International Institute for Applied Systems Analysis
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Cross-sectoral ISIMIP and PROCLIAS Workshop

22-26 April 2024. PIK, Potsdam

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

PROCLIAS

IAMC Integrated Assessment Modeling Consortium Founded 2007

What do we mean by emulation

emulate
/ˈɛmjʊleɪt/

…
COMPUTING
reproduce the function or action of (a different computer, software system, etc.).

Why emulate?

You don't have access to the original models
You don't have the computing power, expertise or budget to run them
You need only a reduced form representation of the results
You need to do it orders of magnitude faster
You need flexibility to explore huge sample spaces and behaviours
…
You like to reduce lifetimes of careers and knowledge into a few equations
You want to irritate whole communities
Because you don't let perfect be the enemy of progress

Emulation of global mean temperature

CMIP6 Earth System Models

40 models, 49 modelling groups

IPCC WG3 climate emulators

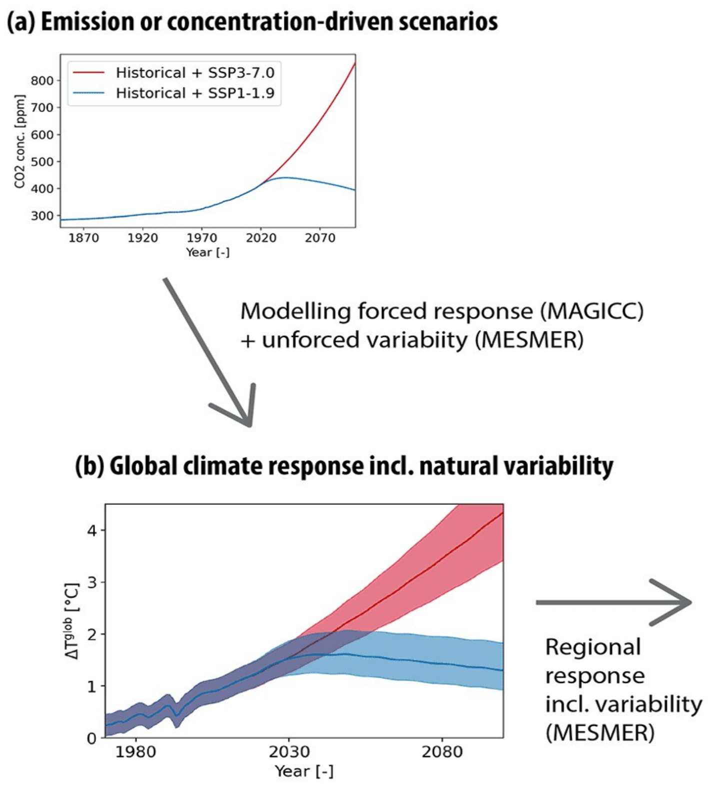
2 “simple climate models”: FaIR, and MAGICC, calibrated to the CMIP6 ScenarioMIP ensemble

Similar headline results, 5-50 billion times less computational

WCRP CMIP6
World Climate Research Programme

Emulators!

- **Simple Climate Models** (MAGICC, FaIR, OSCAR, HECTOR,…)
- Primarily aimed at emulating atmosphere, CO_2 ppm, radiative forcing and global temperature
- Limited spatial resolution, probabilistic, annual timeseries

