Year-to-Date Global Temperature
for 2016 and the other seven warmest years on record
The Climate Changes Naturally
Dr. Shepherd....
Climate Change 101 For Non-Climatologists

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Director, UGA Atmospheric Sciences Program
2013 President, American Meteorological Society
Host, Weather Channel’s WxGeeks
@DrShepherd2013

Affected by Sea Level 13 to 15 Million by 2100 (Hauer et al 2016) Figure from Time Magazine
Why it Matters...

Industry Awakens to Threat of Climate Change

WASHINGTON — Coca-Cola has always been more focused on its economic bottom line than on global warming, but when the company lost a lucrative operating license in India because of a serious water shortage there in 2004, things began to change.

Today, after a decade of increasing damage to Coke's balance sheet as global droughts dried up the water needed to produce its soda, the company has embraced the idea of climate change as an economically disruptive force.

"Increased droughts, more unpredictable variability, 100-year floods every two years," said Jeffrey Seabright, Coke's vice president for environment and water resources, listing the problems that he said were also disrupting the company's supply of sugar cane and sugar beets, as well as citrus for its fruit juices. "When we look at our most essential ingredients, we see those events as threats."

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Via New York Time
Indicators of the society and climate interface challenges.....

<table>
<thead>
<tr>
<th>Key Impacts as a Function of Increasing Global Average Temperature Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global mean annual temperature change relative to 1980-1999 (°C)</strong></td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td><strong>WATER</strong></td>
</tr>
<tr>
<td>Increased water availability in moist tropics and high latitudes**</td>
</tr>
<tr>
<td>Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes**</td>
</tr>
<tr>
<td>Hundreds of millions of people exposed to increase water stress**</td>
</tr>
</tbody>
</table>

1 Significant is defined here as more than 40%.
2 Based on average rate of sea level rise of 4.2 mm/year from 2000 to 2080.
2016: HOTTEST YEAR SO FAR
Land and Ocean Temperature Percentiles Jan-Apr 2016

Source: NOAA

CLIMATE CENTRAL
What is Climate?

- **Climate** is the long-term statistical properties of the atmosphere for an area.
- *Weather is different from Climate. Weather is your Mood, Climate is your personality*

Climate is described by long-term conditions:

- Averages
- Seasonal and multi-year cycles
- Extremes
- Spatial patterns
- Air masses
- Trends
When people say climate change isn't happening because it's snowing where they are...

THE SHIP CAN'T BE SINKING

MY END JUST ROSE 200 FEET

Reinvented by Amuza for iFunny :)
Climate Variability

Climate variability comes from a number of causes, including oscillations in factors that contribute to energy balance and non-periodic changes in solar radiation and atmosphere-ocean interactions.

Examples:
- Ice ages (100,000 year long cycles related to orbit around sun)
- Pacific Decadal Oscillation (related to 30-40 year oscillations in Pacific Ocean temperatures)
- Sunspots (related to 11 year sunspot cycle—iffy)
- El Nino Southern Oscillation (related to interactions between tropical Pacific ocean and atmosphere)—3 to 5 year cycles on average
- Arctic Oscillation (short-term variations in atmospheric pressure in North Atlantic—week to month variation)
But, the temperatures are increasing, while solar irradiance (output) is decreasing
Factors Involved in Climatic Change

Changes in Earth’s Orbit

- Milankovitch cycles refer to regular natural variations in the Earth’s orbit around the sun.
  - Obliquity -- 41,000-year period
  - Eccentricity -- 100,000-year period
  - Precession -- 27,000-year period
Past to Present

Atmospheric carbon dioxide (CO₂) concentrations (ppm)

Temperature variations (°C)

Source: UNEP
Factors Involved in Climatic Change

- Changes in Radiation-Absorbing Gases

Graph showing concentrations of greenhouse gases from 0 to 2005:

- Carbon Dioxide (CO₂)
- Methane (CH₄)
- Nitrous Oxide (N₂O)

Kiehl and Trenberth 1997
Figure 2. Radiative Forcing Caused by Human Activities Since 1750

<table>
<thead>
<tr>
<th>Long-lived greenhouse gases</th>
<th>Carbon dioxide</th>
<th>Methane</th>
<th>Halogenated gases</th>
<th>Nitrous oxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-lived gases that create ozone or create or destroy other greenhouse gases</td>
<td></td>
<td></td>
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<tr>
<td>Aerosols (solid or liquid particles)</td>
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<tr>
<td>Changes in clouds due to aerosols</td>
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<tr>
<td>Change in albedo* due to land use</td>
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<tr>
<td>Natural</td>
<td></td>
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<tr>
<td>Change in energy from the sun</td>
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<tr>
<td>Net total due to human activities</td>
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</tr>
</tbody>
</table>

