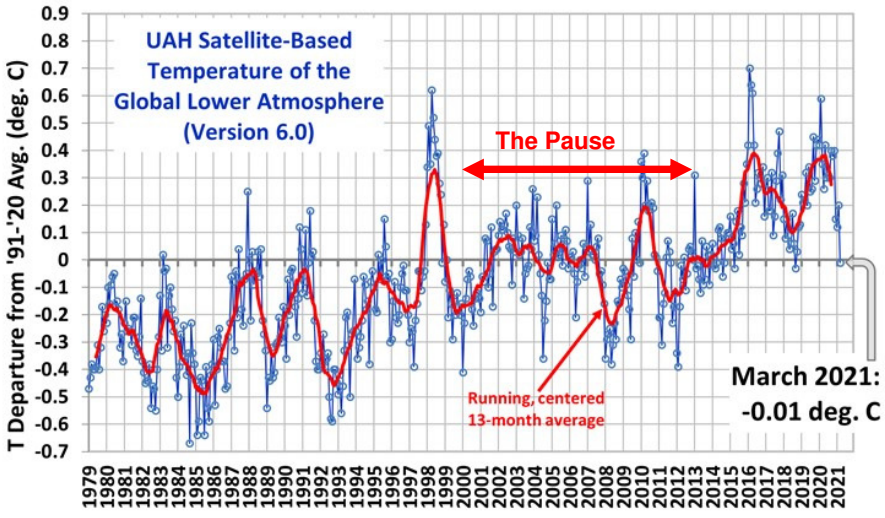
The Hot and Cold of Climate

Osher Lifelong Learning Institute
University of Richmond, October 2024 - Part II

Review



The Pause: 2000 to 2013?

THE BIG QUESTION

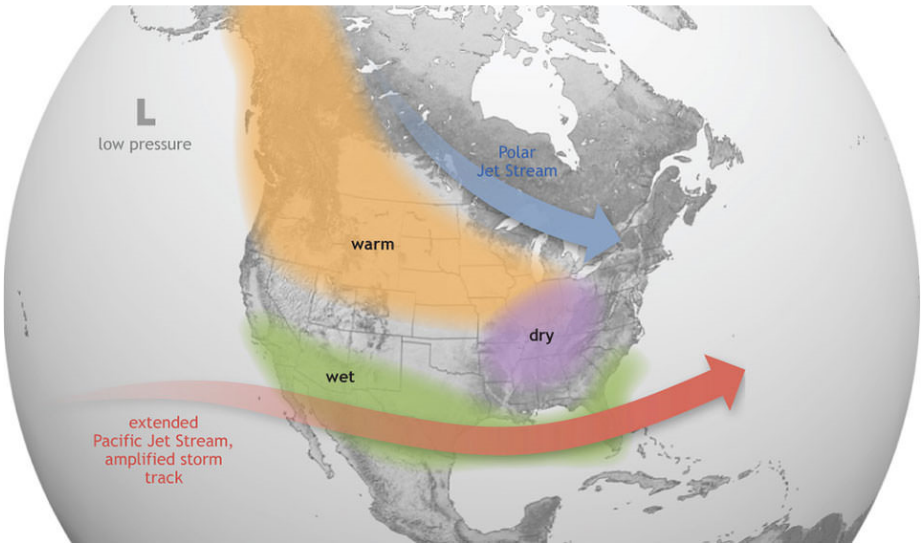
To what extent is the recent rise in temperature due to human activity versus nature?

Handout Correction:
www.climateforu.com
should read
www.climateforyou.com

Weather Phenomena

- Pacific Decadal Oscillation (PDO) - Long-term Pacific Ocean weather fluctuation.
- PDO waxes and wanes ~20 – 30 years.
- Just to complicate things more, there are also the AMO (Atlantic Multidecadal Oscillation), El Niño, La Niña, and the ENSO – El Niño Southern Oscillation
- El Niño and La Niña – Can Artificial Intelligence improve long-term predictability?

El Niño



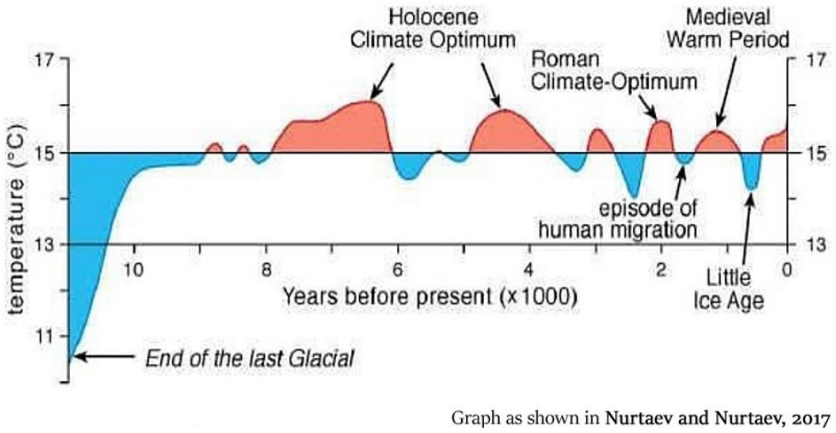
Volcanic Eruptions

- Volcanic eruptions produce aerosols that provide a nucleus for the water droplets that form clouds.
- Mt. Pinatubo 1991 eruption (Philippines). 2nd largest eruption in 20th century (1912 Novarupta Alaska larger)
- Released 10 billion tonnes (10 km^3) of magma and 20 million tons of SO_2
- Cooled the planet ~0.5°C

Mt. Pinatubo Today

NATURAL VARIABILITY
THE SUN AND COSMOS

Climate Optimums and the Little Ice Age

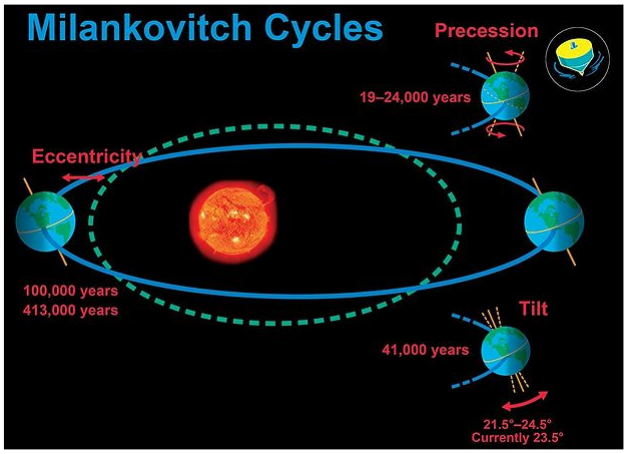


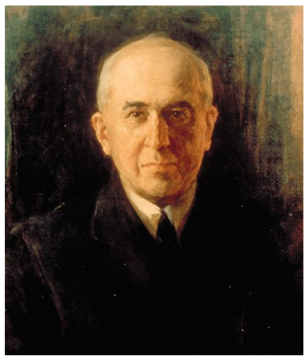
Graph as shown in **Nurtaev and Nurtaev, 2017**

Holocene Optimum 4,000-8,000 years ago, temperature ~1-2°C above present?

MILANKOVITCH CYCLES

- Milutin Milankovic (1879-1958), Serbian mathematician, astronomer, climatologist, geophysicist, civil engineer and popularizer of science

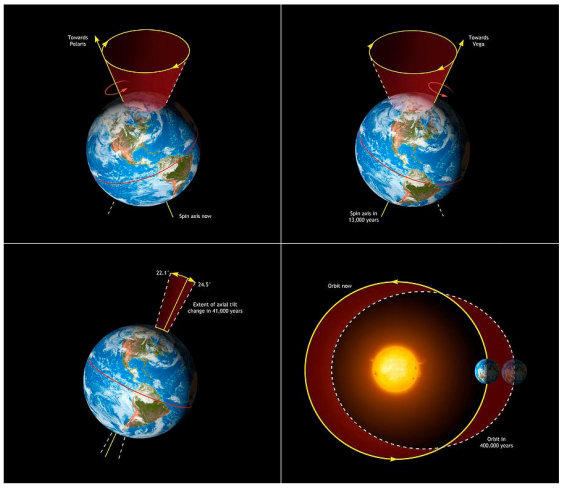




MILANKOVITCH CYCLES

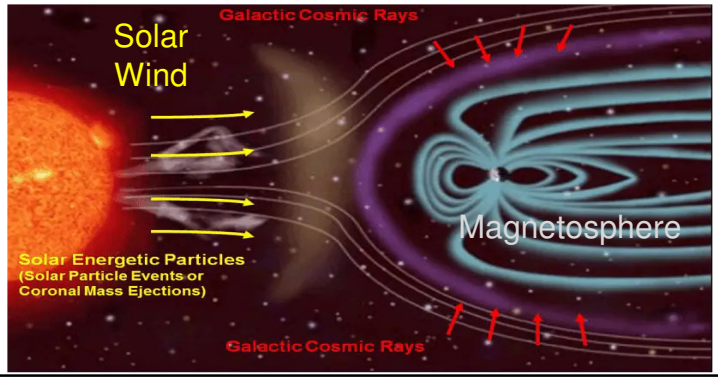
Glaciation (and ice ages) associated with combination of Earth's celestrial mechanics—precession of the equinoxes, variation in orbital eccentricity, and obliquity cycles

Correlation of the Milankovitch parameter with the time rate of change of ice volume is about as good as any correlation in geophysics



Effect of Sun on Climate?

