

# Explainable AI: Why so salty?

Predicting salt intrusion on the Amsterdam-Rhine Canal

10 January 2024

Technical session DigiShape

Paula Lambregts & Thomas Stolp





## Agenda

- **Introduction**
- **Context**
- **Predictive model**
- **Explainable AI**
- **Closure**

# Introduction

## Lead-up



Study on salt intrusion mouth ARK



Rijkswaterstaat

Application Machine Learning for prediction of salt intrusion ARK

DigiShape Seedmoney project – Explainable AI: Why so Salty?



# Introduction

## NZK/ARK in the news

### Debiet in m3/s

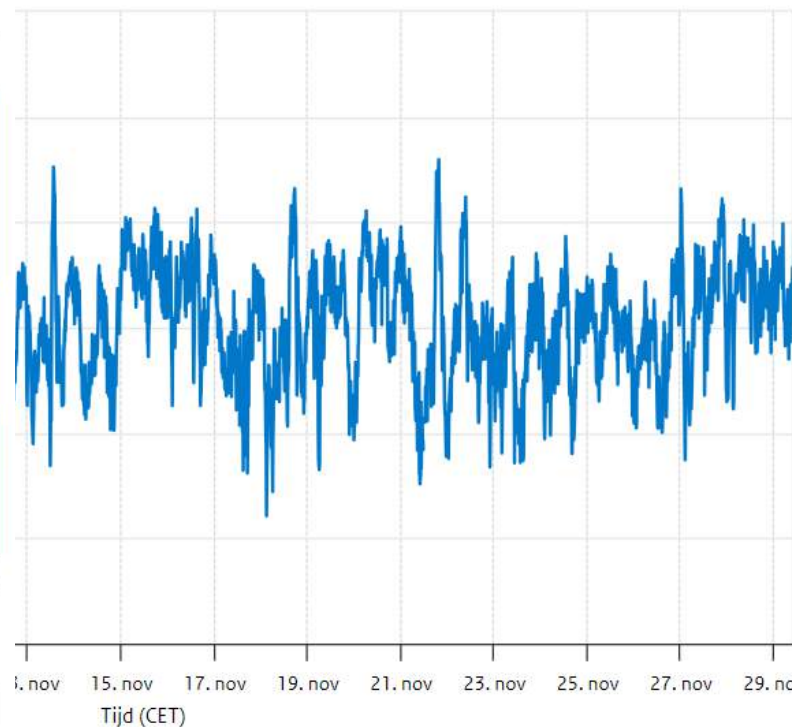
🕒 Weesp | Laatste meting: **86,47 m3/s** op 29-11-2023 10:50

### Chloride in mg/l

🕒 Diemen (NAP -1.4m) | Laatste meting: **68 mg/l** op 29-11-2023 09:30



Refresh Opslaan Export/Delen



Debiet in m3/s

Ciarán  
ng

erstromingen door  
rekken met de  
id.”





## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal



Noordzeekanaal

## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal

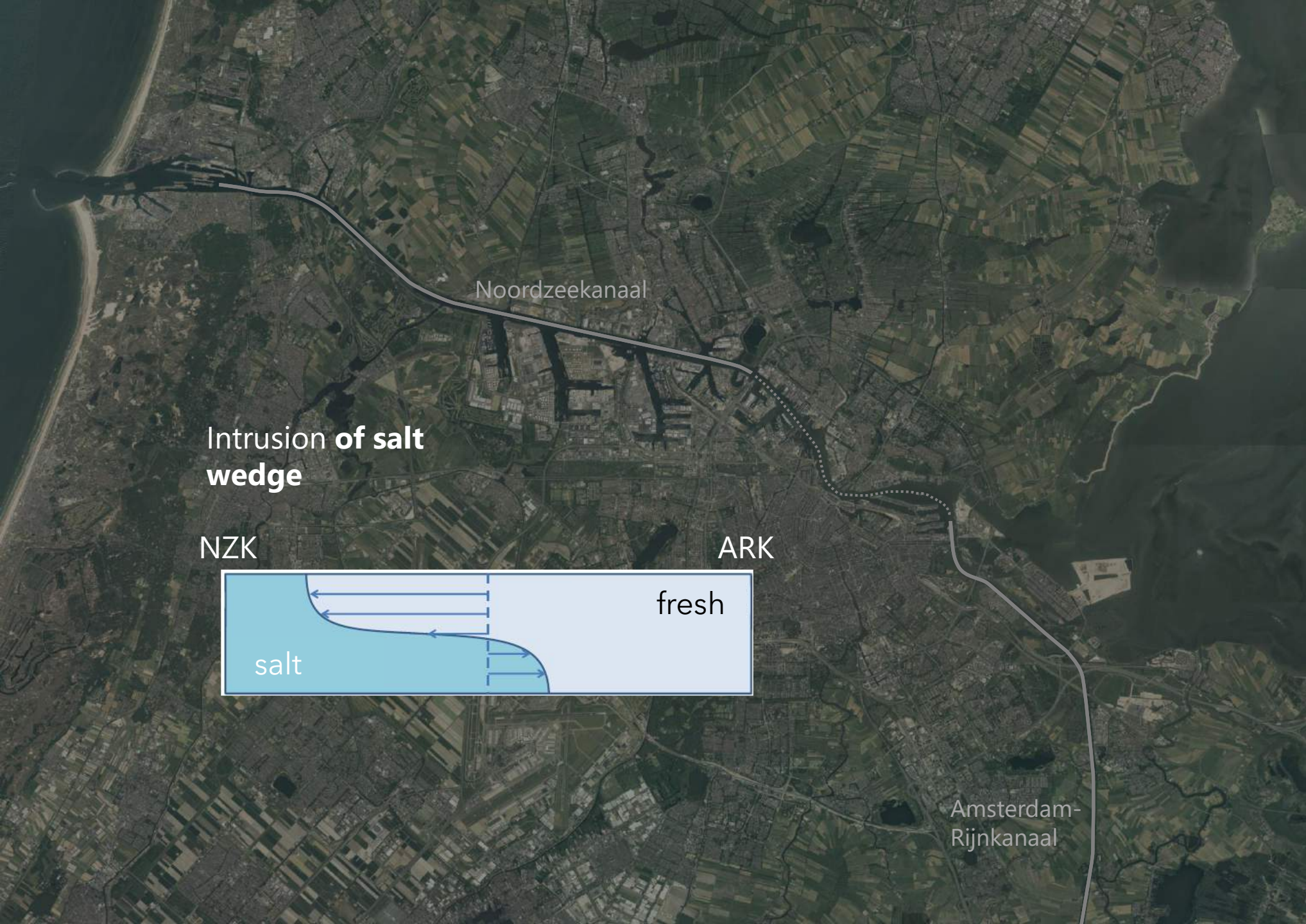


Noordzeekanaal

Amsterdam-  
Rijnkanaal

**Context**  
Salt intrusion on  
the Amsterdam-  
Rhine Canal

**Context**  
Salt intrusion on the Amsterdam-Rhine Canal





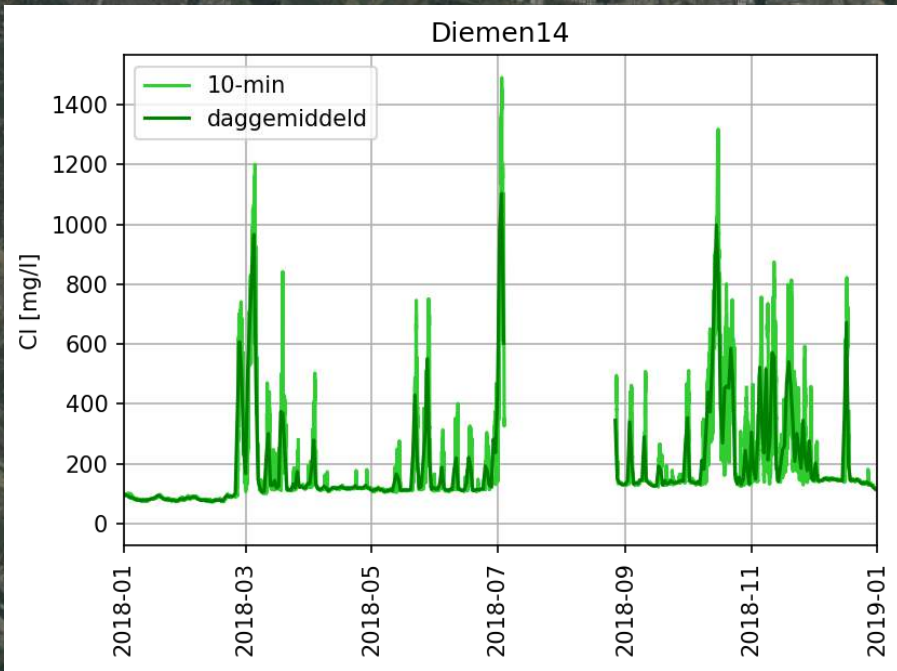


**Monitoring points  
of salt intrusion**

**Context**  
Salt intrusion on  
the Amsterdam-  
Rhine Canal

**Context**  
Salt intrusion on the Amsterdam-Rhine Canal

**Monitoring points of salt intrusion**



Velserkom

Spaarndammerpolder

Noordzeekanaal

Zijkanaal C

NDSM

Diemen

Amsterdam-Rijnkanaal



## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal

**Context**  
Salt intrusion on  
the Amsterdam-  
Rhine Canal



Noordzeekanaal

**Critical points** for salt  
intrusion

Driemond

Vecht

Nigtevecht

Drinking water



## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal



## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal

## Context

### Salt intrusion on the Amsterdam-Rhine Canal

#### Salt load, IJmuiden



#### Features:

- Exchange volume Sluices IJmuiden
- Exchange volume Noordersluis and Zeesluis IJmuiden
- Gravity drainage and pumping discharges IJmuiden



## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal





## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal



**Wind, intensity  
and direction**

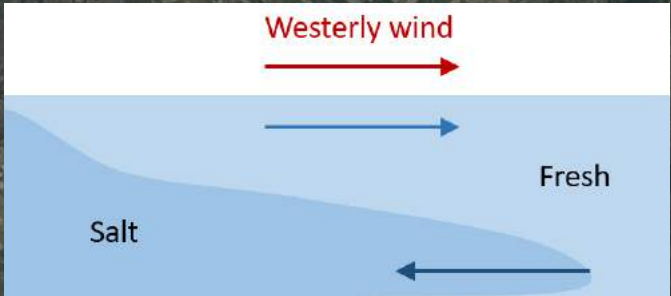
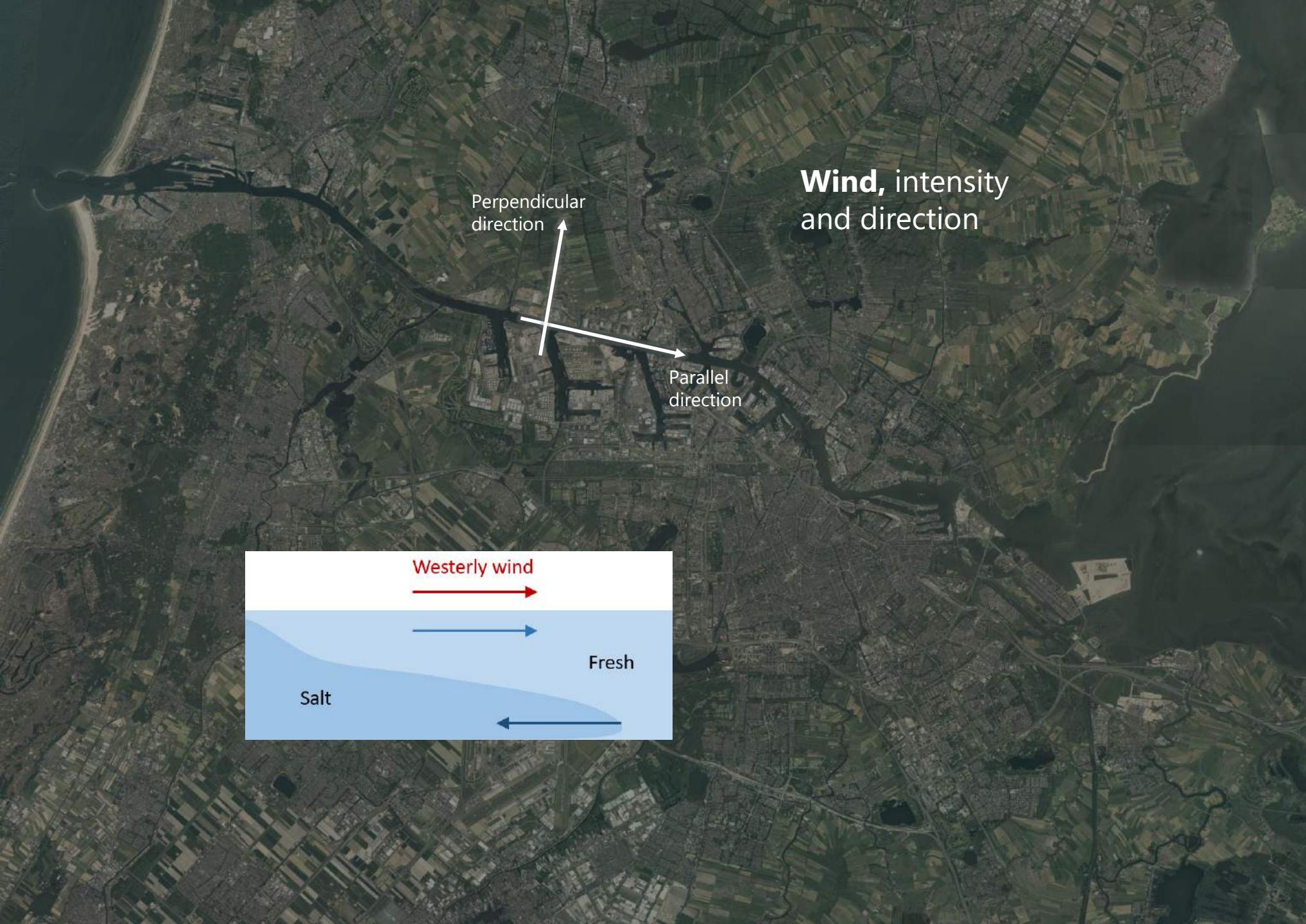
Perpendicular  
direction

Parallel  
direction

**Context**  
Salt intrusion on  
the Amsterdam-  
Rhine Canal

# Context

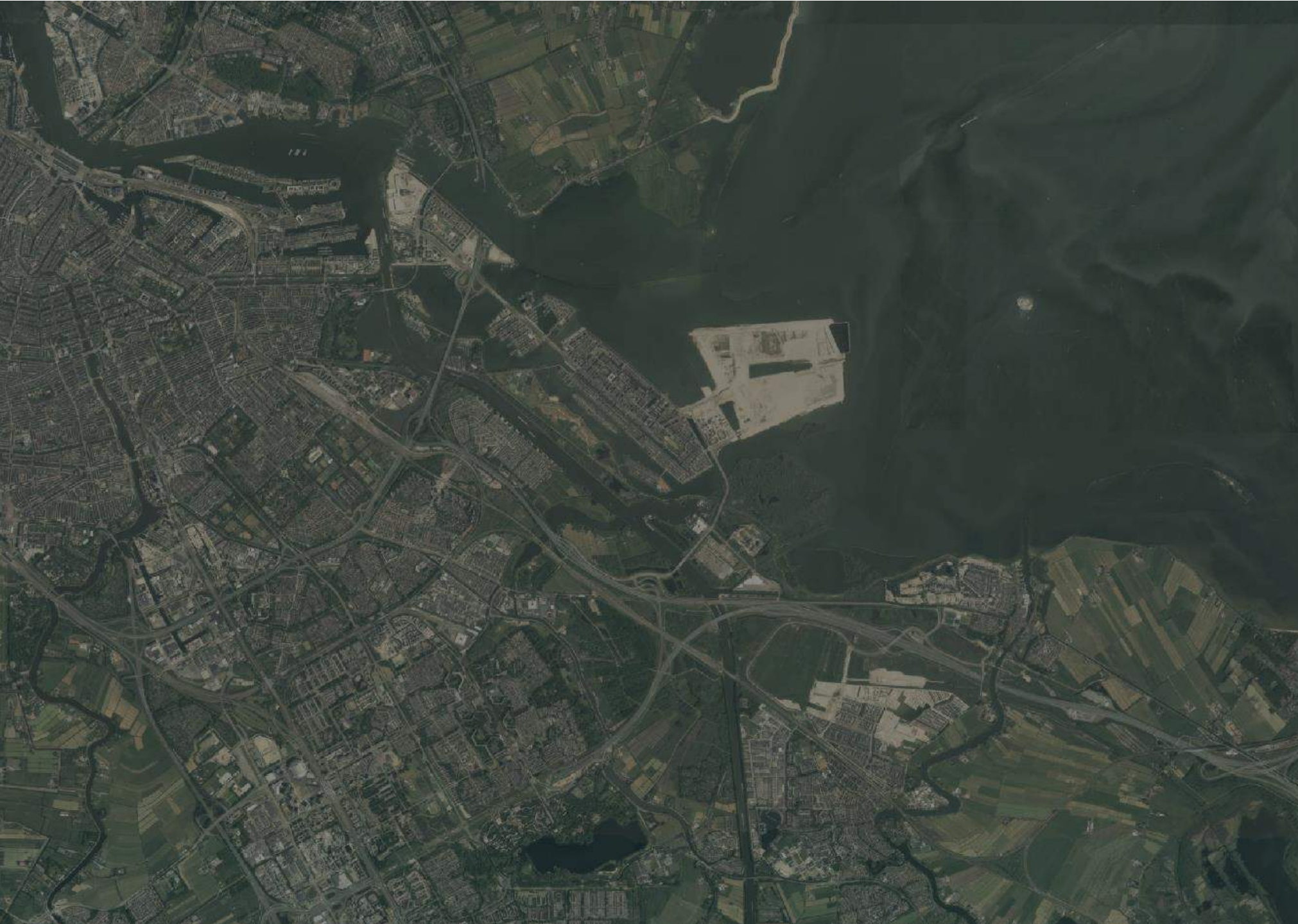
## Salt intrusion on the Amsterdam-Rhine Canal





## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal



## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal



**Shipping intensity** at the  
Amsterdam-Rhine canal

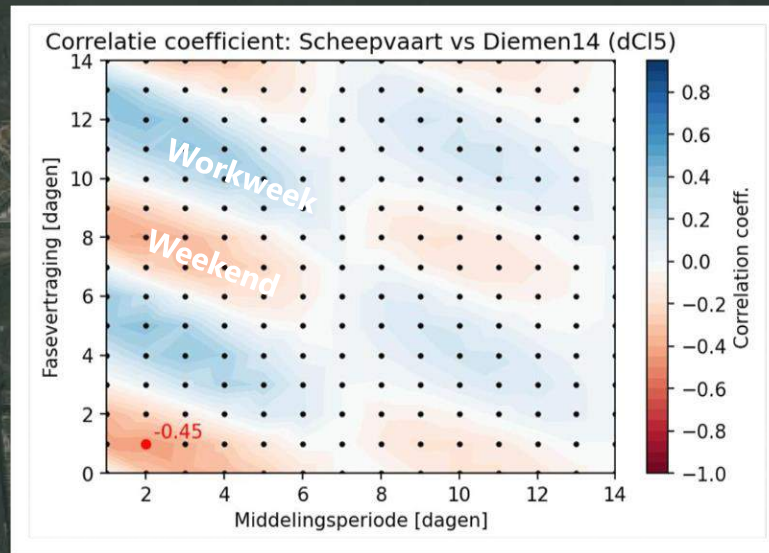
## Context

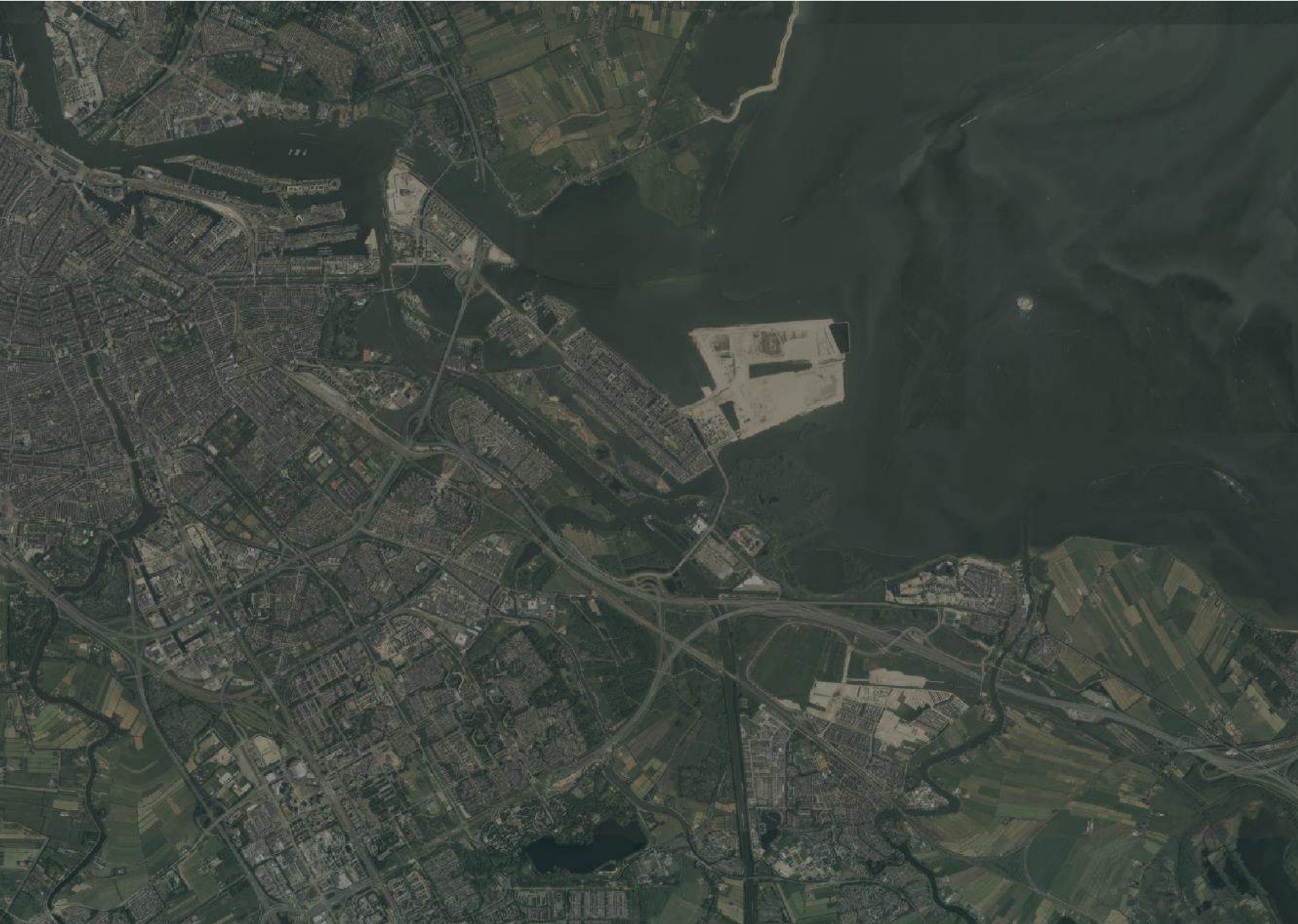
Salt intrusion on  
the Amsterdam-  
Rhine Canal

# Context

## Salt intrusion on the Amsterdam-Rhine Canal

Shipping intensity at the Amsterdam-Rhine canal





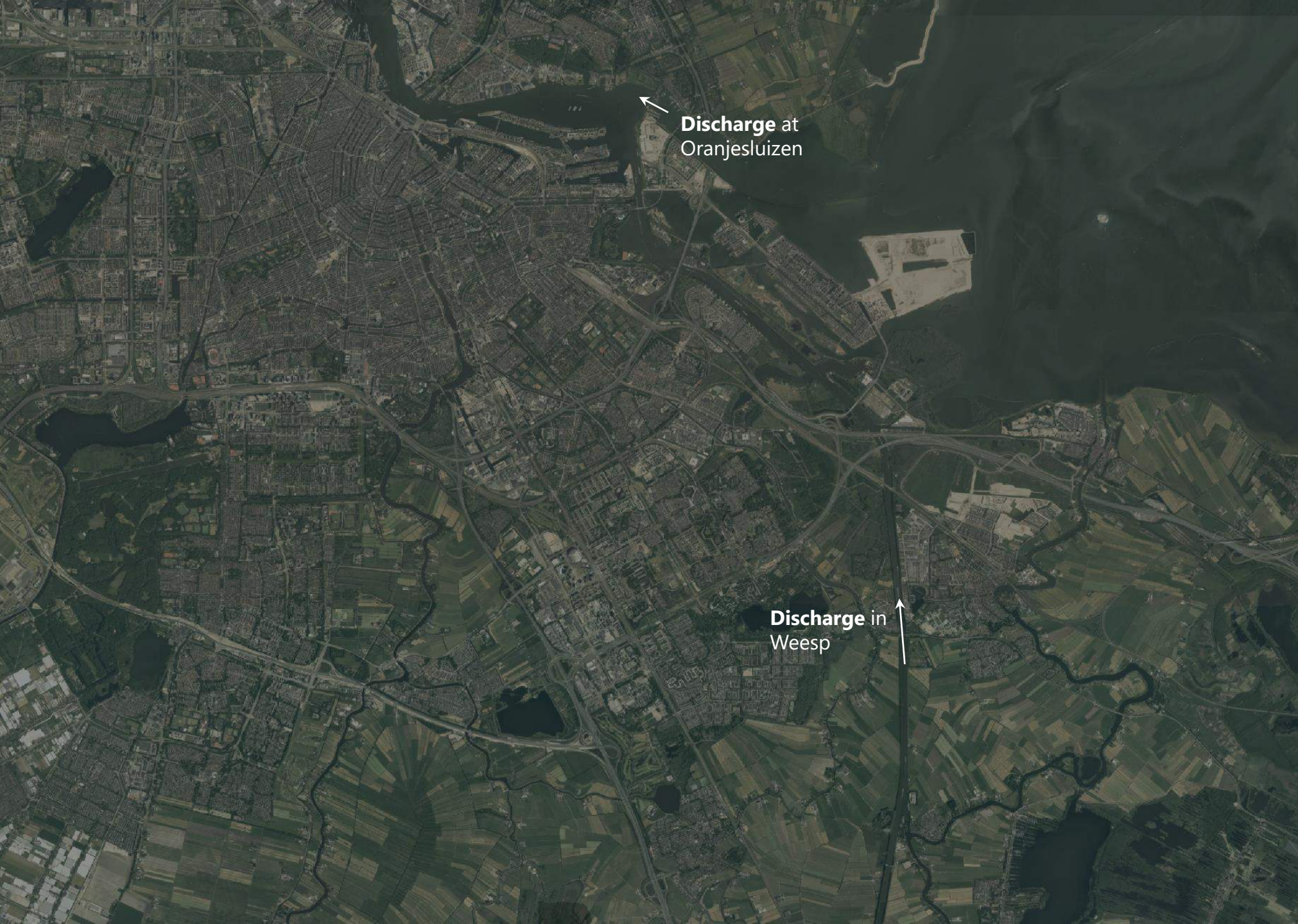
## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal





**Context**  
Salt intrusion on  
the Amsterdam-  
Rhine Canal



## Context

Salt intrusion on  
the Amsterdam-  
Rhine Canal

## Context

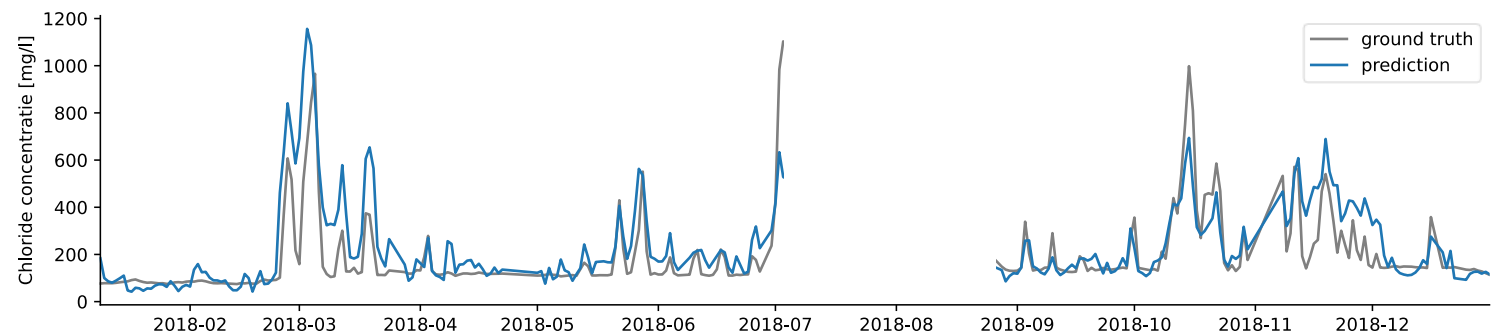
### Key factors

- Discharge in Weesp
- Daily discharge fluctuations
- Sum of negative discharges
- Hourly discharge fluctuations
- Absolute windspeed
- Wind component parallel to NZK
- Wind component perpendicular to NZK
- Discharge Oranjesluizen
- Exchange volume sluices IJmuiden
- Exchange volume Noordersluis and Zeesluis IJmuiden
- Salt load IJmuiden
- Gravity drainage and pumping discharges IJmuiden
- Lateral discharges NZK
- Shipping intensity ARK

## Predictive model

### Predictive modelling using ML

- Neural network
- Optimisation of parameters & structure network
- Features selection conform linear model
- Features with different lags and averaging periods
- Daily averages
- Test year 2018 dry–extremely

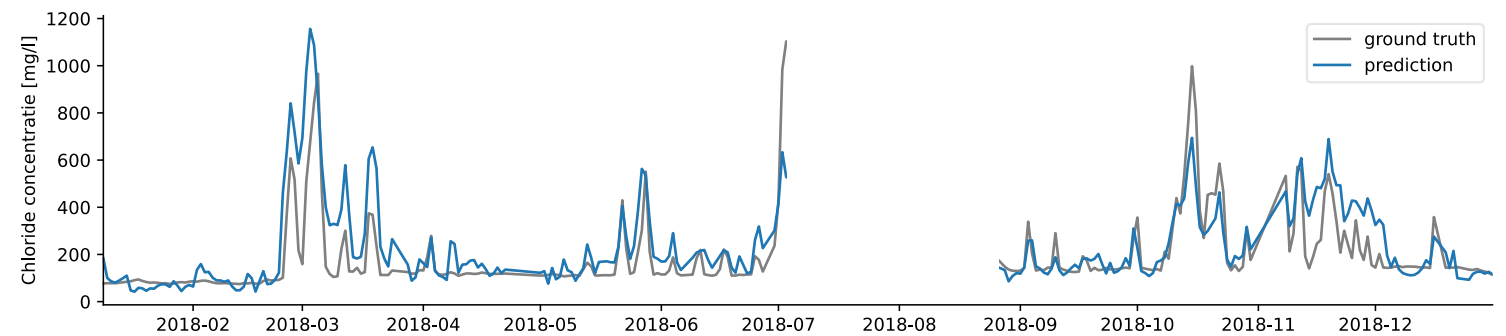


Prediction of salt concentrations in Diemen using a neural network.

# Predictive model

## Predictive modelling using ML

- Neural network
  - Dares to predict peaks
  - Without prior knowledge for year 2018

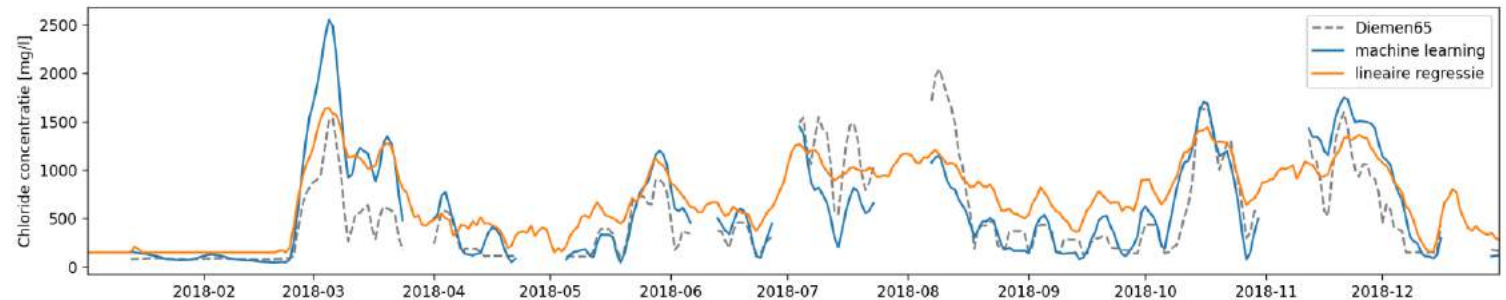


Prediction of salt concentrations in Diemen using a neural network.

## Predictive model

### Comparison linear model

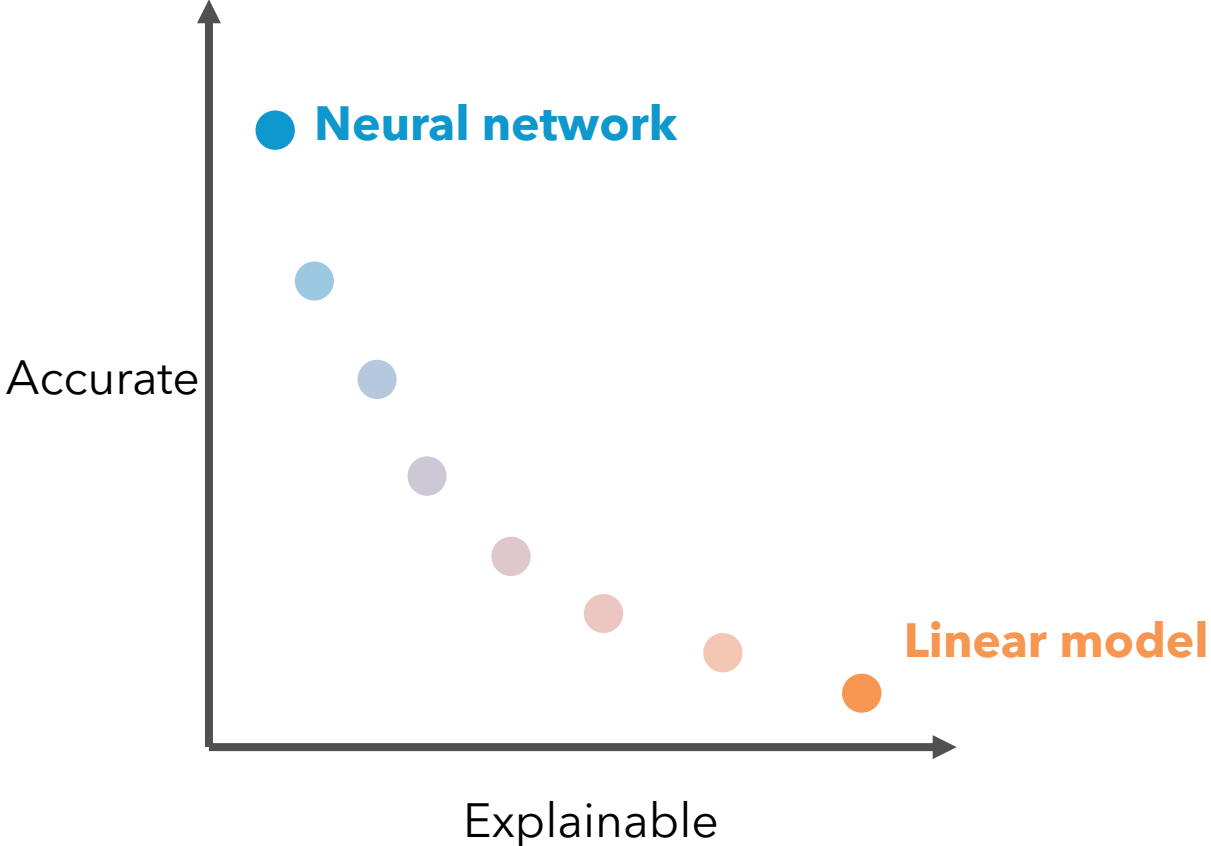
- ML model gives more distinctive outcomes
  - Linear model shows average trend, ML model includes peaks
- ML model can also predict periods with low salt concentrations
- Linear model more transparent



Prediction of salt concentrations in Diemen using a neural network.

