POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

Integrating growth damages in IAMs: Persistencies and channels

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Based on work with Anselm Schultes, Gunnar Luderer, Elmar Kriegler, Ottmar Edenhofer, Tobias Geiger, Hazem Krichene, Inga Sauer

Leibniz Association

Increasing empirical evidence for persistency and for differentiated effects

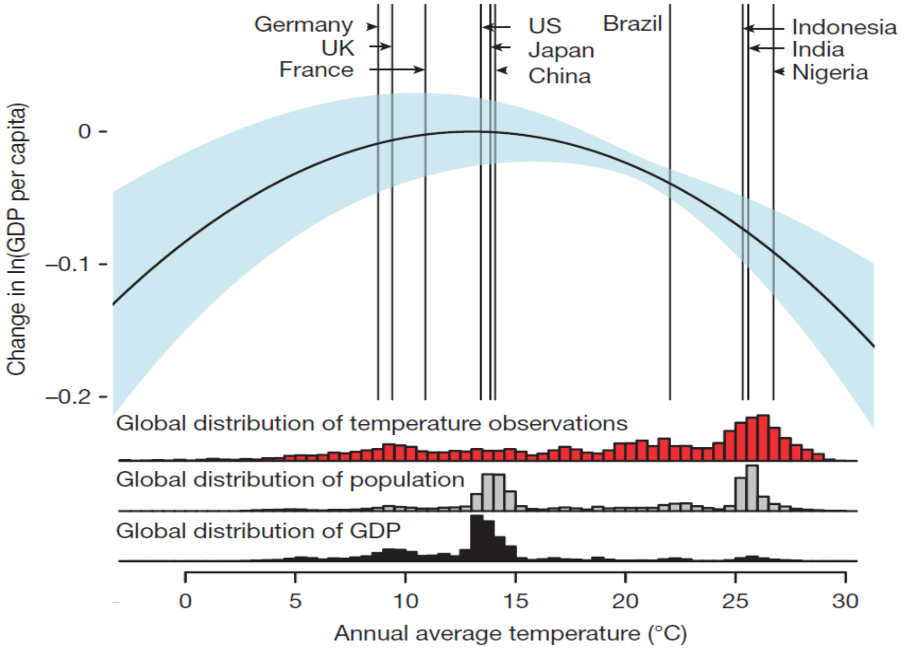
Short-term / aggregate level (high confidence)

- Nonlinear response of economic production to (annual) temperature fluctuations
    - Provides no understanding of the underlying processes / impact channels
    - What is the role of climate extremes?

Long-term impacts of climate extremes (low confidence)

- Tropical cyclones and droughts may have adverse impacts on economic development in the long run

[Berlemann & Wenzel 2016/'18,. Hsiang & Lina, 2014]



Among others: Burke et al. 2015, Kalkuhl & Wenz 2018, Pretis et al. 2018. 2018

Basis: Cross sectoral consistent bio-physical impact simulations – The Inter-Sectoral Impact Model Intercomparison Project (ISIMIP)

Climate data
(daily, 0.5° x 0.5°)
Historical observations
+
Projections
CMIP 5/6

Socio-economic input
(population, land-use, GDP, agricultural + water management)

Historical observations
+
Future Projections (SSP)

Impact Models (global + regional)

- Water
- Agriculture
- Coastal infrastructure
- Biomes
- Health
- Permafrost
- Energy
- Biodiversity
- Marine Ecosystems

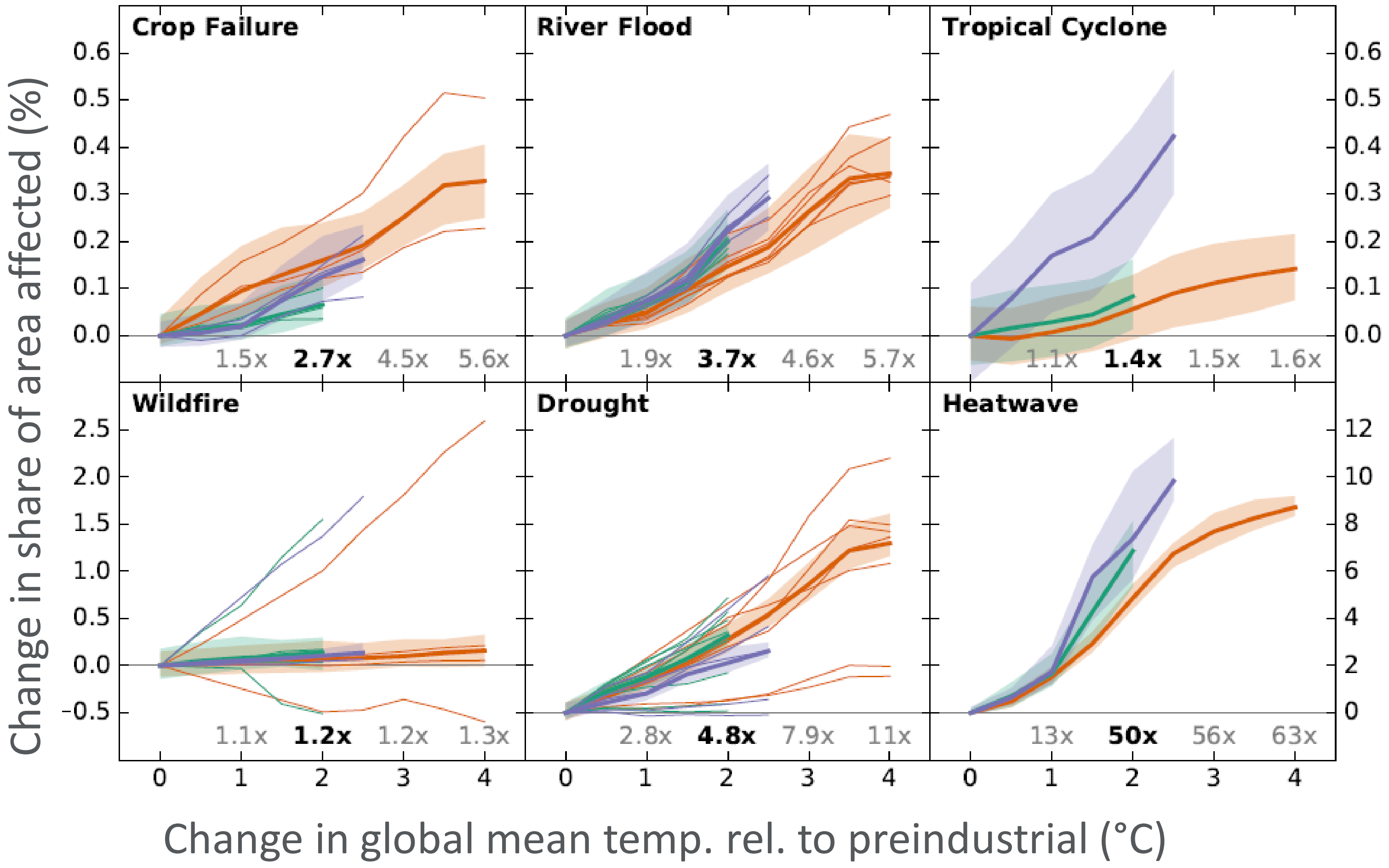
Main objectives

- Temporally and spatially explicit impact simulations
- Impact attribution
- Future projections of climate risks

ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

- Permits separation of climate and socio-economic drivers

Global area affected by climate extremes



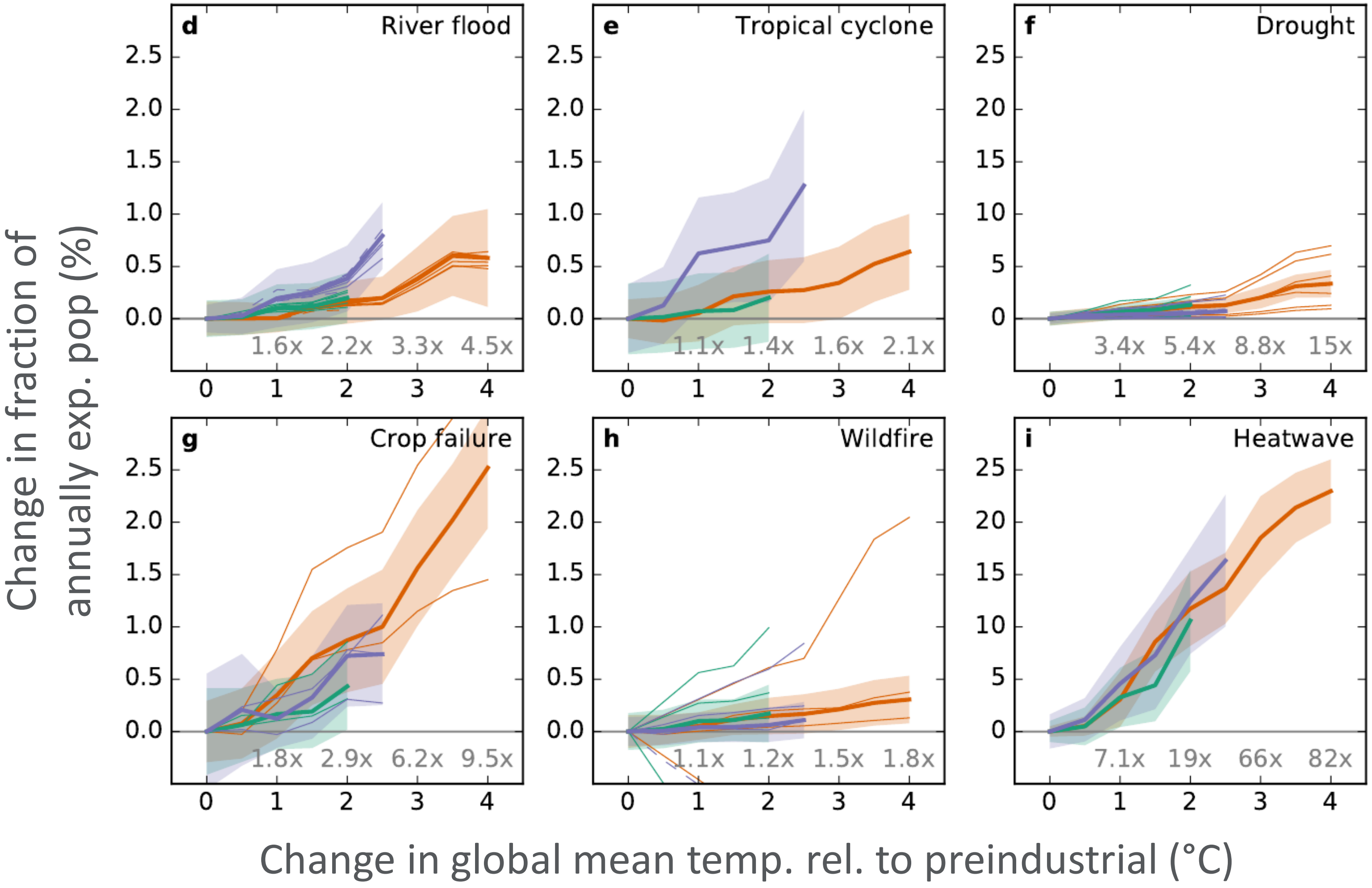
Colors = Climate models

Shading = Impact model uncertainty

Work in progress

[Lange et al., submitted]

People affected globally by climate extremes



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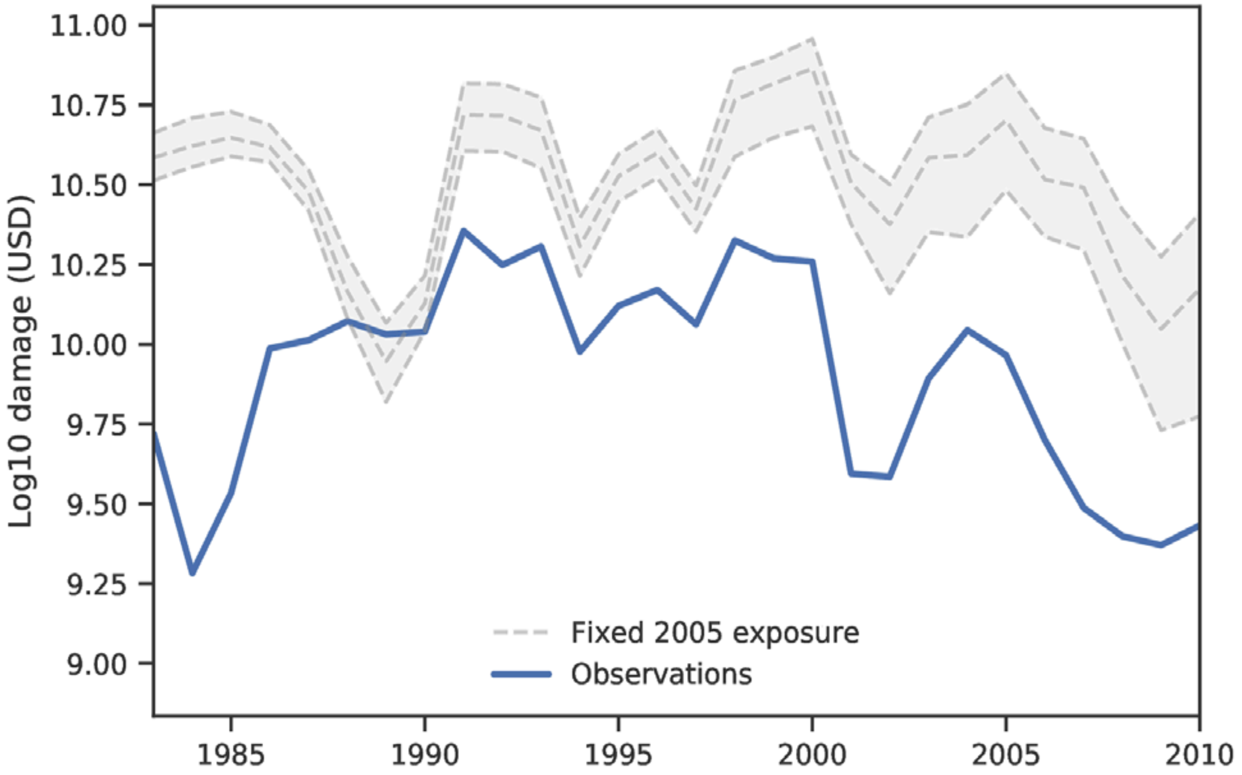
Historical warming has almost tripled global population annually exposed to extreme events

Work in progress

[Lange et al., submitted]

Direct losses: Past economic losses of river floods – East Asia



Work in progress

Short-term loss variability captured well by river flood simulations driven by observed weather

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[Geiger, Reese et al. in prep.]

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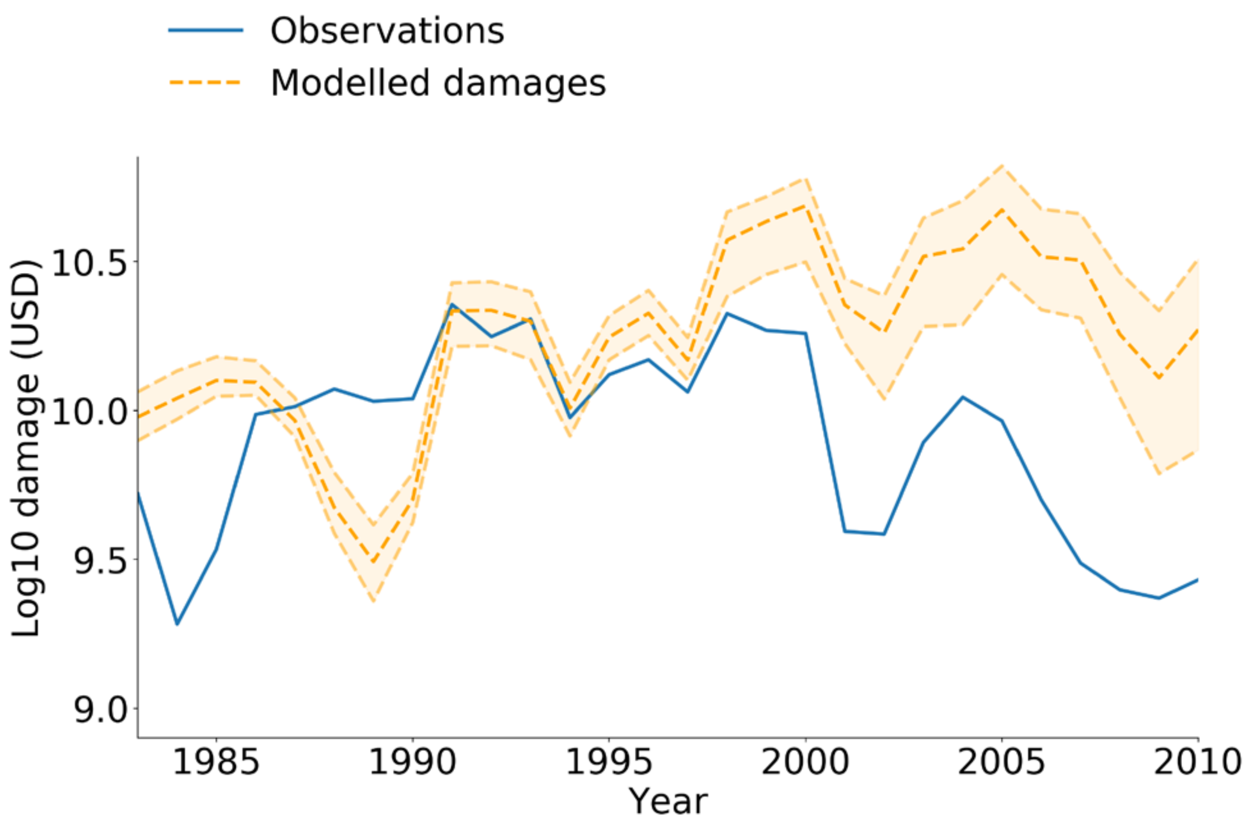

