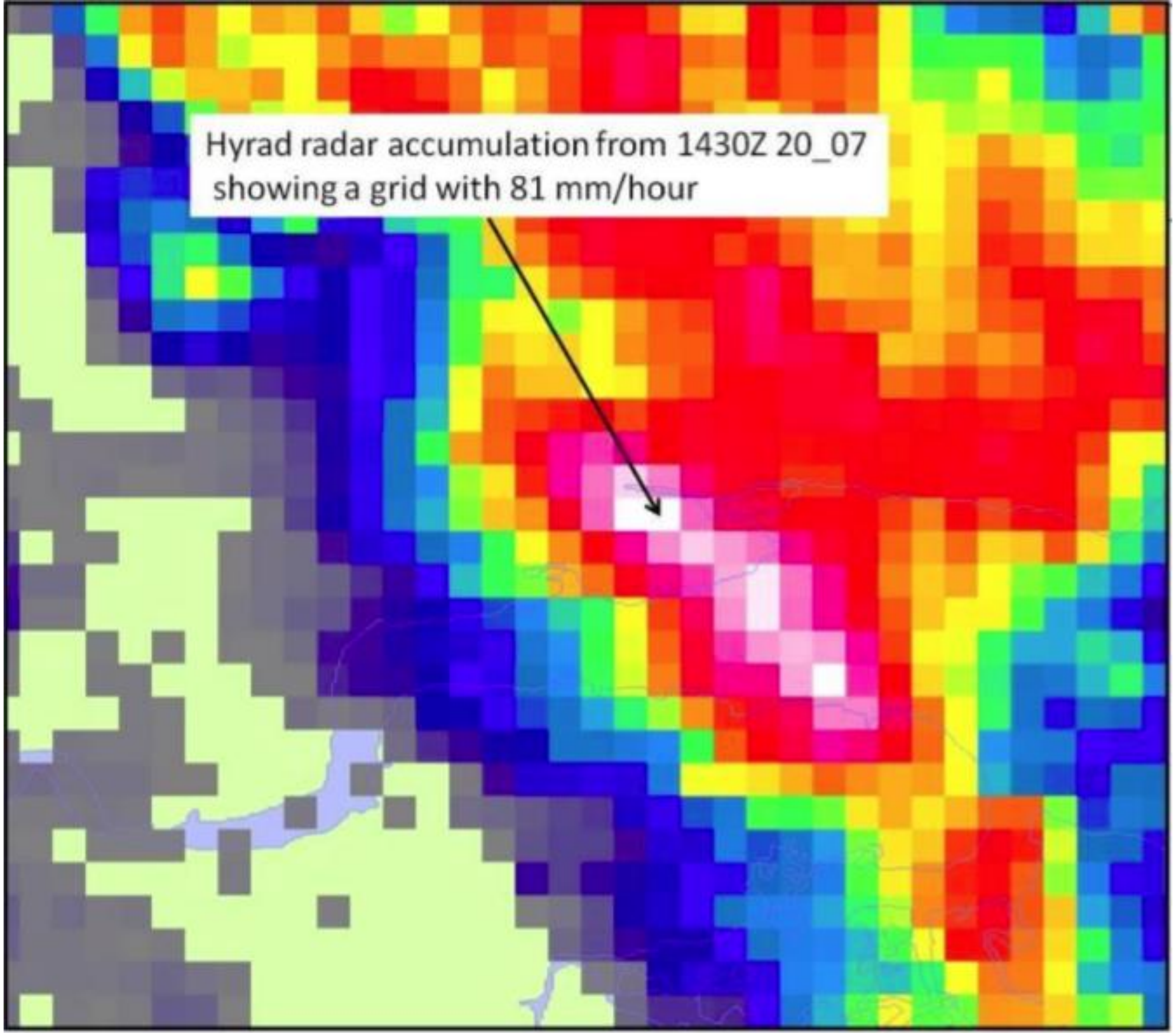
Sampling spatially variant rare rainfall events

Alastair Gregory, Ana Osojnik

Jacques Vanneste, Michal Branicki, Onno Bokhove, Oliver Sheridan-Methven,
Albert Chen, Sandhya Patidar, Pelin Sertyesilisik, Carlo Cafaro

Overview

- Background and motivation
- A toy model: Wetropolis
- A relationship between flood damage and rainfall impact
- Problem formulation and results

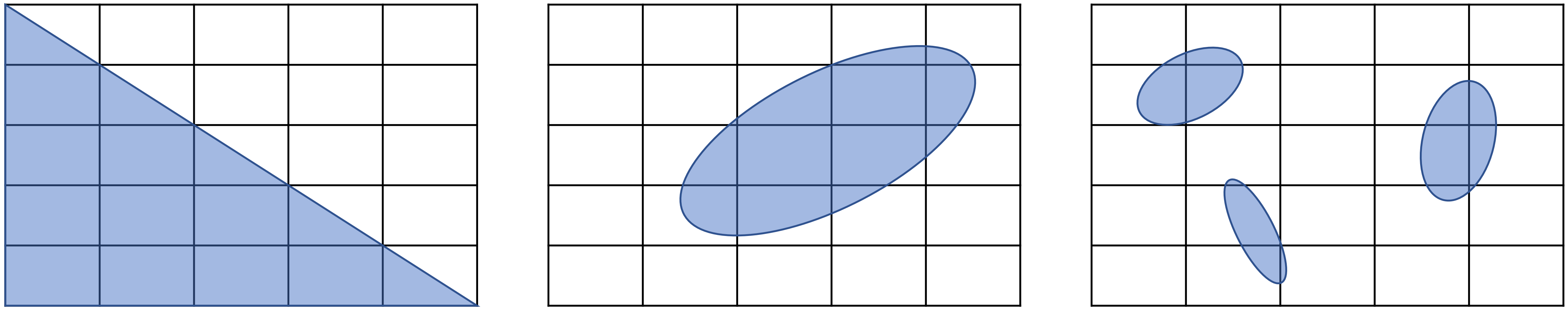

Hyrad radar accumulation from 1430Z 20_07
showing a grid with 81 mm/hour

Assumptions

- There exist data and storm events which have been recorded previously.
- We have a measure of the cost/damage caused by a flooding event.
- From historical data we know the statistical and spatial properties of everyday rainfall.