# Predictive model

## AI versus conventional techniques



## Predictive model

### ML-model raises questions

- Can we predict something that we do not fully understand?
- Can we explain what we see in the measurements?
- What happens if we adjust key factors (e.g. more discharge)?
- Can this help us decide when to take which measures to combat salt intrusion?





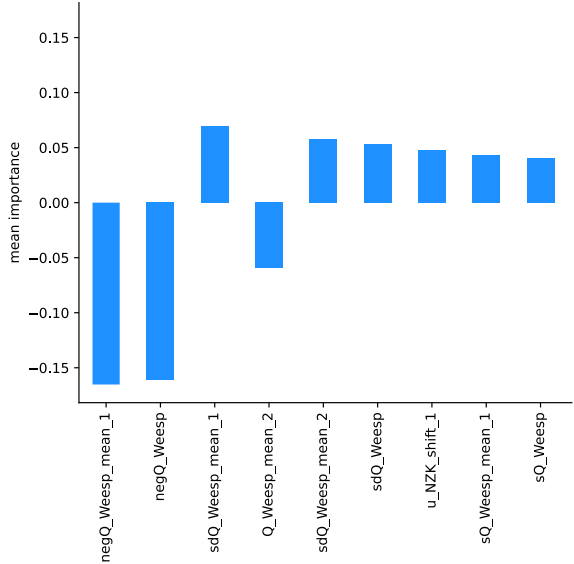
## Predictive model Statement

*“Within the water sector, there is a strong demand for explainability of data-driven models”*

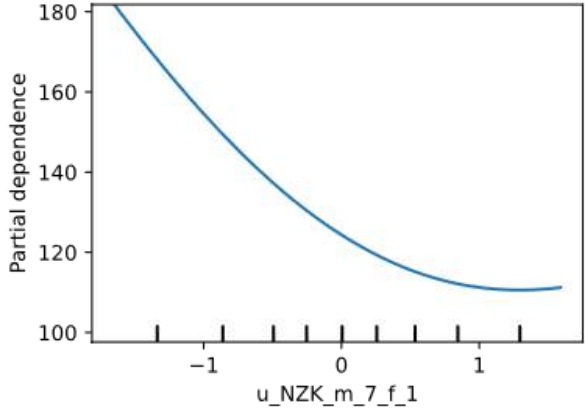
*“Binnen de watersector is een sterke behoefte aan uitlegbaarheid van data-gedreven modellen”*

# Explainable AI Techniques

- **Ranking**



- **Dependence**



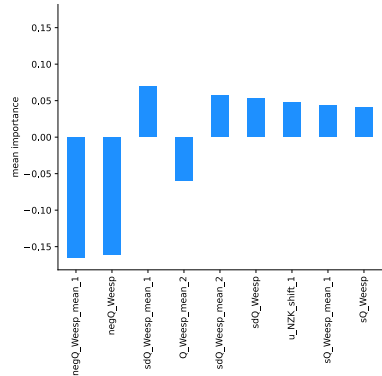
- **Visualisation**

Highest salt concentration in Diemen -6.5 m NAP



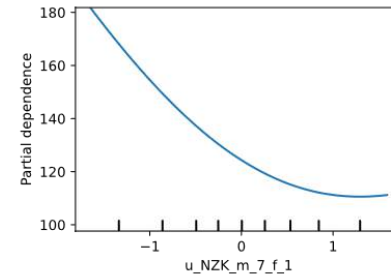
# Explainable AI Techniques

## • Ranking



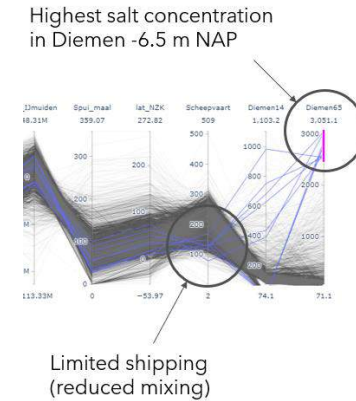
- I. Permutation feature importance
- II. Leave One Feature Out (LOFO)
- III. SHAP mean importance

## • Dependence



- I. Partial dependence plot (PDP)
- II. Accumulated local effects (ALE)
- III. SHAP mean importance

## Visualisation

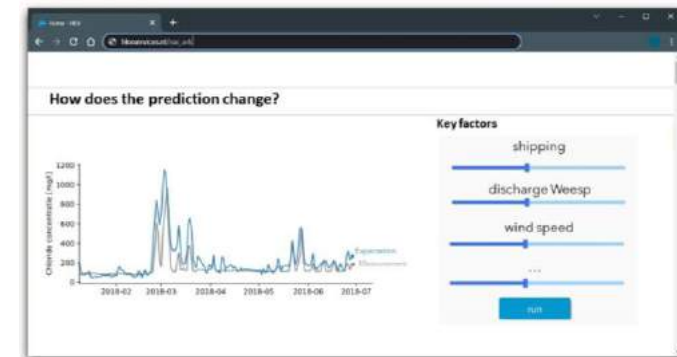
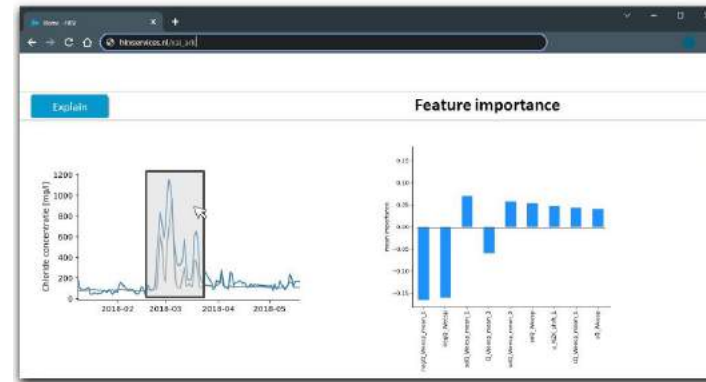


- I. Parallel coordinate plot
- II. Visual (interactive) interpretability

# Explainable AI

## Introducing the tool

- Goal: Increase confidence in outcome of ML-models
- Method: Increase insight in model outcome using Explainable AI techniques
- Target user: users of operational predictive models



# Get to know XAI

## 1. What causes the salt peak in beginning of March?

### 1. Feature importance

- Permutations
- Complete test set
- Selecting section of interest



### 2. Changing key features

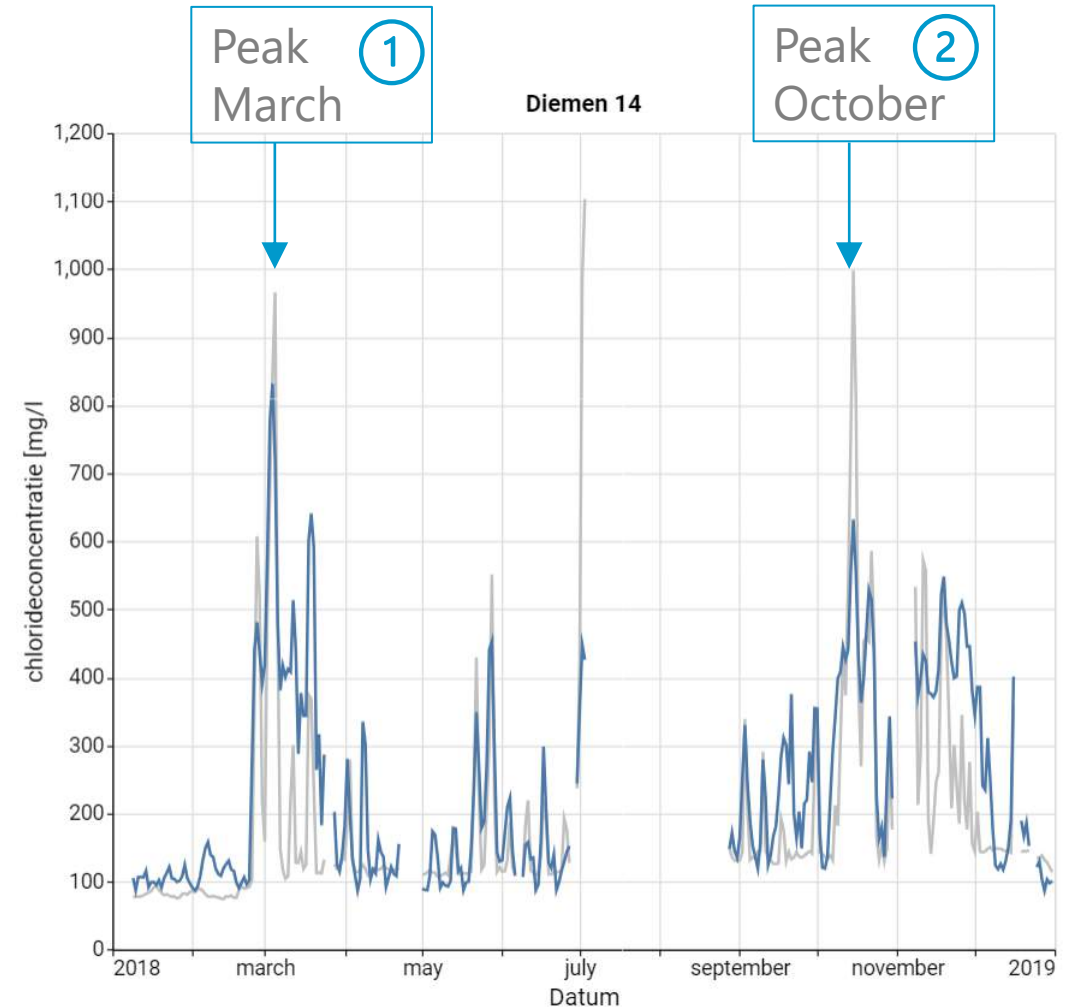
- Adjust variables over a selected time range
- Visualize distributions for warning of "out of training" predictions



# Explainable AI Questions

- ① Which features have **largest contribution** to the predicted salt peak in beginning of March?
- ② Can you **change the conditions** so that the salt peak in October does not exceed 500 mg/l?

