National Aeronautics and Space Administration
Goddard Institute for Space Studies

Goddard Space Flight Center
Sciences and Exploration Directorate
Earth Sciences Division

Correlated Extremes for Agriculture and Food Security Applications

Alex Ruane, Climate Impacts Group
NASA Goddard Institute for Space Studies, New York
Columbia University Center for Climate Systems Research

Correlated Extremes Workshop
May 30, 2019

Presentation represents author, not necessarily NASA

COLUMBIA

Outline

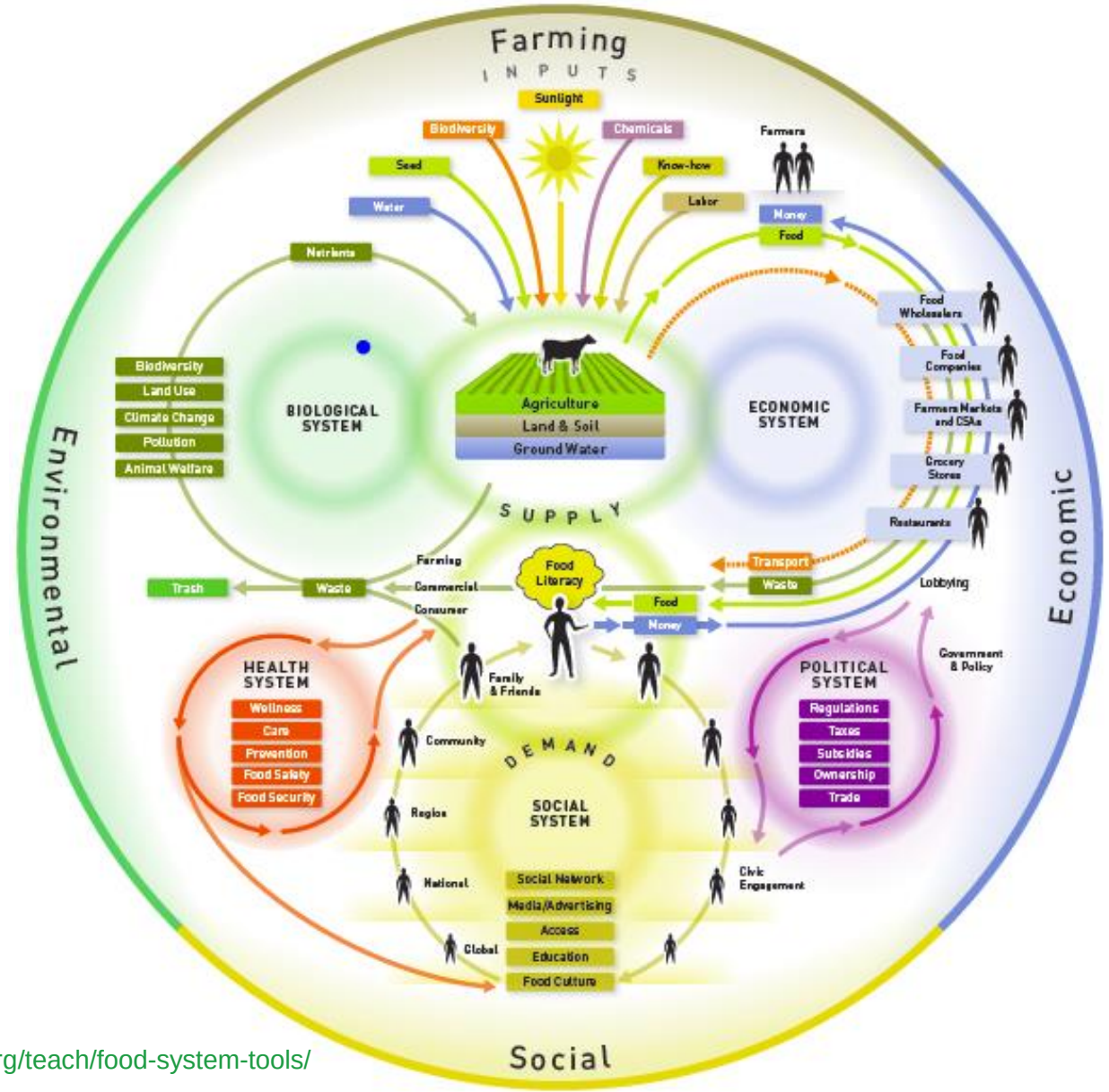
- **Agriculture and Food Security are vulnerable to correlated extremes**
  - Compound Extremes
  - Concurrent Extremes
  - Sequential Extremes
- **Complex nature of food systems can exacerbate or buffer ‘shocks’**
- **Designing models and simulations to explore extreme responses**
- **Bonus opportunities for contribution (IPCC and GRAF)**

Correlated Extremes in the Agricultural Sector and Broader Food System


Nestlé
FIBRA MAIS
O MAIS RICO em FIBRAS
350 g
CORN FLAKES
ULTRA BALL
SUCRILHOS
Moça Flakes
ESTRELITAS
MEL
CRUNCH CEREAL
NESCAU
FROOT LOOPS
4,19
5,99
8,49
7,49
6,99
7,49
5,99
7,49
6,49


Hipercard

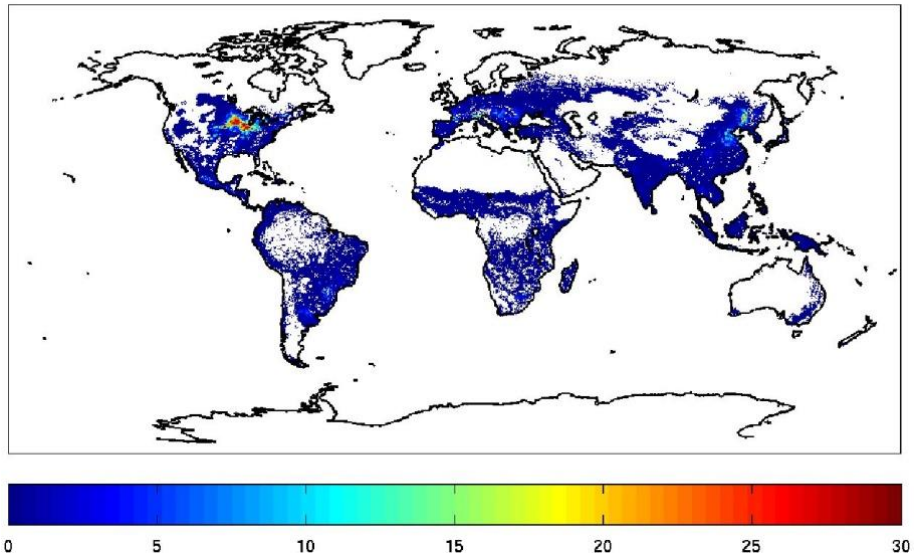
The Complex Food System



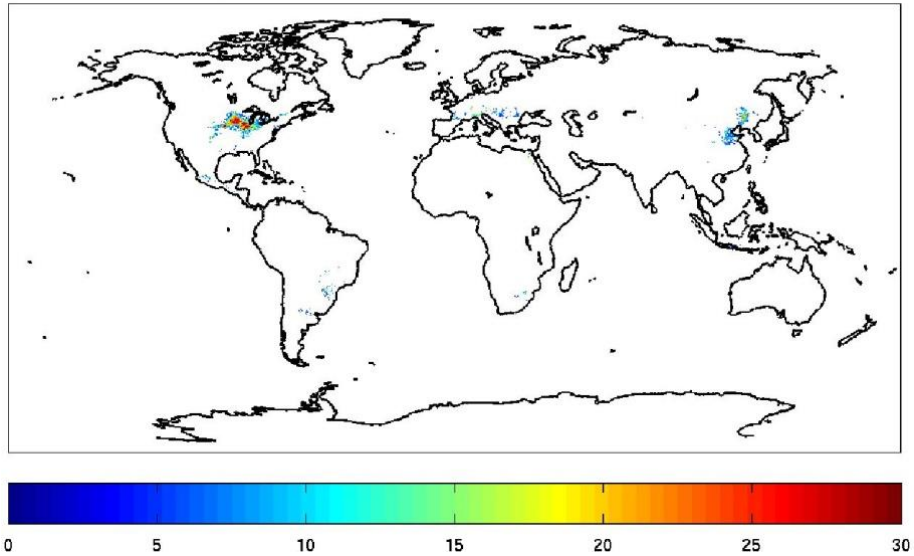
http://www.nourishlife.org/teach/food-system-tools/

