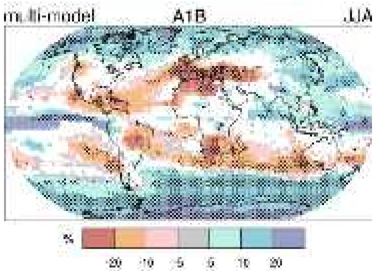
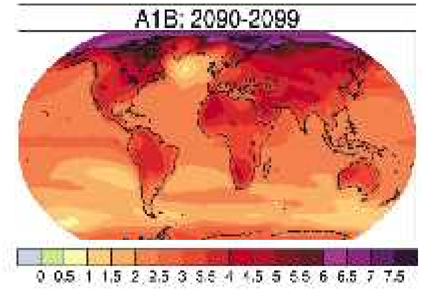


IPCC WGI AR4
Figure SPM-7



IPCC WGII AR4
Fig SPM-6

Biophysical Climate Change Effects on Agro-ecosystems

U.S. EPA,USDA and Agri-Food Canada Workshop

Forestry, Agriculture & Climate Change:
Modeling to Support Policy Analyses

September 26-29, 2011

Cynthia Rosenzweig

NASA/Goddard Institute for Space Studies

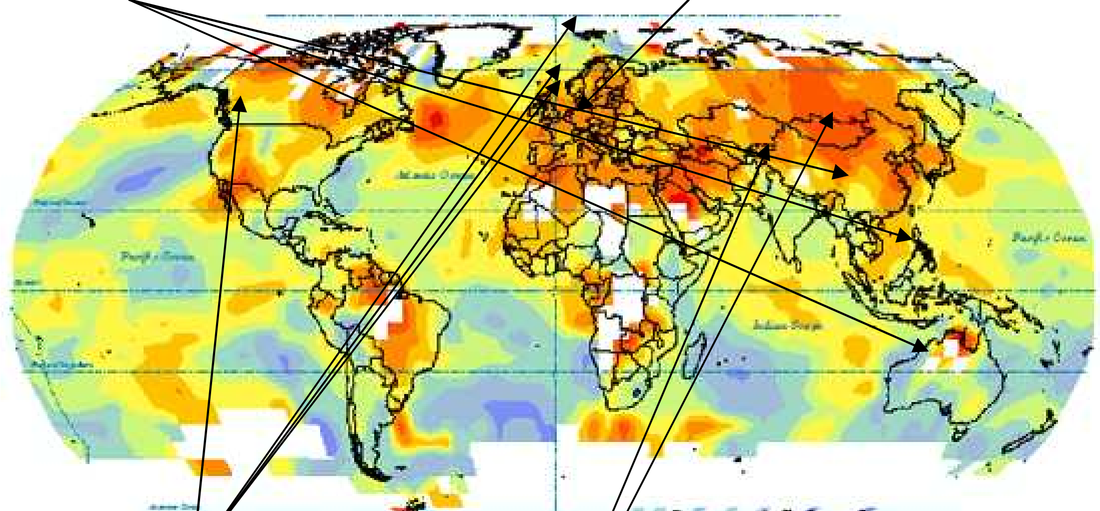
Outline

- Biophysical responses of agricultural crops
- Data and models
- Adaptation
- Gaps and uncertainties
- Agricultural Model Intercomparison and Improvement Project (AgMIP)

Observed Impacts on Agriculture

Yields

Phenology



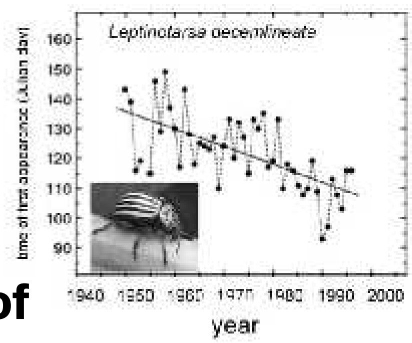
1973-2002 Annual temperature trends

Management practices, forest fires, earlier pests and diseases

<-1.2C to >1.2C

Livestock

IPCC WGII AR4



In a six-decade long study at a biological research station in Spain, increasing earlier time of first appearance for the potato beetle was found.

Gordon and Sanz, 2005; Gutierrez et al., 2010

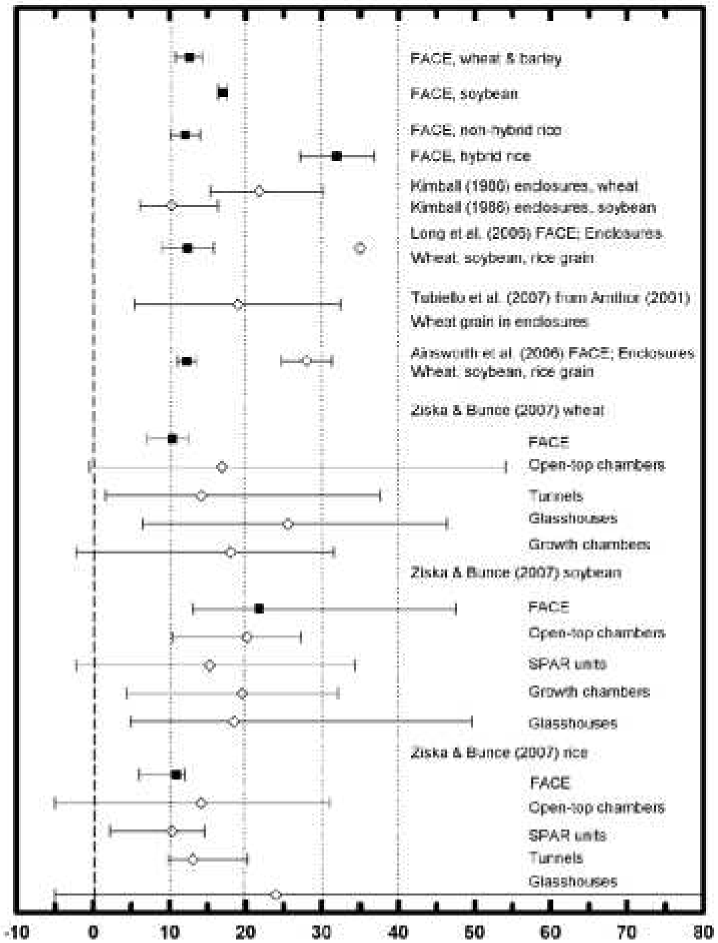
From AR4:

- **High temperature effect on rice yield**
- **Earlier planting of spring crops**
- **Increased forest fires, pests in N America and Mediterranean**
- **Decline in livestock productivity**

Since AR4:

- **Growing season precipitation has decreased in food insecure regions of the western rim of the Indian Ocean (Funk et al 2008, Funk and Brown 2009)**
- **Longer growing season in Canada observed based on earlier start and later end (Qian et al 2010)**
- **Non-linear relationship between increasing temperatures and tropical maize yields in Africa (Lobell 2011)**

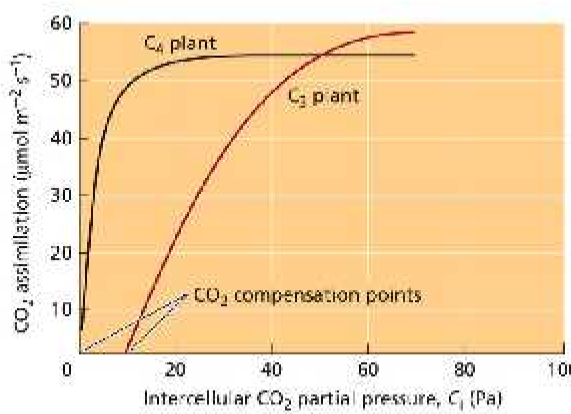
CO_2 Yield Responses



Relative C3 crop yield changes due to elevated CO_2 (%)

Kimball 2010

- Biomass/yield with +200ppm increased by FACE in C3 species, but not in C4 except under water stressed conditions. Average C3 yield increase is ~16% in FACE.
- Low soil N often reduces these gains.
- Likely no significant difference in C3 grain crops response to elevated CO_2 between FACE and enclosure experiments.
- Important for simulation.