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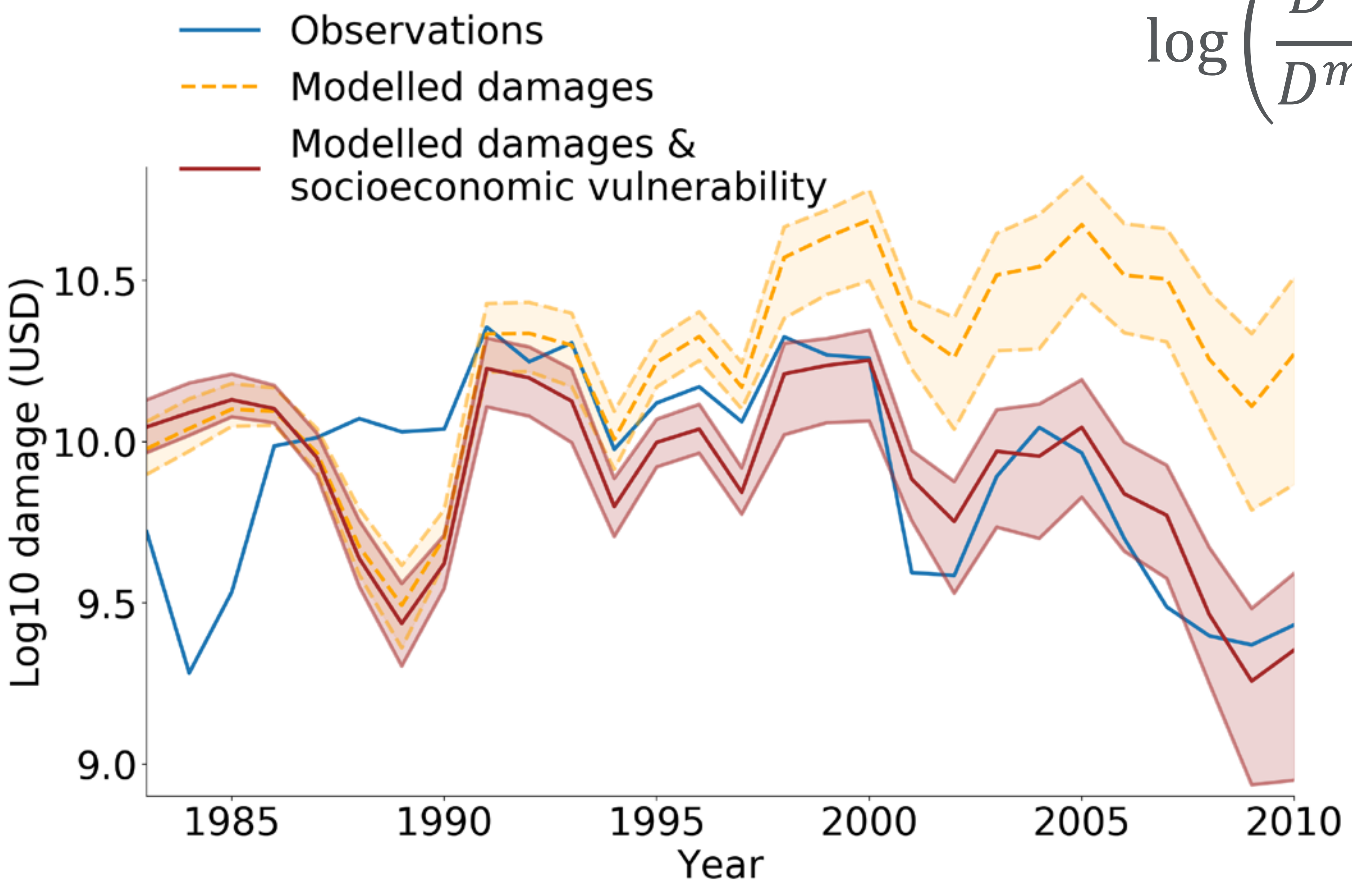
Short-term loss variability captured well by river flood simulations driven by observed weather

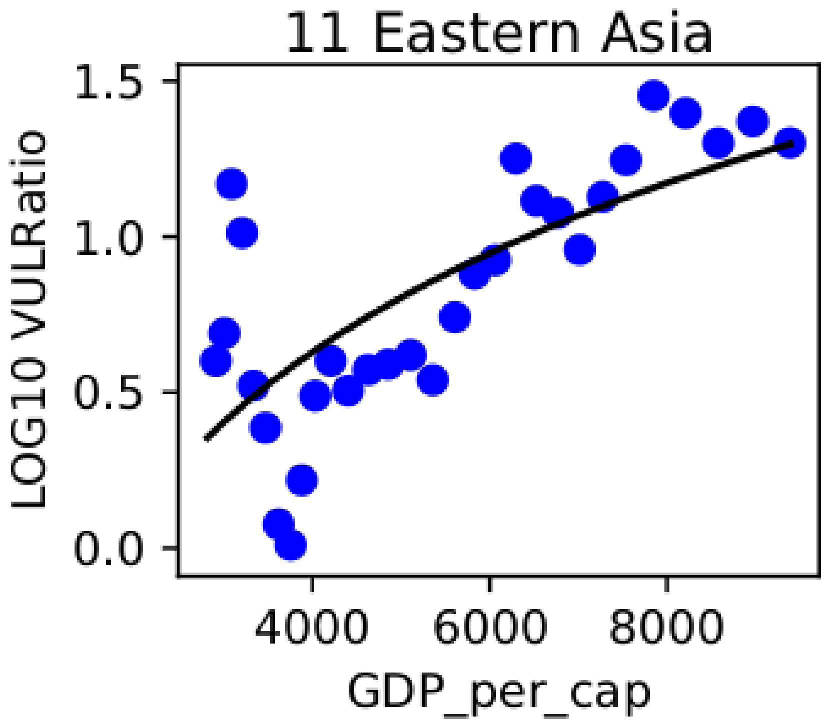
[Geiger, Reese et al. in prep.]

Direct losses: Past economic losses of river floods – East Asia

Socioeconomic vulnerability:

$$\log\left(\frac{D^{obs}}{D^{mod}}\right) = \alpha_j + \beta_j \log(GDP_{cap})$$





