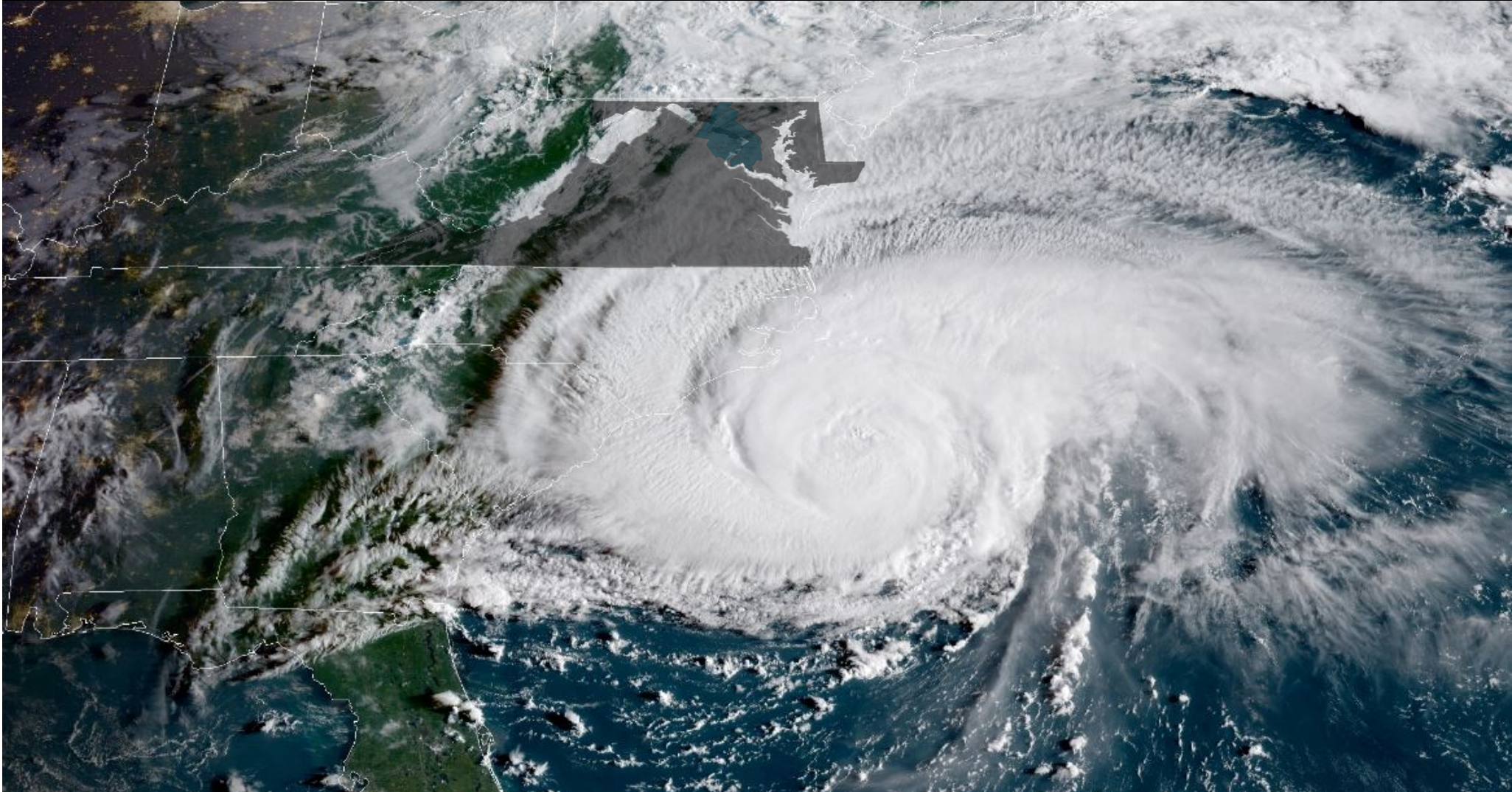
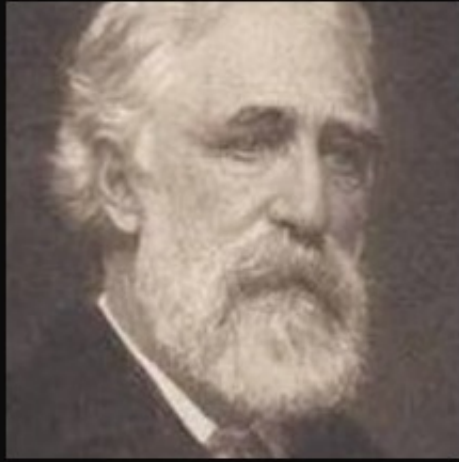


# Metropolitan Washington at Risk: Predicting and Preparing for the New Normal

Jim Kinter

George Mason University





Everybody talks about the weather, but nobody does anything about it.

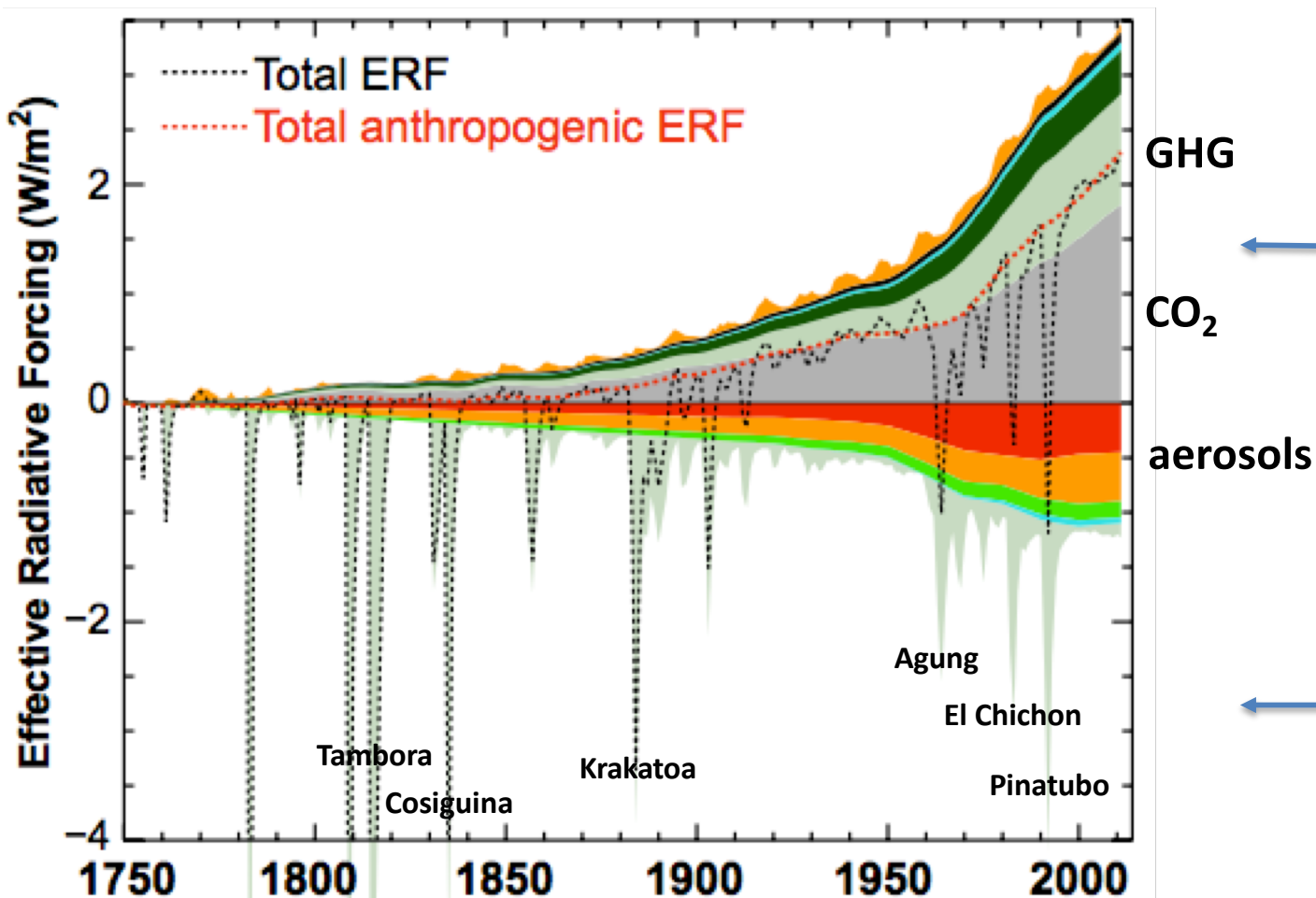
~ Charles Dudley Warner

(Mark Twain quoted *him*)

... In reality, **we all are** inadvertently doing something about the weather – **we are changing it.**

**Global climate – the probability and statistics of weather – is undeniably changing, and the likelihood is high that human activities have caused the majority of the change observed in the past half-century.**

# How Have Humans Influenced Climate?



Human activities emit gases that enhance the greenhouse effect - CO<sub>2</sub>, and aerosols – which causes a **planetary energy imbalance**

