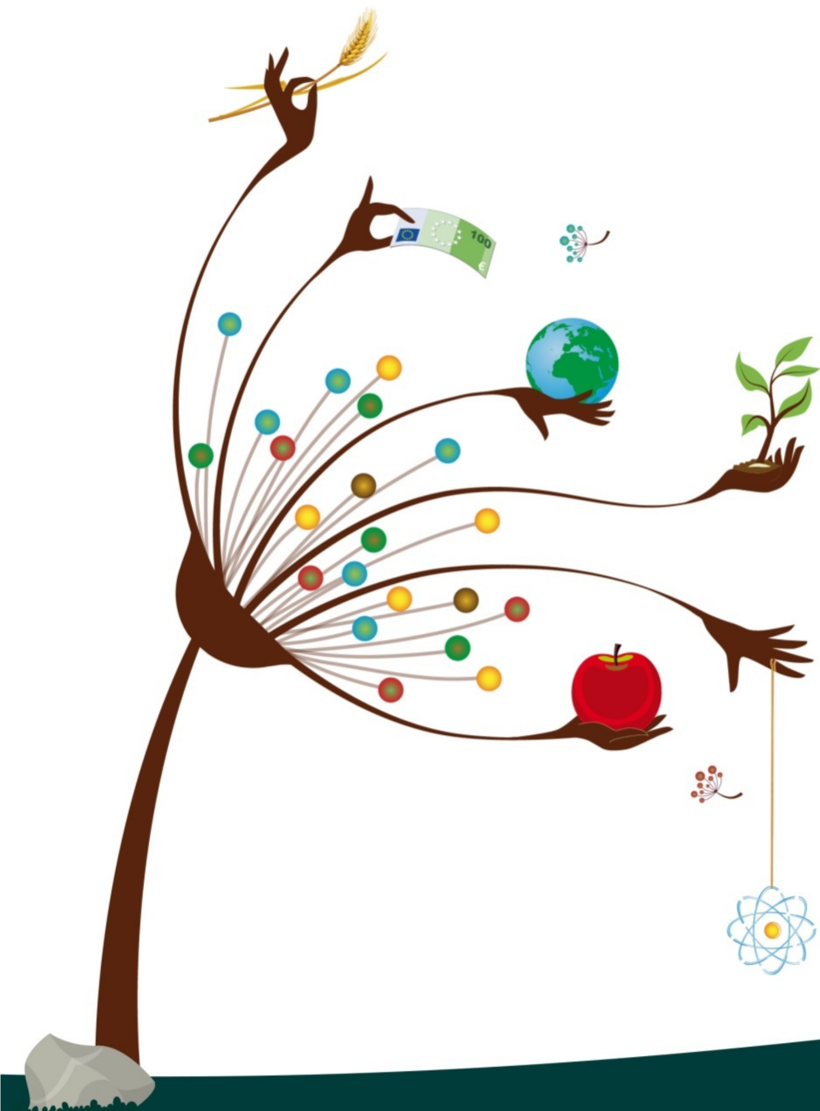

The European Commission's science and knowledge service

Joint Research Centre

Modelling the Impacts of Climate Extremes

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thanks to *Lorenzo Alfieri, Luc Feyen, Valerio Lorini, Gustavo Naumann, Ad de Roo, Peter Salamon*

Outline

- Modelling climate and hydrological extremes: why and how?
- Impacts on water resources
- Flood and drought risk concepts
- Modelling future flood impacts
- Modelling future drought conditions

Hydrological and flood models at JRC

Why?

- JRC supports the design and implementation of climate and water related policies
  - disaster risk management for Europe and the World (e.g. emergency response)
  - influence of policy and land use changes on water resources
  - climate change impacts on water resources and hydrological extremes

How?

- We develop monitoring and forecasting systems for flood and droughts
- We produce analyses of hydrological processes under present and future climate and socio-economic conditions

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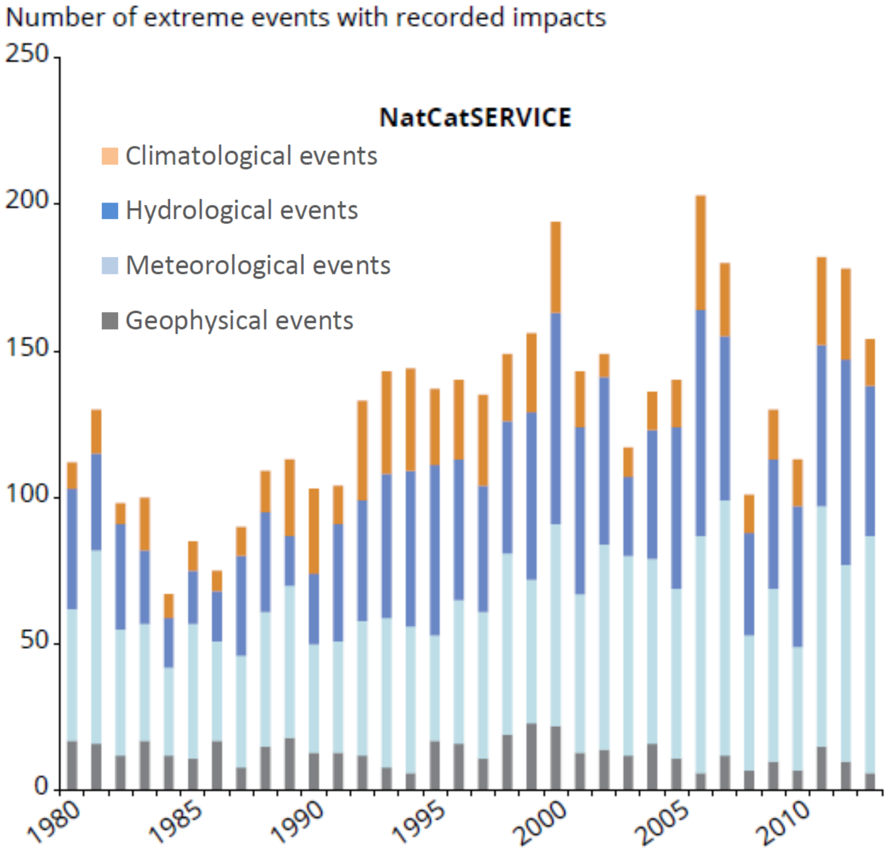
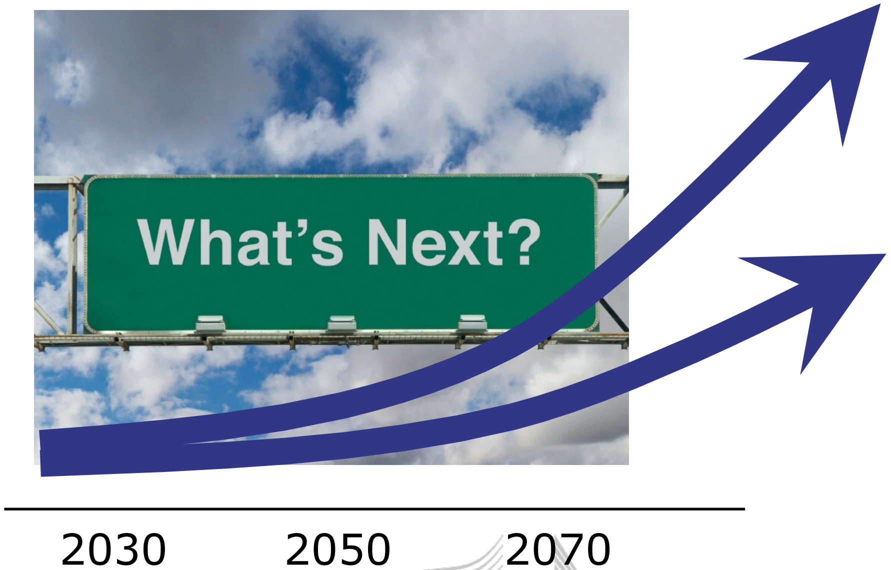
Why modelling climate-related risk?

- Climate-related hazards have huge socioeconomic impacts (e.g. flooding caused more than $1 trillion and 220,000 fatalities globally in 1980–2013)
- Climate and socioeconomic change are likely to increase impacts in the future



Understanding future disaster risk is indispensable for **planning suitable adaptation measures** to safeguard population and secure core functions of our societies.



Climate extremes

National Geographic

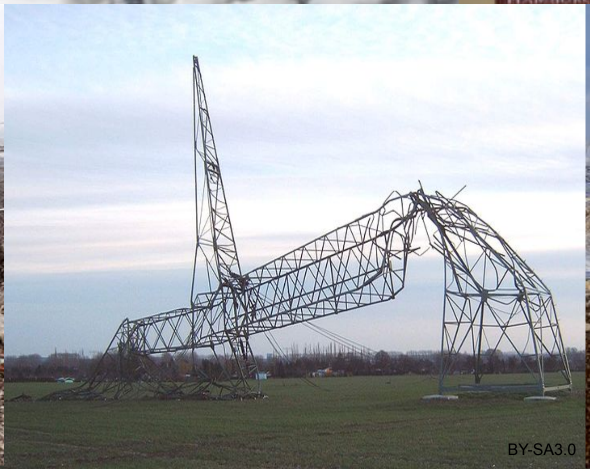
Travel

BY-SA3.0

Dalje

National Geographic

Travel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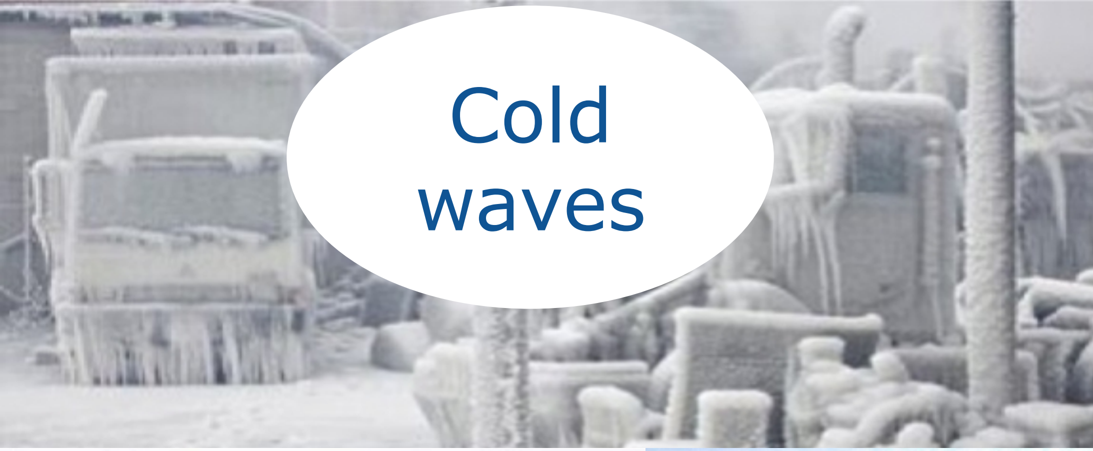
Dalje


Cold waves


River flooding
National Geographic


Drought
Travel


Storms
BY-SA3.0


PORT DE BAYONNE
ACCÈS INTERDIT
Sauf Service
Coastal flooding


Heat waves
Dalje


Wildfires

Why modelling risk at global scale?

- Many climatological extreme events are connected to, or driven by, short and long term global weather systems (e.g. El Niño)
- Major events may have significant economic and social impacts in all parts of the world due to interconnected global economy
- Local risk models not available/feasible in many regions of the globe
- Increasing request from international bodies (e.g. Red Cross, UNISDR, etc), governments, private companies (construction, insurance etc), NGOs

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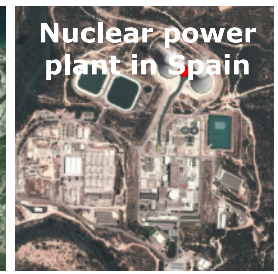
Risk analysis – methodological framework

present

Climate hazards

Frequency and intensity of hazards

Exposed assets (Vulnerability)



Reported Damages

Risk analysis – methodological framework

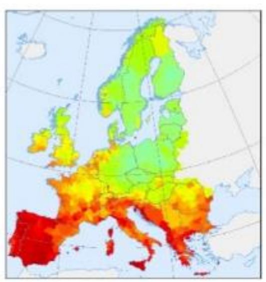
present

TIME

future

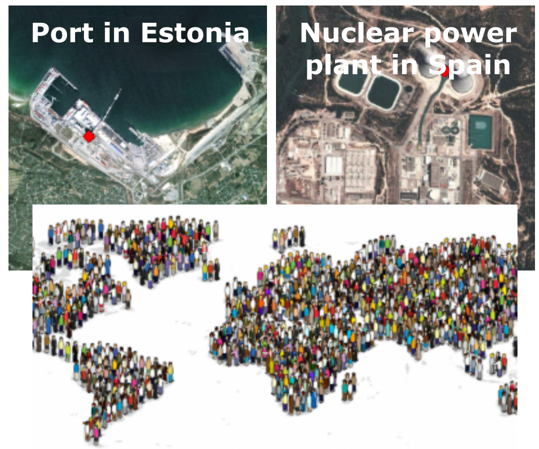
Climate hazards

Frequency and intensity of hazards



Change in the frequency and intensity of hazards

Exposed assets (Vulnerability)



Reported Damages

Future human and economic impacts

Water resources and global warming

- Under present climate conditions, there is imbalance between natural supply and demand in many regions

- Natural supply and demand are sensitive to climate change

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Water resources and global warming

- Under present climate conditions, there is imbalance between natural supply and demand in many regions

- Natural supply and demand are sensitive to climate change

- How will water availability (soil water stress, water exploitation etc.) change in Europe and around the world with global warming?

