

Modeling the Impacts of Climate Change and Extreme Events on Food

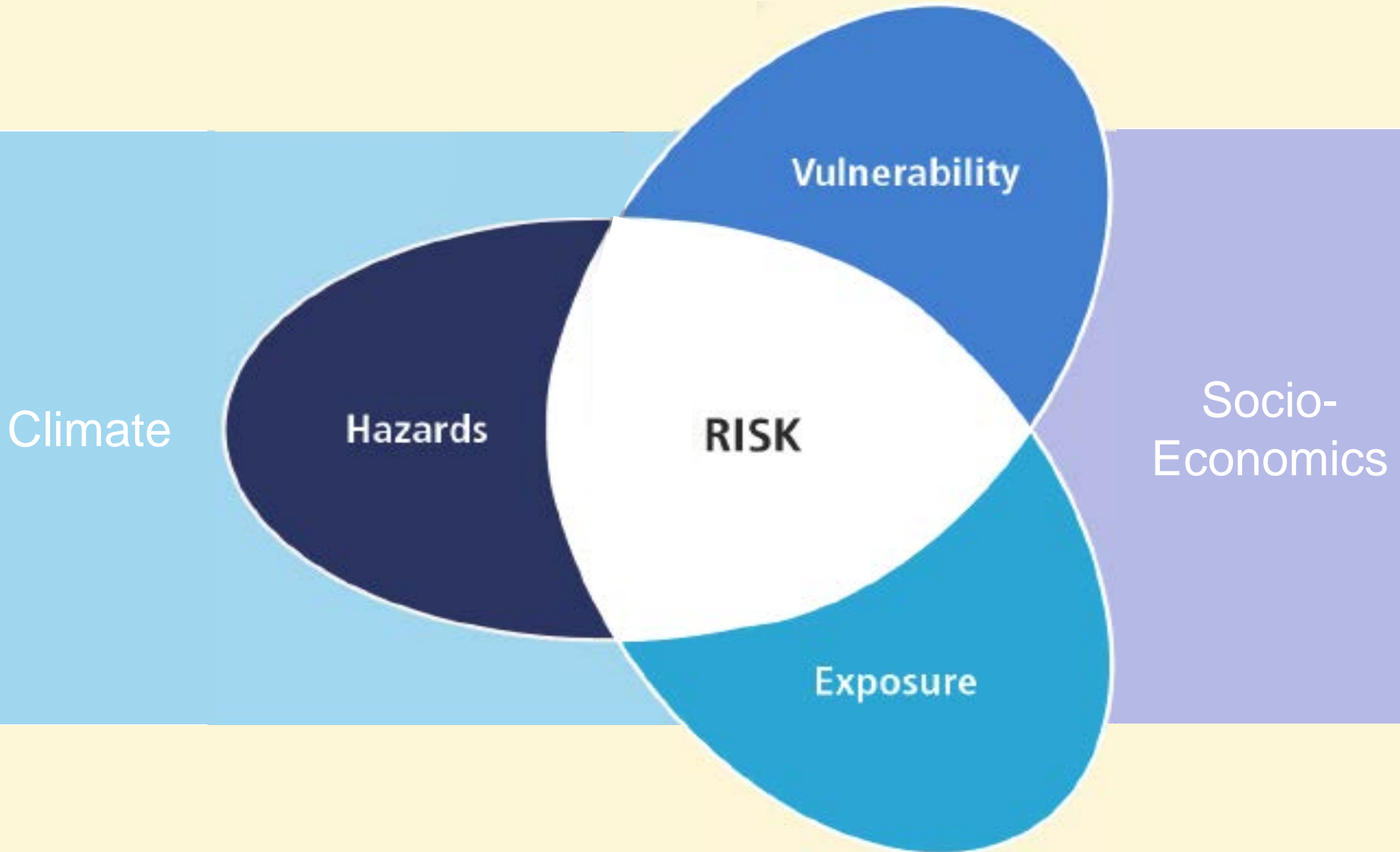


Alex Ruane, NASA Goddard Institute for Space Studies, New York, USA

Asia-Pacific Economic Cooperation (APEC) Climate Symposium, Piura, Peru
September 16th, 2016



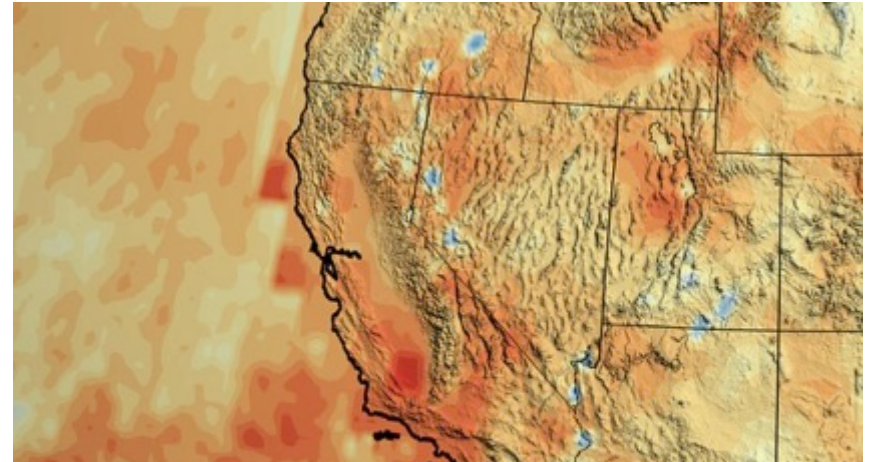
Goddard Institute for Space Studies
New York, N.Y.





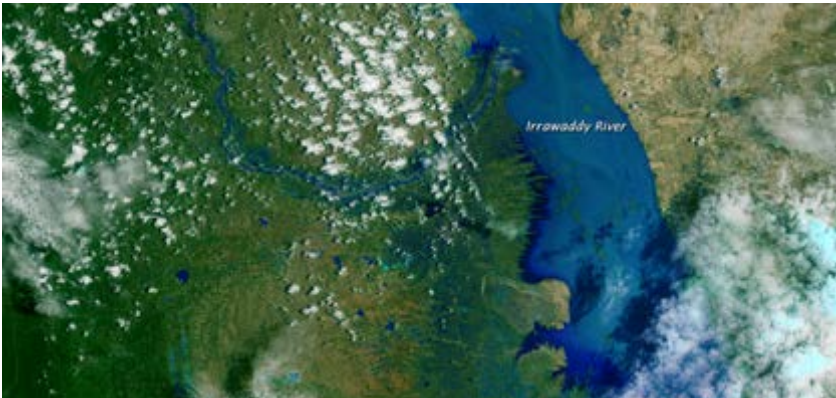
Corn shows the effect of the drought in Texas in August 2013

U.S. Department of Agriculture/Bob Nichols



California's accumulated precipitation "deficit" from 2012 to 2014

NASA/Goddard Scientific Visualization Studio



Satellite image of flooding in Burma (Myanmar) August 2015

NASA Earth Observatory images by Joshua Stevens



Severe flooding in August 2015 in Pakistan wipes out harvest

Image:Rueters/London

Food Security is more than just farm production

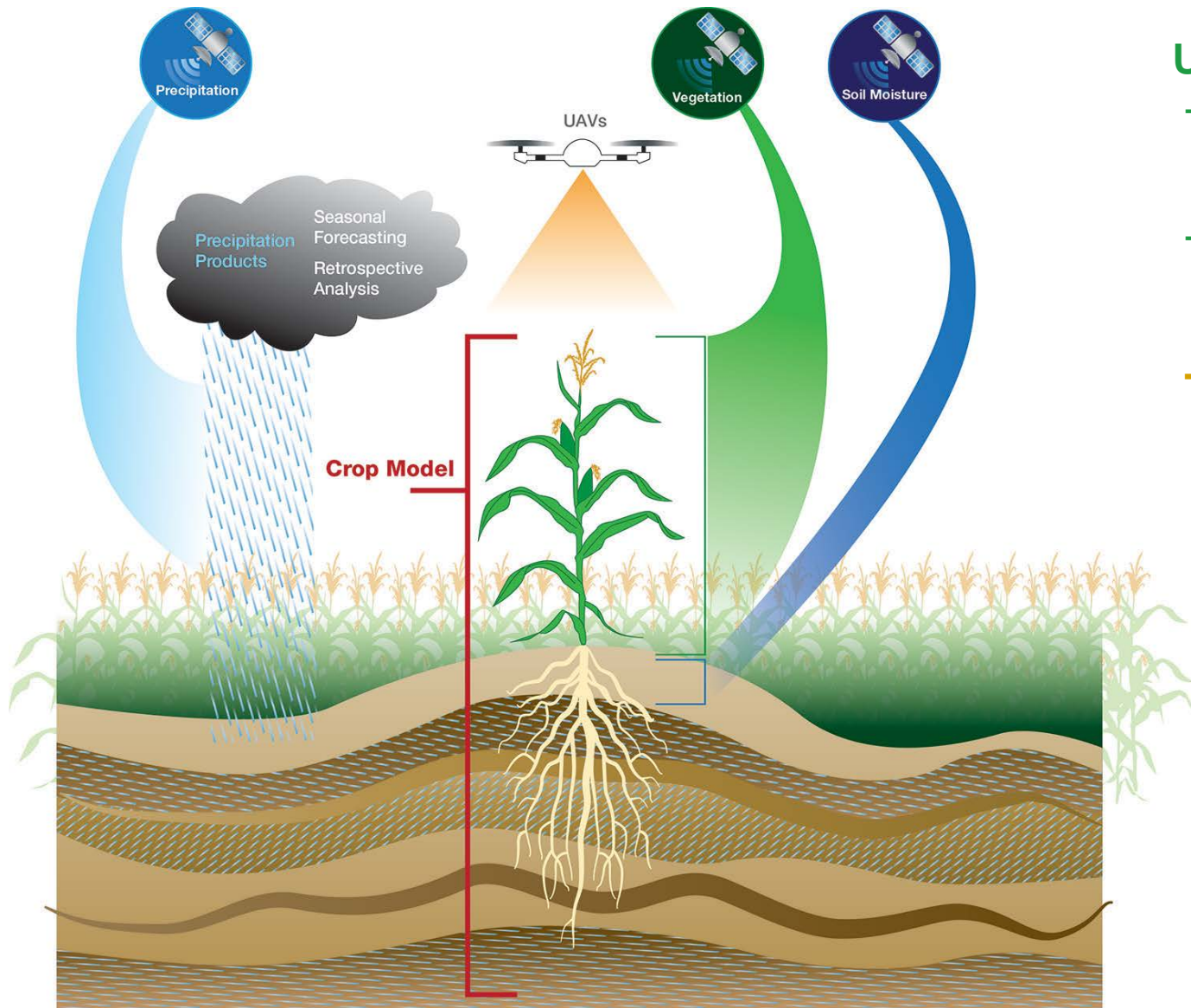


- Availability, access, utilization, and stability of food supply all important for food security

Impacts of nutrient deficiencies depend on age

➤ **First 1000 days of life are critical**

Agricultural economies and food value chains act differently when stressed by shifts in climate, economics, or policies

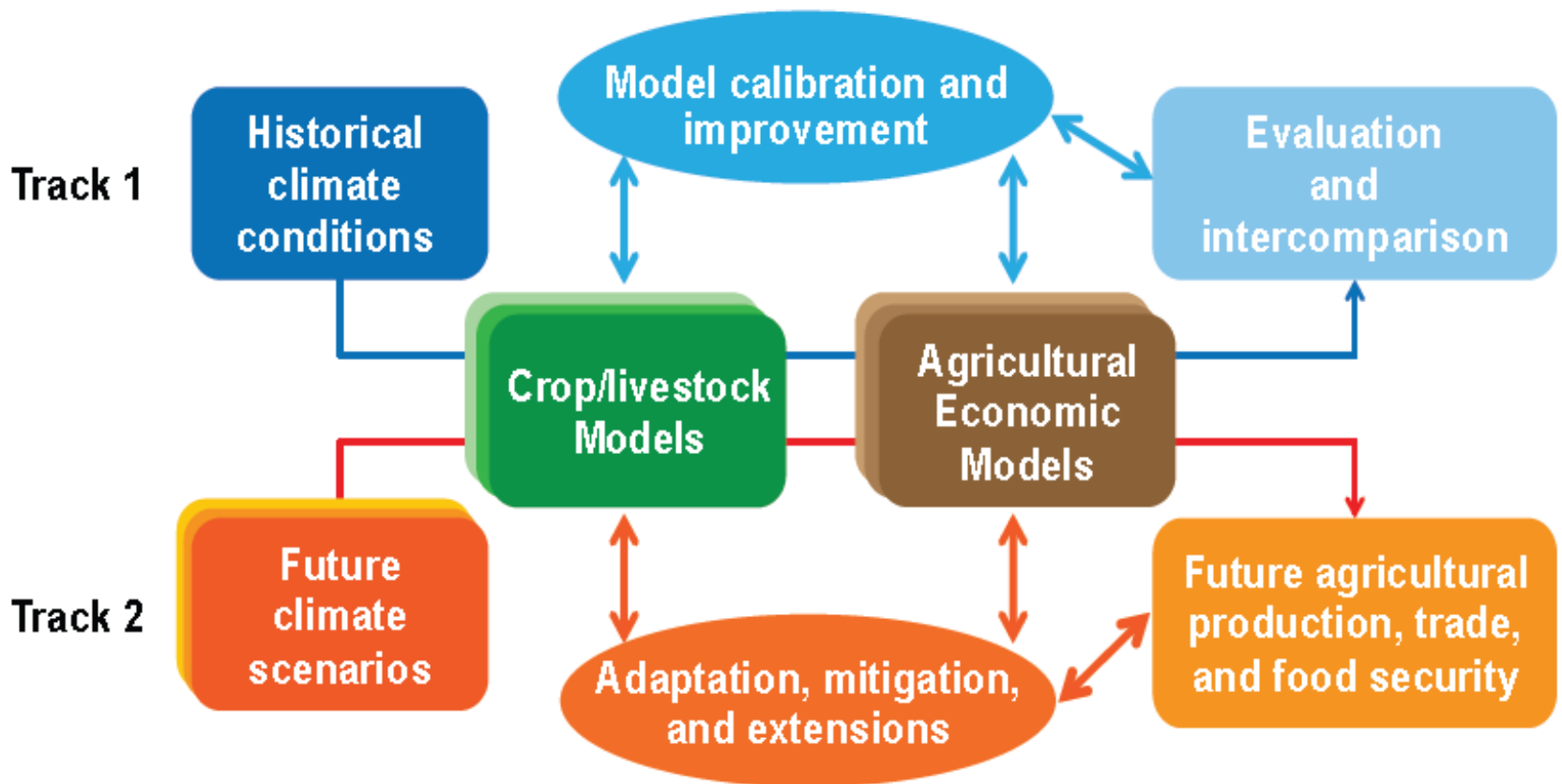


Utilize available tools:

