POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

Towards a better understanding of temperature impacts on economic performance:

subnational effects & day-to-day variability

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NAVIGATE-ENGAGE

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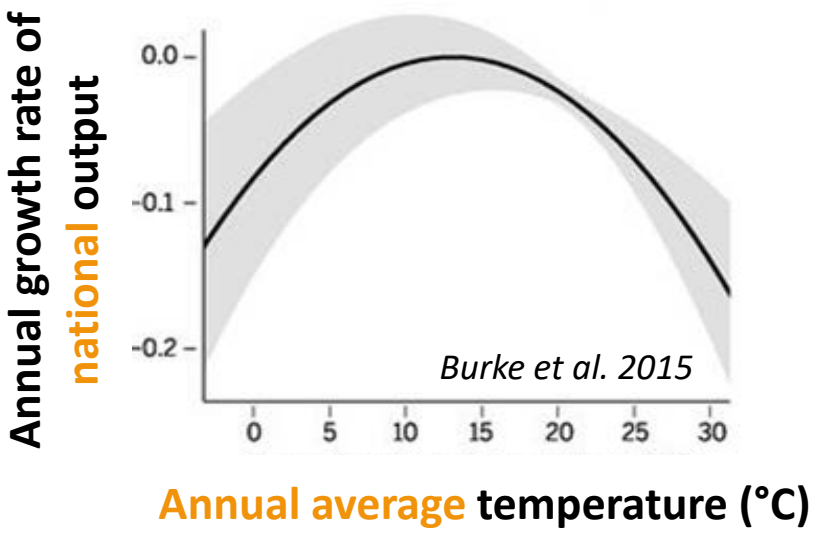
Motivation

- **Damage functions in Integrated Assessment Models (IAM) have been criticized for poor theoretical and empirical foundation** *Pindyck 2013; Farmer et al., 2015; Stern 2016*
- **Recent advances in integrating empirically-derived damage functions in IAMs with important implications for climate policy** *Moore & Diaz, 2015; Ueckerdt et al., 2019; Glanemann et al., 2020; Hänsel et al., 2020; Kikstra et al., 2021*
- **However: Empirical estimates of temperature impacts on GDP differ vastly** *Newell et al., 2021; Piontek et al., 2021; Bastien-Olvera & Moore, WP*
  - Regional heterogeneity of impacts
  - Role of adaptation
  - Growth or level effects
  - ...



Towards a better understanding ...

Paper 1:

Subnational data instead of aggregation at country-level

→ enables estimation of economic effects at different time scales

The impact of climate conditions on economic production. Evidence from a global panel of regions☆

Matthias Kalkuhl [a,b,*], Leonie Wenz [a,c,d]

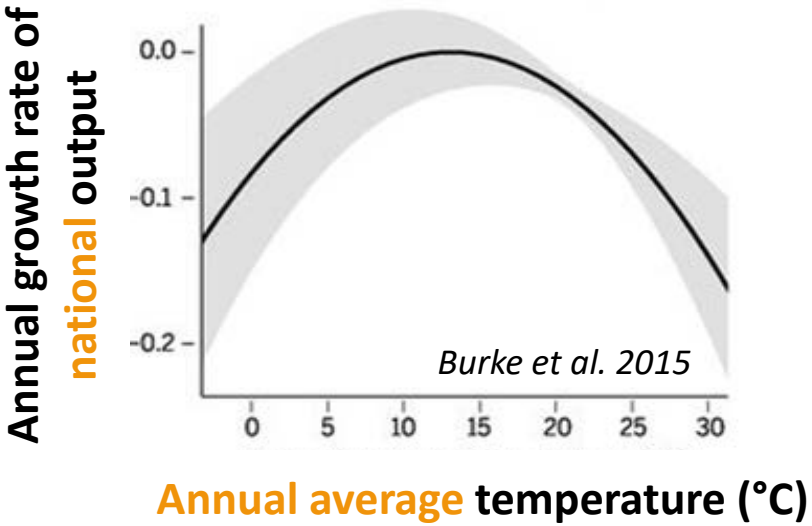
Paper 2:

Day-to-day temperature variability in addition to annual mean temperature

→ what agents are actually exposed to

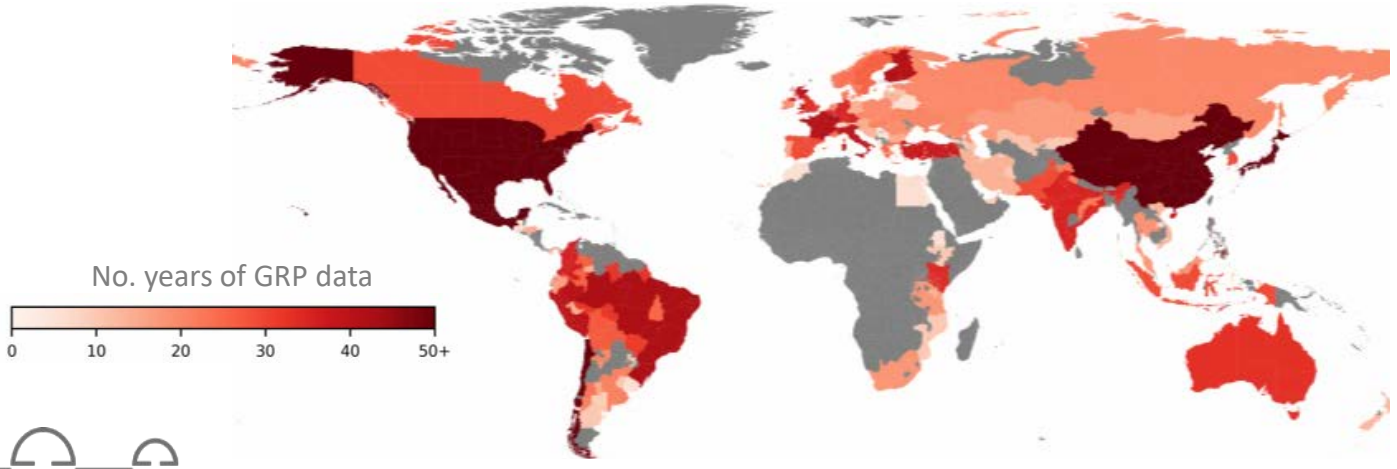
Day-to-day temperature variability reduces economic growth

Maximilian Kotz [1,2], Leonie Wenz [1,3,4] ✉, Annika Stechemesser [1,2], Matthias Kalkuhl [3,5] and Anders Levermann [1,2,6]



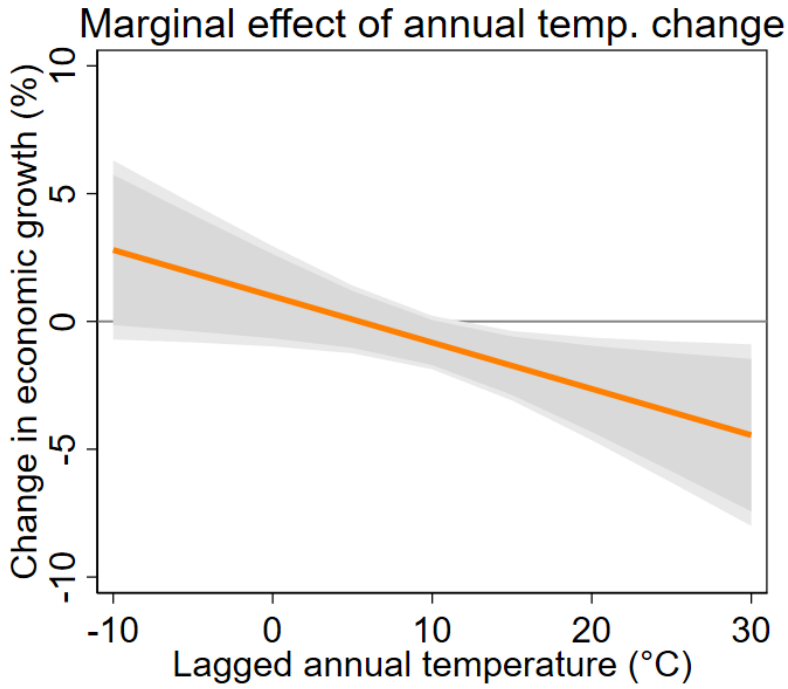
The MCC-PIK Database of Subnational Economic Output (DoSE)

