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Quantifying the effects of boundary condition uncertainty in nested flood modelling of complex hydraulic systems

María Bermúdez[1], Jeffrey C. Neal[2], Paul D. Bates[2], Gemma Coxon[2], Jim E. Freer[2], Luis Cea[1] and Jerónimo Puertas[1]

[1] School of Civil Engineering, University of A Coruña, Spain

[2] School of Geographical Sciences, University of Bristol, UK

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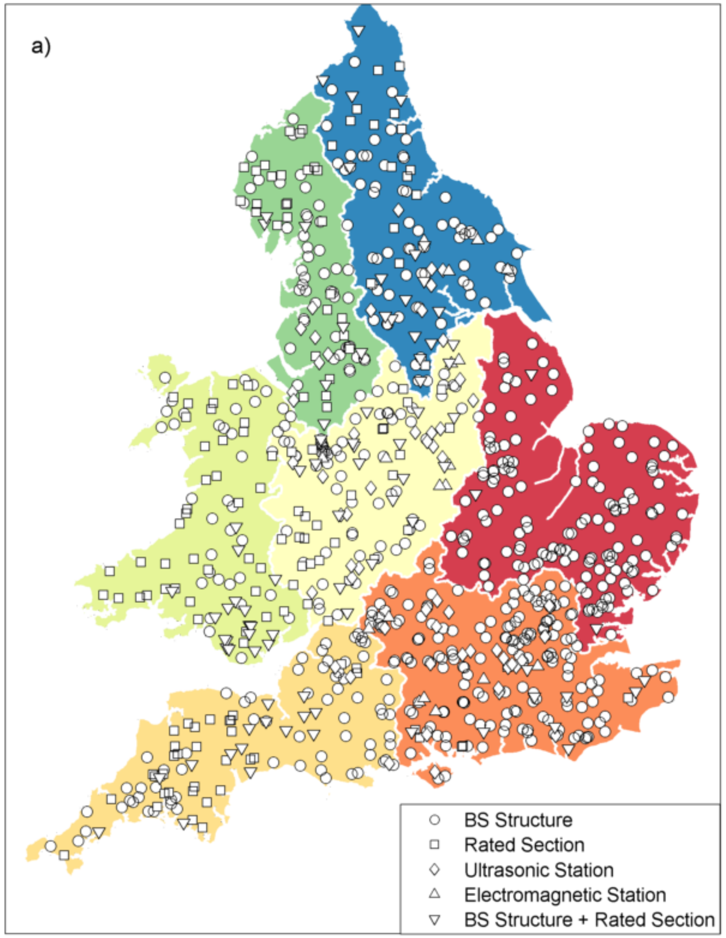
Introduction

FLOOD INUNDATION MODELS

Flow data to provide model inflow and outflow BC

- Upstream boundary: input flow rate
- Dowstream boundary: water stage

- Data from nationally maintained gauging stations
- Measured water levels converted to discharge by means of rating curves



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Introduction

- Rating curves generally treated as deterministic relationships
- Limited number of gauges → Flow needs to be routed to the boundary of the model domain → Complex modelling approaches → Hydraulic model cascade

- Method to incorporate the rating curve uncertainty into the predictions of a reach-scale flood inundation model
- Study the propagation of the uncertainty through numerical hydraulic models and its effects on model performance

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Methodology

Stage-discharge measurement data

↓

LOWESS fitting
Error model

→

At gauging locations:
Discharge uncertainty bounds
Ensemble of Q time series

↓

Regional hydraulic model
(simplified physics)

→

At boundaries of local model:
Ensemble of Q and wse time series

↓

Local hydraulic model
(full 2D, high res)