LISFLOOD forced with climate projections
(e.g. Euro-Cordex projects – 11 model outputs)

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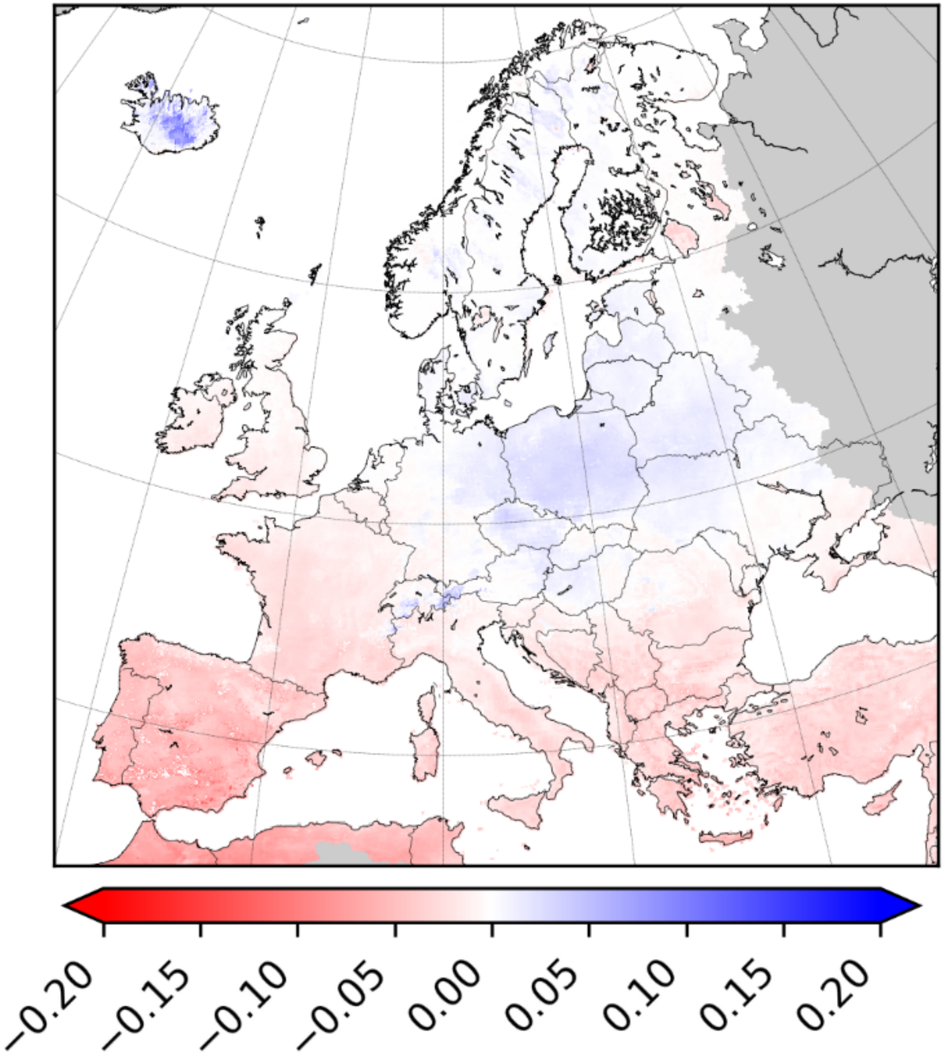
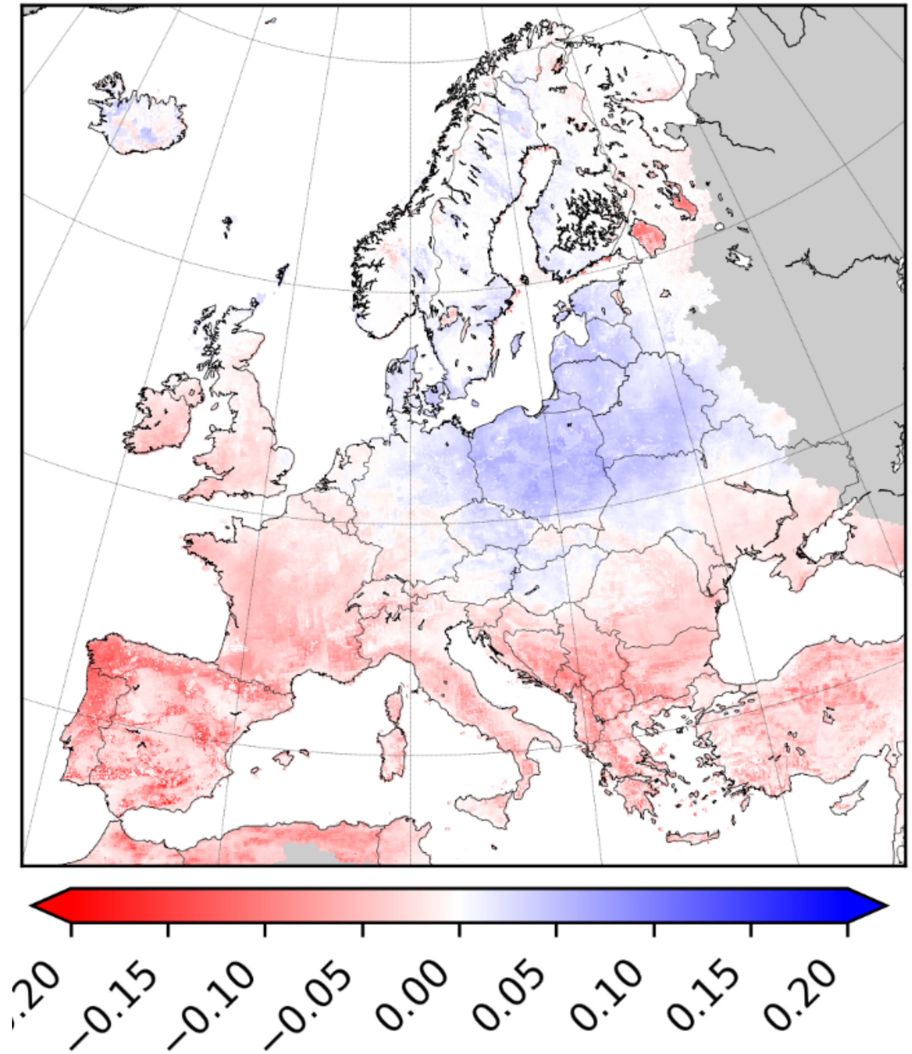
LISFLOOD with Euro-Cordex model outputs: 2°C warmer climate

Change in annual soil water stress

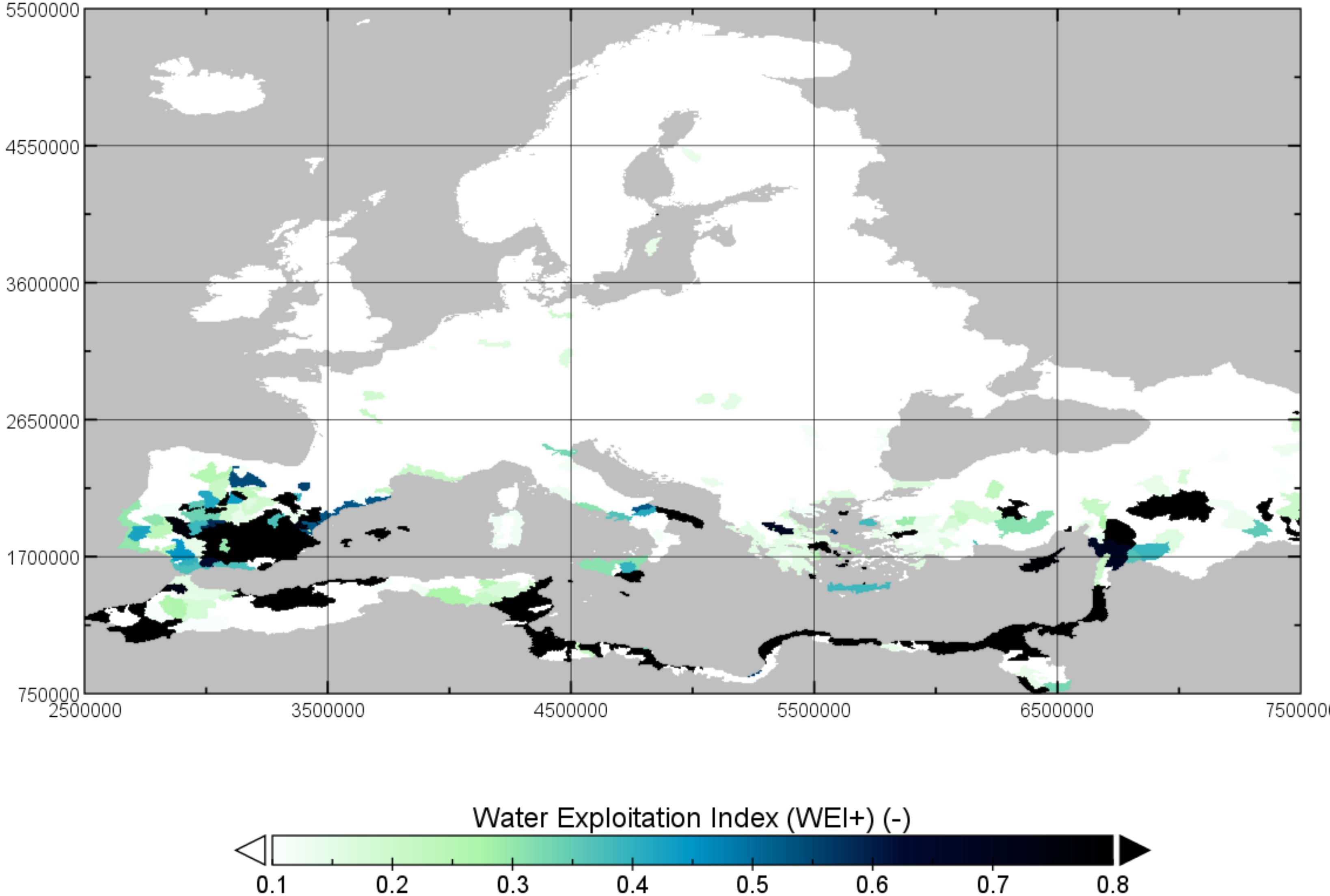


Change in JJA soil water stress

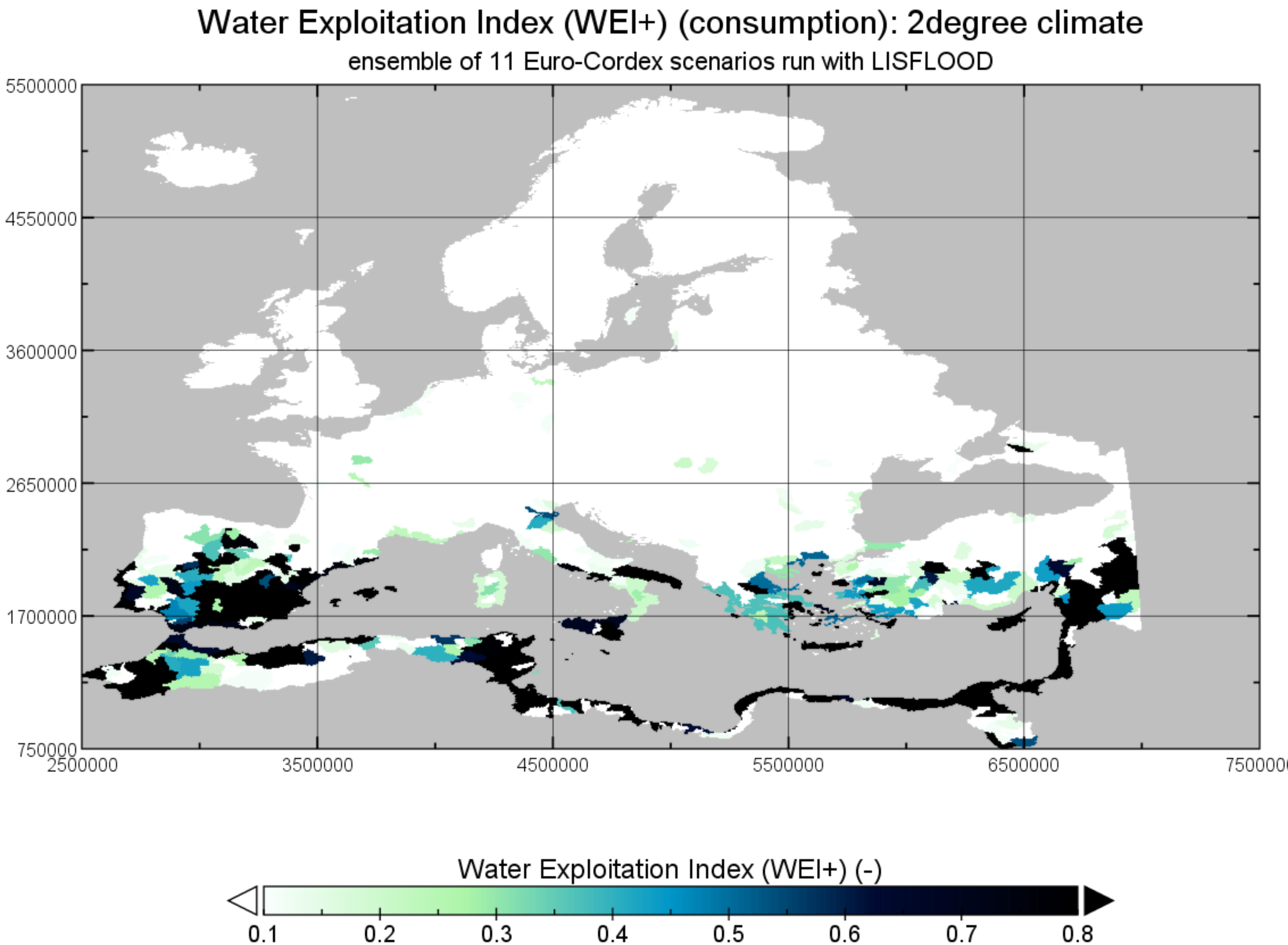


Water Exploitation Index (WEI+) (consumption): 1990-2016

LISFLOOD reference run forced with observed meteo data (JRC-EFAS)



