FSE STANFORD

CENTER ON FOOD SECURITY AND THE ENVIRONMENT

Global Food Policy and Food Security Symposium Series

Climate Change and Agricultural Adaptation

David Lobell, Assistant Professor, Environmental Earth System Science, FSE Center Fellow

Stanford University

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Stanford University

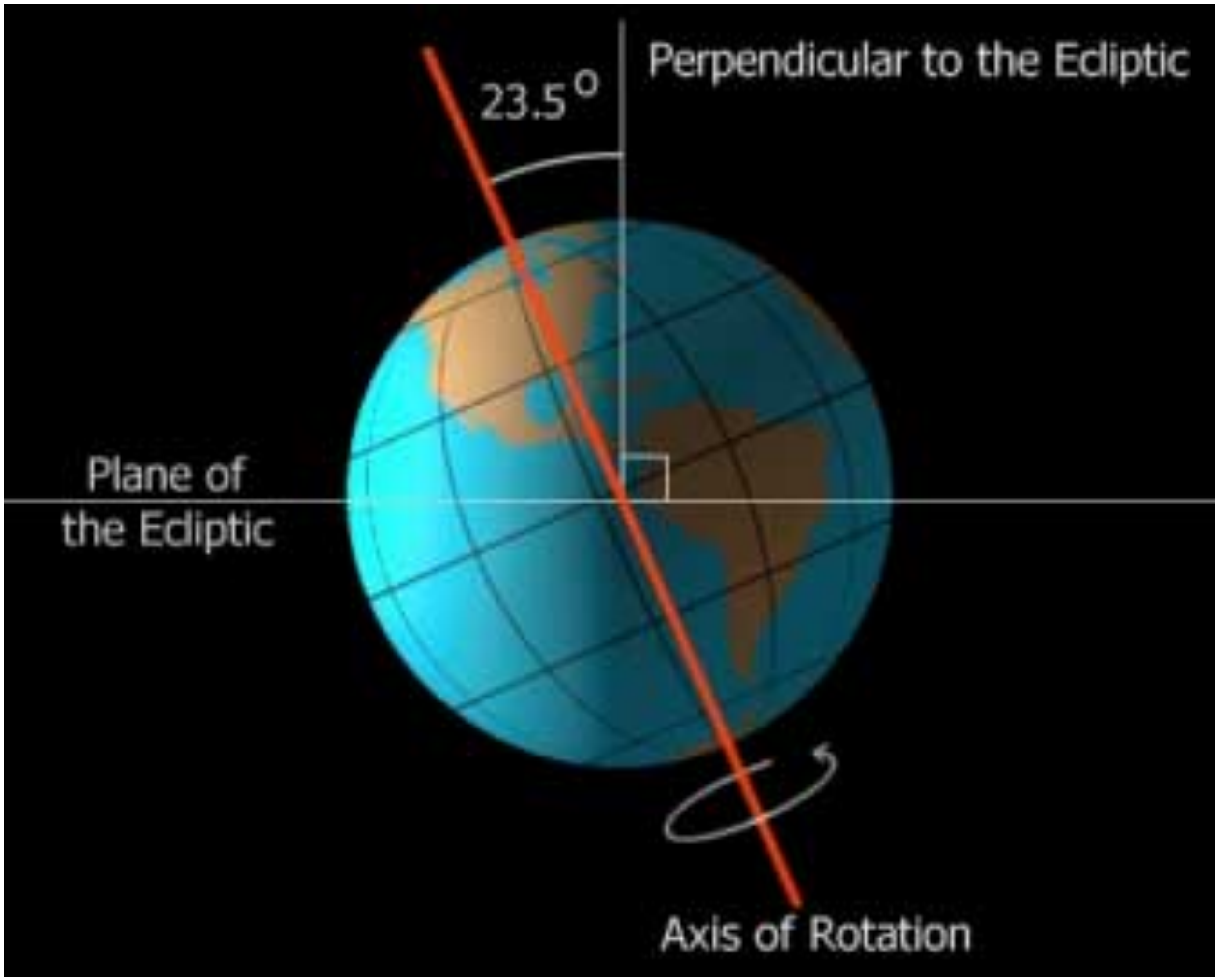
FREEMAN SPOGLI INSTITUTE FOR INTERNATIONAL STUDIES

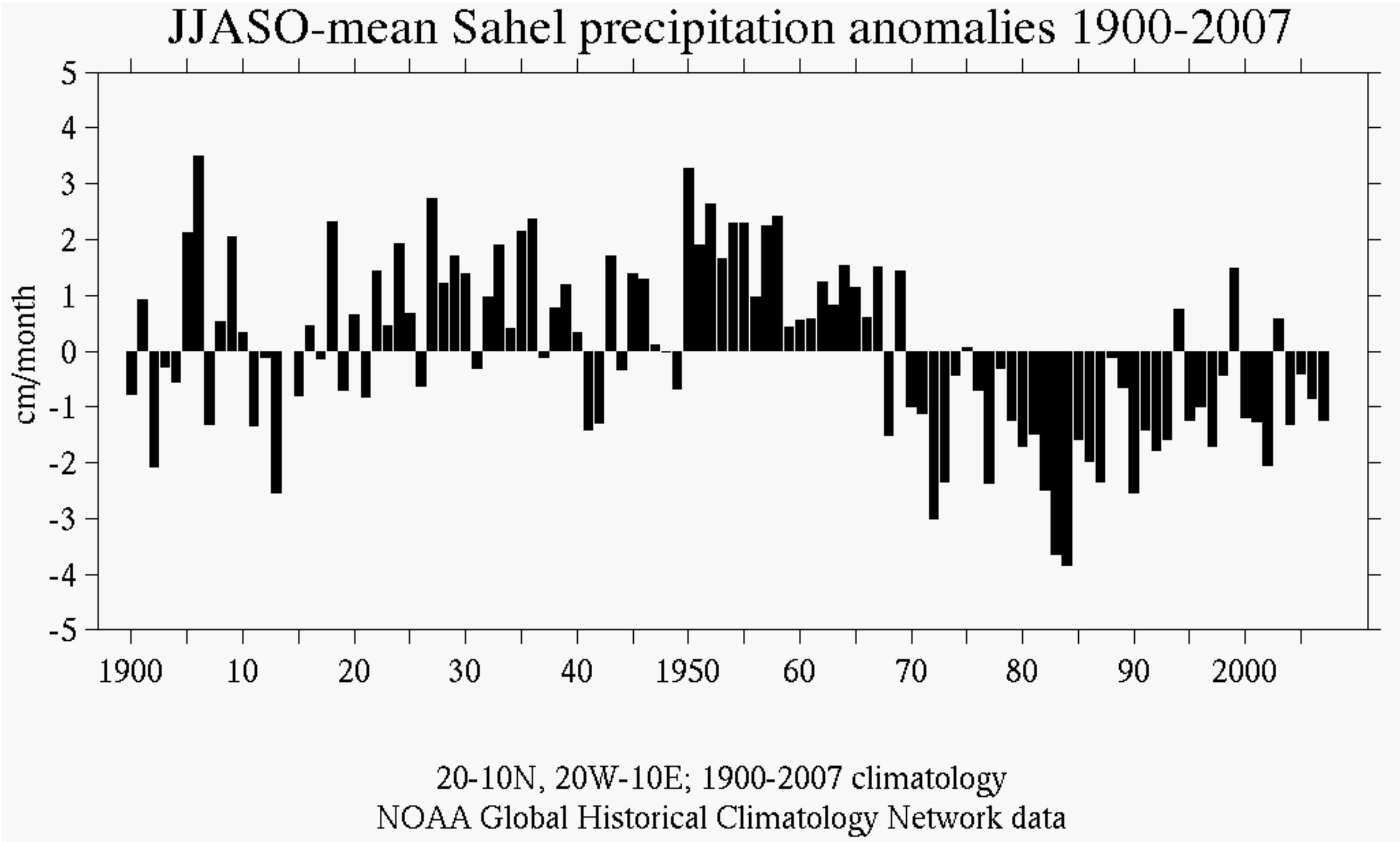
WOODS INSTITUTE FOR THE ENVIRONMENT STANFORD UNIVERSITY

Outline

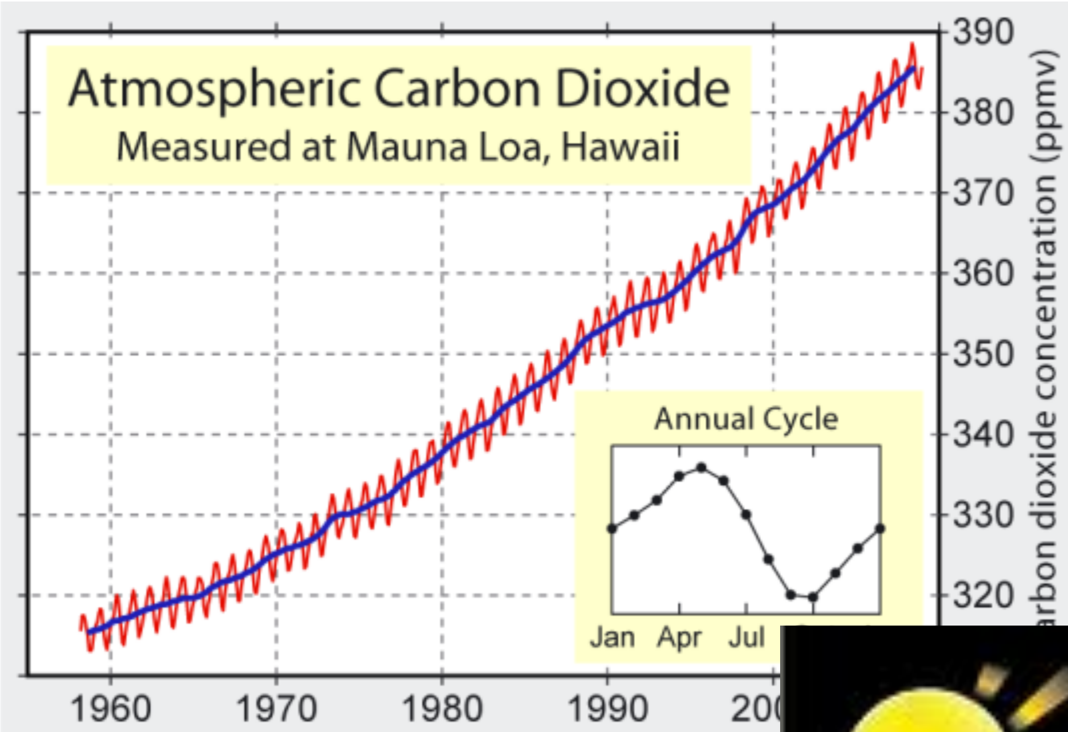
1. Relevant lessons from climate science
2. Implications for food security
3. Implications for food policy

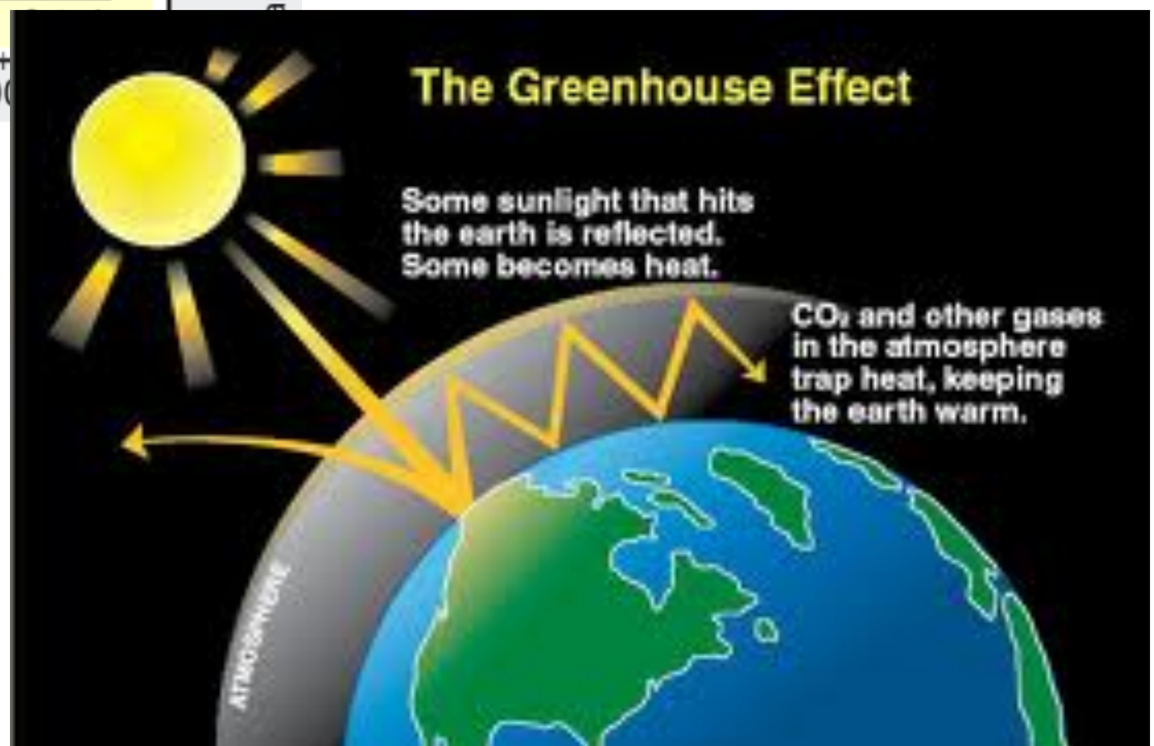
Climate Variability = natural variations that occur because of <u>internal dynamics</u> in the climate system




JJASO-mean Sahel precipitation anomalies 1900-2007
cm/month
5
4
3
2
1
0
-1
-2
-3
-4
-5
1900
10
20
30
40
1950
60
70
80
90
2000
20-10N, 20W-10E; 1900-2007 climatology
NOAA Global Historical Climatology Network data

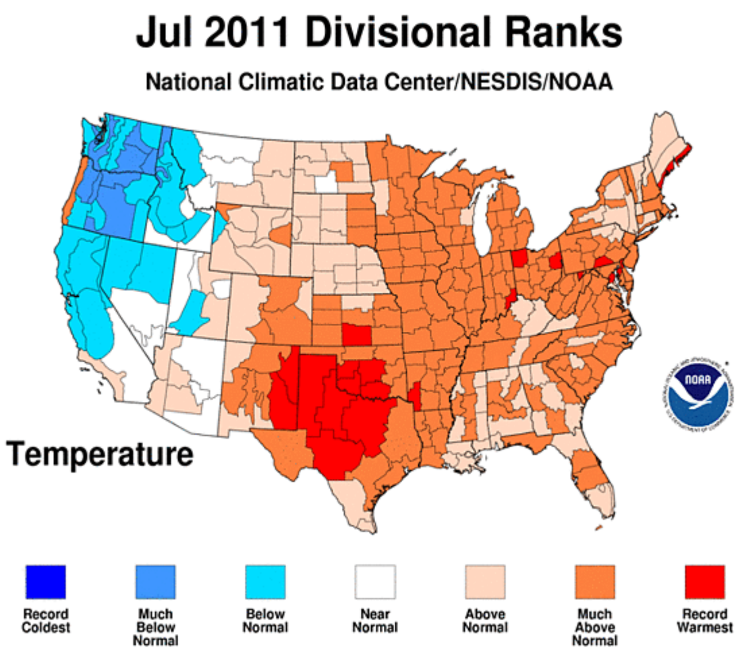
Climate change = changes that occur because of external forcings of the climate system, such as from higher CO_2

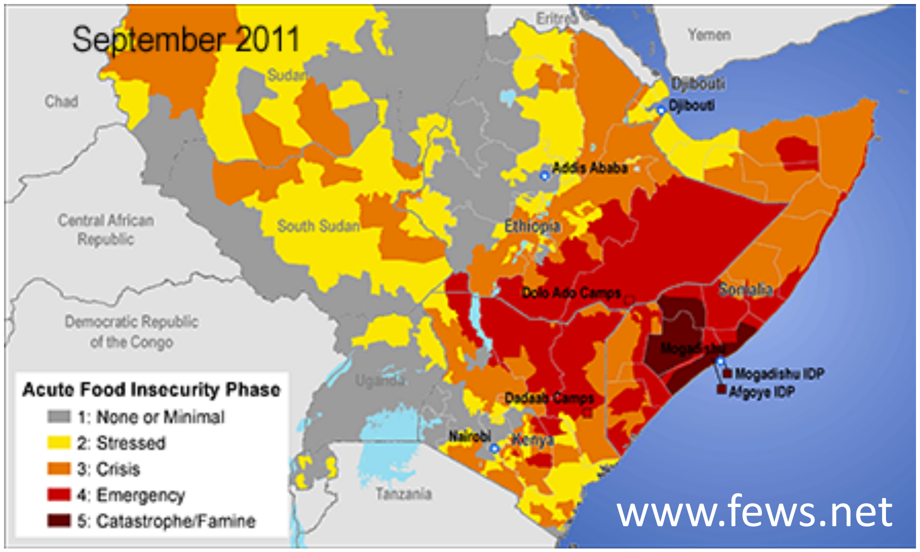




Both variability and change matter, and they are often hard to separate

In 2011: we've seen drought in E Africa, heat waves in US, flooding in Thailand.





