POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

Updating the Social Cost of Carbon - Available Impact projections

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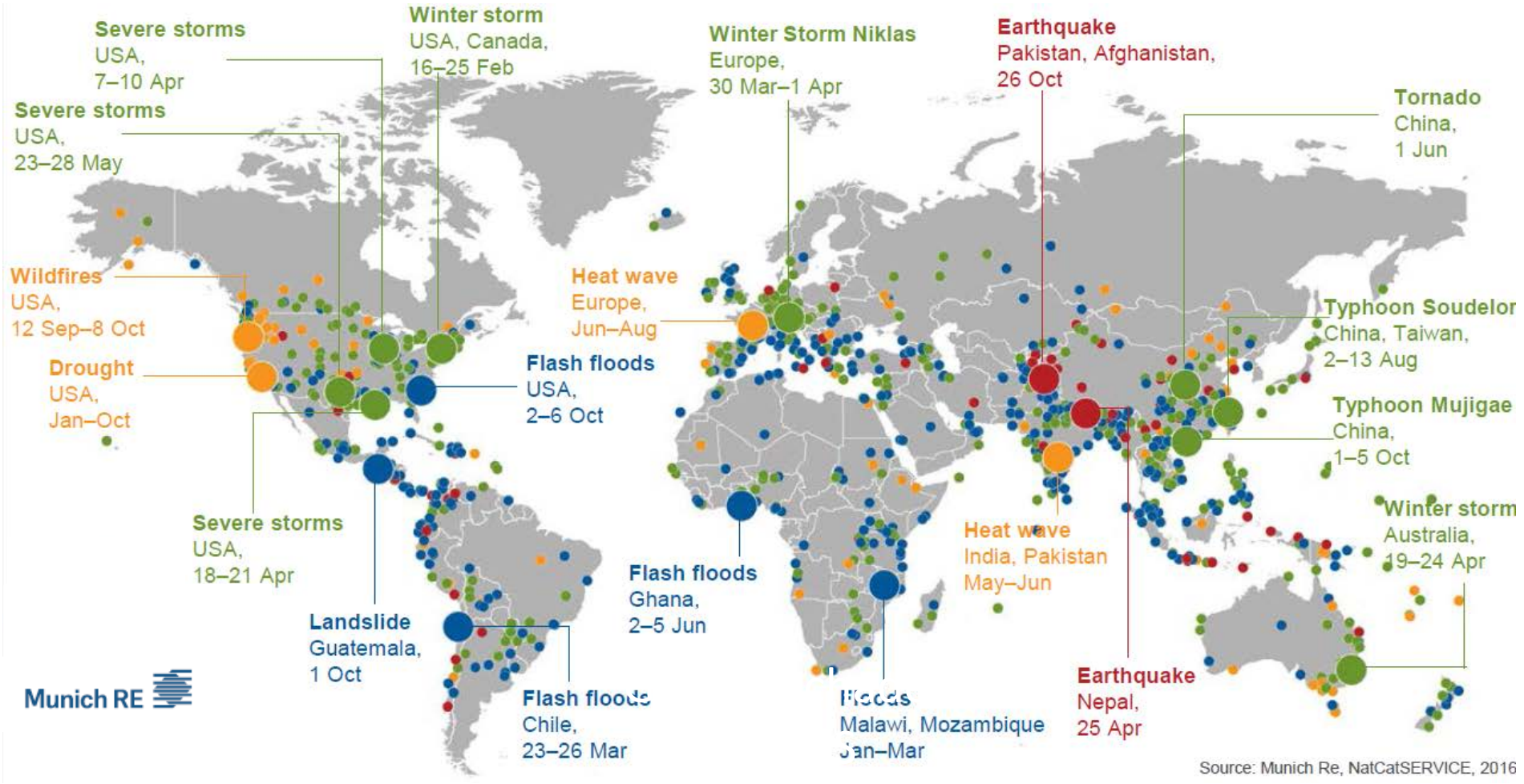
5 May 2016

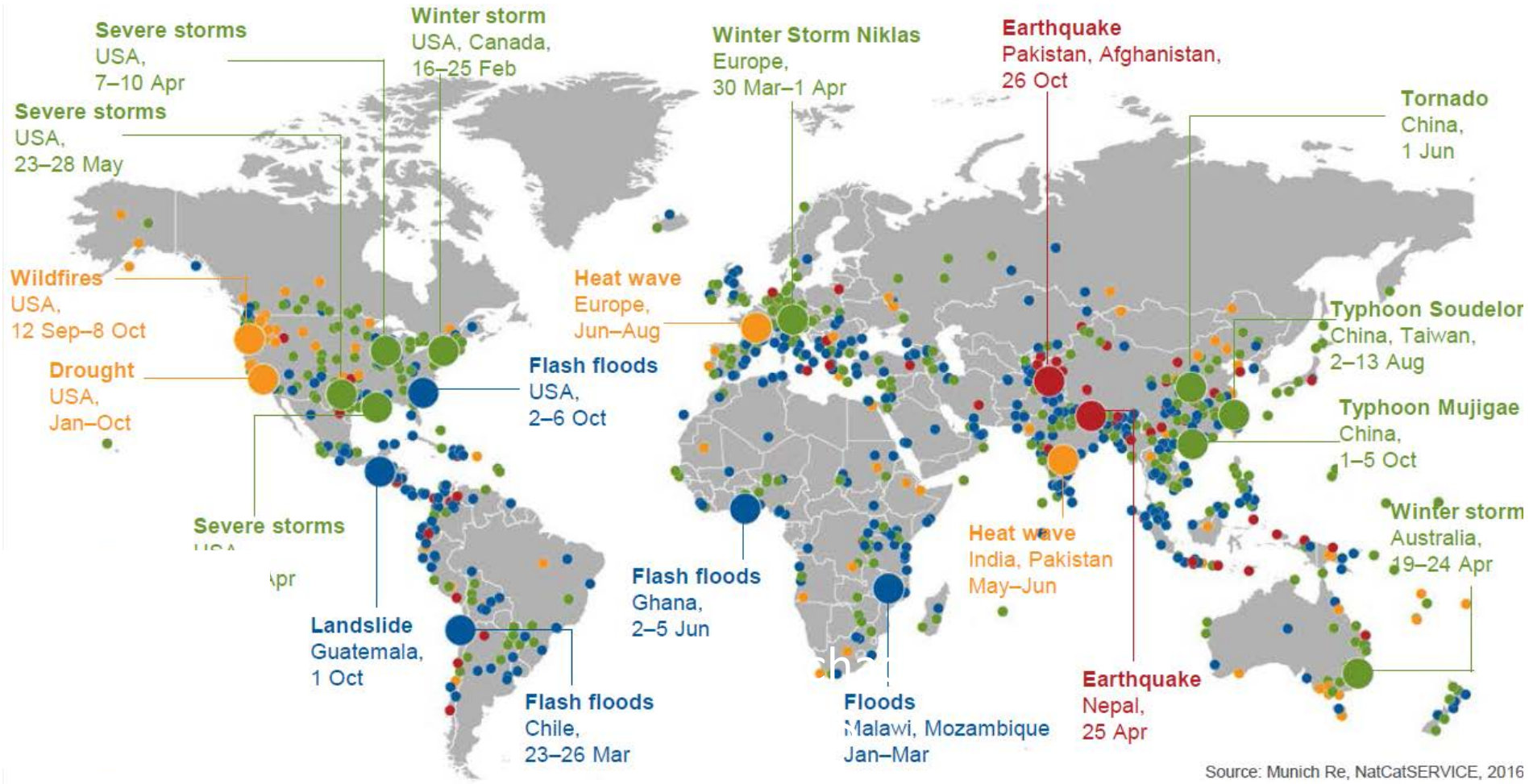
Leibniz Association

Natural disasters 2015



- **Geophysical events** (Earthquake, tsunami, volcanic activity)
- **Hydrological events** (Flood, mass movement)
- **Meteorological events** (Tropical storm, extratropical storm, convective storm, local storm)
- **Climatological events** (Extreme temperature, drought, wildfire)

Extreme events in a 1.5°C or 2°C-world?



Source: Munich Re, NatCatSERVICE, 2016

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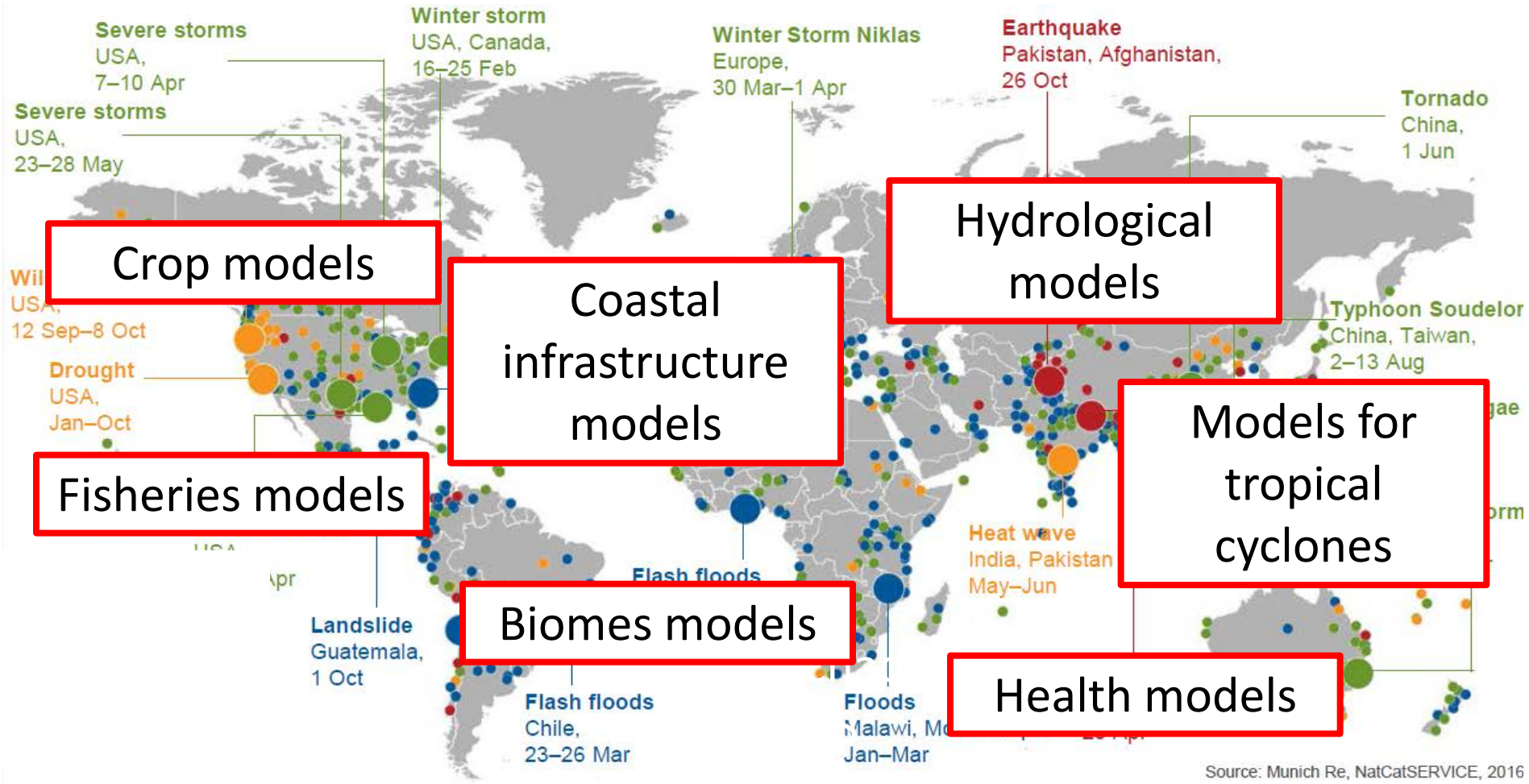
Extreme events in a 1.5°C or 2°C-world?