WEI+ = net water consumption / (local available water + upstream inflow)



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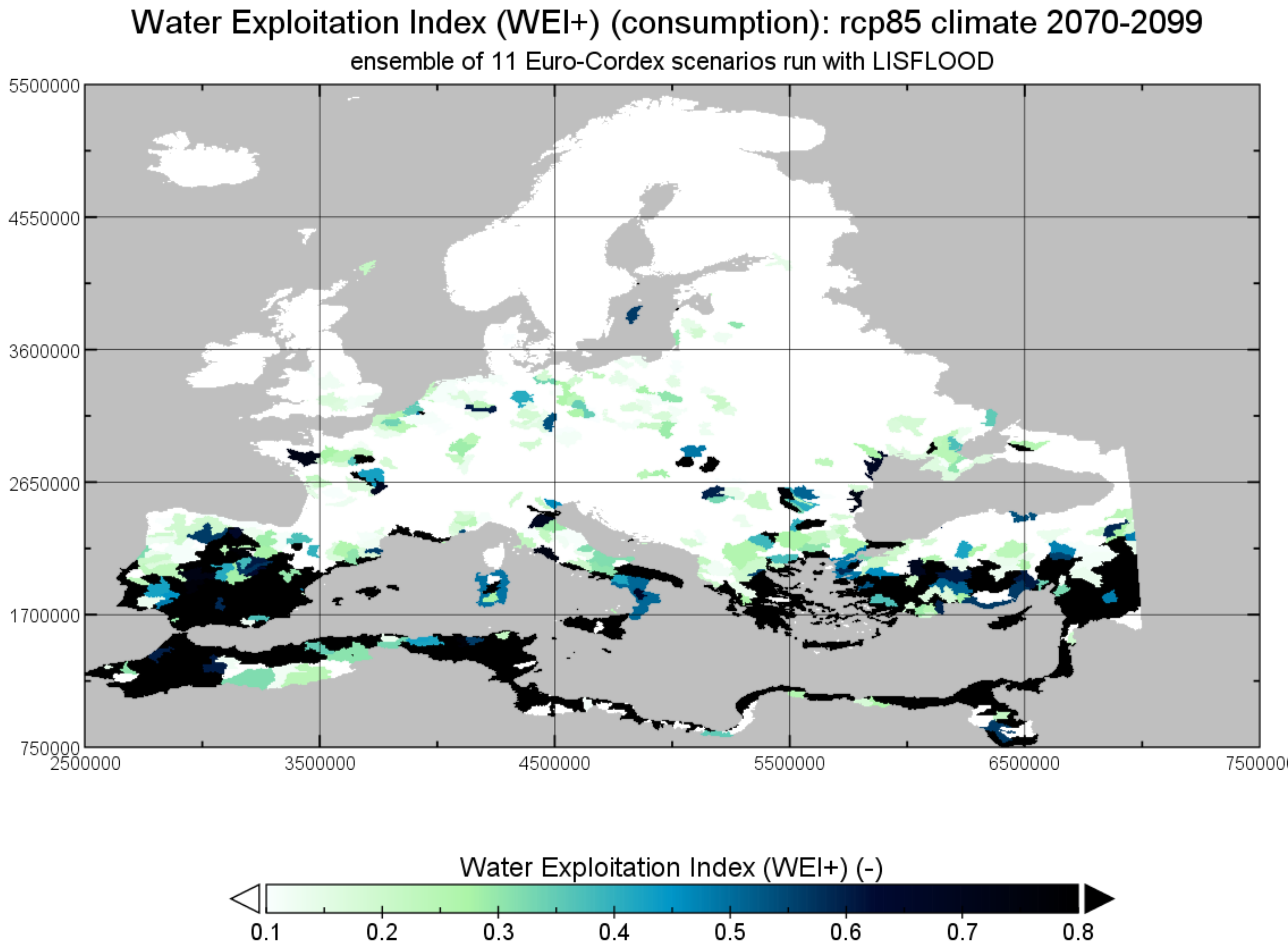
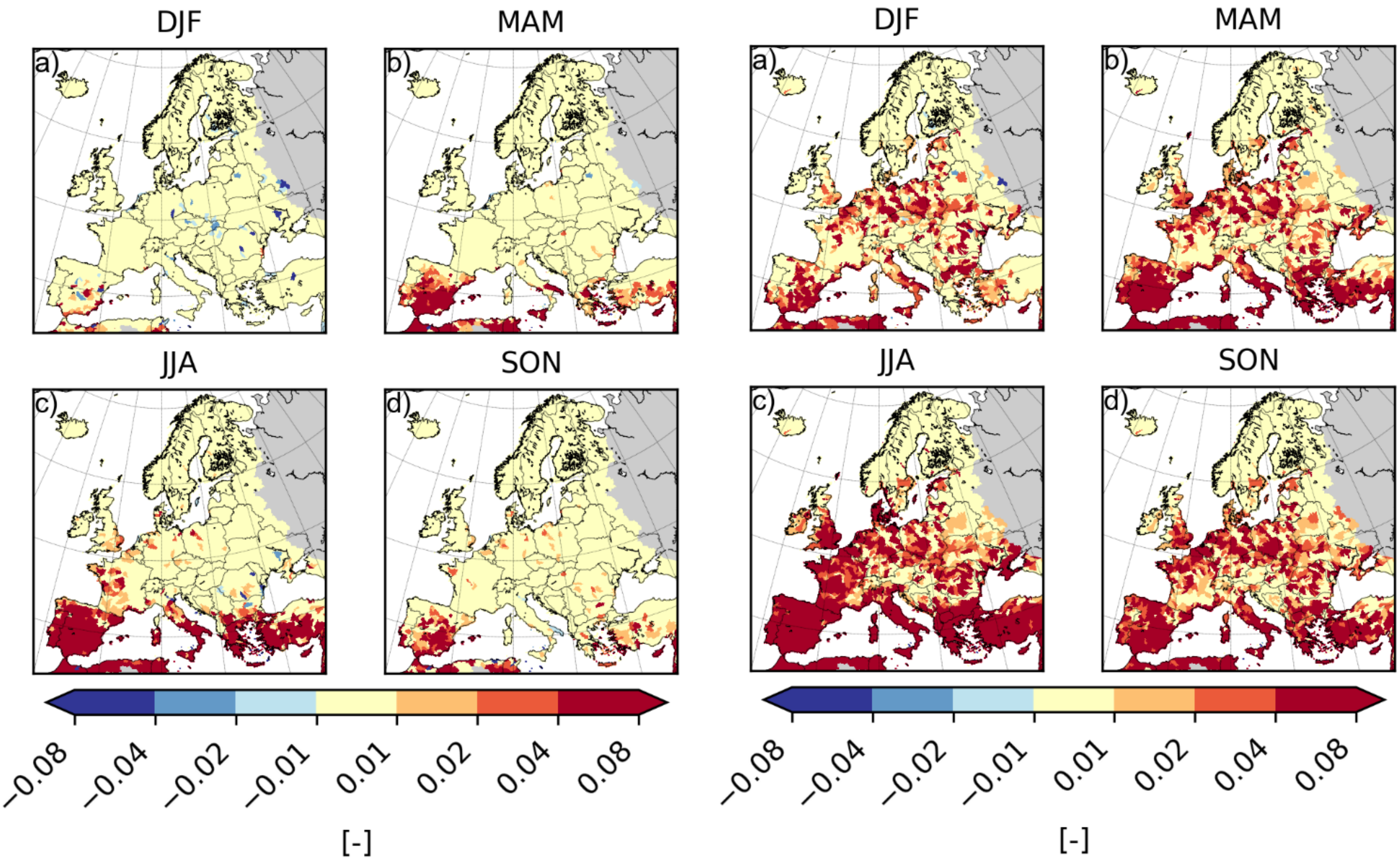

Water Exploitation Index (WEI+) (consumption): rcp85 climate 2070-2099
ensemble of 11 Euro-Cordex scenarios run with LISFLOOD
5500000
4550000
3600000
2650000
1700000
750000
2500000
3500000
4500000
5500000
6500000
7500000
Water Exploitation Index (WEI+) (-)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Seasonal change in Water Exploitation Index (WEI+)

2°C temperature change | **2070-2099 RCP8.5**



LISFLOOD forced with 11 Euro-Cordex model outputs

Hydrological extremes and global warming

- Drought and river flooding have a wide range of impacts and implications on societies

- How will hydrological extremes develop around the world with global warming?

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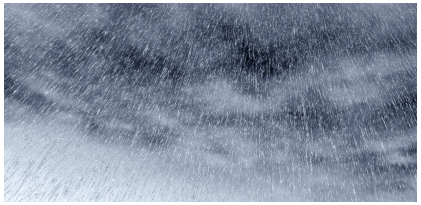
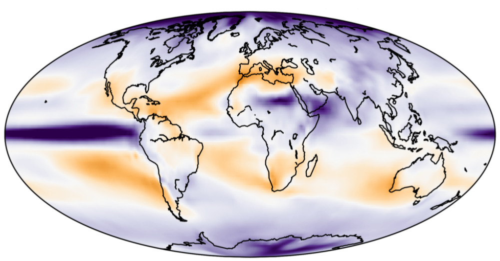
Global drought hazard assessment

