AgMIP The Agricultural Model Intercomparison and Improvement Project

Agricultural Impacts of Climate Change: Site- and Grid-based Assessments of Core Biophysical Responses




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Joint Global Change Research Institute 2015 Integrated Assessment Workshop
December 1st, 2015; College Park, Maryland

NASA

Columbia University

The University of Chicago

Computation Institute

Overview

How can agricultural modeling community inform the development of more accurate yield/production responses in integrated assessment models?

- **Introduction to AgMIP**
- **AgMIP Global, site-based, and networked approaches to gauging yield response to climate change factors**
- **Collaborative way forward**

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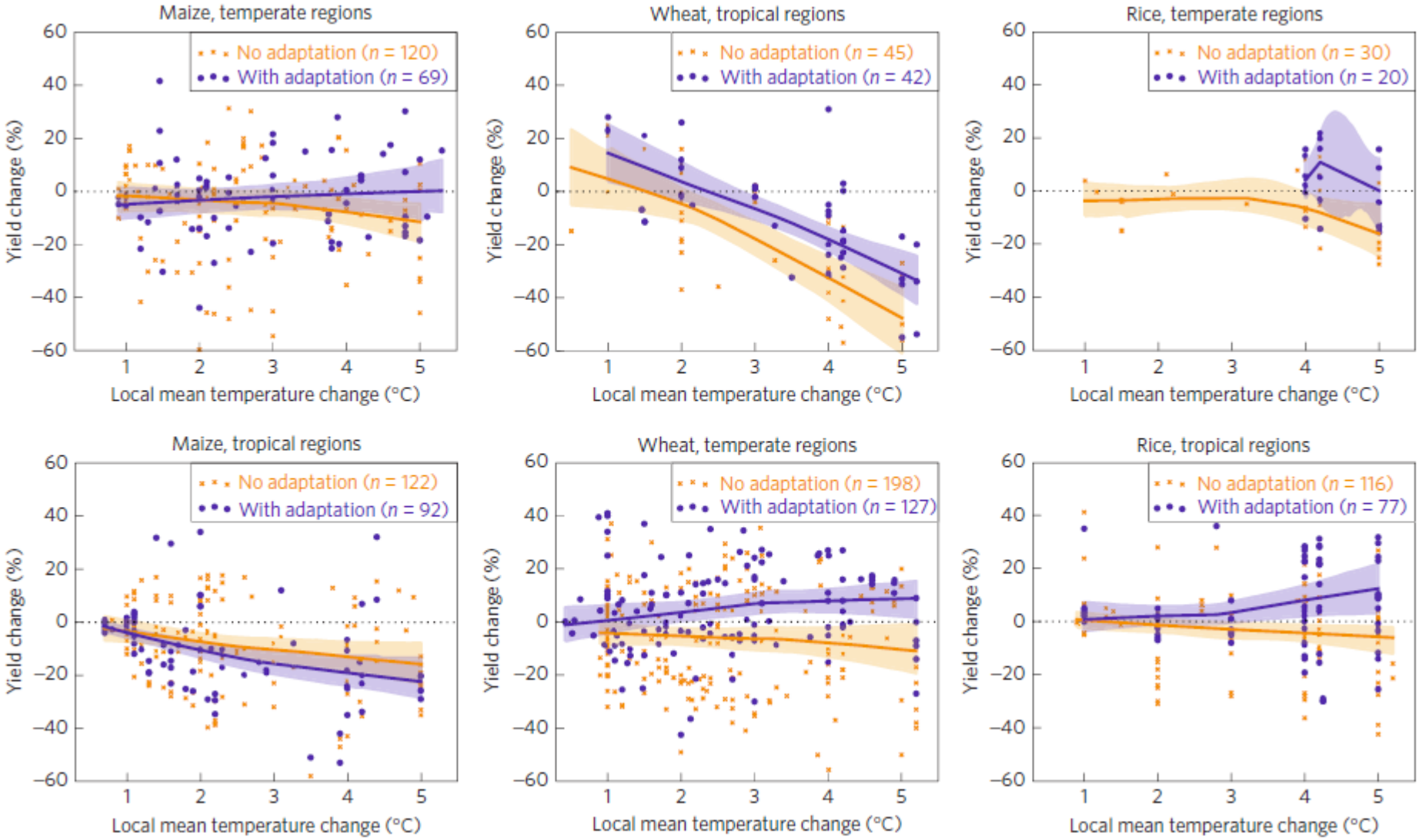
Crop Responses are Not Clear

(Meta-analysis by Challinor et al., Nature Climate Change and IPCC WG2)



Difficult to make sense out of incredibly diverse studies

The Agricultural Model Intercomparison and Improvement Project (AgMIP)

AgMIP The Agricultural Model Intercomparison and Improvement Project

AgMIP Mission

Provide effective **science-based agricultural decision-making models and assessments** of **climate variability and change** and **sustainable farming systems** to achieve **local-to-global food security**

Near Arusha, Tanzania

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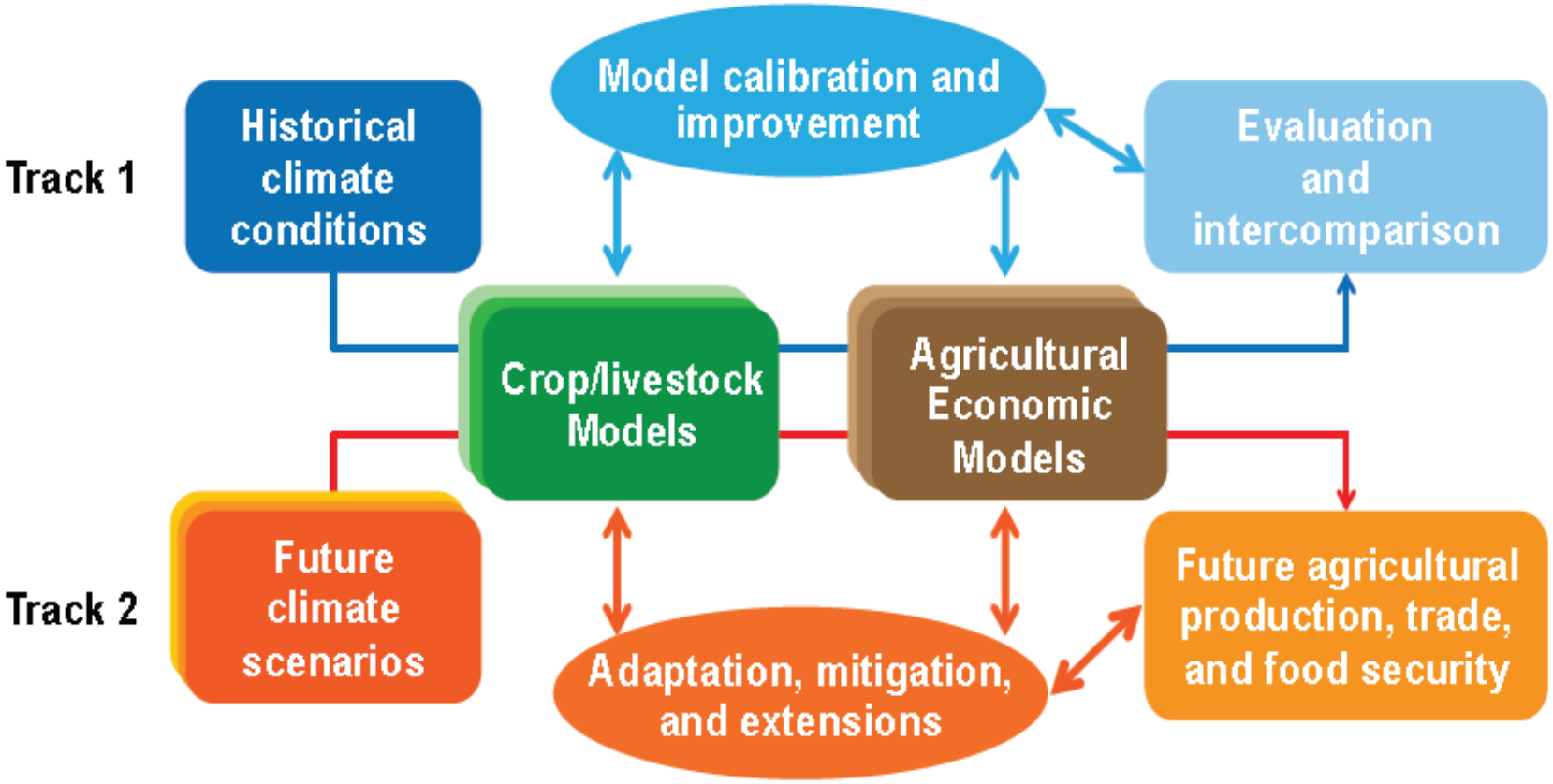
AgMIP Approach Enables *Testing* of Farm and Policy Strategies



Rosenzweig et al., 2013 AgForMet

Current AgMIP Activities

Rosenzweig et al., 2015; Climate Change and Agroecosystems, Volume 3 Part 1

AgMIP is an international community of 800+ **climate scientists**, **agronomists**, **economists**, and **IT experts** working to improve assessments of **future food security**

