Global Warming: Coming Ready or Not!

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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!
Running a fever:
Seeing the doctor

- **Symptoms**: the planet’s temperature and carbon dioxide are increasing
- **Diagnosis**: human activities are causal
- **Prognosis**: the outlook is for more warming at rates that can be disruptive and will cause strife
- **Treatment**: mitigation (reduce emissions) and adaptation (planning for consequences)
What Is Causing the Warming?

Emissions of carbon dioxide pollution

Courtesy Scott Mandia

Changing atmospheric composition: $\text{CO}_2$

Mauna Loa, Hawaii

Data from Climate Monitoring and Diagnostics Lab., NOAA. Data prior to 1974 from C. Keeling, Scripps Inst. Oceanogr.
Fossil Fuel Emissions

Accumulated Emissions: 1751-2010

- U.S.: 27%
- Rest of World: 14%
- China: 10%
- Russia: 7%
- Japan: 4%
- U.K.: 6%
- Germany: 6%
- Ships/Air: 2%
- Can./Aust.: 3%
- India: 3%
- Rest of Europe: 18%

2010 Emissions

- U.S.: 17%
- Rest of World: 25%
- China: 24%
- Rest of Europe: 9%
- Germany: 2%
- U.K.: 2%
- Japan: 4%
- Russia: 5%
- India: 6%
- Ships/Air: 3%
- Can./Aust.: 3%
2007 emissions: Population matters

China biggest emitter

- 14% more than US
- Per capita Pop.
  - U.S.: 19.4 0.31
  - Russia: 11.8 0.14
  - E. U.: 8.6 0.50
  - China: 5.1 1.33
  - India: 1.8 1.14

Netherlands Environmental Assessment Agency 2008
Population explosion

Population Growth Rate

World population development

Billions

0.2 1
0.5 1650
1: 1804
2: 1927
3: 1960
4: 1974
5: 1987
6: 1999
7: 2011

Billions: time

Developing countries
Industrialized countries
The Natural Greenhouse Effect: clear sky

Clouds also have a greenhouse effect

Kiehl and Trenberth 1997
The Greenhouse Effect

Solar radiation passes through the clear atmosphere.

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.

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 amounts to 175 PetaWatts
\[=175,000,000\text{ billion Watts.}\]
About 122 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 122 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.
Solar irradiance

The drop of 1.2 W m$^{-2}$ since 2001 is equivalent to -0.2 Wm$^{-2}$ in radiative forcing.
Global Warming is Unequivocal
IPCC: approved 113 govts

Since 1970, rise in:
- Global surface temperatures
- Tropospheric temperatures
- Global SSTs, ocean Ts
- Global sea level
- Water vapor
- Rainfall intensity
- Precipitation extratropics
- Hurricane intensity
- Drought
- Extreme high temperatures
- Heat waves
- Ocean acidity

Decrease in:
- NH Snow extent
- Arctic sea ice
- Glaciers
- Cold temperatures
The seas are warming up, turning sour, and losing breath

Nicolas Gruber (Phil Trans Roy Soc 2011)

- Higher SSTs, higher ocean Temperatures,
- Sea ice melt
- Increased stratification
- Global sea level rise
- Acidification (increased dissolved CO2)
- Oxygen loss (deoxygenation: nutrients from land)
- Corals in hot water: bleaching
- Phytoplankton on the wane
- Dead zones increasing

Phytoplankton bloom off Norway, MODIS, NASA 24 Jul 2004
Porites coral, Kirabati, May 2010
Global temperature and carbon dioxide: anomalies through 2011

Base period 1900-99; data from NOAA
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.
Human impacts on climate related to water

- Warming: more heat, higher temperatures
- The atmosphere can hold more water vapor
  - 4% per °F = observed
- Over wet areas (ocean) => more moisture
- More heat → more evaporation → more precipitation
- Longer dry spells, more drought (where not raining)
- More intense rains/snows
- More intense storms

More floods and droughts
Most precipitation comes from moisture convergence by weather systems.

Rain comes from moisture convergence by low level winds:

More moisture means heavier rains.
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
- earlier runoff and peak streamflow
- snow pack is therefore less
- soil moisture is less as summer arrives

- the risk of drought increases substantially in summer
- Along with wild fire
Trends 1948-2004 in runoff by river basin
Based on river discharge into ocean

Dai et al. 2009
North Atlantic hurricanes have increased with SSTs.

