Creating Hourly Weather Timeseries for Future Climates

Approaches to Forward Looking Datasets

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

www.epri.com

Acknowledgements

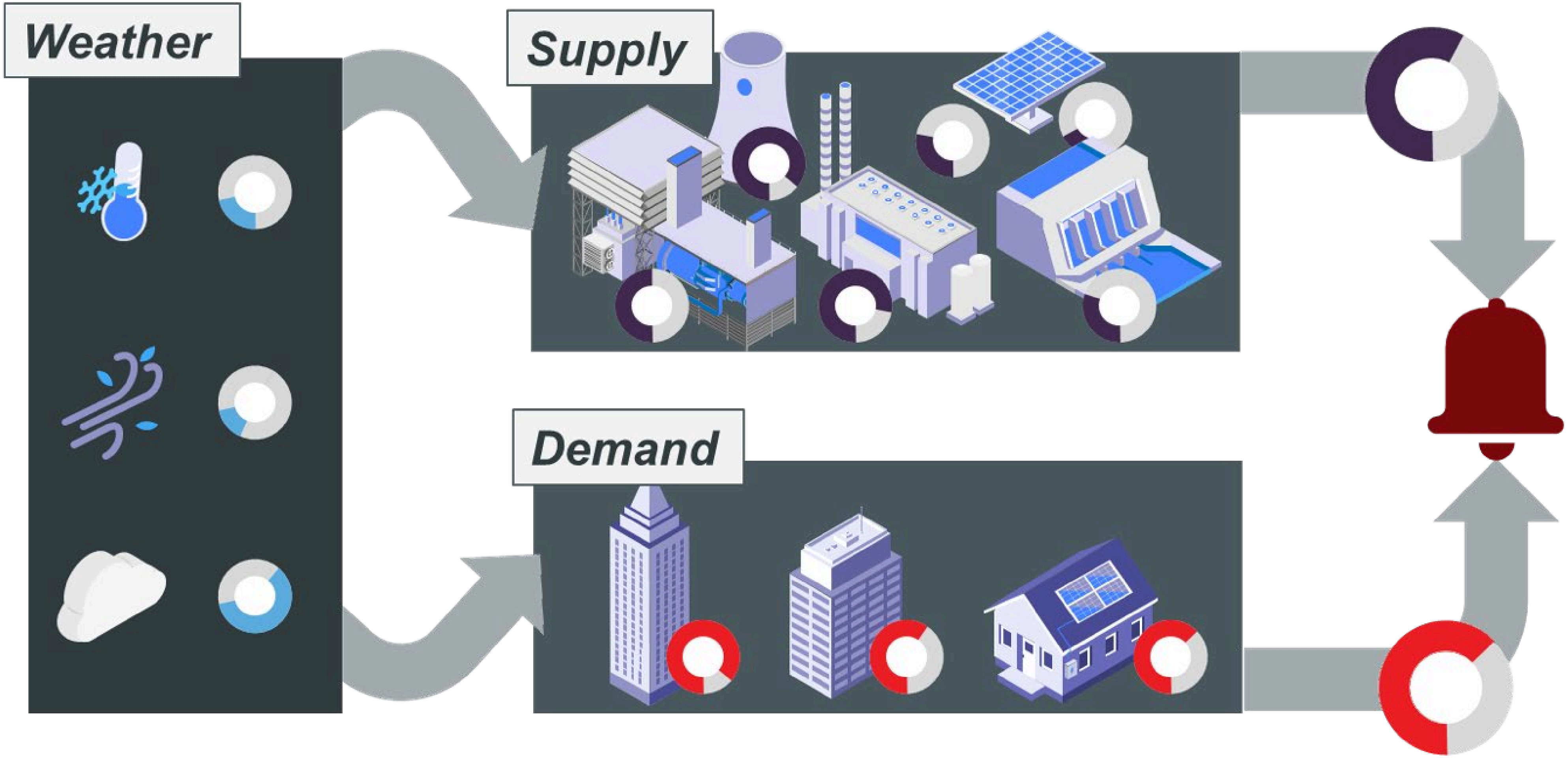
Erik Smith, PhD
Technical Leader
EPRI

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?

EPRI

Idea: combine historical data and climate projections

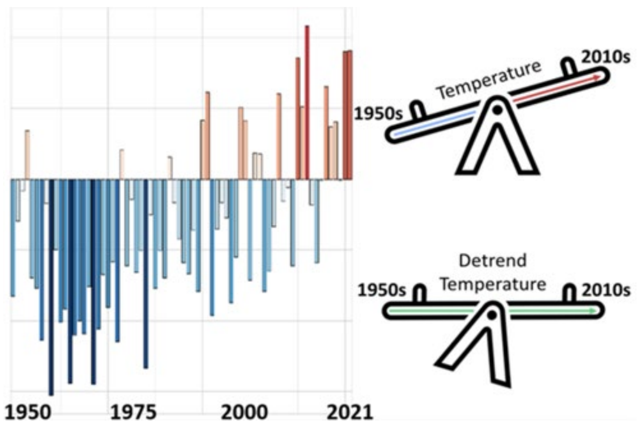
Historical Data	Climate Projections
Hourly data	Daily data
Realistic variability - Scales of weeks, months, & years from 72 years of historical weather (1950-2021)	Limited variability - Variability is constrained to the underlying physical model; typically not well-captured
Historical years only - Can't 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