- Direct observation
 - Surveys and reports
- Remote sensing
 - Surveys and reports
- **Crop Models**
 - Allow estimation of within-plant and below-ground status and processes
 - May be configured for a variety of management conditions
 - Driven by weather and climate conditions
 - Capable of simulating non-linear effects

The image shows a vibrant agricultural scene with terraced fields. The upper portion of the image is dominated by rows of tall, green corn plants. Below the corn, there are several terraces of rice seedlings, which appear as bright green patches. In the lower foreground, three people are working in a rice field. One person is wearing a white shirt and a white headscarf, another is in a red shirt and red headscarf, and the third is in a red shirt and a dark headscarf. The background is a dense forest of green trees. The overall scene is bright and colorful, representing a healthy agricultural environment.

The Agricultural Model Intercomparison and Improvement Project (AgMIP)



Rosenzweig et al., 2013 AgForMet

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

Some AgMIP Meetings for A-P Region:

- East Asia:

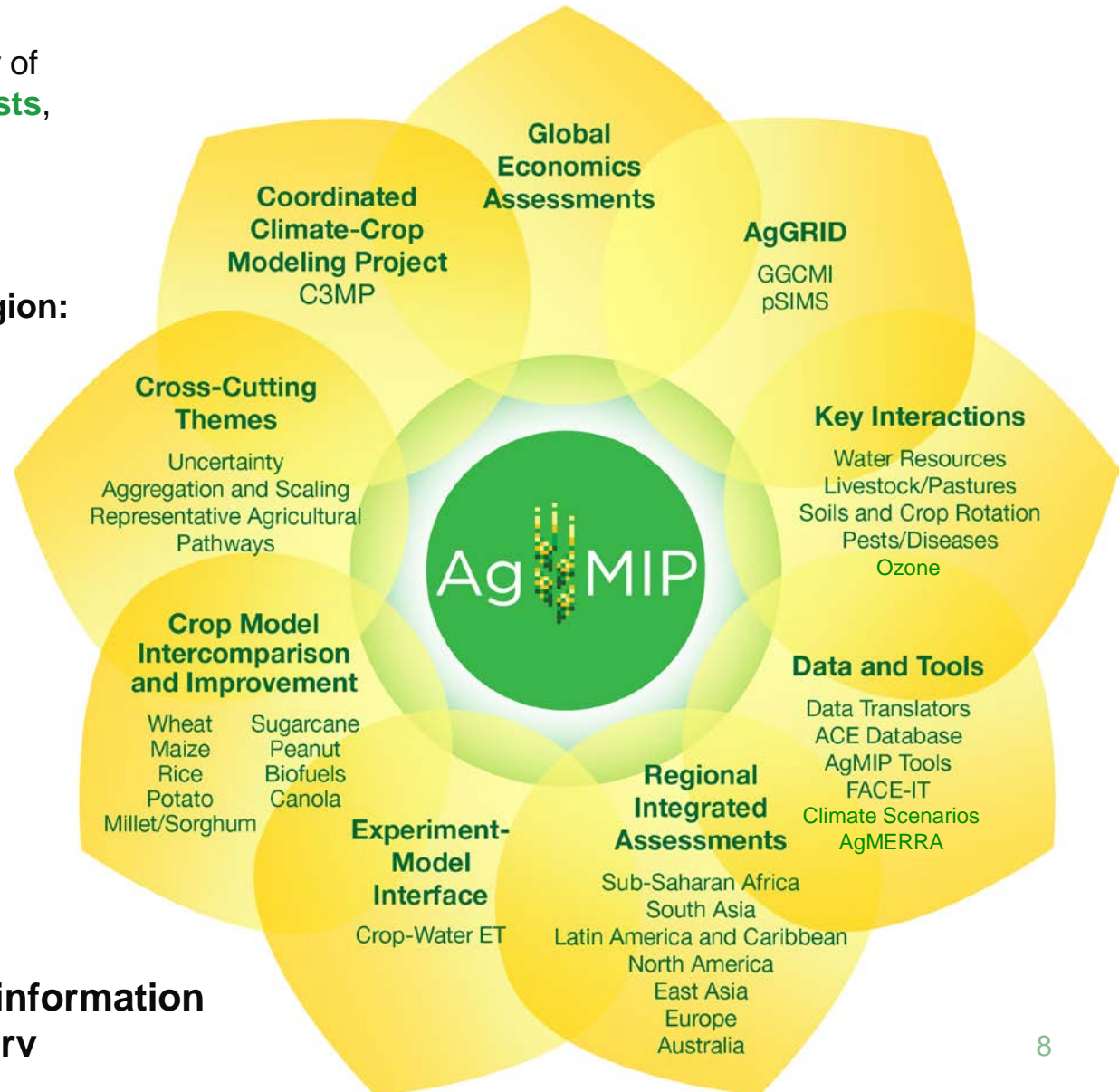
- October, 2011 (China)
- December, 2012 (Philippines)
- October, 2013 (China)
- September, 2016 (South Korea)

- Latin America:

- August, 2011 (Brazil)
- September, 2013 (Brazil)
- September, 2015 (Colombia)

- North America:

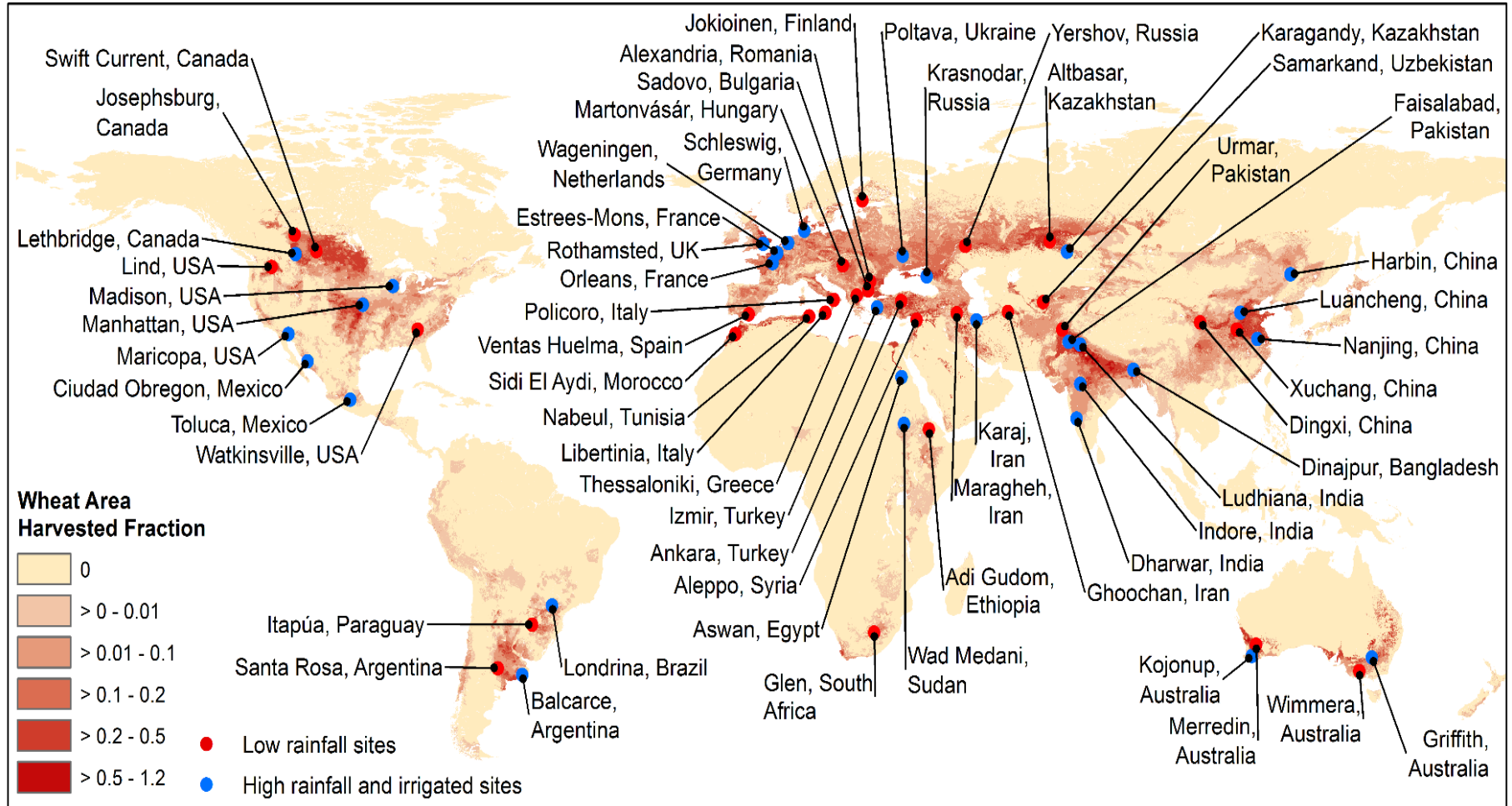
- October, 2010 (USA)
- October, 2011 (USA)
- October, 2013 (USA)
- June, 2013 (Mexico)
- February, 2015 (USA)



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

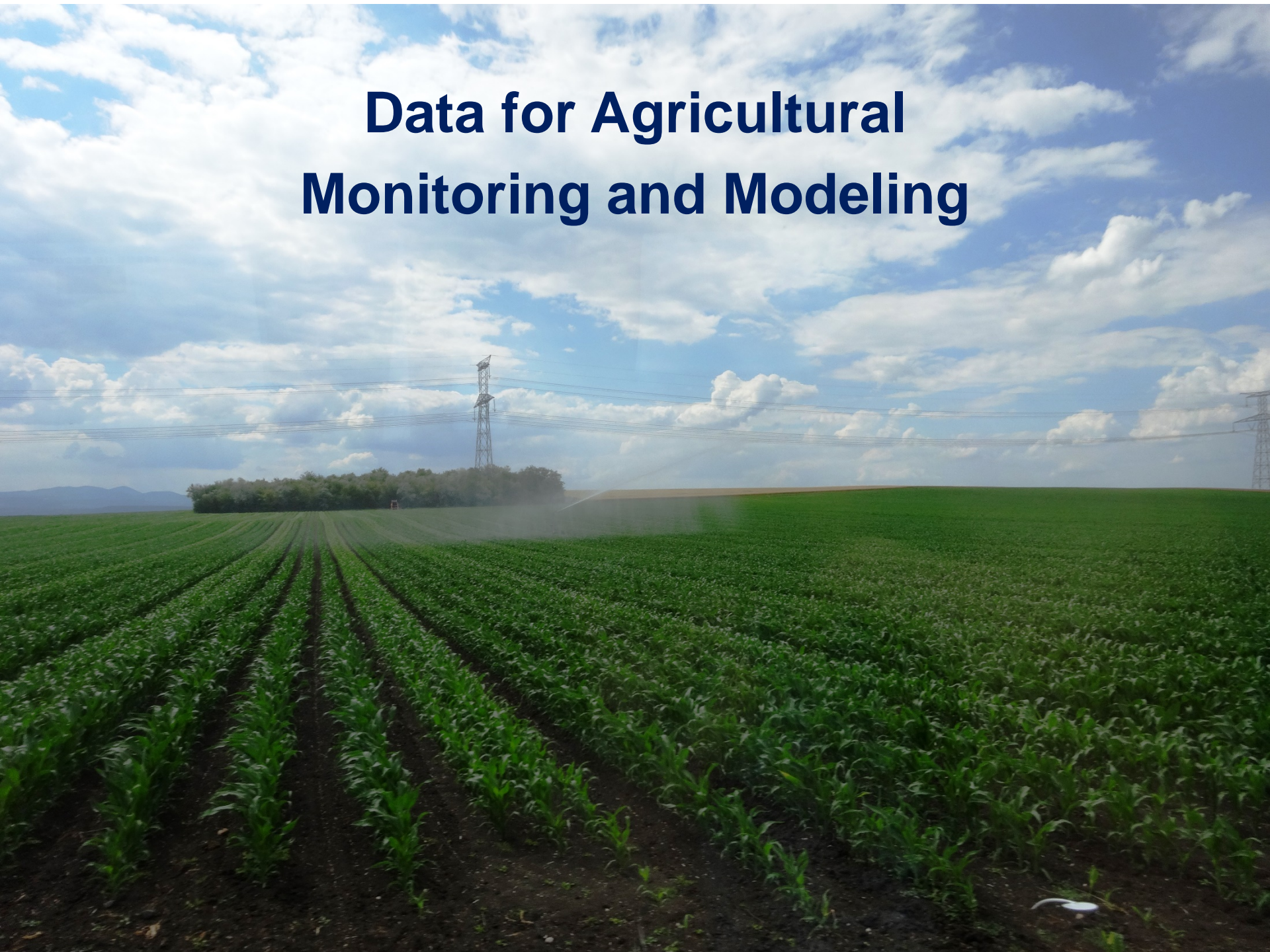
- **Improved Models and Understanding:** Increased focus on heat stress and crop water / evapotranspiration processes; more diverse applications
- **Representative Site Networks:** Allows for detailed model calibration and representation of broader production regions
- **High-performance Computing:** Parallel processing on clusters enables unprecedented computational power
- **Multi-model Frameworks:** Consistently outperform individual models
- **Improved Climate Data:** Continuing advances in historical data and forecasts on various time horizons
- **Data Assimilation:** Machine learning and improved remote sensing tools can constrain crop models