- Variation in the solar wind (i.e., charged particles) affects the Earth's magnetosphere
- Variation in magnetosphere varies cosmic ray flux hitting the atmosphere.
- Result is variation of cloud formation which in turn changes the Earth's albedo affecting temperatures

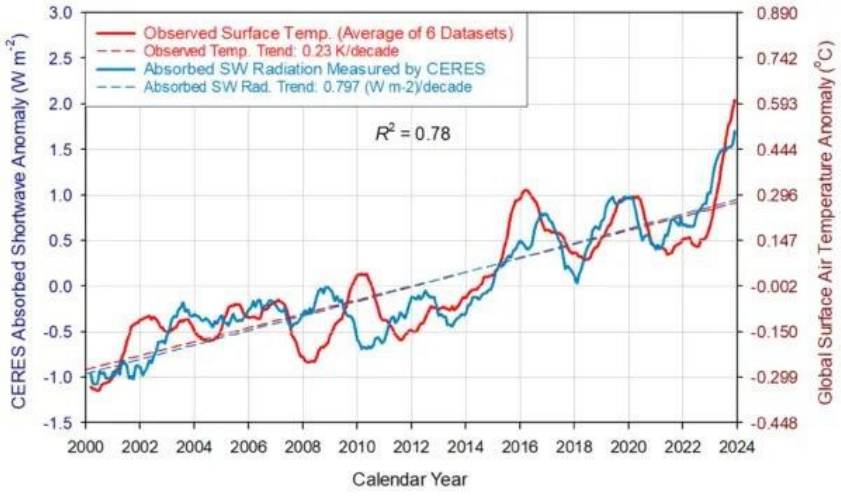


Svensmark et al. 2017

Theory of Effect of Cosmic Rays on Climate

- Cosmic rays ionize molecules in atmosphere attracting other molecules to create aerosols
- Water vapor condenses around aerosols to form clouds
- Solar Wind interacts with Earth's magnetosphere which modifies number of cosmic rays striking the atmosphere
- Varies amount of cloud formation → cools or warms surface
- 10 oscillations of solar activity have occurred over the last 7000 years (Jack Eddy)

Claim: Warming of past 24 years was entirely caused by the observed decreases in the Earth's albedo (that is, reflected sunlight)



How Large Is Natural Variability?

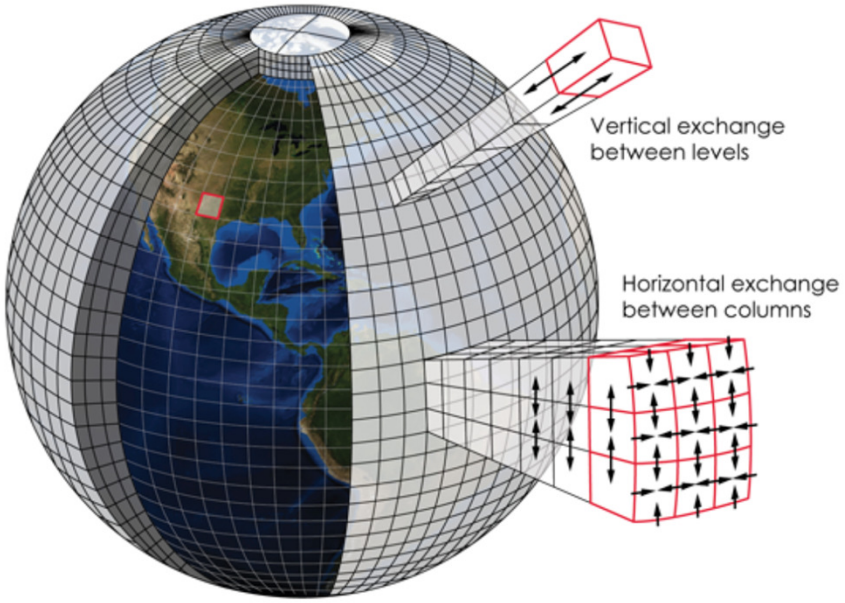
- Tongwen Wu et al (2019) estimated that weather patterns (e.g., AMO + PDO) accounted for 30% of the warming over the past 140 years.
- Attributed remaining warming to CO_2.
- Ignored other possible sources of natural variability—e.g., solar wind, solar magnetic field, solar output and longer term climate oscillations (e.g., ~1,000 year Eddy cycle)
- Ronan Connolly and 22 co-authors (2021) comprehensive review of literature on impact of solar variations on warming.
- Concluded that between **0 and 100%** of the warming in the Northern Hemisphere due to solar variability.
- Conclusion:

Magnitude of Natural Variability is **NOT** Known

PREDICTING THE FUTURE - MODELS

- GCM – General Circulation Climate Model
- Developers claim that models tend to validate that warming is caused by CO_2 (i.e., human activity)
- Gaps in models not covered by fundamental physics must be filled by empirical correlations and assumptions.
- Example: Cannot model turbulence (chaotic fluid motion)
- Too many free variables all interacting to an unknown degree with each other. Difficult to determine actual sensitivities from experiment or observation.
- Key parameter is **Climate Sensitivity** – Amount of surface warming that results from a doubling of atmospheric CO_2 content from its preindustrial background (nominally equal to a change from 300 to 600 ppmv by volume)

Climate Model Grid or Nodalization



Model structure:

1. Navier-Stokes equations
2. Empirical correlations
3. Fudge factors

Navier–Stokes Equations
3 – dimensional – unsteady
Glenn Research Center

Coordinates: (x,y,z)
Velocity Components: (u,v,w)
Time: t Pressure: p
Density: ρ Stress: τ
Total Energy: Et
Heat Flux: q
Reynolds Number: Re
Prandtl Number: Pr

Continuity:
$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0$$

X – Momentum:
$$\frac{\partial(\rho u)}{\partial t}+\frac{\partial(\rho u^2)}{\partial x}+\frac{\partial(\rho uv)}{\partial y}+\frac{\partial(\rho uw)}{\partial z}=-\frac{\partial p}{\partial x}+\frac{1}{Re_r}\left[\frac{\partial \tau_{xx}}{\partial x}+\frac{\partial \tau_{xy}}{\partial y}+\frac{\partial \tau_{xz}}{\partial z}\right]$$

Y – Momentum:
$$\frac{\partial(\rho v)}{\partial t}+\frac{\partial(\rho uv)}{\partial x}+\frac{\partial(\rho v^2)}{\partial y}+\frac{\partial(\rho vw)}{\partial z}=-\frac{\partial p}{\partial y}+\frac{1}{Re_r}\left[\frac{\partial \tau_{xy}}{\partial x}+\frac{\partial \tau_{yy}}{\partial y}+\frac{\partial \tau_{yz}}{\partial z}\right]$$

Z – Momentum
$$\frac{\partial(\rho w)}{\partial t}+\frac{\partial(\rho uw)}{\partial x}+\frac{\partial(\rho vw)}{\partial y}+\frac{\partial(\rho w^2)}{\partial z}=-\frac{\partial p}{\partial z}+\frac{1}{Re_r}\left[\frac{\partial \tau_{xz}}{\partial x}+\frac{\partial \tau_{yz}}{\partial y}+\frac{\partial \tau_{zz}}{\partial z}\right]$$

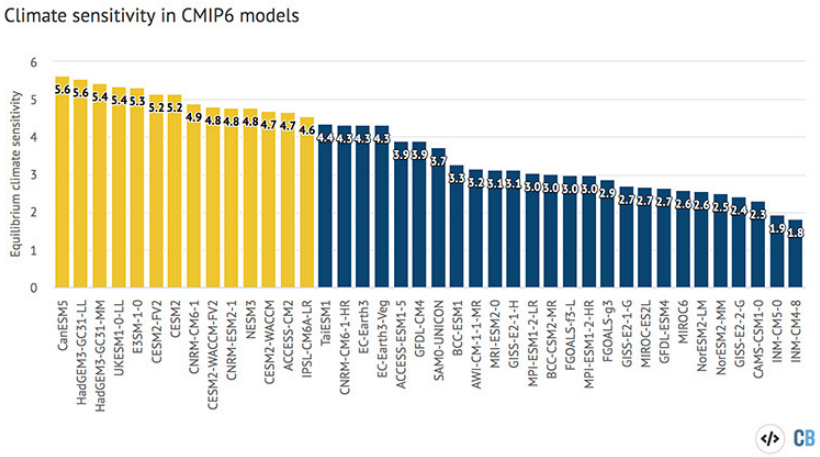
Energy:
$$\frac{\partial(E_t)}{\partial t}+\frac{\partial(uE_t)}{\partial x}+\frac{\partial(vE_t)}{\partial y}+\frac{\partial(wE_t)}{\partial z}=-\frac{\partial(up)}{\partial x}-\frac{\partial(vp)}{\partial y}-\frac{\partial(wp)}{\partial z}-\frac{1}{Re_r Pr_r}\left[\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}+\frac{\partial q_z}{\partial z}\right]$$
$$+\frac{1}{Re_r}\left[\frac{\partial}{\partial x}(u\tau_{xx}+v\tau_{xy}+w\tau_{xz})+\frac{\partial}{\partial y}(u\tau_{xy}+v\tau_{yy}+w\tau_{yz})+\frac{\partial}{\partial z}(u\tau_{xz}+v\tau_{yz}+w\tau_{zz})\right]$$

Models are so complex that a 1/10th reduction in grid size would increase run times from months to over a CENTURY!