(shaded) Important or desired characteristic

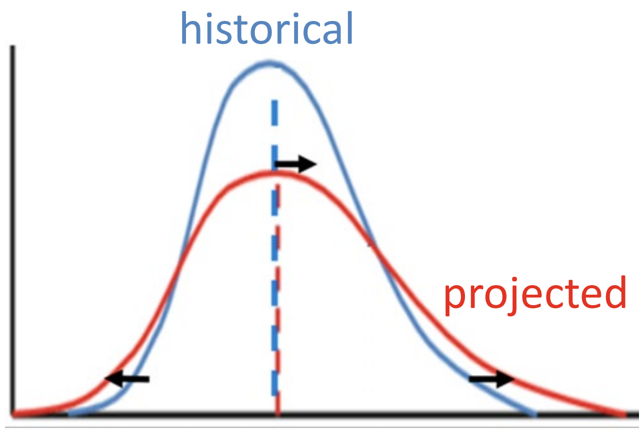
*Note: we currently only shift temperature profiles (and precipitation where relevant), maintaining historical hourly correlation with wind and solar (which haven't been shown by GCMs to shift distribution)

High-level overview of our method

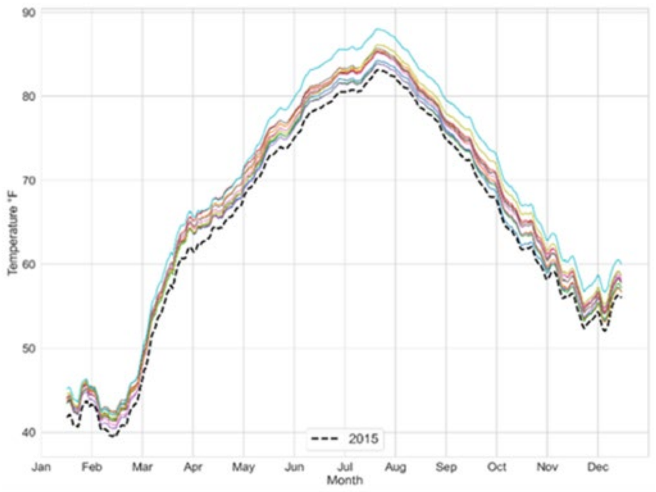
(1) **Detrend historical data** using representative years with natural variability



(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 x **M** climate models x **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**

