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Characterizing Heat Waves and Cold Snaps in the WECC

Casey Burleyson, Cameron Bracken, and Nathalie Voisin

IM3

GODEEEP
Grid Operations, Decarbonization, Environmental and Energy Equity Platform
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Driving Questions

- What is a typical duration for heat waves and cold snaps impacting the WECC? How many BAs are typically affected by a heat wave or cold snap?
- Are the 10% most impactful (according to load) heat waves and cold snaps representative in duration and affected BAs? Or are they unique? How many events do we need to represent in studies?
- What are reasonable assumptions on compounded impacts during heat waves and cold snaps? How does renewable energy potential change during a typical heat wave or cold snap?

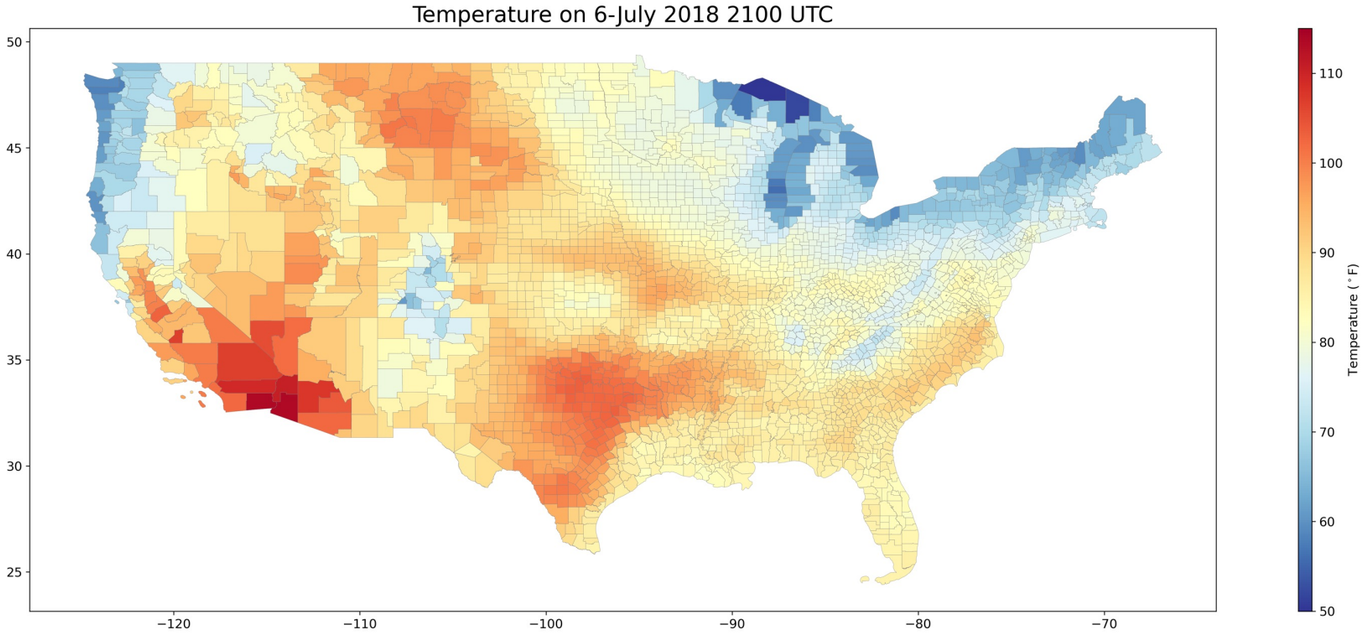
PNNL's Climate Forcing Dataset

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



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

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.

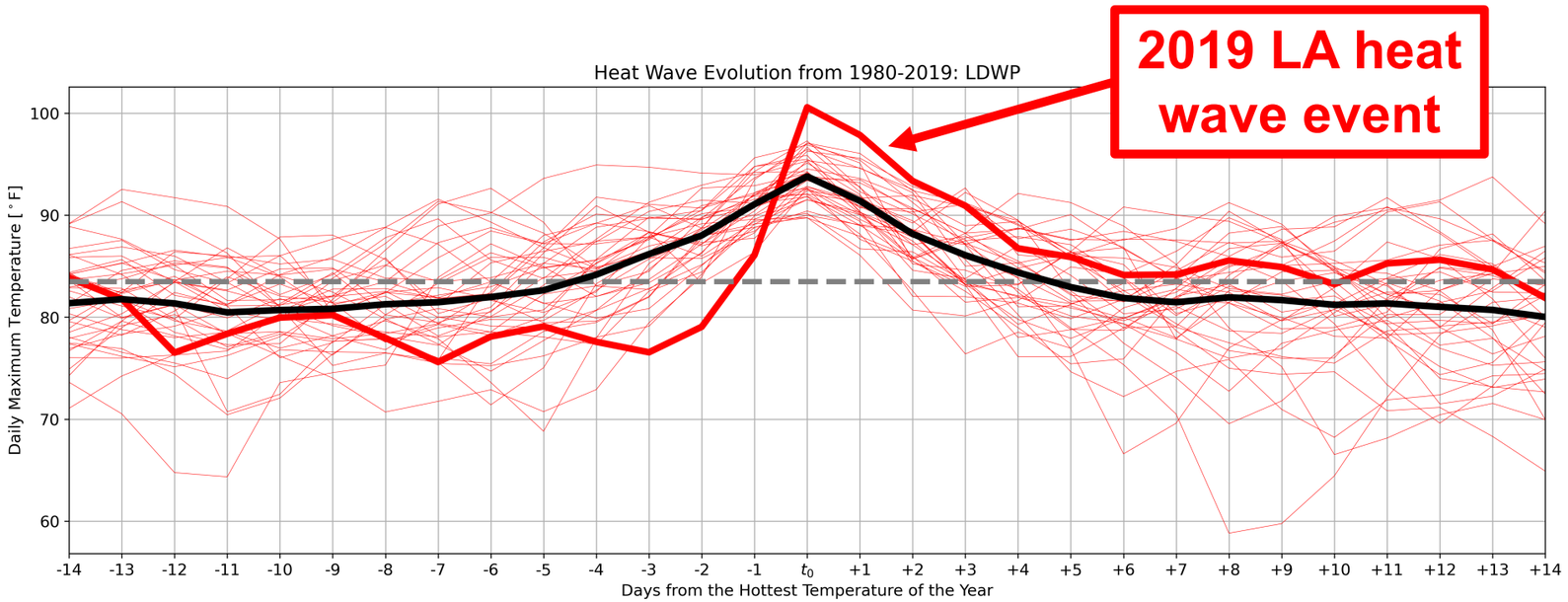
https://tgw-data.msdlive.org/

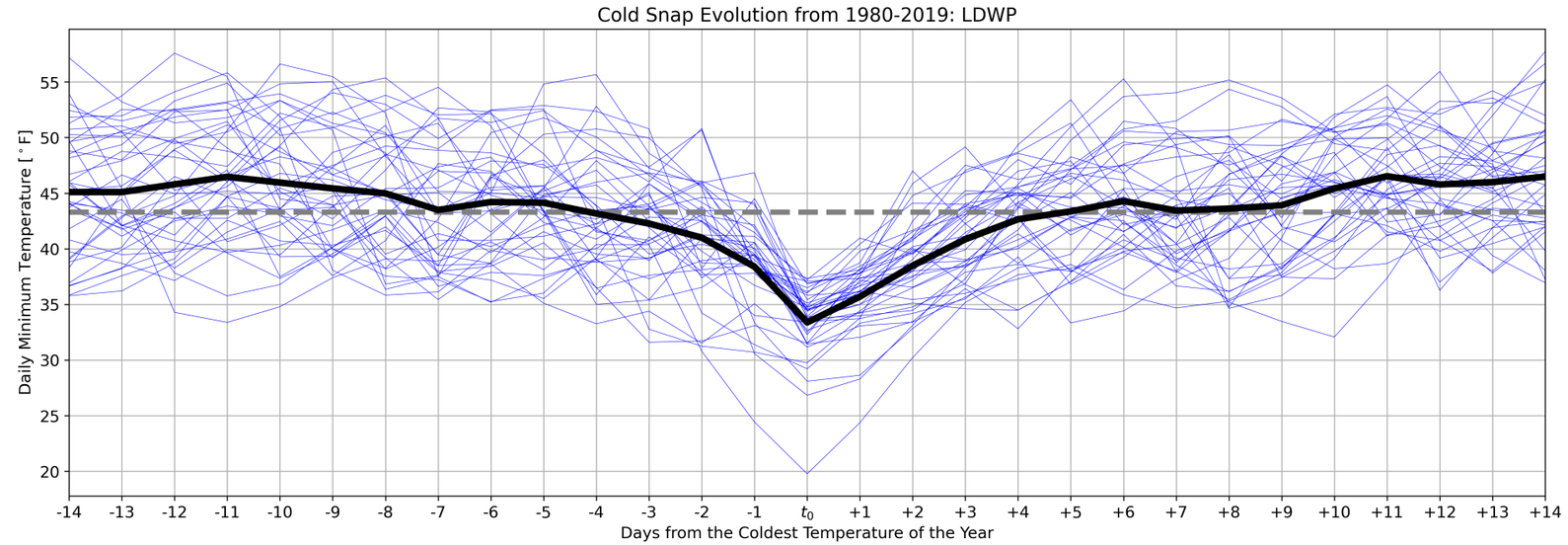
- **Historic data reproduces observed sequence of past events (1980-2019)**
- 1/8 deg (~12 km^2) resolution
- 25 hourly and 250+ three-hourly variables
- Model output is first spatially-averaged by county then population-weighted to create annual 8760-hr meteorology time series for each BA across the U.S.

