Health Impacts of Climate Change

Michael Wysession, Professor of Geophysics
Executive Director, Center for Teaching and Learning
Department of Earth and Planetary Sciences
Washington University, St. Louis, MO
HREM, Oahu, March 10, 2025

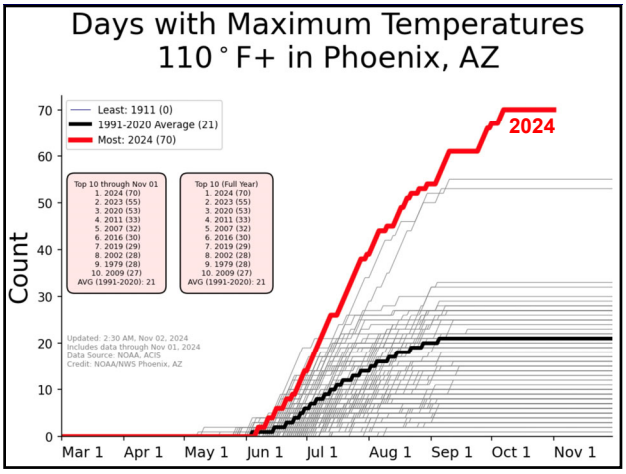
1

How *Climate Change* Impacts Health

- Heat: Heat Stress, Heat Stroke

2

Days with Maximum Temperatures 110 °F+ in Phoenix, AZ



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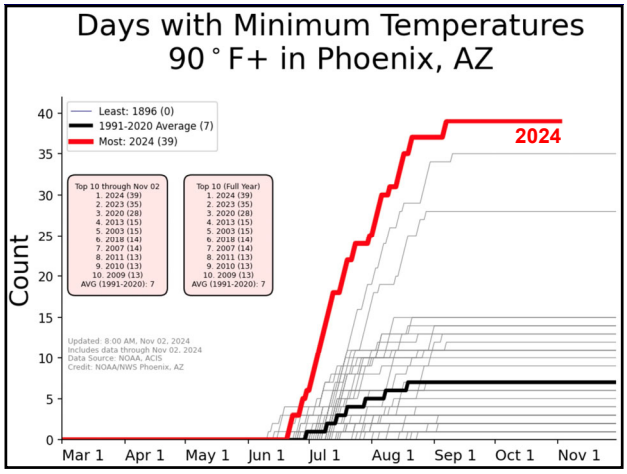
Days with Minimum Temperatures 90 °F+ in Phoenix, AZ



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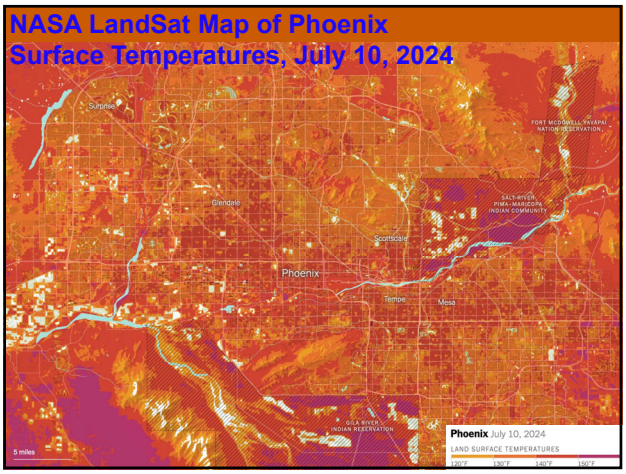
NASA LandSat Map of Phoenix Surface Temperatures, July 10, 2024



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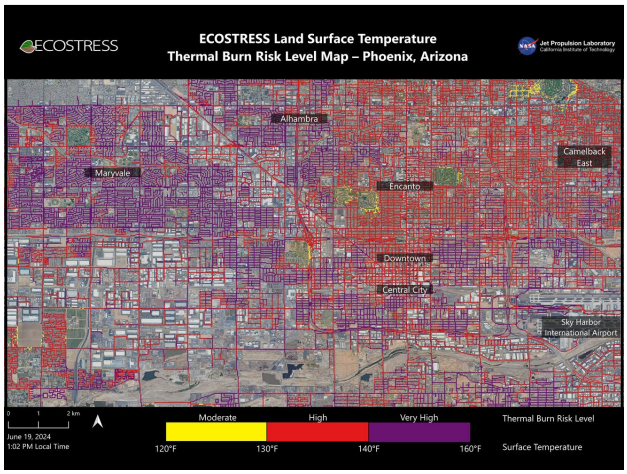

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The New York Times

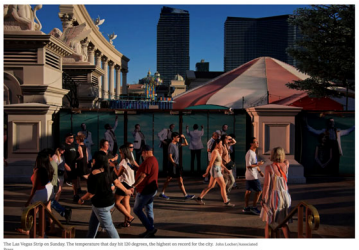
Extreme Heat | U.S. Tracker | Global Tracker | How to Stay Safe | Heat Waves, Explained | Heat's Physical Toll | Effect on the Brain

120 ºF on Thursday, July 11

(Fifth Straight Day of >115 ºF)

Las Vegas Heat Breaks Records and Stuns Even the Forecasters

A brutal heat wave that has gripped the West for days will shift eastward on the weekend, while much of sweltering Houston still lacks electricity.



The Las Vegas Strip on Sunday. The temperature that day hit 120 degrees, the highest on record for the city. John Locher/Associated Press

7

National Weather Service HeatRisk

Risk guidance for the impacts of extreme heat

Category		Risk of Heat-Related Health Issues (Without Effective Cooling/Adequate Hydration)	How common?	Actions to Take
0	Little/ No Risk	Little to no risk from expected heat.	Very common across the U.S.	No preventative actions needed.
1	Minor Impacts	This level of heat is tolerable for most. Minor risk for extremely heat-sensitive groups.	Very common across the U.S.	Increase hydration, reduce time in strong sunshine, use windows/fans to cool rooms
2	Moderate Impacts	This level of heat affects most individuals sensitive to heat.	Fairly common most of the U.S., especially across the South	Increase hydration, reduce time in strong sunshine, use windows/fans to cool rooms
3	Major Impacts	This level of heat affects anyone without effective cooling and/or adequate hydration.	Uncommon for most, but fairly common across the South	Consider cancelling outdoor activities. Fans may not be adequate for indoor cooling.
4	Extreme Impacts	This level of heat is rare and/or long duration with little to no overnight relief.	Rare for most, but occurs a few times a year in the South, especially the Desert Southwest	Strongly consider staying indoors. Fans are not adequate against this level of heat. Check on vulnerable people.

damweather.com
Source: NWS/CDC
DM

8

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damweather.com
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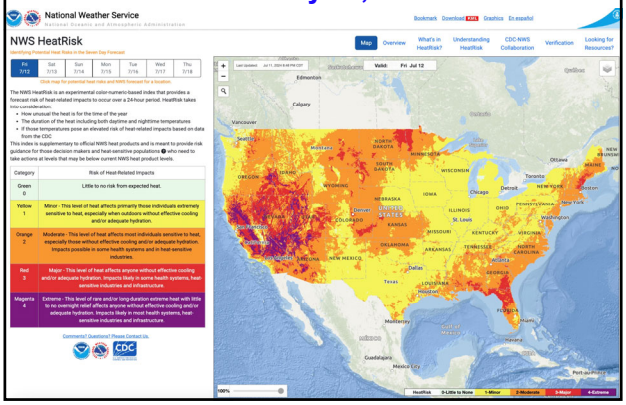
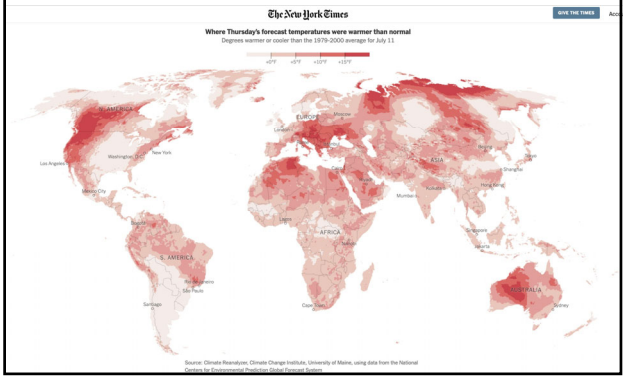
National Weather Service 4-Level "Heat Risk" Metric: July 12, 2024



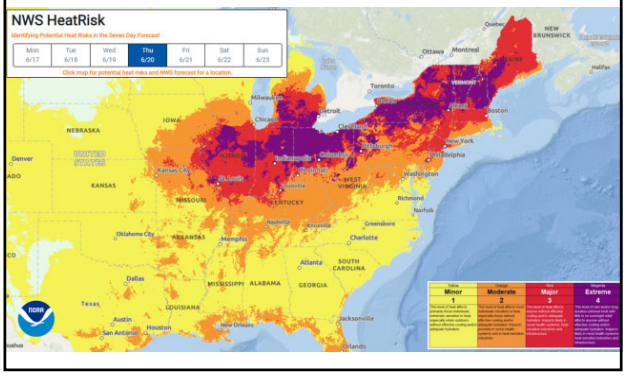
10

Thursday, July 11: Global Temperature Anomalies



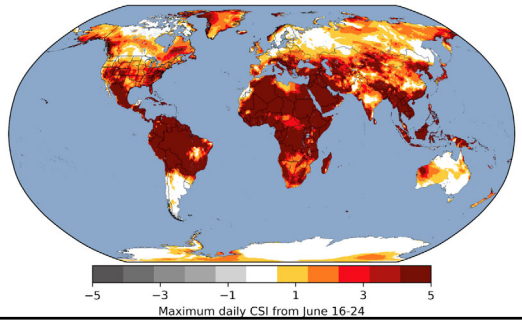
11

Heat Wave of June 16-24, 2024, as it Reached the Eastern United States



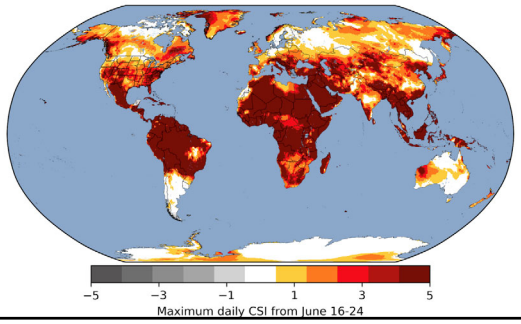
12

During the Heat Waves of June 16-24, 2024, 5 Billion People Experienced Extreme Heat



13

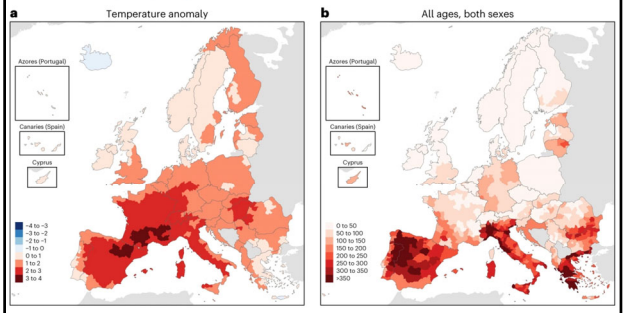
→*Climate Change Made this Heat Wave 35 Times More Likely to Have Occurred*



14

61,672 Europeans Died During the 2022 Summer Heat Waves

→ Could Top 120,000 Deaths by 2050



[Ballester et al., *Nature Medicine*, 2023]

15

Health Hazards of Extreme Heat

Mild Heat Illnesses
- Heat Rash
- Swelling of Hands and Feet
- Heat Syncope (Fainting)

Heat Exhaustion
- Headache
- Nausea
- Vomiting
- Dizziness

Heat Stroke
- Core body Temps Above 104 ºF
- Confusion
- Seizures and Other Mental Status Changes
- Brain Damage
- Muscle Breakdown
- Kidney Failure

16

Potential Actions Needed (Minutes Matter):

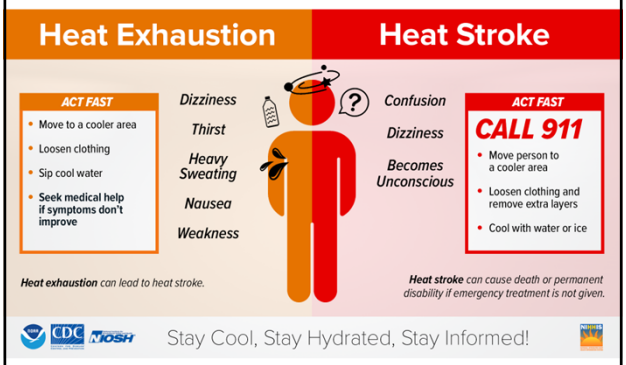
- Cool Patients as Fast As Possible
  - →Cold Water or Ice Bath
- Hydrate Quickly and Restore Electrolytes
  - → IV Fluids
- Cardiopulmonary Bypass