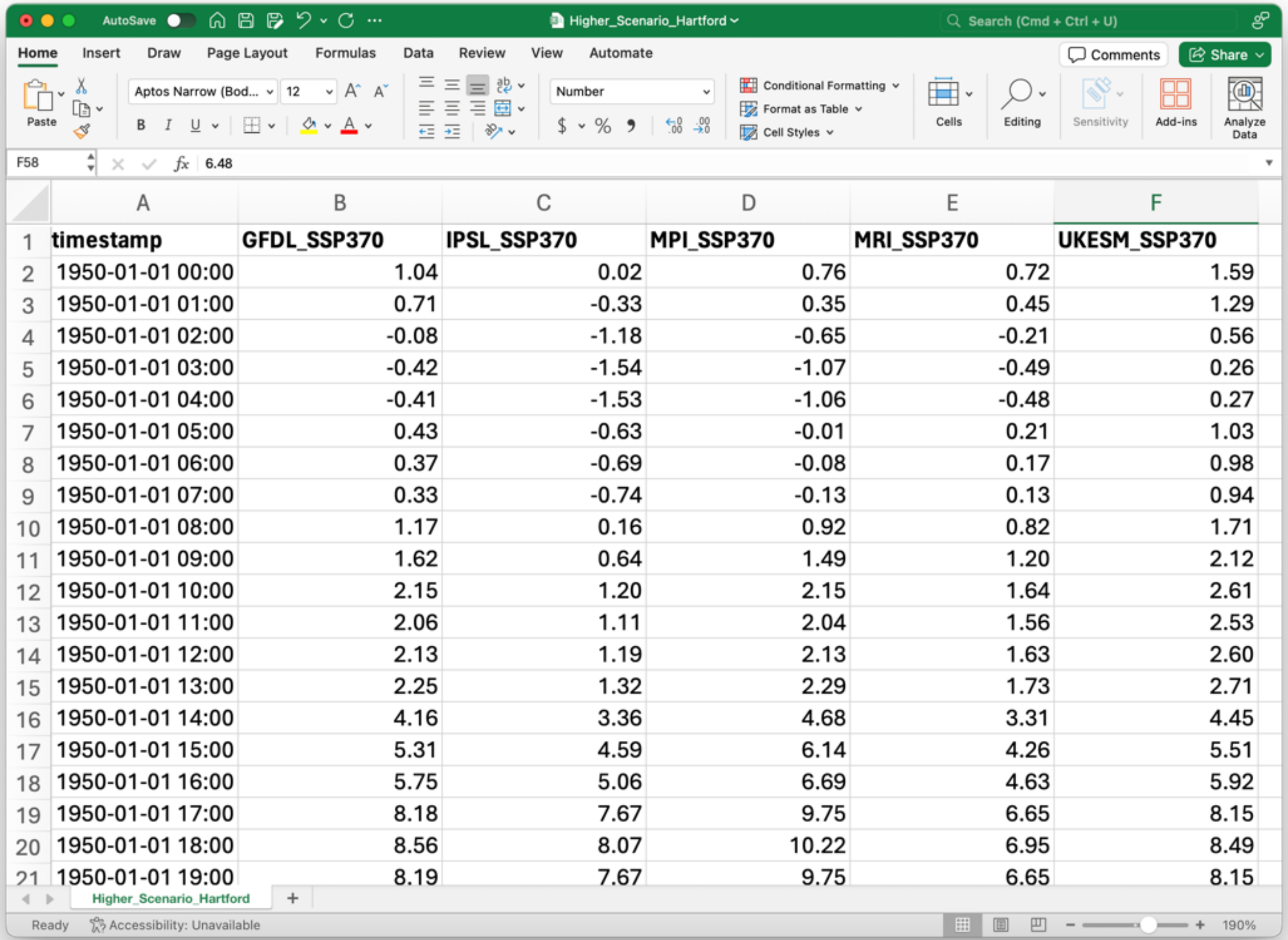
720 versions of 2030 weather

EPRI

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

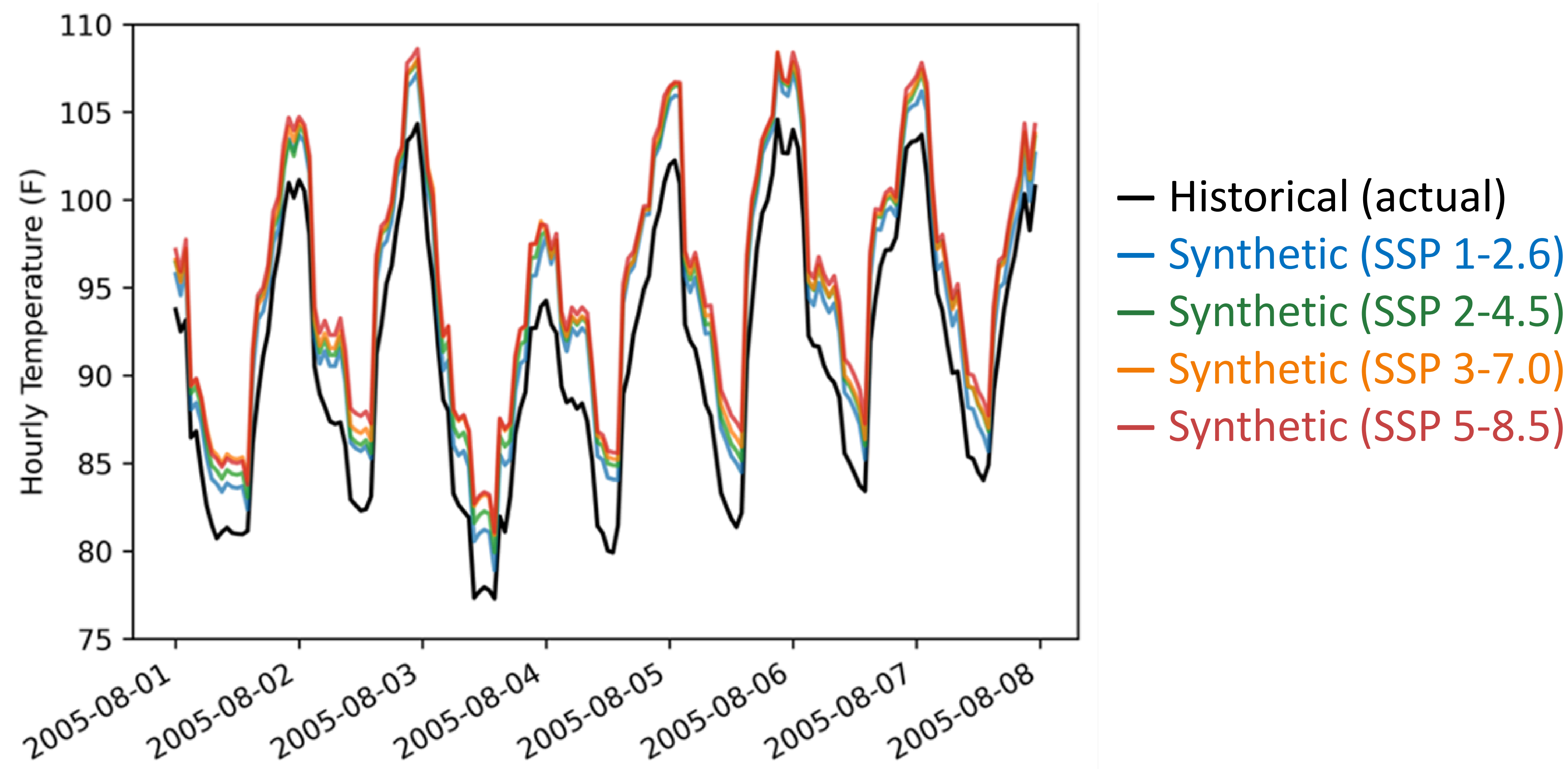


	A	B	C	D	E	F
1	timestamp	GFDL_SSP370	IPSL_SSP370	MPI_SSP370	MRI_SSP370	UKESM_SSP370
2	1950-01-01 00:00	1.04	0.02	0.76	0.72	1.59
3	1950-01-01 01:00	0.71	-0.33	0.35	0.45	1.29
4	1950-01-01 02:00	-0.08	-1.18	-0.65	-0.21	0.56
5	1950-01-01 03:00	-0.42	-1.54	-1.07	-0.49	0.26
6	1950-01-01 04:00	-0.41	-1.53	-1.06	-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

