

Creating Hourly Weather Timeseries for Future Climates

Approaches to Forward Looking Datasets



David Larson, PhD
Technical Leader, EPRI
DLarson@epri.com

Acknowledgements



Erik Smith, PhD
Technical Leader
EPRI



Delavane Diaz, PhD
Program Manager
EPRI

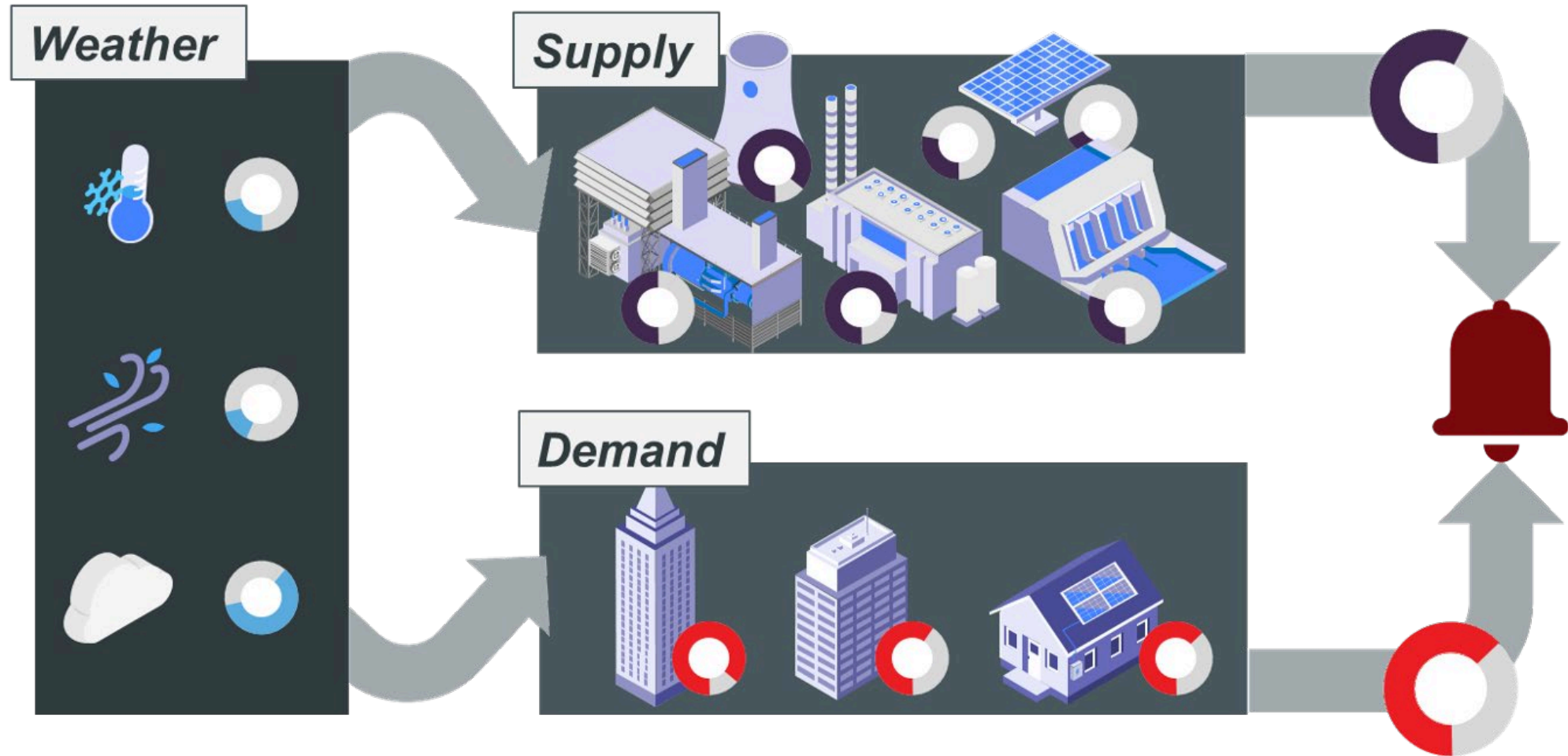


Dan Kirk-Davidoff, PhD
Sr Technical Leader
EPRI



Felicia Chang, PhD
Research Staff
EPRI

Motivating example: Resource Adequacy



Need hourly data that reflects future weather extremes

Need hourly resolution, forward-looking weather data

- Global Climate Model (GCM) data is widely available...
- **But** GCM data is typically daily resolution
- Interpolating (daily-to-hourly) is simple...
- **But** can miss important patterns
- Customized dynamic downscaling is powerful...
- **But** is typically expensive and not widely available

What can we do today?

Idea: combine historical data and climate projections

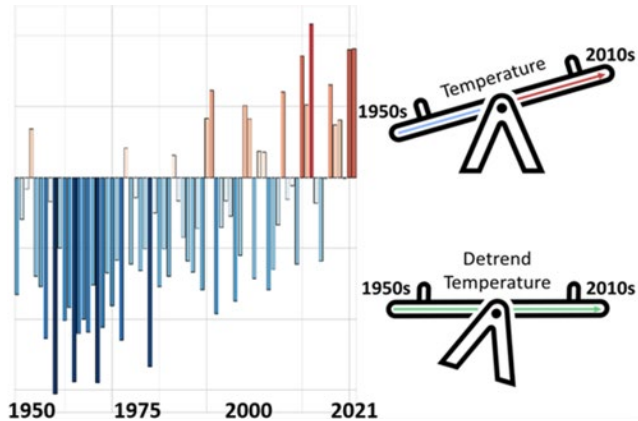
Historical Data	Climate Projections
Hourly data	Daily data
Realistic variability - Scales of weeks, months, & years from 72 years of historical weather (1950-2021)	Limited variability - Variability is constrained to the underlying physical model; typically not well-captured
Historical years only - Can't represent weather extremes that haven't happened	Future years + historical simulations - Can capture how the climate will change - Can represent weather that has never happened
Preserves physical link between variables - Variables are dynamically consistent since they come from the same dataset (ERA5)	Projection data lacks variables at hourly resolution - Physical link is absent when interpolating daily data or using variables from different sources
All variables available - i.e., 10 m & 100 m wind speeds	Limited number of variables - i.e., 10 m wind speeds only

 Important or desired characteristic

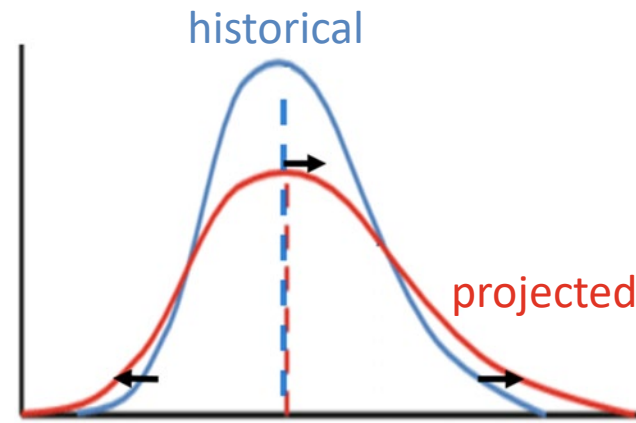
*Note: we currently only shift temperature profiles (and precipitation where relevant), maintaining historical hourly correlation with wind and solar (which haven't been shown by GCMs to shift distribution)

