Public Hearing – Pennsylvania CO2 and Climate
House Environmental Resources & Energy Committee
28 October 2019

Testimony of David R. Legates, PhD, CCM
University of Delaware

I am David R. Legates, professor and climatologist, at the University of Delaware. I also hold a joint appointment in the Department of Applied Economics and Statistics as well as in the Physical Ocean Science and Engineering program. I served as the Delaware State Climatologist from 2005 to 2011 and was a founder of the Delaware Environmental Observing System, a statewide network for environmental monitoring and analysis. I was part of the US delegation that negotiated a protocol for the first climate data exchange program with the Soviet Union in 1990. I am recognized as a Certified Consulting Meteorologist by the American Meteorological Society and was the recipient of the *2002 Boeing Autometric Award* in Image Analysis and Interpretation by the American Society of Photogrammetry and Remote Sensing. I would like to thank both the Chairman and the Committee for the opportunity to provide my perspective of forty years of experience on climate change.

It is a privilege for me to offer my views on the science involving carbon dioxide and climate change. I might best be described as a statistical hydroclimatologist – someone who researches the interactions between water and climate from an observational setting. I have investigated biases in our evaluation of precipitation owing to errors in precipitation gage measurement and how they influence satellite and radar estimates. I also have been involved with the analysis of hydrological data to assess the impact of climate variability and change.

Let me begin with the climate consensus. Nearly all climatologists agree that climate is much more than average weather. Climate is changing because it always has changed and always will – it is dynamic and variable. Humans can and do influence the Earth's climate. The urban heat island is a classic example of that influence. Carbon dioxide and other trace gases in the atmosphere have increased due largely to human activity. Globally, air temperature has risen by about two degrees Fahrenheit over the last century with about half of that warming occurring before 1940. A 97% consensus exists only for these very basic issues. The "real" climate change discussion focusses on (1) to what extent are humans responsible for the recent climate change we see, (2) what are the future consequences of climate change, both natural and anthropogenic, and (3) what should our response strategies be?

I am familiar with the Climate Change Action Plan for the State of Delaware – a state that is less open to discussing facts on both sides of the issue than is Pennsylvania. But what underlies all attempts at climate stabilization is the belief that carbon dioxide is a magical control knob for the Earth's climate. Thus, draconian measures are required to achieve greenhouse gas reductions to alleviate future disastrous weather events.

As a climatologist who has studied the Earth's climate for nearly forty years, I have learned that carbon dioxide is not a climate control knob; it is merely a minor player in climate change. Water vapor is the most important greenhouse gas and it accounts for nearly 90% of the net warming of the planet due to the radiative impact of the Earth's atmosphere. Moreover, estimates of the effect of a doubling of carbon dioxide on mean global air temperature have been adjusted steadily downward in recent years. Current scientific understanding has reduced that estimate such that a doubling of carbon dioxide will yield a warming of only about 2 degrees Fahrenheit.

Why is that? Because although carbon dioxide will absorb outgoing long-wave energy (what we call heat), the climate system is extremely intricate – a very marvelous system in beauty and complexity exceeded only by life itself. A change to one component necessarily results in a change to many other components such that feedbacks in the system serve to regulate the climate. As we learn more about the climate system, we understand just what we do not know – and see how everything in the climate system is linked together.

Warmer conditions, such as what we currently are experiencing, exhibit less climate variability than colder conditions. The Equator-to-Pole temperature gradient drives the poleward transport of energy in the climate system. Under a warmer world, the Tropics warm but the Poles warm even more. Consequently, the Equator-to-Pole temperature gradient lessens and the outbreak of much severe weather – driven by the interaction of cold polar air with warm tropical air – diminishes. Hurricane landfalls, for example, were much more frequent in South Carolina, New England, and China during colder periods.

Historically, civilization has thrived under warmer conditions and struggled when global temperatures plummeted. More vegetation and longer growing seasons are partly responsible but, simply put, colder temperatures kill more people than warmer temperatures. We have currently entered a warmer period in human history. But I do not believe humans are responsible for most of this warming as many other factors exist to cause climate to change. So, to create a Climate Change Action Plan to ‘stabilize’ the Earth’s climate is like trying to keep the Sun from shining. We cannot halt something that for all history has been variable and so all such attempts at “climate stabilization” are doomed to failure.

But mean global air temperature is not that which is important – weather events that create the most damage and cause the most deaths are. So, let us look at the data.

First, consider daily high temperature records in the United States – are daily high air temperatures becoming more frequent? No. Compared to the heat waves of the 1930s, our summers are not the worst heat we have ever experienced. Moreover, ten of the eleven hottest years occurred before 1960. Note that daily maximum air temperature is connected directly to greenhouse gas warming. During hot afternoons, the atmosphere should be well-mixed, and the warming is physically connected with levels in the atmosphere that are associated with the enhanced greenhouse effect. By contrast, low temperatures at night are indeed showing a warming trend; but nighttime temperatures are associated with a shallow inversion layer and affected less by greenhouse gases and more by land use impacts, such as the urban heat island. Thus, the observed warming is not attributable to carbon dioxide concentrations; but rather, to changing land use patterns.

Extreme precipitation in the United States also has exhibited a significant increase over the past several decades with the largest upward trend in the northeastern states. However, this trend is not tied to rising greenhouse gas concentrations but rather, to a change in the way in which we measure precipitation. In the early 1990s, the National Weather Service adopted the Automated Surface Observing System (or ASOS) as its replacement for its manual measurements of precipitation at first-order weather stations. The newer precipitation gages are more efficient in measuring precipitation which causes a jump discontinuity in the precipitation record. The extensive ASOS network in the Northeast provides the strongest signal there; in the Midwest and Western states, Cooperative Observer Network data (which have always been manual observations) are used to enhance the data

coverage which, consequently, reduces the effect of ASOS stations there. Thus, no real trend exists that can be tied to changing concentrations of greenhouse gases.

