RAIN Workshop:
Climate change and weather modelling
Dublin, Ireland
9 November 2015

Extreme river discharges and storm surges in Europe

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Fot. D.P.

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This project is funded by the European Union

Extreme hydrological events

River floods

Coastal floods

Source: Barredo (2007) Nat. Hazards 42, 125–148

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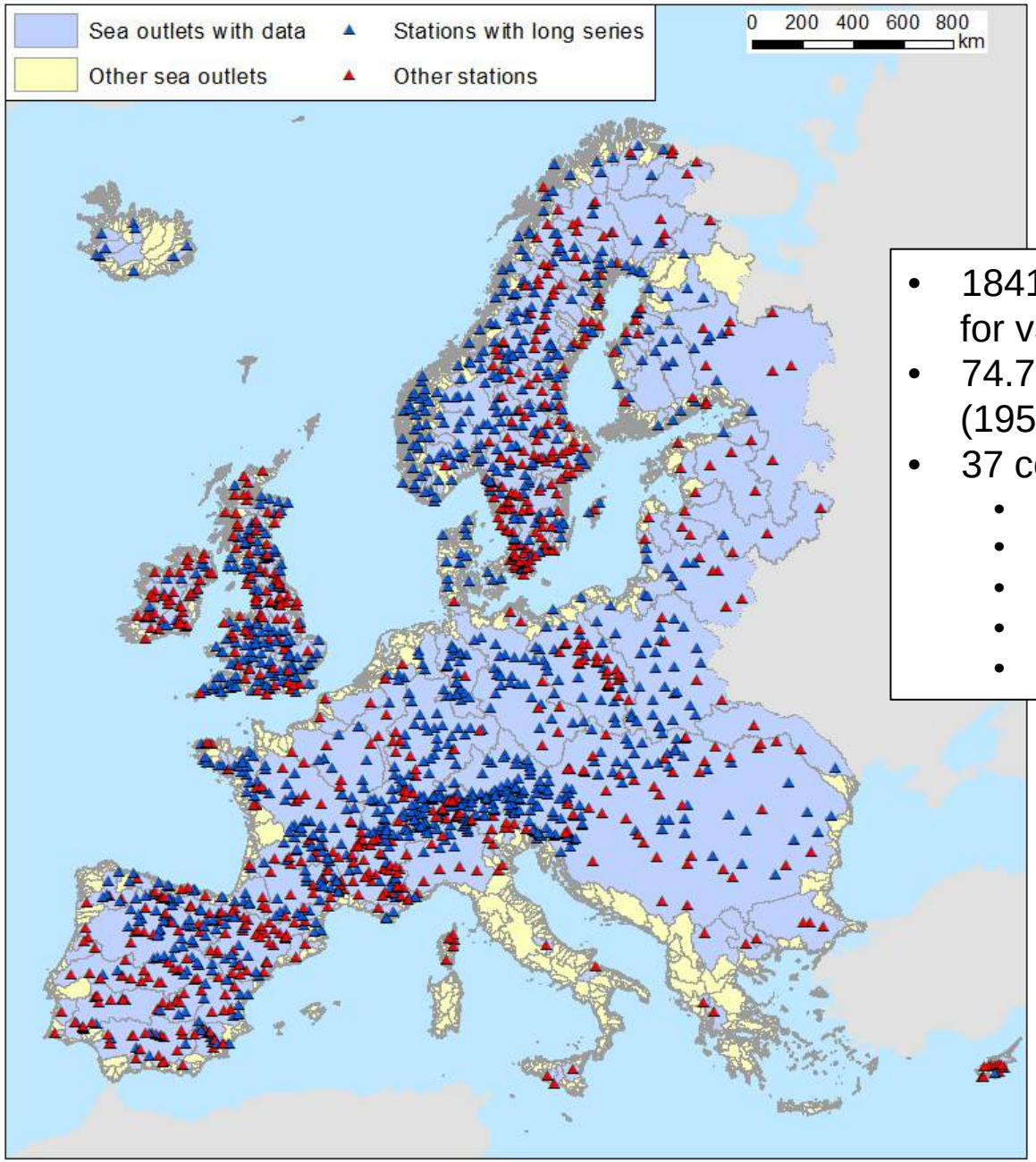
RAIN PROJECT

Rivers

Source: Vogt et al. (2010) “Main Rivers of Europe”, http://ccm.jrc.ec.europa.eu/

TU Delft

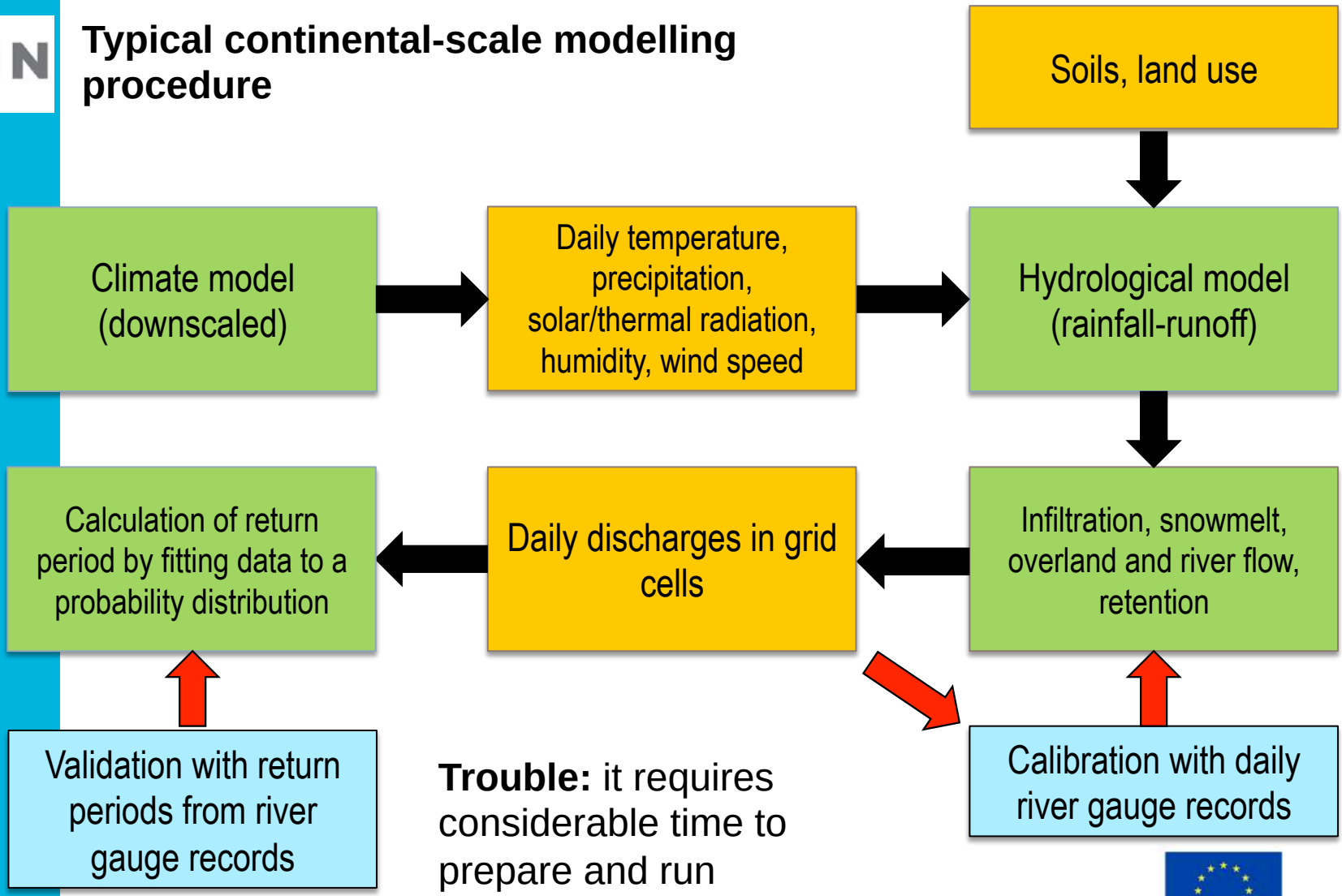
River discharge measurement stations



- 1841 stations (1125 for validation)
- 74.757 station-years (1950-2005)
- 37 countries
  - France 14%
  - Spain 14%
  - Sweden 14%
  - UK 12%
  - Germany 9%

