Future Changes in Climate, Sea Level and Hydrology

Anthony J. Broccoli
Department of Environmental Sciences
Rutgers University
broccoli@envsci.rutgers.edu

Delaware River Basin Commission
West Trenton, NJ
July 19, 2006

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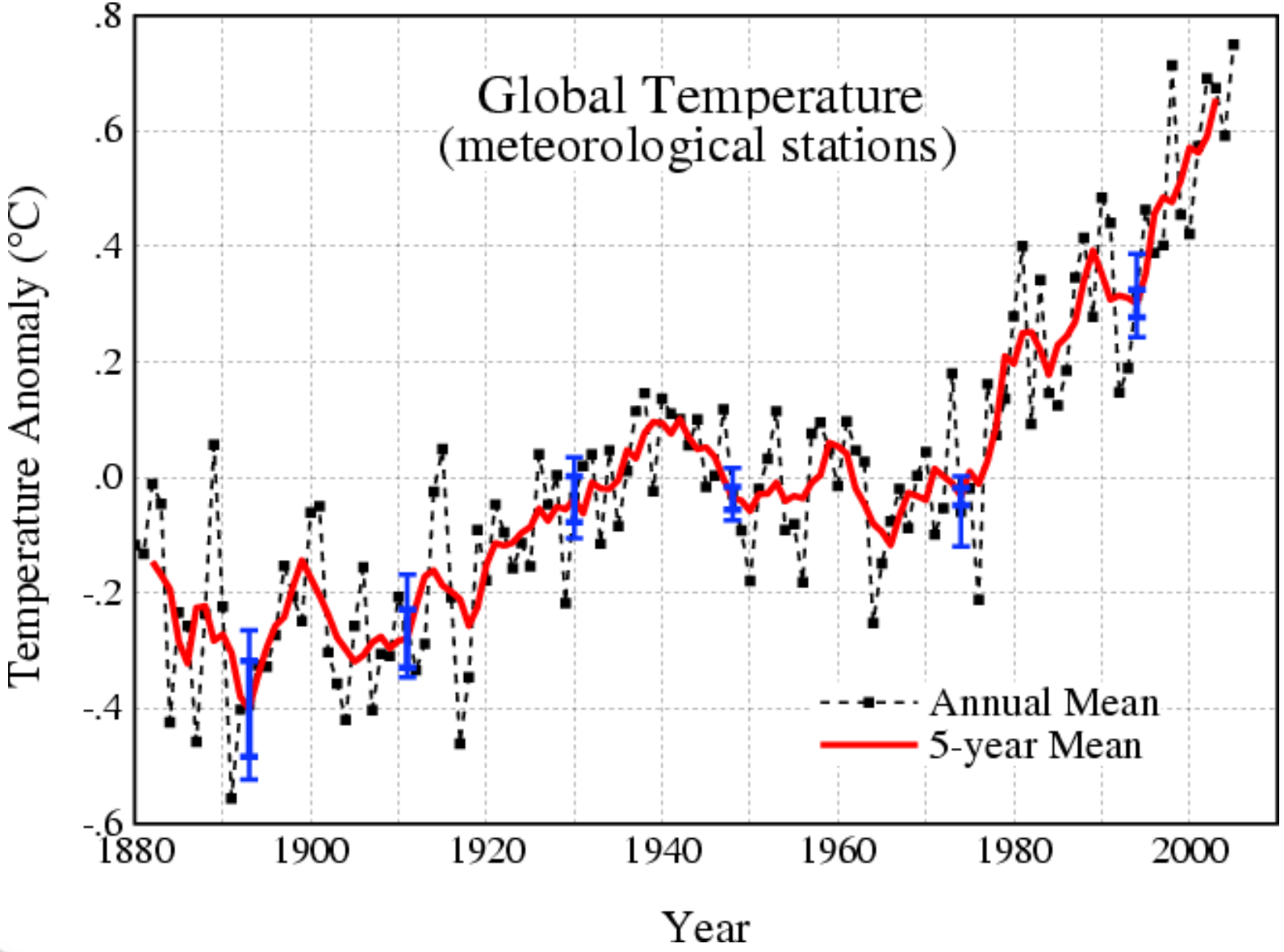

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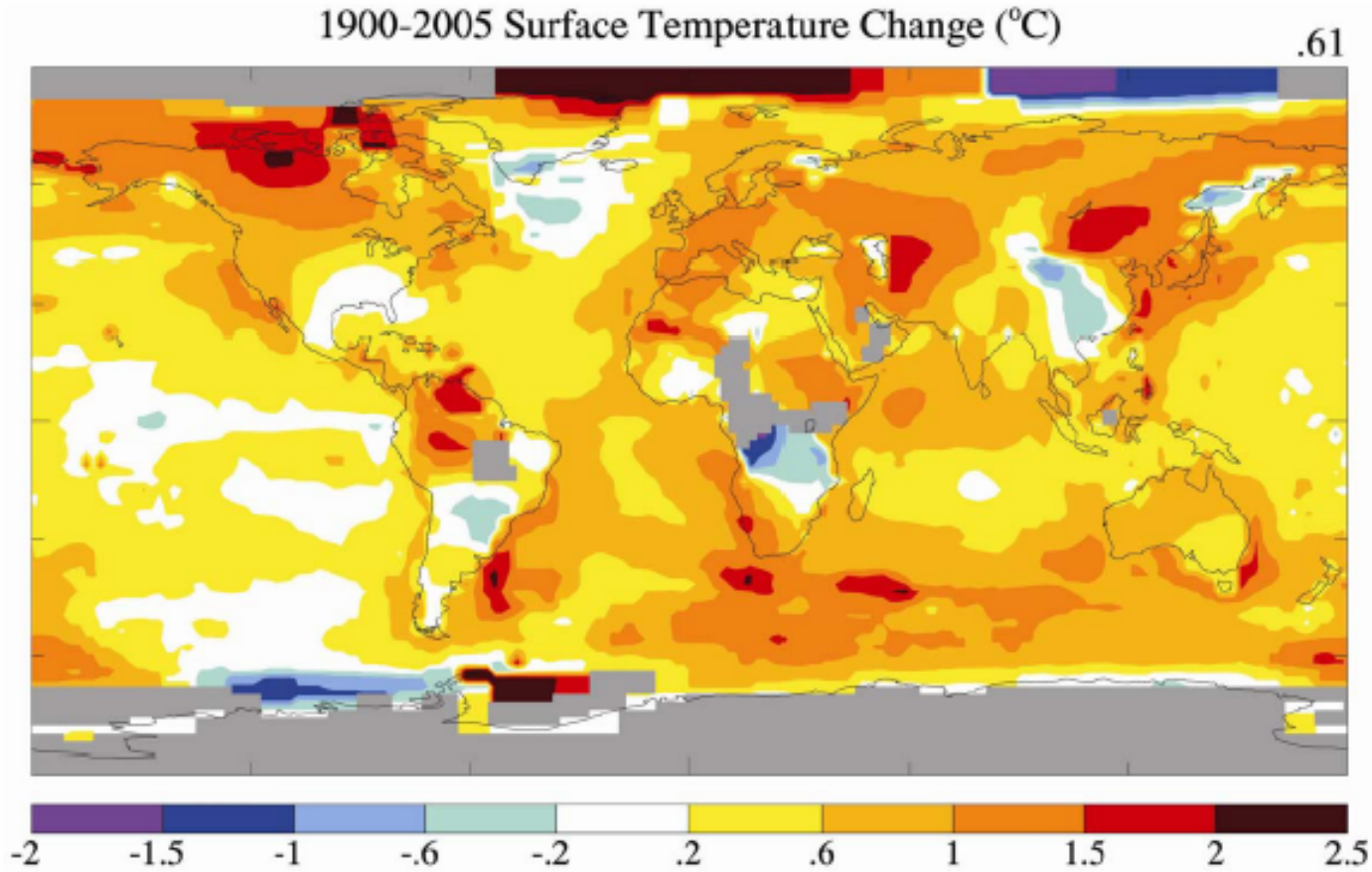

Change of surface temperature index based on local linear trends using surface air temperature over land and SST over ocean.

Sources: Hansen et al., *JGR*, **106**, 23947, 2001; Reynolds and Smith, *J. Climate*, **7**, 1994; Rayner et al., *JGR*, **108**, 2003.

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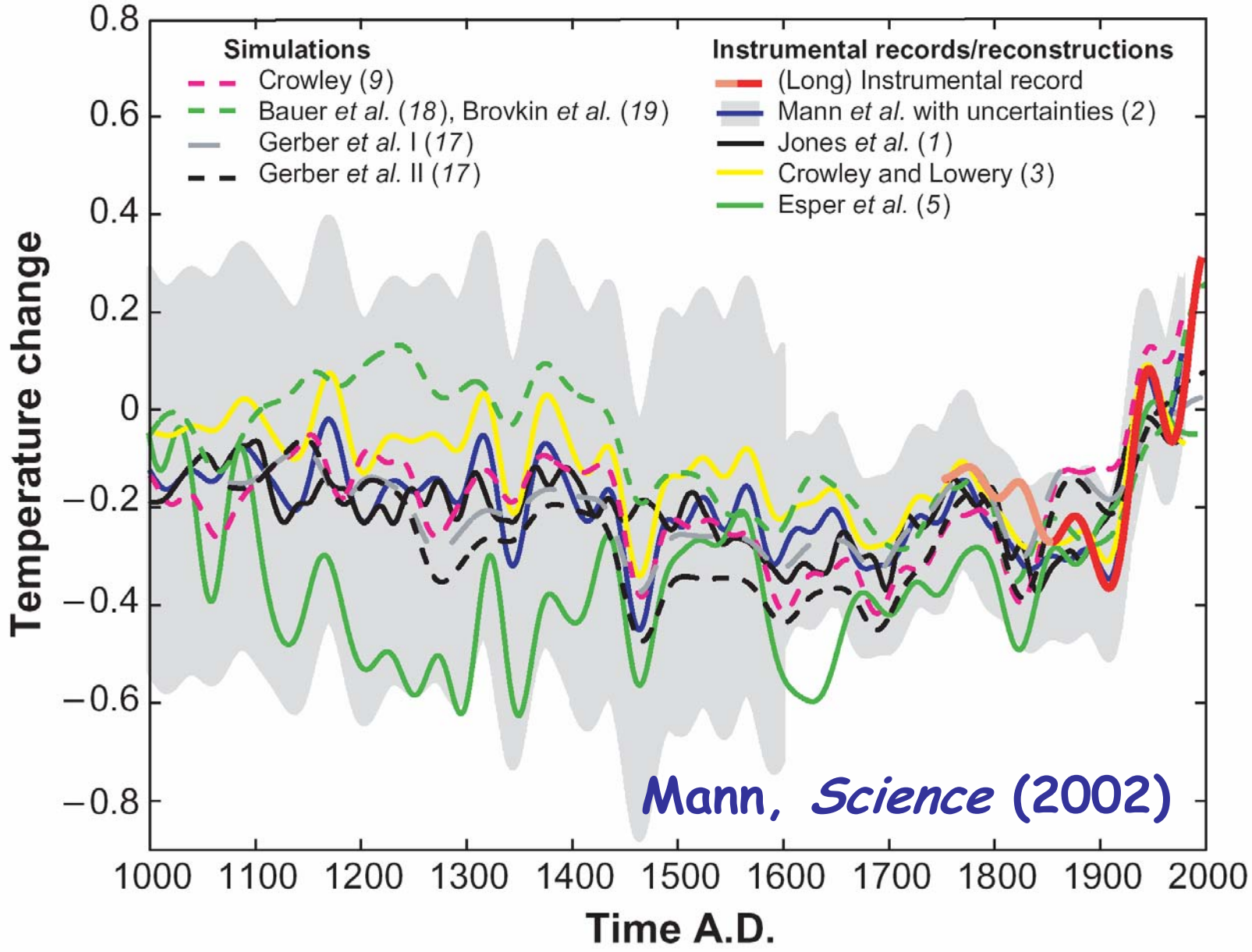

