# Future flood extents: capturing the uncertainty associated with climate change

---


Lila Collet, Lindsay Beevers, Sophia Vauclin, Faye Entwistle

l.f.collet@hw.ac.uk



Rain, Rivers and Reservoirs 2016

Edinburgh, Scotland

28/09/2016

# Need for Uncertainty in Climate Change Impact Assessment

- Floods in the UK: causing over £5B of damage since 2000, up to £1B / year for flood defences maintenance

- UKCP09: national downscaled probabilistic dataset

- Flood Risk Assessment in the UK: deterministic approach

→ develop a statistical framework for uncertainty analysis in FRA

# Project aim

AIM:

Assess the impact of CC uncertainty on the 100-year RP flood peak and subsequent flood hazard in the UK

Structure:

- the **uncertainty** related to the **EV model** parameterisation (single CC ensemble member);
- the **uncertainty** related to the **climate model** parameterisation (with the 11 climate-change ensemble members);
- the combined EV/CM **uncertainty**;

- **Cascade** this combined uncertainty through to Flood Hazard on the River Don

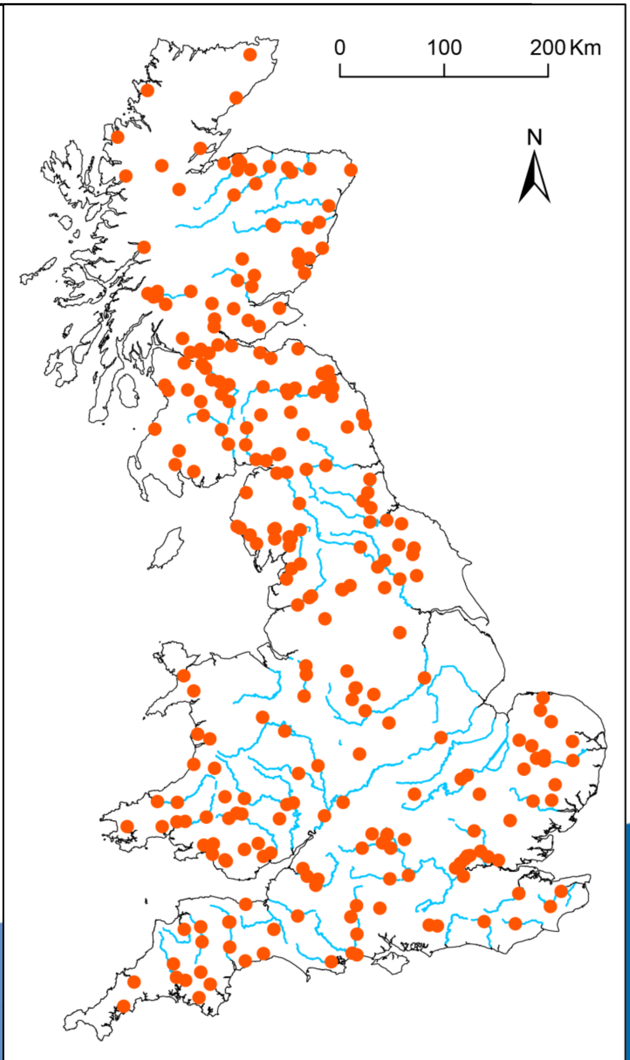
# Future Flow Hydrology

*Future Flow Hydrology* database (CEH):
simulated daily flow from 1958-2098 derived from a Regional CM (HadRM3-PPE-UK) for an 11-member ensemble.

→ Uncertainty in RCM parameterisation

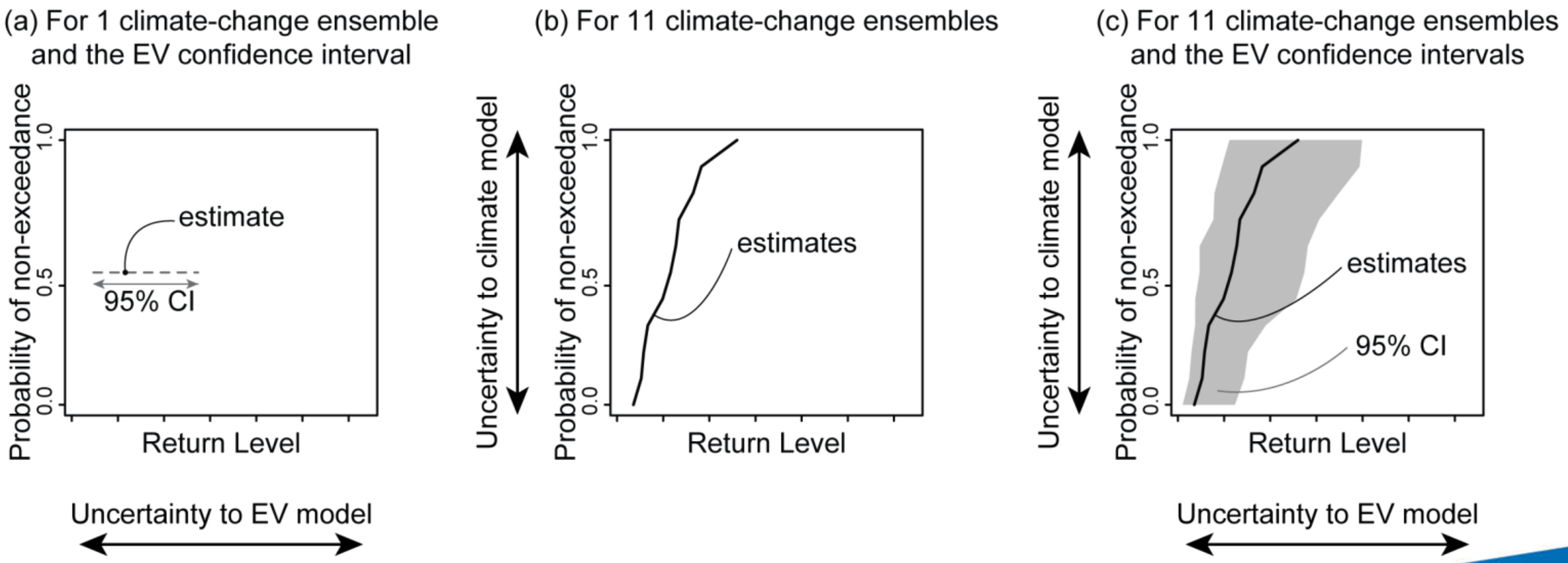
→ Result analysis on the baseline (1961-1990) and the 2080s (2069-2098)

271 gauging stations in the UK.



