

Climate: What Is Changing, and Should We Be Concerned?

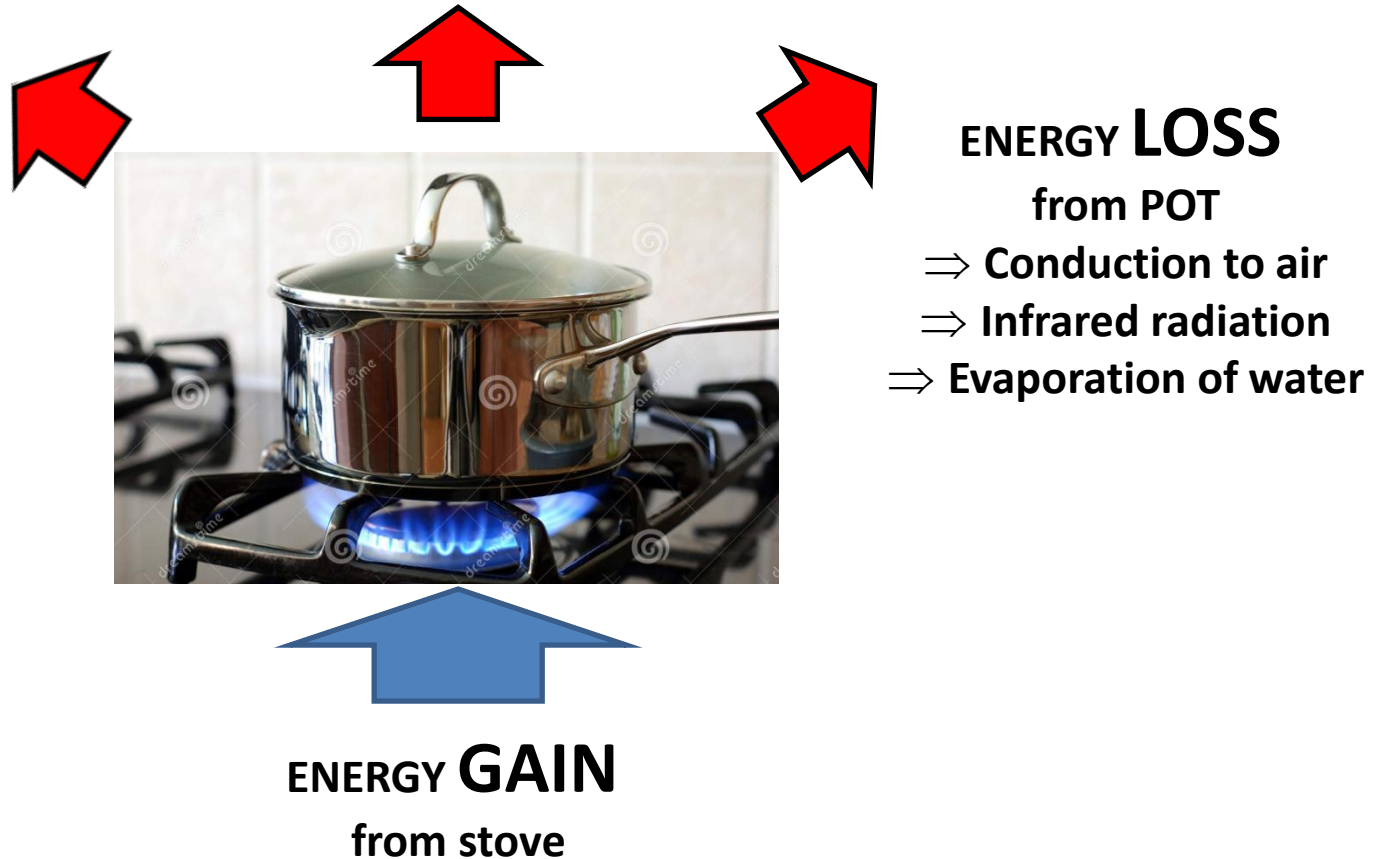
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Principal Research Scientist
The University of Alabama in Huntsville
March 15, 2018

Overview

- 1) Climate change includes unpredictable, natural components, and until we understand those, we will have difficulty predicting “global warming”.
- 2) There is little to no evidence that severe weather events (e.g. lightning, windstorms, tornadoes, floods) have worsened, despite modest warming.

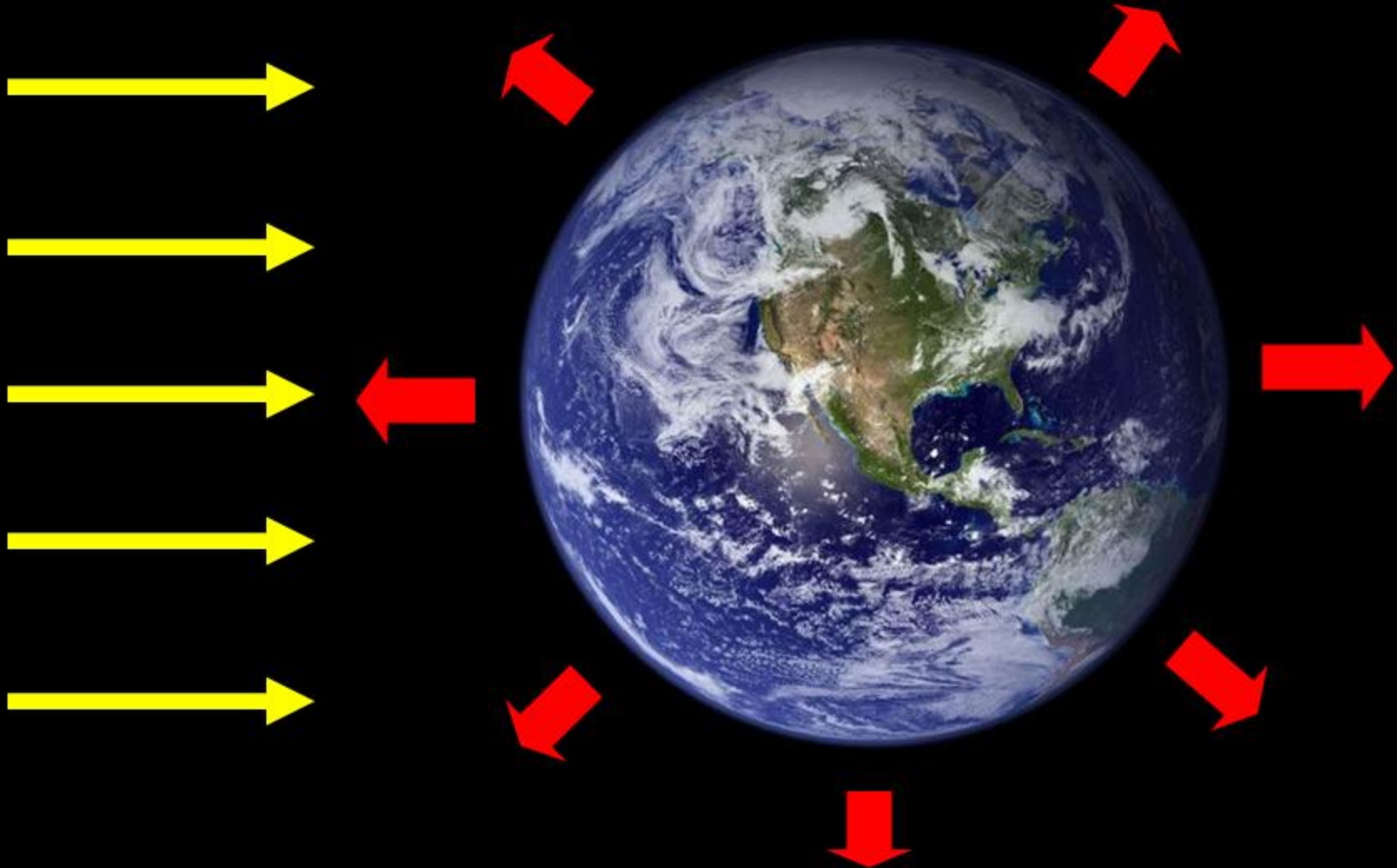
Understanding Climate Change Starts with Conservation of Energy

- Temperature change in anything is almost always caused by an *imbalance* between energy gain and energy loss.



Earth's Energy Balance

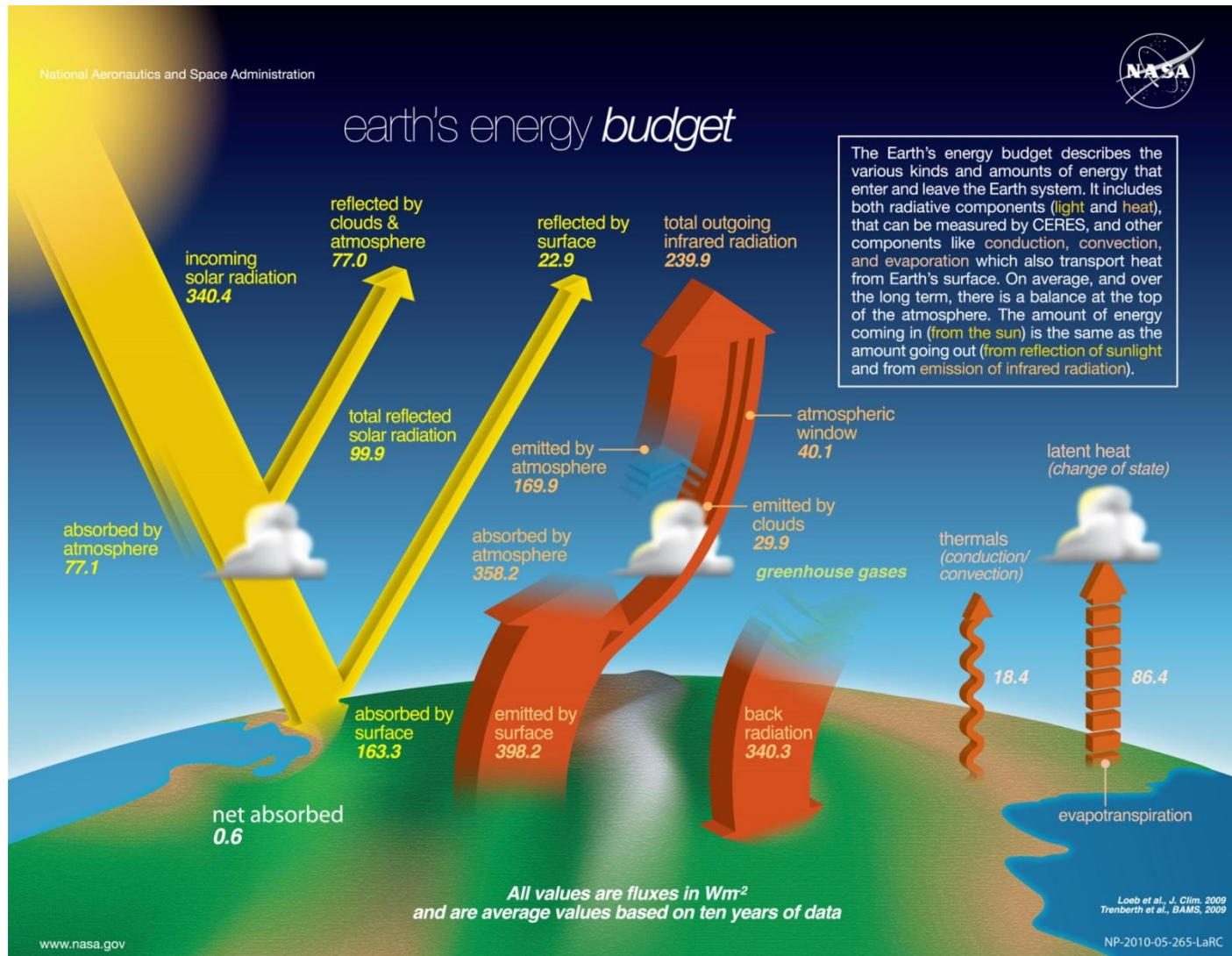
Absorbed Sunlight = Emitted Infrared Radiation



The global average energy flows in and out are estimated to be ~ 240 Watts per sq. meter

Components of Earth's Average Energy Balance

a change in any one of these will change the temperature!



All energy fluxes (transfers) are in Watts per sq. meter.

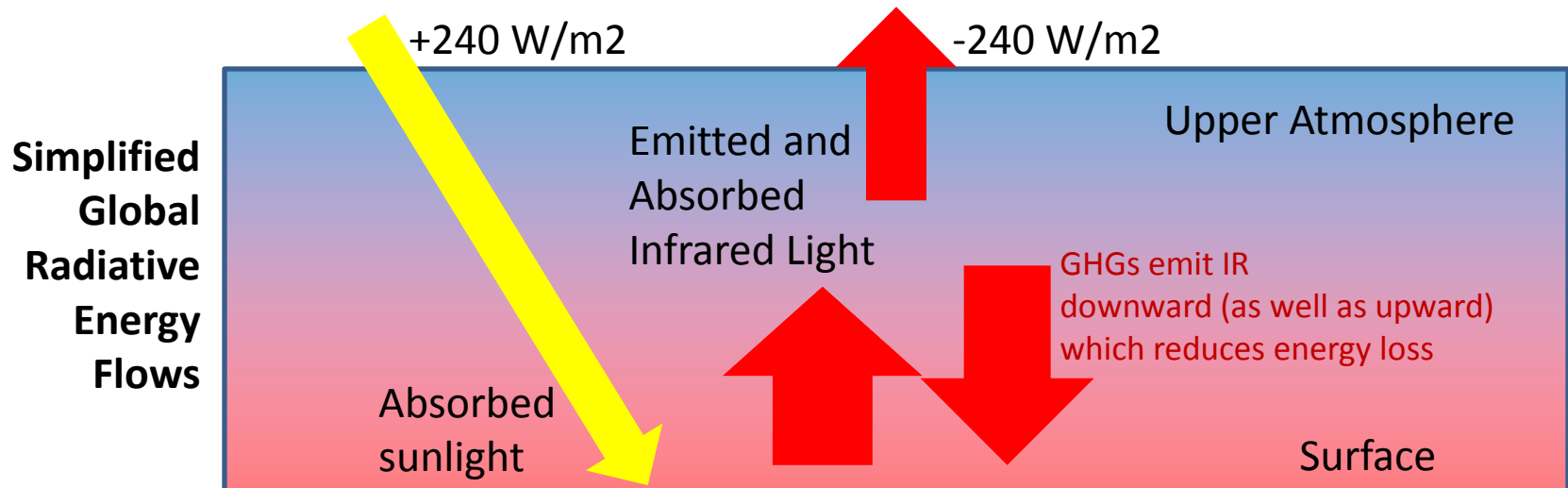
(1 Watt = 1 Joule per second of energy transfer; a 2,000 calorie daily diet contains 8,373, 600 Joules)

The “Greenhouse Effect”

Affects the Rate of Global Infrared Energy LOSS

(Earth’s ability to cool itself to outer space)

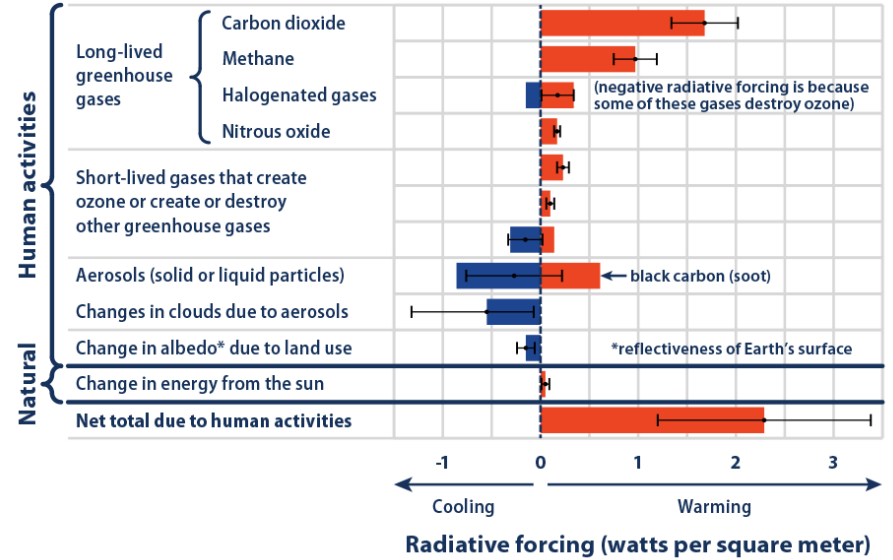
- “Greenhouse” gases in the atmosphere (mainly water vapor and CO₂) absorb and emit IR energy. They act like a “radiative blanket” over the earth.
- Any planetary atmosphere with greenhouse gases will be warmer in the lower layers, and colder in the upper layers, than without those gases (e.g. Manabe & Strickler, 1964).