Next, consider hurricanes. The global number of tropical storms and hurricanes shows no net change since the satellite era began in the early 1970s. Neither is there a significant change in the number of major hurricanes (Category 3-5) or in the number of hurricanes making landfall. Indeed, in the United States, we see that the central pressure of the most extreme storms making landfall has not been decreasing; only two of the top twenty-five storms for central pressure at landfall occurred in the last thirty years. Moreover, the accumulated energy of all tropical storms has not changed over the past fifty years.

Consider also tornadoes. The annual number of tornadoes since the advent of the Next Generation of NOAA weather radars has not changed and, in fact, the number of strong tornadoes in the United States has actually decreased over the past fifty years. In addition, the length of time between the strongest tornadoes, F5/EF5, has steadily increased over the same time period. Again, much of this can be explained by the reduction of the Equator-to-Pole temperature gradient and the reduced contrast between warm, moist Tropical air and cold, dry Polar air that feeds tornadic activity.

Sea level, while important to areas in southeastern Pennsylvania along the Delaware River, has risen steadily over the past 120 years but shows no correlation with increasing carbon dioxide concentrations. At the US Coast Guard Station in Philadelphia, sea level is likely to rise another 9½ inches by 2100, but half of that rise in sea level is due to coastal subsidence due to Glacial Isostatic Adjustment from the unloading of glacial ice since the last Ice Age some 22,000 years ago.

Floods and droughts…no trend there either. I could go on with climate statistics, but these tell the story. By contrast, climate models suggest a dramatic warming in response to an increase in carbon dioxide. However, that warming has always exceeded the observed trend, in large part since models are tuned to yield a warming of about 6 degrees Fahrenheit which, by most assessments, is extraordinarily high. Regarding climate model trends relative to observations for the global troposphere – the level of the atmosphere in which we find all weather – John Christy, State Climatologist for Alabama and professor at the University of Alabama in Huntsville, commented, "the climate model simulations used in the IPCC Assessment…indicate their response to carbon dioxide on average is two to five times greater than reality. In strict statistical testing, we can say that the models on average fail a simple hypothesis test." The unintended consequence of tuning climate models to a higher degree of climate sensitivity has been to make the models wrong. Thus, I have little faith in climate models to predict the future.

I have watched issues of climate stabilization play out in Delaware. I implore the Commonwealth of Pennsylvania to **not** make the same mistake. Let me provide you with an example from Delaware. To facilitate a green economy and cut carbon dioxide emissions, the State of Delaware has given millions of dollars to Bloom Energy to create green energy jobs. We are on the hook for another ten years of subsidies. This boondoggle is funded by Delmarva Power ratepayers through a feed-in tariff which has made electricity in Delaware more expensive. Amazingly, Delaware declared natural gas as a renewable energy resource – but only if consumed in a Bloom Energy fuel cell. This allowed Bloom Energy to qualify for subsidies under the Renewable Portfolio Standards Act (RPSA). Less than 300 jobs were ultimately created, and the removal of hazardous waste that Bloom claimed its fuel cells do not create has been an ongoing problem. Presently, a consortium of both Conservative and Environmental groups is fighting to get the

Bloom Energy deal repealed. Unfortunately, the Delaware State Legislature has no spine and refuses to remedy the problem. And all of this has occurred as a direct result of our intent to lower greenhouse gas emissions according to their climate action plan.

Let me conclude by saying that no one should vote to make electricity less affordable and more expensive, especially for the poor. High-cost electricity does not “create jobs”, and history has shown it destroys them as energy-intensive businesses will flee the state. And when all is said and done, Pennsylvania’s climate will be virtually unaffected for all the pain these policies will cause.