Katrina
August 2005
The 2005 season broke many records.
North Atlantic hurricanes have increased with SSTs from 1944-2006. N. Atlantic hurricane record best after 1944 with aircraft surveillance. Marked increase after 1994 and percentage of intense hurricanes is increasing Thru 2011.
Isaac Aug 28, 2012

Courtesy NASA
Sea level is rising: from ocean expansion and melting glaciers

Since 1992 Global sea level has risen 55 mm (2.2 inches)

To 2003: 60% from expansion (ocean temperatures)
40% from melting glaciers/land ice.

2003-10: 1.5 mm/yr from melting land ice.

2010-11: big dip contribution from rain on land.

AVIS: from TOPEX, Jason 1, Jason 2. Ann cy removed, IB, GIA applied.
Evidence for reality of climate change

Glaciers melting

1909
Muir Glacier, Alaska

1941
2004

Toboggan Glacier
Alaska

2000

Increased Glacier retreat since the early 1990s

1900
1990
2003
Alpine glacier, Austria
Snow cover and Arctic sea ice are decreasing

Arctic sea ice area decreased by 40% in summer 2007: 22% ($10^6 \text{ km}^2$) lower than 2005  
2012 lowest on record

Late August 2012

NSIDC; NASA
Climate change and extreme weather events

Changes in extremes matter most for society and human health

With a warming climate:
- More high temperatures, heat waves
- Wild fires and other consequences
- Fewer cold extremes.

More extremes in hydrological cycle:
- Drought
- Heavy rains, floods
- Intense storms, hurricanes, tornadoes
The environment in which all storms form has changed owing to human activities.
Frequency of summer temperature anomalies (how often they deviated from the historical normal of 1951-80) over the summer months in the northern hemisphere. Source: NASA/ Hansen et al. 2012 http://climatecrocks.com/2012/08/05/hansen-on-the-new-math-of-extreme-events/
Russia  Aug 2010

>50,000 lives lost
Record heat
Wild fires

India:  Jul-Aug 2010

Pakistan:  Jul-Aug 2010

Courtesy NASA
Australia

Flooding Queensland Early Jan 2011
SSTs: JJA 2010

- Hurricanes 2nd most active
- Pakistan floods July-Aug
- Queensland floods Dec-Jan
- Colombia floods Aug-Dec

Trenberth 2012, Cli Change
Flooding on the Mississippi:

There were multiple “1-in-500 year” or “1-in-100 year flood events within a few years of each other in parts of the Basin...

1993
Then again in 2008.
And now: 2011

AP 2000; NYT 2011 Peter Gleick
Arizona on fire
June 7-14, 2011

Biggest fire ever
(also Mexico)

Drought, heat, worst wild fire in Texas history!
Bastrop State Park: 14,000 acres,
Nearly 600 homes destroyed. 5 Sept 2011

JJA 2011: Hottest on record
January-December 2011 Statewide Ranks
National Climatic Data Center/NESDIS/NOAA

Precipitation

1 = Driest
117 = Wettest

Texas Statewide Precipitation 1895-2011
Northeast Region Precipitation 1895-2011
Recent US climate extremes

March 2012
Colorado on Fire: June 2012

Flagstaff fire: above NCAR, circled.
High Park fire 259 houses, 1 death

Waldo Canyon fire
346 homes...
News Outlets Avoid Topic Of Climate Change In Wildfire Stories

http://mediamatters.org/research/2012/07/03/study-media-avoid-climate-context-in-wildfire-c/186921
U.S. Temperatures
Jan-Jul 2012
Hottest on record

Aug 2011-Jul 2012
Hottest year on record

NCDC, NOAA
Meanwhile: record flooding elsewhere:

**Southern Russia**
Early July 2012
172 dead
11 inches of rain
Water rose 12 feet in mins
Poor warnings

**Southern Japan**
6-12 July 2012
Torrential rain (> 10”): flash floods, mudslides
>32 dead or missing.
400,000 evacuated.