Important to know the distinction

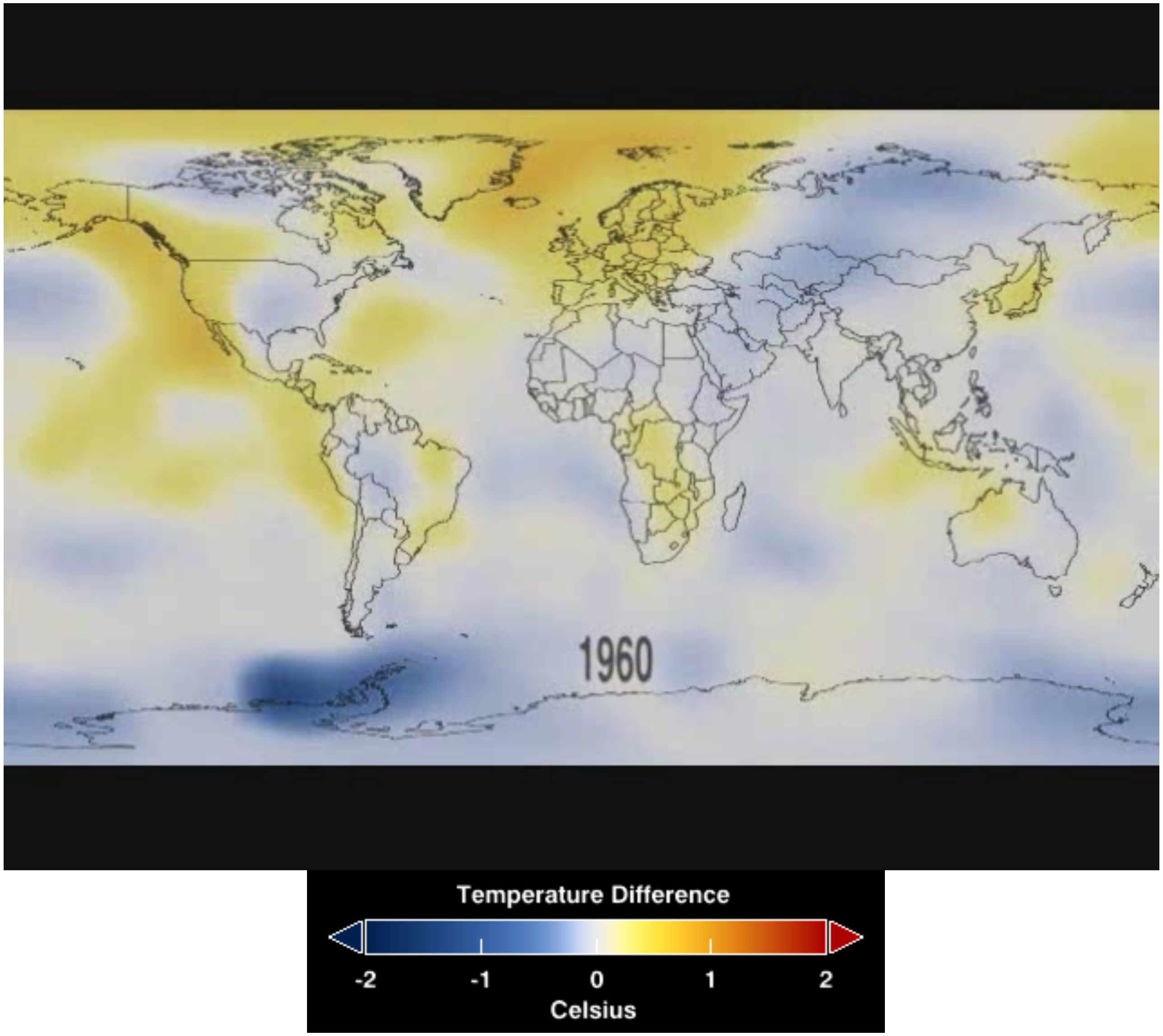
- Not every climate event or trend is the result of greenhouse gas emissions

- Climate change does not simply increase variability, or necessarily affect the same aspects of the climate system

Climate Science

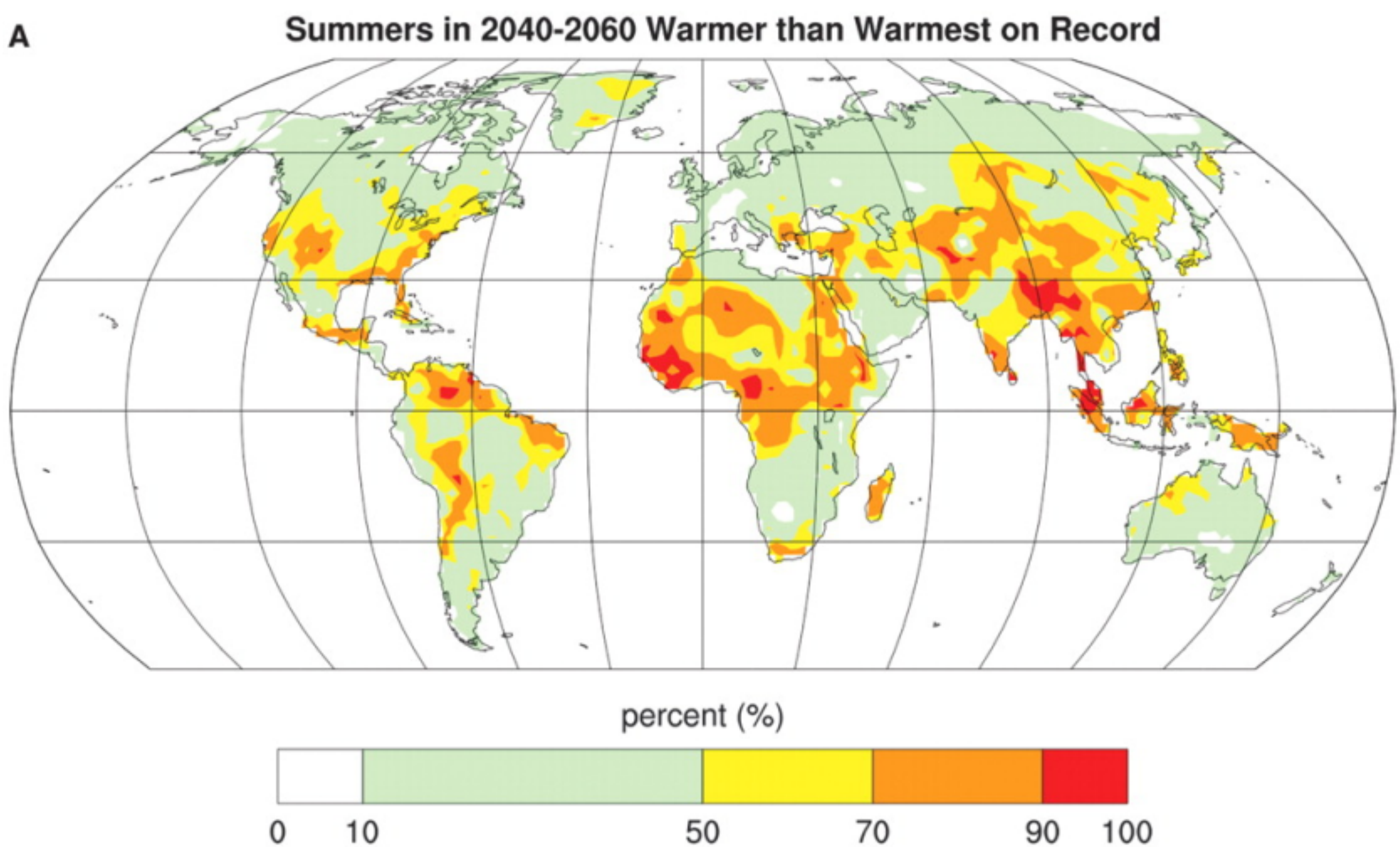
- 3 things we know well
- 3 things we don't

Things we know: 1) Warming



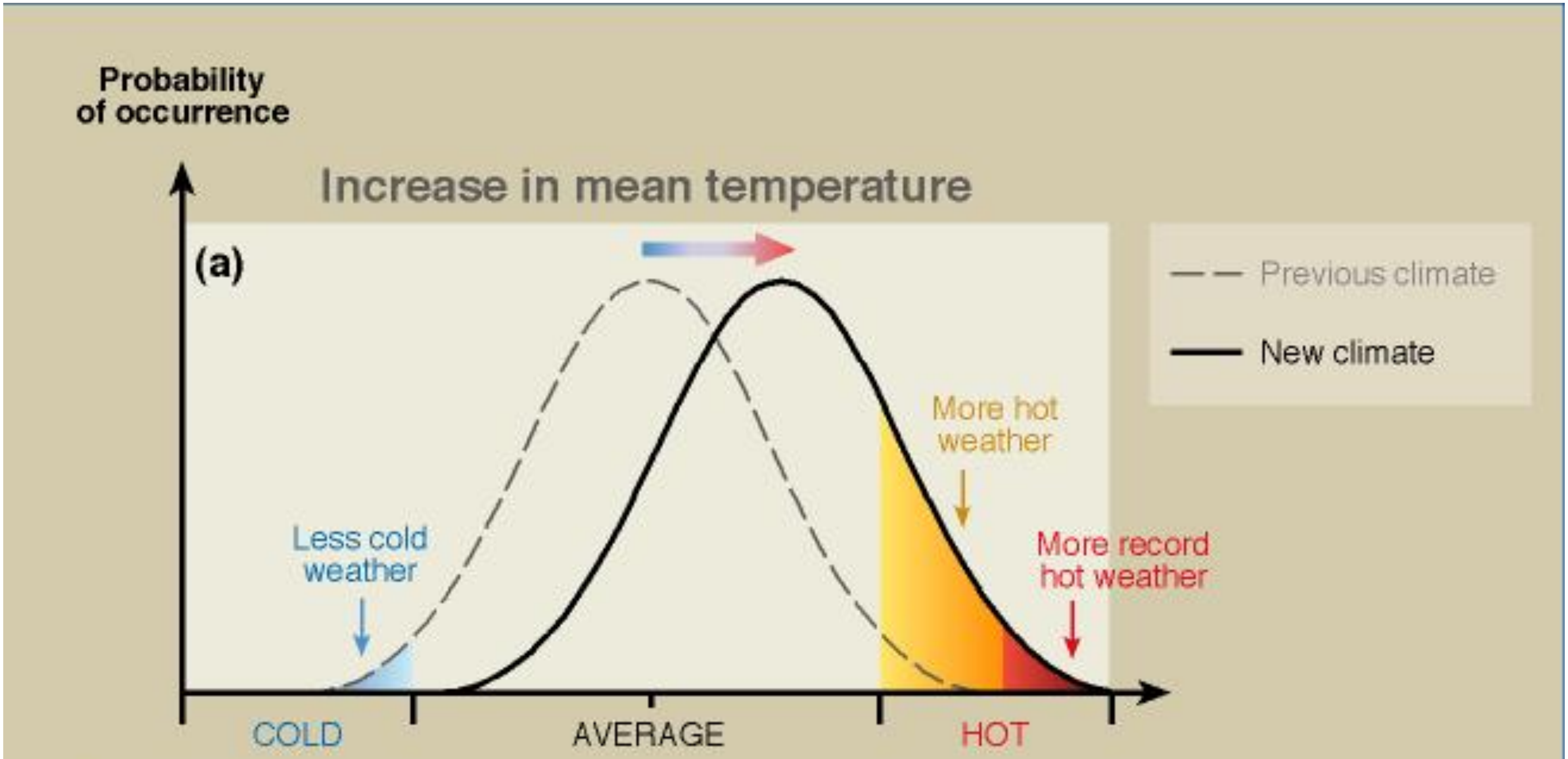
Source: NASA GISS

Things we know: 1) Warming



Battisti and Naylor 2009 *Science*

1) Warming: Hot extremes become more common

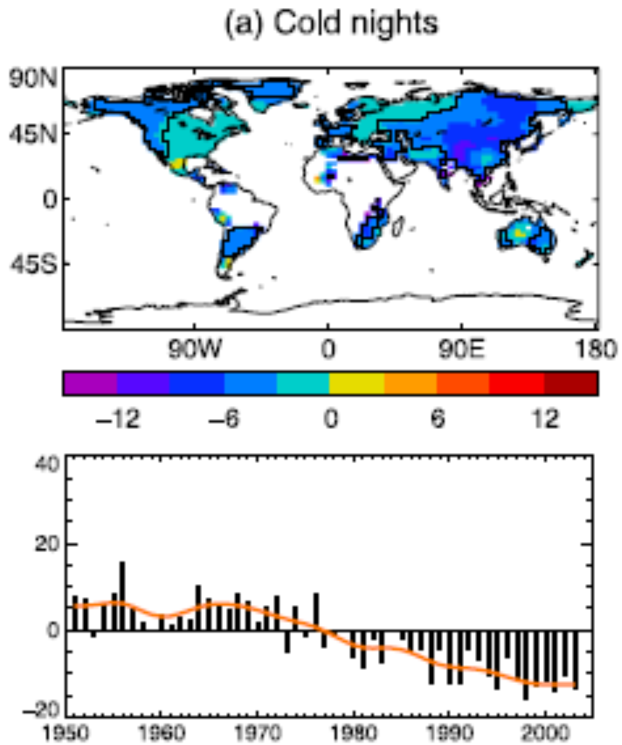


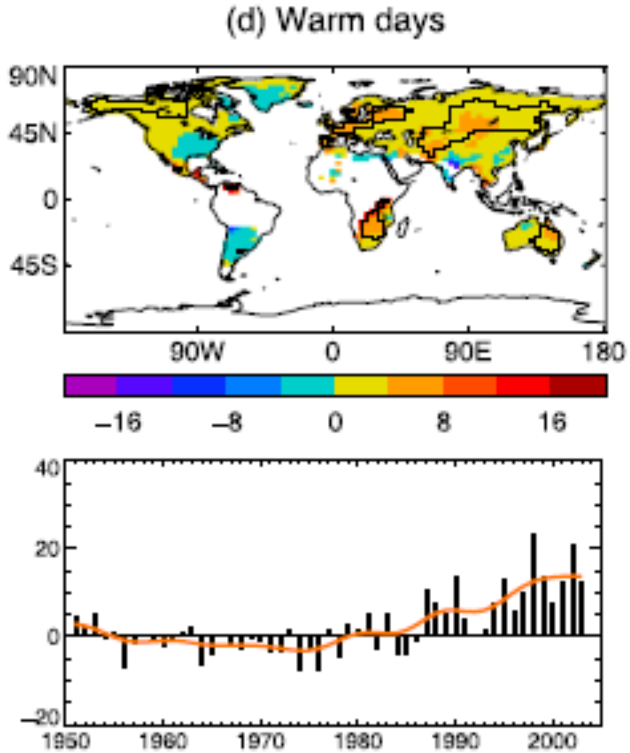
IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

