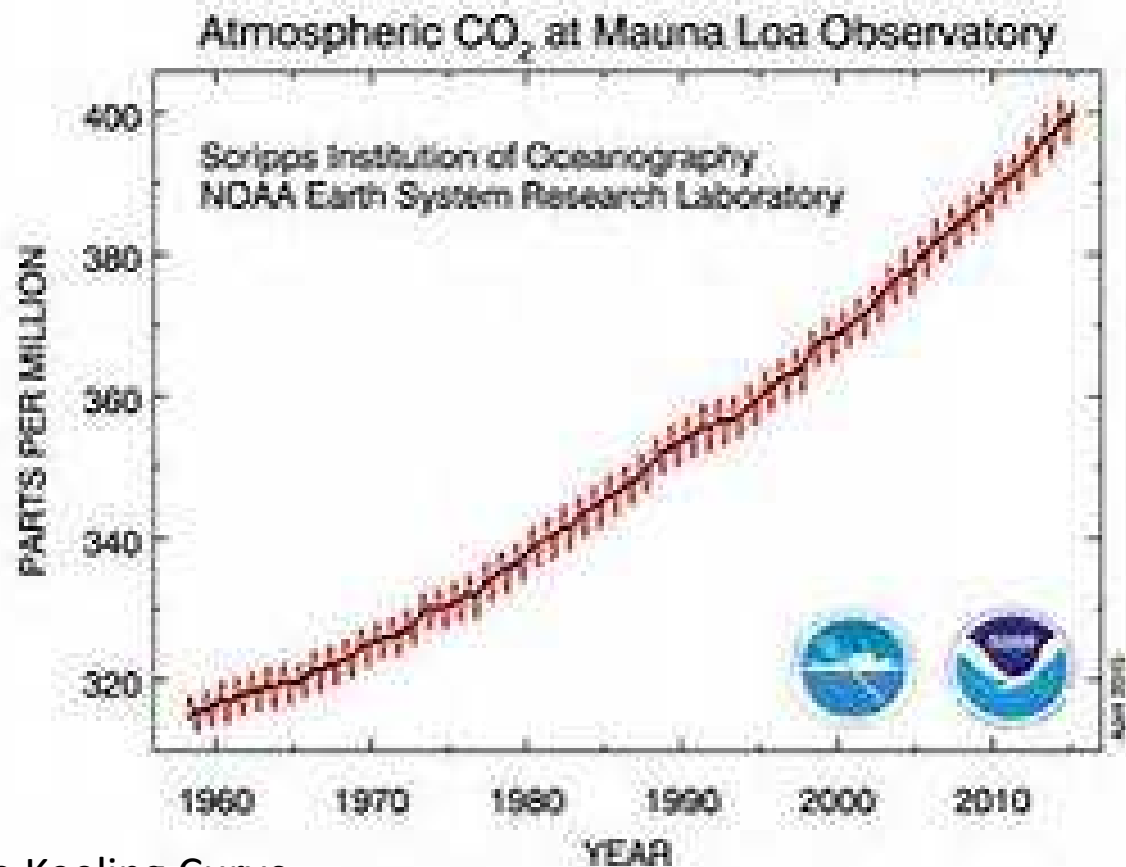


The carbon dioxide thermostat

Compiled by Phil Nelson, 2017



We were warned



The Keeling Curve

Charles David Keeling, Scripps Institution of Oceanography

“Keeling’s measurements of the global accumulation of carbon dioxide in the atmosphere set the stage for today’s profound concerns about climate change. They are the single most important environmental data set taken in the 20th century.”

C.F. Kennel, 2006



CO2 levels mark 'new era' in the world's changing climate

By Matt McGrath BBC Environment correspondent, Oct 24, 2016

Levels of CO2 in the atmosphere have surged past an important threshold and may not dip below it for "many generations". The 400 parts per million benchmark was broken globally for the first time in recorded history in 2015. But according to the WMO, 2016 will likely be the first full year to exceed the mark.



The air sampling station at Mauna Loa observatory in Hawaii which recorded CO2 levels going through 400ppm

Warm air holds more water vapor than cold air (a lot more)

In the warm tropics, the water evaporates putting large quantities of water vapor in the air; this intercepts the outgoing radiation, further warming the air and water. In the polar regions, temperatures are so cold that almost no vapor is in the air, so its greenhouse effect is effectively nil.

A 10C increase of air temperature doubles the amount of water vapor it can hold.

