A Center for
Robust Decision Making on Climate and Energy Policy

Past and future weather-induced risk in crop production

Joshua Elliott

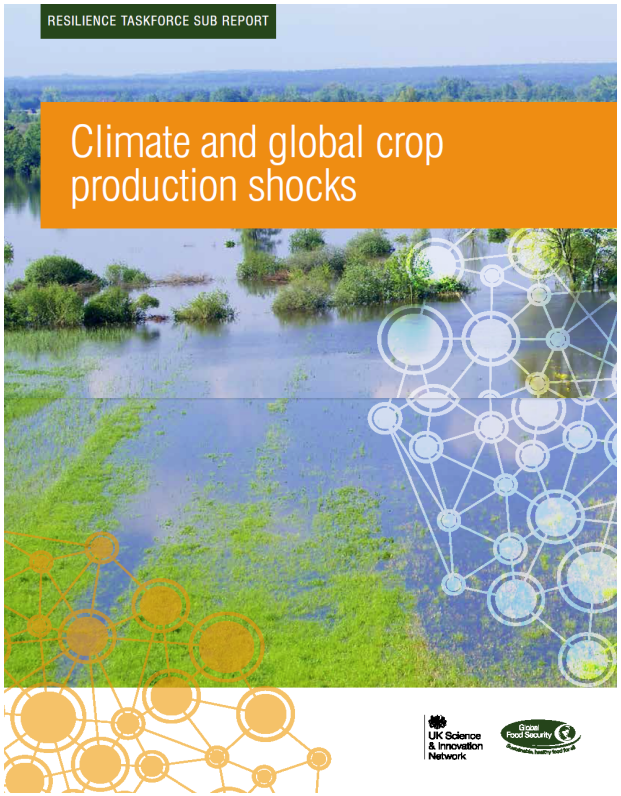
University of Chicago and Argonne National Lab Computation Institute
Columbia University Center for Climate Systems Research and NASA GISS

rdcep
A Center for Robust Decision Making on Climate and Energy Policy

AgMIP

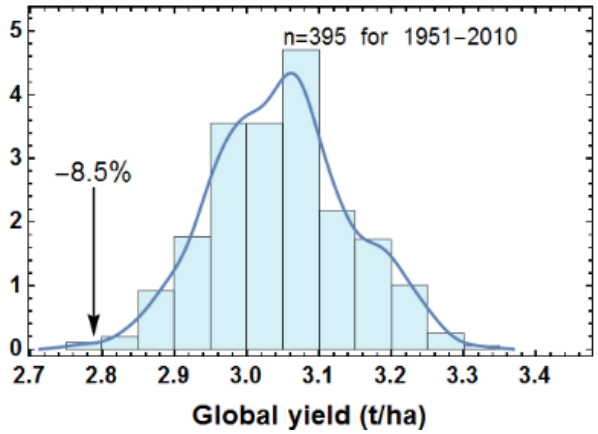
UK-US Taskforce on Extreme Weather and Global Food System Resilience

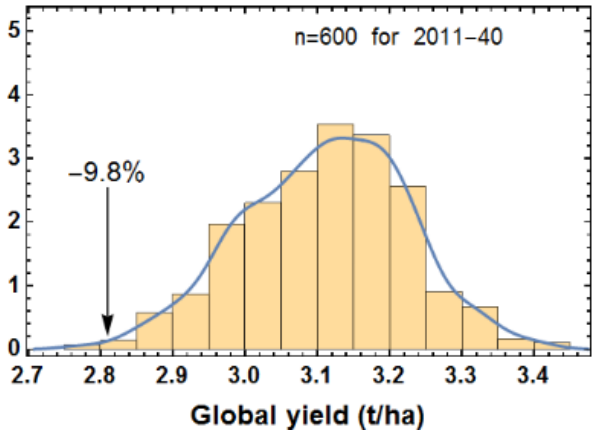
- Three teams
  - Climate extremes and ag impacts
  - Government and market response
  - Impacts to economies and health
- Study vulnerability of food system to extremes (1-in-200 year events)
  - Opportunities for coordinated risk management
  - Improve functioning of international markets
  - Bolster national resilience to shocks
  - Adapt agriculture for changing climate

