Global Warming and Extreme events

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Climate Science is Easy

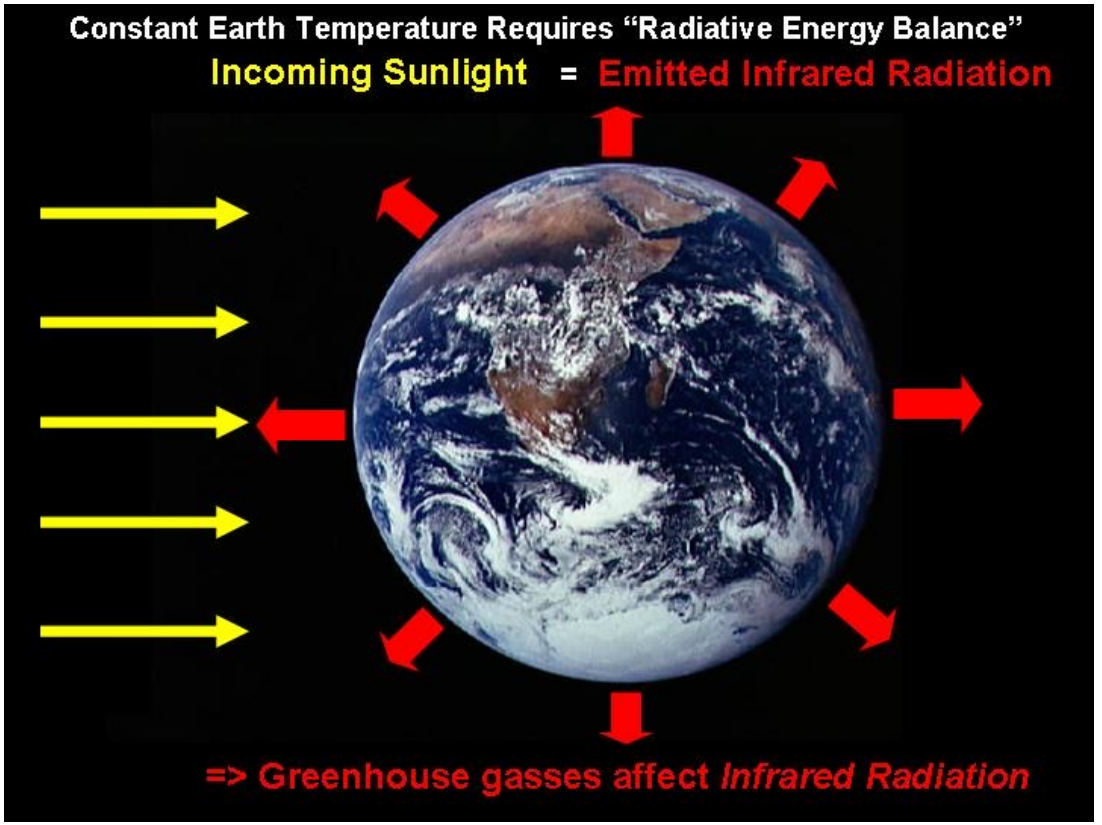
Equilibrium climate: the incoming and outgoing energy are nearly equal

= 122,400 trillion watts (240 watts/m ^{2} x 510 trillion square meters)

This equilibrium was at 14°C for nearly 10,000 years; currently this equilibrium is at 15°C