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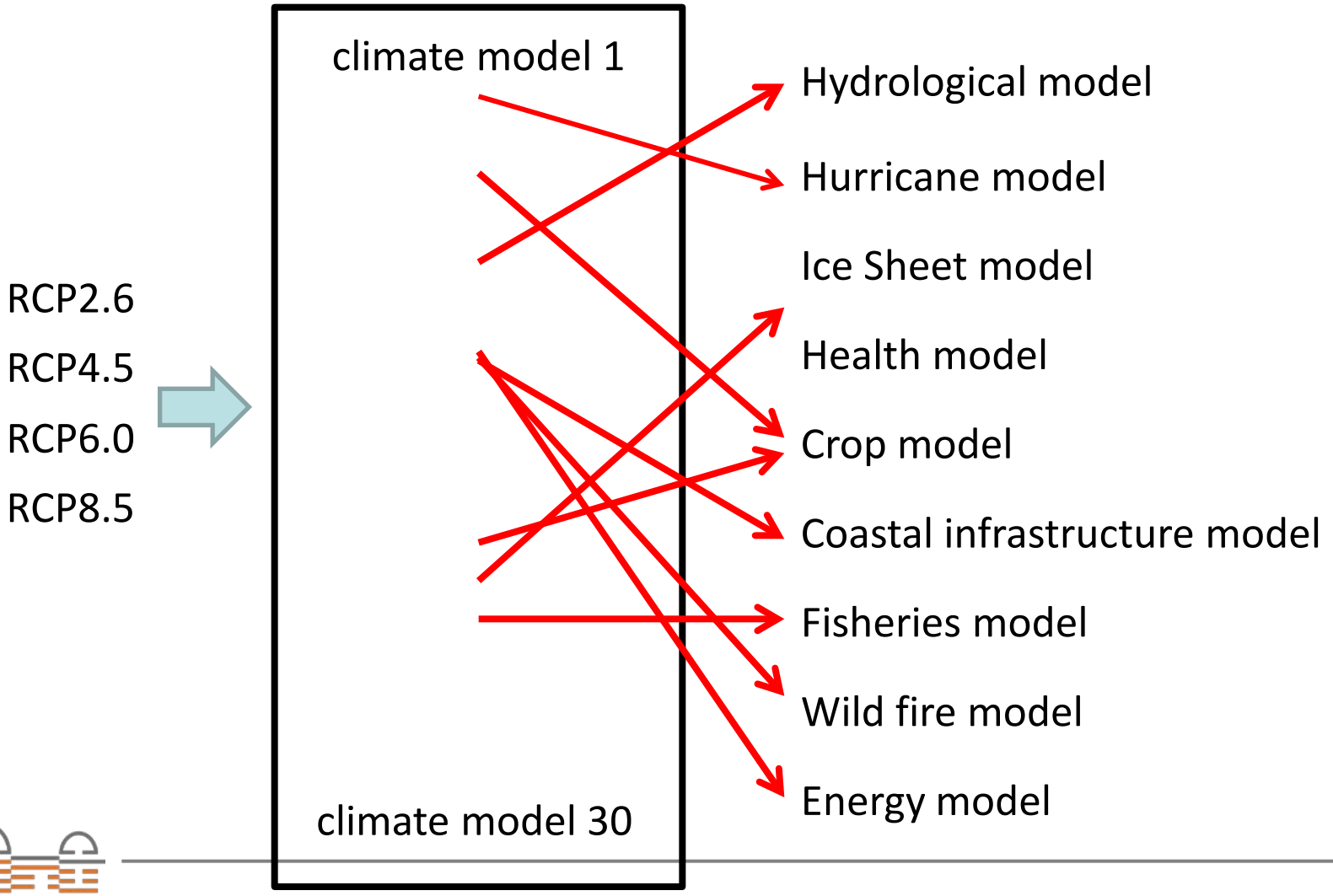
A small step for the individual modeller – a large one for climate impacts research



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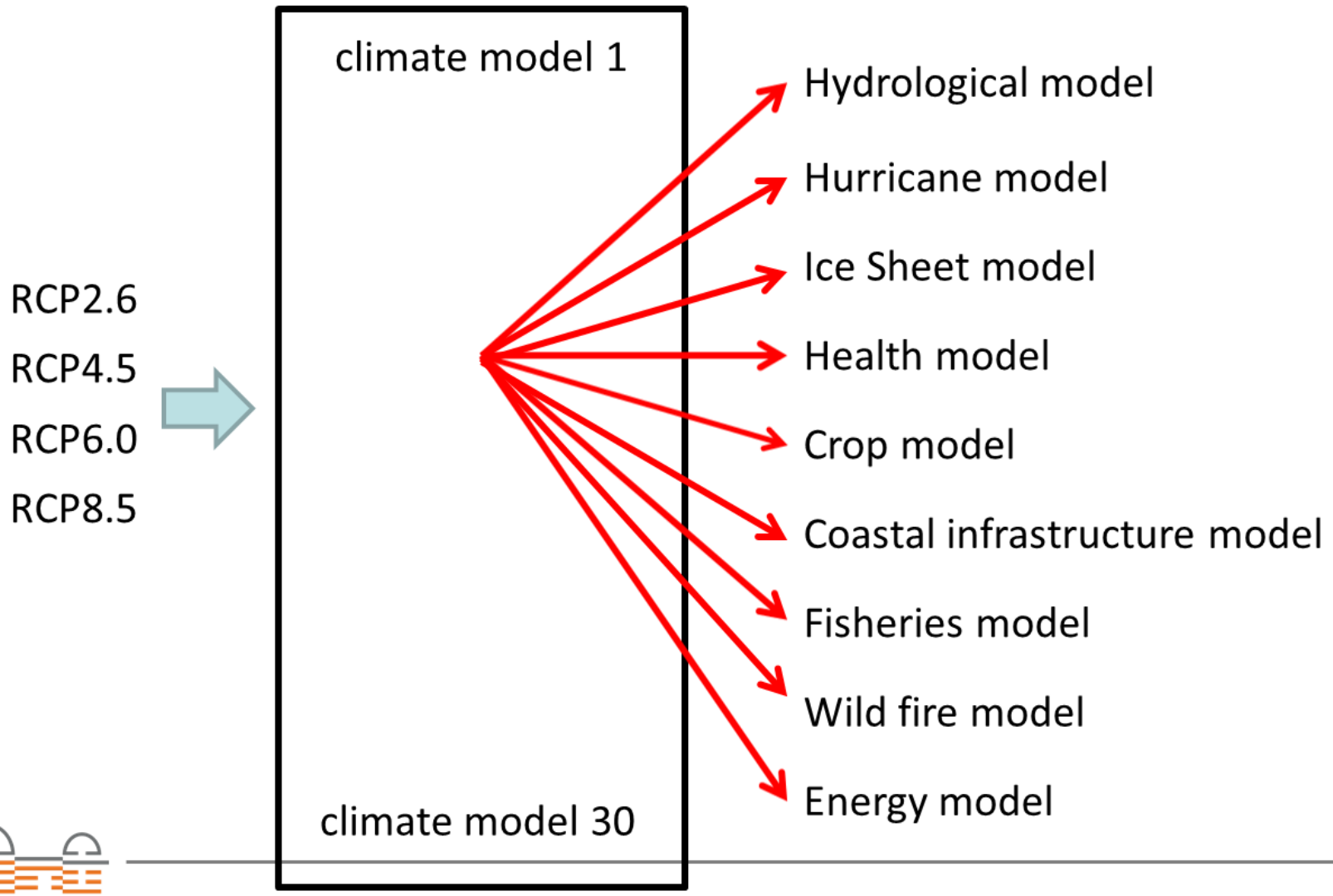

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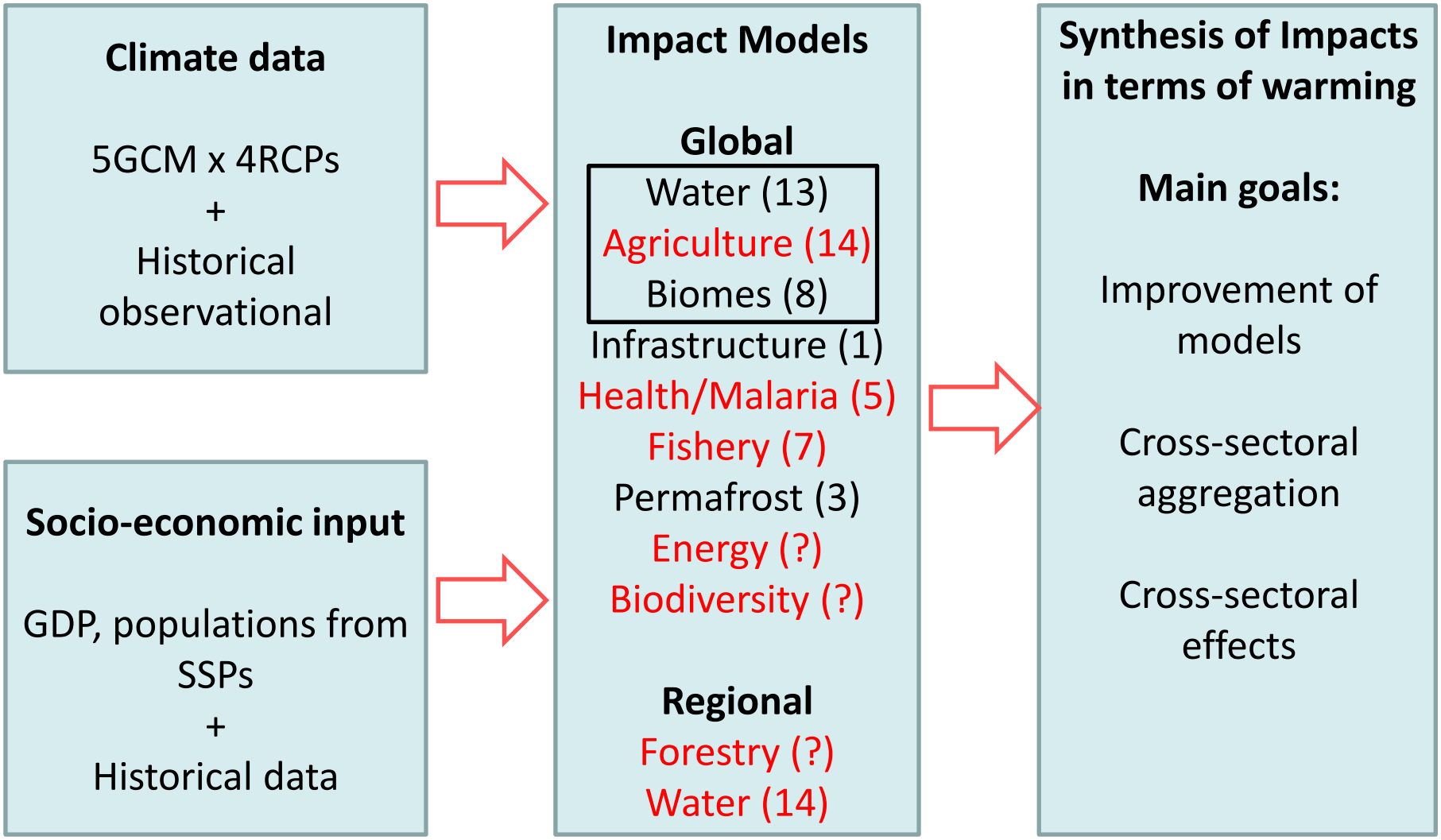
Major areas of impact modeling

Models participating in ISIMIP



Standard output variables

provided by ISIMIP models (on 0.5° x 0.5° grid)

Water

Daily runoff, discharge, flooded areas, flood depth

Biomes

Monthly carbon fluxes and pools

Agriculture

Annual crop yields (pure crop runs) under rainfed conditions and irrigation, required amount of irrigation water to reach full irrigation

In progress

Fisheries

Total catch

Energy

Energy demand, renewable potentials (e.g. hydropower) and production, energy mixes and prices

Health

Population at risk of malaria, heat and cold related mortality, heat induced losses in labor productivity

Much more to do on *Health* …

Wide spread consequences

- Heat-induced mortality
- Heat-induced reduction in labor productivity
- Distribution of vector born-diseases (Malaria, Dengue)
- Diarrhoeal diseases
- Malnutrition

Available models

- Mostly empirical approaches building on simple climate indicators (temperature and precipitation) could be extended by using more process-based risk indicators (e.g. flood events as trigger of infectious diseases)

Required input data

Impact model requirements

- Temporal resolution: Daily
- Spatial resolution: 0.5° x 0.5°
- Bias correction
- List of required variables is provided to CMIP6

➢ ISIMIP3 may provide set of higher resolution input data

More critical issue:

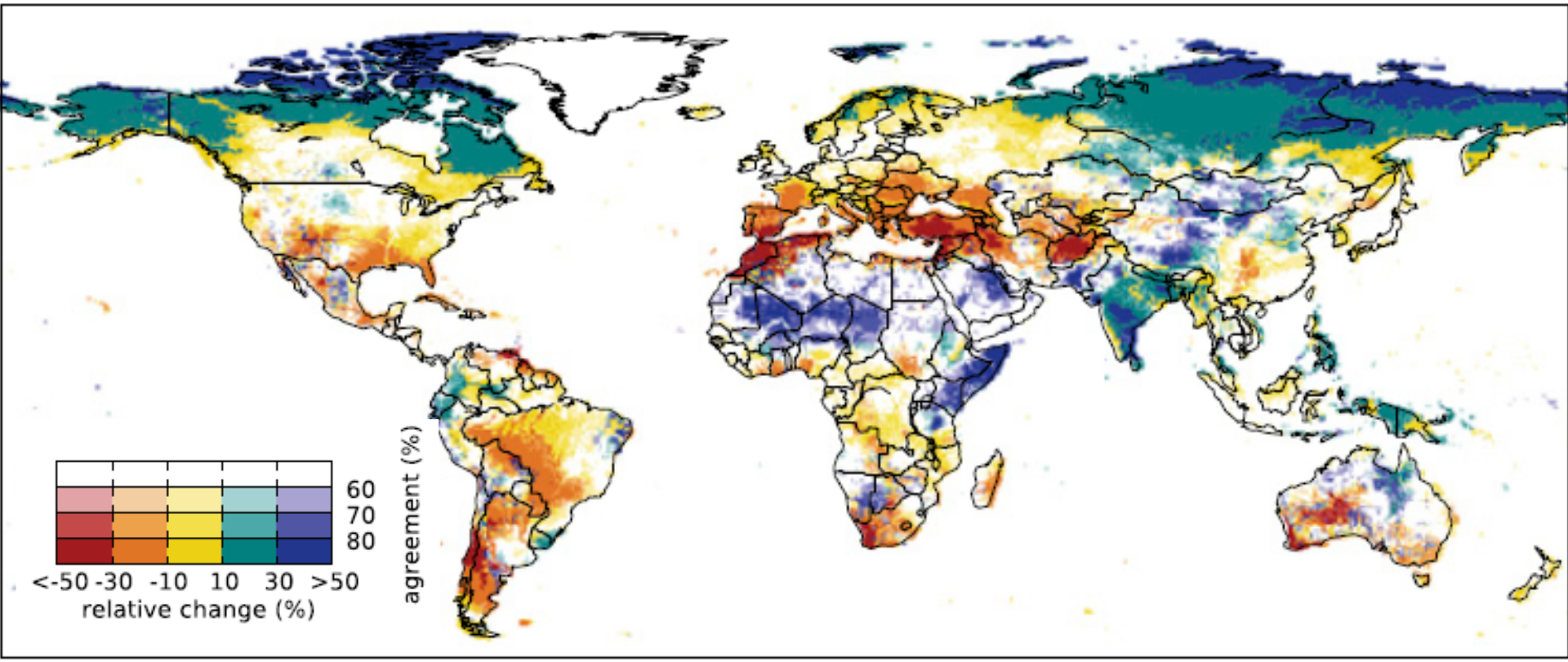
Detailed representation of human management