Children at High Risk
- Sweat Less
- Hydrate Less

Older People at High Risk
- More likely to have chronic medical conditions such as diabetes, kidney disease and heart failure
  - → Interfere with the body's ability to regulate temperature and balance fluids
- Treatments like blood pressure medications that keep the heart rate down or diuretics that clear fluid out of the body
  - → Impair the body's ability to compensate for extreme heat
- People with depression or dementia may also not realize they're thirsty and forget to drink water

17

Better Public Messaging: *NOAA, CDC, NIH*



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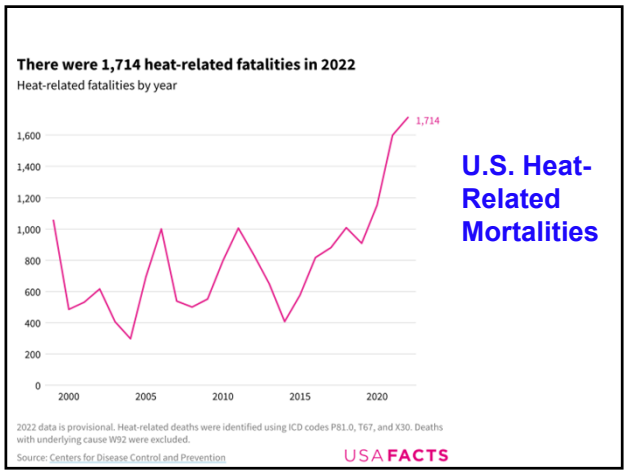
Better Public Messaging
Weather.Gov/Heat

19



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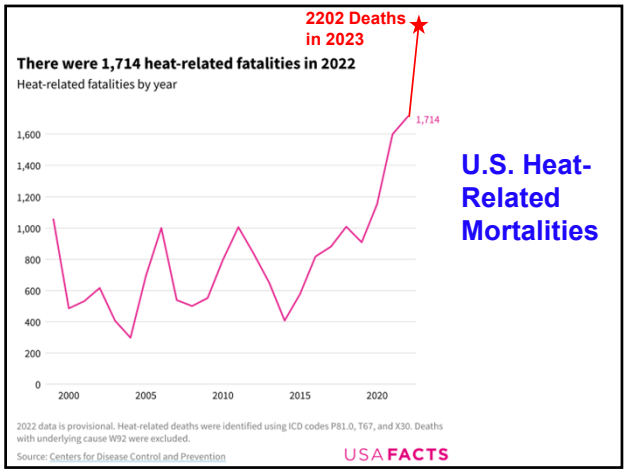

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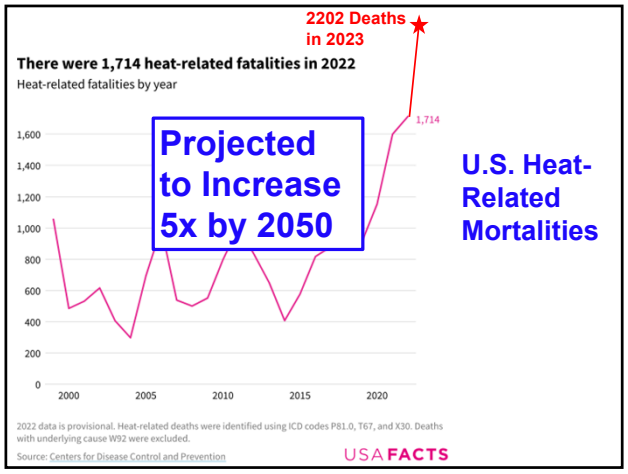

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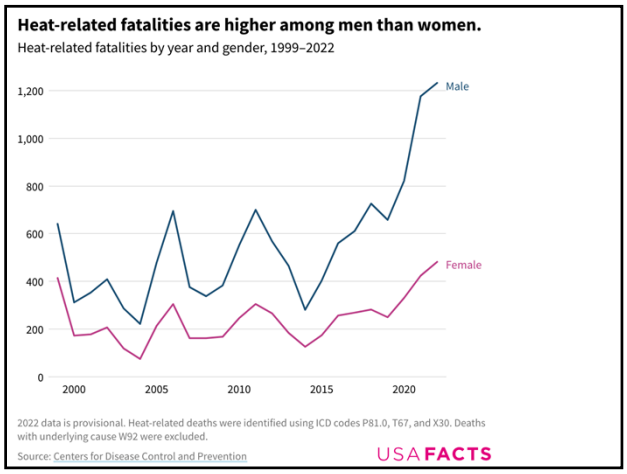

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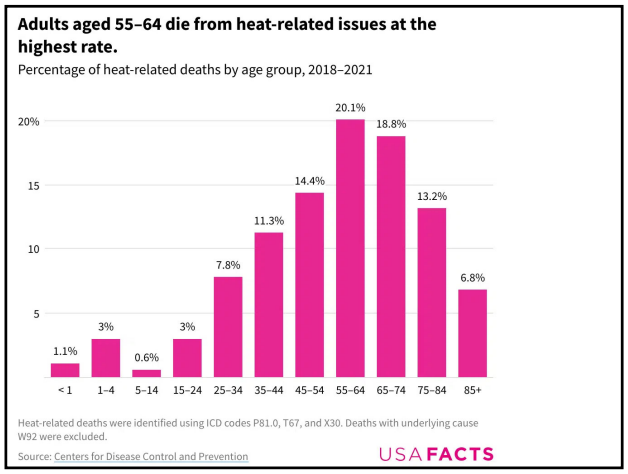
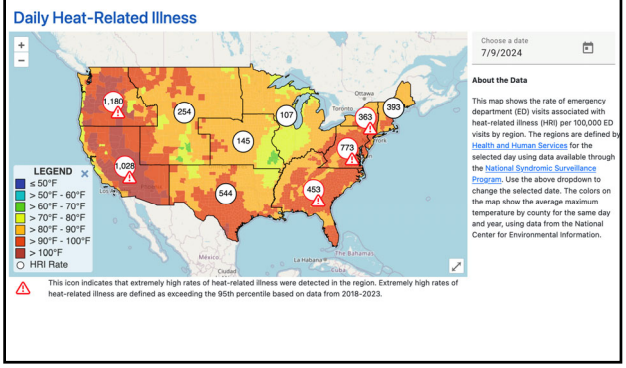


24

U.S. Heat-Related Emergency Department Visits: July 9, 2024



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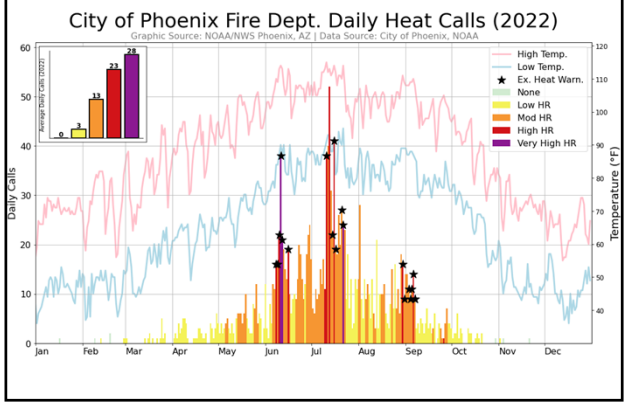

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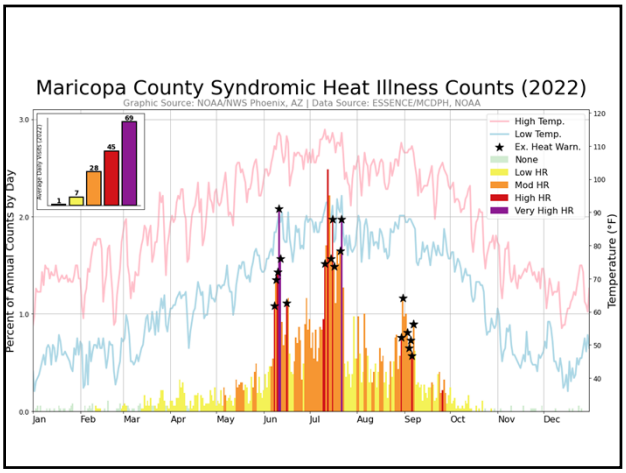
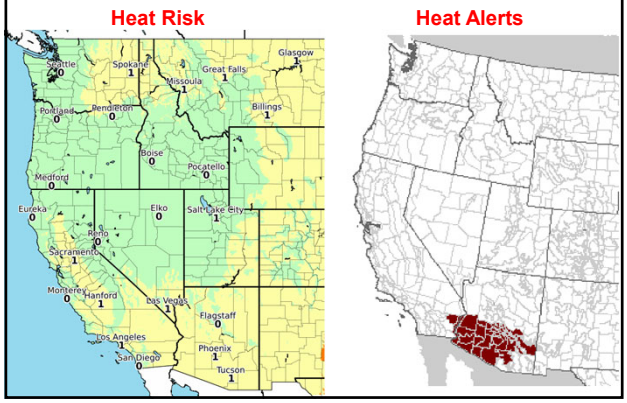


27

National Weather Service: June, 2017



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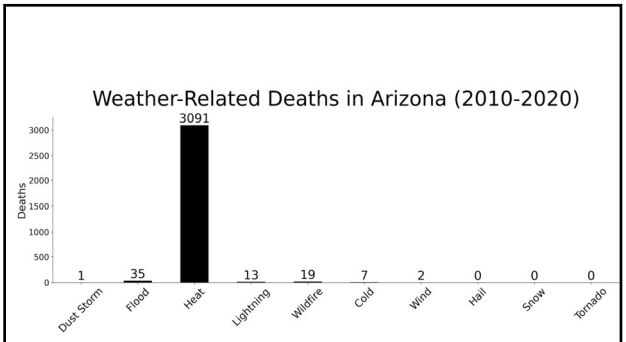
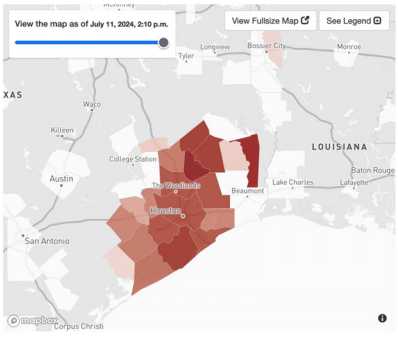


(NOAA, Arizona Department of Health Services)

29

July 11, 2024: >1,100,000 People in Houston Without Electricity

Texas power outage map



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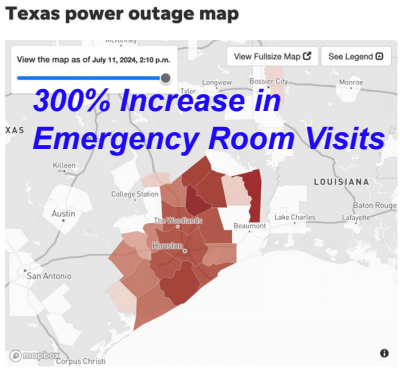


31

Be Prepared for Sustained Electrical Grid Power Failures

Hospitals in Houston 'Backed Up' After Hurricane, as Millions in U.S. Swelter

The health care system in Houston, where more than a million customers lack power, was overwhelmed because some patients couldn't be discharged amid a punishing heat wave.

Share full article 24

July 11, 2024

Officials suspect heat as the cause of more than 90 deaths in the West reported this month, though each death requires a full investigation and could take months to sort out. Raquel Natalicchio, via Getty Images

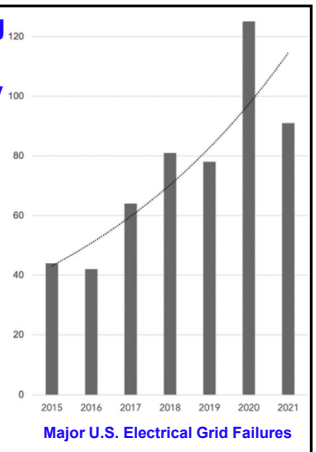
32

33

"How Blackouts during Heat Waves Amplify Mortality and Morbidity Risk"

[Stone et al., *Environ. Sci. Tech.*, 2023]

Simulated an Electrical Blackout During a 5-Day Heat Wave in Phoenix, Arizona



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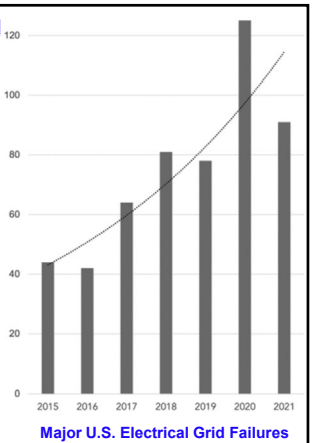
→ ***~1% of the City Died (~13,000)***



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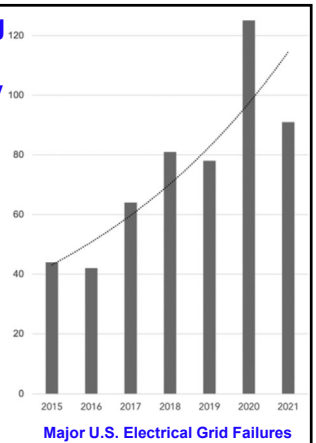
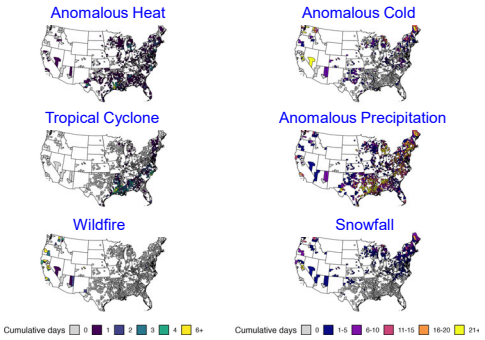
→ ***~50% Required Emergency Medical Care (~817,000)***