Large volcanic eruptions have a major, **short-lived cooling effect.**

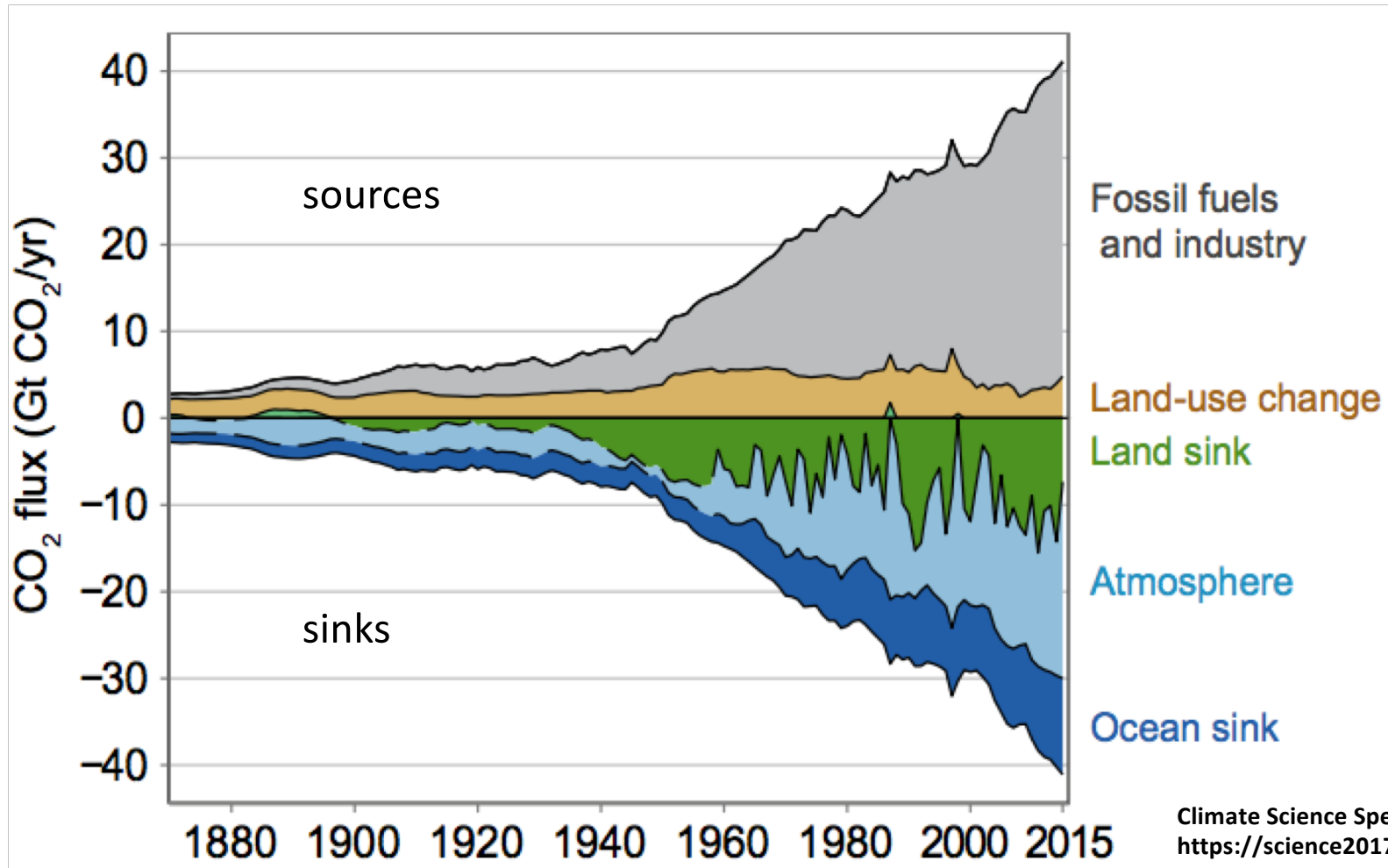
Human activities have increased the effective radiative forcing by more than 2  $W/m^2$ , most of it due to CO<sub>2</sub> emissions. Future scenarios of up to 8.5  $W/m^2$  are considered plausible by 2100.



**2 W/m<sup>2</sup> amounts to 1 million Gigawatts for the Earth as a whole  
(a large power plant produces 1-2 Gigawatts)**

**Adding 2 W/m<sup>2</sup> is like suspending a household light bulb every 20' over the Earth  
(every 10' if forcing reaches 8 W/m<sup>2</sup>)**

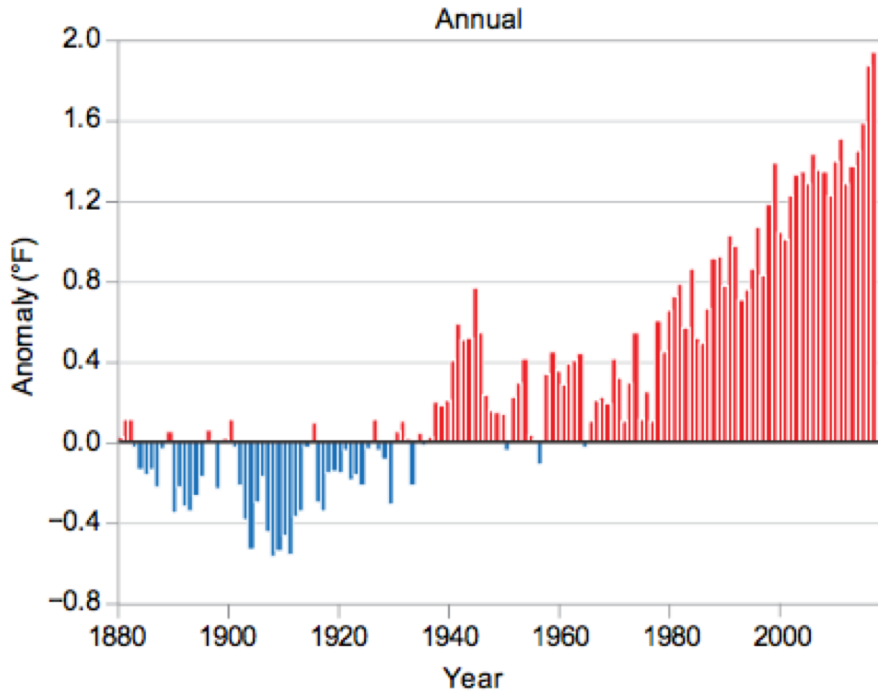
# Where Does the CO<sub>2</sub> Come From? Where Does it Go?



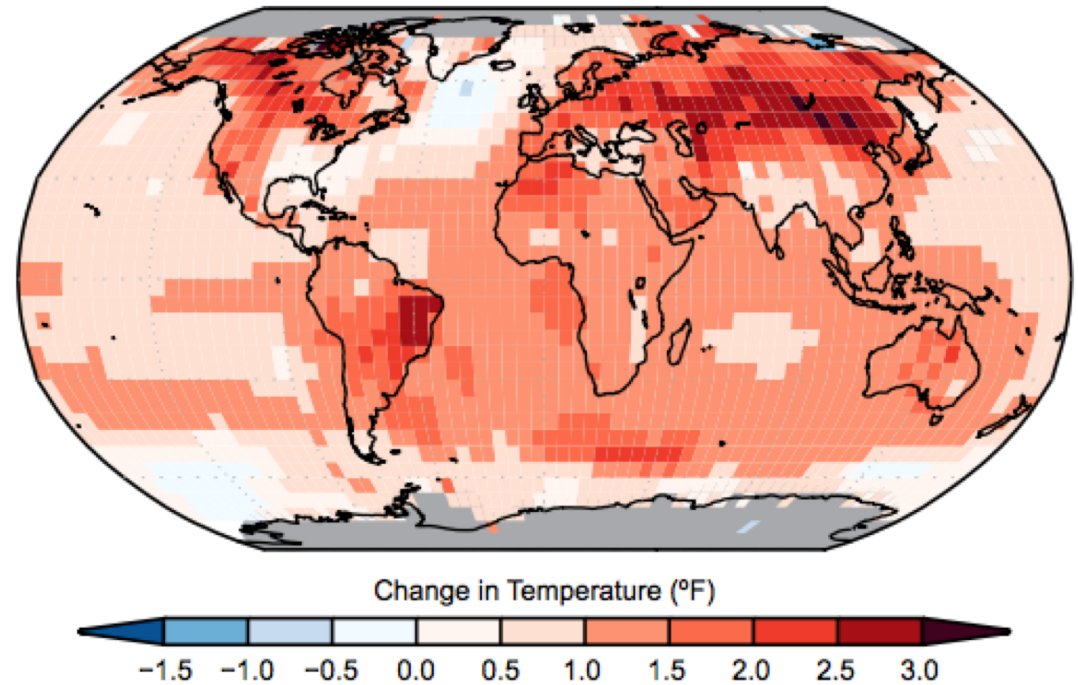
**About ½ the 40 billion metric tons CO<sub>2</sub> emitted from fossil fuel combustion, cement production and land use change stays in atmosphere. About 30% winds up in ocean.**

# What is Increasing Atmospheric CO<sub>2</sub> and GHG Doing to Global Climate?

Global Land and Ocean Temperature Anomalies



Surface Temperature Change

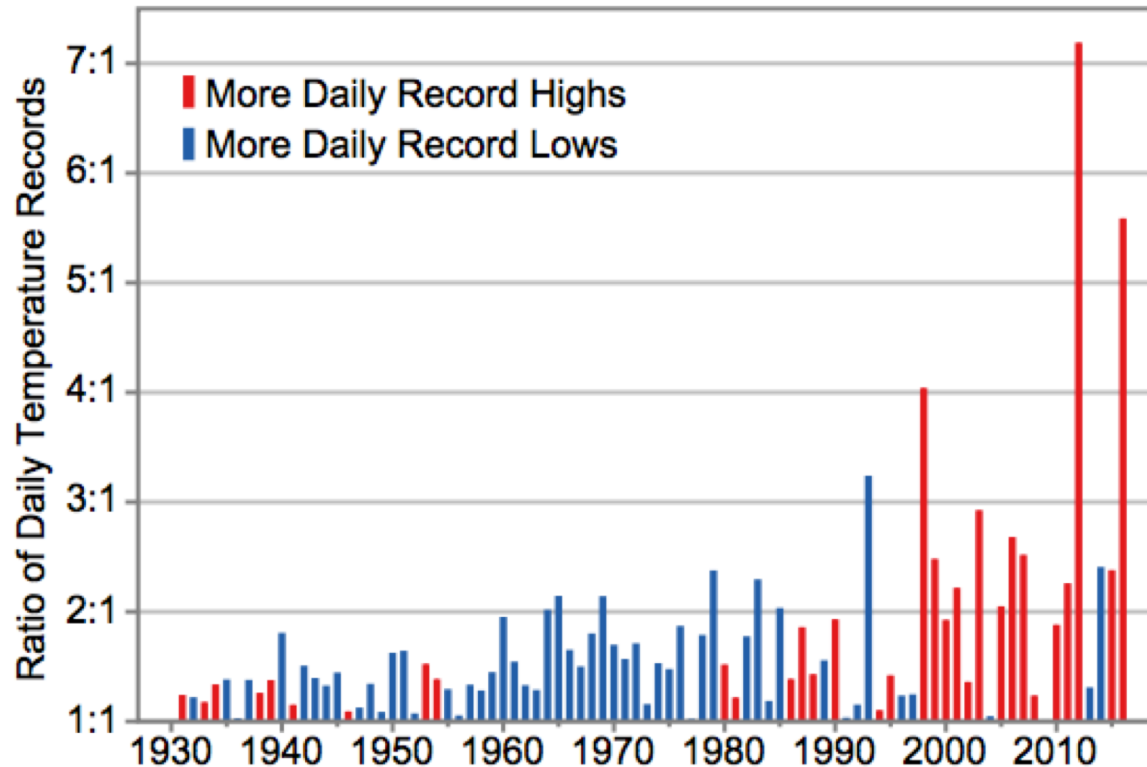


Climate Science Special Report, USGCRP  
<https://science2017.globalchange.gov/>

**Global average surface temperature has risen by about 1.8°F (1.0°C) since we have had enough measurements to reliably estimate it. The Arctic is warming about twice as fast.**