Visit www.agmip.org for more information and to sign up for AgMIP listserv

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Worldwide Science Community

1st Global Oct 2010

2nd Global Oct 2011

4th Global Oct 2013

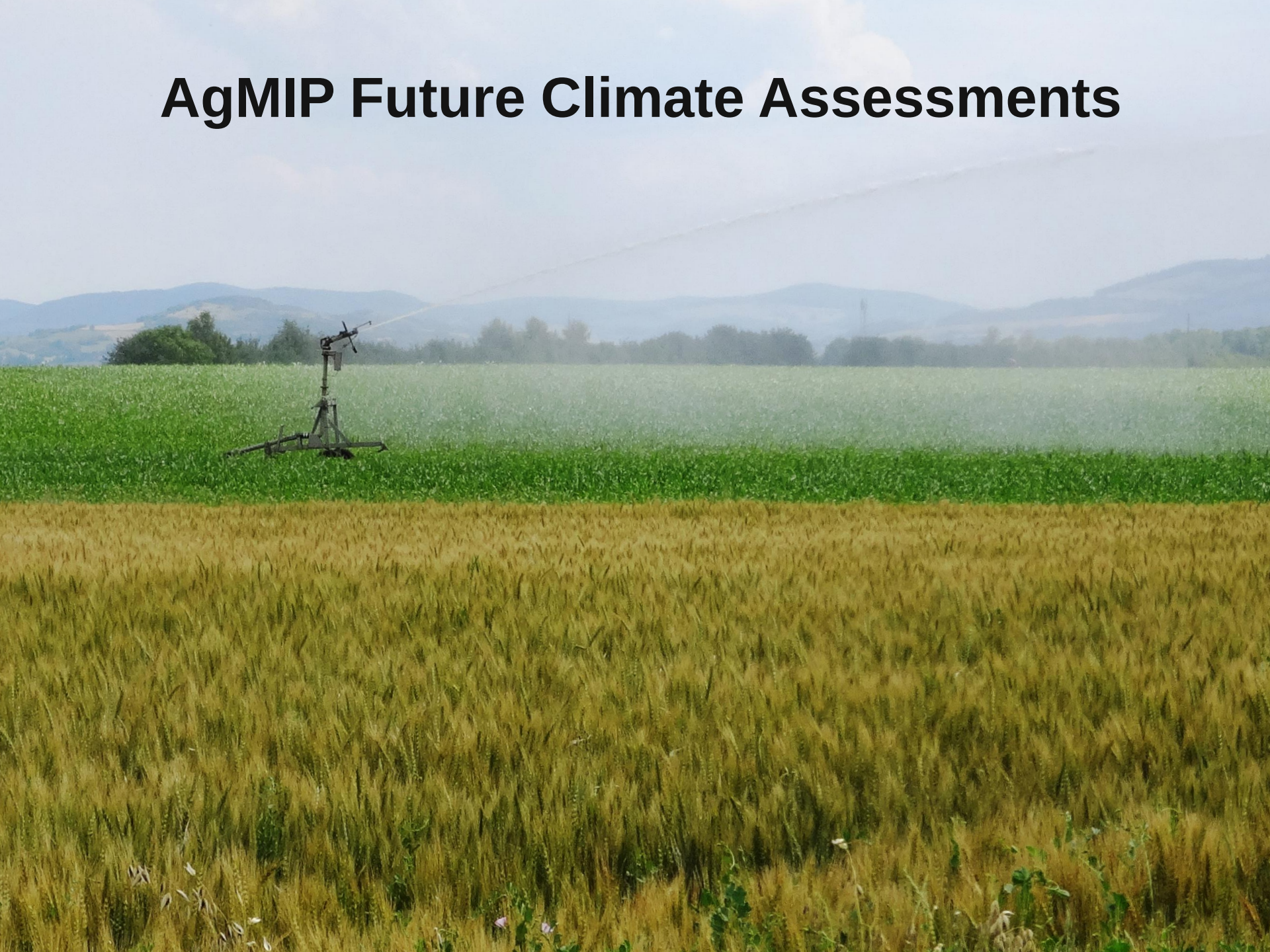
5th Global Feb 2015

Sub-Saharan Africa #3

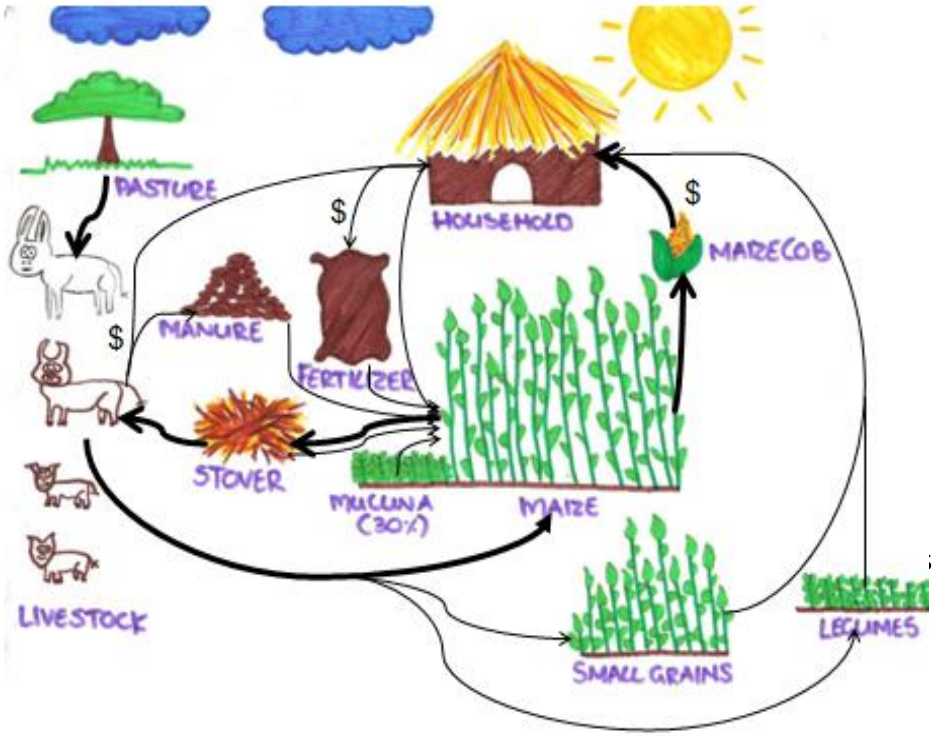
South Asia #3

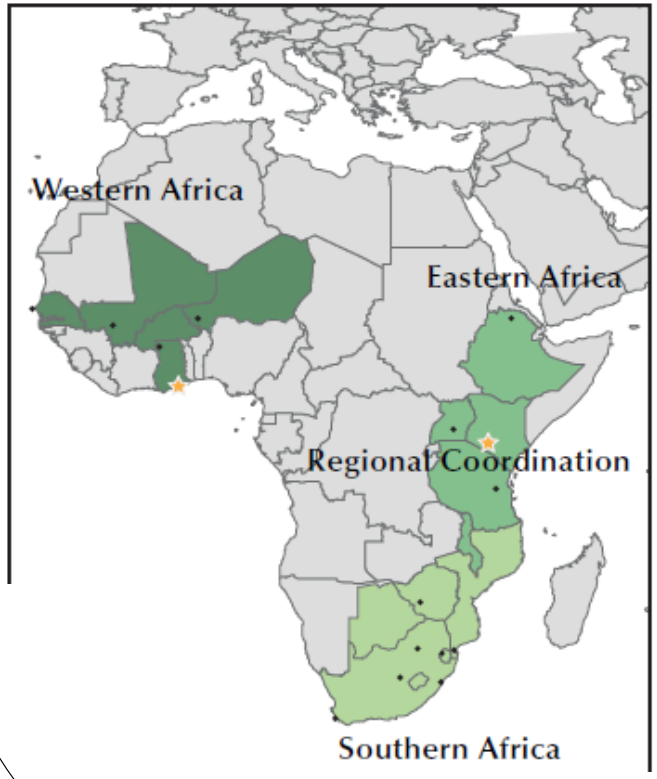
3rd Global Oct 2012

AgMIP Future Climate Assessments

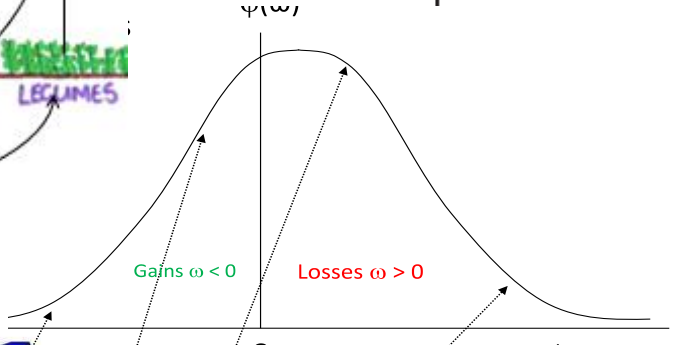


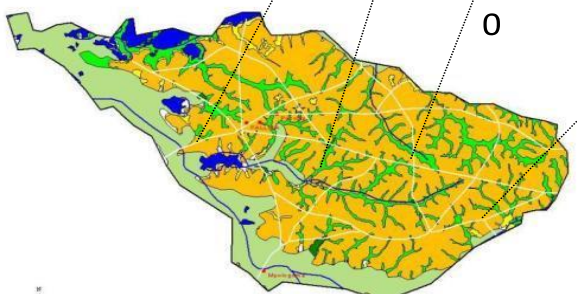
AgMIP SSA and SA RRTs





Regional Research Teams: Farming systems; biophysical & socioeconomic models





Map of a heterogeneous region

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

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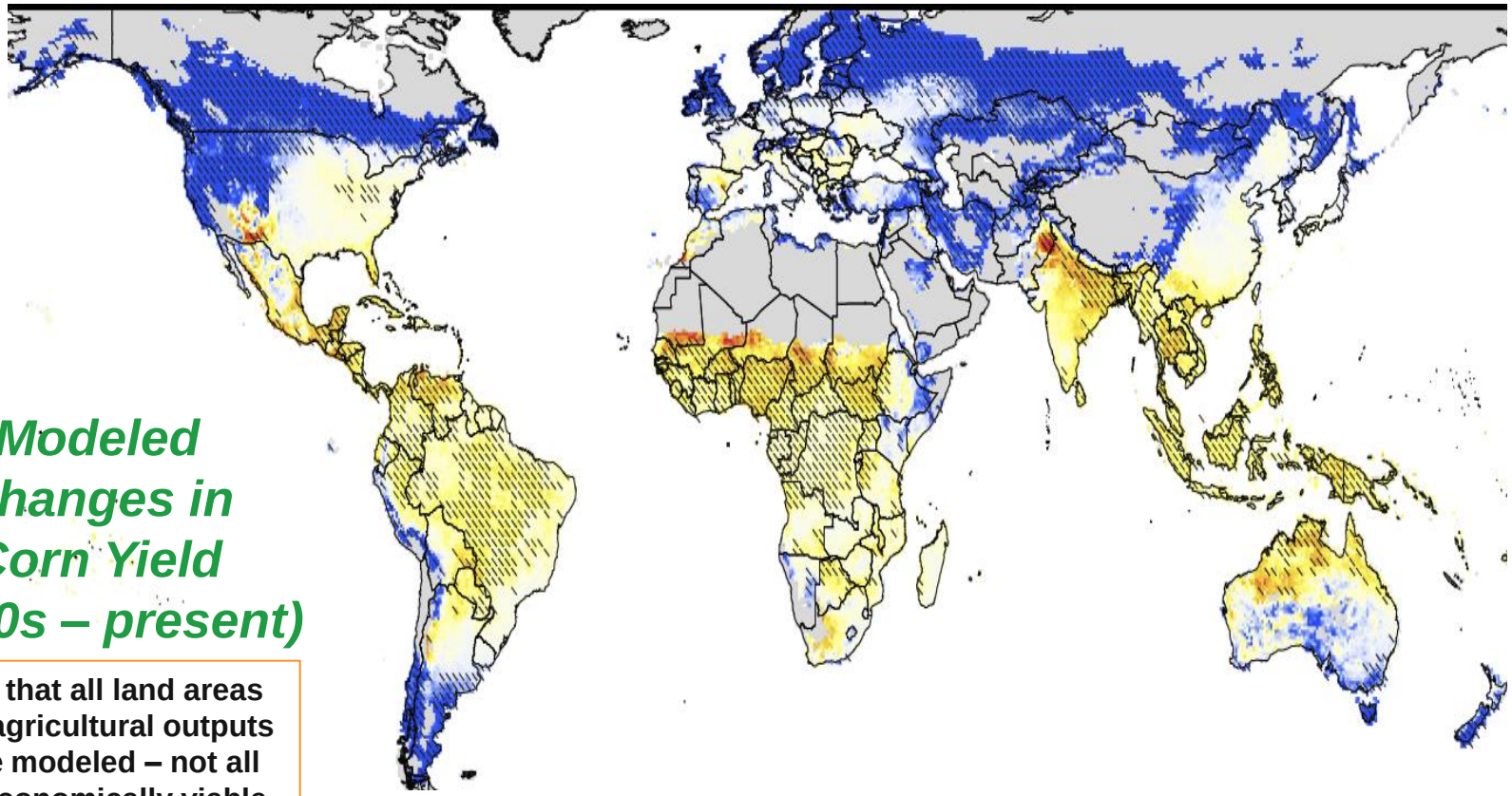

Modeled Changes in Corn Yield (2080s – present)