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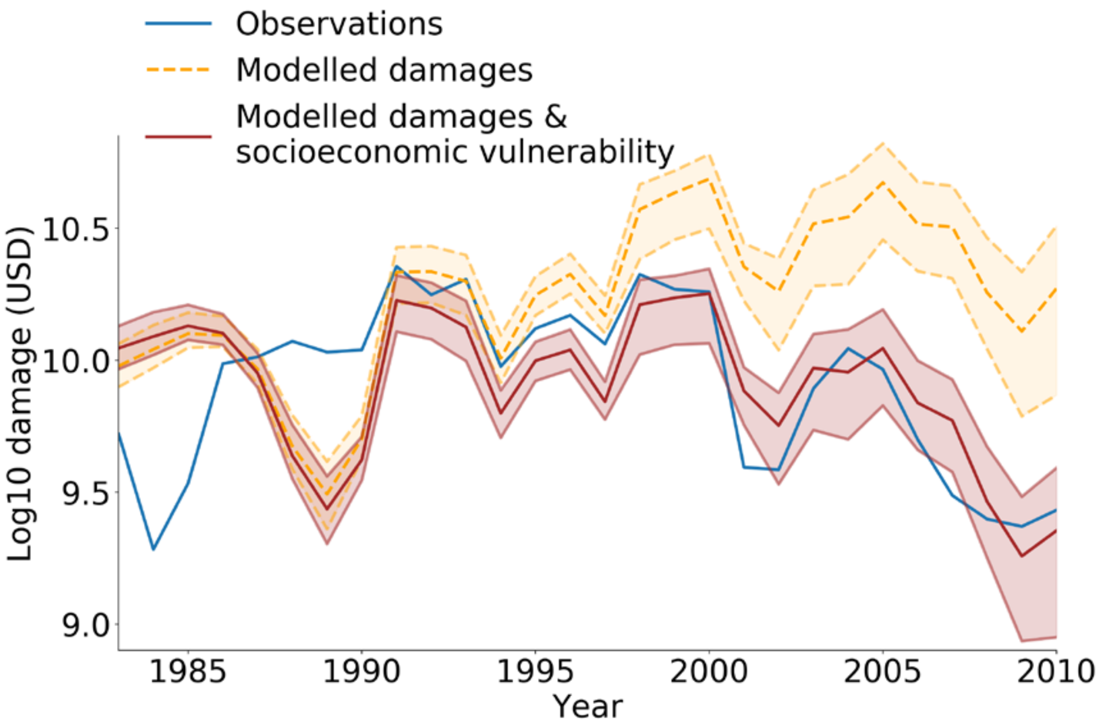
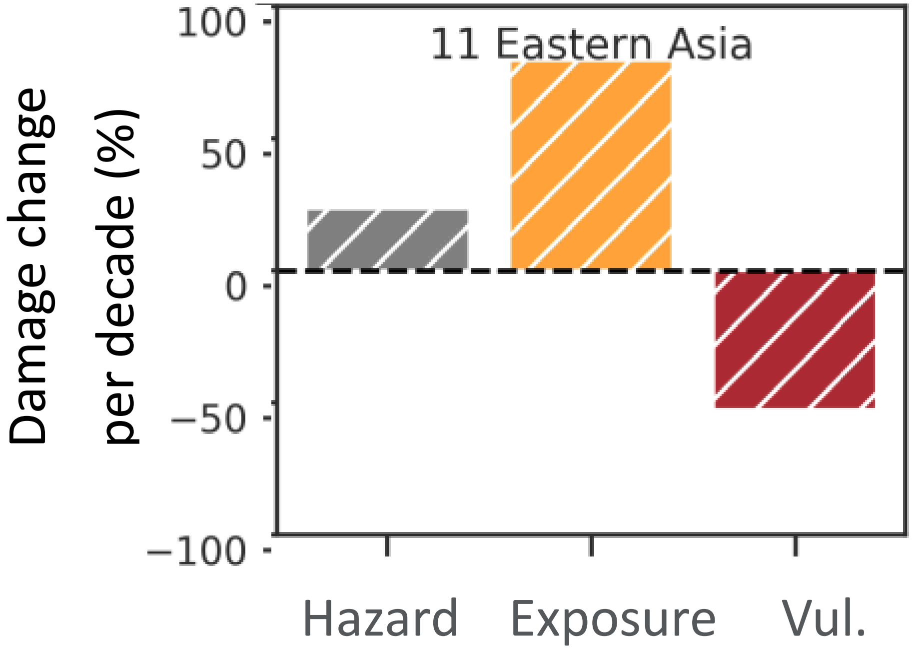
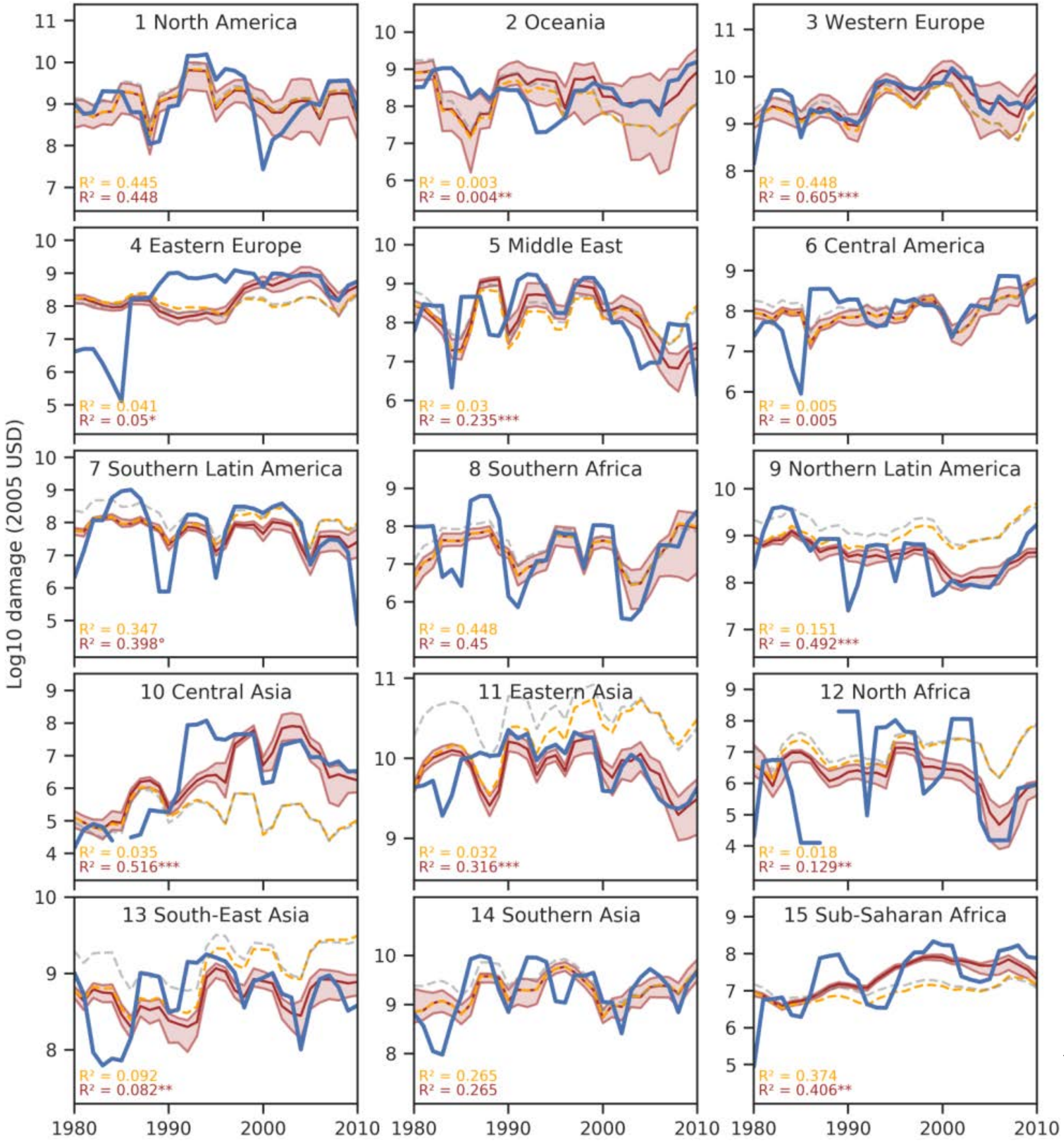




Work in progress

Recent loss reductions in East Asia could be explained by substantial investments in flood protection in China

Reproducing past economic losses of river floods – Global



Work in progress

[Geiger, Reese et al. in prep.]

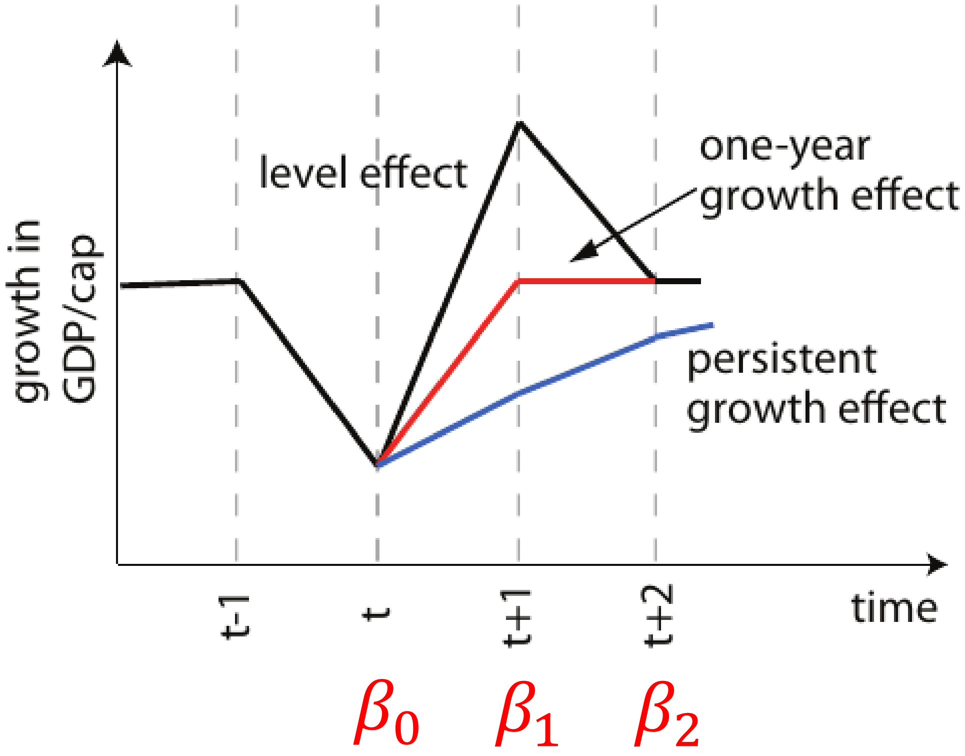
Persistencies of damages

- For **each disaster category**: Correlate historical economic growth rates with **people affected** by climate extremes

unperturbed growth path
(country fixed effects)

