Back-to-front impact modelling – using impact response surfaces with probabilistic projections of climate and population change across sectors and European regions

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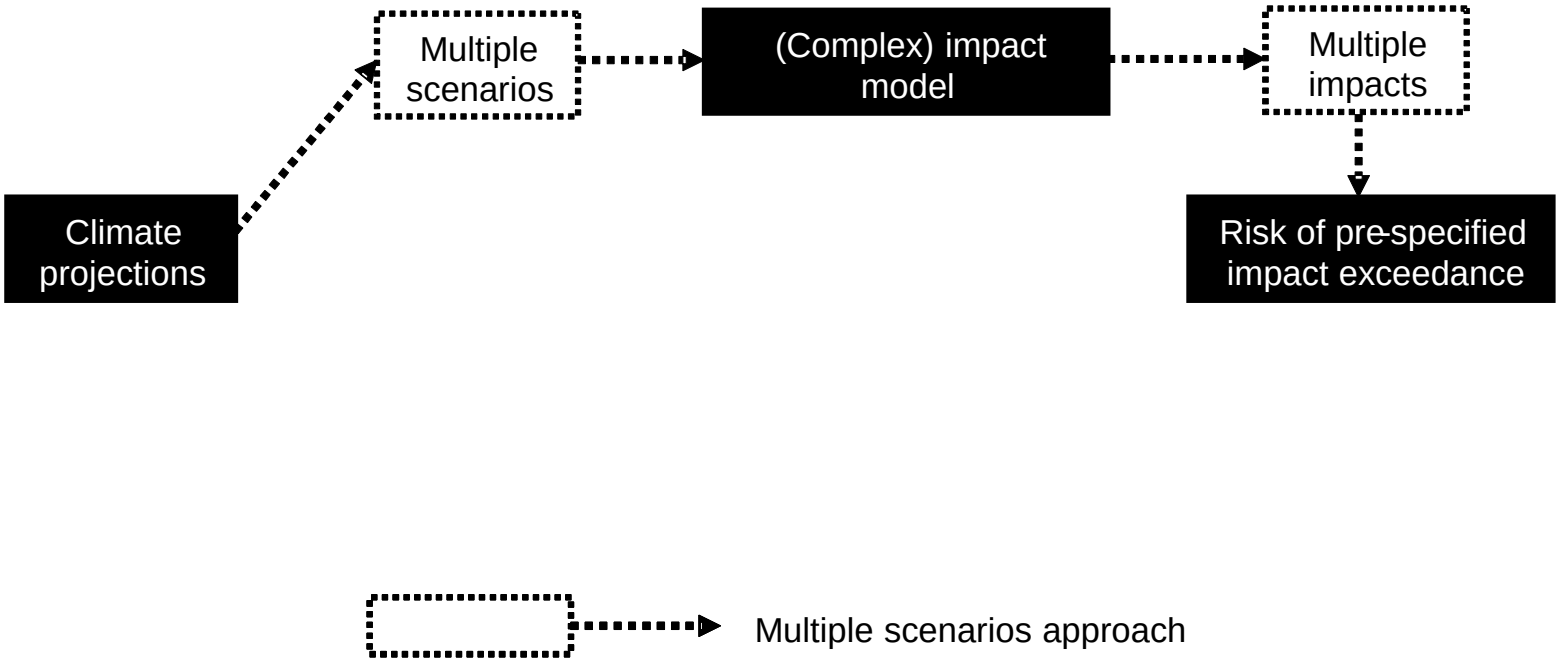
Outline

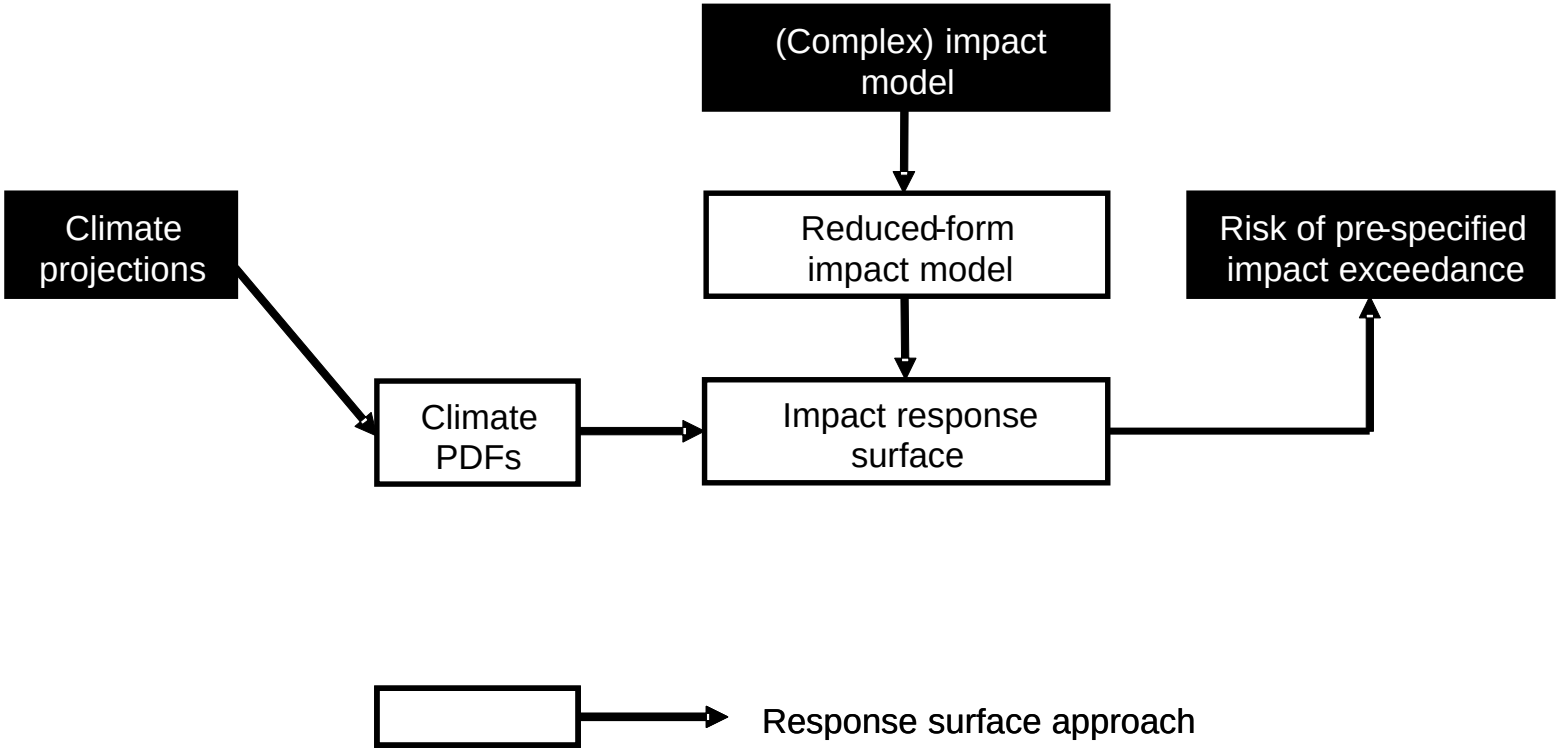
- Back-to-front impact modelling
- Example of an impact response surface (IRS)
- IRS study to compare across sectors and European regions
- Probabilistic projections of climate and population to estimate impact risk
- Conclusions

