

# Wild weather trends: Climate change and extreme events in the past, present, and future.

Jason Samenow  
Weather editor, The Washington Post  
Association of Metropolitan Water Agencies  
Water Policy Conference  
March 21, 2016

# about me

lifelong weather enthusiast

atmospheric science degrees

- B.A. University of Virginia
- M.S. University of Wisconsin

climate change analyst, U.S. EPA, 2001-2010

founded CapitalWeather.com 2004, absorbed by  
Washington Post 2008

Washington Post weather editor since 2010



# About the Capital Weather Gang

Washington Post's weather team

Blog, social media, radio voice for NPR affiliate, print, video

2 full-time meteorologists

– 20 contributing freelance writers

Broad mix: Local → National → International Weather

Weather adjacent topics: Climate change, space weather, astronomy

Commitment to reader engagement, communicating uncertainty



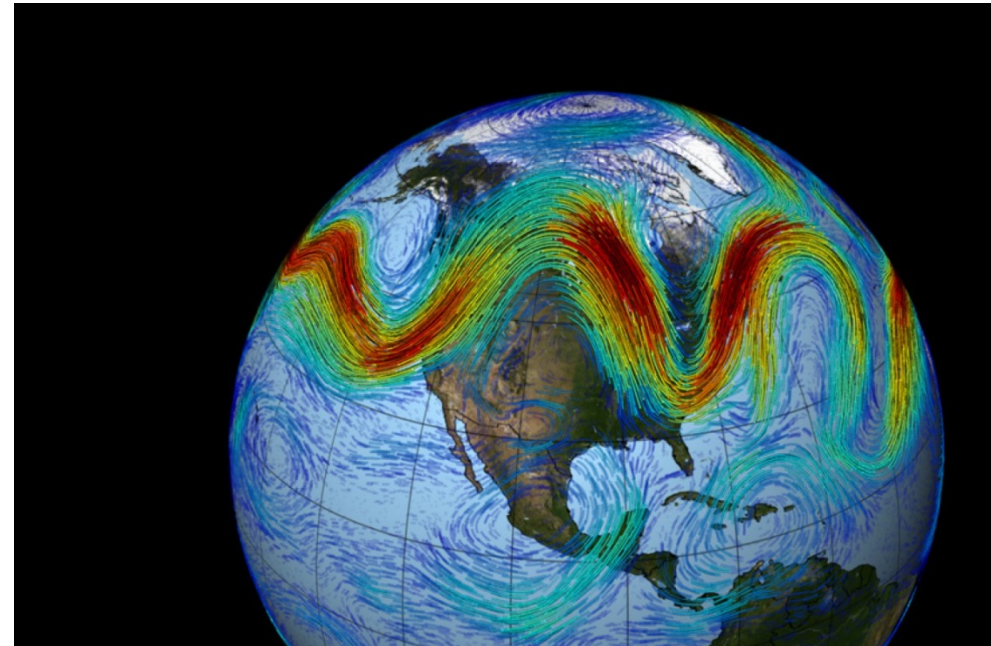
# talk outline

The climate is changing: the evidence

The near term forecast

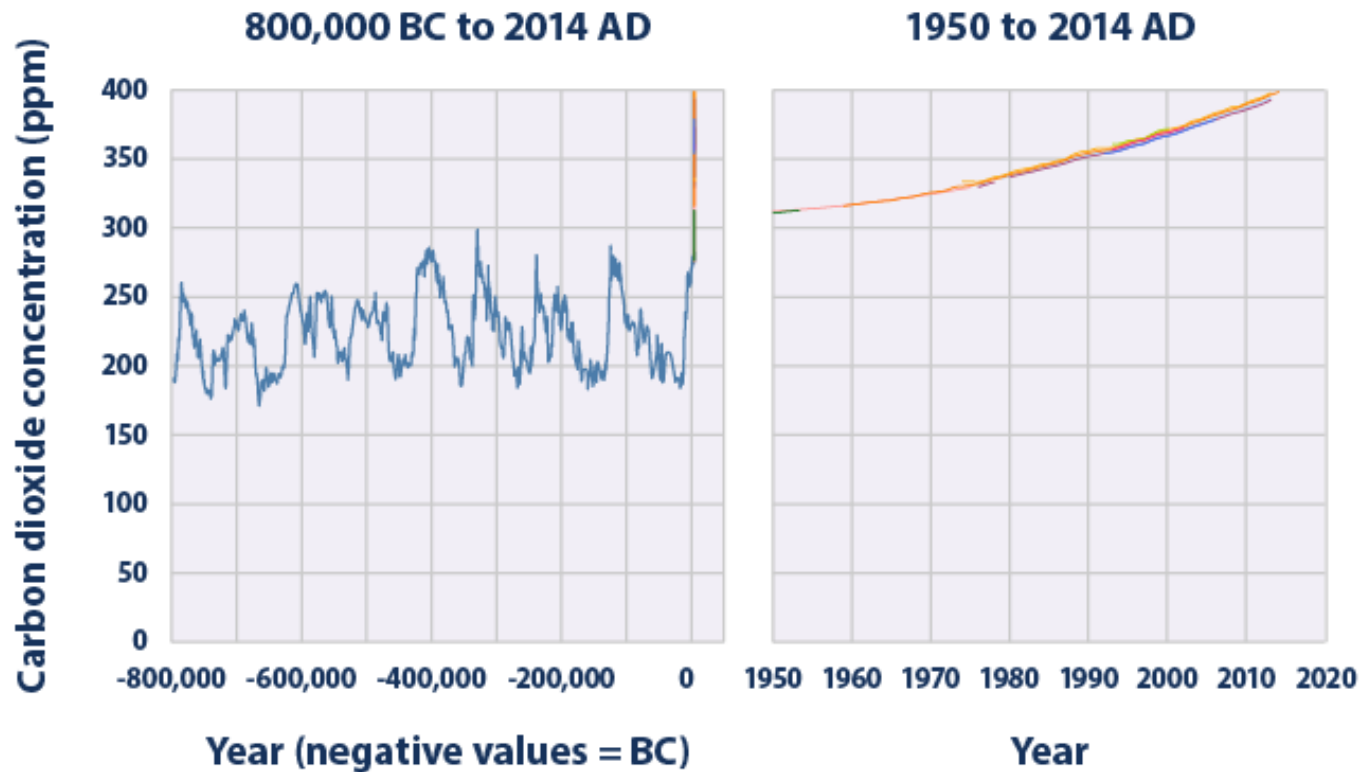
The long term forecast

Questions and answers



# Climate change evidence: Inexorable rise in CO<sub>2</sub> concentrations

Global Atmospheric Concentrations of Carbon Dioxide Over Time

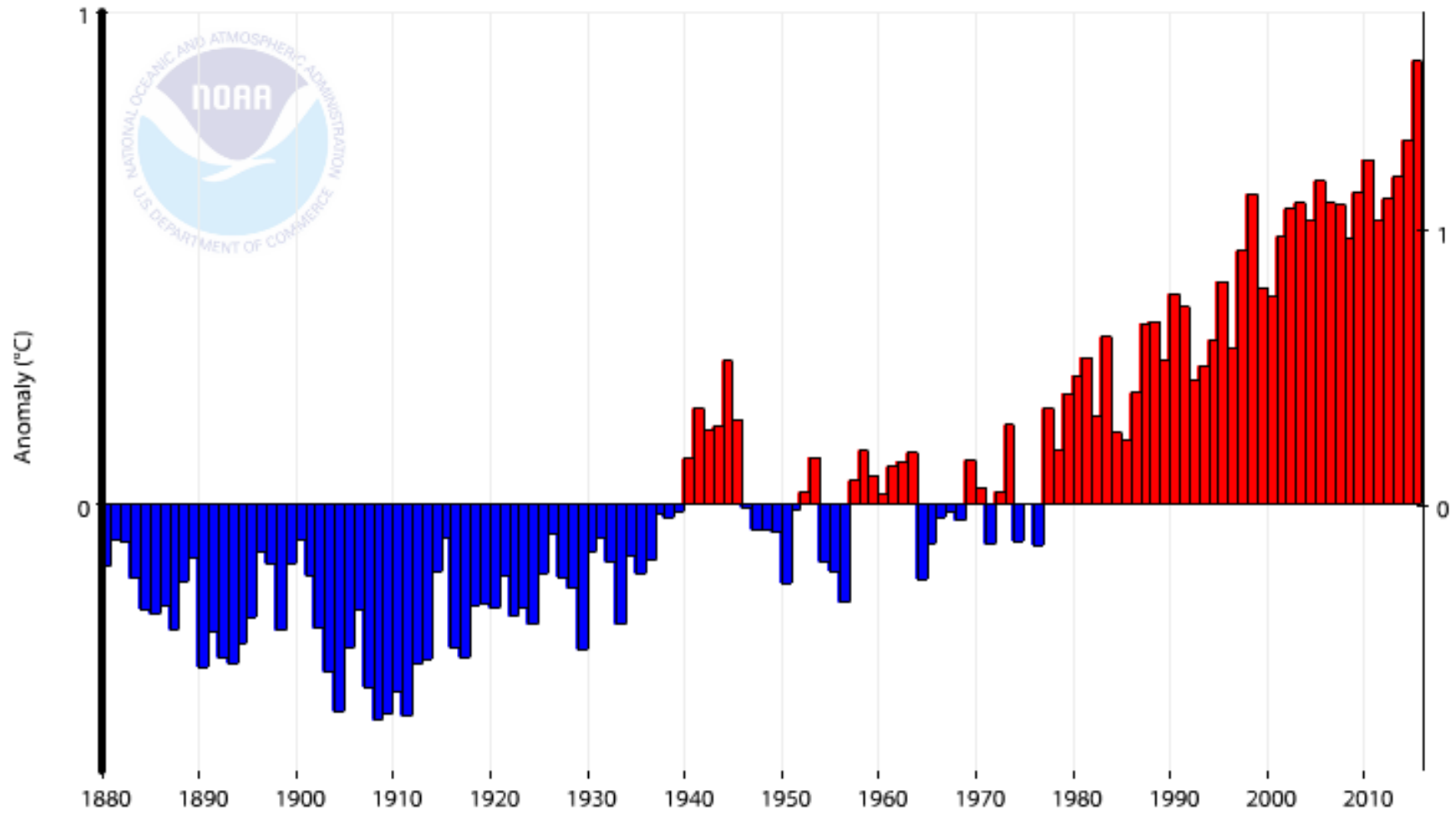


Data source: Compilation of 10 underlying datasets. See [www.epa.gov/climatechange/indicators/ghg/ghg-concentrations.html](http://www.epa.gov/climatechange/indicators/ghg/ghg-concentrations.html) for specific information.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/indicators](http://www.epa.gov/climatechange/indicators).

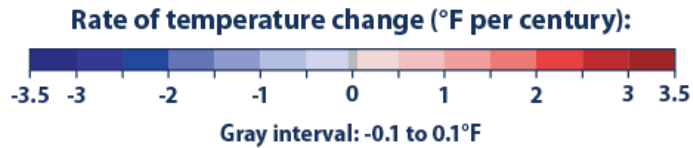
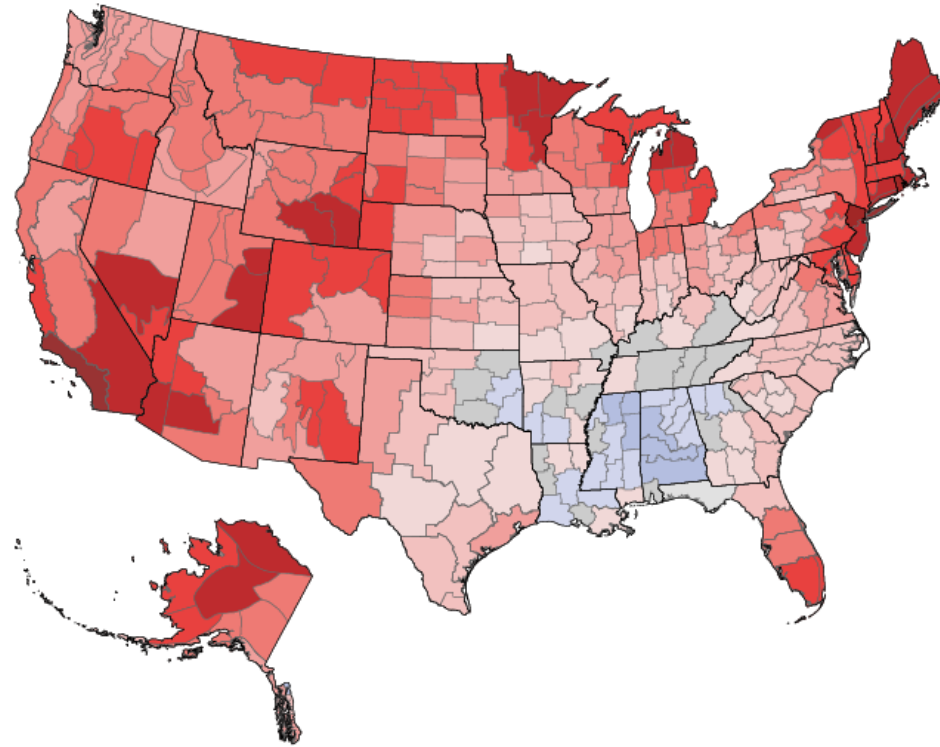
# Climate change evidence: Global temperatures are rising

