# Climate Change: The Reality, the Inevitable, and Hope for the Future

Jim Kinter
George Mason University





# Category 4 Ian Wipes Out FMB

## September 2022

The News Press

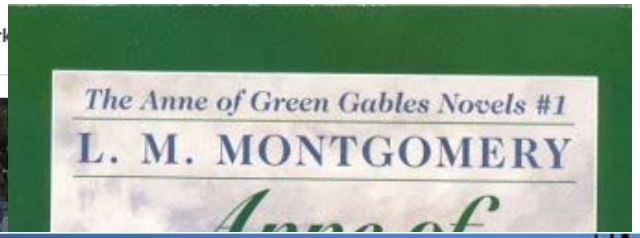
New York Times

Death toll: (at least) 131

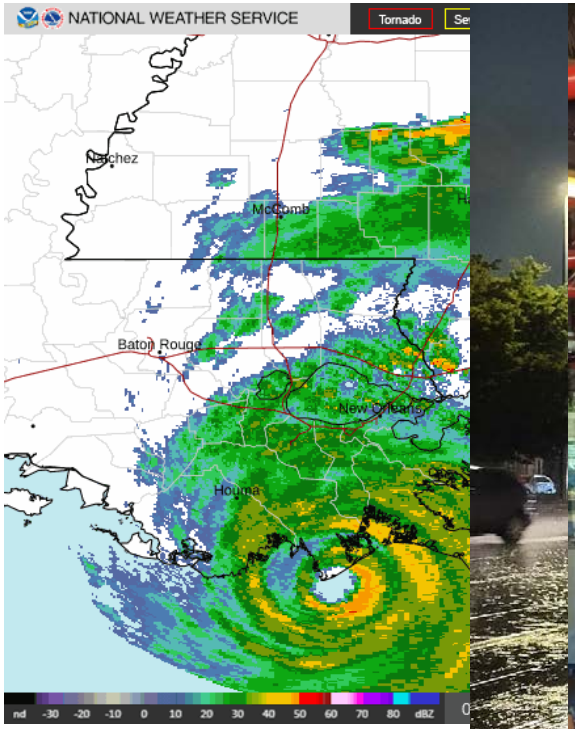
# Hurricane Fiona Devastates Puerto Rico
# September 2022 (5 years after H. Maria did the same)


Puerto Rico, 20 Sep 2022

# Hurricane Fiona – in Canada!


# Hurricane Ida Strikes Louisiana *and* New York
# Aug. 23 – 4 Sep 2021



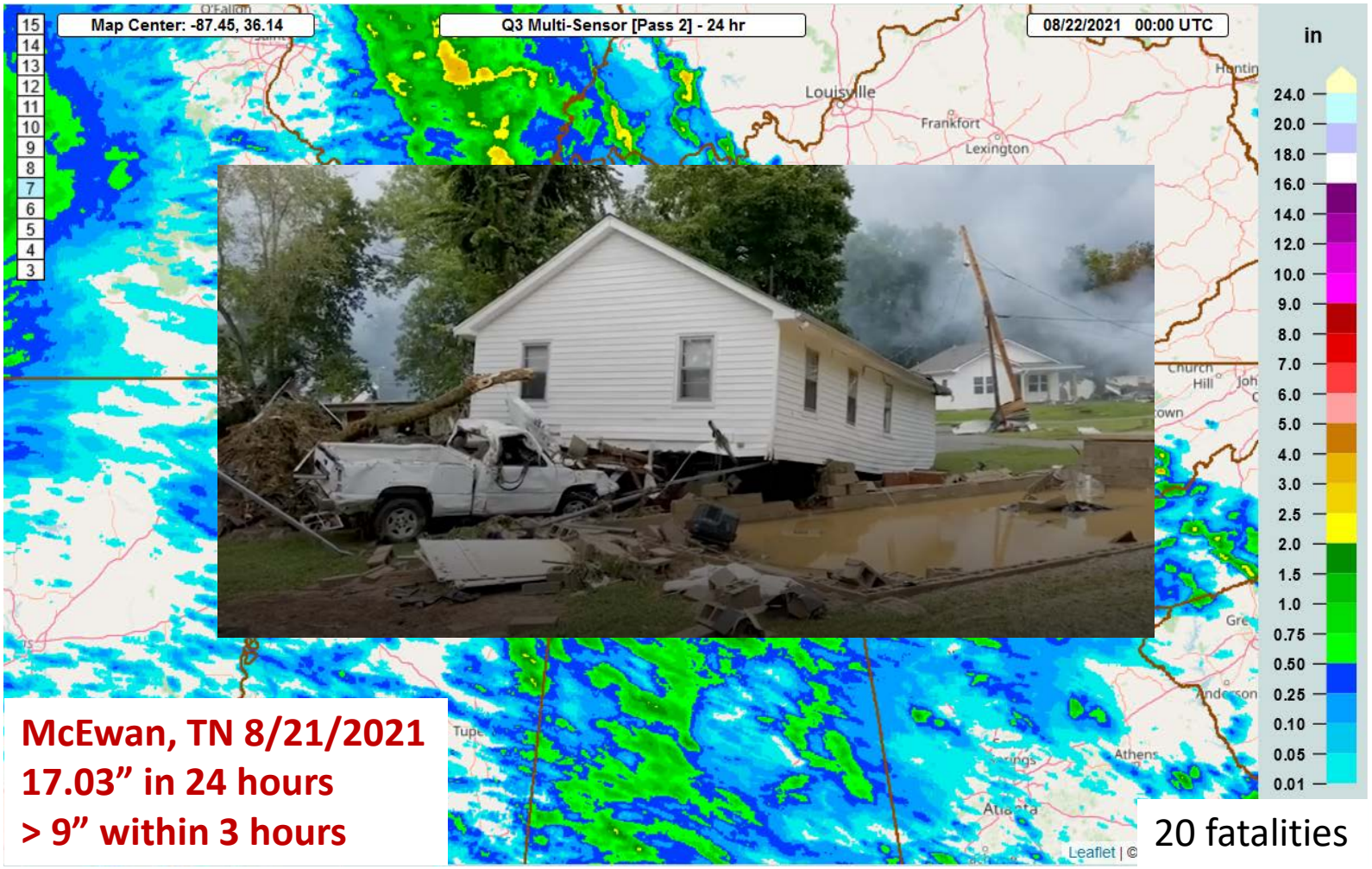

New York City Subway

- Category 4 at landfall
- 112 people died
- $50 billion damages
- > 1 million lost power
- Gulf coast oil production shut down
- NFL Cardinals-Saints game postponed

COLA Center for Ocean-Land-Atmosphere Studies

GEORGE MASON UNIVERSITY

# Tennessee 2021: 17” Rain in 24 Hours




**McEwan, TN 8/21/2021**
**17.03” in 24 hours**
**> 9” within 3 hours**

20 fatalities

# Pakistan August 2022: More than 1,500 People Killed by Flooding

**33 million people have been displaced; will they become climate "refugees"?**

**NYT, August 28, 2022**

# Drought → Mega-Drought

**New York Times**
**16 Aug 2021**

## *In a First, U.S. Declares Shortage on Colorado River, Forcing Water Cuts*

Arizona farmers will take the initial brunt, but wider reductions loom as climate change continues to affect flows into the river.

Lake Mead, top left, and Boulder City, Nev., in July. The last time the lake was anywhere near full was two decades ago. Patrick T. Fallon/Agence France-Presse — Getty Images

**Lake Mead and Boulder City, NV, which used to be near the lake.**

Park visitors explored a part of Lake Powell in Big Water, Utah, in June that used to be underwater. Justin Sullivan/Getty Images

**Area of Lake Powell that was under water until recently.**

# California 2021: 1500 Sq. Mi. Burned

**Dixie Fire: 7/13/21 – present; > 1200 buildings destroyed**

**Taylorsville, CA 13 Aug 2021 Noah Berger, AP**

# The Western US Going Up in Flames … Yet Again in 2022

**Mosquito Fire**
**9/6 – 9/22 (60% contained)**
**76,575 acres burned**

# European Heat Records Breaking Every Year

CAPITAL WEATHER GANG

## Europe is seeing its warmest weather on record so late in the year

High temperatures have soared into the 70s and 80s — more like late summer than almost November

By Ian Livingston

October 31, 2022 at 2:26 p.m. EDT

ire River (Wash. Post 9/8/2022)

Calais, France on 10/30/2022
(Wash. Post. 11/1/2022)

# Unsurvivable Heat

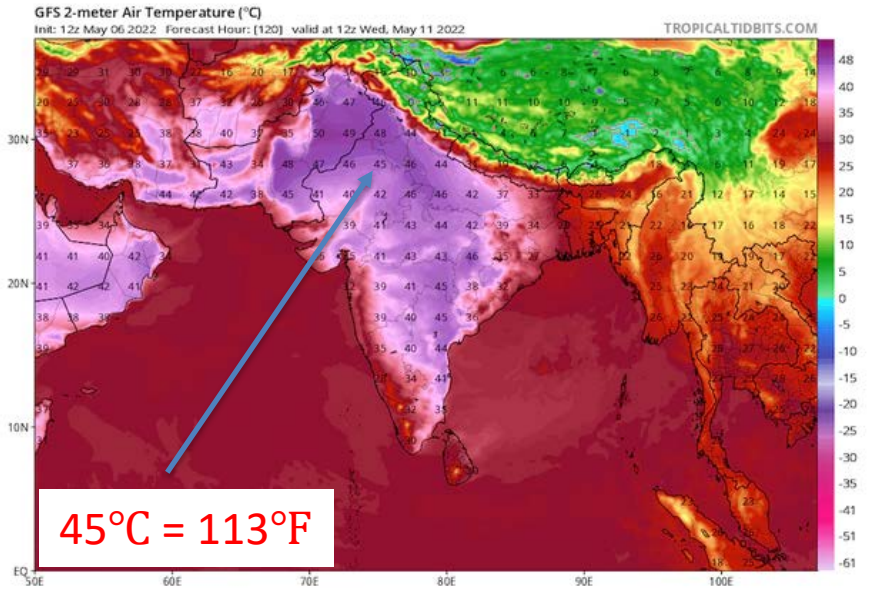
The Washington Post
*Democracy Dies in Darkness*