→

In the area of interest:
Depth and velocity fields

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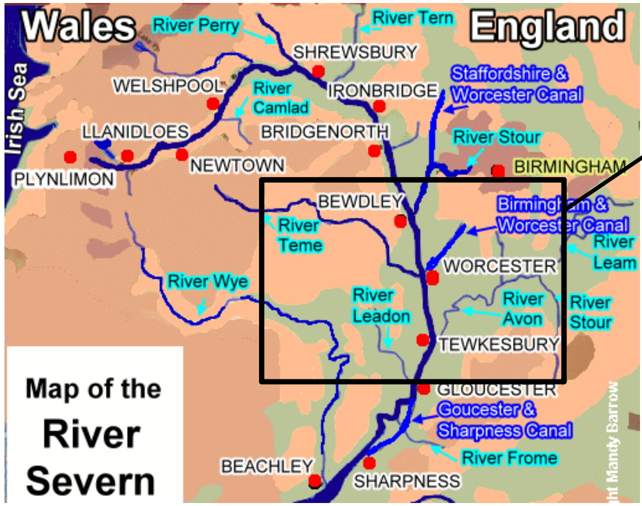
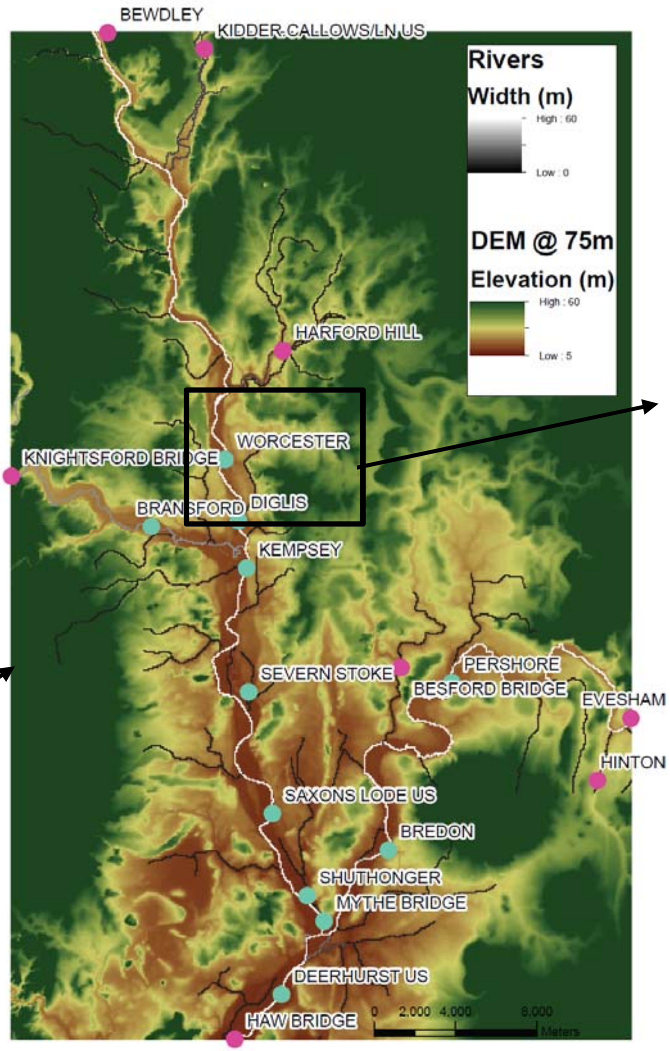
Case study

River Severn

- Regional model: 60 km, 5 tributaries
- Local model: 7 km, city of Worcester
- Up and downwnstream BC relevant
- Flood event: 20-27 July 2007,