Experimenting on a small planet, by W.W. Hay, 2013

H₂O vapor is concentrated around the tropics

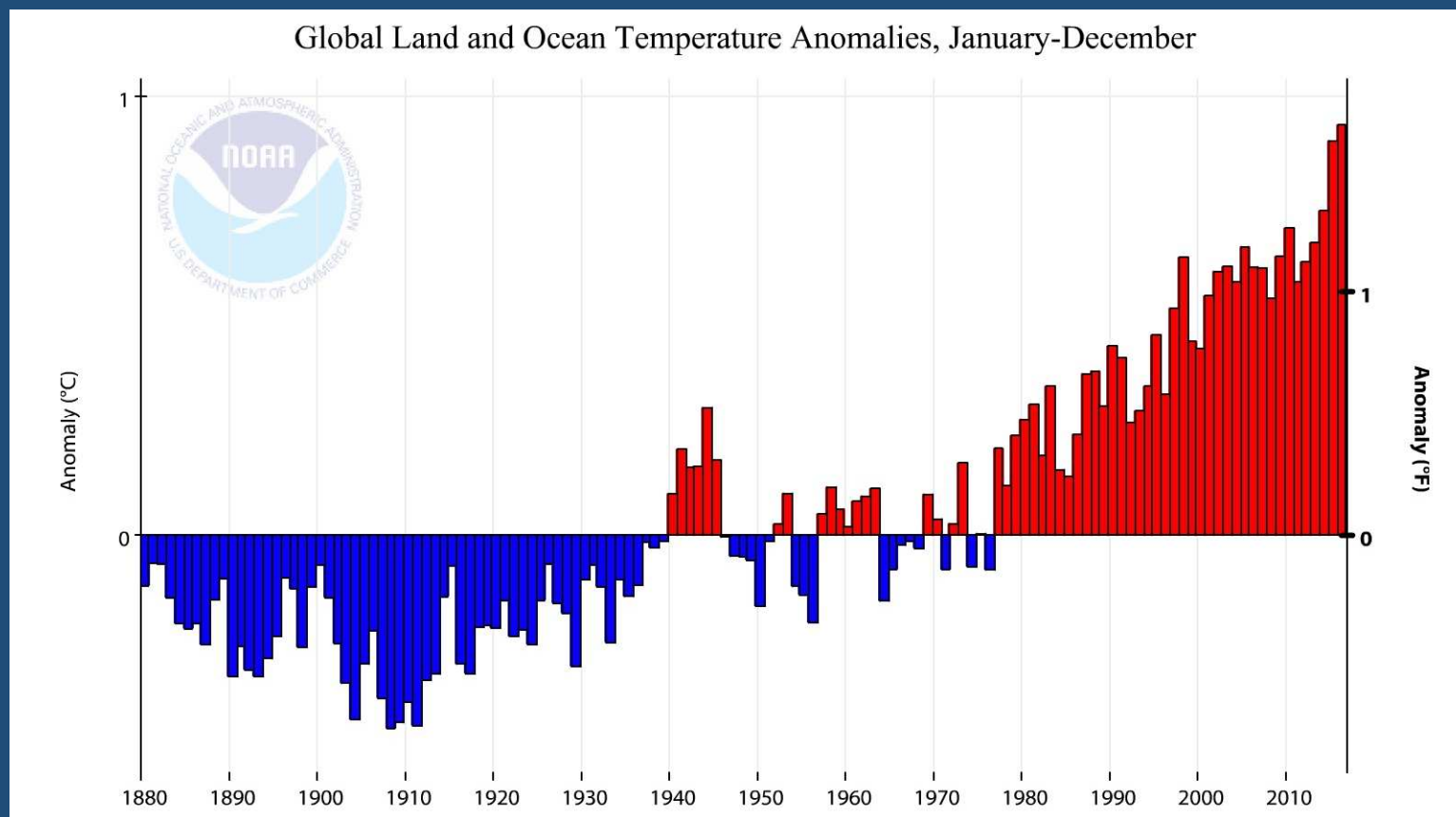
CO₂ is distributed throughout the atmosphere



Based on fig 19.4, W.W. Hay

Confirmed: 2016 the Warmest Year in History of Global Recordkeeping

Weather Underground, 18 Jan 2017



Departure from the 20th-century average for the global January-through-December temperature for the years 1880 - 2016. This year has seen the warmest temperatures on record for the year-to-date period, following previous global record highs in 2014 and 2015. Image credit: NOAA/National Centers for Environmental Information (NCEI).

