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Living with global uncertainty

Flood inundation risk under climate and social change

Professor Paul Bates

18 May 2012

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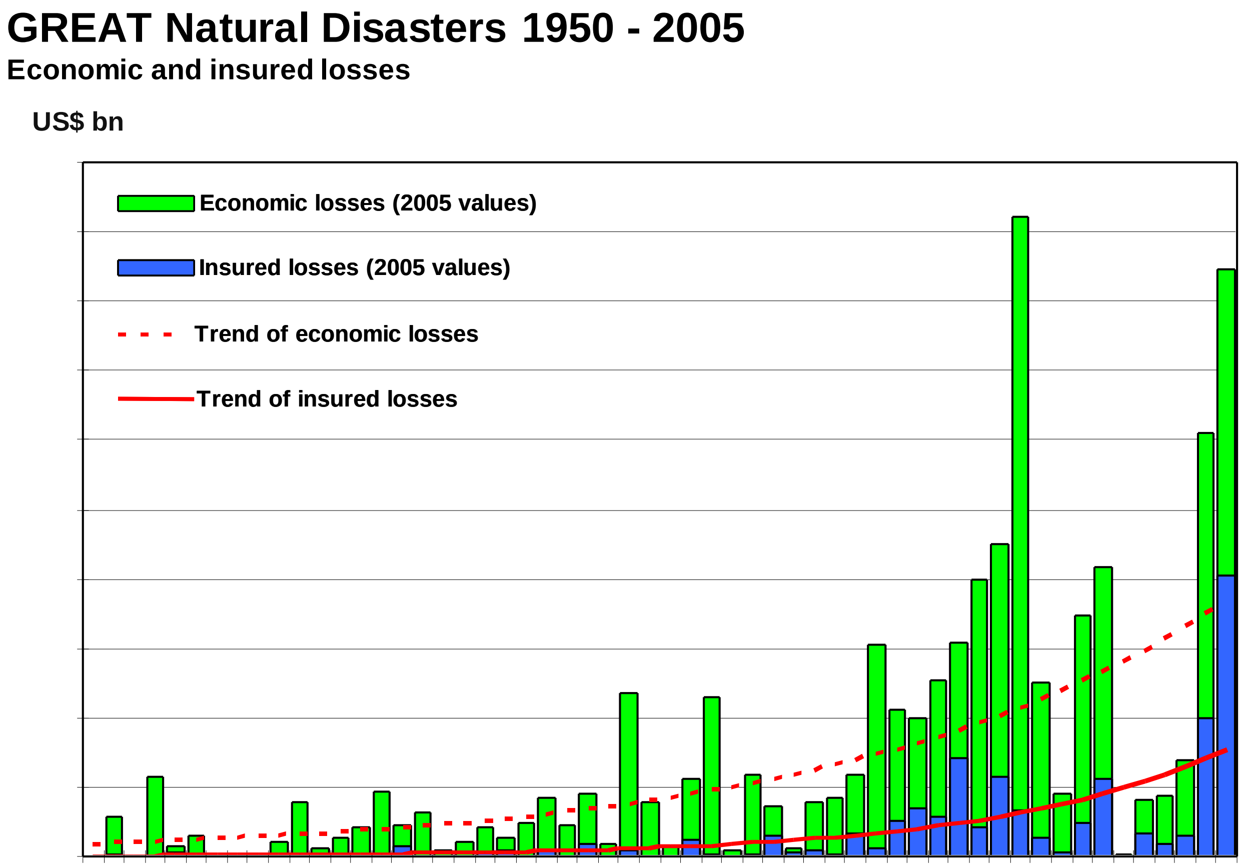
Natural disasters trends



Bristol hazard research

- earthquake engineering
- volcanoes
- floods
- landslides
- disease (animals/crops)
- evolutionary biology
- statistics and uncertainty analysis
- process mathematical models
- climate change risk
  (e.g. sea level, more storms)

Flood risk research

- Major strength at Bristol for over a decade
- Key contributions
  - Demonstrated the critical importance of terrain in flood risk mapping
  - Developed new tools for hyper-efficient 2D modelling to take advantage of LiDAR data
  - Championed rigorous validation and benchmarking of 2D models using field data
  - Developed new methods for dealing with uncertainty

Example: LISFLOOD-FP model

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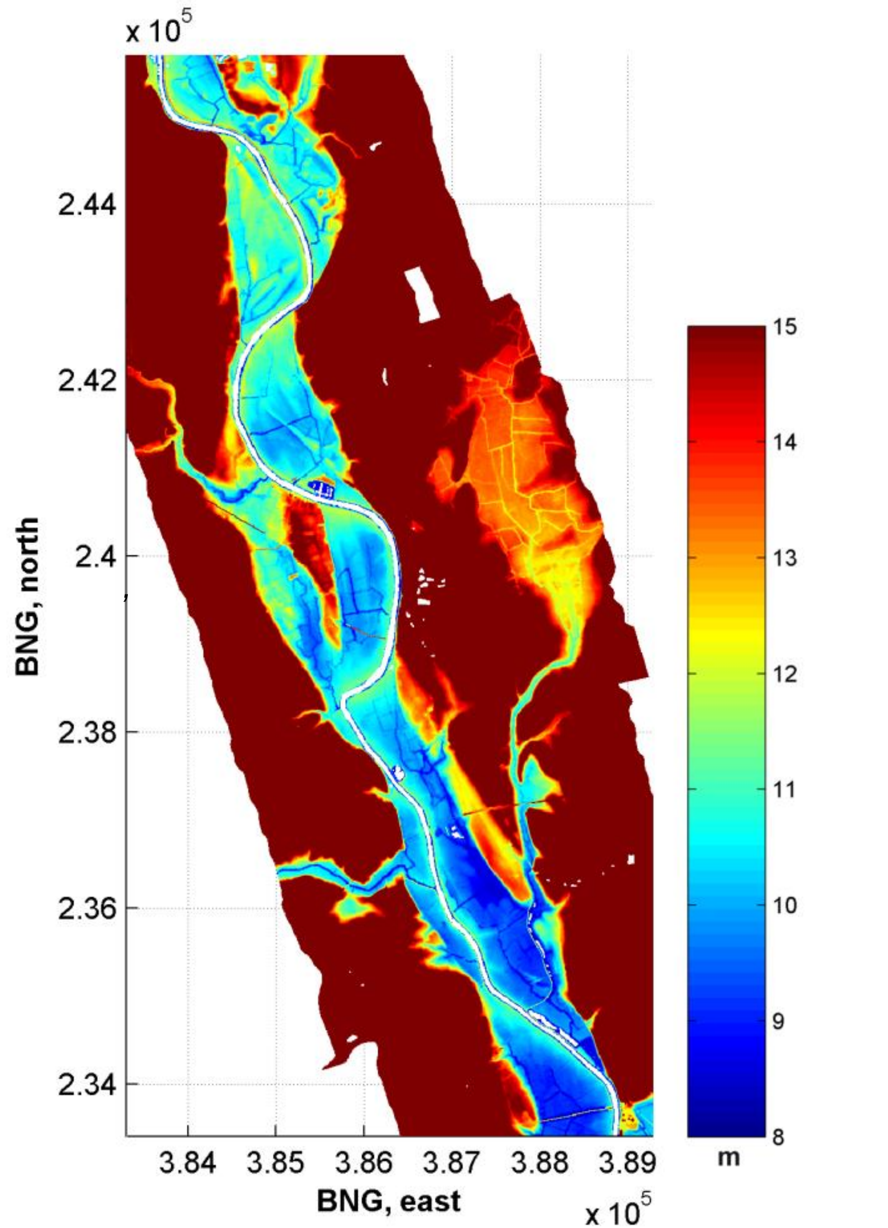
Environment Agency LiDAR digital elevation model (DEM) at 3m resolution.



