The contribution to future flood risk in the Severn Estuary from extreme sea level rise due to ice sheet mass loss

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"Research methods and tools are urgently needed to enhance the assessment of exposure, vulnerability and risks associated to flood disasters, in order to improve the development of adequate prevention, mitigation and preparedness measures".

KULTURisk, 2012.

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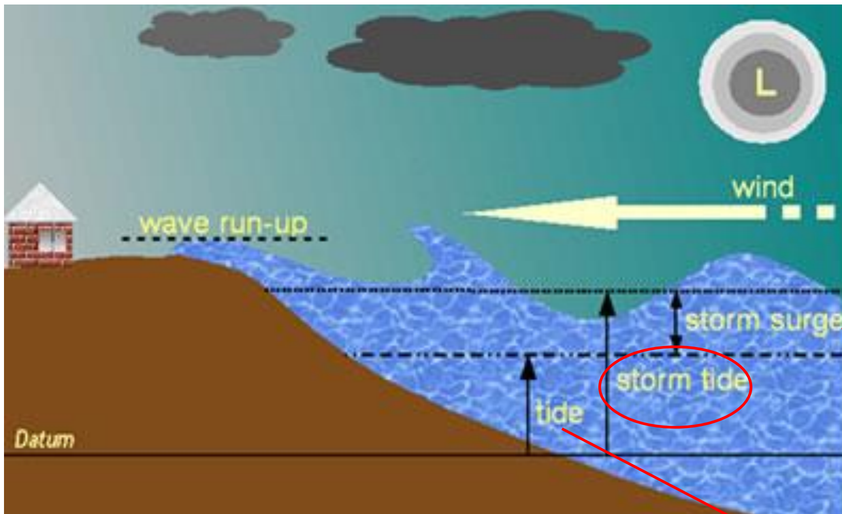
Contents

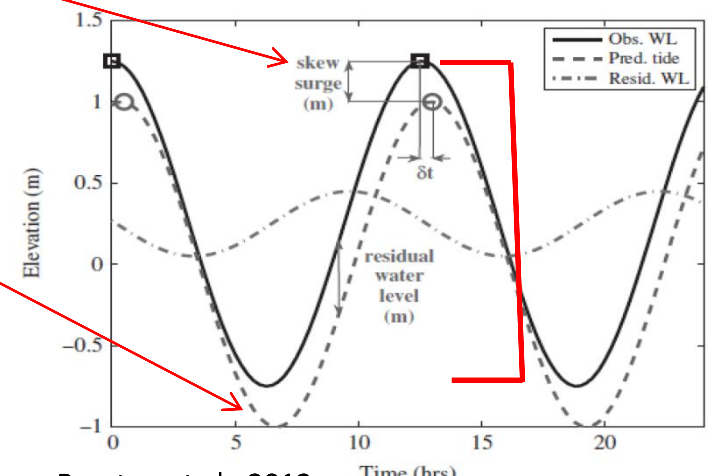
- Coastal flooding
- Future sea levels
- Ice sheet uncertainty
- KULTURisk case study
- A probabilistic risk assessment
- Conclusions