1) Warming: Changes in extremes

Observed Changes since 1950:

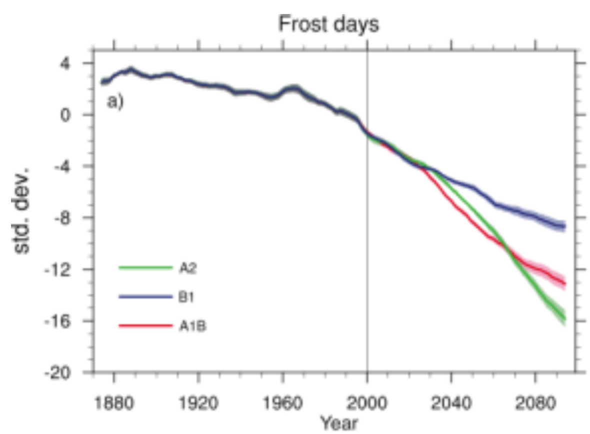
Map of trends

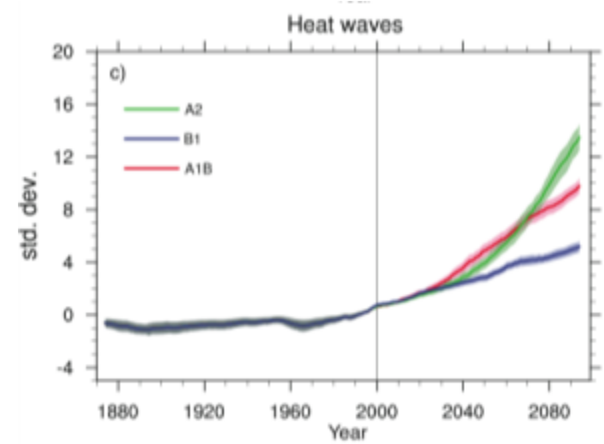




Time series of global average

Projected Changes to 2100:

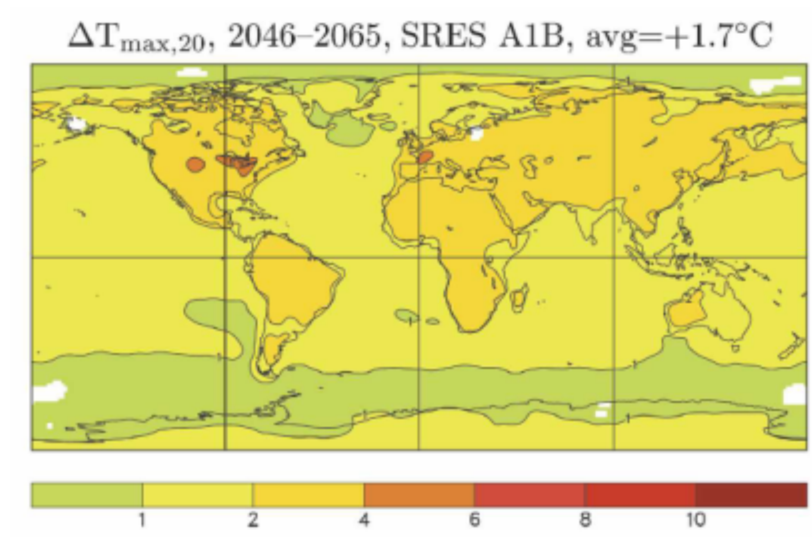




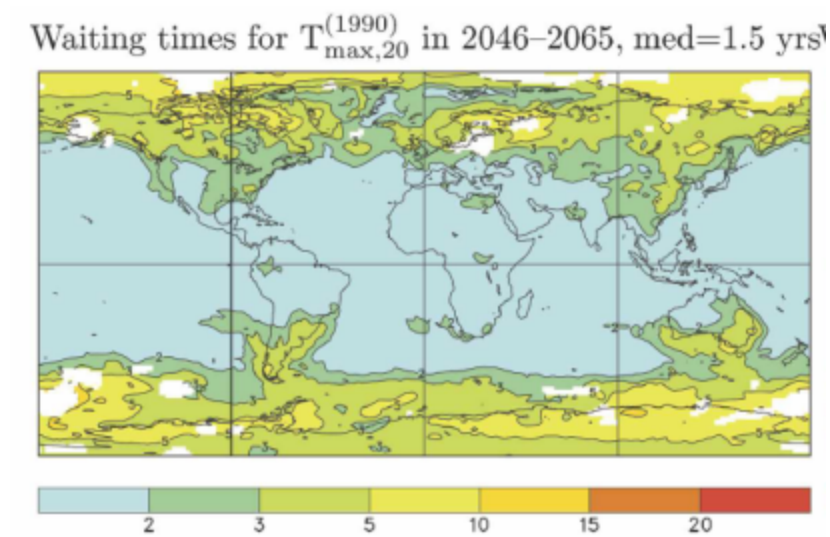
Alexander et al. 2006, Tebaldi et al. 2006, IPCC AR4 2007

1) Warming: Hot extremes become more common

Warmest days will get much warmer

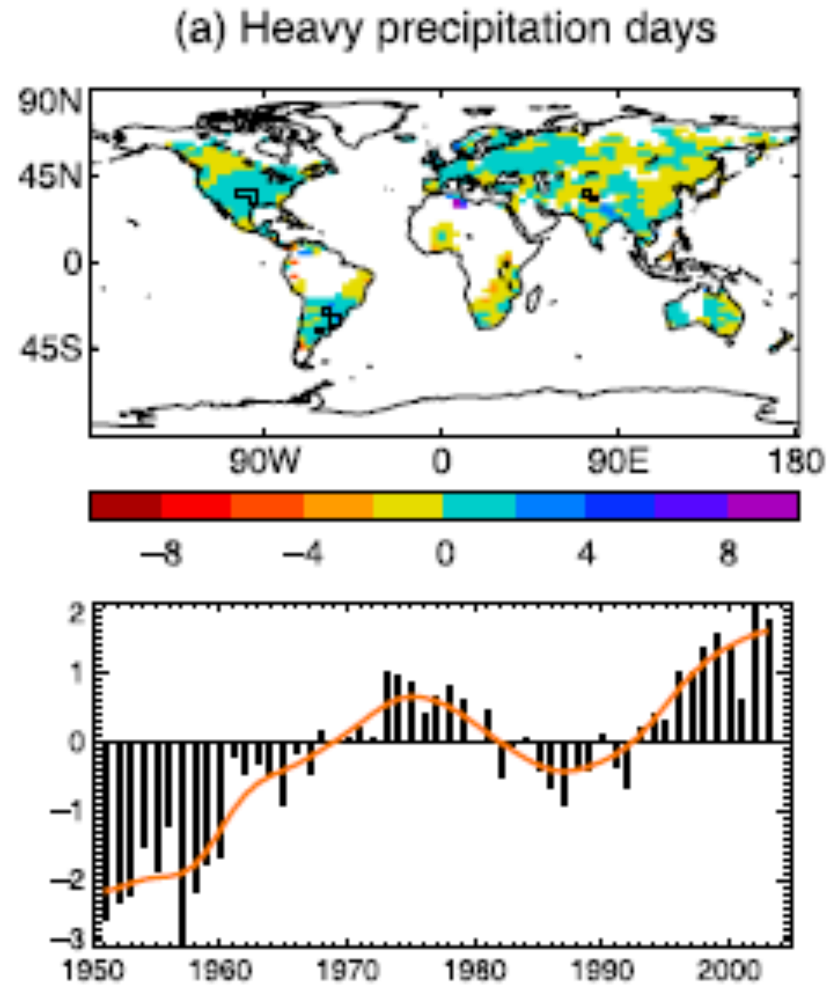


Current extremes will become more common



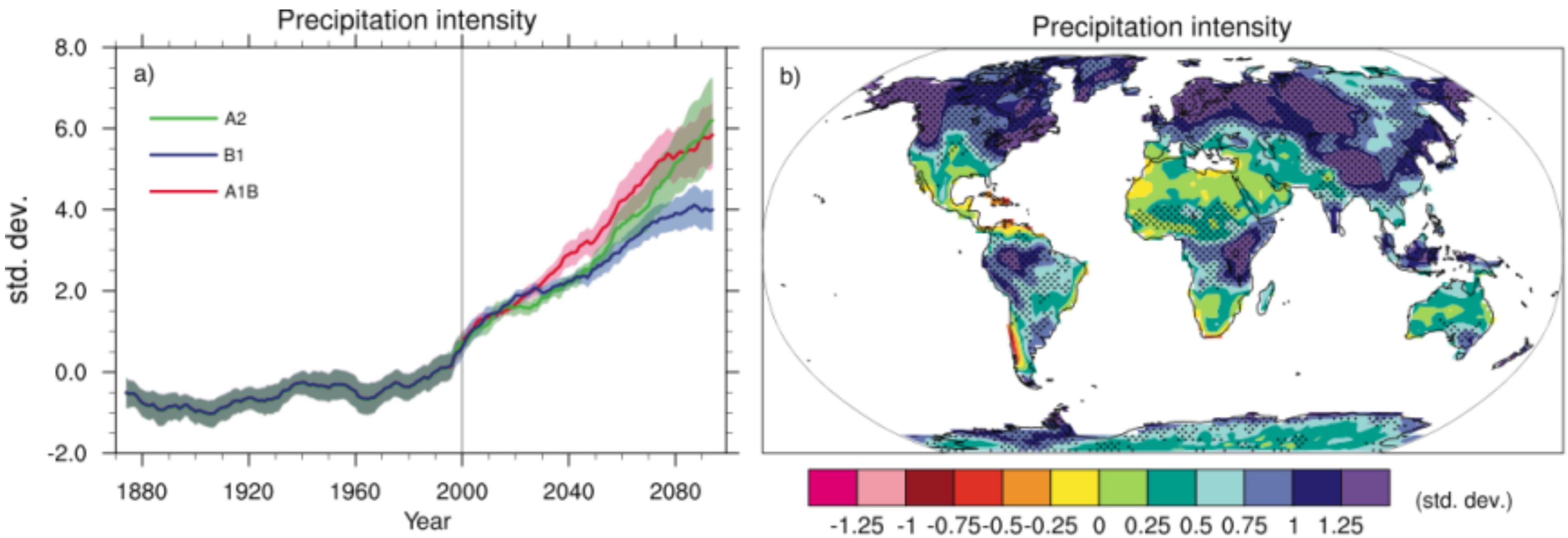
Kharin et al. 2007

Things we know: 2) Heavy rainfall becoming more common



Alexander et al. 2006

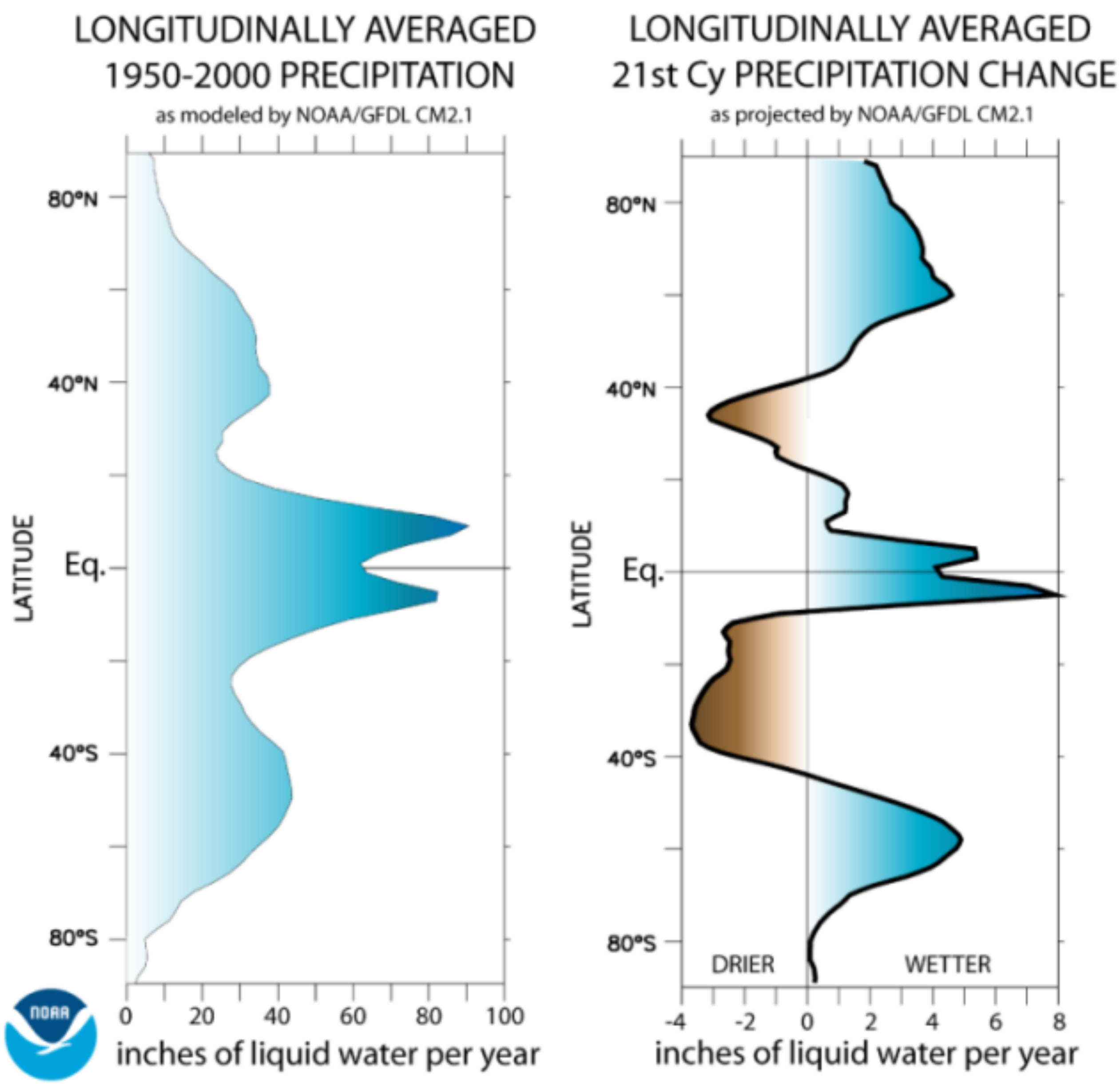
Things we know: 2) Heavy rainfall becoming more common



