SAND2011-3225C

Climate Change, Technology, and Global Security

Powering the Future
Speaker Series
University of Vermont, 3 May 2011

Rob Leland
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Director, Climate Security Program
Sandia National Laboratories

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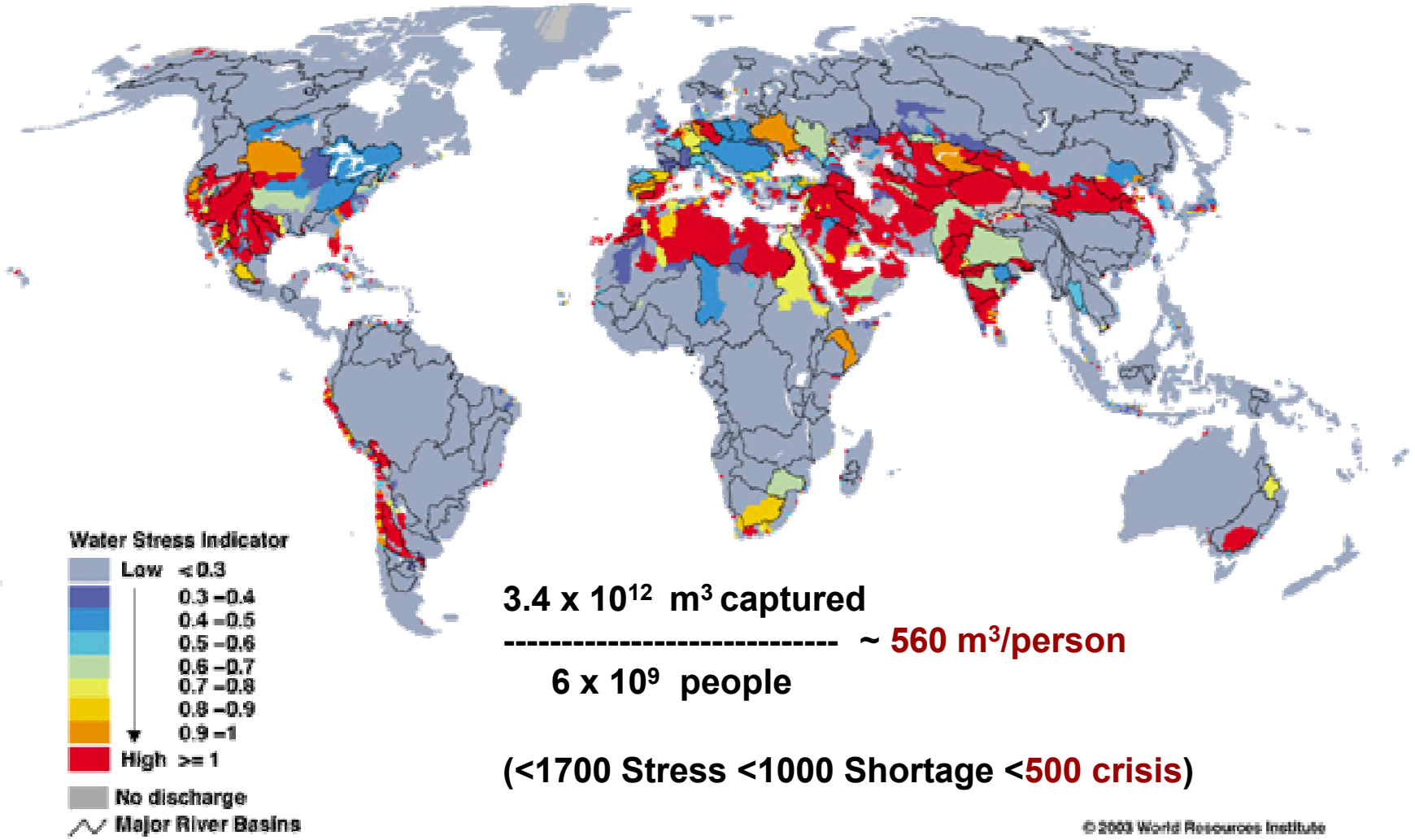
The freshwater shortage…

… is globally acute



3.4×10^{12} m^3 captured

6×10^9 people ~ **560 m^3/person**

(<1700 Stress <1000 Shortage <500 crisis)

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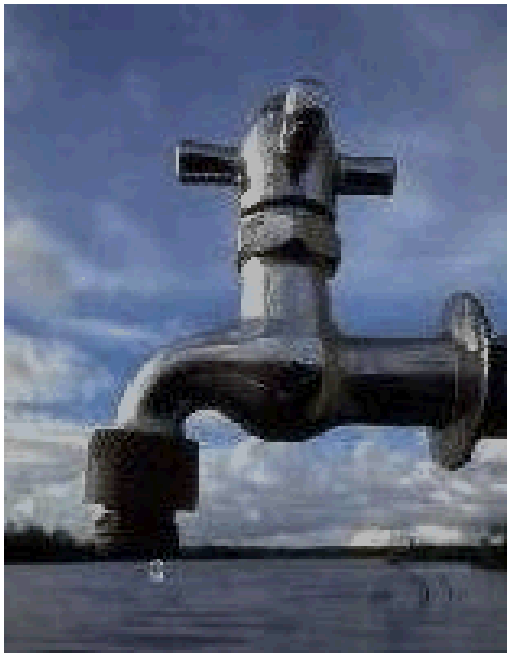
Which means …



- 80 Countries with 40% of the world population suffer from water shortage.
- 1 billion people drink unsafe water each day.
- A child dies every 10 seconds from contaminated drinking water.

Main take-away

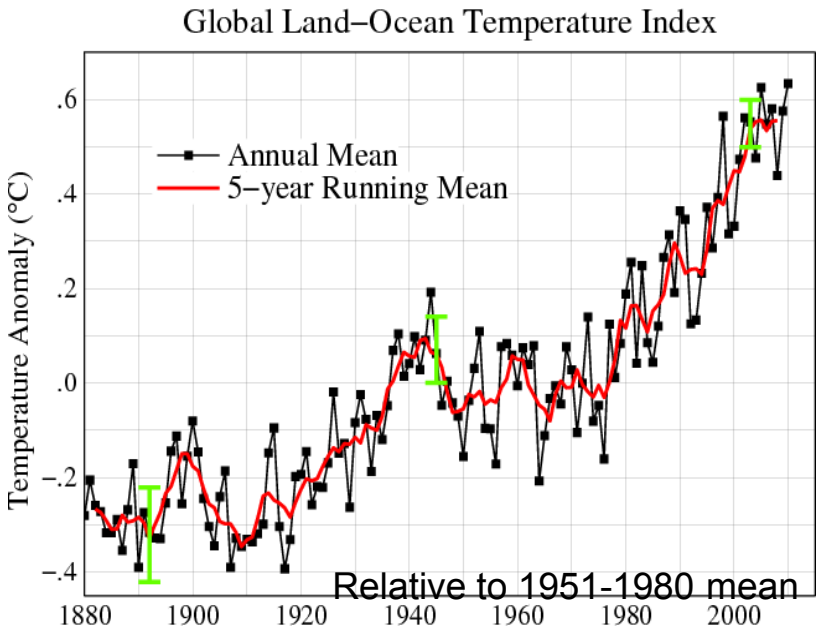
We need a deeper and broader collaboration between the technical and policy communities to address the very serious challenges climate change will pose to human society.

Key messages

- Climate change will pose very serious challenges to human society
- These challenges will manifest in environmental, economic and social problems with high impact on international stability and global security
- Technically deep approaches to key problems can help to mitigate these impacts
- In isolation, these technical approaches will fail -- a deeper & broader collaboration between the technical and policy communities is needed

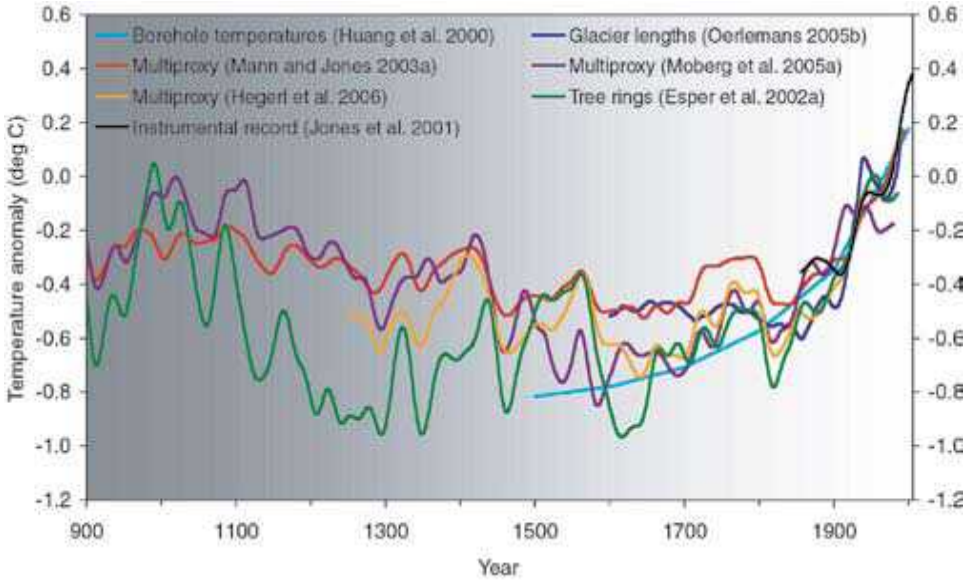
Climate change will pose very serious challenges to human society.

The planet has been warming for over a century



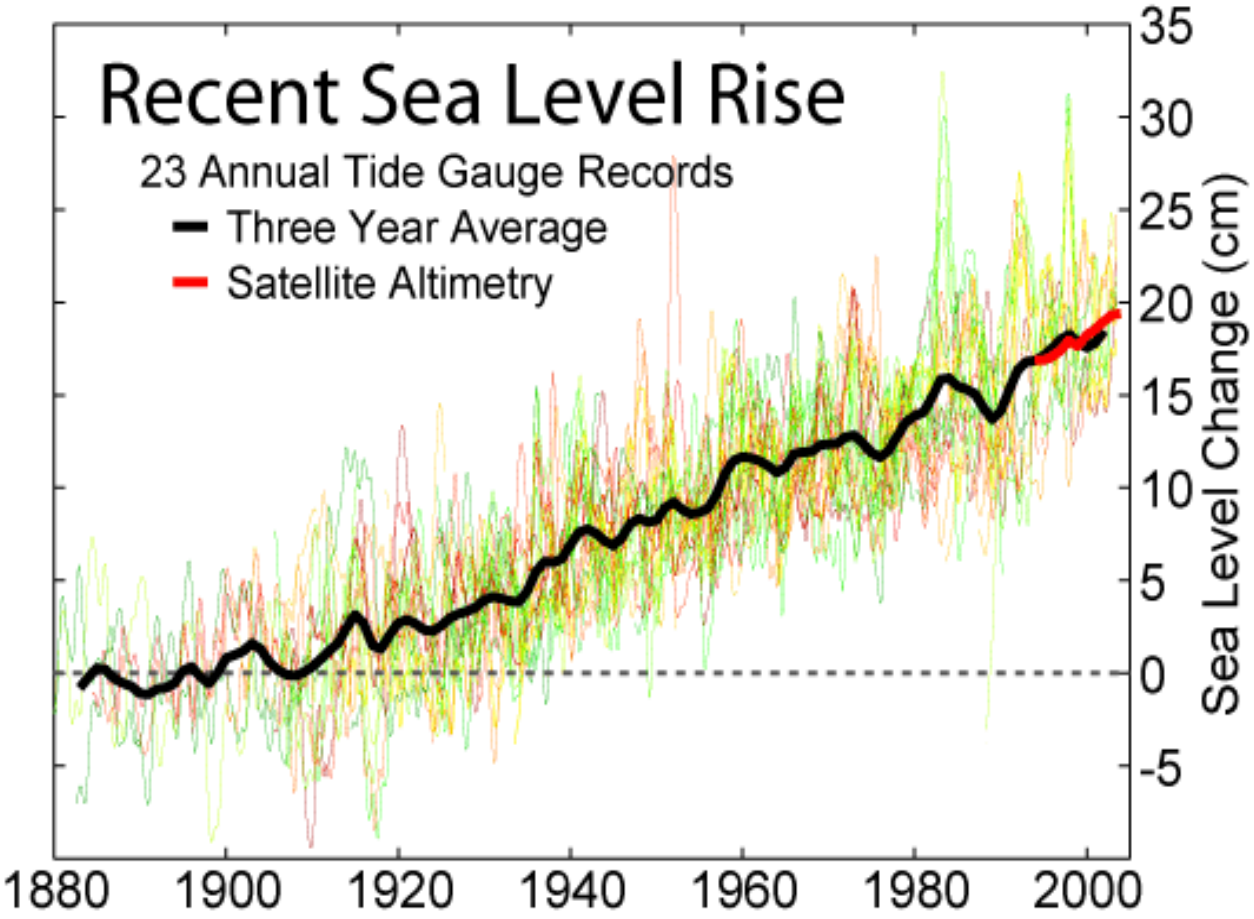
NASA Goddard Institute for Space Science.