Coastal Flooding



http://www.mfe.govt.nz

www.reuters.com

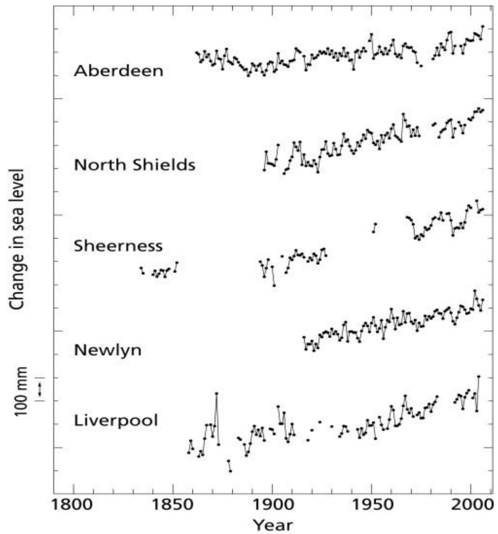


Royston et al., 2012

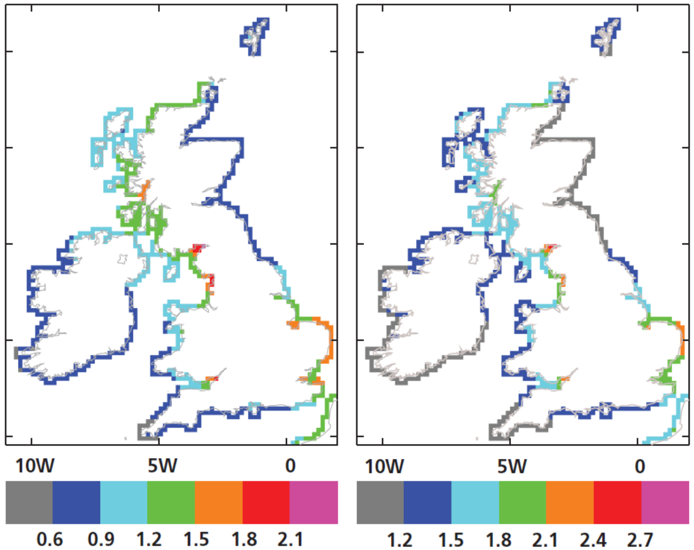
Often due to combination of:

- High spring tide
- Storm surge
- Waves

Future flood risk



Mean Sea Level UK, DEFRA.gov.uk



Present day skew surge (left) and predicted 2100 skew surge (right)
Lowe et al. (2009)

Greater urbanisation at the coast = Increase in assets at risk

Limited resources and significant time taken to construct defences means that decisions and planning is needed now.

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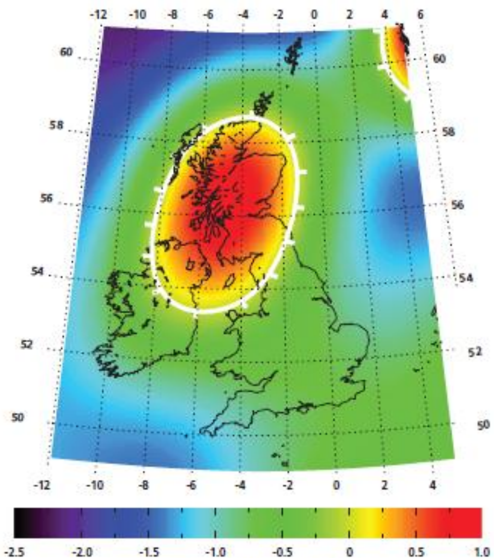
Sea level rise projections: UKCIP

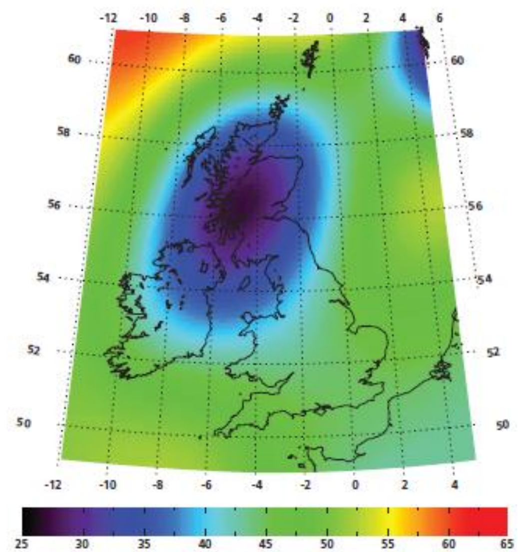
Lowe et al., 2009

Includes:

- 3 emission scenarios
- Thermal expansion from 11 atmospheric-ocean models
- Ice contribution and regional scaling
- Vertical land movement in the UK added to give relative SLR



Vertical land movement (mm/yr)



Relative sea level (cm)

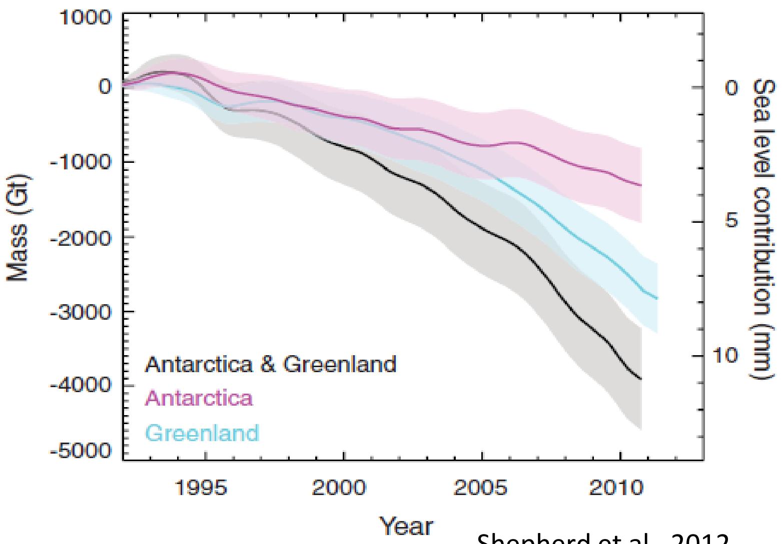
Commonly used projections

E.g. Defence height guidelines in the UK (*DCLG, 2012*)

