



POTSDAM INSTITUTE FOR  
CLIMATE IMPACT RESEARCH



# The Global Gridded Crop Model Intercomparison – an AgMIP activity

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# GGCMI in a nutshell

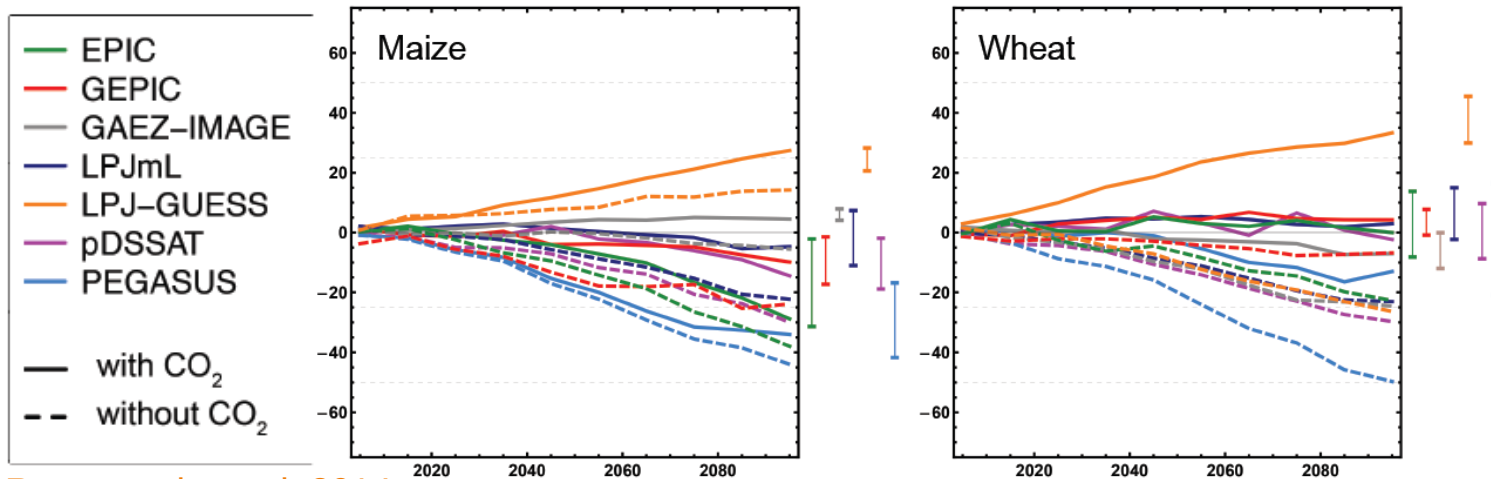
- **AgMIP + ISIMIP = GGCMI**
- **just started Phase 3**
  - **fast track (ISIMIP special issue, future projections)**
    - 7 models, 20 papers, large uncertainties require more investigations
  - **Phase 1 (ISIMIP 2a + more): historic period**
    - 14 models, 13 papers, common patterns in evaluation
  - **Phase 2 (no ISIMIP equivalent): CTNW-A**
    - 12 models, 5 papers (and counting), emulation and response types
  - **Phase 3 (ISIMIP 3a/b): CMIP6-based future projections**
    - 24 modeling groups indicated interest, 13 delivered so far