$$g_{j,t} = g_{j,t}^{0} + \sum_{l=0}^{L} \beta_l P_{j,t-l}$$

climate losses



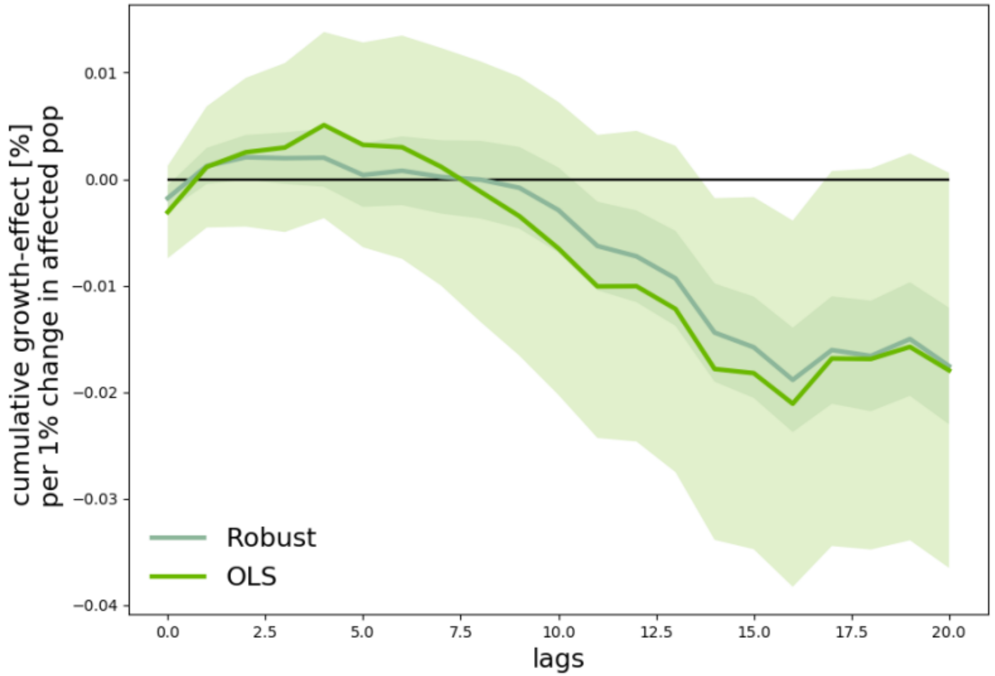
[Hsiang,2014]
[Berlemann & Wenzel (2016&"18]

Long-term impacts of tropical cyclones & fluvial floods (global)

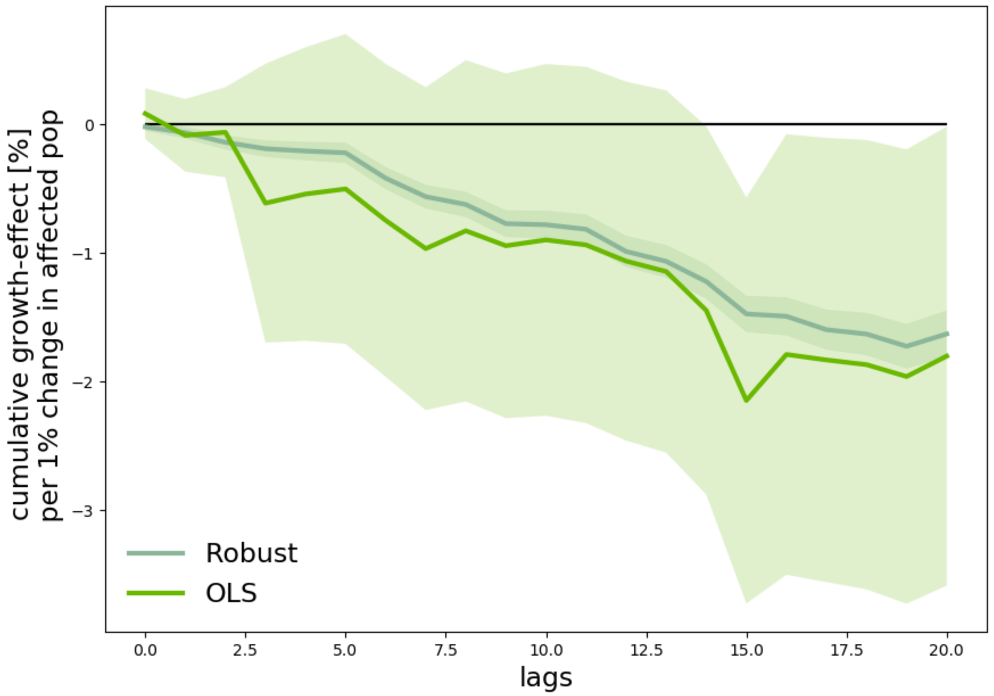
- Cumulative growth-effect k years after exposure:

$$\Omega_k = \sum_{l=0}^{k} \beta_l$$

Tropical cyclones



Fluvial floods



Work in progress

Tropical cyclones and fluvial floods reduce GDP growth in the long-term

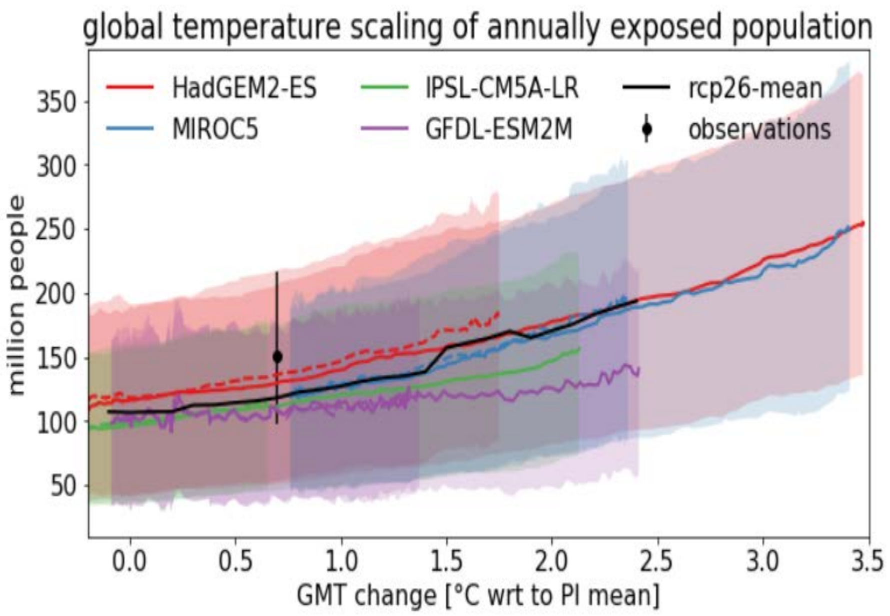
[Krichene et al., in prep].

From event-based to temperature-dependent damage functions

- Ensemble of timeseries of growth losses from ISIMIP
  - 2 RCP x 4 GCM x N impact models x SSP2

$$\delta_{j,t}(\{P_{j,t-l}\}_{l=0}^{L}) = \sum_{l=0}^{L} \beta_l P_{j,t-l}$$

- Hope
  - For each SSP scenario, share of affected people can be expressed as function of global mean temperature change
  - $\delta_{j,t}(\{P_{j,t-l}\}_{l=0}^{L})$ → $\delta_j(P_j(\Delta T))$