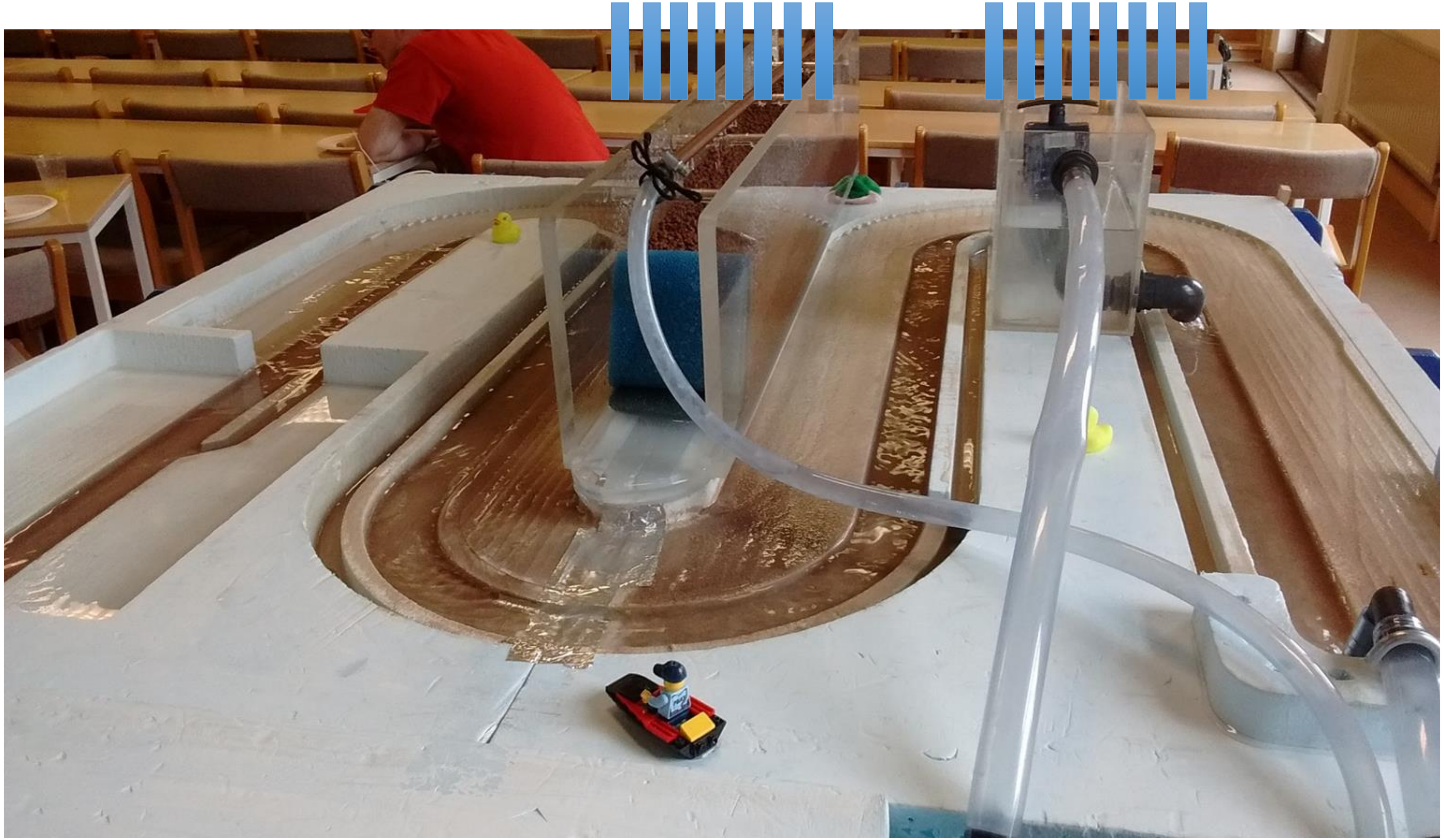
Spatially dependent rainfall model

Potential Ideas: Pattern recognition

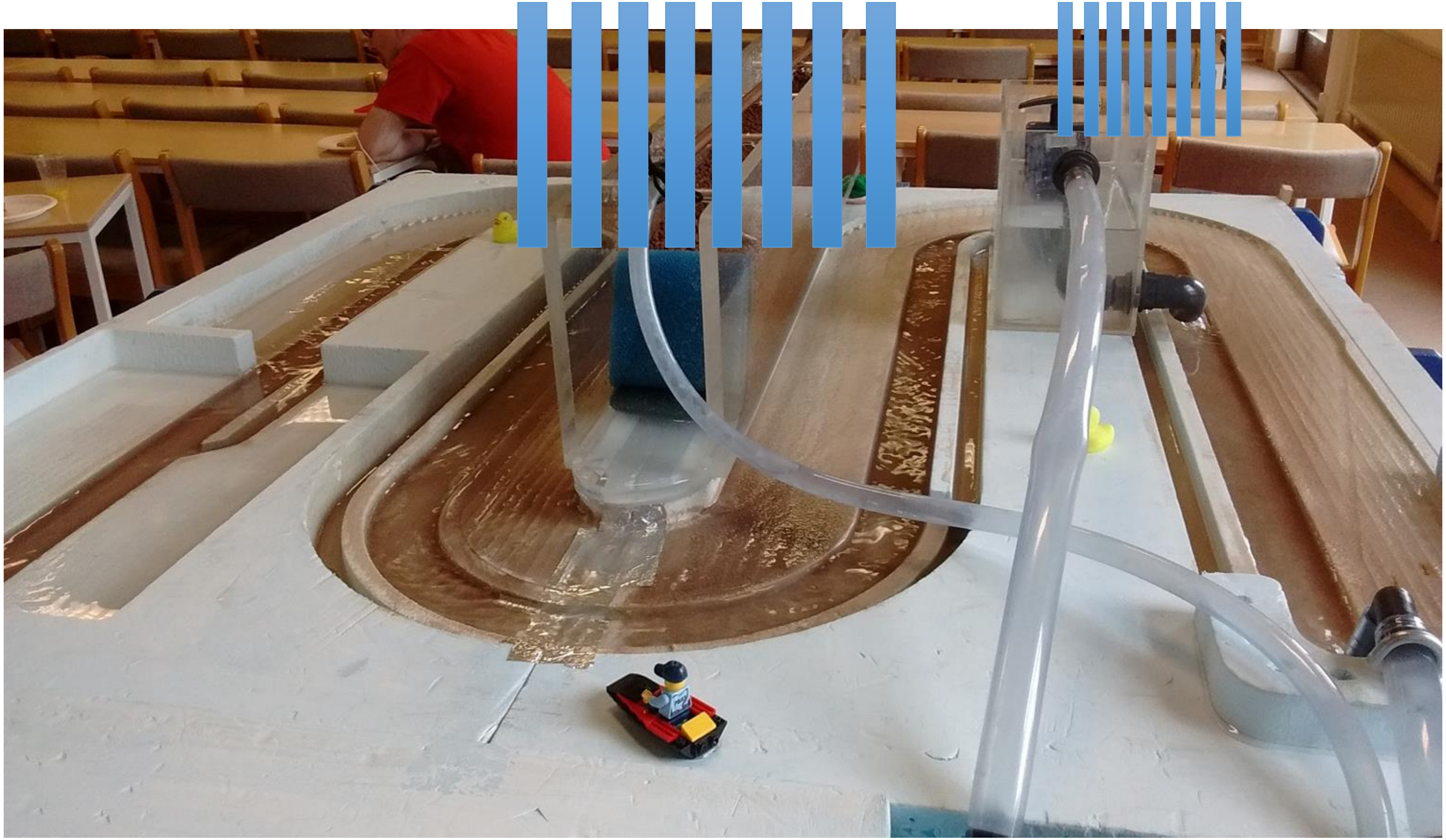


The black-box model

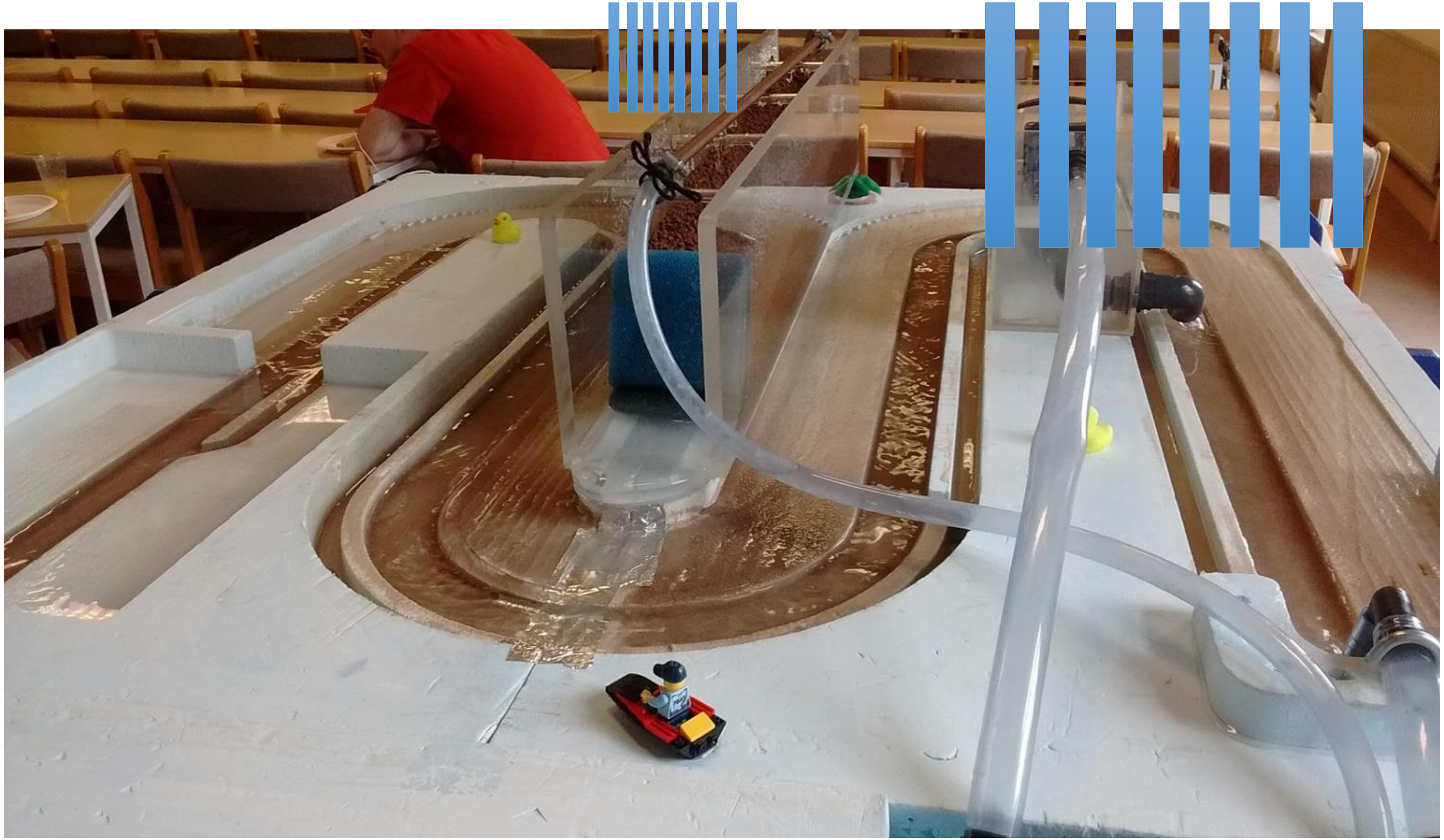
The Wetropolis model



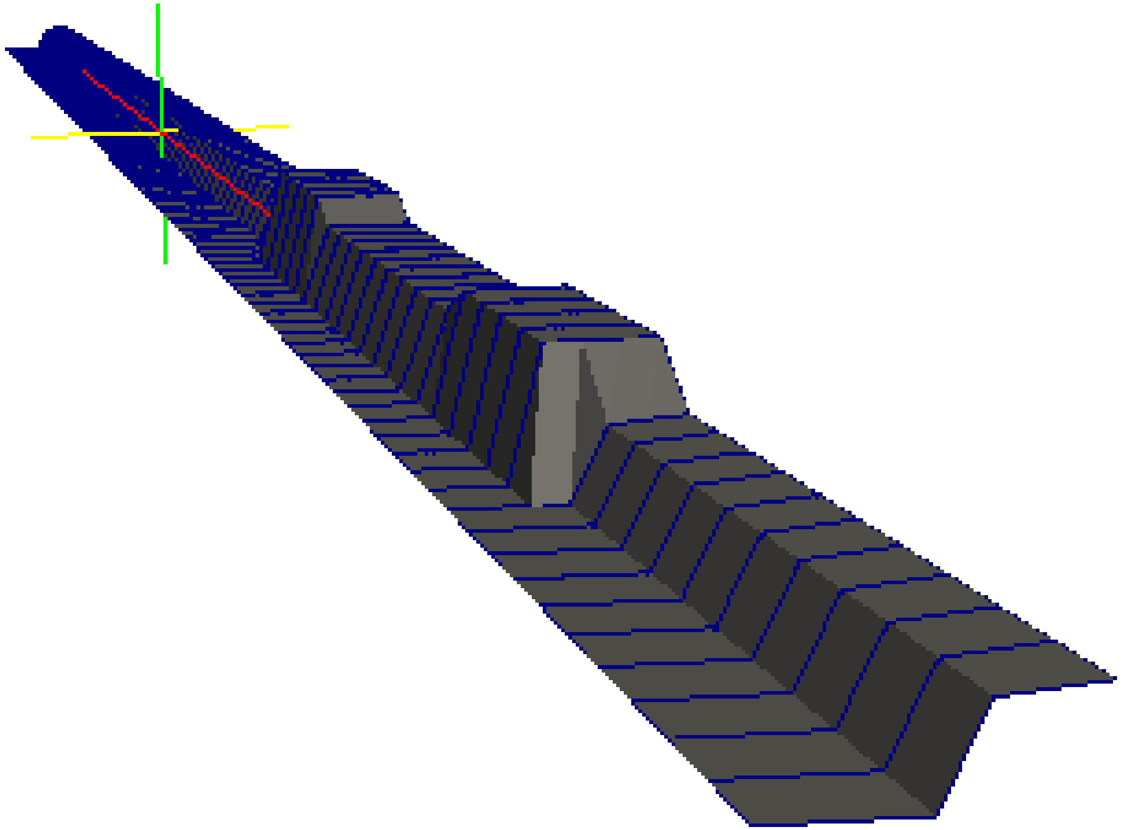
The Wetropolis model

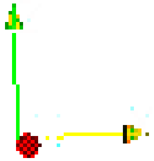