e.g. fertilizer input, land use patterns, dams, …

Agreement across models

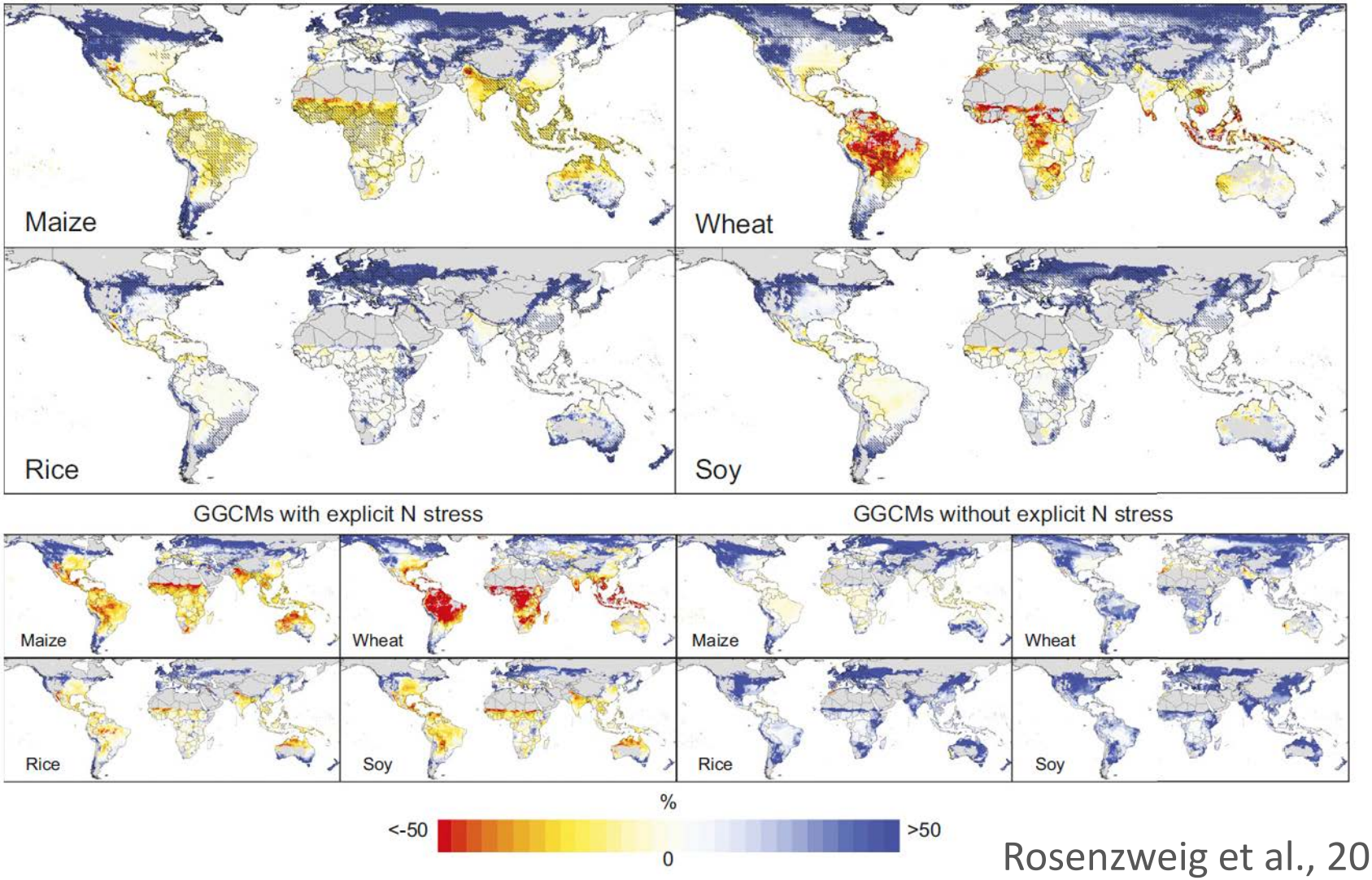
Water:

Changes in discharge at 2°C compared to present day levels



Agriculture:

Crop yield change in 2100 under RCP8.5



Rosenzweig et al., 2014

Main areas of concern

for future projections

Agriculture

- Representation of CO2 fertilization (difficult to constrain from observations but potentially from field experiments)

Water

- Representation of evapotranspiration in low-flow regimes
- Representation of ice melting

Biomes

- Representation of CO2 fertilization effect
- Representation of mortality

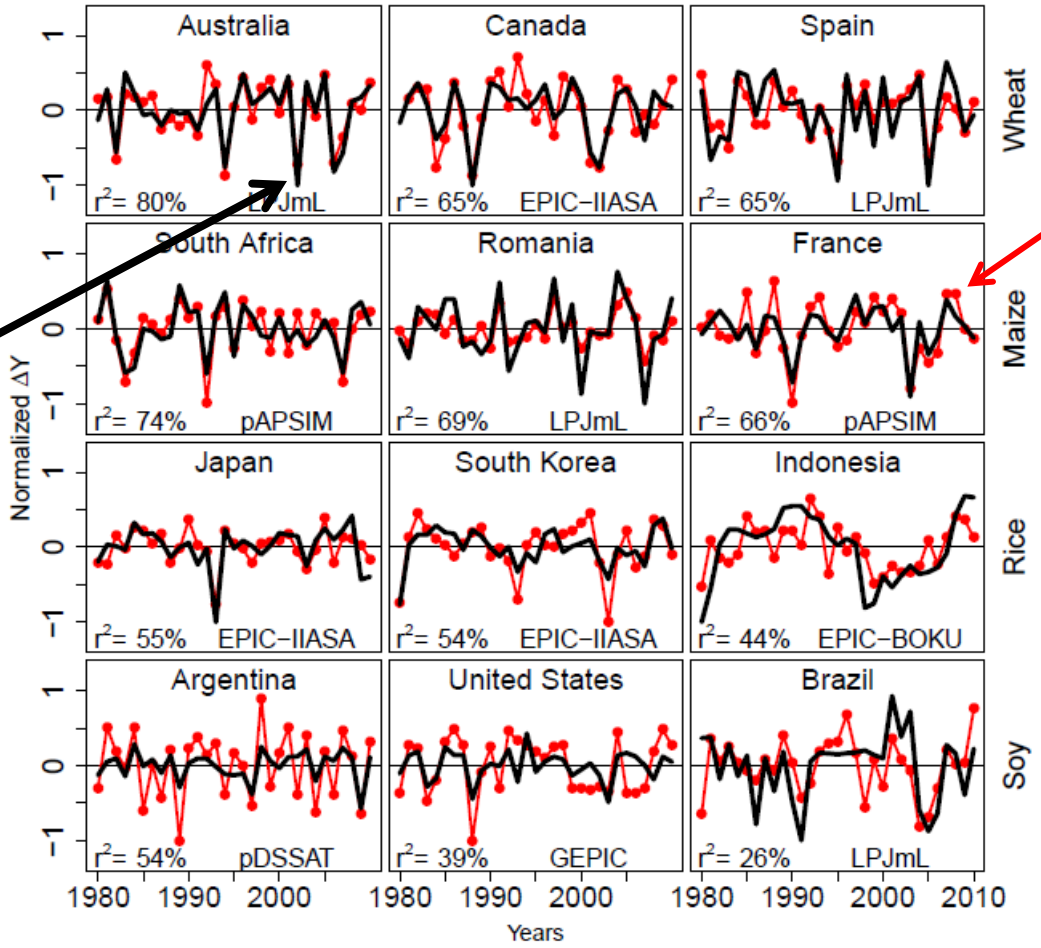
Model assessment

Impacts model evaluation is different from climate model evaluation

Direct comparison with observations

Reported national yields FAO

Weather fluctuations + Management changes



Simulated national yields

Weather fluctuations

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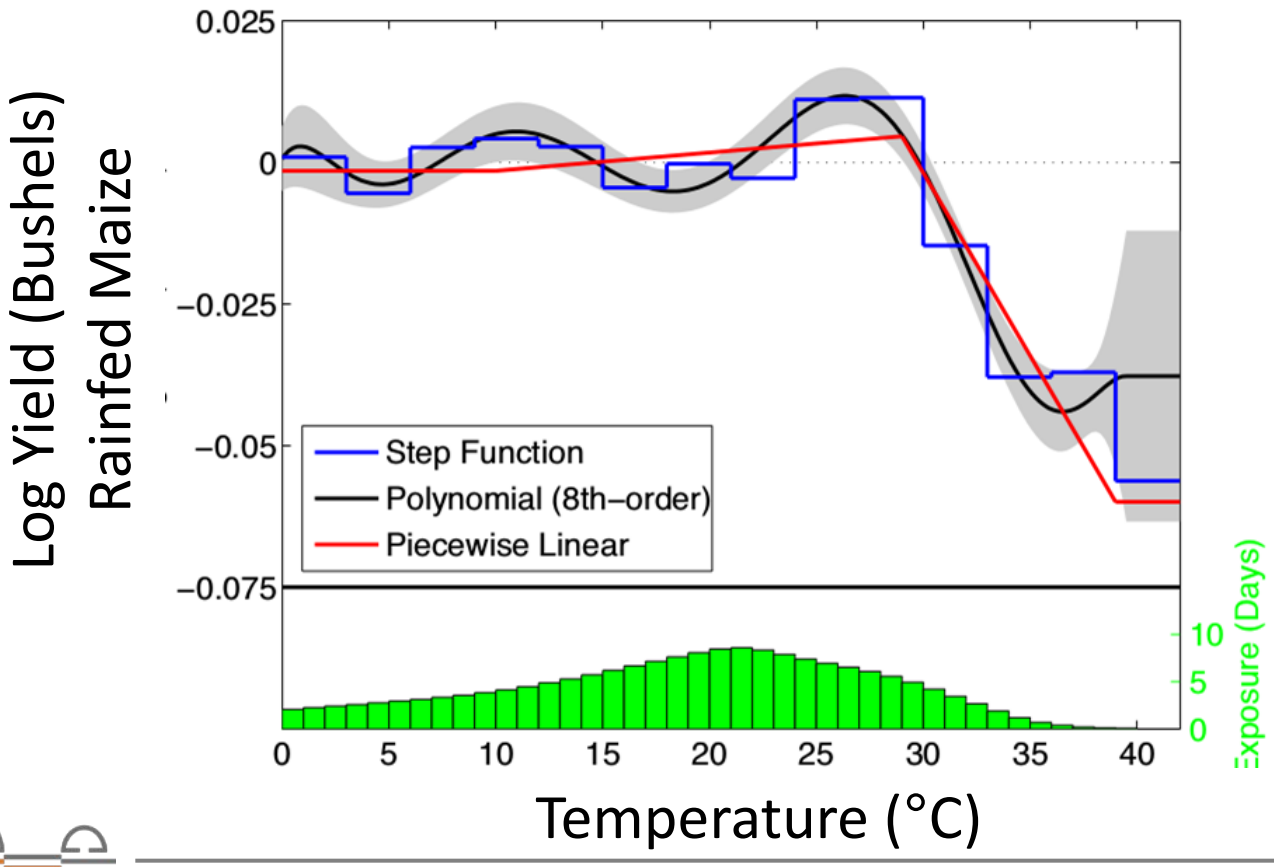
Frieler et al., submitted

Statistical approaches

to extract pure weather effects from observations

$$\log(Y_{it}) \sim \alpha + \beta P_{it}^2 + \sum_{T=0,3,6,\ldots}^{39} \gamma_T \left[\Phi_{it}(T+3) - \Phi_{it}(T)\right] + c_i + t_s + \epsilon_{it}$$



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Schlenker et al., PNAS, 2009

