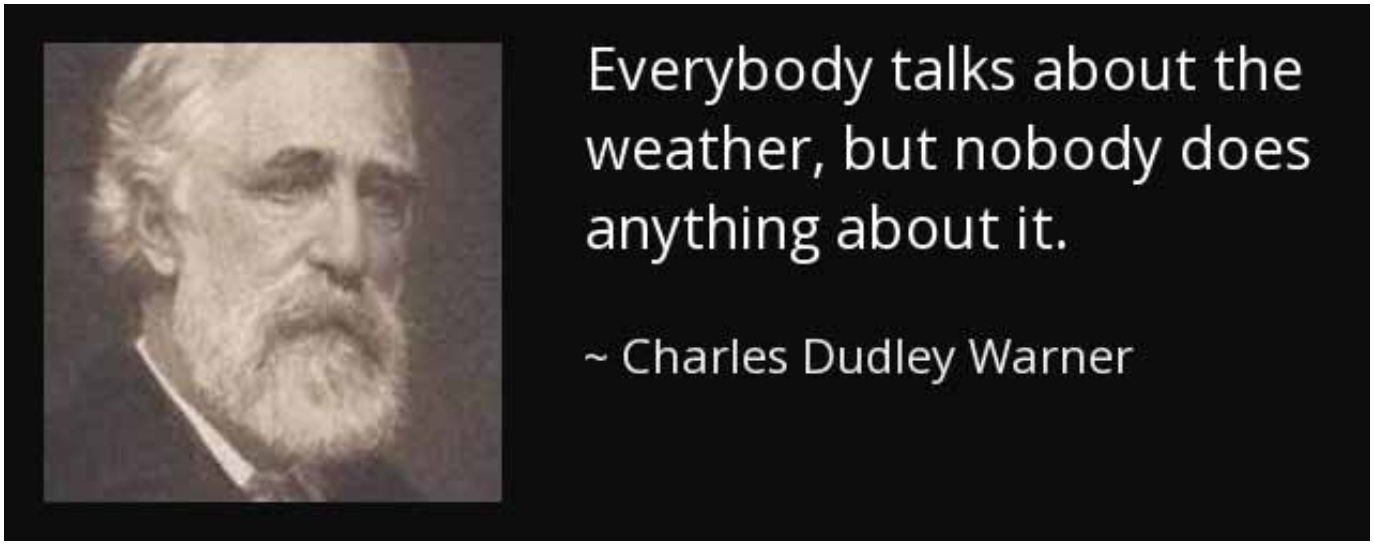
Commonwealth at Risk: Predicting and Preparing for the New Normal

Jim Kinter
George Mason University

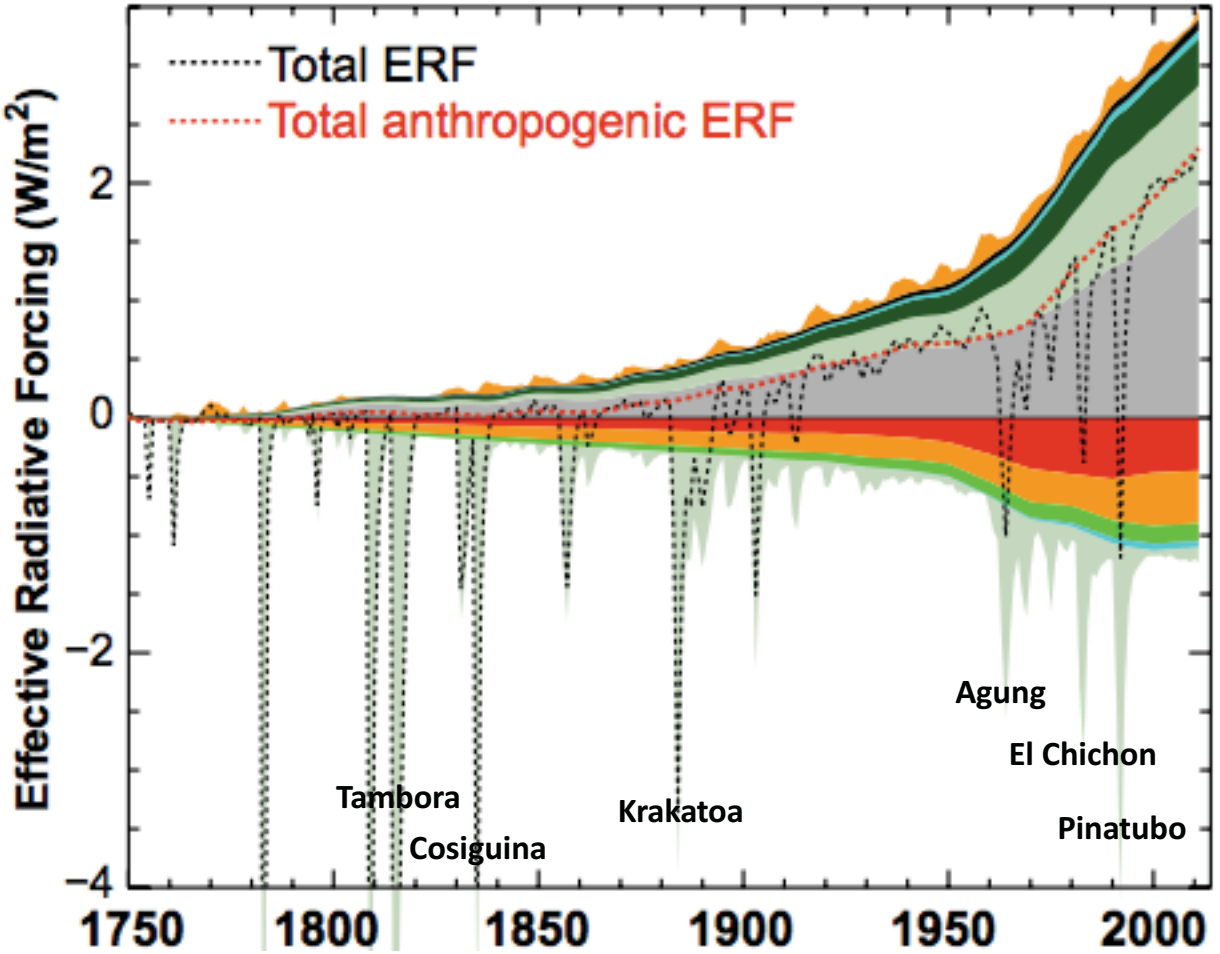


(Mark Twain quoted *him*)

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

Global climate, the 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?



GHG

CO_2

aerosols

Human activities emit greenhouse gases, including CO_2, and aerosols

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

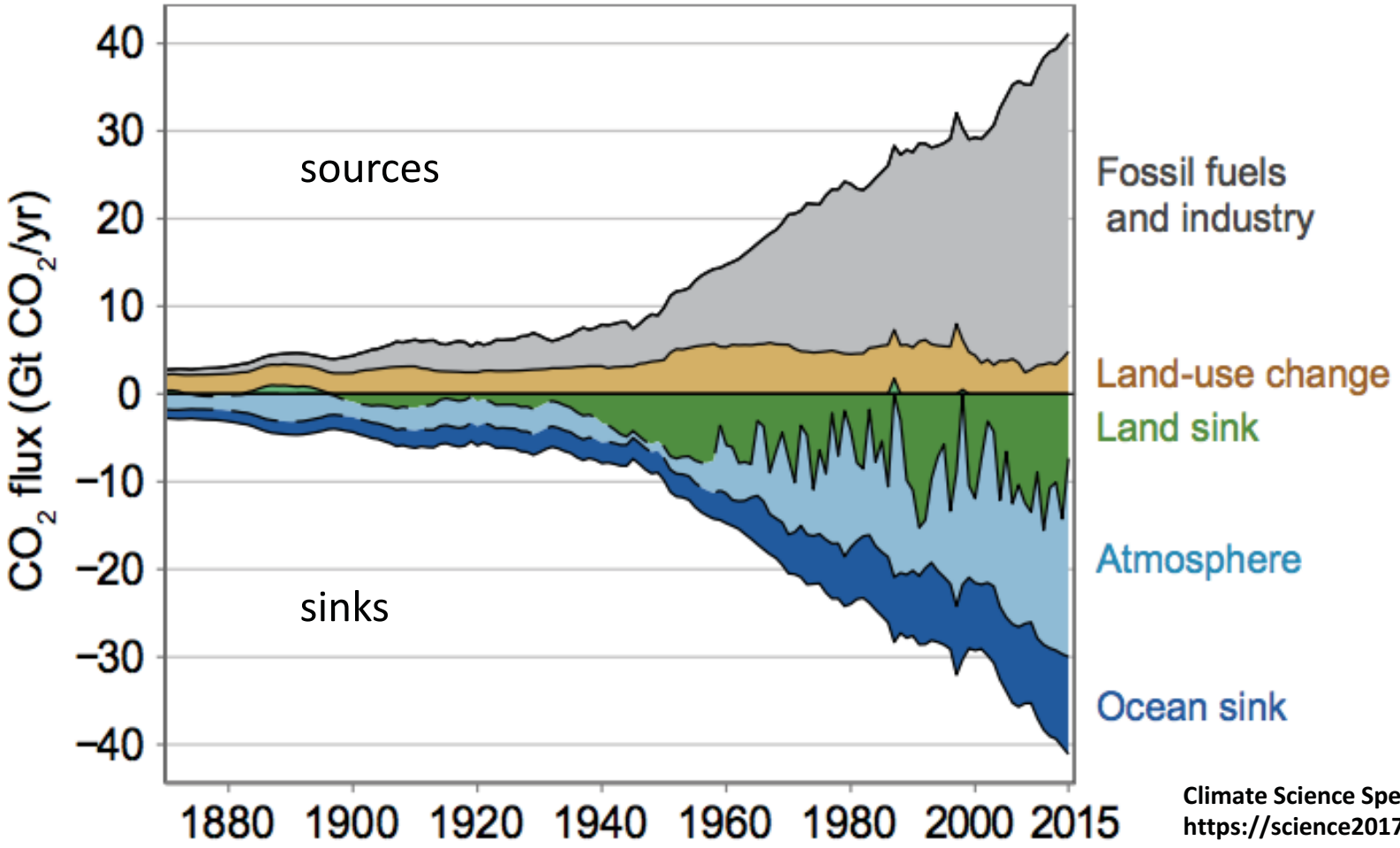
Large volcanic eruptions have a major, short-lived cooling effect.

Human activities have increased the effective radiative forcing by more than 2 W/m², most of it due to CO_2 emissions. Future scenarios of 2.6, 4.5, 6.5 and 8.5 W/m² are used to gauge future climate change.

2 W/m^2 is 1 million Gigawatts for the Earth as a whole
(a large power plant or hydroelectric dam produces 1-2 Gigawatts)

Adding 2 W/m^2 is like suspending a household light bulb over every 20' X 20' patch of Earth

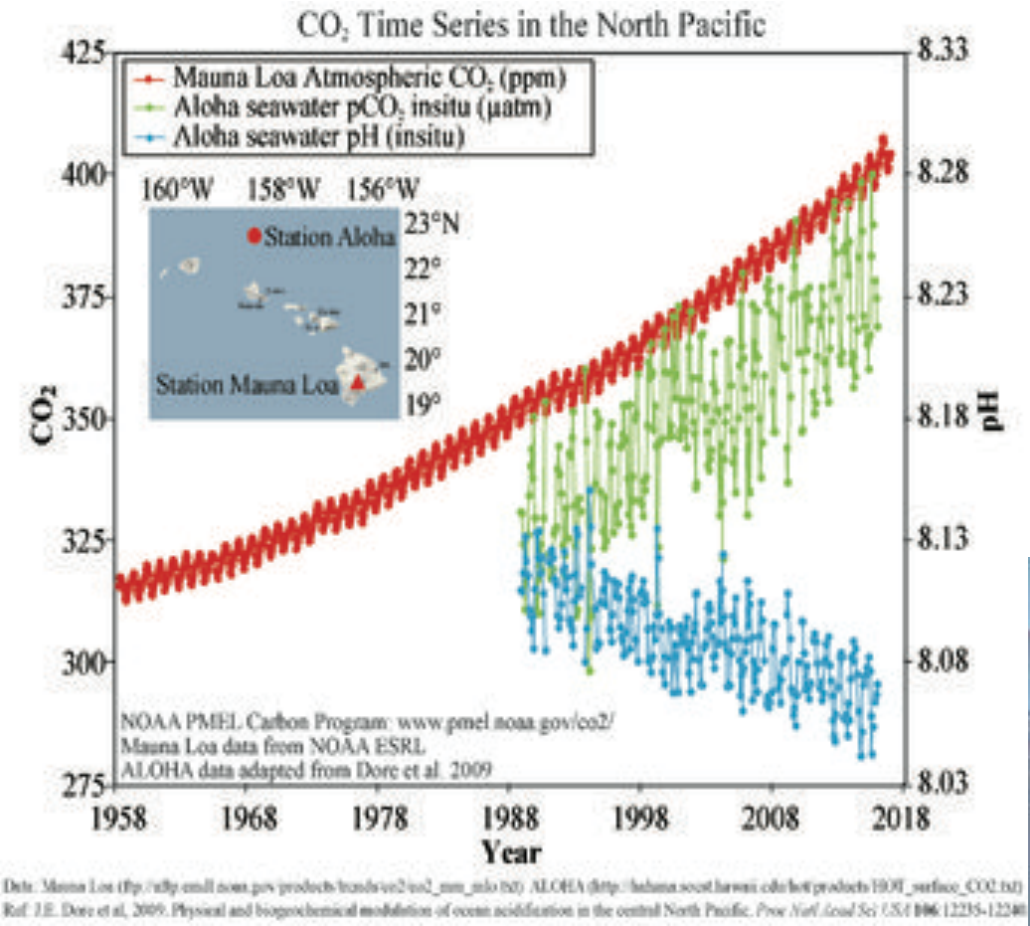
Where Does the CO_2 Come From? Where Does it Go?