# Method

Automatically compute on each gauging station for GEV and GP with the MLE method:



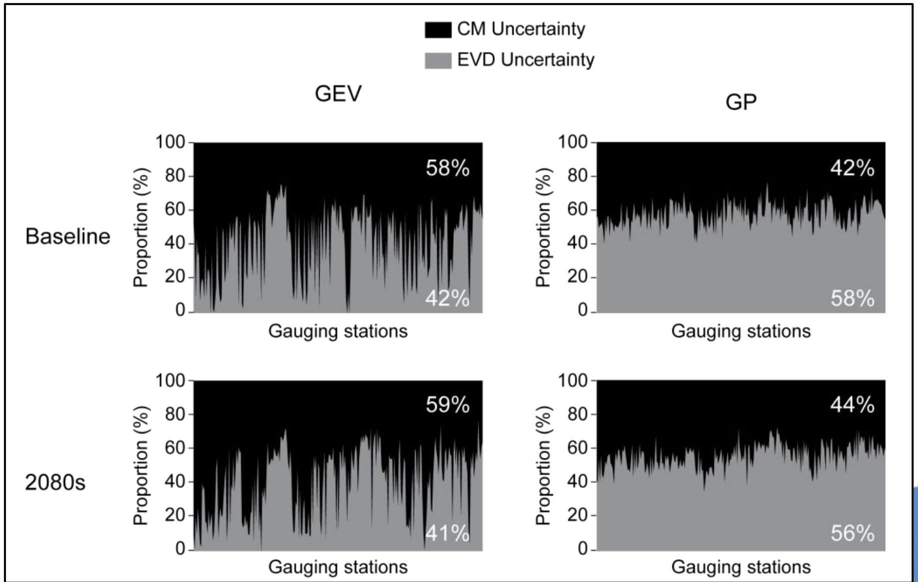
# Probabilistic runoff

Combined uncertainties:

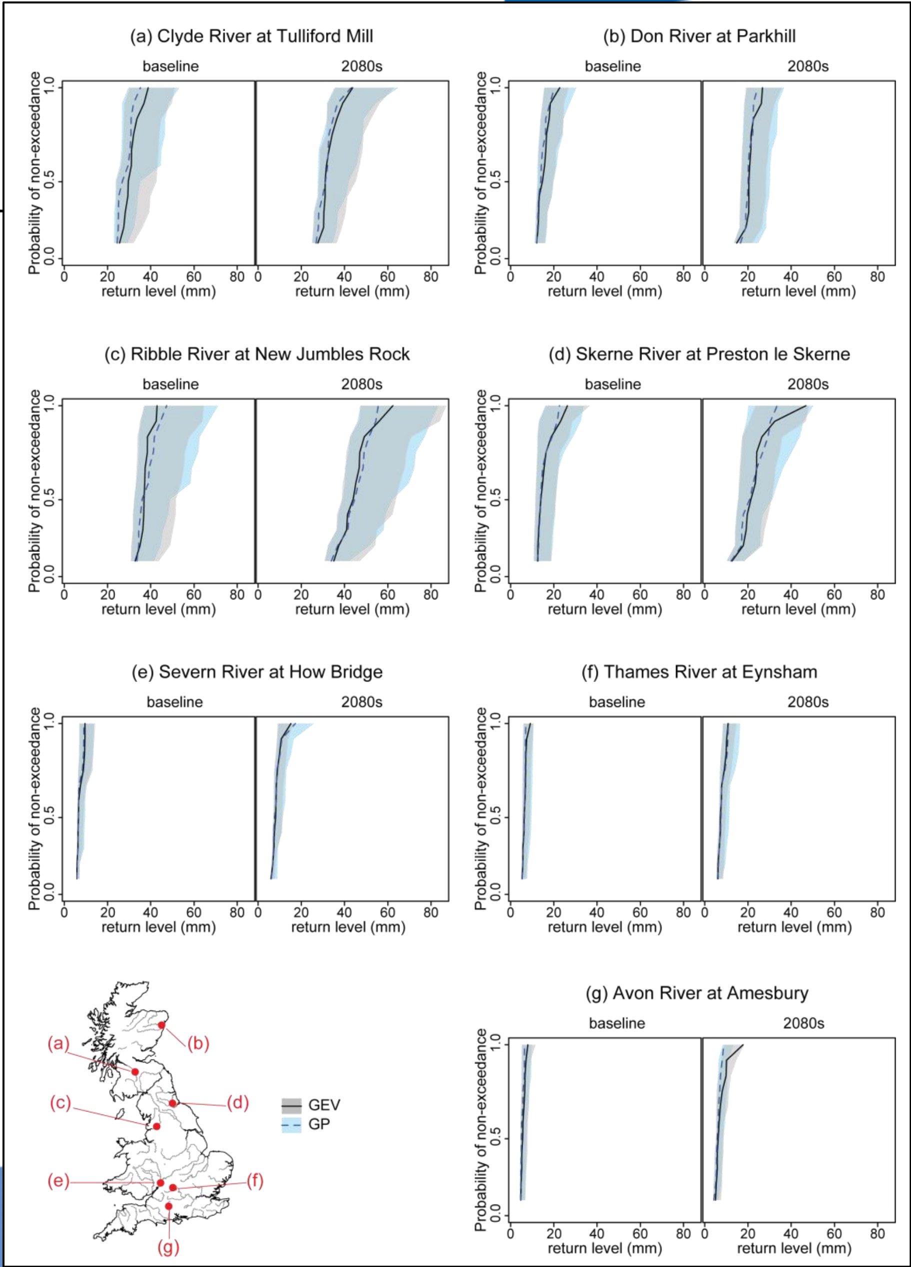
→ Highest 100-yr RP flood in the west

→ Increase in 100-yr RP flood from baseline to future

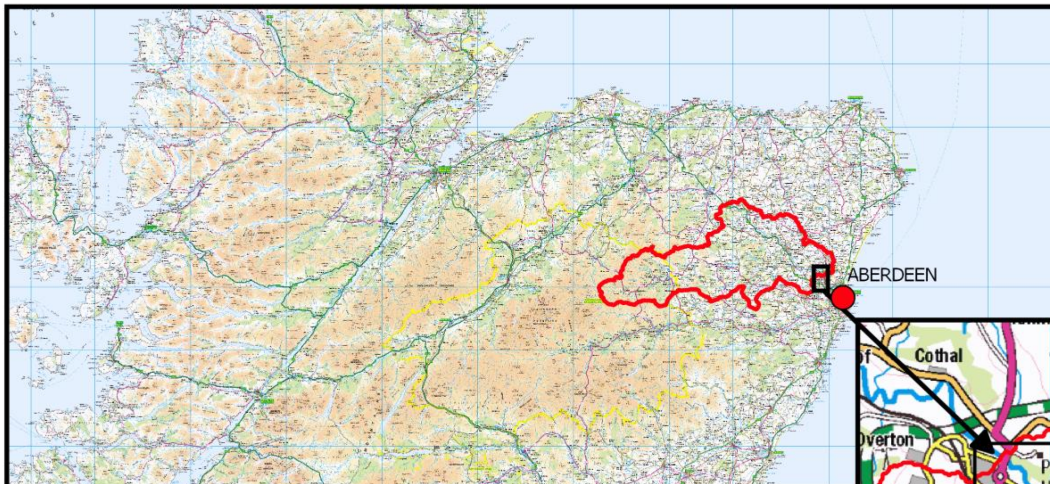
→ Increase in uncertainties from baseline to future

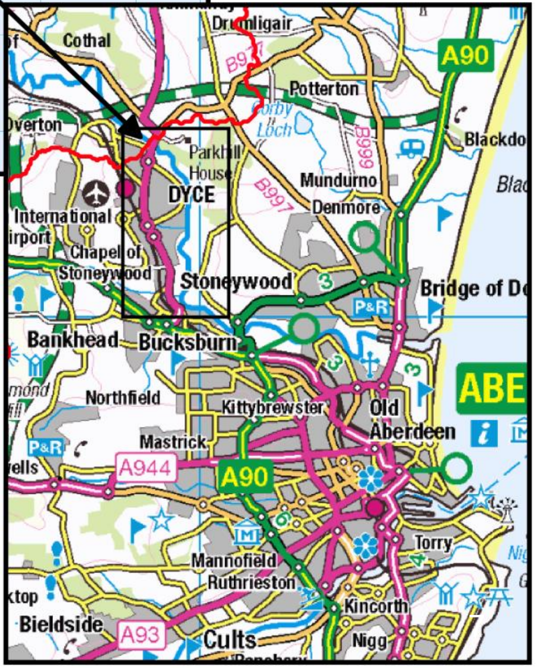



Collet et al. (subm.) Climate Change



# Case Study: The Don River




The Independent, 01/2016

# Lisflood (1D-2D model)

Simplification of the Shallow-Water equations (momentum and continuity)

$$\underbrace{\frac{\partial Q_x}{\partial t}}_{\text{local acceleration}} + \underbrace{\xcancel{\frac{\partial}{\partial x}\left(\frac{Q_x^2}{A}\right)}}_{\text{convective acceleration}} + \underbrace{gA\frac{\partial (h+z)}{\partial x}}_{\text{water slope}} + \underbrace{\frac{gn^2 Q_x^2}{R^{4/3}A}}_{\text{friction slope}} = 0,$$

1D: river channel

2D: floodplain

$$\frac{\partial A}{\partial x} + \frac{\partial Q_x}{\partial x} = 0,$$

Model built on a 20m- grid for a 5-km river reach with SEPA data (Lidar digital terrain model, Manning's n)

Calibration/Validation statistics: F=D/(B+C+D)

| | Observed Dry | Observed Wet |
|---|---|---|
| Model Dry | A = Dry/dry | B = Predicted dry but observed wet |
| Model Wet | C= Predicted wet but observed dry | D = Wet/wet |

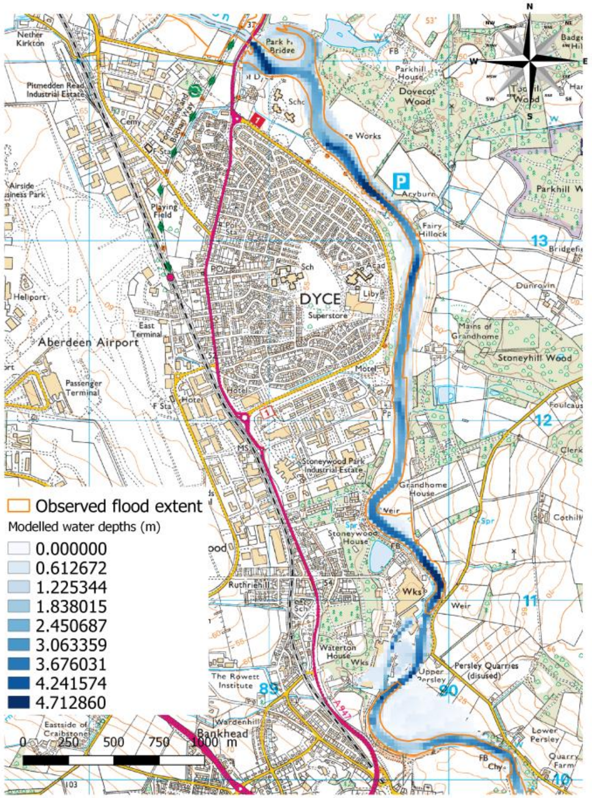
# Lisflood model

## Calibration Validation

| 100-yr RP | 200-yr RP | 1000-yr RP |
|---|---|---|
| F=0.54 | F=0.74 | F=0.76 |

River Don (Abderdeen)

