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Grid Operations,
Decarbonization,
Environmental and
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Integration of Climate Forecasts in Bulk Power System Studies

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Bracken, and Nathalie Voisin



PNNL is operated by Battelle for the U.S. Department of Energy



Assertions

1. The existing grid is weather sensitive.
2. Weather characteristics (e.g., extremes) are changing rapidly.
3. The grid is also changing rapidly.
4. A high renewables grid will be even more weather sensitive.

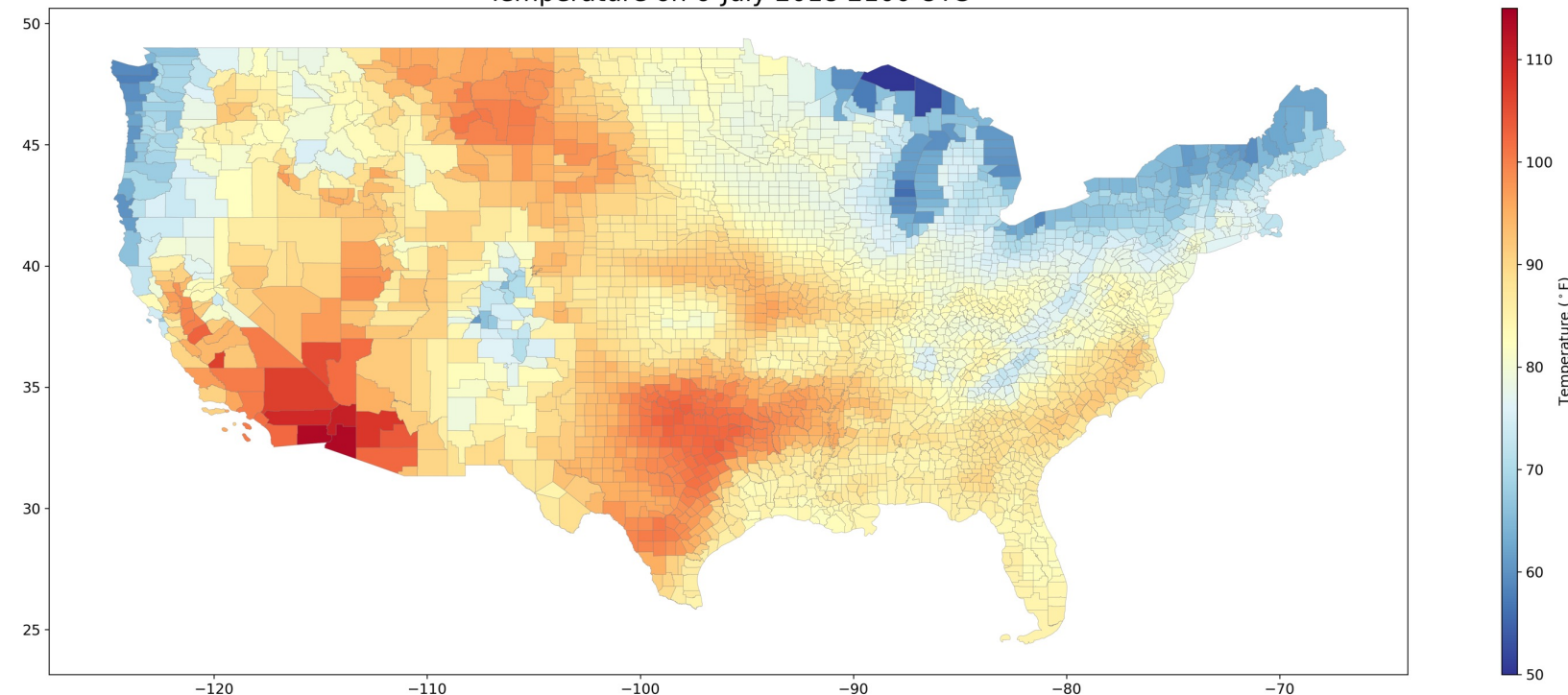
LOS ANGELES LOS ANGELES WEATHER

'Unprecedented' heat wave sets new records

Fire danger is high

By [Elijah Chiland](#) | Updated Jul 6, 2018, 5:43pm PDT | 30 comments

Temperature on 6-July 2018 2100 UTC



Thousands without power in Los Angeles after high demand due to heat wave

By Dakin Andone, CNN
Updated 8:19 PM EDT, Sat July 7, 2018
[f](#) [t](#) [e](#) [p](#)

Records Broken as Heat Wave Bakes Southern California

• Edited By: [Naqshib Nisar](#) • [Reuters](#) • Last Updated: JULY 07, 2018, 12:56 IST



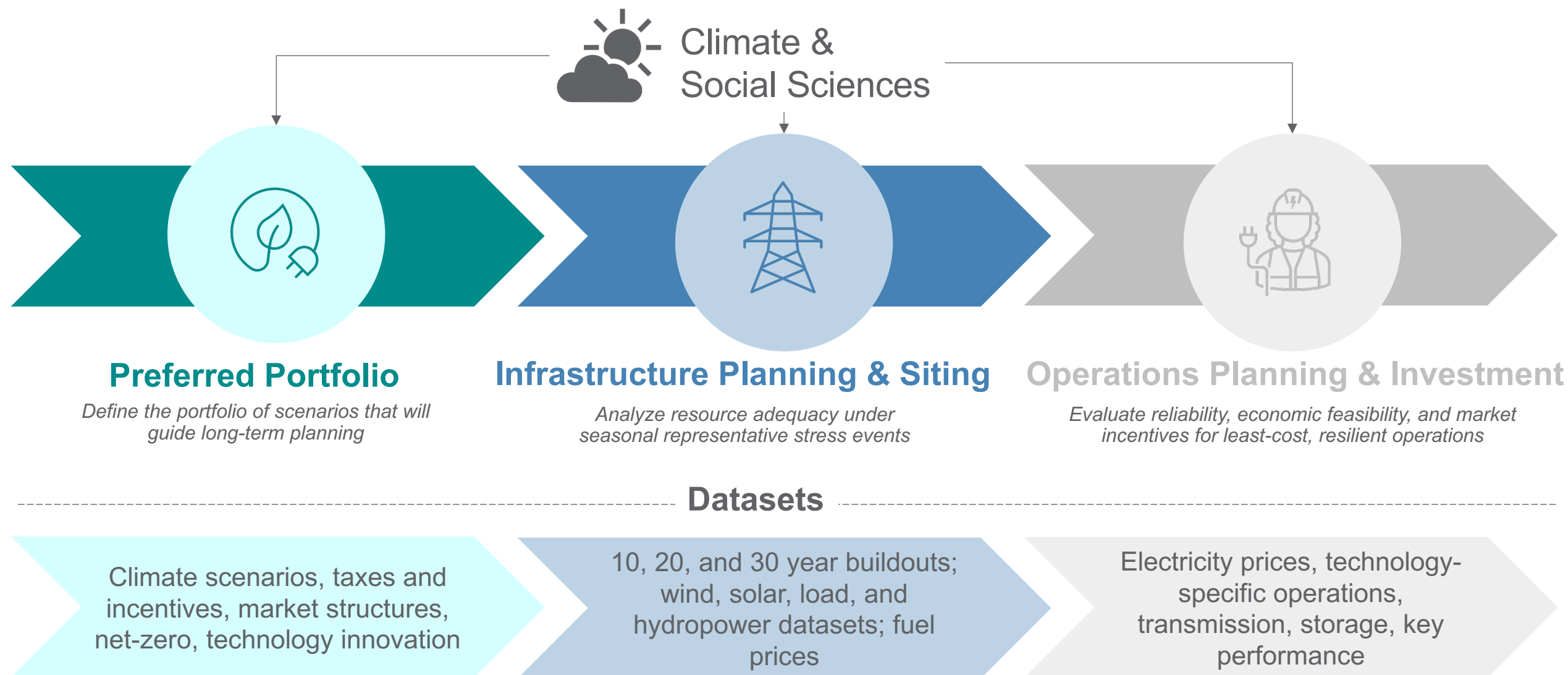
High temperatures will exceed 100 degrees Fahrenheit (37 Celsius) in Los Angeles and San Diego on Saturday, the National Weather Service said in a series of excessive heat warnings and advisories.

Key Messages

To assess the resilience and reliability of the bulk power system, it is critical to evaluate system performance:

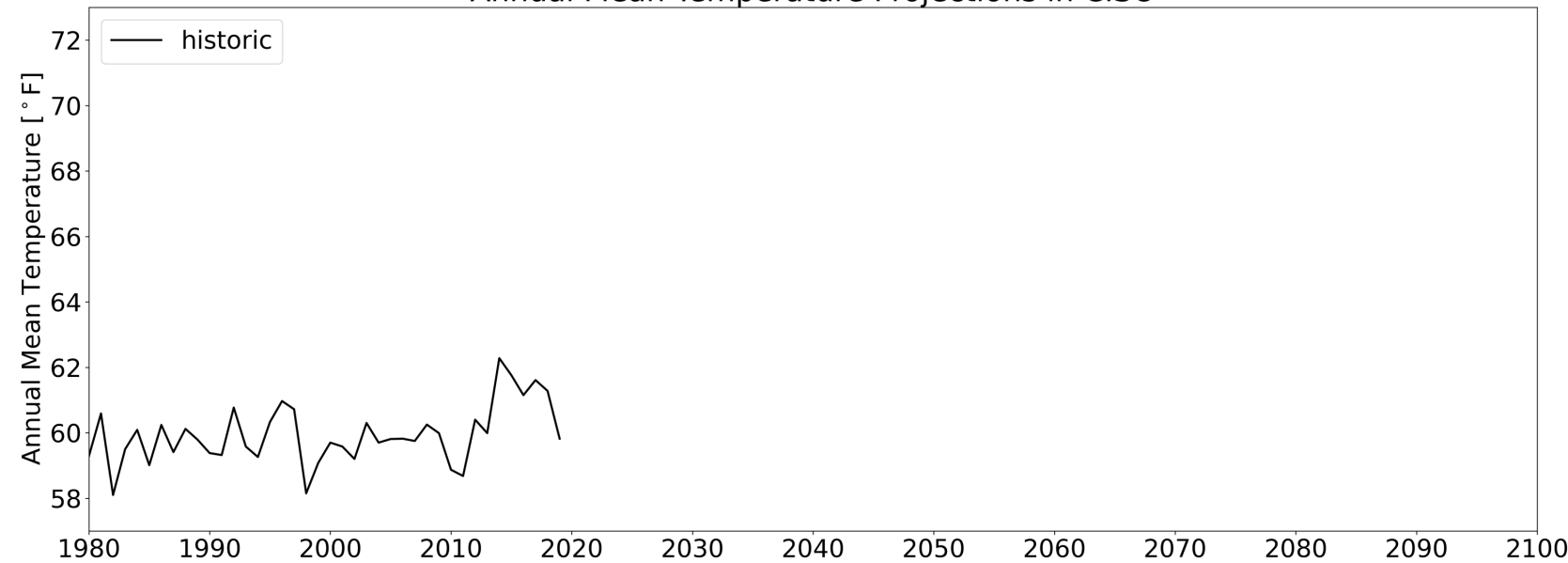
1. With coincident load-wind-solar-hydro conditions;
2. Across a wide range of historical and projected weather conditions.