- **Regional income data (Gross Regional Product, GRP)**
  - >29.500 observations: 77 countries, >1500 regions, 1900-2014
  - Sources: national statistical agencies, central banks, reports, yearbooks
  - Exchange rates: FRED St. Louis
- **Sectoral breakdown: agriculture, services, manufacturing**
- **Mapped with gridded climate data (ERA5, CRU)**
- **Ongoing effort to extend in time and space (version 1 published)**



Subnational analysis reveals substantial economic losses from temperature changes

- Robust evidence that temperature changes affect productivity levels considerably and non-linearly (α, β)
- No evidence for impacts on long-run growth rate (γ)



Annual panel model

$$g_{i,t} = \alpha \Delta T_{i,t} + \beta \Delta T_{i,t} T_{i,t} + \gamma_1 T_{i,t} + \gamma_2 T_{i,t}^2 + p_i(t) + \mu_i + \eta_t + \epsilon_{it}$$

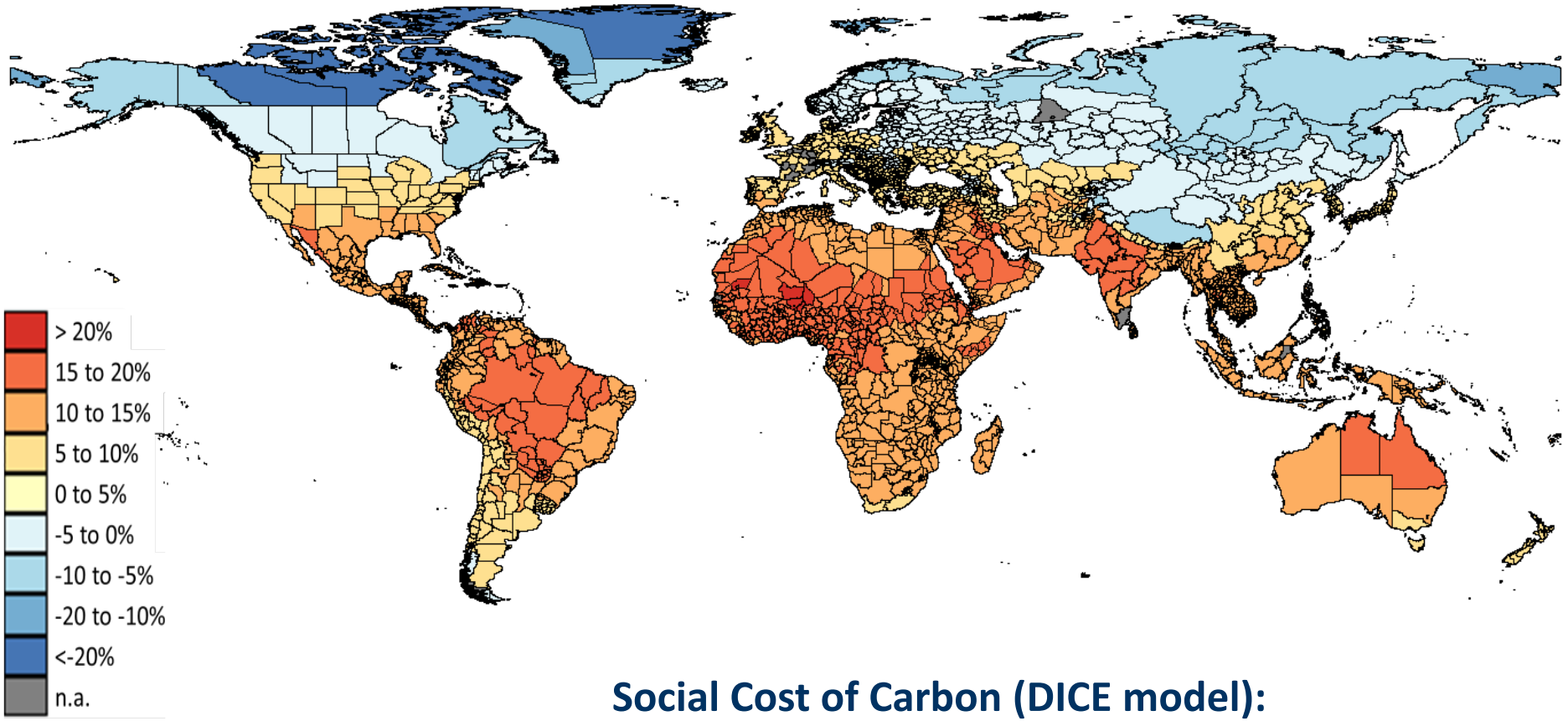
per capita growth rate at region i in year t (log change)

region-specific polynomial time trend

Region and year fixed effects

Regression tables
Robustness checks

Economic losses under RCP-8.5 in 2100



Social Cost of Carbon (DICE model):