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

About ½ of the 40 billion tonnes emitted CO_2 from fossil fuel combustion, cement production and land use change winds up in the atmosphere. About ½ the rest winds up in the ocean.

What is Increasing CO_2 Doing to the Ocean?



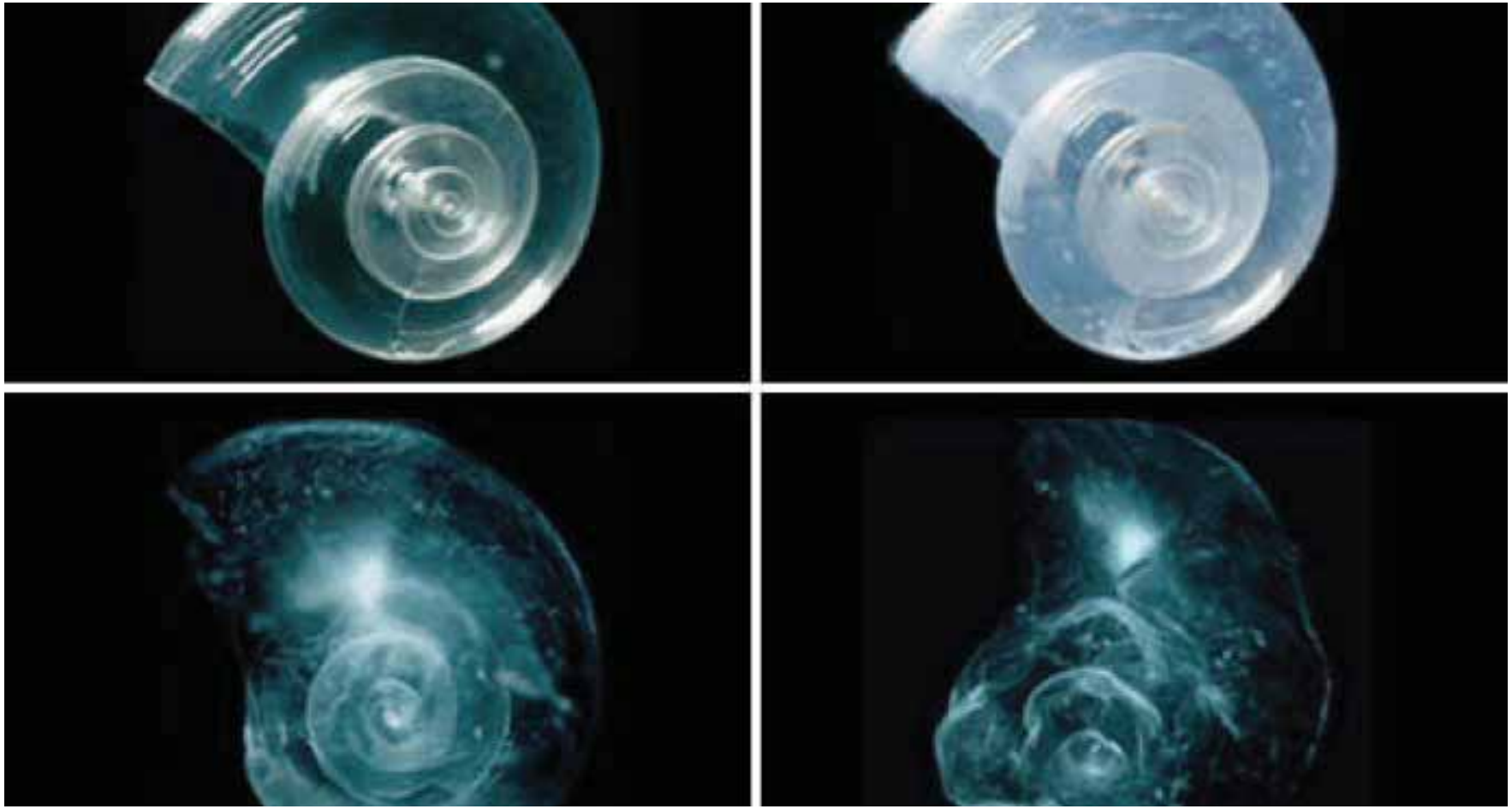
Data: Mauna Loa (ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt) ALOHA (http://hahana.soest.hawaii.edu/hot/products/HOT_surface_CO2.txt)
Ref: J.E. Dore et al, 2009: Physical and biogeochemical modulation of ocean acidification in the central North Pacific. *Proc Natl Acad Sci USA* 106:12235-12240

CO_2 dissolves in seawater and forms a weak solution of carbonic acid, lowering ocean pH.

Courtesy NOAA PMEL

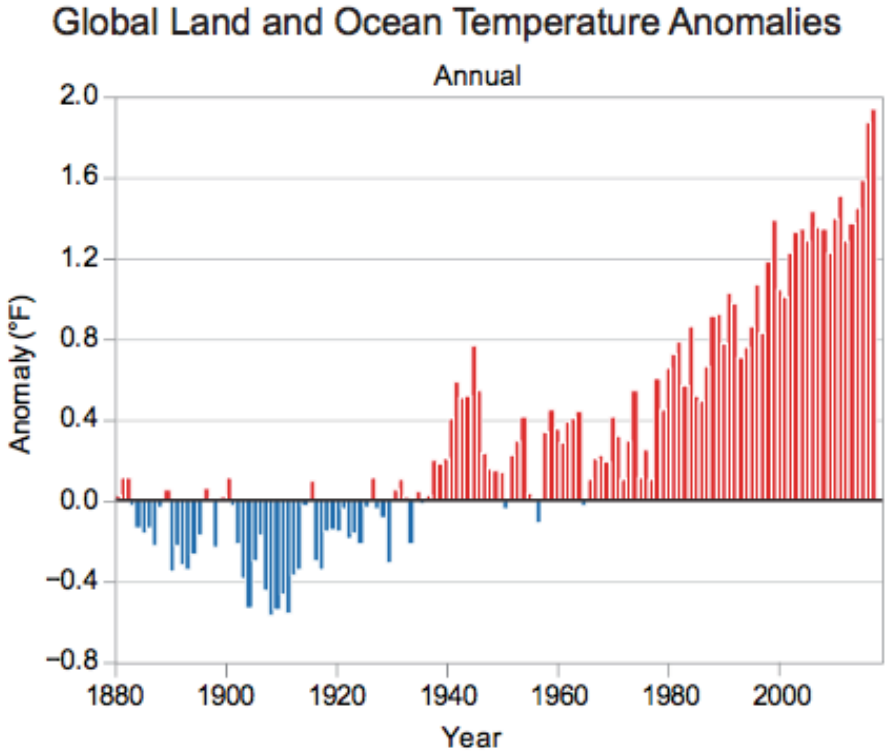
What is Increasing CO_2 Doing to Ocean Life?

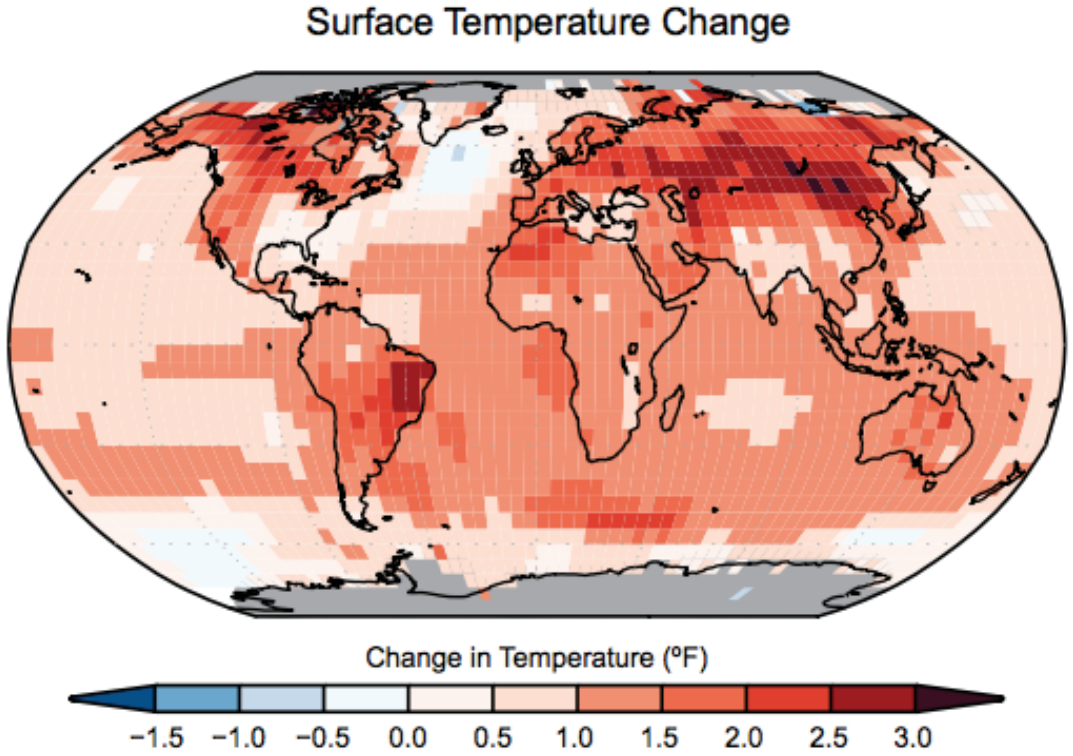
Pteropod shell in suppressed pH seawater dissolves in 45 days.



Courtesy Smithsonian

What is Increasing Atmospheric CO_2 and GHG Doing to Global Climate?

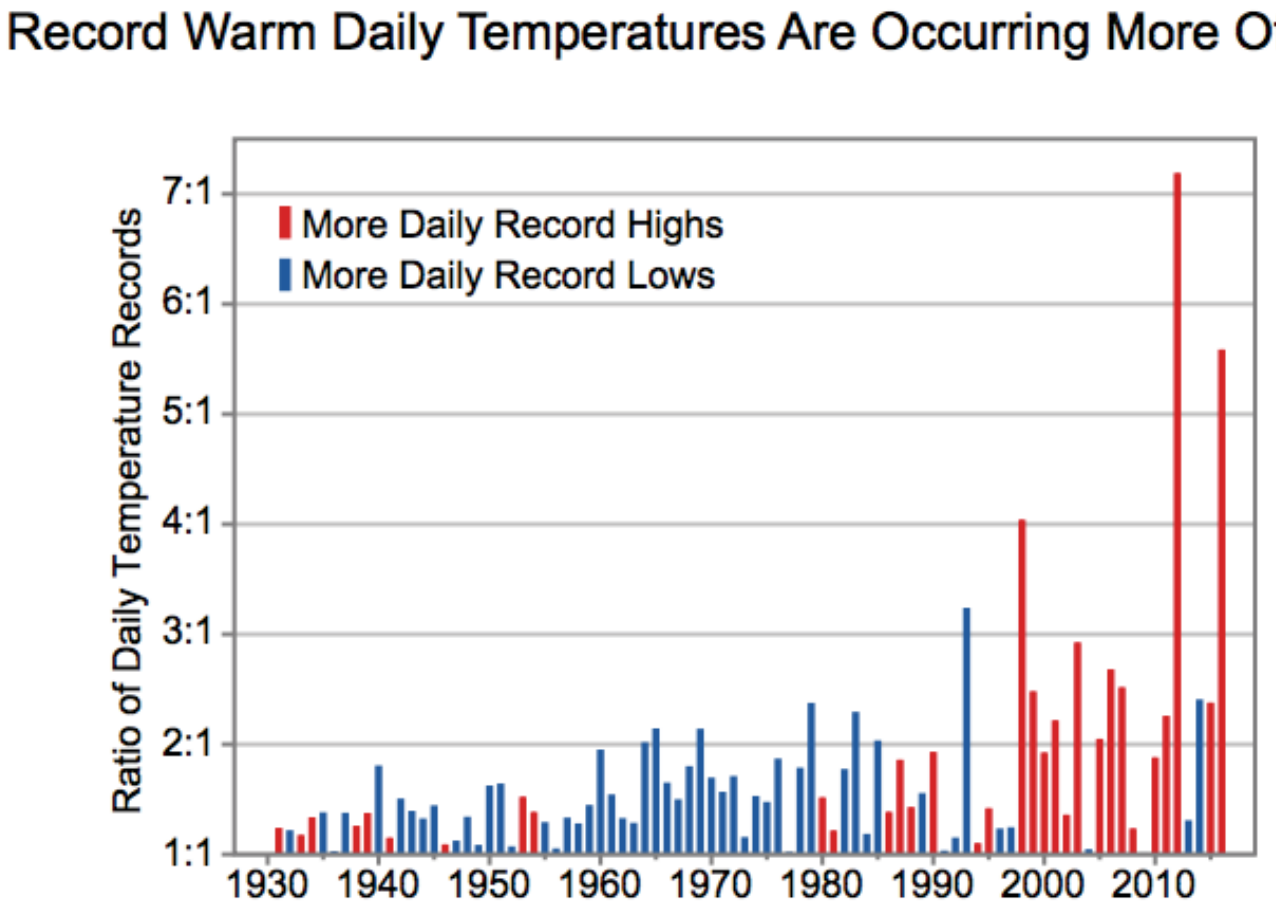




Climate Science Special Report, USGCRP
https://science2017.globalchange.gov/

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

Why Are We Concerned about 1ºC?



