

Anthropogenic Climate Change is Not Yes or No", It's How Much"?

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What do I do?

I am a physical oceanographer

© I am a climate modeler

• I study currents, tides, turbulencegenerally, the processes that move water, energy, and pollutants

I use supercomputers, differential
 equations, statistics, and observations



Work on what you love! The Earth

Why it matters to me

Why it should matter to you

Why it should matter to your students

Breakhing contributes to CO2 buildup?

"Pollution; none of us are supporting putting substances into the atmosphere or the waterways that might be pollutants, but carbon dioxide is not a pollutant. If Senator Wong was really serious about her science she would stop breathing because you inhale air that's got 385 parts per million carbon dioxide in it and you exhale air with about ten times as much, and that extra carbon comes from what you eat. So that is absolute nonsense." (Ian Plimer)



Requires quantitative appreciation

Image: Skeptical Science



Residence time: \$Bucks in the Bank\$\$\$

Steady-state:

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- Income=pay/time=expenses/time=outflow
 - Steady savings in account (constant \$ reservoir)
- What if you lose your job?



- How long does it take to deplete the account?
 - Savings/(expenses/time)=Savings/Outflow=Drain time
- Get a new job, and save EVERYTHING!
 - How long does it take to build up back up savings?
 - Savings/(pay/time)=Savings/Income=Build time
- In steady-state, Income=Outflow, so
 Drain time=build time=residence time



Mauna Loa 1958 - 2016



"Keeling" curve. shows our Carbon budget is not balanced! Updated here by Pieter Tans, NOAA

Breakhing contributes to CO2 buildup?

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Dilution is the Solution to Pollution...

- Pollutant: Any substance present in the environment in harmful concentration, which adversely alters the environment.
- Qualitative Pollutant versus
 Quantitative Pollutant

Requires quantitative understanding

So, in a mulshell...

- The Earth is capable of absorbing some excess atmospheric carbon (land, life, ocean, rocks).
- It is the rate of emission that's the problem.
- Burning fossil fuels globally means taking millions of years worth of buried fossils and putting them in the atmosphere fast!

Global warming isn't just a carbon problem, though...

Carbon toxicity isn't the problem (except ocean acidification), it's that carbon dioxide affects energy on Earth.

> Is Energy A Pollulant????

Quantitative: Surface Energy Budget



Superbugets: Global Climate Models

A collection of physical, chemical, biological, and geological relationships and budgets-often constructed using sets of nonlinear partial differential equations solved numerically on a model grid.

> Requires quantitative appreciation!!!!



Why do we want climate models? Understanding, Experiments, Projections.



Source: IPCC AR4, 2007 via Kasting, Kump & Crane



Source: IPCC AR4, 2007 via Kasting, Kump & Crane



How awesome are climate models?

- These include *everything we know* about the atmosphere, ocean, cryosphere, biosphere, and lithosphere that might affect the climate!
- Any one of these systems is enormously complicated—way too hard to solve the equations by hand—but using supercomputers we can experiment with the modeled system as a whole.
- "All models are wrong, but some models are useful." — Statistician George Box, 1978



What it may take to get a model to have these eddies:



We can't even forecast the weather two weeks ahead. How can we project the climate a century ahead?



6 day forecast error



FIG. 3. Evolution of forecast errors from 1981 to 2012 for (a),(c) NH and (b),(d) SH. Operational forecasts (blue) and ERA-Interim (green). Note that before 1986, the operational analysis is used to verify the operational forecasts; after 1986, ERA-Interim is used for the verification (with an overlap of 6 months to the present).

Well, Weather forecasts are getting better and better! (Magnusson & Kallen 2012), But...



ECCO Movie: Chris Henze, NASA Ames

tau / qflux / theta200m / kppMLD

Jan 1 00:30 2001



Weather, Atmosphere Fast

Ocean, Climate Slow

3.4m of ocean water has same heat capacity as the WHOLE atmosphere



ECCO Movie: Chris Henze, NASA Ames

00:30 2001

Jan 1

tau / qflux / theta200m / kppMLD

Weather, Atmosphere Fast

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Source: IPCC AR4, 2007 via Kasting, Kump & Crane



What's the same among the As? the budgets



Prediction & Attribution: Effects of Anthropogenic Forcing





Natural

IPCC AR5, 2013

Sources of uncertainty in projected global mean temperature



Don't trust the models? How do we observe that there's excess energy? One important way: Sea Level Rise

Most of the excess energy ends up in the oceans

Water expands when it warms

Melting ice & snow on land takes up energy and also adds ocean water Another reason to care about ocean warming—and to observe it (by subtraction): Sea Level Rise



IPCC AR5, 2013

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OK-there's a problem

What can we do?

