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Higher-Resolution IA Models

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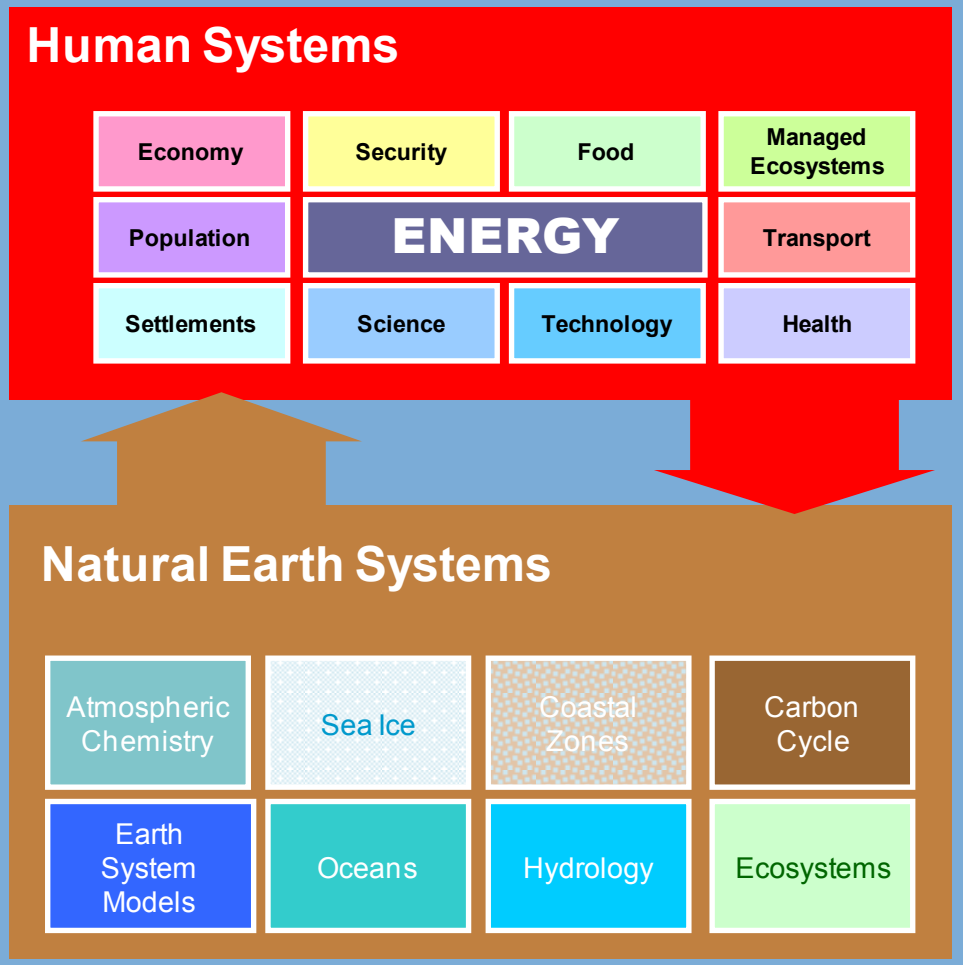
November 13, 2015

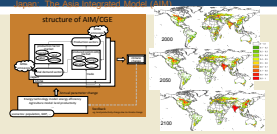
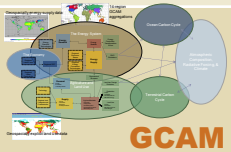
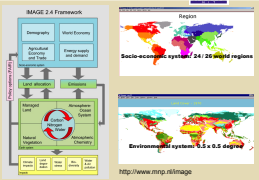
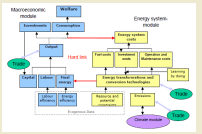
Higher-Resolution IA Models

Higher-Resolution Integrated Assessment (IA) Models

- Capture interactions between complex and highly nonlinear systems
- In the context of mitigation, they have traditionally focused on cost-effectiveness analysis
- They are increasingly being used to explore climate impacts, with a particular focus on energy-water-land interactions
- They are part of a larger stream of IA research that includes multi-model approaches to bridge scales



Higher-Resolution IA Models and Teams

Model	Home Institution	
AIM Asia Integrated Model	National Institutes for Environmental Studies, Tsukuba Japan	
GCAM Global Change Assessment Model	Joint Global Change Research Institute, PNNL, College Park, MD	
IGSM Integrated Global System Model	Joint Program, MIT, Cambridge, MA	
IMAGE The Integrated Model to Assess the Global Environment	PBL Netherlands Environmental Assessment Agency, Bildhoven, The Netherlands	
MESSAGE Model for Energy Supply Strategy Alternatives and their General Environmental Impact	International Institute for Applied Systems Analysis; Laxenburg, Austria	The image cannot be displayed. Your computer may not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.
REMIND Regionalized Model of Investments and Technological Development	Potsdam Institute for Climate Impacts Research; Potsdam, Germany	

The Global Change Assessment Model (GCAM): A Higher-Resolution IA Model

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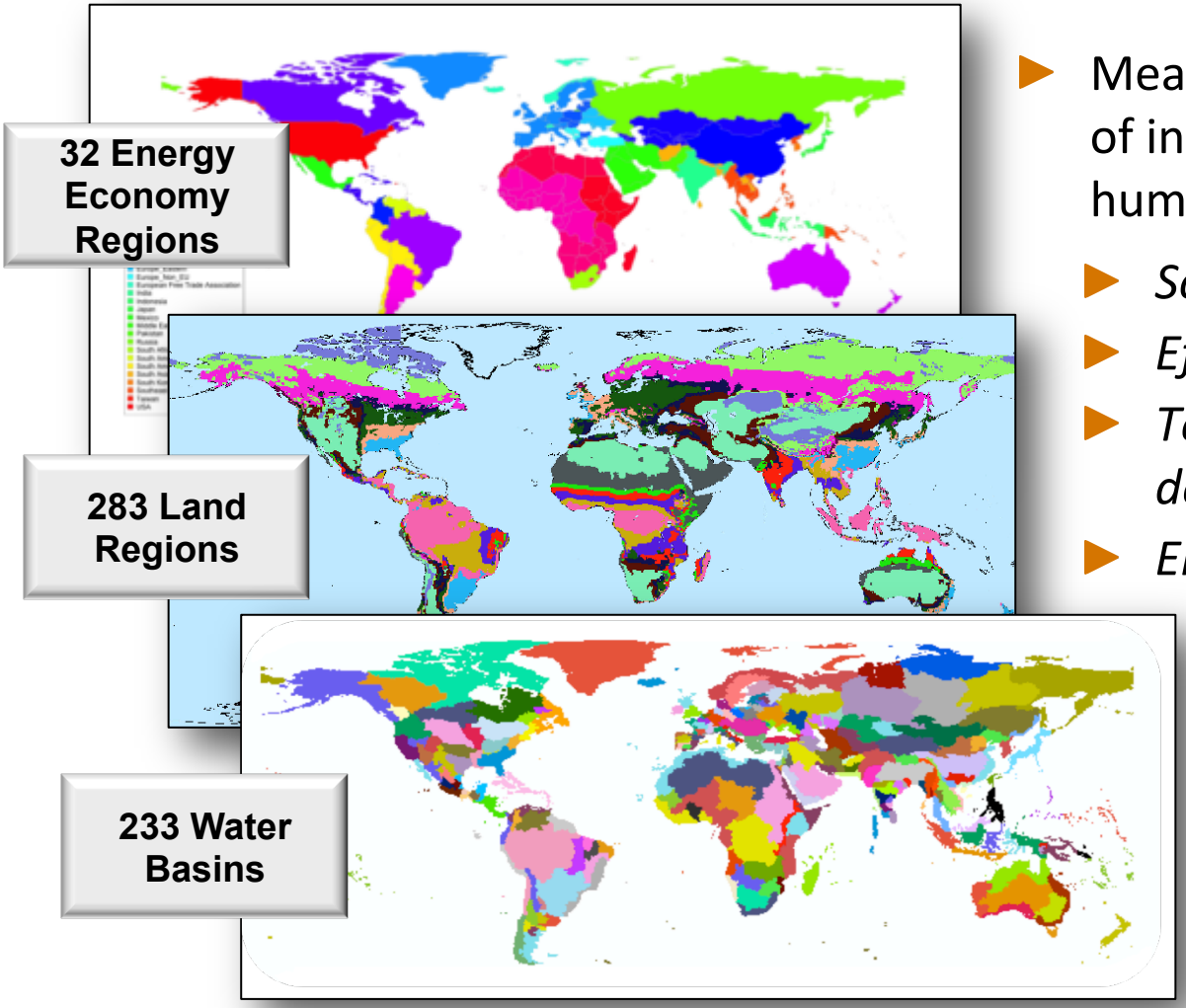
- GCAM is a **global integrated assessment model**
- GCAM links **Economic**, **Energy**, **Land-use**, **Water**, and **Climate** systems



- Meant to analyze consequences of interdependencies between human and Earth systems
  - *Socioeconomic development*
  - *Effects of climate*
  - *Technology and resource developments*
  - *Energy and other policies*