Tracking a Global Commodity

Maize Production (1000s of kg)



Top Regions Accounting for 90% of World Maize Production



Data from Monfreda et al., 2002

Correlated Extremes for Food Systems

Food Security:
Availability, Access, Utility, Stability

Compound Extremes:

- Hot/wet: Livestock and labor productivity; Disease pressure
- Hot/dry: Crop production, water resources
- Hot/Ozone: Crop production

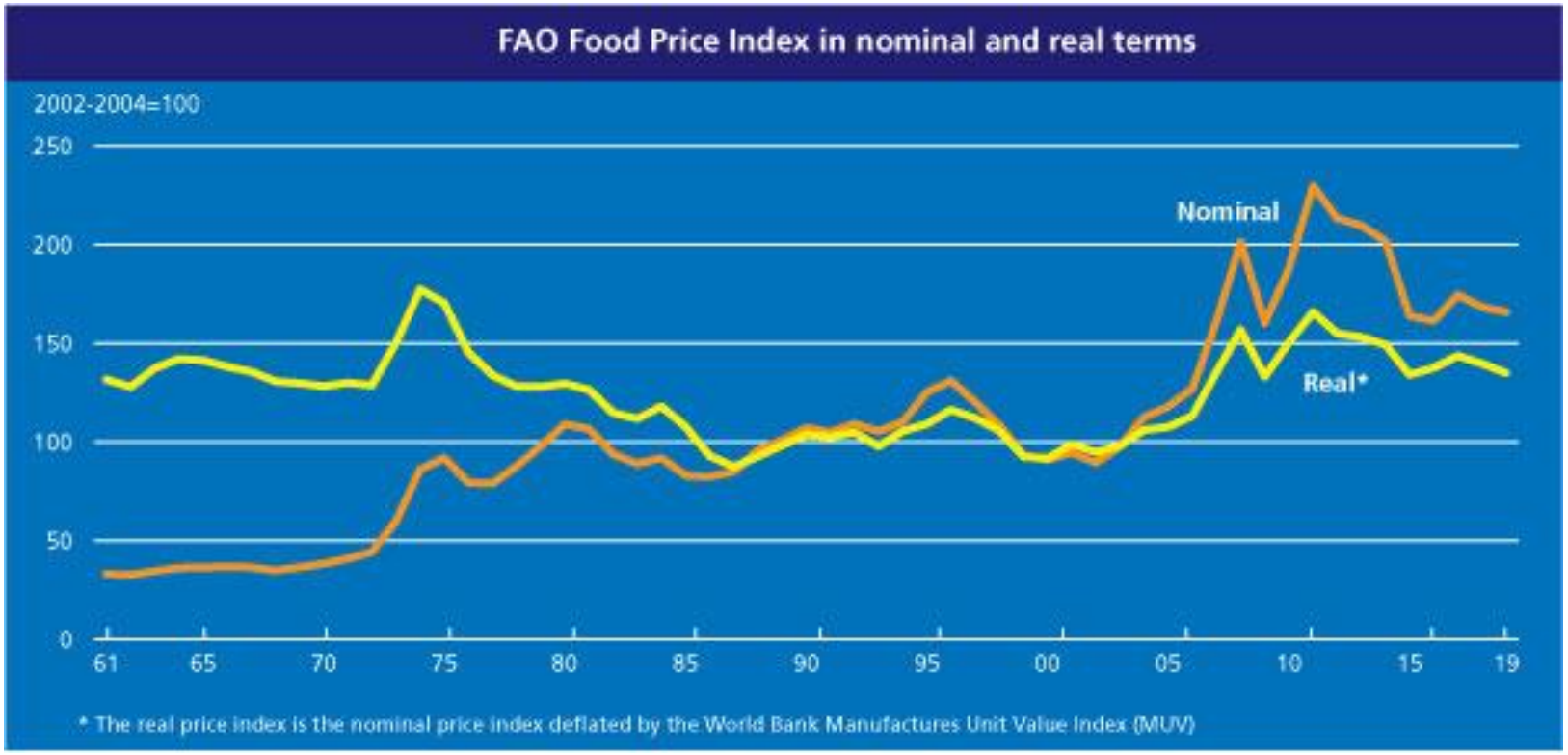
Concurrent Extremes:

- Multi-breadbasket failure
- Crop production loss and interruption of market access

Sequential Extremes:

- Early warm spell followed by frost
- Early season wet spell followed by late season drought

