The State of Decision-Relevant Regional Climate Projections

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U.S. Department of Energy | Office of Science
HYPERFACETS
A Framework for Improving Analysis and Modeling of Earth System and Intersectoral Dynamics at Regional Scales

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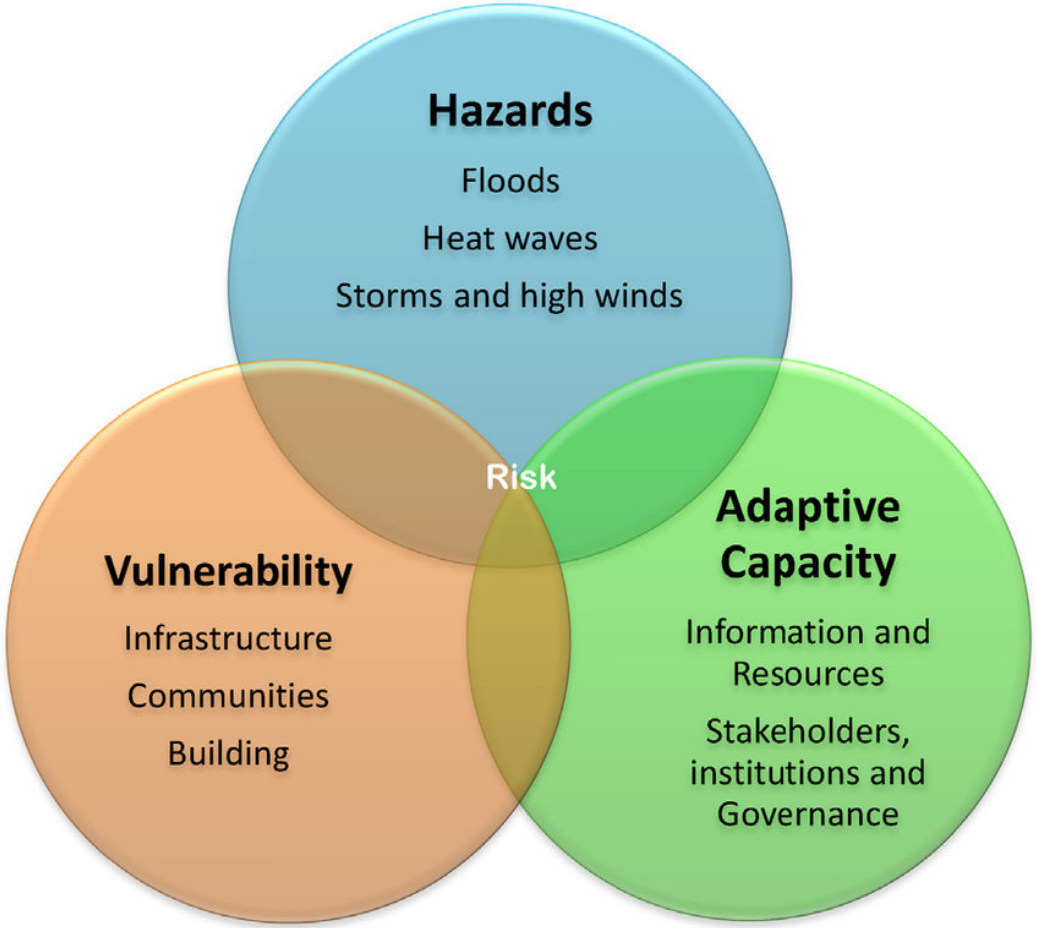
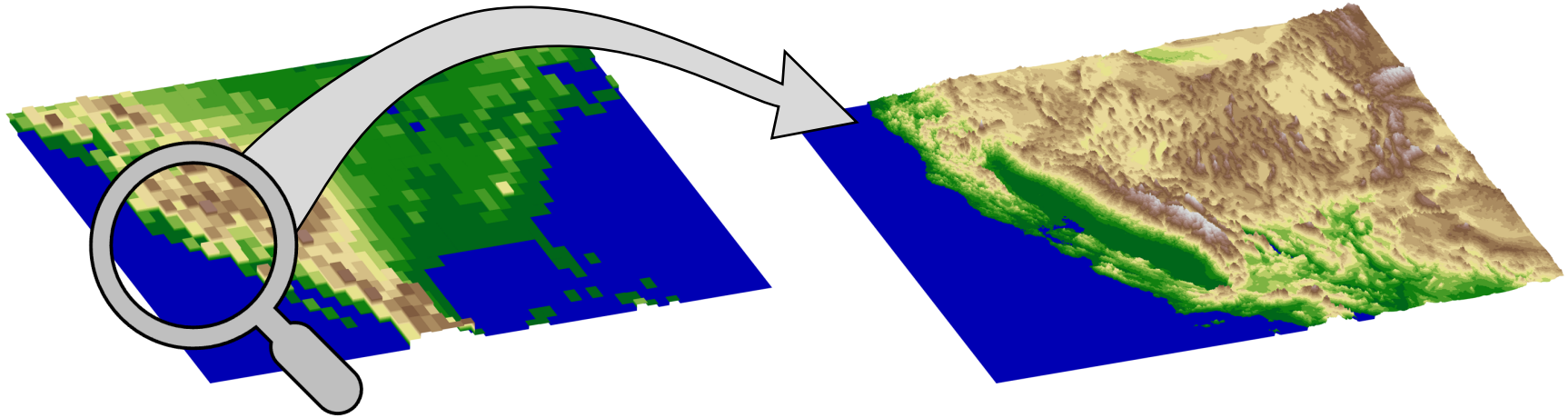
User Needs for Decision-Relevant Climate Data