- Determine time of Initial Conditions (ICs)
- Adjust correlations and fudge factors to produce global average climate history from ICs

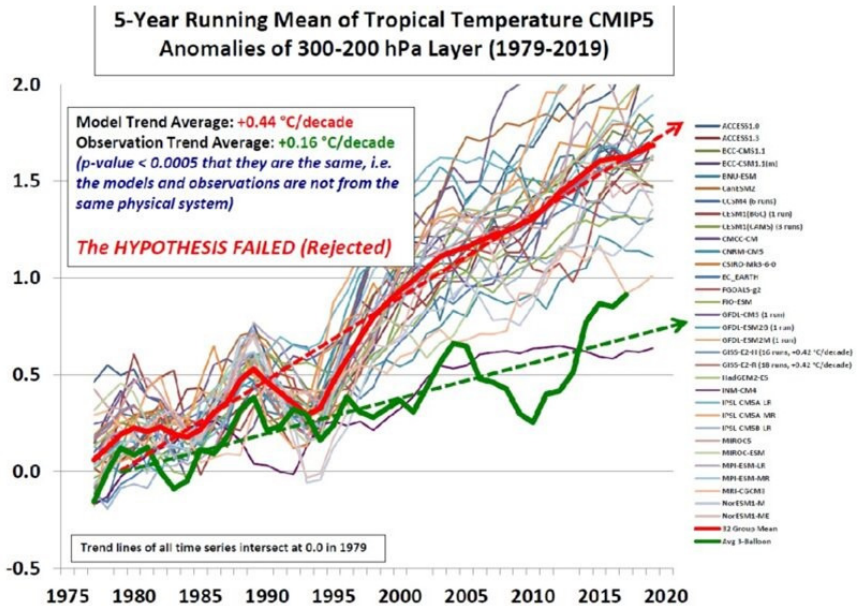
ECS – Equilibrium Climate Sensitivity

~40% of CMIP6 climate model ECS predictions are rejected by the IPCC as being unreasonably high (yellow below) Ref. CarbonBrief



Modeling Hazards

- Applying empirical correlations outside range of validation or uncertainty in range of applicability
- Insufficient benchmarking or validation
- Use of fudge factors instead of Physics
- **Tendency or incentive to have model verify what developer or funding agency hopes to be the answer (?)**
- Small uncertainty early on can multiply with time
- Complexity of climate system beyond present capability of accurately modeling.
- Model predictions are NOT data



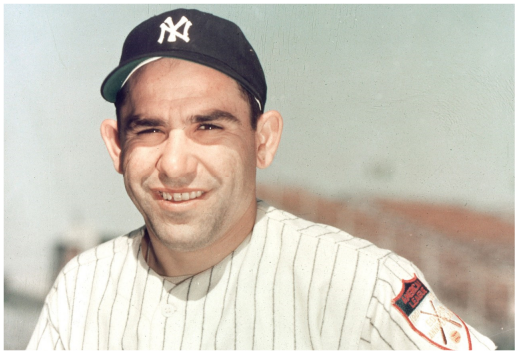
Weather balloon data (reanalysis) – solid green line

A word of Caution

"Trying to predict the future is like trying to drive down a country road at night with no lights while looking out the back window."
-- Peter Drucker

Or in the immortal words of one of the great philosophers of the twentieth century…

"It's tough to make predictions, especially about the future.
-- Yogi Berra

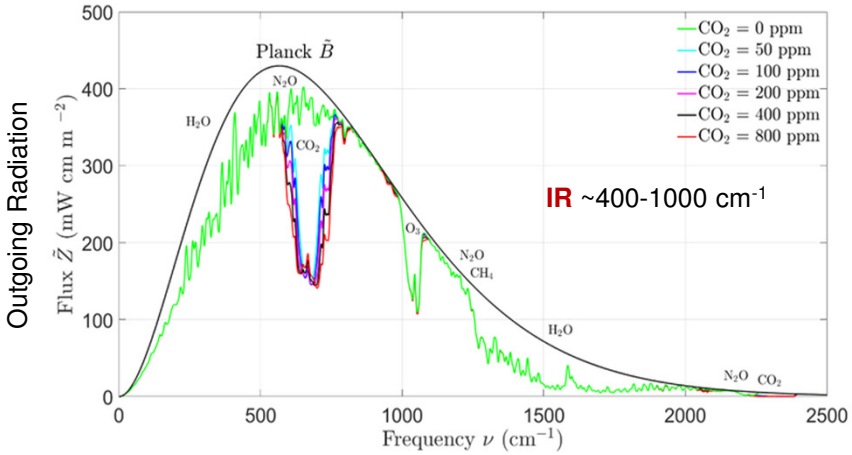


Is Climate Sensitivity Linear?

Top (**black**) line = solar energy flux with no atmosphere

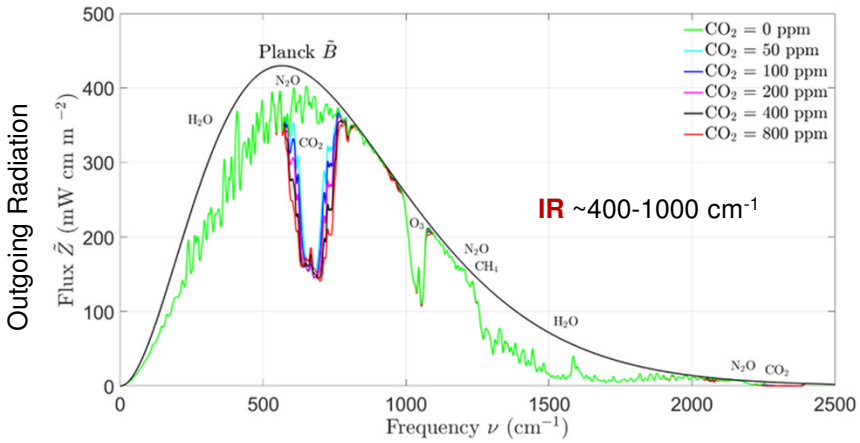
Farther below the black line → less radiation leaked to space

Green line = Atmosphere except no CO_2



Black line: CO_2 400 ppm → CO_2 has noticeable effect → Further 7.6% reduction in escaped radiation versus no CO_2

Red line: CO_2 800 ppm → Further **0.8%** reduction in escaped radiation versus 400 ppm CO_2

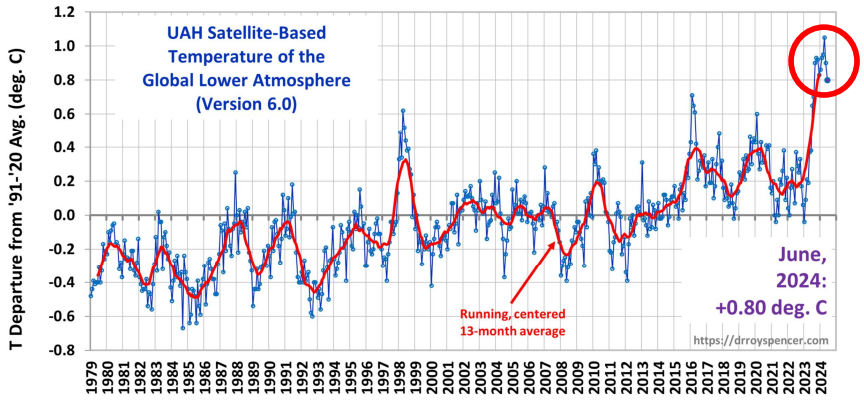


Conclusion: Climate Sensitivity **NOT** Linear

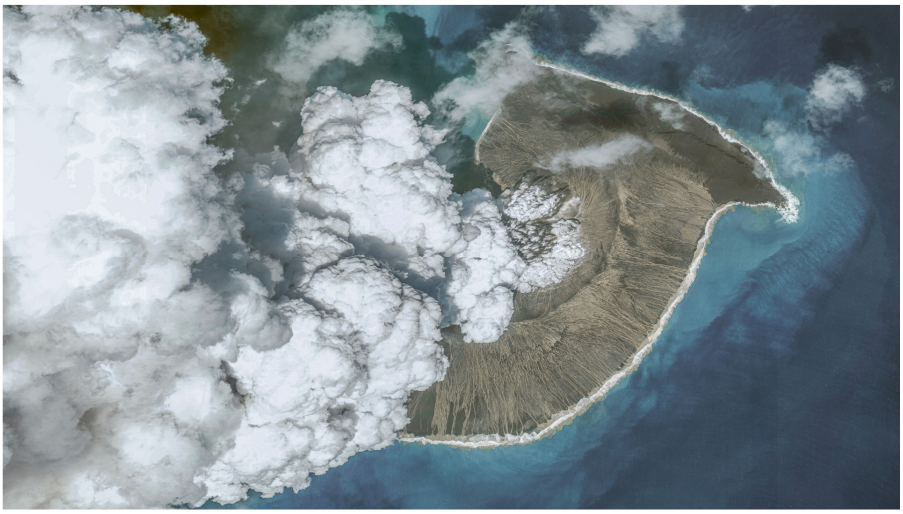
The 2023 Temperature Anomoly

- Jump in 2nd half of 2023 through early 2024
- Many previous records exceeded by > 0.2°C
- Models don't predict → CO_2 not the culprit!

April 2024 +1.05°C



Possible Suspect
Tonga-Hunga Eruption



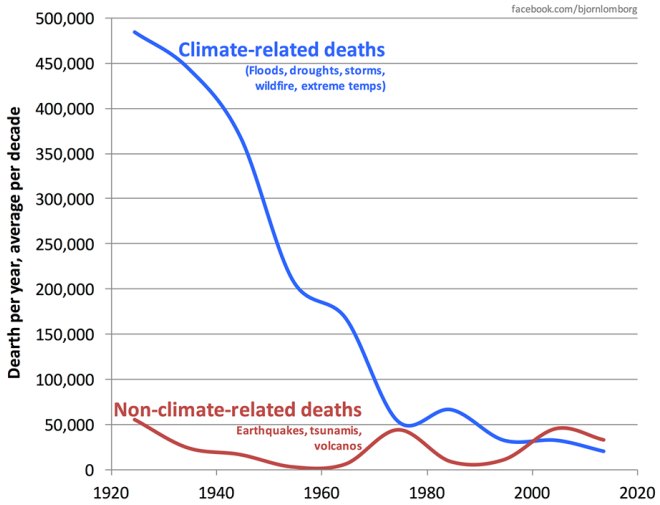
Tonga-Hunga Volcanic Eruption

- January 2022
- Filled stratosphere with 146 million tons of water vapor
- 10-15% increase is total atmosphere water vapor
- Some argue for increased warming, others for cooling due to formation of ice crystals in stratosphere
- Why the 14-16 month delay between eruption and temperature anomaly?
- Tambora eruption April 1815 (tens to hundreds of thousands of fatalities)
- Effect not felt until following year, 1816 "The Year Without a Summer"

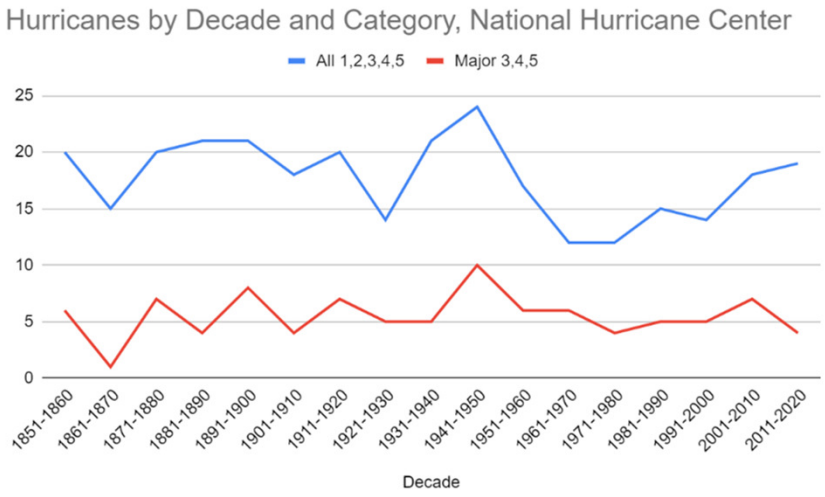
CLIMATE – IT'S COMPLICATED

Are Things Getting Worse?