Global Land and Ocean Temperature Anomalies, January-December



# Climate change evidence: U.S. temperatures are rising

Rate of Temperature Change in the United States, 1901–2014



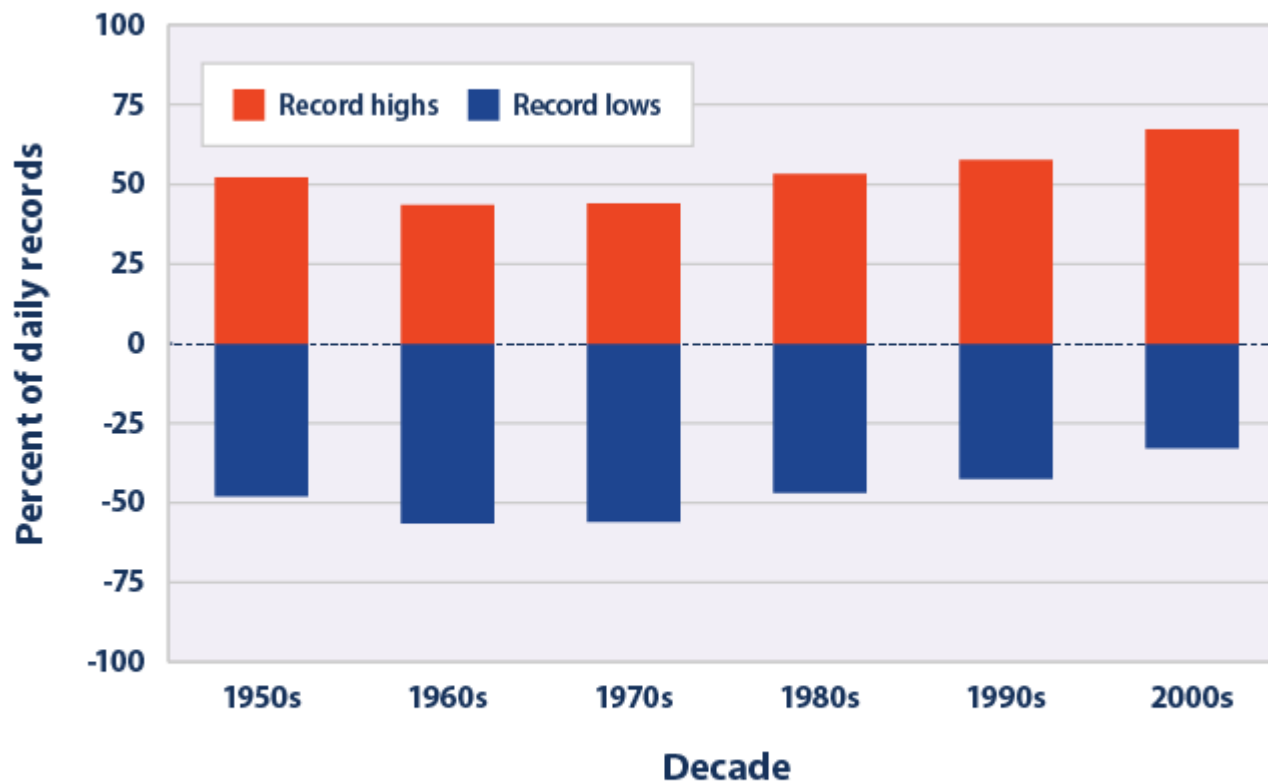
\*Alaska data start in 1925.

Data source: NOAA (National Oceanic and Atmospheric Administration). 2015. National Centers for Environmental Information. Accessed April 2015. [www.ncei.noaa.gov](http://www.ncei.noaa.gov).

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/indicators](http://www.epa.gov/climatechange/indicators).

# Climate change evidence: Record high temperatures outpacing record low temperatures

Record Daily High and Low Temperatures in the Contiguous 48 States, 1950–2009

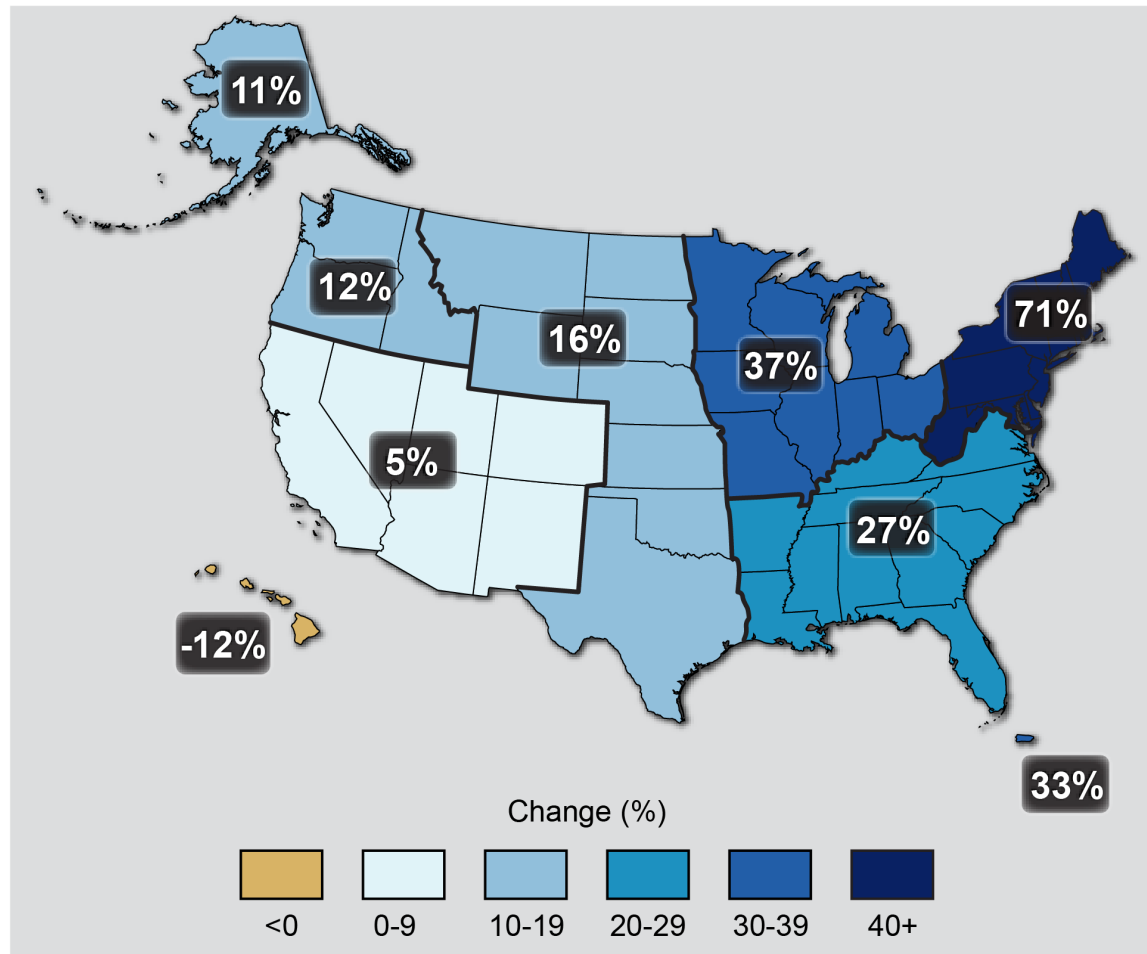


Data source: Meehl, G.A., C. Tebaldi, G. Walton, D. Easterling, and L. McDaniel. 2009. Relative increase of record high maximum temperatures compared to record low minimum temperatures in the U.S. *Geophys. Res. Lett.* 36:L23701.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/indicators](http://www.epa.gov/climatechange/indicators).

# Climate change evidence: More heavy rain and snow

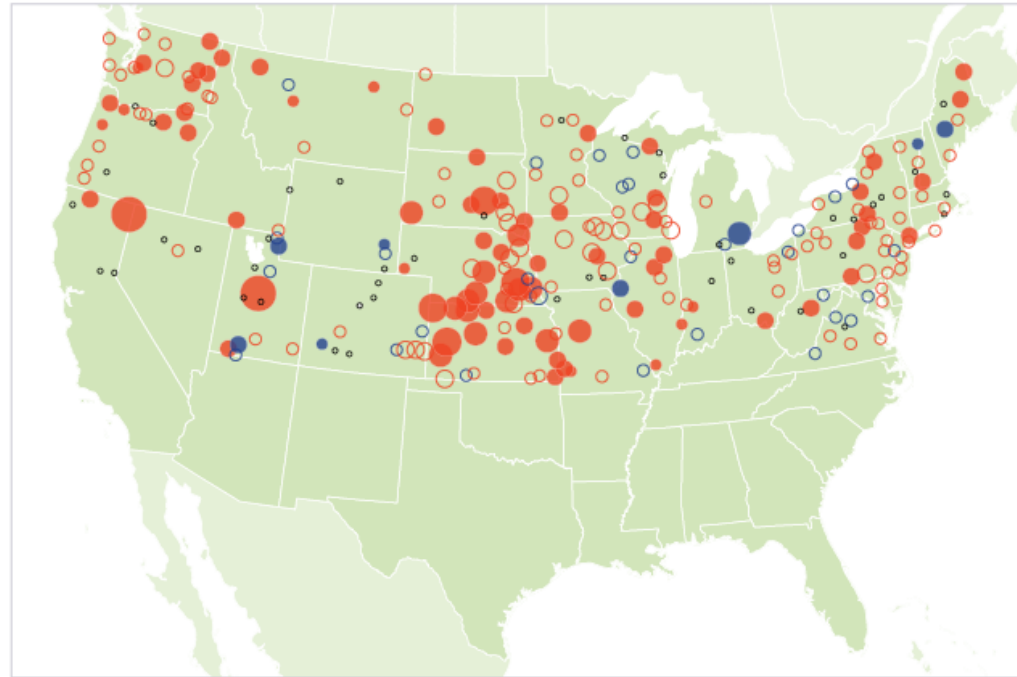
Observed Change in Very Heavy Precipitation



National Climate Assessment, 2014

# Climate change evidence: More precipitation falling as rain than snow

Change in Snow-to-Precipitation Ratio in the Contiguous 48 States, 1949–2015



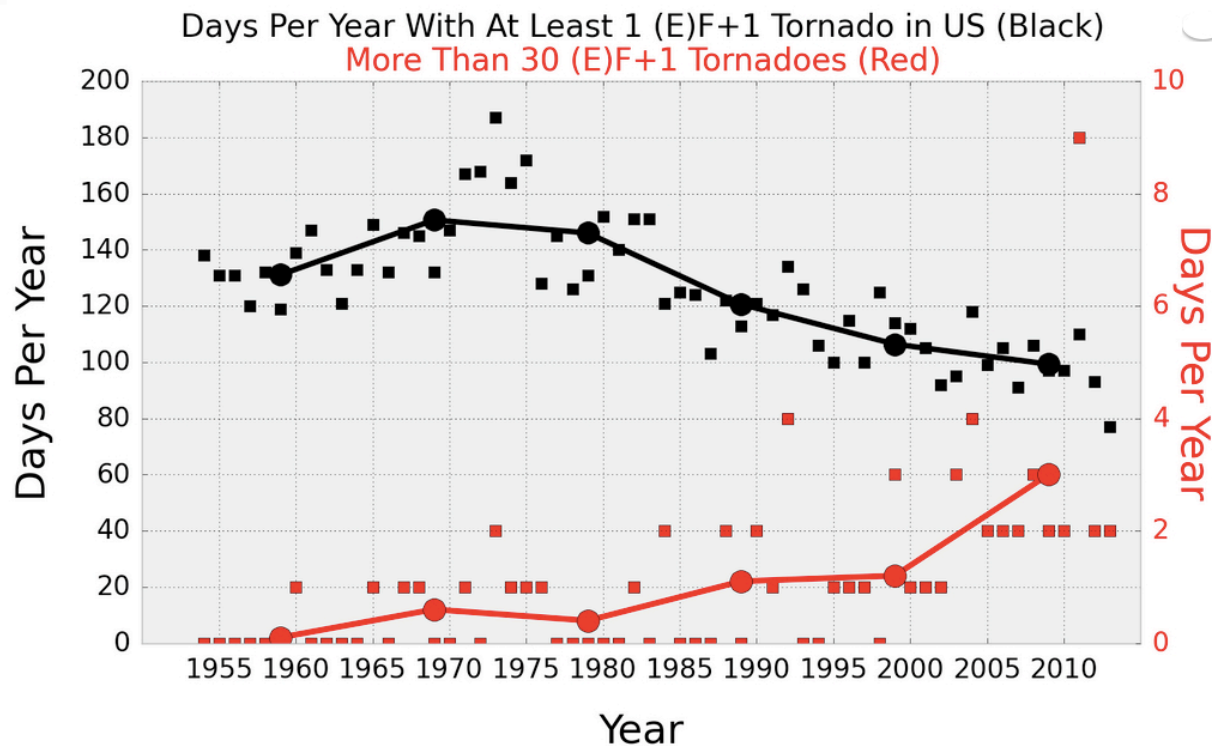
Filled circles represent statistically significant trends.  
Open circles represent trends that are not statistically significant.