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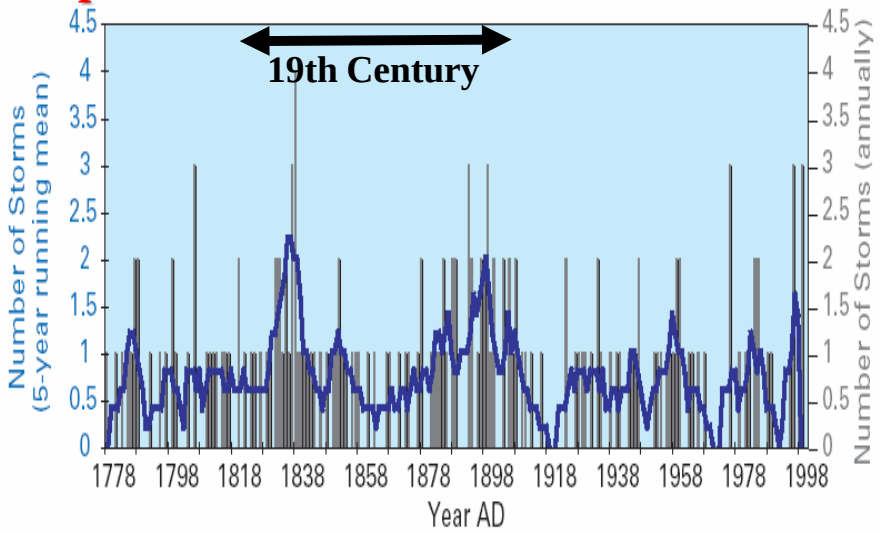
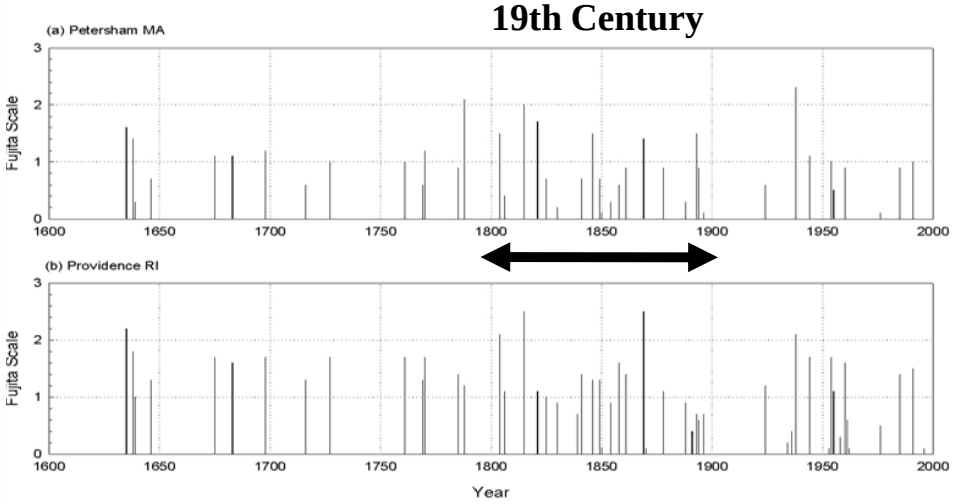
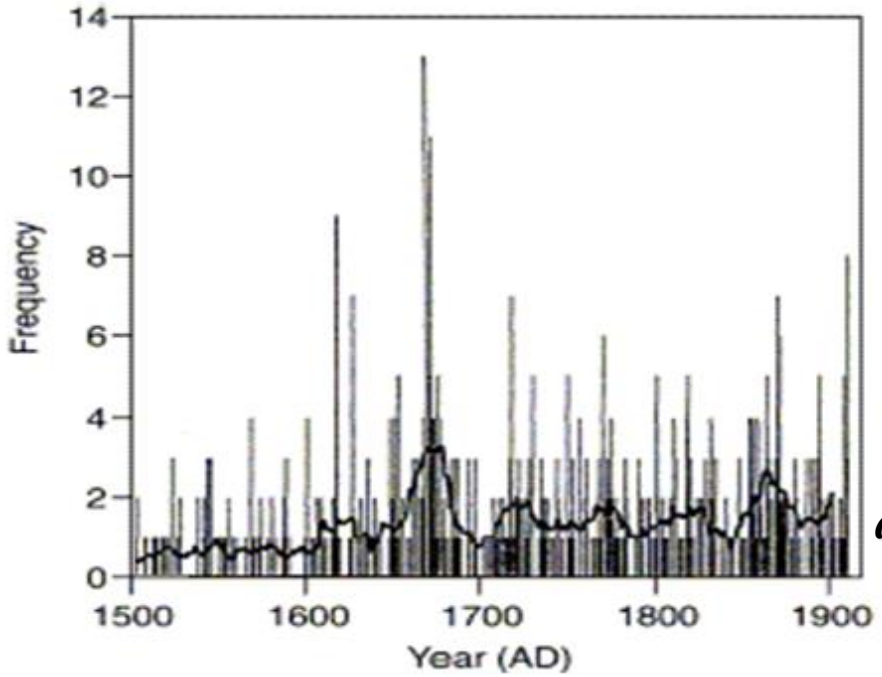
Impacts of Hurricanes in Charleston SC



