 3D for the Waal River* (Master's thesis, University of Twente).

Data preprocessing

Three techniques

- Improved the removing of outliers in training data
- Stream coordinate transformation
- Wavelet reconstruction

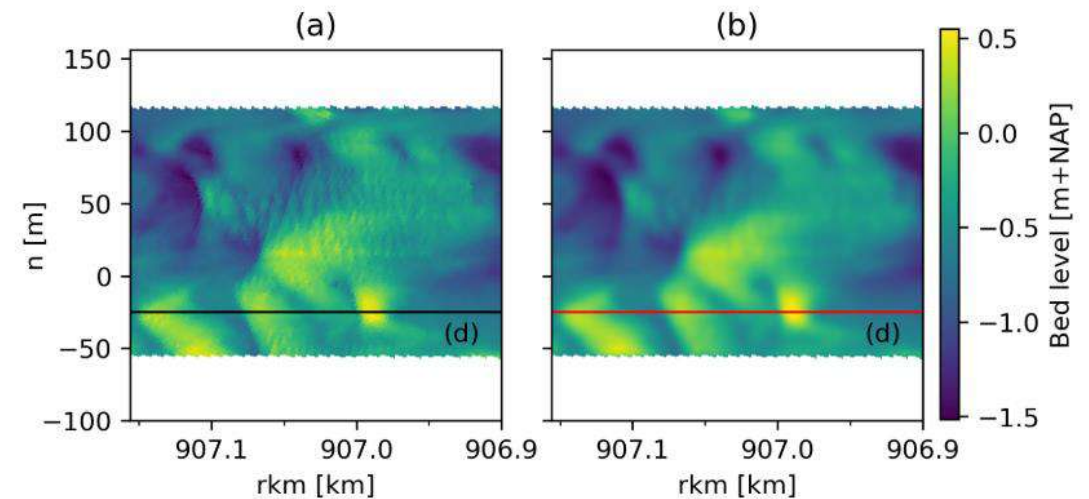


* Laar, L. I. (2024). *Two data-driven approaches for predicting bed levels in 3D for the Waal River* (Master's thesis, University of Twente).

Data preprocessing

Three techniques

- Improved the removing of outliers in training data
- Stream coordinate transformation
- Wavelet reconstruction