Precipitation Intensity = total rain / # rainy days

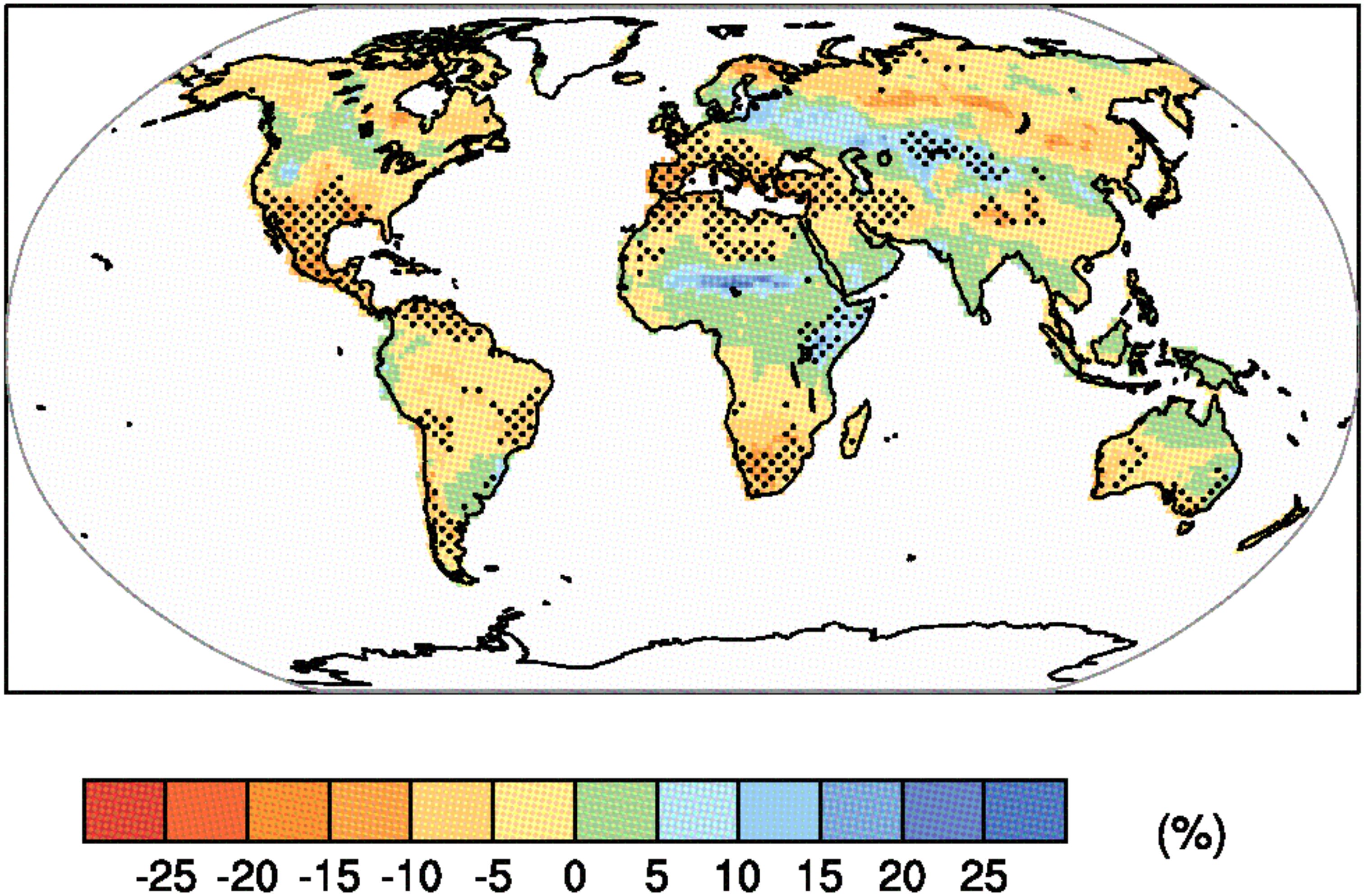
Tebaldi et al. 2006, IPCC AR4 2007

Things we know: 3) Dry areas generally become drier



Things we know: 3) Dry areas generally become drier

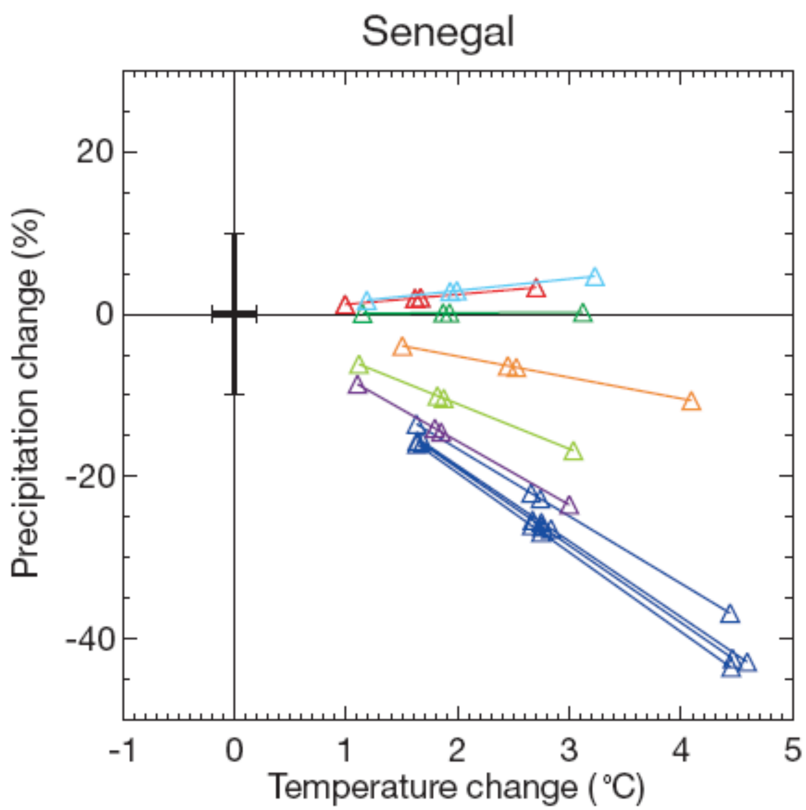
Average climate model projections of soil moisture change by 2080



IPCC 2007

Things we don't know: 1) Local Rainfall Changes

Changes in Senegal annual mean rainfall and temperature, 2050 relative to 1960-1990



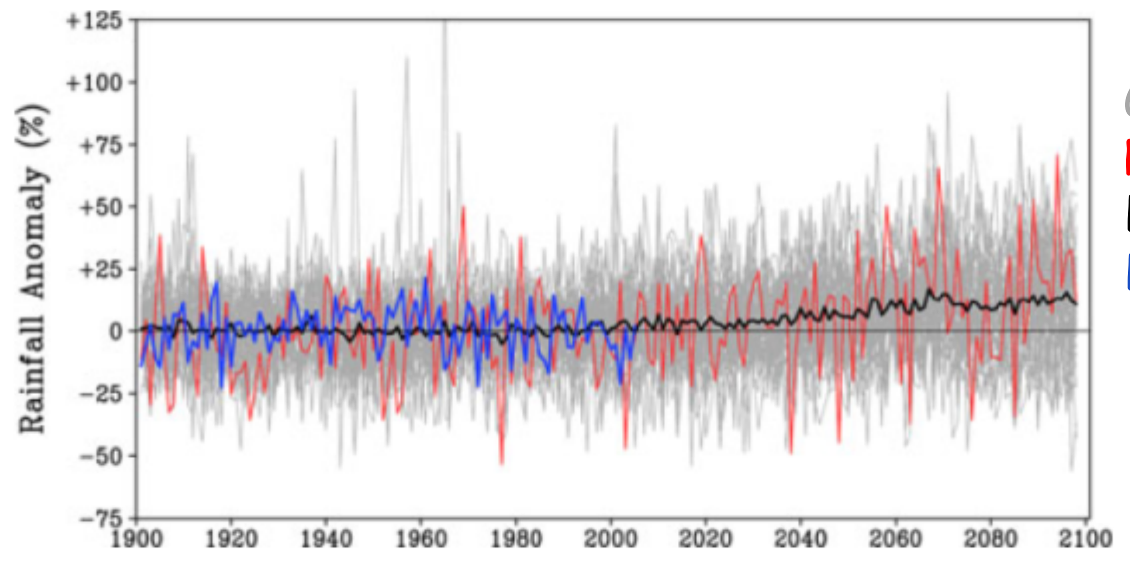
Different colors = different climate models

Different points = 4 emission scenarios per model

Hulme et al. (2001)

Things we don't know: 1) Local Rainfall Changes

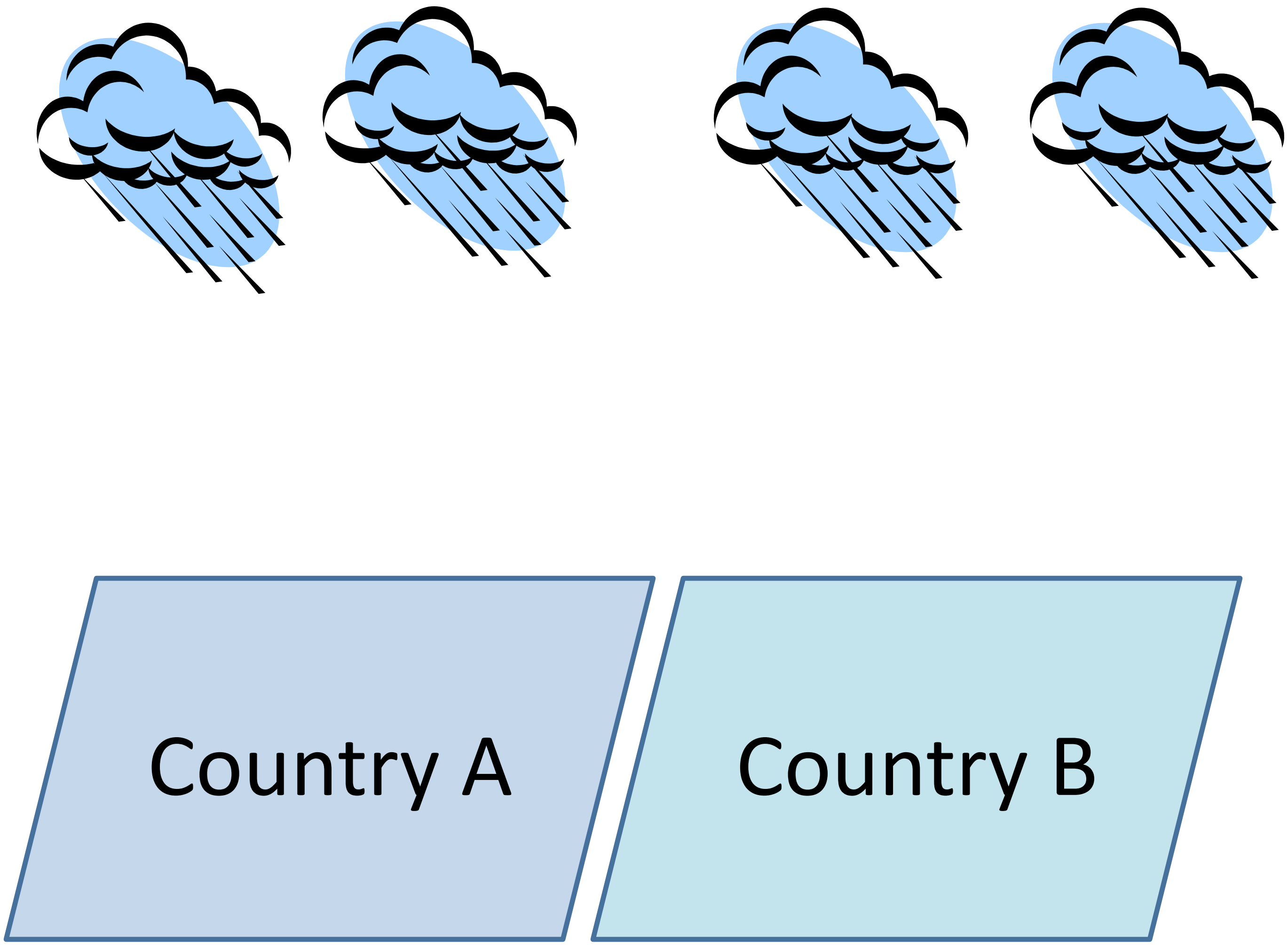
Changes in Indian monsoon rainfall



Gray = individual models
Red = Hadley model
Black = model average
Blue = observations

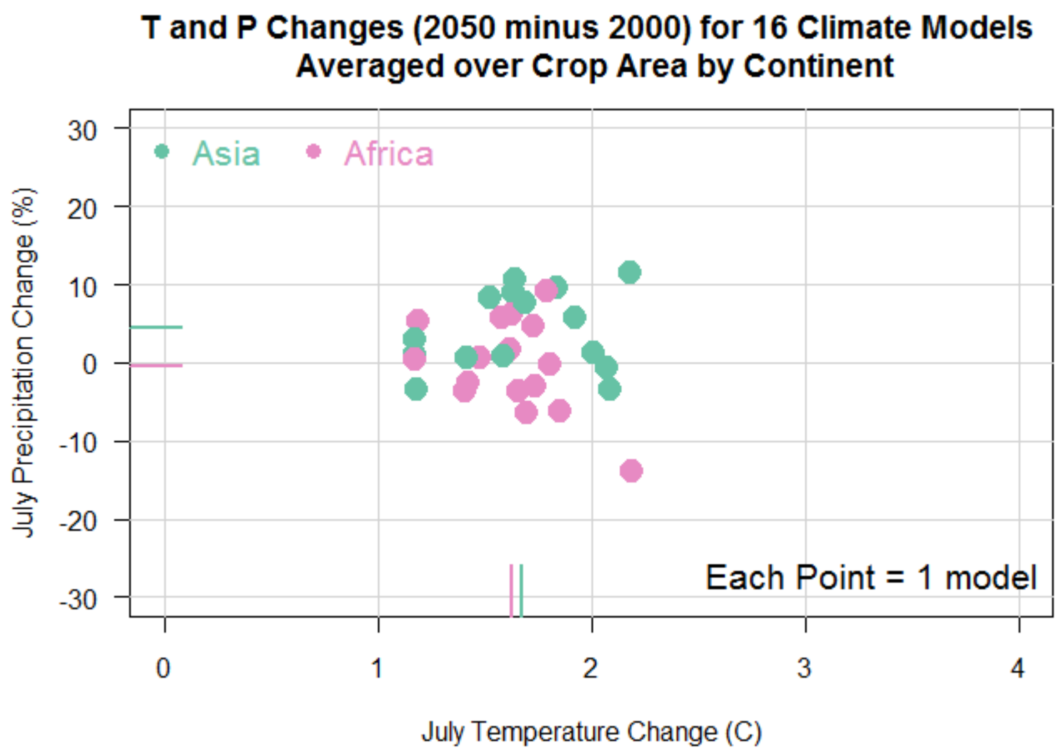
Kumar et al. (2010)