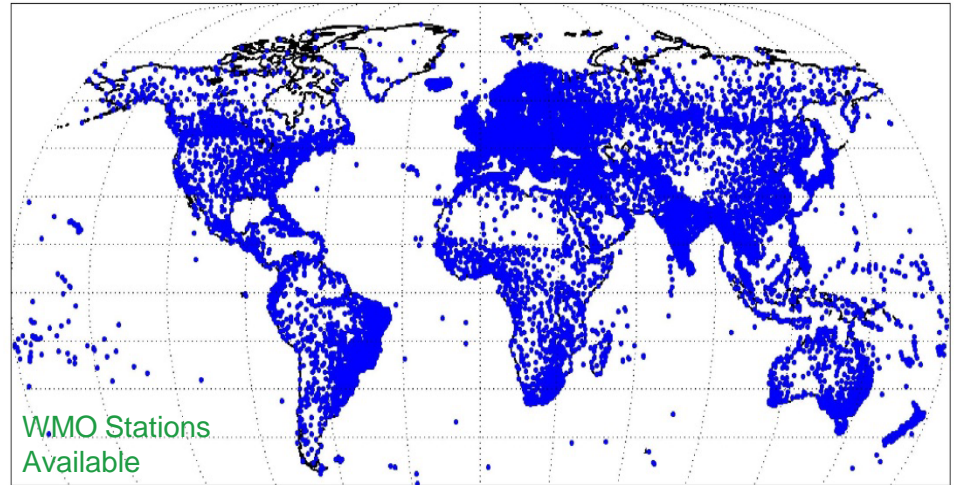
Sites where 34 Wheat Models have been configured for analysis by the AgMIP Wheat Team Phase 3 (Senthold Asseng, Frank Ewert, Pierre Martre, et al.)

Data for Agricultural Monitoring and Modeling

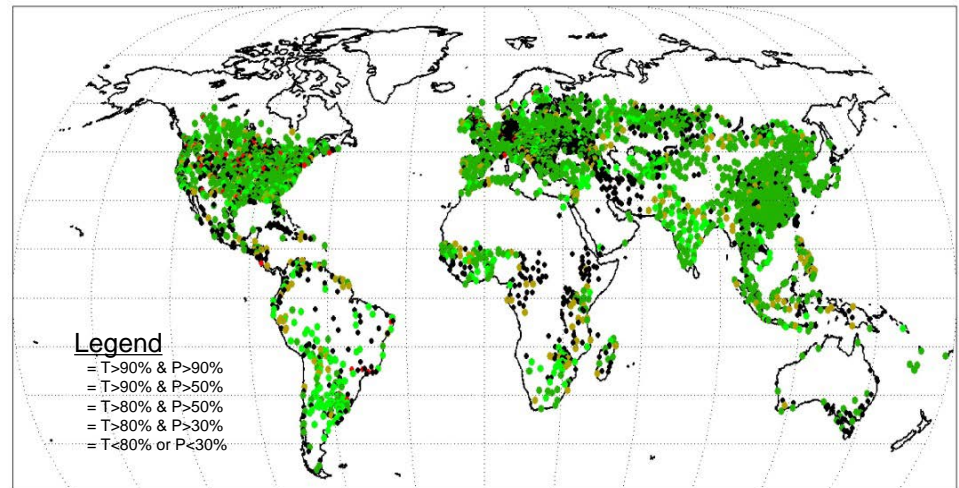


Historical Weather and Climate Information is Not Easy to Obtain

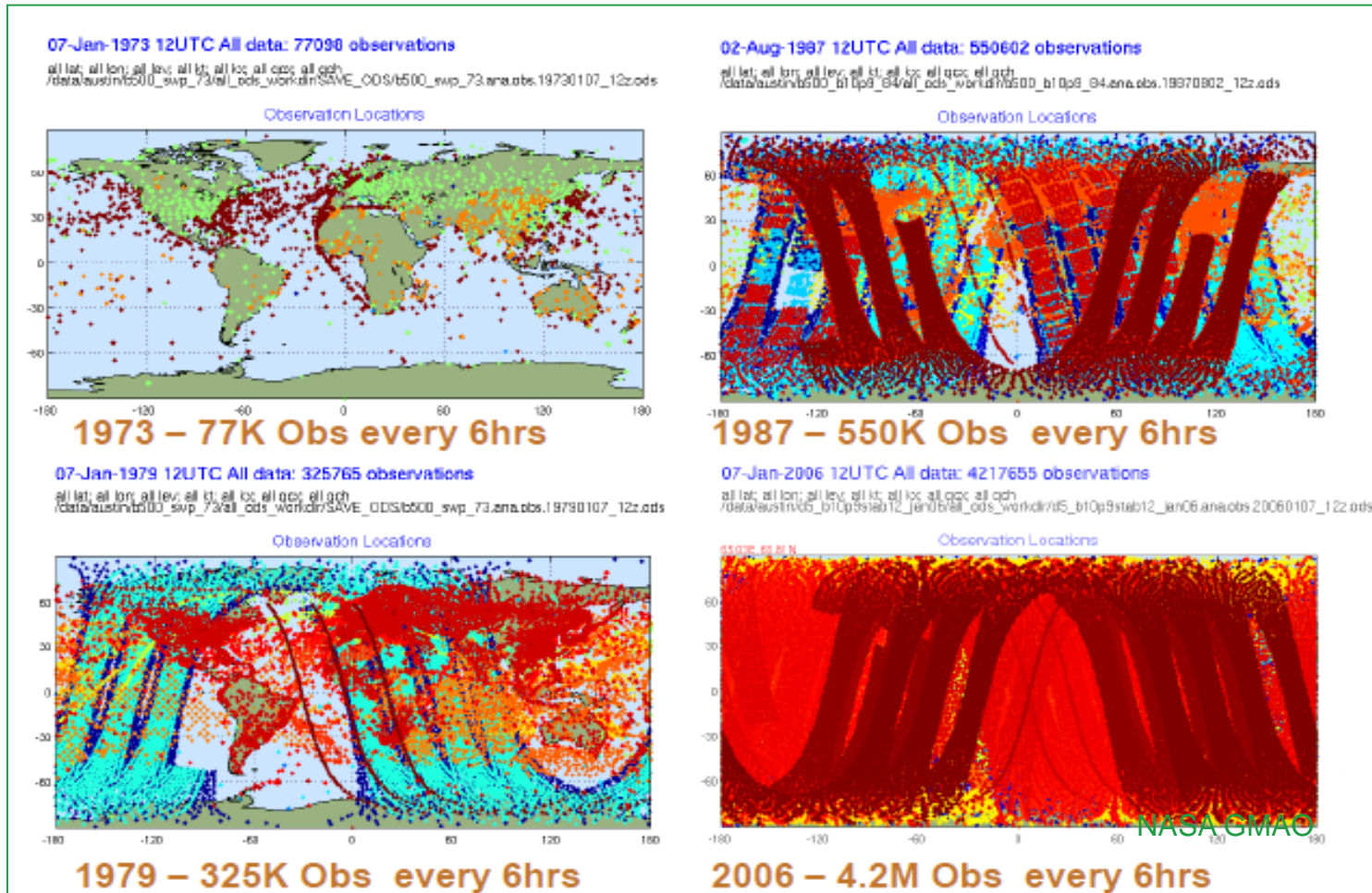
World Meteorological Organization stations:



Subset with useful climatologies:

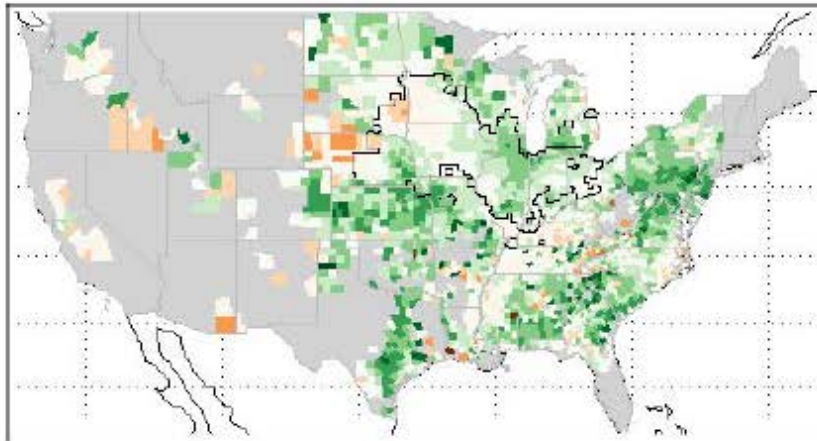


Reanalysis:

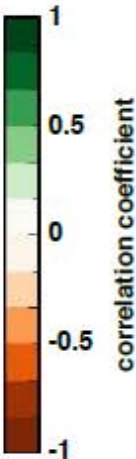
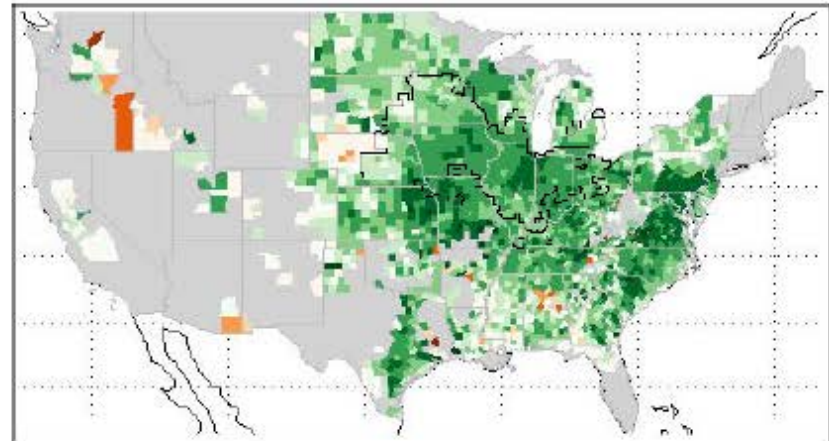


Climate Forcing Datasets – combine process-based models with gridded and satellite observations (e.g., AgMERRA, WATCH, GRASP)

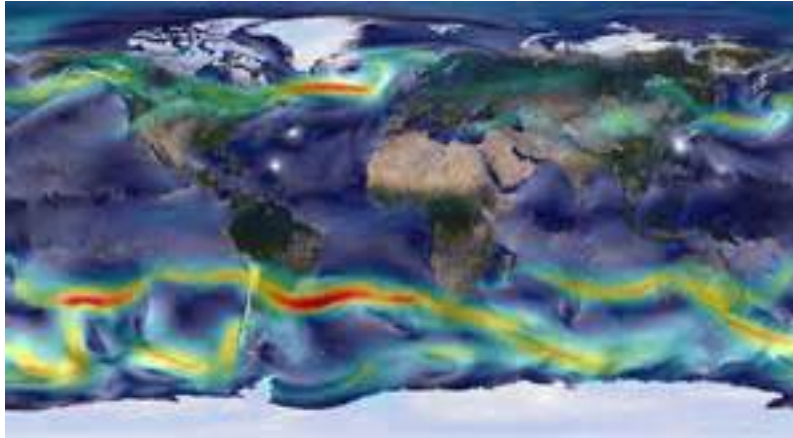
NASS v. CFSR



NASS v. AgCFSR



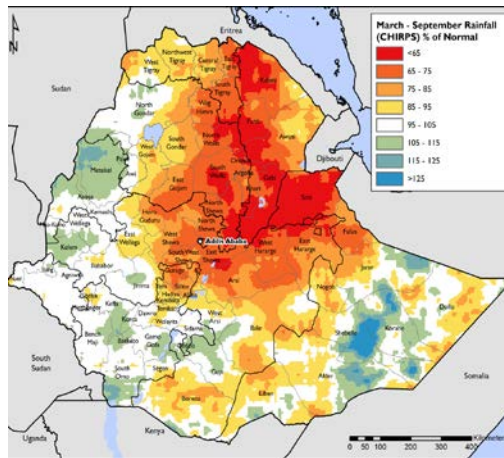
Above: 1980-2010 Correlations between National Agricultural Statistics Service (NASS) County-level production and that simulated by pDSSAT using CFSR (left) and AgCFSR (right) climate data (from Glotter et al., 2016). Note dramatic improvement in correlations over major agricultural regions including the US Corn Belt (outlined in black).