GISS Surface Temperature Analysis (GISTEMP) is based on many peer reviewed references (see notes). Includes meteorological stations and sea surface temperatures
http://data.giss.nasa.gov/gistemp/



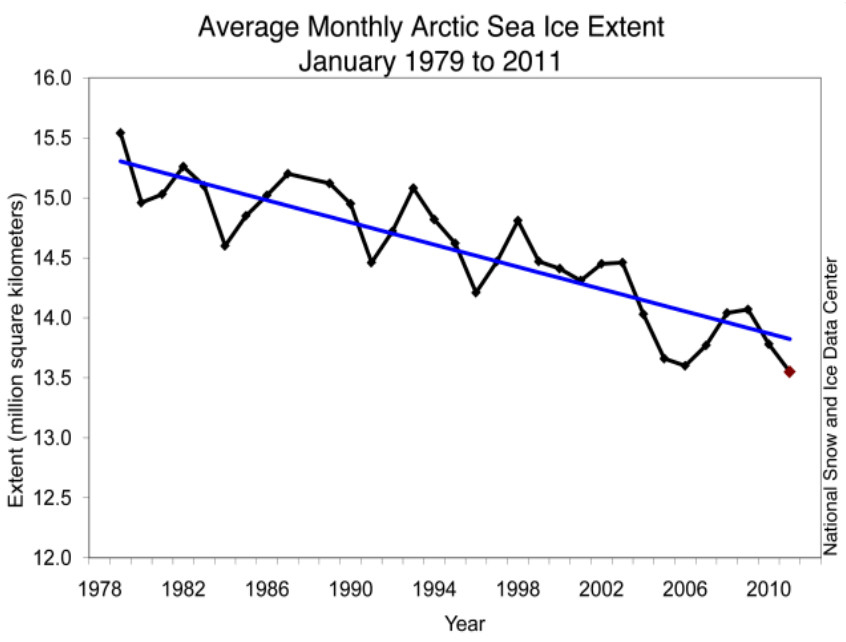
Surface Temperature Reconstructions for the Last 2000 Years (**National Research Council**, 2006)

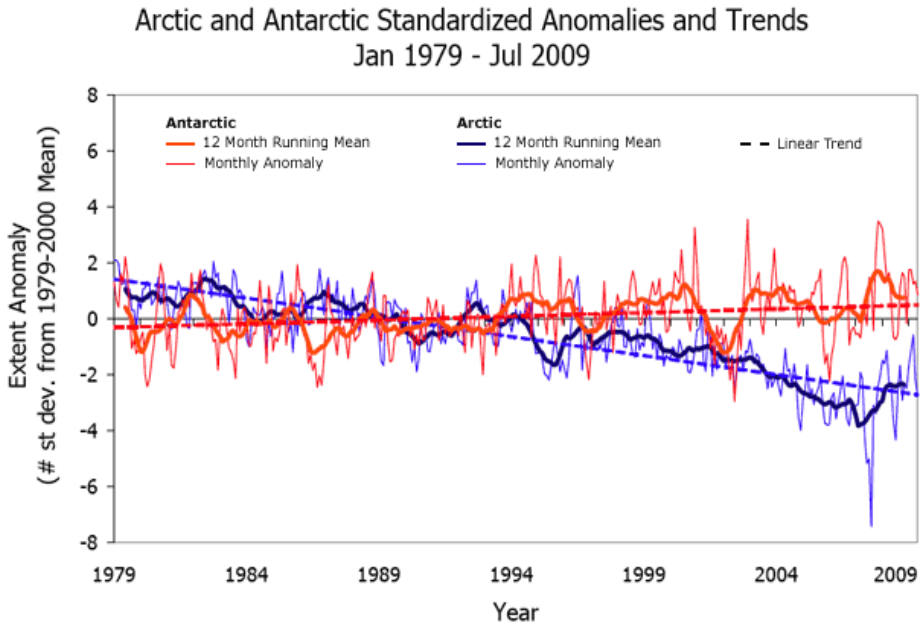
The sea is rising



Bruce C. Douglas (1997). "Global Sea Rise: A Redetermination". ***Surveys in Geophysics*** 18: 279-292. DOI:10.1023/A:1006544227856.

Sea ice extent is declining





National Snow and Ice Data Center, current operational data based on Defense Meteorological Satellite Program (DMSP) F17 Special Sensor Microwave Imager/Sounder (SSMIS) using **NASA-developed methods**. See: http://nsidc.org/arcticseaicenews/disclaimer1.html

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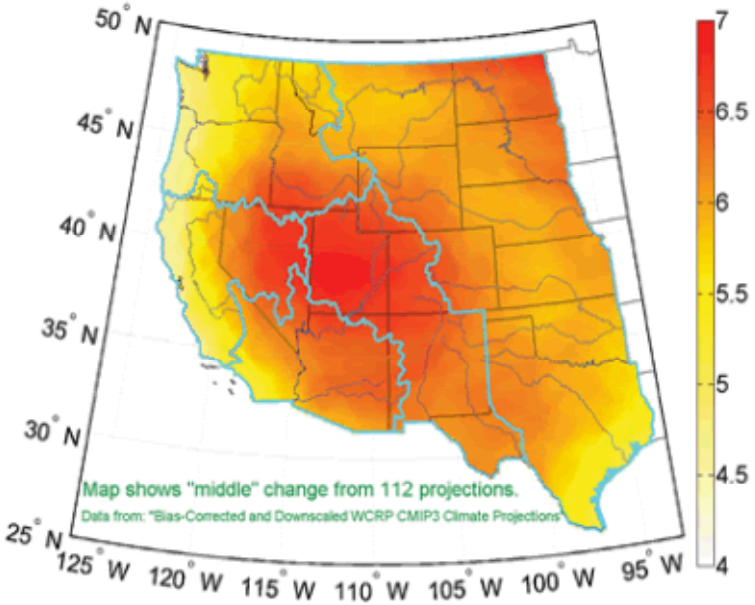
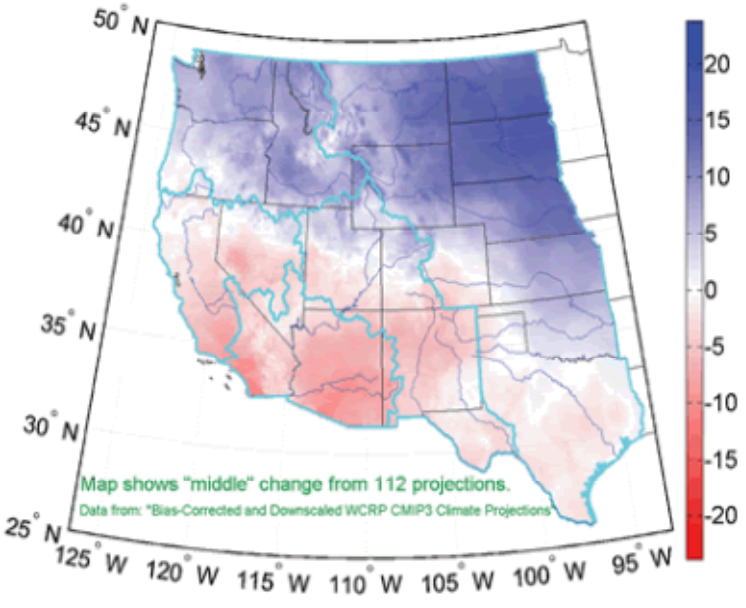
Climate change and water shortage linkage



Projected median temperature change in degrees Fahrenheit (°F) (of 112 climate projections) over the Western United States, 2070–2099 relative to 1950–1979.



Projected median percentage precipitation change (of 112 climate projections) over the Western United States, 2070–2099 relative to 1950–1979.

Climate Change will Affect Availability of Fresh Water Case Study: Bureau of Land Reclamation report, April 2011

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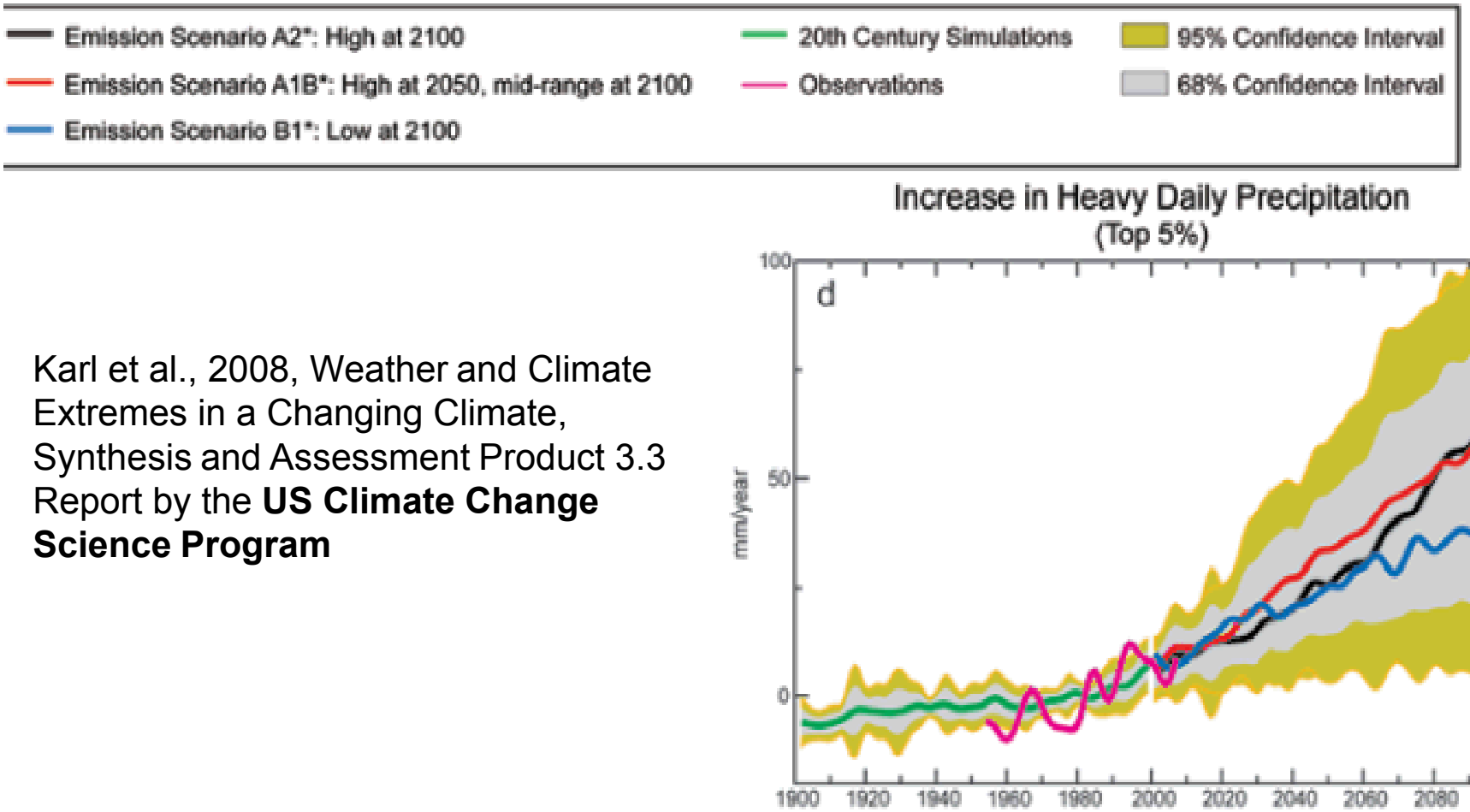
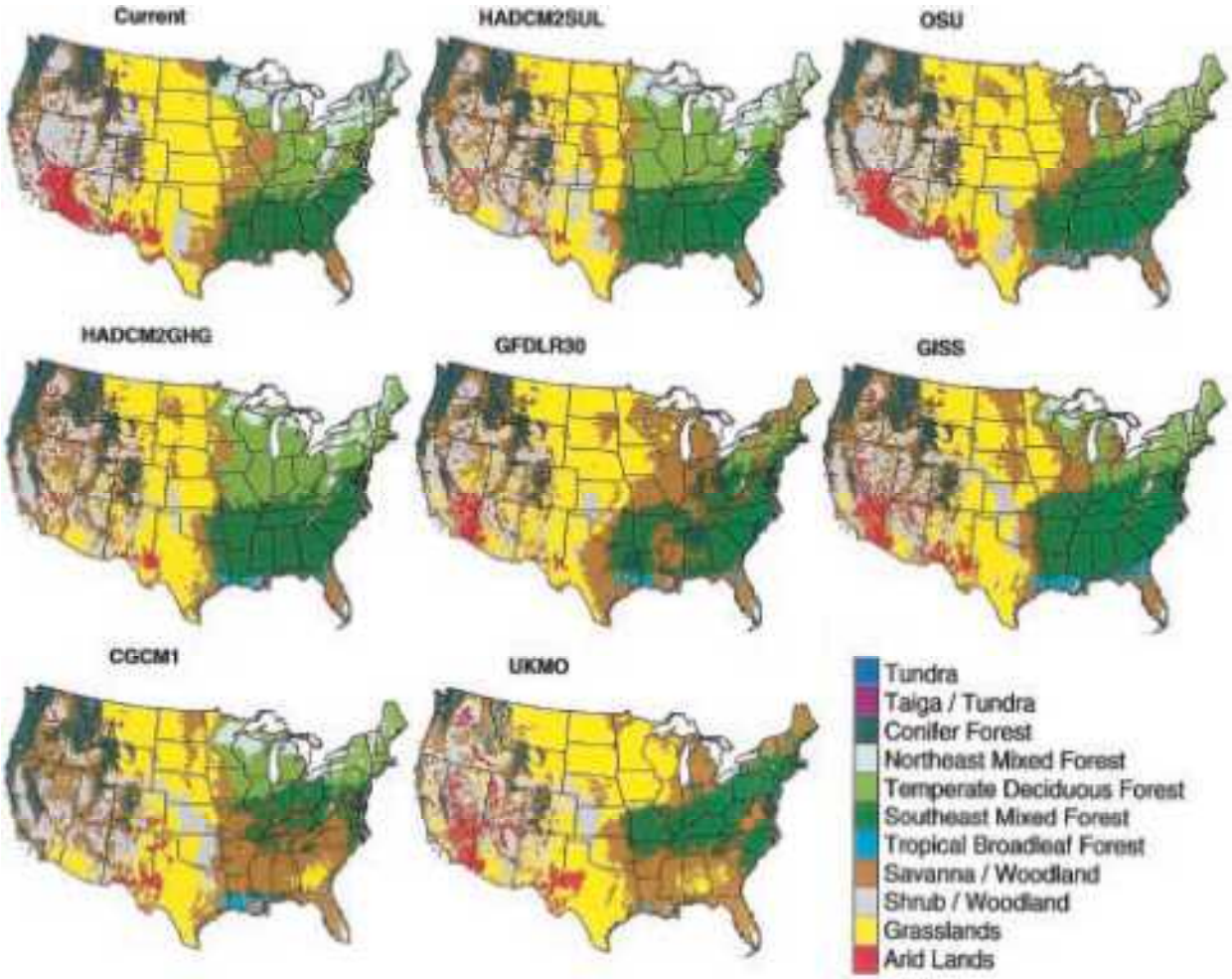
Frequency of severe weather events is predicted to increase markedly