Back-to-front impact modelling



Source: Fronzek et al. 2010, doi:10.1007/s10584-009-9679-y

Back-to-front impact modelling



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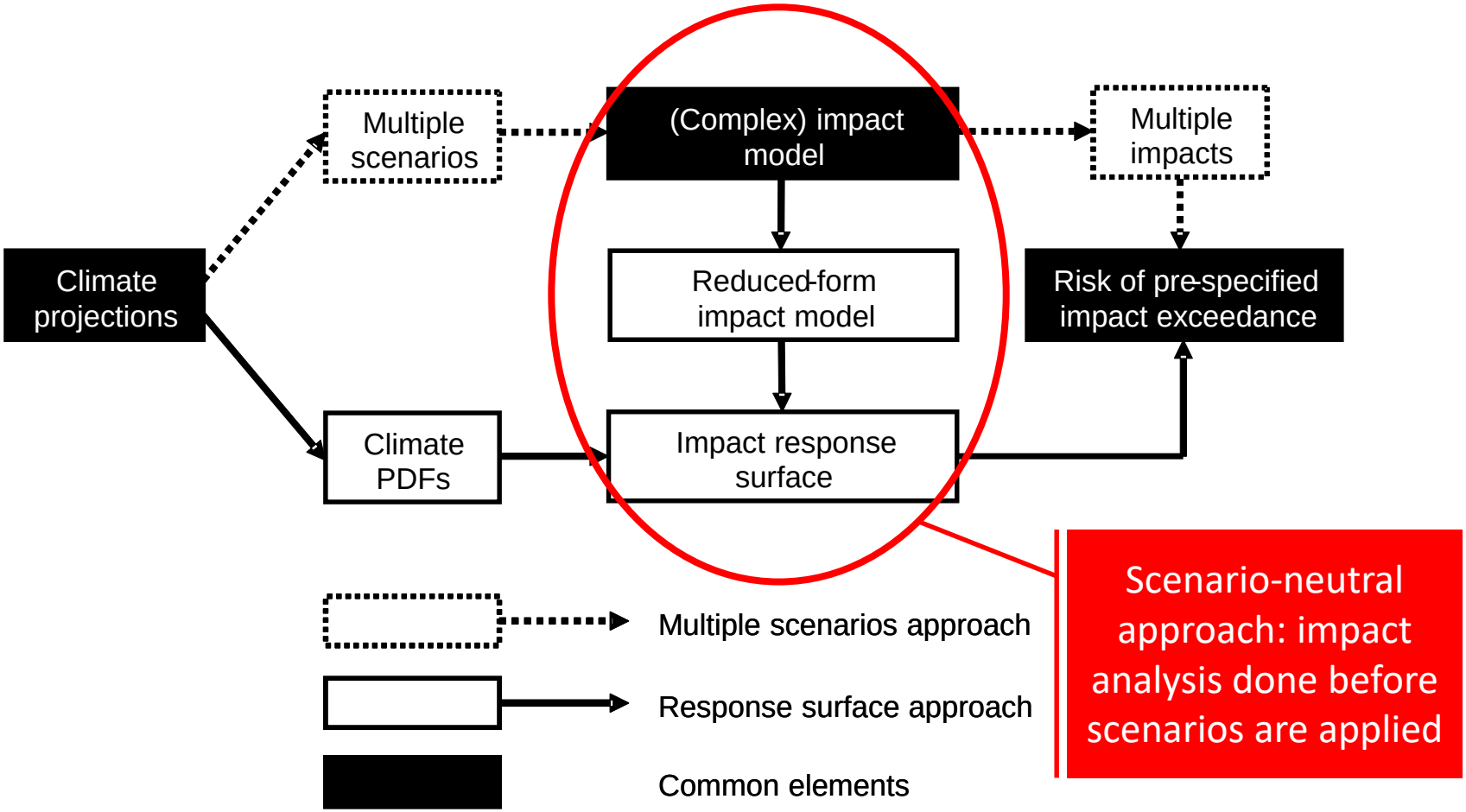
Back-to-front impact modelling

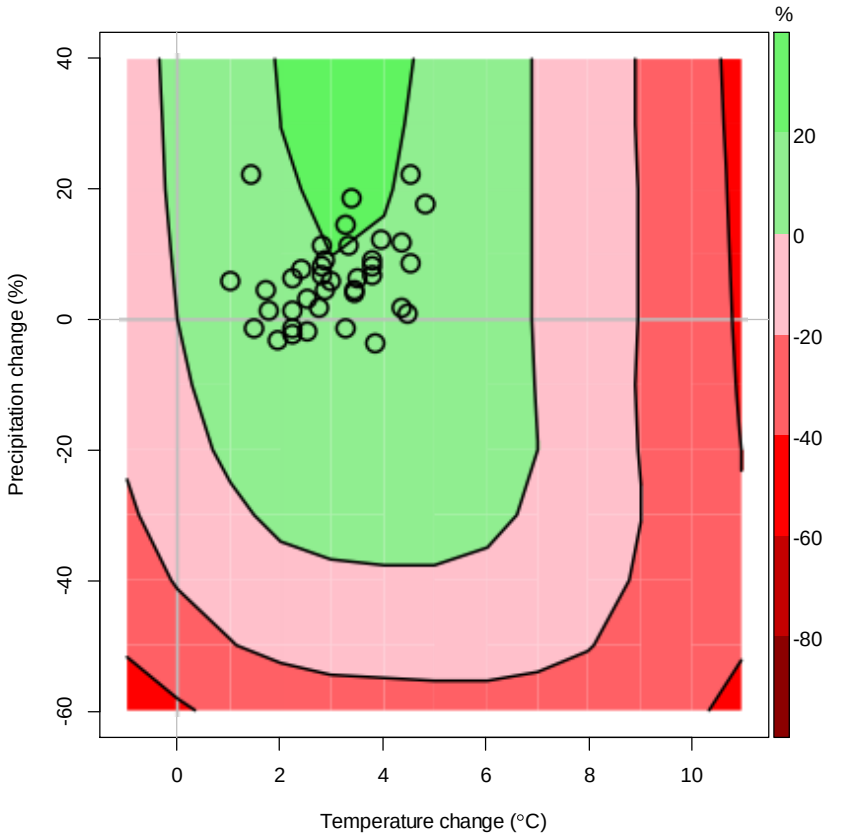


Source: Fronzek et al. 2010, doi:10.1007/s10584-009-9679-y

Example of an impact response surface (IRS)

- Sensitivity analysis to fixed perturbations to:
  - mean annual temperature (between -1 and +11 °C; 1 °C increments), and
  - precipitation (-60 to +40 %; 10 % increments)
- Overlay climate change projections on top of IRS (CMIP5 RCP8.5, 2071-2100)

Change relative to baseline in NPP simulated with VISIT, British Isles



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Sensitivity across sectors and regions

Regional Environmental Change
https://doi.org/10.1007/s10113-018-1421-8

ORIGINAL ARTICLE

CrossMark

Determining sectoral and regional sensitivity to climate and socio-economic change in Europe using impact response surfaces

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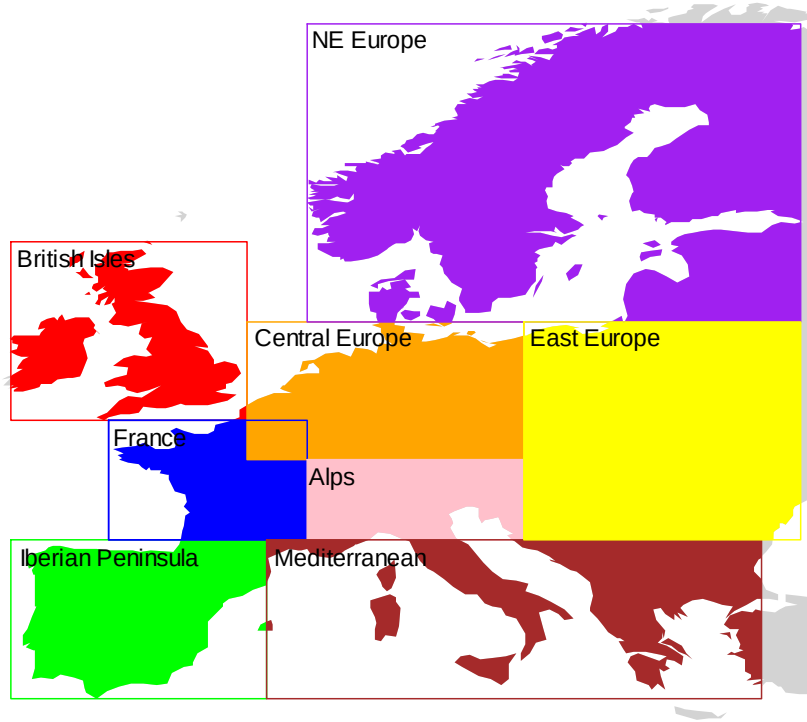
Sensitivity study across sectors and regions