High-level overview of our method

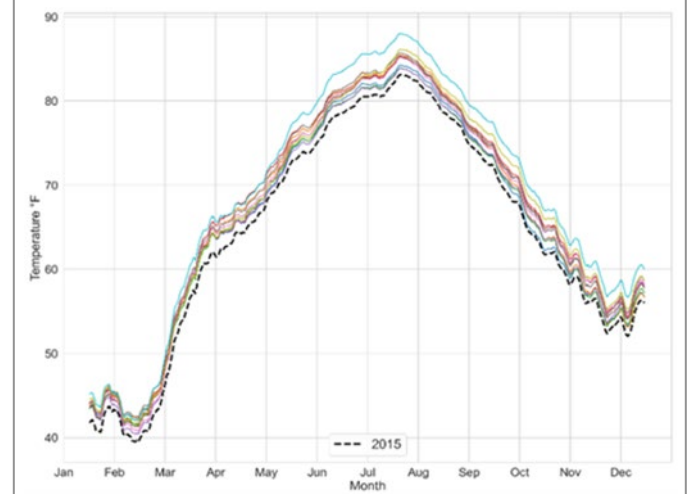
(1) **Detrend historical data** using representative years with natural variability



(2) Calculate **distributional shift** from GCM historical simulation to project period



(3) **Shift historical data** using the deltas (shift) calculated in step 2



Can use multiple GCMs as input

How much data does this method generate?

N years of historical data $\times$ **M** climate models $\times$ **P** emission scenarios

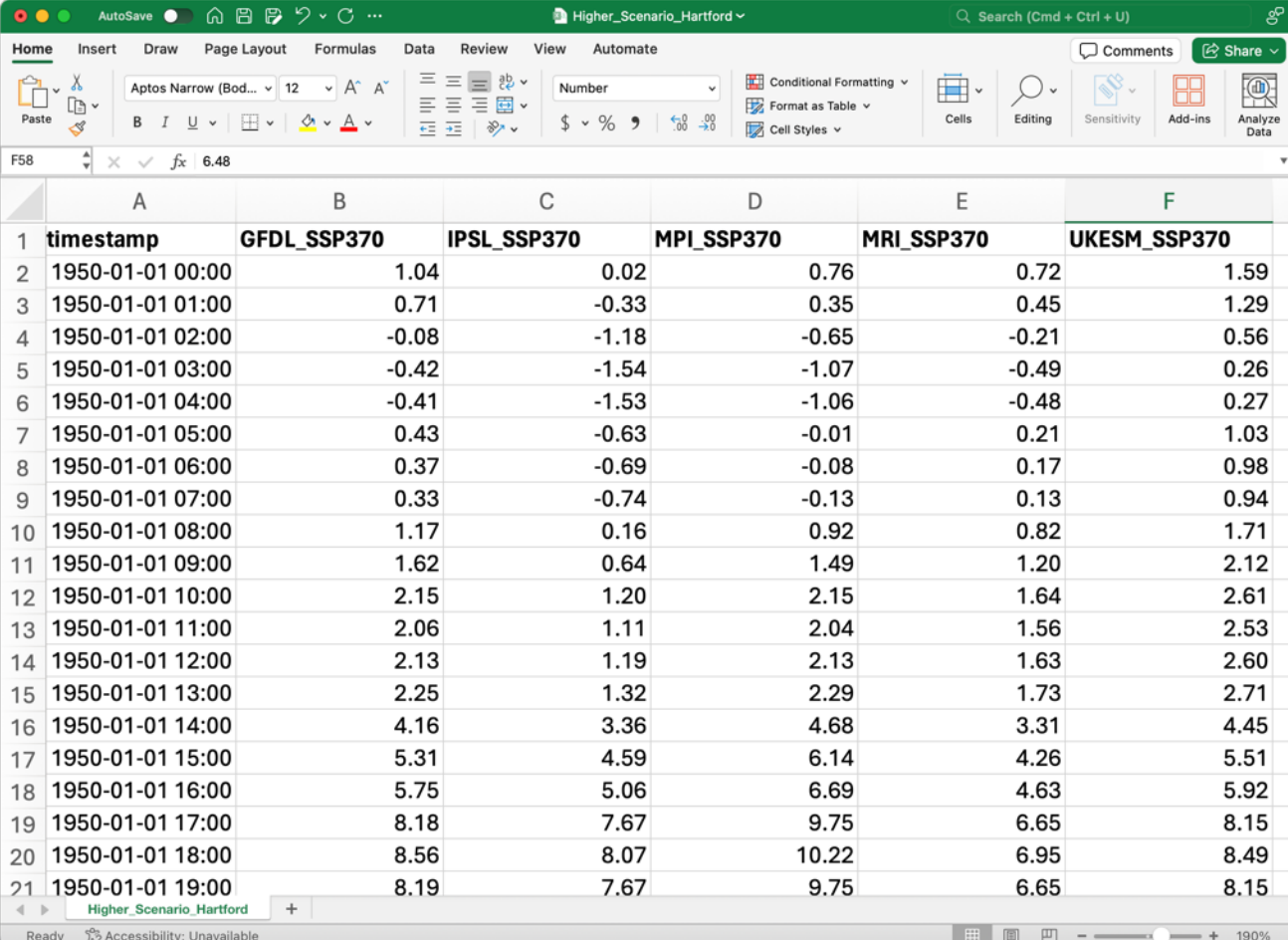
Example:

- 72 years historical data (ERA5)
- 5 climate models (CMIP6)
- 2 emissions concentration scenarios

