Global Warming: Coming ready or not!

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Help!
I wish to dedicate this lecture to
Jim Hurrell

Good health Jim!
The recent IPCC report has clearly stated that “Warming of the climate system is unequivocal” and it is “very likely” caused by human activities.

Moreover, most of the observed changes are now simulated by climate models over the past 50 years adding confidence to future projections.
2007: The Nobel Peace Prize goes to the Intergovernmental Panel on Climate Change (IPCC) and Albert Arnold (Al) Gore Jr. "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change".
1988 - The establishment of the IPCC

**Role of the IPCC:**

The role of the IPCC is to **assess** on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. Review by experts and governments is an essential part of the IPCC process.
1988 - The establishment of the IPCC
   WMO, UNEP
1990 - First IPCC Assessment Report
1992 - IPCC Supplementary Reports
   1992- Adoption of the UNFCCC
   1994- Entry into force of the UNFCCC
         Ratified by 189 countries
1994 - IPCC Special Report
1995 - Second IPCC Assessment Report
   1996 - COP-2, 1997 - COP-3
   1997- Adoption of Kyoto Protocol at COP-3
   2005 Feb 16- Kyoto Protocol ratified by 164 countries
         (But not by USA or Australia)
2001 - Third IPCC Assessment Report
2002 - COP-8, 2003 - COP-9
2007 - Fourth IPCC Assessment Report
Scenarios of future emissions of greenhouse gases, aerosols

Scenarios of future concentrations of greenhouse gases and aerosols

Assessment of observations, processes and models

Projections of future climate: The response, global, regional

Impacts

Mitigation Policy options

Adaptation

Feedbacks
A major strength of the IPCC process has been the **intergovernmental** process, through reviews and then approval of the **Summary for Policy Makers** on a word-by-word basis. This provides ownership.

But it has also been subject to criticism as it is much more political. In principle, this process is designed to provide a report in which the content is **determined by the science** while **how it is stated** is determined jointly with the governments. Hence it aids communication between scientists and politicians.

**NOTE:** In terms of impact of the report, the process is as important as the report itself.
The atmosphere is a "global commons." Air over one place is typically halfway round the world a week later, as shown by manned balloon flights.

The atmosphere is a dumping ground for all nations for pollution of all sorts. Some lasts a long time and is shared with all. **One consequence is global warming!**
Changing atmospheric composition: $CO_2$

Data from Climate Monitoring and Diagnostics Lab., NOAA. Data prior to 1974 from C. Keeling, Scripps Inst. Oceanogr.
CO2 emissions in different regions in 2000 in terms of emissions per capita (height of each block); population (width of each block); and total emissions (product of population and emissions per capita = area of block).

Source: M. Grubb, http://www.eia.doe.gov/iea/
TONNES OF CO₂ EMISSIONS PER CAPITA, 2003

Source: World Resources Institute.
Key issue:
What is your carbon footprint?
The Natural Greenhouse Effect: clear sky

Clouds also have a greenhouse effect

Kiehl and Trenberth 1997
The Greenhouse Effect

Some solar radiation is reflected by the Earth and the atmosphere.

Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth’s surface and the lower atmosphere.

Solar radiation passes through the clear atmosphere.

Most radiation is absorbed by the Earth’s surface and warms it.

Infrared radiation is emitted from the Earth’s surface.
The incoming energy from the sun is 342 W m\(^{-2}\): annual global mean. It amounts to 175 PetaWatts = 175,000,000 billion Watts. About 120 PW is absorbed.

The biggest power plants in existence are 1000 MegaWatts and we normally think of units of 1 KiloWatt (= 1 bar heater), or a 100 W light bulb.

So the energy from the sun is 120 million of these power stations. It shows:

1) Direct human influences are tiny vs nature.
2) The main way human activities can affect climate is through interference with the natural flows of energy such as by changing the composition of the atmosphere.
Global Warming is unequivocal

<table>
<thead>
<tr>
<th>Since 1970, rise in:</th>
<th>Decrease in:</th>
</tr>
</thead>
<tbody>
<tr>
<td>❖ Global surface temperatures</td>
<td>NH Snow extent</td>
</tr>
<tr>
<td>❖ Tropospheric temperatures</td>
<td>Arctic sea ice</td>
</tr>
<tr>
<td>❖ Global SSTs, ocean Ts</td>
<td>Glaciers</td>
</tr>
<tr>
<td>❖ Global sea level</td>
<td>Cold temperatures</td>
</tr>
<tr>
<td>❖ Water vapor</td>
<td></td>
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<tr>
<td>❖ Rainfall intensity</td>
<td></td>
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<td>❖ Precipitation extratropics</td>
<td></td>
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<tr>
<td>❖ Hurricane intensity</td>
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<tr>
<td>❖ Drought</td>
<td></td>
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<tr>
<td>❖ Extreme high temperatures</td>
<td></td>
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<tr>
<td>❖ Heat waves</td>
<td></td>
</tr>
</tbody>
</table>
Global mean temperatures are rising faster with time.