Variable	Units
Temperature	K
Specific Humidity	kg kg^{-1}
Shortwave Radiation	W m^{-2}
Longwave Radiation	W m^{-2}
Wind Speed	m s^{-1}

Heat Wave and Cold Snap Duration in LDWP

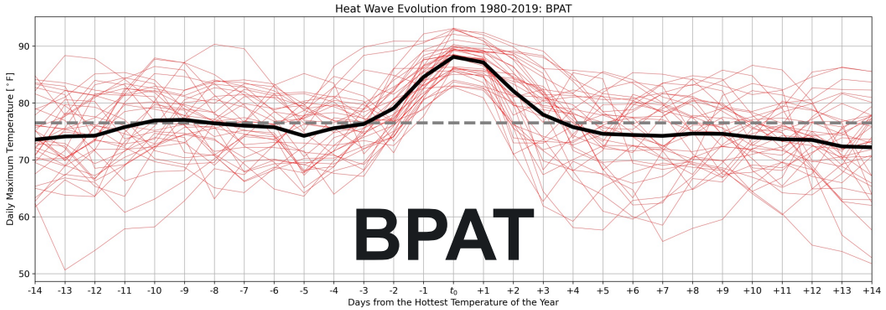
- Analyzed the hottest and coldest day of each year (1980-2019) in each BA in the WECC
- **Typical heat waves and cold snaps last ~6-7 days and are, on average, symmetric about the maximum/minimum temperature day**
- We could use these event dates and meteorology time series to select extreme hot/cold events to study

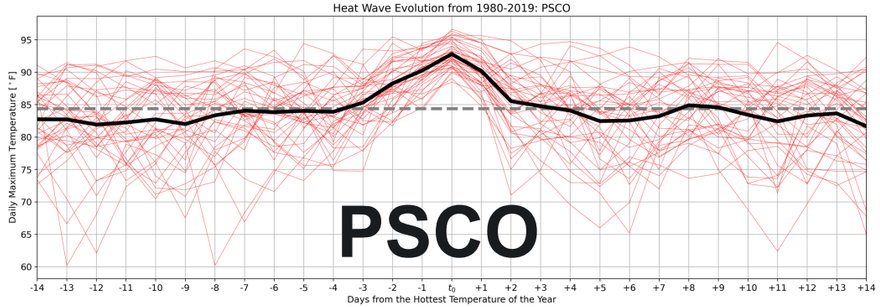


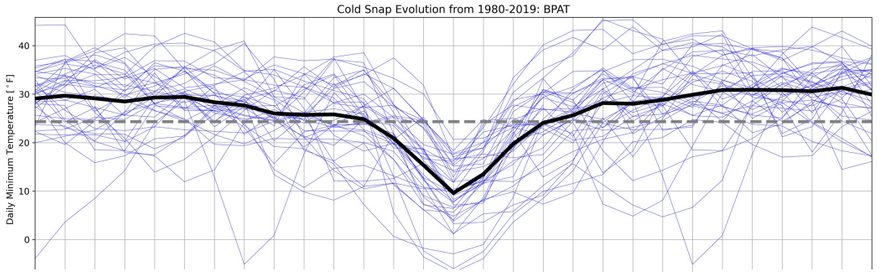


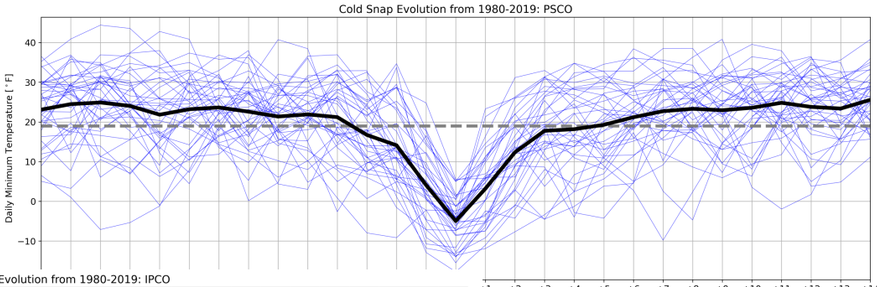
Heat Wave and Cold Snap Duration

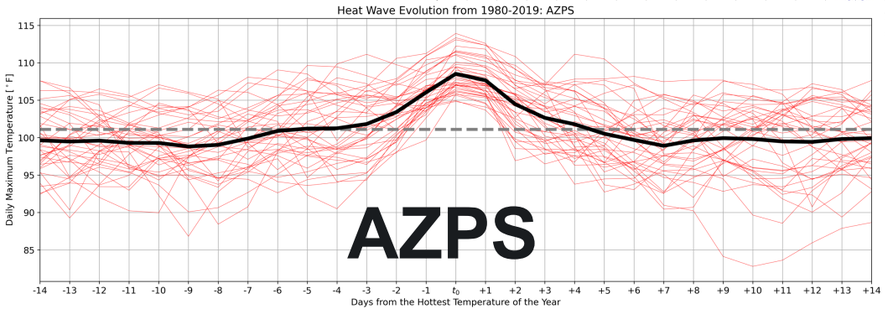
- Patterns are consistent across BAs in the WECC

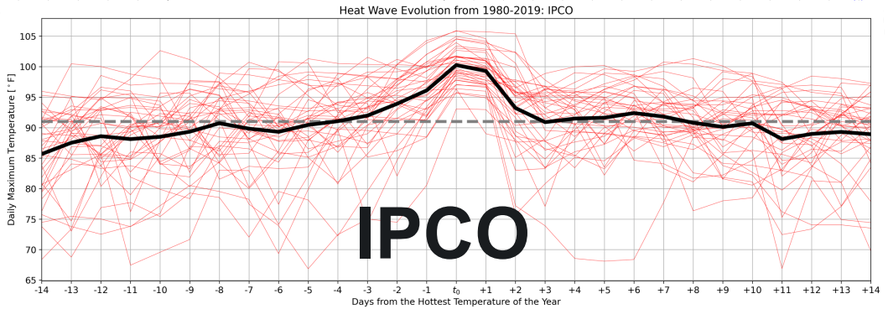


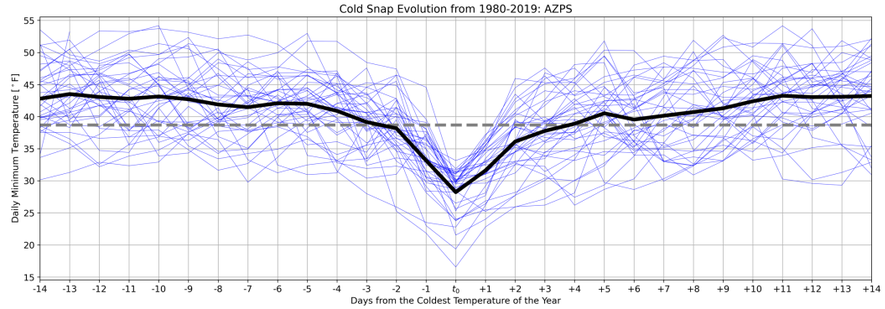


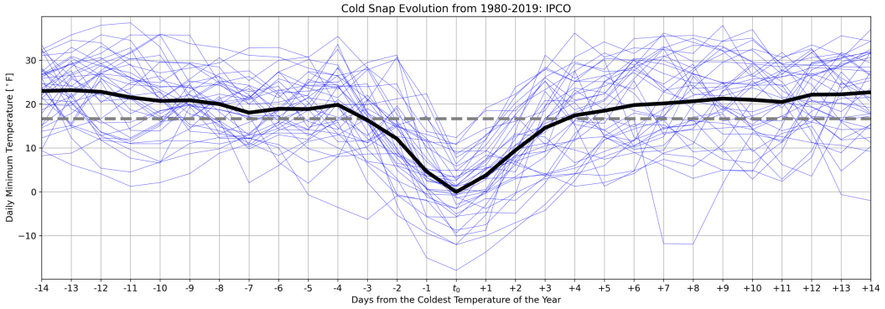












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10th Percentile of Heat Waves and Cold Snaps from 1980-2019