finished

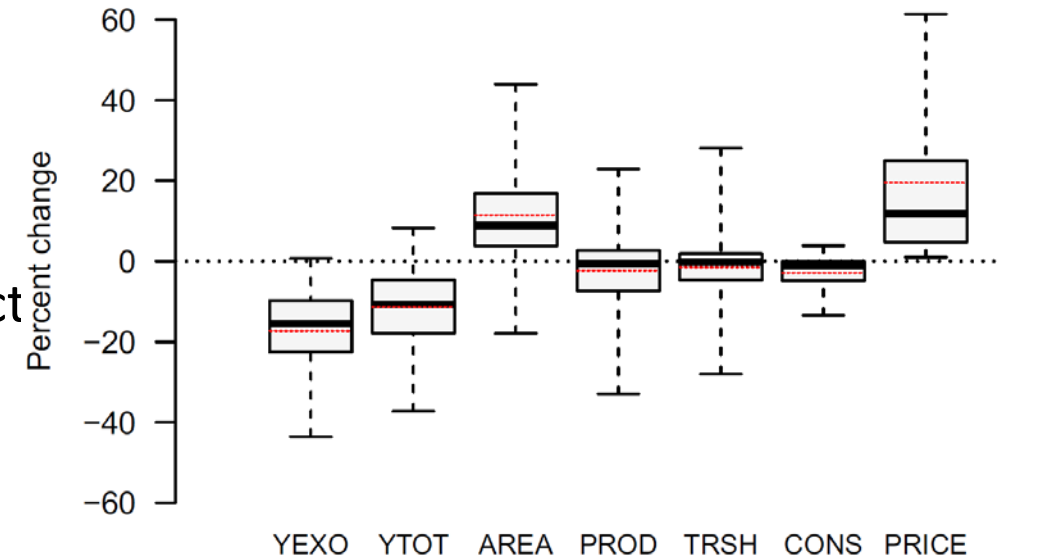
active

# Finished Phases: setting the scene

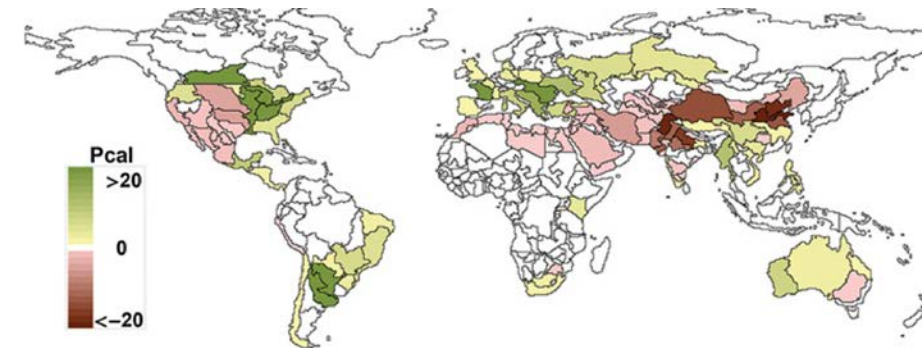
- ISIMIP fast track:
  - first comprehensive model intercomparison project (MIP) of global crop yield projections
  - large model spread
  - unclear where uncertainties come from
  - Interaction with global economics & water sector



[Rosenzweig et al. 2014](#)



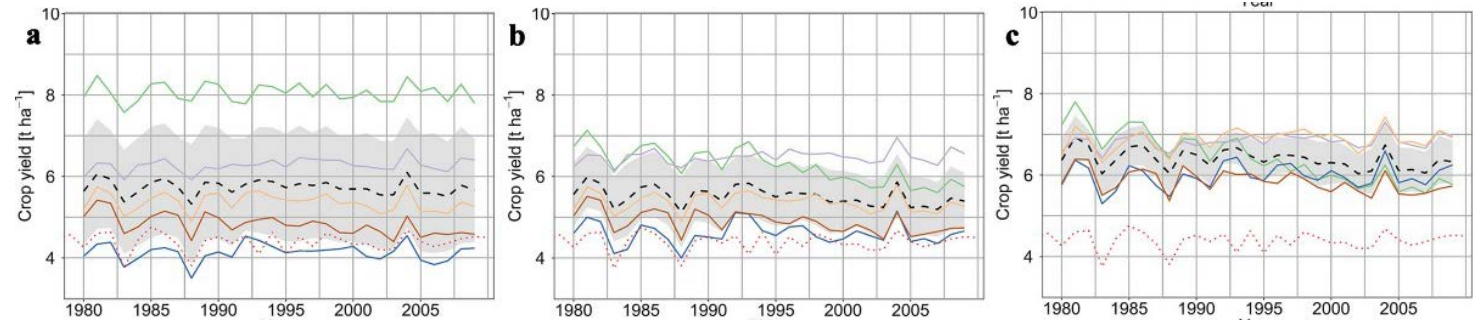
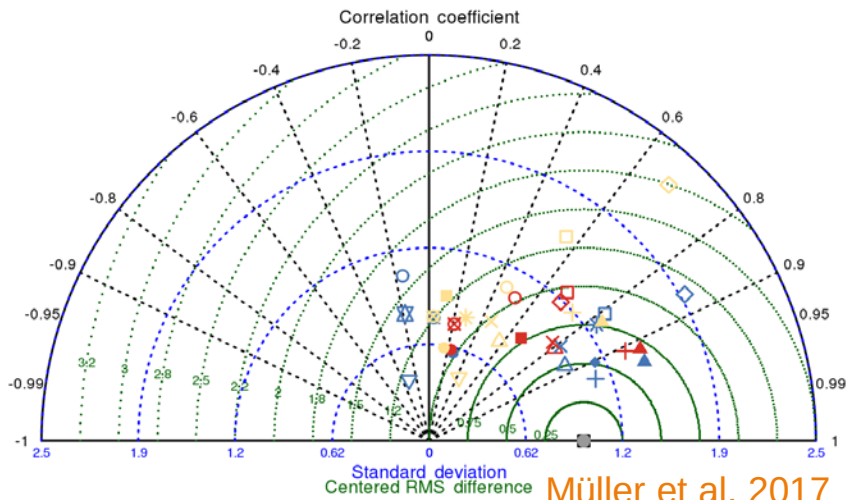
[Nelson et al. 2014](#)



