AgMIP The Agricultural Model Intercomparison and Improvement Project

# Impacts, Adaptation, and Vulnerability Models for Agriculture and Land

   


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Energy Modeling Forum, Snowmass, Colorado, USA

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Goddard Institute for Space Studies
New York, N.Y.

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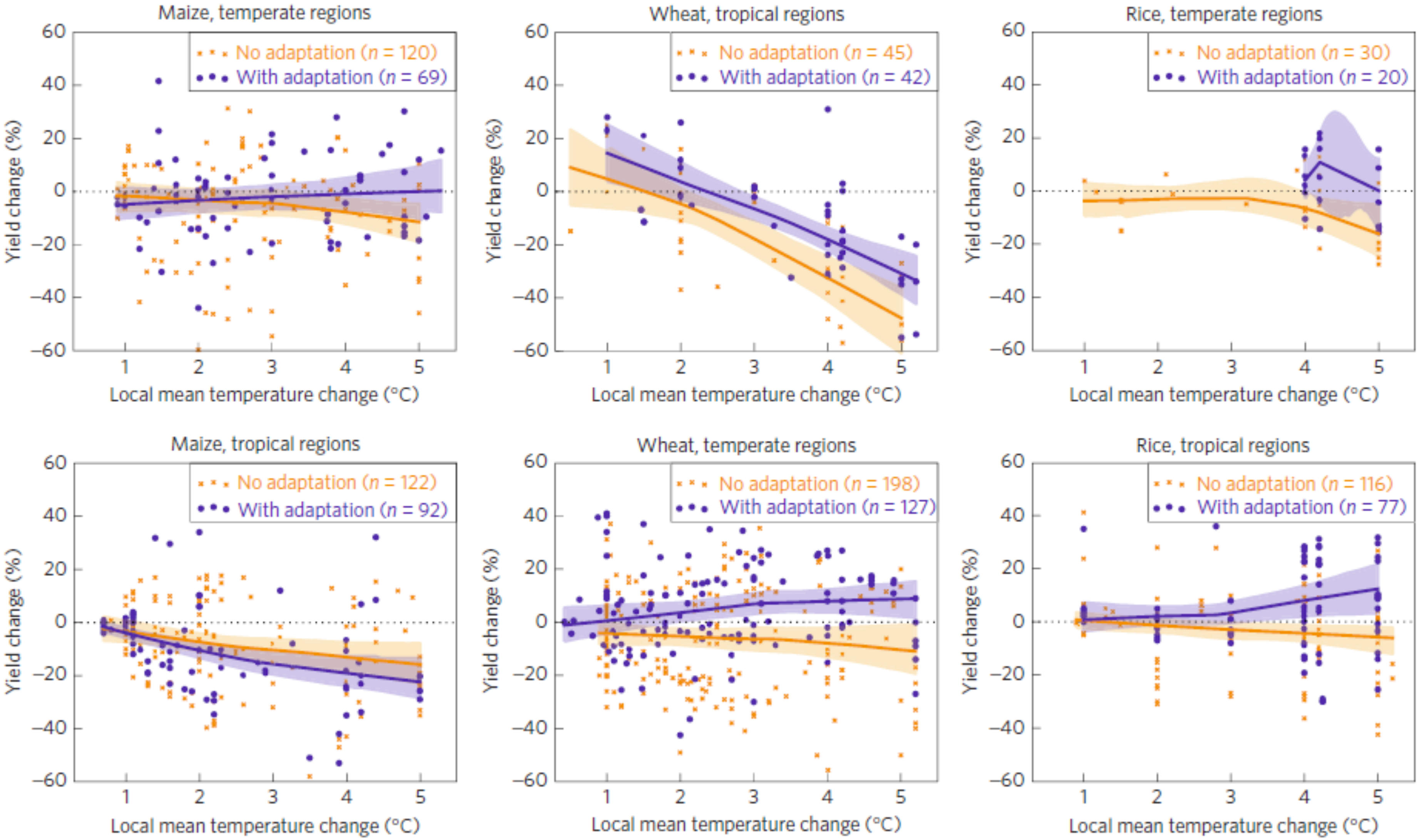
# Systematic Approach Needed for Agricultural Modeling

Meta-analysis by Challinor et al.




Difficult to make sense out of incredibly diverse studies

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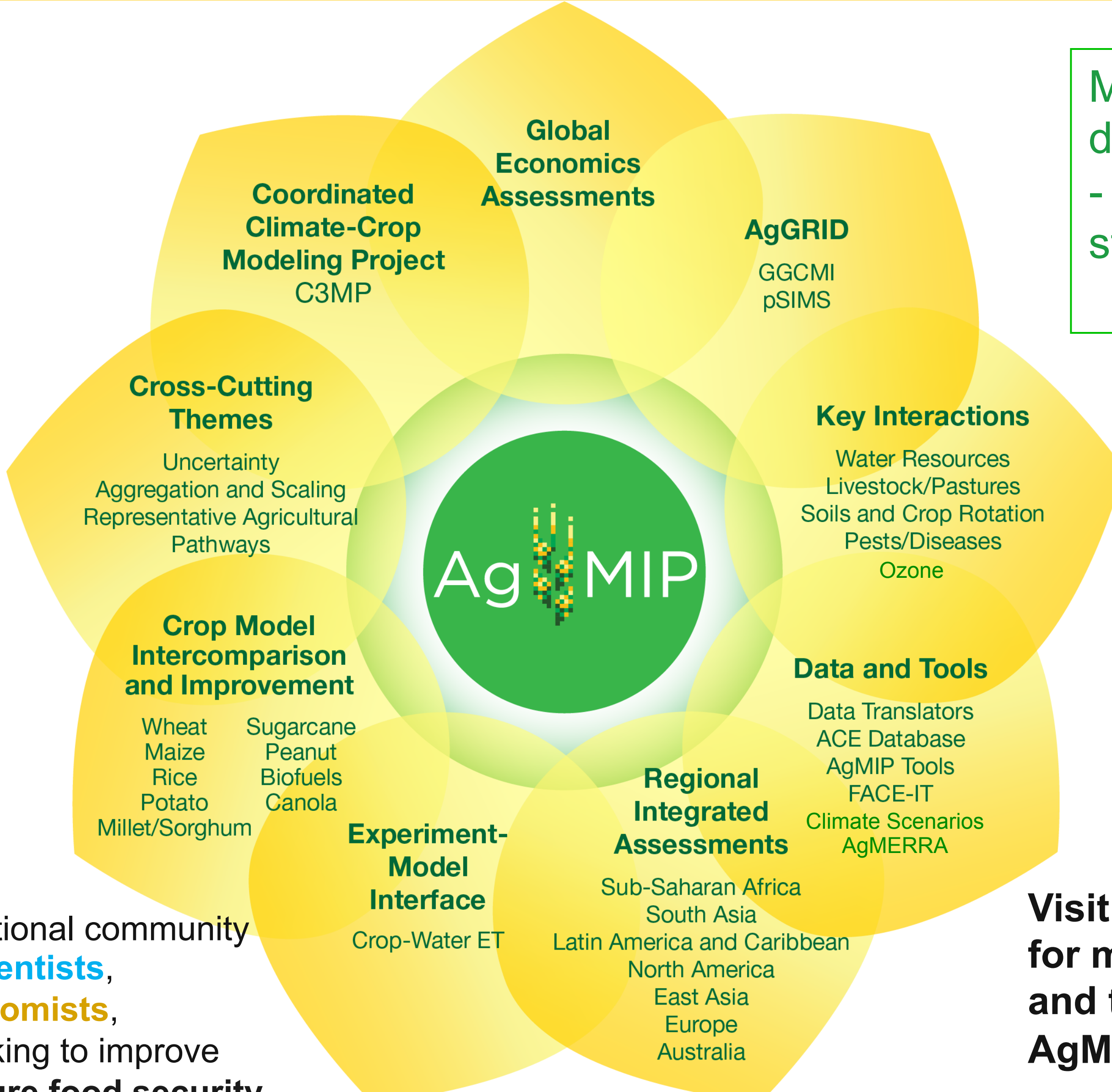
# Current AgMIP Activities




Modelers have different paths:
- inform IAMs
- stand-alone assessments

AgMIP is an international community of 850+ **climate scientists**, **agronomists**, **economists**, and **IT experts** working to improve assessments of **future food security**

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# Modeling Global Agricultural Production

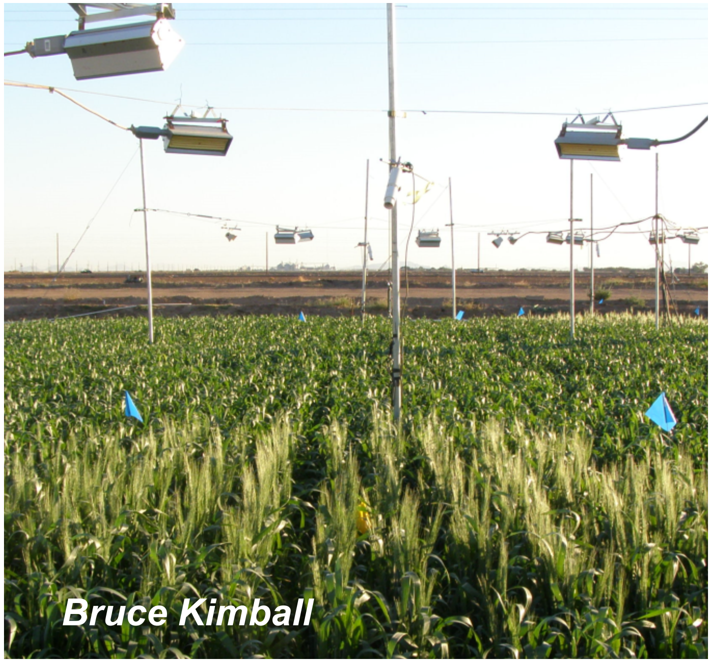
## Point-based model development

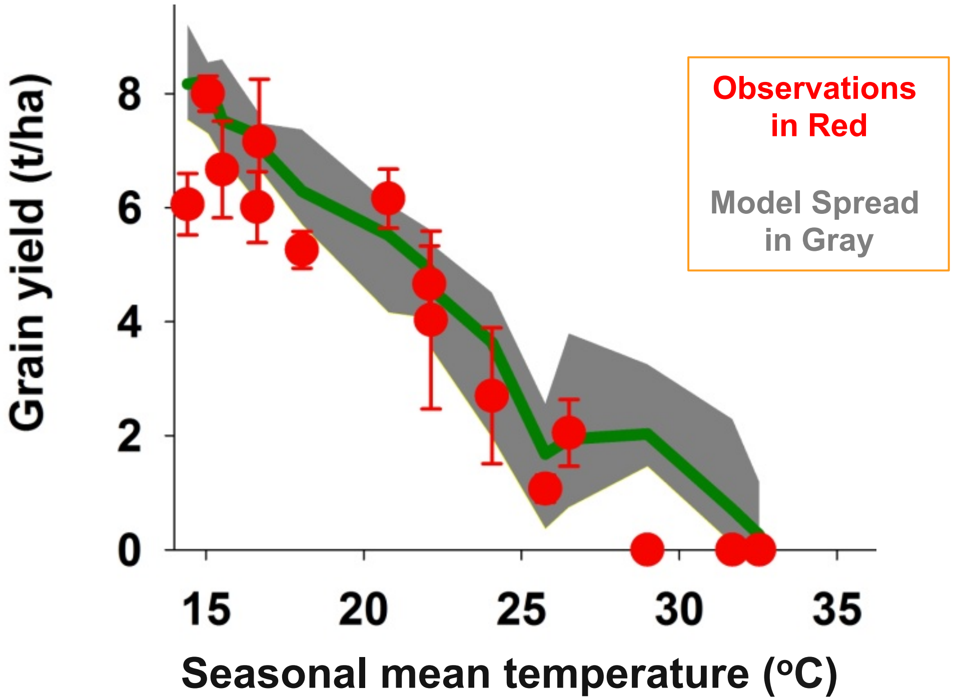
# Wheat response to temperature extremes

