Synthetic Hourly Weather Profiles for Future Climates

Localized temperature 8760s for company applications

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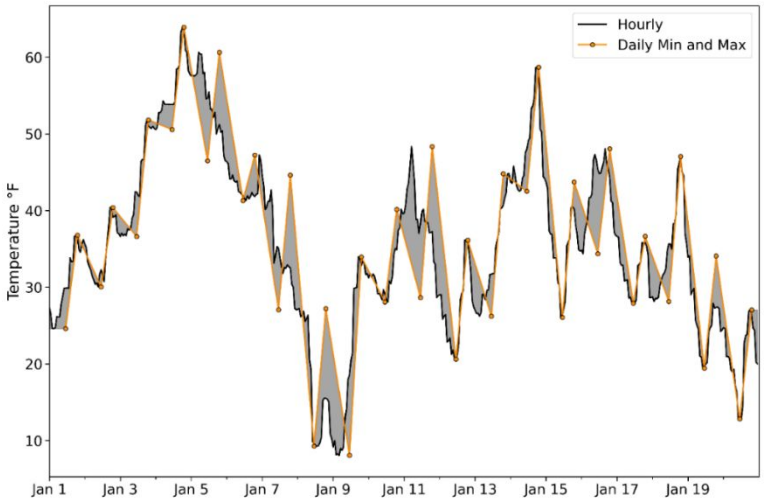
Overview

- Climate data gap
- EPRI's method for filling this gap
- Some quick examples to show how method works

Background on future synthetic hourly weather profiles

Motivation: Global climate model (GCM) projections typically have daily resolution, whereas most power system applications require hourly data



Example: Hourly vs Daily Temperature

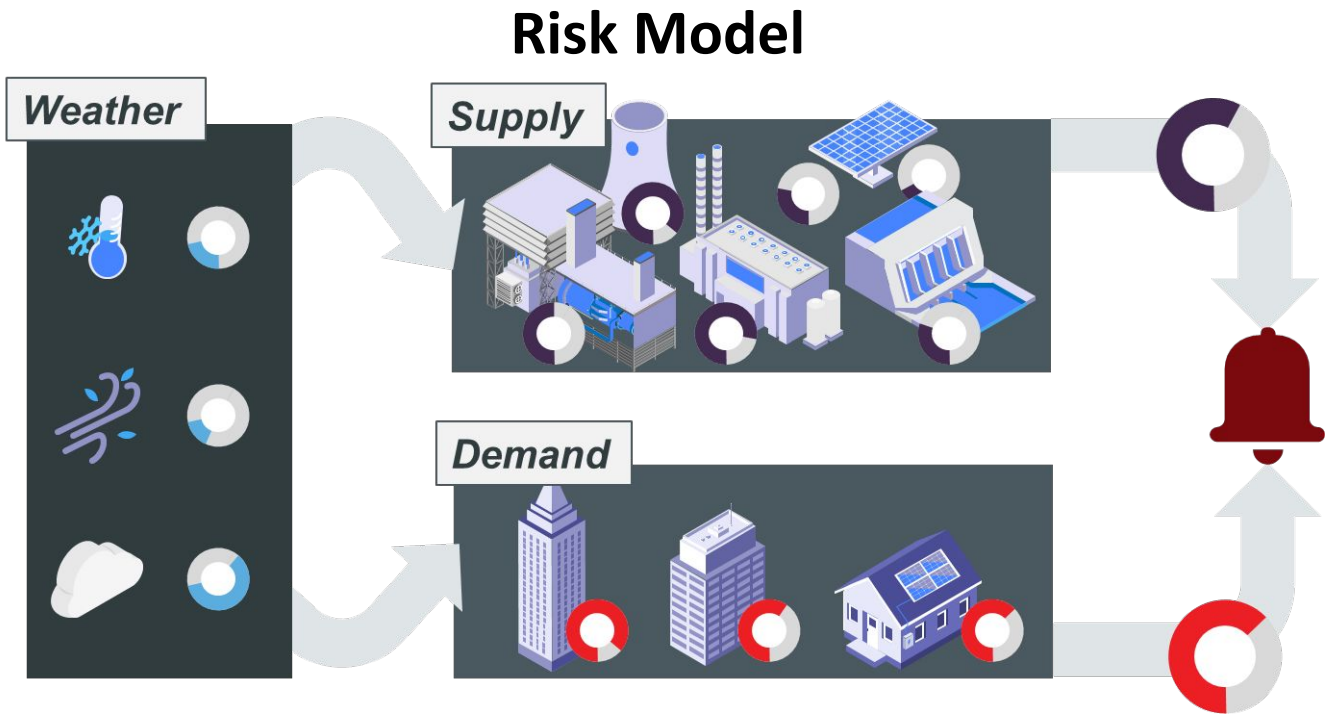
- Interpolating between daily values can miss important patterns (see figure)
- Customized dynamical downscaling can offer hourly resolution (but expensive, computationally and $$)
- Historical weather records capture real-world variability and preserve physical link between meteorological variables
- We present an innovative approach that leverages “best” of both historical and projection datasets to create 720 realistic synthetic hourly weather profiles