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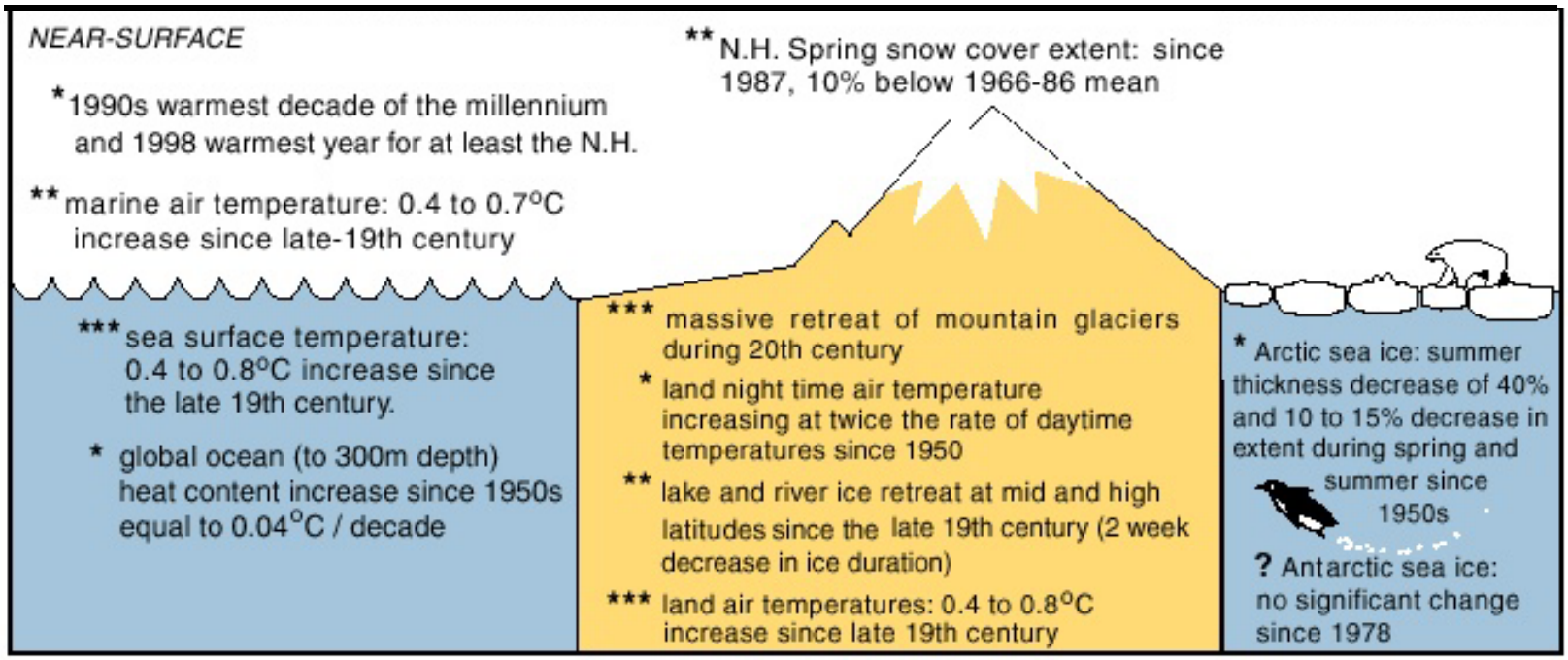
Temperature Indicators



Likelihood:

*** Virtually certain (probability > 99%)
** Very likely (probability ≥ 90% but ≤ 99%)
* Likely (probability > 66% but < 90%)
? Medium likelihood (probability > 33% but ≤ 66%)

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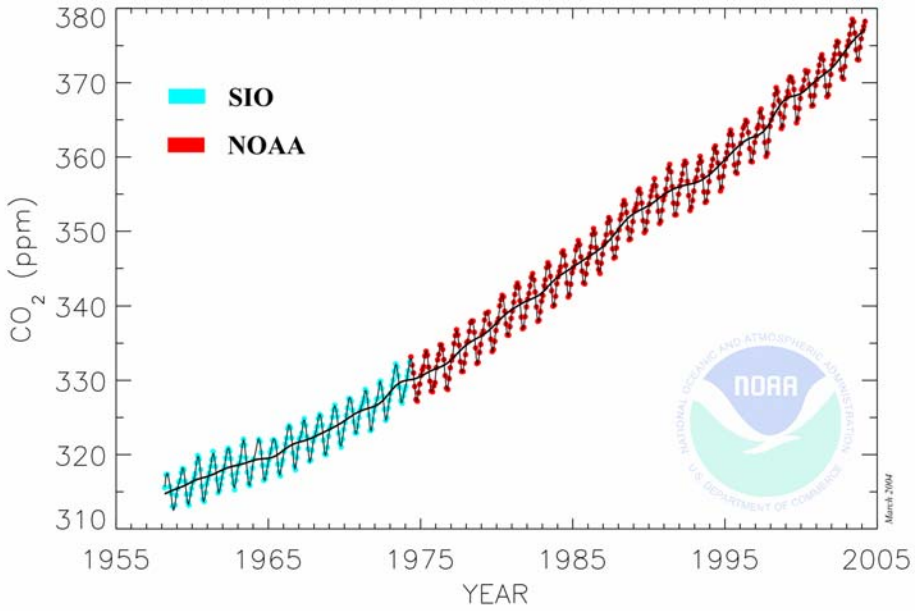
Mauna Loa Monthly Mean Carbon Dioxide



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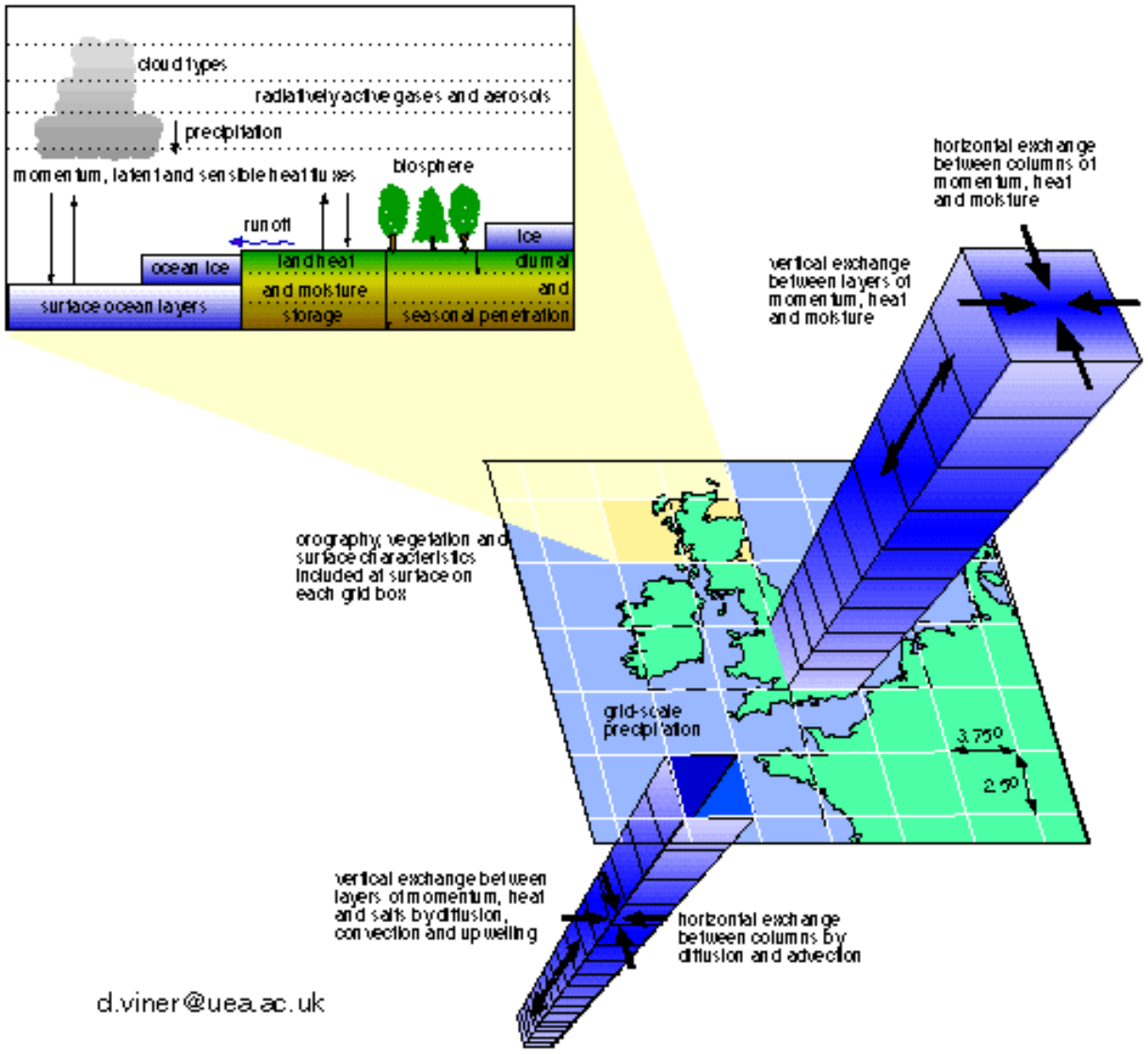
Coupled Climate Model Schematic