Asseng et al., 2014; Nature Climate Change

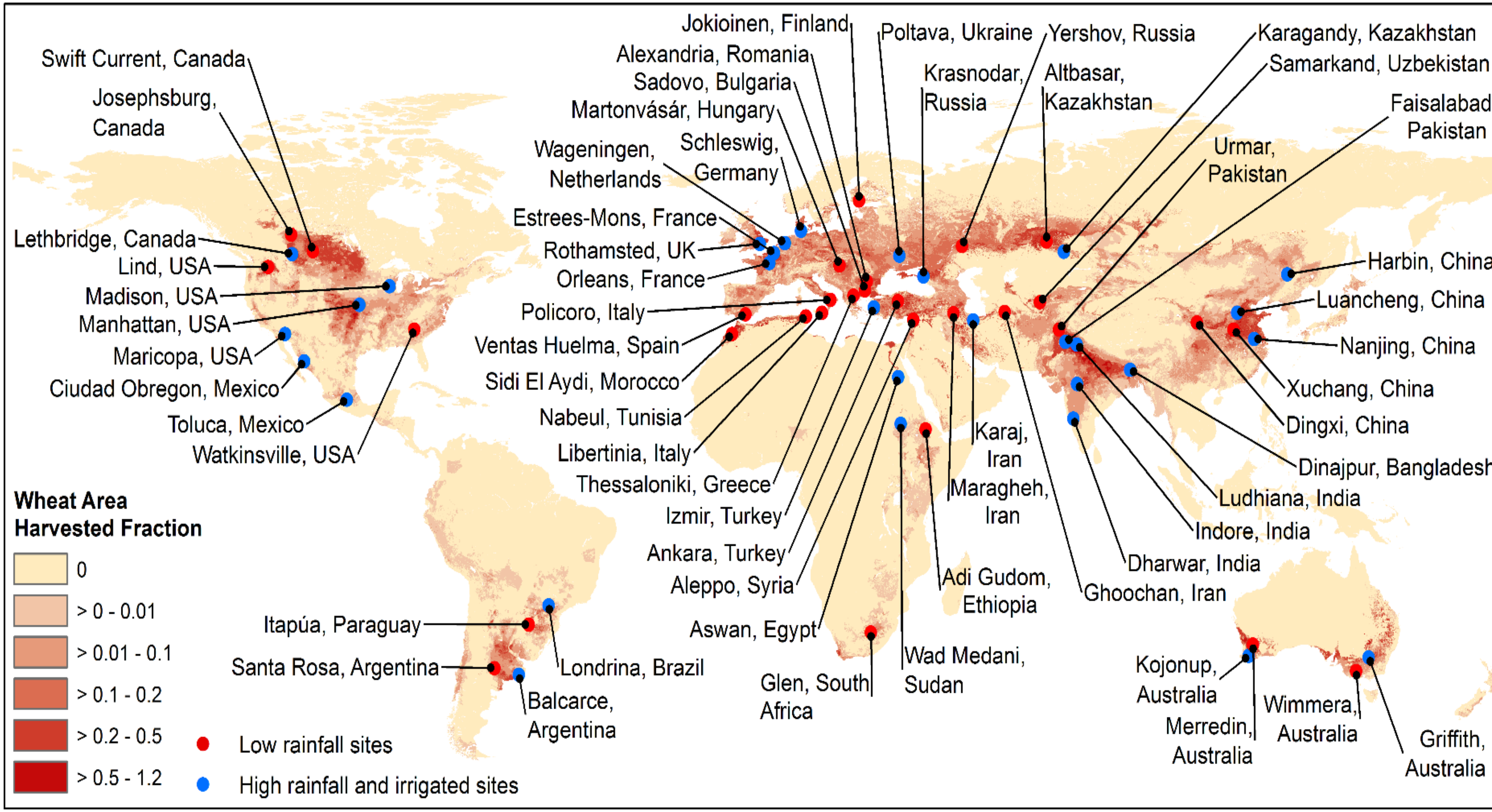
**The AgMIP Wheat Team compared 30+ wheat models against field trial data from the Hot Serial Cereals experiment in Maricopa, Arizona**

**Also examined CIMMYT trials of heat extremes.**



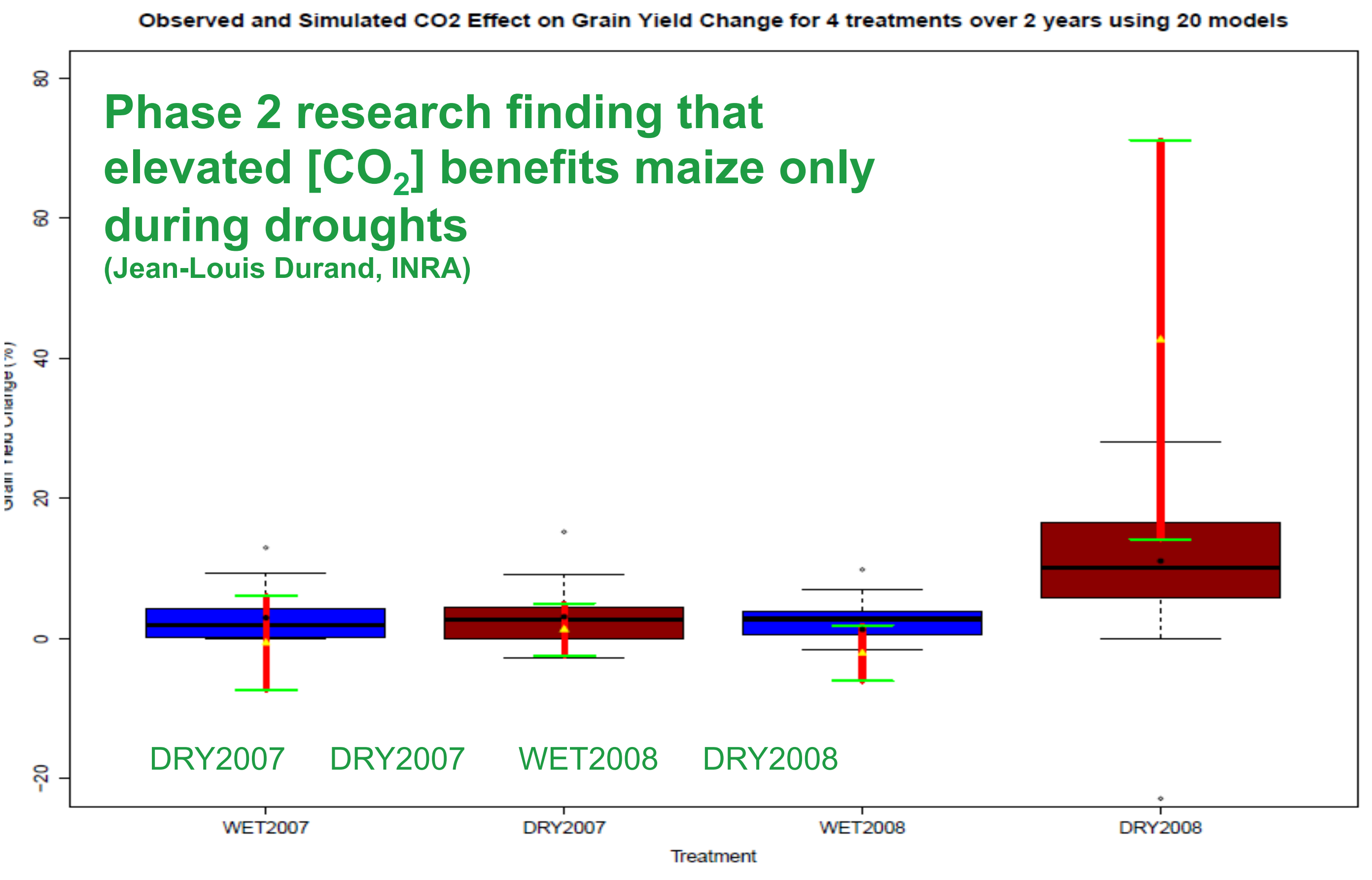



# Representative Networks for Multi-model Analysis




**Sites where 34 Wheat Models have been configured for analysis by the AgMIP Wheat Team Phase 3 (Senthold Asseng, Frank Ewert, Pierre Martre, et al.)**