# Why Are We Concerned about 1°C?

Record Warm Daily Temperatures Are Occurring More Often



Climate Science Special Report, USGCRP  
<https://science2017.globalchange.gov/>

**More record high temperatures means more energy consumption (which in turn drives more CO<sub>2</sub> emission), more heat emergencies, more illness and death for the weak and infirm.**

# Record Warm in February? Bring It On!

Capital Weather Gang

## Washington surges to 82 degrees, its warmest temperature ever recorded so early in the year

By **Jason Samenow** February 21 [✉ Email the author](#)



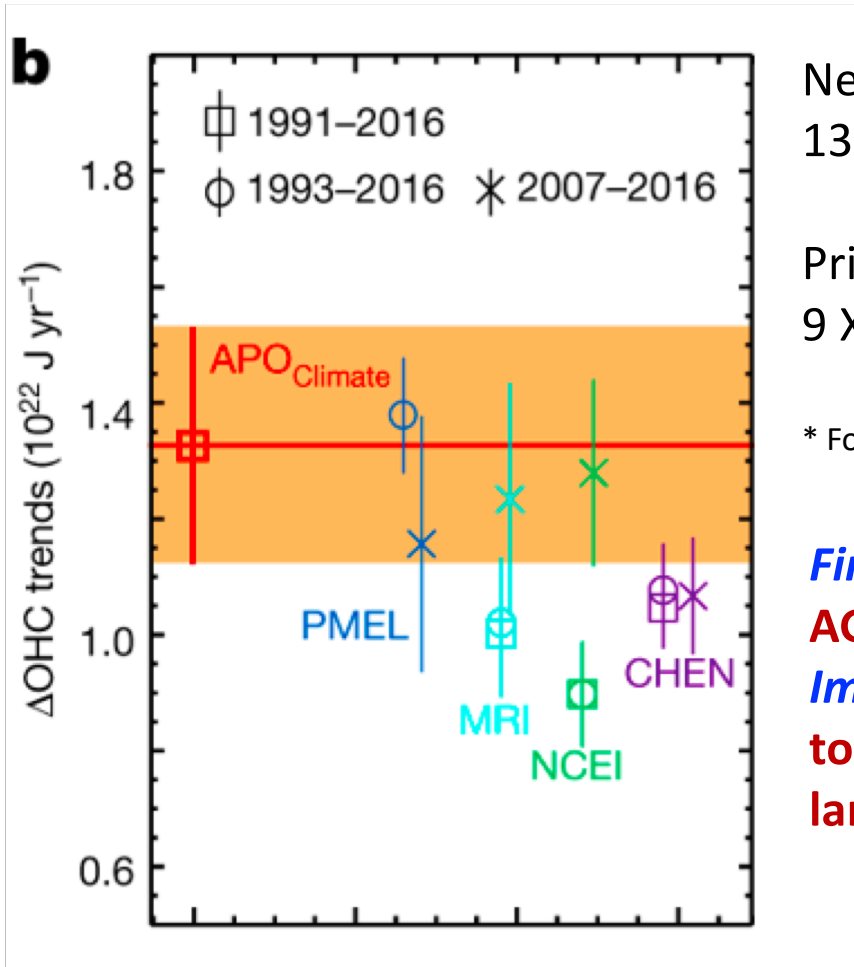
# Too Much of a Good Thing?

Capital Weather Gang

## Iranian city soars to record 129 degrees: Near hottest on Earth in modern measurements

By **Jason Samenow** June 29, 2017  Email the author

# Ocean Heat Uptake May Be Greater Than We Thought



New estimate:  
 $13 \times 10^{22}$  J/decade

Prior estimate\*:  
 $9 \times 10^{22}$  J/decade

\* For comparable period of record

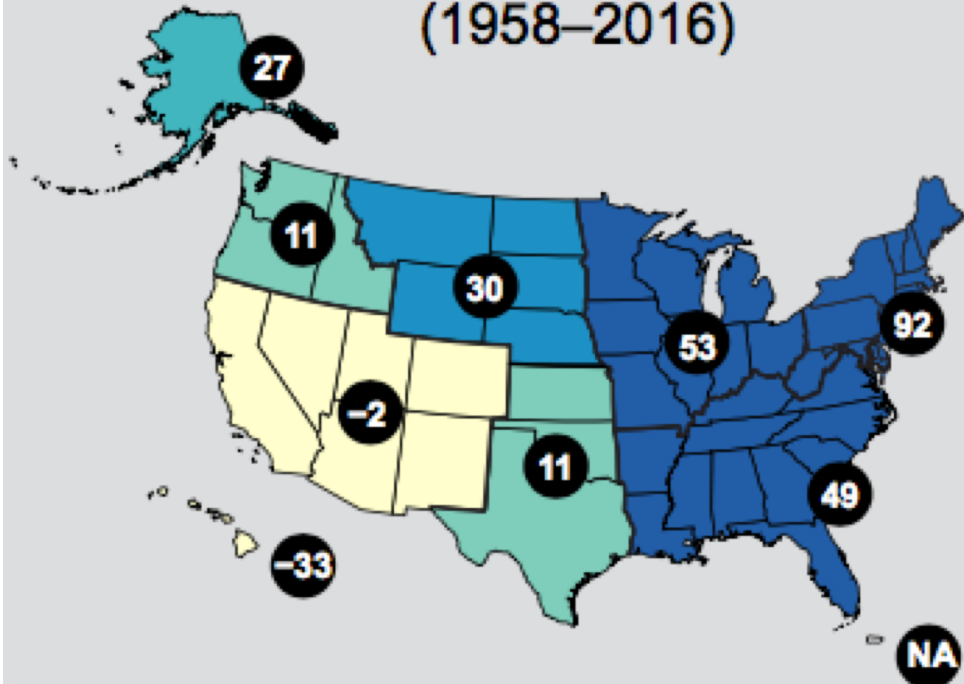
**Finding:** Oceans are absorbing more excess heat due to AGW than previously measured

**Implication:** Climate is more sensitive than we thought to CO<sub>2</sub> emission, and the resulting impacts may be larger and occur sooner.

Quantification of ocean heat uptake from changes in atmospheric O<sub>2</sub> and CO<sub>2</sub> composition  
Resplandy et al., *Nature*, 1 Nov 2018

# ... and It's Not Just the Heat

Number of 5-yr, 2 Day Events  
(1958–2016)



**Extreme precipitation has increased across much of the US.**

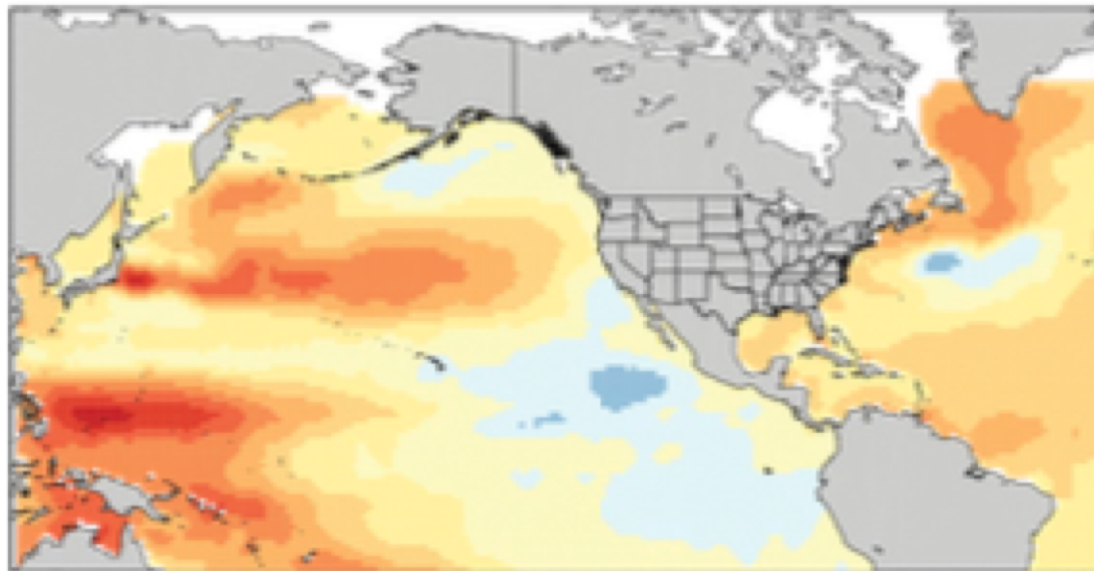
**This is consistent with what we expect global warming to do to the hydrologic cycle.**

SE US, including VA, has experienced 49% increase in number of 2-day events with a precipitation total exceeding the largest 2-day amount that is expected to occur, on average, only once every 5 years

