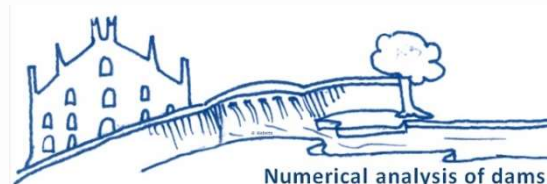


# Interpretation of dam monitoring data combining visualisation tools and machine learning

F. Salazar, A. Conde (CIMNE)  
R. Kohler, F. Landstorfer (Verbund)

**CIMNE<sup>R</sup>**



**ICOLD-BW**  
9<sup>th</sup>-11<sup>th</sup> September 2019  
**MILANO**

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# 1. INTRODUCTION

## Trends in dam monitoring

- Automatisisation
- Increased reading frequency
- Databases of increasing size

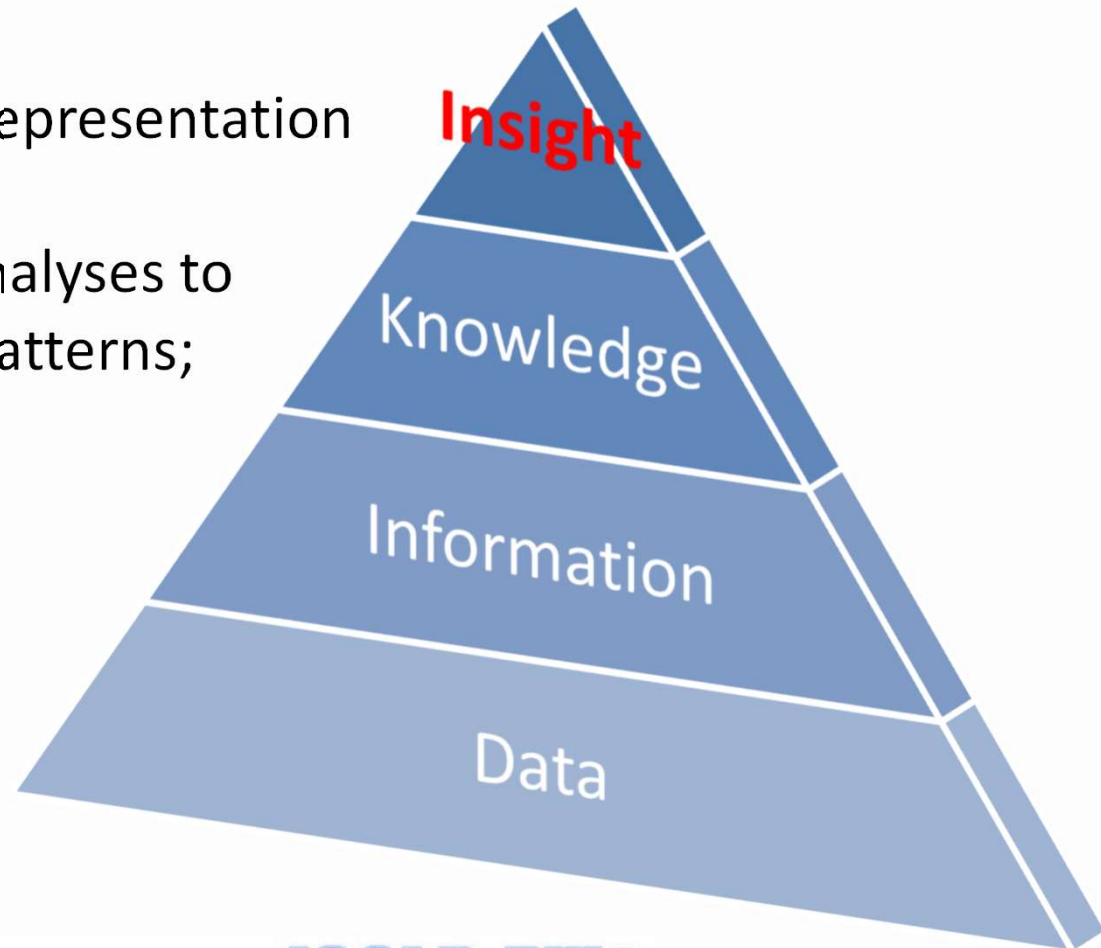
## Challenges to software tools:

- Data fusion-homogeneisation-cleaning-fixing
- Visualisation
- Analysis

# 1. INTRODUCTION

## Priorities of ICOLD Committee on Dam Surveillance:

- Data processing and representation techniques;
- Effective diagnostic analyses to determine behavior patterns;