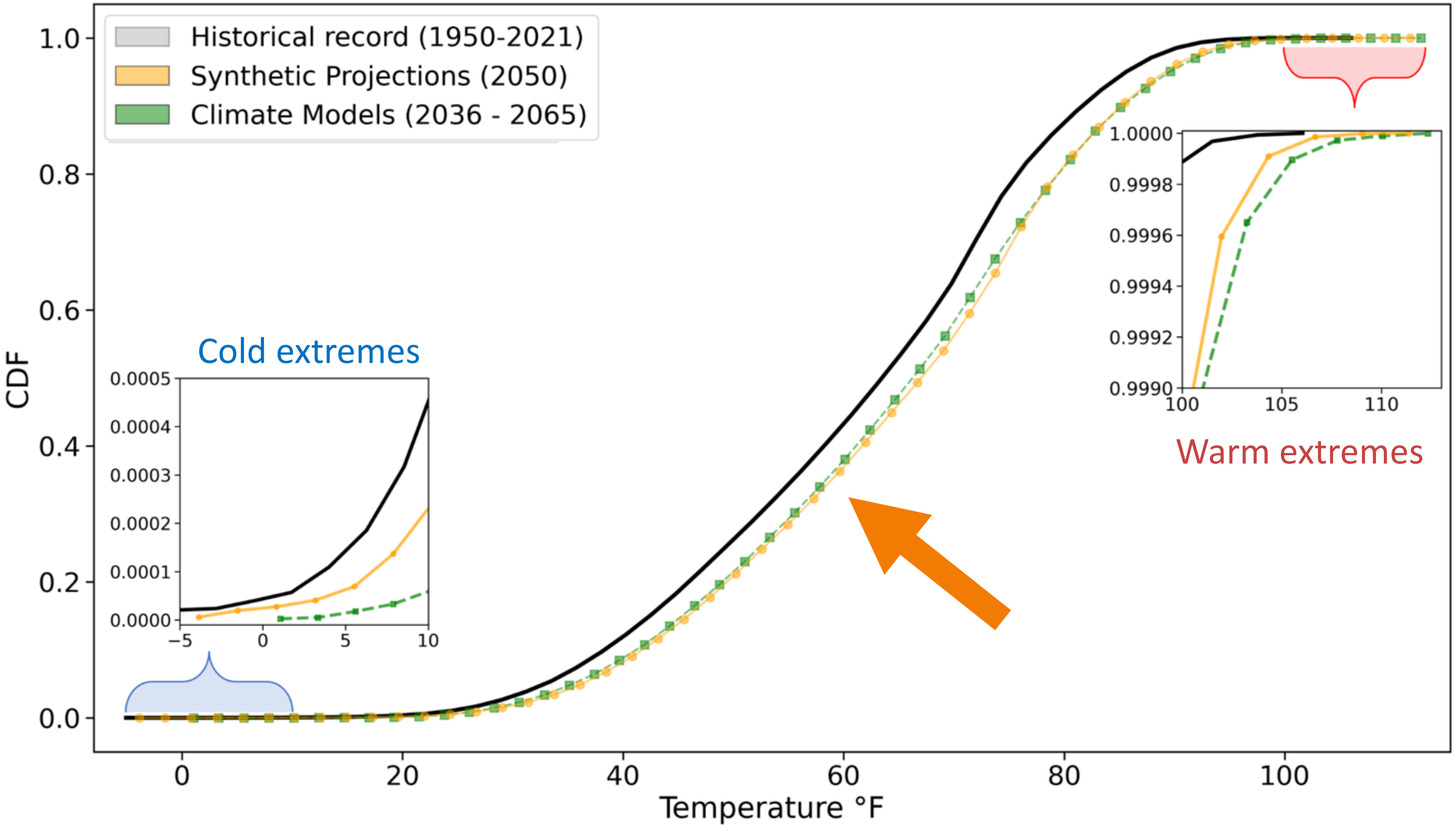
Synthetic data captures peaks and natural variability



Shifted temperature hourly timeseries (2050 climate)

EPRI

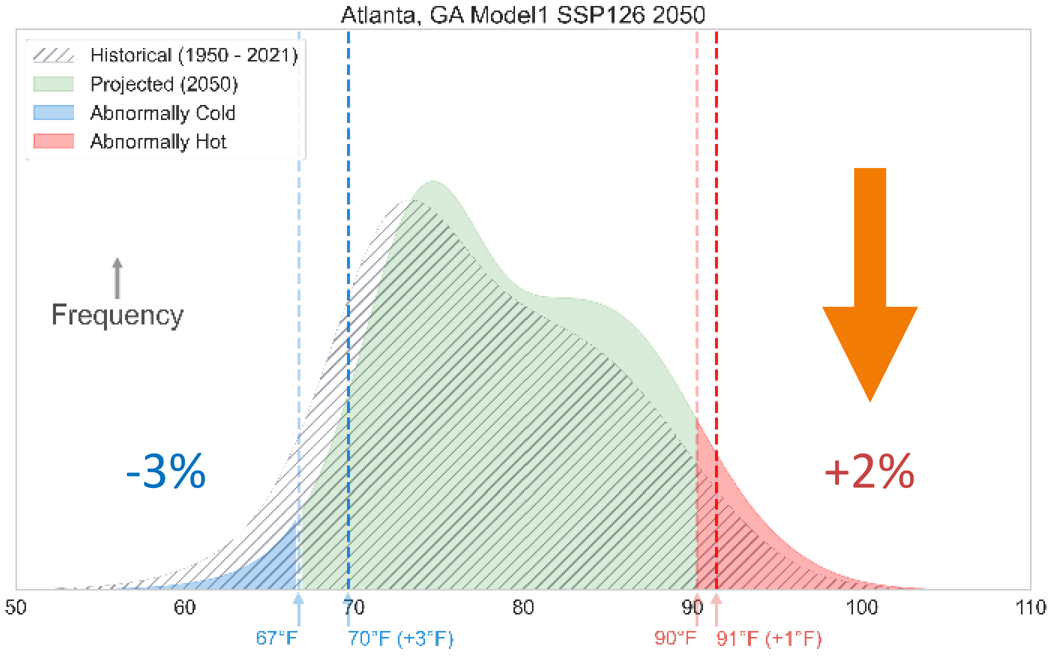
Also capture extremes (tails of the distribution)