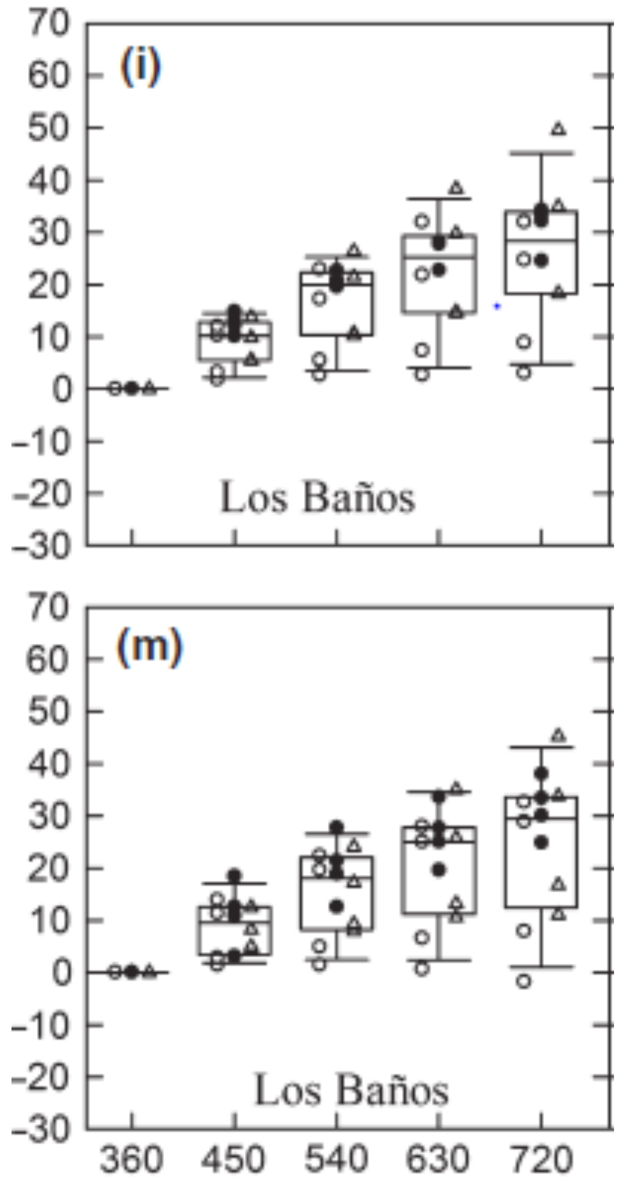
# AgMIP Maize Team Responses



# AgMIP Rice Team

**13 Rice Models run in various scenarios of temperature increase**

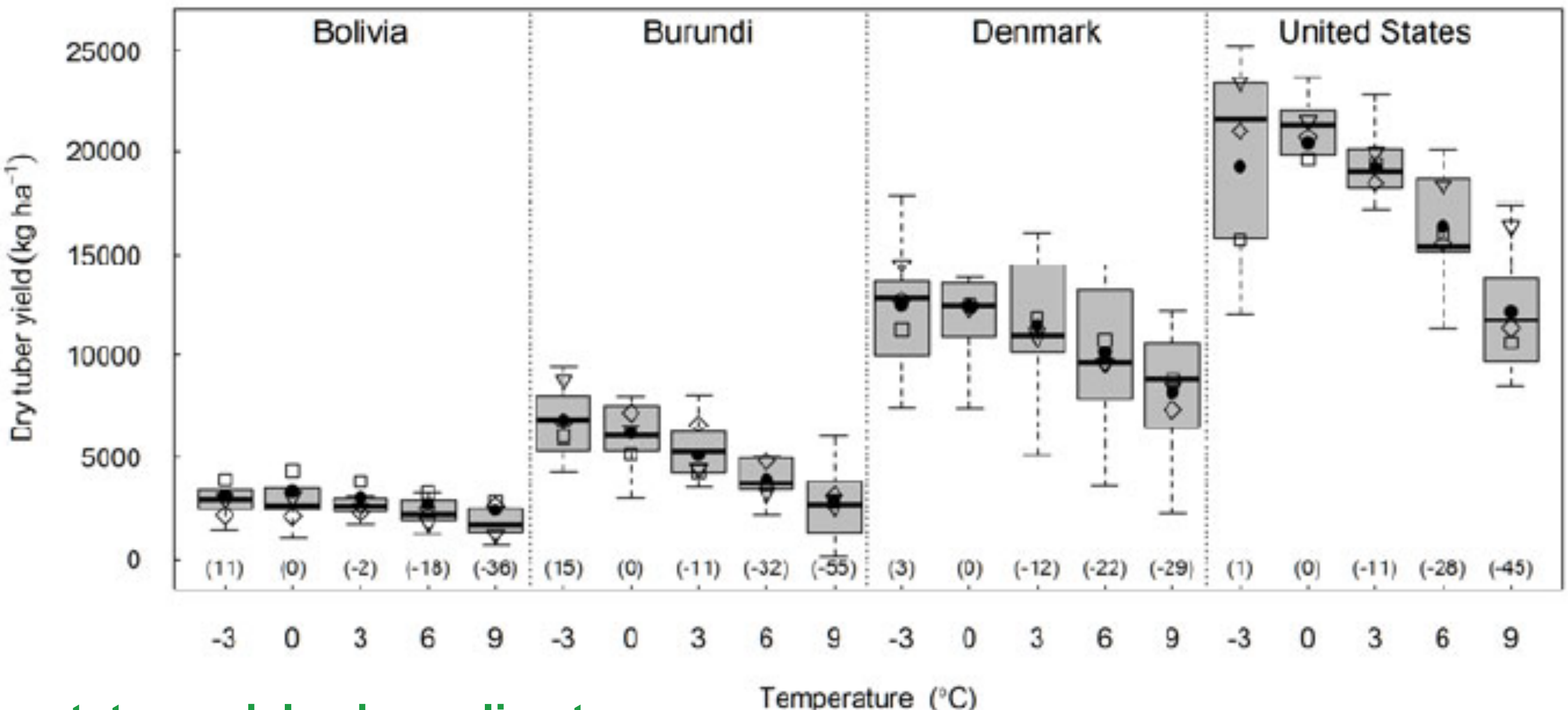
- Non-linear interactions between temperature and carbon dioxide concentration changes




**[$CO_2$] response at current temperatures**

**[$CO_2$] response with +3 °C warming**

## Potato Yield Responses to Increasing Temperature




**8 potato models show climate responses in diverse systems (and related uncertainties)**

# Modeling Global Agricultural Production

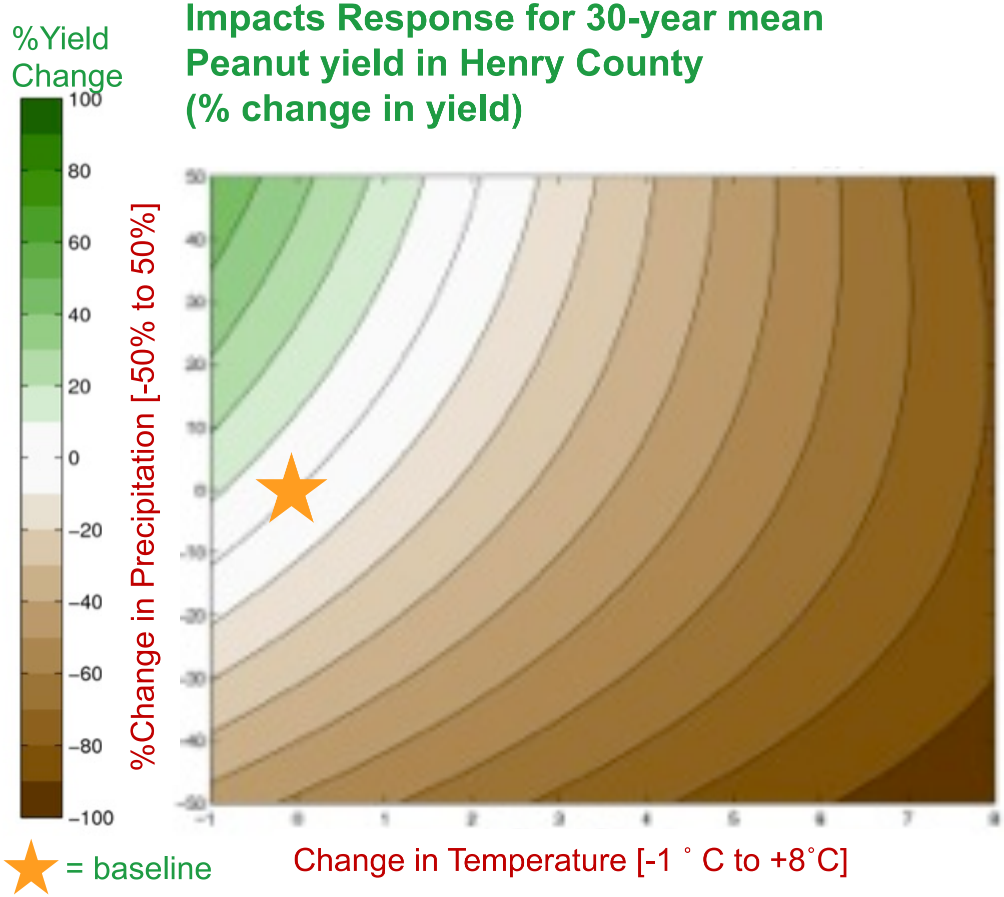
## Developing Agricultural Response Surfaces

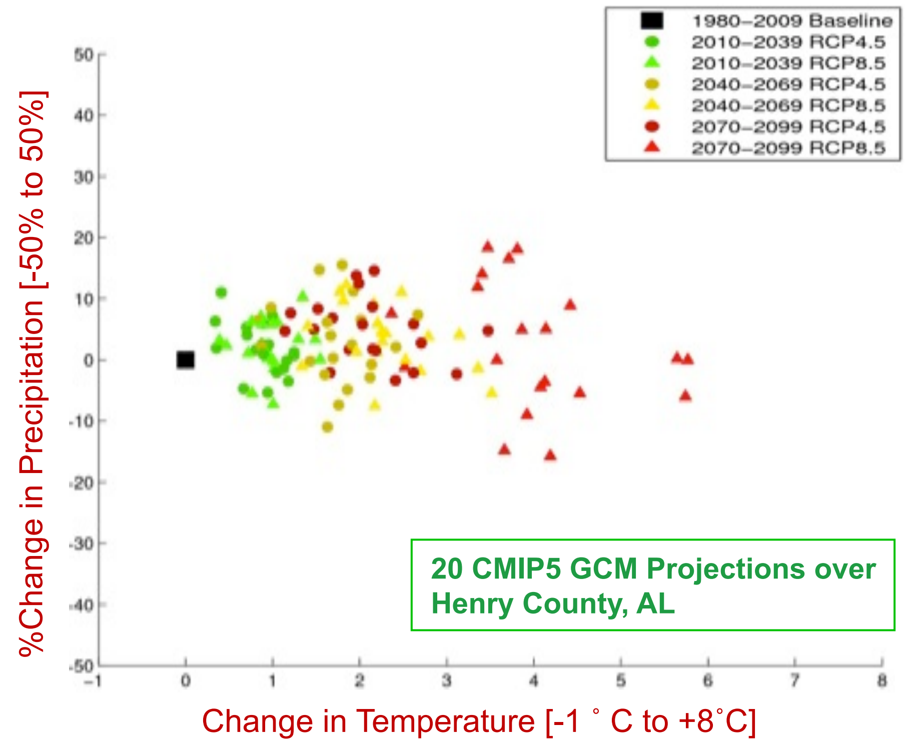
# Impacts Response Surface Analysis
## Focus on understanding key responses

