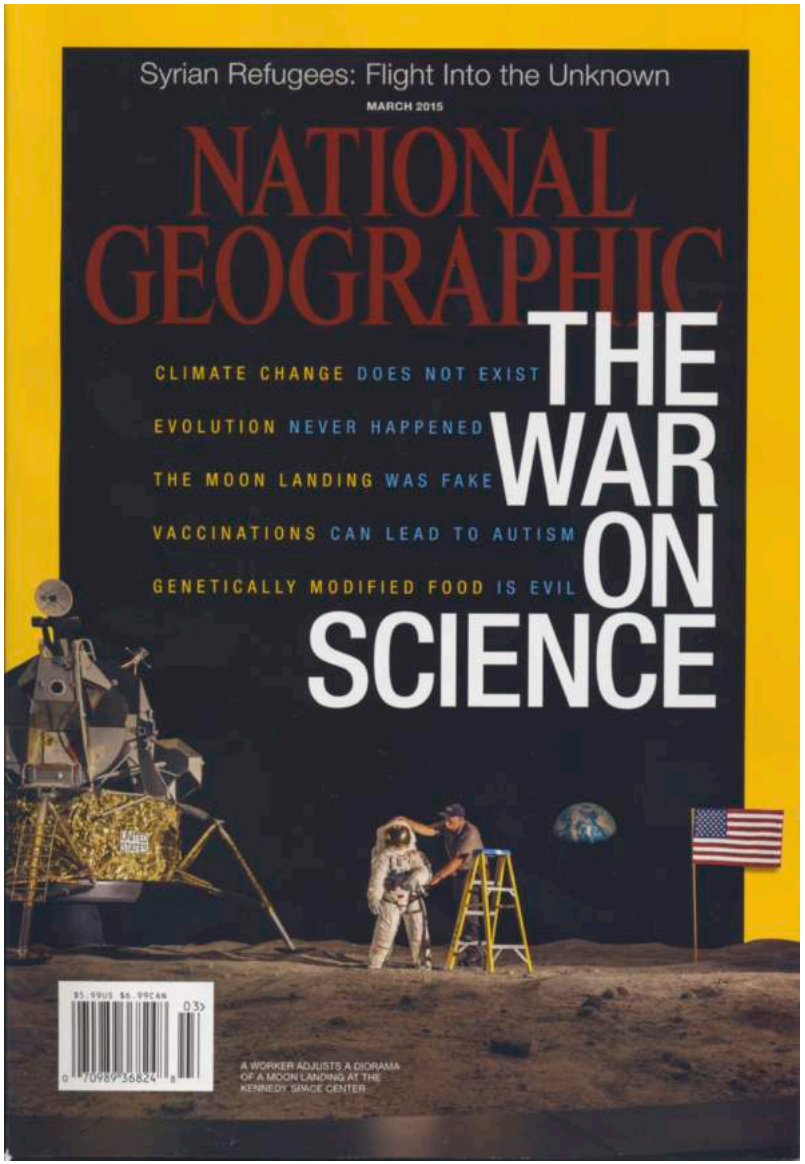
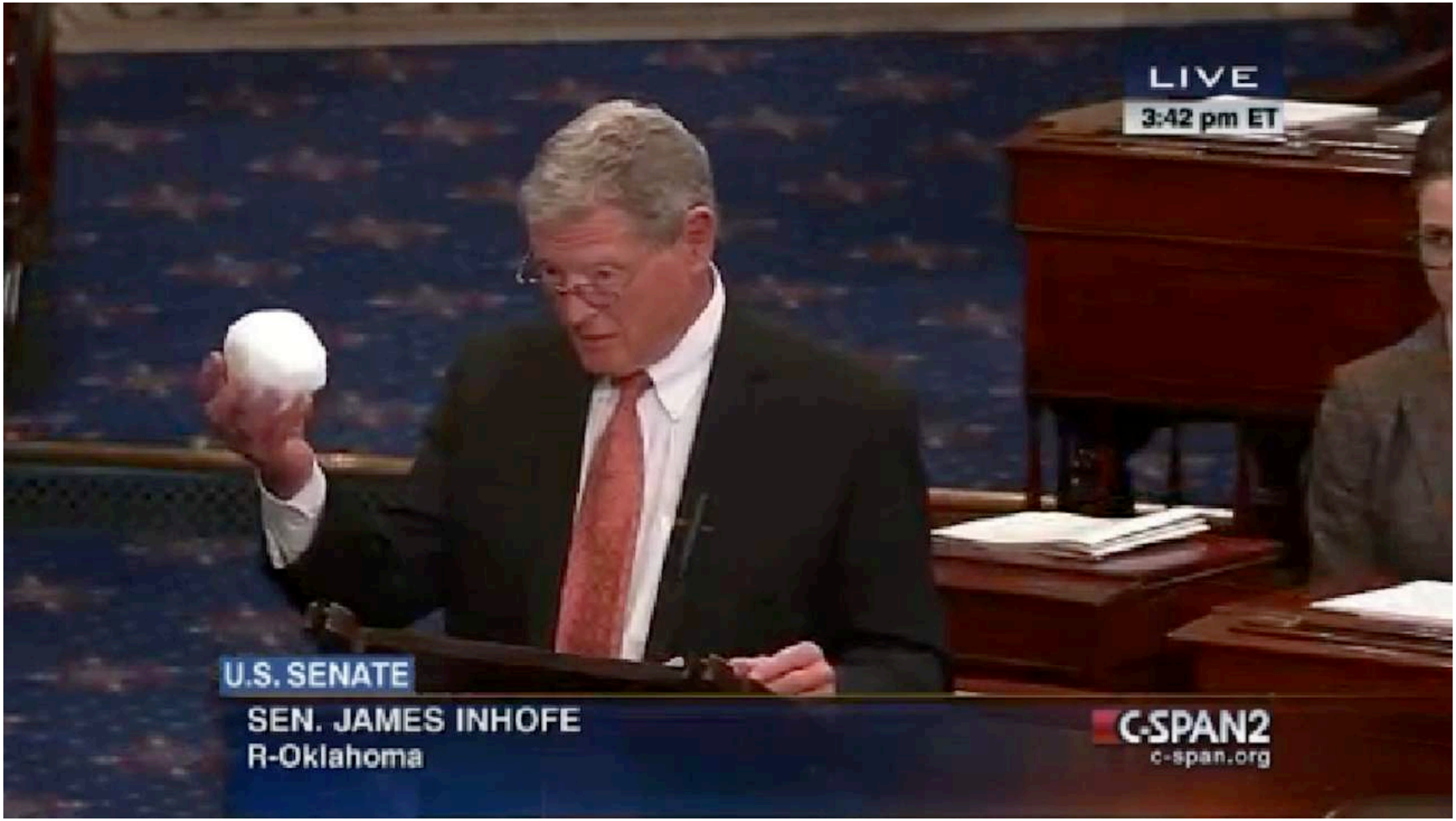
The War on Science:

Climate Change in an Era of Doubt

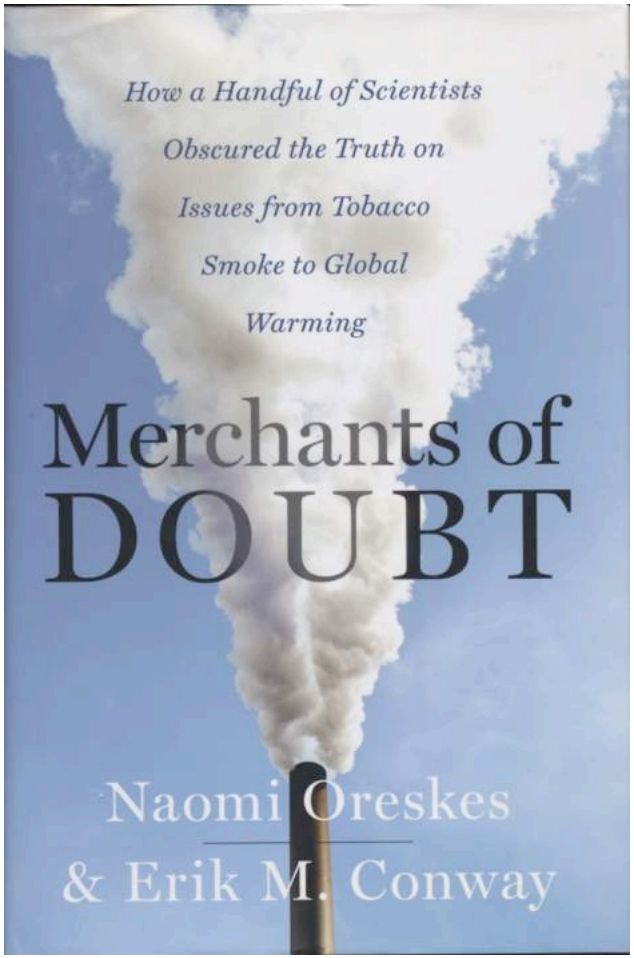
William I. Newman, Ph.D.

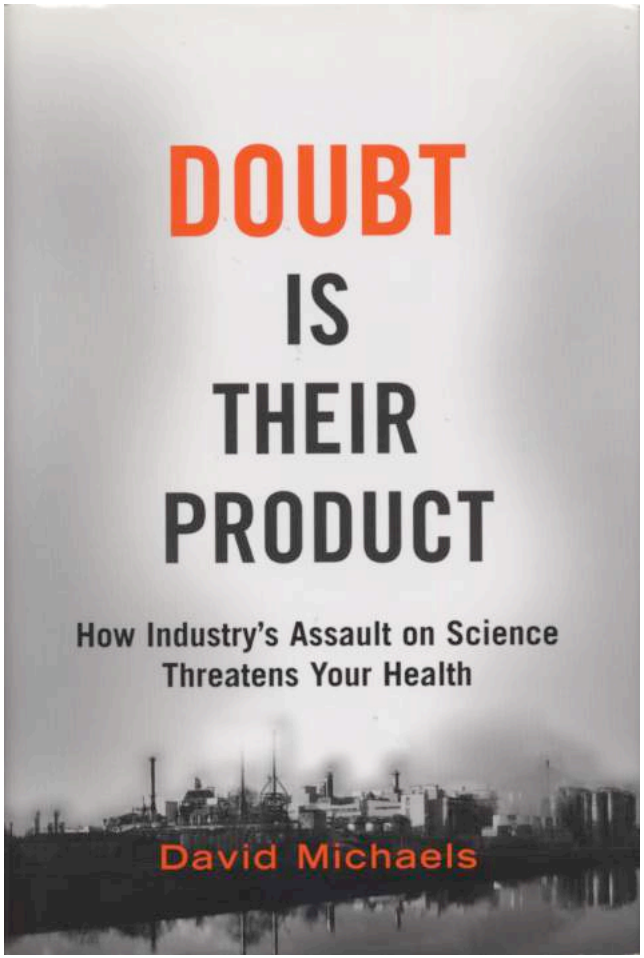
March 12, 2017


Syrian Refugees: Flight Into the Unknown
MARCH 2015
NATIONAL GEOGRAPHIC
CLIMATE CHANGE DOES NOT EXIST
EVOLUTION NEVER HAPPENED
THE MOON LANDING WAS FAKE
VACCINATIONS CAN LEAD TO AUTISM
GENETICALLY MODIFIED FOOD IS EVIL
THE WAR ON SCIENCE
A WORKER ADJUSTS A DIORAMA OF A MOON LANDING AT THE KENNEDY SPACE CENTER.


