

2017

Some Key Climate Infographics



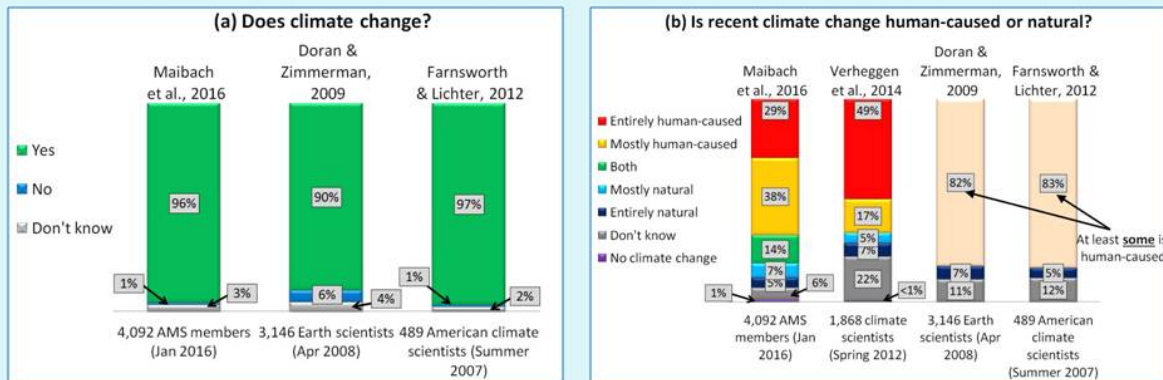
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Is there a scientific consensus on climate change?

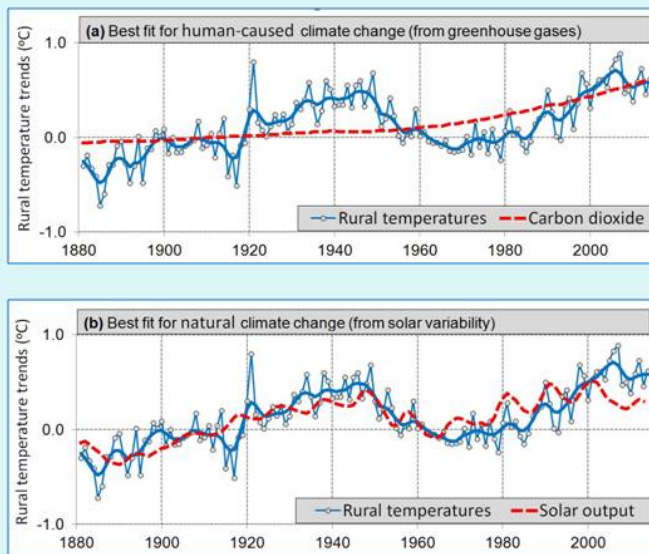


Several surveys of the scientific community have shown more than 90% of scientists agree that the climate changes and that there has been a general global warming since the late 19th century. This has led to the popular belief that more than 97% of scientists think climate change is man-made. This is **not** true. There is considerable ongoing debate among the scientific community over how much of this global warming is man-made and how much is natural.

References

Maibach et al., 2016. "A 2016 national survey of American Meteorological Society member views on climate change". George Mason University, Center for Climate Change Communication
 Verheggen et al., 2014. *Environ. Sci. Technol.*, Vol. 48, pp8963-8971. doi: 10.1021/es501998e
 Doran & Zimmerman, 2009. *Eos Trans. AGU*, Vol. 90, pp22-23. doi: 10.1029/2009EO030002
 Farnsworth & Lichter, 2012. *Int. J. Public Opinion Res.*, Vol. 24, pp93-103. doi: 10.1093/ijpor/edr033

Global warming: human-caused or natural?



The latest IPCC reports (2013) did not properly correct for urban heating bias in their temperature data. They also did not look at all the published solar output models.