9 May 2022

## India tries to adapt to extreme heat but is paying a heavy price

100 B hours/yr lost labor hours
Schools dismissed at 11 am

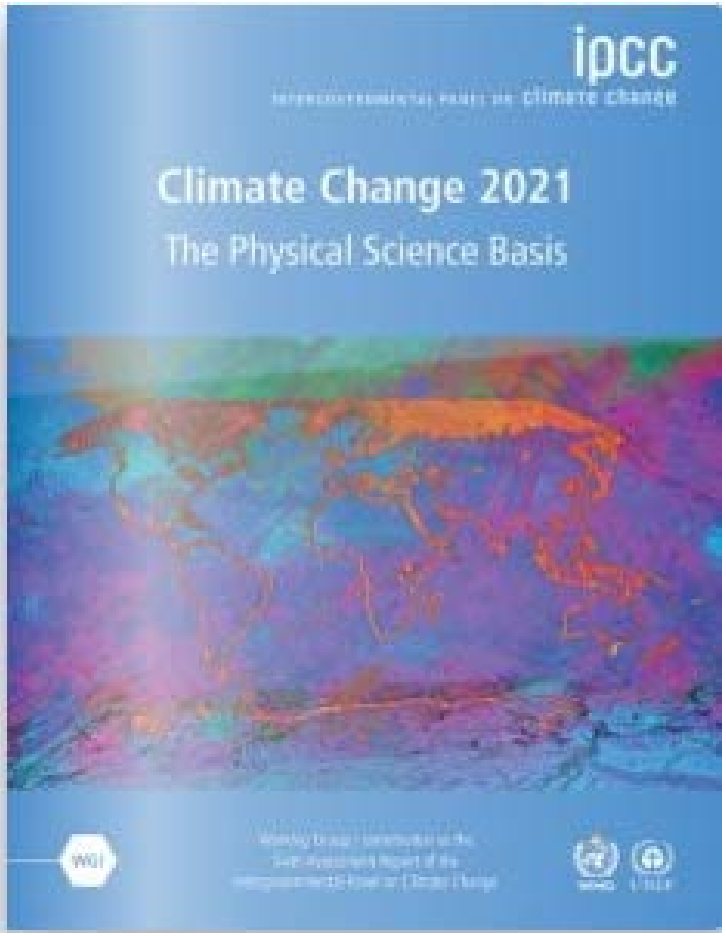
A farmer pours water on himself while working at a wheat farm in Punjab, India, on May 1. (T. Narayan/Bloomberg News)




Forecast temperatures (in Celsius) on Wednesday from the American (GFS) model at 12 UTC, which is 5:30 p.m. in Delhi. (TropicalTidBits.com)

# Enough Examples!
# What Does Science Tell Us?

# Intergovernmental Panel on Climate Change Assessment Report



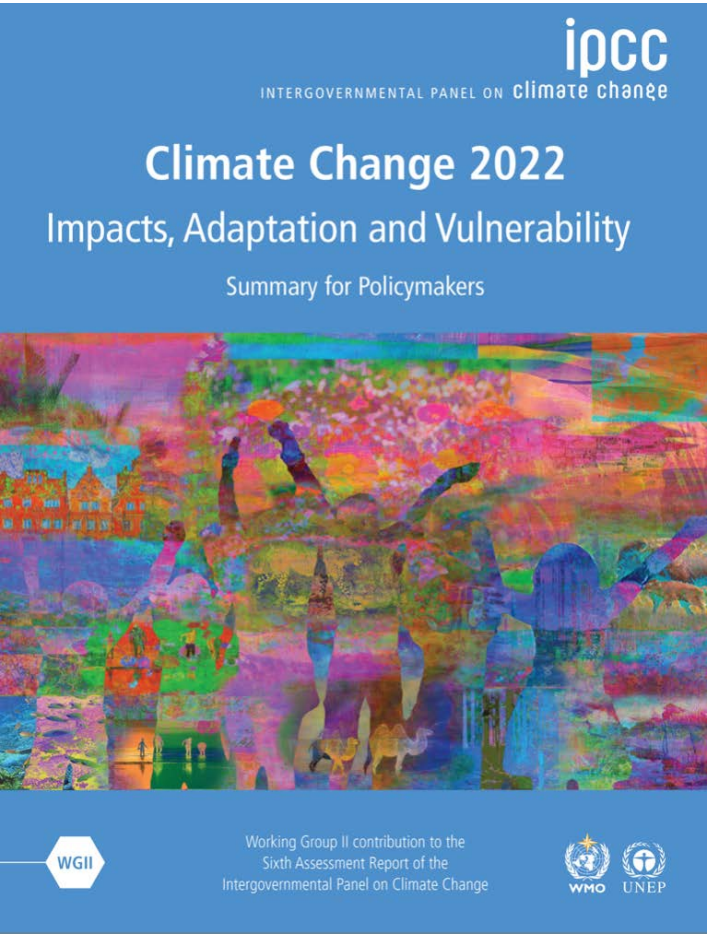

**Climate Change 2021, Vol. 1 - Working Group I**
**The Physical Science Basis (3,949 pp)**
**(released 9 August 2021; 6th AR since 1990)**

234 authors from 65 countries
78,000+ comments/edits received

**195 countries approved**

https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

# Intergovernmental Panel on Climate Change Assessment Report

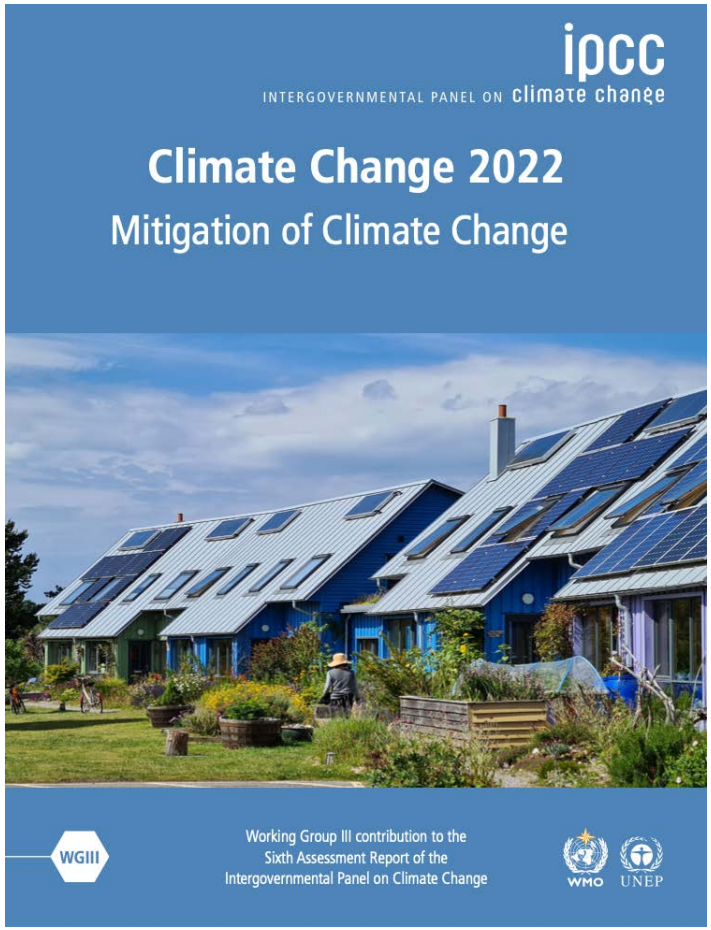



**Climate Change 2021, Vol. 2 - Working Group II Impacts, Adaptation and Vulnerability (3,675 pp) (released 27 February 2022; 6th AR since 1990)**

270 authors from 67 countries
62,418 comments/edits received

https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

# Intergovernmental Panel on Climate Change Assessment Report




**Climate Change 2021, Vol. 3 - Working Group III Mitigation of Climate Change (2,913 pp) (released 4 April 2022; 6th AR since 1990)**

278 authors from 65 countries
59,212 comments/edits received

https://www.ipcc.ch/report/sixth-assessment-report-working-group-iii/

# 10,000 pages: 4 Big Messages

## reconfirmed in the 2021-22 IPCC AR 6

- **Climate is changing faster than at any time in past 2 million years**
  - **It is virtually unavoidable for the global average temperature to reach 1.5°C above pre-industrial level by 2050.**
- **Humans who burn fossil fuel are primarily responsible**
  - **The 6th assessment in 2021 by the IPCC is more certain than ever.**
- **The consequences are serious; the impacts are largely negative**
  - **Earth is 1.1 °C warmer than pre-industrial times → more frequent & intense extreme events with widespread losses and damage to nature and people.**
  - **If the rate of carbon emission does not change, Earth will warm by more than 2.5°C, which is dangerous, and by possibly as much as 3-5°C, which is catastrophic.**
  - **The most vulnerable people and systems are disproportionately affected.**
  - **Some impacts are irreversible as systems are pushed beyond their ability to adapt.**