Karl et al., 2008, Weather and Climate Extremes in a Changing Climate, Synthesis and Assessment Product 3.3 Report by the **US Climate Change Science Program**

Global ecosystems are expected to be substantially impacted

Earth's ecosystems are predicted to be substantially impacted



Simulated vegetation distribution for the conterminous US (10-km resolution) under the seven GCM climate scenarios (Bachelet et al., **Ecosystems**, 2001).

These challenges will manifest in environmental, economic and social problems with high impact on international stability and global security

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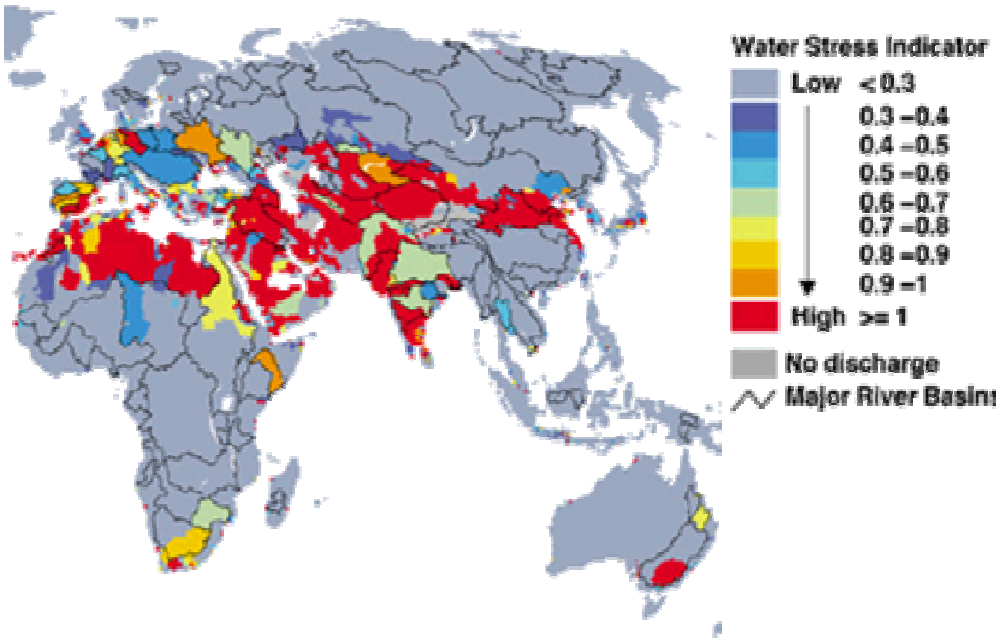
An example of the linkage between climate change and international stability

- **Golan Heights**
  - Source of river Jordan; with west bank provides 2/3 of Israel's water
- **West Bank**
  - >50% of Israel's future water supply
- **Gaza**
  - Population 1M, water supply nearly exhausted
- **Lebanon**
  - Primary source for water to Negev
- **Egypt/Sudan**
  - 82% of Nile comes from Ethiopia; Sudan controls flow to Egypt
- **Korean Peninsula**
  - Confrontation over Kumgansan Dam
- **Southwestern US**
  - Protracted drought; border tension driven by migration



Middle East

- **10% of world's population, 2% of water**

Water (m^3/person/yr)	1990	2025
Israel	470	310
Jordan	260	80
Saudi Arabia	160	50

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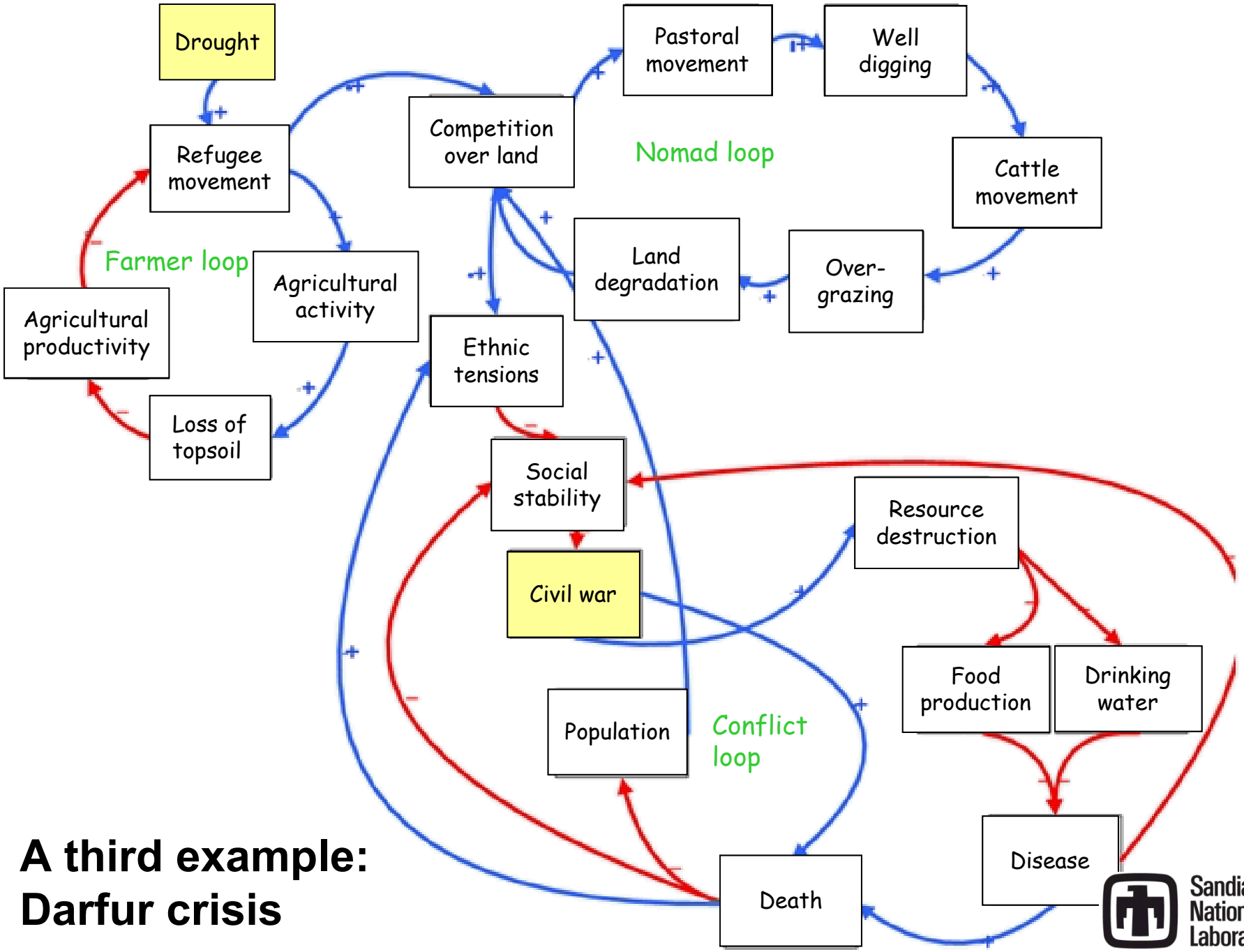
Another case study of linkage: Mesopotamia

- Tigris & Euphrates = main water sources for Syria and Iraq, but emanate from Turkey
- Turkey is a moderate Islamic nation and a NATO member
- 1974: Iraq and Syria nearly go to war over the Euphrates
- 1983: Turkey begins massive Anatolia dam project (~20 dams)
- 1990: Turkey reduces Euphrates to trickle to fill Ataturk dam; crop failures and power loss in Iraq
- 1991: During Gulf War UN coalition considers stopping Euphrates at Ataturk dam, Iraq uses human shields on dams
- …

"Turkey stands at the crossroads of almost every issue of importance to the United States on the Eurasian Continent" -- Amb. Richard Holbrooke



A third example: Darfur crisis

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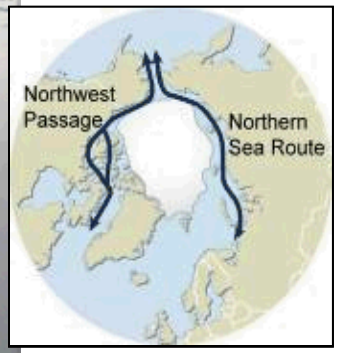
Climate change is a global operational security issue

THE TIMES

May 14, 2009

Russia warns of war within a decade over Arctic oil and gas riches



nature.com

May 14, 2009

Russia hints at Arctic war

Russia is banging its Arctic war drums again this week…

The role of the arctic may be transformed

- Up to 25% of mineral reserves in Arctic
- 80% of trade may go over new sea routes
- New infrastructure, support, and industry
- Regional economic boom predicted
- Chinâs supply chains may go north
- Russia is hub of expansion and tension
- Increased operational security challenges
- Likely unexpected & global feedbacks

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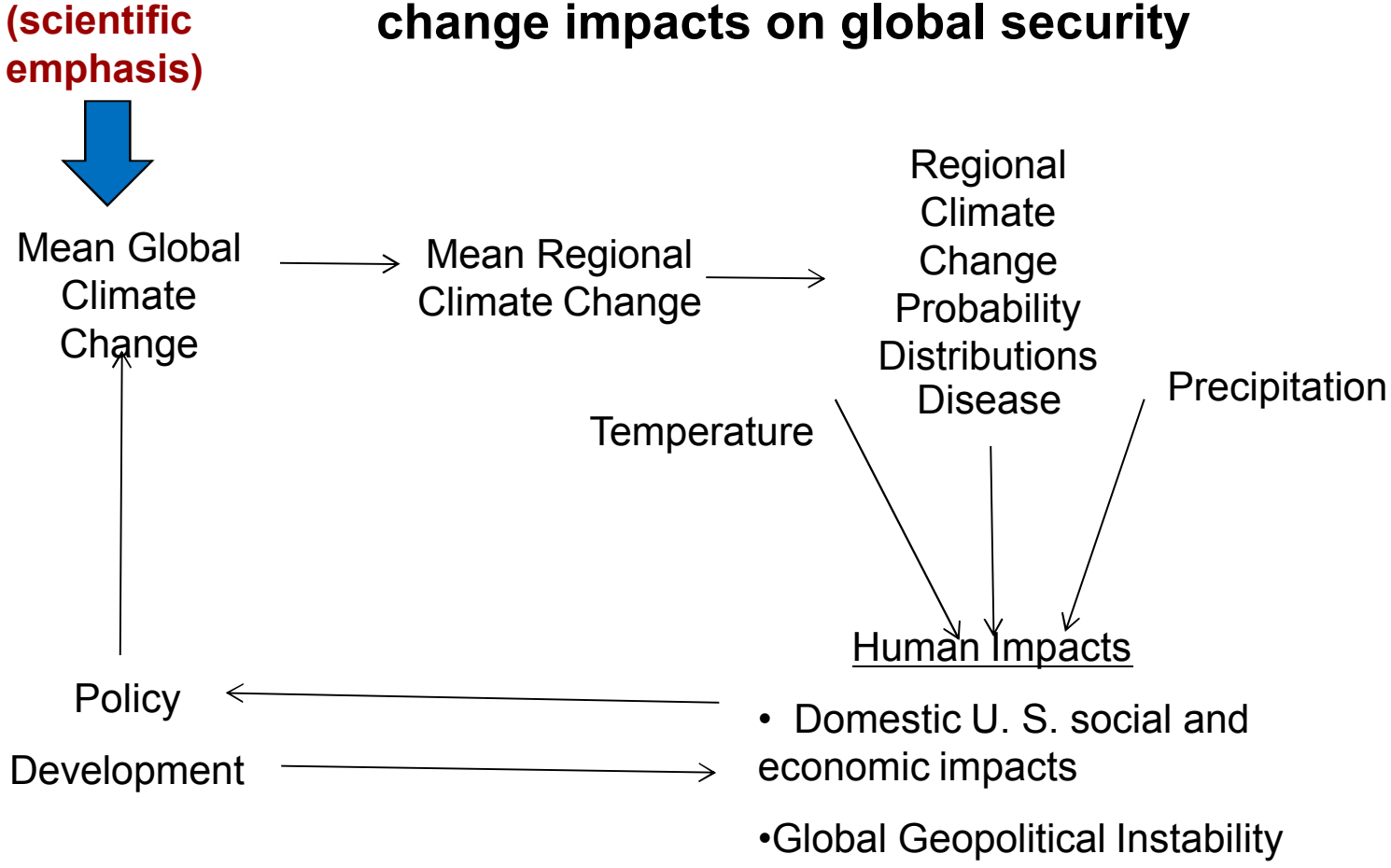
Technically deep approaches to key problems can help to mitigate these impacts