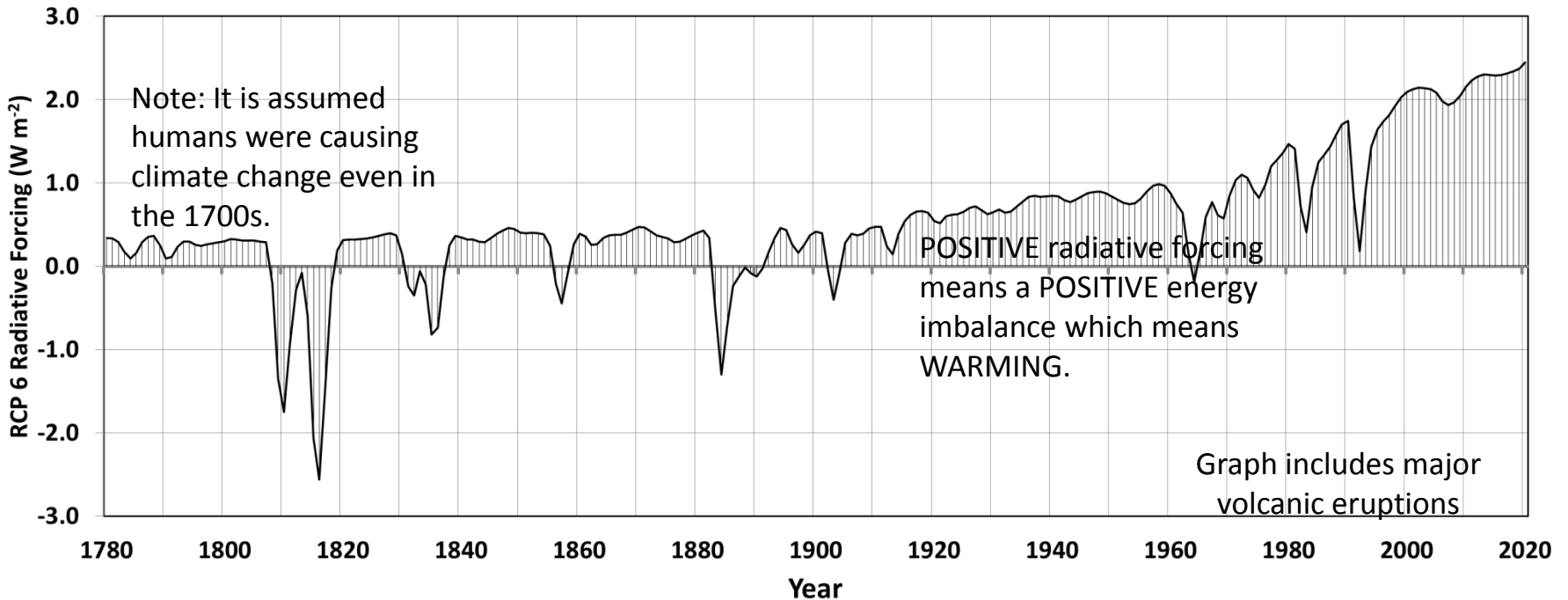
The U.N. IPCC assumes climate is naturally STABLE and BALANCED, ...unless humans interfere.

They assume a “forcing/feedback” paradigm of climate change, where if the climate system energy balance is forced out of equilibrium (e.g. from CO2), it warms until “feedbacks” stop the warming.

Radiative Forcing Caused by Human Activities Since 1750

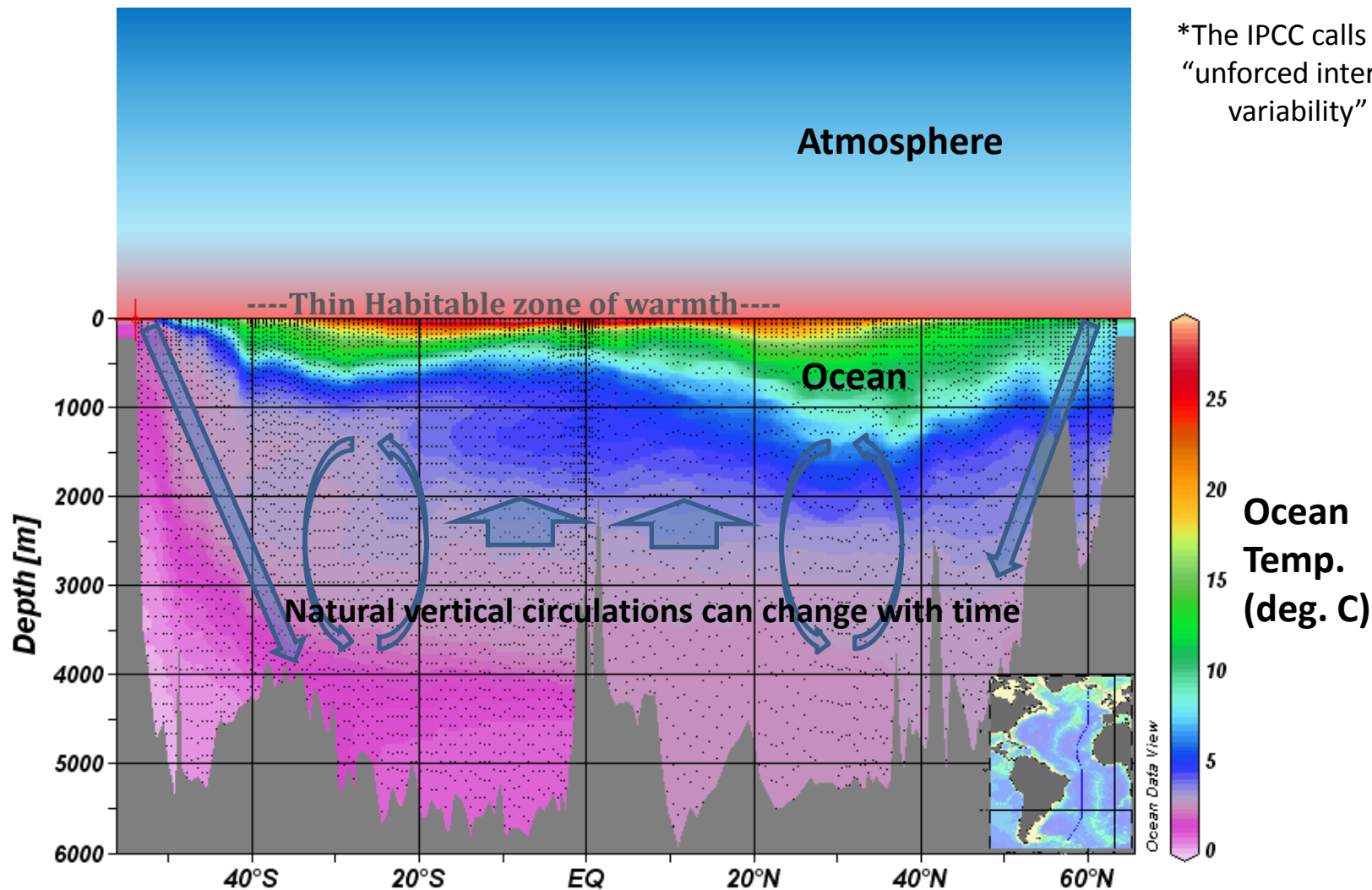


Data source: IPCC (Intergovernmental Panel on Climate Change). 2013. Climate change 2013: The physical science basis. Working Group I contribution to the IPCC Fifth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. www.ipcc.ch/report/ar5/wg1.



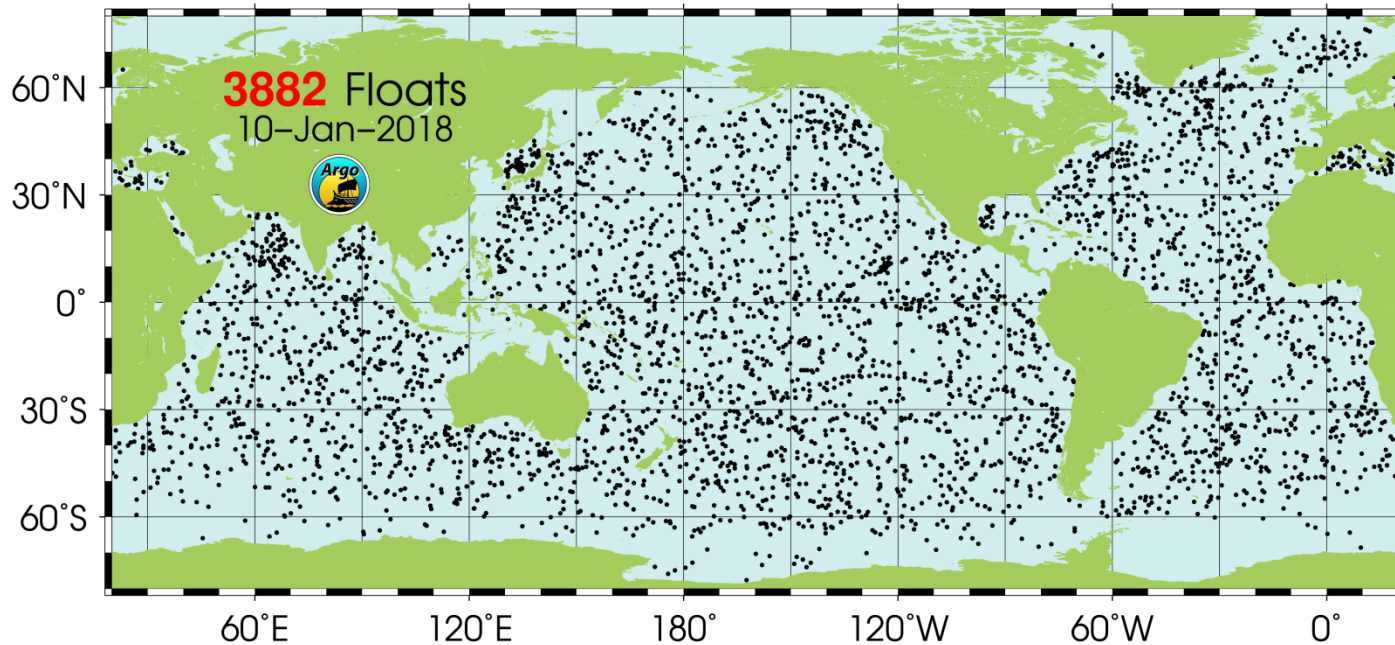
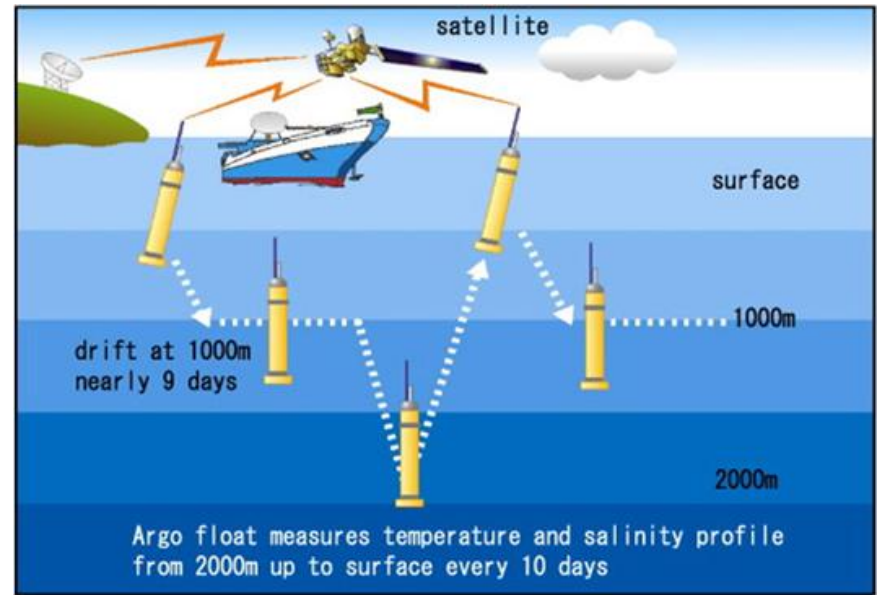
Ignored in the “External Forcing” Paradigm of Climate Change: “Internal Forcing”* Causing NATURAL Climate Change

Humanity lives in a relatively thin zone of warmth between the cold upper atmosphere and the cold depths of the global ocean (38-39 deg. F average temperature)...any change in ocean circulation can cause warming (or cooling)



**FACT: Ocean Heat Content has been increasing:
Best “Barometer” of Global Energy Imbalance**

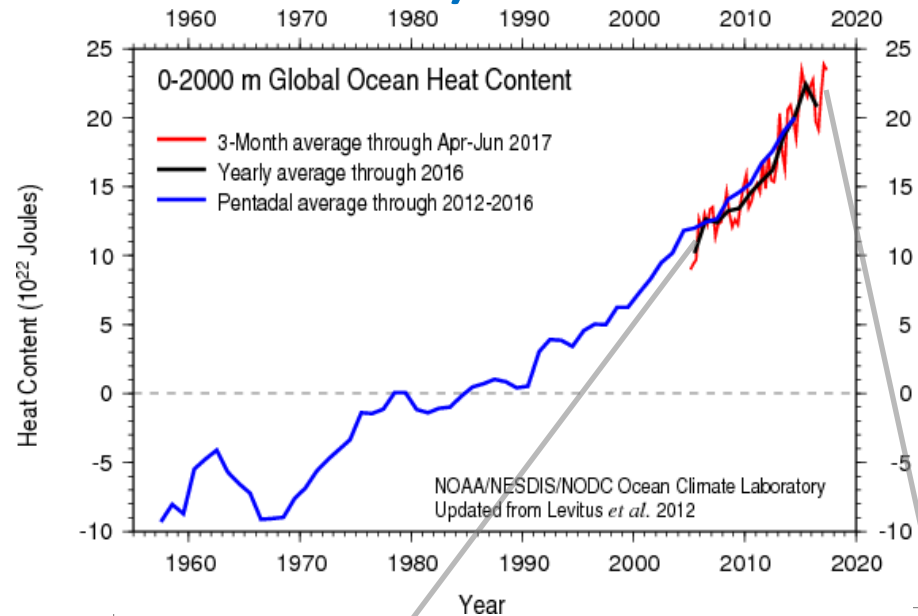
- Scattered measurements of 0-700m layer from the 1950s to 2000
- Good global coverage with Argo floats since about 2005, to a depth of 2,000 m



Recent Warming: Ocean Heat Content (Climate Drama Exhibit #1)

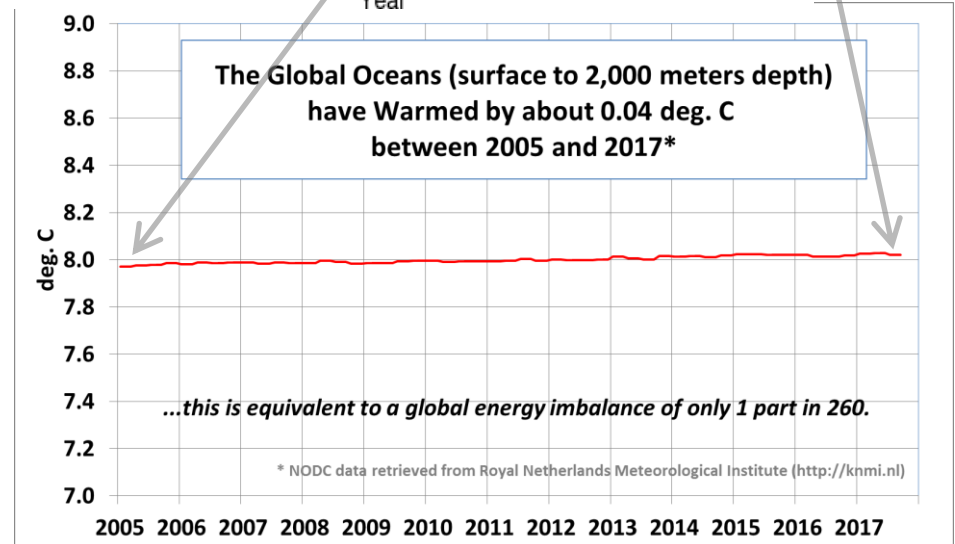
*Since 2005, the deep oceans
have heated by 10^{23} Joules! (OMG)*

This graph =>
came from..