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https://science2017.globalchange.gov/

More record high temperatures means more energy consumption (which in turn drives more CO_2 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

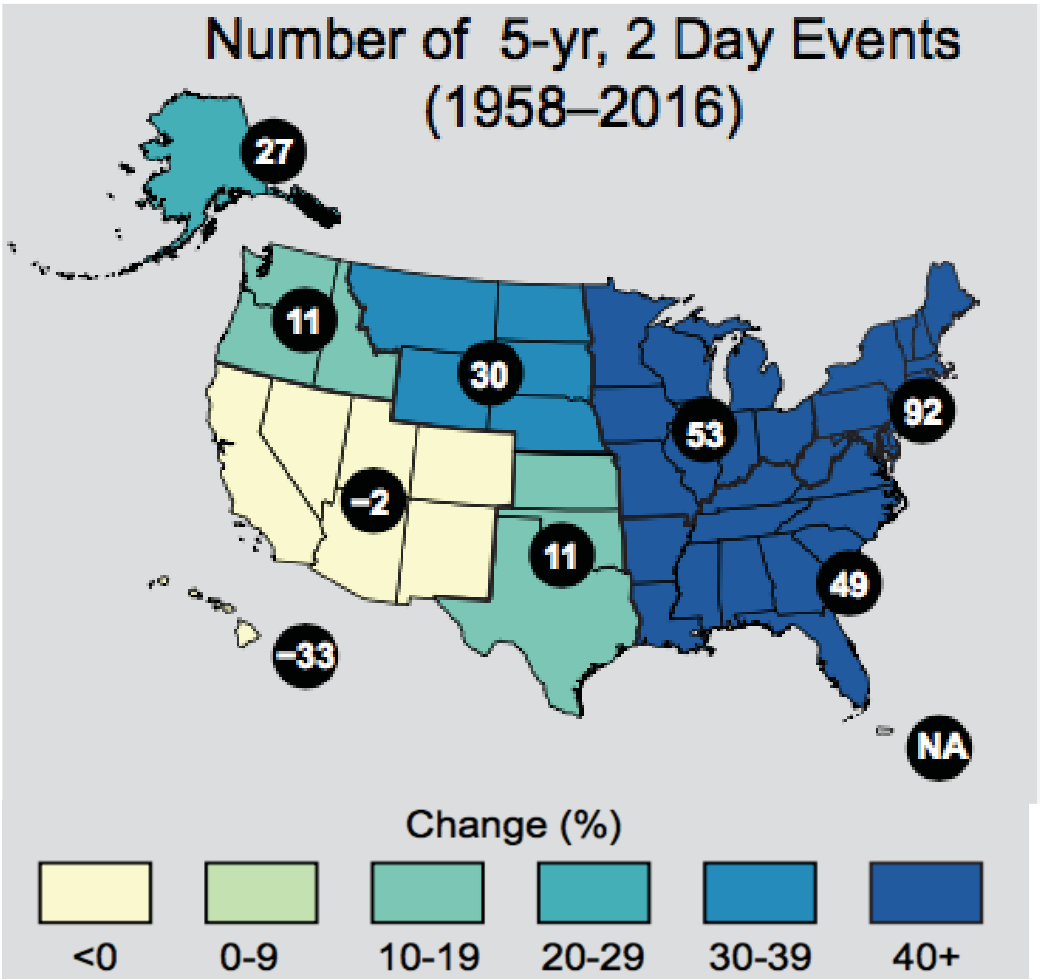
Too Much of a Good Thing?

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

… and It's Not Just the Heat



Climate Science Special Report, USGCRP
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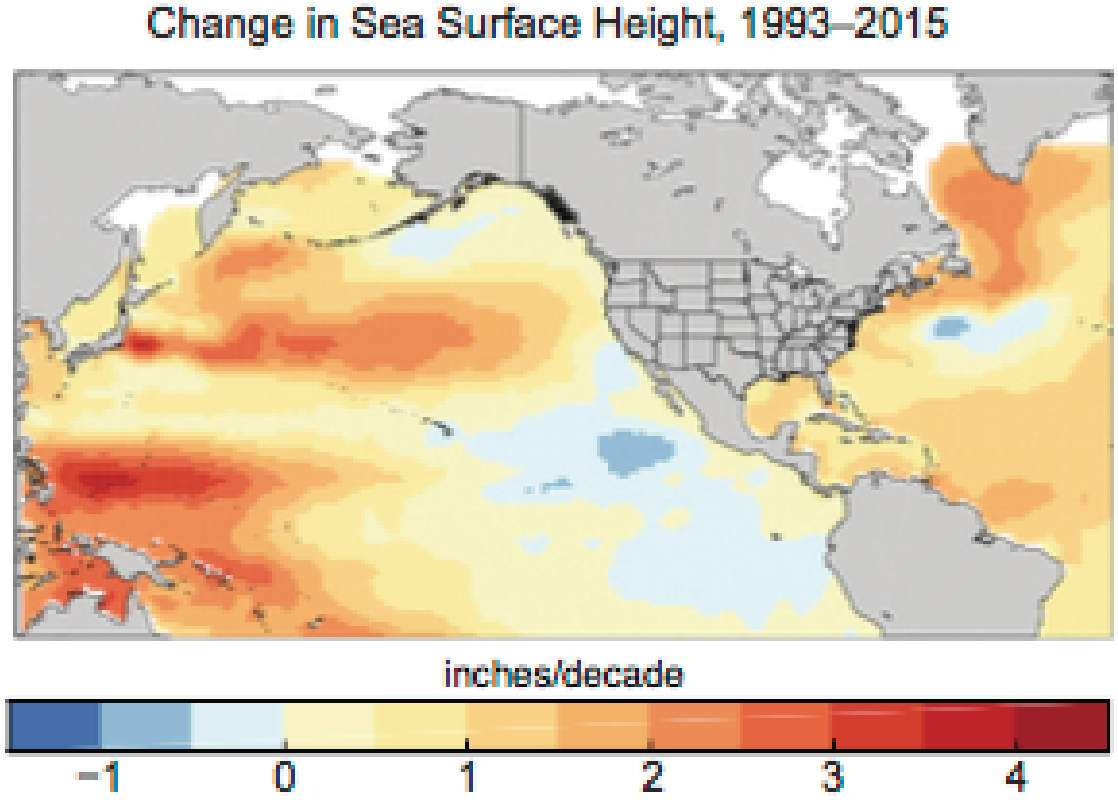
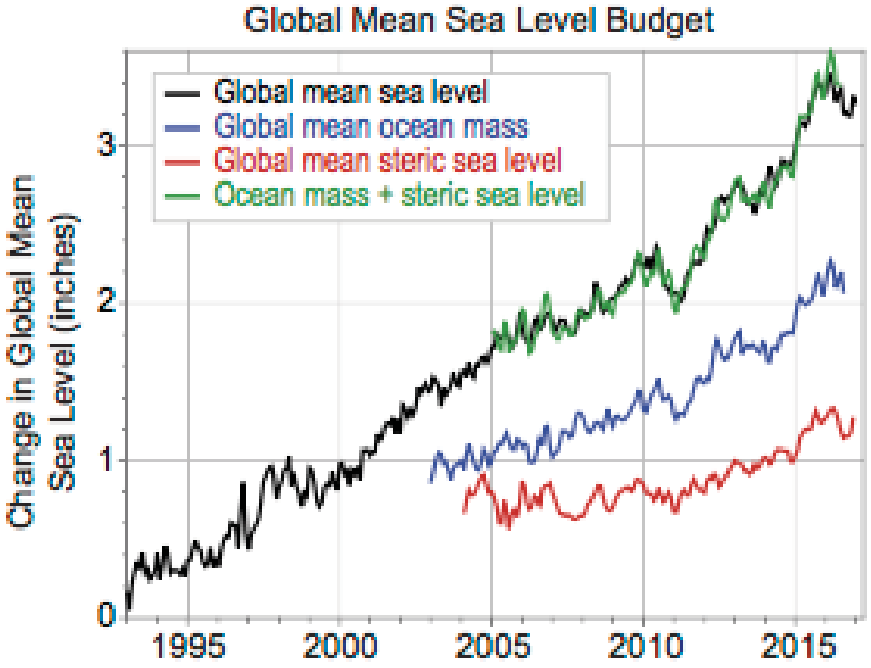
Extreme *precipitation* has increased across much of the US.

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

← SE US has experience 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

… and the Oceans are Rising





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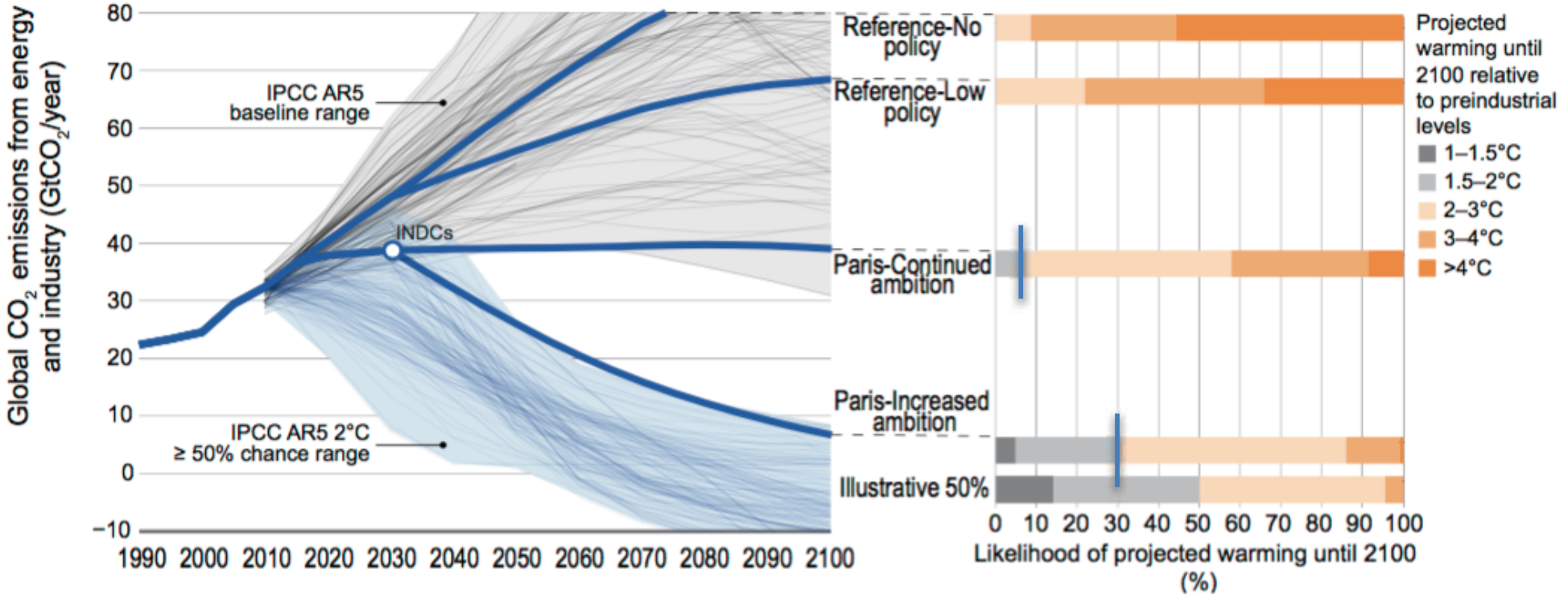
https://science2017.globalchange.gov/

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

What Can We Expect Humans to Do in the Future?



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

The global average surface temperature has changed by 1ºC since pre-industrial times. 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 2ºC by 2100.