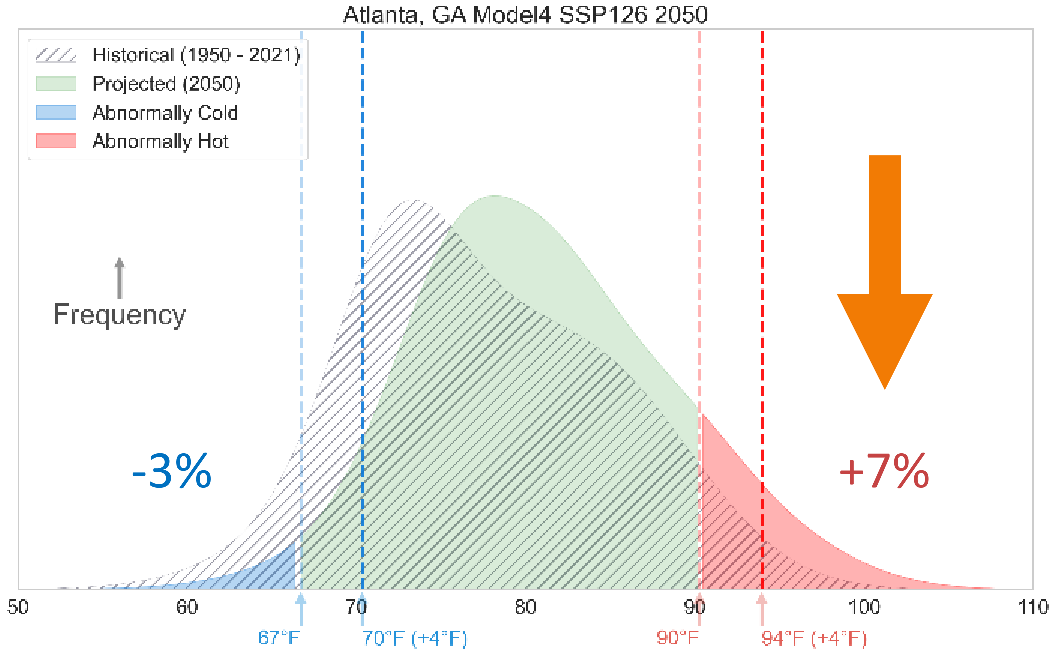
Distribution of temperature in historical vs synthetic vs GCM