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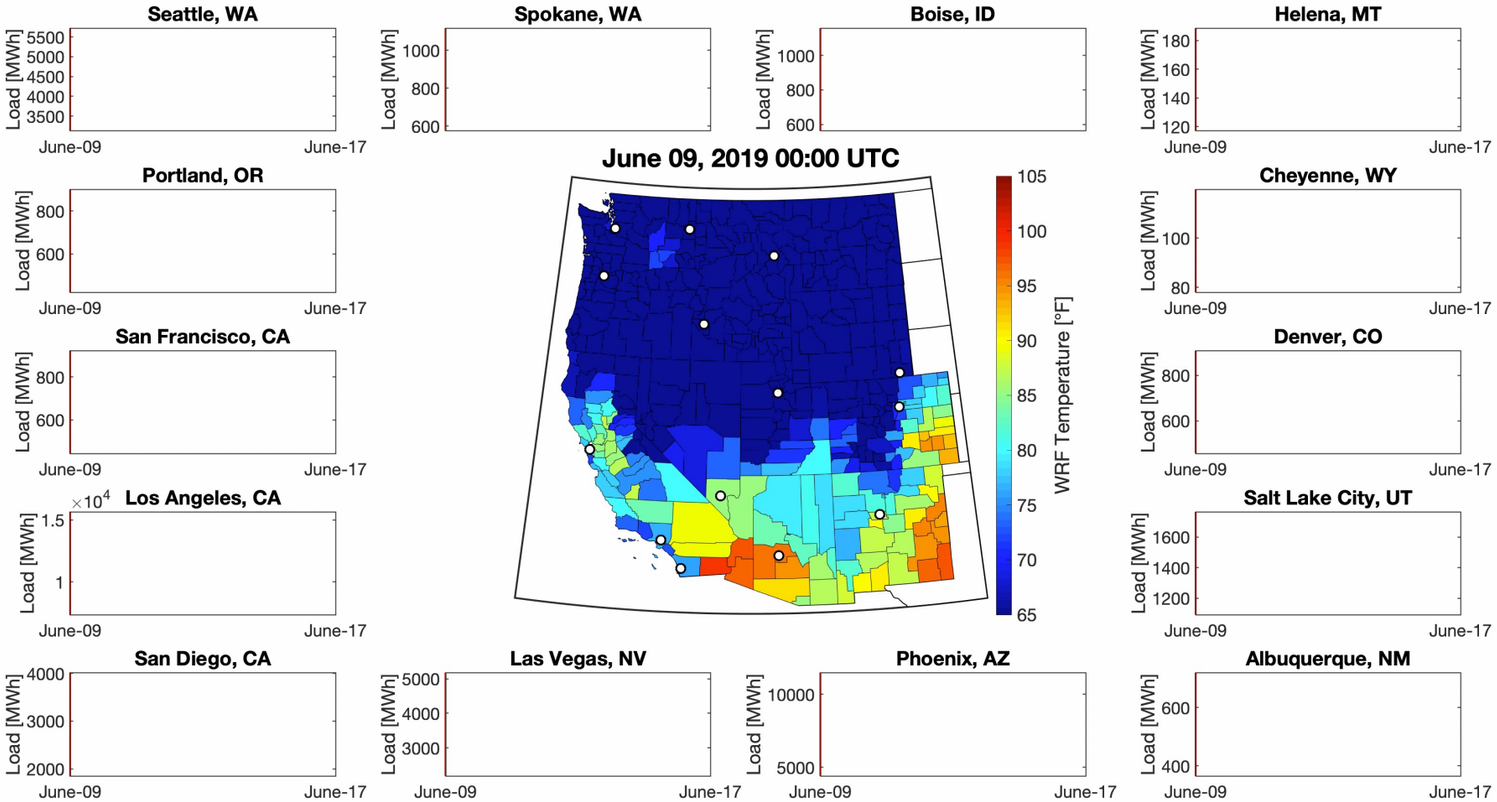
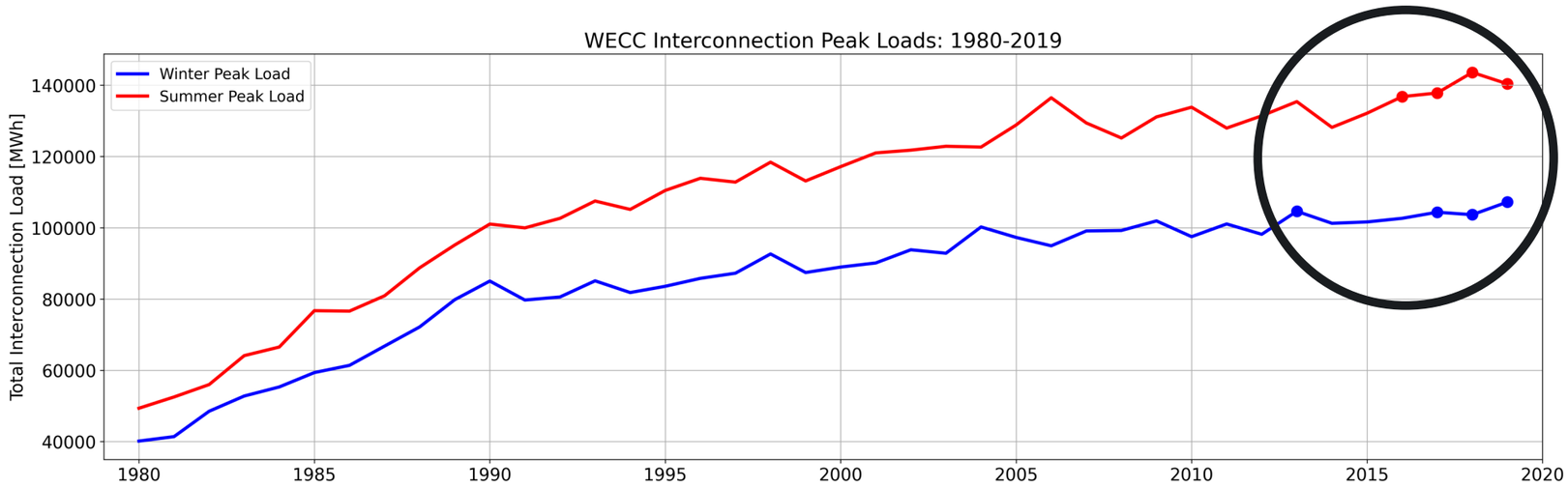
Total ELectricity Loads (TELL) Model

- Projects the evolution of hourly electricity demand in response to changes in weather and climate
- Based on a series of machine learning models trained on historical (2015-2019) loads and meteorology
- Projections are scaled to match GCAM-USA's state-level, annual loads that account for energy policy, population and GDP, building technology, and fuel price changes
- **Output is hourly projections of electricity demand at the county-, state-, and BA-scale that are conceptually and quantitatively consistent with one another**