Why Does Virginia Need Climate Science?

The citizens and businesses of the United States, the Commonwealth of Virginia and the city of Fairfax are not exempt from the changes Earth will experience during the rest of this century.

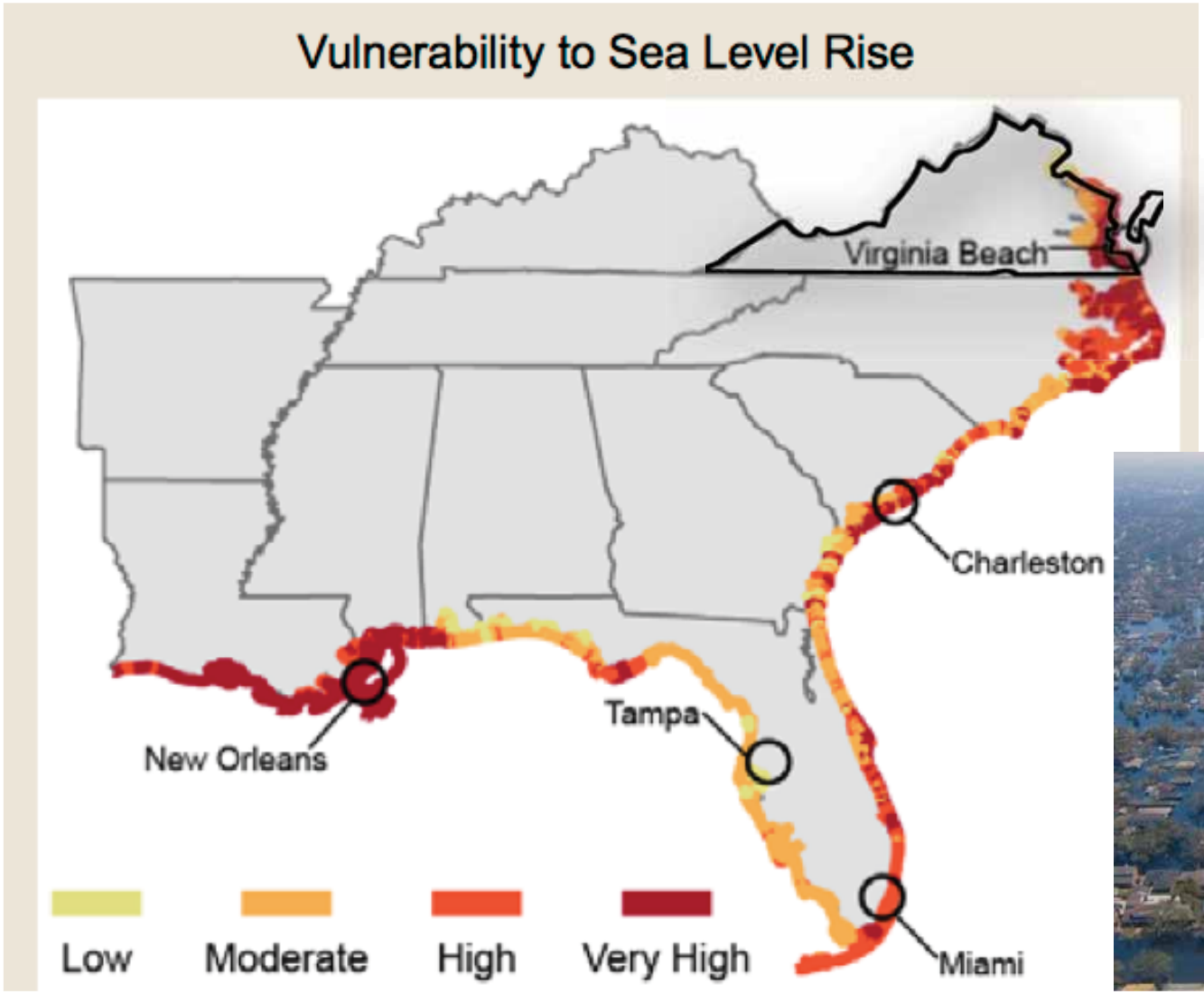
There will be a new normal.

We all need to prepare for it.

Why Does Virginia Need Climate Science?

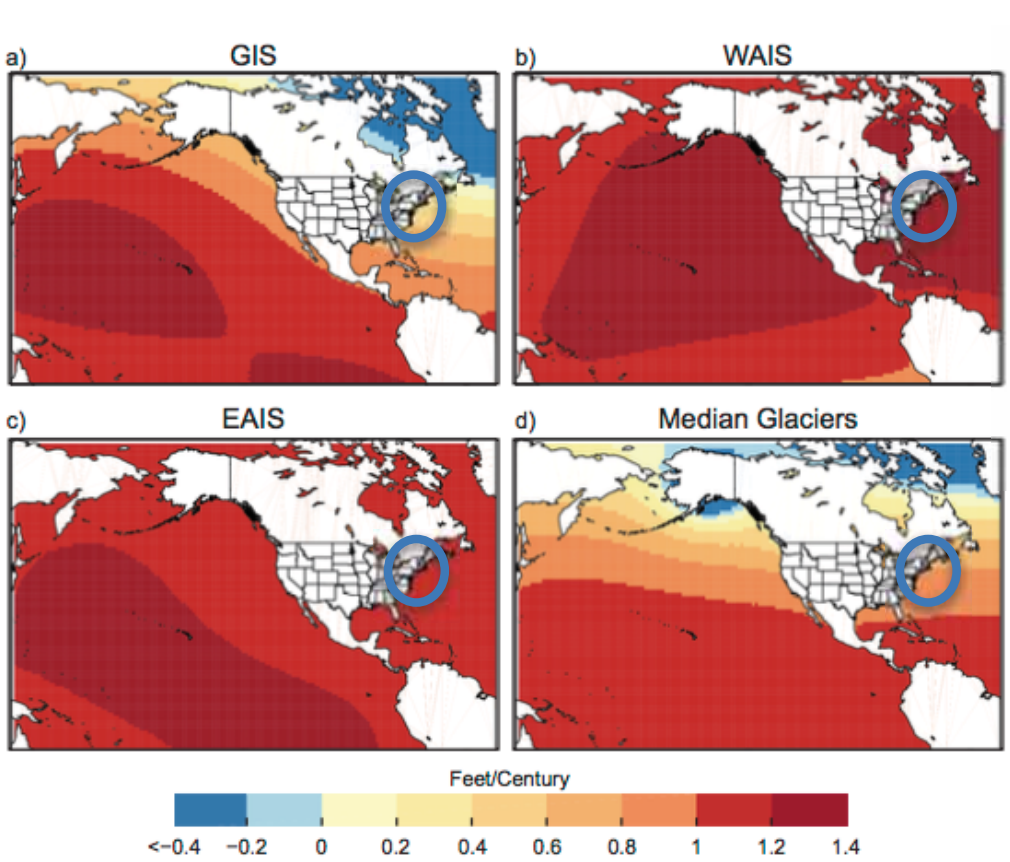
- **Virginia is already impacted** by climate change in the Tidewater region, where sea level rise is apparent and expected to accelerate.

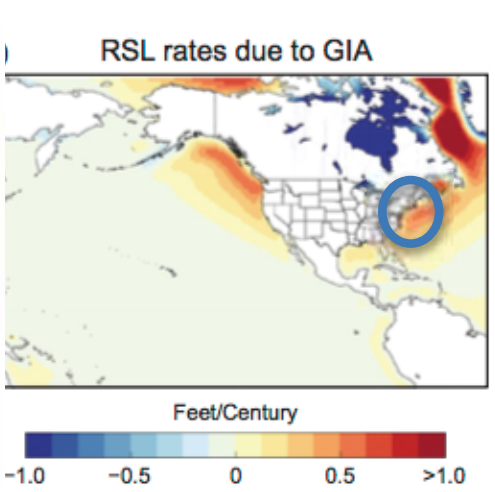
Vulnerability to Sea Level Rise

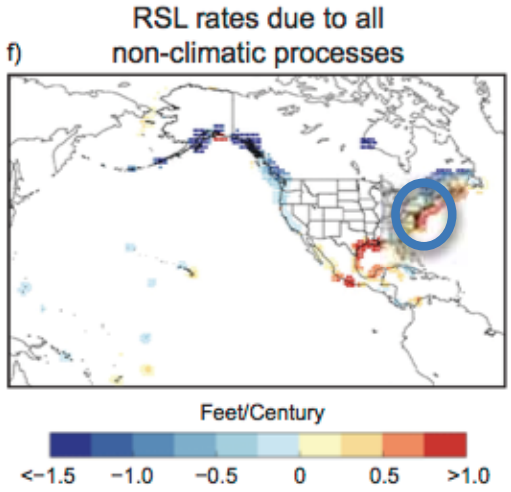


U.S. National Climate Assessment 2014

Double-double Whammy!







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

- Ocean warming
- Melting ice sheets and glaciers

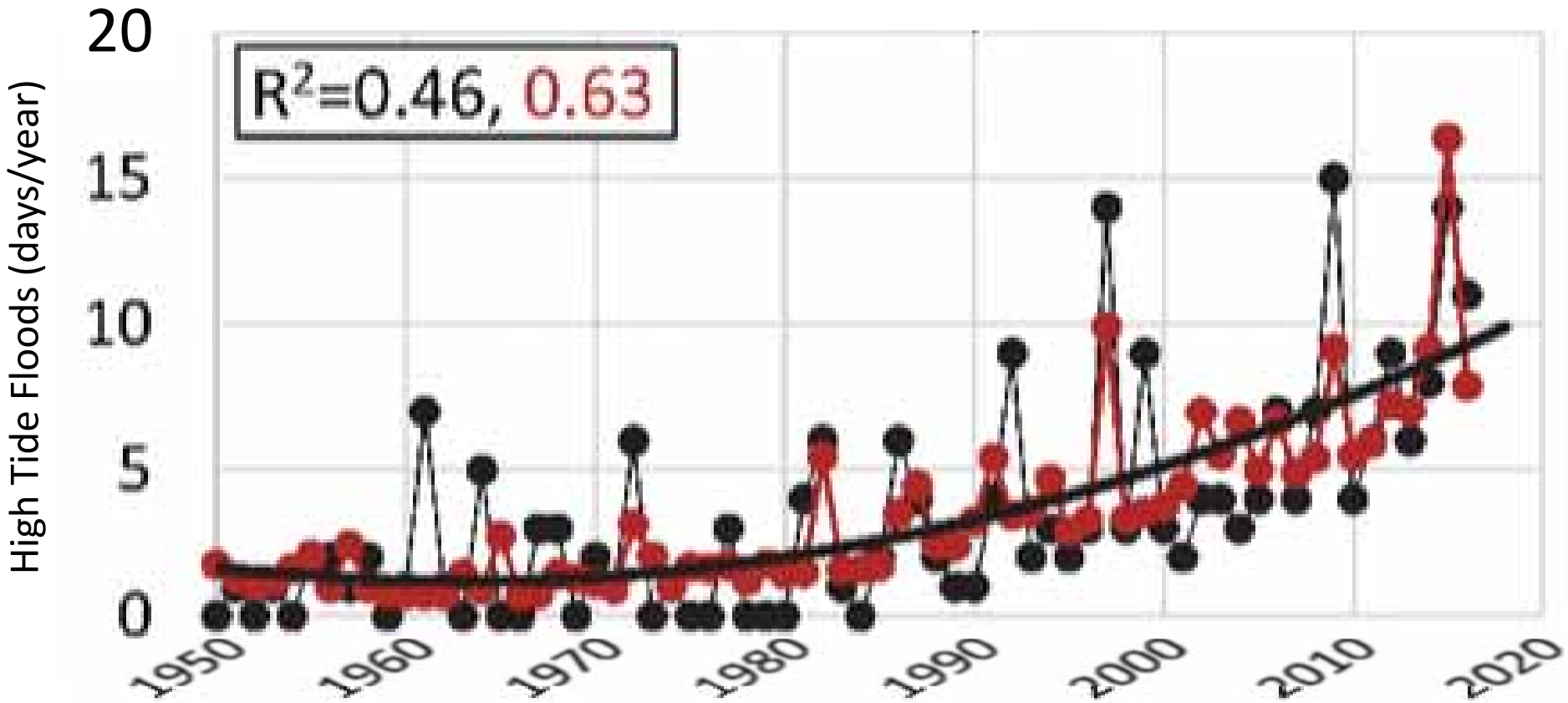
- Glacial-isostatic adjustment
- Sediment compaction

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 and sediment compaction.