(negative radiative forcing is because some of these gases destroy ozone)

Radiative forcing (watts per square meter)

Cooling 0 1 2 3 Warming
So is the Earth’s Climate Warming?
Global Land and Ocean Temperature Anomalies, February

NOAA
2015 WAS THE WARMEST YEAR ON RECORD AND THE WORLD IS JUST GETTING HOTTER

2015 average temp 58.62°F
2002 58.62°F
This was the 4th time in the 21st century that the record has been broken

15 of the 16 warmest years on record have been in the 21st century

Average temperature
57.6° 57.8° 58.0° 58.2° 58.4° 58.6°

2015 58.62°
2014 58.33°
2010 58.26°
2013 58.19°
2005 58.17°
2009 58.13°
1998 58.13°
2012 58.12°
2007 58.10°
2006 58.10°
2003 58.10°
2002 58.08°
2011 58.03°
2004 58.03°
2008 57.97°
2001 57.97°

For 39 years in a row the average temperature has been over the average for the 20th century

The temperature increase is accelerating
Since 1970 the global temp has been increasing 0.31°F per decade
Since 1880 the global temp has been increasing 0.13°F per decade

Note: Gray areas signify missing data.
Note: Ocean data are not used over land nor within 100km of a reporting land station.
How to Predict Climate

You can predict climate by predicting trends, but that depends on things continuing the same way they have in the past. Not always a good assumption!

Instead, climatologists use climate models to simulate the future climate based on physics and predictions of future CO2 and other emissions.
Weather vs. Climate Models

Weather models are designed to predict detailed hourly weather information for up to 7 days across a continent.

Emphasis: short term, individual storm evolution

Climate models are designed to predict multi-year climate conditions across the entire globe.

Emphasis: long-term, seasonal to multi-year average climate conditions
Models can be used to separate out the effects of individual factors to see what effect each factor has on the temperature trend.
It’s Rate of Change Not Magnitude……

- When your body has a 1 to 2 C degree fever your body responds

- Climate models project 3 to 6 degrees C of warming in the next 100 years

- Past natural changes of this magnitude took 1000s to 100000s of years to occur, our changes are happening in 10s of years
Trends in Record Highs vs Record Lows

Source: G. Meehl and NCAR/UCAR
So what are some of the implications of the climate system warming?
Weather Fatalities

- **Flood**: 155
- **Lightning**: 82
- **Tornado**: 31
- **Hurricane**: 48
- **Heat**: 110
- **Winter**: 43
- **Cold**: 70
- **Wind**: 46
- **Rip Currents**: 45

- **Weather Fatalities for 2015**
- **10 Year Average (2006-2015)**
- **30 Year Average (1986-2015)**
Hurricane Patricia, Strongest Hurricane Record, and Something Different
Extreme Extremes
A Baking Analogy

Cookie = an event
Ingredients = factors that align to cause an event
Baking surface and oven temperature = conditions in which the event occurred

Tinker with an ingredient, baking surface, or oven temperature, you still end up with a cookie, but it might result in a slightly different texture, color, taste.
Hydroclimate variability in the SE

Figure 3.8: Area of the SEUS under severe and extreme dry events (SPEI ≤ -1.5, in red) and severe and extreme wet events (SPEI ≥ 1.5, in blue), for 3-month and 12-month SPEI and for the period 1896-2012

S. Bernardes (2013), Bernardes, Shepherd, and Madden (2014), NSF Coweeta LTER
Confidence in capabilities for attribution of specific events

Understanding of effect of climate change on event type
<table>
<thead>
<tr>
<th>Event Class</th>
<th>Capabilities of Climate Models to Simulate Event Class</th>
<th>Quality/Length of the Observational Record</th>
<th>Understanding of Physical Mechanisms that Lead to Changes in Extremes as a Result of Climate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme cold events</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Extreme heat events</td>
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<tr>
<td>Droughts</td>
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<tr>
<td>Extreme rainfall</td>
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<tr>
<td>Extreme snow and ice storms</td>
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<td>○</td>
<td>●</td>
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<tr>
<td>Tropical cyclones</td>
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<tr>
<td>Extratropical cyclones</td>
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<tr>
<td>Wildfires</td>
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<tr>
<td>Severe convective storms</td>
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