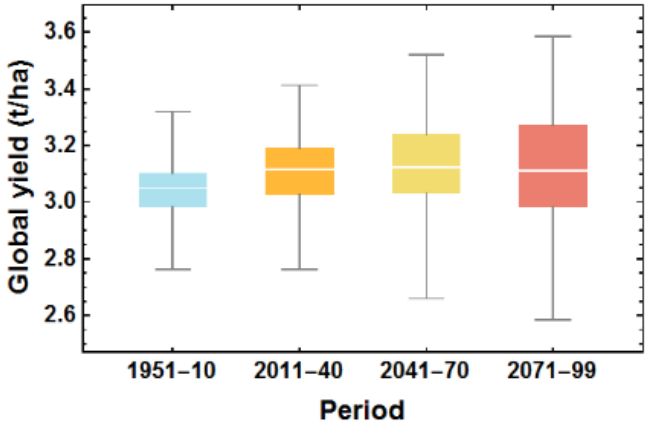


Non-stationary risk in agriculture

- Compare past & future distributions from ensembles of global crops models produced in AgMIP/ISI-MIP
  - Extreme (-) percentiles, variance & skewness of distributions generally getting worse
  - Global 1-in-100 year historical event occurs almost 1-in-30 years within only several decades



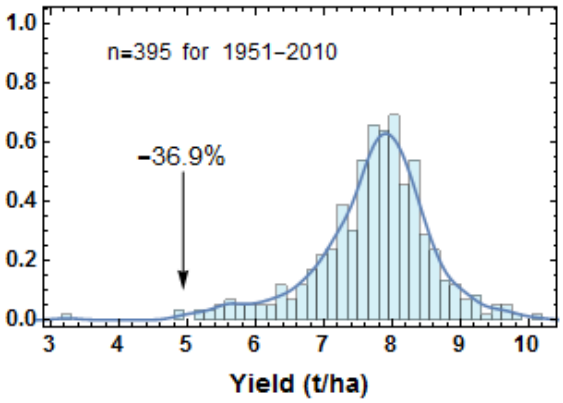


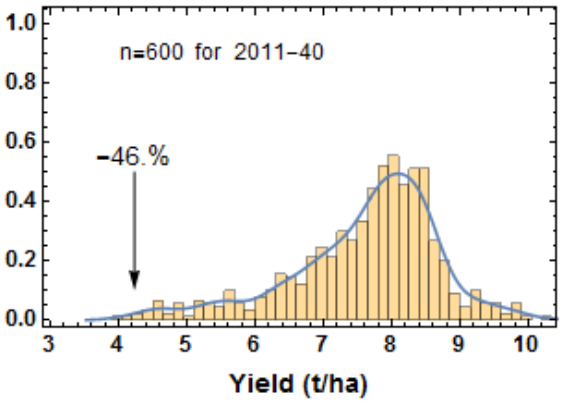


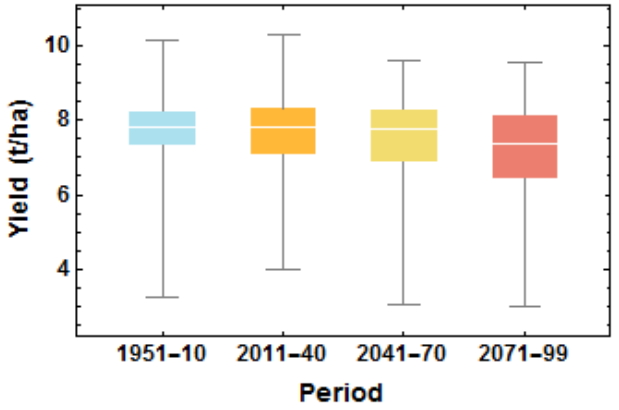
Reproduced from **Extreme weather and resilience of the global food system**
Prepared for the UK-US Taskforce on Extreme Weather and Global Food System Resilience

Regional effects sometimes very large

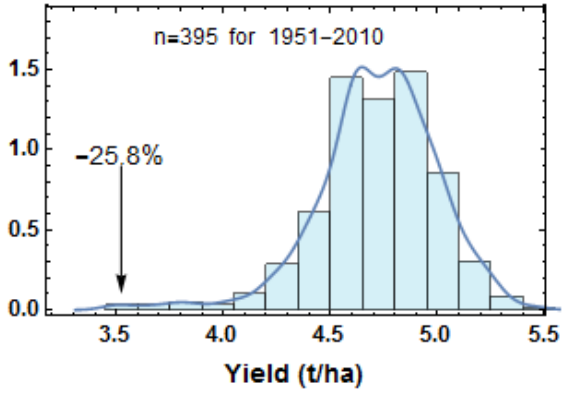
- US maize, 1-in-200 year event ~25% worse in near-term

