Future Changes in Climate, Sea Level and Hydrology

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Delaware River Basin Commission
West Trenton, NJ
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Questions About Climate Change

• How has the climate changed in the past?
• How is the climate expected to change in the future?
• How will climate change affect sea level and hydrology?
• How can we meet the challenges of climate change?
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1900-2005 Surface Temperature Change (°C)

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

Temperature Indicators

**N.H. Spring snow cover extent: since 1987, 10% below 1966-86 mean**

- **1990s warmest decade of the millennium and 1998 warmest year for at least the N.H.**
- **marine air temperature: 0.4 to 0.7°C increase since late-19th century**
- **sea surface temperature: 0.4 to 0.8°C increase since the late 19th century.**
- **global ocean (to 300m depth) heat content increase since 1950s equal to 0.04°C / decade**
- **massive retreat of mountain glaciers during 20th century**
- **land night time air temperature increasing at twice the rate of daytime temperatures since 1950**
- **lake and river ice retreat at mid and high latitudes since the late 19th century (2 week decrease in ice duration)**
- **land air temperatures: 0.4 to 0.8°C increase since late 19th century**
- **Arctic sea ice: summer thickness decrease of 40% and 10 to 15% decrease in extent during spring and summer since 1950s**
- **Antarctic sea ice: no significant change since 1978**

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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Coupled Climate Model Schematic
Future Climate Forcing Scenarios

(a) CO₂ emissions

(b) CO₂ concentrations

Scenarios:
- A1B
- A1T
- A1FI
- A2
- B1
- B2
- IS92a
Several models all SRES envelope

Model ensemble all SRES envelope

Bars show the range in 2100 produced by several models

Environmental Sciences
Rutgers University

THE STATE UNIVERSITY OF NEW JERSEY
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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.
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.
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)
Future Global Sea Level Projections
Effects of Sea Level Rise on the Coastal Environment

from M. D. Beevers, Princeton University
Effects of Climate Change on Hydrology: Floods and Droughts?

Cannonsville Reservoir, Dec. 2001

Delaware River, Sept. 2004

Easton-Phillipsburg Bridge, June 2006
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)
Annual mean rainfall rate change (2071-2100) minus (1961-1990), mm/day
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Global CO$_2$ Emissions

- Electricity production: 33%
- Refineries: 13%
- Industrial processes: 24%
- Transportation: 5%
- Other (incl. Heating): 25%
2004 Portions of CO₂ Emissions

Fossil Fuel CO₂ emissions by source country in 2004.

Source: Hansen et al, J. Geophys. Res., to be submitted
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.
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.
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.
Variations of the Earth’s surface temperature: years 1000 to 2100

Departs in temperature in °C (from the 1990 value)

Observations, Northern Hemisphere, proxy data

Global instrumental observations

Projections

Several models all SRES envelope

Bars show the range in year 2100 produced by several models

Scenarios
- A1B
- A1T
- A1FI
- A2
- B1
- B2
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Fig. SPM-10b

IPCC TAR Synthesis Report
Are Intense Hurricanes Becoming More Frequent?

Webster et al., Science, 16 September 2005
Potential Climate Change Impacts

Climate Changes
- Temperature
- Precipitation
- Sea Level Rise

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
Climate Change and the Coastal Environment
Storm Surge Raises Water Levels

Harvey Cedars, March 1962
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)
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. Even moderate warming will drastic changes in the Oregon and Washington Cascades.