Calculating river discharges

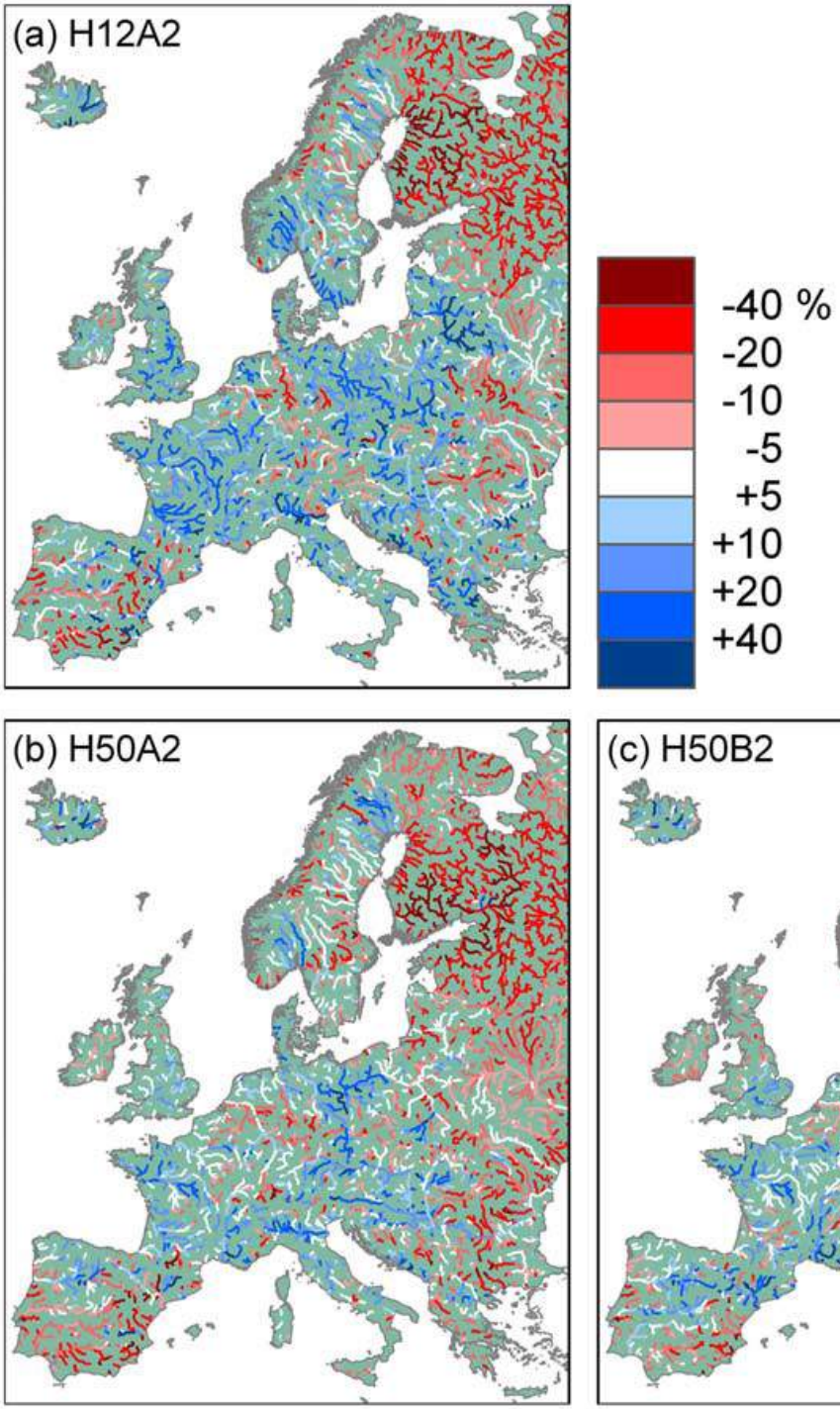
Typical continental-scale modelling procedure



Trouble: it requires considerable time to prepare and run

This project is funded by the European Union

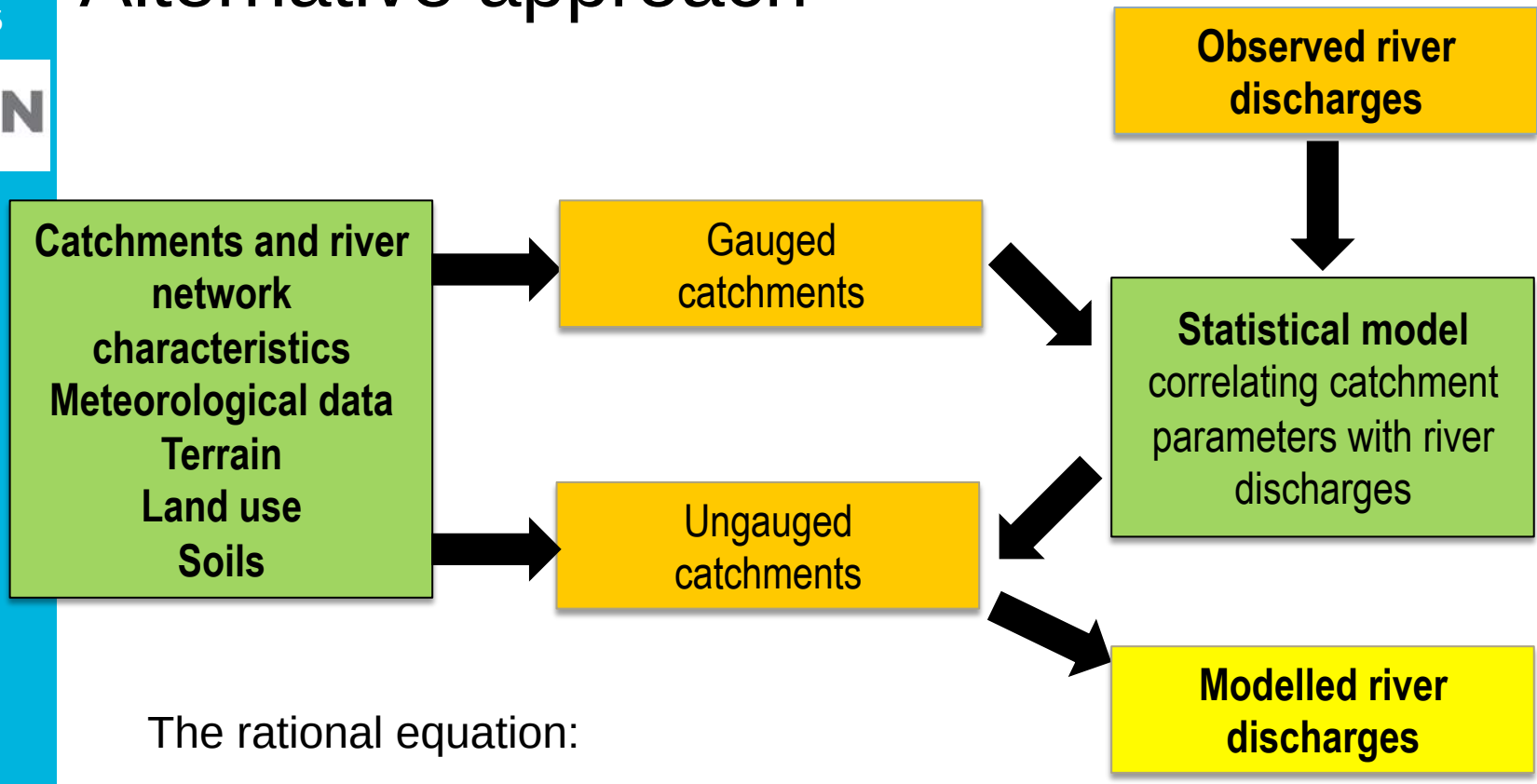
Calculating river discharges



Relative change in 100-year discharge (2071-2100 to 1961-90)

Source: Dankers and Feyen (2008) J. Geophys. Res. 113:D19105

Alternative approach



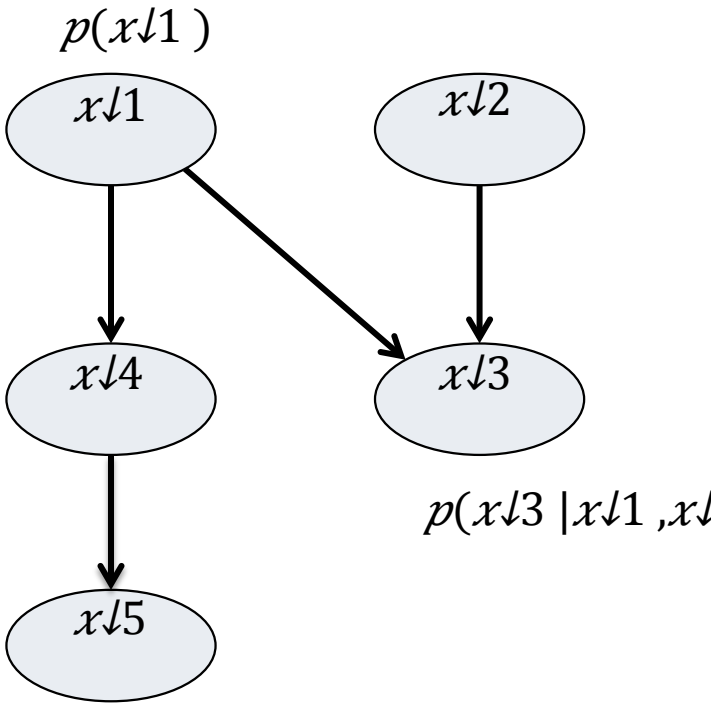
The rational equation:

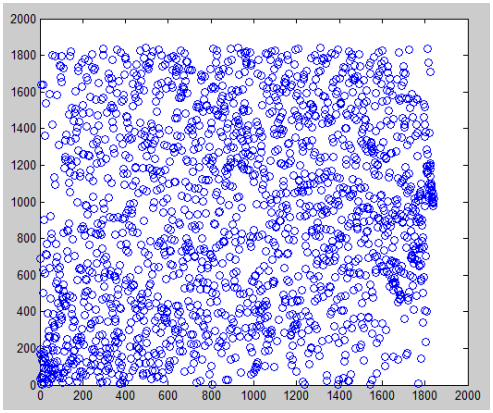
$$Q = c \times i \times A$$

Q = peak discharge
c = runoff coefficient
i = rainfall intensity
A = drainage area