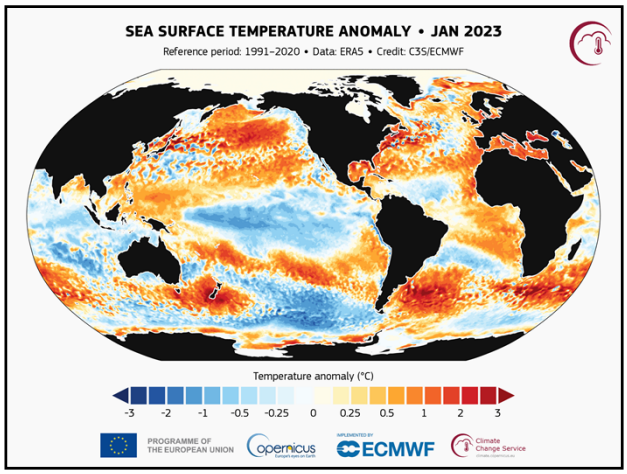
36

Many Regions are Susceptible to Extreme Weather Events that Can Impact Electricity Power Stability



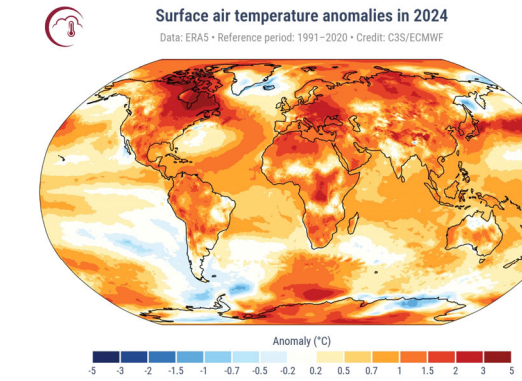
[Spatiotemporal patterns of individual and multiple simultaneous severe weather events co-occurring with power outages in the United States, 2018–2020; Do et al., PLOS Climate, 2025]

37



38

Global Temperature Anomalies in 2024, Relative to 1991-2020



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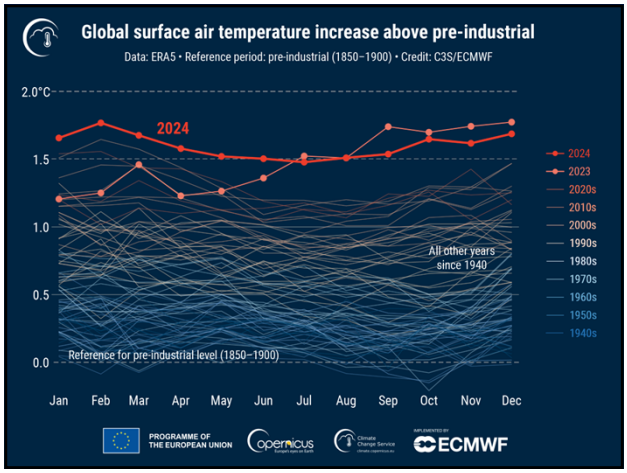

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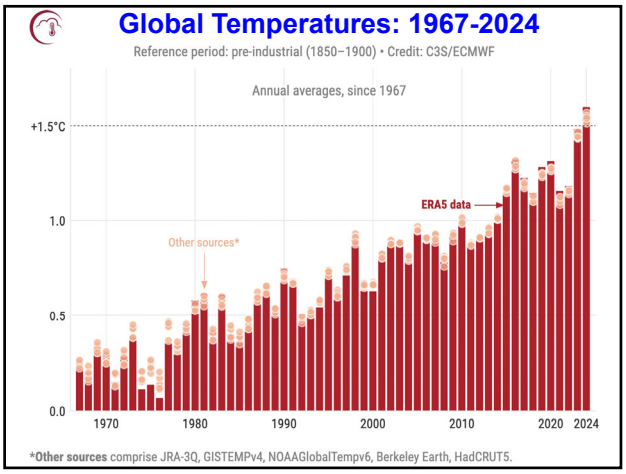
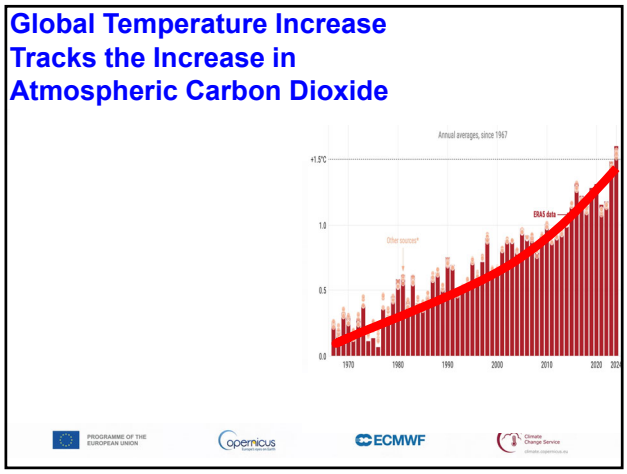
Global Temperatures: 1967-2024



41

Global Temperature Increase Tracks the Increase in Atmospheric Carbon Dioxide



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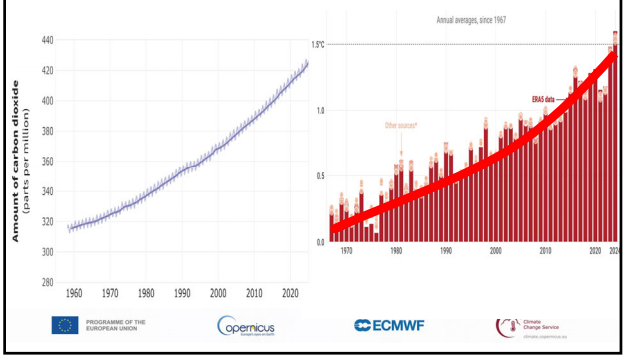
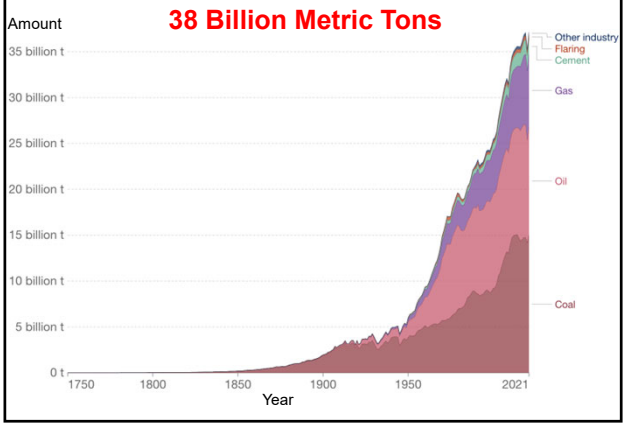


43

Carbon Dioxide Emissions by Type



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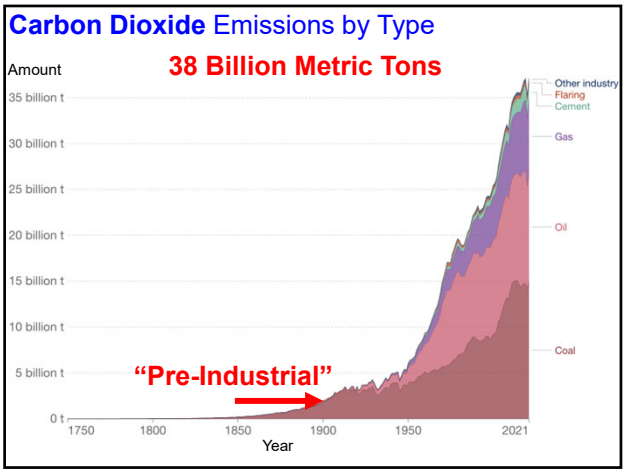

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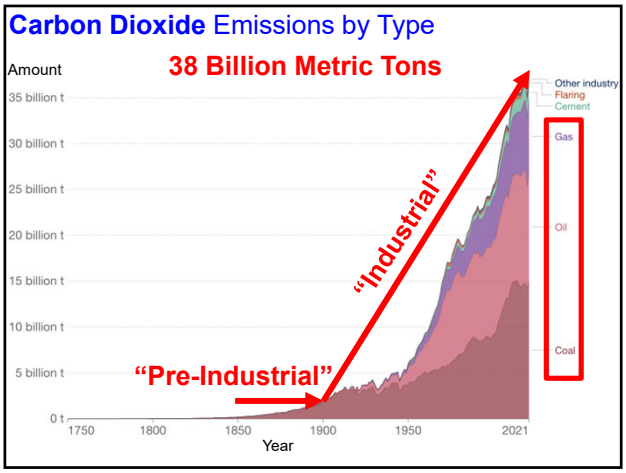


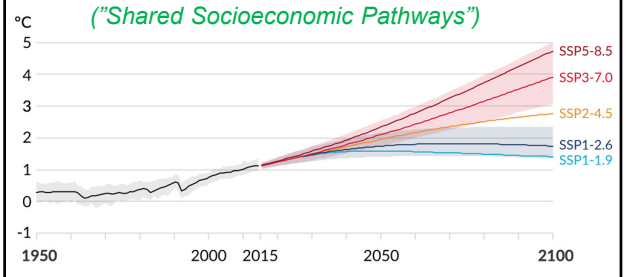
46

Future Global Temps Depend on Us:

→ ***Pathway SSP1-2.6: Rapid CO_2 Cutback***

→ ***Pathway SSP5-8.5: "Business as Usual"***

("Shared Socioeconomic Pathways")



IPCC AR6 (Assessment Report #6 of the Intergovernmental Panel on Climate Change)

47

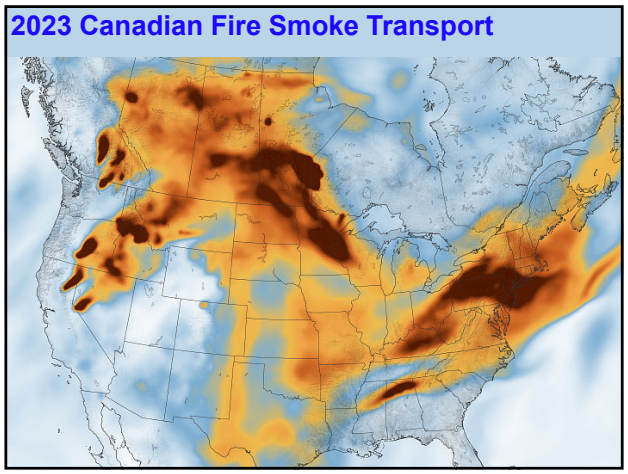
How *Climate Change* Impacts Health

- *Heat: Heat Stress, Heat Stroke*
- Temperature Changes: Fires, Spread of Parasites

48

49

2023 Canadian Fire Smoke Transport



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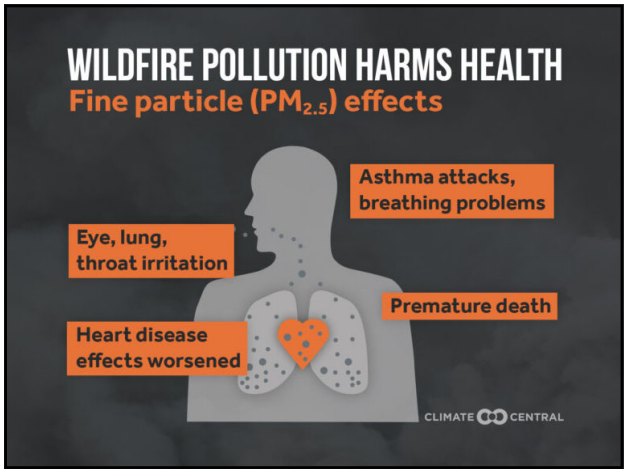

