Global Warming affects us all: What must be done?

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Help!

Photo Credit/Crédit photographique: Dun Crobie
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.
Climate

The atmosphere is a “global commons.” Air over one place is typically half way 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.
Fossil Fuel CO$_2$ Emissions

Accumulated Fossil Fuel CO$_2$ (1850-2004)

- U.S.: 28.1%
- China: 7.6%
- Russia: 7.6%
- Japan: 3.9%
- India: 2.4%
- Rest of World: 15.6%
- Ship/Air: 3.5%
CO$_2$ 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.
Global Warming is unequivocal

<table>
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<th>Since 1970, rise in:</th>
<th>Decrease in:</th>
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<td>Heat waves</td>
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<td>Ocean acidity</td>
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Global mean temperatures are rising faster with time.

Warmest 13 years:
Global SSTs are increasing: base period 1901-70

°C
Sea level is rising:
from ocean expansion and melting glaciers

Since 1992
Global sea level has risen 48 mm
(1.9 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                2000
Muir Glacier, Alaska

A. Circa 1900
B. Recent

Photo Source: Munich Society for Environmental Research

1900                2003
Alpine glacier, Austria
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.

Severity Index (PDSI) for 1900 to 2002.

The time series (below) accounts for most of the trend in PDSI.
Heat waves and wild fires

Impacts on human health and mortality, economic impacts, ecosystem and wildlife impacts
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
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)

°C

1900 1920 1940 1960 1980 2000

Meehl et al, 2004: J. Climate
The movie simulation is replaced by global mean values.
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
Combined effects of increased precipitation intensity and more dry days contribute to mean precipitation changes

IPCC
Global warming is happening!
Global Warming Actions

Adapt
Technological Fix

Mitigate
Prevent Problem

Future generations
Precautionary Principle

Values

Vested Interests
Equity

Do Nothing
No Problem

Sustainable Development
Mitigation:

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 (CO₂, CH₄, N₂O, HFCs, PFCs, SF₆)
- Provisions for “flexible” market mechanisms: international trading system, credits, etc.
- 176 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 (CO₂).
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. 

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.

Raupach et al 2007 PNAS
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.
A freeze on emissions means that concentrations of carbon dioxide continue to increase.

We can slow global warming down!
Disruption arises more from rapid change than from the climate per se.

Mitigation effects mainly payoff beyond 2040.
So we must adapt to climate change: we will adapt, whether unplanned (disruptive untold damage and loss of life), autonomously, or planned.
Adaptation to climate change

- Assess vulnerability
- Devise coping strategies
- Determine impacts of possible changes
- Plan for future changes

Requires information
The climate is changing: It is likely to continue to change! Regardless of the success of mitigation actions:

We need a comprehensive information system to:

- Observe and track the climate changes and forcings as they occur.
- Analyze global products (with models)
- Understand the changes and their origins
- Validate and improve models
- Initialize models; predict future developments
- Assess impacts regionally: on environment, human activities and sectors such as agriculture, energy, fisheries, water resources, etc.

Such a system will be invaluable regardless of magnitude of global warming

T et al 2003
Weather prediction

- Weather prediction is a problem of predicting the future evolution of the atmosphere for minutes to days to perhaps 2 weeks ahead.
- It begins with observations of the initial state (and their uncertainties) and analyses into global fields, then use of a model of the atmosphere to predict all of the future evolution of the turbulence and eddies for as long as is possible.
- Because the atmosphere is a chaotic fluid, small initial uncertainties or model errors grow rapidly in time and make deterministic prediction impossible beyond about 2 weeks.
Climate prediction

- Climate prediction is a problem of predicting the patterns or character of weather and the evolution of the entire climate system.
- It is often regarded as a “boundary value” problem. For the atmosphere this means determining the systematic departures from normal from the influences from the other parts of the climate system and external forcings (e.g., the sun).
- The oceans and ice evolve slowly, providing some predictability on multi-year time scales.
- But because there are many possible weather situations for a given climate, it is inherently probabilistic.
- Human influences are now the main predictable climate forcing.
Weather and climate prediction

