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Challenges and opportunities of an integrated perspective on impacts, adaptation and mitigation

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Thanks to Marina Andrijevic, Edwards Byers, Shinichiro Fujimori, Jarmo Kikstra, Adriano Vinca

Acknowledged support

IAMC Integrated Assessment Modeling Consortium Founded 2007

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

PROCLIAS

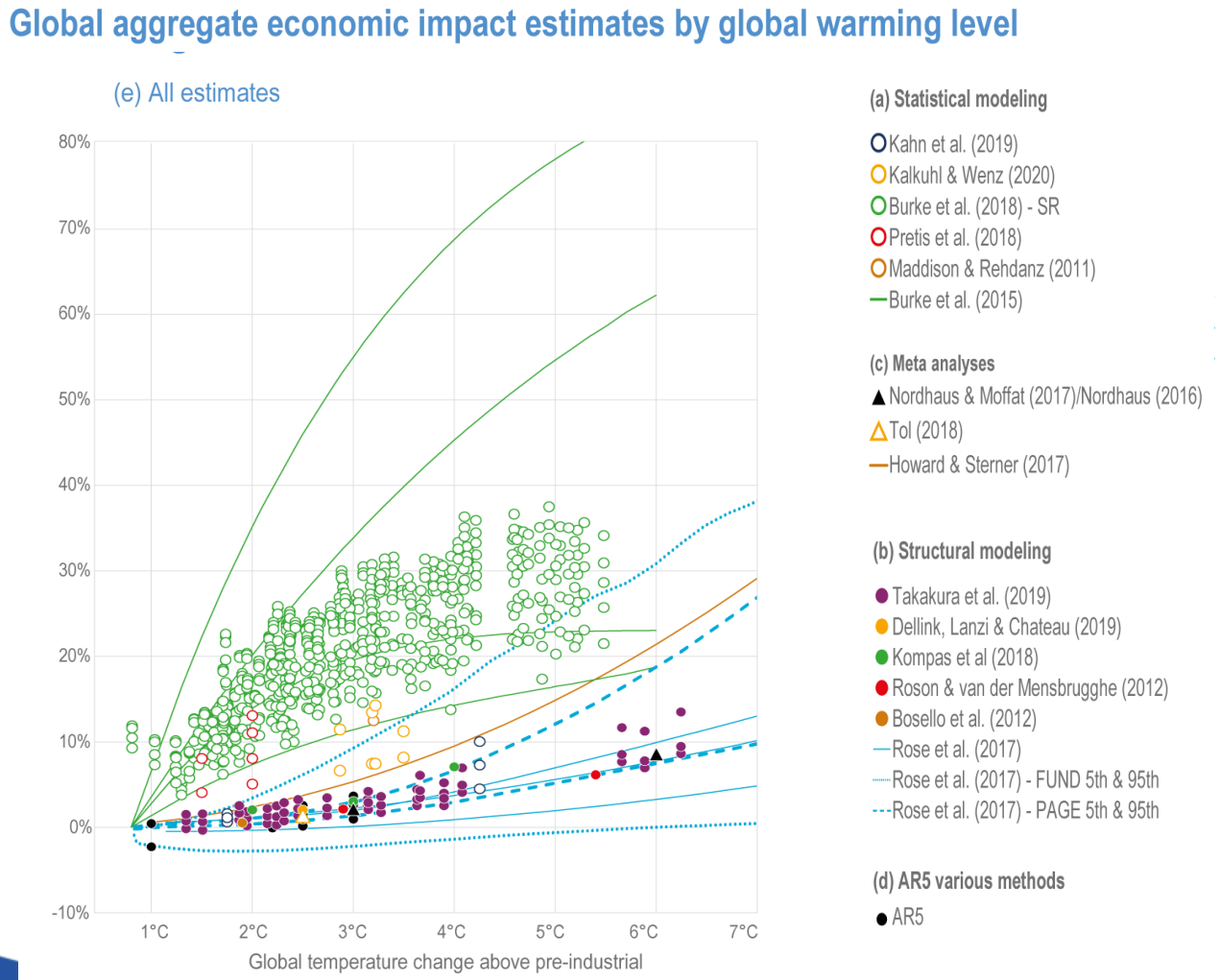
Towards achieving a better integration of adaptation, migration and impacts

- Improved understanding of the risks of climate impacts (thanks to ISIMIP et al!)
- Increasing recognition that impacts, adaptation and vulnerabilities need to be reflected in mitigation scenarios

However:

- Impacts are often calculated for different sectors and for specific temperature thresholds with limited consideration of socioeconomic dynamics (and change)
- Mitigation pathways rarely consider impacts or adaptation (eg, SSPs)
- Current tools make it difficult to portray a consistent picture of how mitigation and adaptation interact
- Need to find a bridge to close the gap between the communities

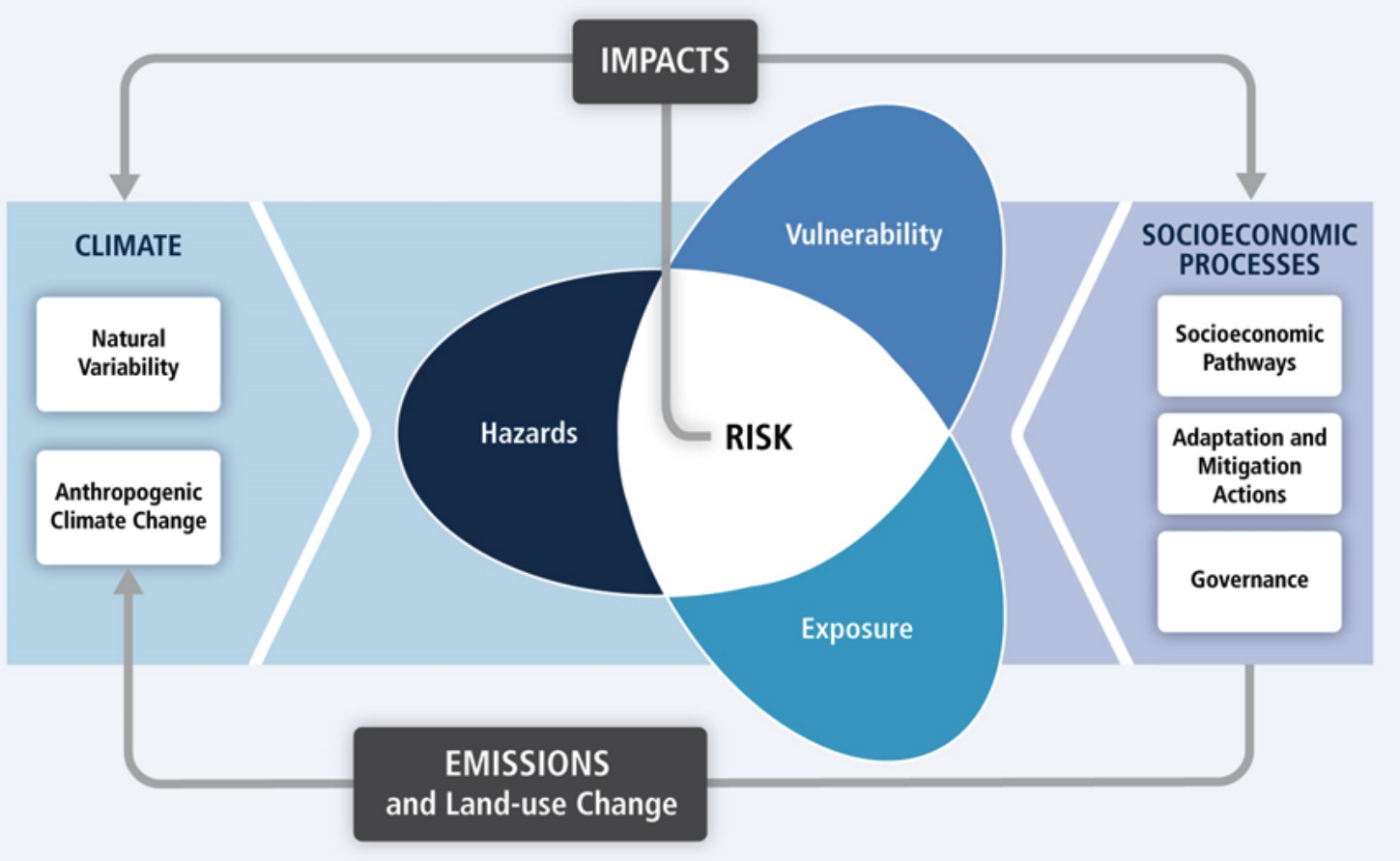
For the first time the IPCC AR6 concludes that avoided impacts of 2C are paying off economically