**Left: Cross Sections of Emulated Impacts Response for 30-year mean Peanut yield in Henry County (% change in yield)**

**Right: 20 CMIP5 GCM ΔT and Δ P projections over Henry County, AL; 2 RCPs and 3 time slices**

From Ruane et al., 2014



# Sites included in AgMIP's Coordinated Climate-Crop Modeling Project

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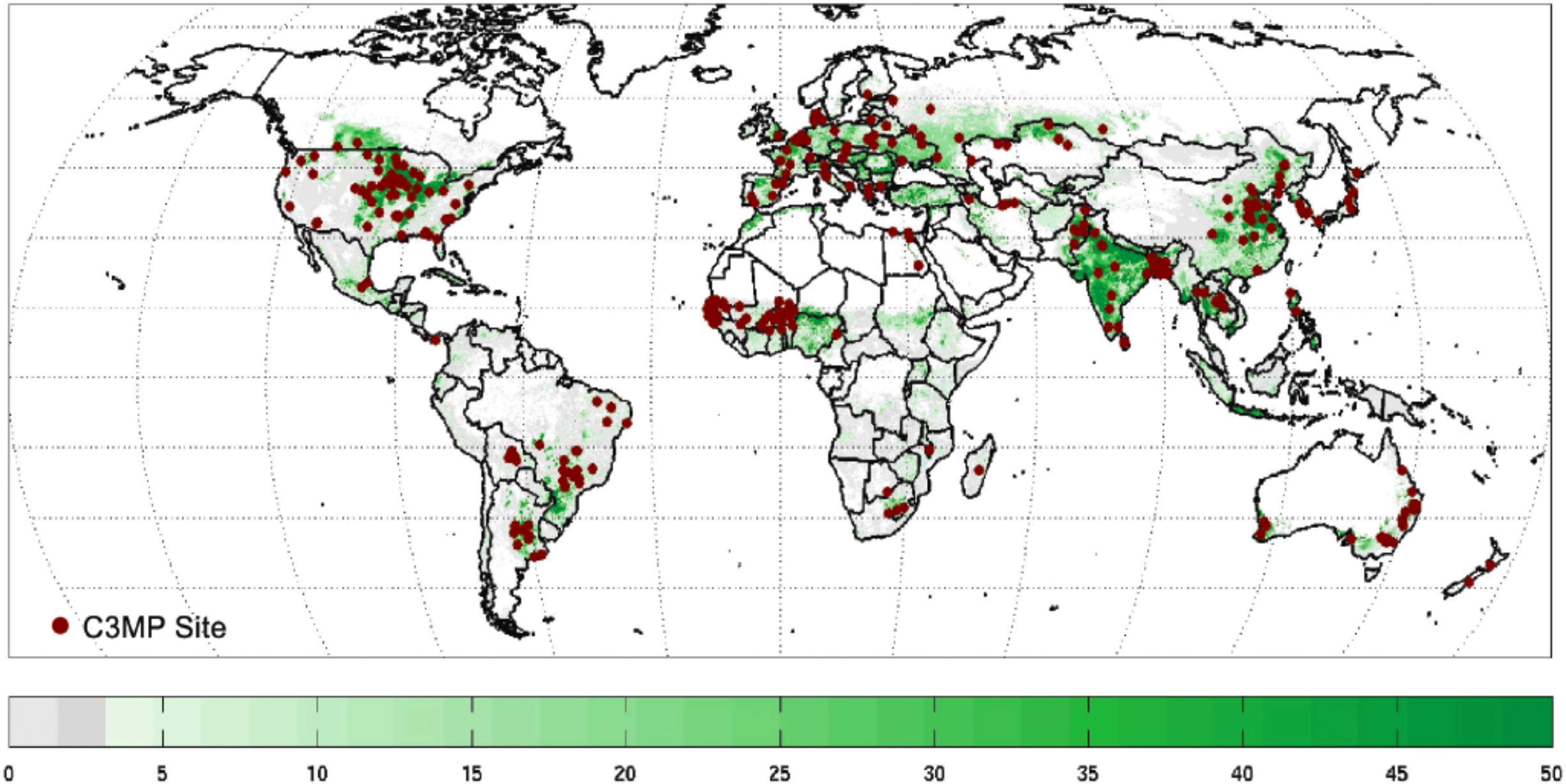
## All C3MP Submitted Sites and Major Croplands (Percentage Area)




**C3MP submitted site (1137 sites as of August, 2015)**

Green = fractional crop land area data from Monfreda et al. (2008)

From McDermid et al., 2015

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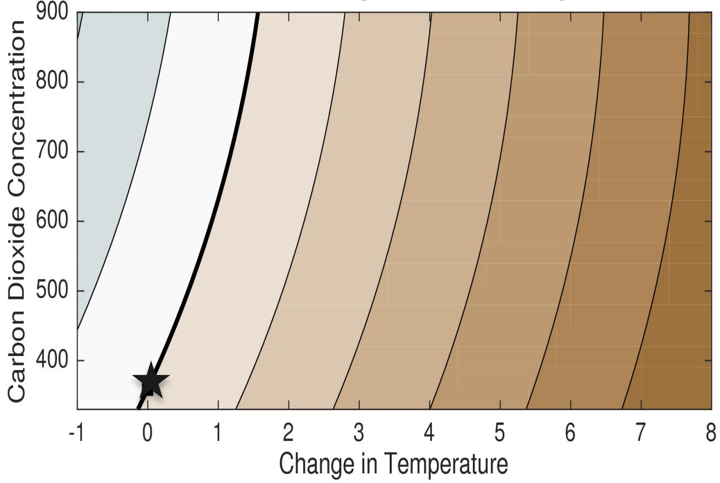
# Crop responses vary by species

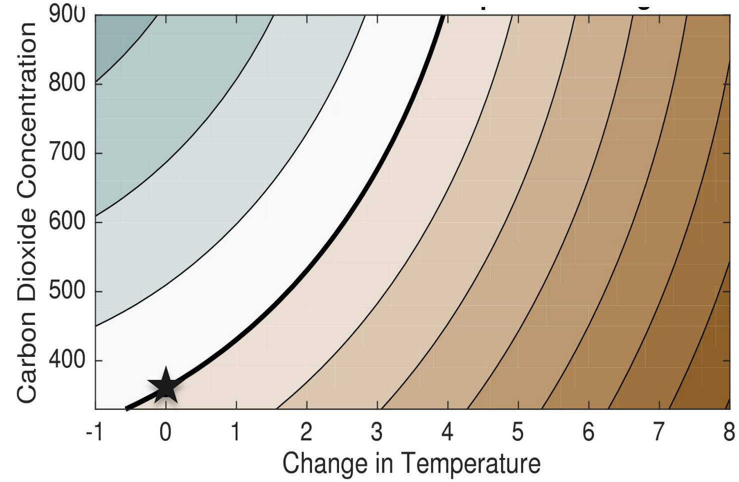
$[CO_2]$

ΔT

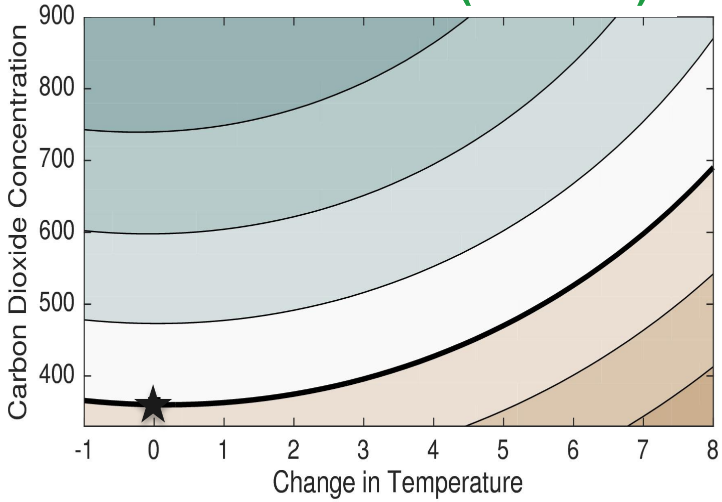
## Maize (135 sets)



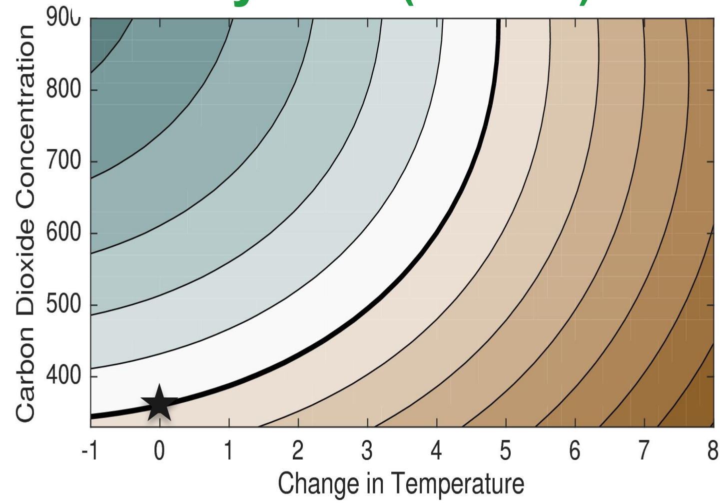

## Rice (48 sets)




## Winter Wheat (75 sets)



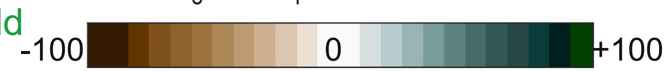

## Soybean (92 sets)



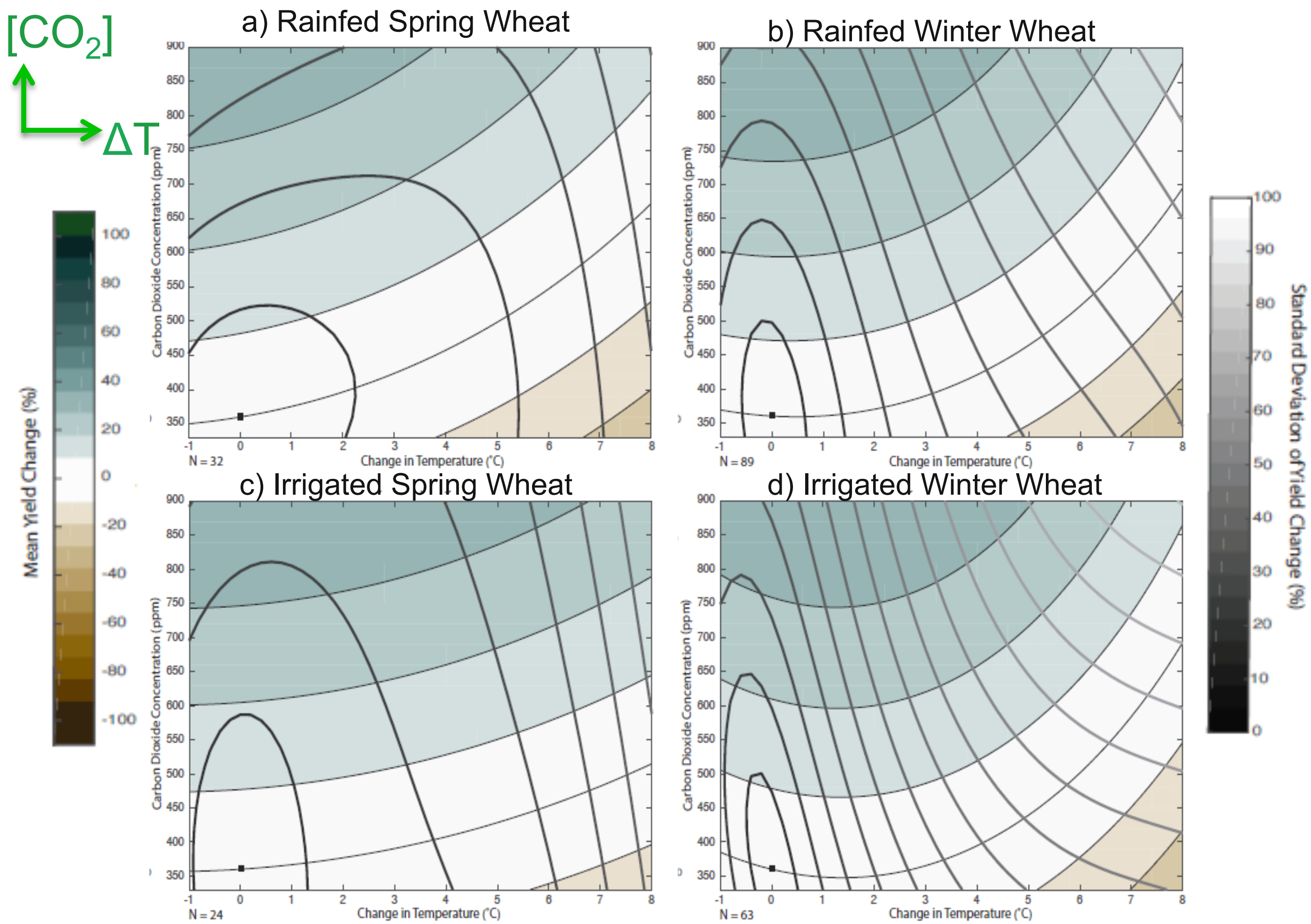

Note: Rain-fed results shown for all species

Preliminary results from C3MP; Mavromatis et al. (forthcoming)