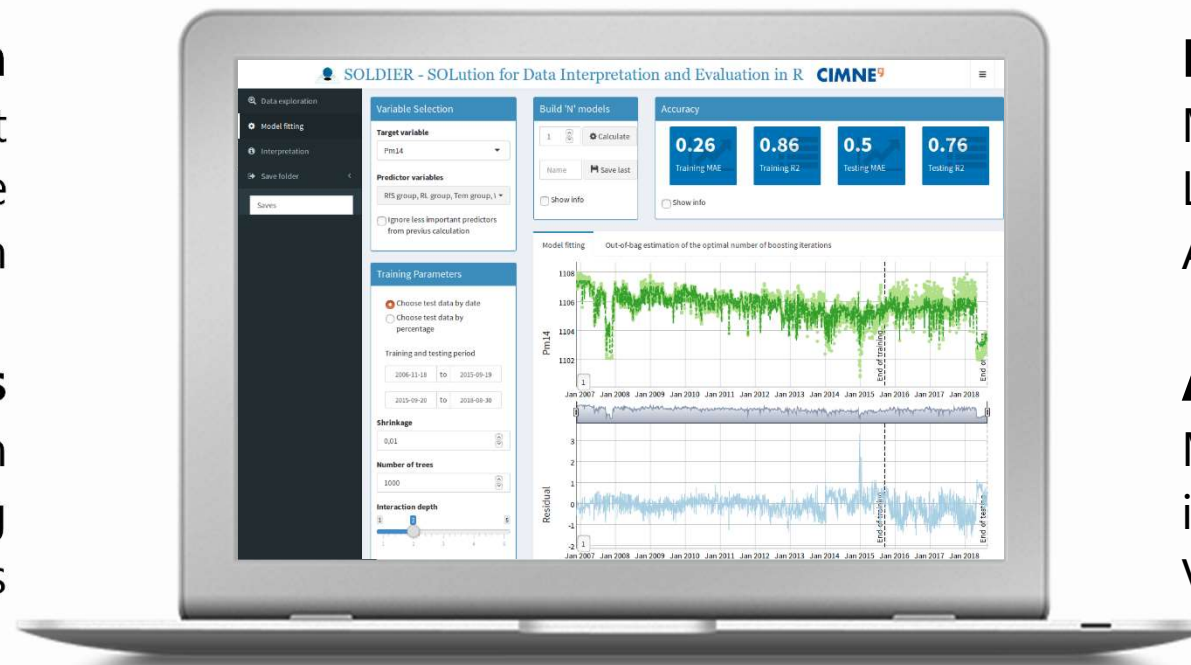
# 1. INTRODUCTION

## Exploration

Import  
Interactive  
visualization

## Pre-process

Fusion  
Cleaning  
Fixing errors



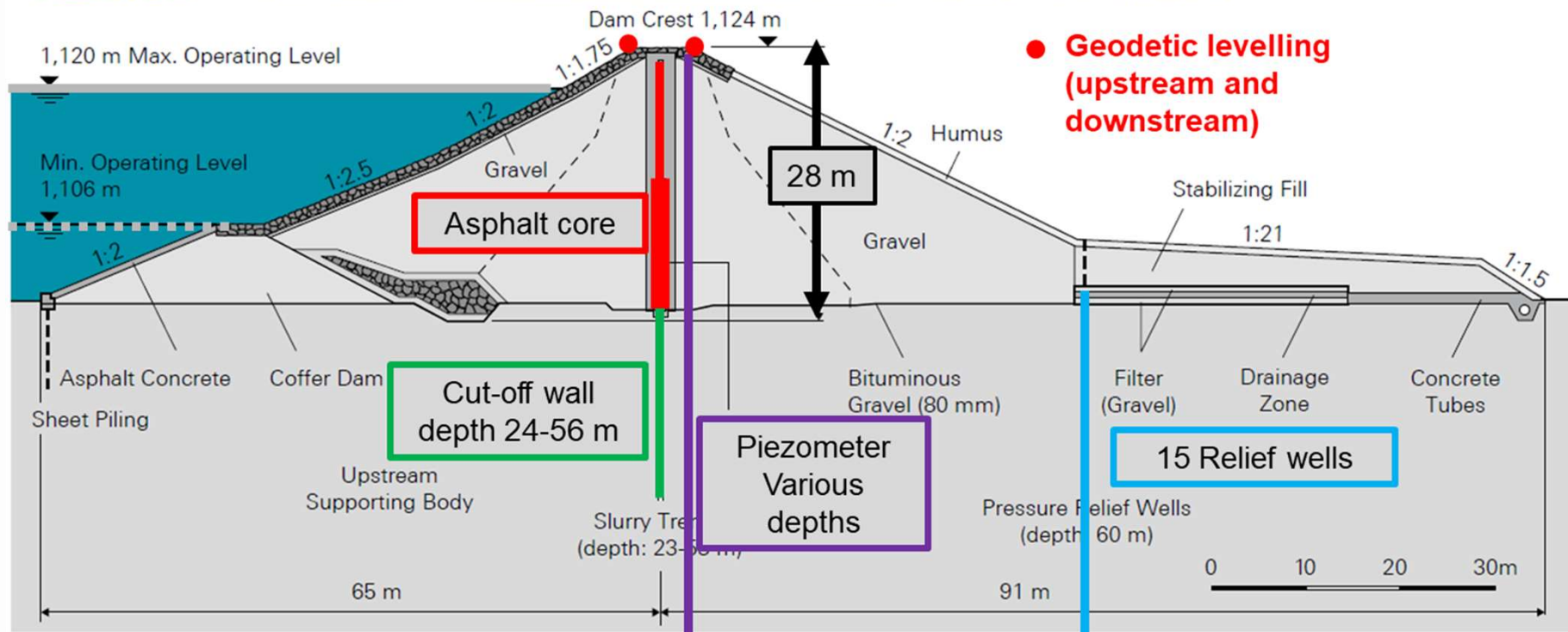
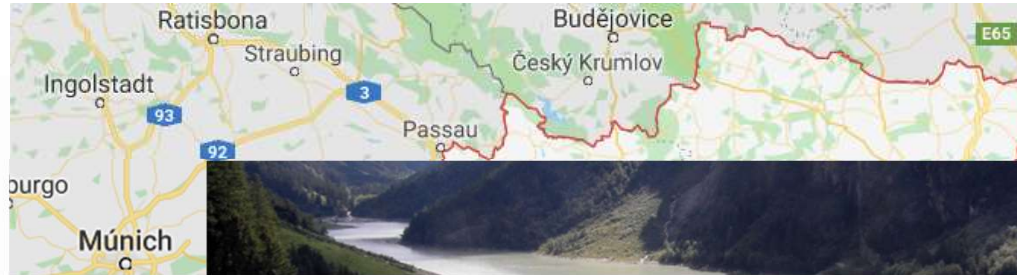
## Model fitting

