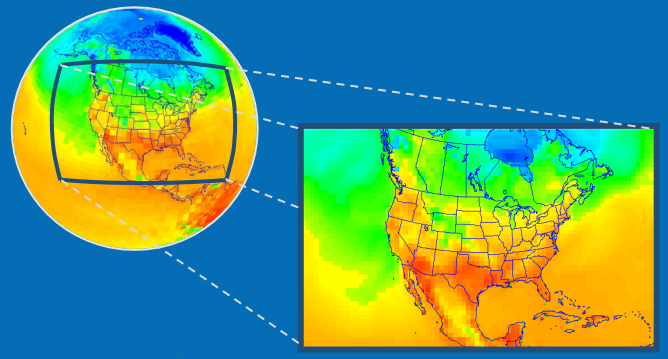
EPA United States Environmental Protection Agency

EPA Tools and Resources Webinar:

Temperature, Precipitation, & More: Datasets for Comprehensive Analysis of Local Climate Change Impacts



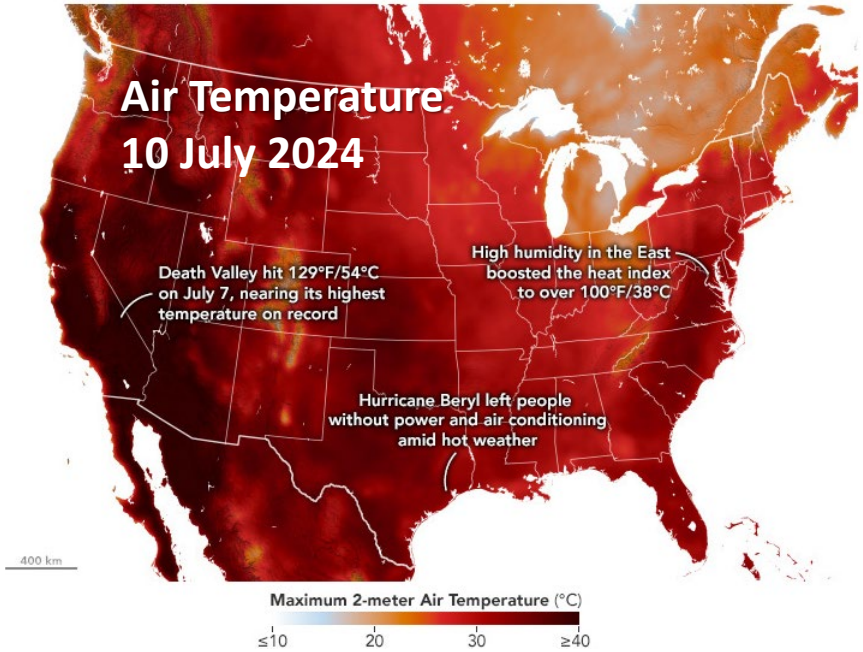
Tanya Spero, Jeff Willison, and Megan Mallard

US EPA Office of Research and Development

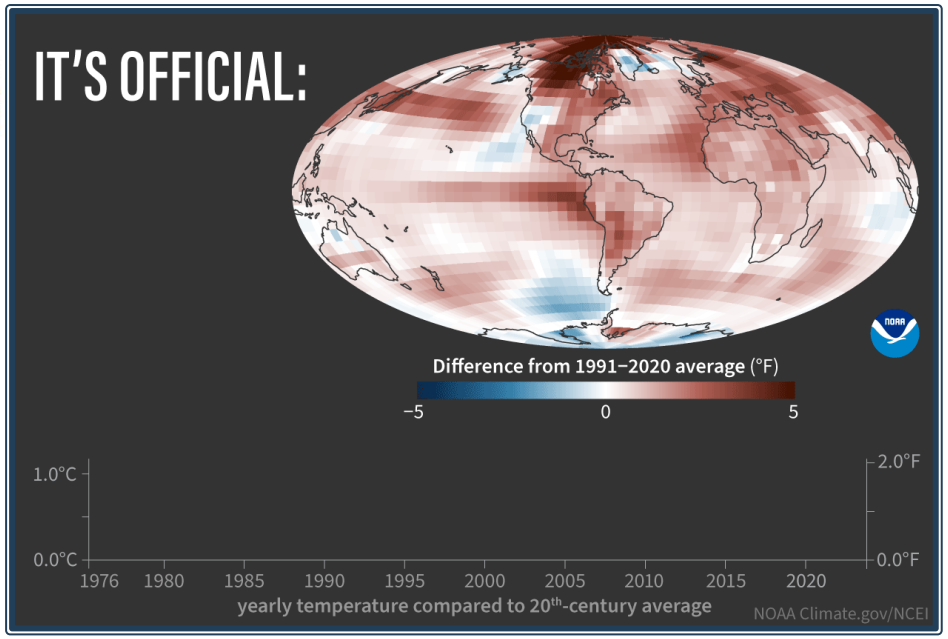
17 July 2024

edde

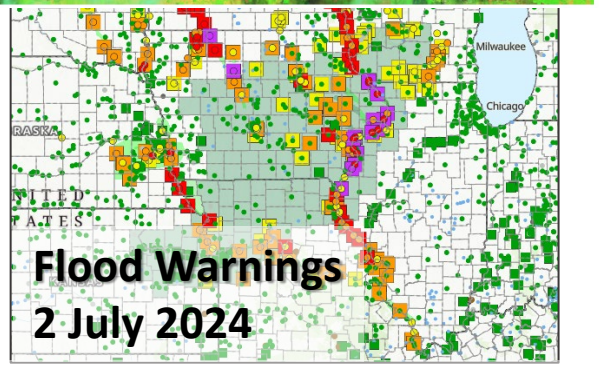
Weather and climate are changing!



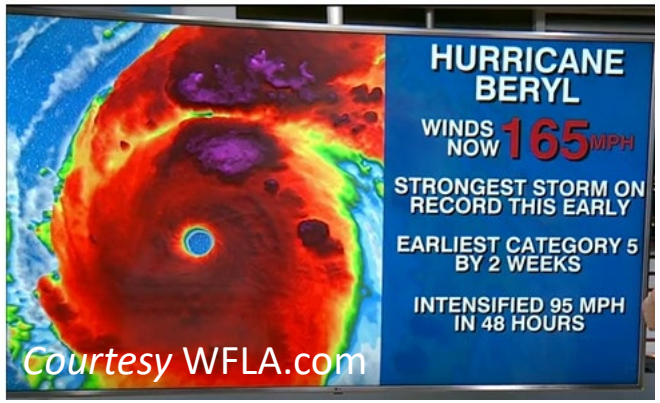
https://earthobservatory.nasa.gov

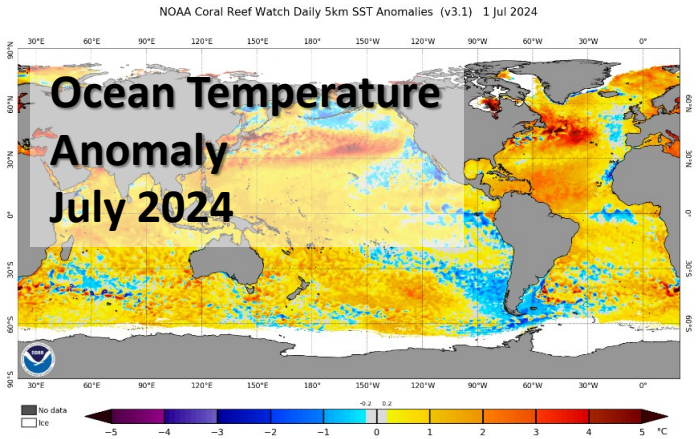


https://www.climate.gov

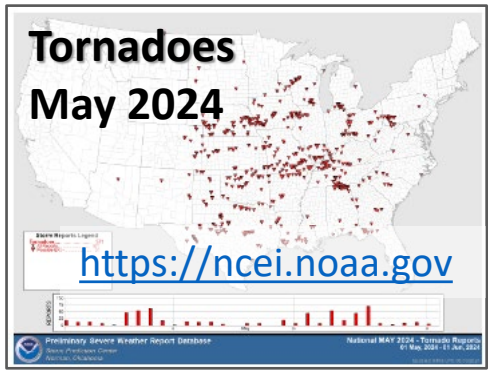


https://weather.gov/fsd/flooding



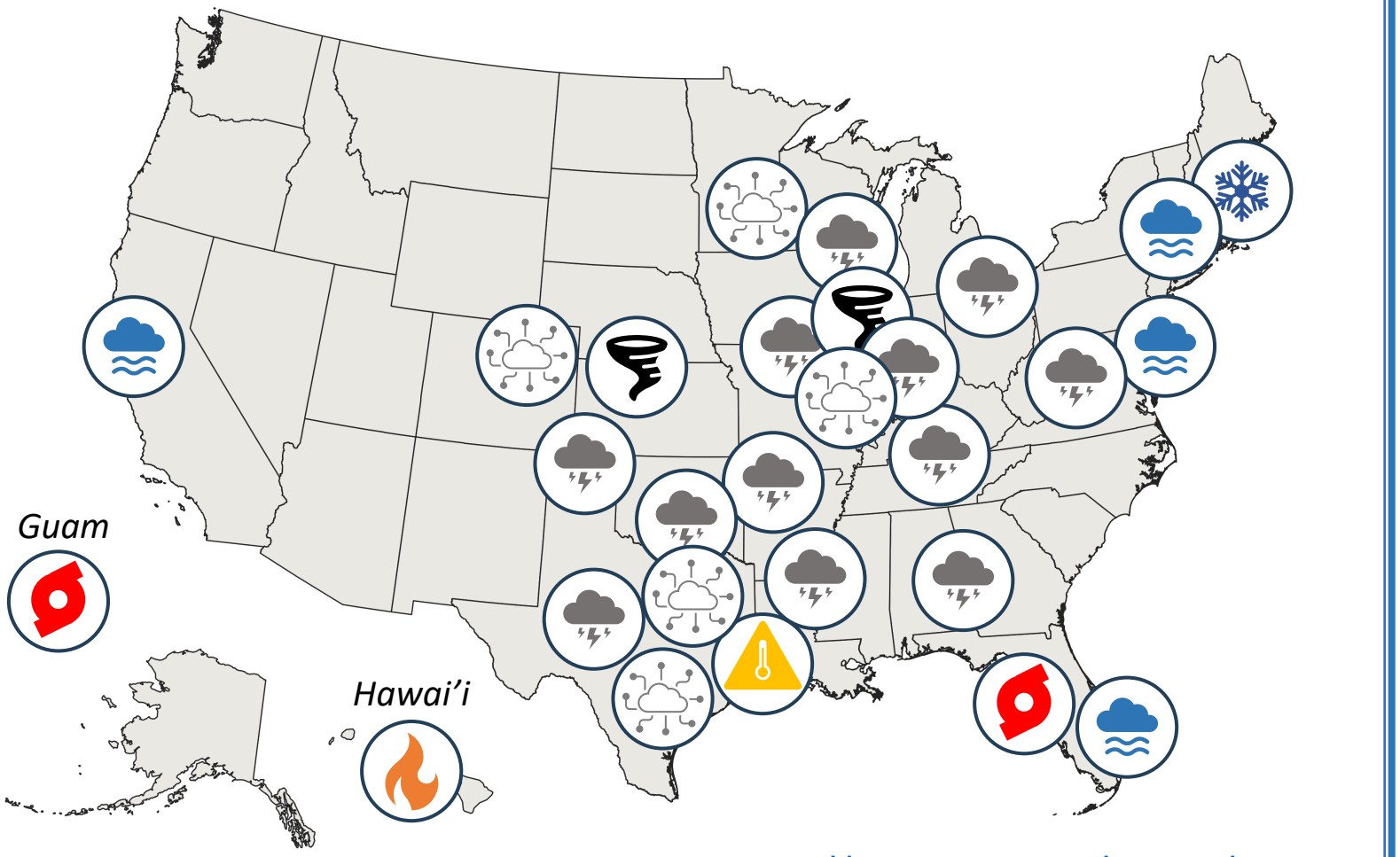


https://ospo.noaa.gov/Products/ocean/sst/anomaly/



Extreme Weather Events are Frequent & Costly!