- $140 (2020) - $750 (2100)

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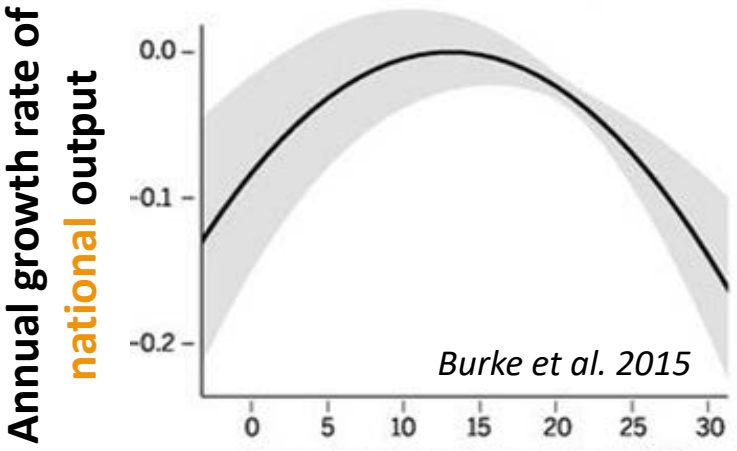
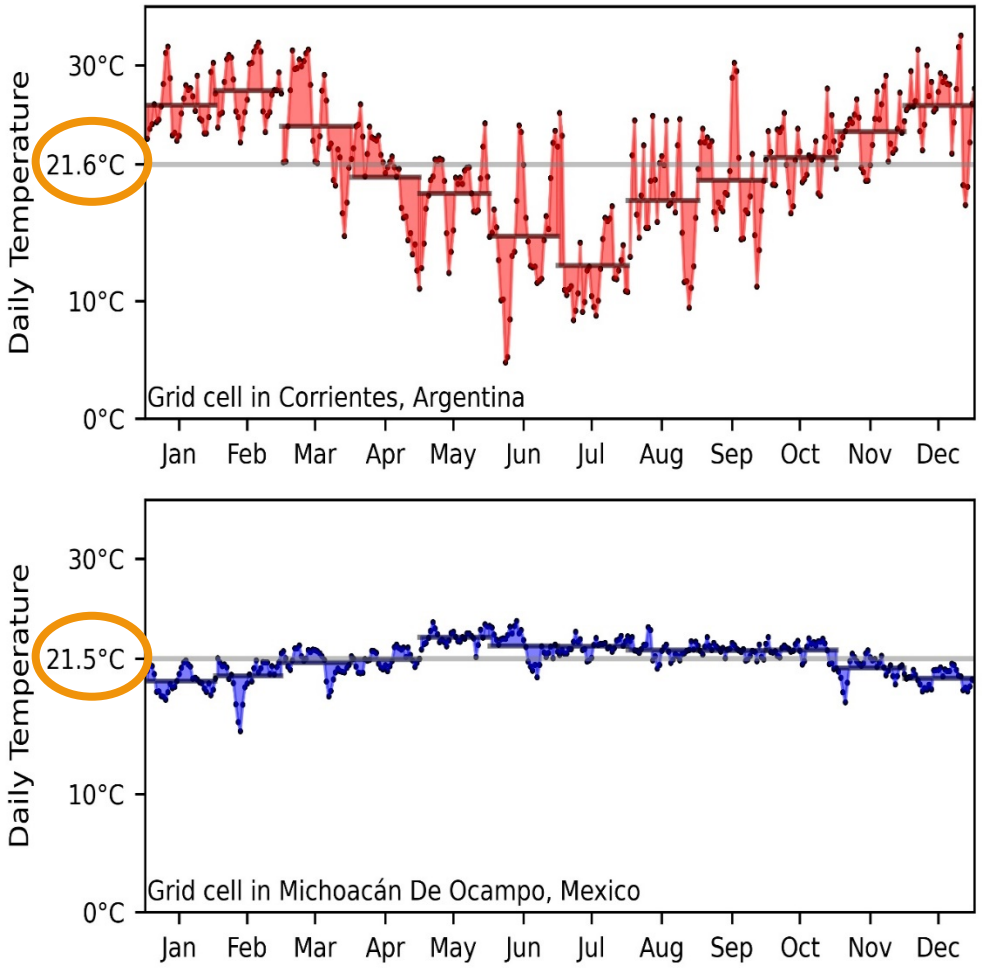