Scale Matters



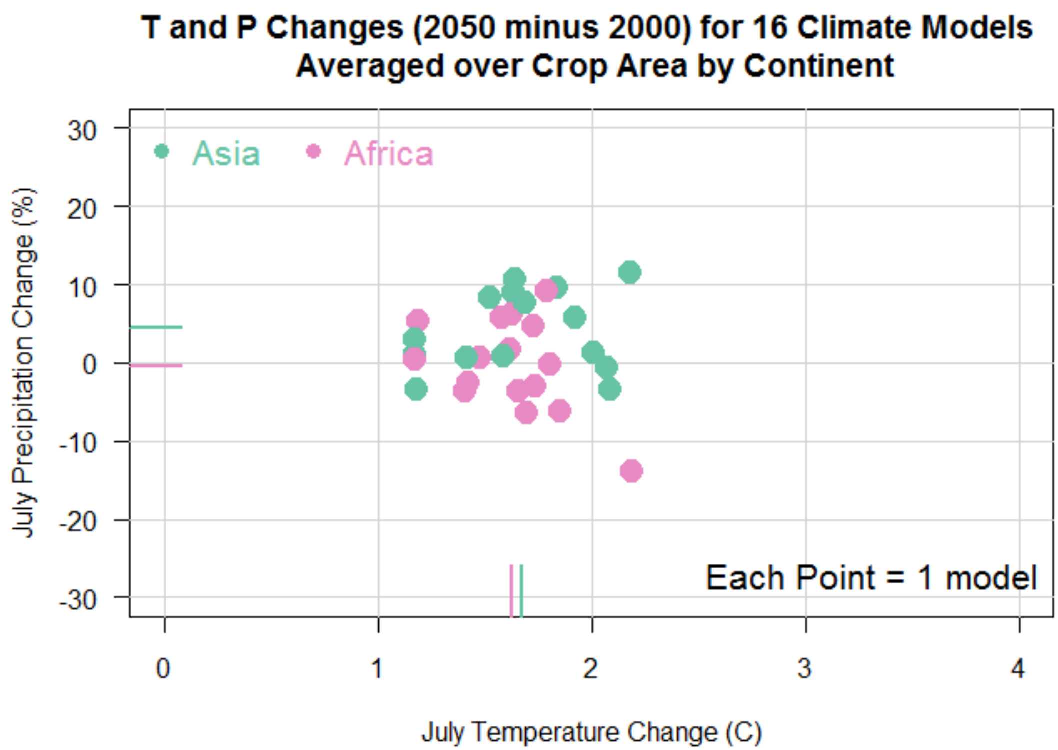
Things we don't know: 1) Local Rainfall Changes

Averaged over continent, changes in rainfall will likely be <10% over 50 years



Average trends: <1 %/decade
Range of trends: -2 to +2%/decade

Things we don't know: 2) Rate of warming



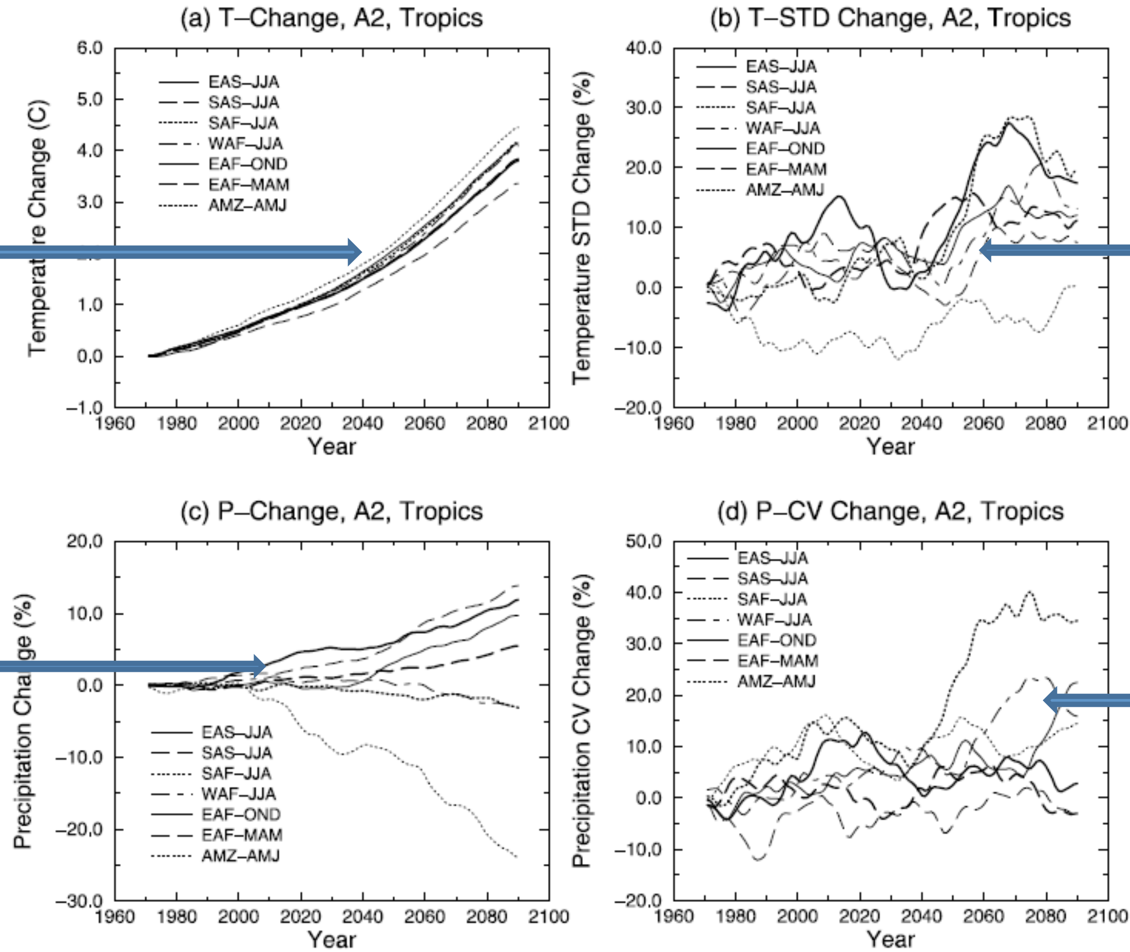
Average trends: <1 %/decade
Range of trends: -2 to +2%/decade

Average trends: 0.3 °C/dec
Range of trends: 0.2 to 0.5 °C/dec

Things we don't know: 3) year-to-year variability

Average model change for mean T

Average model change for T variability



Average model change for mean precip

Average model change for precip variability

Giorgi and Bi (2005). EAS=East Asia, SAS=South Asia, SAF=Southern Africa, WAF=Western Africa, EAF=Eastern Africa, AMZ=Amazon

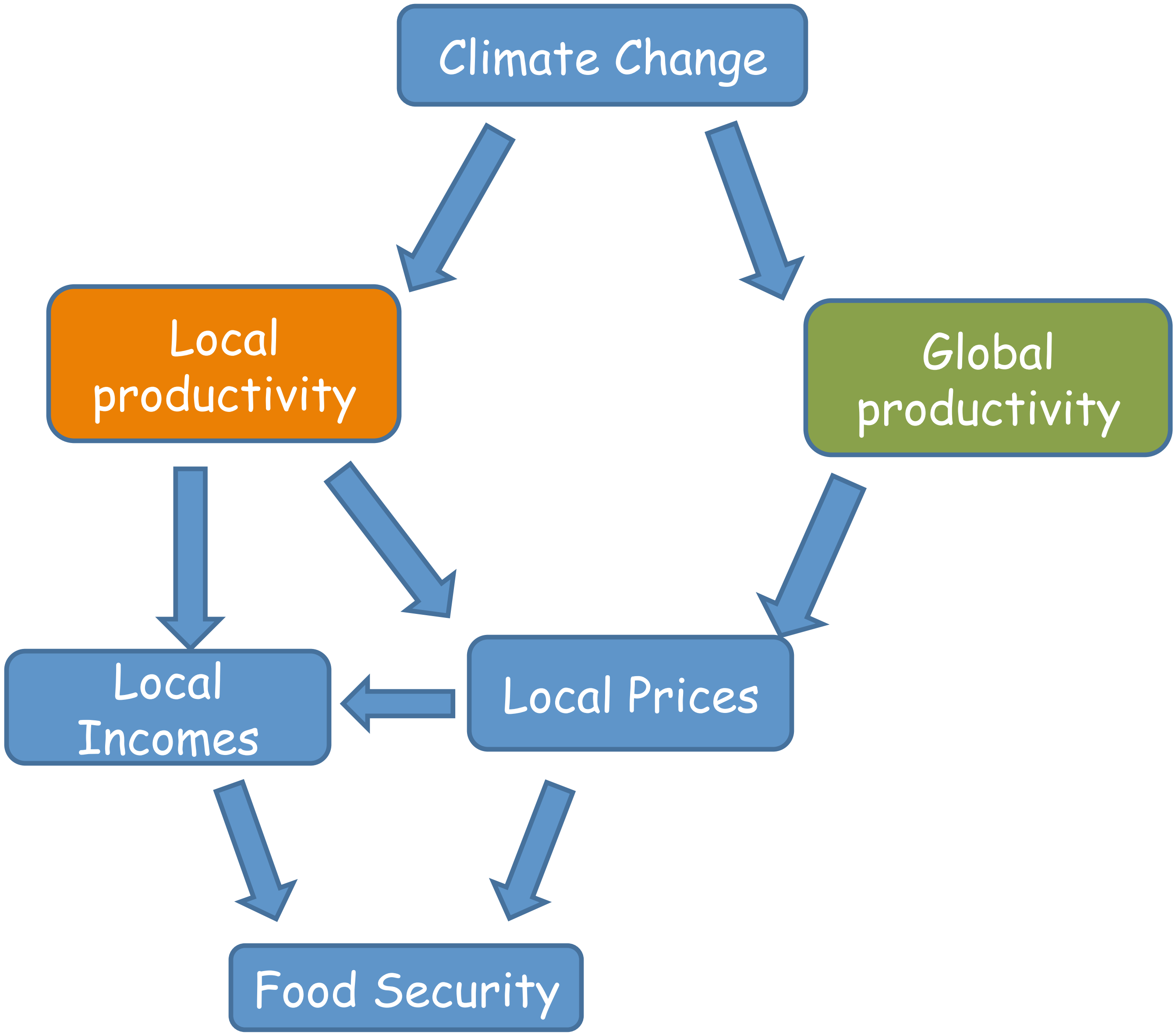
Outline

1. Relevant lessons from climate science
   - -trends toward more heat, heavy rain, and drought will continue
   - -broad scales easier than local scales