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



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

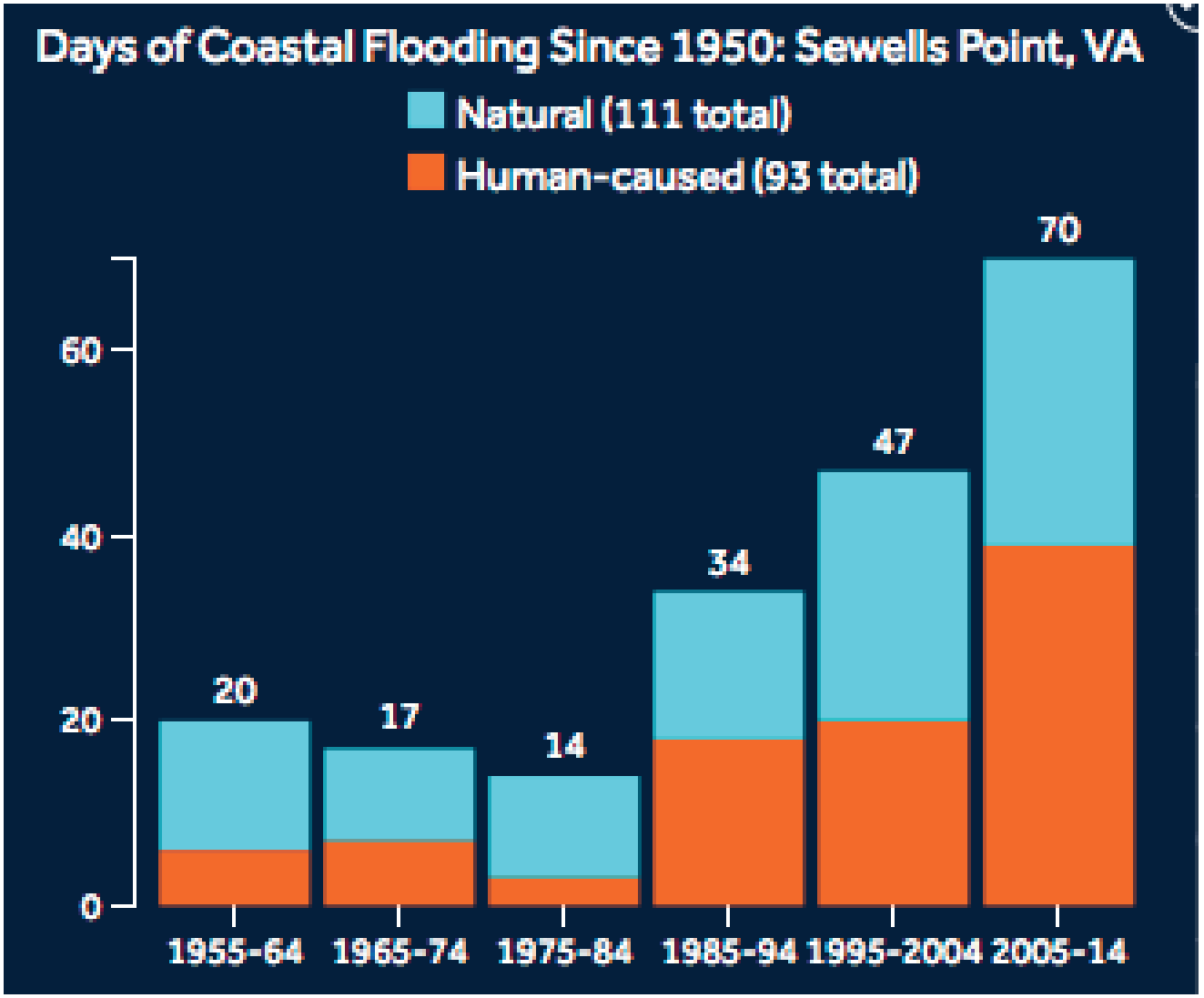
Projection of “Nuisance” Flooding

Today’s flood in Norfolk will become the 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)

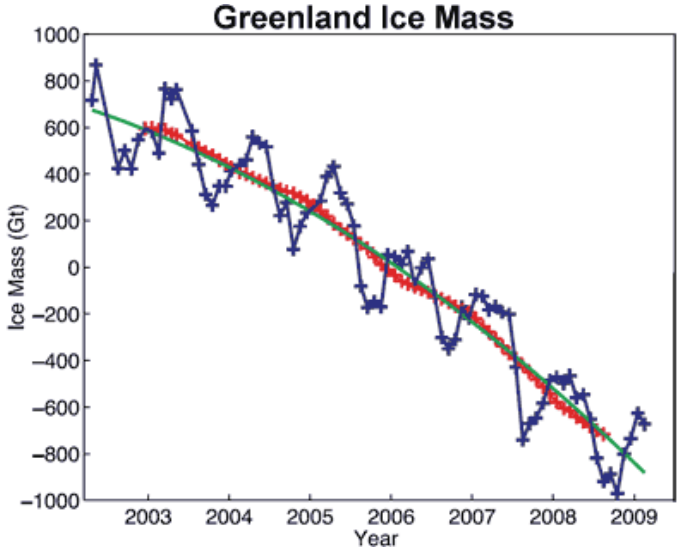
Why Are Nuisance Floods Increasing?

Coastal Flooding – Sewells Point, VA

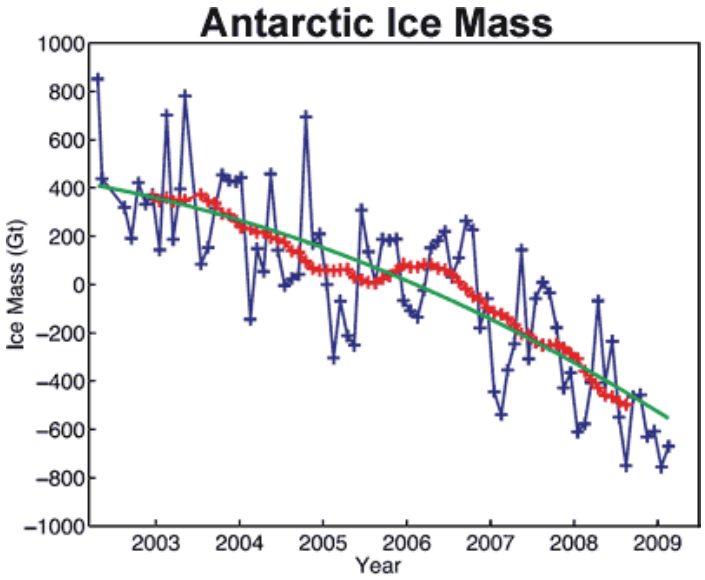


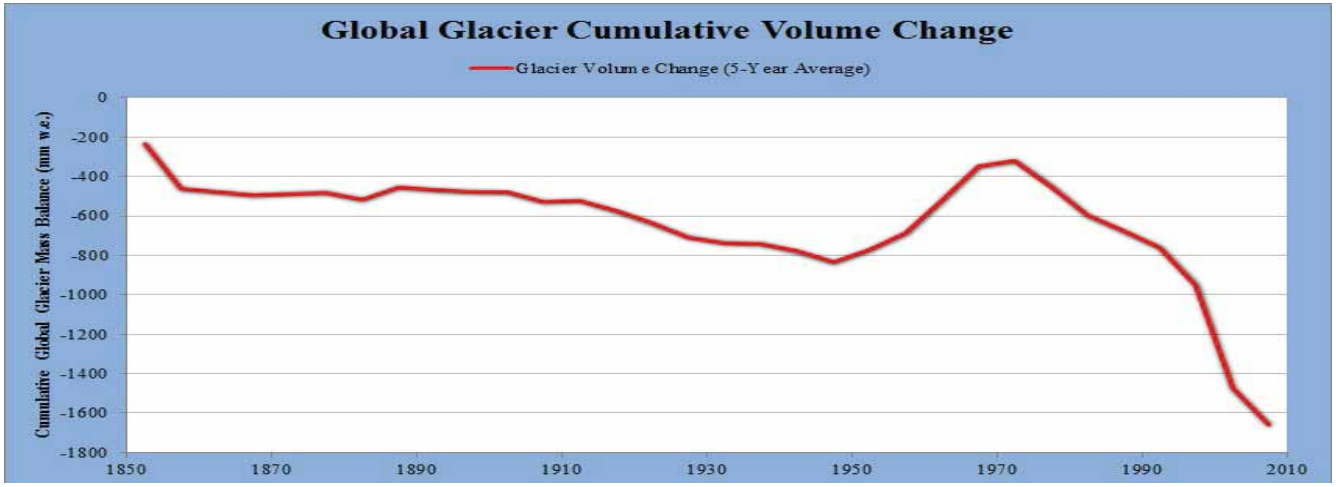
Climate Central
August 2017

Why Does Virginia Need Climate Science?



Accelerating **melting of the Greenland and west Antarctic ice sheets and global glaciers will *raise sea level even faster***





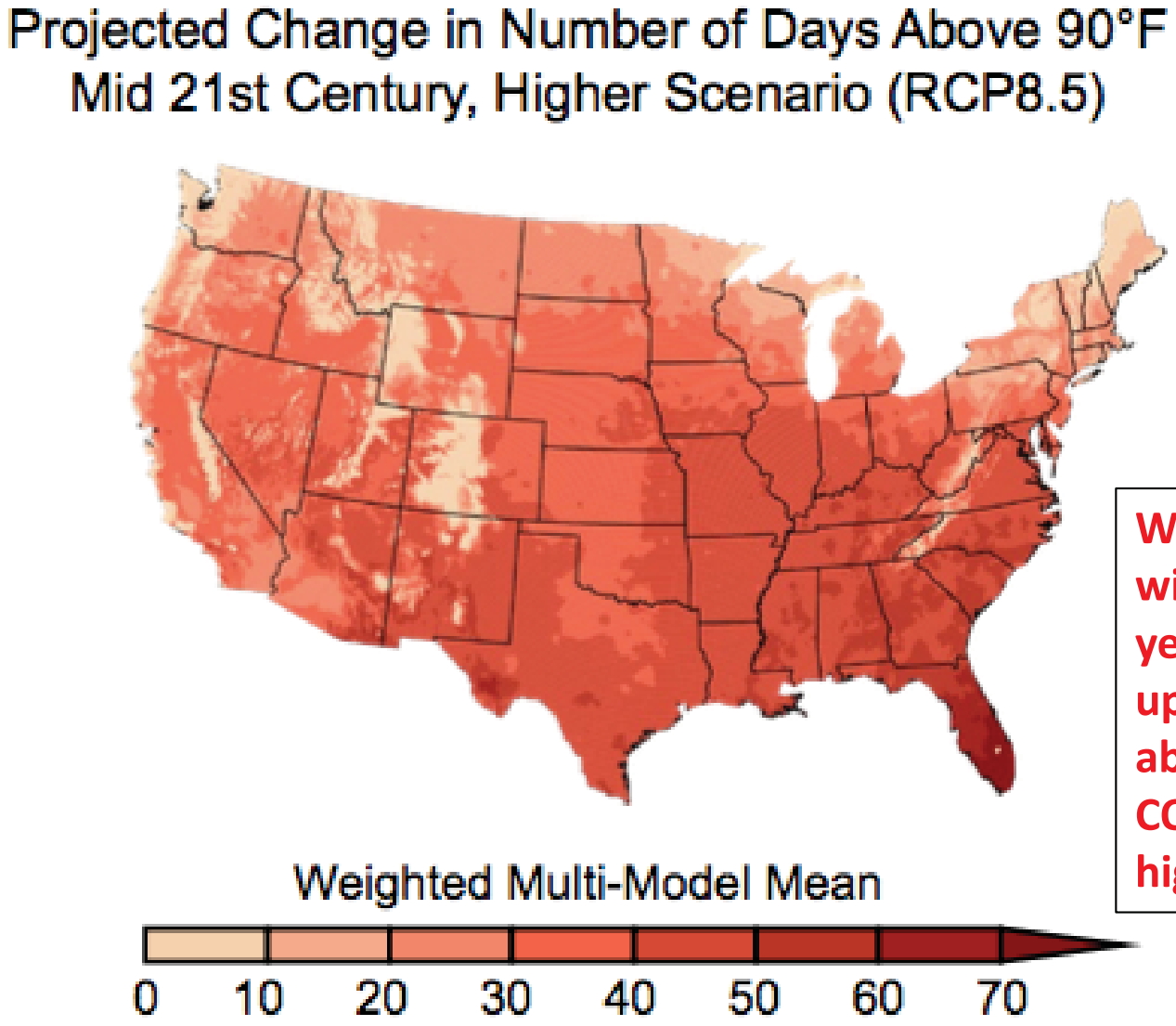
Source: Skeptical Science

New subglacial lakes discovered in Greenland accelerating melting – *ZME Science*

Why Does Virginia Need Climate Science?