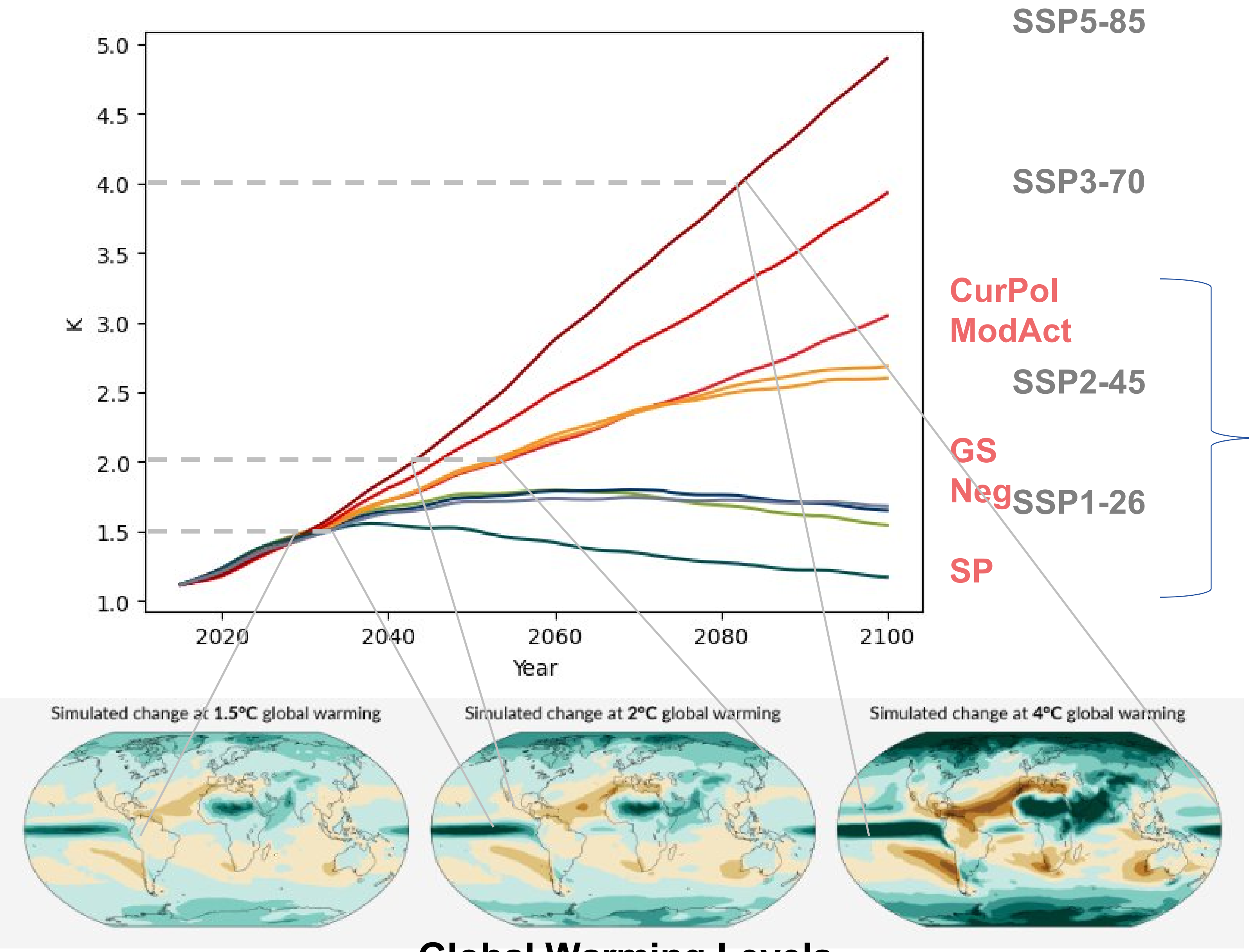


Beusch et al. 2022. GMD

Earth System emulators (MESMER, STITCHES, fldgen…, PRIME)
- Gridded climate variables, at annual or monthly resolution as timeseries with natural variability
- Temperature, precipitation, soil moisture, fire weather,…

More spatial climate emulator examples

	PRIME	MESMER	STITCHES	RIME
Variables	Large ESM variable set	Temperature, precip, FWI, sm	Full ESM variable set (T, P, RH, Wind…)	Any indicator by GWL
Time	Annual & monthly	Annual & monthly	Annual, monthly, day	Annual
Variability	Yes	Yes	Yes	No
Mode	Probabilistic	Probabilistic	Probabilistic	Deterministic climate pcts, SSPs
Runtime	~1 day	minutes	minutes, per ESM	seconds
Strengths	Land-climate complexity, multivariate	Speed, uncertainty	Multivariate	Simplicity, wide indicator set
Reference	Mathison et al. (preprint)	Beusch et al. 2020	Tebaldi et al. 2022	Byers et al. (in prep.)



