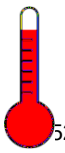
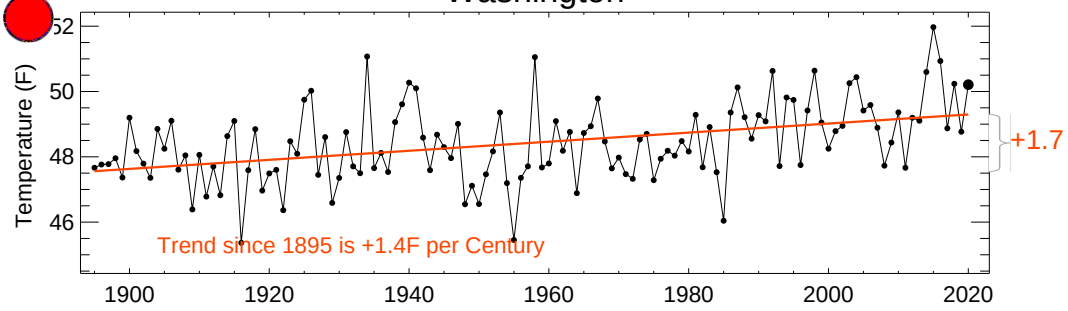
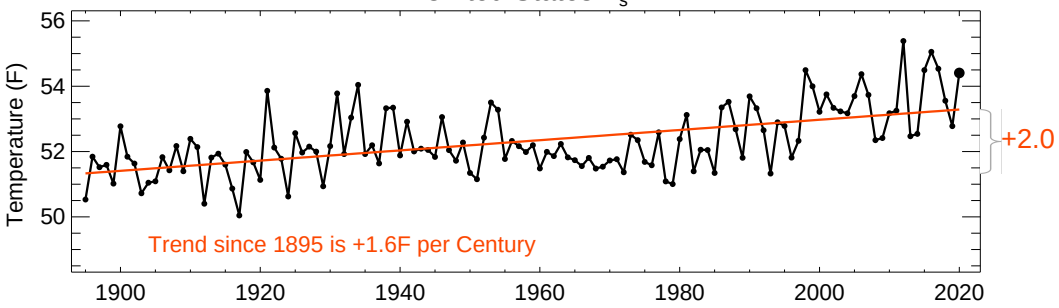
Atmospheric Surface Temperature (T_s)



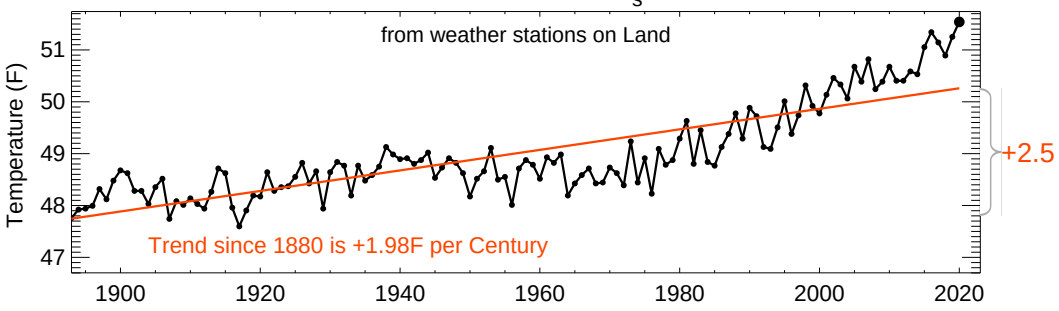
Washington



United States T_s



Global mean T_s



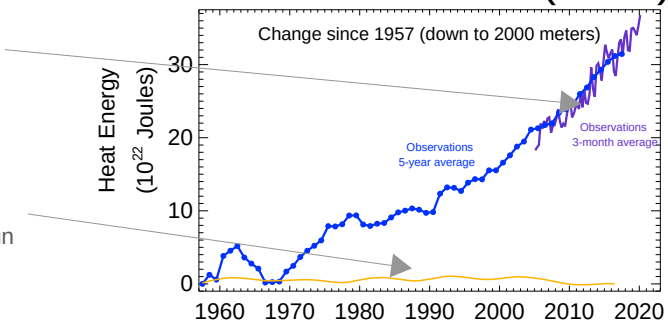
3%

of heat energy trapped by CO_2 is absorbed by the Atmosphere

Global Ocean Heat Content (OHC)