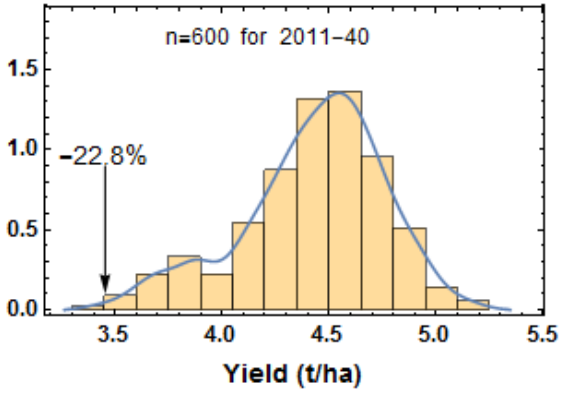


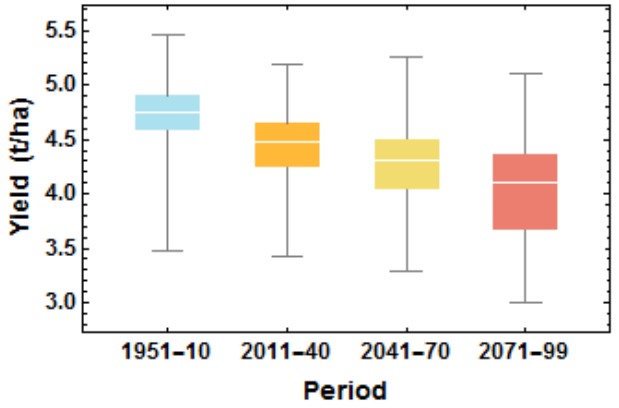




- China maize, no change at extreme tail, though skewness becomes much more negative





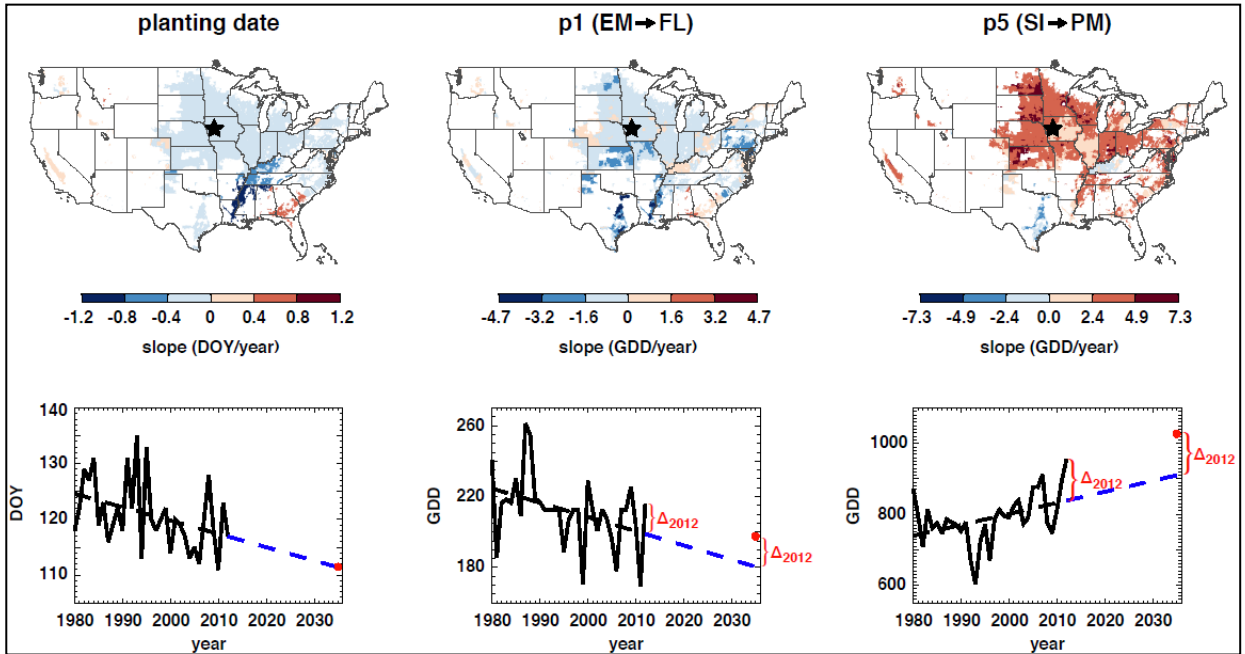


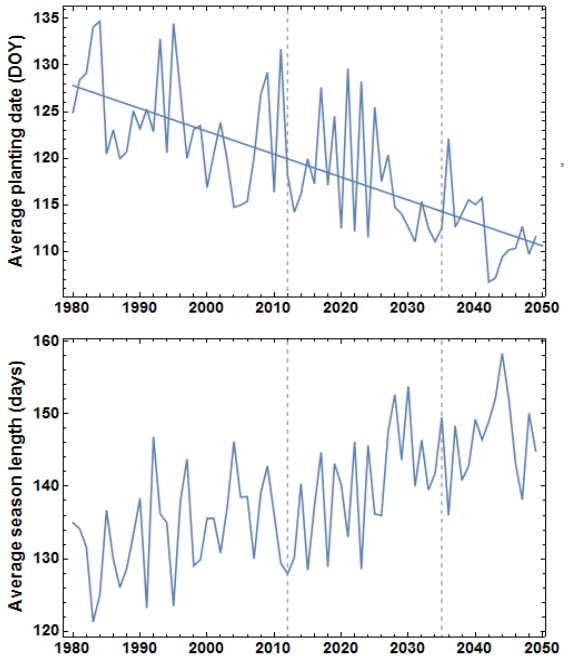
Integrated analysis of climate and extremes