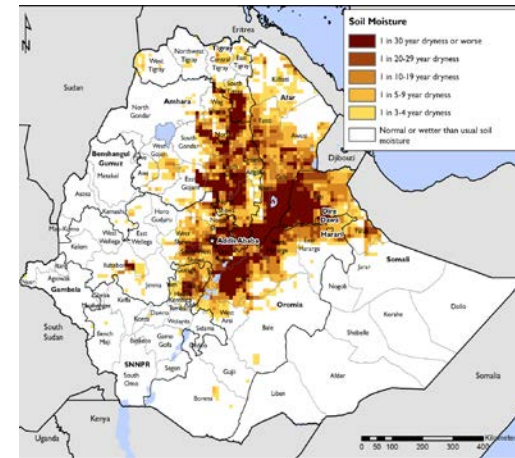
GEOS-5 from NASA GMAO



IMERG Precipitation (NASA)



CHIRPS Precipitation anomalies

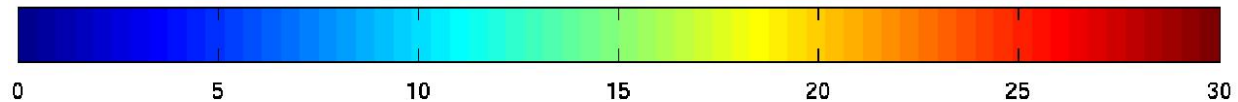
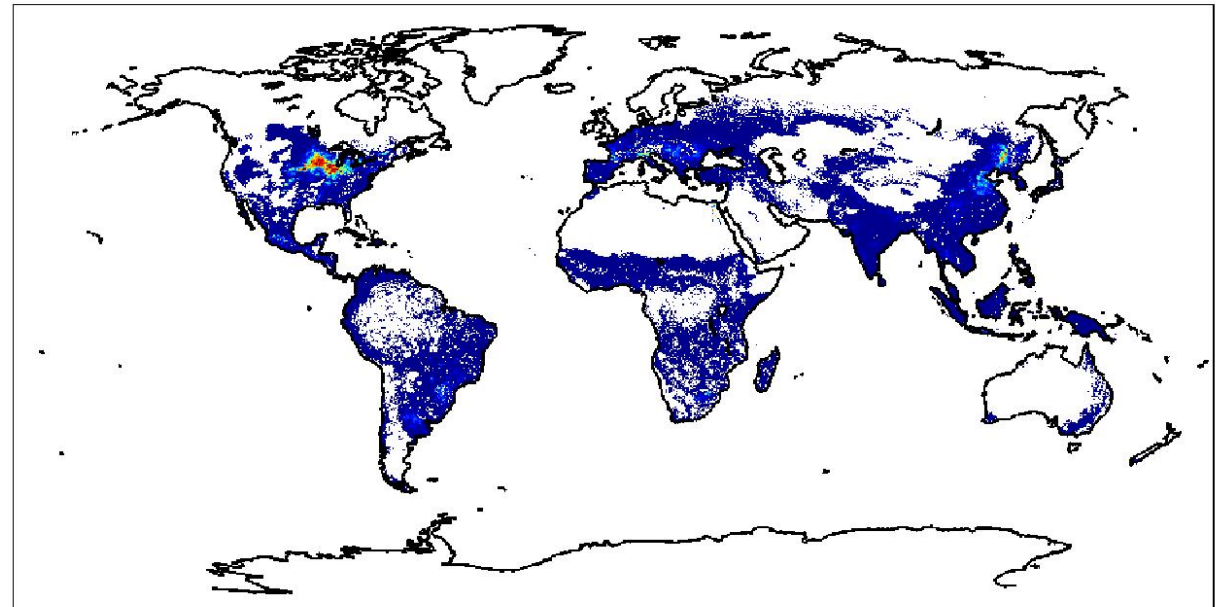


FEWS-Net Land Data Assimilation System (FLDAS) soil water anomalies

Still need: leaf wetness for pests and diseases

- **UN Food and Agricultural Organization** (mostly national; not always reliable)
- **USDA Foreign Agricultural Service** and other yield estimators
- **US National Agricultural Statistical Service (NASS)** and similar in other countries
- **Very few high-quality field experiments**, especially long-term agricultural research stations

Maize Production (1000s of kg)




Monitoring and Forecasting Seasonal Production



Uses a combination of remote sensing, meteorological indicators, and field reports to estimate supply changes as information to stabilize commodity markets.

<http://www.usda.gov/oce/commodity/wasde/latest.pdf>



United States
Department of
Agriculture

ISSN: 1554-9089

World Agricultural Supply and Demand Estimates

**Office of the
Chief Economist**

WASDE - 556

**Agricultural Marketing Service
Farm Service Agency**

Approved by the World Agricultural Outlook Board

**Economic Research Service
Foreign Agricultural Service**

August 12, 2016

WHEAT: Projected U.S. supplies for 2016/17 are raised on a larger crop that is partially offset by lower imports. U.S. wheat production is raised for all 5 major wheat classes. Projected imports are lowered 5 million bushels on larger supplies of U.S. spring wheat. All wheat exports for 2016/17 are projected 25 million bushels higher to 950 million on expectations of an improved competitive situation and a sharp reduction of EU wheat production, which is expected to benefit North American suppliers. Feed and residual use is raised 30 million bushels on the larger domestic crop. The increased use offsets the higher supplies and ending stocks are slightly lower. The season-average farm price is lowered 5 cents on the low end and 15 cents on the high end to \$3.35 to \$4.05 per bushel.

Global wheat supplies for 2016/17 are raised 2.3 million tons on a 4.9-million production increase that is partially offset by a decrease in beginning stocks. The Russia wheat crop is raised 7.0

Use a combination of remote sensing, meteorological indicators, and surveys to identify problematic areas and compute final production numbers about 6 months after the season's end.

<http://apps.fas.usda.gov/psdonline/>

USDA United States Department of Agriculture
Foreign Agricultural Service

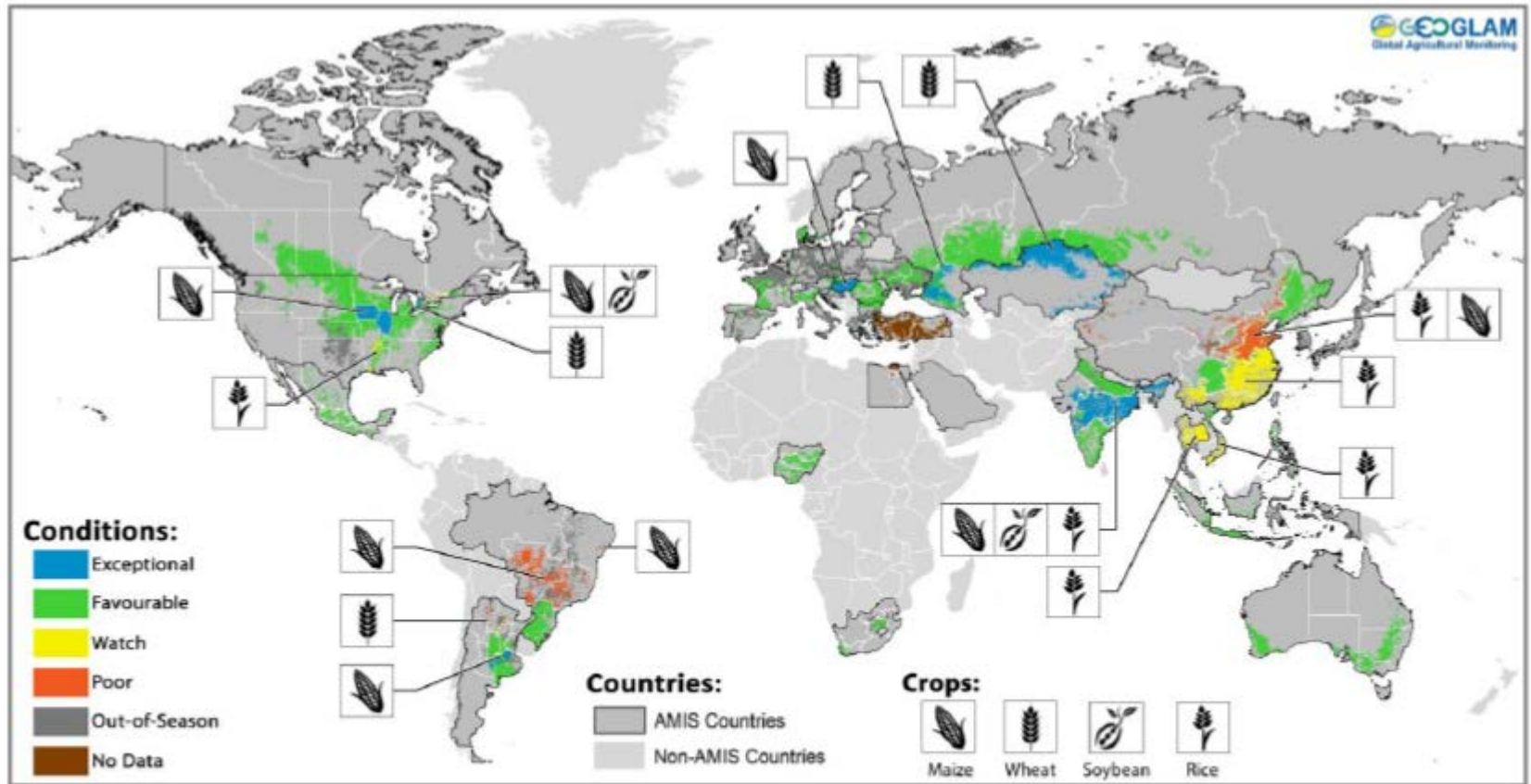
World Corn Production, Consumption, and Stocks

Local Marketing Years, Thousand Metric Tons
Date Created 08/12/2016 12:04:50 PM

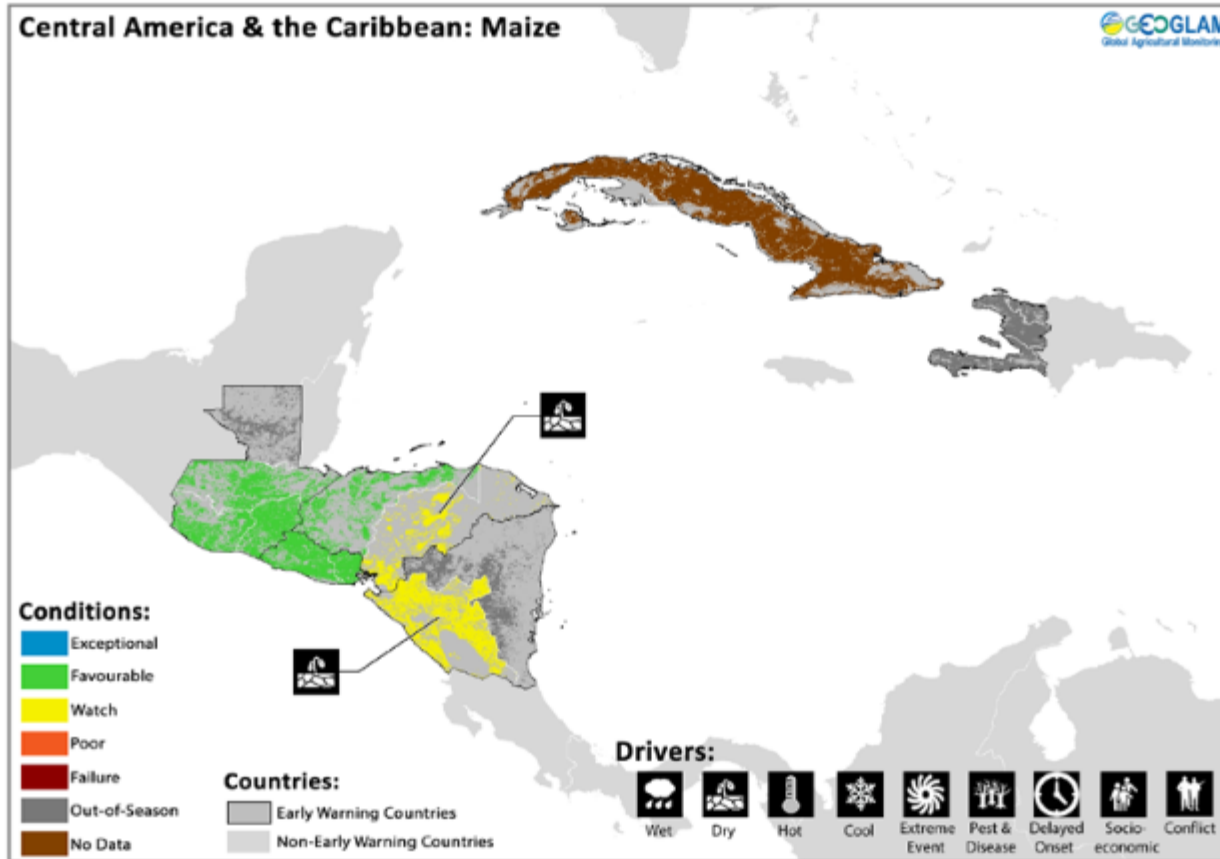
[Download File](#) (Spreadsheet Format)