Relevance: Various utility functions could utilize this type of future hourly data, such as resource adequacy or other risk analysis, system planning, load projections, line ratings, asset/engineering design standards, among others

Context: EPRI's Resource Adequacy Initiative

EPRI is conducting a probabilistic energy security study to better understand operational risks under future weather extremes

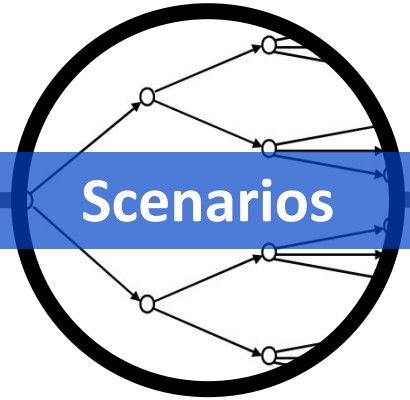
- Leverage historical data and climate projections to create future synthetic ***weather*** profiles as inputs to the risk model
- Determine the scenarios that lead to ***demand*** straining or exceeding ***supply***



Resource Adequacy study explores multiple levels of uncertainty to develop a comprehensive dataset

Climate Change

Weather Events



Scenarios

Random Events

Goal: Develop a synthetic set of hourly weather years (synchronous profiles of temperature, wind and solar) that are representative of the target year's modeled climate change

- Represent future climate with a set of climate model output data sets representing alternative pathways
- Use historical profiles to inform bias correction and downscaling of climate model to hourly resolution.

72 Historical years normalized & mapped to
x 5 Climate models representing
x 2 Emissions concentration scenarios

= **720** **Weather year profiles per target study year**

720 versions of 2030 weather

Source: https://gcaptain.com/earth-weather-visualized/

High-level approach to Future Synthetic Profiles

We can leverage the important characteristics from both the historical and climate projection datasets

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

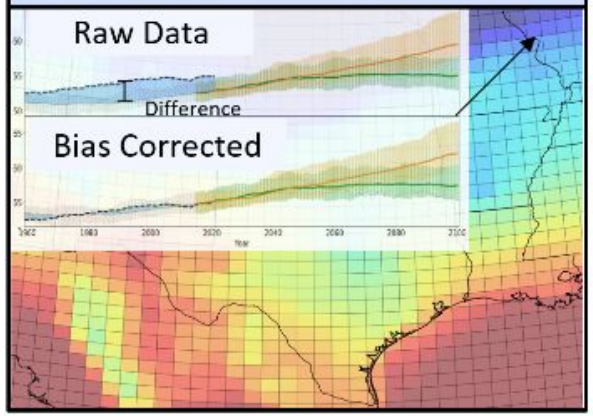
Important or desired characteristic

*Currently we 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)

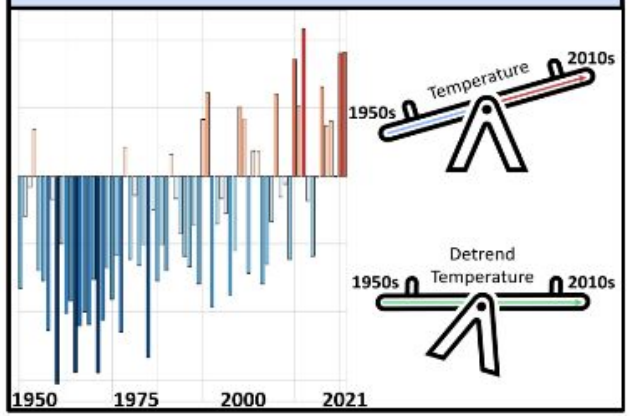
Overview of Data & Methods

- Historical data: ERA5
  - 1950 – 2021 (72 years)
- Projected Data: 5 CMIP6 models from Inter-Sectoral Impact Model Intercomparison Project (ISI–MIP)
  - SP1-2.6 (lower emission scenario) and SSP3-7.0 (higher emission scenario)
- Historical and projected data is available for entire globe

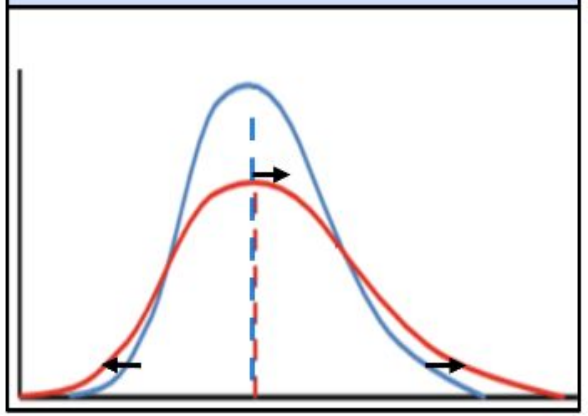
Step 1: Spatial bias-correction to localize climate projections (standard practice)