# Messages

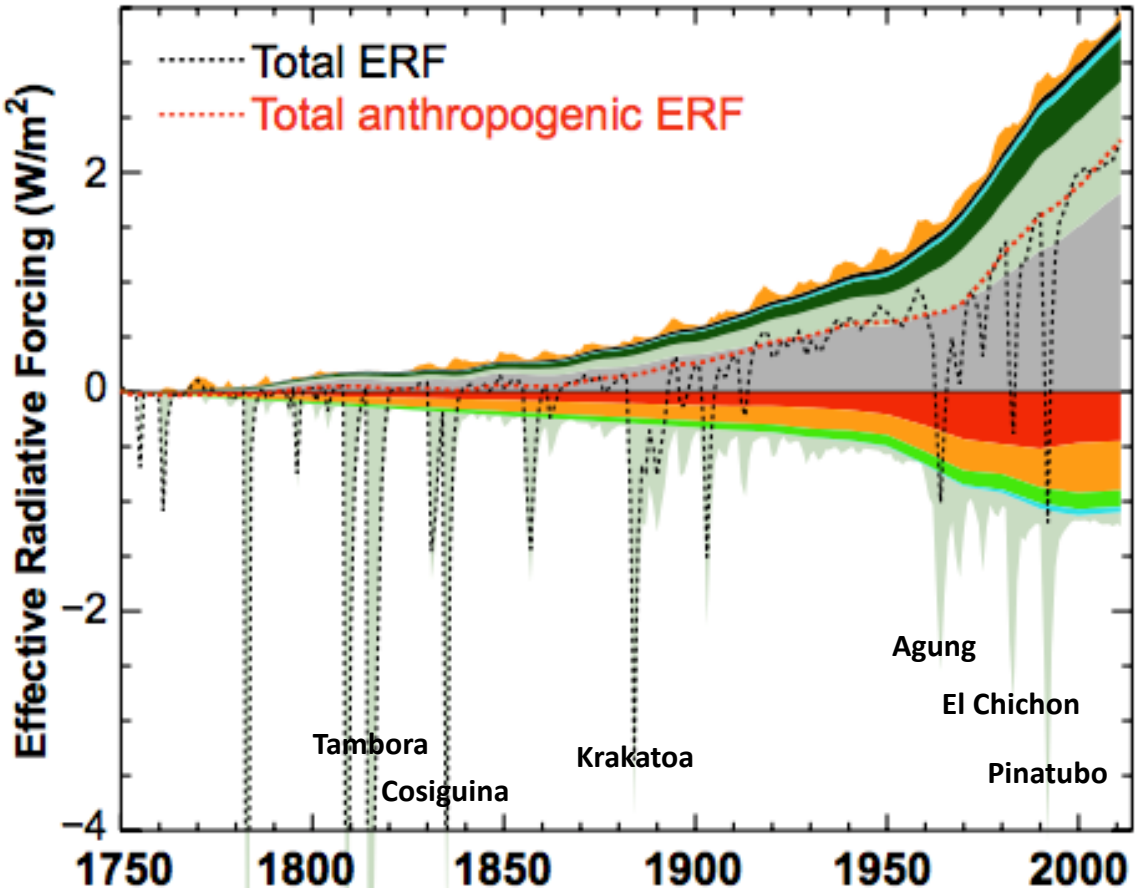
– **There is hope**

- **We have the technology, and commitments to address climate change are growing**

**Bold, aggressive action in this decade can avoid even more dangerous climate conditions in the latter half of this century**

# Climate is Changing Fast; Humans are Responsible

# Humans Are Changing the Equilibrium




GHG

$CO_2$

aerosols

land use

Human activities emit greenhouse gases, including $CO_2$, and aerosols

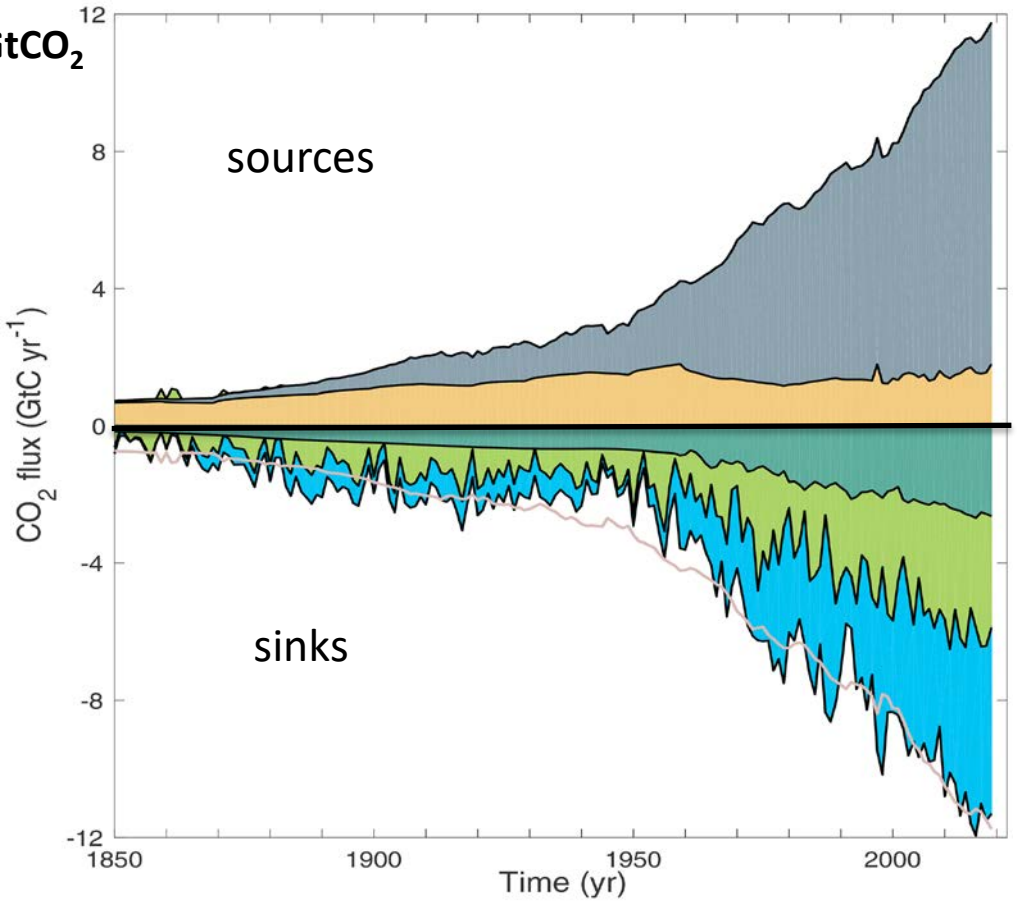
Large volcanic eruptions have a major, short-lived cooling effect.

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

Human activities have increased the effective radiative forcing by more than 2 W/m$^2$, mostly due to $CO_2$ emissions. Future scenarios of up to 8.5 W/m$^2$ by 2100 are considered plausible.

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

**11 GtC = 40 $GtCO_2$**




Fossil fuel combustion

Land-use change

Ocean absorption

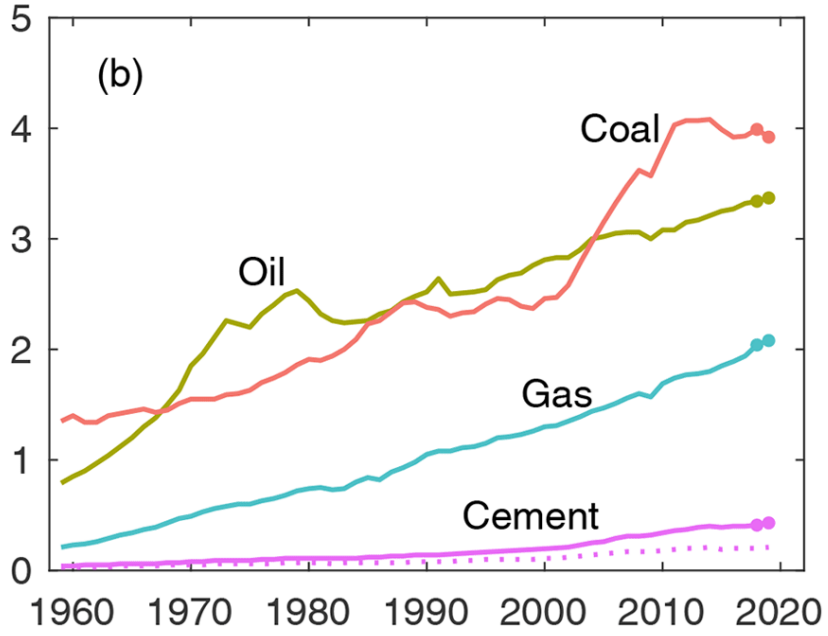
Land absorption

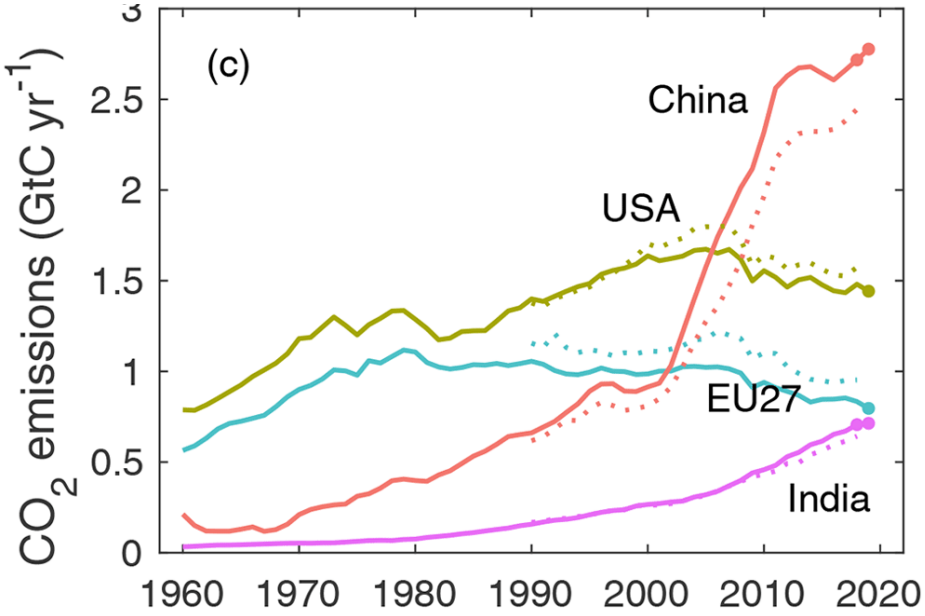
Atmosphere

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

**About ½ the 11 billion metric tons of carbon, emitted from fossil fuel combustion, cement production and land use change, stays in atmosphere. About 42% of the rest ends up in ocean.**

# Where Does the Anthropogenic $CO_2$ Come From?




**5 GtC = 18 $GtCO_2$**

**About 36% of the 11 billion metric tons carbon emitted globally results from burning coal. About 25% of emissions originate in China. Prior to 2000, the US was responsible for 25%.**

# The Consequences are Serious, and The Impacts are Negative

(spoiler alert: the following facts are grim and depressing … stay alert for potential solutions)