  summer rain storm, largest damage





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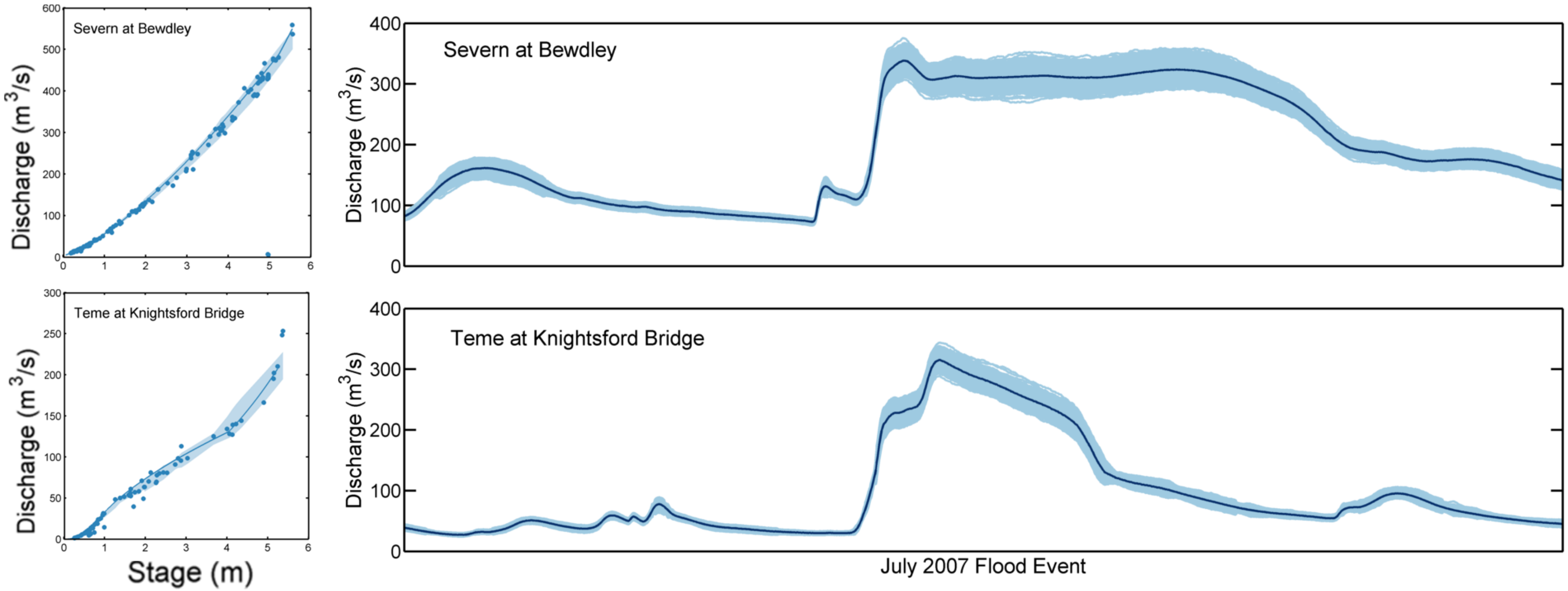
Rating Curve Uncertainty

Stage-discharge measurement data → Non-parametric local weighted regression (LOWESS) fitting → Discharge uncertainty bounds + Error model: error time series + Original discharge time series → **1000 realisations of the discharge time series**



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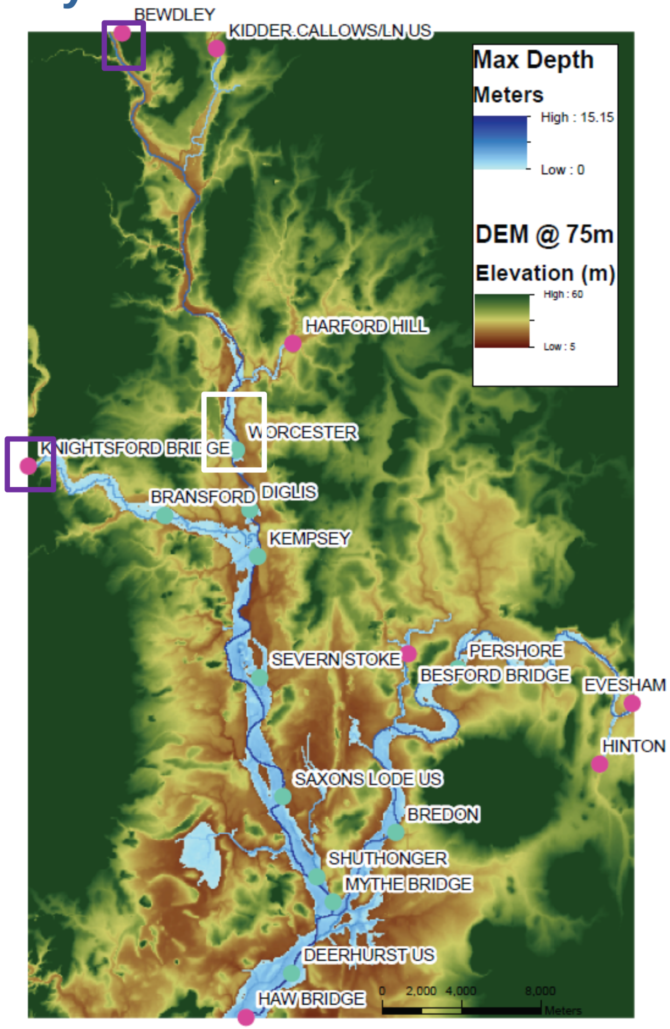
Hydraulic model cascade