Consistent Integration of Climate Information Throughout the Long-Term Planning Process

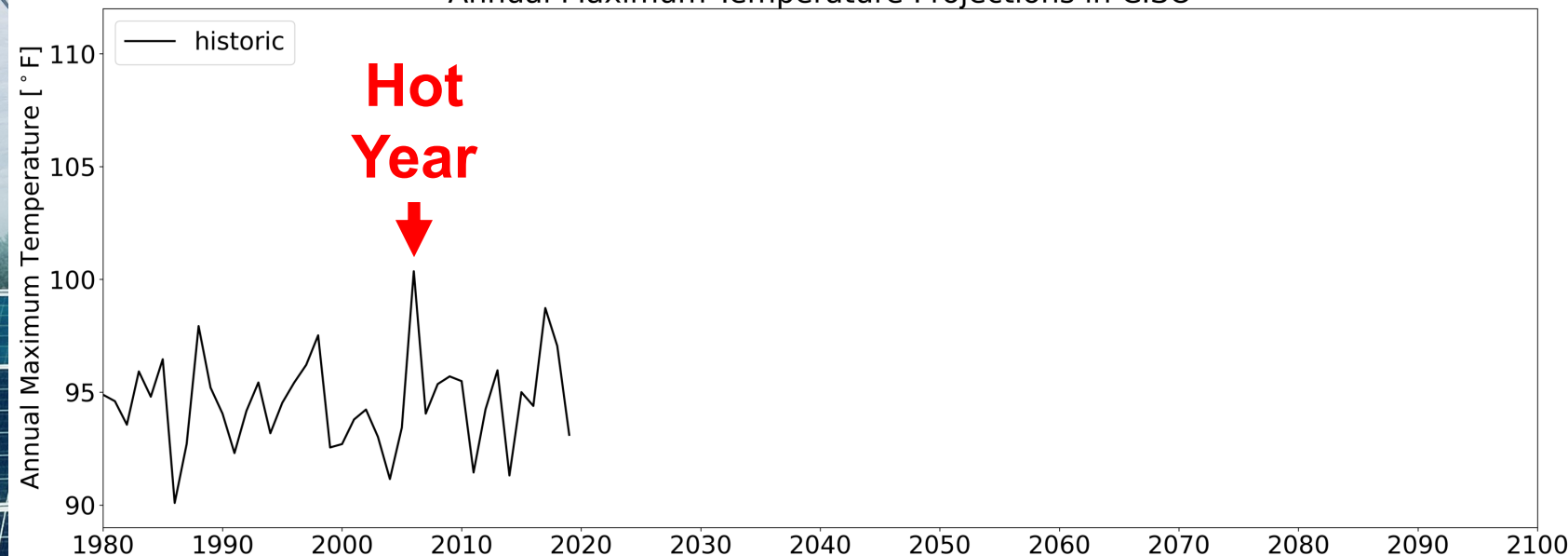


U.S. Climate Projection Dataset

Annual Mean Temperature Projections in CISO



Annual Maximum Temperature Projections in CISO

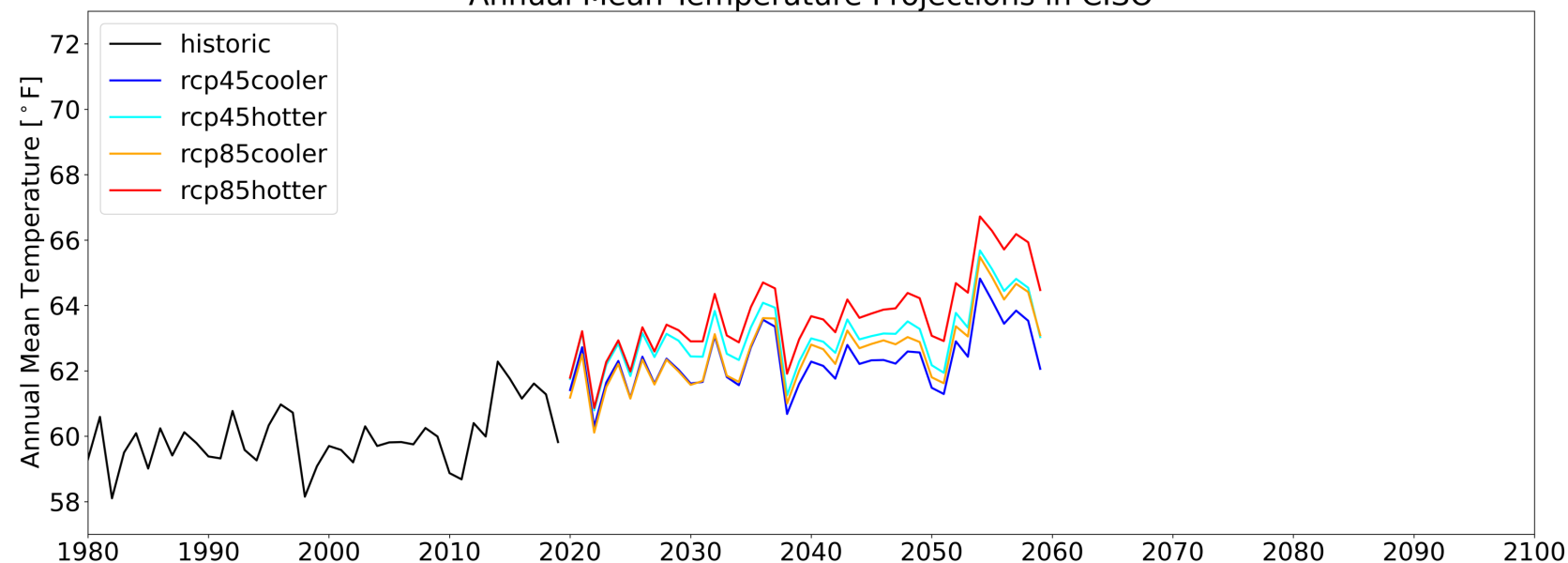


- Historic data reproduces observed sequence of past events (1980–2019)
- Sequence is repeated twice in the future (2020–2059 and 2060–2099) with additional warming gradually applied
- 1/8 deg (~12 km) resolution, U.S., hourly
- 25 hourly and 250+ three-hourly variables
- Output is first spatially-averaged by county then population-weighted to create annual 8,760-hr meteorology time series for 54 BAs across the U.S.

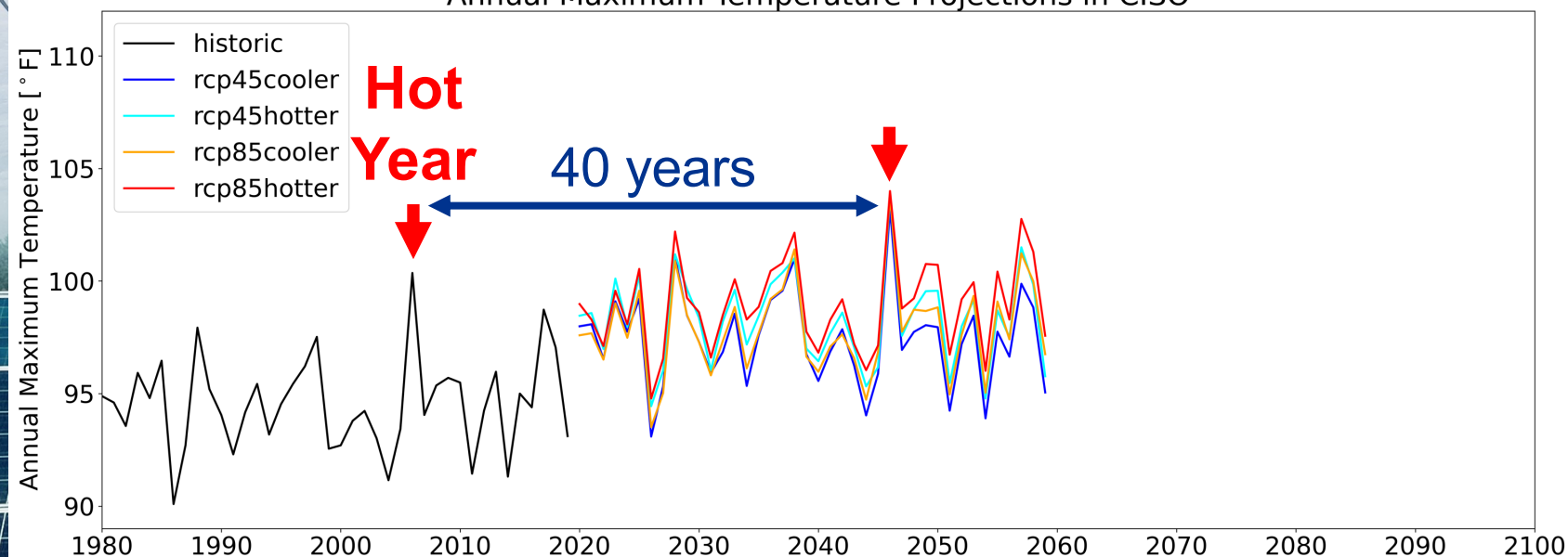
Climate data was developed with DOE Sc funding and is publicly available:
<https://data.msdlive.org/records/cnsy6-0y610>