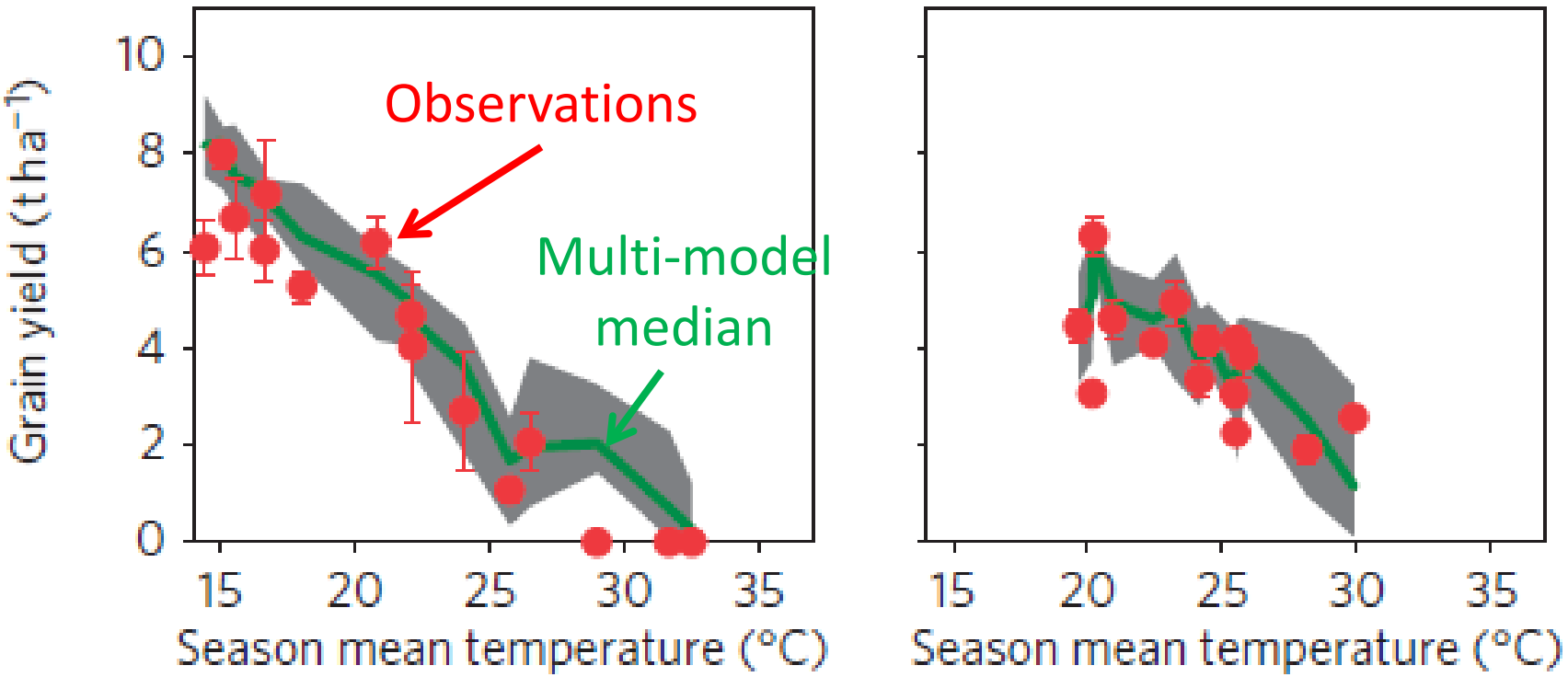
Comparison with simulations

Comparison to field experiments

Wheat

Experimental setting A

Experimental setting B

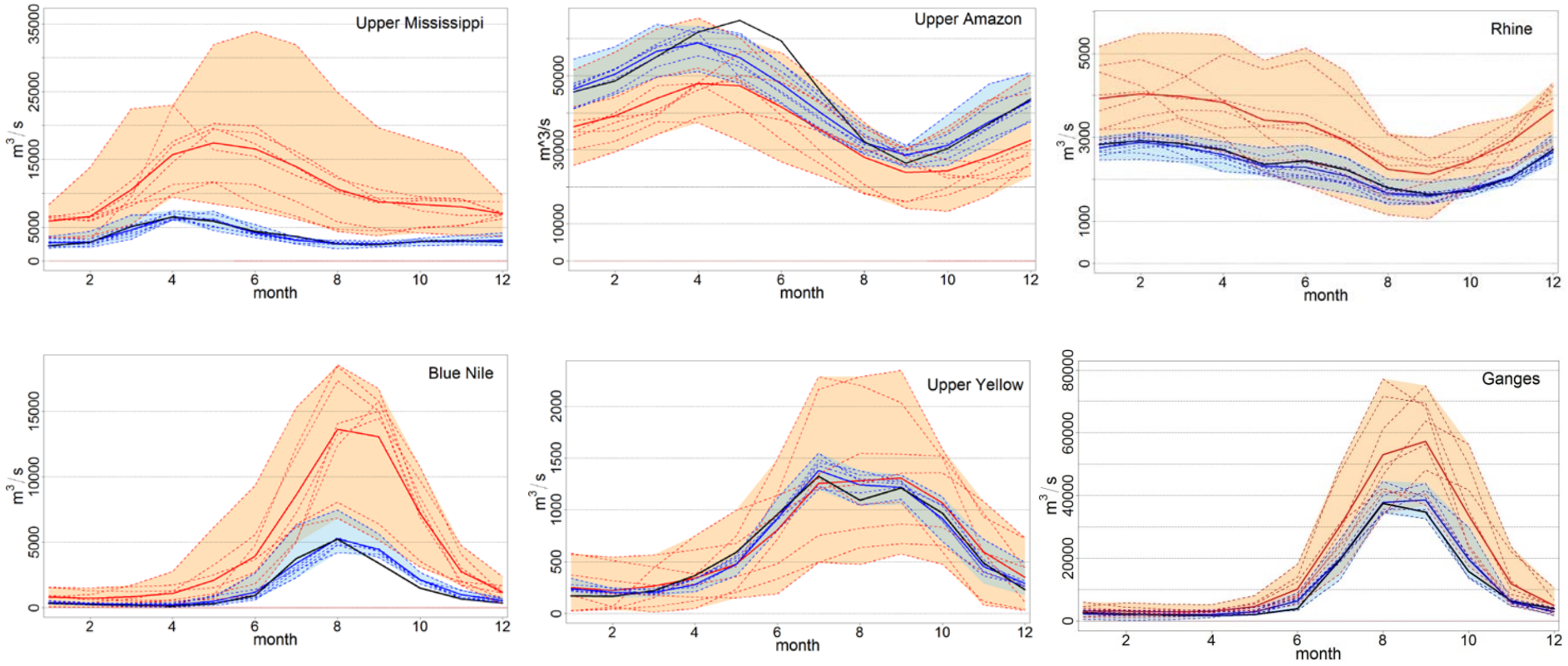


Asseng et al., NCC, 2014

Comparison of global & regional simulations

Historical runs (1971-2000)

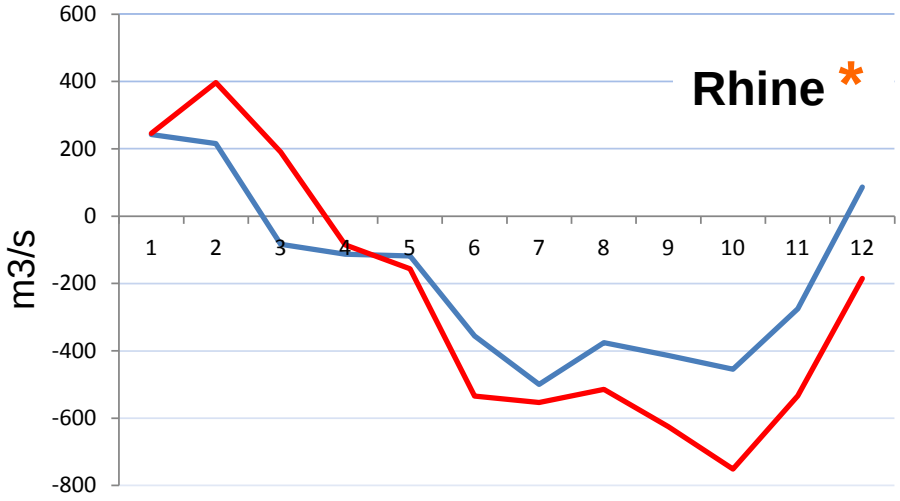
River discharge

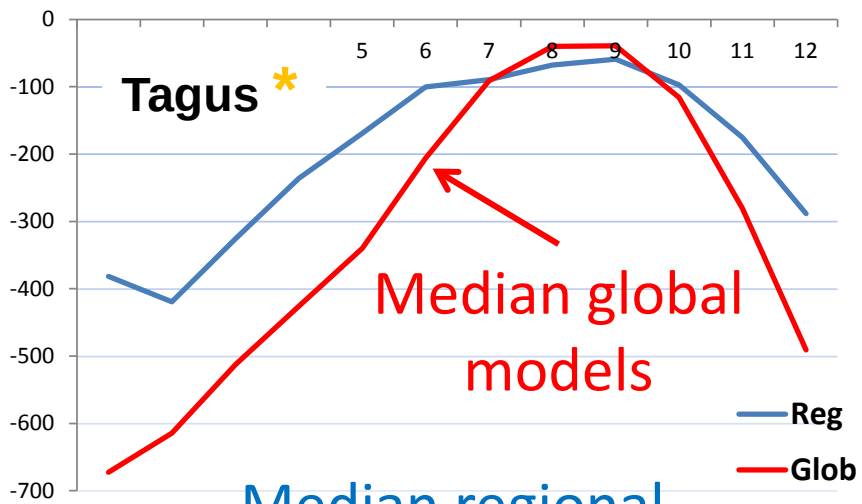


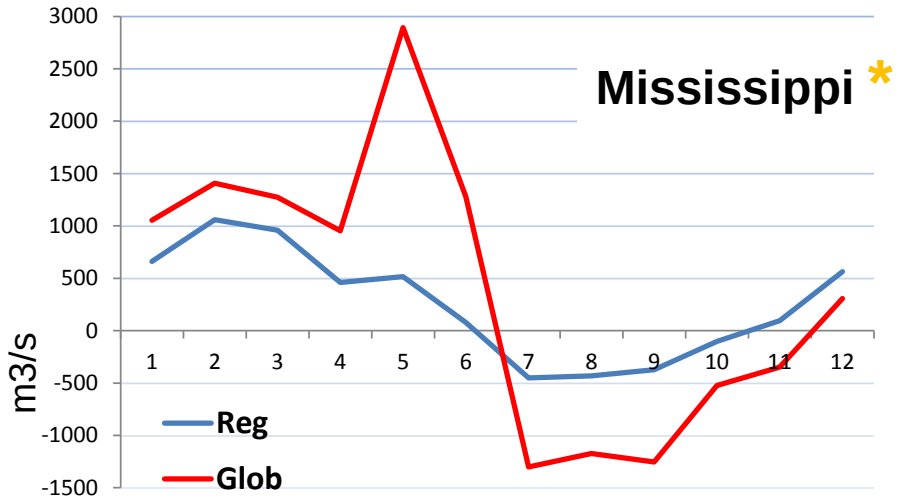
- Hattermann et al. 2015, Climatic Change, in review

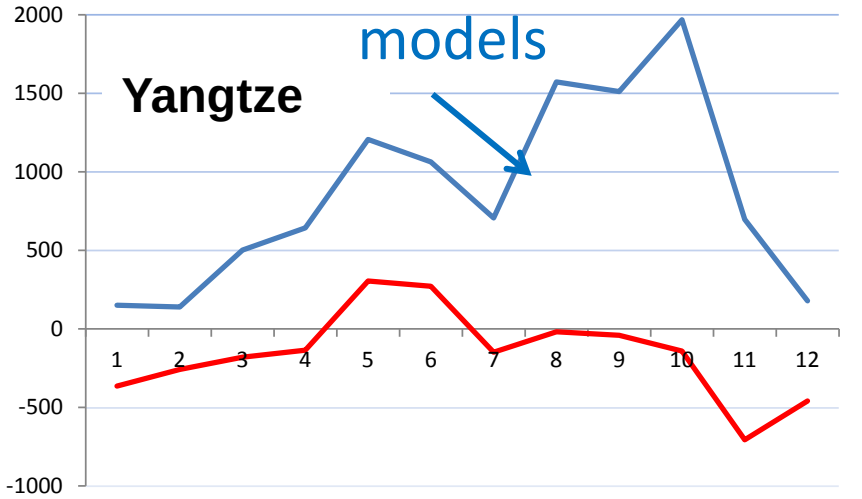
Future projections

(2071-2100 versus 1971-2000)









Hattermann et al. CC, in review

Continuous monitoring of progress
within ISIMIP

For many sectors the multi-model median seems to best reproduce observations

Special Issue in Environmental Research Letters:
"Impacts of Extreme Weather Across Sectors“
Submission deadline November 1

Each ISIMIP round intended to include same set of historical simulations to track model improvement

Use of impact models for economic damage assessment

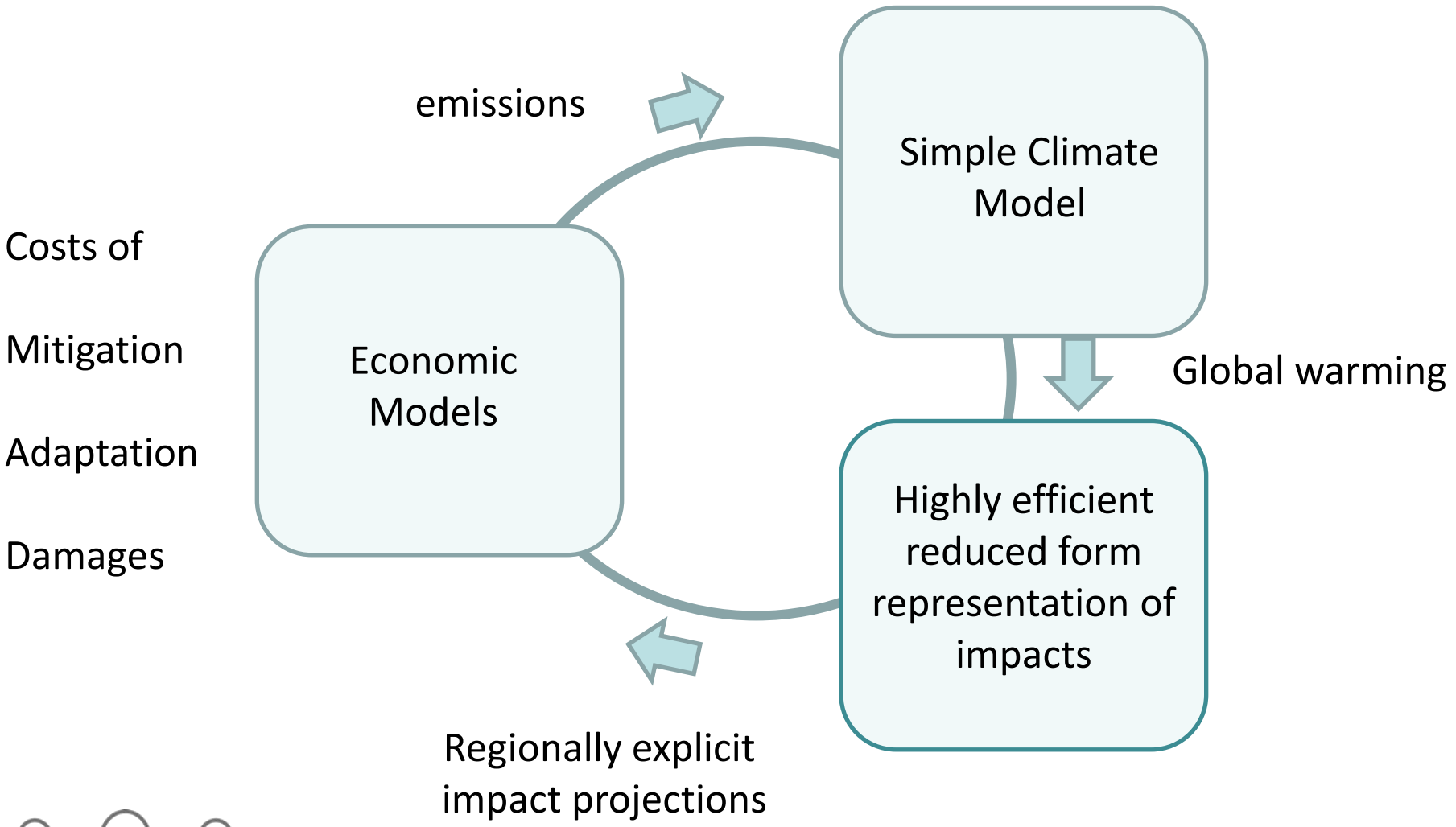
There is much more process-understanding than currently represented in stylized damage functions