...these
measurements =>

*Since 2005, the deep oceans
have warmed by 0.04 deg. C (...yawn)*

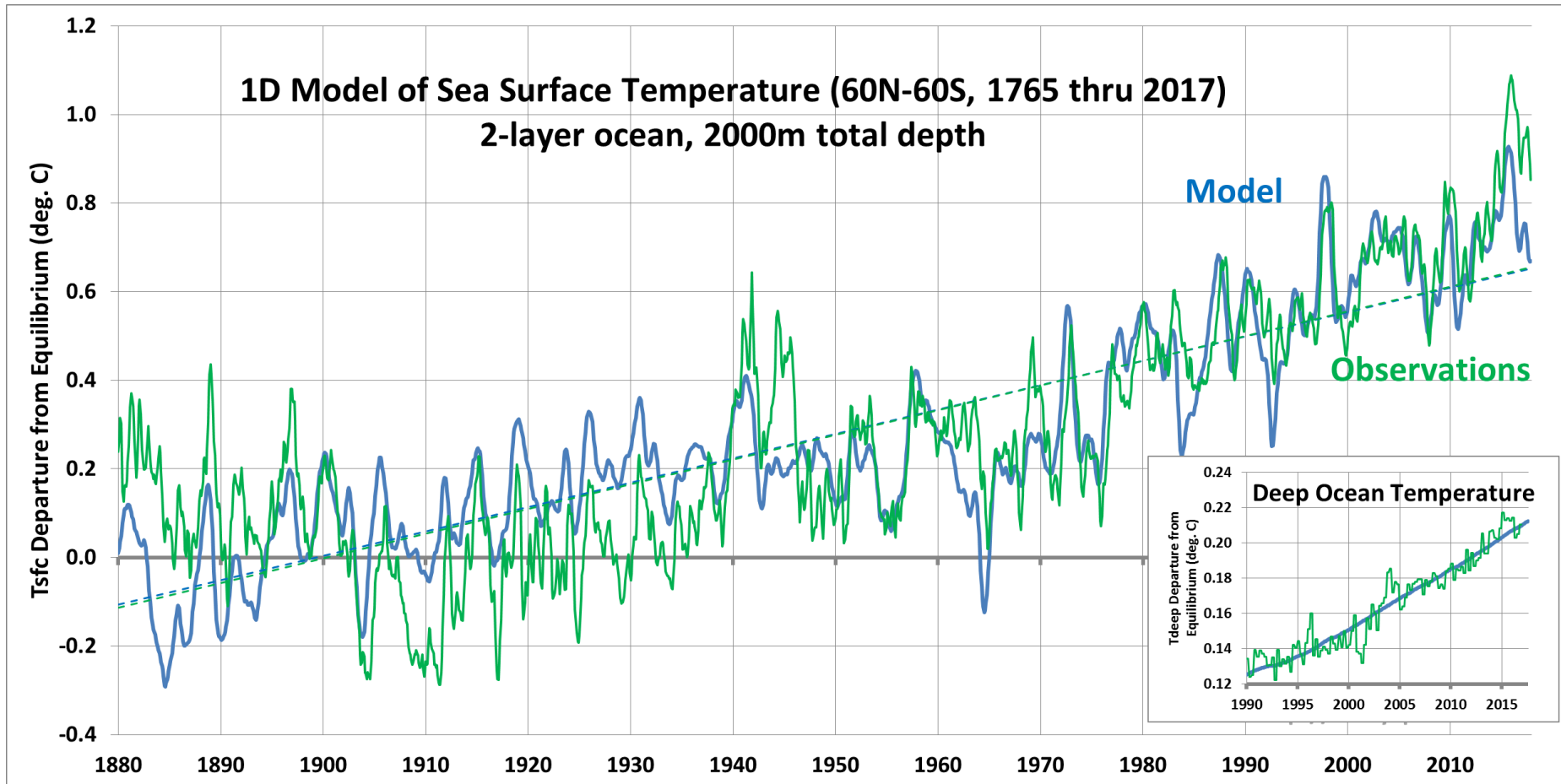


Factoid: 4 years of global ocean warming = same amount of energy released as in the 2004 Indian Ocean earthquake (which lasted 8-10 minutes).

Some of my Research into Natural Influences on Climate Change:

A 2-layer model of ocean temperature change which includes the observed history of El Nino, La Nina, and traditional “radiative forcings”, can closely mimic observed temperature variations, and with an equilibrium climate sensitivity of only 1.5 deg. C (IPCC models average ECS=3.4 deg. C)

(The goal of energy policy changes is to reduce future warming to 1.5 – 2.0 deg. C)



The energy imbalance involved in climate change is **SMALL**, generally less than 1% of average absorbed sunlight and emitted infrared radiation.

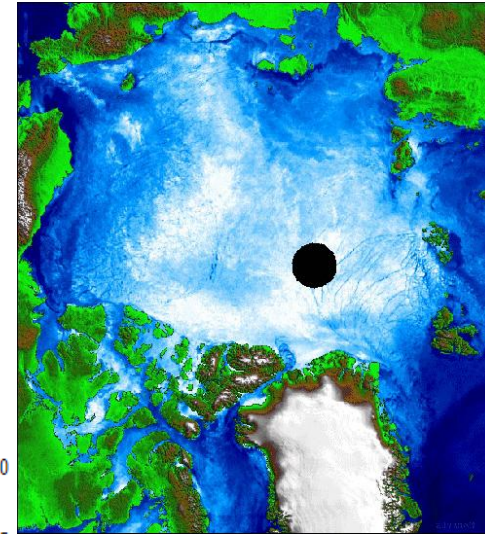
FACT: The Energy Imbalance necessary to explain the Ocean Heat Content increase “observed” since the 1950s is *only 1 part in 600, or about 0.39 Watt per sq. meter* (Levitus et al., 2012).

FACT: Our best satellite measurements of the radiative balance of the Earth are accurate to only 5-10 W per sq. m. (Loeb et al.) Thus, we cannot actually measure the <1 W CO₂-caused radiative energy imbalance. It is inferred.

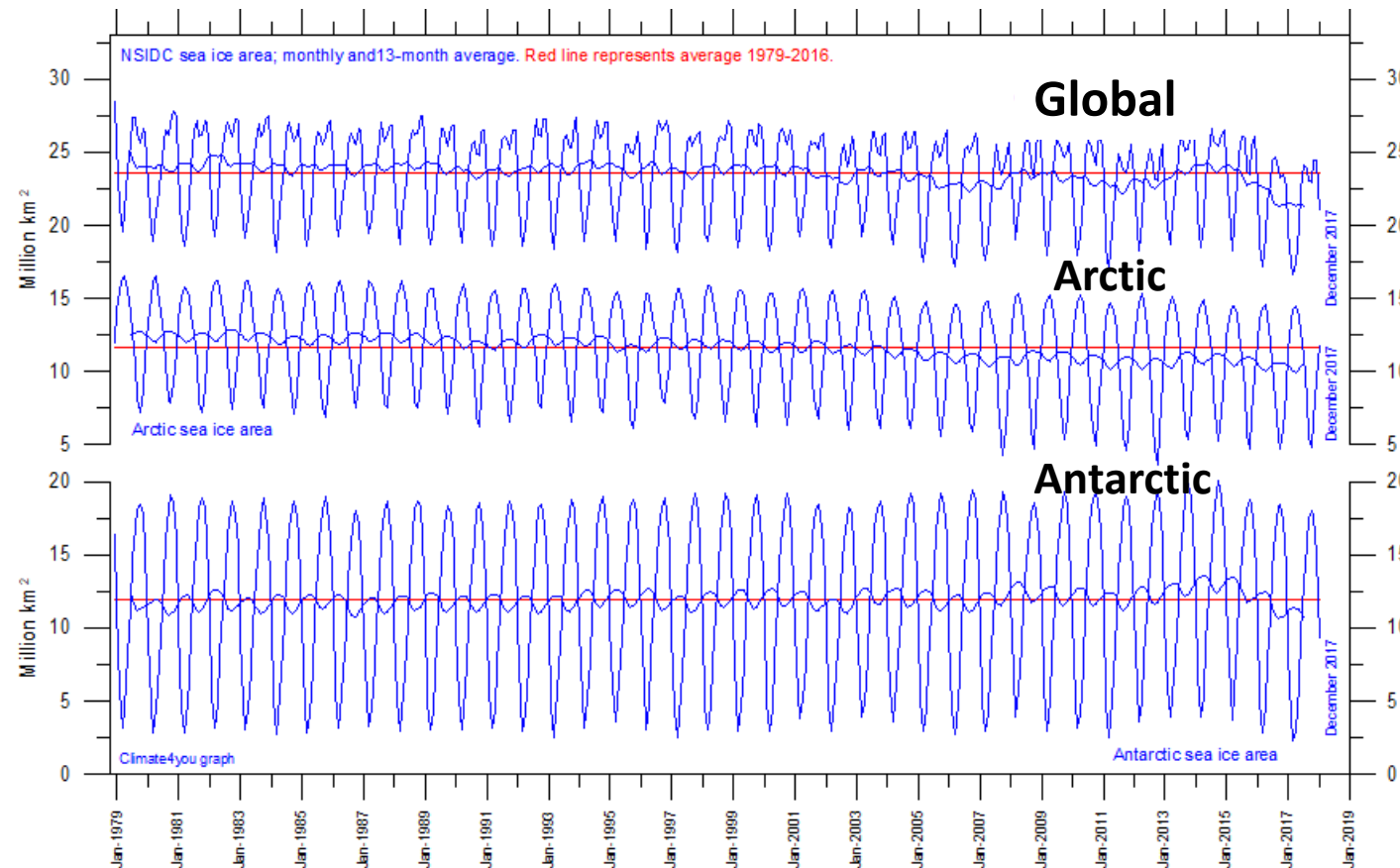
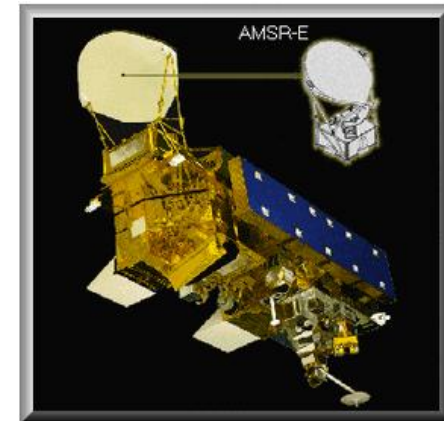
FACT: Our measurements and knowledge of the physical processes that control the Earth’s energy balance are nowhere near good enough to explain the inferred 1 part in 600 imbalance. It took many years of “tweaking” to get climate models to that level of stability (more later).

Arctic Sea Ice Decline since 1979

- Arctic has warmed faster than anywhere
- Sea ice monitored with satellites since 1979 (poor coverage before then)
- Increasing summer melt consistent with enhanced warming over N. Hemisphere landmass (and then some! Ice-albedo feedback?)
- Sea ice decline not happening in the Antarctic
- NOT KNOWN if previous Arctic warming 1920s-1930s had the same effect, Arctic is naturally influenced by changes in “venting” of the polar region by Pacific and Atlantic multi-decadal oscillations (*Tokinaga et al., 2017 PNAS*)



NASA AMSR-E
Arctic Sea Ice



...but it's happened before (1920s-1930s)

“...in late years a most interesting phenomenon has been observed – a **warming of the Arctic**, as evidence by a gradual and universal decrease in ice abundance. The main evidence of this general warming of the Arctic are:

- **“Retreating of glaciers** and “melting away” of islands... Ahlman terms the rapid retreating of the Spitzbergen glaciers “catastrophic”.
- **“Rise of air temperature.** (Over the last 20 years) the average temperature of the winter months has steadily increased...
- **“Rise in temperature of Atlantic water which enters the Arctic Basin...**the temperature of surface water and of Gulf Stream water has steadily risen...
- **“Decrease in ice abundance....**15% to 20% (over 20 years)...
- **“Change in cyclone routes.** There is no doubt that the increase in air temperatures, increase in Atlantic water temperatures, intensification of ice drift, etc., are closely connected with an intensification of atmospheric circulation, and in particular with a change in cyclonic activity at high latitudes.
- **“Biological signs of warming of the Arctic.** ...fish have ranged further and further to the north...cod in large quantities have appeared along the shores of Spitzbergen and Novaya Zemlya...also mackerel, dolphin where formerly were not found...during recent years fishing has gradually shifted into the Arctic waters, and this unquestionably must be ascribed in considerable degree to the warming of these waters....
- **“Ship navigation.** ...a number of ship voyages (were made) which could hardly have been accomplished in the preceding cold period.
- **“Still more remarkable is the fact that the warming of the Arctic is not confined to any particular region.”**

- From N.N. Zubov's classic reference book *Arctic Ice* (late 1930s)

Warming In the Arctic: Evidence of Natural Climate Change

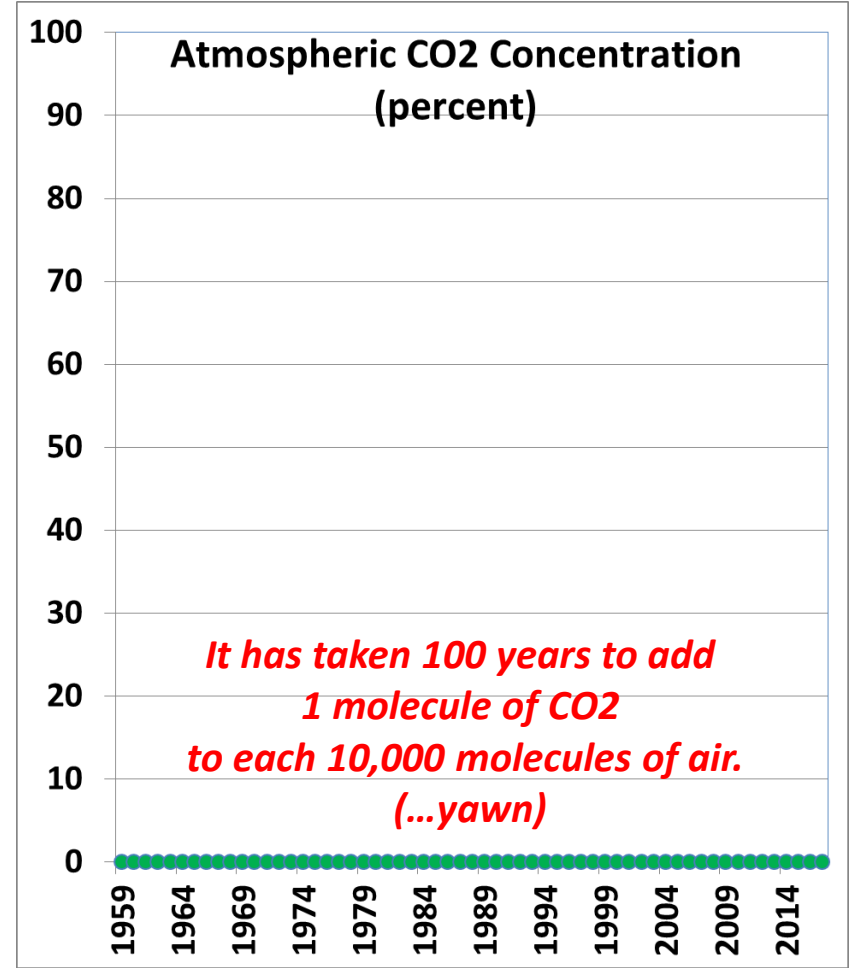
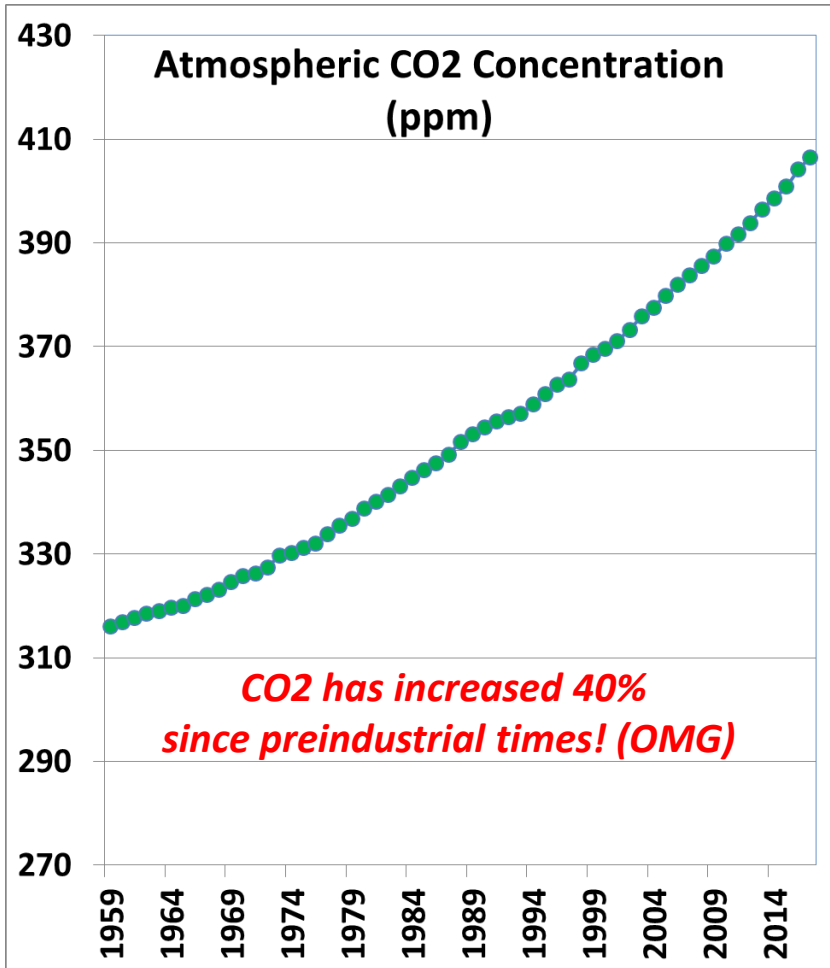
Tree stumps (dated to be 1,000-2,000 years old) at the terminus of receding Mendenhall Glacier (Alaska) reveal that glaciers change naturally (consistent with natural sea level changes and global temperature changes?)