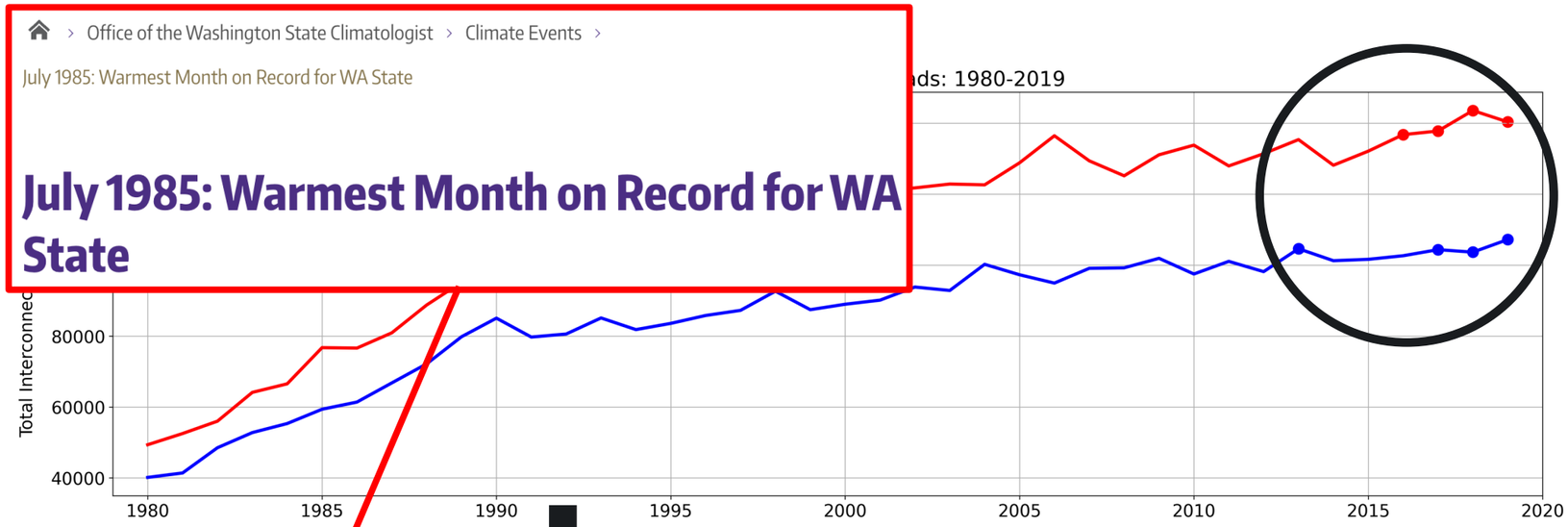


Historical Interconnection Loads

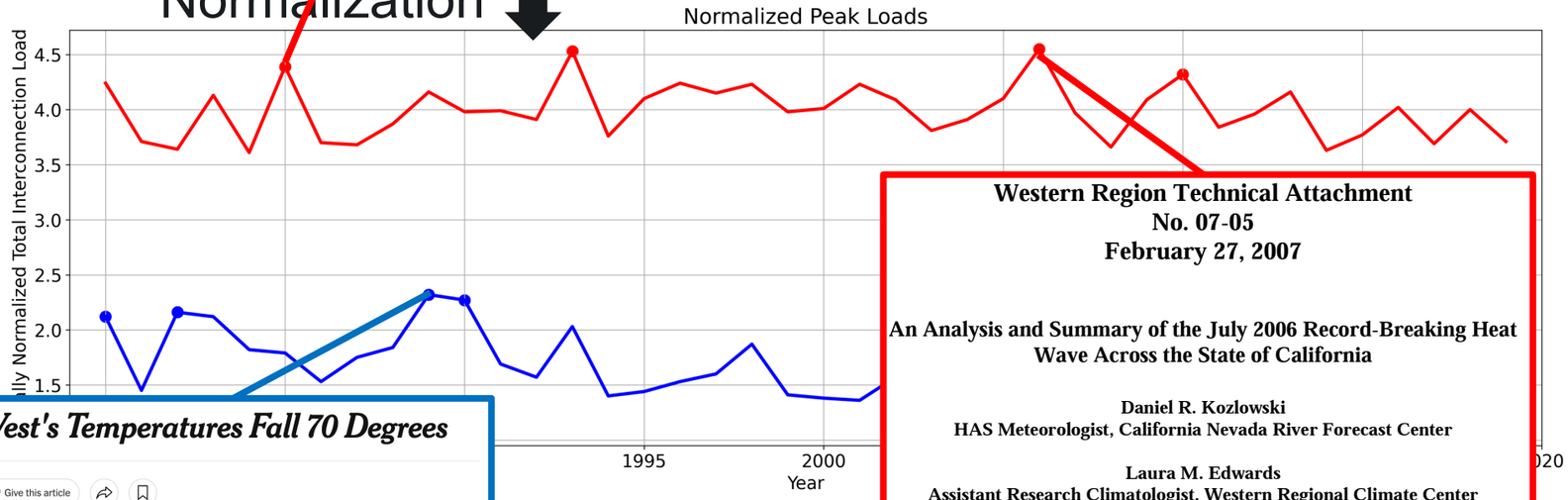


- Historical weather ➡ TELL ➡ historical loads
- Sum across BAs in the WECC to get an hourly total load time series for the WECC from 1980-2019
- Identify peak summer (JJA) and winter (DJF) load events for each year
- **Normalization allows us to explore historical events that were impactful even if their absolute loads wouldn't be considered extreme now**

Historical Interconnection Loads



Normalization




West's Temperatures Fall 70 Degrees

Give this article

By The Associated Press

Feb. 2, 1989

Western Region Technical Attachment
No. 07-05
February 27, 2007

An Analysis and Summary of the July 2006 Record-Breaking Heat Wave Across the State of California

Daniel R. Kozlowski
HAS Meteorologist, California Nevada River Forecast Center

Laura M. Edwards
Assistant Research Climatologist, Western Regional Climate Center

- Historical weather ➡ TELL ➡ historical loads
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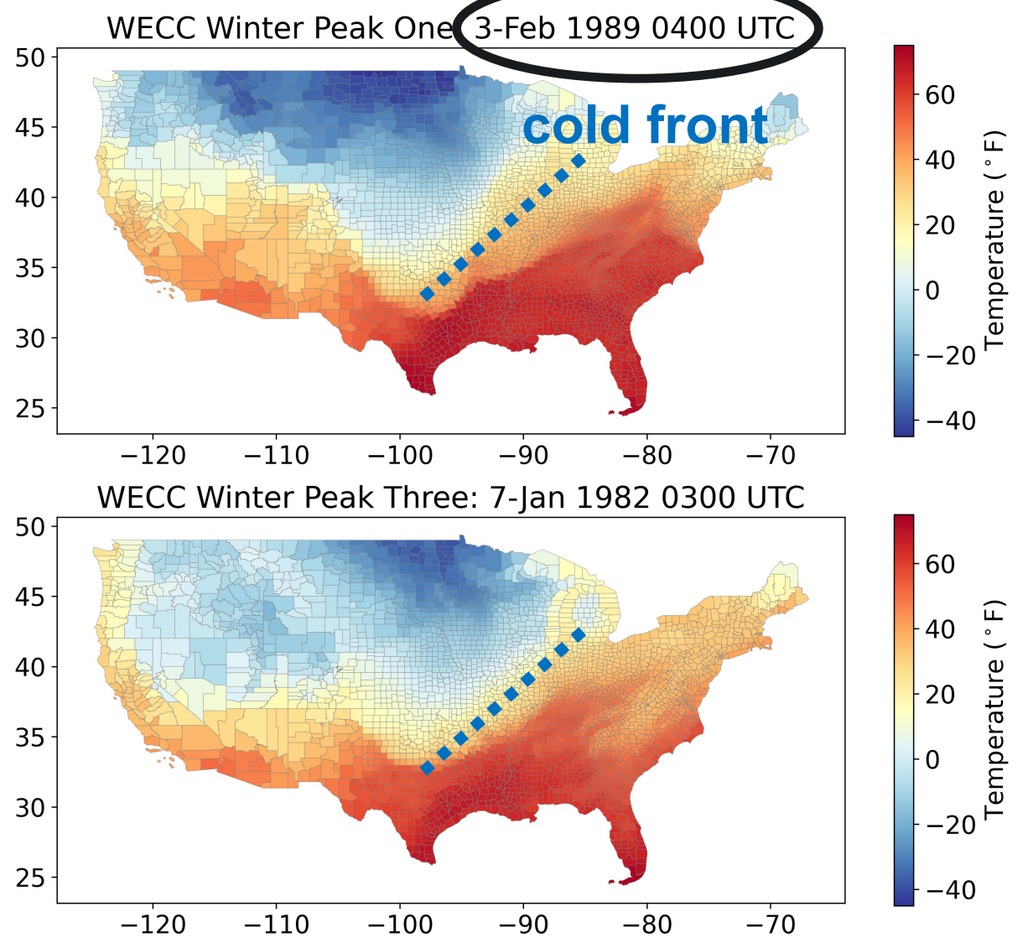
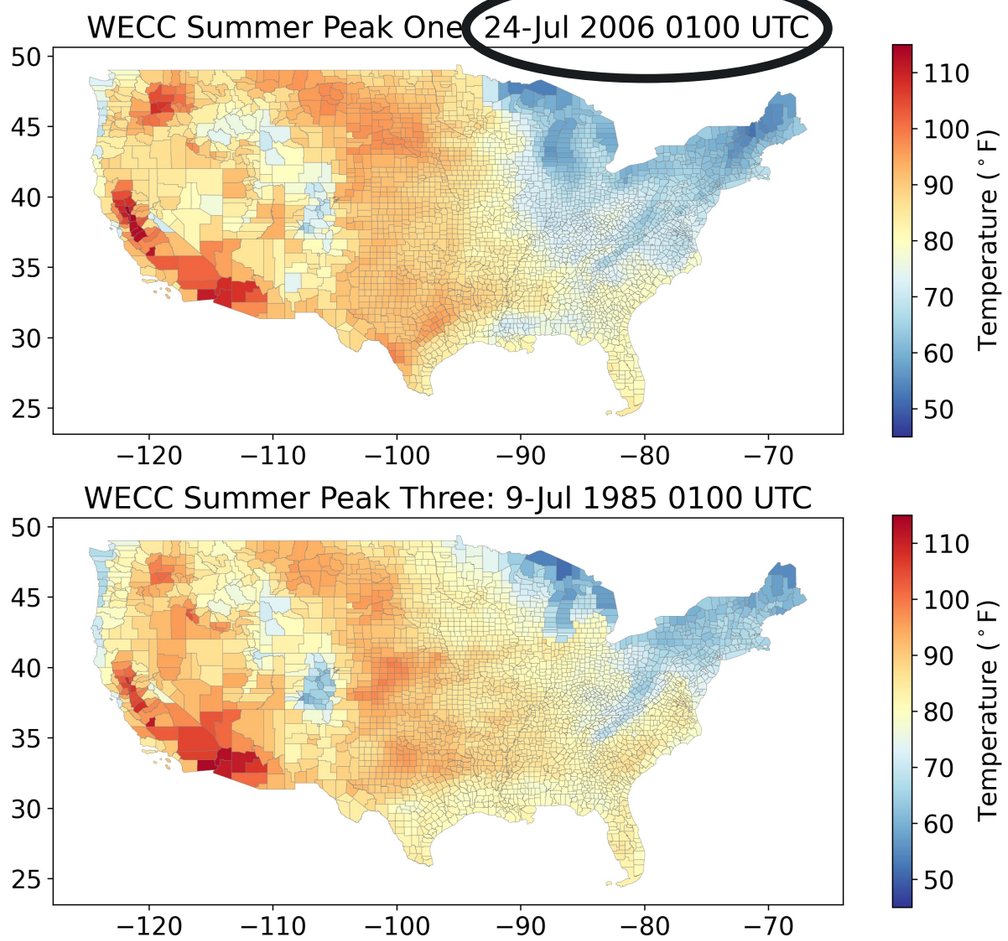
Four Highest Historical Winter Loads