Decision-relevant climate data is essential for mitigation and adaptation planning across a variety of regions and sectors. However, this data also needs to be:

- **Salient:** Localized to regions of interest for stakeholders and decision-makers. Including variables of relevance for a given application.
- **Credible:** Historically validated, capturing relevant processes and right for the right reasons.
- **Authoritative:** Backed by independent experts.
- **Accessible:** Ready for use.



What is Downscaling?



Many different **global climate model (GCM)** simulations have been conducted as part of the **Coordinated Model Intercomparison Project (CMIP)**.

These cover both historical periods (what was possible) and future periods (what will be possible).

However, CMIP GCM data is typically too coarse for decision-makers, who are interested in **resolving local scales** (individual mountain peaks, towns, valleys and coastlines) and **assessing local impacts** (e.g., extreme weather, renewable energy production).

Downscaling techniques allow GCM output to be **enhanced to decision-relevant scales**, making it relevant on local scales and for understanding scale-sensitive phenomena.

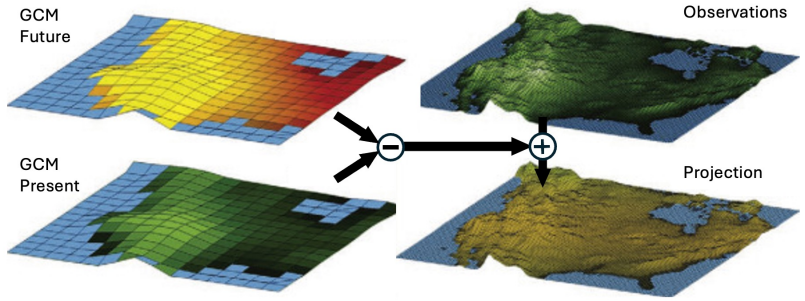
Types of Decision-Relevant Data Products

Statistically Downscaled Products (SDPs): Data products based on empirical and algorithmic relationships between coarse and fine scales, generally derived from observations (e.g., LOCA2, STAR-ESDM).

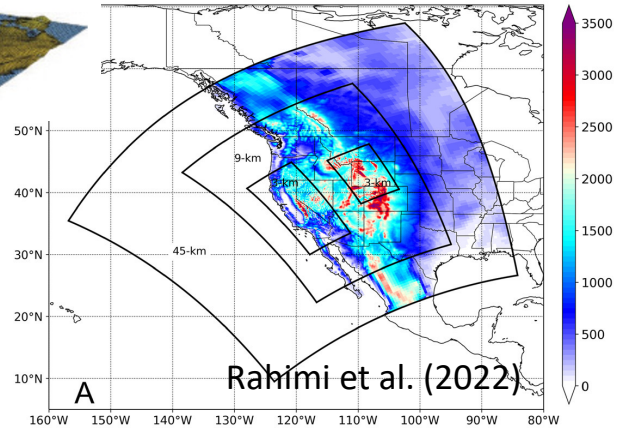
Dynamically Downscaled Products (DDPs): Data produced by regional climate models forced by coarse-resolution climate model inputs or reanalysis data.

Regionally-Refined Models (RRMs): Data produced using global climate models with nested or refined grids over a region of interest (e.g., DOE's E3SM).

Artificial Intelligence / Machine Learning (AI/ML): Cutting-edge and exploratory techniques for downscaling using data-driven methods.