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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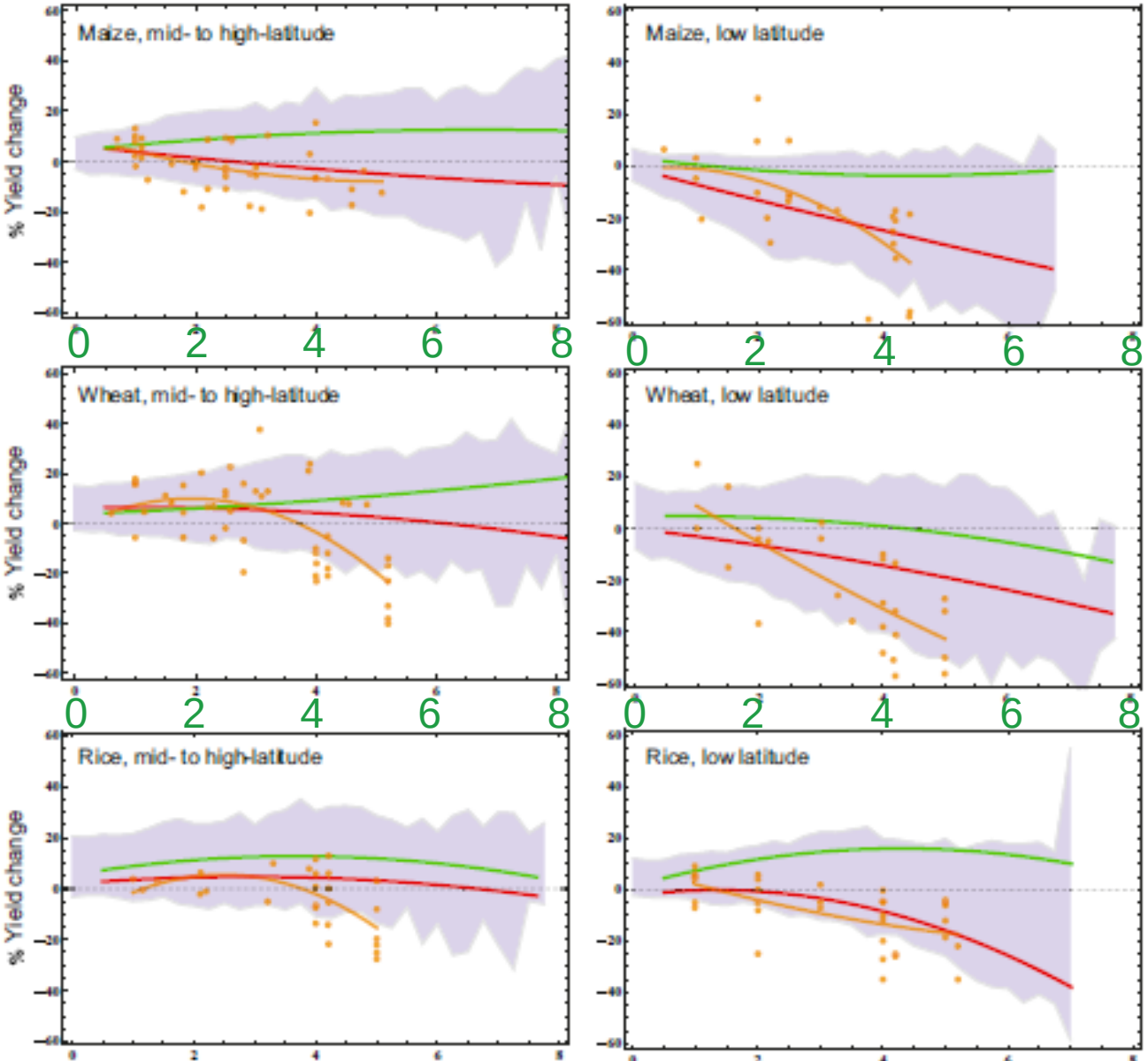
Response in leading food-producing units:

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



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

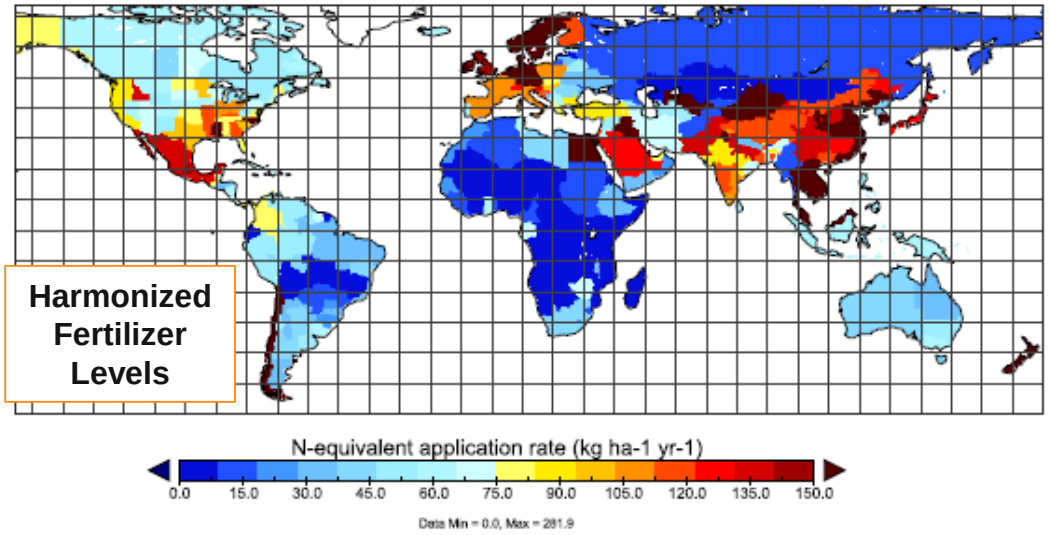
Rosenzweig et al., 2013

GGCMI Protocols – Phase 1

Elliott et al., 2015 (GMD)

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

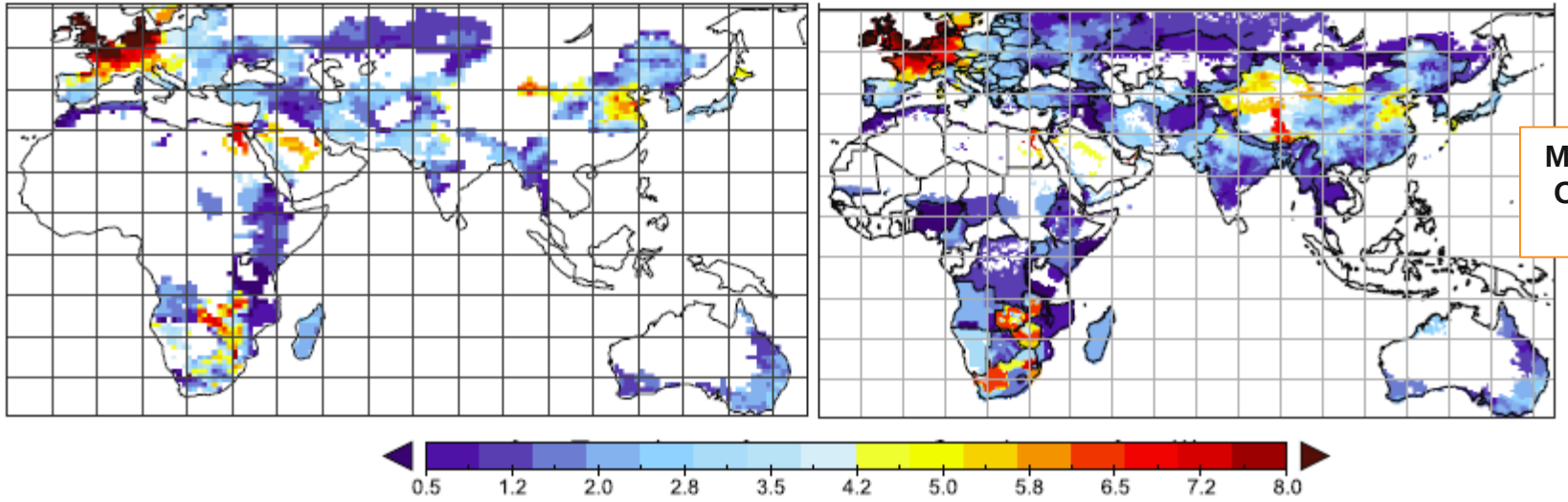
- 9 climate datasets
- 21 GGCMs
- Standardized simulation protocols
- Coordinated data analysis



Harmonized Fertilizer Levels

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

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



Multiple Yield Observation Datasets

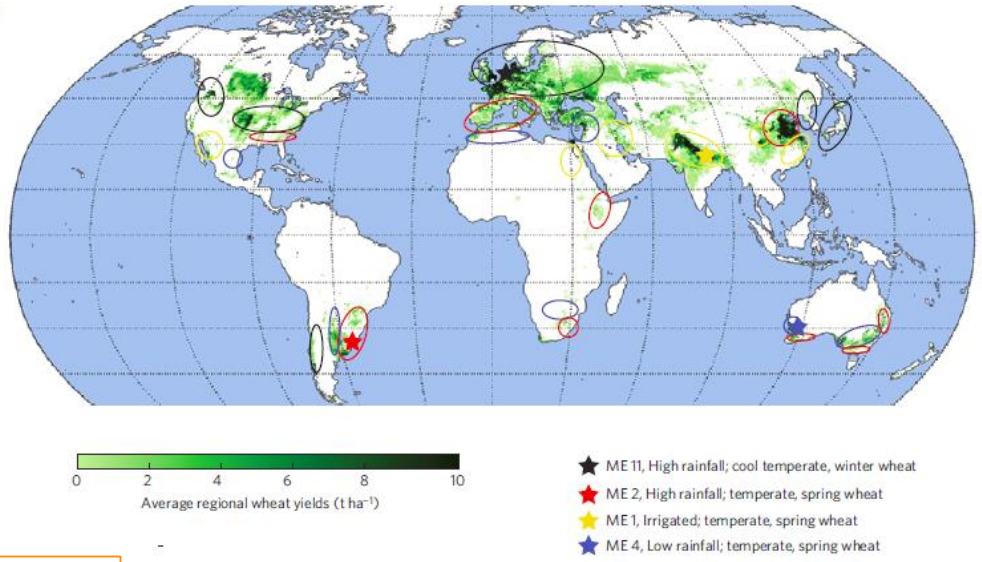
Crop response to core climate change factors

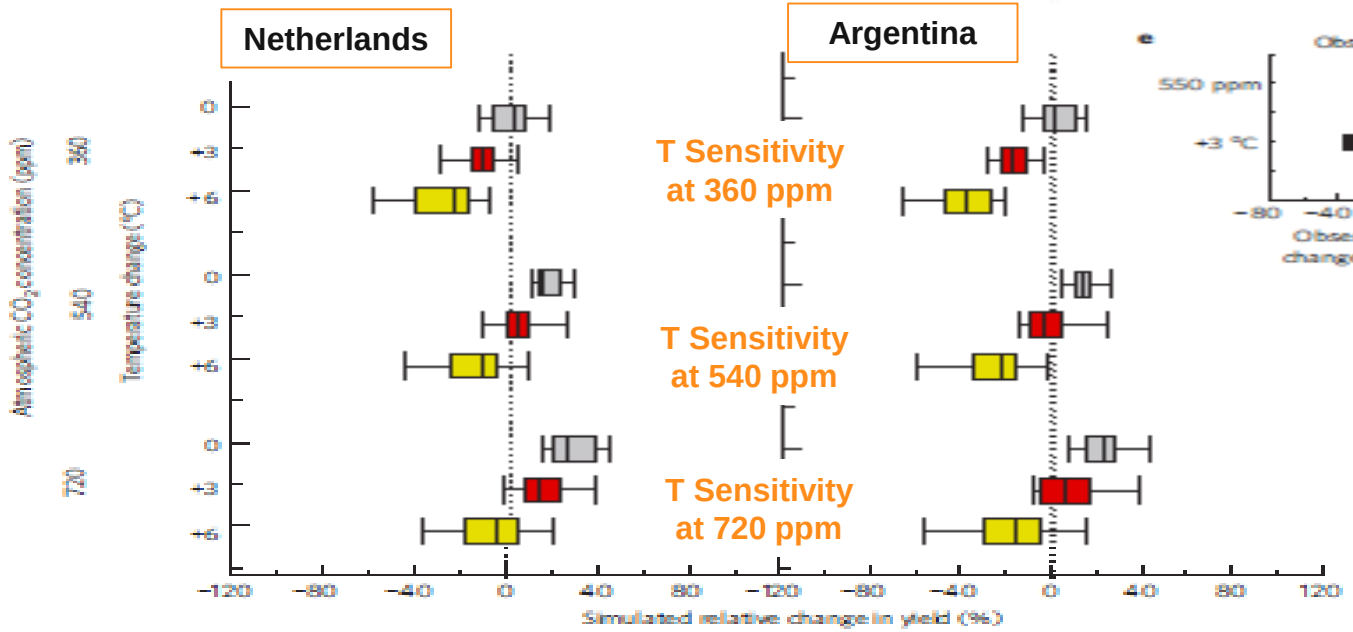
AgMIP Wheat Pilot Responses

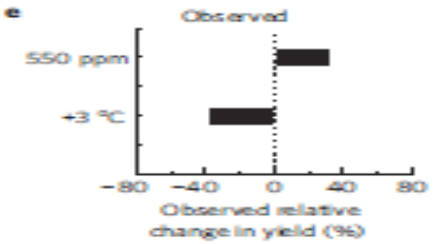
(Asseng et al., 2013; Nature Climate Change)

