The need for mitigation and adaptation

Some evidence from evidence from the social cost of carbon under partial growth effects and interannual temperature variability

Jarmo Kikstra
kikstra@iiasa.ac.at

NAVIGATE/ENGAGE expert workshop
21 September 2021

Preparing late is being flexible?

Imperial College London

IIASA

Some questions and answers from yesterday (and today):

- **Macro-economics for climate change:**
  - ⇒ very uncertain, but evidence of very big impacts?
- **What are impacts, and which are the biggest?**
  - ⇒ requires process-based understanding, necessary examples for policymakers.
  - ⇒ only looking at climatic temperatures is not good enough.
- **Adaptation pathways**:
  - ⇒ learning how and to what extent we can deal with the impacts (processes) that are coming; little evidence yet?

Preparing late is being flexible?

Some questions and answers from yesterday:

- **Macro-economics for climate change:**
  ⇒ very uncertain, but evidence of very big impacts.
- **What are impacts, and which are the biggest?**
  ⇒ requires process-based understanding, necessary examples for policymakers
  ⇒ only looking at climatic temperatures is not good enough.
- **Adaptation pathways**:
  ⇒ learning how and to what extent we can deal with the impacts (processes) that are coming; little evidence yet?

What can we already do in terms of modelling?

The modelling in this presentation

Some questions and answers from yesterday:

- **Macro-economics for climate change:**
  ⇒ very uncertain, but evidence of very big impacts?
- **What are impacts, and which are the biggest?**
  ⇒ requires process-based understanding, necessary examples for policymakers
  ⇒ only looking at climatic temperatures is not good enough.
- **Adaptation pathways**:
  ⇒ learning how and to what extent we can deal with the impacts (processes) that are coming; little evidence yet?

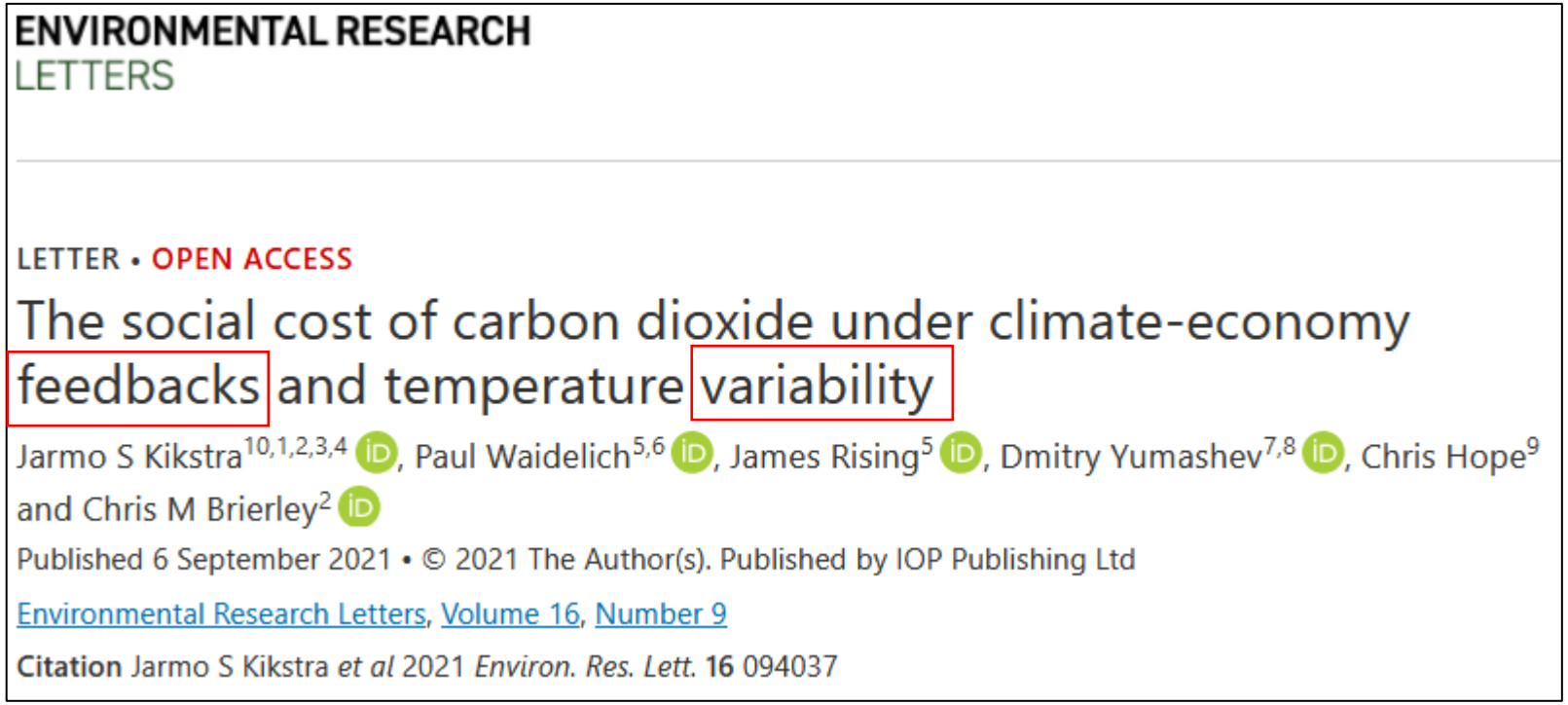
Kikstra et al. (2021)
Environ. Res. Lett.
10.1088/1748-9326/ac1d0b.

The basis for this presentation

Imperial College London

IIASA

PAGE IAM



ENVIRONMENTAL RESEARCH
LETTERS

LETTER • OPEN ACCESS

The social cost of carbon dioxide under climate-economy feedbacks and temperature variability

Jarmo S Kikstra[10,1,2,3,4], Paul Waidelich[5,6], James Rising[5], Dmitry Yumashev[7,8], Chris Hope[9] and Chris M Brierley[2]

Published 6 September 2021 • © 2021 The Author(s). Published by IOP Publishing Ltd

Environmental Research Letters, Volume 16, Number 9

Citation Jarmo S Kikstra *et al* 2021 *Environ. Res. Lett.* **16** 094037

Kikstra et al. (2021)
Environ. Res. Lett.
10.1088/1748-9326/ac1d0b.

The basis for this presentation

PAGE IAM

ENVIRONMENTAL RESEARCH
LETTERS

LETTER • OPEN ACCESS

The social cost of carbon dioxide under climate-economy feedbacks and temperature variability