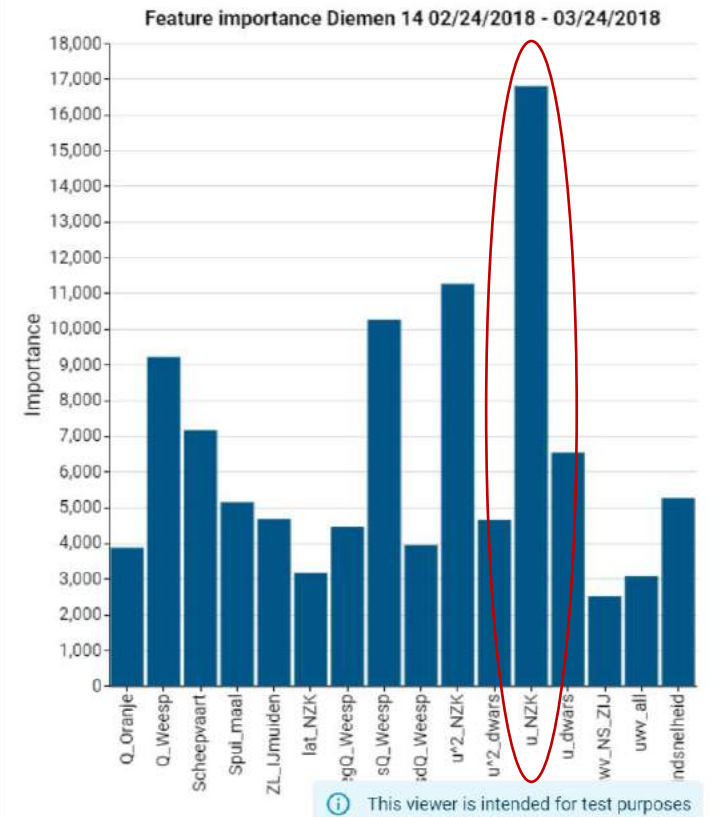
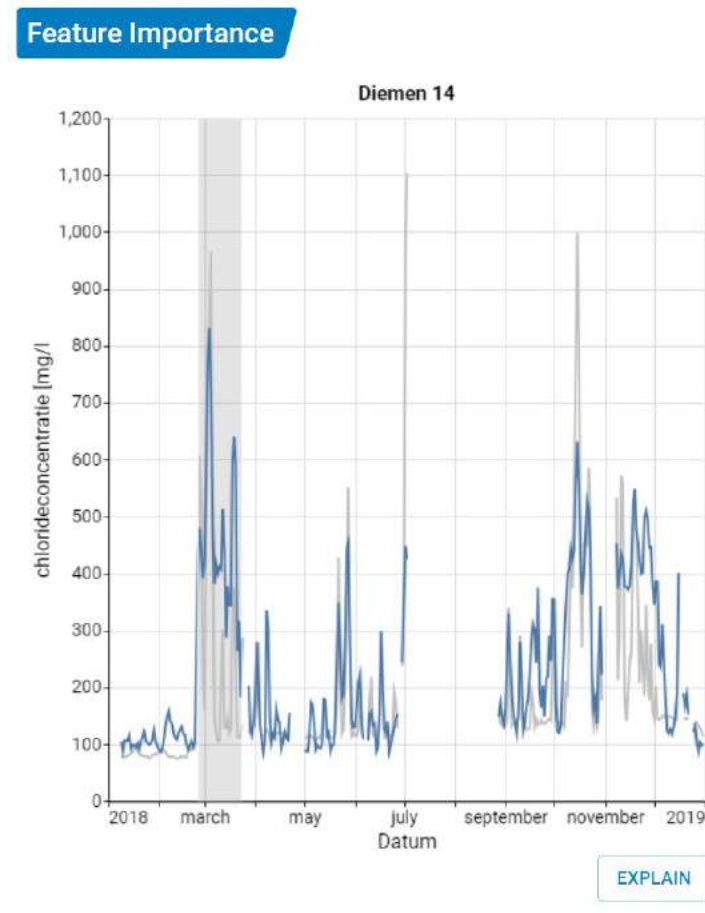
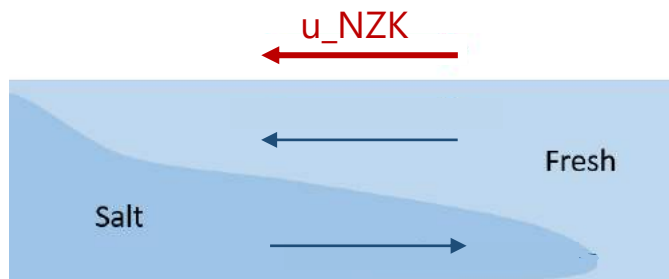
[https://dmmangrove.hkvservices.nl/xai\\_ark/](https://dmmangrove.hkvservices.nl/xai_ark/)