SLR Uncertainty: The ice sheet contribution

IPCC projections may significantly underestimate SLR (*Lowe et al., 2009*)

- Collapse of WAIS – evidence in previous interglacial periods (*Scherer et al., 1998; Deschamps et al., 2012*)
- Increased rate of mass loss over last 2 decades (*Gardner et al., 2011; Moon et al., 2012; Shepherd et al., 2012*)
    - Questionable length scales
- Semi-empirical approaches predict more extreme SLR than IPCC and UKCIP (*Jevrejeva et al., 2012*)



Shepherd et al., 2012

Rapid SLR within next 100-200 years is not impossible (*Pfeffer et al., 2008; Bamber and Aspinall., 2013*)

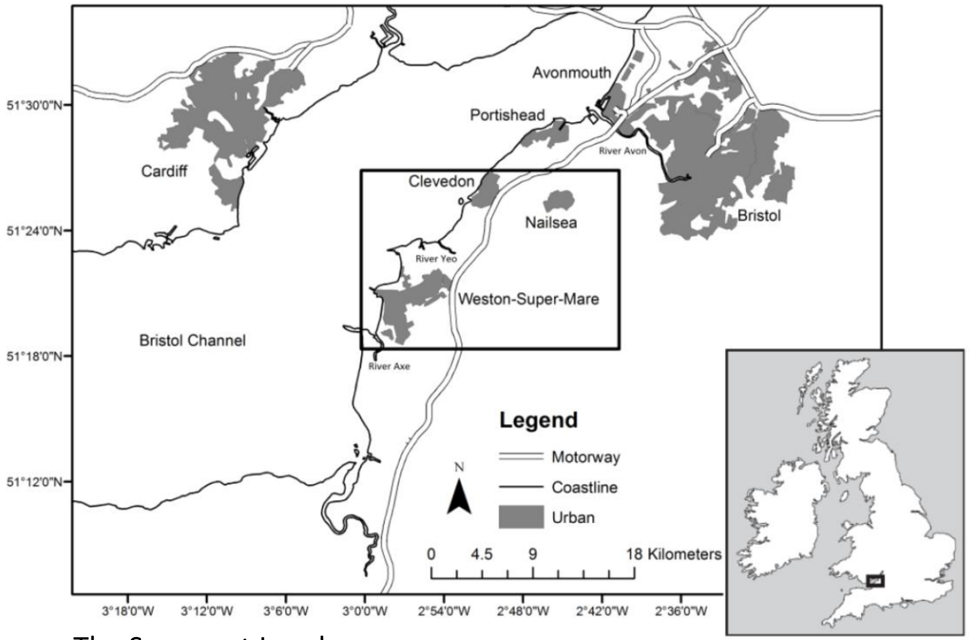
UKCIP address this possibility by including a separate scenario (H++) range

- 0.93 – 1.9m SLR
- based on Red Sea sediment data during the last interglacial (*Rohling et al., 2008*)

KULTURisk case study: aim

- Examine the impact on a deterministic flood risk estimation due to sea level rise uncertainty

Study Site



The Somerset Levels

- 20 km length of North Somerset coastline, UK
- 2 main urban centres:
  - Weston-Super-Mare
  - Clevedon
- Large, flat floodplain below 7m OD
- Extensive grazing lands
- Population of 90,000
- Defences essential - currently 1:200 yr and 1:50 yr along coast and rivers, respectively

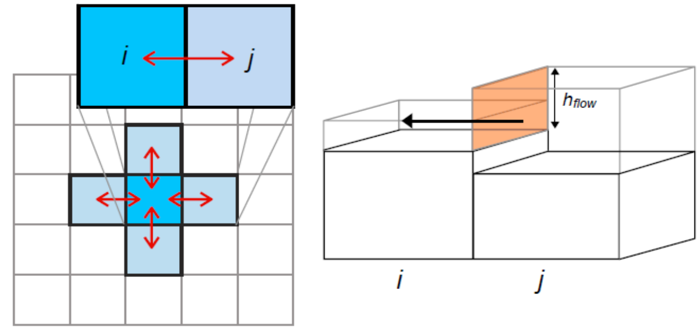
LISFLOOD-FP

Hydrodynamic model first introduced by *Bates and De Roo (2000)*

- 2D storage cell approach

Recent version uses the local inertial approximation of the full shallow water equations (*Bates et al., 2010*)