Photosynthesis response to CO_2

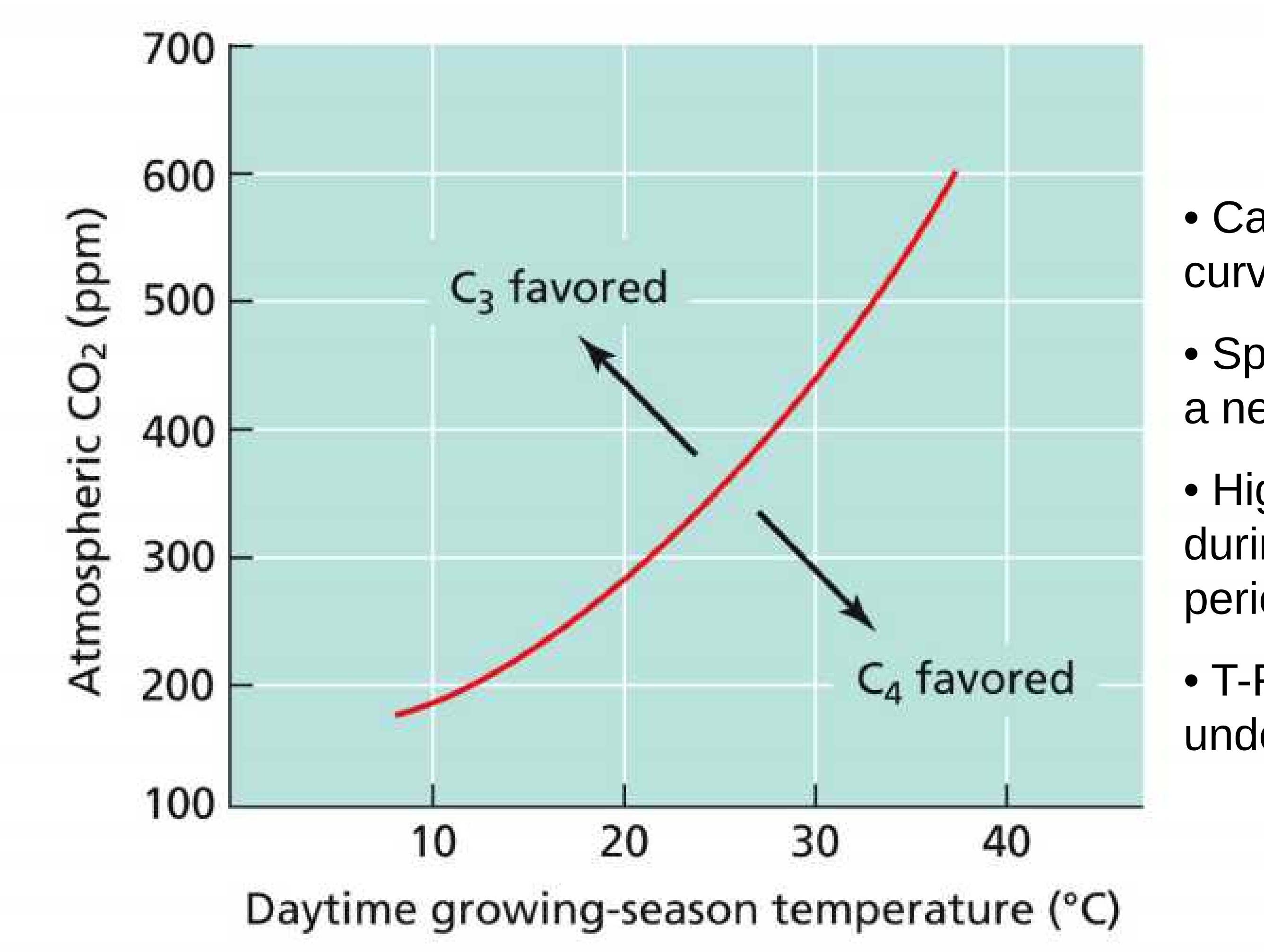
C_3 Plants	C_4 Plants
Wheat	Corn
Rice	Sorghum
Soybean	Sugarcane
Barley	

Elevated CO_2 can also favor weeds

Crop	Weed	Increasing $[CO_2]$ favors	Environment	Reference
A. C_4 Crops/C_4 Weeds				
Sorghum	*Amaranthus retroflexus*	Weed	Field	Ziska (2003)
B. C_4Crops/C_3 Weeds				
Sorghum	*Xanthium strumarium*	Weed	Glasshouse	Ziska (2001)
Sorghum	*Albutilon theophrasti*	Weed	Field	Ziska (2003)
C. C_3Crops/C_3 Weeds				
Soybean	*Chenopodium album*	Weed	Field	Ziska (2000)
Lucerne	*Taraxacum officinale*	Weed	Field	Bunce (1995)
Pasture	*Taraxacum and Plantago*	Weed	Field	Potvin and Vasseur (1997)
Pasture	*Plantago lanceolate*	Weed	Chamber	Newton *et al.* (1996)
D. C_3 Crops/C_4 Weeds				
Fescue	*Sorghum halapense*	Crop	Glasshouse	Carter and Peterson (1983)
Soybean	*Sorghum halapense*	Crop	Chamber	Patterson *et al.* (1984)
Rice	*Echinochloa glabrescens*	Crop	Glasshouse	Alberto *et al.* (1996)
Soybean	*A. retroflexus*	Crop	Field	Ziska (2000)

Ziska 2010

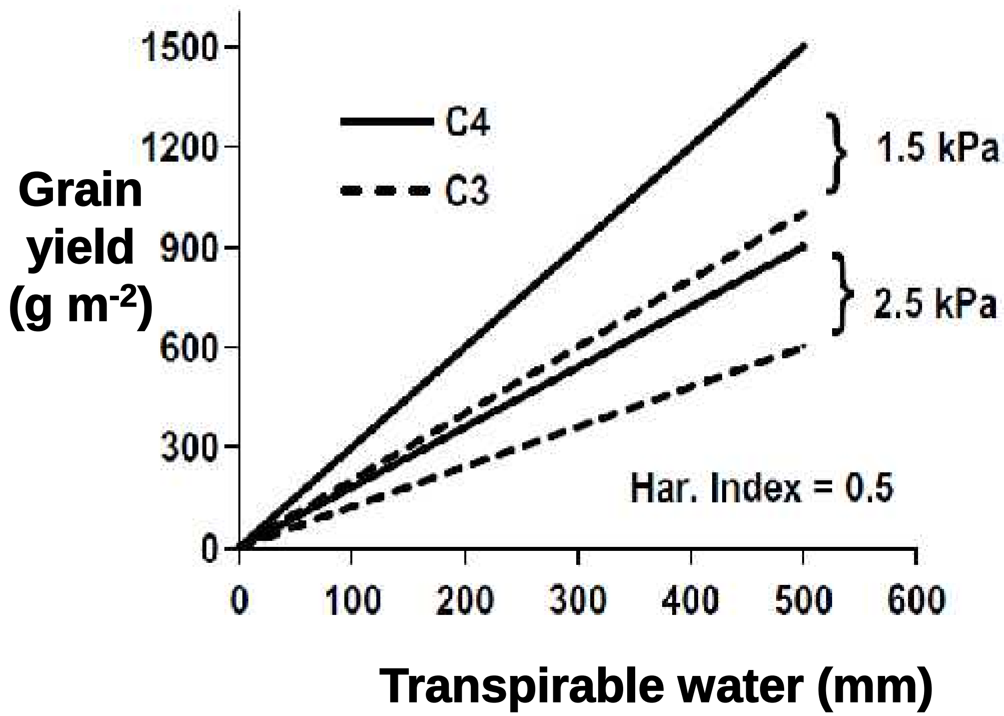
Crop Response to Temperature



PLANT PHYSIOLOGY, Fourth Edition, Figure 9.23 © 2006 Sinauer Associates, Inc.