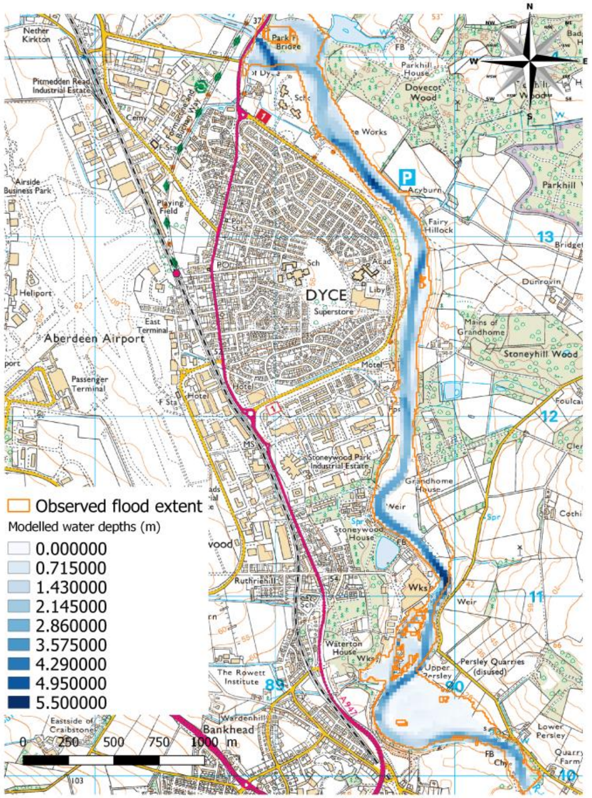
Qmax = 454 m3/s - Return Period ~ 100 years - Fstat = 0.53




Sources: SEPA, Digimap Edina, Future flow Database

River Don (Abderdeen)

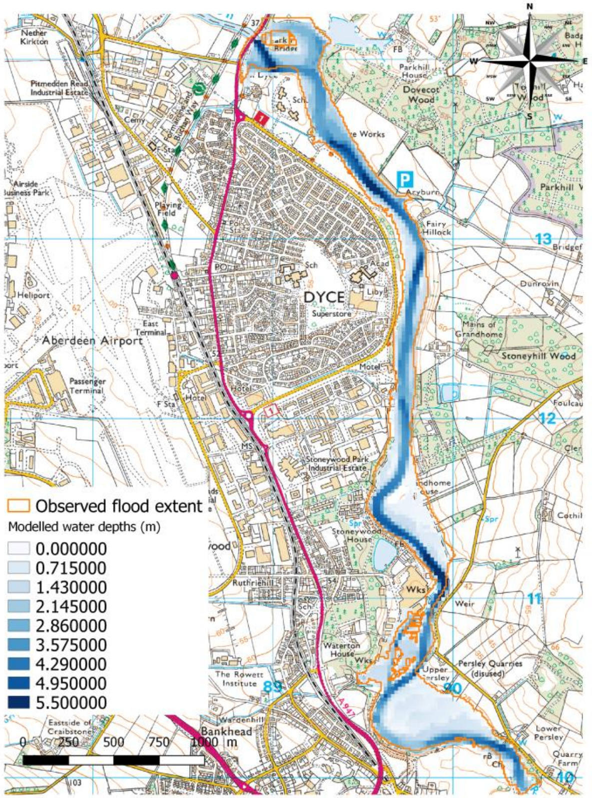
Qmax = 572.4 m3/s - Return Period = 200 years - Fstat = 0.74




Sources: SEPA, Digimap Edina, Future flow Database

River Don (Abderdeen)

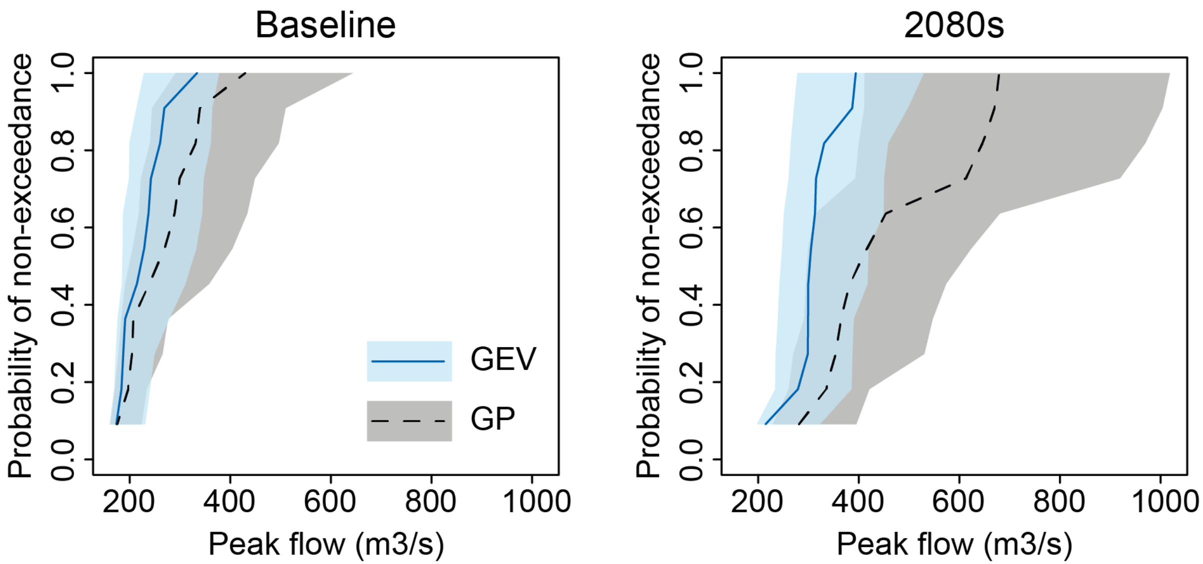
Qmax = 707.4 m3/s - Return Period = 1000 years - Fstat = 0.76