= 720 Weather year profiles per target study year
720 versions of 2030 weather

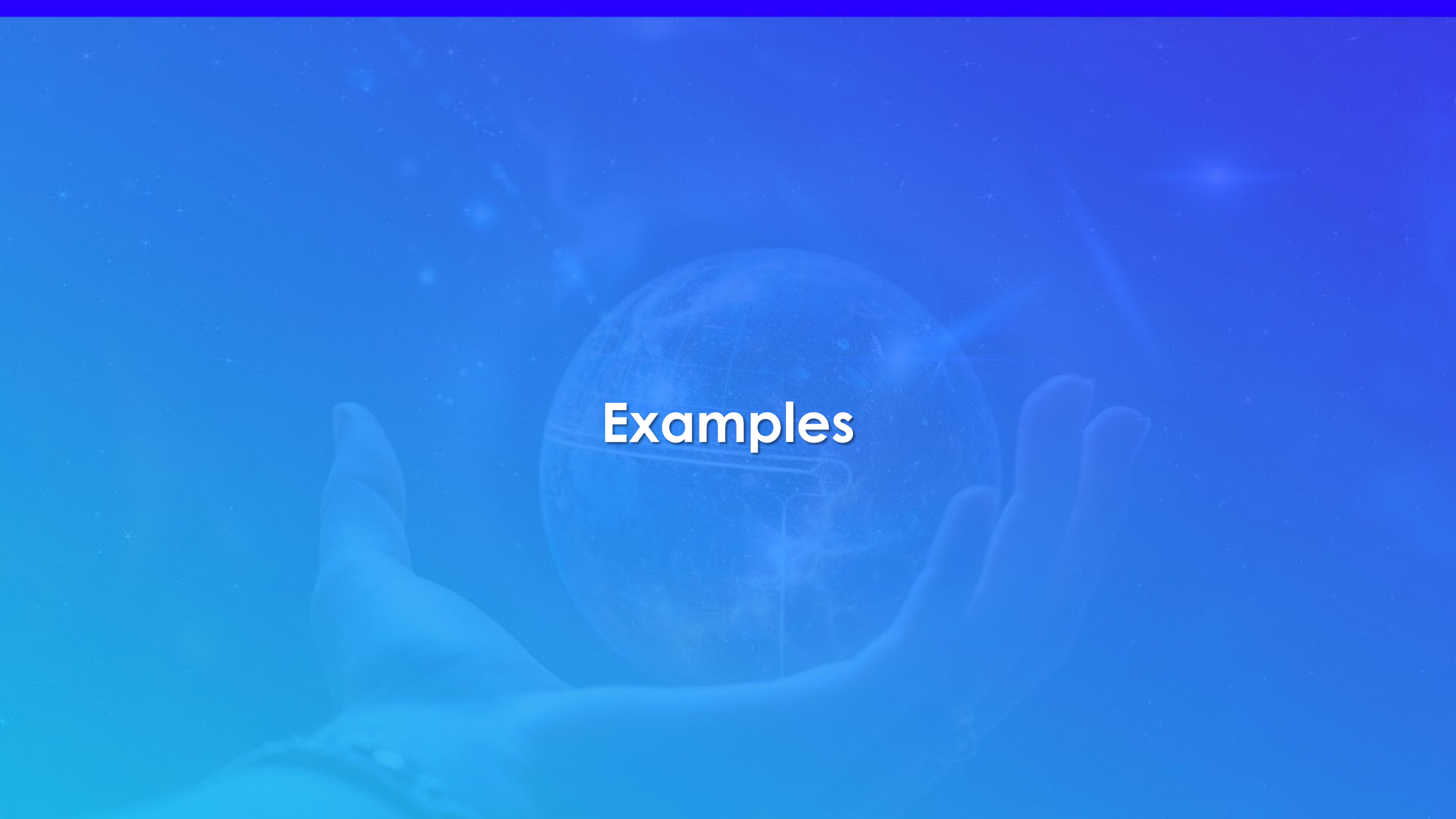
What does the output look like?

- Timestamp
- 1 column per GCM and emissions scenario
- **Example: GFDL_SSP370**
 - GFDL = GCM
 - SSP-3.70 = higher emissions scenario



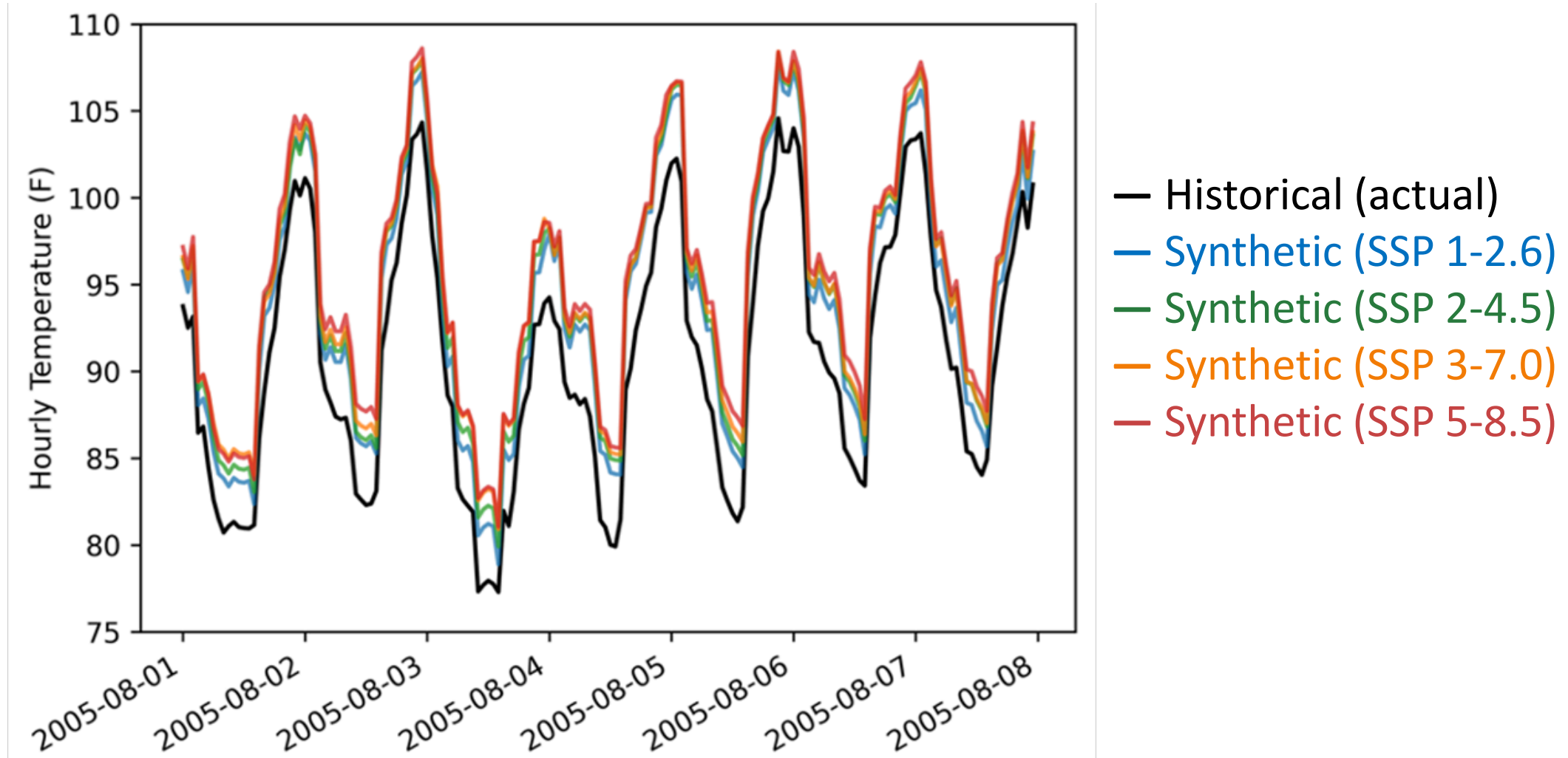
	A	B	C	D	E	F
1	timestamp	GFDL_SSP370	IPSL_SSP370	MPI_SSP370	MRI_SSP370	UKESM_SSP370
2	1950-01-01 00:00	1.04	0.02	0.76	0.72	1.59
3	1950-01-01 01:00	0.71	-0.33	0.35	0.45	1.29
4	1950-01-01 02:00	-0.08	-1.18	-0.65	-0.21	0.56
5	1950-01-01 03:00	-0.42	-1.54	-1.07	-0.49	0.26
6	1950-01-01 04:00	-0.41	-1.53	-1.06	-0.48	0.27
7	1950-01-01 05:00	0.43	-0.63	-0.01	0.21	1.03
8	1950-01-01 06:00	0.37	-0.69	-0.08	0.17	0.98
9	1950-01-01 07:00	0.33	-0.74	-0.13	0.13	0.94
10	1950-01-01 08:00	1.17	0.16	0.92	0.82	1.71
11	1950-01-01 09:00	1.62	0.64	1.49	1.20	2.12
12	1950-01-01 10:00	2.15	1.20	2.15	1.64	2.61
13	1950-01-01 11:00	2.06	1.11	2.04	1.56	2.53
14	1950-01-01 12:00	2.13	1.19	2.13	1.63	2.60
15	1950-01-01 13:00	2.25	1.32	2.29	1.73	2.71
16	1950-01-01 14:00	4.16	3.36	4.68	3.31	4.45
17	1950-01-01 15:00	5.31	4.59	6.14	4.26	5.51
18	1950-01-01 16:00	5.75	5.06	6.69	4.63	5.92
19	1950-01-01 17:00	8.18	7.67	9.75	6.65	8.15
20	1950-01-01 18:00	8.56	8.07	10.22	6.95	8.49
21	1950-01-01 19:00	8.19	7.67	9.75	6.65	8.15