Deaths from Climate and non-Climate Catastophes, 1920-2017



OFDA/CRED International Disaster Database, www.emdat.be, averaged over decades 1920-29, 1930-39, ..., 2010-2017



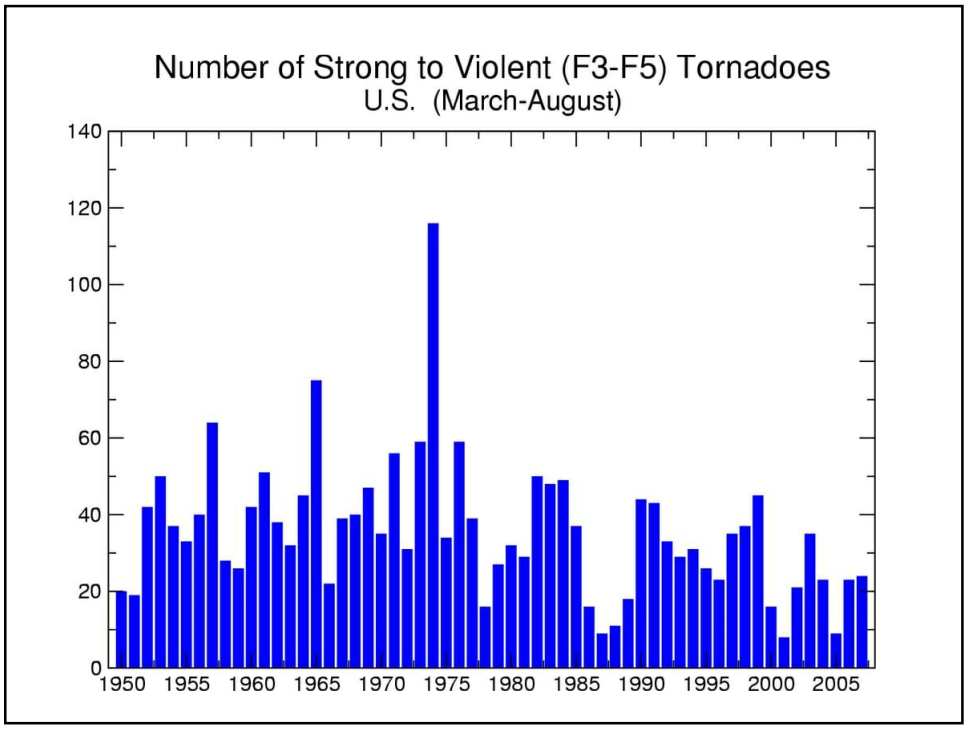
- 120-year US hurricane record → no overall change (actually, slight decrease)
- 12-year US hurricane 'drought' of category 3 or more following Katrina & Wilma (2005)

Bigger, More Frequent Storms? (cont.)

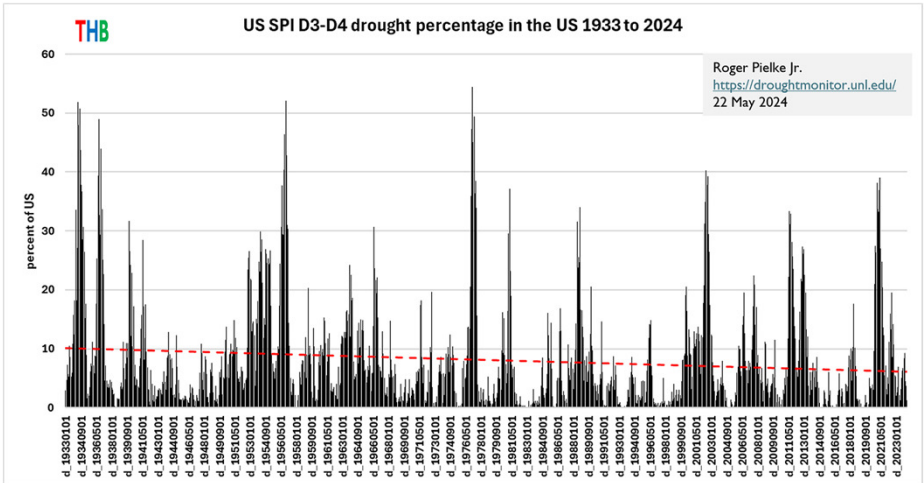
- Hurricane Harvey (2017): 1st major hurricane to make landfall in the U.S. since 2005, after a 12-year major hurricane drought
- Great Galveston Category 4 Hurricane of 1900 took between 6,000 and 12,000 lives, most due to storm surge and flooding (deadliest natural disaster in U.S. history)

July 8-10 & 15, 1916 – Two Successive Storms

- 22 inches of rain in western North Carolina
- 8 feet of flooding in Asheville, NC
- French Broad River, 21 ft (17 ft above flood stage)
- Hurricane Helene: Asheville 14 inches of rain, Busick, NC ~31 inches of rain



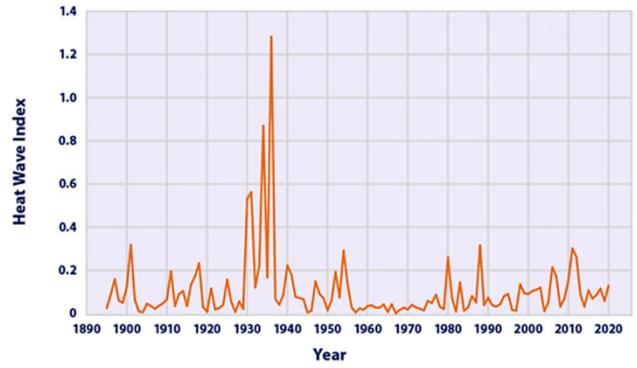
No trend in U.S. extreme drought conditions



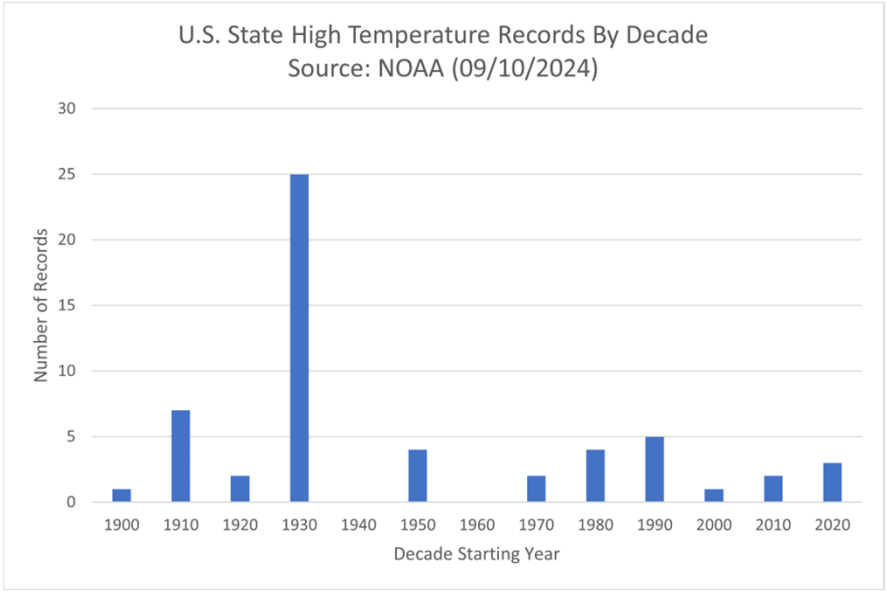
Climate Change Indicators: Heat Waves

This indicator describes trends in multi-day extreme heat events across the United States.