Climate is the Mother of Weather

Instabilities of the mean climate produce day to day weather

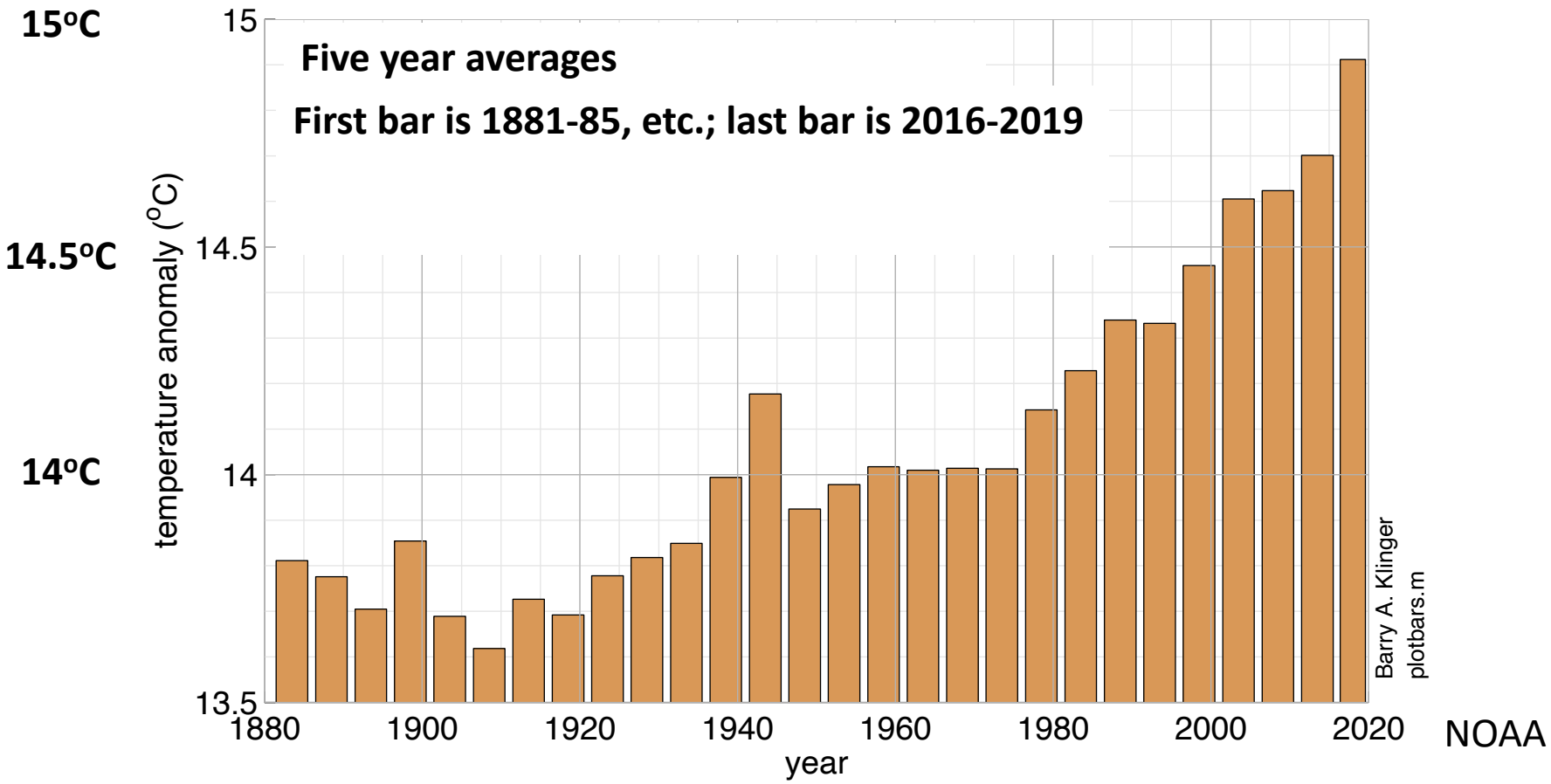


Total incoming energy (SUN) = total outgoing energy (Earth)
= 122,400 trillion watts (240 watts/m^2)

Global Warming

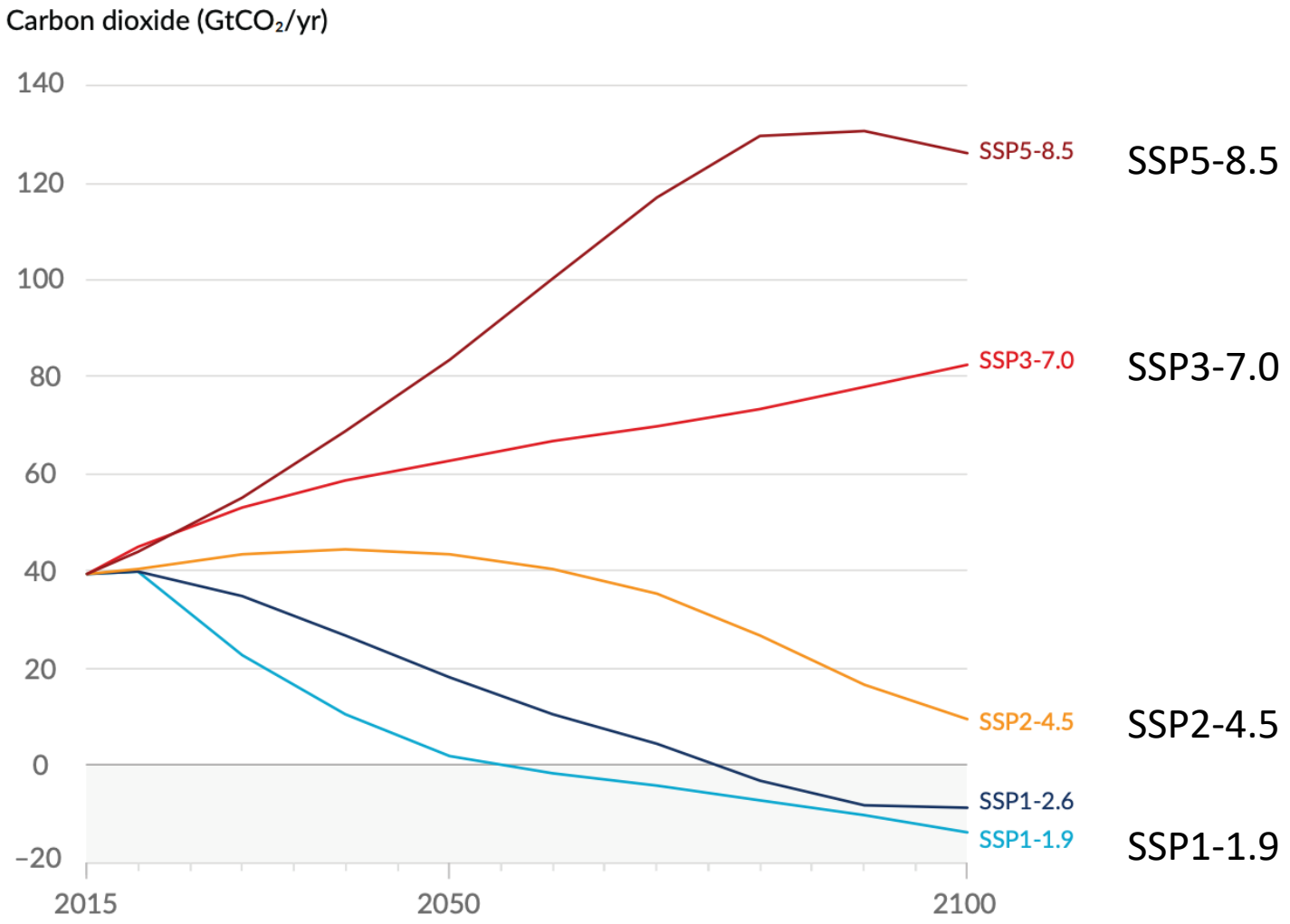
Increase in the average temperature of the Earth's near surface air and oceans

Rate of increase of T and CO2 is unprecedented



100 year (1901-2000) average global mean temp. = 14 °C (57.18 °F)