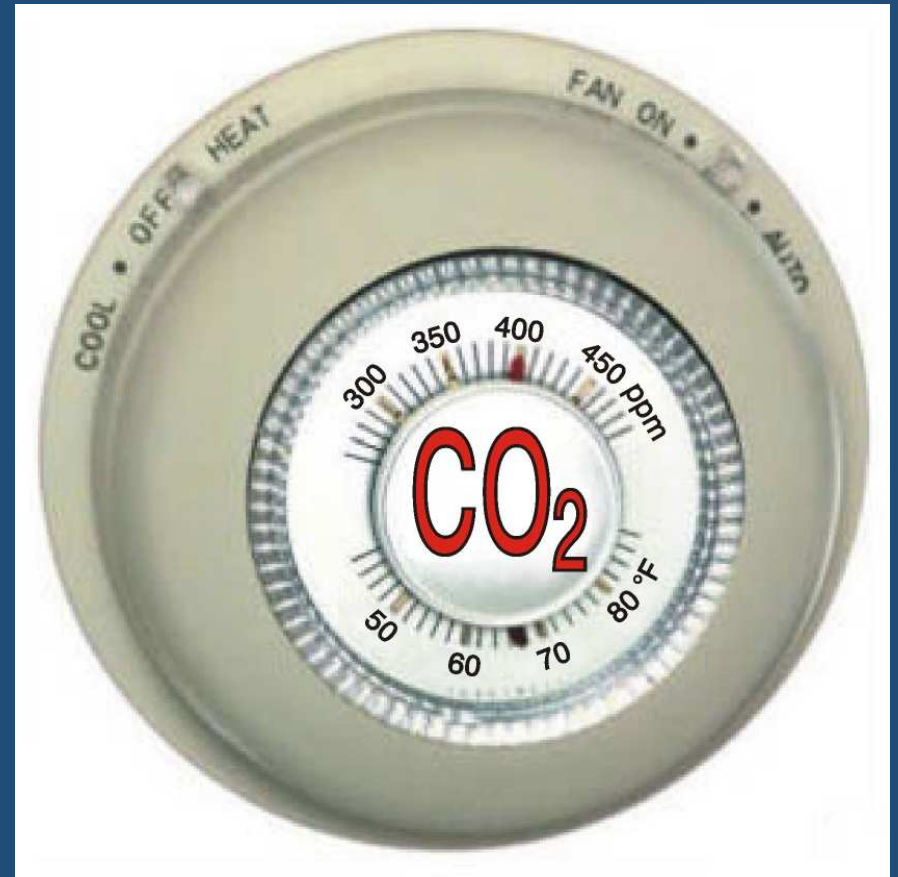
Carbon dioxide —
so little does so much

Carbon Dioxide Controls the Earth's Temperature

Water vapor and clouds are the major contributors to Earth's greenhouse effect, but the planet's temperature ultimately depends on the atmospheric level of carbon dioxide.

Carbon dioxide, methane, and other gases provide the core support for the greenhouse effect. Without them, water vapor would quickly precipitate from the atmosphere, plunging the earth into an icebound state.

Hence the “thermostat” shown in the picture.



NASA GISS: Lilly Dell Valle

Based on papers by Lacis et al, 2010, Science and Schmidt 2010, J. Geophysical Res.



Human
Activity



Warmer Air,
Warmer Water
(Global Warming)

More Water Vapor
and Clouds



Atmosphere
Biosphere
Cryosphere
(Climate Change)



Heat Waves

Attribution confidence for extreme heat: high

Hyderabad, India, May, 2015
Fifth deadliest heat wave in recorded history, 113 F



Delhi, India, May, 2015

Man sprays ice cream truck so ice cream won't melt, 112 F



The Indian Express

Himalyan foothills, India, April, 2016

The Greed for Timber, and Climate Change, Have Made Himalayan Foothills a Tinderbox

NASA



Thewire.in

Phalodi, India, May 2016

"Like heat waves coming out of a clay oven", 124 F

Sydney Morning Herald



Photo: Rajesh Kumar Singh



AP



AP

ABC News

Northern India, 2016

Unused water pipes provide shelter in May's record temperatures



Justin Rowlatt, BBC South Asia

Kuwait Fries in 54°C (129.2°F) Heat

By: Jeff Masters , 3:01 AM GMT on July 22, 2016

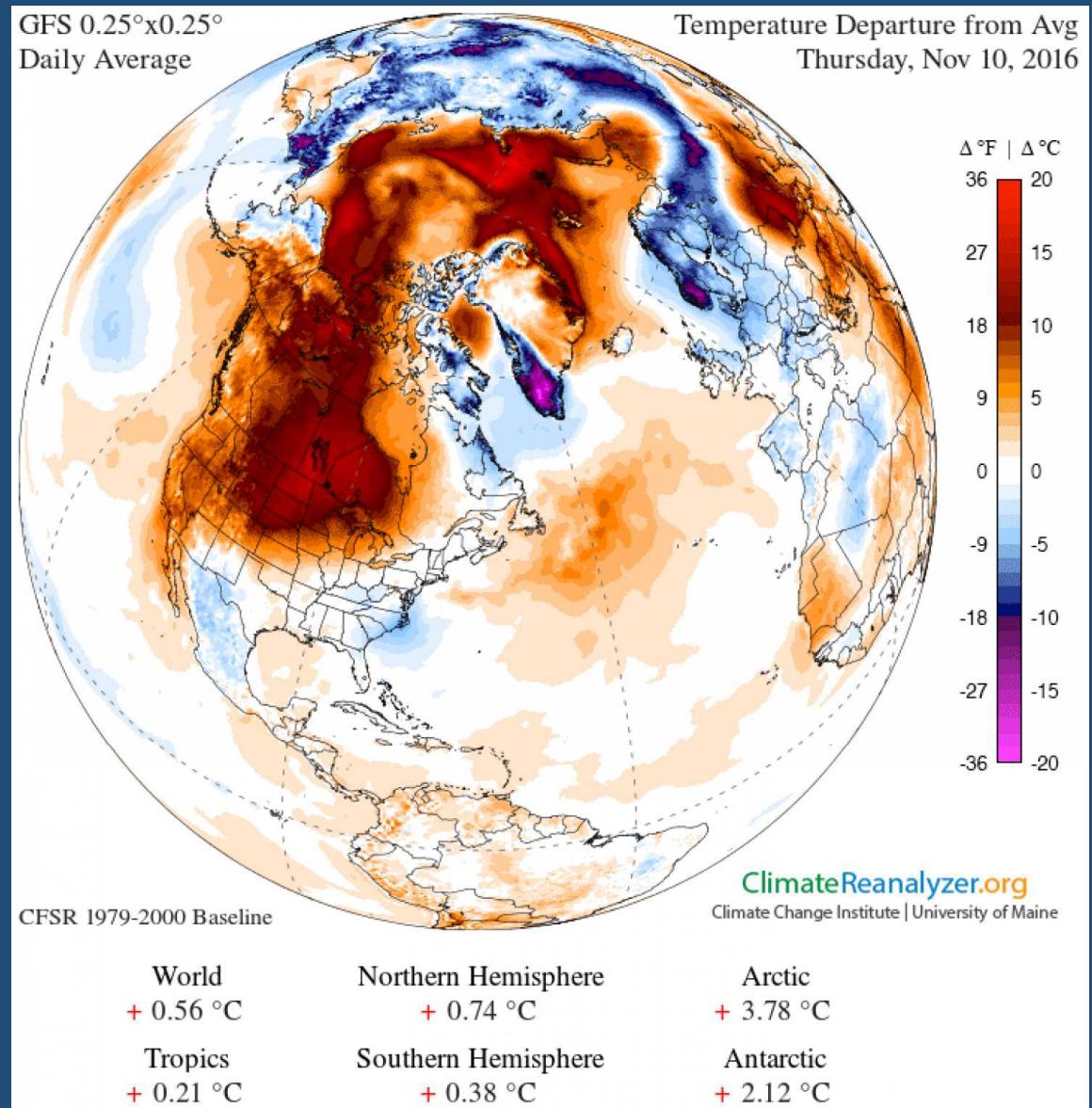
It was a historic day in the annals of meteorology on Thursday, July 21, 2016 in the Middle East, where the temperature in Mitribah, Kuwait soared to an astonishing 54°C (129.2°F). If verified, this would be Earth's hottest temperature ever reliably measured outside of Death Valley, California, according to wunderground's weather historian Christopher C. Burt. The temperature is likely to be verified, since Thursday's incredible heat also extended into Iraq, which set their all-time heat record: 128°F (53.4°C) at Basrah.