27 Wheat Models run in various scenarios of temperature and [CO_2] increase

- Diverse responses at 4 sites representing major areas
- Not a strong sensitivity to level of observational data
- Uncertainty grows as climate changes increase





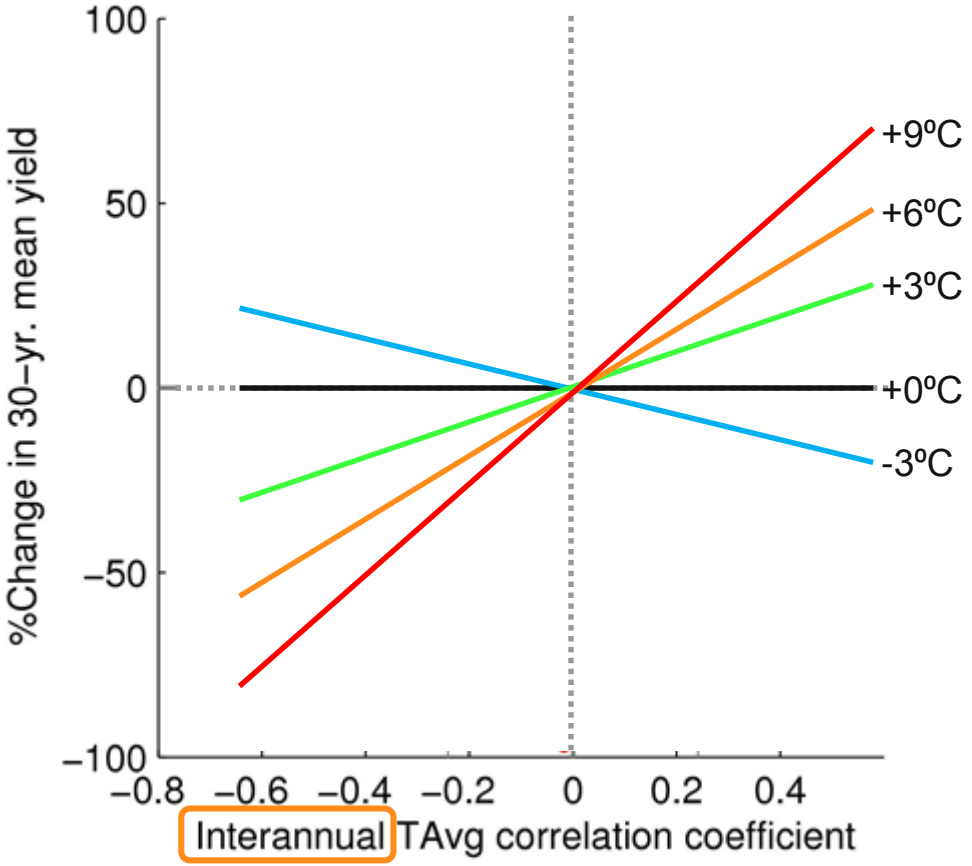


Agro-climatic Responses in Wheat Team Simulations -- Ruane et al., 2016

Interannual yield response to temperature variation

vs.

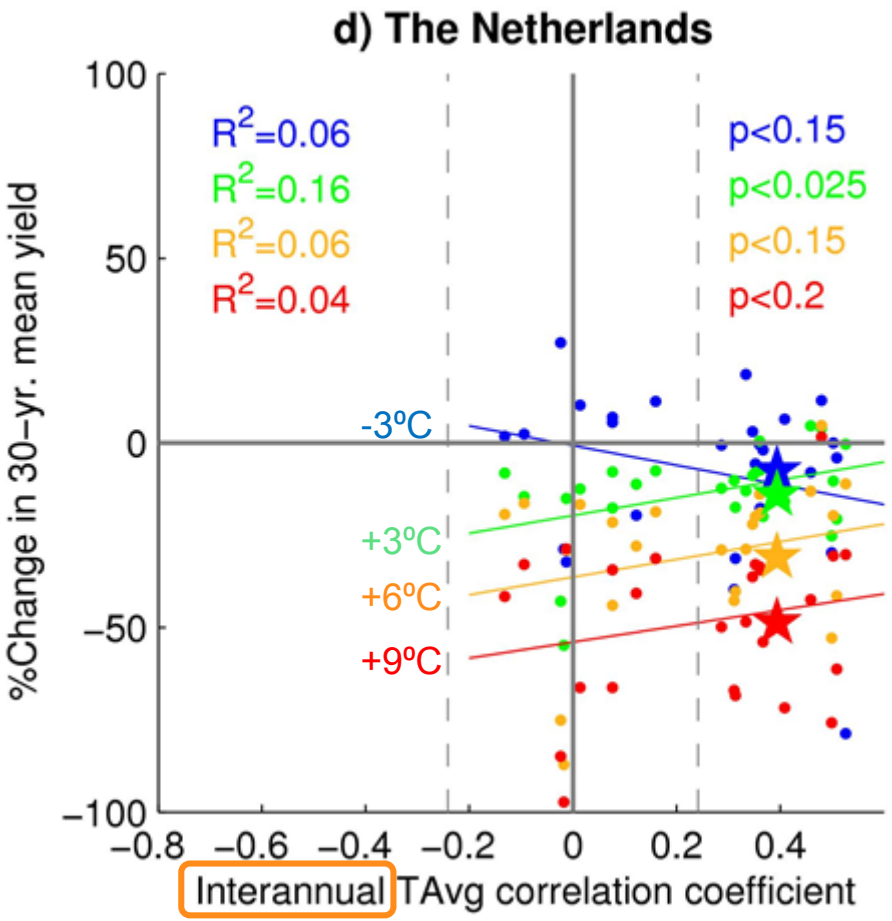
30-year mean yield response to given levels of *climate change*



Agro-climatic Responses in Wheat Team Simulations -- Ruane et al., 2016

Yield response to interannual climate variation not necessarily a good proxy for long-term climate change

(each dot represents an individual model; star represents ensemble average)

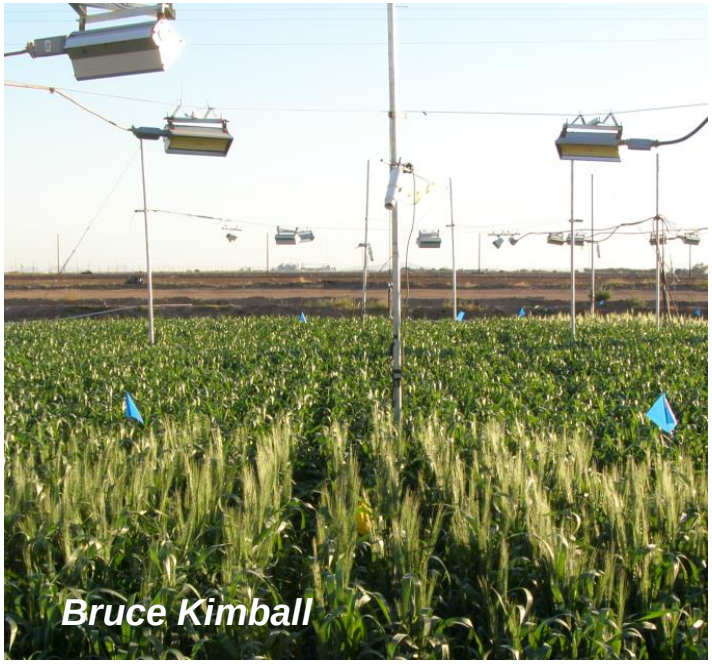


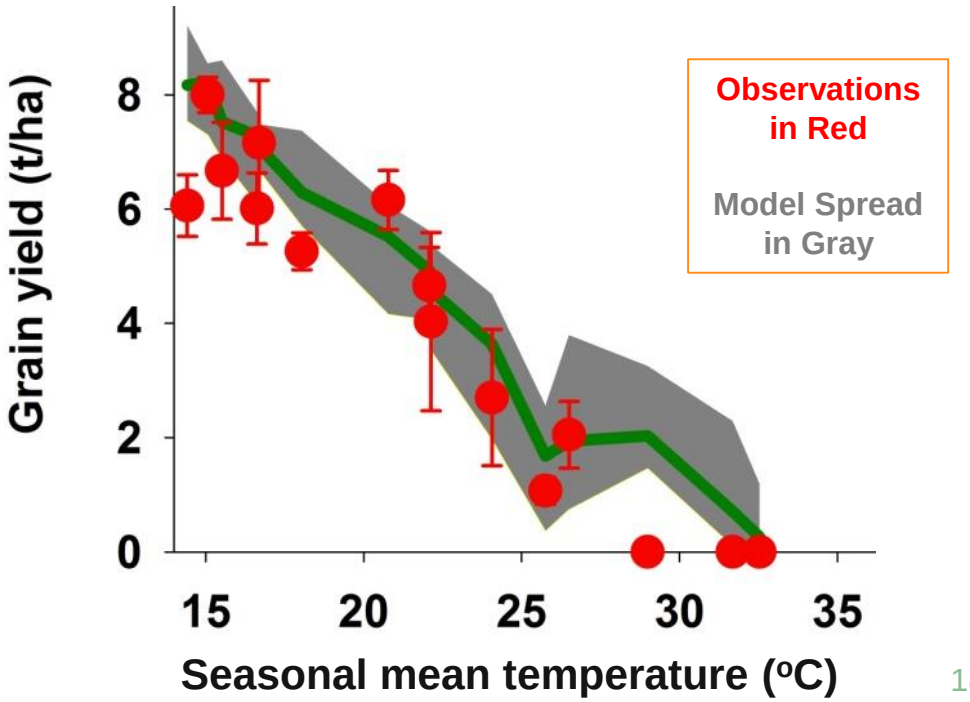
Wheat response to temperature extremes

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.