Climate Science Special Report, USGCRP  
<https://science2017.globalchange.gov/>

# ... and the Oceans are Rising

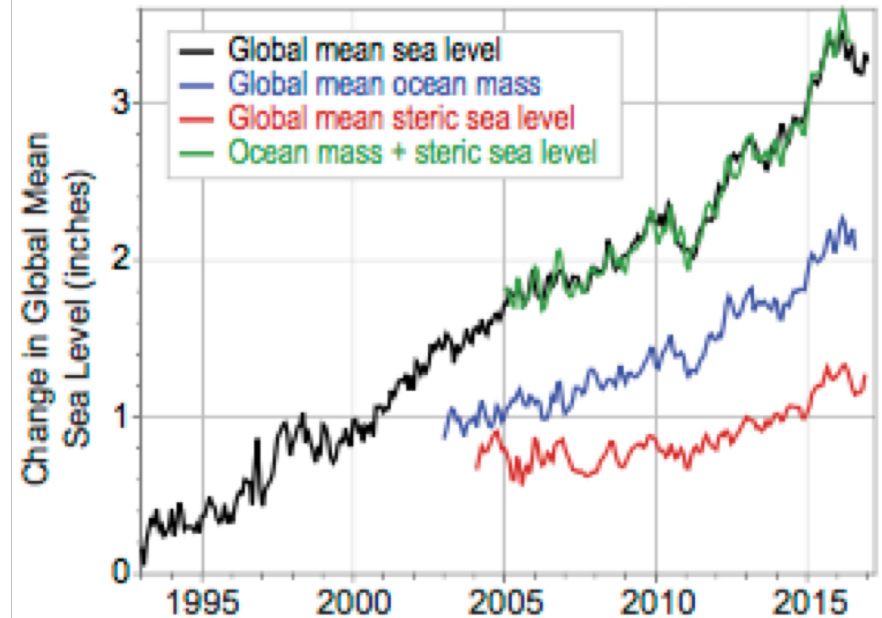
Change in Sea Surface Height, 1993–2015



inches/decade



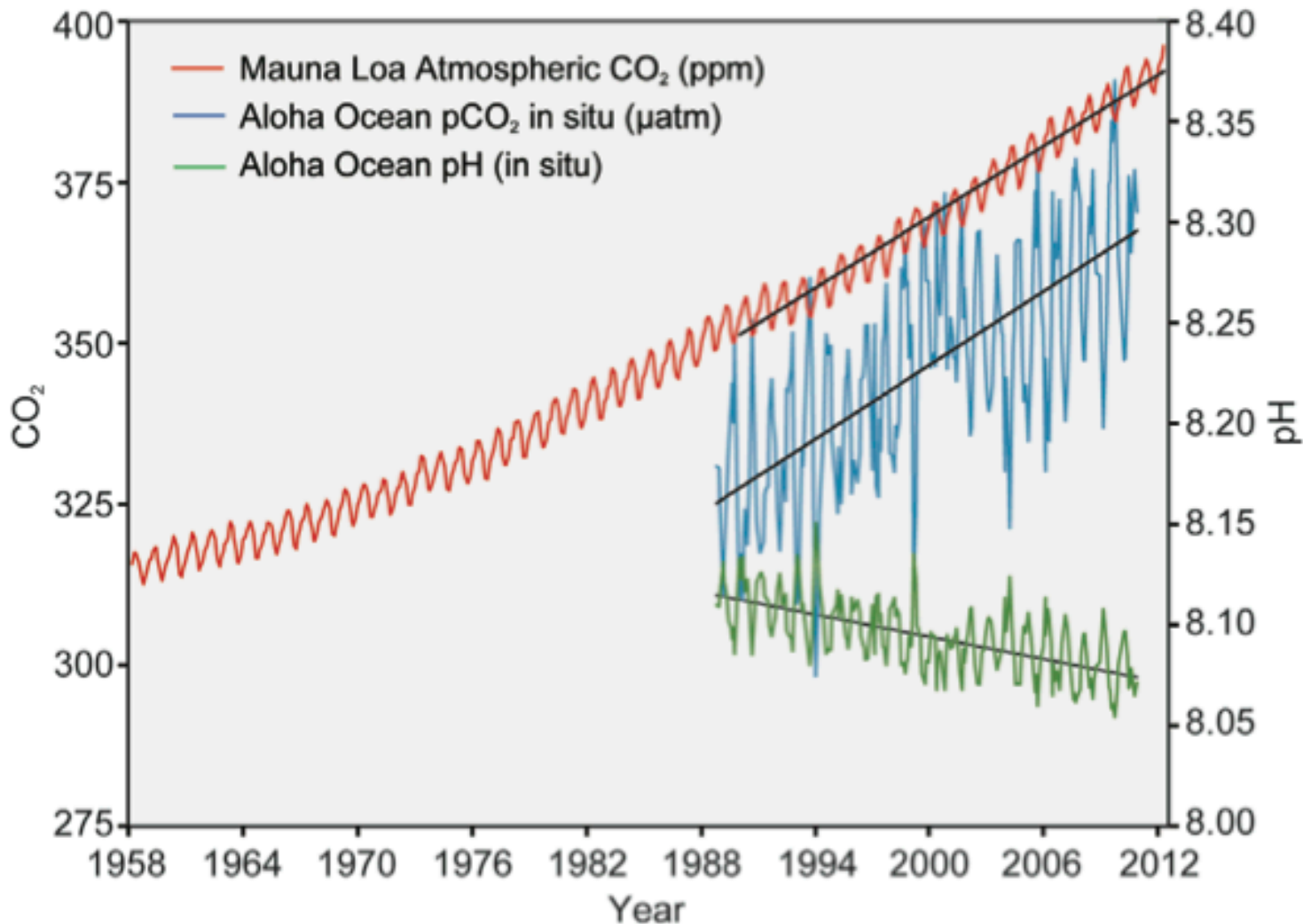
Global Mean Sea Level Budget



Climate Science Special Report, USGCRP  
<https://science2017.globalchange.gov/>

**Coastal areas have already experienced increasing MSL due to (1) expansion of sea water as the ocean warms and (2) melting of ice in glaciers and ice sheets in Greenland and Antarctica.**

# ... and Becoming More Acidic



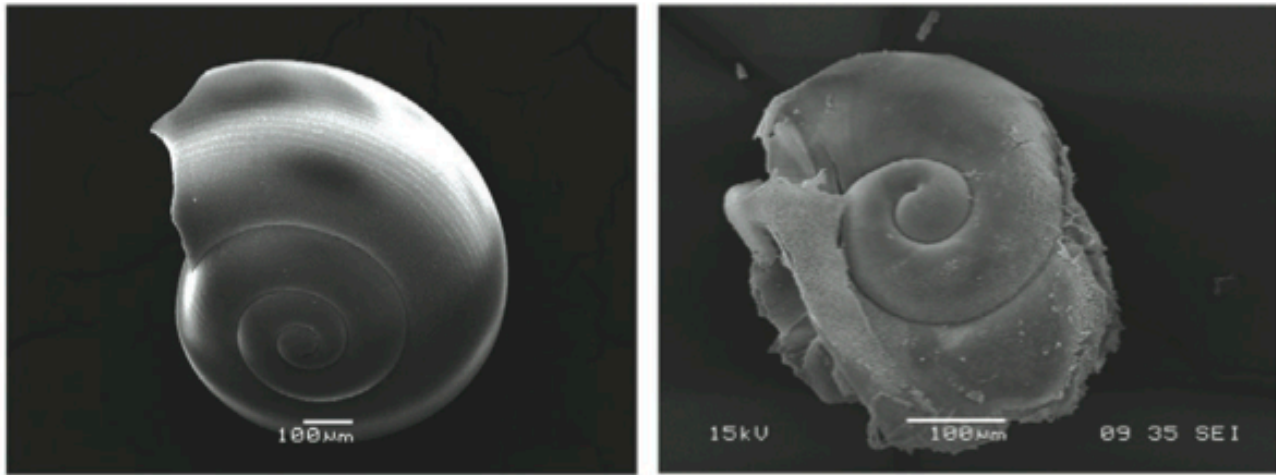
**Over the past 300 million years, ocean pH has been slightly basic, averaging about 8.2. Today, it is around 8.1, a drop of 0.1 pH units, representing a 25% increase in acidity over the past two centuries.**

**-- Nat. Geo. (2017)**

<http://nca2014.globalchange.gov/>

# Ocean Acidification

## Shells Dissolve in Acidified Ocean Water



Pteropods, or “sea butterflies,” are eaten by a variety of marine species ranging from tiny krill to salmon to whales. The photos show what happens to a pteropod’s shell in seawater that is too acidic. On the left is a shell from a live pteropod from a region in the Southern Ocean where acidity is not too high. The shell on the right is from a pteropod in a region where the water is more acidic. (Figure source: (left) Bednaršek et al. 2012<sup>e</sup> (right) Nina Bednaršek).

**CHESAPEAKE BAY  
IMPACT: Ocean  
acidification could  
threaten ability of  
oysters to create and  
maintain their shells**

# The Washington Region Needs to Build Resilience to Climate Variability and Change

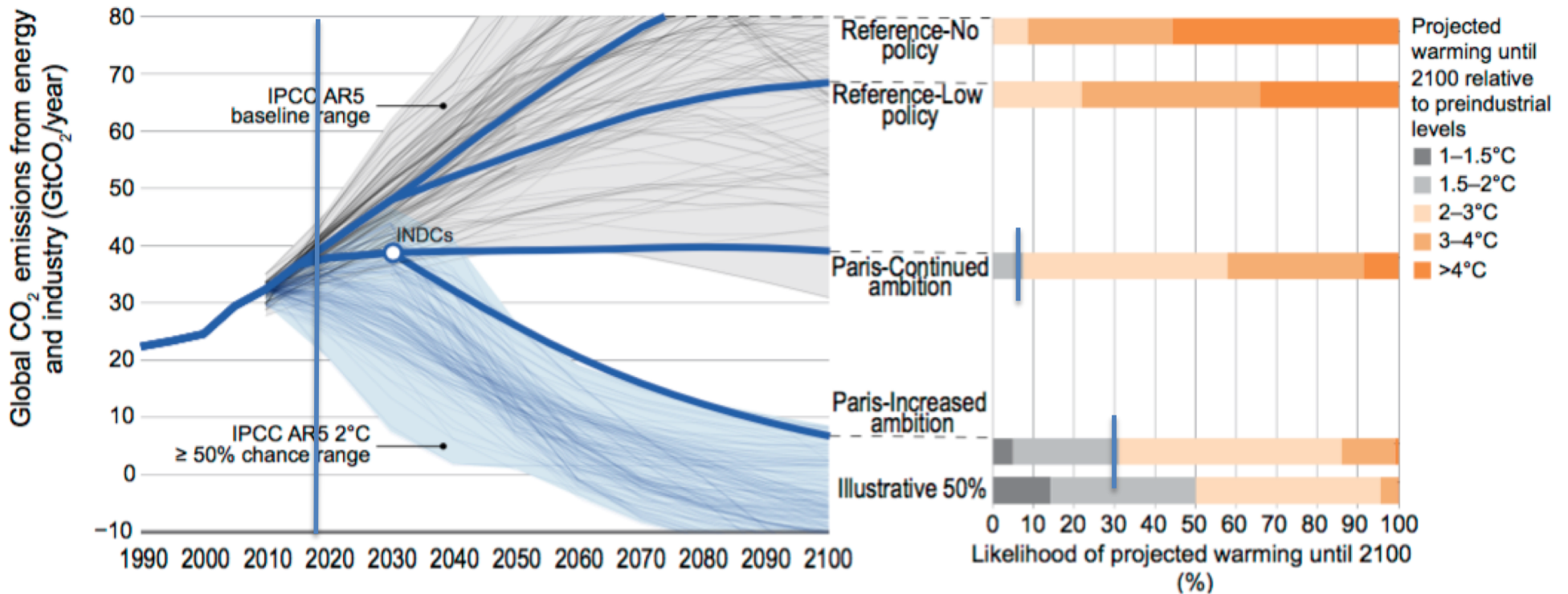
- *National Climate Assessment* and many other reports highlight several **critical concerns for the Southeast** US, including Metropolitan Washington
- **2008 Virginia Governor's Climate Change Commission and 2015 Governor's Climate Change and Resiliency Update Commission** called for more research and action to address climate change
- Maryland codified Commission on Climate Change in 2015 to advise the Governor and General Assembly "on ways to **mitigate the causes of, prepare for, and adapt to the consequences of climate change**".
- Bringing the *global* climate change problem down to the *state/regional* level **makes the topic accessible** and gives people a **sense of purpose** to strive toward greater resiliency