We should use it

Main issues

- Translation into economic indicators
- Scaling with global mean temperature

Closing the loop – efficiently



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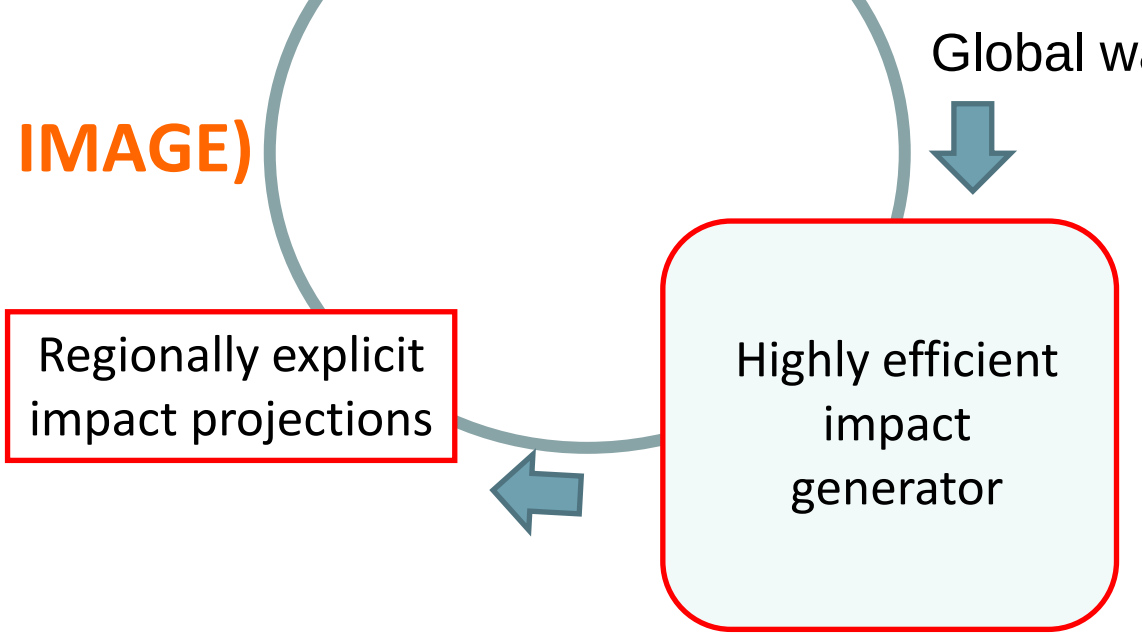
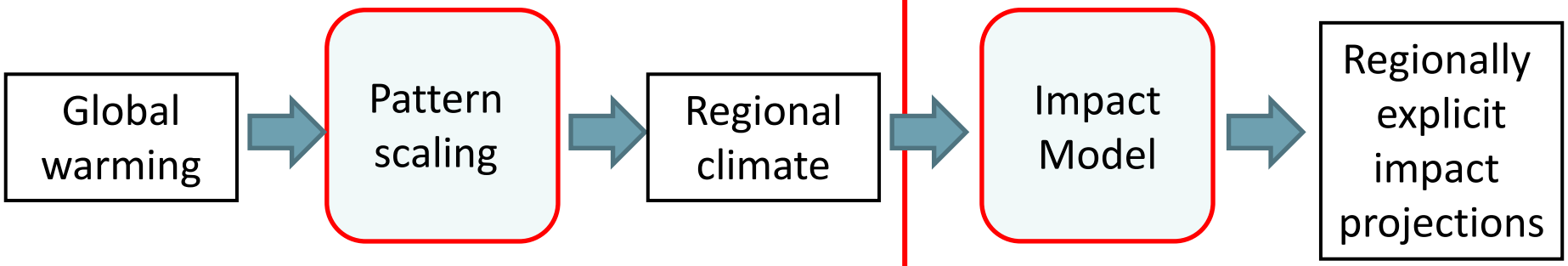
Different ways to incorporate impacts

Option 1
(e.g. used in IMAGE)



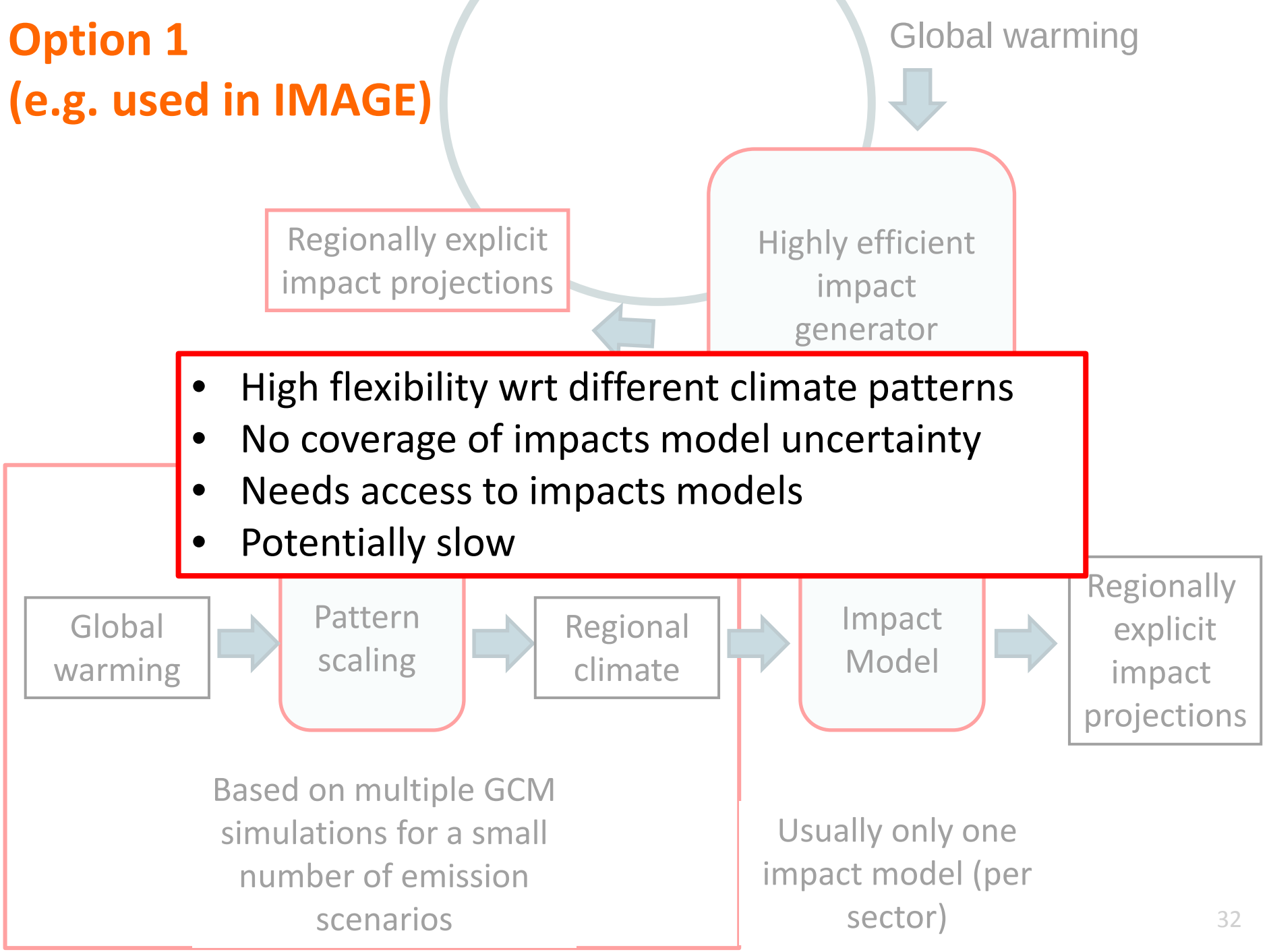
Well established



Based on multiple GCM simulations for a small number of emission scenarios

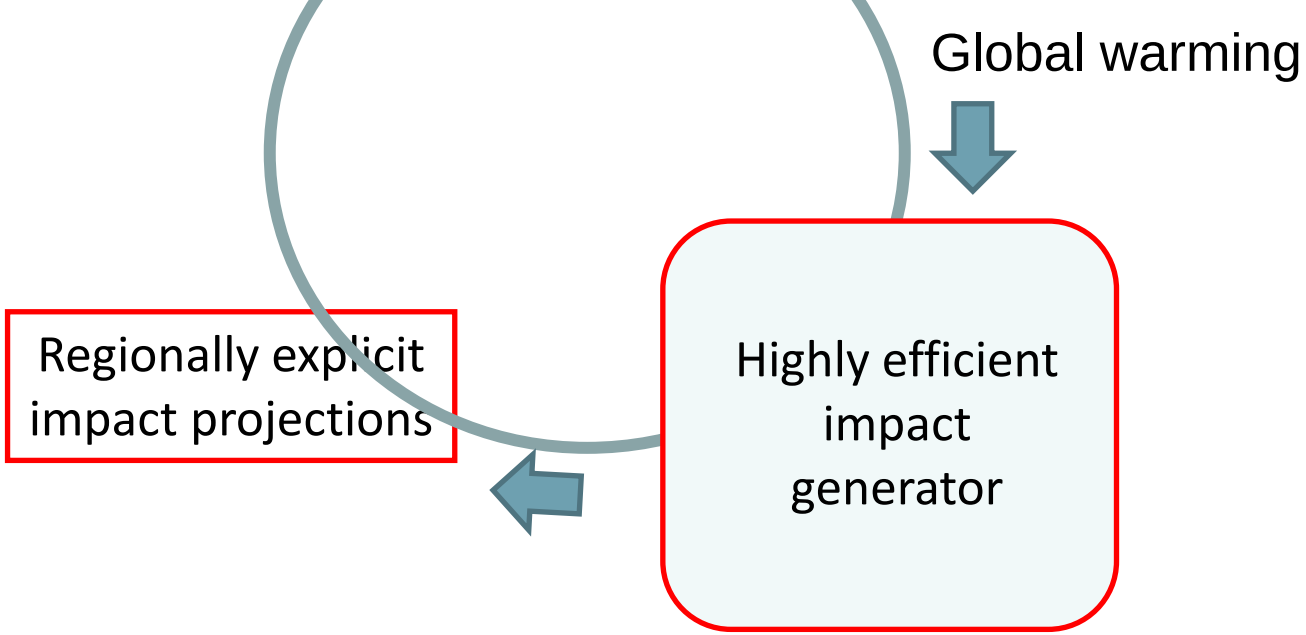
Usually only one impact model (per sector)

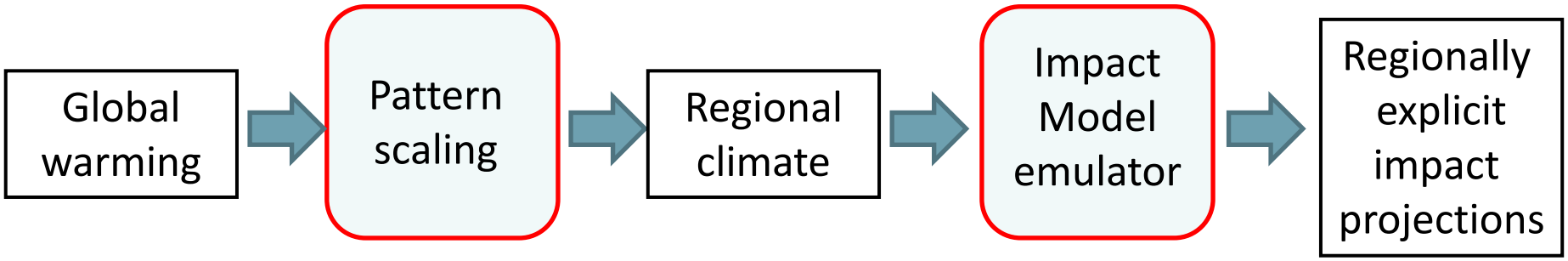
Option 1
(e.g. used in IMAGE)



- High flexibility wrt different climate patterns
- No coverage of impacts model uncertainty
- Needs access to impacts models
- Potentially slow

Option 2:

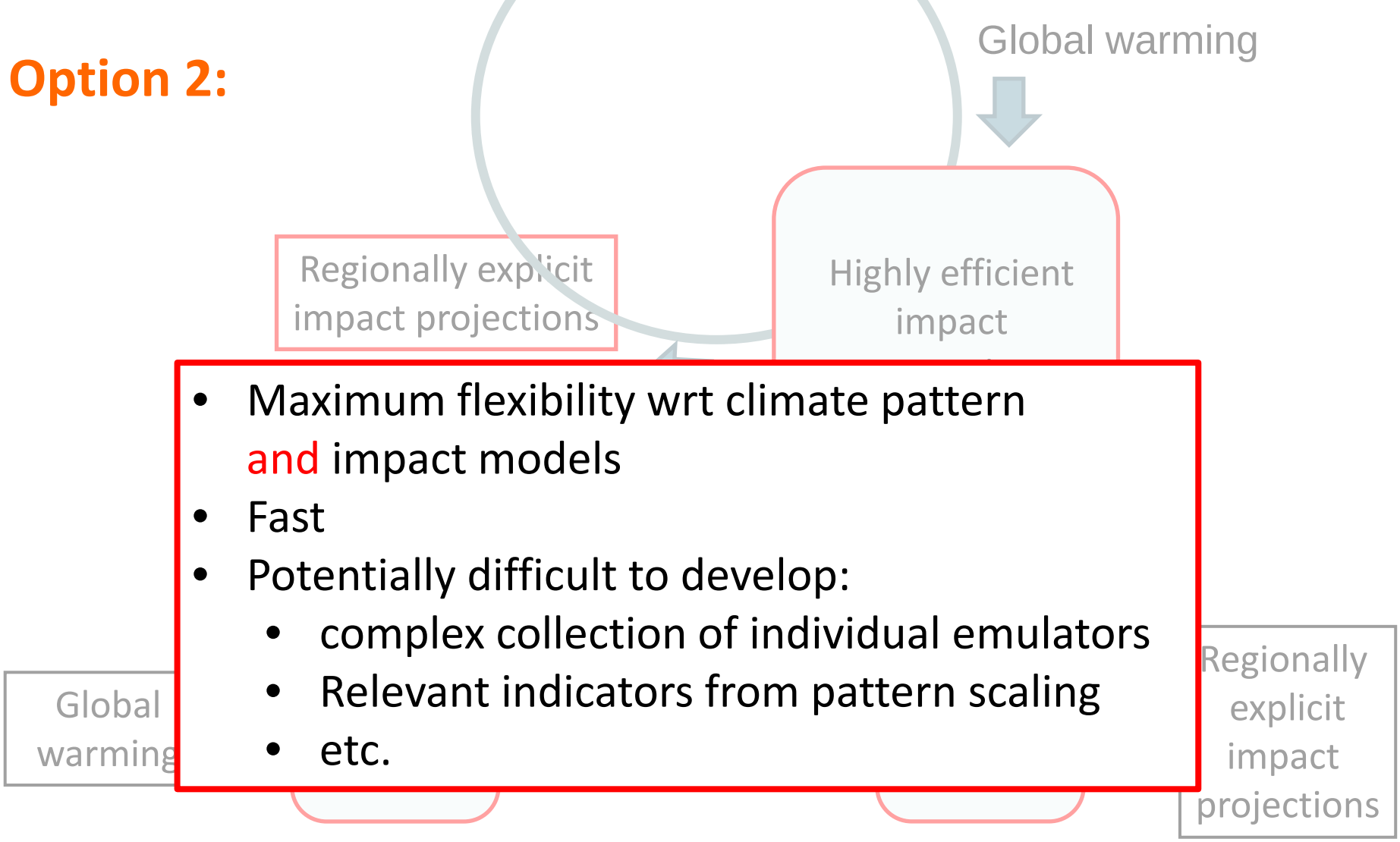




Based on multiple GCM simulations for a small number of emission scenarios

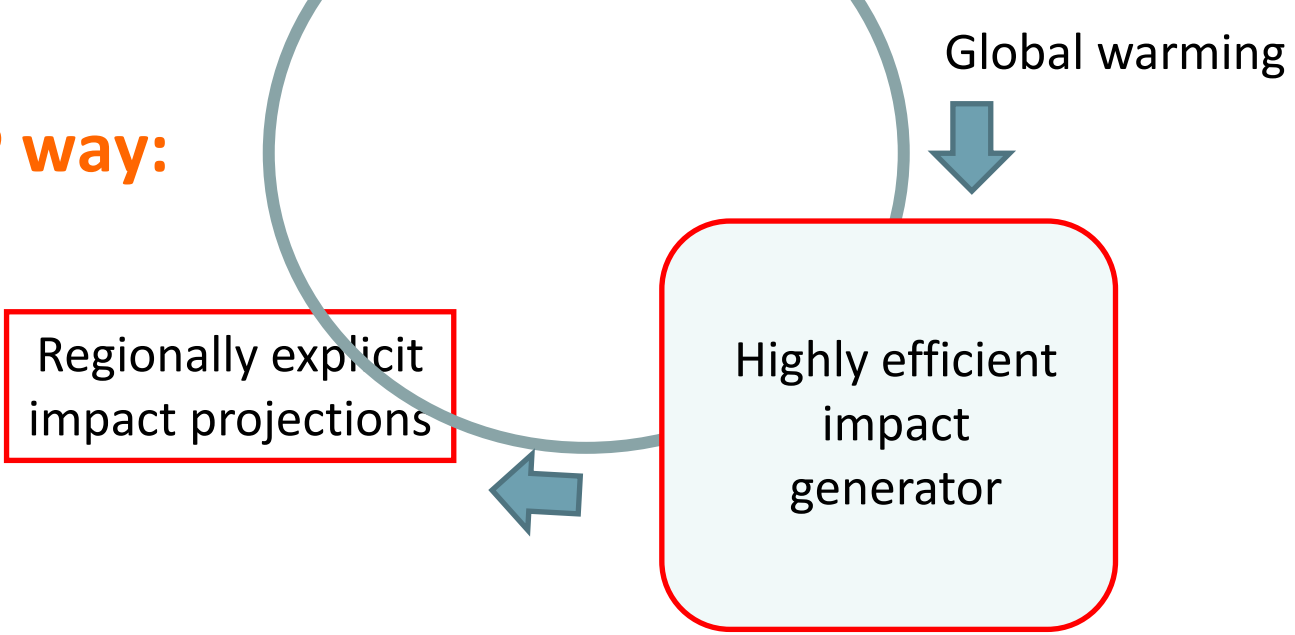
Relationship between regional climate indicators and impacts derived from multiple impact model simulations

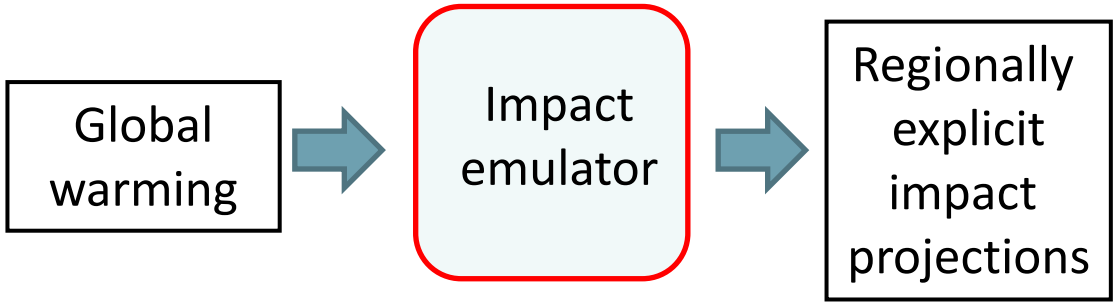
Option 2:



- Maximum flexibility wrt climate pattern and impact models
- Fast
- Potentially difficult to develop:
  - complex collection of individual emulators
  - Relevant indicators from pattern scaling
  - etc.

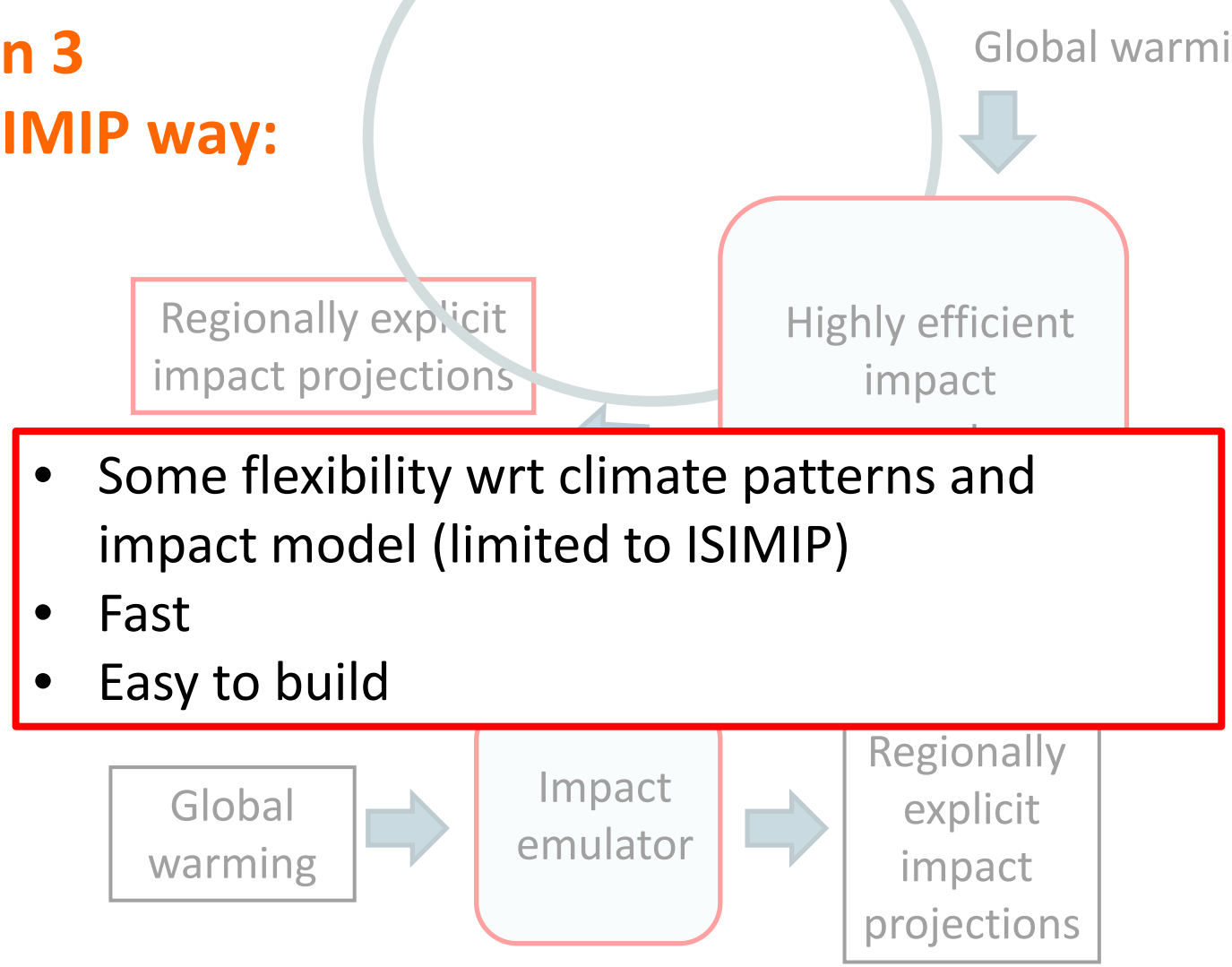
Option 3
the ISIMIP way:





A set of multi-GCM-multi-Impact Model simulations for a limited number of scenarios

Option 3
the ISIMIP way:

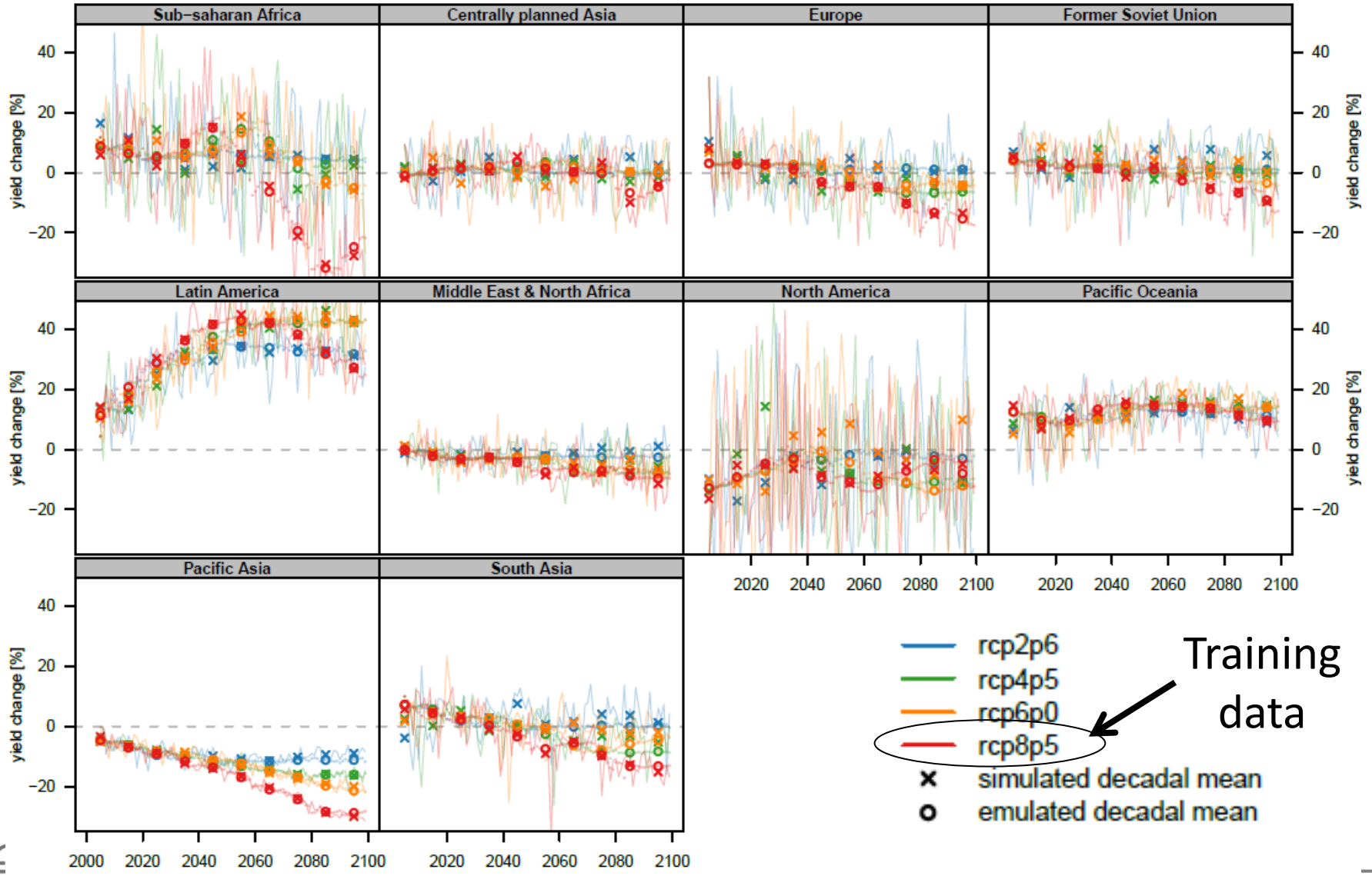


- Some flexibility wrt climate patterns and impact model (limited to ISIMIP)
- Fast
- Easy to build