- As the time-scale is extended, the influence of anomalous boundary forcings grows to become noteworthy on about seasonal timescales.
- The largest signal is El Niño on interannual time scales.
- El Niño involves interactions and coupled evolution of the tropical Pacific ocean and global atmosphere. It is therefore an initial value problem for the ocean and atmosphere.
- In fact all climate prediction involves initial conditions of the climate system, leading to a seamless (in time) prediction problem.
Predictability of weather and climate

Weather forecasts

Seasonal to interannual (ENSO)

Climate Predictions
without anthropogenic and with anthropogenic influences
Seamless Suite of Forecasts

Climate Change

Forecast Uncertainty

Boundary Conditions

Weather Prediction

Initial Conditions

Benefits

Forecast Lead Time

Outlook

Guidance

Watches

Forecast

Threats Assessments

State/Local Planning

Environment

State/Local Planning

Energy

Commerce

Health

Recreation

Reservoir Control

Hydropower

Agriculture

Fire Weather

Transportation

Space Operation

Flood Mitigation & Navigation

Protection of Life & Property

Forecast Uncertainty

1 Week

2 Week

Days

Hours

Minutes

Years

Seasons

Months

Forecasts

Watches

Outlook

Guidance

Threats Assessments

Forecasts

Watches

Seamless Suite of Forecasts

Forecast Lead Time
There have been no *revolutionary* changes in weather and climate model design since the 1970s.

- Same dynamical equations, with improved numerical methods
- Comparable resolution
- Similar parameterizations
- A modest extension of the included processes

And the models are somewhat better.

Meanwhile, computing power is up by a factor of a million.

- Model resolution has increased.
  - Horizontal resolution has quadrupled (at most).
  - The number of layers has tripled.
- More processes have been introduced.
- Parameterizations have become a little more elaborate.
- Longer runs
- More runs: ensembles

Adapted from D. Randall (CSU)
5 Dimensions of Climate Prediction

(Tim Palmer, ECMWF)

Simulation complexity

Resolution

Ensemble size

Timescale

Data assimilation/
initial value forecasts

All require much greater computer resource and more efficient modeling infrastructures
End-to-end Forecast System

Forecast

Downscaling

Application model

non-linear transformation

Probability of Precip & Temp…

Probability of Crop yield or disease…
Future needs: A climate information system

- Observations: in situ and from space
- Data processing and analysis
- Data assimilation and model initialization
- Better, more complete models
- Ensemble predictions: many time scales
- Statistical models: applications
- Information: regional, sectoral
Imperative

A climate information system

- **Observations**: forcings, atmosphere, ocean, land
- **Analysis**: comprehensive, integrated, products
- **Assimilation**: model based, initialization
- **Attribution**: understanding, causes
- **Assessment**: global, regions, impacts, planning
- **Predictions**: multiple time scales
- **Decision Making**: impacts, adaptation

An Integrated Earth System Information System
Climate Information System

Possible Threats for Summer 2020:
Drought, hot, dry & unhealthy

- Melting permafrost
- Major fires
- Agricultural production at 50%, blowing dust
- Health warning: Limit outdoor activities; expect brownouts
- Swimming and Fishing prohibited
- Major fisheries regime change likely
- Air quality alerts: 75% of days
- Frequent flooding and Asian dust threats continue
- High danger of toxic CO2 releases
- Expect fisheries downturn; health threats
- 21 Tropical storms: 10 above normal
- African bacteria alerts

New environmental forecast products will be feasible

Forecast for 2020 (in 2019)?
What is your carbon footprint?

- You will be affected by climate change (you are already)
- You will be affected by legislation designed to address climate change (whether good or bad)
The Challenge:
Sustainable Management of an Ever-Changing Planet