- Virginia 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
- Virginia is impacted by changes in weather in the mid-Atlantic
  - More intense heat waves
  - More frequent severe weather, e.g. excessive rainfall

Extreme Warm



Climate Science Special Report, USGCRP
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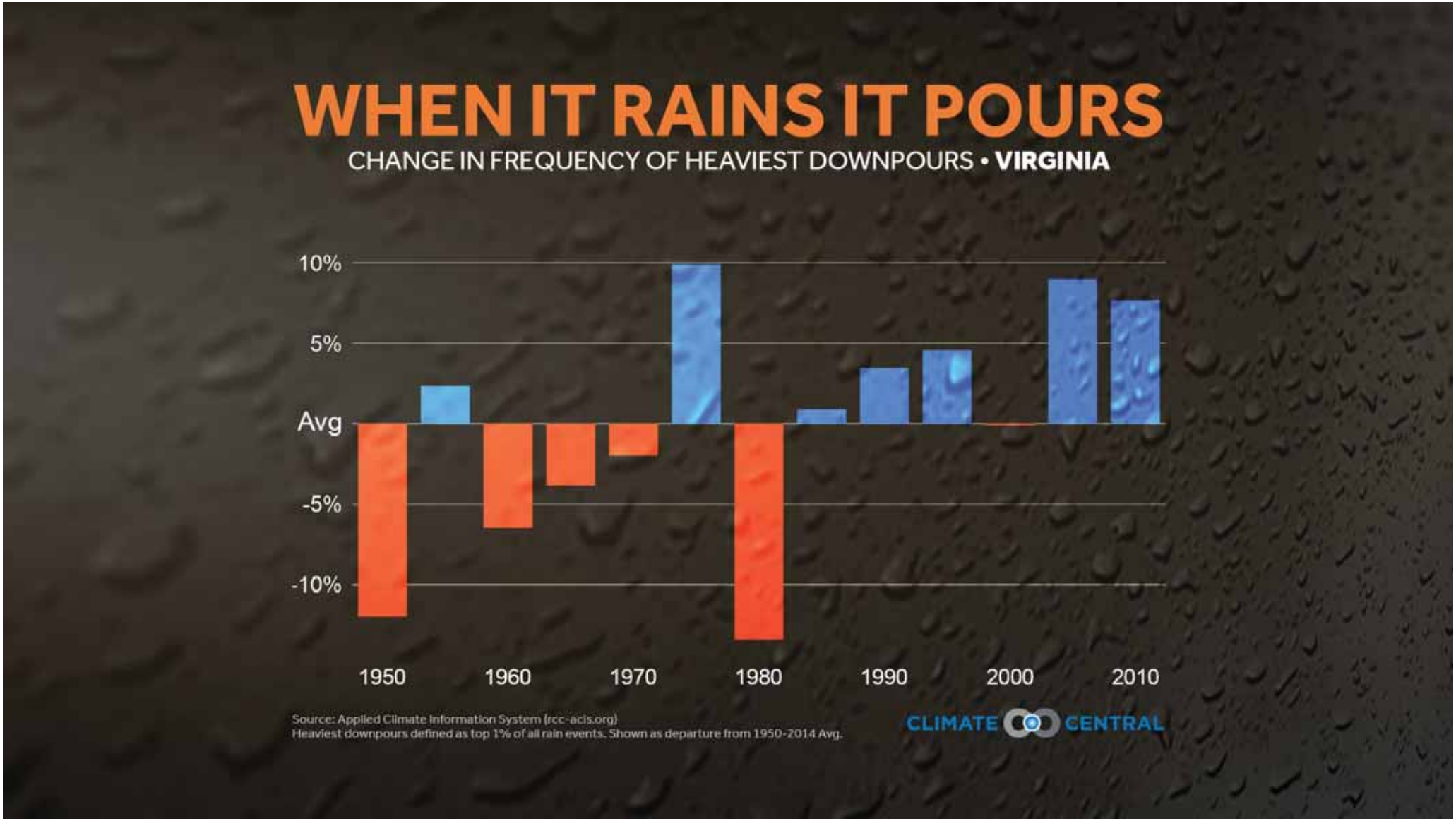
Within the next 40 years, there will be 40-50 *more* days each year with highs above 90ºF and up to 30 more days with highs above 95ºF in southeastern US, if CO_2 emissions continue on the high scenario trajectory.


WHEN IT RAINS IT POURS
CHANGE IN FREQUENCY OF HEAVIEST DOWNPOURS • VIRGINIA
10%
5%
Avg
-5%
-10%
1950
1960
1970
1980
1990
2000
2010
Source: Applied Climate Information System (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

Why Does Virginia Need Climate Science?

- Virginia 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
- Virginia 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 Maria – September 2017

Juana Matos, Puerto Rico, 22 Sep 2017

Hurricane Irma – September 2017

St. Martin 6 Sep 2017

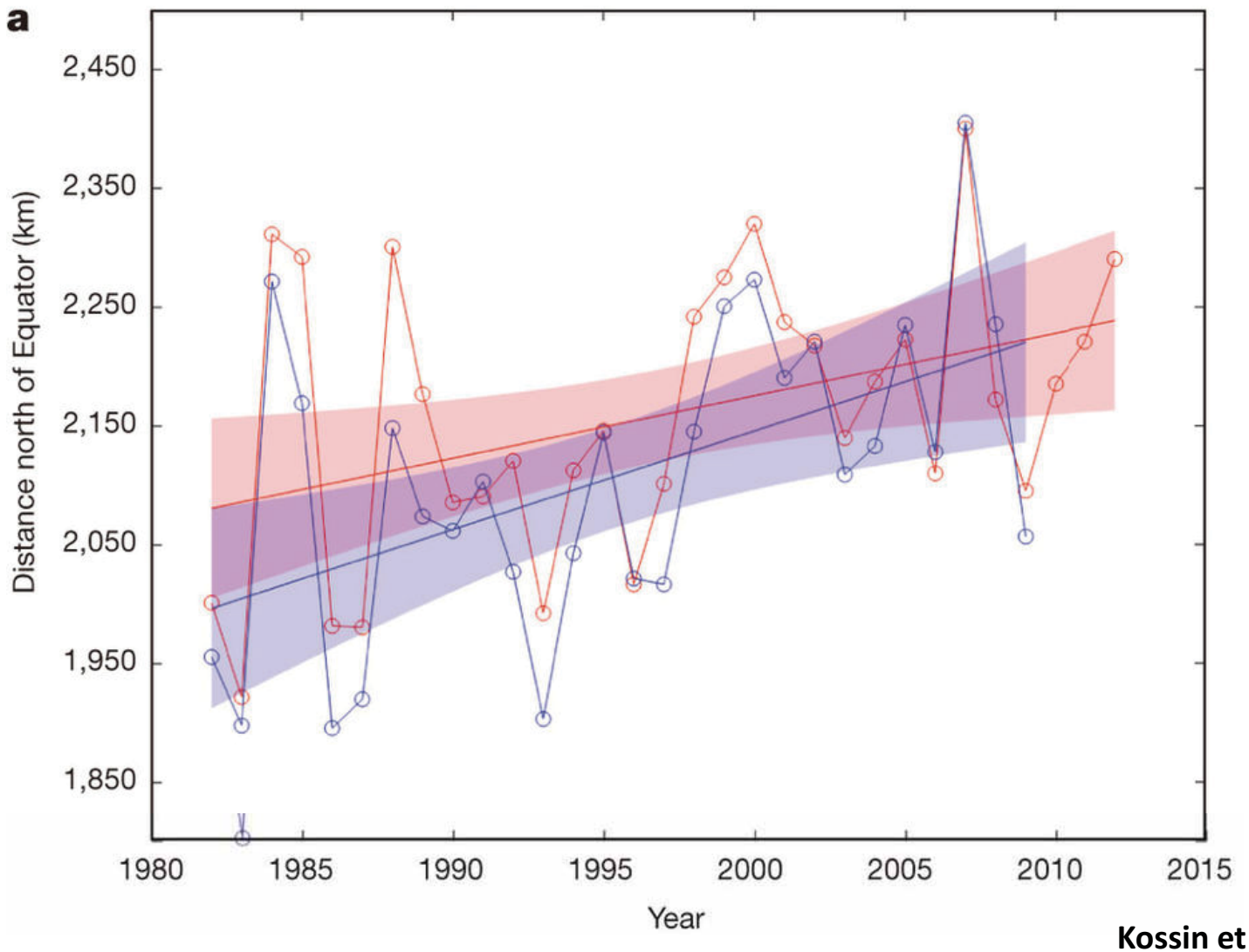
Hurricane Harvey – August 2017

Houston 27 August 2017

Hurricane Sandy – October 2012

Queens, NY, 30 October 2012

Tropical Cyclones are Creeping Northward

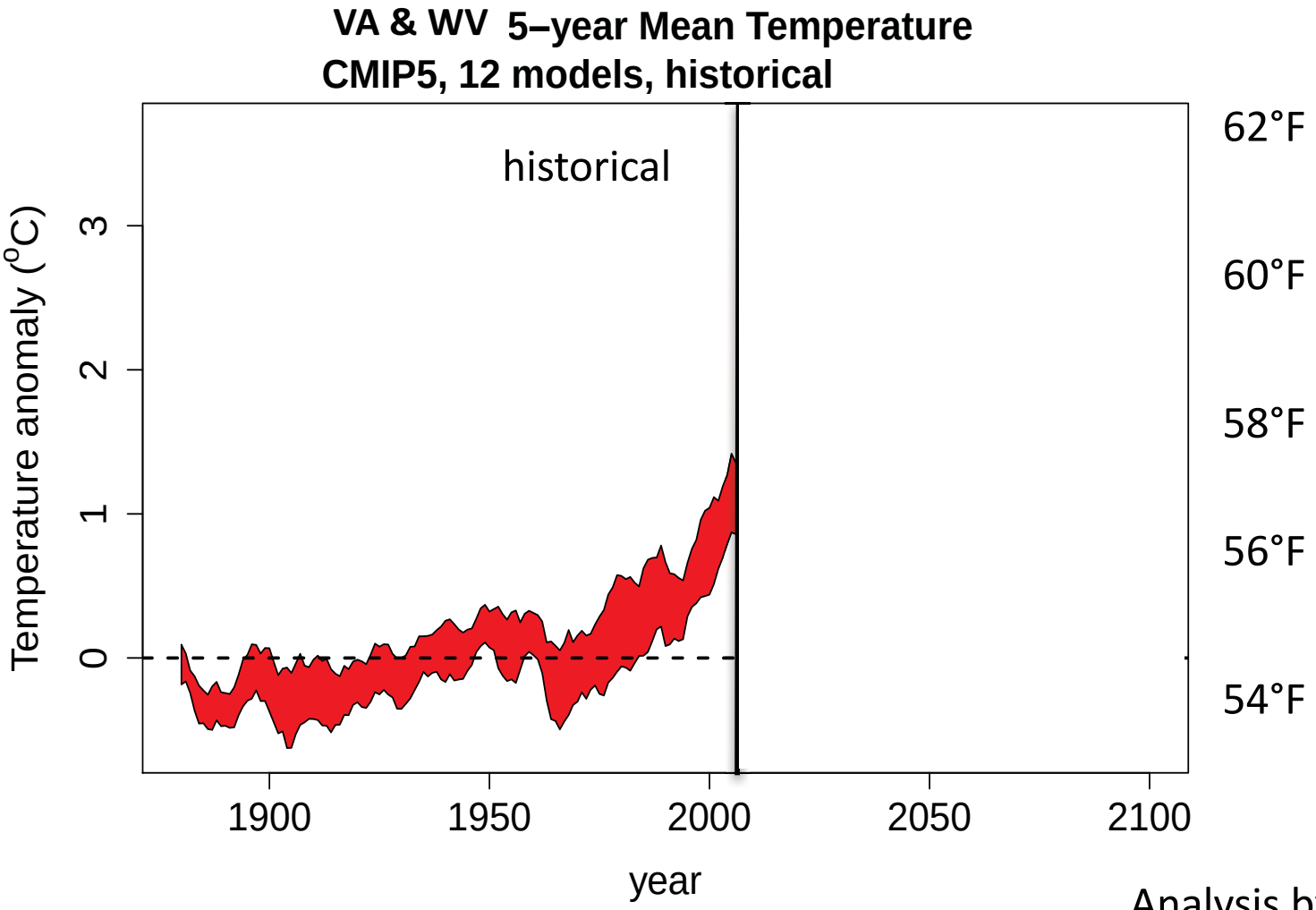


Kossin et al. 2014 (*Nature*)

What If Sandy Hit Coastal Virginia?