Mean yield %change



# C3MP Mean Wheat Yield
# Differential responses and uncertainty




**Mean Yield response from spring and winter wheat sites around the world**

Colors = emulated mean yield %changes

Gray contours = uncertainty (lighter is more uncertain)

**Differences from:** Models, management, soils, cultivar, current climate



From Mavromatis et al., forthcoming

# Impacts Response Surface analysis

Extremes change differently than average year

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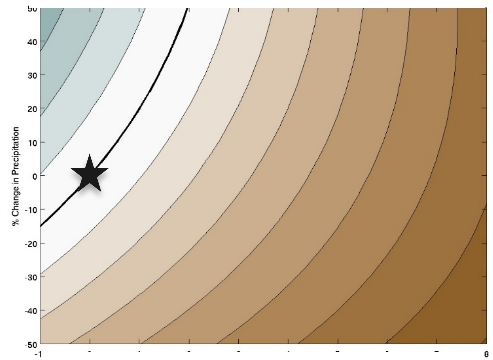
**Response of 126 C3MP Rainfed Maize Sites to:**

**ΔP**

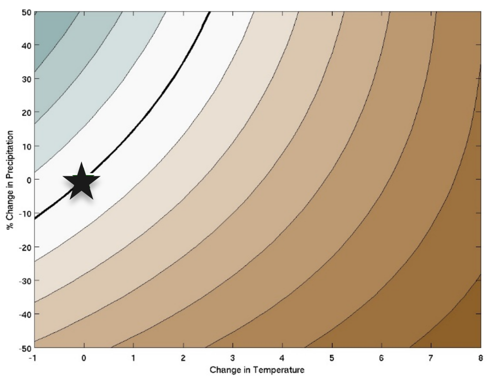
**ΔT**

$[CO_2]$ = 360ppm

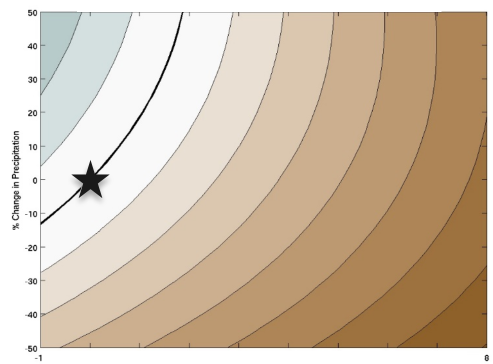
**Warmest 3 years**



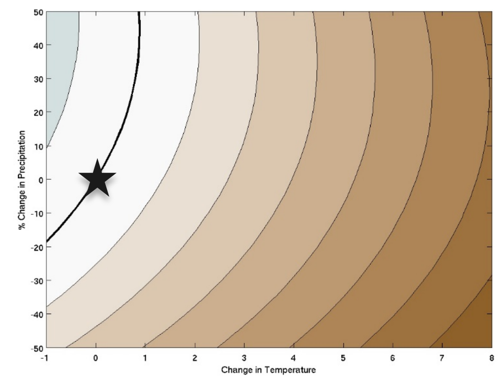

**Driest 3 years**



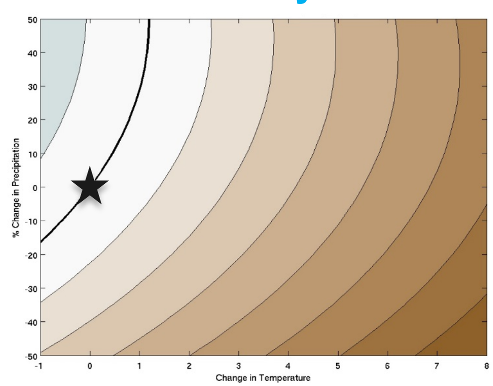

**All Years**



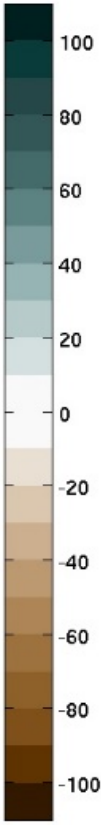

**Wettest 3 years**




**Coolest 3 years**



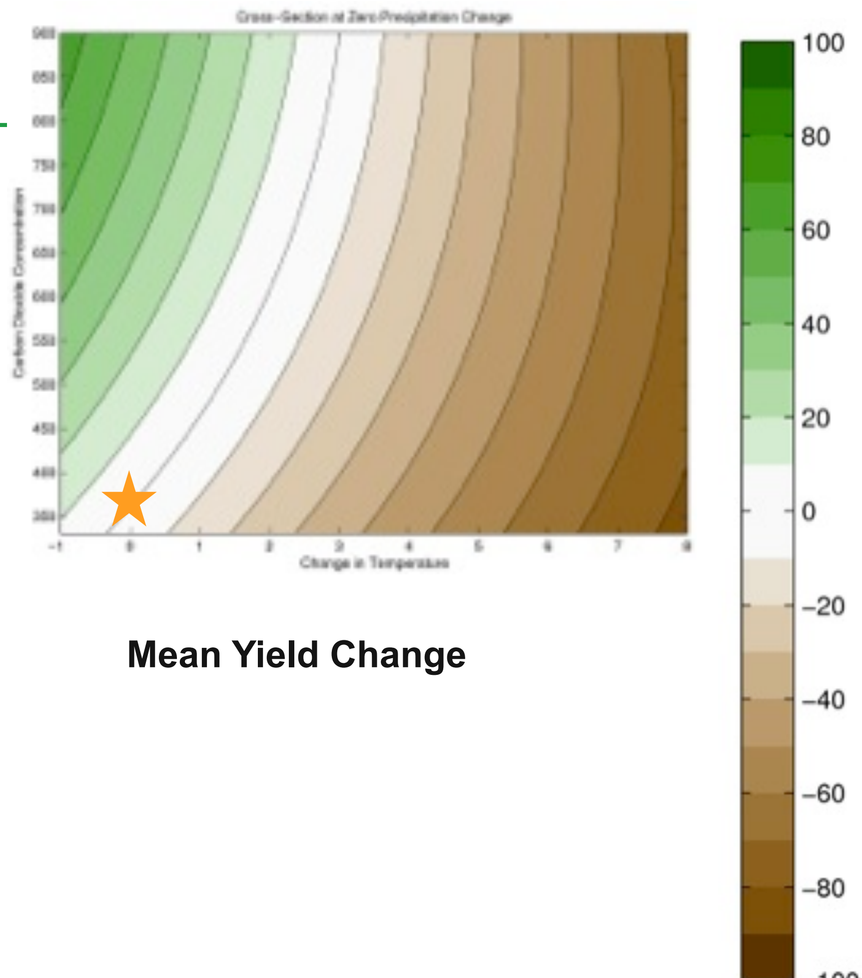

Yield Change (% of baseline mean)