d.viner@uea.ac.uk

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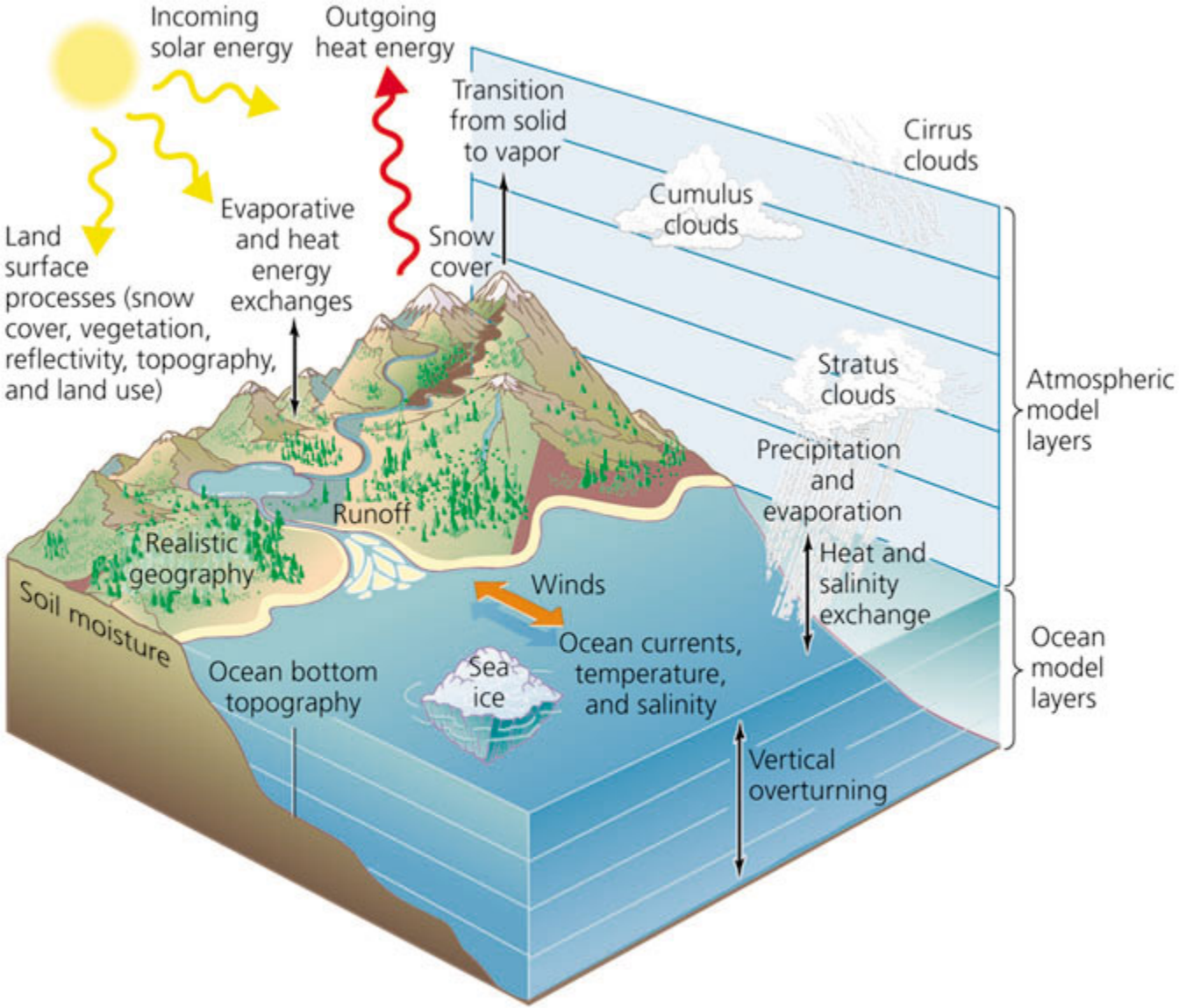

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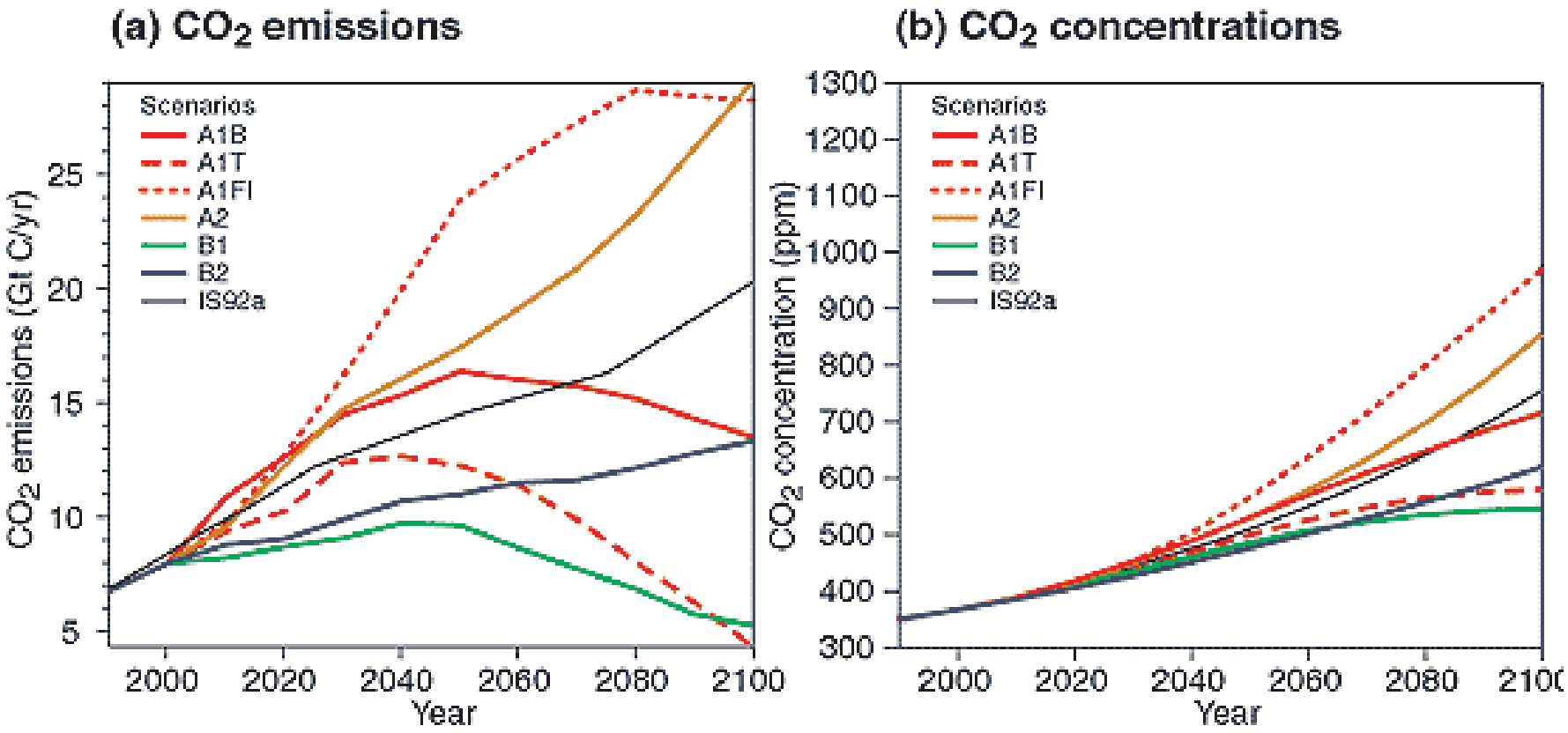
Future Climate Forcing Scenarios



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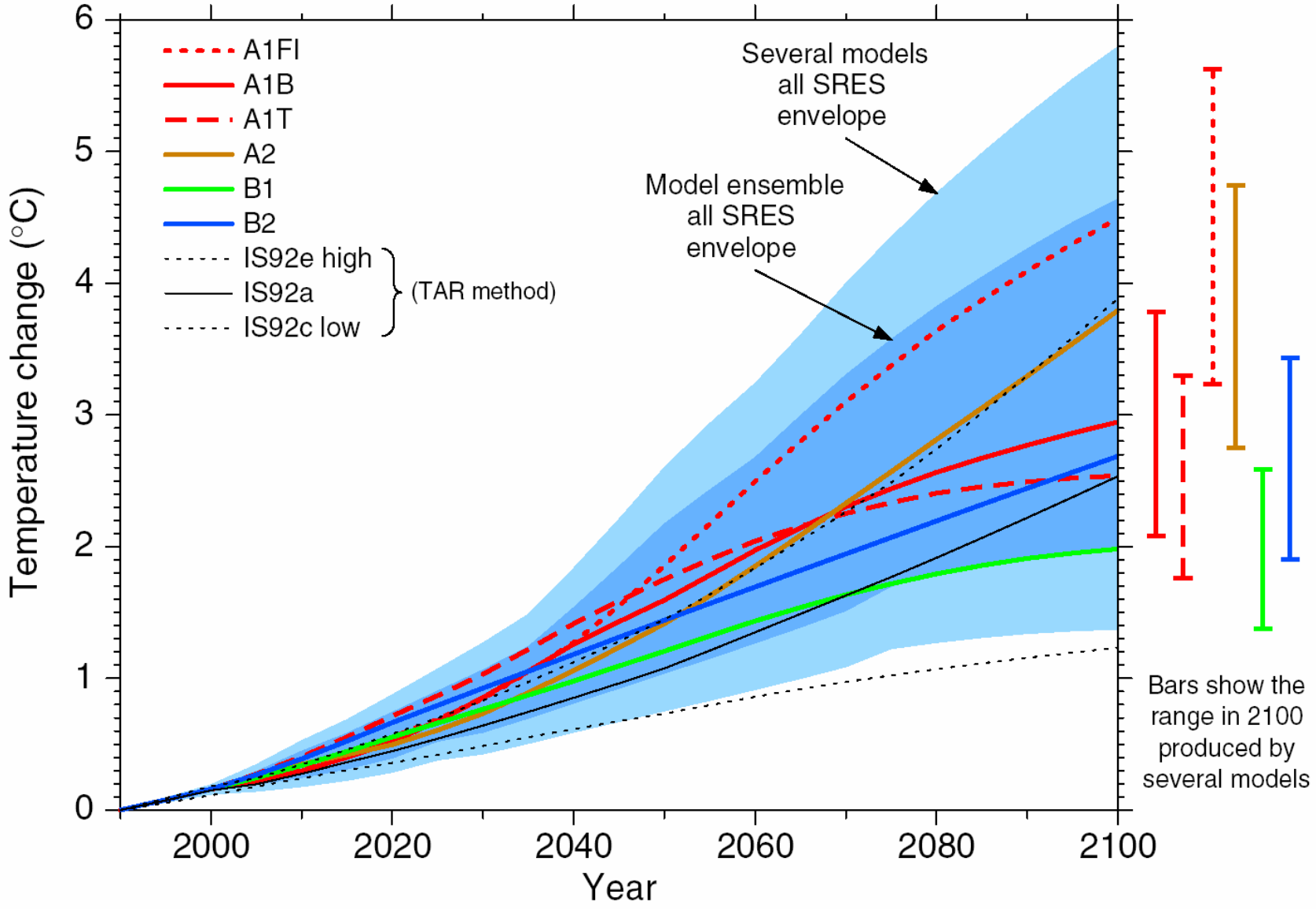