Nested hydraulic modelling approach

Regional-scale model: LISFLOOD-FP

- Shallow water wave without advection
- Cartesian grid
- Channel flows as subgrid-scale process (Neal et al., 2012)
- 100 m DTM, observed channel geometry from cross-sections, shape follows power law → Poster session
- Manning's roughness coefficients from look-up table
- Calibration C_d of weir

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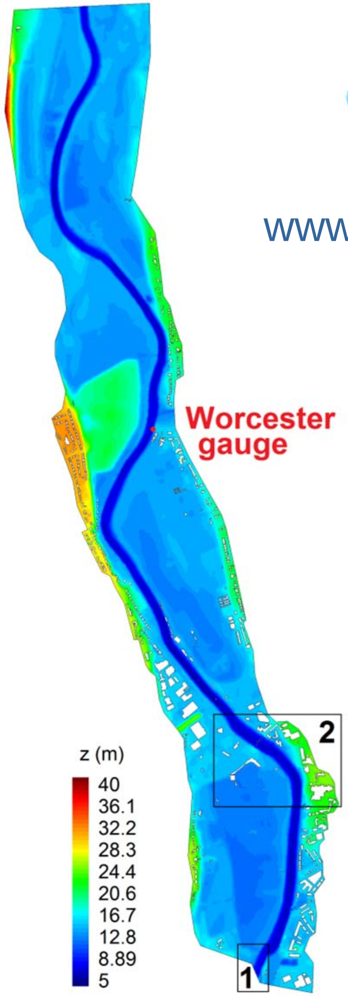
Hydraulic model cascade



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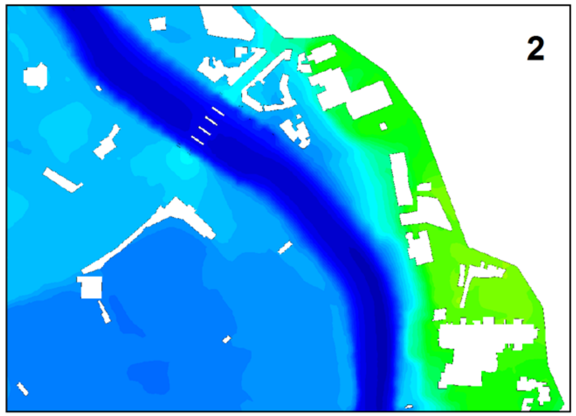
Local-scale model: IBER

- Full 2D Saint Venant equations
- Unstructured grid (~200.000 elements, 21 m^2 average size)
- Grid-scale modelling of urban area
- Manning's roughness coefficients from look-up table

1



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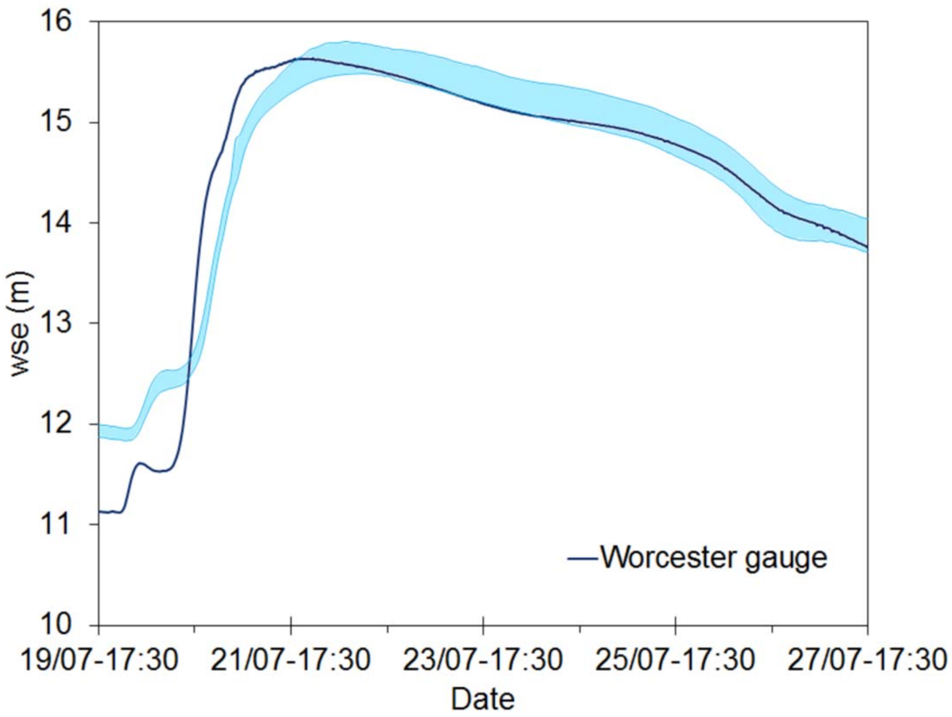
Model performance evaluation