North America is flooded in warmth and there is no sign of real winter

Washington Post, 10 Nov 2016

The United States experienced its third-warmest October on record, and warmth has continued through the first third of November.

[This fall has been so warm, some cities are setting records for latest first freeze]



Temperature difference from normal over the Northern Hemisphere, Nov. 10, 2016. (Climate Reanalyzer, Climate Change Institute, University of Maine, USA.)

Denver beats 75-year-old warmth record as thermometer hits 78 degrees

Denver Post, 16 Nov 2016



Denver surpassed a temperature record that stood since shortly before the bombing of Pearl Harbor Wednesday — a day before snow is predicted to fall in Denver.

On Nov. 16, 1941, the high temperature was 77 degrees. A thermometer at Denver International Airport, where Denver's official temperature is recorded, registered 78 degrees at 1 p.m., according to the National Weather Service in Boulder.

New Record High Temperatures across Northeast Colorado set February 16th

Only Stations with a Period of Record of 30+ Years shown

There has never been a hotter February day in Denver, Colorado Springs or Pueblo

The temperature reached 80 degrees — yes, seriously — at Denver International Airport

Denver Post 17 Feb 2017

Location	Record Temp	Feb 16 th	Old Temp	Previous	Station Age Years
AKRON - CO Plains Rgnl AP	73°	2017	68°	2011	81
Bailey	61°	2017	60°	1970	117
Boulder	73°	2017	69°	1982	125
Cabin Creek	54°	2017	45°	2004	50
Denver Area / now DIA	75°	2017	70°	1970	146
Denver Stapleton	76°	2017	70°	1970	70
Evergreen	70°	2017	63°	1996	57
Ft Collins	70°	2017	67°	2011	125
Ft Morgan	75°	2017	65°	1982	122
Genoa	60°	2017	60°	2011	48
Georgetown	57°	2017	54°	1996	125
Grand Lake 1 NW	49°	2017	47°	1997	79
Grant	55°	2017	52°	1970	55
Greeley UNC	75°	2017	74°	2011	51
Gross Rsvr	63°	2017	57°	2011	40
Hohnholz Ranch	49°	2017	49°	2011	33
Karval	69°	2017	69°	1991	38
Kassler	75°	2017	72°	1996	100
Lakewood	70°	2017	69°	1970	56
Limon AP	70°	2017	65°	2011	48
Lindon 5NWN	66°	2017	62°	2011	30
New Raymer 21N	69°	2017	66°	2011	31
Northglenn	77°	2017	69°	2014	34
Ralston Rsvr	69°	2017	62°	2014	40
Strontia Springs Dam	70°	2017	68°	1996	34



National Weather Service – Denver / Boulder



The previous record-high February daily temperature in Denver was 77 degrees, reached in both 2006 and — you're reading this right — 1890, the weather service said in a tweet. The city's average high temperature in June is 81 degrees.

Hot Winter Eclipses Averages

Bruce Finley, Denver Post, 27 Nov 2016



havayolu101.com

Denver has been a whopping 9 degrees warmer in March.

The recent precipitation in the mountains had boosted February snowpack in all the major river basins to higher than normal, except for the Yampa River Basin.