The Wetropolis model

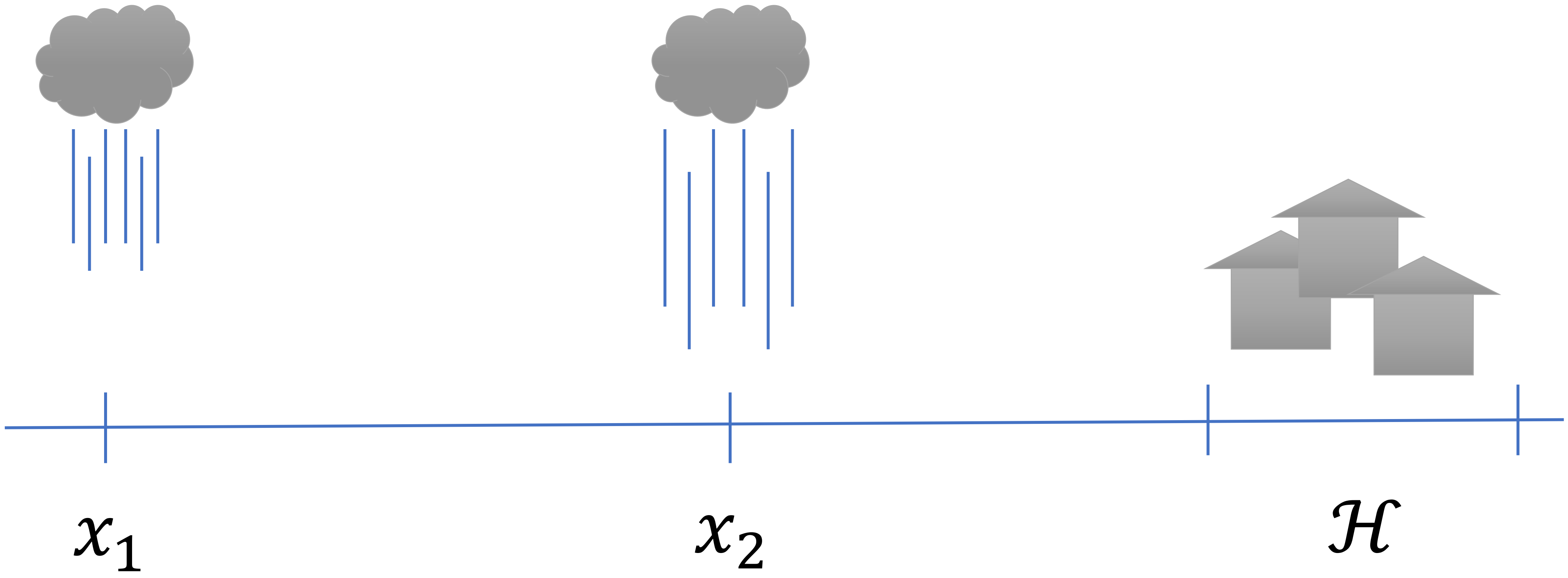


2D rendering





The 1D Wetropolis model



The impact metric

- Rainfall intensity $r(x,t)$.
- For now we assume that there is some damage metric , D, which we can compute.
- We introduce the impact metric

$$\mathcal{I}[f] = \iint f(x,t)\, r(x,t)\, dt\, dx\ .$$

Rainfall simulation

- We simulate rain via a Markovian transition matrix, which is spatially correlated between the two locations of rainfall.
- This is an example of the transition matrix for one rainfall location:

	R	D
R	**0.445**	**1-0.445**
D	**0.226**	**1-0.226**

Hydraulic model

- The height and velocity of the flow are computed from a 1D finite volume model of river flow.