- Sensitivity analysis to perturbations in two variables (climate or socio-economic)
- Regional aggregates of results to 8 European sub-regions
- Results plotted as impact response surfaces (IRSs)



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Impact indicators and models

Impact indicator	Model	Sensitivity variables
Agriculture		
Yield of 3 major crops	M-GAEZ	Temperature (T) x Precipitation (P)
NPP	VISIT	T x P
Low river flows (Q95)	WaterGAP3	T x P
Intensive agricultural land use	SFARMMOD	T x P x population x tech. development x CO2
Forestry		
Basal area of 5 tree species	ForClim v3.3	T x P
Tree biomass for 3 species	LandClim v1.4	T x P
Forest land use	SFARMMOD	T x P x population x tech. development x CO2
Biodiversity		
Mean species abundance index	GLOBIO	T x agricultural land use
Human health		
Heat excess mortality	AIM/Impact[health]	T x population
Flooding		
People affected by coastal floods	CFFlood	Sea-level rise (SLR) x population (SLR x GDP)
High river flows (Q5)	WaterGAP3	T x P

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Range and intervals of perturbations

Driver	Min	Max	Interval	n
Temperature	-1°C	+11°C	1°C (-1 – 5) or 2°C (5 – 11)	10
Precipitation	-60%	40%	10%	11
Regional sea-level rise	0 m	2.5 m	0.25 m	11
CO2 level	350 ppm	950 ppm	100 ppm	7
Population[1]	-90%	+210%	30%	11
GDP[1]	0%	+700%	25% (0 – 100), 100% (100 – 300) or 200% (300 – 700)	10
Agricultural land use	-10%	30%	5%	9
Yield changes due to techn. dev.	-50%	100%	50%	4

[1]) Ranges approx. covering the SSP ranges across all European countries in the IIASA SSP database.

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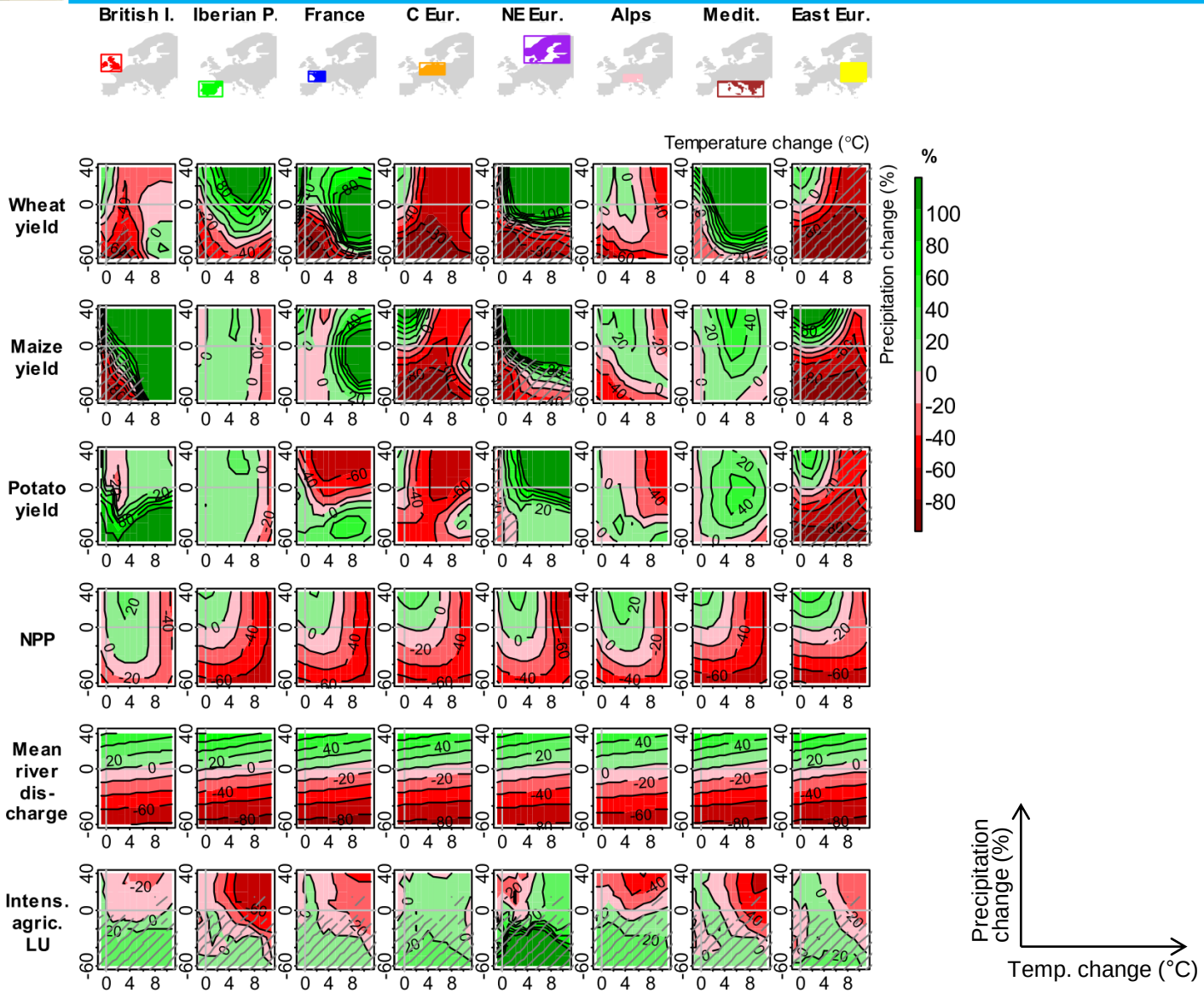
Impact response surfaces: agriculture



Source: Fronzek et al. 2018, doi:10.1007/s10113-018-1421-8

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Impact response surfaces: forests