WGIII SPM: (based on WGII-WGIII cross-cut)

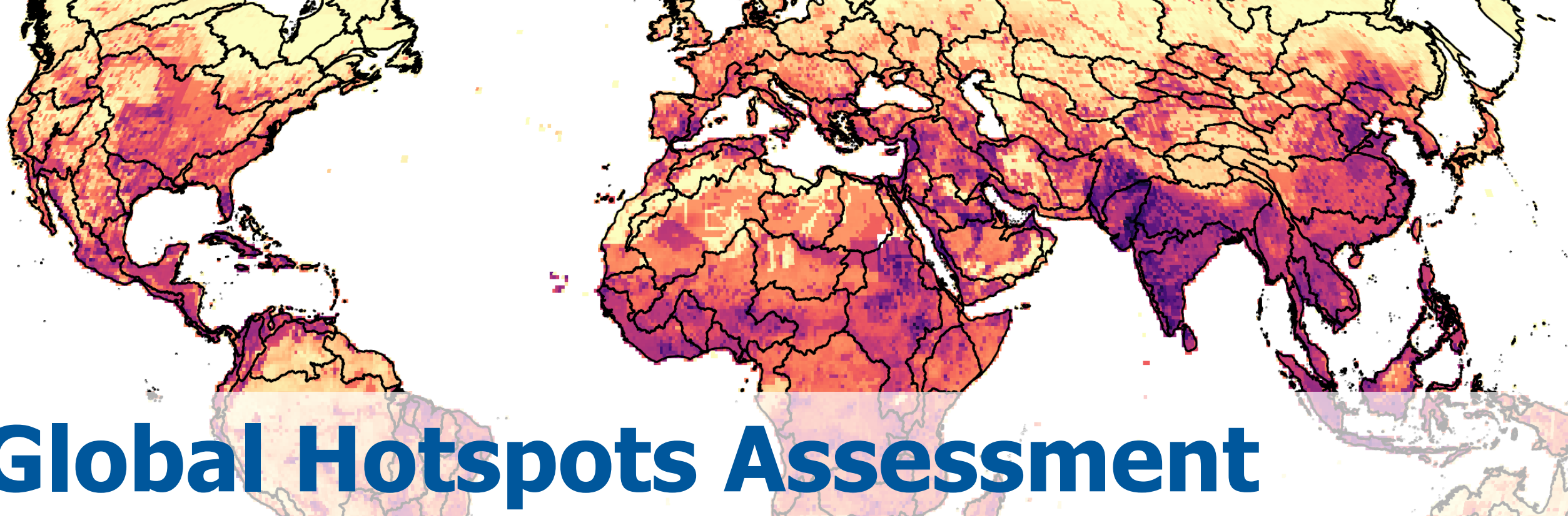
Models that incorporate the economic damages from climate change find that the global cost of limiting warming to 2°C over the 21st century is lower than the global economic benefits of reducing warming, unless: (i) climate damages are towards the low end of the range; or, (ii) future damages are discounted at high rates (medium confidence).

Comprehensive assessments of climate risks along all three sides of the propeller needed



New innovations:

- Hazards (e.g., new emulators),
- Exposure (e.g., granular socio-economic data, machine learning, satellite imagery),
- Vulnerability (e.g., scenario-resolved adaptive capacity)



Global Hotspots Assessment

ISWEL Project
Byers et al, 2018

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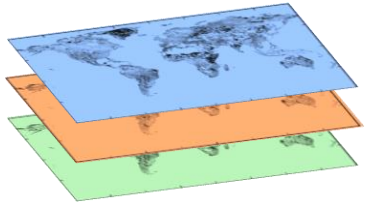
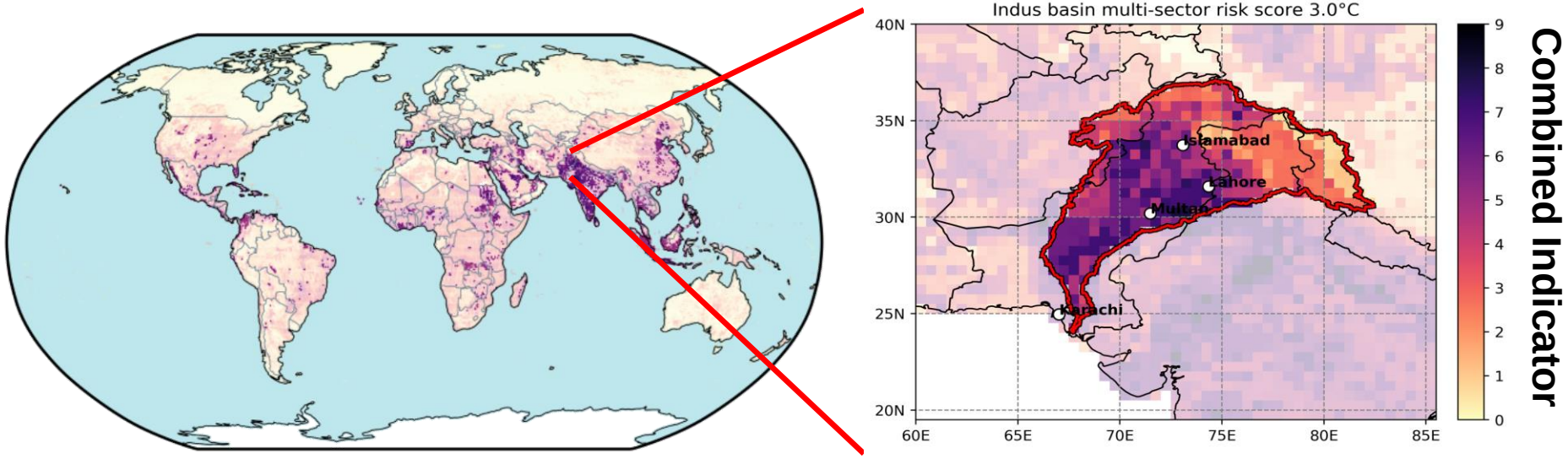
UNIDO