- Can shift photosynthesis curve positively
- Speed-up of phenology is a negative pressure on yield
- High-temperature stress during critical growth periods
- T-FACE experiments now underway.

Yield Response to Water
Extreme events – Drought

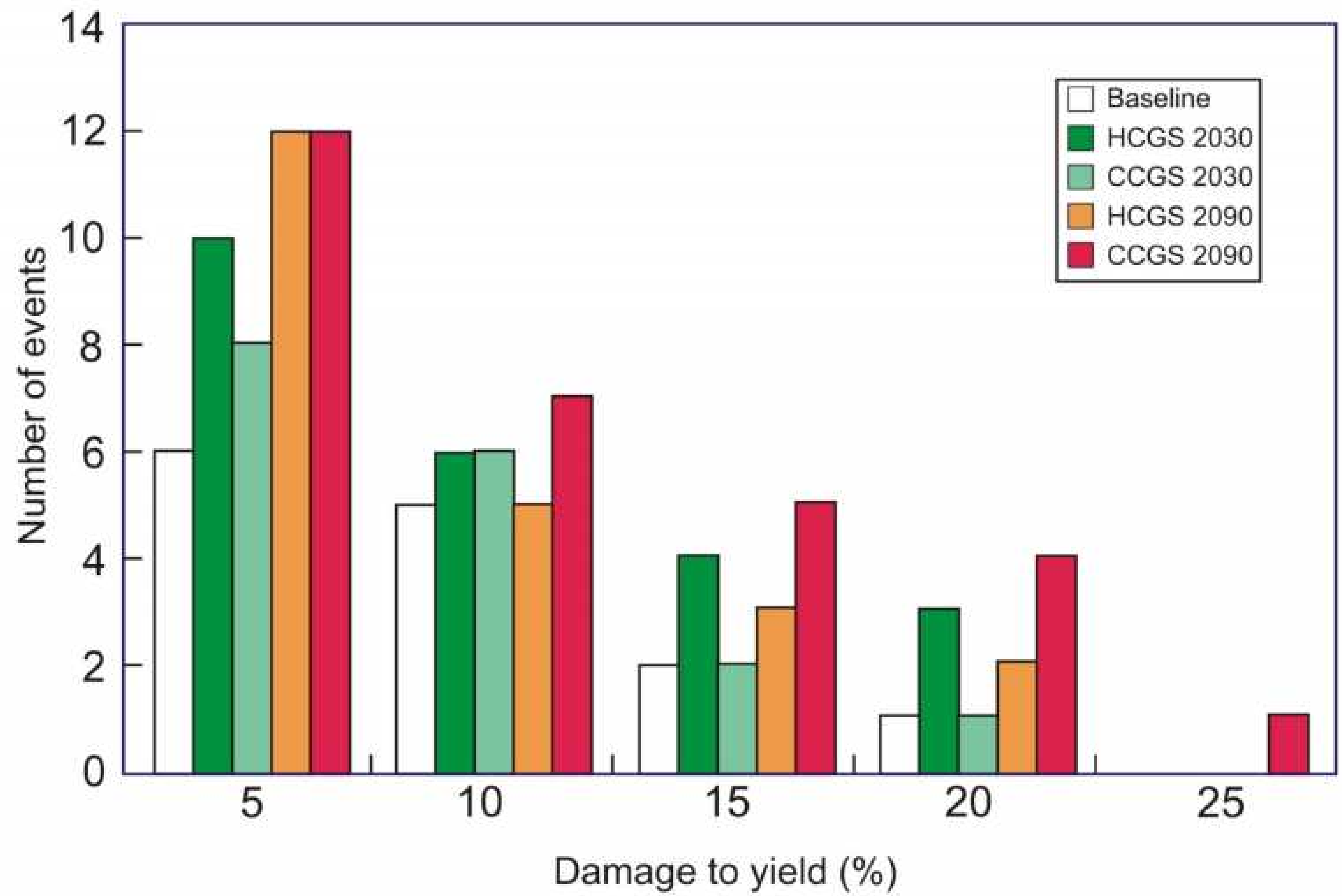


Maximum grain yield plotted as a function of the amount of transpirable soil water available through the growing season. Two vapor pressure deficit environments are presented. C4 crops favored at both higher and lower water stress.

- Crops need water – through precipitation or irrigation
- Drought stress affects yield during critical growth periods
- Excess water can be damaging as well

Sinclair 2010

Extreme Events – Floods

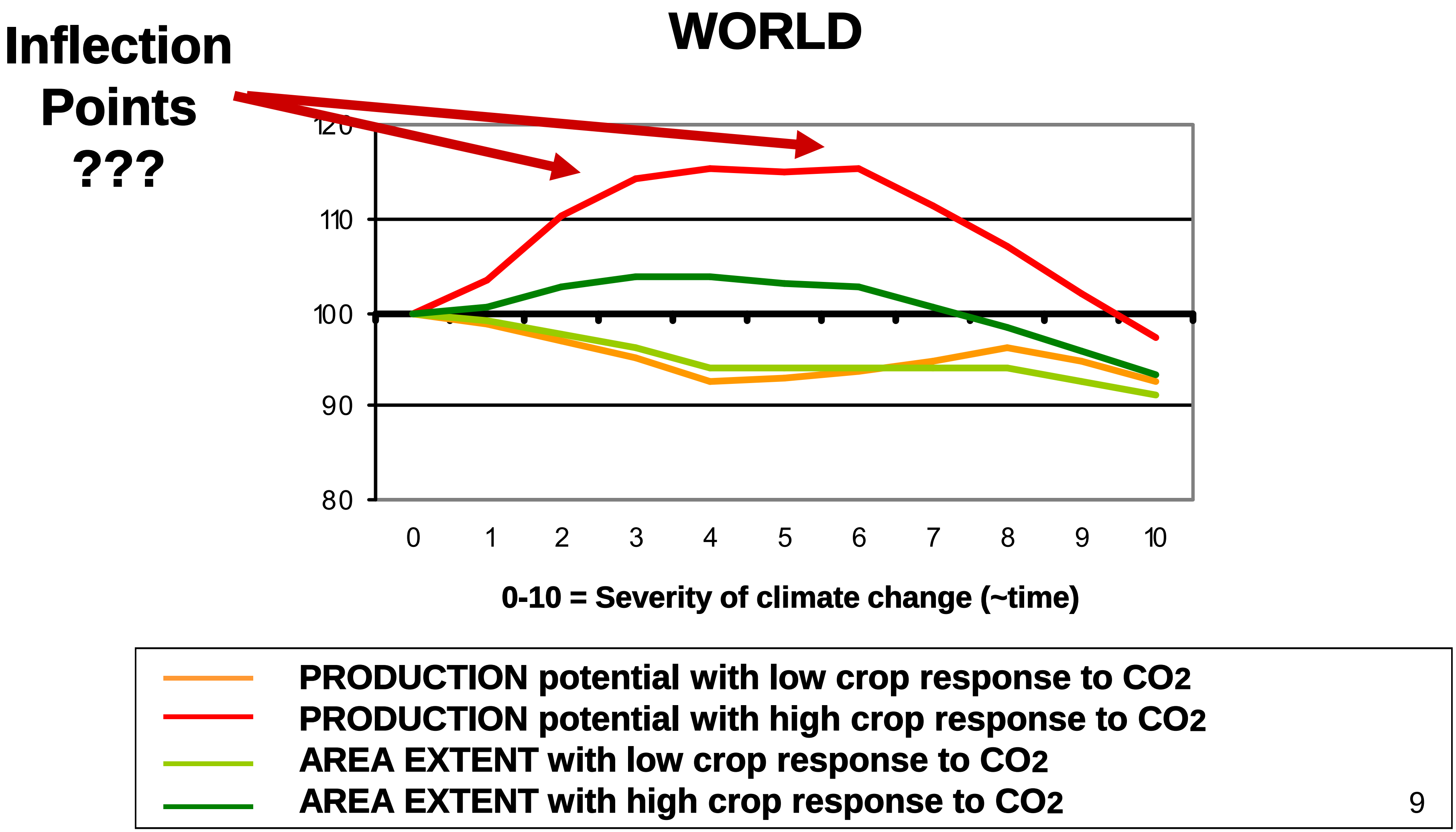


Number of events causing damage to maize yields due to excess soil moisture conditions, averaged over all study sites, under current baseline (1951–1998) and climate change conditions. Events causing a 20% simulated yield damage are comparable to the 1993 US Midwest floods.