Beyond annual averages: Day-to-day temperature variability

- **Hypothesis**: Temperature variability matters at much shorter time scales (exposure of agents)
- Possible channels: health impacts, crop yields, planning, investment risks, ...
- Measure for seasonally-adjusted day-to-day temperature variability

$$\tilde{T}_y = \frac{1}{12}\sum_{m}^{12}\sqrt{\frac{1}{D_{m,y}}\sum_{d}^{D_{m,y}}(T_{d,y} - \bar{T}_{m,y})^2}$$

Nr. of days per month | Daily temp. | Monthly mean temp.



Day-to-day temp. variability reduces growth

$$g_{i,t} = F(\bar{T}_{i,t}) + \lambda \tilde{T}_{i,t} + \mu_i + \eta_t + \varepsilon_{i,t}$$

Regional growth rate | Function of annual mean temp. | Daily temp. variability | Region and year fixed effects

$$\lambda = -0.054 \pm 0.005$$

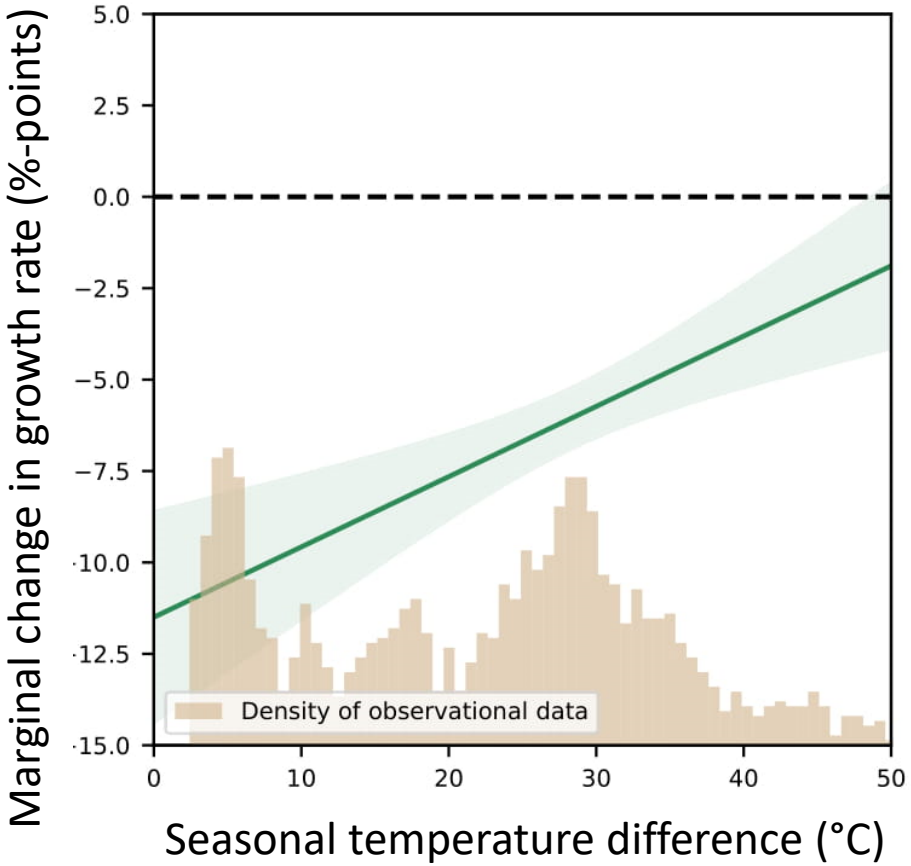
+1°C increase of day-to-day temperature variability ➡ 5 percentage point reduction in regional growth rates

✺ Independent of and in addition to the effect of annual average temperature $\bar{T}$
➡ separate effects

Effect modulated by location

$$g_{i,t} = F(\bar{T}_{i,t}) + \lambda_1 \tilde{T}_{i,t} + \lambda_2 \tilde{T}_{i,t} \cdot \hat{T}_r + \mu_i + \eta_t + \varepsilon_{i,t}$$