From a system perspective, our collective effort appears not well balanced

Needed: a systemic understanding of climate change impacts on global security



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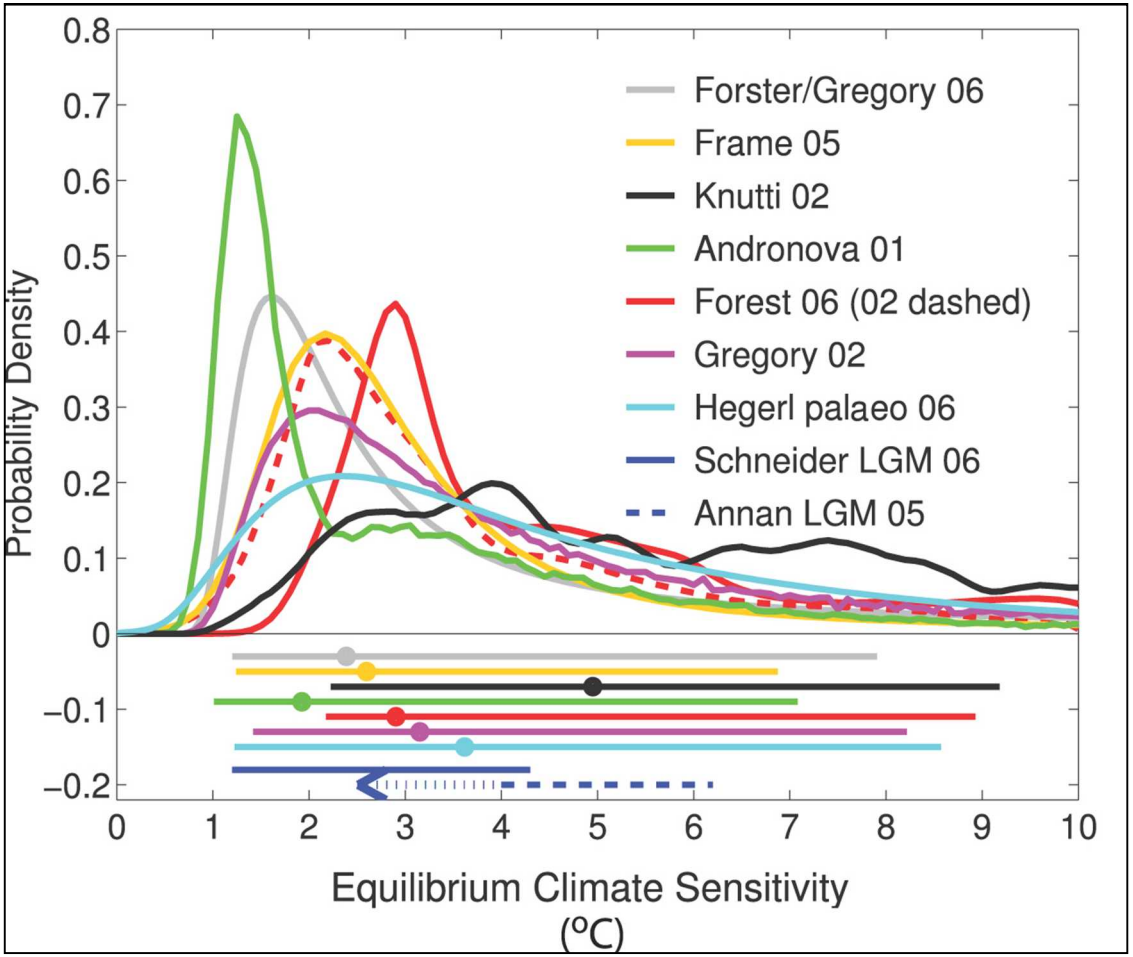
Arguably, we've invested a lot of effort in solving the not-most-important problem



Source: Hegerl, et al. (2007).

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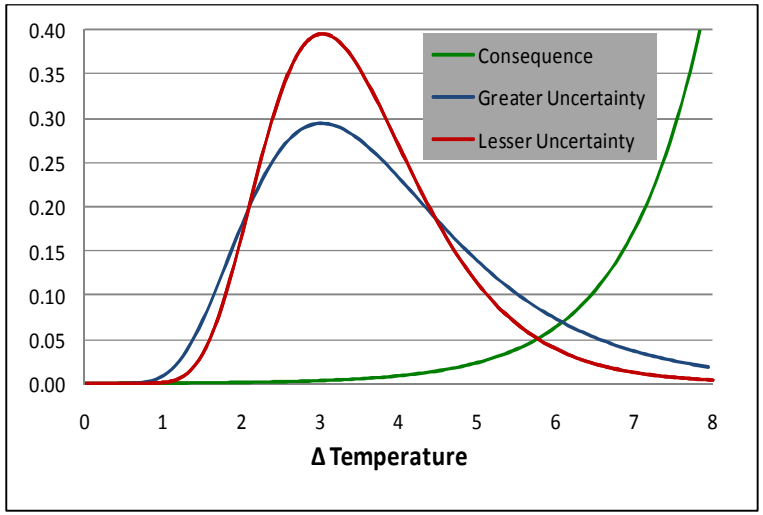
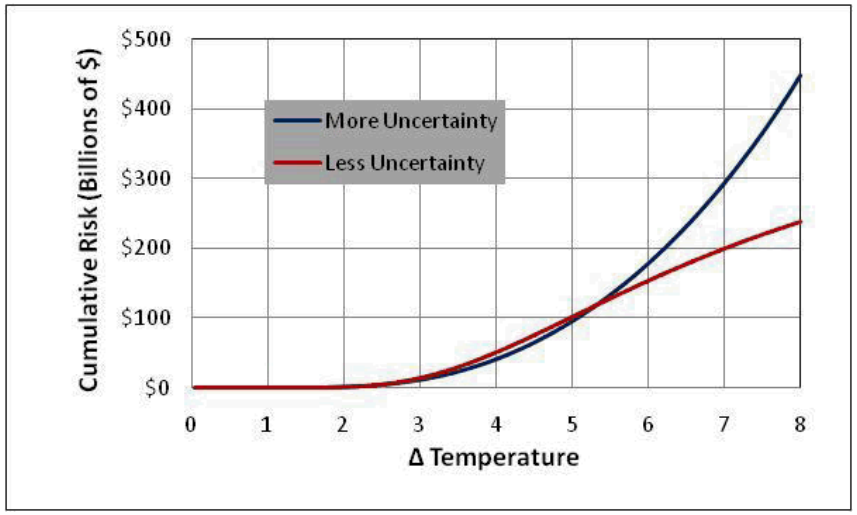
Societal risk may actually be concentrated in the tails (rather than the mean) of the distribution



Sample probability distributions with typical consequence function



How uncertainty amplifies the tail of the risk distribution

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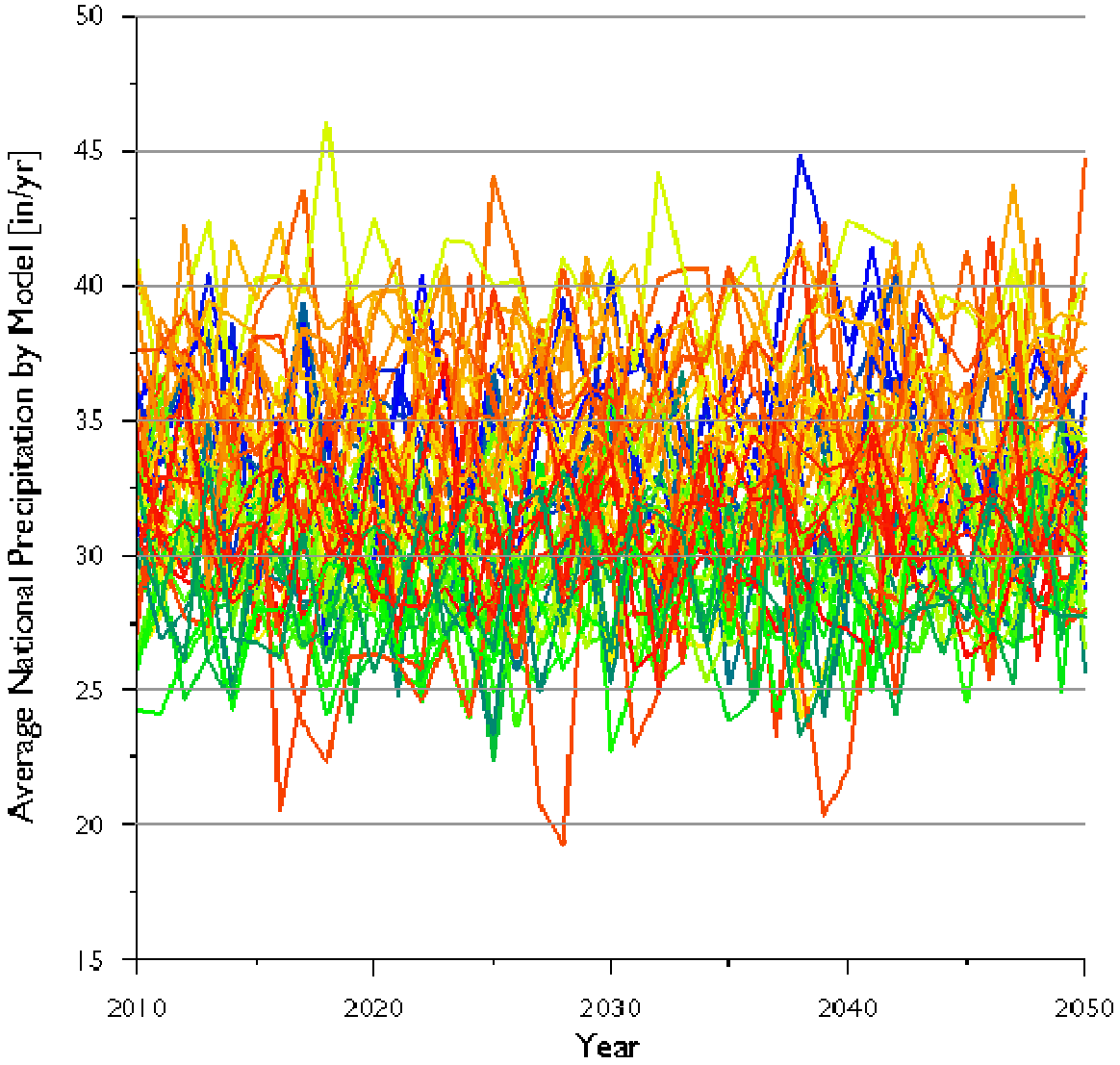
Furthermore, uncertainty makes the job of the policy maker a very tough one



IPCC Ensemble of 53 Climate model runs predicting precipitation

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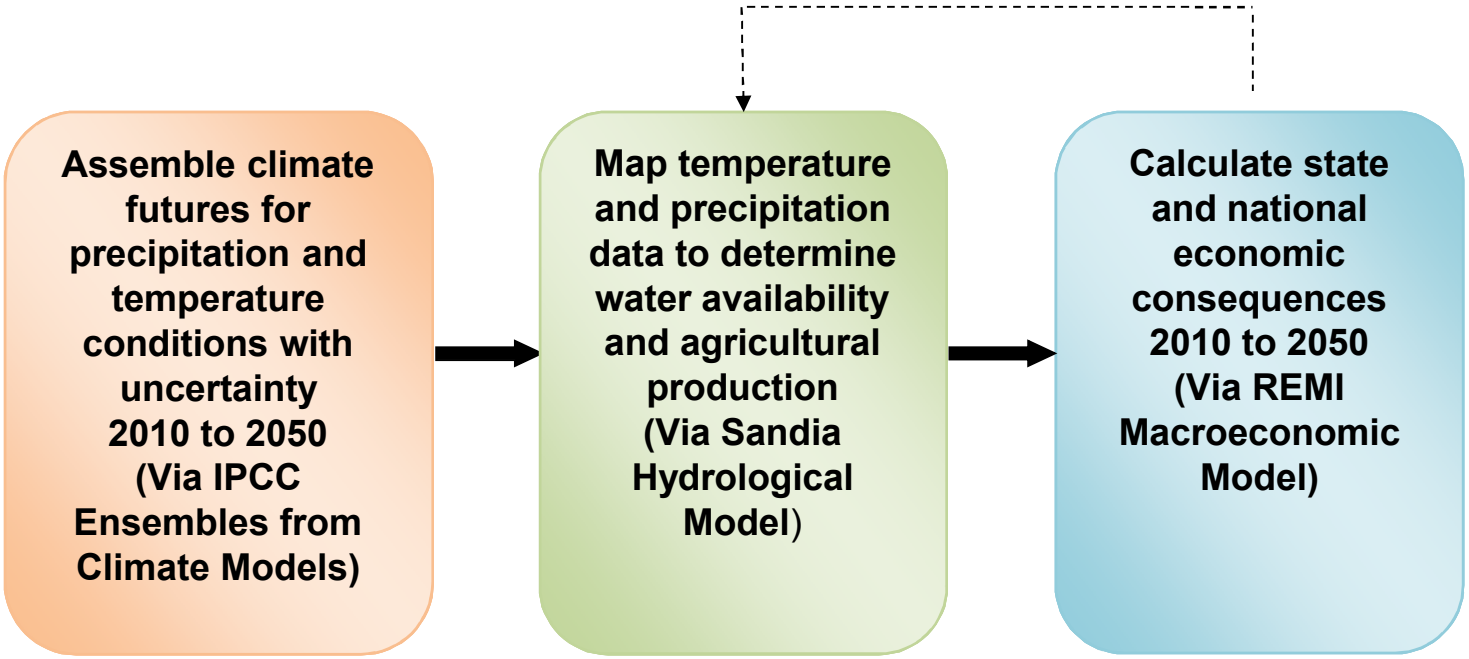
How to make sense of all this?