Future Annual Emissions Scenarios of CO2



IPCC AR6 2022 Figure SPM.4

AR6

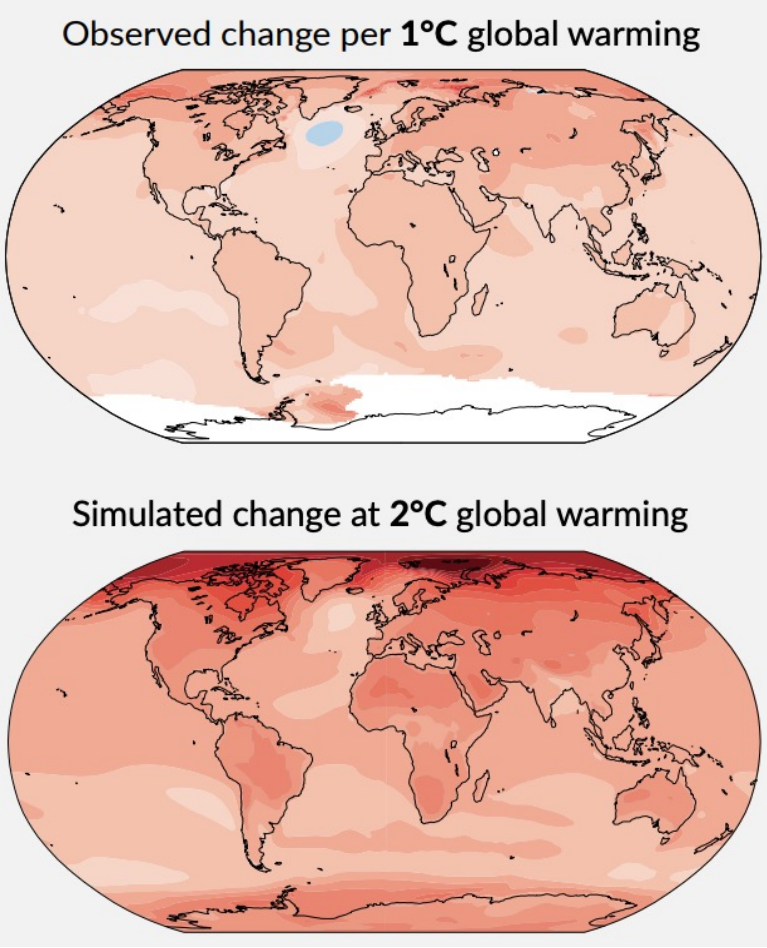
Future Annual Emissions Scenarios of CO2 and projected long-term (2081-2100) Temp.

- **SSP1-1.9: Emissions decline to net-zero by 2050 (1.0 to 1.8°C)**
- **SSP2-4.5: Emissions remain current level until 2050 (2.1 to 3.5°C)**
- **SSP3-7.0: Emissions double from current level by 2100 (2.8 to 4.6°C)**
- **SSP5-8.5: Emissions double from current level by 2050 (3.3 to 5.7°C)**

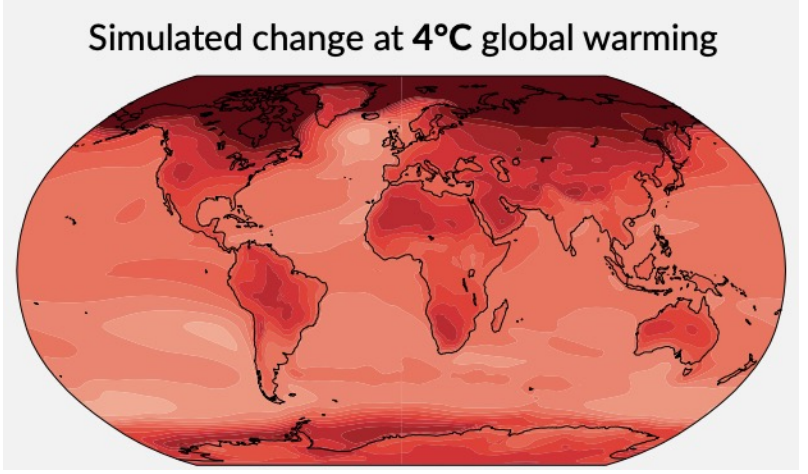
SSP3 - 7.0 means scenario 3 and radiative forcing 7 watts/m^2