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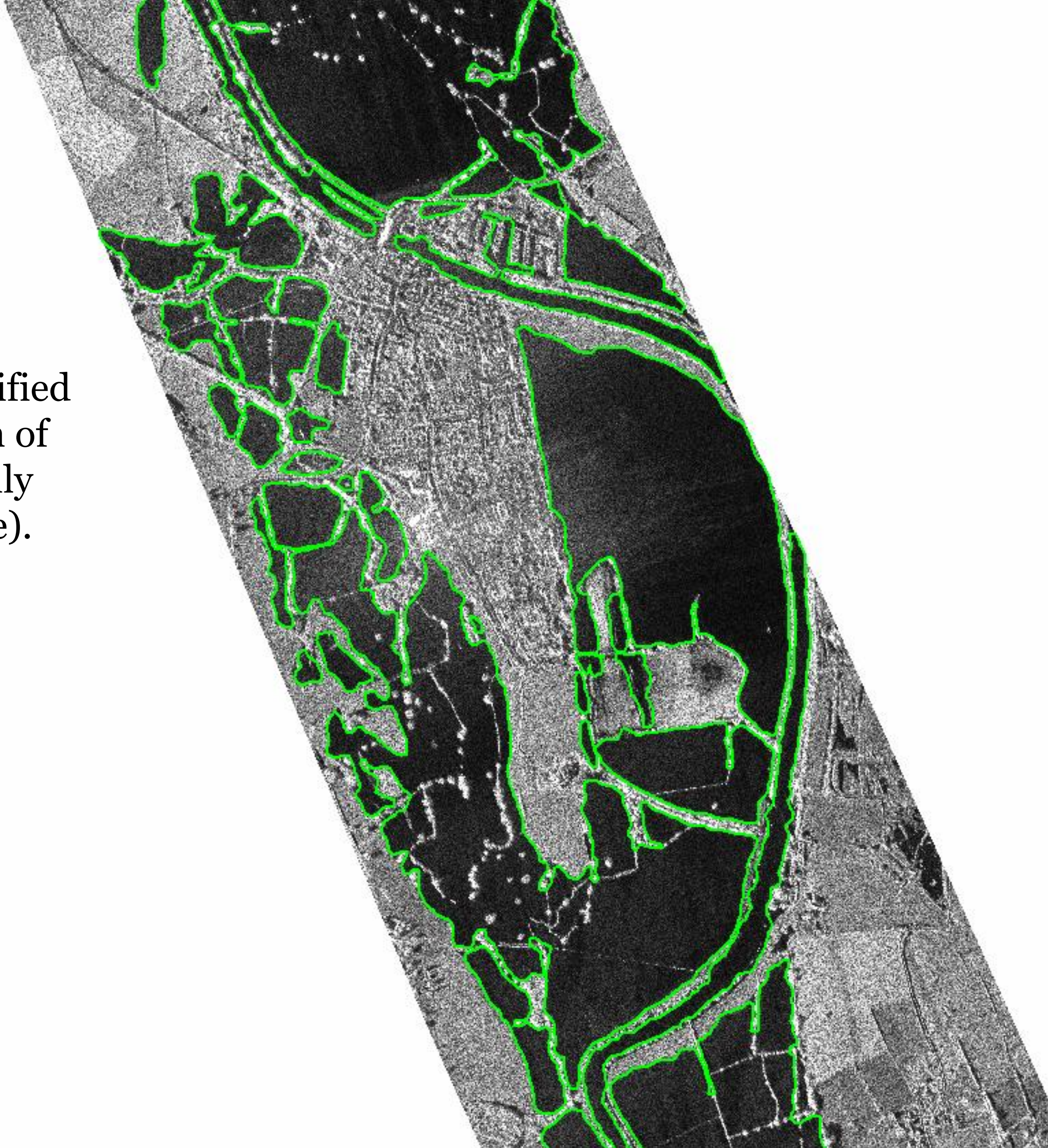
Airborne Synthetic Aperture Radar classified at a spatial resolution of 1m, using a statistically active contour (Snake).



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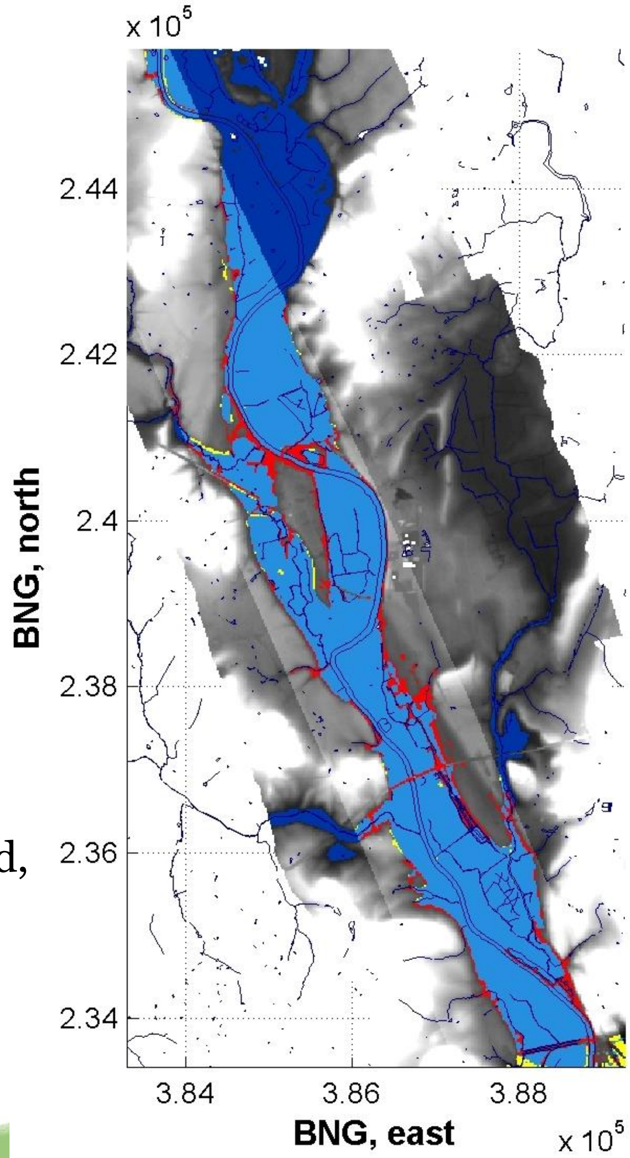
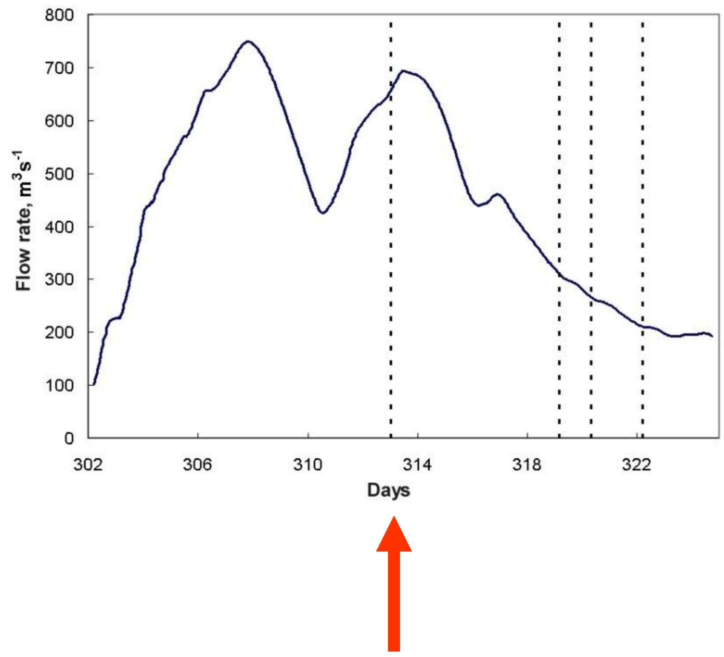
LISFLOOD-FP modelling





= correct

= over-prediction

= under-prediction

= predicted as flooded, no ASAR coverage

Model fit = 89%

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New LISFLOOD-FP formulation

Continuity Equation

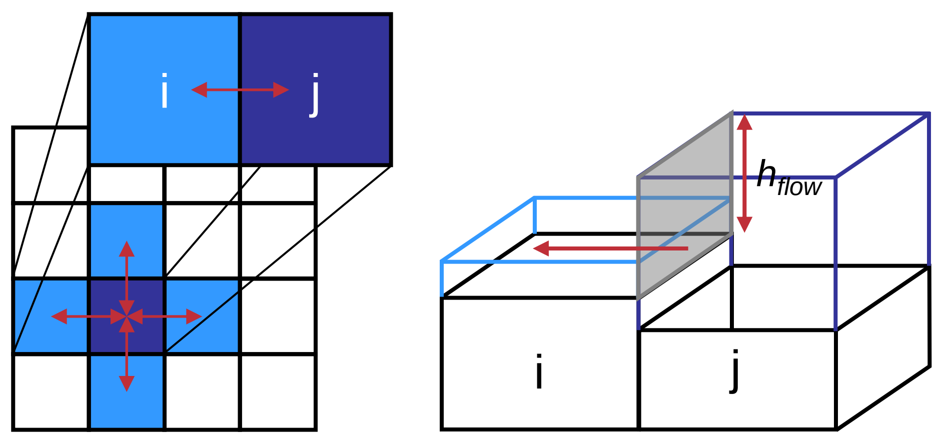
Continuity equation relating flow fluxes and change in cell depth

$$\frac{\Delta h^{i,j}}{\Delta t} = \frac{Q_x^{i-1,j} - Q_x^{i,j} + Q_y^{i,j-1} - Q_y^{i,j}}{\Delta x^2}$$