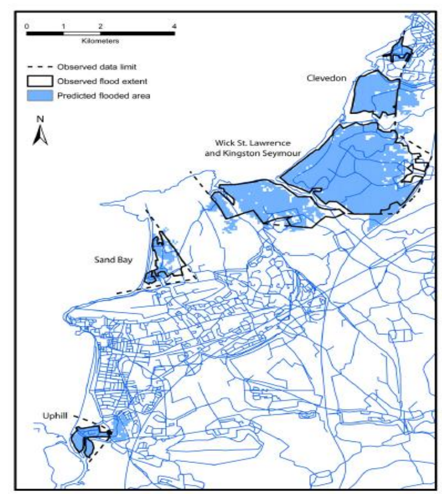
- Shown to perform well in sub-critical flow conditions (*de Almeida and Bates, accepted*)



Bates et al. (2005)

Used in previous flood risk assessments in the region

- *Purvis et al. (2008); Lewis et al. (2011); Smith et al. (2012)*



Smith et al. (2012)

3 fundamental datasets required:

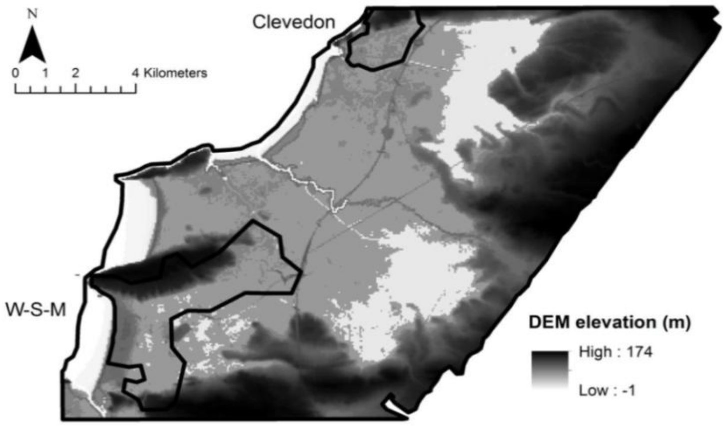
- DEM
- Manning's roughness map
- Boundary conditions

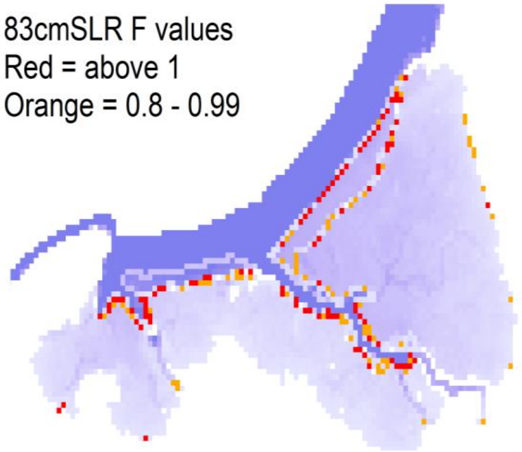
LISFLOOD-FP

DEM:
- 50 m resolution

Landcover type:
- Mastermap and CORINE

Manning's *n*:
- Standard USGS for non-urban cover types
- Calibrated urban roughness of 0.09 after *Smith et al. (2012)*





Defence-floodplain edges given as weir equations to reduce areas of super-critical flows

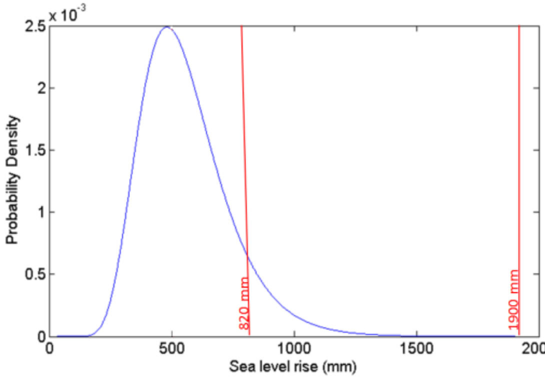
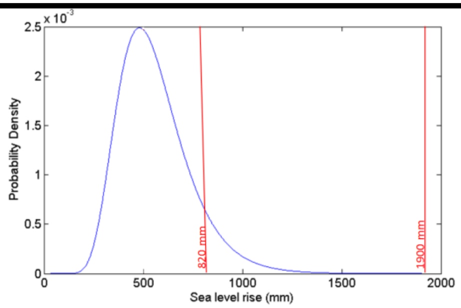


Fig. 2. MSLR scenarios considered.