Method allows capturing differences in GCMs

(a) Colder Model

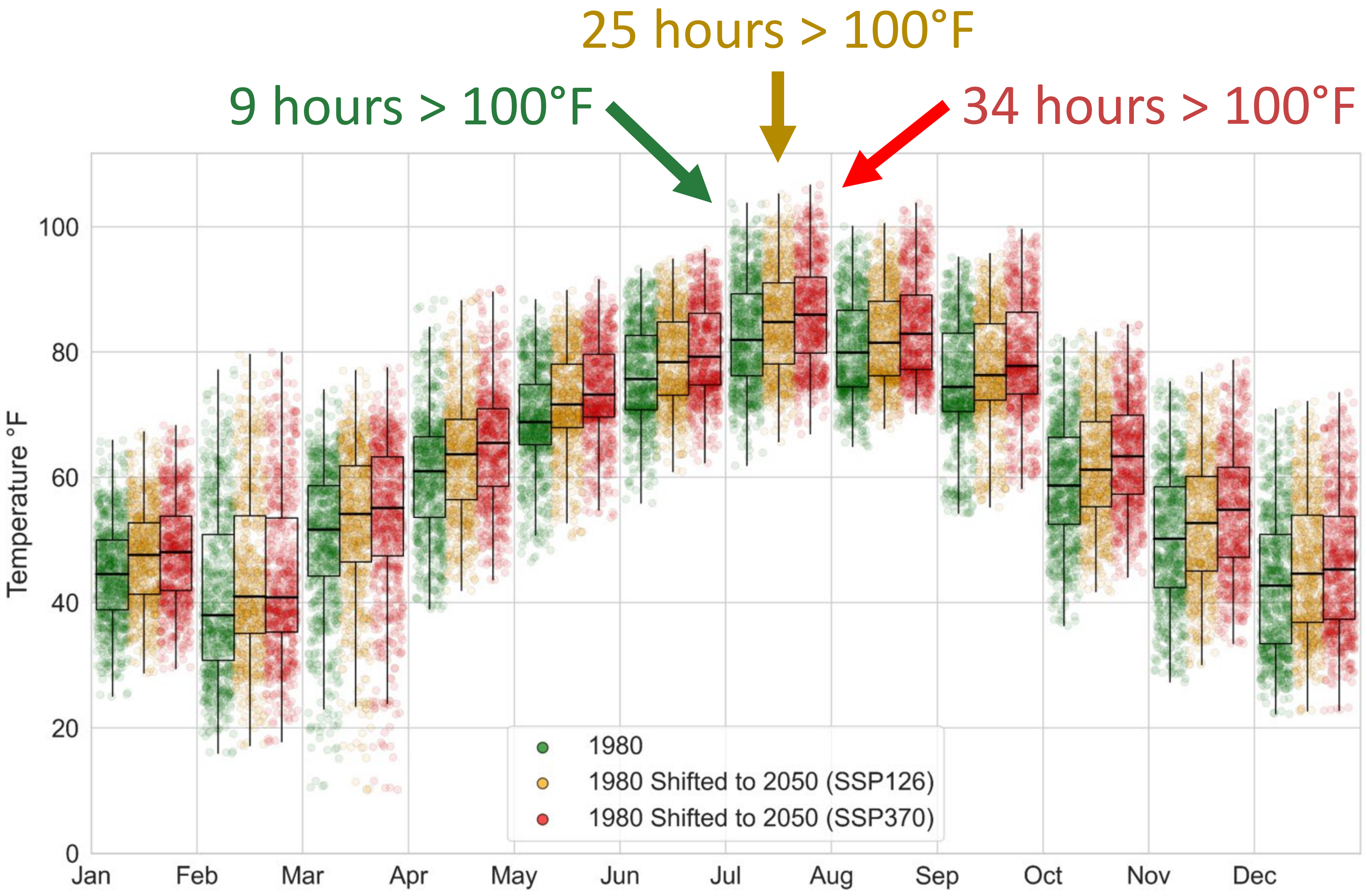


(b) Warmer Model



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

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

https://www.epri.com/READi

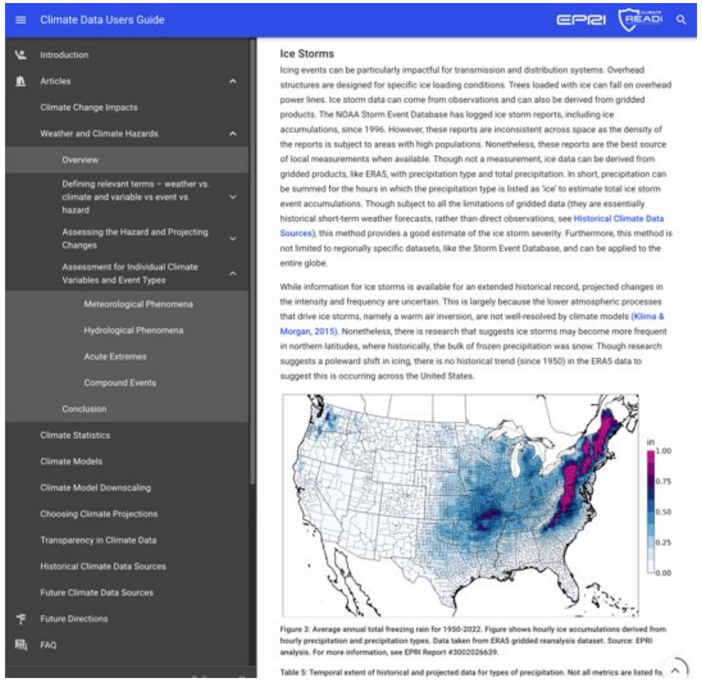
Load Forecasting Initiative

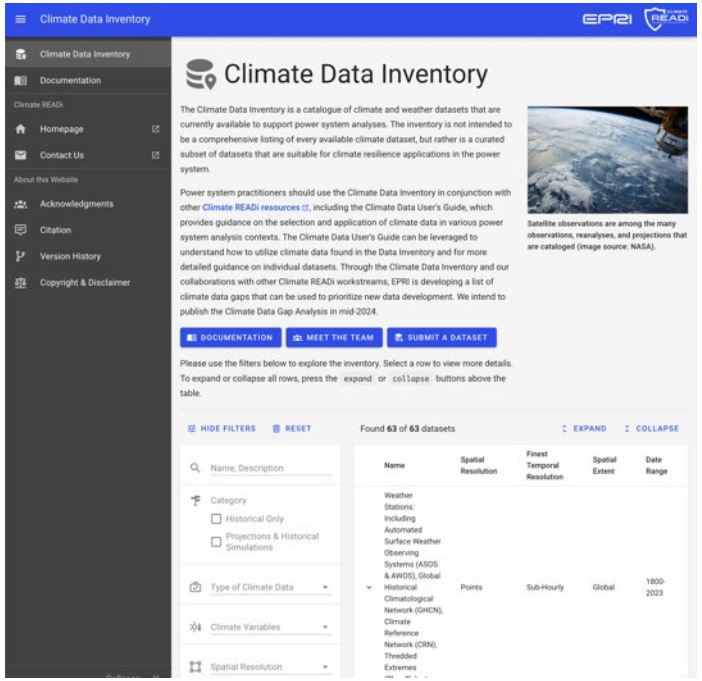
- Address critical needs in load forecasting across operations and planning timescales

https://msites.epri.com/LFI

Resources from EPRI's Climate READi:

Climate Data Users Guide	Climate Data Inventory	Climate 101



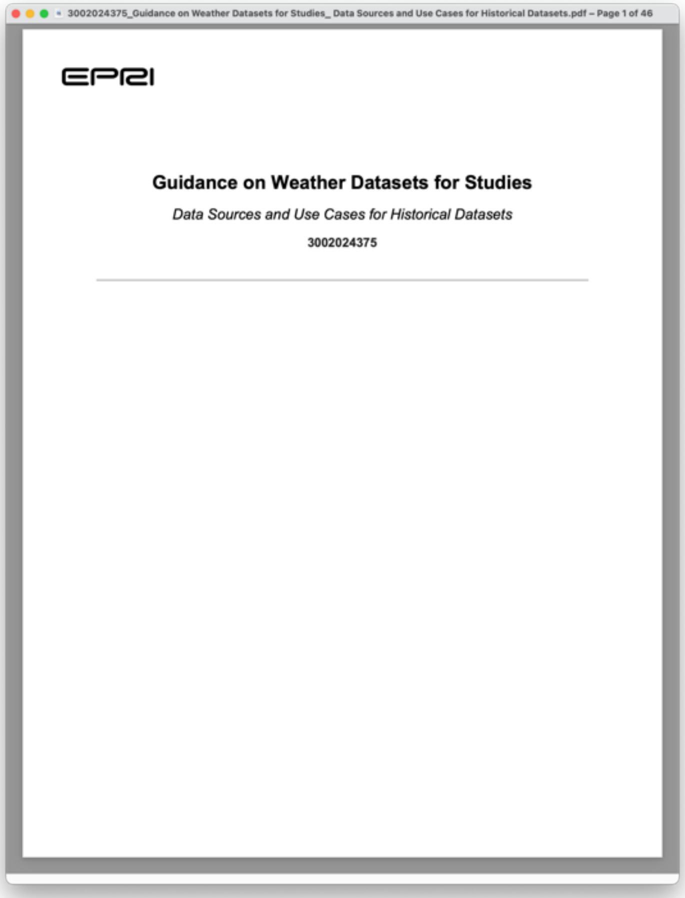


...and more available at https://www.epri.com/READi

Two relevant public reports:

[Guidance on Weather Datasets for Studies]

[READi Insights: Downscaling]