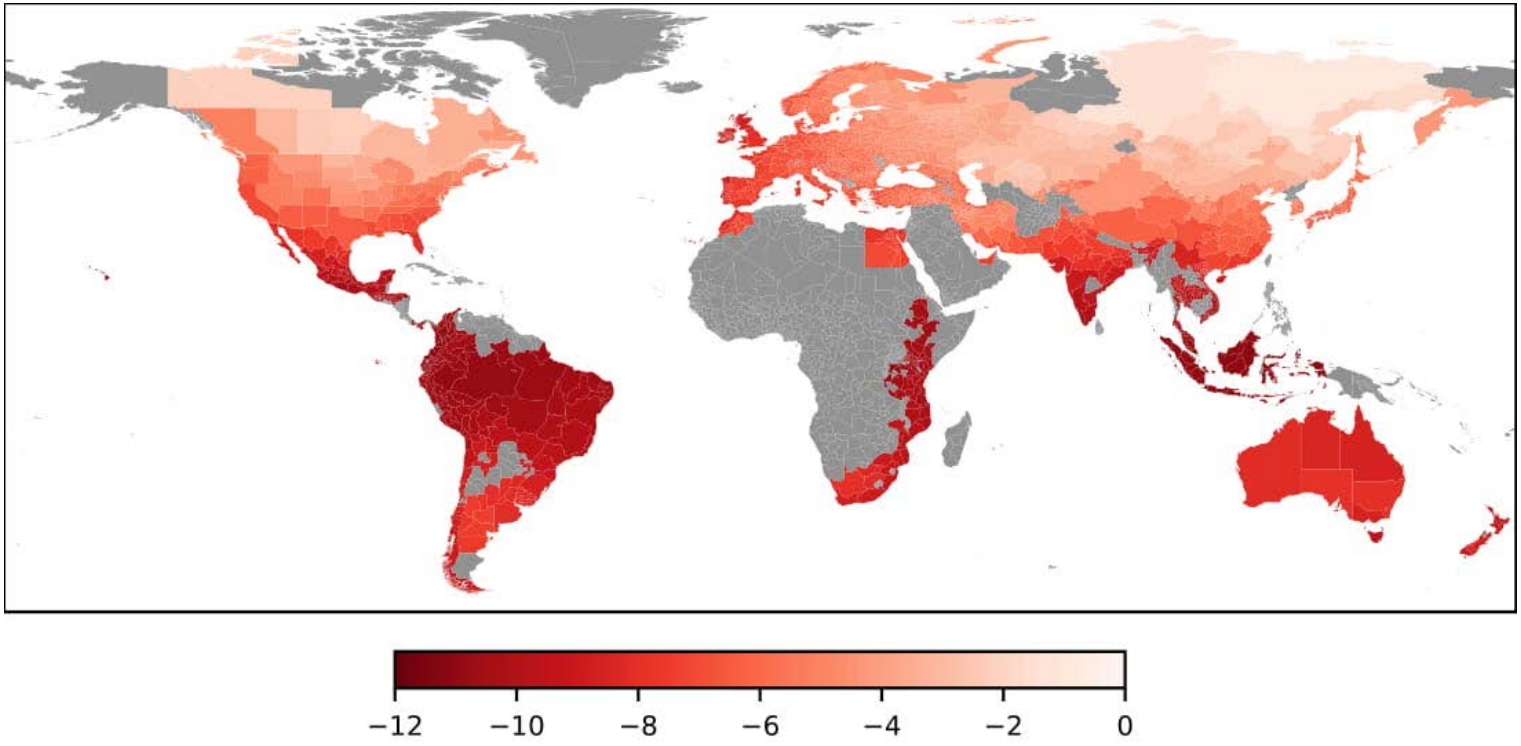
Regional growth rate | Function of annual mean temp. | Daily temp. variability | Region and year fixed effects



Familiarity with temperature variations because of strong seasonal cycle $\hat{T}_r$