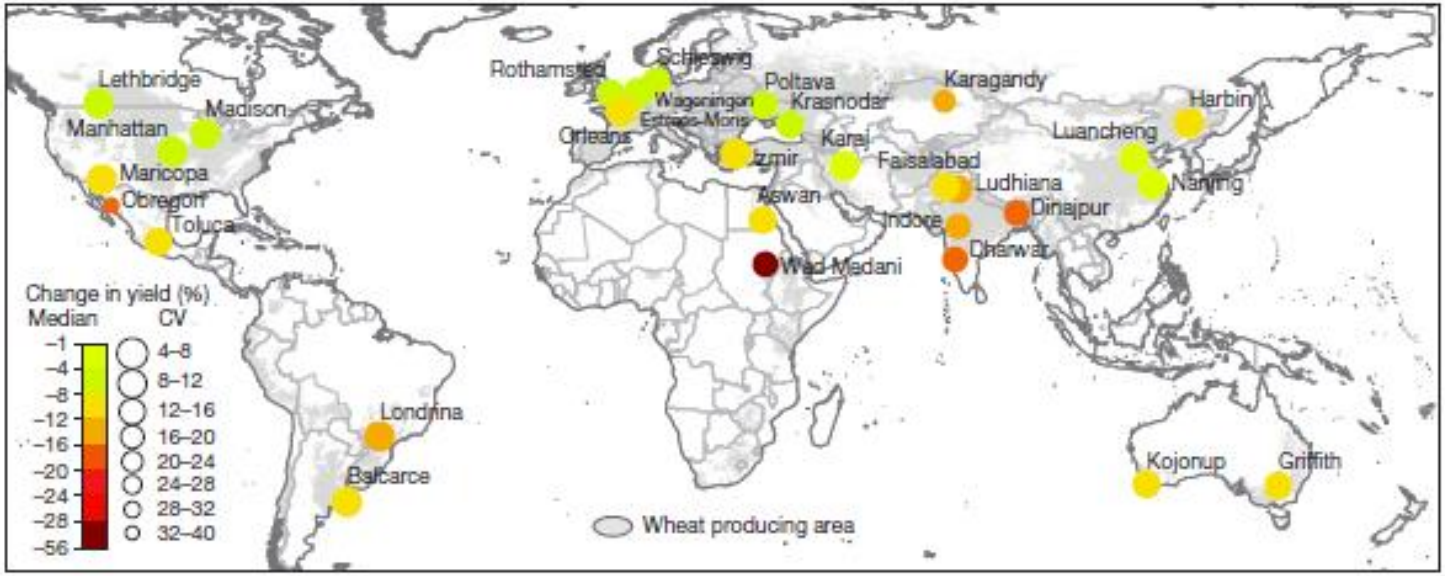




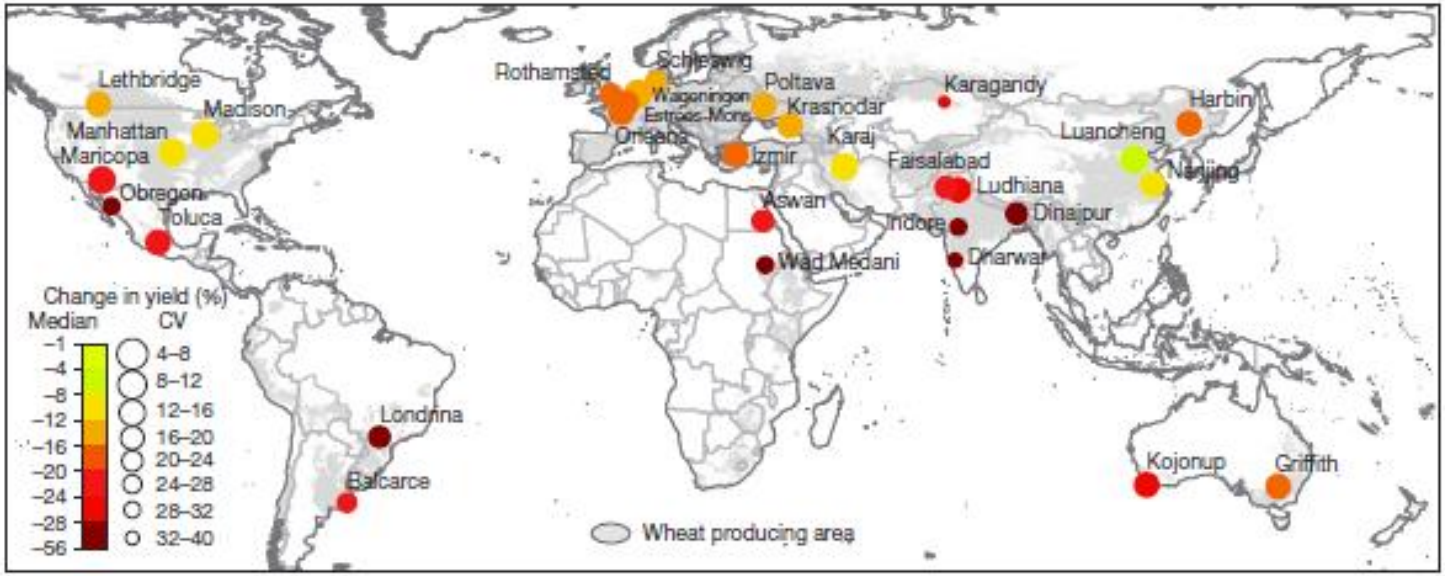
Wheat response to temperature extremes

Asseng et al., 2014; Nature Climate Change

Yield Changes in +2 ºC World



Yield Changes in +4 ºC World

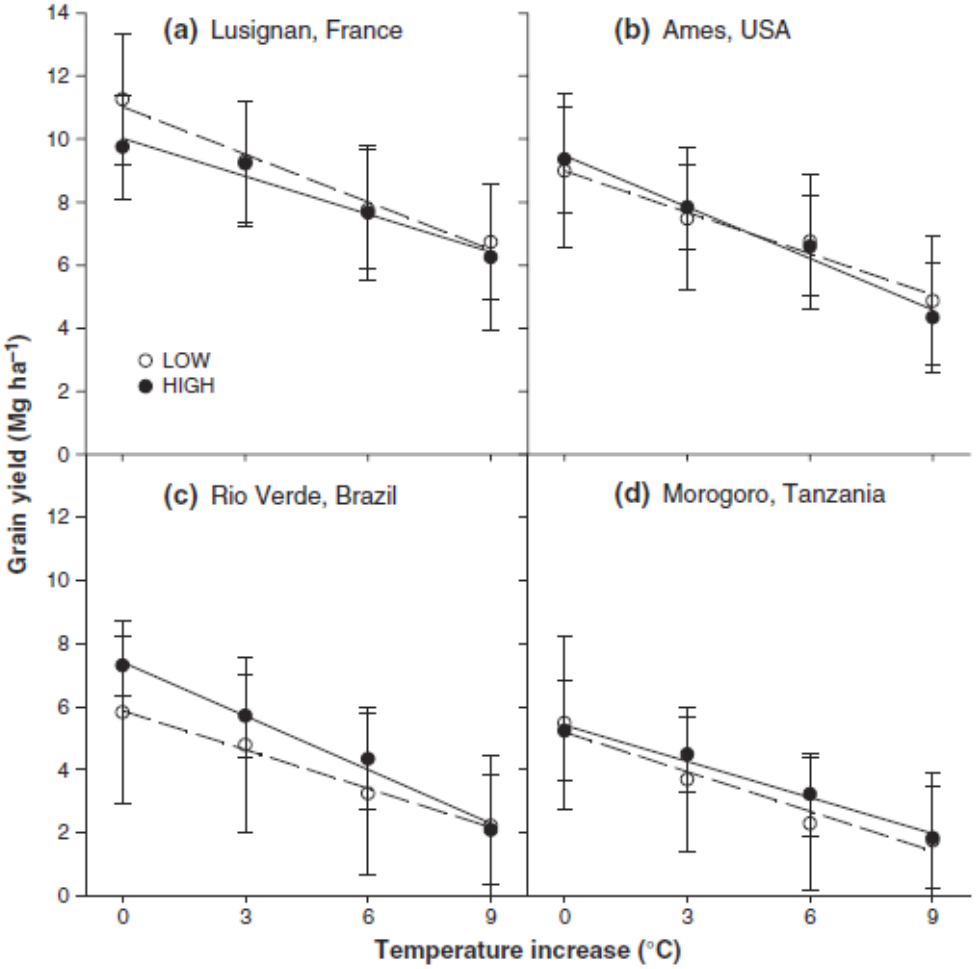


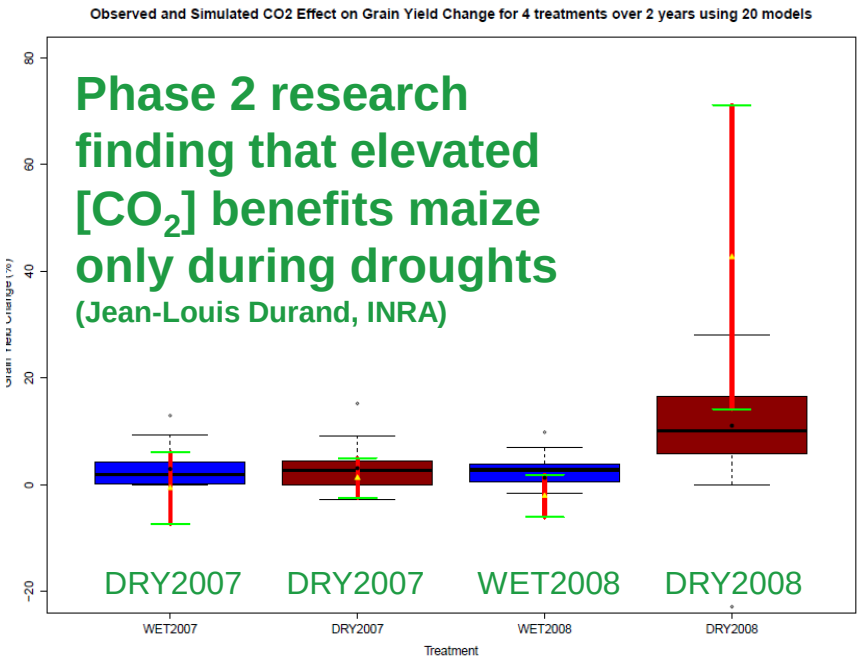
AgMIP Maize Team Responses

Bassu et al., 2014

19 Maize Models run in various scenarios of temperature increase

- Nearly linear response

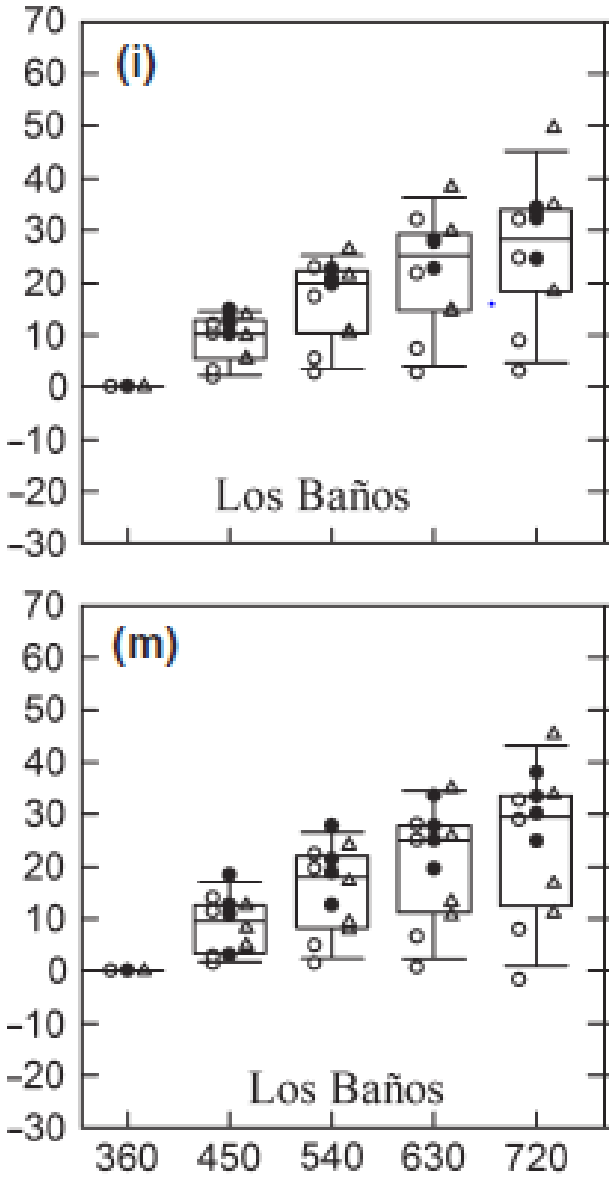




AgMIP Rice Team

13 Rice Models run in various scenarios of temperature increase

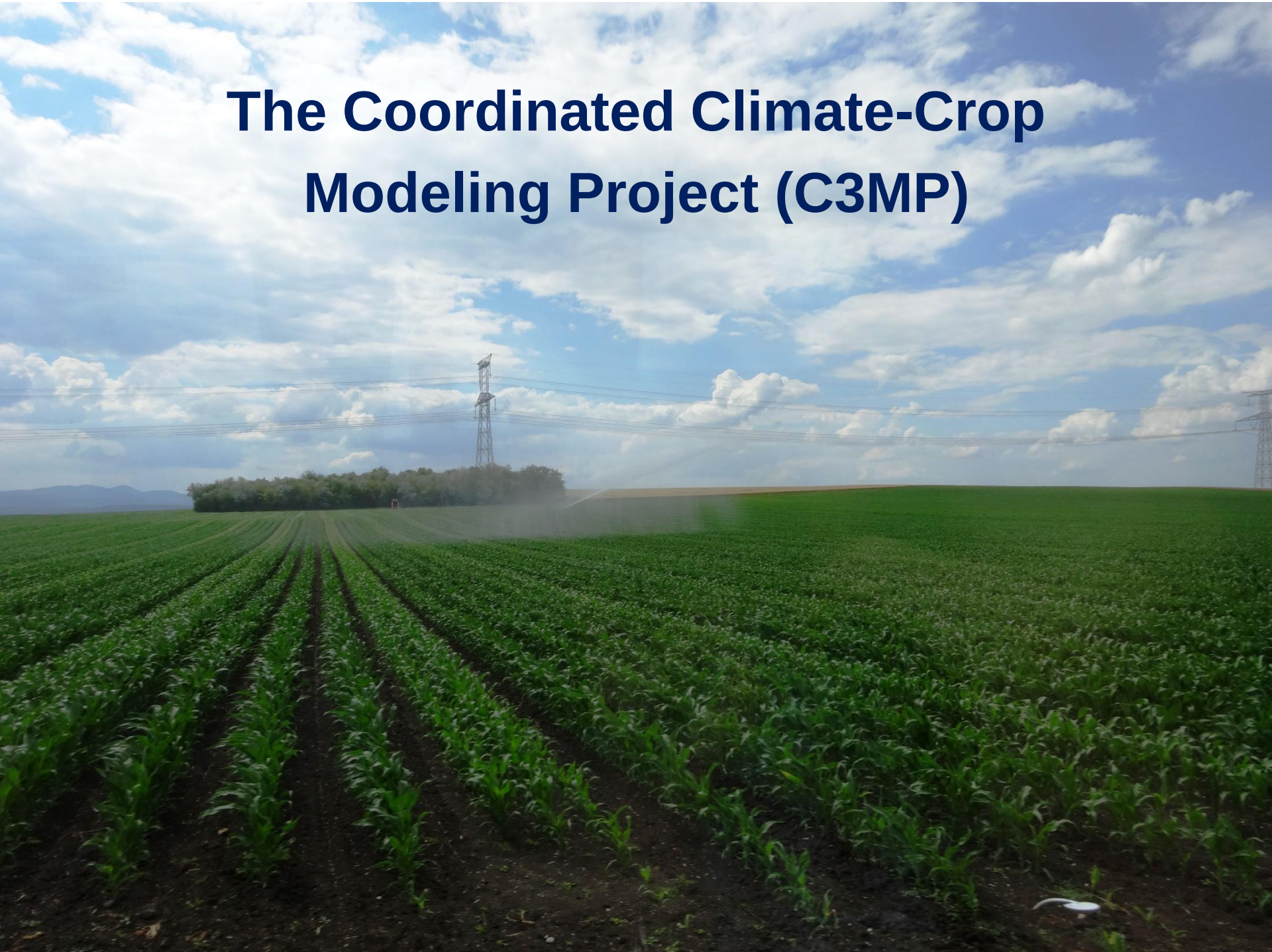
- Non-linear interactions between temperature and carbon dioxide concentration changes



[CO_2] response at current temperatures

[CO_2] response with +3 ºC warming

The Coordinated Climate-Crop Modeling Project (C3MP)



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C3MP: Motivation and Objective

Motivation

