CLIMATE CHANGE
THE KNOWNS, THE KNOWN UNKNOWNS,
AND THE UNKNOWN UNKNOWNS

Stephen E. Schwartz

Jefferson’s Ferry Public Affairs Committee Forum
South Setauket NY
June 27, 2011

http://www.ecd.bnl.gov/steve
As we know, there are known knowns; there are things we know we know.

We also know there are known unknowns; that is to say we know there are some things we do not know.

But there are also unknown unknowns—the ones we don’t know we don’t know.

Donald Rumsfeld
SCIENTIFIC EVIDENCE FOR GLOBAL WARMING

Stephen E. Schwartz

Jefferson's Ferry Public Affairs Committee Forum
March 13, 2003

SOME CHILLING CONSIDERATIONS ABOUT GLOBAL WARMING

Stephen E. Schwartz

Jefferson’s Ferry Public Affairs Committee Forum

January 14, 2008

http://www.ecd.bnl.gov/steve
KNOWN
The Greenhouse Effect

Some solar radiation is reflected by the Earth and the 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.

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.

$CO_2$, Carbon Dioxide
KNOWN
BUT WRONG
THE GREENHOUSE EFFECT

EARTH’S ENERGY BUDGET: A DELICATE BALANCE

- Sunlight heats the Earth.
- The warm Earth radiates energy (in the form of infrared radiation, or heat) back out to space.
- Some of this infrared radiation is trapped in the atmosphere, giving Earth its temperate climate.

This is the greenhouse effect.

Global average temperature 15°C or 59°F

Without it, the Earth’s climate would be like the moon’s, harsh and severe.

Global average temperature -19°C or -2°F
KNOWN
Global carbon dioxide concentration over the last thousand years
GLOBAL ANNUAL TEMPERATURE ANOMALY, 1880-2010

Data: Goddard Institute for Space Studies
About 2 km shorter.
Terminus replaced by artificial lake.
Decrease in length about 15 meters per year.
In 2003, decrease was 30 m in length and 6.5 m in thickness.

http://www.worldviewofglobalwarming.org/pages/glaciers.html
GRINNELL GLACIER
GLACIER NATIONAL PARK 1911 - 2000

http://www.worldviewofglobalwarming.org/pages/glaciers.html
GLACIER AX010, NEPAL, 1978-2004

http://snowman.ihas.nagoya-u.ac.jp/download/photo/AX010.html
Muir Glacier, William O. Field on 13 August 1941 and by Bruce F. Molnia on 31 August 2004
UPSALA GLACIER, ANDES, ARGENTINA

1928

2004
RHONE GLACIER, VALAIS, SWITZERLAND
1859 - 2001

Glacial retreat is 2.5 km.
Base is 450 meters higher.

http://www.worldviewofglobalwarming.org/pages/glaciers.html
KNOWN UNKNOWNS
ARIZONA FIRES
Sierra Vista, Arizona, June, 2011

Third largest fire in Arizona history.
ARIZONA FIRES
Monument Fire, Arizona, June, 2011
MISSISSIPPI RIVER FLOOD

Vicksburg, Mississippi, May, 2011

Second highest flood on record; highest since 1937.
FLOODS IN NORTH DAKOTA
Souris River, Minot North Dakota, June 27, 2011

The river surpassed its 1881 record level of 1,558 feet above sea level, and flooded an estimated 4,000 homes in the city.
Devastating EF5 multiple-vortex tornado that struck Joplin, Missouri, late in the afternoon of Sunday, May 22, 2011.
Seven tornadoes from Connecticut to Maine in rare New England outbreak.
1,140 confirmed tornadoes reported in the US in 2011 as of June 23, 2008. 537 U. S. deaths, compared to 564 in the 10 years prior.
Slight shift in probability distribution can greatly increase probability of extreme events.
KNOWN
2009 COPENHAGEN ACCORD ENDORSES 2°C (3.6 °F) MAXIMUM TEMPERATURE RISE

The Heads of State, Heads of Government, Ministers, and other heads of the following delegations present at the United Nations Climate Change Conference 2009 in Copenhagen:  
Albania, Algeria, Armenia, Australia, Austria, Bahamas, Bangladesh, Belarus, Belgium, Benin, Bhutan,  
Tonga, Trinidad and Tobago, Tunisia, United Arab Emirates, United Kingdom of Great Britain and Northern Ireland, United Republic of Tanzania, United States of America, Uruguay and Zambia,  

*Have agreed* on this Copenhagen Accord which is operational immediately.