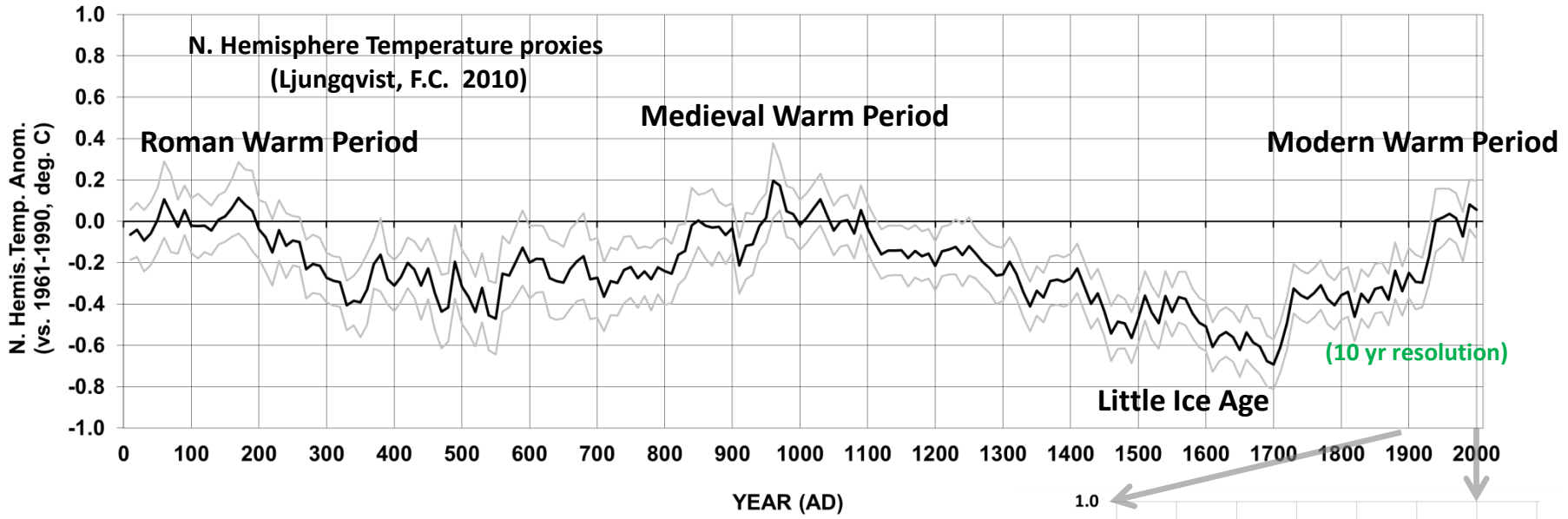


Yes, Atmospheric CO2 Has Been Increasing

- CO2 is increasing at only 50% of rate of human emissions (half absorbed by nature).
- CO2 has a small concentration (currently 4 parts CO2 per 10,000 of air).
- The CO2 “greenhouse gas” effect has sound theoretical and laboratory basis.
- The GHG effect of other gases (methane, nitrous oxide, other gasses) is relatively small

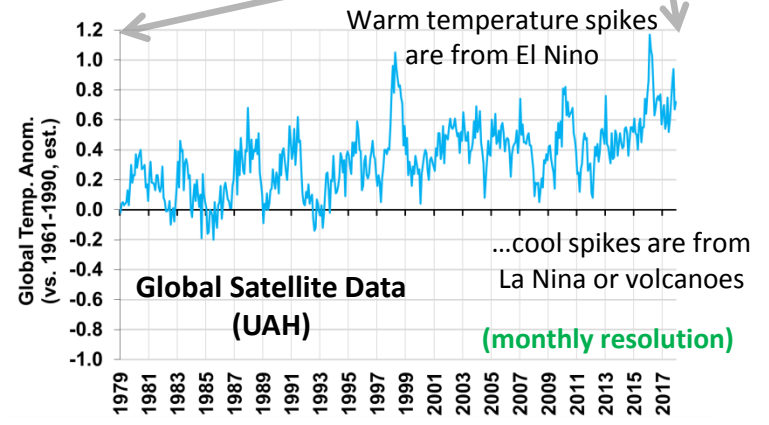
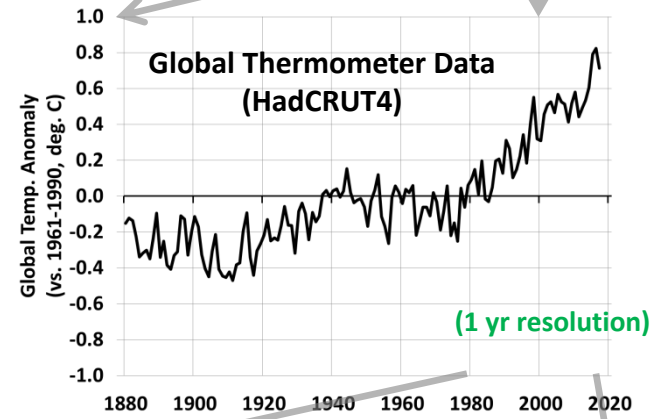
Climate Drama Exhibit #2





Is recent warming unusual in the context of the last 2,000 years?

We don't know, because our temperature measurements prior to the 1900s are physically indirect and geographically incomplete.



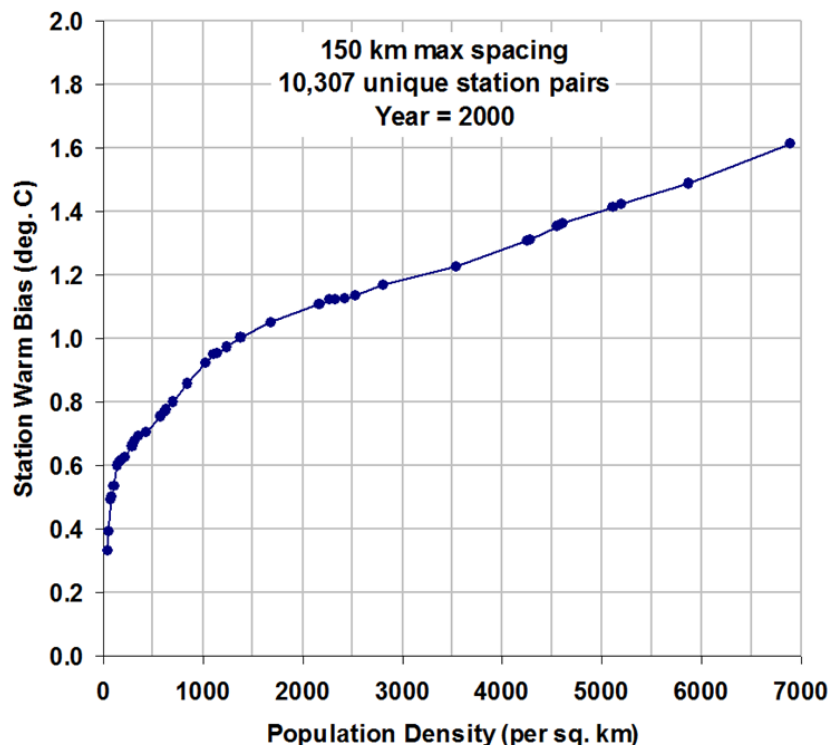
Global Temperature Measurement Uncertainties

- **Thermometer** measurements too geographically sparse to be useful before ~1880
 - Temperature “proxies” required before that time, unknown accuracy (Mann “Hockey Stick” widely criticized)
 - Sparseness less of a problem when many years averaged together
 - Urban Heat Island (UHI) effect causes spurious warming
 - “Homogenization” adjustments by NOAA are suspect (rural sites adjusted to match urban, rather than vice versa?)
- **Weather Balloons** (radiosondes) even more sparse; only available since 1950s
- **Satellites** cover the Earth, but only since 1979
- **ALL measurements** affected by sensor changes, need adjustments thru time
 - thermometers (e.g. mercury-in-glass transition to thermistors)
 - weather balloons (various manufacturers, sensor design changes)
 - satellites (sensor design changes)

Are Global Surface Temperature Trends Exaggerated?

...concerns over the Urban Heat Island effect...

Nearby pairs of global surface stations with different population densities clearly show the warming effect of human development on temperatures (Spencer, 2010, unpublished).

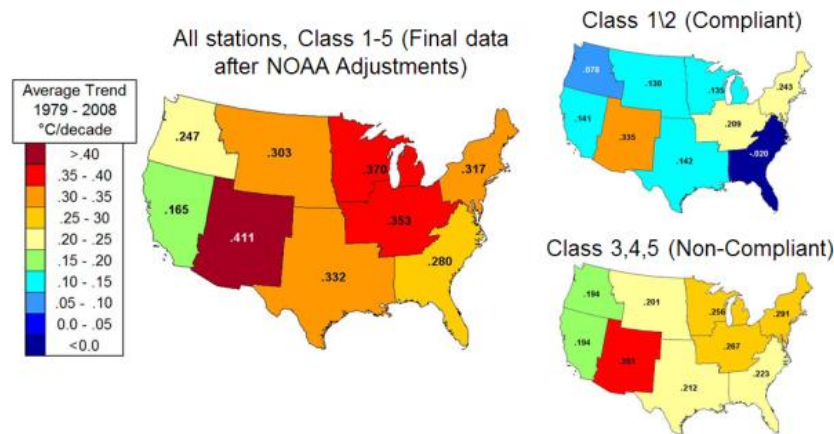


Using only “pristine” stations reduces U.S. Average warming by about 50% compared to official NOAA “adjusted” temperatures (Watts, Jones, McIntyre, Christy, 2012, unpublished)

Comparison

All Rated Stations in the CONUS

What the compliant thermometers (Class 1&2) say: **+ .155°C/decade**
What the non-compliant thermometers (Class 3,4,5) say: **+ .248°C/decade**
What the NOAA final adjusted data says: **+ .309°C/decade**

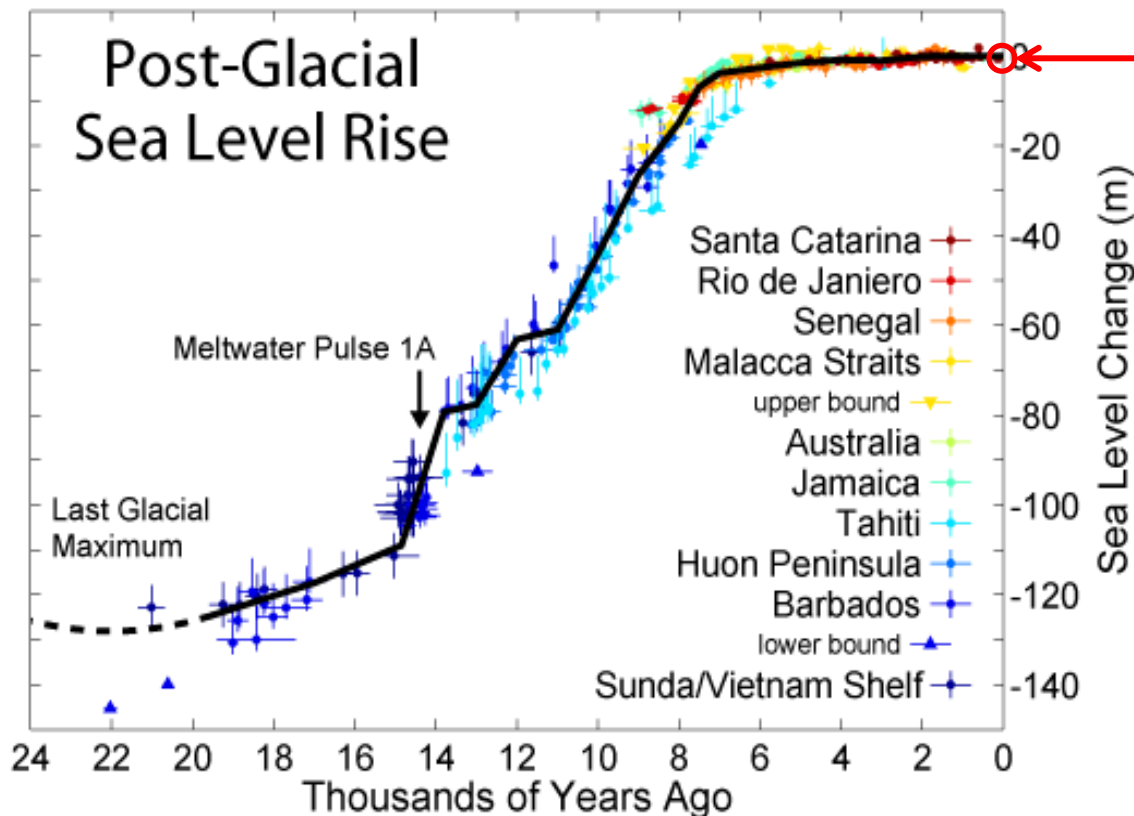


Sea Level Rise

“Sea level” has different but related meanings;
Humans are most interested in this one:

The level of the sea where it touches the land at any given point.