Global analysis of multi-sector hotspots



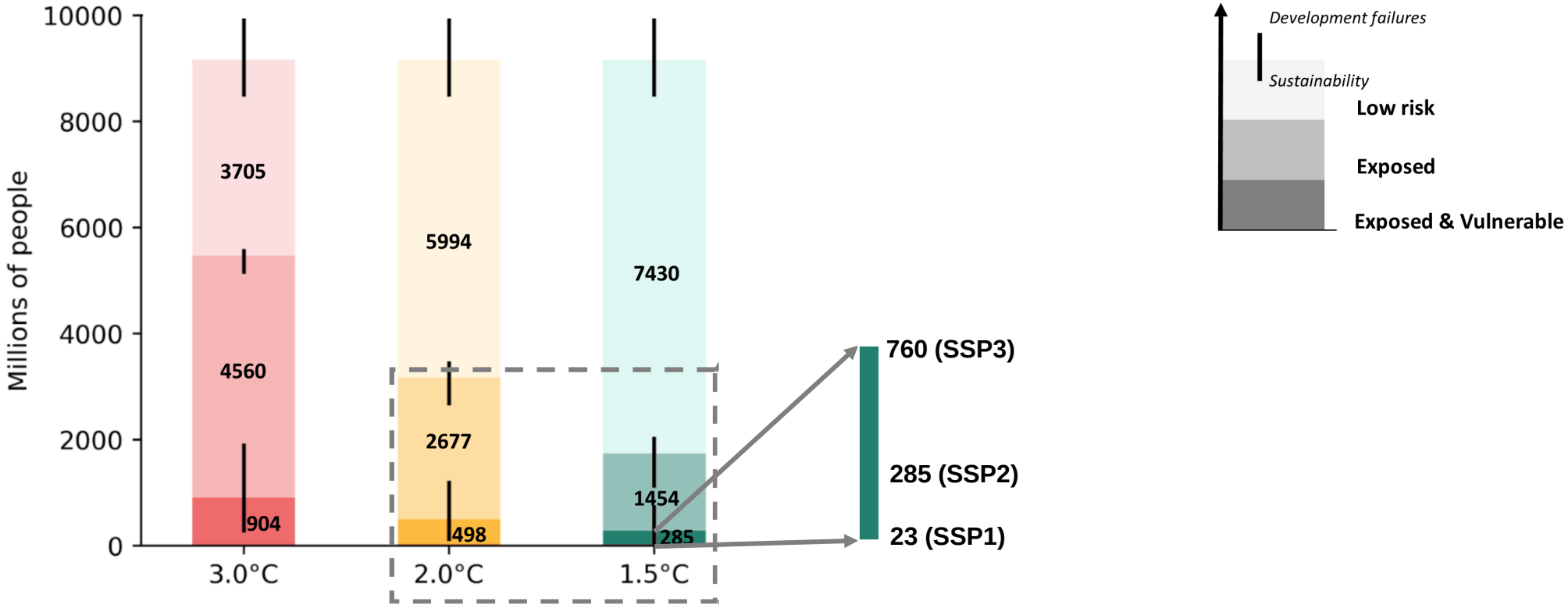


- **3 socioeconomic scenarios** – SSPs 1, 2 & 3
- **3 climate change scenarios** – 1.5, 2.0 and 3.0° C

Water	***Energy***	***Land***	***$ Socioeconomics***
Water stress index	Clean cooking access	Crop yield change	Population density
Non-renewable GW abstraction	Heat event exposure	Environmental flow exploitation	Income levels
Drought intensity	Cooling demand growth	Habitat degradation	
Peak flows risk	Hydroclimate risk to power	Nitrogen leaching	
Seasonality			
Inter-annual variability			

Byers et al. (2018, ERL)

People at risk of multisectoral hot-spots



But GMT & SSP scenario uncertainties are considerable…
and vary from place to place

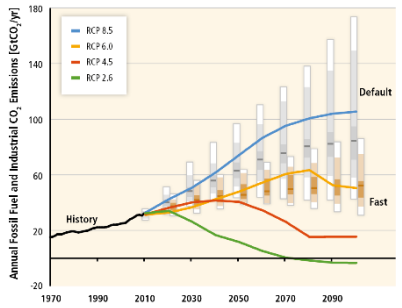
Byers et al. (2018, Environmental Research Letters)

Typical IAM framework

Emission scenario

Socioeconomic scenario

RCP

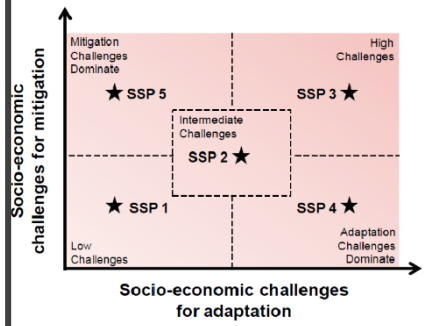


Climate change

RCP8.5
RCP6.0
RCP4.5
RCP2.6

2°C

SSP



SSP1: Sustainability
SSP2: Middle of the Road
SSP3: Reginal Rivalry
SSP4: Inequality
SSP5: Fossil-fueled Development

GHG emissions constraint

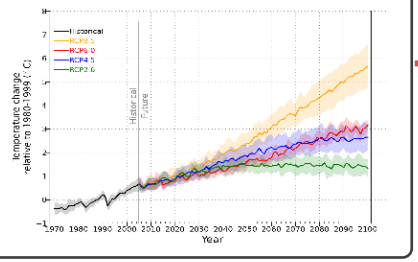
GHG concentration

Socioeconomic assumptions

Gridded population and so on

Climate model

Climate



Crop model

Crop yield

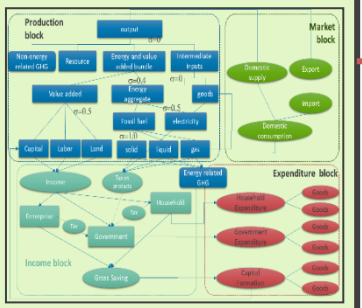
Water model

Water resource

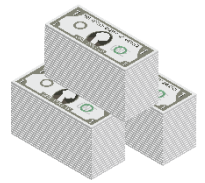
Health model

Number of Death

IAM (AIM/CGE)