SUPPLY



DEMAND



High resolution climate projections

Accumulated water deficits over 12-month periods

Standardized Precipitation Evapotranspiration Index SPEI-12

Peak over threshold analysis on SPEI-12 series

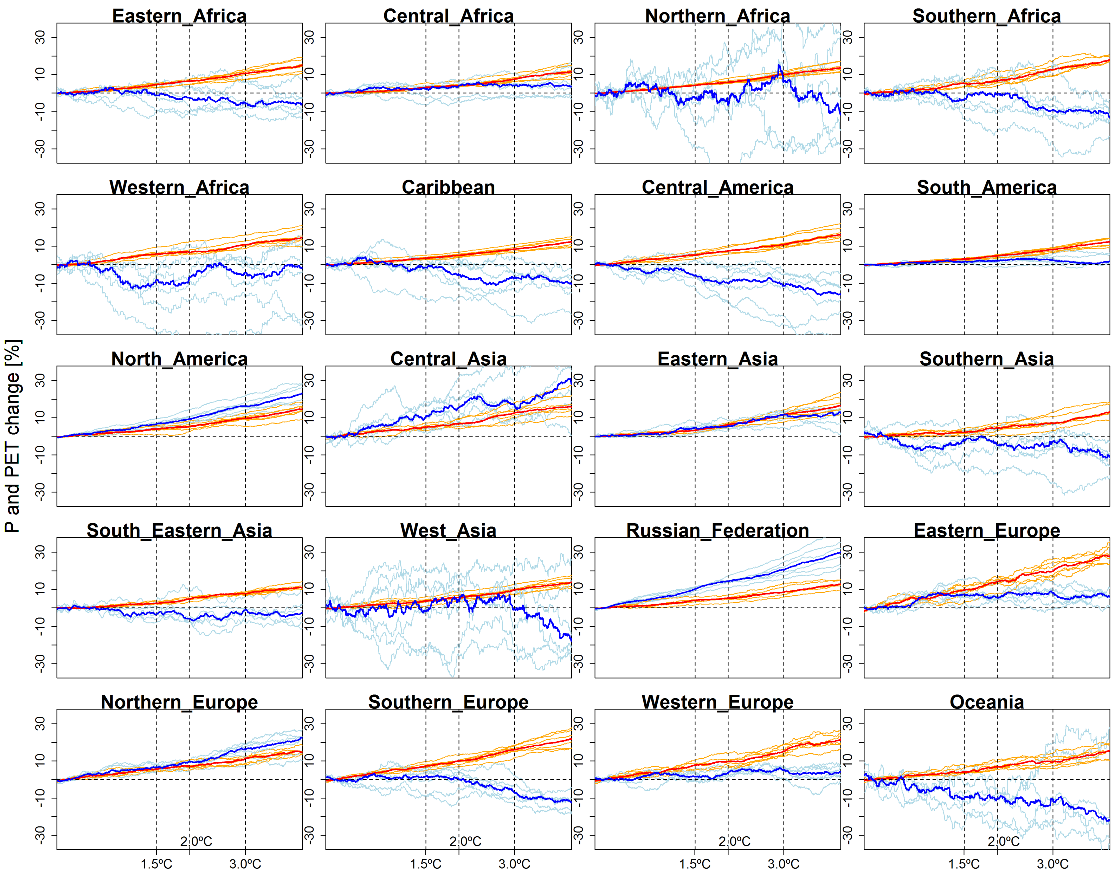
Frequency

Magnitude

Duration

Naumann et al., GRL 2018

Changes in natural supply and demand



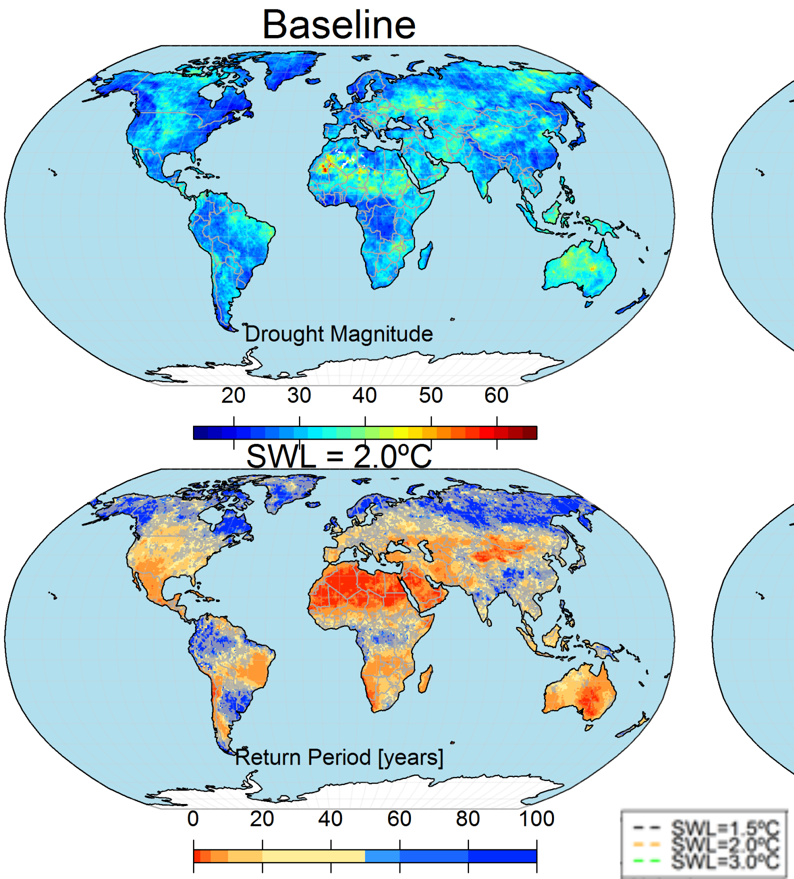
Naumann et al., GRL 2018

- A progressive increase in moisture demand (evapotranspiration) with warming is projected with high confidence for all macro-regions.
- Projected change in supply (average precipitation) differs widely across regions

➢ If warming continues at the present rate, water supply-demand deficits would increase fivefold

Changes in drought frequency

If warming continues at the present rate, current 1-in-100-year droughts would occur every two to five years for most of Africa, Australia, southern Europe, southern and central United States, Central America, the Caribbean, north-west China, and parts of Southern America.

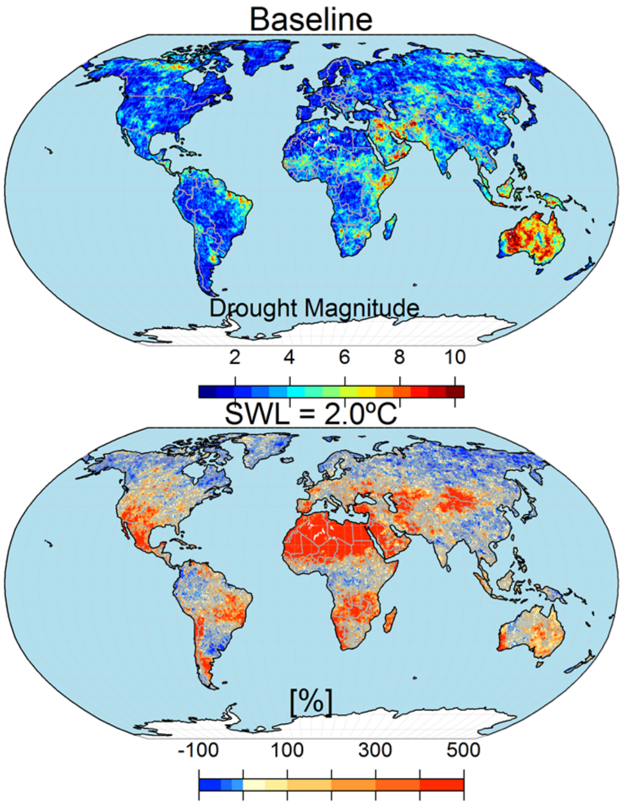


Magnitude of 50-yr drought in baseline and future return period for this drought magnitude at different warming levels (1.5°C, 2.0°C and 3.0° C).

Naumann et al., GRL 2018

Changes in drought magnitude

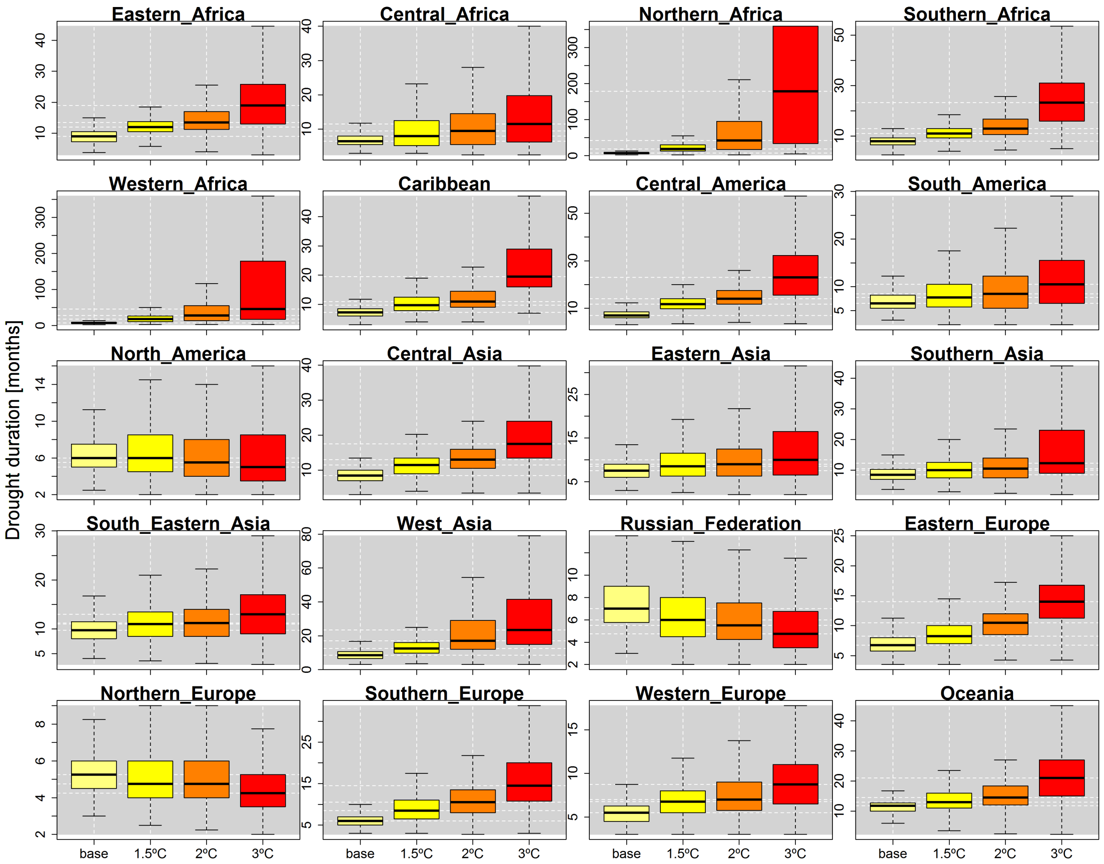
- We found that the magnitude of droughts is likely to double in 30% of the global landmass under stringent mitigation policies (1.5°C)



Naumann et al., GRL 2018

Baseline drought magnitude (upper-left plot) and relative changes [%] in drought magnitude with respect to the baseline for three global warming levels (1.5°C, 2.0°C, 3.0°C).

Changes in drought duration



Drought duration in months for the baseline and three global warming levels (1.5°C, 2.0°C, 3.0°C).

2/3 of global population will experience a progressive increase in drought conditions with warming.

For drying areas, drought duration are projected to rise at rapidly increasing rates with warming,

