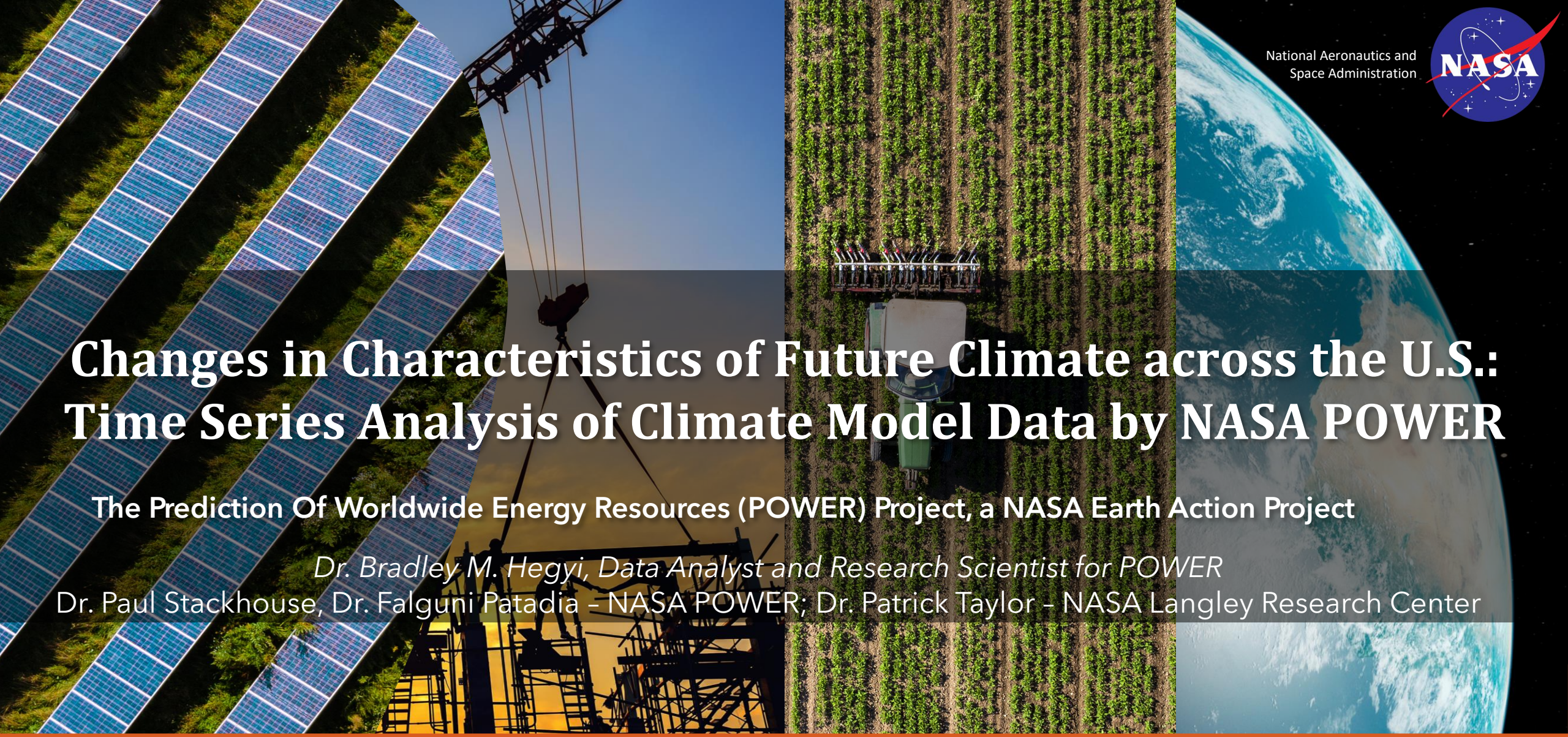

National Aeronautics and Space Administration

# Changes in Characteristics of Future Climate across the U.S.: Time Series Analysis of Climate Model Data by NASA POWER

## The Prediction Of Worldwide Energy Resources (POWER) Project, a NASA Earth Action Project


*Dr. Bradley M. Hegyi, Data Analyst and Research Scientist for POWER*

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**Team Members:**

- Bradley Macpherson, Madison Broddle, Christopher Higham, Claire Baldacci, Zoe Waring, Valeria Green, Benjamin Landes, Nikhil Aluru, & A. Jason Barnett – Booz Allen Hamilton (BAH)
- Taiping Zhang, Colleen Mikovitz, **Bradley Hegyi**, & Neha Khadka – Analytical Mechanics Associates (AMA)

# Prediction Of Worldwide Energy Resources (POWER)

Aiming to improve the nation's public/private capability for integrating environmental data from NASA Earth Observations, analysis and modeling, particularly information related to surface solar irradiance, to support increased **renewable energy development, building energy sustainability,** and **agroclimatology applications**.

https://power.larc.nasa.gov/


**Goal of Future Climate Data Services:**
Create data products that support these three user groups.

https://power.larc.nasa.gov

Check out the newly released enhanced Data Access Viewer. We welcome your feedback at larc-power-project@mail.nasa.gov.

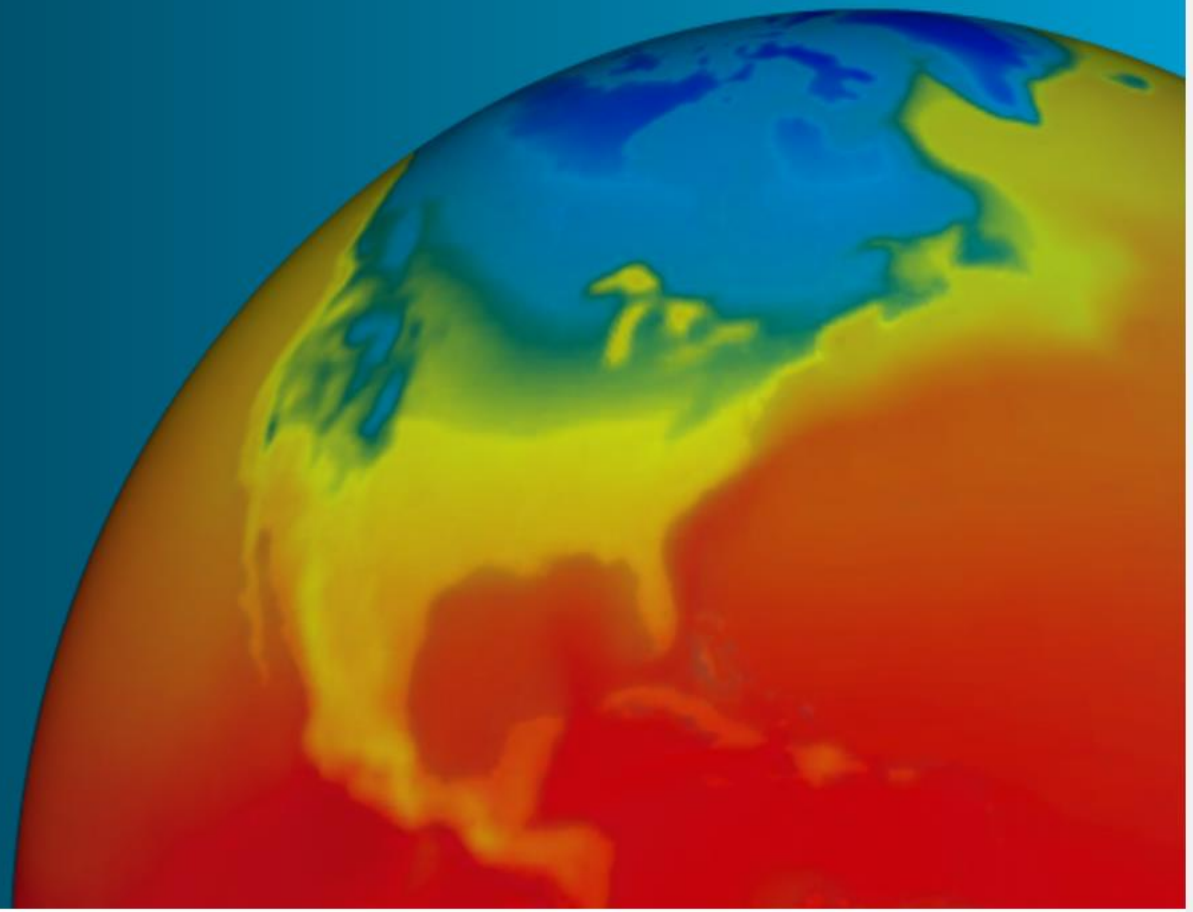
NASA Prediction Of Worldwide Energy Resources

DATA ACCESS DOCUMENTATION RESOURCES ABOUT CONTACT

# The POWER Project

Provides solar and meteorological data sets from NASA research for support of renewable energy, building energy efficiency and agricultural needs.