The Complex Food System

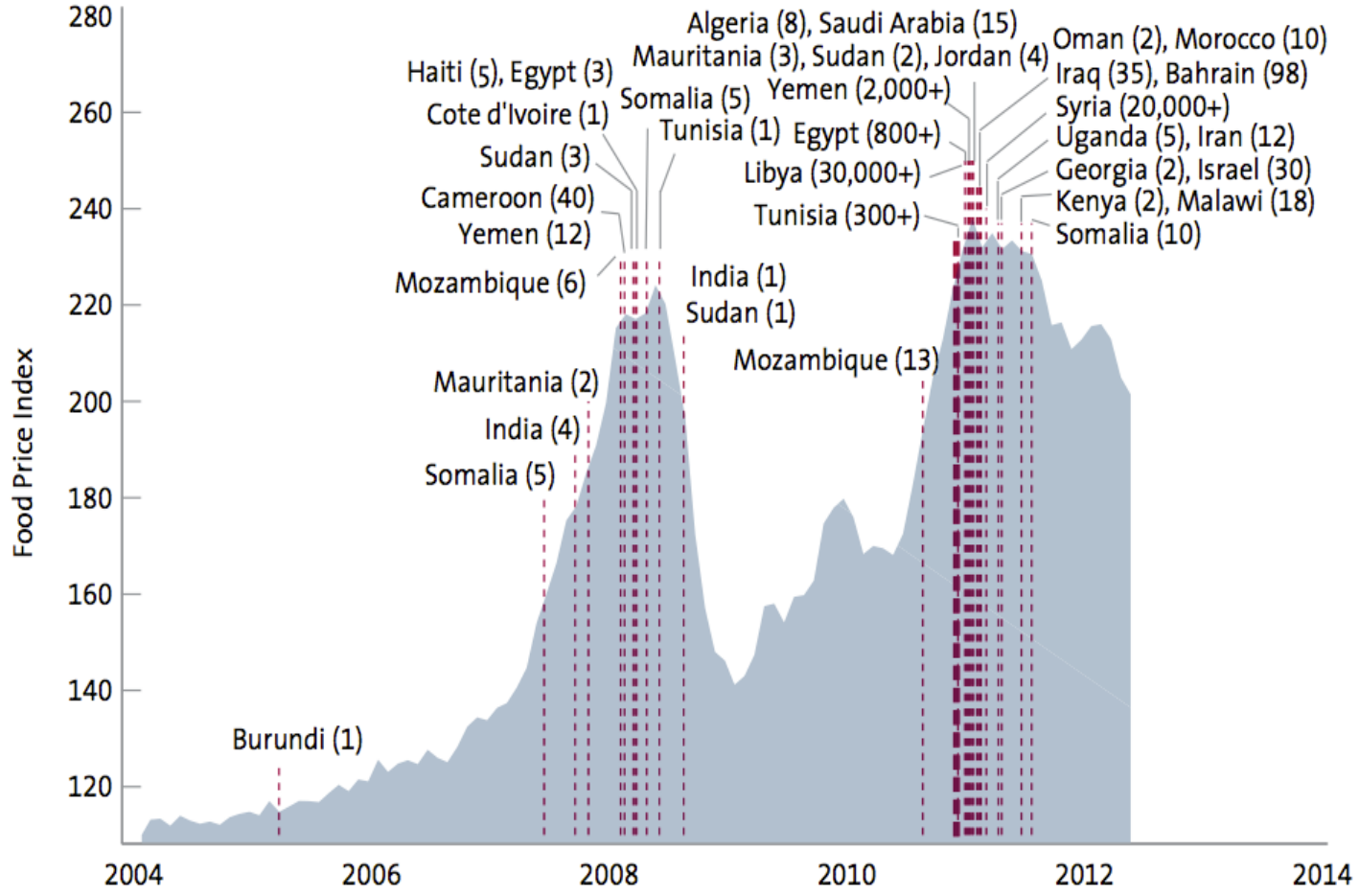


Assumption of perpetually declining food prices now called into question.

Spikes due to: drought, heat waves, and wildfires causing poor production in some regions; energy price spikes, declining food stocks, trade policy, expansion of biofuels

Consequences: increased number of malnourished, shift in diets, reduced spending on other essentials, gender-based outcomes, social unrest, migration

Food price spikes can exacerbate instability

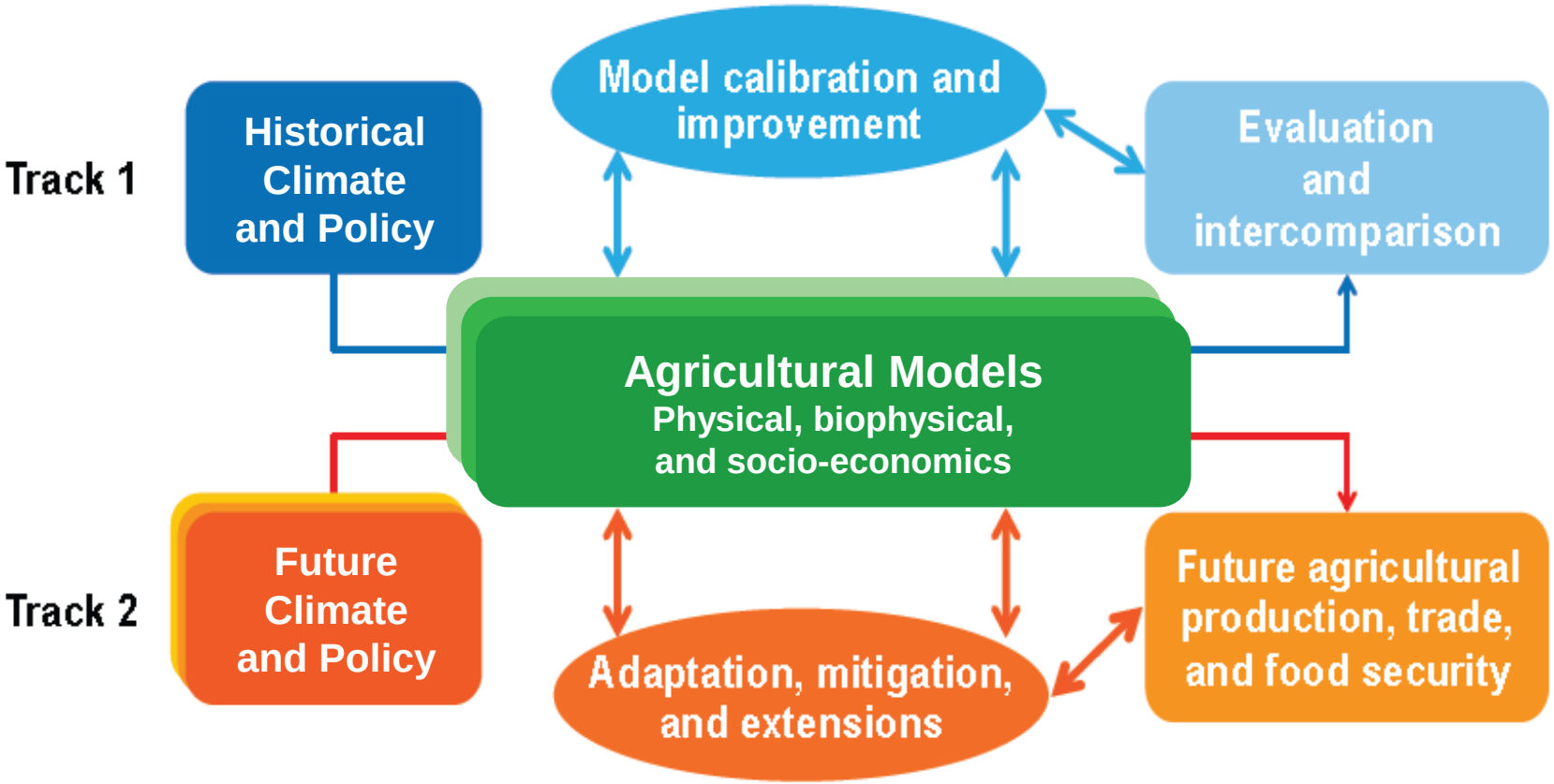


Red dashed lines correspond to the beginning dates of "food riots" and protests in North Africa and the Middle East between 2004 and 2011. The overall death toll is indicated in parentheses next to each country.

Source: Lagi, Bertand, Bar-Yam 2011.

The Agricultural Model Intercomparison and Improvement Project (AgMIP)

AgMIP Enables *Evaluation* of Agricultural Risk and *Testing* of Risk Reduction Strategies