Annual mean temperature change relative to 1850-1900

1°C



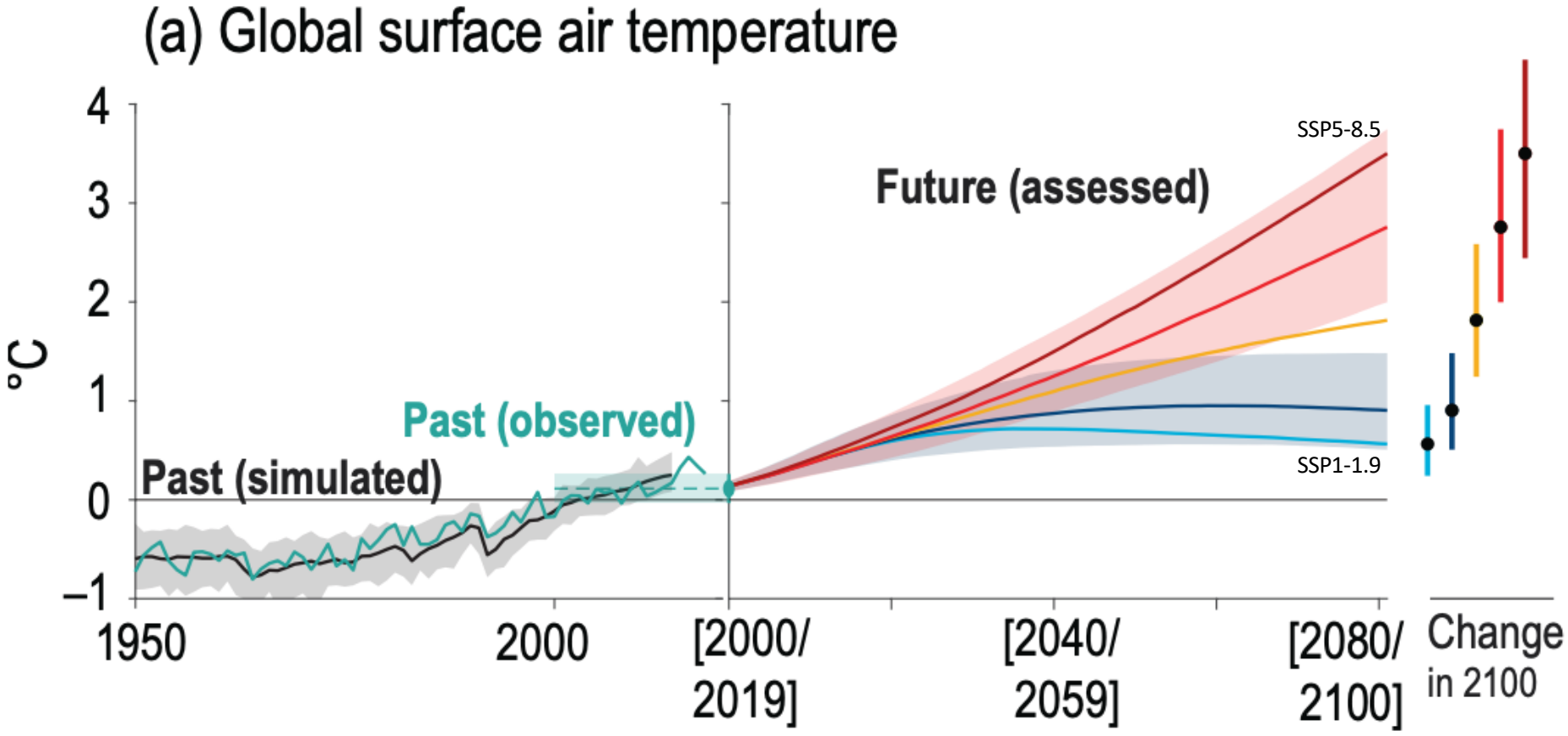
2°C



4 °C

IPCC AR6 2022 Figure SPM. 5

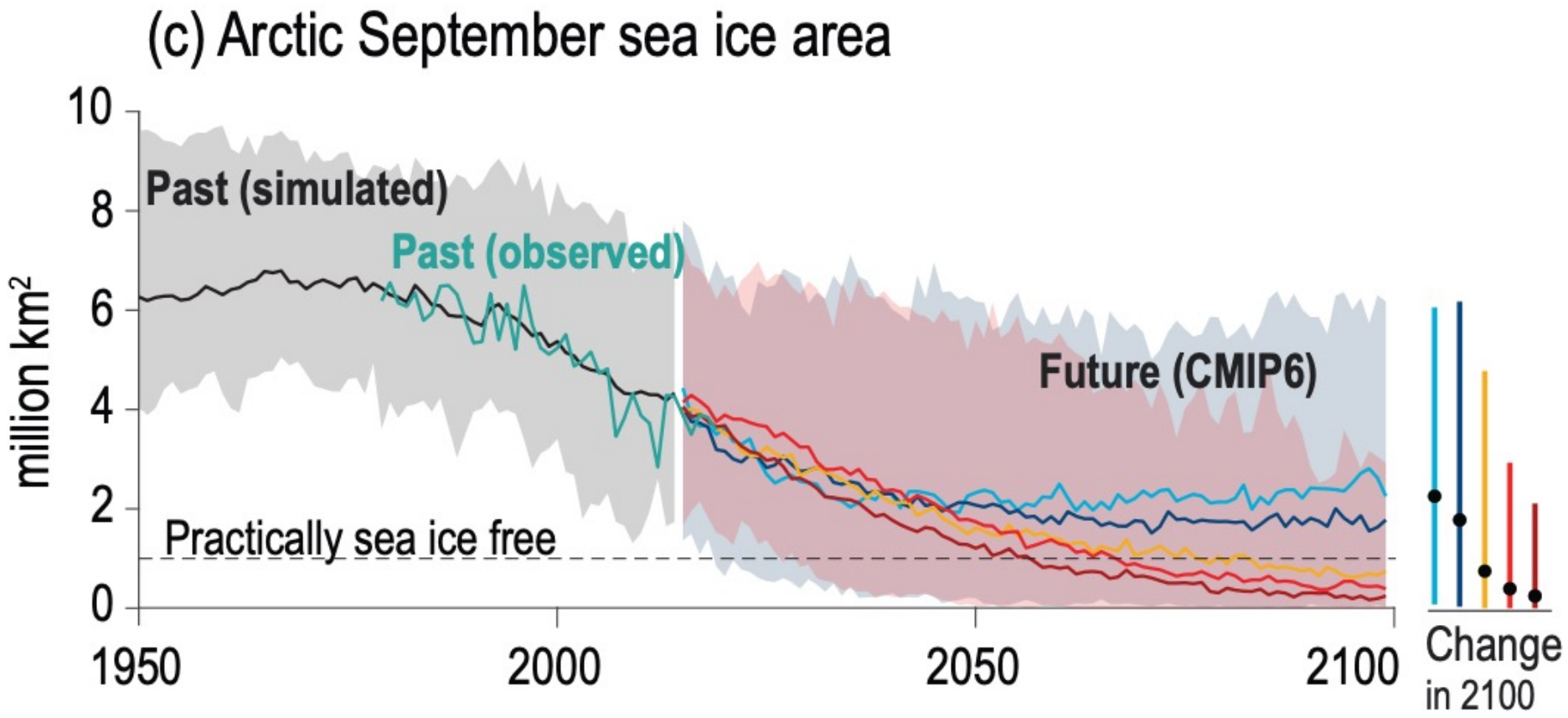
Recent and Future Change of Global Surface Air Temperature



AR6

IPCC AR6 2022 Figure TS.8

Recent and Future Change of September Sea Ice



IPCC AR6 2022 Figure TS.8

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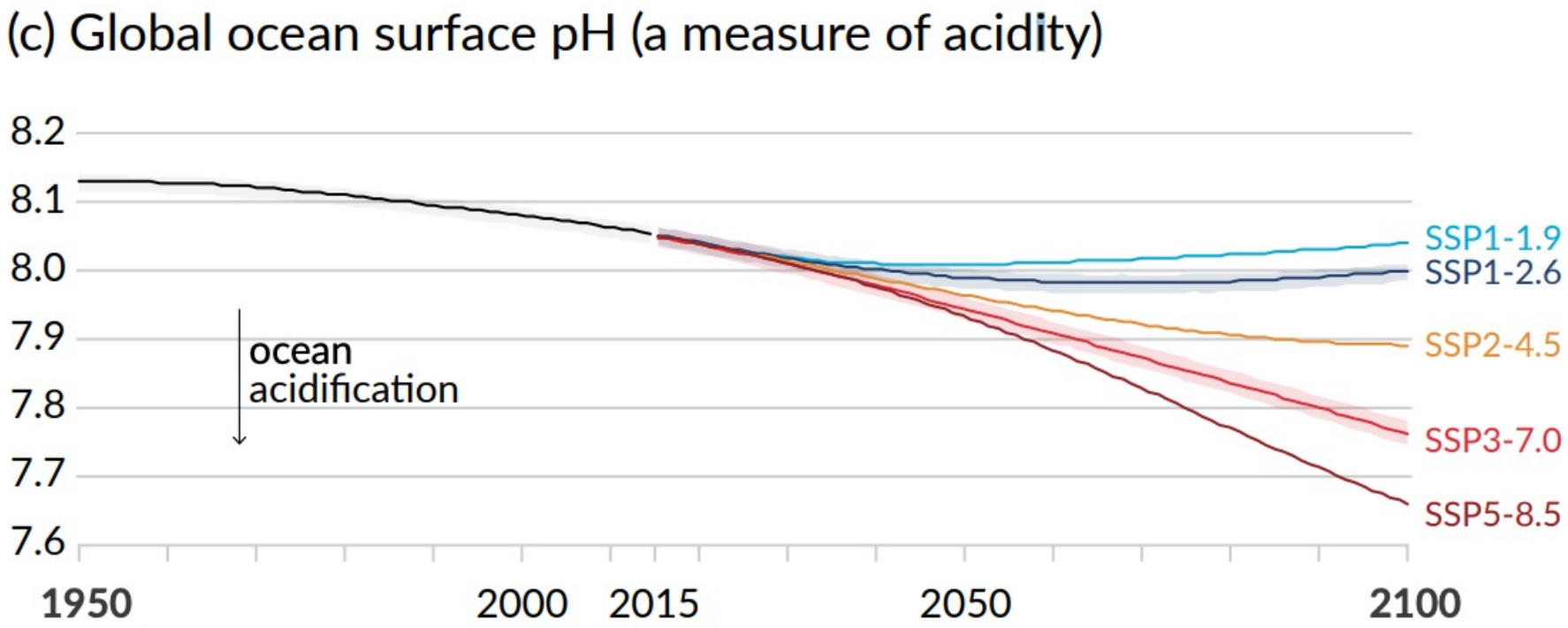
Global Ocean Surface pH (a measure of acidity)