[Elliott et al. 2014](#)

# Finished Phases: setting the scene II

- GGCM Phase 1: model evaluation
  - mixed model performance ([Müller et al. 2017](#)), better in high-input regions, best for maize, worst for rice
    - online model evaluation tool <https://mygeohub.org/tools/ggcmevaluation>
  - parameterization as important as model itself ([Folberth et al. 2019](#))
  - aggregation ([Porwollik et al. 2017](#)) and climate data ([Ruane et al. 2021](#)) uncertainties



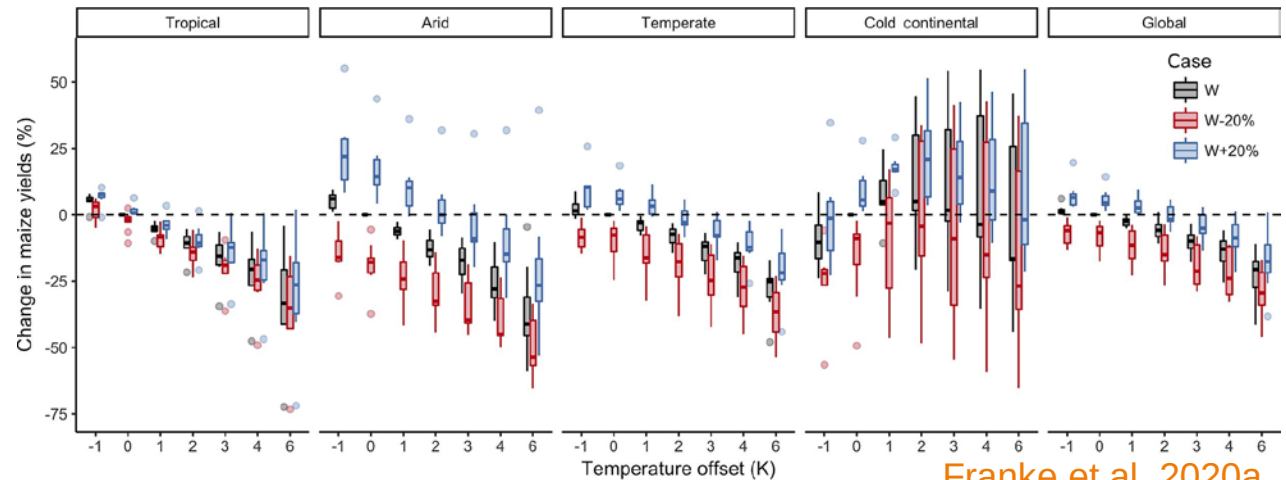
[Folberth et al. 2019](#)

# Active Phase 2: the experiment

The CTWN-A data cube: Regular disturbances of 31-year AgMERRA weather data

- Carbon dioxide: 360, 510, 660, 810 ppm ( $n_C=4$ )
- Temperatures:  $-1^{\circ}\text{C}$  to  $+6^{\circ}\text{C}$ , skipping  $5^{\circ}\text{C}$  ( $n_T=7$ )
- Water supply: -50 to +30, skipping -40 + fully irrigated ( $n_W=9$ )
- Nitrogen supply: 10, 60, 200 kgN/ha ( $n_N=3$ )
- Adaptation: regain lost growing season under warming (yes/no)

The full CTWN-A experiment is described by [Franke et al. \(2020a\)](#).