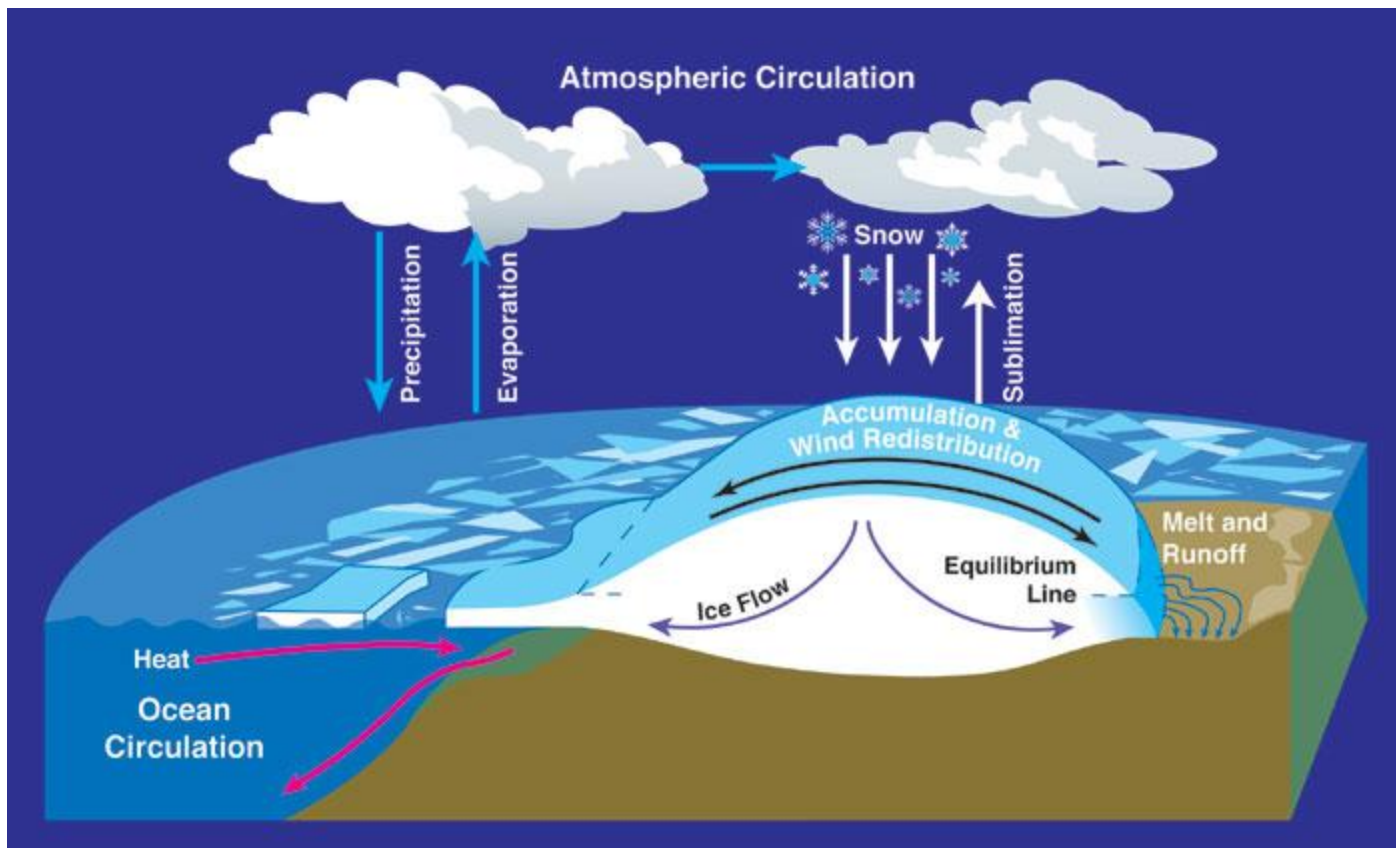
Global sea level has risen about 130 m (426 ft.) in the last 24,000 years due to melting of glaciers that existed during the Last Ice Age



The period we are interested in: +/- ~200 yrs from today

Today's **NATURAL** variations in **GLOBAL** sea level are driven by:

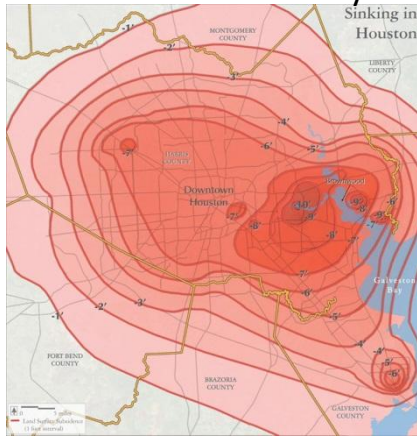
- Changes in land storage of precipitation (esp. snow on ice sheets, glaciers)
- Natural warming of the ocean since the Little Ice Age (thermal expansion of water)
- ICE SHEETS (Greenland and Antarctica) are the big wildcards
 - Warming can cause decreasing (or even increasing) ice sheet mass balance
 - Isostatic land “rebound” as weight of glaciers is removed



..and increases in LOCAL sea level are **ADDITIONALLY** affected by:

Land Subsidence

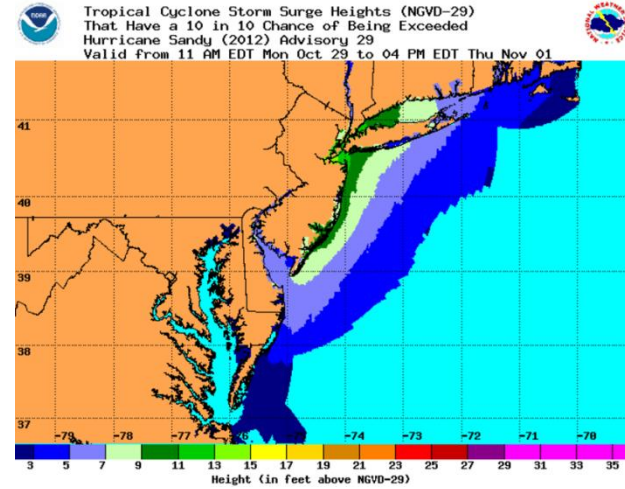
Houston, TX: Up to *10 ft* sinking since 1920 due to groundwater withdrawal, increases flood risk because it ruins the efficiency of city drainage systems



Other examples:
Miami Beach,
Norfolk, VA,
New Orleans.

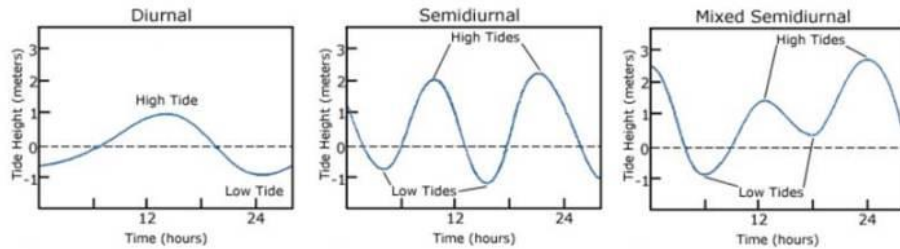
Wind-Driven Storm Surge

e.g. Hurricane Sandy, California Coastal Erosion during winter



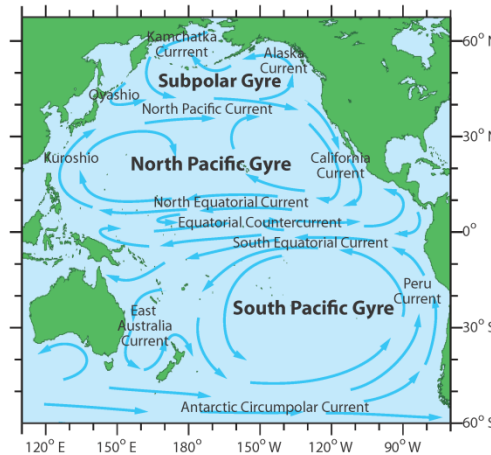
Daily Tides along Global Coastlines

Very location-dependent in terms of magnitude



Changes in Atmospheric Wind Patterns and Ocean Gyres

El Nino. La Nina. NAO. PDO, etc.



Center of gyres have sea level up to 1 m higher than edges of gyres

Tide Gauges and Sea Level Since 1850s

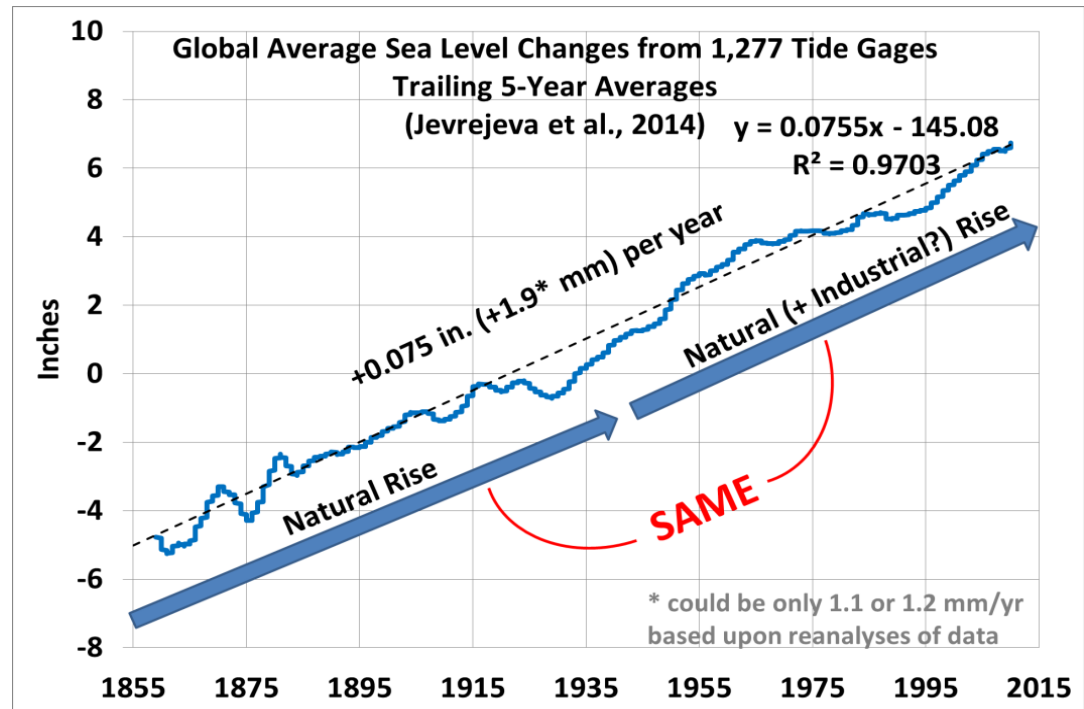
Sea Level has been rising before CO2 was a factor

“Although the global network of tide gauges comprises a poorly distributed sea level measurement system, it offers the only source of historical, precise, long-term sea level data.”

- U. of Colorado Sea Level Research Group

It would be difficult to convincingly argue that pre-1940 sea level rise was due to CO2, so how can one argue that sea level rise post-1940 was due to CO2? (Sea level rise should be accelerating)

“...climate models tend to systematically underestimate the observed sea level trends, particularly in the first half of the 20th Century.” Meyssignac et al., 2017 J. Climate)



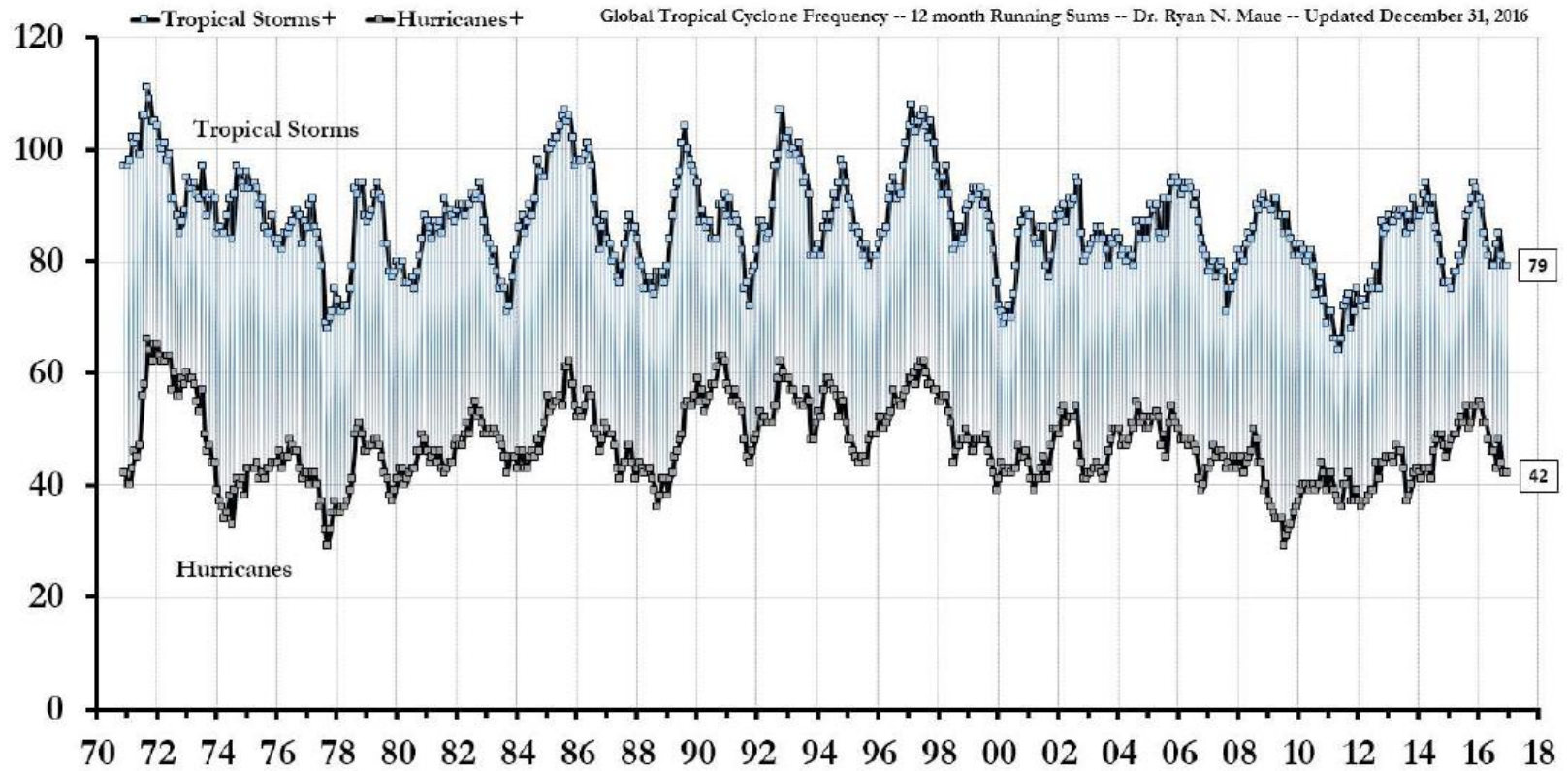
My Opinion on Sea Level Rise:

Vulnerability of coastal communities to damage from the ocean is dominated by non-GHG processes (natural sea level rise; wind-driven storm surges and wave activity; tidal flooding; land subsidence; natural erosion). Building within a few feet of sea level has always been risky, with or without human-caused climate change. The human-caused component is likely (1) small, and (2) difficult to quantitatively establish.



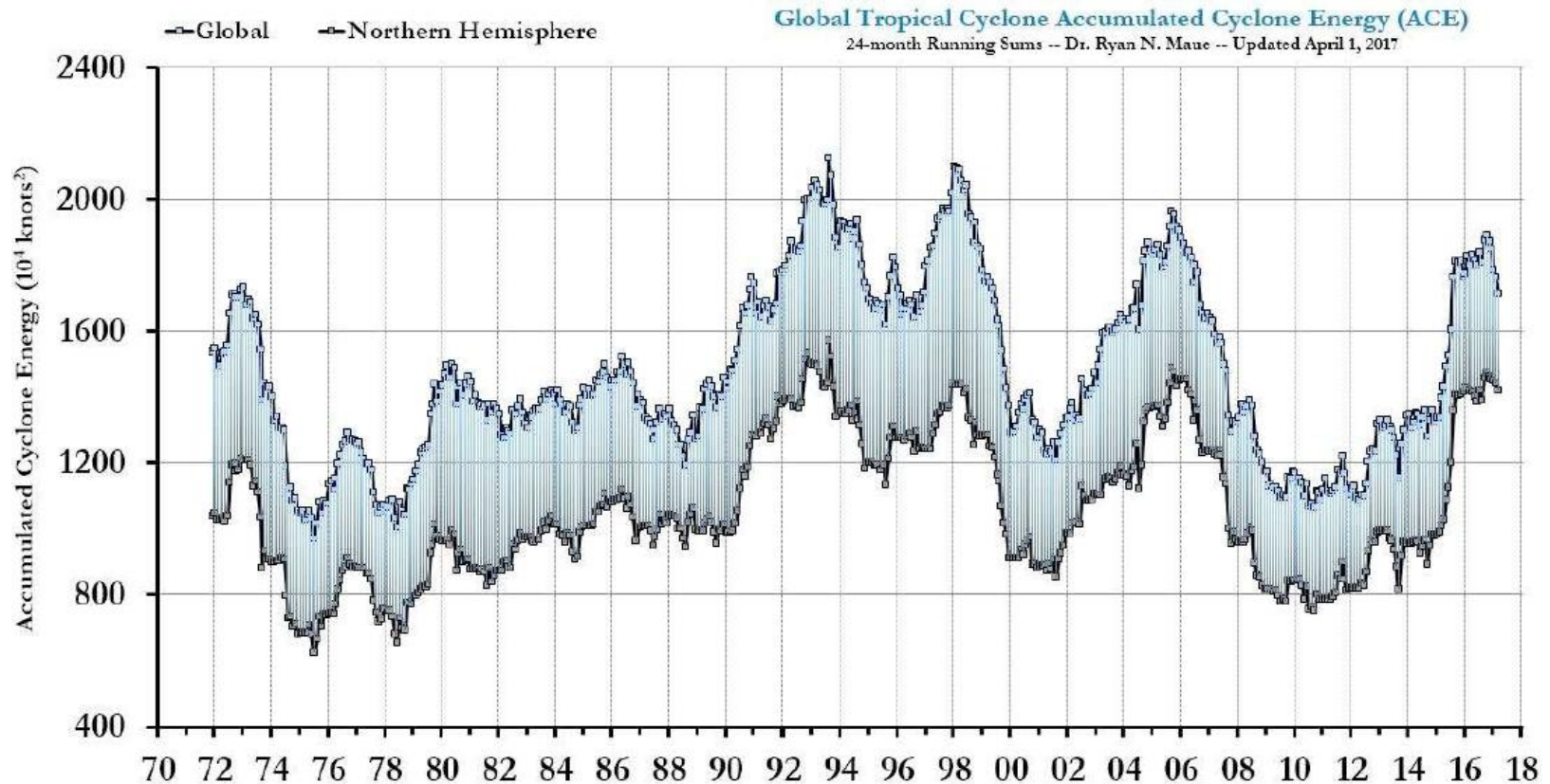
Hurricane Frequency is Not Increasing

Global Hurricanes (1971 to 2016)