*Supported by NASA Earth Science's Applied Sciences Program*



## POWER's Web-Based Docs Pages

- Data Methodology
- Data Services Documentation
- Data Access Tutorials

POWER is hosting its **2nd Annual Virtual Global Community (GloCo) Summit event** scheduled to be held on **October 11th & 12th, 2023**. You can view registration information, the agenda, and

# Goals of climate data services

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POWER is currently working to develop data products that provide projections in the future climate of quantities important to our user groups. These projections are taken from the latest set of climate model runs (Coupled Model Intercomparison Project Phase 6 [CMIP6]).

**Three challenges:**

1. **Model data is coarse.**
2. **Over 100 models exist in the latest set.**
3. **What will be future emissions of greenhouse gases?**

# Challenges to Using Climate Model Data

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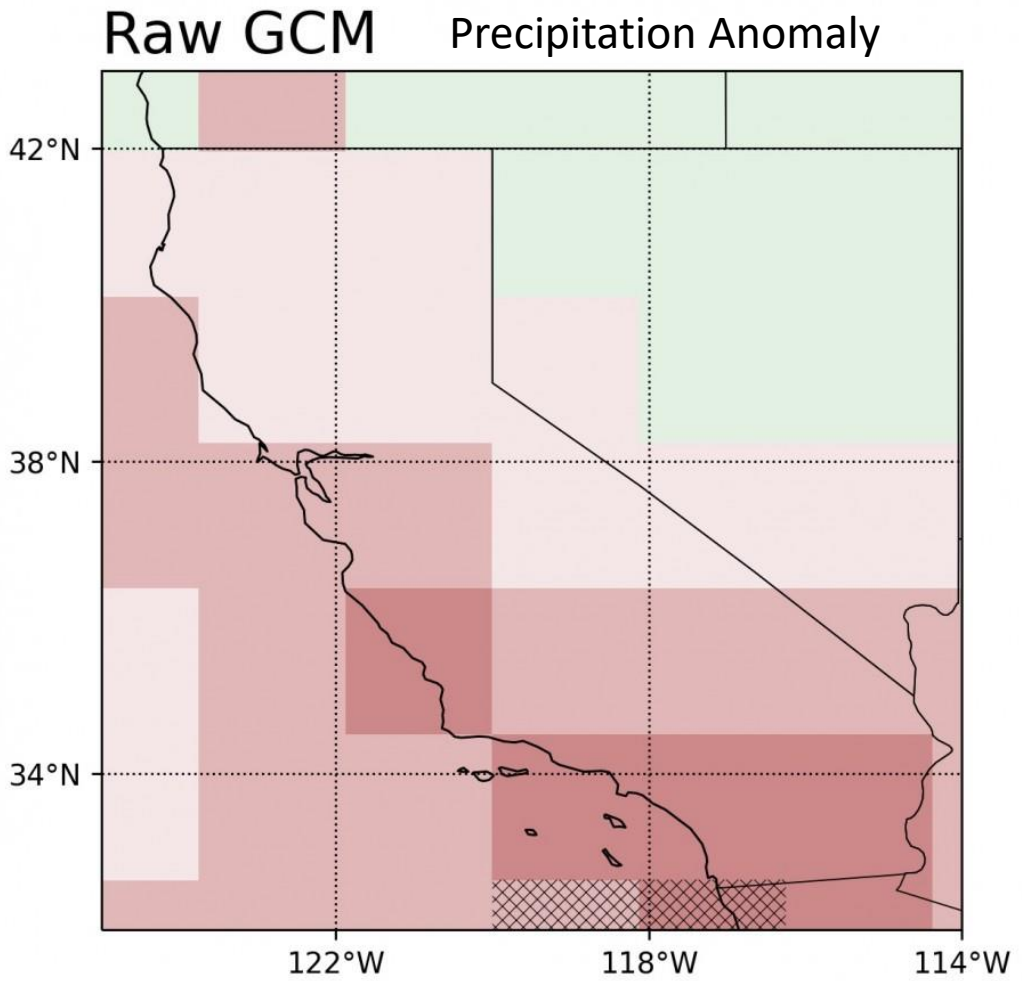
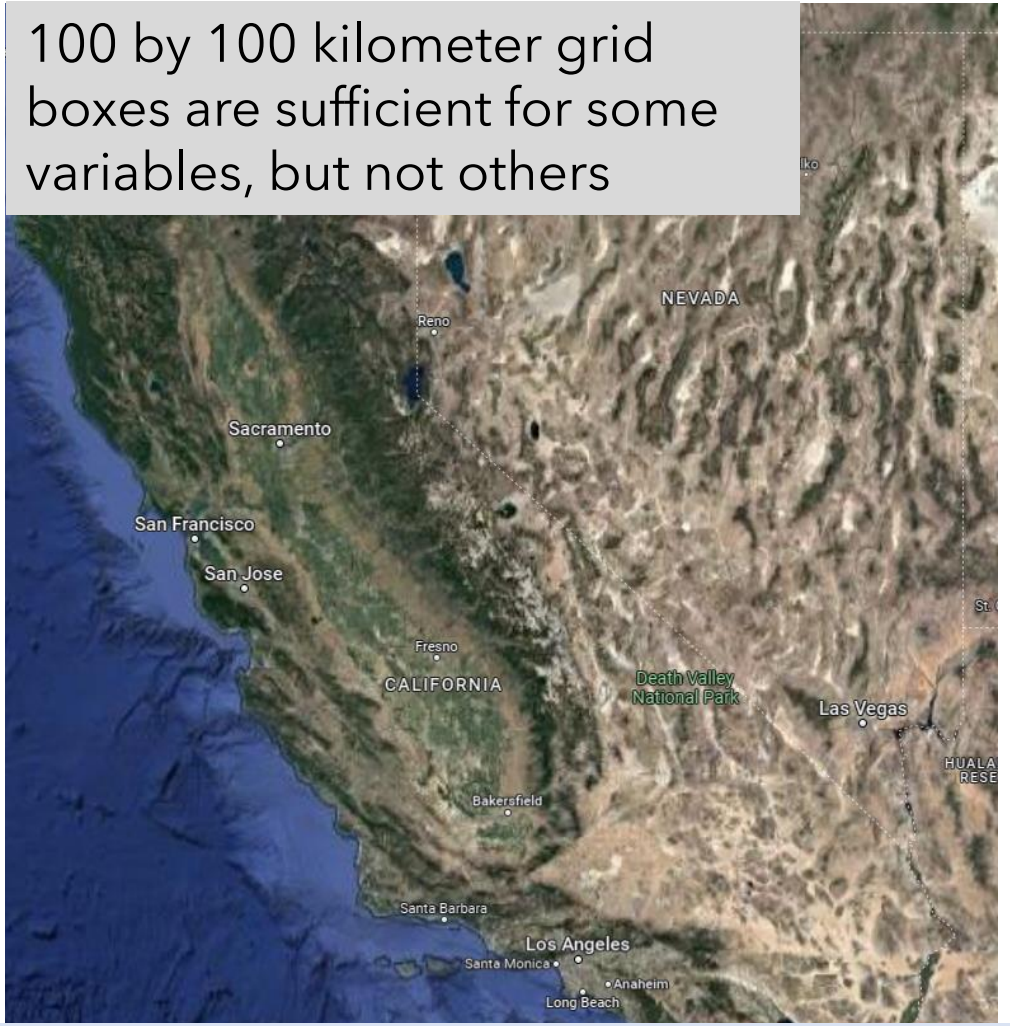
**Challenge #1:** Model data is coarse




100 by 100 kilometer grid boxes are sufficient for some variables, but not others