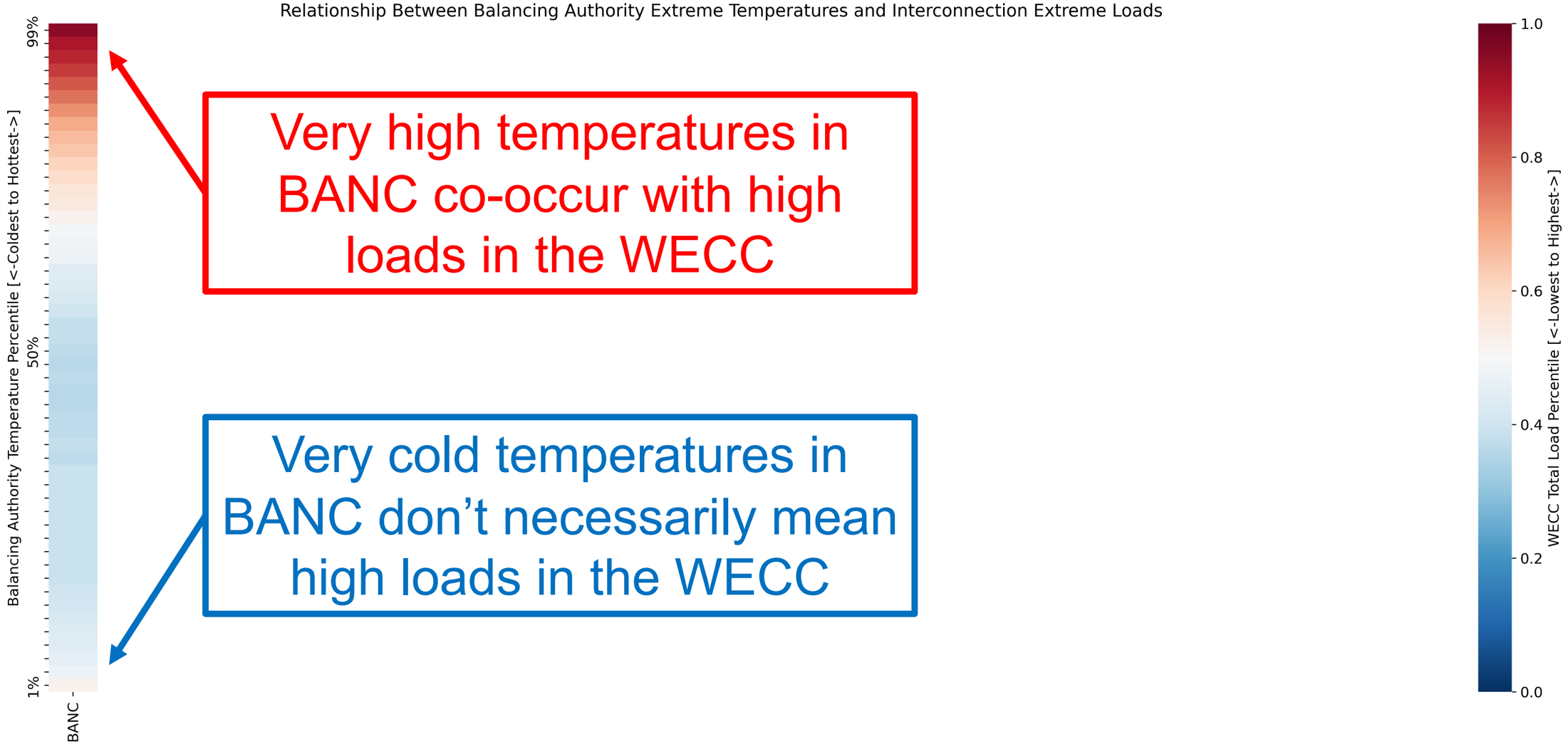
- Cold snaps tend to be focused on the PNW and extend eastward into the Dakotas
- Temperatures during extreme cold snaps tend to be moderate in the SW and California

Four Highest Historical Summer Loads



- Heat waves are spatially broader
- Hottest in the SW, but extreme heat expands from the PNW through the midwest and Texas

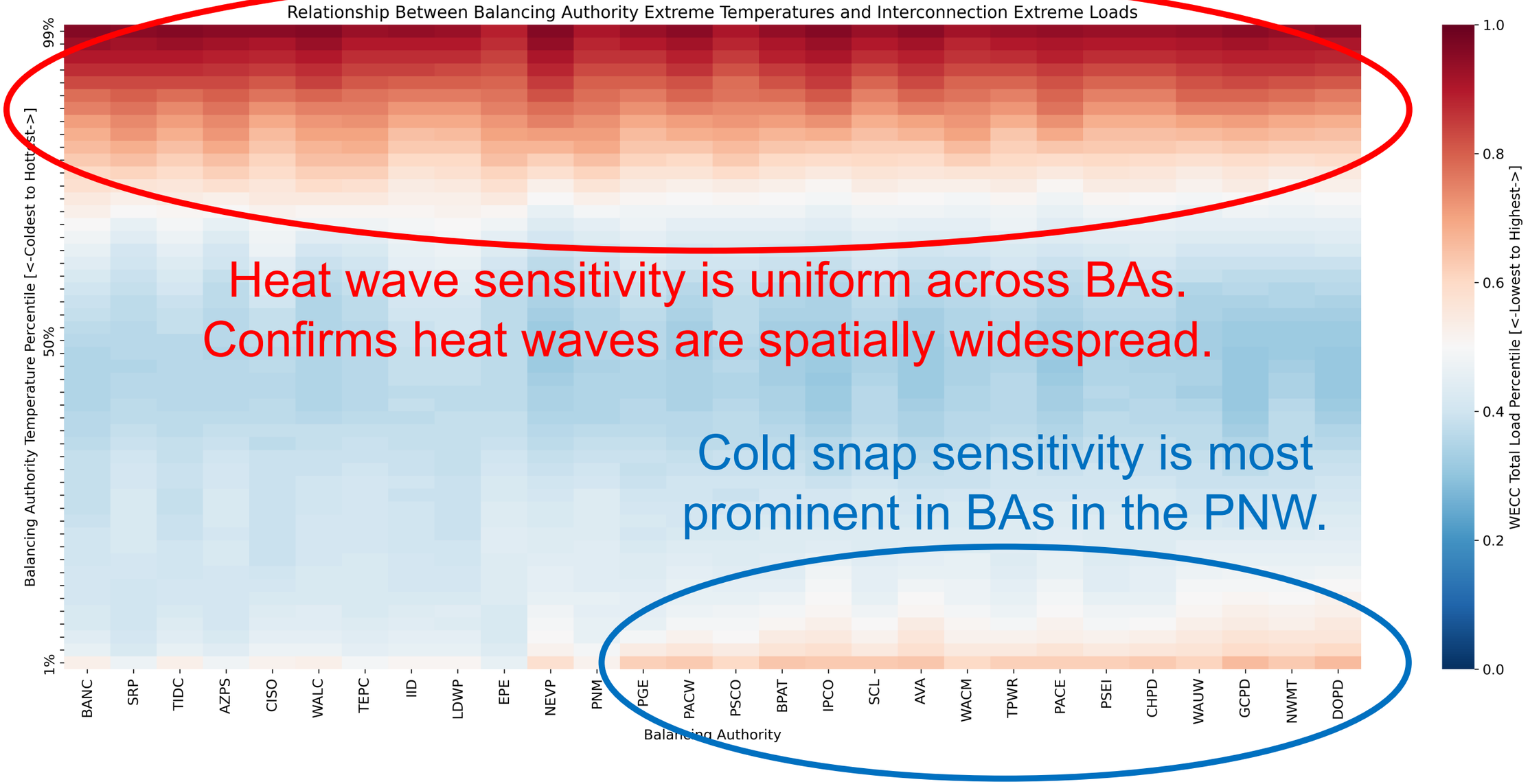
Are the Four Cases Representative?



