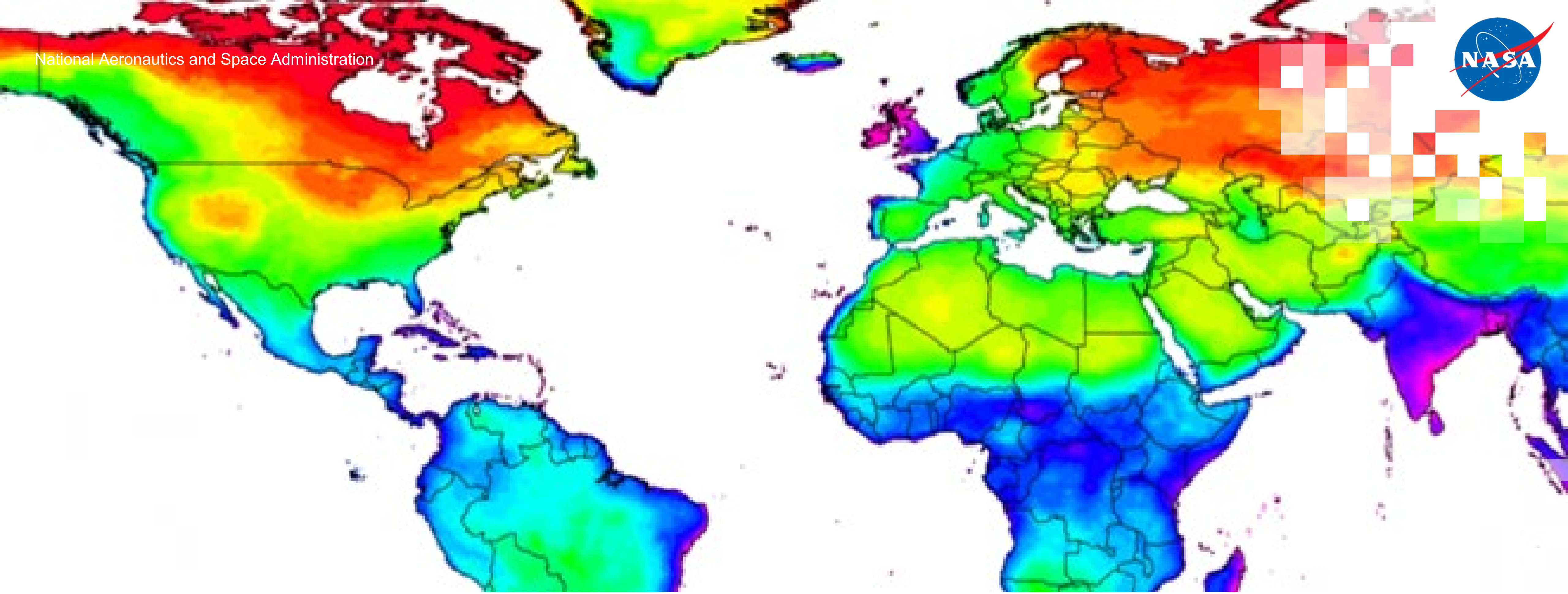
National Aeronautics and Space Administration

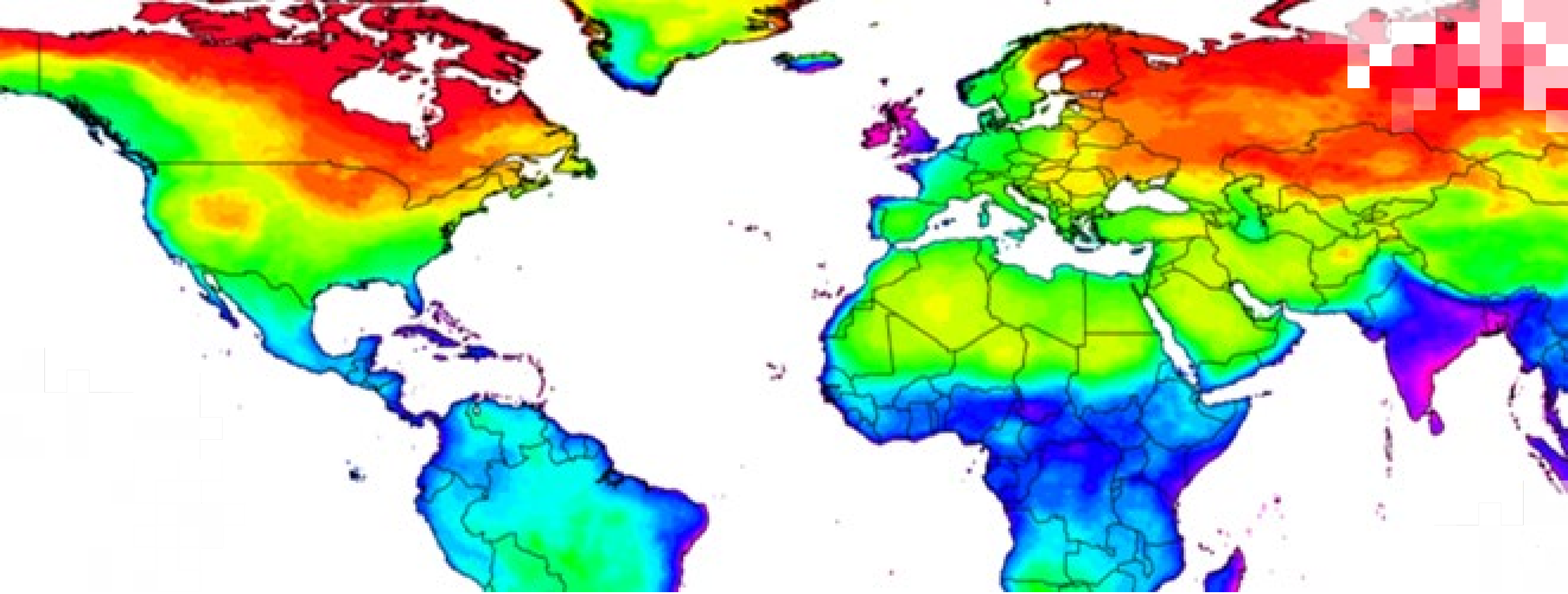


Assessing Extreme Weather Statistics using NASA Earth eXchange Global Daily Downscaled Projections Coupled Model Intercomparison Project Phase 6 (NEX-GDDP-CMIP6)

Part 1: NEX-GDDP-CMIP6 Overview, Data Access, and Application using Google Earth Engine

Amita Mehta (612, GESTAR II), Dr. Bridget Thrasher (Climate Analytics Group)

September 10, 2025



About ARSET

About ARSET

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- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.

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- Cost-free
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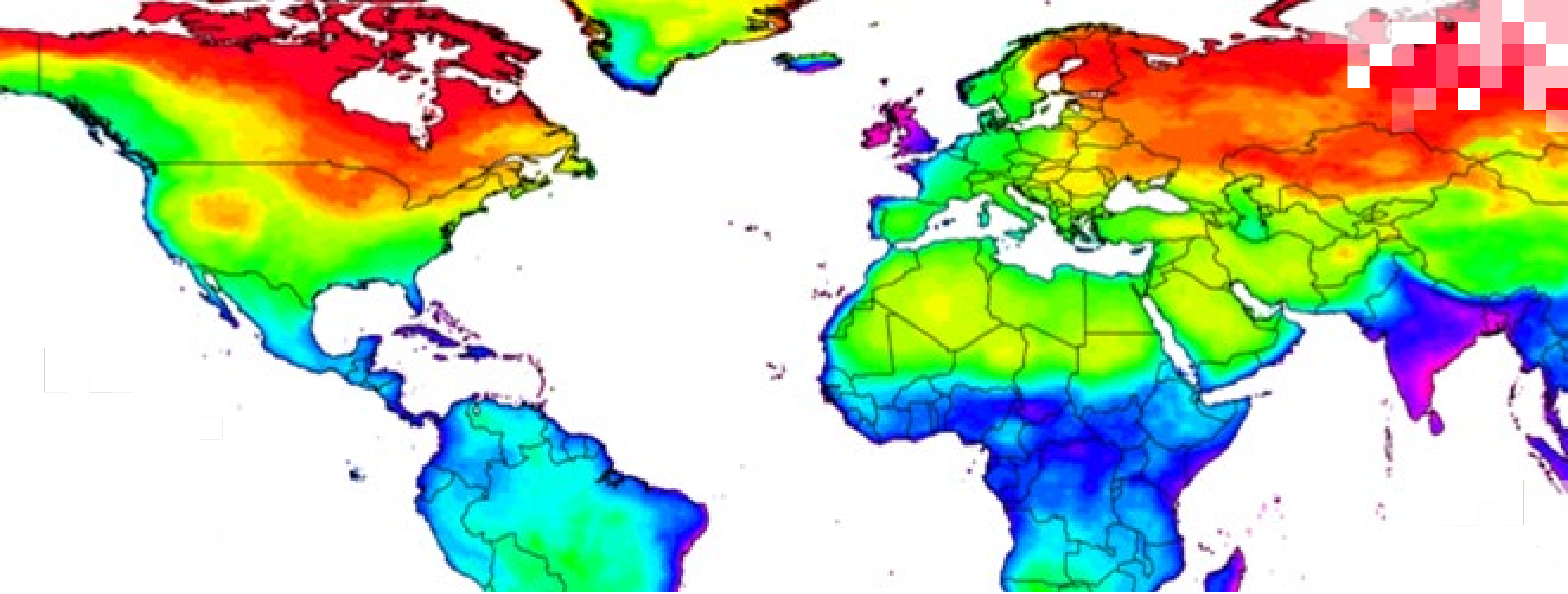
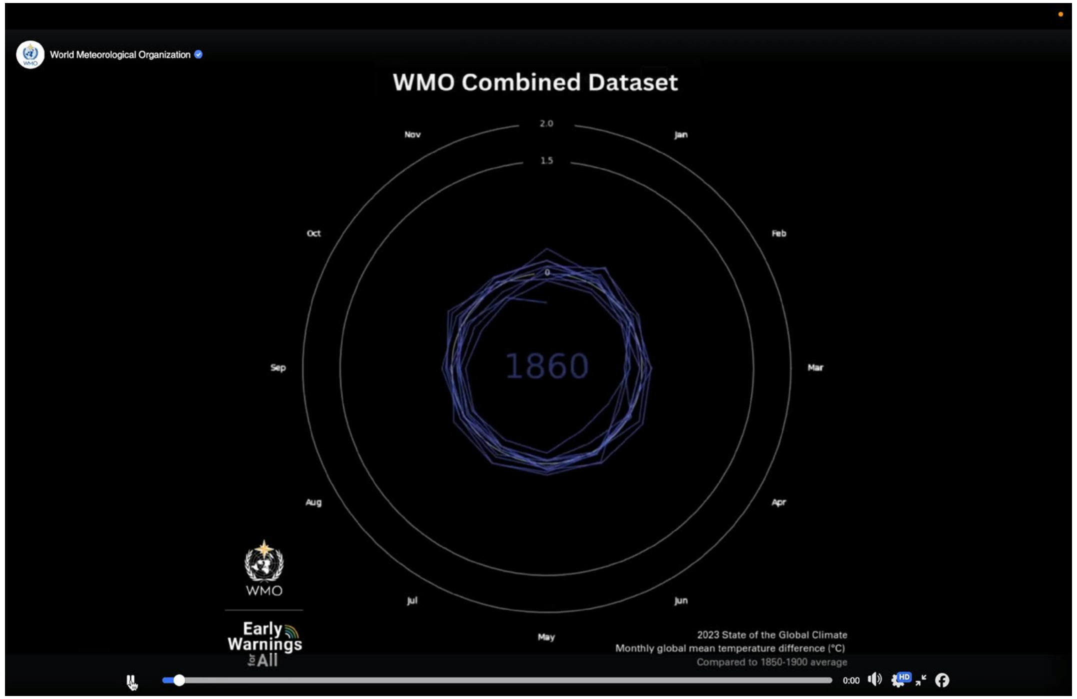


Assessing Extreme Weather Statistics using NASA Earth eXchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6)

Background

Why Study Extreme Events?

- The frequency and intensity of extreme weather events, including heat and cold waves, heavy precipitation and droughts, and wildfires, have increased fivefold in the last 50 years (World Meteorological Organization).
- Earth observations from NASA allow monitoring of extreme events (NASA) from the last 20+ years to near-real time (NASA Worldview).
  - **For developing regional adaptation and mitigation strategies, however, it is crucial to assess how the extreme events will unfold over the coming decades.**



🌍 The latest WMO European State of the Climate 2024 report details the spiraling effects of weather and climate impacts.

⚡ Extreme weather continues to bring devastating consequences globally, with the report also highlighting significant economic and social upheavals.

Global Climate Models

- There are 100+ Earth System Models (ESMs) from 50+ modeling institutions.
- Leading modeling groups have coordinated simulations of climate change scenarios within the auspices of the Coupled Model Intercomparison Project (CMIP Phase 6 is the current phase).
- Modeling institutions are constantly improving their models (e.g., higher resolution, improved physics and chemistry, more processes).
- The CMIP6 Global Climate Models (GCMs) provide predictions and projections of extreme events.