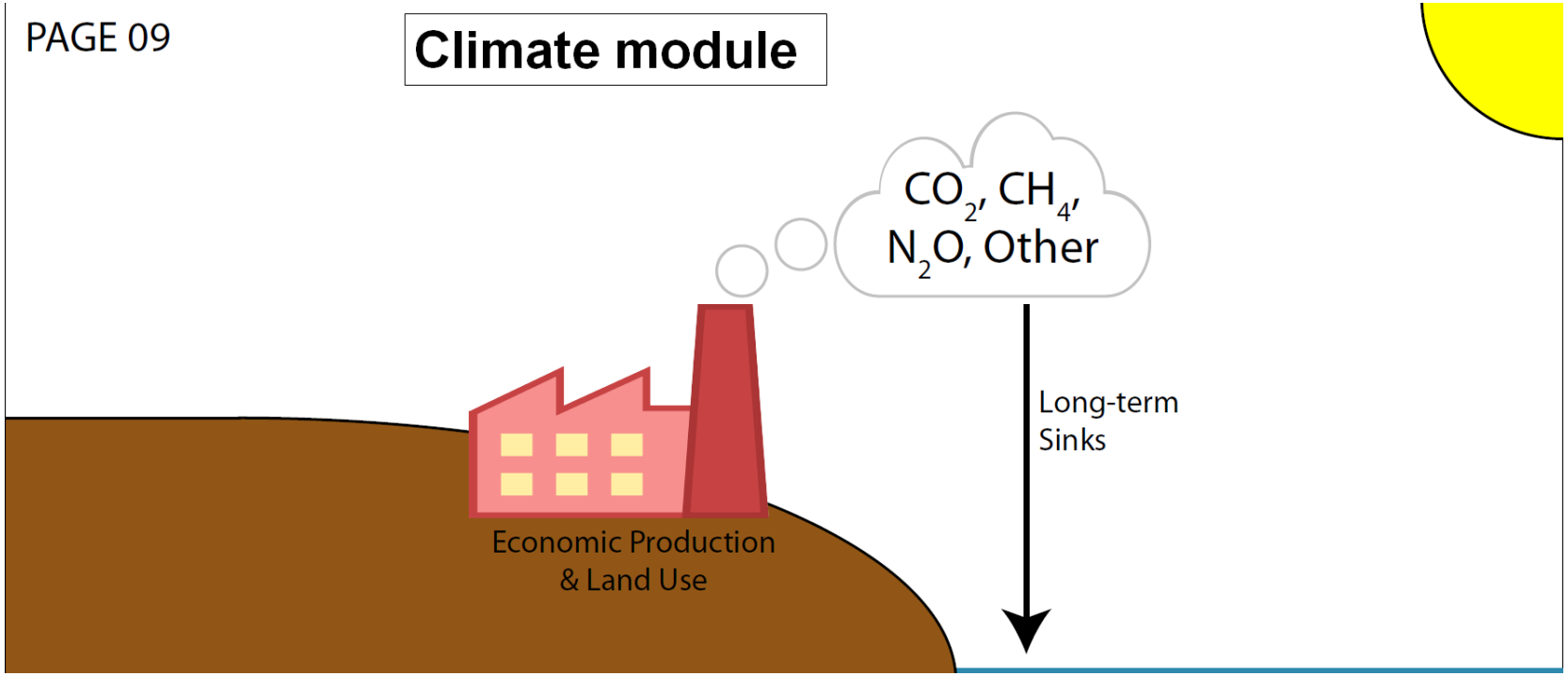
Jarmo S Kikstra[10,1,2,3,4], Paul Waidelich[5,6], James Rising[5], Dmitry Yumashev[7,8], Chris Hope[9] and Chris M Brierley[2]

Published 6 September 2021 • © 2021 The Author(s). Published by IOP Publishing Ltd

Environmental Research Letters, Volume 16, Number 9

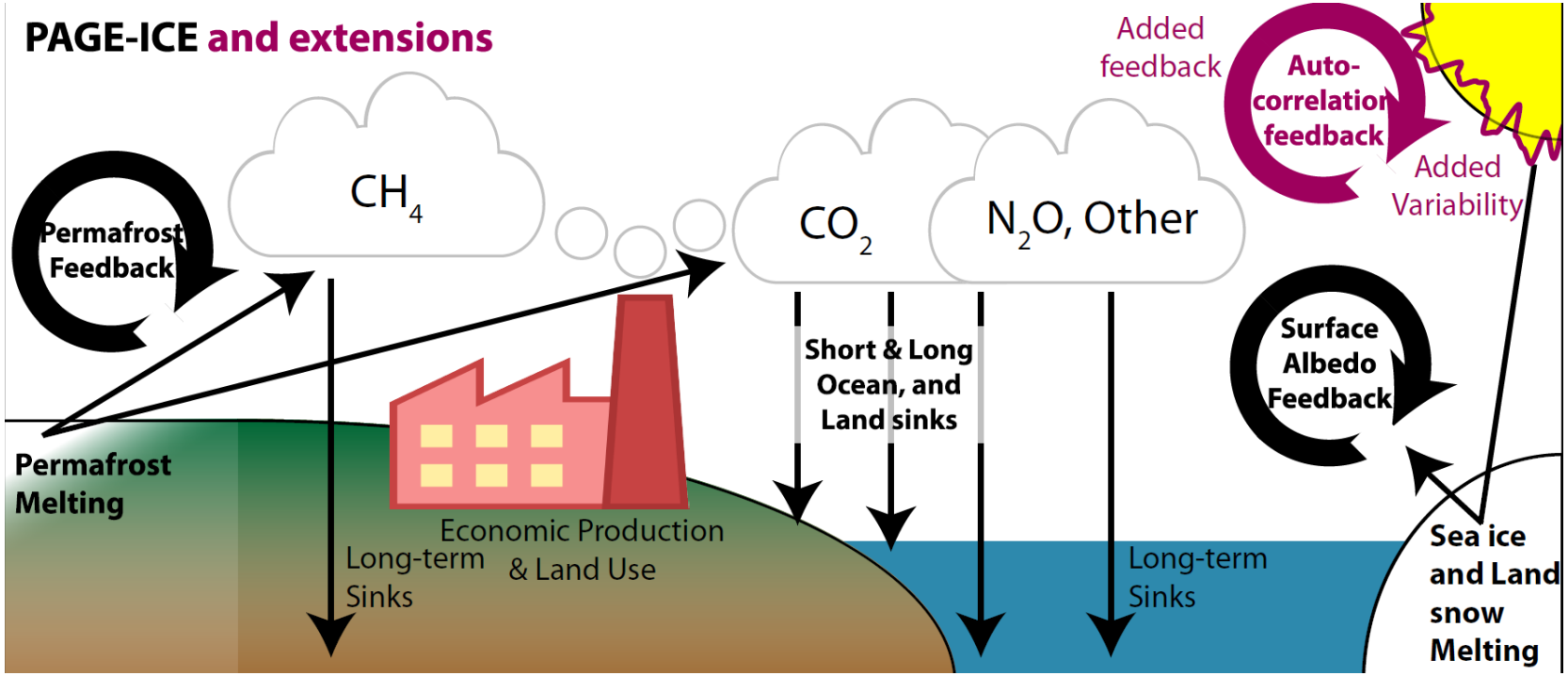
Citation Jarmo S Kikstra *et al* 2021 *Environ. Res. Lett.* **16** 094037

The setup for this study



Kikstra et al. (2021)
Environ. Res. Lett.
10.1088/1748-9326/ac1d0b.