LIVE
3:42 pm ET
U.S. SENATE
SEN. JAMES INHOFE
R-Oklahoma
C-SPAN2
c-span.org

Scholarly works addressing topic:



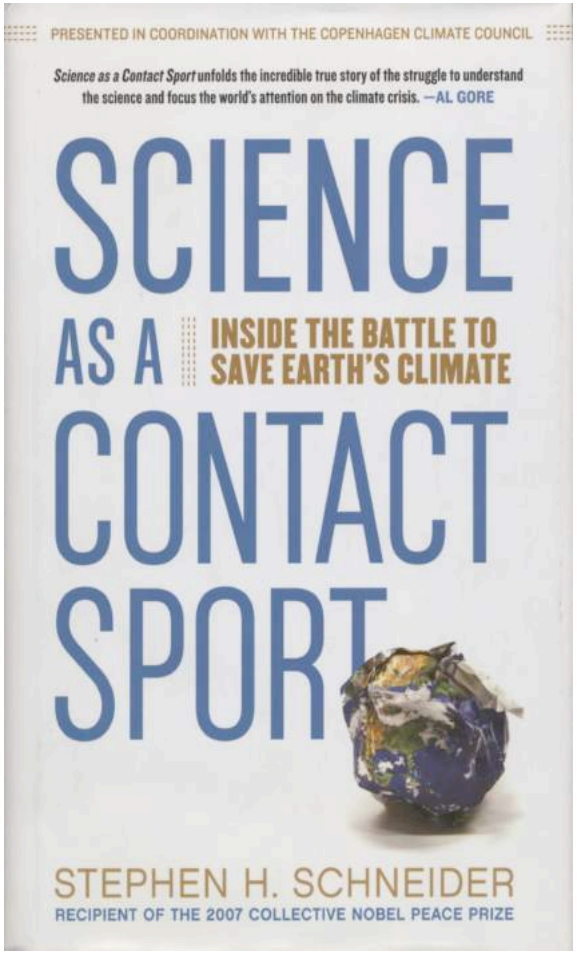


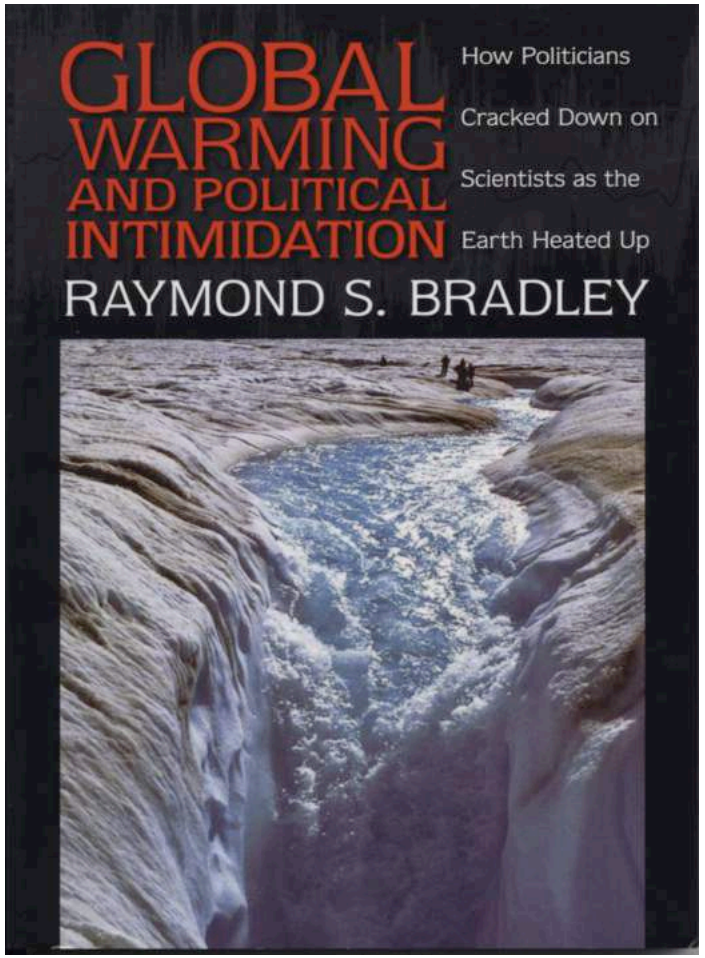
Tobacco industry following Surgeon General Luther Terry's report (1963)

How disinformation is produced

- Techniques developed by tobacco industry
  - Issue or claims are controversial
  - Quality of data is poor, possibly fraudulent
  - More time needed to get better data
- Same methods employed today regarding
  - Climate change
  - Evolution
  - Moon landing
  - Vaccinations
  - Genetically modified food

Acceptance of science at post-war low; another special interest group

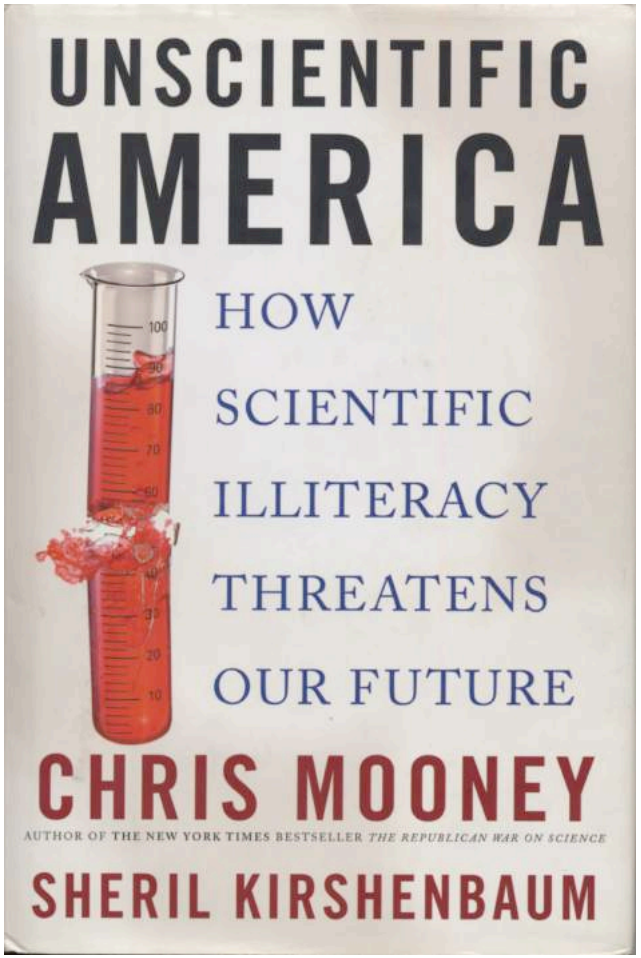


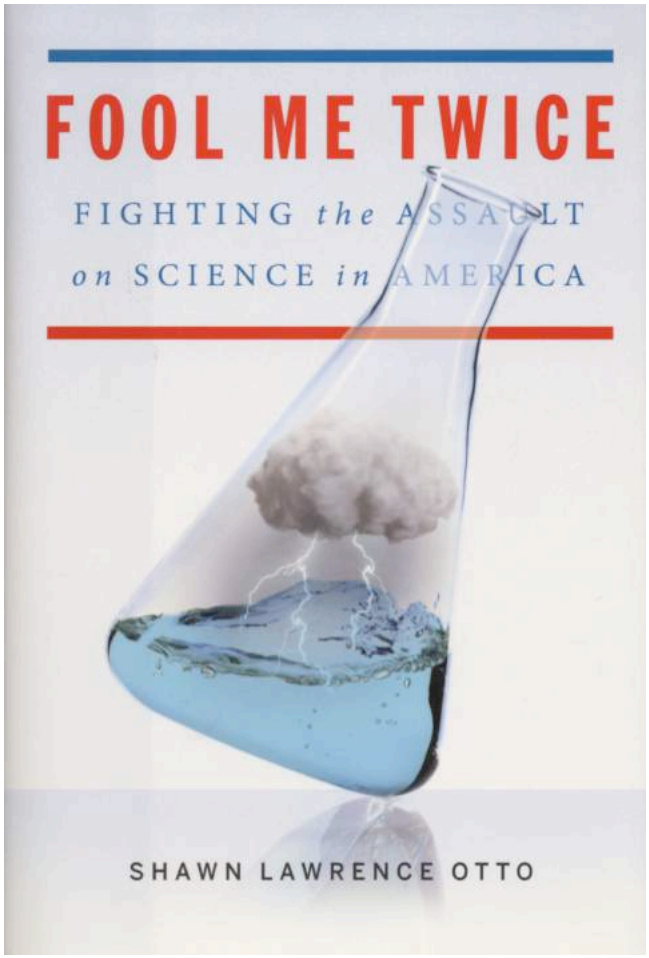


Blend of diminished quality of science education and post-modernism

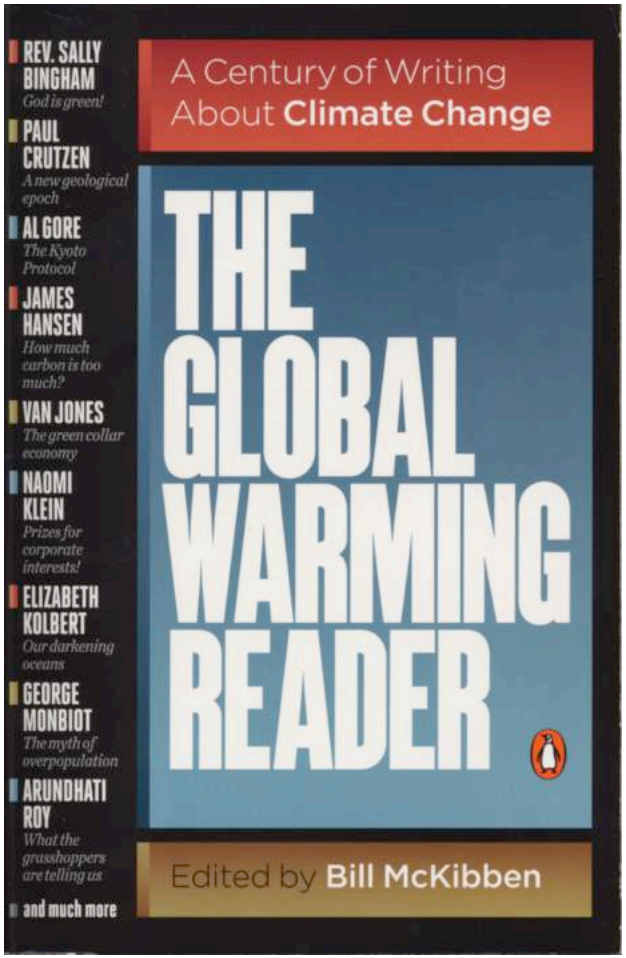
- Ranking of American secondary school science and mathematics is 21 and 26 (out of 30)
- Self-esteem (Gates Foundation) #1
- Postmodernism's "other ways of knowing," non-acceptance of statistics, innumeracy, confirmation bias, cognitive dissonance
- Lecture room examples: "triangle of life" and rejection of MMR/TDaP vaccines