# From IPCC AR6 WGI



## Hot Extremes Over Land

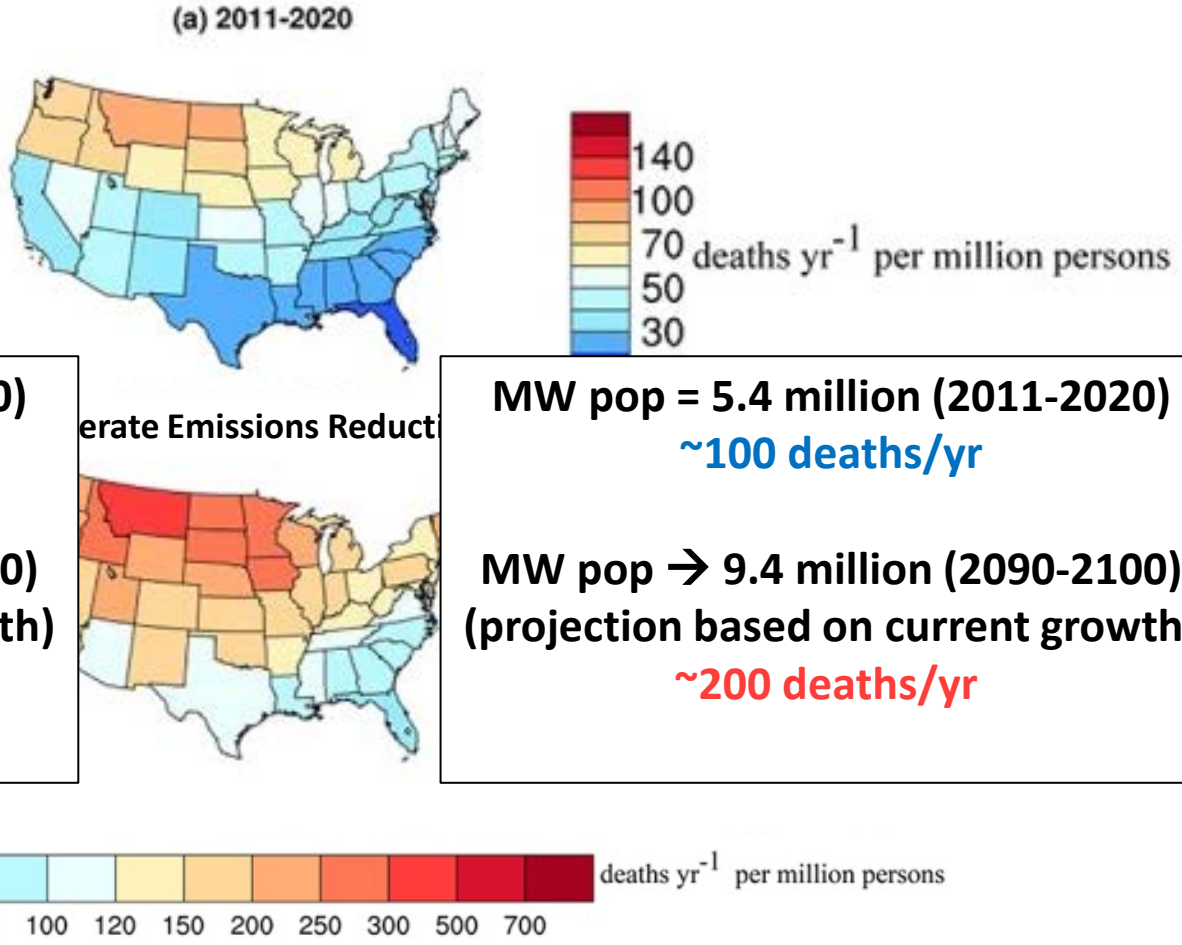
**projected to be more intense and more frequent with each additional increment of global warming**

## 50-year event in 1850-1900

| | | |
|---|---|---|
| **+1.1 (Now):** | **2.2°F warmer; every 10 yrs** | **(the new extreme)** |
| **+1.5°C:** | **3.6°F warmer; every 6 yrs** | **(the inevitable extreme)** |
| **+2.0°C:** | **4.8°F warmer; every 3-4 yrs** | |
| **+4.0°C:** | **9.5°F warmer; every 1-2 yrs** | **(the future?)** |

# Heat & Humidity → Human Mortality*

(*) assuming no adaptation to higher summer temperature




**MW pop = 5.4 million (2011-2020)**
**~100 deaths/yr**

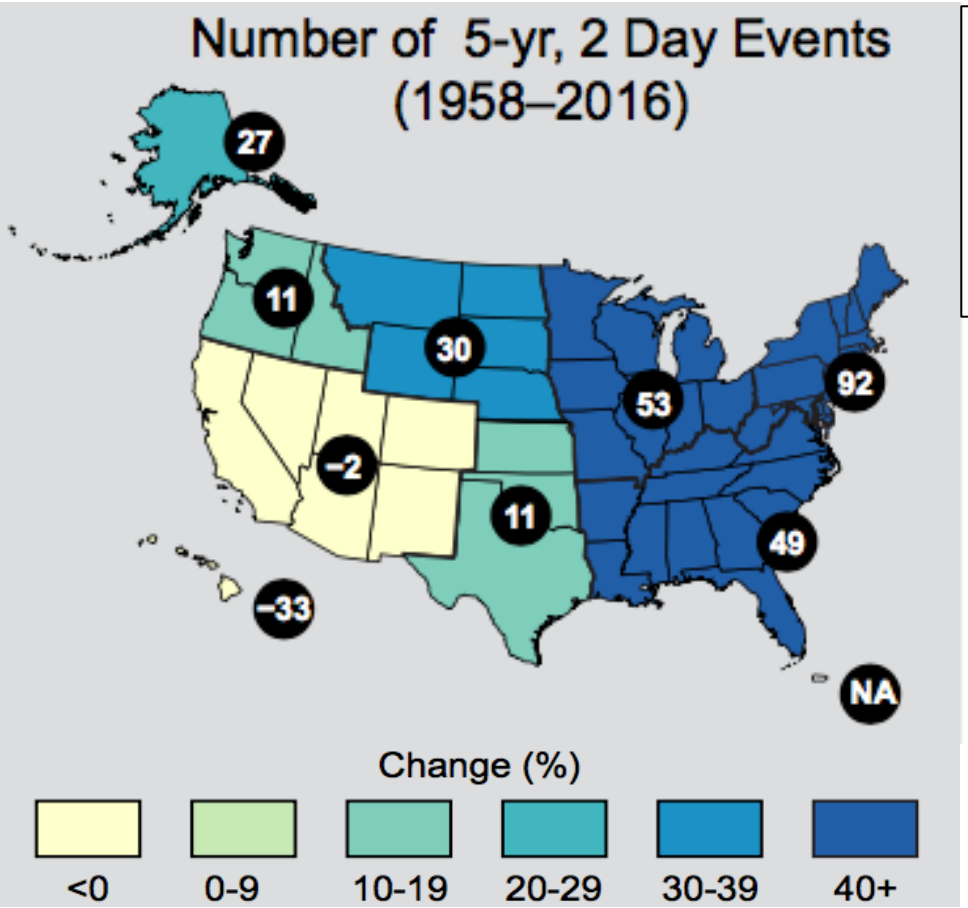
**MW pop → 9.4 million (2091-2100)**
**(projection based on current growth)**
**~1300 deaths/yr**

**MW pop = 5.4 million (2011-2020)**
**~100 deaths/yr**

**MW pop → 9.4 million (2090-2100)**
**(projection based on current growth)**
**~200 deaths/yr**

Shindell et al. 2021: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7125937/

# Global Warming → Extreme Rainfall is Already Happening




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

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

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

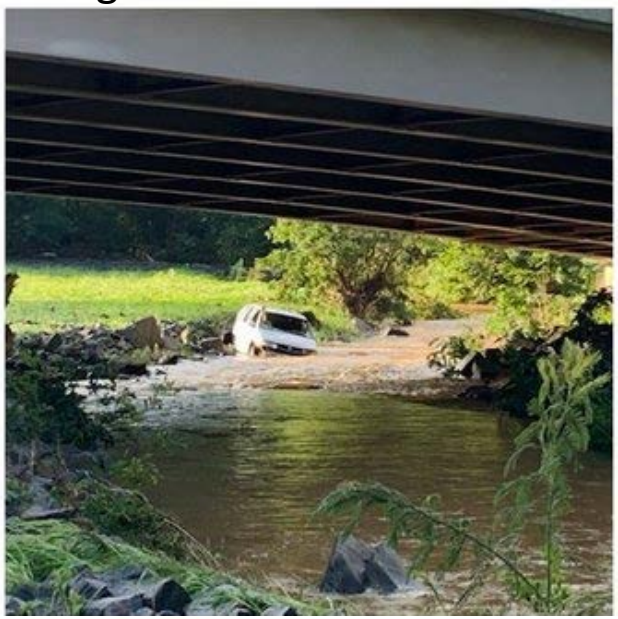
SE US, including VA, has experienced 49% increase in number of 2-day events with a precipitation total exceeding the largest 2-day amount that is expected to occur, on average, only once every 5 years

# Extreme Rainfall → Flash Floods

The Washington Post
*Democracy Dies in Darkness*

## Nine rescued amid flash-flooding as creek rises 9½ feet in Loudoun County

Leesburg, VA
6 August 2020



WUSA9

# Extreme Rainfall → Flash Floods

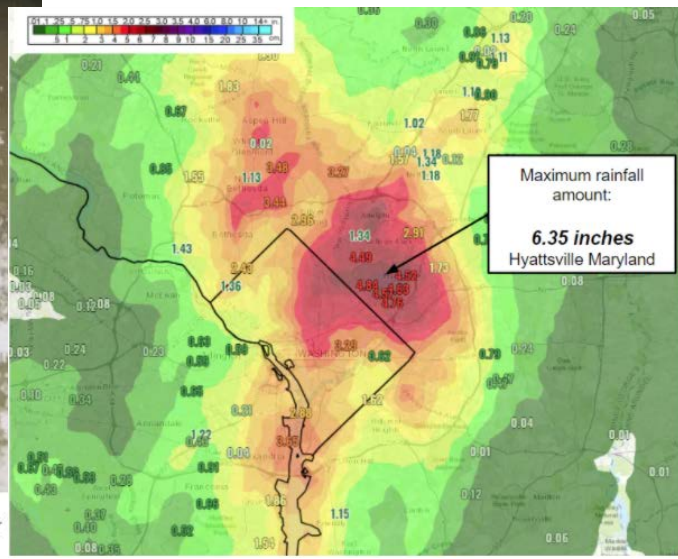
The Washington Post
*Democracy Dies in Darkness*

Capital Weather Gang

**How Thursday's flood unfolded in the Washington region and why it was so hard to forecast**


Flash flooding in a backyard in the Del Ray neighborhood of Alexandria, Va., after heavy rains soaked the area Thursday. (Peter Jamison/The Washington Post)

4th time in 2020 with > 2" rain in one day (record is 6 days)