- **The typical spatial resolution of GCMs is lower than 1x1 degree latitude-longitude.**
- **For regional applications, NASA Earth eXchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6) provide global, high resolution, bias-corrected projections of daily weather parameters from CMIP6 GCMs at 0.25x0.25-degree resolution.**

Global Climate Projection

NEX-GDDP Climate Evolution Projection

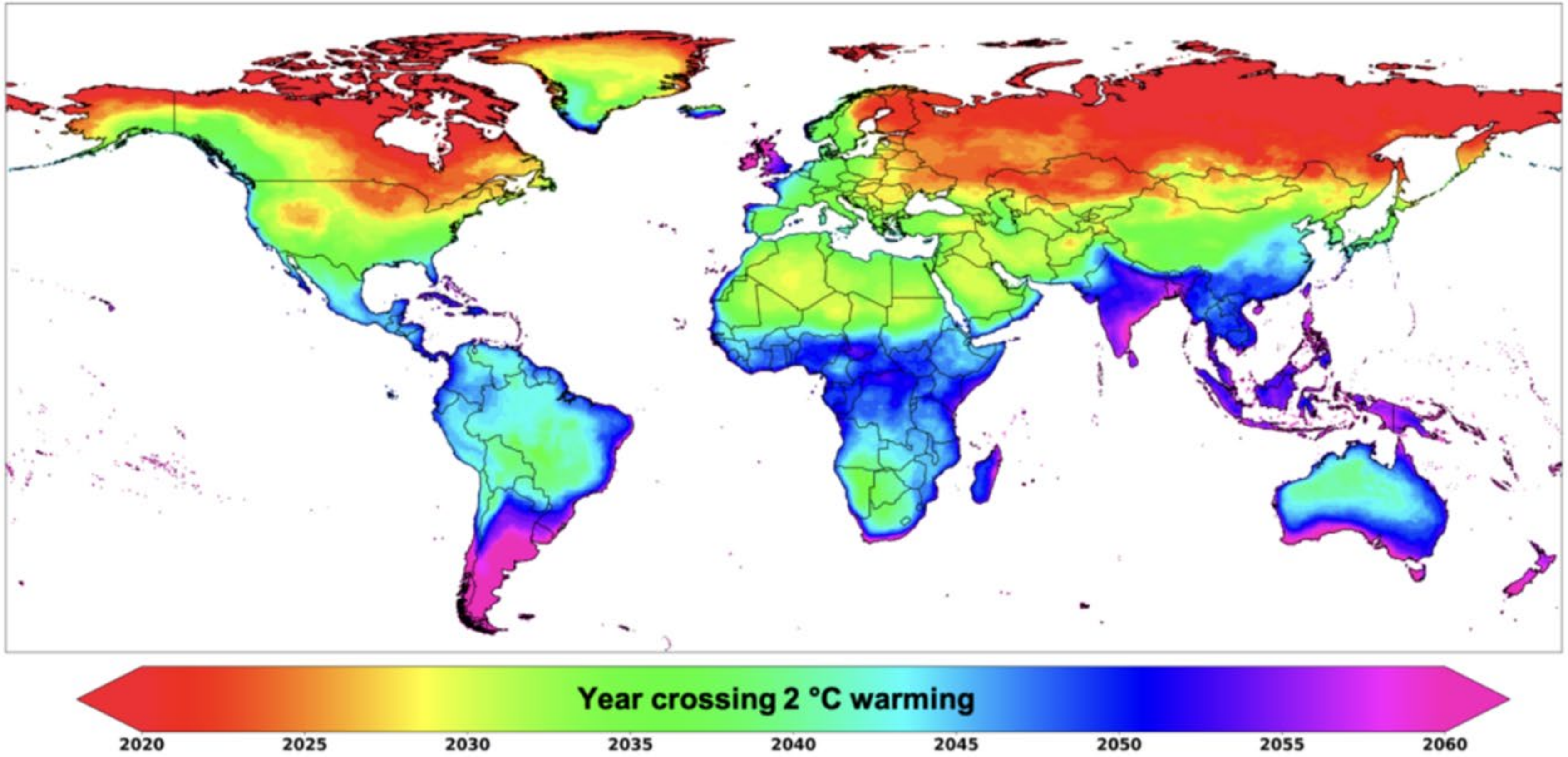


Figure. Spatial pattern of years exceeding the 2-degree warming with respect to the baseline period (1950-1979). The 15-year moving average of the ensemble median of near-surface air temperature from 35 CMIP6 models (SSP585 scenario) was used in detecting the years exceeding the 2-degree warming.

Training Learning Objectives

By the end of this training, participants will be able to:

- Identify available daily, high-resolution geophysical parameters from NEX-GDDP-CMIP6 to assess extreme weather statistics at a regional scale.
- Access daily temperature and precipitation data for a region of interest to calculate and analyze weather statistics using NEX-GDDP-CMIP6 data in Google Earth Engine.
- Visualize maps of extreme weather statistics for a region of interest using NEX-GDDP Dashboard.
- Customize provided Python/Jupyter notebook scripts to calculate extreme weather statistics for a region of interest.
- Assess projected statistics of extreme heat and cold wave events, and excess and deficit precipitation events from NEX-GDDP-CMIP6 at regional scale during the 21st century to evaluate risk for a region of interest.

Prerequisites

- Fundamentals of Remote Sensing
- Drought Monitoring, Prediction, and Projection using NASA Earth System Data. NASA Applied Remote Sensing Training Program (ARSET): Part-3.
- Selecting Climate Change Projection Sets for Mitigation, Adaptation, and Risk Management Applications.
- Climate Change Monitoring and Impacts Assessment using NASA Earth Observations.

- **Create a user account on Google Earth Engine and register to a noncommercial Cloud Project**

  (go to the Cloud Project and then scroll down to 'Get Started')

- **Access the following sites:**

  https://nasa-arset.nationalsciencedatafabric.org

  https://nationalsciencedatafabric.org/nasa-arset

Training Outline

Part 1

NEX-GDDP-CMIP6 Overview, Data Access and Application using Google Earth Engine

September 10, 2025

Part 2

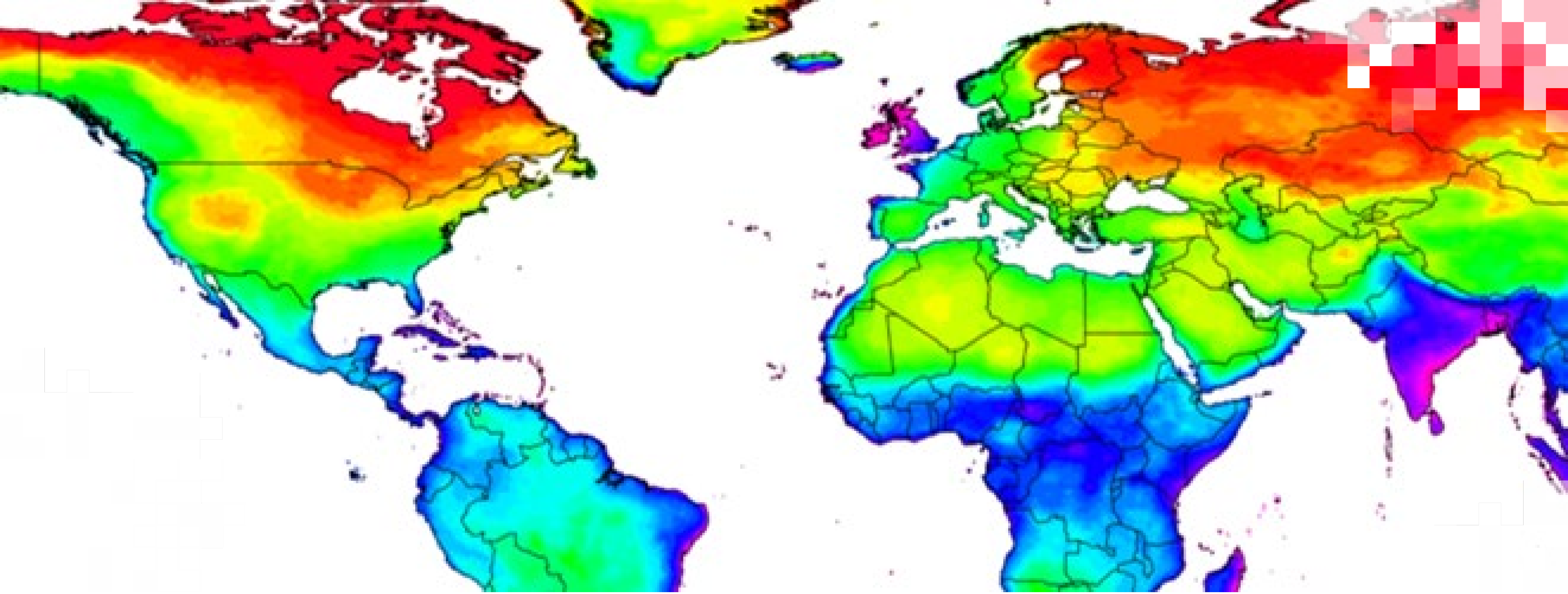
Extreme Event Statistics during 21st Century using NEX-GDDP Data

September 17, 2025

Homework

Opens September 17 – Due October 17 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.



Part 1: NEX-GDDP-CMIP6 Overview, Data Access and Application using Google Earth Engine

Part 1 Objectives

By the end of Part 1, participants will be able to:

- Identify NEX-GDDP-CMIP6 data characteristics
- Recognize how to access and analyze GDDP data for applications using Google Earth Engine

Part 1 Outline

- Overview of NEX-GDDP-CMIP6 Project and Data
- Demonstration: Analysis of extreme event statistics from GDDP data using Google Earth Engine (GEE)
    - Case study region: Nebraska in United States
    - Seasonal extreme cold and hot event frequencies
    - Seasonal extreme wet and dry event frequencies
- Hands-on Exercise: Repeat the case study on your GEE account

How to Ask Questions

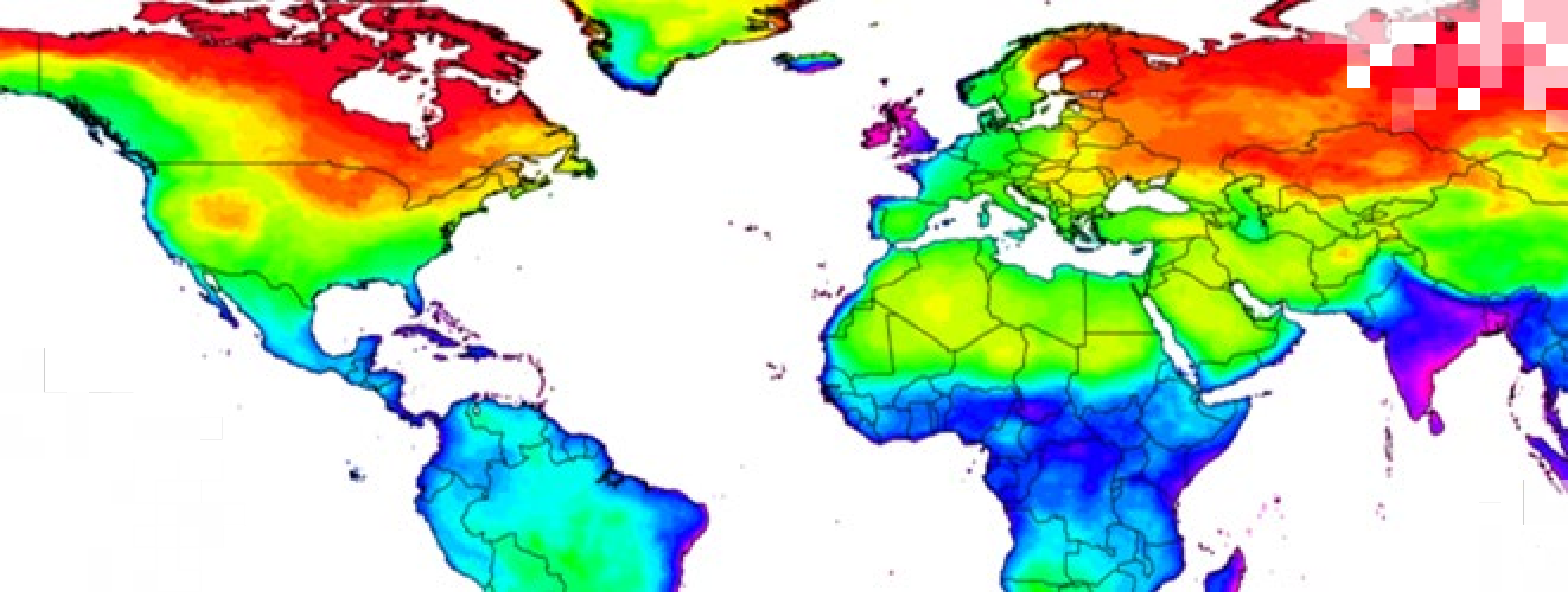
- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

Part 1 – Trainer

Dr. Bridget Thrasher

Climate Scientist

Climate Analytics Group



Overview of NEX-GDDP-CMIP6

Dr. Bridget Thrasher

What is NEX?