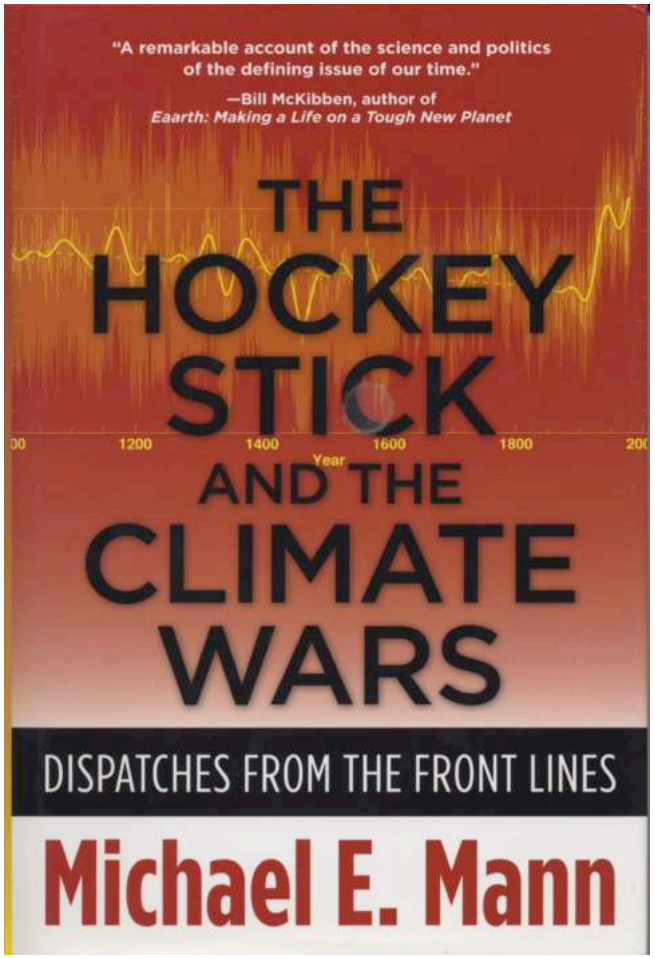
Role of scientific illiteracy





Global warming and Climate wars





Some scientists in the news regarding anthropogenic climate change

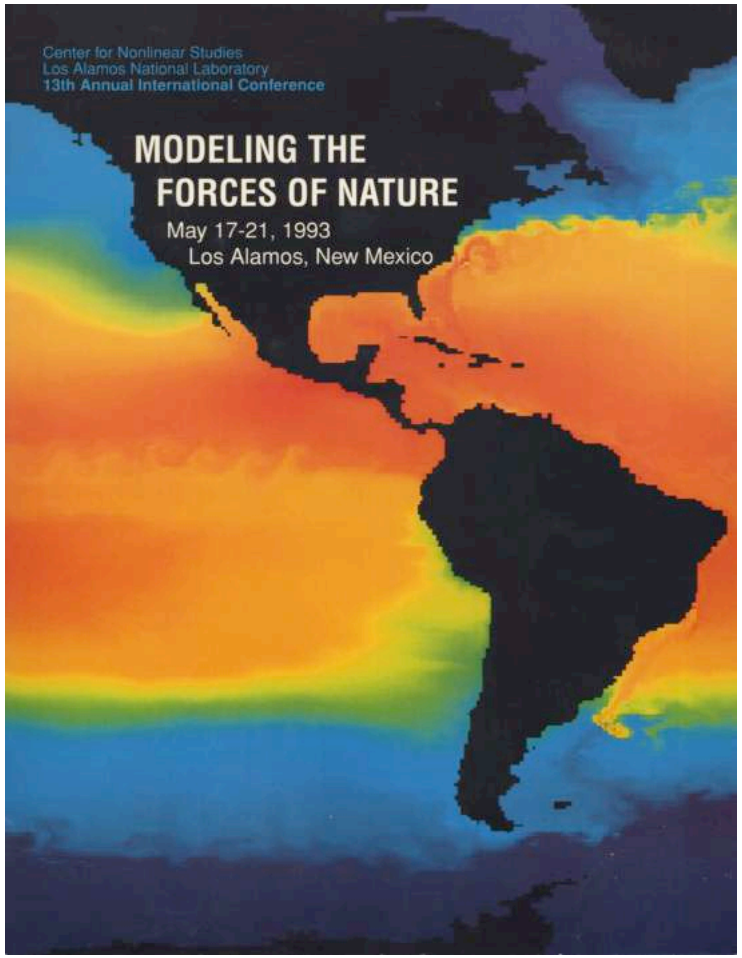
Acknowledge

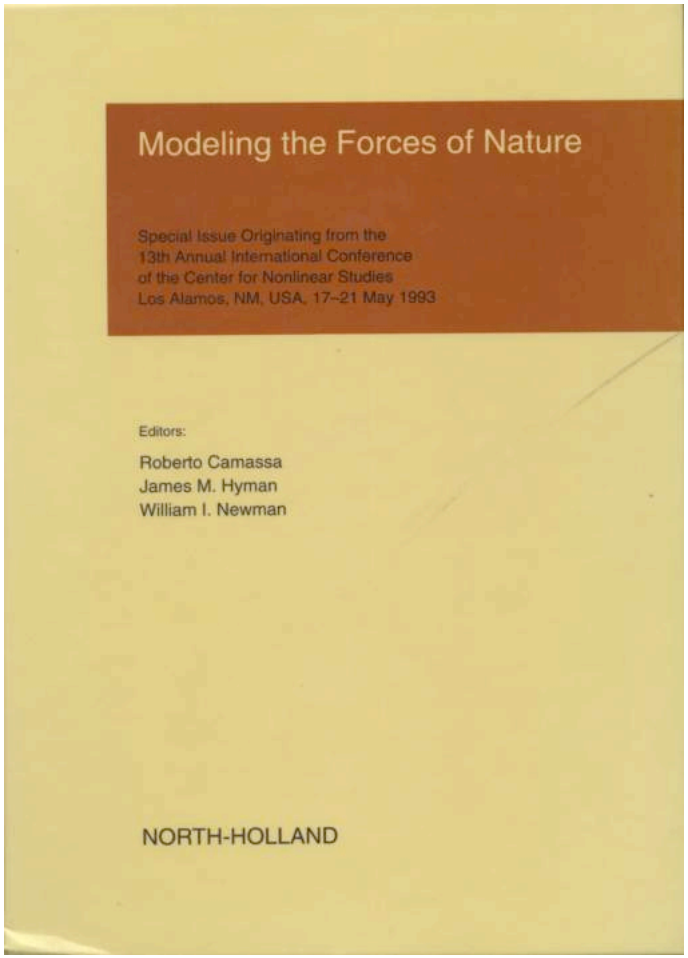
- Richard Muller, Berkeley, high-energy physicist; supported by Koch brothers but published research *confirming* change and human role
- Kerry Emanuel, MIT dynamic meteorologist (formerly UCLA); op-ed in *LA Times* calling it real

Denies

- Richard Lindzen, MIT atmospheric scientist; claimed CO_2 increase helps produce more clouds that reflect away sunlight—evidence does not support; disavowed by colleagues
- Wei-Hock "Willie" Soon, aerospace engineer, part-time CfA, supported by Koch ($1.2 x 10^6), solar UV

Modeling the Forces of Nature





Theoretical modeling under attack

Newsjournal of the Society for Industrial and Applied Mathematics

siam news

Volume 45/ Number 10
December 2012

The Dawn of the Age of Ignorance and Misinformation

By William I. Newman

There emerged after the Renaissance a remarkable period (beginning around 1650–1700) often called the Age of Enlightenment, when Western Europe was freed from ignorance and misinformation. There evolved a belief that the application of intellectual approaches together with experiments could provide reproducible explanations for essentially all the mysteries of the cosmos. The scientific method had been born. Out of this rationalist milieu emerged the notion that, if we knew all the laws of nature and possessed a machine capable of computing the dynamical evolution of every atom, we would be able to calculate indefinitely into the future the state of all things. In many regards, this perspective established the raison d'être of the scientific community. With overwhelming evidence in support of these ideas, the general population came to accept the outcome of scientific investigations in all things.

In the last half century, we have witnessed a grave decline in the public's acceptance of scientific evidence and even the scientific method. Postmodernism presented many challenges in academe and, of wider concern, the notion that science is but one of many approaches to problem solving and that "scientific results" are not necessarily better, let alone reliable. During recent weeks, we have witnessed the public's abandonment of science in connection with a number of events. Among them are the Italian trial and sentencing of six seismologists to six years in prison for failing to predict the 2009 magnitude 6.3 L'Aquila earthquake, the warnings issued for Hurricane Sandy and its destructive potential, and the magnitude 7.7 Queen Charlotte Islands earthquake and subsequent tsunami warning. Also portending grave consequences is the public's response to the emergent role of climate change and its effects on humanity.

The underlying complexity of the natural world greatly exacerbates this problem. The Earth is a remarkably complicated place. The interactions of its oceans and atmo-

See **Misinformation Age** *on page 8*

SIAM News Welcomes New Editor-in-Chief

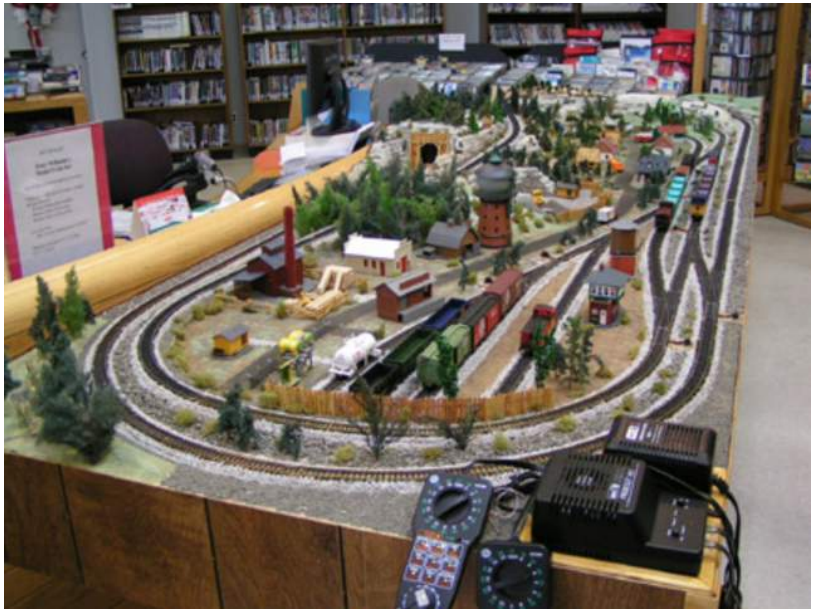
In January, Hans Kaper will officially move into the newly created position of editor-in-chief of *SIAM News*. His very successful trial run as a guest editor of our ICIAM 2011 coverage bodes well for an increasingly lively, well-rounded, and authoritative publication.

A SIAM Fellow (class of 2009), Kaper was named Senior Mathematician Emeritus at Argonne National Laboratory on his retirement in 2008. Many readers will know him from his tenure (2001–2008) as a program director at the National Science Foundation. He is currently an adjunct professor in the Department of Mathematics and Statistics at Georgetown University, and he maintains ties in Illinois as an adjunct professor in the School of Music at the University of Illinois at Urbana–Champaign.

He identifies his current research interest as the application of dynamical systems techniques to the Earth's climate system. In related projects, he is a co-author of the forthcoming SIAM book *Mathematics and Climate*, co-director of the NSF-funded Mathematics and Climate Research Network, and a SIAM representative to Mathematics of Planet Earth 2013. He worked recently with *SIAM News* staff to assemble a new editorial board, whose names appear on page 2.

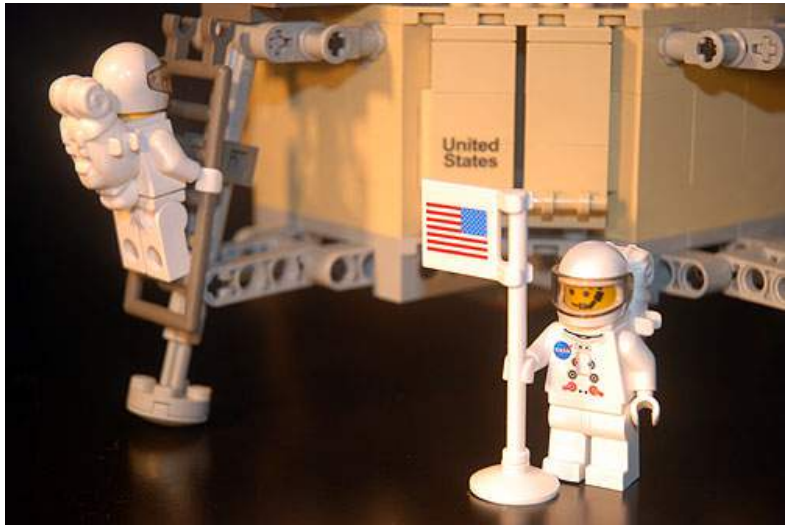
In recent weeks, an unsettling real-world development—the ruling of an Italian judge in the case of six seismologists on trial for having failed to pinpoint the time of an earthquake that devastated the town of L'Aquila—set Kaper and the new editorial board in motion. A request to William Newman of UCLA for a perspective on the implications of the Italian case rapidly produced the article at the left. This issue, says editorial board member Mac Hyman, "could affect any of our members engaged in using mathematical analysis and models, including computer simulations, to make predictions where there are economic or public health consequences."

Public does not understand meaning of “models”

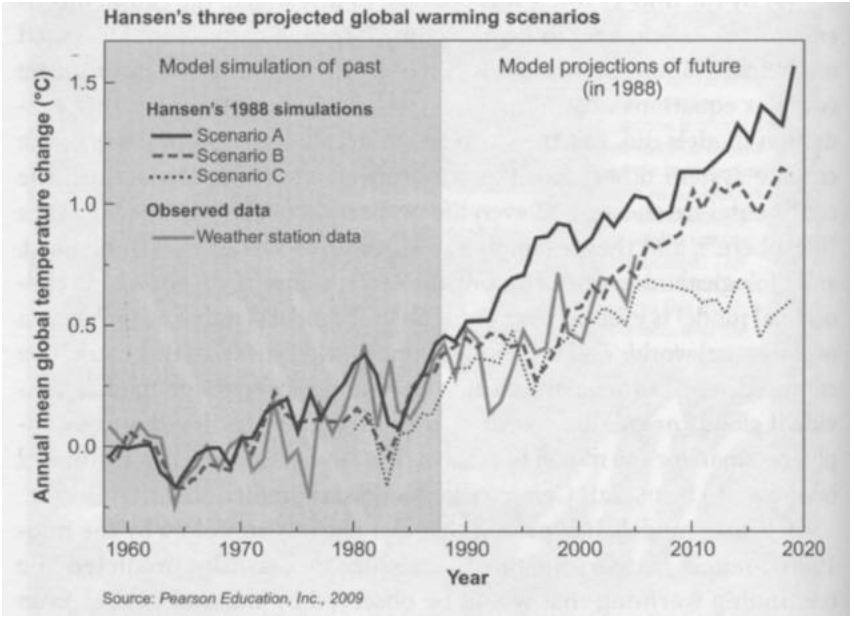


Scientific models?