IPCC AR6 2022 Figure SPM. 8

Advances and Increasing Confidence in Climate Models in Attributing Global Warming to Human Activities: *AR1 (1990) - AR6(2022):*

(Likely: 66-100%; Very Likely: 90-100%; Extremely Likely: 99-100%)

The observed global warming is:

- **1990 (AR1): Broadly consistent with predictions**
- **1995 (AR2): The balance of evidence suggests a discernible human influence**
- **2001 (AR3): The warming observed…is attributable to human activities**
- **2007 (AR4): Very likely due to the observed increase in GHG *(Nobel Peace Prize)***
- **2014 (AR5): Extremely likely to have been the dominant cause**
- **2022 (AR6): It is unequivocal that human influence has warmed the A,O,L**

Global Warming Projections (°C)

Charney et al., (1979): 1.5 - 4.5

- IPCC-1 (1990): 1.9 - 5.2
- IPCC-2 (1995): 1.5 - 5.7
- IPCC-3 (2001): 1.4 - 5.8
- IPCC-4 (2007): 1.1 - 6.4
- IPCC-5 (2013): 0.3 - 4.8
- IPCC-6 (2022): 3.3 - 5.7

Climate Sensitivity: Global Warming by Doubling CO2 from Pre-industrial Level

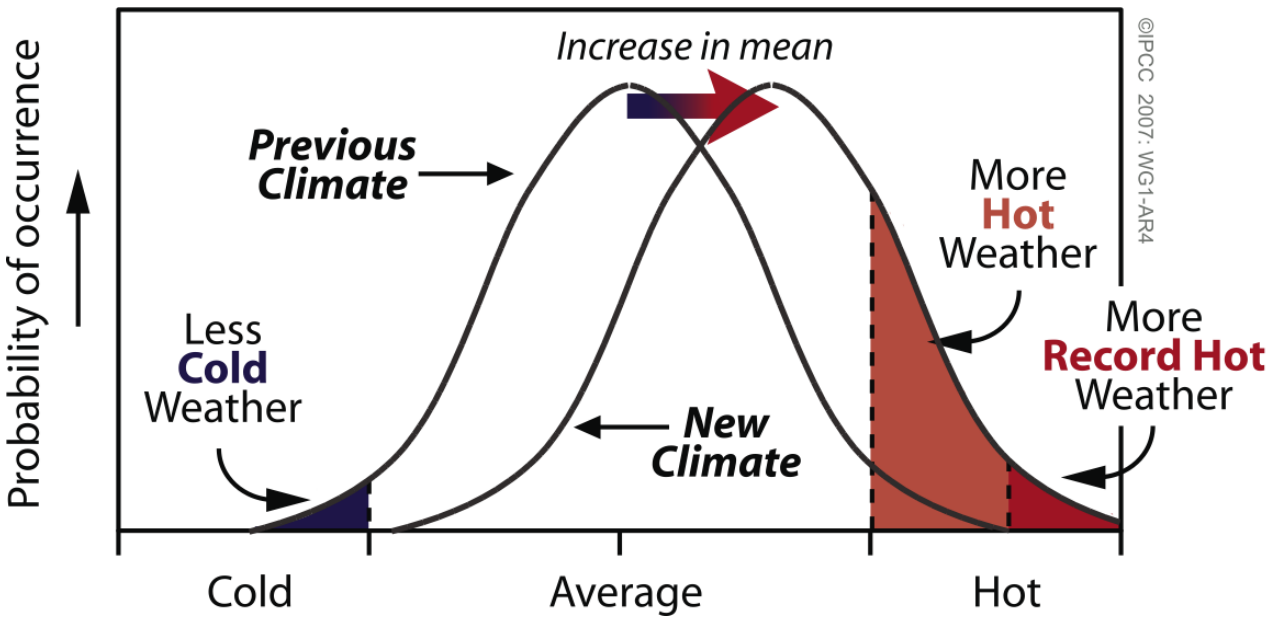
From 280 ppm (1780) to 560 ppm

Hot Models in CMIP6: For CMIP5 models, the highest climate sensitivity was 4.5 °C for CMIP6 models, 20% of models have climate sensitivity ≥ 5 °C

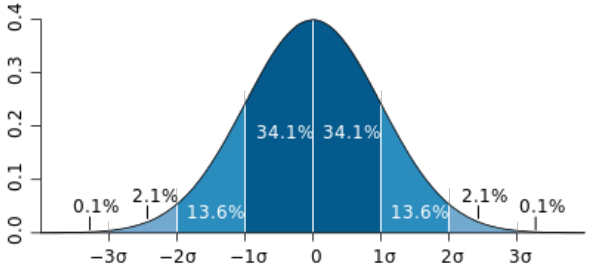
- Charney (1979): 3.0
- Hausefather et al (2022): 2.3 - 4.7

Charney committee (1979): Global Warming due to doubled CO2 will be in the range of 1.5 – 4.5 °C, 3 °C

What is an Extreme Event?