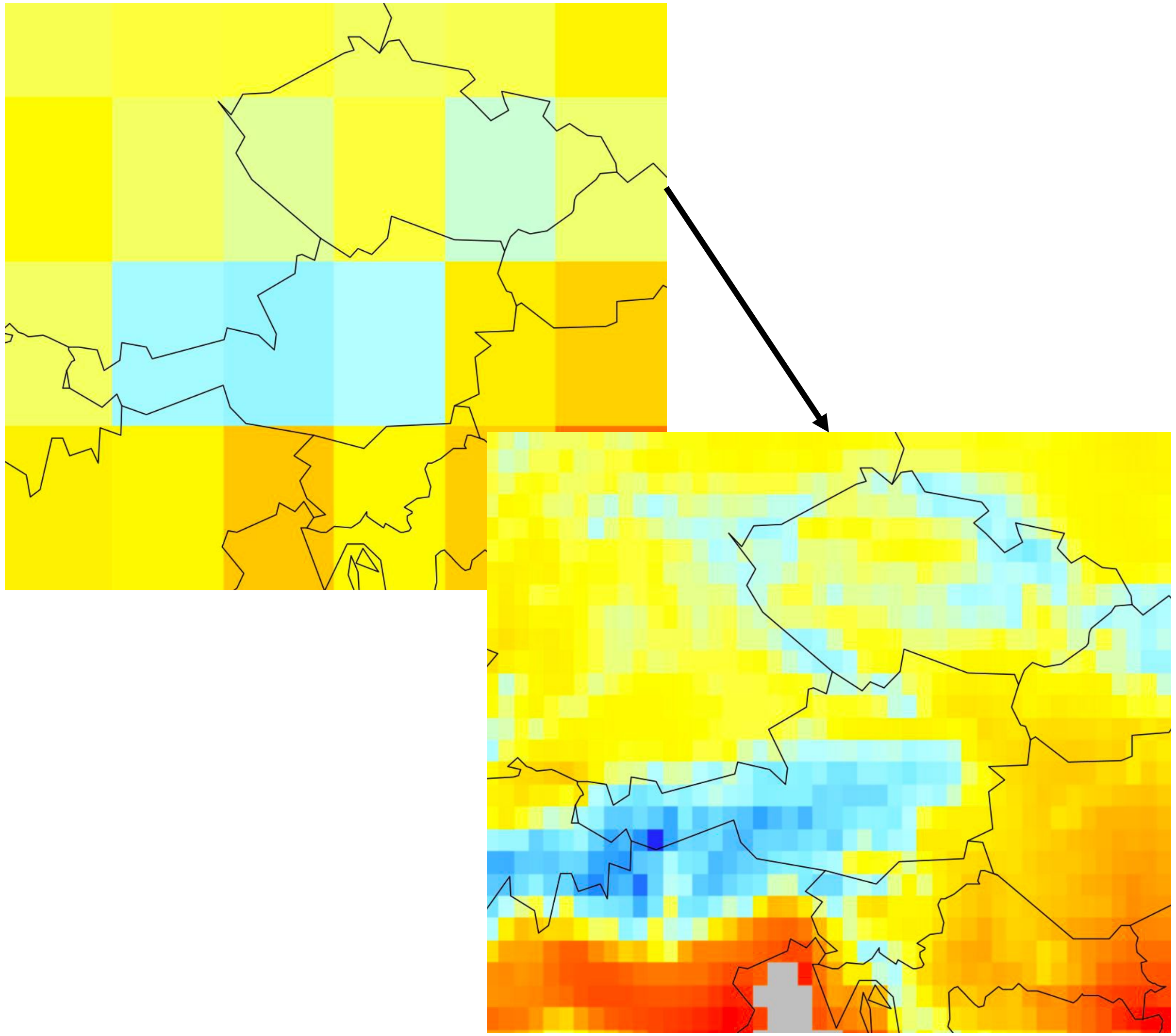
- NASA Earth eXchange (NEX)
  - Collaborative supercomputing and data analytics platform.
  - Improves availability of Earth science data from NASA missions and other sources (e.g., models, analysis tools, and research results).
  - Centralized environment that fosters knowledge sharing, collaboration, and innovation.
  - Available to researchers supported through Research Opportunities in Space and Earth Science (ROSES) and Flight Projects.

What is NEX?

- Also supports:
  - NASA's MEaSUREs program
  - NASA's Carbon Monitoring System (CMS) program
  - Global Ecosystem Dynamics Investigation (GEDI) program
  - National climate assessment (NCA)
  - Geostationary research
  - Advanced Information Systems Technology (AIST) program
  - Applied sciences program
  - Large-scale visualizations of data from NASA's Earth Observing System Data and Information System (EOSDIS)

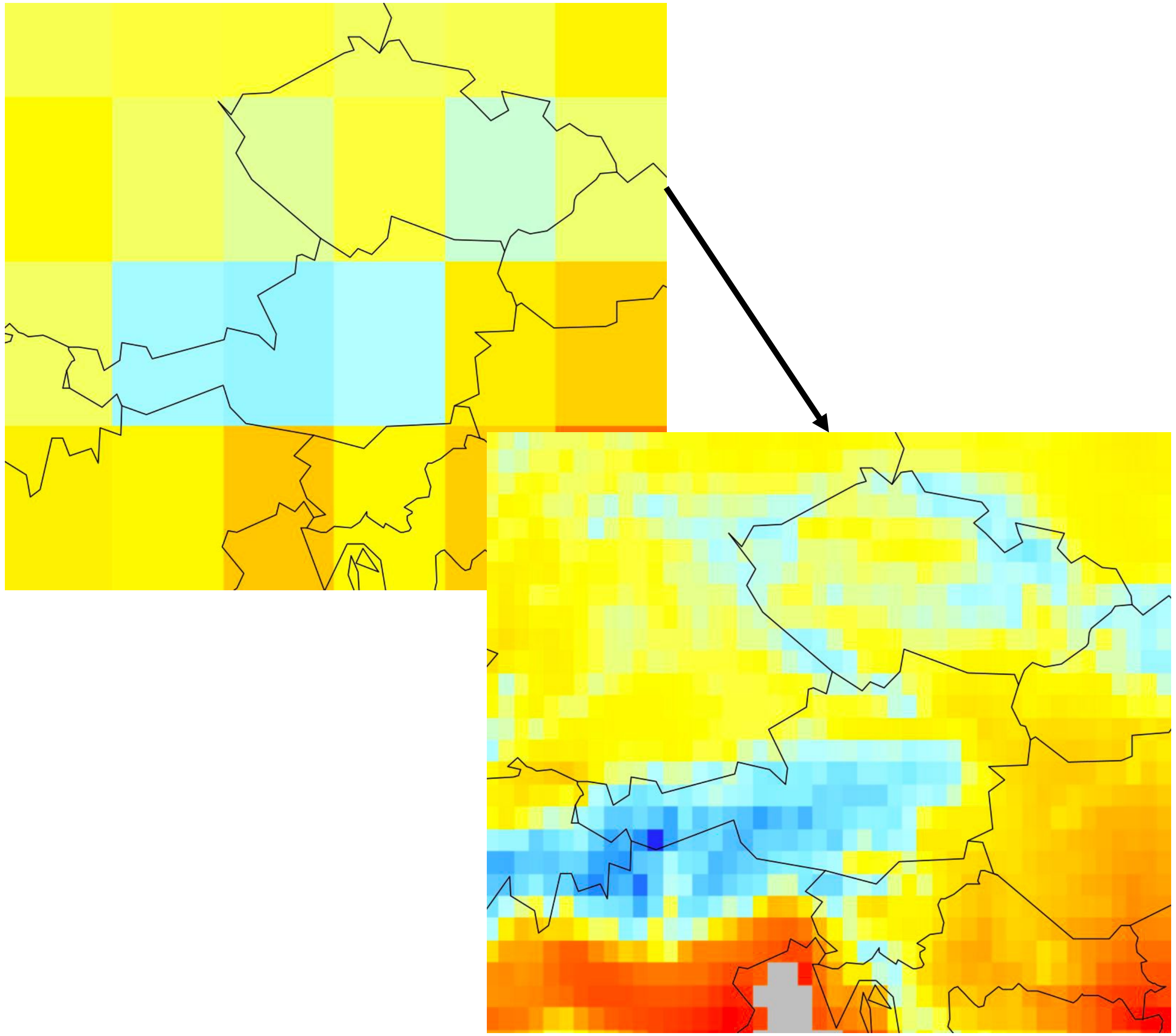
What is Downscaling?

- Process that transforms coarse-resolution climate model data into high-resolution, fine-scale information suitable for regional and local impact studies.
- Two types of methods:
  - Dynamical
    - Uses regional climate model (RCM) driven on the boundaries by GCM data.
  - Statistical
    - Uses statistical relationships between large-scale and local climate variables.



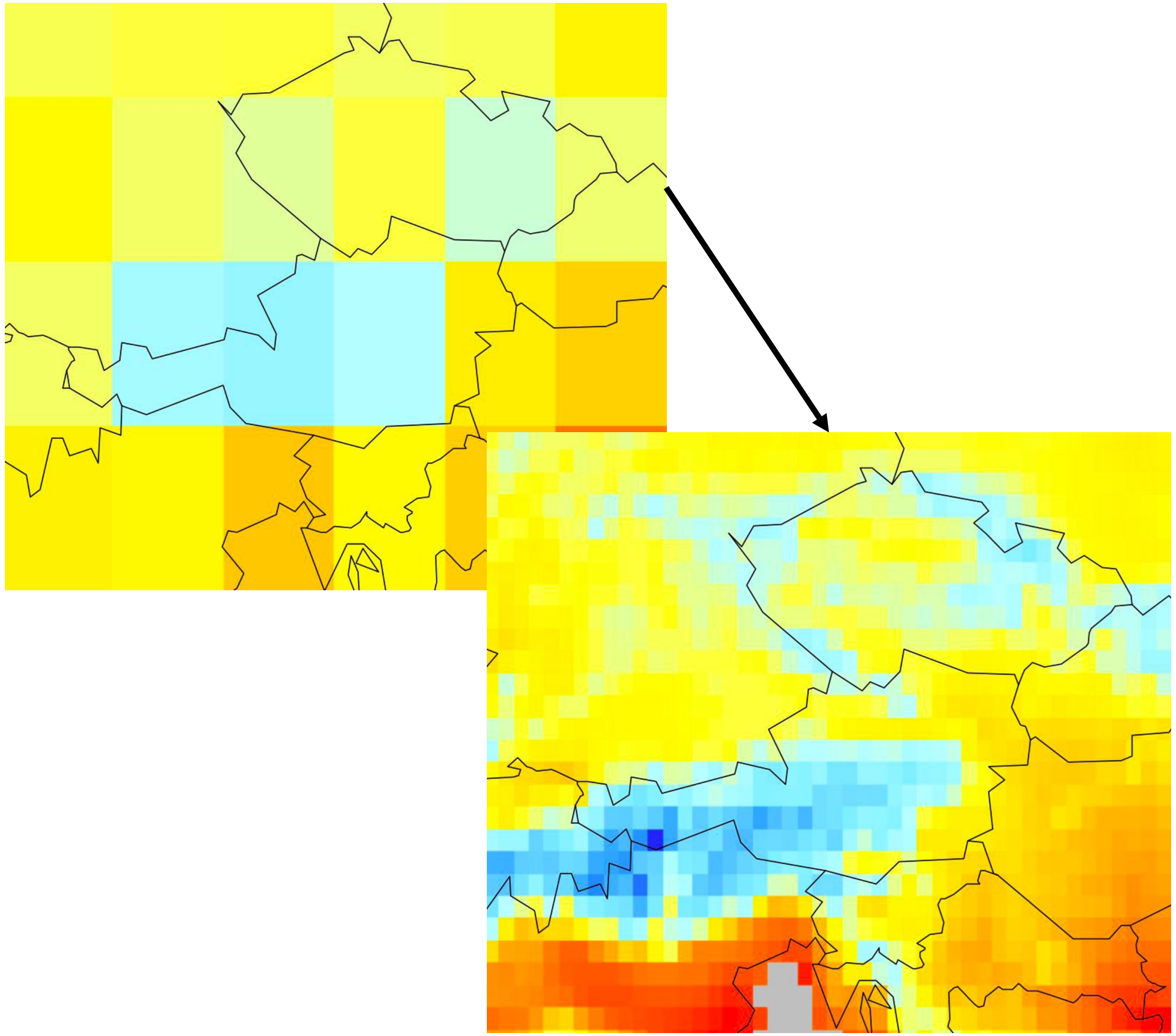
What is Dynamical Downscaling?

- Dynamical downscaling
  - Advantages:
    - Does not rely on the the stationarity assumption.
    - Does not require observations or reanalysis as input.
  - Disadvantages:
    - Computationally expensive.
    - RCMs inherit uncertainty and bias from the GCMs used to drive them.
    - Significantly limited to replicating the broader atmospheric patterns set by the GCMs.



What is Statistical Downscaling?

- Statistical downscaling
  - Advantages:
    - Models are calibrated to adjust GCM biases.
    - Spatial coverage and resolution is determined by reference data.
    - Computationally inexpensive.
  - Disadvantages:
    - Relies on the validity of the statistical relationships.
    - Output variables limited to those provided by the reference data.



What is NEX-GDDP-CMIP6?