GDP

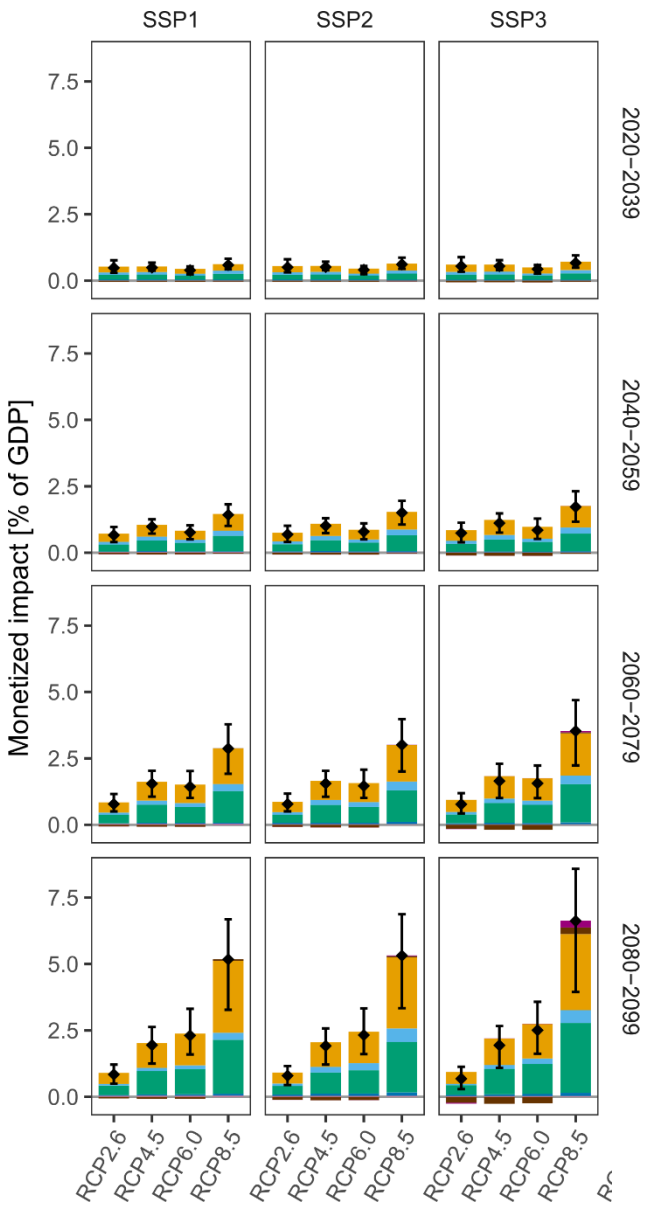


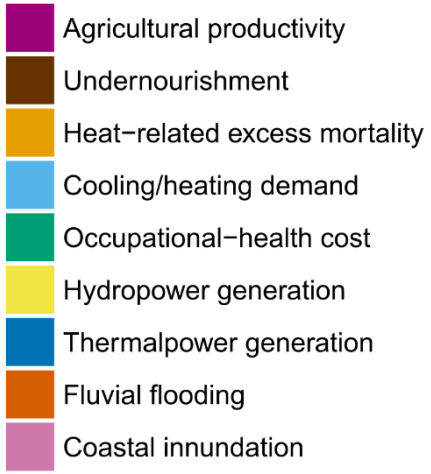
Climate impact for each sector

Total climate loss

AIM model: Fujimori, Hasegawa et al

Example outcome: monetized impact of different sector





CAVEATS:

- Monetization implies value judgements, hence need to presented together with social and physical impacts
- Some impacts are incomparable because of different
- methodologies,
- small economic impact does not necessarily mean it is not important.

AIM model: Fujimori, Hasegawa et al

Multiple sectors and multiple policy objectives
(Vinca et al, forthcoming)

Climate policy

2.6 W/m^2 target

SDG measures

Food	Heathy (EAT-Lancet) diet, reduce food waste
Water	Efficiency improvements, environmental flow constraints, piped water access, wastewater treatment
Energy	Maximized electrification, RE, energy access cooling gap
Life on land	Protected natural land (>30%)

Based on: Doelman et al. 2022, MESSAGE-ACCESS, Van Vuuren et al., 2019, Parkinson et al., 2019, Frank et al., 2021, Hasegawa et al., 2015, Pastor et al., 2019

Climate impacts
RCP 2.6, 6.0

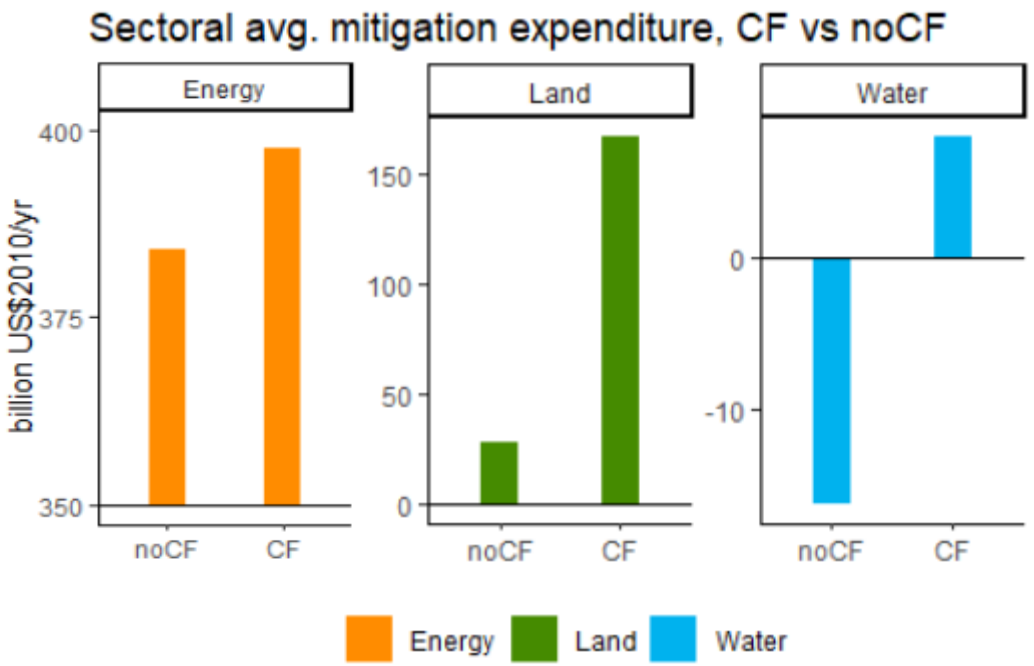
- Hydrology: Precipitation pattern/runoff, groundwater intensity
- Crop Yield changes
- Renewable energy
- Cooling/heating demand
- Desalination potential
- Power plant cooling capacity