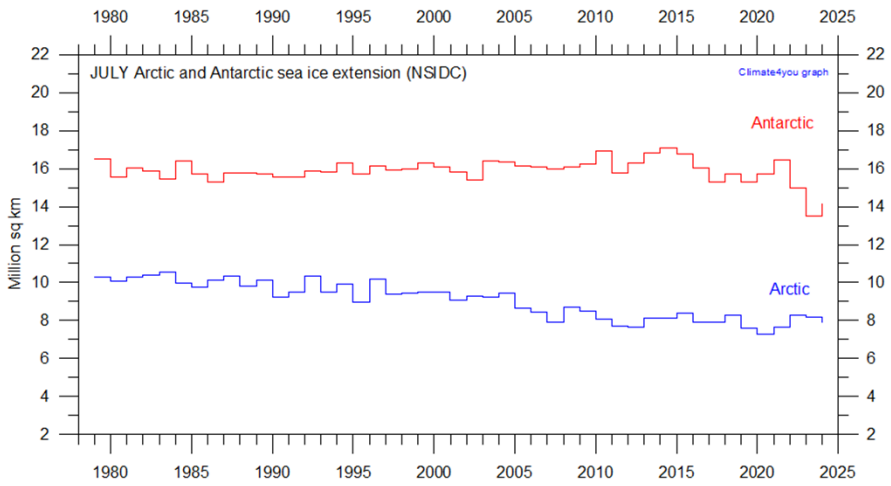
Figure 3. U.S. Annual Heat Wave Index, 1895–2020

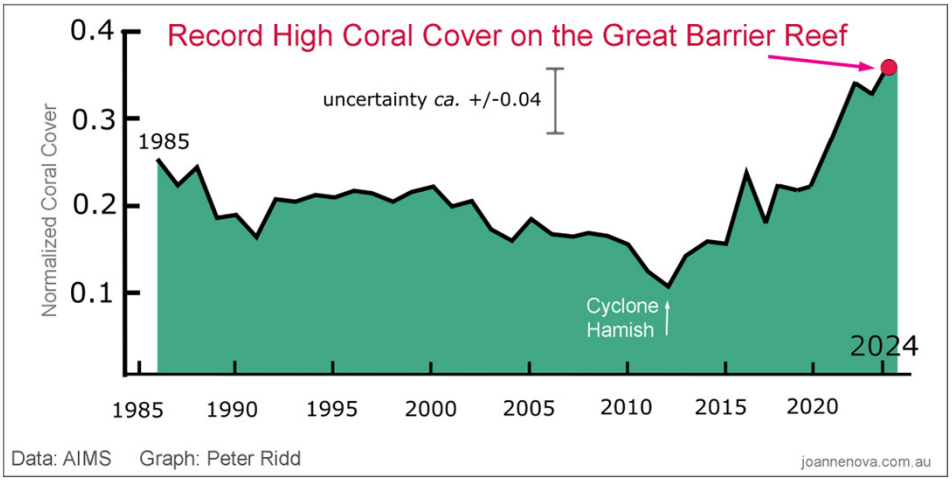


This figure shows the annual values of the U.S. Heat Wave Index from 1895 to 2020. These data cover the contiguous 48 states. An index value of 0.2 (for example) could mean that 20 percent of the country experienced one heat wave, 10 percent of the country experienced two heat waves, or some other combination of frequency and area resulted in this value.



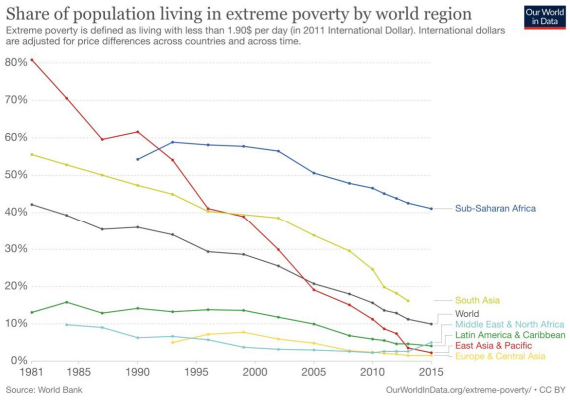
Polar Sea Ice





Greatest threats to reef are cyclones and crown-of-thorns starfish plagues

-- Ridd



From 1981 to 2015, the global population living in extreme poverty fell from **44% to 10%**

ENVIRONMENTAL PROGRESS

Source: Oxford University's Our World in Data

Global food production

World agricultural production has risen faster than human population.

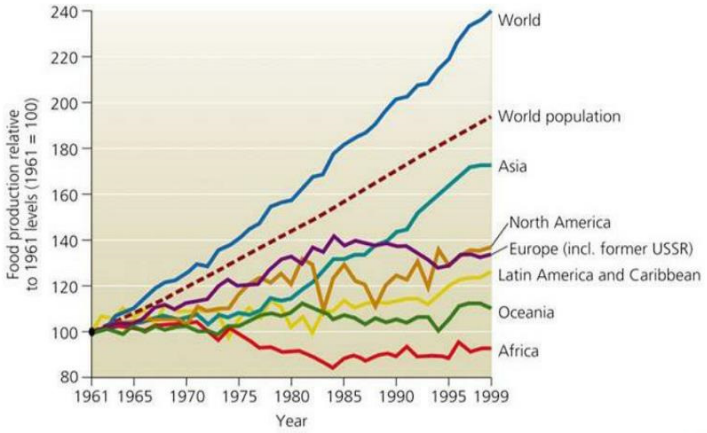
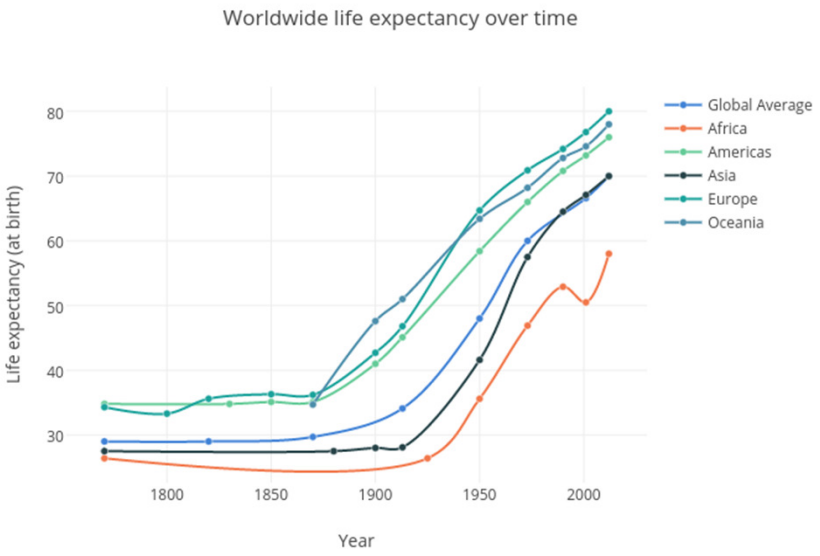


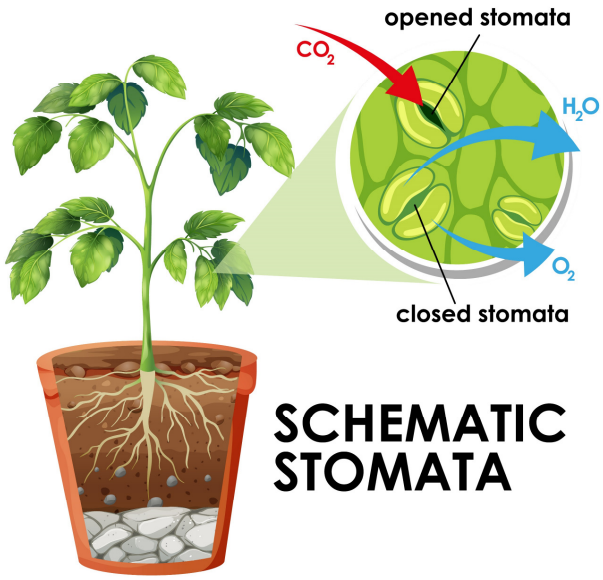
Figure 9.1

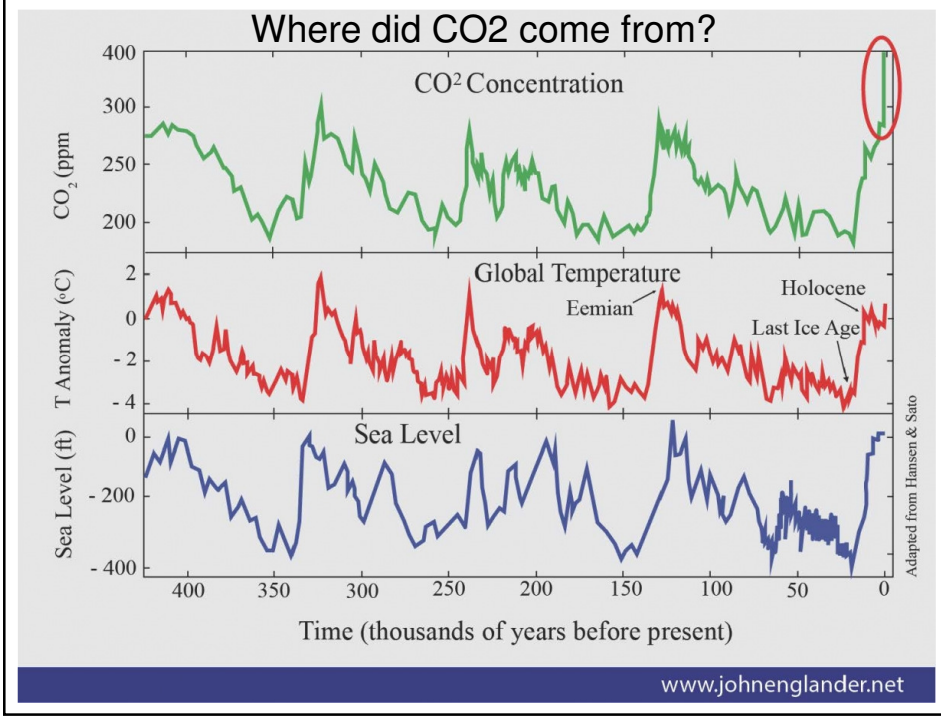


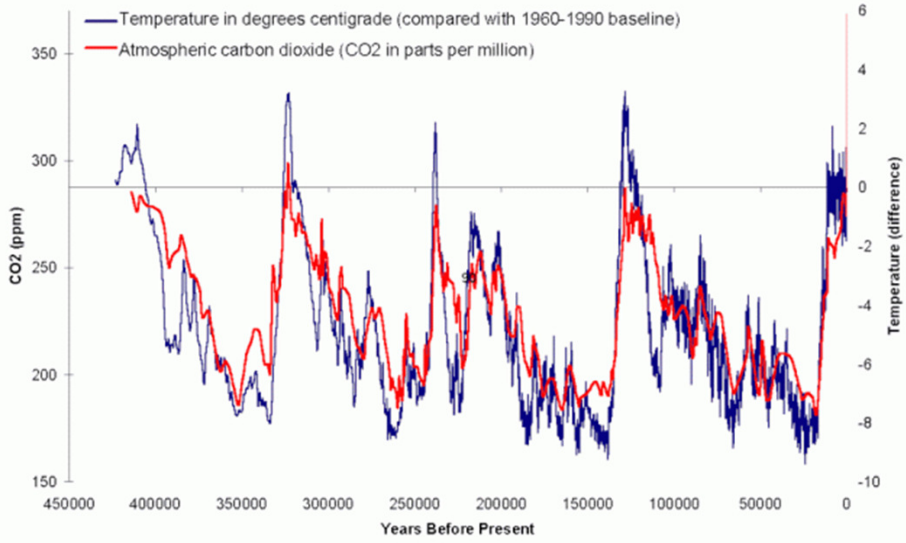
THE ELEPHANT IN THE ROOM?