SLR Scenarios
- UKCIP 95%
- UKCIP H++

RRA



SLR Scenarios

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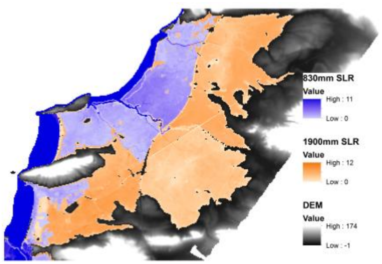
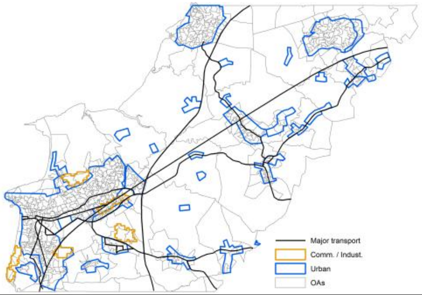


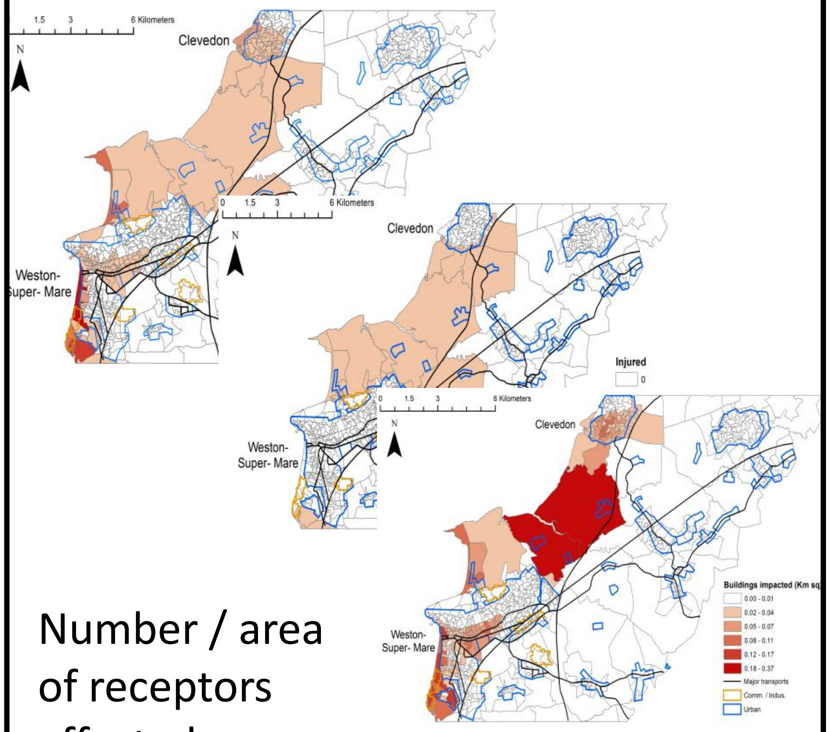
LISFLOOD-FP

- Depth
- Velocity



Landcover Mapping

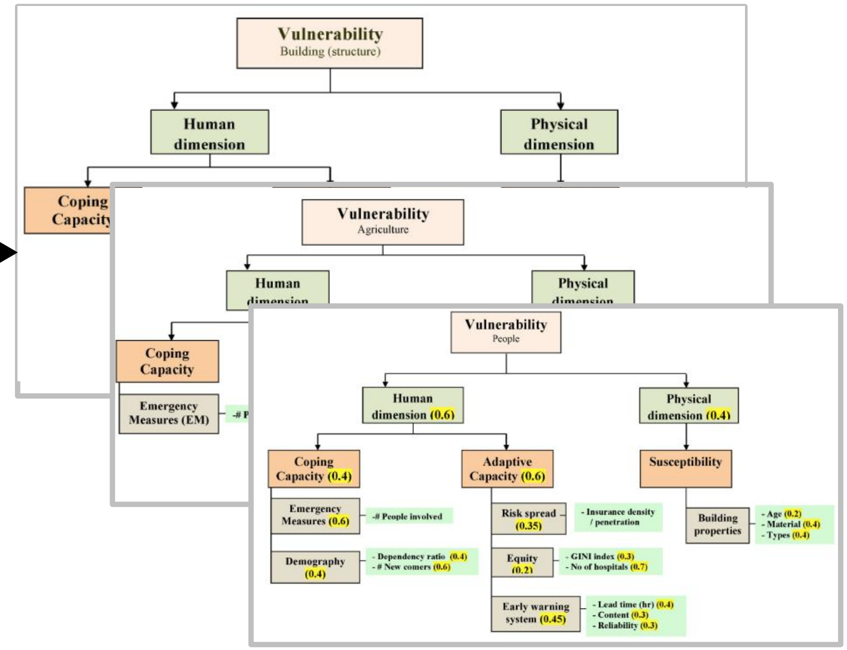
- CORINE
- MasterMap



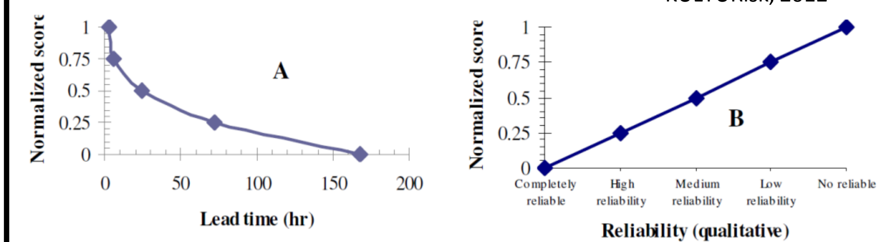
Number / area of receptors affected

S-RRA

KULTURisk, 2012



KULTURisk, 2012



Regional vulnerability to flood events

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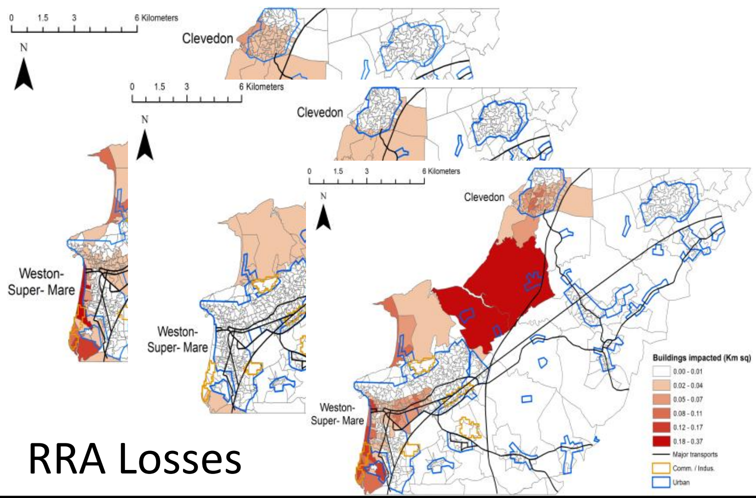