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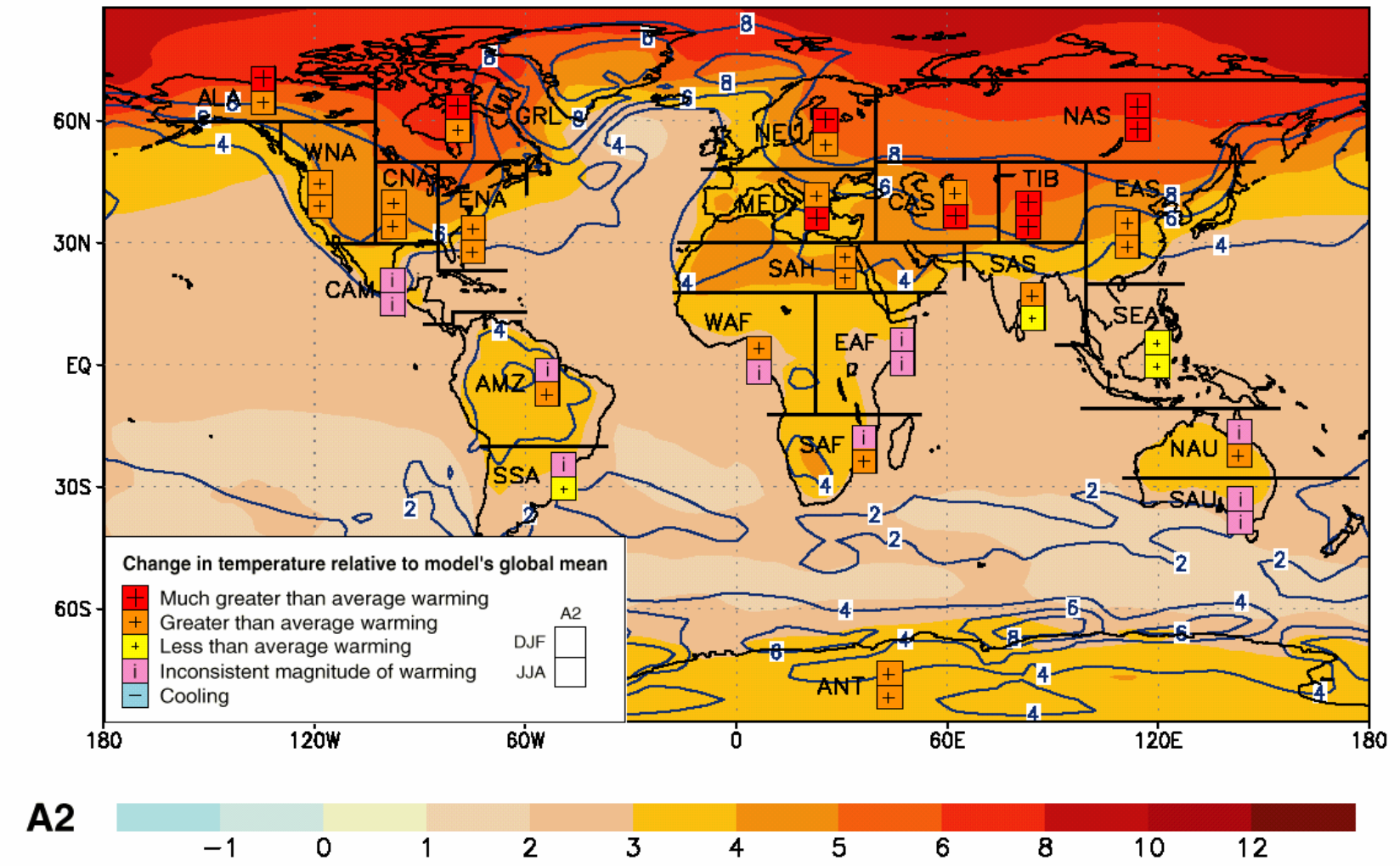

Annual mean temperature change (2071-2100) minus (1961-1990), °C

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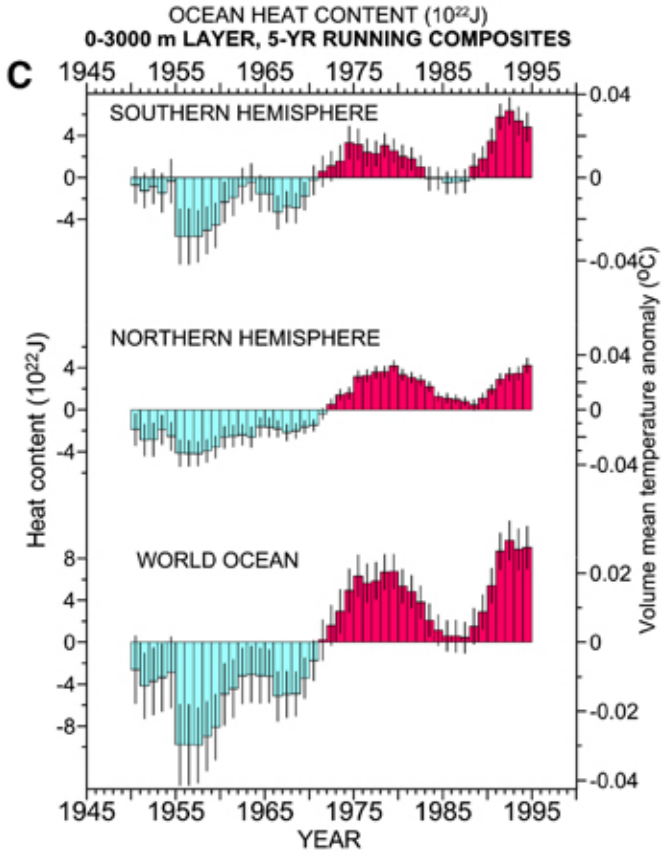
Why Will Sea Level Rise?

Thermal Expansion:

Warmer water is less dense than colder water.



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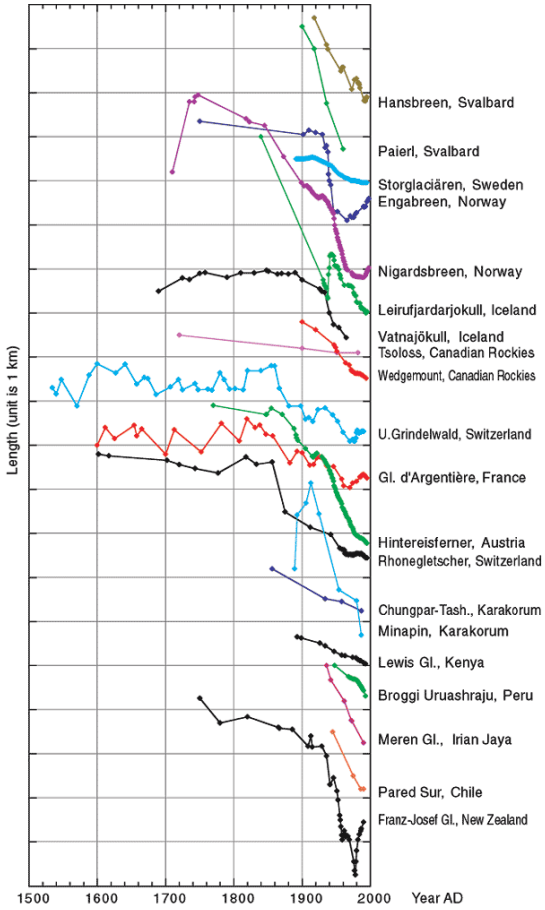
Why Will Sea Level Rise?

Melting Glaciers and Ice Caps:

Water released by the melting of ice on land adds to the volume of the oceans.



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Surface Melt on Greenland

Melt descending into a moulin, a vertical shaft carrying water to ice sheet base.

Source: Roger Braithwaite, University of Reading (UK)

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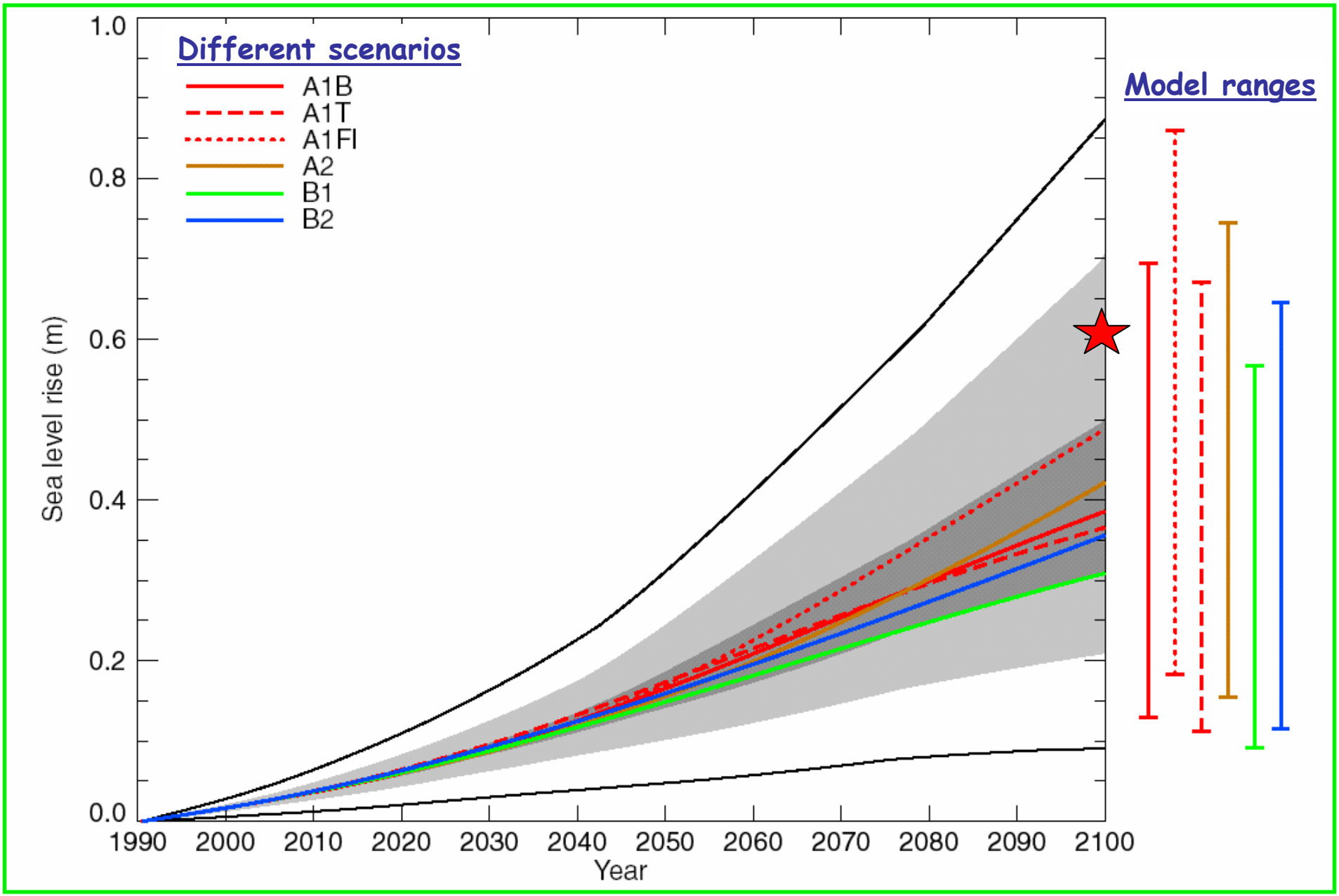
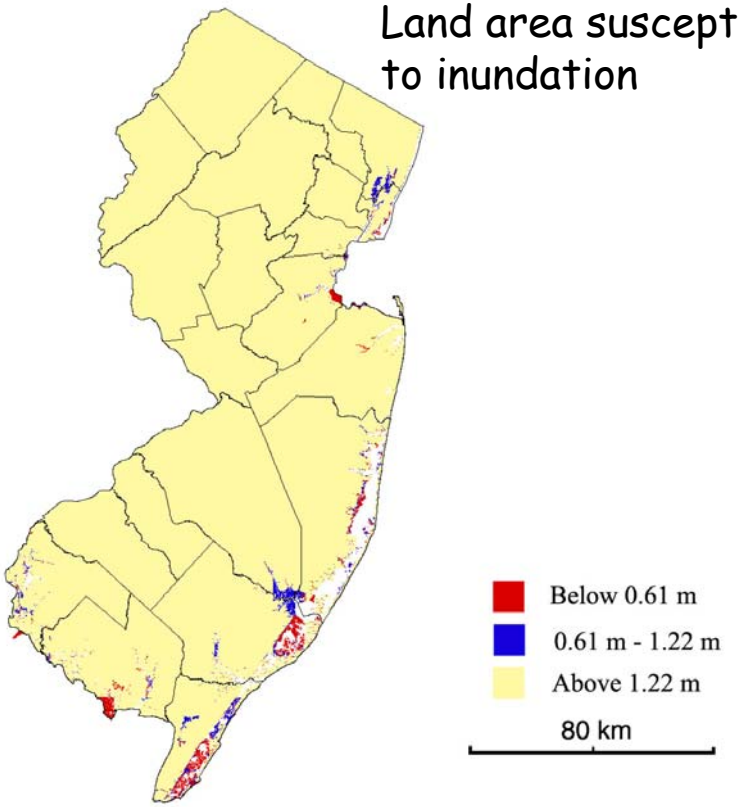
Future Global Sea Level Projections