Data source: NOAA (National Oceanic and Atmospheric Administration), 2015. National Centers for Environmental Information. Accessed May 2015. [www.ncdc.noaa.gov](http://www.ncdc.noaa.gov).

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/indicators](http://www.epa.gov/climatechange/indicators).

# Tornadoes increasingly coming in packs

2014 studies (Elsner et al. and Brooks et al.): Big tornado outbreaks featuring densely concentrated tornado outbreaks on the rise



# Climate change evidence: Little overall trend in drought, but regional droughts intensified

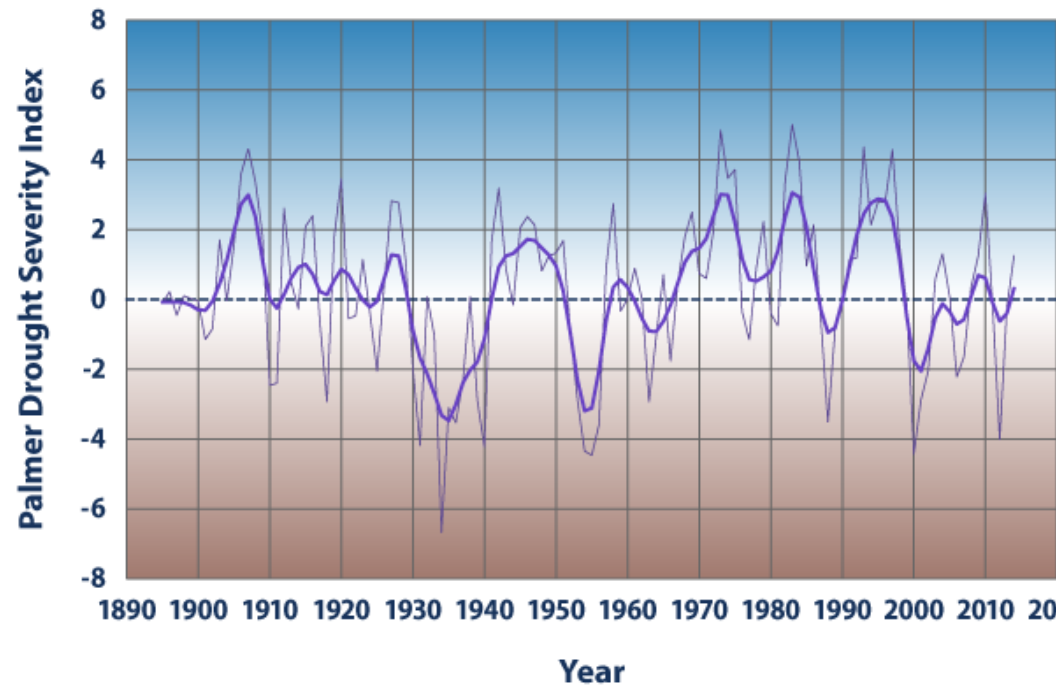
trend overall, but some evidence  
ional droughts intensified

California Sierra Nevada snowpack  
s lowest in 500 years last spring; no  
ow on Apr. 1 – normal 66.5” (1<sup>st</sup> time  
record)

August 2015 study on California  
drought: “Precipitation is the primary  
ver of drought variability but  
thropogenic warming is estimated to  
ve accounted for 8–27% of the  
served drought anomaly in 2012–  
14 and 5–18% in 2014.”

[onlinelibrary.wiley.com/doi/  
10.1002/2015GL064924/full](http://onlinelibrary.wiley.com/doi/10.1002/2015GL064924/full)

Average Drought Conditions in the Contiguous 48 States, 1895–2014

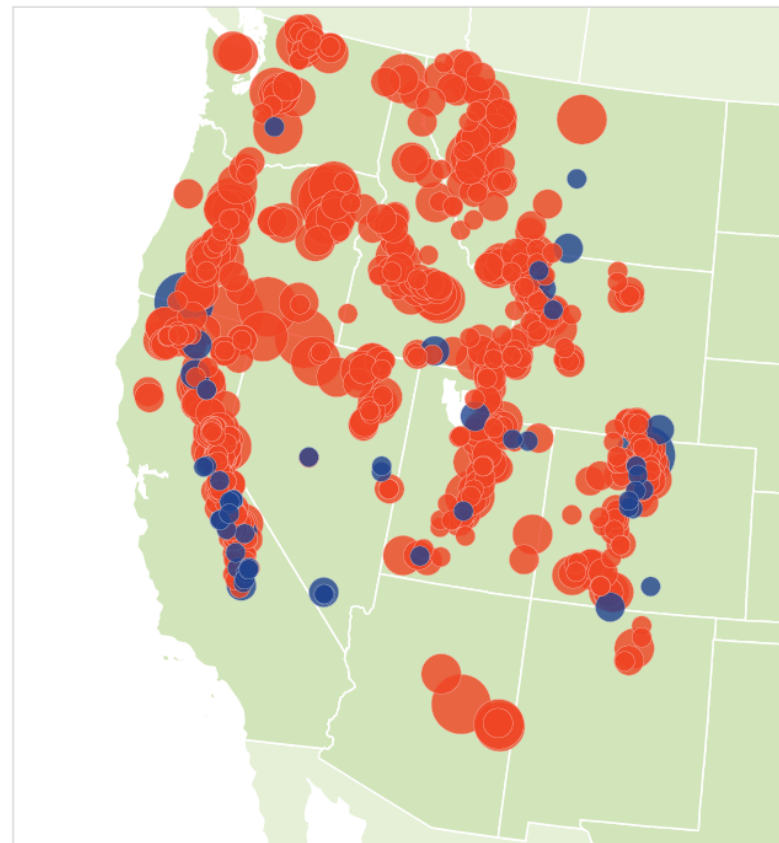


Data source: NOAA (National Oceanic and Atmospheric Administration). 2015. National Centers for Environmental Information. Accessed March 2015. [www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.js](http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.js).

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/in](http://www.epa.gov/climatechange/in)

# Climate change evidence: Declining western snowpack

Trends In April Snowpack In the Western United States, 1955–2015



Percent change:

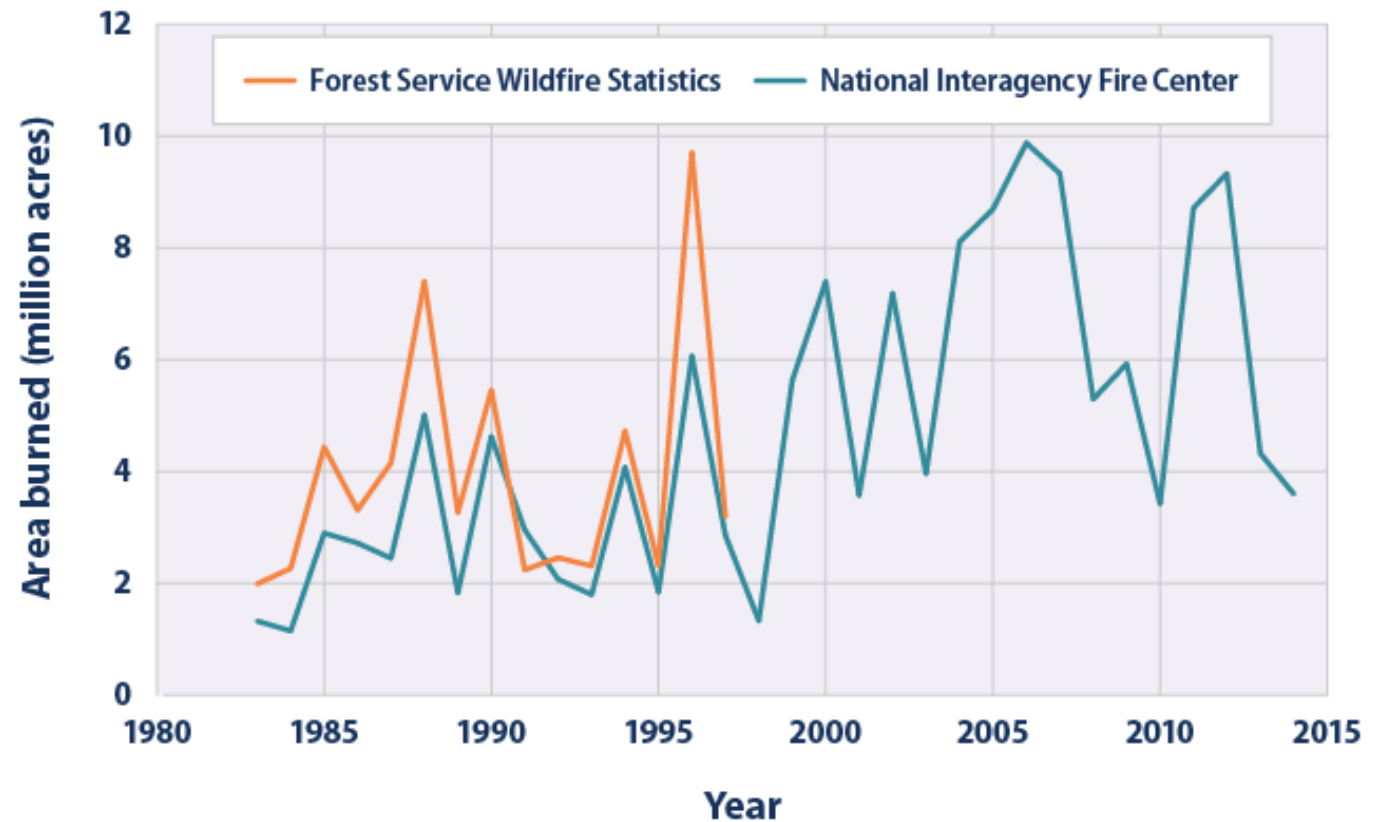


Data source: Mote, P.W., and D. Sharp. 2015 update to data originally published in: Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier. 2005. Declining mountain snowpack in Western North America. *B. Am. Meteorol. Soc.* 86(1):39–49.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/indicators](http://www.epa.gov/climatechange/indicators).

# Wildfire trends

Wildfire Extent in the United States, 1983–2014



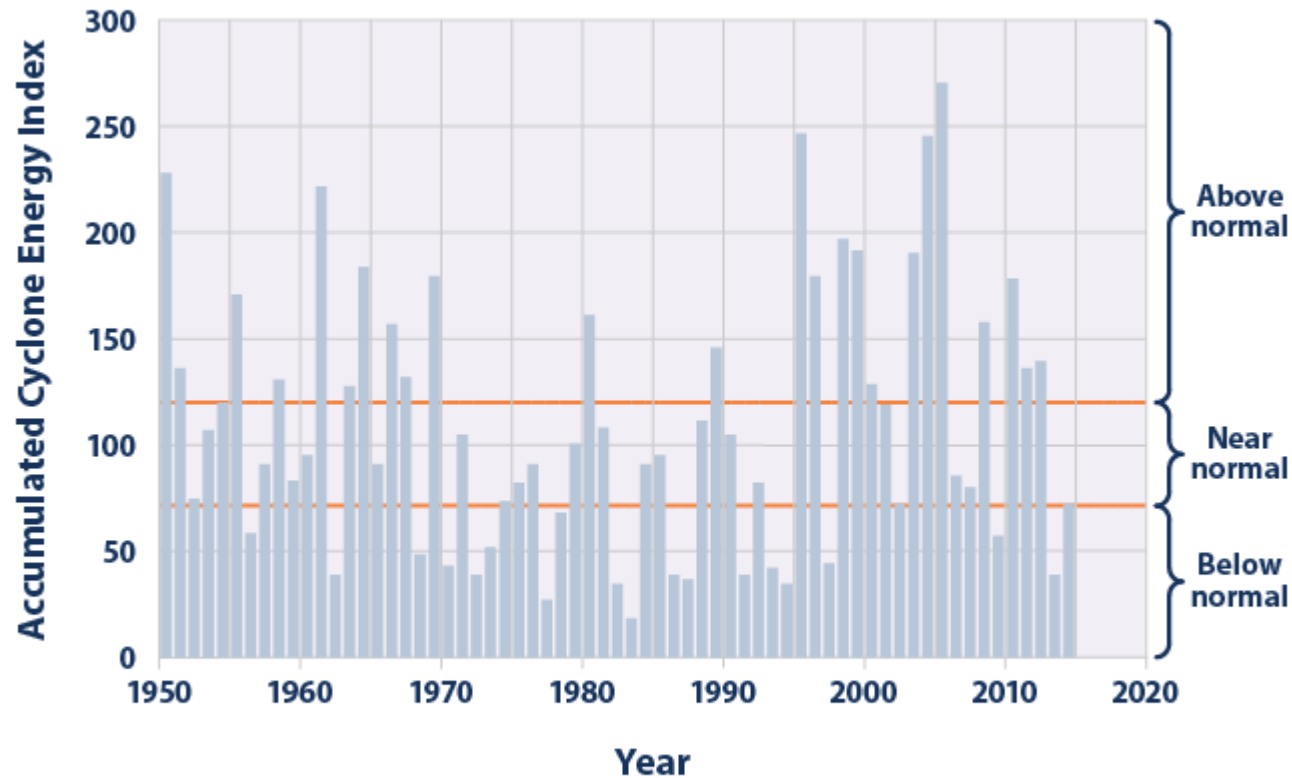
Data sources:

- NIFC (National Interagency Fire Center). 2015. Total wildland fires and acres (1960–2014). Accessed March 2015. [www.nifc.gov/fireInfo/fireInfo\\_stats\\_totalFires.html](http://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html).
- USDA (U.S. Department of Agriculture) Forest Service. 2014. 1991–1997 wildland fire statistics. Prepared by USDA Forest Service, State and Private Forestry, Fire and Aviation Management staff, and supplemented with historical records provided by Forest Service staff, April 2014.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/indicators](http://www.epa.gov/climatechange/indicators).