Very high temperatures in BANC co-occur with high loads in the WECC

Very cold temperatures in BANC don't necessarily mean high loads in the WECC

Are the Four Cases Representative?



Heat wave sensitivity is uniform across BAs.
Confirms heat waves are spatially widespread.

Cold snap sensitivity is most prominent in BAs in the PNW.

Findings

- Heat waves typically last about 6-7 days with a symmetric pattern of temperature increases and decreases about the peak day. The most impactful heatwaves, from a load perspective, are spatially widespread over the WECC. The four worst heat wave events happened in July and early August as opposed to the end of the summer (when hydropower is at its annual minimum).

- Cold snaps in the WECC also last 5-7 days. The cold snaps might need to be selected based on their impact on the northern BAs. Because they are associated with strong cold frontal passages it is somewhat more challenging to select a representative cold snap. The four worst cold snaps from the past 40 years happened in December and January (when reservoirs are typically at their lowest point).

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Availability of Renewables During Climate Extremes

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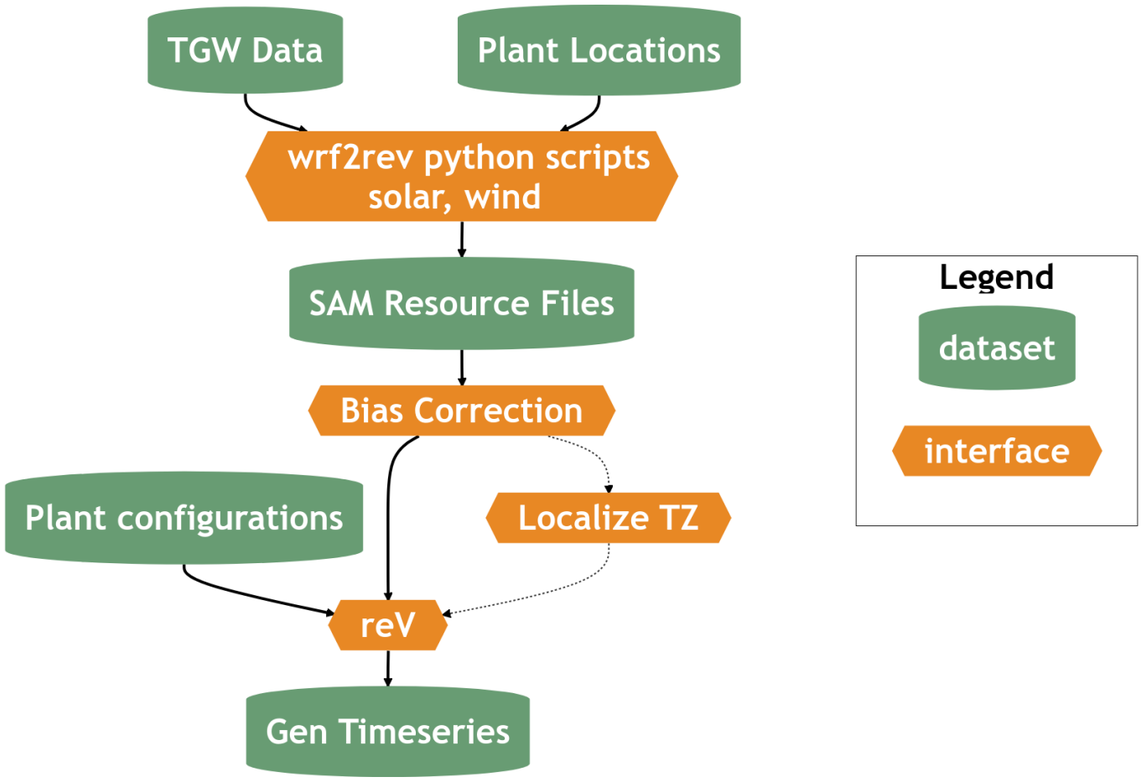
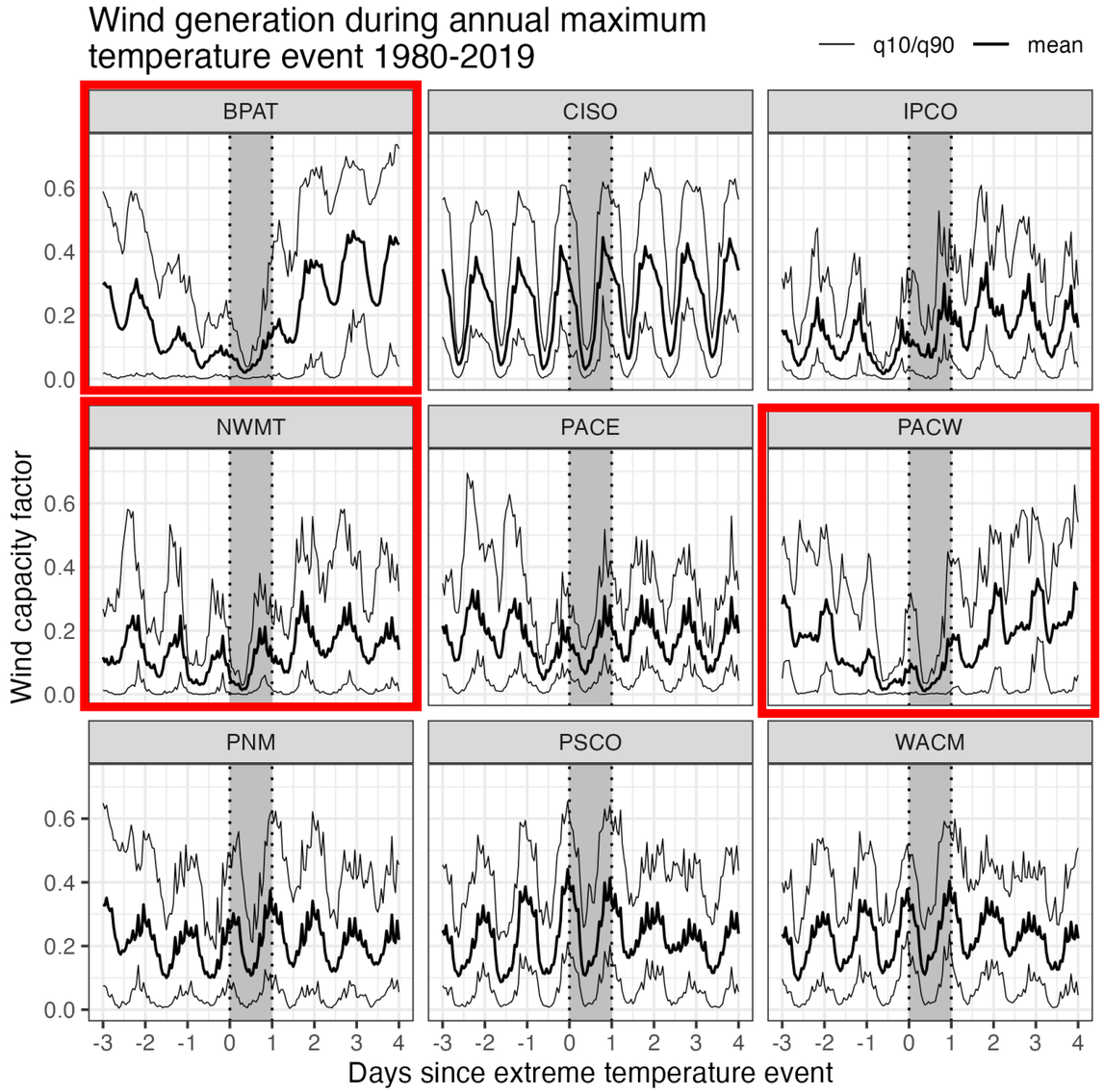
Wind and Solar Generation Timeseries