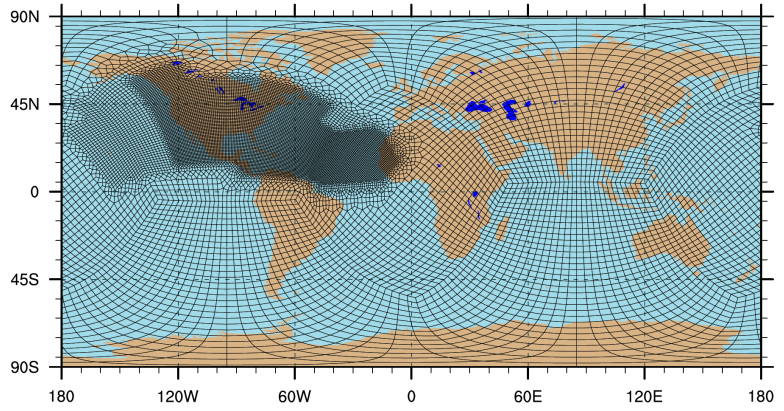


Left: *A basic technique used for statistical downscaling.*



Right: *Nested dynamical downscaling domains used in recent work by UCLA.*

Rahimi et al. (2022)



Left: *A regionally-refined E3SM mesh used by the DOE HyperFACETS project to develop a high-resolution ensemble for the CONUS.*

Many New Climate Data Products over CONUS

Statistically Downscaled Products	Grid Spacing	Years
Localized Analogues v2 (LOCA2)	6km / 3km Calif.	1950-2100 (multiple)
Seasonal Trends and Analysis of Residuals (STAR) Empirical-Statistical Downscaling Model (ESDM)	4km	1950-2100 (multiple)
Multivariate		(multiple)

Which data should we use?

Dynamically		
Argonne Dyn		future (x3 models)
IM3/HyperFACETS TGW Ensemble	12km	40 hist + 40 PGW (x8 scenarios)
PNNL Western US Product	6km	42 hist + 30 PGW (x5 ensemble)
Western U.S. Dynamically Downscaled Dataset	9km and 3km	40 hist + 85 SSP370 (x9 ensemble)
NCAR CONUS1 Product	4km	13 hist + 13 RCP8.5
NCAR CONUS2 Product	4km	21 hist + 21 RCP8.5
NCAR CONUS404 Product	4km	42 hist + 44 SSP370

State of the Science