Rosenzweig et al. 2001

Global Effects of Climate Change are Positive in Short Term and Negative in Long Term

Percent Change in Food Production Potential



Statistical Approach

• Uses historical data to estimate statistical relationships between observed crop yields as a function of observed climate variables.

• Uses these relationships to project the yield impact of changes in climate.

Advantages

Relationships should integrate biophysical responses to climate variables; based on observations; data availability is improving.

Disadvantages

The approach does not explain process-based changes; does not represent out-of-sample conditions; does not incorporate the effects of CO_2.

Data: yearly yield/aggregated 1^o 4-hourly reanalysis, monthly, growing season, degree days climate; Spatial resolution: crop reporting districts; country level

Expert System Approach

• Uses soil capability, climate, crop calendar, and simple productivity relationships to estimate production potential of agricultural systems.

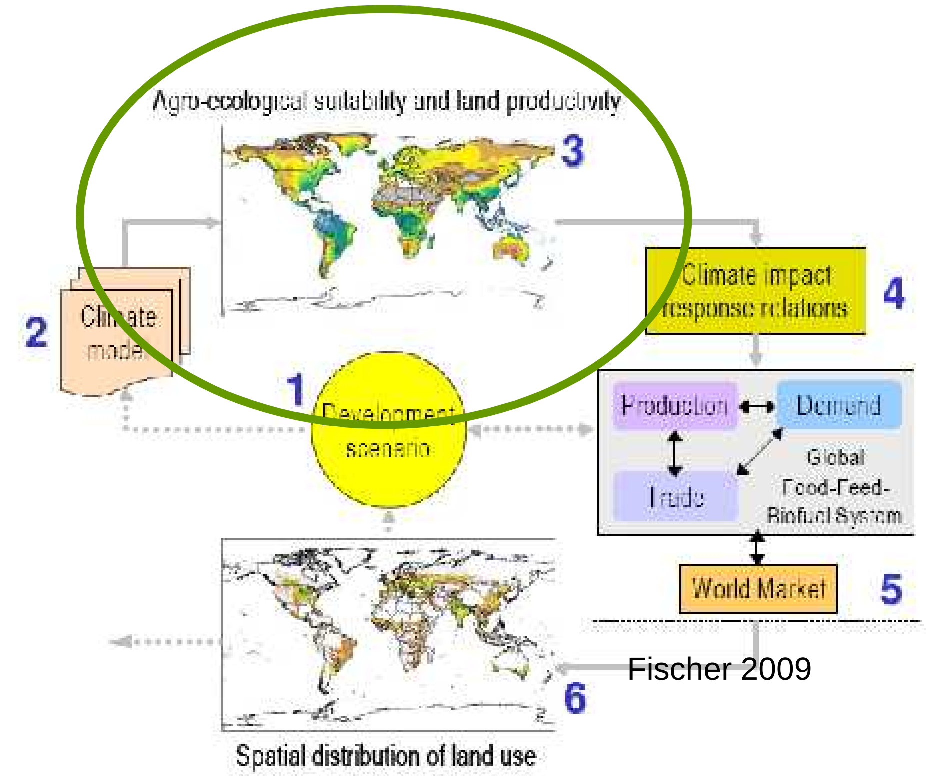
• Use calculator to project effect of changes in climate on production potential.

Advantages

Projects changes in both production potential and spatial extent of cropping systems; global extent.

Disadvantages

Results not easily validated in current climate. Processes are represented by simplified relationships.



Fischer 2009

GAEZ Data: yearly yield/monthly climate; soils; crop calendars; ag systems; Spatial resolution 5'x5' lat/long

Dynamic Process Crop Models

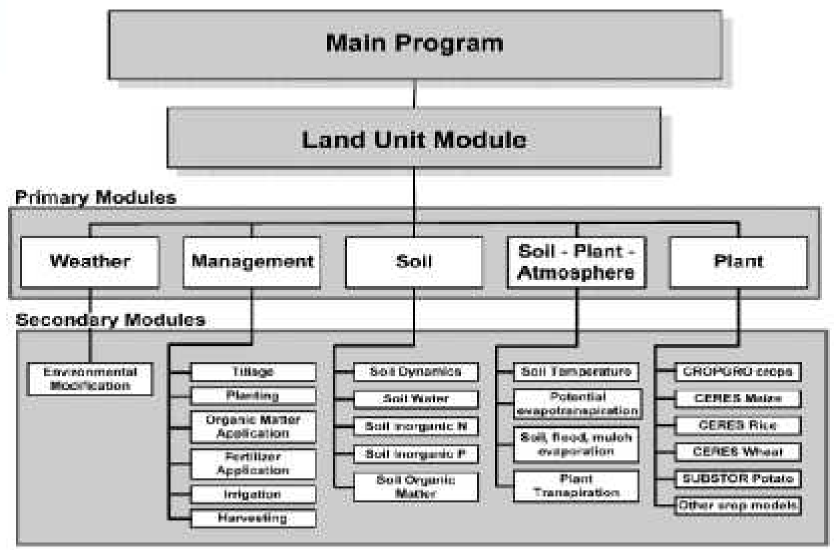
Advantages

- Explicit simulation of processes affected by climate, including CO_2 effects on growth and water use.
- Management practices included.
- Cultivar characteristics can be tested for ‘design’ of adapted varieties.
- Testable with experimental field data.

Disadvantages

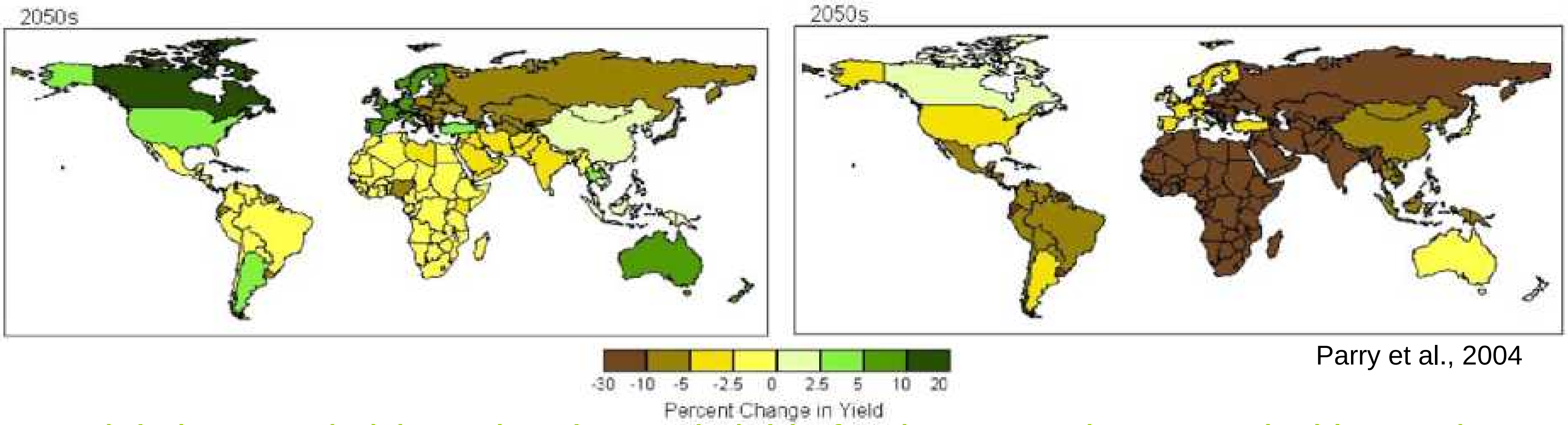
- Not all biophysical processes included.
- Aggregation from sites to regions challenging.
- Data availability varied.