# The Washington Region Needs to Build Resilience to Climate Variability and Change

- **Energy**
  - Mostly fossil fuel (coal, natural gas) and nuclear power sources
  - Substantial coal and uranium resources, strongly affected by national and international markets and policy changes
- **Coastal Zone, Chesapeake Bay and Potomac River**
  - The economy and citizens' health/livelihood depend on coastal zone & Chesapeake Bay
- **Norfolk**
  - Largest naval base and 3<sup>rd</sup> busiest commercial port in eastern US
  - 2<sup>nd</sup> most vulnerable place in US to sea level rise – infrastructure will be severely compromised
- **National Capital Region**
  - Nearly 6 million inhabitants - public health emergencies (heat waves) and nuisance flooding near the tidal Potomac
- **Piedmont and Appalachian Mountains Regions**
  - Natural landscape and communities: challenged and under-resourced



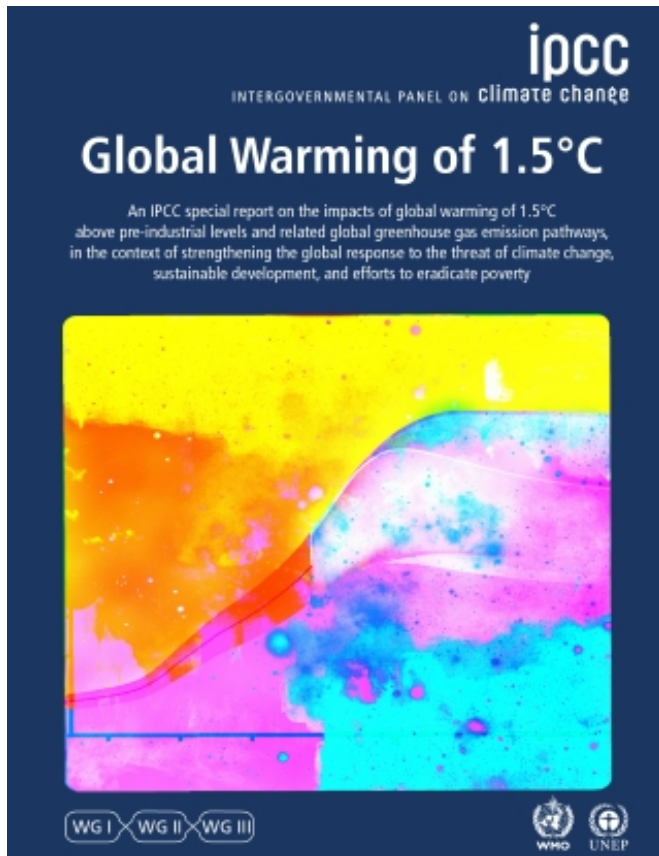
# What Can We Expect Humans to Do in the Future?



Climate Science Special Report, USGCRP  
<https://science2017.globalchange.gov/>

**We are halfway to a “dangerous” global average surface temperature increase of 2 °C. Even if the Paris climate agreement, with US rejoining, is upheld through 2030 and beyond, we have only an 8% chance of keeping the total warming to less than 2 °C by 2100.**

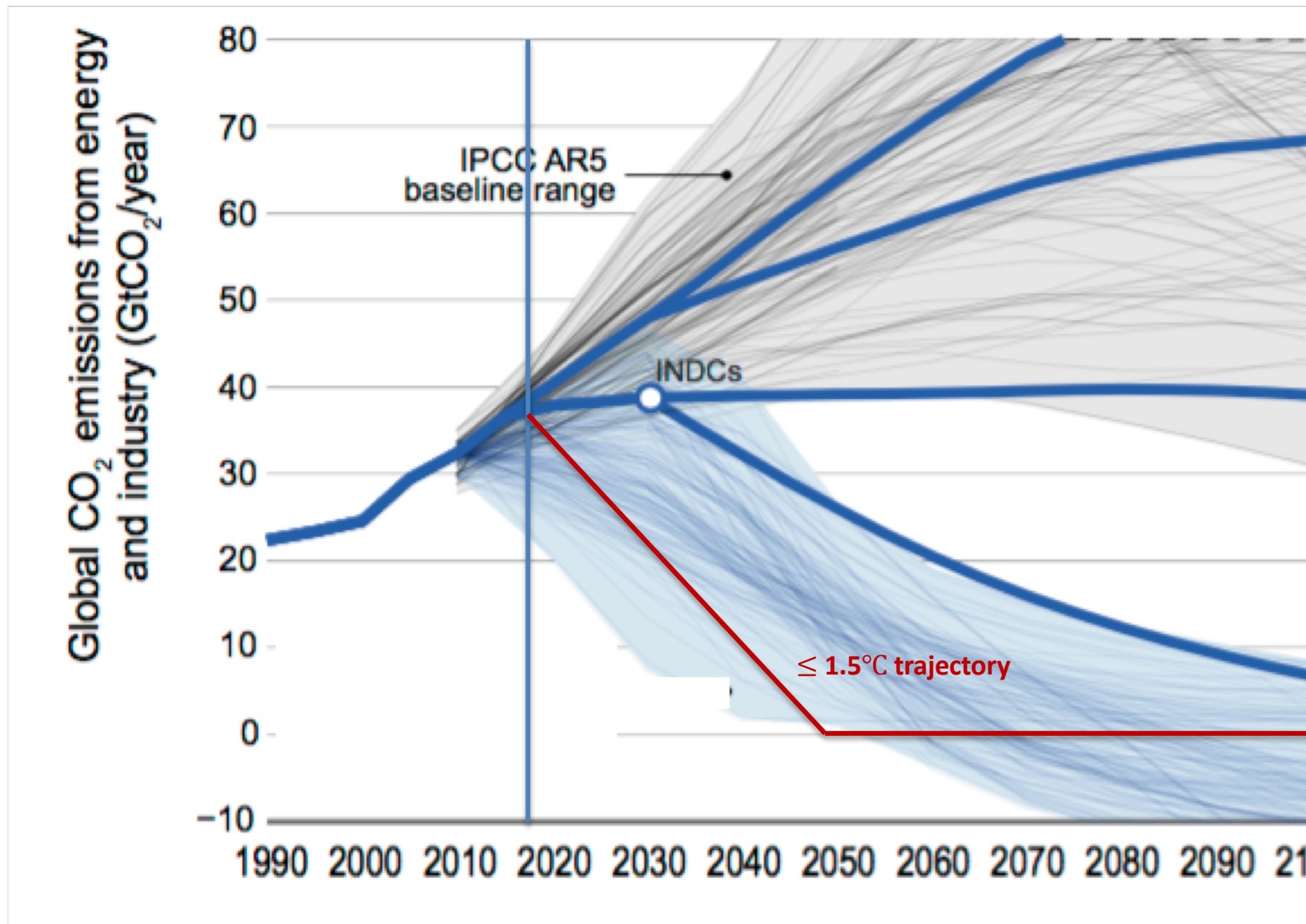
# Is 2°C the Right Threshold for “Dangerous Climate Change”?



<http://www.ipcc.ch/report/sr15/>  
(October 2018)

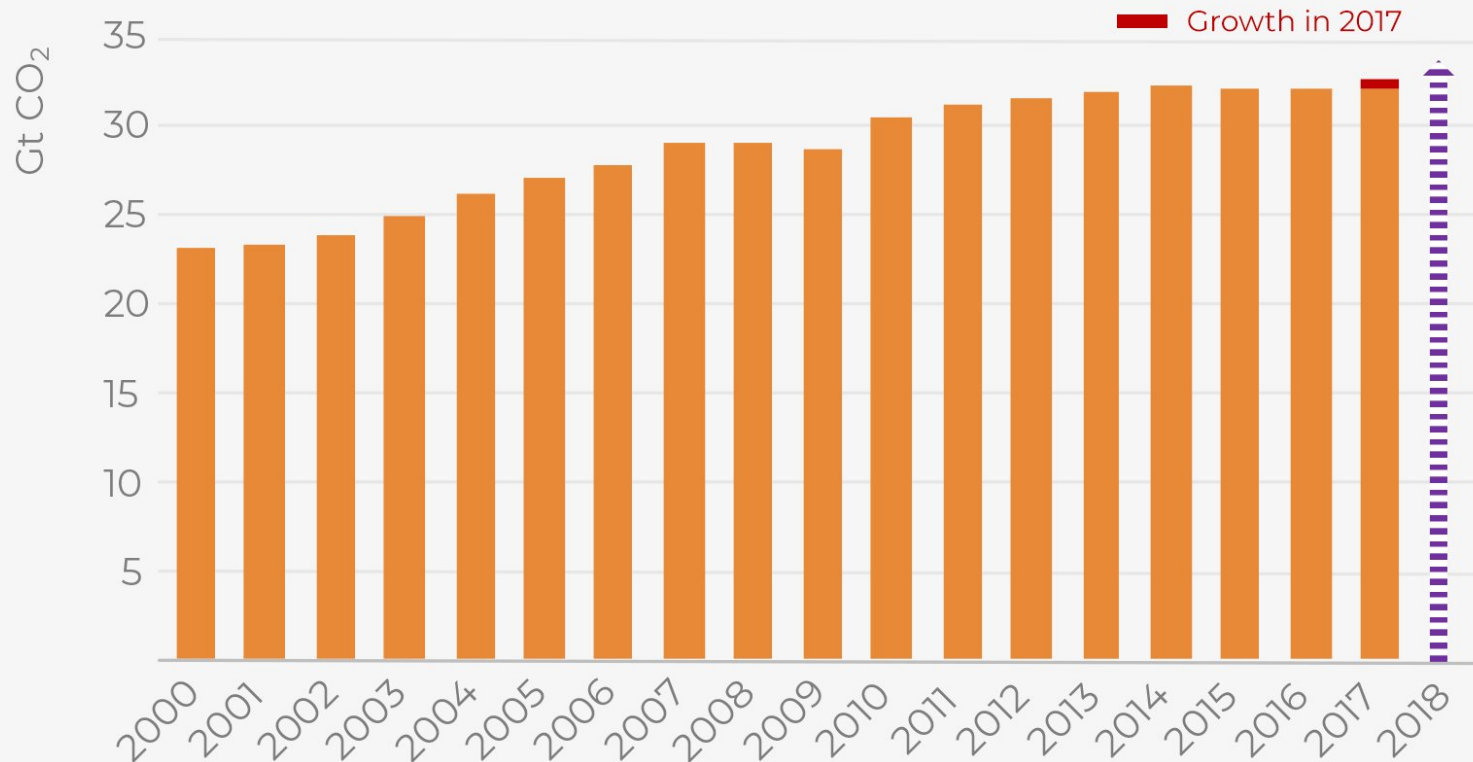
- Climate has changed 1°C so far: **more frequent heatwaves**; higher frequency/intensity/amount of **heavy precipitation events**; and increased **risk of drought** in the Mediterranean region
- To keep warming below 1.5°C: Reduce all anthropogenic CO<sub>2</sub> emissions **to net zero globally around 2050** and make concurrent deep reductions in other GHG (esp. methane)
- Benefits of ≤ 1.5°C warming: **Limit risks** of increases in extreme events

# Keeping Climate Change Below 2 °C is Very Challenging



# What is the Actual Trajectory?

Global energy-related CO<sub>2</sub> emissions  
IEA Analysis



The only year with a decline in global emissions was 2009



# Washington Region Needs **Climate Science to Help Build Resilience to Climate Variability and Change**

The citizens and businesses of the United States, the Mid-Atlantic and the Washington Region are not exempt from the changes Earth will experience during the rest of this century.