- Understand climate and extremes
  - **Need**: understand present risk, coincidence, and non-stationarity
  - **Requires**: Large fixed-forcing ensembles (>1000 years)
- Management, technology and adaptation
  - **Need**: Trends and adaptations interact w/ extremes and resource demand to impact system-wide risk
  - **Requires**: Better data and models of technological change and detailed scenario analysis
- Resource availability
  - **Need**: Depleting groundwater will increase vulnerability in key agricultural regions
  - **Requires**: Improved reps of irrigation and integration with groundwater models

Technology and development

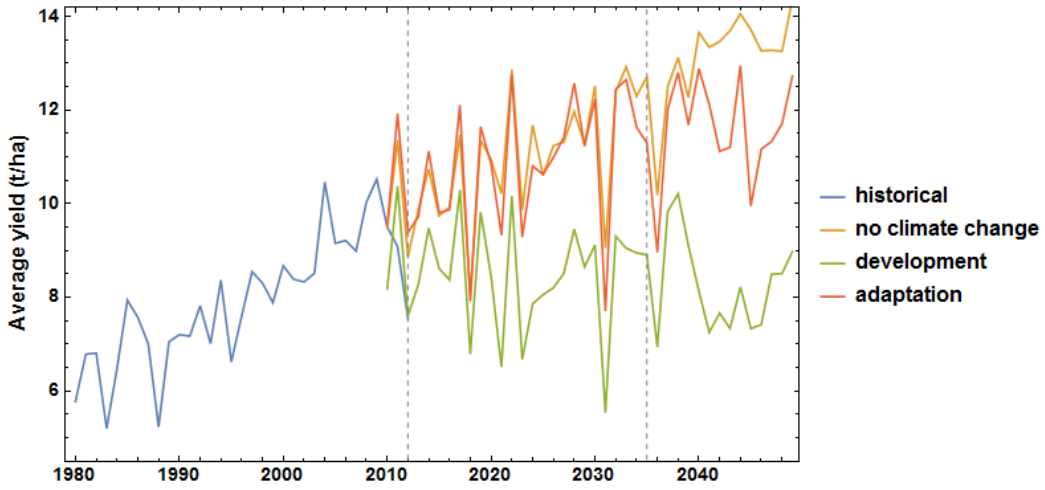
- Trends in planting date and season length expected to continue in absence of climate
  - ~20% increase in maize season from 1980-2050
  - Accounts for > 1/2 of yield trend from 1980-2012



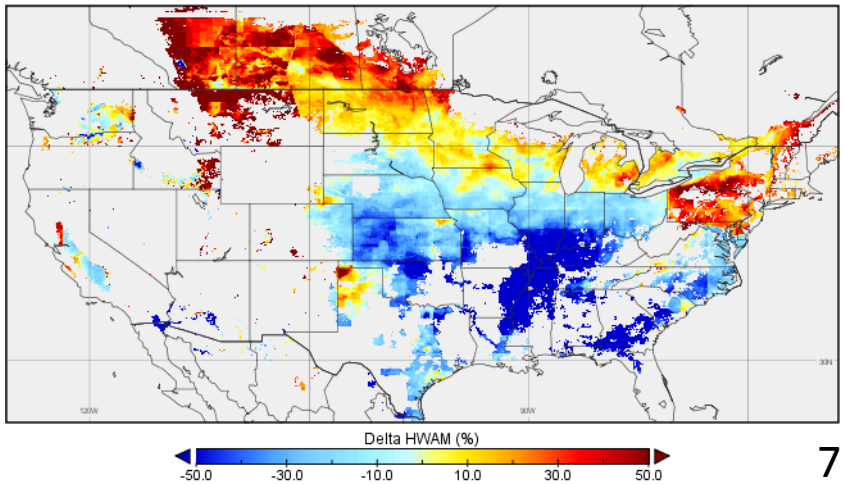


Technology and adaptation

- W/o warming, yield growth continues through 2050
- W/ perfect adapt, most impact removed until 2040s
  - -13.9% loss in yield in 2040s relative to no-climate baseline
- Big % incr. in Canada and Northern states
- Declining yields across most of the southern states