- Statistically downscaled output from CMIP6
  - Daily global ¼-degree output
  - 35 CMIP6 models
  - Historical experiment (1950–2014)
  - *Four Shared Socioeconomic Pathways (SSP)+Representative Concentration Pathways (2015–2100):
    - **SSP1**-2.5 – sustainability to 2.5 W/m^2 radiative forcing by 2100
    - **SSP2**-4.5 – middle of the road to 4.5 W/m^2 radiative forcing by 2100
    - **SSP3**-7.0 – regional rivalry to 7.0 W/m^2 radiative forcing by 2100
    - **SSP5**-8.5 – fossil fuel development to 8.5 W/m^2 radiative forcing by 2100
  - Recently released version 2.0

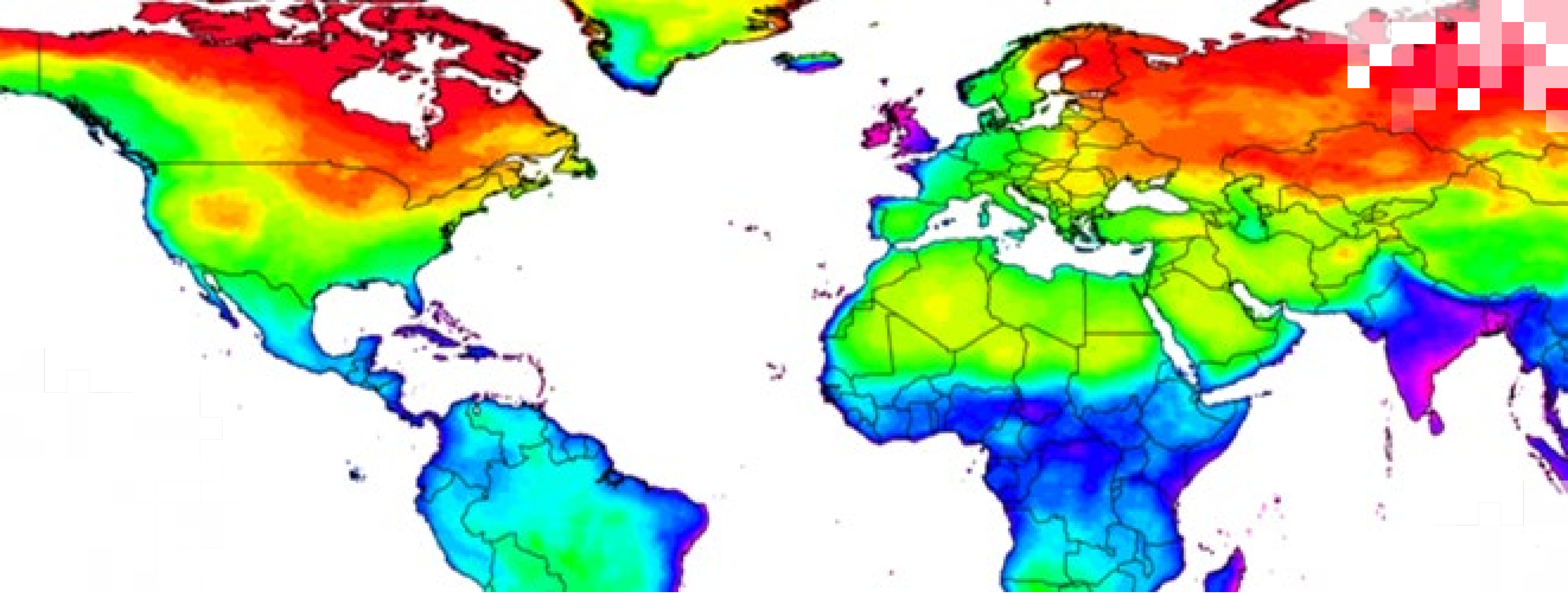
*Drought Monitoring, Prediction, and Projection using NASA Earth System Data. NASA Applied Remote Sensing Training Program (ARSET): Part-3.

NEX-GDDP-CMIP6 Data Parameters

- Nine geophysical parameters:
  - hurs: relative humidity (%)
  - huss: specific humidity (kg/kg)
  - pr: precipitation flux (kg/m^2/s)
  - rlds: surface downwelling longwave radiation (W/m^2)
  - rsds: surface downwelling shortwave radiation (W/m^2)
  - sfcWind: near-surface average wind speed (m/s)
  - tas: average temperature (tas, degrees K)
  - tasmax: maximum temperature (tasmax, degrees K)
  - tasmin: minimum temperature (tasmin, degrees K)

NEX-GDDP-CMIP6 Data Format

- File description:
  - One year, one variable per file (>100,000 files in total)
  - NetCDF-4 classic format at level 5 deflation
  - CF-1.7 metadata conventions
  - ~250 MB per file
  - Combined total volume of ~30 TB
  - Available through Creative Commons Zero (CC0) license



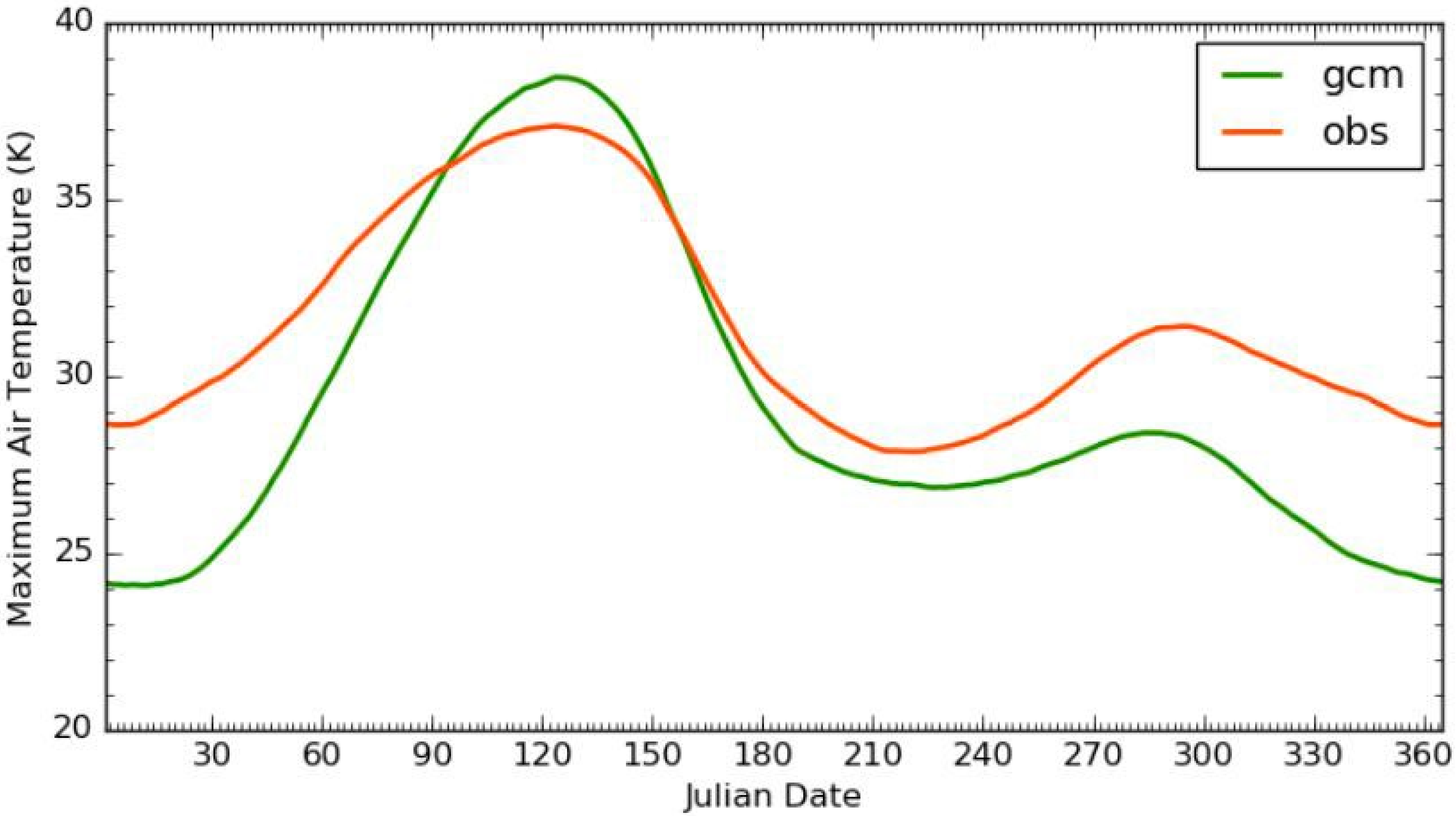
How was GDDP Created?

How was GDDP Created?

- Bias Correction/Spatial Disaggregation (BCSD) method:
  - First developed by Wood et al., 2002, for downscaling monthly GCM output
  - Modified by Thrasher et al., 2012, for daily GCM output
  - Requires gridded observations or reanalysis reference dataset at target horizontal resolution
    - GDDP uses the Princeton Global Forcing dataset (PGF, aka GMFD)
    - Processed version of PGF can be found on the Climate Analytics Group (CAG) Google Drive
  - Reference period must overlap with CMIP historical experiment
    - GDDP reference period of 1960–2014
  - Quantile mapping scheme followed by interpolation of residuals

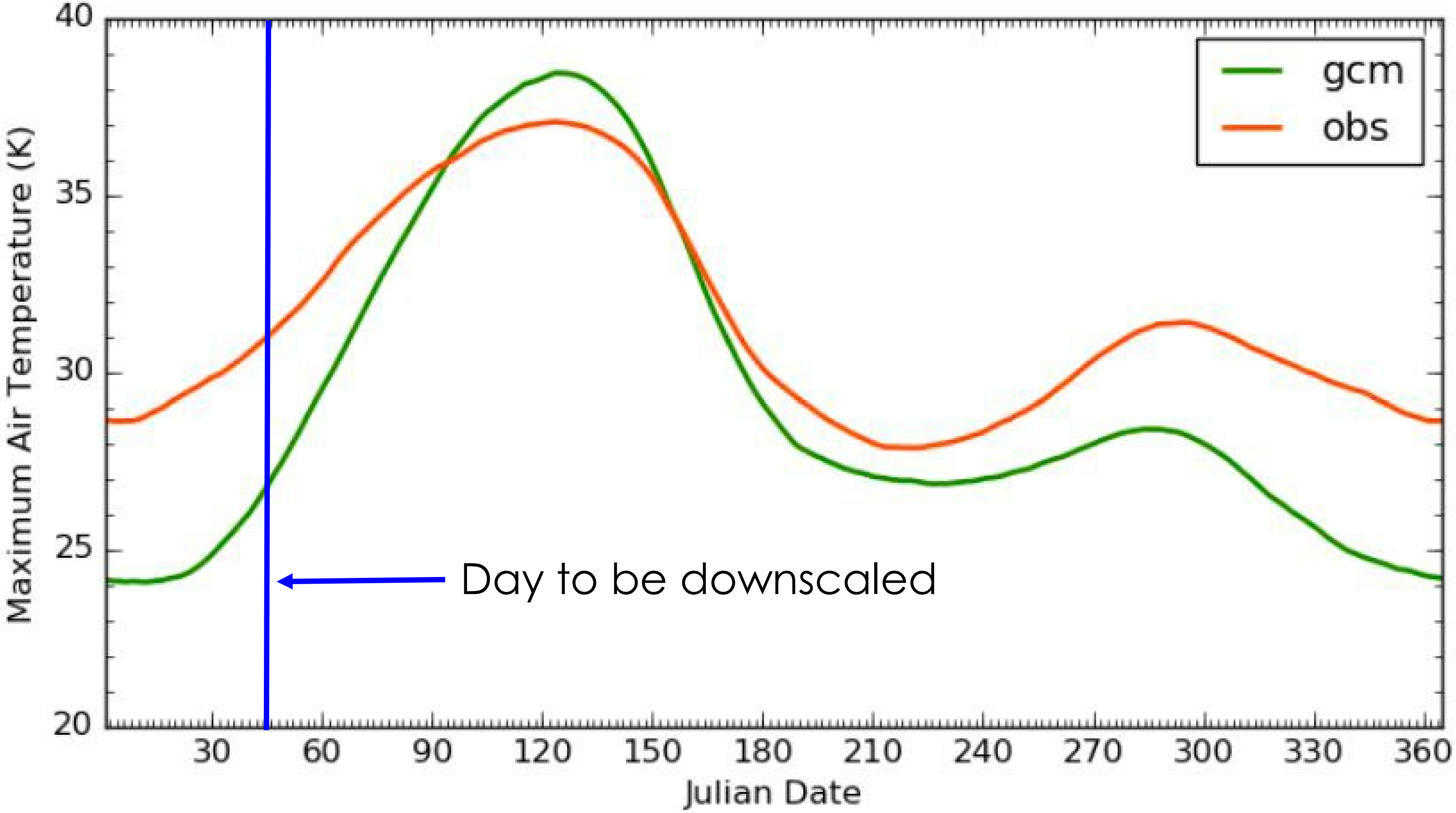
How was GDDP Created?