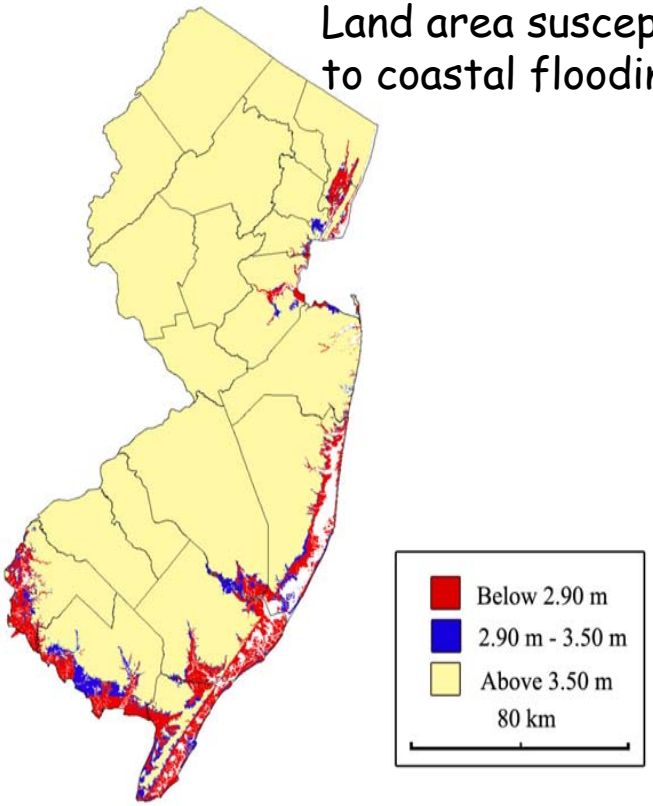


Effects of Sea Level Rise on the Coastal Environment

Land area susceptible to inundation



Land area susceptible to coastal flooding



from M. D. Beevers, Princeton University

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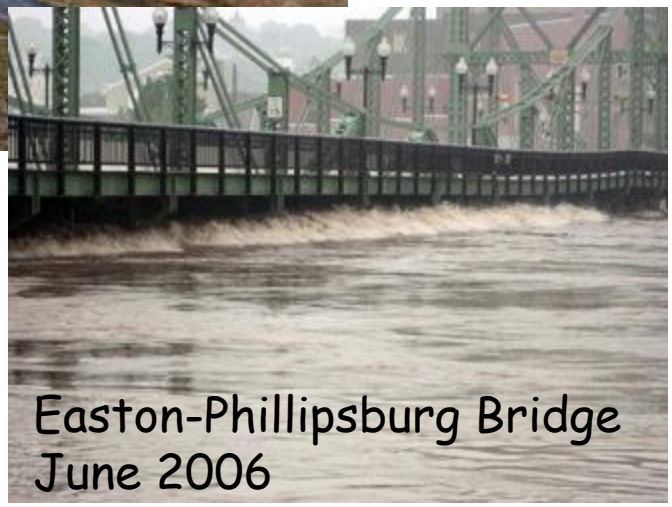
Effects of Climate Change on Hydrology: Floods and Droughts?



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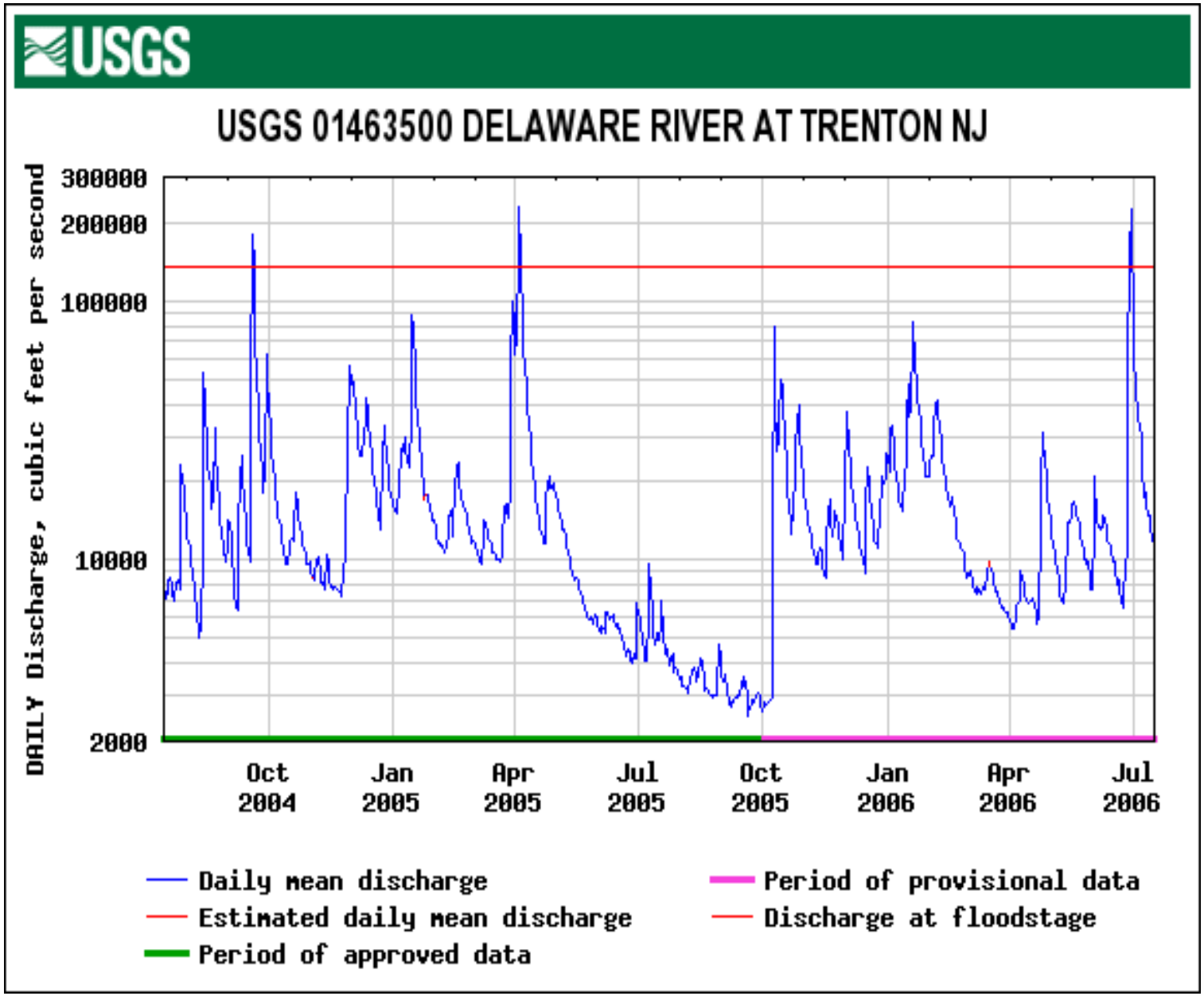

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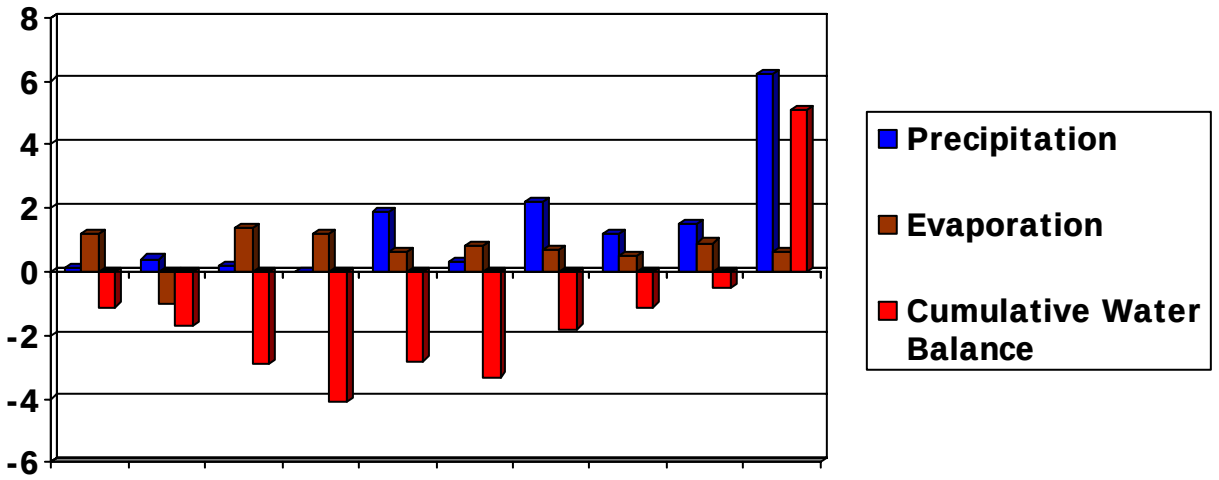
Global Warming and the Hydrologic Cycle

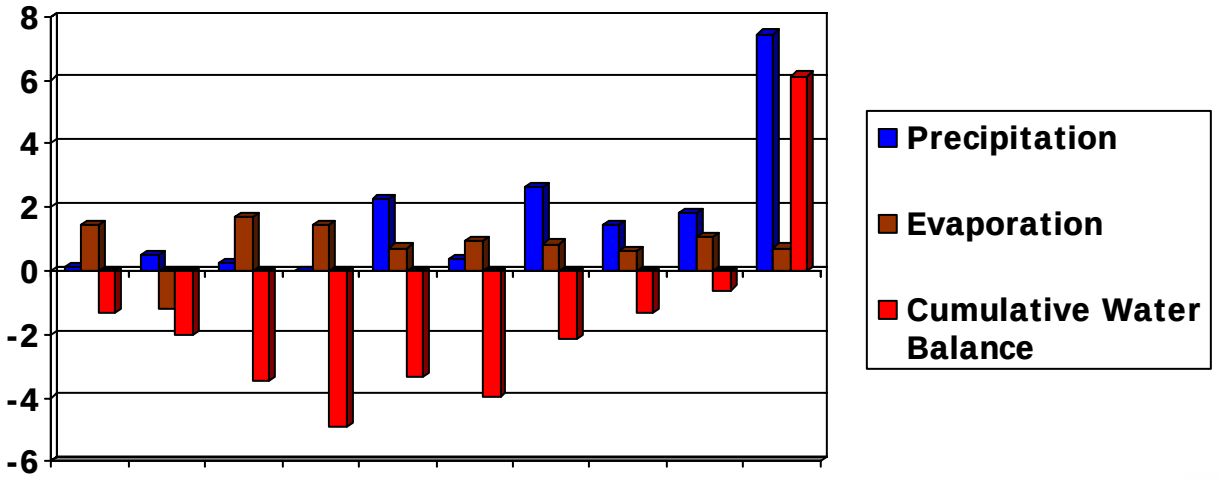
- The downward flux of radiative energy (i.e., sunlight and infrared radiation) at the surface is balanced by evaporation and sensible heating.
- If the downward flux of energy increases, then evaporation will increase.
- On a global basis, evaporation and precipitation must balance.
- Thus as the earth warms, both evaporation and precipitation will increase.