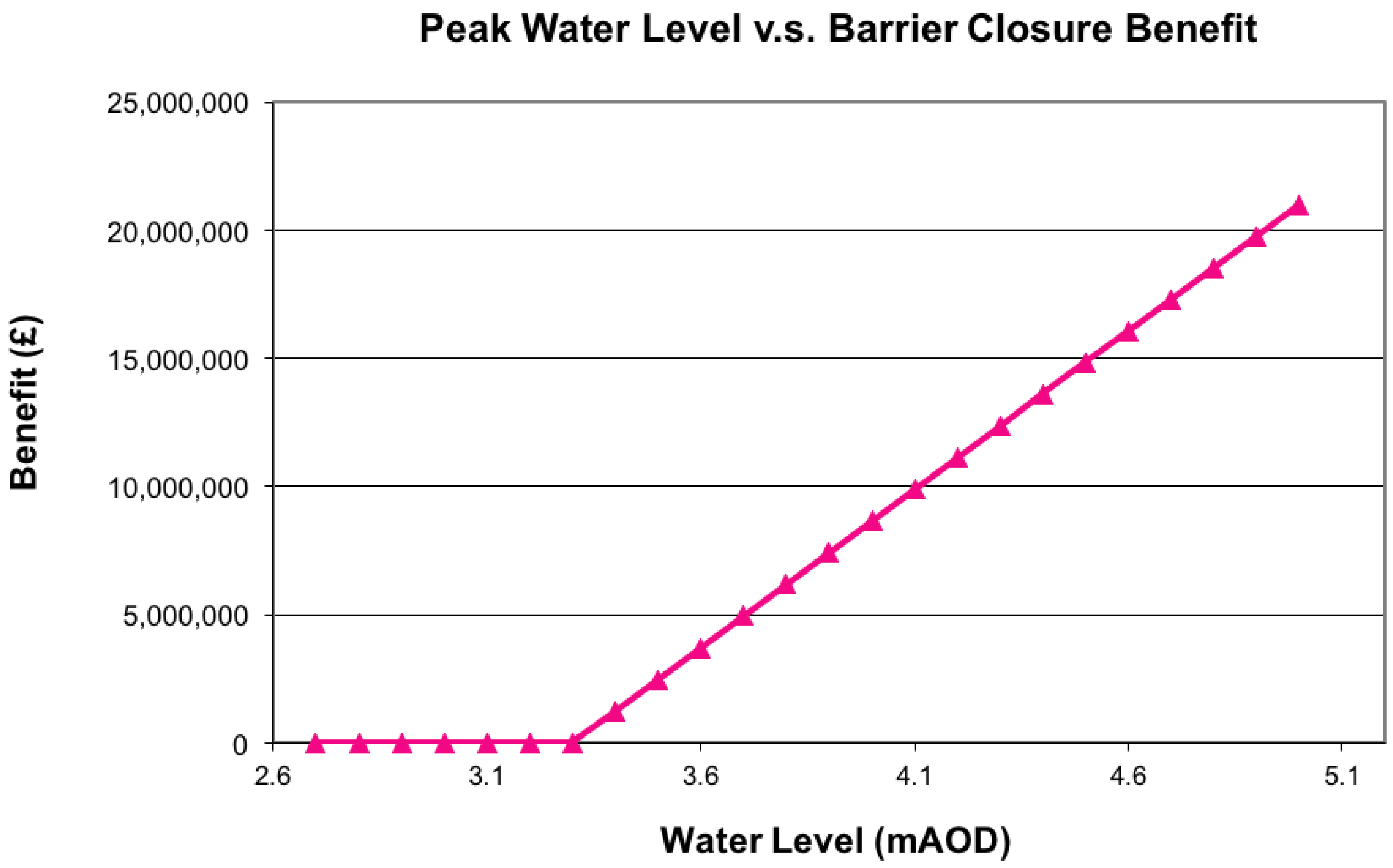
Kinematic model or nonlinear conservation law in h for $u > 0$ with $A = w_r h$:

$$\partial_t(w_r h) + \partial_x\left(w_r h R(h)^{2/3}\sqrt{-\partial_x b}/C_m\right) = 0$$

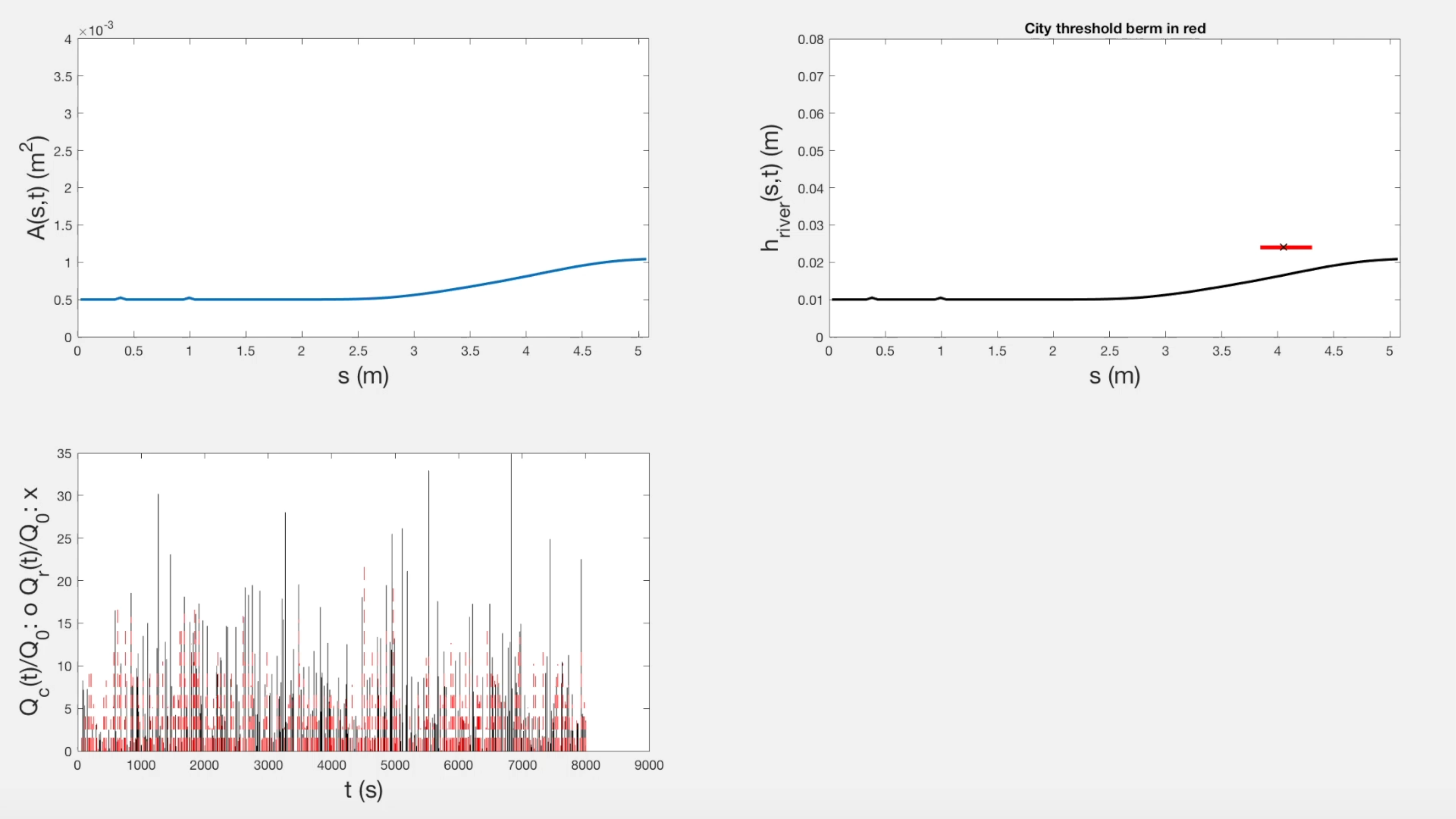
- Damage metric D is computed via an integral approximation of