Source: Fronzek et al. 2018, doi:10.1007/s10113-018-1421-8

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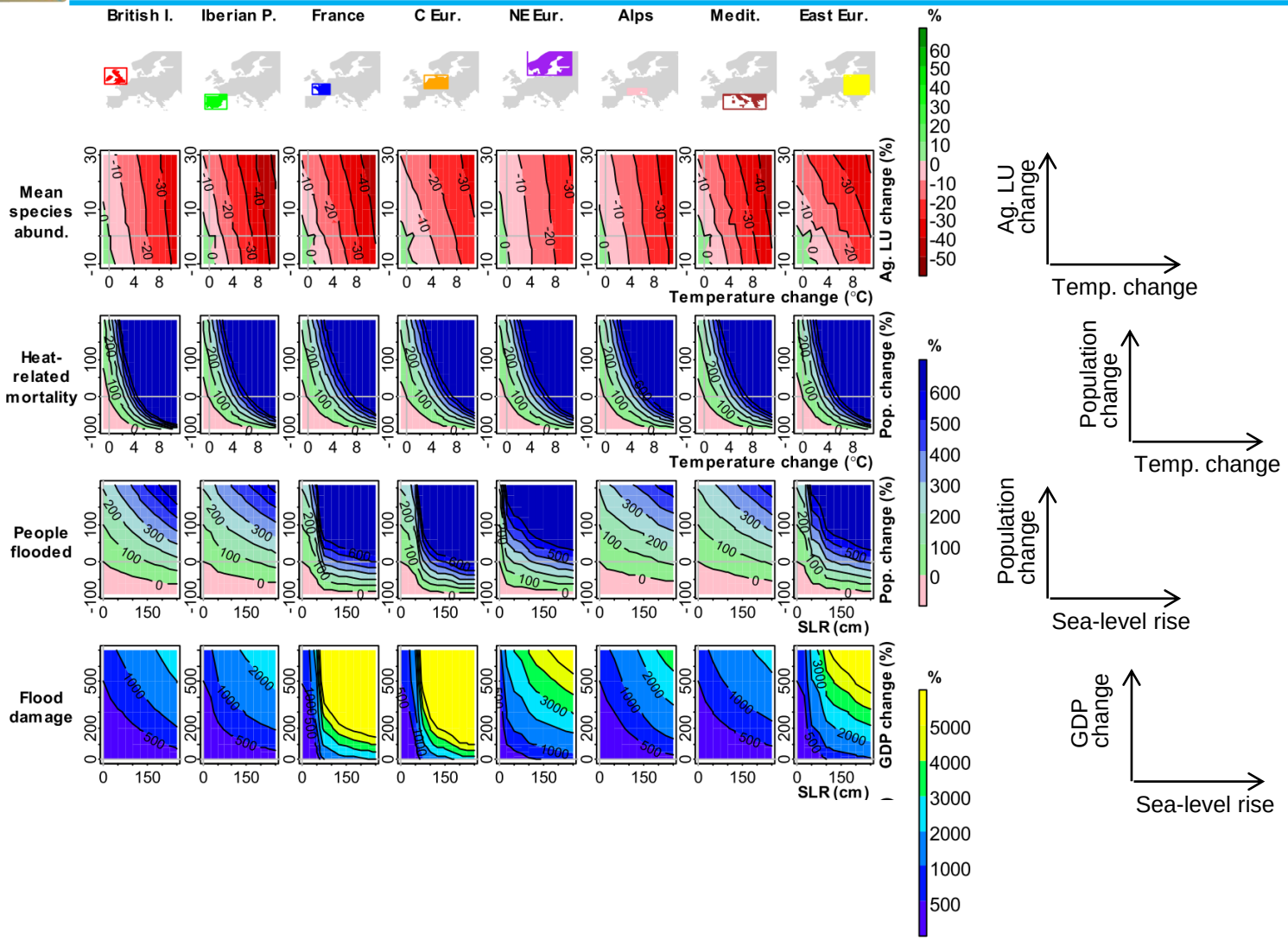
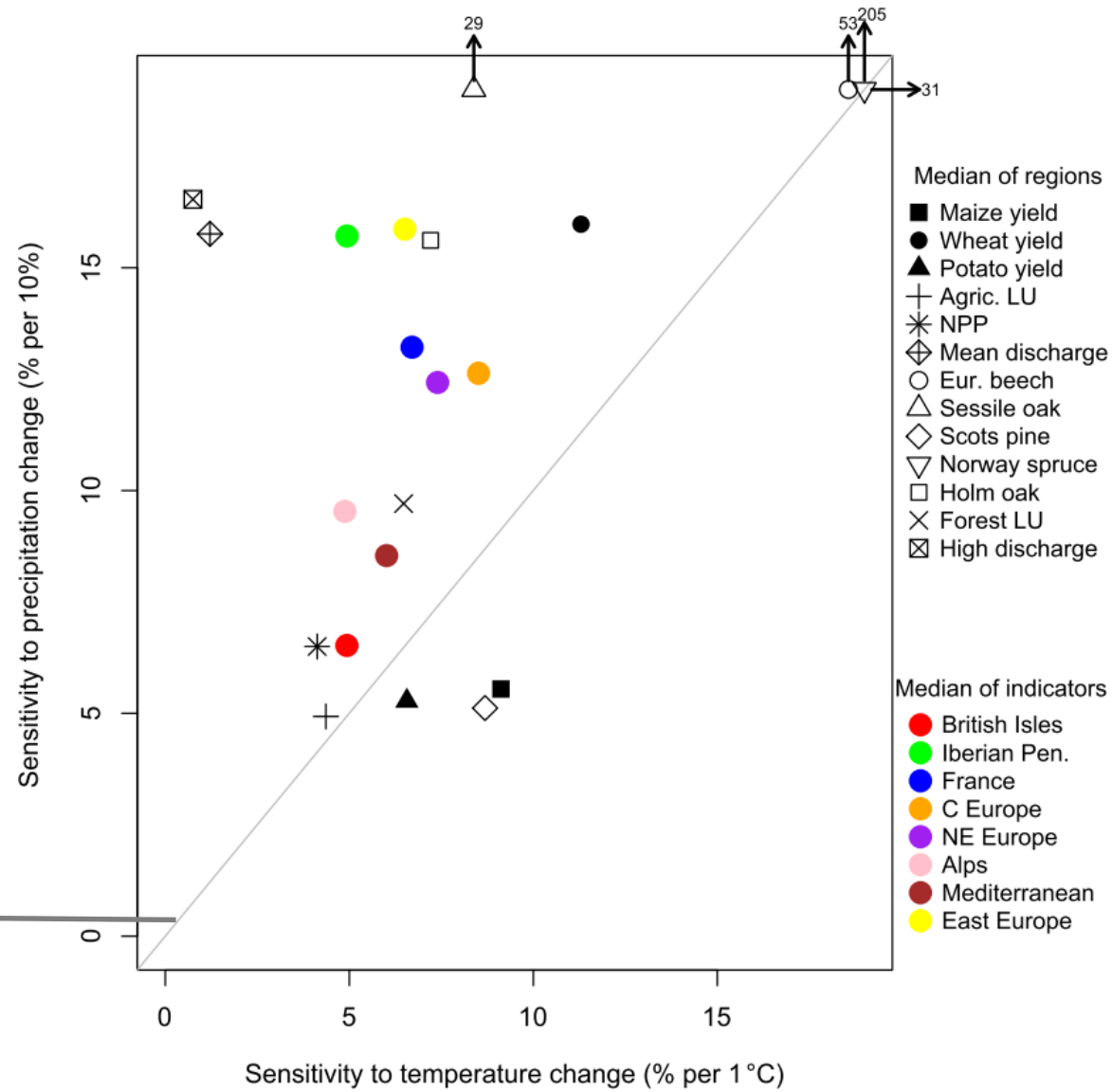
Impact response surfaces for so-econ drivers



Source: Fronzek et al. 2018, doi:10.1007/s10113-018-1421-8

Average sensitivity per indicator and region

Sensitivity of 13 impact indicators to changes in temperature and precipitation averaged across ranges of perturbations defined for each region by twenty-first century CMIP5 RCP8.5 projections.