	2012/13	2013/14	2014/15	2015/16	2016/17 Jul	2016/17 Aug
Production						
Argentina	27,000	26,000	28,700	28,000	34,000	36,500
Brazil	81,500	80,000	85,000	68,500	80,000	80,000
Canada	13,060	14,194	11,487	13,600	12,500	12,000
China	205,614	218,490	215,646	224,580	218,000	218,000
Ethiopia	6,158	6,492	6,580	5,050	6,300	6,300
European Union	59,142	64,931	75,840	59,083	63,831	62,104
India	22,258	24,259	24,170	21,000	23,000	24,500
Indonesia	8,500	9,100	9,000	9,300	9,600	9,600
Mexico	21,591	22,880	25,480	25,000	24,200	24,500
Nigeria	7,630	7,700	7,515	7,000	7,200	7,200
Philippines	7,261	7,532	7,671	7,500	8,000	8,000
Russia	8,213	11,635	11,325	13,168	14,000	14,000
Serbia	3,750	5,900	7,700	6,000	7,000	7,000
South Africa	12,365	14,925	10,629	7,000	13,000	13,000
Ukraine	20,922	30,900	28,450	23,333	26,000	26,000
Others	91,579	94,580	97,335	96,125	94,779	94,779
Subtotal	596,543	639,518	652,528	614,239	641,410	643,483
United States	273,192	351,272	361,091	345,486	369,333	384,916
World Total	869,735	990,790	1,013,619	959,725	1,010,743	1,028,399

Conditions at a glance for AMIS countries (as of August 28th)

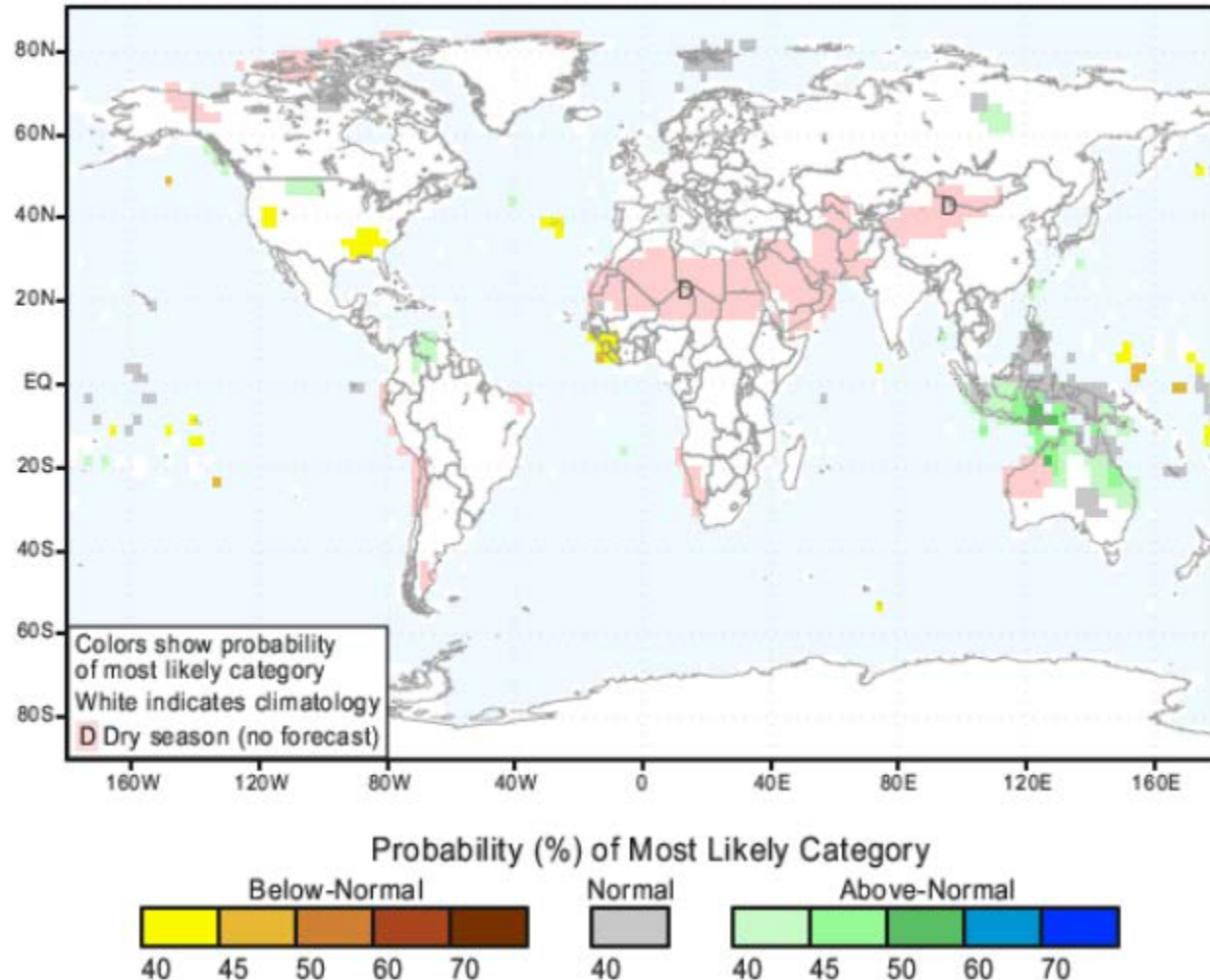


Crop condition map synthesizing information for all four AMIS crops as of August 28th. Crop conditions over the main growing areas for wheat, maize, rice, and soybean are based on a combination of national and regional crop analyst inputs along with earth observation data. Crops that are in other than favourable conditions are displayed on the map with their crop symbol.



Crop condition map synthesizing information for maize as of August 28th. Crop conditions over the main growing areas are based on a combination of inputs including remotely sensed data, ground observations, field reports, national, and regional experts. **Conditions that are other than favourable are labeled on the map with their driver.**

IRI Multi-Model Probability Forecast for Precipitation for September-October-November 2016, Issued August 2016



Probabilistic Forecasts tell us basic chances of below-normal, normal, or above-normal conditions

- Based largely on sea-surface temperature anomalies and large-scale oscillations like El Niño, North American Oscillation, or the Madden-Julian Oscillation
- Not all places have a significant forecast

- **Crop models can be run for retrospective analyses and forecast mode**

1980 ... 2016 -6 months -60 days -15 days **Present** +15 days +60 days +6 months

Retrospective Climate Analyses

Climate Forcing Datasets for Agriculture

Archived by Climate-System Historical Forecast Project (CHFP)

Archived by Subseasonal to Seasonal Project (S2S)

Archived by THORPEX Interactive Grand Global Ensemble (TIGGE)

Examples: NCEP/NCAR Reanalysis, MERRA-2, ERA-Interim, CFSR

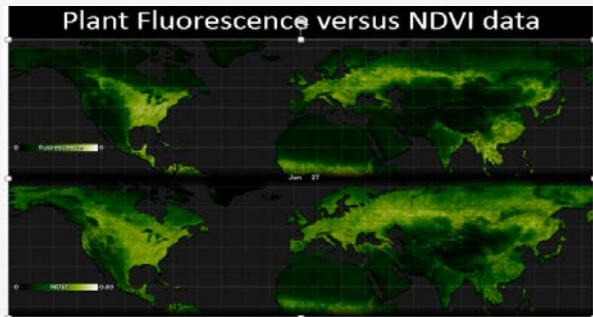
Examples: AgMERRA, WFD-EI, DayMet, CHIRPS, IMERG

Seasonal Forecasts

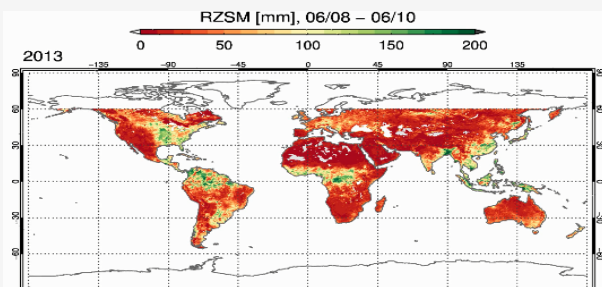
Sub-seasonal Forecasts

Weather Forecasts

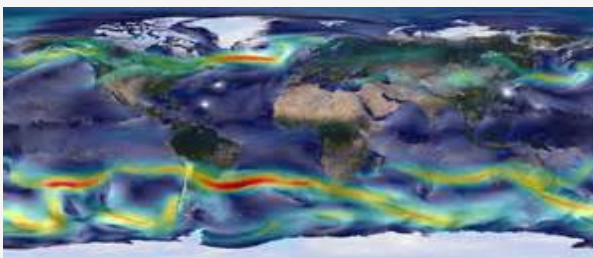
Developing Areas – Data assimilation for agricultural models



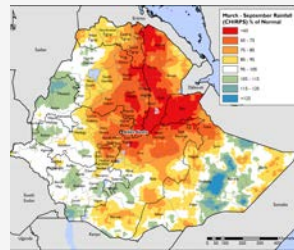
Fluorescence from OCO-2 & NDVI



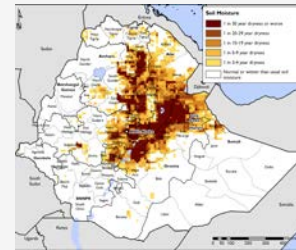
Soil Moisture anomalies from SMAP/SMOS



GEOS-5 and MERRA-2 from GMAO



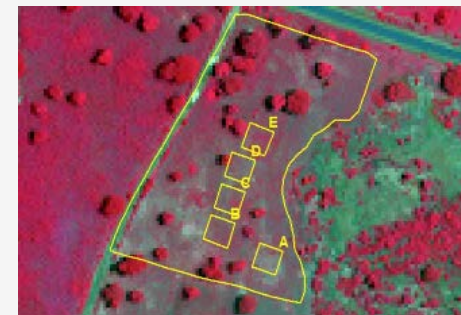
CHIRPS Precipitation anomalies



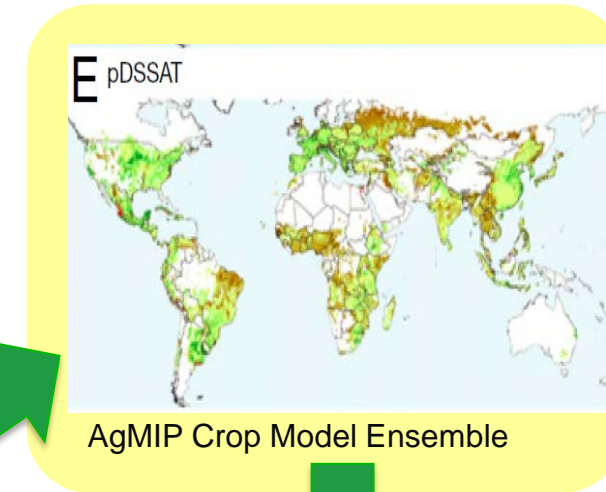
FLDAS soil water anomalies



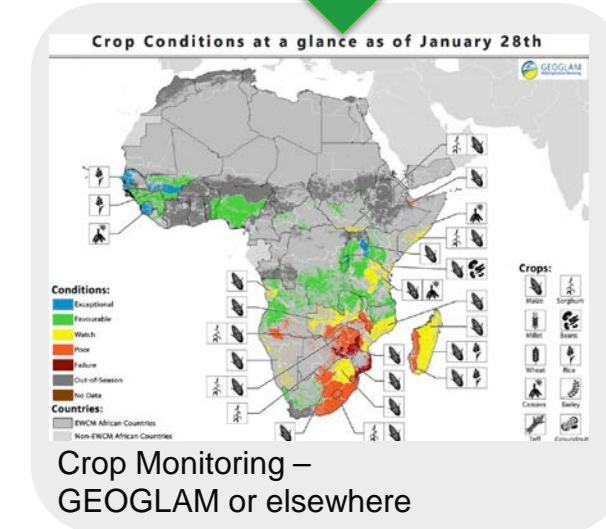
IMERG Precipitation



High-resolution NDVI



AgMIP Crop Model Ensemble



Crop Monitoring – GEOGLAM or elsewhere

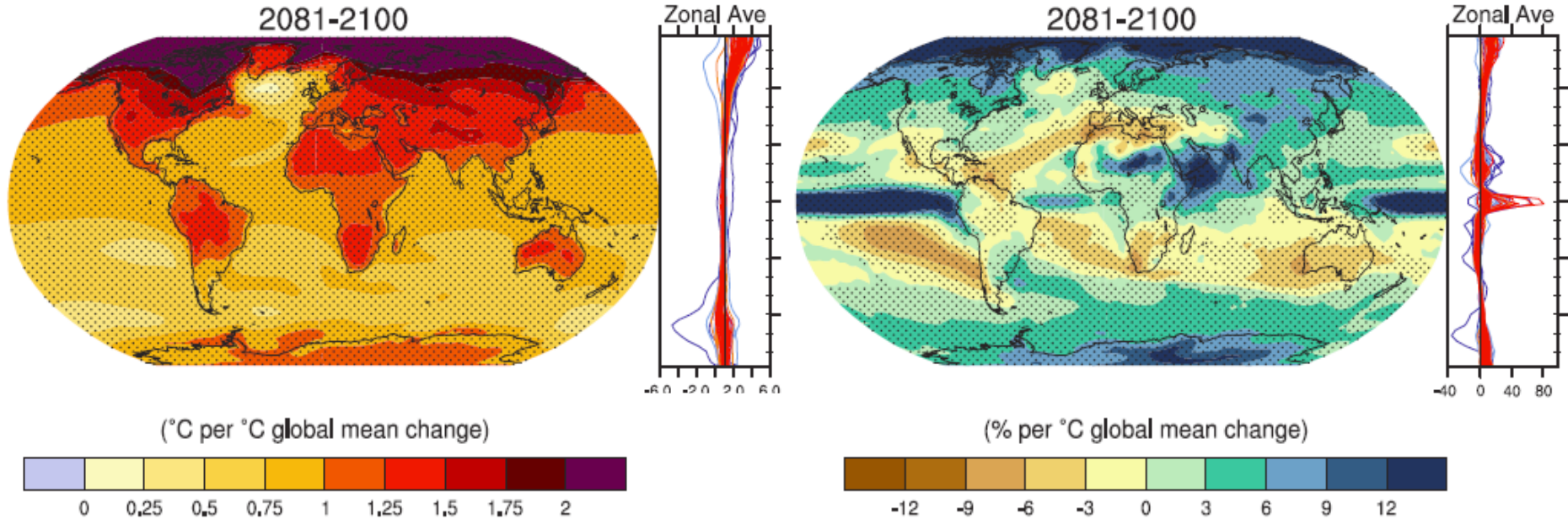
Understanding Global Changes and Potential Responses of a Linked System