- Runs in **5-year time-steps.**
- GCAM is a community model
- Documentation available at: **wiki.umd.edu/gcam**

IA Models Have Become Increasingly Complex Over the Last 30 Years

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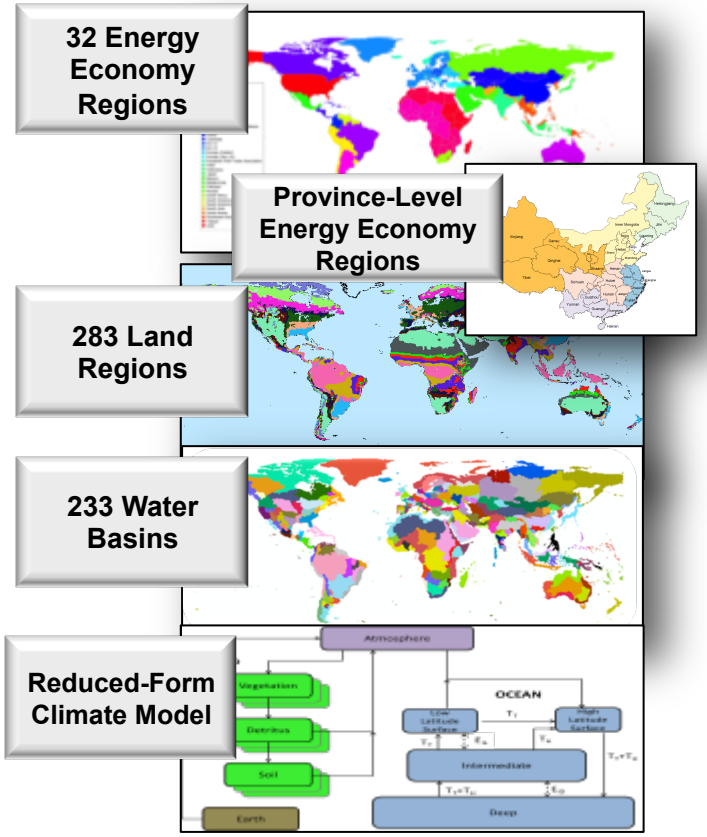
Automation System

Data Development System

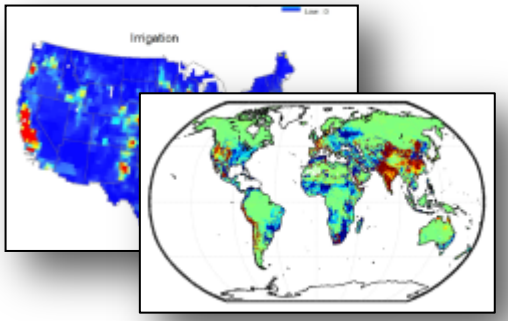
- EIA
- IEA
- GTAP
- HYDE
- SAGE
- OECD
- FAO
- IMAGE
- MIRCA
- Aquastat
- USDA
- USGS
- CDIAC
- IIASA
- Others

Papers: Houghton, Rogner, others

GCAM Core: Dynamic Integration



Disaggregation Models



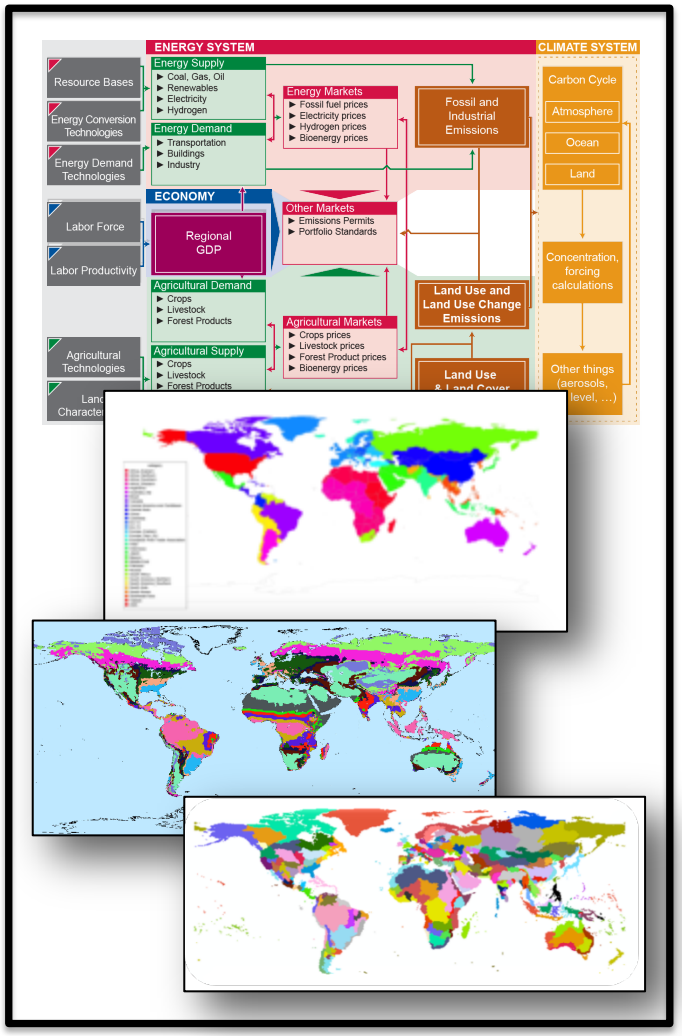
- Digital Map of Irrigated Areas
- MODIS
- Union of Concerned Scientists
- Gridded Livestock of the World
- Others

Papers: Friedl, Portmann, Sleeter, Radeloff, others

Inputs and Output

Scenario Assumptions

- Socioeconomic assumptions
- Energy, land use, and water technologies
- Policies
- Resources



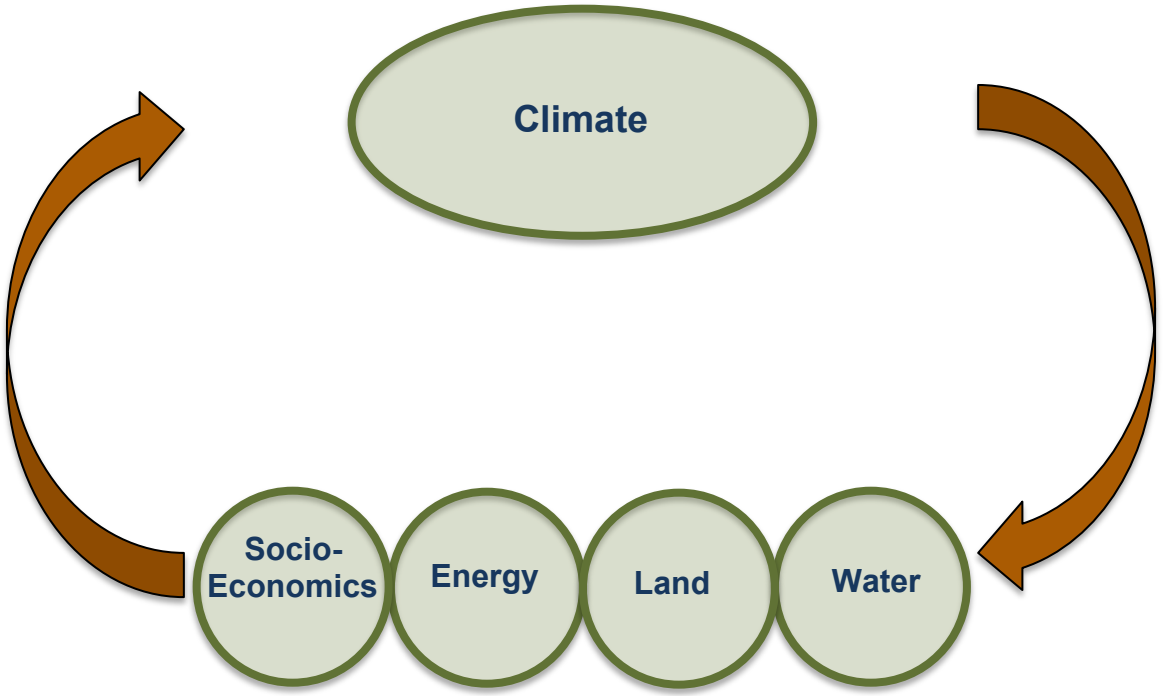
Scenario Outputs

- **Prices and production quantities**:
  - Energy sectors
  - Transportation
  - Primary energy resources
  - Agricultural products
- **Land use**
  - Crops (by type)
  - Pasture
  - Unmanaged
- **Water demand**
  - Raw demand by sector
  - Response to scarcity
- **Greenhouse gases**
- **Economic indicators**
  - Economic losses
  - Income transfer