Machine  
Learning  
Algorithms

## Analysis

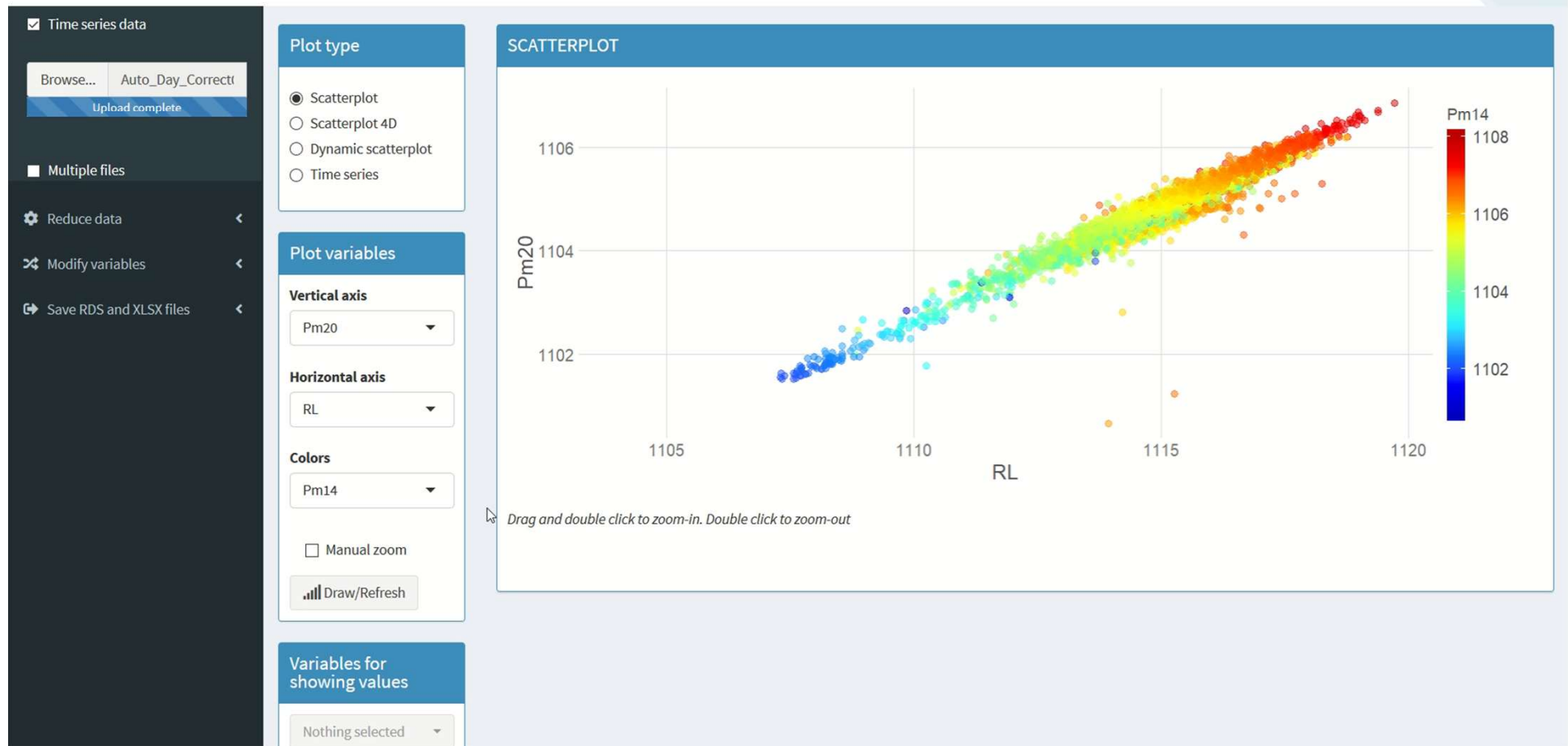
Model  
interpretation  
Visualization

## 2. Case Study: Eberlaste Dam

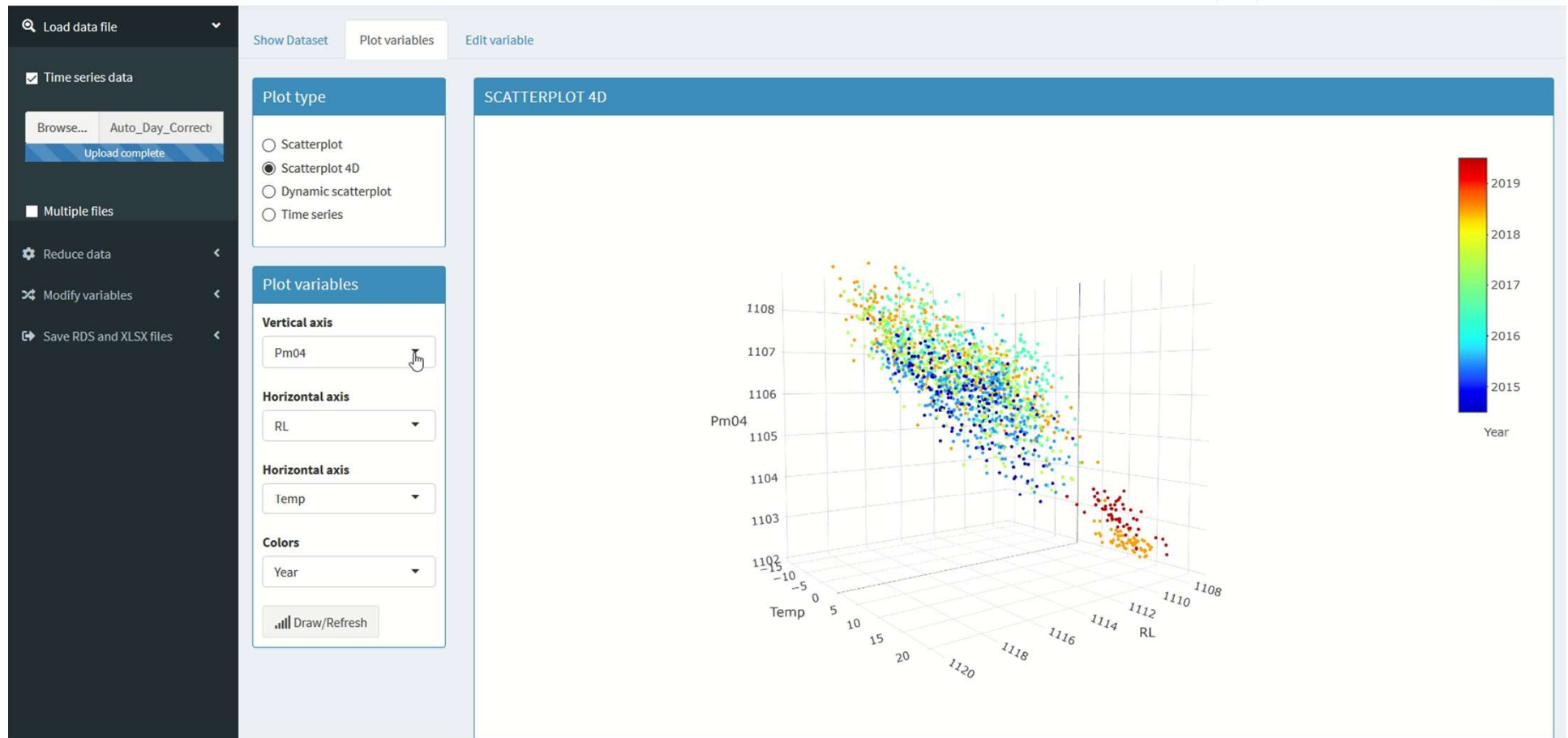




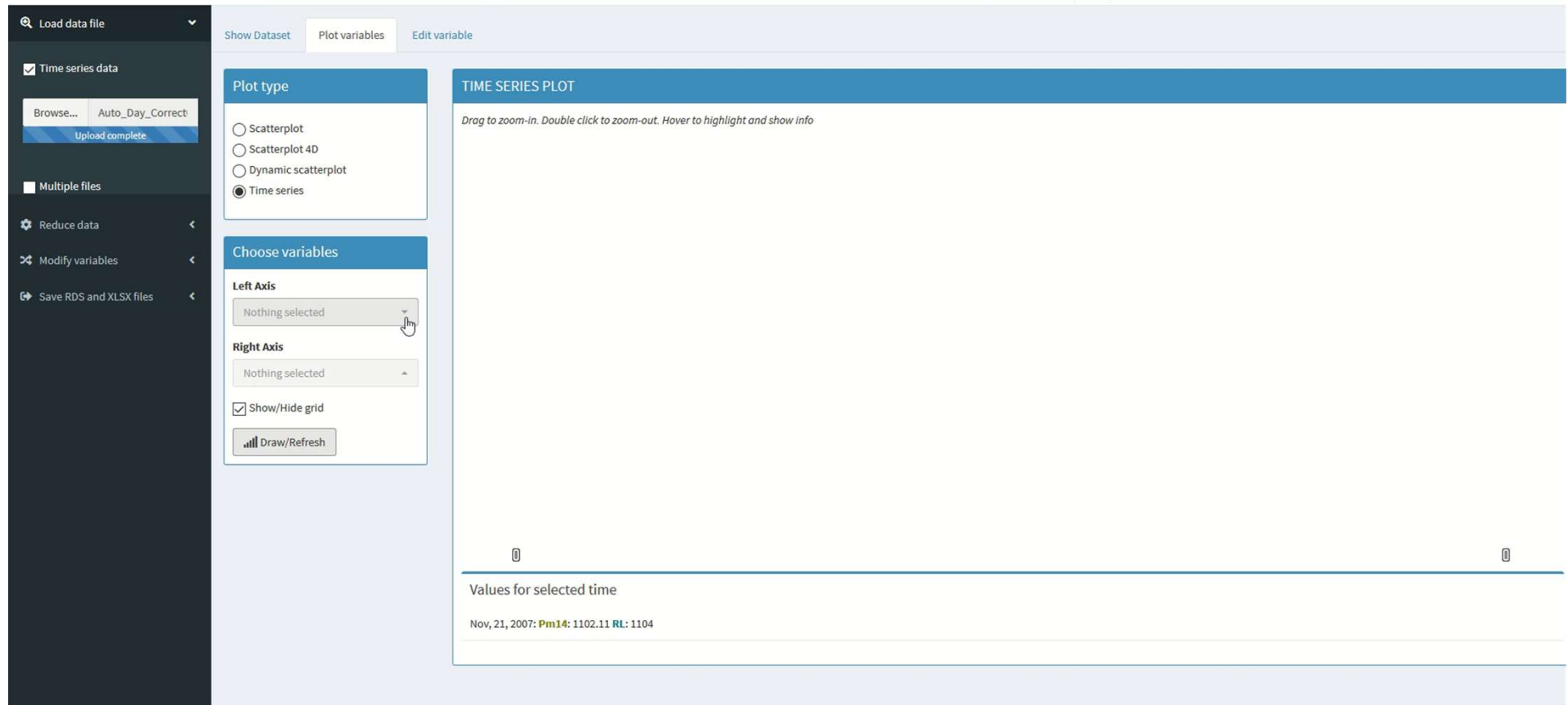
# 3. Exploration. Scatterplot



# 3. Exploration. 4D-scatterplot

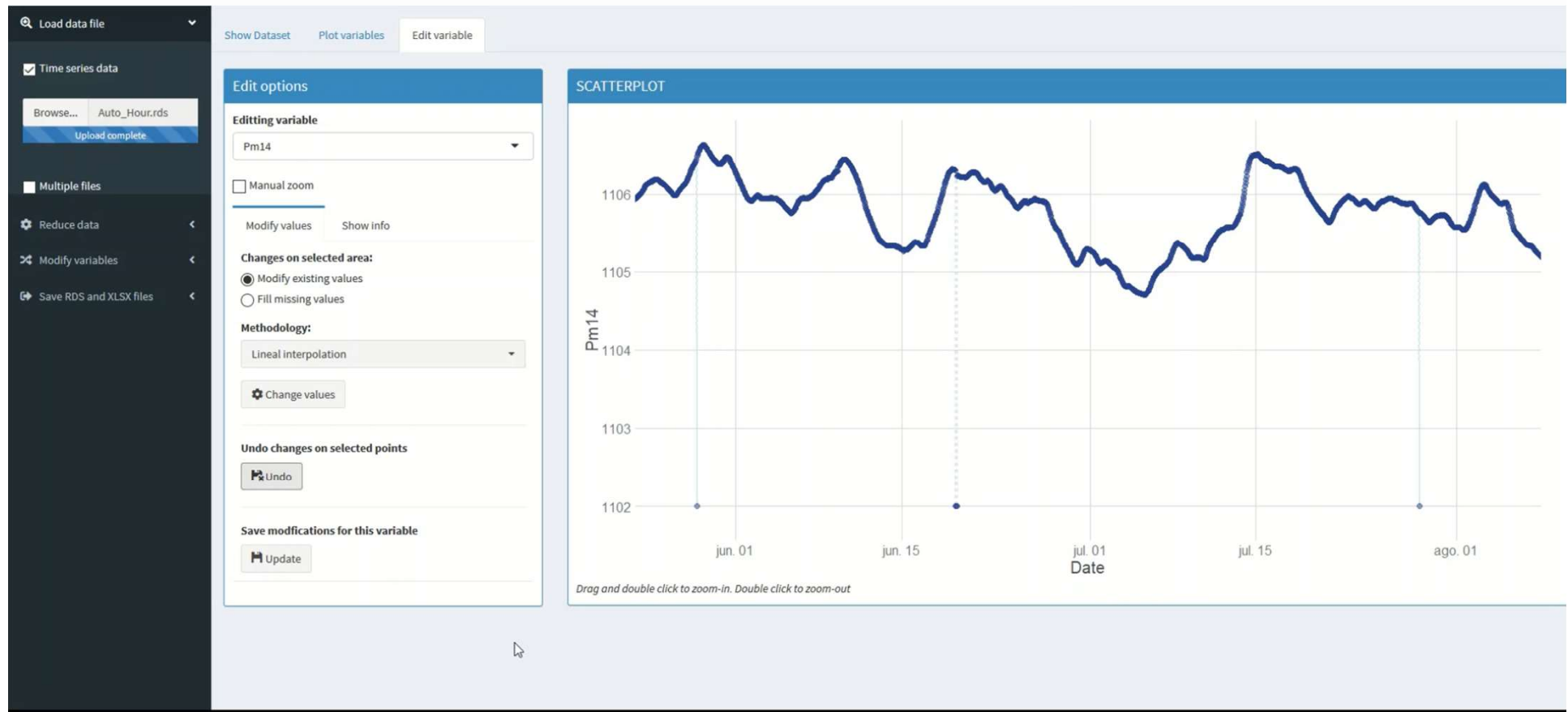


# 3. Exploration. Time series





# 4. Fixing errors



# 5. Model fitting

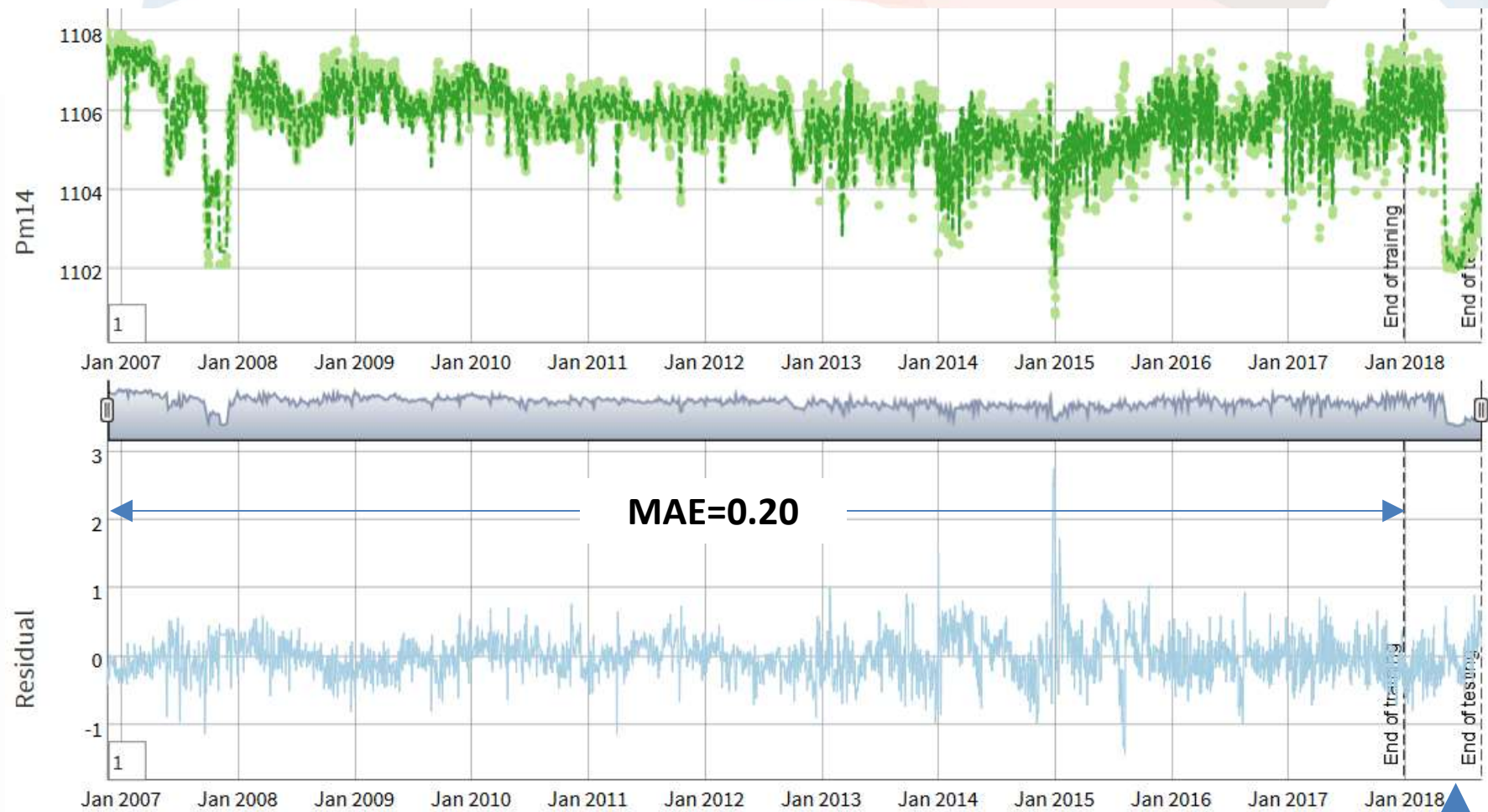


# 5. Model fitting. The algorithm

## Boosted Regression Trees (BRTs)

- More accurate on average
  - Robust
  - Easier and less explored than NNs
  - Any type of input (numerical, categorical)
  - No need for data normalization
  - Automatic input selection
- 
- Salazar, F., Toledo, M. A., Oñate, E., & Morán, R. (2015). **An empirical comparison of machine learning techniques for dam behaviour modelling.** *Structural Safety*, 56, 9-17.
  - Salazar, F., Toledo, M. Á., Oñate, E., & Suárez, B. (2016). **Interpretation of dam deformation and leakage with boosted regression trees.** *Engineering Structures*, 119, 230-251.
  - Salazar, F., Toledo, M. Á., González, J. M., and Oñate, E. (2017) **Early detection of anomalies in dam performance: A methodology based on boosted regression trees.** *Struct. Control Health Monit.*, doi: 10.1002/stc.2012.