# Extreme Rainfall → Flash Floods

4 WASHINGTON LOCAL CORONAVIRUS U.S. & WORLD WEATHER INVESTIGATIONS THE SCENE NEWSLETTERS

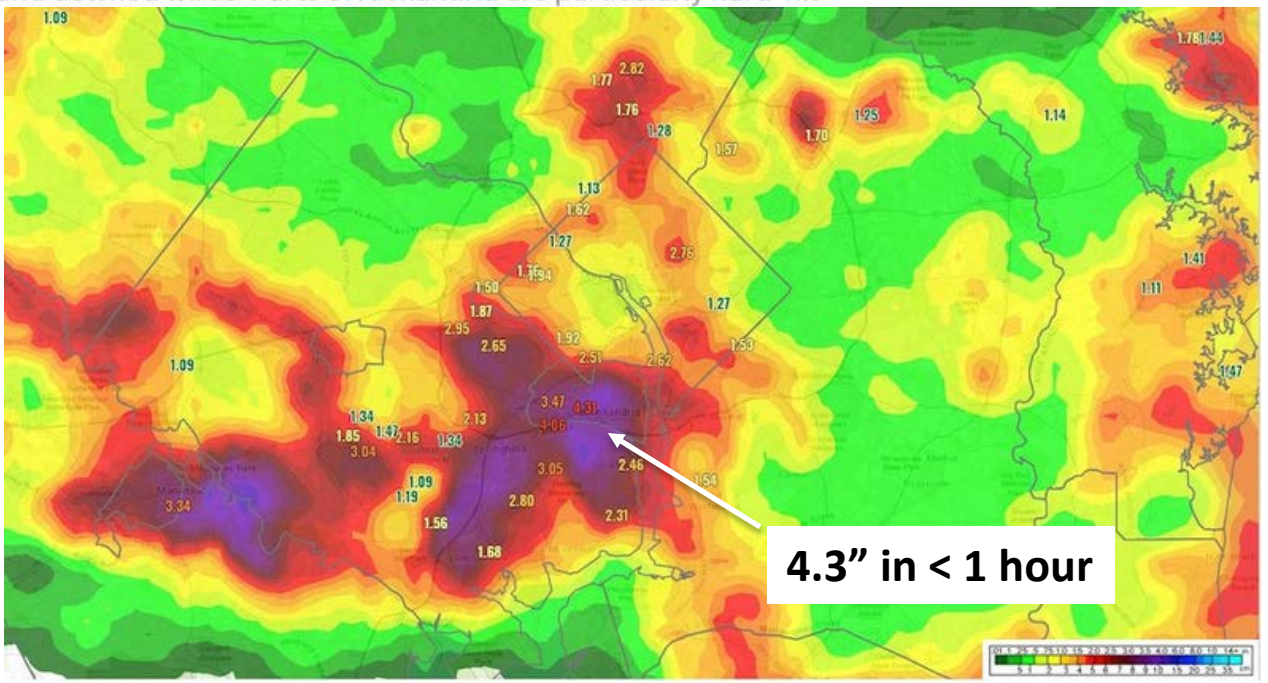
High COVID Transmission Areas | Mask & Vaccine Guidance | Bijan Ghaisar | LGBTQ Rights in Loudoun Schools | 4 Your Home | Ready 4 School | Changing Minds

**14 August 2021**

FLOODING

## Northern Virginia Sees Flooding, Water Rescues After Heavy Rain

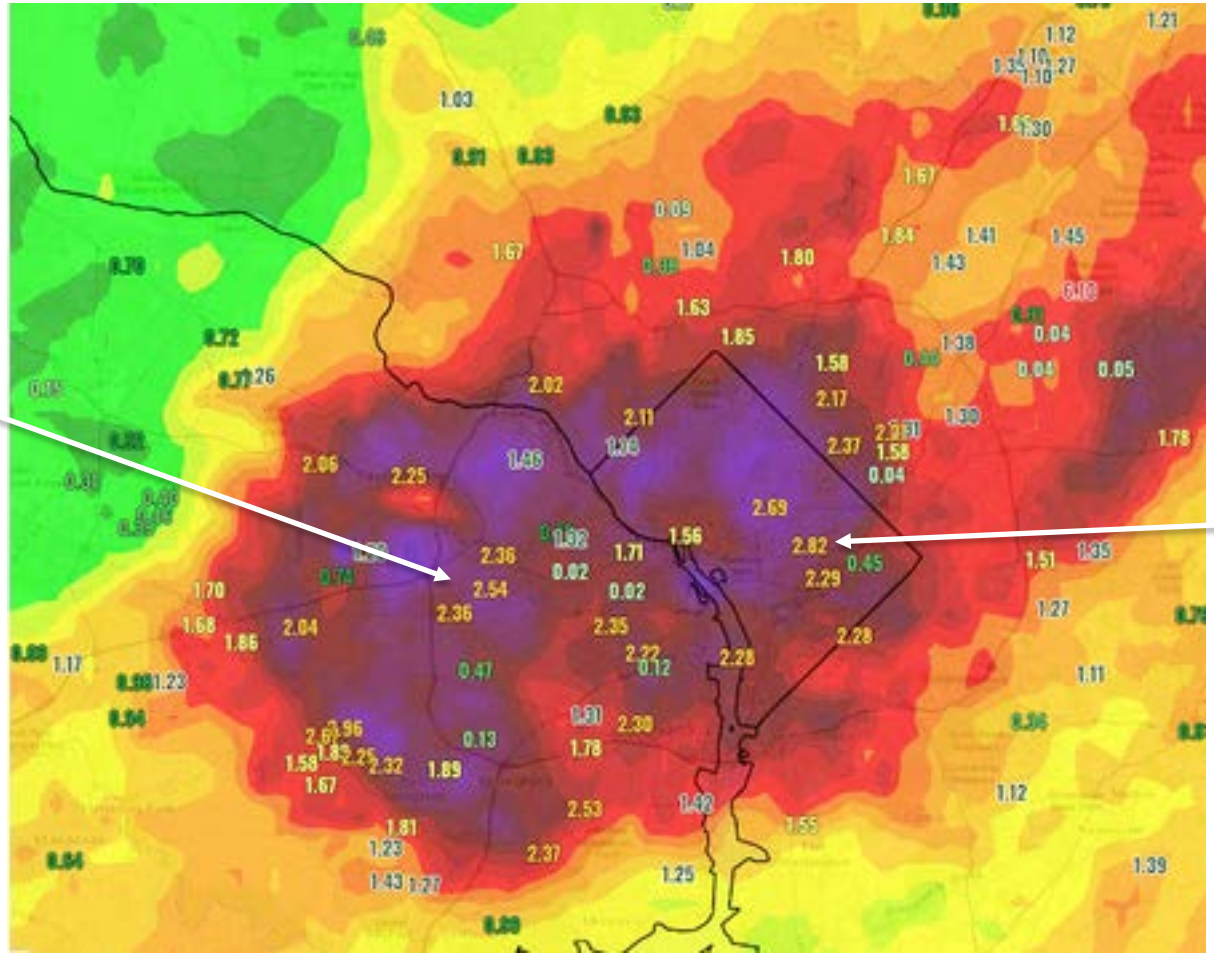
Streets are closed due to flooding, fallen trees and downed wires. Parts of Alexandria are particularly hard-hit

# Extreme Rainfall → Flash Floods

**20 August 2021**

**2.54”**
**in 4 hrs**



**2.82”**
**in 4 hrs**

# Extreme Rainfall: Ellicott City, 27 May 2018


Reuters / Todd Marks

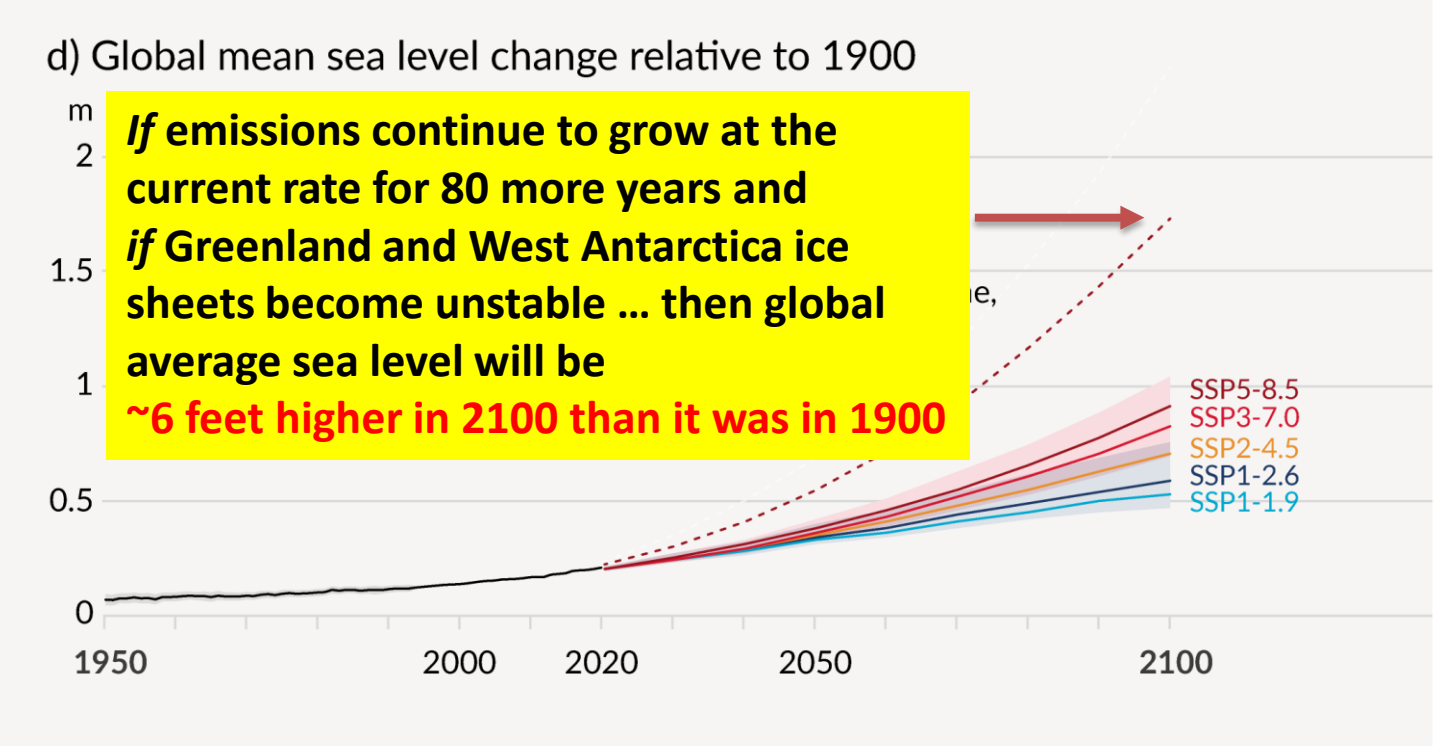
**Second "1000-year flood" in 2 years!**