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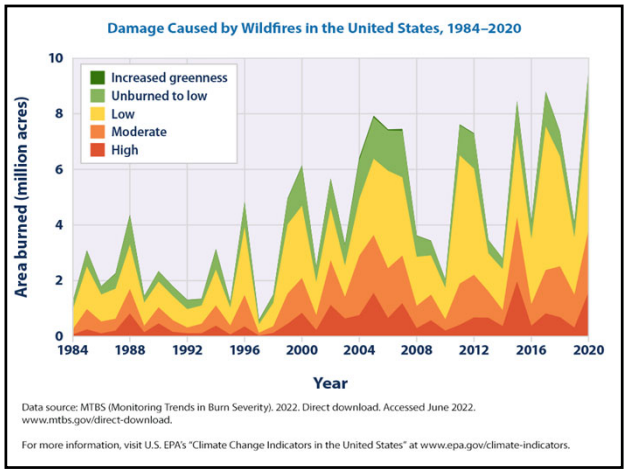
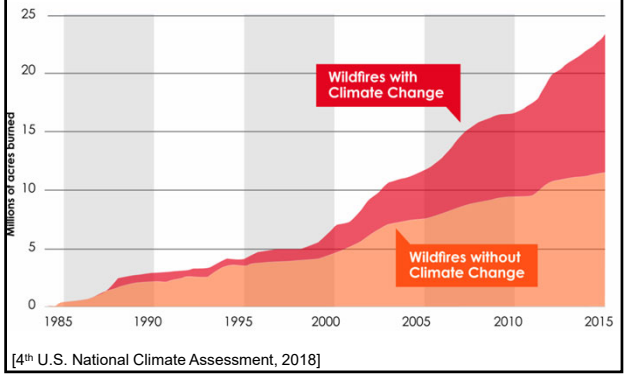


52

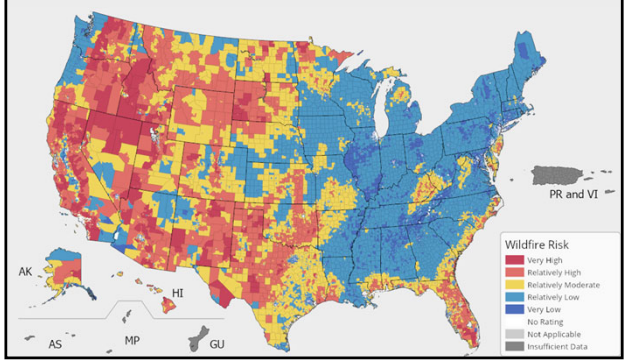
Increase in Western U.S. Land Burned Due to Climate Change



[4th U.S. National Climate Assessment, 2018]

53

Wildfire Risk (FEMA – Federal Emergency Management Administration)



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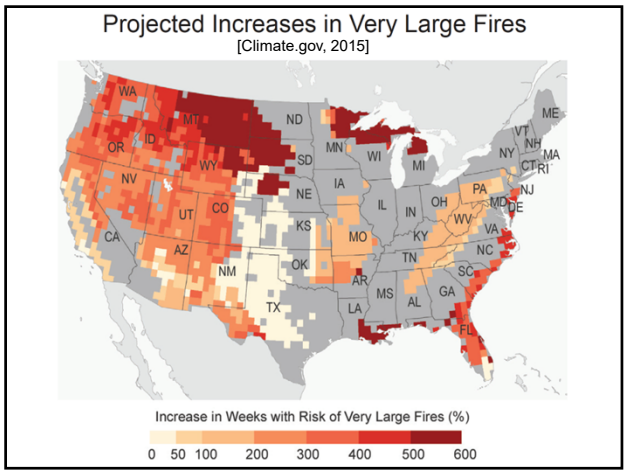

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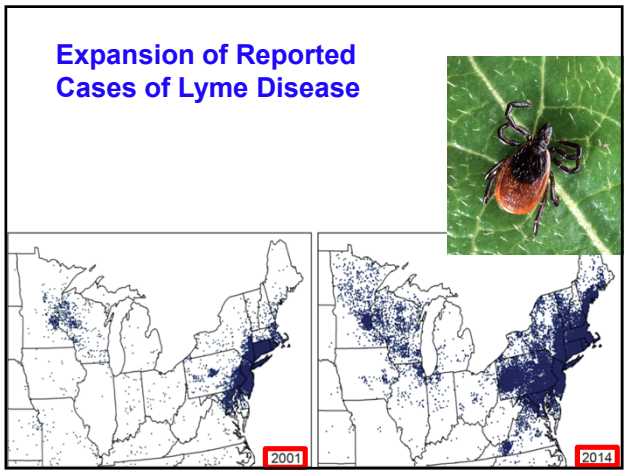

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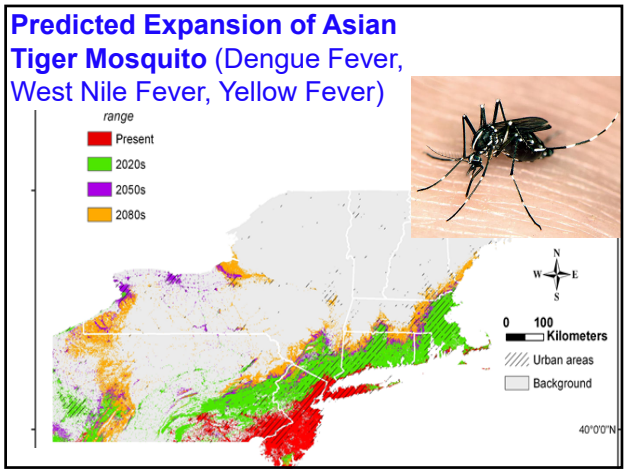

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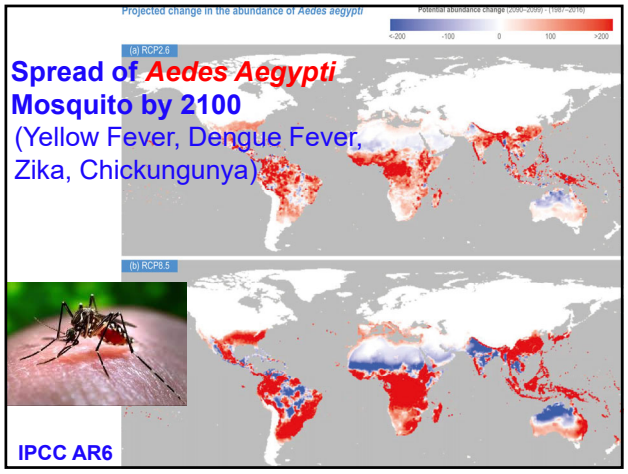

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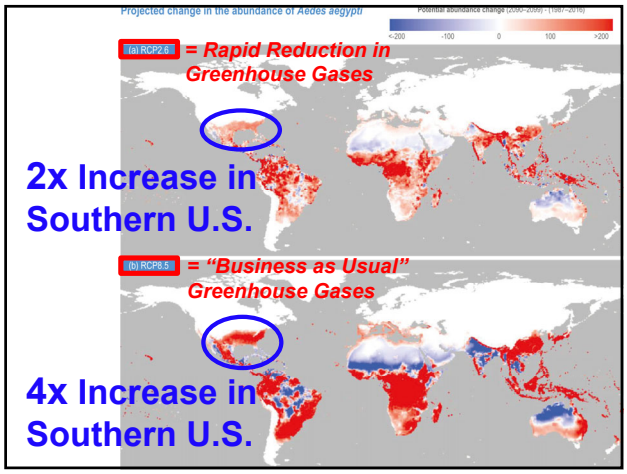

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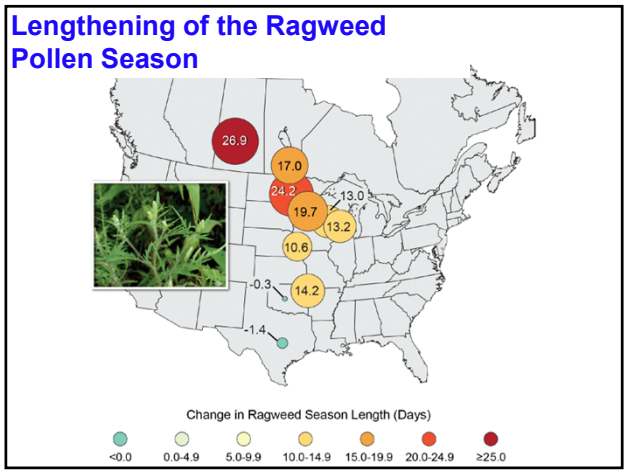
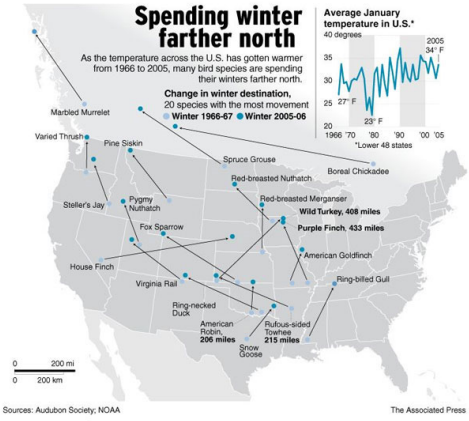


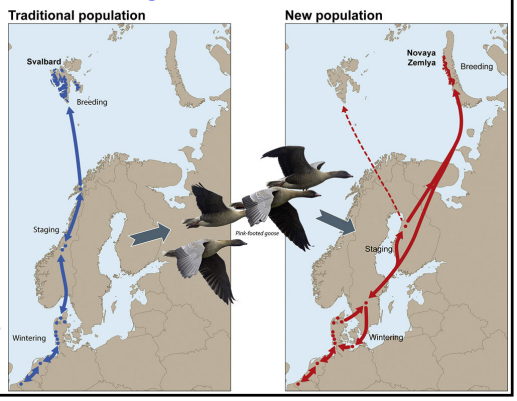
60

Northward Shift in Annual Bird Migration Patterns



61

Sudden Shift in Annual Bird Migration Patterns Due to Climate Change



[Madsen et al., *Current Biology*, 2023]

62

How *Climate Change* Impacts Health

- *Heat: Heat Stress, Heat Stroke*
- *Temperature Changes: Fires, Spread of Parasites*
- Water Distribution Changes: Droughts, Floods, Water-borne Diseases, Fungal Infections

63

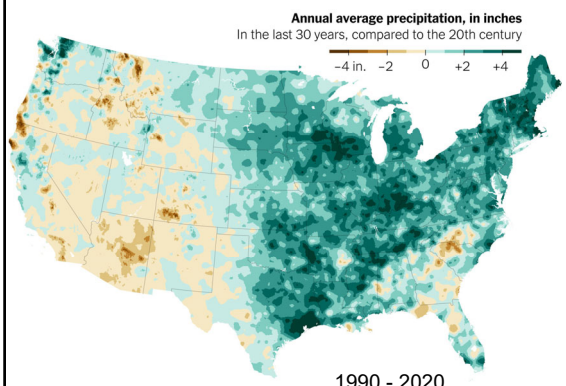
Weather-Related Morbidity/Mortality

- Increases in the incidence and intensity of extreme weather events such as hurricanes, floods, droughts, wildfires

Hurricane Beryl, Houston, TX, July 9, 2024

64

NOAA



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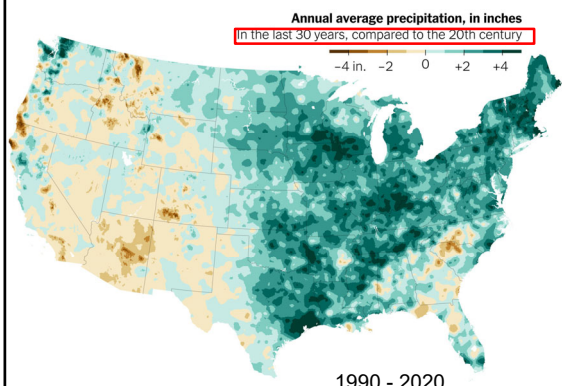
NOAA



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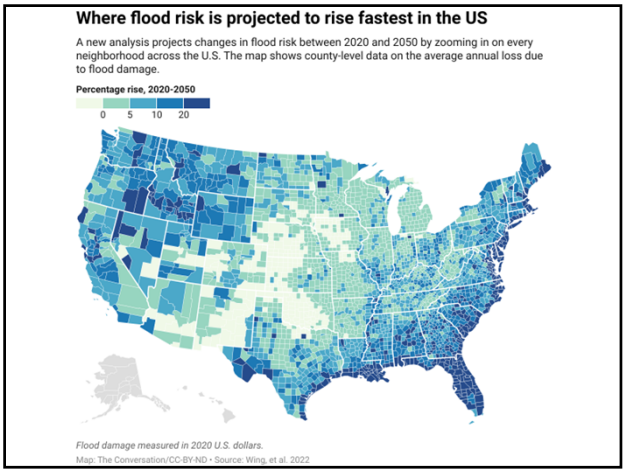
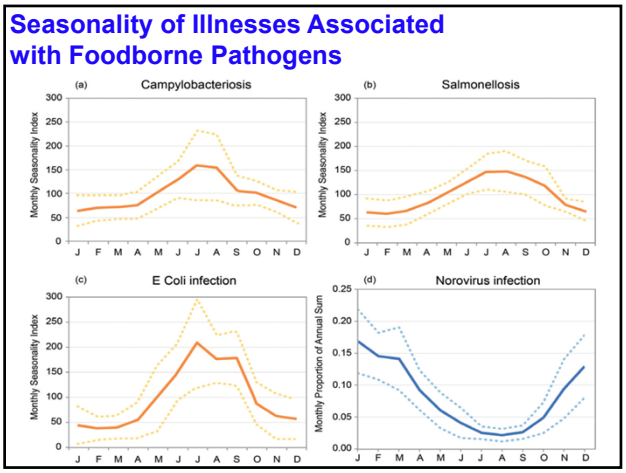