U.S. 2023 Billion-Dollar Weather and Climate Disasters



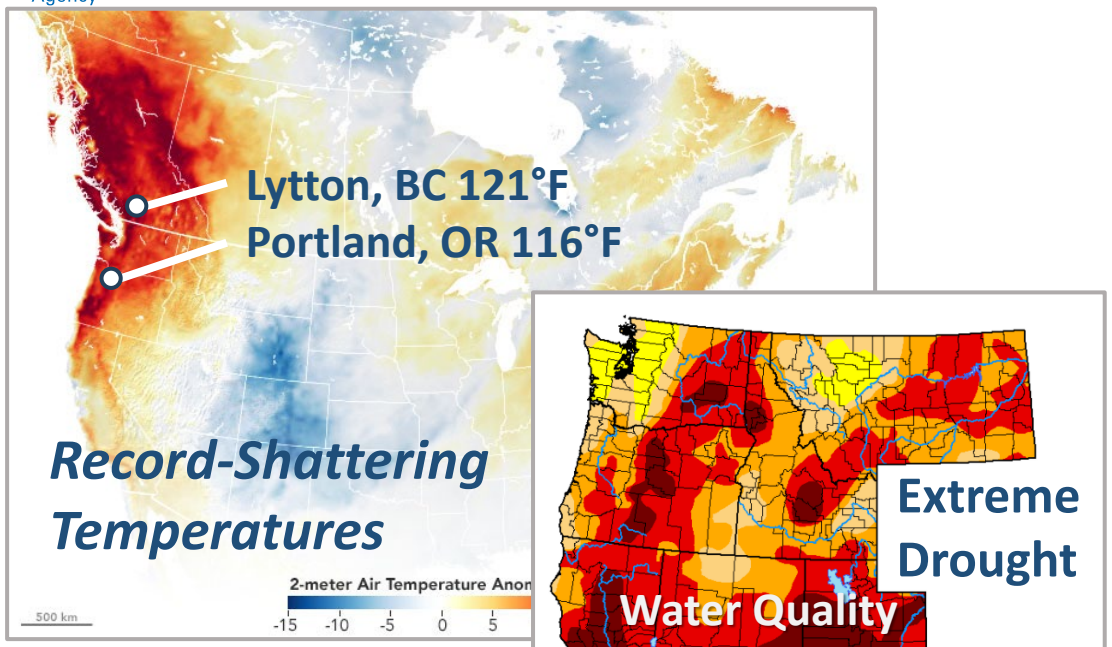
Adapted from https://ncei.noaa.gov/access/billions

U.S. had 28 billion-dollar disasters in 2023.

- 19 severe storm events
- 4 floods
- 2 tropical cyclones
- 1 wildfire
- 1 drought / heat wave
- 1 winter storm

Previous single-year record was 22 billion-dollar disasters in 2020.

EPA United States Environmental Protection Agency



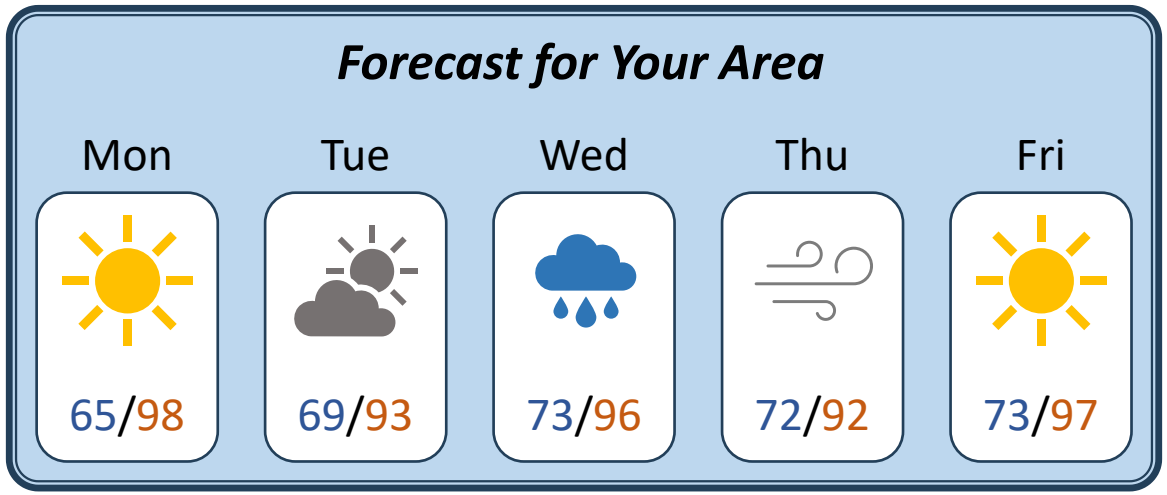
Summer 2021

"With further global warming, **every region is projected to increasingly experience concurrent and multiple changes in climatic impact-drivers**."

IPCC Sixth Assessment Report
Working Group I – The Physical Science Basis
August 2021

Weather ("Now") vs. Climate ("Over Time")

Weather: ***Short-term (minutes to days) variations***		***Climate:*** ***Longer-term (month or more) averages***
The high temperature today is 98°F.	⟷	The *normal* high temperature is 98°F.
We received 4" of rain this month.	⟷	The *normal* precipitation for July is 4".
We received 3" of rain in two hours.	⟷	3" of rain in two hours is 25-year event.