Momentum Equation

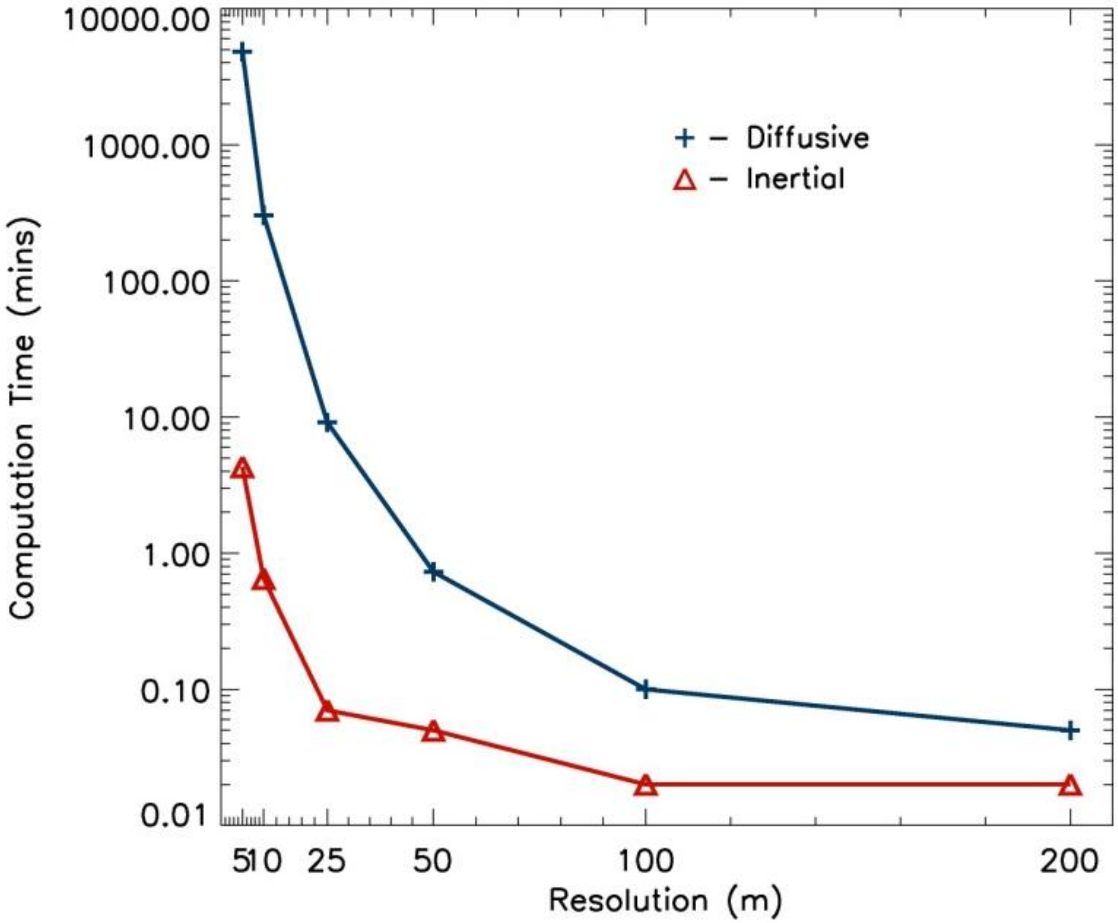
Flow between two cells now calculated using:

$$Q = \frac{q - g h_{flow} \Delta t \frac{\Delta (h + z)}{\Delta x}}{(1 + g h_{flow} \Delta t n^2 q / h_{flow}^{10/3})} \Delta x$$



Representation of flow between cells in LISFLOOD-FP

New equation speed up



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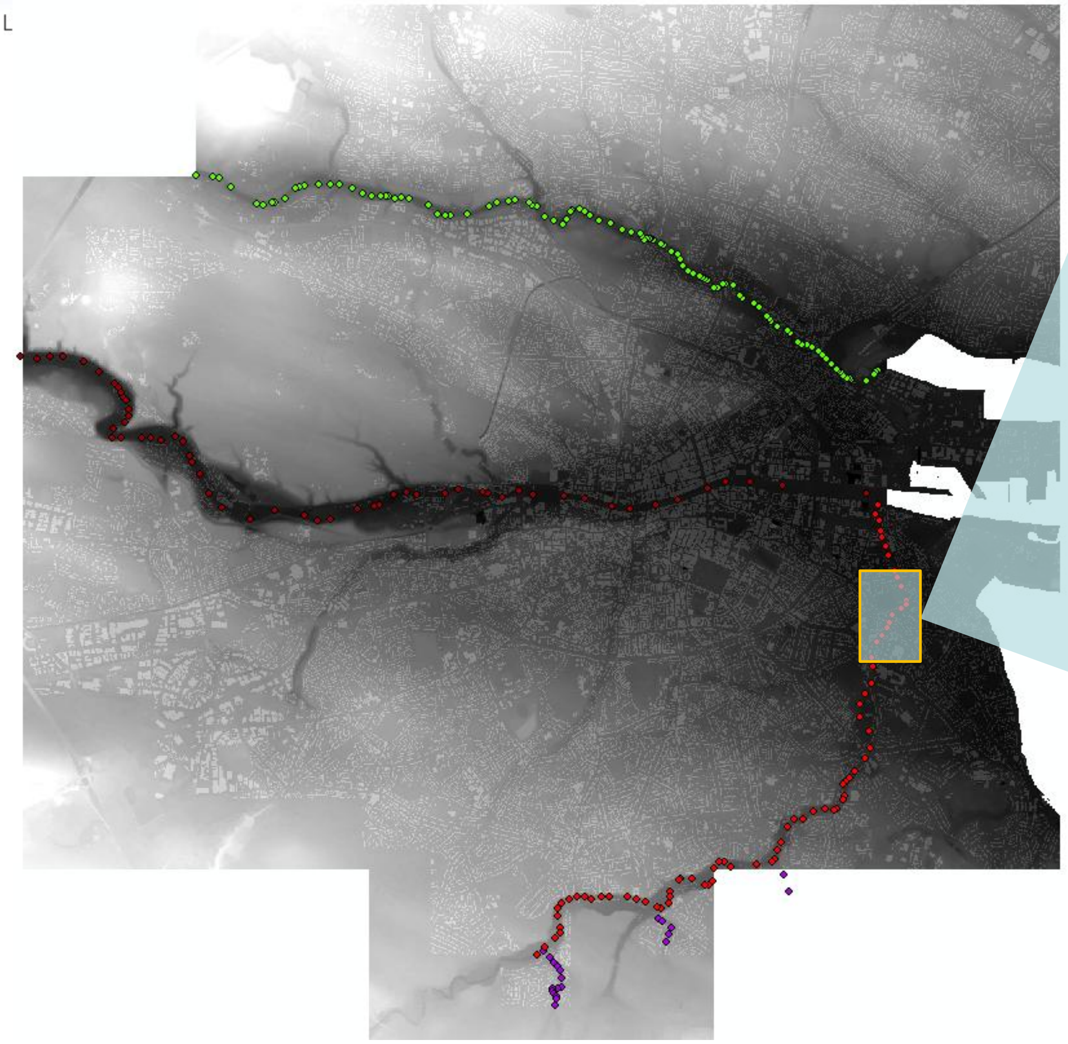
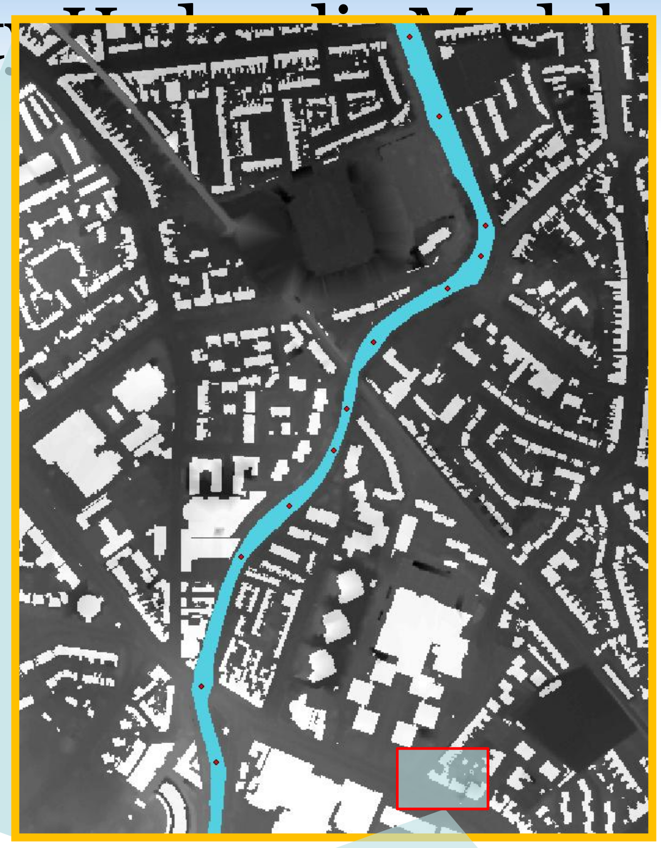
Dublin Cit