Impacts of Hurricanes in New England

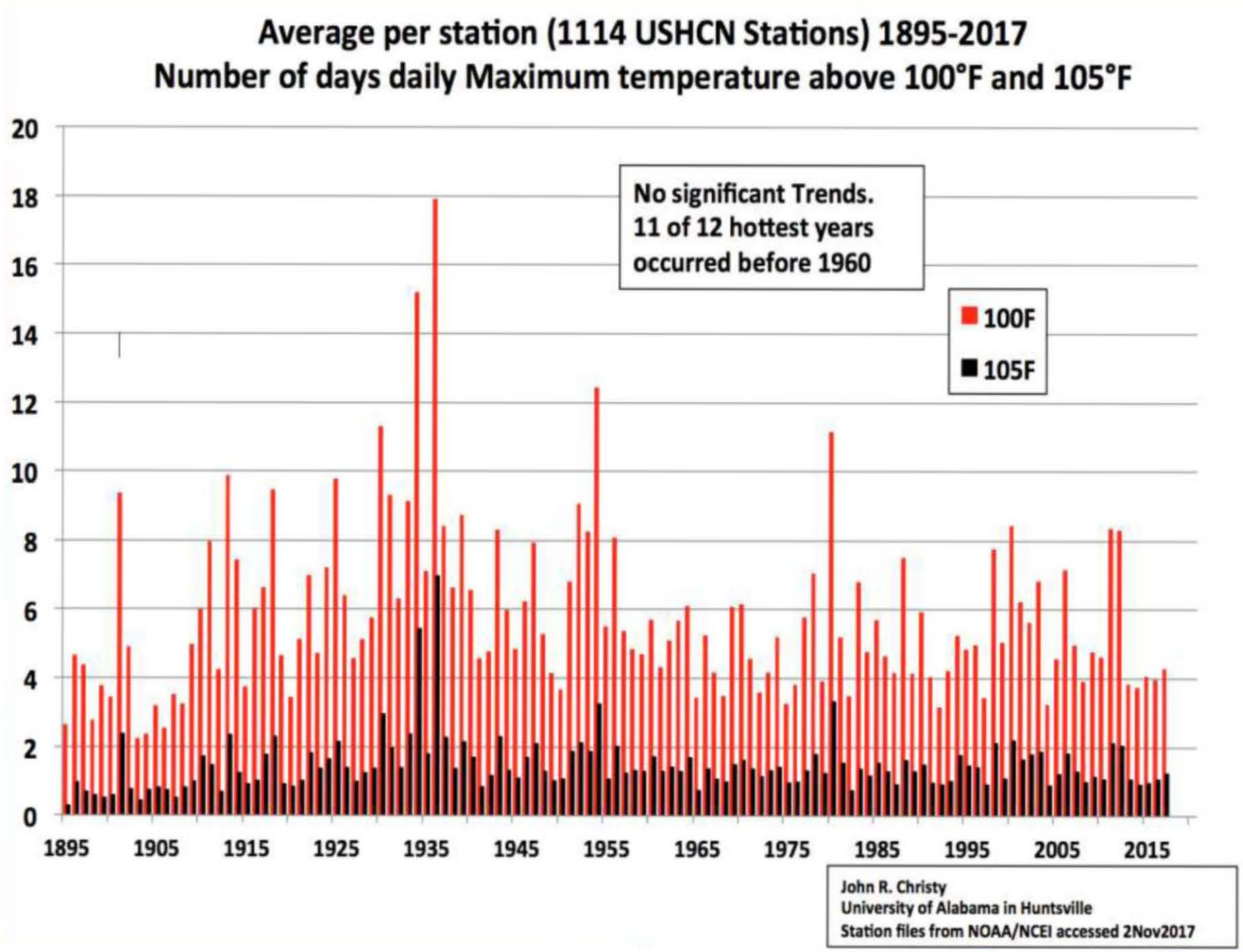


The colder 19th century was the most hurricane-active period

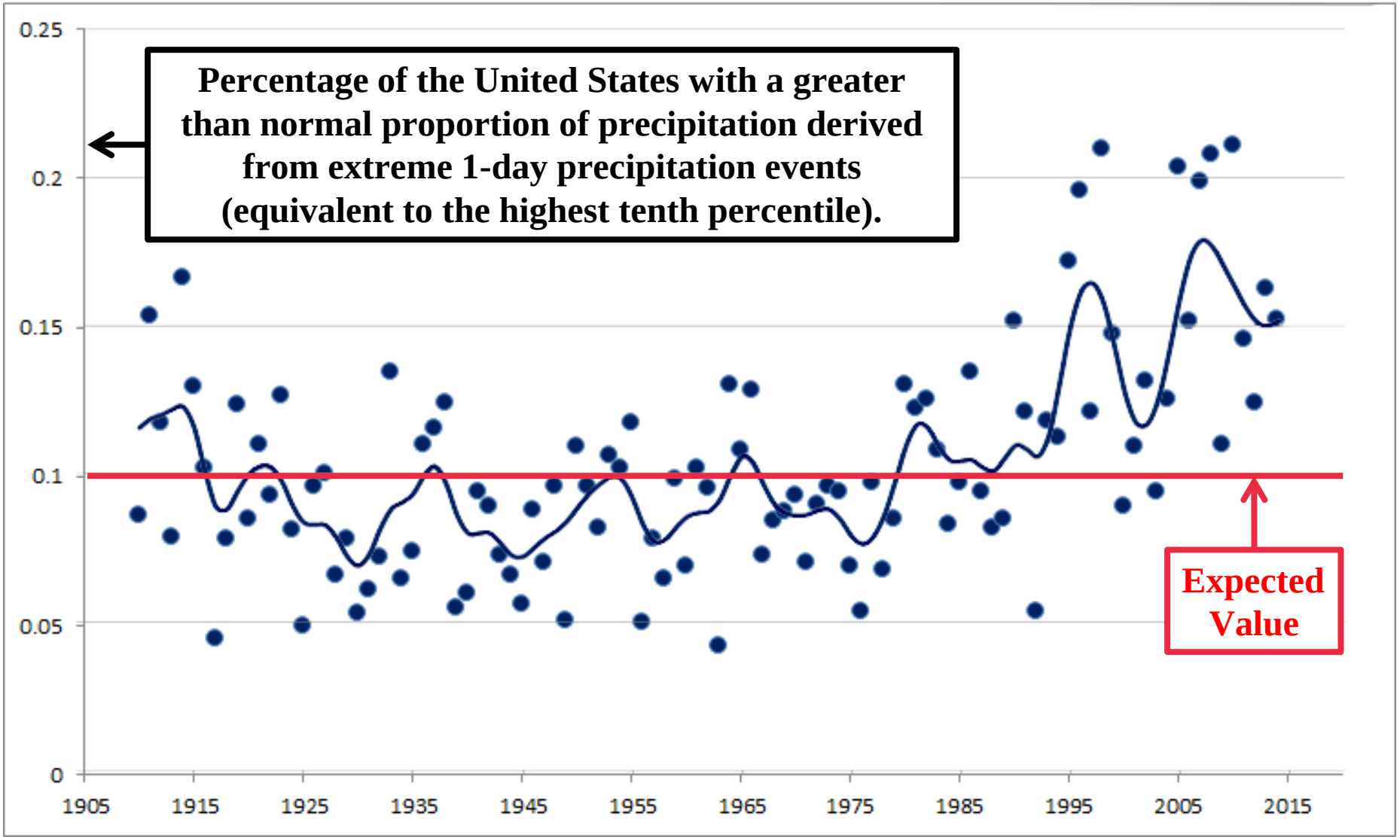


A 1,000-year history of typhoon landfalls in Guangdong, southern China, reconstructed from Chinese historical documentary records

"Remarkably, the two periods of typhoon strikes in Guangdong (AD 1660-1680, 1850-1880) coincide with two of the coldest and driest periods in northern and central China."