$$D = \iint (h(x,t) - h_c)^+ u(x,t)\, dt\, dx$$

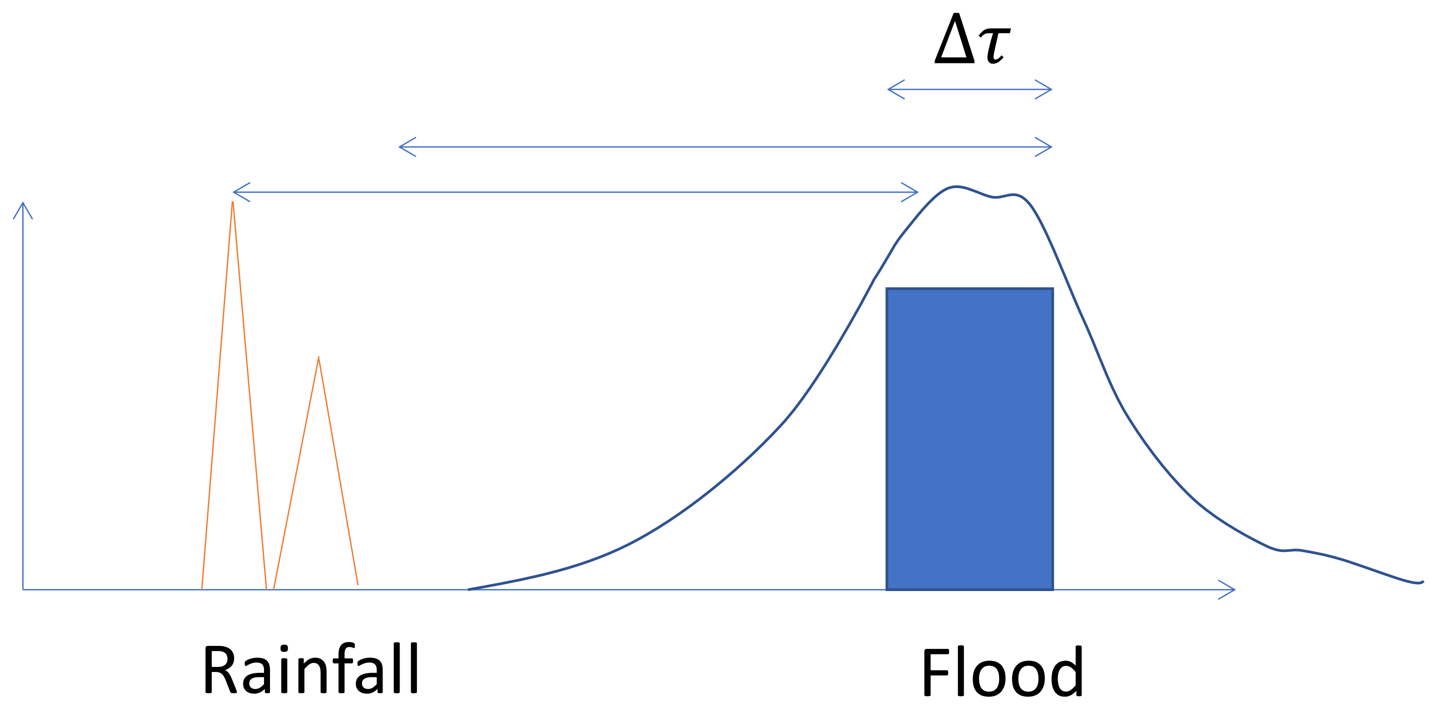
Costal surge flooding damage metrics



Hydraulic model



Matching rainfall to flood events



Problem formulation

- This leads to the minimisation problem $\min_f ||D \; - \mathcal{J}[f]||^2$.
- In an ideal world we would find the optimal solution to the above problem. However in practice we discretize f.