Climate and Highly-Resolved IA Models

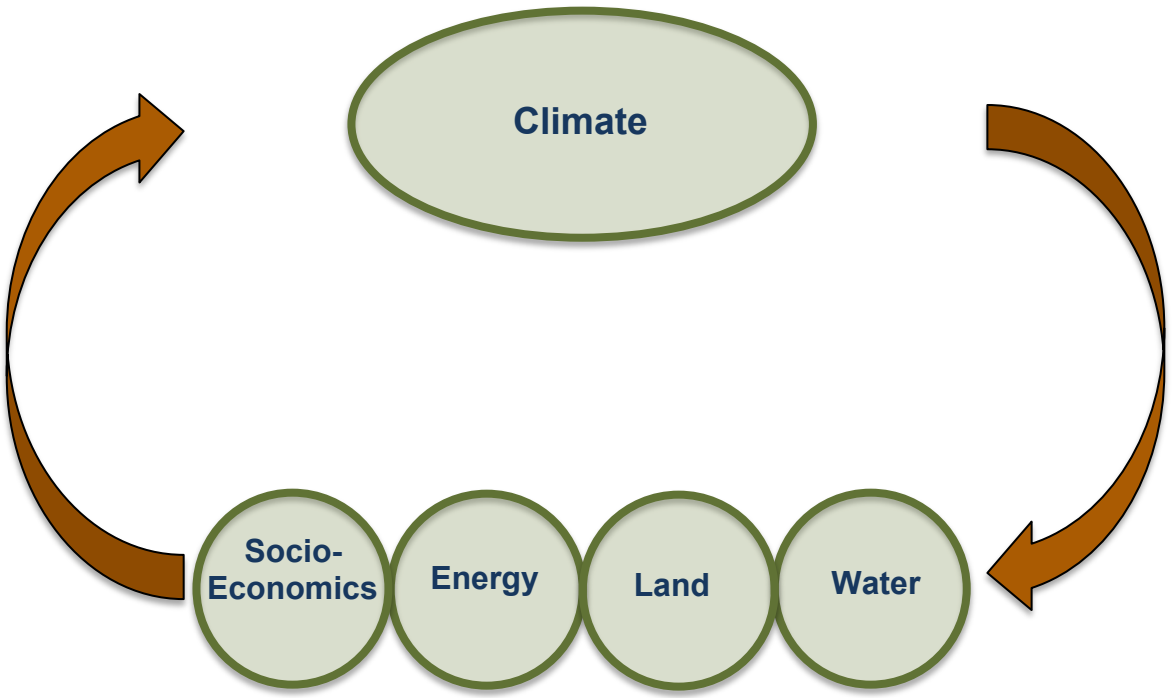
Closing the Climate in IA Models

Strategies for climate mitigation



Climate effects on human systems

The Challenges of Full-Coupling in Highly-Resolved IA Research



Challenge 1. Spatially- and temporally-resolved climate information that effectively represents uncertainty

Challenge 2. Intermediate Responses (e.g., response surfaces for agricultural yields)

Challenge 3. “Hooks” to take on climate or intermediate information in IA models, incorporating higher-resolution phenomenon

A Range of Ways to Treat Climate Impacts

Process Representation — **Parameterized Impacts**

Producer of Damage Information

Large Energy-Water-Land Focus

Consumer of Damage Information

Impact on Building Energy Expenditures

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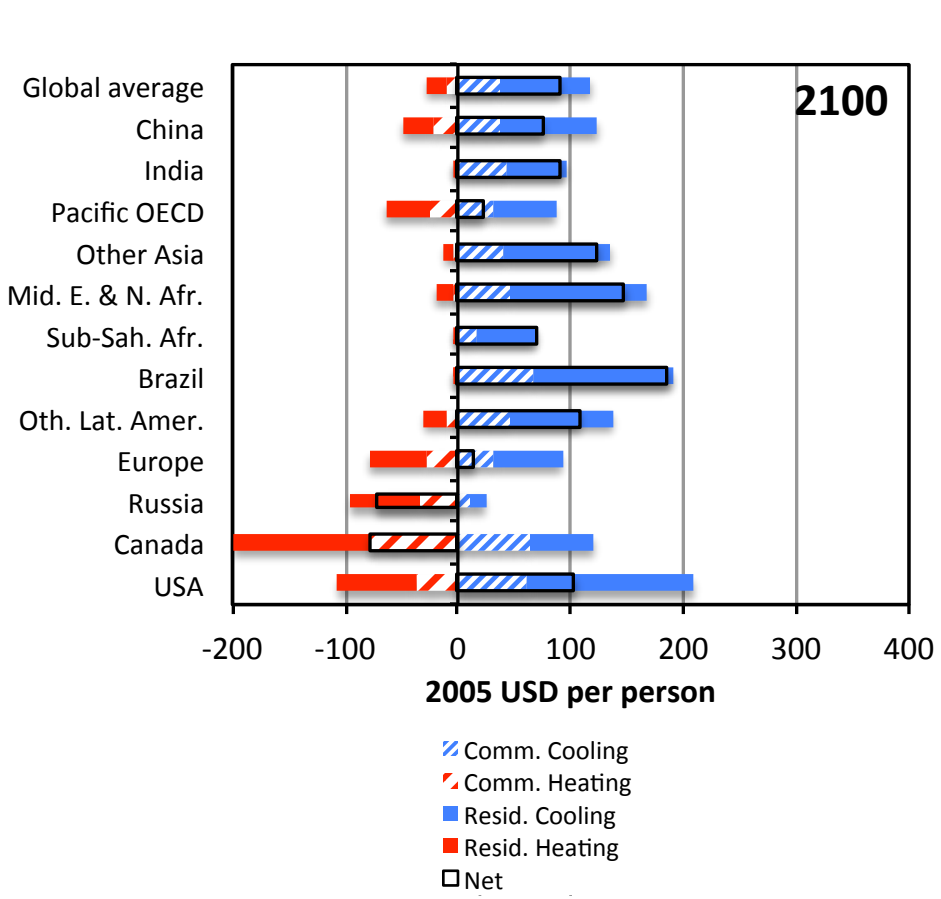
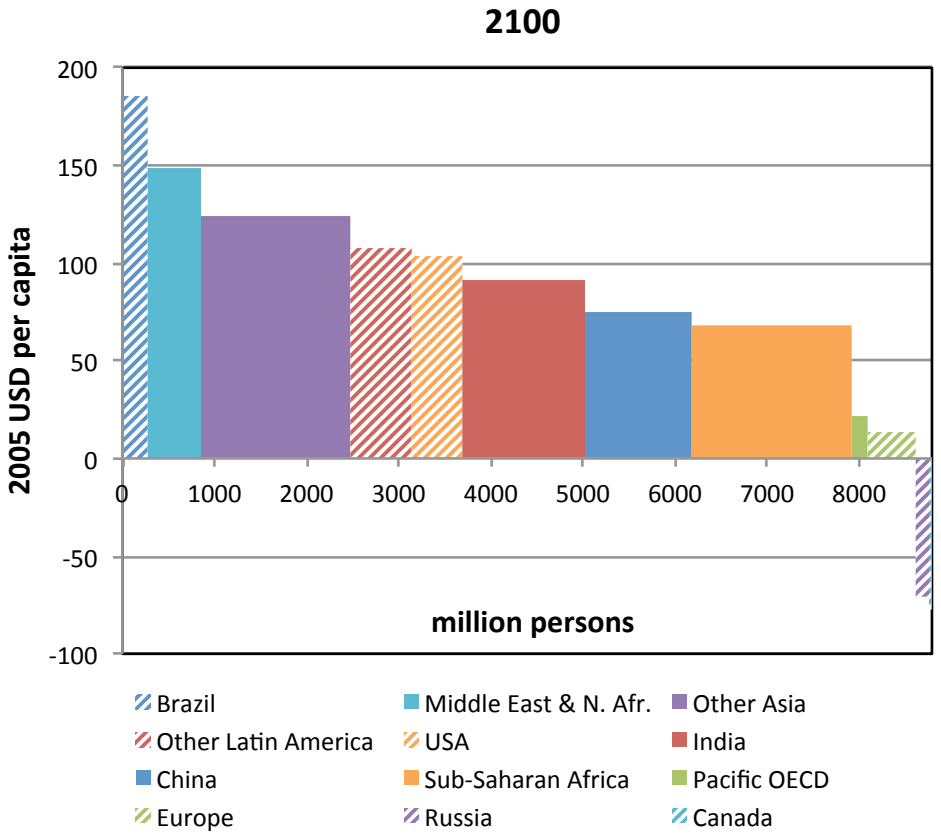
Change in energy expenditures for heating & cooling