- **Step 1:** Bias Correction
  - GCM output does not match observations



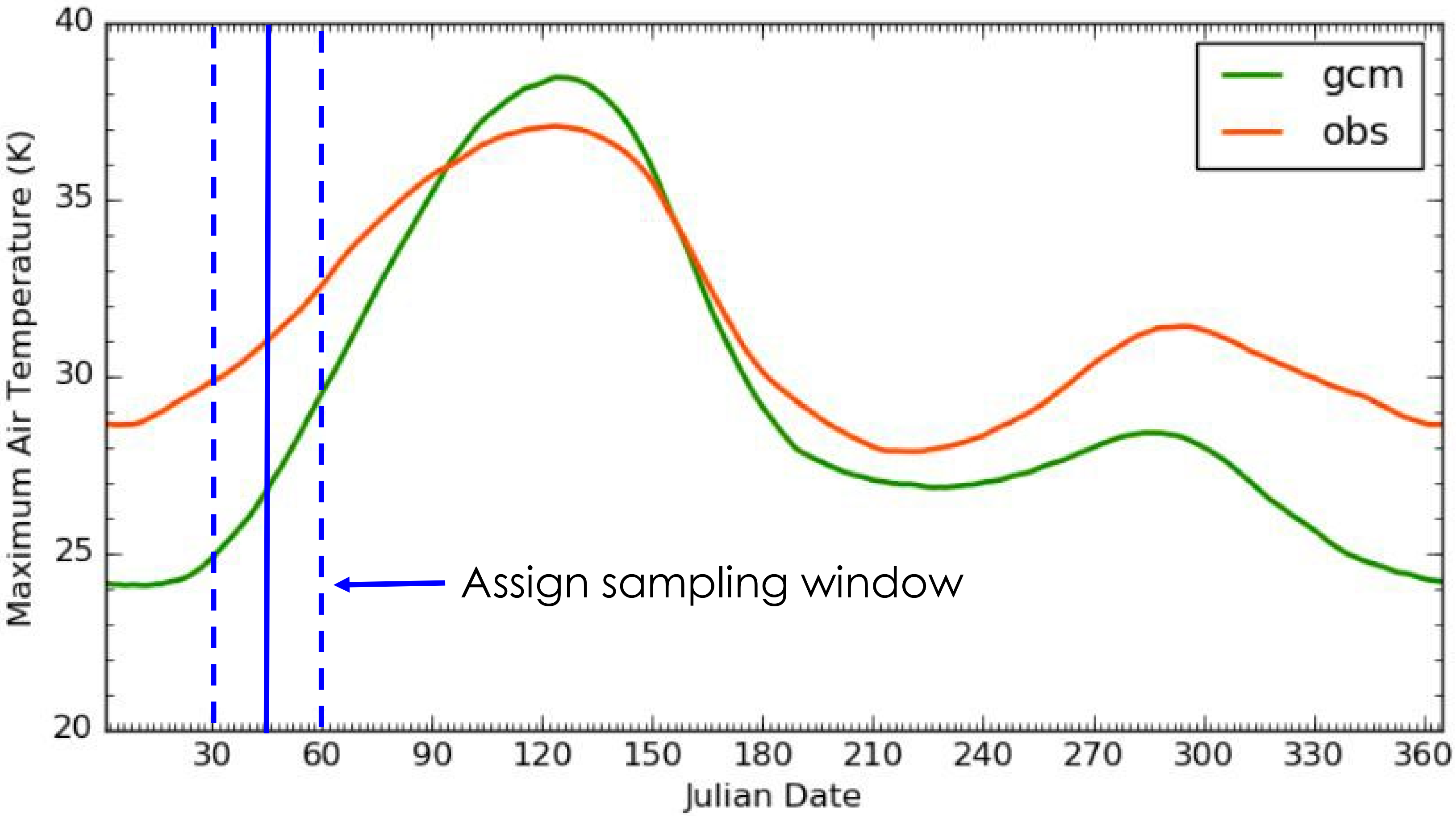
How was GDDP Created?

- **Step 1:** Bias Correction
  - Example for 14 Feb (Julian day 45)



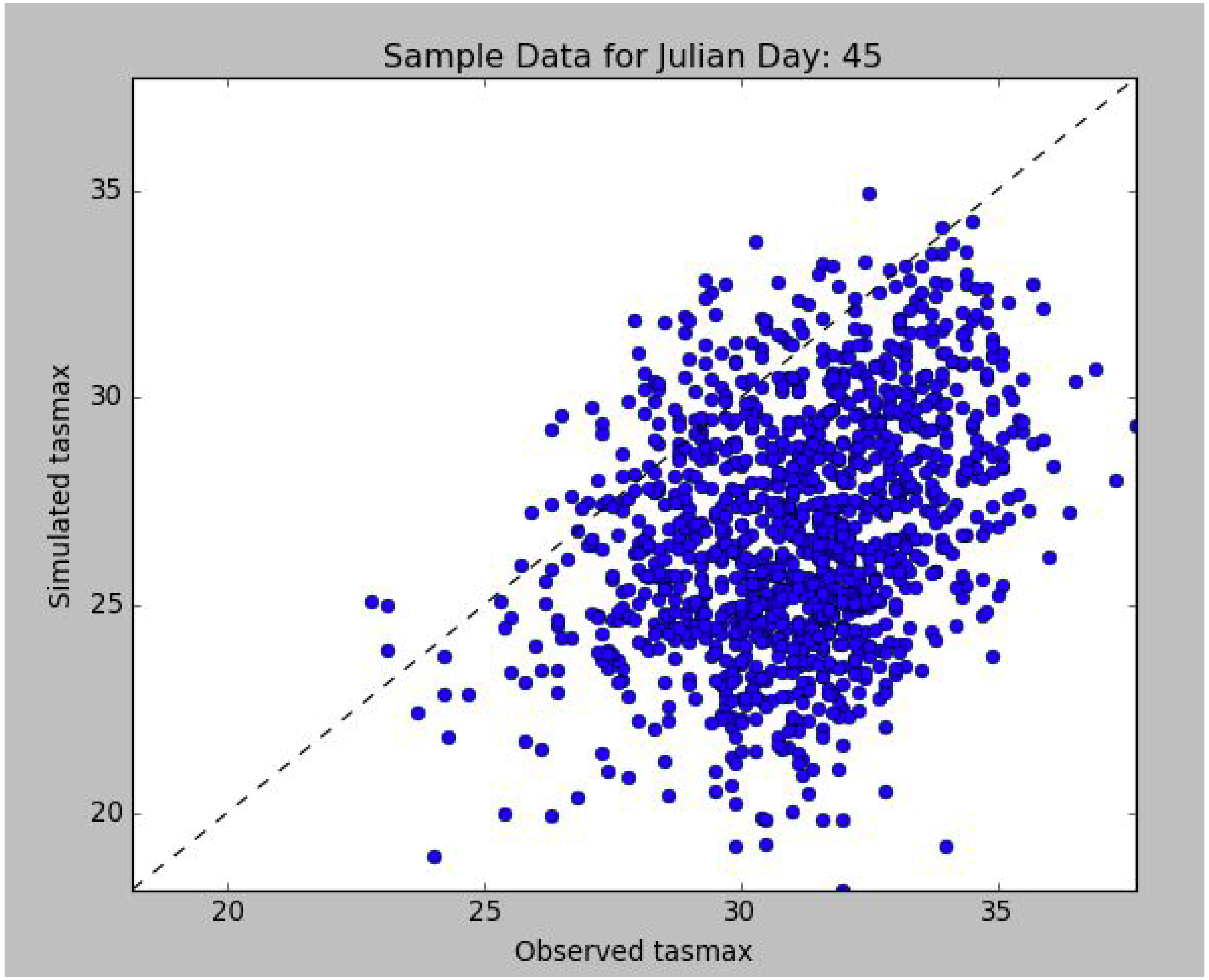
How was GDDP Created?

- **Step 1:** Bias Correction
  - Sampling window of +/- 15 days



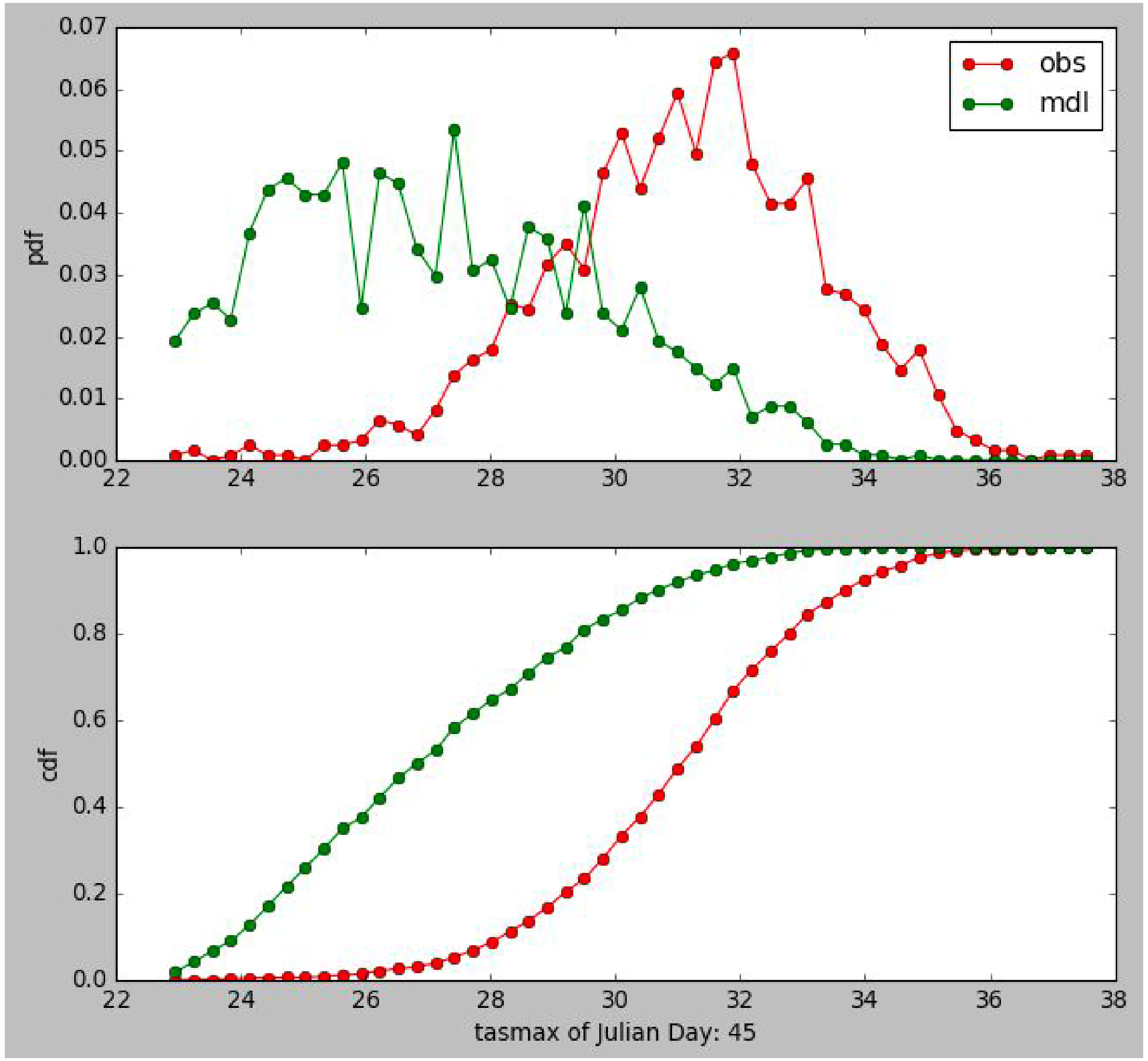
How was GDDP Created?

- **Step 1:** Bias Correction
  - Gather values within sampling window over all year in reference period



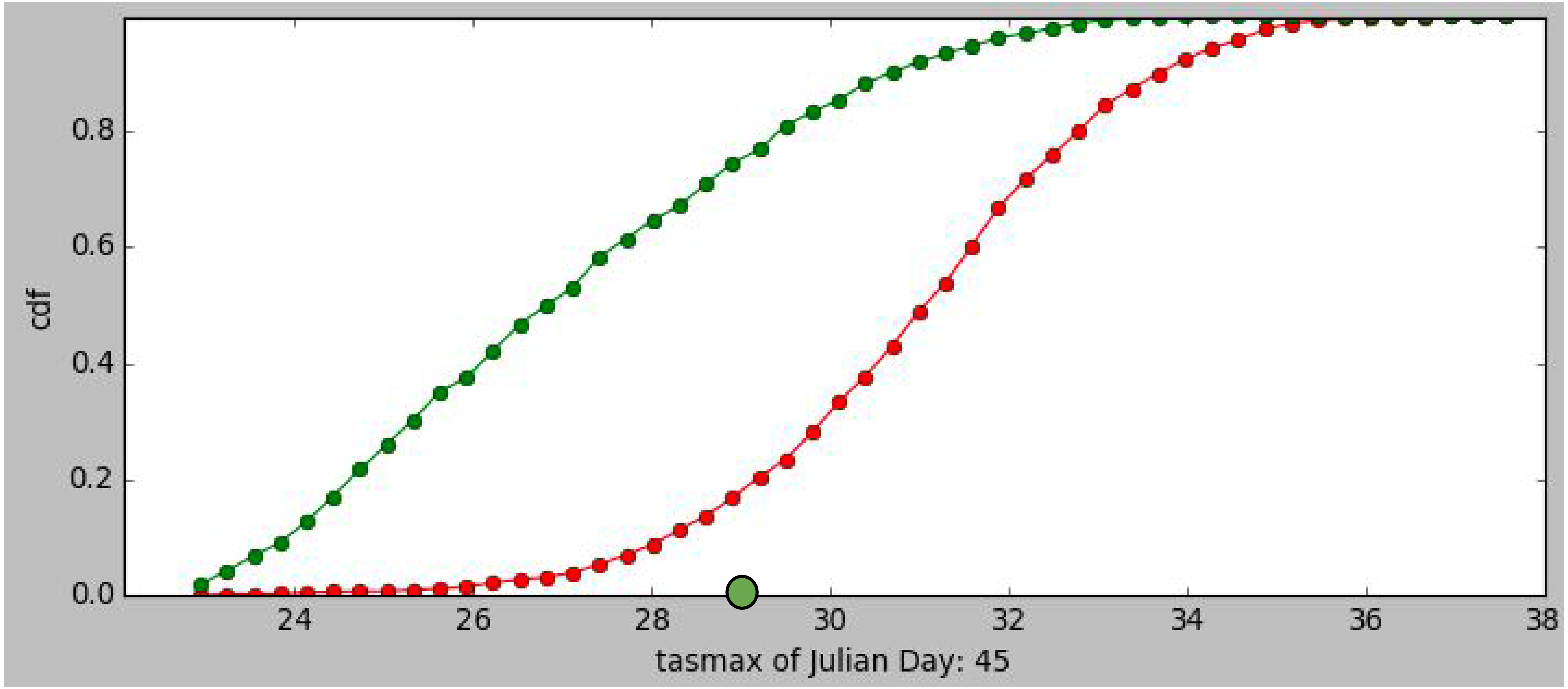
How was GDDP Created?