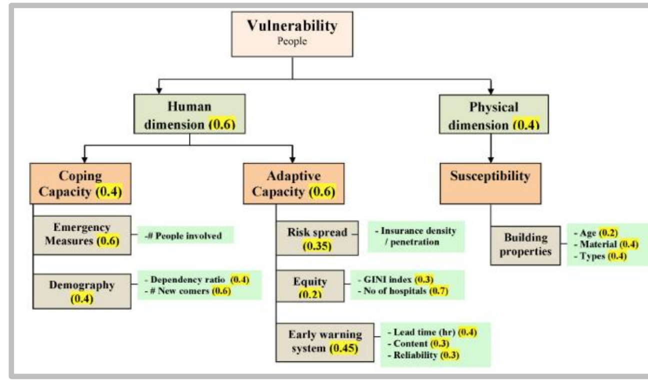
SERRA



RRA Losses

Scaled by:



Corresponding regional vulnerability scores

Financial loss

People:
- Losses: Deaths, Injuries, Trauma, Emergency services, Disruption
- Estimation: Value of Statistical Life

Buildings:
- Losses: Structure, Content and Business
- Estimation: Depth Damage curves, Per head revenue, Corporate tax rates, Duration of disruption, Salt water

Agriculture:
- Losses: Productivity
- Estimation: Financial returns per hectare

Risk by 2100

Risk (£ million / yr)	830mm SLR	1900mm SLR
	SERRA	SERRA
People	£0.74	£14.3
Buildings	£2.41	£13.6
Agriculture	£0.01	£0.02
Total	£3.15	£27.9