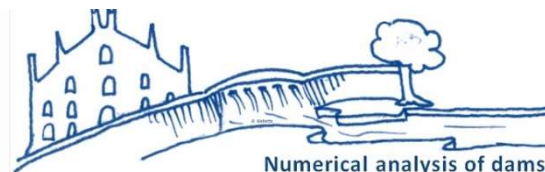
# 5. Model fitting



MAE=Mean Absolute Error

MAE=0.23

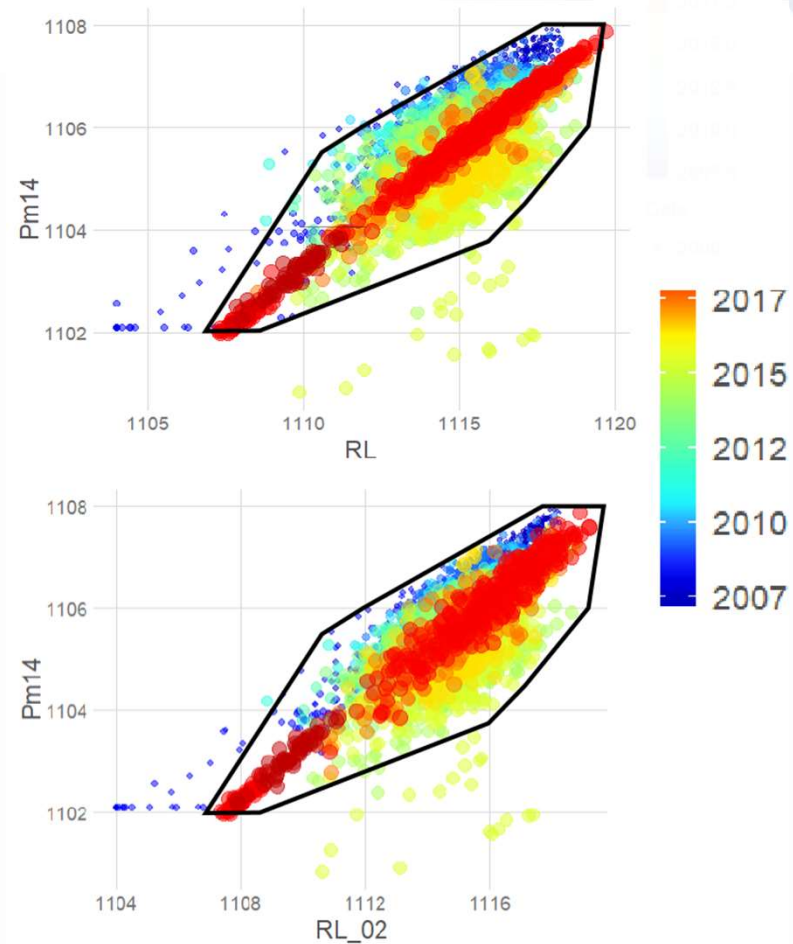