Naumann et al., GRL 2018

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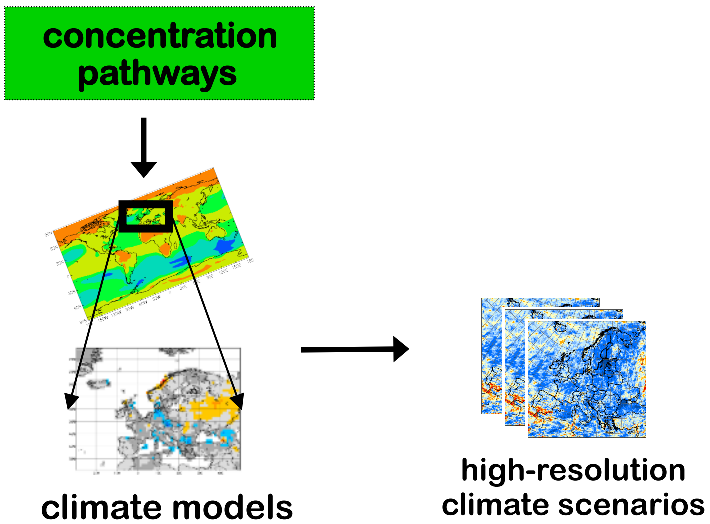
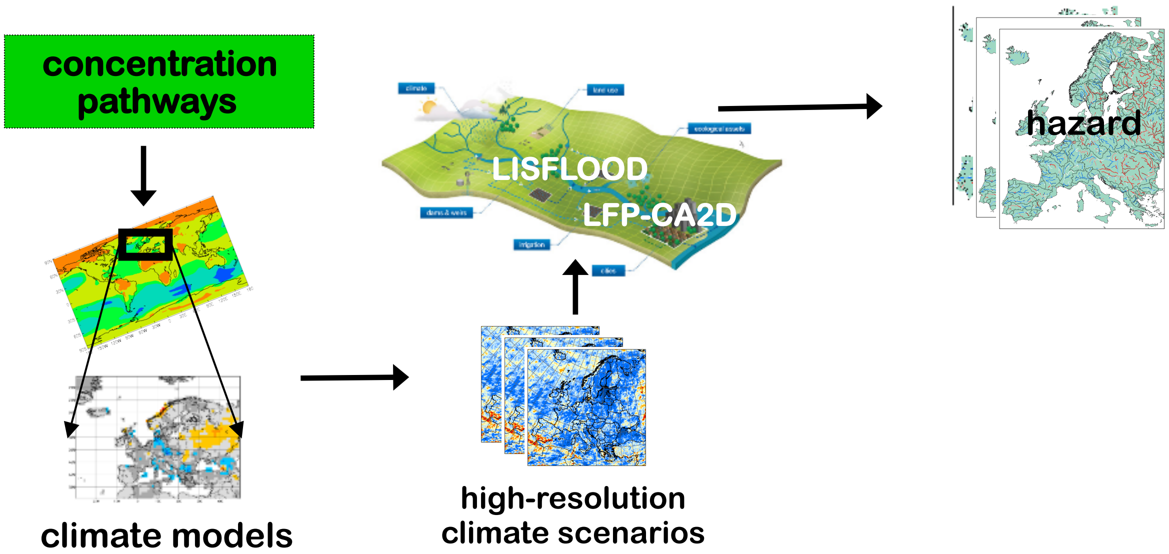
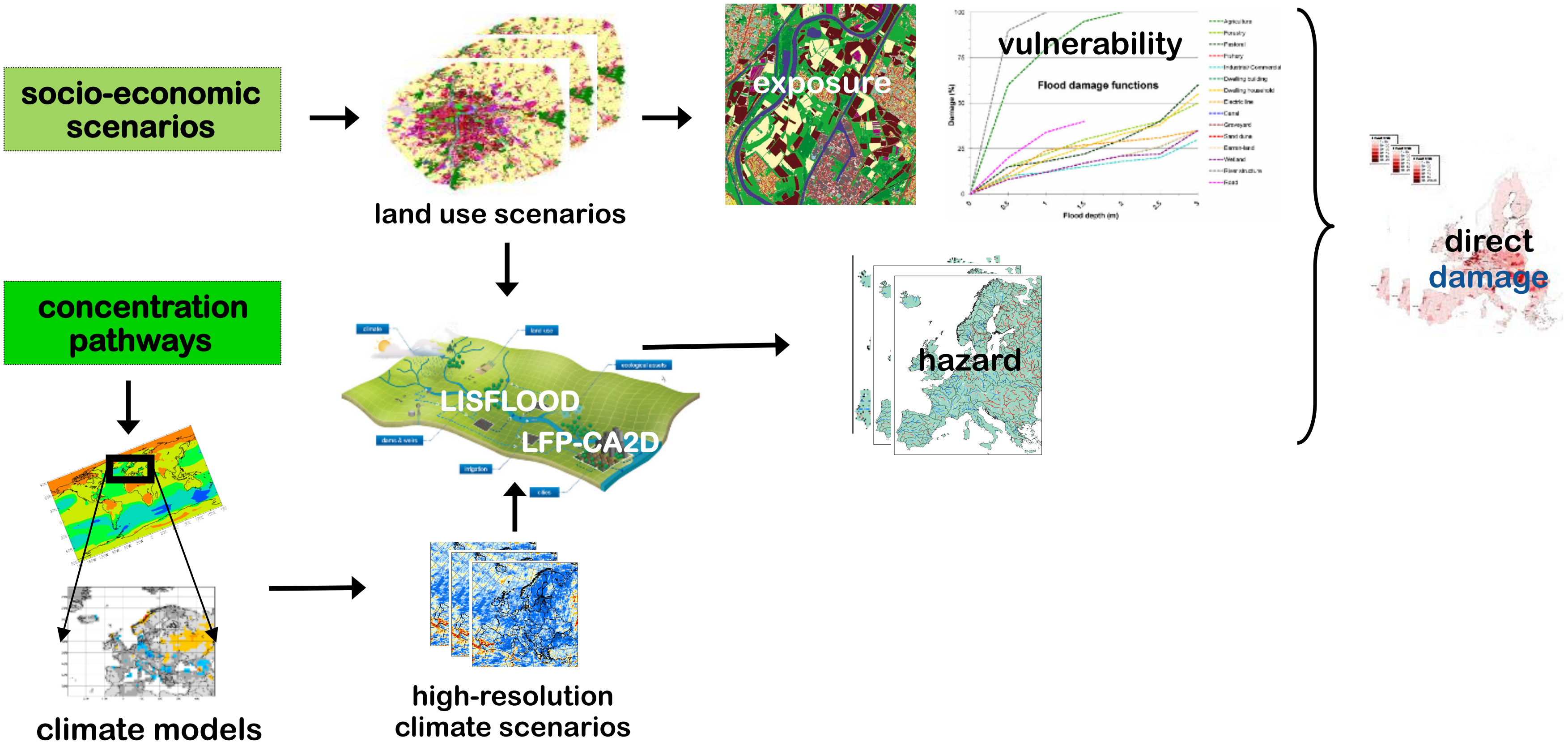
River flood hazard and risk assessment



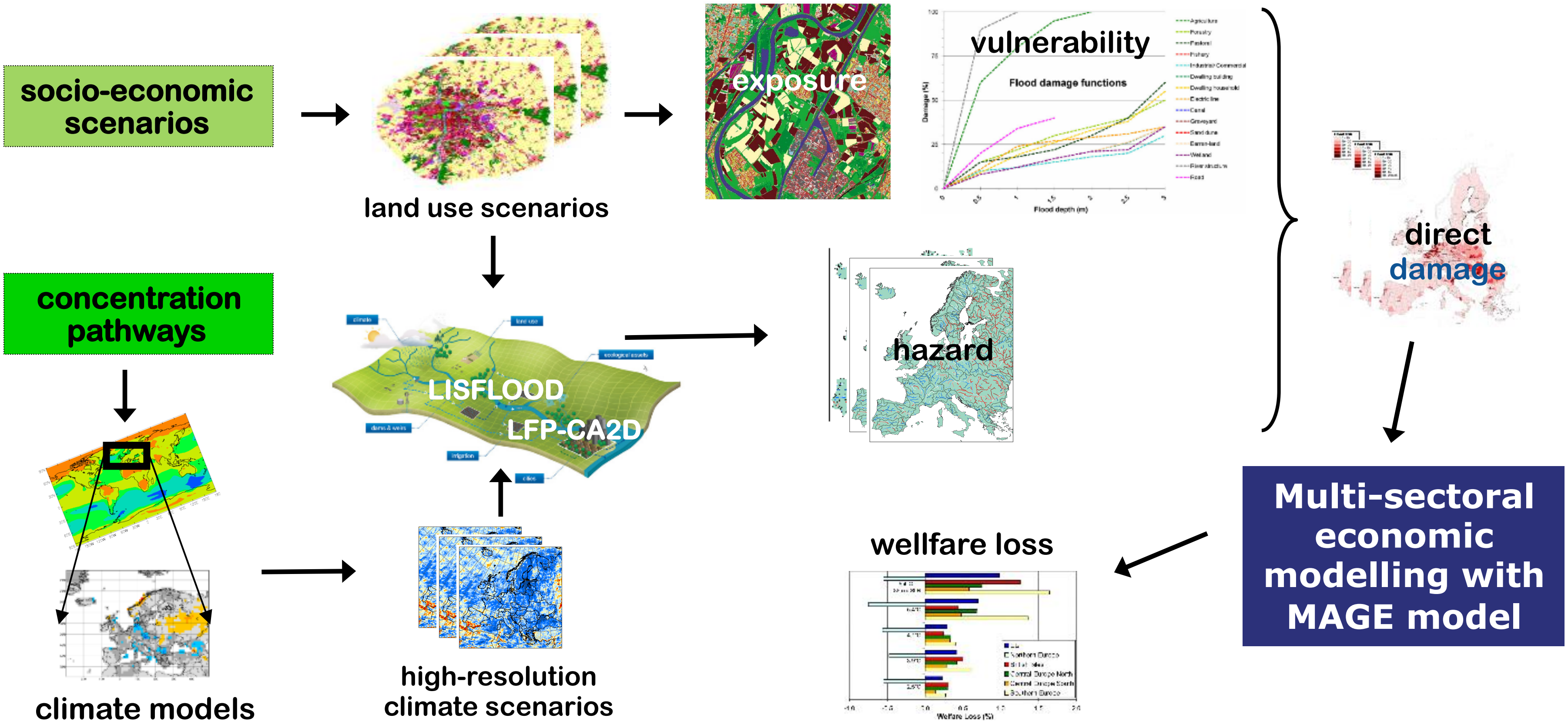
River flood hazard and risk assessment



River flood hazard and risk assessment



River flood hazard and risk assessment



Risk components – river flooding

- **Hazard:** probability and magnitude of relevant flood events
  - Type of flood process(es)
  - Probability of occurrence
  - Flood extent, water depth, flow velocity
  - Sediment and pollutant load
- **Exposure** of population and assets
  - Population distribution
  - Land use distribution
  - Location of critical infrastructures, cultural heritage buildings…
- **Vulnerability** of population and assets
  - Flood protection measures
  - Emergency plans
  - Damage functions of structures
  - Supply and distribution networks etc.

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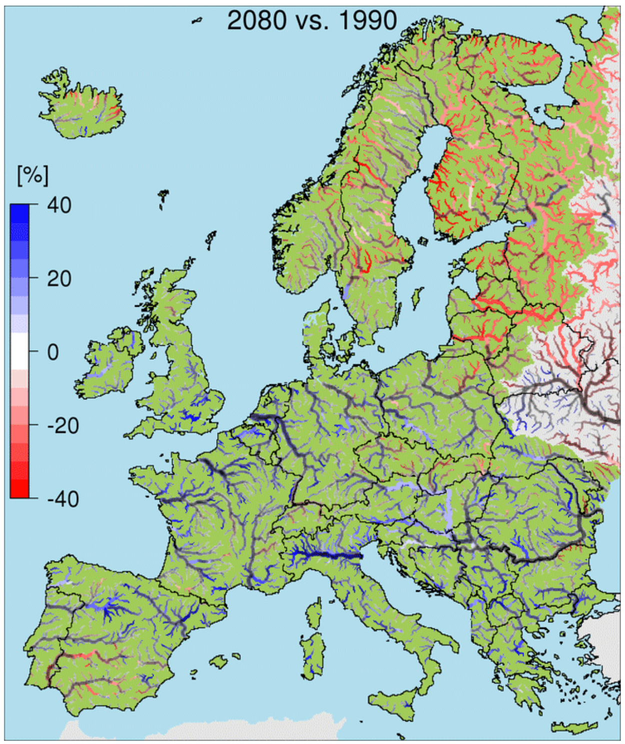
Future flood risk in Europe

- Seven climate projections from the EURO-CORDEX database (RCP 8.5)
- Runoff and river flow simulated with the LISFLOOD model
- Peak Over Threshold (POT) and L-moments EVA routine to identify frequency and magnitude of relevant flood events
- flooding processes simulated with the LISFLOOD-FP model
- EU datasets of exposure (Corine LC), flood protection (Jongman et al. 2014) and flood-loss relations (Huizinga et al 2007)
- future socio-economic and land scenarios considered (SSPs) under present-day vulnerability conditions
- Quantified impacts: population exposed, direct damages
- Evaluation of adaptation measures

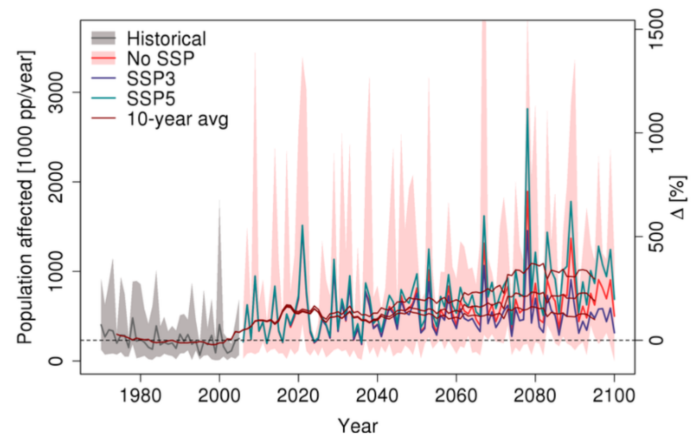
Future flood risk in Europe

- Presently, 216,000 people exposed and €5.3 billion damages annually.
- Under a 2°C global warming scenario (early 2040s for RCP8.5) and current socio-economic conditions, flood impacts could more than double
- For the period 2071-2100, over 700,000 people annually exposed to floods while direct flood damages could see a more than three-fold increase