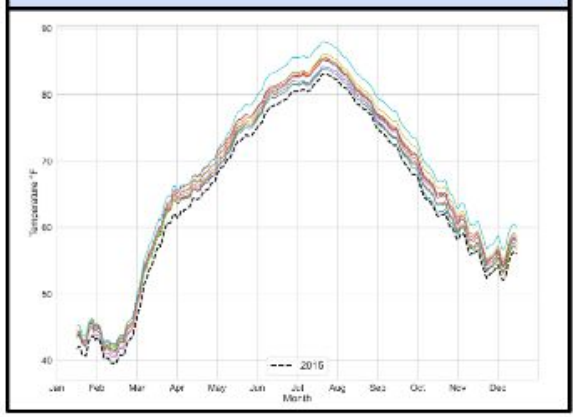
Step 2: Detrend historical data using representative years with natural variability



Step 3: Calculate **distributional shift** from GCM historical simulation to projection period

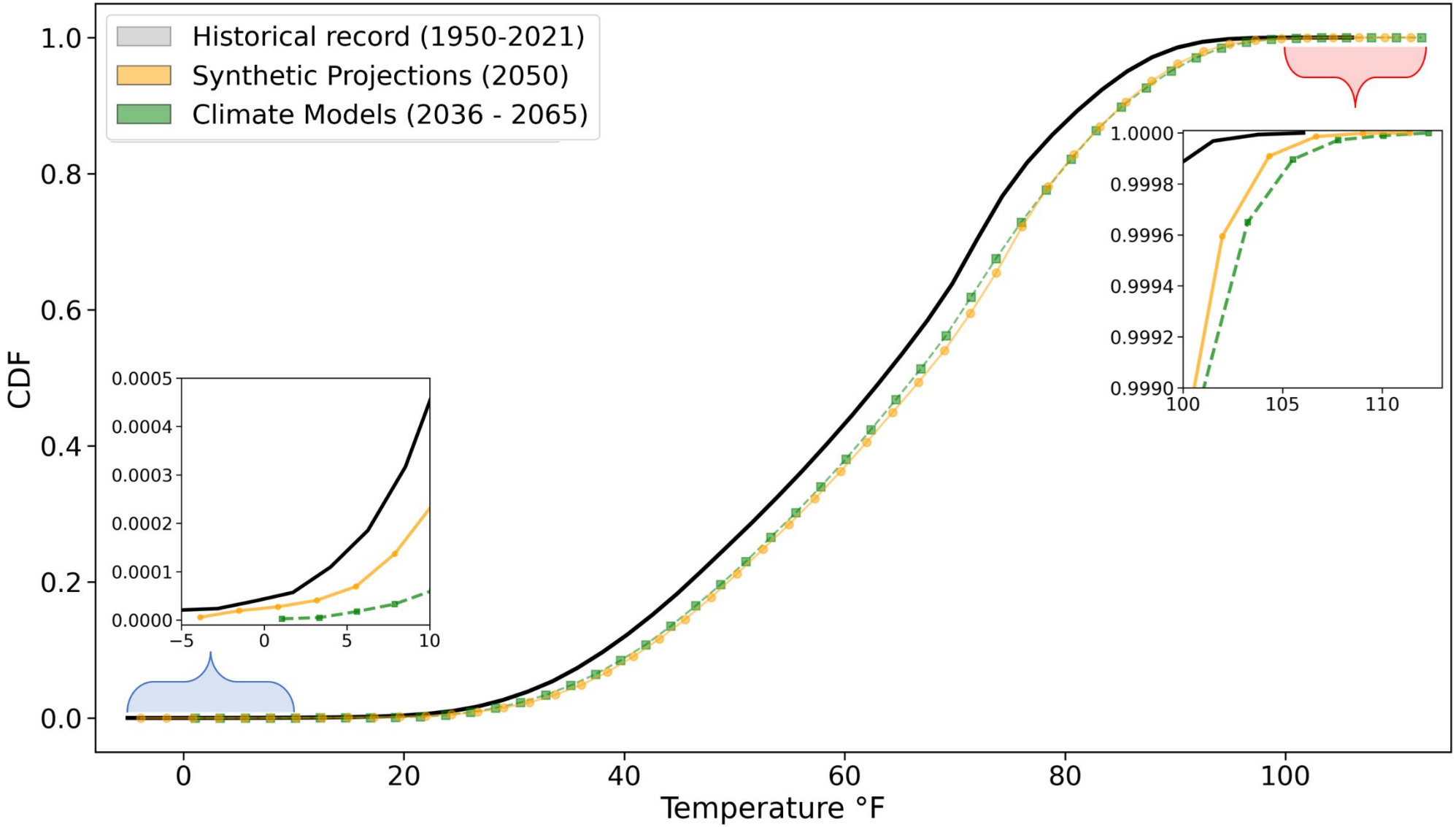


Step 4: Apply temperature delta for monthly quantile to historical data



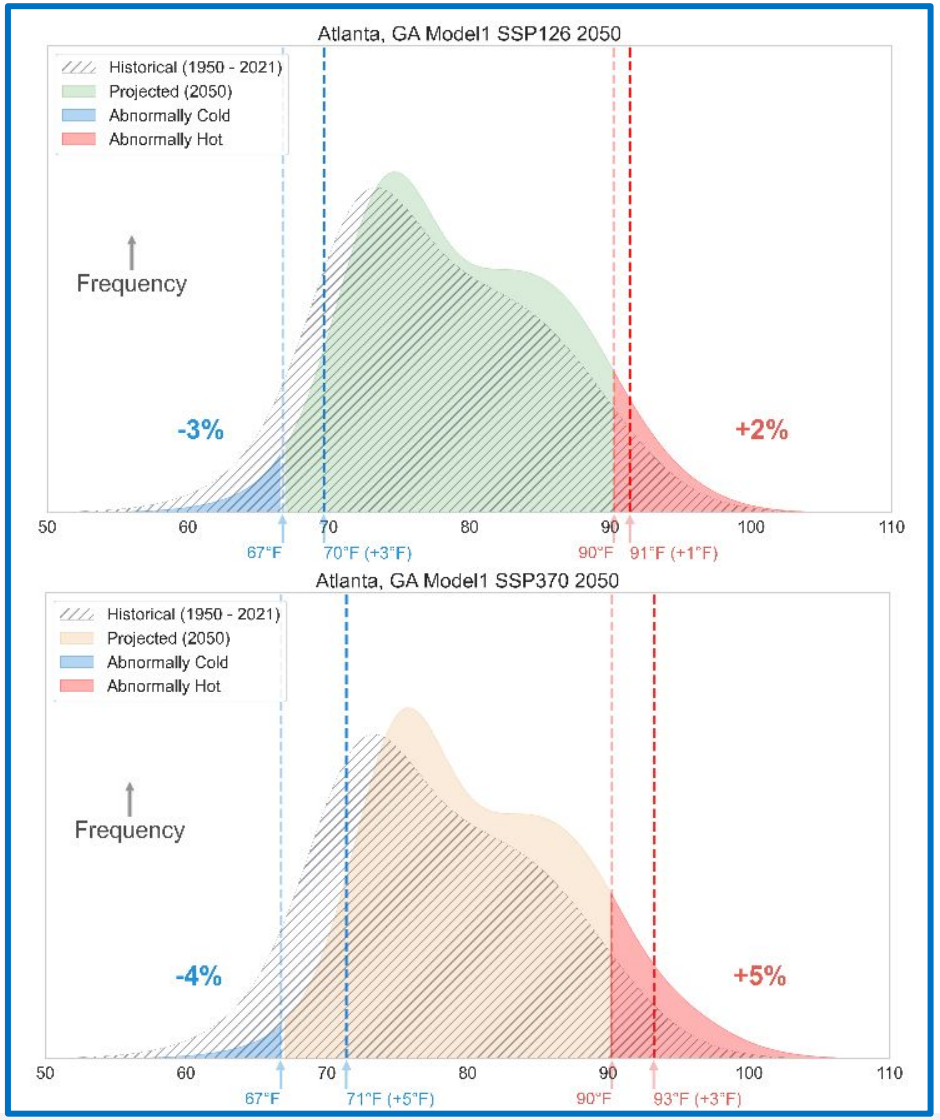
Examples

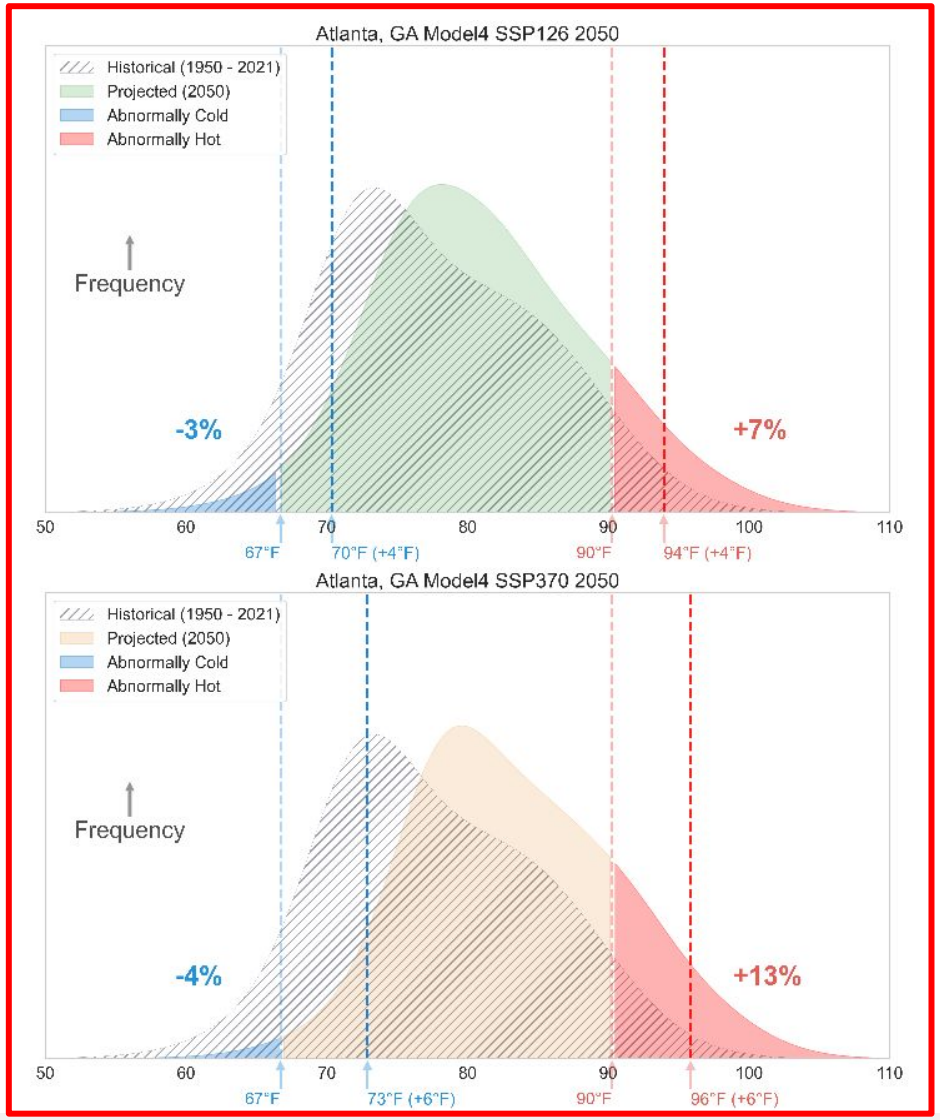
Synthetic weather profiles capture extremes