1. We underline that climate change is one of the greatest challenges of our time. We emphasise our strong political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities. To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change. We recognize the critical impacts of climate change and the potential impacts of response measures on countries particularly vulnerable to its adverse effects and stress the need to establish a comprehensive adaptation programme including international support.
KNOWN
UNKNOWN
UNKNOWN
From Forcing by Long-lived Greenhouse Gases
Why Hasn’t Earth Warmed as Much as Expected?

Stephen E. Schwartz
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Ralph A. Kahn
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John A. Ogren
NOAA/Earth System Research Laboratory, Boulder, Colorado

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ALLOWABLE FUTURE CO$_2$ EMISSIONS

So as not to commit the planet to increase in global temperature greater than the agreed maximum, 2°C

ABSTRACT

The observed increase in global mean surface temperature (GMST) over the industrial era is less than 40% of that expected from observed increases in long-lived greenhouse gases together with the best-estimate equilibrium climate sensitivity given by the 2007 Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Possible reasons for this warming discrepancy are systematically examined here. The warming discrepancy is found to be due mainly to some combination of two factors: the IPCC best estimate of climate sensitivity being too high and/or the greenhouse gas forcing being partially offset by forcing by increased concentrations of atmospheric aerosols; the increase in global heat content due to thermal disequilibrium accounts for less than 25% of the discrepancy, and cooling by natural temperature variation can account for only about 15%. Current uncertainty in climate sensitivity is shown to preclude determining the amount of future fossil fuel CO$_2$ emissions that would be compatible with any chosen maximum allowable increase in GMST; even the sign of such allowable future emissions is unconstrained. Resolving this situation, by empirical determination of the earth’s climate sensitivity from the historical record over the industrial period or through use of climate models whose accuracy is evaluated by their performance over this period, is shown to require substantial reduction in the uncertainty of aerosol forcing over this period.

Even the sign of allowable future emissions is unknown.
If climate sensitivity is low, we have approximately 40 years at current emission rates.
If climate sensitivity is high, we are already overcommitted by 40 years.
NOT WELL KNOWN
KNOWN
KNOWNS
ATMOSPHERIC CARBON DIOXIDE
Time series 1700 - 2003

Law Dome (Antarctica)
Siple (Antarctica)
Mauna Loa (Hawaii)
That can’t be right.
That must be well known.
DEFORESTATION AS A SOURCE OF ATMOSPHERIC CO₂
Prior to 1910 CO$_2$ emissions from land use changes were dominant.

Subsequently fossil fuel CO$_2$ has been dominant and rapidly increasing!
ATtribution of Increase in Atmospheric CO$_2$

Comparison of cumulative CO$_2$ emissions from fossil fuel combustion and land use changes with measured increases in atmospheric CO$_2$.

Prior to 1970 the increase in atmospheric CO$_2$ was dominated by emissions from land use changes, not fossil fuel combustion.
CO₂ from land use emissions – not fossil fuel combustion – was the dominant contribution to atmospheric CO₂ over most of the 20th century. Fossil fuel is dominant now, roughly 2:1.
UNKNOWN
UNKNOWN
UNKNOWN
UNKNOWN
Hello. Tonight we review 2008's CLIMATE SCIENCE - the KNOWNS, the KNOWN UN-KNOWNS and the UN-KNOWN UN-KNOWNS.

So, Doc - these pesky UN-KNOWN UN-KNOWNS? WHAT are they and HOW MANY of them are there?

Er...I DON'T KNOW!

And you call yourself an EXPERT?
KNOWN
WHERE IS ALL THIS CO$_2$ COMING FROM?

WHO IS RESPONSIBLE?
WHERE IS THIS CARBON DIOXIDE COMING FROM?

WE ARE ALL RESPONSIBLE.

Burning a gallon of gasoline in your car puts 5 pounds of carbon in the atmosphere as carbon dioxide (CO₂), and it will stay there for decades — maybe a century!

Other sources are home heating and electric power production.
Global Atmosphere, Global Warming

Questions about Global Warming
- Is it real?
- Is it important?
- What is it due to?
- How much more can we expect?
- Are we seeing just the tip of the iceberg?

Research at Brookhaven National Laboratory is helping to answer these questions.