67

Flooding of Sewage Treatment Plant (Atlanta, GA), Sep 23, 2009

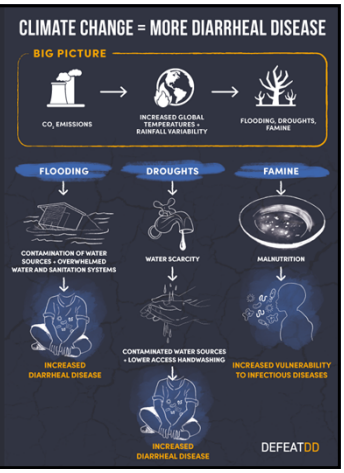
68

Seasonality of Illnesses Associated with Foodborne Pathogens



69

"Every 1ºC Increase in Global Temperatures Leads to a 7% Increase in Diarrhea"



[Mellor et al., 2016]

70

Waterborne Diseases

- Increased Red Tides of Algal Blooms

"Red Tide"

(La Jolla, CA)

71

Waterborne Diseases

- Increased Exposure to Freshwater Algal Blooms

Silverwood Lake (San Bernardino County, CA)

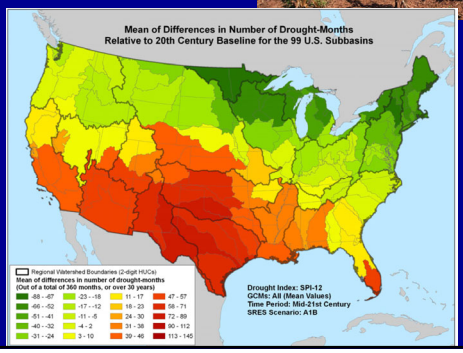
72

How *Climate Change* Impacts Health

- *Heat: Heat Stress, Heat Stroke*
- *Temperature Changes: Fires, Spread of Parasites*
- *Water Distribution Changes: Droughts, Floods, Water-borne Diseases, Fungal Infections*
- Agricultural Failures : Famines

73

Projected Drought Increase by Mid-21st Century



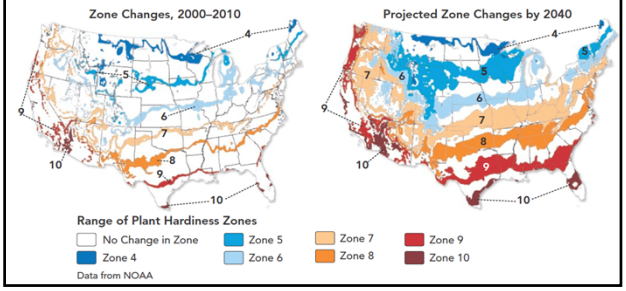
74

Northward Shift In Plant Zones

Northward Shift Plant hardiness zones define geographic areas where certain plants thrive under a particular set of climate conditions. These conditions are largely a function of average annual extreme low temperatures. Zone 4 has the coldest temperatures while Zone 10 has the warmest.

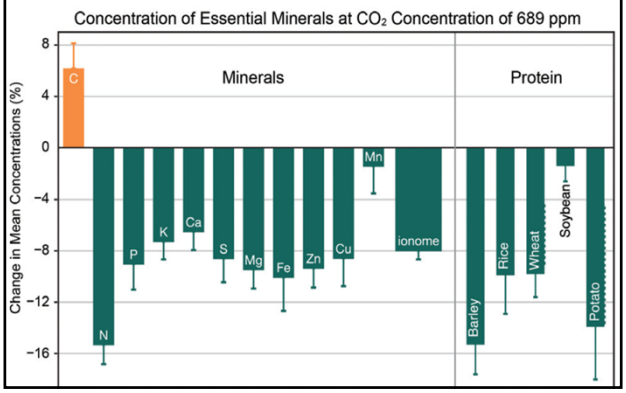
The widths of the colored bands show the locations of the plant zone boundaries over the 10-year period between 2000 and 2010.

The widths of the colored bands show how the plant zone boundaries are projected to expand and shift by 2040.



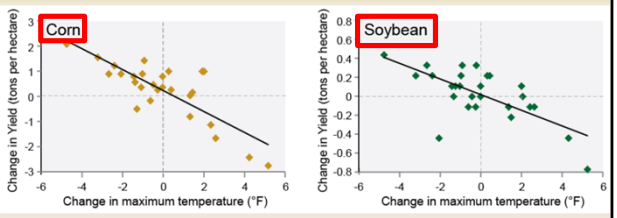
75

Crop Nutrition Decreases with Elevated CO_2



76

Crop Yields Decline Under Higher Temperatures



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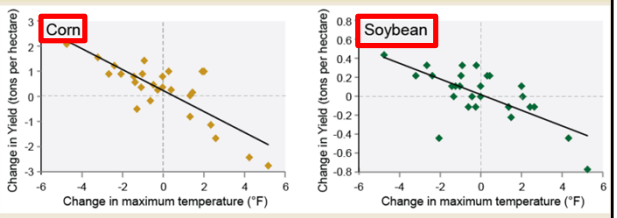
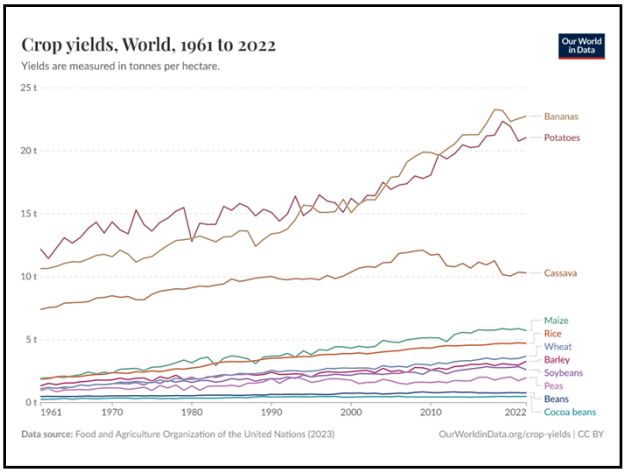
Crop Yields Decline Under Higher Temperatures



Expect to see increasing rates of malnutrition

78

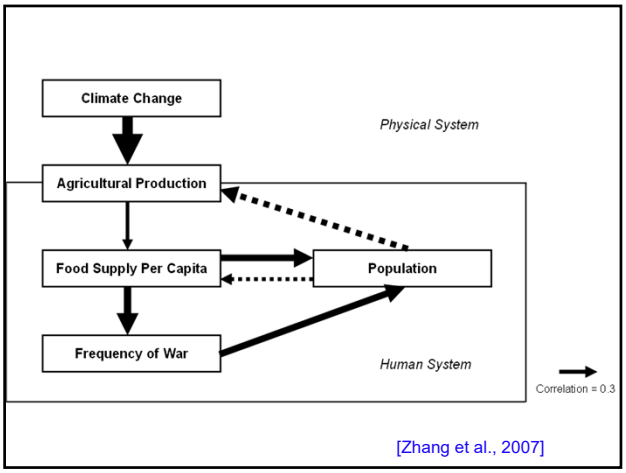


79

How *Climate Change* Impacts Health

- *Heat: Heat Stress, Heat Stroke*
- *Temperature Changes: Fires, Spread of Parasites*
- *Water Distribution Changes: Droughts, Floods, Water-borne Diseases, Fungal Infections*
- *Agricultural Failures: Famines*
- Human Migrations: Spread of Diseases, Conflict, and Warfare

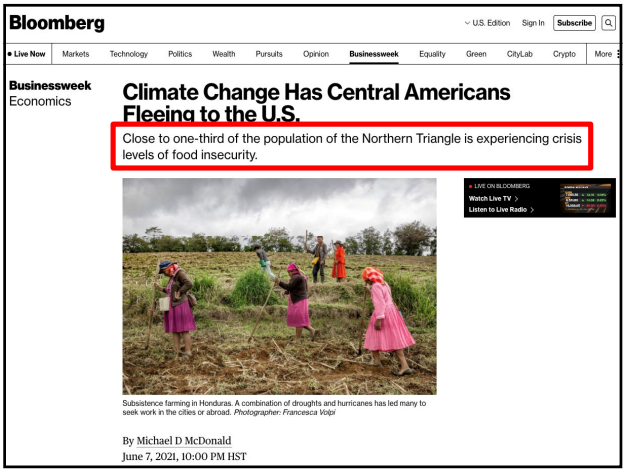
80



[Zhang et al., 2007]

81

82



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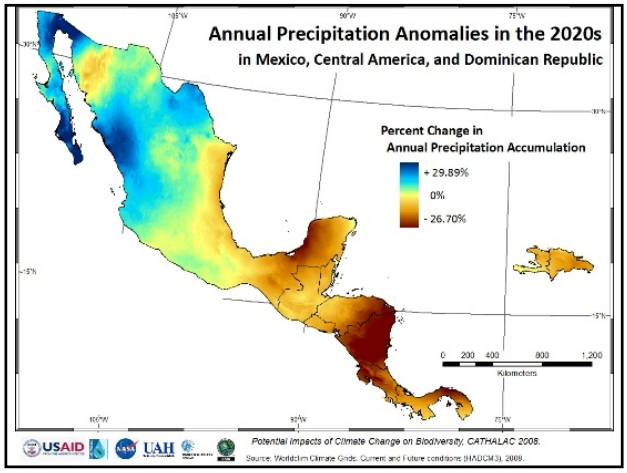

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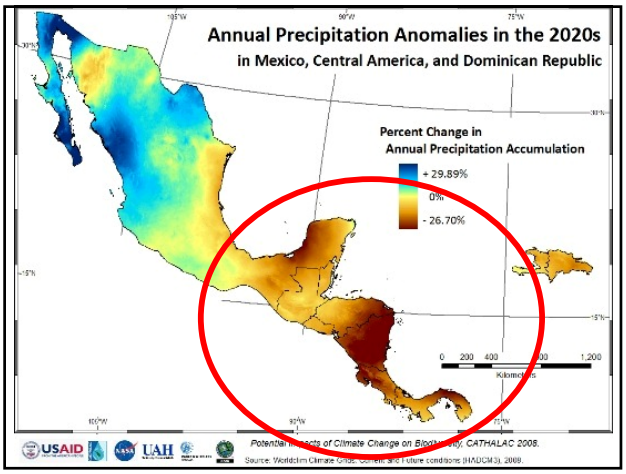

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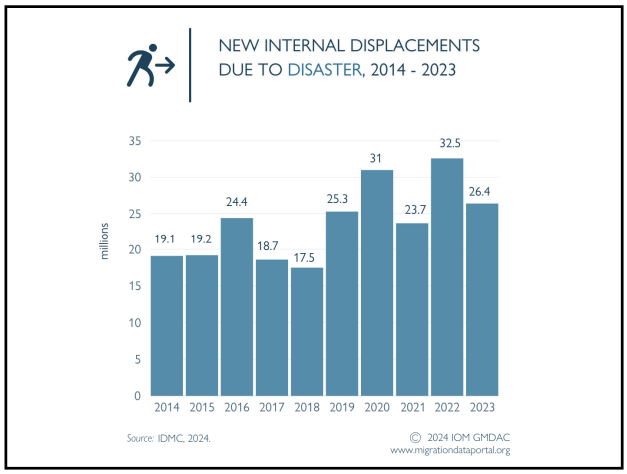

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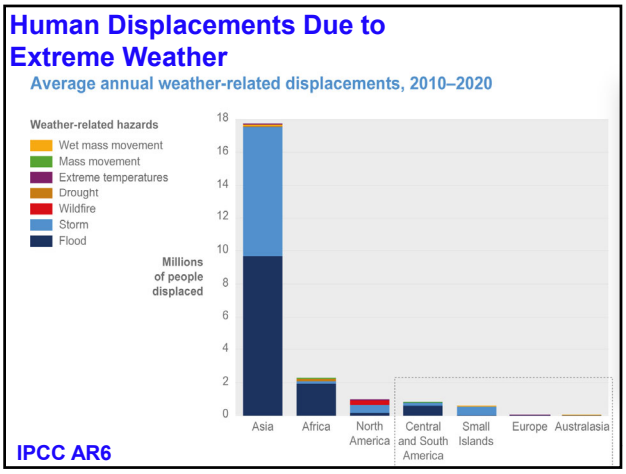

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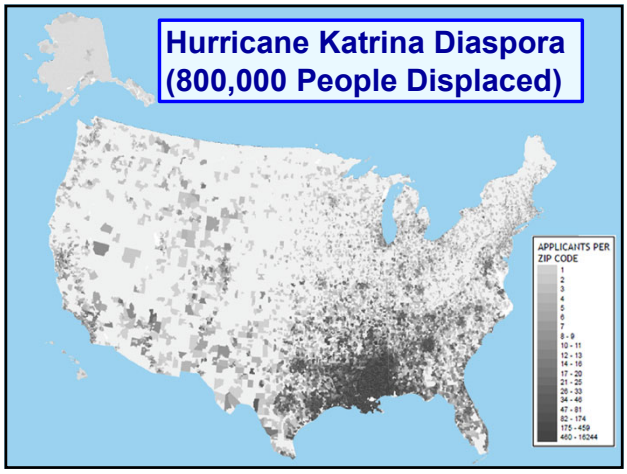