Shifted temperature distributions for specific GCM/SSP realization

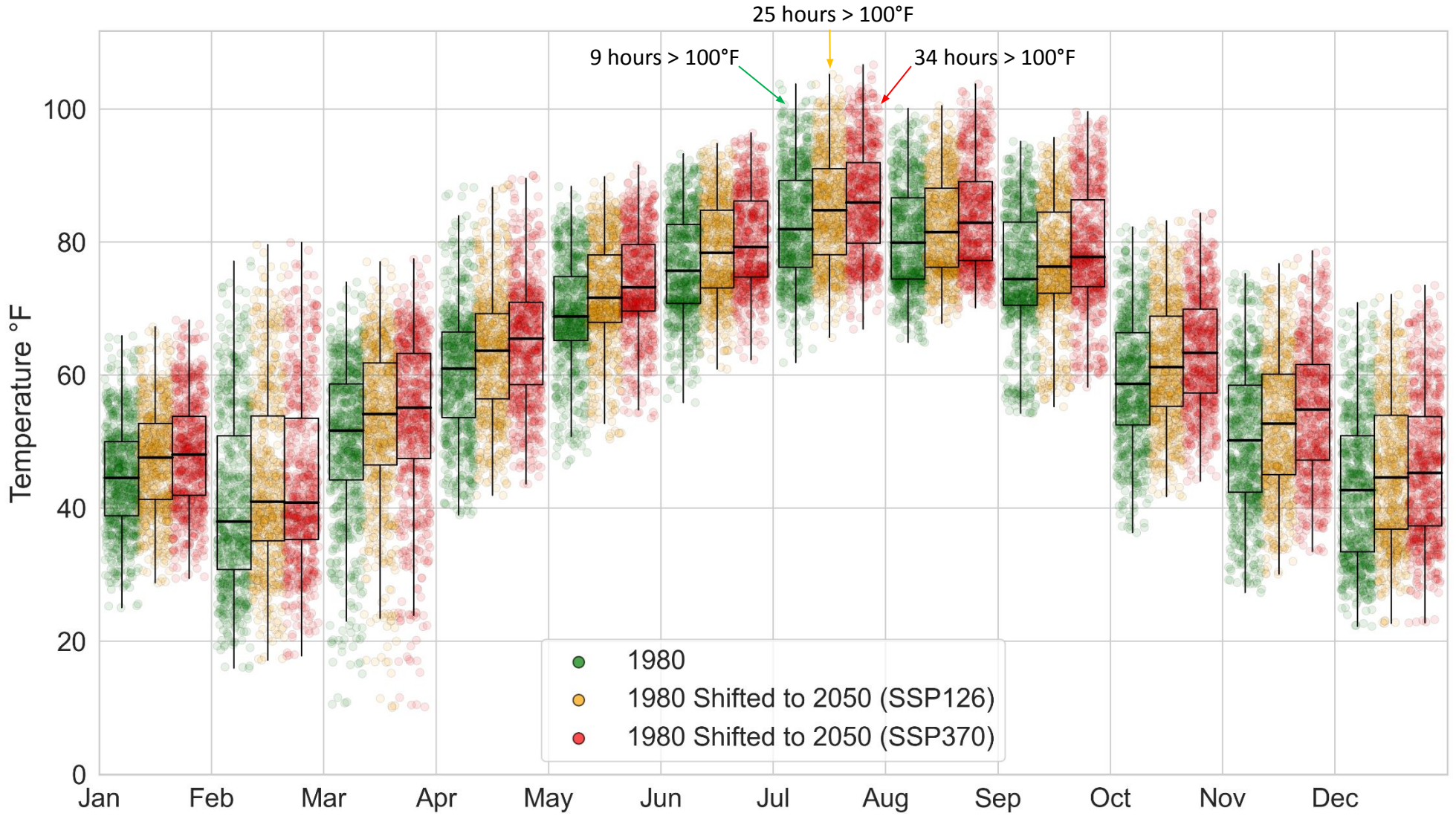
Colder Model