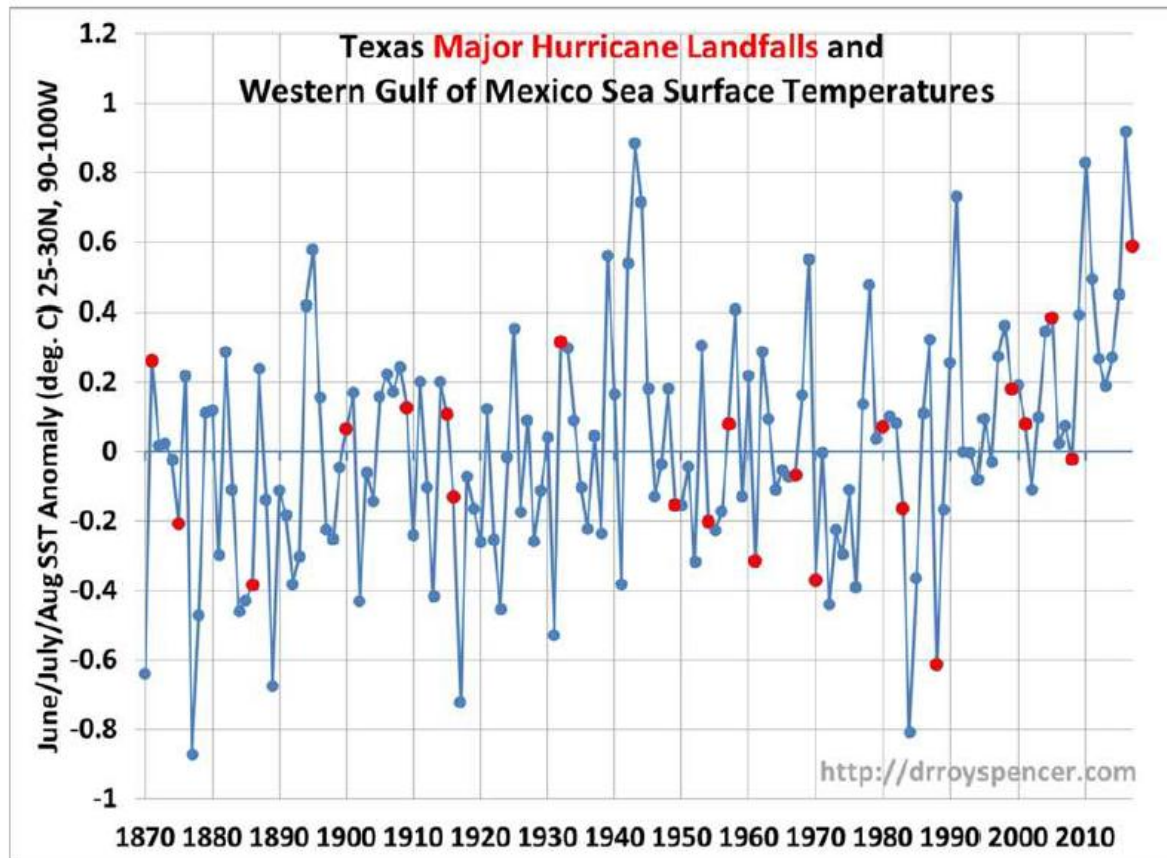
Hurricane Energy is Not Increasing

Global Hurricane Energy (1971 to 2017)

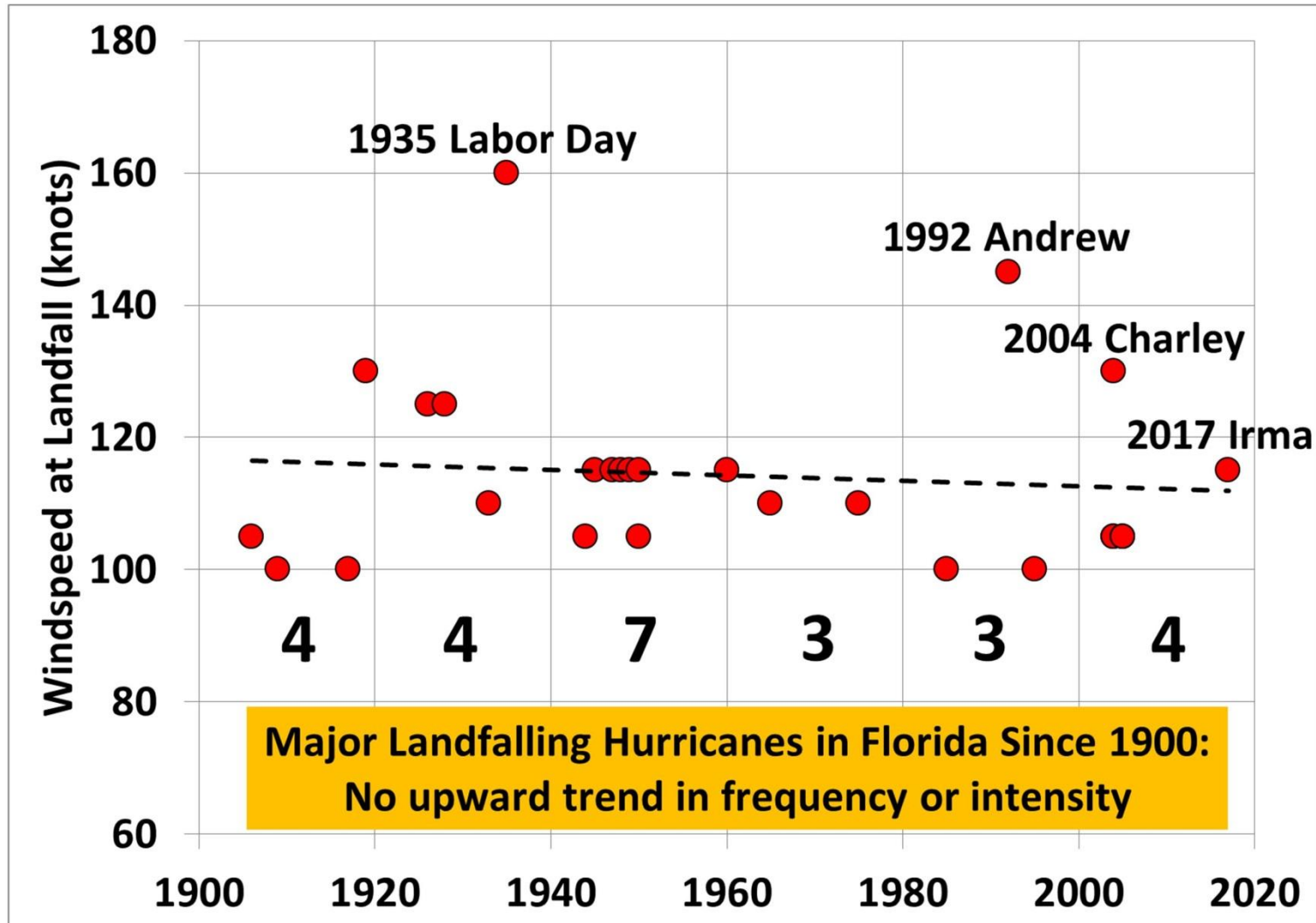


Hurricane Harvey Flooding was Due to the storm stalling by the coast

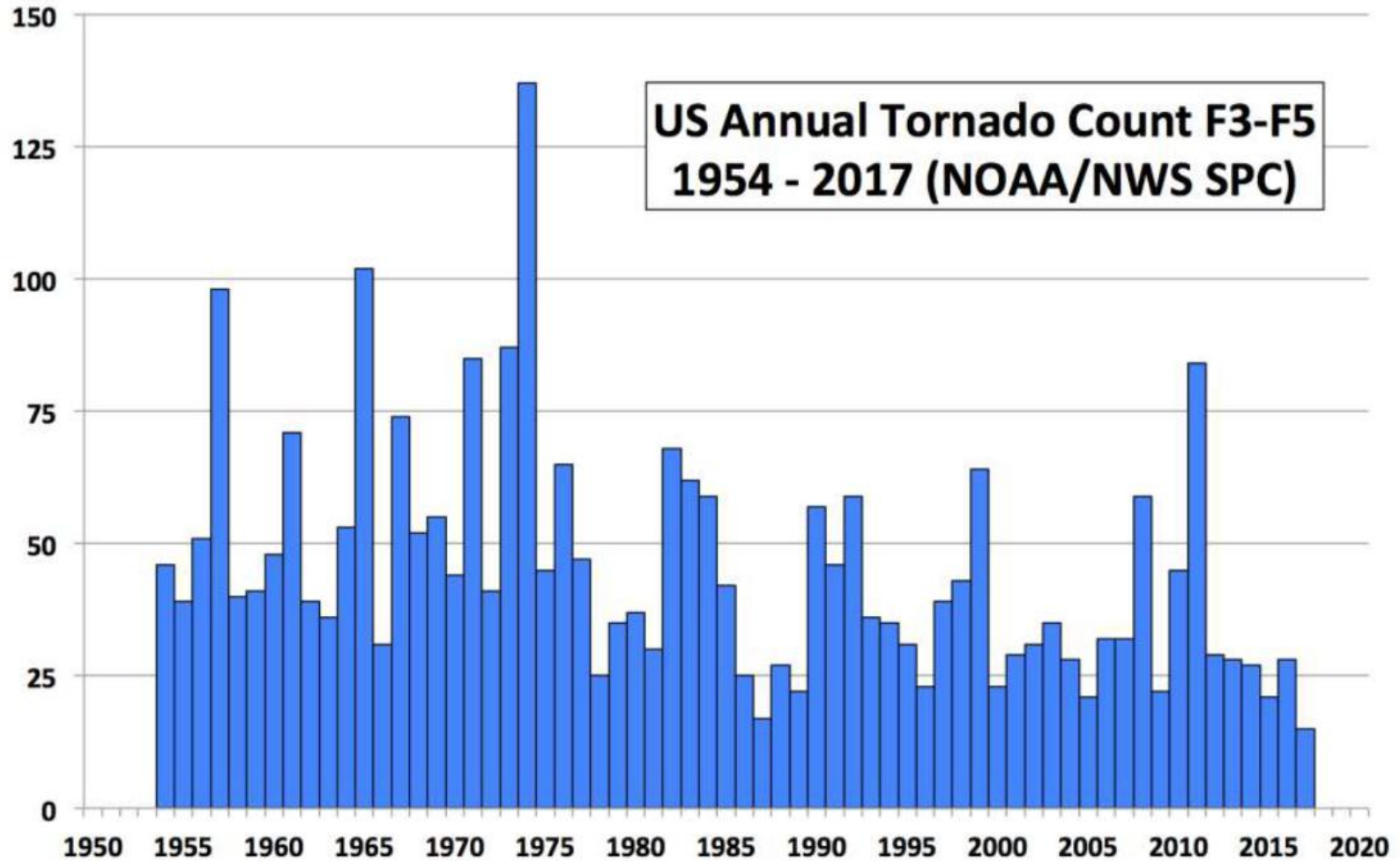
If we examine all of the **major hurricane strikes in Texas since 1870** and note the sea surface temperature departures from normal in the western Gulf of Mexico (Hadley Centre SST data accessed from climexp.knmi.nl), we see that *half of those major hurricanes occurred when water temperatures were below average, and half when water temperatures were above average.* (Spencer 2017)



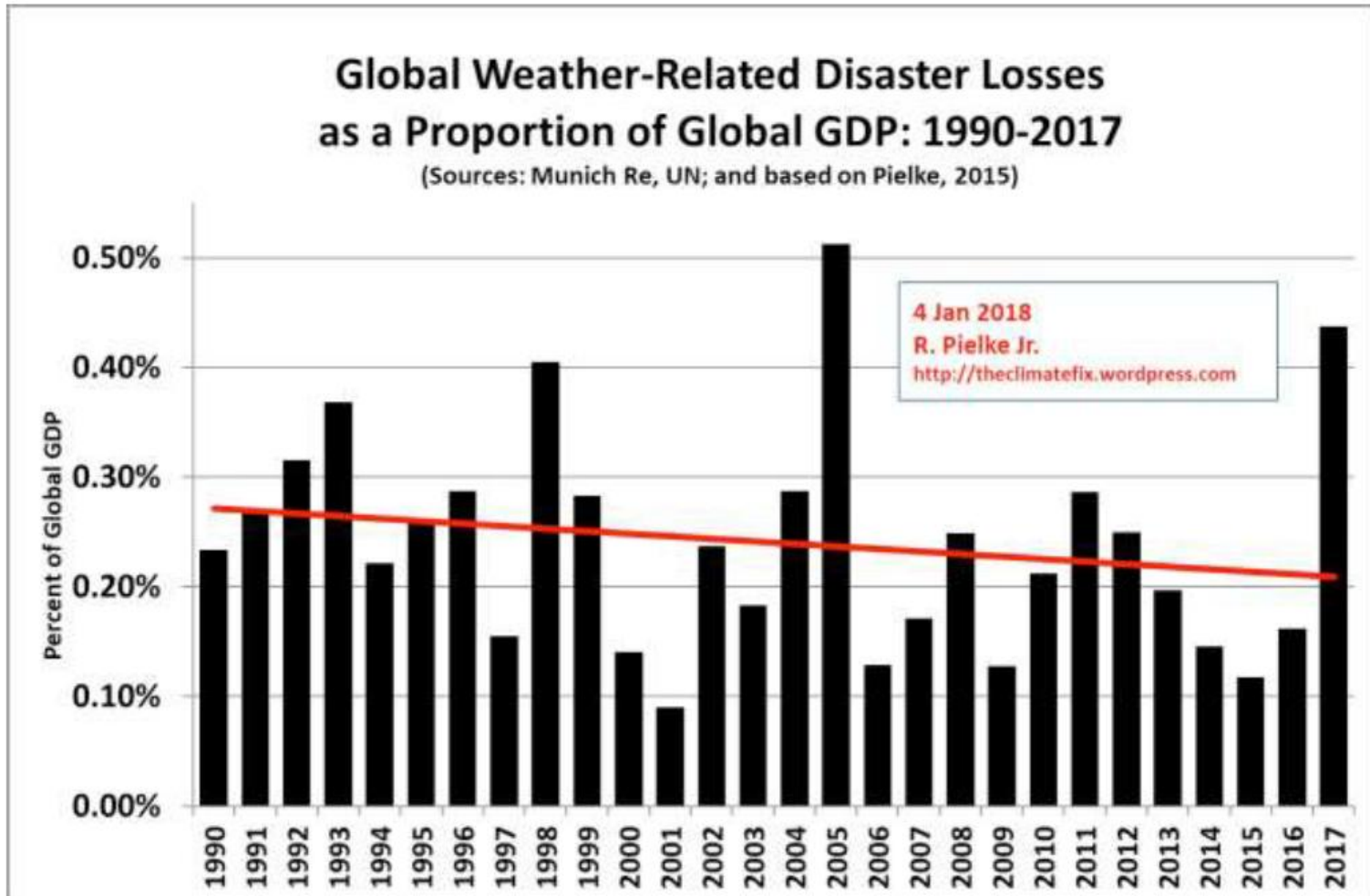
Even with 2017 Hurricane Irma, Florida Major Hurricane Strikes Not Trending Upward