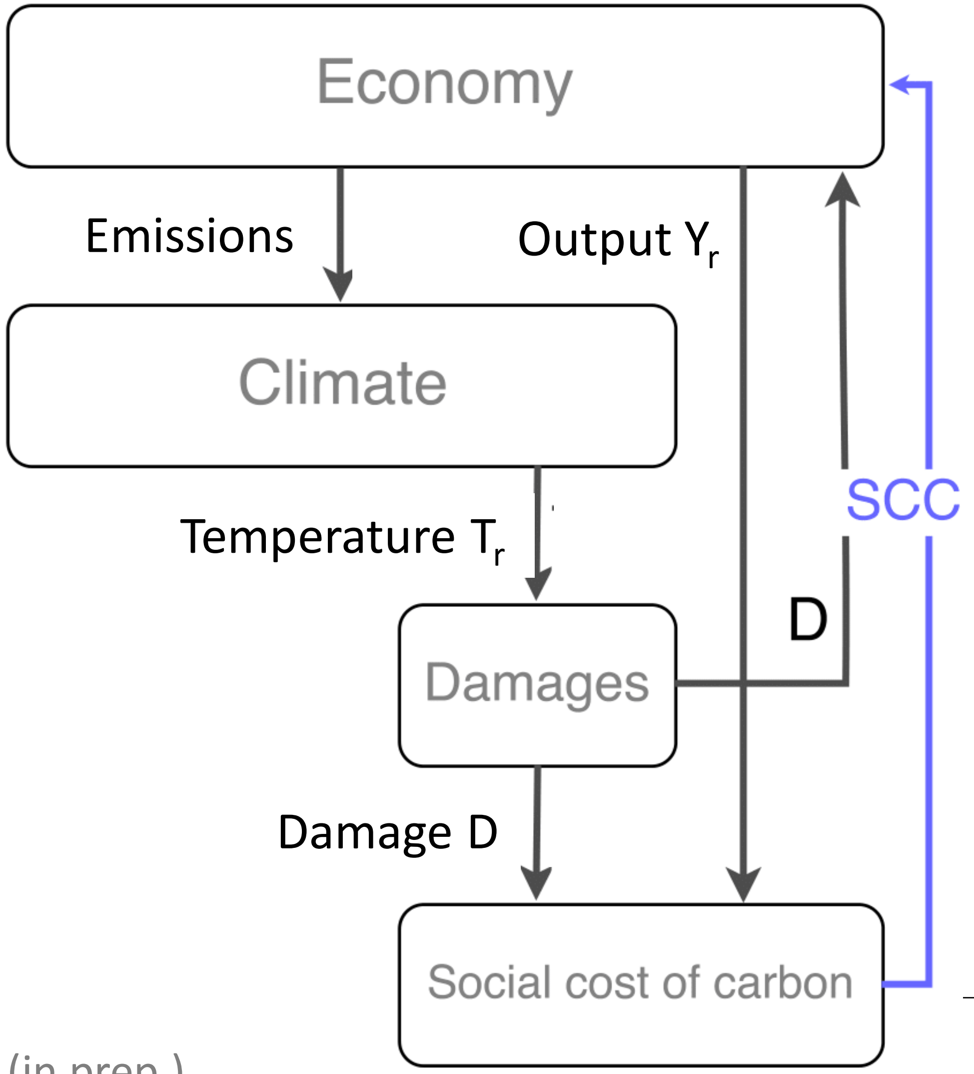


[Geiger et al., in prep]

Integration in IAMs

Integrated assessment with soft-coupled damage and climate module

- → Impacts internalized through social cost of carbon as a price on emissions
- → Advantage: higher process detail and flexibility on climate and damage modeling side



Analytical expression of the Social Cost of Carbon

unperturbed income

discount factor

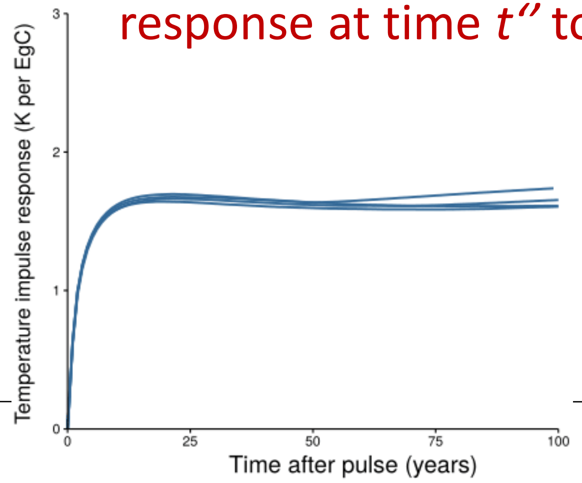
damage factor

For output damages:

$$SCC_t = \sum_r \sum_{t'=t}^{T} \Phi_{t',t} Y_{r,t'} D_{r,t'} \sum_{t''=t}^{t'} \Theta_{r,t',t''}(T) \kappa_{r,t''} \Delta T_{t'',t}$$

$\kappa_{r,t''} \Delta T_{t'',t}$: regional temperature response at time t'' to emissions at t

$\Theta_{r,t',t''}$: marginal damage from incremental temperature increase

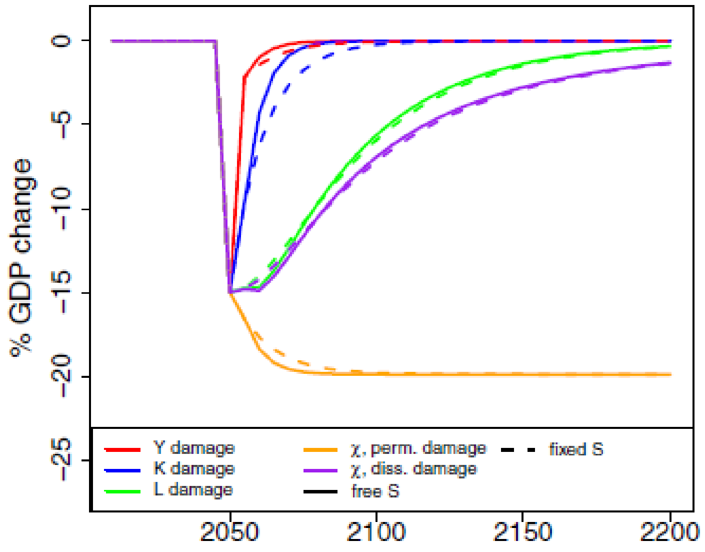


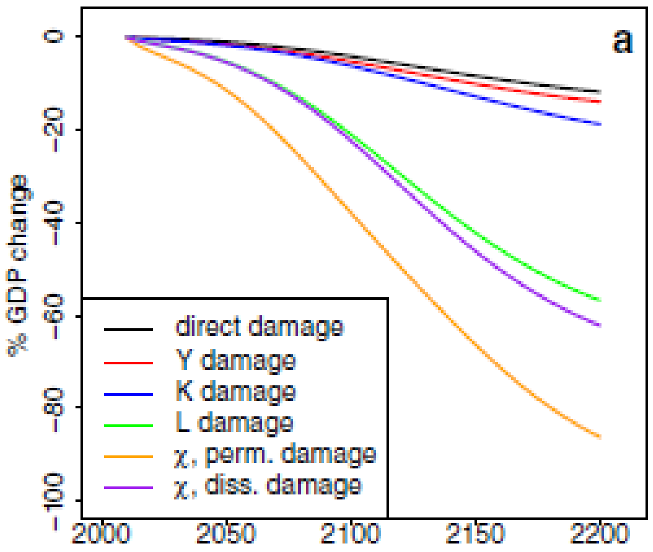
Schultes et al. (in prep.)

Persistence as key characteristic of damages

- Few empirical constraints – literature points to about 15 years
- Our channel study:
  - half-life time depends on channel & dynamics (endogenous vs. exogenous growth, savings rate)
  - accumulation of shocks with higher persistence leads to high damages