**GCM – General Circulation Model: The scientific name for the types of climate models used for projection**

# Challenges to Using Climate Model Data

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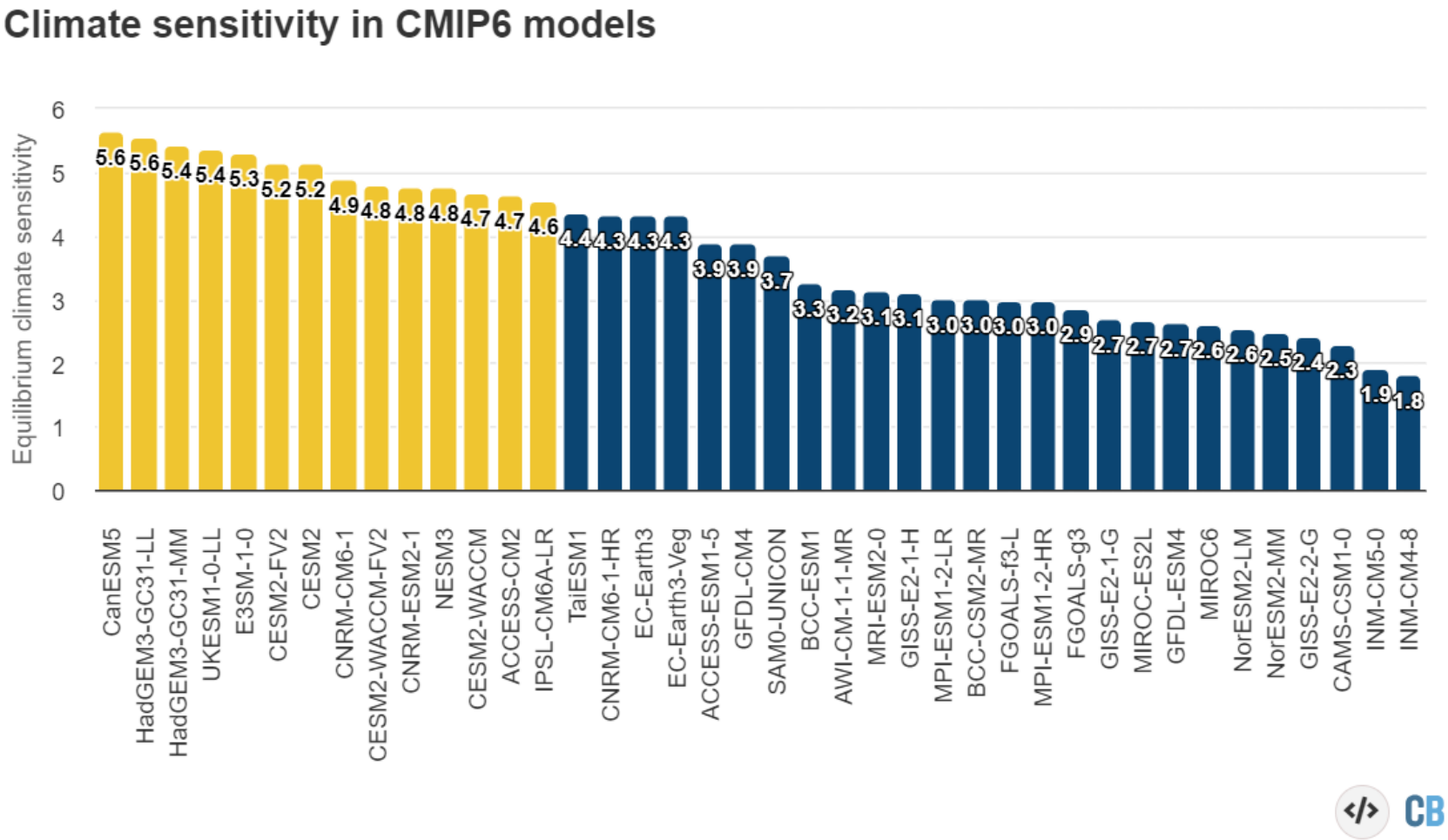
**Challenge #2:** Over 100 climate models exist in latest set (CMIP6)




Each model has a different response to climate change

Plotted: Global temperature response to doubling CO2 (Climate sensitivity: 1.83-5.67 degrees Celsius)

# Challenges to Using Climate Model Data

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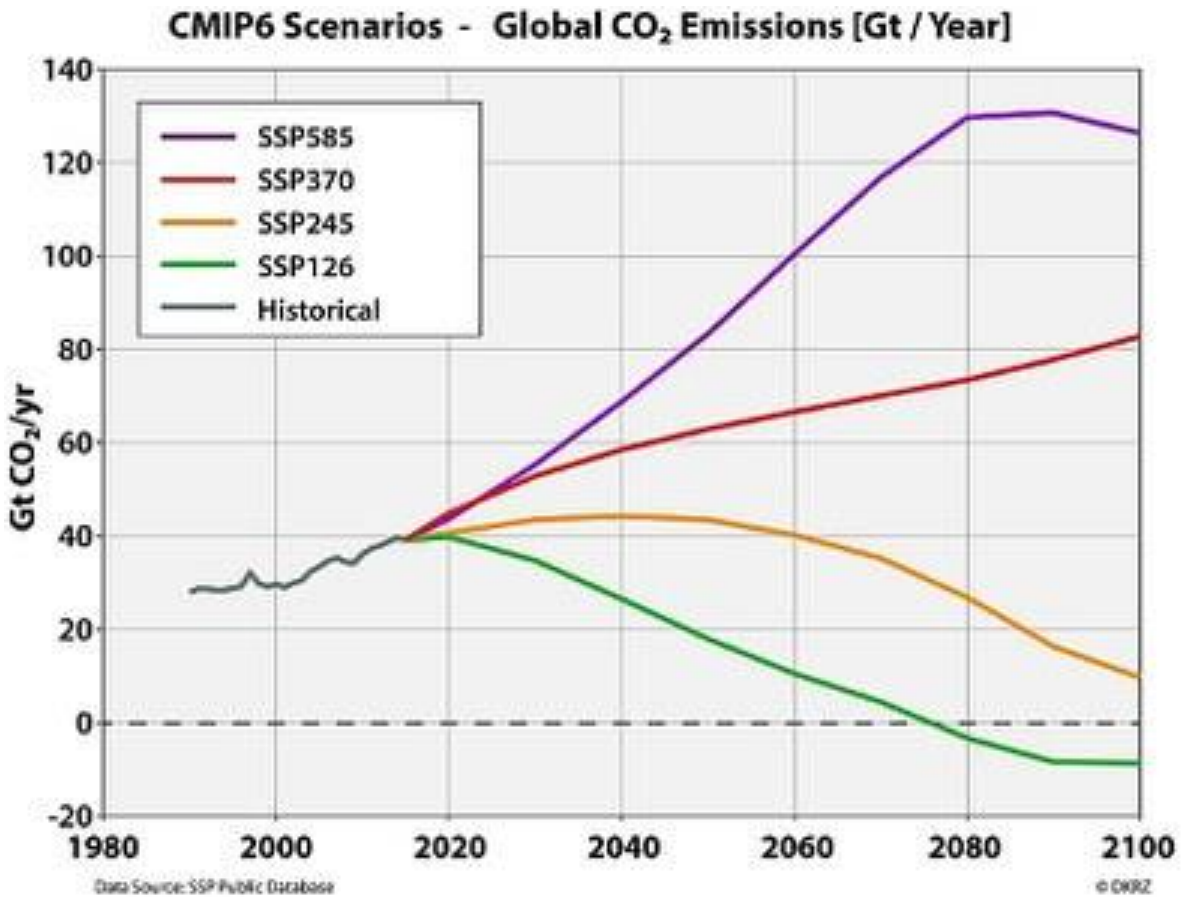
**Challenge #3:** Future Emissions Uncertainty




**Emissions keep accelerating?**

**Steady increase?**

SSP: Shared Socio-economic Pathways: Possible groups of decisions made by society/policymakers