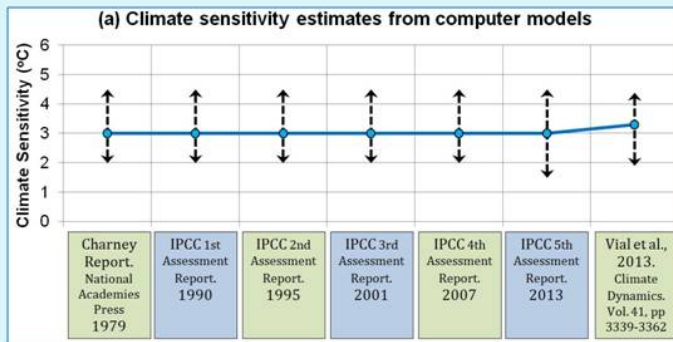
Recently, we developed a rural temperature dataset for the Northern Hemisphere which is **not** affected by urban heating biases (Soon, Connolly & Connolly, 2015). We also considered a recent estimate of solar output trends by the team in charge of NASA's ACRIIM satellites (Scafetta & Willson, 2014).

It seems that *after correcting for urban bias*, global temperatures since 1880 are better described by solar output than greenhouse gases. This suggests recent climate change is mostly natural, and **not** mostly human-caused as the IPCC had thought.

References

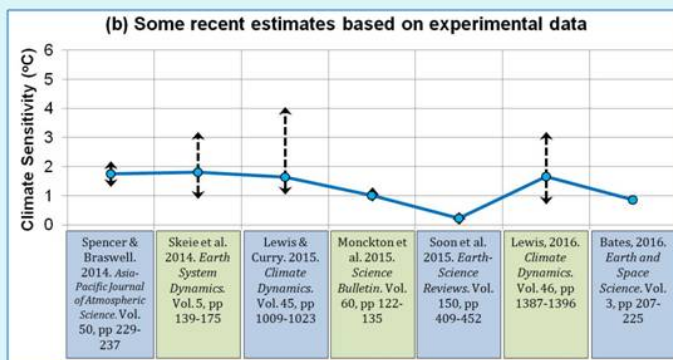
Rural temperature data: Soon, Connolly & Connolly (2015). *Earth-Science Reviews*. Vol. 150, pp 409-452.
 Carbon dioxide data: Schmidt and others (2011). *Geoscience Model Development*. Vol. 4, pp 33-45.
 Solar output data: Scafetta & Willson (2014). *Astrophysics and Space Science*. Vol. 350, pp 421-442.
 IPCC report: IPCC (2013). Working Group 1, 5th Assessment Report. www.ipcc.ch

What is the “climate sensitivity”?



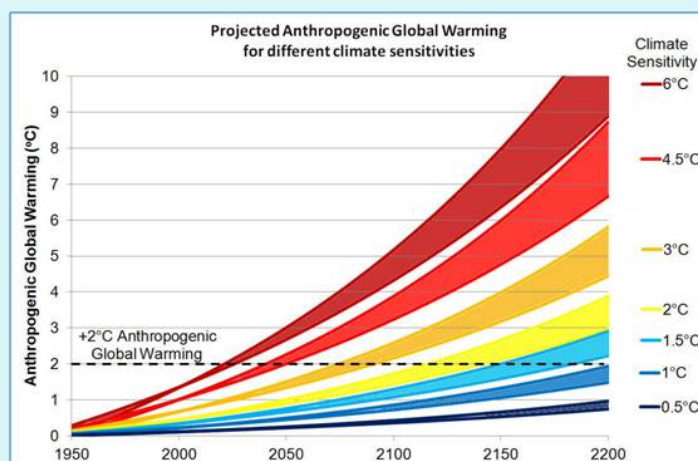
The “climate sensitivity” is the amount of global warming in °C that is expected to occur from a doubling of carbon dioxide concentrations.

Estimates of this value from computer climate models vary from 2°C-4.5°C, but are typically about 3°C. The IPCC reports and current predictions of future climate change are based on these estimates.



However, in the last few years, several studies based on experimental data have suggested that the true climate sensitivity is much lower than the models assume.