Simple formatting (CSV) compatible with wide range of tools



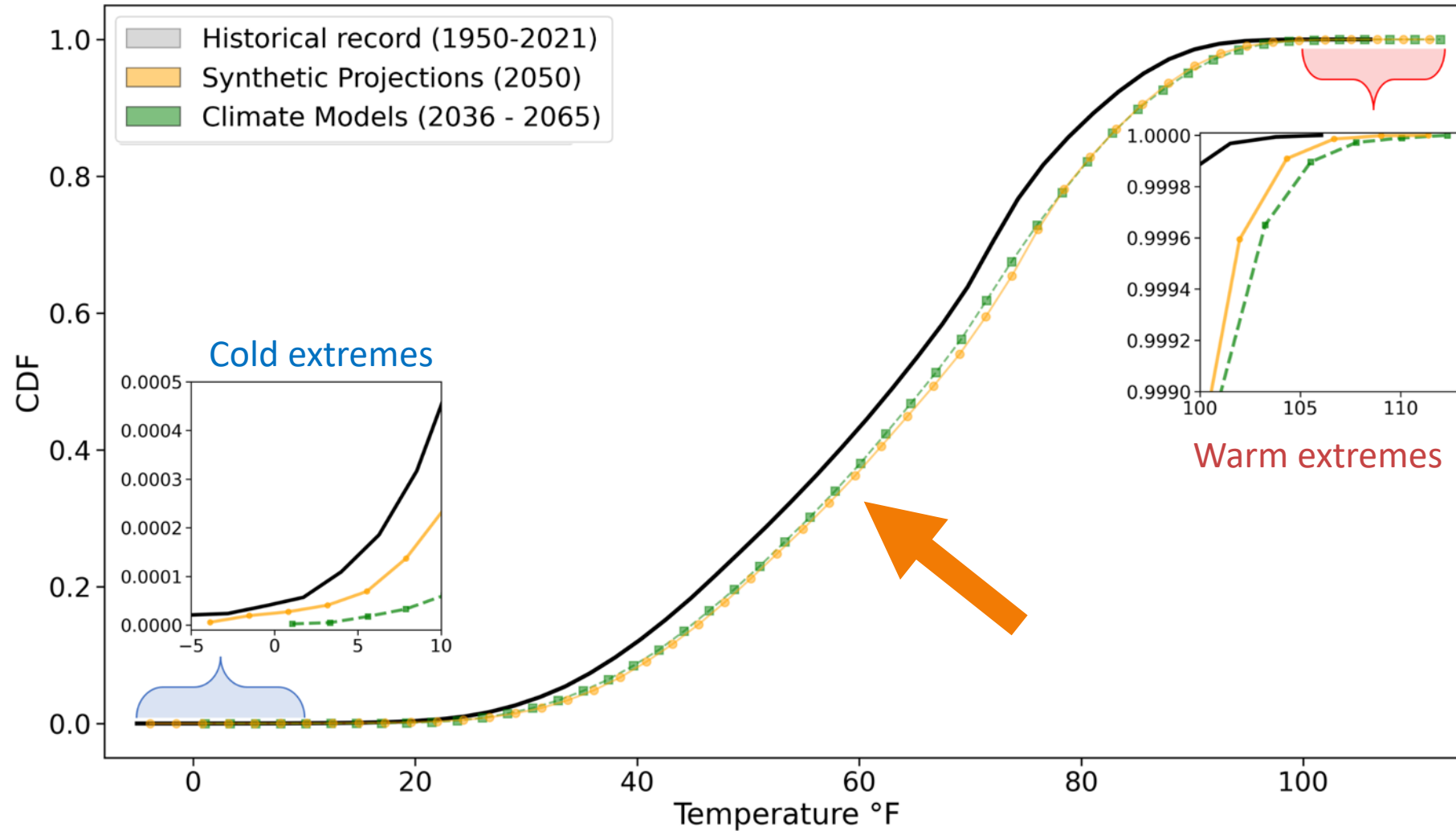
Examples

Synthetic data captures peaks and natural variability



Shifted temperature hourly timeseries (2050 climate)