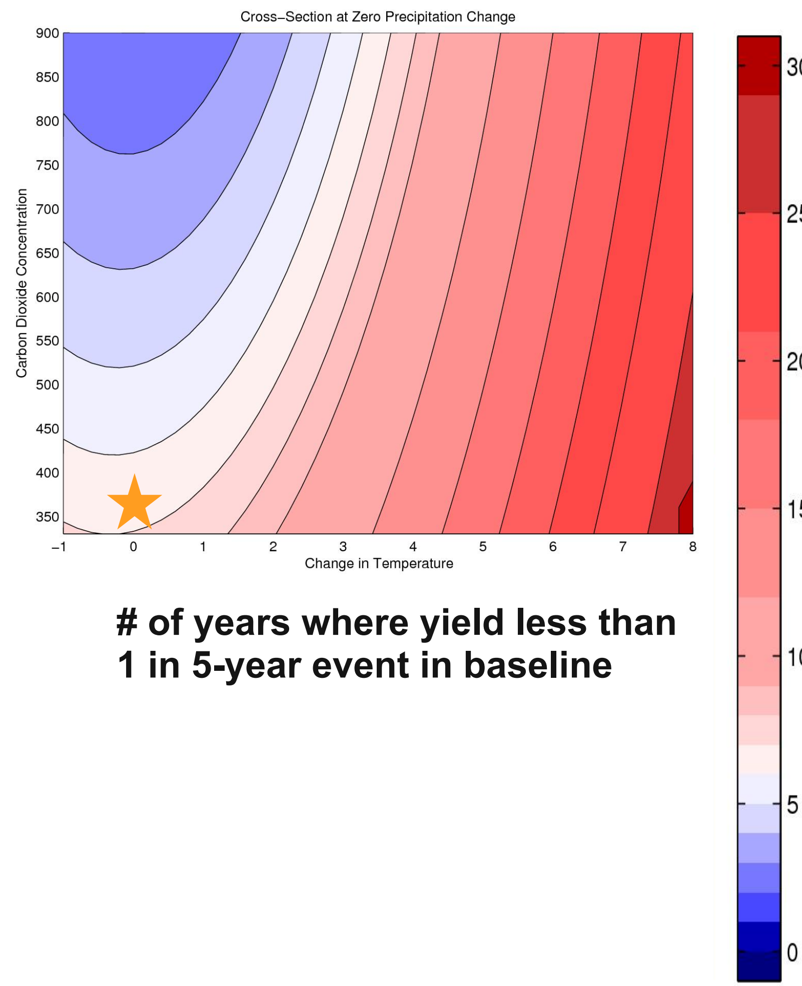

Preliminary Results from Ruane et al., in preparation

# Impacts Response Surface Analysis
## Focus on Frequency of Extreme Years

$[CO_2]$ ↑ → $\Delta T$




**Mean Yield Change**



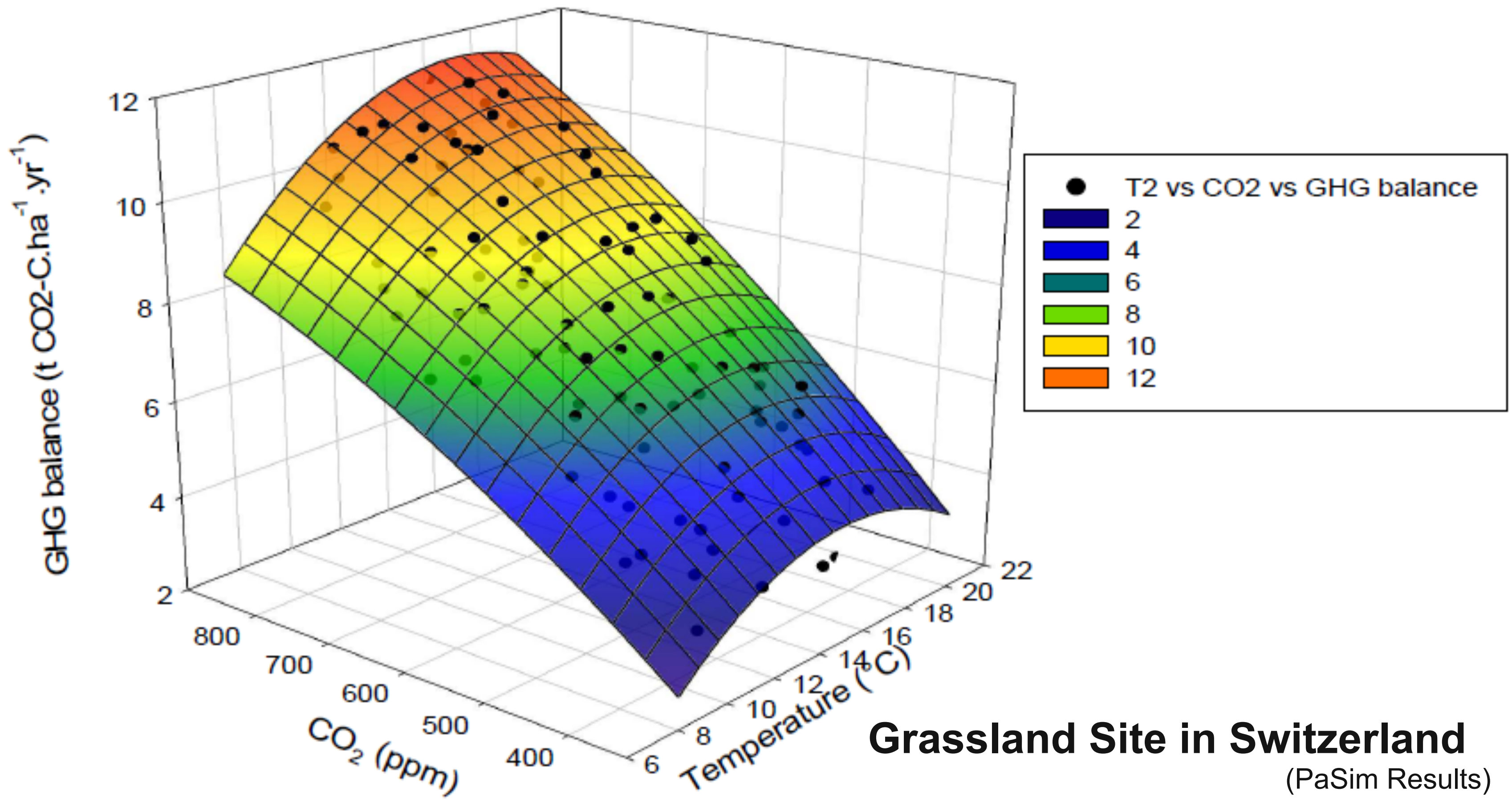

**# of years where yield less than 1 in 5-year event in baseline**

Henry County, Alabama, USA, Peanuts

★ = baseline

**T * C * GHG balance at field scale;**

Precipitation baseline = 1149.70 mm (mean value from 30 years climate data – 1980-2009)




**Grassland Site in Switzerland**

(PaSim Results)

Thanks to:
Raphaël Martin, Katja Klumpp, Gianni Bellocchi, Jean-Francois Soussana, and Fiona Ehrhardt

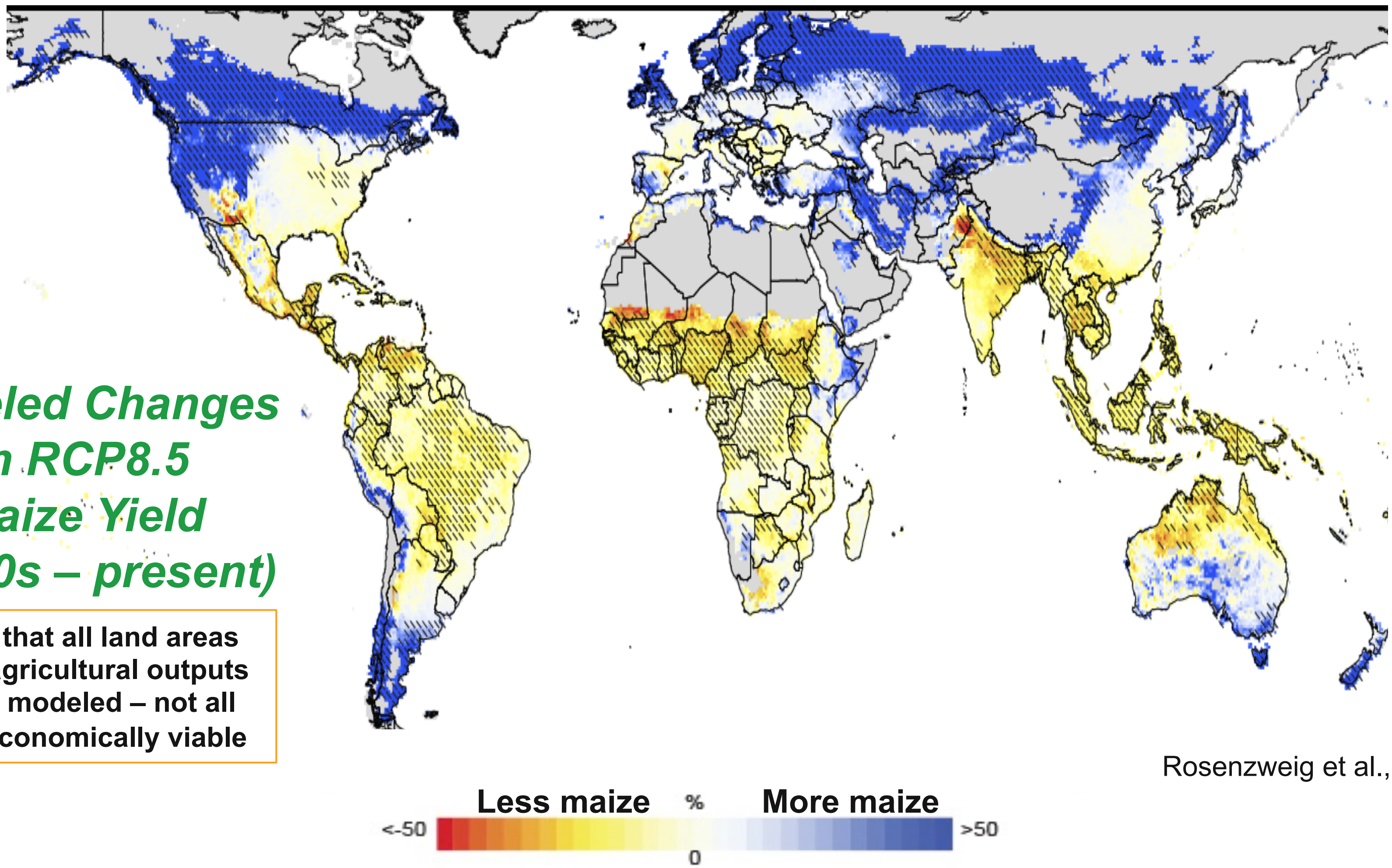
# Modeling Global Agricultural Production

## Global Gridded Agricultural Models

# Ensemble Results Allow Metrics of Uncertainty

***Modeled Changes in RCP8.5 Maize Yield (2080s – present)***

**Note that all land areas with agricultural outputs were modeled – not all are economically viable**




Rosenzweig et al., 2013

5 GCMs, 7 GGCMs; hatched = 70% agreement in sign of change

# AgMIP/ISI-MIP Global Gridded Crop Model (GGCM) Assessment

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**Response in leading food-producing units:**

- Geospatial differences
- Non-linear
- No grace period
- Persisting Uncertainties

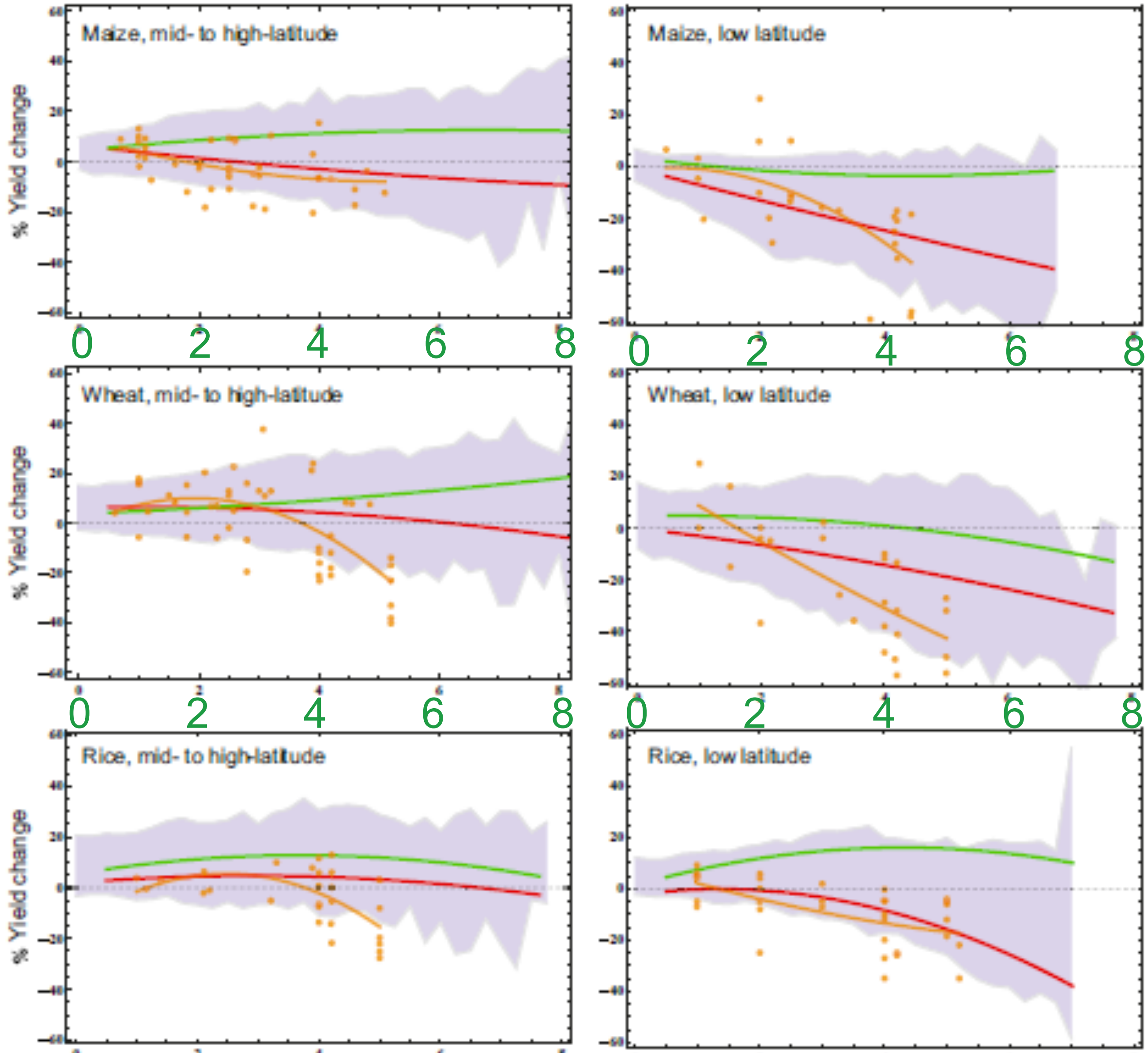
*Note that models differ:*

*- Vegetation models*

*- Crop models*

*- Models coupled to ESMs*

**Yield Change vs. local temperature change**
**Green = Models without N limitations**
**Red = Models with N limitations**
**Orange = Meta-analysis from IPCC AR4**