To mobilize the international community of crop modelers for a coordinated investigation of climate vulnerability and climate change impacts for AgMIP.

Objectives

To improve understanding of the impact of climate change on agricultural production across a wide variety of crops, locations, and modeling approaches

Every crop modeler in the world is invited to participate

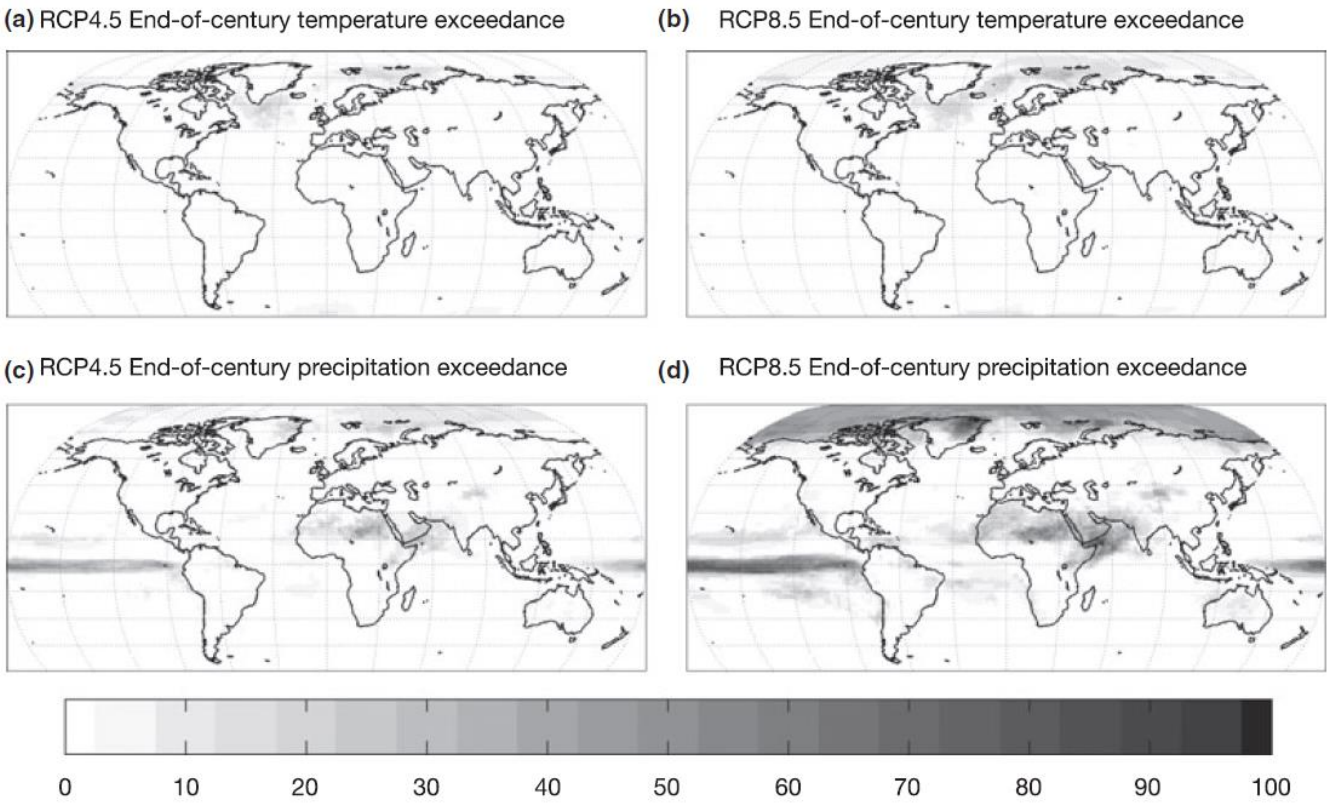
Visit www.agmip.org/c3mp or contact c3mp@agmip.org for more information

Exploring the Responses of plausible Carbon-Temperature-Water Space

Each participant runs 99 sensitivity tests exploring a range of temperature, precipitation, and [CO_2] conditions

This range covers the vast majority of agricultural regions through the end of the 21st century

Climate metric	Lower bound	Upper bound
Temperature change (ΔT)	−1 °C	+8 °C
Precipitation change (ΔP)	−50%	+50%
Carbon Dioxide Concentration ([CO_2])	330 ppm	900 ppm