Our approach: Bayesian Networks

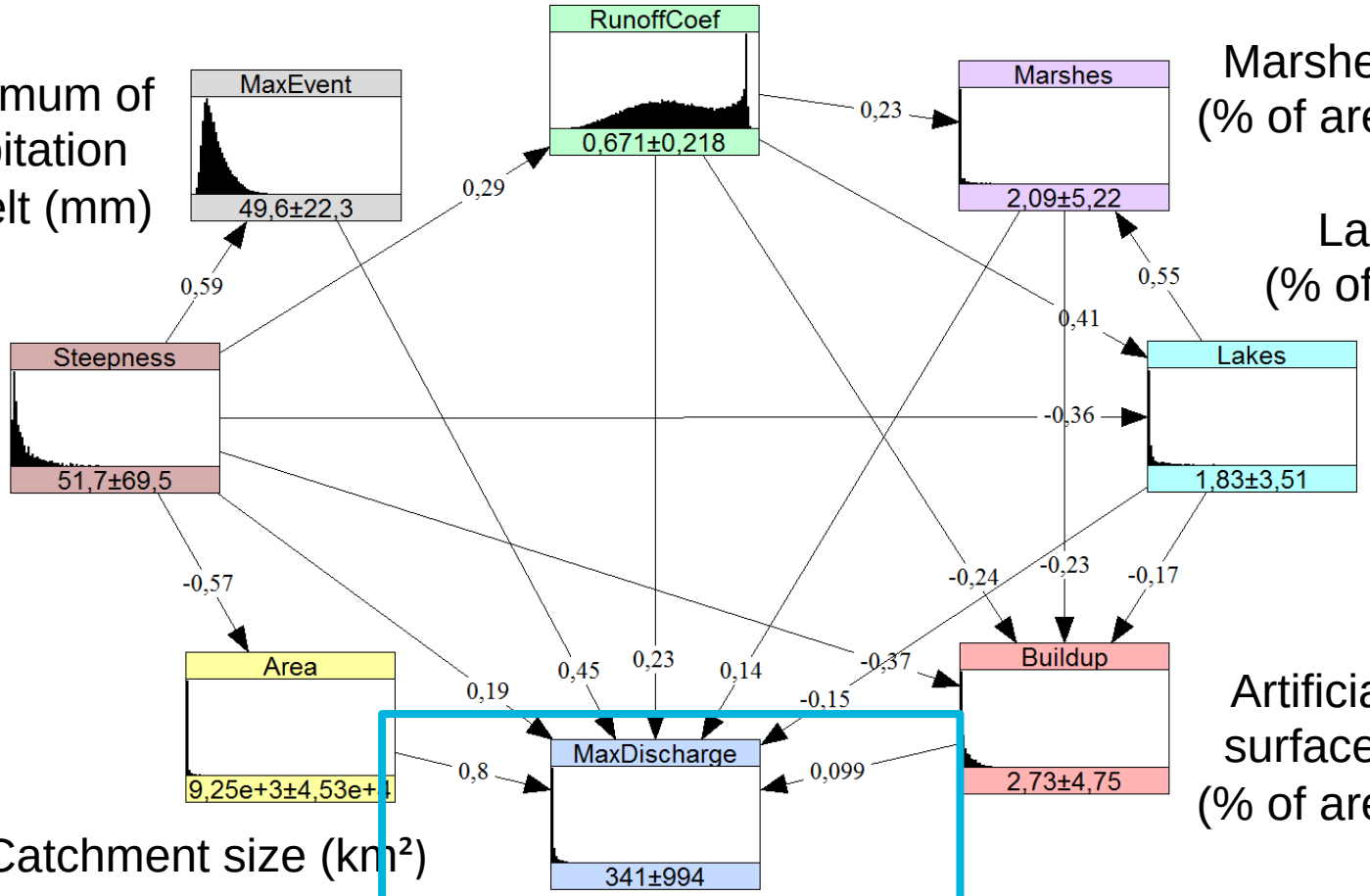
- A probabilistic graphical model that encodes a set of random variables and their probabilistic interdependencies:
  - Nodes represent variables (river discharge and catchment parameters)
  - Links represent child-to-parent dependencies
  - The conditional probability distribution describes each node conditioned on its parents (in this case: normal/Gaussian copulas)





The model

Annual maximum of daily total runoff divided by *MaxEvent*



Annual maximum of daily precipitation and snowmelt (mm)

Marshes (% of area)

Lakes (% of area)

Terrain steepness (‰)

Artificial surfaces (% of area)

Catchment size (km²)

Annual maximum of daily discharge (m³/s)

The model

Annual maximum of daily total runoff divided by *MaxEvent*

Annual maximum of daily precipitation and snowmelt (mm)

Terrain steepness (‰)

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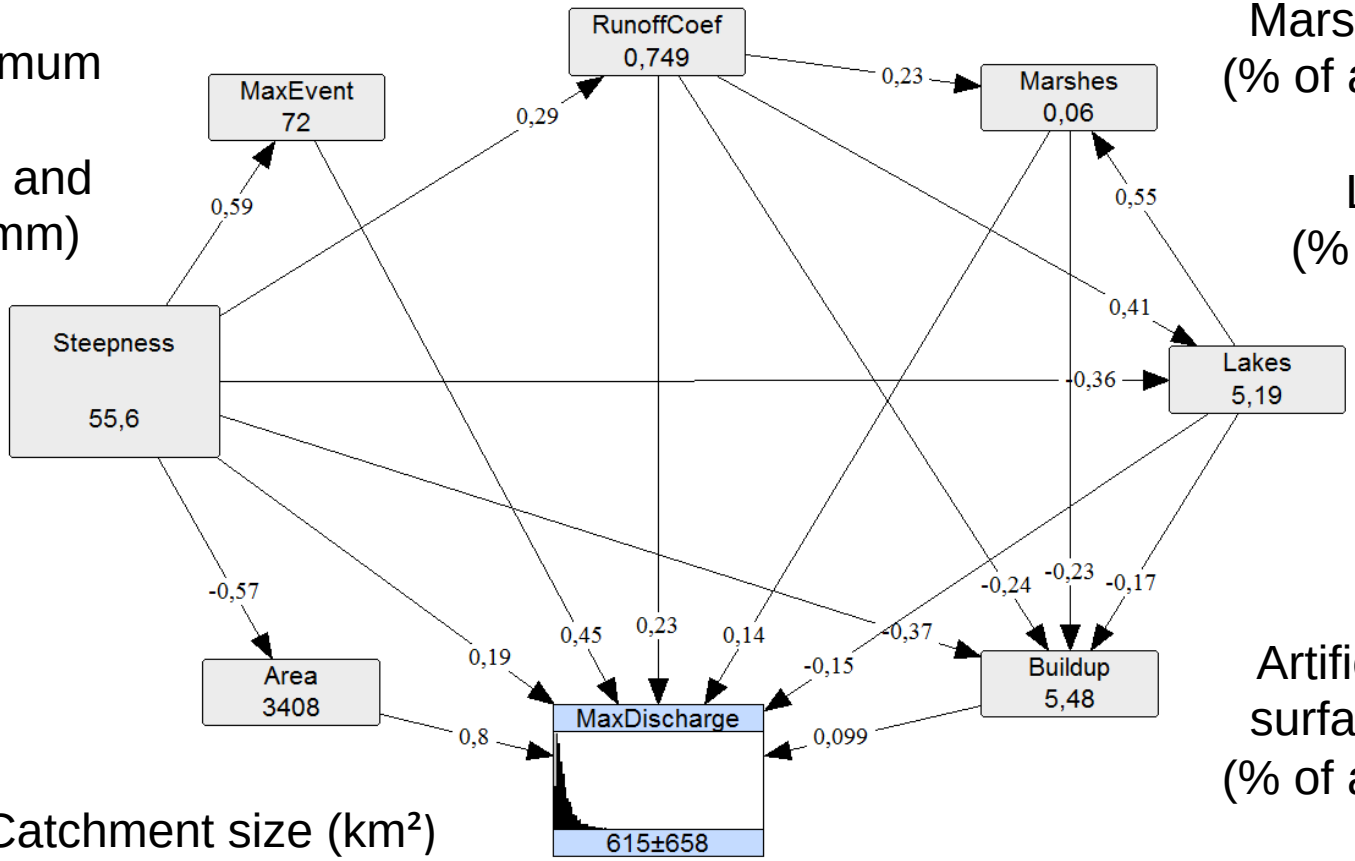


Catchment size (km²)

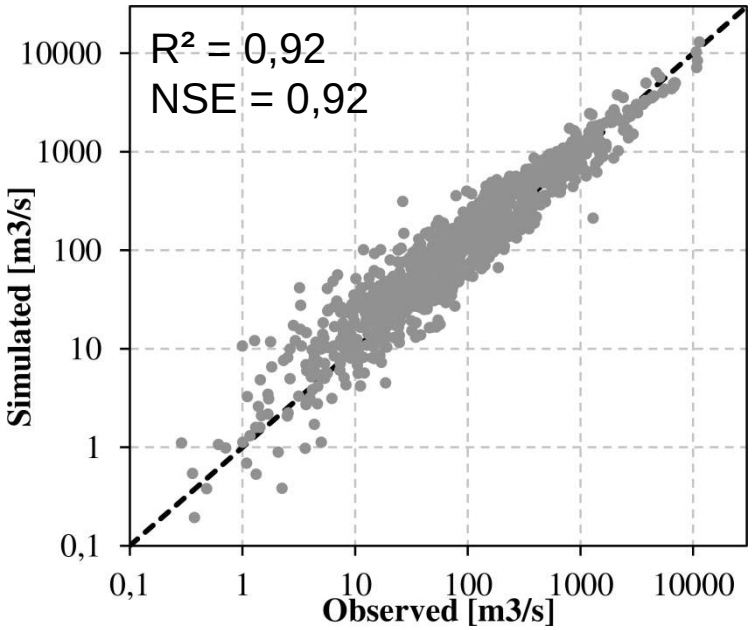
Annual maximum of daily discharge (m³/s)
Observed: 783 m³/s