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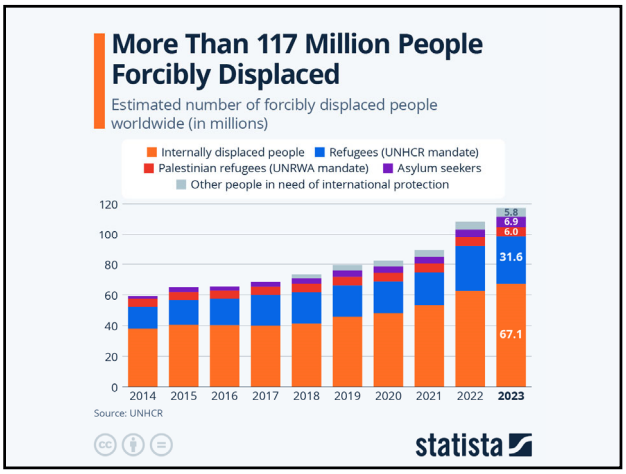

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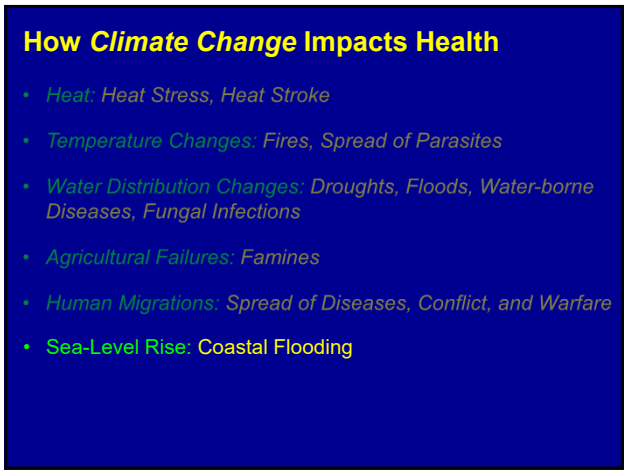

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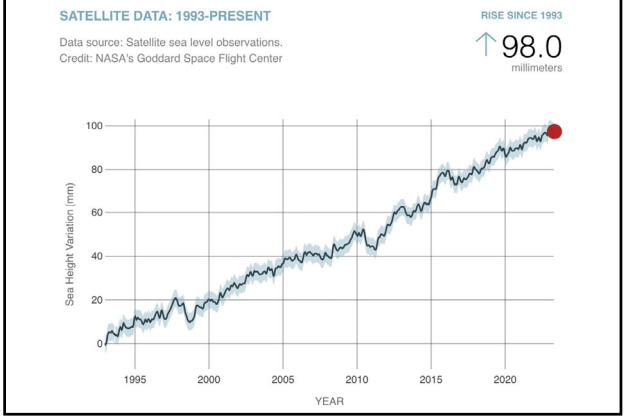
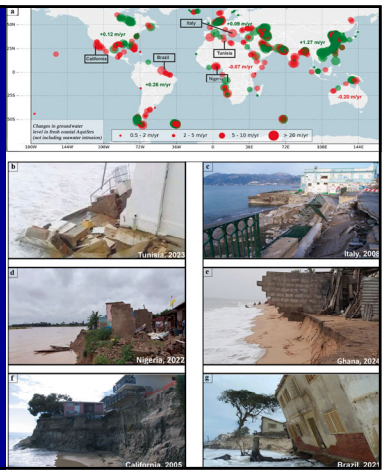
Sea Level Rise



91

Coastal Communities are Collapsing due to Sea-level Rise, Coastal Flooding, and Salt-Water Inclusion

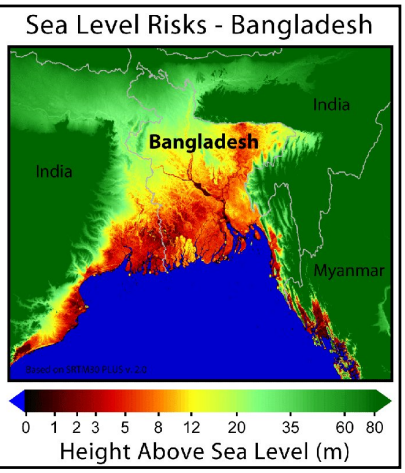
[Fouad et al., *Geophys. Res. Lett.*, 2025]



92

"Salinity in Drinking Water and the Risk of (Pre)Eclampsia and Gestational Hypertension in Coastal Bangladesh"

[Khan et al., PLoS One 2014]



93

Risks of Flooding: Affecting ~100 Million People by 2030

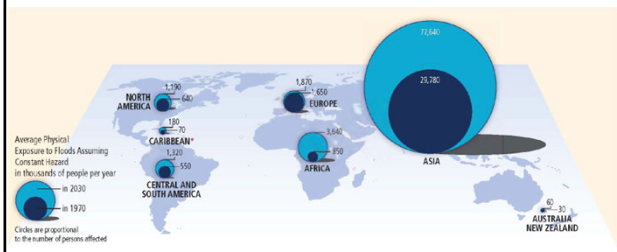


FIGURE 2.9 The projected increase in the number of people (in thousands) exposed to floods in 2030 compared to those in 1970. Only catchments bigger than 1,000k m^2 were included in analysis; therefore, only the largest islands in the Caribbean are covered. Source: IPCC, 2012; Solterra Solutions, 2012.

94

Sunny-Day Flooding: Increasingly Common in Coastal Communities

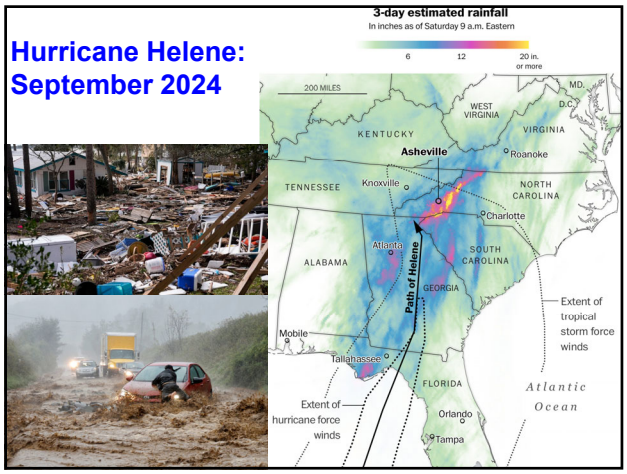
→ Worsens Impacts of Hurricane Flooding

95

Household Mold After Flooding

96

Hurricane Helene: September 2024

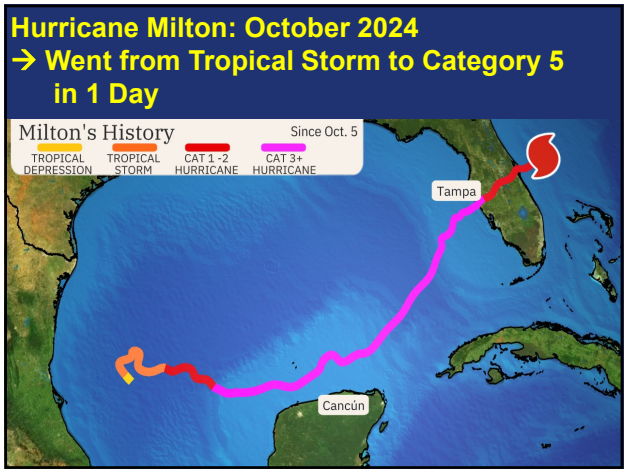


97

Hurricane Milton: October 2024 → Went from Tropical Storm to Category 5 in 1 Day

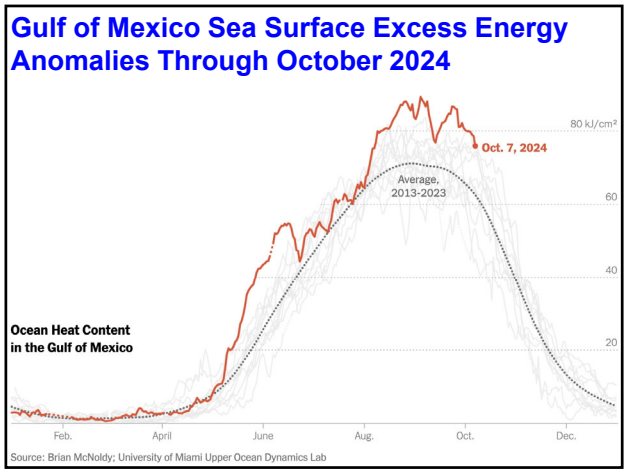
98

Hurricane Milton: October 2024 → Went from Tropical Storm to Category 5 in 1 Day



99

Gulf of Mexico Sea Surface Excess Energy Anomalies Through October 2024



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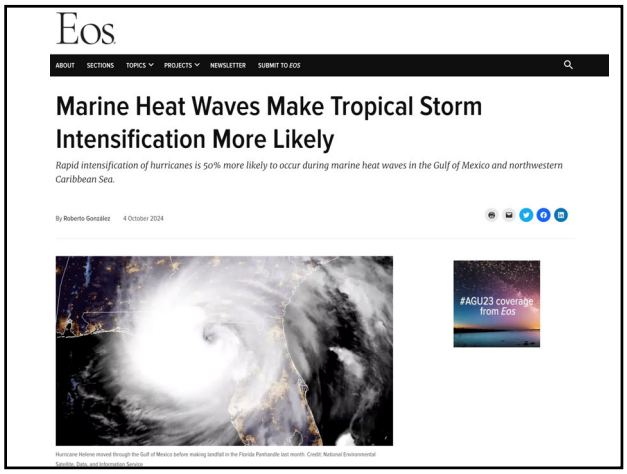
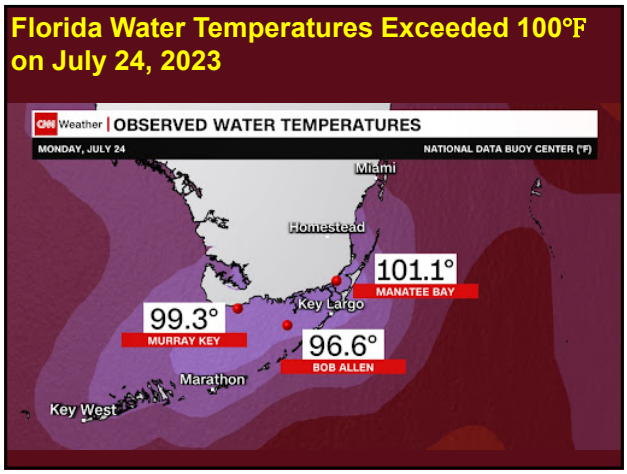


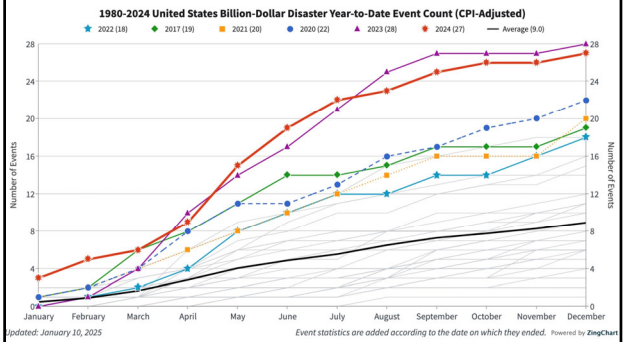
101

Florida Water Temperatures Exceeded 100°F on July 24, 2023



102

2023-2024: 28/27 U.S. Climate/Weather Billion-Dollar Disasters (Largest Ever)

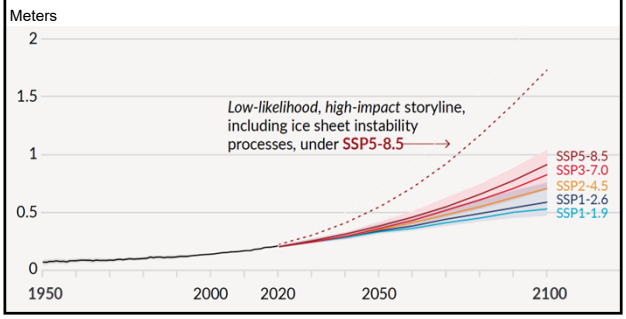


[https://www.ncei.noaa.gov/access/billions/]

103

SIXTH ASSESSMENT REPORT
Working Group I – The Physical Science Basis
ipcc climate change

IPCC Forecasts: *SEA LEVEL RISE* accelerates, increasing impacts of coastal storms



104

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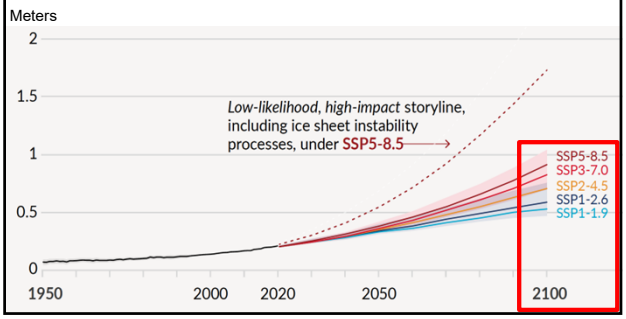