Hypothetical Weekly Water Balance

Present



Future (x1.2)



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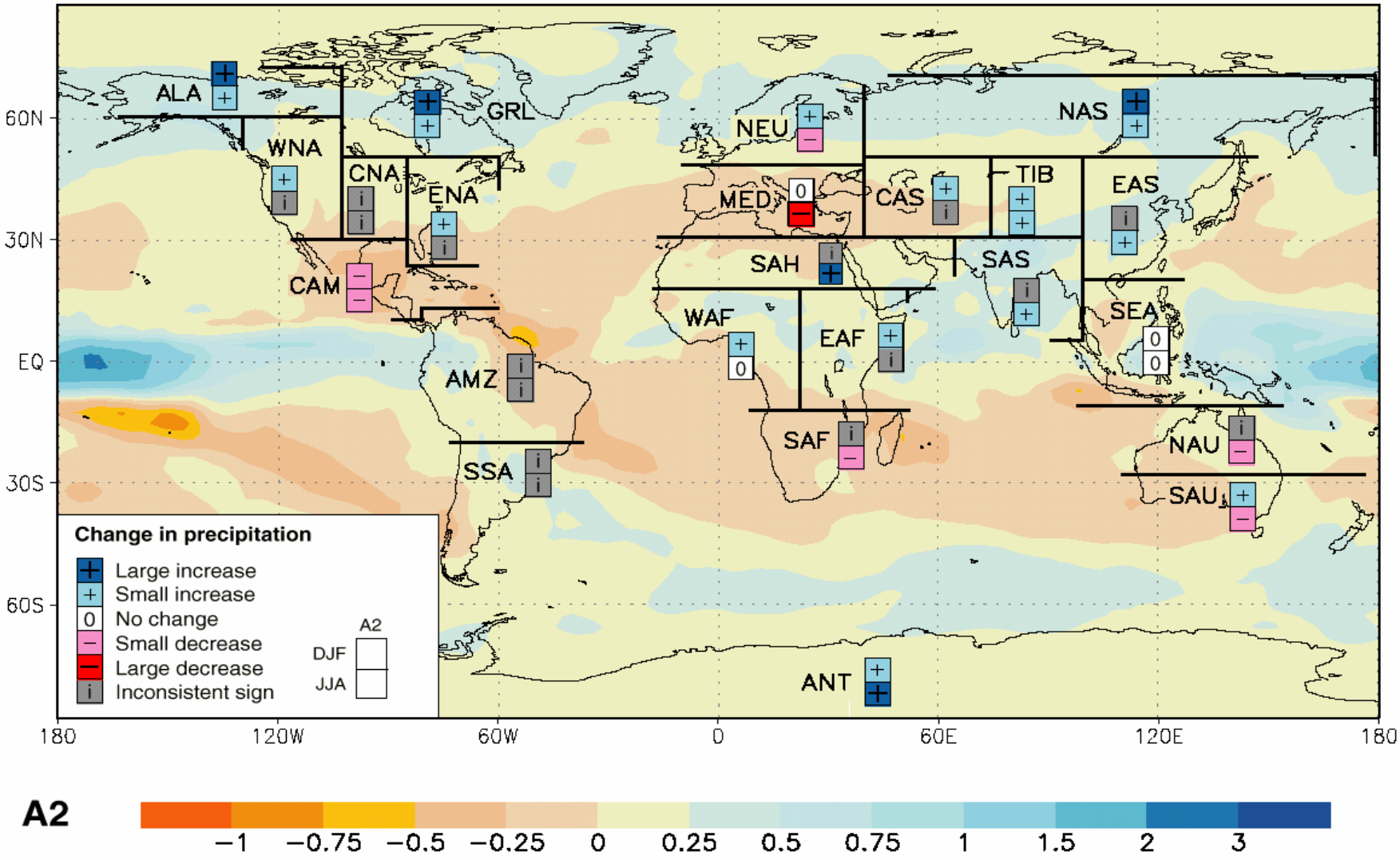

Annual mean rainfall rate change (2071-2100) minus (1961-1990), mm/day

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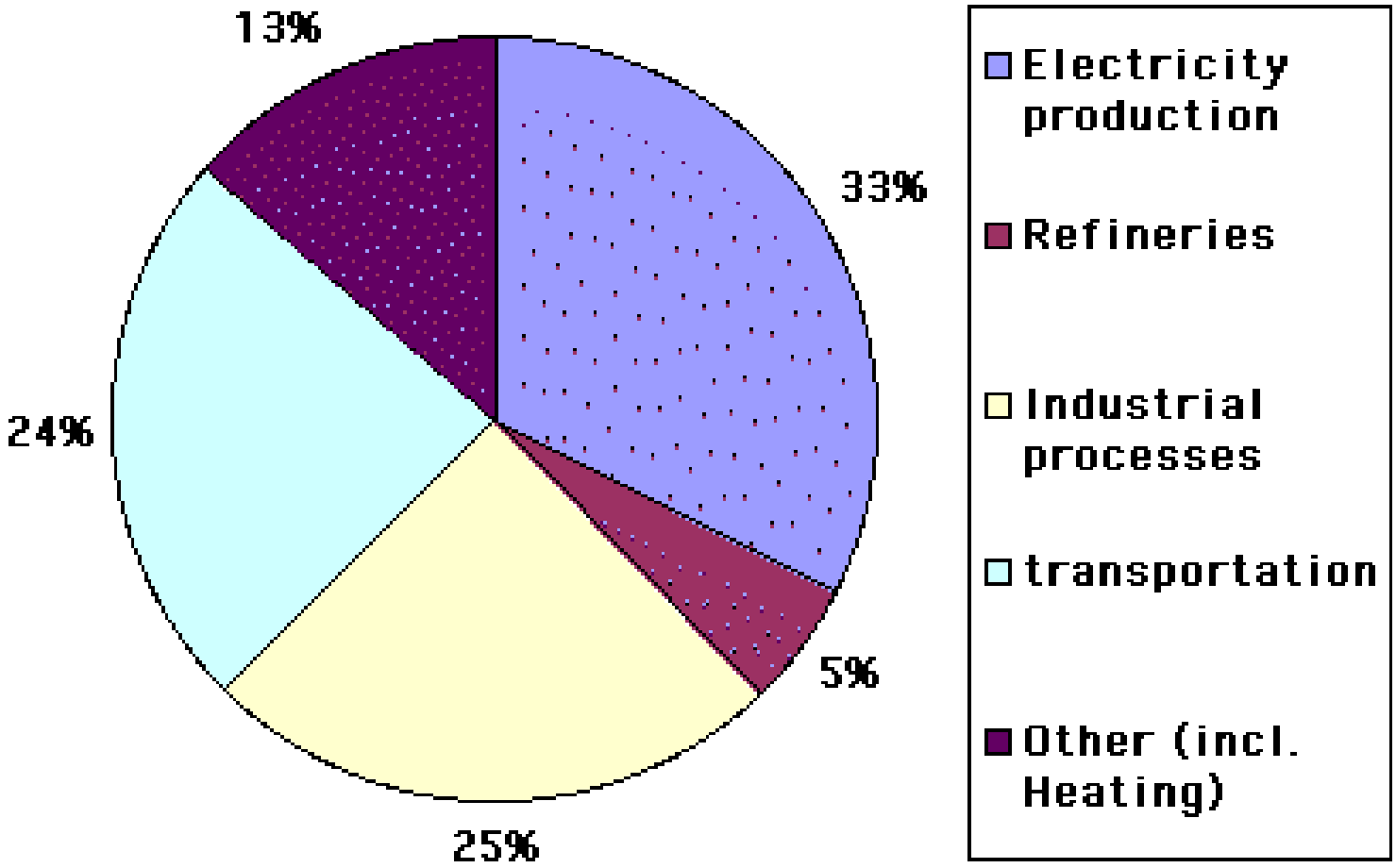
Global CO_2 Emissions



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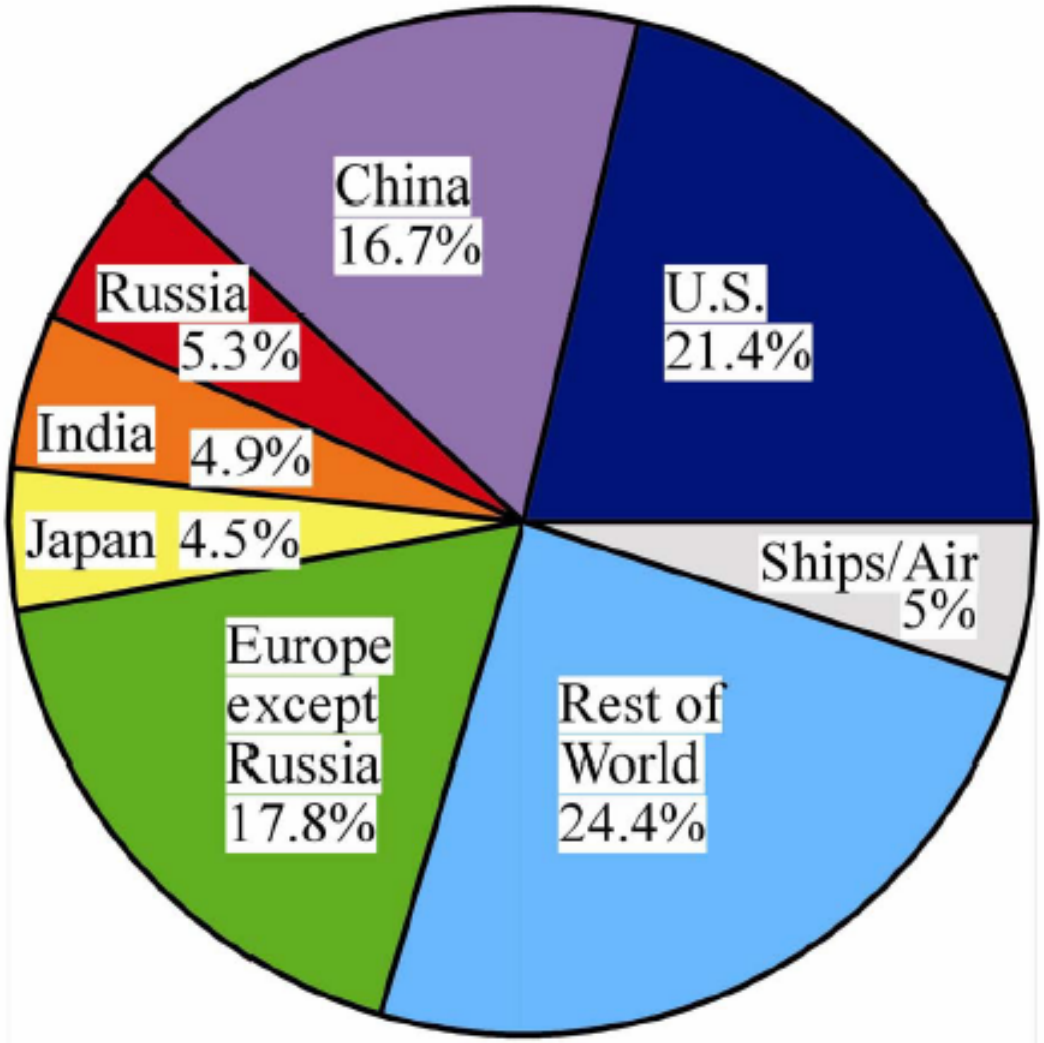
2004 Portions of CO_2 Emissions



Fossil Fuel CO_2 emissions by source country in 2004.