WSE time series at Worcester gauge



- NSE
  - Minimum NSE: 0.89
  - Maximum NSE: 0.92
- RMSE (m)
  - Minimum RMSE: 0.35
  - Maximum RMSE: 0.41

- Timing rising limb
- Overprediction low flows

Local hydrology – Regional model calibration

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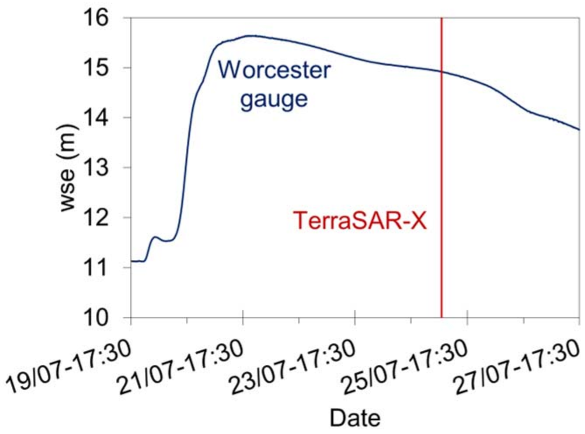
Model performance evaluation

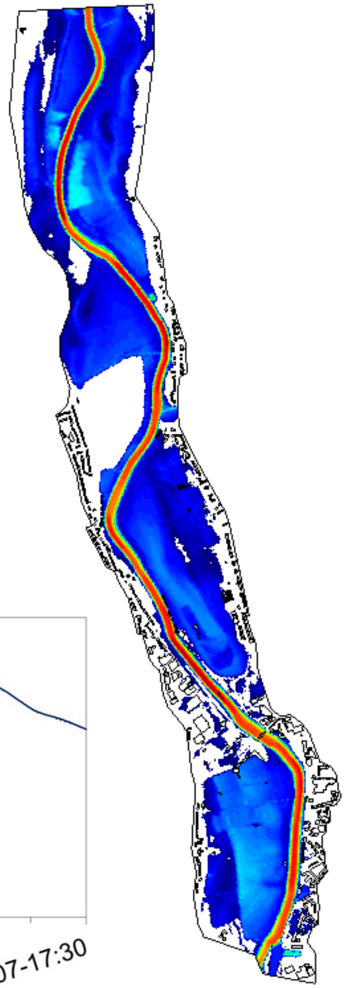
Spatial inundation prediction 25 Jul – 06:34 h

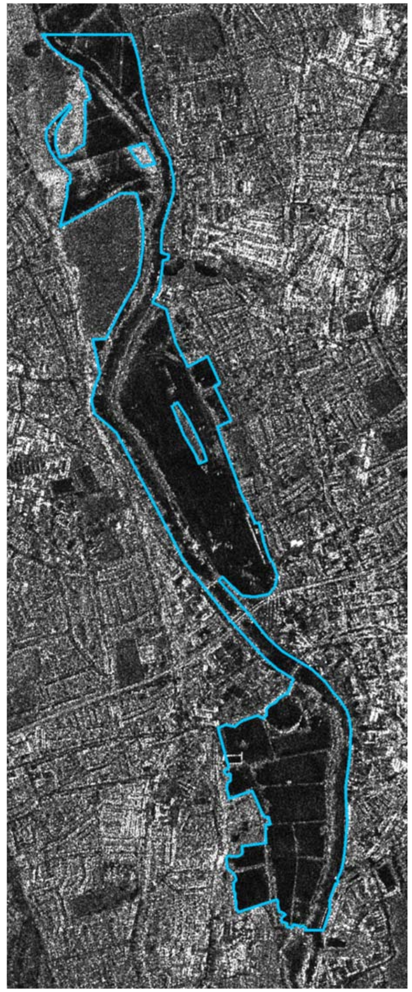
- Flood extent (km^2)
  - Minimum: 2.45
  - Maximum: 2.63