Strong Tornado Frequency has decreased in recent decades



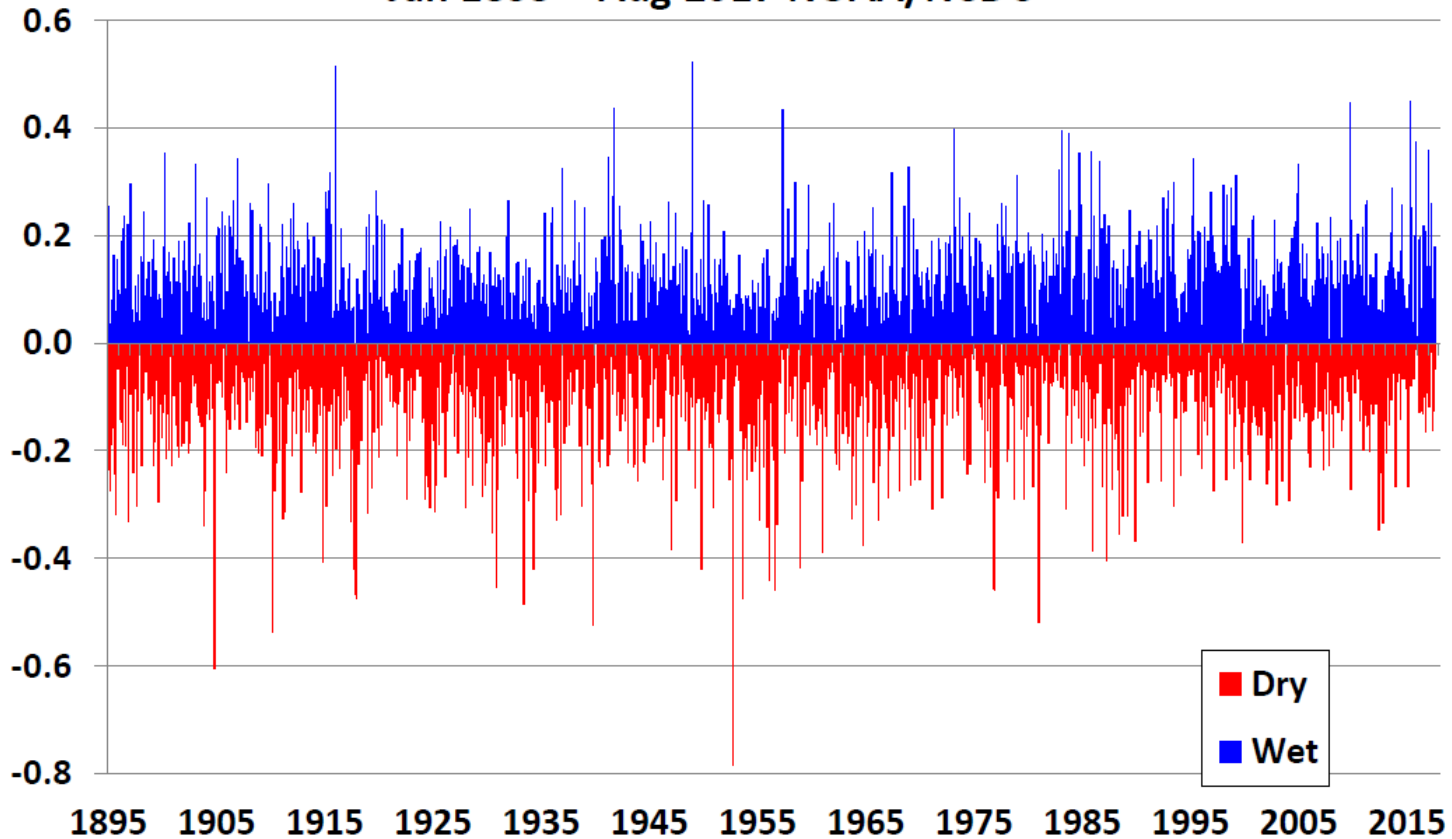
Weather-related damages have increased, but only because wealth and infrastructure have increased.



No long-term trends in U.S. floods or droughts...

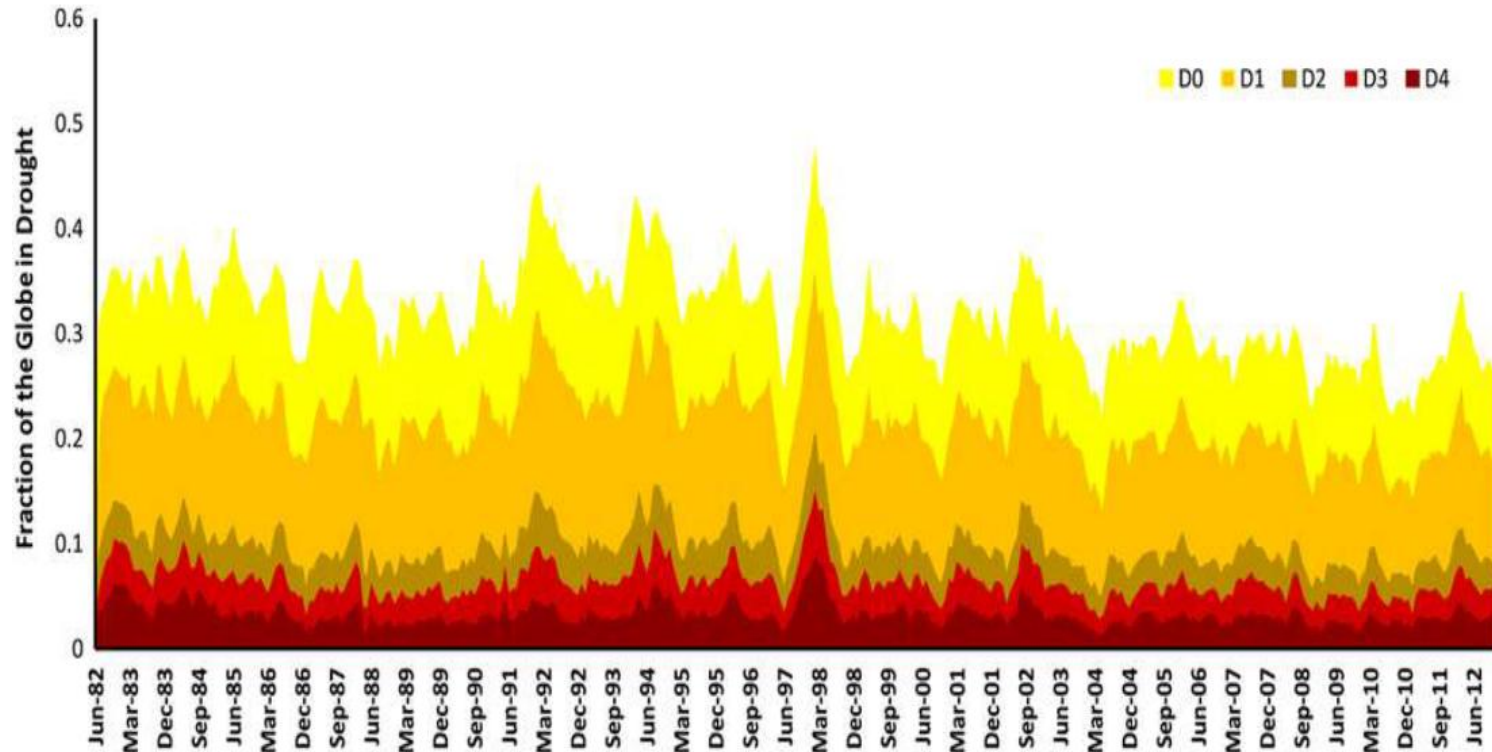
Monthly Fraction of US with Very Wet (floods) or Very Dry (drought) Conditions

Jan 1895 – Aug 2017 NOAA/NCDC



...the same is true of global droughts.

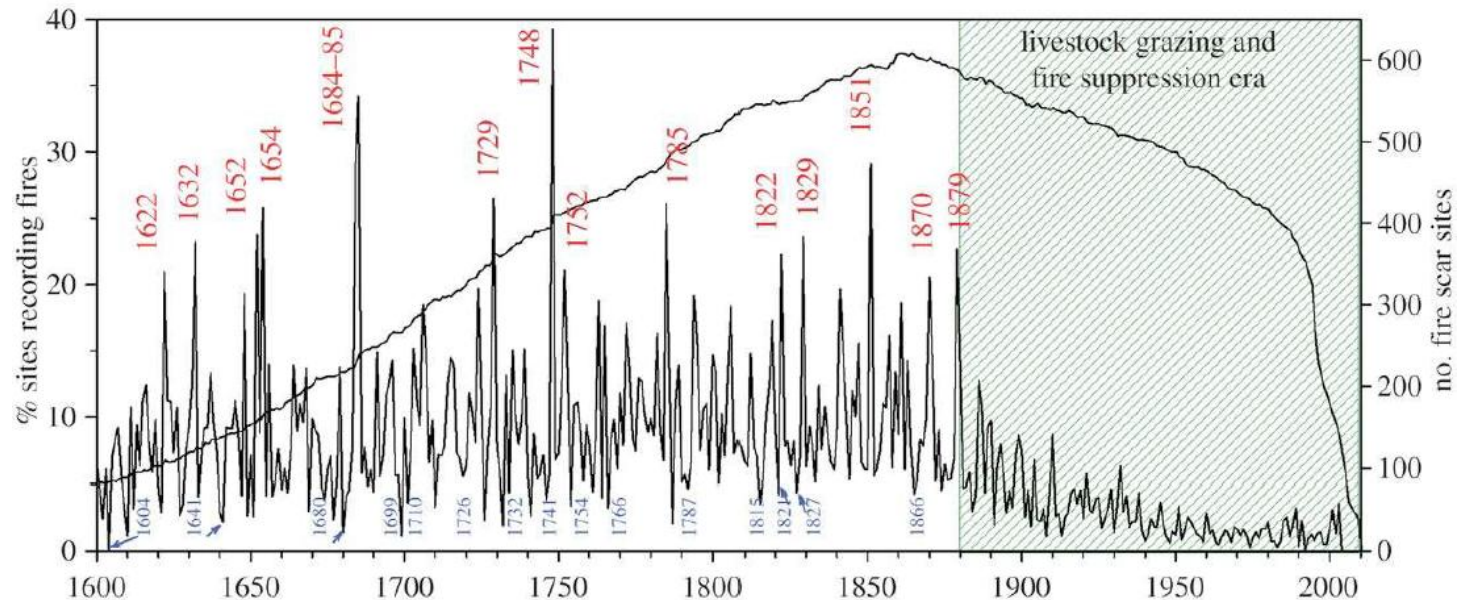
Global Drought Indices 1982-2012



Hao et al. 2014

North American wildfires were much more common before we began suppressing them.

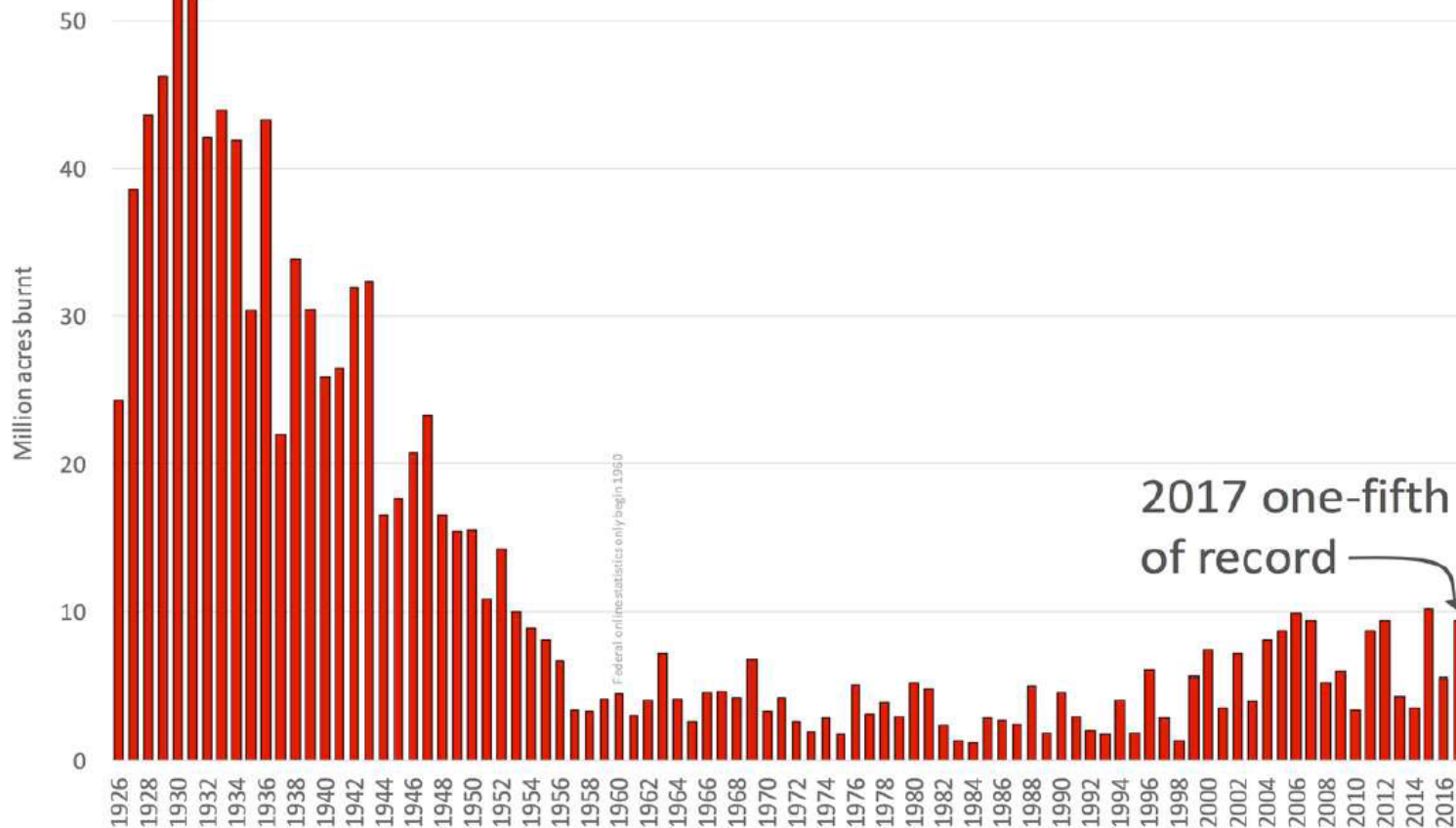
(and guess what happens when you let the “fuel” build up?)



Incidence in wildfires in North America 1600-2000

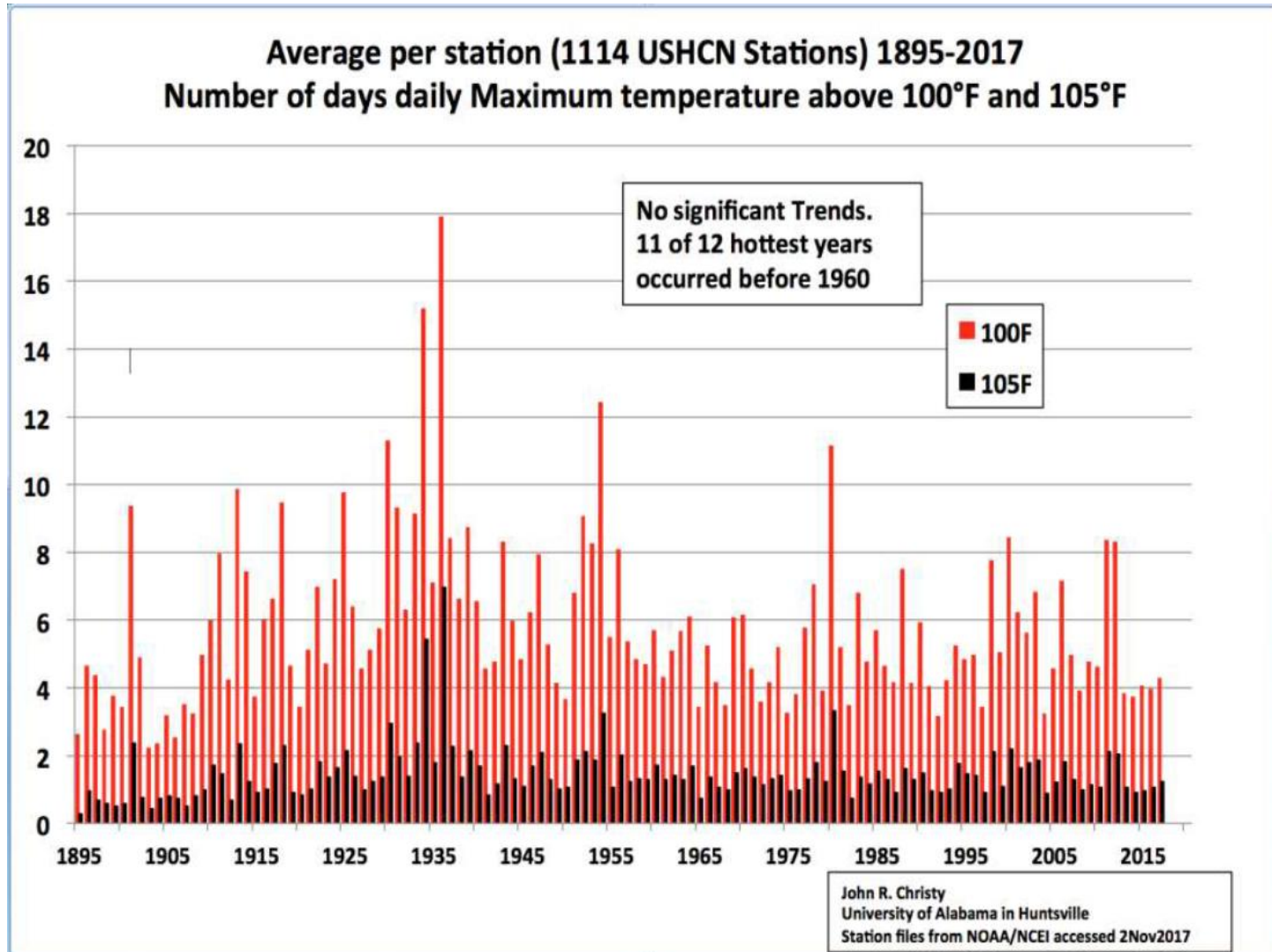
U.S. wildfire history is a reflection of land use practices, not climate change.