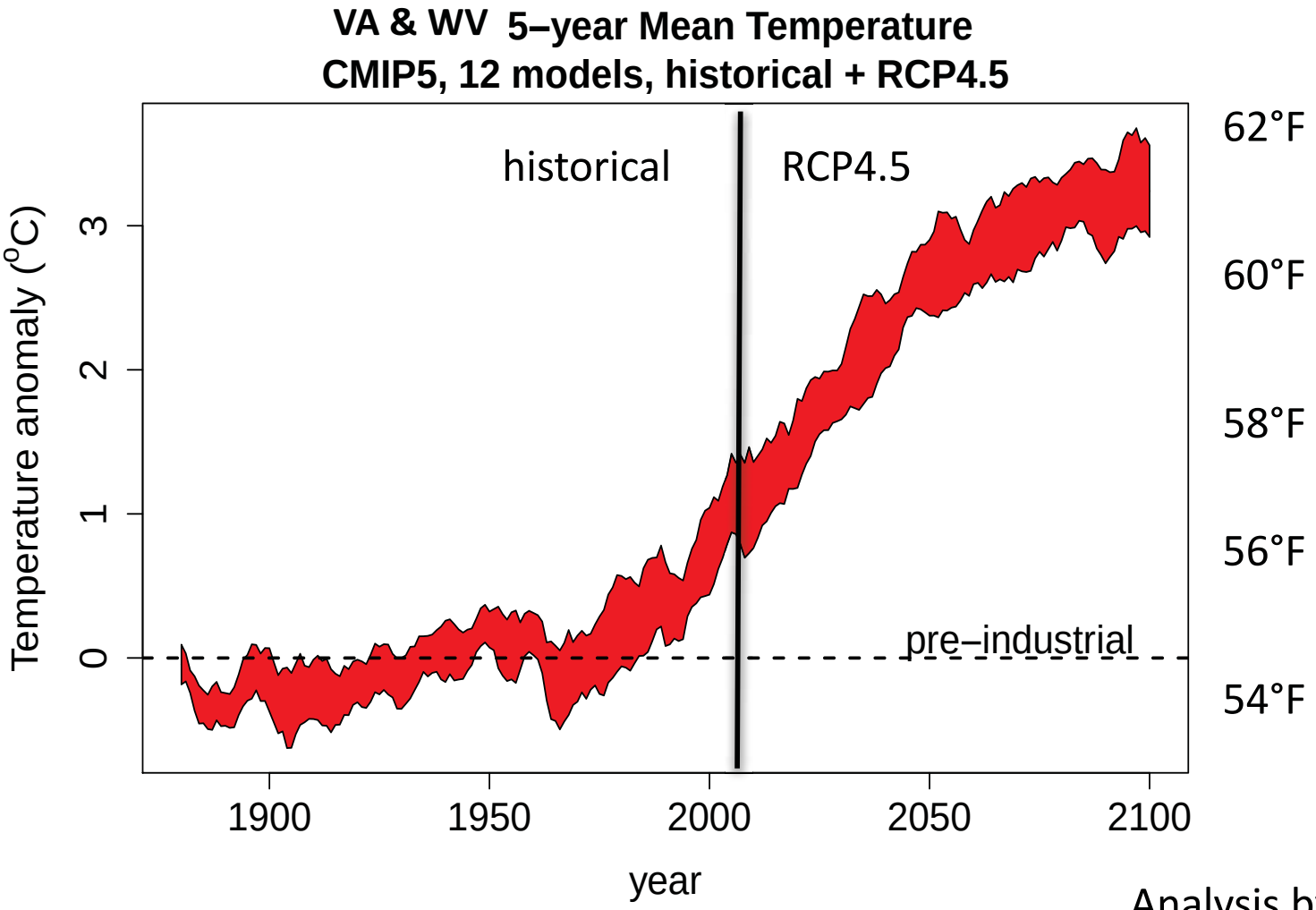
COLA Hi-Res Simulation: ~10-year return period for Mid-Atlantic landfalling TCs … will they become more frequent?

Virginia is Warming



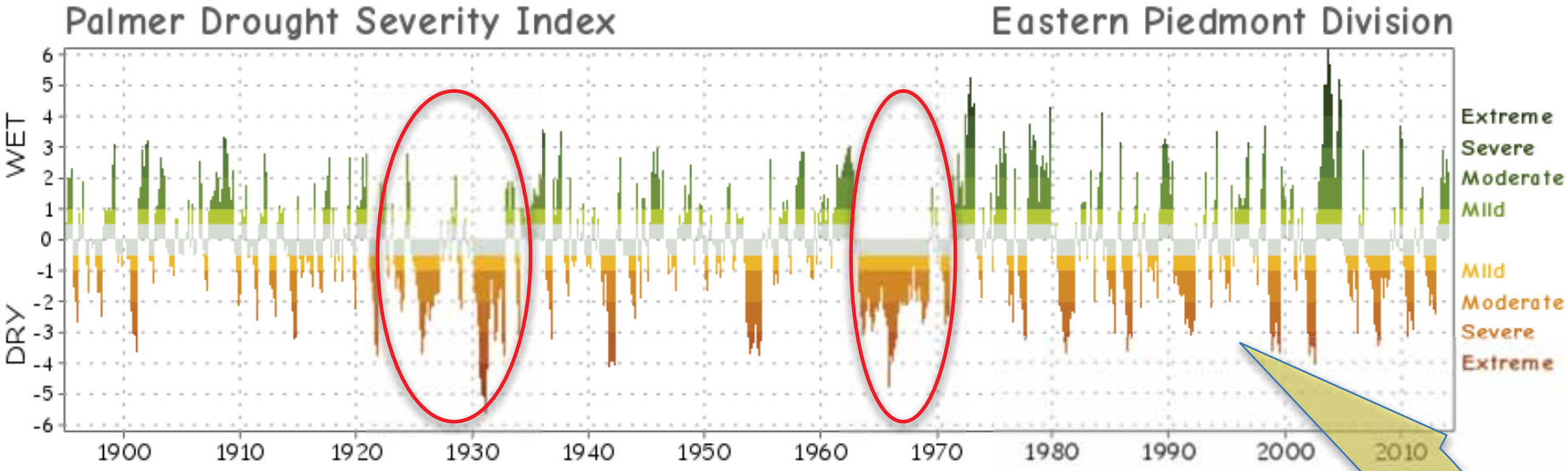
Analysis by T. DelSole

Virginia is Warming



Analysis by T. DelSole

Virginia Climate Divisions - Drought



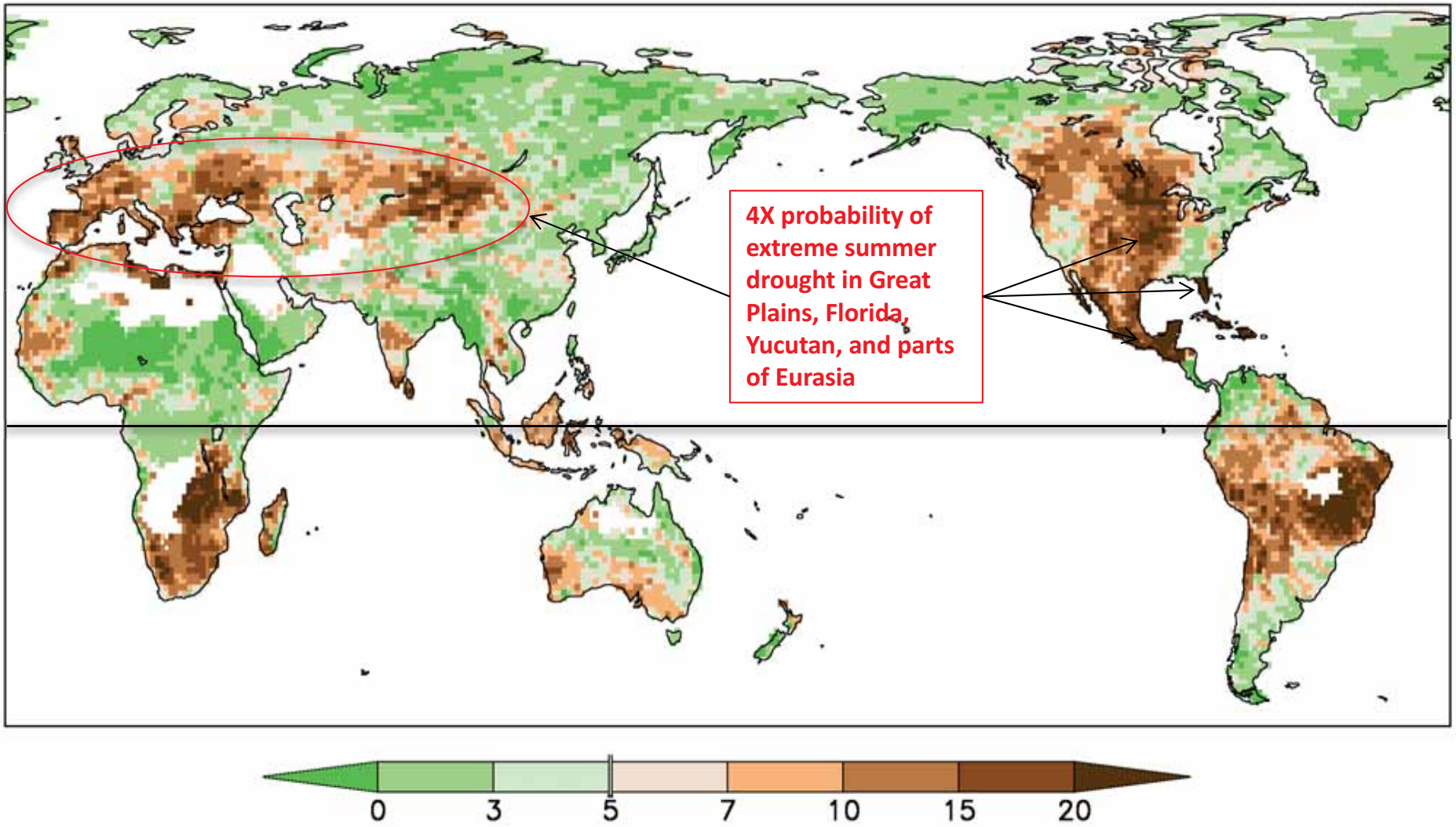
Some climatic zones in Virginia are susceptible to prolonged, severe drought.

courtesy J. Adams

Severe Weather

Excessive **shortage of rainfall** when it persists, also called meteorological drought, can cause stressed ecosystems, agricultural failure and limited or poor quality water supply

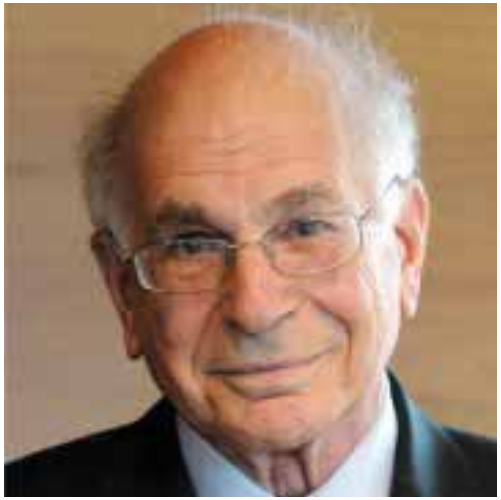
COLA Simulation of Future Change in Extreme Summer Drought
Late 20th C to Late 21st C



10th Percentile Drought: Number of years out of 47 in a simulation of future climate (2071-2117) for which the June-August mean rainfall was less than the 5th driest year of 47 in a simulation of current climate (1961-2007).

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

What Can We Do?

- Have a Community Climate Action Plan
  - Communicate
  - Ameliorate
  - Mitigate
  - Innovate

Communicate

- Simple, clear messages, repeated often, by trusted sources. – Ed Maibach (GMU)
  - NB: **Climate change is not a simple question, so it doesn't have a simple answer** … the message is not so clear or simple, e.g. extremes of precipitation at both ends are likely to increase.
  - NB_2: **Trust takes a long time to build and an instant to destroy**.
  - NB_3: Most of us trust relatives, friends and few others. Given the scarcity of climate scientists, **it is unlikely that you are related to someone who is a reliable source on this question**!

Ameliorate

- **Prepare for the new normal** to lessen the impact of climate change on community resources and people
  - Understand what community assets and groups are at risk
  - Determine likelihood of bad events
  - Insurance, infrastructure, incentives

Mitigate

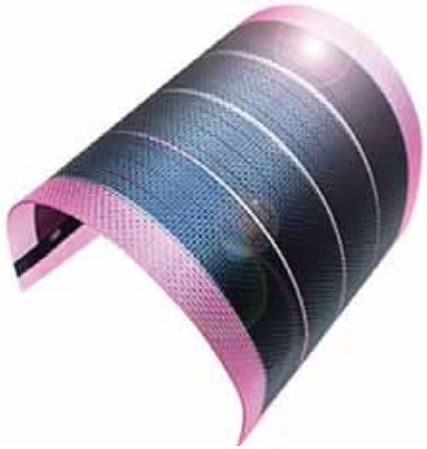
- CO_2 and CH_4 are the sources of the problem, so **reduce the concentrations of these compounds in the atmosphere**
  - **Reduce emissions:** alternative energy practices and sources that don't rely on combustion of fossil fuel
  - **Capture and sequester:** Devise ways to get CO_2 and CH_4 out of the atmosphere

Innovate

- **Population center design** – climate-friendly cities
- **Agricultural practices** – save topsoil, reduce nitrogen and phosphorus, no-till farming
- **Energy conservation** measures
- **Non-fossil-fuel energy generation** systems

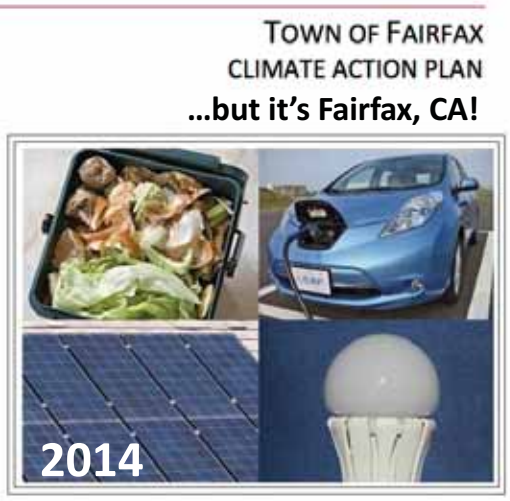
Example: Organic Photo-Voltaics

Unlike the solar cells you're used to seeing, organic photovoltaics are made of compounds that are dissolved in ink and can be printed and molded using simple techniques. The result is a low-weight, flexible, semi-transparent film that turns the energy of the sun into electricity.