Source: Hansen et al, J. Geophys. Res., to be submitted

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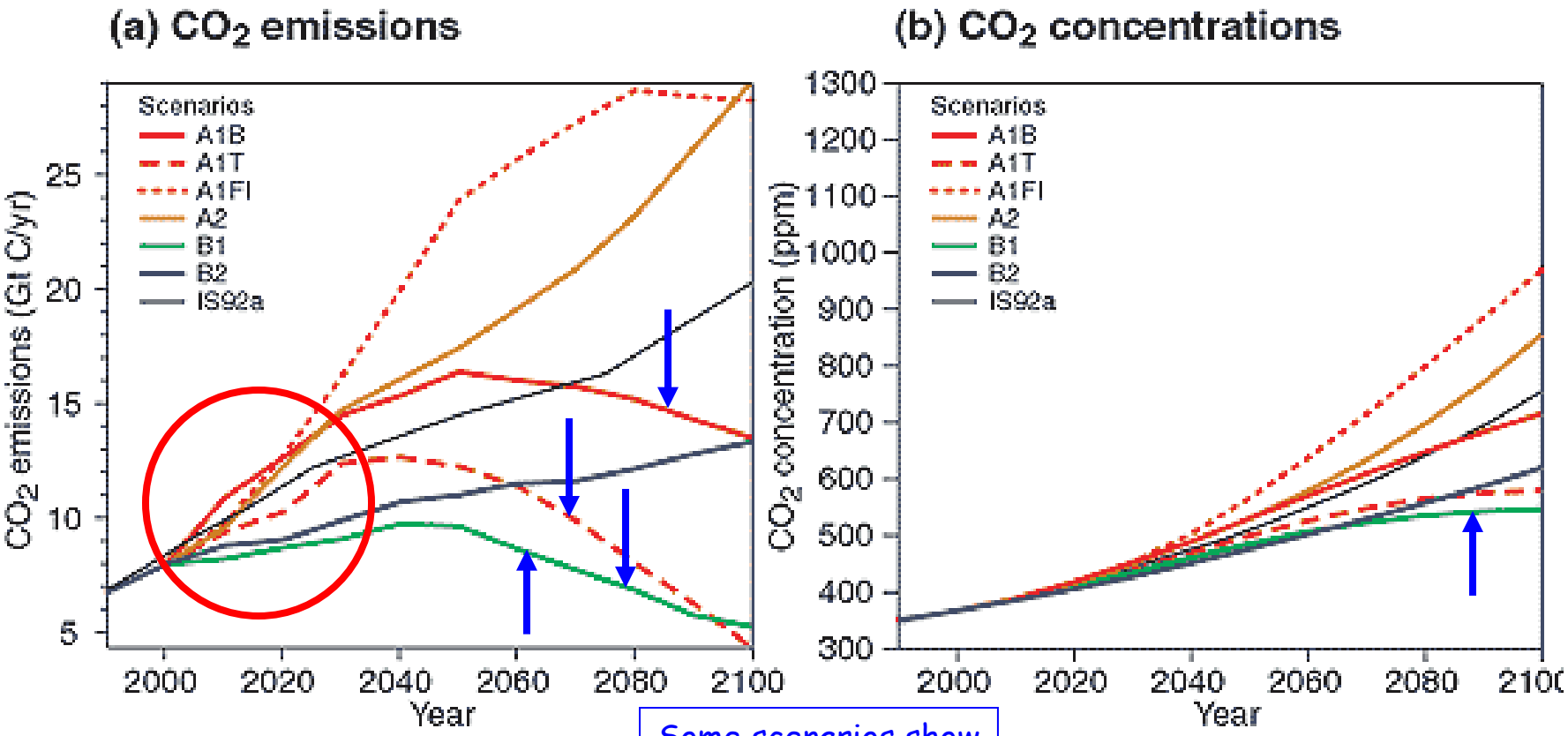
Future Climate Scenarios



All scenarios show increasing emissions during next several decades

Some scenarios show decreased emissions in latter half of 21st century

Even with aggressive reductions in emissions, CO_2 would rise to 2x preindustrial levels

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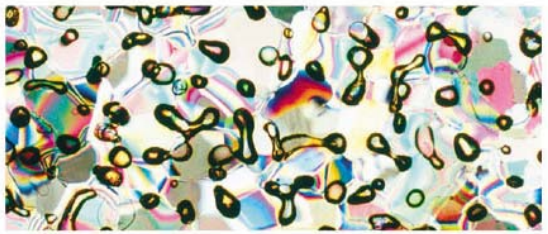
Managing Climate Change

- Mitigation: Reduce emissions of carbon dioxide and other greenhouse gases.
- Adaptation: Increase the resilience of society to climate change.
- Knowledge: Develop a better understanding of the details of future climate change.
- Leadership: Raise public awareness of the challenges posed by climate change and the need to mitigate and adapt.

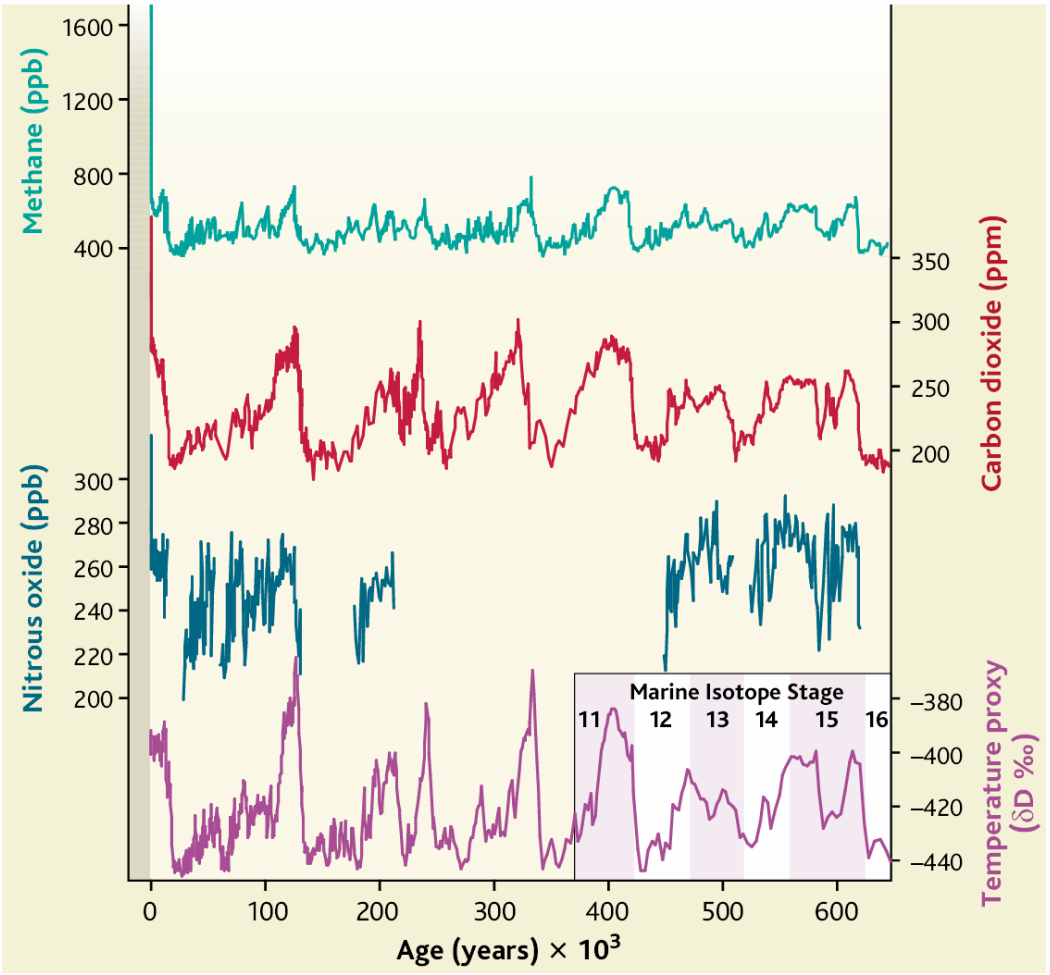

©Craig Haveman

(a) Ice core



(b) Micrograph of ice core

Brook, E., 2005: Tiny bubbles tell all, *Science*, **310**, 1285-1287.



The long view. The greenhouse gas (CO_2, CH_4, and NO_2) and deuterium (δD) records for the past 650,000 years from EPICA Dome C and other ice cores, with marine isotope stage correlations (labeled at lower right) for stages 11 to 16 (*2*, *3*). δD, a proxy for air temperature, is the deuterium/hydrogen ratio of the ice, expressed as a per mil deviation from the value of an isotope standard (*4*). More positive values indicate warmer conditions. Data for the past 200 years from other ice core records (*20*–*22*) and direct atmospheric measurements at the South Pole (*23*, *24*) are also included.