Same relative change in impact to 10% precipitation change than 1°C temperature change

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Source: Fronzek et al. 2018, doi:10.1007/s10113-018-1421-8

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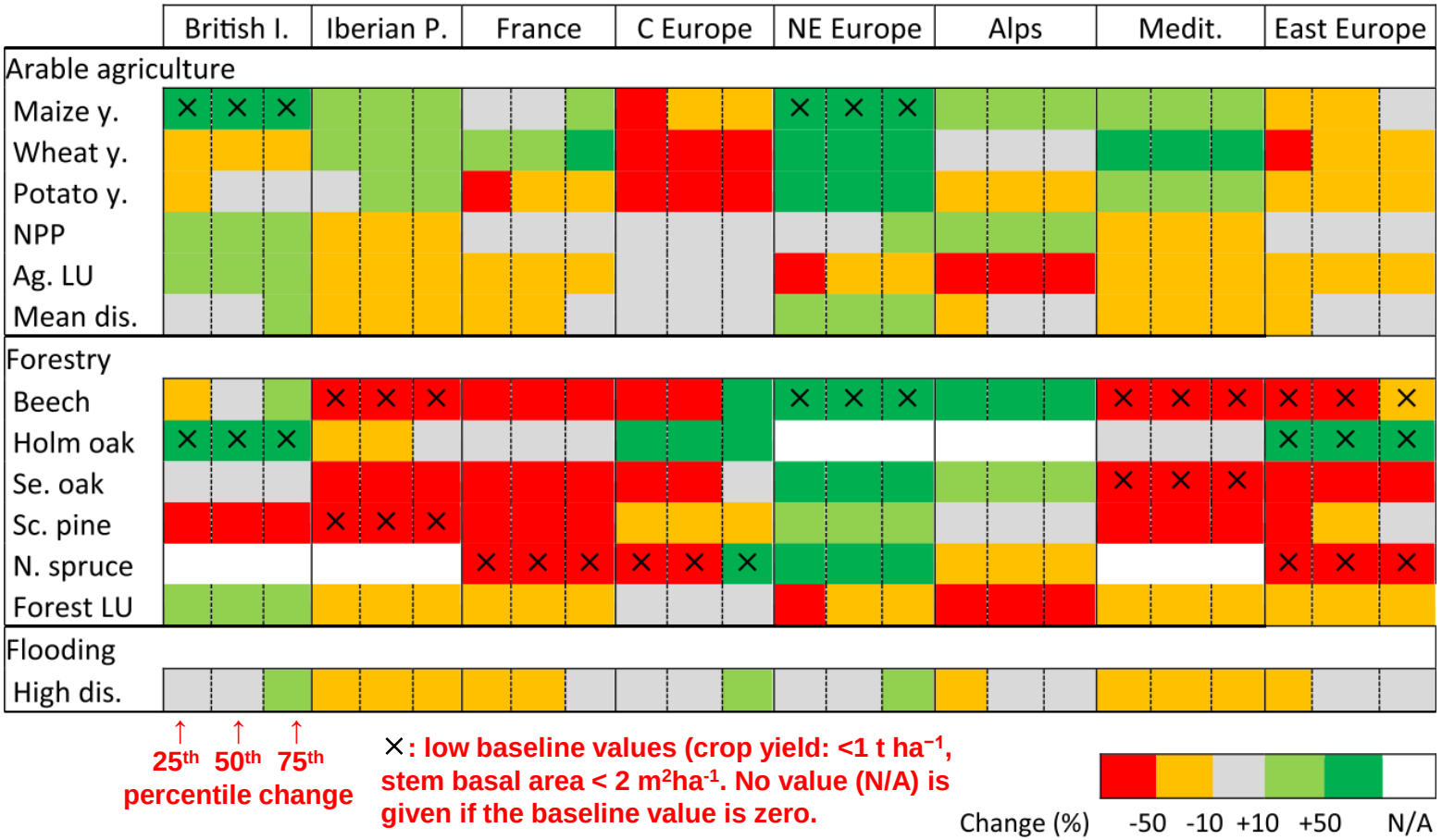
Evaluating IRSs with climate projections

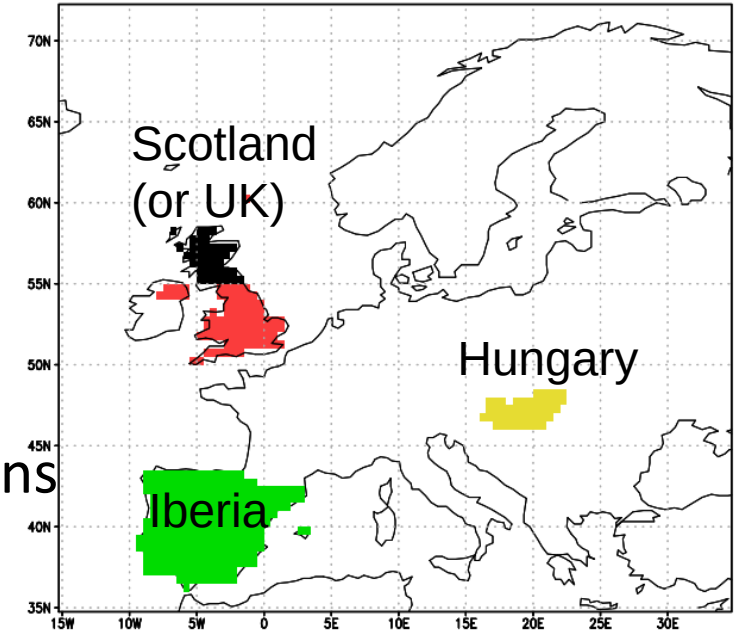
%-changes of impact indicators for an RCP8.5 ensemble for 2070-2099 relative to 1981-2010



Source: Fronzek et al. 2018, doi:10.1007/s10113-018-1421-8

Protocol for IRS-phase 2

- Extending the first phase by making some of the assumptions more realistic
  - Seasonal weights of temperature and precipitation changes (instead of constant perturbations for all days of the year)
  - Including CO2 effect for crop yield model
  - Regions-specific ranges of perturbations to drivers
- Regional aggregates of results to 3 IMPRESSIONS regional case study regions
- Results plotted as impact response surfaces (IRSs)
- Combining IRSs with probabilistic projections of drivers for risk assessment



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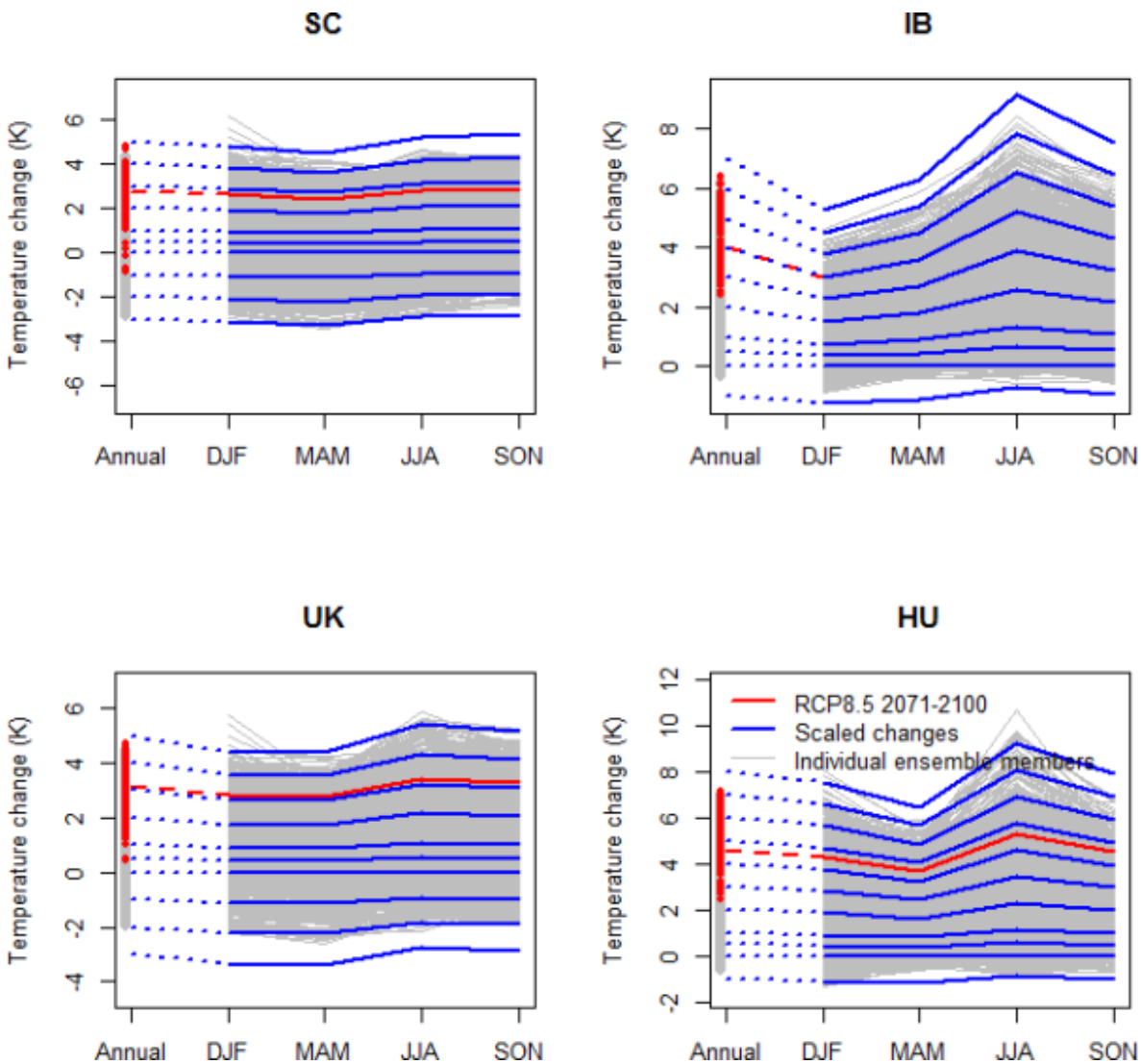
Seasonal weights for annual T and P changes