- **Step 1:** Bias Correction
  - Generate cumulative distribution functions (CDFs)



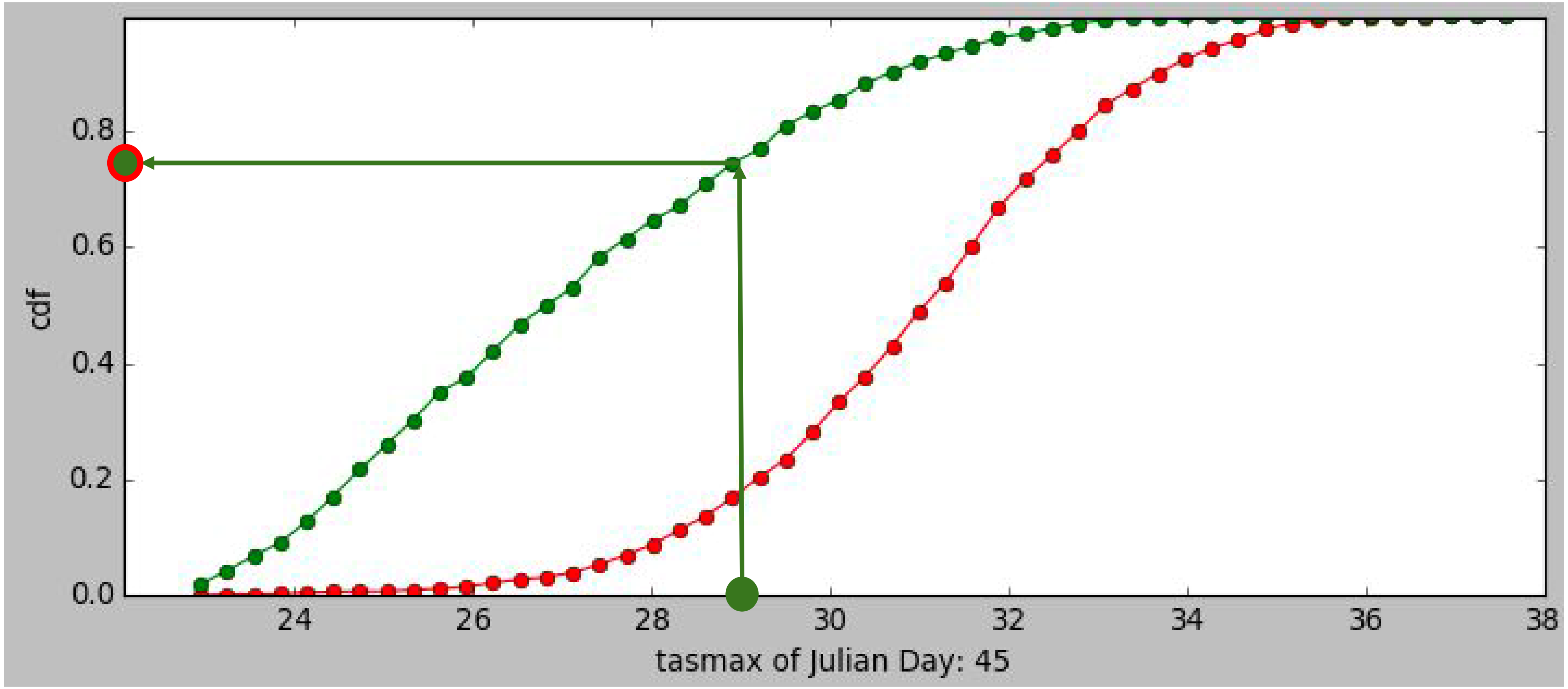
How was GDDP Created?

- **Step 1:** Bias Correction
  - Example of quantile mapping, GCM value = 29°C



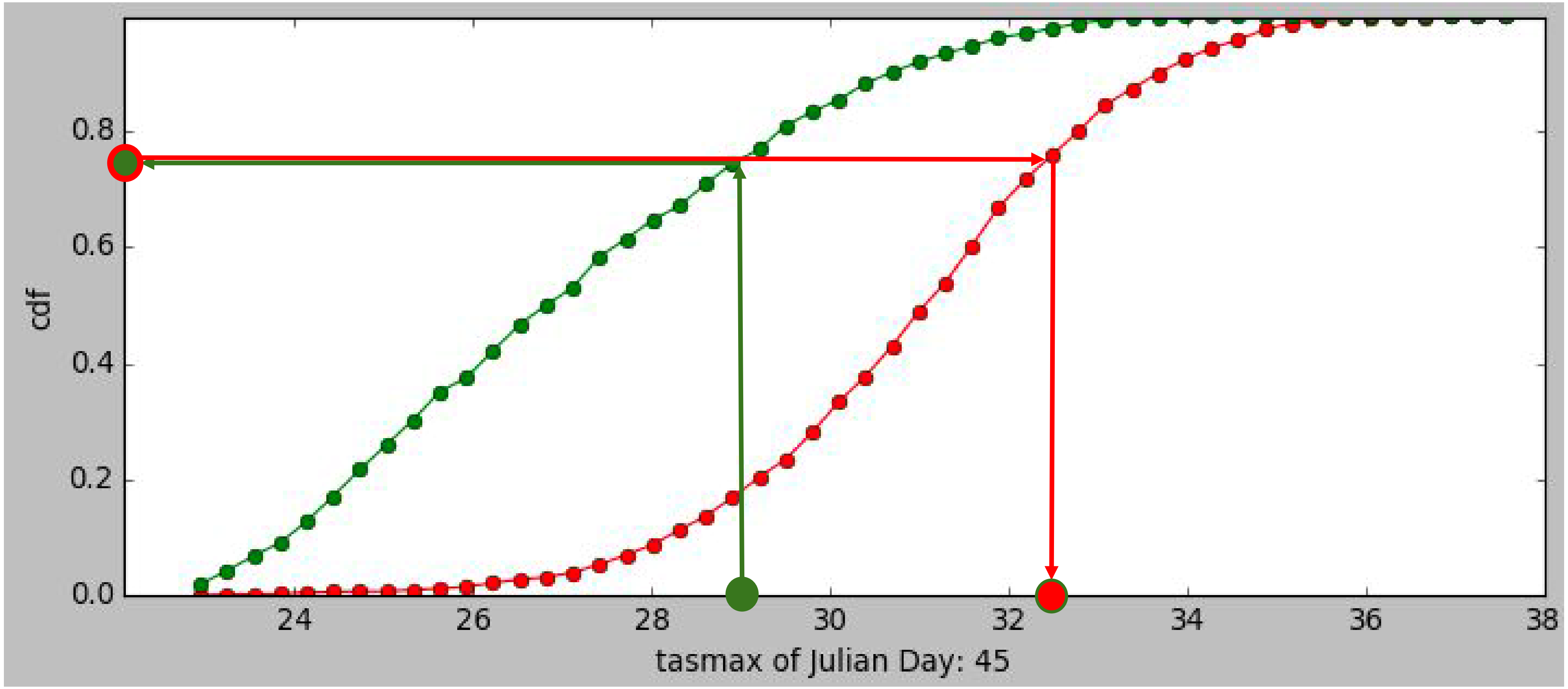
How was GDDP created?

- **Step 1:** Bias Correction
  - GCM value of 29°C equates to 0.78 quantile



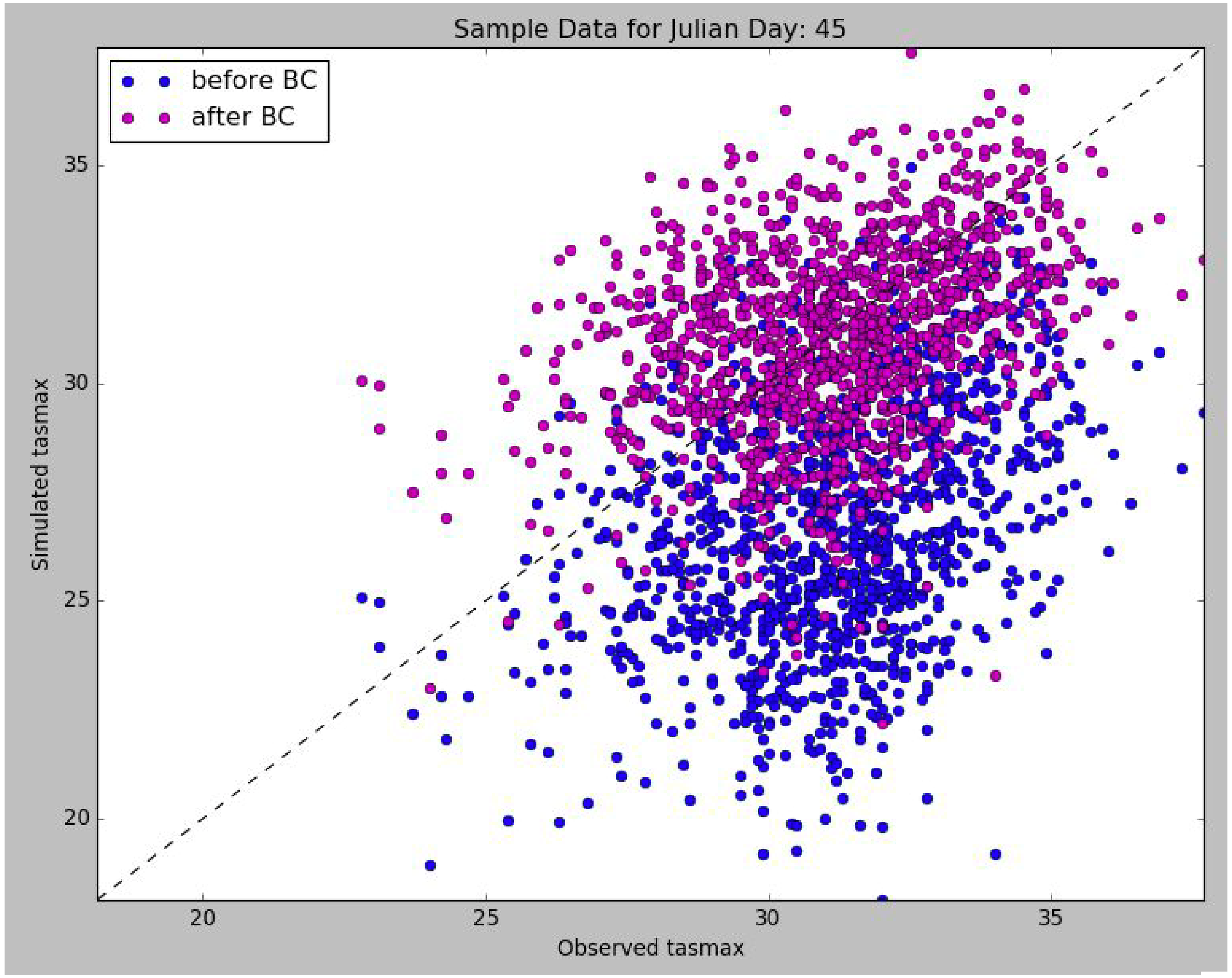
How was GDDP Created?

- **Step 1:** Bias Correction
  - Quantile of 0.78 equates to 32.5°C in observations



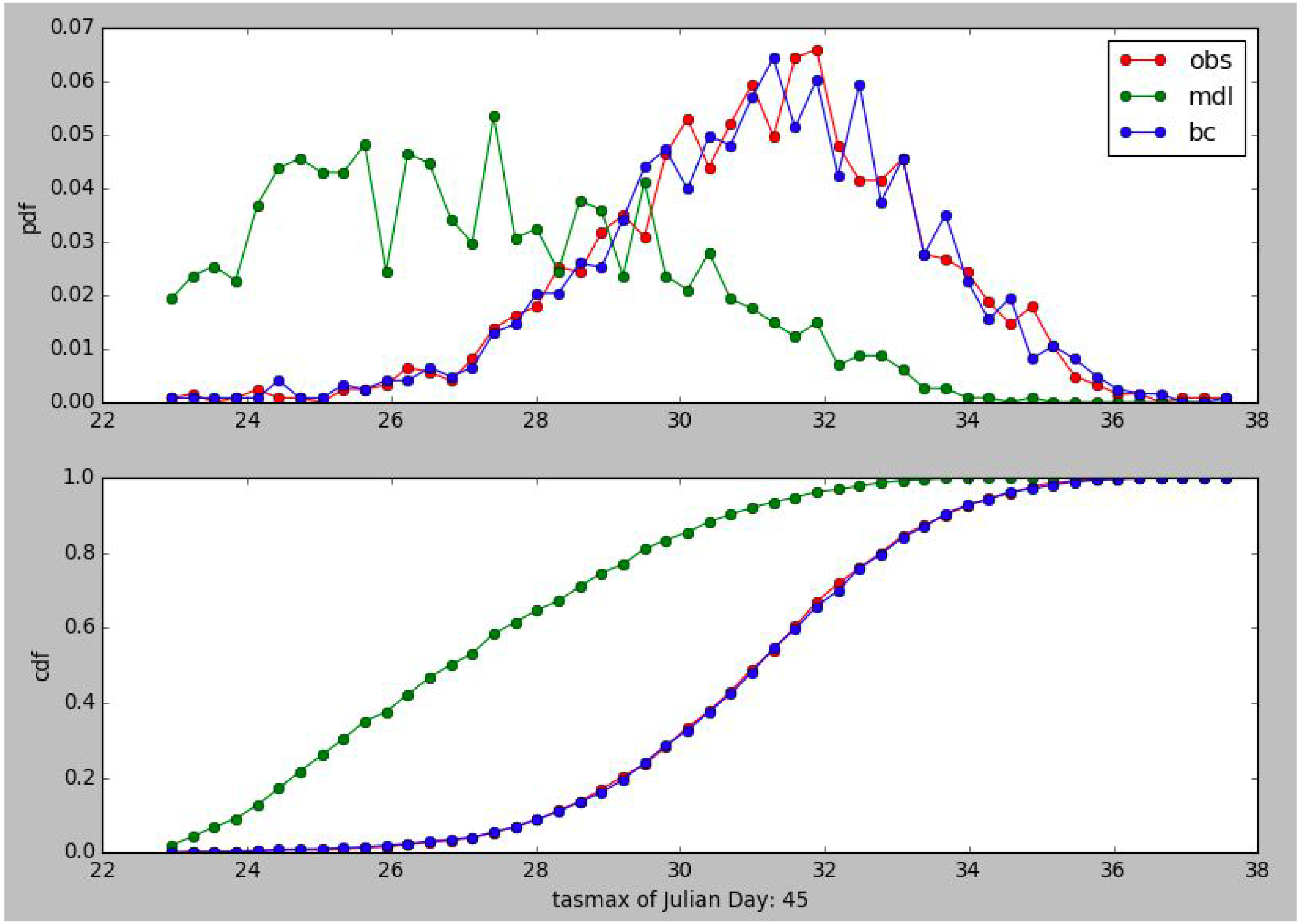
How was GDDP Created?