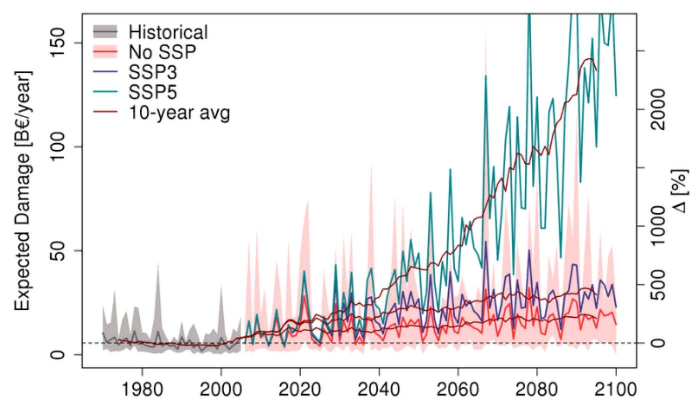


Relative change in 100-year peak flow

Alfieri et al., HESS 2015



Expected annual people exposed to river flooding

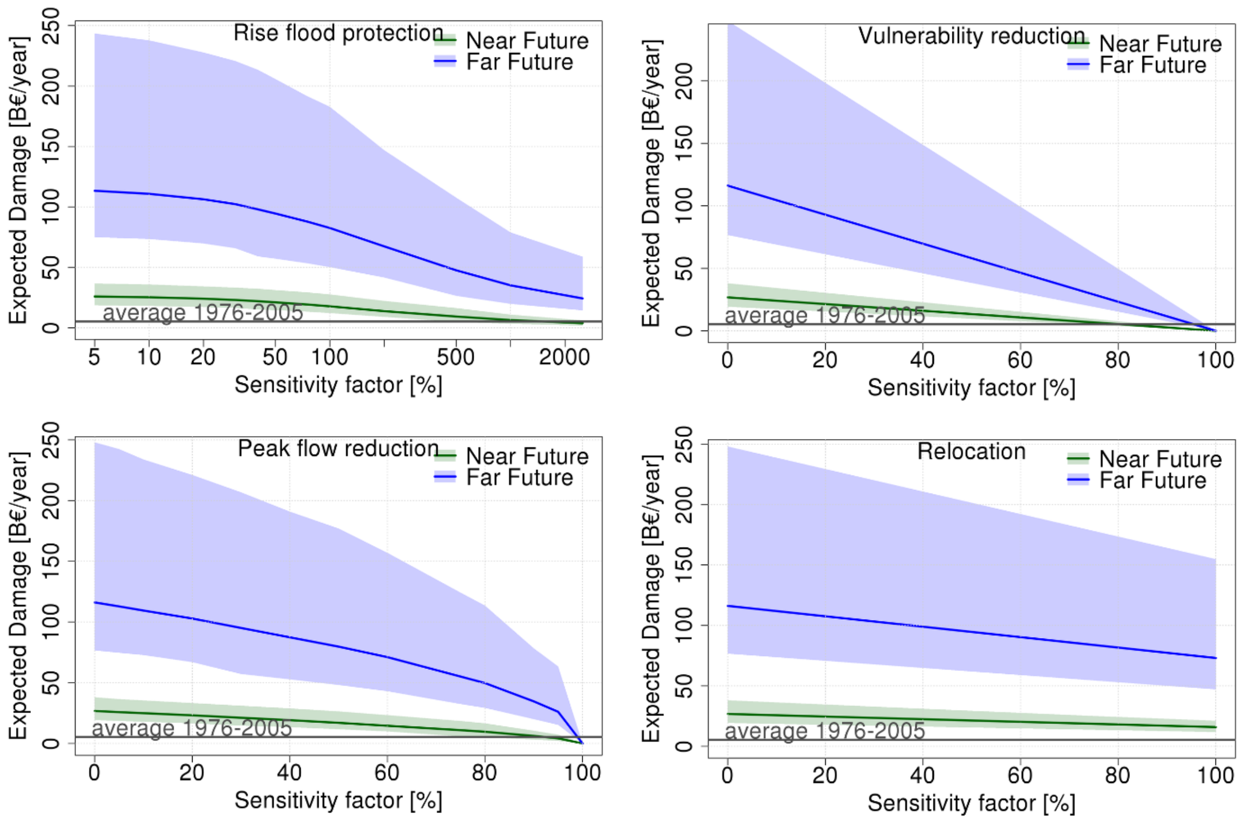


Expected annual damage from river flooding

Alfieri et al., 2015

Adaptation to river flooding

- Different adaptation measures can be put in place
- However, their effectiveness and convenience has to be evaluated
- Ongoing research on cost/benefit analysis

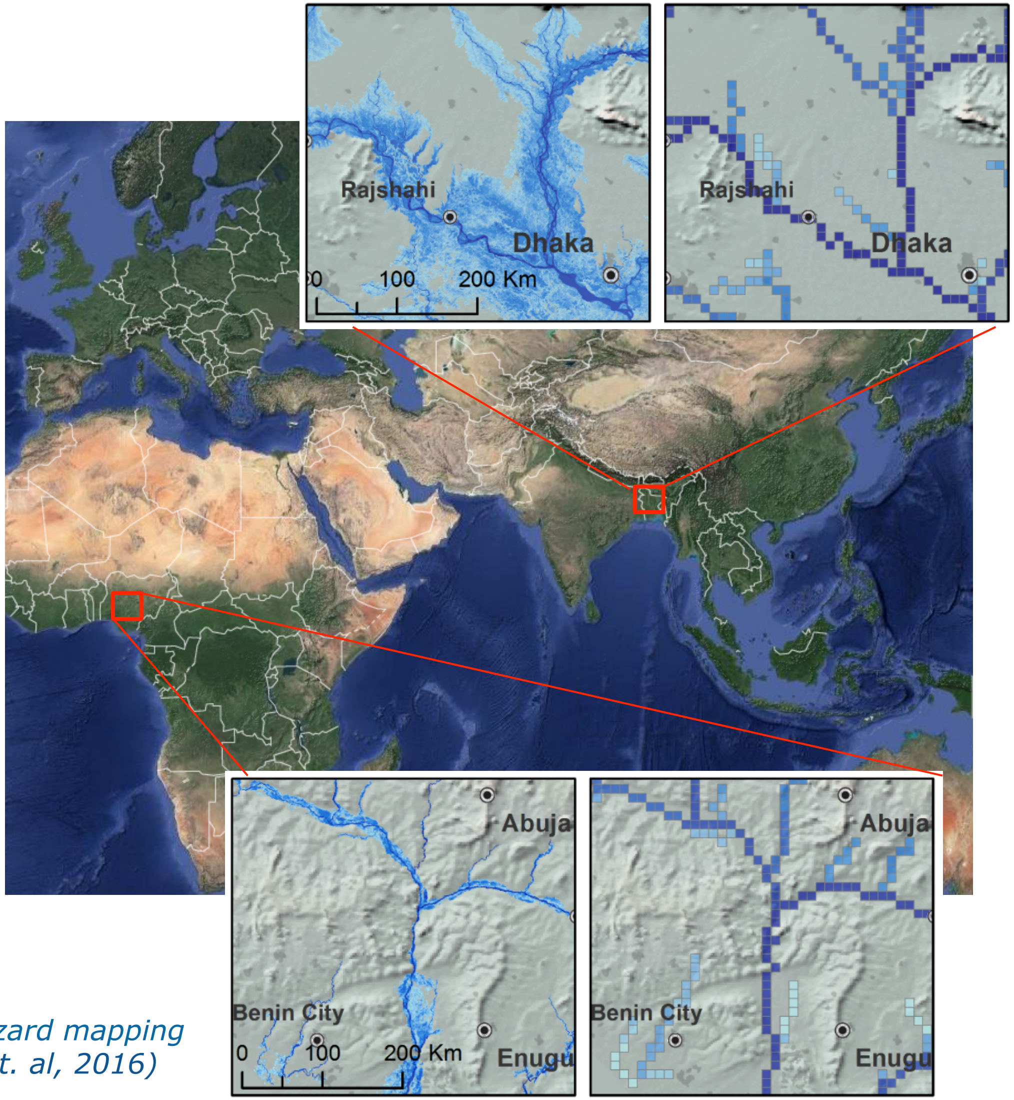


Reduction in expected annual damage for different flood adaptation strategies (sensitivity analysis)

Alfieri et al., Climatic Change, 2016

Future global flood risk

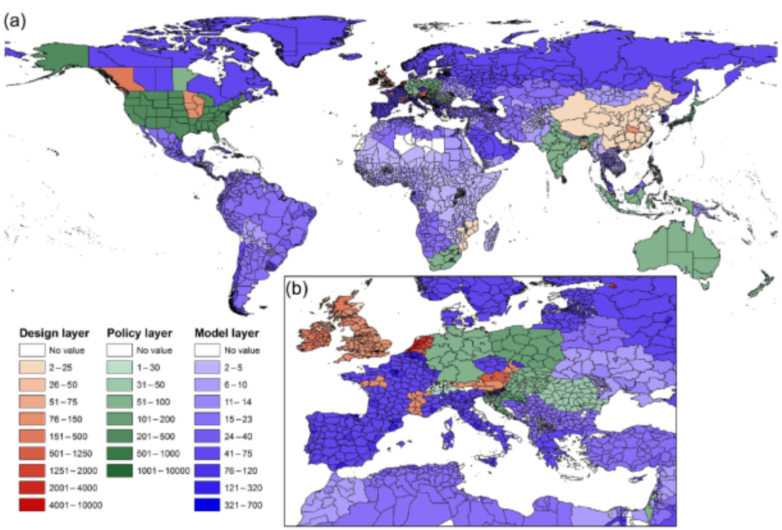
- Different GCMs projections: downscaled EC-EARTH database and ISIMIP ensemble (10 GHMs x 5 GCMs) for RCP 8.5
- Runoff, river flow and flooding simulated with different models (CaMaFLood, LISFLOOD-CA2D)
- Multisectoral economic modelling
- future socio-economic and land scenarios considered (SSPs) under present-day vulnerability conditions
- Quantified impacts: population exposed, number of fatalities, direct damages, welfare changes (indirect economic effects)



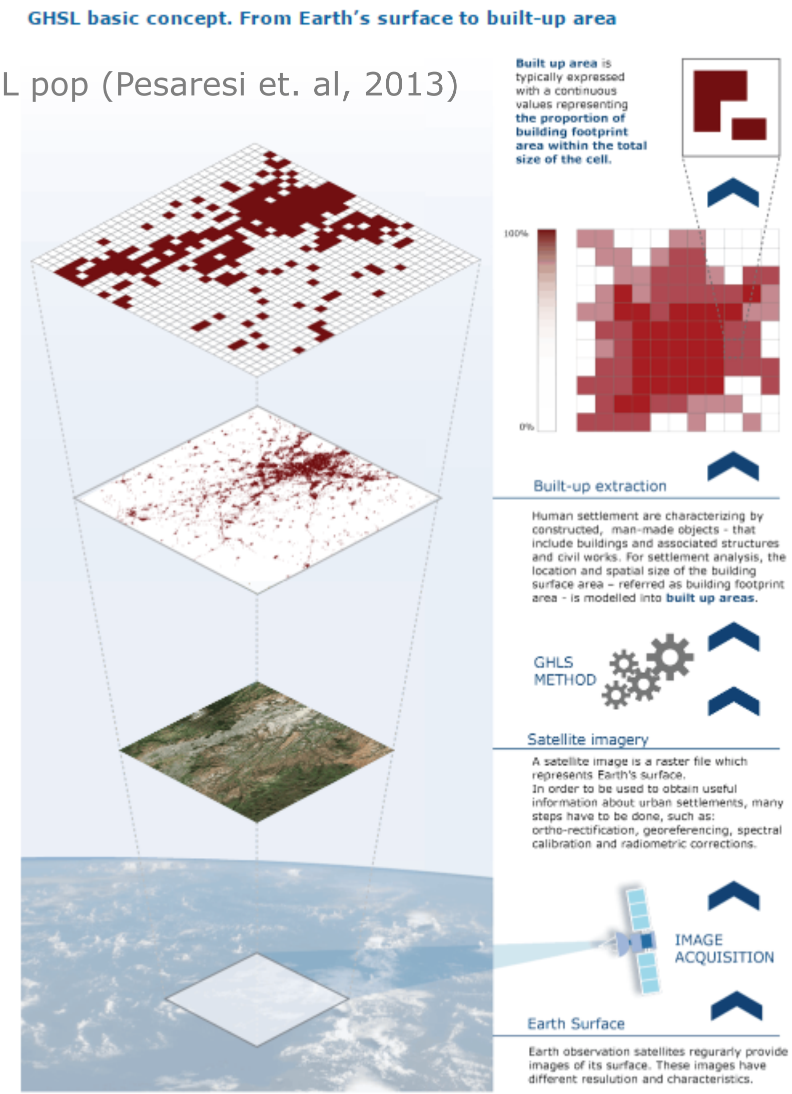
Flood hazard mapping (Dottori et. al, 2016)

Global flood risk: exposure and vulnerability

- Population maps from Global Human Settlement Layer (GHSL)
- Land use from GlobCover 2009
- Global flood damage functions at continental/country scale (Huizinga et al., 2017) with GDP data
- Economic modelling for welfare impacts
- Flood defence information (FLOPROS)



FLOPROS (Scussolini et. al, 2016)



GHSL pop (Pesaresi et. al, 2013)