  5% of total area
- Flood Area Index (%)
  - Minimum: 79.0
  - Maximum: 81.8

$$F = \frac{P^{11}}{P^{11} + P^{01} + P^{10}}$$







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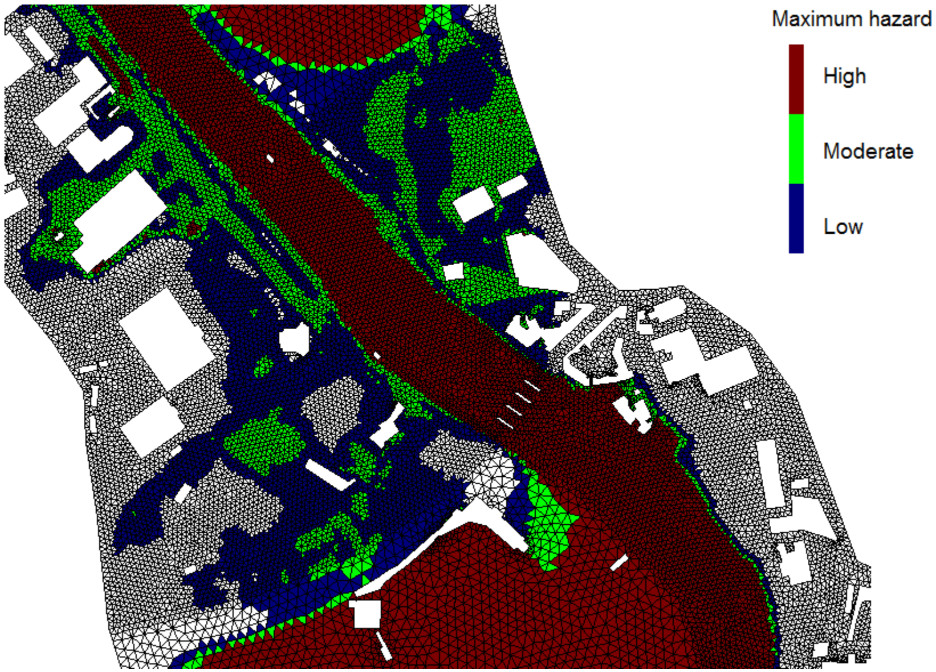
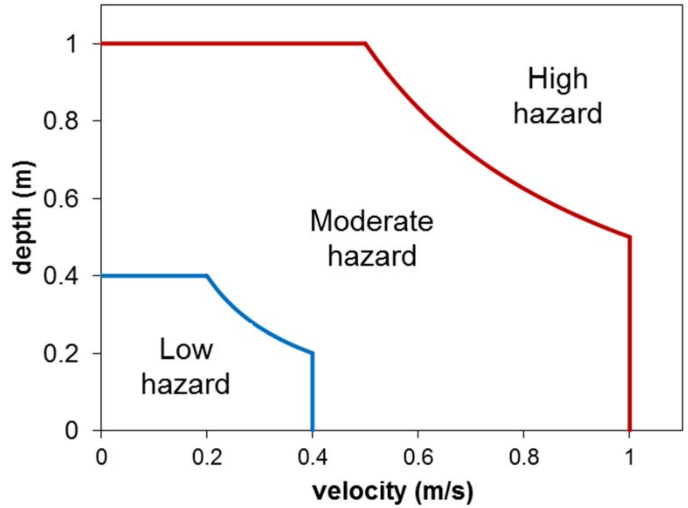
Model performance evaluation

Hazard mapping: maximum hazard 19-27 July





	Hazard areas (km^2)	
	High	No hazard
Min	2.05	0.81
Max	2.38	0.93
	9%	3.5%

(of total area)