Mellingen (CH), Reuss river, 2005

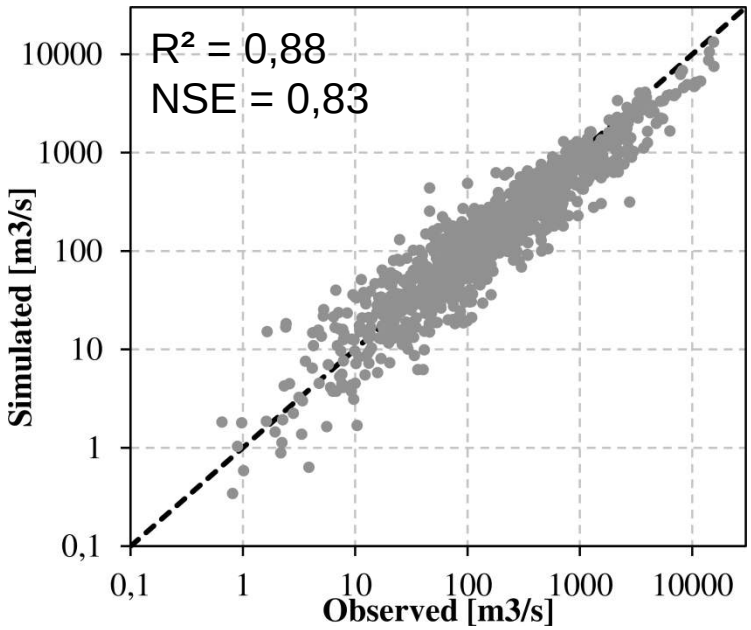
Validation

1125 stations, 30-year periods

- Average annual maxima



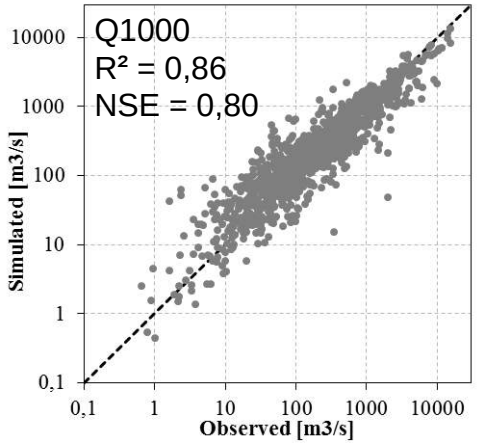
- Annual maxima with 100-year return period

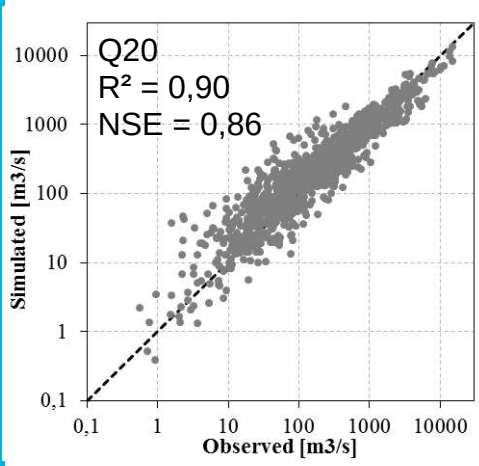


Validation

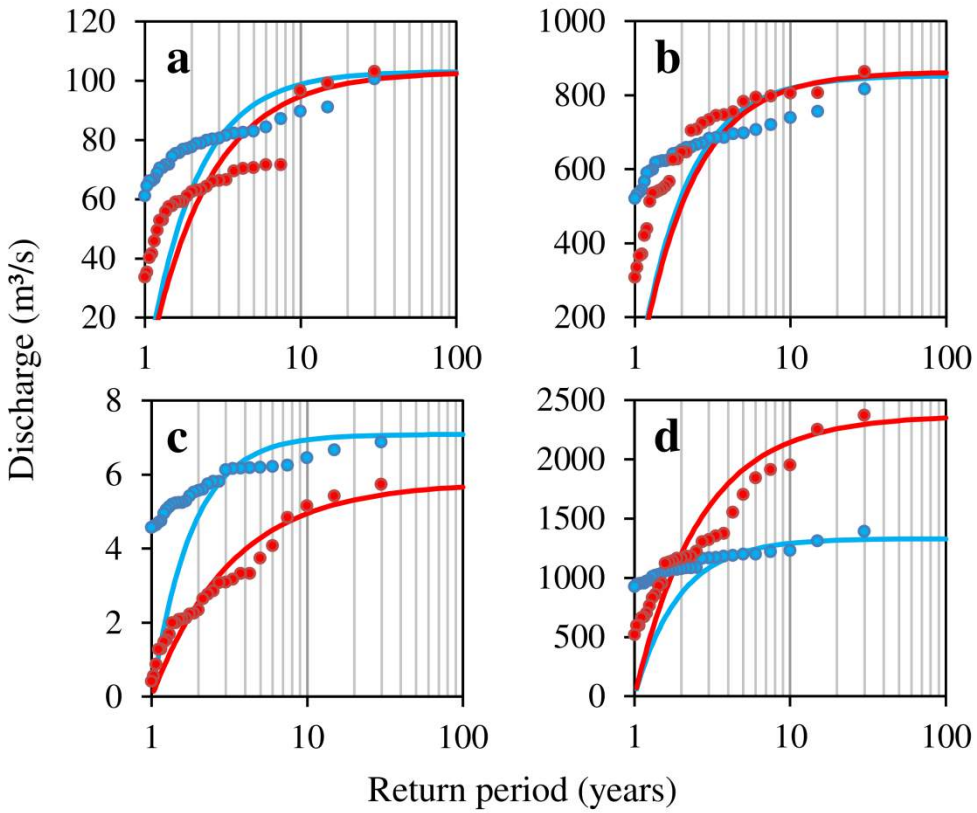
1125 stations, 30-year periods

- Return periods





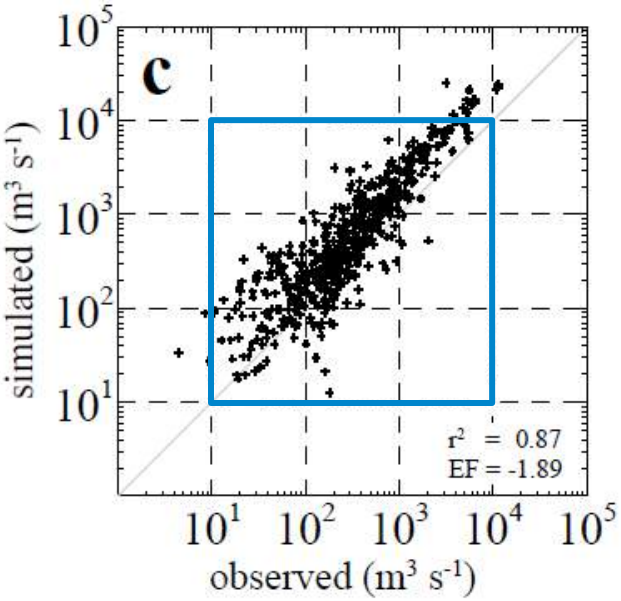
Simulated • and observed • discharge



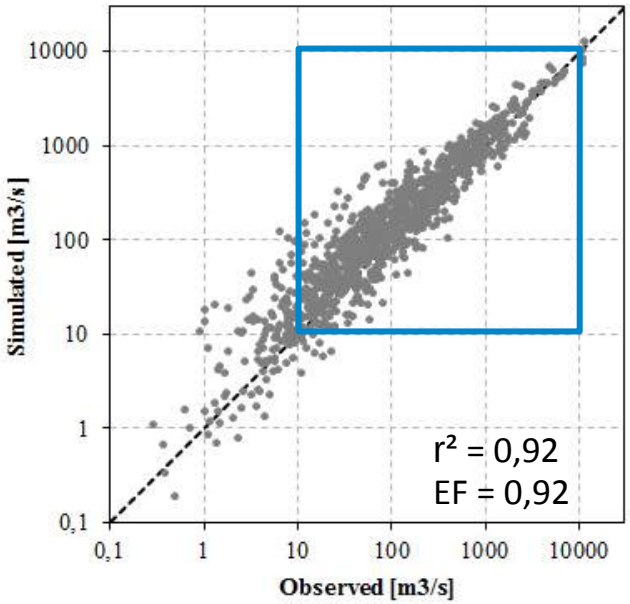
Comparison

Average annual maxima

- Rojas et al. (2011), 1961-1990, 552 stations (without bias correction)



