Math 5421
An Introduction to Mathematical Climate Models

Spring 2025
1:25 – 3:20 Tuesdays and Thursdays
Blegen Hall 155

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course website
https://www-users.cse.umn.edu/~mcgehee/Course/Math5421/

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An Introduction to Mathematical Climate Models

Introductions

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Math 1901
Freshman Seminar
Mathematical Climate Models

Syllabus

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Is the climate changing?

Floods

Droughts

Fires

Heat

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SCIENTIFIC AMERICAN

SEPTEMBER 30, 2024 | 6 MIN READ

Hurricane Helene's Devastation Shows No Region Is Safe from Climate-Fueled Disaster

Hurricane Helene fueled catastrophic flooding from Florida to Appalachia, leaving millions without power

The swath of devastation, which cut hundreds of miles inland from Florida's Gulf Coast into southern Appalachia, is a stark reminder of the worsening impacts of climate change. Rising temperatures are fueling stronger, deadlier hurricanes with impacts that can ripple across the country.

It's also an indicator that no regions are immune to the dangers of climate-fueled disasters. Asheville, North Carolina — which experienced some of the worst hurricane-related flooding in the nation — has previously been described as a "climate haven."

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Hoover Dam, USA

www.arcentral.com/story/opinion/op-ed/joannaallhands/2021/05/20/lake-mead-likely-tier-2-shortage-2023-impact-arizona/5183361001/

www.wsj.com/articles/europes-key-rivers-fall-to-critical-levels-aggravating-energy-crunch-11660216554

Loire River, France

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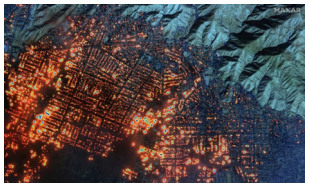
fires

Los Angeles burning



The LA county wildfires could be the costliest in US history, early estimates say

January 11, 2025 AP

https://www.scientificamerican.com/article/destructive-los-angeles-fires-explained-in-photos/

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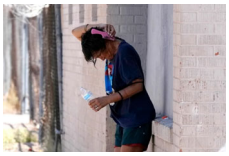
heat

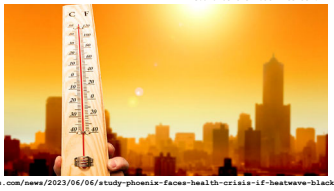
The New York Times

Phoenix's Month in Hell: A 31-Day Streak of Record Heat Ends

A continuous stretch of days reaching or exceeding 110 degrees has filled emergency rooms. On Monday, the city hit 108 degrees, breaking the run, but setting a new, brutal record.



https://www.accuweather.com/en/weather-news/phoenix-heat-wave-could-be-the-most-intense-on-record-for-the-city/1562782



https://azcapitoltimes.com/news/2023/06/06/study-phoenix-faces-health-crisis-if-heatwave-blackout-hit-at-same-time/

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Discussion Question

What is the difference between weather and climate?

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Discussion Questions

What is the difference between weather and climate?

Which of the previous slides depict weather, and which climate?

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How can we quantify climate?

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How can we quantify climate?

What is Global Mean Temperature (GMT)?

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How can we quantify climate?

What is Global Mean Temperature (GMT)?

How can we measure GMT?

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Paris Agreement 2015

https://www.npr.org/sections/thetwo-way/2015/12/12/459502597/2-degrees-100-billion-the-world-climate-agreement-by-the-numbers

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Paris Agreement 2015

Article 2

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

https://www.youtube.com/watch?v=I-4F5MJEeqs

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Global Mean Temperature

How can we measure GMT?

Mathematics

The surface temperature is a function from the surface of the Earth to a real number. We simply compute the average by integrating this function over the surface of the Earth (a sphere) and divide by the surface area.

Measurement Issues:

How do we define the temperature on the surface of the Earth? The temperature of the top of the soil or surface rocks? The surface ocean temperature? The surface of the ice? What about the air temperature?

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Global Mean Temperature

How can we measure GMT?

Mathematically:

The surface temperature is a function from the surface of the Earth to a real number. We simply compute the average by integrating this function over the surface of the Earth (a sphere) and divide by the surface area.

Statistical Issues:

We have measurements only at a finite number of places. For the ocean, the places move around and are at different locations at different times. (Think of ships and autonomous floats.) How do we interpolate the data to estimate the global mean?

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Global Mean Temperature

How can we measure GMT?

Mathematics

The surface temperature is a function from the surface of the Earth to a real number. We simply compute the average by integrating this function over the surface of the Earth (a sphere) and divide by the surface area.

Political Issues:

What do we mean by holding the global average temperature below some value? Do we average over a day and demand that the daily average never get above that value? Maybe average over a month? A year? Two years? A decade? Thirty years?

What do we mean by the pre-industrial temperature?