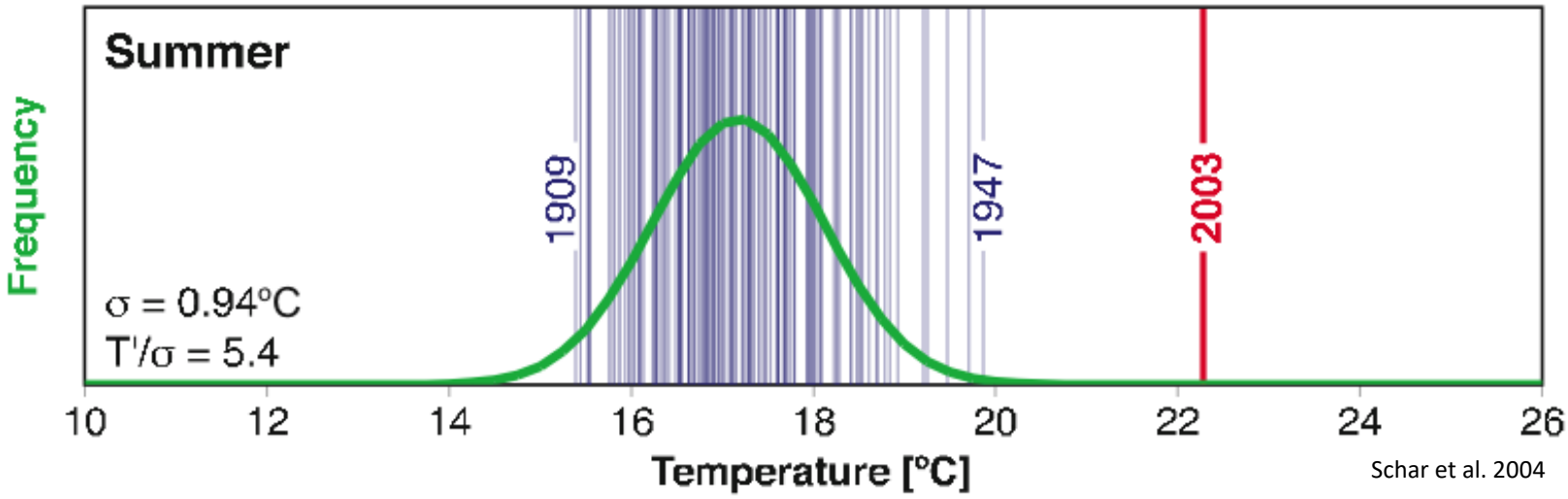


Assume that weather is a normally distributed random variable



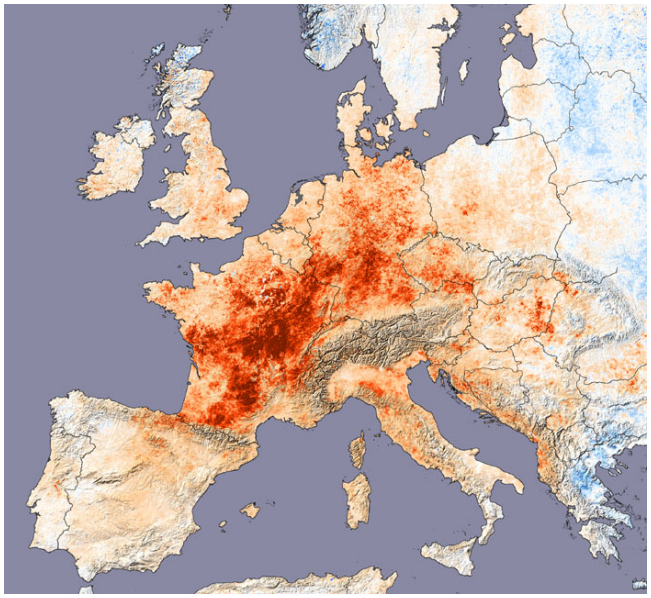
Definition: use either a relative threshold (e.g. 90th percentile) or absolute threshold (e.g. 35°C)
(calculate duration or intensity)

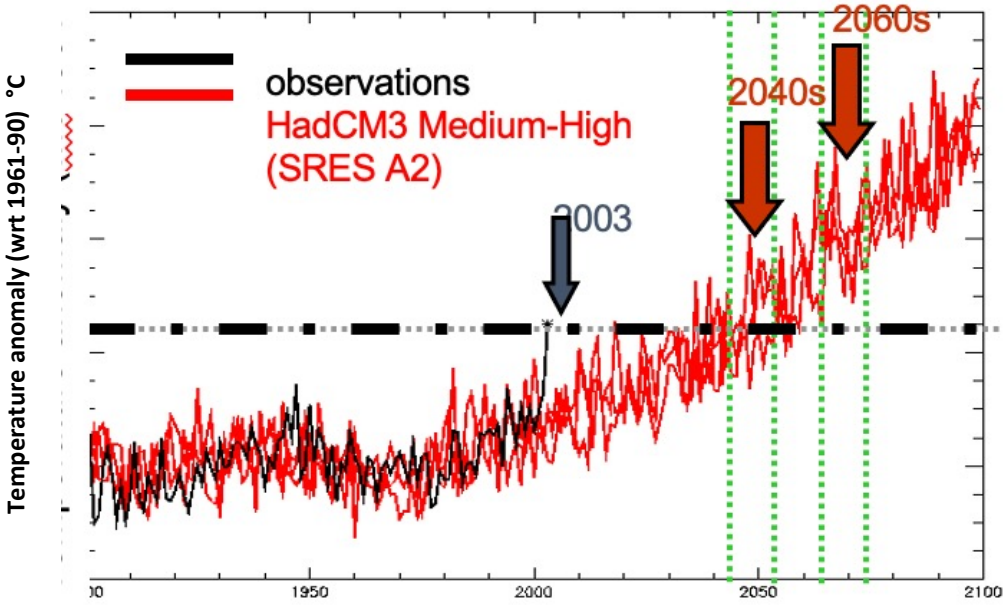
Summer Temperature in Switzerland



Schar et al. 2004

European heat wave of 2003





IPCC 2022 Assessment of Extreme Events (AR6)