Warmest 12 years:

<table>
<thead>
<tr>
<th>Period</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0.177±0.052</td>
</tr>
<tr>
<td>50</td>
<td>0.128±0.026</td>
</tr>
<tr>
<td>100</td>
<td>0.074±0.018</td>
</tr>
<tr>
<td>150</td>
<td>0.045±0.012</td>
</tr>
</tbody>
</table>

Years °/decade

IPCC
Land surface temperatures are rising faster than SSTs

Annual anomalies of global average SST and land surface air temperature

IPCC
Controlling Heat

Human body: sweats

Homes: Evaporative coolers (swamp coolers)

Planet Earth: Evaporation (if moisture available)

e.g., When sun comes out after showers,

the first thing that happens is that the puddles dry up before temperature increases.
Air holds more water vapor at higher temperatures

A basic physical law tells us that the water holding capacity of the atmosphere goes up at about 7% per degree Celsius increase in temperature. (4% per °F)

Observations show that this is happening at the surface and in lower atmosphere: 0.6°C since 1970 over global oceans and 4% more water vapor.

This means more moisture available for storms and an enhanced greenhouse effect.
Land precipitation is changing significantly over broad areas. Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability.
Proportion of heavy rainfalls: increasing in most land areas

Regions of disproportionate changes in heavy (95\textsuperscript{th}) and very heavy (99\textsuperscript{th}) precipitation

IPCC
Declining **Snow Pack** in many mountain and continental areas contributes to drought

- more **precipitation** falls as rain rather than snow, especially in the fall and spring.
- **snow melt** occurs faster and sooner in the spring
- **snow pack** is therefore less
- **soil moisture** is less as summer arrives

- the risk of **drought** increases substantially in summer
- Along with **wild fire**
Drought is increasing most places

Mainly decrease in rain over land in tropics and subtropics, but enhanced by increased atmospheric demand with warming.

The time series (below) accounts for most of the trend in PDSI.

IPCC
Rising greenhouse gases are causing climate change, and arid areas are becoming drier while wet areas are becoming wetter.

Water management: dealing with how to save in times of excess for times of drought - will be a major challenge in the future.
Heat waves and wild fires

Impacts on human health and mortality, economic impacts, ecosystem and wildlife impacts
Extremes of temperature are changing!

Observed trends (days) per decade for 1951 to 2003:

5th or 95th percentiles

From Alexander et al. (2006)
Heat waves are increasing: an example

Central Europe JJA temperature (anomalies from 1961-90)

Extreme Heat Wave
Summer 2003
Europe
30,000 deaths

Trend plus variability?

IPCC
Absence of warming by day coincides with wetter and cloudier conditions.

Increases in rainfall and cloud counter warming
North Atlantic hurricanes have increased with SSTs

N. Atlantic hurricane record best after 1944 with aircraft surveillance.

Global number and percentage of intense hurricanes is increasing

Marked increase after 1994

IPCC
Global SSTs are increasing: base period 1901-70
Sea level is rising: from ocean expansion and melting glaciers

Since 1993 Global sea level has risen 43 mm (1.7 inches)

- 60% from expansion as ocean temperatures rise,
- 40% from melting glaciers

Steve Nerem
Evidence for reality of climate change

Glaciers melting

1900                2003
Alpine glacier, Austria

1909
Toboggan Glacier
Alaska

1900
2003
Muir Glacier, Alaska

A. Circa 1900

B. Recent

Photo Source: Munich Society for Environmental Research
Snow cover and Arctic sea ice are decreasing. 

**Arctic sea ice area decreased by 2.7% per decade (Summer: -7.4%/decade)**

2007: 22% (10^6 km^2) lower than 2005

**Spring snow cover shows 5% stepwise drop during 1980s**
Increasing melt zones.

Melt descending into a moulin: a vertical shaft carrying water to the base of the ice sheet.