- Only **statistically and dynamically downscaled** products available for operational use

- **Statistical products** are the most mature
  - Most ensemble members
  - Multiple future trajectories
  - Generally available at ~5km grid spacing

- However, statistical methods are trained on historical data
  - Some evidence they **may underestimate future precipitation extremes**

- Statistical methods also (largely) only offer daily temperature and precipitation data
  - Some exceptions (e.g., NEX-GDDP at 25km using satellite training)

- Work is underway to develop bias-corrected dynamically downscaled products for operational use
  - Most promising at present is ClimRR product (Argonne National Lab) at ~12km grid spacing
  - For the Northeastern United States, work by Muge Komurcu (NASA) https://doi.org/10.1029/2018EA000426

Why Do Users Choose Particular Data Products?

Selection of climate data products often occurs via:

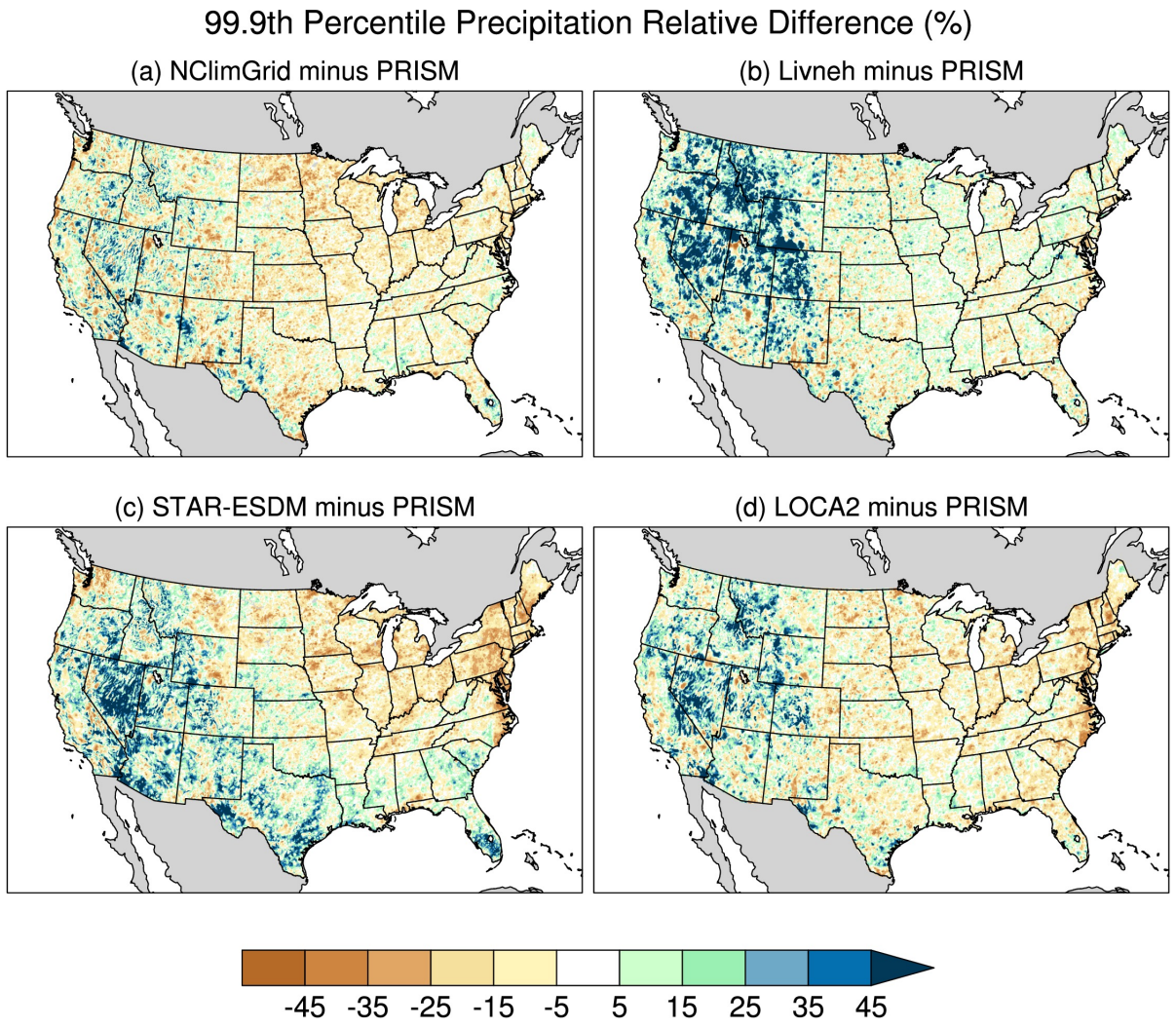
- Word-of-mouth
- Existing collaborations
- Agency affiliation
- Government mandate
- Use elsewhere
- Highest resolution available
- It's what's available