Warmer Model

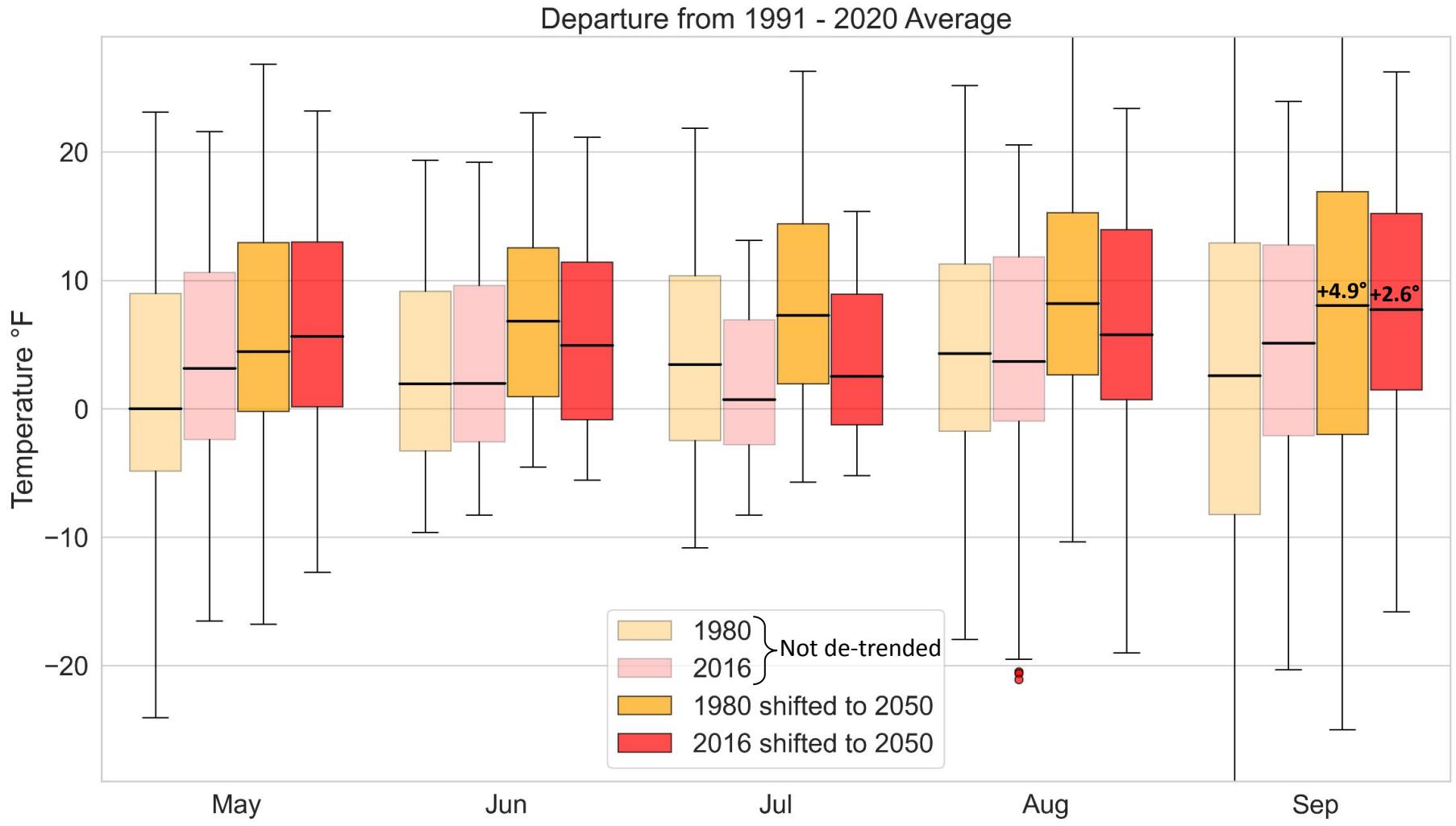
1980 (a warm year) shifted to 2050 synthetic profiles