**Reduction?**

**Negative emissions?**

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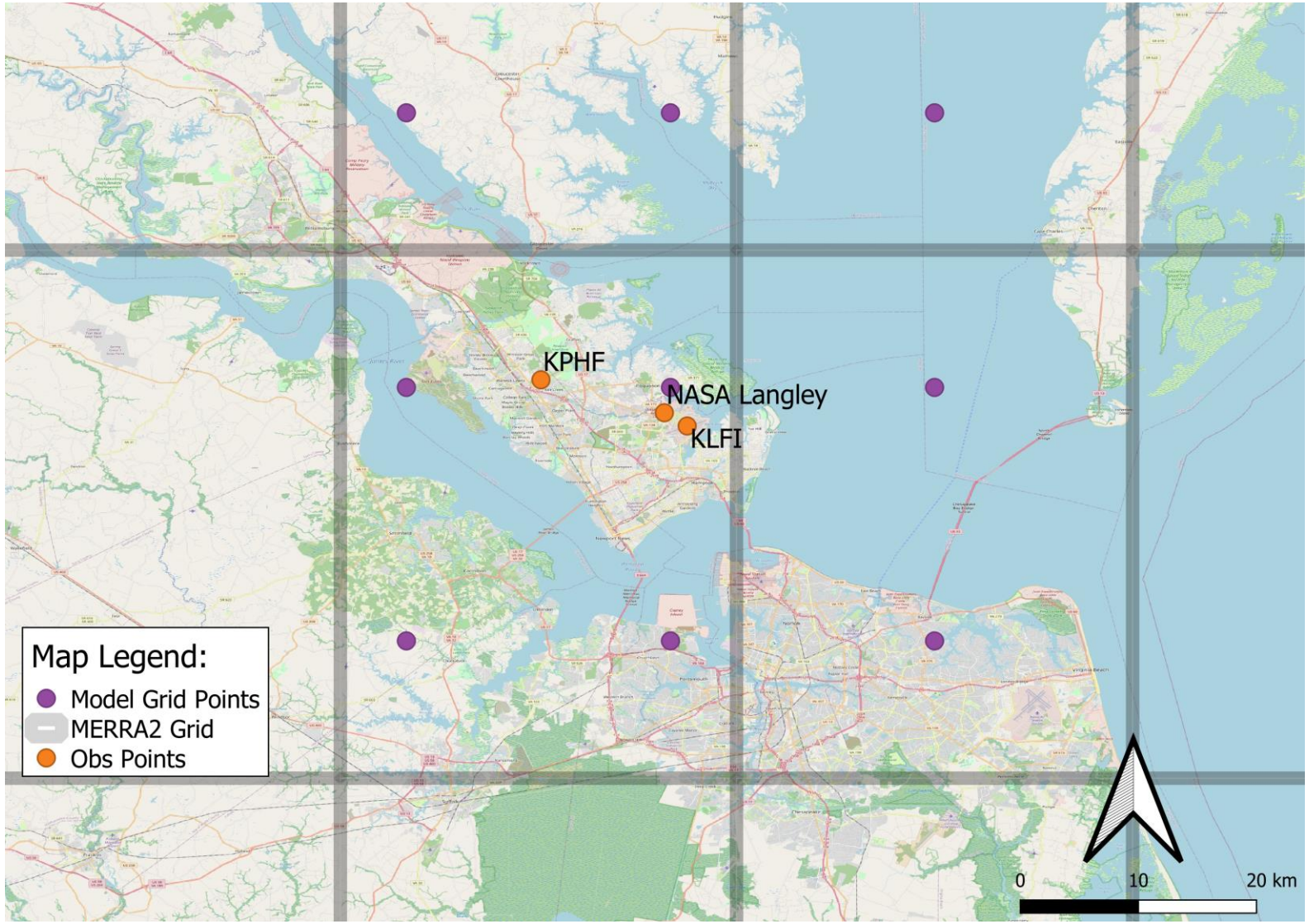
# Solution to Coarse Model Data

**Whole map area: ~ 1-2 grid boxes in raw model data**

**Gray boxes: Reanalysis data (MERRA2)**

**Purple grid points: downscaled model data**

Downscaled data greatly increases spatial resolution of the data.

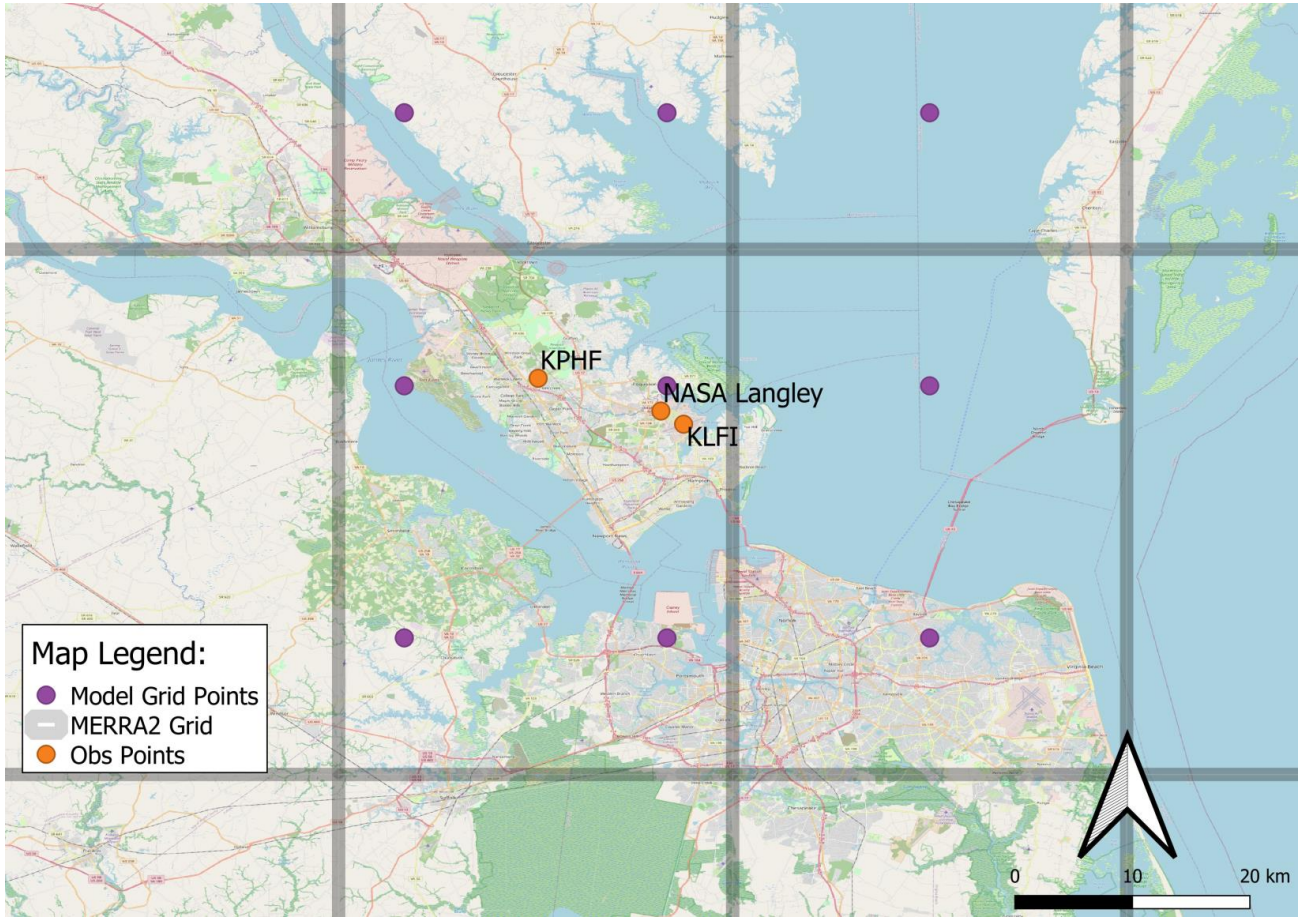



**Challenge #1:** Model Data is coarse

# Solution to Coarse Model Data

## NASA Earth Exchange (NEX) GDDP-v6 dataset

- Characteristics
  - Daily data, 60°S-90°N, 180°W-180°E
  - 0.25 degree latitude and longitude spacing
  - 9 meteorological variables
  - 34 CMIP6 models available




**Challenge #1:** Model Data is coarse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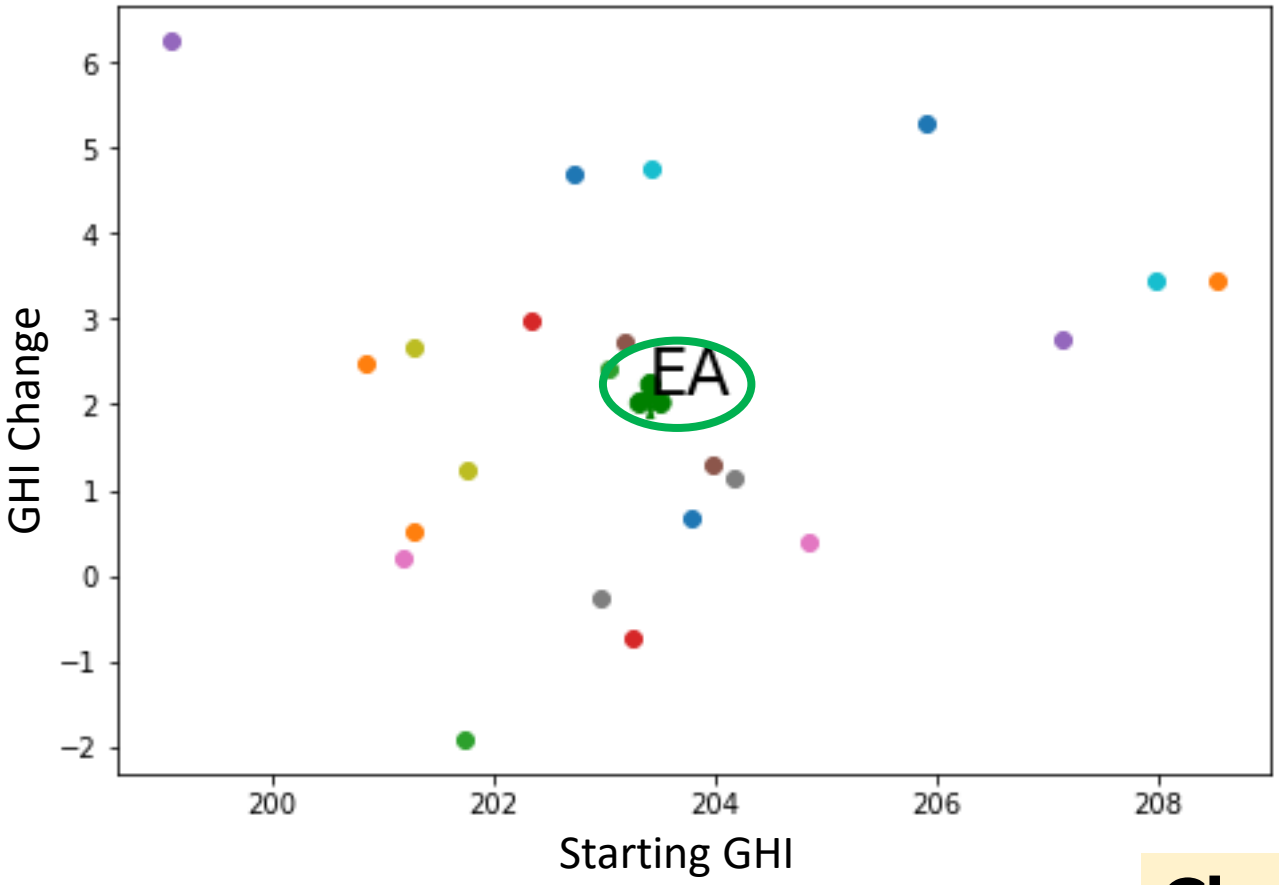
# Quantities available

