An Introduction to Global Climate Change

Robert S. Webb
NOAA ESRL Climate Analysis Branch
formerly the Climate Diagnostics Center (CDC)
Boulder, Colorado

American College of Preventative Medicine
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Overview

• Global Climate Change: Trends & Projections

• North America: Trends & Projections

• Parting Thoughts

“I'm starting to get concerned about global warming.”

“Long term, I'm worried about global warming—short term, about freezing my ass off.”
What is Climate

Climate is the aggregated **pattern** of weather, meaning averages, extremes, timing, spatial distribution of...

- hot & cold
- cloudy & clear
- humid & dry
- drizzles & downpours
- snowfall, snowpack, & snowmelt
- blizzards, tornadoes, & typhoons

Climate change means **altered patterns**.

Global average temperature is just one measure of the state of the global climate as expressed in these patterns.

Small temperature changes $\rightarrow$ big changes in the patterns

(after Holdren NCES, 2008)
What is an extreme event

(a) Temperature

Cold temperature extremes

Hot temperature extremes

(b) Precipitation

Heavy precipitation extremes

Increase in Probability of Extremes in a Warmer Climate

(a) Temperature

Previous climate

Less cold weather

New climate

More record hot weather

(b) Precipitation

Less light precipitation

New climate

More heavy precipitation

(CCSP SAP 3.3)
Global Temperatures are increasing

Green bars show 95% confidence intervals

the 15 hottest years all occurred since 1990

http://data.giss.nasa.gov/gistemp/graphs/
2007 Surface Temperature

Warmest

9th Warmest
Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level.
Warm nights increasing
Cold nights decreasing

Frequency of occurrence of cold or warm temperatures for 202 global stations for 3 time periods: 1901 to 1950 (black), 1951 to 1978 (blue) and 1979 to 2003 (red).
The frequency of heavy precipitation events has increased over most land areas - consistent with warming and increases of atmospheric water vapor while more intense and longer droughts have been observed since the 1970s, particularly in the tropics and subtropics.
Greenhouse gas concentrations

Compared to natural changes over the past 10,000 years, the spike in concentrations of CO$_2$ & CH$_4$ in the past 250 years is extraordinary.

Humans are responsible for the recent dramatic increase emissions. Fossil CO$_2$ & CH$_4$ lack carbon-14, and the observed drop in atmospheric C-14 is measurable.

(IPCC AR4 WG1, 2007)
Best estimate of global radiative forcing

<table>
<thead>
<tr>
<th>RF Terms</th>
<th>RF values (W m⁻²)</th>
<th>Spatial scale</th>
<th>LOSU</th>
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</thead>
<tbody>
<tr>
<td>Long-lived greenhouse gases</td>
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<tr>
<td><strong>CO₂</strong></td>
<td>1.66 [1.49 to 1.83]</td>
<td>Global</td>
<td>High</td>
</tr>
<tr>
<td><strong>N₂O</strong></td>
<td>0.48 [0.43 to 0.53]</td>
<td>Global</td>
<td>High</td>
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<tr>
<td><strong>CH₄</strong></td>
<td>0.16 [0.14 to 0.18]</td>
<td>Global</td>
<td>High</td>
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<tr>
<td><strong>Halocarbons</strong></td>
<td>0.34 [0.31 to 0.37]</td>
<td>Global</td>
<td>High</td>
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<tr>
<td>Ozone</td>
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<tr>
<td>Stratospheric</td>
<td>-0.05 [-0.15 to 0.05]</td>
<td>Continental to global</td>
<td>Med</td>
</tr>
<tr>
<td>Tropospheric</td>
<td>0.35 [0.25 to 0.65]</td>
<td>Continental to global</td>
<td>Med</td>
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<tr>
<td>Stratospheric water vapour from CH₄</td>
<td></td>
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<tr>
<td>Surface albedo</td>
<td>-0.2 [-0.4 to 0.0]</td>
<td>Local to continental</td>
<td>Med</td>
</tr>
<tr>
<td>Land use</td>
<td>0.1 [0.0 to 0.2]</td>
<td>Continental to global</td>
<td>Med</td>
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<tr>
<td>Black carbon on snow</td>
<td></td>
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<tr>
<td>Direct effect</td>
<td>-0.5 [-0.9 to -0.1]</td>
<td>Continental to global</td>
<td>Med</td>
</tr>
<tr>
<td>Total Aerosol</td>
<td>-0.7 [-1.8 to -0.3]</td>
<td>Continental to global</td>
<td>Low</td>
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<tr>
<td>Cloud albedo effect</td>
<td></td>
<td></td>
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<tr>
<td>Linear contrails</td>
<td>0.01 [0.003 to 0.03]</td>
<td>Continental to global</td>
<td>Low</td>
</tr>
<tr>
<td>Solar irradiance</td>
<td>0.12 [0.06 to 0.30]</td>
<td>Global</td>
<td>Low</td>
</tr>
<tr>
<td>Total net anthropogenic</td>
<td>1.6 [0.6 to 2.4]</td>
<td></td>
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</tbody>
</table>
Ranges of projected surface warming
multi-model averages for different emission scenarios and assessed ranges of warming

(IPCC AR4, 2007)
Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999

Continents Warm 50% more than oceans
Observed & simulated continental & global scale changes in surface temperature

observed change (black line); climate models simulations using natural (blue) and anthropogenic (red) forcings
Projected percent changes in precipitation for the period 2090–2099 (relative to 1980–1999)