Impacts Response Surface Analysis
Focus on understanding key responses

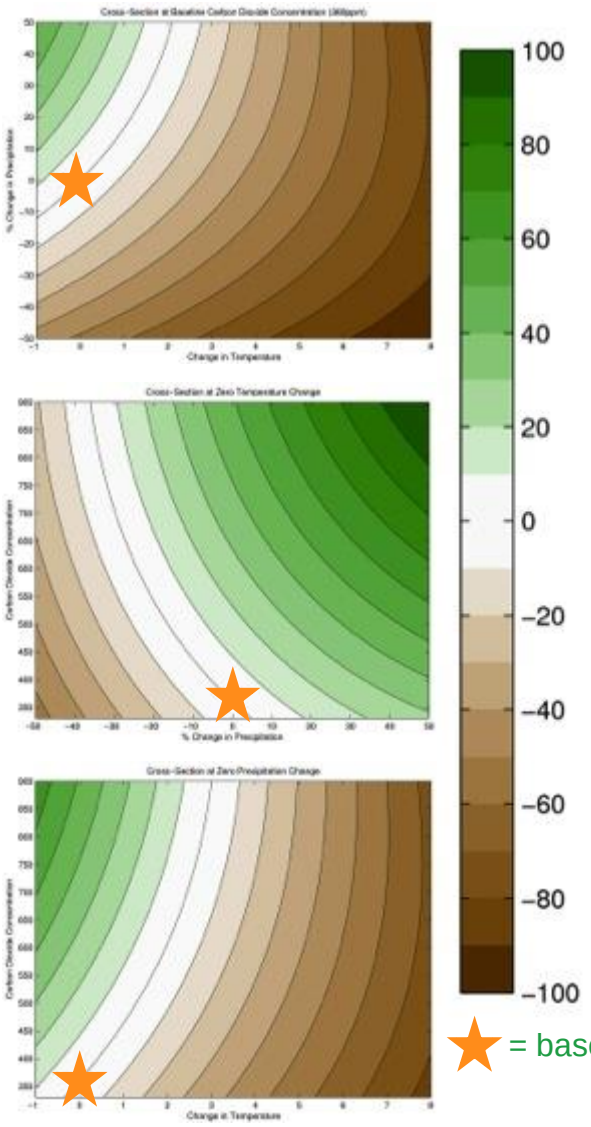
This row proxy for climate variability

ΔP vs ΔT

$[CO_2]$ vs ΔP

This row crucial for climate change

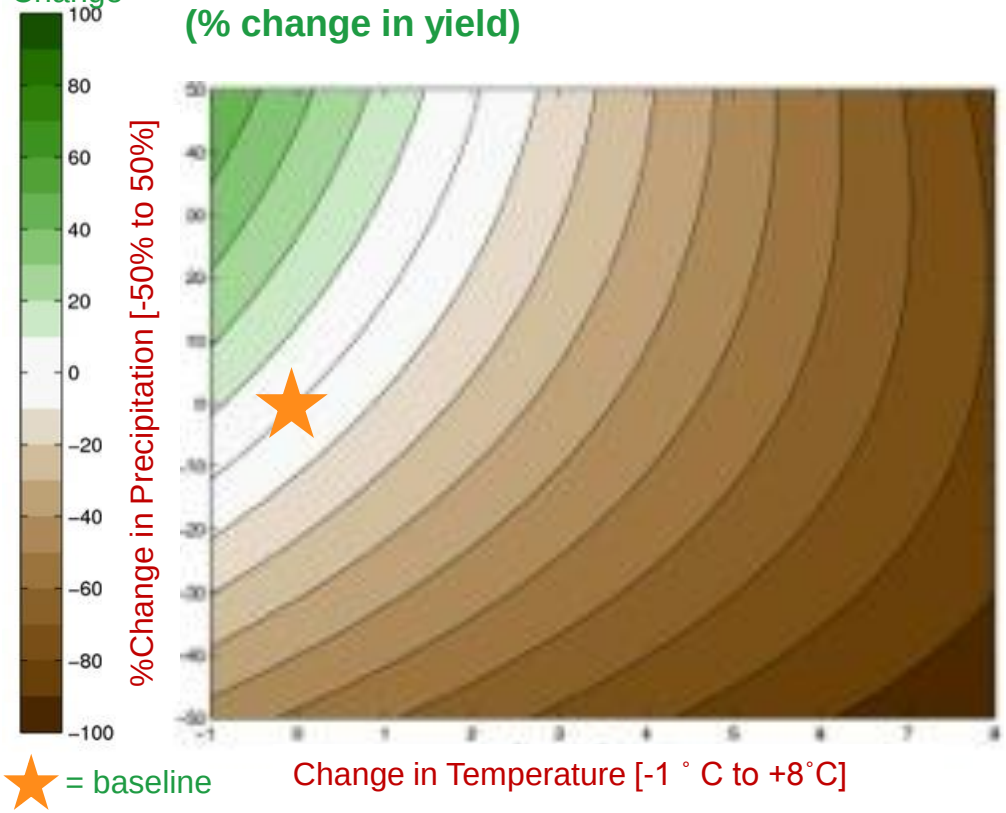
$[CO_2]$ vs ΔT



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

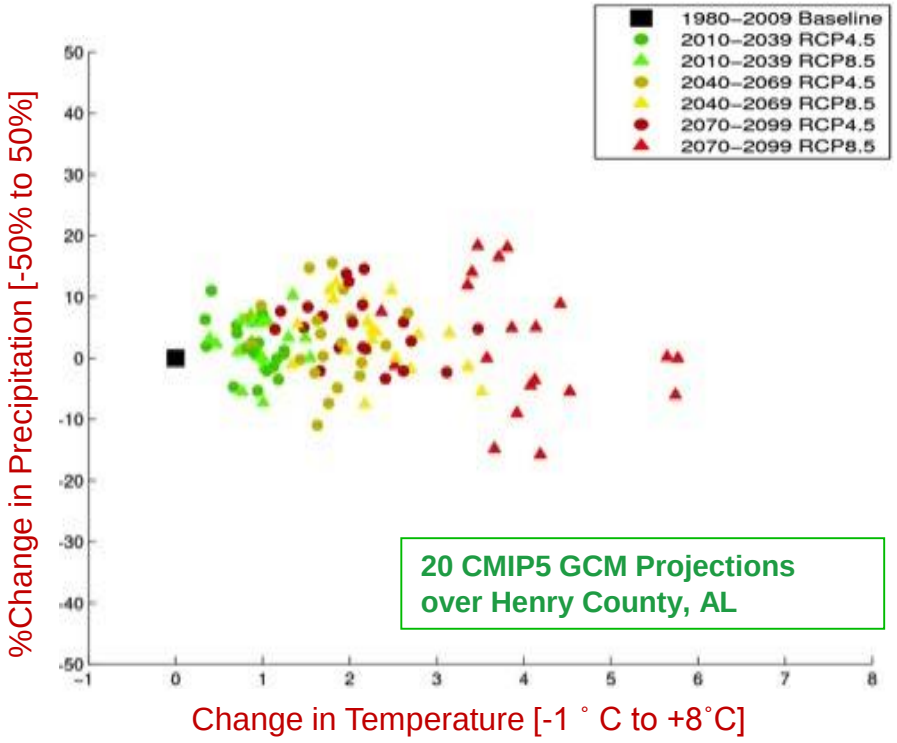
Impacts Response Surface Analysis
Focus on understanding key responses

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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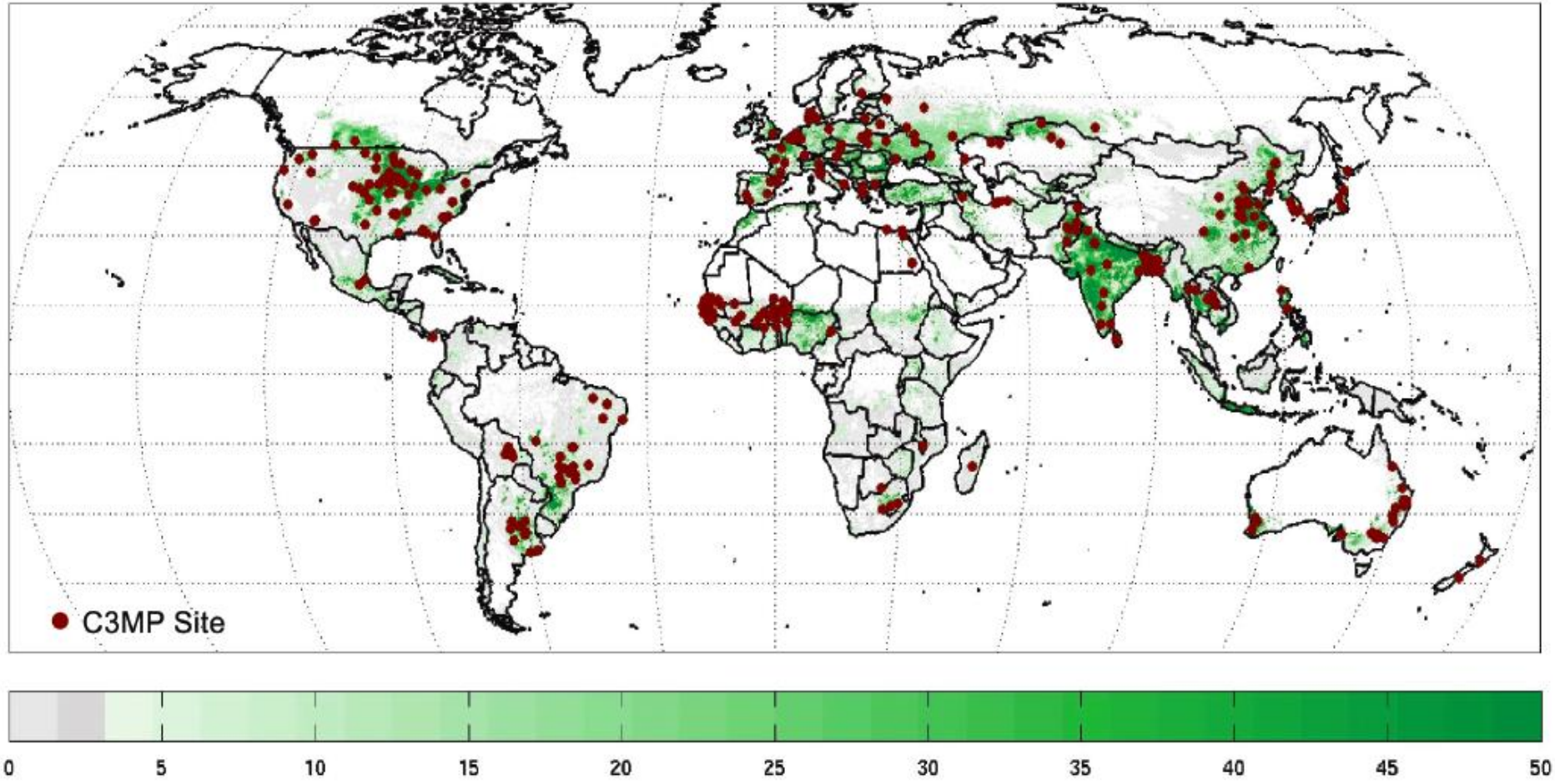
All C3MP Submitted Sites and Major Croplands (Percentage Area)



- **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

The AgMIP Coordinated Climate-Crop Modeling Project (C3MP): Methods and Protocols

Sonali P. McDermid[1,2], Alexander C. Ruane[2], Cynthia Rosenzweig[2], Nicholas I. Hudson[3], Monica D. Morales[3], Prabodha Agalawatte[55], Shakeel Ahmad[60], L. R. Ahuja[4], Istiqlal Amien[54], Saseendran S. Anapalli[4], Jakarat Anothai[5], Senthold Asseng[6], Jody Biggs[63], Federico Bert[8], Patrick Bertuzzi[9], Virender S. Bhatia[10], Marco Bindi[11], Ian Broad[12], Davide Cammarano[13], Ramiro Carretero[8], Ashfaq Ahmad Chattha[50], Uran Chung[14], Stephanie Debats[56], Paola Deligios[64], Giacomo De Sanctis[15], Thanda Dhliwayo[14], Benjamin Dumont[7], Lyndon Estes[56], Frank Ewert[16], Roberto Ferrise[11], Thomas Gaiser[16], Guillermo Garcia[8], Sika Gbegbelegbe[17], Vellingiri Geethalakshmi[18], Edward Gerardeaux[19], Richard Goldberg[3], Brian Grant[20], Edgardo Guevara[21], Jonathan Hickman[22], Holger Hoffmann[18], Huanping Huang[23], Jamshad Hussain[50], Flavio Barbosa Justino[24], Asha S. Karunaratne[25], Ann-Kristin Koehler[26], Patrice K. Kouakou[61], Soora Naresh Kumar[27], Arunachalam Lakshmanan[18], Mark Lieffering[57], Xiaomao Lin[28], Qunying Luo[29], Graciela Magrin[21], Marco Mancini[11], Fabio Ricardo Marin[52], Anna Dalla Marta[11], Yuji Masutomi[30], Theodoros Mavromatis[31], Greg McLean[32], Santiago Meira[21], Monoranjan Mohanty[33], Marco Moriondo[11], Wajid Nasim[60], Lamyaa Negm[34], Francesca Orlando[11], Simone Orlandini[11], Isik Ozturk[35], Helena Maria Soares Pinto[52], Guillermo Podesta[53], Zhiming Qi[36], Johanna Ramarohetra[37], Muhammad Habib ur Rahman[50], Helene Raynal[38], Gabriel Rodriguez[21], Reimund Rötter[58], Vaishali Sharda[6], Lu Shuo[39], Ward Smith[20], Val Snow[59], Afshin Soltani[40], K. Srinivas[41], Benjamin Sultan[66], Dillip Kumar Swain[42], Fulu Tao[43], Kindie Tesfaye[44], Maria I. Travasso[21], Giacomo Trombi[11], Alex Topaj[65], Eline Vanuytrecht[51], Federico E. Viscarra[45], Syed Aftab Wajid[50], Enli Wang[46], Hong Wang[47], Jing Wang[39], Erandika Wijekoon[55], Lee Byun-Woo[48], Yang Xiaoguang[39], Ban Ho Young[48], Jin I. Yun[49], Zhigan Zhao[39], and Lareef Zubair[55]

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Crop responses vary by species