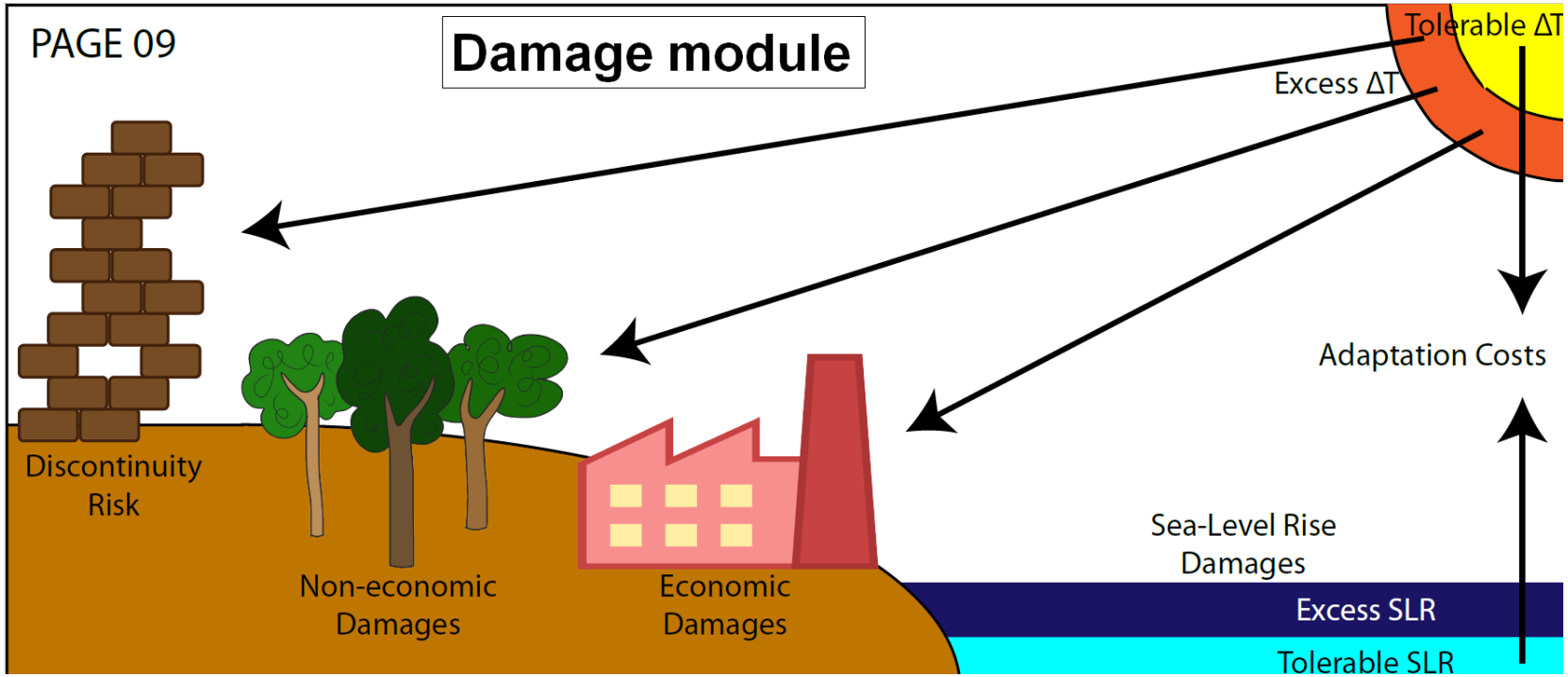
The setup for this study



Black: updates already in PAGE-ICE (Yumashev et al. 2019)
Purple: new elements introduced by Kikstra et al. 2021

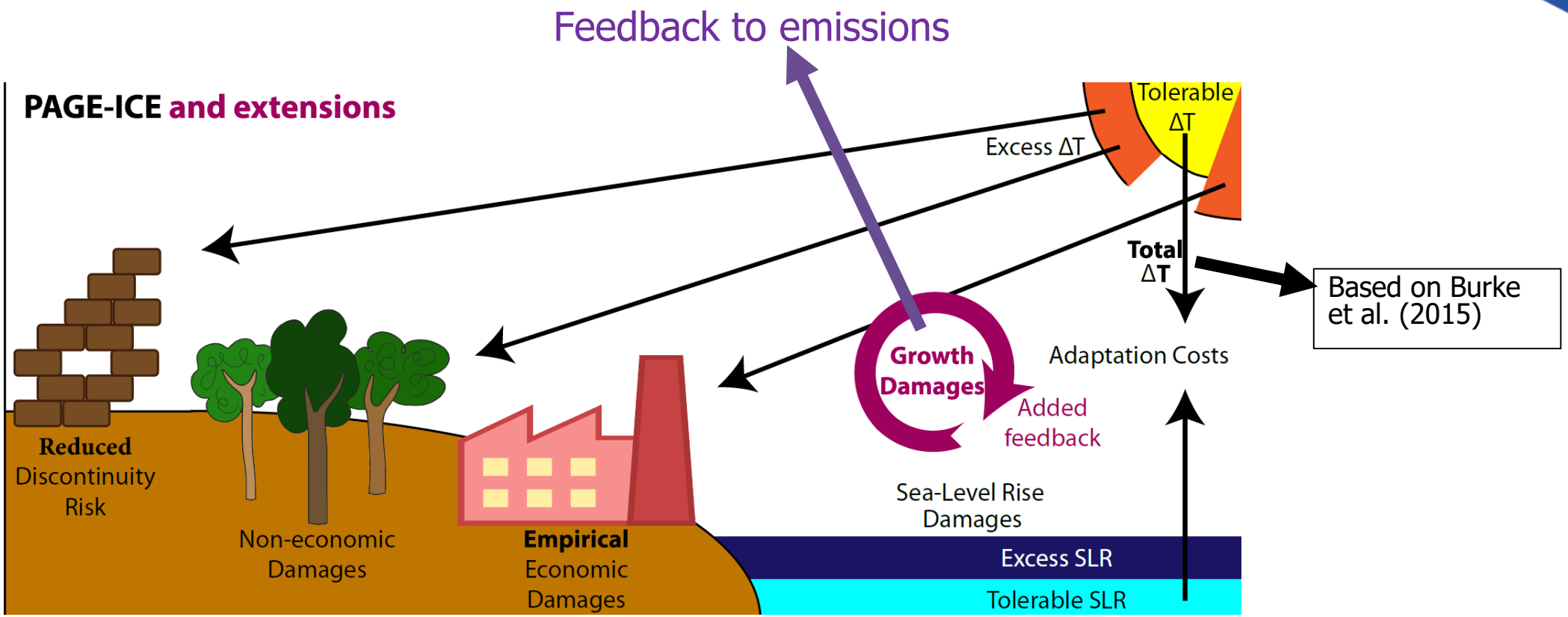
Kikstra et al. (2021)
Environ. Res. Lett.
10.1088/1748-9326/ac1d0b.

The setup for this study



Kikstra et al. (2021)
Environ. Res. Lett.
10.1088/1748-9326/ac1d0b.

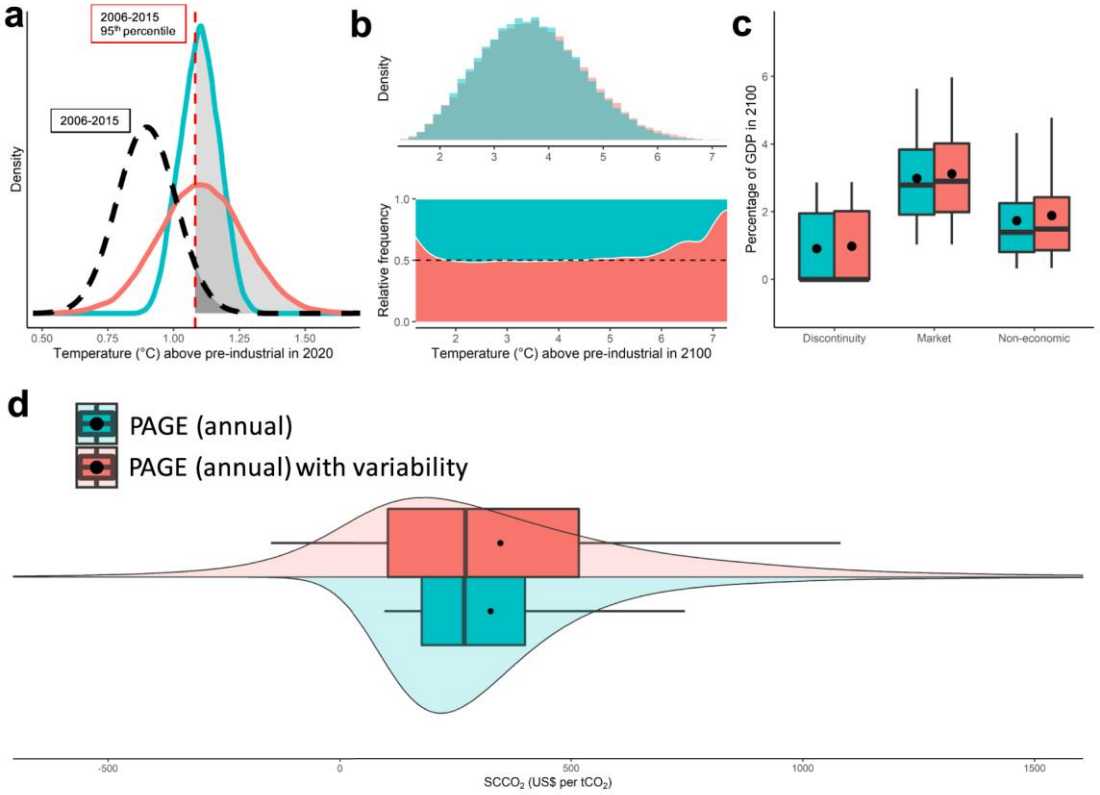
The setup for this study



Black: updates already in PAGE-ICE (Yumashev et al. 2019)
Purple: new elements introduced by Kikstra et al. 2021

Kikstra et al. (2021)
Environ. Res. Lett.
10.1088/1748-9326/ac1d0b.