105

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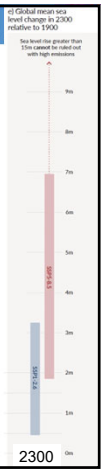
IPCC Forecasts: *SEA LEVEL RISE* accelerates, increasing impacts of coastal storms

Global mean sea level change by 2300 relative to 1900

Sea level rise greater than **15 meters** cannot be ruled out with high emissions



106

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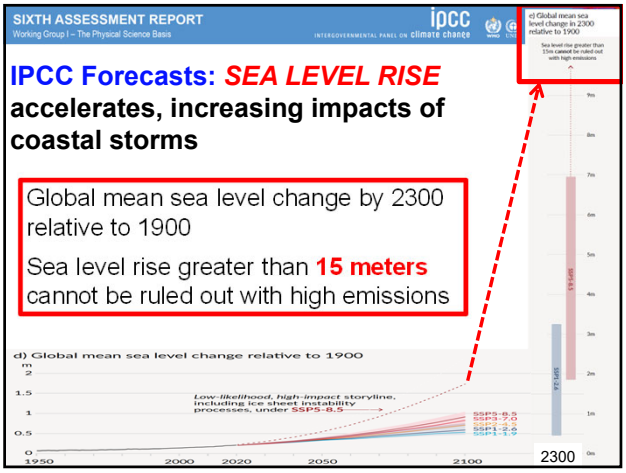
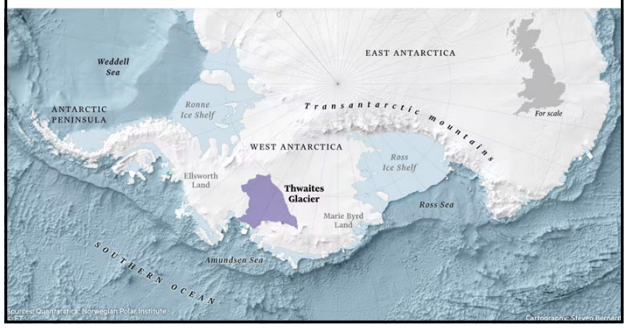


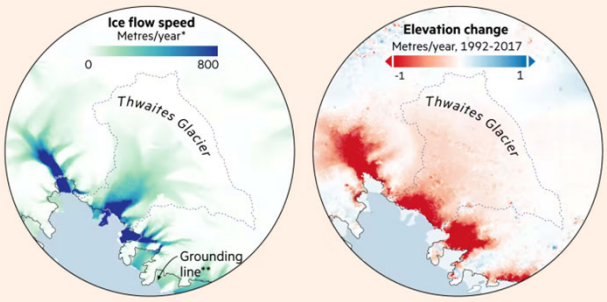
107

Thwaites Glacier: Increasingly At-Risk of Collapse



108

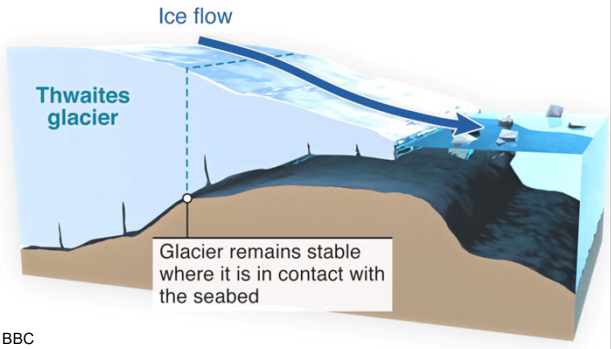
Now Flowing up to 1 Kilometer per Year and Thinning by Meters per Year



[Financial Times]

109

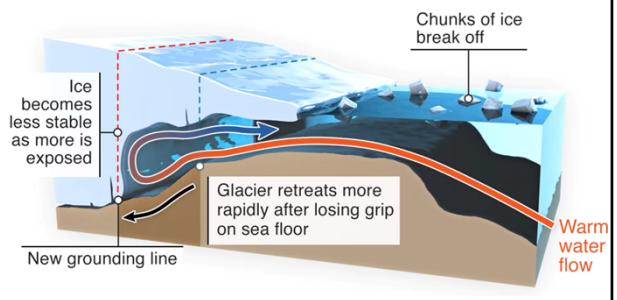
Thwaites Glacier is Normally Stably Grounded on the Sea Floor



BBC

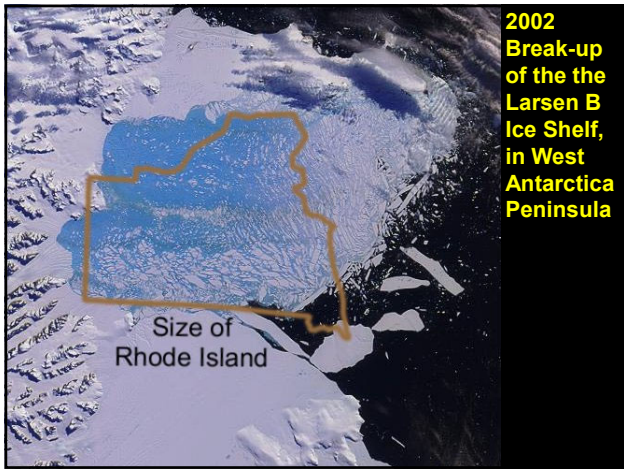
110

Thinning and Sub-Glacial Melting by Warm Currents is Putting it at Risk of Losing its Grounding



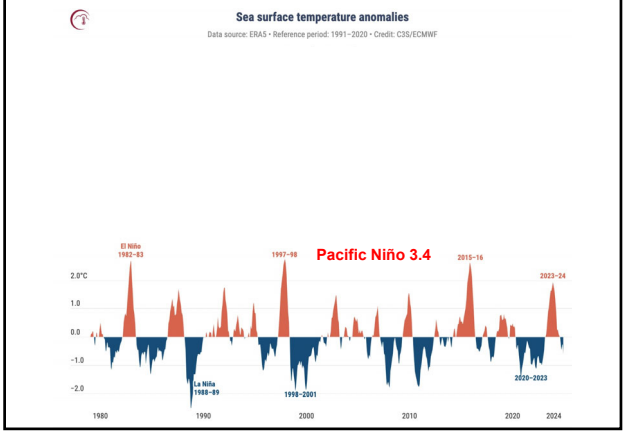
BBC

111



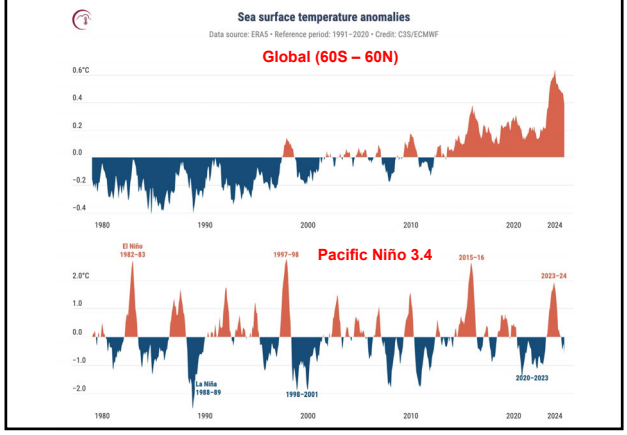
112

Sea Surface Temperature Anomalies (Through 2024)

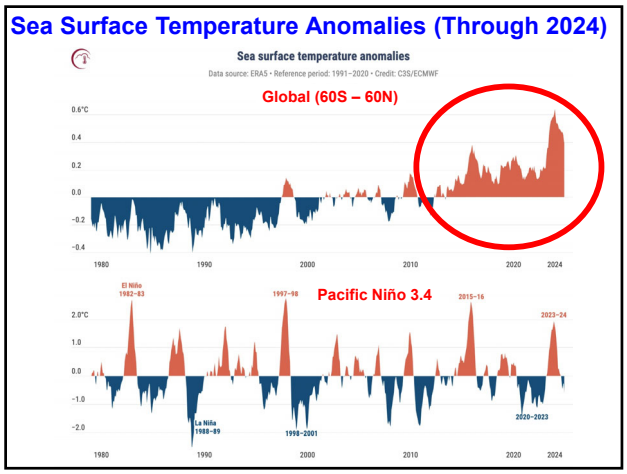


113

Sea Surface Temperature Anomalies (Through 2024)



114



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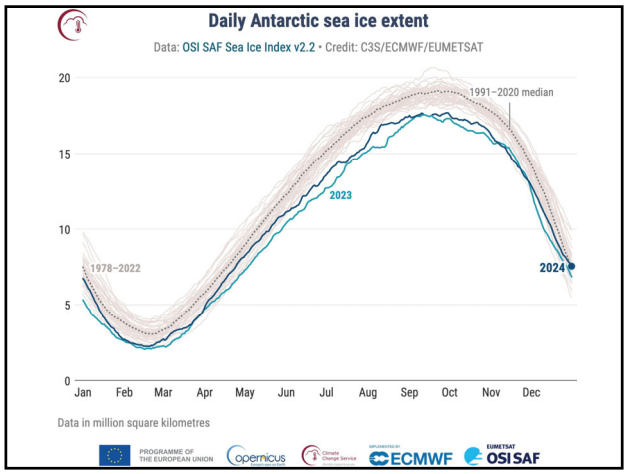

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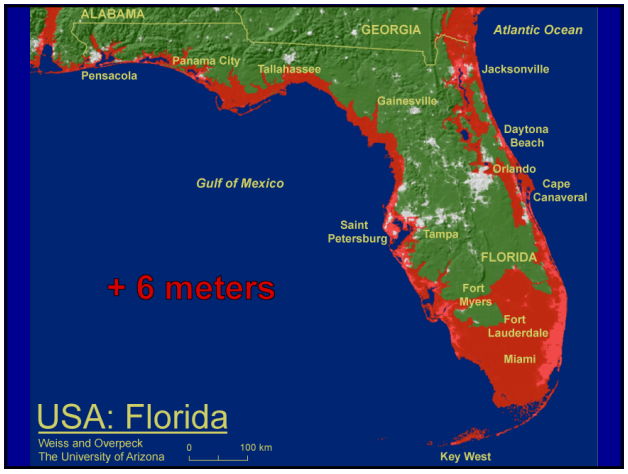

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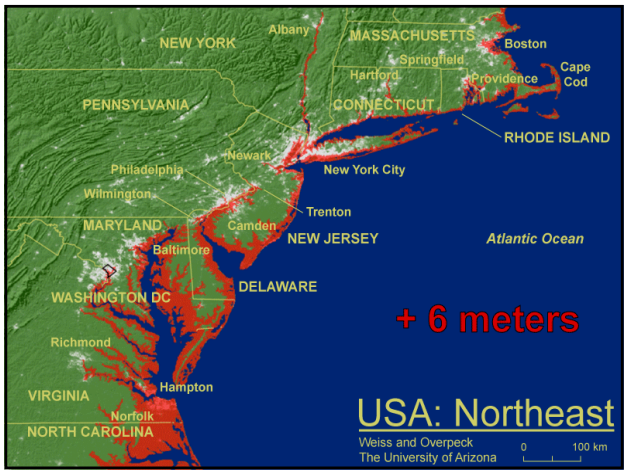

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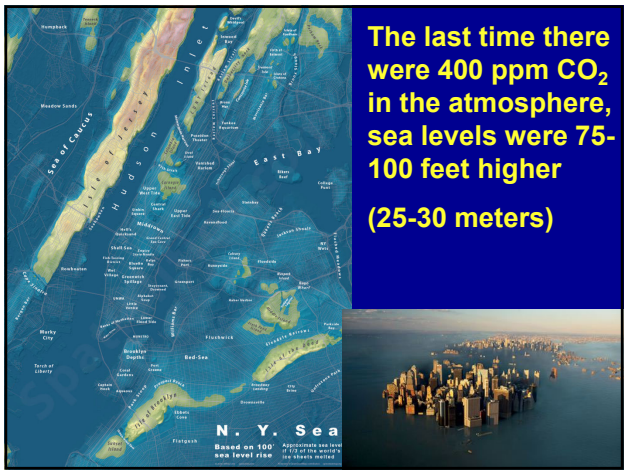

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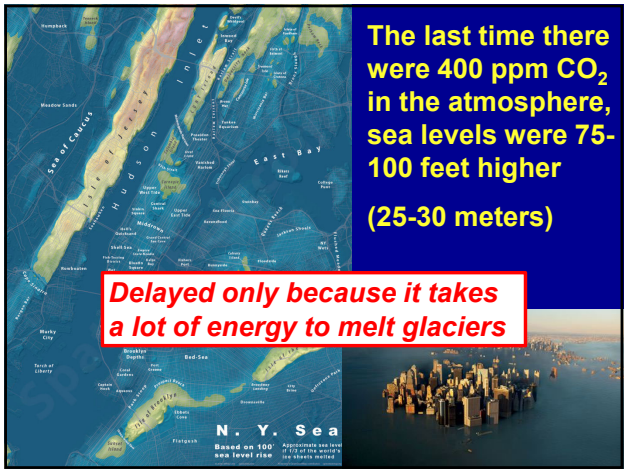