Global Warming Levels

Break free from the RCP-SSPs?

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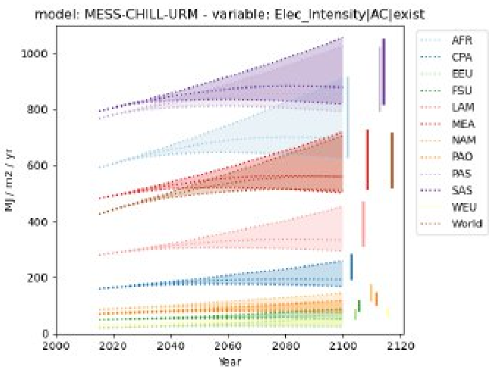
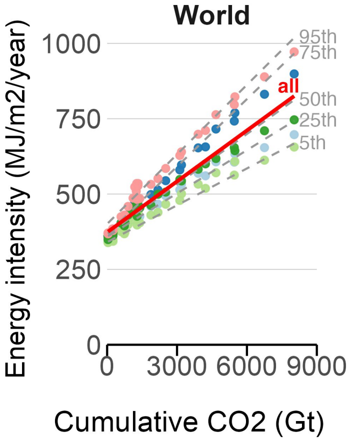
Cooling energy impact model emulation

Applied to **CHILLED-STURM-MESSAGEix**

CHILLED



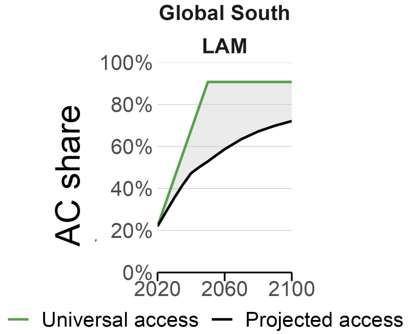


3 SSPs x 5 GCMs
= 15 pathways

+

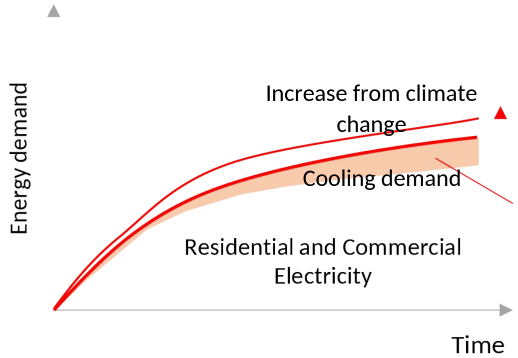
STURM

Scenario-specific building stock characteristics, AC access, and behaviour of building occupants