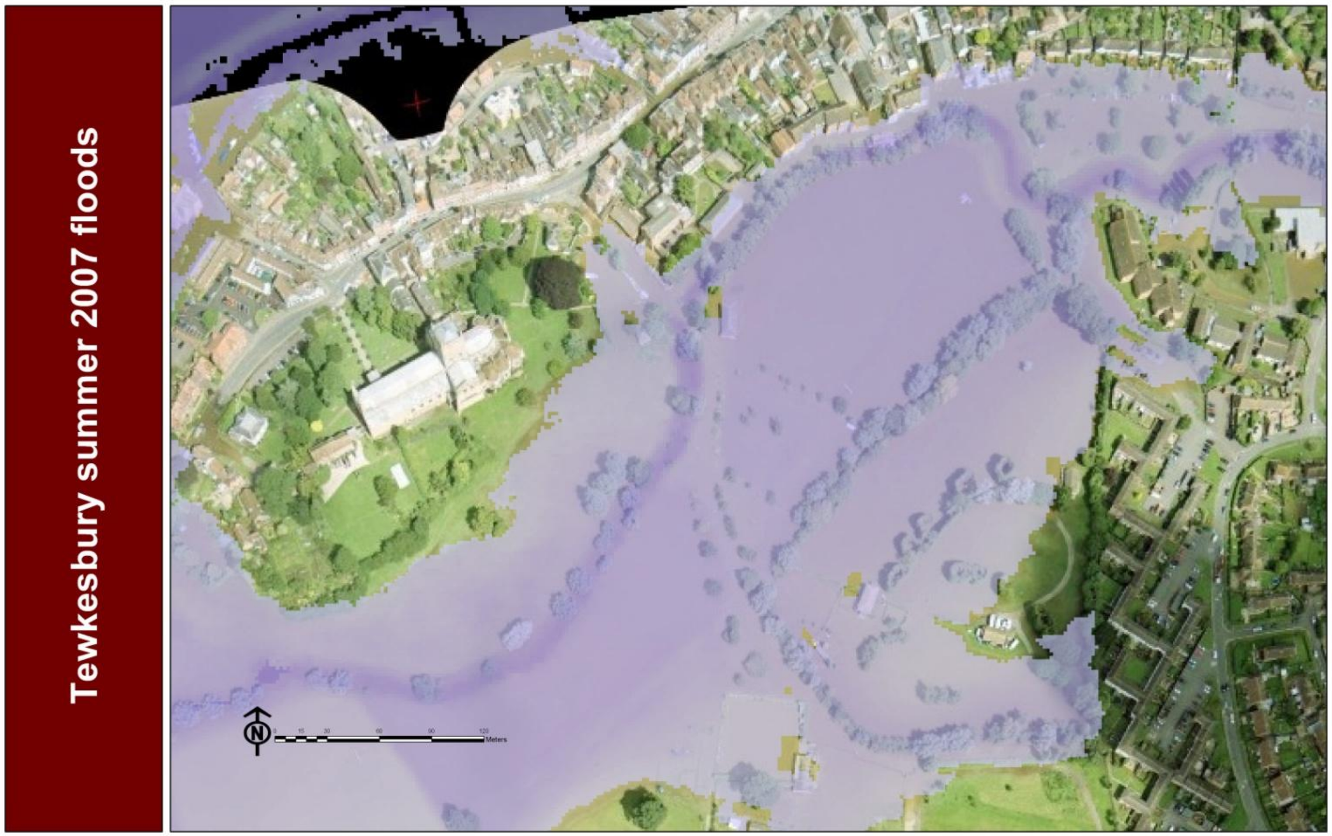


2 m

Baltimore, USA

Does it work?

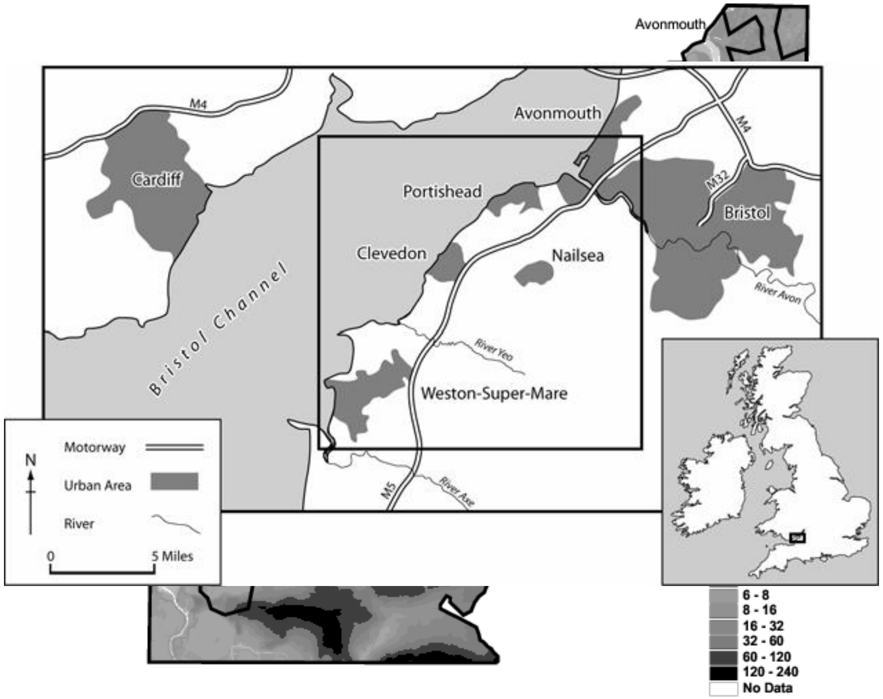
- Whole city flood modelling at 2m resolution – Tewkesbury, UK summer 2007



Risk analysis under uncertainty

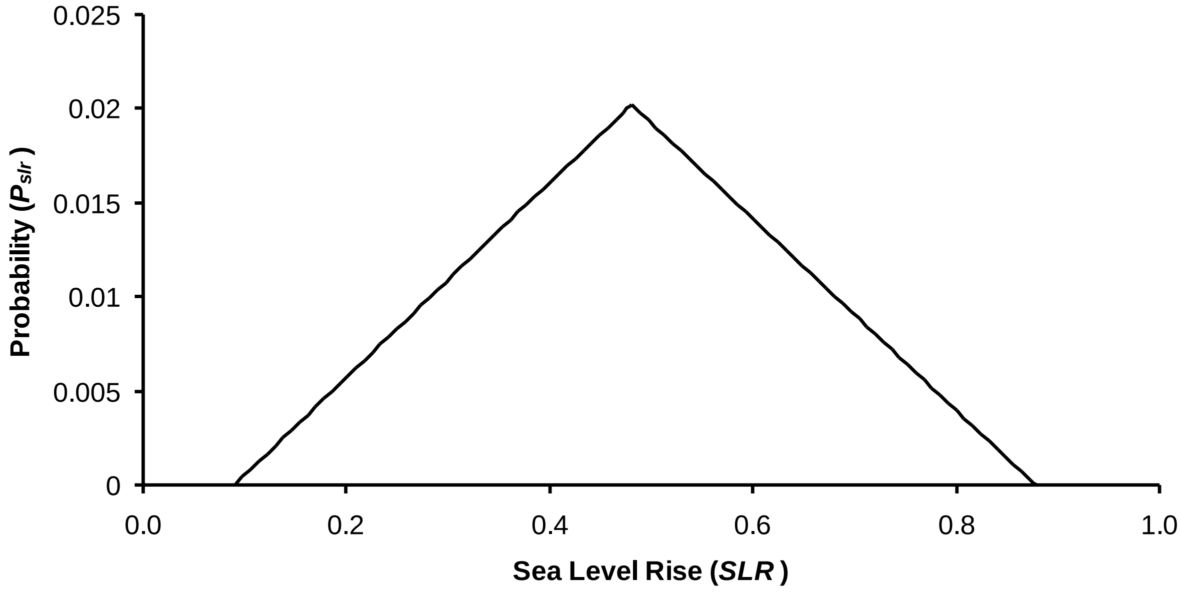
- IPCC Third Assessment Report estimates sea level by 2100 will be between 9 and 81cm higher than today

- Attempt to evaluate the impact of this uncertainty for a future 1 in 200 year flood event on the Somerset coast in the UK



Uncertain future flooding

- Convert IPCC estimate to a probability distribution and add to water levels for a 1 in 200 year extreme tidal event