Public does not understand and is easily mislead



Misrepresentation of models

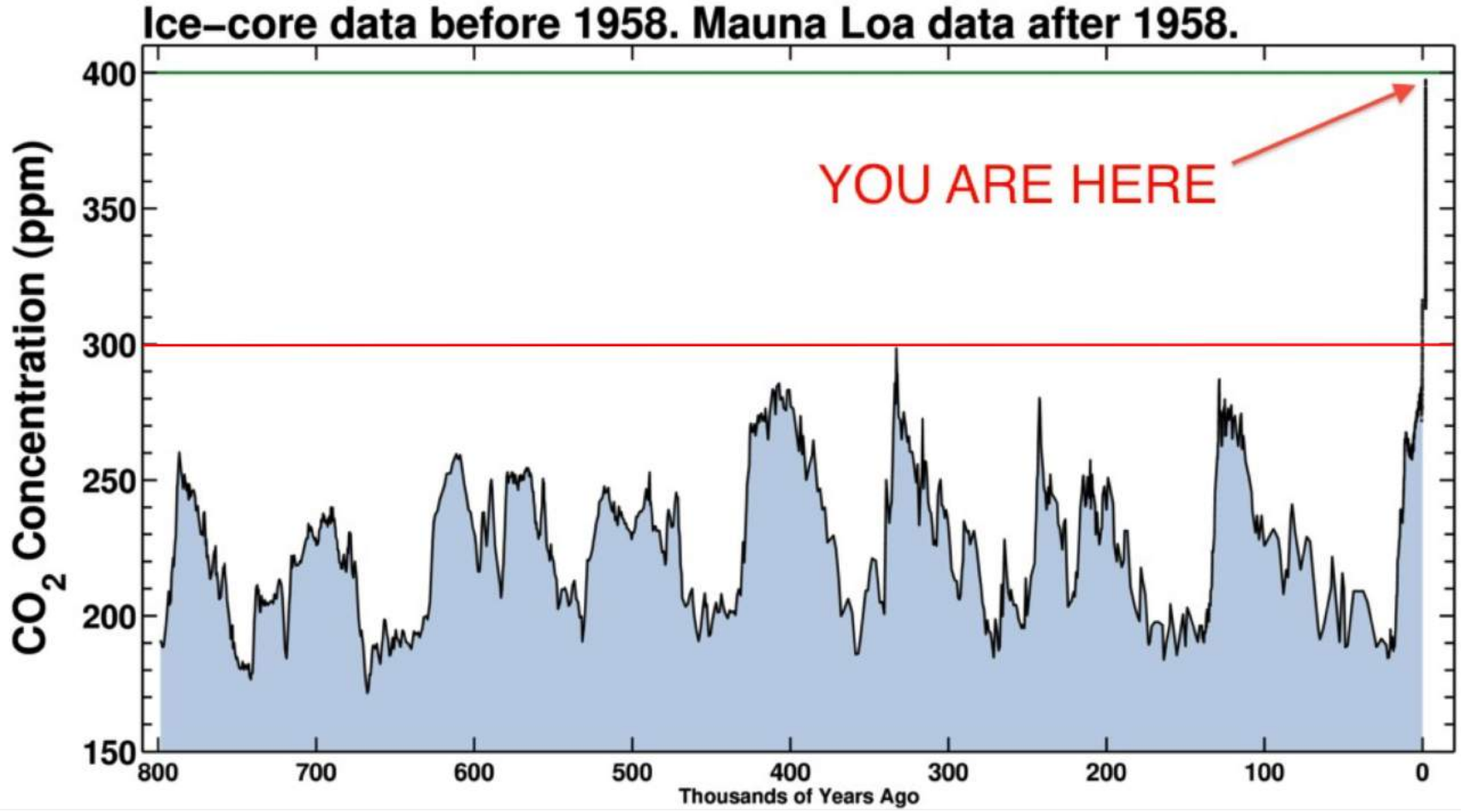


- Climate change deniers claim that models don't work, citing Hansen's projections
- He failed to predict Mt. Pinatubo eruption!
- But agreement between favored model and weather station data very good

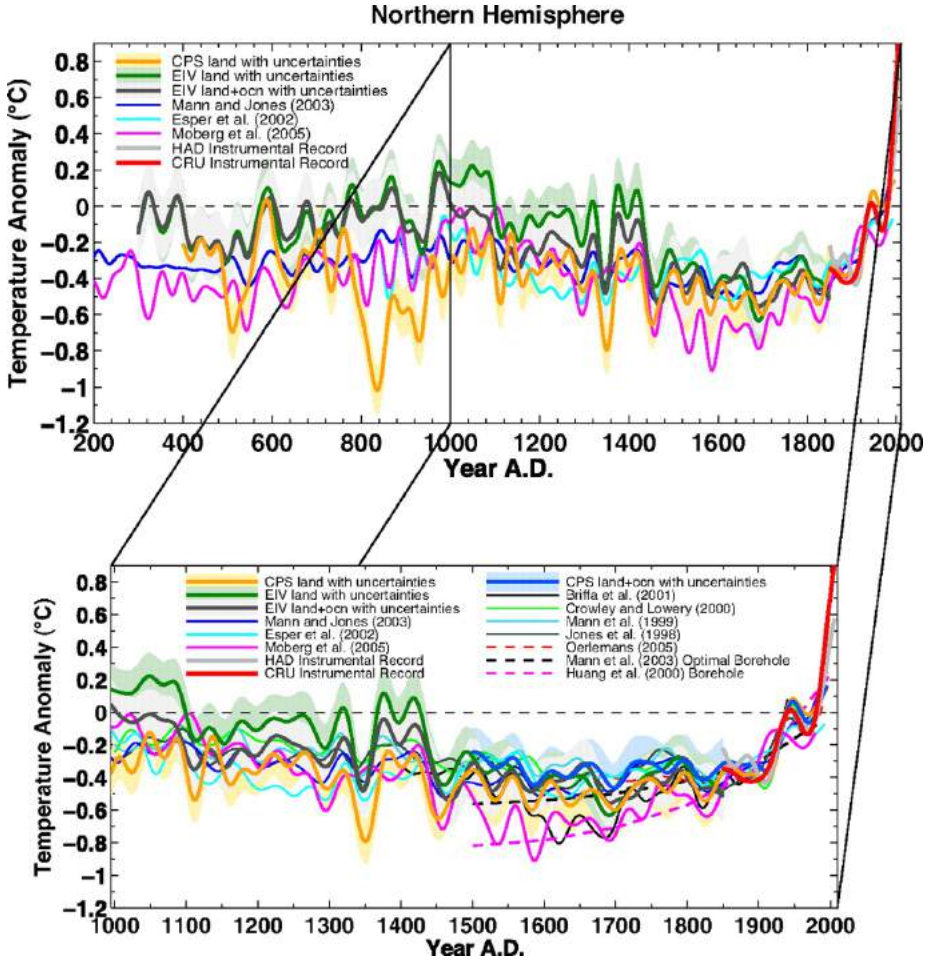
Best practice approach to communicating with media/public

- How do we know that ***we*** did it?
- Approach
  - Post-industrial revolution data (global picture)
  - Individual metrics (identifies *our* role)
  - Role of uncertainties and extreme weather events
  - Possibly say something about some of my work

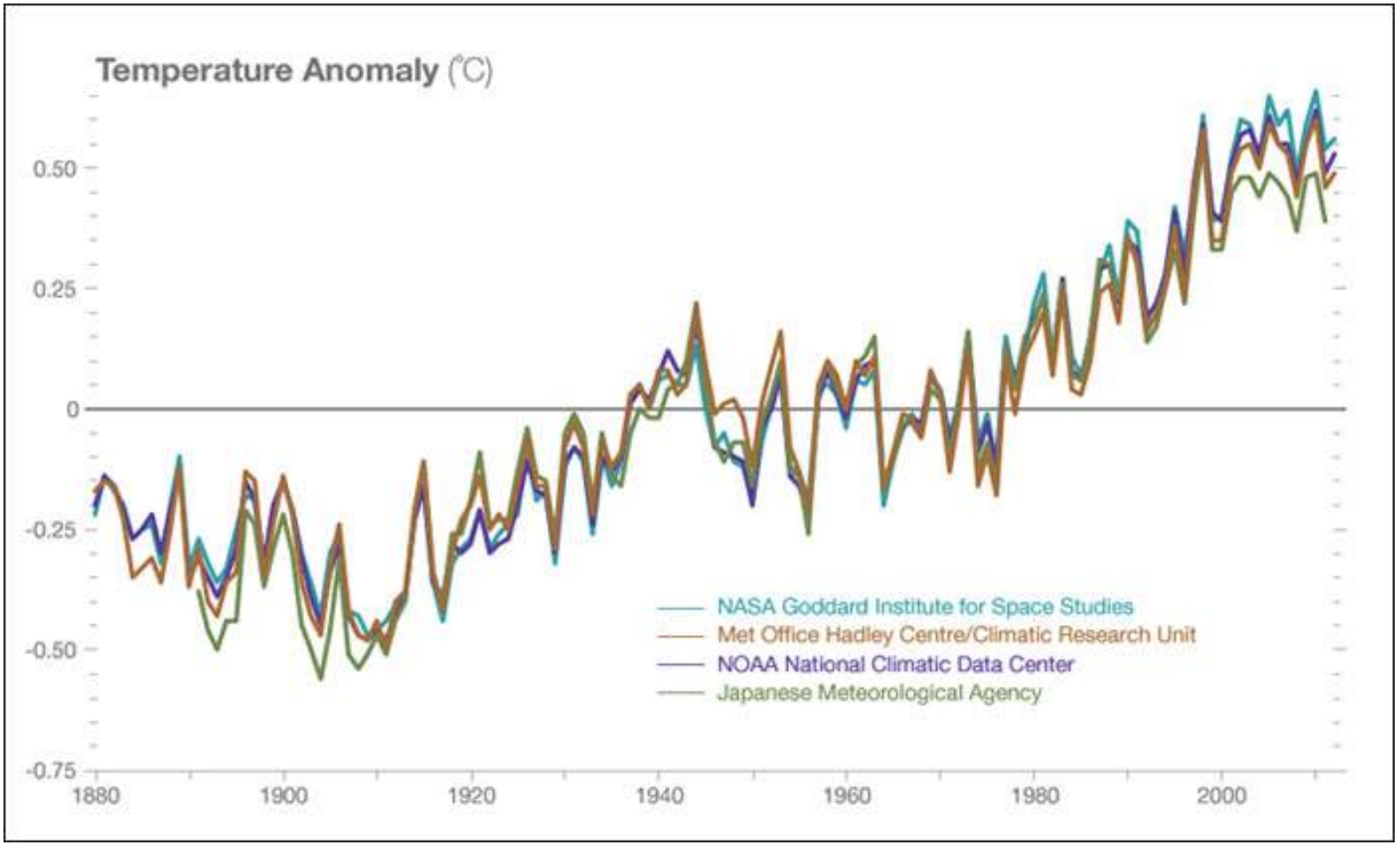
Why is the present era special? (Milankovitch cycle shown)