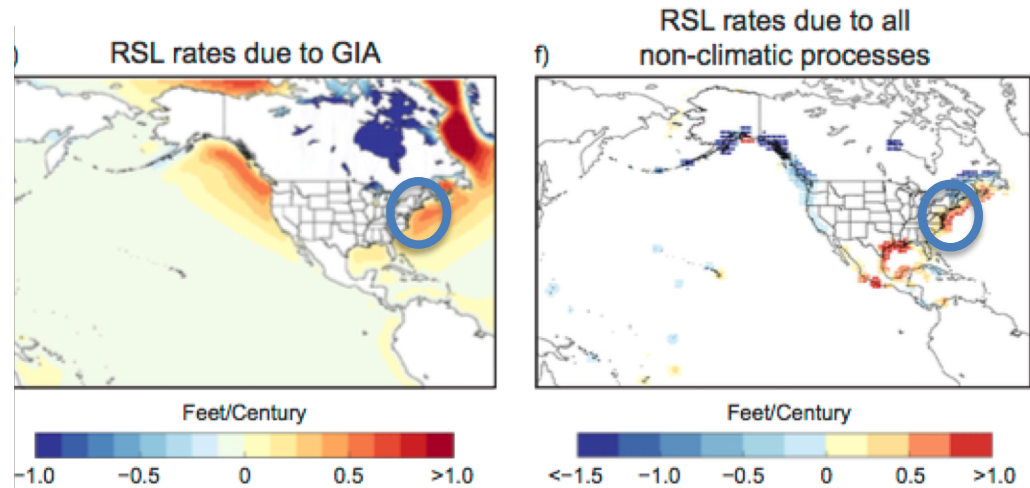
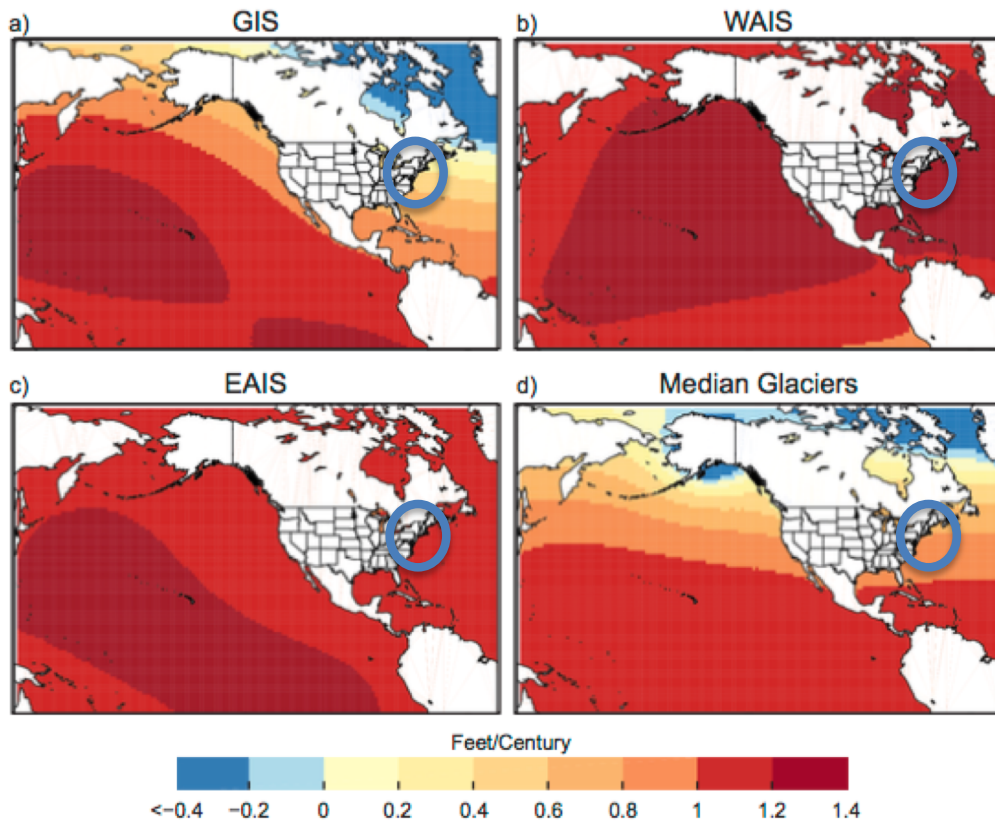
**There will be a new normal.**

**We all need to prepare for it.**

# Why Does the Washington Region Need to Act?

- **The Washington Region is already impacted** by climate change in the Tidewater region, where sea level rise is apparent and expected to accelerate.

# Double-double Whammy!



Climate Science Special Report, USGCRP  
<https://science2017.globalchange.gov/>

- Ocean warming
- Melting ice sheets and glaciers
- Glacial-isostatic adjustment
- Sediment compaction

**In addition to *global* sea level rise due to warming oceans, the Virginia coast will experience even greater local increases due to melting of the ice sheets in Greenland and Antarctica, melting glaciers, glacial-isostatic adjustment (GIA) and sediment compaction.**

# We're Already Experiencing It



Nuisance (high-tide) floods: Sunny-day, nonfatal flooding that closes roads, seeps into basements, and generally causes a nuisance

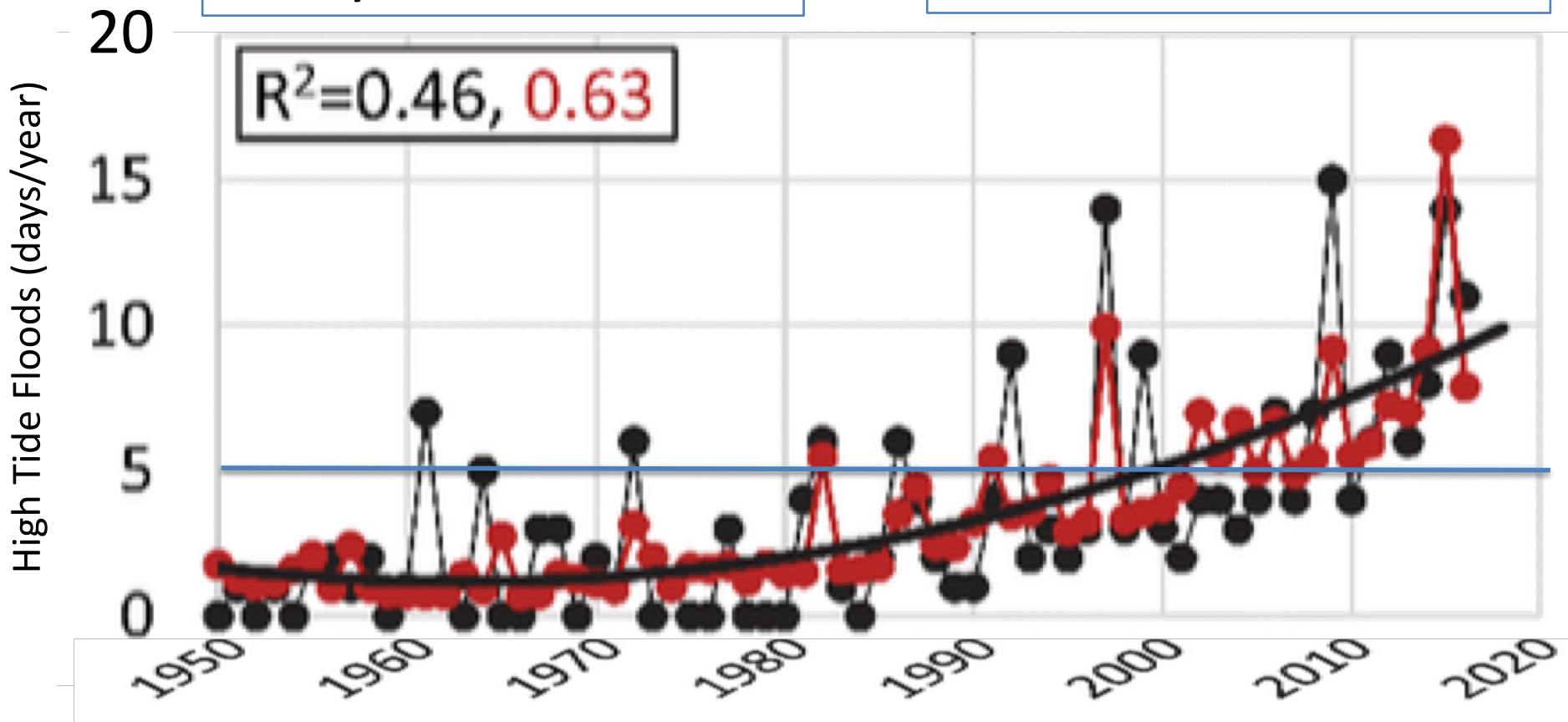
Norfolk, VA 11 July 2015



# High Tide Floods – Norfolk VA

3 years w/ >5 events 1950-1980  
 ~½ the years have no events

13 years w/ >5 events 1986-2016  
 No year without any events



- Observations
- Regression Quadratic Fit
- Trend+ENSO

NOAA Tech Rep NOS CO-OPS 086 (Feb. 2018)  
 Patterns and Projections of High Tide Flooding  
 Along the US Coastline