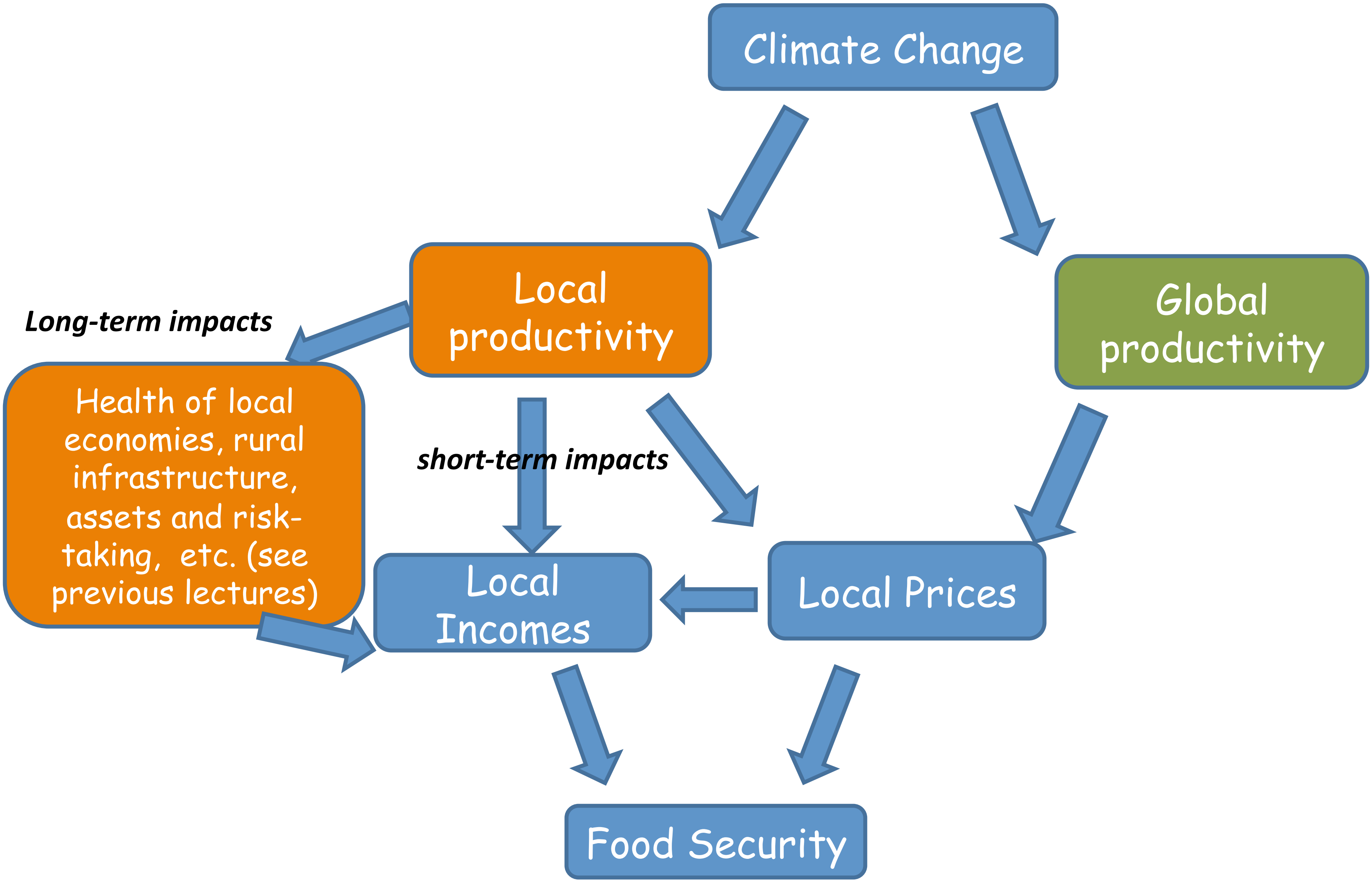
2. Implications for food security

3. Implications for food policy

Two pathways of climate impacts on food security



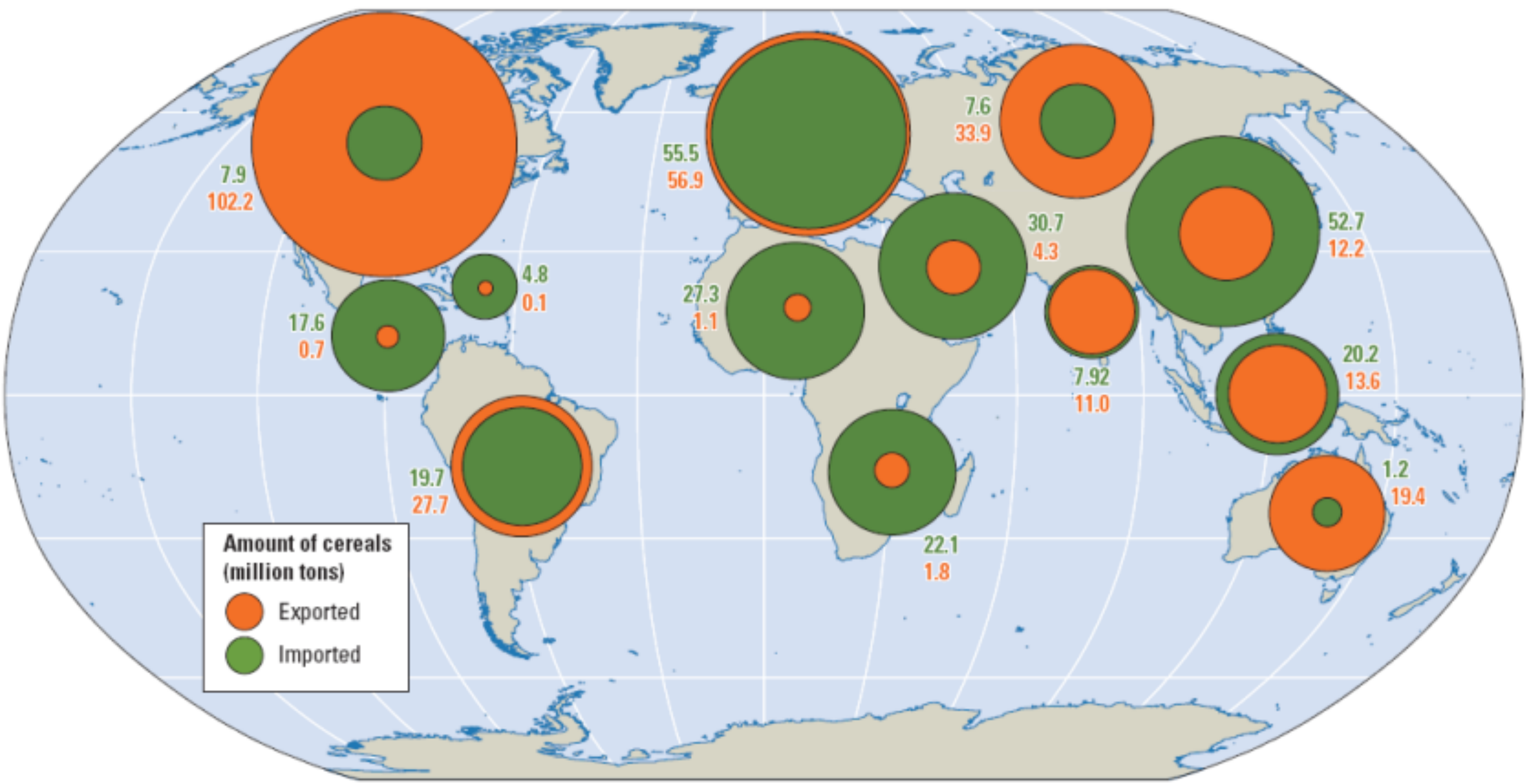
Two pathways of climate impacts on food security



The importance of global productivity

Africa imports >40% of rice and >60% of wheat consumption

Map 3.5 World grain trade depends on exports from a few countries



Source: FAO 2009c.

Effects on Productivity

	High Latitude	Low Latitude
Higher CO_2:	++	+
Drought:	--	--
Heavy Rain:	-	--
Warming:	+/-	--

Why does temperature matter for agriculture?

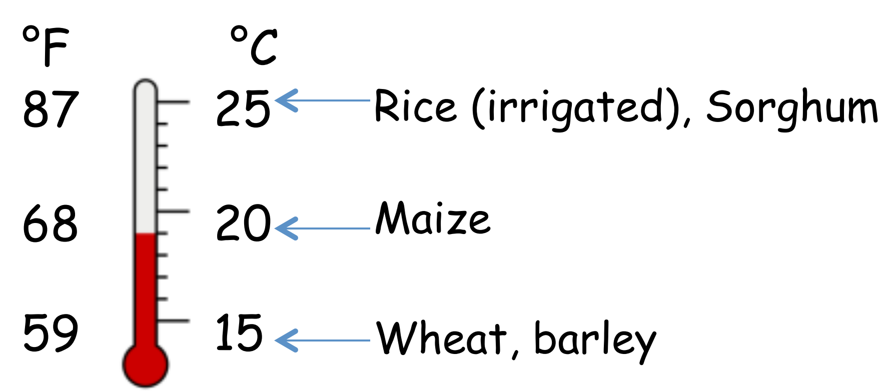
Five main reasons:

1. Crop growth – photosynthesis, respiration
2. Crop development – duration of key stages (e.g., grain filling)
3. Water stress – greater vapor pressure deficits drive more water loss
4. Cell damage – high temperatures can cause irreversible damage (e.g., spikelet sterility)
5. Biotic stress – pests and diseases develop more quickly

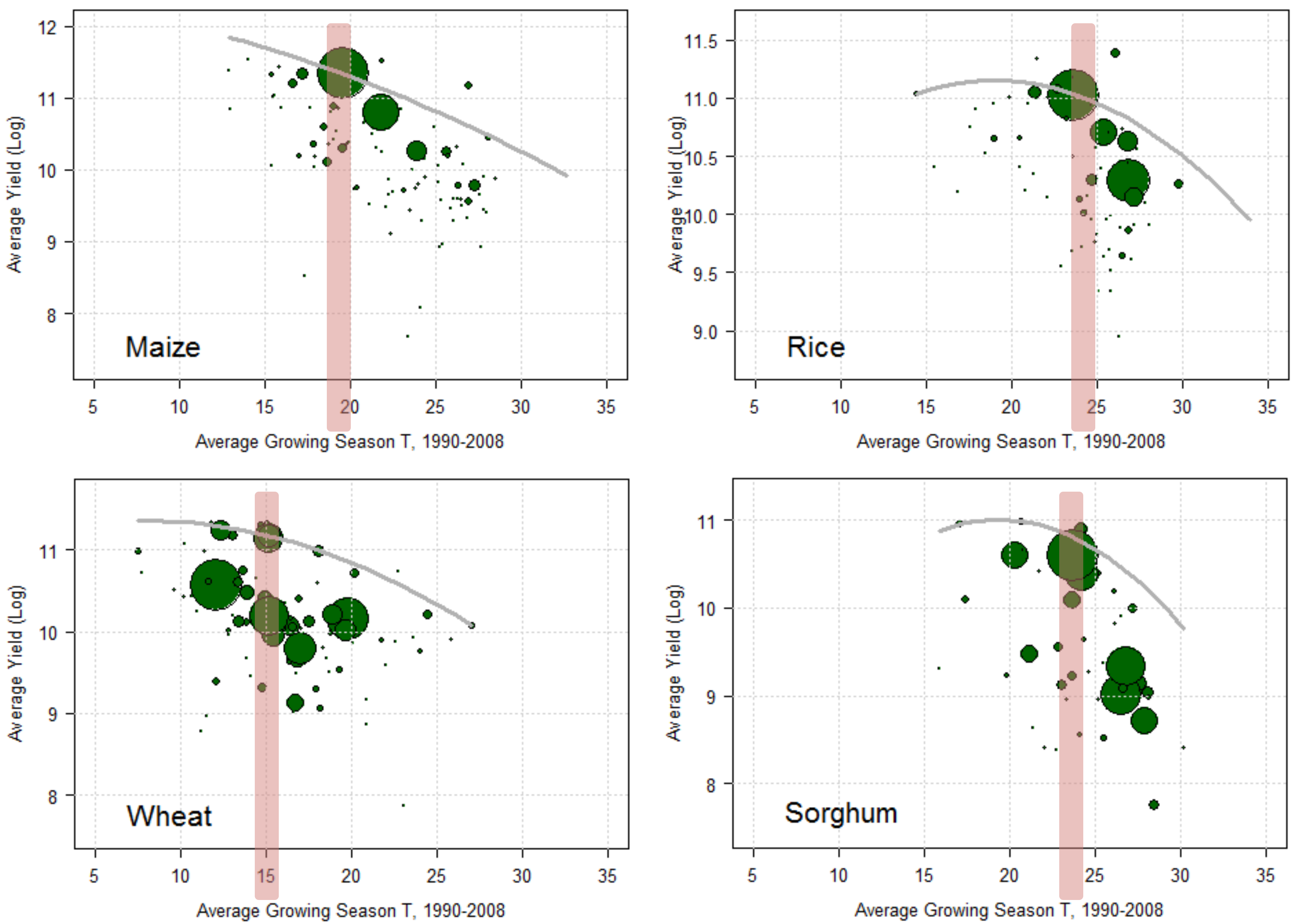
Temperature effects depend primarily on:

- Crop type

"optimum" mean temperature for yields:



These optima are evident even in cross-country comparisons



Data from Lobell et al. 2011, *Science*

Why does temperature matter for agriculture?

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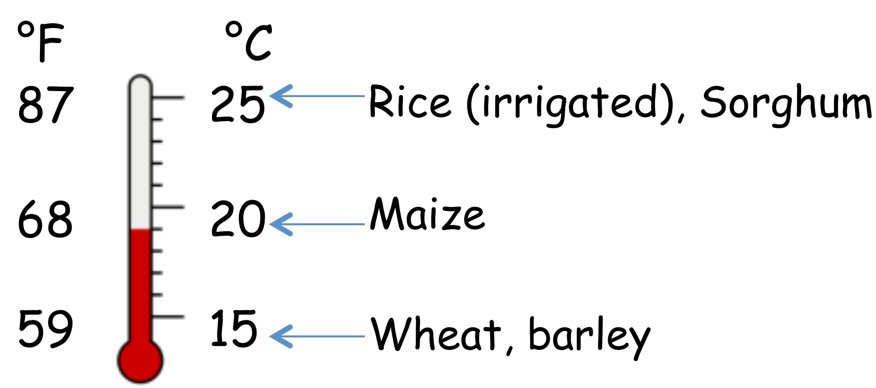
5. Biotic stress – pests and diseases develop more quickly

Temperature effects depend primarily on:

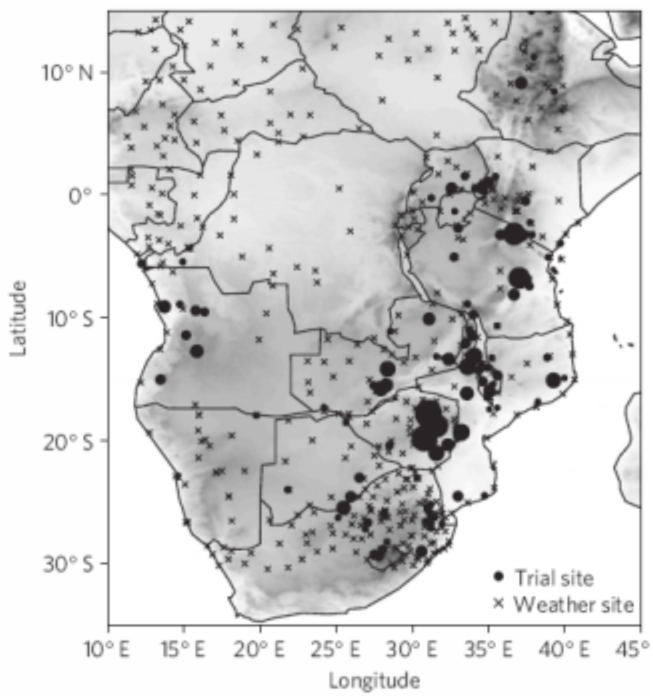
- Crop type
- Well-fertilized vs. nutrient poor
- Rainfed vs. irrigated

"optimum" mean temperature for yields:

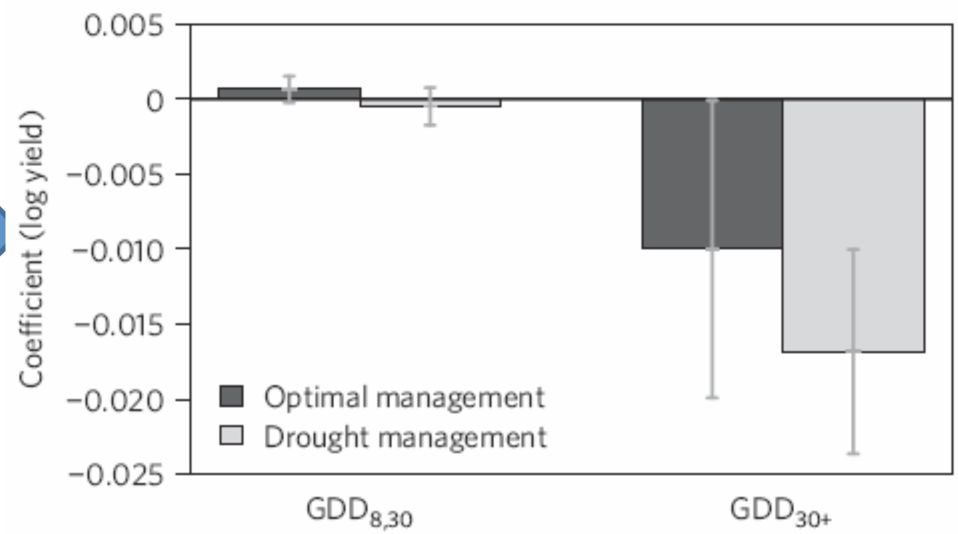


More heat = more need for water

Field trials



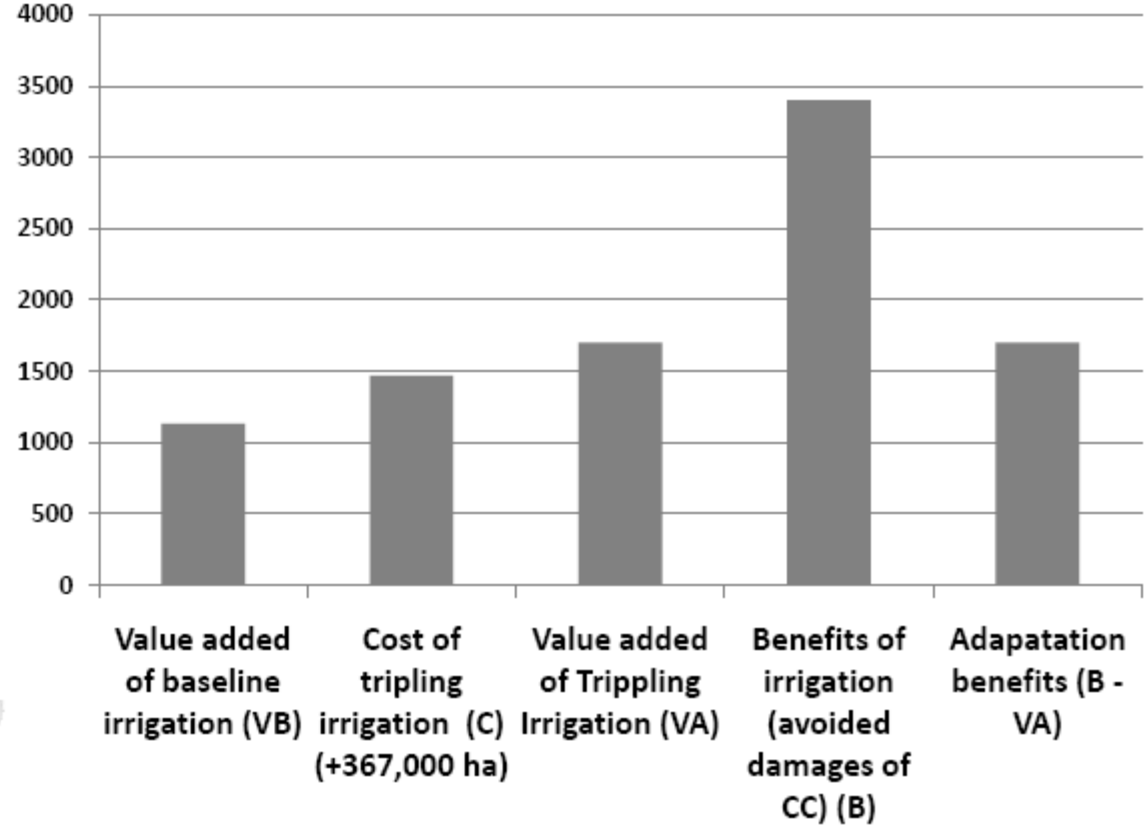
Rapid yield loss >30°C



Lobell, Banziger et al. 2011, *Nature Climate Change*

More heat = more need for water

Costs & Benefits of Irrigation in the Zambezi River Basin (US$ million)