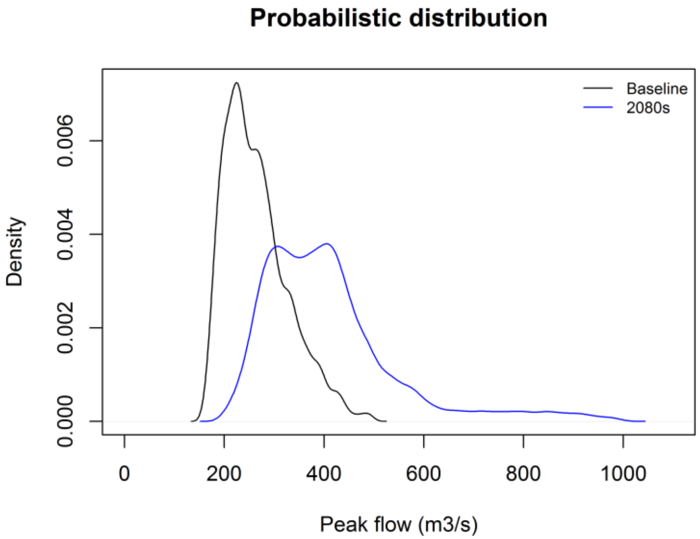



Sources: SEPA, Digimap Edina, Future flow Database

# Probabilistic Flood Mapping: Monte Carlo Sampling

→10 000 samples of peak flow



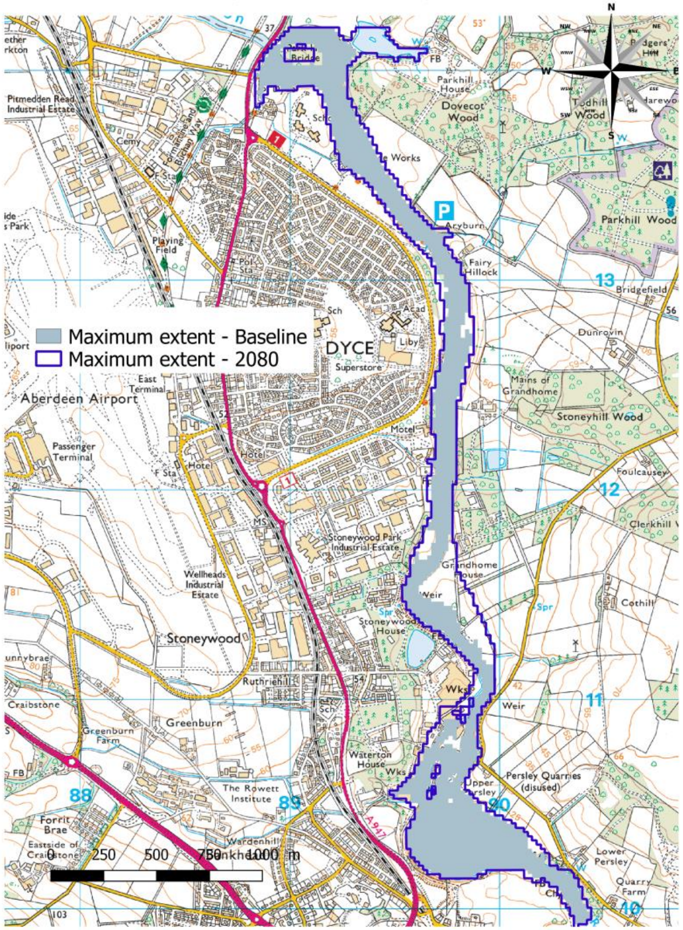

| | Baseline | 2080 | % increase |
|---|---|---|---|
| Mean $Q_p$ ($m^3/s$) | 265.07 | 408.22 | + 54.0% |
| Max $Q_p$ ($m^3/s$) | 498.98 | 996.53 | + 99.9% |

# Probabilistic Flood Maps

Percentage increase in flood extent from the baseline to the 2080s

| % extent | % increase |
|---|---|
| 100% | 22.5% |
| 95% | 21.6% |
| 75% | 27.0% |

River Don (Abderdeen) - Maximum extents from the probabilistic maps




Sources: SEPA, Digimap Edina, Future flow Database

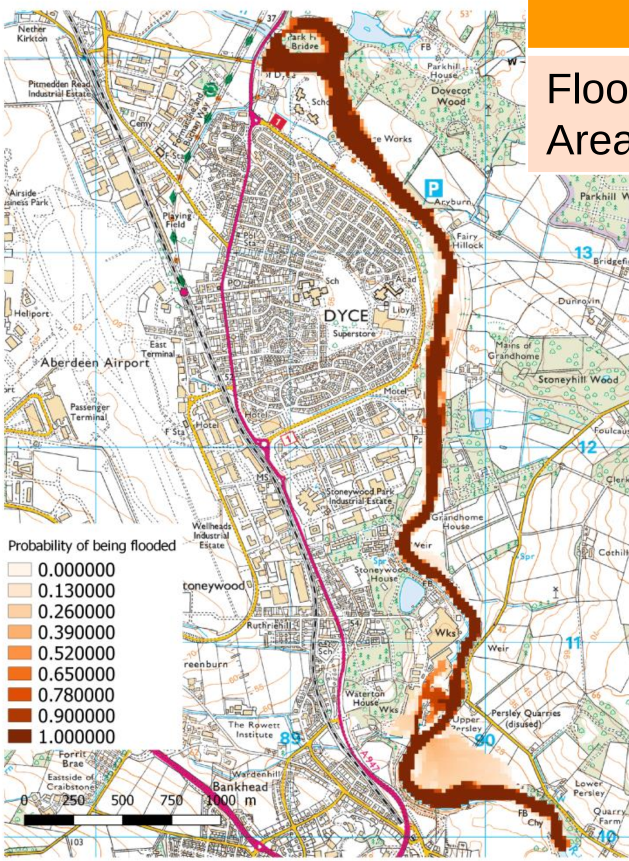
# Uncertainty Analysis on the baseline

| | CM U | Total U | Change |
|---|---|---|---|
| Flooded Area ($km^2$) | 0.62 | 0.73 | +18% |