Climate data from CCSM A2 scenario

Impact on Building Energy Expenditures

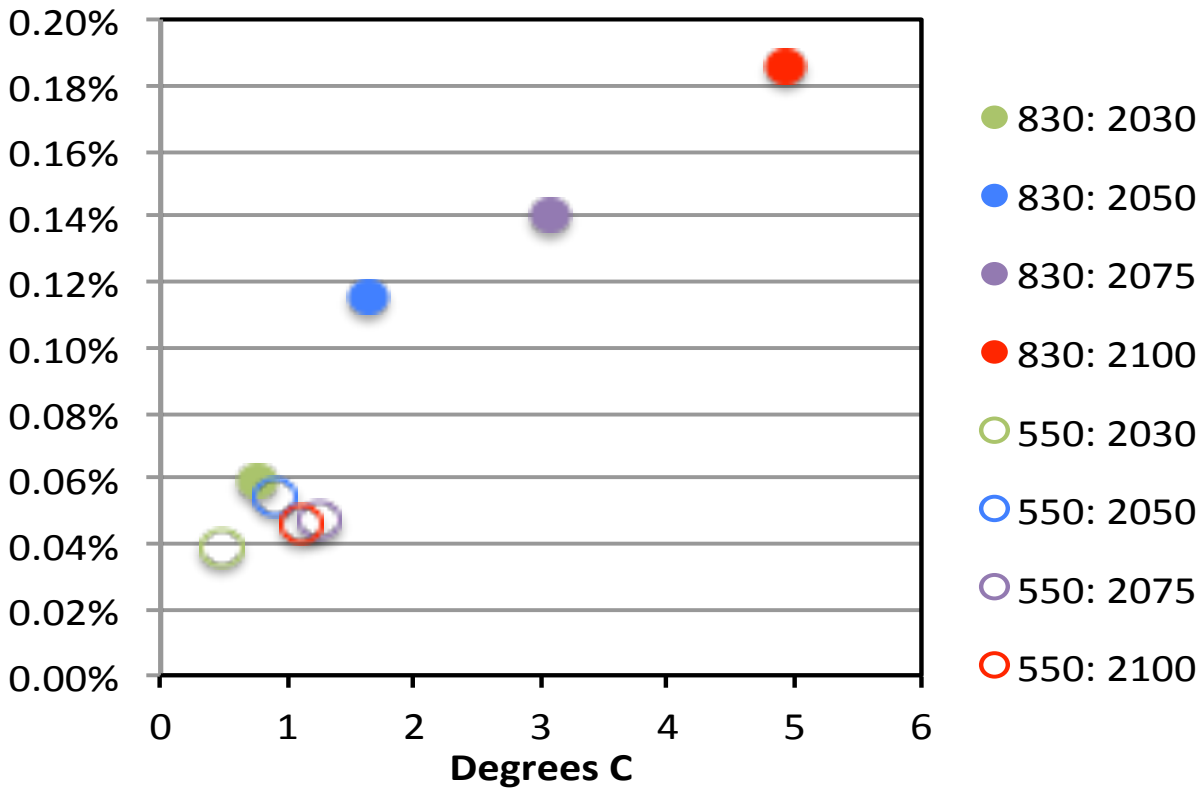
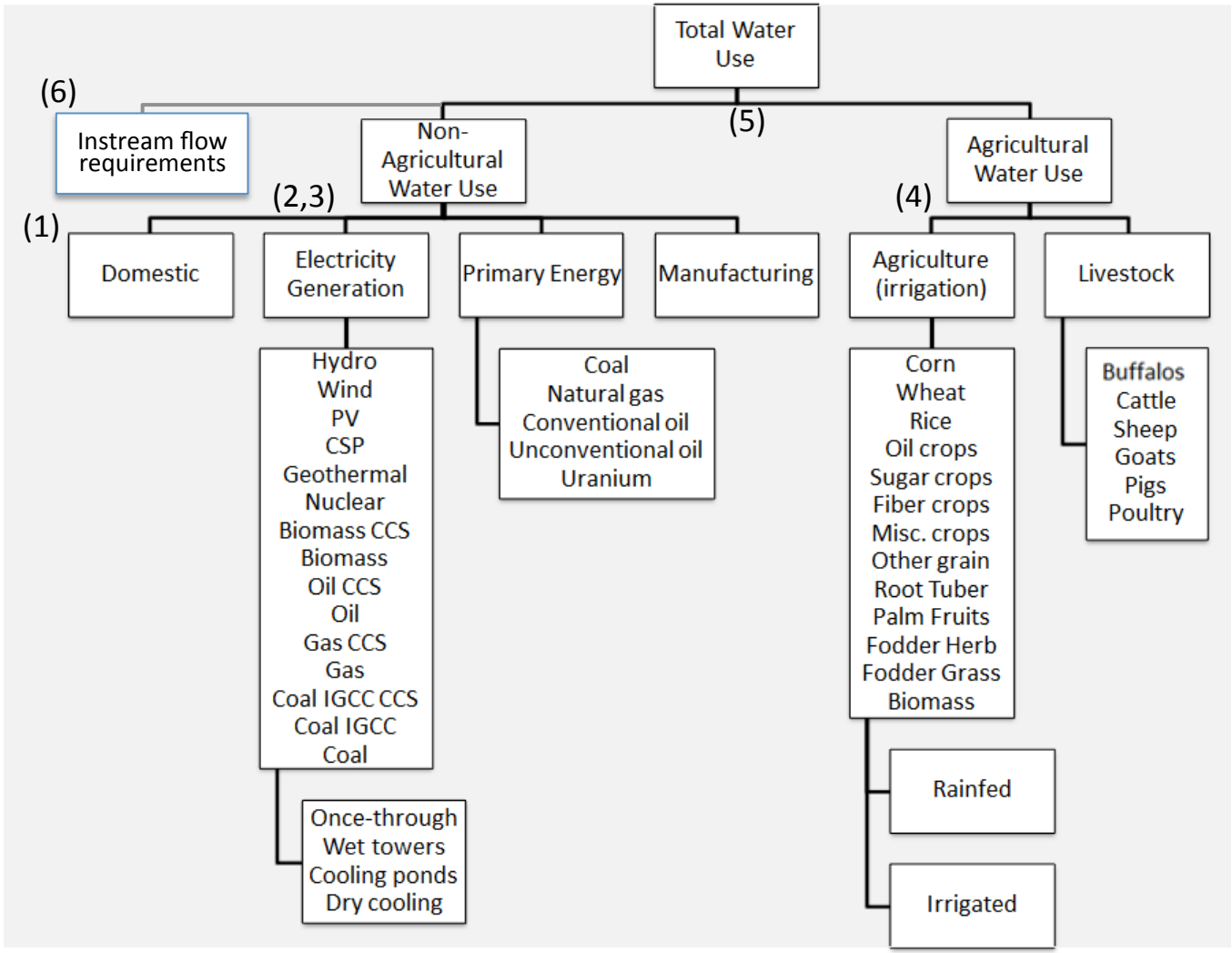


Figure 12: Global average additional expenditures per unit of income on heating and cooling as a function of the increase in global average surface temperature from 2010.

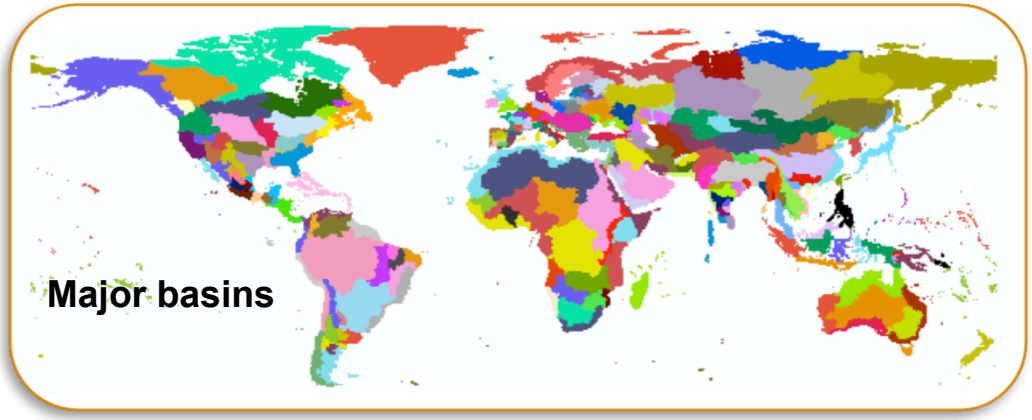
Water Demands in GCAM



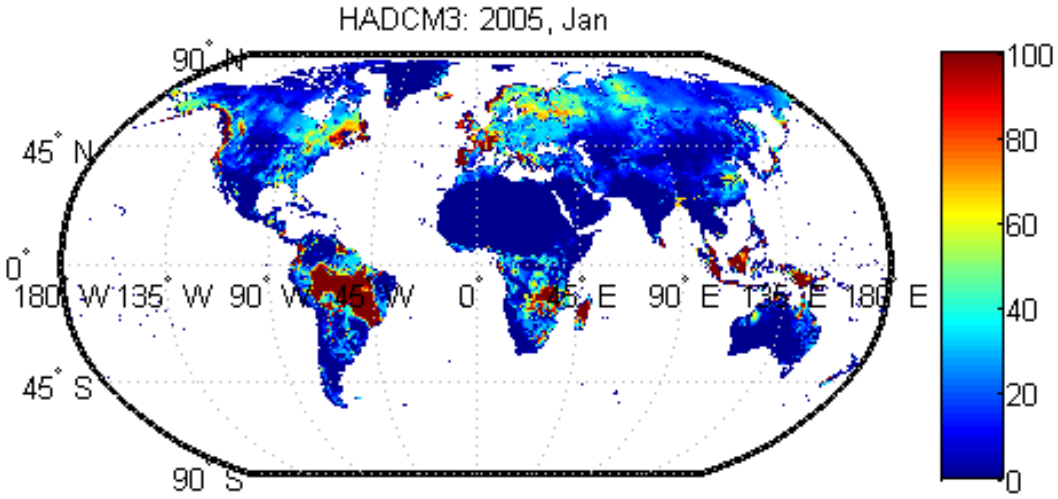
GCAM tracks water demands for several sectors, subsectors, and technologies, & at various spatial scales

(1) Hejazi et al. (2013). Hydrological Sciences Journal
(2) Kyle et al. (2013). Int. J. of Greenhouse Gas Control
(3) Davies et al. (2013). Advances in Water Resources
(4) Chaturvedi et al. (2013). Mitigation & Adaptation Strategies for Global Change.
(5) Hejazi et al. (2014). Technological Forecasting and Social Change
(6) Kim et al. (in review). Climatic Change

Transforming Climate Information to Streamflow



- Global hydrologic model
- Modified River Transport Model scheme
- 233 Basins



Hejazi et al. 2014. Hydrology & Earth Sys. Sc.