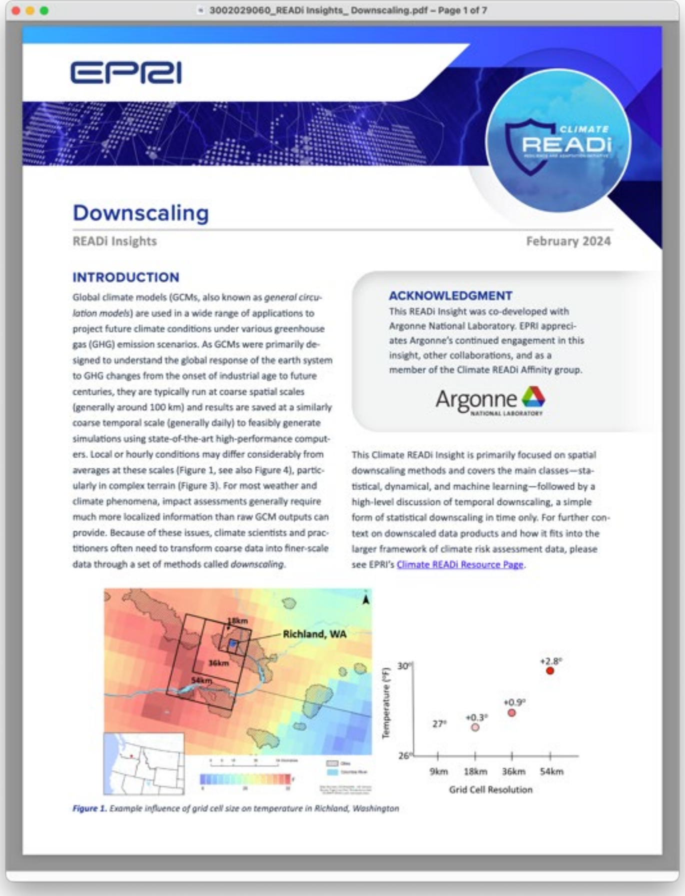

3002024375_Guidance on Weather Datasets for Studies_ Data Sources and Use Cases for Historical Datasets.pdf – Page 1 of 46

EPRI

Guidance on Weather Datasets for Studies

Data Sources and Use Cases for Historical Datasets

3002024375


3002029060_READi Insights_ Downscaling.pdf – Page 1 of 7

EPRI

CLIMATE READi

Downscaling

READi Insights

February 2024

INTRODUCTION

Global climate models (GCMs, also known as *general circulation models*) are used in a wide range of applications to project future climate conditions under various greenhouse gas (GHG) emission scenarios. As GCMs were primarily designed to understand the global response of the earth system to GHG changes from the onset of industrial age to future centuries, they are typically run at coarse spatial scales (generally around 100 km) and results are saved at a similarly coarse temporal scale (generally daily) to feasibly generate simulations using state-of-the-art high-performance computers. Local or hourly conditions may differ considerably from averages at these scales (Figure 1, see also Figure 4), particularly in complex terrain (Figure 3). For most weather and climate phenomena, impact assessments generally require much more localized information than raw GCM outputs can provide. Because of these issues, climate scientists and practitioners often need to transform coarse data into finer-scale data through a set of methods called *downscaling*.

ACKNOWLEDGMENT

This READi Insight was co-developed with Argonne National Laboratory. EPRI appreciates Argonne's continued engagement in this insight, other collaborations, and as a member of the Climate READi Affinity group.

Argonne NATIONAL LABORATORY

This Climate READi Insight is primarily focused on spatial downscaling methods and covers the main classes—statistical, dynamical, and machine learning—followed by a high-level discussion of temporal downscaling, a simple form of statistical downscaling in time only. For further context on downscaled data products and how it fits into the larger framework of climate risk assessment data, please see EPRI's Climate READi Resource Page.

Figure 1. Example influence of grid cell size on temperature in Richland, Washington