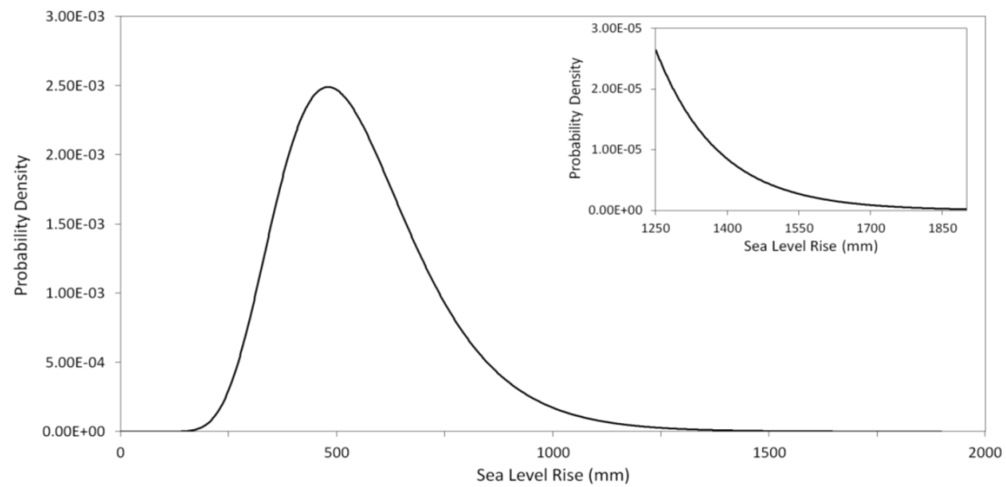
Probabilistic assessment of uncertainty: aim

- Assess the contribution to future coastal flood risk to the Somerset Levels from unlikely, yet plausible SLR scenarios

LISFLOOD-FP: Boundary conditions

Boundary Conditions:
Considered SLR by 2100 with a 1:200 yr event

- UKCIP high scenario 5% / 95% estimates
- Extended distribution to 1.9m (H++ *Lowe et al., 2009*)
- 1 mm sampling = 1900 scenarios



Use UKCIP as:

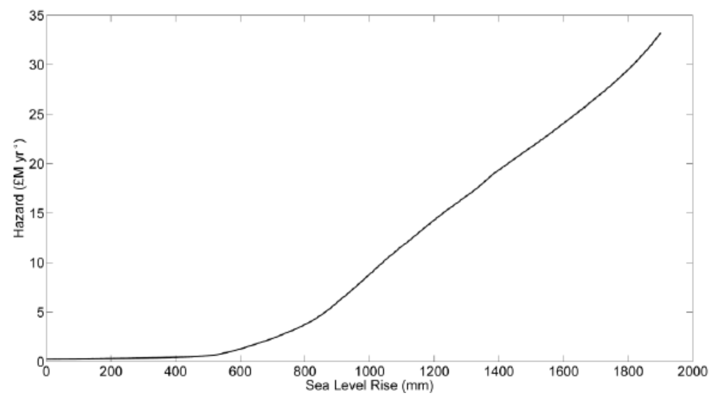
- commonly used in UK policy and research
- values are UK regional specific
- 1.9m SLR is the largest feasible (*Pfeffer et al., 2008*) – useful value to constrain the distribution

Assume no change in climate induced surge return period in the coming century, after *Lewis et al. (2011)*

Results: Flood hazard

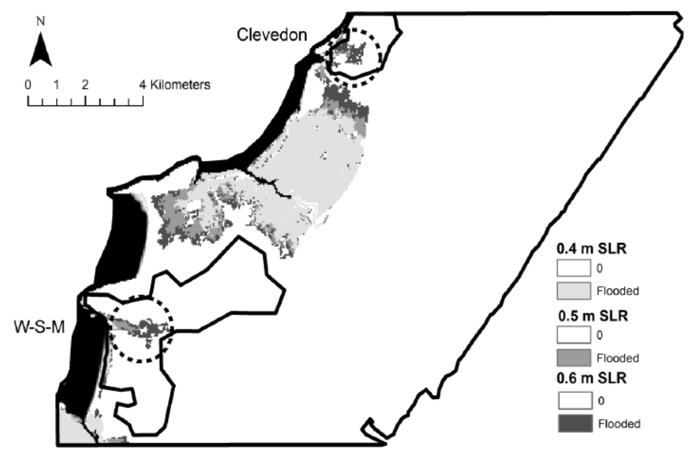
Unsurprisingly, hazard increases with SLR

- Slope increase at approx. 0.5m SLR
    - Flooding of urban areas
- Hazard increases once all areas flooded due to severity of flood



Costs likely to increase more rapidly from ~0.5m SLR

- Projections by UKCIP contain this value by 2070s, 2060s, 2050s in low, med, high scenarios
- Gives indication of time by which action is required