Based on: *ISIMIP 2b (Frieler et al. 2017),Byers et al., 2018, Gernaat et al., 2021 etc.)*

NAVIGATE

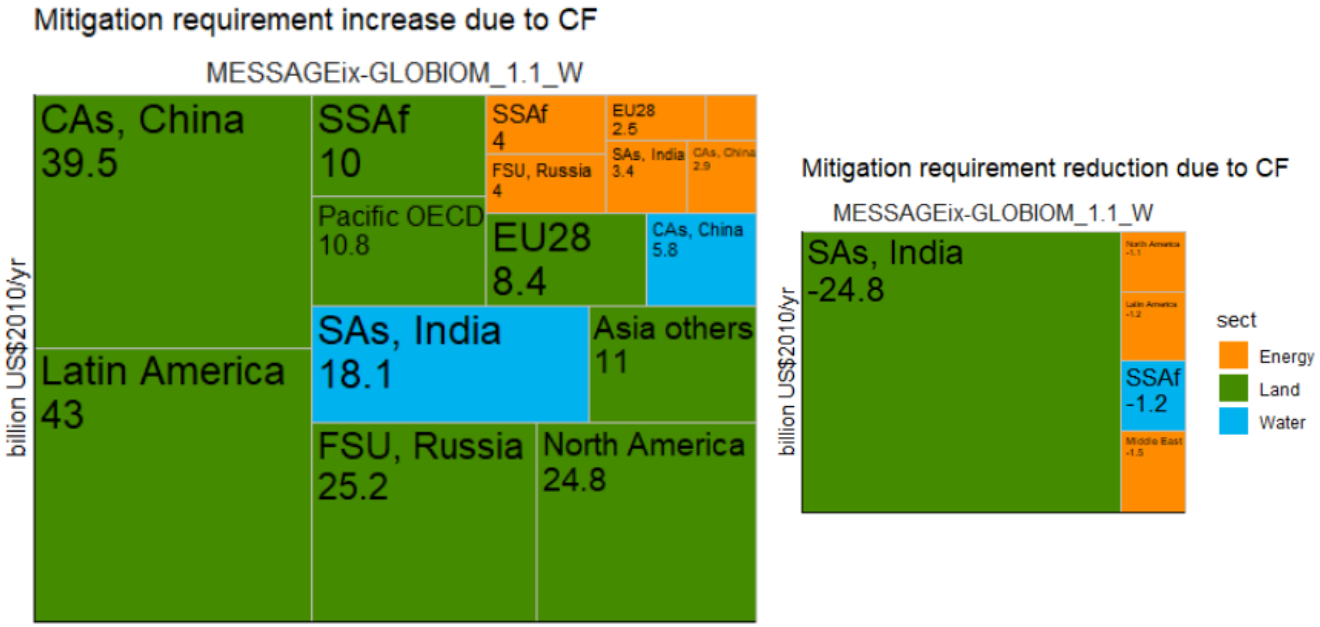
Mitigation investments substantially affected under climate change impacts

Global average mitigation investments increase by > **44%**



Main domains: Energy/Water/Land

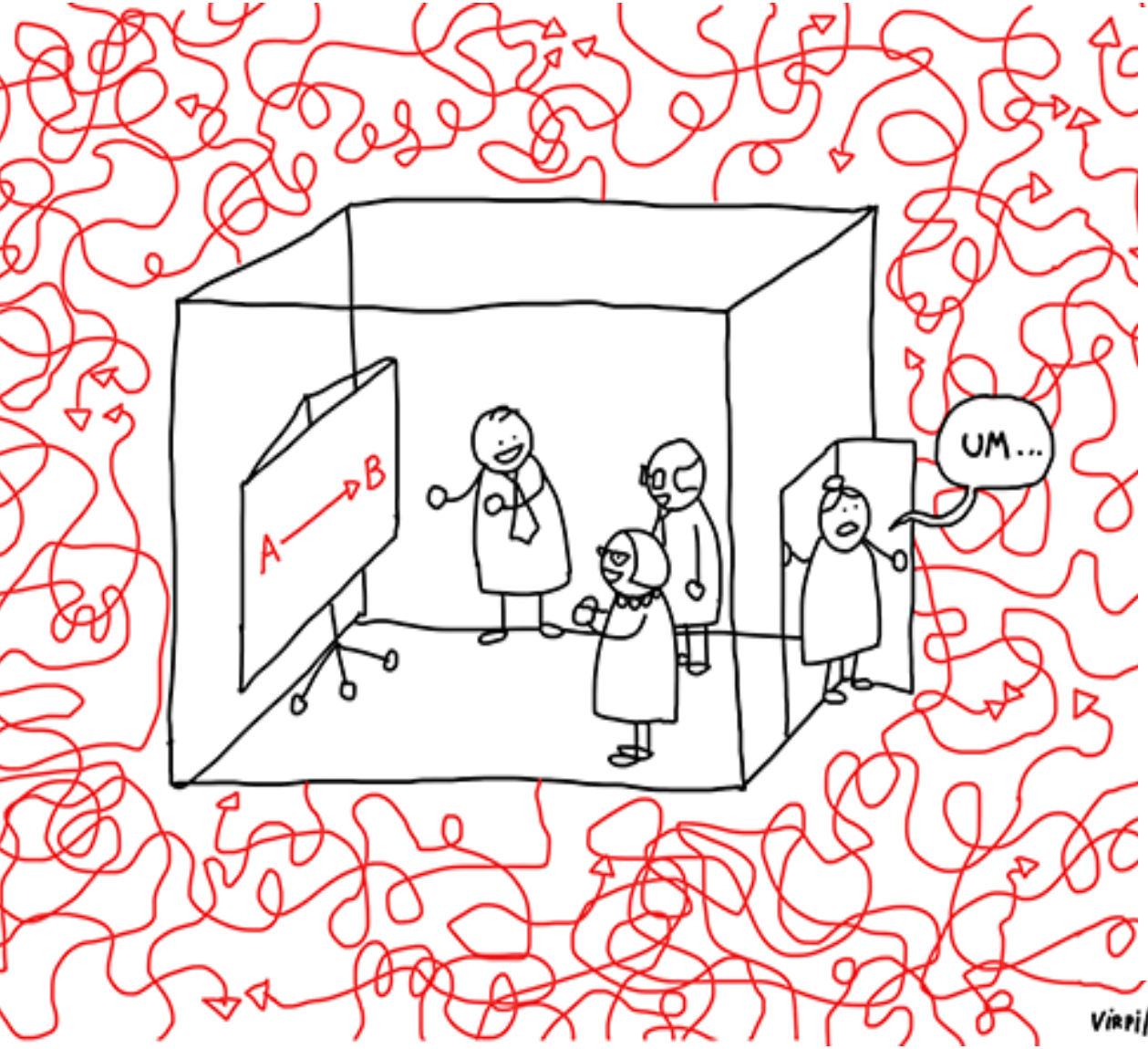
Regionally diverse insights: In some regions and sectors investments increase, in others they can also decline