In coming decades, the world is asking the agricultural sector to:

- Produce more food to provide healthy food for growing and developing populations**
- Adapt to climate change**
- Mitigate emissions from agricultural lands**

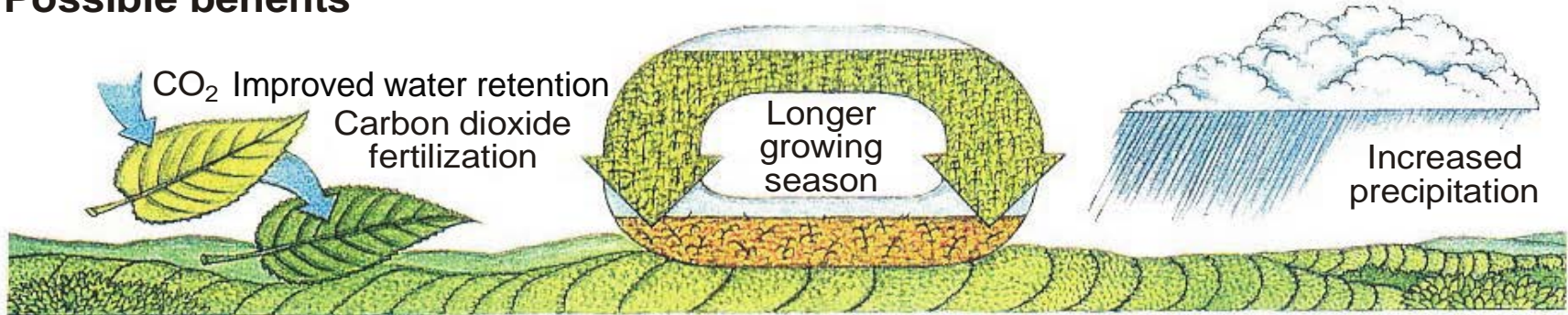
The Average Climate Is Changing



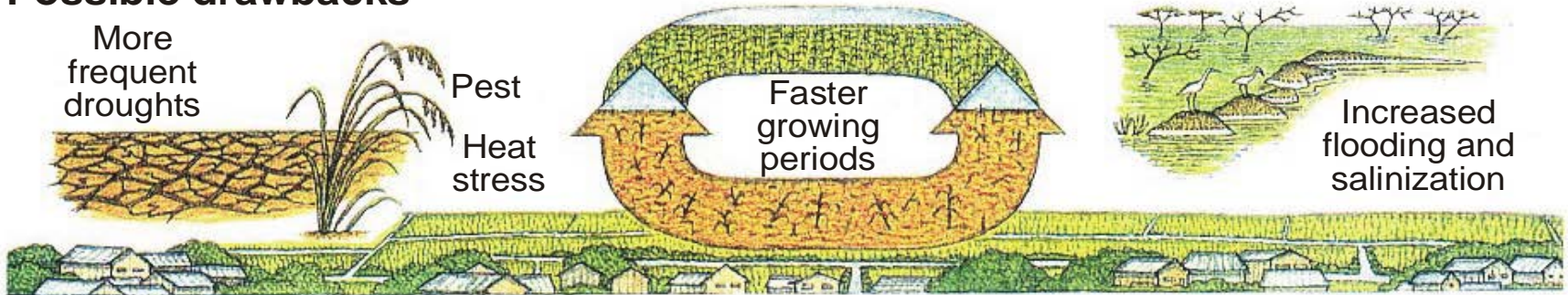
- Climate change is projected to increase temperatures and shift patterns of precipitation.
- Temperature increase is not uniform, with land areas and high-latitudes warming at a greater rate than the global average
- In general -- more rain where it already is wet, less where it is dry

Based upon Bengtson, J., Scientific American, 1992

Possible benefits



Possible drawbacks

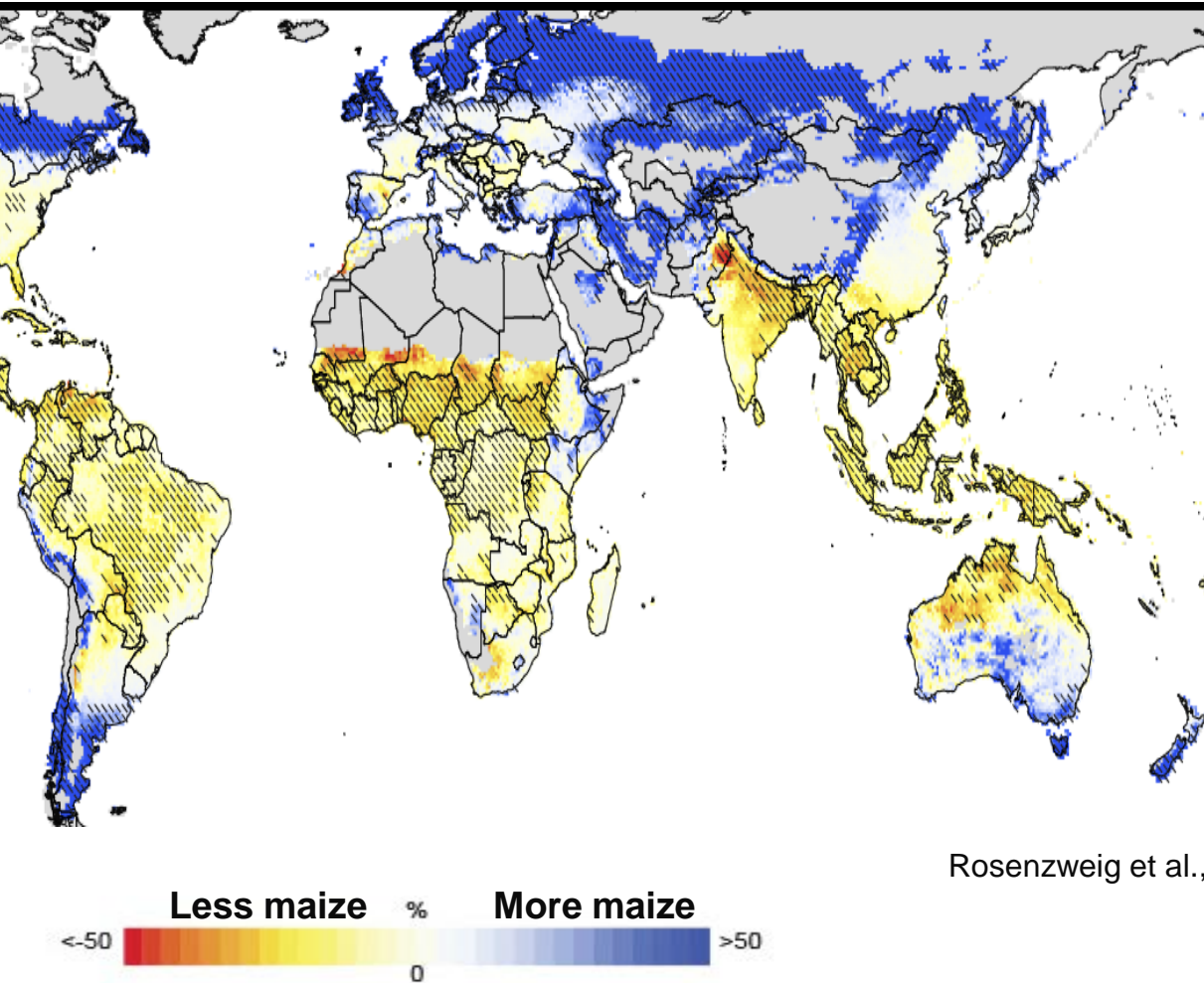


Based upon Bongaarts, J., Scientific American, 1992

- Niche growing areas are particularly vulnerable
- Additional fertilizers and water transport will be necessary to maintain current crop locations

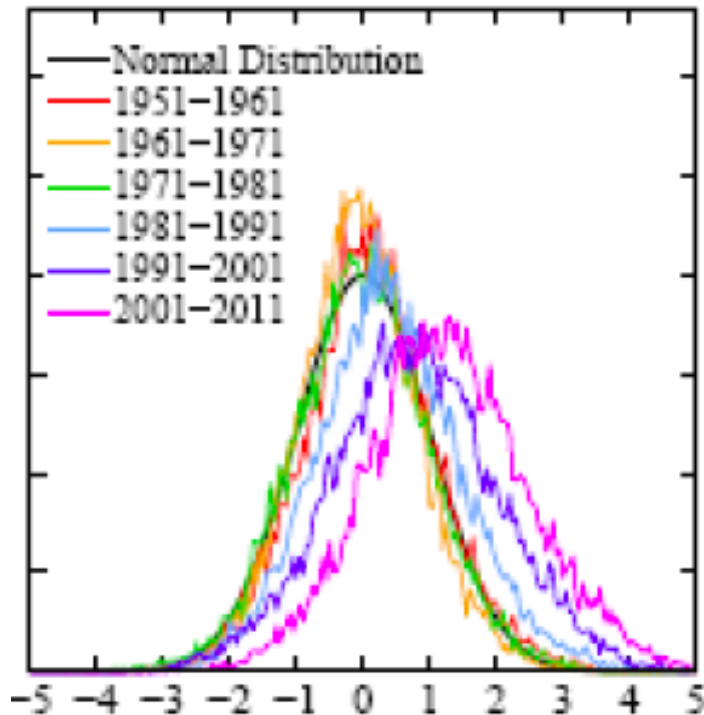
Modeled Changes in RCP8.5 Maize Yield (2080s – present)