| Quantity | Units |
|---|---|
| **Daily Mean Surface Air Temperature** | **Degrees Celsius** |
| **Daily Maximum Surface Air Temperature** | **Degrees Celsius** |
| **Daily Minimum Surface Air Temperature** | **Degrees Celsius** |
| Specific Humidity | Grams per kilogram (g/kg) |
| Relative Humidity | Percent (%) |
| **Downwelling Solar Flux** | **Kilowatt Hours per Square Meter** |
| Downwelling Longwave Flux | Watts per Square Meter |
| **Daily Mean Surface Wind Speed** | **Meters per Second** |
| Daily Precipitation | Millimeters |
| Heating Degree Days | Degree Days |
| Cooling Degree Days | Degree Days |

# Solution to Model Uncertainty

**Ensemble** Average




- Choose a large group of models (removing outliers if needed)
- Average the models over the quantity that you are interested in. The mean value is the **ensemble average.**

**Advantage**: Easy to implement
**Disadvantage**: Averaging smooths out variability

**Challenge #2:** Over 100 CMIP6 models exist

# Solution to Model Uncertainty

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## Choose Representative Spread of Models

| Model - Slope | Rank |
|---|---|
| CMCC-ESM2 | 1 |
| ACCESS-CM2 | 2 |
| BCC-CSM2-MR | 11 |
| IPSL-CM6A-LR | 21 |
| INM-CM5-0 | 22 |

- Rank the models by value for a quantity that you are interested in.
- Use the model with the highest, lowest, and median value.

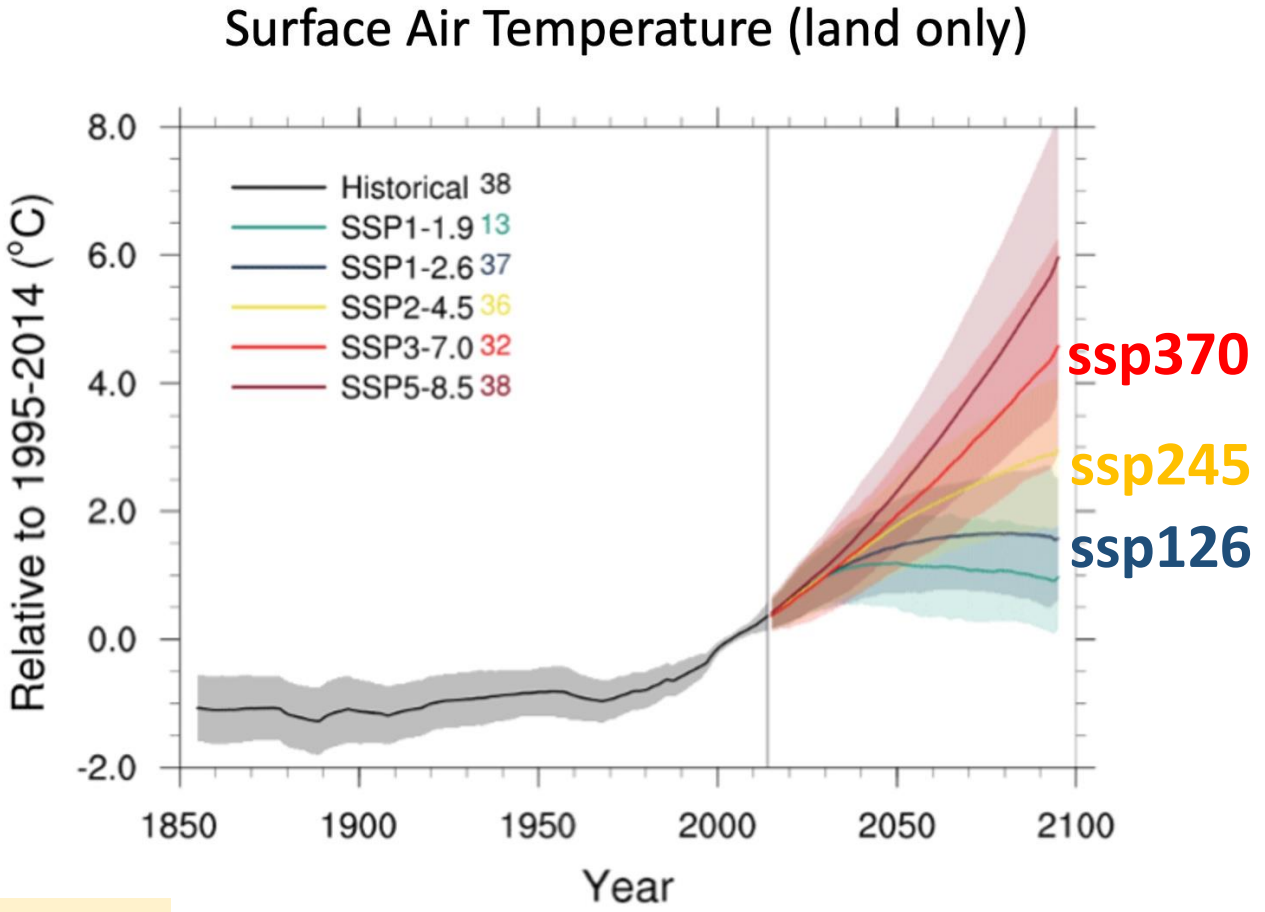
**Advantage**: Highlights range of possibilities
**Disadvantage**: Complexity