[Franke et al. 2020a](#)

## Active Phase 2: the emulators

$$\begin{aligned} Y = & K_1 \\ & + K_2 C + K_3 T + K_4 W + K_5 N + K_6 C^2 \\ & + K_7 T^2 + K_8 W^2 + K_9 N^2 + K_{10} C W \\ & + K_{11} C N + K_{12} T W + K_{13} T N + K_{14} W N \\ & + K_{15} C T + K_{16} T^3 + K_{17} W^3 + K_{18} C^3 + K_* N^3 \\ & + K_{19} T W N + K_{20} T^2 W + K_{21} W^2 + K_{22} W^2 N \\ & + K_{23} C W N + K_{24} C T N + K_{25} C T W + K_{26} N^2 C \\ & + K_{27} N^2 T + K_{28} N^2 W + K_{29} T^2 N + K_{30} T^2 C \\ & + K_{31} W^2 C + K_{32} C^2 W + K_{33} C^2 T + K_{34} C^2 N \end{aligned}$$

The CTWN-A emulators are trained on the CTWN-A data cube, fitting a 3<sup>rd</sup>-order polynomial regression model

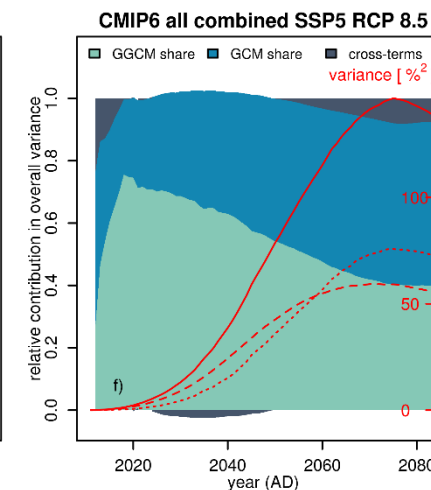
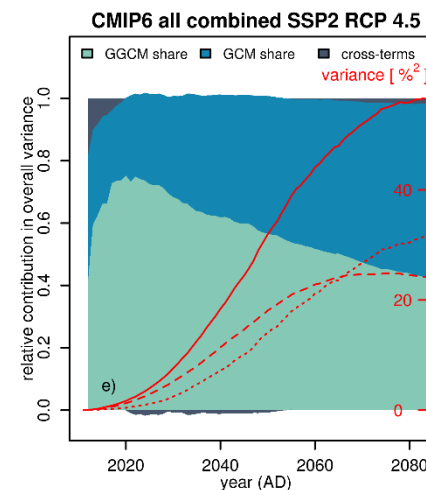
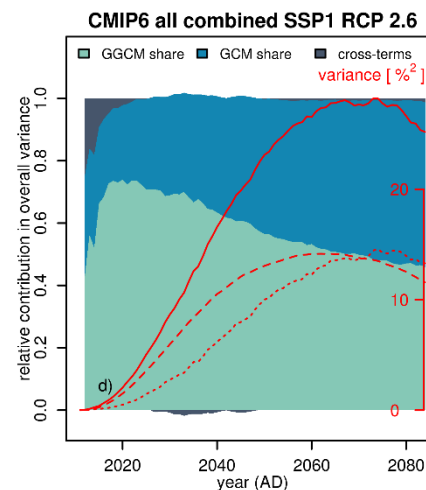
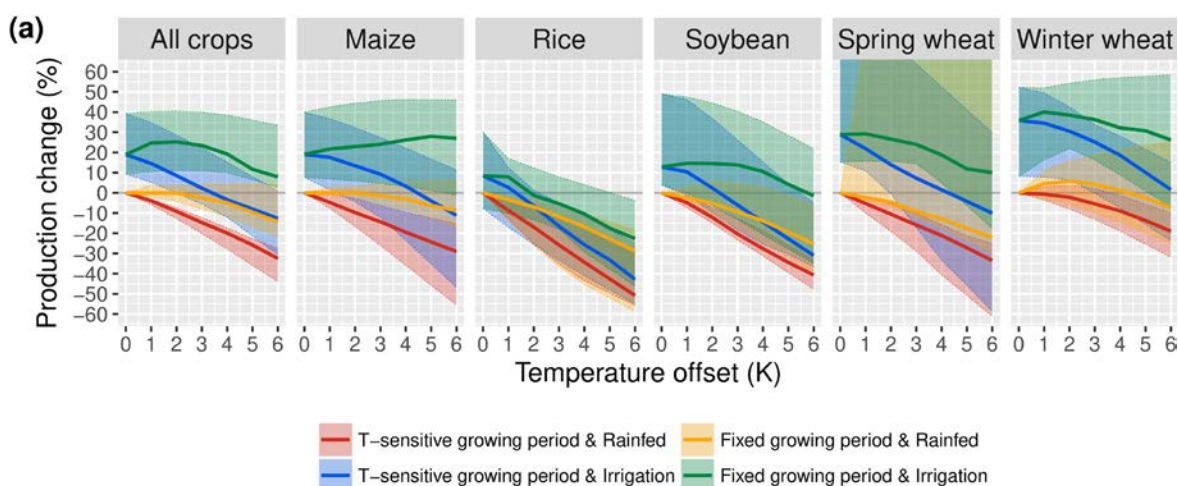
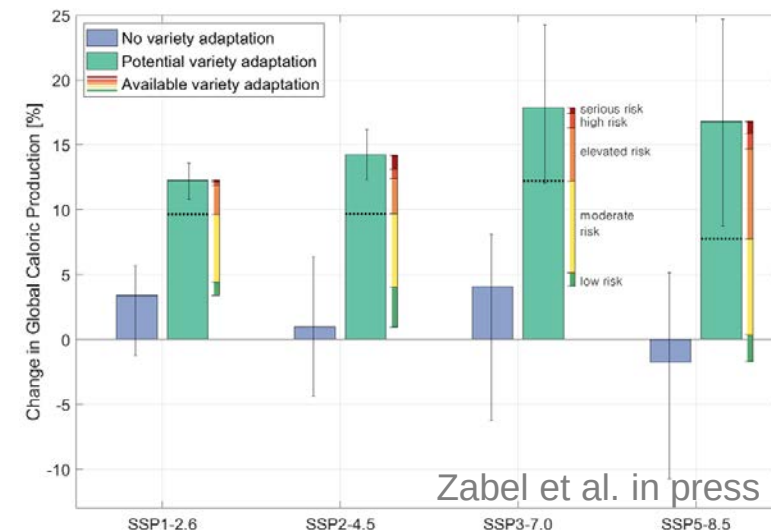
- for each 0.5° grid cell, crop and crop model with
- C, T, W, and N as regressors and
- fitting individual models for irrigated and rainfed as well as adapted (A1) and non-adapted (A0) systems.