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

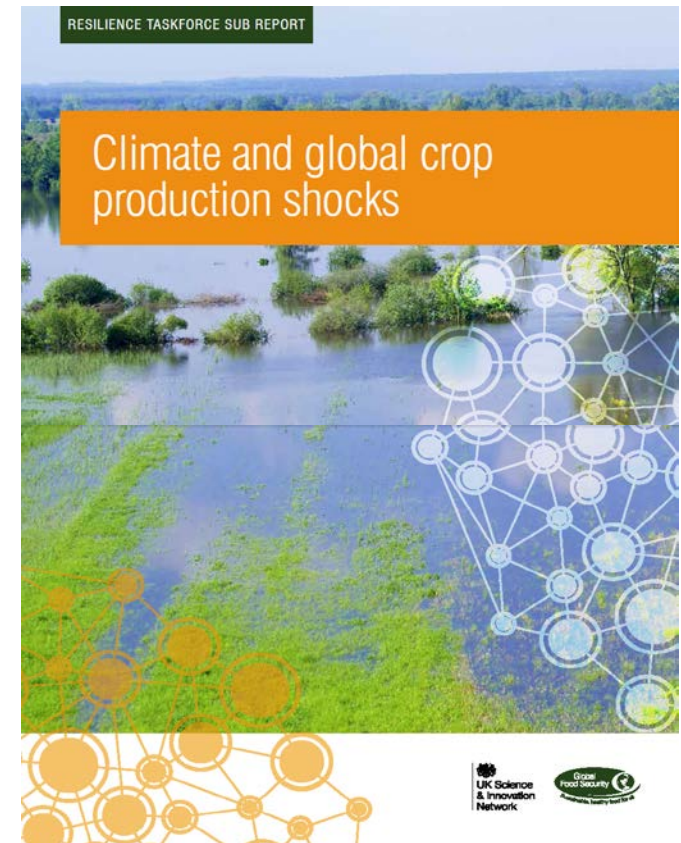


Rosenzweig et al., 2013

Climate Change Is Altering the Probability of Extreme Events

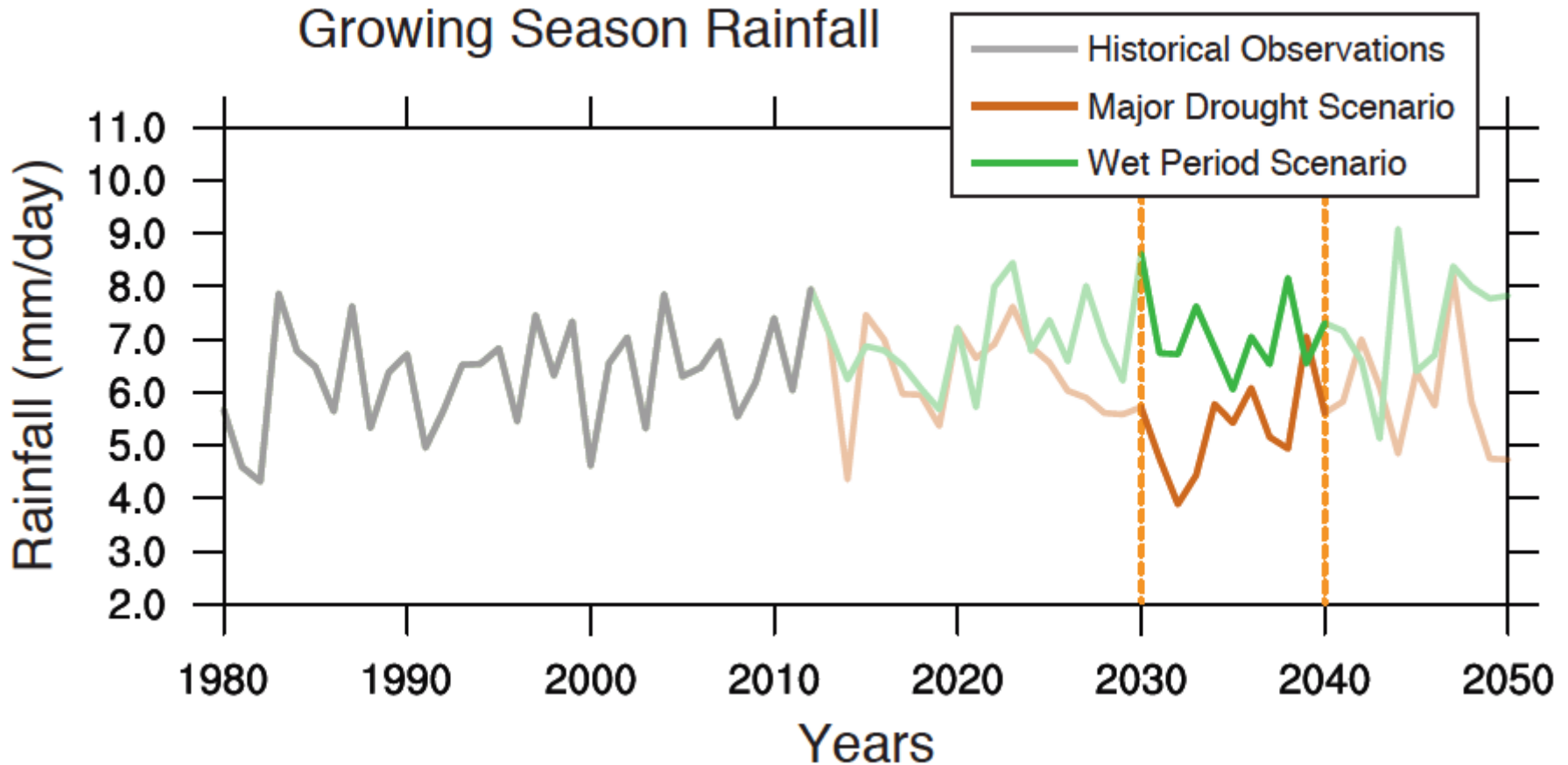


Left: Shifting Temperature distributions from Hansen et al., 2012



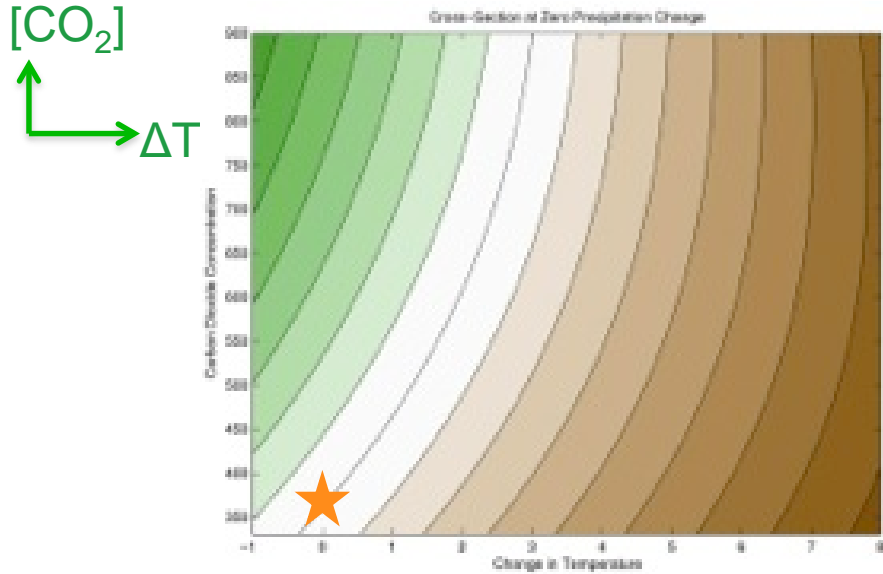
Right: US-UK Task Force Report

- Shifts in average conditions can also alter patterns of climate variability and extremes
- Rainfall is expected to come in less frequent, but more intense, storms
- Climate change can lead to more frequent extremes and thresholds being exceeded
- Crop model projections suggest 1-in-100 Global corn production extreme may occur once every 30 years in the coming decades

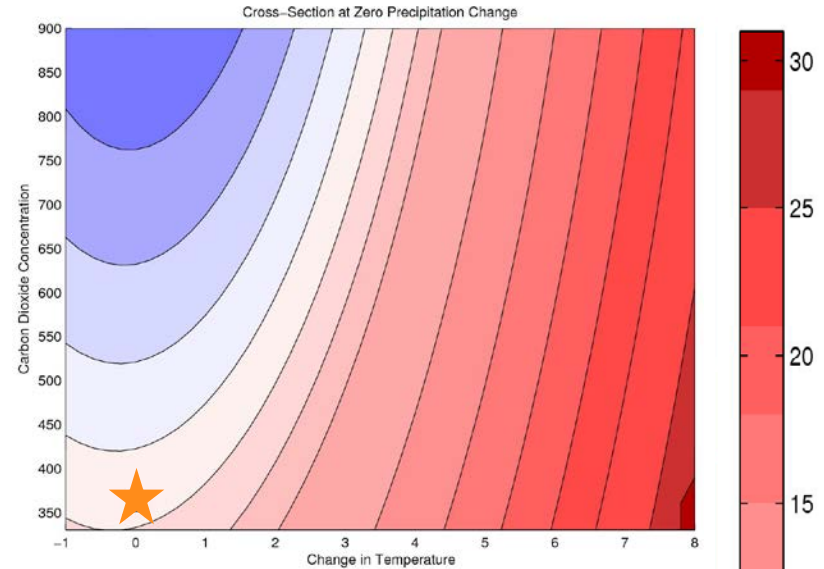


- Probabilistic climate extreme scenarios of growing season rainfall in the 2030s for Navrongo, Ghana, combining observed natural variability with CMIP5 climate projections.
- 95th percentile wet period and drought for the 2030s decade shown

Impacts Response Surface Analysis Focus on Frequency of Extreme Years



Mean Yield Change

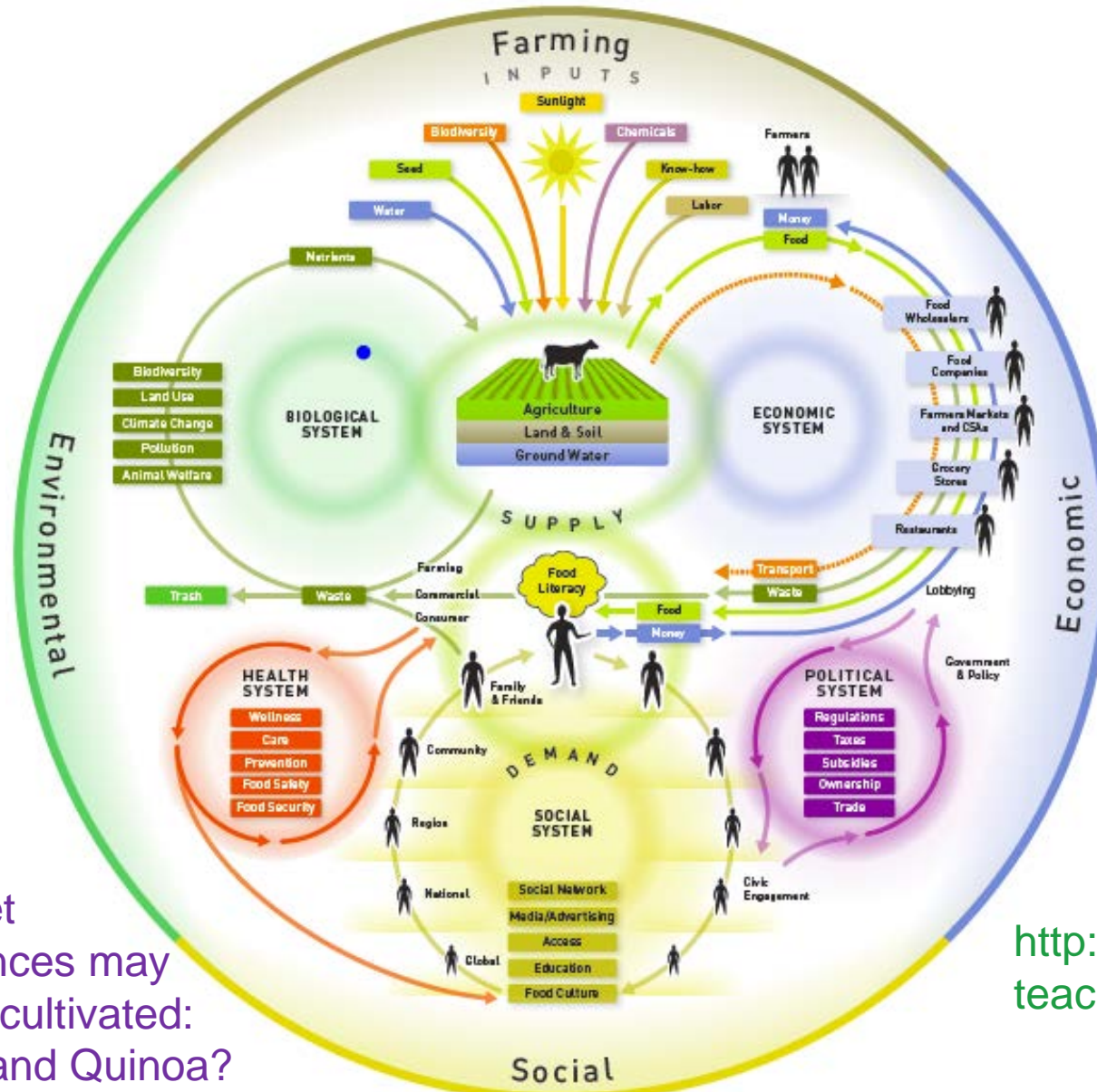


of years where yield less than 1 in 5-year event in baseline

★ = baseline

Henry County, Alabama, USA, Peanuts

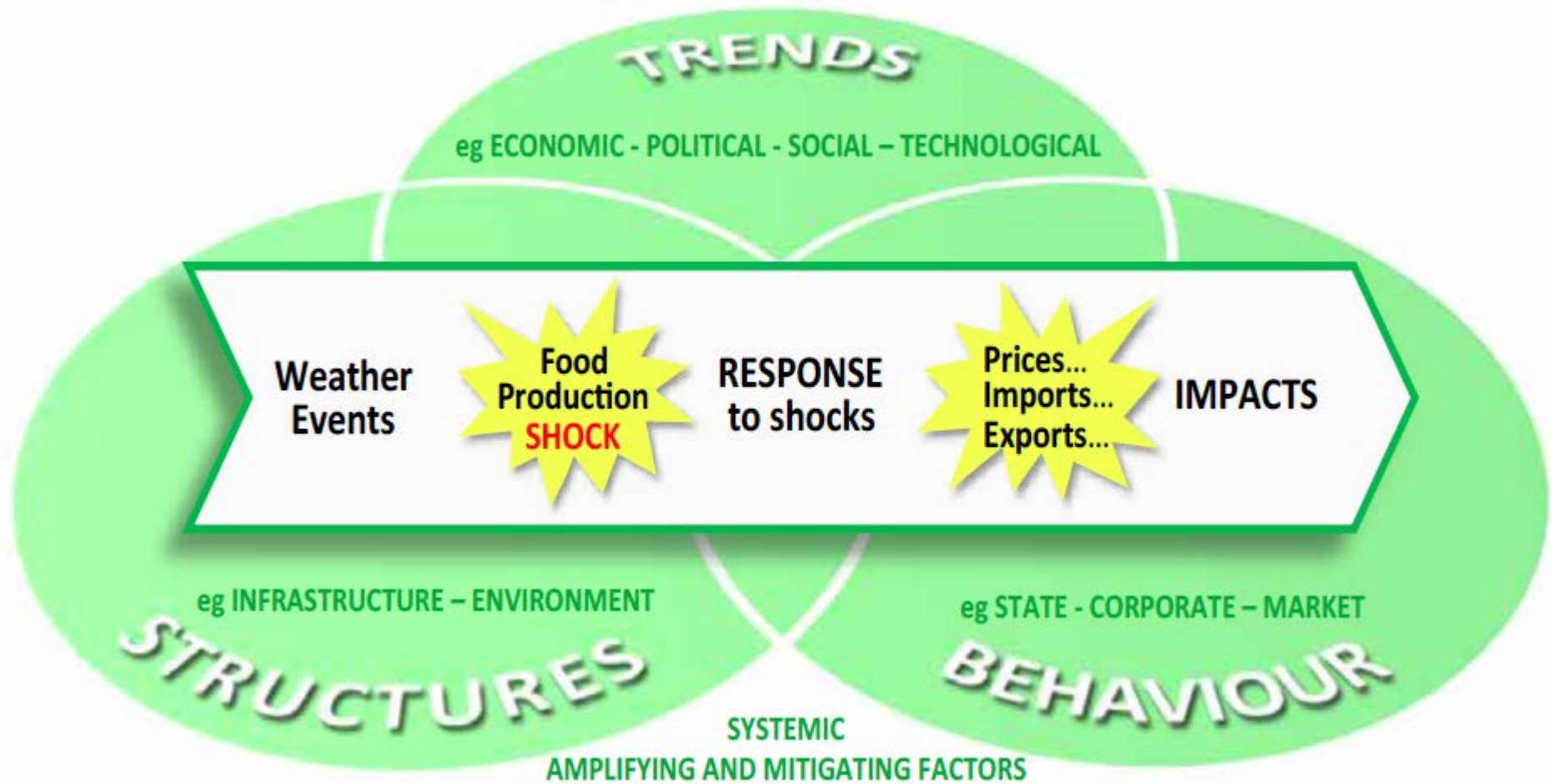
Many Leverage Points for Increasing Resilience



New diet preferences may also be cultivated: Tilapia and Quinoa?