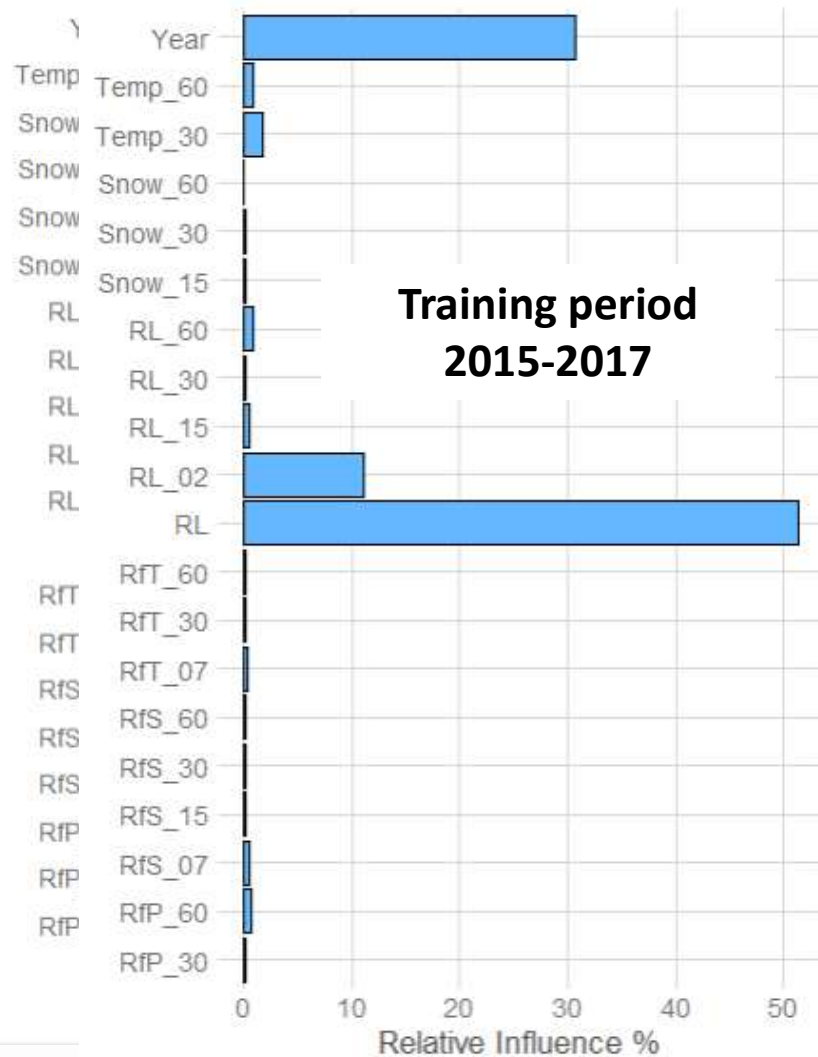
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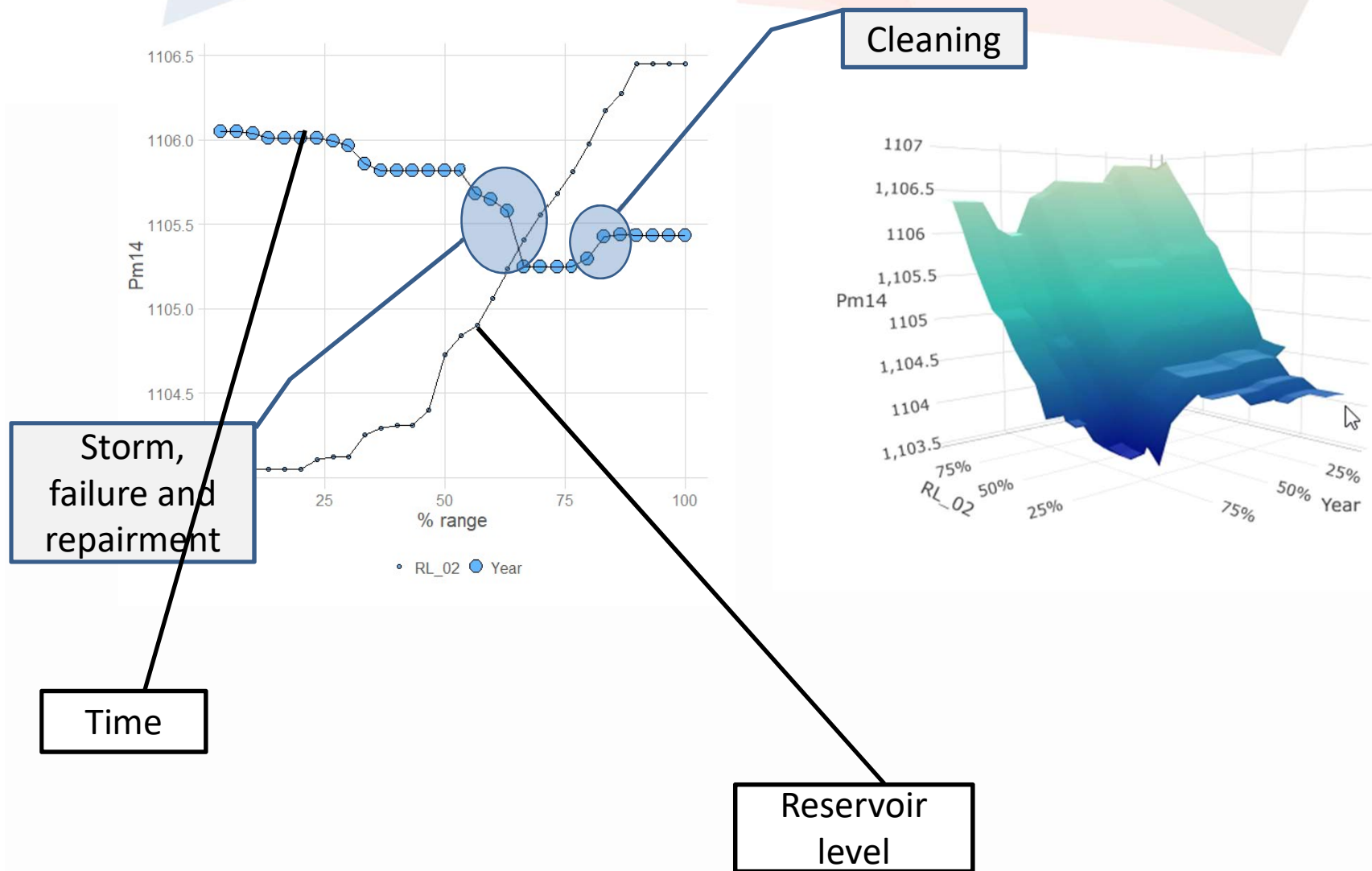