- This study, 1125 stations



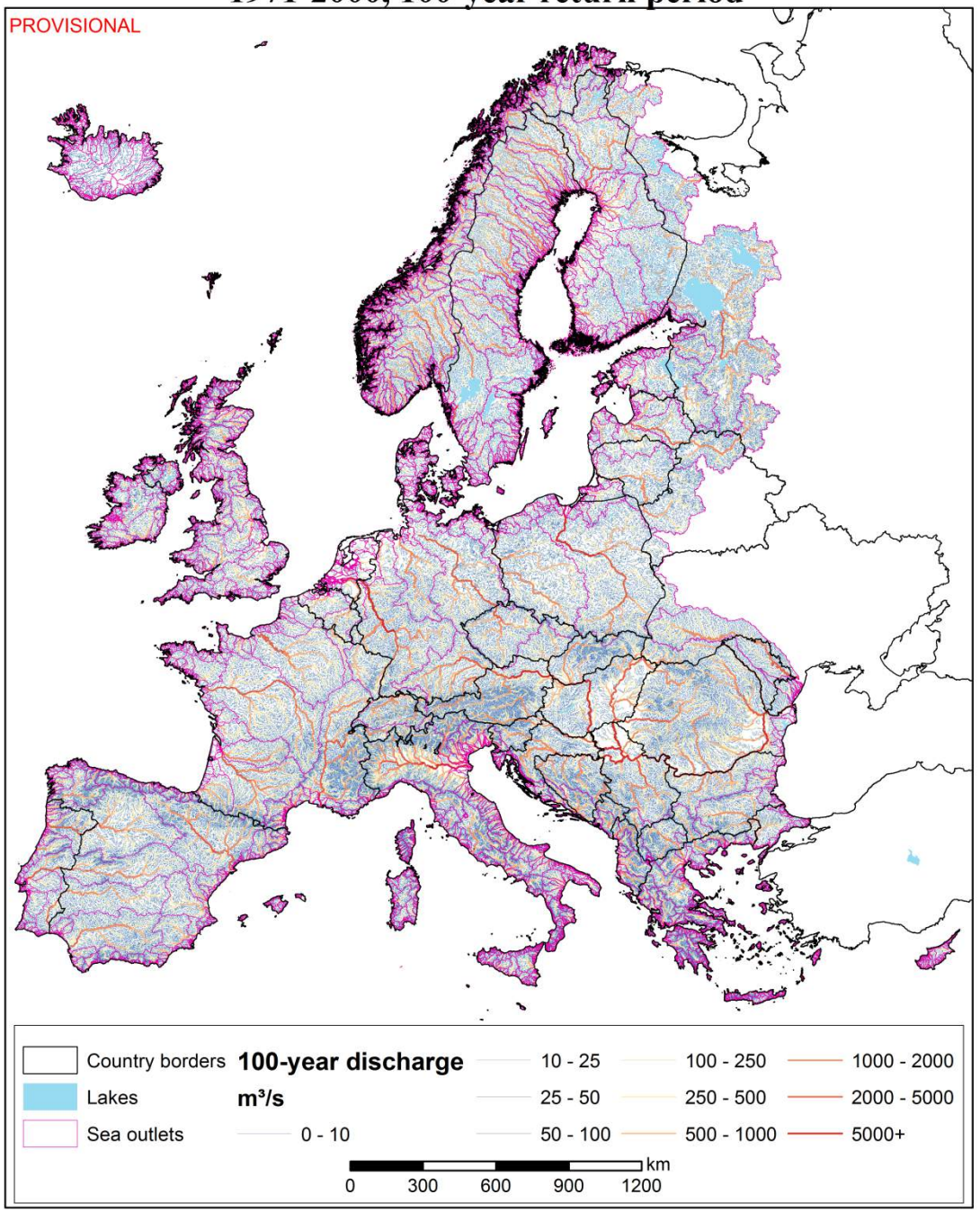
Source: Rojas et al. (2011) Hydrol. Earth Syst. Sci. 15, 2599–2620

Application

Full database of river discharges and flood extents for 831.125 river sections

- 1971-2000
- 2021-2050
- 2071-2100
- RCP4.5
- RCP8.5

Expected date:
May 2016



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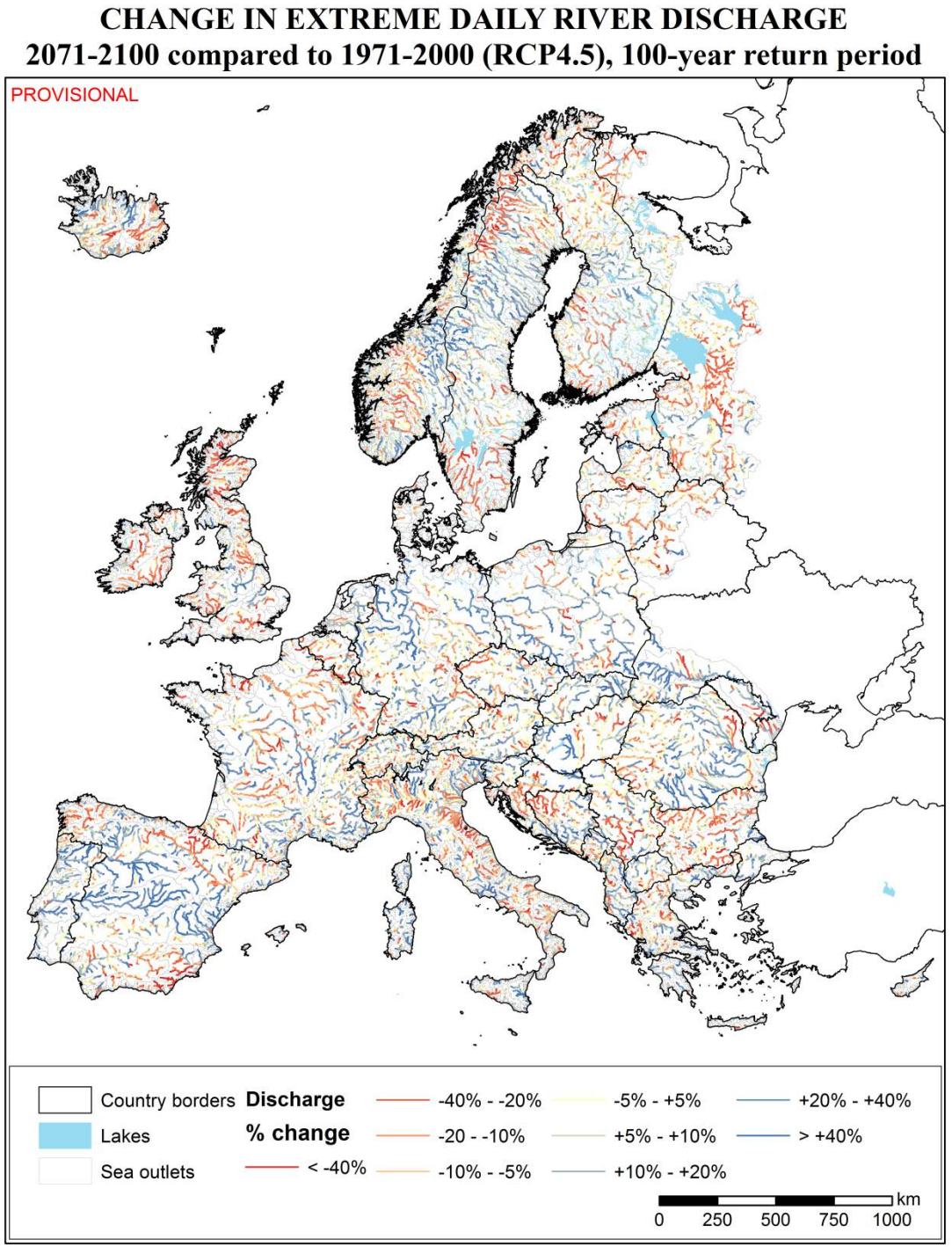

Flood extent

JRC flood map from 2D flood modelling

Basin	100-year flood zone (km²)	of which: urban (km²)
Danube	61187	2328
Wisla	8403	212
Elbe	7906	472
Oder	7168	247
Po	5129	133
Rhine	4537	555
Loire	3651	176
Rhone	3185	194
Weser	2517	117
Seine	2255	244
Other	73267	2511