$$Risk = \iint_{\tau,P} Consequence(t,p) \times dt \times dp$$

p = probability
t = time

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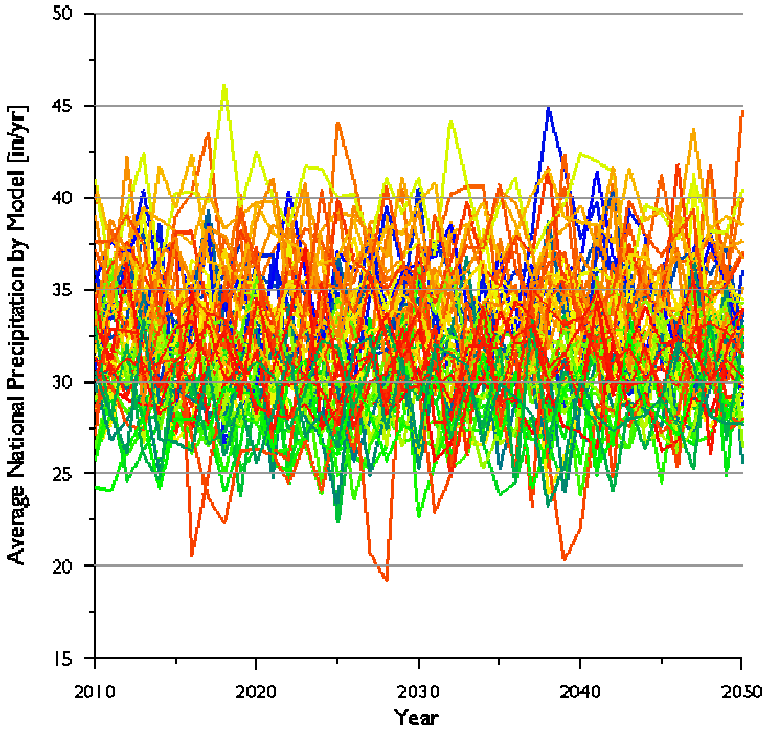
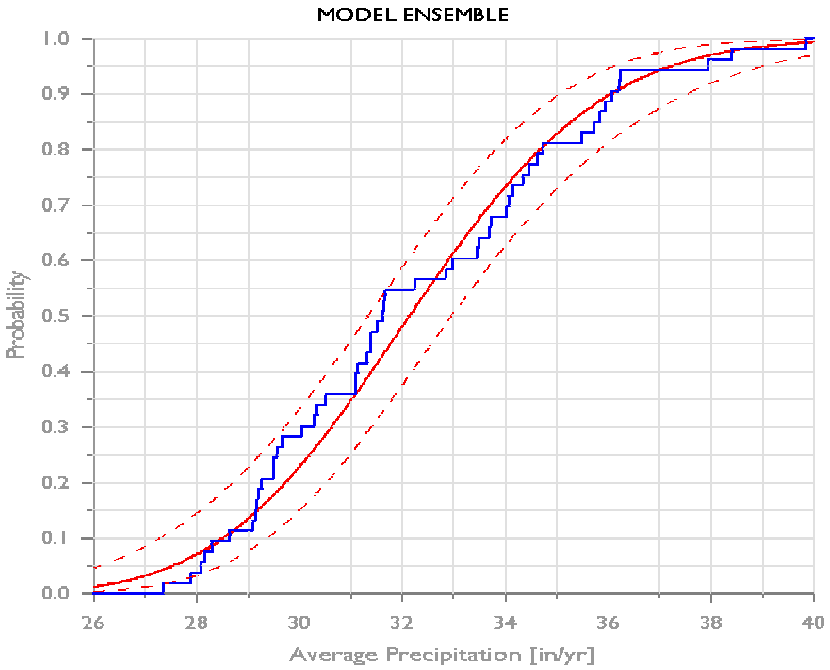
From “noise” to understanding





IPCC Ensemble of 53 Climate model runs transformed to *“exceedance” probability*

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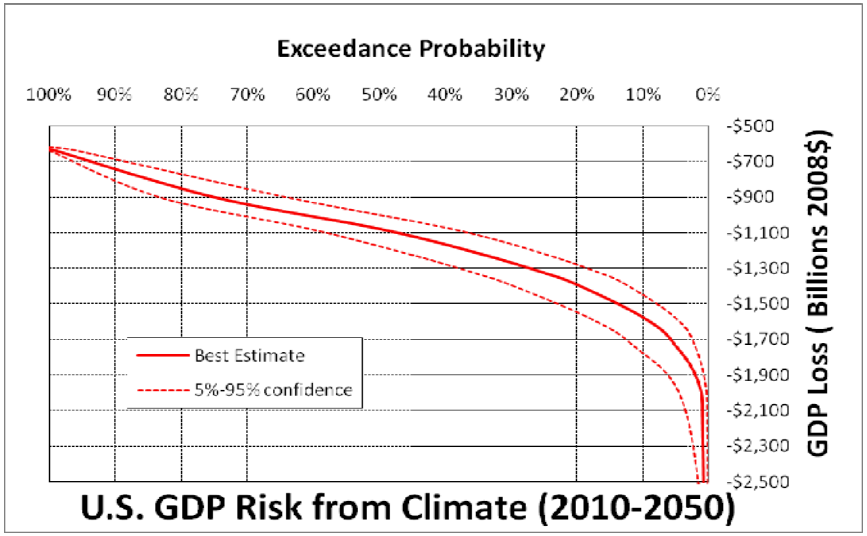
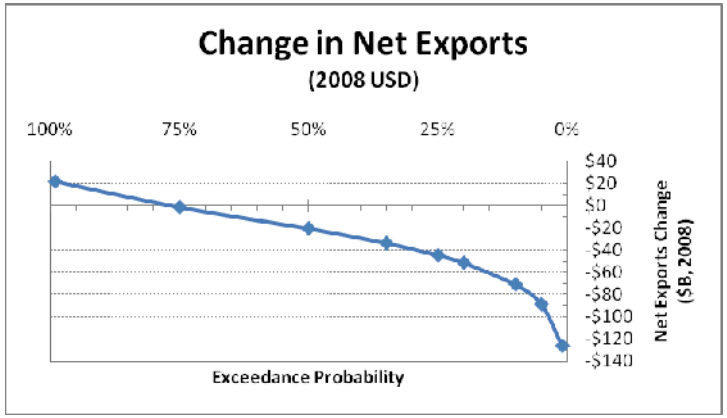
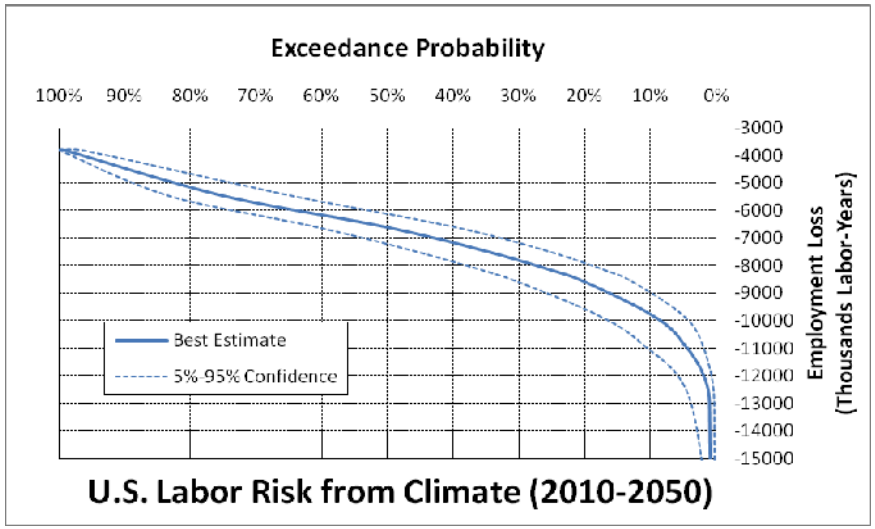
A prototype version of a climate change national risk assessment



- Continental US states; world fixed
- Precipitation only
- 70 economic sectors
- Business & population migration over 2010 to 2050





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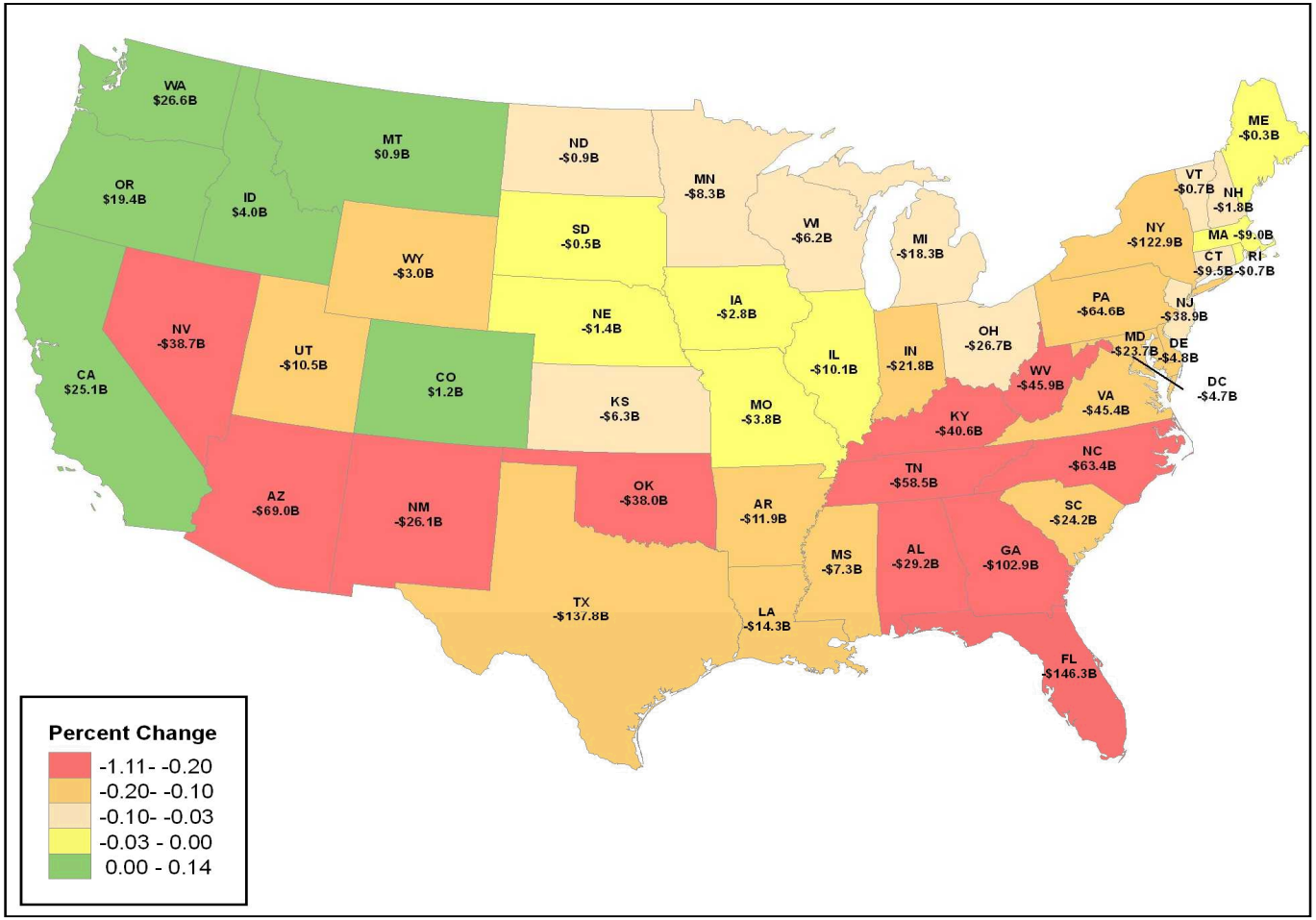
Predicted GDP risk by state (subject to limitations of the study)