What can we do? Teach!

"When I do teach about climate change, I emphasize ..."



Teachers' emphasis. Teachers reported emphasis on causes of global warming, among those devoting an hour or more to the topic (see SM for details on calculation).

Pulitzer et al. Science, 2016

Survey: Do you think human activity is a significant contributing factor in changing mean global temperatures? (Doran & Zimmerman 2009)



Fig. 1. Response distribution to our survey question 2. The general public data come from a 2008 Gallup poll (see http://www.gallup.com/poll/1615/Environment.aspx).

Albernative or Disinformation? How many of you got one of these?

- Who is the NIPCC?
- Are they the same as the IPCC?
- Tidn't they win a Nobel Prize with AL Gore?

Why Scientists Disagree About Global Warming

The NIPCC Report on Scientific Consensus



Craig D. Idso · Robert M. Carter · S. Fred Singer Foreword by Marita Noon

IPCC VS. NIPCC?

 The gold standard of recording climate
 change consensus

United Nations
 Intergovernmental
 Panel on Climate
 Change

@ (UN IPCC, not NIPCC)

INTERGOVERNMENTAL PANEL ON CLIMATE CHARGE

CLIMATE CHANGE 2013 The Physical Science Basis

WORKING GROUP I CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WGI



Question: By Show of Hands Indicate Whether You Have Heard that the IPCC is

- A) Wrong
- B) Independent Police Complaints Commission of England & Wales
- C) Together with Al Gore, they invented the internet
- D) The Intergovernmental Panel on Climate Change, a nonpolitical group that reviews peer-reviewed climate science and summarizes it for policymakers, who won a Nobel Peace Prize shared with Al Gore.



Image: Al Gore's Google+



01-IntroClimate

Image: fotobridge.com

The Opinion Pages | OP-ED CONTRIBUTOR

Sowing Climate Doubt Among Schoolteachers

By CURT STAGER APRIL 27, 2017



THE HEARTLAND INSTITUTE 🄎

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Craig D. Idso · Robert M. Carter · S. Fred Singer Foreword by Marita Noon



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INTERGOVERNMENTAL PANEL ON CLIMPTE CHARGE

CLIMATE CHANGE 2013

The Physical Science Basis

Teach Accurate Sources.

- realclimate.com, desmogblog.com, skepticalscience.com
- Better Yet (but require quantitative appreciation!):
 - Peer-Reviewed Journals: Science, Nature, Bulletin of the American Meteorological Society, Journal of Climate, etc.
 - Scientific Societies: AMS, AGU, AAAS, National Academies, etc.
 - Govt & Public-funded Research:
 US National Parks, NOAA, NASA, EPA, ONR, WMO, UN Intergovernmental Panel on Climate Change (IPCC)



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Tesla Noether

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We can all hope for a genius lo save us...

But, we can all do our part to make the job easier...

What can we do?

Greenhouse Gas Emissions by Economic Sectors



IPCC AR5, 2013

Solve the problem with changes in one industry?

Dieting equivalent:

Lose weight by only eliminating desserts.



Diet equivalent: Consistently make good choices benefits from quantitative appreciation



Cleaner power plants

Obama-era policies for reducing greenhouse gas emissions









California: a climate battle brewing



Or, don't quibble about the details and address it all at once

The Opinion Pages | OP-ED CONTRIBUTORS

A Conservative Case for Climate Action

By MARTIN S. FELDSTEIN, TED HALSTEAD and N. GREGORY MANKIW FEB. 8, 2017

Diet equivalent: Count calories

Carbon Dividends" make polluters pay a "dividend" to everyone else to buy the ability to emit carbon.

On-again-off-again regulation is a poor way to protect the environment."

How to reduce carbon isn't a science question, it's a political one!

What can we do? Diet equivalent: Weight loss pill GeoEngineering If ENERGY is the problem, maybe change the energy cycle (a.k.a. GeoEngineering): Green roofing/albedo modification Second Ecosystem modification—plant trees, alter carbon pathways... Inhibit solar input (cloud brightening, stratospheric aerosols...) "First, Do No Harm": Side Effects?

WHAT WE CAN'T DO: NOTHING

We can ignore the problem for now...then adapt.

We are affecting the global climate. We can choose paths to reduce the effect, or we will adapt to the changing climate. Diet equivalent to adaptation: Treat the diseases that come with obesity

How to handle climate change is part science, part technology, part politics.

All require quantitative thinking.

What we can do is teach our students quantitative skills and an appreciation for accurate, precise information.