Multiple adaptation options (desalination, water recycling, irrigation, power plant cooling, demand-response…) – but **adaptation capacity** not considered in most analysis

Vinca et al, forthcoming

Many challenges to represent impacts in global IAMs

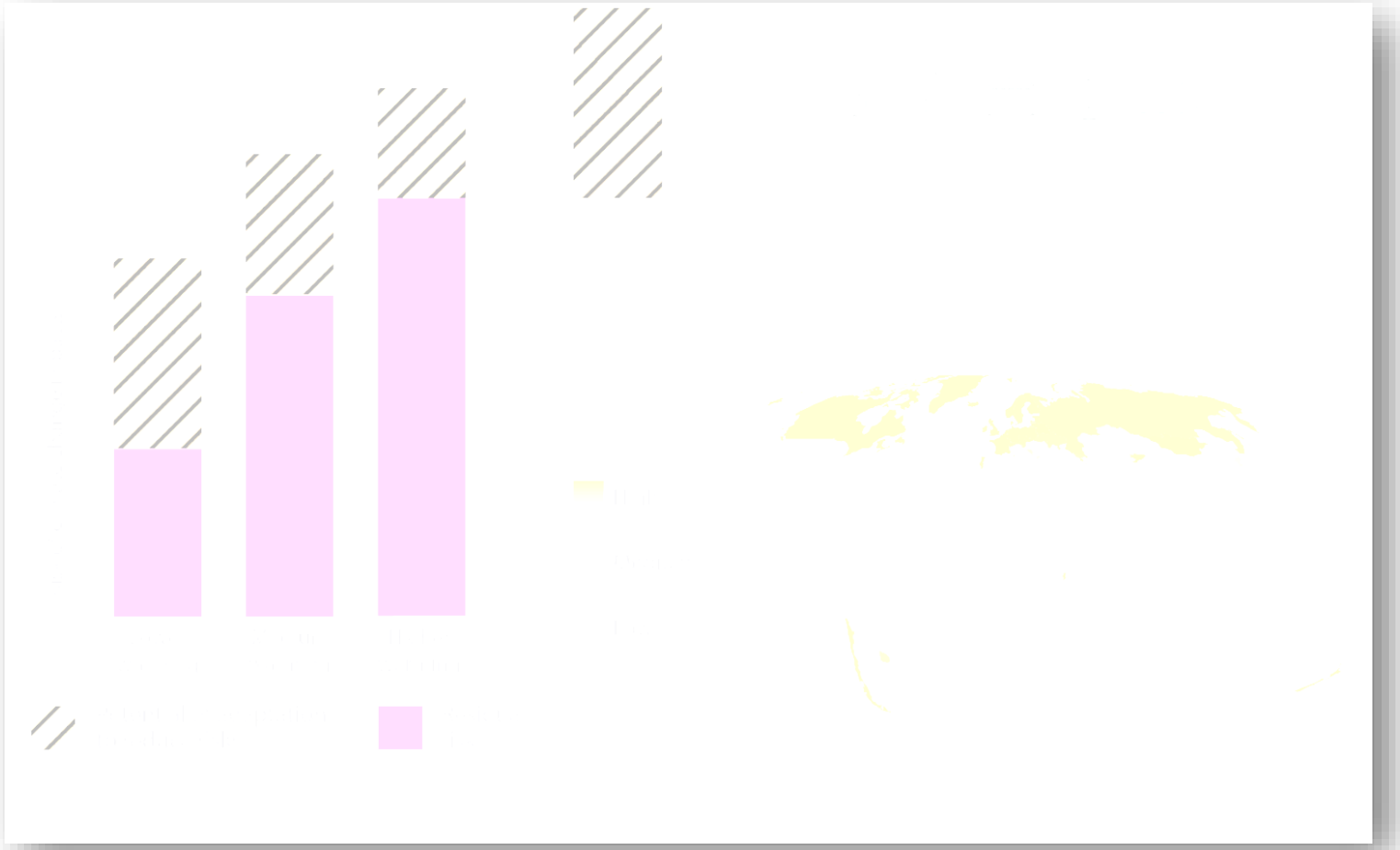


- Efforts represent initial steps towards integration of biophysical and economic impacts
- Better representation of extremes and temporal and spatial granularity
- Improved understanding of hydrological uncertainties and responses needed
- Translation to macroeconomic impacts (distributional issues)
- Impact trajectories constraint by RCP-SSP combinations
- Better representation of adaptation

Adaptation

- More than half of SSP-based publications come from the impacts, adaptation and vulnerability (IAV) research, but only about 3% focus on adaptation (based on Green et al., 2022)
- Critical need to represent adaptation better in impact models and IAMs (van Maanen et al., 2023)
- Only when we include adaptation explicitly, we will be able to robustly identify climate risk & residual impacts
- Integration of adaptation required for identifying mitigation options that improve climate resilience (adaptation synergies & trade-offs)
- A promising approach to bring adaptation to many assessments, particularly the SSPs, are dynamic adaptive capacity pathways (Andrijevic et al., forthcoming)

Improving adaptation in IAMs (and impacts models)



Some adaptation already exists in Impact Models and IAMs, e.g., irrigation, desalination, dry cooling, water storage, AC

Adaptation options, if represented, are often binary

Capacities vary by sector, climate impact, country, through time

e.g. adaptation to heat-stress varies by climate, location, income urbanization, inequality,….,