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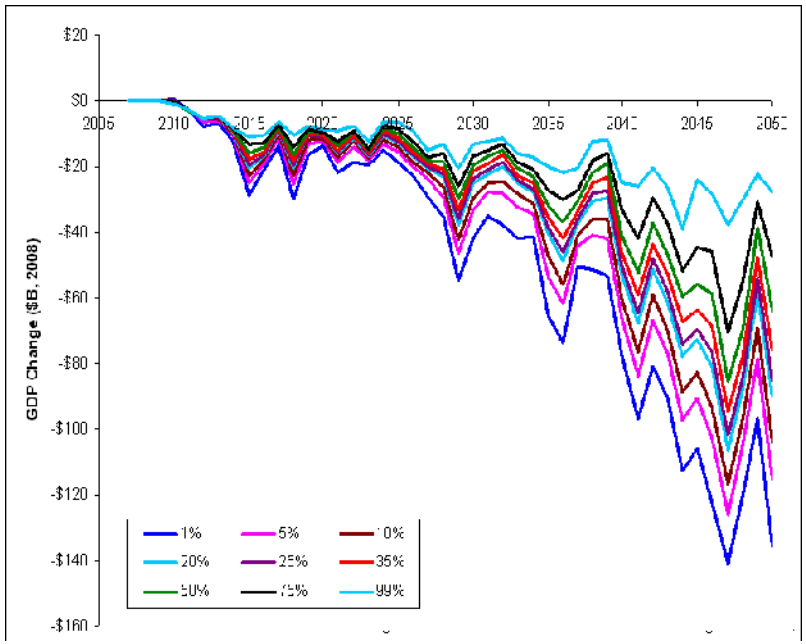
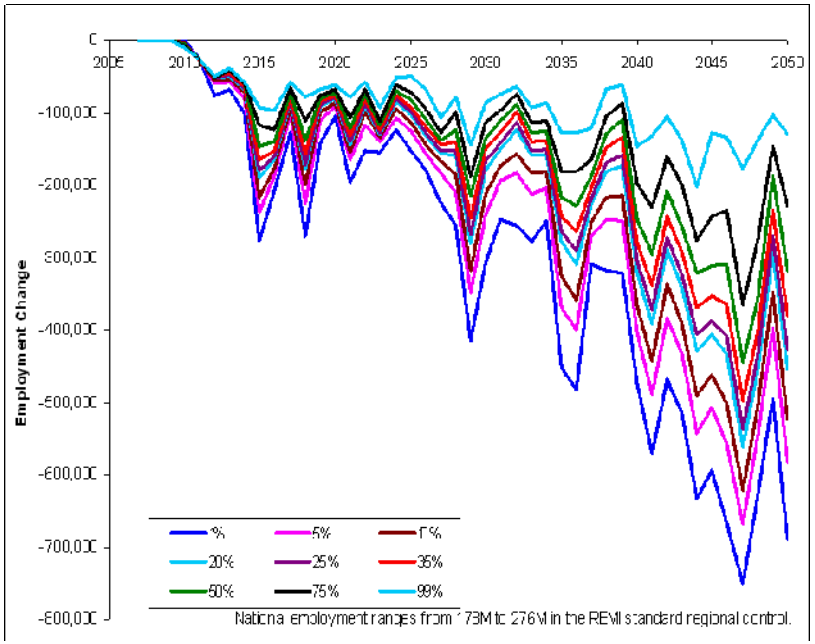
Volatility is a dominating risk factor



Annual U.S. GDP impacts



Annual U.S. employment impacts

Volatility brings the average future climate impacts into the present

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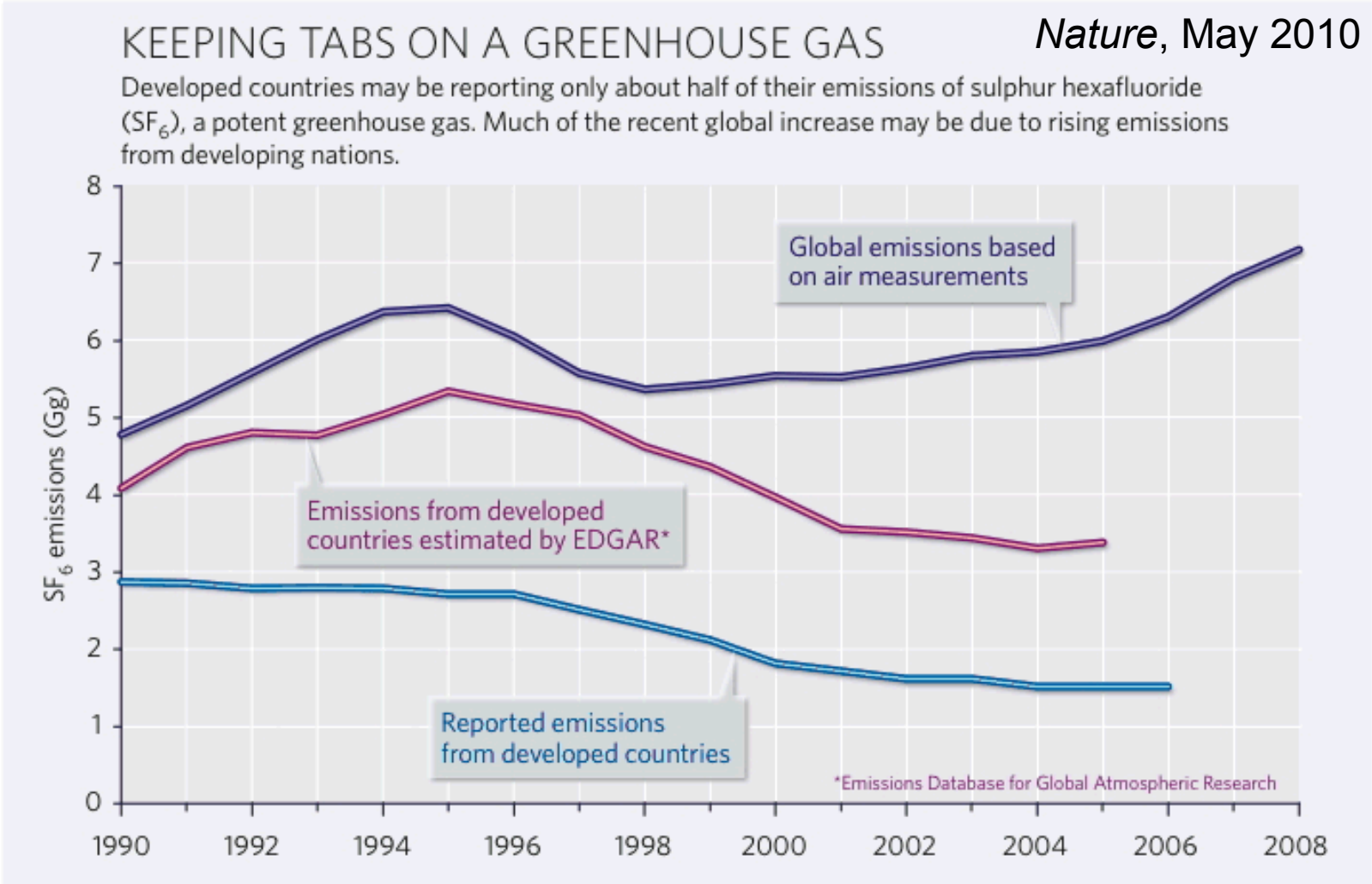
Current green house gas estimation methods are inaccurate

Nature, May 2010



I. LEVIN ET AL./ATMOS. CHEM. PHYS **10**, 2655–2662; 2010

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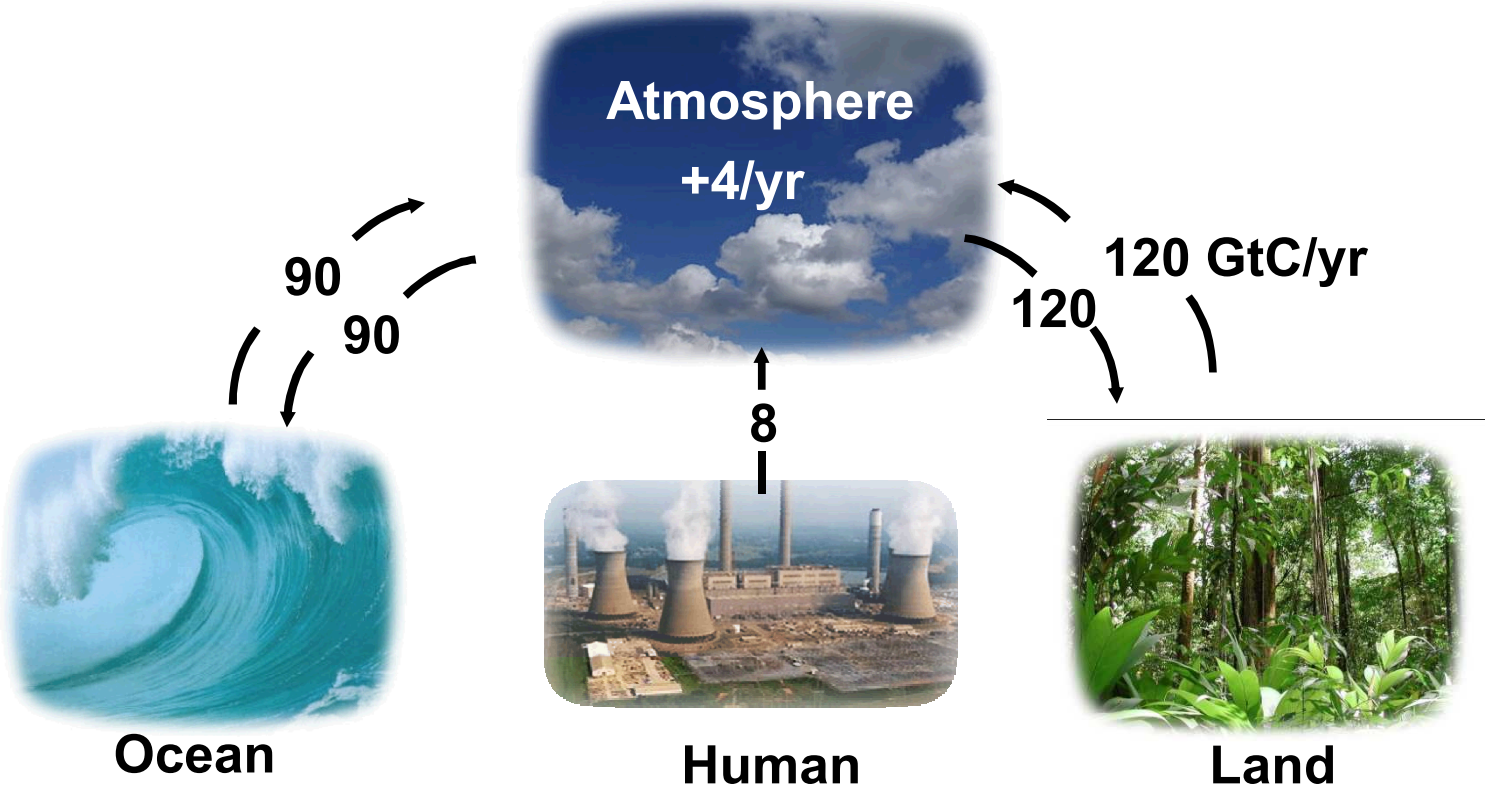
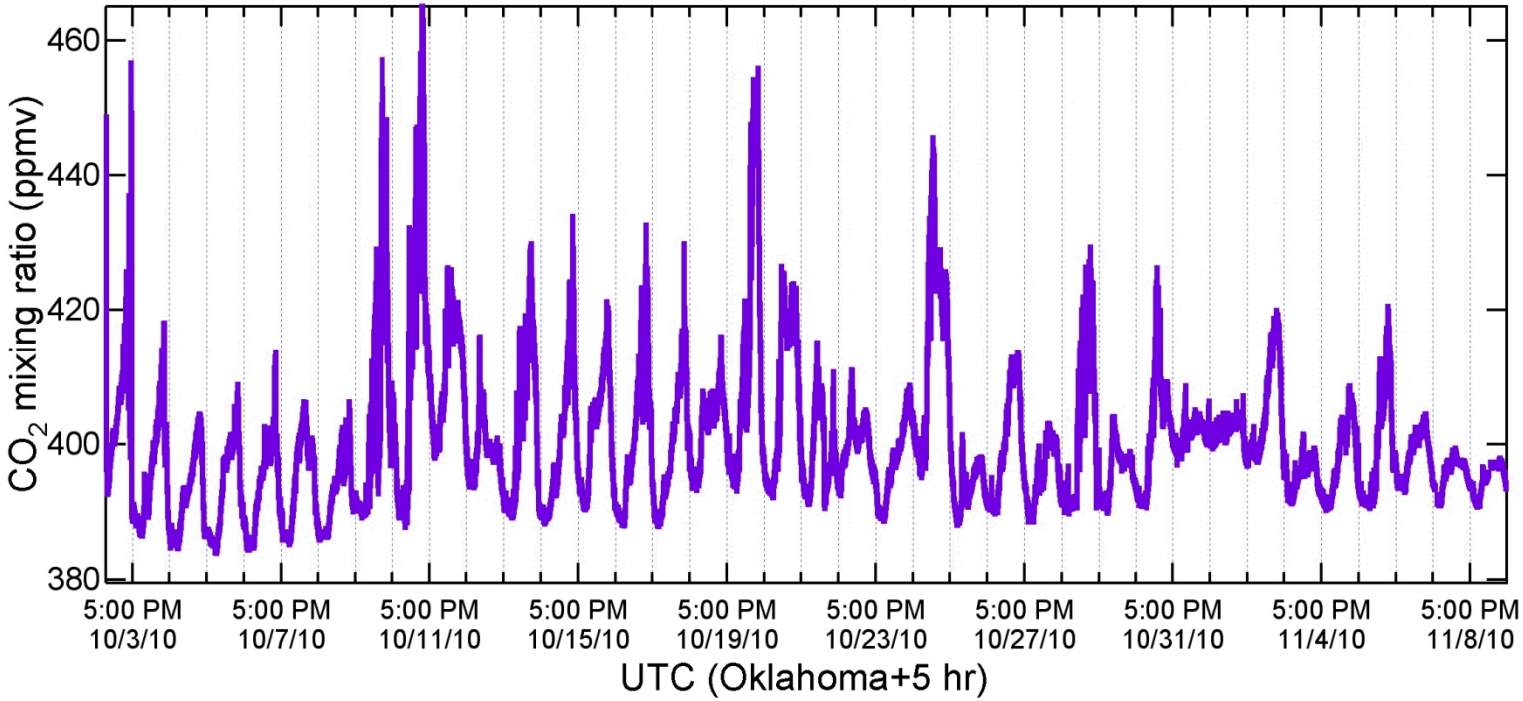
We are looking for a small signal