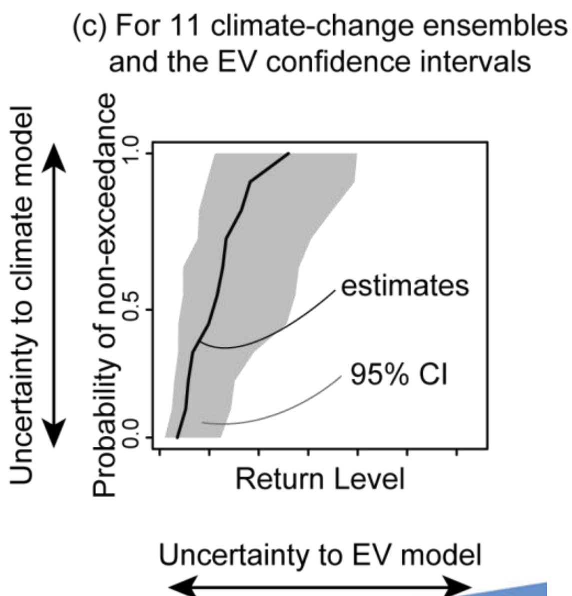
Total uncertainty

River Don (Abderdeen)

Probabilistic map - Baseline



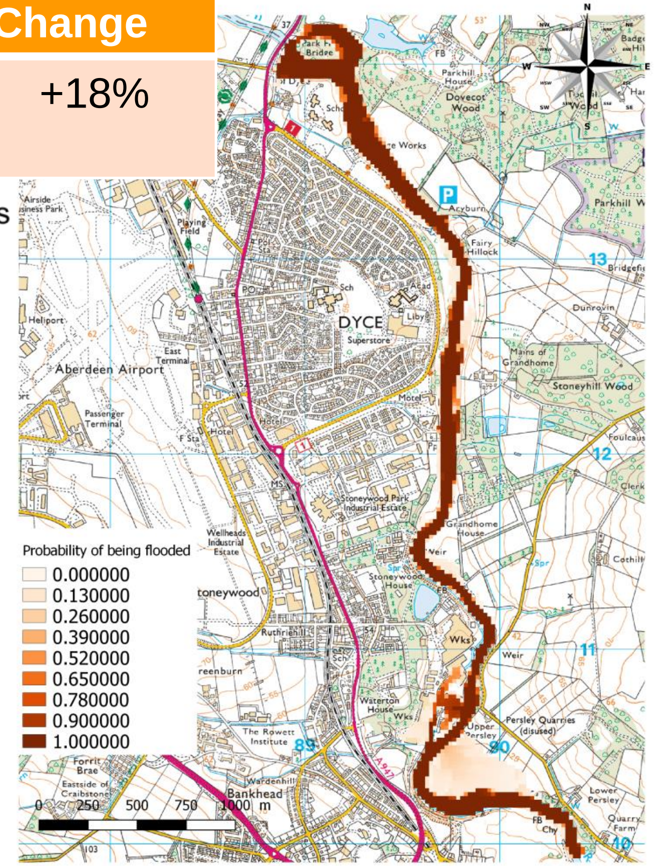

Sources: SEPA, Digimap Edina, Future flow Database




Climate Model Uncertainty

River Don (Abderdeen)

Probabilistic map - Baseline - CMU sampling



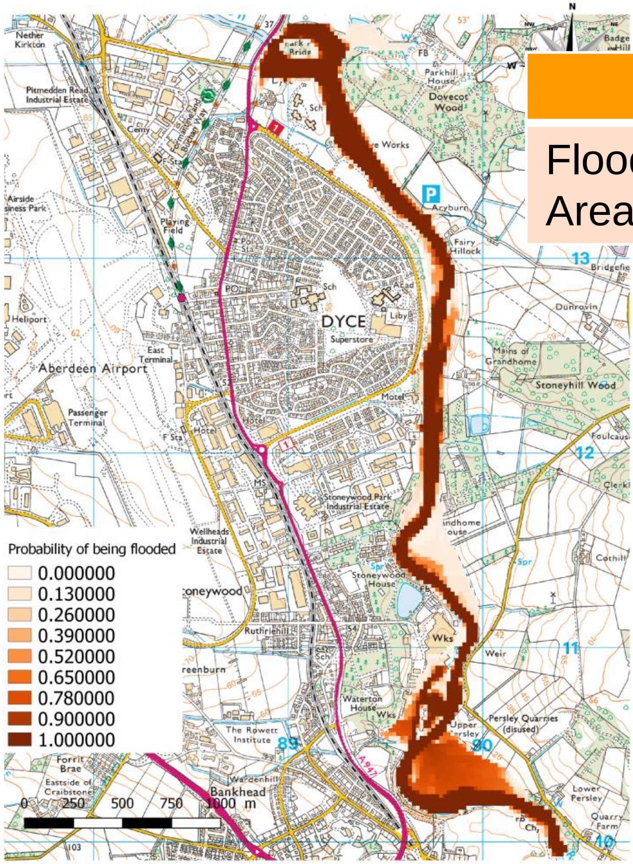

Sources: SEPA, Digimap Edina, Future flow Database

# Uncertainty Analysis on the 2080s

## Total uncertainty

River Don (Abderdeen)