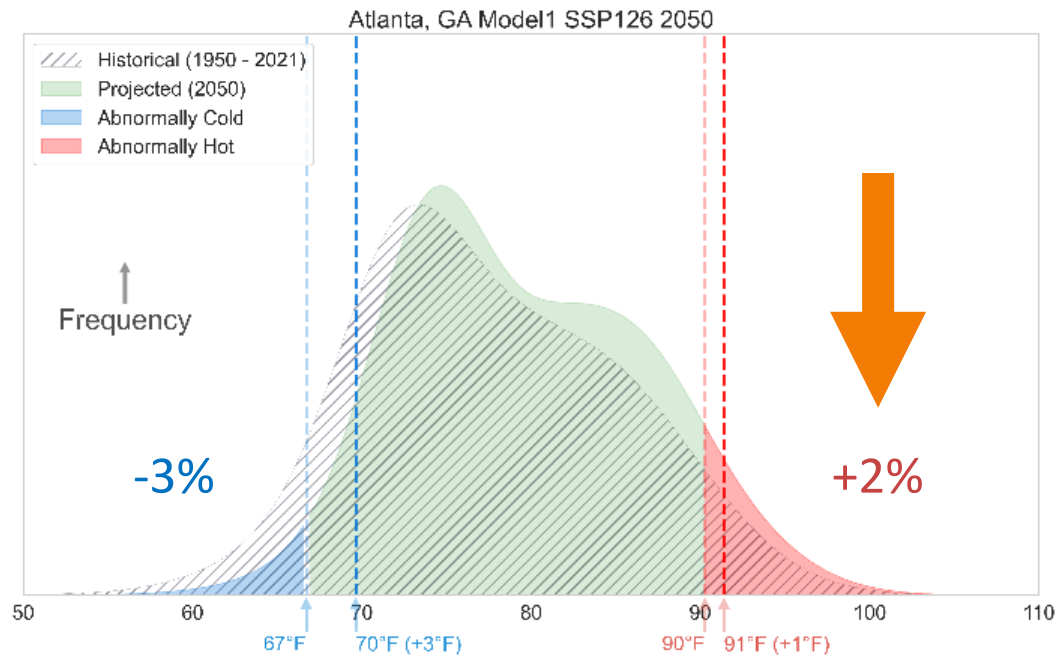
Also capture extremes (tails of the distribution)



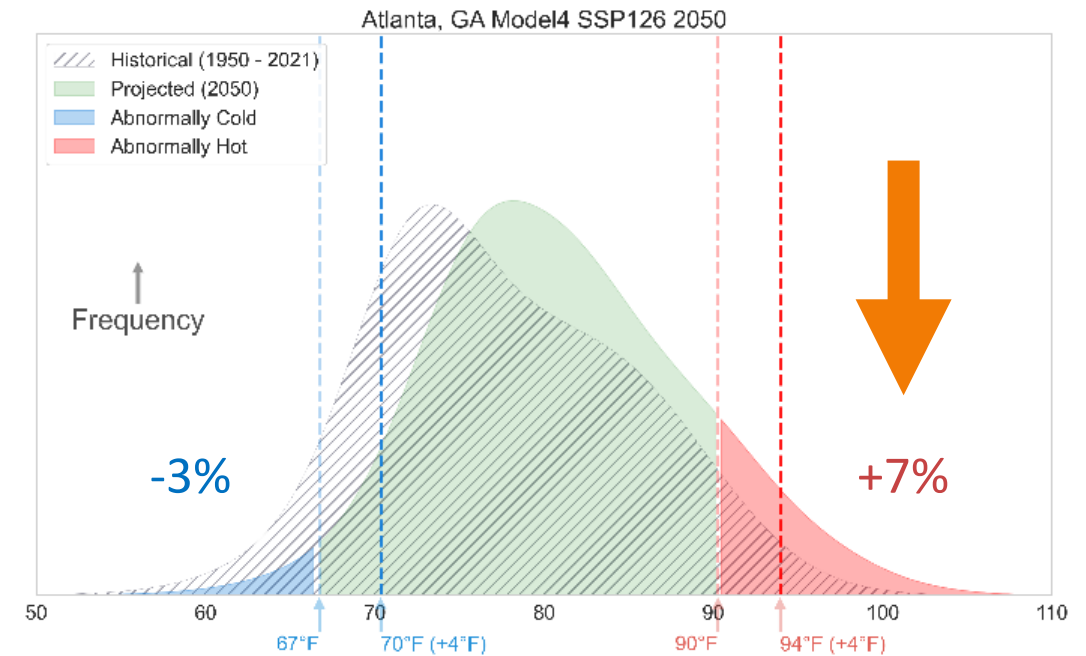
Distribution of temperature in historical vs synthetic vs GCM

Method allows capturing differences in GCMs

(a) Colder Model

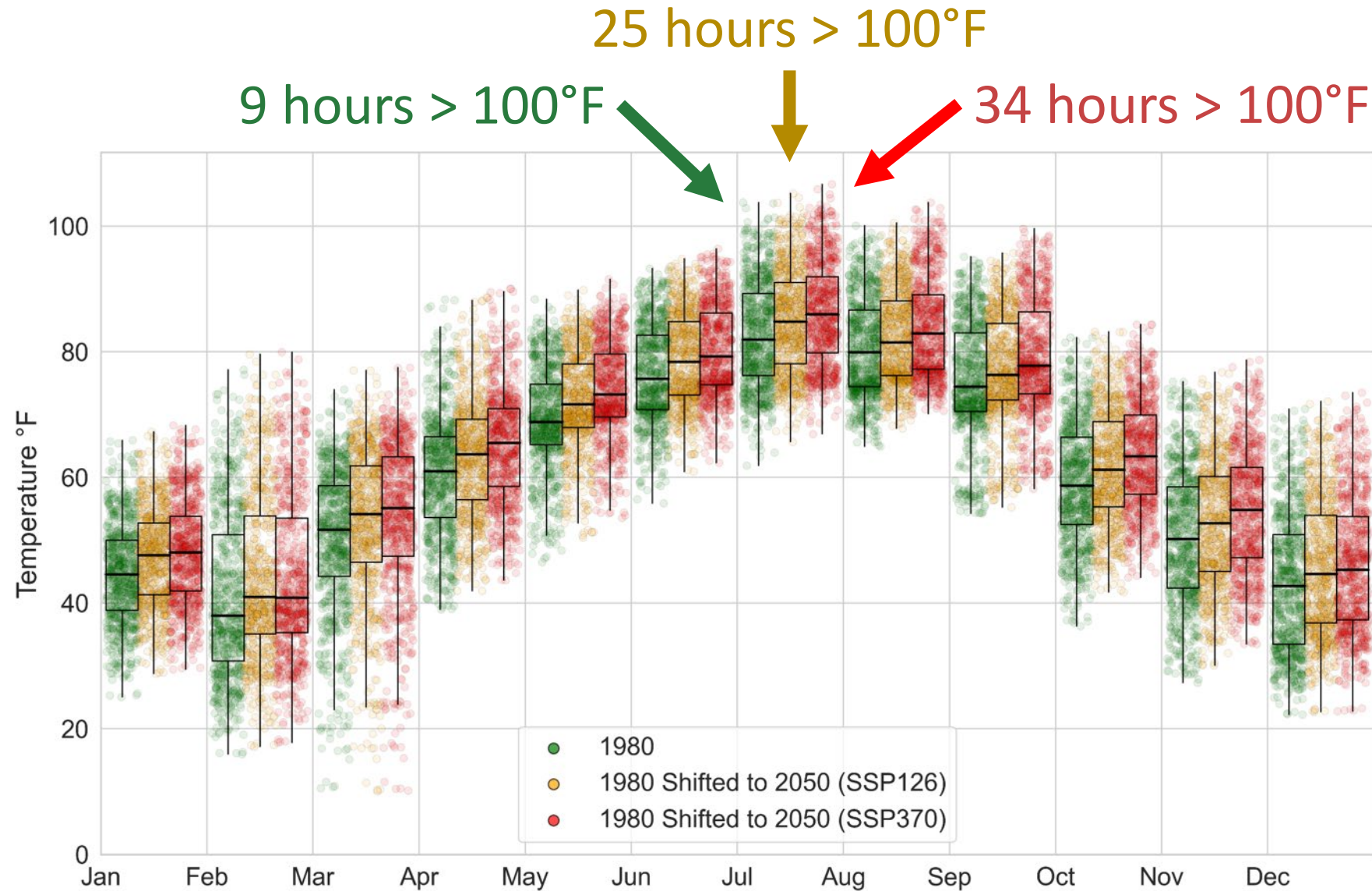


(b) Warmer Model



Shifted temperatures between a “colder” and “warmer” GCM

1980 (a warm year) shifted to 2050 synthetic profiles*



*Based on one GCM (MRI). SSP126 is a lower climate scenario, SSP370 is the higher climate scenario.