- Biogenic component dominates
- CO_2 is long-lived (hundreds to thousands of years)
- Picking out the anthropogenic component is *challenging*…

…in a noisy environment



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A combined space and land-based sensing program can address this

- Tracer-based GHG attribution with uncertainty quantification
- Land, sea, air, space network of tracer and GHG measurements
- Sensor placement guided by uncertainty analysis
- Source estimates sufficient to support treaty verification

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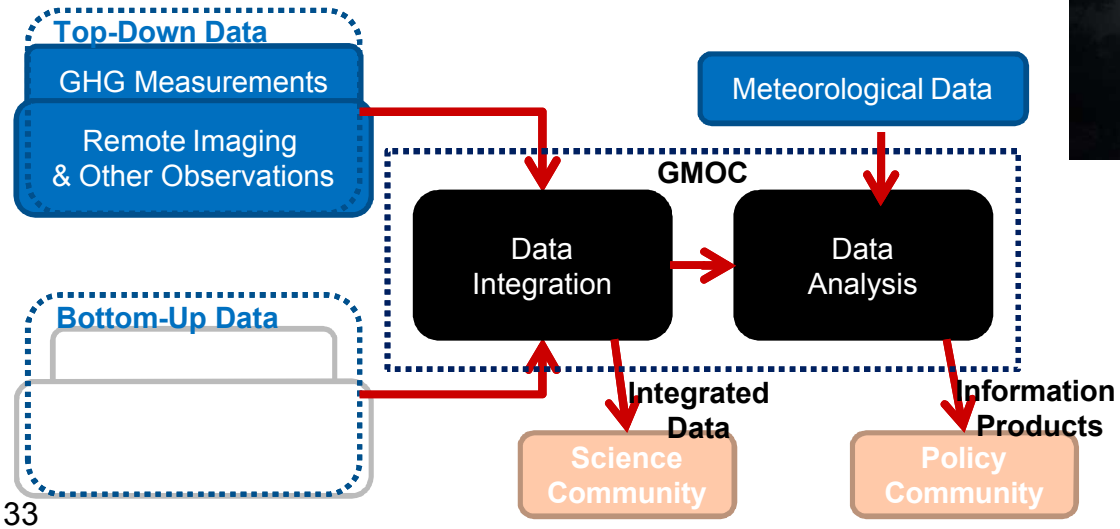
Proposed Green House Gas Information System

Enable verifying compliance with a future international carbon treaty via The Greenhouse Gas Information System (GHGIS)

- **DOE/BES funded SNL, LANL, LLNL, JPL collaboration for 6 month scoping study**
- **Discriminate anthropogenic GHG emissions & attribute to country of origin**
- **Includes space, air, and ground sensor assets integrated at an Ops Center**



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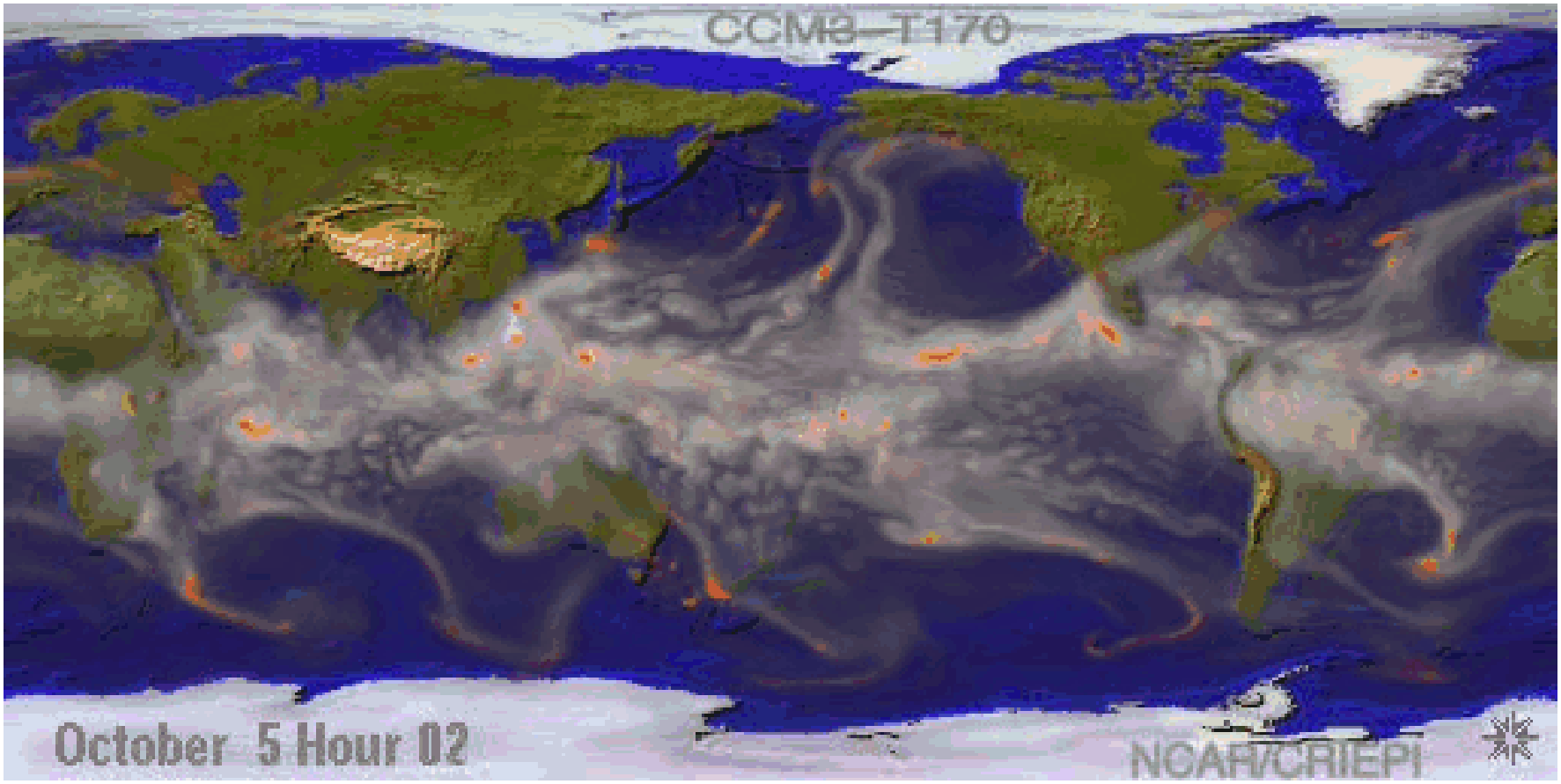
Supercomputing simulations help us understand how the climate will respond to changes in forcing



Water vapor (white) and total precipitation (orange)

Source: http://www.vets.ucar.edu/vg/CCM3T170/index.shtml

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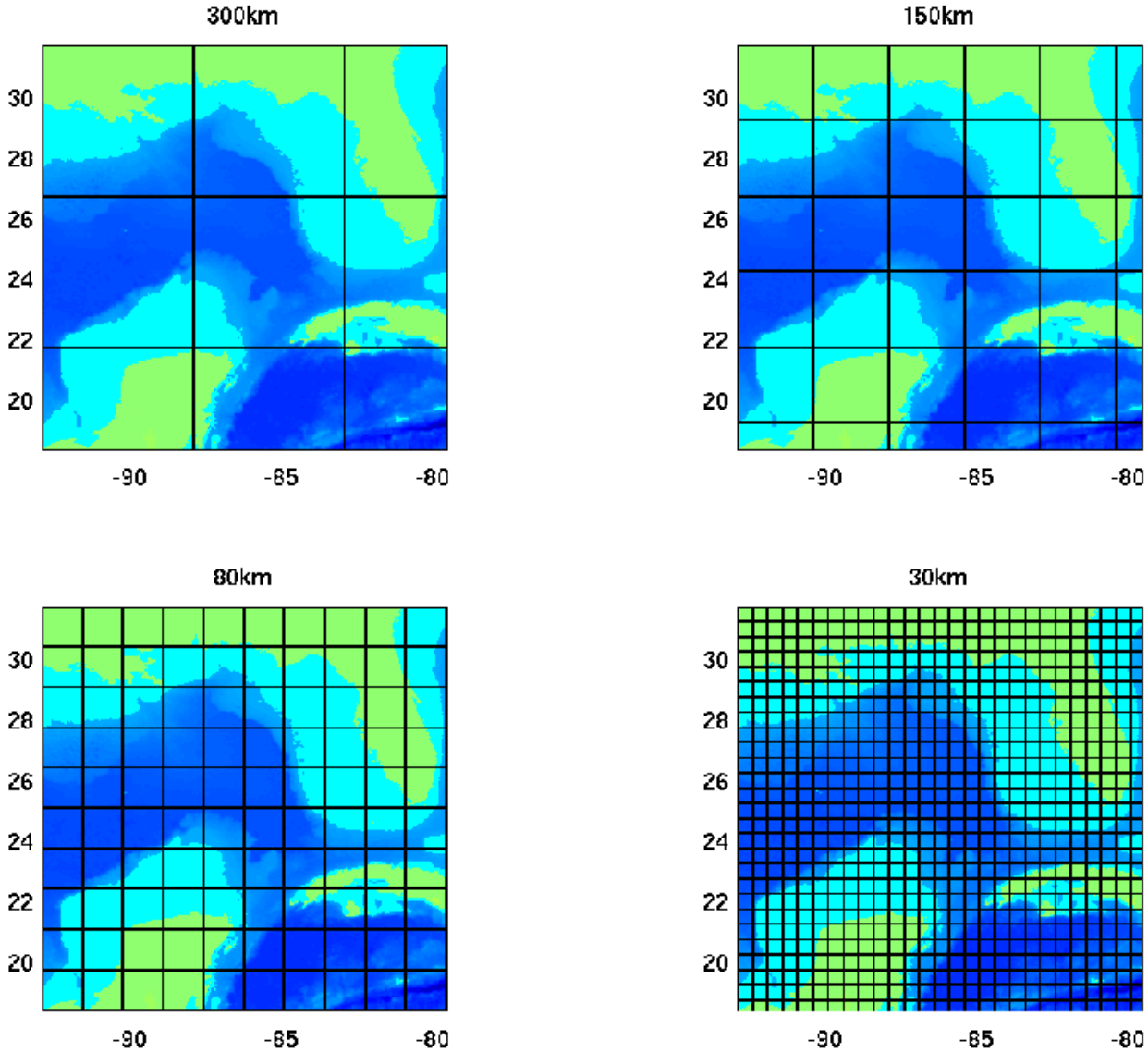
But there resolution matters quite a bit