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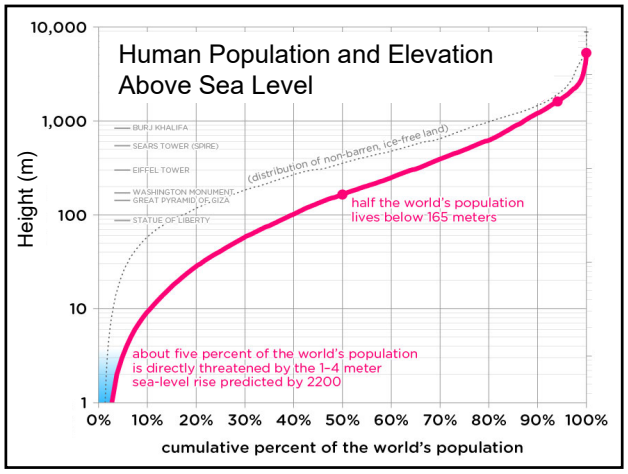

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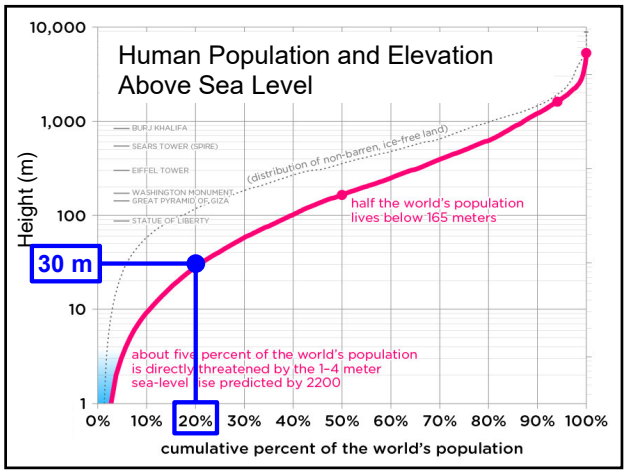

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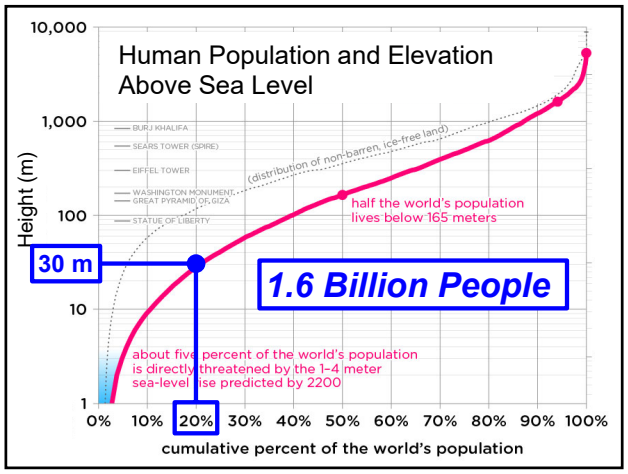
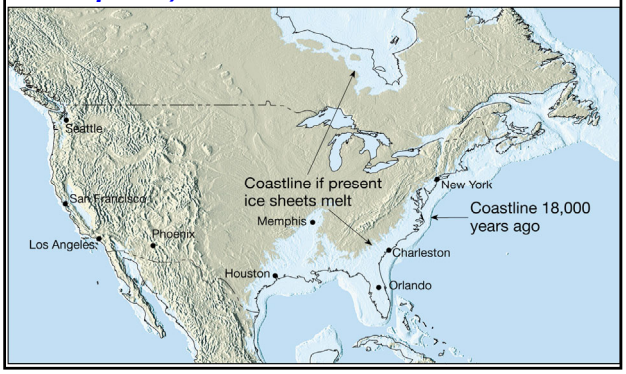


126

North America with a 230-foot Sea-Level Rise *(the last time there were >750 ppm CO_2 in the Atmosphere)*



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North America with a 230-foot Sea-Level Rise *(the last time there were >750 ppm CO_2 in the Atmosphere)*

128

North America with a 230-foot Sea-Level Rise *(the last time there were >750 ppm CO_2 in the Atmosphere)*

129

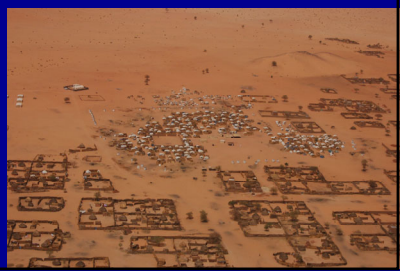
How *Climate Change* Impacts Health

- *Heat:* Heat Stress, Heat Stroke
- *Temperature Changes:* Air Quality, Spread of Parasites
- *Water Distribution Changes:* Droughts, Floods, Water-borne Diseases, Fungal Infections
- *Agriculture Fails:* Famines
- *Human Migrations:* Spread of Diseases, Conflict, and Warfare
- *Sea-Level Rise:* Coastal Flooding
- Mental Health Disease: Stress, Depression, Loss

130

Mental Health and Stress-Related Disorders

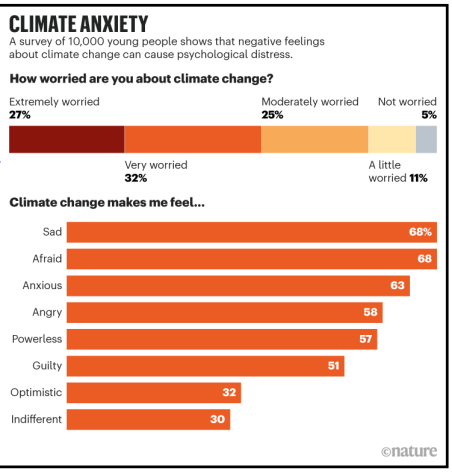
- Geographic displacement of populations
- Damage to property
- Loss of loved ones
- Chronic stress



131

84% of Young People are Moderately to Extremely Worried About Climate Change

[Hickman et al., *SSRN*, 2021]

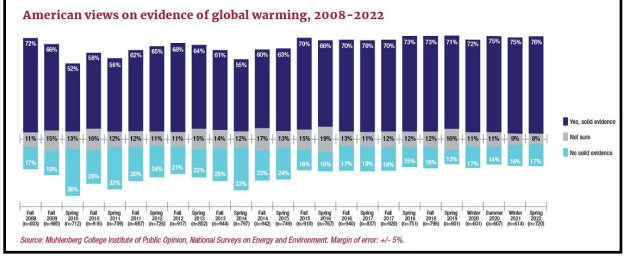


132

Most American Say There is "Solid Evidence" of Global Warming

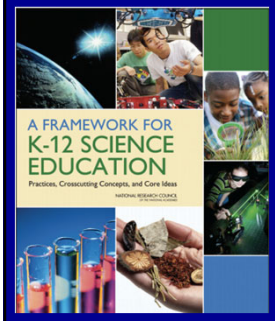
→ *But Almost no change Since 2008*

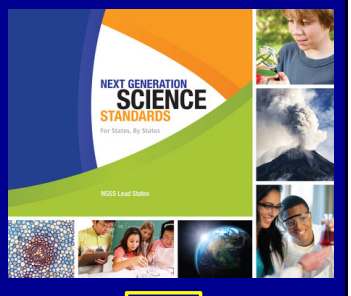
→ *Only 7% of Americans had an Earth Science Course in High School*



133

New Science Standards for Most States Require Substantial High School Climate Science





134

NGSS Science Standards

Middle School: Grade-Banded Standards, 6-8
- 1 year of Life Science
- 1 year of Physical Science (Chemistry & Physics)
- 1 year of Earth and Space Science

High School: Grade-Banded Standards, 9-12
- 1 year of Life Science
- 1 year of Physical Science (Chemistry & Physics)
- 1 year of Earth and Space Science

135

NGSS Science Standards

Middle School: Grade-Banded Standards, 6-8
- 1 year of Life Science
- 1 year of Physical Science (Chemistry & Physics)
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High School: Grade-Banded Standards, 9-12
- 1 year of Life Science
- 1 year of Physical Science (Chemistry & Physics)
- 1 year of Earth and Space Science

136

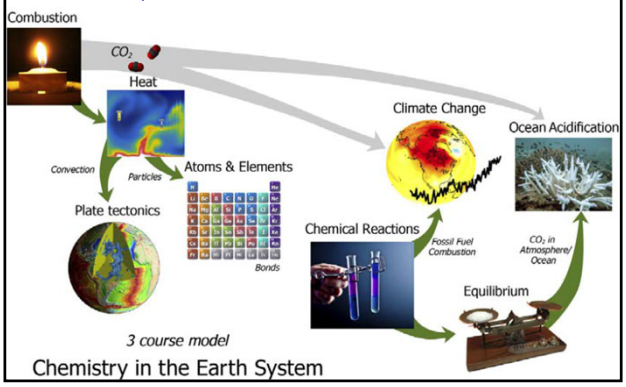
NRC Framework: The *Core Ideas* of Science

Physical Science	Life Science	Earth and Space Science
PS1 Matter and Its Interactions	LS1 From Molecules to Organisms: Structures and Processes	ESS1 Earth's Place in the Universe
PS1A Structure and Properties of matter	**LS1A Structure and Function**	**ESS1A The Universe and Its Stars**
PS1B Chemical Reactions	**LS1B Growth and Development of Organisms**	**ESS1B Earth and the Solar System**
PS1C Nuclear Processes	**LS1C Organization for Matter and Energy Flow in Organisms**	**ESS1C The History of Planet Earth**
PS2 Motion and Stability: Forces and Interactions	**LS1D Information Processing**	ESS2 Earth's Systems
PS2A Forces and Motion	LS2 Ecosystems: Interactions, Energy, and Dynamics	**ESS2A Earth Materials and Systems**
PS2B Types of Interactions	**LS2A Interdependent Relationships in Ecosystems**	**ESS2B Plate Tectonics and Large-Scale System Interactions**
PS2C Stability and Instability in Physical Systems	**LS2B Cycles of Matter and Energy Transfer in Ecosystems**	**ESS2C The Roles of Water in Earth's Surface Processes**
PS3 Energy	**LS2C Ecosystem Dynamics, Functioning, and Resilience**	**ESS2D Weather and Climate**
PS3A Definitions of Energy	**LS2D Social Interactions and Group Behavior**	**ESS2E Biogeology**
PS3B Conservation of Energy and Energy Transfer	LS3 Heredity: Inheritance and Variation of Traits	ESS3 Earth and Human Activity
PS3C Relationship Between Energy and Forces	**LS3A Inheritance of Traits**	**ESS3A Natural Resources**
PS3D Energy and Chemical Processes in Everyday Life	**LS3B Variation of Traits**	**ESS3B Natural Hazards**
PS4 Waves and Their Applications in Technologies for Information Transfer	LS4 Biological Evolution: Unity and Diversity	**ESS3C Human Impacts on Earth Systems**
PS4A Wave Properties	**LS4A Evidence of Common Ancestry**	**ESS3D Global Climate Change**
PS4B Electromagnetic Radiation	**LS4B Natural Selection**	
PS4C Information Technologies and Instrumentation	**LS4C Adaptation**	
	LS4D Biodiversity and Humans	

137

California H.S. Integrated 3-Course Model

Chemistry in the Earth System: Integrating Chemistry and Earth and Space Science

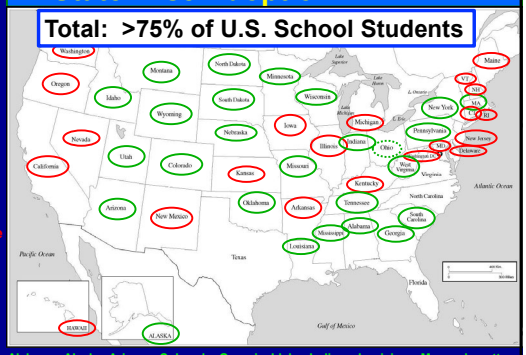


138

NGSS Adopting States:
Arkansas
California
Connecticut
Delaware
Dist. of Col.
Hawaii
Illinois
Iowa
Kansas
Kentucky
Maine
Maryland
Michigan
Nevada
N. Hampshire
New Jersey
New Mexico
Oregon
Rhode Isl.
Vermont
Washington

Next Generation Science: State-wise Adoption

Total: >75% of U.S. School Students



NGSS Adopting: Alabama, Alaska, Arizona, Colorado, Georgia, Idaho, Indiana, Louisiana, Massachusetts, Minnesota, Mississippi, Missouri, Montana, Nebraska, New York, North Dakota, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Utah, West Virginia, Wisconsin, Wyoming

139

"Civilization is a Race Between Education and Catastrophe"

--H.G. Wells

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140

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141