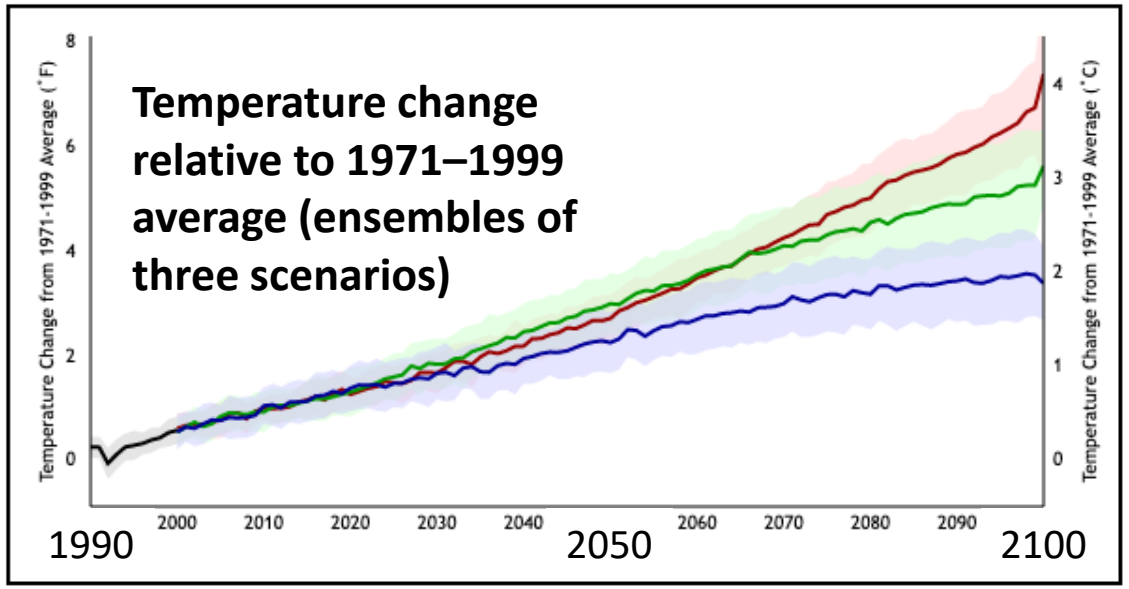


Image courtesy of https://climate.gov

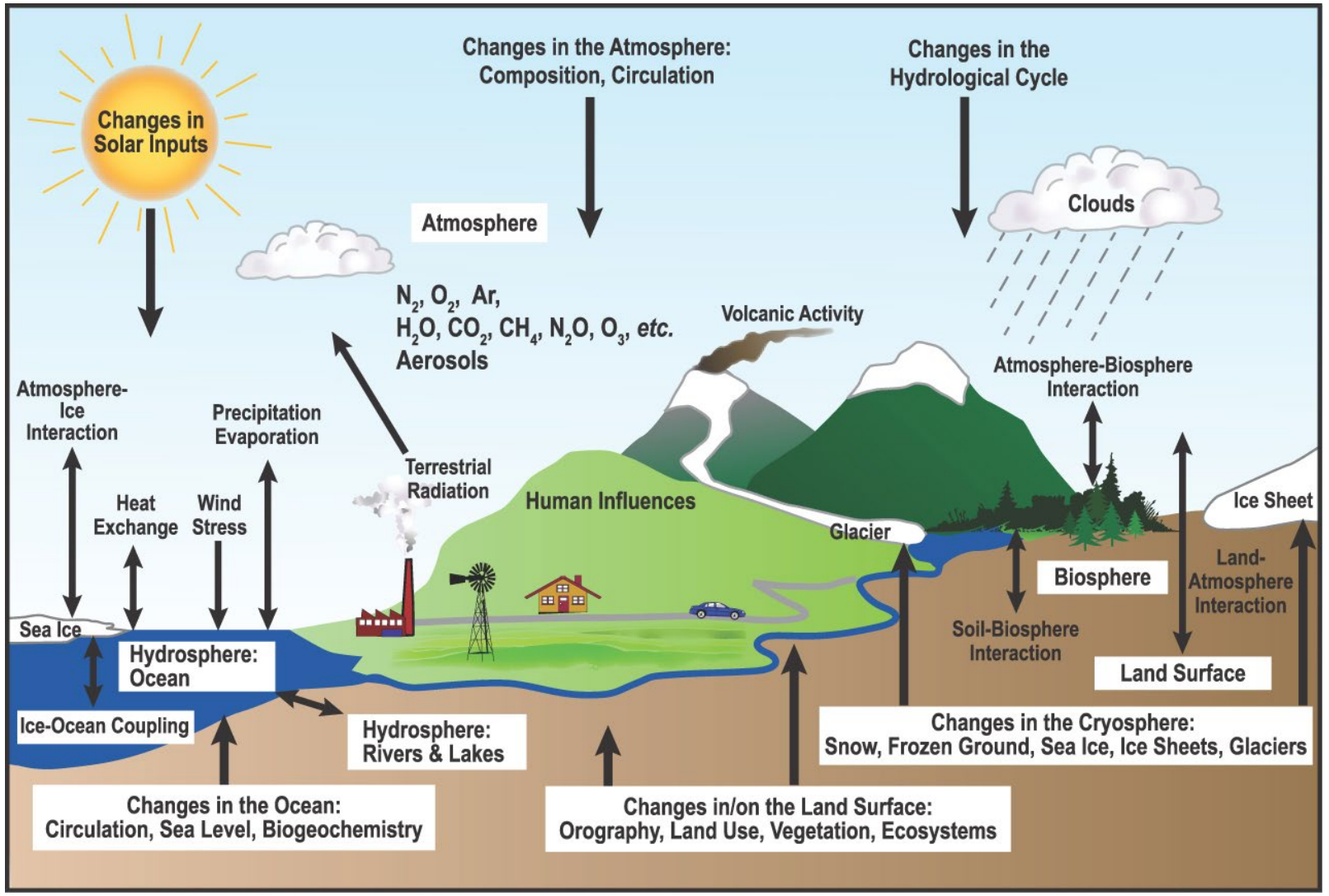
Weather Modeling vs. Climate Modeling

Weather Modeling: ***Prediction for a given time/place***		***Climate Modeling:*** ***Projection under a scenario***
Informed by observations and current conditions.	⟷	Informed by trends.
Specific to time/location/event.	⟷	Broadly representative in time/space.
“Initial Value Problem”	⟷	“Boundary Value Problem”

Quantifying potential changes to extreme weather in the context of a changing climate can help communities become resilient and to appropriately practice risk management.

Global Climate Modeling [Conducted Elsewhere]

- Dozens of climate model experiments are organized by the United Nations' Intergovernmental Panel on Climate Change
- **Expensive and sophisticated models**
- Centuries simulated, from 1800s-2100 (and beyond).



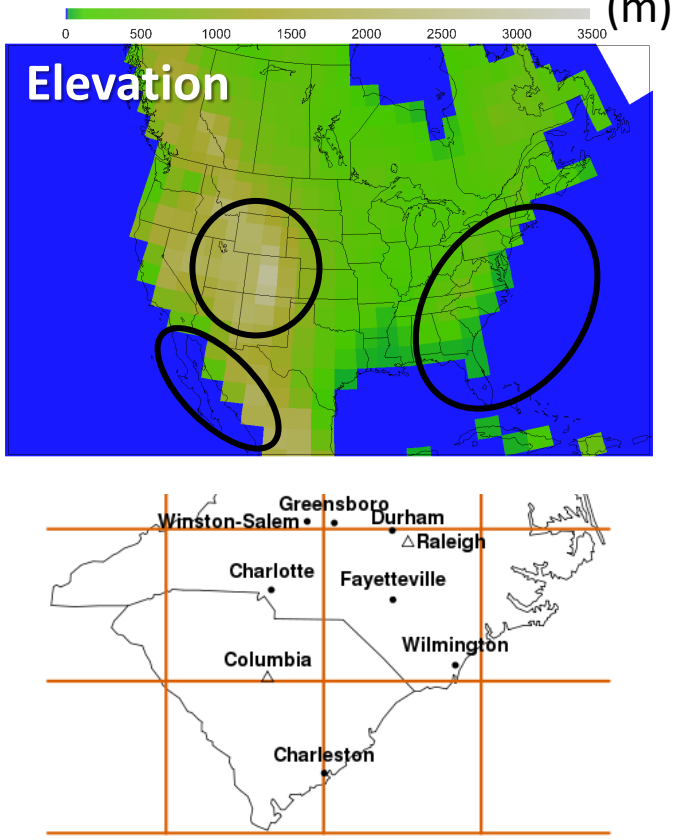
Images courtesy of https://www.carbonbrief.org/qa-how-do-climate-models-work/ *and* https://en.wikipedia.org/wiki/Supercomputer

While generalizations can be made, climate changes are not uniform in space or in time.

Climate change can disproportionally affect different populations.

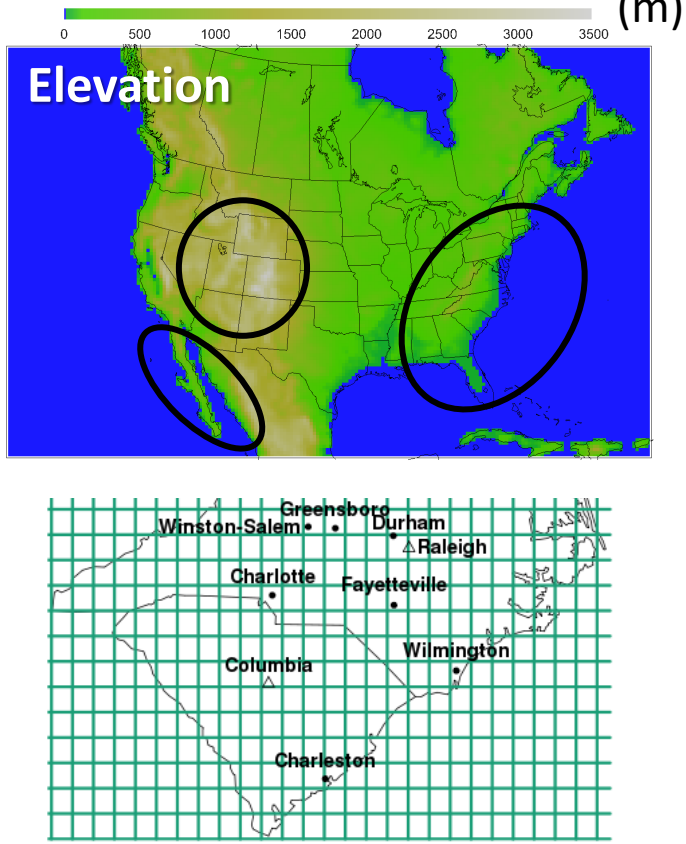
Problem: *Global* climate models are low resolution.

2° × 2.5° *Global* Model



Low Resolution

36-km *Regional* Model



High Resolution

Details gained via regional climate modeling are essential for examining local effects of climate change on human health and the environment.

Problem: Low resolution in ***time*** can affect result and interpretation!

- Global models often provide daily output!
  - *Select data available at 6-hourly increments
- Impactful and extreme events are often sub-daily!
  - Exposure applications (*e.g.*, heat/humidity and air quality)
  - Hydrological applications (*e.g.*, water quantity and quality)
  - Flash floods are sub-daily phenomena.

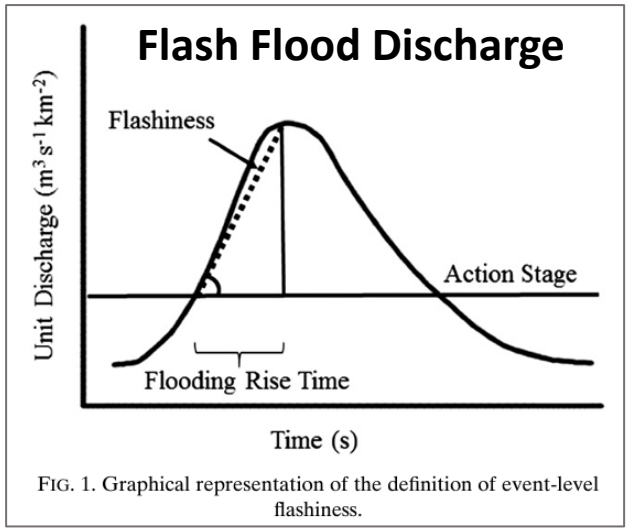
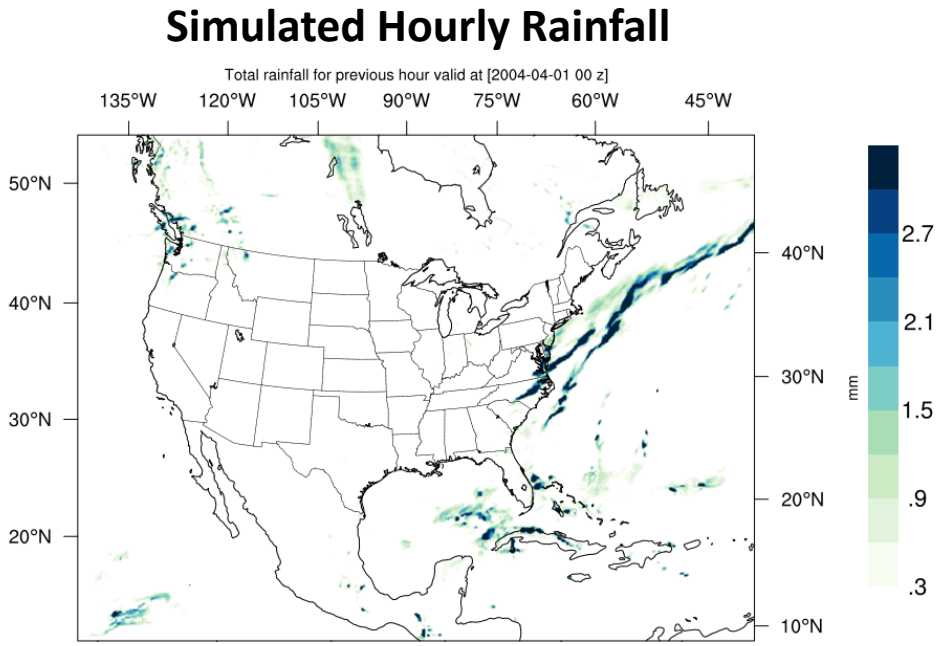
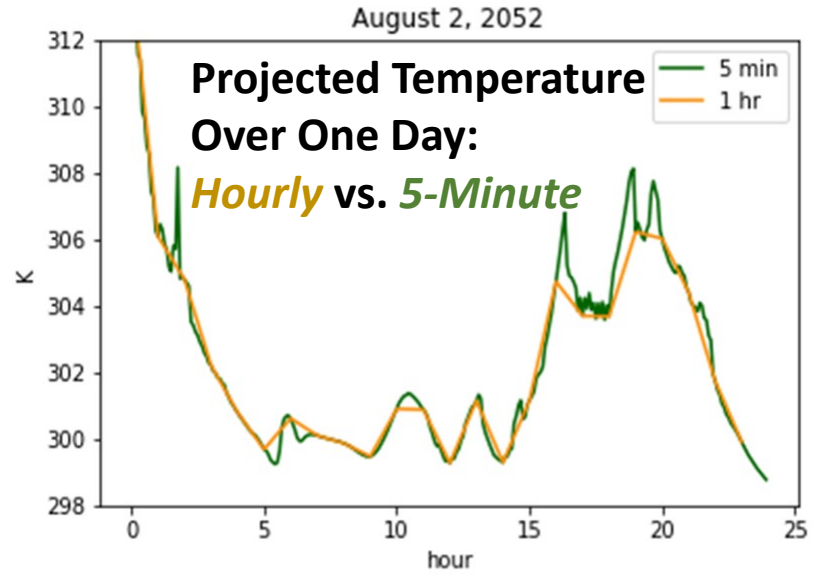