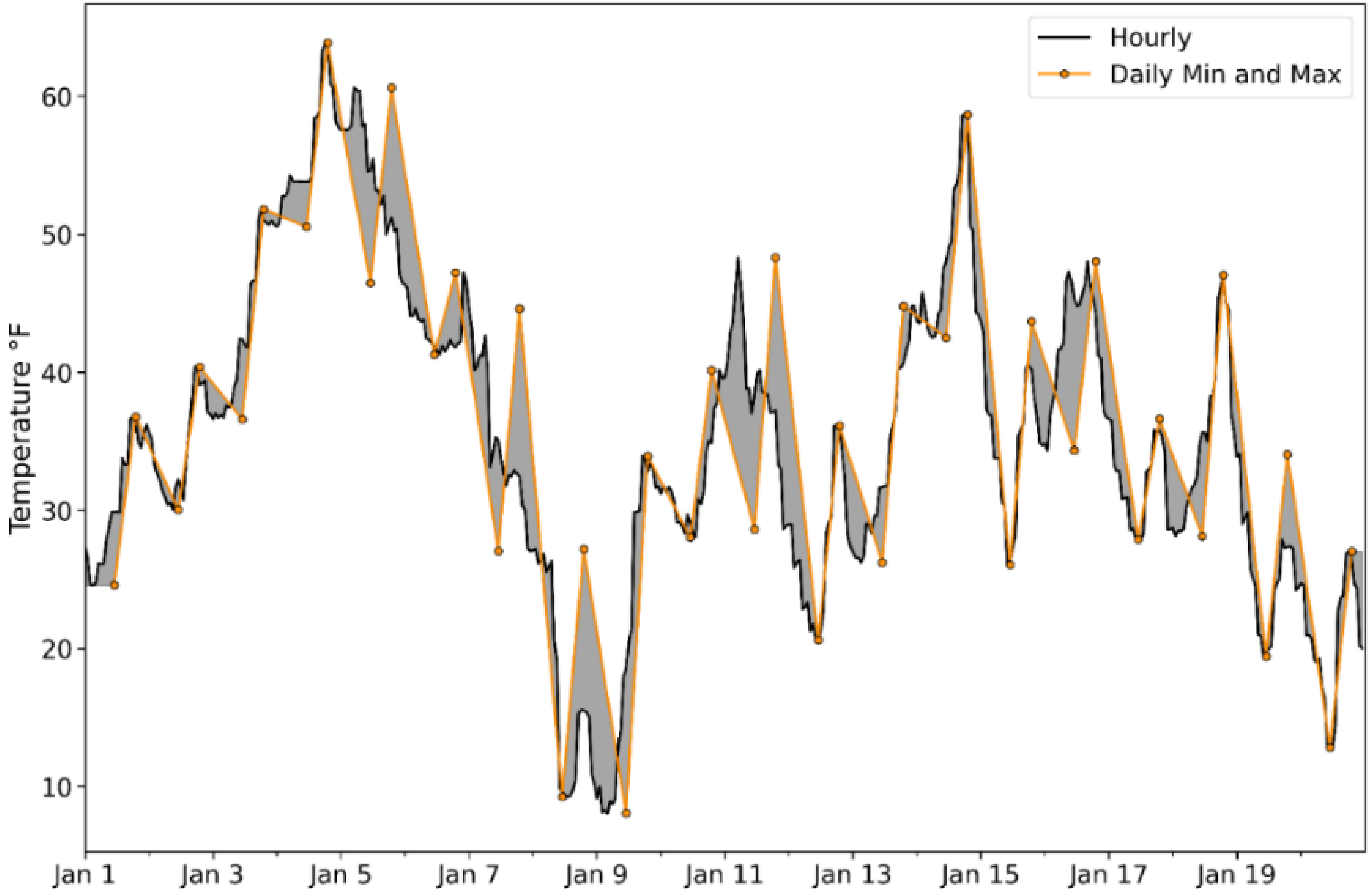
EPRI

TOGETHER…SHAPING THE FUTURE OF ENERGY®

in X f

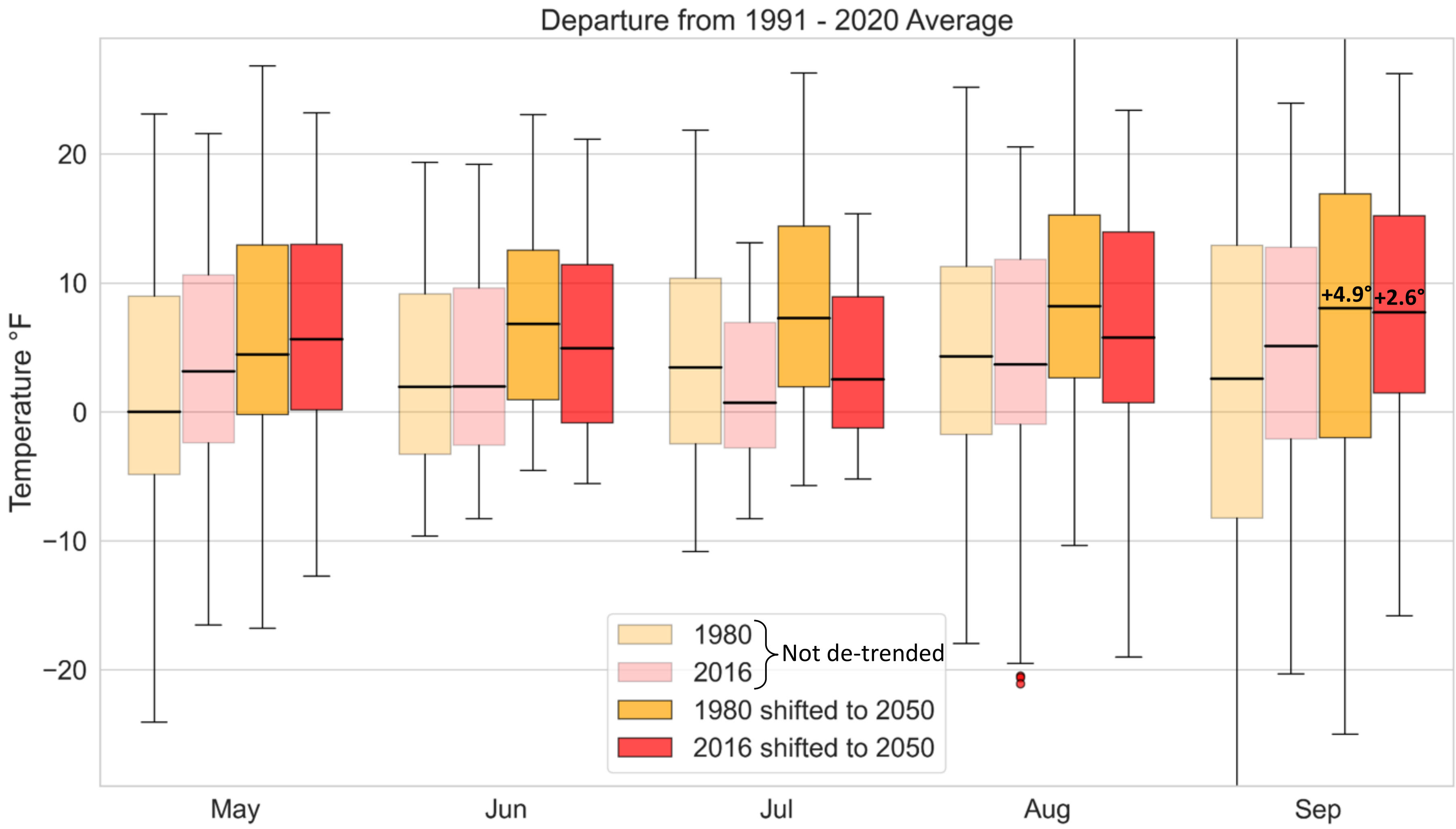
www.epri.com

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