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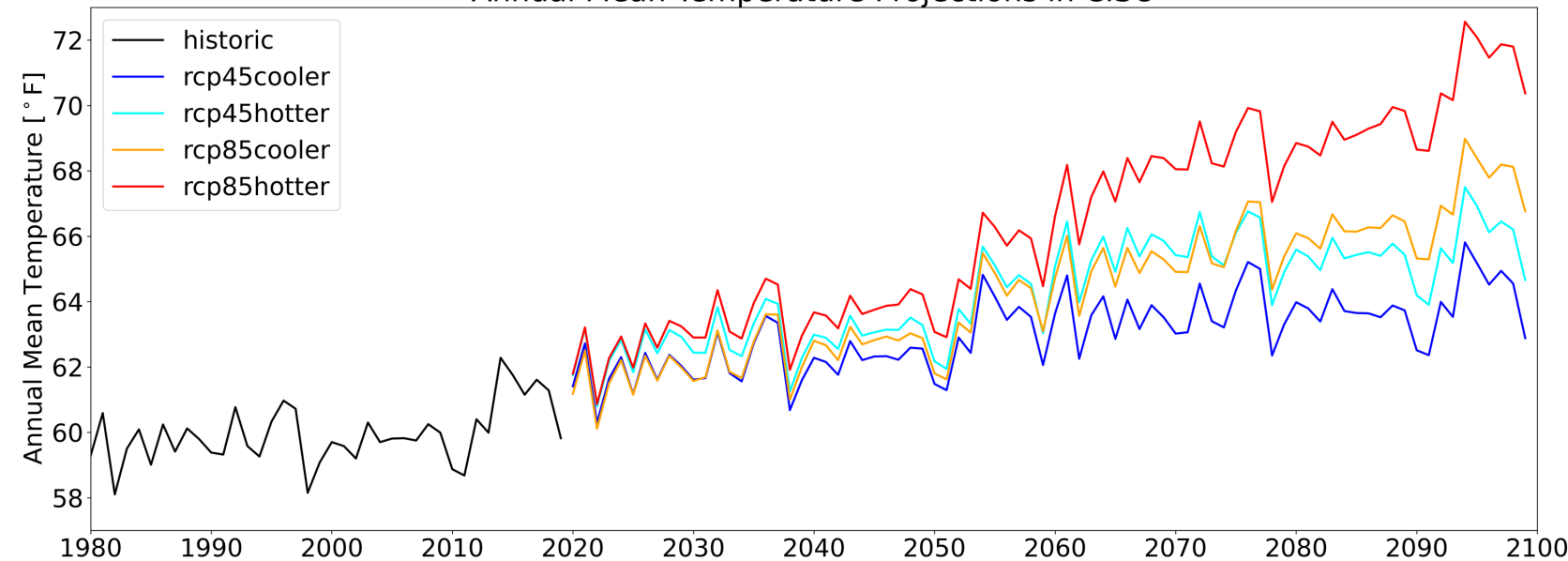


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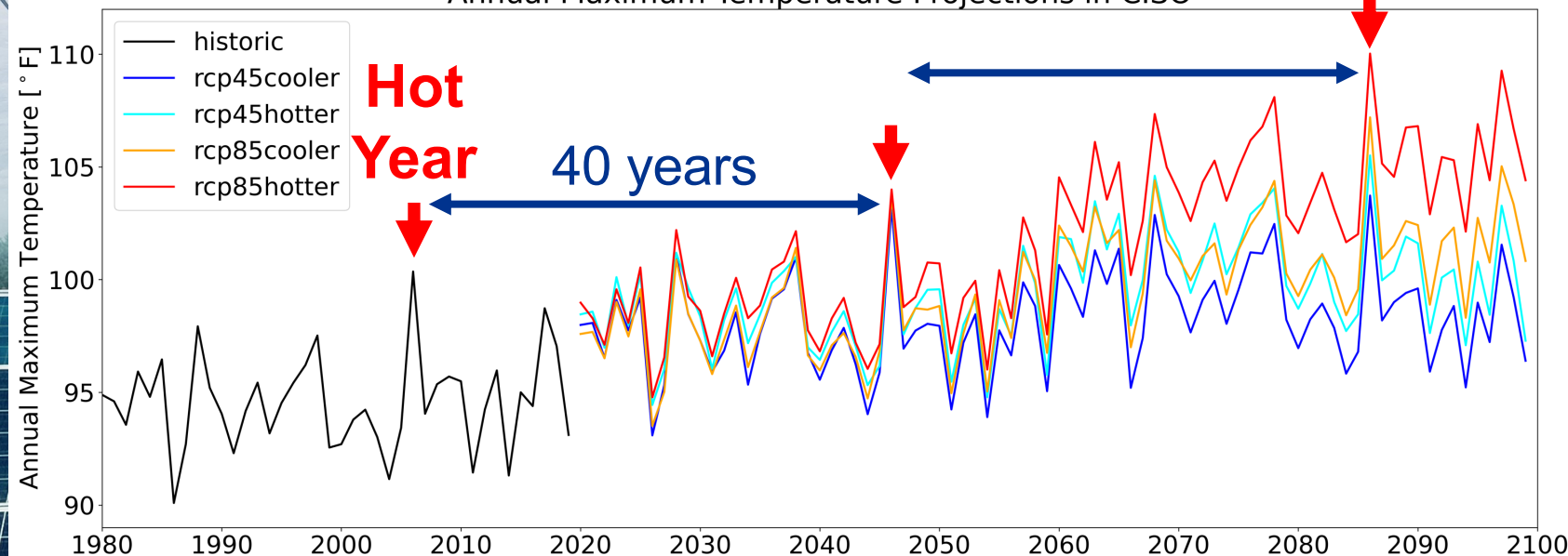
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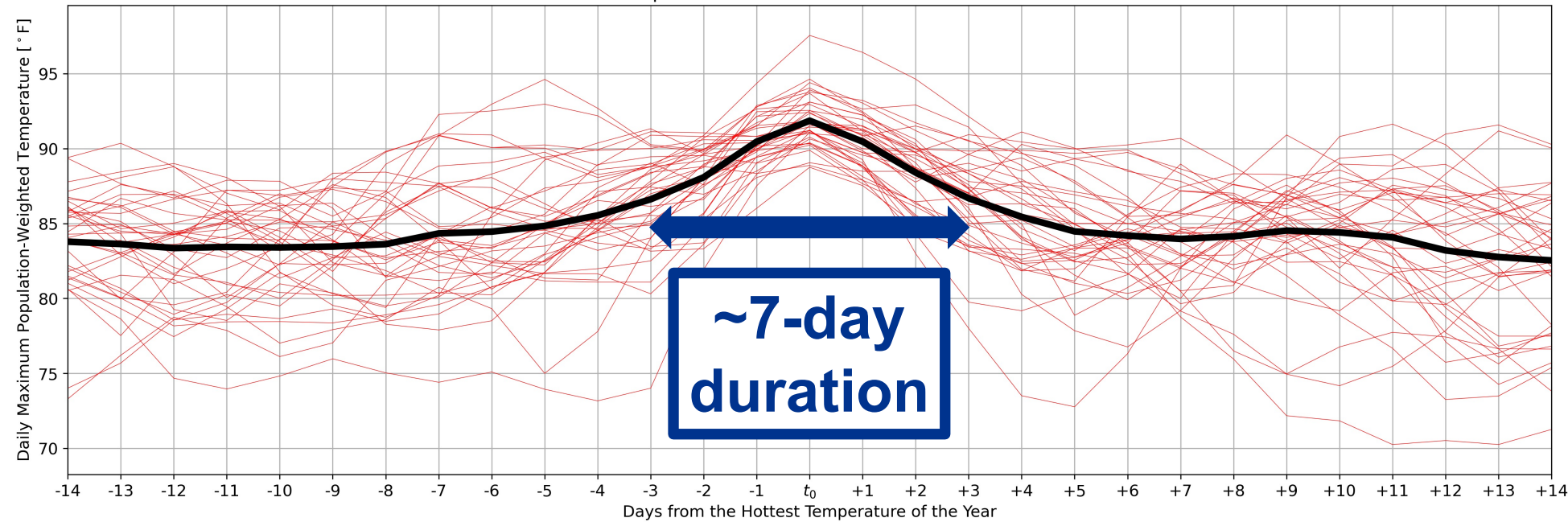


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Designing Stress Tests Based on Heat Wave Dynamics

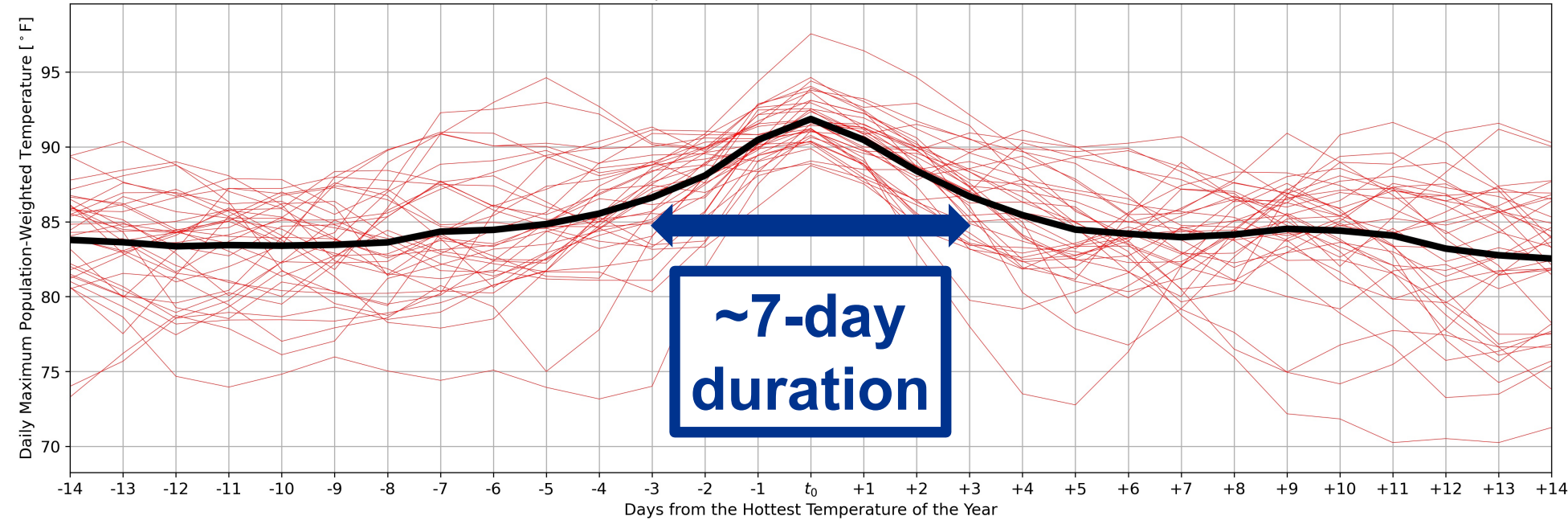
Heat Wave Temperature Evolution in the WECC from 1980-2019