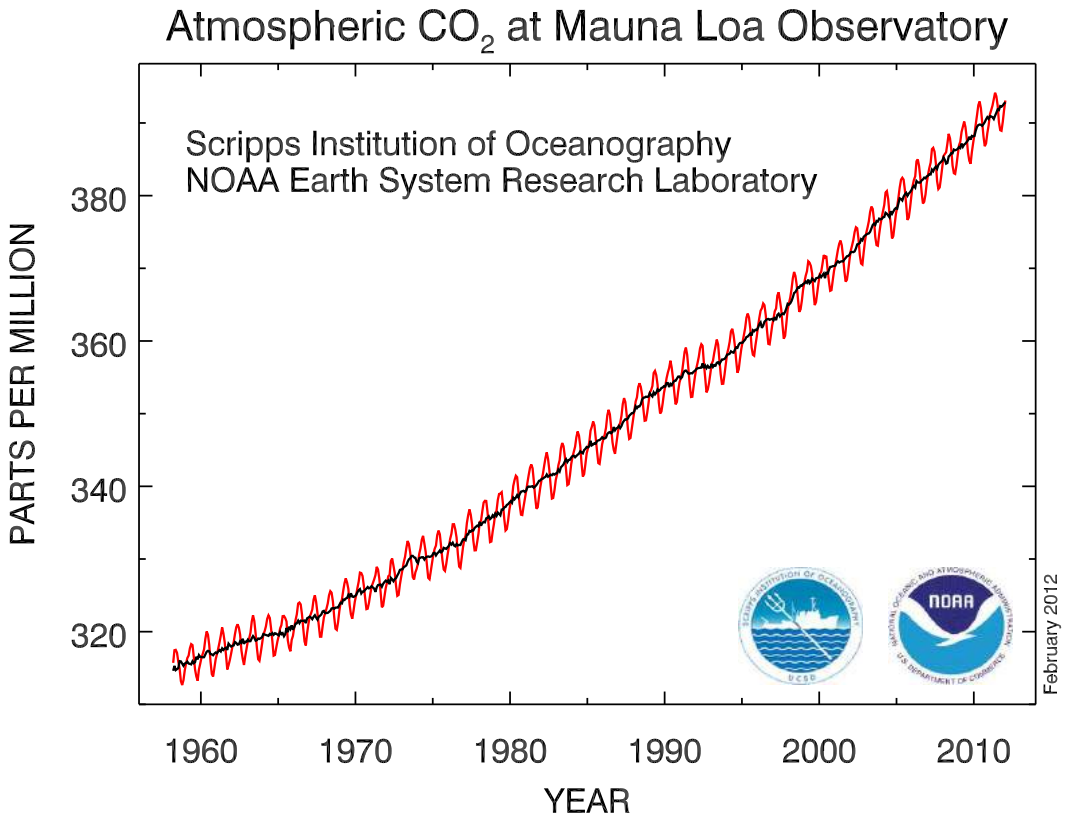
Amplify on this theme; “hockey stick”



Further amplify on post-industrial revolution



Keeling Curve



97% climate scientists agree

PNAS PNAS PNAS

Expert credibility in climate change

William R. L. Anderegg[a,1], James W. Prall[b], Jacob Harold[c], and Stephen H. Schneider[a,d,1]

[a]Department of Biology, Stanford University, Stanford, CA 94305; [b]Electrical and Computer Engineering, University of Toronto, Toronto, ON, Canada M5S 3G4; [c]William and Flora Hewlett Foundation, Palo Alto, CA 94025; and [d]Woods Institute for the Environment, Stanford University, Stanford, CA 94305

Contributed by Stephen H. Schneider, April 9, 2010 (sent for review December 22, 2009)

Although preliminary estimates from published literature and expert surveys suggest striking agreement among climate scientists on the tenets of anthropogenic climate change (ACC), the American public expresses substantial doubt about both the anthropogenic cause and the level of scientific agreement underpinning ACC. A broad analysis of the climate scientist community itself, the distribution of credibility of dissenting researchers relative to agreeing researchers, and the level of agreement among top climate experts has not been conducted and would inform future ACC discussions. Here, we use an extensive dataset of 1,372 climate researchers and their publication and citation data to show that (*i*) 97–98% of the climate researchers most actively publishing in the field support the tenets of ACC outlined by the Intergovernmental Panel on Climate Change, and (*ii*) the relative climate expertise and scientific prominence of the researchers unconvinced of ACC are substantially below that of the convinced researchers.

citation analyses | climate denier | expertise | publication analysis | scientific prominence

ENVIRONMENTAL SCIENCES

Preliminary reviews of scientific literature and surveys of climate scientists indicate striking agreement with the primary many diverse and nonexpert stakeholders.

Because the timeline of decision-making is often more rapid than scientific consensus, examining the landscape of expert opinion can greatly inform such decision-making (15, 19). Here, we examine a metric of climate-specific expertise and a metric of overall scientific prominence as two dimensions of expert credibility in two groups of researchers. We provide a broad assessment of the relative credibility of researchers convinced by the evidence (CE) of ACC and those unconvinced by the evidence (UE) of ACC. Our consideration of UE researchers differs from previous work on climate change skeptics and contrarians in that we primarily focus on researchers that have published extensively in the climate field, although we consider all skeptics/contrarians that have signed prominent statements concerning ACC (6–8). Such expert analysis can illuminate public and policy discussions about ACC and the extent of consensus in the expert scientific community.

We compiled a database of 1,372 climate researchers based on authorship of scientific assessment reports and membership on multisignatory statements about ACC (*SI Materials and Methods*). We tallied the number of climate-relevant publications authored or coauthored by each researcher (defined here as *expertise*) and counted the number of citations for each of the researcher's four highest-cited papers (defined here as *prominence*) using Google Scholar. We then imposed an a priori criterion that a researcher must have authored a minimum of 20 climate publications to be considered a climate researcher, thus reducing the database to 908 researchers. Varying this minimum publication cutoff did not materially alter results (*Materials and Methods*).

We ranked researchers based on the total number of climate publications authored. Though our compiled researcher list is not comprehensive nor designed to be representative of the entire climate science community, we have drawn researchers from the most high-profile reports and public statements about ACC. Therefore

Author contributions: W.R.L.A. and J.H designed research; W.R.L.A. and J.W.P. performed research; W.R.L.A. analyzed data; and W.R.L.A., J.W.P., J.H., and S.H.S. wrote the paper.

The authors declare no conflict of interest.

Freely available online through the PNAS open access option.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1003187107/-/DCSupplemental.

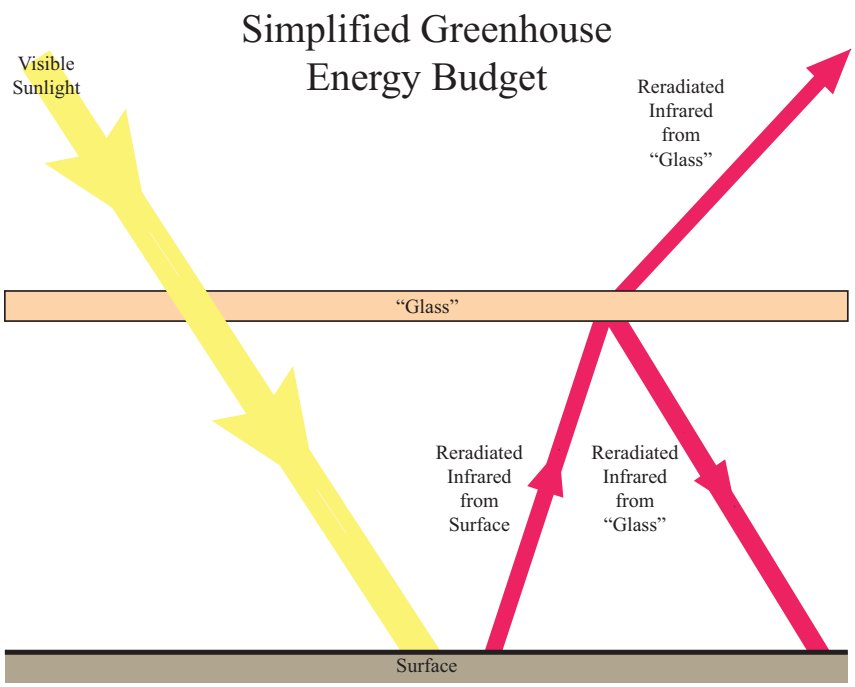
Climate v. weather

- Climate more than the “average” of weather
- Weather forecasts assume that physical aspects of environment remains fixed; e.g., atmospheric composition, solar radiation
- Climate responds to long-term changes in both
- Our planet’s surface highly inhomogeneous
- Compare with complexity of human body
  - Fever has non-uniform effect; e.g. face vs. extremities
  - Small imbalances have dramatic outcomes

Greenhouse effect & car analogy

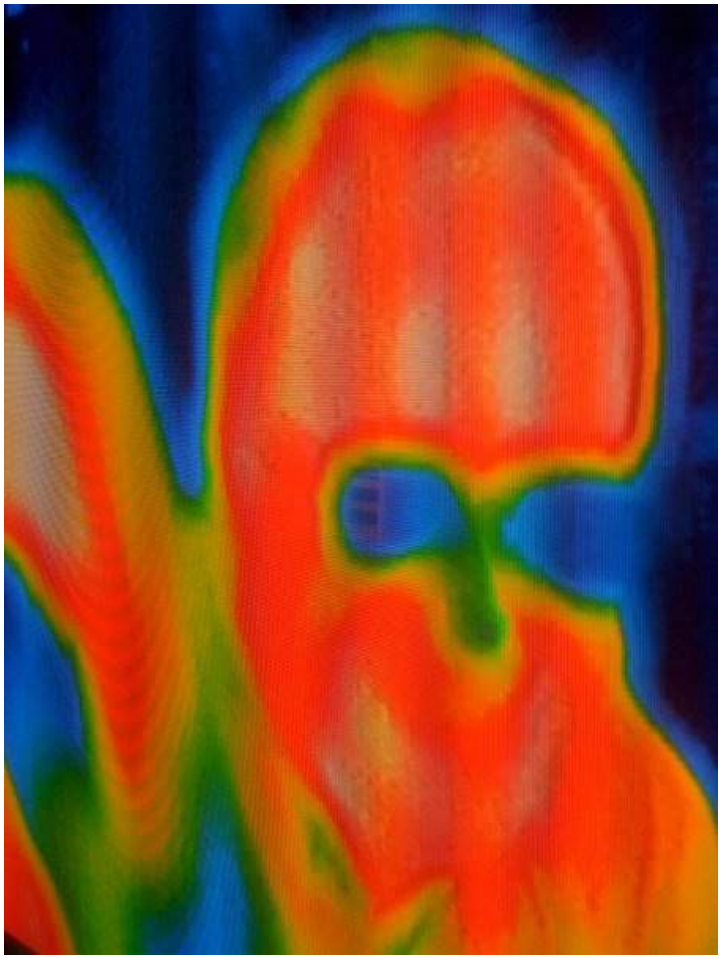
- Discovered in 19th century by Fourier, Pouillet, Tyndall, and Arrhenius
- Glass (SiO_2) and carbon dioxide (CO_2) molecules have similar structure
- CO_2 associated with extreme temperatures on Venus (can melt lead—Pollack and Sagan, 1965)