Data: daily T, P, SR; cultivar characteristics; soils, management; yearly yield
Spatial resolution: Site-based; aggregated to regions, countries



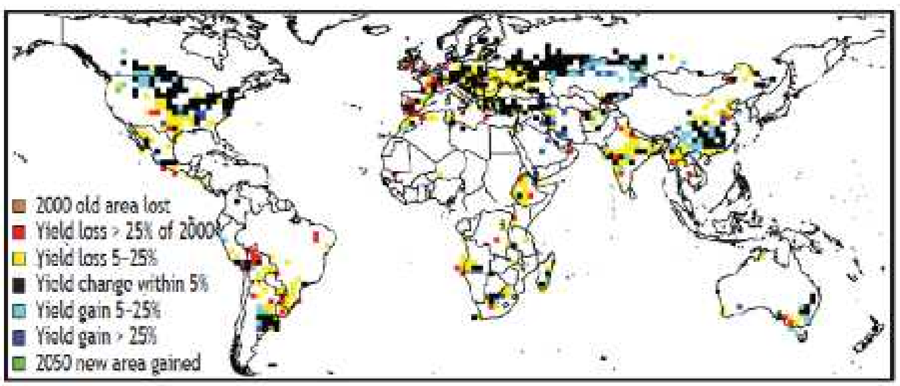
Jones 2010

Projected Yield Changes 2050s



Parry et al., 2004

Potential changes (%) in national cereal yields for the 2050s (compared with 1990) under the HadCM3 SRES A2a scenario with and without CO_2 effects (DSSAT)



IFPRI 2011

Yield Effects with CO_2, rainfed wheat CSIRO A1B (DSSAT)

Parry et al.	-30% to +20%
IFPRI	-25% to +25%
GAEZ	-32% to +19%

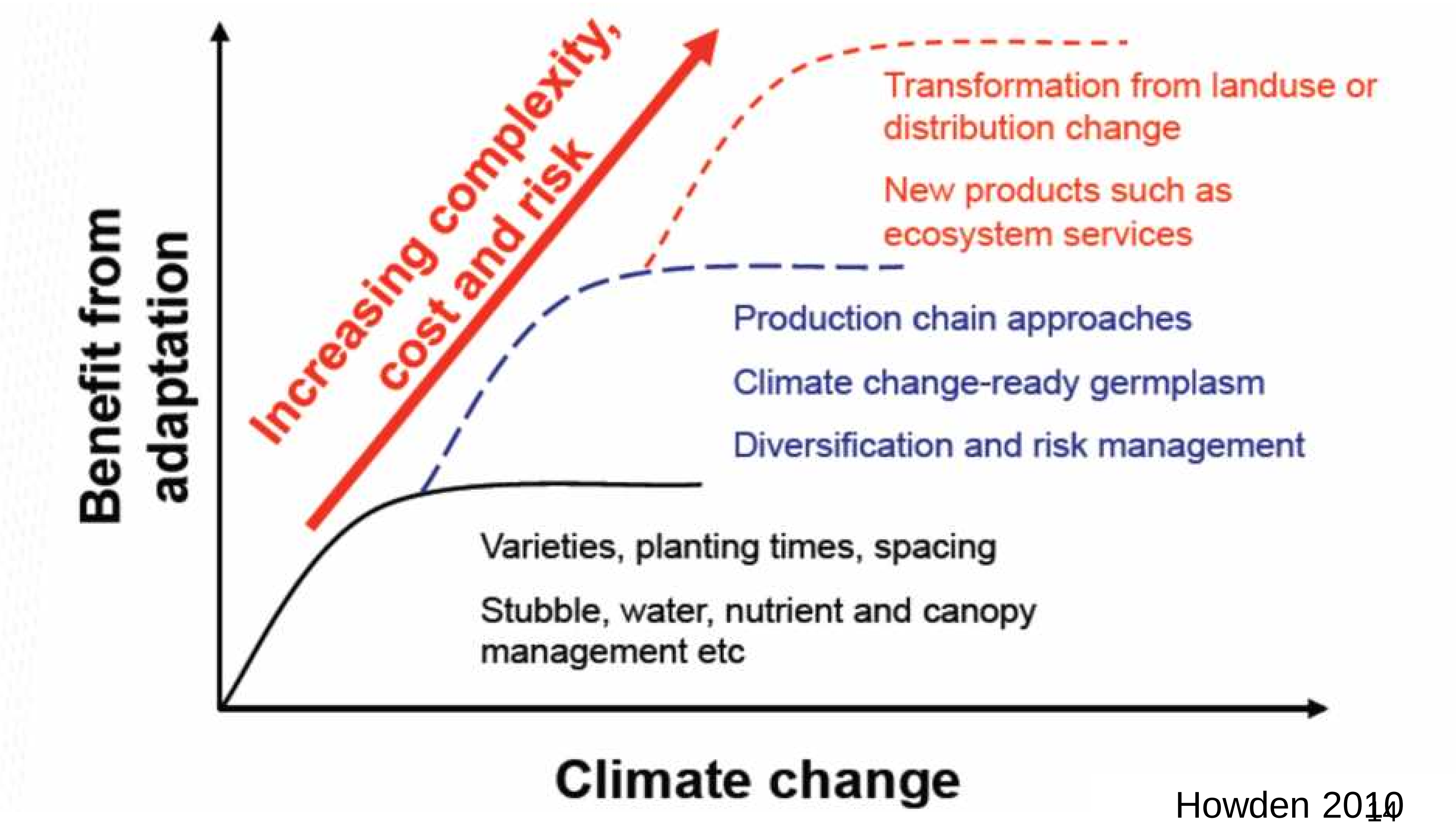
GAEZ IIASA 2009 rain-fed cereals Hadley A2
North America -7 to -1%; Europe -4 to 3;
Central Asia 14-19%; Southern Africa -32 to -29