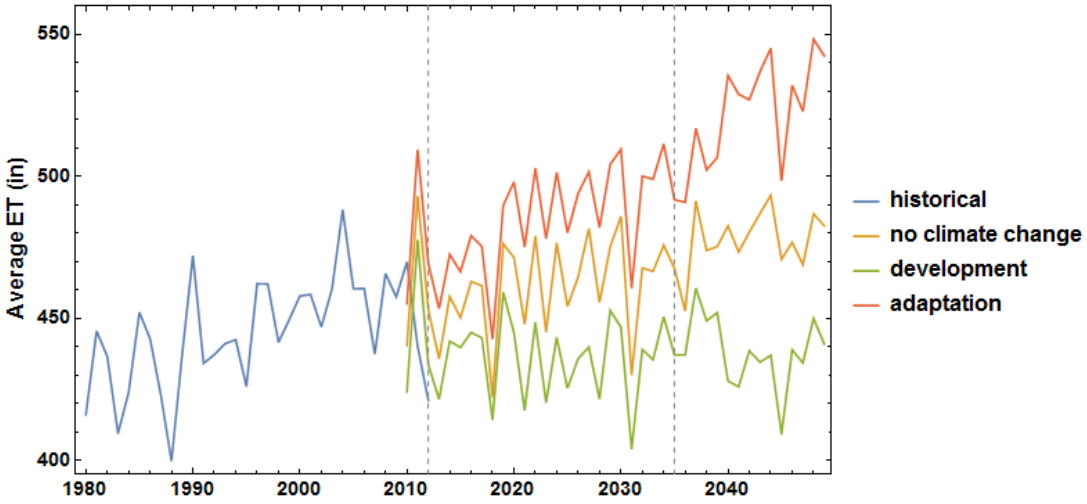


2040s yield, warming+adaptation vs. no-climate baseline (%)



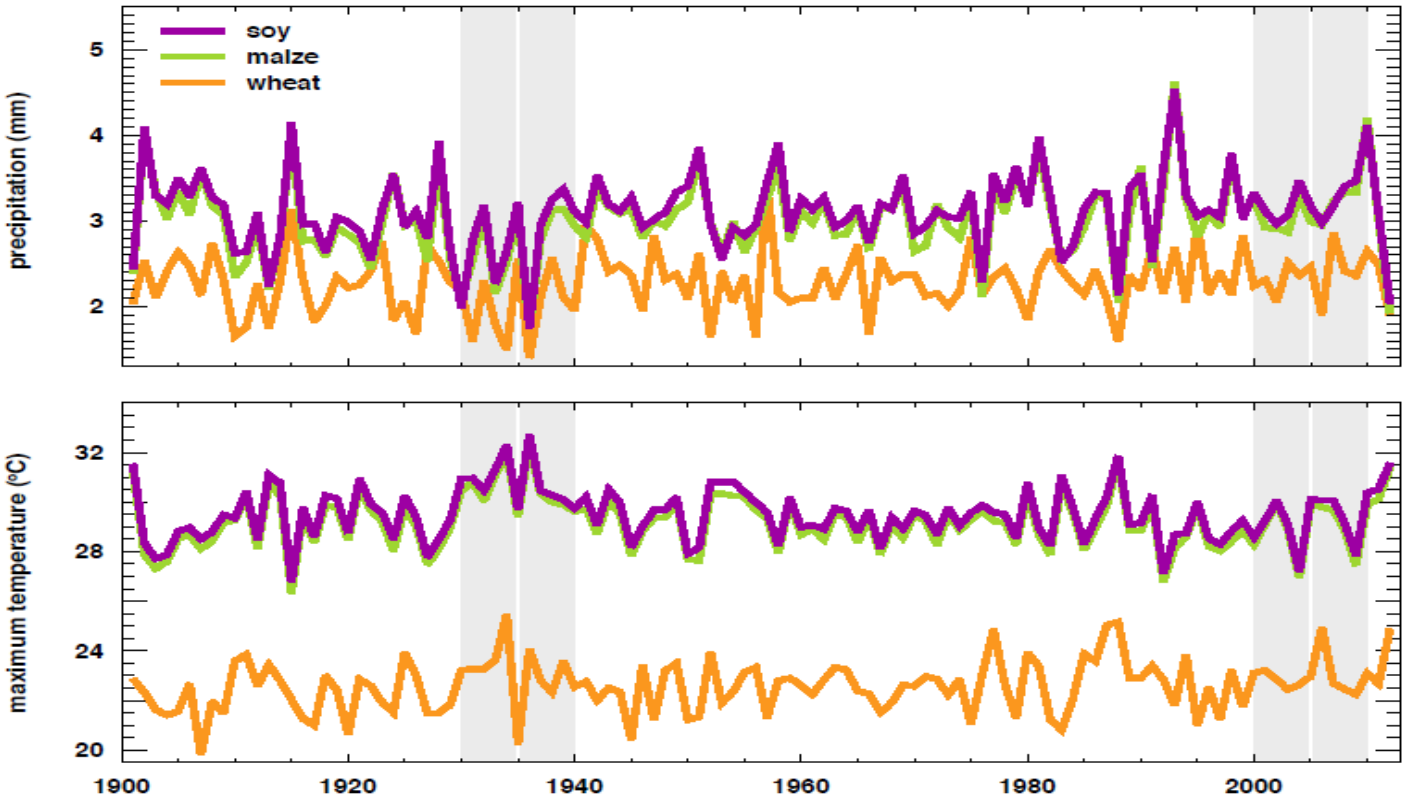
Thirstier crops (technology and water)