Greenhouse effect and energy budget



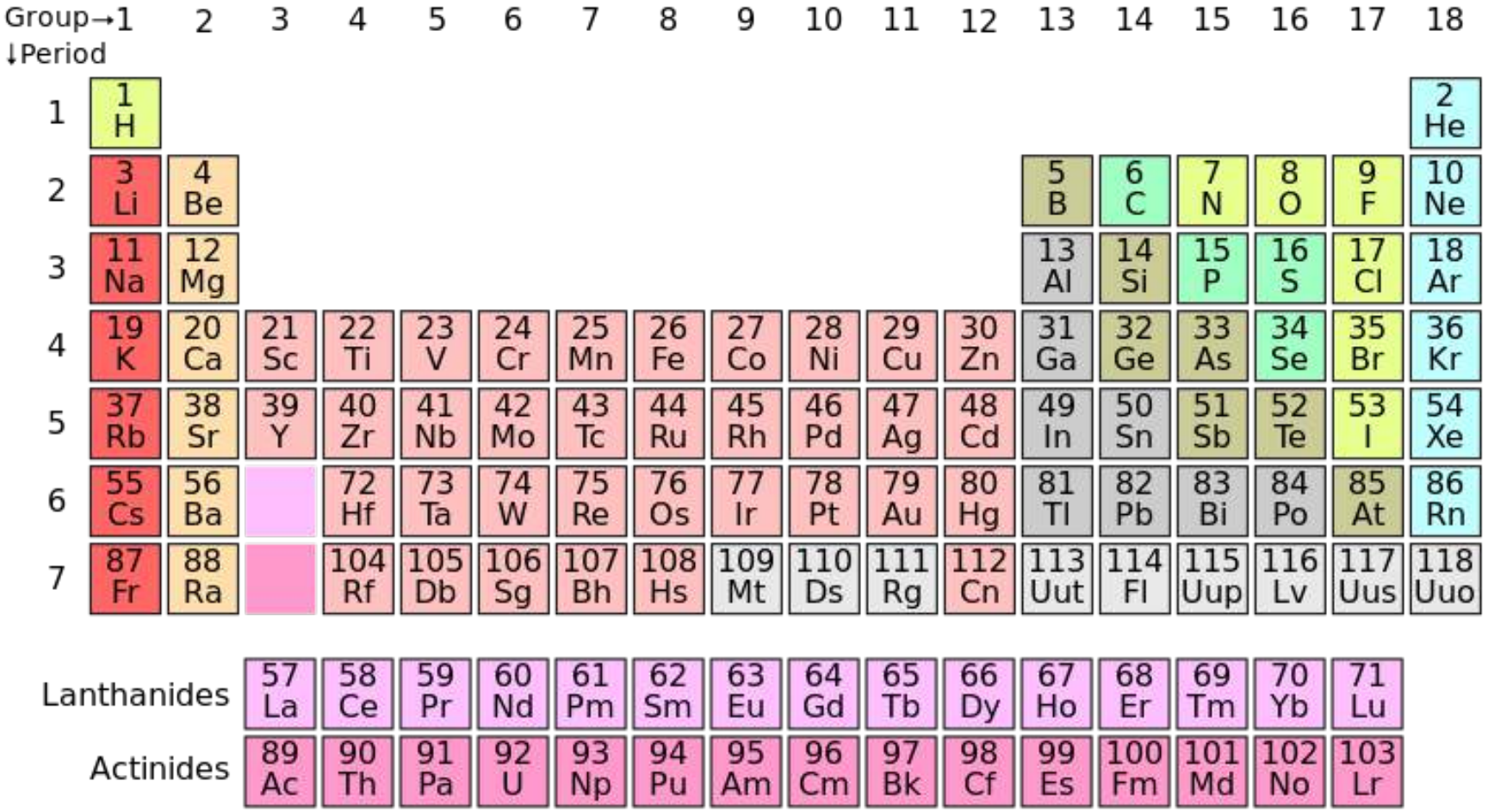
- Sunlight passes through atmosphere relatively unaffected; heats surface of Earth which re-radiates energy in the infra-red (IR)
- « Glass » is now a secondary heat source
- IR is what is detected by night-vision devices

Greenhouse effect



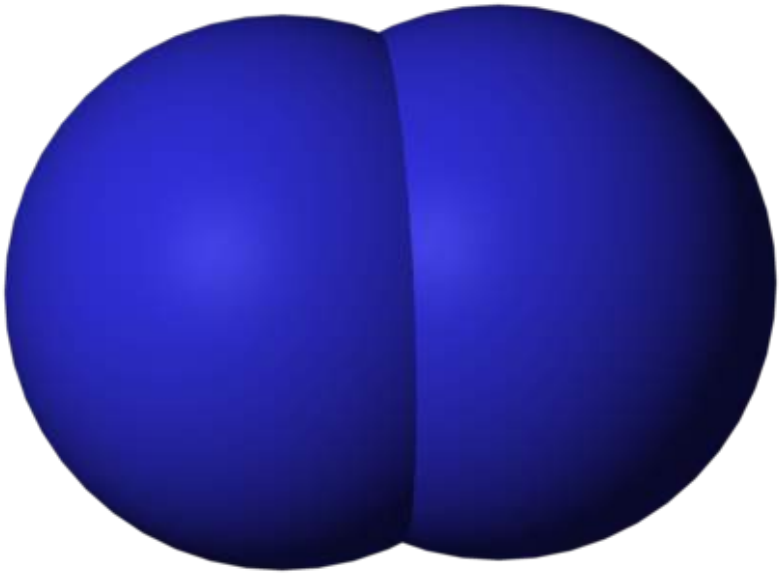
- Photo taken at JPL (glass lenses block IR from my body)
- Why does CO_2 behave like SiO_2 glass?
- Your car (left out in the sun) is like a “green-house”; how does it relate to atmospheric CO_2?

Molecular structure and vibrational IR

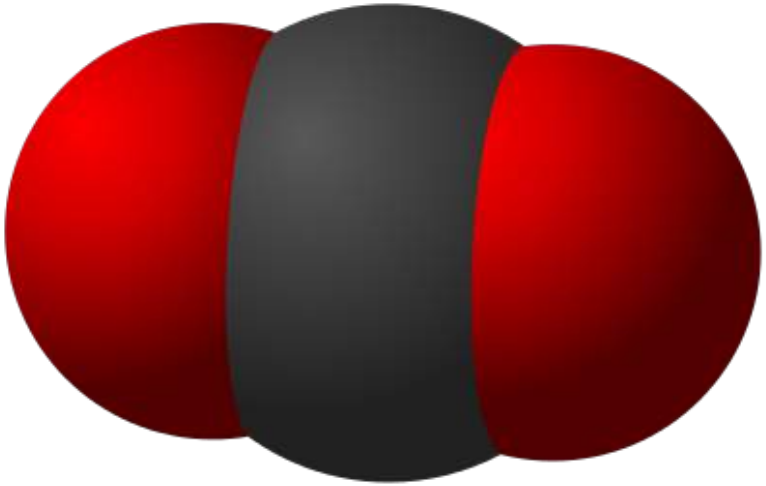


Molecular structure and transitions

Diatomic



Triatomic



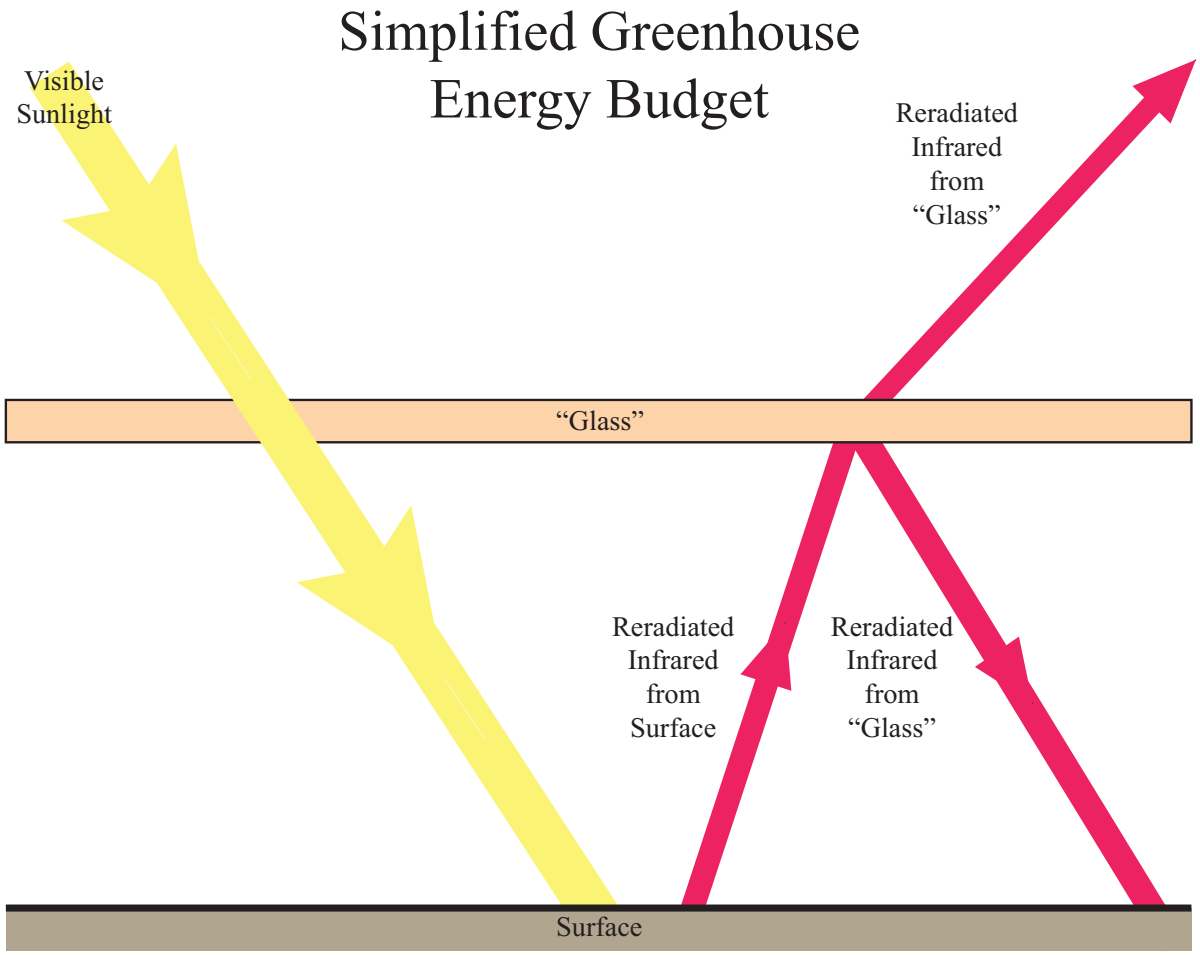
Some facts and figures

- CO_2 like SiO_2 millions of times more efficient at absorbing vibrational IR than N_2 and O_2 (forbidden transition in molecular physics)
- CO_2 now 400 ppm of atmosphere; 120 ppm is anthropogenic
- If CO_2 could settle out of atmosphere at STP, it would be up to 2-story window
- If it were to “freeze” as dry ice, it would be as thick as your windshield

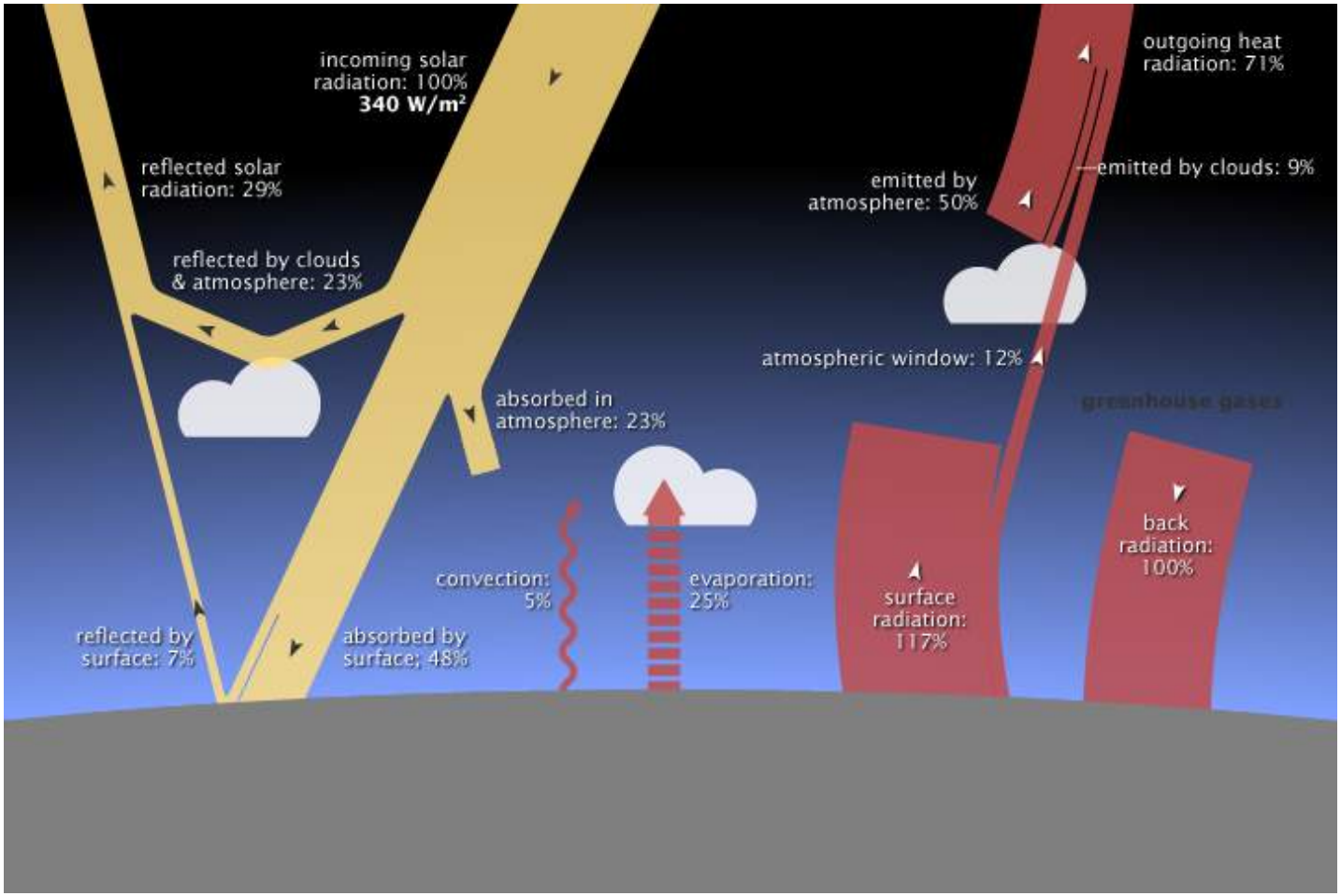
Greenhouse effect

- In greenhouse, heated soil radiates IR which passes through diatomic N_2 and O_2 in air
- Glass (SiO_2) molecules absorb (vibrate) and re-radiate IR; reason why your car heats up in sun—heated glass acts as secondary source
- Carbon dioxide (CO_2) behaves like glass (tri-atomic); similar mol. structure, cf. sci-fi theme