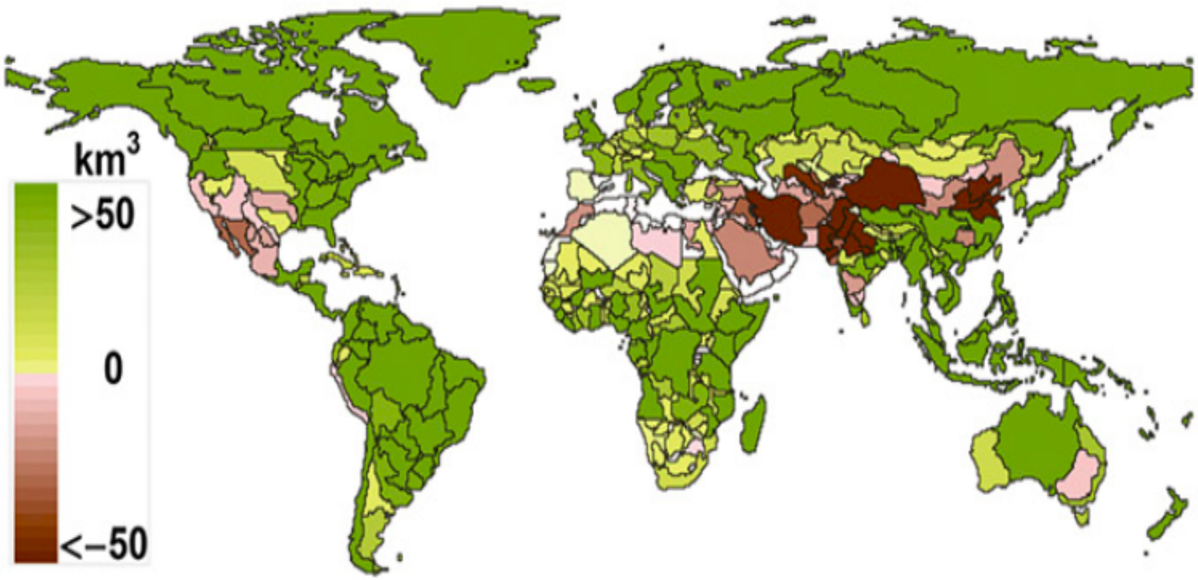


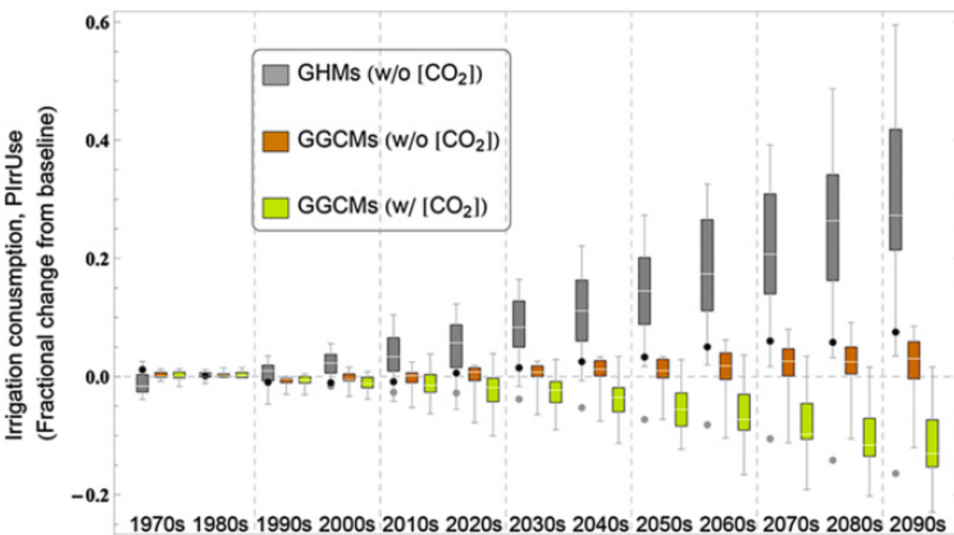

Rosenzweig et al., 2013

# AgMIP/ISI-MIP Global Gridded

## Irrigation differs from Water/Ag perspective

**Right**: Median abundance or deficit of irrigation water using existing irrigated lands at end of 21st Century (RCP8.5)




**Left**: Irrigation consumption depends on modeled sector and CO2 effects

Elliott et al., 2014

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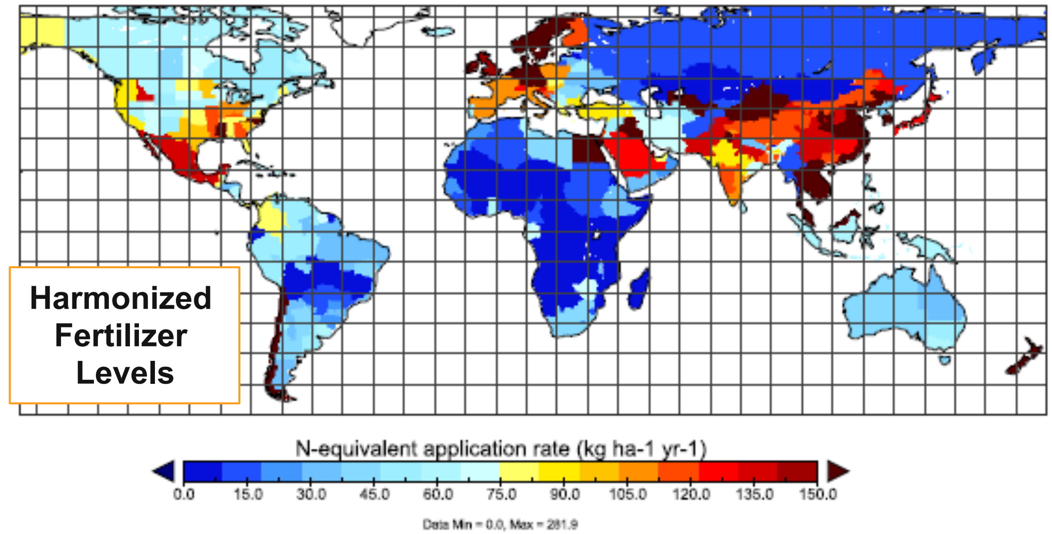
# New efforts to harmonize and validate GGCMs

Elliott et al., 2015 (GMD)

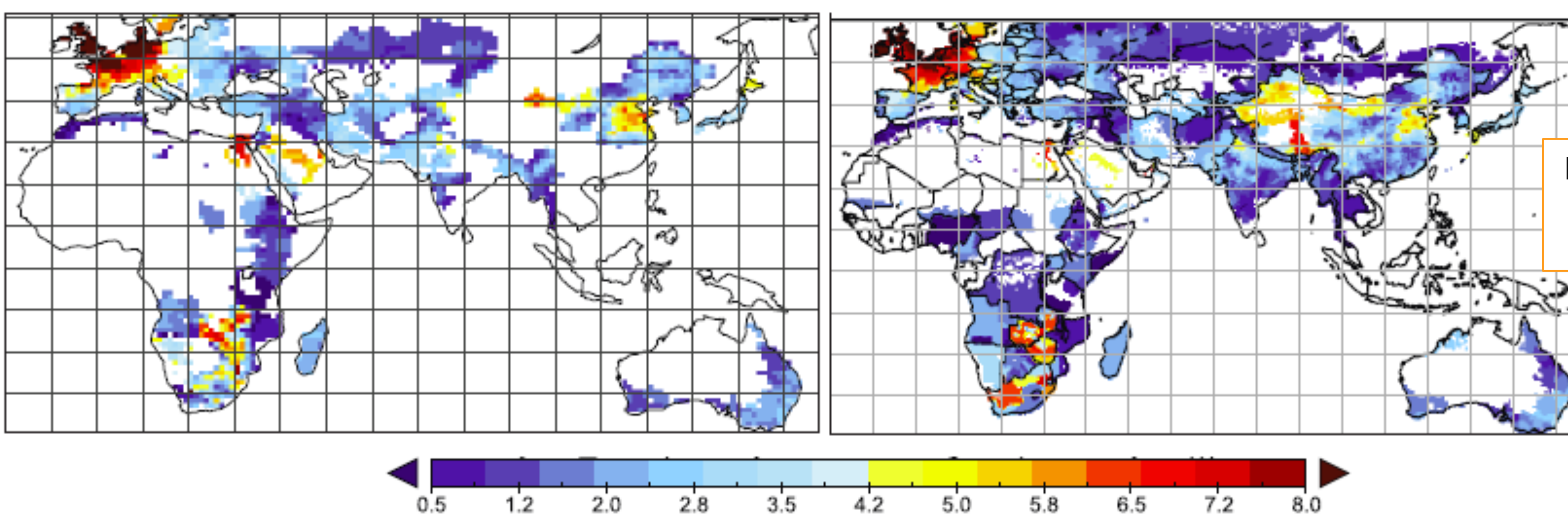
Deliberate approach to model evaluation, validation, and intercomparison in historical period climate.

- 9 climate datasets
- 21 GGCMs
- Standardized simulation protocols
- Coordinated data analysis




A) Wheat Yield – Iizumi et al. 2013 (t/ha)

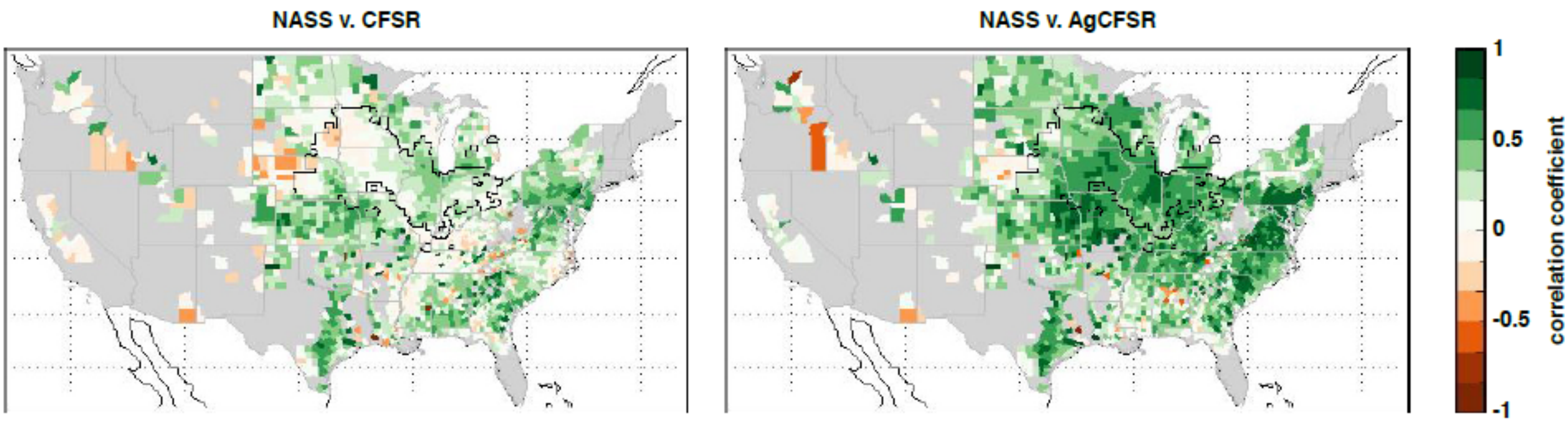
B) Wheat Yield – Ray et al. 2012 (t/ha)