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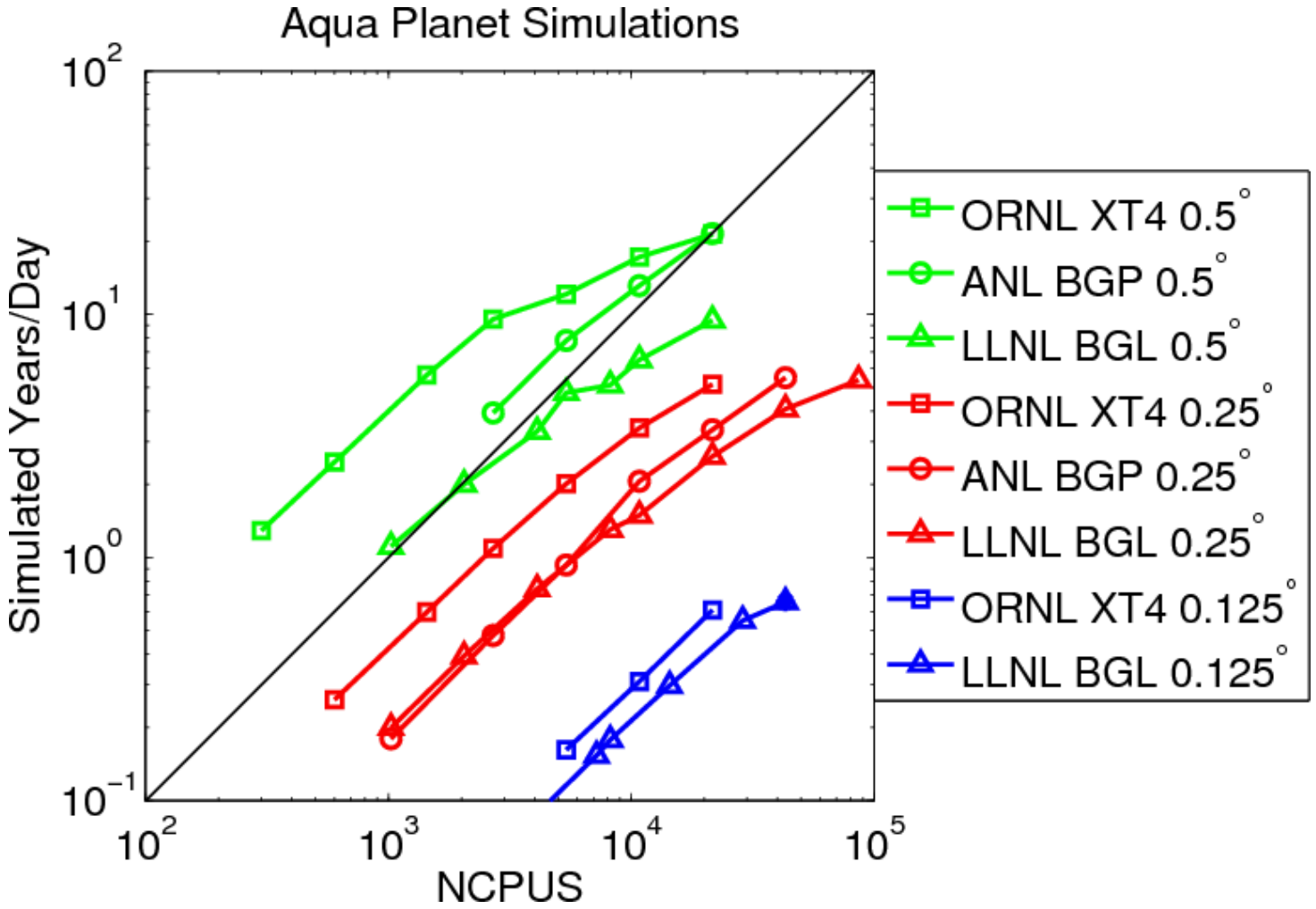
And hence their scalability really matters



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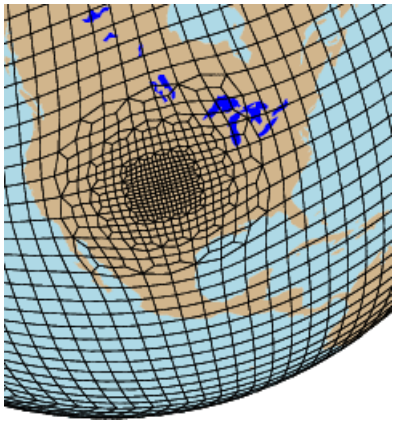
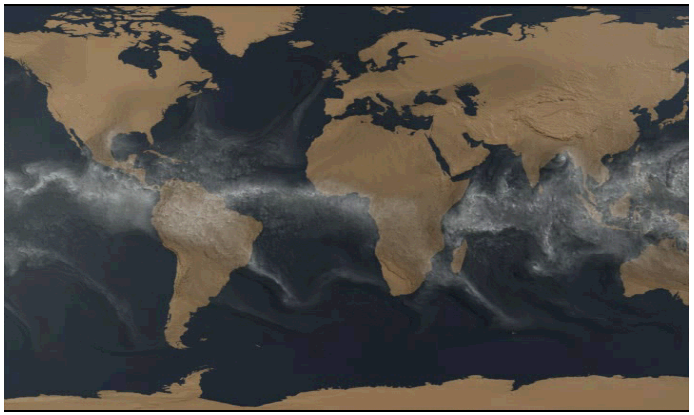
We are striving for regional simulations with quantified uncertainty

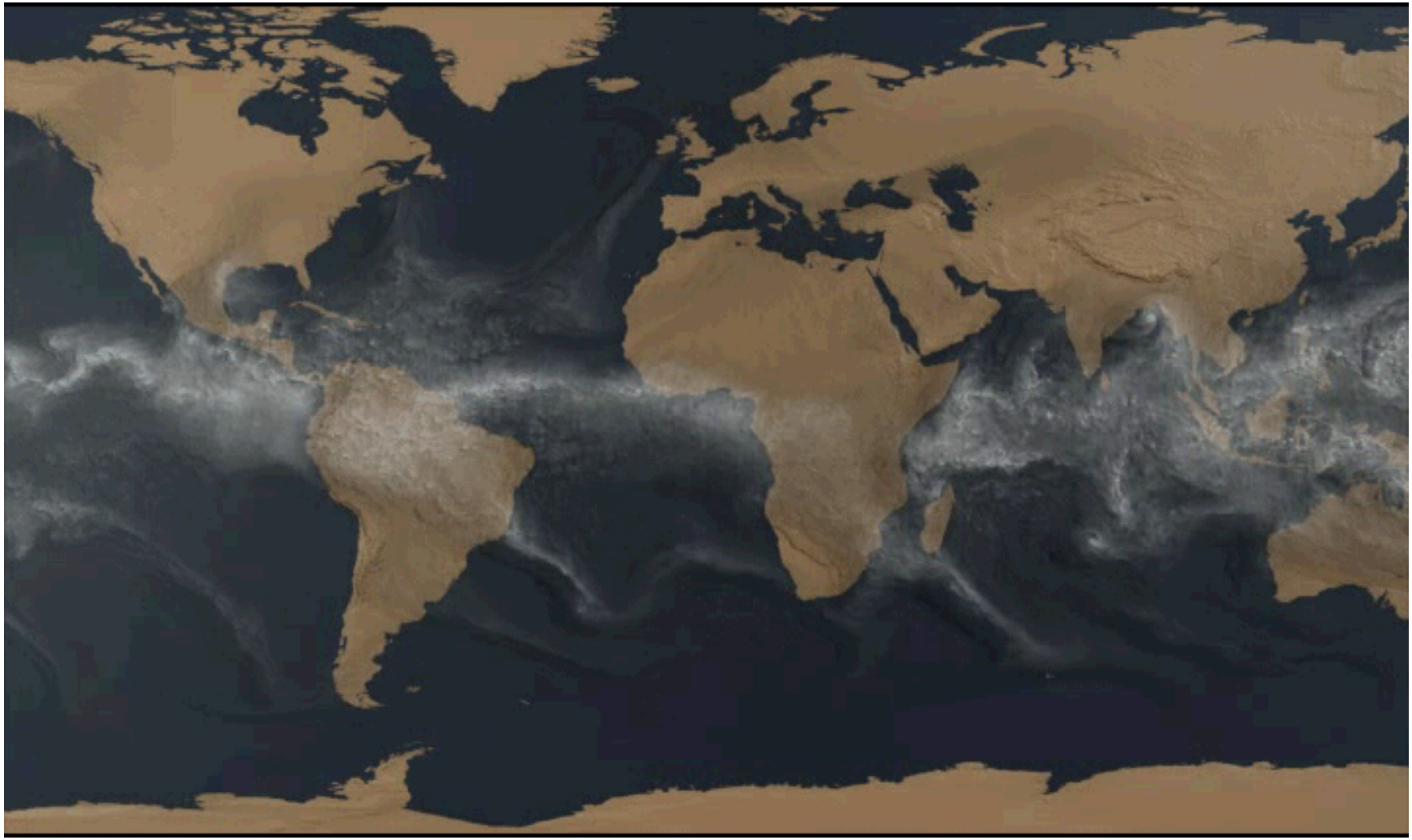
Examples: (left) cubed-sphere for uniform high resolution, (right) a global 1 degree grid smoothly transitioning to 1/8 degree over the Southern Great Plains ARM site.



- **13km resolution (IPCC is currently at 175km)**
- **170K cores (ORNL Jaguar, 4.6 Simulation Years per Day)**



The most highly resolved global atmospheric simulation to date



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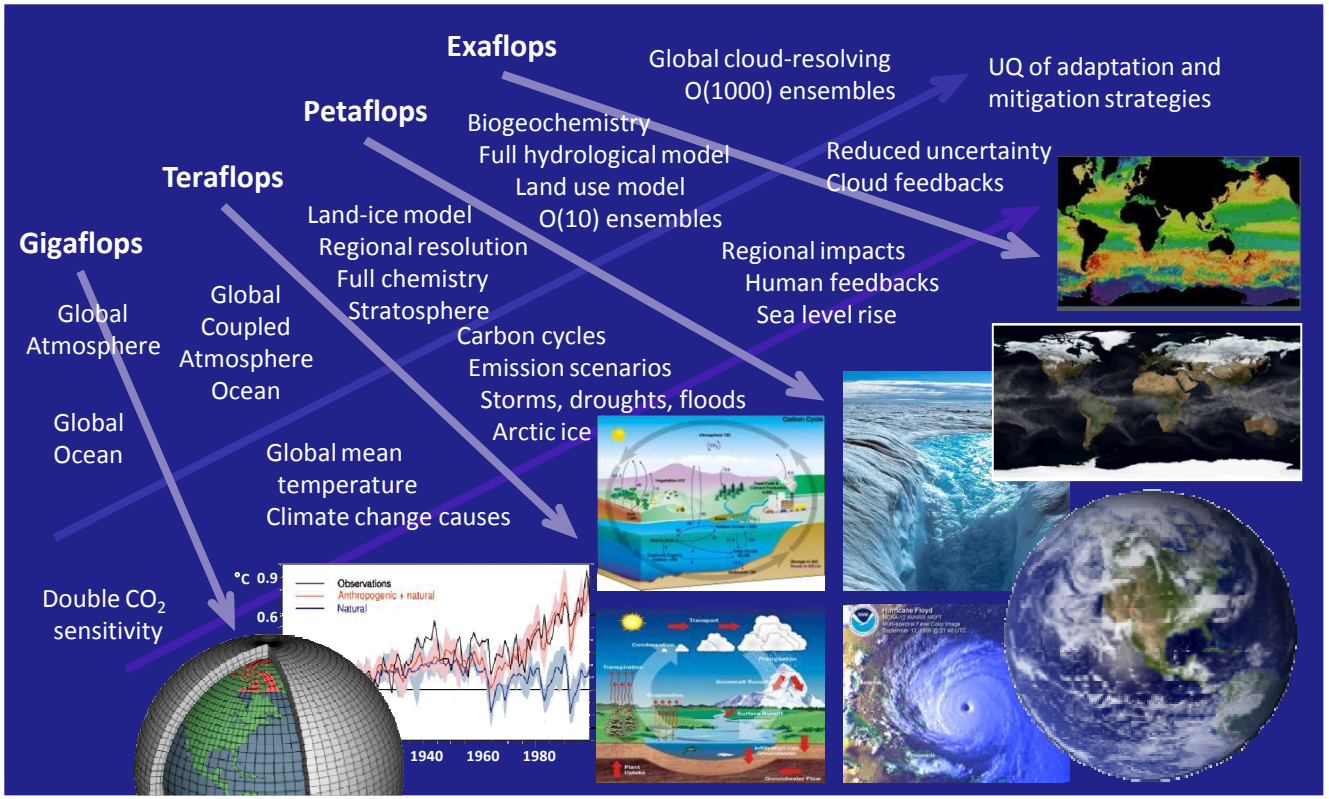
Putting it all together (technically)

Develop a globally cloud-resolving, multiscale earth system model with integrated physics, chemistry, biology, and uncertainty quantification.



The road to exascale will enable robust climate simulations with quantified uncertainties for assessment of climate change adaptation and mitigation strategies.

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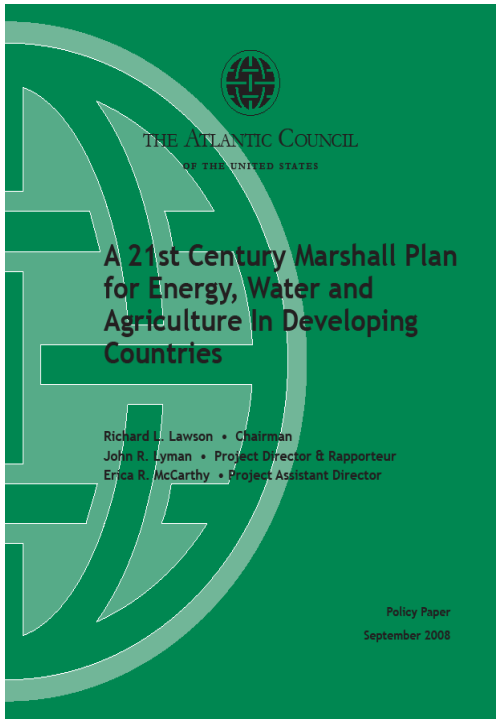
In isolation, these technical approaches will fail – a deeper and broader collaboration between the technical and policy communities is needed

An example of a technology-policy collaboration

Create a "21st Century Marshall Plan" for energy, water and agriculture in developing countries

"Win the war without fighting the battle" – Collaboration w/ Atlantic Council to inform US foreign aid paradigm for energy-water-agriculture sustainability in developing countries



History:

- SNL and AC co-develop "Marshall Plan" culminating in the 2008 policy report.
- Focus on countries meeting certain governance criteria and eager to collaborate.

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My thoughts on collaboration

- C.P. Snow
- What the scientists can bring
- What the policy makers can bring
- “Powering the Future”

Your thoughts?