Probabilistic map - Future



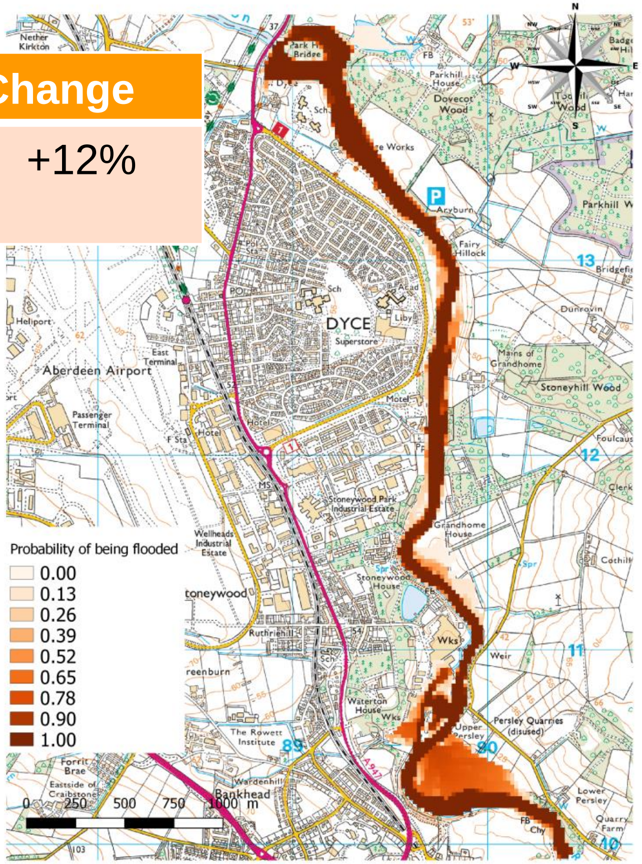

Sources: SEPA, Digimap Edina, Future flow Database

| | CM U | Total U | Change |
|---|---|---|---|
| Flooded Area ($km^2$) | 0.84 | 0.94 | +12% |

## Climate Model Uncertainty

River Don (Abderdeen)

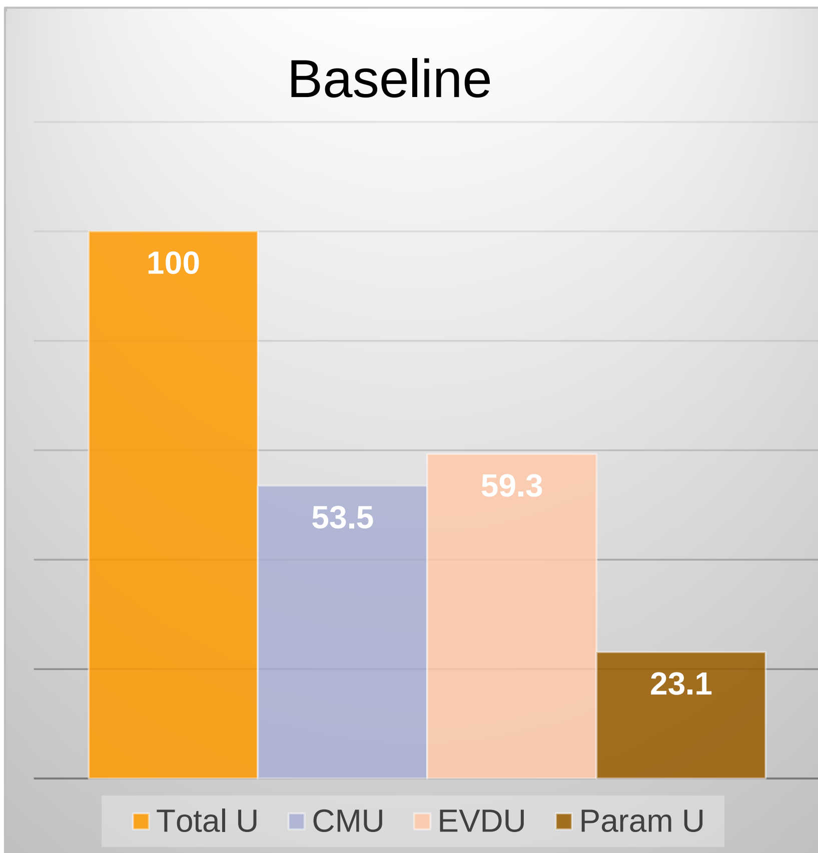
Probabilstic map - Future - CMU

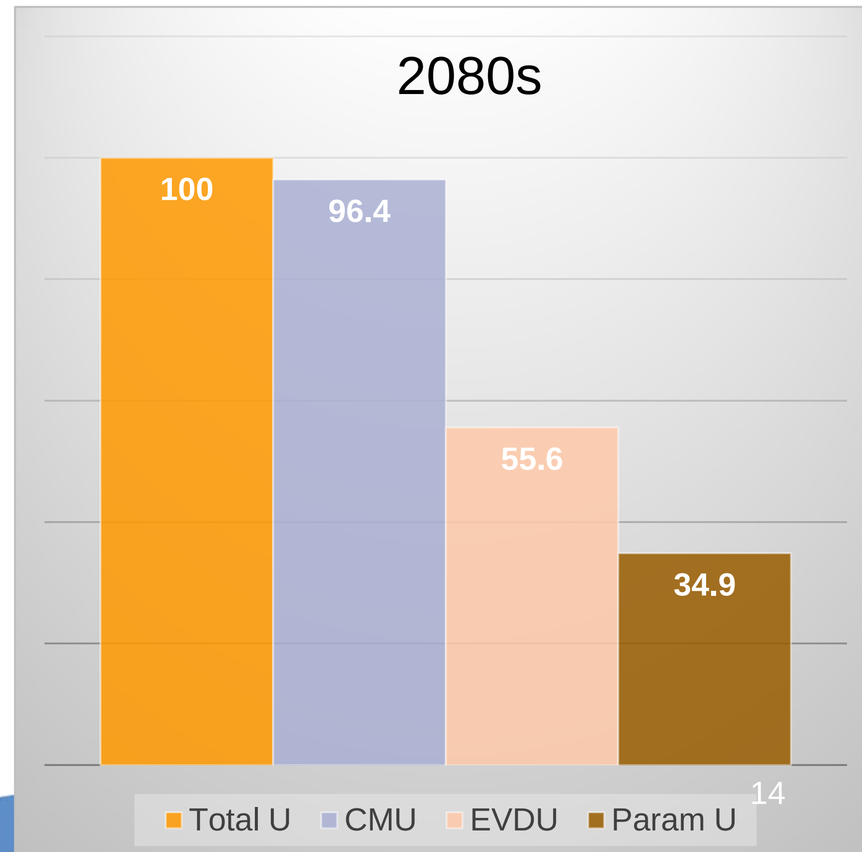



Sources: SEPA, Digimap Edina, Future flow Database

# Change in different sources of uncertainty

Ratios of standard deviation for the flood extent distribution



# Conclusions & Perspectives

- Lisflood useful for full Monte Carlo approach
- River Don: Increase in peak flow from baseline to 2080s:
  Mean: +50%, Standard deviation: +100%
- River Don: Increase in floodplain from baseline to 2080s:
  Mean: +20%, Standard deviation: +30%
- Application to consultants'/decision-makers' needs