Policy implications of the Climate Sensitivity debate



As can be seen from the chart on the left, the actual value of the Climate Sensitivity strongly influences the amount of human-caused global warming we should expect if our CO₂ emissions continue to rise business-as-usual, i.e., if we do nothing to “decarbonize” our economy.

If the Climate Sensitivity is 3°C or higher, then we are likely to pass the 2015 Paris Agreement’s “+2°C limit” before the end of the century if we continue business-as-usual...

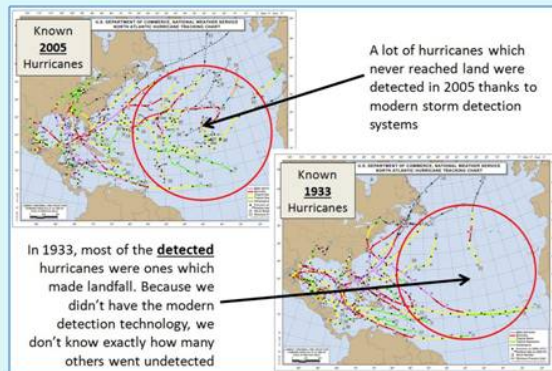
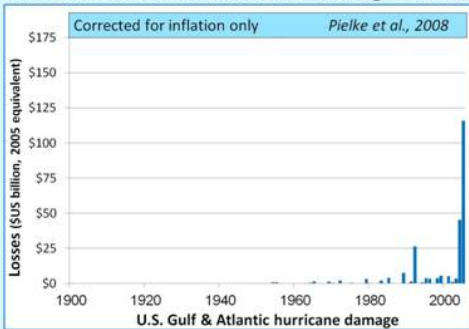
Global warming under business-as-usual growth

The projections above are taken from a previously unpublished study carried out by two of us (Dr. Ronan Connolly and Dr. Michael Connolly) with the late Prof. Robert M. Carter (1942-2016). They show the amount of human-caused (“anthropogenic”) global warming to expect if the world continues “business-as-usual” depend critically on how high the “Climate Sensitivity” to CO₂ is.

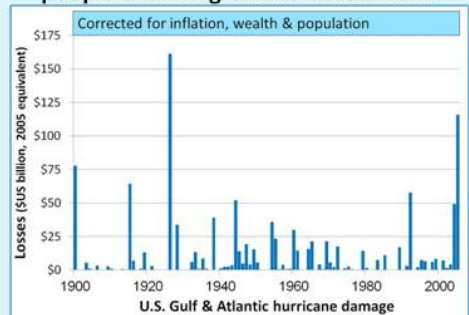
...But, if the Climate Sensitivity is 1.5°C or less, then we would not pass this limit this century even if we continue business-as-usual. It would also suggest that the models have been overestimating the human contribution to recent global warming.

Are we seeing more extreme weather? Hurricanes as a case study

The uncorrected hurricane damage data:



After correcting for the fact that more people are living on the coasts now:



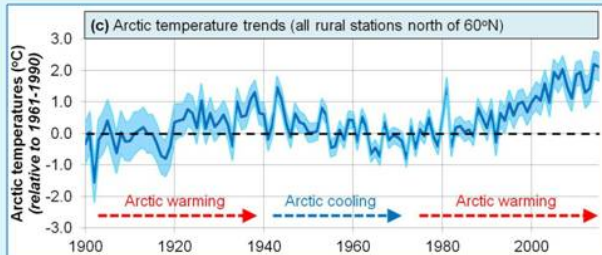
We are inundated with stories in the news of extreme weather disasters. So, it can *seem* like we're seeing unusual climate change. But, this is misleading :

1. We are now **detecting** more extreme weather, because our weather observation systems have dramatically improved (Landsea et al., 2010)
2. Because the world's population has increased, more people are living in at-risk regions (Pielke et al., 2008)

References

- Landsea et al. (2010). Journal of Climate, 23, 2508–2519.
- Pielke et al. (2008). Natural Hazards Review, 9:29-42.