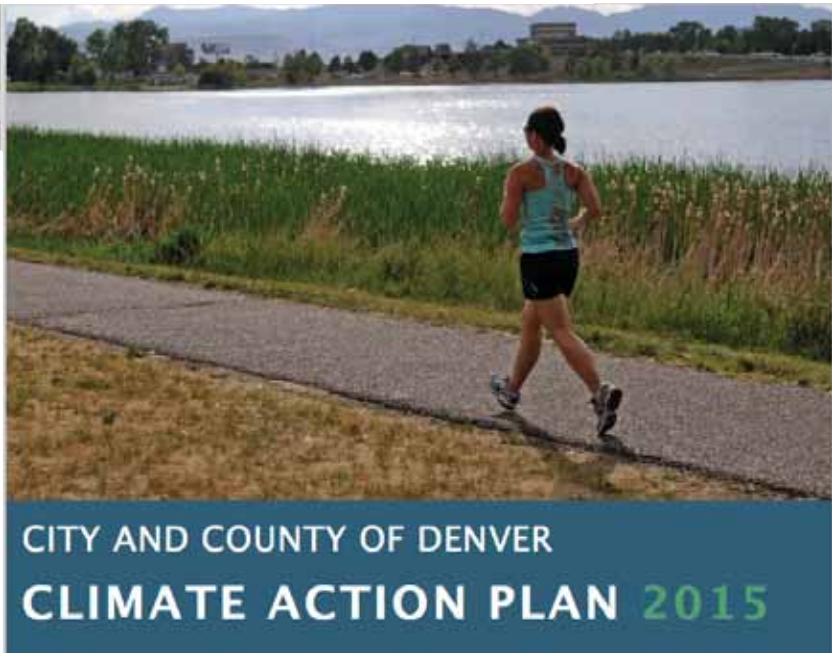


Ultra-thin: Compact size (19.5*8*0.1cm) ,weight:27g ,highly portable
Waterproof: high quality material, sturdy and durable.
Foldable: the biggest advantage, can be folded
Apply: use your imagination to create a variety of products, solar charging clothes, solar panel phone charger, power for outdoor wireless sports headphones, UAV power supply, and so on

Many Cities have Climate Action Plans



2009



Virginia Needs a Climate Action Plan

- **Mitigate**: **Executive Directive 11**: Reducing Carbon Dioxide Emissions from Electric Power Facilities And Growing Virginia's Clean Energy Economy (McAuliffe, 2017)
- What about Communicate, Ameliorate and Innovate?

- Virginia already has a lot of intellectual assets to attack the climate change problem …

COLA at Mason

- **Center for Ocean-Land-Atmosphere Studies – COLA**
- **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
- 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
- **COLA scientists are working with others at Mason** including the Center for Climate Change Communication, the Institute for Philosophy and Public Policy and the department of Environmental Science and Policy

Center for Ocean-Land-Atmosphere Studies & GMU Ph.D. Program in Climate Dynamics

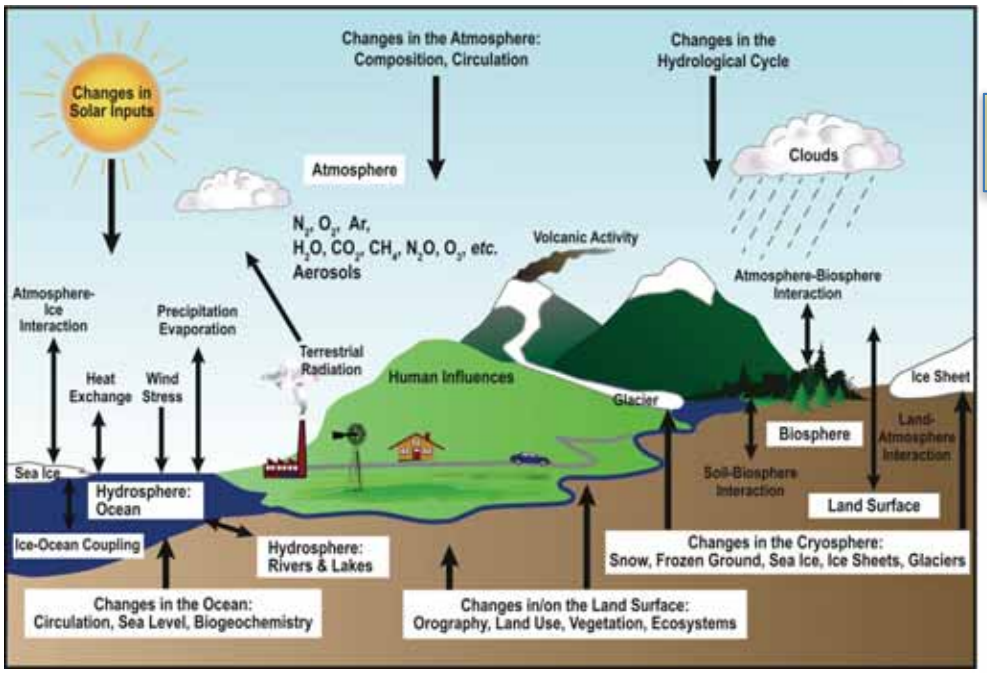
Faculty

Natalie Burls	Asst. Prof.	PhD, Cape Town
Tim DelSole	Prof.	PhD, Harvard
Paul Dirmeyer	Prof.	PhD, Maryland
Bohua Huang	Prof.	PhD, Maryland
Jim Kinter	Prof.	PhD, Princeton
Barry Klinger	Assoc. Prof.	PhD, MIT/WHOI
Kathleen Pegion	Asst. Prof.	PhD, Mason
Ed Schneider	Univ. Prof.	PhD, Harvard
J. Shukla	Univ. Prof.	PhD, BHU; ScD, MIT
Cristiana Stan	Assoc. Prof.	PhD, Colorado State
David Straus	Prof.	PhD, Cornell

Scientists Have …

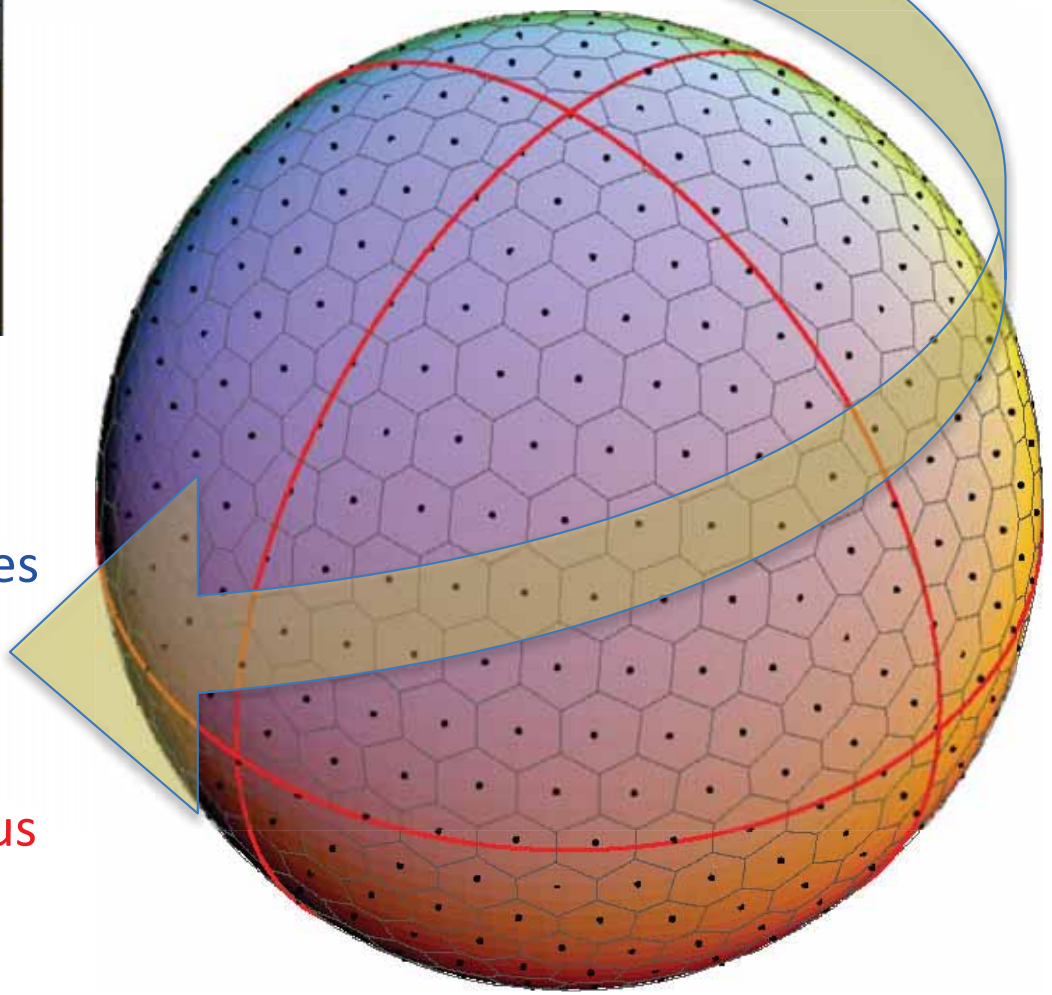
- Developed or contributed to new and innovative approaches for climate research
- Established a scientific basis for quantitative, dynamical seasonal and decadal prediction
- Made fundamental contributions to climate applications of information theory
- Contributed to national leadership in climate science, national and international program integration
- Achieved important breakthroughs in high-resolution seamless weather and climate prediction

Earth System Modeling – Petascale Computation



- Equations of motions and laws of mass and energy conservation to predict rate of change of:

T, P, V, q, etc. (A, O, L, CO_2, etc.)



- 10 Million Equations:

100,000 Points × 100 Levels × 10 Variables

- With Time Steps of: ~ 10 Minutes

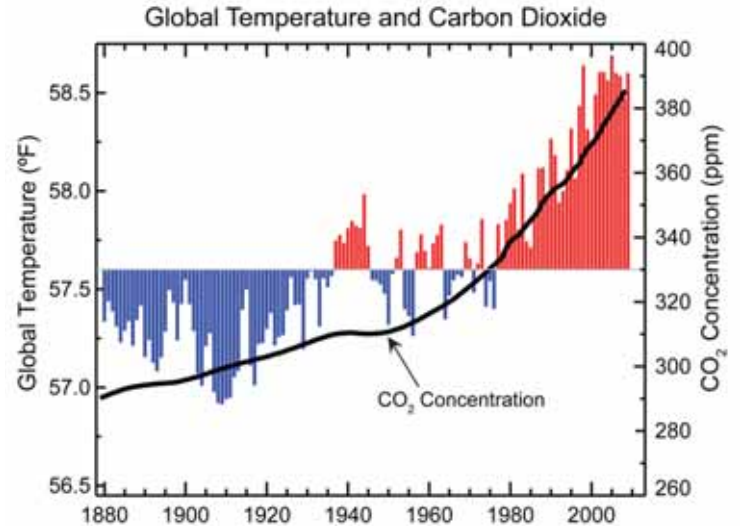
- How do we solve 10 million simultaneous equations over 5 million times? Supercomputers!

Mason Educating Next Generation of Climate Scientists

- **Mason Climate Dynamics Ph.D. program:** unique 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 (17 current students; 37 Ph.D. graduates since 2002)
- **B.S. in Atmospheric Science:** fundamental training in meteorology and computational atmospheric sciences
- **Mason Core resources and learning opportunities**

CLIM 101: Global Warming - Weather, Climate and Society

- General Education Natural Science course
- Offered since 2008 … 108 students enrolled in 2017
- Surveys both scientific and societal issues
- Enables students to critically examine arguments being discussed by policy makers, corporations, and the public
- Highlights: guest lectures by Profs. Andrew Light, Tom Lovejoy, and Ed Maibach
- Students prepare "briefings" to the Governor of Virginia on the impact of changing climate



Instructors: Jim Kinter and Jagadish Shukla

Summary

- Earth, the US, Virginia and Fairfax **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