Sharing not permitted

International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Closing the loop between integrated assessment and climate risk research - Rapid climate risk emulation

Edward Byers, **Michaela Werning**, Volker Krey, Keywan Riahi

IAMC Integrated Assessment Modeling Consortium Founded 2007

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

EGU

EGU General Assembly

CL3.2.5 Techniques and advances in climate emulation, economics and integrated assessment

25th April 2023 – 14:00-17:55

Emulating climate impacts and exposure from IAM scenarios

IAM scenarios
+ SCM (FaIR, MAGICC etc)
= rapid climate risk emulation

Aim: Exogenously assess the climate impacts and exposure from IAM emissions scenarios

Background:

Expanding number of emulations (e.g. SCMs) that estimate global warming from an input emissions scenario (e.g. FaIR, MAGICC, OSCAR, etc) – annual timeseries, global and macro-region variables.

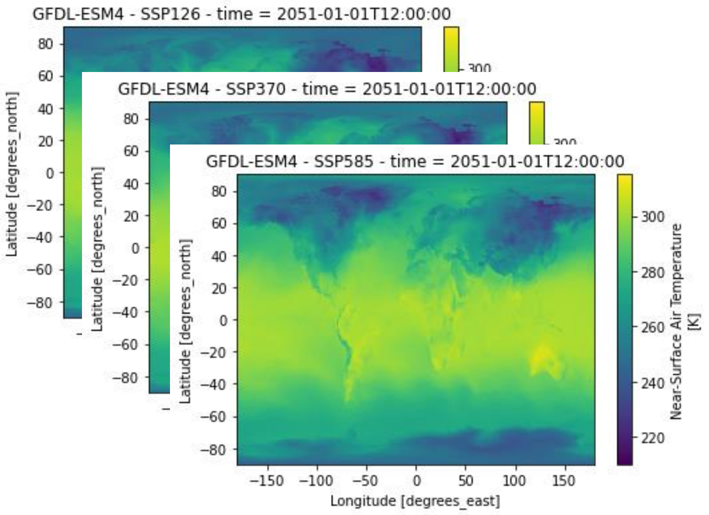
- More recently, new approaches to extend this with grid-level assessment, and more climate-related variables (e.g. temperatures, precipitation (MESMER))

Here:

- Extend approaches for climate impacts and risk assessment – e.g. heatwaves, drought => population exposed
    - Pre-process: Climate impacts & exposure data (e.g. from ISIMIP impact models)
    - Input: Global mean temperature projection (+IAM scenario), e.g. from AR6 Scenarios database
    - Output: Maps & table data of land/population exposure to impacts

Workflow: Pre-processing impacts data

ISIMIP input data (5 CMIP6 GCMs, 3 RCPs) → Calculate indicators for different GCM/ RCP/ Δ GMT) combinations → Calculate **multi-model means** for each indicator → Calculate **difference** between historical data and future projections



Precipitation

- Heavy precipitation days
- Wet & very wet days
- Precipitation intensity index
- Consecutive dry days

Temperature

- Heat wave intensity
- Tropical nights

Energy demands

- Cooling degree days

Hydrology

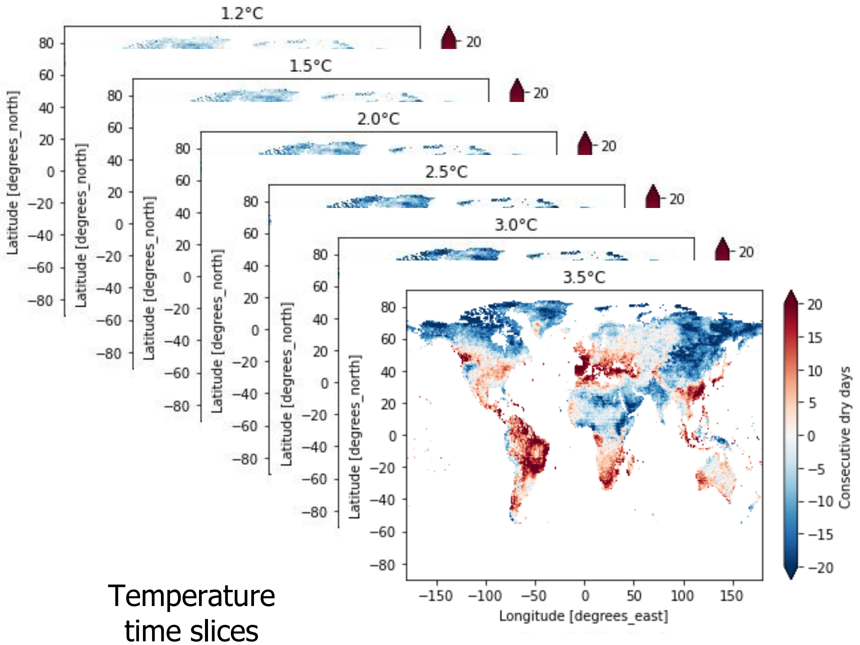
- Drought intensity
- Seasonality
- Interannual variability
- Water stress