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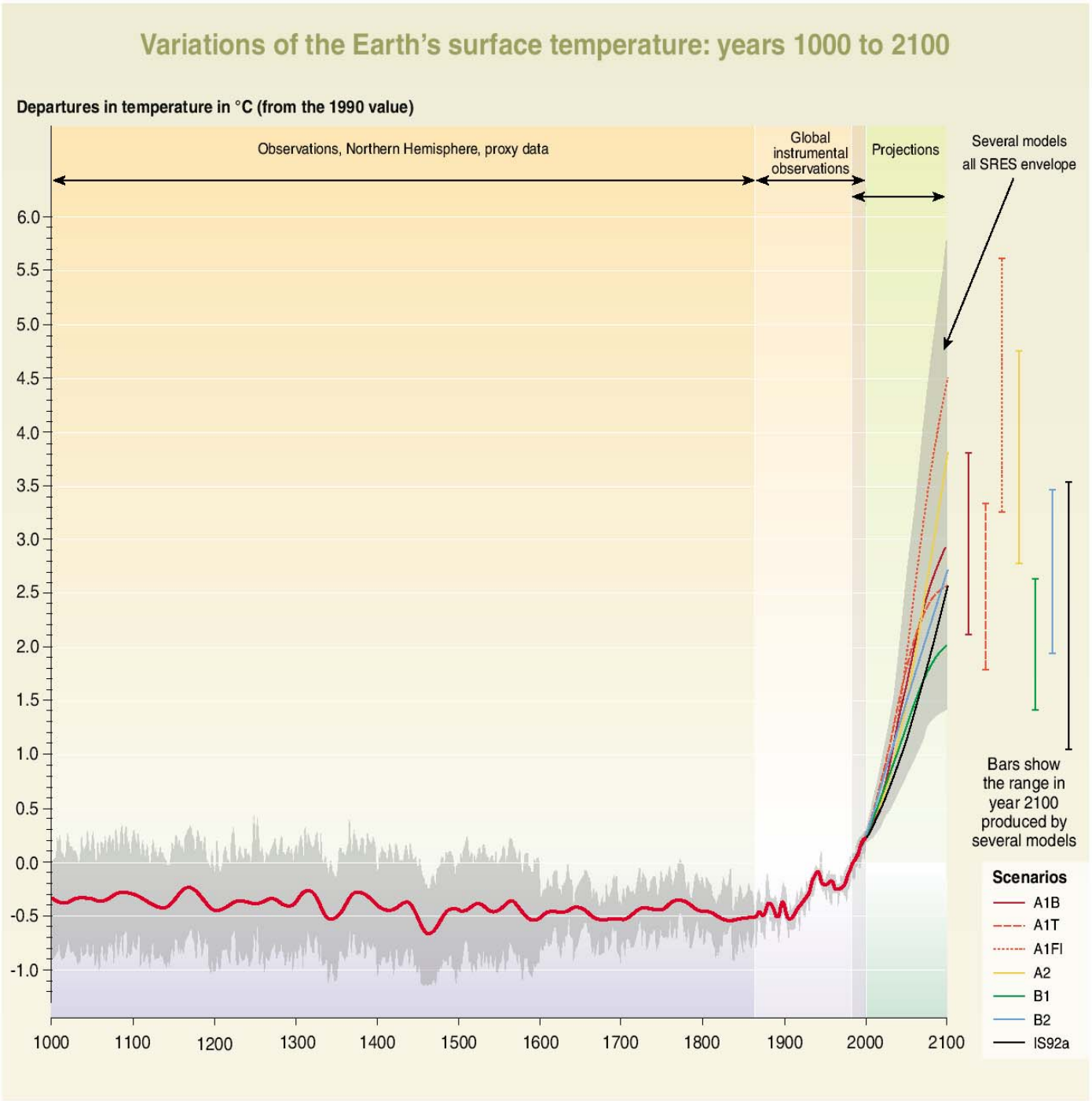
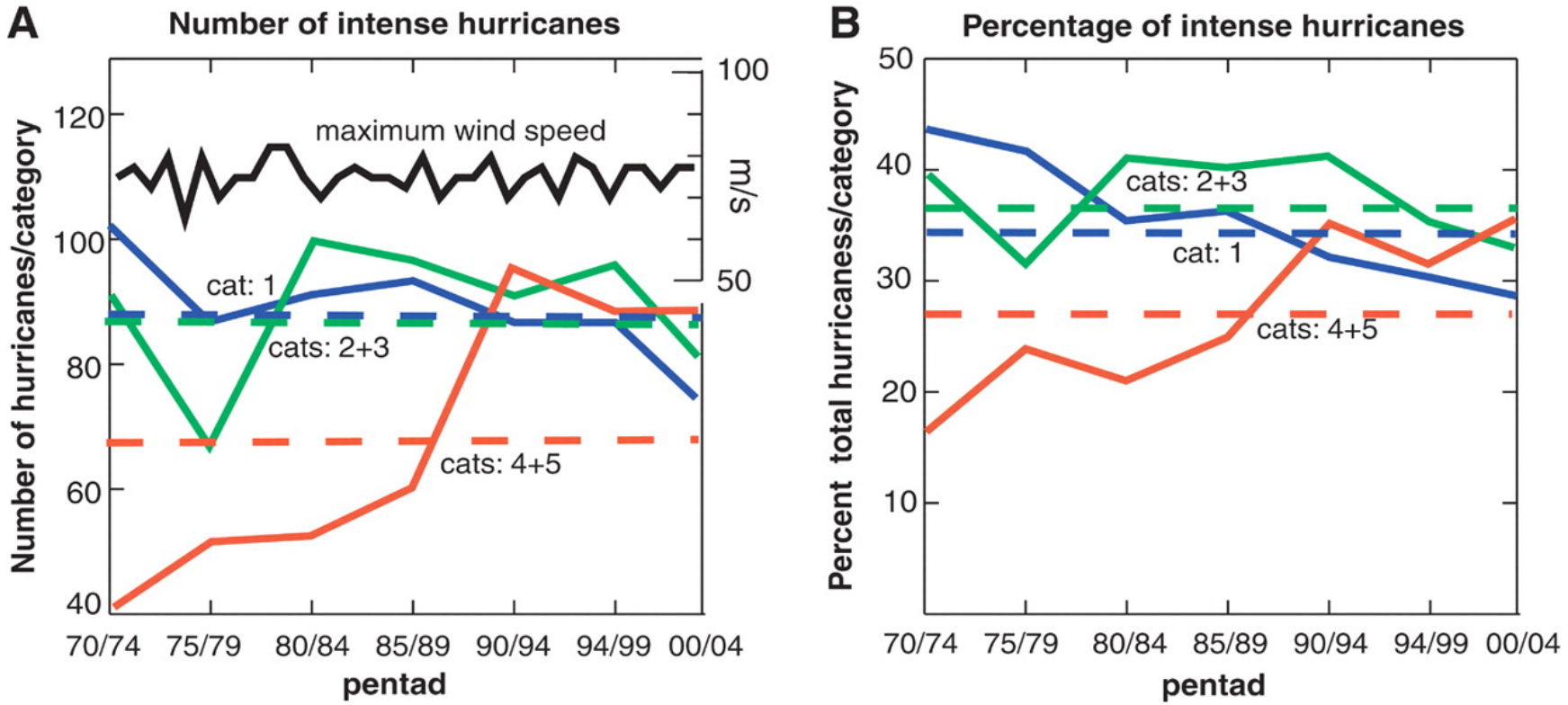


Fig. SPM-10b

IPCC TAR Synthesis Report

Are Intense Hurricanes Becoming More Frequent?



Webster et al., *Science*, 16 September 2005

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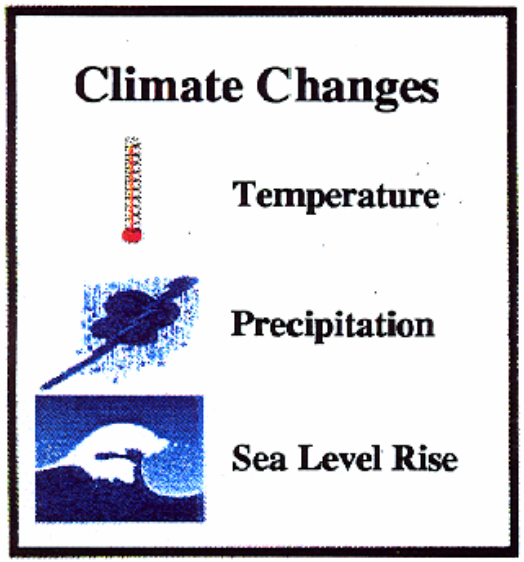
Potential Climate Change Impacts



Health Impacts
- Weather-related Mortality
- Infectious Diseases
- Air Quality-Respiratory Illnesses

Agriculture Impacts
- Crop Yields
- Irrigation Demands

Forest Impacts
- Forest composition
- Geographic range of forests
- Forest health and productivity

Water Resource Impacts
- Water supply
- Water quality
- Competition for water

Impacts on Coastal Areas
- Erosion of beaches
- Inundation of coastal lands
- Additional costs to protect coastal communities

Species and Natural Areas
- Loss of habitat and species

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Climate Change and the Coastal Environment

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Storm Surge Raises Water Levels

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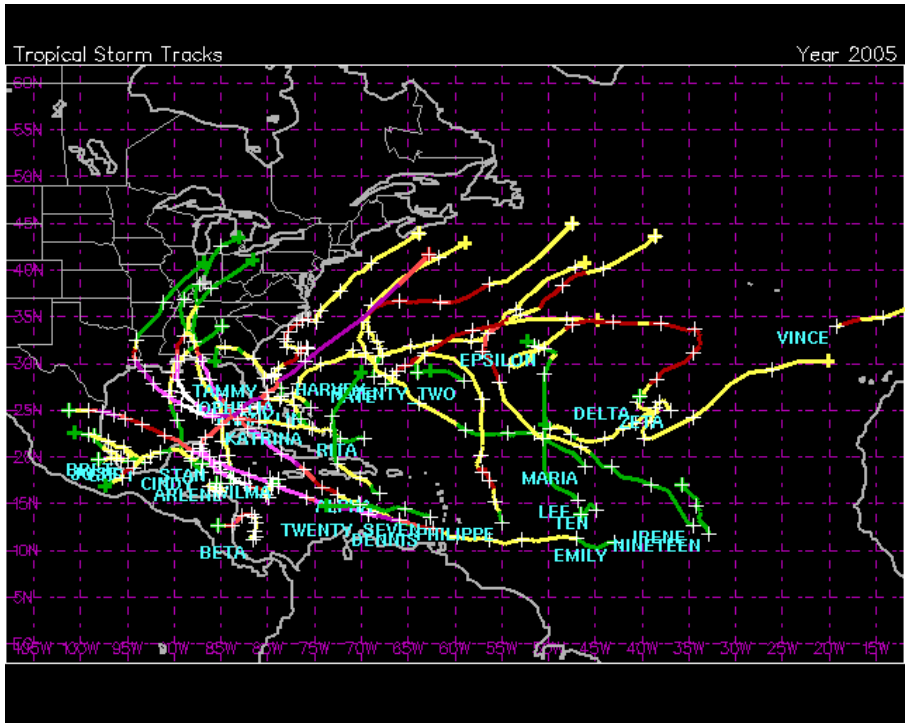
2005 Atlantic Hurricane Season



- 27 named tropical storms (all-time record)
- 15 hurricanes (all-time record)
- 7 major hurricanes
- 3 category-five hurricanes (Katrina, Rita, Wilma)
- Lowest barometric pressure ever measured in an Atlantic hurricane (Hurricane Wilma: 882 mb)

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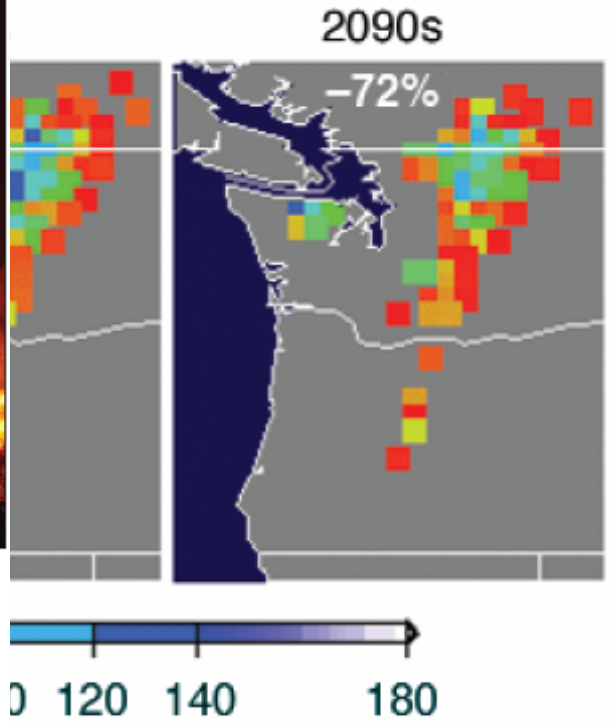
Service, Robert, 2004, *Science.*

News Focus

In a region already prone to water shortages, researchers now forecast that rising temperatures threaten the American West's hidden reservoir: mountain snow

As the West Goes Dry

Dangerous consequences. Over the next century, larger winter and spring runoffs from melting snow are expected to increase flooding and catastrophic wildfires.



uivalent (cm)

at even moderate warming will dras-
ne Oregon and Washington Cascades.