**Challenge #2:** Over 100 CMIP6 models exist

# Solution to Future Climate Uncertainty

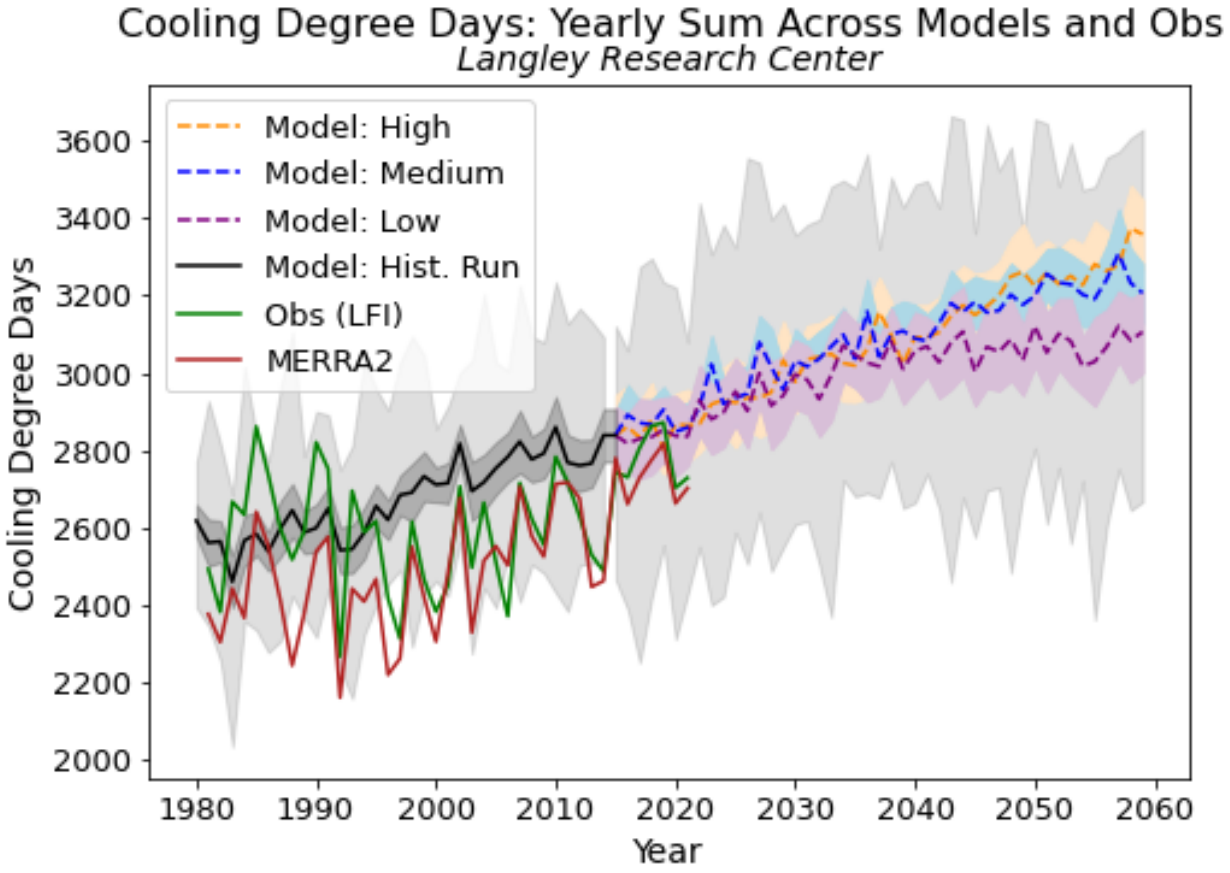
## Consider three emissions scenarios

- High (SSP3-7.0): ~4.2°C warming by 2100
- Medium (SSP2-4.5): ~2.9°C warming by 2100
- Low (SSP1-2.6): ~1.8°C warming by 2100




**Challenge #3:** Future Emissions Uncertainty

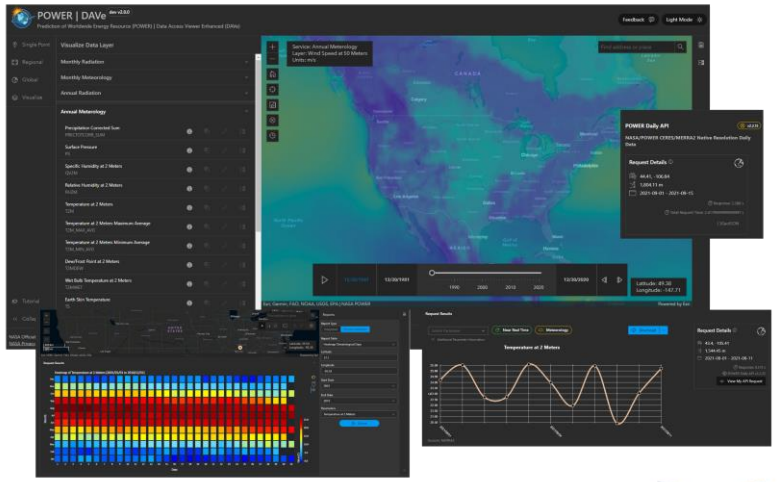
# Bias corrections

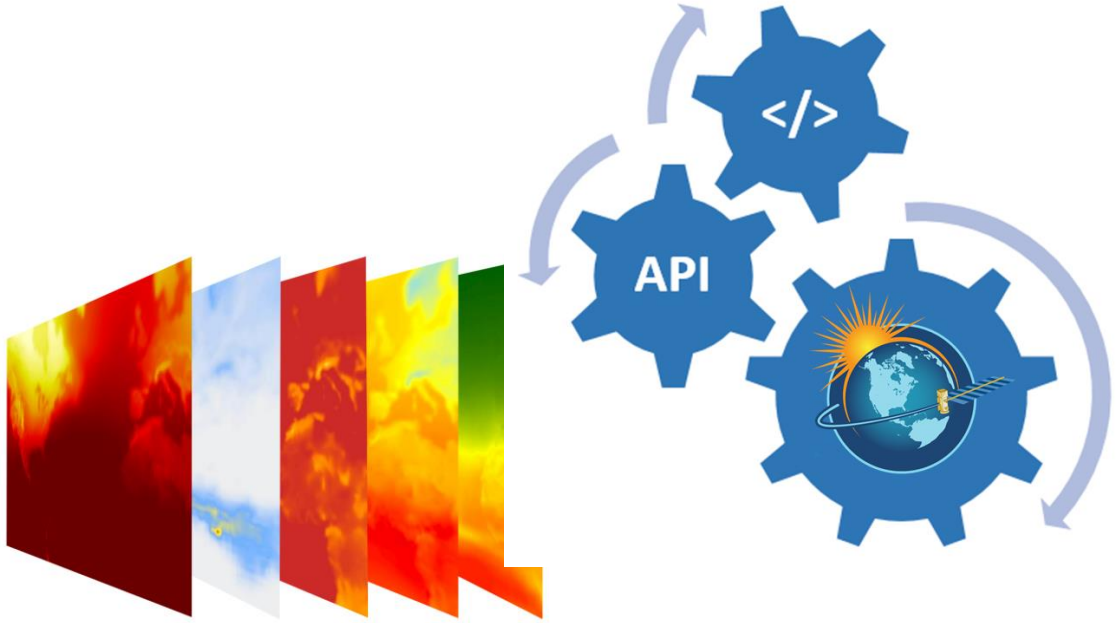



- Matching projection values at start of the period with observations and NASA MERRA2 reanalysis or CERES data
- Bias calculated by comparing model historical run average and observation (green) or reanalysis (red) average over the same period
- Calculated for each of the basic quantities available

# Future Projection Data from POWER

- Bias-corrected time series available on a data visualization tool (select locations across U.S.)
- Data Application Programming Interface (API)
- Direct access on Amazon Web Services (AWS) cloud