# Projection of “Nuisance” Flooding

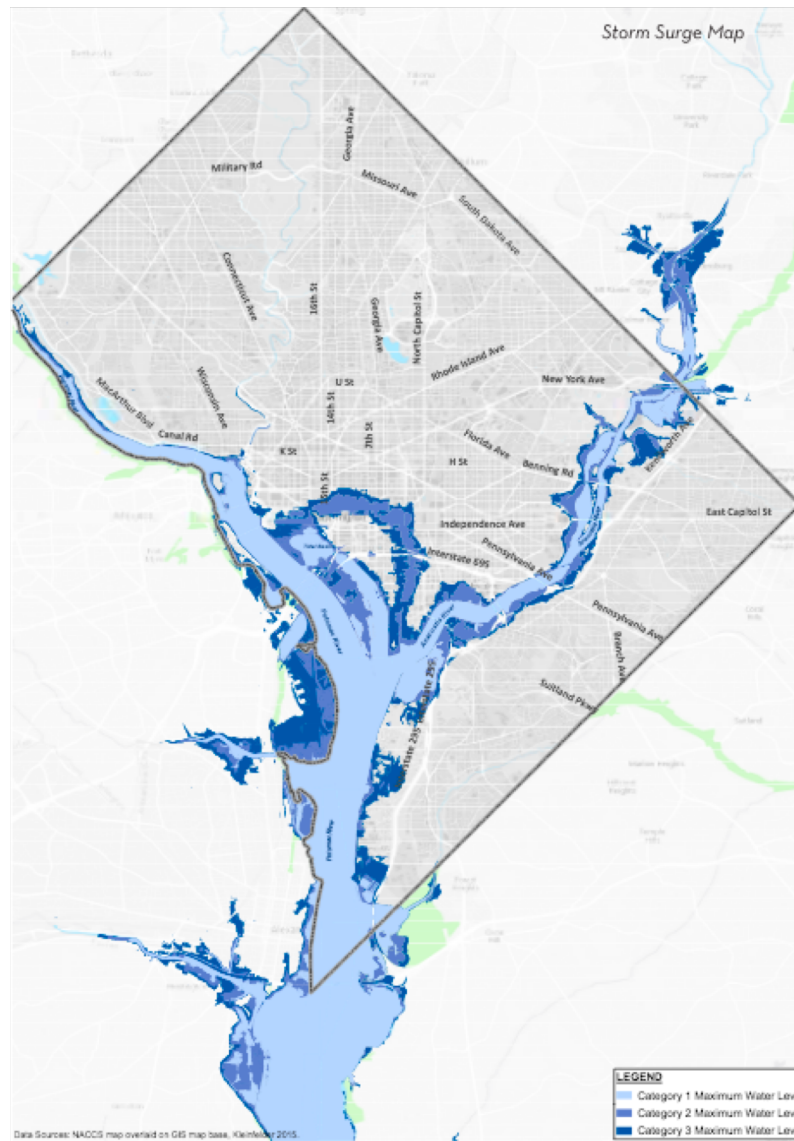
**Today’s flood in Norfolk will become the daily high tide by the 2060s**

**- NOAA Tech Rep NOS CO-OPS 086: Patterns and Projections of High Tide Flooding Along the US Coastline (Feb. 2018)**

# Annapolis High Tide Flooding



# DC Storm Surge Potential



# Jefferson Island?

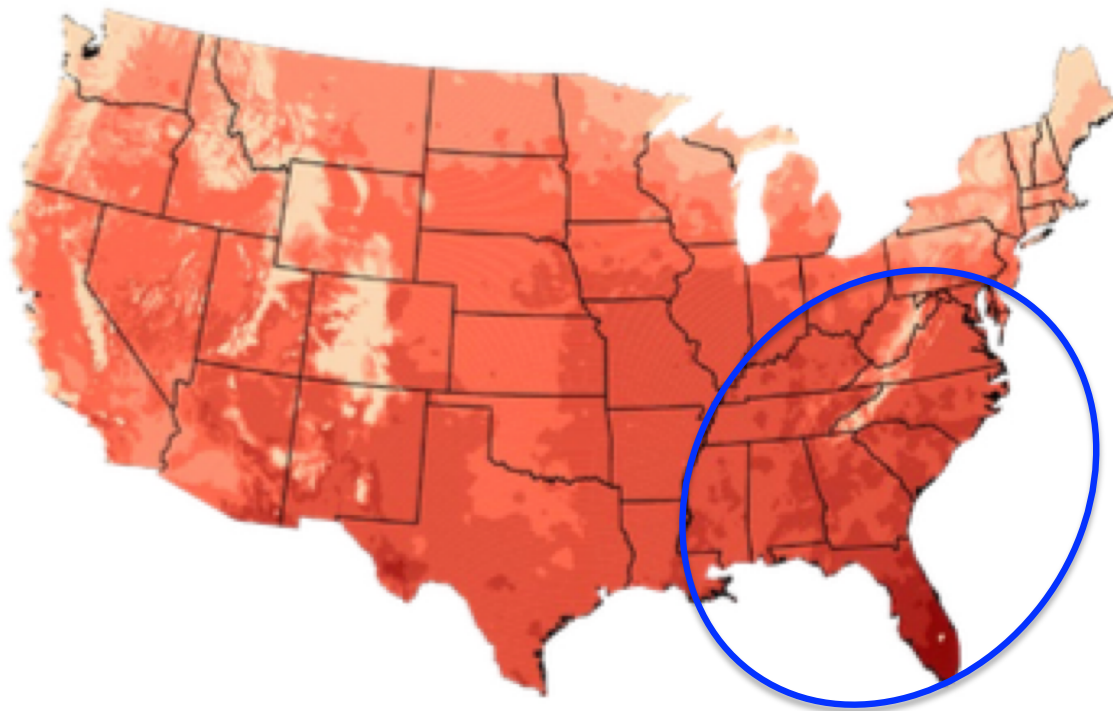


# Why Does the Washington Region Need to Act?

- The Washington Region is already impacted by climate change in the Tidewater region, where sea level rise is apparent and expected to accelerate.
  - Accelerating melting of the Greenland and west Antarctic ice sheets and global glaciers will raise sea level faster
- The Washington Region is impacted by changes in weather in the mid-Atlantic
  - More intense heat waves
  - More frequent severe weather, e.g. excessive rainfall

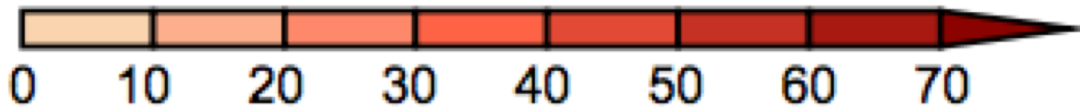
# Extreme Warm

Projected Change in Number of Days Above 90°F  
Mid 21st Century, Higher Scenario (RCP8.5)



**Within the next 40 years, there will be 40-50 \*more\* days each year with highs above 90°F and up to 30 more days with highs above 95°F in southeastern US, if CO<sub>2</sub> emissions continue on the high scenario trajectory.**

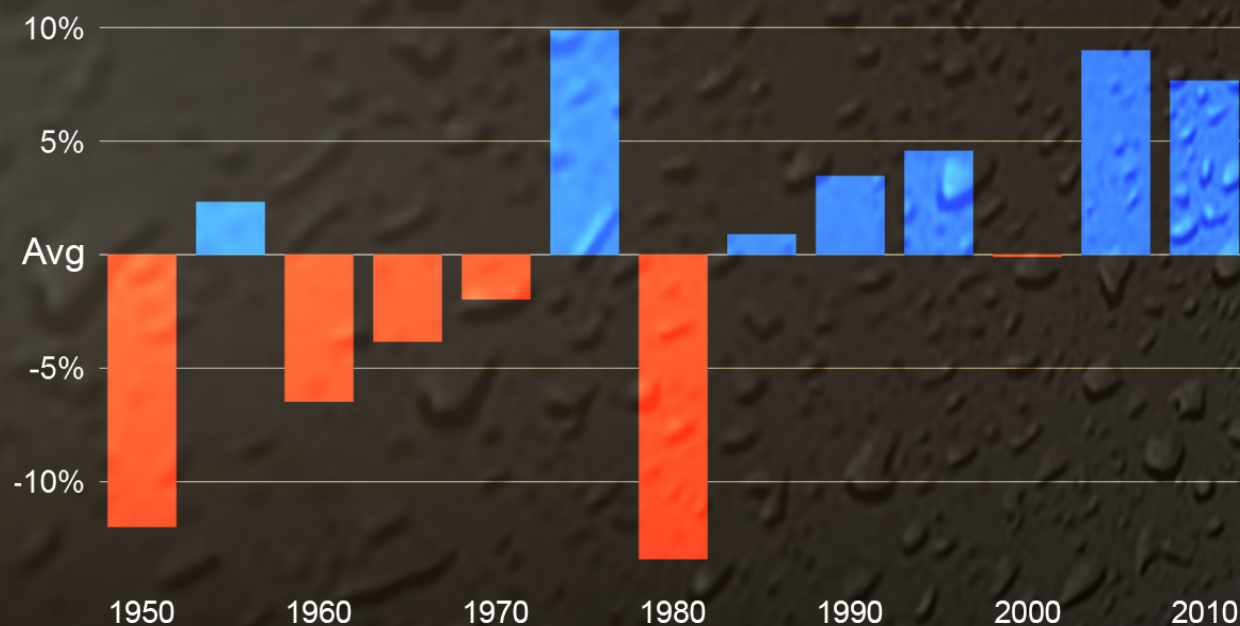
Weighted Multi-Model Mean



Climate Science Special Report, USGCRP  
<https://science2017.globalchange.gov/>

# WHEN IT RAINS IT POURS

CHANGE IN FREQUENCY OF HEAVIEST DOWNPOURS • VIRGINIA



Source: Applied Climate Information System ([rcc-acis.org](http://rcc-acis.org))  
Heaviest downpours defined as top 1% of all rain events. Shown as departure from 1950-2014 Avg.