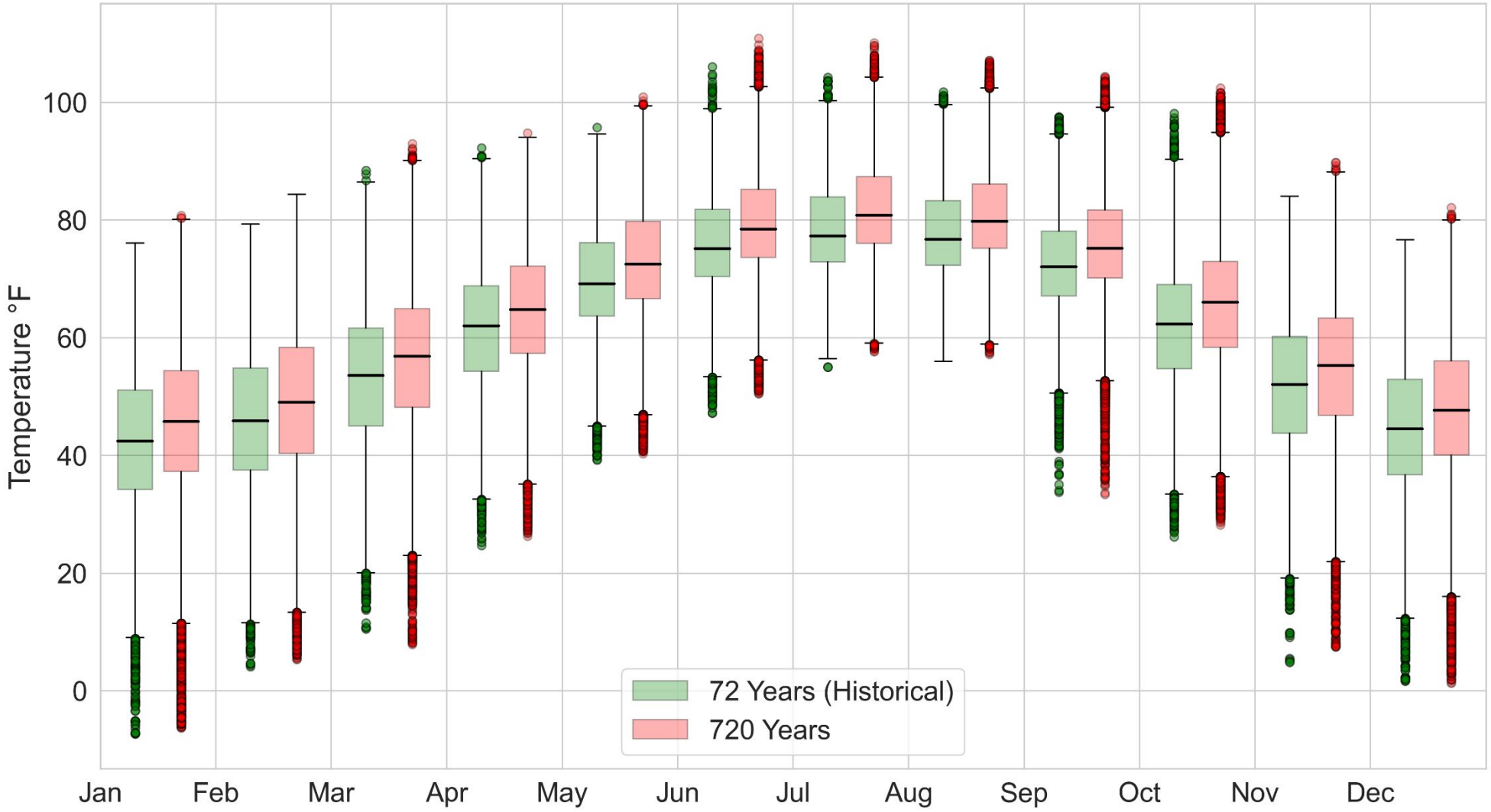
Based on one GCM (MRI). SSP126 is a lower climate scenario, SSP370 is the higher climate scenario.