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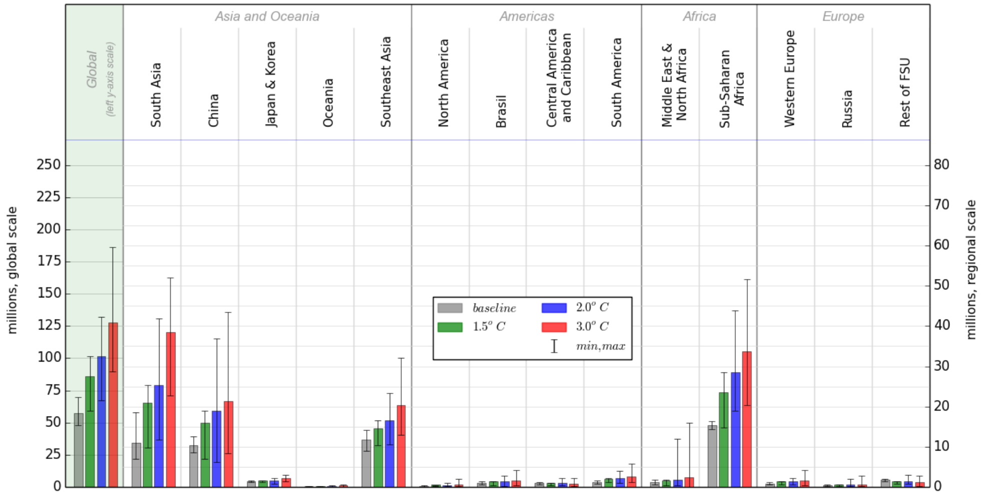
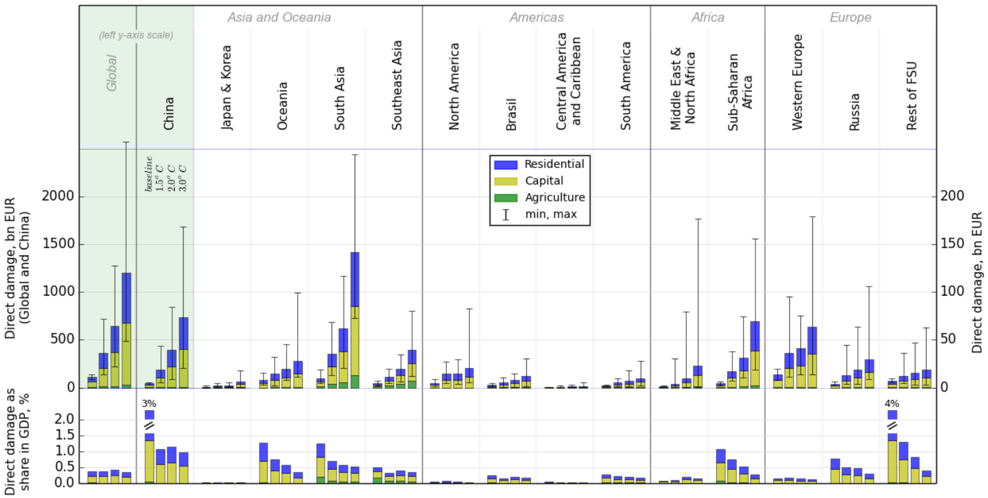
Future global flood risk



people exposed (top) and fatalities (bottom) for the SSP5 (ensemble average and min-max spread)

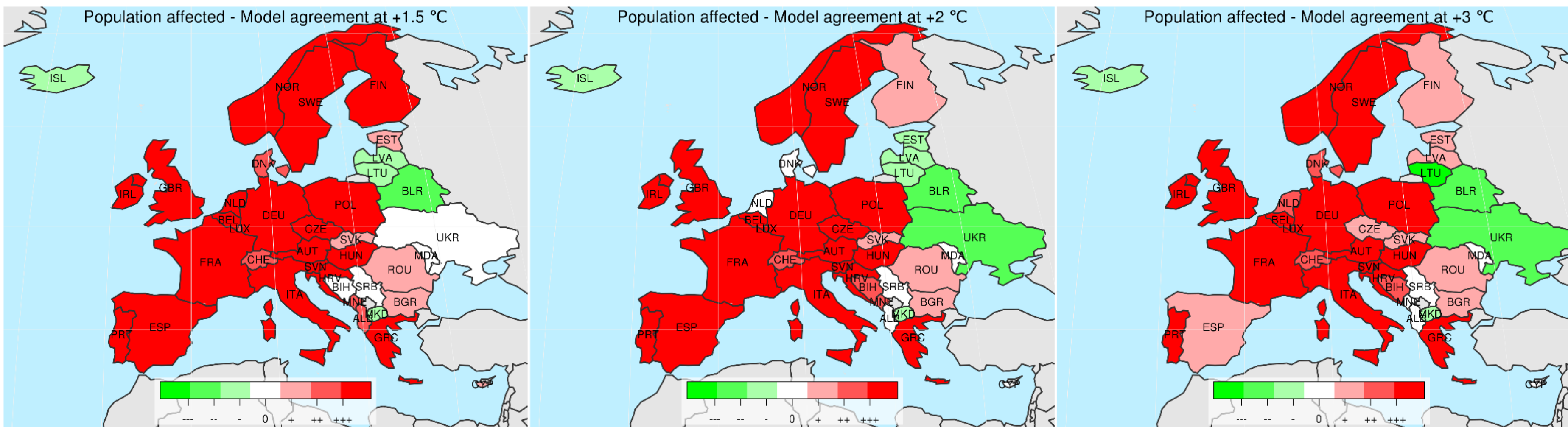


- Flood risk is projected to rise in most parts of the world, with impacts increasing with the level of warming.
- Human impacts could double at 2ºC and triple in a 3ºC warmer world
- Flood impacts are further shown to have an uneven regional distribution, with the greatest losses observed in the Asian continent at all analysed warming levels.
- Higher warming implies higher uncertainty in projections of potential human and economic impacts.

See Dottori et al., Nature Climate Change (2018)

Multi-model risk projections in Europe

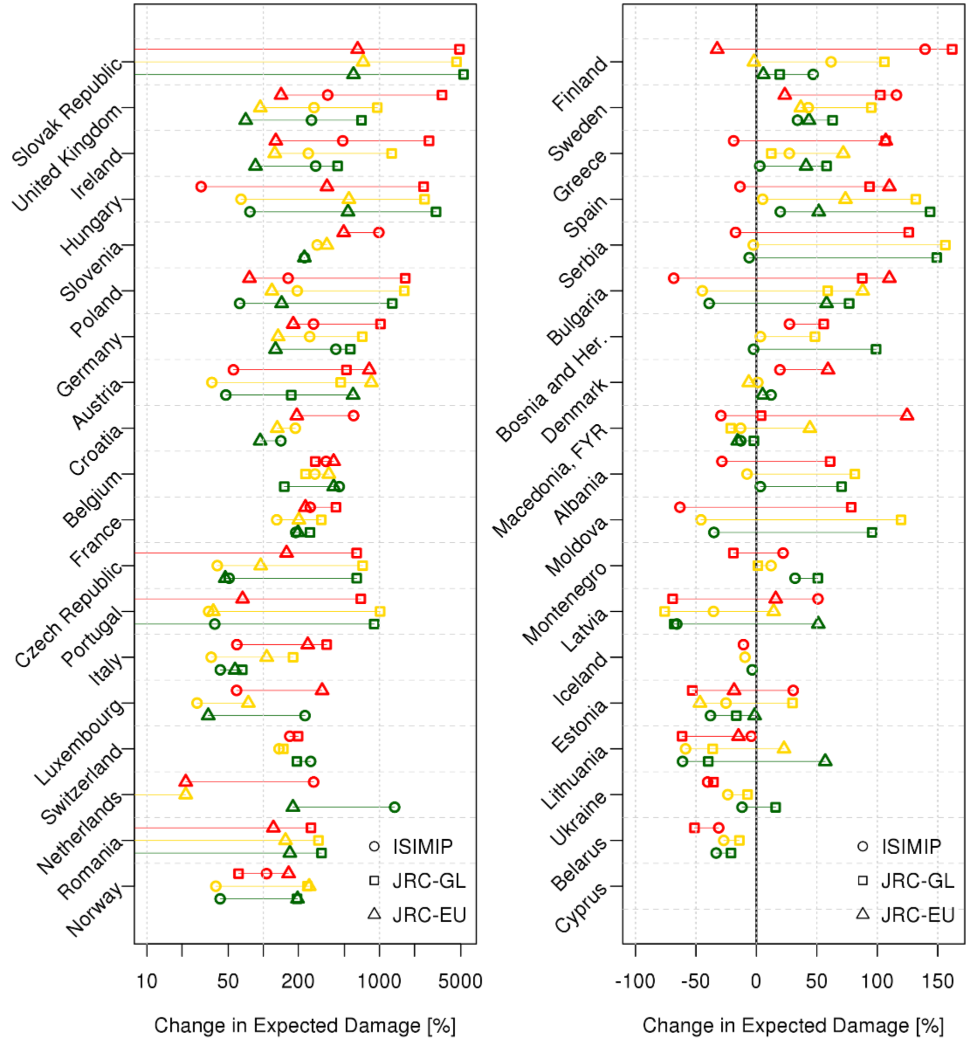
- We compare three different model ensembles (1 European, 2 Global)
- All flood risk projections show increasing trend in most of Western and Central European countries, and on a decreasing trend in Eastern countries.
- Considerable increase in flood risk even under the most optimistic scenario of 1.5 ºC warming



Changes in population affected by river floods at 1.5ºC (left), 2ºC (center), and 3ºC (right). Darker shades of red (green) indicate larger agreement on increasing (decreasing) flood risk as compared to present values.

See Alfieri et al., Climate (2018)

Multi-model risk projections in Europe

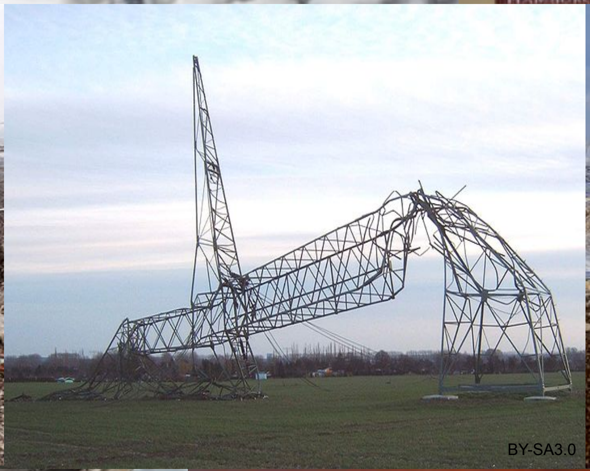


- Despite qualitative agreement, models show large variability
- Changes in flood risk for each model along the SWLs are smaller than the changes among models

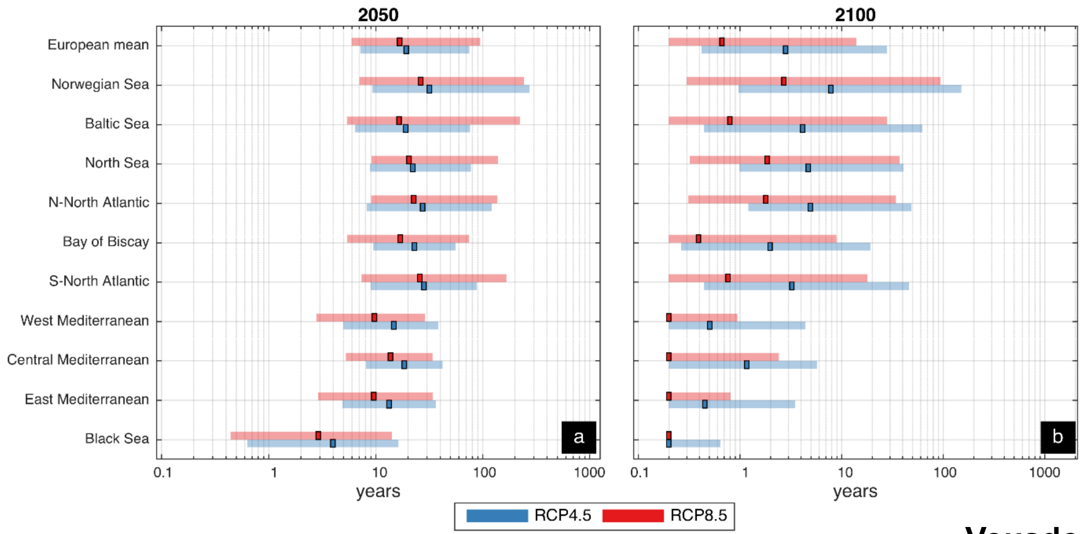
Relative average change in expected impacts for 1.5 ºC (green), 2 ºC (yellow), and 3 ºC (red) warming scenarios with respect to the baseline. Note that the x-axis in the left plot uses a logarithmic scale

See Alfieri et al., Climate (2018)

Impacts on other climate extremes

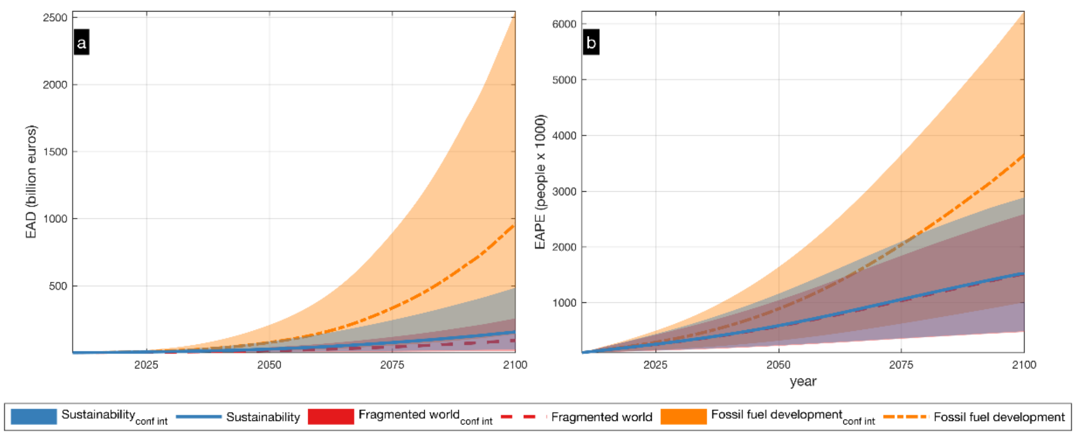


Future coastal flood risk in Europe



By the end of this century, 5 million Europeans currently under threat of a 100-year Extreme Sea Level could be annually at risk from coastal flooding.