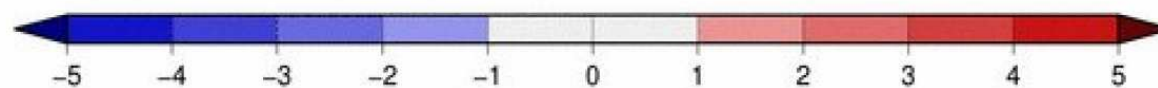
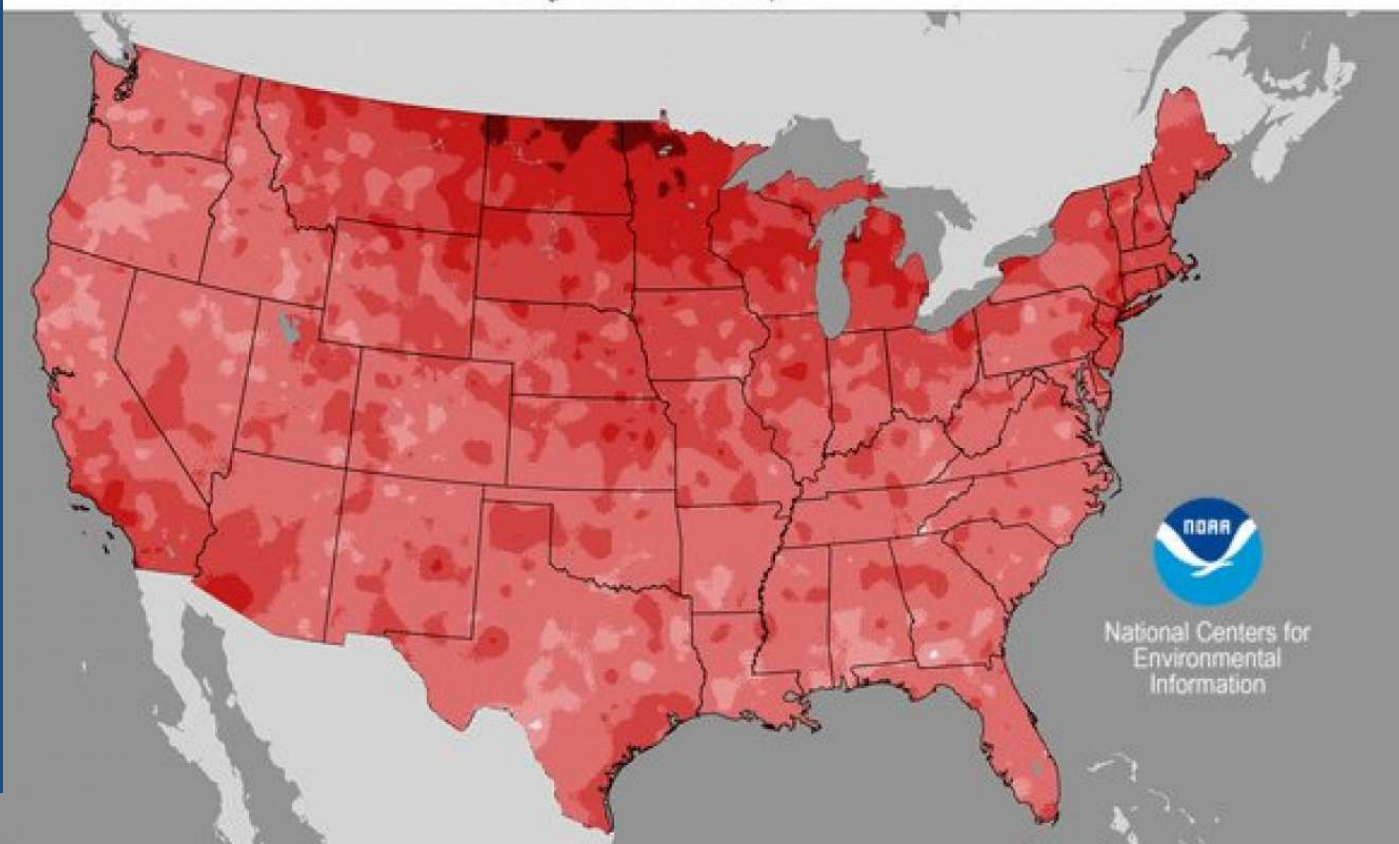
U.S. posts second-warmest year on record, breadth of warmth 'unparalleled' Washington Post, 9 Jan 2017

All of the Lower 48 states registered one of their top-seven warmest years. "The breadth of the 2016 warmth is unparalleled in the nation's climate history," NOAA said. "No other year had as many states breaking or close to breaking their warmest annual-average temperature."