Average per station (1114 USHCN Stations) 1895-2017
Number of days daily Maximum temperature above 100°F and 105°F
No significant Trends.
11 of 12 hottest years
occurred before 1960
100F
105F
20
18
16
14
12
10
8
6
4
2
0
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
2015
John R. Christy
University of Alabama in Huntsville
Station files from NOAA/NCEI accessed 2Nov2017

Extreme 1-Day Precipitation Events for the United States



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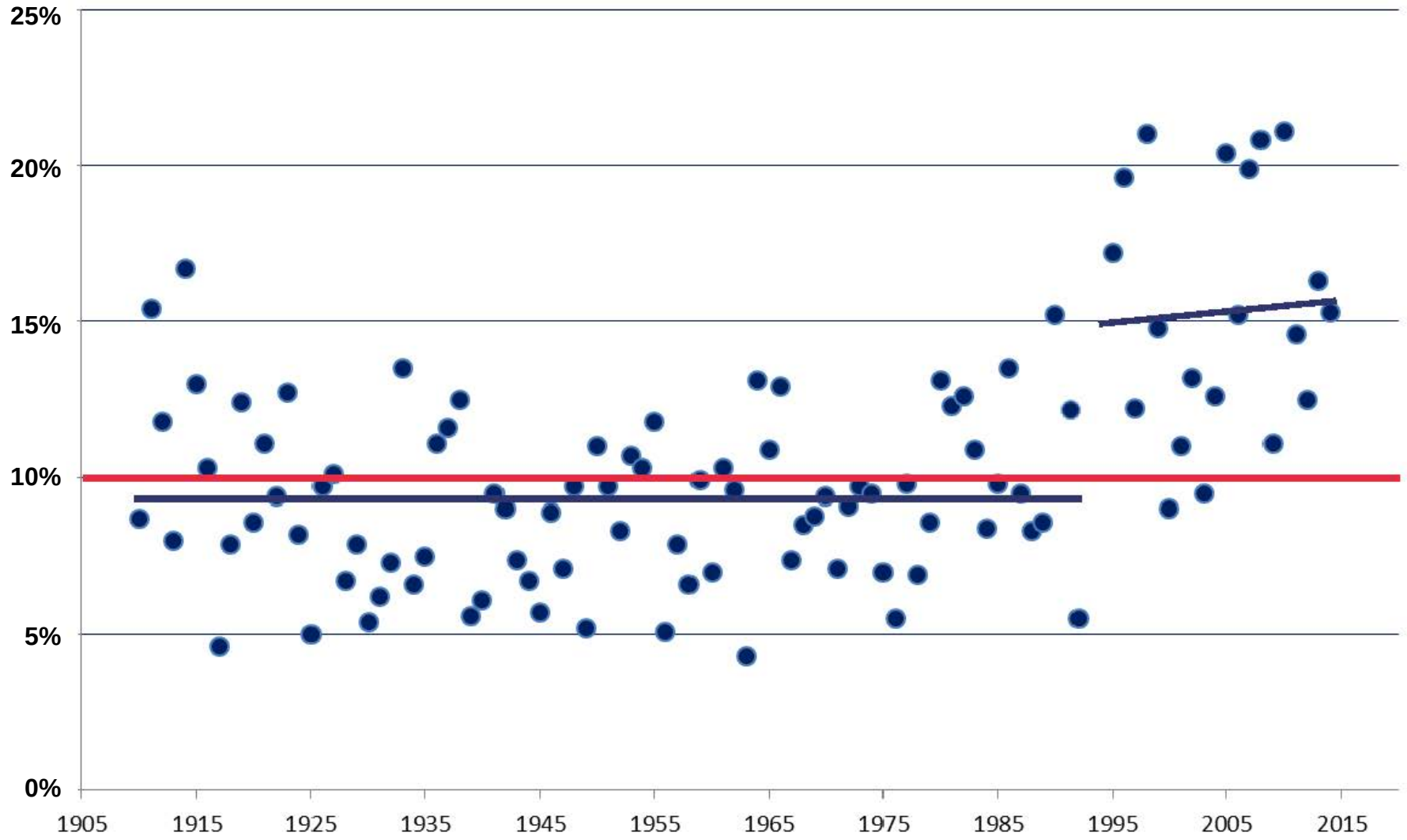
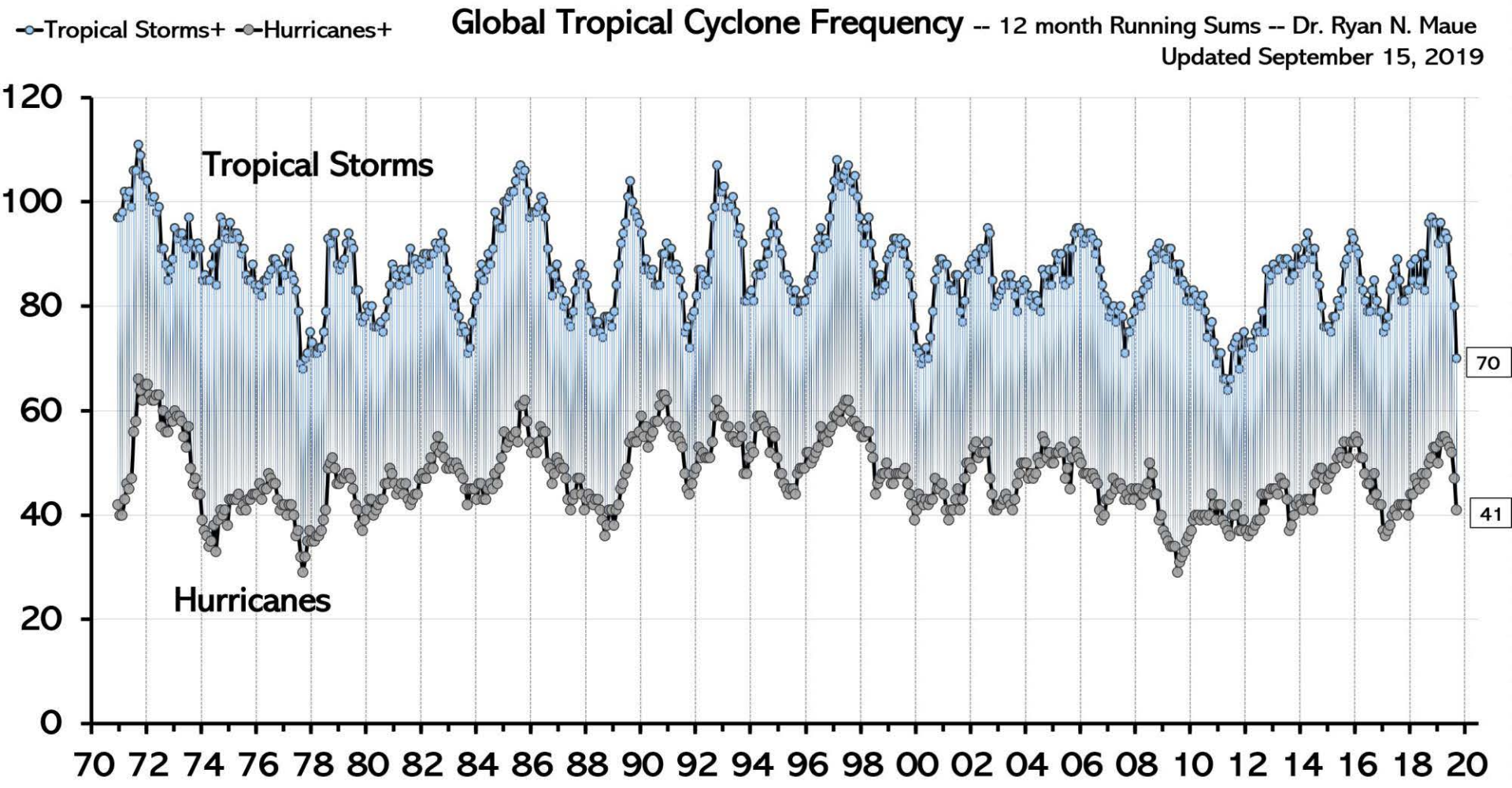
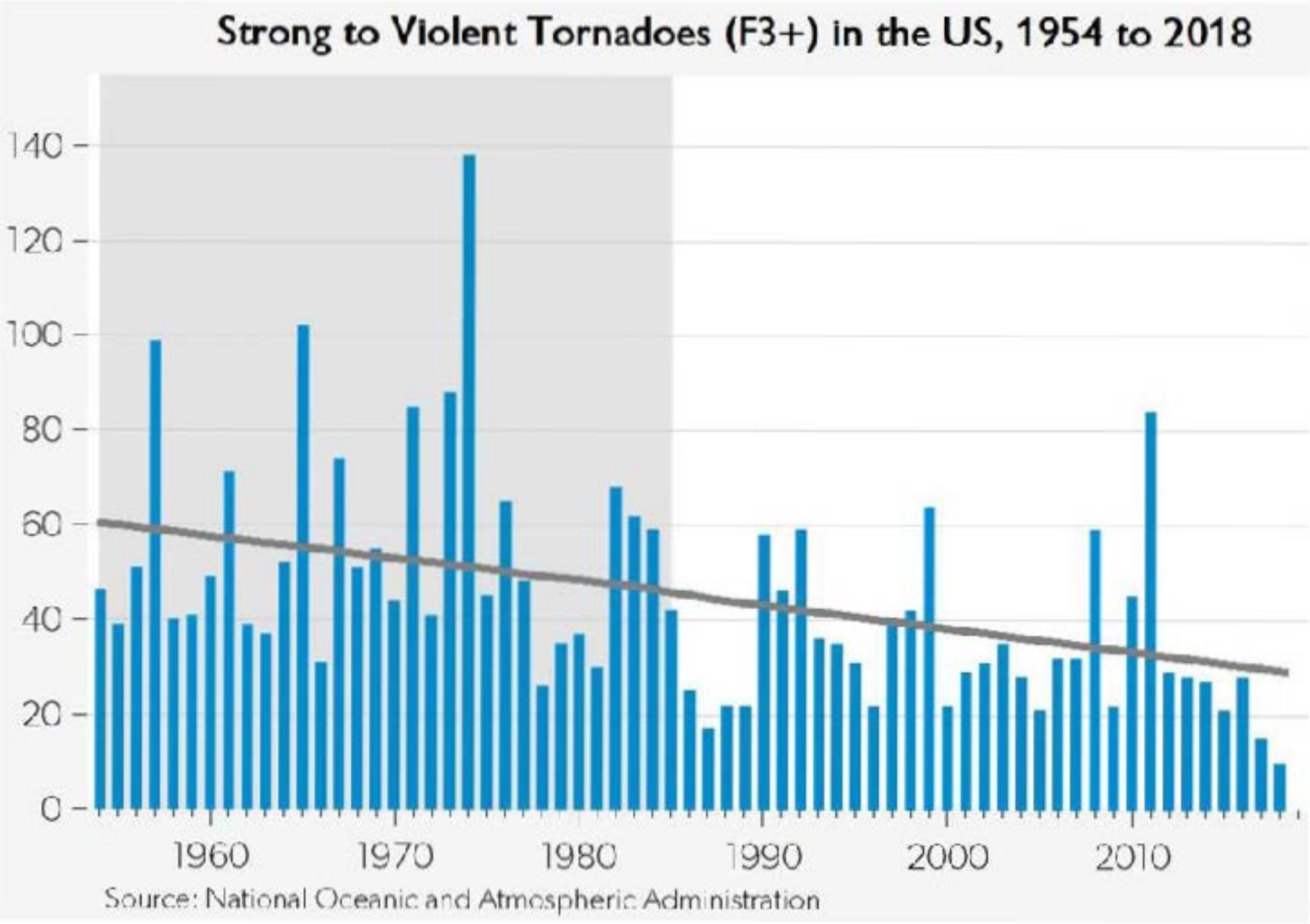
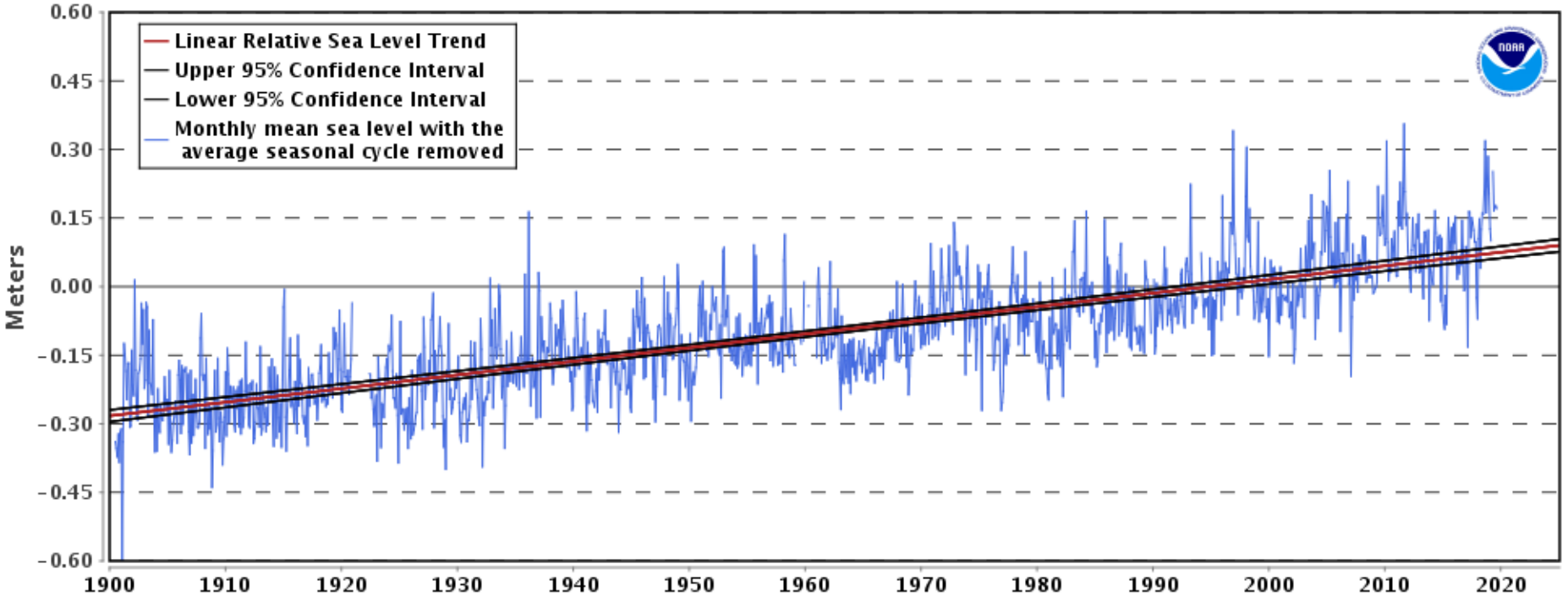