# Climate change evidence: Little trend in Atlantic hurricane activity

North Atlantic Tropical Cyclone Activity According to the Accumulated Cyclone Energy Index, 1950–2014



Data source: NOAA (National Oceanic and Atmospheric Administration). 2015. The Atlantic Hurricane Database Re-analysis Project. [www.aoml.noaa.gov/hrd/hurdat/comparison\\_table.html](http://www.aoml.noaa.gov/hrd/hurdat/comparison_table.html).

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/indicators](http://www.epa.gov/climatechange/indicators).

# Major hurricane drought: Longest on record

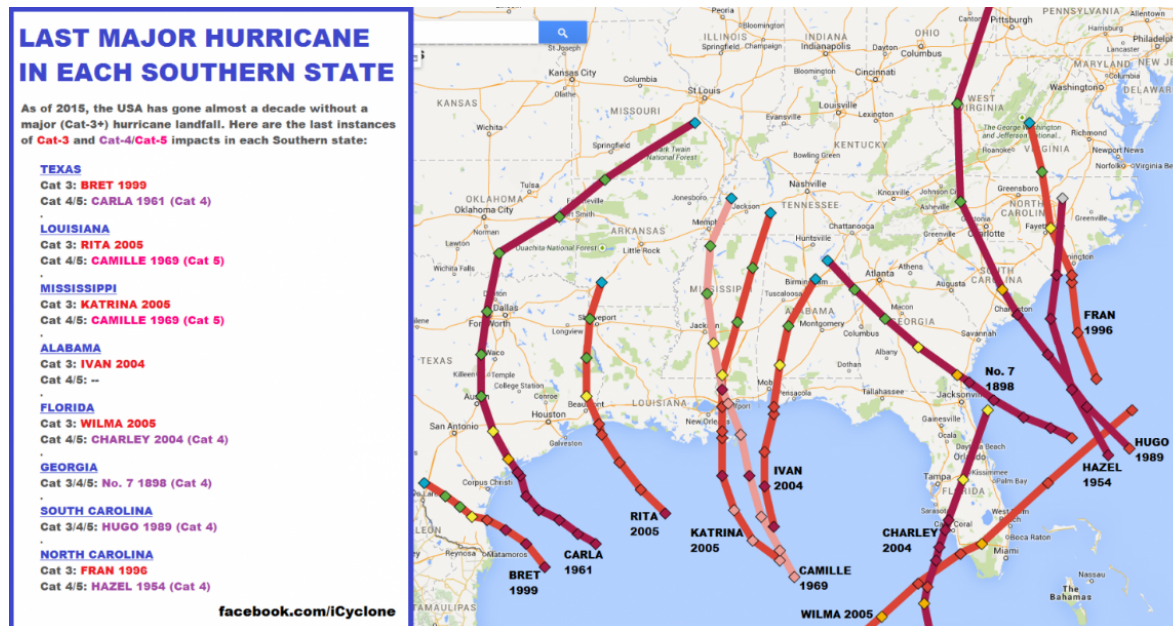
Fastest major hurricane to strike U.S.: Wilma, 2005

Florida has not been hit since 2005 (on average 3 hit every 4 years)

Vulnerability increasing? Complacency, coastal population increase and development boom

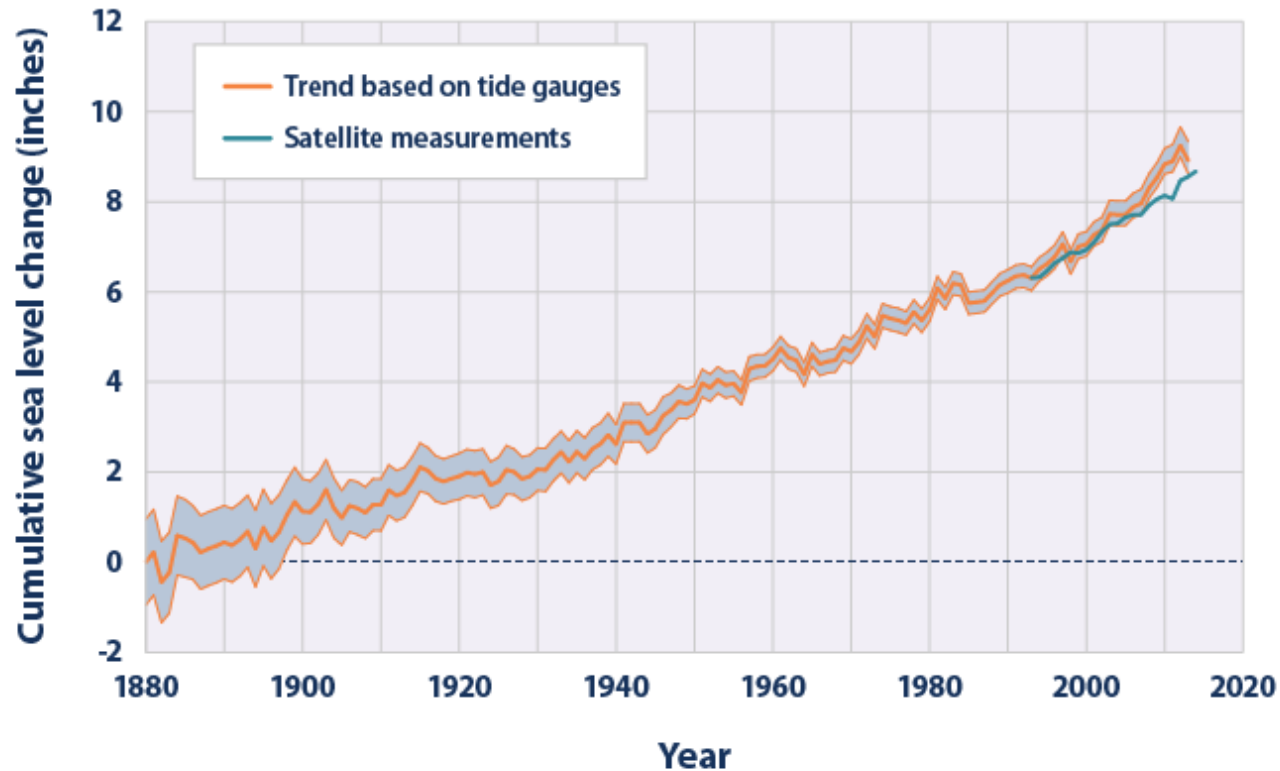
Category can be misleading: Sandy (Cat 1) and Ike (Cat 2) very destructive but not major

This is not evidence for or against climate change



# Climate change evidence: Rising seas

Global Average Absolute Sea Level Change, 1880–2014



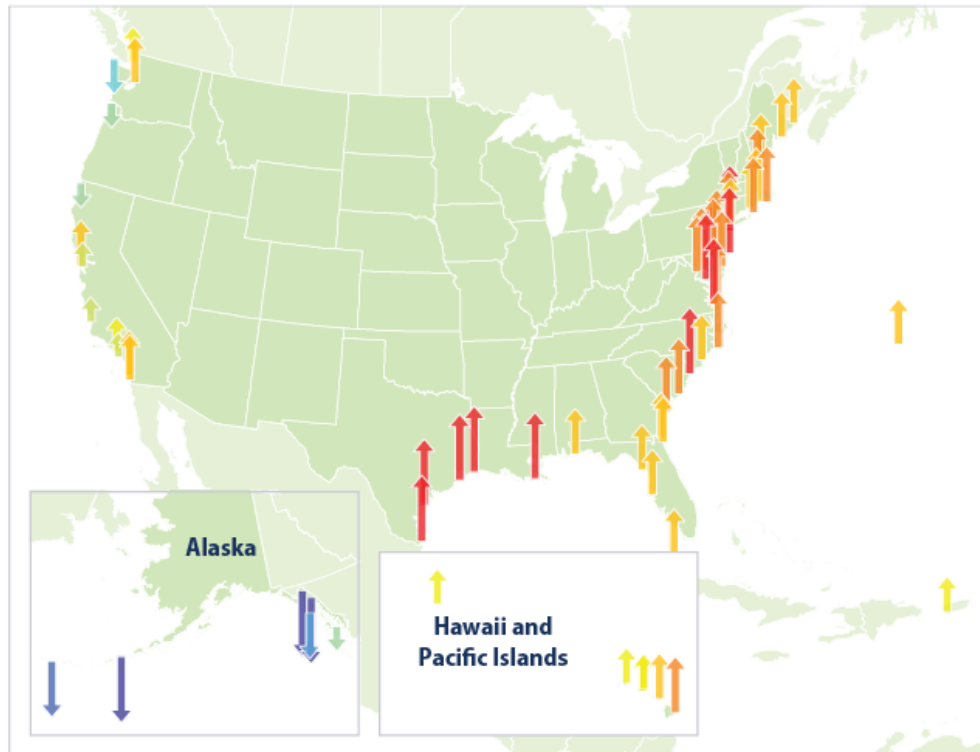
Data sources:

- CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2015 update to data originally published in: Church, J.A., and N.J. White. 2011. Sea-level rise from the late 19th to the early 21st century. *Surv. Geophys.* 32:585–602. [www.cmar.csiro.au/sealevel/sl\\_data\\_cmar.html](http://www.cmar.csiro.au/sealevel/sl_data_cmar.html).
- NOAA (National Oceanic and Atmospheric Administration). 2015. Laboratory for Satellite Altimetry: Sea level rise. Accessed June 2015. [http://ibis.grdl.noaa.gov/SAT/SeaLevelRise/LSA\\_SLR\\_timeseries\\_global.php](http://ibis.grdl.noaa.gov/SAT/SeaLevelRise/LSA_SLR_timeseries_global.php).

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/indicators](http://www.epa.gov/climatechange/indicators).

# Climate change evidence: Rising seas (2/2)

Relative Sea Level Change Along U.S. Coasts, 1960–2014



Relative sea level change (inches):



Data source: NOAA (National Oceanic and Atmospheric Administration). 2015 update to data originally published in: NOAA. 2009. Sea level variations of the United States 1854–2006. NOAA Technical Report NOS CO-OPS 053. [www.tidesandcurrents.noaa.gov/publications/Tech\\_rpt\\_53.pdf](http://www.tidesandcurrents.noaa.gov/publications/Tech_rpt_53.pdf).

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climatechange/indicators](http://www.epa.gov/climatechange/indicators).