- 1980-2012, yield incr. almost 70%, H_2O only +8%
  - W/o climate change, trend projected to continue
- But w/ warming and adaptation, water use accelerates
- Tech development and adaptation costs water
  - +6.3% increase in irrigation demand without any warming
  - +16% increase with climate change and adaptation



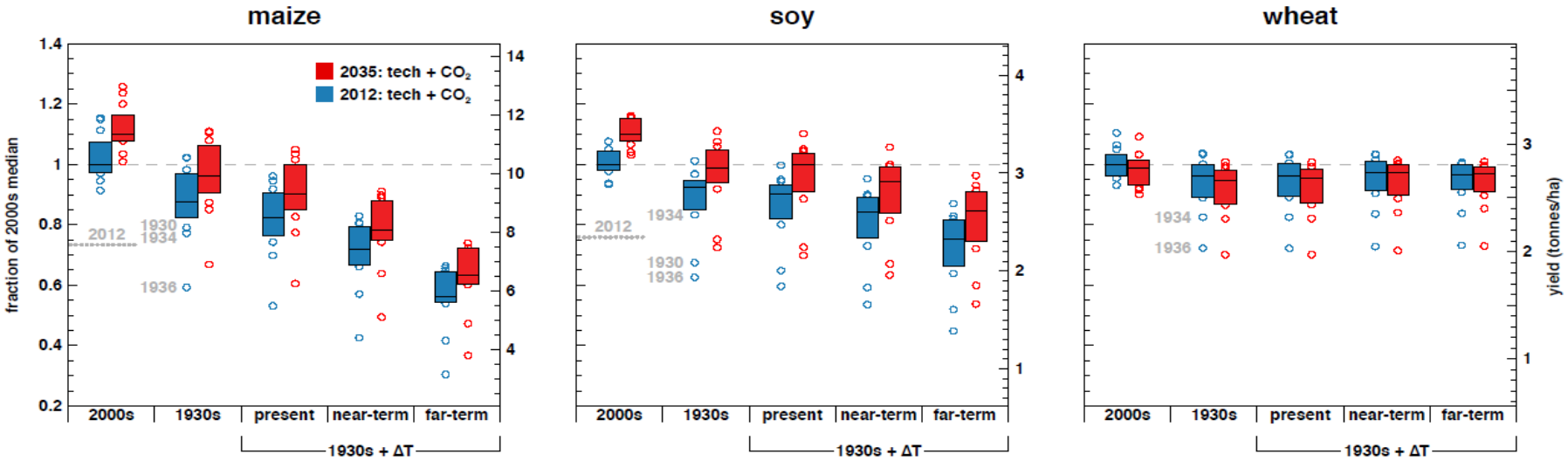
Regional extreme climate scenarios

- Sufficient ensembles generally not yet available*
  - Use historical extremes as analogs for future conditions
  - The 1930s Dust Bowl era hottest/driest in >100 yrs



Technology and extremes

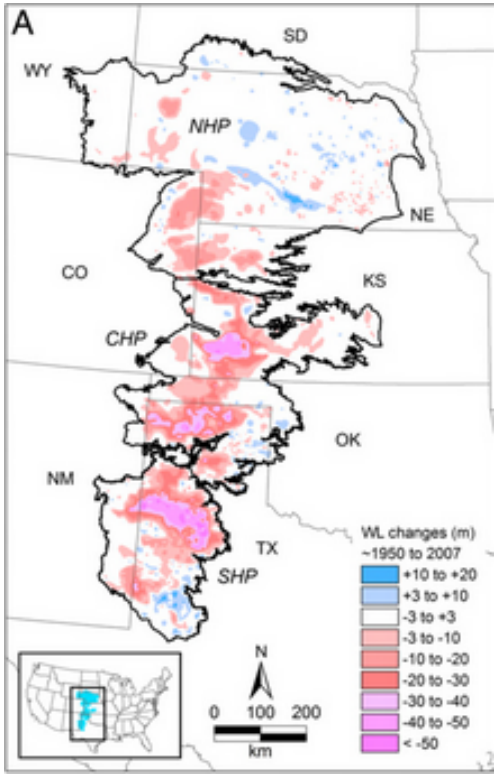
- Consider 1930s droughts w/ and w/o baseline mean warming
- Consider 2012 and estimated 2035 technology scenarios