NSIDC (above)
Braithwaite: Univ. Manchester
Natural forcings do not account for observed 20th century warming after 1970

Global Temperature Anomalies
from 1890-1919 average

- Observations
- Natural (volc+solar)
- Anthropogenic + Natural (volc+solar+ghg+sulf+ozone)

Meehl et al, 2004: J. Climate
Precipitation increases very likely in high latitudes
Decreases likely in most subtropical land regions
This continues the observed patterns in recent trends
Arctic sea ice disappears in summer by 2050
Already 2007 lowest on record by 22%

Abrupt Transitions in Summer Sea Ice

- Gradual forcing results in abrupt Sept ice decrease
- Extent decreases from 80 to 20% coverage in 10 years.
- Relevant factors:
  - Ice thinning
  - Arctic heat transport
  - Albedo feedback

Holland et al., GRL, 2006
Context:

400,000 years of Antarctic ice core records of Temperatures, Carbon dioxide and Methane.


Last ice age glacial: 20,000 years ago
Atmospheric Carbon Dioxide Concentration and Temperature Change

- CO₂
- Temp.

- CO₂ concentration in the atmosphere (Antarctic Ice Core)
- Temperature changes through time compared to the present temperature
The UN Framework Convention on Climate Change

- Ratified by 189 countries
- Ratified by the US
- Article 2 is statement of the objective
- Convention entered into force 21 March 1994
Kyoto Protocol

- A legal instrument under UNFCCC
- Requires net reduction in developed country averaged annual GHG emissions of 5% (US 7%) over the period 2008-12 compared to 1990 levels
- “Basket” of GHGs (CO$_2$, CH$_4$, N$_2$O, HFCs, PFCs, SF$_6$)
- Provisions for “flexible” market mechanisms: international trading system, credits, etc.
- 175 countries have ratified
- Protocol was ratified; took effect Feb 16, 2005.
- US withdrew in 2001. In 2004 US emissions were 16% (20%) over 1990 levels for GHG (CO$_2$).
What about a carbon tax?

Anyone can burn stuff and put Carbon Dioxide into the atmosphere as a waste product. If there was a value to Carbon Dioxide then this would presumably be reduced.

A carbon tax, carbon emission limits, or pollution fines are designed to create a cost for burning carbon products, like coal and oil.

Cap and Trade: Given a target (such as in the Kyoto Protocol) only so much can be burned and credits to allow burning can be traded (carbon emissions trading).

Such a solution can be equitable if implemented across the board. But it can favor those who pollute if a country does not subscribe.
Coal fired power stations have been brought on line at a rate of 2 per week over the past 5 years. China leads with one every 3 days or so (560 new plants from 2002 to 2006 and 113 GigaWatts of coal fired power). (200 MW each)

Far from decreasing carbon dioxide emissions, the trend is much worse than “business as usual” and higher than A1FI.

Raupach et al 2007 PNAS

In 2030 global emissions will likely be up by 59% relative to 2004 according to the U.S. Energy Information Administration in its annual International Energy Outlook in May 2007.
The **Kyoto Protocol** basically calls for a **freeze** on emissions to 1990 levels for developed countries. Similarly, the Montreal Protocol for ozone depletion initially called for a freeze on CFC emissions and only later was this changed to a phase out.

A freeze on emissions means that concentrations of carbon dioxide continue to increase. Climate continues to change, temperatures rise and sea level continues to rise.
We can slow global warming down!
Disruption arises more from rapid change than from the climate per se.

Mitigation effects mainly payoff beyond 2050. So we **must** adapt to climate change: we will adapt, whether unplanned (disruptive untold damage and loss of life), autonomously, or planned.
Many things you can do:

• Use energy efficient light bulbs.
Many things you can do:

- Walk, bicycle
- Drive less, and drive fuel efficient vehicles
- Use biofuels
Many things you can do:

- Do not overheat or overcool:
- Set thermostat to 76°F in summer
- Set to 66°F in winter (82°F in Japan)
- Wear a sweater
Many things you can do:

• Use solar power:
• Dry your clothes on the clothes line
• Some HOAs ban clothes lines: clothes lines are environmentally beautiful
Many things you can do:

• Insulate your house etc:
Many things you can do:

- Use renewable energy
- Reduce coal fired power (unless carbon capture and storage employed)
Many things you can do:

- **VOTE!**
- Vote for responsible candidates
- **Most important!**
Our house
The Challenge: Sustainable Management of an Ever-Changed Planet
Our extended forecast includes global warming & the catastrophic end of the human race. But for the weekend, it's looking like sunny skies, mild temperatures, & a general apathy toward environmental concerns.

Back to you, Jim.