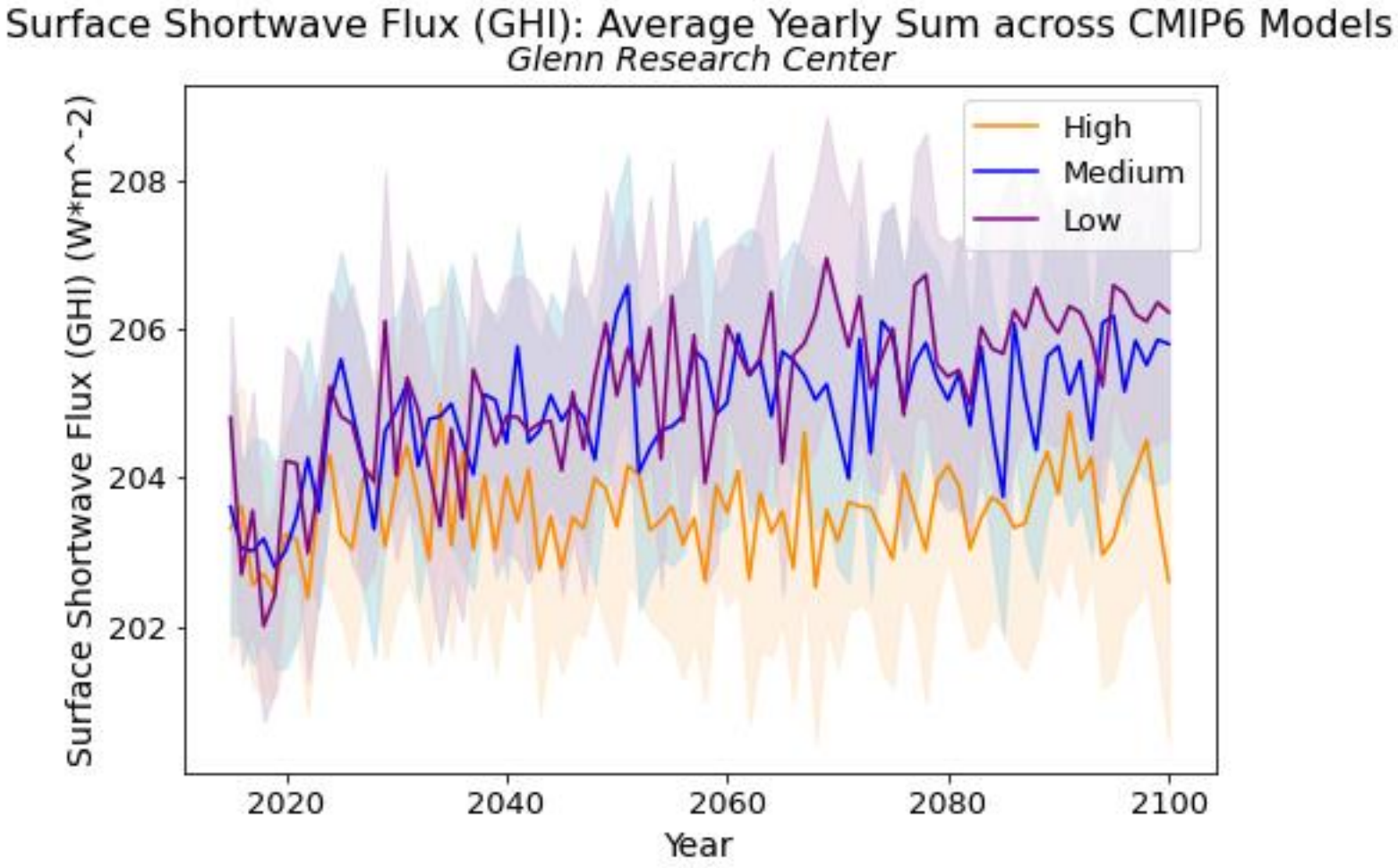

Future development:

- Geographic Information systems (GIS) Image services

# Plots Available: Annual Time Series

**With this plot, a user can:**

- Track long-term trends
- Show differences between emissions scenarios

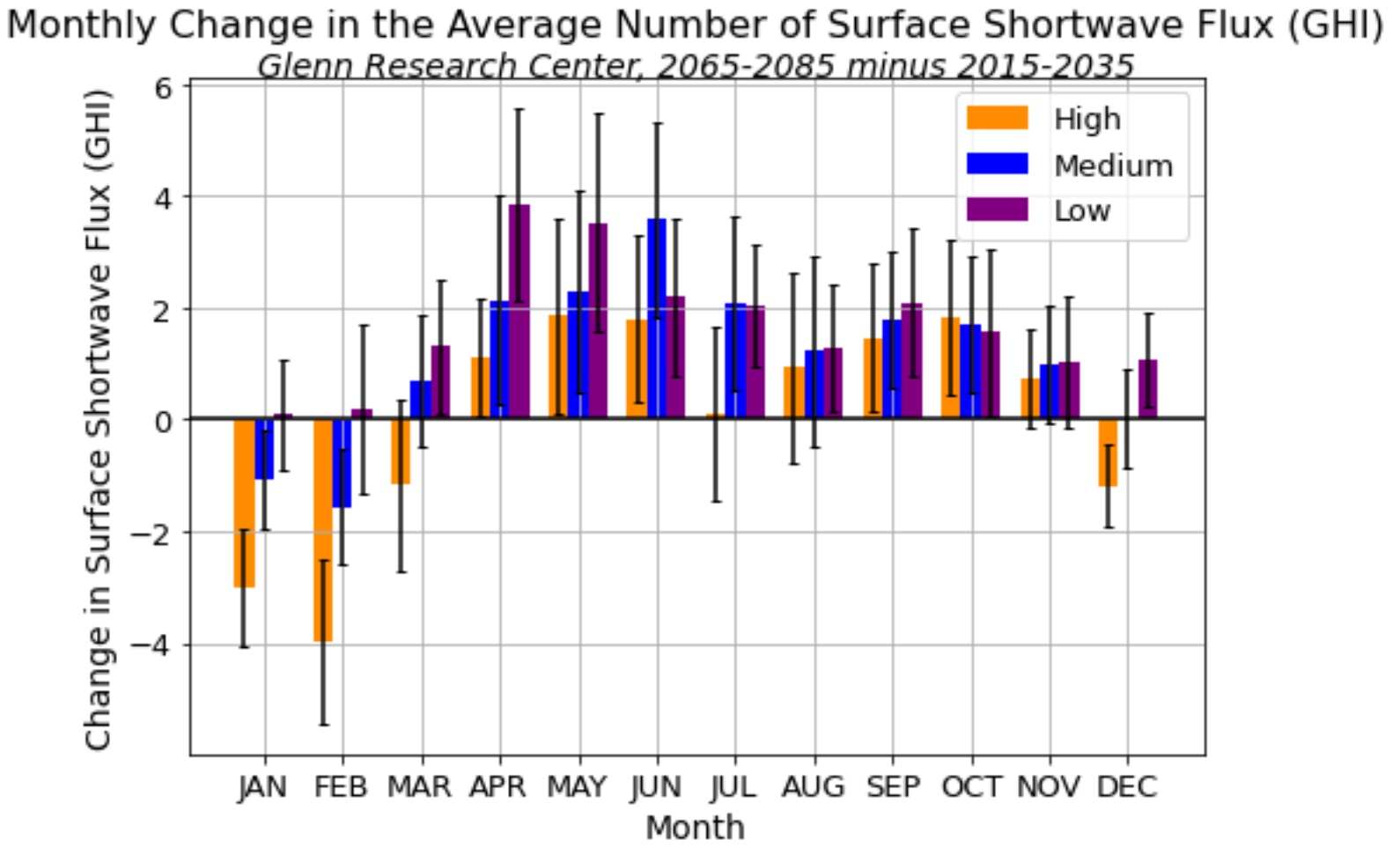



More details forthcoming in journal article (under review): Hegyi et al. 2023 submitted to *Energy*