- NOAA: 300-925 percent increase in nuisance flooding since 1960s U.S. coasts

[http://www.noaanews.noaa.gov/stories2014/20140728\\_nuisanceflooding.htm](http://www.noaanews.noaa.gov/stories2014/20140728_nuisanceflooding.htm)

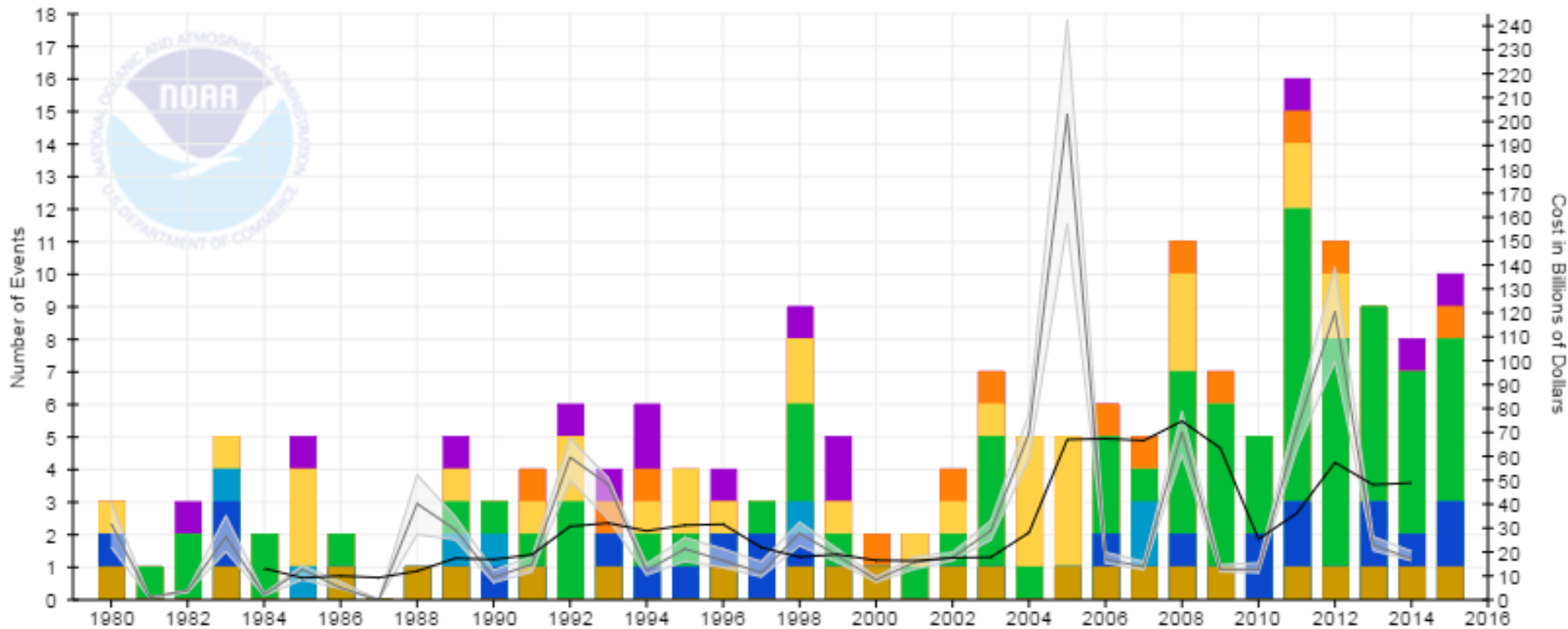
- Study, September 2015 (PNAS): In NYC, 500 year flood is now 25 year flood – flood heights have risen 4 feet since 850 AD

<http://www.pnas.org/content/early/2015/09/24/1513127112>

# Climate change evidence: Billion dollar weather disasters in the U.S.

Billion-Dollar Disaster Event Types by Year (CPI-Adjusted)

- Winter Storm
- Wildfire
- Trop Cycl
- Severe Storm
- Freeze
- Flooding
- Drought
- Cost w/ 95% CI
- 5-Year Mean



# Observed evidence conclusions

Warming signal consistent across indicators

Increasing warm weather extremes (and fewer cold weather extremes)

Increasing heavy precipitation

No apparent trend in hurricanes and drought in U.S. (“Other trends in severe storms, including the intensity & frequency of tornadoes, hail, and damaging thunderstorm winds, are uncertain” – U.S. Climate Assessment, 2014)

Climate signal in disaster losses inconclusive and controversial; exposure the biggest driver

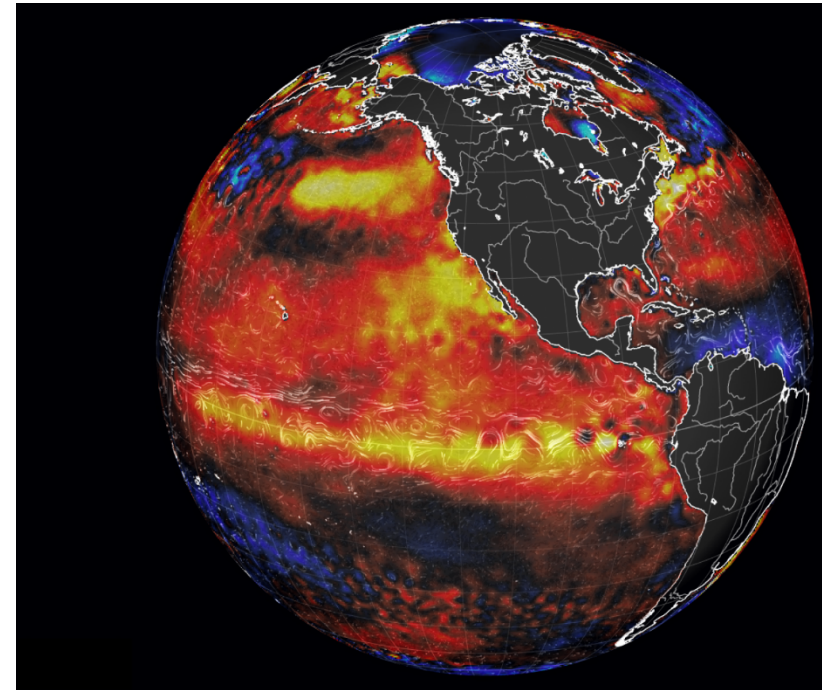


# The near term forecast: Through the summer

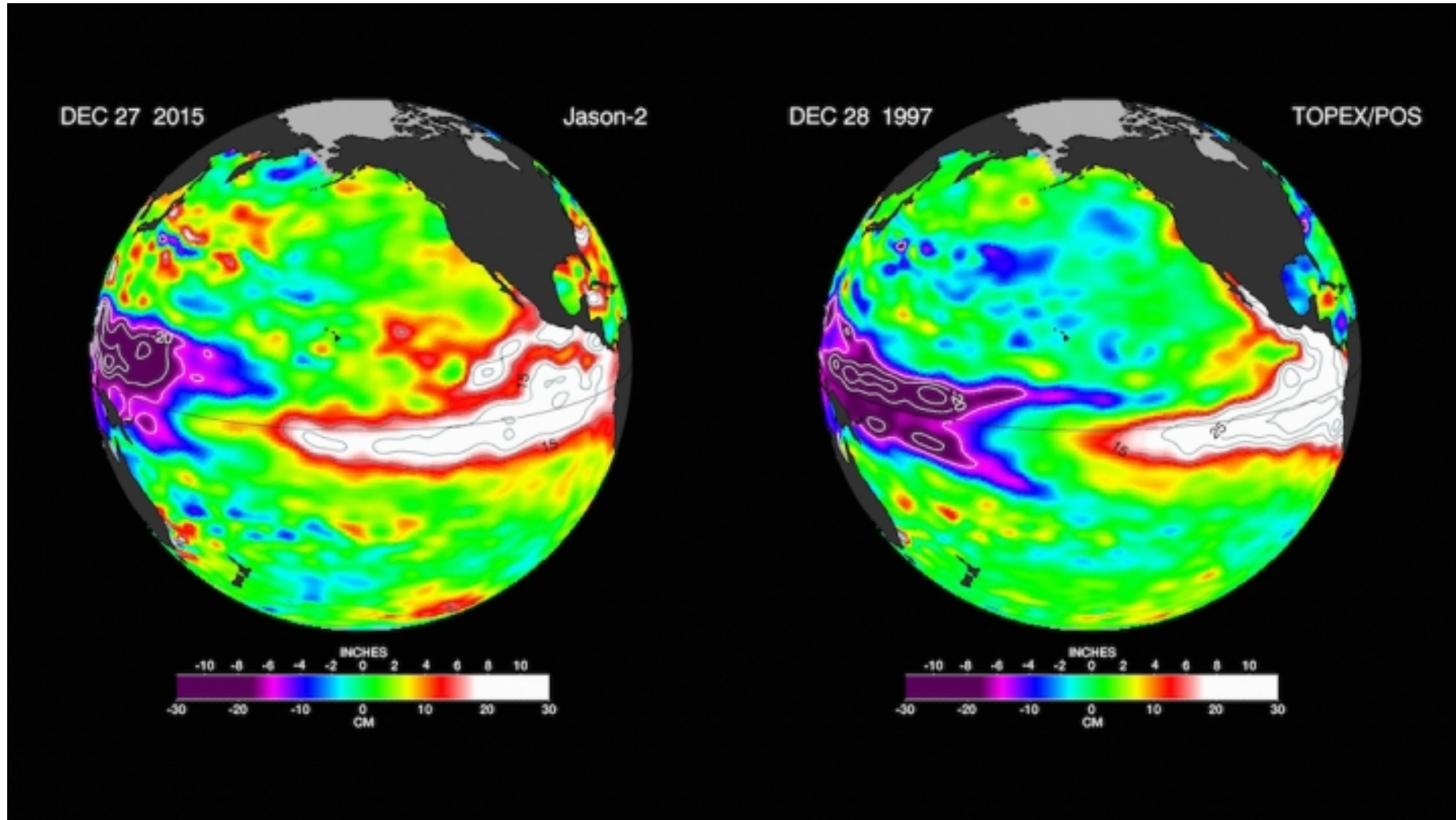
El Nino to wane

California drought to continue

Potential for hot summer

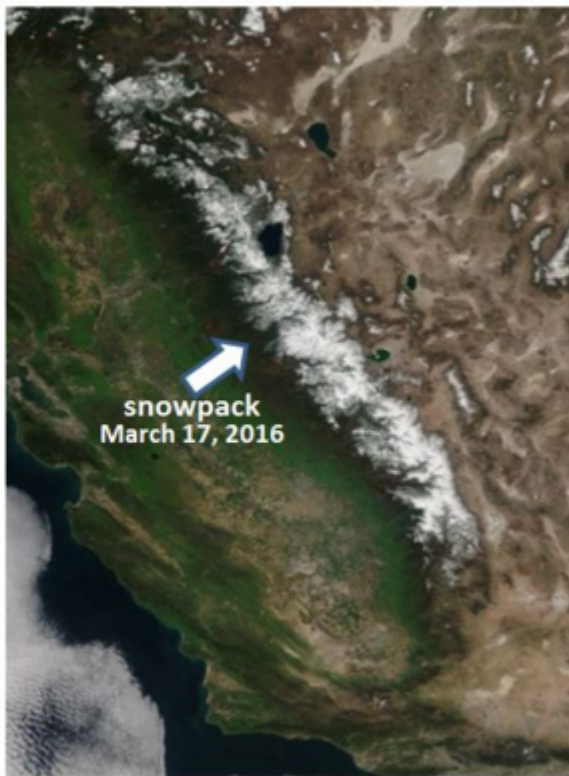


# 2015-2016 El Niño: Among the strongest on record



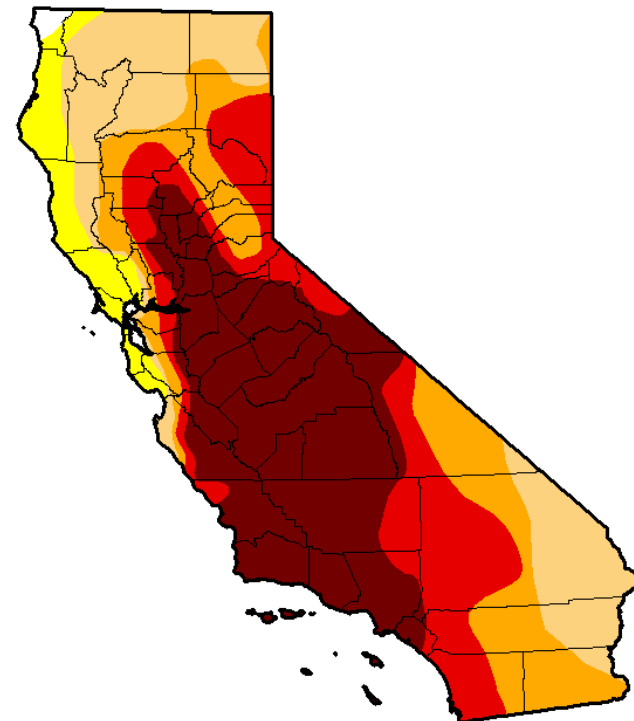
# California water situation

Snowpack situation has improved, but drought is still serious



NOAA

## U.S. Drought Monitor California



March 15, 2016  
(Released Thursday, March 10, 2016)  
Valid 8 a.m. EDT

	Drought Condition		
	None	D0-D4	D1-D4
Current	0.43	99.57	93.28
Last Week 3/8/2016	0.43	99.57	97.49
3 Months Ago 12/15/2015	0.14	99.86	97.33
Start of Calendar Year 12/29/2015	0.00	100.00	97.33
Start of Water Year 9/29/2015	0.14	99.86	97.33
One Year Ago 3/17/2015	0.16	99.84	98.11

**Intensity:**

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extremely Dry
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text for forecast statements.