Mean Temperature Departures from Average

January–December 2016

Average Period: 20th Century



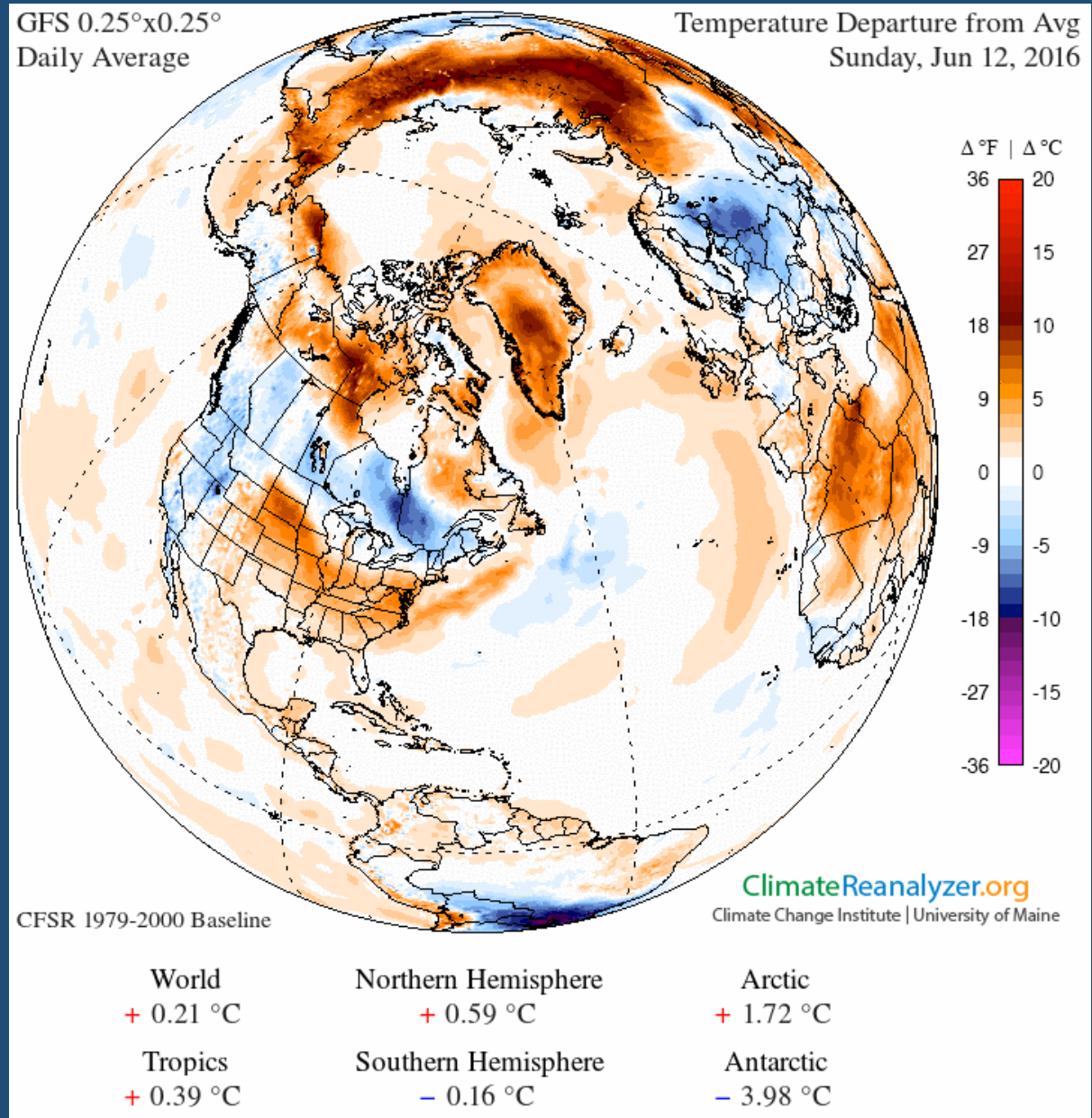
Created: Wed Jan 04 2017

Degrees Fahrenheit

Data Source: 5km Gridded (nClimGrid)