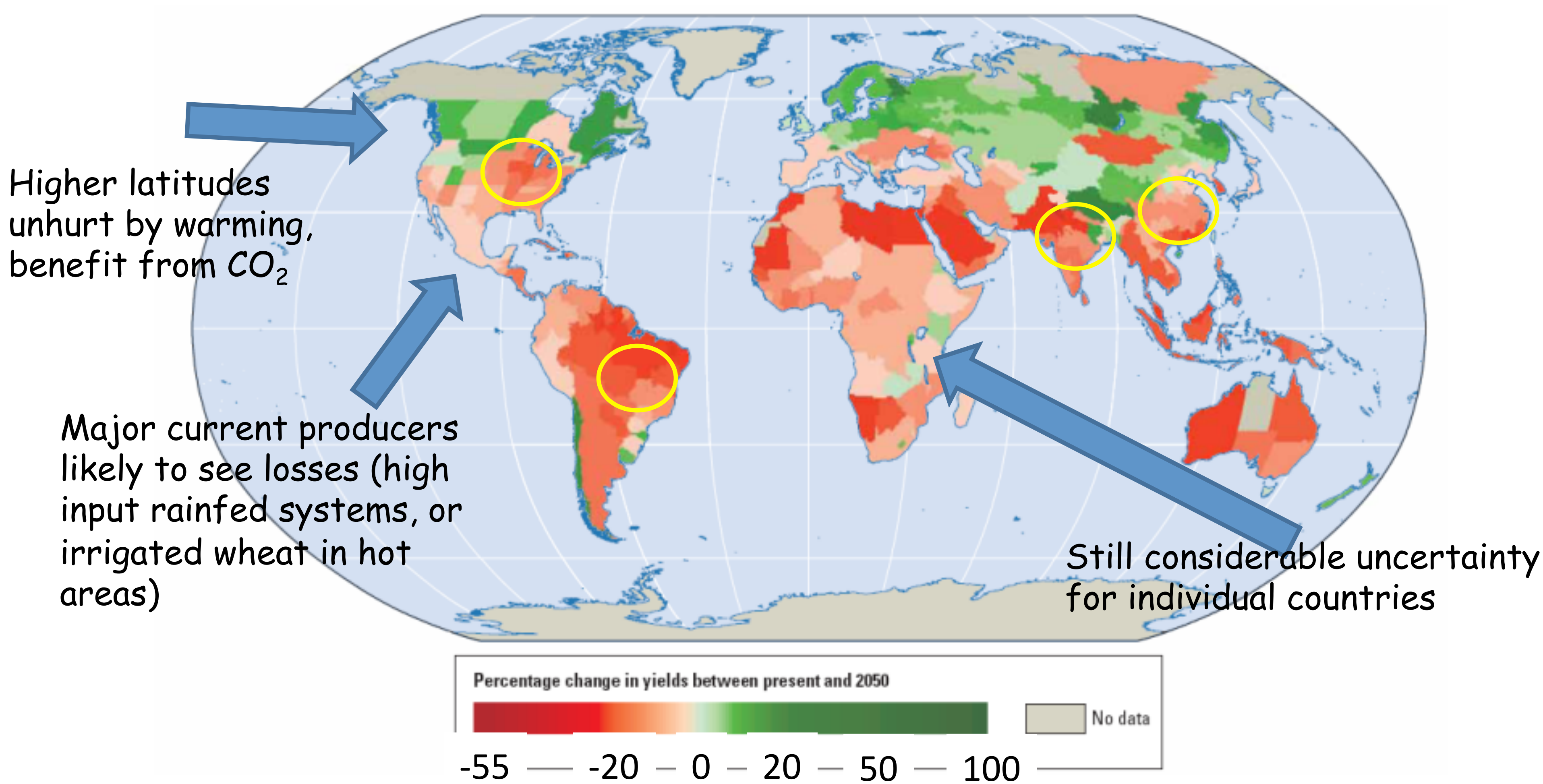


Maize: From 1.06 Mt/hectare to 7.5 Mt/ha
Rice: From 1.1 Mt/ha to 4-5 Mt/ha

World Bank, 2011

Projected impacts on local productivity

Map 1 Climate change will depress agricultural yields in most countries in 2050, given current agricultural practices and crop varieties



Muller et al., World Bank Dev. Report 2010

Implications for food security

Local productivity:

•Still a lot of uncertainty on local scale productivity impacts

•But less uncertainty in *relative* impacts: Africa & South Asia likely to be impacted more than other regions

•And less uncertainty on need to adapt to warming: will be a big challenge in Africa & South Asia

•Still a poor understanding of changes in variability, but plausible that variability will go up

Global productivity:

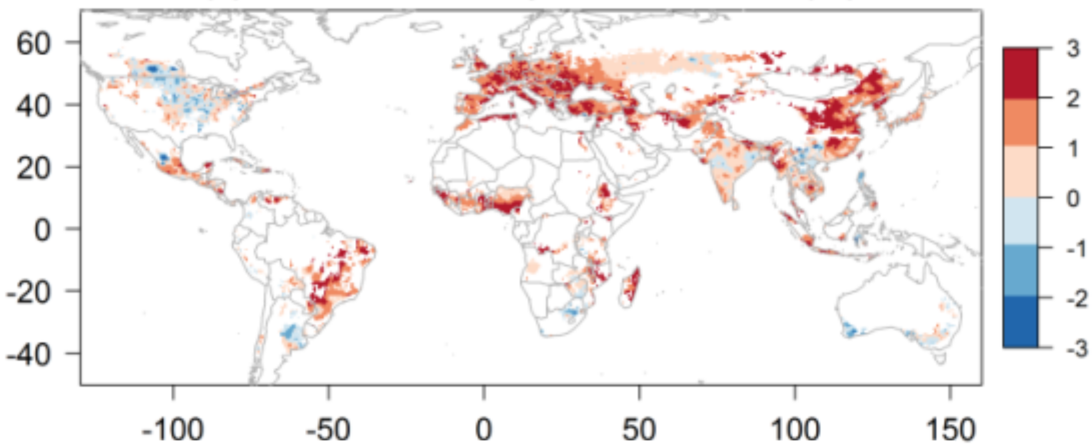
•Gains from high CO_2 likely to compensate for climate-related losses in next two decades, with some crops better off than others

•Beyond that, upward pressure on prices will affect net consumers

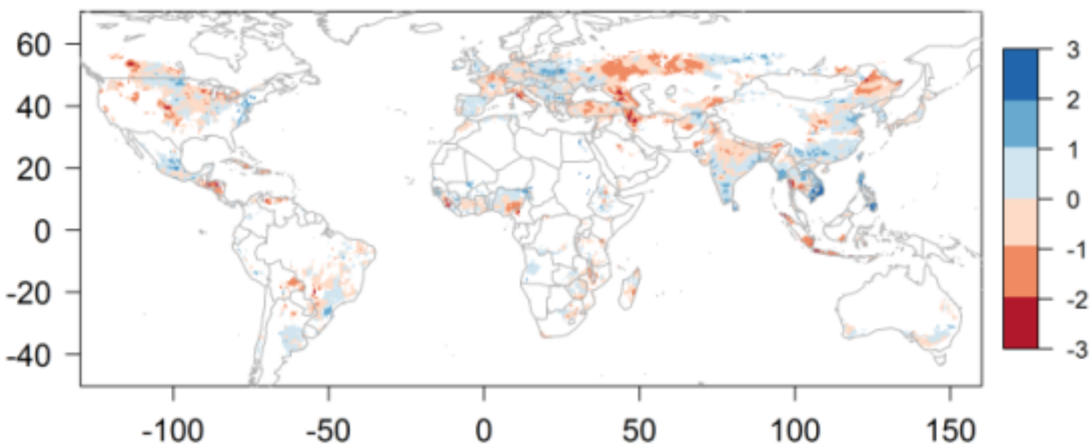
•Still a poor understanding of the potential for more price spikes, but plausible as major producers move further from their optimum conditions

Implications are not just about the future

Trend in growing season temperature (# of sd)



Trend in growing season precipitation (# of sd)



Warming since 1980 has lowered global maize and wheat yields by ~5% (1-2% per decade); little effect on rice and soybean (Lobell et al. 2011, *Science*).

Implications for Food Policy

Funds for Climate Adaptation

- So far:
  - <$1 billion total has been disbursed for adaptation
  - Very fragmented mix of bilateral and multilateral funds
  - >75% of disbursed funds going to mitigation activities

- In 2010, countries agreed to a target of $100B/yr by 2020 (Green Climate Fund) for assisting developing countries with both adaptation and mitigation

- Questions remain about follow-through and additionality, but an order of magnitude rise in resources for adaptation seems likely

Data Source: http://www.climatefundsupdate.org/

So how will it be used?

"BUT YOU CAN'T BLAME EVERYTHING ON GLOBAL WARMING!"

Adaptation Options

Some common distinctions:

- Autonomous vs. Planned
- Hard vs. Soft
- Resilience building vs. impact avoiding

TABLE ES-4

KEY ADAPTATION OPTIONS IN MOZAMBIQUE

	Planned Adaptation	Autonomous Adaptation
Hard	■ Flood control dikes and levies ■ Coastal flood control gates ■ Dams and irrigation channels ■ *Improved roadways* ■ *Improved communication infrastructure* ■ Improved hospitals and schools	■ More robust buildings ■ Farm-scale water storage facilities ■ Deep wells to provide drinking water for people and animals ■ *Grain storage facilities* ■ Improved food processing equipment
Soft	■ Improved early warning of climatic hazards, and of dam releases ■ Better planning and management of forest, fish, and other natural resources ■ Resettlement of populations to lower risk zones ■ *More credit and financial services for small businesses and rural development* ■ *Better education and information for the rural areas* ■ Improved health care, social services, and social support for all people	■ Better utilization of short season, drought resistant crops to prepare for drought, floods, and cyclones ■ Diversification of flood and drought risk by maintaining fields in both highland and lowland areas ■ Better household and community management and use of natural resources, including wild fruits ■ Practice of soil conservation agriculture ■ Migration to lower risk areas ■ *Diversification of livelihoods away from agriculture* ■ Better planning of how much grain to save for personal consumption, and how much to sell for income generation

Note: The options in plain text respond directly to climate hazards, while those in *italics* represent measures to increase the population's adaptive capacity, or make them more resilient to shocks to their livelihoods.
Source: World Bank 2010g.

(World Bank 2010)

Some existing viewpoints:

- Focus on adapting to current variability, because it will get easy buy-in, build institutions, help with many aspects of climate change

- Focus on developing mitigation activities in agriculture, because that is where the money is, and it will do more to build resilience than any other adaptation activity

- Focus on diversifying economy away from agriculture, because other sectors are less vulnerable to weather shocks

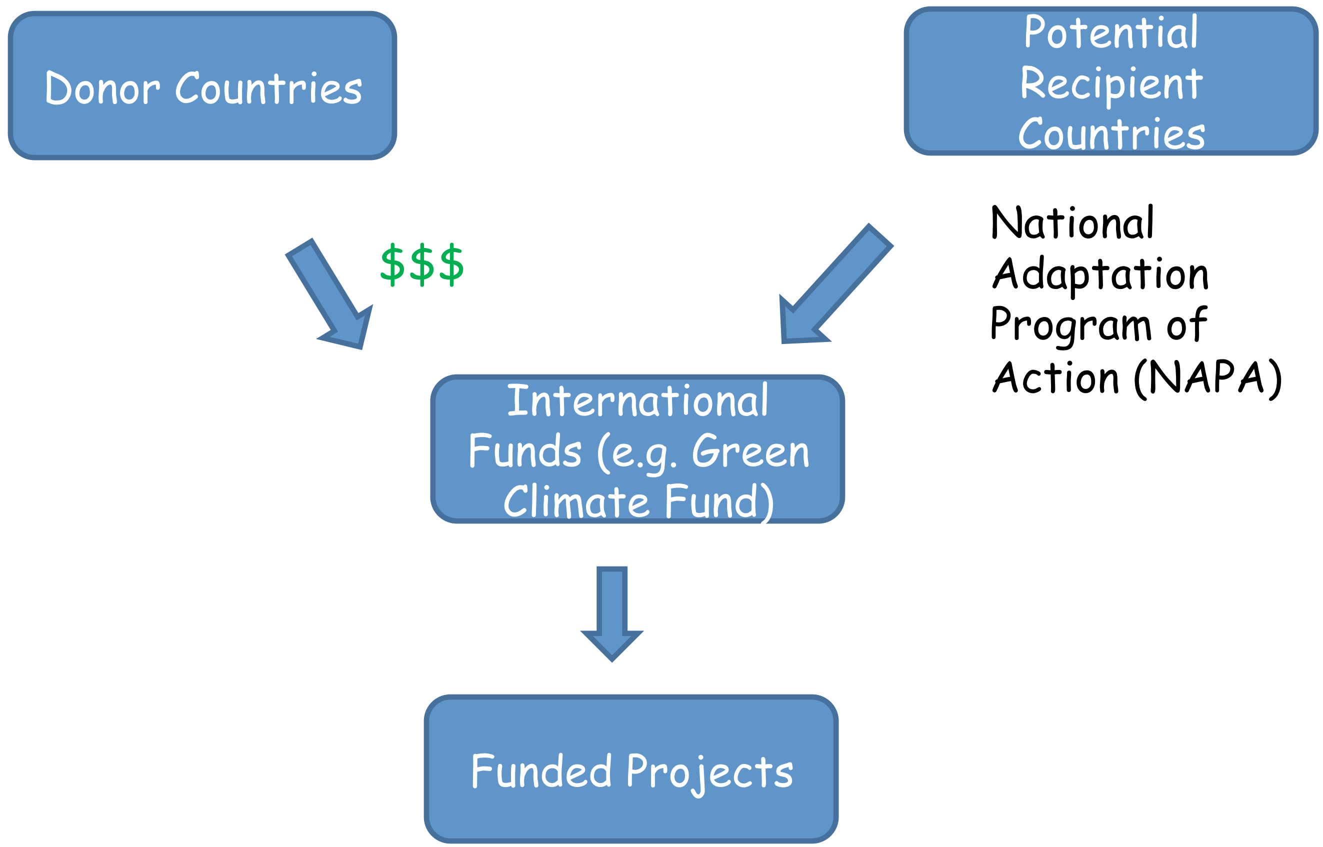
- Focus on "building resilience" at local scales, because "all adaptation is local"

Some shortcomings:

- Focus on adapting to current variability
    - Too much emphasis on things that aren't trending (average rainfall) compared to things that are (temperature)
- Focus on developing mitigation activities in agriculture
    - Important, but still unproven. not a replacement for adaptation
- Focus on diversifying economy away from agriculture,
    - To what? (can't skip agriculture, see other lectures)
- Focus on "building resilience" at local scales

A focus on country or sub-country scales

The (main) mechanism of international adaptation funding:



National Adaptation Program of Action (NAPA) in Niger

Appendix X. II Table 10: *List of priority options and their ranking*

4/24/2006Option	**Ranking**
Introducing fodder crop species in pastoral areas	1
Creating Livestock Food Banks	2
Restoring basins for crop irrigation	3
Diversifying and Intensifying crop irrigation	4
Promoting peri-urban market gardening and livestock farming	5
Promoting income-generating activities and developing mutual benefit societies	6
Water control	7
Producing and disseminating meteorological data	8
Creating Food Banks	9
Contributing to fight against climate-related diseases	10
Improving erosion control actions (CES/DRS) for agricultural, forestry and pastoral purposes	11/12
Disseminating animal and crop species that are most adapted to climatic conditions	11/12
Watershed protection and rehabilitation of dump-off ponds	13
Building of material, technical and organizational capacities of rural producers	14

This local emphasis feeds back to science, with an obsession on the weakest part of climate science

IRIN humanitarian news and analysis
a service of the UN Office for the Coordination of Humanitarian Affairs

CLIMATE CHANGE: Soon every African village will know what the weather may bring

Photo: Jaspreet Kindra/IRIN

A village like Ha Tsiu in Lesotho may know how climate change might affect the rainfall over their area

JOHANNESBURG, 2 November 2011 (IRIN) - Information about how climate change may affect any city, town or village in Africa until the next century will be available by mid-2012 as scientists localise global climate data.

