ERO Enterprise Process for TPL-008-1 Benchmark Weather Event Development and Maintenance

Standards Development and Engineering Process Document
December 2024

Background

This Electric Reliability Organization (ERO) Enterprise Process for TPL-008-1[1] Benchmark Weather Event Development and Maintenance addresses how ERO Enterprise staff will develop and maintain a library of benchmark weather events (herein as the Weather Event Library) to be used by Planning Coordinators and Transmission Planners for TPL-008-1 studies. Per Requirement R2 of TPL-008-1 and consistent with directives outlined in FERC Order No. 896[2], Planning Coordinators and Transmission Planners will have benchmark temperature events available, via the Weather Event Library to select from, when developing their benchmark planning cases.

Purpose

The purpose of this process document is to formalize a repeatable approach to develop and maintain the Weather Event Library. While both the TPL-008-1 study requirements and this process are in the initial stages of development, it is essential that industry is informed of this process and how it will be designed and implemented, following the completion of NERC Project 2023-07. This process document outlines an initial set of process objectives and approach, but is not considered to be complete at this time. This document will be revised, as needed, throughout the development of NERC Project 2023-07 and in future updates of the benchmark temperature events.

Document Maintenance

NERC will maintain this document to ensure it is consistent with acceptable and publicly available practices. This document will be reviewed as it is implemented. Updates will be made by NERC Standards Development and Engineering, as needed, to reflect lessons learned as the process matures. Any substantive changes to this process, supplemental/attached criteria, or other guidance to be used by NERC in developing additional benchmark events, archiving/removing benchmark events, or other modifications to the Weather Event Library, will be reviewed in consultation with NERC Legal, NERC Compliance Assurance, Zone Entity staff, and FERC. Approved substantive revisions to this document will be detailed in the Appendix and broadly communicated to industry.

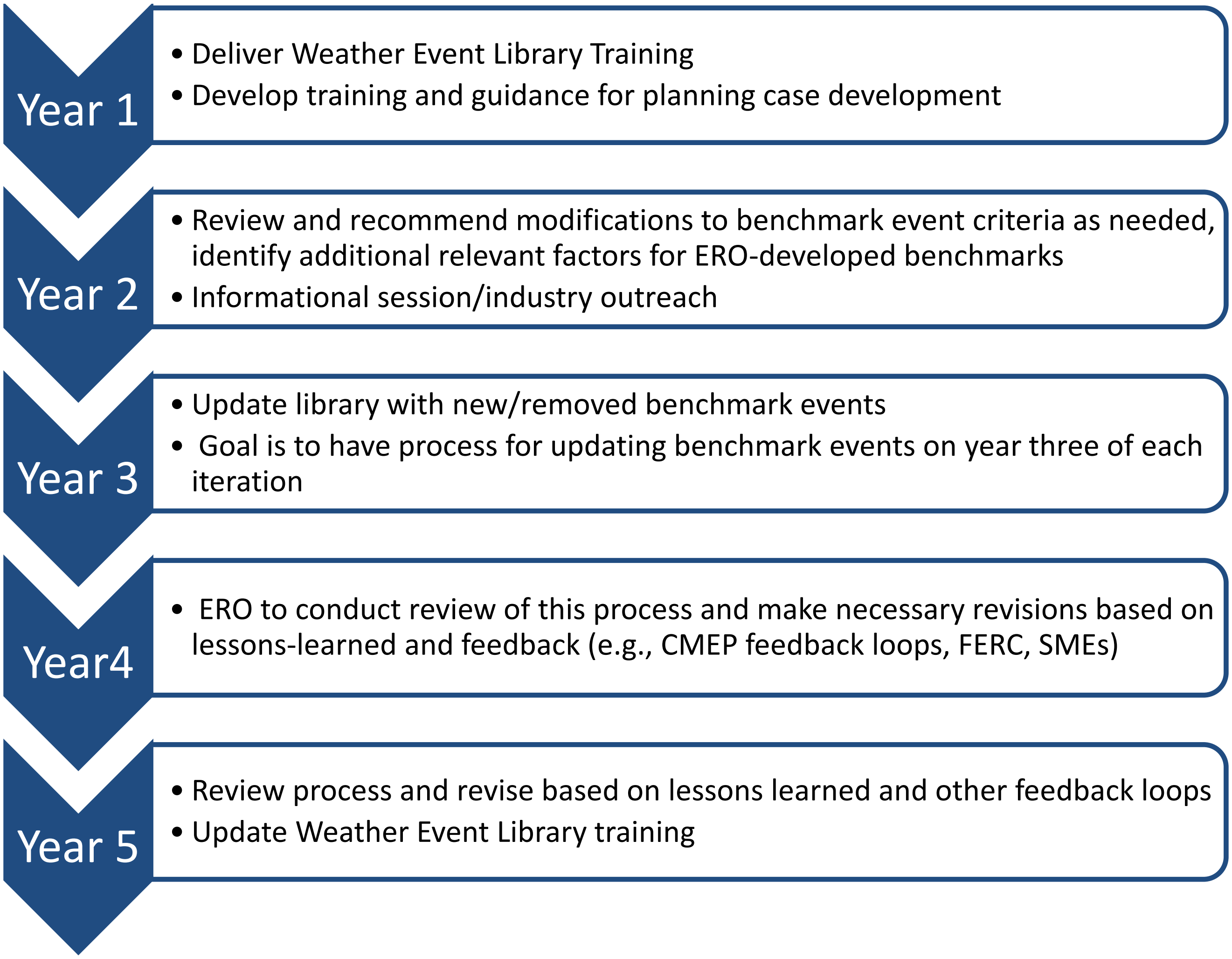
[1] *Link pending final approval of TPL-008-1*
[2] FERC Docket No. RM22-10-000; Order No. 896; https://www.ferc.gov/media/e-1-rm22-10-000; June 15, 2023