Costs, speed and efficacy of adaptation also vary

Andrijevic et al., forthcoming, Nature Climate Change

Representing adaptation capacity in global climate change assessments

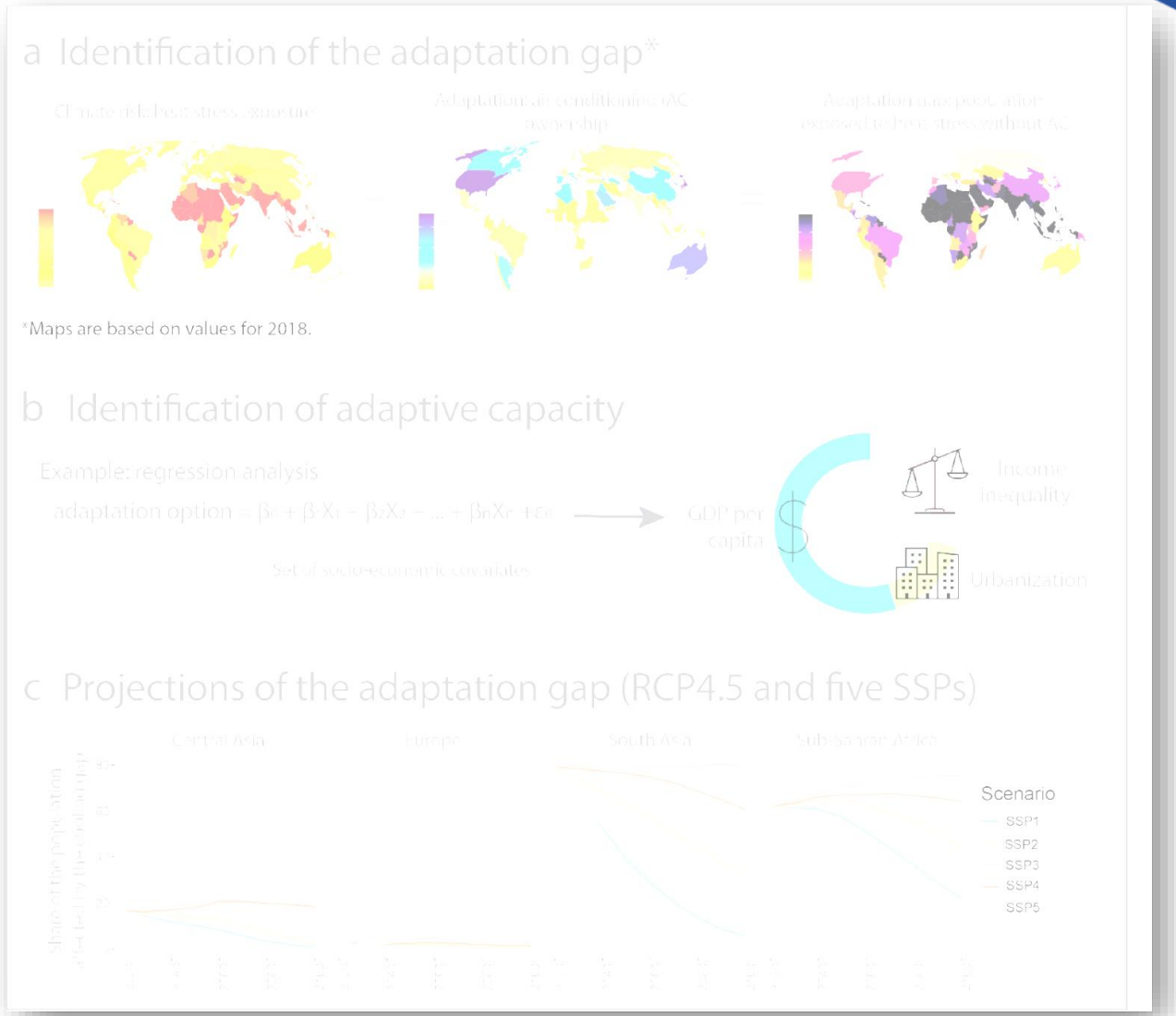
The Adaptation Gap, and the Capacity to Adapt, are complex functions of biophysical and socioeconomic conditions

Need to understand the limits to adaptation – irreducible, residual risk

Framework for representing adaptation capacities in IAMs (constrain adaptation at the country-level to be more realistic)

Improved representation of Mitigation-Adaptation synergies & tradeoffs

Consistent use of SSP-bound adaptation assumptions could facilitate adaptation intercomparison, in Impact Models & IAMs



Andrijevic et al., forthcoming, Nature Climate Change
Andrijevic et al., 2021, ERL

Using impacts emulators

- The community is constrained to explore climate impacts based on SSP-RCP trajectories/combinations
- 90% of IAM scenarios in AR6 were SSP2
- ISIMIP3 – SSP1-26, SSP3-70, SSP5-85…. SSP2?
- Climate impacts emulation can help with
  - Covering the scenario space and filling key policy relevant gaps
  - Integration of impacts into IAMs (sectoral emulators – biophysical or economic damages, adaptation capacity, etc…)
  - Connected to specific mitigation pathways, emulators can help with ex-post and fast-track assessment of avoided impacts
- Great that impact emulator modelling is listed as an activity of the ISIMIP cross-sectoral science team

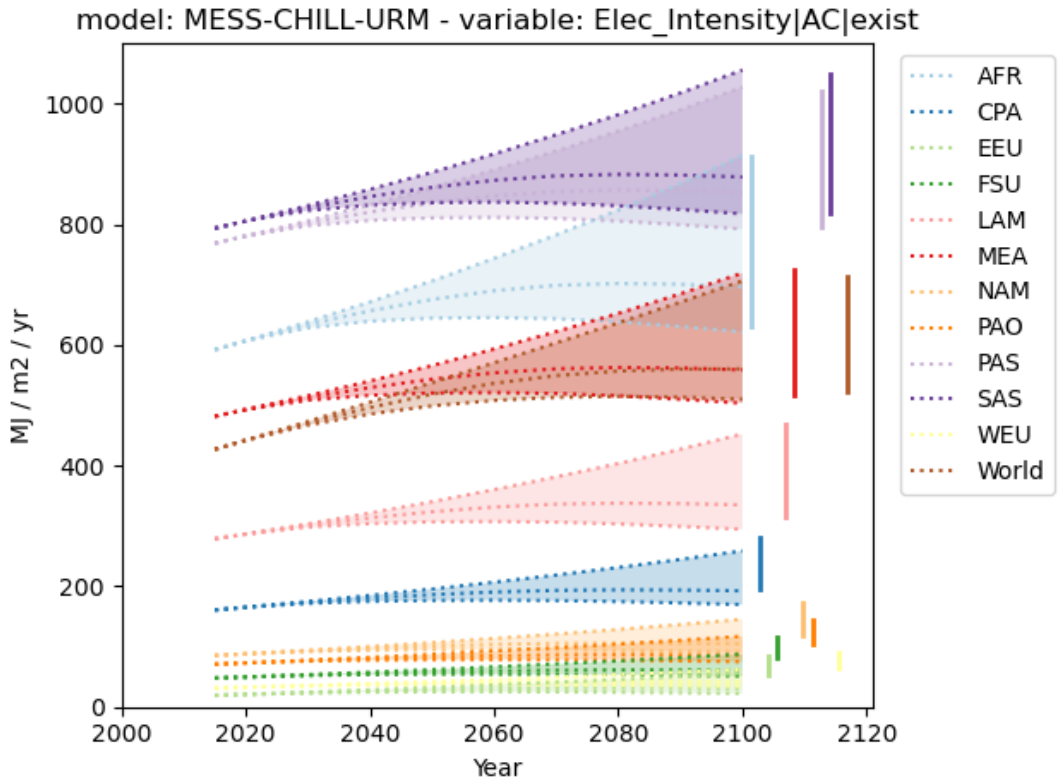
CHILLED model emulation with regional response functions

CHILLED emulator

CC scenarios using regional response function

Input: Emissions|CO2, cumulative at each timestep, for any unseen scenario

Output: Temporal projections of energy intensity, by region, building type, cooling method, SSP



MESSAGEix

3 standard runs

- 1.5 °C
- 2 °C
- Current Policies (~3 °C)

CHILLED is a gridded space cooling/heating demand model (Mastrucci et al. 2018), – inputs to MESSAGEix