Land

- Low intensity land cover
- Crop yields

Air pollution

- Ambient PM2.5



Temperature time slices

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

Workflow: Calculate population & land exposure

Calculate **exposure** **above threshold**

→

Calculate country/region statistics of **affected land area / population**

Available statistics:

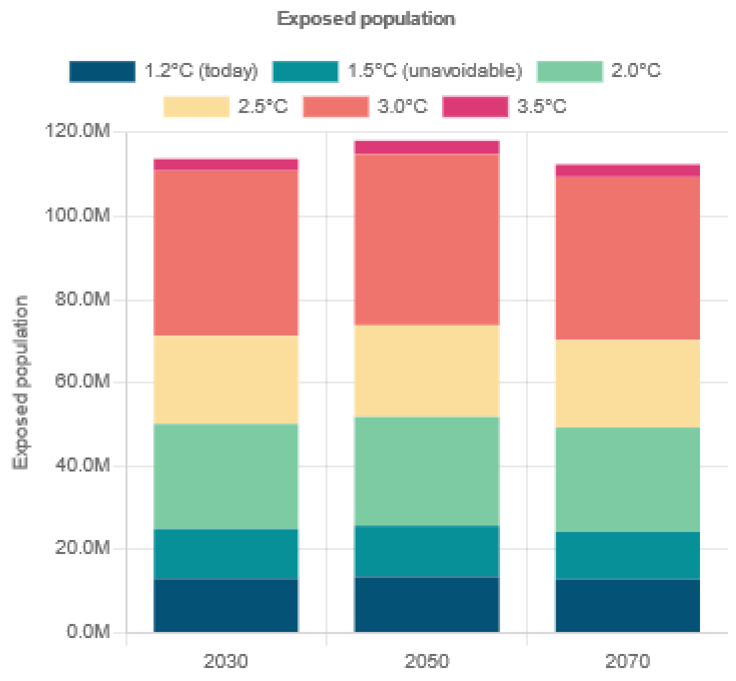
Hazard/Difference value for country/region

- weighted by population
- weighted by land area

Above threshold: e.g.
- Water stress index >0.3
- x% increase in Tropical Nights
- x% reduction in crop yields

Exposure statistics:

- Exposed land area
- Exposed land area %
- Exposed population
- Exposed population %
- + High/Low population ranges

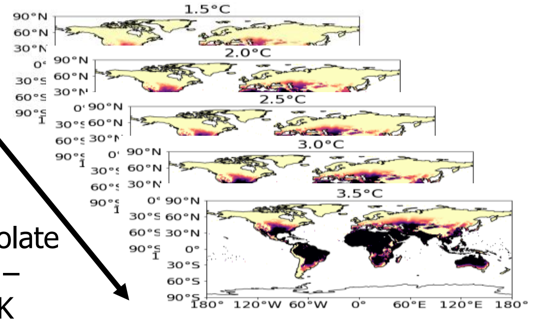


Population exposed to consecutive dry days in Brazil

25-04-2023

Workflow: Map impacts

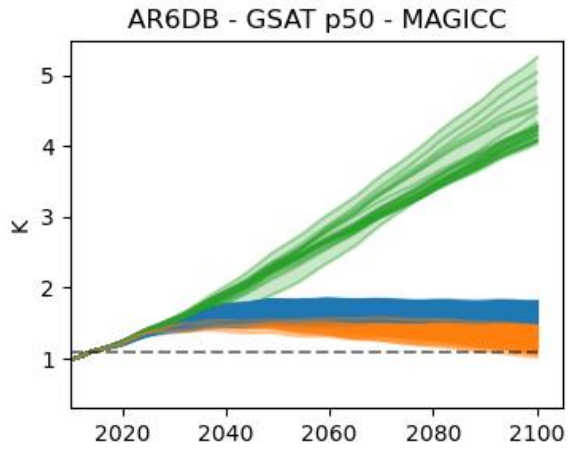
Create **database of impacts and exposures** (GMT, year, SSP, region)