- **It is virtually certain that hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s. It is very likely that human influence is the main contributor.**

- ***Changes in aerosol concentrations have likely slowed the increase in hot extremes in some regions***

- **Marine heatwaves have approximately doubled in frequency since the 1980s**

- **The frequency and intensity of heavy precipitation events have increased since the 1950s over most land area. Human-induced climate change is likely the main driver**

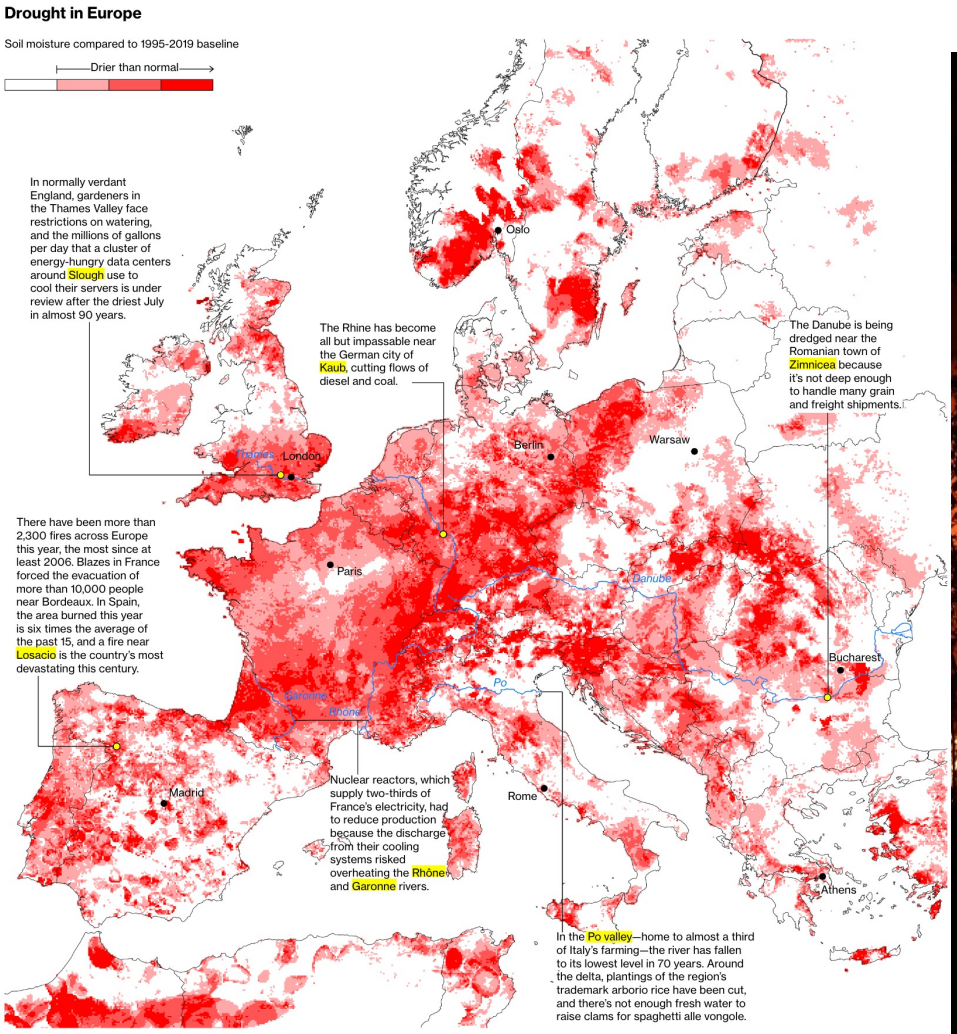
IPCC 2022 Assessment of Extreme Events (AR6)

- **It is likely that the global proportion of major (Category 3–5) tropical cyclone occurrence has increased over the last four decades**

- **Event attribution studies of specific strong tropical cyclones provide limited evidence for anthropogenic effects on tropical cyclone intensifications so far, but high confidence for increases in precipitation**

- **There is low confidence in long-term (multi-decadal to centennial) trends in the frequency of all-category tropical cyclones.**

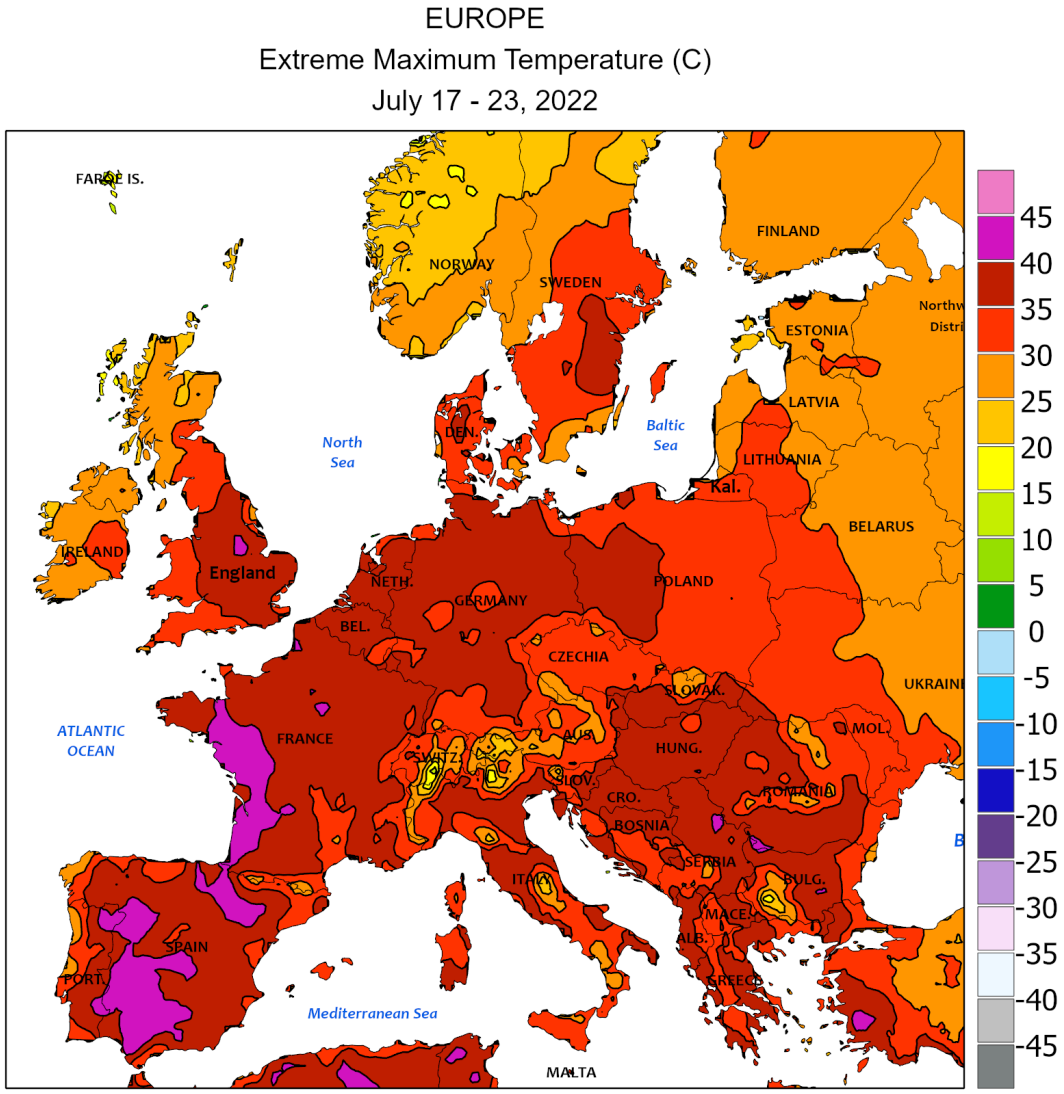
Europe Is Living Through Its Worst Heat Wave Since the Renaissance