Computationally expensive, constrained by SSP-RCP

4% increase in total electricity demand, just from climate impacts on AC, in the ~3 °C scenario

SPARCCLE Modelling chain

MESMER & ISIMIP indicators of hazards

Vulnerability, damages, adaptation

Tools, data & models

Earth Observations	AI
Disaster records	CLIMADA
Demographic projections	CATSIM

Sectoral impacts

- **WATER**: Renewable water resources, water temperature, hydro-electric potential
- **AGRICULTURE & LAND**: Crop yield, biomass potential, burned areas
- **HEALTH**: Heat stress and heat mortality
- **ENERGY**: Demand, supply, powerplants, heating/cooling demand
- **INFRASTRUCTURE**: Damage to capital assets and service disruption
- **FINANCE**: Increased risk premiums for climate-vulnerable assets
- **LABOUR**: Labour productivity impacts of heatwaves and climate extremes

Integrated assessment, synergies & trade-offs

IMAGE MESSAGEix
PRIMES GLOBIOM-G4M

Socio-economic assessment of climate risks and risk reduction options

GEM-E3 RICE50+ DSK
d-PLACE MIMOSA

AR6 Climate "pipeline" (WGI – WGIII handshake)

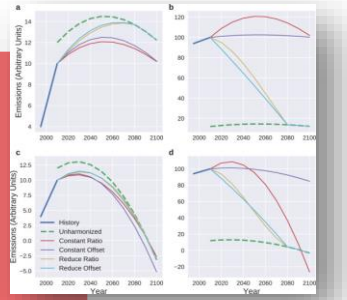
IAM reported emissions in AR6 database

IAMC Integrated Assessment Modeling Consortium Founded 2007

Standardized data template

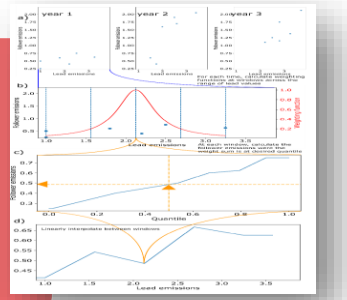
HARMONIZATION
AGREEING ON A HISTORICAL BASELINE (RCMIP, CEDS)

(Gidden et al., 2018)



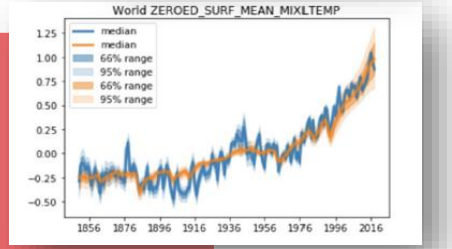
INFILLING
INFERRING NON-REPORTED EMISSIONS TRAJECTORIES FOR 22 EMISSIONS SPECIES

(Lamboll et al., 2020)



PROBABILISTIC CLIMATE ASSESSMENT
TEMPERATURE OUTCOMES

(MAGICC7, FAIR 1.6)
(Kikstra et al., 2023)



WG I climate assessment

- ✓ Building a bridge between communities
- ✓ Assess 1000s of scenarios
- ✓ Community standards and methods
- ✓ Transparent and open framework
- ✓ Adaptable and reproducible
- ✓ Community "endorsement" and vetting

Open-source framework to provide a community resource

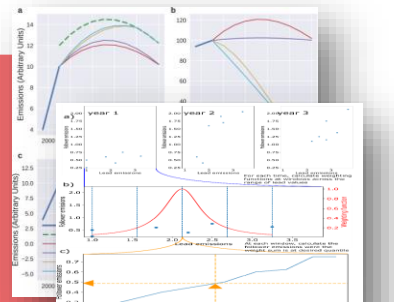
Findable Accessible Interoperable Reusable

IAM reported emissions in AR6 database

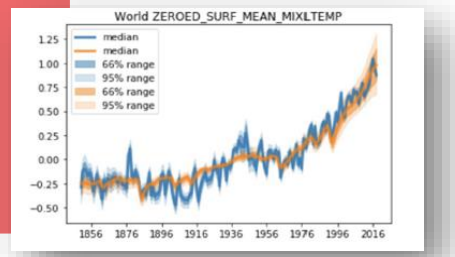
IAMC
Integrated Assessment Modeling Consortium
Founded 2007

Standardized data template

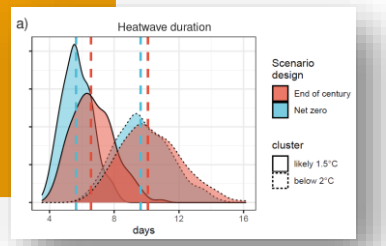
Emissions
Socio-economics



CLIMATE from WGI-III
Vulnerability consistent with WGII



Impact Emulators
Damage functions
Biophysical impacts (hydrology)
Extremes
Sectoral responses



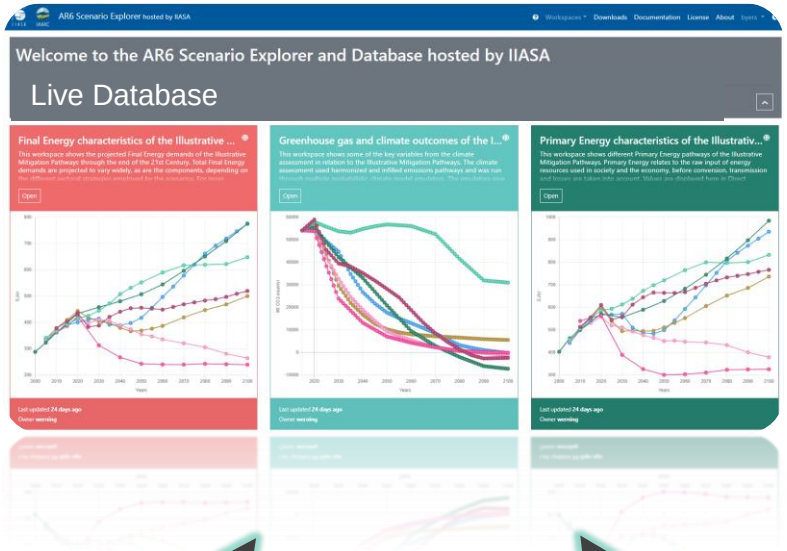
WG II impacts assessment

Similar linkages possible between WGII-III

- Huge utility: improved and consistent representation of both mitigation costs and benefits (avoided impacts)
- Can build on existing emulators (damages, vulnerability, exposure)
- Need broader community vetting process (setting standards organized, eg, by ISIMIP?)
- WGII AR7 priorities to work towards better integration?
- Who is the group that could move this forward (ISIMIP+IAMC)?

Extensions to provide tailor-made information to different user groups

Continues submission of scenarios



annual vetting cycle

"bolt-on" modules:

Climate Assessment

- Multiple emulators
- (MAGICC, FAIR,..)
- Open-SCM

Impact Assessment

- physical risks
- economic damages
- ISIMIP++

Thank you!

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