FIG. 1. Graphical representation of the definition of event-level flashiness.

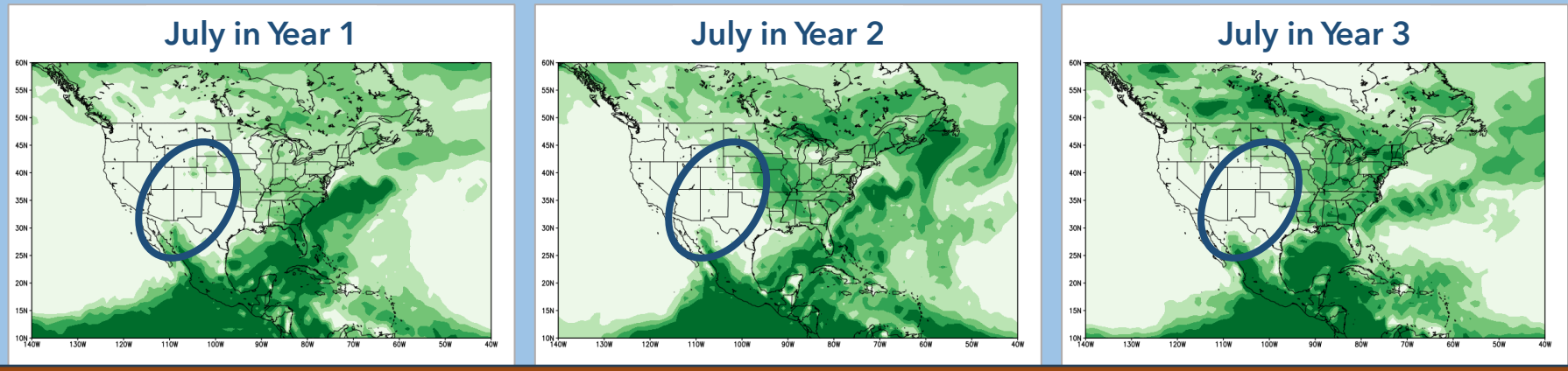
Saharia et al. (2017)





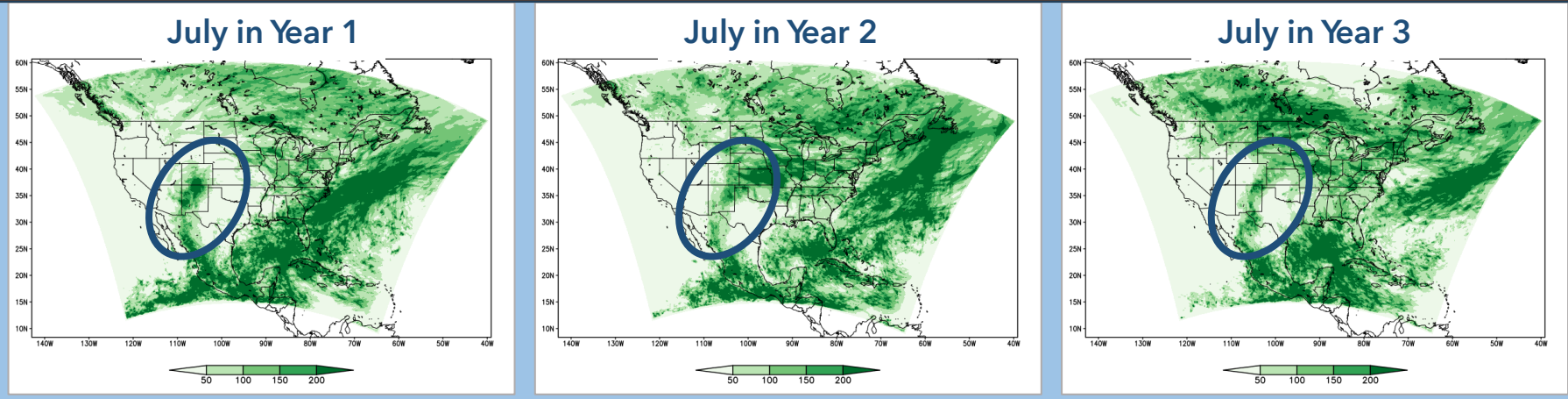
Problem: Low resolution in ***space*** can affect result and interpretation!

Global Climate Model



Regional model provides "local" physics that allow monsoon rains to be simulated.

Regional Climate Model



Images courtesy of J. Bowden

Multiple methods to explore potential climate changes

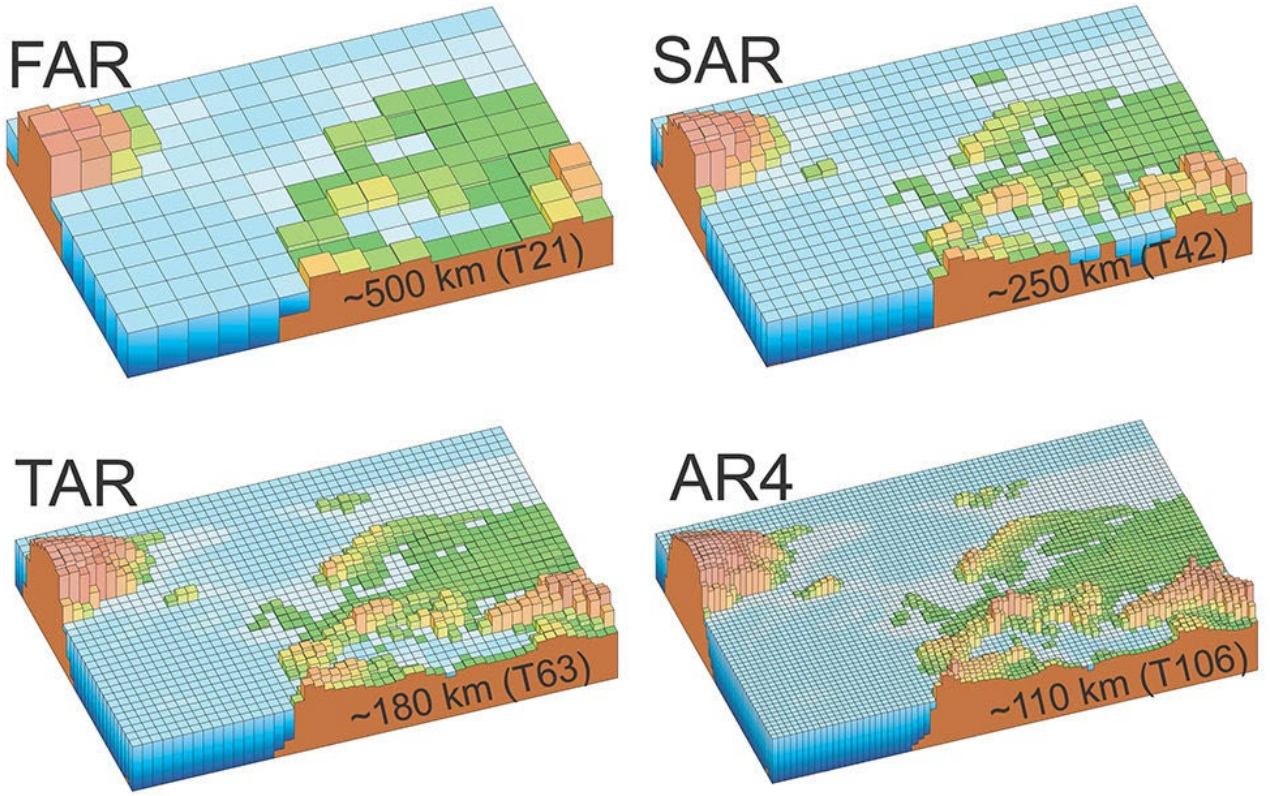
- Observation Trends
- Global Climate Models
- Statistical Downscaling
- Dynamical Downscaling
- Event-Based Modeling
- AI Modeling

"All models are wrong, but some are useful."

George E. P. Box, Statistician

A Solution: Downscaling the Global Models

- **Downscaling** allows us to better resolve features of interest in both space and time.
- Over the past few decades, advances in scientific knowledge and computing power contributed to more informed and higher-resolution global and regional climate datasets.