MESSAGEix

Adjust electricity demand of different carbon mitigation scenarios



From days to seconds

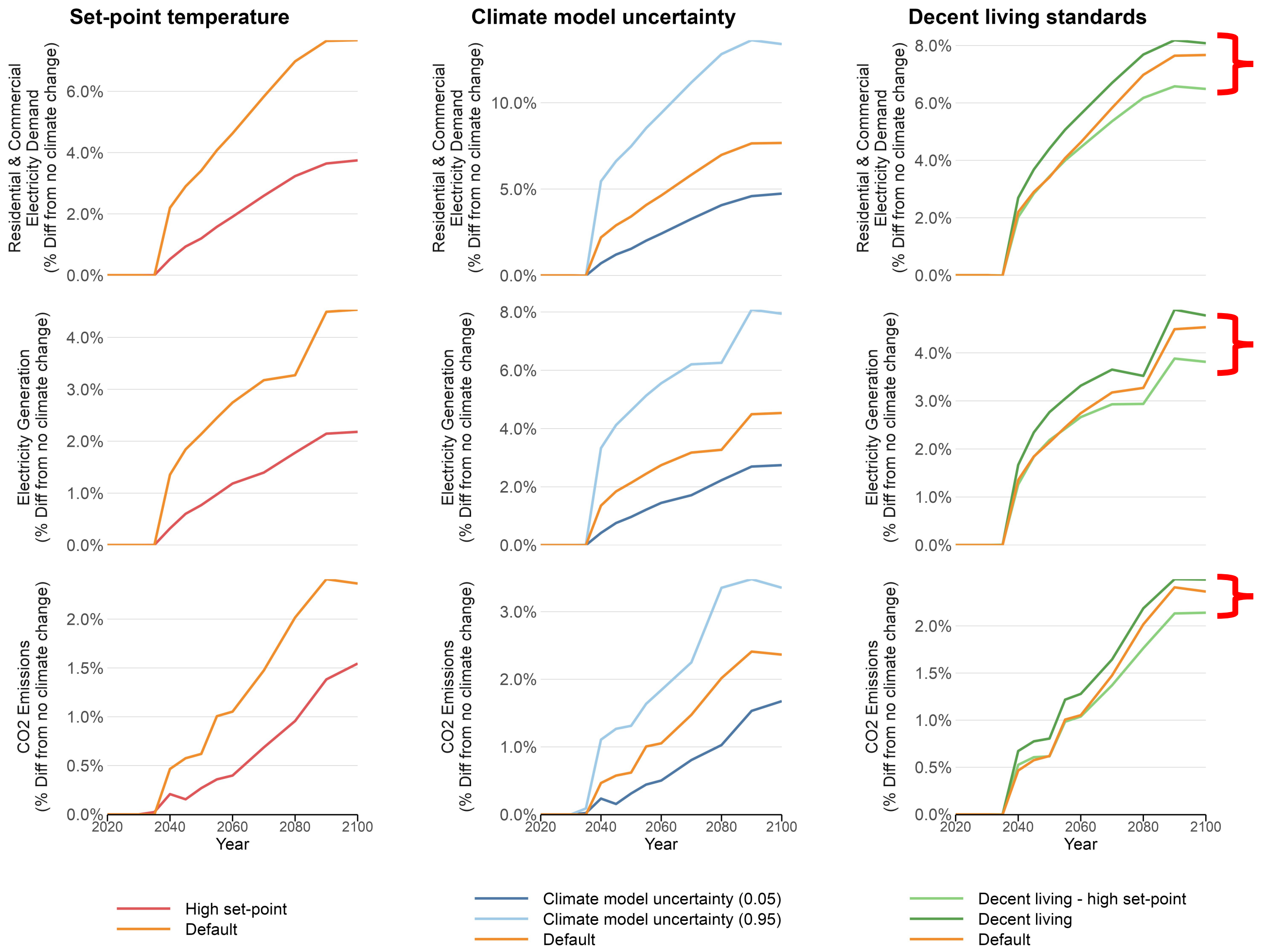
Endogenize climate impacts in IAM

Emissions scenario flexibility

Byers et al. in review

Dynamics between decent living standards and set point temperature

Global results under Current Policy scenario

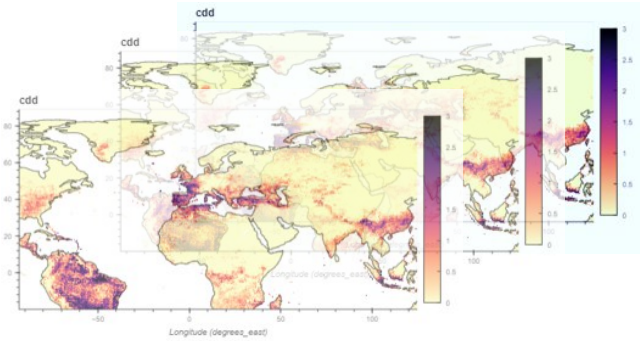


Reductions from higher set-point temperature more than offset the additional energy required by providing DL access under the current policy scenario.