**Author:**  
Richard Heim  
NCEI/NOAA

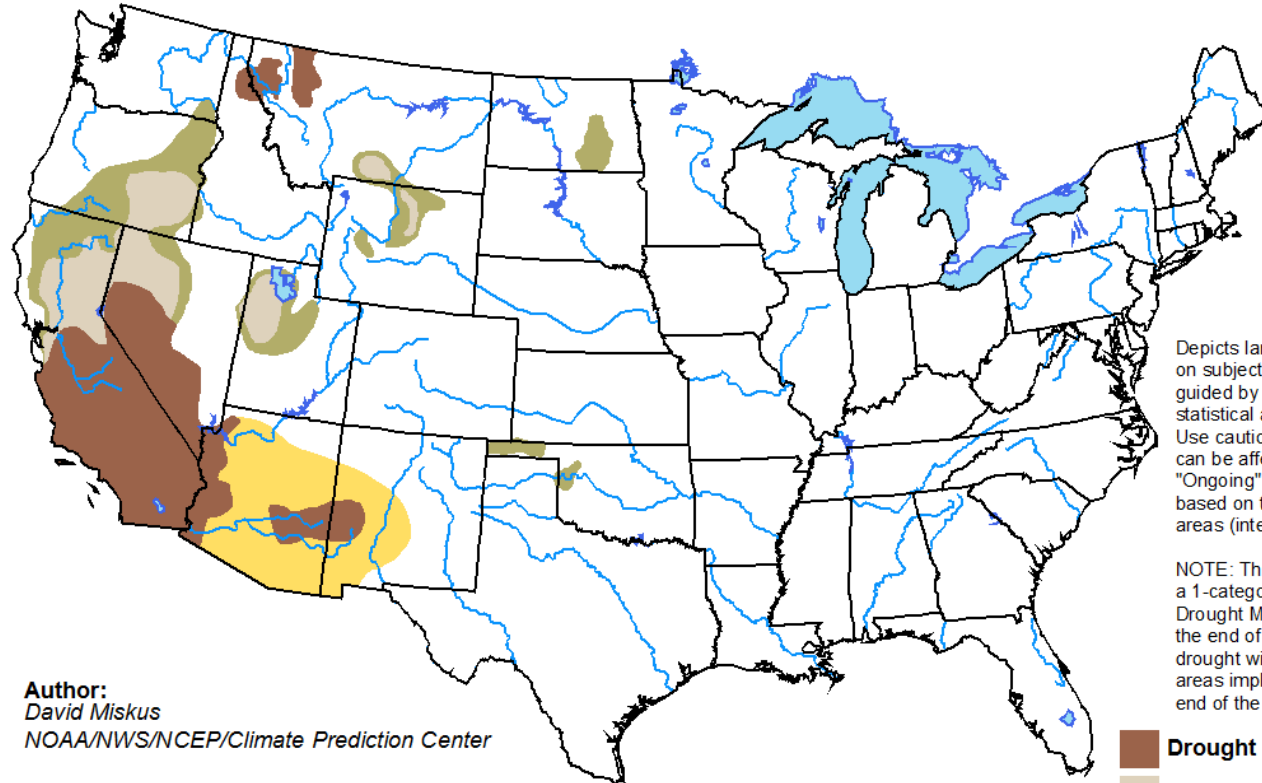


<http://droughtmonitor.noaa.gov>

# OAA Spring Drought Outlook

## U.S. Seasonal Drought Outlook Drought Tendency During the Valid Period





Valid for March 17 - June 30, 2016  
Released March 17, 2016

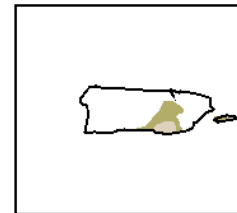
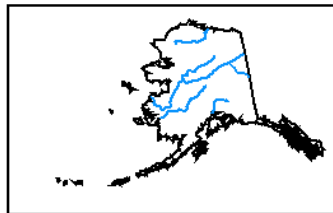


Author:  
David Miskus  
NOAA/NWS/NCEP/Climate Prediction Center

Depicts large-scale trends based on subjectively derived probabilities guided by short- and long-range statistical and dynamical forecasts. Use caution for applications that can be affected by short lived events. "Ongoing" drought areas are based on the U.S. Drought Monitor areas (intensities of D1 to D4).

NOTE: The tan areas imply at least a 1-category improvement in the Drought Monitor intensity levels by the end of the period, although drought will remain. The green areas imply drought removal by the end of the period (D0 or none).

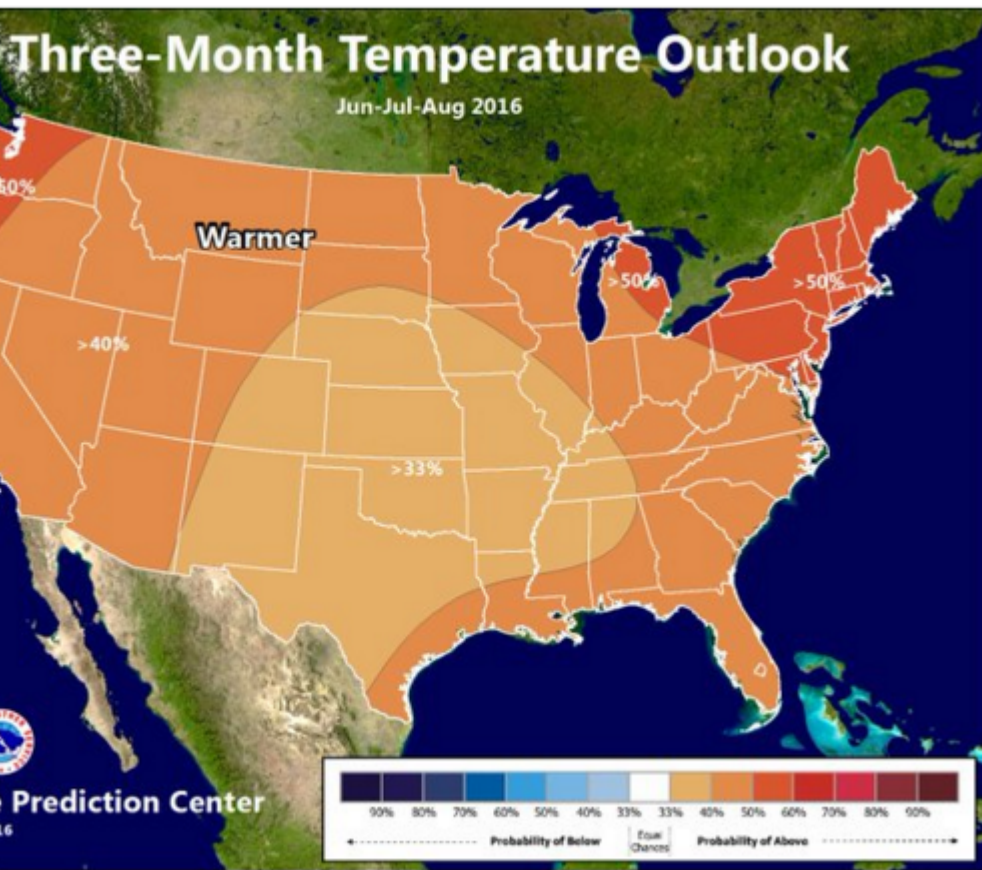
-  Drought persists
-  Drought remains but improves
-  Drought removal likely
-  Drought development likely



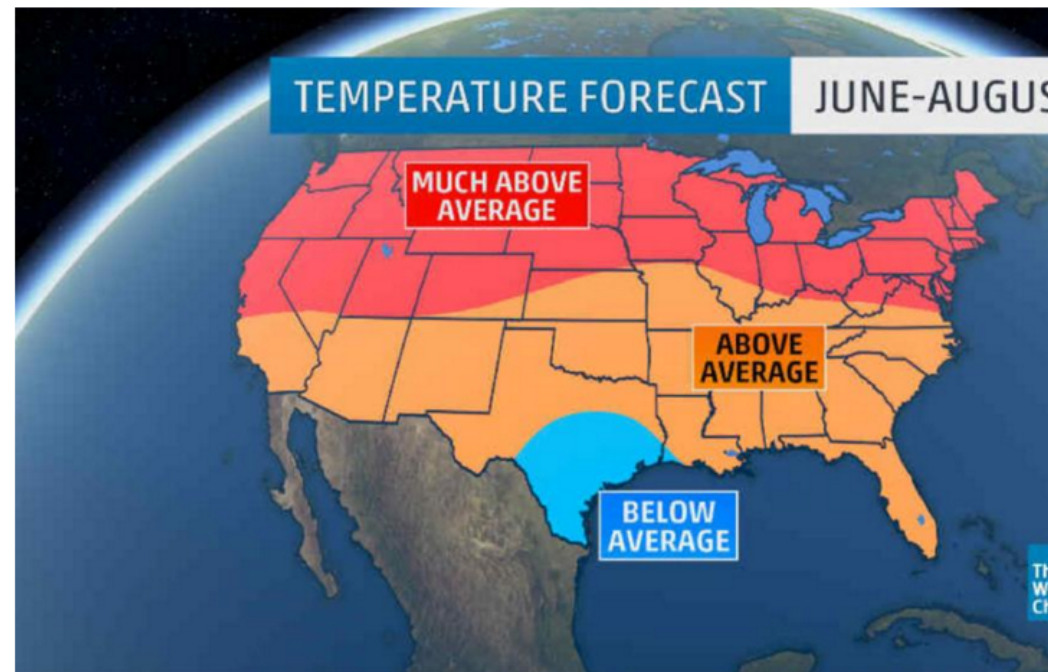
<http://go.usa.gov/3eZ73>

# he summer?

Summers following big El Ninos have been hot: 1998, 20  
- for example



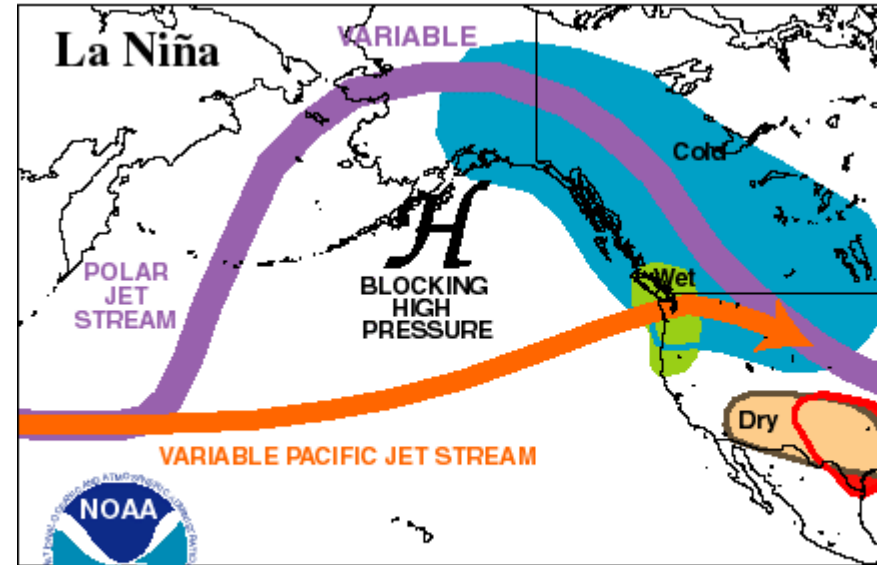
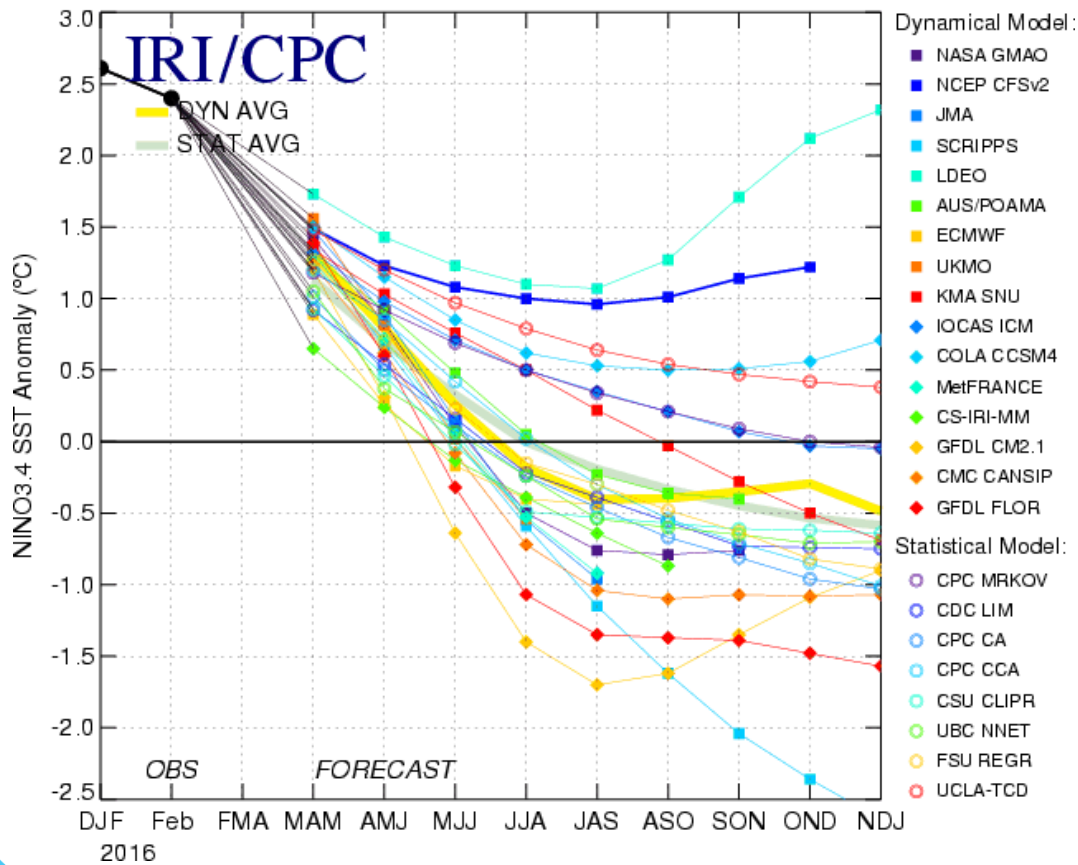
NOAA