They can well reproduce simulated climate change impact scenarios, including simulations based on GCM projections with inter-annual variability.

The full CTWN-A emulator suite is described by [Franke et al. \(2020b\)](#).

# Phase 2 insights: uncertainties & adaptation power

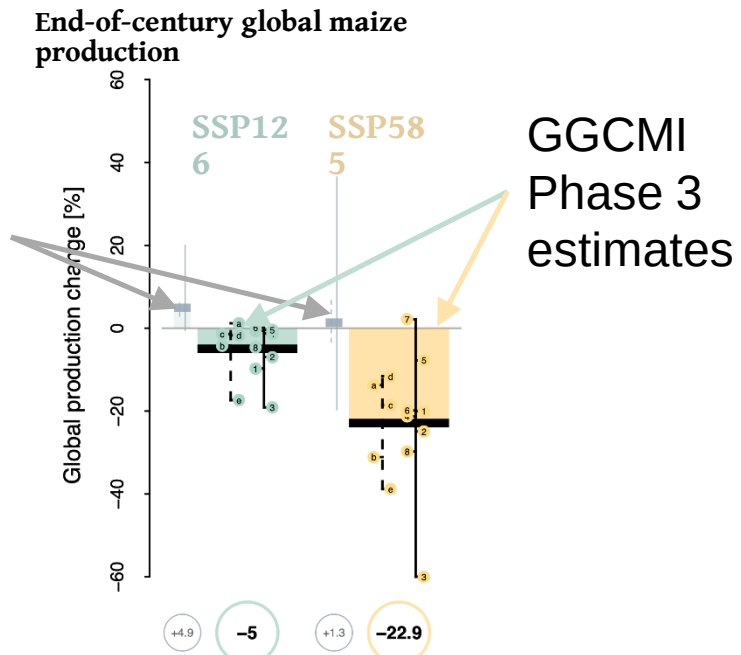
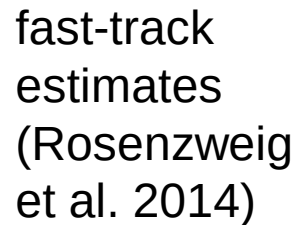
- adaptation with large potentials to increase yields
- uncertainties from climate projections en par with those from crop models at end of 21<sup>st</sup> century, but much smaller earlier
- response types differ by region and model