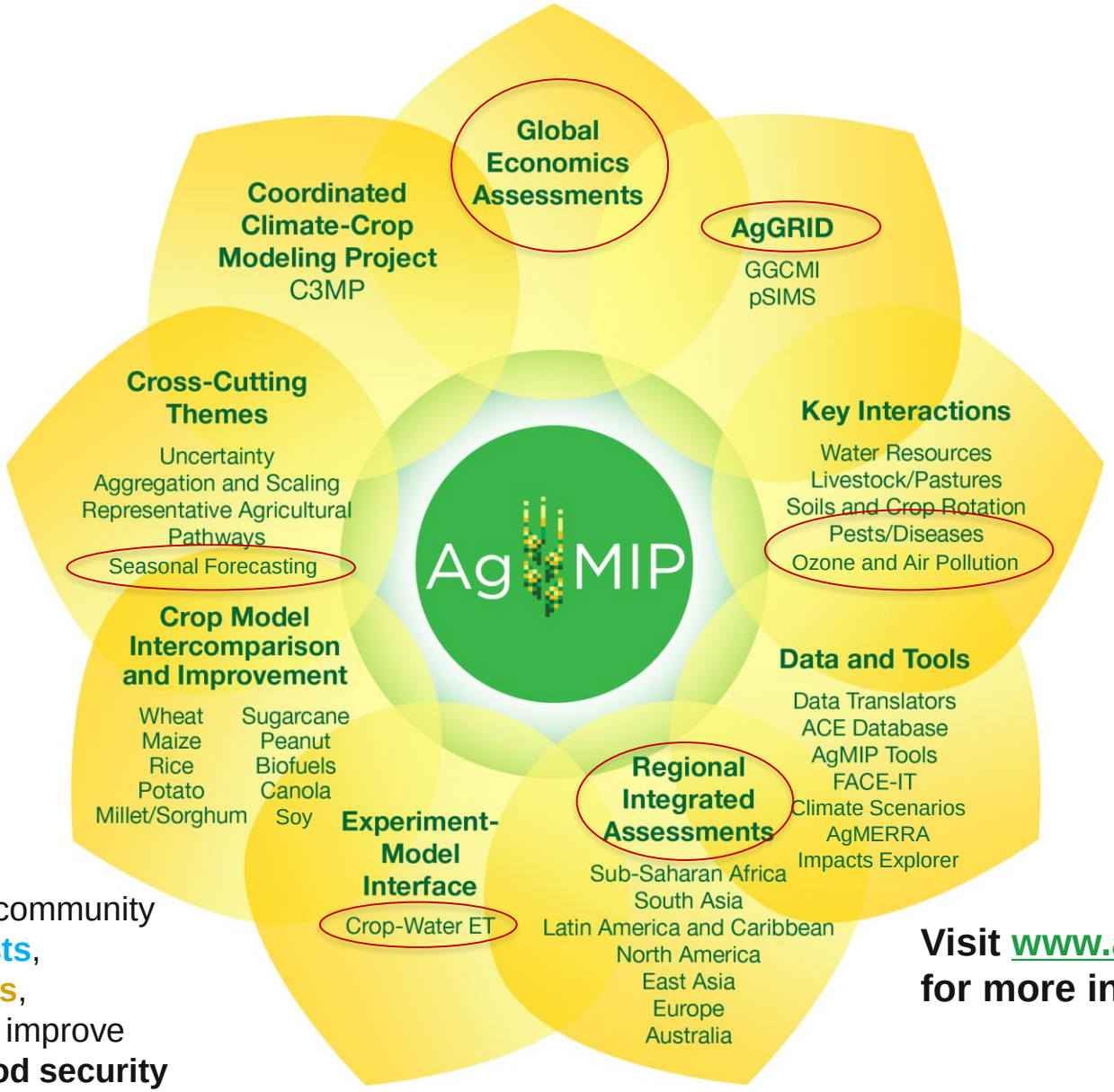


Modified from Rosenzweig et al., 2013 AgForMet

The Agricultural Model Intercomparison and Improvement Project (AgMIP) was created in 2010 to provide a community for systematic improvement and application of multi-disciplinary, multi-model, multi-scale frameworks for agricultural development and food security.

Current AgMIP Activities

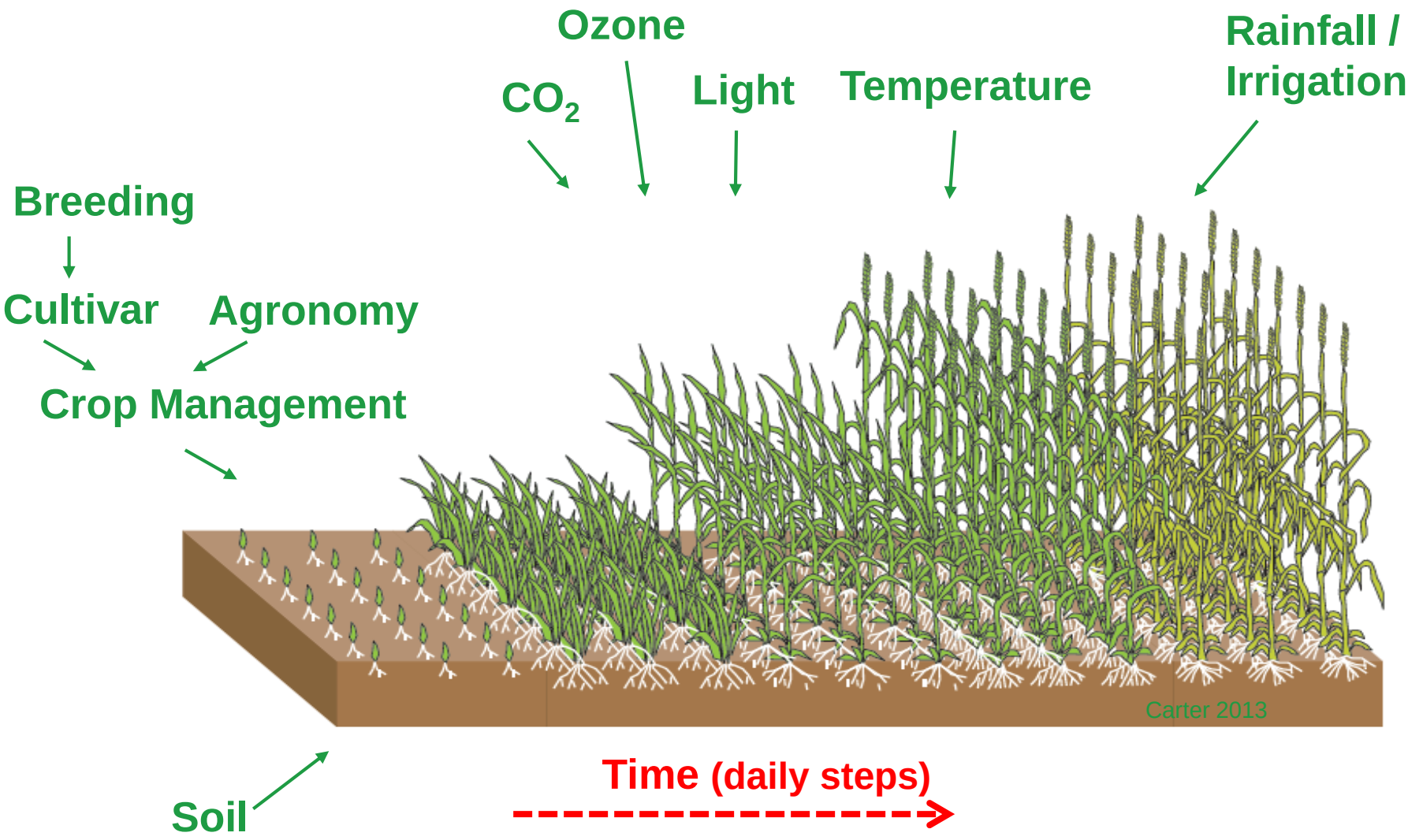
Building an integrated framework across scales, disciplines, and models



AgMIP is an international community of 1000+ **climate scientists**, **agronomists**, **economists**, and **IT experts** working to improve assessments of **future food security**