A better basis for selection:

- Comprehensively validated and evaluated
- Complete documentation
- Methodology supported by experts

Consideration of multiple data products is generally recommended for decision-making, but incompatibilities and inconsistencies means multiple products are rarely used in practice.

Evaluation of LOCA2 and STAR-ESDM



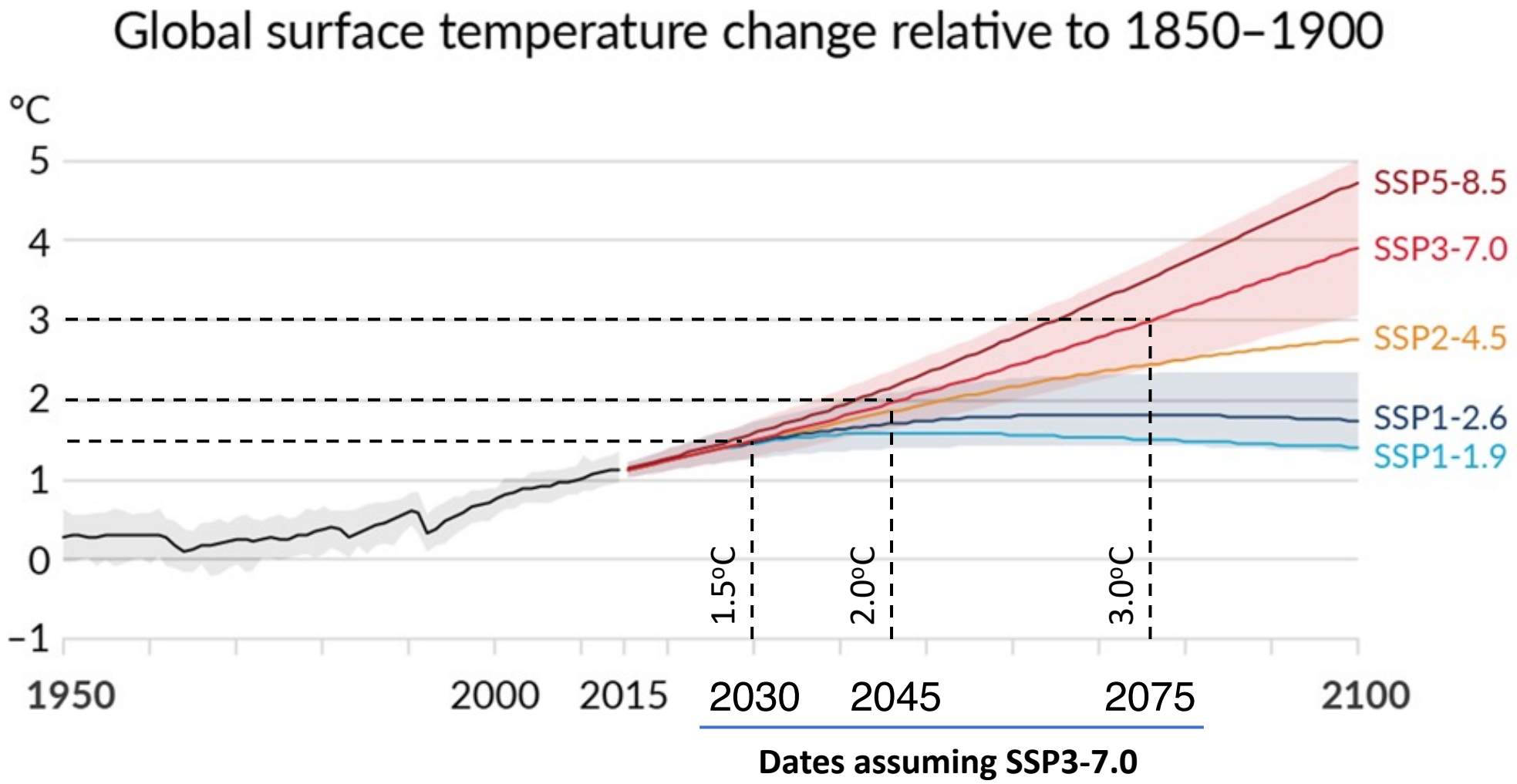
LOCA2/STAR-ESDM Validation Report

Developed by the Program for Climate Model Diagnosis and Intercomparison (PCMDI)