A set of multi-GCM-multi-Impact Model simulations for a limited number of scenarios

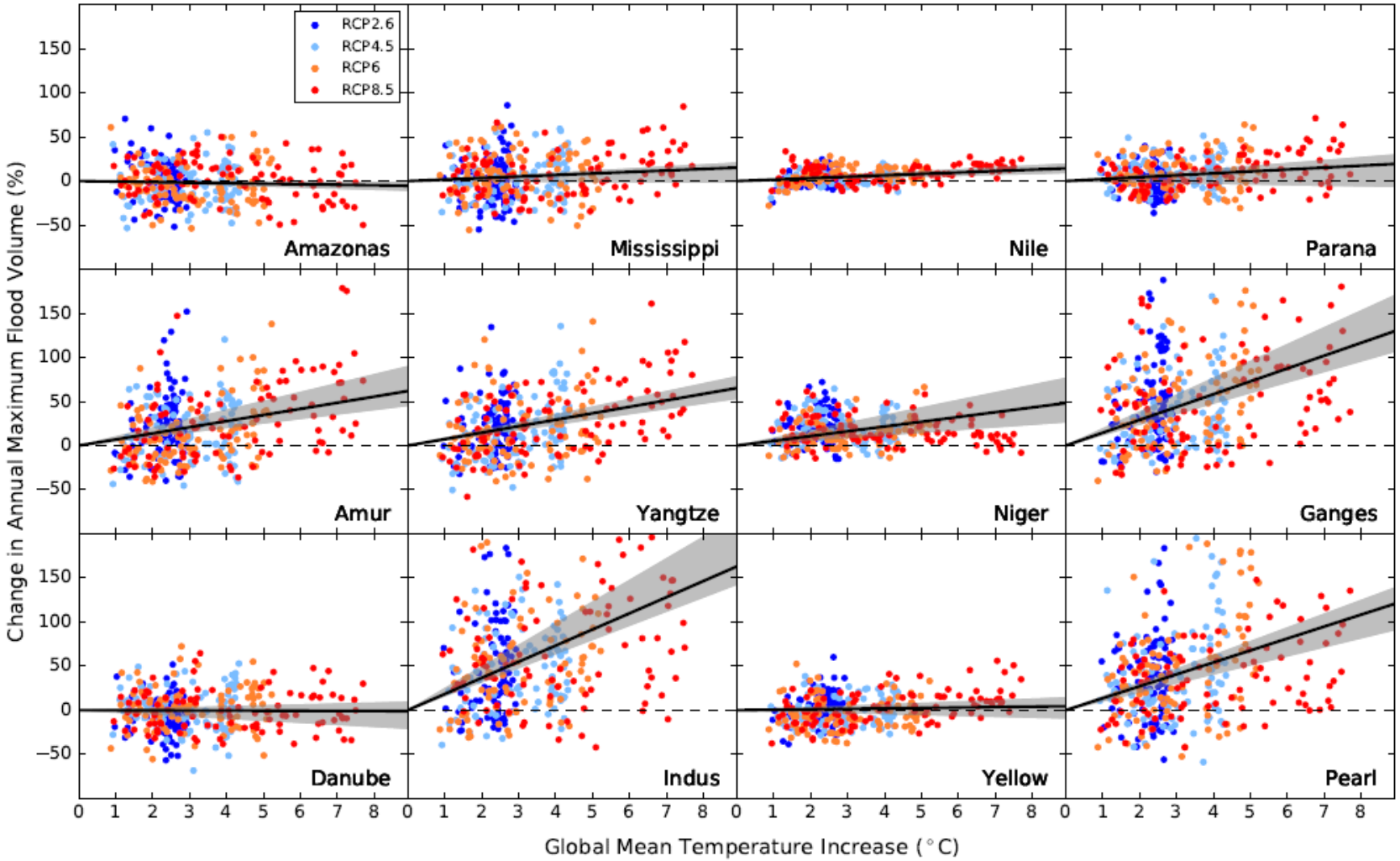
Availability of reduced impact models

Most basic approach: Temperature binning

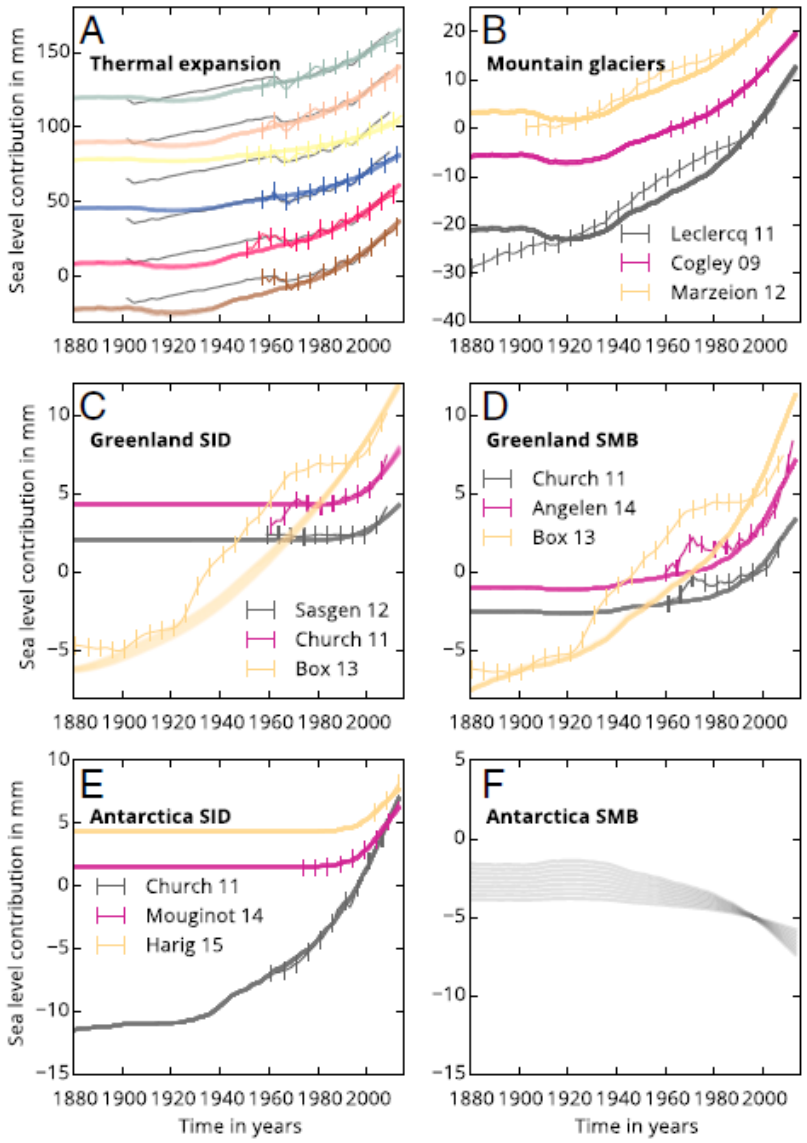


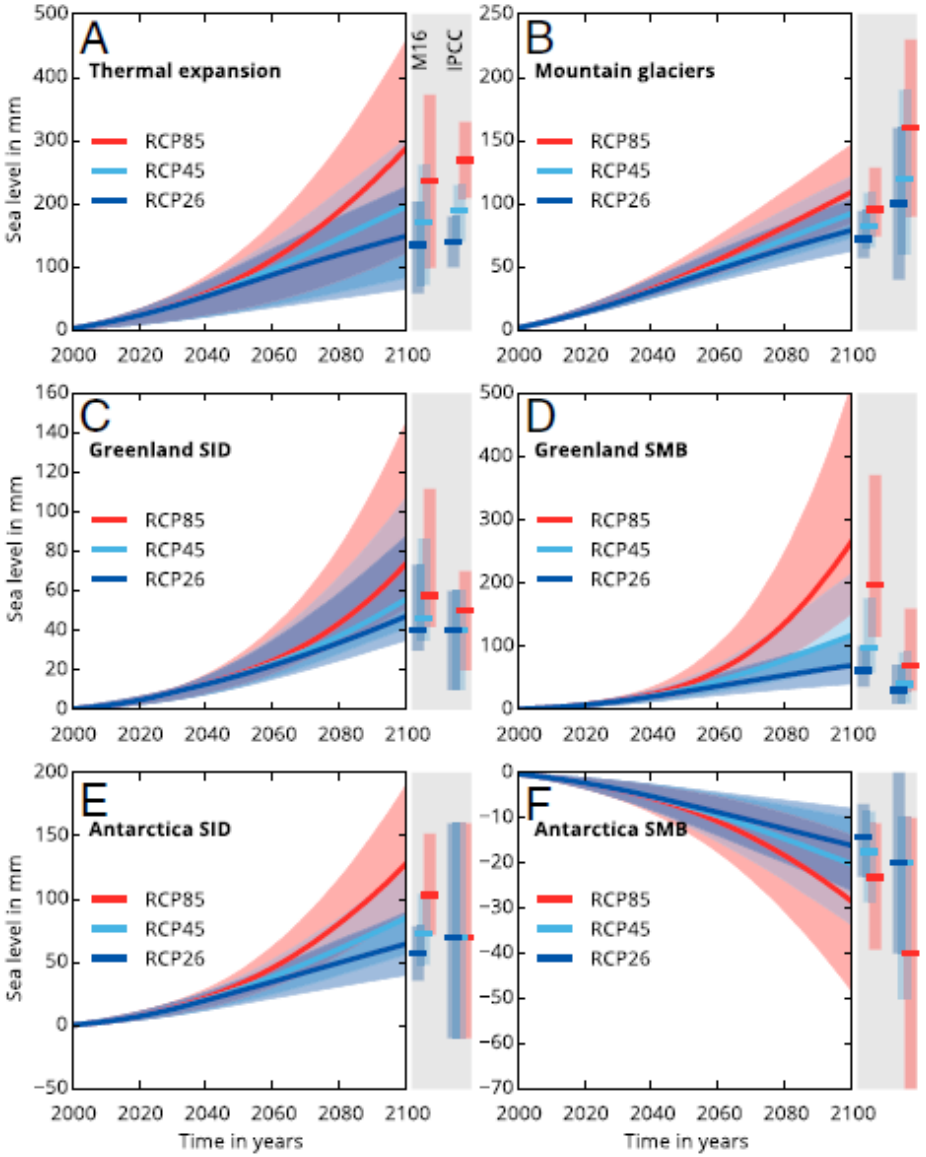
Emulated LPJmL Maize yield changes with CO2 effect for climate model HadGEM2−ES and emulator method 2