A quick note on variability

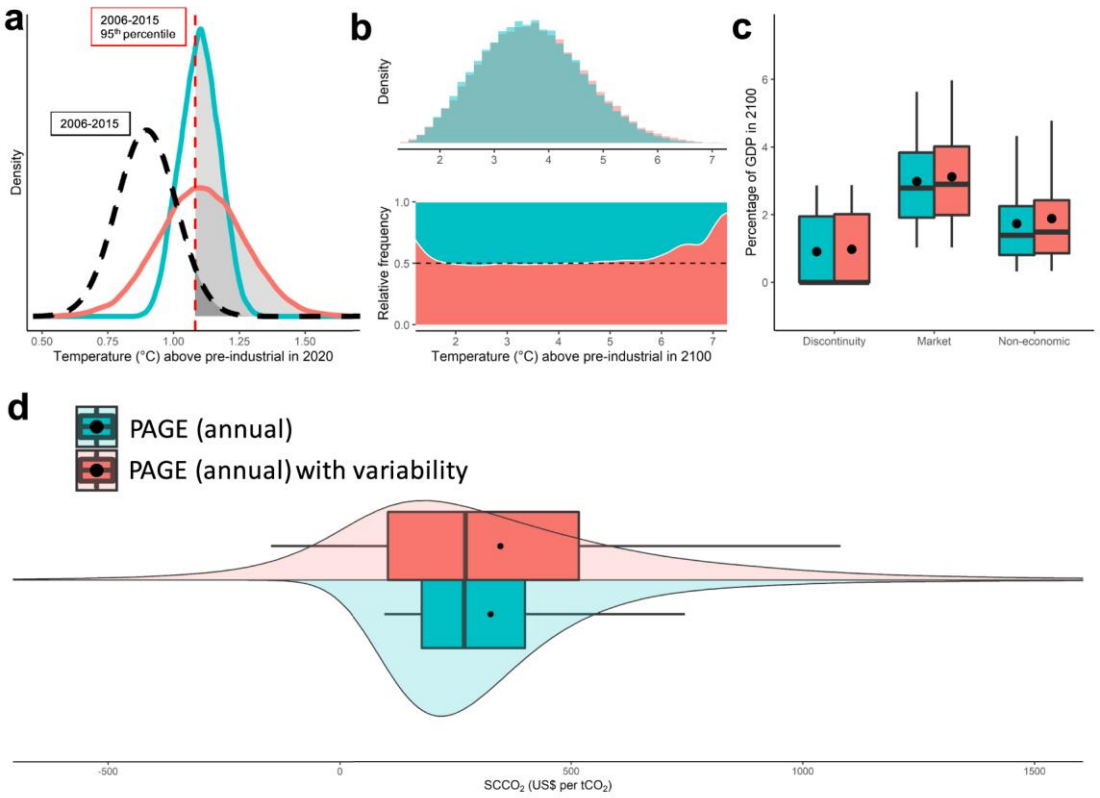


- More realistic/correct, especially in the near-term
- Small increase in mean
- Effects more in the tails

- N.B. Interannual temperature variability is not the same as extremes or day-to-day variability

Kikstra et al. (2021)
Environ. Res. Lett.
10.1088/1748-9326/ac1d0b.

A quick note on variability



- More realistic/correct, especially in the near-term
- Small increase in mean
- Effects more in the tails

- N.B. Interannual temperature variability is not the same as extremes or day-to-day variability

Note: all results in this presentation are for SSP2-4.5.
However, we have implemented more and GDP-emissions (SSP-RCP) combinations are quite easy to add now in Mimi-PAGE.

Kikstra et al. (2021)
Environ. Res. Lett.
10.1088/1748-9326/ac1d0b.

Estimating partial persistence

Simple growth effects model:

$$GDP_{r,t} = GDP_{r,t-1} \cdot (1 + \underbrace{g_{r,t}}_{\text{Growth rate}} - \underbrace{\rho}_{\textbf{Persistence parameter}} \cdot \underbrace{\gamma_{r,t-1}}_{\text{Contemporary economic damages}})$$

For *k* lags:

$$\rho = \frac{\sum_{j=0}^{k} \beta_{1,j} + 2\beta_{2,j} \cdot \text{Temperature}_{i,t}}{\beta_{1,0} + 2\beta_{2,0} \cdot \text{Temperature}_{i,t}}$$

Estimating partial persistence

Regression results:

- Limited statistical power, but **some significance on global level for first lag**
- Implied persistence: 52.8%

	GDPpc Growth	GDPpc Growth	GDPpc Growth	GDPpc Growth	GDPpc Growth	GDPpc Growth
Temperature	0.0127***	0.0136***	0.0106**	0.00 949**	0.00 933*	0.00 920*
	(3.36)	(3.64)	(3.00)	(2.65)	(2.49)	(2.50)
Temperature squared	−0.000 487***	−0.000 517***	−0.000 456***	−0.000 441***	−0.000 446***	−0.000 459***
	(−4.11)	(−4.33)	(−3.97)	(−3.75)	(−3.62)	(−3.87)
L.Temperature		−0.00 674	−0.00 413	−0.00 549	−0.00 578	−0.00 459
		(−1.56)	(−1.10)	(−1.35)	(−1.43)	(−1.36)
L2.Temperature			−0.00 613	−0.00 638	−0.00 681	−0.00 698
			(−1.63)	(−1.76)	(−1.86)	(−1.95)
L3.Temperature				−0.00 143	−0.000 885	−0.000 993
				(−0.57)	(−0.31)	(−0.38)
L4.Temperature					−0.00 111	−0.00 214
					(−0.42)	(−0.82)
L5.Temperature						0.00 176
						(0.37)
L.Temperature squared		0.000 244*	0.000 206	0.000 240	0.000 245	0.000 228*
		(2.01)	(1.81)	(1.95)	(1.97)	(2.03)
L2.Temperature squared			0.000 123	0.000 126	0.000 133	0.000 146
			(1.14)	(1.22)	(1.28)	(1.43)
L3.Temperature squared				−0.0000 509	−0.0000 779	−0.0000 882
				(−0.59)	(−0.78)	(−0.92)
L4.Temperature squared					0.000 101	0.000 143
					(1.01)	(1.35)
L5.Temperature squared						−0.0000 658
						(−0.43)
Resulting ρ	100%	52.81%	27.82%	28.36%	10.25%	20.81%
5th Monte Carlo percentile	—	0.55%	−73.40%	−101.57%	−143.72%	−94.44%
95th Monte Carlo percentile	—	91.34%	87.77%	106.52%	94.79%	93.10%
N	6584	6519	6398	6277	6155	6031
bic	−19 806.5	−19 677.9	−19 377.4	−19 125.8	−18 744.0	−18 400.4
ll	10 127.4	10 080.4	9942.9	9829.6	9655.6	9500.5

t statistics in parentheses. Standard errors are clustered at the country level.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

1 lag

More lags

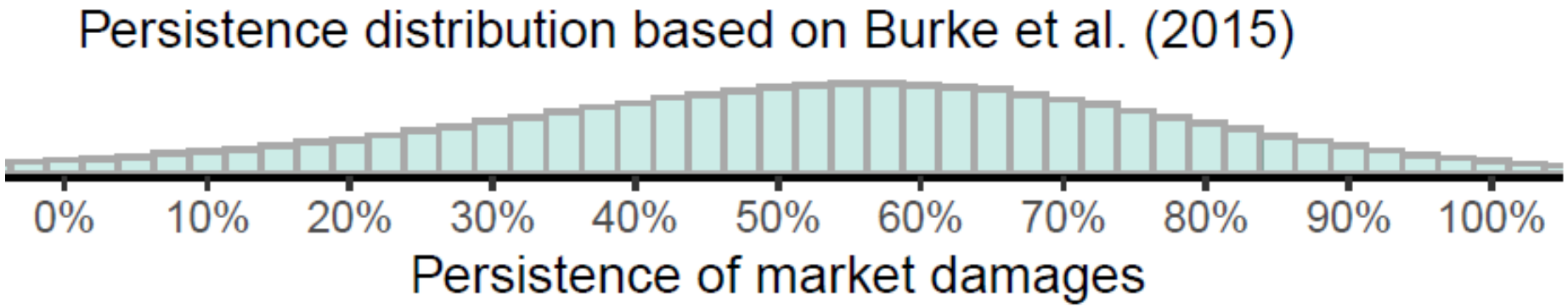
Linear effects

Quadratic effects

Estimating partial persistence

Regression results:

- Limited statistical power, but **some significance on global level for first lag**
- Implied persistence: 52.8%
- **Distribution of ρ estimate:**
  - ⇒ **mean 50.1% (34.5%–69.0%, interquartile range)**



Bastien-Olivera & Moore method

Notes:

- Increases statistical power, because it does not require estimating more and more lags
- Significance reaches until 3-yr filter (or 5-yr at p<0.10)
  ⇒ With this data, new method does not provide substantially different results
- (Coincidentally?) 10-yr filter pretty close to 1-lag ρ estimate

	(1) Unfiltered	(2) 3 year filter	(3) 5 year filter	(4) 10 year filter
Temperature	0.012 933***	0.012 211**	0.009 065	0.009 761
	(3.41)	(2.79)	(1.71)	(0.90)
Temperature^2	−0.000 490***	−0.000 436**	−0.000 299	−0.000 258
	(−4.11)	(−3.24)	(−1.88)	(−0.95)
Resulting ρ	100.00%	89.00%	61.09%	52.72%
5th percentile	—	69.33%	9.36%	−60.29%
95th percentile	—	102.40%	91.38%	118.25%
N	6535	6535	6535	6535
BIC	−19 634.1	−19 632.5	−19 620.8	−19 615.5
ll	10 045.5	10 040.3	10 034.4	10 031.8

t statistics in parentheses. Standard errors are clustered at the country level.
Percentiles are estimated via 5000 cluster bootstrap samples.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Author's calculations based on the data provided by Burke *et al* (2015).

Regional partial persistence

Poorer vs Richer regions (split following median GDP per capita):

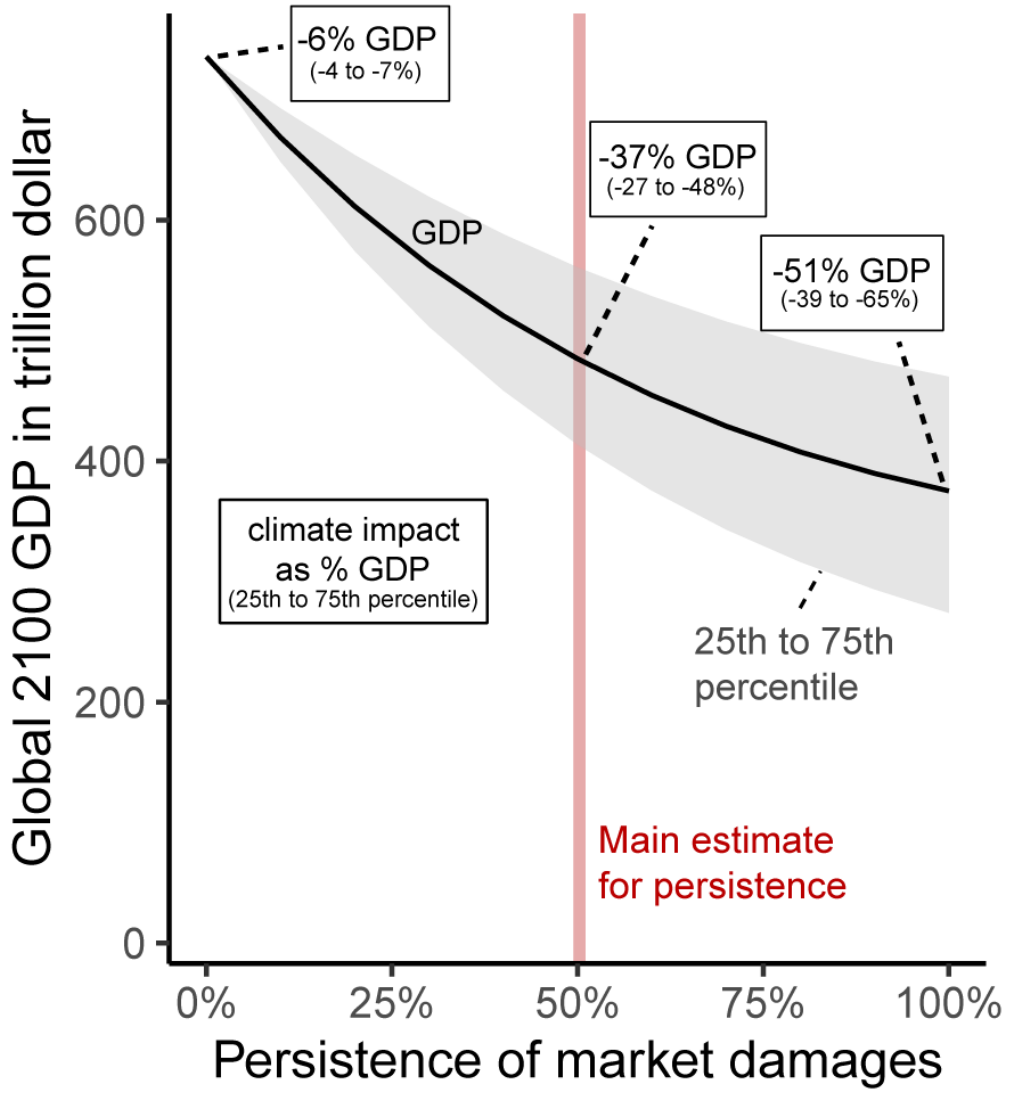
- **Uncertainty too large, no statistical significance on first lag.**

Indicative/Explorative results

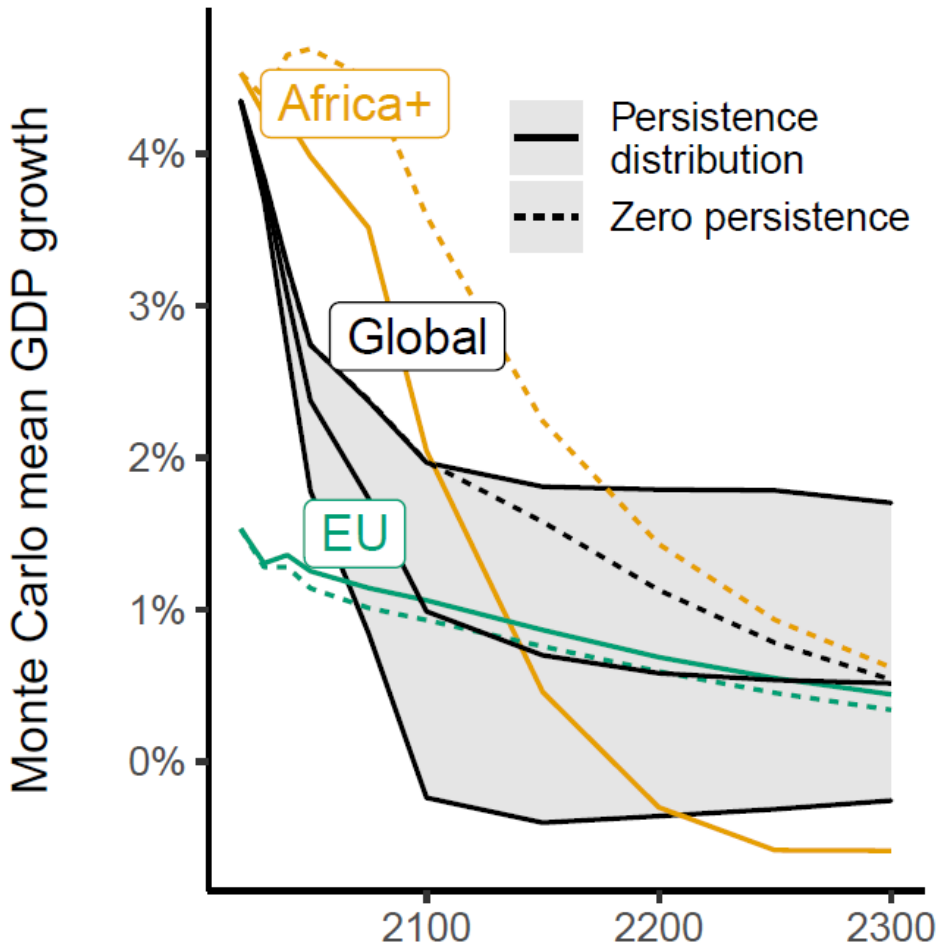
- Kikstra et al. method, first lag, counterintuitive:
  - ⇒ Richer: 62% (5th percentile: -96%; 95th percentile: 147%)
  - ⇒ Poorer: 42% (5th percentile: -147%; 95th percentile: 135%)
- Bastien-Olvera & Moore, 10-yr filter (3-yr filter), more intuitive:
  - ⇒ Richer: -3% (70%)
  - ⇒ Poorer: 108% (112%)