Images courtesy of https://www.carbonbrief.org/qa-how-do-climate-models-work/

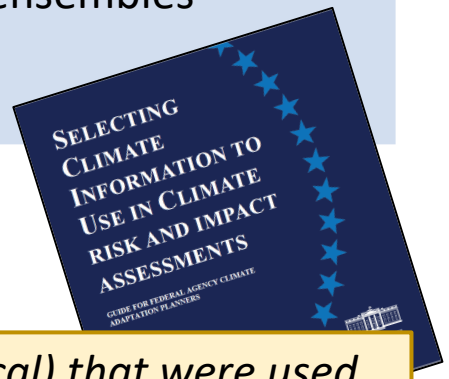
Most Widely Used Downscaling Variants

Statistical Downscaling

Pros	Cons
Computationally "cheap" to produce	"Stationarity" constraint to historical record
Often very high spatial resolution (<10-km)	Lack of physical consistency between fields
Larger ensembles	Limited fields, only available near surface at daily increments

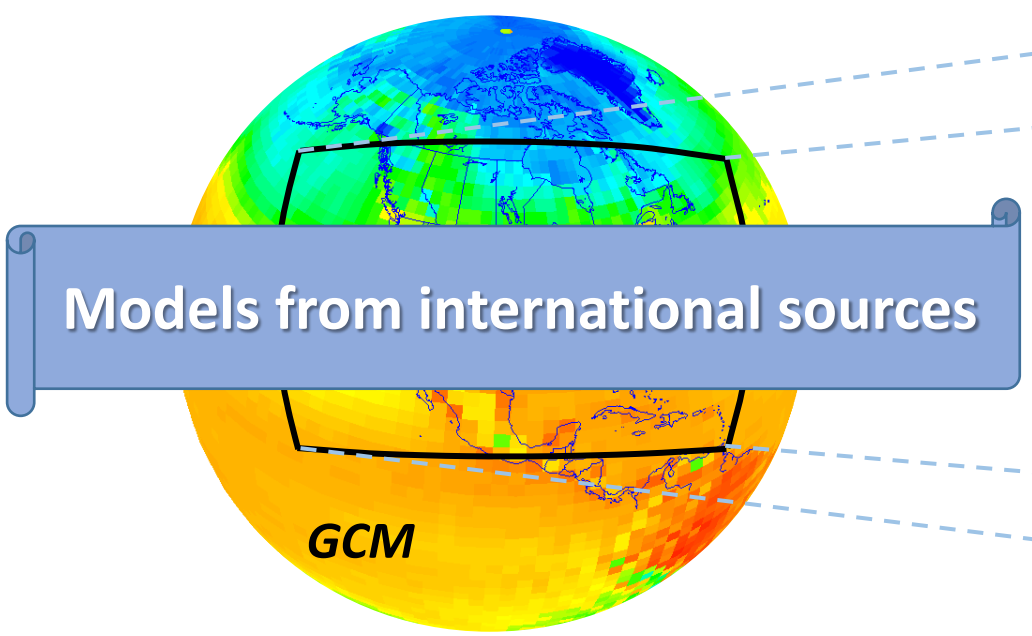
Dynamical Downscaling

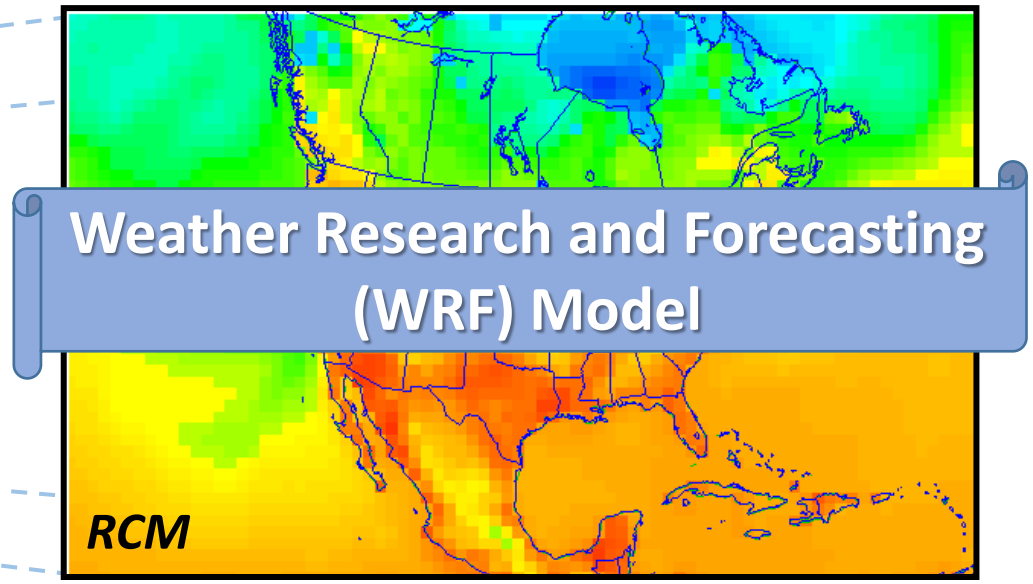
Pros	Cons
Physically consistent and realistic atmospheric dynamics	Computationally expensive
Possible to output at very high temporal resolution (i.e., sub-hourly)	Coarser horizontal resolution
3D view of atmosphere allows for more mechanistic understanding	Smaller ensembles



"Agencies should also consider the pros and cons of the downscaling techniques (statistical and dynamical) that were used to derive the downscaled datasets and caveat their results appropriately." — Office of Science & Technology Policy (2023)

Our Approach – Dynamical Downscaling





Global climate model (GCM) creates coarse **gridded** future climate with **world-wide** coverage.

Regional climate model (RCM) generates **gridded higher-resolution** climate predictions over **focal area** using a **physics-based** model.

More detail in local effects from:

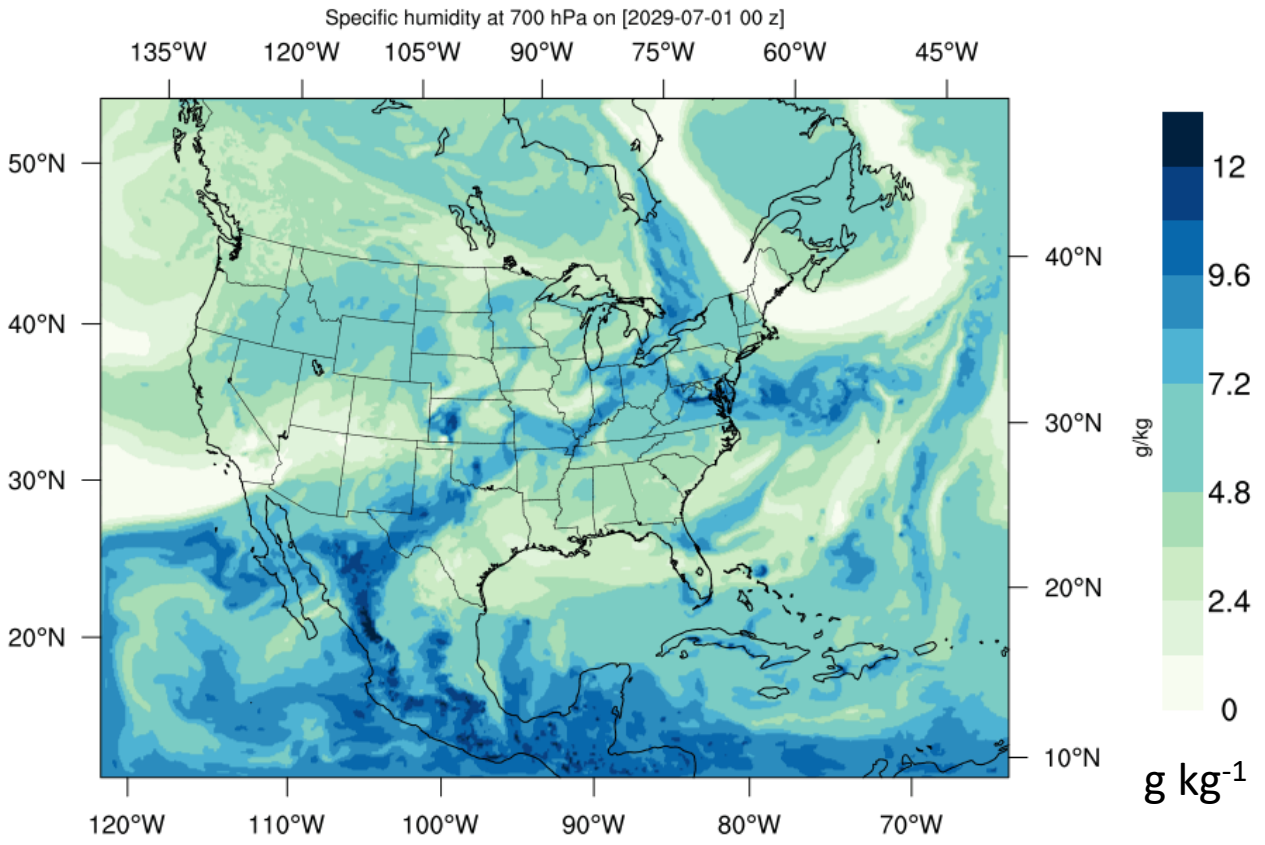
- scale-appropriate physics
- topography & land/water interfaces
- urban areas (population centers)

Introducing EDDE

EPA Dynamically Downscaled Ensemble

- ✓ Developed using open-source Weather Research and Forecasting (WRF) Model
- ✓ State-of-the-science physics options
- ✓ Backed by peer-reviewed publications
- ✓ Designed to holistically address Agency-relevant environmental issues
- ✓ Can be used to explore impacts on air quality, health, flooding, wildfires, tropical cyclones, and more!

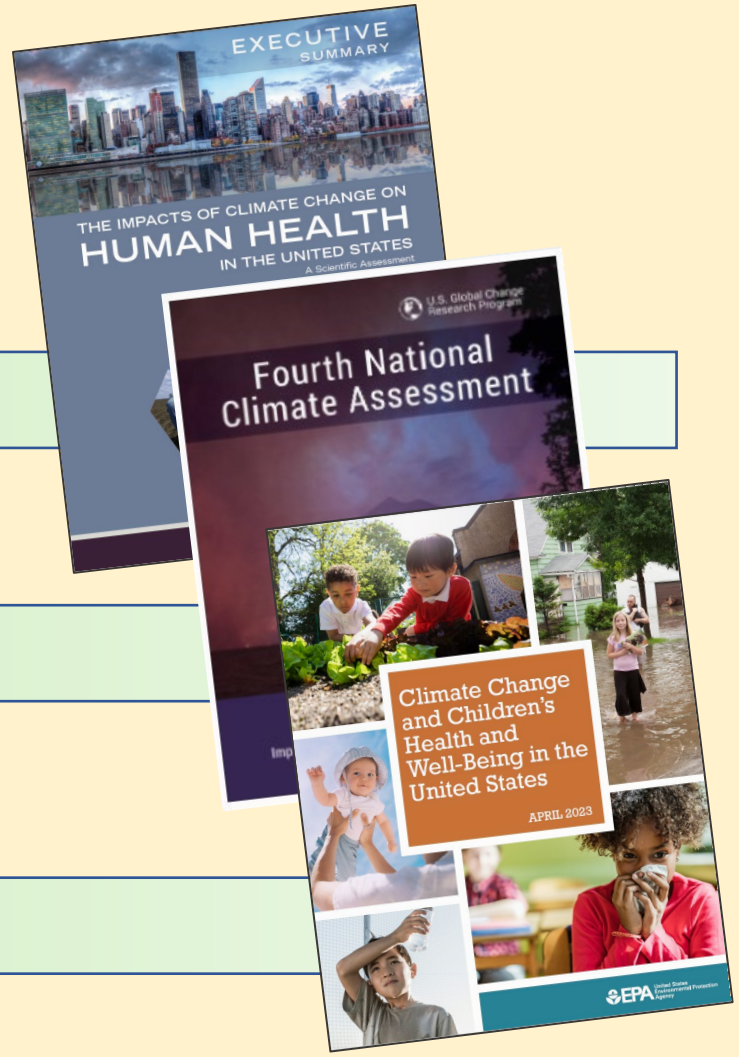
Simulated Hourly Moisture at ~10,000 feet AGL