Visit www.agmip.org for more information

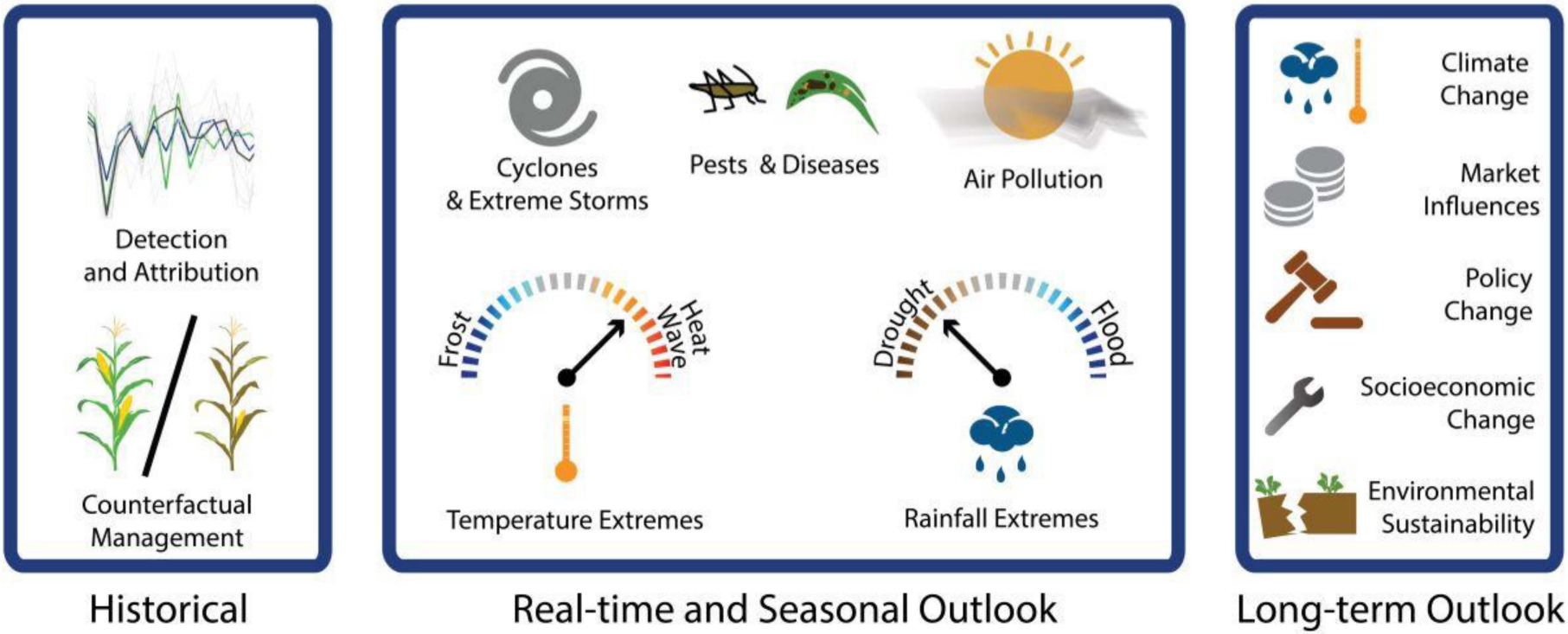
Process-based Cropping Systems Models Capable of Compounding Impacts Across Time and Hazards



Slide courtesy of Senthold Asseng, UFlorida

Applications Across Time Horizons

Can we find/generate/respond to correlated extremes?



Ruane et al., in prep

Designing Experiments to Explore Unobserved Agro-Climate Conditions

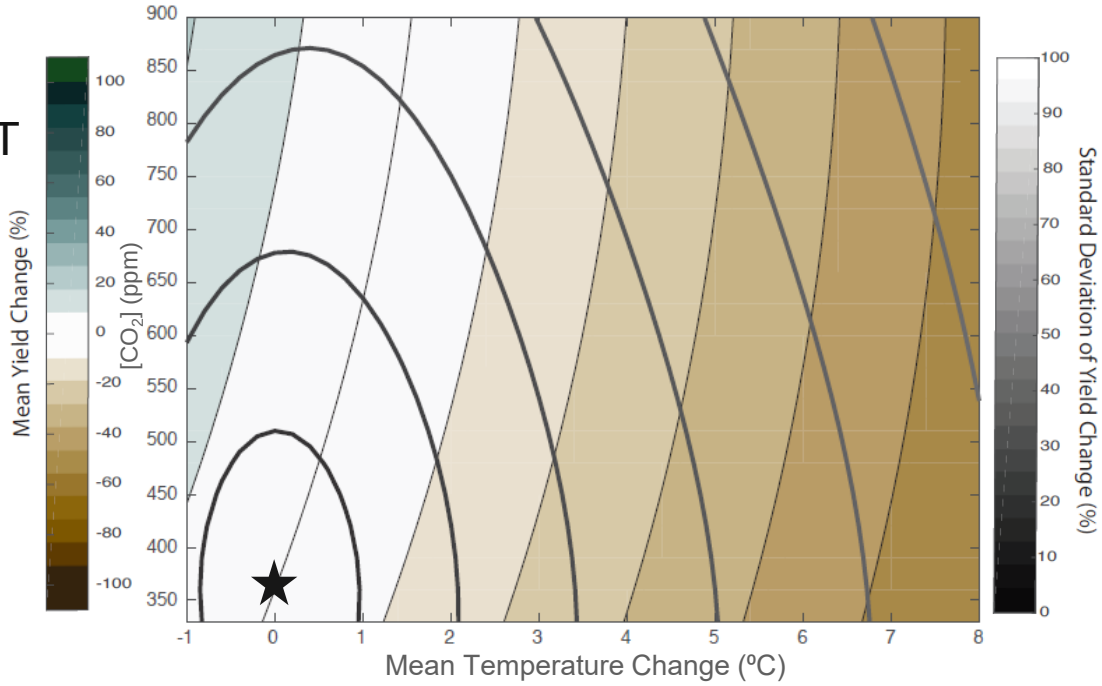
The AgMIP Global Gridded Crop Model Intercomparison (GGCMI Phase 2) examines **CO_2-temperature-water-nitrogen-adaptation** sensitivity tests across multiple crops, models, and farm systems

Impacts on yield, water use, and nutritional quality

$[CO_2]$

ΔT

Mean Yield response (% change) from 106 rain-fed maize sites around the world



Colors = emulated mean yield changes

Gray contours = uncertainty

(lighter is more uncertain)