# Thank you

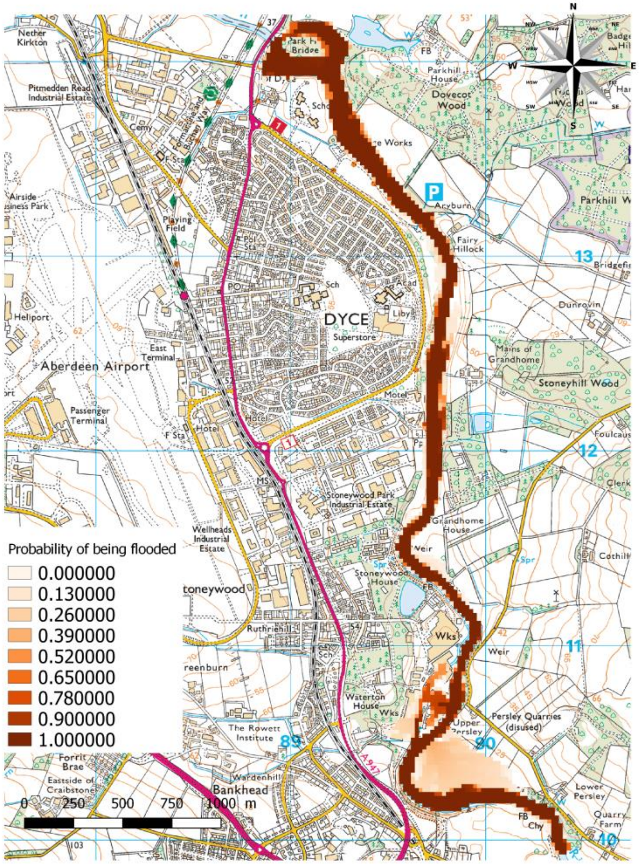
Acknowledgements: SEPA Scottish Environment Protection Agency data and hydrology

# Probabilistic Flood Maps

Baseline

River Don (Abderdeen)

Probabilistic map - Baseline

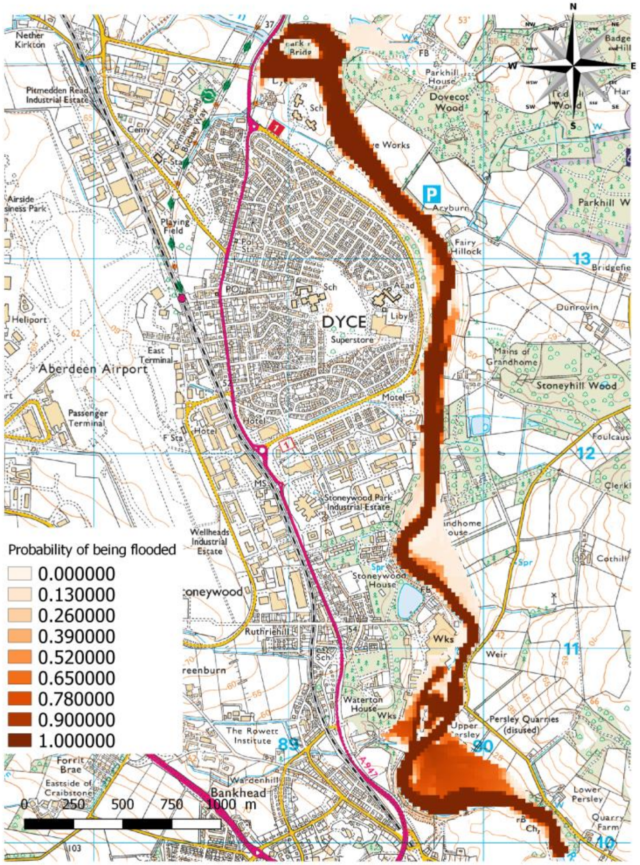



Sources: SEPA, Digimap Edina, Future flow Database

2080s

River Don (Abderdeen)

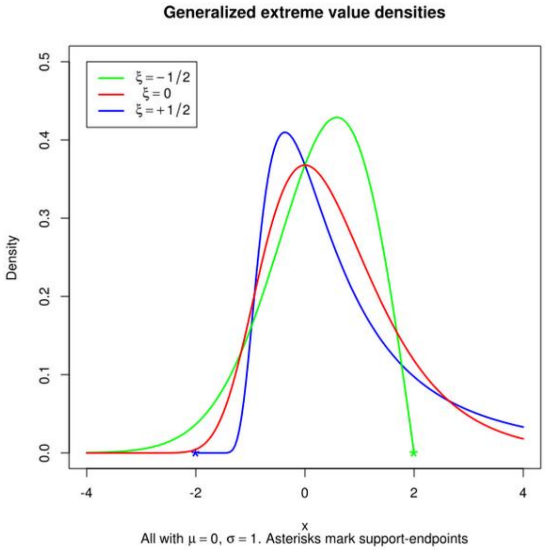
Probabilistic map - Future




Sources: SEPA, Digimap Edina, Future flow Database

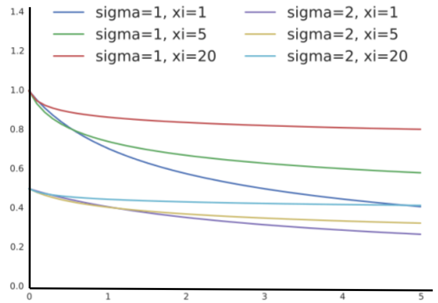
# Extreme Value Theory

Hypothesis: data series (BM or POT) are *independent and identically distributed* (idd) random variables.




GEV: $$G(z) = \exp\left\{-\left[1+\xi\left(\frac{z-\mu}{\sigma}\right)\right]^{-1/\xi}\right\}$$

GP: $$H(y) = 1-\left(1+\xi\frac{y}{\sigma}\right)^{-1/\xi}$$




$\mu$: location parameter, $\sigma>0$: scale parameter, $\xi$: shape parameter

z: BM data, y: POT data