- Requires climate information from GCMs as inputs
- Monthly temporal scale
- 0.5x0.5 degree spatial resolution

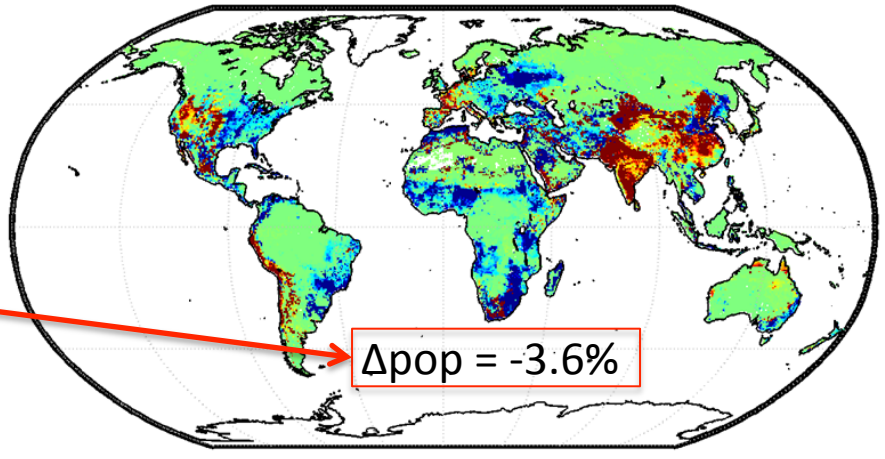
What are the Implications of Different Land Use and Bioenergy Pathways on Water Scarcity?

- Human system dynamics have a critical influence on future water scarcity
- The percent of global population living in grids classified as water scarce in 2095 depends substantially on the role of bioenergy in future pathways.

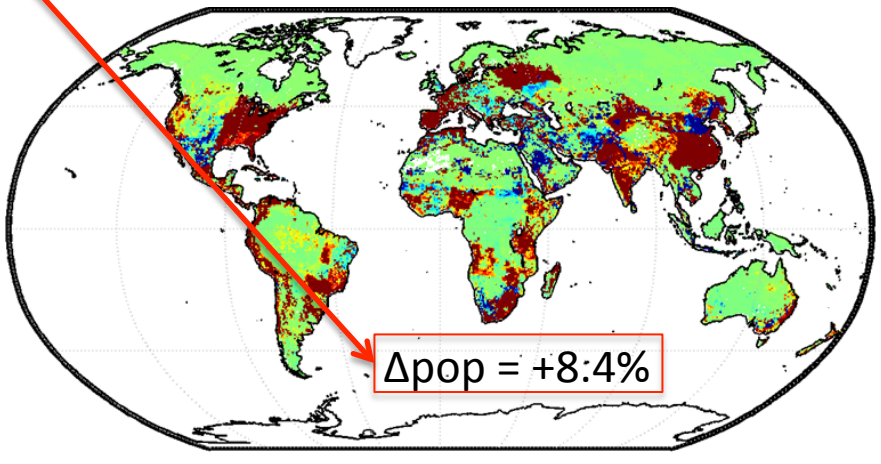
Figures show water scarcity associated with different pathways toward roughly 4 W/m^2 relative to a higher-emissions reference scenario leading to forcing of roughly 8.5 W/m^2. Scarcity defined as annual water demand over annual water supply.

Hejazi et al. 2014. Hydrology & Earth Sys. Sc.

Limited biomass production scenario



Extreme biomass production scenario



Linked model experiments will be a key approach for integrated assessment

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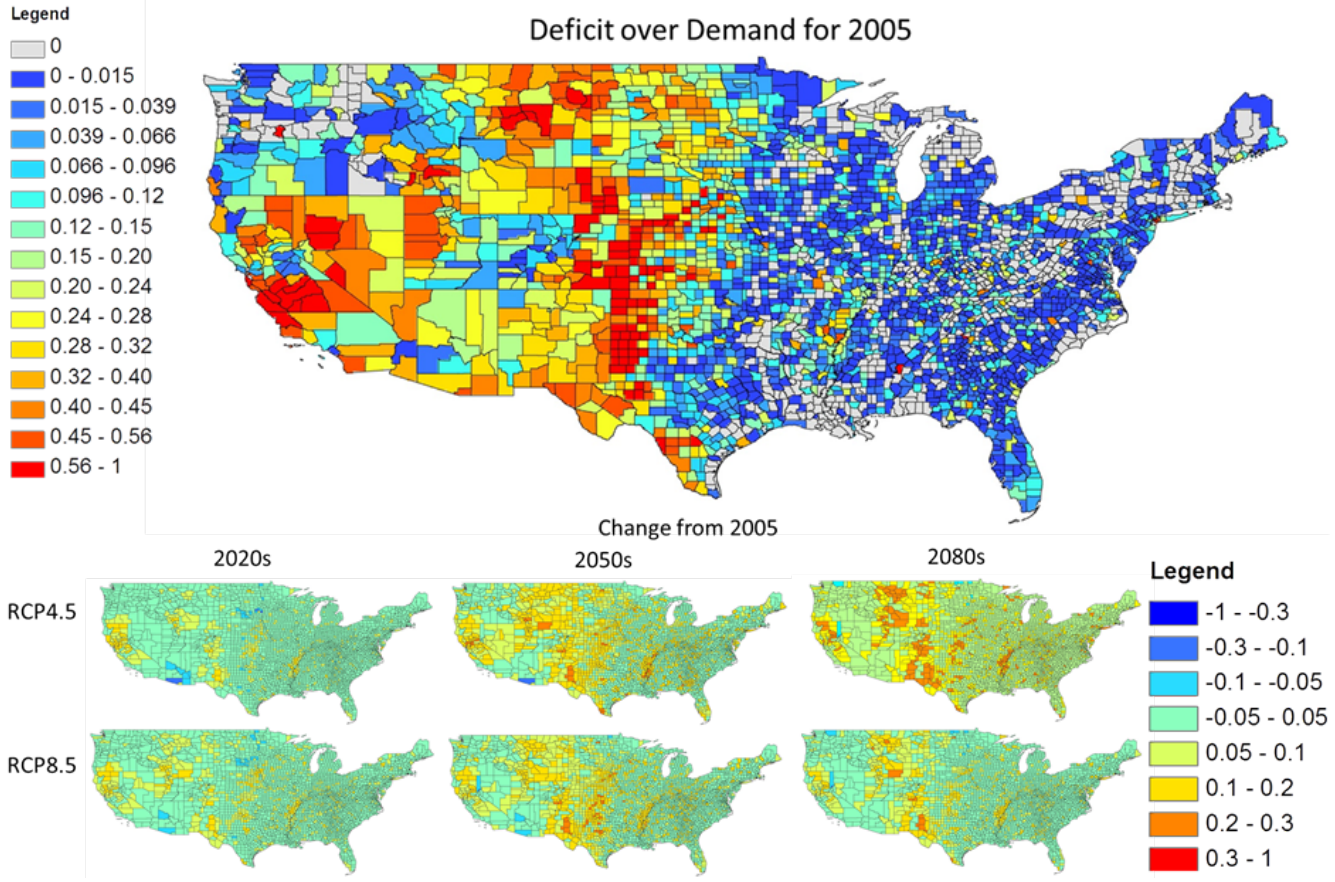
Linking GCAM-USA, a regional Earth system model, and a coupled hydrology-water management model,

Annual county scale water deficit as a fraction of demand



Hejazi, Mohamad I., et al. "21st century United States emissions mitigation could increase water stress more than the climate change it is mitigating." Proceedings of the National Academy of Sciences 112.34 (2015): 10635-10640.