Smaller effect size

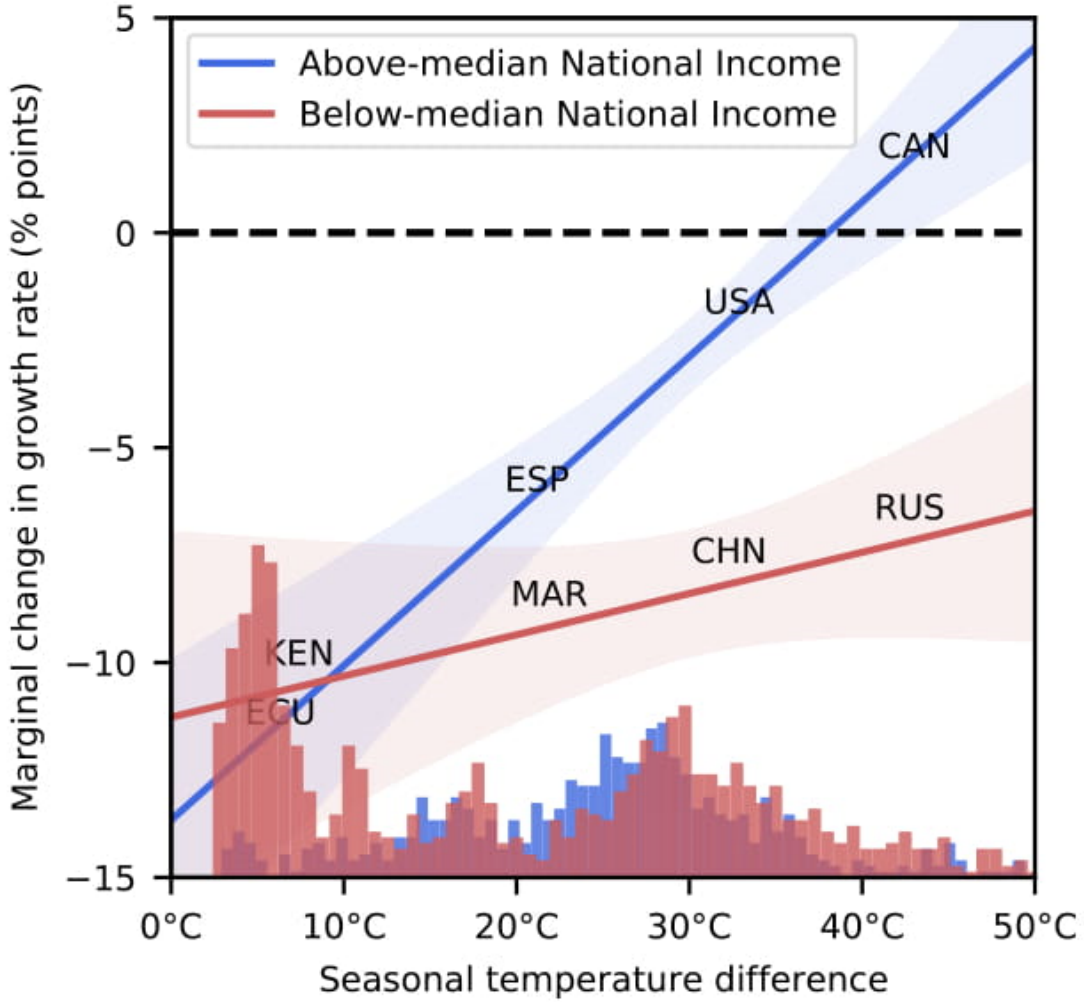
Effect modulated by location - spatial heterogeneity



Change in growth rates per extra degree of day-to-day temperature variability (% points)