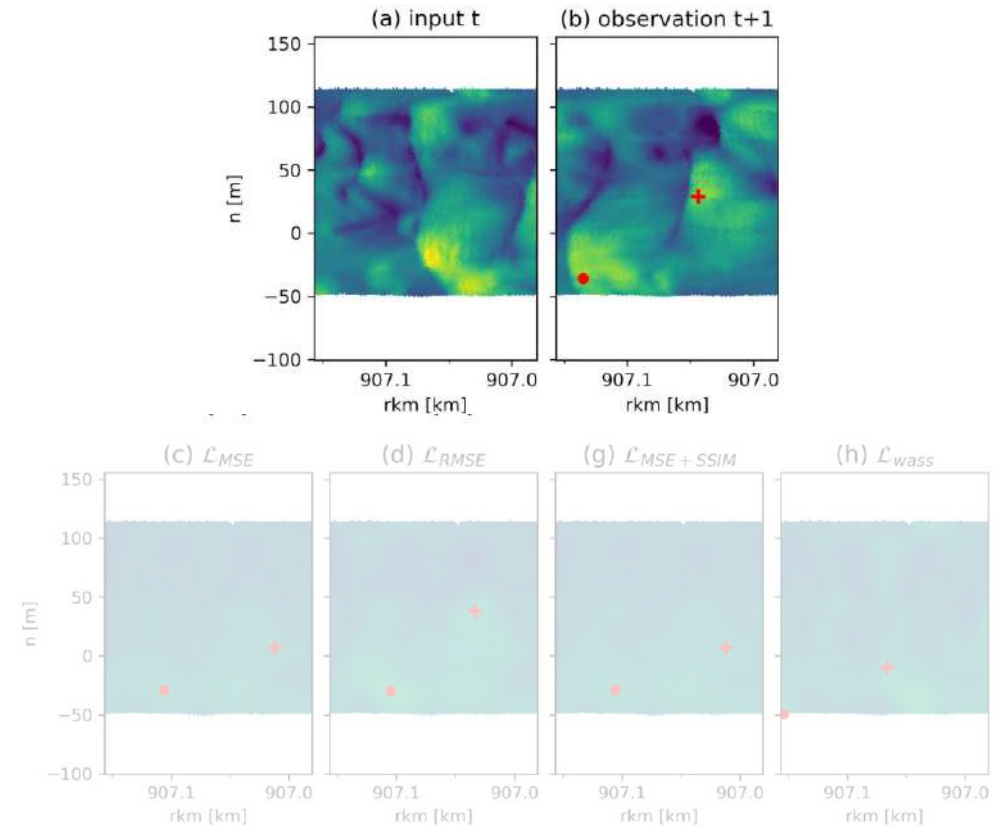


* Laar, L. I. (2024). *Two data-driven approaches for predicting bed levels in 3D for the Waal River* (Master's thesis, University of Twente).

Discussion

Results

- Testing different loss functions
- Smooth output, also some fading

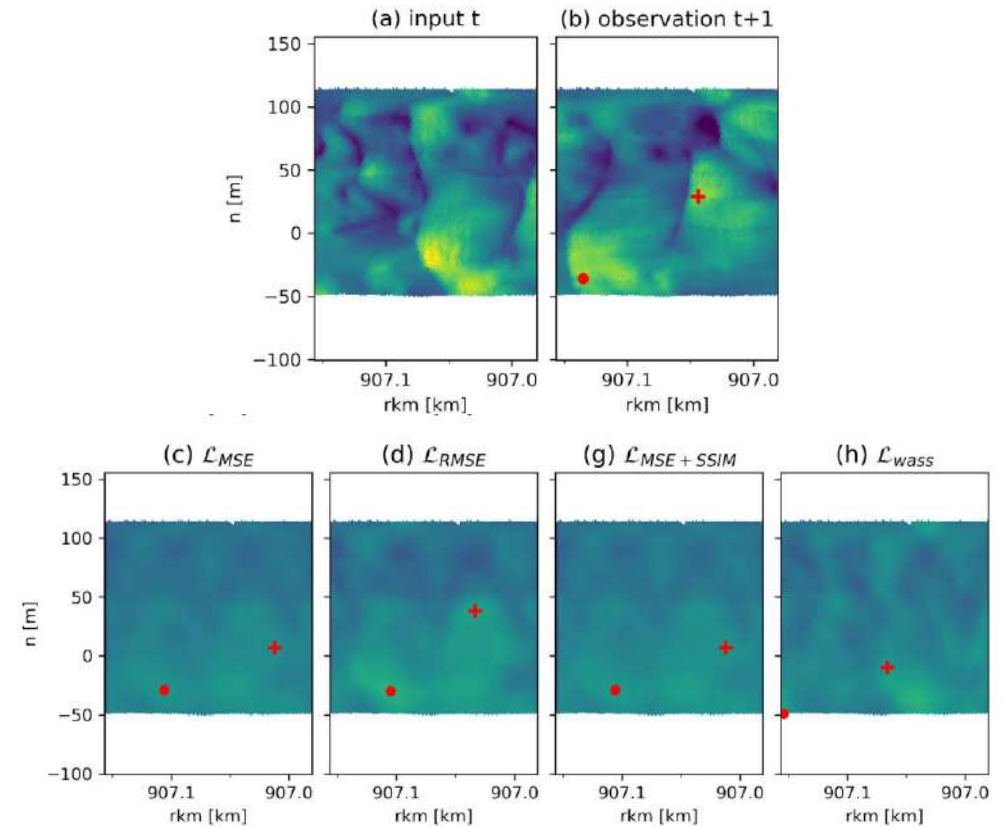


* Laar, L. I. (2024). *Two data-driven approaches for predicting bed levels in 3D for the Waal River* (Master's thesis, University of Twente).

Discussion

Results

- Testing different loss functions
- Smooth output, also some fading



* Laar, L. I. (2024). *Two data-driven approaches for predicting bed levels in 3D for the Waal River* (Master's thesis, University of Twente).

Discussion Questions

Thanks for your attention

Thomas Stolp
stolp@hkv.nl