The emerging frontier – fully coupled water supplies and demands within an integrated framework

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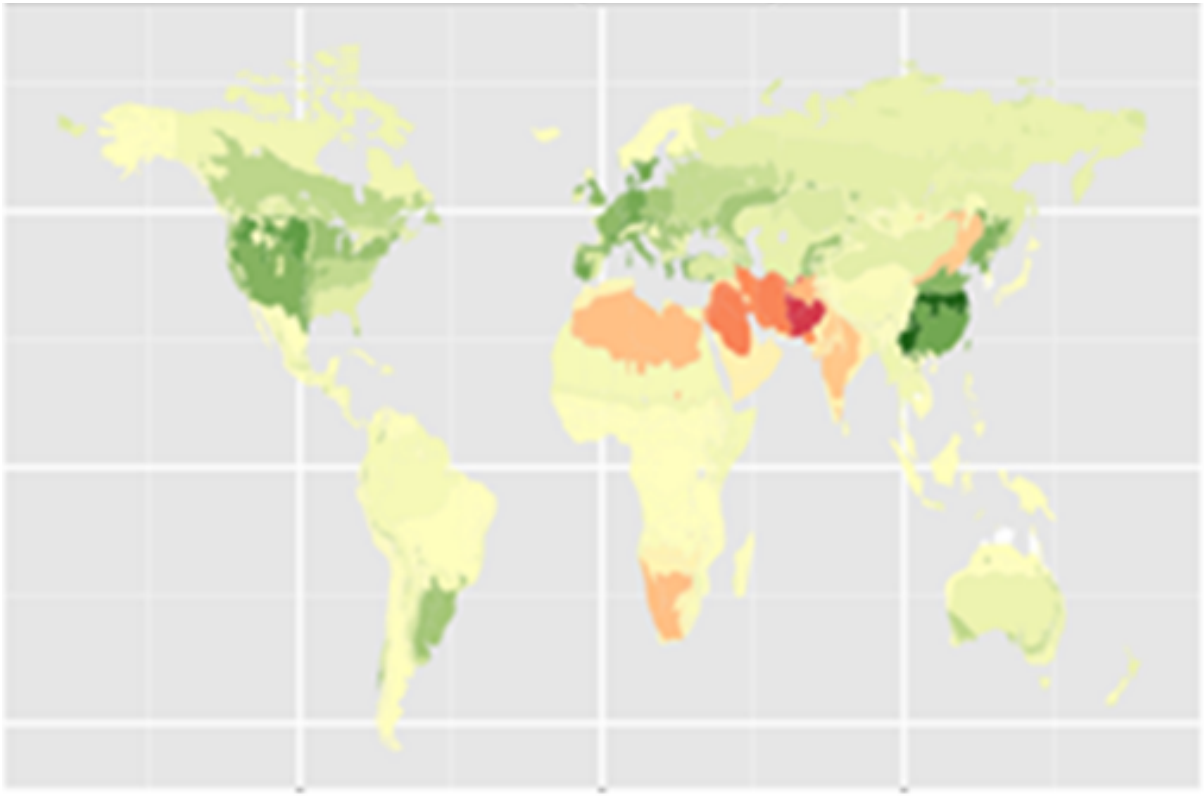
- Adaptive decisions to water scarcity will alter agricultural and land use patterns
- Non-renewable groundwater availability and extraction costs are key determinants of withdrawal projections.

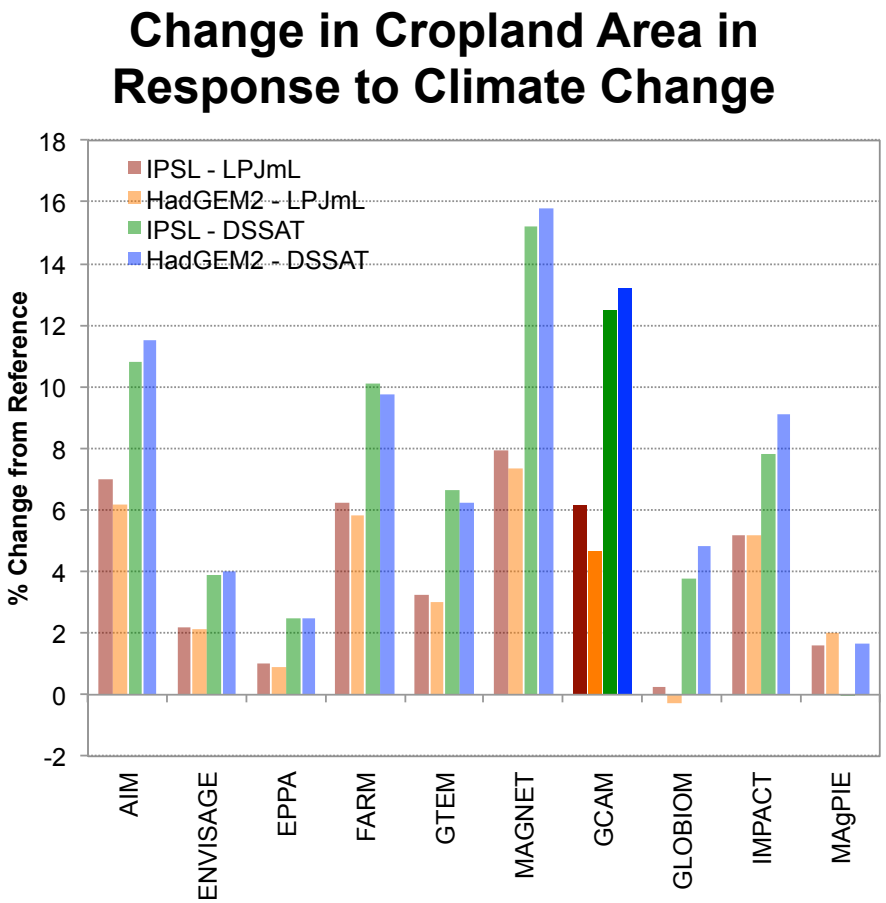
Percent changes in wheat production in 2100



Kim et al. (accepted). Climatic Change

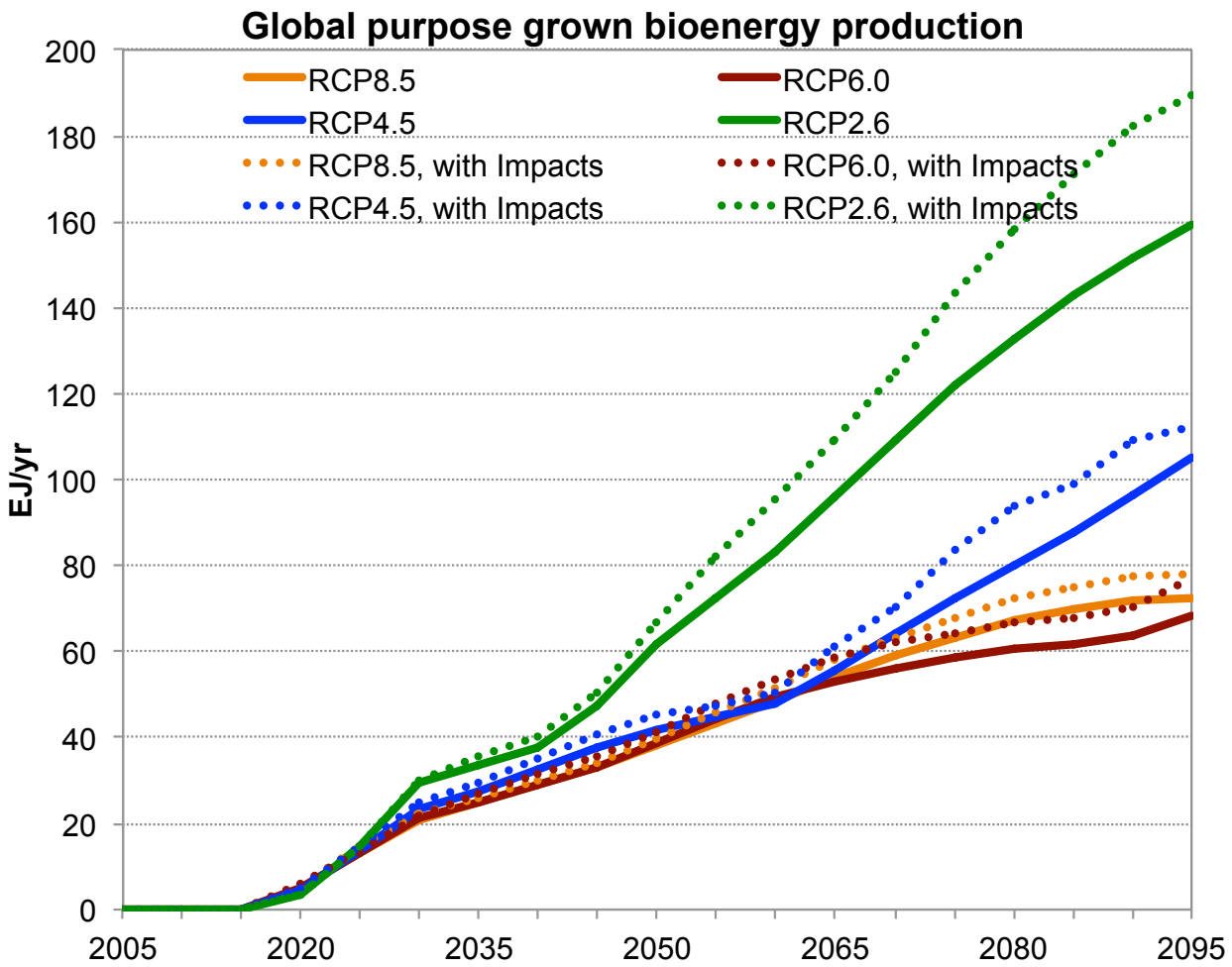
Climate Change Could Alter the Extent of Cropland Area Required to Feed a Growing Population

- **Question:** What is the effect of climate change on agriculture and land use?
- **Key Results:** The inclusion of changes in climate, without CO_2 fertilization, results in an expansion of cropland globally.