Is the Arctic sea ice melting at an unusual rate?



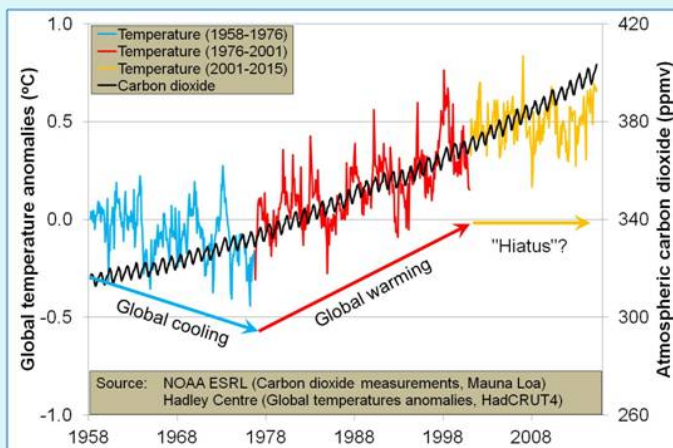
Since the start of the satellite records in 1979, the average Arctic sea ice extent has been in decline. This has contributed to the popular belief that humans are causing unprecedented changes in the Arctic through our carbon dioxide emissions. However, this is misleading for several reasons:

1. The records only began in 1979
2. Antarctic sea ice extent has *increased* over the same period
3. The start of the satellite era coincidentally occurred just after about 30 years of Arctic cooling

Data sources

- Sea ice extent data taken from National Snow & Ice Data Center (NSIDC) www.nsidc.org
- Arctic temperatures calculated from NOAA's GHCNv3 dataset www.ncdc.noaa.gov/ghcnm/

Is carbon dioxide the main driver of global temperatures?



Since 1958, scientists have been continuously monitoring the concentration of carbon dioxide (CO₂) in the atmosphere (black 'zig-zag' line in the figure). Over this period, the IPCC's global temperature record has seen:

1. Global cooling (1950s-70s)
2. Global warming (1970s-90s)
3. Almost constant (start of 21st century to present)

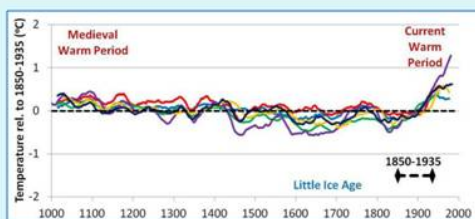
The recent "pause" or "hiatus" in global warming was not predicted by the models.

Data sources

- Carbon dioxide measurements: NOAA Earth System Research Laboratory: www.esrl.noaa.gov
- Global temperatures: UK Met. Office's Hadley Centre: www.metoffice.gov.uk/hadobs/hadcrut4/

Temperatures of the last 1000 years

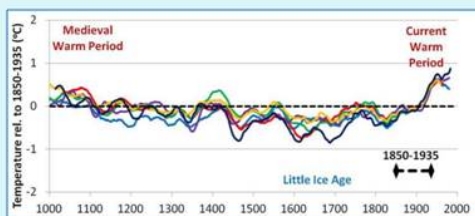
To estimate temperatures before the 19th century, climate scientists use "temperature proxies", e.g., tree rings and ice cores. Results depend on the proxy data used and the averaging method:



"Hockey stick" estimates

Some proxy reconstructions suggest temperatures were fairly static until the Industrial Revolution, when temperatures started to rise dramatically

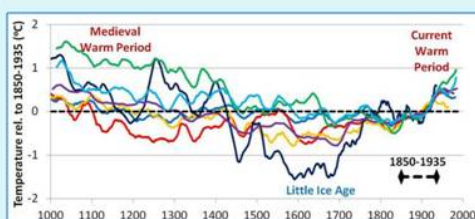
- Jones98
- Mann1999
- Crowley00
- Mann03
- Christiansen11
- Shi13 (CPS)



Warm "Current Warm Period" estimates

Others suggest current temperatures are the highest in over 1000 years, but that it was also quite warm during the Medieval Warm Period

- D'Arrigo06
- Jukes07
- Heger07
- Mann08 (CPS)
- Christiansen12
- Shi13 (PC10+AR2)



Warm "Medieval Warm Period" estimates

Others suggest that it was just as warm (if not warmer) during the Medieval Warm Period as now.