# Sea Level Is Rising

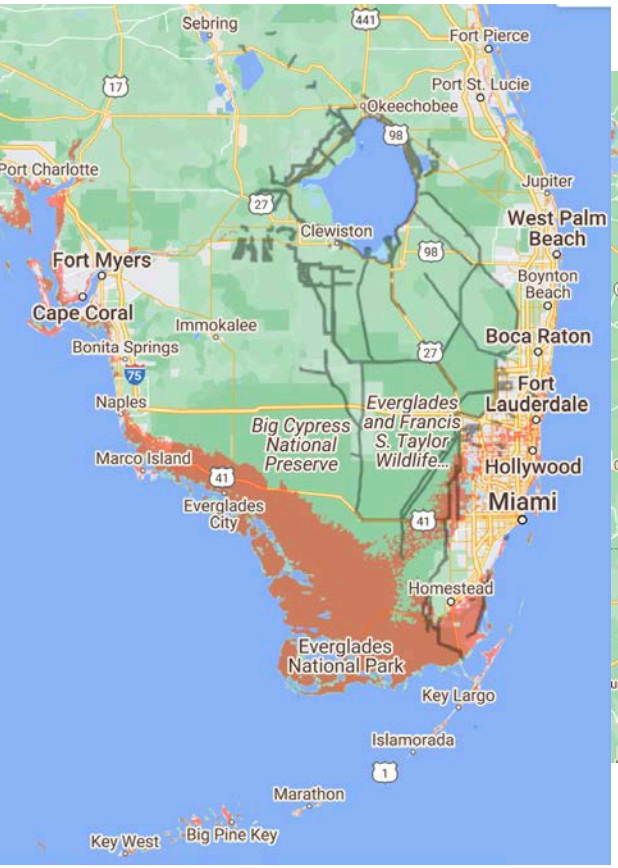


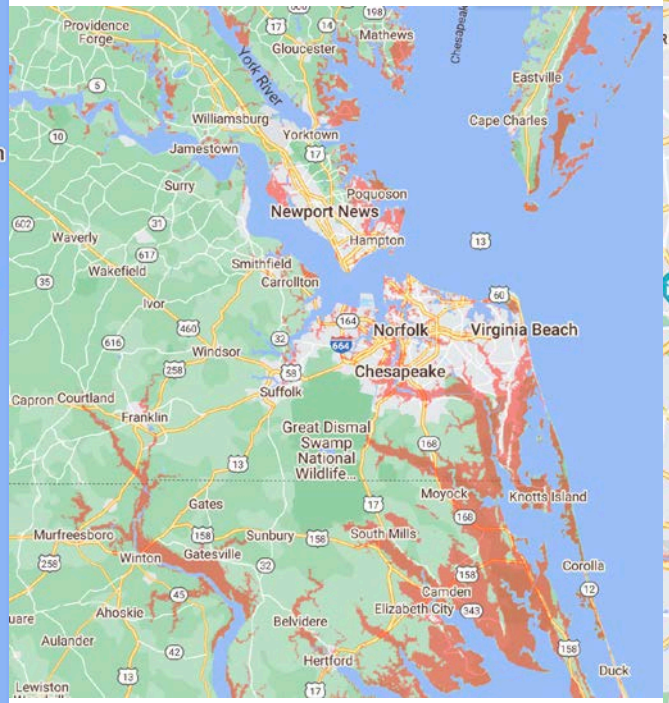
**Human activities affect all the major climate system components, with some responding over decades and others over centuries**

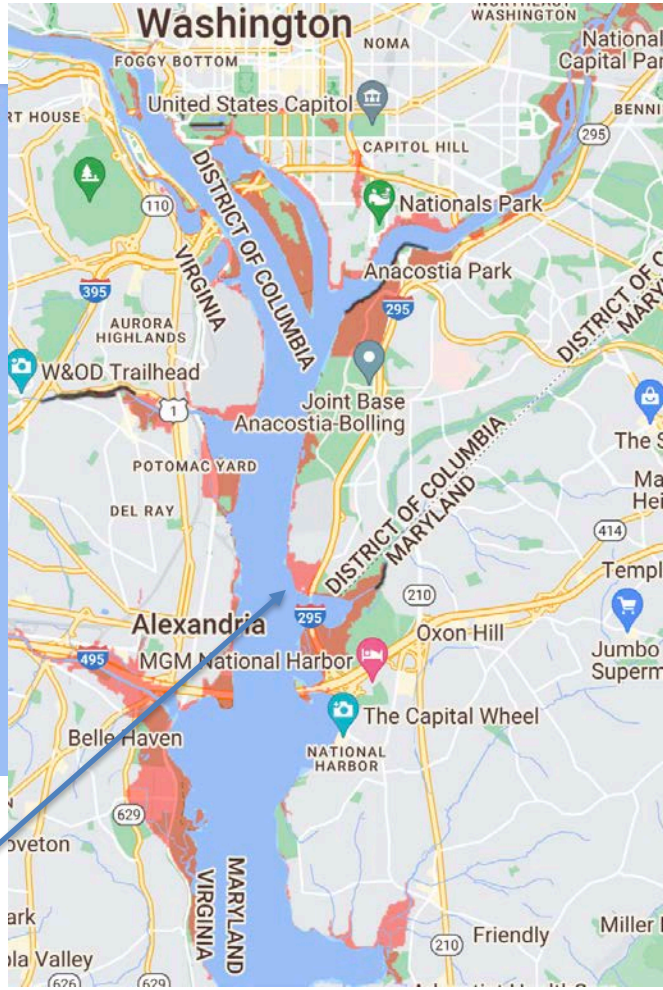
*Figure SPM.8*



# Current Trajectory → 2100 without GHG Emissions Reductions




**Courtesy Climate Central**
**https://coastal.climatecentral.org/map**

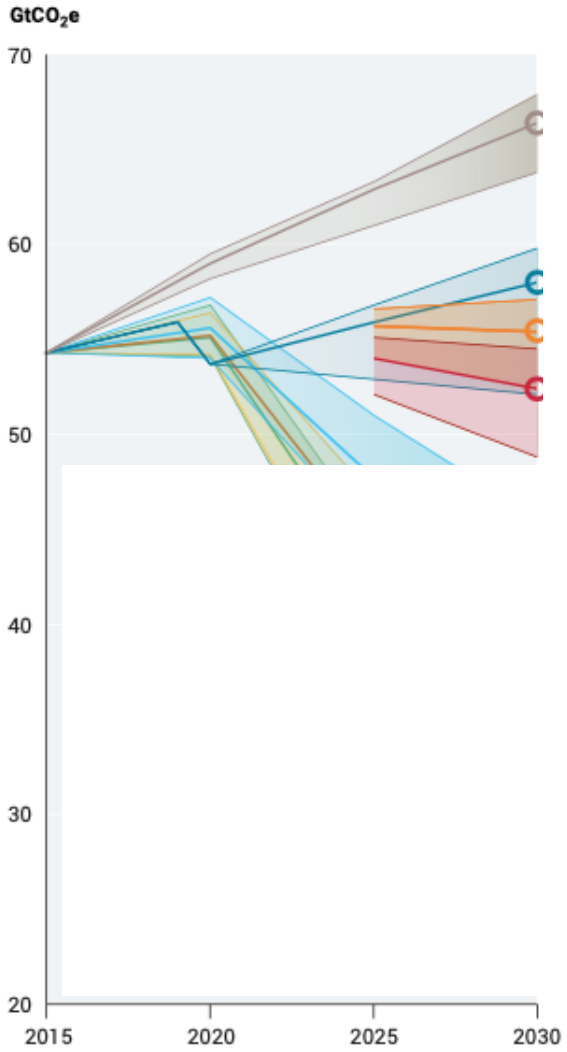
**Blue Plains Waste-water Treatment Plan**

# There is Hope

# Decarbonize

- The solution is obvious: **Reduce the concentrations of carbon dioxide ($CO_2$), methane ($CH_4$) and other GHG in the atmosphere**
  - **First, stop digging the hole and reduce emissions:**
    - Use fewer processes that emits $CO_2$ and $CH_4$ (conservation)
    - Use more alternative energy sources that don't rely on fossil fuels
  - **Then, capture and sequester:** get C out of the atmosphere
- This is simple to say … but it is far from easy!
  - **Transform the energy infrastructure** built over the past 140 years to a non-polluting system in less than 30 years
  - **Then do it again** to meet the 110-170% increase in demand (EVs, electric homes, electric industries)