WRF is available from https://github.com/wrf-model/WRF

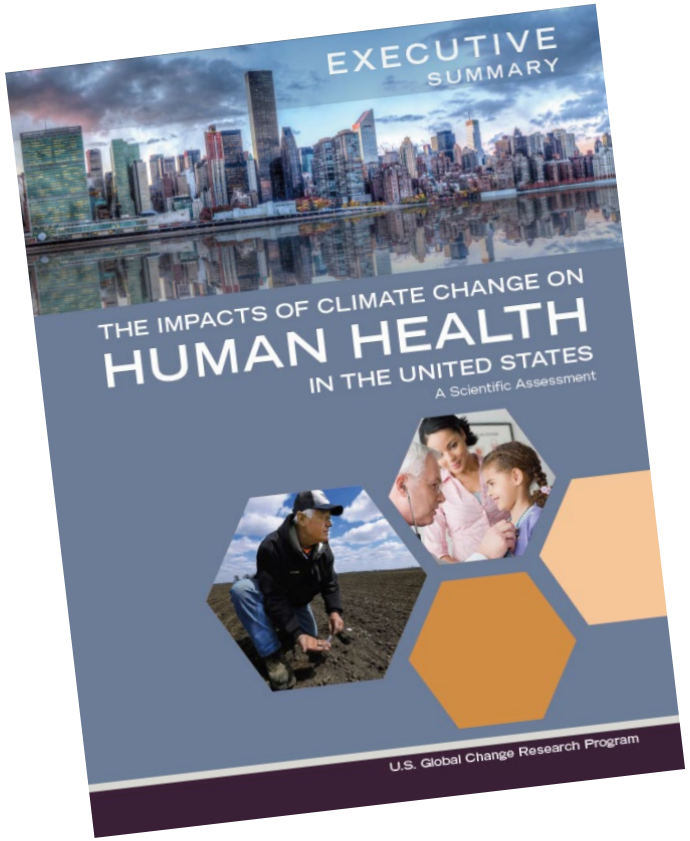
Hourly Dynamically Downscaled Data for the CONUS: Continuous Simulations with 3D Archived Output

Global Climate Model		*Scenario*	
1995 – 2005	GISS	RCP 6.0	2025 – 2035
1975 – 2005	CESM	RCP 4.5	2025 – 2100
		RCP 6.0	2025 – 2055
		RCP 8.5	2025 – 2100
1995 – 2005	GFDL	RCP 8.5	2025 – 2100



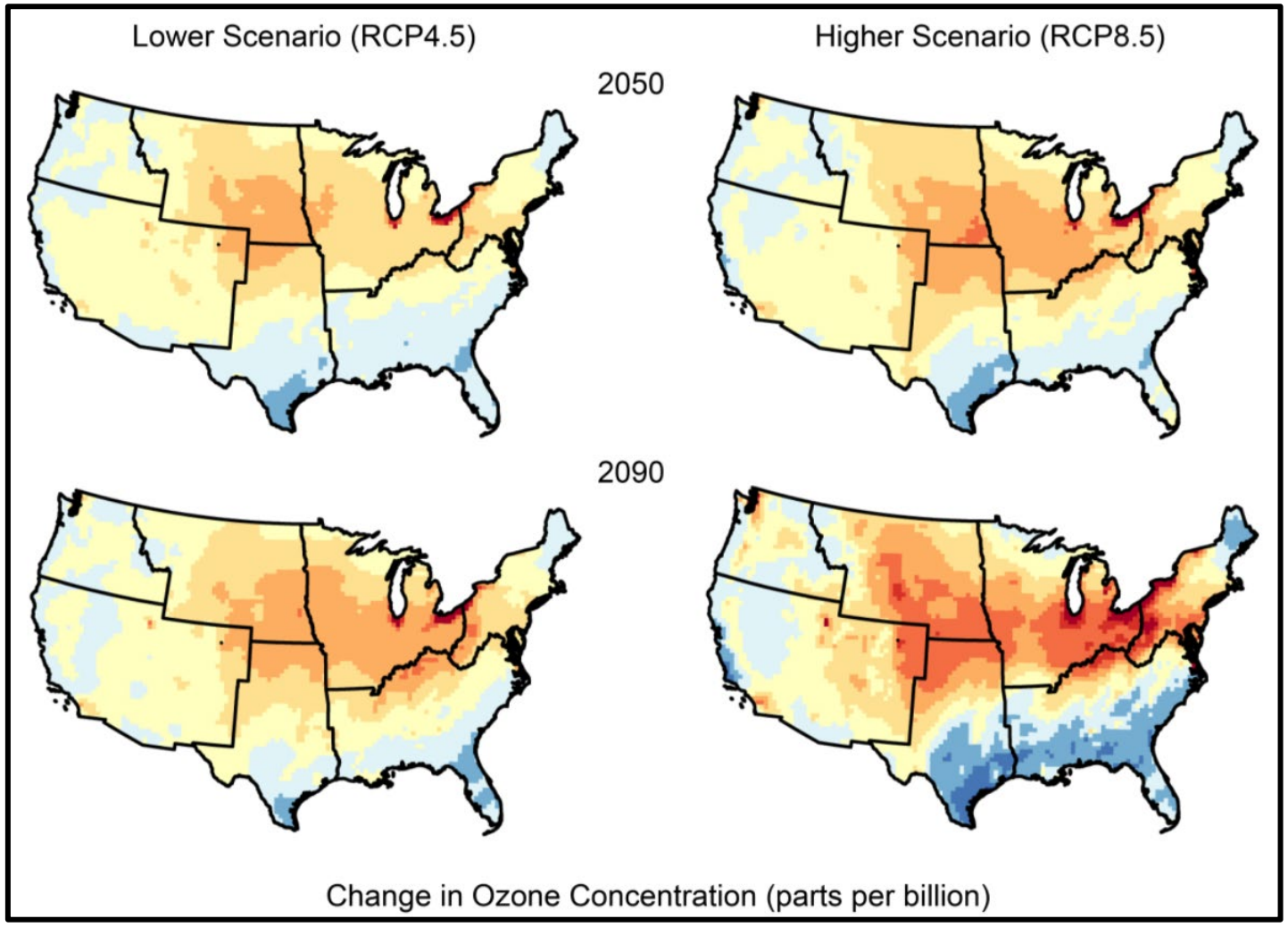
*RCP = "Representative Concentration Pathway" (scenarios from CMIP5, prior generation of global modeling)

EDDE in Action: Impacts of Climate Change on Air Quality



https://health2016.globalchange.gov

Projected Changes in Ozone at 2050 & 2090 under Two Scenarios

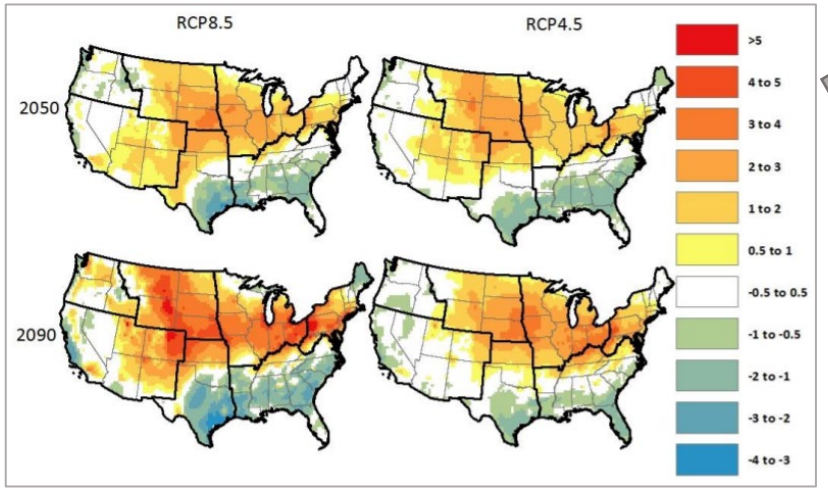


https://www.globalchange.gov/nca4

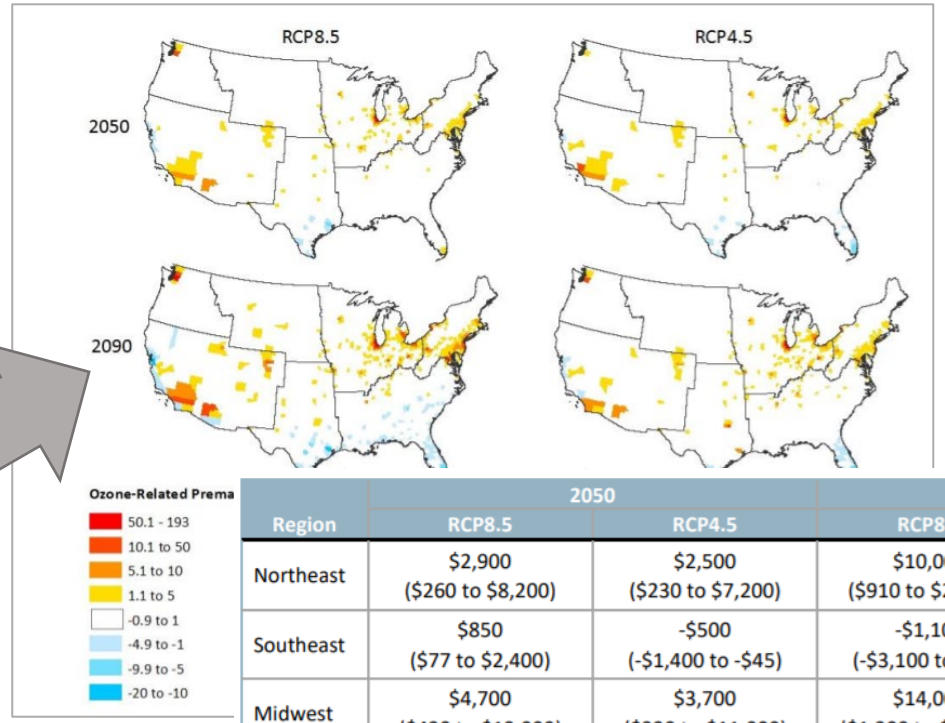
EDDE in Action: Impacts of Climate Change on Air Quality and Human Health