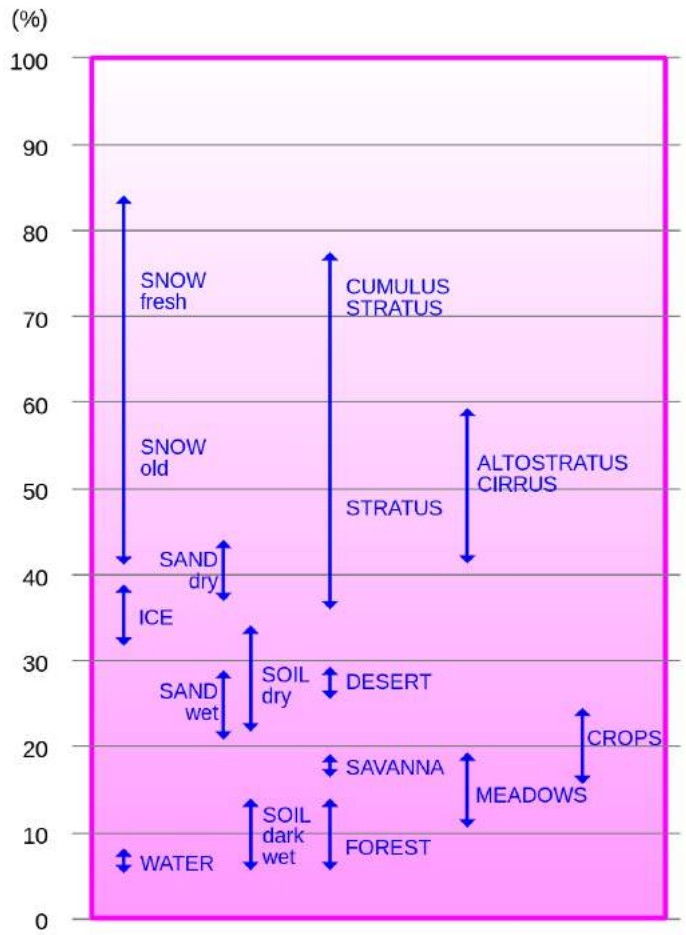
Simplified greenhouse energy budget



More realistic energy budget



Variable reflectivity of surface



- Different landforms absorb sunlight with different efficiencies (60-90%)
- Snow and ice absorb much less (as little as 20%)
- Melting ice in arctic results in massive increase in absorption of sunlight

Different heat capacity and heating/cooling rate of water vs. land

- Early morning, land heats up faster than ocean; temperature difference drives “land breeze”; pattern reverses after sunset giving “sea breeze”
- Same principle applies to all landforms and bodes of water; temperature gradients drive (thermal) winds and ocean currents
- Small changes in heating can create different temperature gradients and alter wind patterns, ocean currents, and precipitation patterns
- Oceans 700x more massive than atmosphere

Sea level rise vs. “storm surge”

- Current rate is 3 mm/yr, less than 1”/decade; has doubled over last 30 years
- Most observed rise due to heating/expansion of ocean water
- Storm surge issue due to “sea surface temperature” anomaly in Caribbean, presently more important
- Should all glaciers melt/migrate, sea level rise could be as great as 28 m

Where do ***you*** fit in? Some climate "math" (arithmetic)

- *Drive 1 mile, put 1 lb of CO_2 into atmosphere*
- 1 gallon of gas weighs 6.4 lb (0.8 specific gravity) and typical car gets 20 mpg
- Burning octane in presence of oxygen
  $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$
  In pounds: $\frac{6.4}{20}\frac{16*(12+2*16)}{2*(8*12+18*1)}=0.988$
- Typical annual mileage (including "proxy"):
  12,000 miles →6 tons

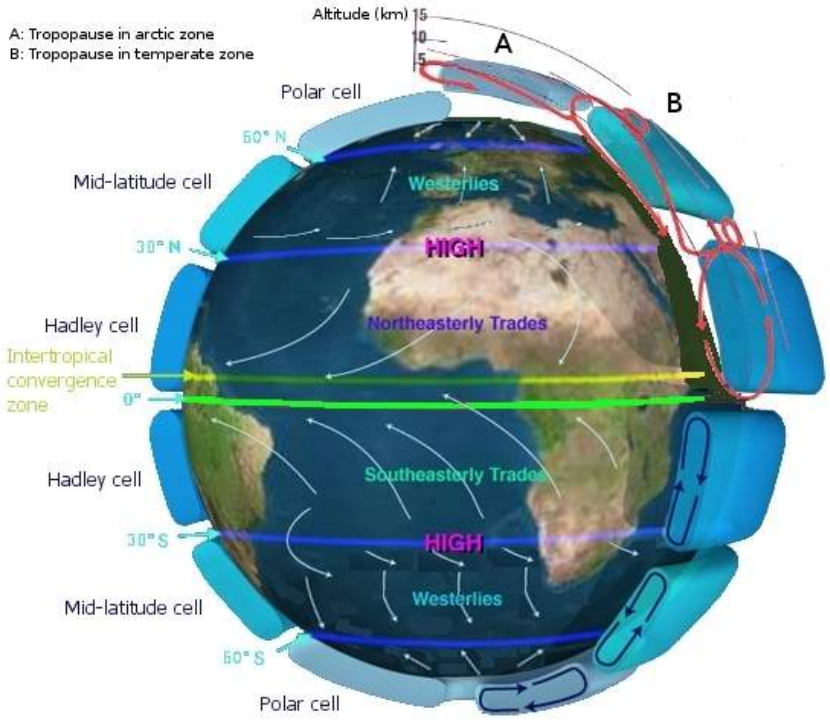
Where do ***you*** fit in?

- "Transportation" is 30% of total; average CO_2 consumption per American per year: 20 tons
- Global consumption is presently 33 *billion* metric tons per year, < 5 tons/human/yr
- Atmospheric CO_2 now over 400 ppm; 280 ppm before industrial revolution; never > 300 ppm
- Greenhouse temperature rise 33° C or 59° F
- Human production of CO_2 rising 2.3%/yr; prevailing rate unchecked gives 1100 ppm at end of century; unsustainable

Some more energy math

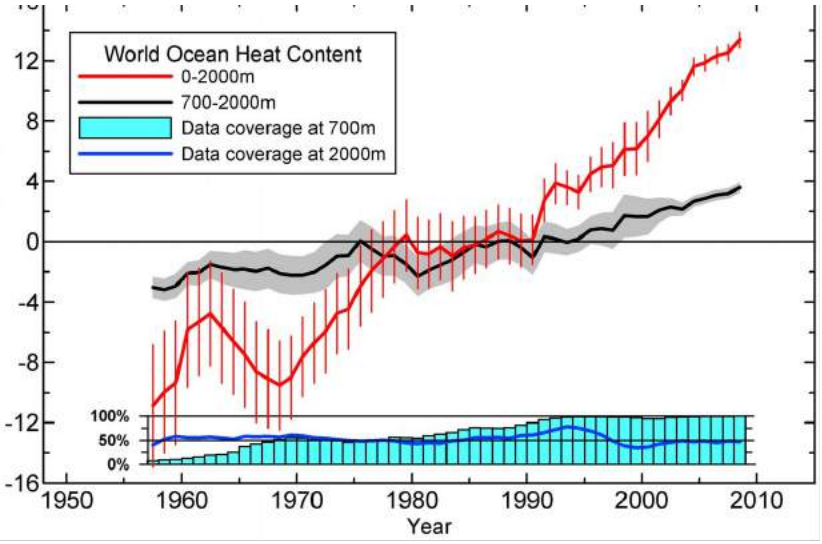
- Converting all energy used in 1 yr to electrical power units, we use 10,700 W or 10.7 kW
- Human body consumes around 100 calories (kcal) per hour = 150 W
- 1 Hp = 746 W; 300 Hp car > 200 kW
- We use energy today at rates per person 1000 times greater than the pioneers
- Fossil fuel burning not sustainable; ergo, conflict with industry (especially energy)

Warming produces massive changes in global circulation and jet stream



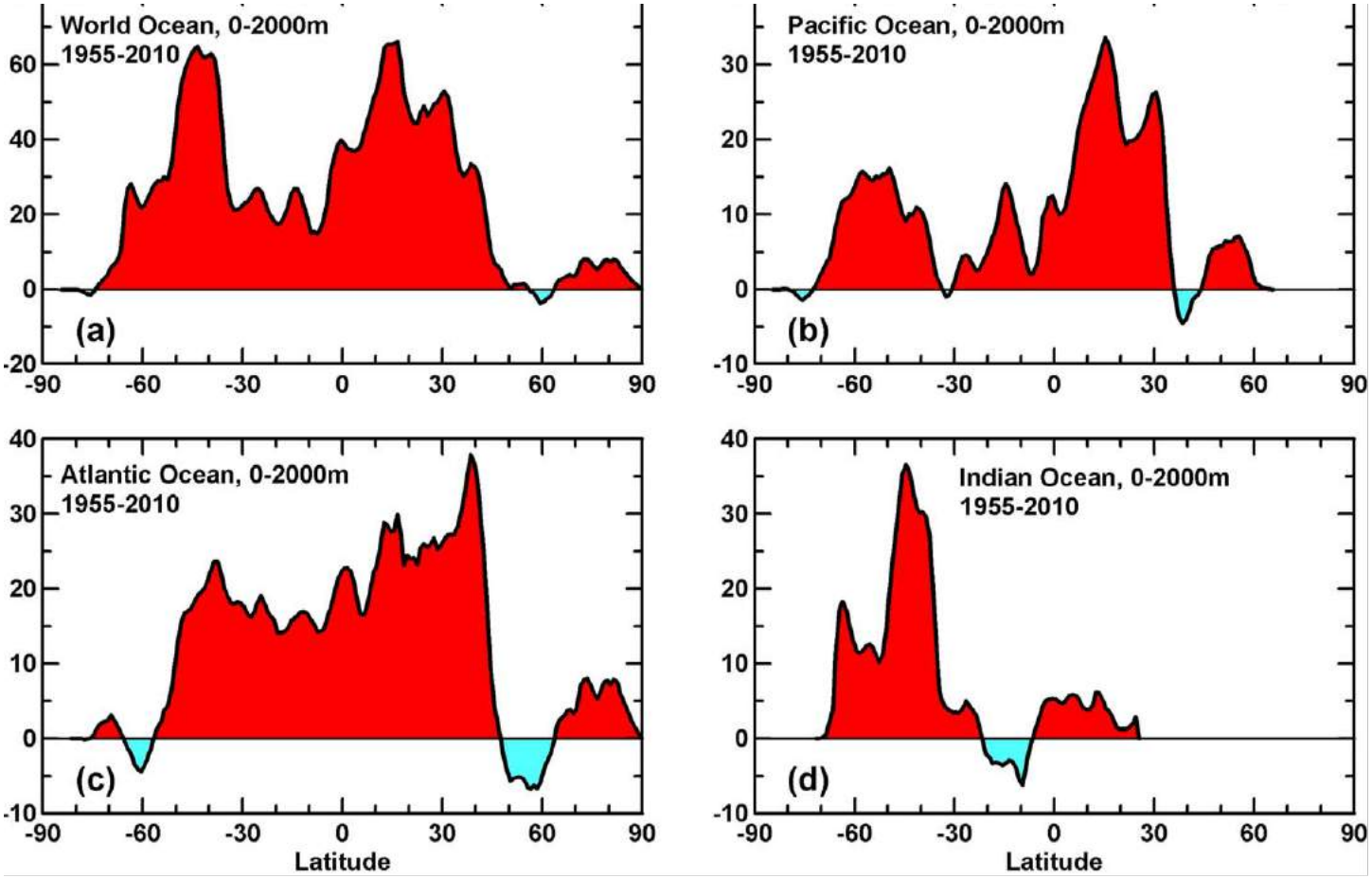
- Changing wind patterns and locations of planetary waves alters delivery of cold air masses and precipitation pattern
- Our future will show much more variability, extreme weather, and possible desertification