Vousdoukas et al., Earth's Future, 2016



Increase of coastal flood impacts with 2 to 3 orders of magnitude by 2100

Vousdoukas et al.,
Nature Climate Change, 2018

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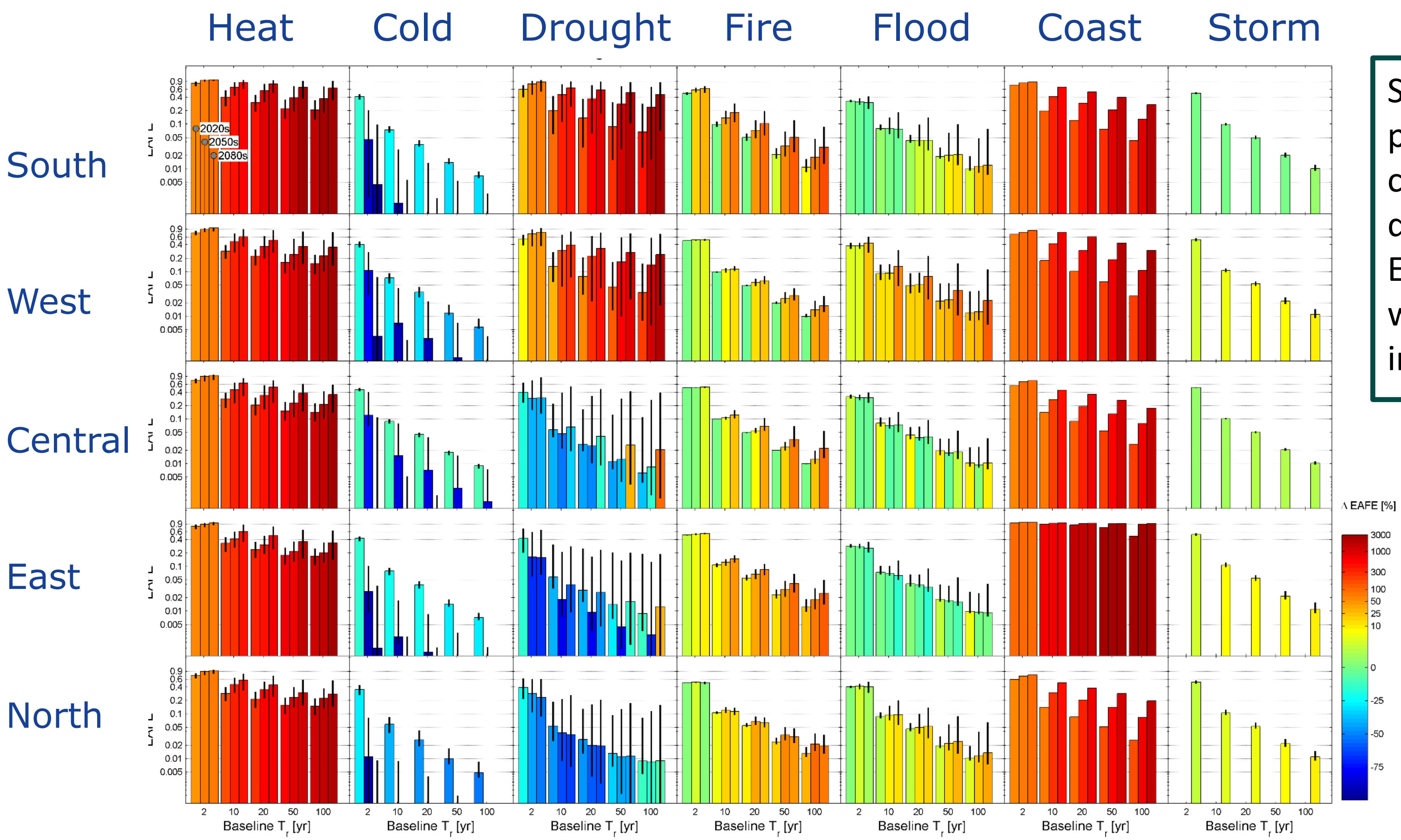
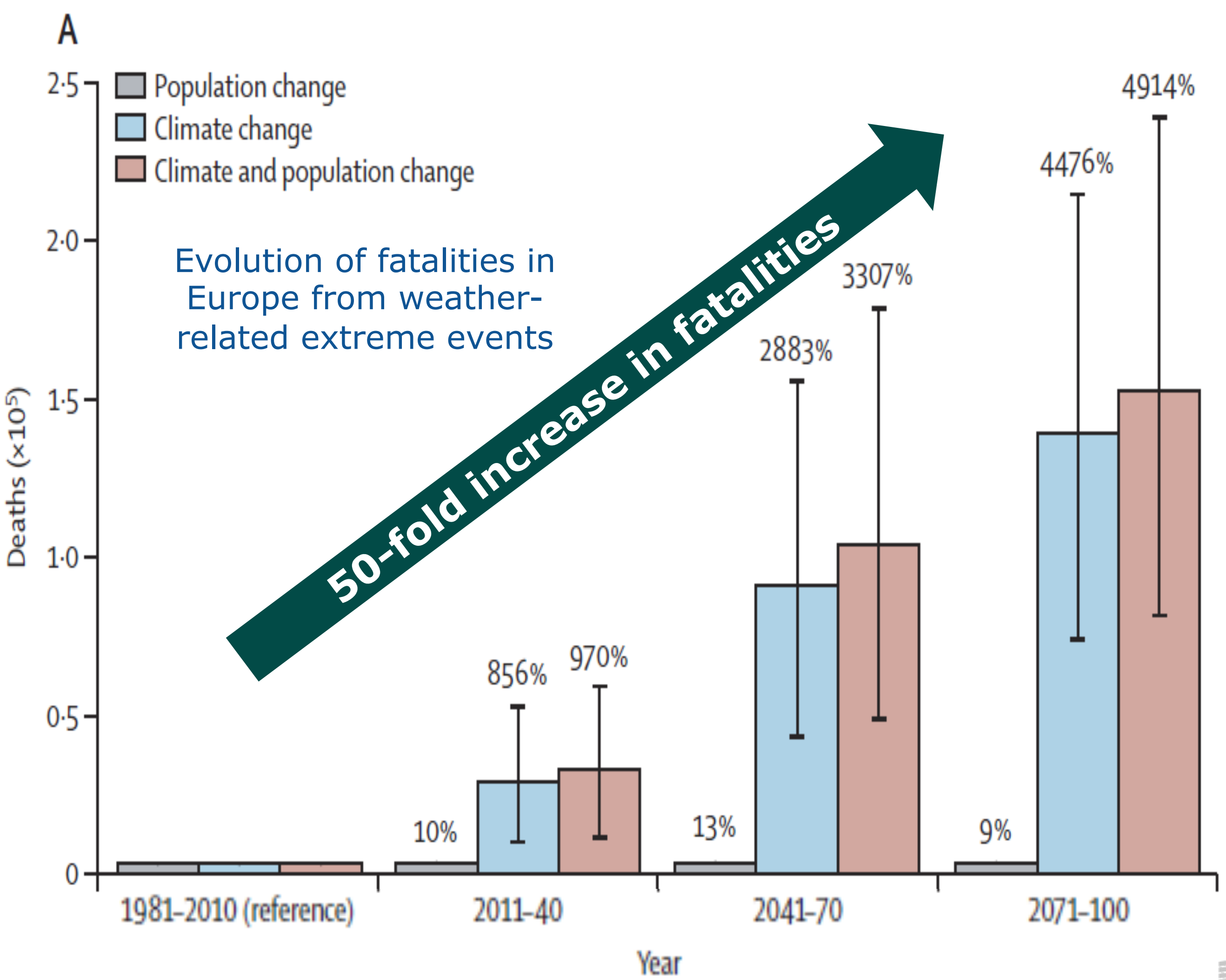
Projections of multiple hazards in Europe



Strongest rise projected in heat and coastal hazard, for droughts in Southern Europe. Cold waves will become less important.

Forzieri et al., Climatic Change, 2016

Impact on Europe's population

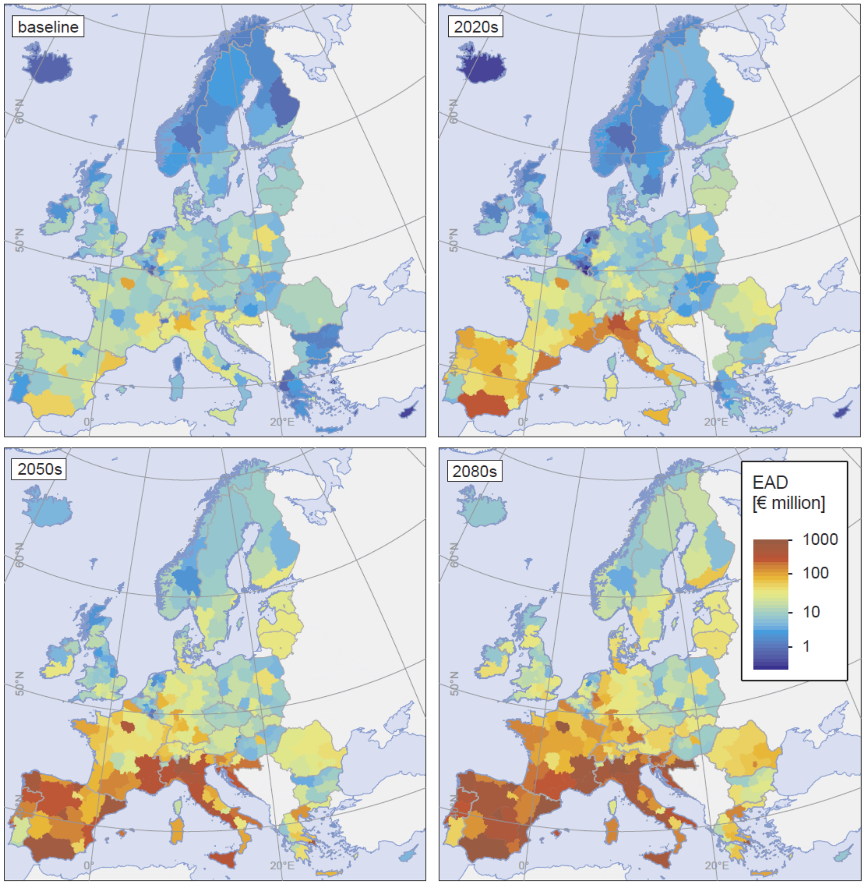


Weather-related disasters could affect about two-thirds of the European population annually by the year 2100, compared to 5% at present.

Forzieri et al., The Lancet Planetary Health, 2017

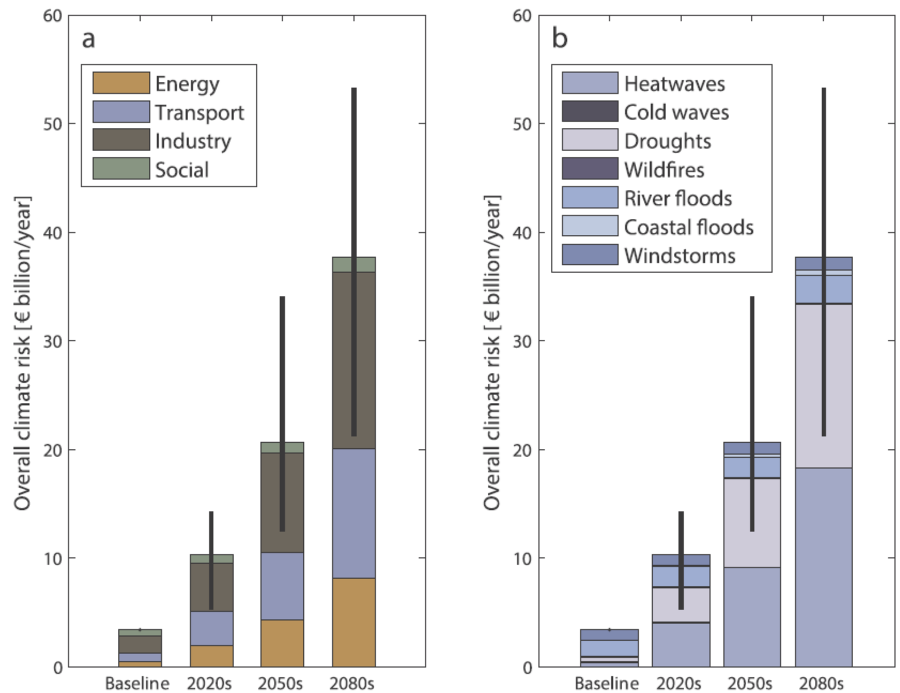
40

Multi-hazard damages to critical infrastructures in Europe



Spatial patterns of overall climate hazard risk to critical infrastructures in the different time periods

Evolution in the 21st century of ***climate hazard damages to critical infrastructures*** *in Europe under a business-as-usual emissions scenario*



Forzieri et al., Global Environmental Change, 2017

Thank you!