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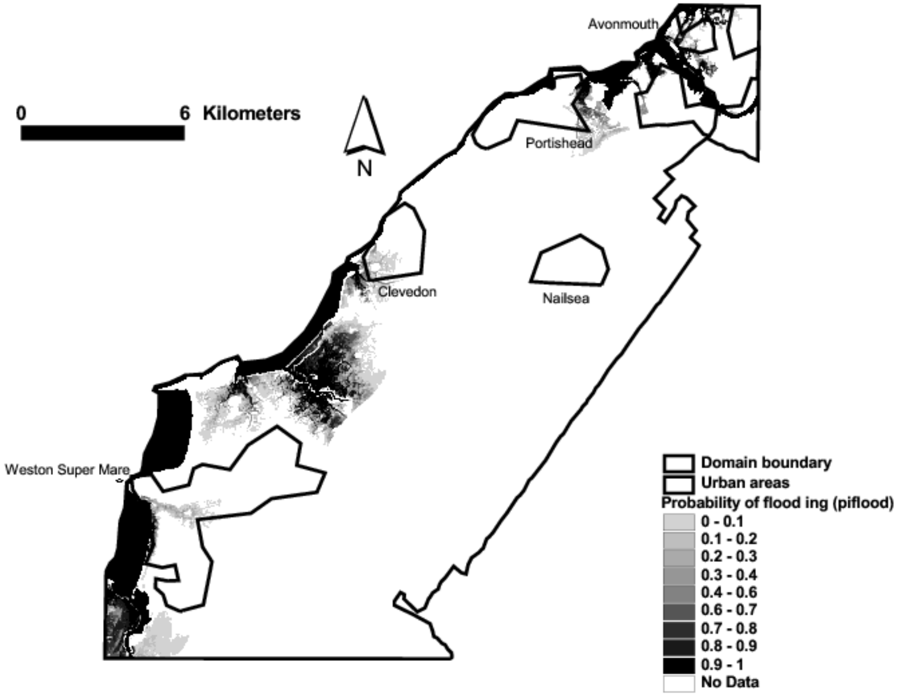
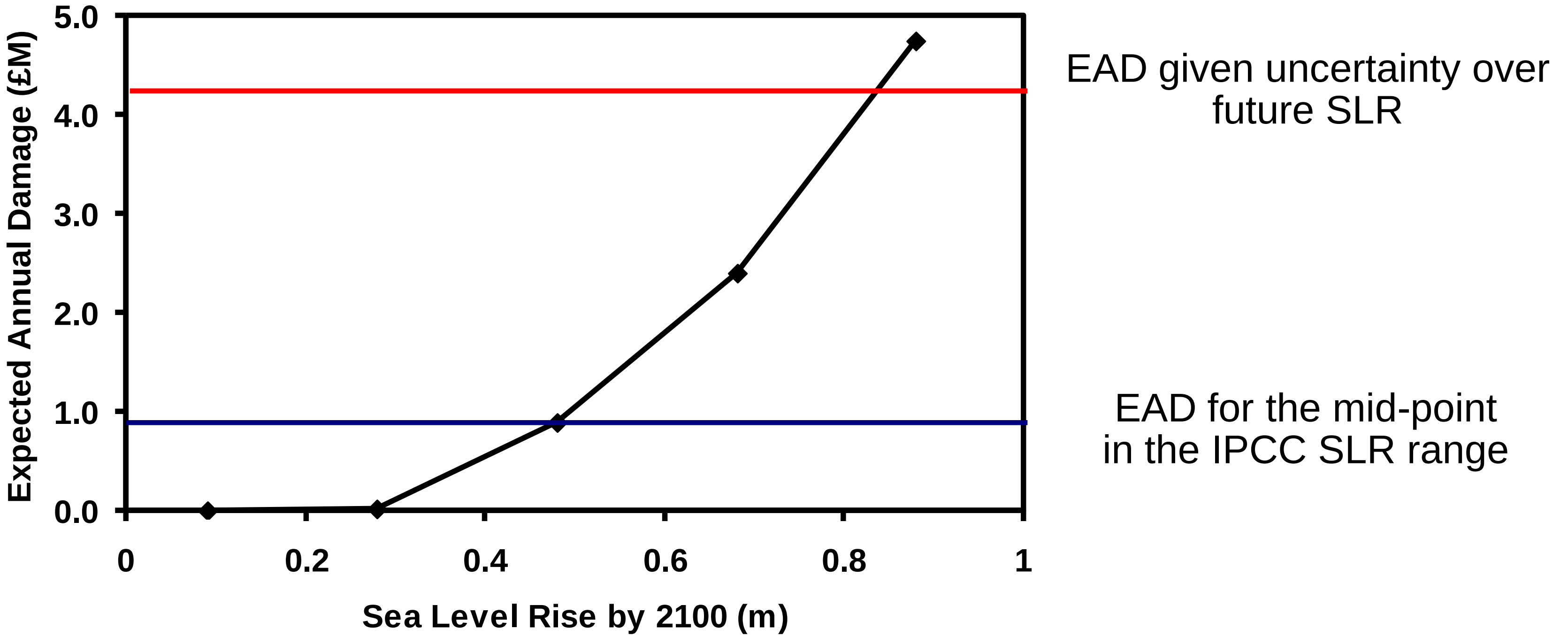
Uncertain future flooding

- Run an MC analysis to calculate the probability of flooding in each cell weighted by uncertainty over future SLR



Deterministic vs. uncertainty weighted modelling

- Calculate expected annual damages for different scenarios



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DEMON

Developing Enhanced impact MOdels for integration with Next generation NWP and climate outputs

Storm risk mitigation

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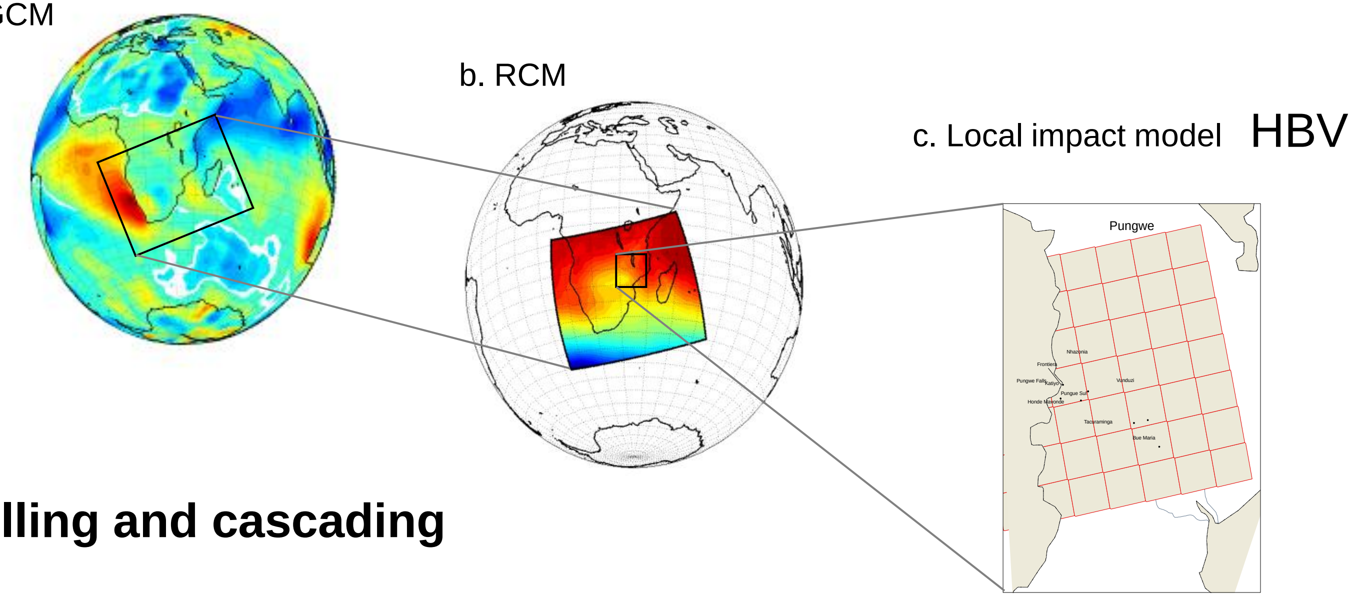
Shrewsbury, Shropshire – future flooding under climate change?