Source: Redrawn from Nelson et al. (2014)
Results from the Agricultural Model Intercomparison Project

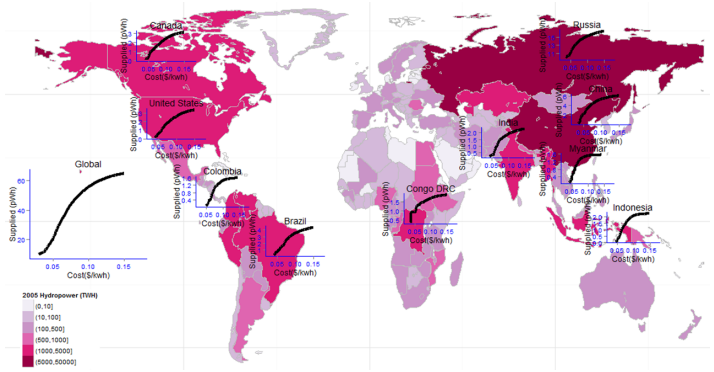
Agriculture Impacts



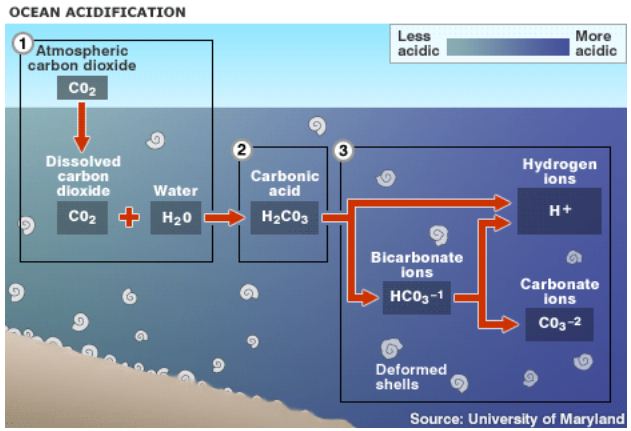
Source: Kyle, P., C. Mueller, K. Calvin and A. M. Thomson (2014). "Meeting the Radiative Forcing Targets of the Representative Concentration Pathways in a World with Agricultural Climate Impacts." Earths Future 2(2): 83-98.

Many More Examples of IA Impacts Analysis

Hydropower



Ocean Acidification



Water Temperature and Thermal Cooling

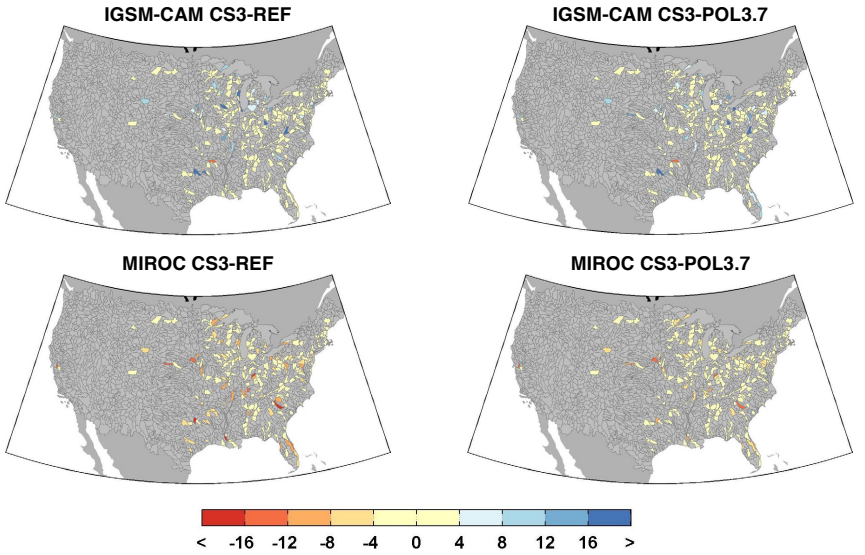


Figure 13. Changes in withdrawal allowed for HUCs with once-through cooling technology in 2050.

From: Water Body Temperature Model for Assessing Climate Change Impacts on Thermal Cooling, Ken Strzepek, Charles Fant, Yohannes Gebretsadik, Megan Lickley, Brent Boehlert, Steven Chapra, Eric Adams, Andrzej Strzepek and C. Adam Schlosser

Challenge: Climate Variability and Extreme Events

Example: Electricity Impacts

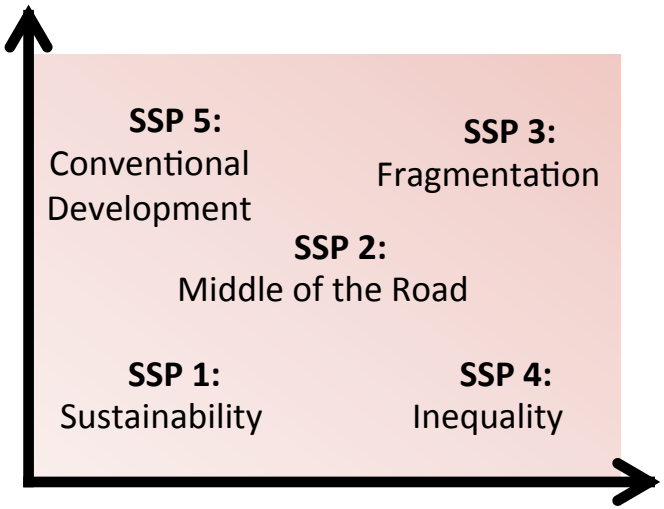
Electricity investments need to consider the confluence of demand increasing and supply decreasing effects:

- heat waves effecting both supplies and demands
- low wind
- droughts

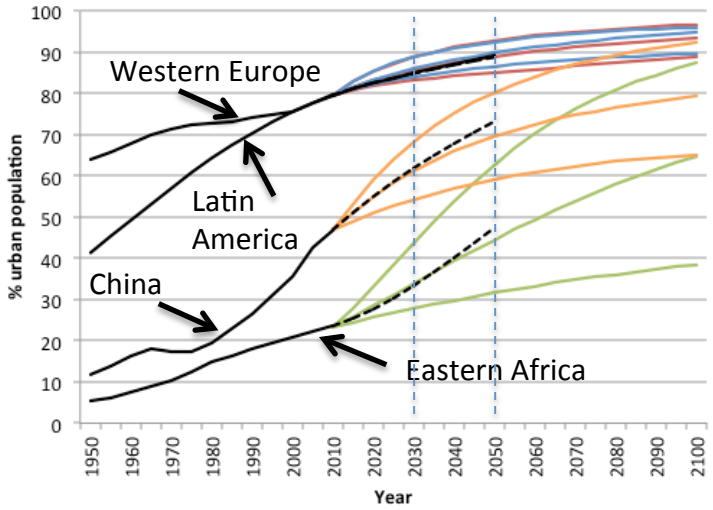
Along with demand management, storage, infrastructure more generally

Bottom line: For IA research to explore these factors, it needs to address events taking place on the time scale of days to weeks to years and at local to regional scales.