Interpolate ΔGMT – 0.01° K

```
<xarray.Dataset>
Dimensions:           (gmt: 251, year: 91, ssp: 3,
                       region: 226)
Coordinates:
  * gmt               (gmt) float64 1.2 1.206 ... 3.5
  * year              (year) int64 2010 2011 ... 2100
  * ssp               (ssp) object 'SSP1' 'SSP2' 'SSP3'
  * region            (region) object 'AFG' ... 'world'
Data variables: (12/189)
    iavar|Exposure|Land area
    iavar|Exposure|Land area|%
    iavar|Exposure|Land area|High
    iavar|Exposure|Land area|High|%
    iavar|Exposure|Land area|Low
    iavar|Exposure|Land area|Low|%
    ...
    sdii|Hazard|Difference
    sdii|Hazard|Difference|Land area weighted
    sdii|Hazard|Difference|Population weighted
    sdii|Hazard|Risk score
    sdii|Hazard|Risk score|Land area weighted
    sdii|Hazard|Risk score|Population weighted
```

Input **temperature trajectory** from emission scenarios (e.g. AR6)



Perform **multi-index lookup** of trajectory

Million people exposed to X → **2100**

gmt	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1.20	82.0	82.7	83.4	84.0	84.7	85.4	85.9	86.5	87.0	87.5	88.0	88.6	89.1	89.6	90.1	90.6
1.21	83.3	84.0	84.7	85.4	86.1	86.8	87.3	87.9	88.4	88.9	89.5	90.0	90.5	91.0	91.6	92.1
1.22	84.7	85.4	86.1	86.8	87.5	88.2	88.7	89.3	89.8	90.3	90.9	91.4	91.9	92.5	93.0	93.6
1.23	86.0	86.7	87.4	88.1	88.9	89.6	90.1	90.7	91.2	91.7	92.3	92.8	93.4	93.9	94.5	95.0
1.24	87.3	88.1	88.8	89.5	90.2	91.0	91.5	92.1	92.6	93.2	93.7	94.3	94.8	95.4	95.9	96.5
1.25	88.7	89.4	90.1	90.9	91.6	92.3	92.9	93.5	94.0	94.6	95.1	95.7	96.2	96.8	97.4	97.9
1.26	90.0	90.7	91.5	92.2	93.0	93.7	94.3	94.9	95.4	96.0	96.6	97.1	97.7	98.2	98.8	99.4
1.27	91.3	92.1	92.8	93.6	94.4	95.1	95.7	96.3	96.8	97.4	98.0	98.5	99.1	99.7	100.3	100.8
1.28	92.7	93.4	94.2	95.0	95.7	96.5	97.1	97.7	98.2	98.8	99.4	100.0	100.6	101.1	101.7	102.3
1.29	94.0	94.8	95.6	96.3	97.1	97.9	98.5	99.1	99.6	100.2	100.8	101.4	102.0	102.6	103.2	103.7
1.30	95.3	96.1	96.9	97.7	98.5	99.3	99.9	100.5	101.1	101.6	102.2	102.8	103.4	104.0	104.6	105.2
1.31	96.7	97.5	98.3	99.1	99.9	100.7	101.3	101.9	102.5	103.1	103.7	104.3	104.9	105.5	106.1	106.7
1.32	98.0	98.8	99.6	100.4	101.2	102.0	102.6	103.3	103.9	104.5	105.1	105.7	106.3	106.9	107.5	108.1
1.33	99.3	100.2	101.0	101.8	102.6	103.4	104.0	104.7	105.3	105.9	106.5	107.1	107.7	108.3	109.0	109.6
1.34	100.7	101.5	102.3	103.2	104.0	104.8	105.4	106.1	106.7	107.3	107.9	108.5	109.2	109.8	110.4	111.0
1.35	102.0	102.9	103.7	104.5	105.4	106.2	106.8	107.5	108.1	108.7	109.3	110.0	110.6	111.2	111.9	112.5
1.36	103.4	104.2	105.0	105.9	106.7	107.6	108.2	108.9	109.5	110.1	110.8	111.4	112.0	112.7	113.3	113.9