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# Is a Nina on the way for next winter?

Mid-Mar 2016 Plume of Model ENSO Predictions



Climate Prediction Center/NCEP/NWS

# the long-term outlook

A warmer world

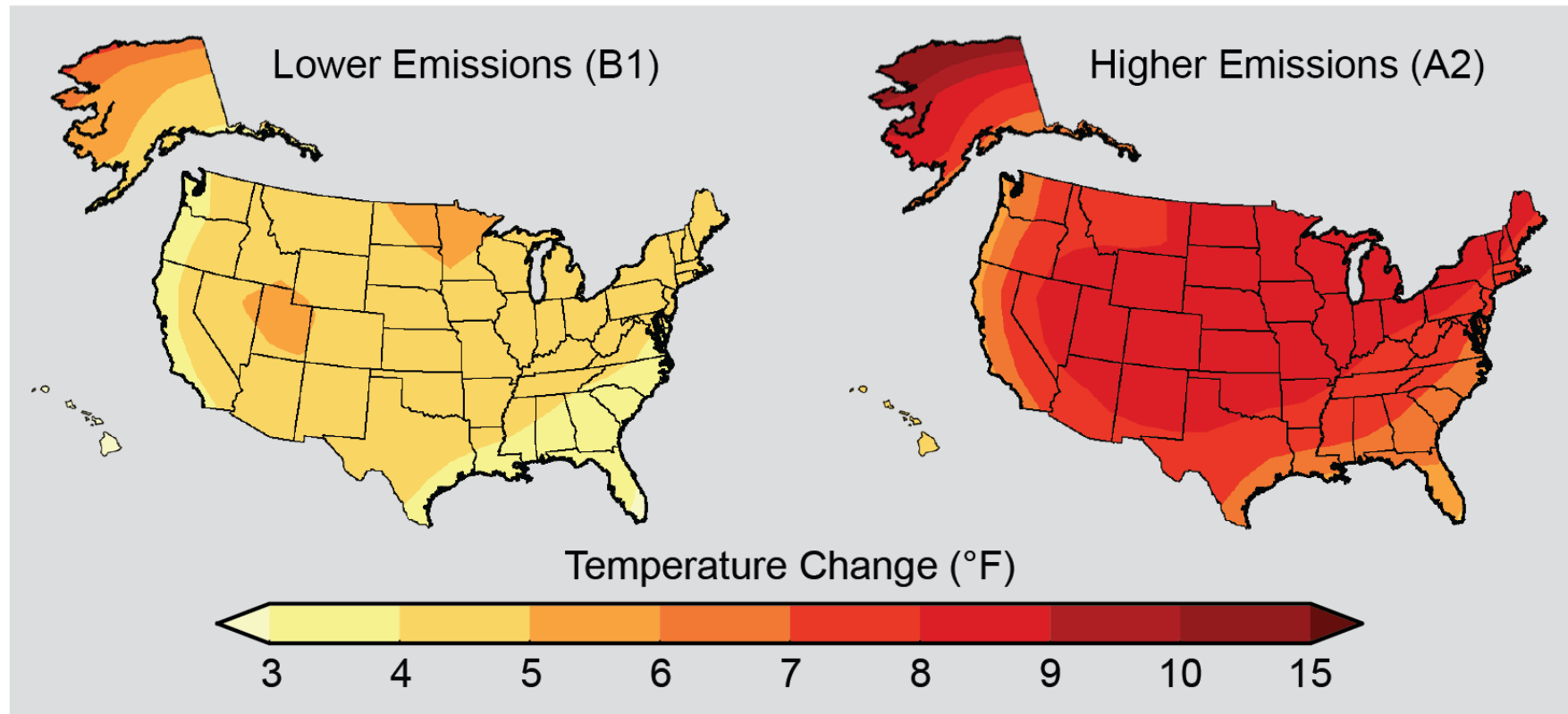
A wetter world

A more extreme world?



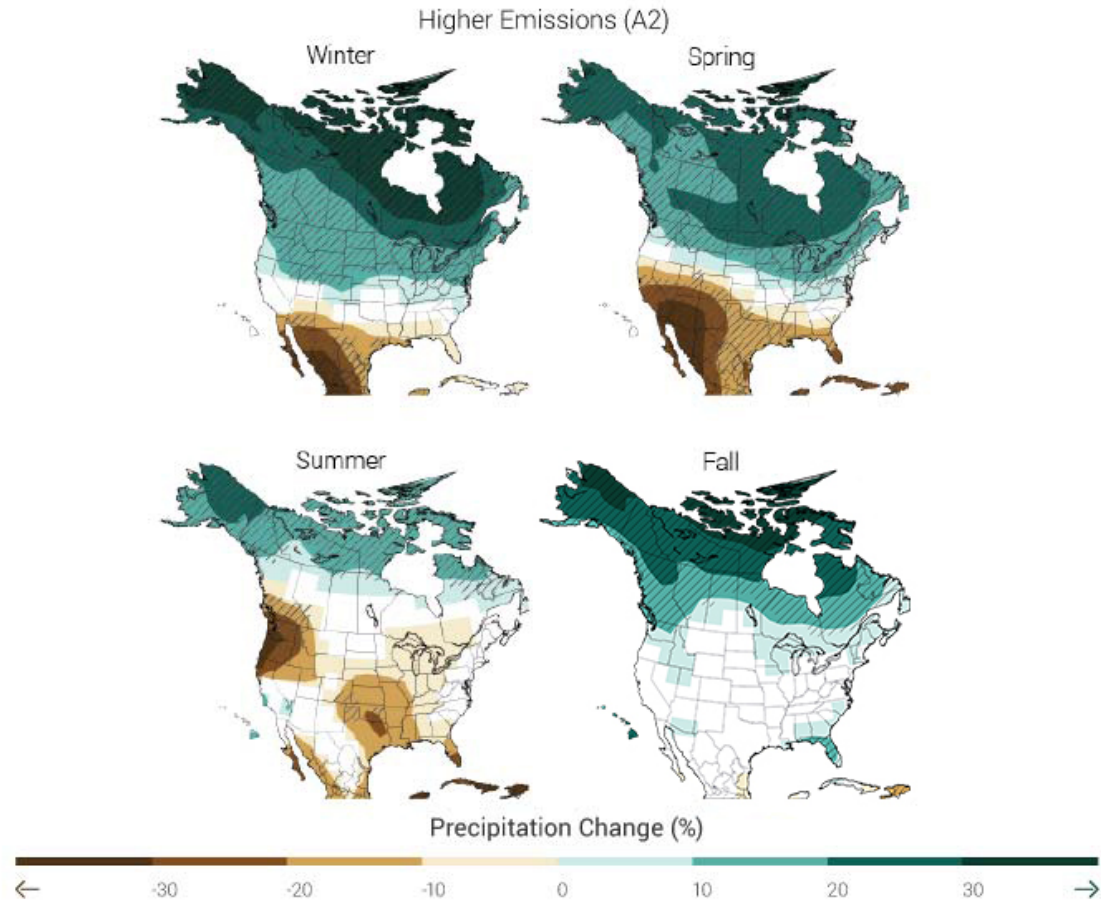
# U.S. Temperatures: Substantial warming, especially for high emissions

Projected Temperature Change



# U.S. Precipitation: Wetter north, drier south

Projected Precipitation Change by Season



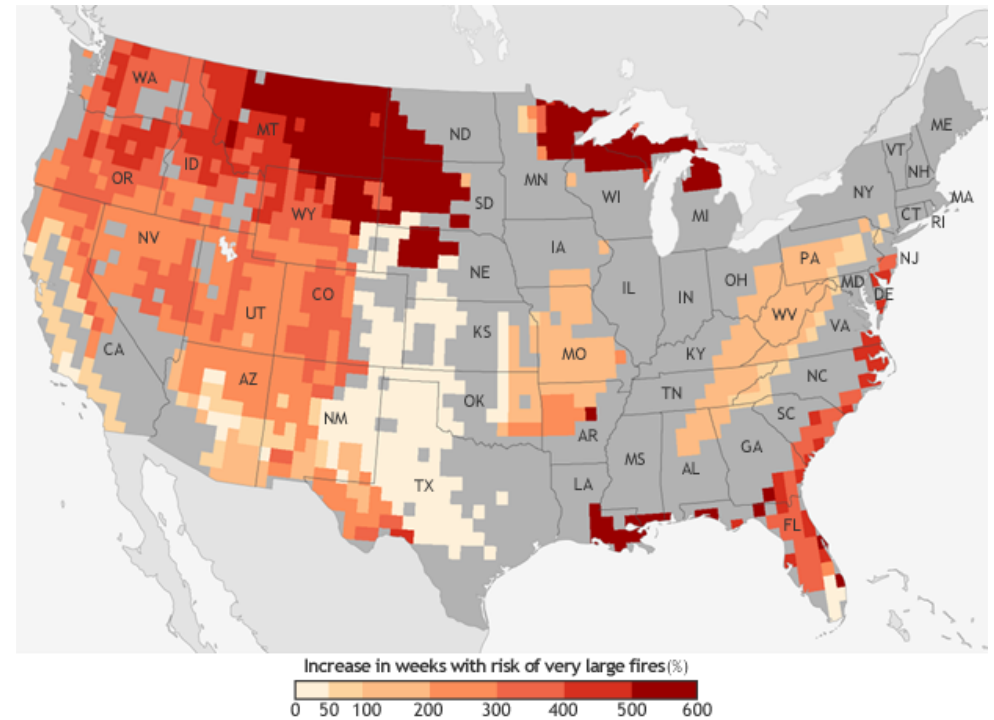
National Climate Assessment, 2014

# Wildfire risk to increase

DAA: Possible six-fold increase in weeks w/ risk of very large fires by mid century

EPA 2015 report: By 2100, twice as much land burning per year – representing area exceeding the size of Massachusetts. (<http://www2.epa.gov/cira/climate-impacts-benefits-wildfire>)