Schlenker & Lobel Africa multi GCMs
-22 to -2% statistical approach

w/o adaptation

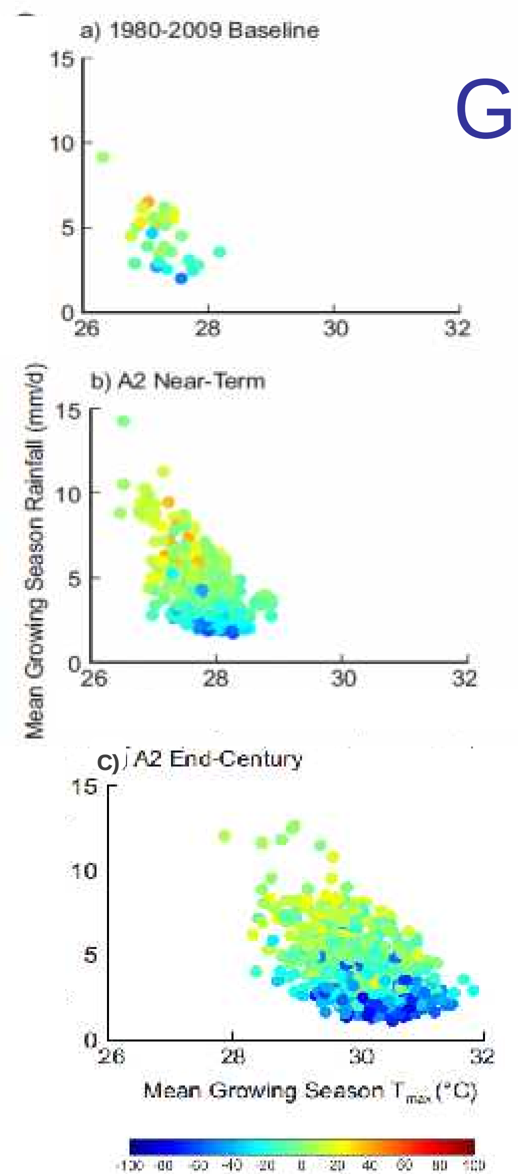
Progressive Levels of Adaptation

Challenges and Opportunities



Howden 2010

Gaps and Uncertainties

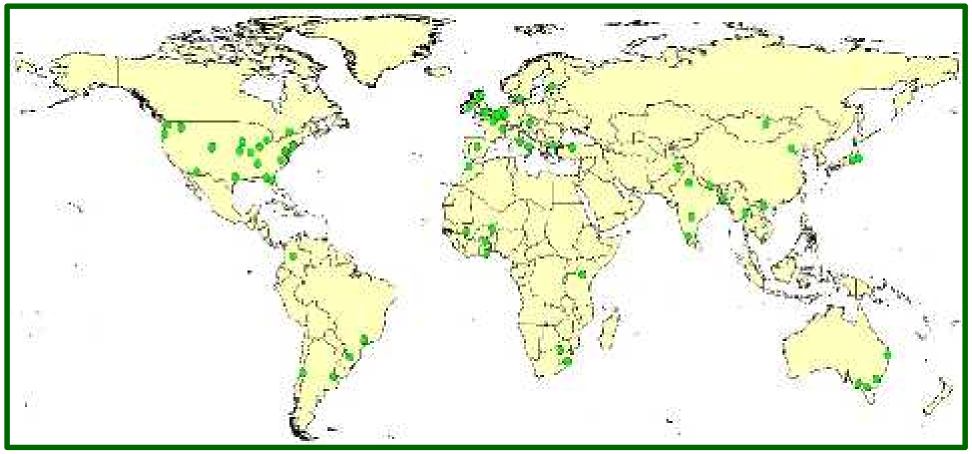


Simulated maize yield (as % change from 1970-1999 mean) sensitivity under constant CO_2 versus growing season temperature and rainfall. Los Santos, Panama. From Ruane et al 2012

- **Precipitation – battle of T and P**
- **Models and methods are still constrained in their ability to simulate extreme weather events.**
- **The interactions of warmer temperature with CO_2 and ozone need continued experimental research and simulation development.**
- **Effects of changes in evapotranspiration on soil moisture and crop yield and wider interactions with water availability is poorly understood.**
- **Pests**
- **Scale of simulation influences results.**
- **Yield gaps and plateaus.**
- **Lack of multi-model comparisons and assessments.**

AgMIP

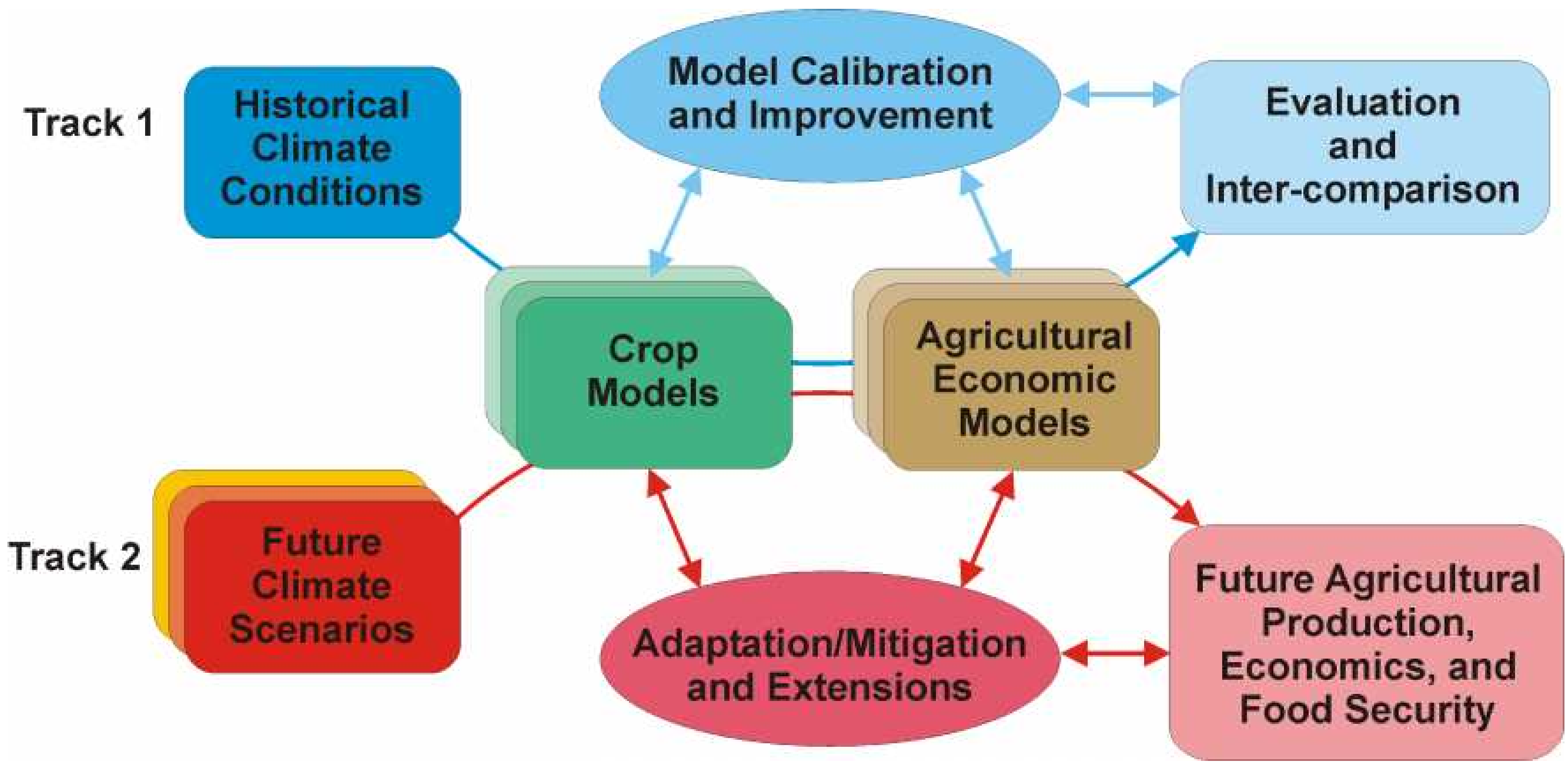
AgMIP The Agricultural Model Intercomparison and Improvement Project



Website, forum, and list-serve
http://www.agmip.org
>270 members

Kickoff Long Beach CA Oct 2010
Wheat Pilot Study Amsterdam April 2011
South America Campinas Brazil Aug 2011