Change in flood hazard due to climate change



parameter uncertainty analysis

End-to-End modelling and cascading uncertainties

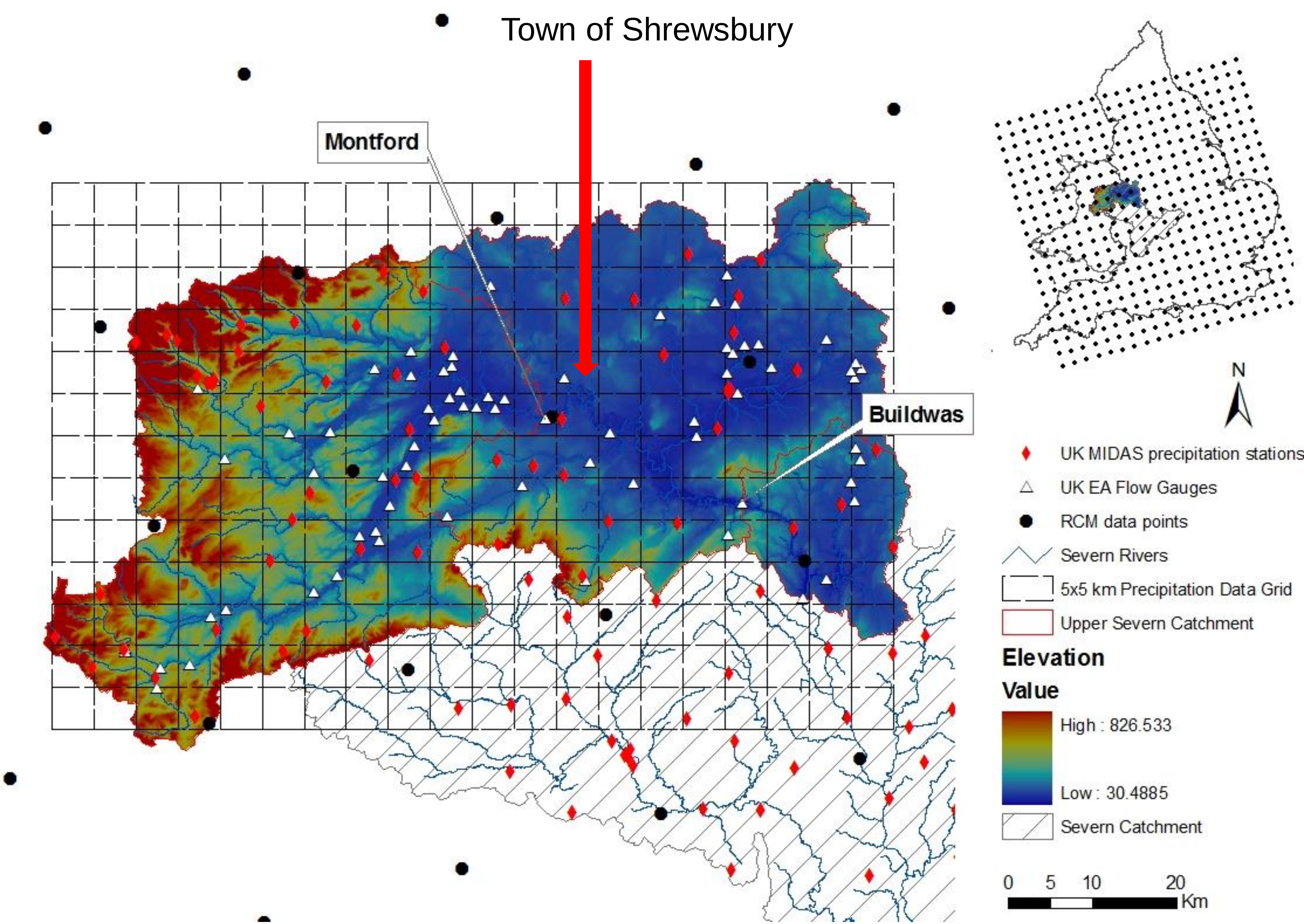
“grand” ensemble:

1. multi-model RCMs (ENSEMBLES) cascaded directly into hydrology impact model
2. ensemble of single RCM (UKCP09) cascaded directly into hydrology impact model
3. Perturbed Physics Ensemble – future rainfall overlain on impact model response surfaces

ENSEMBLES — 16 RCMs

UK CLIMATE PROJECTIONS — 11 members

Harris et al (2010) — 10000 paired precip-temp samples from Joint Probability Distribution



Town of Shrewsbury
Montford
Buildwas
N
UK MIDAS precipitation stations
UK EA Flow Gauges
RCM data points
Severn Rivers
5x5 km Precipitation Data Grid
Upper Severn Catchment
Elevation
Value
High : 826.533
Low : 30.4885
Severn Catchment
0 5 10 20
Km

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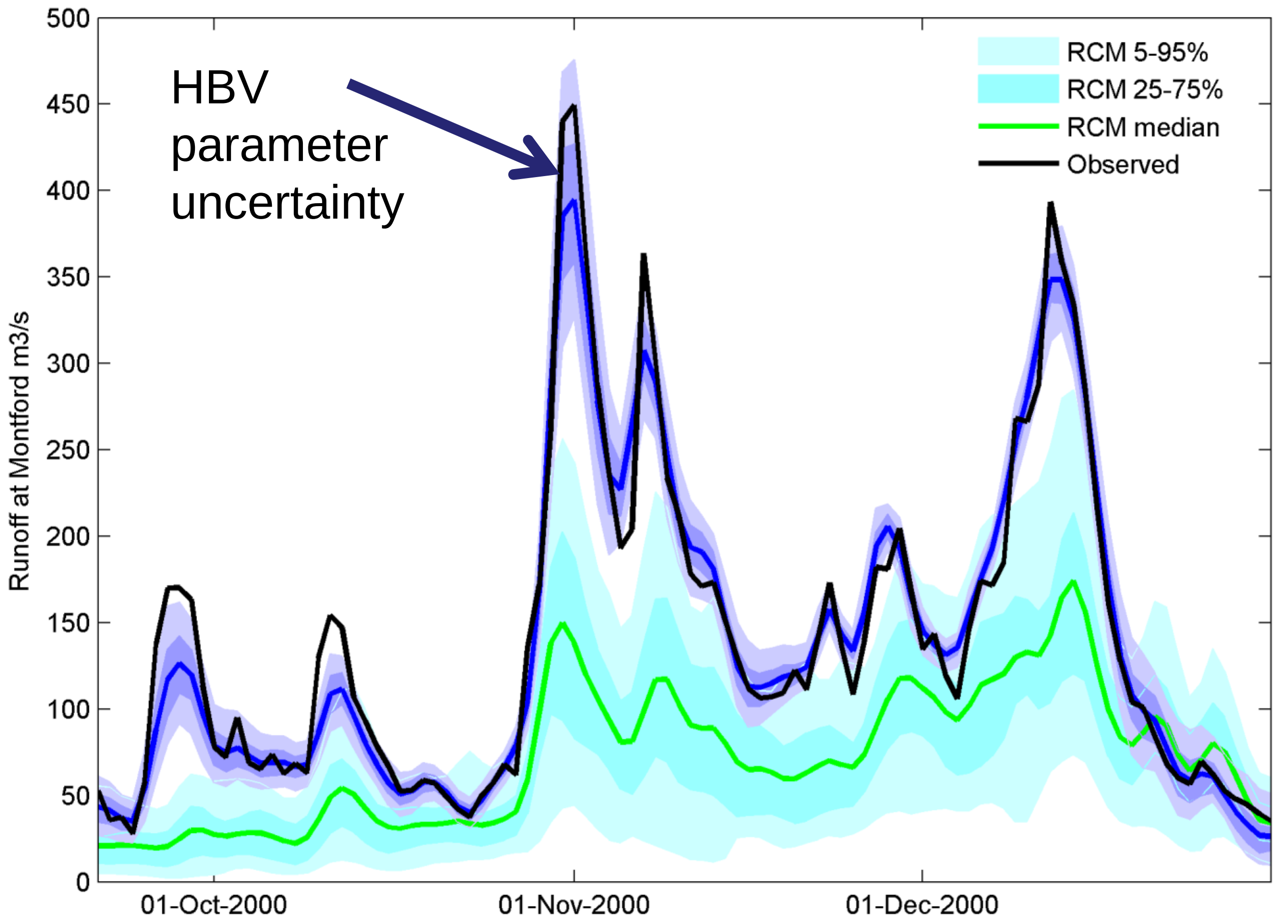
HBV model – using 'raw' UKCP09 and ENSEMBLES



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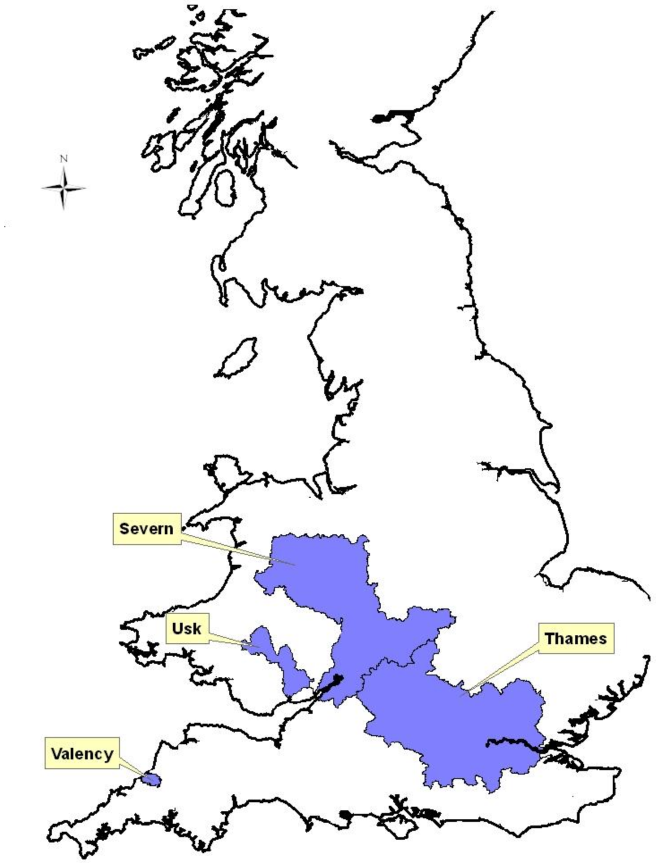
Future flood risk