Tropical Storms+ Hurricanes+
Global Tropical Cyclone Frequency -- 12 month Running Sums -- Dr. Ryan N. Maue
Updated September 15, 2019
Tropical Storms
Hurricanes
70
41
120
100
80
60
40
20
0
70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 00 02 04 06 08 10 12 14 16 18 20


Strong to Violent Tornadoes (F3+) in the US, 1954 to 2018
140
120
100
80
60
40
20
0
1960
1970
1980
1990
2000
2010
Source: National Oceanic and Atmospheric Administration

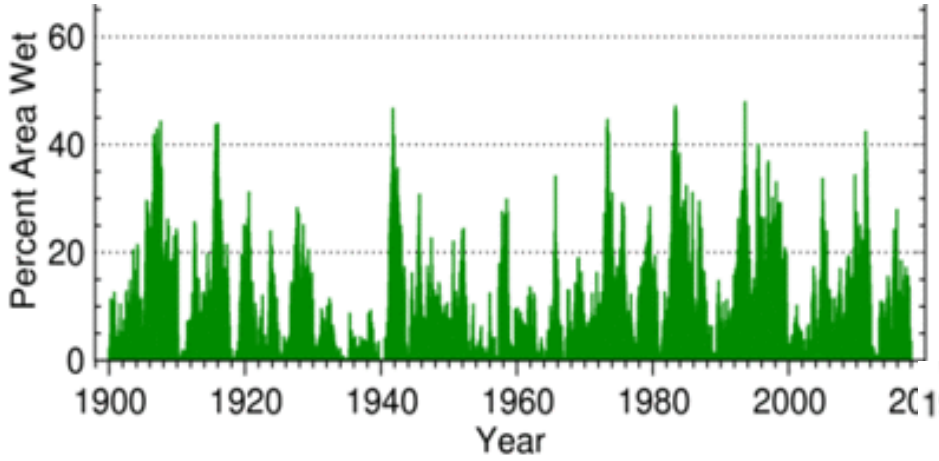
8545240 Philadelphia, Pennsylvania **1.173 ± 0.075 inches per decade**