US Forest Area Burned 1926-2017



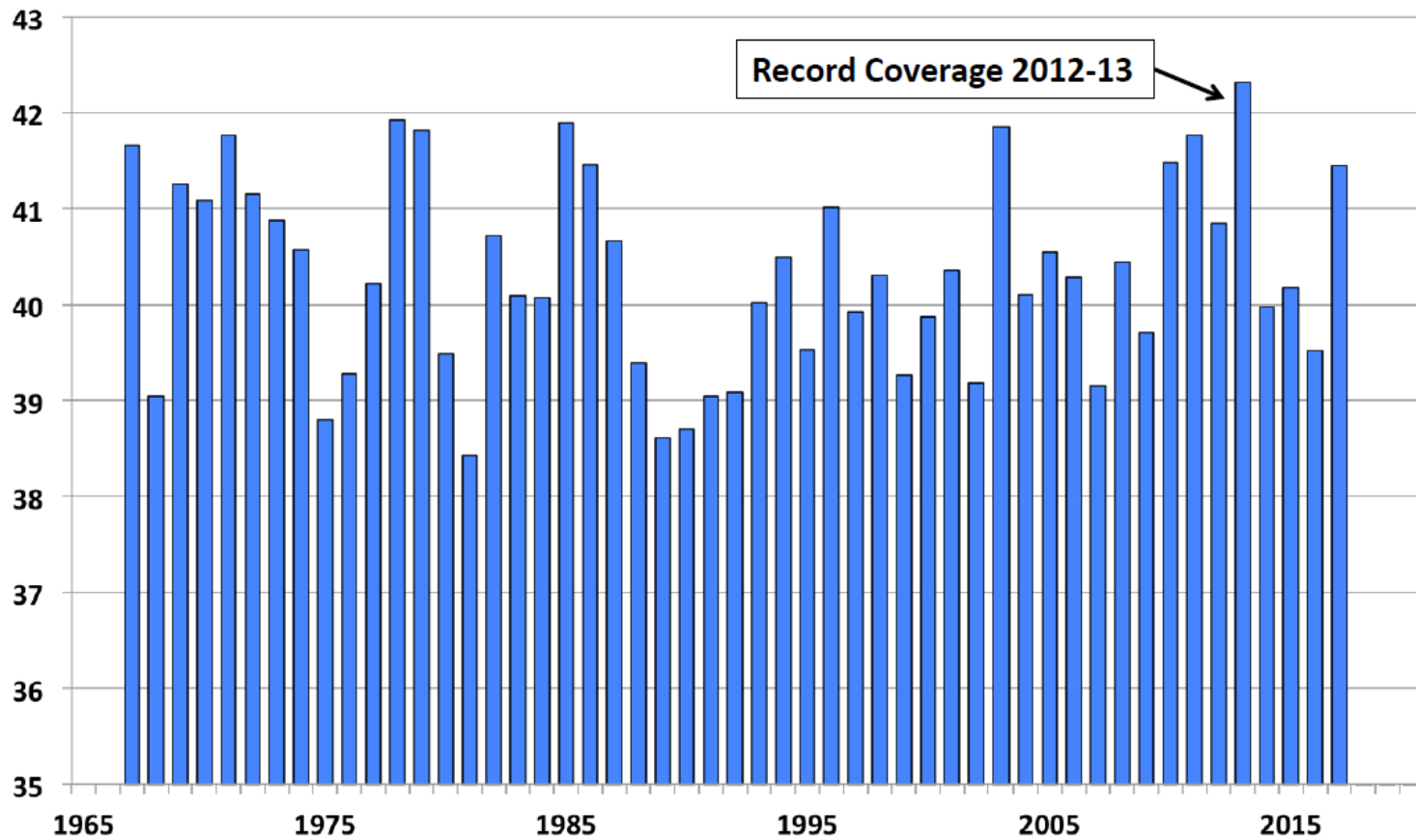
Source: National Interagency Fire Center, data 1960-2016, http://www.nifc.gov/fireinfo/fireinfo_state_totalFires.html, 2017 data until Oct 13, adjusted to similar fraction burnt area over past 9 years
Historical Statistics of the United States - Colonial Times to 1970 Vol 1, Series L48-55, 1926-70, perfect overlap for 1960-70. facebook.com/bjornlomborg

No increase in very hot days in the U.S.



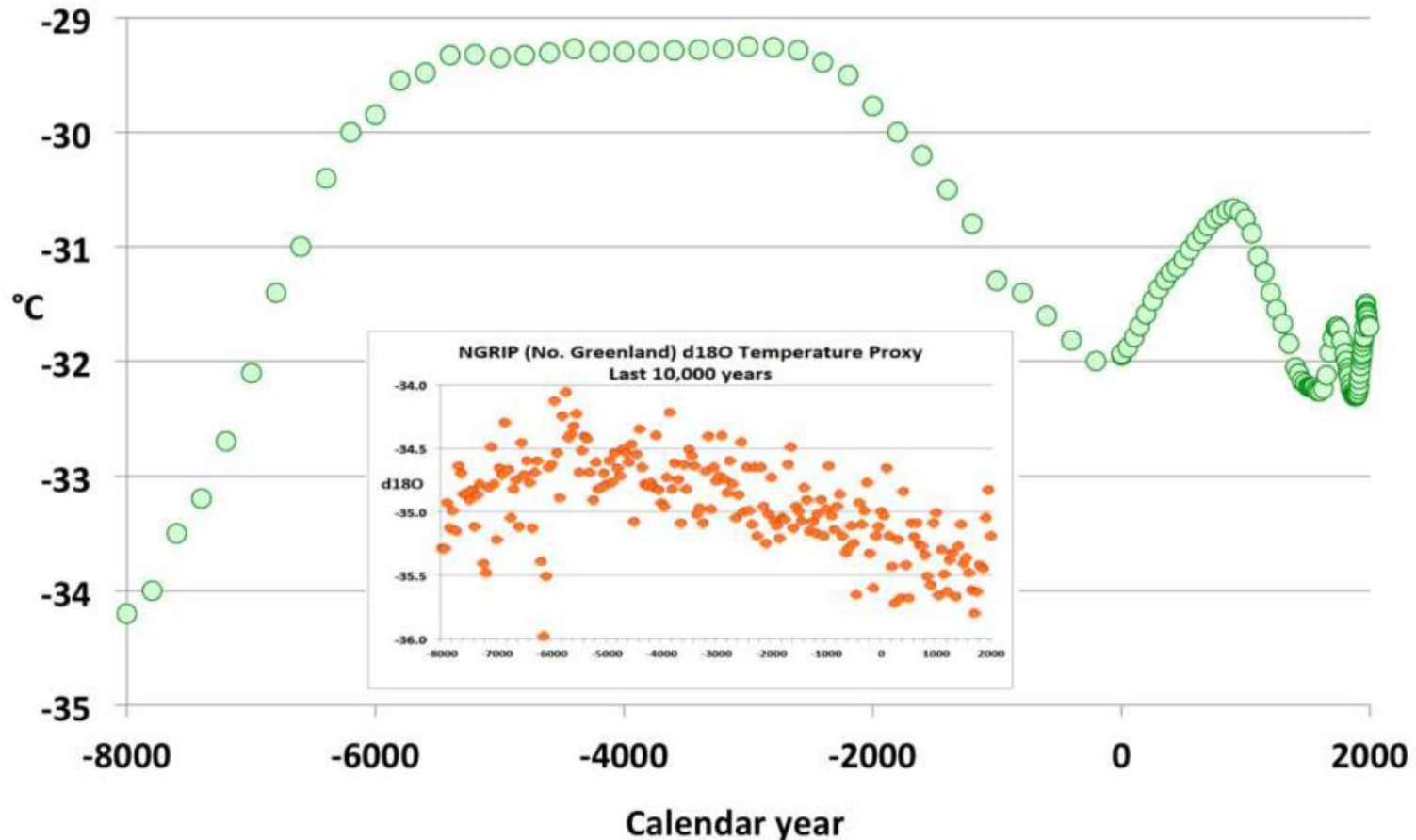
No trend in N. Hemisphere snow extent.

NH SNOW EXTENT Million KM²
Average November to April

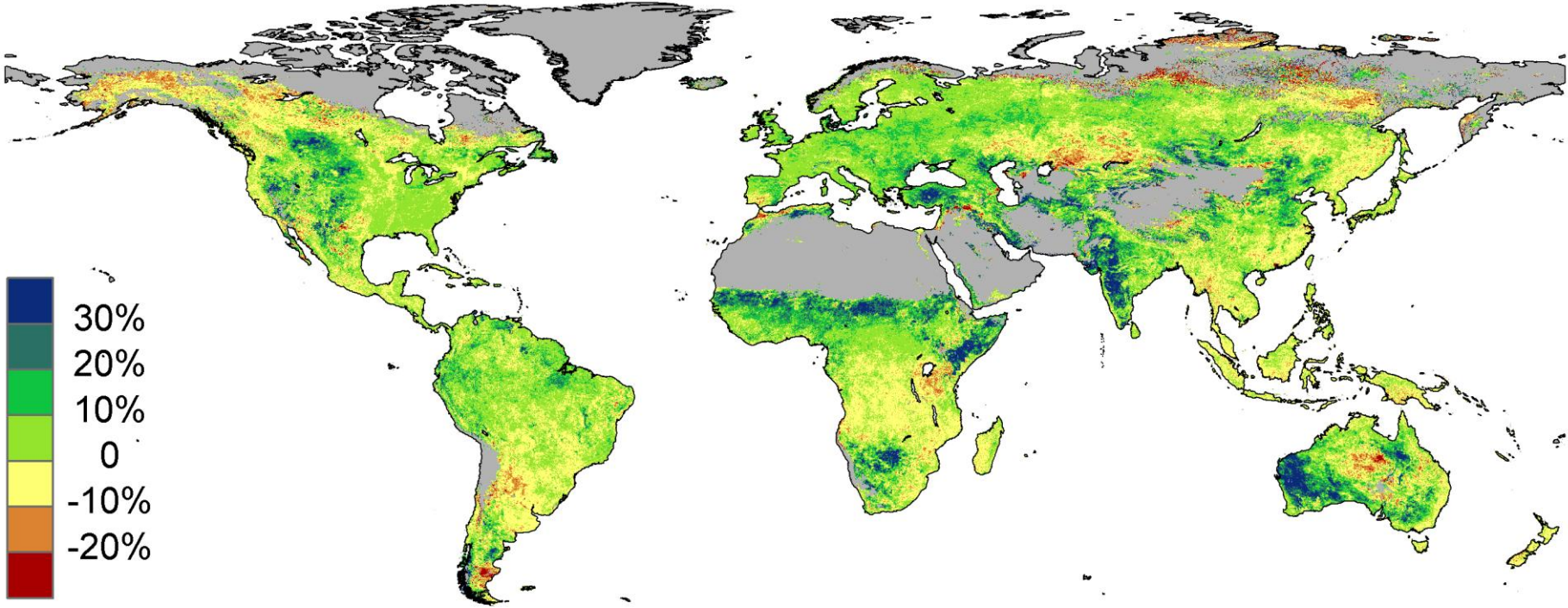


Greenland borehole temperatures suggest warmer climate 1,000 years ago (Medieval Warm Period) and 2,000 years ago (Roman Warm Period)

Greenland Air Temperature Last 10,000 Years
Borehole Reconstruction
Dahl-Jensen et al. 1998



Increasing CO2 has led to global greening as measured by satellites since the 1980s

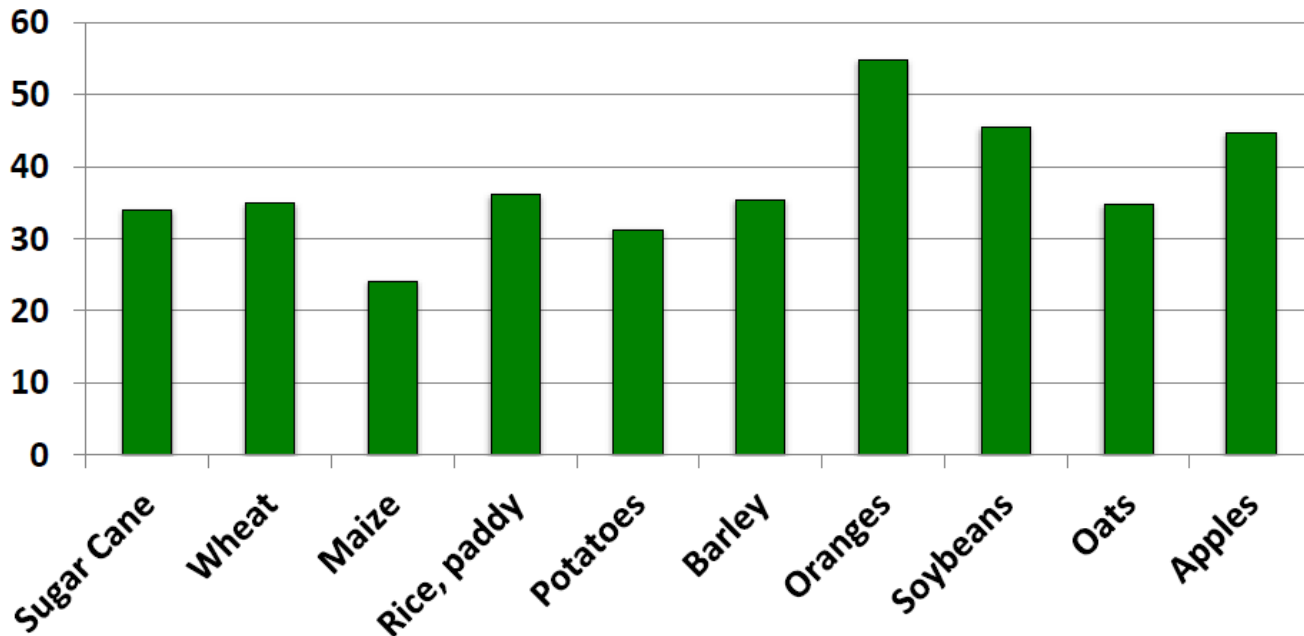


More atmospheric CO2 has been demonstrated to improve agriculture (est. \$3 trillion benefit since 1961)

Benefits? (Offsets Damage Functions)

Only one model explicitly includes fertilization (FUND) but underestimates it by 2-3 times

Percent Yield Increase 1961-2011 from extra CO2



Idso (2013) \$3.2 Trillion for this period
(\$9.8 Trillion for 2012-2050)

Lightning strikes might be fewer in a warmer world

(due to convective storms becoming slightly more “tropical”)

“Lightning strikes could drop by 15% as climate change causes global temperatures to soar by 5°C in 2100”

- Scientists looked at the movement of ice particles that form within clouds
- Electrical charges build up in these particles and are discharged during storms
- Increasing temperatures will make it harder for these ice crystals to form
- Thunder storms may become a particularly rare occurrence in the tropics

By [Joe Pinkstone For Mailonline](#)

Published: 12:50 EST, 12 February 2018 | Updated: 12:51 EST, 12 February 2018

Read more: <http://www.dailymail.co.uk/sciencetech/article-5381867/Global-warming-reduce-lightning-strikes.html#ixzz595HBHYpa>

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Summary: My Opinion

What is Relatively Certain About Human-Caused Climate Change? (issues which most “skeptical” scientists agree with the IPCC on)

1. CO₂ is a “greenhouse gas”, and so its increase should cause some lower atmospheric warming and, probably, some portion of observed sea level rise.
2. Based upon theory, there should be about 1 deg. C of direct warming that eventually results from a doubling of atmospheric CO₂. Uncertain feedbacks are required for estimates greater than 1 deg. C.

Where are the Disagreements? (pretty much everything else)

1. How much warming has actually occurred? (measurement problems)
2. How much of the warming is due to humans? (uncertain forcings & feedbacks)
3. Have storminess/drought/floods increased? (I don't think so)

The End