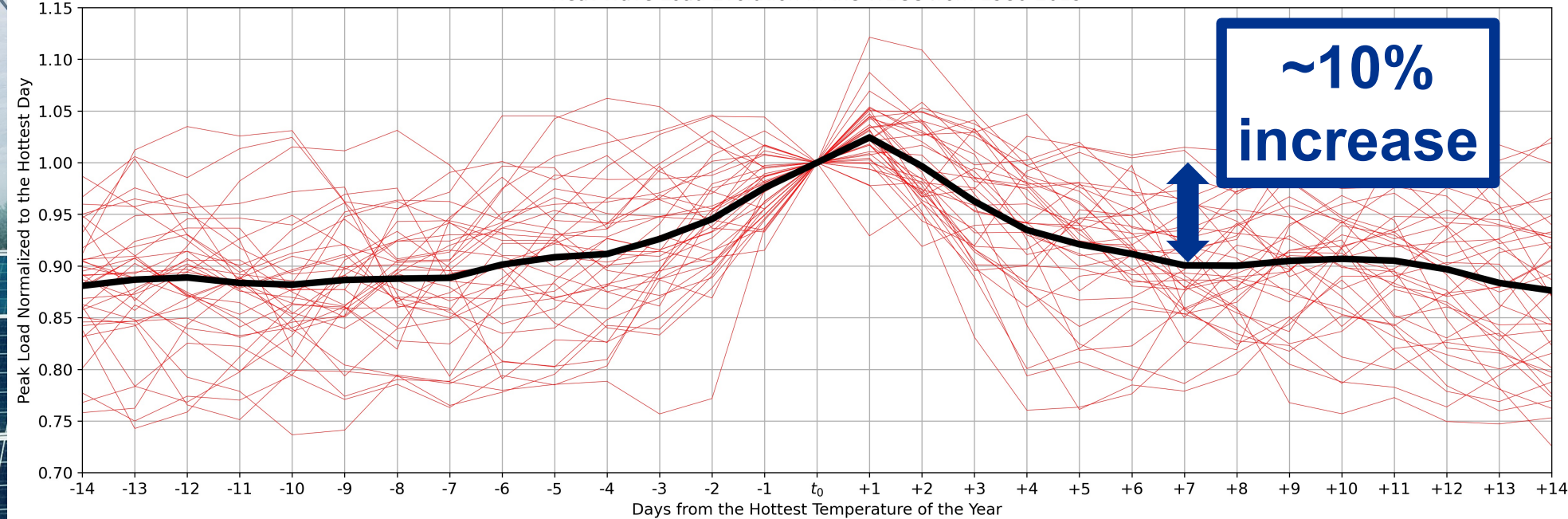
Typical heat waves last ~6-7 days and are, on average, symmetric about the maximum temperature day.

Designing Stress Tests Based on Heat Wave Dynamics

Heat Wave Temperature Evolution in the WECC from 1980-2019



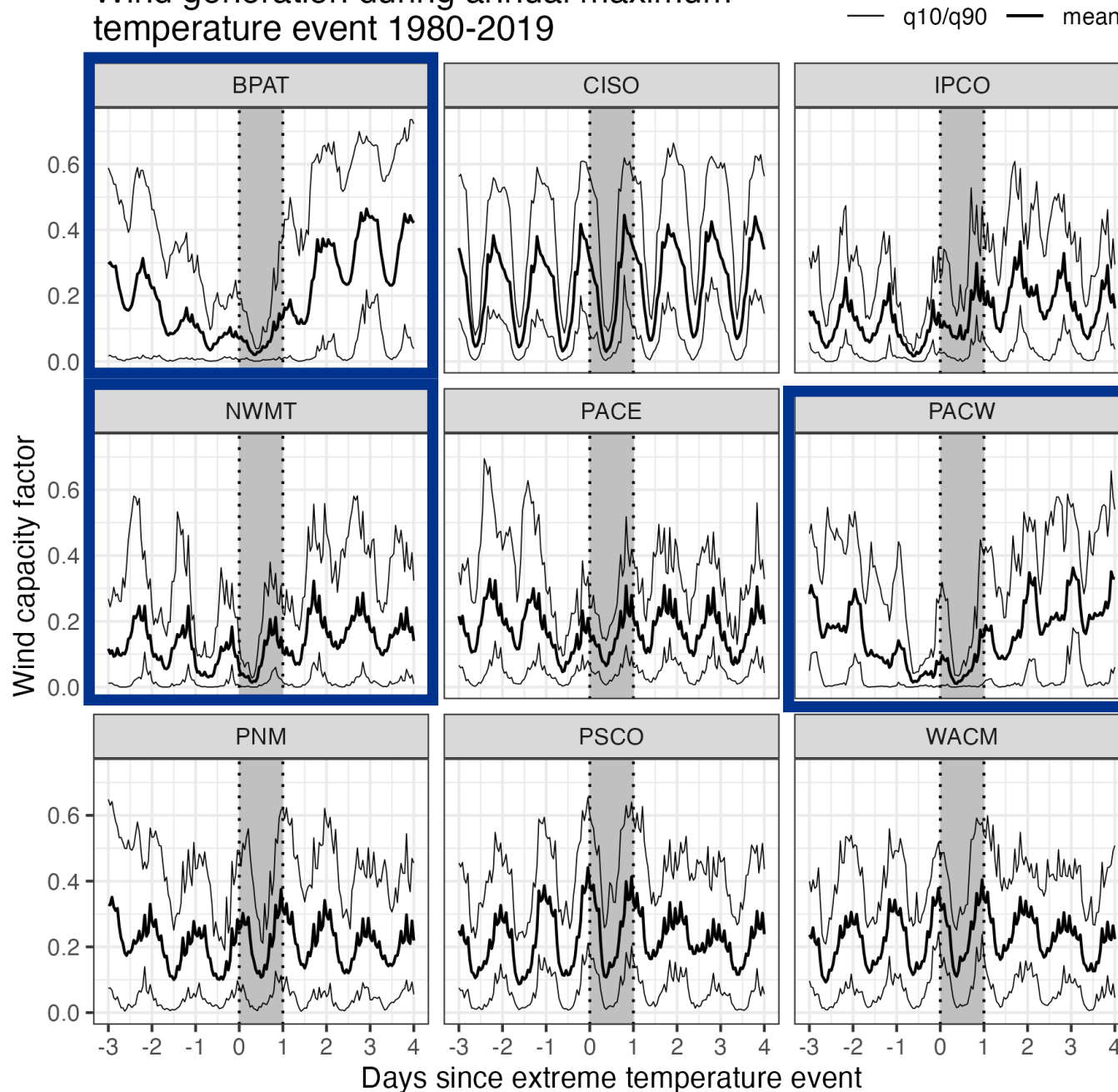
Heat Wave Load Evolution in the WECC from 1980-2019



Heat waves increase peak loads by ~10% on average compared to the background peak loads.