NH Winter

Warmer climate → More Water Vapor in the atmosphere but an expanded belt of subtropical aridity
Changes in the physical and biological systems and surface temperature 1970-2004

(IPCC WG2, 2007)
Observed trends in some biophysical and socio-economic indicators in North America

(IPCC WG1, 2007)
Changes in the percent of days in a year above three thresholds for North America for daily high (top) and low (bottom) temperature
U.S. national average “heat wave” index
defined as warm spells of 4 days in duration with mean temperature exceeding the threshold for a 1 in 10 year event
Area of the U.S. with much above normal daily high and low summer temperatures

b. Summer

c. Summer

CCSP SAP 3.3
Regions in where heavy and very heavy precipitation has increased
Observed & simulated changes in regional surface temperature

- ALA
- CGI
- WNA
- CNA
- ENA

IPCC WG1, 2007
Days in a year averaged over North America when daily low temperature is in the top 10% of warm nights for 1961-90

Increase in Percentage of Very Warm Nights (Top 10%)

- Emission Scenario A2*: High at 2100
- Emission Scenario A1B*: Mid-range at 2100
- Emission Scenario B1*: Low at 2100
- 20th Century Simulations
- 95% Confidence Interval
- 68% Confidence Interval
- Observations

CCSP SAP 3.3
Number of frost days per year averaged over North America
Growing season length averaged over North America
Rainfall on days in the top 5% of heavy precipitation days for the period 1961-1990 averaged over North America
Projected increase in occurrence of extremely rare hot days (a 1 in-20 year event)

(from Wehner 2005)
Possible impacts of climate change due to projected changes in extreme weather and climate events (IPCC, 2007)

<table>
<thead>
<tr>
<th>Phenomenon* and direction of trend</th>
<th>Likelihood of future trends based on projections for 21st century using SRES scenarios</th>
<th>Agriculture, forestry and ecosystems (WGI 4.4, 5.4)</th>
<th>Water resources (WGII 3.4)</th>
<th>Human health (WGII 8.2, 8.4)</th>
<th>Industry, settlement and society (WGII 7.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights</td>
<td>Virtually certain*</td>
<td>Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks</td>
<td>Effects on water resources relying on snowmelt; effects on some water supplies</td>
<td>Reduced human mortality from decreased cold exposure</td>
<td>Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice, effects on winter tourism</td>
</tr>
<tr>
<td>Warm spells/heat waves. Frequency increased over most land areas</td>
<td>Very likely</td>
<td>Reduced yields in warmer regions due to heat stress; increased danger of wildfire</td>
<td>Increased water demand; water quality problems, e.g. algal blooms</td>
<td>Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated</td>
<td>Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor</td>
</tr>
<tr>
<td>Heavy precipitation events. Frequency increases over most areas</td>
<td>Very likely</td>
<td>Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils</td>
<td>Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved</td>
<td>Increased risk of deaths, injuries and infectious, respiratory and skin diseases</td>
<td>Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property</td>
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<tr>
<td>Area affected by drought increases</td>
<td>Likely</td>
<td>Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire</td>
<td>More widespread water stress</td>
<td>Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water-and food-borne diseases</td>
<td>Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration</td>
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<tr>
<td>Intense tropical cyclone activity increases</td>
<td>Likely</td>
<td>Damage to crops; winds (uprooting) of trees; damage to coral reefs</td>
<td>Power outages causing disruption of public water supply</td>
<td>Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders</td>
<td>Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations, loss of property</td>
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<tr>
<td>Increased incidence of extreme high sea level (excludes tsunamis)*</td>
<td>Likely*</td>
<td>Salinisation of irrigation water, estuaries and freshwater systems</td>
<td>Decreased freshwater availability due to saltwater intrusion</td>
<td>Increased risk of deaths and injuries by drowning in floods; migration-related health effects</td>
<td>Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above</td>
</tr>
</tbody>
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Emerging Challenges

Pythons could squeeze lower third of USA

Feb 21, 2008 By Elizabeth Weise, As climate change warms the nation, giant Burmese pythons could colonize one-third of the USA, from San Francisco across the Southwest, Texas and the South and up north along the Virginia coast, according to U.S. Geological Survey maps released Wednesday. The pythons can be 20 feet long and 250 pounds. They are highly adaptable to new environments.
Valuable Resources

IPCC Reports
www.ipcc.ch

CCSP Reports
www.climatescience.gov
Summary of relative direction, magnitude and certainty of health impacts to changes in climate

<table>
<thead>
<tr>
<th>Negative Impact</th>
<th>Positive Impact</th>
<th>Key Adaptations</th>
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<tr>
<td>Very High to High Confidence</td>
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<tr>
<td>- Heatwaves</td>
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<td>Early warning systems, behavioral change</td>
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<td>- Cold-related mortality</td>
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<td>- Restricted distribution of some VBZD</td>
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<td>- Increased range of some VBZD</td>
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<td>- Waterborne disease outbreaks</td>
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<td>Enhance surveillance</td>
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<tr>
<td>- Air pollution-related health outcomes</td>
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<tr>
<td>Medium Confidence</td>
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<td>Enhance emergency response</td>
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<td>- Floods and other extreme events</td>
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CCSP SAP 4.6

(Curriero et al. 2002)
Projected increase in occurrence of extremely high rainfall days (a 1 in-20 year event)

(from Wehner 2005)
Drinking waterborne disease outbreaks and 90 percentile precipitation events

(Curriero et al. 2001)