⇒ Needs more data or better methods.

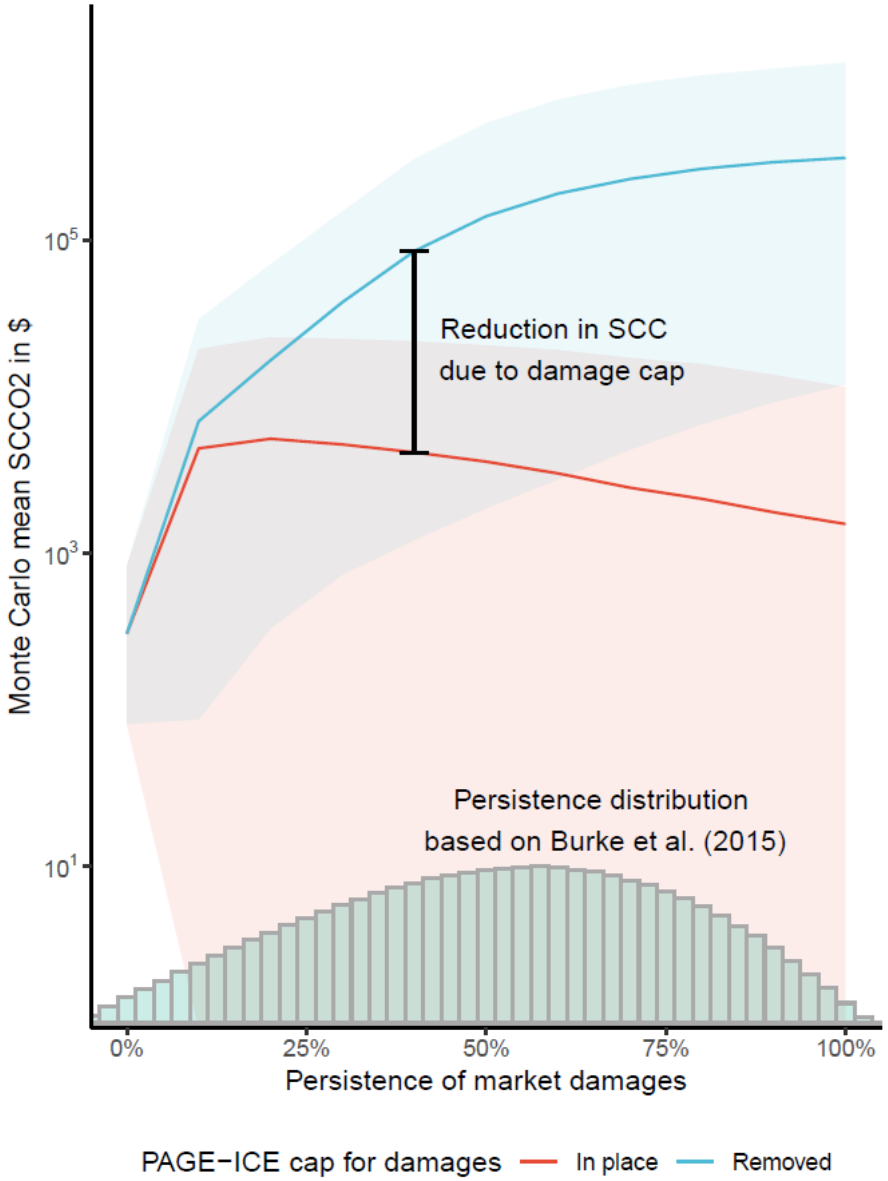
Global GDP in 2100

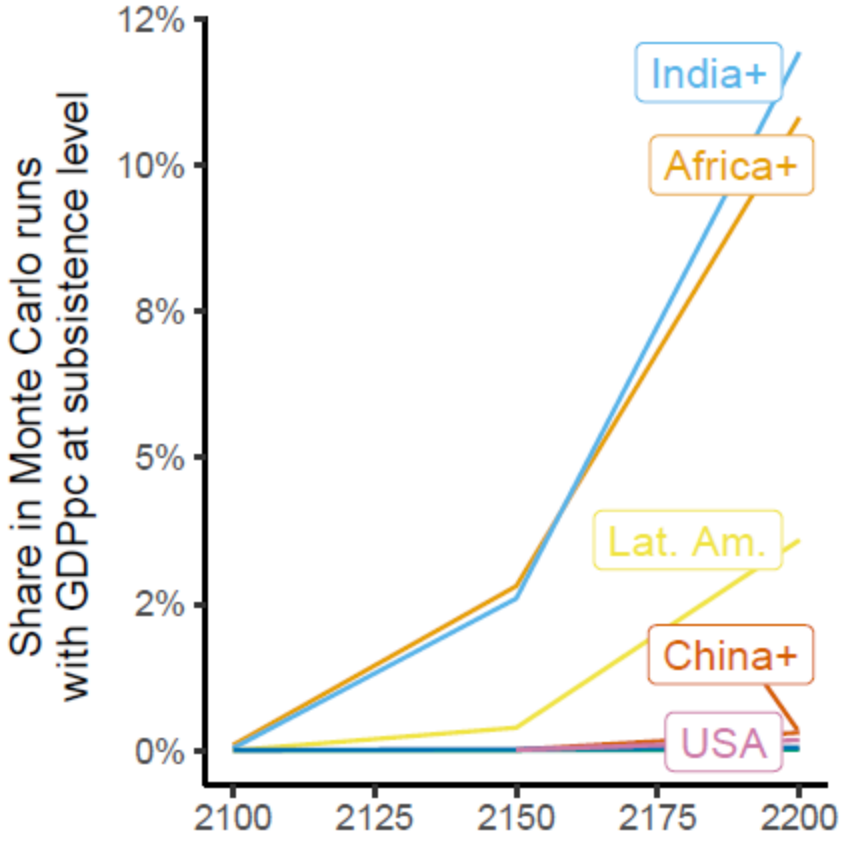


Regionally differentiated effects



Impacts so large that the SCC breaks





Post-2100, no market economy left in some regions

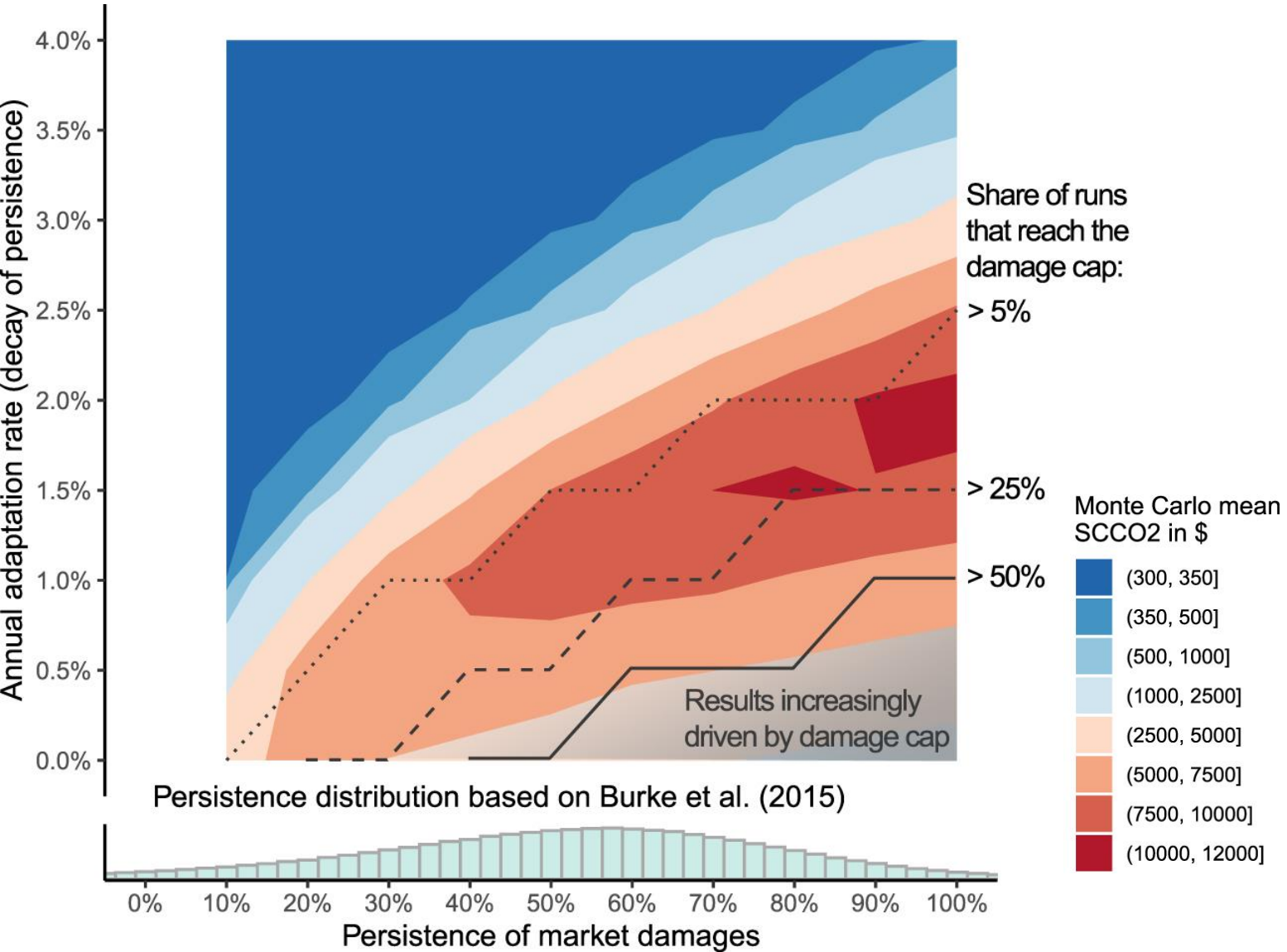
Some important caveats

- Interregional dynamics
- Potential future adaptation

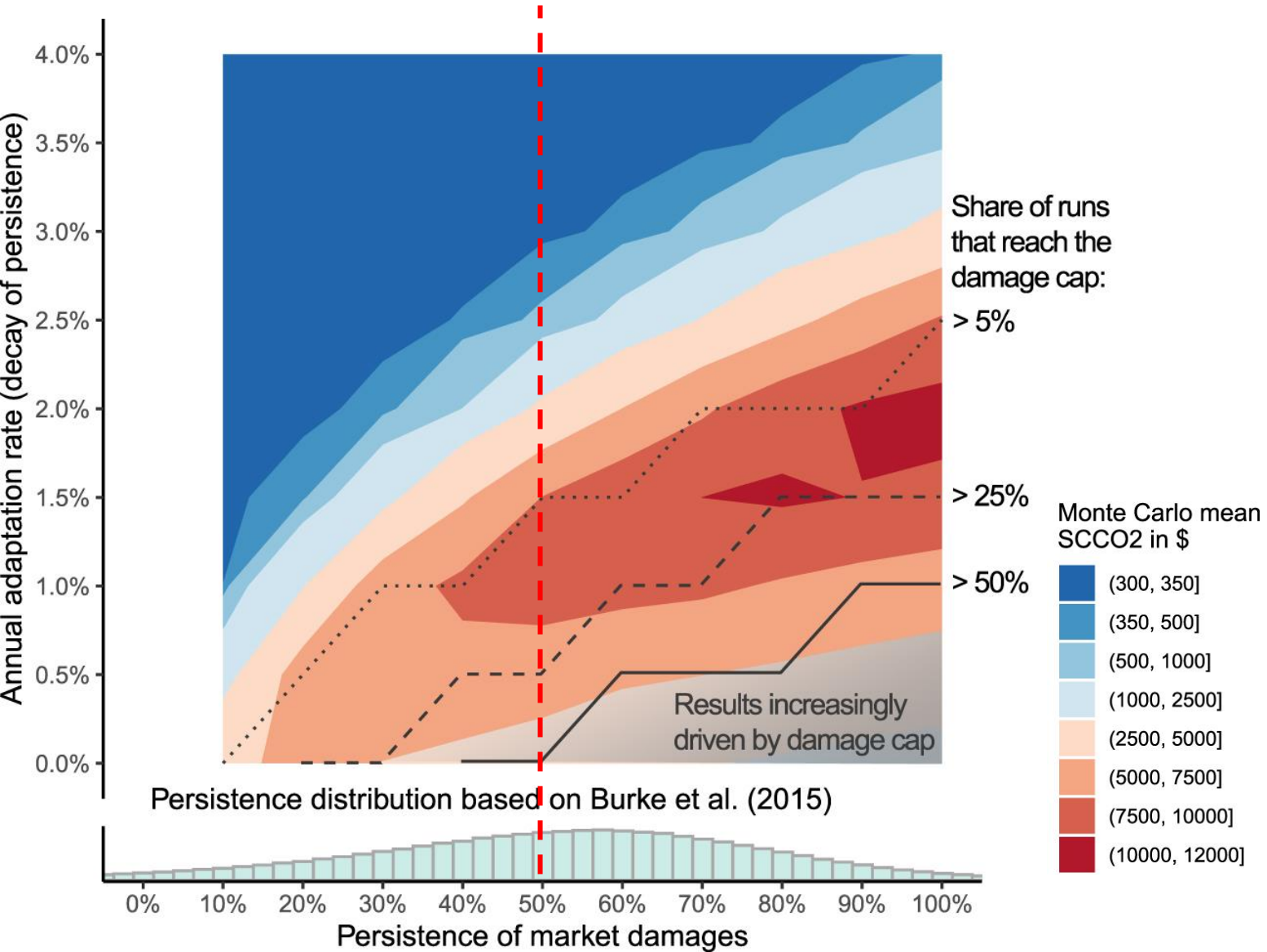
Some important caveats

- Interregional dynamics
- **Potential future adaptation**

Potential future adaptation