Notable Suppression of Wind Generation During Heat Waves

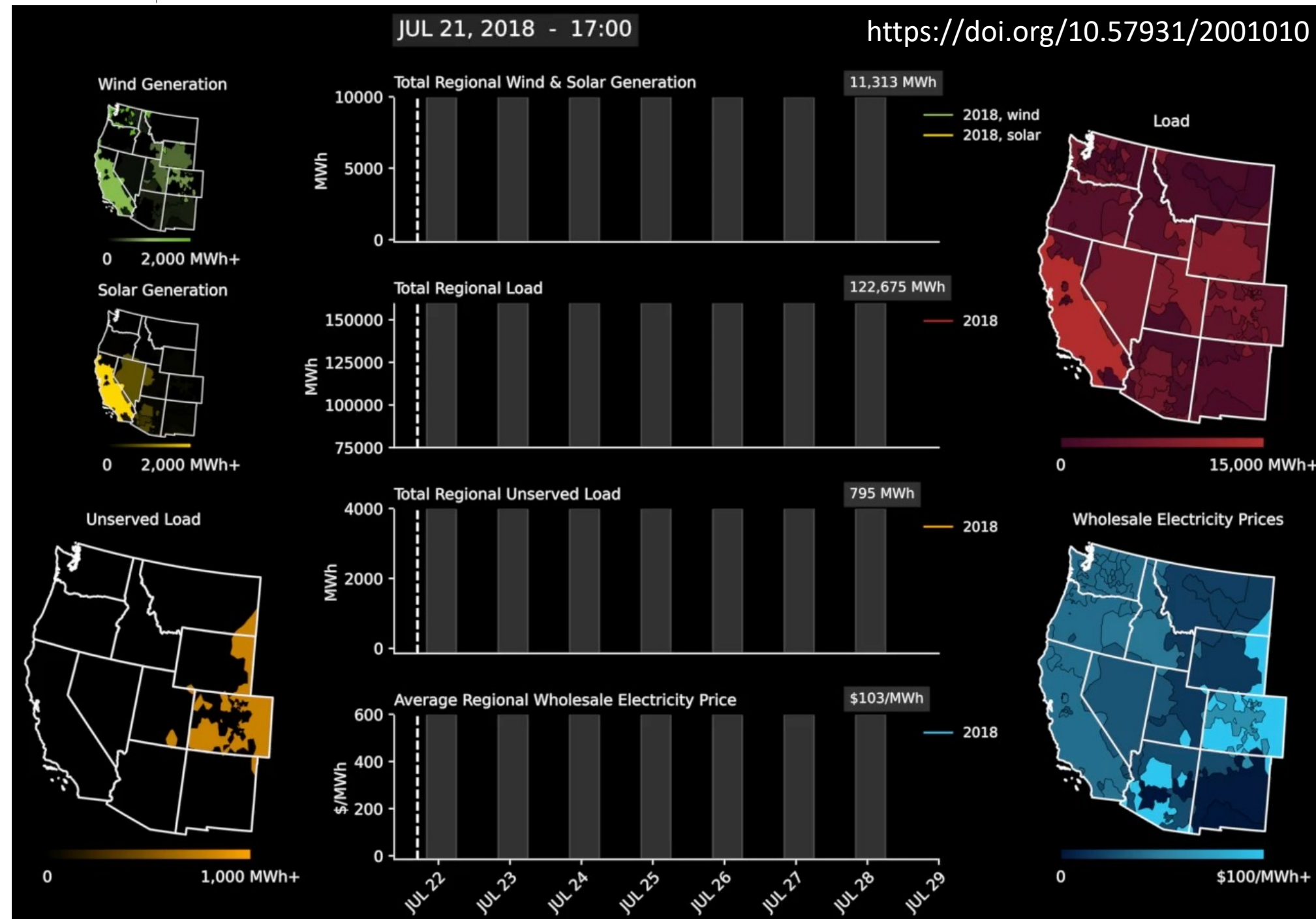
Wind generation during annual maximum temperature event 1980-2019



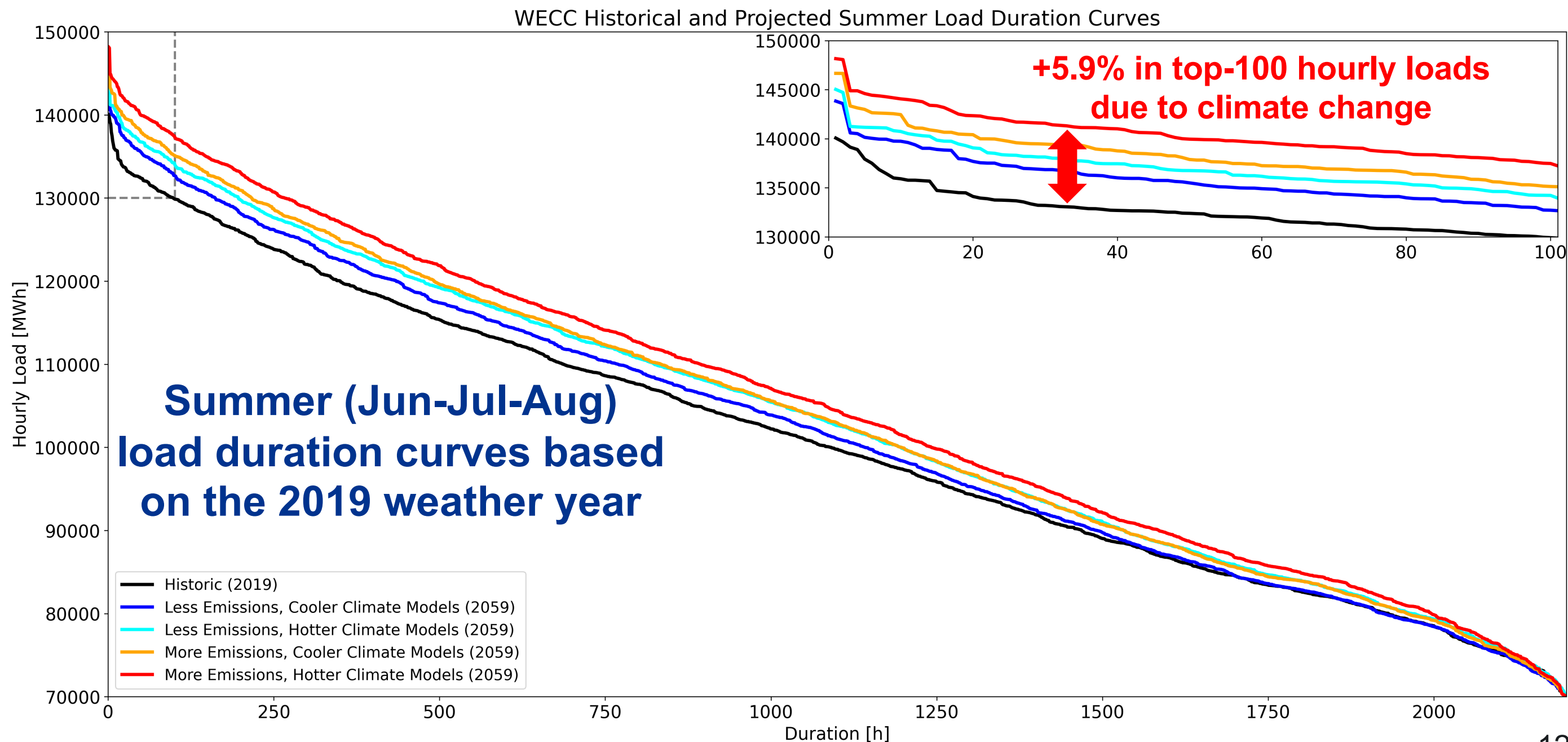
BAs in the Pacific Northwest (e.g., BPAT, PACW, and NWMT) show notable suppression of wind generation during heat waves.



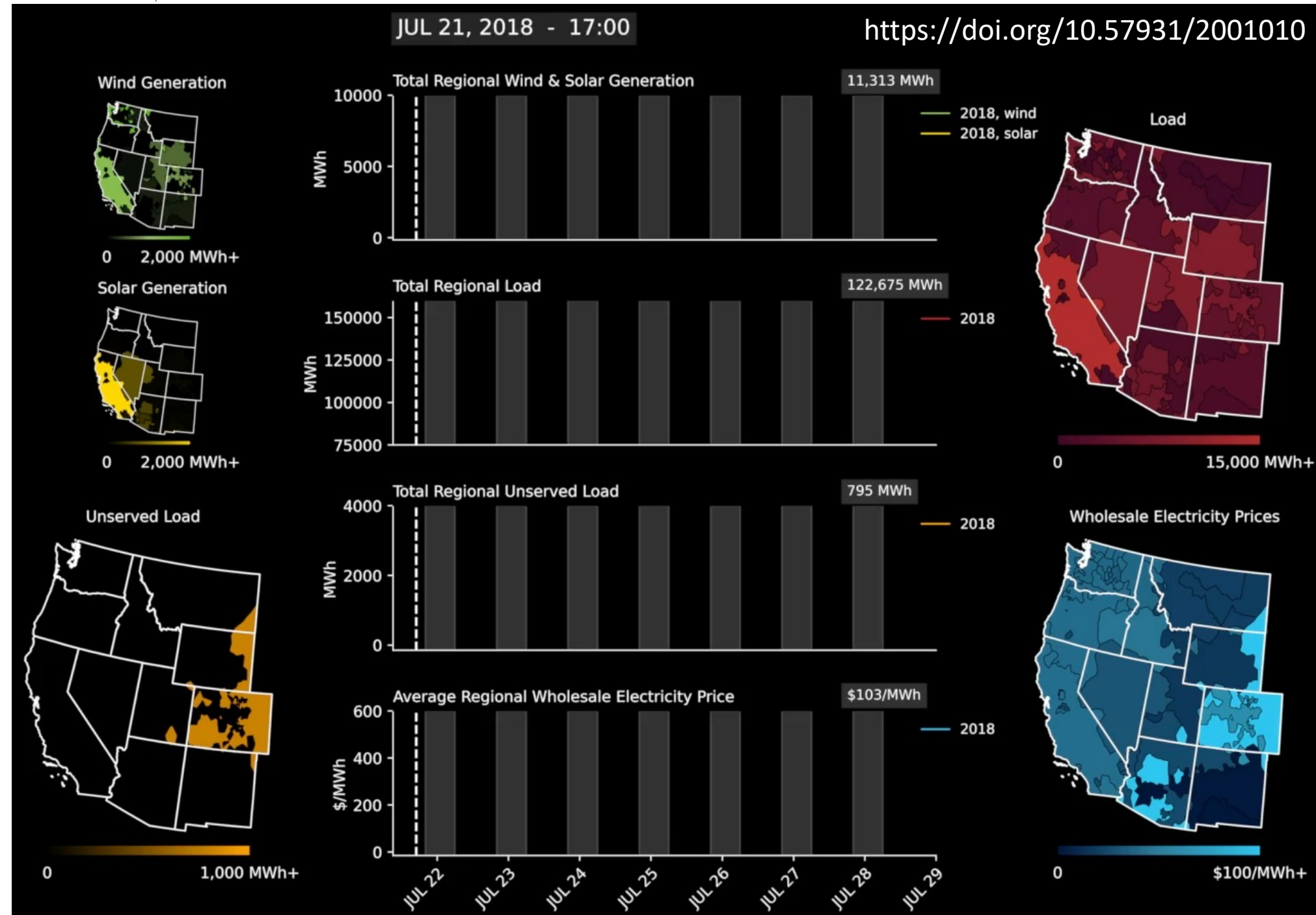
Exploring Historical Heat Wave Grid Stress