PALEOCLIMATE

Estimating Geological CO_2 Levels



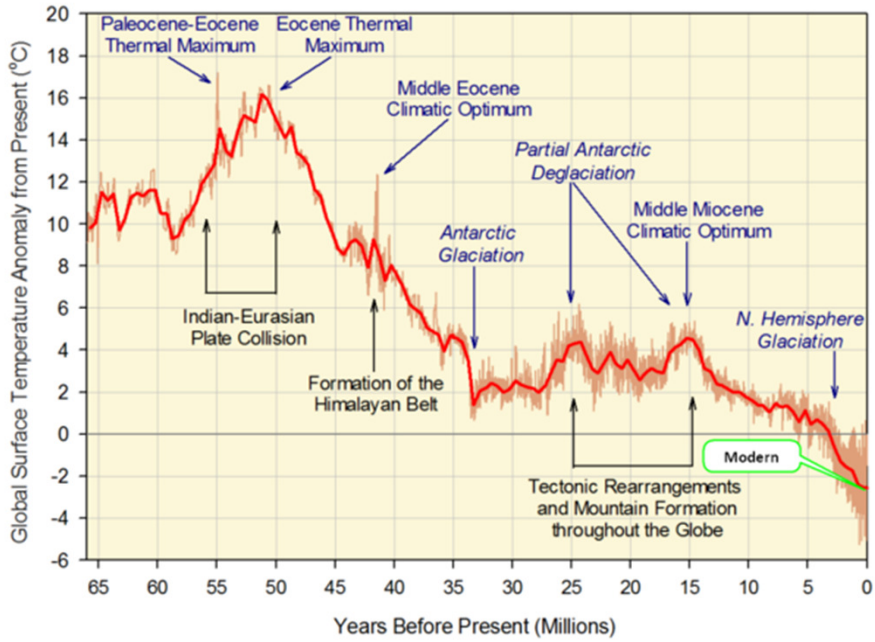




Temperature change Leads CO_2 by centuries

- Warming ocean emits CO_2
- Cooling ocean absorbs CO_2

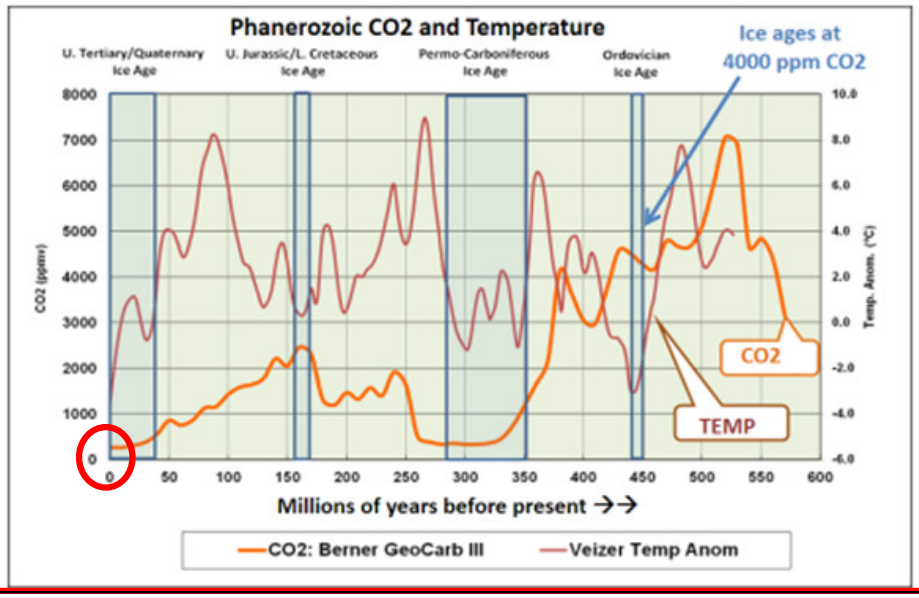
Paleo-Climate



Since the rise of the dinosaurs, the climate has overall been GREAT!

That is … Until Recently

Complex life emerged about 540 million years ago.
During most of this period, CO2 was much higher than today.
And there is little correlation between CO2 and temperature.



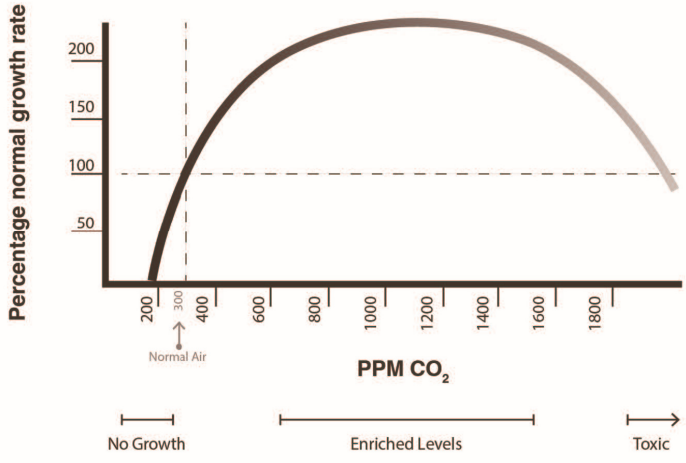
The Carboniferous Period (359 – 299 Ma)

CO_2 sequestered by plants

CO_2 – POLLUTANT OR PLANT FOOD?

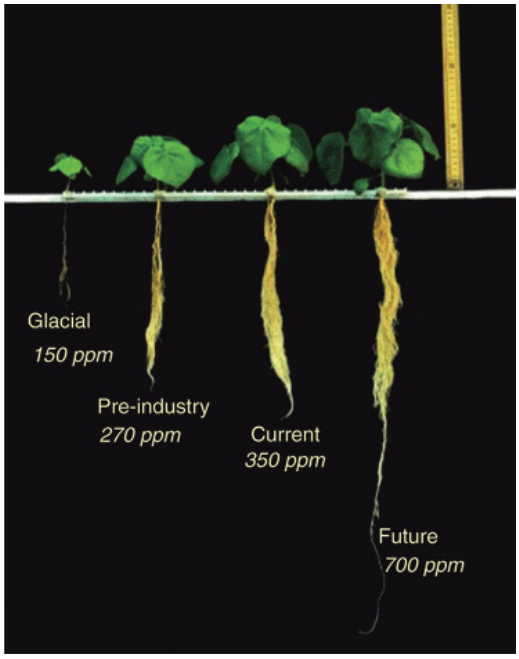
Greenhouse optimal CO_2 levels: 700 to 1800 ppm

Levels > 2000 ppm may cause plant damage

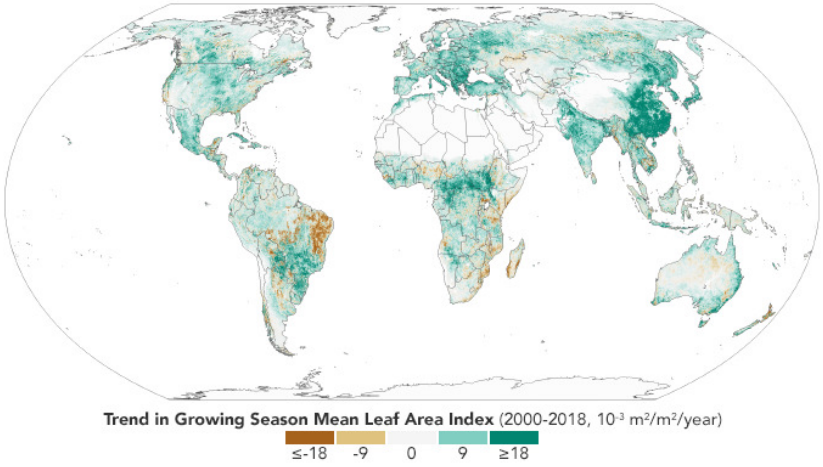


Plant growth after 14 days from germination under various CO_2 level

(Gerhart & Ward, 2010)

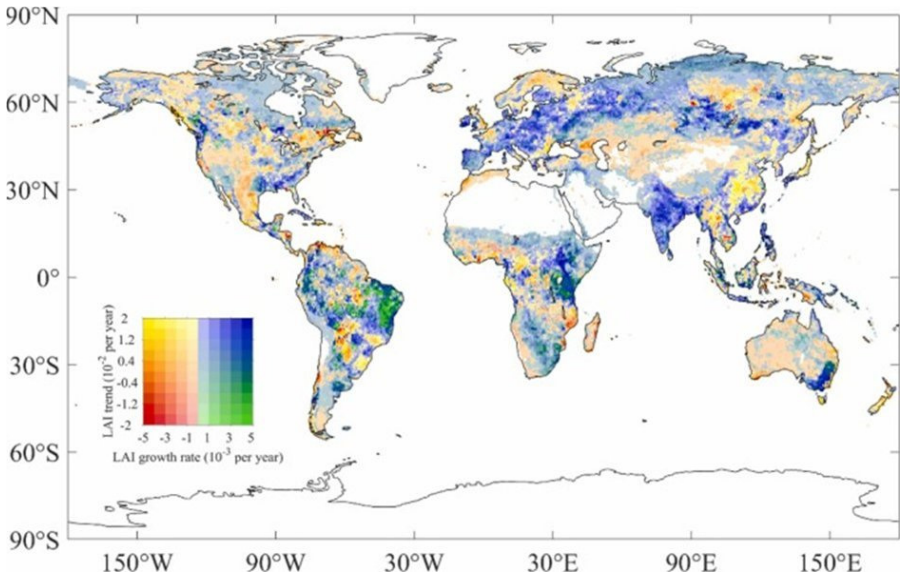


Satellite data shows the Earth is Greening



"The global vegetation cover increased approximately 11- 14%, of which 70% can be attributed to the increased CO_2 in the atmosphere…" over past 100 years. -- Merbach et al

Crop yields expected to be up by 15% by 2050



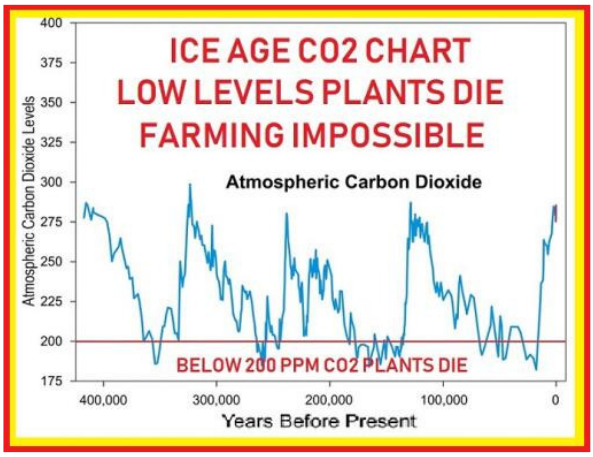
Sahara desert had shrunk by 8% over the previous three decades – Venter et al, 2018

Rainfall increase in northern Sudan

Greening created by agricultural irrigation of fields can “obliterate arid-land ecosystems”

CO_2 Crisis?