Next Steps and Discussion

Summary

- **Need hourly resolution, forward-looking datasets** for a range of power system studies and applications
- Presented method to combine GCM projections (forward-looking) with historical data (hourly) to **create realistic synthetic future weather data**

Benefits of Synthetic Profiles for Future Climates

- Provides hourly projection data when critical for the application
- Captures real-world variability from 72 years of historical data
- Potential to create 1000s of realistic climate-adjusted profiles
- Preserves the physical link between synchronous meteorological variables (temp / wind / solar / precipitation)
 - Not all variables need to be adjusted
- Can include historical years in future scenarios as a lower bound for risk assessments particularly concerned with extreme cold

Limitations

- Point-specific
- Primarily just for temperature
- Can't capture extremes far beyond historical record

More info: contact Erik Smith <ESmith@epri.com>



Related Resources

EPRI R&D Initiatives

Climate READi

- Strengthen the power sector's collective approach to **managing climate risk** to the power system



<https://www.epri.com/READi>

Load Forecasting Initiative

- **Address critical needs** in load forecasting across operations and planning timescales



<https://msites.epri.com/LFI>

Resources from EPRI's Climate READi:

Climate Data Users Guide

Climate Data Users Guide

EPRI READi

Introduction

Articles

Climate Change Impacts

Weather and Climate Hazards

Overview

Defining relevant terms – weather vs. climate and variable vs event vs. hazard

Assessing the Hazard and Projecting Changes

Assessment for Individual Climate Variables and Event Types

Meteorological Phenomena

Hydrological Phenomena

Acute Extremes

Compound Events

Conclusion

Climate Statistics

Climate Models

Climate Model Downscaling

Choosing Climate Projections

Transparency in Climate Data

Historical Climate Data Sources

Future Climate Data Sources

Future Directions

FAQ

Ice Storms

Long events can be particularly impactful for transmission and distribution systems. Overhead structures are designed for specific ice loading conditions. Trees loaded with ice can fall on overhead power lines. Ice storm data can come from observations and can also be derived from gridded products. The NOAA Storm Event Database has logged ice storm reports, including ice accumulations, since 1996. However, these reports are inconsistent across space as the density of the reports is subject to areas with high populations. Nonetheless, these reports are the best source of local measurements when available. Though not a measurement, ice data can be derived from gridded products, like ERA5, with precipitation type and total precipitation. In short, precipitation can be summed for the hours in which the precipitation type is listed as 'ice' to estimate total ice storm event accumulations. Though subject to all the limitations of gridded data (they are essentially historical short-term weather forecasts, rather than direct observations, see [Historical Climate Data Sources](#)), this method provides a good estimate of the ice storm severity. Furthermore, this method is not limited to regionally specific datasets, like the Storm Event Database, and can be applied to the entire globe.

While information for ice storms is available for an extended historical record, projected changes in the intensity and frequency are uncertain. This is largely because the lower atmospheric processes that drive ice storms, namely a warm air inversion, are not well-resolved by climate models (Klima & Morgan, 2015). Nonetheless, there is research that suggests ice storms may become more frequent in northern latitudes, where historically, the bulk of frozen precipitation was snow. Though research suggests a poleward shift in icing, there is no historical trend (since 1950) in the ERA5 data to suggest this is occurring across the United States.

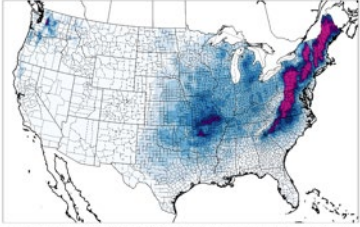


Figure 3: Average annual total freezing rain for 1950-2022. Figure shows hourly ice accumulations derived from hourly precipitation and precipitation types. Data taken from ERA5 gridded reanalysis dataset. Source: EPRI analysis. For more information, see EPRI Report #3002026439.

Table 5: Temporal extent of historical and projected data for types of precipitation. Not all metrics are listed for

Climate Data Inventory

Climate Data Inventory

EPRI READi

Climate READi

Documentation

Homepage

Contact Us

About this Website

Acknowledgments

Citation

Version History

Copyright & Disclaimer

Climate Data Inventory

The Climate Data Inventory is a catalogue of climate and weather datasets that are currently available to support power system analyses. The inventory is not intended to be a comprehensive listing of every available climate dataset, but rather is a curated subset of datasets that are suitable for climate resilience applications in the power system.

Satellite observations are among the many observations, reanalyses, and projections that are cataloged (image source: NASA).

Power system practitioners should use the Climate Data Inventory in conjunction with other [Climate READi resources](#), including the Climate Data User's Guide, which provides guidance on the selection and application of climate data in various power system analysis contexts. The Climate Data User's Guide can be leveraged to understand how to utilize climate data found in the Data Inventory and for more detailed guidance on individual datasets. Through the Climate Data Inventory and our collaborations with other Climate READi workstreams, EPRI is developing a list of climate data gaps that can be used to prioritize new data development. We intend to publish the Climate Data Gap Analysis in mid-2024.

[DOCUMENTATION](#) [MEET THE TEAM](#) [SUBMIT A DATASET](#)

Please use the filters below to explore the inventory. Select a row to view more details. To expand or collapse all rows, press the 'expand' or 'collapse' buttons above the table.

HIDE FILTERS RESET

Found 63 of 63 datasets

EXPAND COLLAPSE

Q Name, Description

Category

Type of Climate Data

Climate Variables

Spatial Resolution

Name	Spatial Resolution	Fixed Temporal Resolution	Spatial Extent	Date Range
Weather Stations Including Automated Surface Weather Observing Systems (ASOS & AWOS), Global Historical Climatological Network (GHCN), Climate Reference Network (CRN), Threshold Extremes	Points	Sub-Hourly	Global	1850-2023

Climate 101

EPRI Research Portfolio Thought Leadership Events Training Journal About Careers

LOGIN/REGISTER

CLIMATE READi RESILIENCE AND ADAPTATION INITIATIVE

Climate 101 Training Series

Value of climate information to electric power sector planning and operations

Climate 101 is designed for electric company asset managers, engineers, operators, and planners who may be exposed to climate data and/or are expected to incorporate it into their respective analyses, but are less familiar with the data's structure, attributes, and use cases. The training intends to provide a foundation for these individuals to engage with climate data providers and analysts in a productive and actionable manner by establishing a common knowledge base on types of climate data, including their applications, and climate modeling, and level setting terminology for climate data types and statistics. A basic understanding of probability and statistics and weather impacts on the power system is assumed, but no further knowledge of climate science is needed.