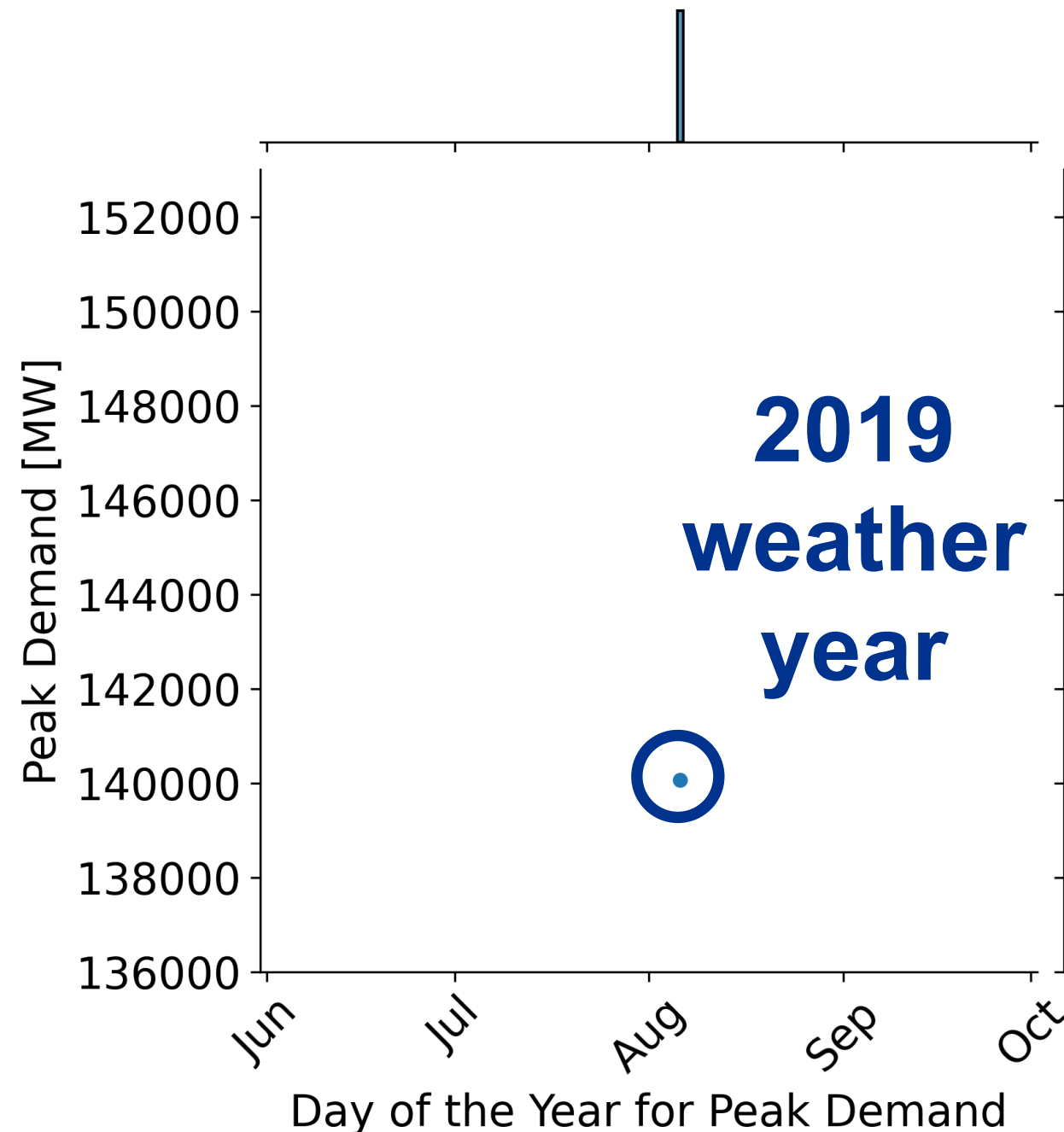
What About Future Heat Waves?



Exploring Future Heat Wave Grid Stress



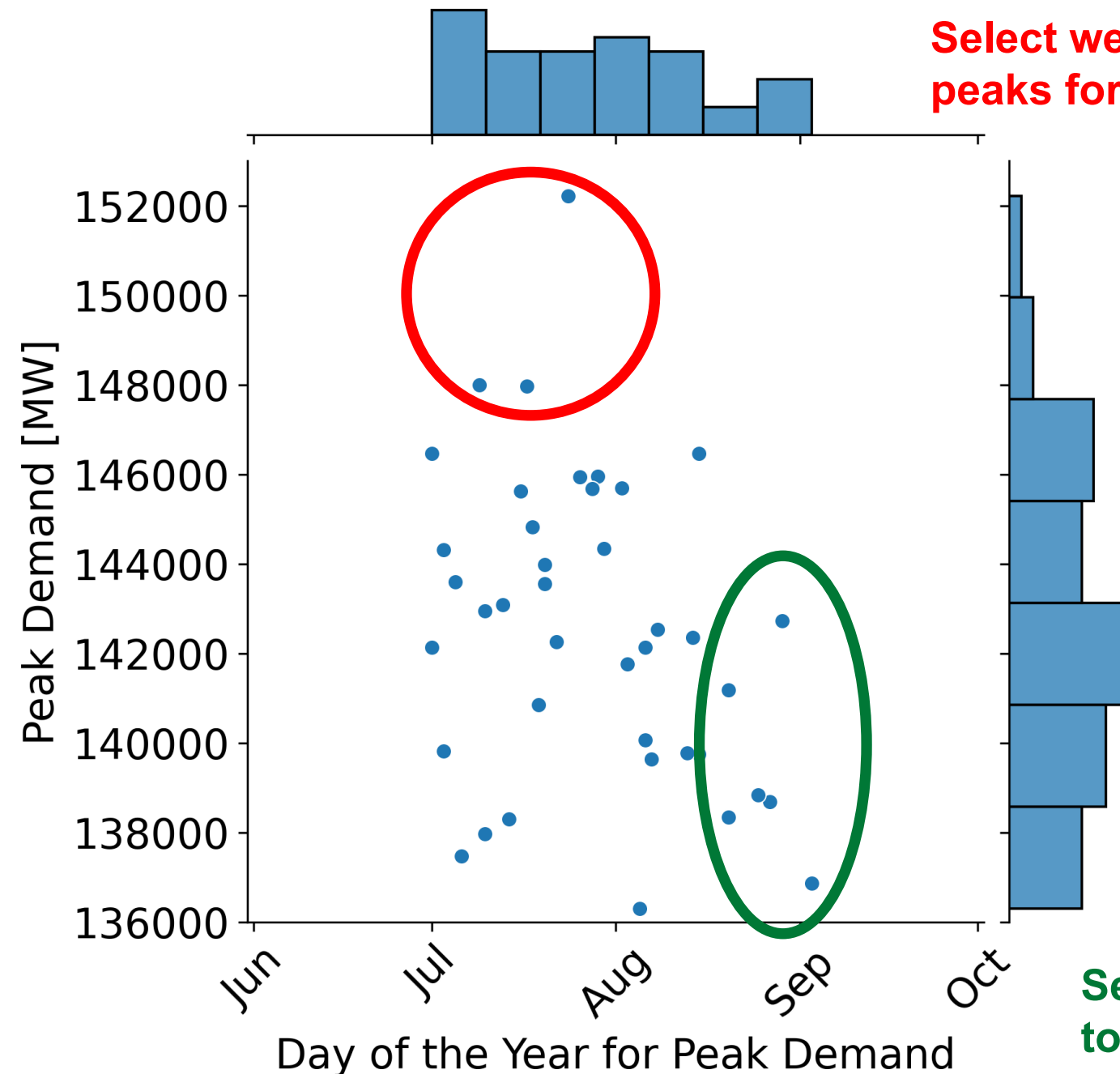
Simulating Multiple Weather Years to Explore Uncertainty



The prior example used a single weather year, but we can run many unique weather years through PNNL's wind, load, and solar models:

- All years have the same total annual energy consumption by design
- Absolute magnitude and timing of peak demand varies significantly depending on the weather each year

Simulating Multiple Weather Years to Explore Uncertainty



Select weather years with extreme peaks for testing resilience...