September 1, 2022, Bloomberg

September 8, 2022, The Local, Firefighter in France attempting to prevent the wildfire from spreading due to wind change

NOAA Map of Europe Surface Temp
July 17-23, 2022

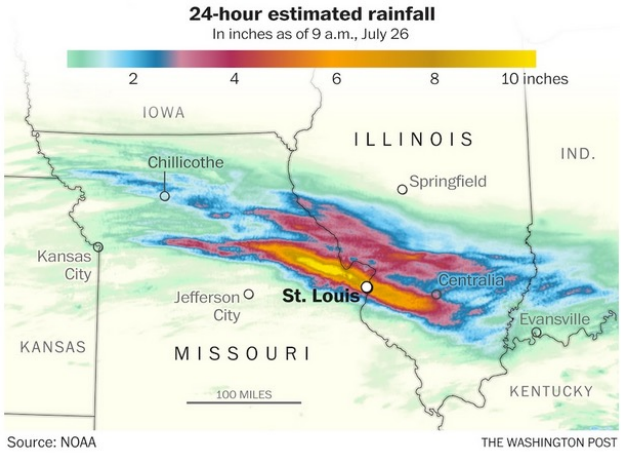


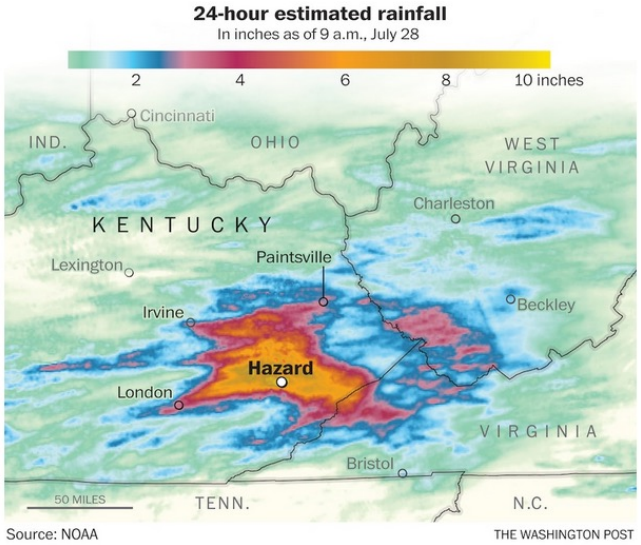
CLIMATE PREDICTION CENTER, NOAA
Computer generated contours
Based on preliminary data

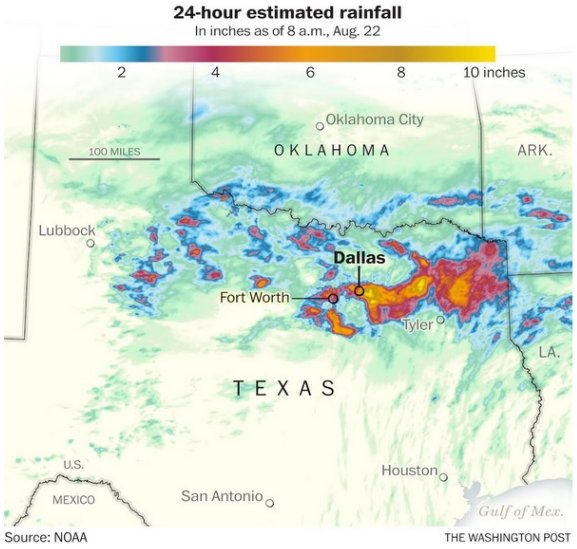
Typhoon Hinnamnor (Japan and South Korea)

NYT Sept 6, 2022

Apocalypse 2022: Three 1000-year Floods







St. Louis, Missouri 7/26/2022

Jackson, Kentucky 7/28/2022

Dallas, Texas 8/22/2022

Members of the Balch Springs Fire Department bring a family of four to higher ground after rescuing them from their home along Forest Glen Lane in Balch Springs, Tex., east of Dallas, on Aug. 22. (Elias Valverde II/AP)

Flash Floods Sweep Through DC, Maryland, Virginia as Storms Pummel Area With 2-4 Inches of Rain

11 August 2022

Five 1,000-year rain events hit the U.S. in five weeks

The Washington Post, August 26, 2022

More than 1,500 People Have Been Killed by Flooding in Pakistan

August 2022

NYT, August 28, 2022

Does Climate Model Sensitivity and Predictability depend on Climate Model Fidelity?

There is some evidence to suggest that models with high fidelity in simulating and predicting short-term climate variability in the current climate, would be more reliable to predict the future climate.

Are current climate models adequate to predict changes in intensity and probability of extreme events?

THANK YOU!

ANY QUESTIONS?