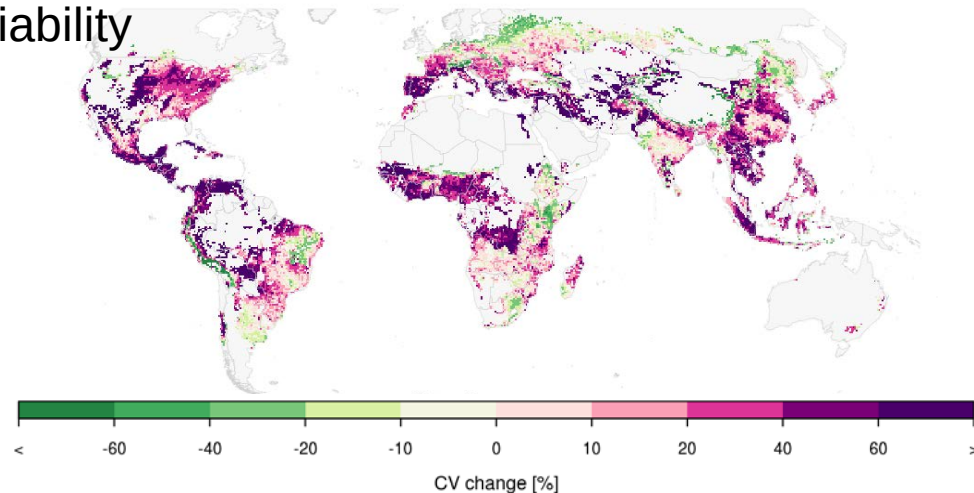
## Active Phase 3: Data submission stage

- first set of model submission available
- remake of fast track with improved data and improved and more models
- broader set of output variables
  - **green background**: quality checked with  QC tool
  - **red background**: QC failed
  - **blue background**: new teams
  - numbers refer to GCMs: 1: UKESM1-0-LL; 2: MRI-ESM2-0; 3: MPI-ESM1-2-HR; 4: IPSL-CM6A-LR; 5: GFDL-ESMA

| #  | GGCM                     | historical | picontrol | ssp126    | ssp370    | ssp585    | crops                               |
|----|--------------------------|------------|-----------|-----------|-----------|-----------|-------------------------------------|
| 1  | ACEA Phase 3             | 1,2        | 1,2       | 1,2       |           | 1,2       | mai,ri1,ri2,soy,swh,wwh             |
| 2  | CROVER Phase 3           | 1,2,3,4,5  | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | mai,ri1,soy,swh,wwh                 |
| 3  | CYGMA Phase 3            | 1,2,3,4,5  | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | mai,mil,ri1,ri2,sor,soy,swh         |
| 4  | DSSAT-Pythia Phase 3     | 2,3,4,5    |           | 2,3,4,5   |           | 2,3,4,5   | mai,swh,wwh                         |
| 5  | EPIC-IIASA Phase 3       | 1,2,3,4,5  | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | mai,ri1,ri2,soy,swh,wwh             |
| 6  | ISAM Phase3              | 1,2,3,4,5  | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | mai,ri1,ri2,soy,swh,wwh             |
| 7  | LandscapeDNDC Phase 3    | 1,2,3,4,5  | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | mai,ri1,ri2,soy,swh,wwh             |
| 8  | LPJ-GUESS Phase 3        | 1,2,3,4,5  | 1,2,3,4,5 | 1,2,3,4,5 |           | 1,2,3,4,5 | bea,mai,mil,ri1,ri2,sor,soy,swh,wwh |
| 9  | LPJmL Phase 3            | 1,2,3,4,5  | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | mai,ri1,ri2,soy,swh,wwh             |
| 10 | PEPIC Phase 3            | 1,2,3,4,5  | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | 1,2,3,4,5 | mai,ri1,ri2,soy,swh,wwh             |
| 11 | pDSSAT Phase 3           | 1,2,3,4,5  |           | 1,2,3,4,5 |           | 1,2,3,4,5 | mai,ri1,ri2,soy,swh,wwh             |
| 12 | PROMET Phase 3           | 1,2,3,4,5  | 1,2,3,4,5 | 1,2,3,4,5 |           | 1,2,3,4,5 | mai,ri1,soy,swh,wwh                 |
| 13 | SIMPLACE-LINTUL5 Phase 3 | 1,2,3,4,5  | 1,2,3     | 1,2,3,4,5 |           | 1,2,3,4,5 | mai,soy, sor,swh,pot,wwh            |