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Impact models in IRS-phase 2

Model	Drivers (X and Y)	Impact Variable (Z)	Regions
AIM/Impact[Health]	T x population	Heat stress excess mortality	IB, HU, UK
M-GAEZ	T x P	Yield of 7 crops	IB, HU, SC
VISIT	T x P	NPP	IB, HU, SC
SWAT	T x P	River discharge for the Xarrama catchment	IB

Simulations from IRS phase 1 can be considered, but:

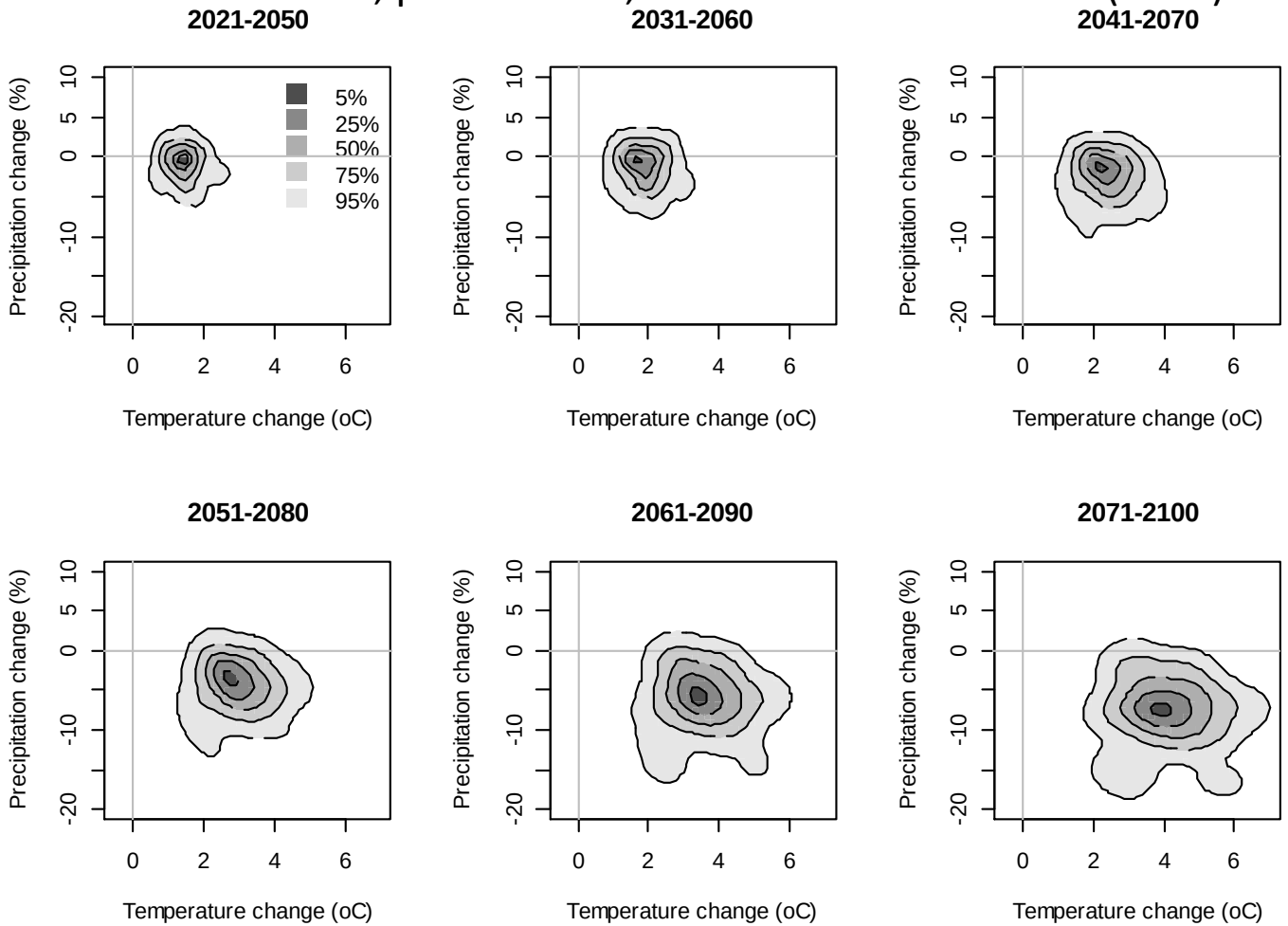
- CFFlood –if we can get hold of probabilistic local sea-level rise projections
- WaterGAP, ForClim – could be used with the caceat of the lack of seasonal weighting
- SFARMOD and CRAFTY land use models – difficult because of inter-regional dependencies, so maybe not

Models for which interest was previously expressed: Lyme disease, SPECIES

Probabilistic projections of climate change for Iberian Peninsula

Resampled CMIP5 projections, RCP8.5, baseline 1981-2010

Source: Jouni Räisänen, pers. comm.; Räisänen & Ruokalainen (2006)