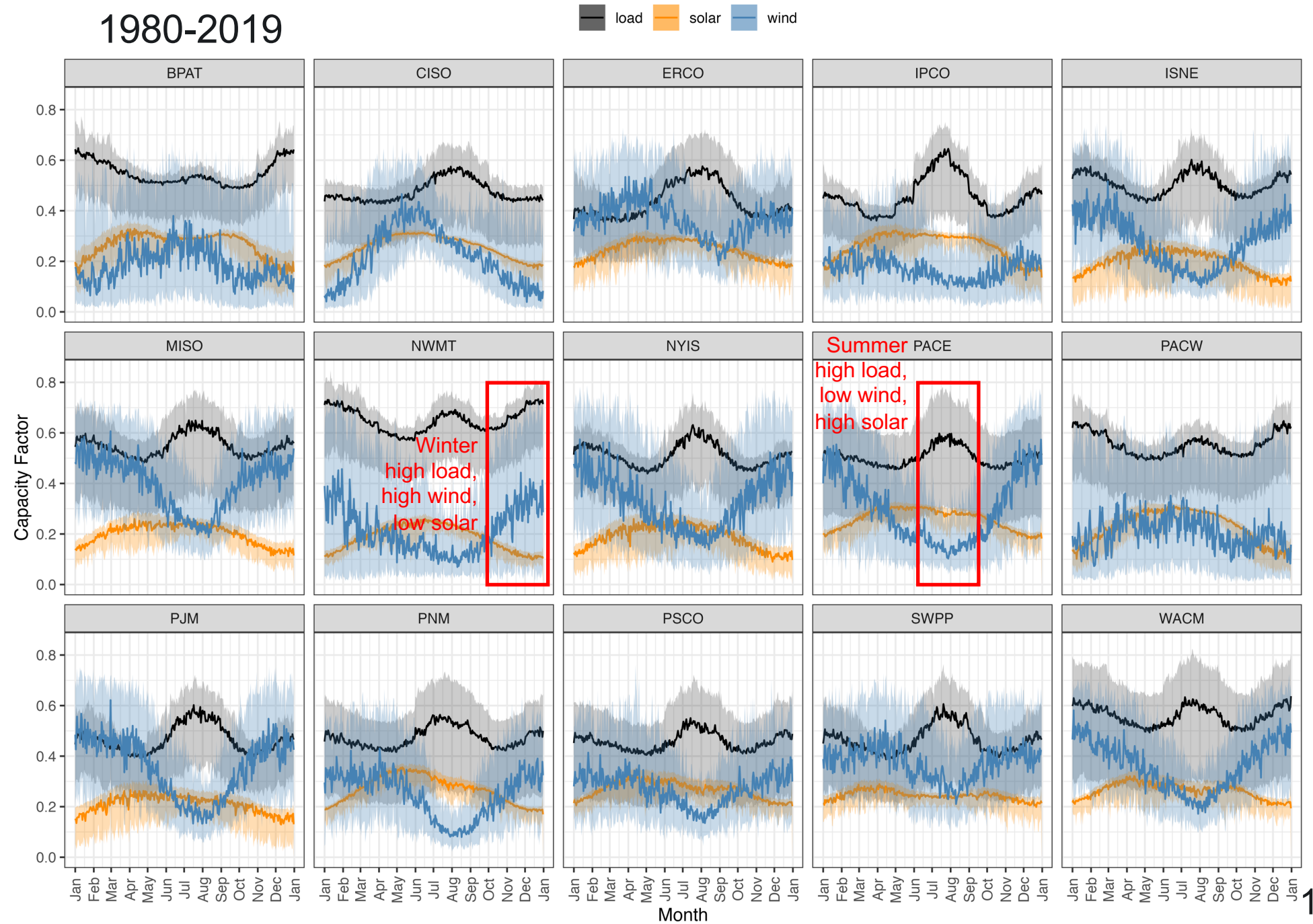
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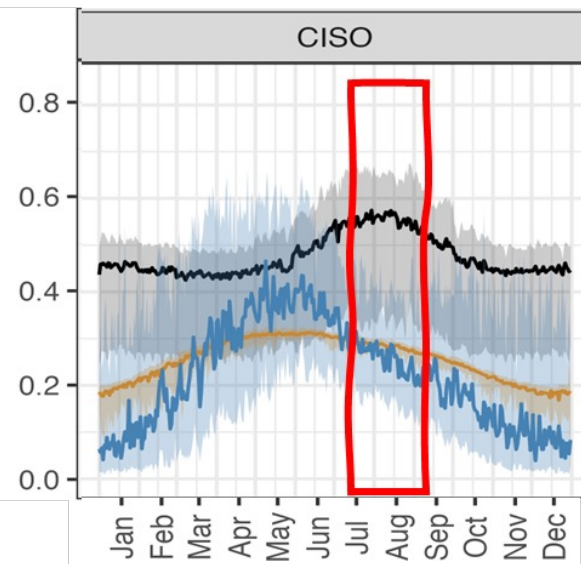
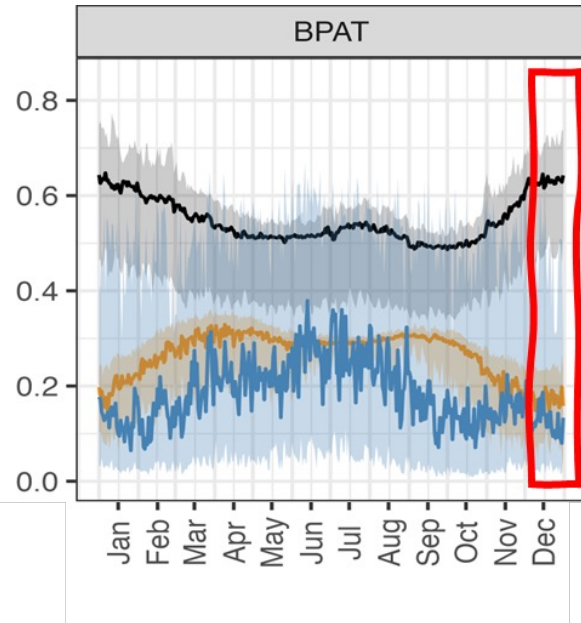
Select weather years with late season peaks to assess reliability with low hydro...

Wind Solar and Load Cycles Vary Depending on the Region and Season

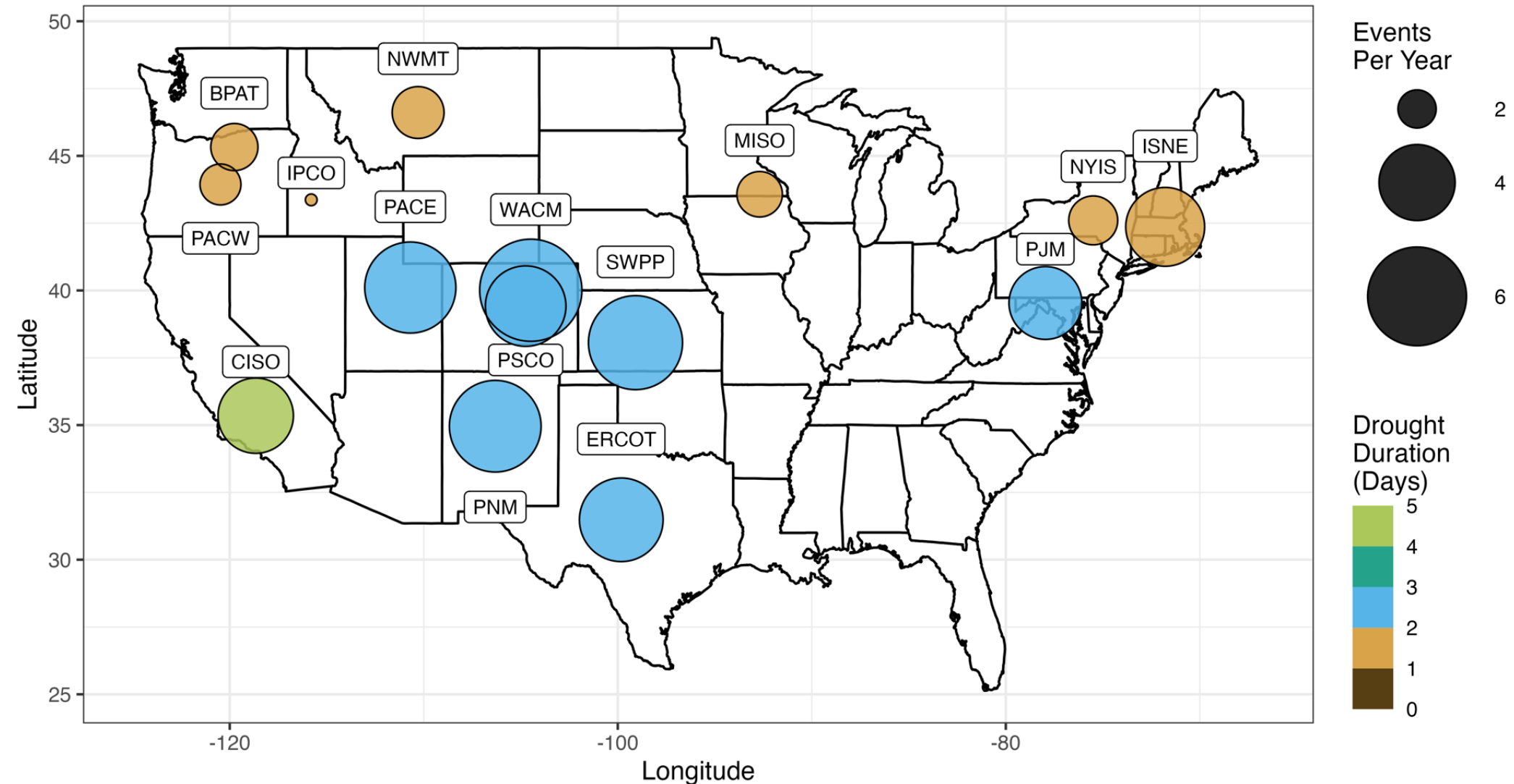
At the seasonal time scale, there is often complementarity between wind and solar to address high load periods. For seasonal droughts, hydro, natural gas and transmission also need to be considered.



Coincident Datasets Help Identify Periods of Potential Stress

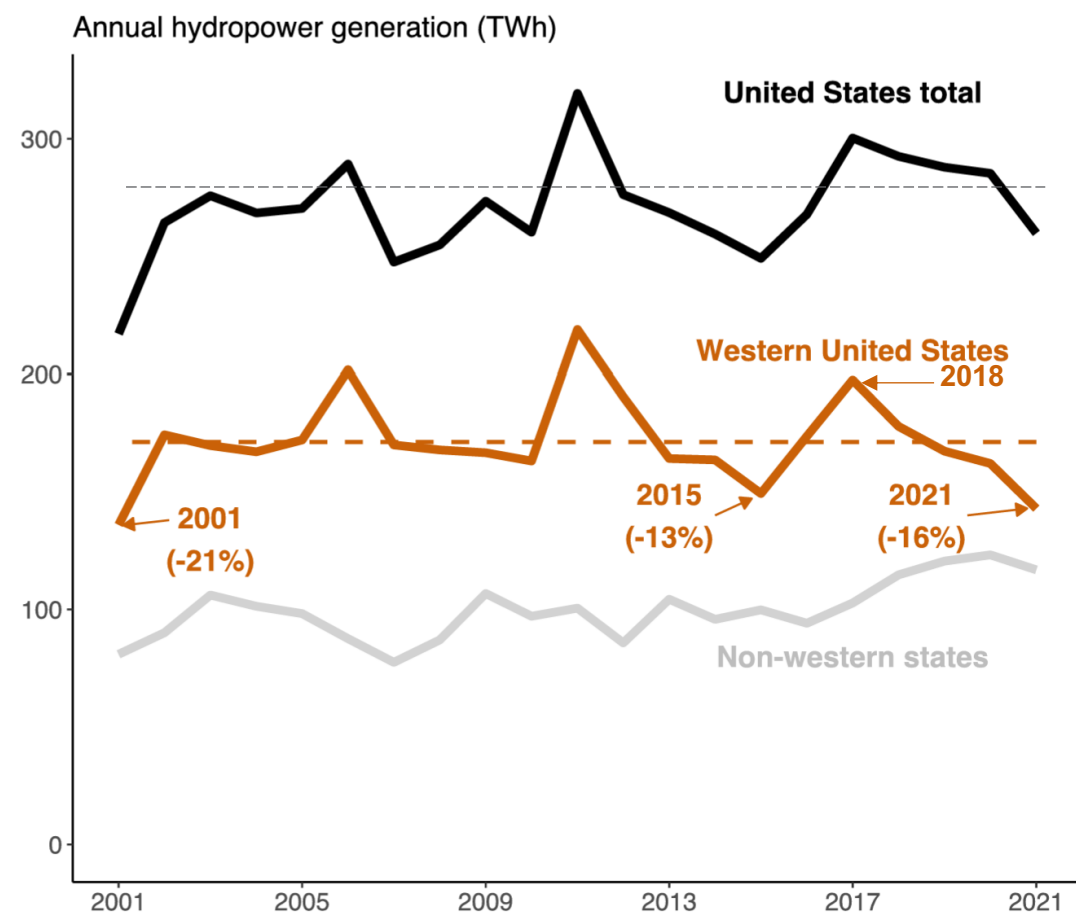


1-day Coincident Wind and Solar Droughts (90th percentile duration)