The Coordinated Regional Climate Downscaling Experiment (CORDEX), an initiative of the World Meteorological Organization and the World Climate Research Programme is now able to render the data from regional climate models to the scale people live in, and deci
at. The information will not only help countries but also communities in their efforts to adapt to changing weather patterns, and to tailor their disaster risk reduction plans.

The effort is geared to feed into the next assessment report of the Intergovernmental Panel on Climate Change (IPCC), due to be released in 2014.

Although CORDEX aims to "downscale" the data for all regions of the world, Africa has been identified as the most vulnerable by the IPCC and a priority for the initiative. Historically the continent has been under-researched, but for the next two years will be a focus for the

Chris Lennard, a scientist at the Climate Systems Analysis Group at the University of Cape Town (UCT) in South Africa, which has one of the only two climate modelling groups downscaling the projections in Africa, said by mid-2012 climate data for people living within 5
each other will be available across Africa.

The other African group, also in South Africa, is based at the Council for Scientific and Industrial Research (CSIR) in Pretoria.

"There are climatologists outside the project who are downscaling up to a 22 km resolution as well," said Lennard. "Although this means data at the scale of cities will be available, when assessing vulnerabilities to climate change in a place like Johannesburg there are
factors that need to be considered external to the city, such as water and food security and power provision, for example."

How it works

Projecting the impact of climate change is a complicated process that takes into account changes in the long-term averages of daily weather patterns and many other factors. Climate models are used to simulate processes that occur in the atmosphere, such as the mo
moisture and heat as well as the possible impact of increasing concentrations of greenhouse gases on these processes.

During two meetings in 2011, over 20 African climate scientists met to analyse CORDEX produced data. They decided to divide Africa into three regions for analysis - Southern, East and West. They then sub-divided the regions according to the common characteristics of the rainfall patterns in them. For instance, West Africa has
Southern and Northern region because the south has two peaks per rainy season and the north has only one.

Climatologists often split regions according to common rainfall patterns because the variables that affect rainfall - movement of air, pressure, temperature, radiation, moisture content - also drive climate change.

Unfortunately, not all African countries can be assessed because of a lack of adequate scientific support and observational data.

During the first stage of CORDEX, scientists tested the ability of the various regional climate models to generate data based on actual climate statistics for the period 1988-2010. "The selected historical timeframe is too small to look at any long-term trends," said Lennard. "We wanted to see how the regional climate models simulated the past so we can say something about how they might simulate the future."

The 14 regional climate models also include factors like the level of small-scale convection, and the interaction between the land surface and the atmosphere. The scientists then work on a consensus position based on the results generated by all the models.

"We have completed this stage and are busy writing up our results so they can be included in the IPCC 5th assessment report," said Lennard.

The teams are now awaiting results of global projections of climate change from 12 global climate modelling groups already at work in Europe, the US and elsewhere.

These groups - including the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy; the Swedish Meteorological and Hydrological Institute; the Danish Meteorological Institute; and the Iowa State University - are among the world's foremost global climate modelling institutions. They have simulated the earth's climate as far back as 1950 and look as far forward as 2100.

"Once the global climate model data become available we will start downscaling them, and the downscaled results will be shared with the African teams for analysis. We expect to have the first downscaled model data early in November," Lennard said.

Making sense of the numbers

The projections are critical for communities that must adapt to a moodier climate with limited resources. Initial IPCC assessment reports tended to focus on global climate models and predictions that did not factor in underlying socioeconomic conditions or the vulnerability of communities, writes Saleemul Huq, one of the IPCC's lead authors.

"So, for example, model-based physical impacts in the Netherlands look similar to those in Bangladesh - in part because the two countries share a similar topography, both being low-lying deltas - but in reality the impacts on people, and the options for adapting to these, are likely to differ widely," Huq notes in a briefing paper for the International Institute for Environment and Development (IIED).

"The Netherlands is technologically and financially rich and can adapt to rising sea levels by raising dykes. Bangladesh, on the other hand, cannot afford to build dykes around its entire coast, even if that was the best adaptation solution." More recent IPCC reports have gone for a "more rounded picture of which countries and regions are at highest risk from climate change".

One of the unique characteristics of the CORDEX Africa campaign is that African climatologists will meet with other African scientists who study vulnerability, adaptation and the impact of climate change on people, to translate the model numbers into meaningful, usable information. Experts from countries that include Benin, Burkina Faso, Ethiopia, Ghana, Kenya, Malawi, Niger, Nigeria, Senegal, South Africa, Swaziland, Uganda, Zambia and Zimbabwe will analyse the data.

"These scientists [who study humanitarian impact of climate change] know for example what thresholds, which, if crossed more frequently would impact detrimentally on communities, so whether the people in a certain area are more vulnerable to five days or eight days of continuous rainfall," said Lennard.

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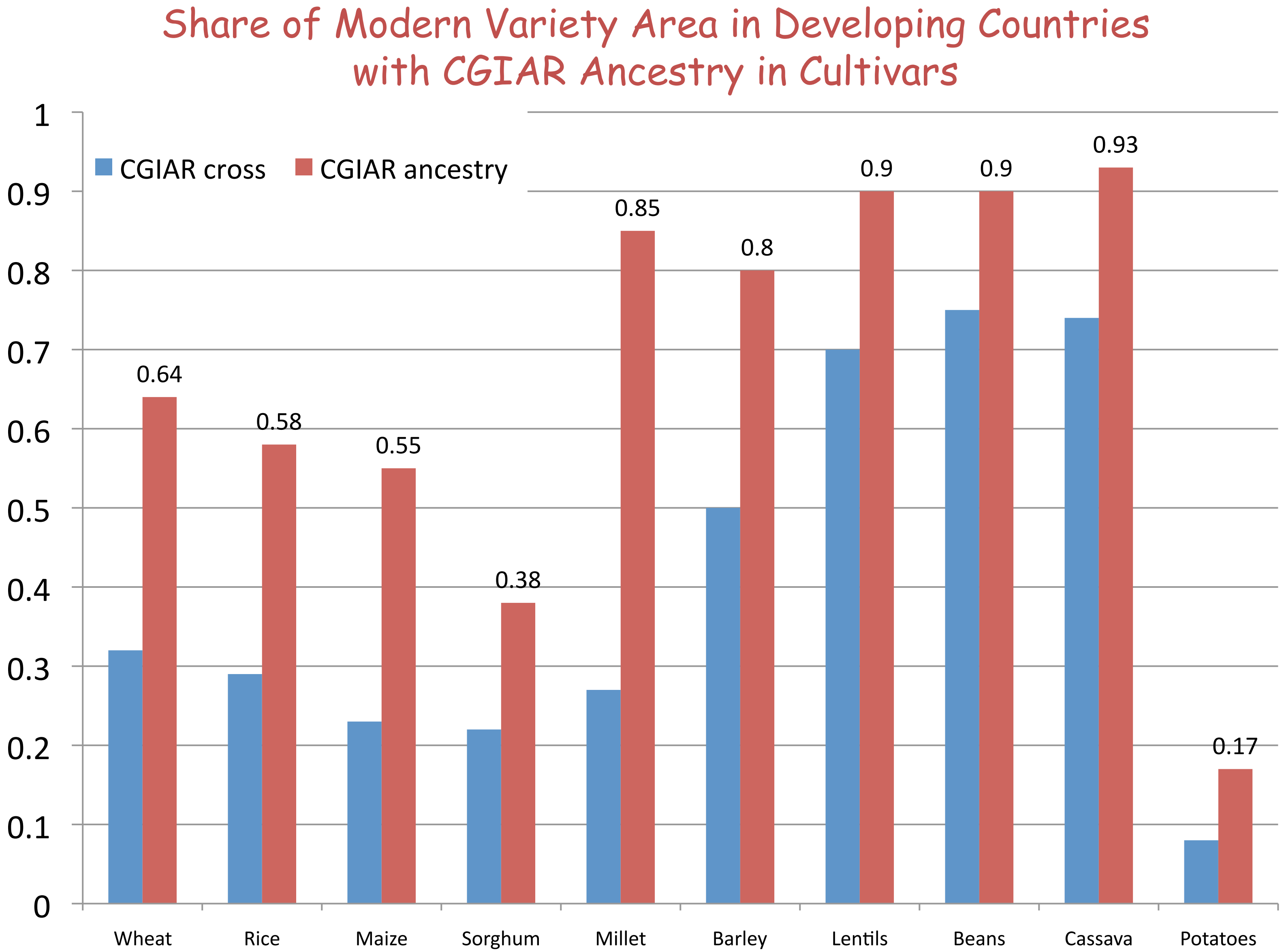
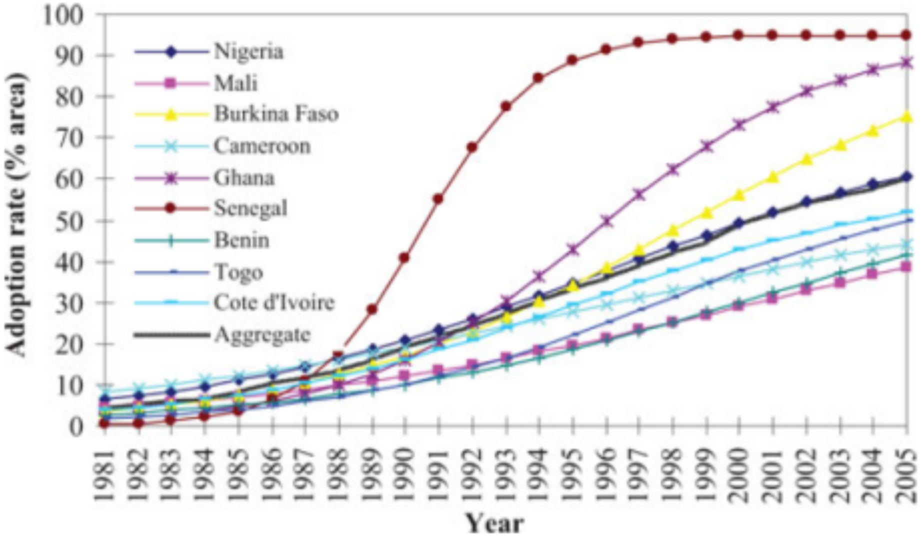
Not only is climate change clearer at broad scales, but investing at these scales has historically been a very good bet



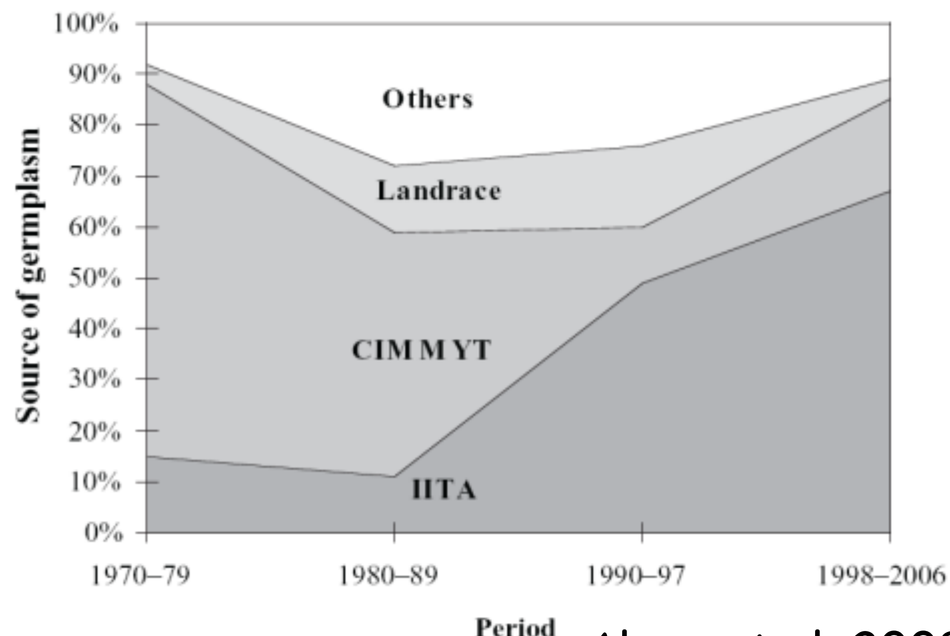
Data source: Renkow and Byerlee 2010, Food Policy

International Networks Have Been Key to Crop Improvement

Adoption rate of modern maize varieties in C and W Africa



Source of new maize germplasm in C and W Africa



Alene et al. 2009

An example of the need for global cooperation

- Not every country will need heat and drought tolerant seeds, but we don't know in advance which ones.

- Historically, crop development has worked best when done by international groups, partnering with national institutes

- Success of crop development will depend on genetic diversity, which takes coordination to collect and preserve

Summary of key considerations for policy makers

For effective adaptation, need to balance between:

- Climate variability vs. change: Not every blip is climate change, there are risks of over-reacting to some changes and not focusing enough on others.

- Local vs. broader efforts: Local resilience is important, but climate uncertainties are typically biggest at local scales, and many useful technologies will emerge from international networks.

- Avoiding impacts vs. building resilience: reducing sensitivity of agriculture to weather is important, but climate will continue to exert a drag on productivity growth. This increases the urgency of raising productivity and completing the structural transformation in sub-Saharan Africa, sooner rather than later.