# We Have Made Progress

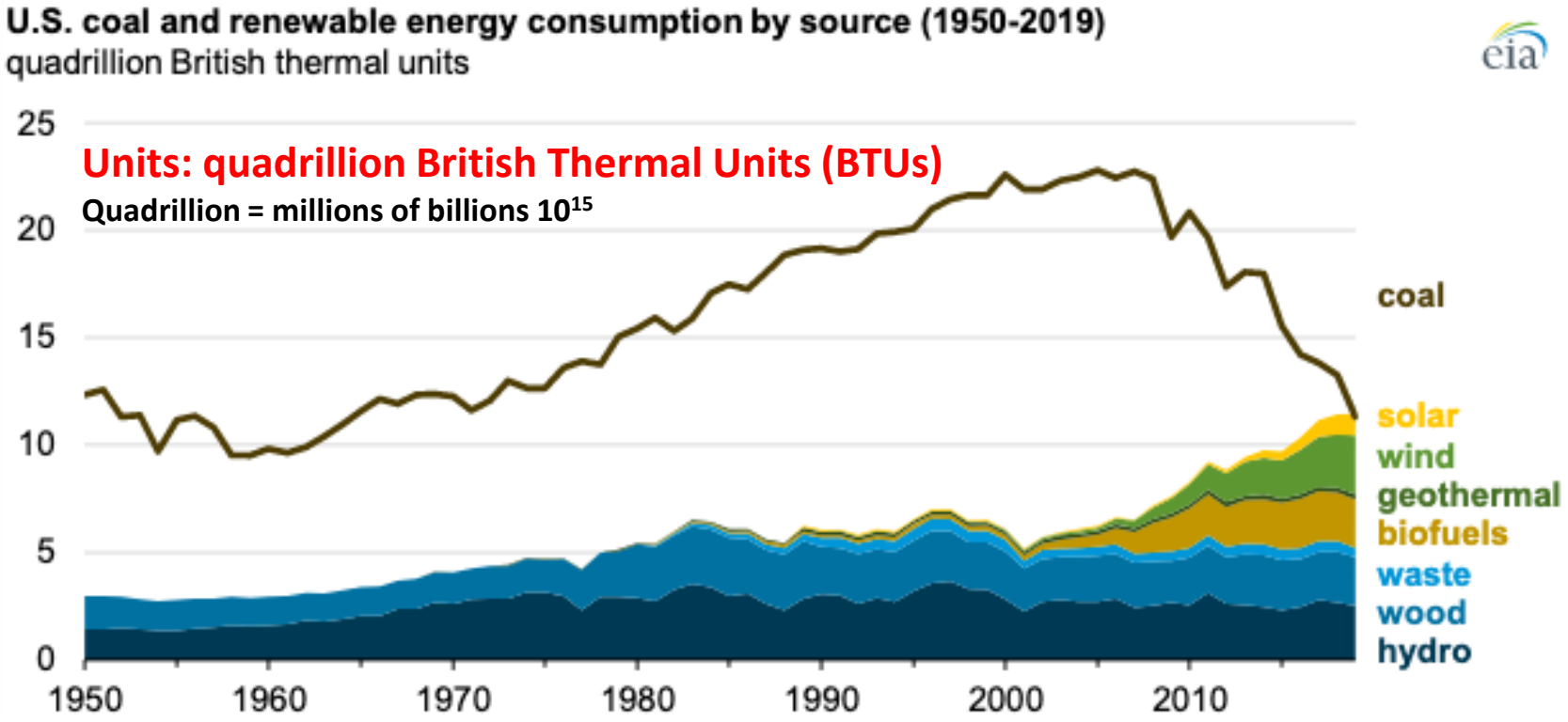



**2010 policy scenario**

**current policy scenario**

**Unconditional NDCs**

# U.S. renewable energy consumption surpasses coal for the first time in over 130 years

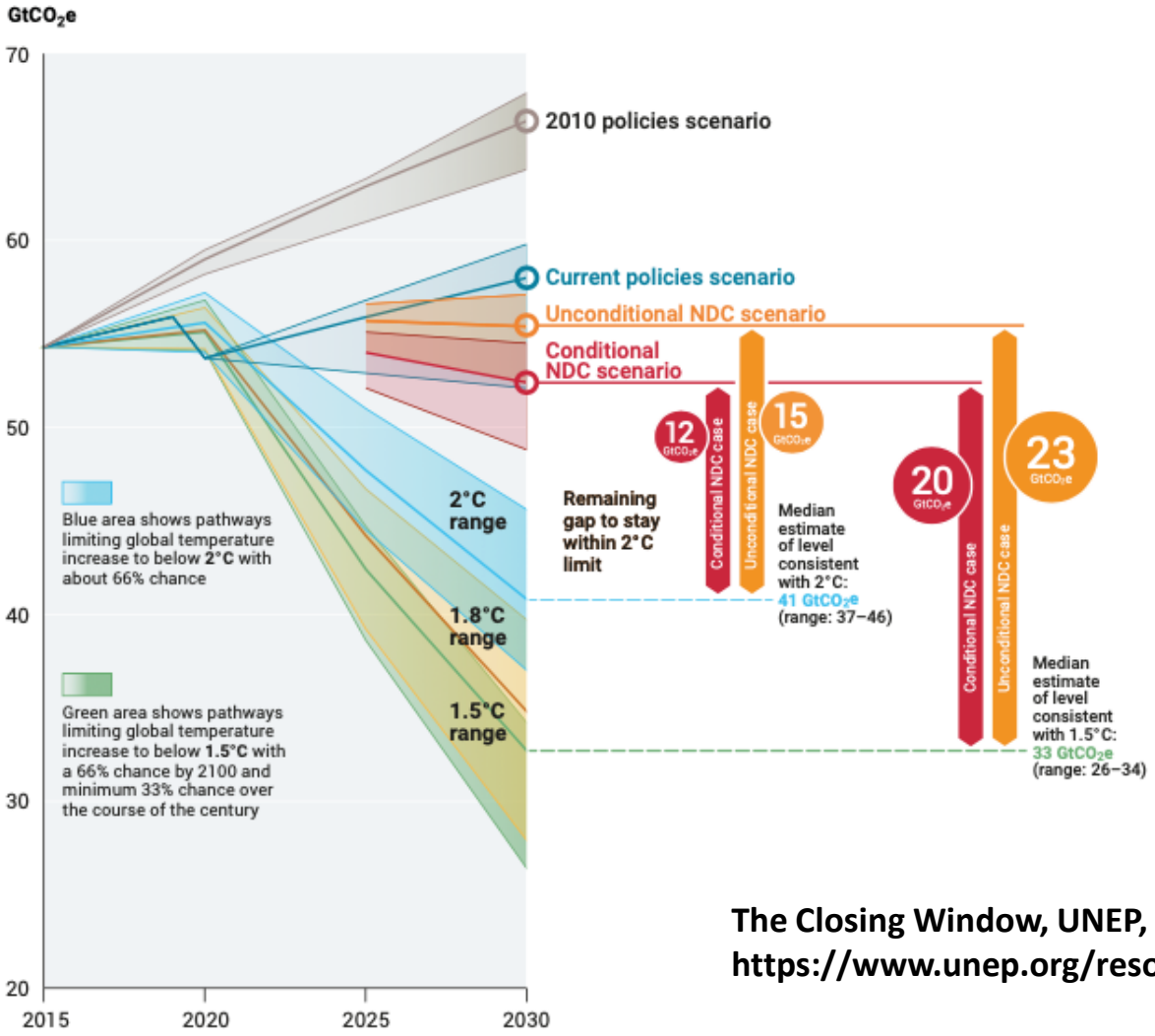



NB – This flipped back in 2022 as a result of global pandemic and Ukraine war disruptions

# Inflation Reduction Act of 2022

- A different approach: instead of establishing a ”real” cost of carbon and letting the market evolve away from fossil fuels …
- **Tax large corporations and close tax loopholes to finance & incentivize clean energy infrastructure for all Americans**
- Avoids the politically infeasible: making what everybody uses for energy more expensive

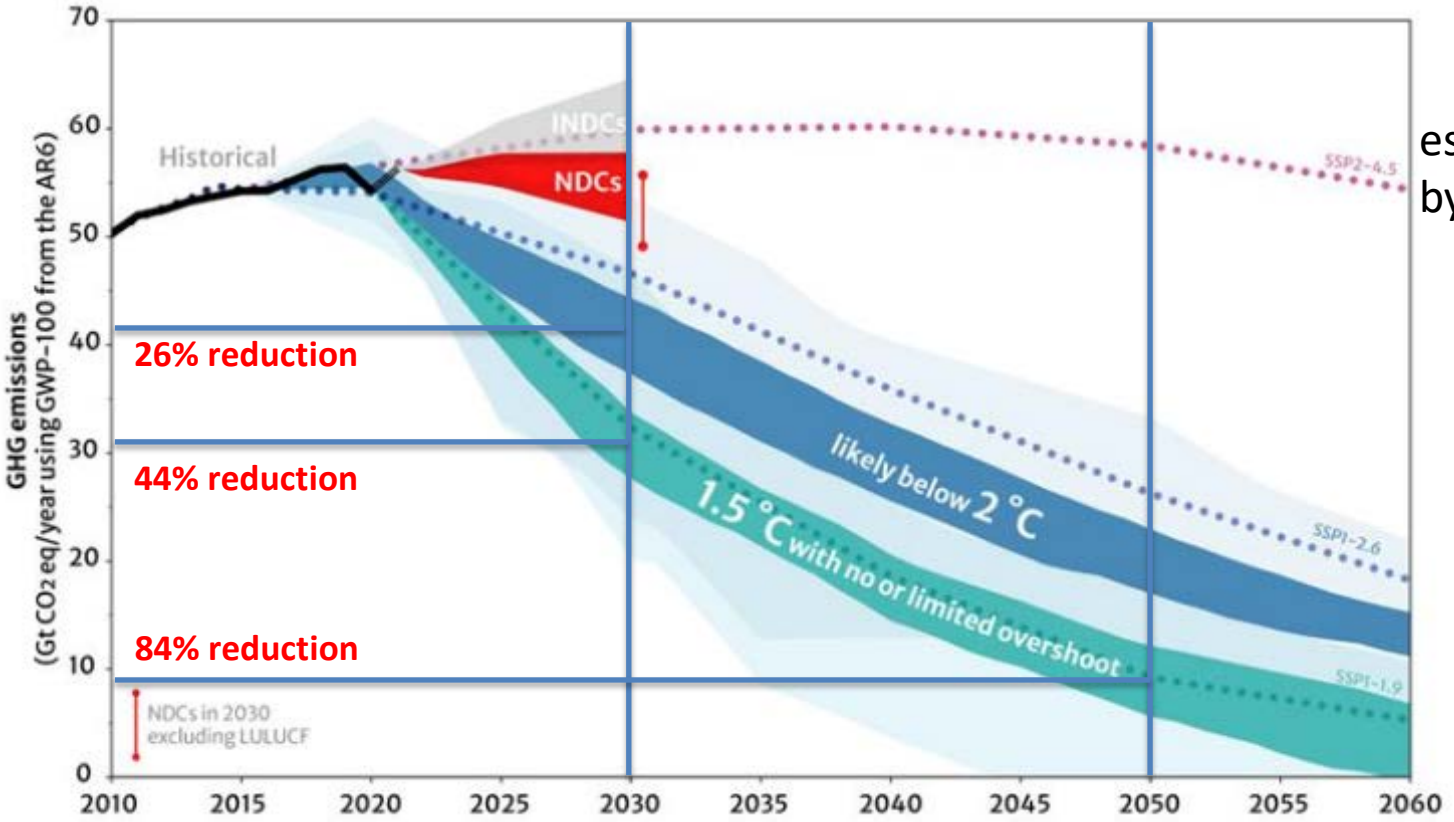
# We Have Made Progress
# … Just Not Enough




**70% too much emission anrticipated in 2030 to keep warming below 1.5 ℃**

**The Closing Window, UNEP, 2022**
**https://www.unep.org/resources/emissions-gap-report-2022**

# United Nations NDC Report (Sep 2021)




estimated +2.7 °C by 2100

**Comparison of global emissions under scenarios assessed in the Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5 °C with total global emissions according to nationally determined contributions**