- PNNL's climate data are processed into wind and solar model input files
- Bias correction is performed on the solar data
- Plant configurations are developed from EIA 860 database for 2021
- The NREL reV model is used to produce generation timeseries for the entire historical period (1980-2019)
- Solar and wind timeseries are aggregated by BA, only BAs with at least 5 wind and solar plants are included

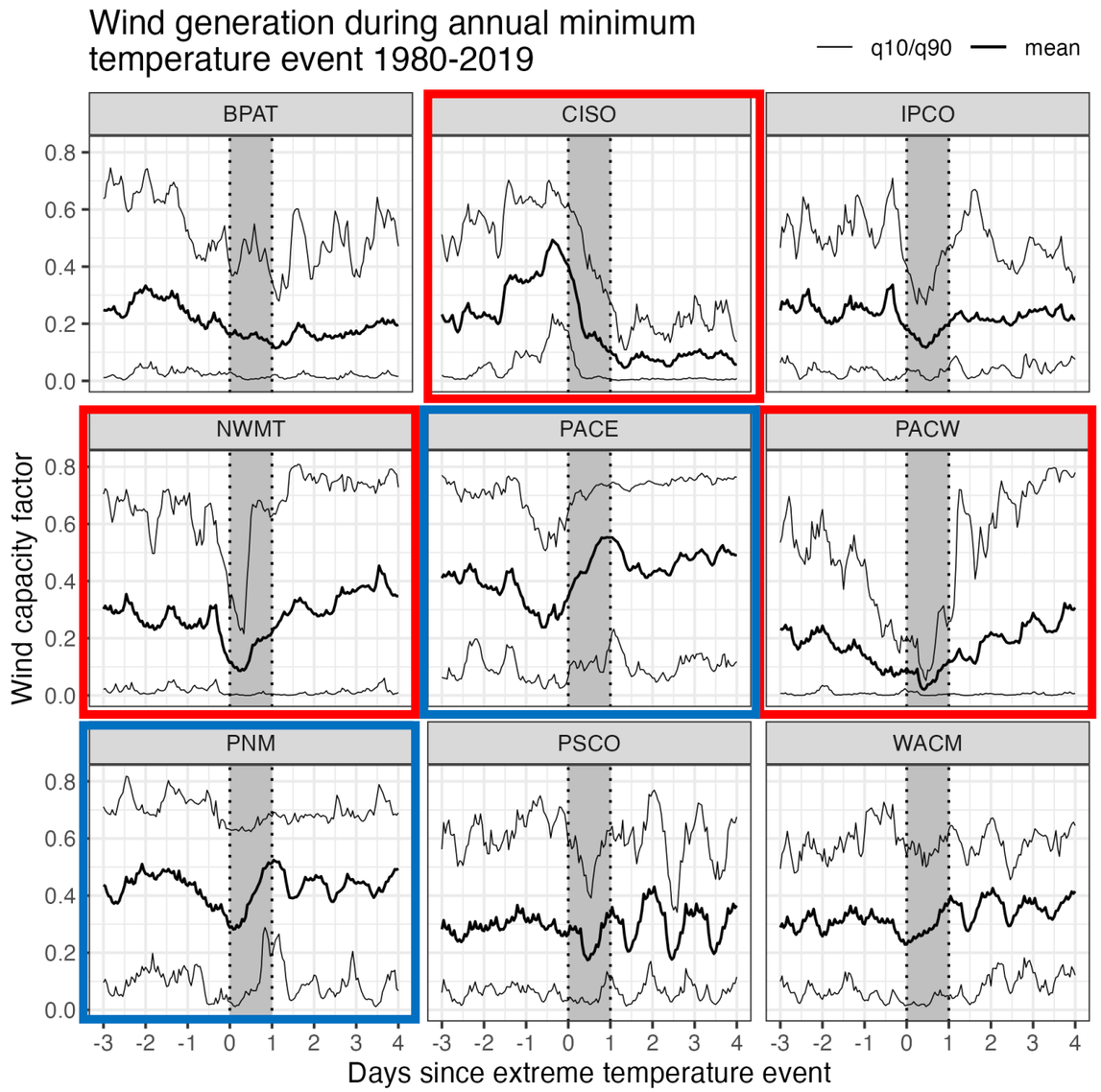
Wind Generation During Heat Waves



- BAs in the PNW show notable suppression of wind during heat wave events (e.g., BPAT, PACW, and NWMT)

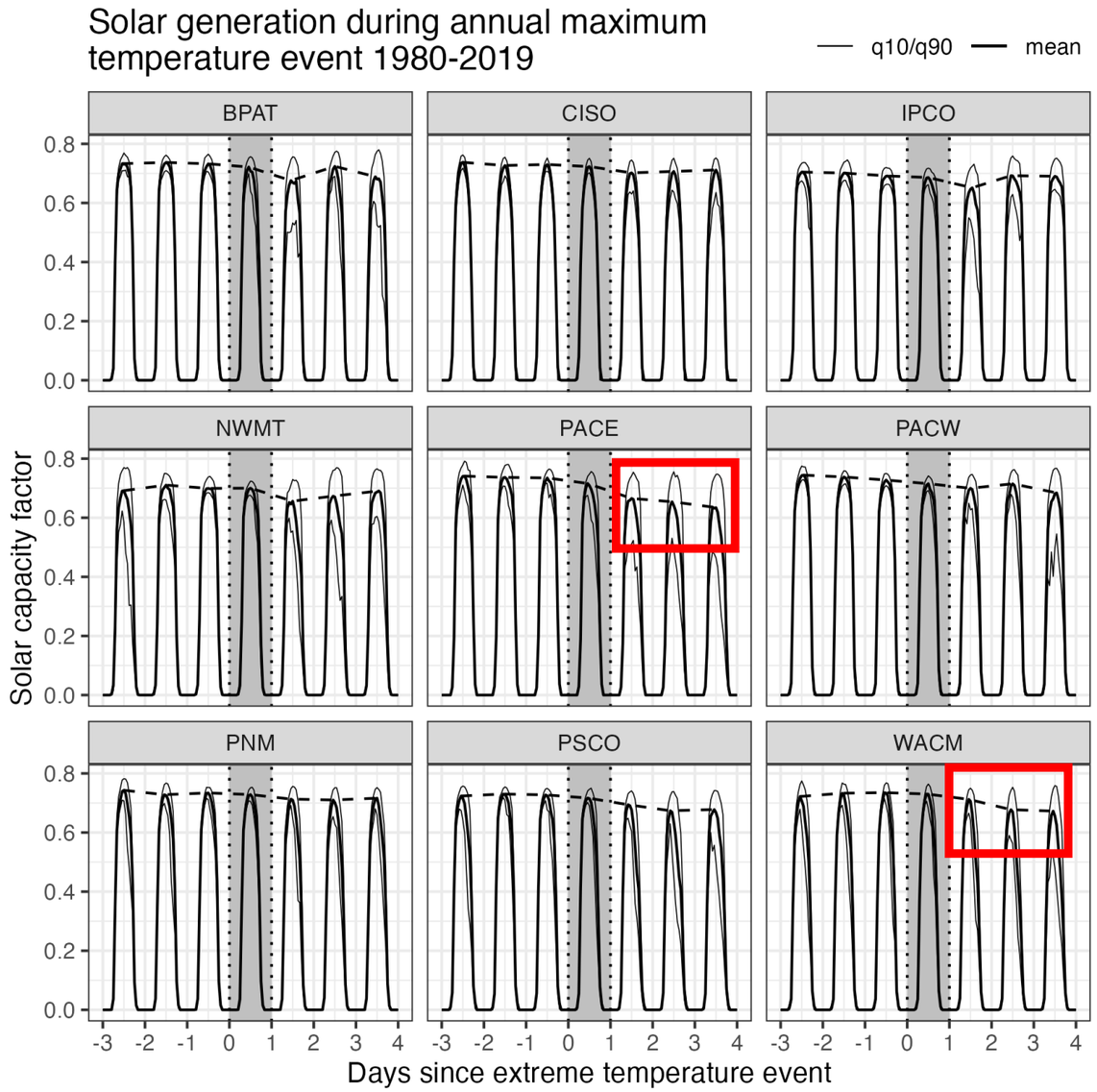
- Normal wind response from other WECC BAs during heat waves