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



Next Steps and Discussion

Summary

- GCM projections lack hourly resolution for company planning but can be leveraged to create realistic synthetic future scenarios

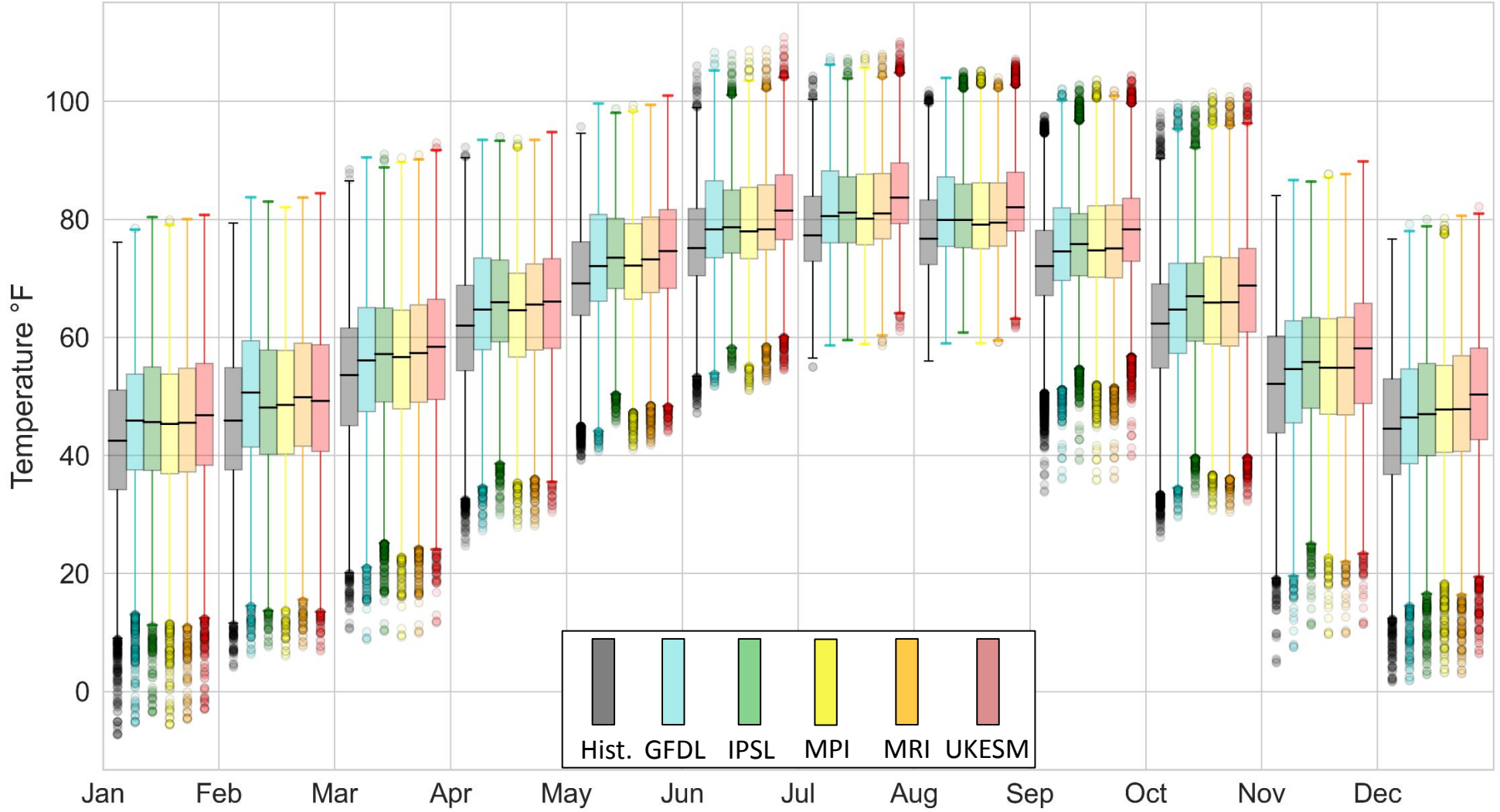
Benefits of Synthetic Profiles for Future Climates

- 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

Appendix

Synthetic projections (720 realizations) for 2050 from each model vs historical (72 years) distributions

(Atlanta, GA)



Example: Historical vs Projected Distributions

Atlanta, GA