One-time shock on different production factors/productivity

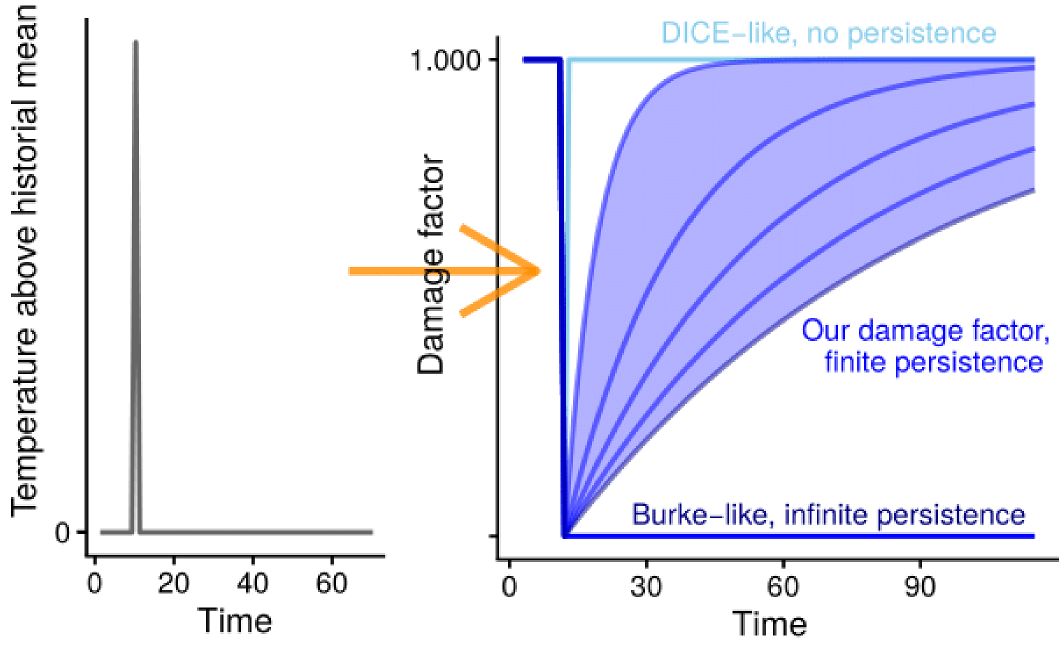




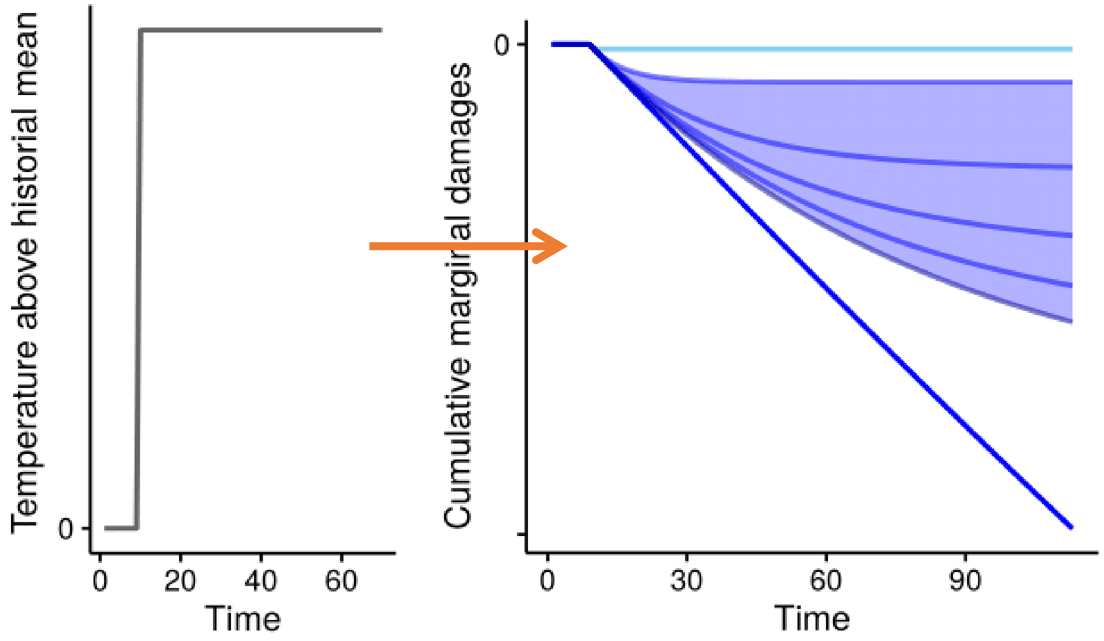
Accumulating shocks

Burke-based damages with different degrees of persistence – uncertainty & adaptation

$$D_{r,t} = \prod_{t'=1}^{t}\left(1 + \delta_{r,t'} 2^{-(t-t')/\tau_H}\right) \text{ with } \delta_{r,t} = \beta_1\left(T_{r,t} - \bar{T}_r\right) + \beta_2\left(T_{r,t}^2 - \bar{T}_r^2\right)$$



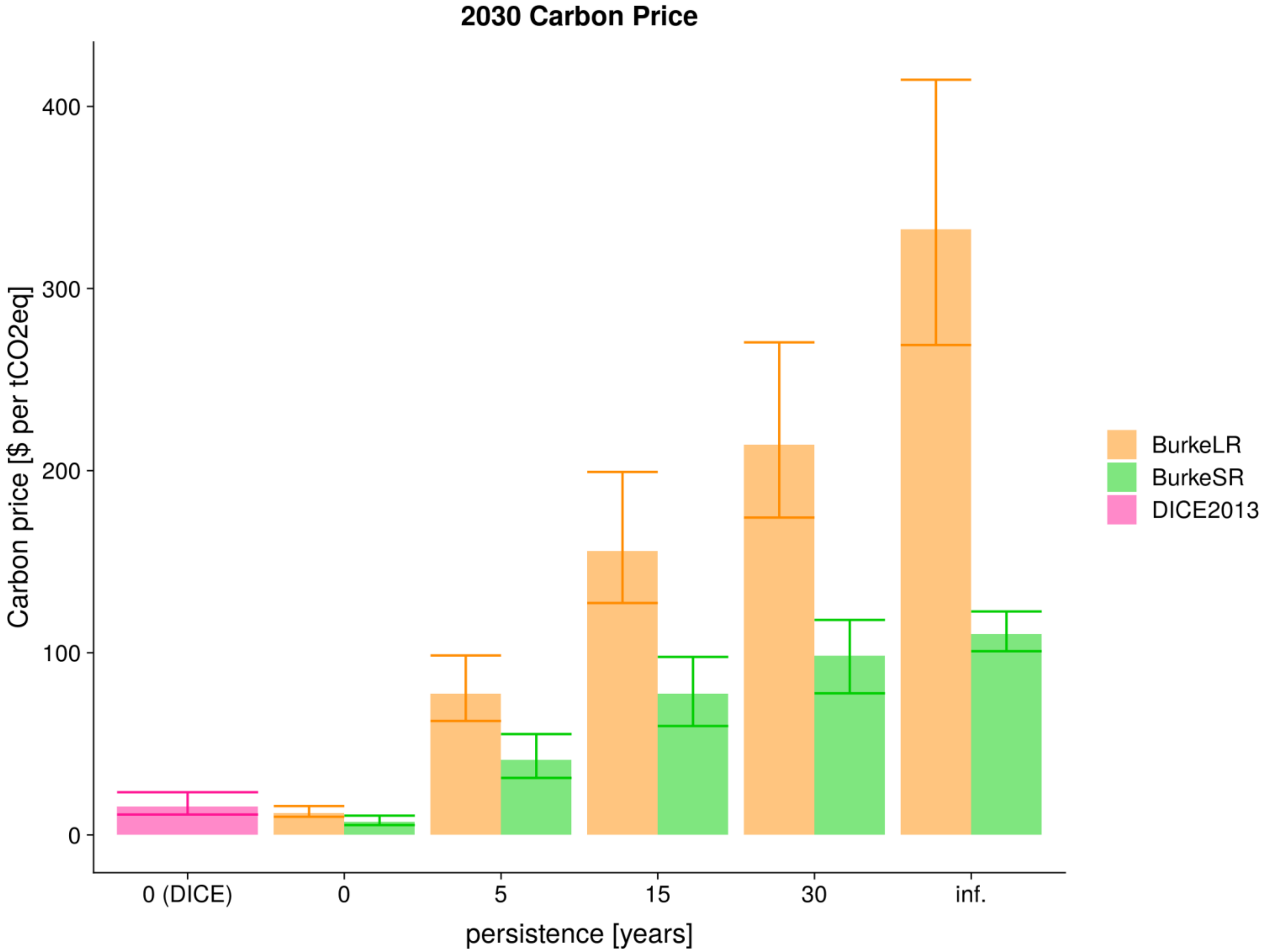
Response to temperature shock



Cumulative effect for step change in T

Schultes et al. (in prep.)

Effect of persistence on near-term carbon prices



- CBA analysis in REMIND IAM
- Uncertainty from climate and socioeconomics (SSP1,2,5)

	β_1	β_2
DICE2013	0	-0.00267
Burke short run	0.0127	-0.0005
Burke long run	-0.0037	-0.0001

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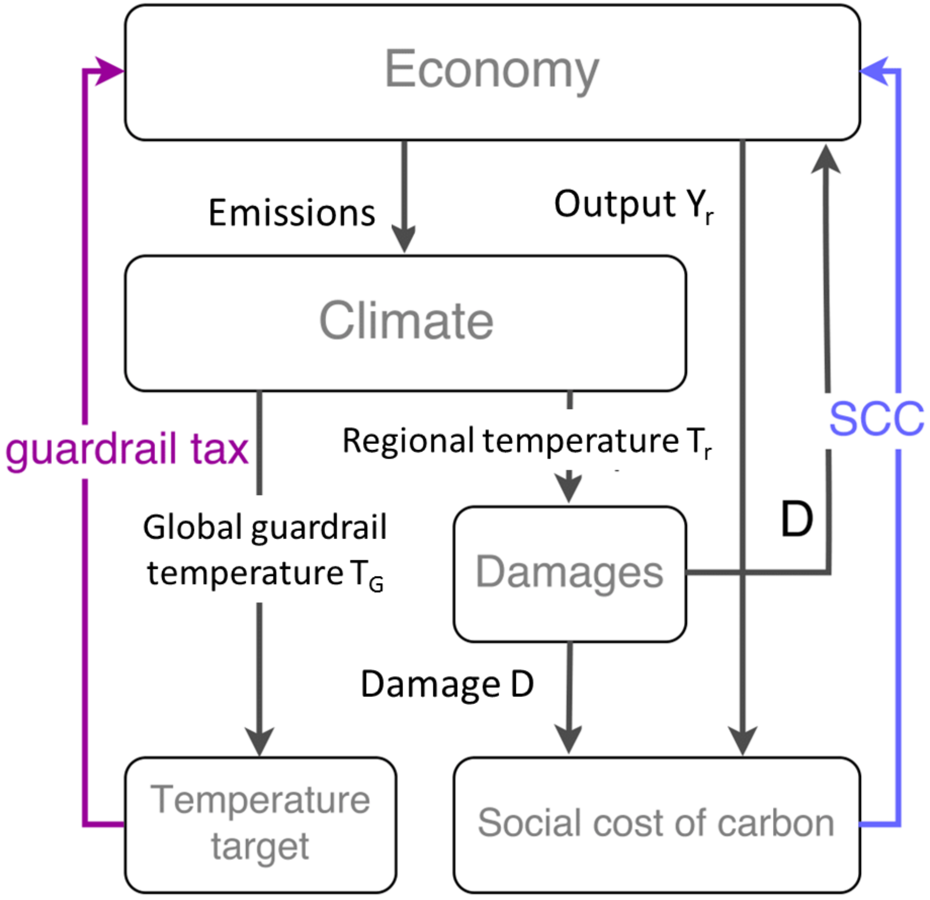
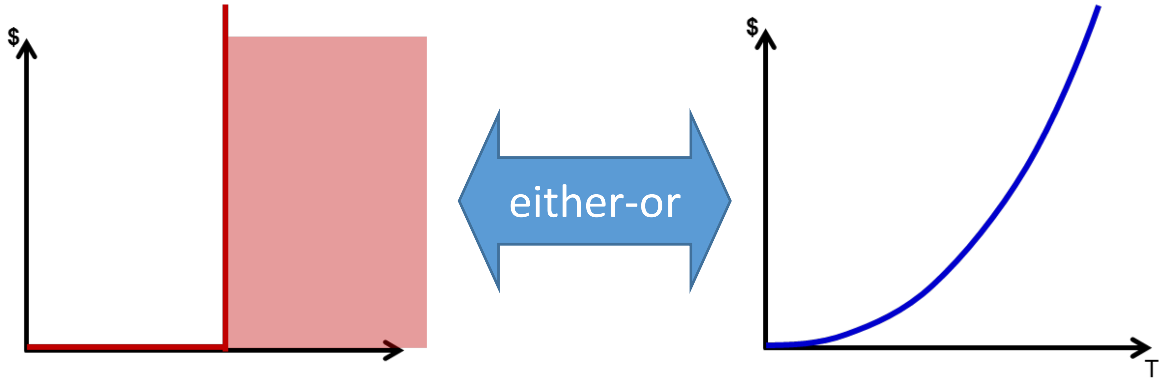
Schultes et al. (in prep.)