## 6. Model interpretation & validation





# 6. Model interpretation

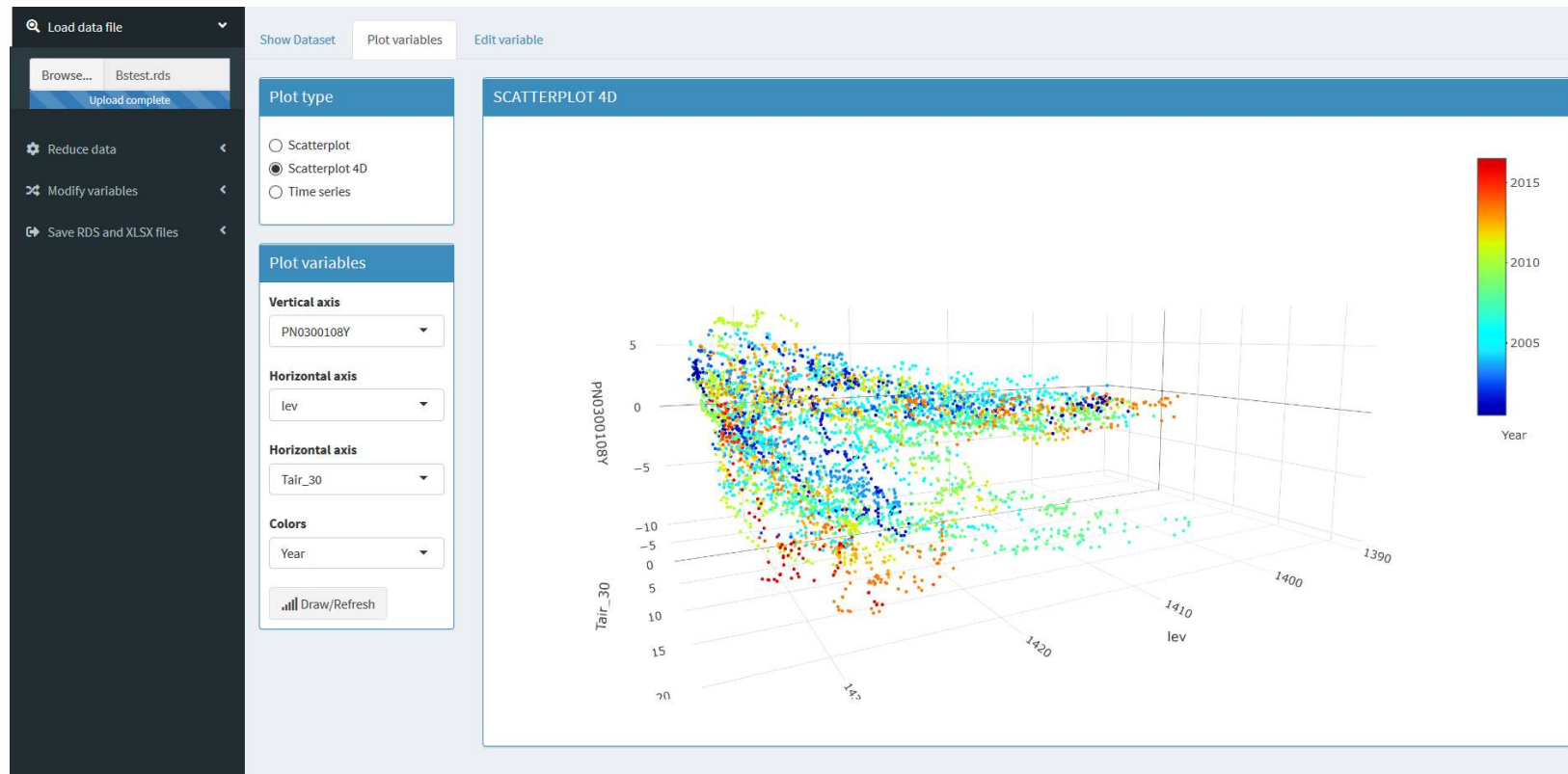


# 7. Conclusions

- Flexible and robust tool
- Useful for any dam typology and response variable
- Can detect small deviations
- Non-linearities and sharp changes can be automatically detected
- Applications
  - Back analysis – Identification of behaviour changes
  - Real time – Detection of deviations from past behaviour

# 7. Conclusions

## Free online versions

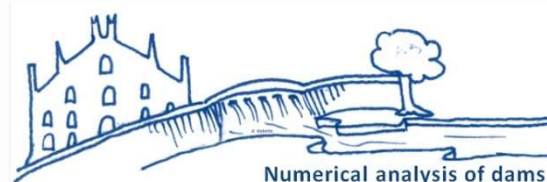




# Thank you

F. Salazar, A. Conde (CIMNE)  
R. Kohler, F. Landstorfer (Verbund)

**CIMNE**<sup>R</sup>



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