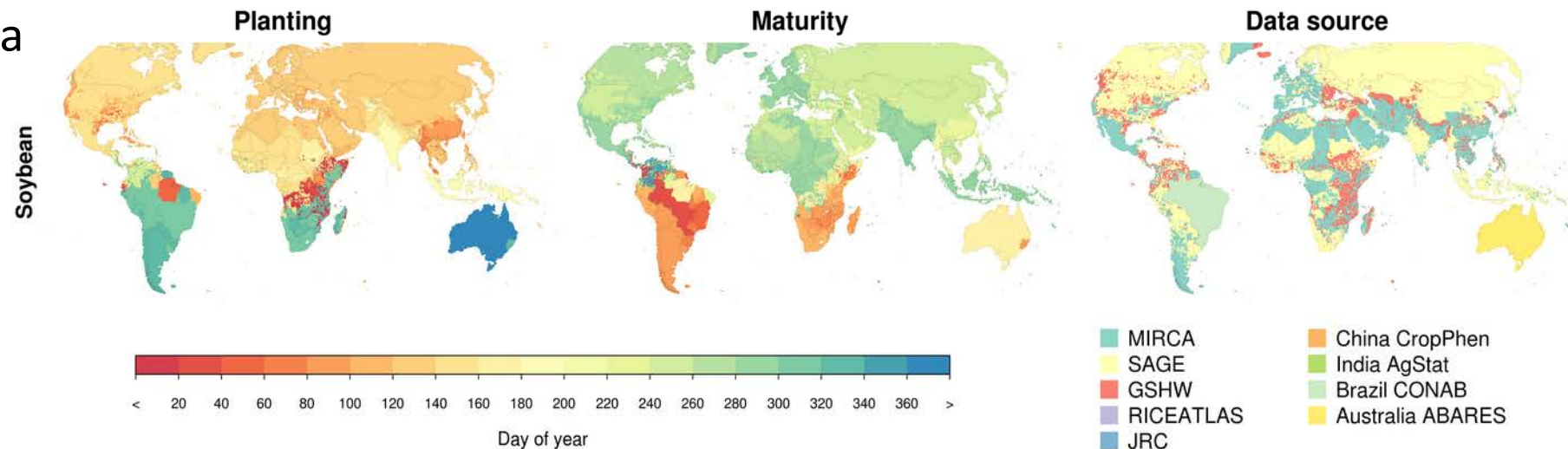


changes in year-to-year  
variability



# Active Phases: How to get involved

- run your model and submit data
- design side activities building on existing protocols
- take published (or latest) data and do your analyses with it
  - We are very much open to support!
- global sims are combined regional sims or are they?
- data collection correction
  - management, data
  - reference data



# 10-year project track record



GGCMI Team

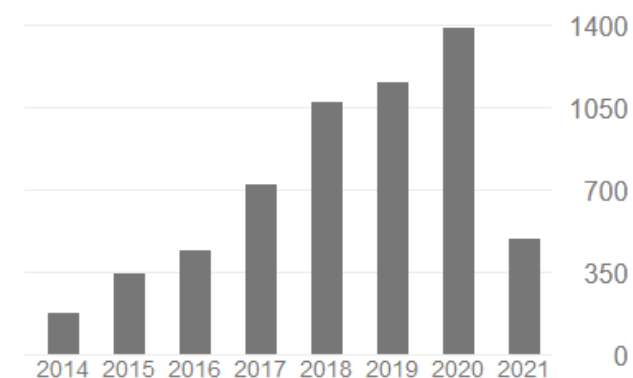
FOLLOW

28 modeling teams and counting  
49 publications and counting (see [here](#))  
142 data sets published on [zenodo.org](#)  
9 team events

| TITLE                                                                                                                                                                                                                                                                             | CITED BY | YEAR |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|------|
| <b>Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison</b><br>C Rosenzweig, J Elliott, D Deryng, AC Ruane, C Müller, A Arnoeth, ...<br>Proceedings of the National Academy of Sciences 111 (9), 3268-3273           | 1469     | 2014 |
| <b>Constraints and potentials of future irrigation water availability on agricultural production under climate change</b><br>J Elliott, D Deryng, C Müller, K Frieler, M Konzmann, D Gerten, M Glotter, ...<br>Proceedings of the National Academy of Sciences 111 (9), 3239-3244 | 695      | 2014 |
| <b>Temperature increase reduces global yields of major crops in four independent estimates</b><br>C Zhao, B Liu, S Piao, X Wang, DB Lobell, Y Huang, M Huang, Y Yao, ...<br>Proceedings of the National Academy of Sciences 114 (35), 9326-9331                                   | 654      | 2017 |
| <b>Climate change effects on agriculture: Economic responses to biophysical shocks</b><br>GC Nelson, H Valin, RD Sands, P Havlík, H Ahammad, D Deryng, J Elliott, ...<br>Proceedings of the National Academy of Sciences 111 (9), 3274-3279                                       | 550      | 2014 |

Cited by

|           | All  | Since 2016 |
|-----------|------|------------|
| Citations | 5862 | 5296       |
| h-index   | 26   | 26         |
| i10-index | 36   | 36         |