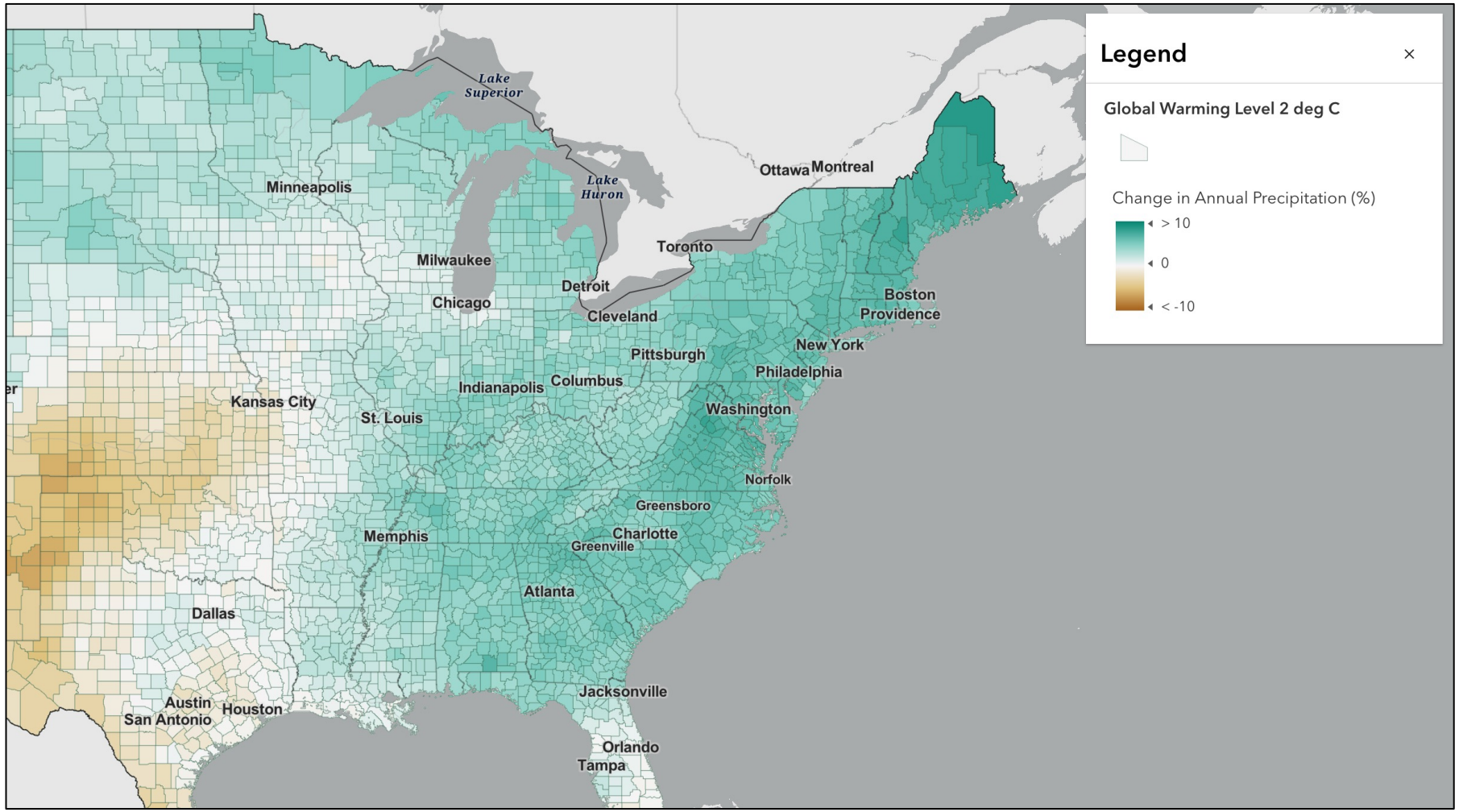
NCA5 Atlas

https://atlas.globalchange.gov/

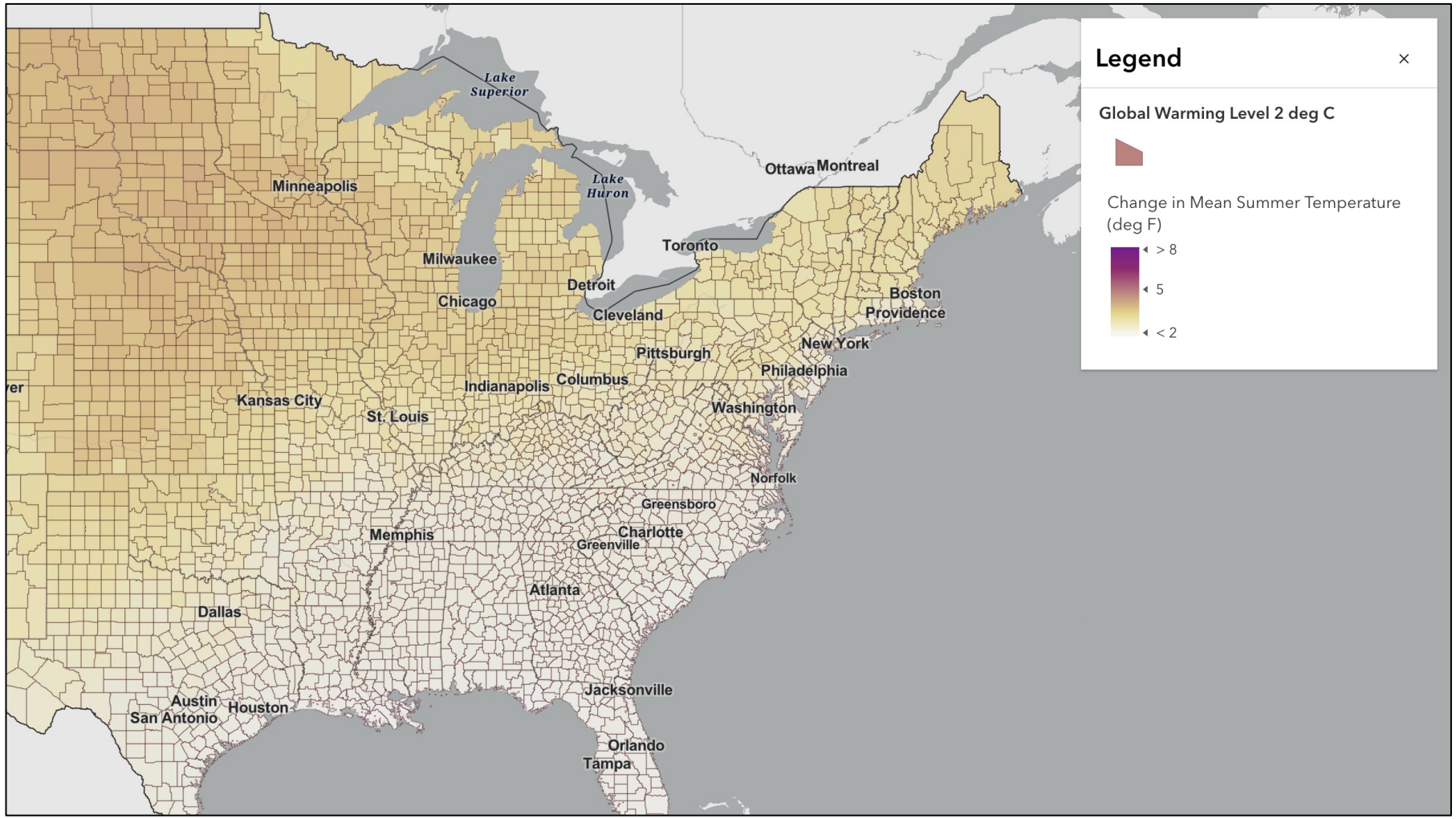
Global Warming Levels