★ = current conditions

$[CO_2]$ = 360, 510, 660, 810 ppm

ΔT = -1 +0 +1 +2 +3 +4 +6 ºC

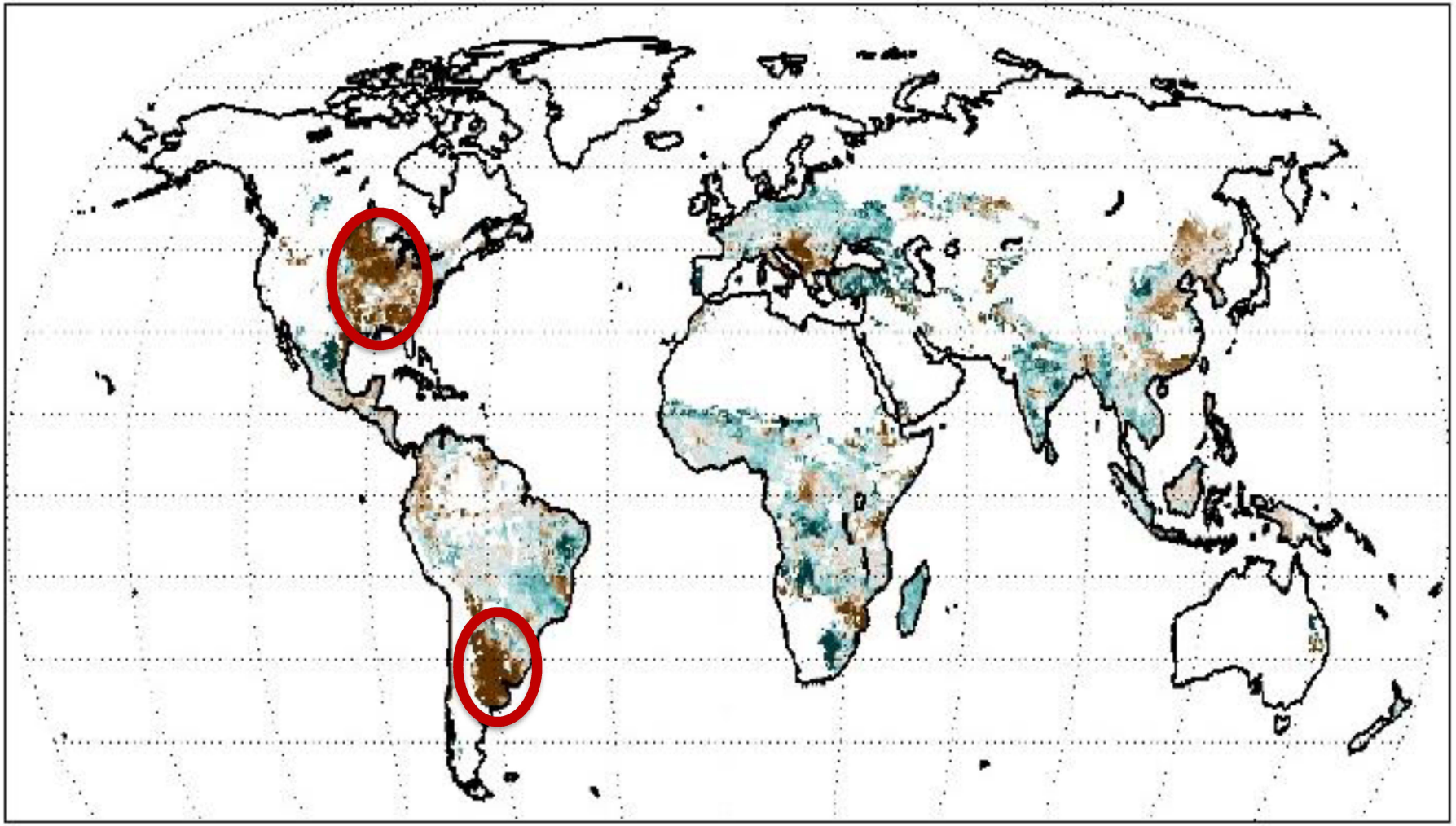
ΔW = -50% -30% -10% +0% +10% +30%

N = 10, 60, 200 kg N/ha

A = Fixed cultivars,
Cultivars selected to restore growing season length

GGCMI Phase 2

1988 Drought



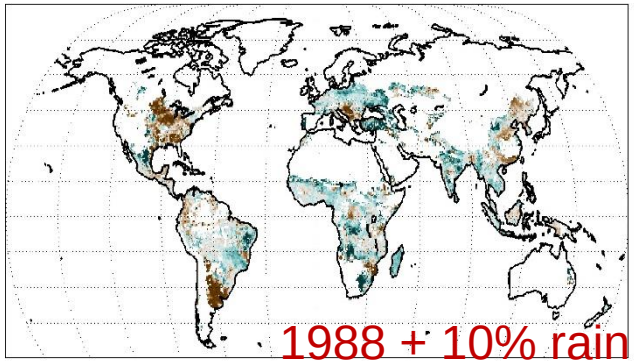
pDSSAT
crop model

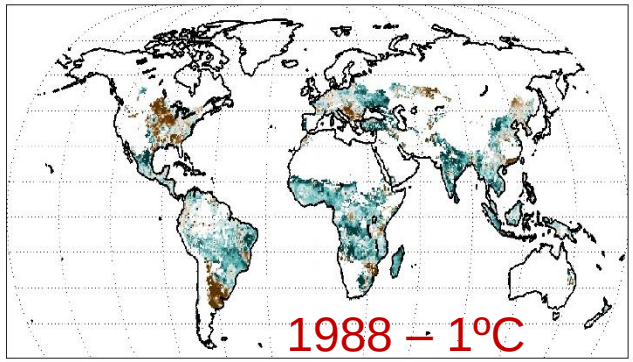
Plausible Events and Climate Change-driven shifts in Risk Profile

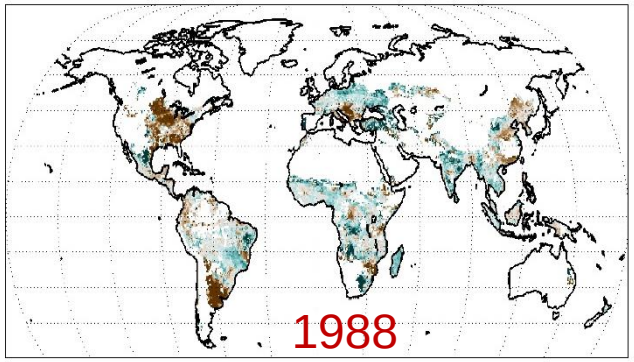
How would 1988 drought have been different if it were:

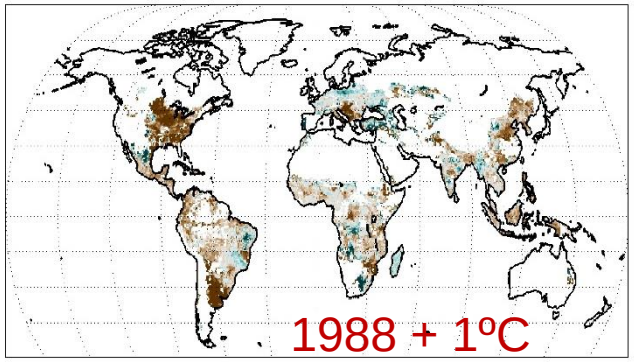
Wetter

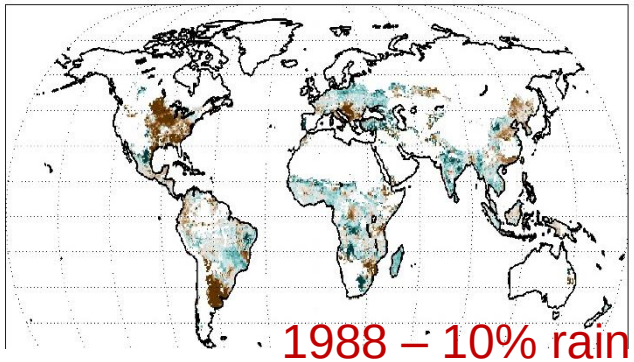
Warmer

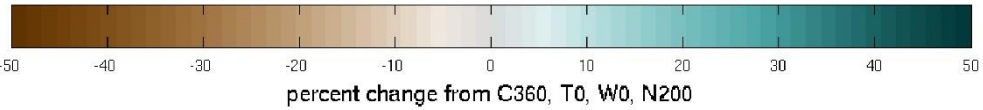








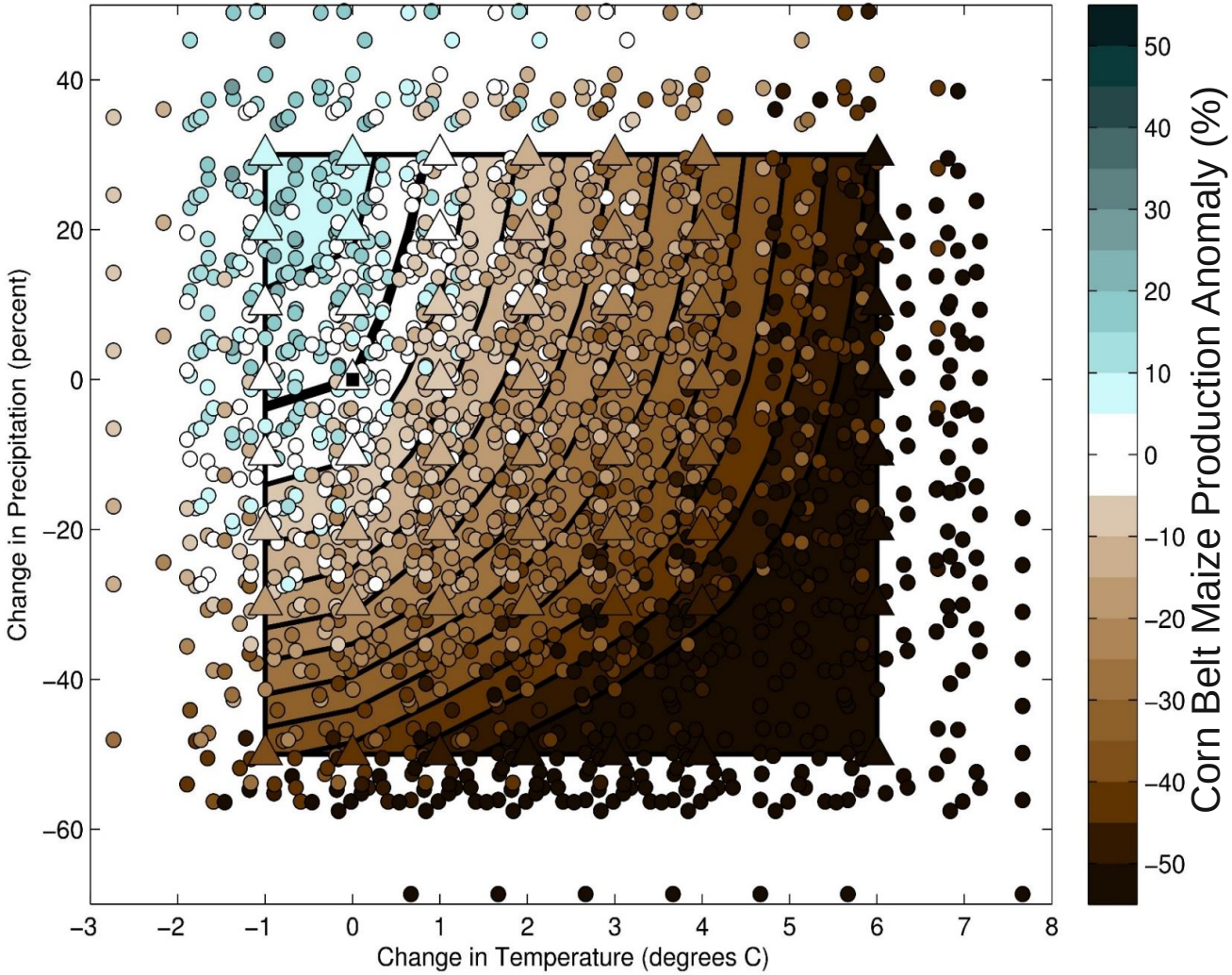




pDSSAT crop model

Many individual years evaluated

Maize Yield by Climate Anomaly in Corn Belt, USA



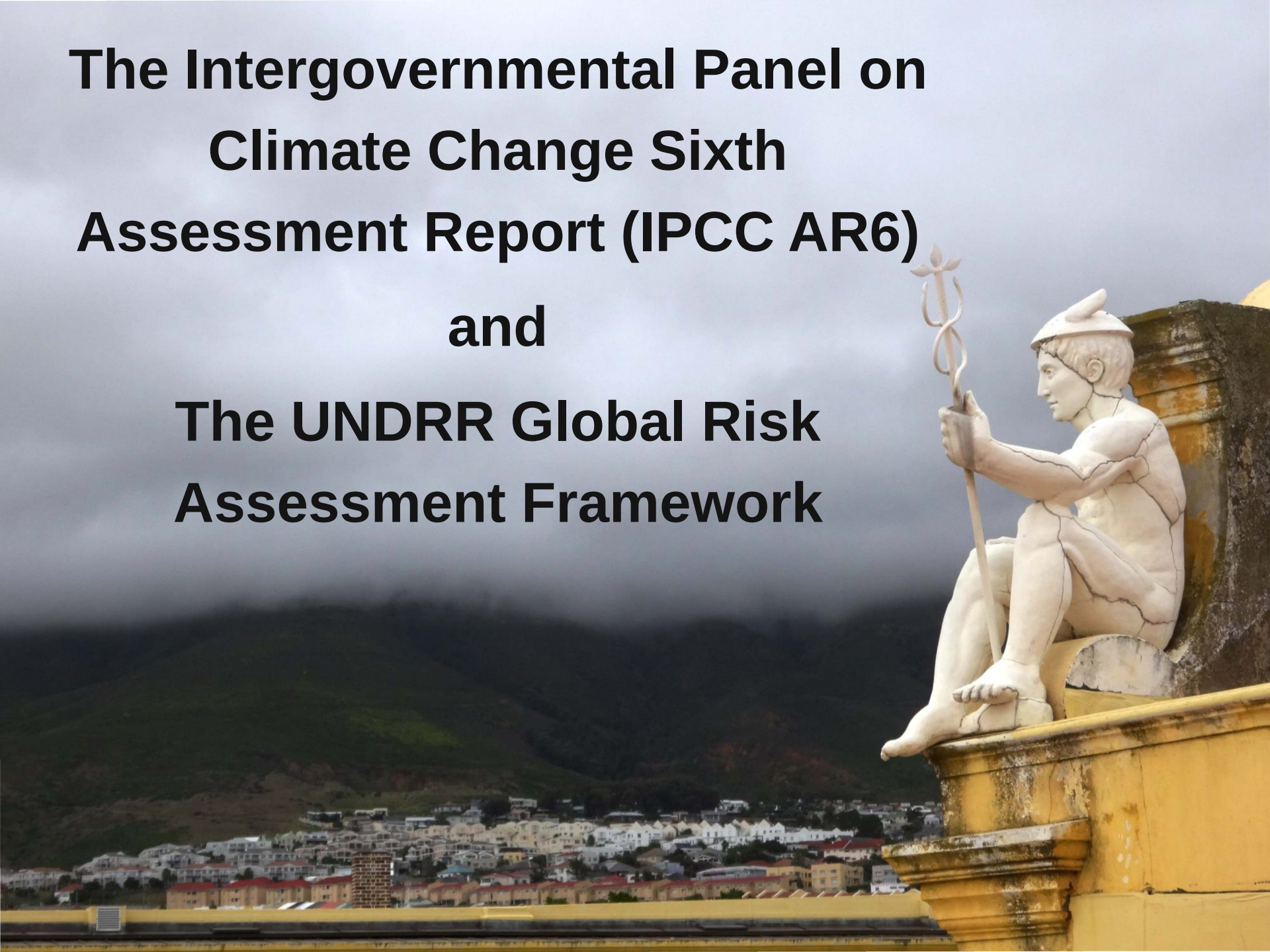
Models uniquely capable of exploring unobserved **climate extremes**, **field environments**, **genetics**, and **farm management** to characterize particular vulnerabilities