EDDE Data

Air Quality Model (CMAQ)



Health Effects Model (BenMAP)



Change in Premature Deaths

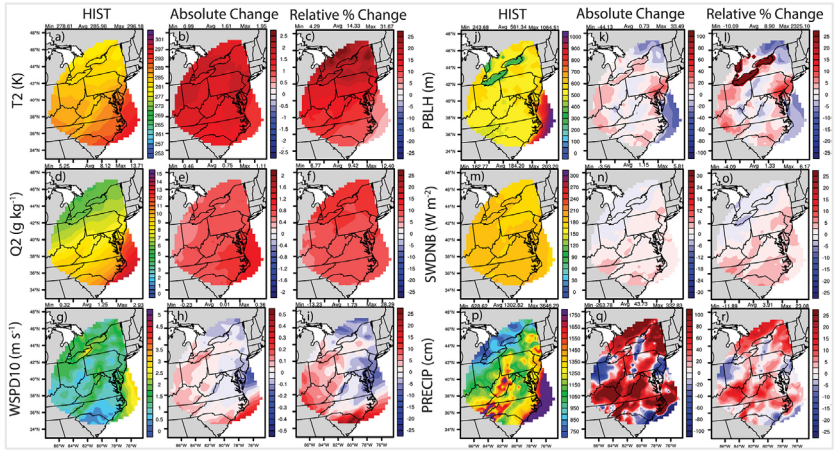
Cost of Excess Deaths

Region	2050		2090	
	RCP8.5	RCP4.5	RCP8.5	RCP4.5
Northeast	$2,900 ($260 to $8,200)	$2,500 ($230 to $7,200)	$10,000 ($910 to $29,000)	$4,700 ($420 to $13,000)
Southeast	$850 ($77 to $2,400)	-$500 (-$1,400 to -$45)	-$1,100 (-$3,100 to -$98)	$1,300 ($120 to $3,800)
Midwest	$4,700 ($420 to $13,000)	$3,700 ($330 to $11,000)	$14,000 ($1,200 to $39,000)	$8,800 ($790 to $25,000)
Northern Plains	$280 ($25 to $810)	$250 ($23 to $720)	$630 ($57 to $1,800)	$440 ($40 to $1,300)
Southern Plains	$40 ($3.6 to $110)	-$53 (-$150 to -$4.7)	-$560 (-$1,600 to -$50)	$1,400 ($120 to $3,800)
Southwest	$770 ($69 to $2,200)	$880 ($79 to $2,500)	$1,700 ($150 to $4,800)	$860 ($77 to $2,500)
Northwest	$240 ($22 to $690)	$65 ($5.8 to $180)	$1,400 ($130 to $4,000)	$450 ($40 to $1,300)
National Total	**$9,800 ($880 to $28,000)**	**$6,900 (-$900 to $21,000)**	**$26,000 (-$2,200 to $78,000)**	**$18,000 ($1,600 to $51,000)**

Fann et al., *JAWMA*, 2015
https://doi.org/10.1080/10962247.2014.996270

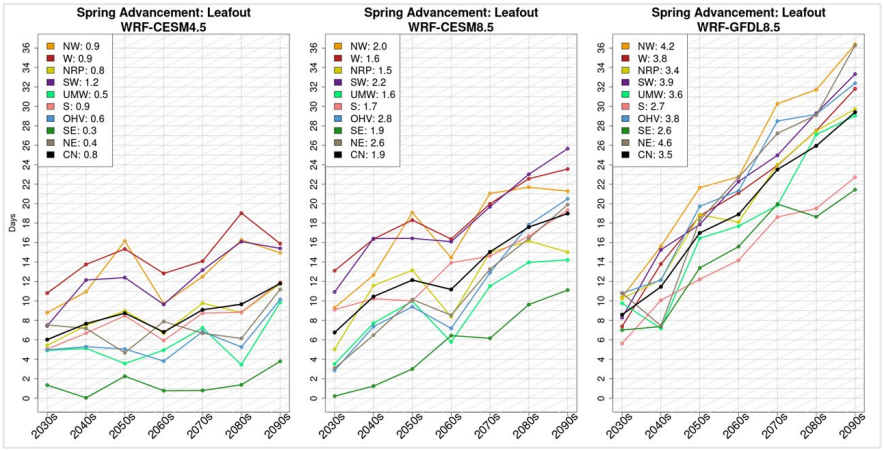
EDDE in Action: Impacts of Climate Change on Ecology and Environment

Nitrogen in the Chesapeake Bay Watershed



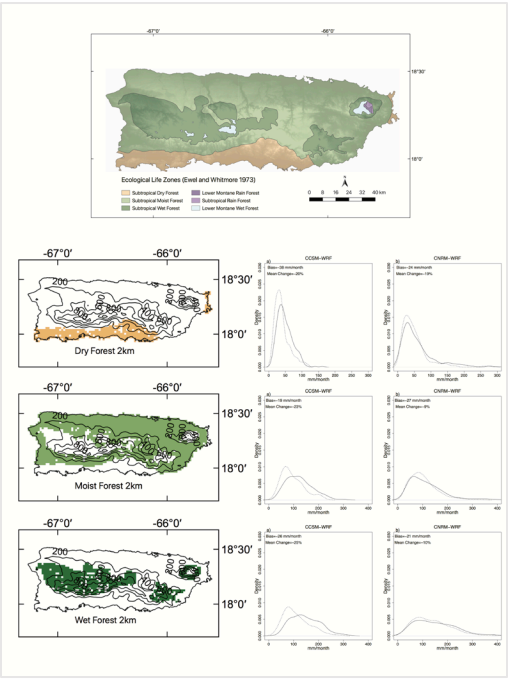
Campbell et al., *JGR-B,* 2018
https://doi.org/10.1029/2019JG005203

Green-up of Plants Advancing Earlier

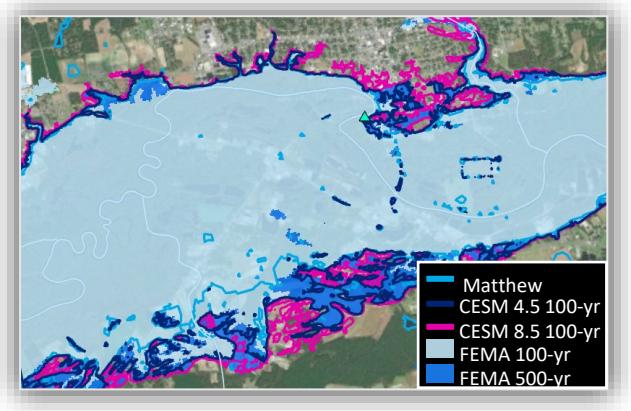


Mallard et al., *JAMC*, 2023
https://doi.org/10.1175/JAMC-D-23-0071.1

Puerto Rico Ecology



Bowden et al., *Int J Clim*, 2021
https://doi.org/10.1002/joc.6810



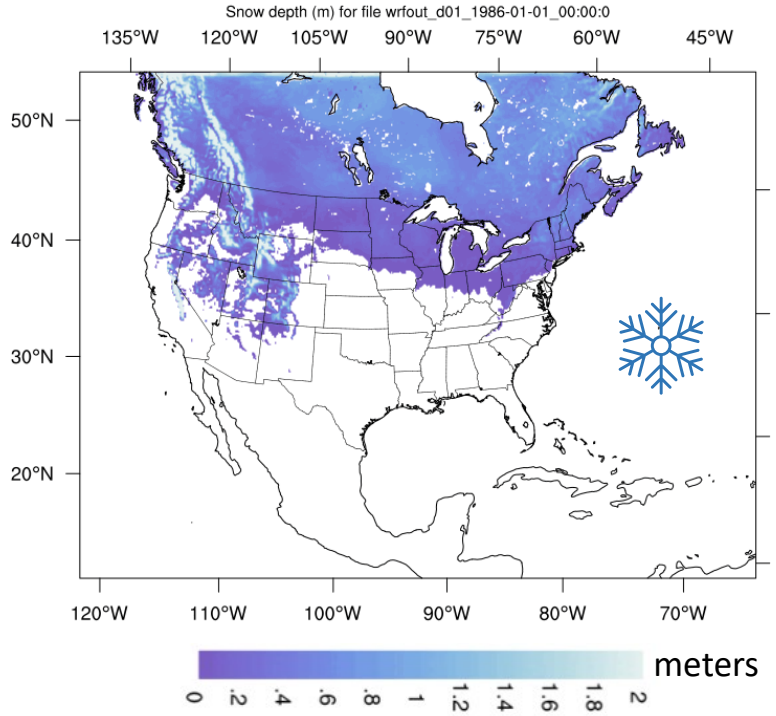
Flooding from Tropical Cyclones and Impact on Disadvantaged Communities

Courtesy of A. Jalowska

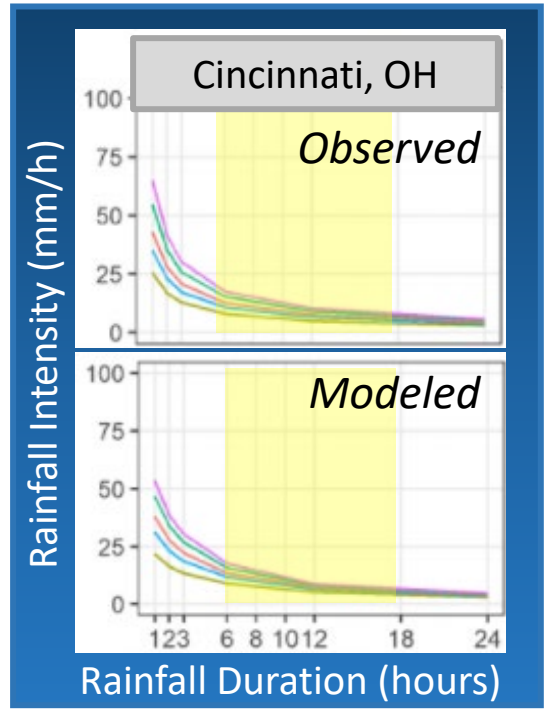
EDDE in Action: Impacts of Climate Change on Snow Hydrology, Extreme Heat/Humidity, and More!

- EDDE design allows for sophisticated analysis of western U.S. hydrology.
- High temporal resolution to explore changes to impactful sub-daily rainfall events.
- Novel output allows for advanced heat/humidity exposure metrics.