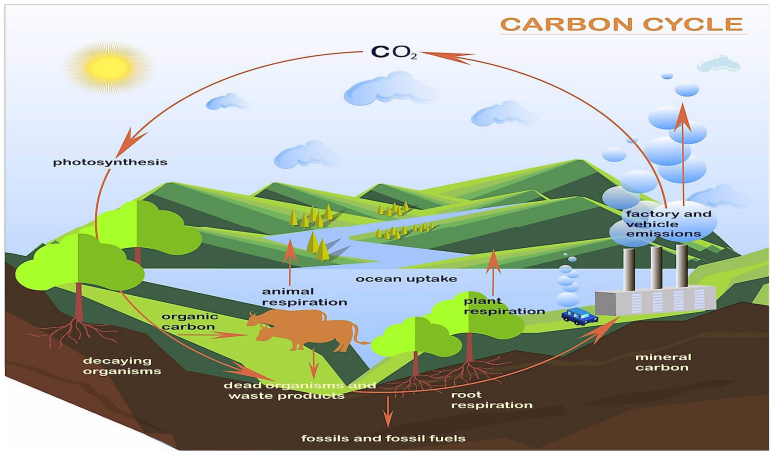
- CO_2 < 150 ppm → **Plants Die**
- Human fossil fuel use and clearing land for crops have increased CO_2 back to 400 ppm, which is still a starvation diet for plants
- Optimum level of CO_2 for plant growth, given enough water and nutrients, is 1,500 ppm. – Patrick Moore, 2015



Major Areas of Uncertainty – Unsettled Science

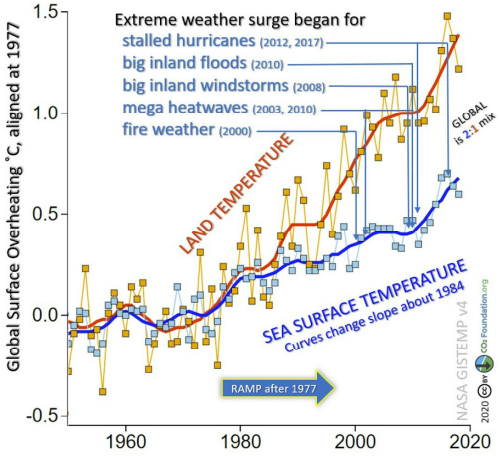
1. CO_2 residence time in the atmosphere; e.g., ocean absorption, biological pump.

   How high will CO_2 rise?



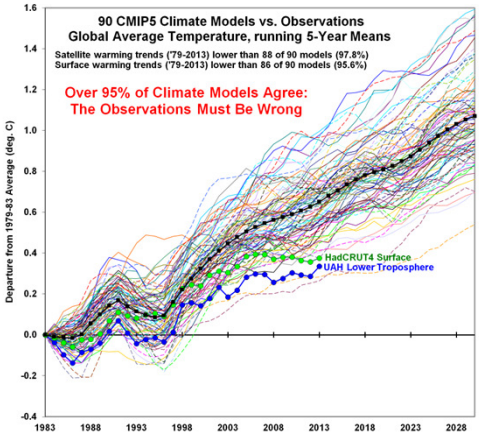
Major Areas of Uncertainty – Unsettled Science

2. Poor quality of temperature record. Disagreement between surface temperatures and those of satellites and balloons. Ship data most unreliable.



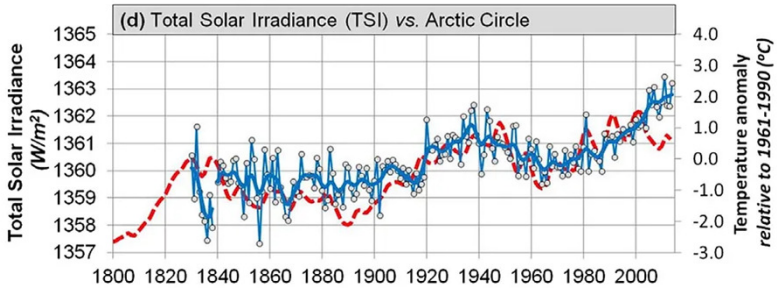
Major Areas of Uncertainty – Unsettled Science

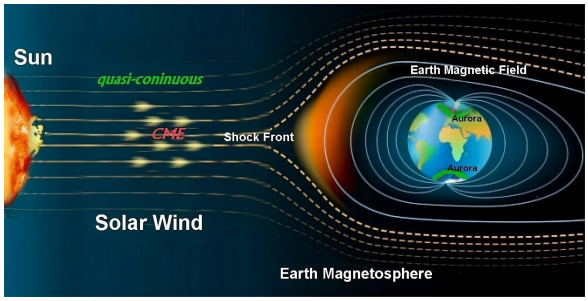
3. GCMs (General Circulation Climate Models) Large variance in predictions. Cannot model key climate phenomena from fundamental physics. Predictions are not DATA.



Major Areas of Uncertainty – Unsettled Science

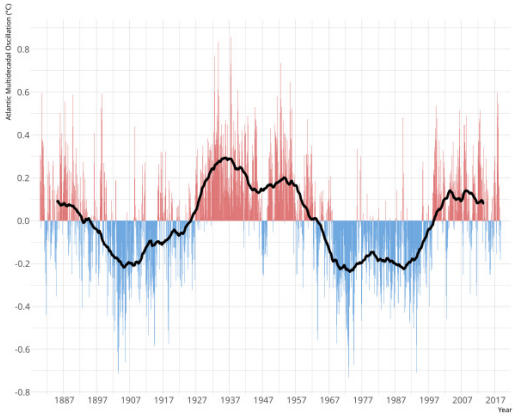
4. Contribution of solar activity unknown.





Major Areas of Uncertainty – Unsettled Science

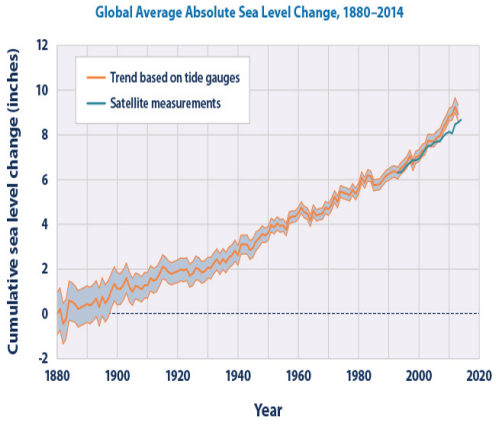
5. Role of ocean currents—El Nino, La Nina, the PDO (Pacific Decadal Oscillation), NAO (North Atlantic Oscillation), etc.—poorly understood.



Atlantic Multidecadal Oscillation

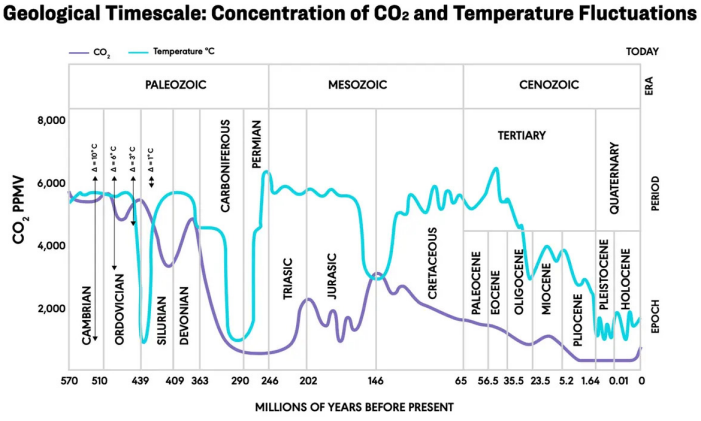
Major Areas of Uncertainty – Unsettled Science

6. Rate of sea level change as a function of warming is uncertain due to impact of increased evaporation from oceans and more rapid accumulation of polar ice.



Major Areas of Uncertainty – Unsettled Science

7. Resolution of paleoclimate trends of CO_2 with temperature. Is the modern warming unique? Why did mid-20th century temperature fall with rising CO_2? Why *The Pause*?



Climate – Politics and Society

Here we **BRIEFLY** address some political and social issues related to AGW

Political Arguments of AGW Proponents

The Precautionary Principle

- Pascal's Wager: Belief in God, whether He exists or not, is the best option
- AGW → Cannot afford the luxury of further study in that the stakes are so high that it is far better to act and discover it was not necessary, than not to act and discover it was.