CLIMATE CENTRAL



# Ellicott City, 30 July 2016



**When it pours there's Trouble, right here in Ellicott City**

Maryland GovPics - Governor Hogan Tours Old Ellicott City  
<https://commons.wikimedia.org/w/index.php?curid=50671750>

# Ellicott City, 27 May 2018



**Second “1000-year flood” in 2 years!**

Reuters / Todd Marks

# Why Does the Washington Region Need to Act?

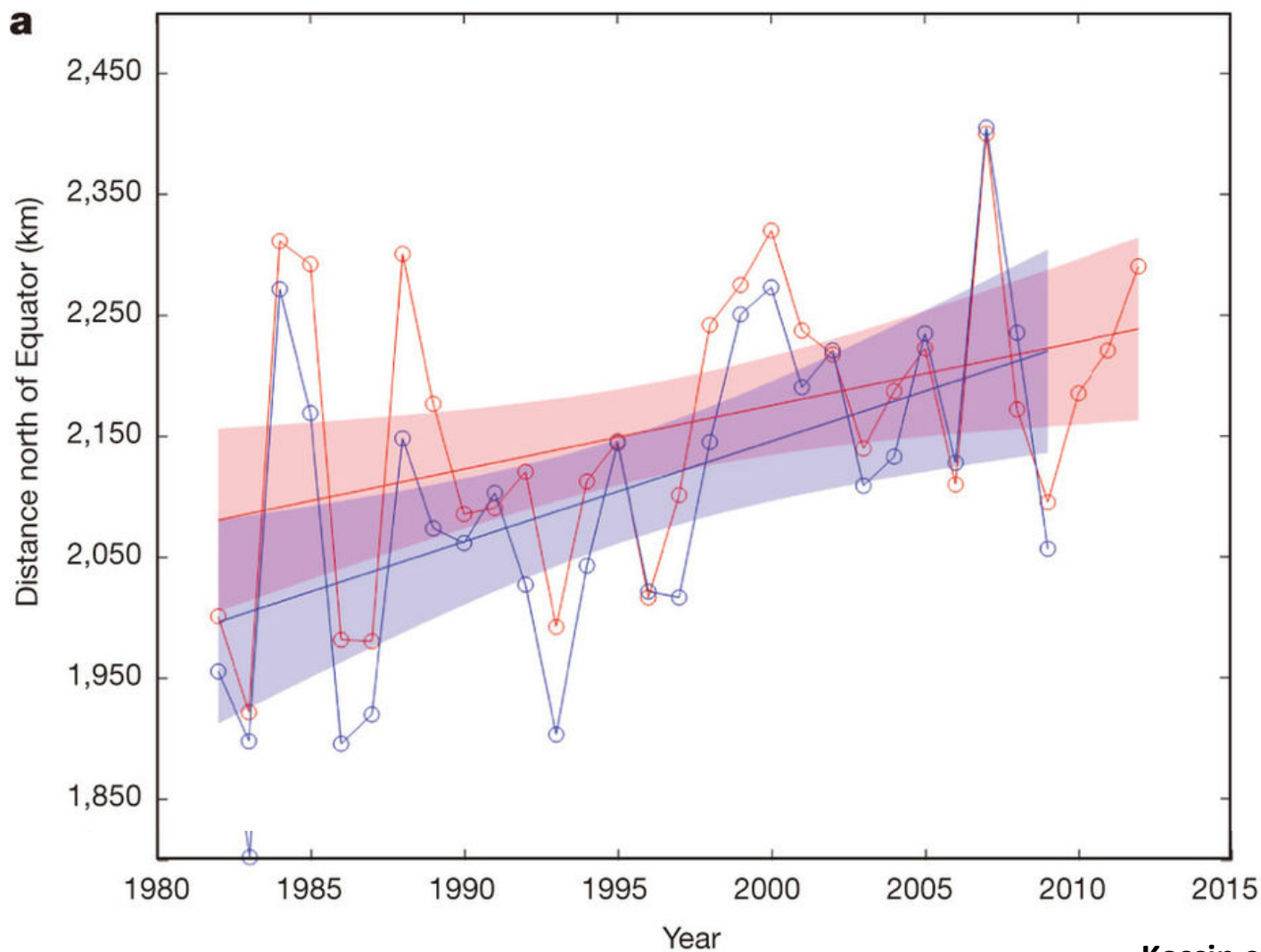
- The Washington Region is already impacted by climate change in the Tidewater region, where sea level rise is apparent and expected to accelerate.
  - Accelerating melting of the Greenland and west Antarctic ice sheets and global glaciers will raise sea level faster
- The Washington Region is impacted by changes in weather in the mid-Atlantic
  - More intense heat waves
  - More frequent severe weather, e.g. excessive rainfall
- The effects of climate change will be manifest through changes in the modes of weather variability that we experience every day
  - **Changes in intensity of tropical storms**
  - Changes in weather influenced by sub-seasonal to seasonal fluctuations such as El Nino

# Hurricane Michael



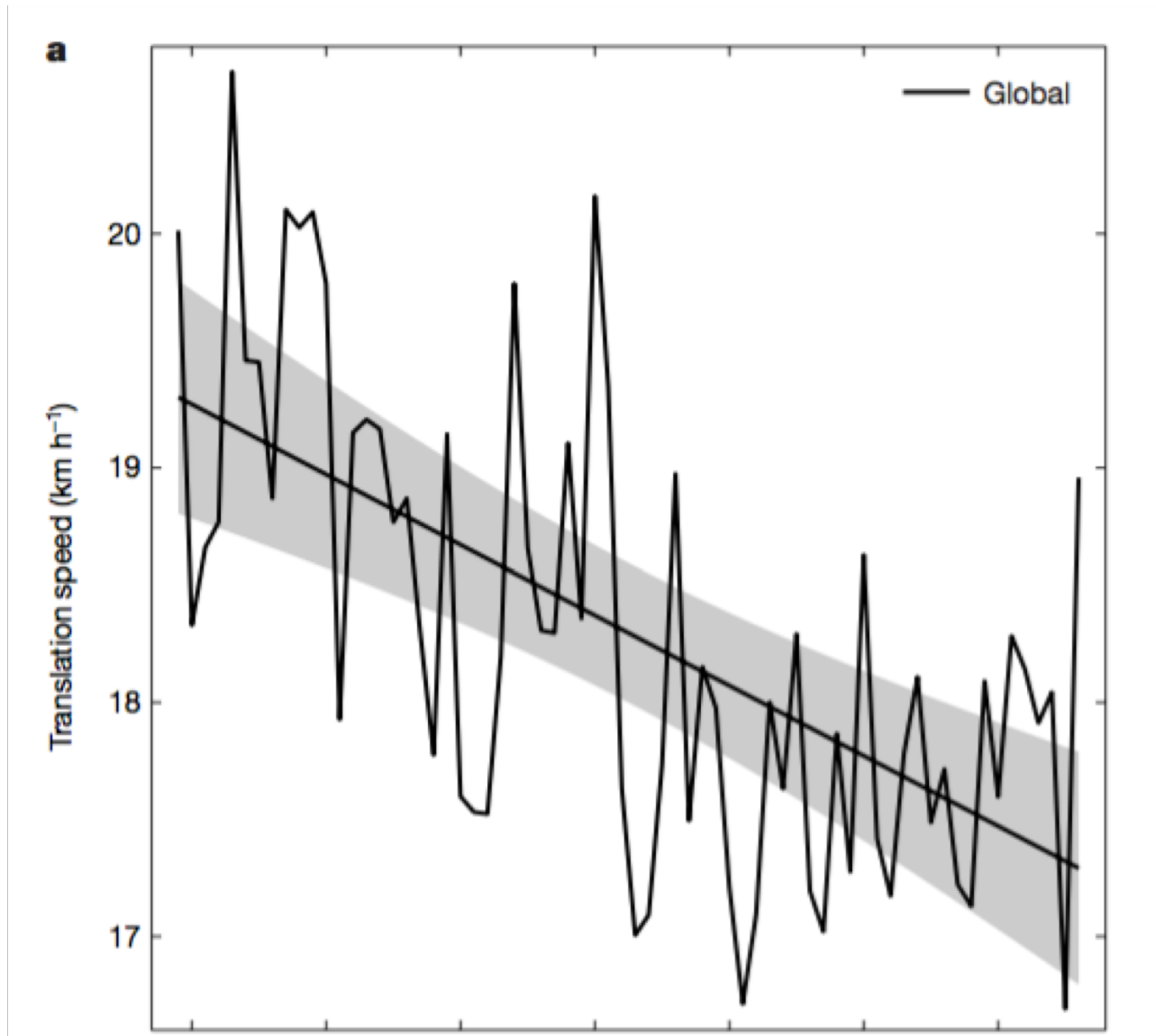
<https://weather.com/storms/hurricane/video/michael-causes-virginia-floods-on-its-deadly-march-northward>

# Tropical Cyclones are Creeping Northward



Kossin et al. 2014 (*Nature*)

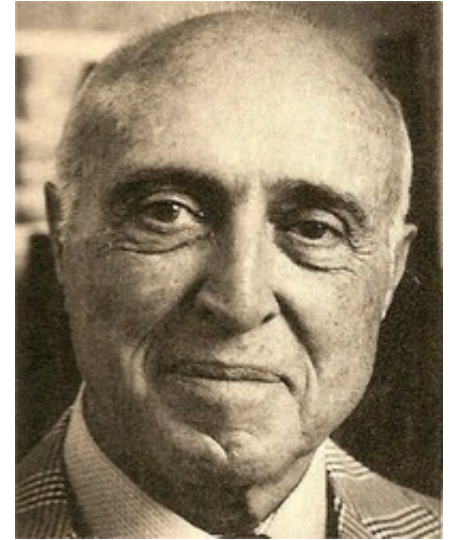
# Tropical Cyclones are Slowing Down



Kossin et al. 2018 (*Nature*)

# Hindsight is 20-20

- “Most people’s hindsight is 20-20.”
  - Attributed to Richard Armour, 1949
- Why didn’t I see that coming?
- How could I have been so stupid?
- Do we want to be saying that in 50 years?



# The “Perfect” Problem

- Climate change is a “perfect” problem that is distant, changes slowly, requires sacrifices **now** to avoid uncertain losses **far in the future**, and the estimates of its effects are contested.
  - Daniel Kahneman, 2002 Nobel laureate in Economics
- Climate change presents us with no deadlines, no geographic location, no single cause or solution and, critically, no obvious enemy







# at Mason

- **GMU hosts the largest single academic group of climate dynamics and climate modeling experts in the U.S.**, including contributors to the IPCC reports
  - “One of top programs in the USA,” -- David Wu
- COLA scientists are **developing or contributing to new and innovative approaches for climate research**
- The Mason Climate Dynamics Ph.D. program is unique in its focus on **training the next generation of climate modelers and analysts** who can improve our understanding of climate variability and our projections of future climate change

# Summary

- Earth, the US, and Metropolitan Washington **face unprecedented challenges** as climate changes and its impacts are felt in socio-economic- and eco- systems
- Being prepared for potential threats and building resilience to the impacts of climate change requires a **good understanding of what is happening, where, when, how much, and why**
- Mason stands ready to help citizens and businesses **adapt to the new normal** that is already here and is expected to change even more in the future (coming soon: Mason Institute for a Sustainable Earth)



**QUESTIONS?**

GOES-16  
First light