AgMIP Two-Track Science Approach



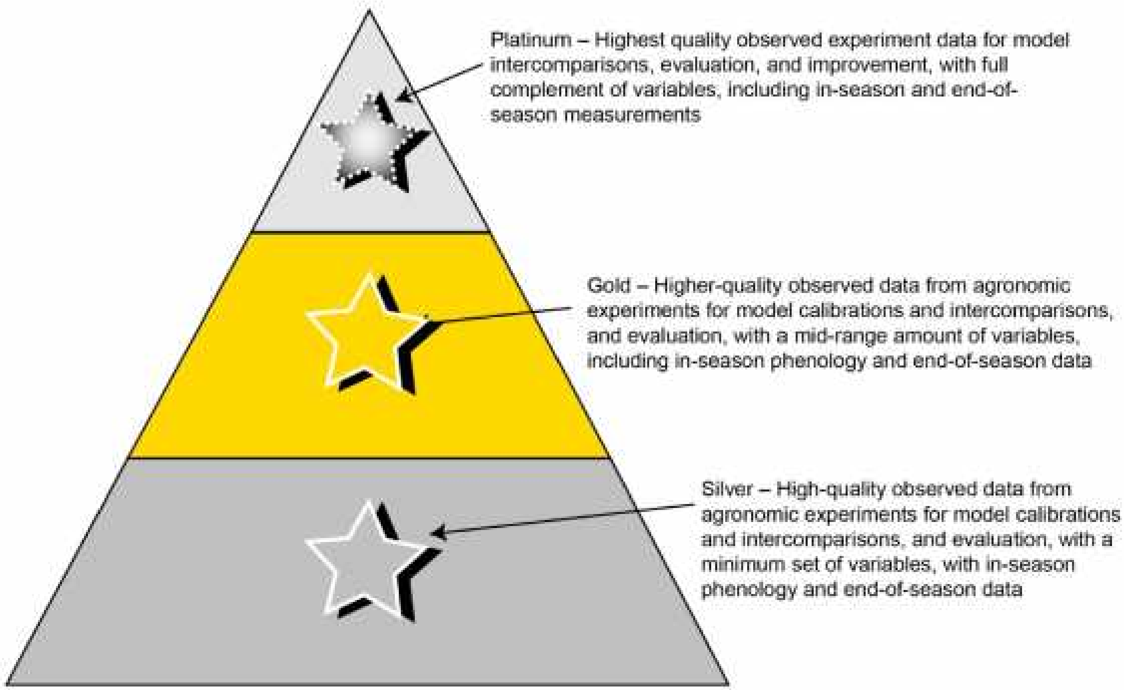
Track 1: Model Inter-comparison and Improvement

Track 2: Coordinated Future Scenario Simulations

AgMIP Cross-Cutting Themes

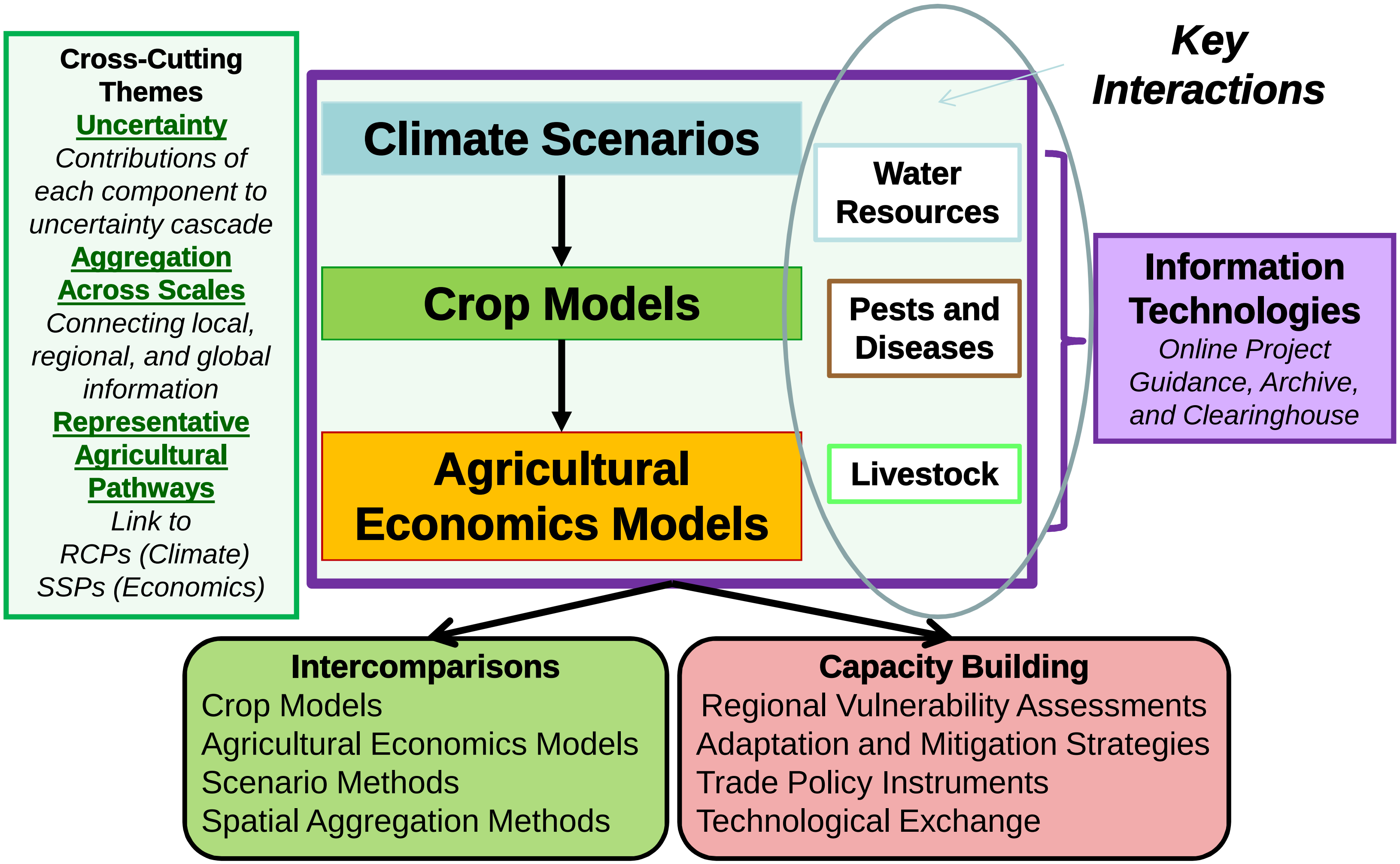
Agricultural Pathways, Uncertainties, and Aggregation