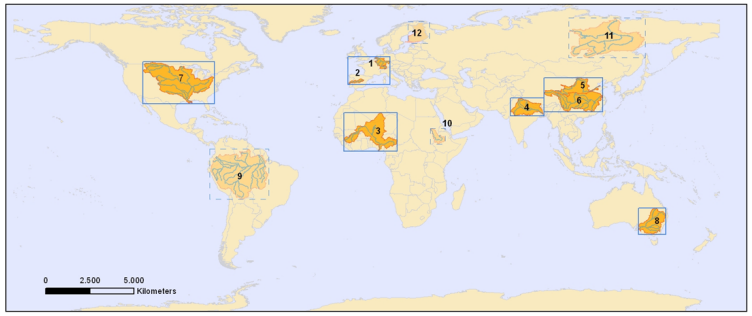


- Worst-year losses ~50% greater than ‘88 or ‘12 droughts
- Damages for maize and soy grow rapidly with temp
- US wheat insensitive to temp, (+) in North cancel (-) in South
- Extreme events marginally less severe with 2035 technology

Next steps

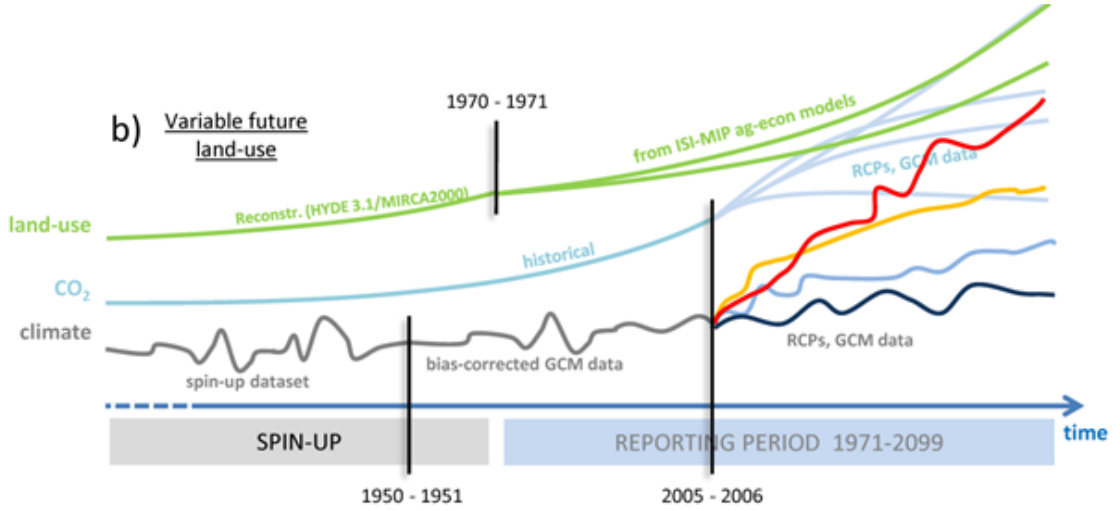
- Integrating w/ groundwater hydrology
- Applying methodology in India
  - Major constraints from depleting resources
- Link to global assessments
  - AgMIP GGCMI, CGRA and ISI-MIP
- Leveraging remote sensing to improve inputs (with GEOGLAM)