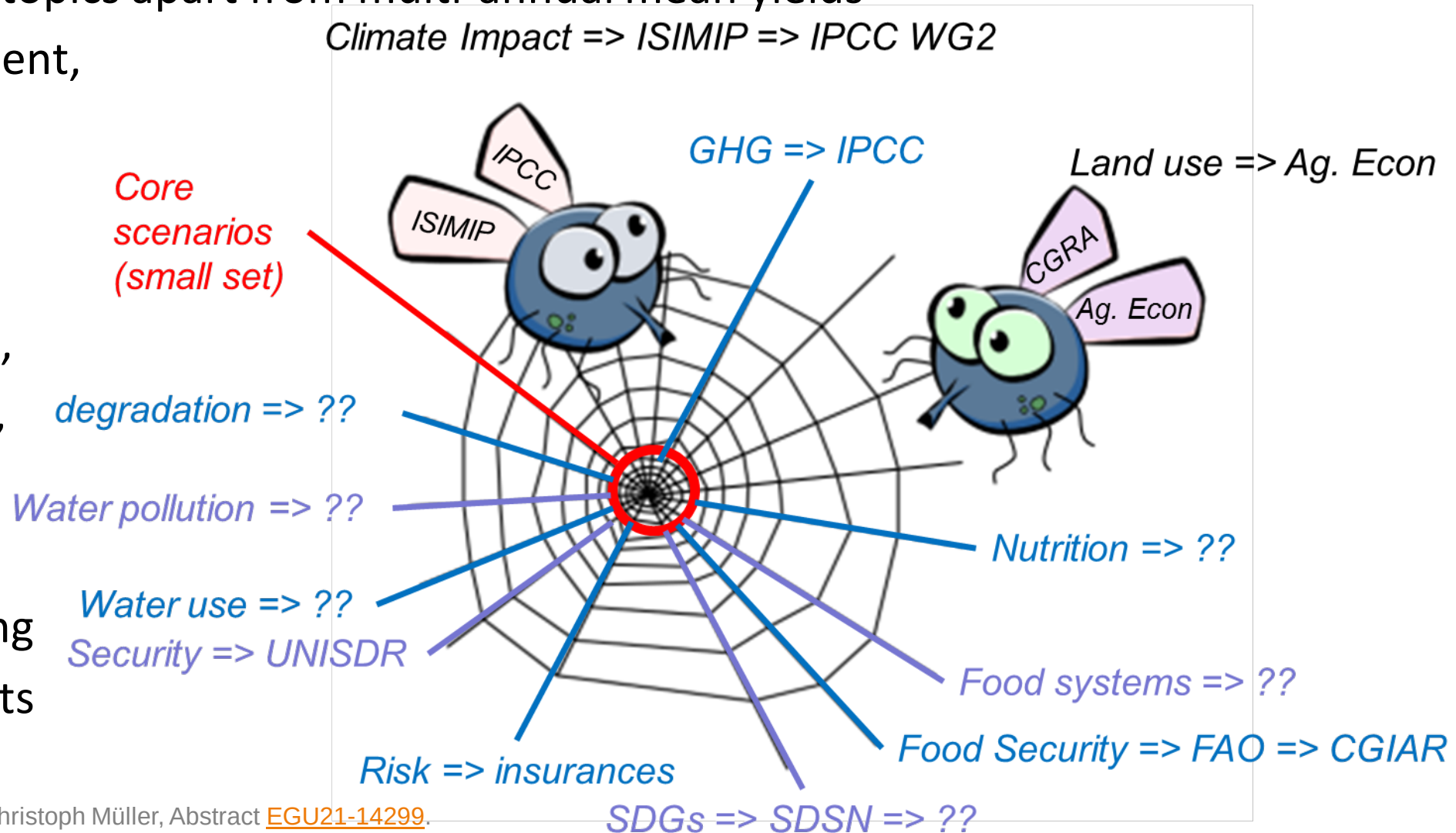


# The future is full of opportunities

additional research topics apart from multi-annual mean yields

- role of management,
- adaptation,
- variability,
- nutrition,
- water limitations,
- biogeochemistry,
- ...

model understanding  
model improvements



# Thanks and invite

- Thanks to all GGCM participants and data suppliers
- Come and join, Phase 3 (improved remake of the ISIMIP fast track in 2012) just starting
  - <https://agmip.org/ag-grid-2/>
  - <https://www.isimip.org/>
- We provide access to a very large data set on crop yields, input data and secondary outputs to help with your own analysis



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