**Beijing**
21-22 July 2012
$2B damage
Worst rains in 61 years: (up to 18 inches)
Natural forcings do not account for observed 20th century warming after 1970

Meehl et al, 2004: J. Climate
Projected temperature change

CCSM Movie

Surface temperature change relative to 1870-1899 baseline

Globally averaged surface temperature change (relative to 1870-1899 baseline)

Krakatau  Santa Maria  Agung  El Chichon  Pinatubo

Gary Strand, NCAR/DOE
Projected Frequency of Extreme Heat: 1-in-20 Year Events. By the end of this century, a once-every-20 year heat wave is projected to occur every other year. Source: U.S. GCRP
Rich get richer and poor get poorer:

Combined effects of increased precipitation intensity and more dry days contribute to mean precipitation changes, increased evaporation also important for soil moisture.

IPCC 2007
This week's "Climate Change: Fact or Fraud?" discussion has been postponed due to the flooding, the sudden blizzard, the firestorm, the tornado warning and the hail the size of coconuts.
Future prospects

To avoid disastrous climate, “the scientific view is that the increase in global temperature should be below 2°C”: about 3.6°F.

To achieve that “deep cuts in global emissions are required”

Copenhagen Accord, 2009.

So far, temperatures have risen 0.8°C. But we are committed already to at least 0.6°C more owing to the slowly warming oceans and long lifetime of CO₂.

In fact 2°C is programming in many problems…
Future impacts

Smith et al
PNAS 2009
Future prospects

Scientists estimate that the total warming depends mostly on the total emissions of greenhouse gases and for 2°C the limit is **565 more gigatons** of carbon dioxide into the atmosphere by midcentury.


CO₂ emissions last year rose to **31.6 gigatons**, up 3.2% from the year before. (Intl Energy Agency)

- US emissions fell slightly (warm winter, recession)
- China’s emissions rose 9.3%

At current rates: we will go through that limit in **16 years**!

How much is available? **2,795 Gigatons** in proven coal, oil and natural gas reserves.

Bill McKibben 2012
Multi-dimensional problem

- Environmental
- Economic
- Human strife
- Trade (tariffs)
- Foreign policy
- Security
- Sustainability
"We will pay for this one way or another. We will pay to reduce greenhouse gas emissions today, and we’ll have to take an economic hit of some kind. Or we will pay the price later in military terms. And that will involve human lives."

GEN. ANTHONY C. ZINNI, former head of the Central Command, on climate change.
We need a price on carbon emissions!

As we have seen this year, there are major costs: billions, to climate change via droughts and wildfires, and floods. [Lives lost, crop loss, crop insurance, wild fire losses, costs of fighting fires, property damage, dislocation, disease, etc]

The costs are not borne by those who cause the problem.

Explicit and implicit subsidies for fossil fuels do not make the playing field level for renewable energy.

The U.S. is a major part of the problem.
Skepticism and denial

Several studies find a widespread relationship between belief in free markets and rejection of climate science.

Endorsement of conspiracy theory also goes with rejection of climate science

* e.g. NASA faked the moon landing
  FBI killed Martin Luther King...

Lewandowsky et al 2012
Skepticism and denial

There are widespread well financed denial campaigns to
• Maintain the status quo
• Undermine scientists
• Oppose possible government regulations

• US Chamber of Commerce
• Exxon Mobile
• American Petroleum Inst
• Western Fuels
• Koch Bros, Scaife,

Often through third parties with euphemistic names:
• Citizens for a Sound Economy
• Americans for Prosperity
• Competitive Enterprise Inst
• Heartland Inst
• Cooler Heads Coalition...

Oreskes and Conway 2010
Dunlap and McCright 2011
WHICH MAKES MORE SENSE?

REGIONAL ENVIRONMENTAL GROUPS AND COMMUNITY ACTIVISTS...

ARE SPENDING THEIR LIMITED OPERATING BUDGETS...

IN A MASSIVE CONSPIRACY WITH 90% OF THE WORLD’S SCIENTISTS...

TO CREATE A WORLDWIDE HOAX AND CRASH THE GLOBAL ECONOMY.

BIG OIL COMPANIES...

ARE SPENDING THEIR OBSCENE PROFITS...

TO BRIBE ANYONE THEY CAN...

TO PROTECT THEIR PROFITS AND LIMIT ANY FUTURE LIABILITY THEIR POLLUTION MAY CAUSE.

Pat Parenteau
Vermont Law School
What if it's a big hoax and we create a better world for nothing?

- Energy independence
- Preserve rainforests
- Sustainability
- Green jobs
- Livable cities
- Renewables
- Clean water, air
- Healthy children
- Etc. etc.
Many things you can do:

Going Green!
There is no Planet B