- **Step 1:** Bias Correction
  - Replace GCM value with observation value at same percentile



How was GDDP Created?

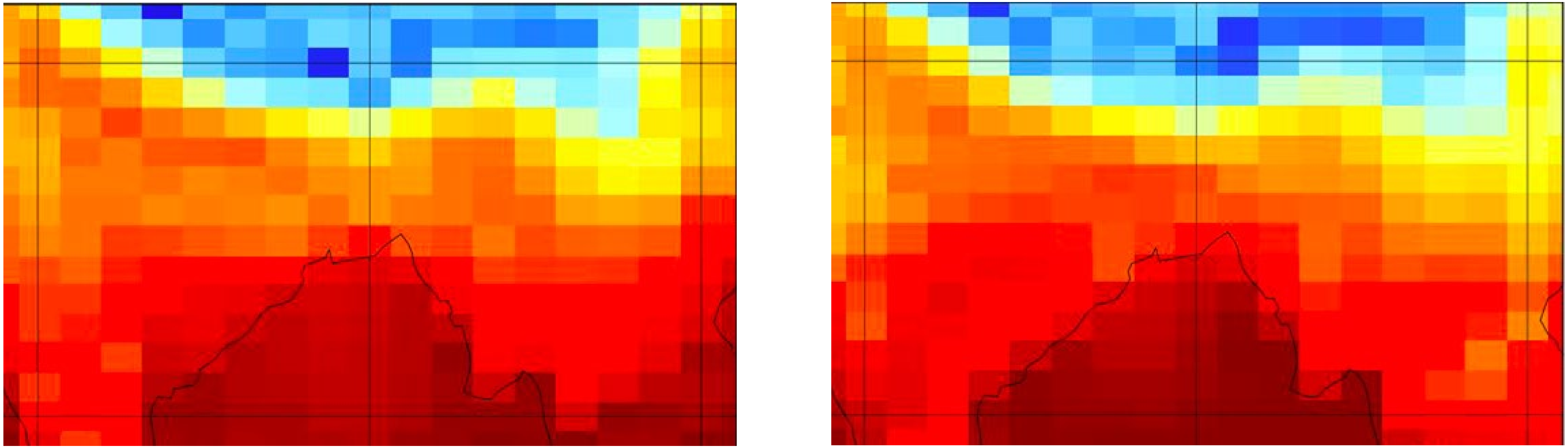
- **Step 1:** Bias Correction
  - Adjusted values now correlated to reference values



How was GDDP Created?

- **Step 1:** Bias Correction

Before After



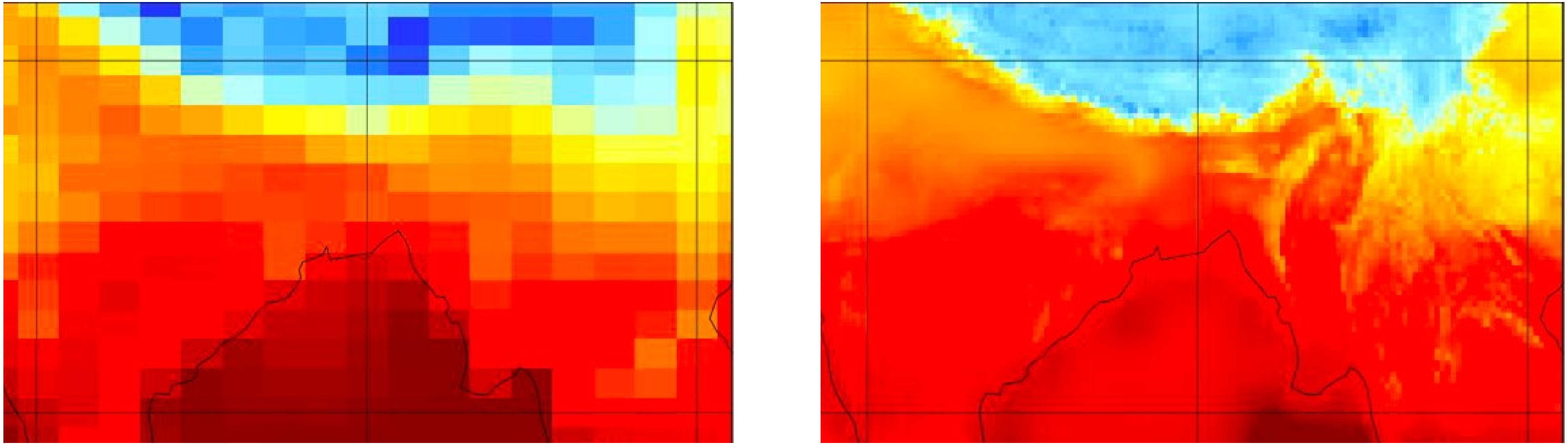
How was GDDP Created?

- **Step 2:** Spatial Disaggregation
  a. Calculate daily climatology of the reference dataset
  b. Aggregate to GCM native grid
  c. Remove GCM-resolution climatology from bias-corrected fields to create residuals
     i. Subtract from temperature
     ii. Divide from other variable
  d. Bilinearly interpolate residuals to target grid of reference dataset
  e. Return climatology calculated in step a to disaggregated residuals
     i. Add to temperature
     ii. Multiply other variables

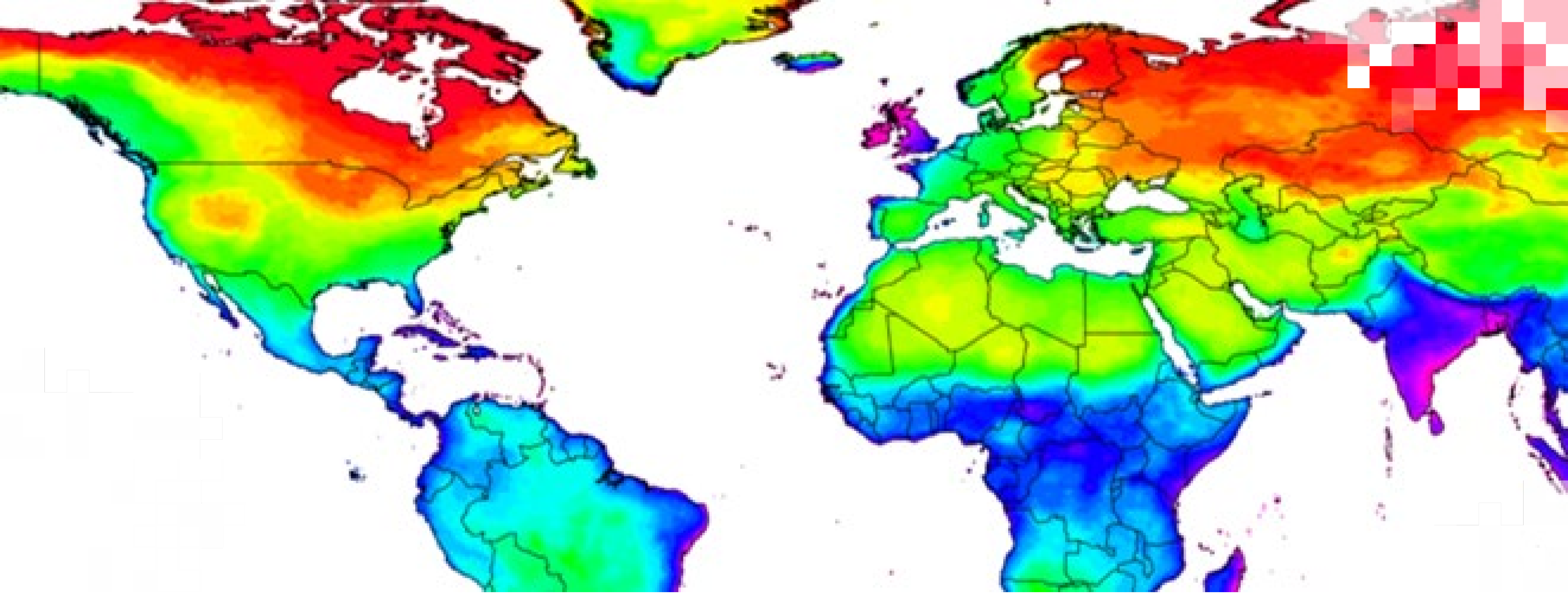
How was GDDP Created?

- **Step 2:** Spatial Disaggregation

Before After



Daily BCSD code available on [Github]



Where can GDDP be Accessed?

Where can GDDP be Accessed?

NCCS THREDDS Data Catalog

Catalog

Dataset	Size	Last Modified
ACCESS-CM2/historical/r1i1p1f1/tasmax/		--
tasmax_day_ACCESS-CM2_historical_r1i1p1f1_gn_1950.nc	244.4 Mbytes	2021-10-27T00:35:33.540Z
tasmax_day_ACCESS-CM2_historical_r1i1p1f1_gn_1951.nc	244.5 Mbytes	2021-10-27T00:35:41.937Z
tasmax_day_ACCESS-CM2_historical_r1i1p1f1_gn_1952.nc	245.2 Mbytes	2021-10-27T00:35:49.924Z
tasmax_day_ACCESS-CM2_historical_r1i1p1f1_gn_1953.nc	244.4 Mbytes	2021-10-27T00:35:58.816Z
tasmax_day_ACCESS-CM2_historical_r1i1p1f1_gn_1954.nc	244.4 Mbytes	2021-10-27T00:36:08.521Z
tasmax_day_ACCESS-CM2_historical_r1i1p1f1_gn_1955.nc	244.4 Mbytes	2021-10-27T00:36:16.895Z
tasmax_day_ACCESS-CM2_historical_r1i1p1f1_gn_1956.nc	245.0 Mbytes	2021-10-27T00:36:25.227Z
tasmax_day_ACCESS-CM2_historical_r1i1p1f1_gn_1957.nc	244.4 Mbytes	2021-10-27T00:36:33.739Z

Authoritative source: NASA Center for Climate Simulation

Where can GDDP be Accessed?

Registry of Open Data on AWS

aws

NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6)

air temperature | climate | climate model | climate projections | CMIP6 | cog | earth observation | environmental | global | model | NASA Center for Climate Simulation (NCCS) | near-surface relative humidity | near-surface specific humidity | netcdf | precipitation

Description

The NEX-GDDP-CMIP6 dataset is comprised of global downscaled climate scenarios derived from the General Circulation Model (GCM) runs conducted under the Coupled Model Intercomparison Project Phase 6 (CMIP6) and across two of the four "Tier 1" greenhouse gas emissions scenarios known as Shared Socioeconomic Pathways (SSPs). The CMIP6 GCM runs were developed in support of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6). This dataset includes downscaled projections from ScenarioMIP model runs for which daily scenarios were produced and

Resources on AWS

Description
The NEX-GDDP-CMIP6 archive. Files are in NetCDF format with the CF-1.7 metadata conventions.

Resource type
S3 Bucket

Amazon Resource Name (ARN)
`arn:aws:s3:::nex-gddp-cmip6`

AWS Region

[Amazon Web Services]

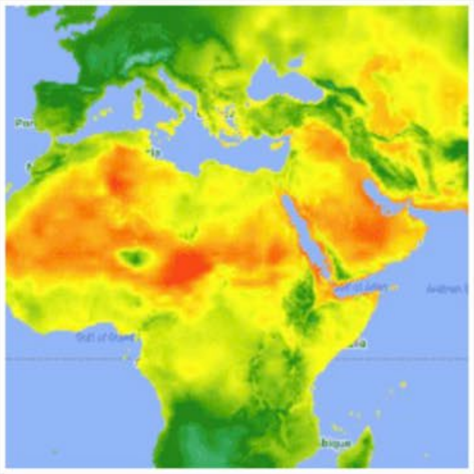
Where can GDDP be Accessed?