Observations from profiling floats

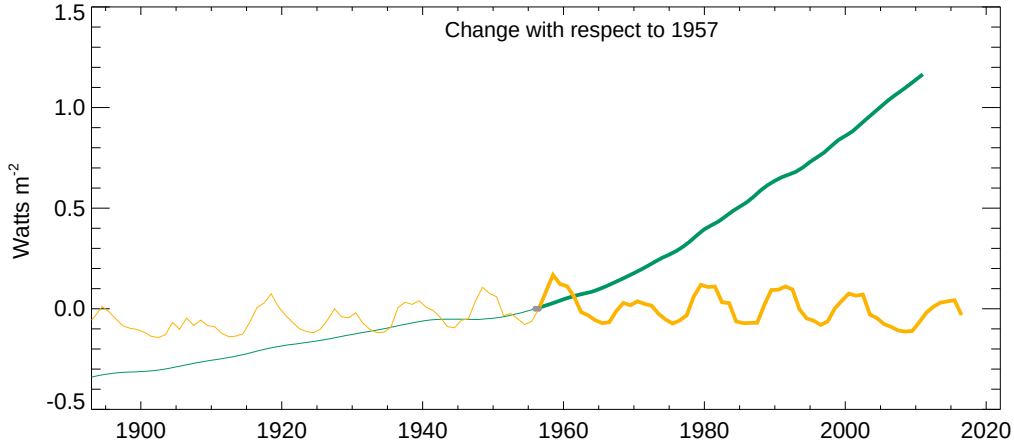
Estimated OHC with pre-industrial CO_2 levels. Only forcing is from the Sun



90%

of heat energy trapped by CO_2 is absorbed by the Ocean

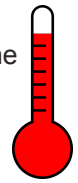
Energy absorbed by Atmosphere, Oceans and Land



Forcing from CO_2

Forcing from Sun

Atmospheric Surface Temperatures (T_s)



The trends for atmospheric surface temperature are from thermometers located at weather stations around the world. For US stations we show the NOAA/NCDC (USHCN v2.5) bias-adjusted annual average values. They are taken from the file: ftp://ftp.ncdc.noaa.gov/pub/data/ushcn/v2.5/ushcn.tavg.latest.FLs.52j.tar.gz
For some years, especially early in the 20th century, the archived values are estimated from surrounding stations. We include these estimated values in our trend plots. See Menne et al. 2009. The state and US trends are simple averages of all the stations located within, no area or population weighting is done.

We show the global surface temperature from land stations *only* and do not include sea surface temperature observations from buoys and ship ballasts. A recent paper (Karl et al 2015) corrects artifacts in the buoy and ship ballast observations used by NOAA. Because, this correction has become so controversial, we only use records from meteorological stations on land, which were generally are unchanged.

Ocean Heat Content (OHC)

The Ocean Heat Content is described in Levitus et al. (2012) and sourced from http://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/. In 1950's oceanographers deployed a network of instruments that measure the temperature of the top 2 kilometers of the oceans. Initially, the network of instruments was sparse, covering only 20% of the ocean surface, so there is large uncertainty to these early global estimates; but today the coverage is near 85% with low OHC uncertainty. We show the heat energy in Joules added to the top 2 kilometers of the ocean since 1957. A Joule is a unit of energy – a 100 Watt bulb uses 100 Joules every second.

Because the ocean's mass is ~250 times that of the atmosphere and because water has a much higher heat capacity than air, 90% of the energy trapped by green house gases is absorbed by the ocean. Only 3% is absorbed by the atmosphere (where we live); ice and glaciers absorb the remaining 7%. So the OHC is the fundamental indicator of global warming.

What mechanism explains all the heat energy warming the Ocean, the Sun, CO_2?

Since 1980 NASA has deployed a series of satellite instruments to monitor the brightness (Total Solar Irradiance, TSI) of the sun. Before that changes in the sun's brightness is from telescopic observations of sunspots. Galileo made the first detailed counts in the 1600's. The sun's brightness is proportional with the sunspot number, so scientists estimate a pre-satellite era TSI based on the historical sunspot number record (Krivova et al 2010). Some (~30%) of the Sun's energy is reflected back to space mainly by clouds, ice and deserts. This 30% does *not* warm the earth. The other (absorbed) portion of energy warms the Atmosphere, Ocean and Land and hence forces the earth's climate. This is the sun's forcing of climate, and is shown by orange trace. The waves are consistent with the known 11-year sunspot cycle. Could the sun explain the observed $30*10^{22}$ Joule change in OHC since 1957? **NO,** When we estimate the OHC based solely on the sun's forcing, it's almost unchanged (orange trace the OHC plot). Its clear the sun can only effect negligible changes in the OHC.

For comparison we also show the additional direct forcing on the earth's climate from CO_2 since 1957. This is driven by the increase in CO_2 concentrations since then. The 1.3 Watts m^{-2} additional forcing from CO_2 dominates the sun's negligible forcing. This is consistent with the conclusion of almost all publishing atmospheric scientists: The continued anthropogenic emission of CO_2, and its associated climate feedbacks, is the only mechanism that can explain our warming climate.

CO_2

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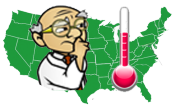

References

Menne, M.J., C.N. Williams, and R.S. Vose, 2009: The United States Historical Climatology Network monthly temperature data, Version 2. Bulletin of the American Meteorological Society, 90, 993-1007.

Karl, T. R. et al. 2015:, Possible artifacts of data biases in the recent global surface warming hiatus, Science http://dx.doi.org/10.1126/science.aaa5632

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Levitus, S., et al. (2012), World ocean heat content and thermosteric sea level change (0–2000 m), 1955–2010, Geophys. Res. Lett., 39, L10603, doi:10.1029/2012GL051106.