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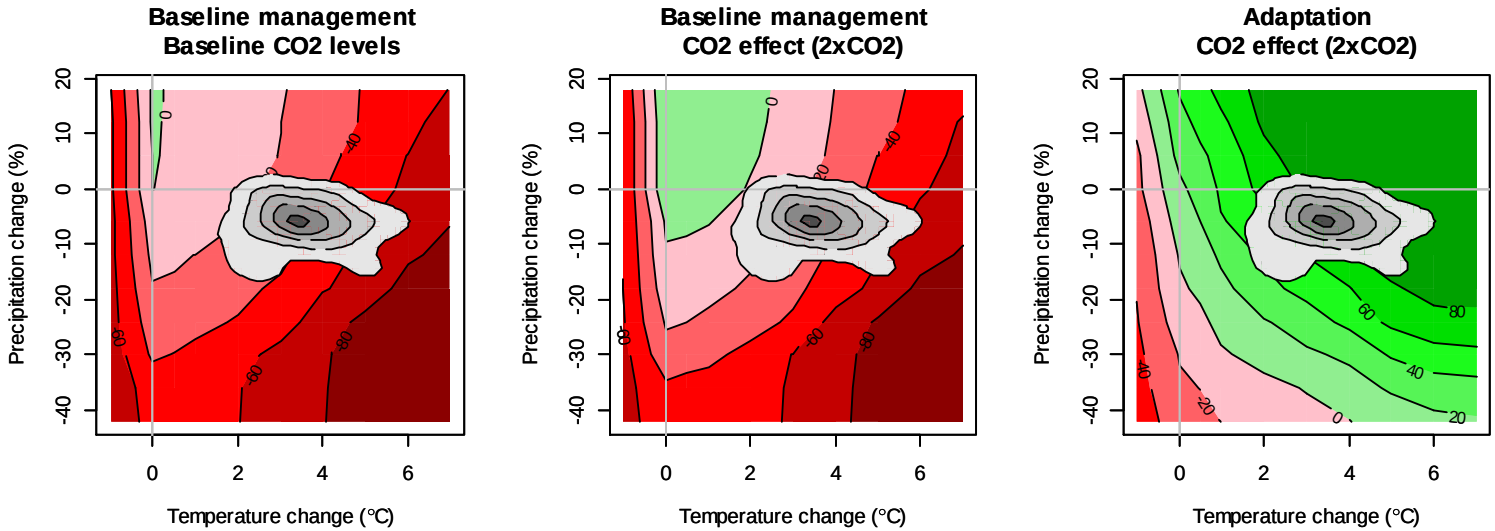
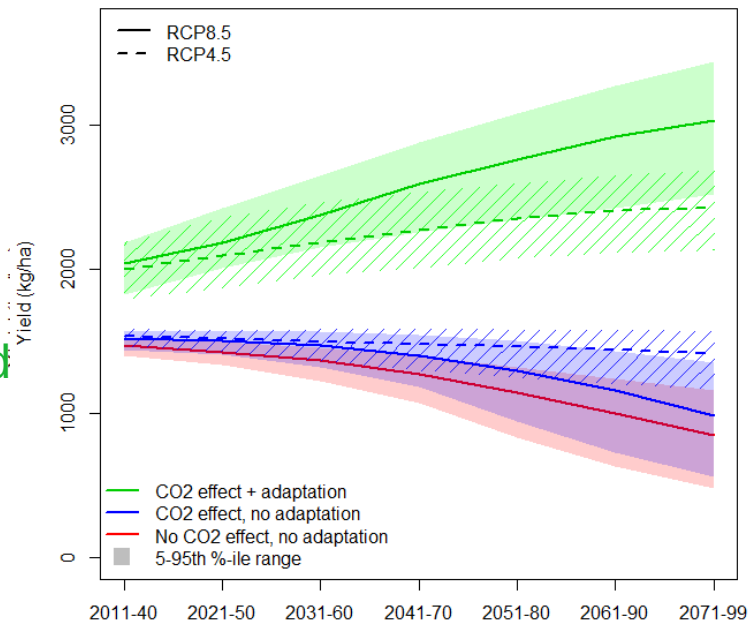
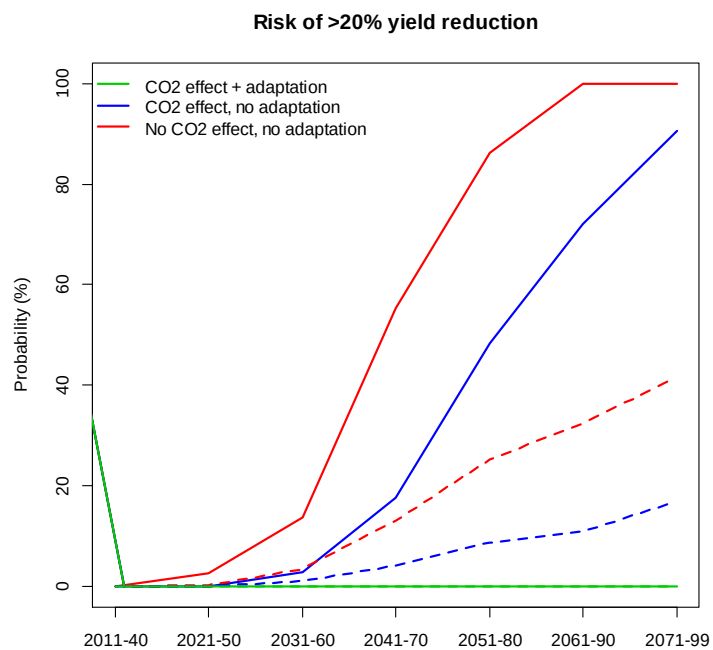
Probabilistic projection of wheat yields, Iberian Peninsula



"Critical" yield threshold





Probabilistic projection of adaptation options: barley yields in Finland

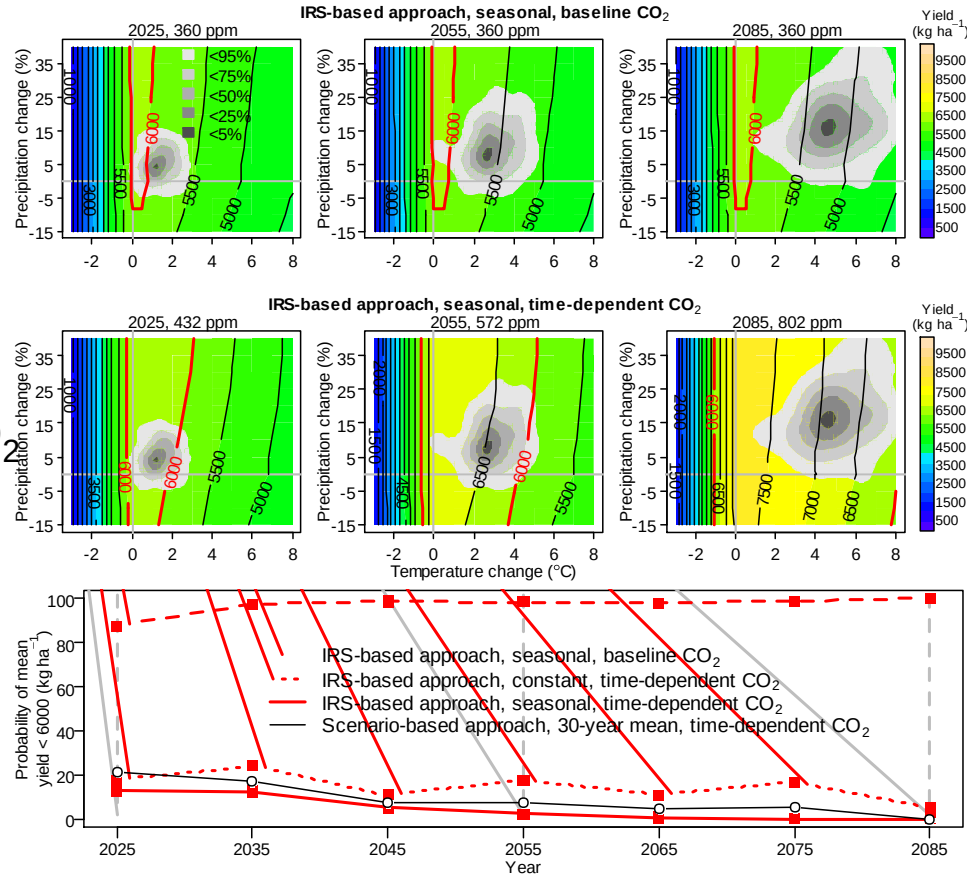
Barley yields simulated with the WOFOST crop model for Jokioinen, Finland

CO2 effect on yields

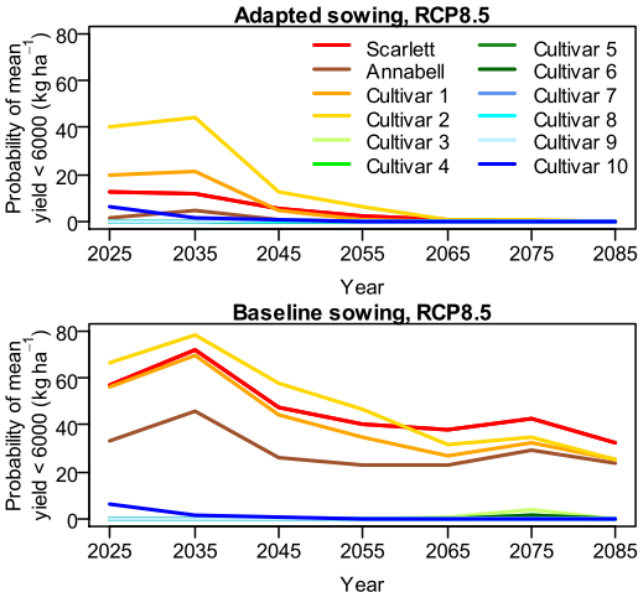
No CO_2 effect

With CO_2 effect

Yield shortfall



Adaptation options: sowing date shift & cultivar change



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Source: Pirttioja et al. 2018, doi:10.1016/j.agrformet.2018.10.006