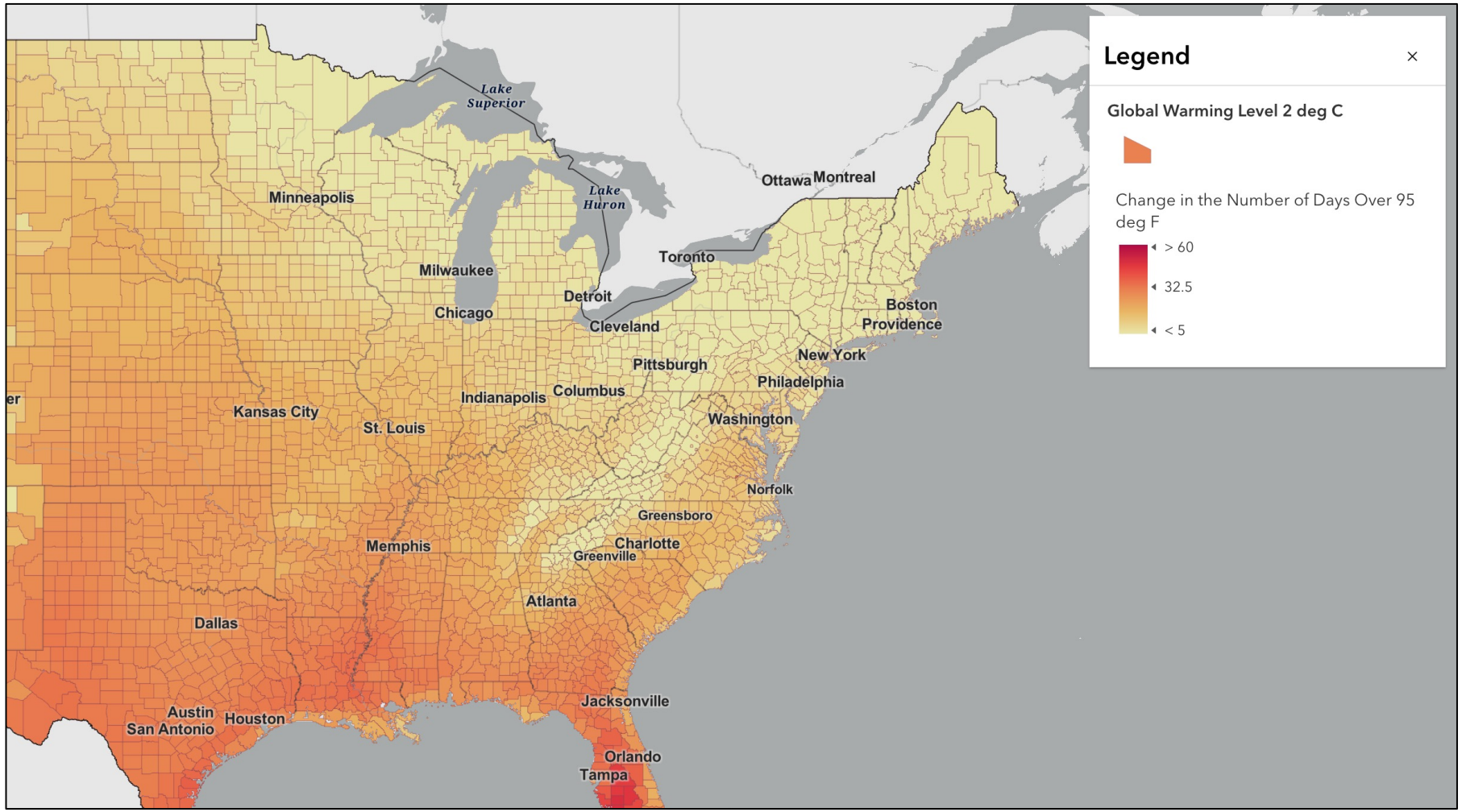
Change in Annual Precipitation (2°C WL)



Change in Mean Surface Temperature (2°C WL)



Change in Number of Days Above 95F (2°C WL)