Rapid emulation of long-term climate impacts & risk indicators

More impacts
Temp & Precip. extremes, drought, CDD, hydrology, crop yield potentials, fire weather, …

RIME
RAPID IMPACT MODEL EMULATOR



SSP and model uncertainties
- Climate-Impact model quantiles
- SSPs for population exposure & vulnerability

IAMC
Integrated Assessment Modeling Consortium
Founded 2007

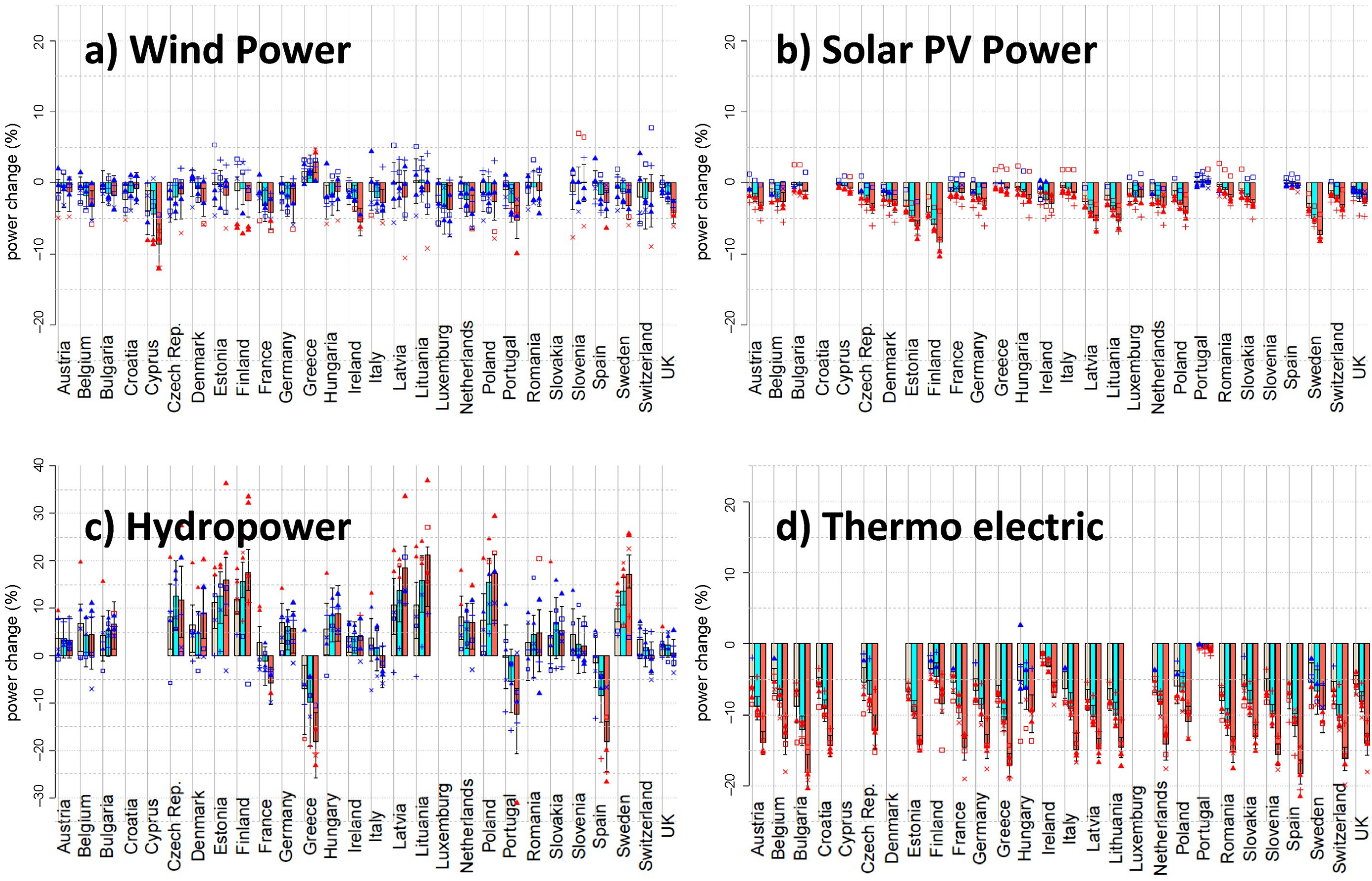
ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