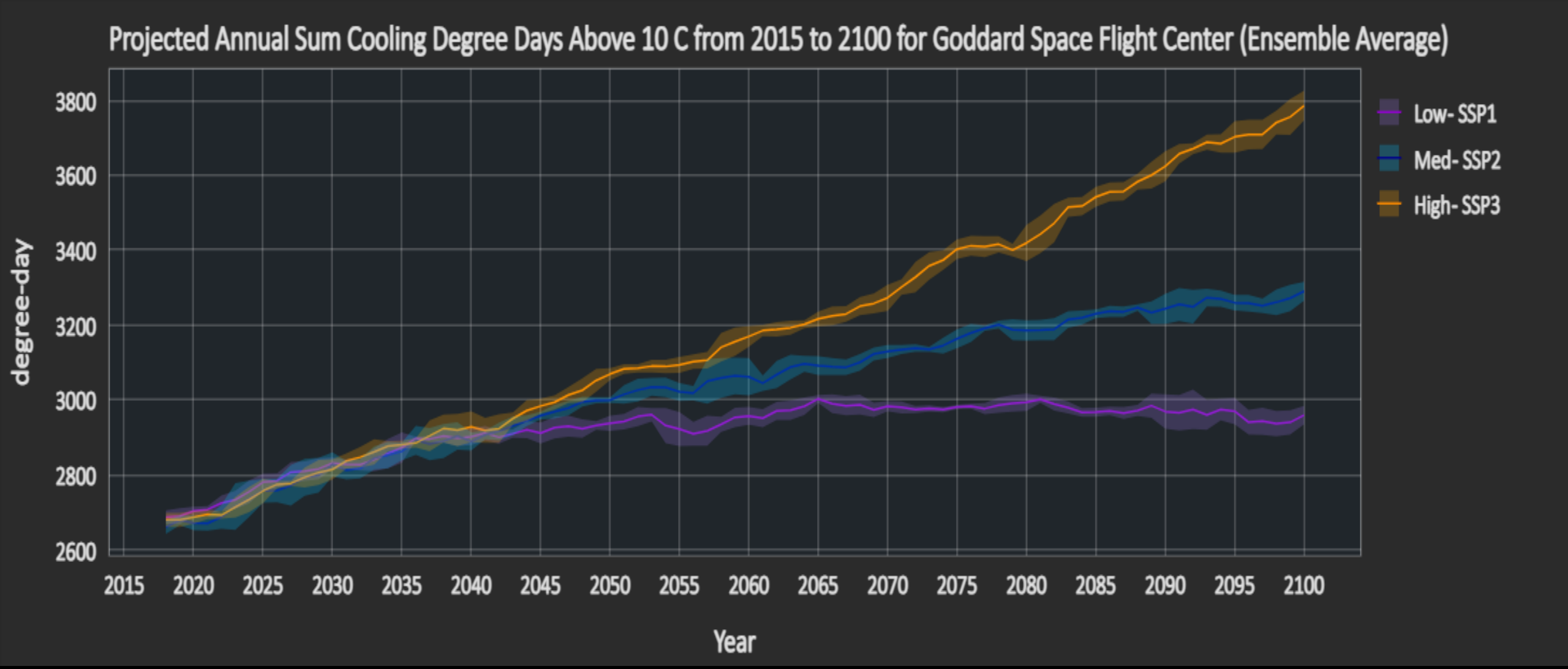
# Plots Available: Monthly Time Series

**With this plot, a user can:**

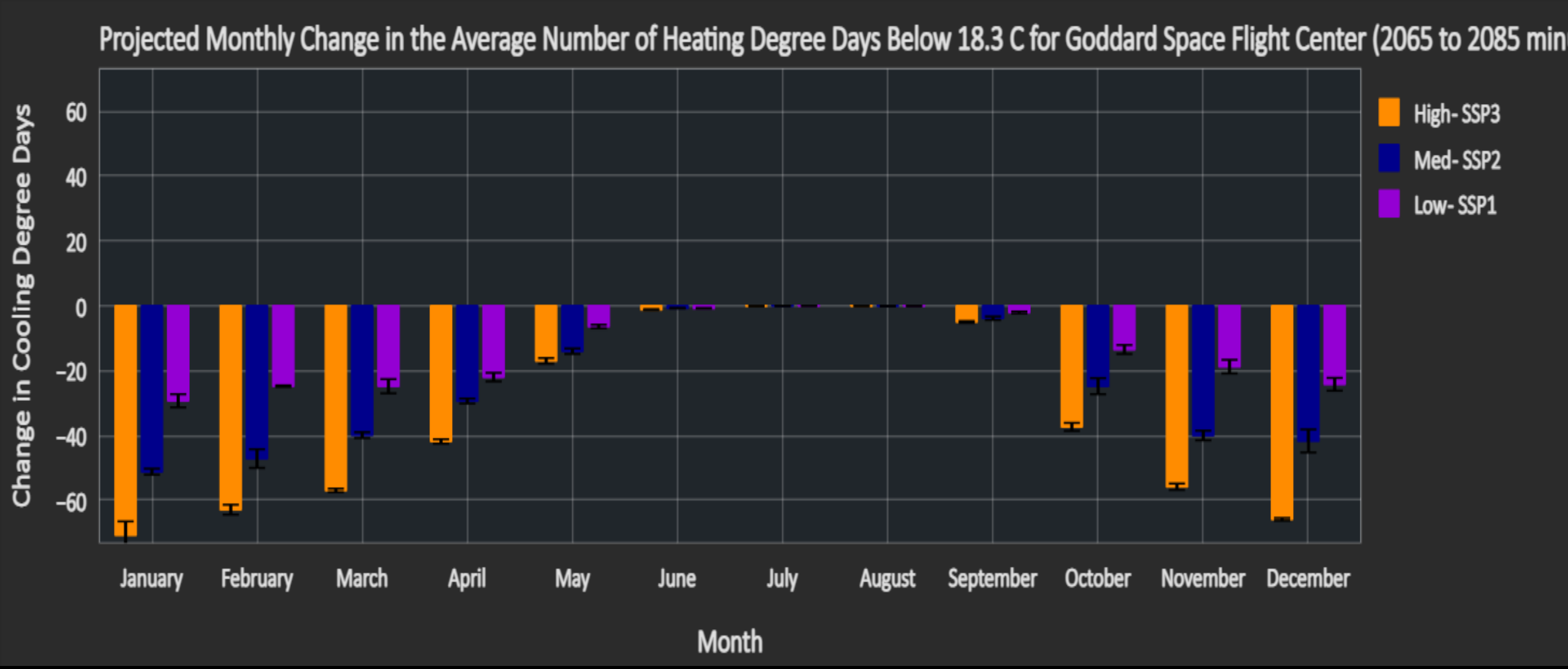
- Quantify the seasonality of changes at any location
- Show differences between emissions scenarios



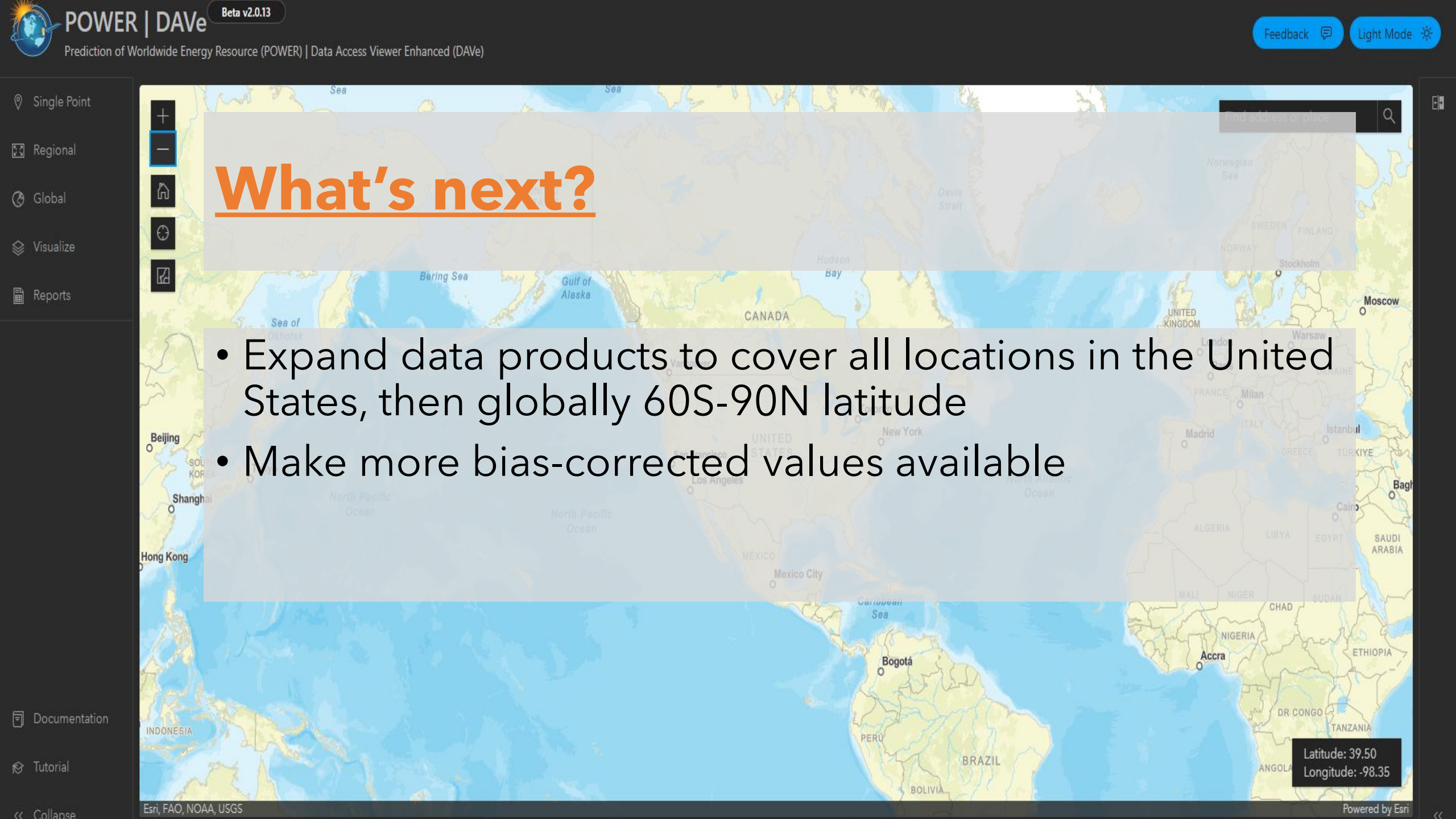

More details forthcoming in journal article (under review): Hegyi et al. 2023 submitted to *Energy*




**Future Annual Time Series**
**Goddard Space Flight Center**
**38.75 degrees North, -76.97 degrees East**
**2015 to 2100**
**Cooling Degree Days**




**Future Monthly Differences**
**Goddard Space Flight Center**
**38.75 degrees North, -76.97 degrees East**
**2065-2085 minus 2015-2035**
**Heating Degree Days**


POWER | DAVe
Beta v2.0.13
Prediction of Worldwide Energy Resource (POWER) | Data Access Viewer Enhanced (DAVe)
Feedback
Light Mode
Single Point
Regional
Global
Visualize
Reports
Documentation
Tutorial
Collapse
What's next?
• Expand data products to cover all locations in the United States, then globally 60S-90N latitude
• Make more bias-corrected values available
Latitude: 39.50
Longitude: -98.35
Esri, FAO, NOAA, USGS
Powered by Esri

# Thank you!

Email: larc-power-project@mail.nasa.gov
Website: https://power.larc.nasa.gov

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**Co-Investigators:**

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