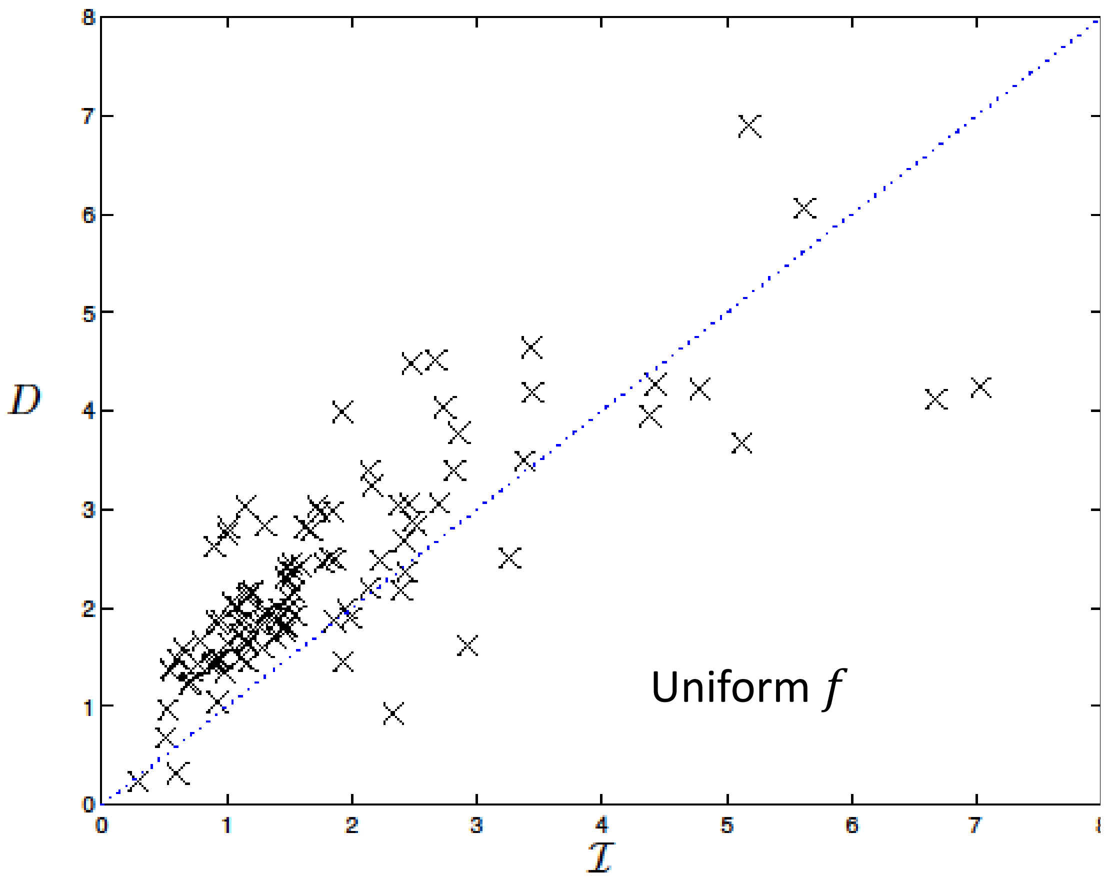
The weighting function

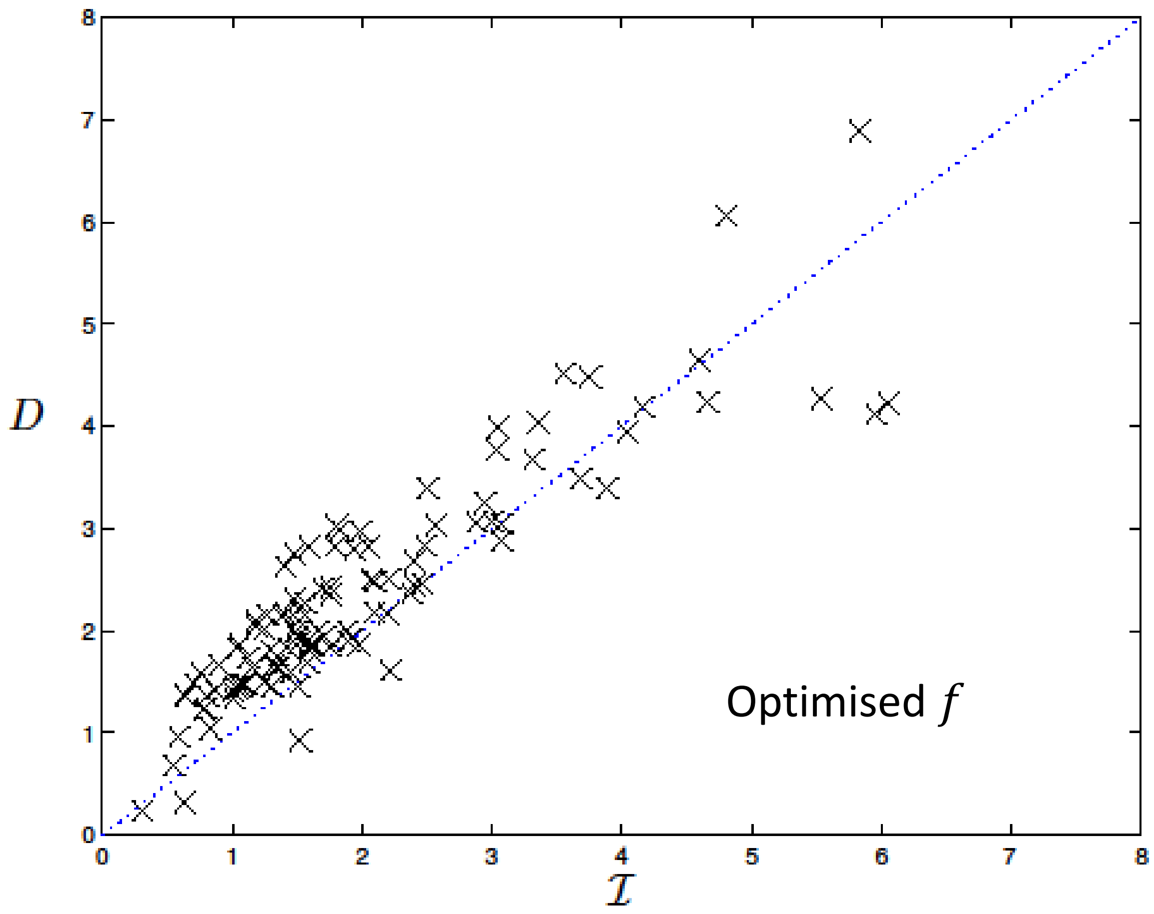
- For a storm event at location x_1 we are only interested in the temporal dependence of f.
- We approximate the temporal dependence by a piecewise constant function $f(t') = \sum \lambda_i \Theta_i$ with fixed bin widths.
- Thus this leads to a regular least squares regression problem.