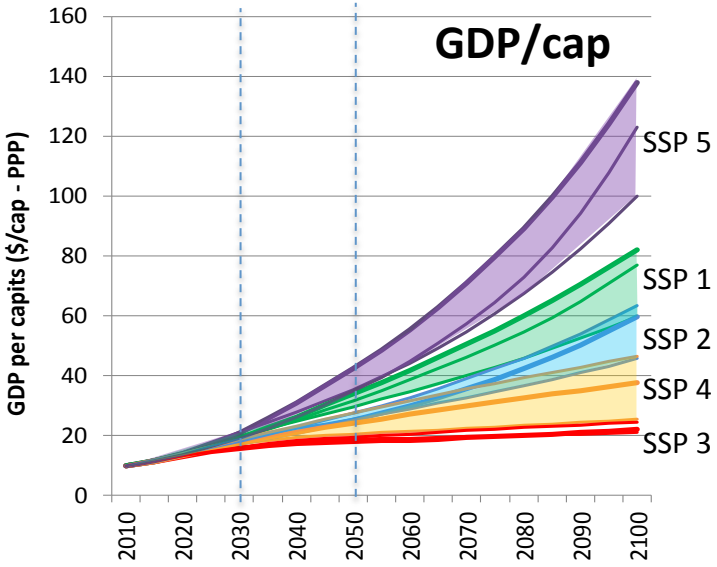
The Shared Socioeconomic Pathways



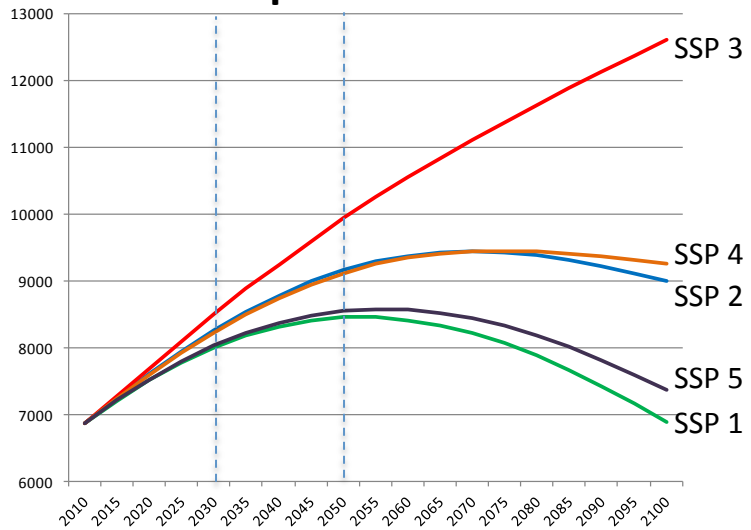
Urbanization



SSP1	Fast
SSP2	Central
SSP3	Slow
SSP4	Fast/Central
SSP5	Fast



Population

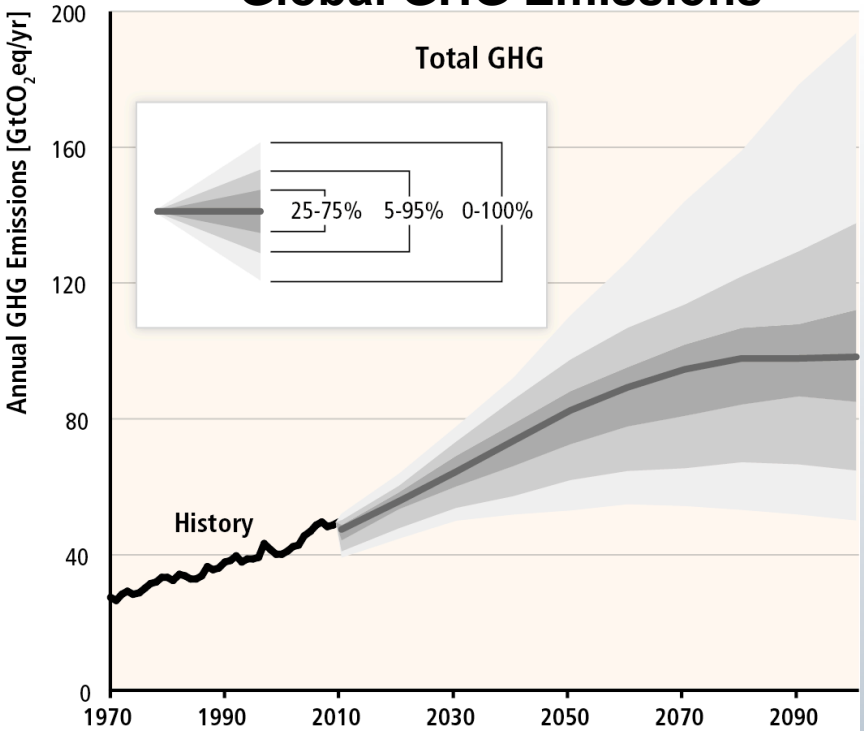


Emissions and concentrations are expected to continue to rise despite improvements in technology.

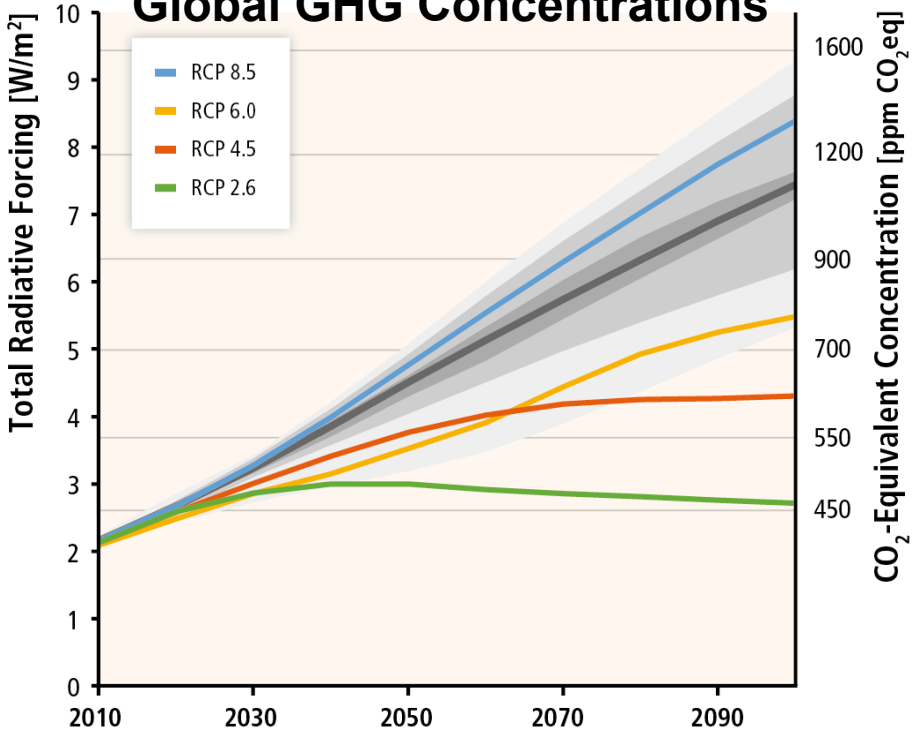
Global mean surface temperature increases in 2100 in baseline scenarios…range from 3.7°C to 4.8°C above the average for 1850–1900 for a median climate response. They range from 2.5°C to 7.8°C when including climate uncertainty (5th to 95th percentile range)

4.5°F to 14°F

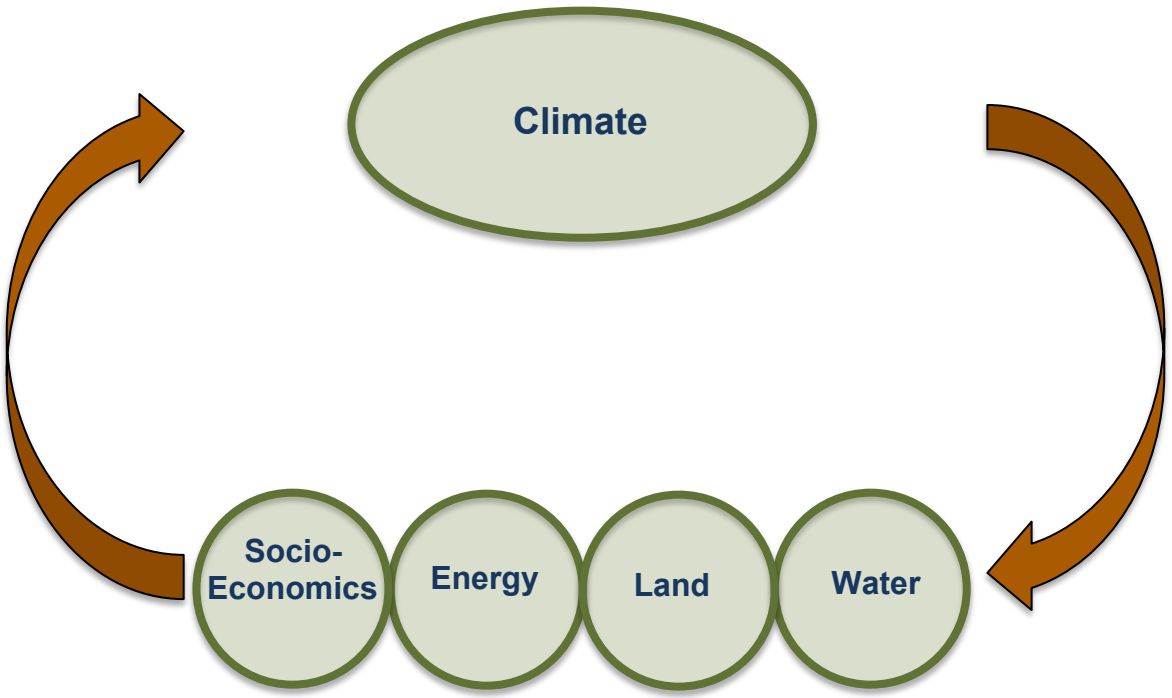
Global GHG Emissions



Global GHG Concentrations



The Challenges of Full-Coupling in Highly-Resolved IA Research



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Questions