- Briffa00
- Esper02
- Moberg05
- Loehle07
- Ljungqvist10
- McShane11
- Shi13 (EIV)

See "Global temperature changes of the last millennium" at www.oprj.net for more information

Basis for most scientists' views on global warming

Doran & Zimmerman, 2009 survey

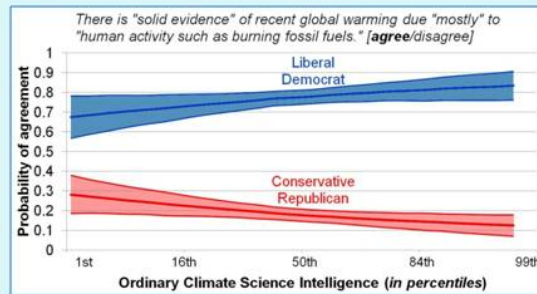
Doran & Zimmerman found that 82% of Earth scientists (N=3,182) believed human activity was a "significant factor" in global warming. They also asked the scientists why they believed this. The results are shown in the tables below:

Q. What do you consider to be the most compelling argument (for man-made global warming)?	%
Coupled change in atmospheric CO ₂ and average global temperatures	73%
Rate of glacial/sea ice melt	11%
Loss of CO ₂ sinks (e.g., deforestation)	2%
All or combination of above factors	5%
CO ₂ and carbon isotope data from rocks, ice core/man-made signal in carbon isotopes	2%
GCM simulations	3%
Rate/magnitude of warming compared with natural rate	1%
IPCC reports/Peer consensus	1%
Physical principles of energy balance	2%
General temperature increases	<1%
Population growth and corresponding demand and production of CO ₂	<1%
Other (write in description)	1%

Q. What do you consider to be the most compelling argument (for natural global warming)?	%
Natural climate cycles (e.g., Milankovitch cycles)	54%
Increased solar input in recent years (e.g., solar flares)	28%
Current or reconstructed temperature record is unreliable	5%
All or combination of above factors	10%
Other (write in description)	4%

Kahan, 2015 study

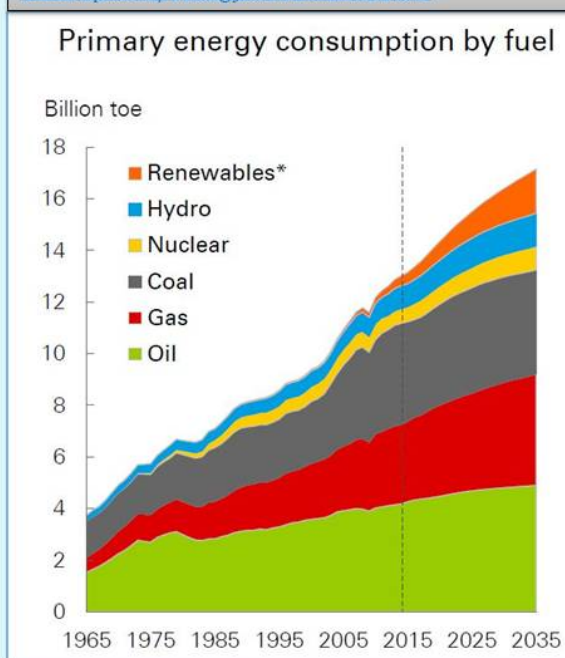
Prof. Dan Kahan has found that most people's views on whether global warming is human-caused or natural depends mostly on their political outlook. The more people know about climate science, the greater the partisan divide:



Scientists working in academia are much less politically conservative than the general public. Research is ongoing to establish exactly how much scientists' political views influence their views on global warming, but it seems to be a substantial factor.