Preliminary results from C3MP; article forthcoming

Several approaches to understand uncertainty in crop responses

Preliminary results from C3MP; article forthcoming

Several approaches to understand uncertainty in crop responses

Preliminary results from C3MP; article forthcoming

Impacts Response Surface analysis

allows examination of how extremes change differently than average year

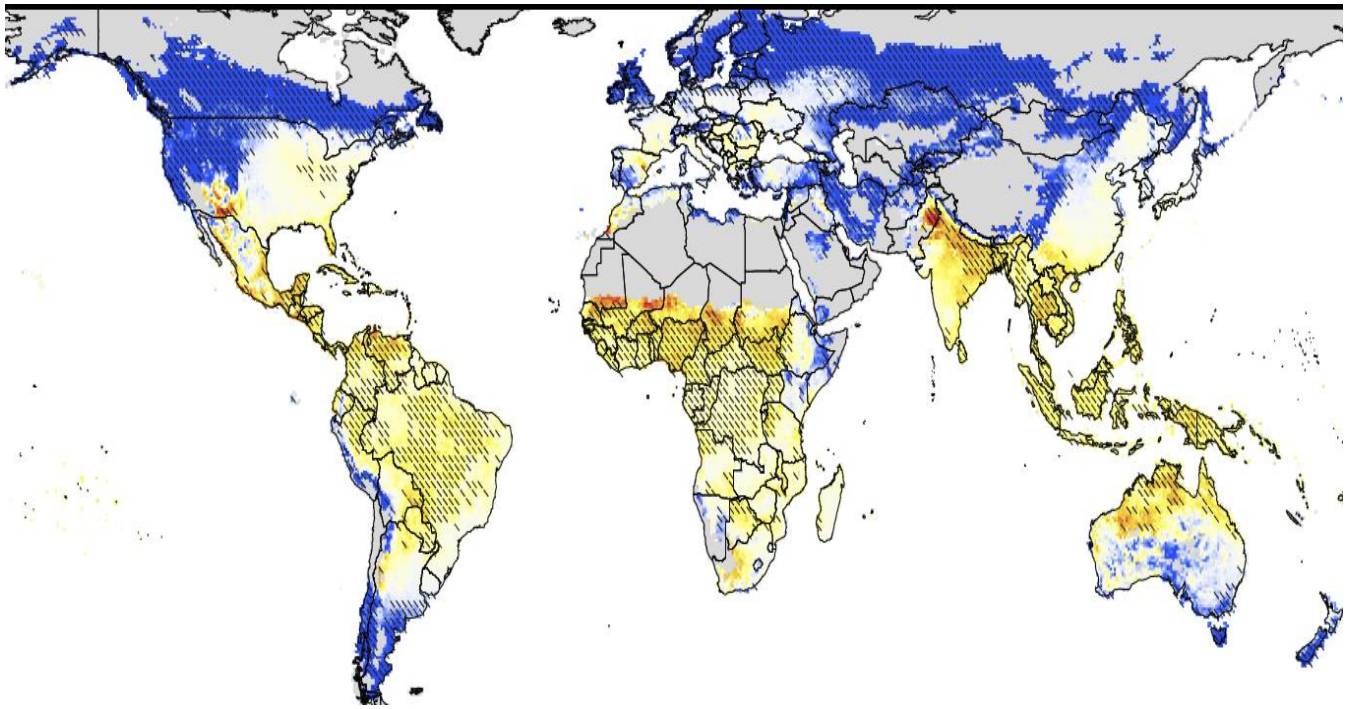
Preliminary Results
from Ruane et al.,
in preparation

Impacts Response Surface Analysis
Focus on Frequency of Extreme Years

Preliminary Results
from Ruane et al.,
in preparation

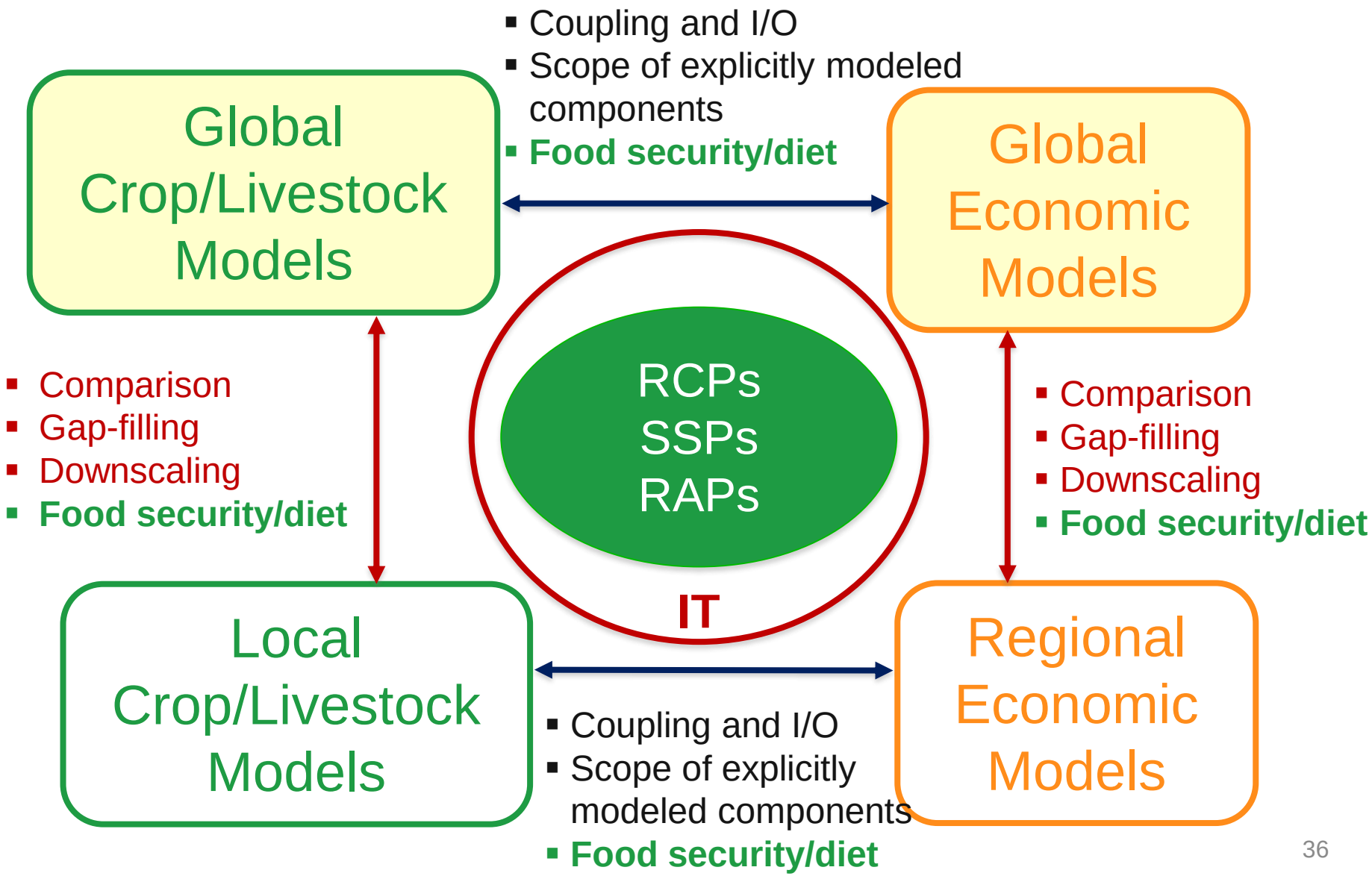
GGCMI Protocols – Phase 2

The AgMIP Global Gridded Crop Modeling Initiative (GGCMI) has developed protocols for full-world **CO2-temperature-water-nitrogen-adaptation** sensitivity tests across multiple crops and crop models.

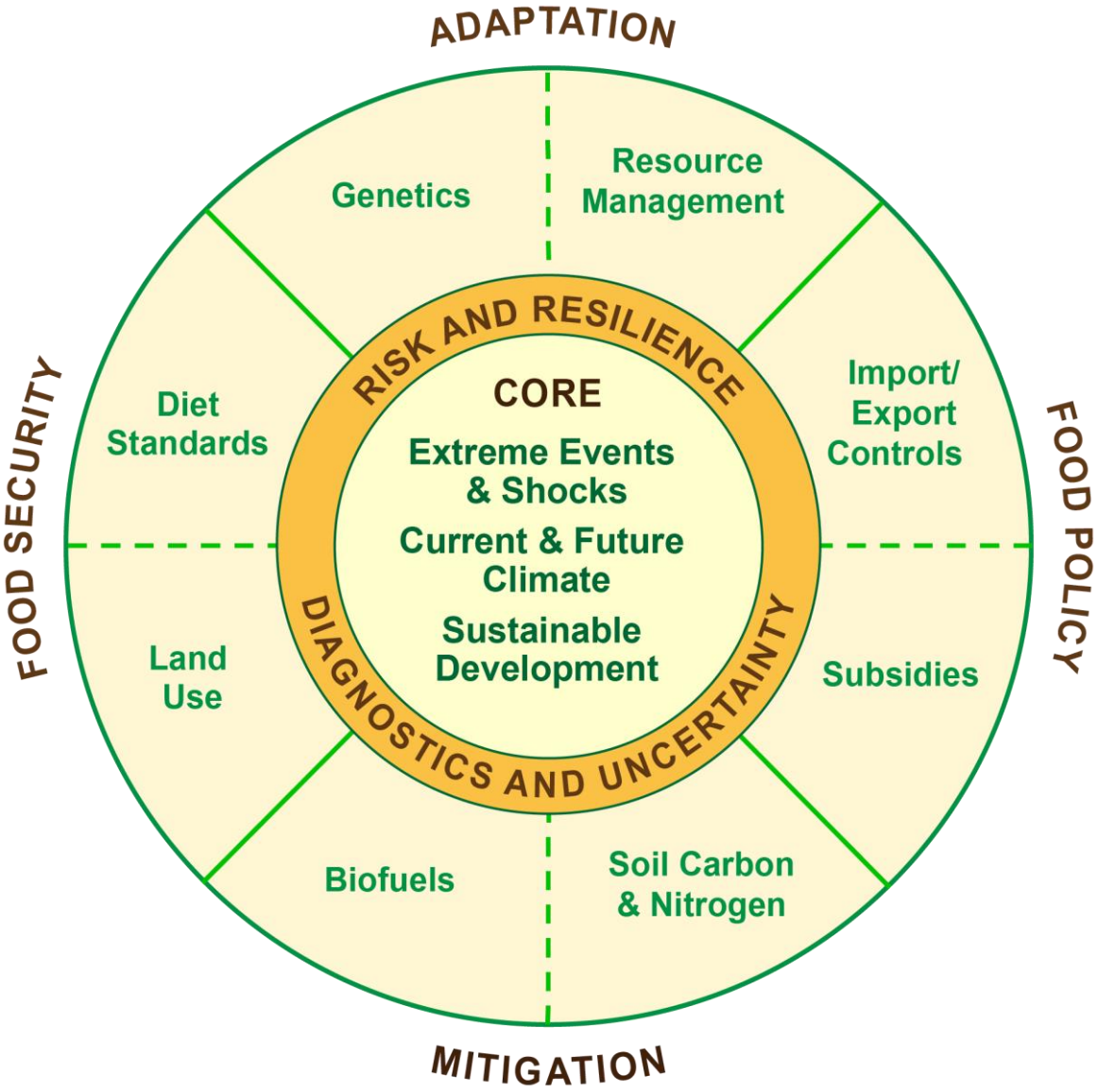


The Coordinated Global and Regional Assessments (CGRA) of Climate Impacts on Agriculture and Food Security

CGRA Building Blocks



CGRA


ADAPTATION
Genetics
Resource Management
FOOD SECURITY
Diet Standards
Import/ Export Controls
FOOD POLICY
Land Use
Subsidies
Biofuels
Soil Carbon & Nitrogen
MITIGATION
RISK AND RESILIENCE
CORE
Extreme Events & Shocks
Current & Future Climate
Sustainable Development
DIAGNOSTICS AND UNCERTAINTY

Potential to Incorporate AgMIP Findings in JGCRI Models

Potential AgMIP-JGCRI Linkages

Developing response functions and approaches utilizing AgMIP Results and Ongoing Research Activities:

- Understanding fundamental response of crops to biophysical drivers of climate change
- Interactive effects may be non-linear, uncertain
- Response to short-term extremes ≠ Response to long-term shifts
- Connections to food system and policy adaptations
- CO_2 x Temperature x Water responses from:
  - ✓ Network of independent sites
  - ✓ Many models on smaller network of sites
  - ✓ Global gridded model ensemble
- ➢ *Start with C3MP network of responses for mean and uncertainty, and then integrate additional results to improve response functions*

Other areas of potential development and mutual interest:

- Global carbon-temperature-water-nitrogen-adaptation sensitivity
- Pattern-scaling; Upstream/downstream emulation
- Climate scenario generation; Shocks and extreme climate events
- Coordinated Global and Regional Assessments (CGRA)
- Bioenergy

Thanks!

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