Earth Engine Data Catalog

Search | English

Home | View all datasets | Browse by tags | Landsat | MODIS | Sentinel | Publisher | Community | API Docs

NEX-GDDP-CMIP6: NASA Earth Exchange Global Daily Downscaled Climate Projections



Dataset Availability

1950-01-01T00:00:00Z–2100-12-31T00:00:00Z

Dataset Provider

NASA / Climate Analytics Group

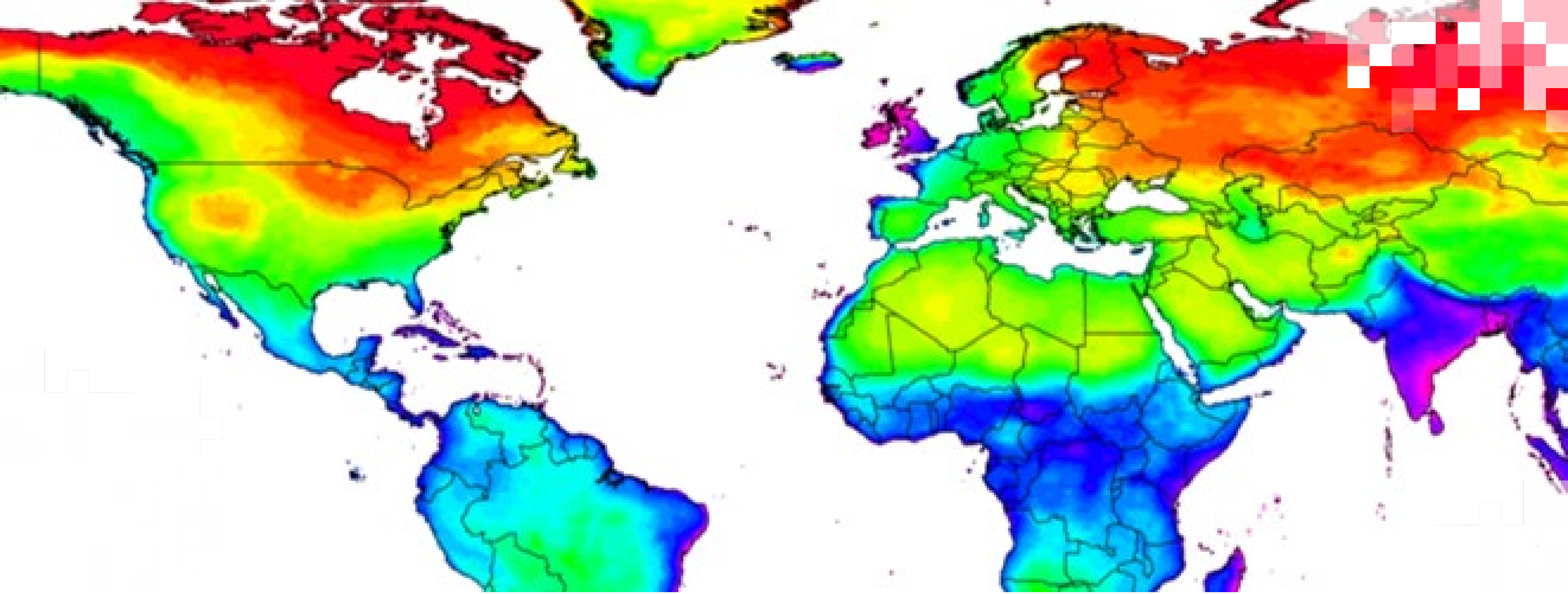
Earth Engine Snippet

```
ee.ImageCollection("NASA/GDDP-CMIP6")
```

Tags

cag climate gddp geophysical nasa nex precipitation temperature

Google Earth Engine



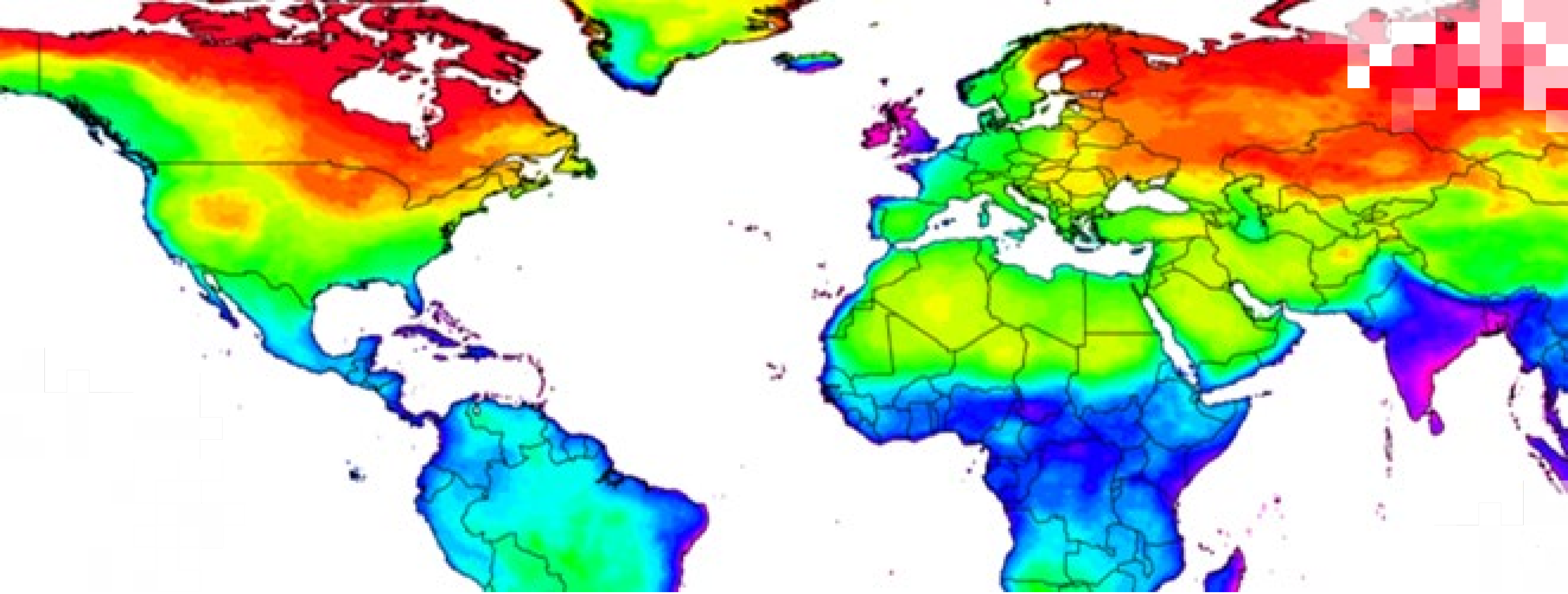
Part 1:
Summary

Summary

- **What is NASA Earth eXchange (NEX)?**
  - Collaborative supercomputing and data analytics platform
  - Improves availability of Earth science data from NASA missions and other sources (e.g., models, analysis tools, and research results)
  - Supports many NASA programs
- **What is downscaling?**
  - Process that transforms coarse-resolution climate model data into high-resolution, suitable for regional and local impact studies
  - Two types of downscaling: dynamical and statistical
- **What is NEX-GDDP-CMIP6?**
  - Statistically downscaled output from 35 of CMIP6 models at daily global ¼-degree output
  - Four SSPs (2.5, 4.5, 7.0, 8.5) from 2015 to 2100
- **How was GDDP created?**
  - Using two steps methodology: bias correction and spatial disaggregation

Summary: Data and Access

- **Nine Daily Downscaled Variables:**
  - Relative and specific humidities
  - Precipitation
  - Surface downwelling longwave and shortwave radiation
  - Near-surface wind speed
  - Minimum, maximum, and average temperatures
- **One file for each year (2015–2100) per variable**
- **Where can GDDP be accessed?**
  - NASA Center for Climate Simulation
  - Amazon Web Services
  - Google Earth Engine



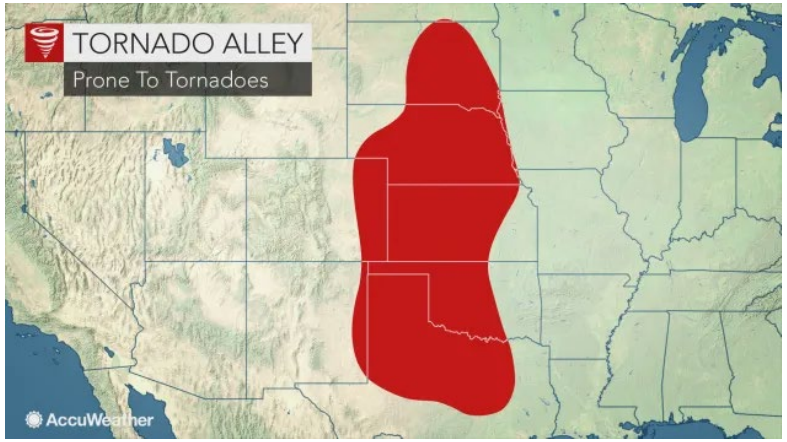
Demonstration
Analysis of Extreme Event Statistics from GDDP data using Google Earth Engine

Case Study

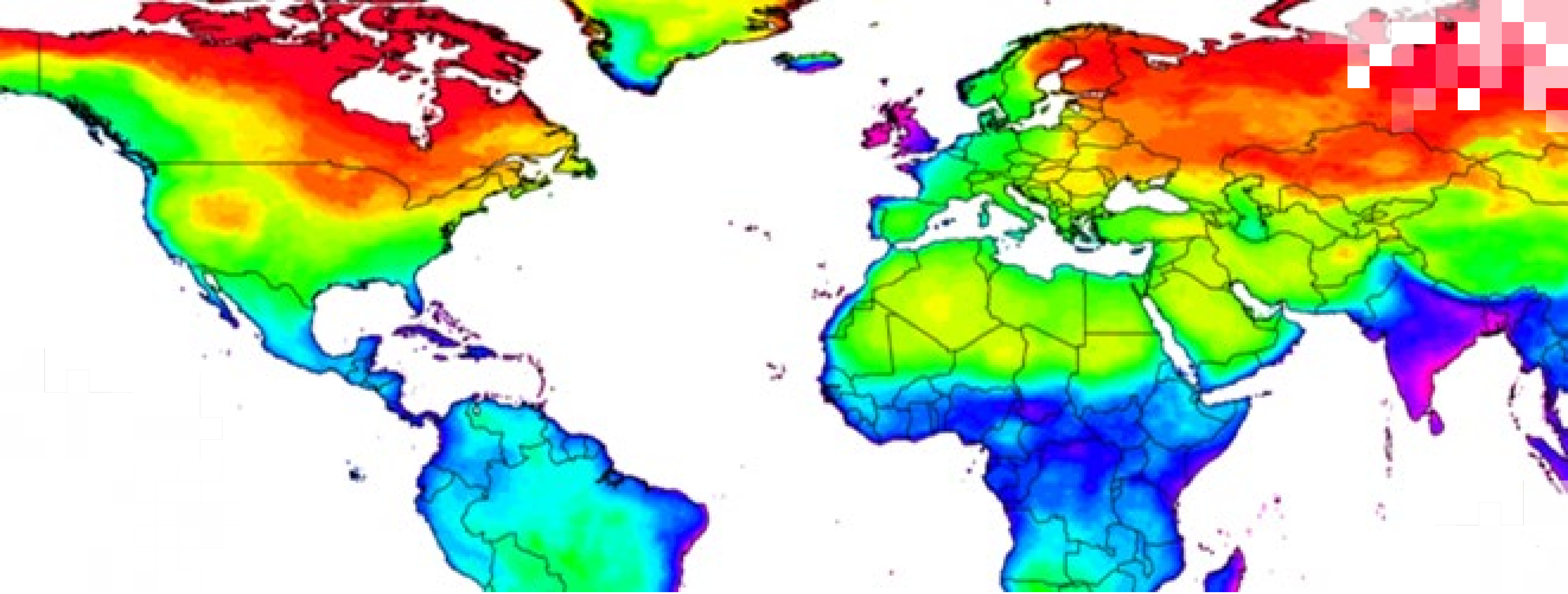
- **Region: Nebraska, USA**
- Nebraska's economy is heavily dependent on agriculture — corn, soybeans, wheat, and cattle farming
- Sensitive to climate variability and change
- Part of Tornado Alley
- **GDDP Analysis (2020–2100)**

GEE Scripts:

- Annual mean temperature and precipitation maps and time series
- Extreme cold events during winter seasons
- Extreme hot events during summer seasons
- Extreme dry and wet events during summer seasons



Tornado Alley



Exercise
Analysis of Extreme Dry and Wet Event Statistics from GDDP data using Google Earth Engine

Exercise

- Use the following GEE script:
  [Extreme dry and wet events during summer seasons]
- Save the script on your GEE account and run the script.
- Examine extreme dry and wet events time series in the 'Console' window.
- As a part of your homework, you will be submitting these time series.

Looking Ahead to Part 2

- Visualize maps of weather statistics for a region of interest using NEX-GDDP Dashboard.
- Using Python/Jupyter Notebook Code for GDDP data access:
  - Customize spatial/temporal selection of GDDP data
  - Calculate frequency and intensity of extreme hot/cold and dry/wet events for a region of interest
- Assess changes in the extreme event statistics over the 21st century for a region of interest.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 17 September 2025
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 17 October 2025**

- **Certificate of Completion:**
  - Attend all live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Acknowledgement

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Thank You!