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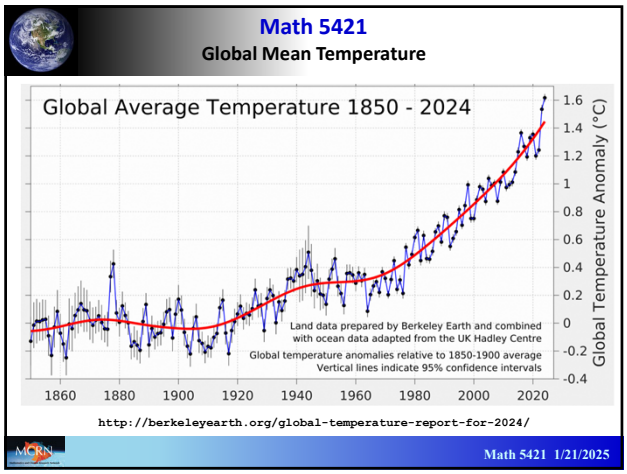
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Global Mean Temperature
Global Average Temperature 1850 - 2024
Global Temperature Anomaly (°C)
Land data prepared by Berkeley Earth and combined with ocean data adapted from the UK Hadley Centre
Global temperature anomalies relative to 1850-1900 average
Vertical lines indicate 95% confidence intervals
http://berkeleyearth.org/global-temperature-report-for-2024/
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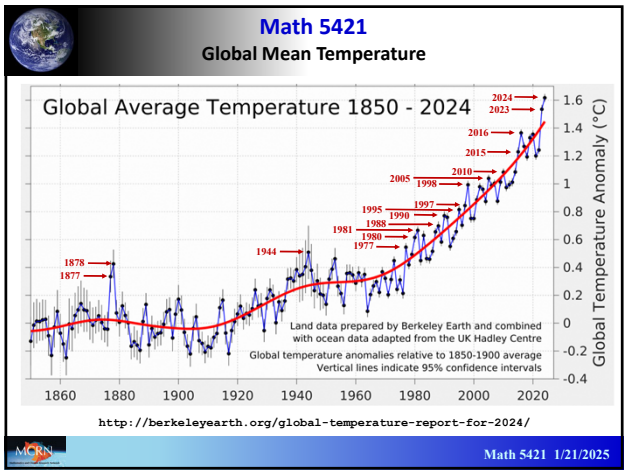
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Global Mean Temperature
Global Average Temperature 1850 - 2024
2024
2023
2016
2015
2010
2005
1998
1997
1995
1990
1988
1981
1980
1977
1944
1878
1877
Global Temperature Anomaly (°C)
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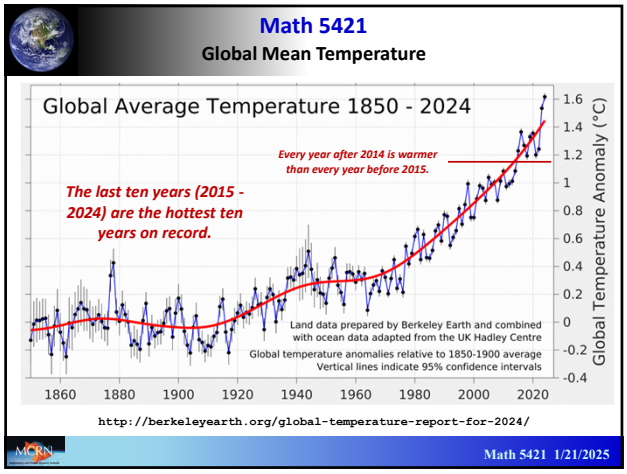
Math 5421
Global Mean Temperature
Global Average Temperature 1850 - 2024
Every year after 2014 is warmer than every year before 2015.
The last ten years (2015 - 2024) are the hottest ten years on record.
Global Temperature Anomaly (°C)
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Global temperature anomalies relative to 1850-1900 average
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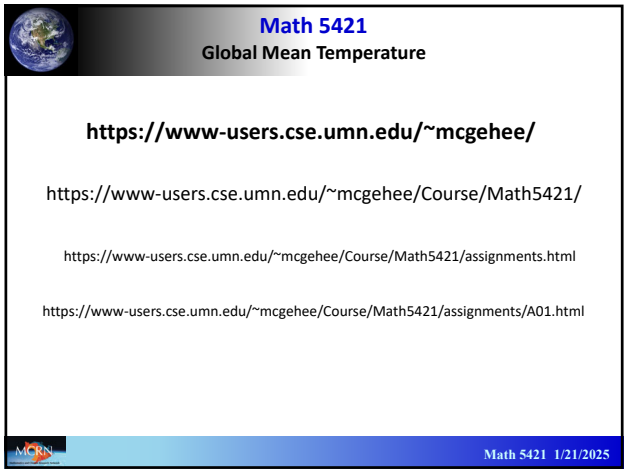
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