Community friendly
Designed for ISIMIP & IAM inter-operability and inter-comparison

Simple Global Warming Level approaches for rapid assessment of climate hazard exposure

New scenario possibilities: chronic impacts

- Deterministic long-term energy projections
- Cooling demand change with climate change based on CDDs or more complex models – rapid emulation of new scenarios, endogenization into IAMs
- Representation of <u>chronic impacts and long term averages</u>:
  - Temperature-based demands – heating, cooling, CDD & HDDs,
  - Capacity factors and resource potentials – wind & solar, water resources, water temperatures, hydropower



Tobin et al. 2018 Vulnerabilities and resilience of European power generation to 1.5 °C, 2 °C and 3 °C warming

New scenario possibilities: acute impacts

Probabilistic extreme event simulation – 100s or 1000s of climate samples

TXx, TNn, etc - ☾ monthly/annual peak temperatures and impacts on

- Peak electricity demands
- Transmission capacities
- Storage and VRE integration

Tas, Precip, Wind, PET, as multivariate inputs into

- Region-scale hydrological and water-resource models
- Probabilistic capacity expansion modelling

ELSEVIER

Applied Energy
Volume 276, 15 October 2020, 115541

Compound hydrometeorological extremes across multiple timescales drive volatility in California electricity market prices and emissions

Yufei Su [a b], Jordan D. Kern [c], Patrick M. Reed [d], Gregory W. Characklis [a b]

LETTER • OPEN ACCESS

Impacts of rising air temperatures on electric transmission ampacity and peak electricity load in the United States

Matthew Bartos[4,1], Mikhail Chester[1], Nathan Johnson[2], Brandon Gorman[1], Daniel Eisenberg[1,3], Igor Linkov[3] and Matthew Bates[3]

Published 2 November 2016 • © 2016 IOP Publishing Ltd

Environmental Research Letters, Volume 11, Number 11

Effects of Climate Change on Capacity Expansion Decisions of an Electricity Generation Fleet in the Southeast U.S.

Francisco Ralston Fonseca*, Michael Craig, Paulina Jaramillo, Mario Bergés, Edson Severnini, Aviva Loew, Haibo Zhai, Yifan Cheng, Bart Nijssen, Nathalie Voisin, and John Yearsley

Cite this: *Environ. Sci. Technol.* 2021, 55, 4, 2522– Article Views Altmetric Citations Share Add to Exp

Balancing-oriented hydropower operation makes the clean energy transition more affordable and simultaneously boosts water security

Zhanwei Liu & Xiaogang He

Nature Water 1, 778–789 (2023) | Cite this article

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SPARCCLE

Thank you.

LIAS
shop
dam

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

PROCLIAS

IAMC Integrated Assessment Modeling Consortium Founded 2007

RIME RAPID IMPACT MODEL EMULATOR

ENGAGE FEASIBILITY OF CLIMATE PATHWAYS

CHILLED linear response functions

- Ensemble:
- 5 ISIMIP3b GCMs
- 3 CMIP6 SSP-RCP pathways: Baseline + SSP1-26, SSP3-70, SSP5-85