Filled contours show smooth fit to seasonal production anomaly as function of mean T, P
Dots represent individual years influenced by correlated extremes and phenological timing

The Intergovernmental Panel on Climate Change Sixth Assessment Report (IPCC AR6)

and

The UNDRR Global Risk Assessment Framework



IPCC Sixth Assessment Report – Enhanced Focus on Risk

Working Group 1:

'Regional Chapters'

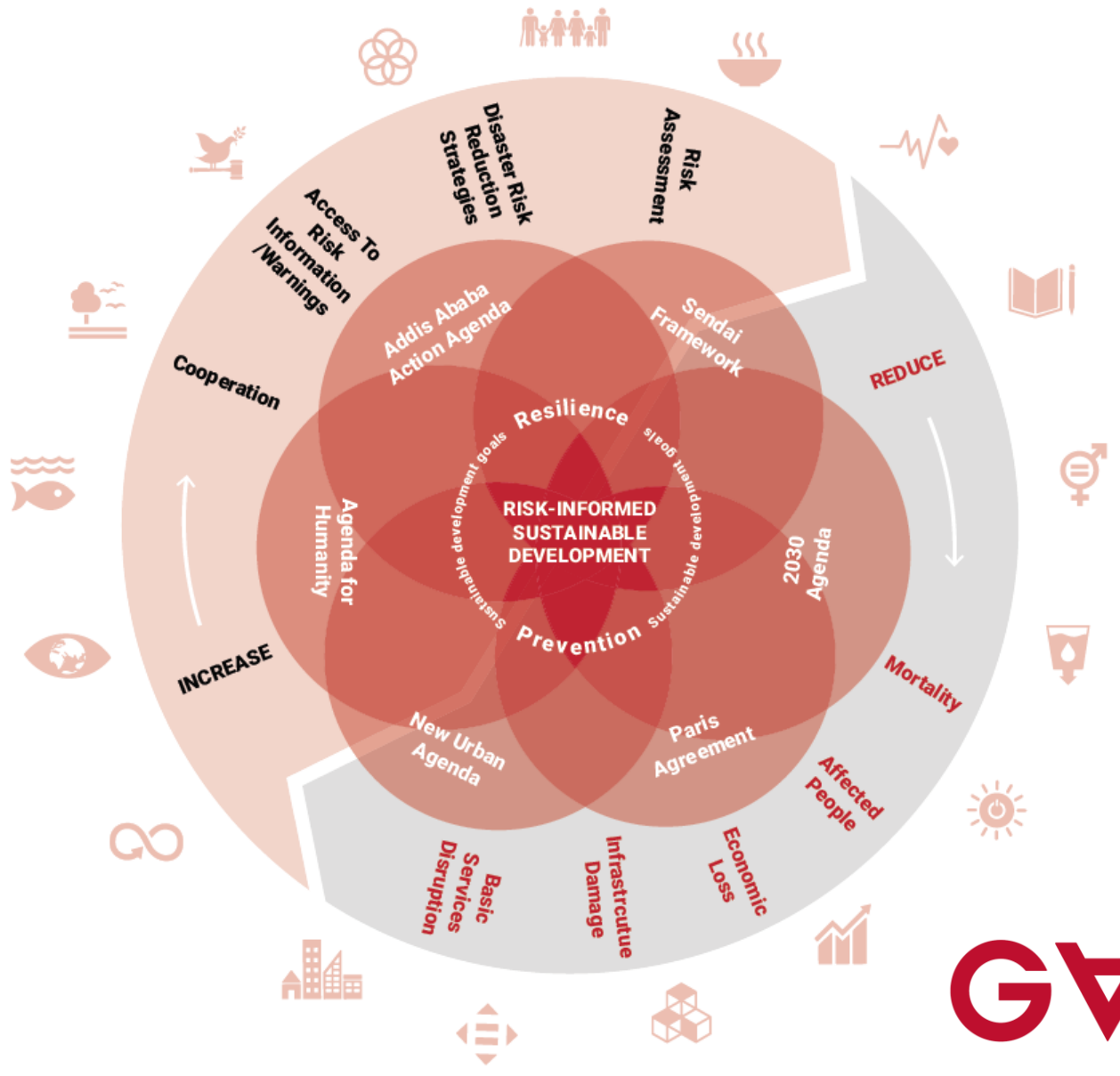
- Chapter 10: Linking global to regional climate change
- **Chapter 11: Weather and climate extreme events in a changing climate**
- **Chapter 12: Climate change information for regional impact and for risk assessment**

- Risk = hazard x vulnerability x exposure
- Impact = a specific realization of a risk

- A climate value becomes a climate hazard when it connects to exposure and/or vulnerability
- Hazards can change in their magnitude, frequency, duration, timing, and/or spatial extent

Submit by December 31st, 2019!

UNDRR Global Risk Assessment Framework



The UNDRR GRAF aims to provide a curated space for disaster systems assessment, providing an infrastructure to foster improved risk information for stakeholders

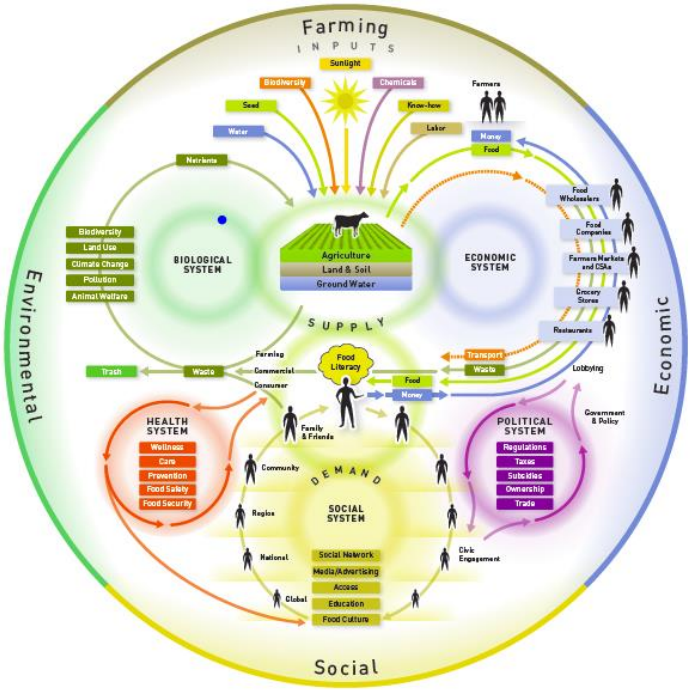
Target: 2030

Check out GAR19

GAR

Summary

- Vulnerabilities to correlated extremes are increasingly recognized within the agricultural sector and broader food system
- Compound, concurrent, and sequential extremes pose unique challenges, particularly when coupled with field management and markets that span many spatial scales and time horizons
- AgMIP is systematically connecting climate to crop, livestock, economics, food security, and nutrition using a coherent modeling framework that captures more complex behaviors of correlated extremes
- Experiments designed to explore historical (as well as hypothetical) extremes aid in big data analysis and planning for resilience and broader risk management
- Opportunities to better connect extremes, hazards, disasters and climate through IPCC and GRAF




Thanks!
alexander.c.ruane@nasa.gov