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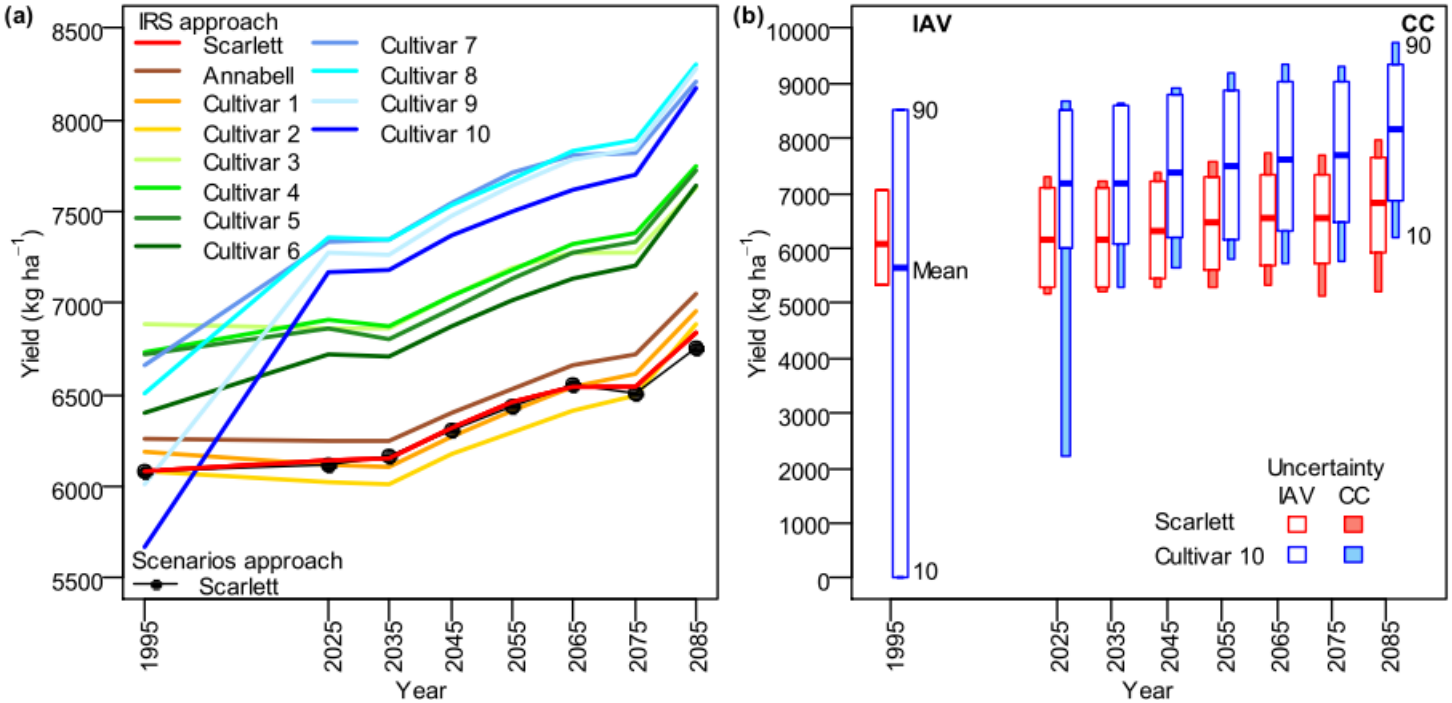
Adaptation options: cultivar change



Source: Pirttioja et al. 2018, doi:10.1016/j.agrformet.2018.10.006

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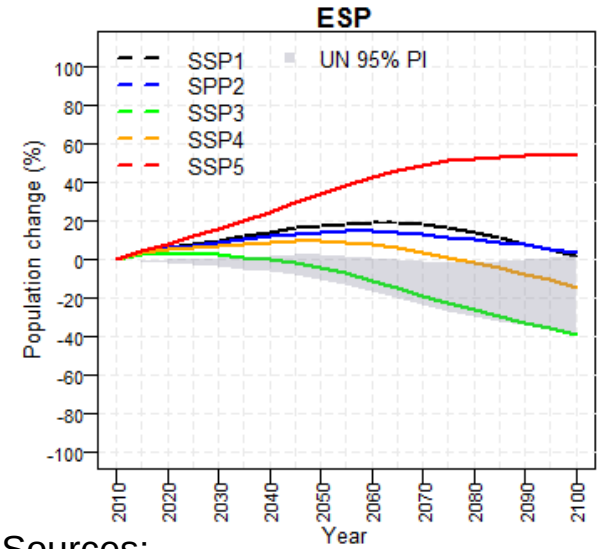
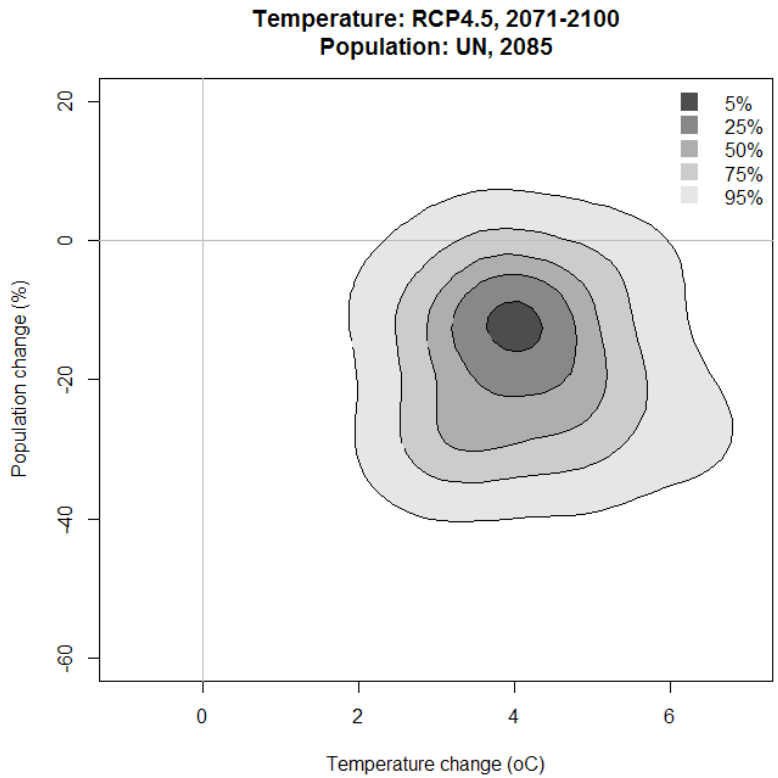
Population and temperature projections for Spain

Ongoing work:

- joint population and climate projections
- Basic assumption: temperature and population changes are independent
- Planned to be used with response surfaces of heat-related mortality



Sources:
Probabilistic: United Nations (2015)
SSP projections: SSP database



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Conclusions

- Impact response surfaces (IRSs) are constructed from a sensitivity analysis of an impact model
- IRSs are ”scenario-neutral” – impact analysis is done first and can then be related to climate scenarios
- IRS analysis allow to attach likelihoods to projected impacts when combined with probabilistic projections of drivers
- Comparison across European regions and sectors:
  - British Isles showed the smallest sensitivity to changes in both temperature (T) and precipitation (P)
  - Central Europe had the strongest median response to T, Eastern Europe for P
  - Lowest T sensitivity for river discharge, largest for Norway spruce productivity