↓ 3.5 °C

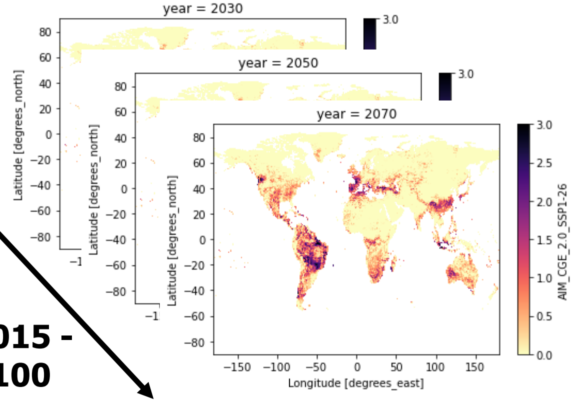
Community consistent output formats

Spatial gridded netCDF format

Multiple indicators, one IAM scenario

```
<xarray.Dataset>
Dimensions:      (lat: 360, lon: 720, year: 86)
Coordinates:
  * lon          (lon) float64 -179.8 -179.2 -178.8 -178.2 ... 178.8 179.2 179.8
  * lat          (lat) float64 89.75 89.25 88.75 88.25 ... -88.75 -89.25 -89.75
  * year         (year) int32 2015 2016 2017 2018 2019 ... 2097 2098 2099 2100
Data variables: (12/18)
    cdd          (lat, lon, year) float64 ...
    dri          (lat, lon, year) float64 ...
    dri_qtot     (lat, lon, year) float64 ...
    iavar        (lat, lon, year) float64 ...
    iavar_qtot   (lat, lon, year) float64 ...
    pr_r10       (lat, lon, year) float64 ...
    ...           ...
    sdd_c        (lat, lon, year) float64 ...
    sdd_c_24p0   (lat, lon, year) float64 ...
    sdd_c_20p0   (lat, lon, year) float64 ...
    sdd_c_18p3   (lat, lon, year) float64 ...
    tr20         (lat, lon, year) float64 ...
    wsi          (lat, lon, year) float64 ...
```