Source: Alfieri et al. (2014) Hydrol. Process. 28, 4067–4077

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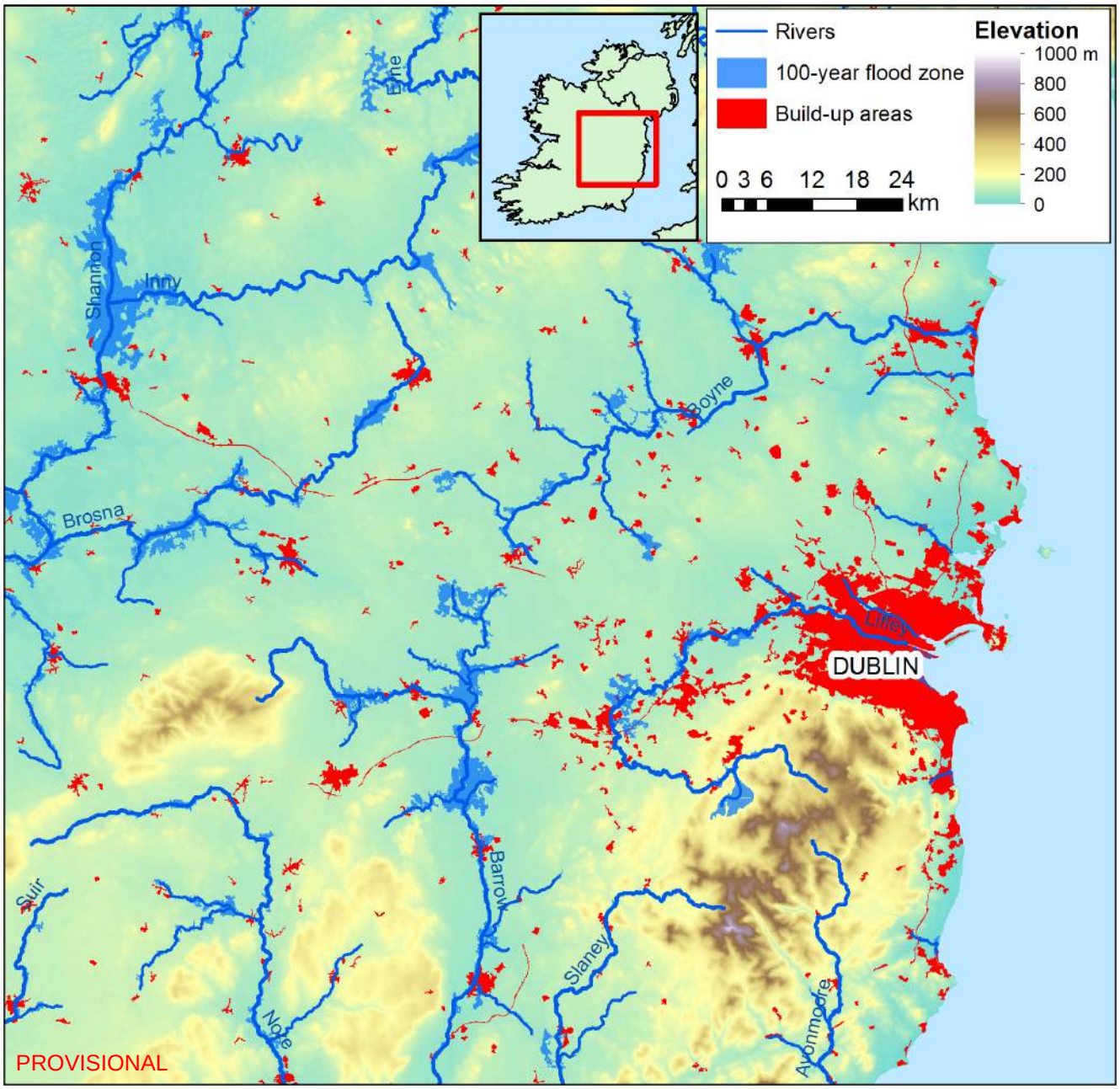
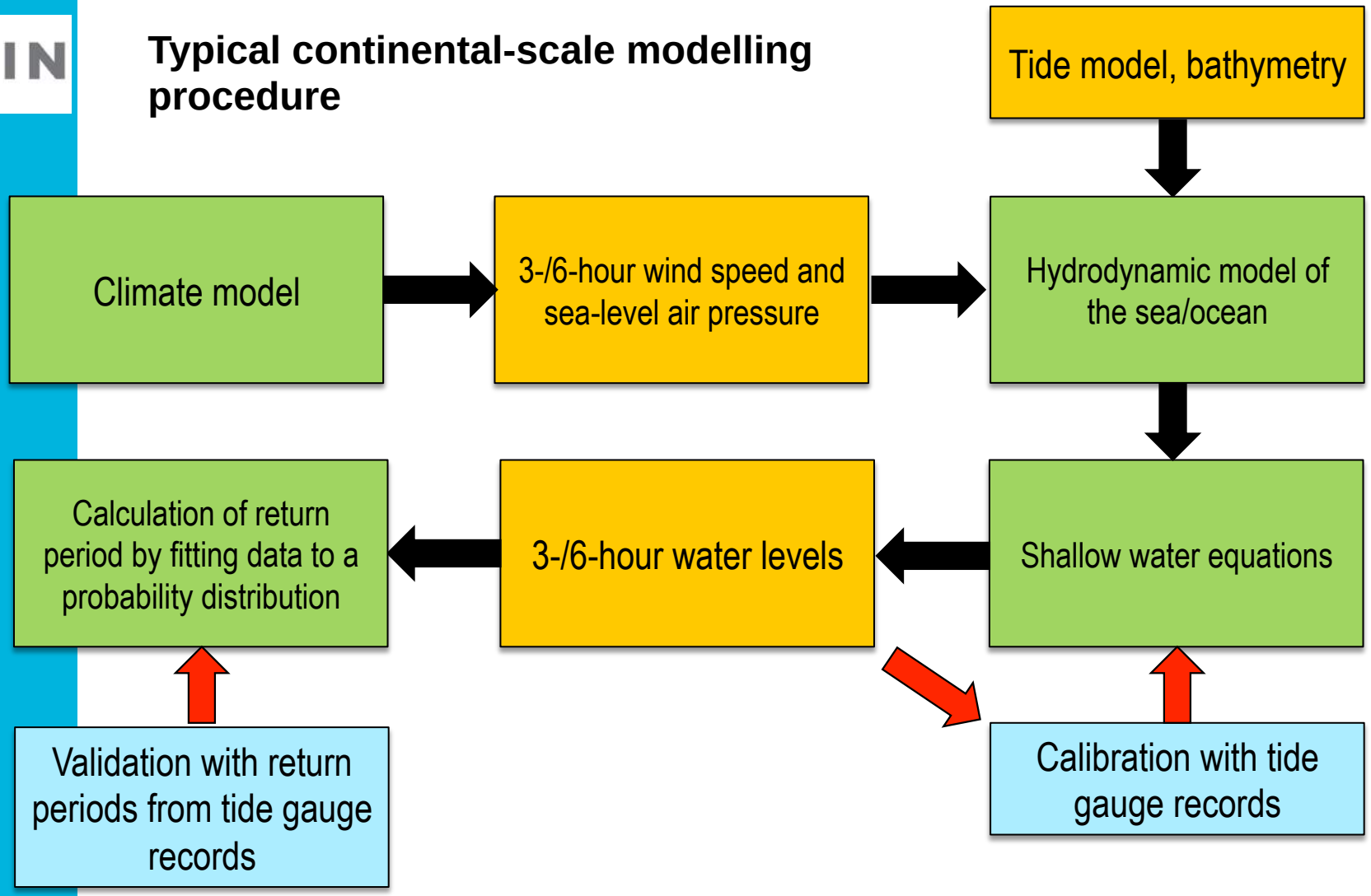
Flood extent