Wind Generation During Cold Snaps



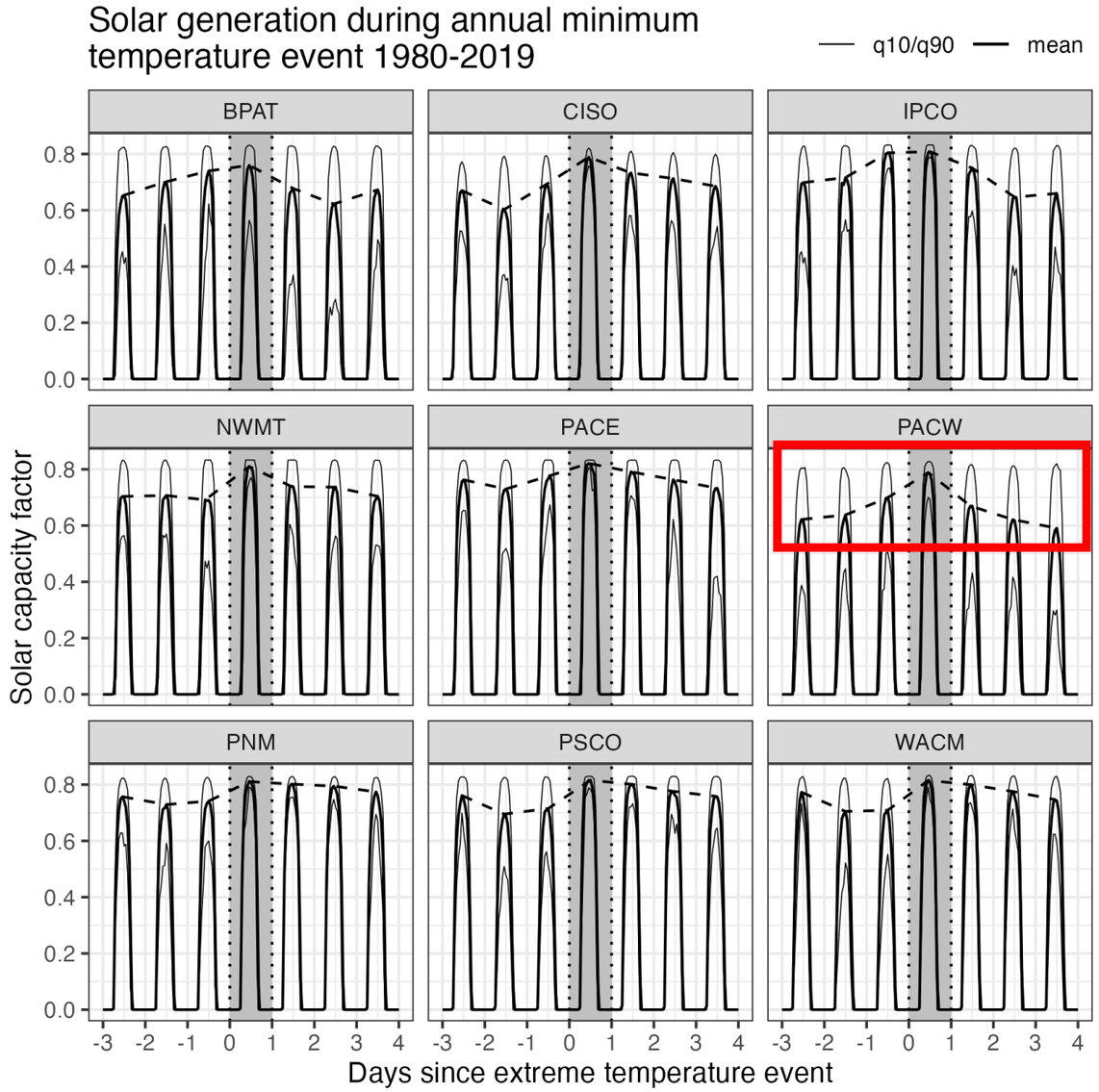
- BA scale wind response during cold events is highly regional
- Wind generation drops off notably in some BAs (e.g., CISO, PACW, NWMT) before and during cold snaps
- Wind generation increases notably in other BAs (e.g., PACE and PNM) on extreme cold days
- Other BA (e.g., BPAT and IPCO) have muted wind response during cold snaps

Solar Generation During Heat Waves



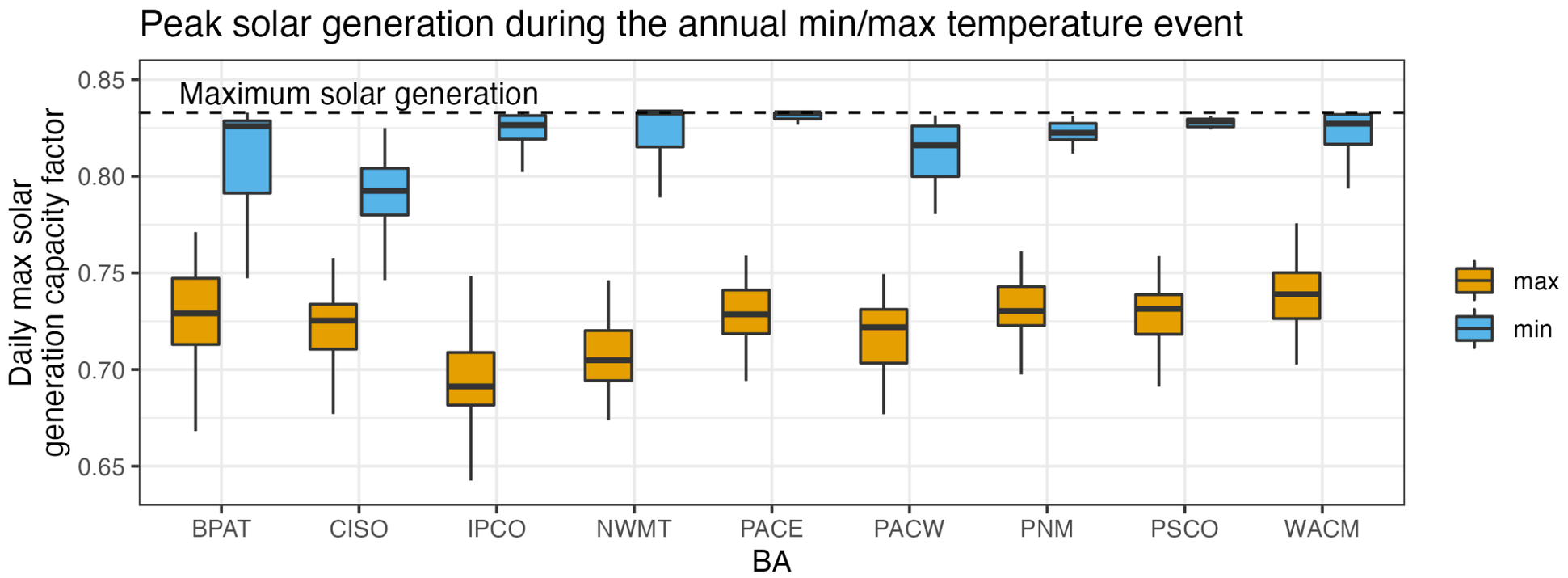
- Peak solar production is largely the same before, during, and after heat waves
- Slight tendency for lower peak production after heat waves in some BAs
- Lower overall production due to panel derating

Solar Generation During Cold Snaps



- Solar generation tends be lower before and after cold snaps
- High solar production on the coldest days
- High overall production due to less panel derating

Peak Solar Generation



- Peak generation during cold snaps is near panel maximum (minus losses) due to limited temperature derating and lack of clouds
- Peak generation during heat waves is reduced due to temperature derating and possibly other meteorological factors (i.e., clouds, haze, and smoke)

Points for Open Discussion

Same events for both 10-year and 20-years out:

	Heat Waves	Cold Snaps
Number of events	Can limit studies to 1-2 events given the typical widespread nature: - A recent one based on data? - A more impactful one based on today's infrastructure and more extreme historical climate?	Possibly consider a couple events: - More attenuated differences between observed and simulated - Stick to observed?
Compounded impact on renewables	- Typically, low wind in the PNW during a heat wave and derated solar – part of representative scenarios and coincident load-wind-solar datasets - If need be, select an event with dropping solar right after the heat wave	- Help select cold snap events compounded with low wind
Other discussion		

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