Understanding Decision-Relevant Regional Climate Data Products Workshop

Co-Lead Paul Ullrich, UC Davis and Lawrence Livermore Nat'l Lab

Co-Lead Daniel Feldman, Lawrence Berkeley Nat'l Lab

Fred Lipschultz, United States Global Change Research Program

Samantha Basille, United States Global Change Research Program

Keith Dixon, National Oceanic and Atmospheric Administration

Kevin Hiers, Strategic Environmental Research and Development Program

Sarah Abdelrahim, Federal Emergency Management Agency

Daniel Barrie, National Oceanic and Atmospheric Administration

David Herring, National Oceanic and Atmospheric Administration

Renu Joseph, U.S. Department of Energy

Kyo Lee, National Aeronautics and Space Administration Jet Propulsion Lab

Tanya Spero, Environmental Protection Agency

United States Global Change Research Program

Understanding Decision-Relevant Regional Climate Data Products Workshop

November 14-16, 2023 in Berkeley, California

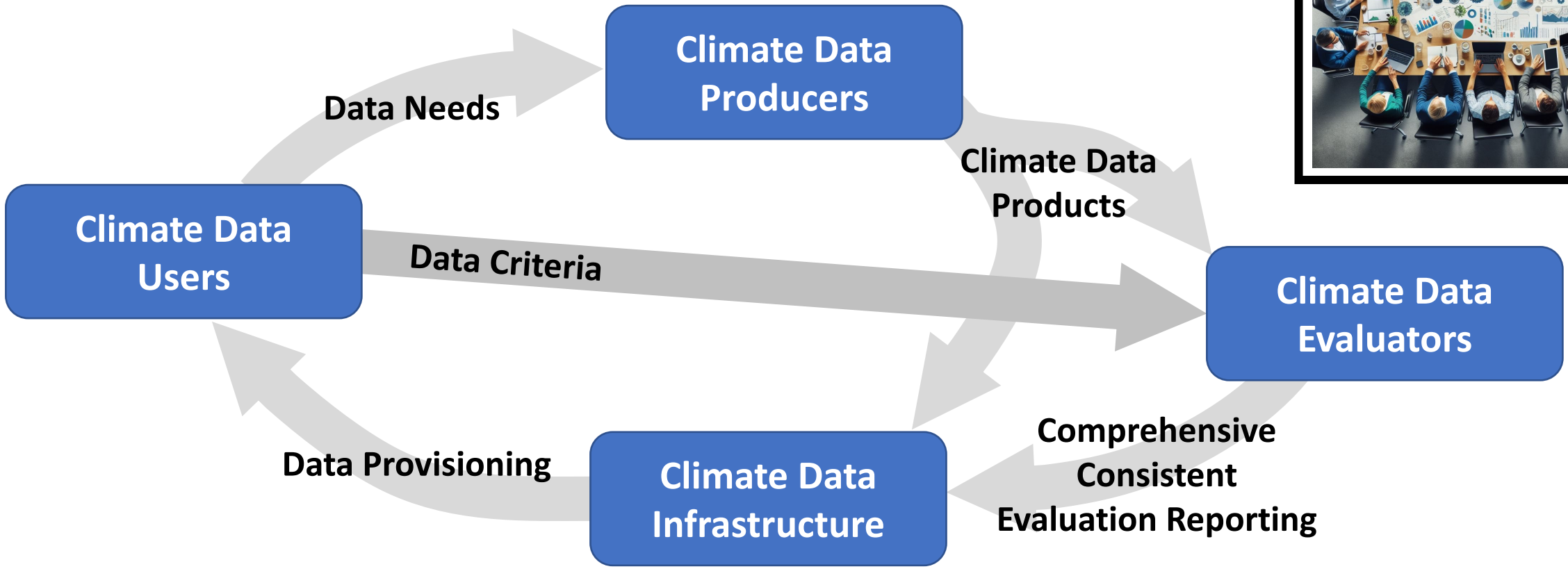
A meeting of scientists from DOE/PCMDI and DOD/SERDP, together with researchers, data producers, end-users and agency representatives to understand the state of the nation's decision-relevant regional climate datasets and projections.

All operational approaches considered, including statistical downscaling, dynamical downscaling, hybrid downscaling, regionally-refined global modeling and AI/ML based methods.

Workshop scope: How to characterize the strengths and weaknesses of decision-relevant climate data products and build bridges between data producers, data analysts and data users.

United States Global Change Research Program

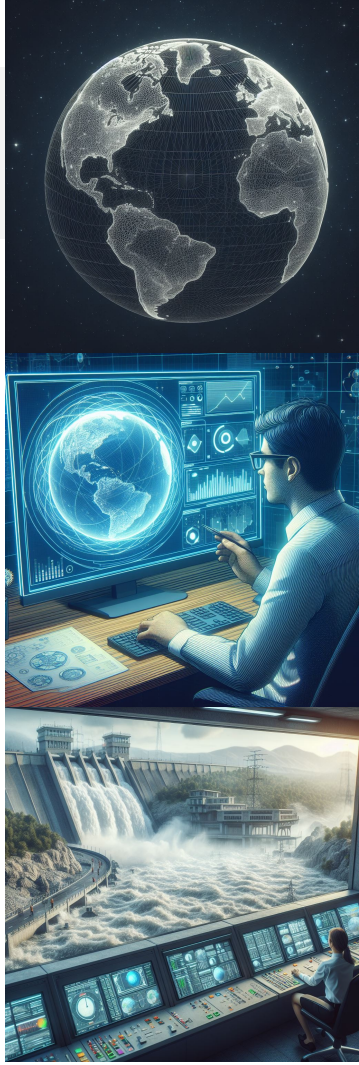
Need for a Community of Practice



Common standards can streamline communication among community members and reduce the effort necessary to incorporate data in the decision process.

Summary

- **Many different climate data products** now available using a variety of methods
- Choosing the right climate data product to use can be difficult and confusing
- The NCA5 Atlas provides summaries of two common statistical downscaling products (averaged together): LOCA2 and STAR-ESDM
    - Both of these products are **good choices for future projections** and **largely agree with one another** for projected change
- We are working towards the development of a **community of practice** to better organize efforts on climate data
- Stay Tuned!



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Thank You!

Questions?

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