What is the welfare optimal response to global warming?



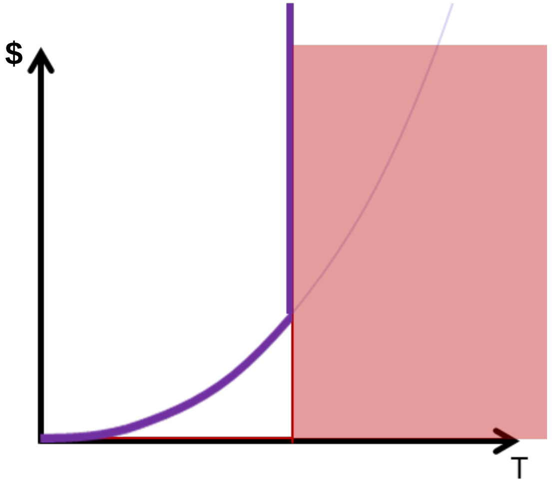
Cost-effectiveness (CEA):

Cost-benefit (CBA):



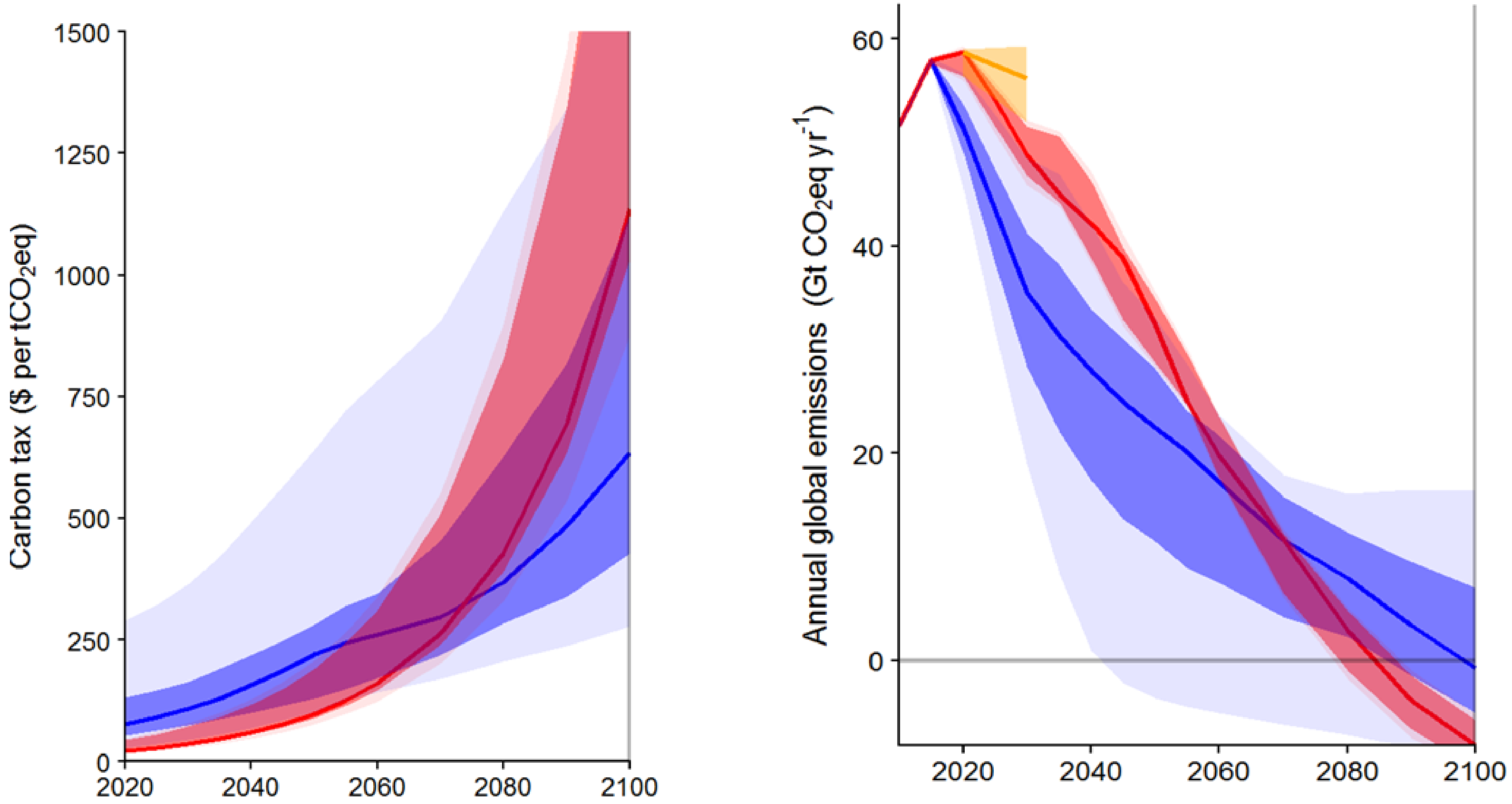
Least total cost (LTC):

- Minimizing the cost of abatement and damage under climate target
- Hedge against long-term changes & tipping points as well as account for near-term marginal damages



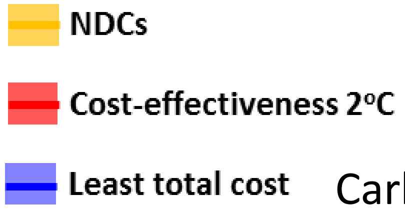
Schultes et al. (in prep.)

Least total cost: More ambitious near-term mitigation



Ensemble:

- Socio-economics: SSP1, SSP2, SSP5
- Climate uncertainty: 5th, 30th, 50th, 70th, 95th percentiles of 2100 temperature distribution in ensemble of RCP2.6 runs with MAGICC6
- Impacts: Burke short-term and long-term specifications, persistence times of 0, 5, 15, 30, ∞



Carbon price = guardrail tax

Carbon price = SCC + guardrail tax

Line: Ensemble median
Dark shading: 20-80th percentile
Light shading: full ensemble

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Schultes et al. (in prep.)

Next step: Closing the loop with ISIMIP impacts

- Channel-specific impacts – expressed either via output effects or directly
- Damages on capital stock from floods & tropical cyclones:
  - $K_{t+1} = (1-\delta)\delta_t^K K_t + I_t$ → for analytical expression of SCC we need to separate perturbed and unperturbed growth path of capital: $K_t = \prod_{t'=0}^{t}\left(1+\tilde{\delta}_{t'}^K\right)K_t^0 = D_t^K K_t^0$?
- Later: labor productivity damages, other channels?

→ What do different damage categories contribute to the SCC?

Conclusions

- Framework to move from biophysical to economic impacts with different steps in evaluation
  - people affected as unifying metric
  - econometric analysis of growth effects
  - use time series directly or construct temperature-dependent damage functions
- Persistence key parameter
- Soft-coupled approach internalizing damages via SCC for more complex damage and climate modules – how far can that go in taking up channel-specific damages (or distributional effects of impacts)
- Least total cost approach to ensure near-term climate action based on comprehensive cost assessmetn - supports more ambitious near-term mitigation