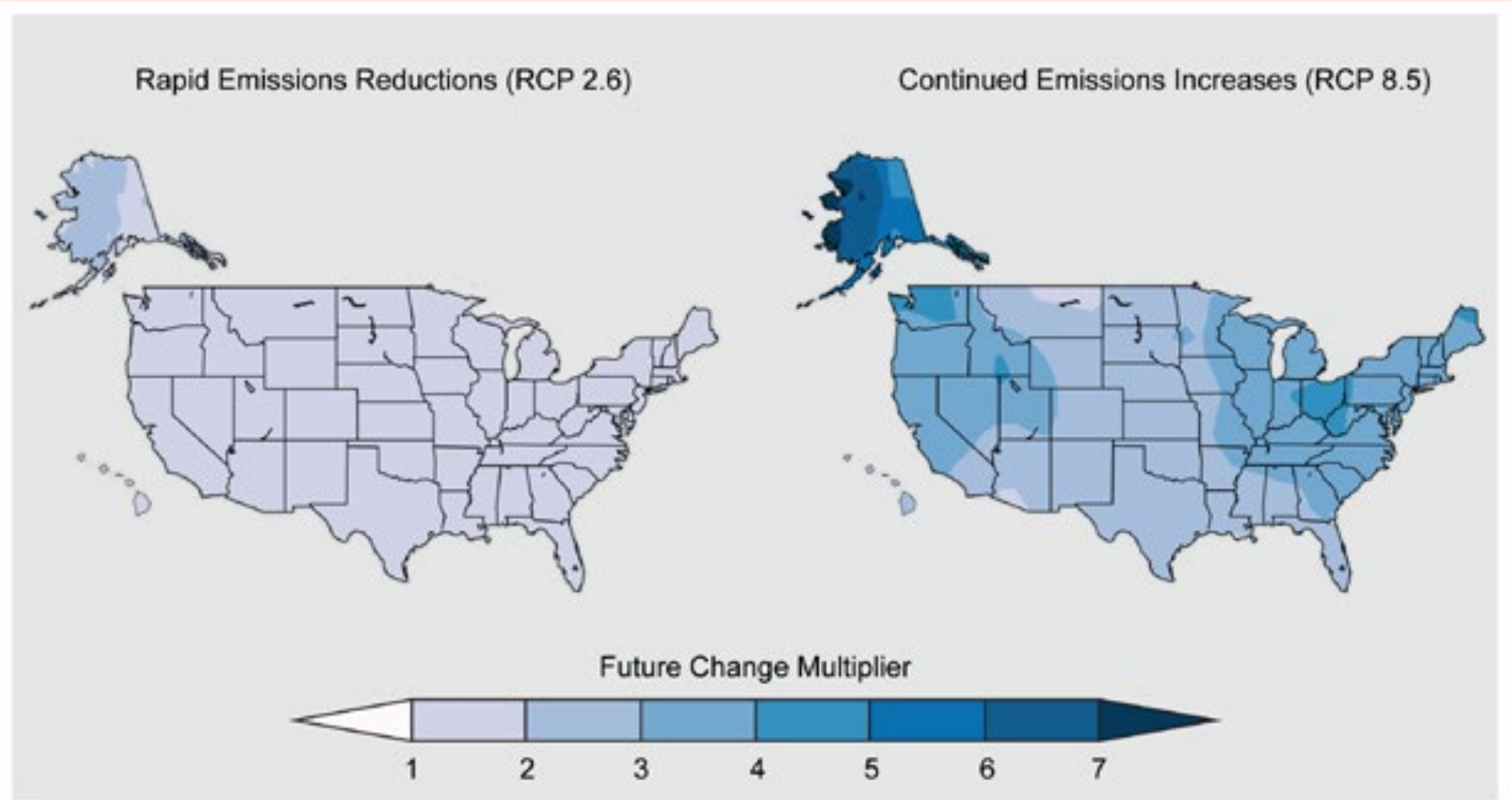
US Forest Service expects to spend \$1.1 billion on fire suppression in 2014, expects to spend \$1.8 billion in a decade



<https://www.climate.gov/news-features/featured-images/risk-very-large-fires-could-increase-sixfold-mid-century-us>

# Increases in extreme precipitation

## Projected Change in Heavy Precipitation Events



# Tornadoes and thunderstorms: Uncertainty on future changes

2013 study (Diffenbaugh et al.): Modeling experiment shows increase in number of days with favorable tornado ingredients in warmer world



# Hurricanes: Gradual increase in intensity projected to emerge

Anthropogenic warming by the end of the 21st century will likely cause hurricanes globally to be more intense on average (by 2 to 11% according to model projections for an IPCC A1B scenario). This change would imply an even larger percentage increase in the destructive potential per storm, assuming no reduction in storm size.

There are better than even odds that anthropogenic warming over the next century will lead to an increase in the numbers of very intense hurricanes in some basins—an increase that would be substantially larger in percentage terms than the 2-11% increase in the average storm intensity.

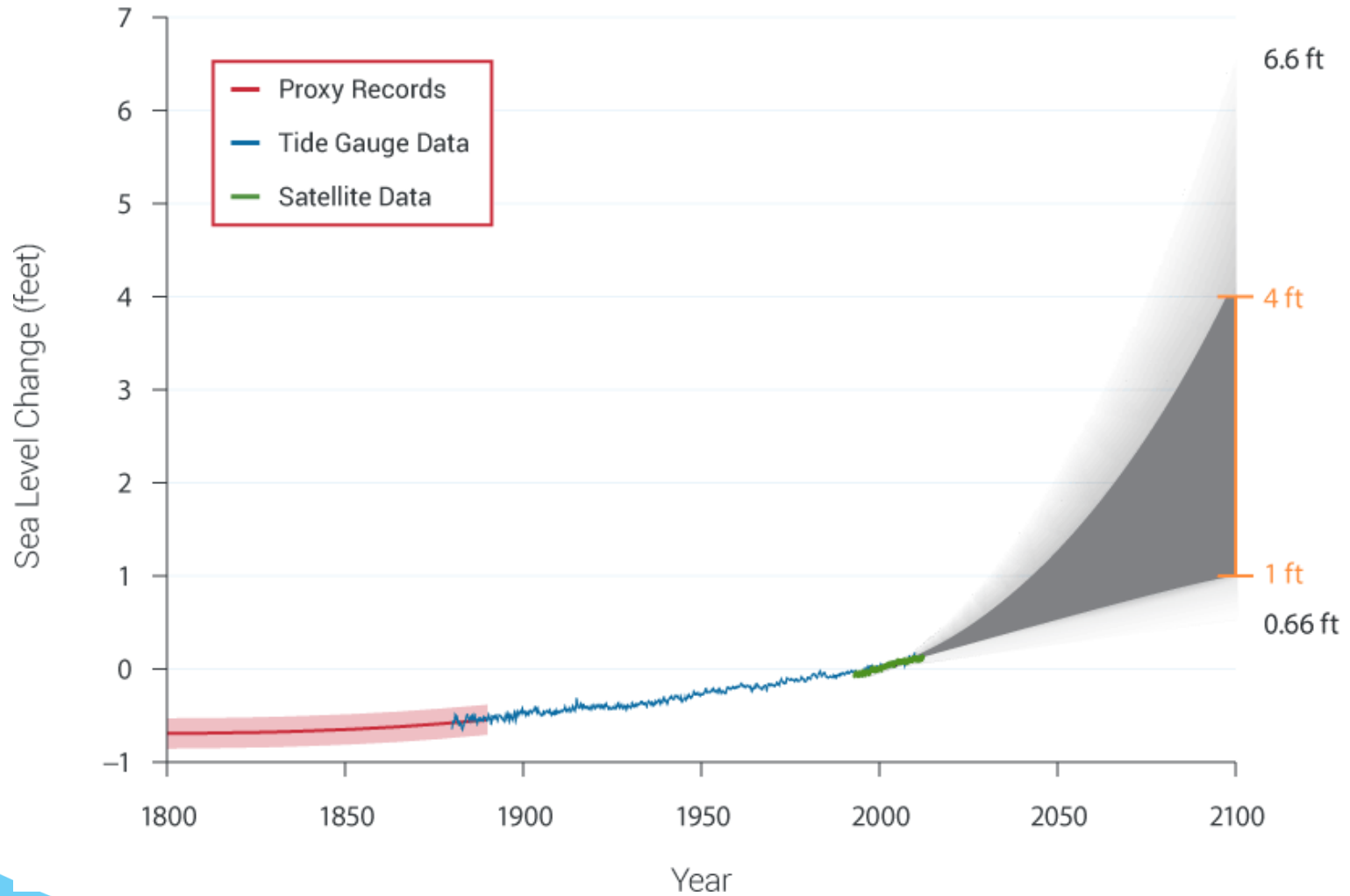
Anthropogenic warming by the end of the 21st century will likely cause hurricanes to have substantially higher rainfall rates than present-day hurricanes, with a model projected increase of about 20% for rainfall rates averaged within about 100 km of the storm center.

Source: <http://www.gfdl.noaa.gov/global-warming-and-hurricanes>



# ising seas, potentially substantially

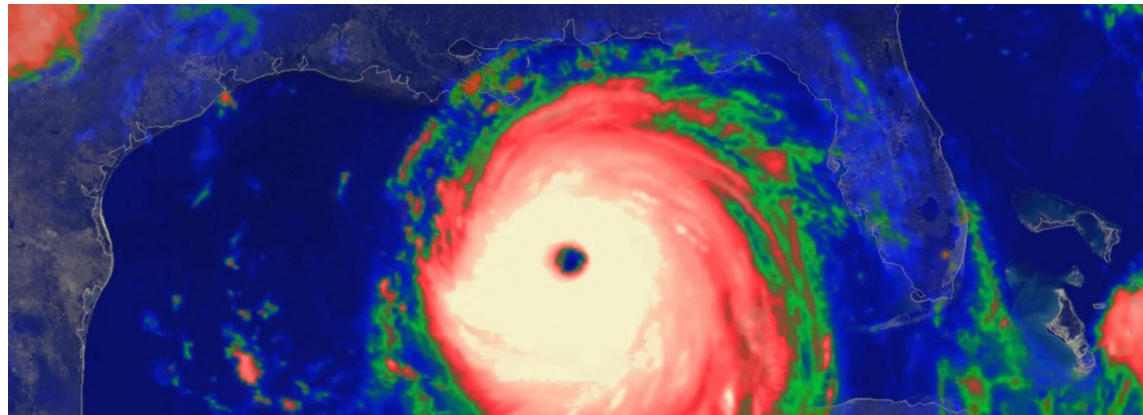
Past and Projected Changes in Global Sea Level



# Increasing risk of costly, devastating event

By 2100: “We estimate that global hurricane damage will be about double owing to demographic trends, and double again because of climate change.” – Kerry Emanuel, MIT and Robert Mendelsohn, Yale economist) (<http://fivethirtyeight.com/features/mit-climate-scientist-responds-on-disaster-costs-and-climate-change/>)

Emanuel study, 2015: Increased probability of ‘grey swan’ - Hurricane w/ 20 ft storm surge in Tampa goes from 1 in 10K yr event to 1 in 700-2,500 yr event in 2100 (<http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2777.html>)

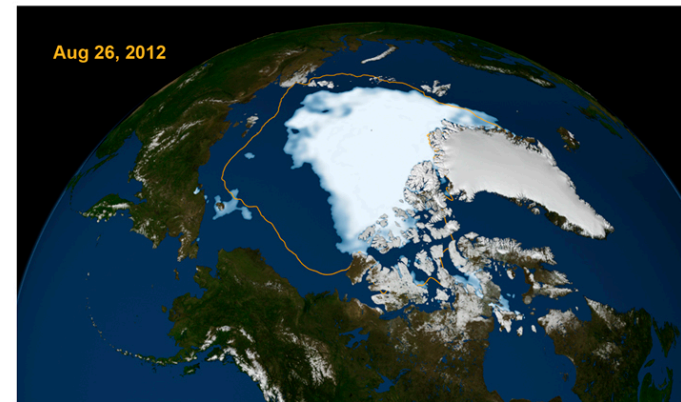
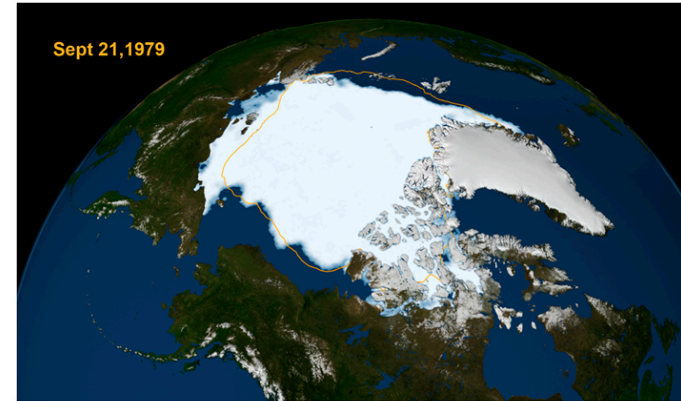


# More erratic jet stream and “stuck” extreme weather?

“Drunk Arctic” hypothesis

Reduction in Arctic sea ice  
decreases temperature contrast  
between poles and mid-latitudes →  
lower, wavier, more erratic jet  
stream

Jet stream more prone to getting  
stuck in extreme positions



# General conclusions

"Prediction is very difficult, especially about the future" – Niels Bohr

What's virtually certain:

- Earth continues to become warmer
- Heavier rain storms
- More hot weather extremes, fewer cold weather extremes
- Seas rise

What's likely:

- Droughts are more intense and longer lasting when they occur
- Wildfires become worse
- Hurricanes gradually become more intense, damaging and costly

What's possible:

- Extreme weather patterns are more persistent due to wavier jet stream
- Tornadoes, severe thunderstorms become more intense, especially during transition seasons



# contact

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