Energy production: Now and the future

Graph from BP Energy Outlook 2017 Edition
www.bp.com/energyoutlook#BPstats



*Renewables includes wind, solar, geothermal, biomass, and biofuels

As of 2015, renewables only account for 3% of our primary energy use.

BP predict that if the world continues major investment into renewables, by 2035 renewables could account for 10% of our primary energy use.

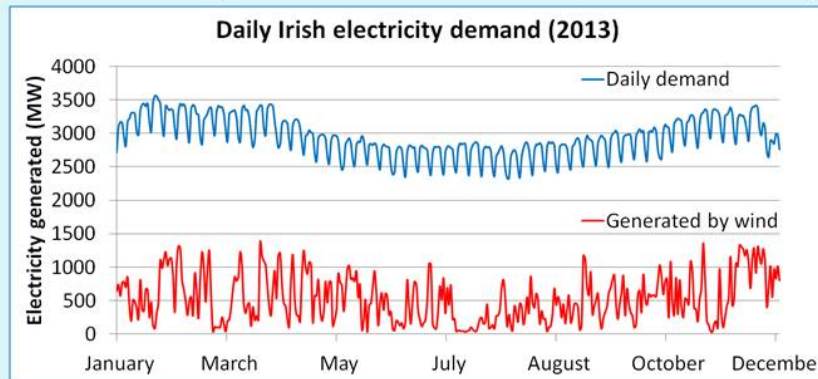
This has important implications:

1. Even with major investment in renewables, 90% of our energy will be from non-renewables by 2035.
2. Renewables are still relatively untested as a primary energy source. Therefore the environmental and economic impacts from the increases use of renewables should be carefully studied and monitored.

The intermittency problem of wind & solar

The current large-scale technologies for producing **baseload** electricity are: coal, gas, oil, nuclear, hydroelectricity and biomass (e.g., wood). Critics of these 6 technologies suggest that we could also use either wind turbines or solar panels. However, both of these technologies are only capable of **intermittent** electricity generation, e.g., the electricity generated on one day can be less than 5% of that on the previous day. The cheap battery storage technology needed to overcome this problem has not been invented yet. Therefore, neither wind nor solar can currently be used as a source for baseload electricity.

Wind farm usage in Ireland as a European case study

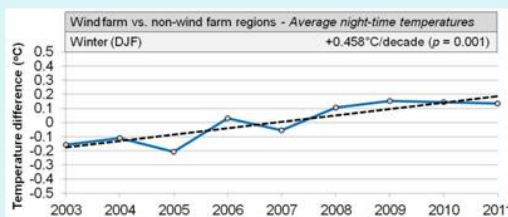
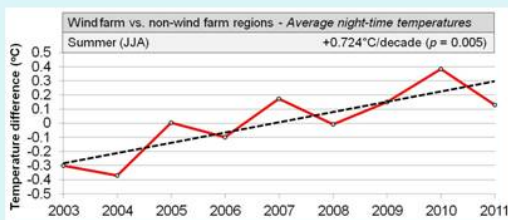


Data source: Eirgrid (www.eirgrid.com downloaded in January 2014)

The climate change caused by wind farms

Climate is the average weather conditions (wind, precipitation, temperature, sunlight, etc). Wind farms can cause substantial climate change on the lee side of the farms (down wind):

- By extracting energy from the wind, this can reduce the water-carrying capacity, sometimes leading to flash flooding. This is known as the “wake effect”.
- The increased turbulence on the lee side leads to greater air-ground mixing, increasing the average night-time soil temperature



Surface temperature trends in west Texas in regions near or far from wind farms. Adapted from Zhou et al. (2012). *Nature Clim. Change.*, 2:539-543



Illustration of wake effect at an offshore wind farm. Hasager et al. (2013), *Energies*, 6:696-716. Photo by Christian Steiness (via Vattenfall).