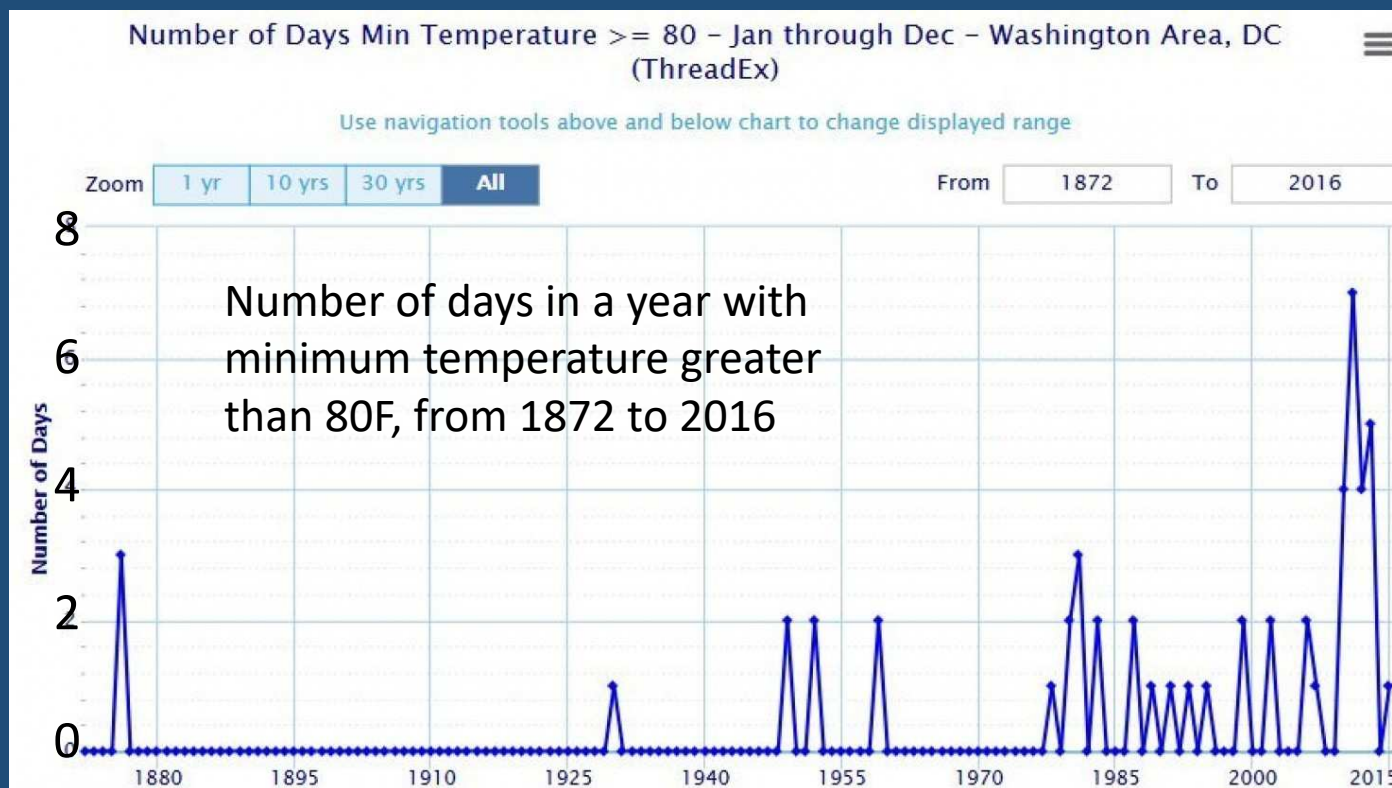
Record temperatures in Greenland

On Thursday June 9, 2016, temperatures in Nuuk, Greenland's capital, reached 75 degrees F. That was the warmest temperature ever recorded in the Arctic country during June, according to Jason Samenow of the Washington Post. "It was warmer in Nuuk than it was in New York City, where the high was only 71 degrees,".



Hot nights have increased at a startling rate in Washington, D.C.

Since the turn of the century, Washington, D.C., has witnessed a stunning increase in unusually warm nights. These are the nights when you walk outside and the heat overwhelms you as if it's the middle of the day. They're now happening five to 10 times more frequently than they used to.



Washington Post July 25, 2016

Sarah Perkins Kirkpatrick, heat wave researcher

abc.net.au Oct 27, 2016

“This is scary. No-one really wants to know that 2C warming means we will have an extra 20 heatwave days here in Australia”.

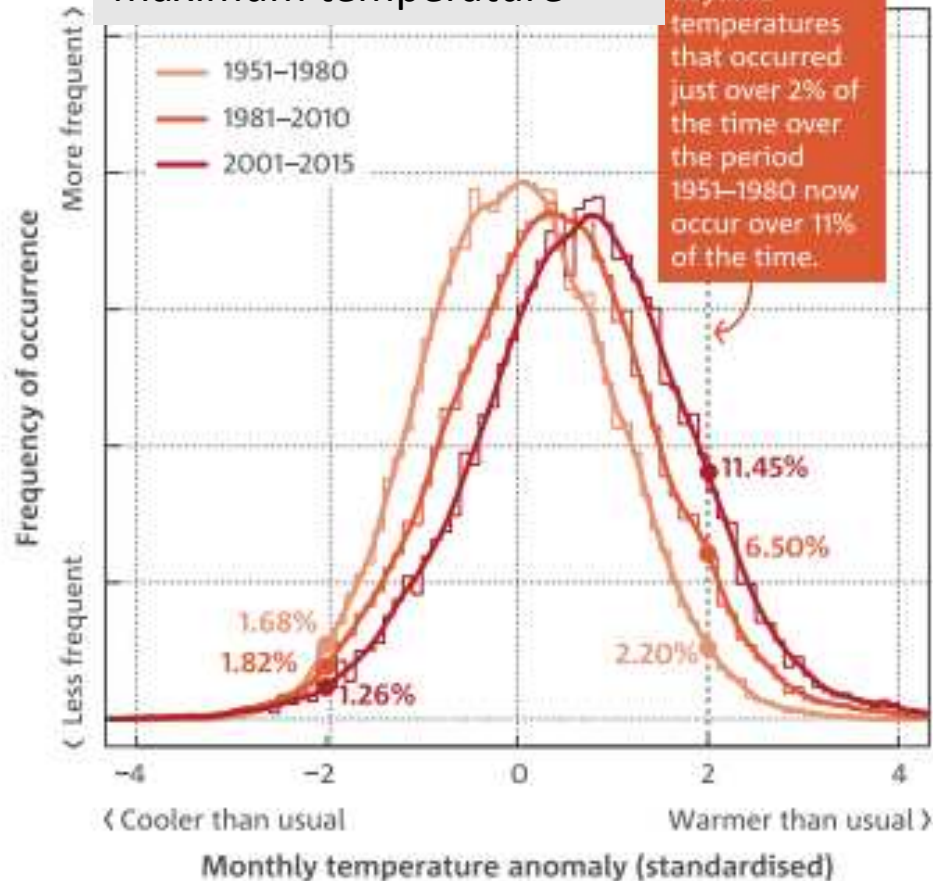
Kirkpatrick worries every day about the figures she sees as a senior heatwave researcher at the University of NSW’s Climate Change Research Centre. “I don’t do this to get depressed. I do this to get things to change, so it doesn’t get as bad as it currently looks like it will.”