Political Arguments of 'Some' AGW Proponents

- Solution requires immediate and drastic action.
- The science is settled.
- "I can't debate a 'conspiracy theorist' because I'd dignify his position"
- No one who questions the consensus can be doing so in good faith—that all critics of the consensus must be dancing to the tune of their paymasters in the fossil fuel.
- Skeptics are akin to holocaust deniers—hence, the term *Climate Denier*

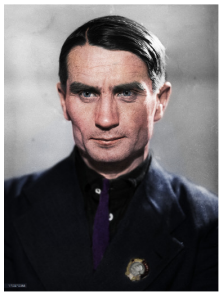
Some Proposed Political Policies

- Senate bill S.729 (2019): "…to prohibit the use of funds to Federal agencies to establish a panel, task force, advisory committee, or other effort to challenge the scientific consensus on climate change…"
- U.S. Senator Sheldon Whitehouse has called for the RICO Act against racketeering to be used to persecute critics of the consensus. (May 2020)
- NGO Stop Ecocide defines ***ecocide*** as "unlawful or wanton acts committed with knowledge that there is a substantial likelihood of severe and either widespread or long-term damage to the environment being caused by those acts". As of 2021, ecocide was a crime in 11 countries including Russia and the Ukraine. (World Economic Forum)

Attempts to shutdown scientific debate
Personal attacks on Skeptics
Criminalization of other viewpoints

Suppression of Lysenko's opposition

- Through a series of intrigues and highly politicized public "discussions", he managed to destroy practically all of his opponents
- More than 3000 biologists were fired, arrested, or executed
- Nikolai Vavilov was disgracefully dismissed from the presidency of the Agriculture Academy in 1938 and died in prison in 1940
- The genetic science in Russia was effectively destroyed until the death of Stalin in 1953
- Despite successive failures, Lysenko remained in the leadership of biology and briefly regained the position of the President of the Academy during Khrushchev



Trofim Lysenko

Political Arguments of 'Some' Skeptics

- The debate is not settled.
- Nature cares nothing for Consensus
- AGW proponents have a strong economic interest—most of them are in the pay of some government bureaucracy

"It is difficult to get a man to understand something, when his salary depends on his not understanding it."
— **Upton Sinclair**

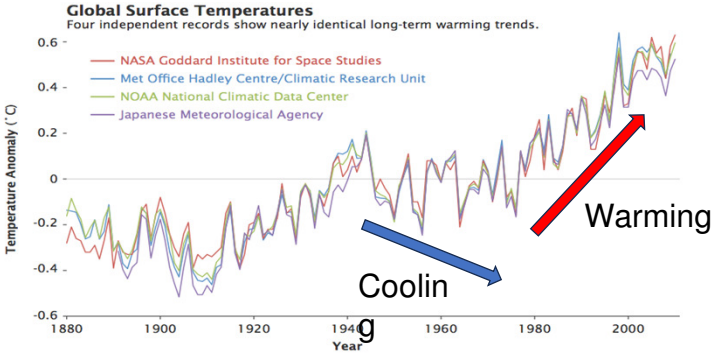
Some Results of Global Warming - A SHORT LIST

- Increased teenage drinking
- More stray cats
- Itchier poison ivy
- More sharks
- Increased malnutrition and disease
- Hurricane (insert name here)
- Crisis in Darfur (western Sudan)
- Havoc on fashion houses
- More earthquakes and volcanic eruptions
- More kidney stones
- Ocean acidification
- Hard times for brothels
- Increase in Cougar attacks
- Frozen penguin chicks
- Summer frost in Africa
- Poorly rising bread dough
- Bony stunted kids in Timor
- Contamination of blood for transfusions
- More landslides in Ireland
- More rape
- Camel deaths in North Africa
- Sex change in reptile
- More lawyers
- Causing the Earth to spin faster

~70% of people aged 16-25 are extremely worried or very worried about the climate, according to a study covering 10 countries and published in *The Lancet* (2022)

- Hundreds of thousands of jobs and billions of dollars in annual spending depend on a Climate Crisis (BloombergNEF: $1.77 trillion in 2023)
- Climatology: from backwater to superstar
- New careers:
  - Master of Science (MS) in Climate is a two-year, 50-credit professional degree that gives graduates from diverse backgrounds an in-depth training in specific areas of climate expertise and prepares them to be climate leaders at community, state, national, and international levels (Columbia University)
  - Climate Officer
  - Masters in Climate Finance
  - Carbon Sequestration Consultant

- 70,000 climate delegates to COP28
- Academic employment and tenure in many fields depends on Research Grant procurement
- Grant procurement in many fields depends on AGW orthodoxy
- James Hansen 1988 Congressional Address with about a decade of warming



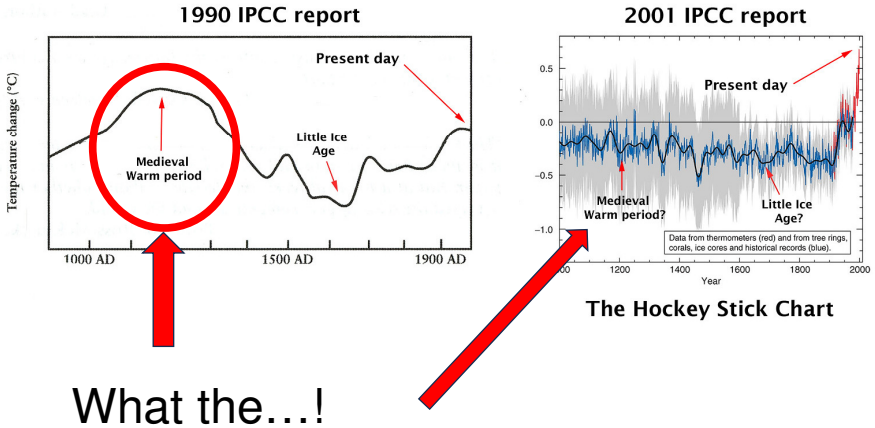
The 'Hockey Stick'

- Michael Mann, Ph.D. 1998, U. of Mass., 1999
- "The Hockey Stick" published 1998 and 1999.
- IPCC 3rd Assessment Report, 2001. Mann named an IPCC lead author and editor of the *Journal of Climate*
- Medieval Climate Optimum disappeared!

Michael Mann

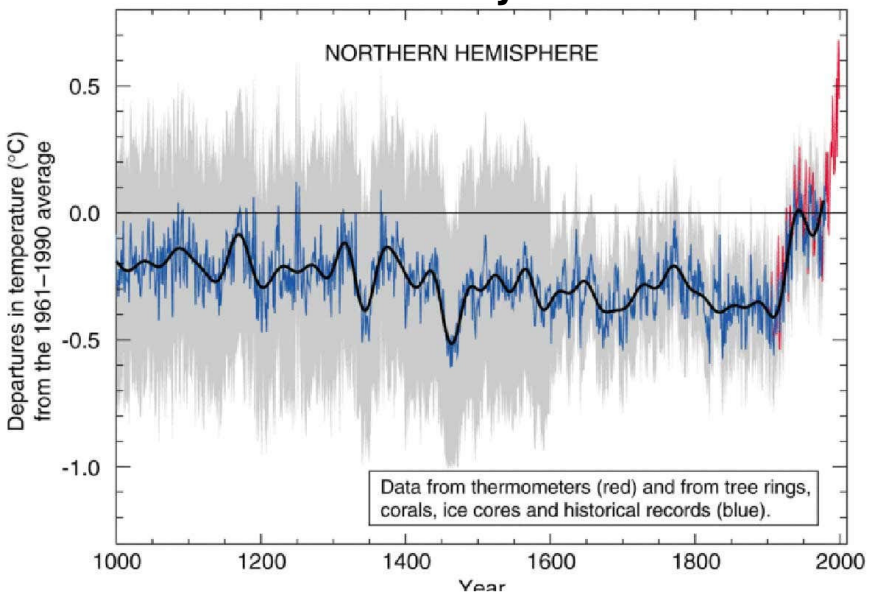
The 'Hockey Stick'

Climate change over the past 1000 years as shown by the IPCC



What the…!
What just happened!

The 'Hockey Stick'



Data up to 1080 mostly based on tree rings

Ruins of a church, part of a Norse pastoral farming and hunting settlement in Greenland during the Medieval Climate Optimum
~980 CE to 15th century

The 'Hockey Stick'

- 2003 Canadian statistician Stephen McIntyre and economist Ross McKitrick examined Mann's work
- Reanalysis showed that the data did not produce the claimed results → Medieval Warm Period reappears
- Algorithm was so broken that using essentially random data still produced a Hockey Stick!
- Hockey Stick is a “proxy reconstruction.” There’s only two things wrong with it--the proxies and the reconstruction.
- Was it malice or incompetence?
- Biggest Concern:

Problems with the paper were not identified by climatologists but by outsiders!

Extraordinary claims (Medieval Warm Period disappeared) need to be backed by extraordinary data

Climategate

- Nov. 2009, whistleblower leaked thousands of emails from the CRU. Second batch two years later.
- Top IPCC scientists consciously misrepresented and actively withheld important information … then attempted to prevent discovery.
  - CRU's Director of Research, Phil Jones
  - National Center for Atmospheric Research (NCAR) climate's analysis section head, Kevin Trenberth
  - Penn State University Michael Mann

- "Let's use Mike's trick to hide the decline." → Erased Data
- "Why should I show you my data when you'll only try to find something wrong with it?"
- Emails available at https://sealevel.info/FOIA/

- **SCIENTISTS ARE HUMAN AND ARE THEREFORE FALLIBLE**
- **THAT A PERSON DOING RESEARCH MIGHT BE A JERK DOESN'T MEAN THERE'S A PROBLEM WITH THE RESEARCH**

IN THE END
IT'S ALL ABOUT THE
DATA

THE BIG QUESTION

To what extent is the recent rise in temperature due to human activity versus nature?

UNANSWERED!

SUMMARY OF
THE PRESENTER'S VIEWS:

- We do not understand climate to the extent that we can confidently predict it
- The science is **NOT** settled
- Attempts to 'silence' and/or 'demonize' skeptics threaten scientific dialog
- On more reliable ground when discussing the consequences of various proposed responses to climate change since those involve Engineering → Part III

CLIMATE:
IT'S COMPLICATED!