Percentage of the United States in Moderate or Extreme Wetness

January 1990 – January 2018

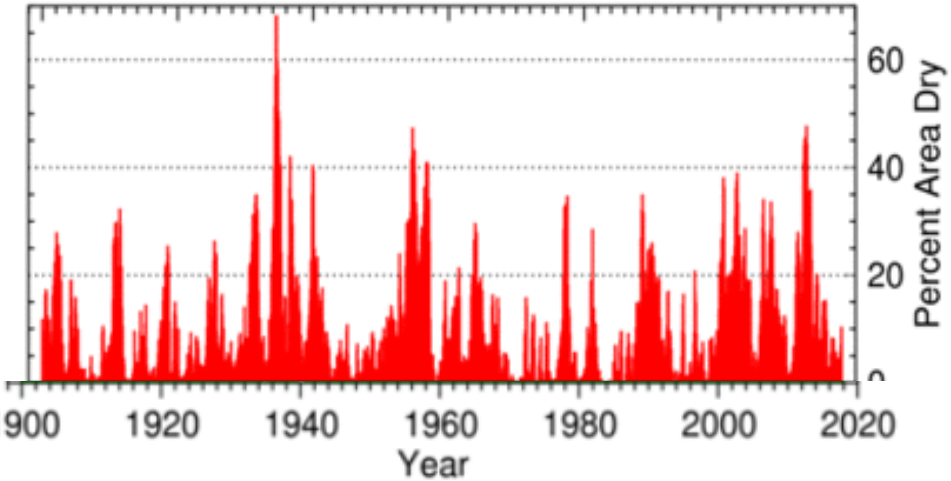
National Climatic Data Center / NESDIS / NOAA



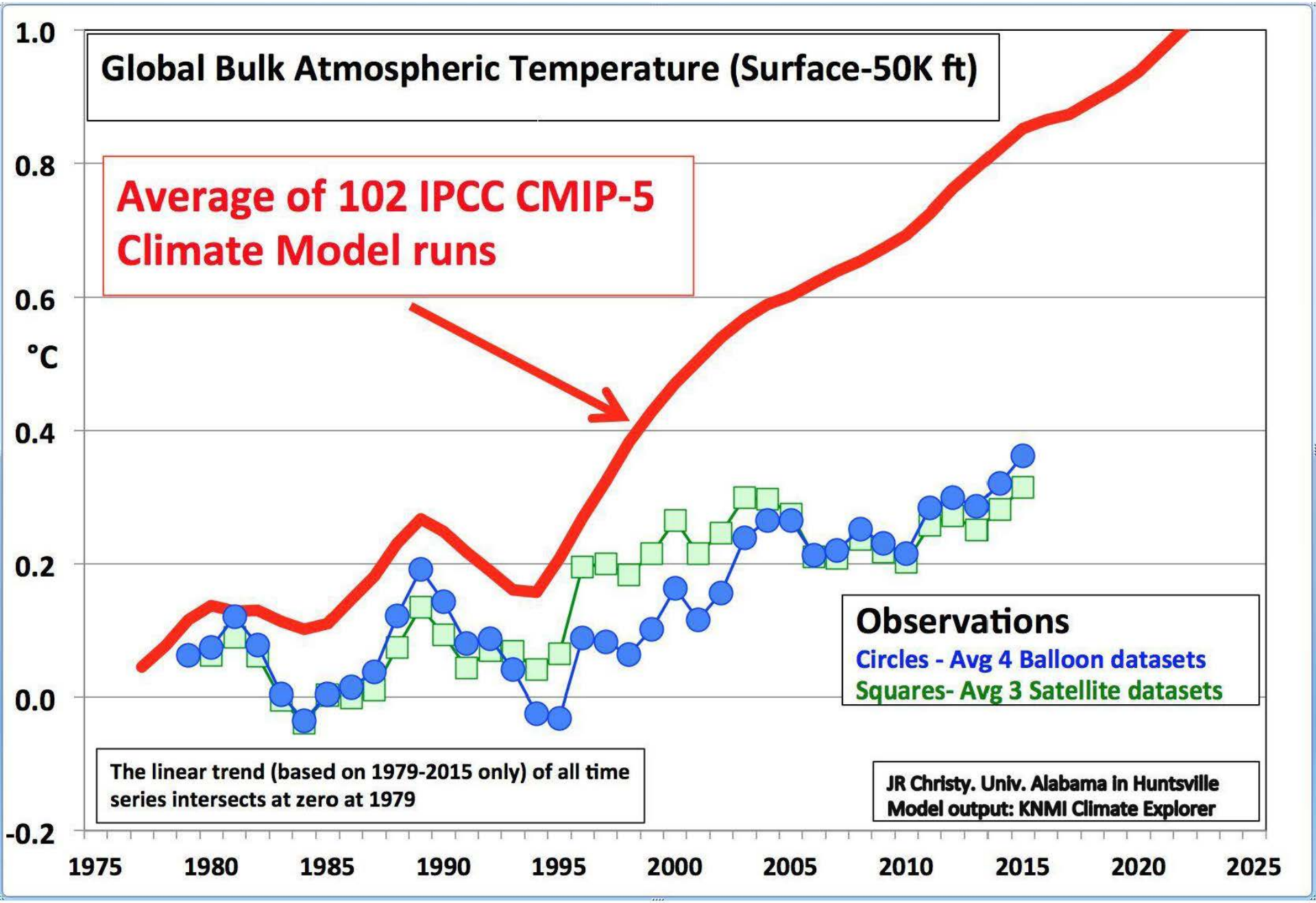
Percentage of the United States in Moderate or Extreme Drought

January 1990 – January 2018

National Climatic Data Center / NESDIS / NOAA



Palmer Drought Severity Index


Global Bulk Atmospheric Temperature (Surface-50K ft)
Average of 102 IPCC CMIP-5 Climate Model runs
1.0
0.8
0.6
°C
0.4
0.2
0.0
-0.2
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Observations
Circles - Avg 4 Balloon datasets
Squares- Avg 3 Satellite datasets
The linear trend (based on 1979-2015 only) of all time series intersects at zero at 1979
JR Christy. Univ. Alabama in Huntsville
Model output: KNMI Climate Explorer

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