Ensemble #	Country	Driving GCM	RCM	Resolution	E-Scenario
1	SWEDEN	ECHAM5-R3	RCA	25 km	A1B
2	SWEDEN	BCM	RCA	25 km	A1B
3	GERMANY	ECHAM5-R3	REMO	25 km	A1B
4	NETHERLANDS	ECHAM5-R4	RACMO	25 km	A1B
5	ITALY	ECHAM5-R5	RegCM	25 km	A1B
6	FRANCE	ARPEGE	HIRHAM	25 km	A1B
7	U.K	HADCM3Q16	HADRM3Q16	25 km	A1B
8	U.K	HADCM3Q3	HADRM3Q3	25 km	A1B
9	U.K	HADCM3Q0	HADRM3Q0	25 km	A1B
10	SWITZERLAND	HadCM3Q0	CLM	25 km	A1B
11	U.K	HADCM3	HadRM3Qk	25 km	A1B
12	U.K	HADCM3	HadRM3Q16	25 km	A1B
13	U.K	HADCM3	HadRM3Q14	25 km	A1B
14	U.K	HADCM3	HadRM3Q13	25 km	A1B
15	U.K	HADCM3	HadRM3Q11	25 km	A1B
16	U.K	HADCM3	HadRM3Q9	25 km	A1B
17	U.K	HADCM3	HadRM3Q6	25 km	A1B
18	U.K	HADCM3	HadRM3Q4	25 km	A1B
19	U.K	HADCM3	HadRM3Q3	25 km	A1B
20	U.K	HADCM3	HadRM3Q0	25 km	A1B

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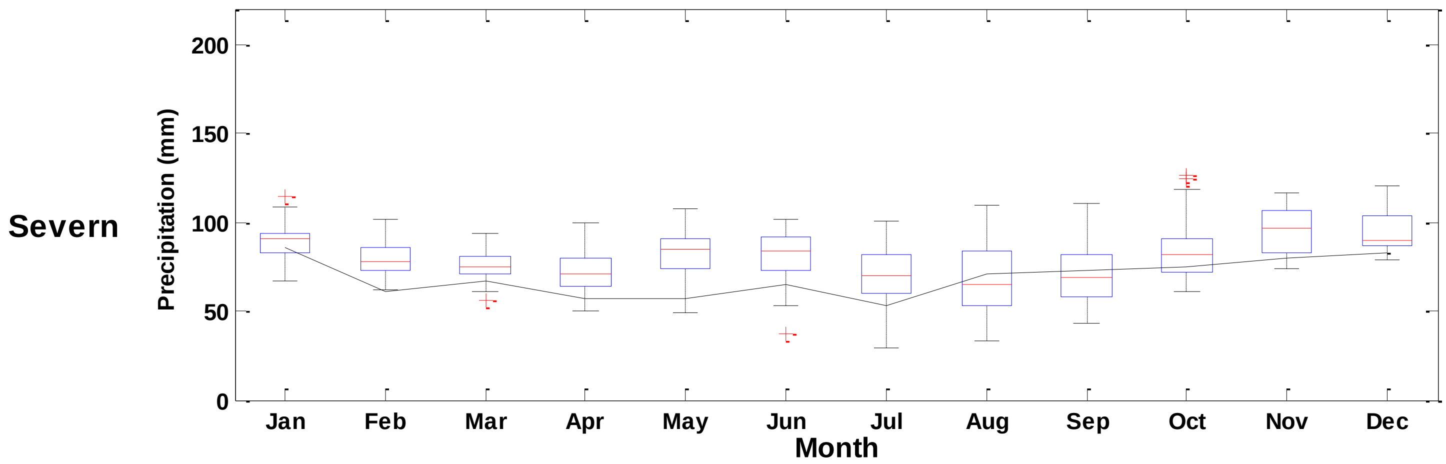
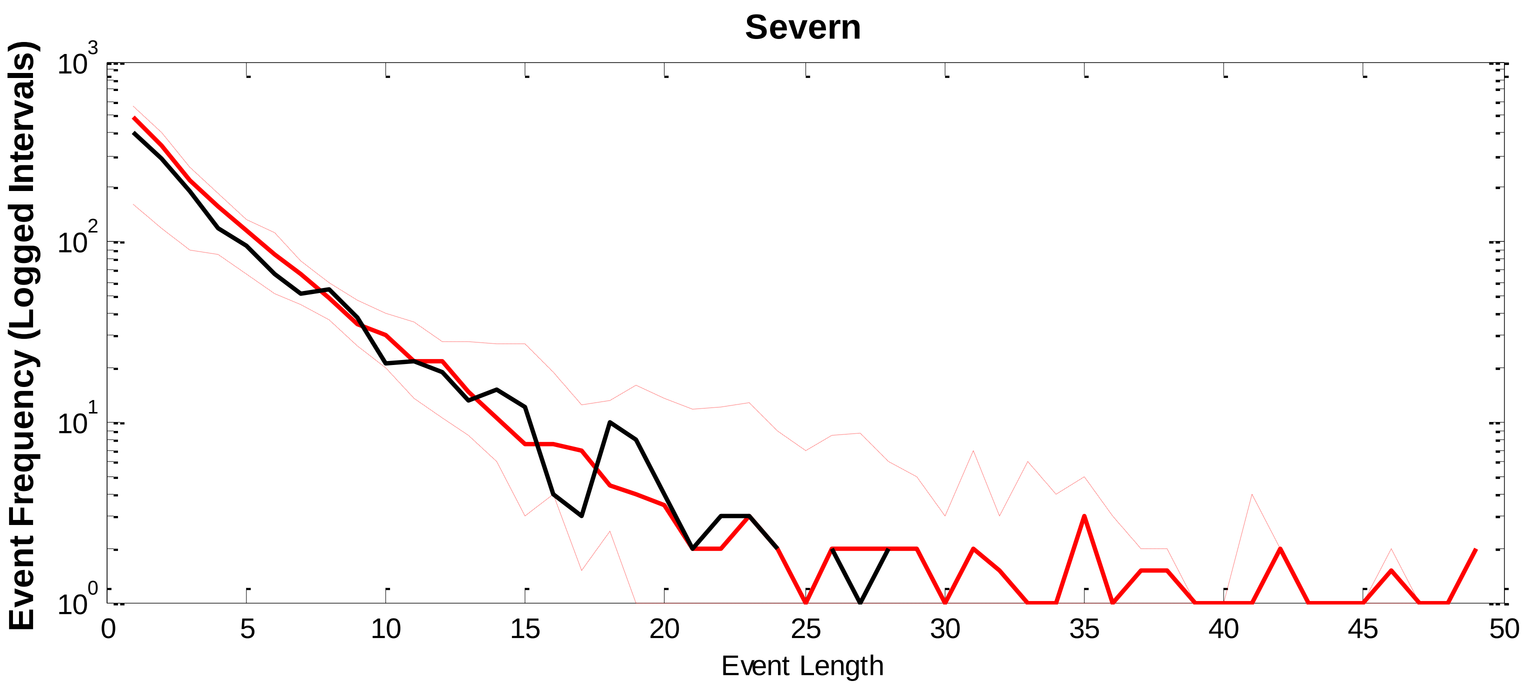
Future flood risk



RCM ensemble skill for monthly precipitation 1970-1999

Future flood risk



Frequency characteristics of RCM precipitation (red), against observed (black).

Dashed lines indicate the 5th and 95th percentiles of RCM output.