Process Overview

The following is a five-year iterative process coinciding with Planning Coordinator and Transmission Planner implementation of TPL-008-1. As TPL-008-1 and associated benchmark event(s) will be submitted to FERC in December 2024, the first iteration of this process will cover five years.

- December 2024
  - Weather Event Library developed and ready to go live for industry.
  - Benchmark Events, for the first five-years required per the TPL-008-1 Reliability Standard, completed and uploaded to the Weather Event Library.
- Year One:
  - ERO to provide Weather Event Library training.
  - ERO to engage with industry subject matter experts (SMEs), Planning Coordinators, research labs, and trade organizations, and NERC technical committees on additional and updated criteria for developing benchmark events.
- Year Two:
  - ERO to initiate review of benchmark event criteria, identify any changes needed to the minimum TPL-008 Requirement R2 criteria for consideration through the standard development process, identify consideration of additional relevant factors/analysis that may be included in future ERO-developed benchmark events, and incorporate feedback from year one.
  - ERO to deliver a webinar and industry outreach.
- Year Three:
  - ERO to develop new benchmark events[3] based on updated temperature data, with consideration to any additional relevant factors that are identified.
  - ERO to update the Weather Event Library with updated benchmark events.
- Year Four:
  - ERO will engage with industry subject matter experts (SMEs), Planning Coordinators, research labs, and trade organizations, and NERC technical committees on additional future information as needed.
- Year Five:
  - ERO to conduct review of this process and make necessary revisions based on lessons-learned and feedback (e.g., CMEP feedback loops, FERC, SMEs)
  - ERO to provide training on benchmark event process and changes to the TPL-008-1 Benchmark Temperature Events Library[4].

[3] Note: This is for the second iteration of benchmark events being developed.
[4] Link to TPL-008-1 Benchmark Temperature Events Library:
https://www.nerc.com/pa/Stand/Project202307ModtoTPL00151TransSystPlanPerfReqExWe/TPL-008-1_Events.pdf



Background for Initial TPL-008 R2 Criteria, Attachment 1 Planning Zones, and the Initial ERO TPL-008-1 Benchmark Temperature

Scoping

While the development of the extreme weather event library was intended to be comprehensive, it was not exhaustive. Instead, this initial assessment is a part of a multi-year effort by NERC and industry to develop a robust, North American weather dataset and detailed process for extreme weather events. In the interim, this library of extreme heat and cold events has notable considerations:

- Only extreme heat and cold temperature events were evaluated. The analysis did not assess other weather events such as hydrologic droughts, wind and solar droughts, wildfires, hurricanes, or other extreme weather events that could jeopardize grid reliability.
- Only historical meteorological data was considered. The analysis did not incorporate climate projections or future weather patterns.

- The analysis identified extreme events over a 43-year historical record and did not give higher priority to recent events
- The study is limited in identifying extreme events, not validating or explaining meteorological drivers of that event
- The analysis relied on historical reanalysis and *modeled* weather data, rather than historical observed data for the United States (A smaller observed dataset was used for Canada).