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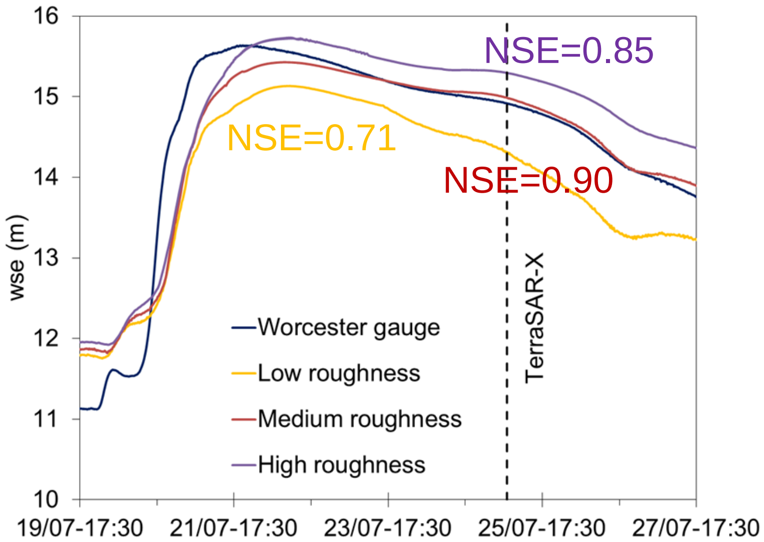
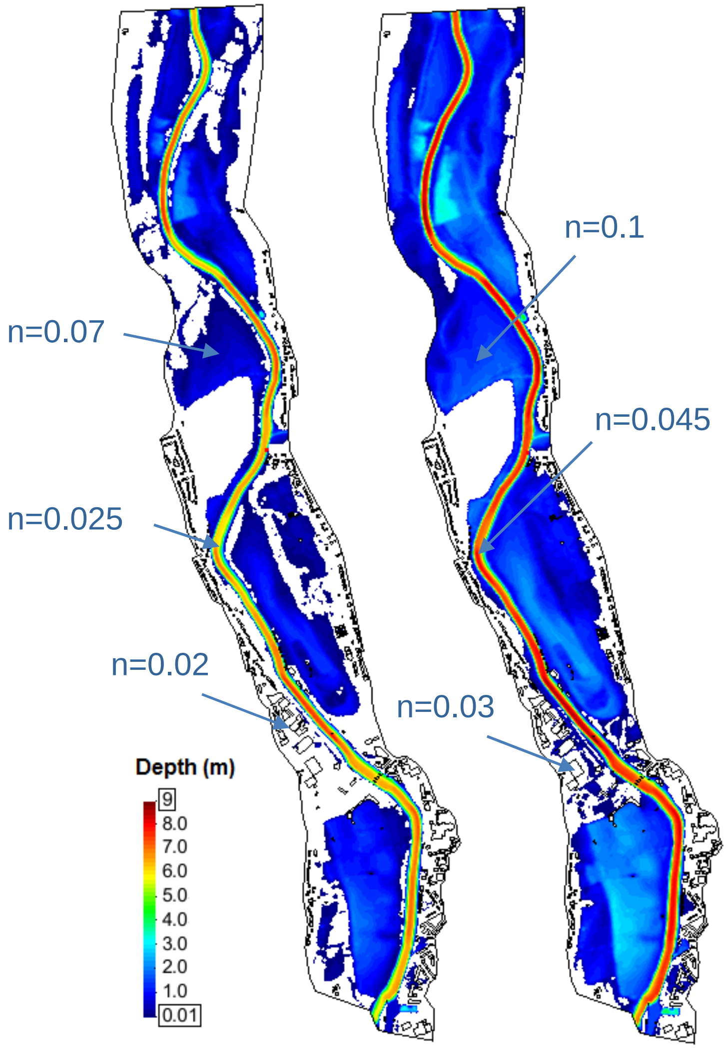
Model performance evaluation

Model parameter uncertainty



	Flood extent (km^2)	Flood Area Index (%)	Hazard areas (km^2) High	Hazard areas (km^2) No hazard
Low	1.90	73.6	1.57	1.14
Medium	2.51	81.0	2.07	0.91
High	2.65	78.1	2.31	0.83
(of total area)	20.5%		20.5%	8%



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Conclusions

- Demonstration of hydraulic model cascade
- External forcing uncertainty leads to small variations in model performance measures in this case
- Highest differences in hazard mapping and potentially in risk mapping
- Importance of local conditions (local hydrology) and model parameter uncertainty (roughness in regional model)

Further work

- Local hydrology uncertainty intro hydraulic model cascade
- Flood risk maps

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