RAIN flood map from 1D flood modelling

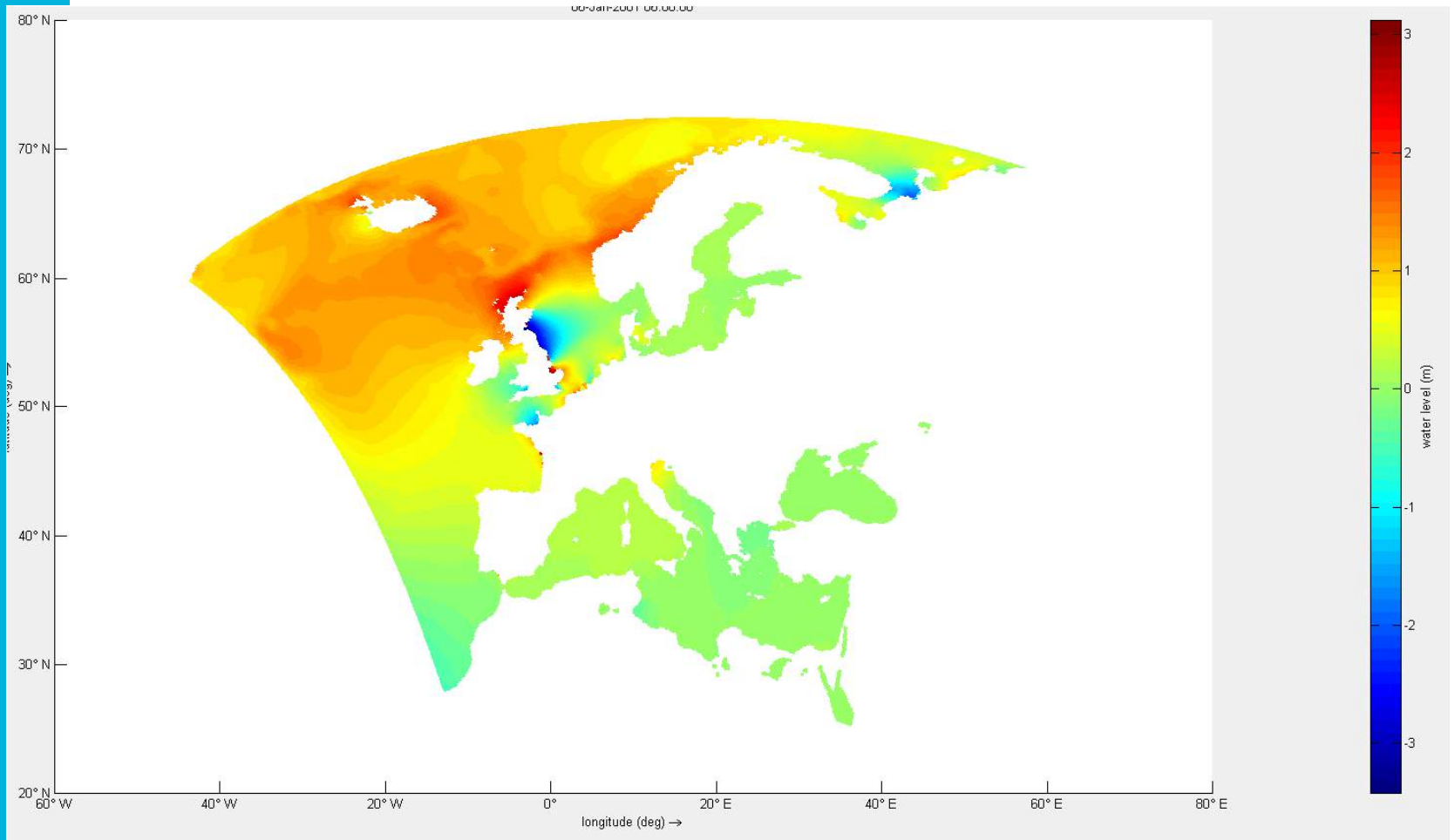


Storm surges

Typical continental-scale modelling procedure

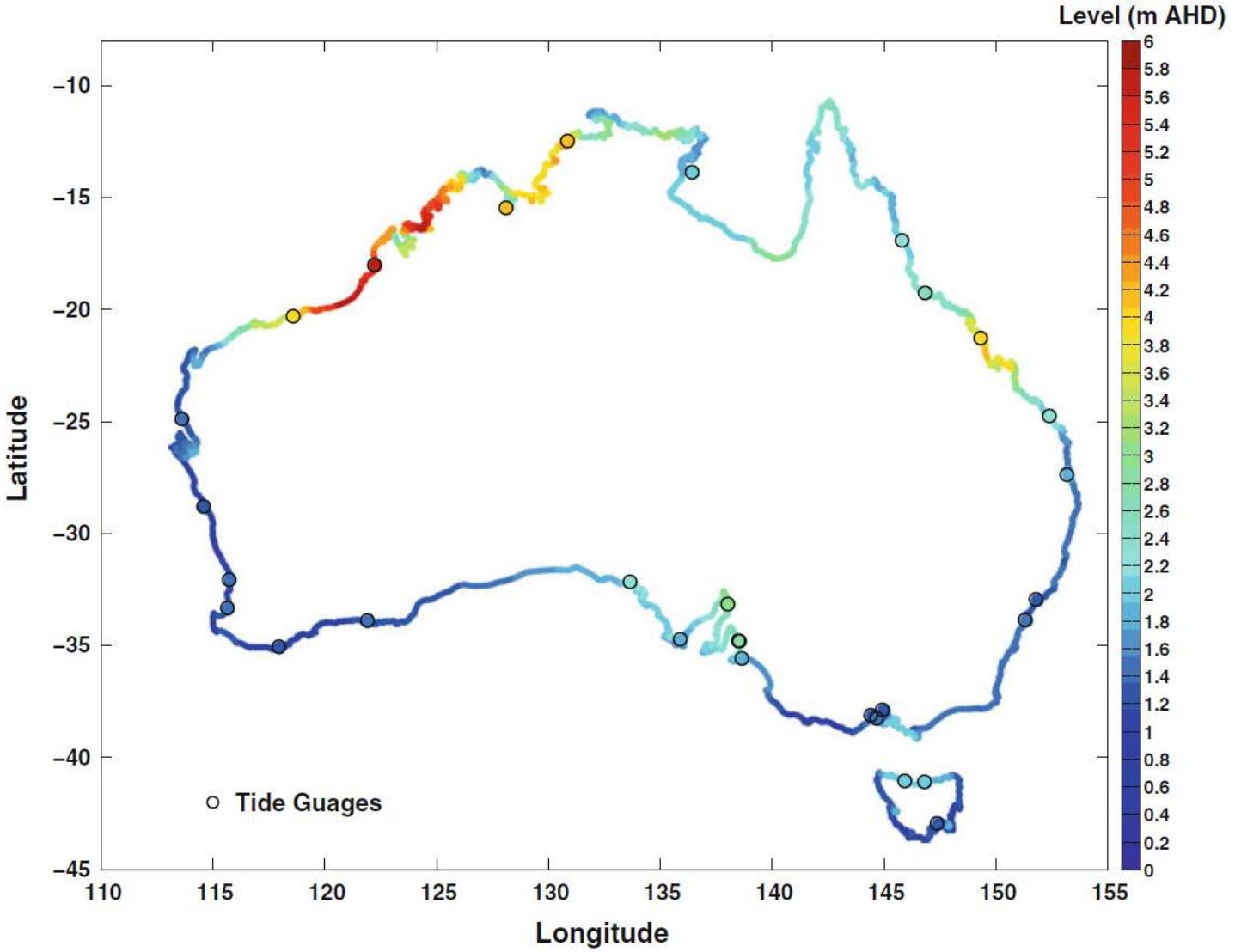


Storm surges



Water levels in Delft3D

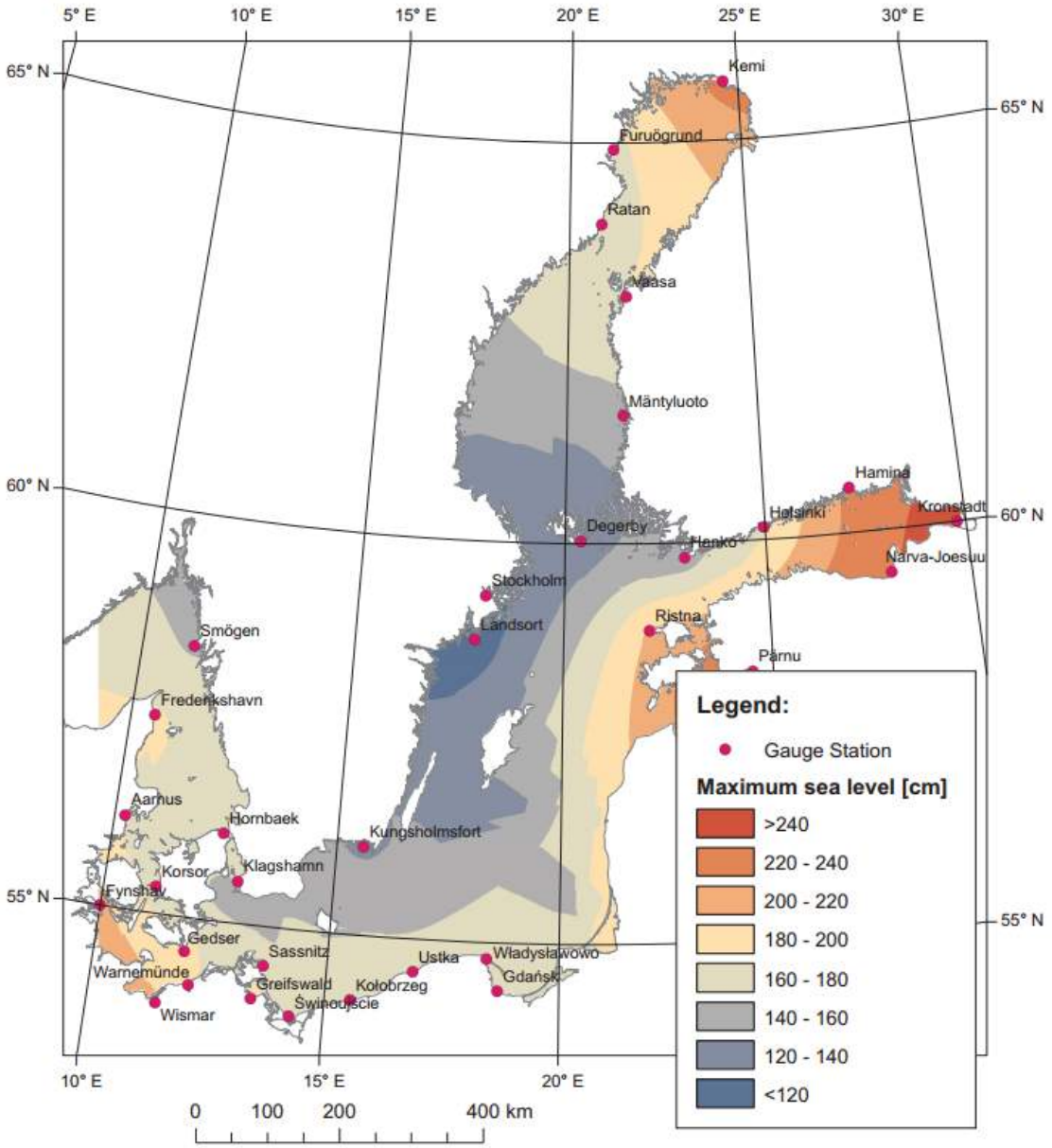
Storm surges



Source: Haigh et al. (2014) Clim. Dyn. 42, 121–138

100-year storm surge heights on the coast of Australia
Calculated by a model of the ocean driven by wind and air pressure.

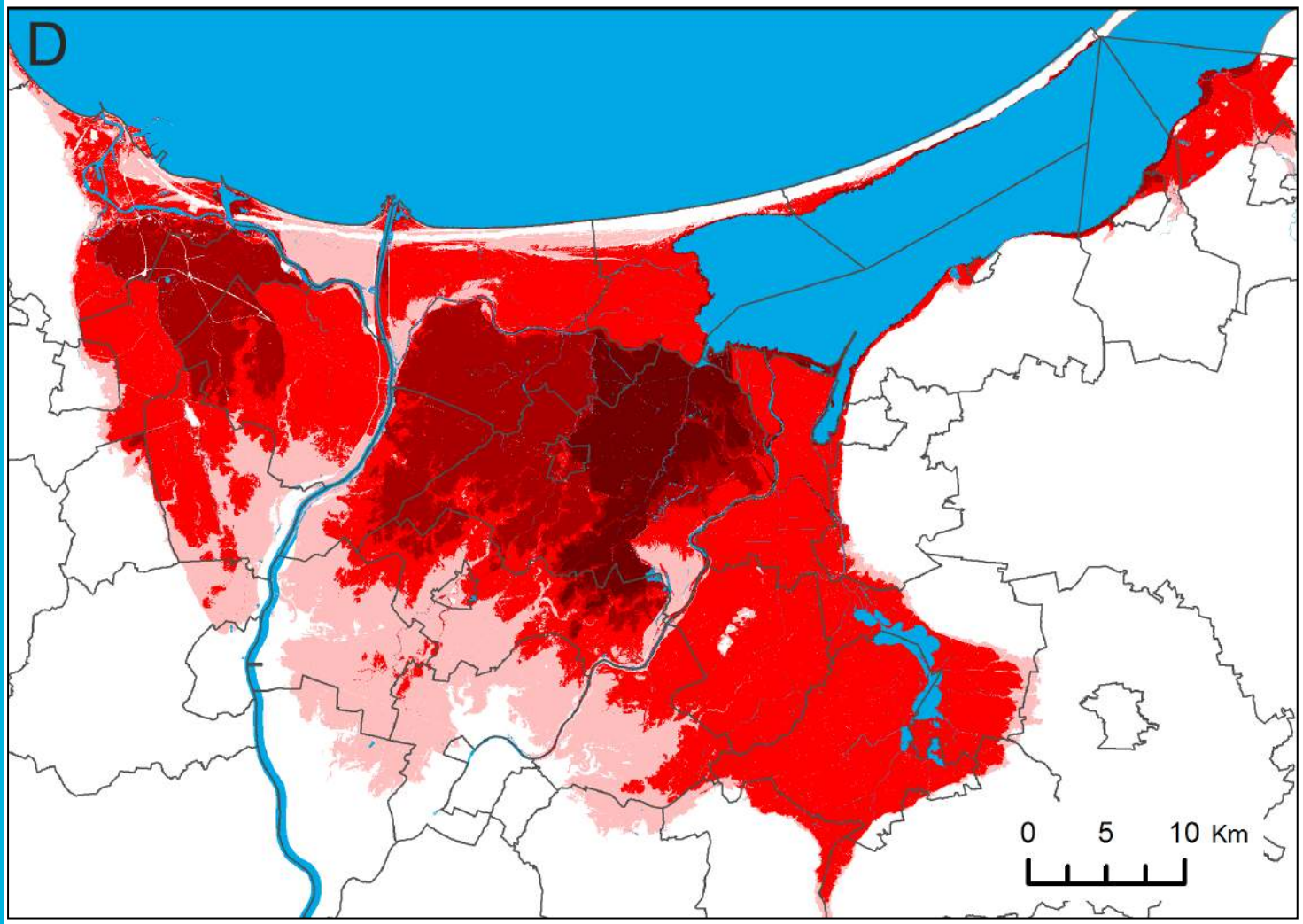
Storm surges



100-year storm surge heights in the Baltic Sea calculated by geostatistical interpolation