Climate 101: Physical Climate Data (Modules 1-3) (3002026223)

Physical Climate Data 101 is a resource for building climate literacy across the electric power industry and is a tool for level setting key concepts and terminology among climate experts and other subject matter experts. It provides access to high-quality, technically rigorous training that is designed to facilitate more productive and collaborative future conversations between electric system planners and operators and climate data specialists.

Introduction and Module 1 - Climate Data Overview

Module 2 - Climate Models, Emissions Scenarios, and Projection Data

Module 3 - Trends and Understanding of Extreme Events

Climate 101: Physical Climate Data Intro & Cl...

Physical Climate Data 101: Climate Mo...

Physical Climate Data 101: Trends and...

View the event or Download Video

View the event or Download Video

View the event or Download Video

READi Insights: Physical Climate Data 101 Course Overview (3002026297)

Offers a brief and concise introduction to the initial three modules in the Physical Climate Data 101 Training Series.

READi Insights: Unpacking Climatological and Power System Operating Extremes (3002026298)

Discusses two definitions of extreme events that may arise from the use of climate data, namely climatological extremes and power system operating extremes.

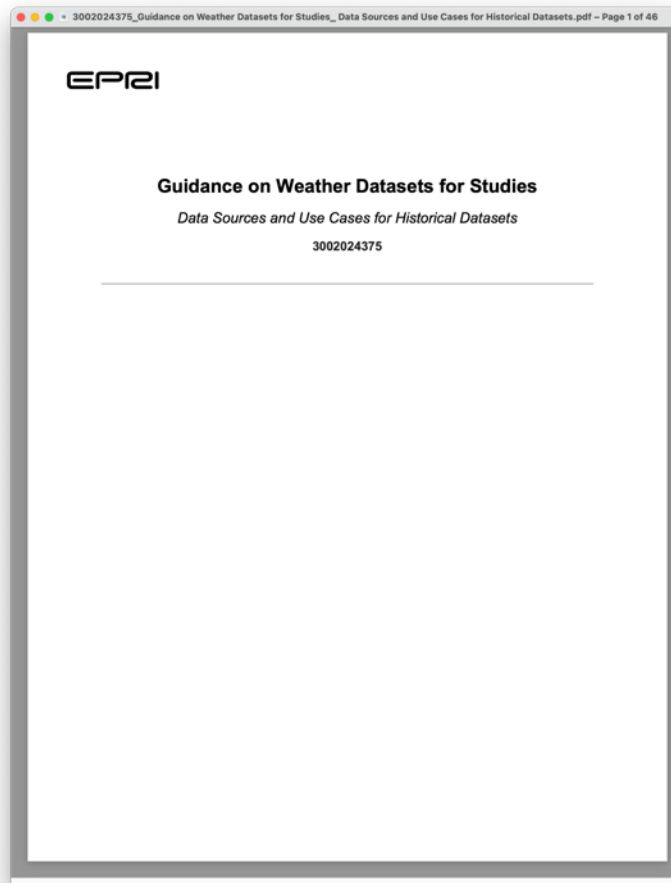
READi Insights: Types of Climate Data and Potential Applications within the Electric Power Sector (3002026299)

Introduces the unique attributes and applications of historical data, near-term predictions, and climate model projections, so that power system personnel can correctly identify and contextualize the proper data for climate-related planning and operations.

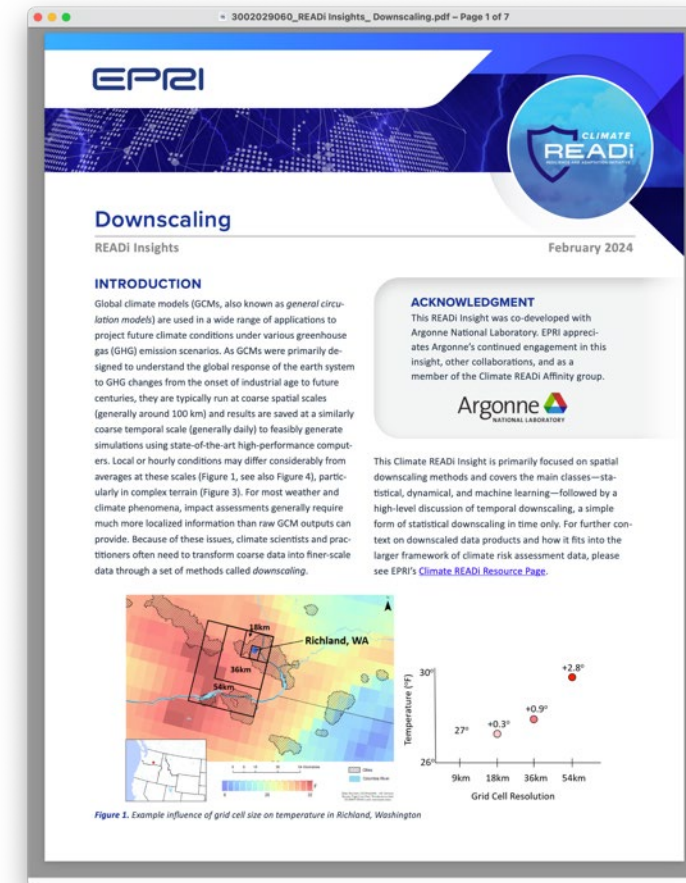
...and more available at <https://www.epri.com/READi>

Two relevant public reports:

Guidance on Weather Datasets for Studies



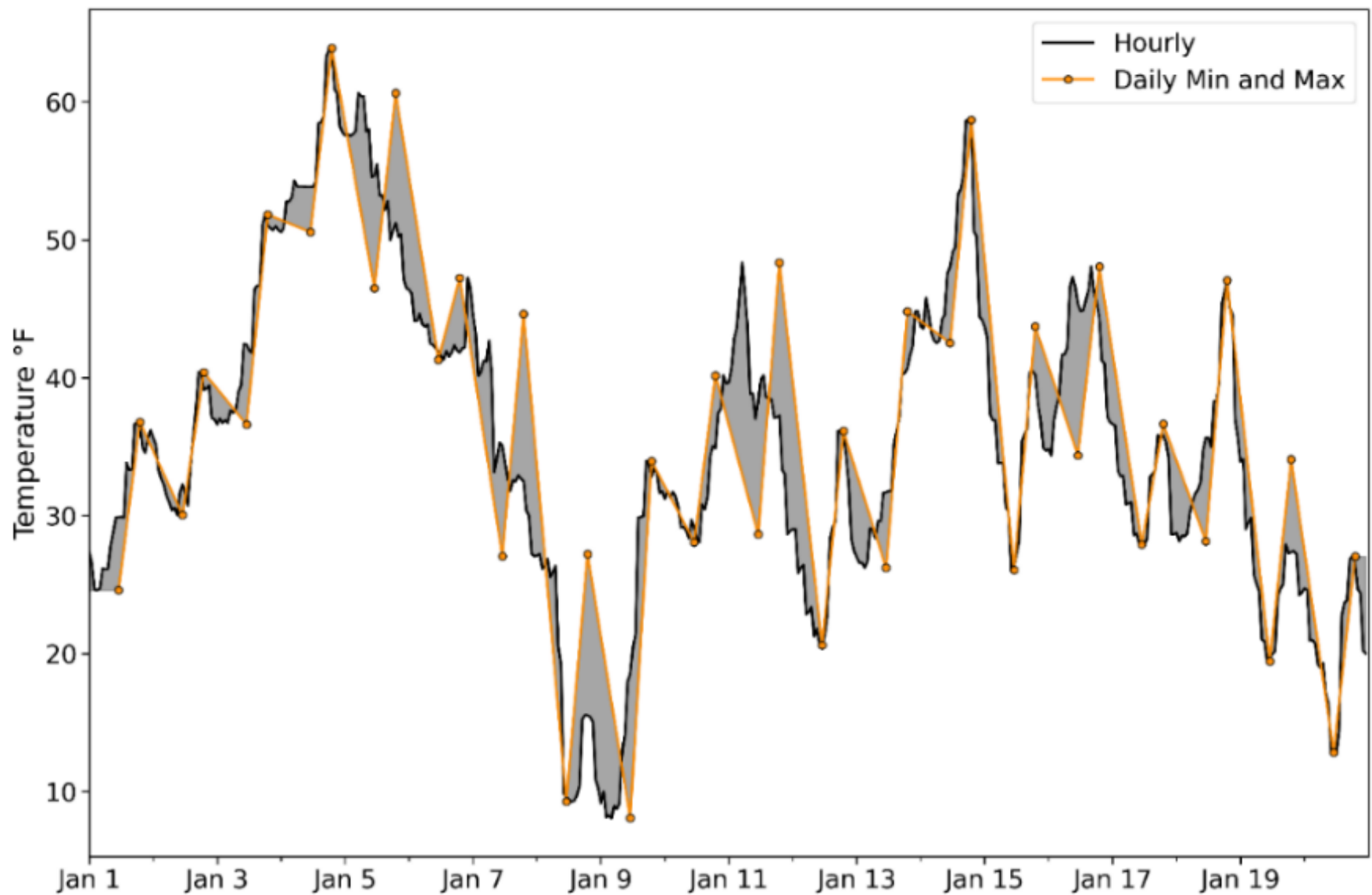
READi Insights: Downscaling





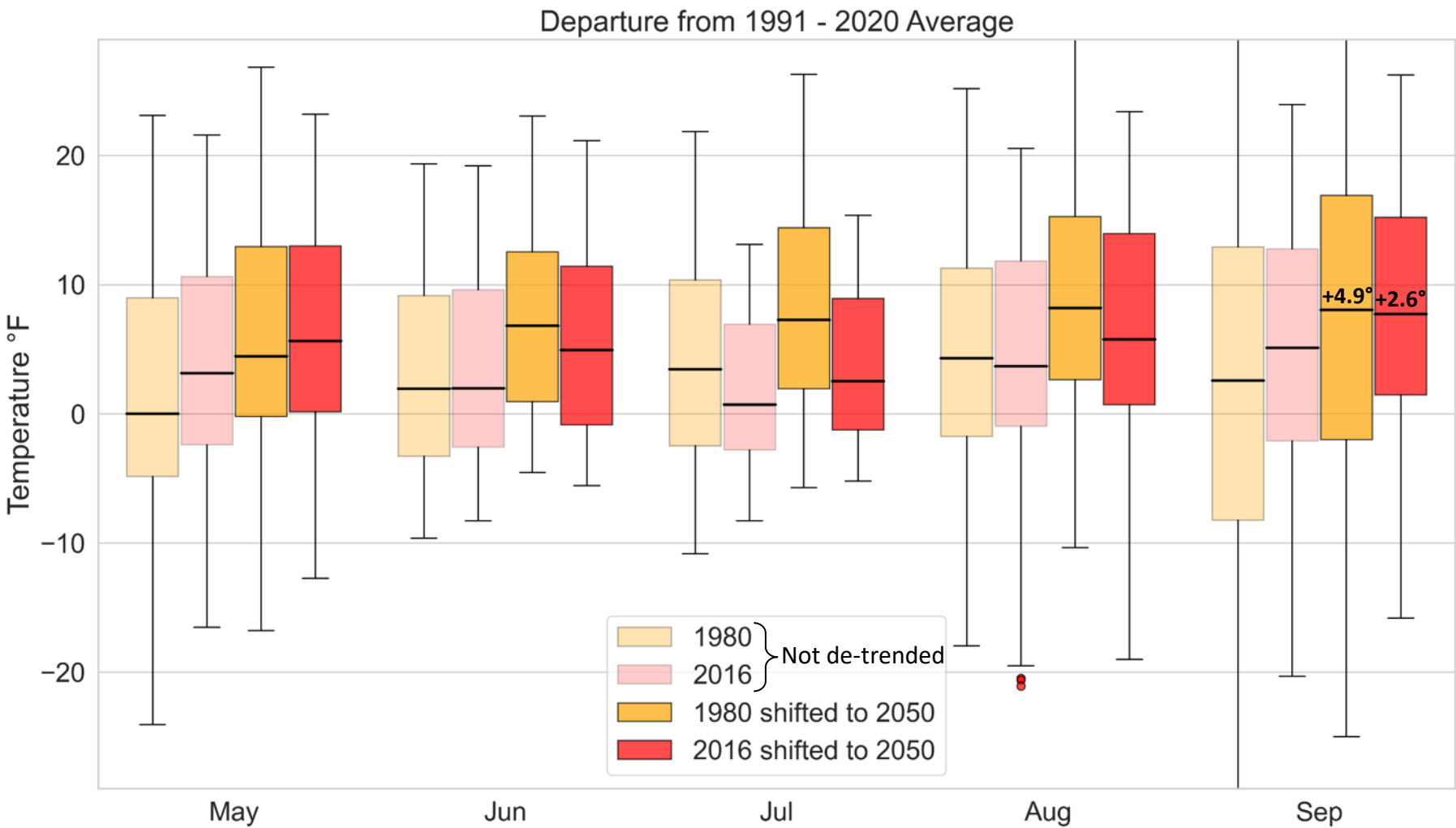
TOGETHER...SHAPING THE FUTURE OF ENERGY®

Example of how daily-to-hourly interpolation fails



Historical climate extremes in a future climate

- The climate warming signal is removed from the historical data
 - Puts emphasis on natural variability
 - An extreme heat event in 1980 may be more extreme than an event in 2016 from a natural variability standpoint



More synthetic years captures more extremes