# Get to know XAI

## 1. What causes the salt peak in beginning of March?

- **Wind parallel to NZK is important.**

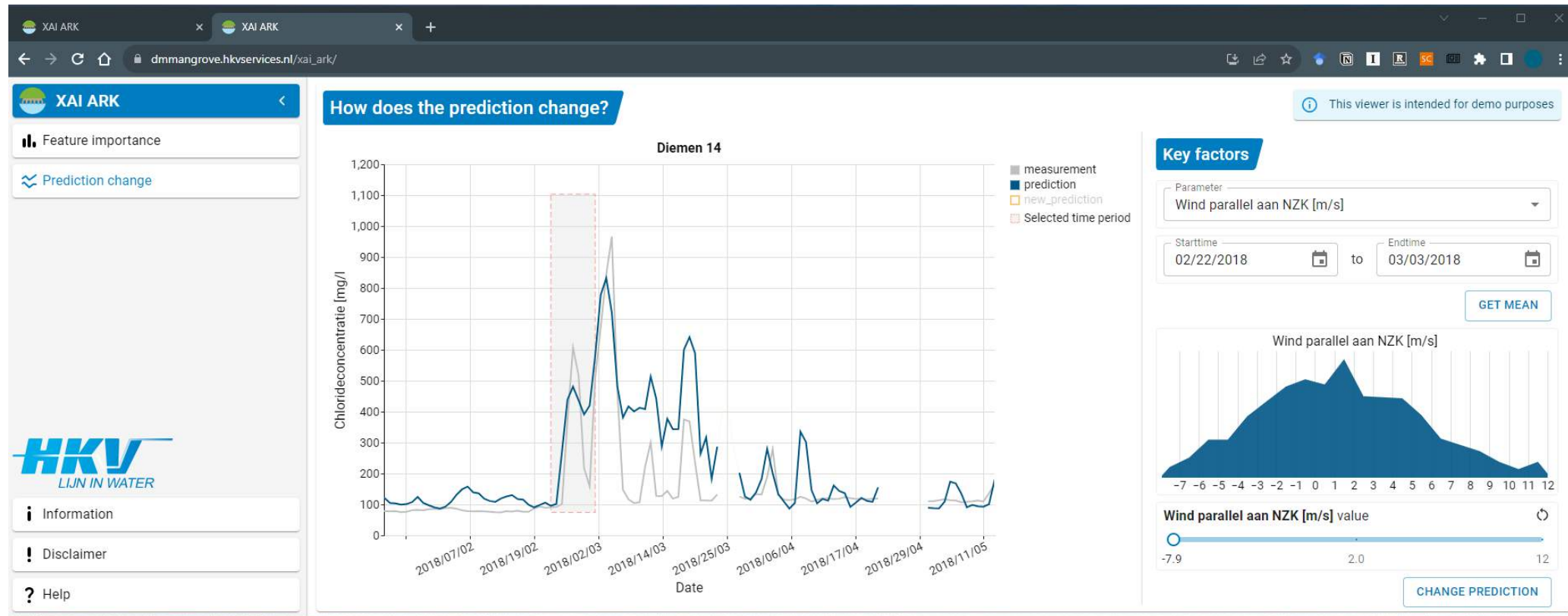


# Get to know XAI

## 1. What causes the salt peak in beginning of March?

Peak March 1

- Change the magnitude of the **wind** parallel to NZK



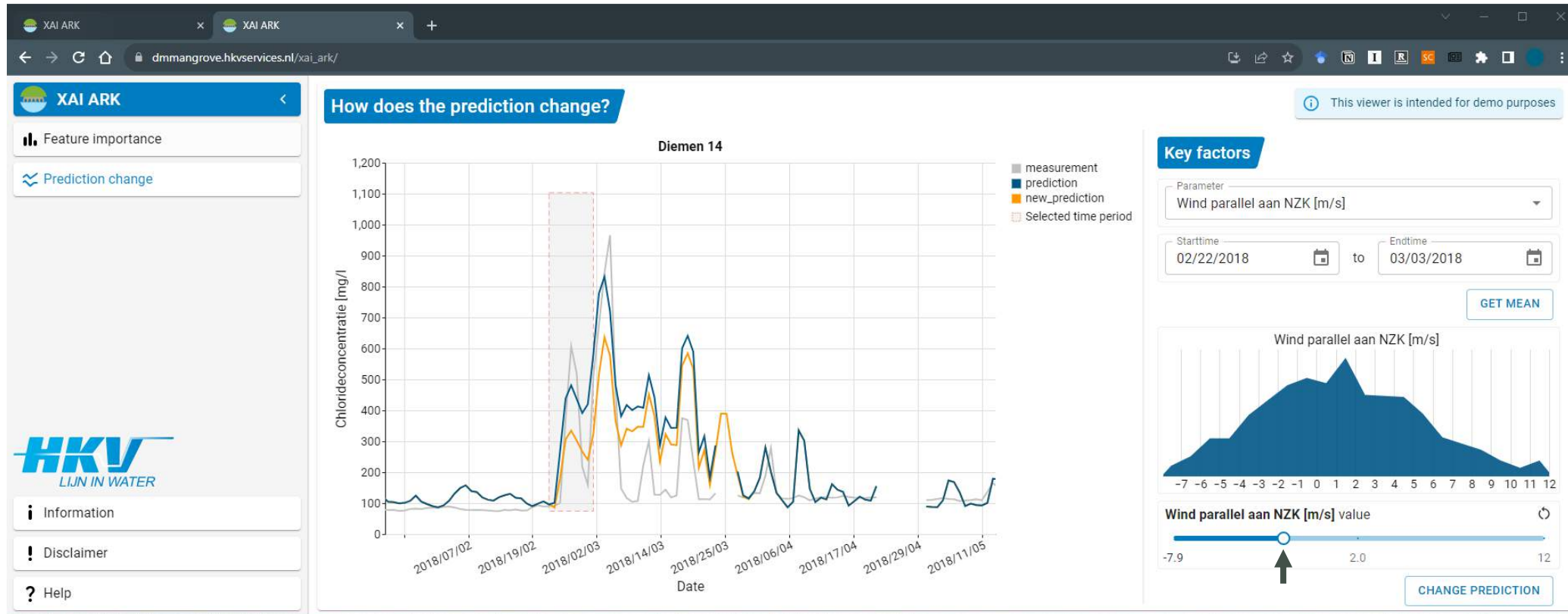


# Get to know XAI

## 1. What causes the salt peak in beginning of March?

Peak March ①

- Change the magnitude of the **wind** parallel to NZK

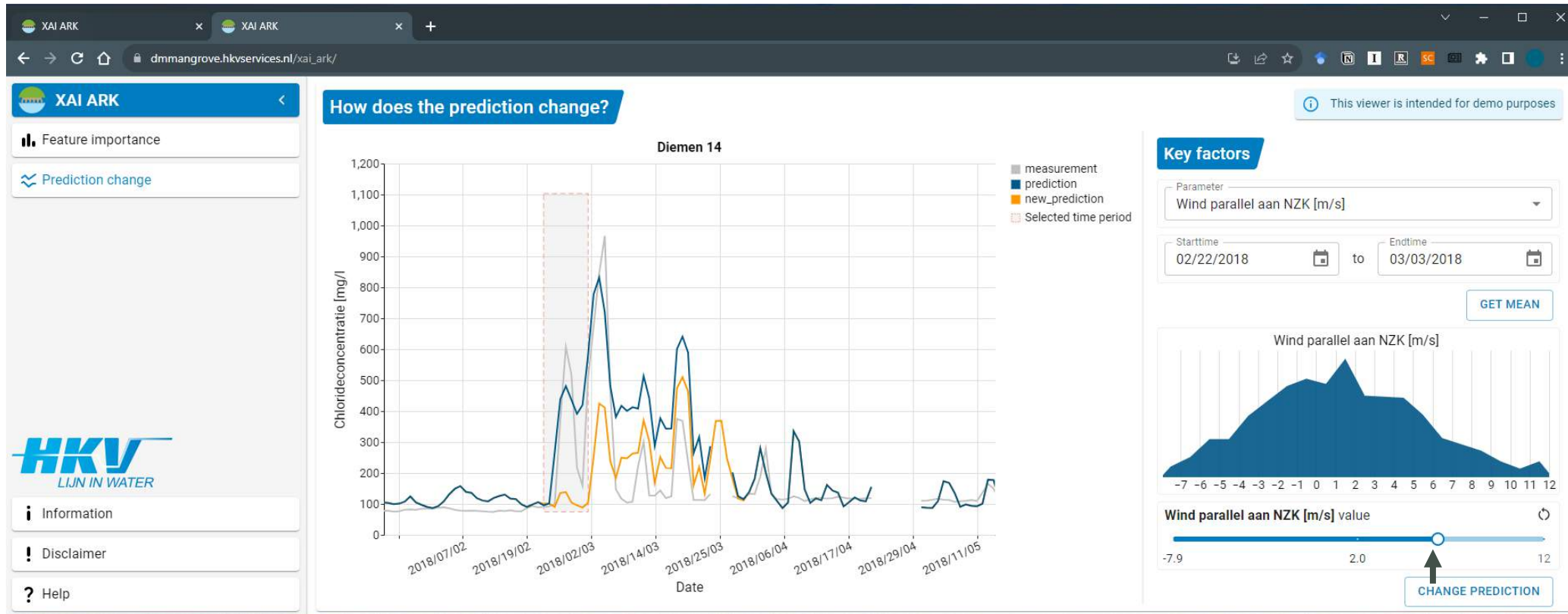


# Get to know XAI

## 1. What causes the salt peak in beginning of March?

Peak March ①

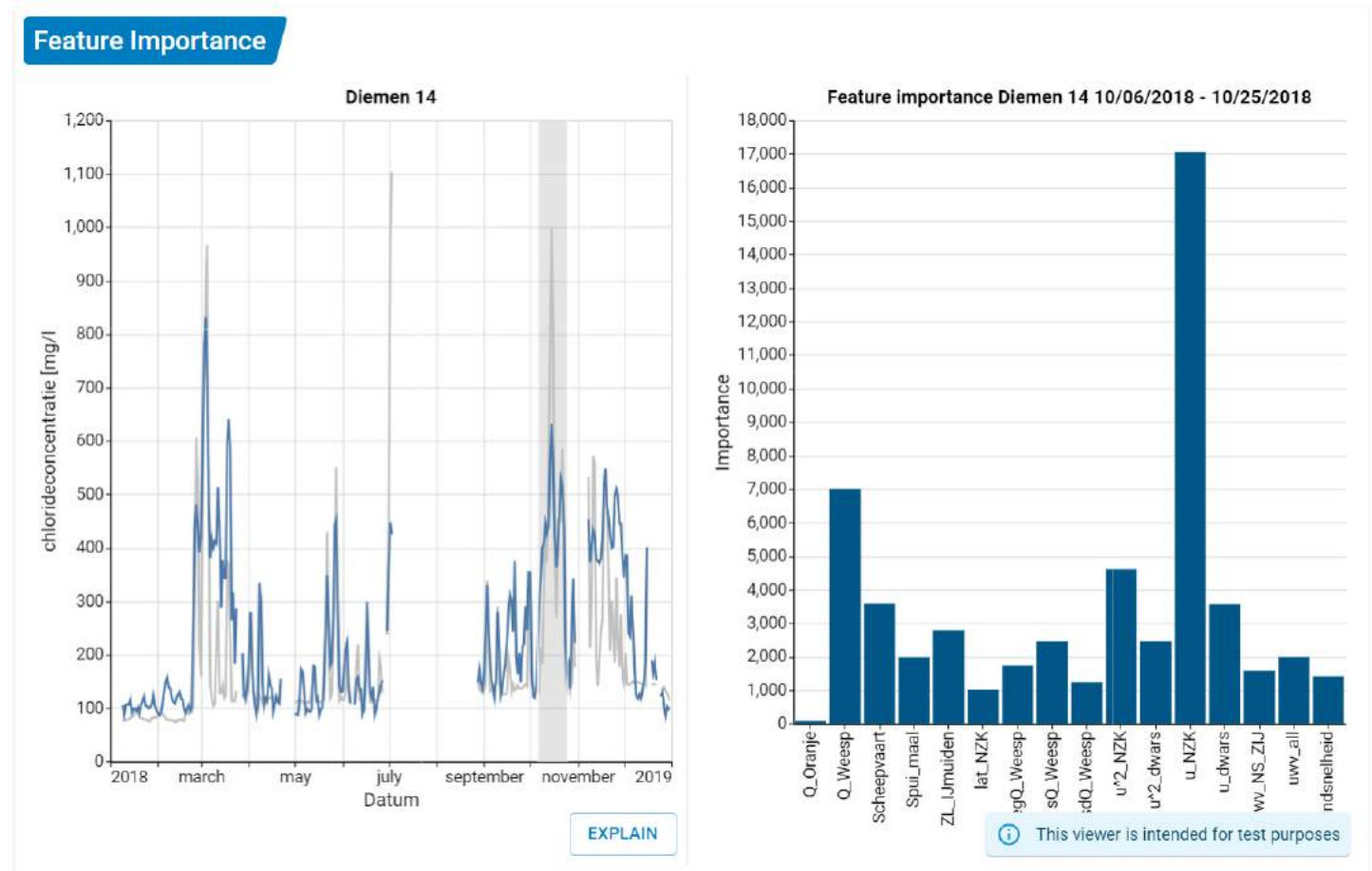
- Change the magnitude of the **wind** parallel to NZK