Source: Wolski et al. (2014) Oceanologia 56, 259–290

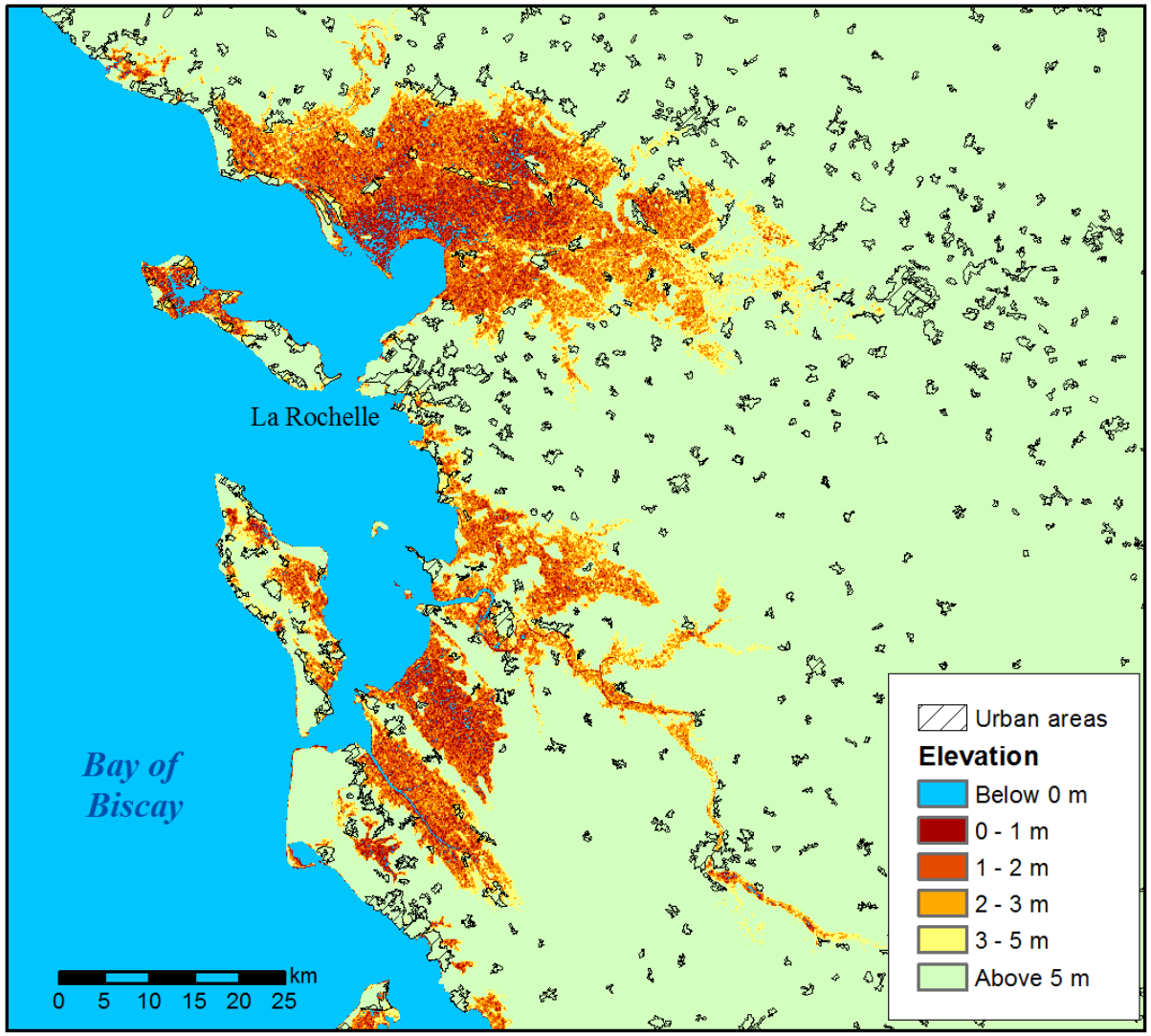
Flood extent



Source: Paprotny and Terefenko (2015) Nat. Hazards Earth Syst. Sci. Discuss., 3, 2493-2536

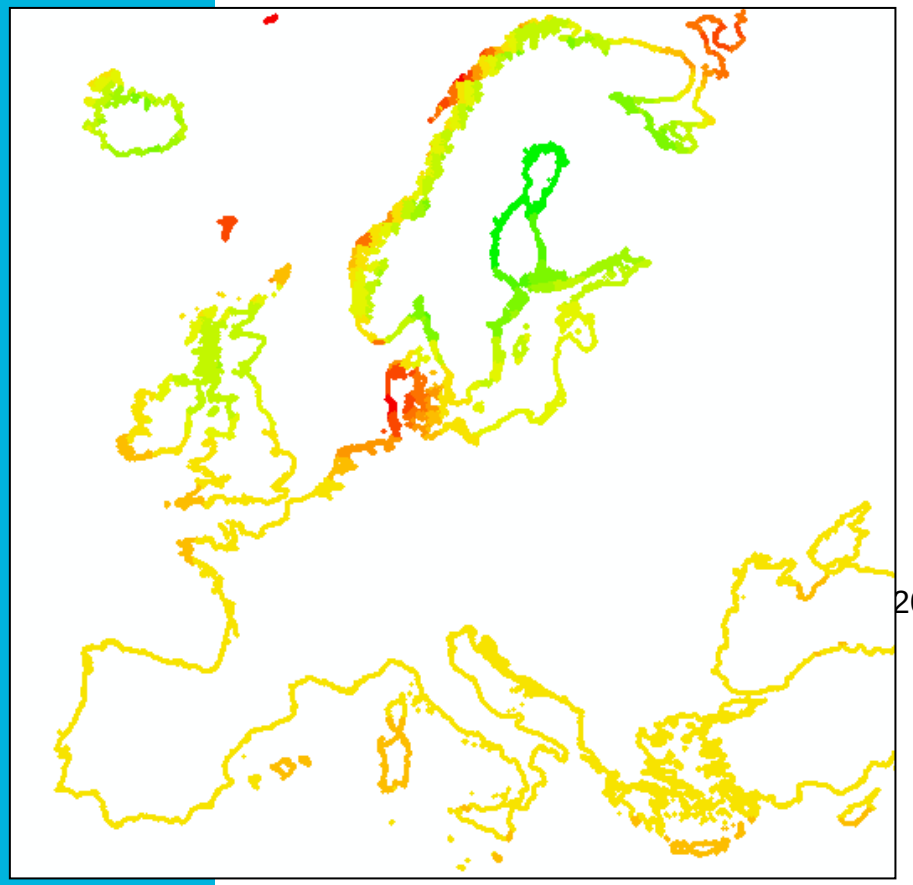
“Bathtub fill” method:
storm surge levels are intersected with the digital elevation model (DEM)

Flood extent

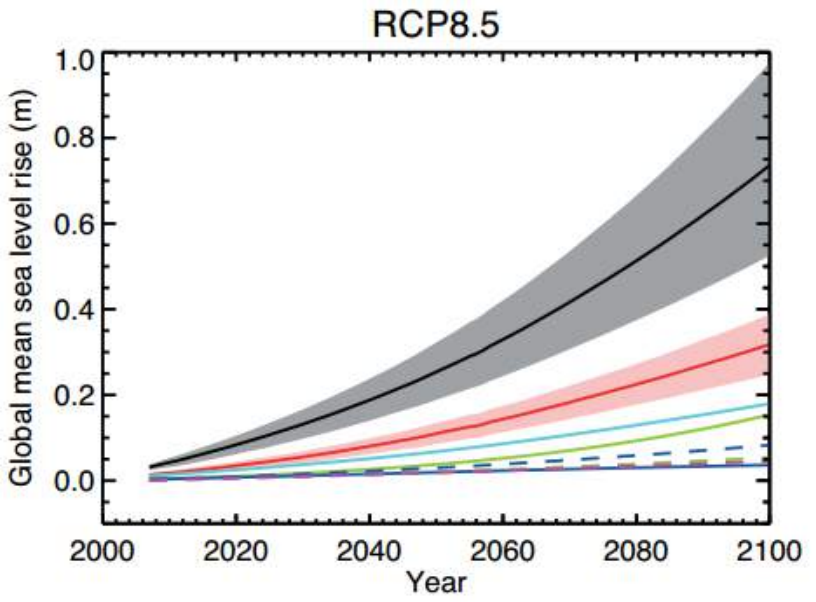


Trouble: the errors in elevation data from continental/global DEMs is often higher than the height of storm surges;
Flood defences are mostly absent.

Storm surges



20



IPCC projections of sea level rise up to 2100

Church et al. (2013) “Sea Level Rise”, IPCC AR5


Thank you!
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Fot. D.P.