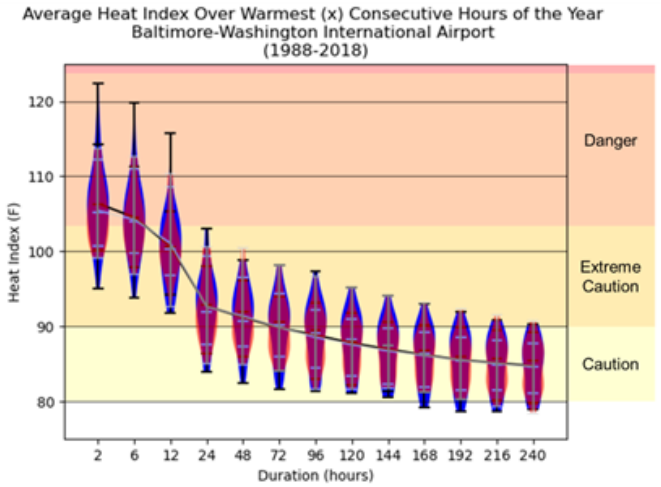
Modeled Snow Depth over a Year



Probabilistic Curves for Extreme Rainfall



Jalowska & Spero, *JGR-A*, 2019
https://doi.org/10.1029/2019JD031584



Probabilistic Curves for Extreme Heat Index

Courtesy of G. Tierney

Comparing EDDE to Statistically Downscaled Data

Advantages

- Not constrained by current historical trends
- More than temperature & precipitation, e.g.,
  - Humidity
  - Wind
  - Soil temperature/moisture
  - Snow
  - Vertical profiles
- Data are dynamically consistent
- Availability of hourly and sub-hourly data
- Facilitates connections to other environmental and assessment models for resilience and adaptation activities.

Limitations

- Fewer scenarios
  - →Smaller spread of possible futures
  - →Cannot explore data using “spaghetti plots”
- Coarser grid spacing
  - →Data are less “localized”, but localized data may have false precision
- No bias correction used
  - →Global climate representation of historical period inherits biases.

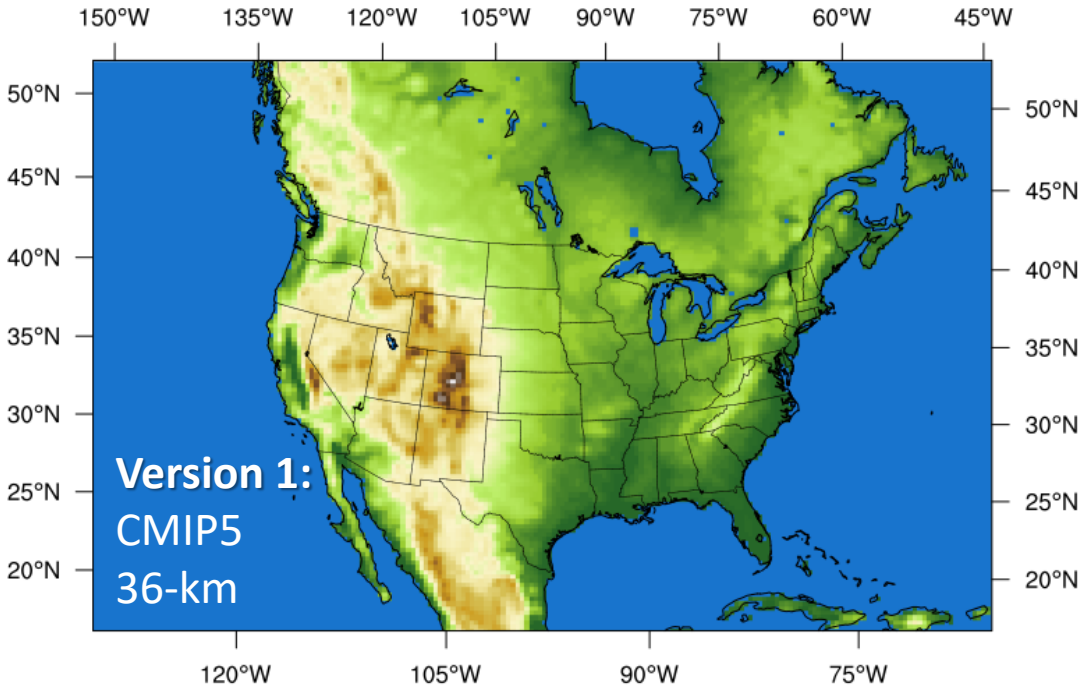
Must select the data source that is **fit for purpose**.

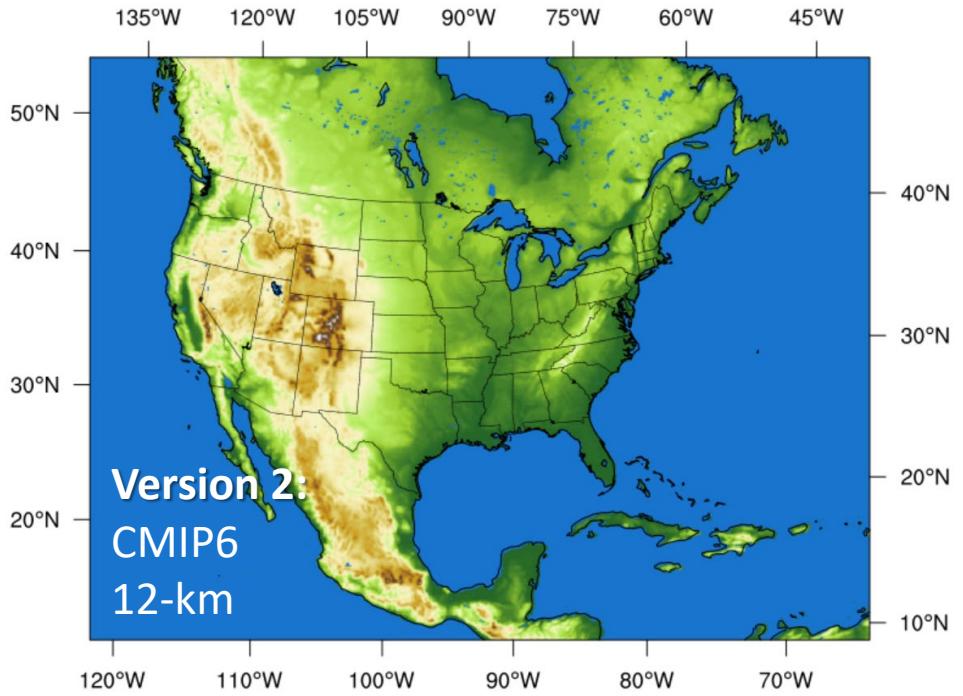
LIVE DEMONSTRATION!

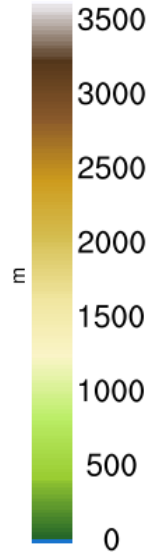
How to:

- Browse model outputs
- Download files
- Make plots

In Progress: EDDE Version 2







1985 – 2015

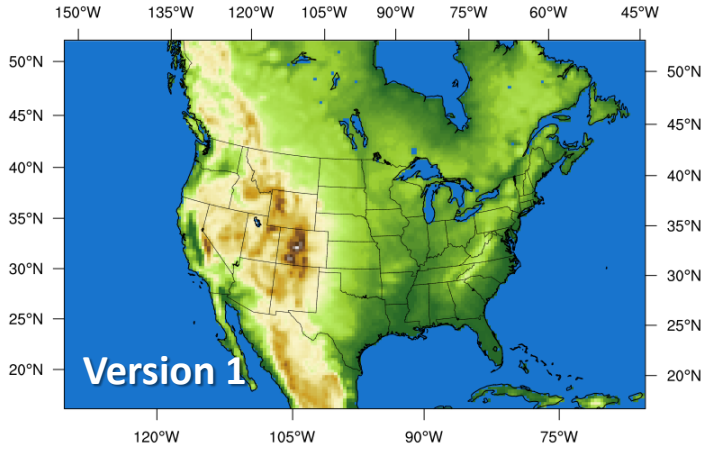
- MPI-ESM1-2-HR
- GFDL-CM4/ESM4
- EC-Earth3-Veg

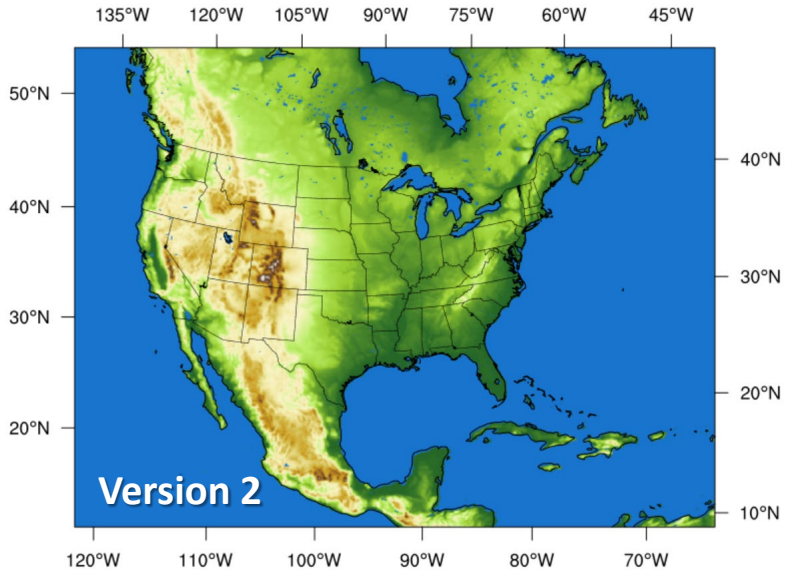
SSP1-26	2025 – 2100
SSP2-45	2025 – 2100
SSP3-70	2025 – 2100

*__SSP__ = “Shared Socioeconomic Pathway” (scenarios from CMIP6, current generation of global modeling)

EDDE Data are Now Available on AWS!

- Comprehensive & dynamically consistent regional climate projections at hourly increments to 2100.
- Expanded suite of atmospheric variables (not just temperature and precipitation).
- Suitable for downstream environmental modeling.
- Additional data available upon request.
- Newer data coming soon!
  - 12-km expanded domain with CMIP6 models.
  - Includes U.S. Caribbean
  - Includes 5-minute output for selected variables.





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Learn more about EDDE:
https://www.epa.gov/climate-research/epa-dynamically-downscaled-ensemble-edde

EDDE on AWS:
https://epa-edde.s3.amazonaws.com/index.html

https://registry.opendata.aws/epa-edde-v1/

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