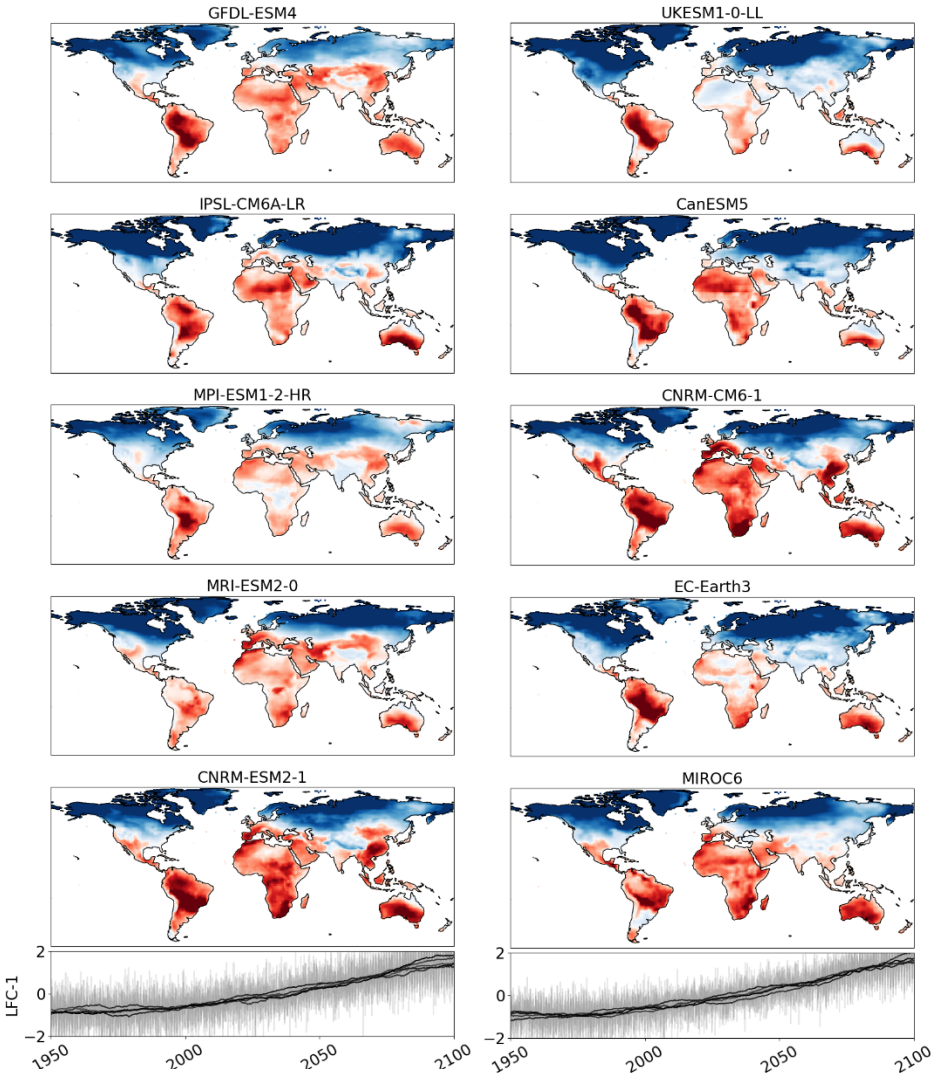
Details

Effect modulated by income



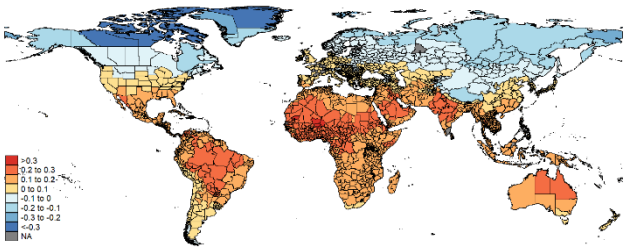
Future evolution of day-to-day temp. variability

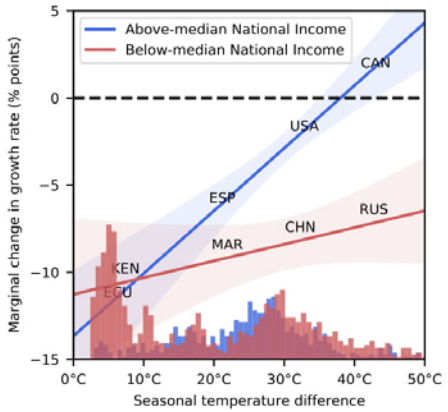
- Low-frequency component analysis to track footprint of greenhouse forcing in day-to-day temp. variability
- Variability has changed with distinct global patterns over the past 65 years
- Under SSP-585: increase by up to 100% at low latitudes and decrease by 40% at northern high latitudes by 2100



Key take-aways

- Subnational analysis: High productivity losses from annual temperature changes
- Implies carbon price that is 2-4 times higher than DICE2016-R, accounting for temperature impacts alone
- Temperature variability away from monthly means exerts strong additional pressure on economies (5 p.p. reduction in economic growth rates on average)
- Effect modulated by socio-geographic factors with low-income, low-latitude regions being the most vulnerable (up to 12 p.p. reduction in growth rates)





Thank you!

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