## Get to know XAI

### 2. Can you change the conditions so that the salt peak in October does not exceed 500 mg/l?

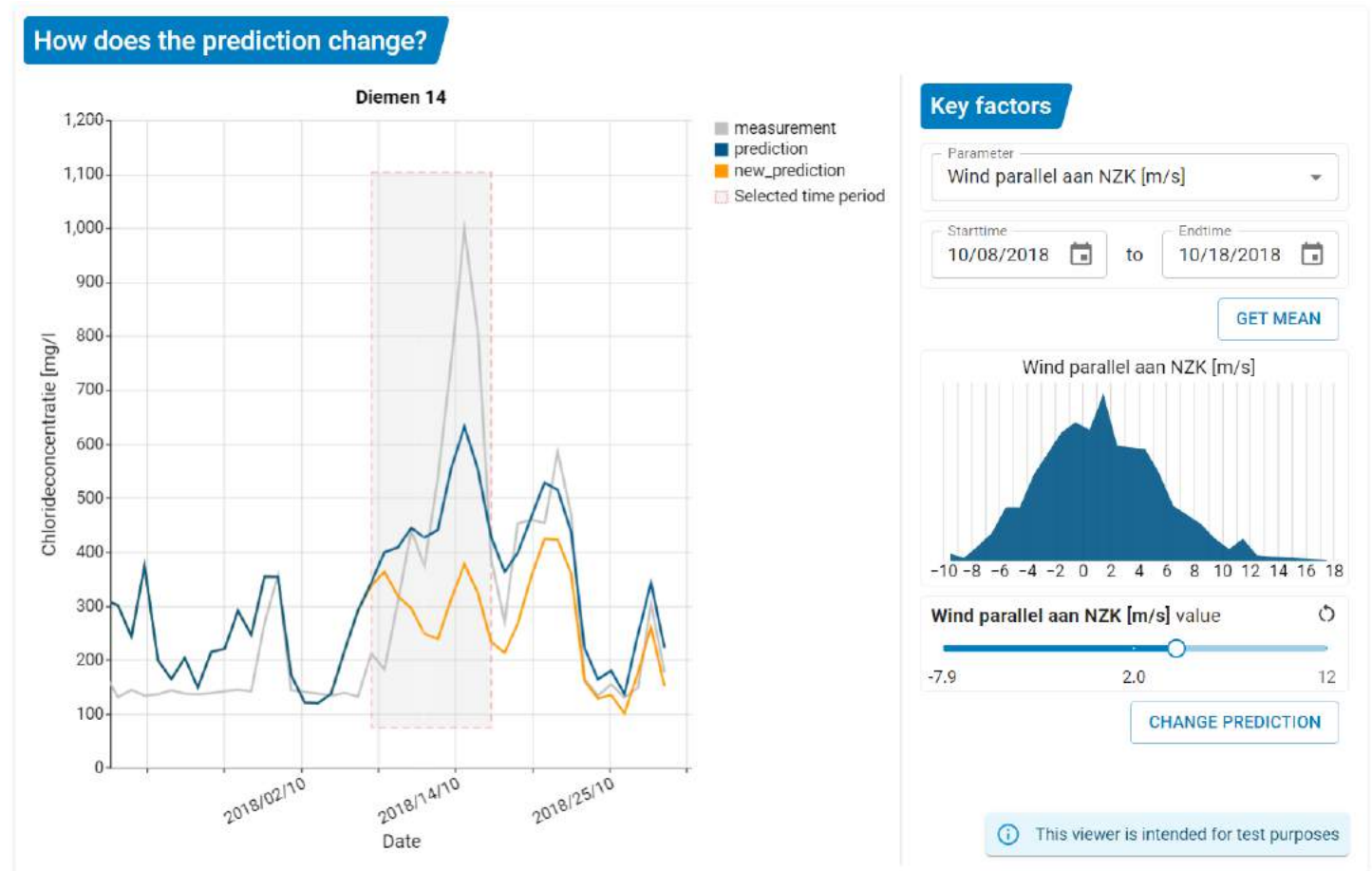
- Wind is important, followed by the discharge.



## Get to know XAI

### 2. Can you change the conditions so that the salt peak in October does not exceed 500 mg/l?

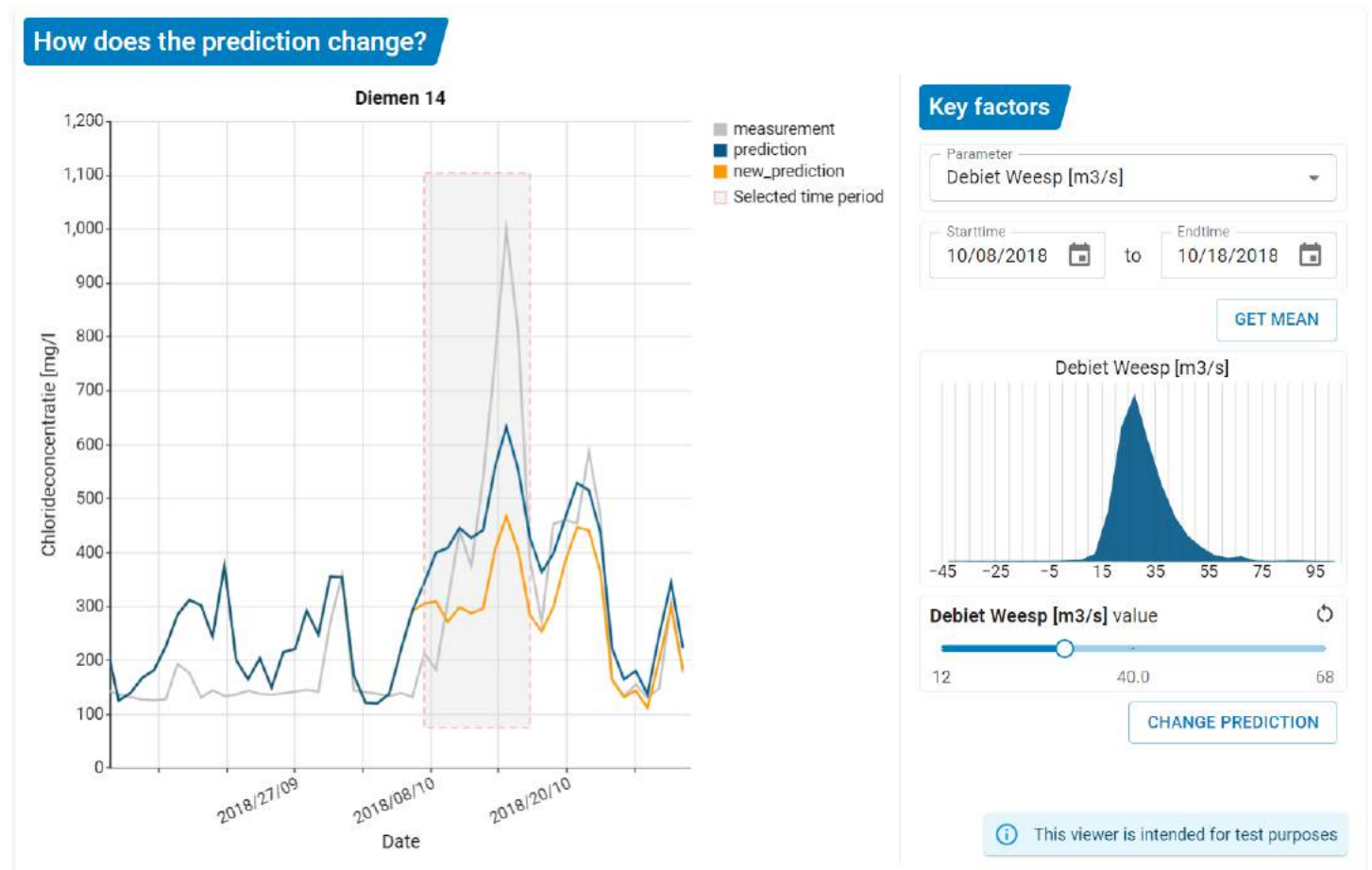
- Changing wind direction lowers the salt peak.



## Get to know XAI

### 2. Can you change the conditions so that the salt peak in October does not exceed 500 mg/l?

- But you can also achieve this by increasing the discharge!



# Explainable AI Demo

- [XAI ARK \(hkvservices.nl\)](https://hkvservices.nl)

## Discussion

### First impressions & future developments

- First reactions?
- Do you work with Explainable AI? On what types of projects?



Source: <https://www.kpsol.com/benefits-using-discussion-forums-knowledge-management-environment/>

## Closure

### What's next?

- Try to find someone who would like to work together to develop these ideas further
- Ultimate goal: Operational along-side a predictive model



Source: <https://medium.com/light-speed-venture-partners/you-raised-seed-money-now-what-49b1ea686ea4>



**Thank you!**

Paula Lambregts (p.lambregts@hkv.nl)

Thomas Stolp (t.stolp@hkv.nl)