Training and testing

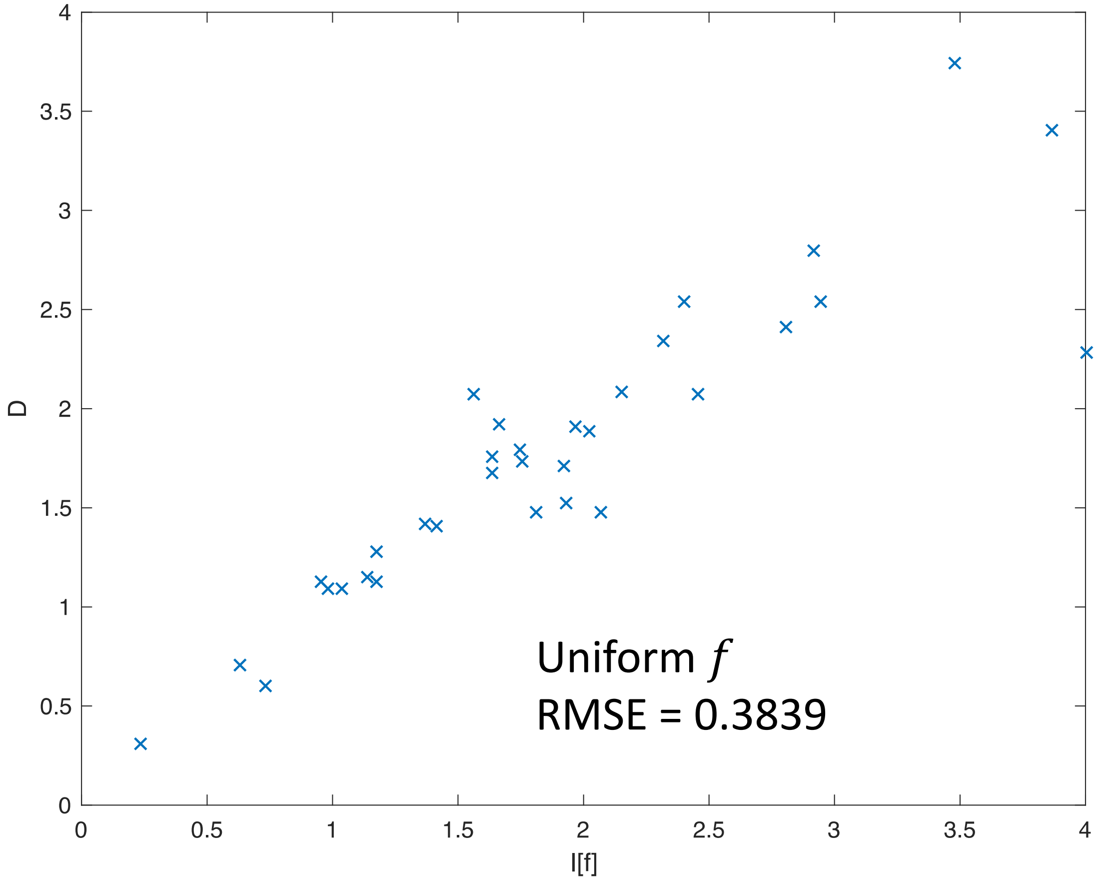
- We run the discretized model over 5000 days, **training** f, with two uncorrelated locations.
- We then **test** the trained f over 500 days.
- We compare the results with respect to the case of a uniform f.

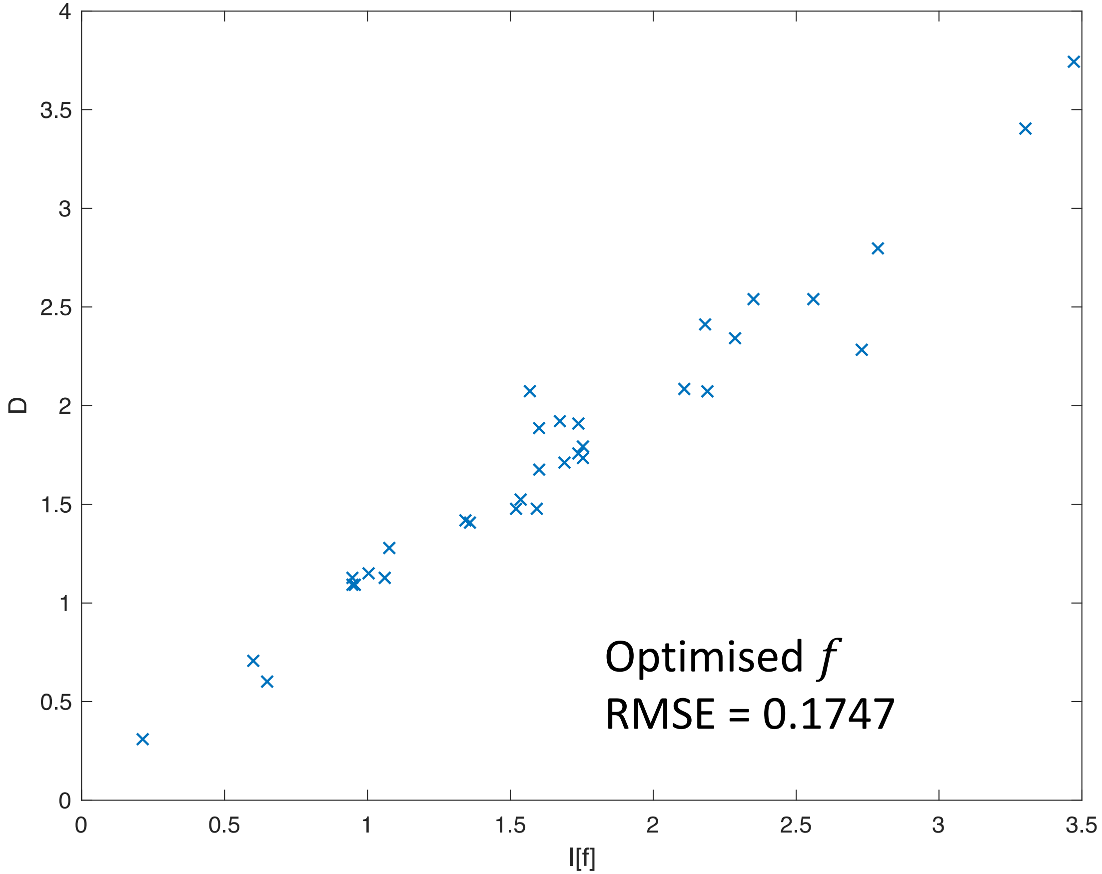
Results - uncorrelated





Results – correlated, Rglimclim





Summary

- We have devised a Markovian model for simulation of uncorrelated and correlated rainfall at two different locations.
- We have analysed output results from the Wetropolis hydraulic model with the rainfall simulation as input.
- We have quantified flood damage, and trained a model to predict flood damage from spatio-temporal rainfall intensity.

Limitations and future directions

- Small spatial and temporal resolution gives us limited insight into storm events, which are usually short.

- A general method of identifying damaging storm events in rainfall, which is independent of the hydraulic model, is needed.

- Our toy model provides a proof of concept, but further work is required.

- **Key point**: Exploiting spatial and temporal structure of rainfall requires training the model from a large set of simulations, which might be overcome with expert opinion.