Example: Flood volume



Sea level rise needs another approach

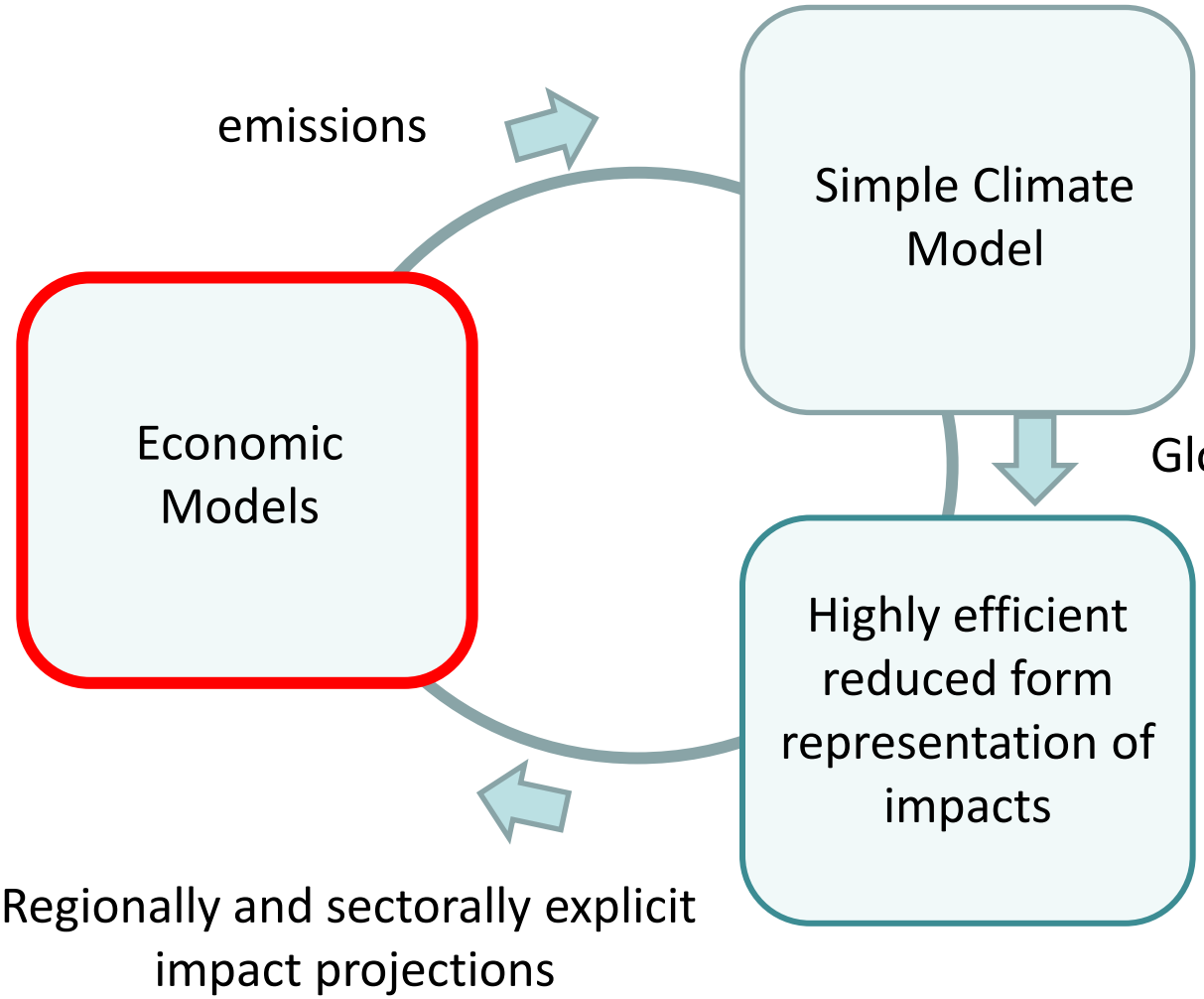




Mengel et al., 2016

Translation into economic indicators

The growth engine



Costs of
- Mitigation
- Adaptation
- Damages

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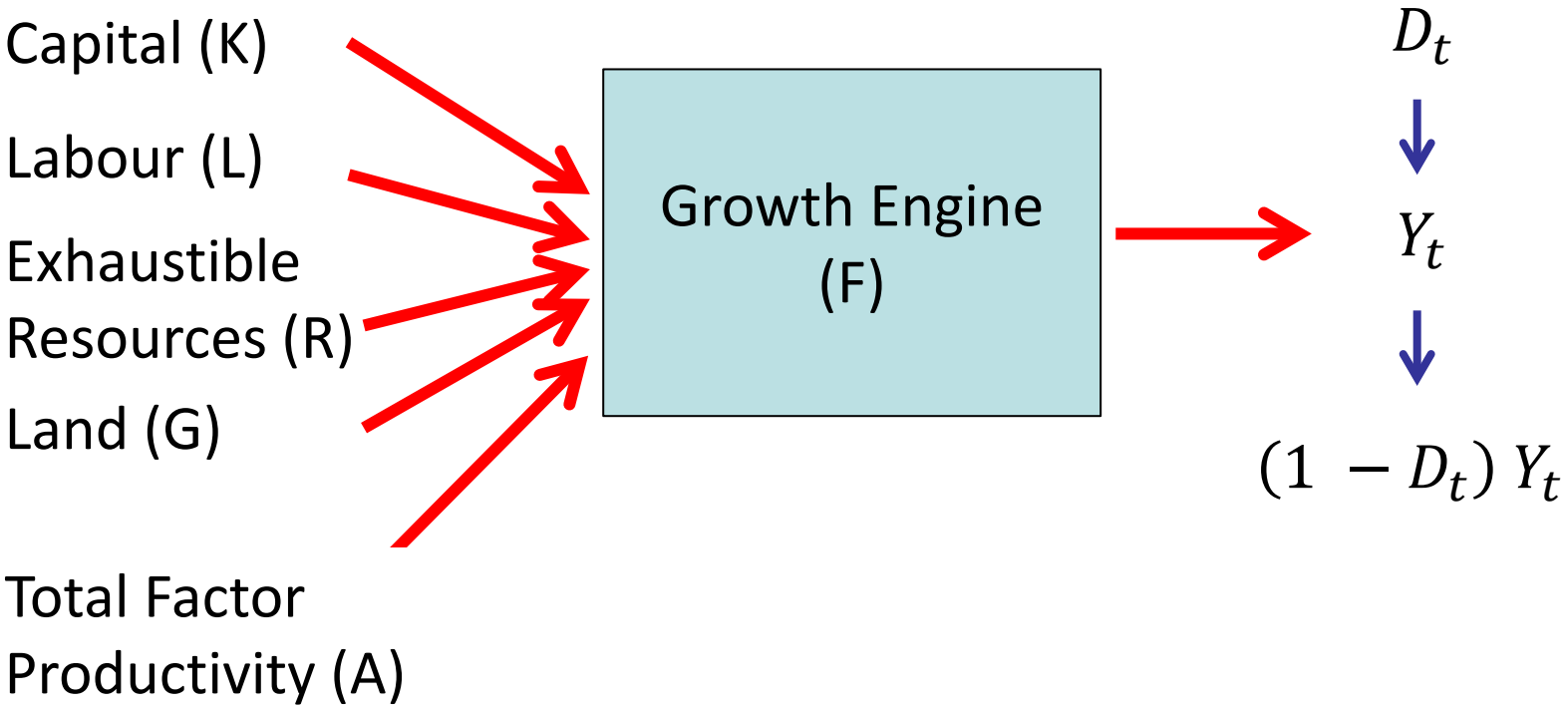
Characteristics of standard damage models

Damages only affect output

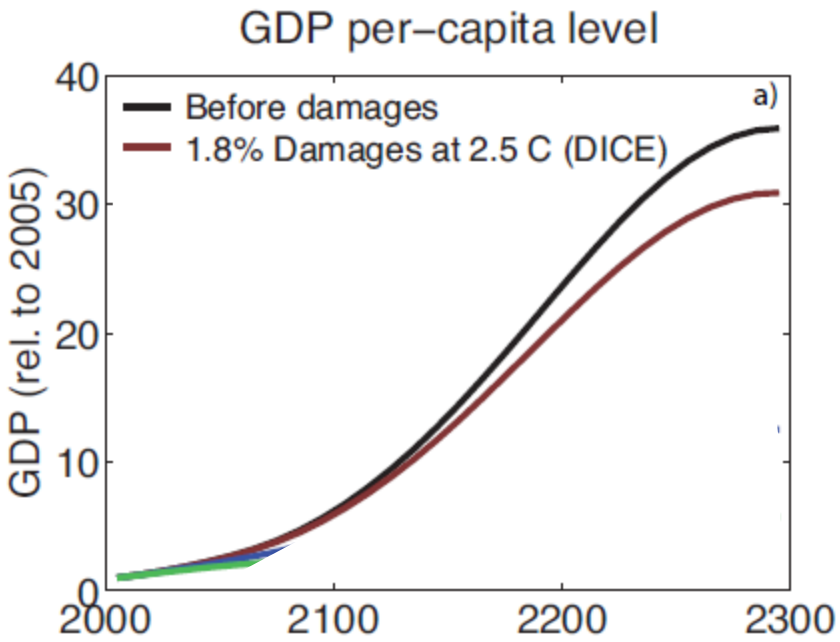
$$Y_t = F(K_t, L_t) = (1 - D_t) A_t K_t^{\alpha} L_t^{1-\alpha}$$ DICE

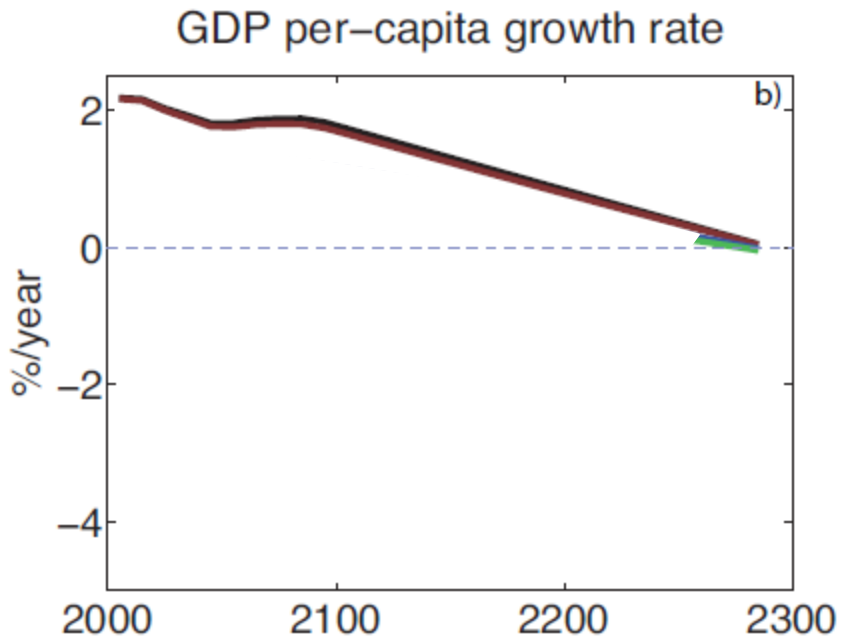
Damages

Exogenous
Total Factor Productivity



Only minor effects on growth rates





Moyer et al. 2013

Damages much higher if growth drivers are affected

Moore and Diaz, 2015:
Temperature effects on both
i) Total Factor Productivity
ii) Capital depreciation

„Economically optimal warming“ reduced from 3.5°C to below 2°C

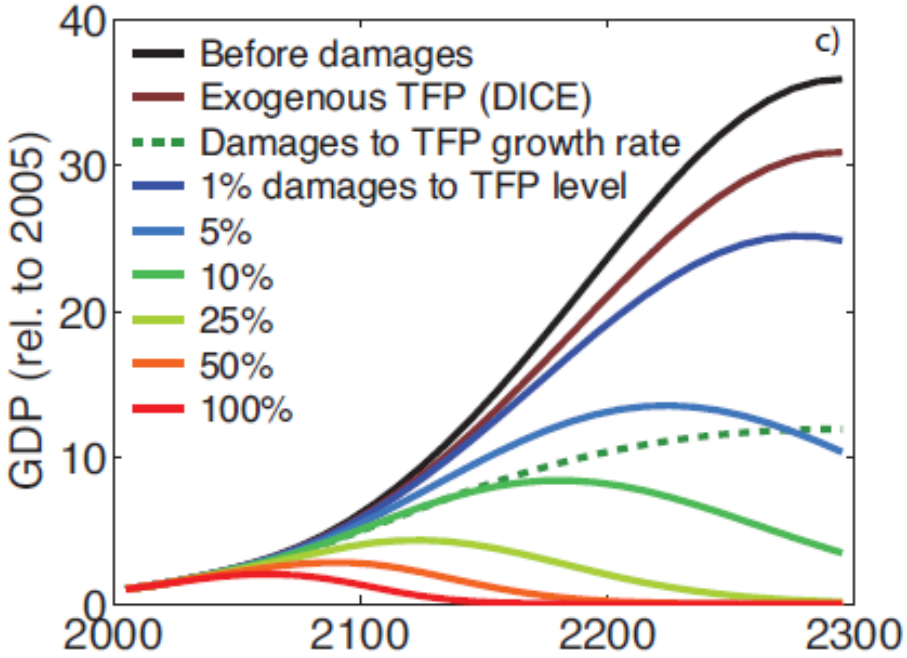
Dietz and Stern, 2015:
Temperature effects on
i) Total Factor Productivity **or**
ii) Capital stocks

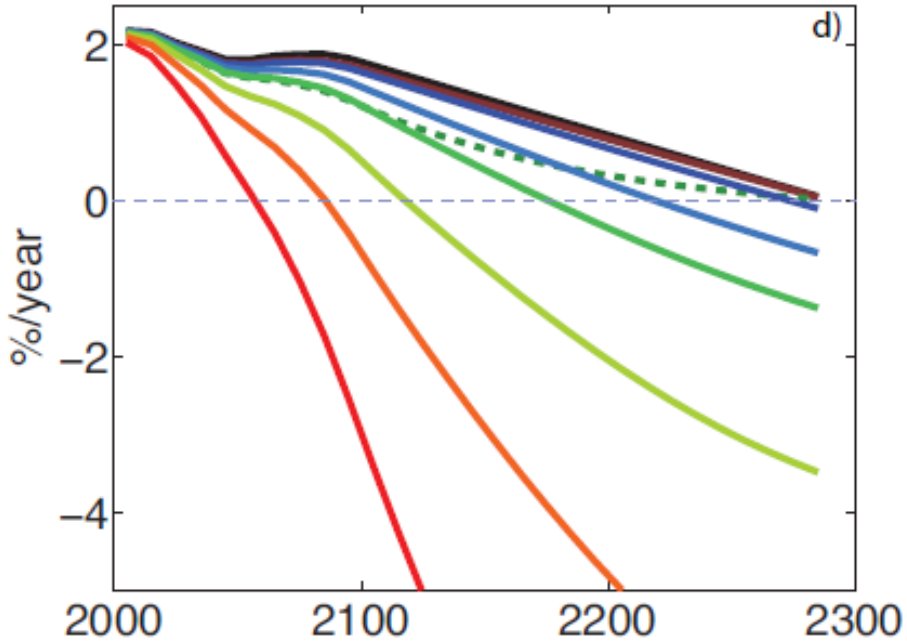
Reduction of increase of per-capita-consumption by
- 10%
- 25%

Moyer et al., 2013:
Temperature effects on
i) Total Factor Productivity

Already small damage to Total Factor Productivity yields negative growth rates

Economic growth assuming climate change reduced total factor productivity





Moyer et al. 2013

Near-term availability of damage indicators

From process-based models

- Reductions in capital stocks from extreme events (empirical damage functions)
- Number of people affected by floods and tropical cyclones
- Changes in agricultural production
- Water scarcity indicators, droughts (national)
- Inundation areas due to sea level rise (+ storm surges)

By empirical approaches

- Changes in heating and cooling demands
- Changes in labor productivity due to heat
- Heat and cold induced mortality

Priority research

Major research tasks

Conceptual improvements:

- Viable way of temporal and spatial aggregation of effects of extreme events
- Structural elimination of perfect forsight facing extreme events
- Economic processes needed to capture the observed long-term growth reduction
- Distributional and equity issues between regions, households and sectors
- Quantifying impacts in economically relevant terms (e.g. effects on stocks and productivities)