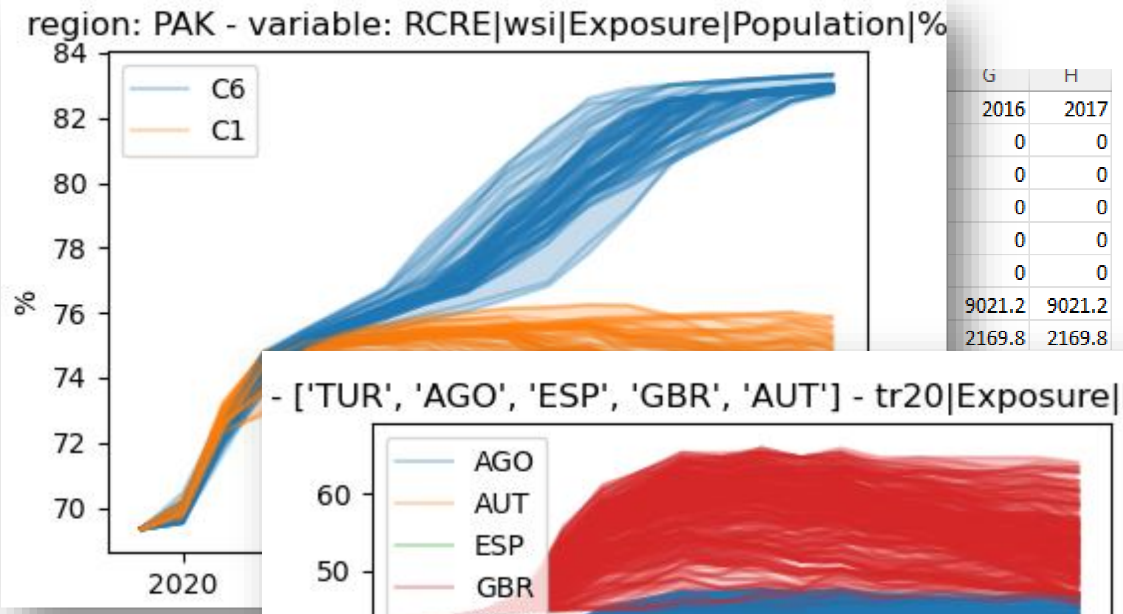
2015 - 2100

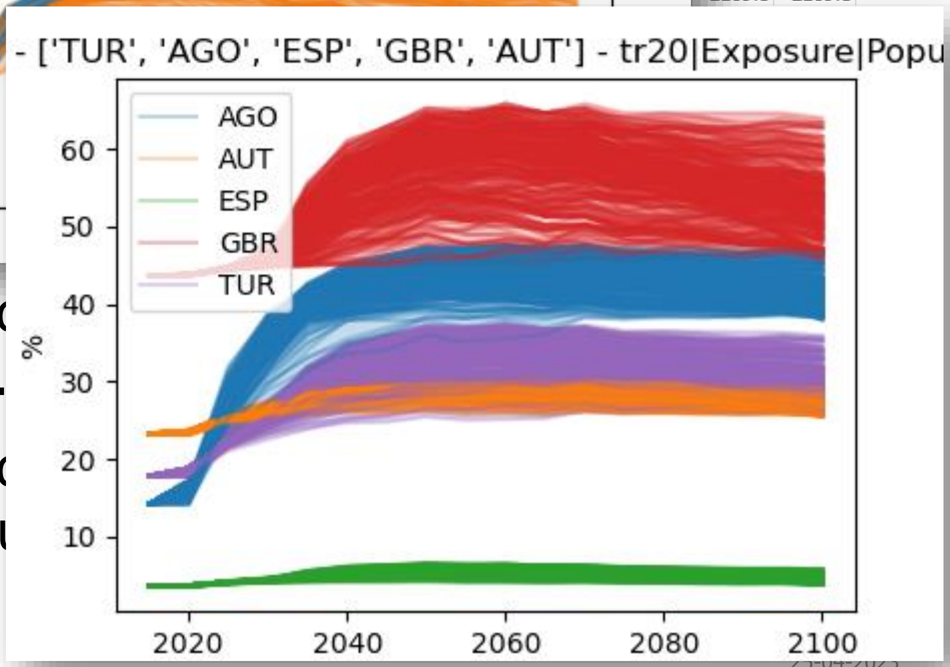


One indicator, multiple IAM scenarios

```
<xarray.Dataset>
Dimensions:              (lat: 360, lon: 720, year: 86)
Coordinates:
  * lon                  (lon) float64 -179.8 -179.2 -178.8 ... 179.2 179.8
  * lat                  (lat) float64 89.75 89.25 88.75 ... -89.25 -89.75
  * year                 (year) int32 2015 2016 2017 2018 ... 2098 2099 2100
Data variables:
    AIM_CGE_2.0_SSP1-26  (lat, lon, year) float64 ...
    GCAM_5.3_SSP_SSP5    (lat, lon, year) float64 ...
```

IAMC tabular format





Aggregate
region e.g.

Multiple in
simple tab

Conclusions

- Various indicators prepared to develop database of gridded and country-level impacts and exposure
- Scripts for interpolation and re-indexing of datasets
  - Input: GMT trajectory by year (.csv)
  - Output: Impact indicators by year (.csv, netCDF)
- Developed in Python: Xarray + Dask parallelized processing
- Fast for single scenarios – large ensembles like AR6 more difficult
- Uncertainties
  - Socioeconomic uncertainty covered
  - Climate model uncertainty possible but not yet
  - Threshold approach

Next steps

- Extend to more indicators + vulnerability
- Launch open source
- Facilitate batch processing of IAM scenarios for online data processing and model intercomparison
- Support assessment of unknown emissions scenarios, including overshoot
- Support IPCC WG1-WG2-WG3 integration

IAM scenarios
+ SCM (FaIR, MAGICC etc)
= rapid climate risk emulation

International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Closing the loop between integrated assessment and climate risk research - Rapid climate risk emulation

Edward Byers, **Michaela Werning,** Volker Krey, Keywan Riahi
Energy, Climate & Environment Program
IIASA

Contact:

byers@iiasa.ac.at
werning@iiasa.ac.at

Implementation

python xarray pyam pandas dask GitHub

Acknowledged support

IAMC Integrated Assessment Modeling Consortium Founded 2007

ISIMIP Inter-Sectoral Impact Model Intercomparison Project