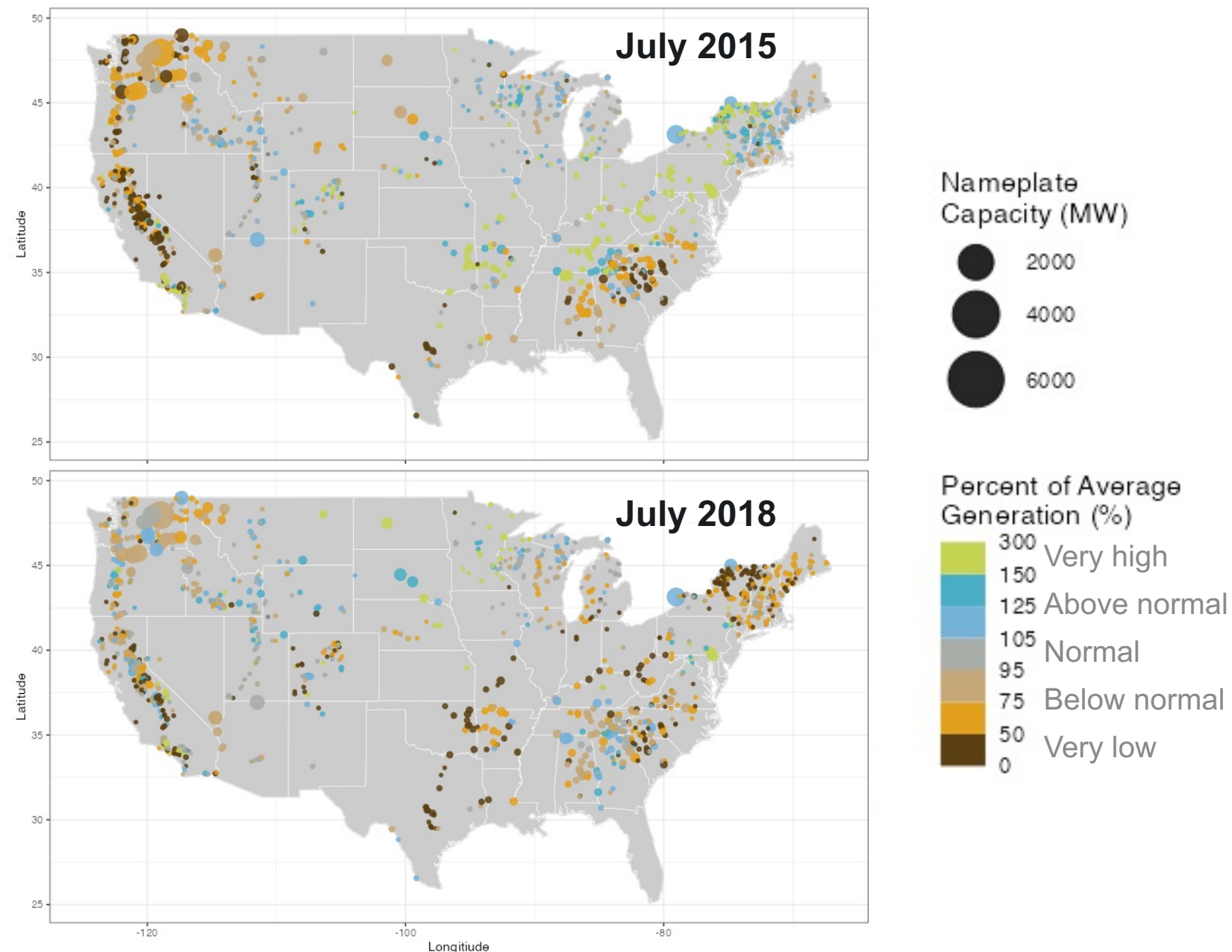


Energy droughts help understand storage and regional transmission needs and whether market mechanisms incentivize those operations.

Hydropower Datasets Are Available for Input Into Power System Models



Interannual variations in hydropower generation are expected and need to be considered in power system studies.



July hydropower generation by power plant. Hydropower datasets include weekly potential generation and flexibility.

Open-source, vetted datasets are available in multiple formats in support of targeted questions by industry.

Choose a Scenario Comparison

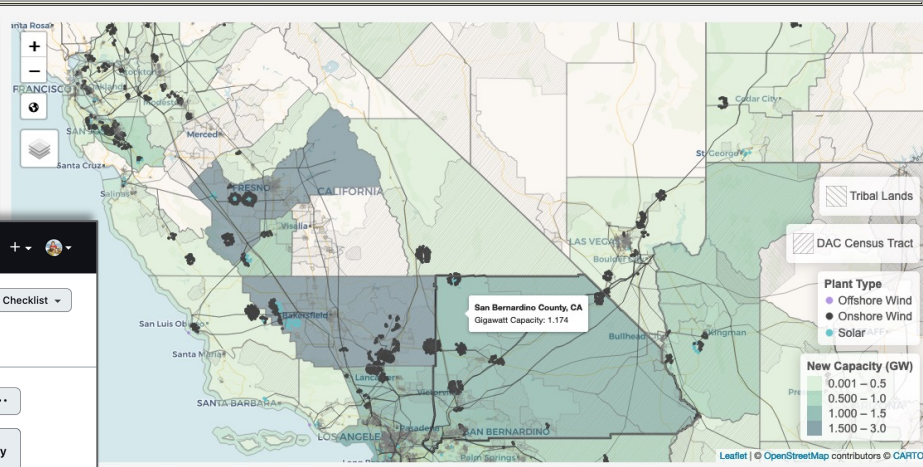
Compare 2035 Clean Grid scenario to 2020 conditions

Choose Aggregation Scale for Map

County

Choose U.S. State(s)

Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico



San Bernardino County, CA
Gigawatt Capacity: 1,174

Plant Type

- Offshore Wind
- Onshore Wind
- Solar

New Capacity (GW)

- 0.001 – 0.5
- 0.500 – 1.0
- 1.000 – 1.5
- 1.500 – 3.0

Search or jump to...

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Code Issues (4) Pull requests Actions Projects (1) Wiki Security Insights Settings

main godeeep / CERF-to-GridView /


thurber updated transportation workflow and notebook; updated readme styles (#19 ... 5d5a8d4 18 days ago History

CERF_testrun.ipynb Updates (#16)


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Open-Source Datasets


Topic: All Resolution: All




Block-level Income Projections for WA
Wan 2023b
DOI 10.5281/zenodo.7869437




Block-level Population Projections for WA
Wan 2023a
DOI 10.5281/zenodo.7402538




GCAM-USA Decarbonization Pathways
Ou et al 2023
DOI 10.5281/zenodo.7838871




Population scenarios for U.S. states
consistent with shared socioeconomic...
Zoraghein et al 2020
DOI 10.5281/zenodo.3796178




Projecting Residential Energy
Consumption across Multiple Income...
Zhang et al 2023
DOI 10.5281/zenodo.7988037




RectifHyd
Turner et al 2023
DOI 10.5281/zenodo.6607824




Solar and Wind Energy Drought Data for
15 BAs in the CONUS
Brackeen et al 2023b
DOI 10.5281/zenodo.8008033




State-level Income Decile Projections
Narayan et al 2023
DOI 10.5281/zenodo.6902357




Thermodynamic Global Warming
Simulations
Jones et al 2022
DOI 10.57931/1885796




Total Load Profiles by BA
Narayanan et al 2023c
DOI 10.5281/zenodo.8067471




Transportation Electrification Load Profiles
Acharya et al 2023
DOI 10.5281/zenodo.7888568




U.S. Balancing Authority Projections of
Hourly Meteorology under Climate Change
Burleyson et al 2023a
DOI 10.57931/1960530



U.S. County Projections of Hourly
Meteorology under Climate Change
Burleyson et al 2023b
DOI 10.57931/1960548



Wind and Solar Capacity Factor Profiles
Burleyson et al 2023a
DOI 10.5281/zenodo.7901614



Wind and Solar Generation by BA
Campbell et al 2023
DOI 10.5281/zenodo.7991870

update_grid_view_database.py GridView Database

Legend

- dataset
- interface

I data provided from gcamextractor, the substation energy
e file
operating and maintenance costs, offshore wind, and
it file and the GridView_mdb database to update

godeeep.pnnl.gov

Key Messages and Results

- To assess the resilience and reliability of the bulk power system, it is critical to evaluate system performance with coincident load-wind-solar-hydro conditions and across a wide range of historical and projected weather conditions.
- We are translating scientific understanding into actionable power-system relevant data and insights for use in long-term planning.
- The conditions that stressed your system in the past may not be the ones that stress your system in the future.
- Innovations:
 - Spatially- and temporally-coincident load, wind, and solar data
 - Capture consistent and realistic impacts on electricity supply and demand for use in stress testing projected infrastructure
 - Quantitative characterization of wind and solar droughts