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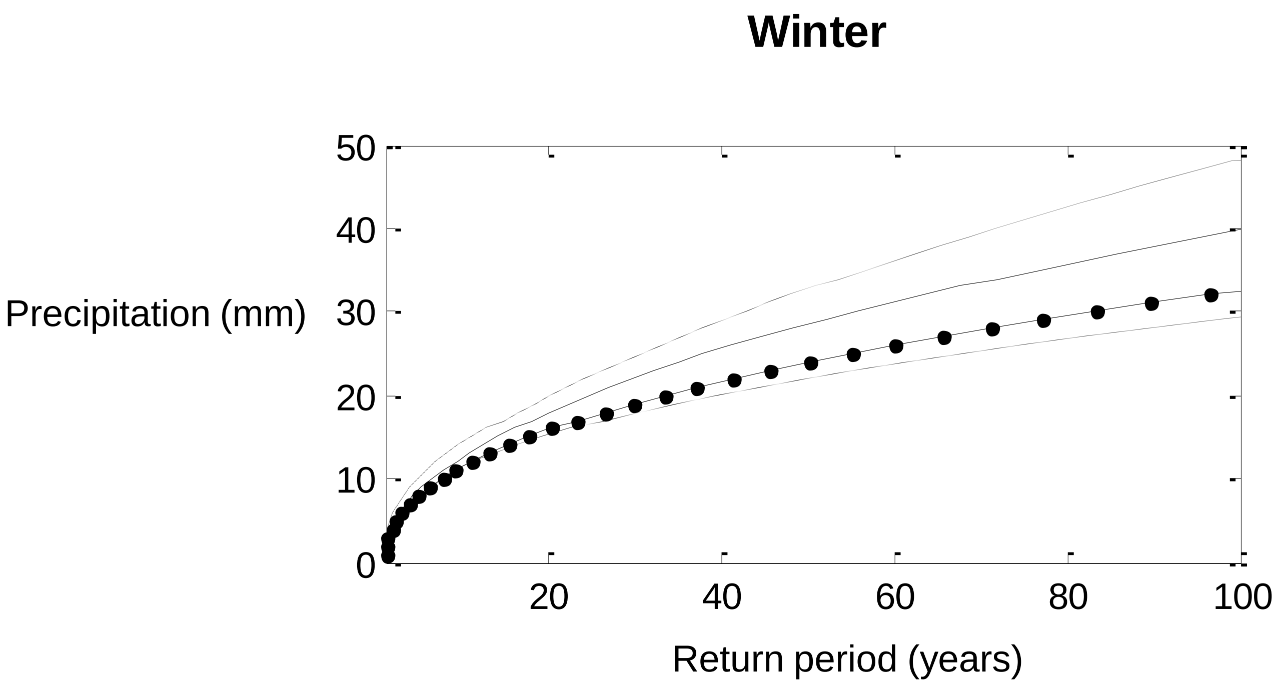
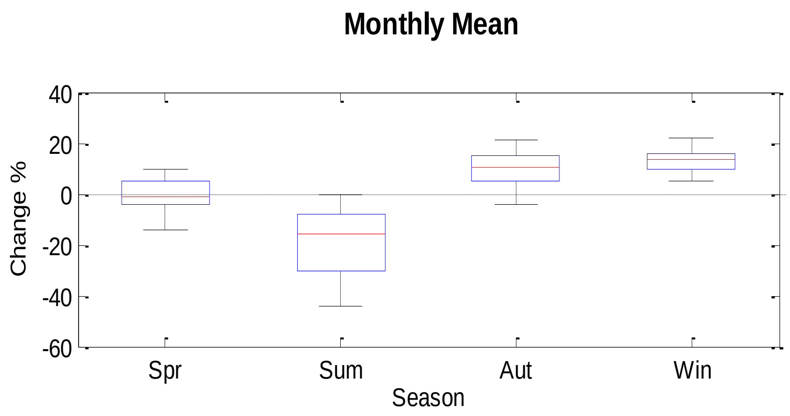


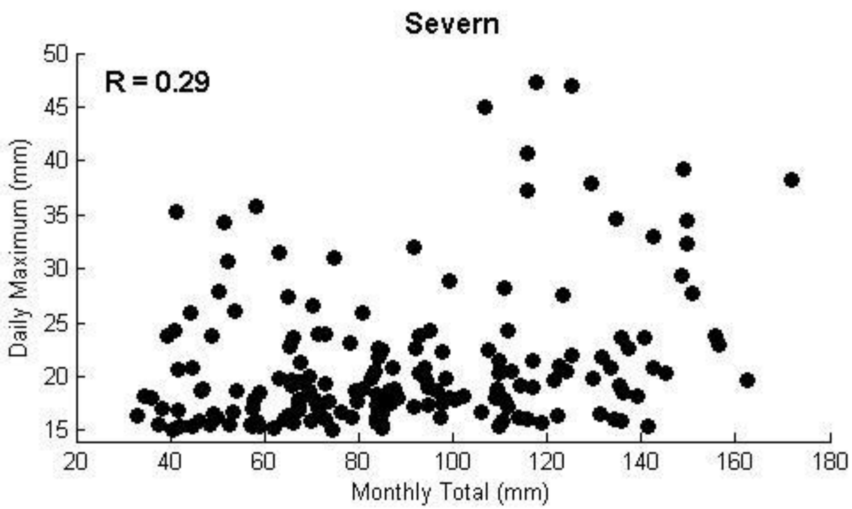
Daily rainfall extreme value distributions for RCMs vs Observed (dotted).

Solid and dashed lines indicate RCM mean and 5th and 95th percentiles respectively.

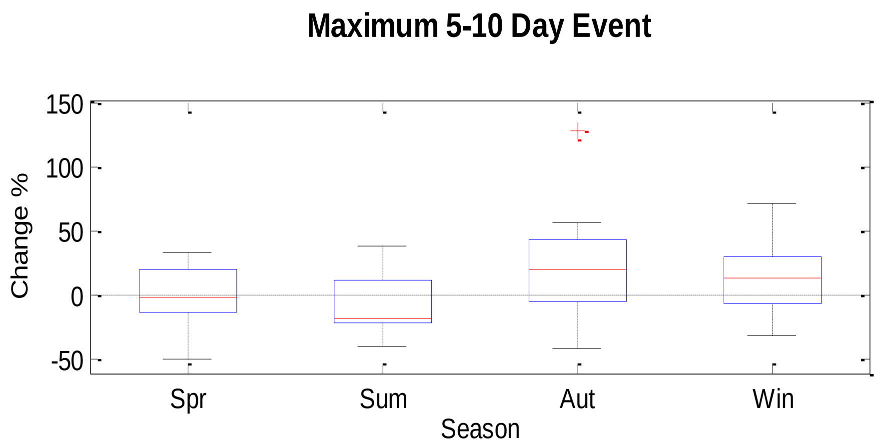
Future flood risk

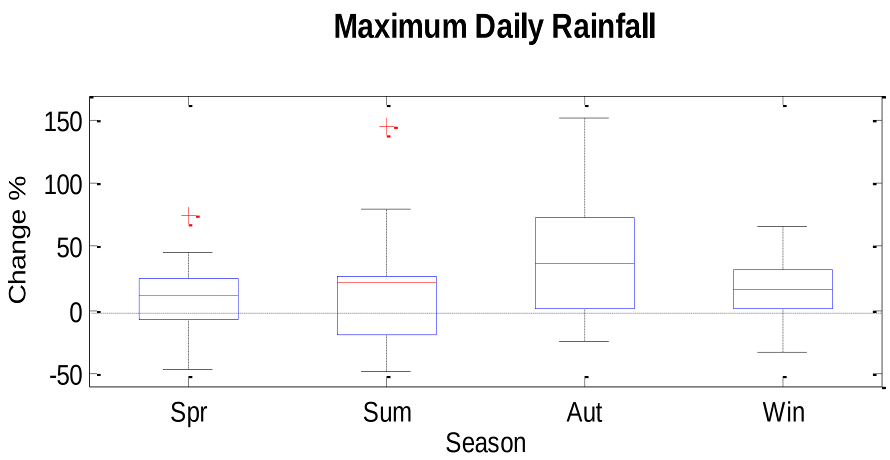
Severn





Future flood risk

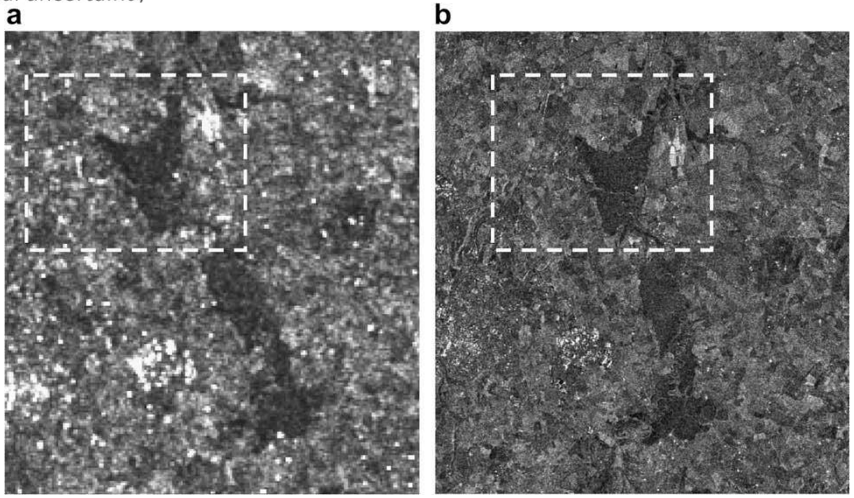




Conclusions

- Hydraulic models can be developed that resolve individual buildings over whole urban areas
- Such schemes also open the way to probabilistic flood risk analysis
- A major application for such techniques is in predicting uncertain future change
- This is possible for sea level rise where the uncertainty in future change can be quantified
- However this is difficult for rainfall generating floods because climate models do not capture extreme rainfall well

Uncertain model-data comparison



Simultaneous SAR acquisitions over a flood

Multiple processing techniques

Predicted probability of flooding given uncertainty over friction parameters

Compare to model simulations using reliability diagrams

Possibility of inundation map