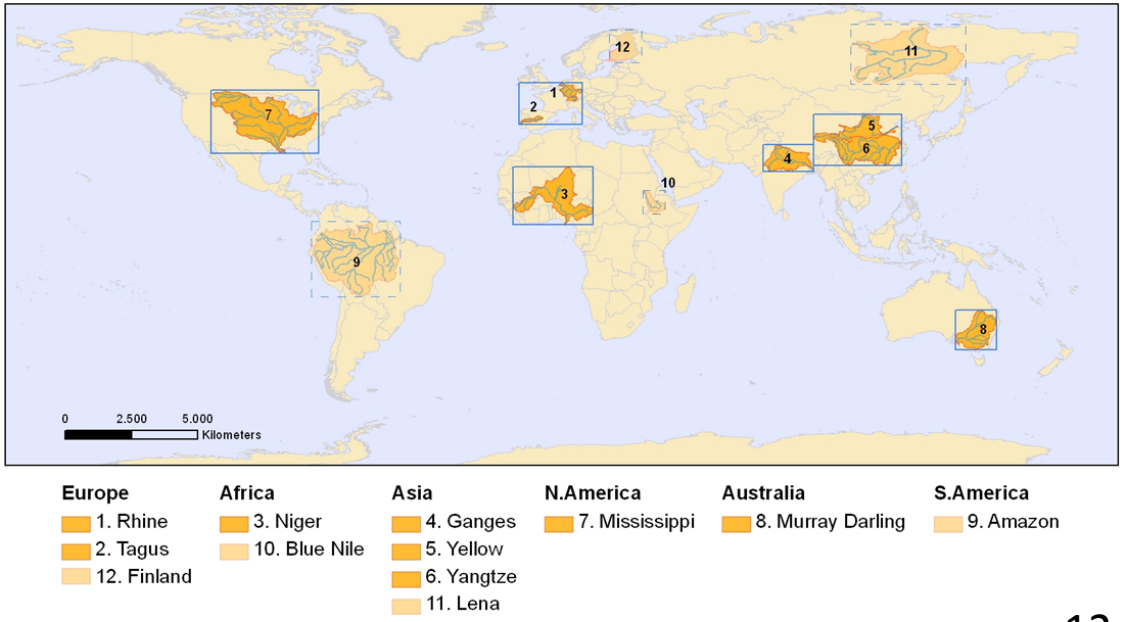




GGCMI Phase 3 and ISI-MIP2.0 (2016)

- Focus on extreme events
- Adding many sectors, including forestry
- Improving cross-sector interactions and land-use change and water.
- Adding a regional focus at the watershed level
- Adaptation to climate





Acknowledgements

rdcep

A Center for Robust Decision Making on Climate and Energy Policy

Collaborators

- RDCEP (rdcep.org)
- AgMIP (agmip.org)
- ISI-MIP (isi-mip.org)
- GGCMI (agmip.org/ag-grid/ggcmi/)
- **UK-US Taskforce on Extreme Weather and Global Food System Resilience**

Support from USDA, UK-AID (DFID), DOE, USAID, NSF, …

Linked global & regional assessments

- Partial solution: AgMIP Linked global and regional assessments of climate, food systems, and extremes.
  - Convening Aspen Global Change Institute workshop in September to discuss protocols for linked assessments
  - Developing methodology and prototypes for North America and South Asia

AgMIP

ASPEN GLOBAL CHANGE INSTITUTE

rdcep
A Center for Robust Decision Making on Climate and Energy Policy

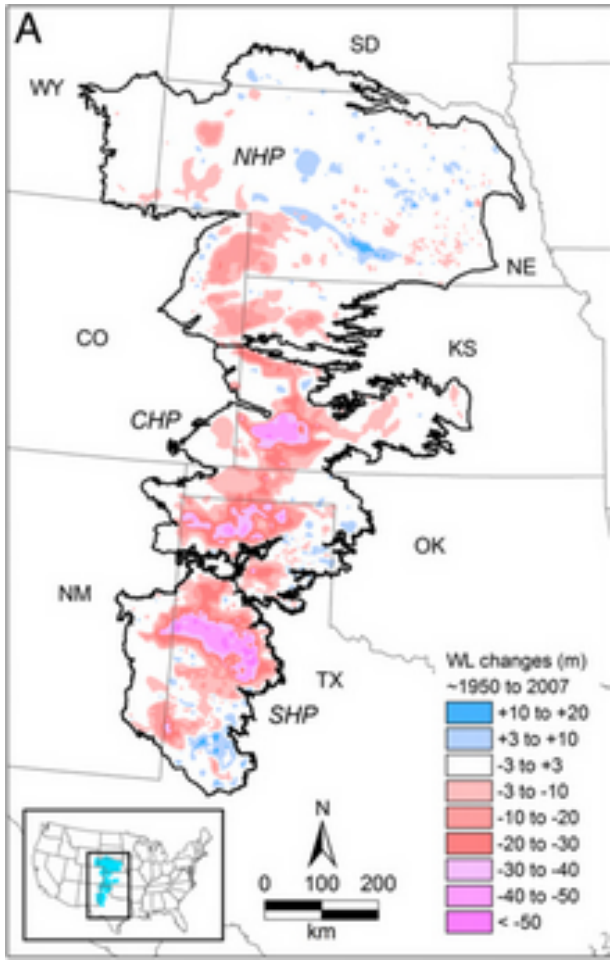
Extremes are bad and may get worse…

- In the United States alone
  - large-scale drought and heat accounted for 12% of billion-dollar disasters from 1980-2011, 25% of monetary damages
  - 1988 drought in the US cost estimated at $79 billion (2013 USD), behind only Hurricane Katrina as most costly weather-related disaster in US history.

- Warming temperatures and shifting precipitation patterns may exacerbate problems, increasing the frequency and/or severity of large-scale droughts in sensitive agricultural regions

Vulnerability and groundwater depletion

- Groundwater accounts for 60% of irrigation and 40% of drinking water in the US
- Warming, management, and adaptation pressures are expected to **increase** demand for irrigation
- Increased CO2 is expected to **decrease** H2O demand, but serious questions remain how well this will translate to the field (especially for C4 crops)



Scanlon et al 2012.

- Impact of a 1930s climate event today would be devastating
  - single-year losses ~50% greater than ‘88 or ‘12 droughts