AgMIP Sentinel Site Pyramind



The Sentinel Site Pyramid

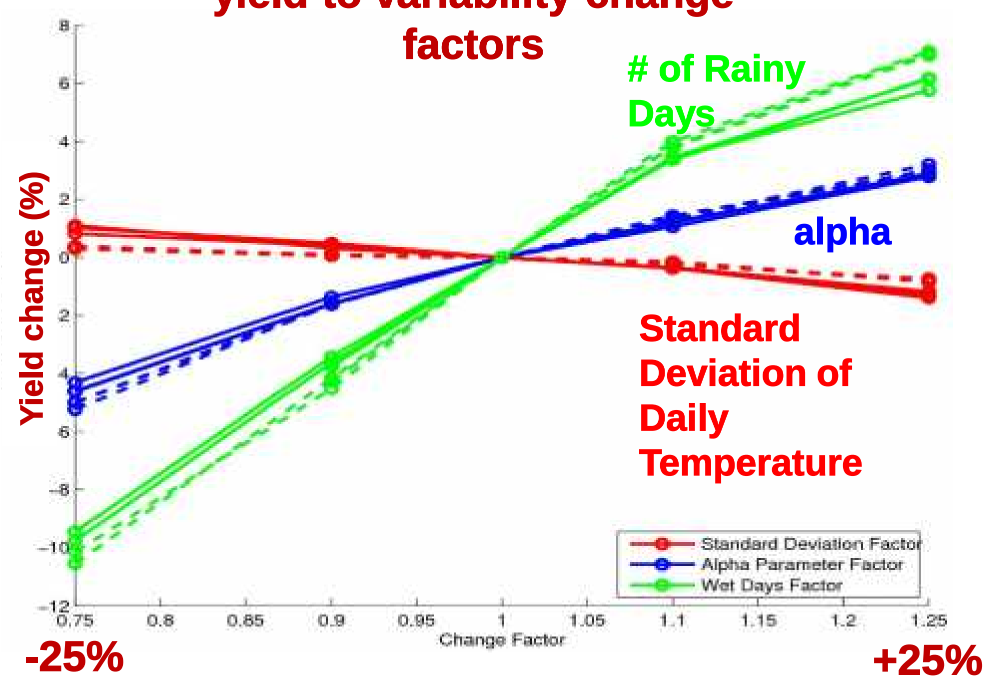
AgMIP Teams and Linkages

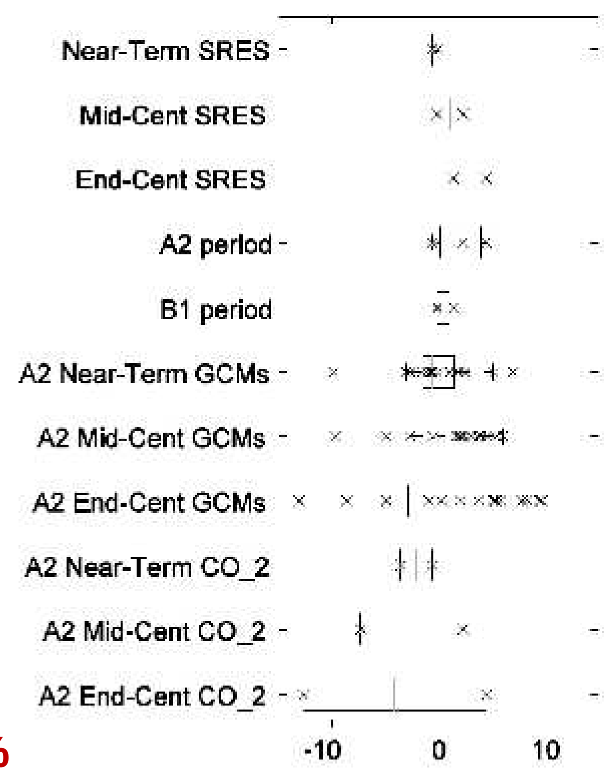


AgMIP Climate Scenarios Team

- Historical and future climate analysis for agricultural regions
- 30-year time-slices for near-term, mid-century, and end-of-century
- Ensemble GCMs and emissions scenarios (Representative Concentration Pathways - ready)
- Sensitivity to changes in temperature, rainfall, and [CO_2]
- Focus on changes in daily and interannual extremes
- Comparisons of downscaling methods and weather generation techniques

Sensitivity of SE USA Corn yield to variability change factors



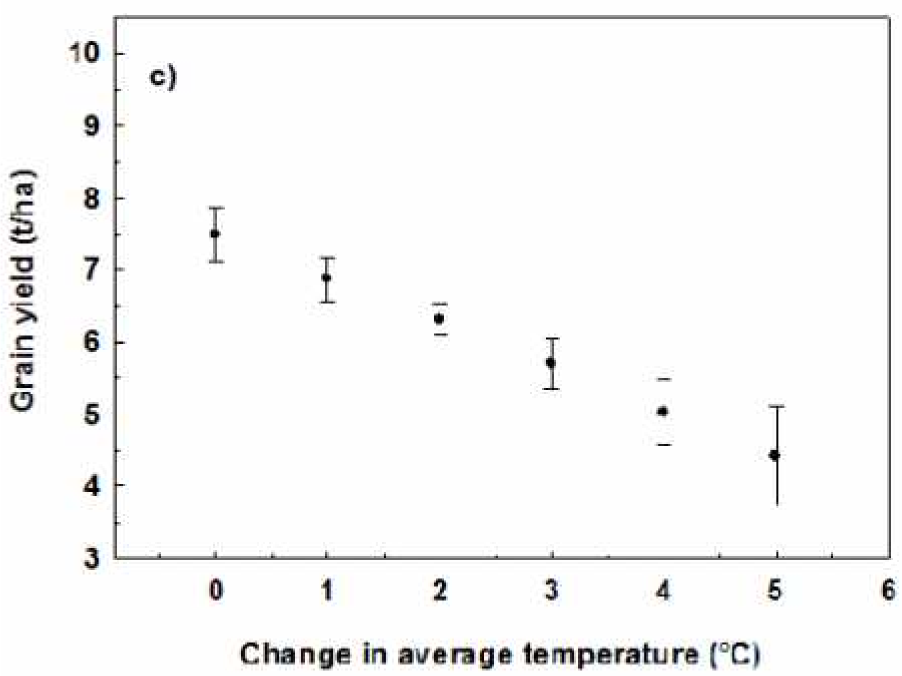


CERES-Maize simulations of Panama Maize Ruane et al., submitted

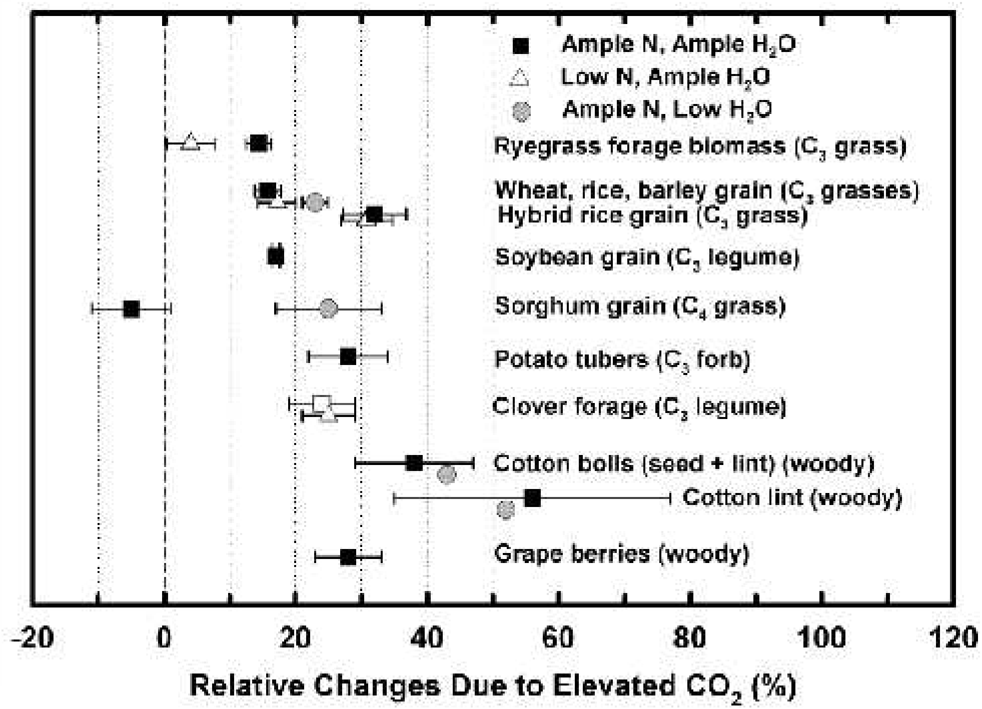
Uncertainty from many factors of climate information

AgMIP Crop Modeling Team

- Process-based crop models to assess conditions that are outside of observed range
- Crucial to have multi-model intercomparisons
- Testing crop models with FACE CO2 and temperature data
- Interactions between [CO_2], rainfall, nitrogen, and temperature



Wheat at Obregon, Mexico 5 crop models
Irrigated, no N-stress; Rosenzweig et al., 2011



FACE Yield response to +200 ppm CO_2
Kimball, 2010; in Hillel and Rosenzweig, 2010

Next Steps for AgMIP

- **Activities**
  - Economic Model Intercomparison
  - UK DFID RFP for African and South Asian participants
  - Regional activities
  - Pilot intercomparisons of climate, crop, economic methods
  - CORDEX agricultural impacts pilots
  - Complementary programs

- **Regional and Global Workshops**
  - Global Workshops just prior to ASA annual meeting (San Antonio, October 13-15, 2011)
  - US National Climate Assessment FACE (Des Moines; 2011)
  - Sub-Saharan Africa (Nairobi; January, 2012)
  - South Asia (Hyderabad; February, 2012)

The Agricultural Model Intercomparison and Improvement Project

For more information:

visit www.agmip.org and join list-serve

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