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

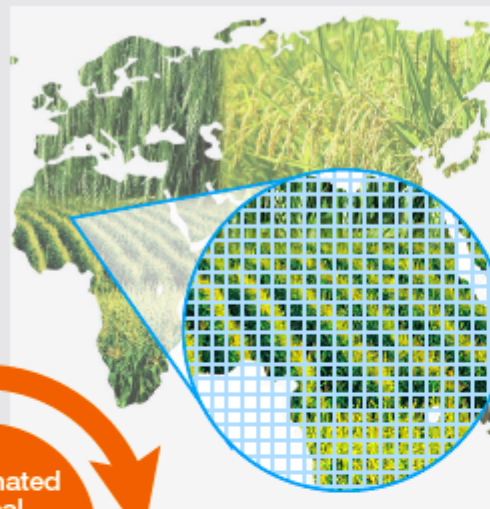
Extreme Events and Human Responses Lead to Important Impacts



Integrated and Coordinated Approach to Understanding Climate Shocks

Regional research

on farming systems using biophysical and socioeconomic models



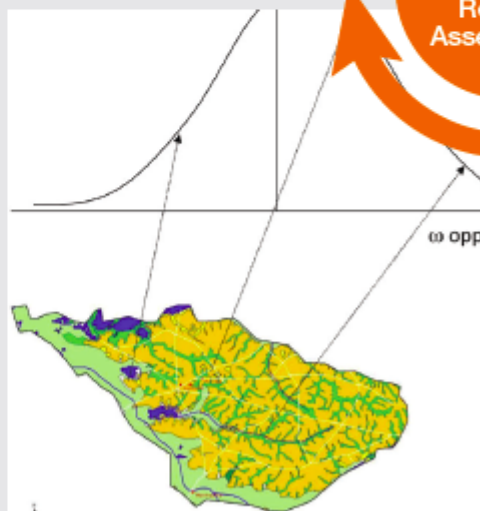
High-resolution gridded crop modeling

for gap-filling and aggregation in each region

Coordinated Global and Regional Assessments

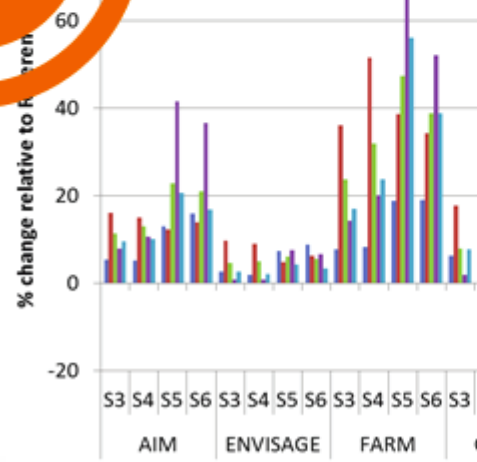
Production systems and regional economics

to respond to price changes



Global economics

with analysis of world and regional prices



Summary and Conclusions



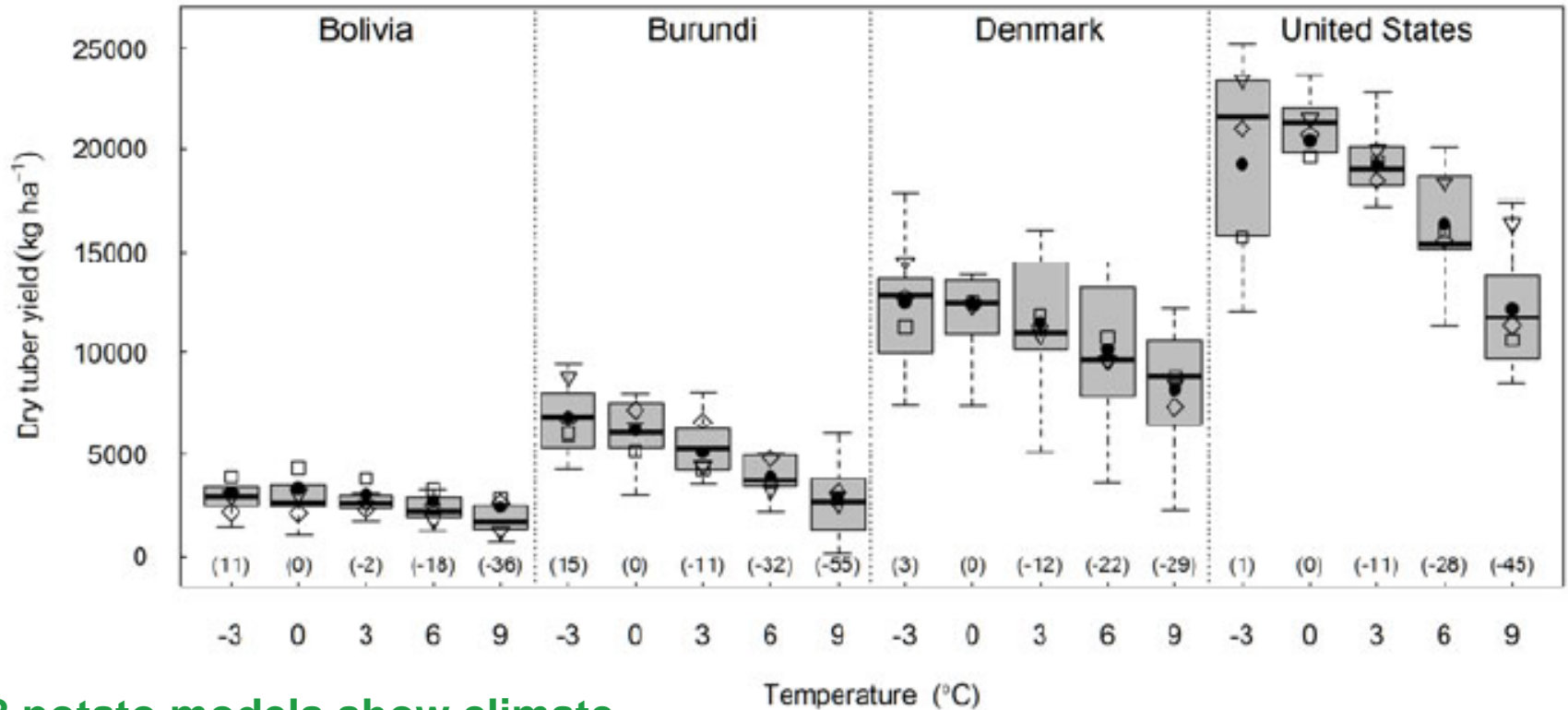
- **Climate variability and extremes require a risk management framework that explores hazards, exposure, and vulnerability**
- **New climate data sets are useful; more agricultural data needed**
 - Fill in gaps between observations
 - Provide probabilistic seasonal estimates and long-term extreme event hazards
- **Crop models have great potential to augment existing agricultural monitoring and assessment systems**
 - Allow identification and prioritization of early interventions and preventive actions
 - Reveal vulnerable regions, systems, and populations
- **Understanding risk of extreme events requires an examination of complex food systems**
 - Includes socioeconomic factors and interactions between local and global impacts
 - Linked food systems can increase exposure but also provide many opportunities to build resilience that we can test
 - ***Great need to set up coordinated networks and assessments***



Thanks!

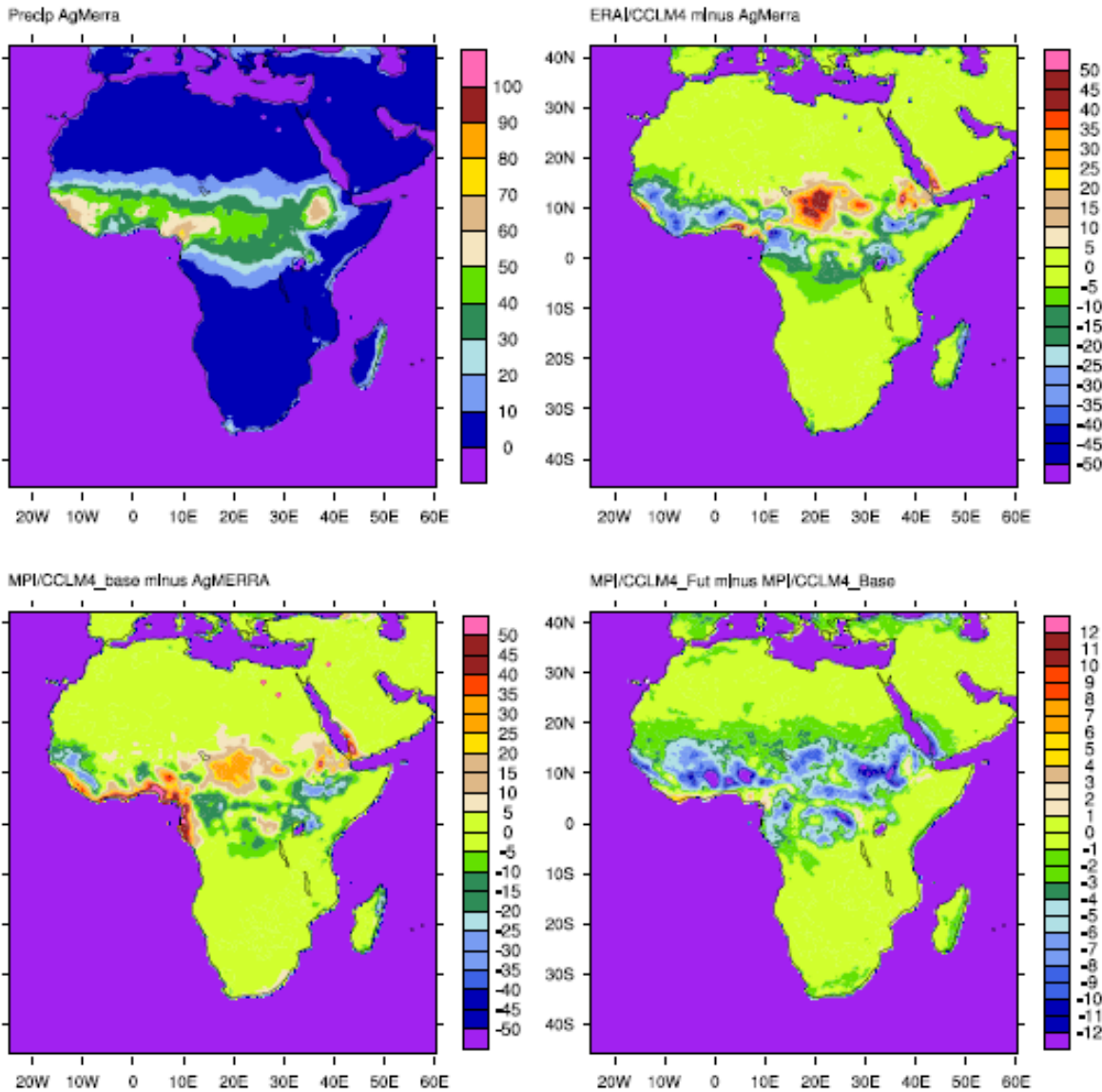
(alexander.c.ruane@nasa.gov)

Potato Yield Responses to Increasing Temperature



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

Seasonal Precip 5mm Rainy Day 30yrs June-Sep (1976-2005)



- Increasing coordination in regional climate modeling to enable more useful intercomparison, ensemble approaches, and data distribution (each uses multiple GCMs and RCMs):
 - ENSEMBLES (Europe)
 - NARCCAP (N. America)
 - CLARIS (S. America)
 - CORDEX

Donatelli et al. have created climate scenarios for crop modeling in Europe based upon ENSEMBLES outputs

- Dynamical models should be able to capture how climate change interacts with finer scale
 - Local-scale circulations (e.g., mountain/valley or land/sea breezes)
 - Complex topography (e.g., differential heating at higher elevations)

Higher resolution does not necessarily mean higher quality