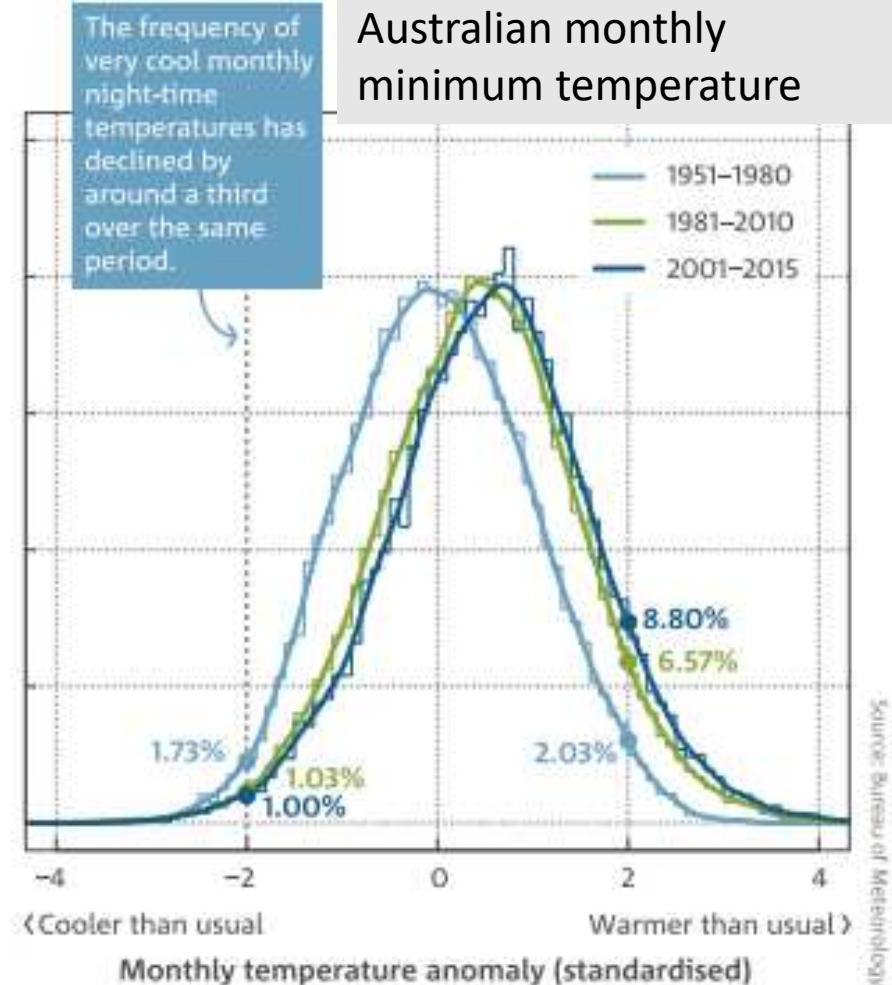
Australia experiencing more extreme fire weather, hotter days as climate changes

Sydney Morning Herald Oct 27, 2016

Australian monthly maximum temperature



Australian monthly minimum temperature



Distribution of monthly day and night-time temperature anomalies (standardised with respect to the 1951-1980 base period) aggregated across 104 locations and all months of the year, for three periods: 1951-1980 (orange, light blue), 1981-2010 (red, green) and 2001-2015 (dark red, dark blue). Very warm months correspond to two standard deviations from the mean. Detection and attribution studies use various methods to understand the significance of these distribution shifts and their cause.

“Extreme events are the primary way people experience climate change”

Quote from a presentation at AGU meeting, December 2016

Human activity implicated in Europe's 2003 heat wave

Greenhouse emissions doubled the risk of a high temperature summer.

Roxanne Khamsi, Nature, 2004

Man-made pollution during the past century doubled the chances of the heat wave that hit Europe last summer, say climatologists. It's the first time that a study has estimated how much human activity increased the risk of a specific weather event.

The sweltering temperatures of August 2003 left many people, particularly the elderly, struggling to cope. The heat wave caused many thousands of extra deaths, while forest fires ravaged large areas of land, causing \$1.6 billion worth of damage in Portugal, for example.

(This is “the landmark 2003 heat wave paper” – Michael Wehner, Lawrence Berkeley Lab, Jan 2017)



The 2003 heat wave triggered thousands of extra deaths, as well as forest fires that caused billions of dollars worth of damage.

©Punchstock

Heat Waves 2013 – Event Attribution

Bulletin American Meteorological Society v. 95, 2014

“Long duration heat waves during the summer and prevailing warmth for annual conditions are becoming increasingly likely due to a warming planet, as much as 10 times more likely due to the current cumulative effects of human-induced climate change, as found for the Korean heat wave of summer 2013.”

Of the nine heat-wave events in 2013 that were studied, all were attributed to anthropogenic climate change, as documented in a special issue of the Bulletin of the American Meteorological Society.

Since 1980, global temperature averages show more hot days and fewer cool nights.

Heat Waves 2015 – Event Attribution

Bulletin American Meteorological Society v. 97, Summary, 2016

“As observed in years past, all the papers that looked at heat events around the world—from Egypt, Australia, Europe, Indonesia, Asia, India, and Pakistan—all found that climate change played a role in increasing the severity of the event.

In addition, many of these events were influenced by both El Niño and natural variability, and in all cases researchers were able to distinguish between these drivers.”



More Water Vapor
and Clouds

Warmer Air,
Warmer Water
(Global Warming)

Atmosphere
Biosphere
Cryosphere
(Climate Change)

HUMAN RESPONSES

Personal
Family, Friends, Neighbors
Town and City
State
National
International

PERSONAL -- Save Energy at Home



GB3 Energy, Golden Colorado

Energy audit, add insulation, replace windows, heating system upgrade, weatherize, crawlspace insulation,

PERSONAL--You Too Can Own an Electric Vehicle

2016 Nissan
Leaf.

All electric,
battery
powered.

100-mile
range on a
charge.



Paul Belanger, owner