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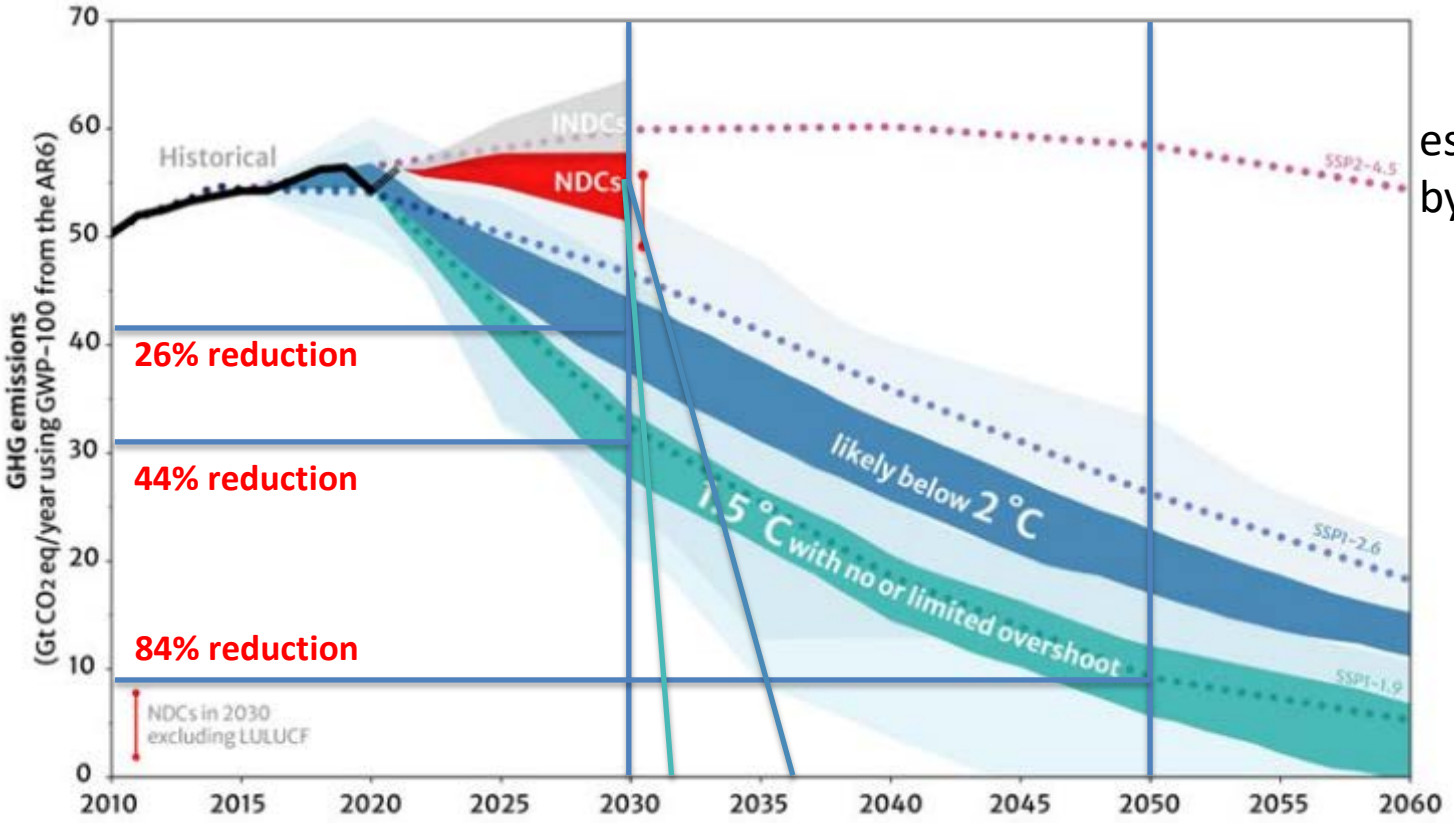



estimated +2.7 °C by 2100

**Comparison of global emissions under scenarios assessed in the Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5 °C with total global emissions according to nationally determined contributions**

**If all countries keep their promises (NDCs) through 2030:**

- **67% chance of GW < 2.0℃: 2020-2030 $CO_2$ emissions = 1,150 Gt → 720 Gt left (2036)**
- **50% chance of GW < 1.5℃: 2020-2030 $CO_2$ emissions = 430 Gt → 70 Gt left (2032)**

# Take-Aways

- Fastest rate of climate change in past 2 million years
- Humans who burn fossil fuel are primarily responsible
- The consequences are serious; the impacts are negative
- There is hope

# People Alive Today …

- ***The first generation*** **to fully appreciate the potential implications of combusting fossil fuel and changing the atmospheric concentrations of $CO_2$, $CH_4$ etc.**

**Manabe and Wetherald, Jan 1975**
(age 90)

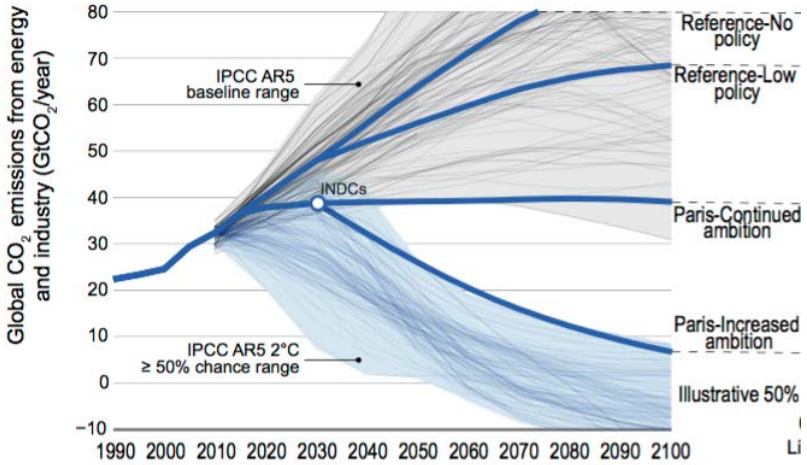
The Effects of Doubling the $CO_2$ Concentration on the Climate of a General Circulation Model[1]

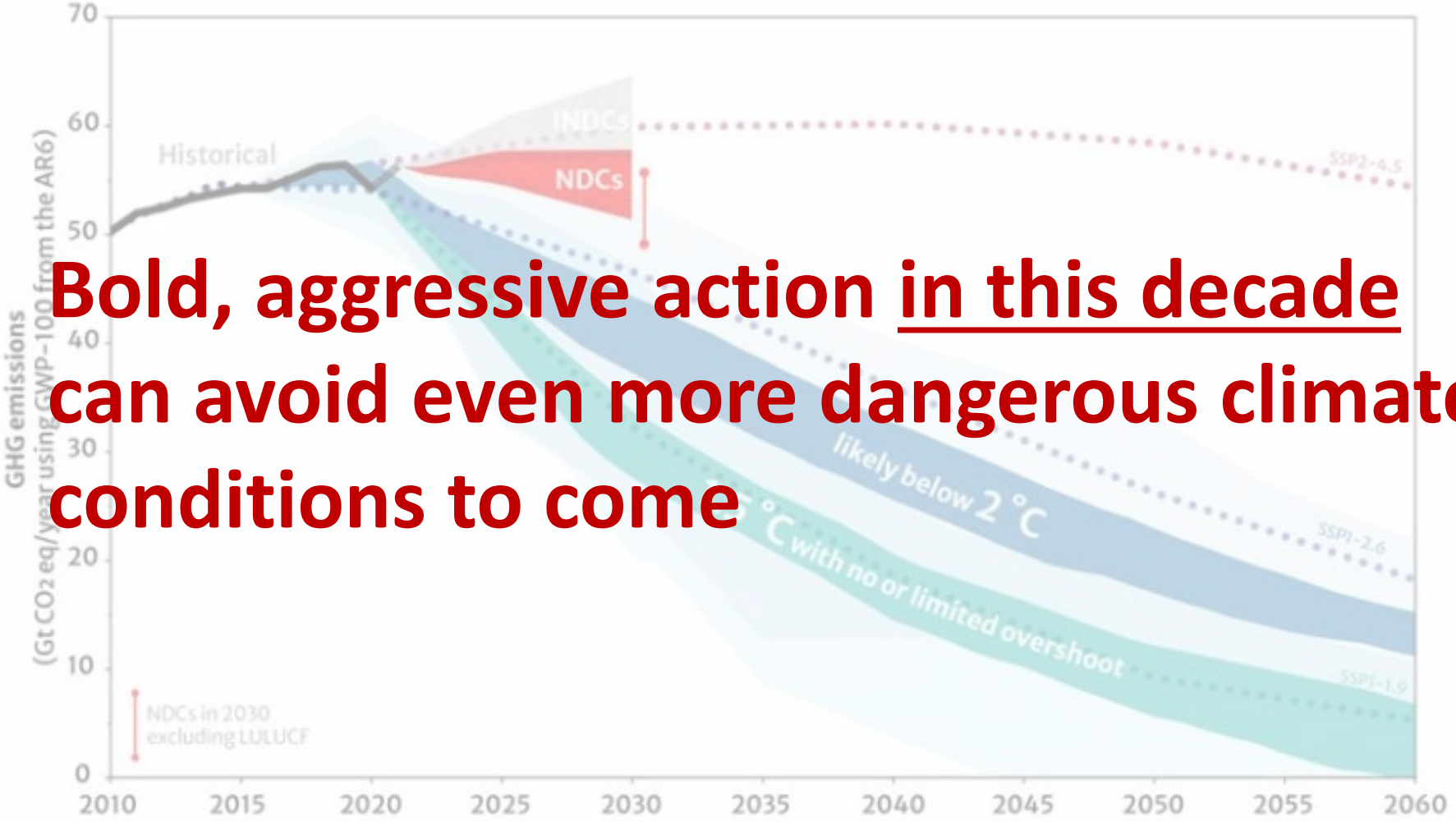
SYUKURO MANABE AND RICHARD T. WETHERALD

*Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University, Princeton, N.J. 08540*

(Manuscript received 6 June 1974, in revised form 8 August 1974)

- ***The last generation*** **that may be able to do what it takes to avoid the potentially dire consequences**






# Bold, aggressive action <u>in this decade</u> can avoid even more dangerous climate conditions to come

# QUESTIONS? COMMENTS?