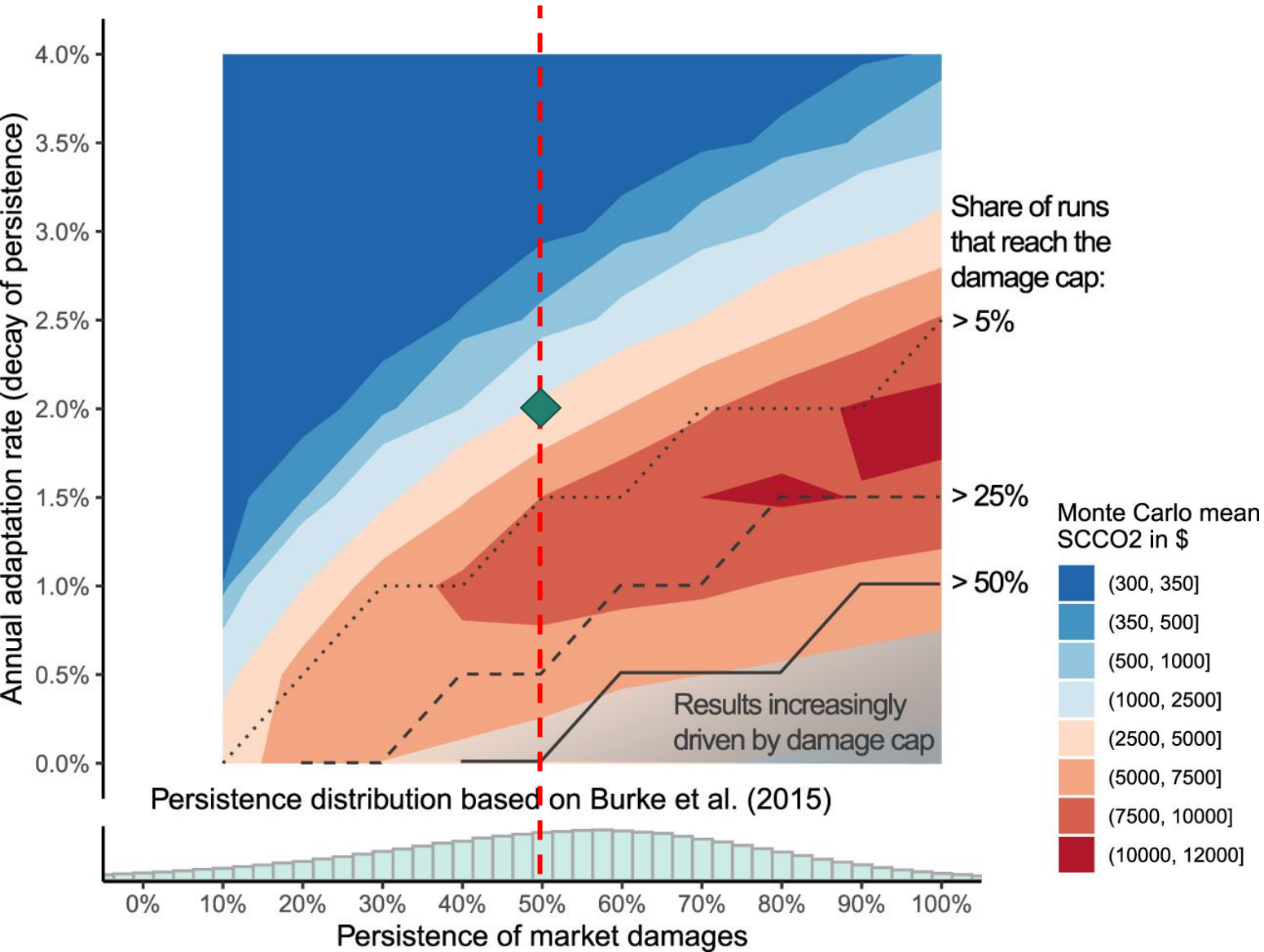


Potential future adaptation



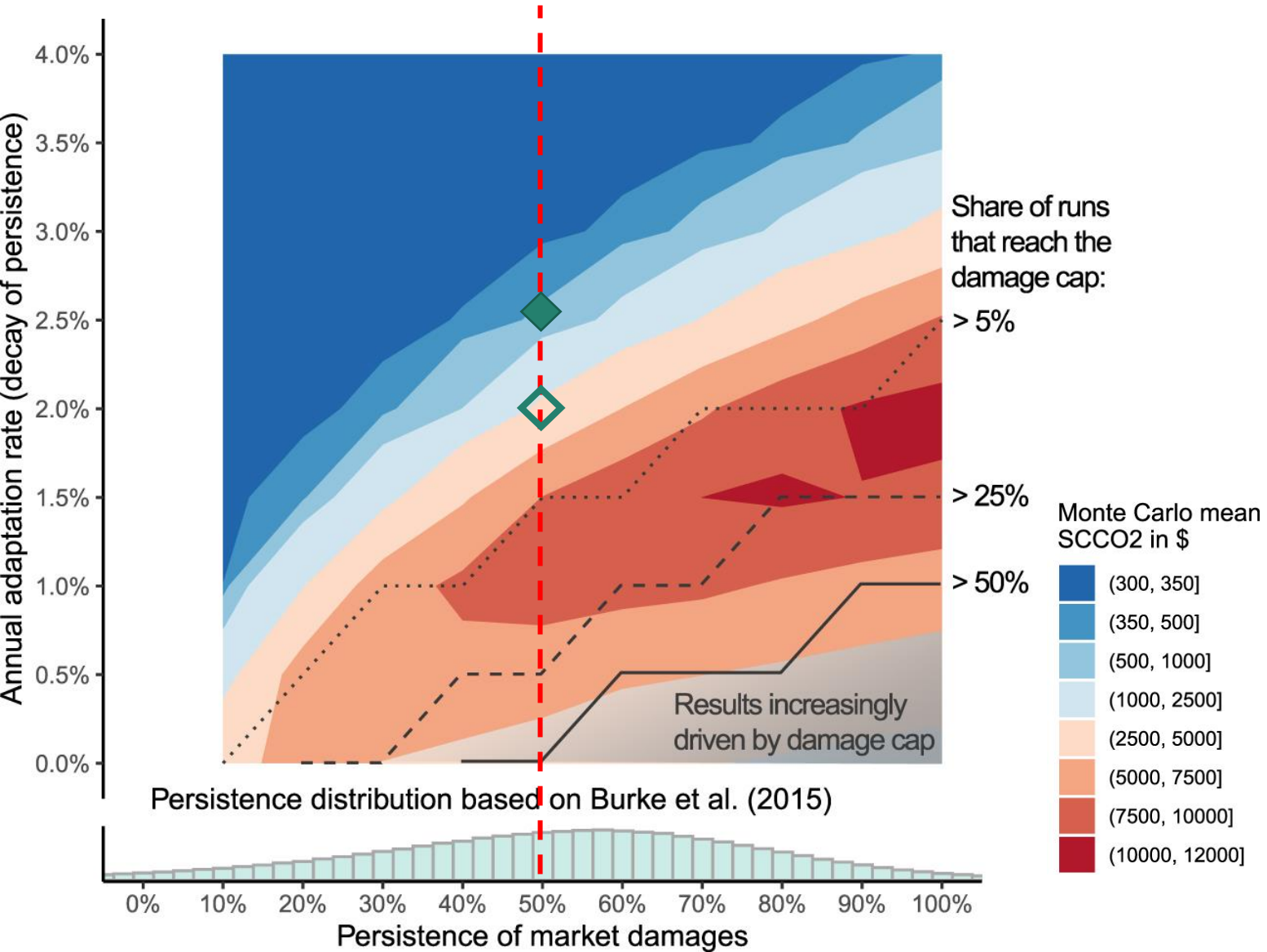
- For 50% persistence,

Potential future adaptation



- For 50% persistence,
  - ⇒ 2% per year
    SCC = $2500

Potential future adaptation



- For 50% persistence,
  - ⇒ 2% per year
    SCC = $2500
- For SCC < $600
  - ⇒ Need to halve persistence within less than 25 years

Looking at the future for modelling

- Better data, more data, and new empirical methods to try to better estimate persistence, across heterogeneous groups. But in the lack thereof…

- Modelling adaptive capacities
- Modelling international dynamics under diverging economic development
- Don’t use impact estimates based on zero persistence

- Pragmatic current approach: partial effects with *precautionary principle*, communicating using risk terminology?

Questions?

Jarmo Kikstra
kikstra@iiasa.ac.at

NAVIGATE/ENGAGE expert workshop
21 September 2021

Grantham Institute and *Centre for Environmental Policy*, **Imperial College London**
International Institute for Applied Systems Analysis (**IIASA**)