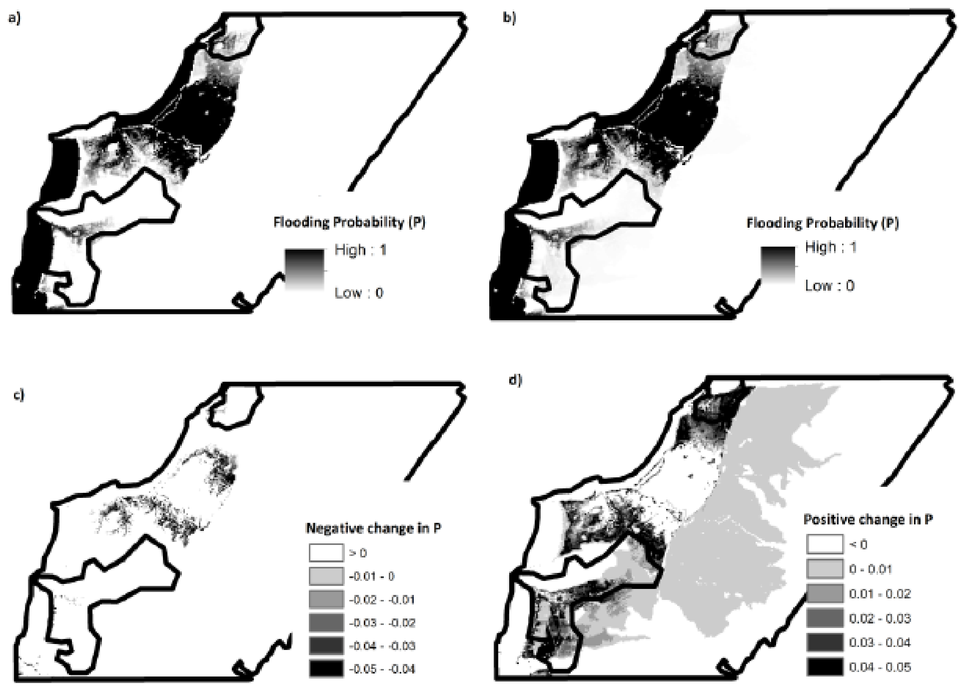


Results: Inundation Probability

Probability of inundation in each cell estimated using:

- 5 – 95% (*e.g. Purvis et al., 2008*)
- 0 – 100%

Low probability tails lead to chance of inundation to significant section of the domain previously considered dry



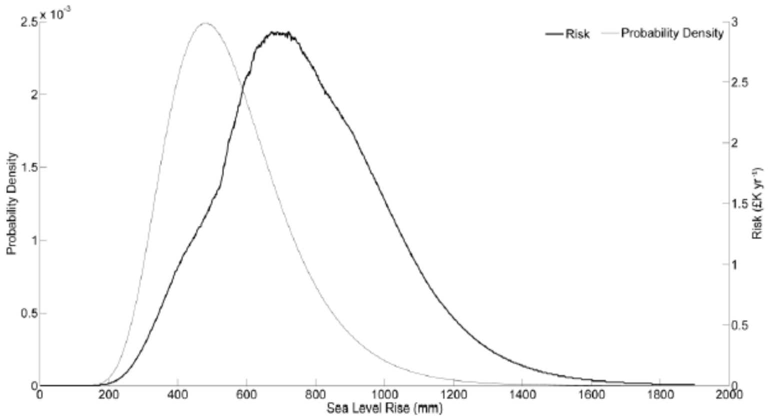
Images a. and b. – probability of inundation given 5-95% and 0-100% distributions respectively.
Images c. and d. – negative and positive change in probability, respectively.

Results: Future Risk

- Low probability scenarios contribute significantly to overall risk
    - Peak risk ~85th percentile
- 91-100 percentile scenarios contribute ~41% of risk
- Excluding low probability scenarios reduces estimated risk by 29.7%
- Current defence height guidelines (*DCLG, 2012*) do not cover top 4% of scenarios
    - £0.38m/yr residual

0.531m	5-95% range	Full distribution
£0.77 m (-53.6%)	£1.17m (-29.7%)	£1.66m

Risk (£m per yr) given estimation of future SLR



Portion of the probability distribution (percentile range)	Contribution to risk (%)
0 - 10%	2.47
11-20%	2.68
21-30%	2.95
31-40%	3.33
41-50%	3.94
51-60%	5.47
61-70%	8.17
71-80%	11.54
81-90%	18.02
91-100%	41.43

Risk (£m per yr) per mm SLR (top) and per 10% range (bottom)

Conclusions

- How future SLR is defined is vital in accurate risk assessment
- Low probability, high loss scenarios associated with rapid ice mass loss contribute significantly to the overall risk
- Excluding such scenarios leads to an underestimation of risk by 29.7% while a deterministic approach more than halves the expected risk
- Future research into causes, duration, and likelihood of rapid ice sheet mass loss is essential for mitigation policy