Oceans: the elephant in the room

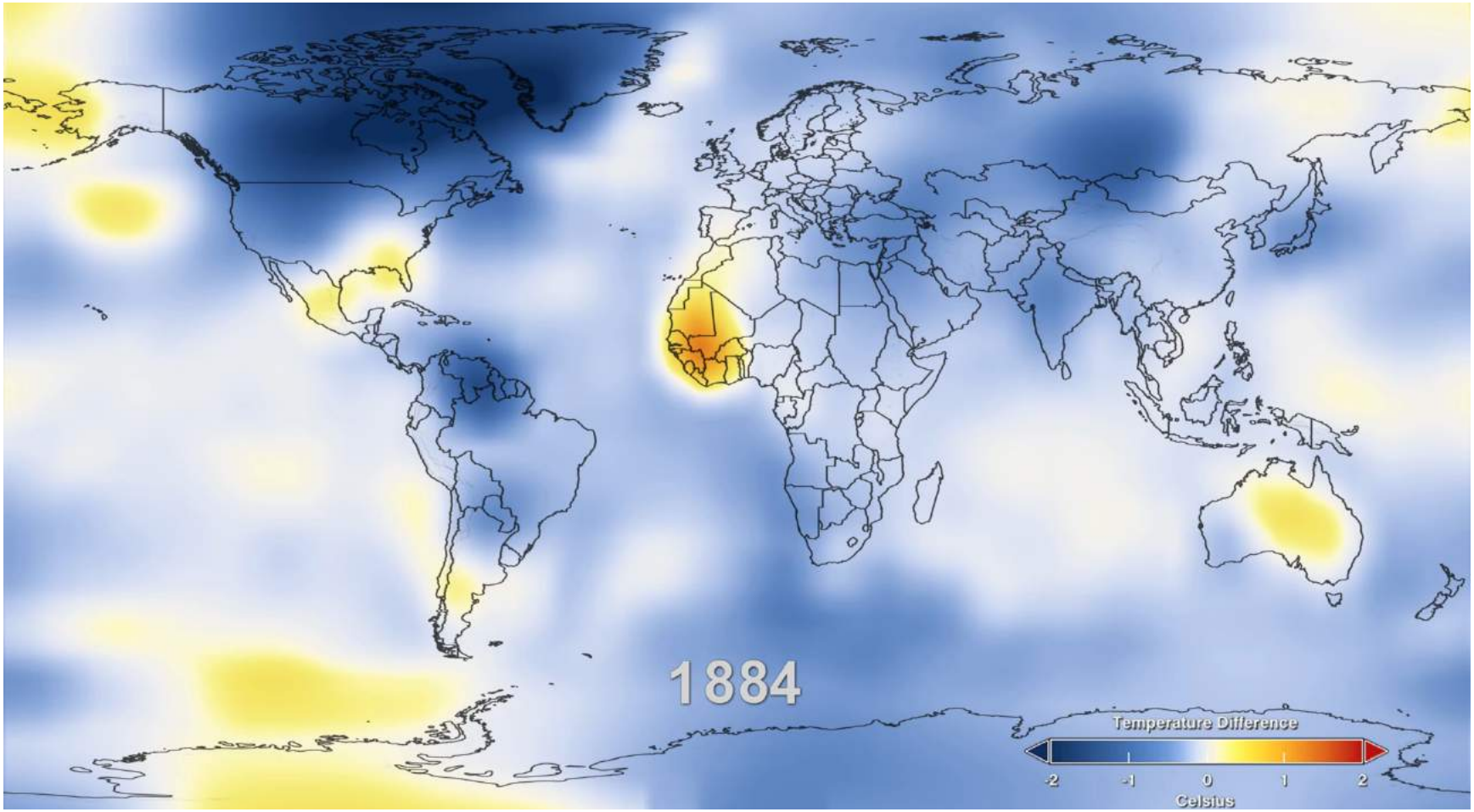


- Oceanic heat content is rapidly increasing; taking up energy that otherwise would heat atmosphere; momentary respite
- Melting of polar ice will eliminate latent heat capacity to moderate summer temperature rise

Overarching trend is oceanic heating, though some latitude regimes cooling



Annual temperature departure from norms over last century



Conclusions

- Diminished levels of public understanding of science makes all of us prone to efforts by deniers of science of all persuasions (economic, religious, etc.)
- Present day environmental concerns unprecedented & unsustainable; 6^{th} extinction
- Elimination of anthropogenic carbon footprint essential to climate stability

Epilog

- Climate change has always been a factor, but never at this speed (apart from impact events)
- CO_2 is major player but no compelling evidence that change in sun's output has a role
- Cloud physics and ocean-atmosphere interaction present major gaps in understanding and barrier to very long-term prediction

Before finishing, my part in the story

ICARUS 26, 451–456 (1975)

Infrared Limb Darkening of the Venus Atmosphere

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An analysis of the limb darkening component obtained by Ingersoll and Orton [*Icarus* **21** (1974), 121–128] from the thermal infrared maps of Venus published by Murray, Wildey, and Westphal [*J. Geophys. Res.* **68** (1963), 4813–4818] and Westphal, Wildey, and Murrary [*Astrophys. J.* **142** (1965), 799–802] shows that the Cytherean cloud tops were close to radiative equilibrium in 1962. A method for obtaining the optical depth, the extinction coefficient, and the extinction scale height from such data is derived and values are extracted from Marov's [*Icarus* **16** (1972), 415–461] standard model of the Venus atmosphere.

I. Introduction

The dependence of intensity observed at infrared wavelengths as a function of position on the Venus disk has been the subject of much discussion in recent years. The most significant contribution to this study has been the extensive set of thermal maps obtained in the 8–14 μm wavelength interval by Murrary *et al.* (1963) and by Westphal *et al.* (1965). Goody (1965) attempted in a preliminary fashion to extract the limb-darkening component from the thermal maps. Recently, Ingersoll and Orton (1974) have analyzed these maps syste-

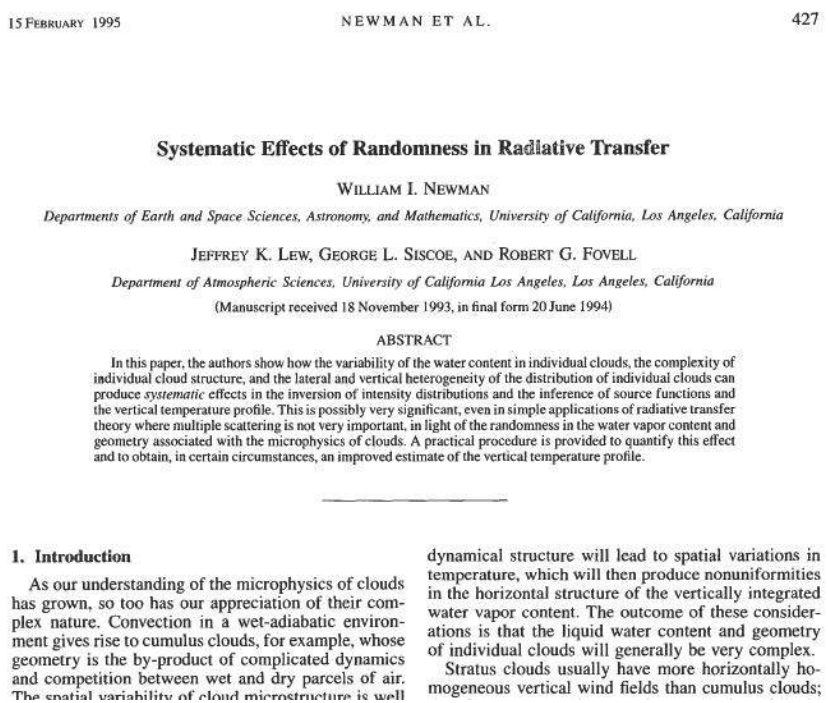
temperature profile obtained by Marov (1972), allowing for an arbitrary amount of isotropic scattering, we then obtain a measure of the dependence of the optical depth and, hence, the extinction coefficient and its scale height upon altitude. Owing to the secular variability of the Venus atmosphere, these conclusions are strictly applicable only to the closing months of 1962.

II. Analysis of Observations

The plane–parallel equation of radiative transfer[1] has the form

- Greenhouse effect discovered in early 19th century
- Pollack and Sagan identified Venus greenhouse but CO_2 did not give radiative equilibrium (RE)
- I showed RE present and due to sulfur compounds found by Hansen & others, filling spectral gap in Pollack/Sagan

Years later, what role does cloud geometry play?



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Systematic Effects of Randomness in Radiative Transfer

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ABSTRACT

In this paper, the authors show how the variability of the water content in individual clouds, the complexity of individual cloud structure, and the lateral and vertical heterogeneity of the distribution of individual clouds can produce *systematic* effects in the inversion of intensity distributions and the inference of source functions and the vertical temperature profile. This is possibly very significant, even in simple applications of radiative transfer theory where multiple scattering is not very important, in light of the randomness in the water vapor content and geometry associated with the microphysics of clouds. A practical procedure is provided to quantify this effect and to obtain, in certain circumstances, an improved estimate of the vertical temperature profile.

1. Introduction

As our understanding of the microphysics of clouds has grown, so too has our appreciation of their complex nature. Convection in a wet-adiabatic environment gives rise to cumulus clouds, for example, whose geometry is the by-product of complicated dynamics and competition between wet and dry parcels of air. The spatial variability of cloud microstructure is well

dynamical structure will lead to spatial variations in temperature, which will then produce nonuniformities in the horizontal structure of the vertically integrated water vapor content. The outcome of these considerations is that the liquid water content and geometry of individual clouds will generally be very complex.

Stratus clouds usually have more horizontally homogeneous vertical wind fields than cumulus clouds;

- With AOS colleagues Lew, Siscoe, & Fovell, we showed shapes of real clouds had major systematic effect on energy budget, much larger than CH_4, etc.
- Climate change deniers sadly use my paper to highlight uncertainties

Statistics of record-breaking events (2010) w/Malamud & Turcotte

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Statistical properties of record-breaking temperatures

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A record-breaking temperature is the highest or lowest temperature at a station since the period of time considered began. The temperatures at a station constitute a time series. After the removal of daily and annual periodicities, the primary considerations are trends (i.e., global warming) and long-range correlations. We first carry out Monte Carlo simulations to determine the influence of trends and long-range correlations on record-breaking statistics. We take a time series that is a Gaussian white noise and give the classic record-breaking theory results for an independent and identically distributed process. We then carry out simulations to determine the influence of long-range correlations and linear temperature trends. For the range of fractional Gaussian noises that are observed to be applicable to temperature time series, the influence on the record-breaking statistics is less than 10%. We next superimpose a linear trend on a Gaussian white noise and extend the theory to include the effect of an additive trend. We determine the ratios of the number of maximum to the number of minimum record-breaking temperatures. We find the single governing parameter to be the ratio of the temperature change per year to the standard deviation of the underlying white noise. To test our approach, we consider a 30 yr record of temperatures at the Mauna Loa Observatory for 1977–2006. We determine the temperature trends by direct measurements and use our simulations to infer trends from the number of record-breaking temperatures. The two approaches give values that are in good agreement. We find that the warming trend is primarily due to an increase in the (overnight) minimum temperatures, while the maximum (daytime) temperatures are approximately constant.

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I. INTRODUCTION

Global warming has received a great deal of attention

mum and minimum temperatures were determined for each day of the year, 1950–2006. For the 7 yr period from January 1, 2000 to December 31, 2006 and for all 2000 stations con-

- Likelihood that imbalance between record-break highs and lows is due to "fluctuations" is 1 part in 3 x 10^6 (5 standard error)
- Deniers claim my (NOAA) data was fabricated