**Multiple Yield Observation Datasets**

# Improved Climate Information

## Climate Forcing Datasets for Agricultural Applications

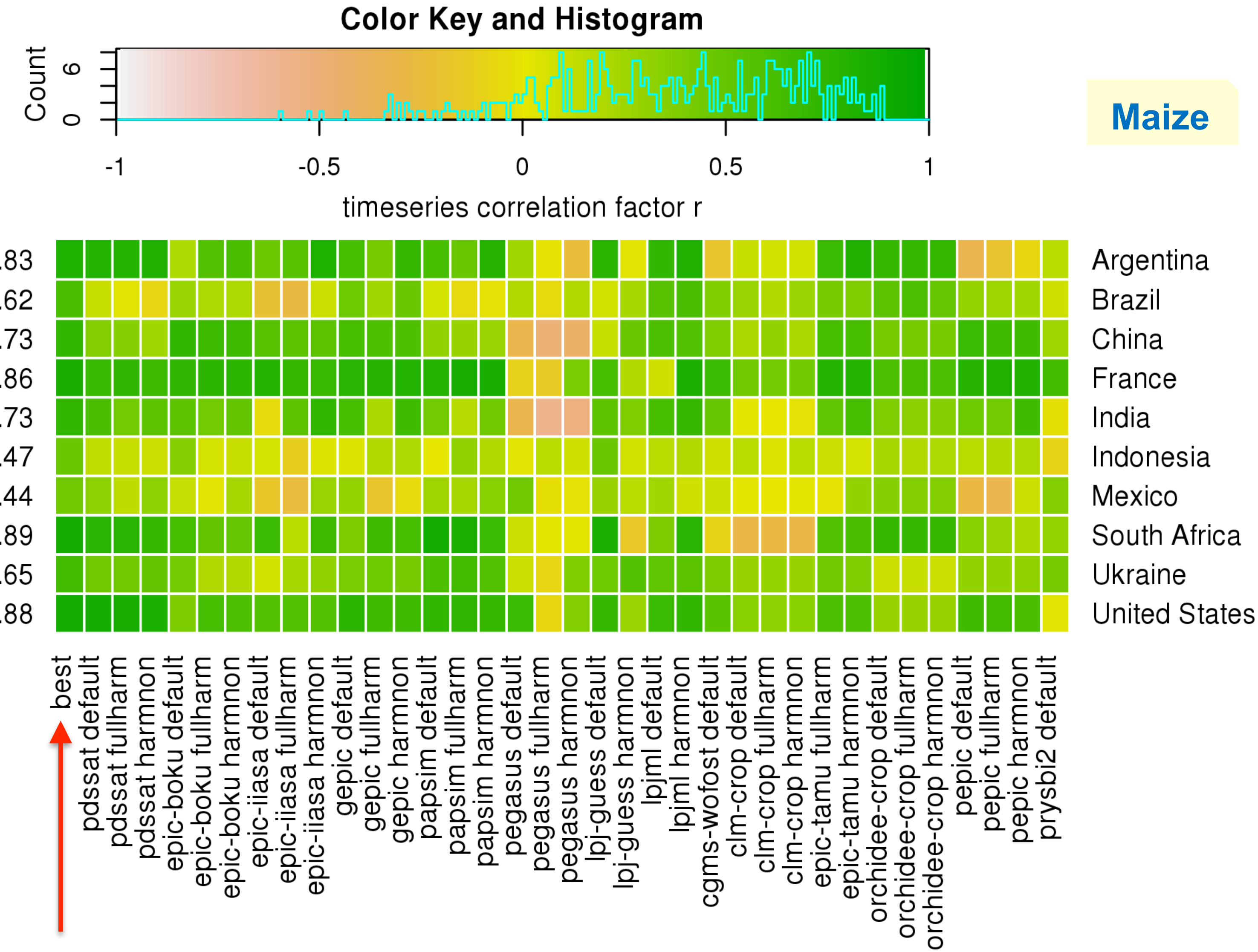



1980-2010 Correlations between National Agricultural Statistics Service (NASS) County-level production and that simulated by pDSSAT using CFSR (left) and AgCFSR (right) climate data (from Glotter et al., 2016).

# Evaluating skill in multi-model ensembles

Courtesy of Christoph Mueller, PIK

**Maize**

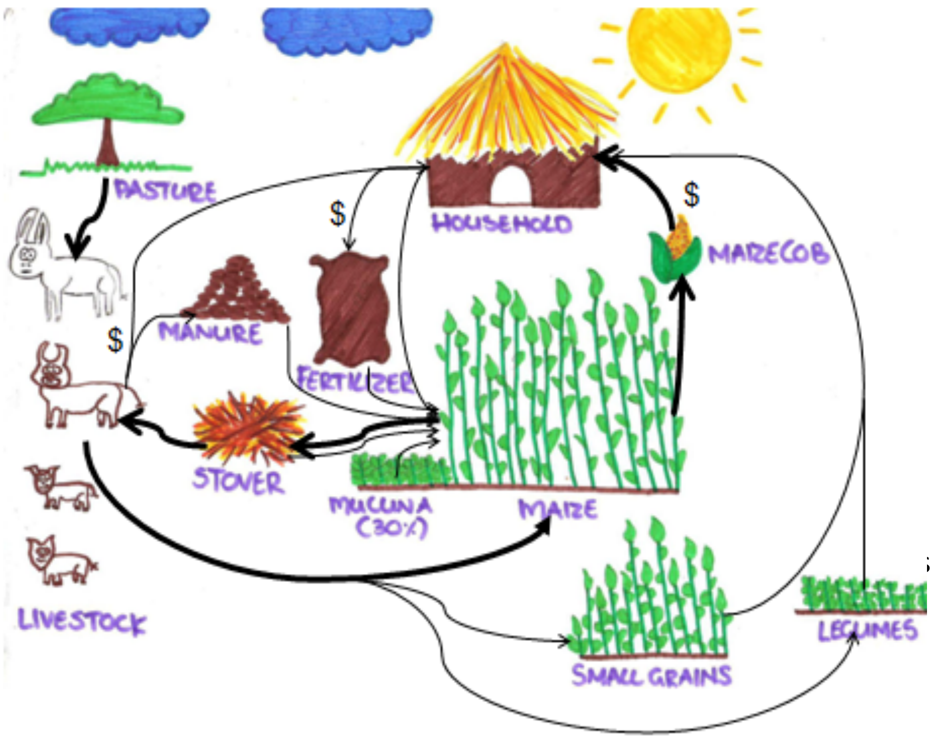


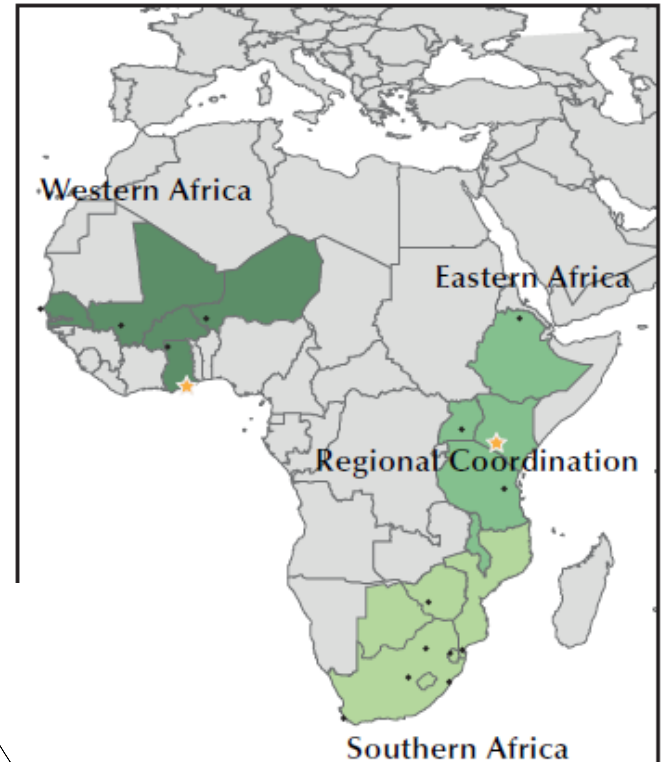
# Modeling Global Agricultural Production

## Adding Regional Context

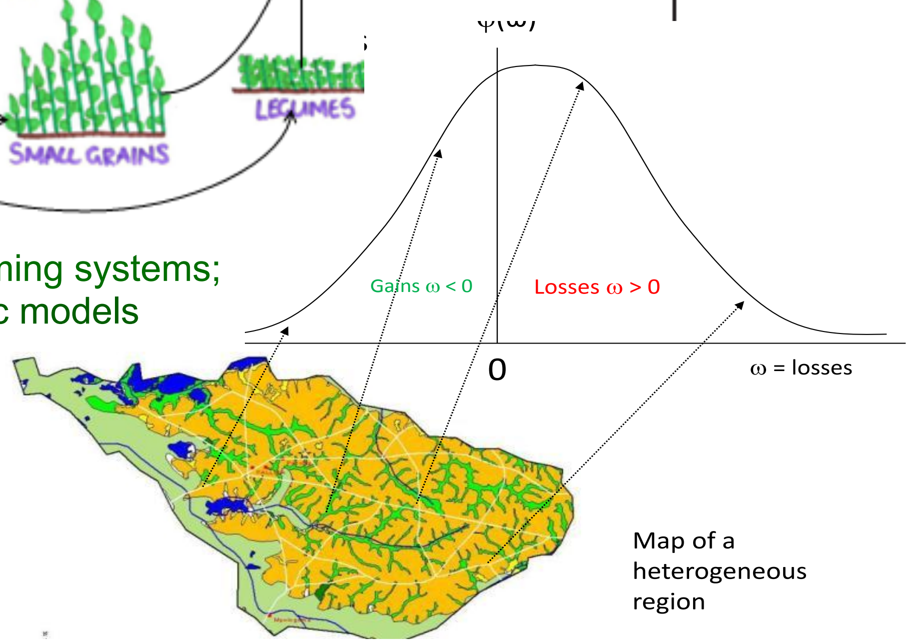
# AgMIP Regional Integrated Assessments

## Regional information across distribution of households




**Regional Research Teams**: Farming systems; biophysical & socioeconomic models




Map of a heterogeneous region

Teams also in South Asia, similar programs begun in North America, Latin America, Europe, and East Asia

# Summary and Next Steps

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# Potential Role of Agriculture and Land Models for IAMs

**Agricultural models can provide transient scenarios, time slice projections, and response functions with uncertainty information:**

- Understanding fundamental response of crops and grasslands to biophysical drivers of climate change
- Interactive effects often non-linear; important thresholds
- Response to short-term extremes ≠ Response to long-term shifts
- Connections to land-use and food system adaptations and policy
- $CO_2$ x Temperature x Water x Nitrogen x Adaptation

**Statistical agricultural models and real-time monitoring:**

- Where panel data exist statistical models can provide skill in current climate – trying to develop more direct comparisons between methods
- GEOGLAM and related remote-sensing products for monitoring

**Coupling Agricultural and Land Models to IAMs and ESMs:**

- Sneakernet coupling still favored but advancing developments in workflows
    - direct coupling challenged by biases in climate and agricultural models
- Coordinated Global and Regional Assessments (CGRA) building useful framework
- Investigate mitigation efforts oriented on Bioenergy; Farm intensification; Land-use
- Land-use changes are determined by much more than just biophysical aspects


Thanks!
(alexander.c.ruane@nasa.gov)