Data Sources

A Pacific Northwest National Laboratory (PNNL) weather dataset[5], used in this study, consists of 43 years (1980-2022) of historical hourly meteorology and roughly 80 years (2020-2099) of projected hourly meteorology. Hourly observations were dynamically downscaled from historical reanalysis of ERA5 data into higher temporal and spatial resolutions using the Weather Research and Forecasting Model (WRF). The model resolution consisted of 12km^2 areas that were spatially-averaged by county and then population-weighted to 54 Balancing Authorities (BAs) in the conterminous United States. The variables included in the final BA weather data are listed in Table 1. While additional parameters like humidity, solar irradiance, and wind speed are available in the dataset, the identification of extreme weather events in this study was solely determined by the temperature value.

Table 1: Weather Variables in PNNL Dataset

Variable	Name	Description	Units
Time	Time_UTC	Hour in Coordinated Universal Time	-
Temperature	T2	2-m temperature	K
Specific Humidity	Q2	2-m water vapor mixing ratio	kg kg^{-1}
Shortwave Radiation	SWDOWN	Downwelling shortwave radiative flux at the surface	W m^{-2}
Longwave Radiation	GLW	Downwelling longwave radiative flux at the surface	W m^{-2}
Wind Speed	WSPD	10-m wind speed (derived from U10 and V10)	m s^{-1}

The PNNL dataset and contributing model were chosen for this study due to the consistency, breadth and granularity of the weather data. The availability of weather data at the BA-level coincides with topology standards in power-system coordination in North America. Temperature observation methods can differ zonally, so a standardized weather model, such as one in the PNNL dataset, offers unparallelled data consistency across large geographical areas.

Topology

The zone topology is a function of Balancing Authority jurisdiction and general knowledge of zonal weather patterns. The goal of the topology was to split the North American System into several distinct zones that have similar electric power system properties (i.e. balancing authority and interconnections) and similar weather or climatological patterns. In the United States, Balancing Authorities with large areas of

[5] Burleyson, C., Thurber, T., & Vernon, C. (2023). Projections of Hourly Meteorology by Balancing Authority Based on the IM3/HyperFACETS Thermodynamic Global Warming (TGW) Simulations (v1.0.0) [Data set]. MSD-LIVE Data Repository. https://doi.org/10.57931/1960530

jurisdiction, exclusively ISOs and RTOs, are assigned their own weather zone. In geographical areas comprised of multiple balancing authorities, generalized weather zones are created to best represent zonal weather patterns.

Table 2: Balancing Authority to Weather Zone Mappings

Zone	Balancing Authorities
Midwest North and South	MISO
New England	ISONE
Central US North and South	SPP
Texas	ERCOT
New York	NYISO
Central Atlantic	PJM
California	5 balancing authorities
Pacific Northwest	10 balancing authorities
Rocky Mountain	3 balancing authorities
Great Basin	4 balancing authorities
Southwest	6 balancing authorities
Southeast	7 balancing authorities
Florida	9 balancing authorities

In addition to the 15 weather zones representing the United States, five weather zones were developed to represent Eastern, Central, and Western Canada. The PNNL weather dataset does not contain data for Canada, so this study compiled observed weather data from weather stations in the lower Canadian Provinces. The 20 weather zones best represent the area of study and complement the granularity of available data. A graphical representation of the final weather zones is shown in Figure 1.

Table 3: Canadian Weather Stations to Weather Zone Mappings.

<table>
<tr><th>Weather Zones</th><th>Province</th><th>Weather Stations</th></tr>
<tr><td rowspan="4">Eastern Canada (Ontario, Quebec, and Maritimes)</td><td>Ontario</td><td>1 weather station</td></tr>
<tr><td>Quebec</td><td>3 weather stations</td></tr>
<tr><td>New Brunswick</td><td>1 weather station</td></tr>
<tr><td>Nova Scotia</td><td>1 weather station</td></tr>
<tr><td rowspan="2">Central Canada</td><td>Saskatchewan</td><td>2 weather stations</td></tr>
<tr><td>Manitoba</td><td>1 weather station</td></tr>
<tr><td rowspan="2">Western Canada</td><td>British Columbia</td><td>2 weather stations</td></tr>
<tr><td>Alberta</td><td>2 weather stations</td></tr>
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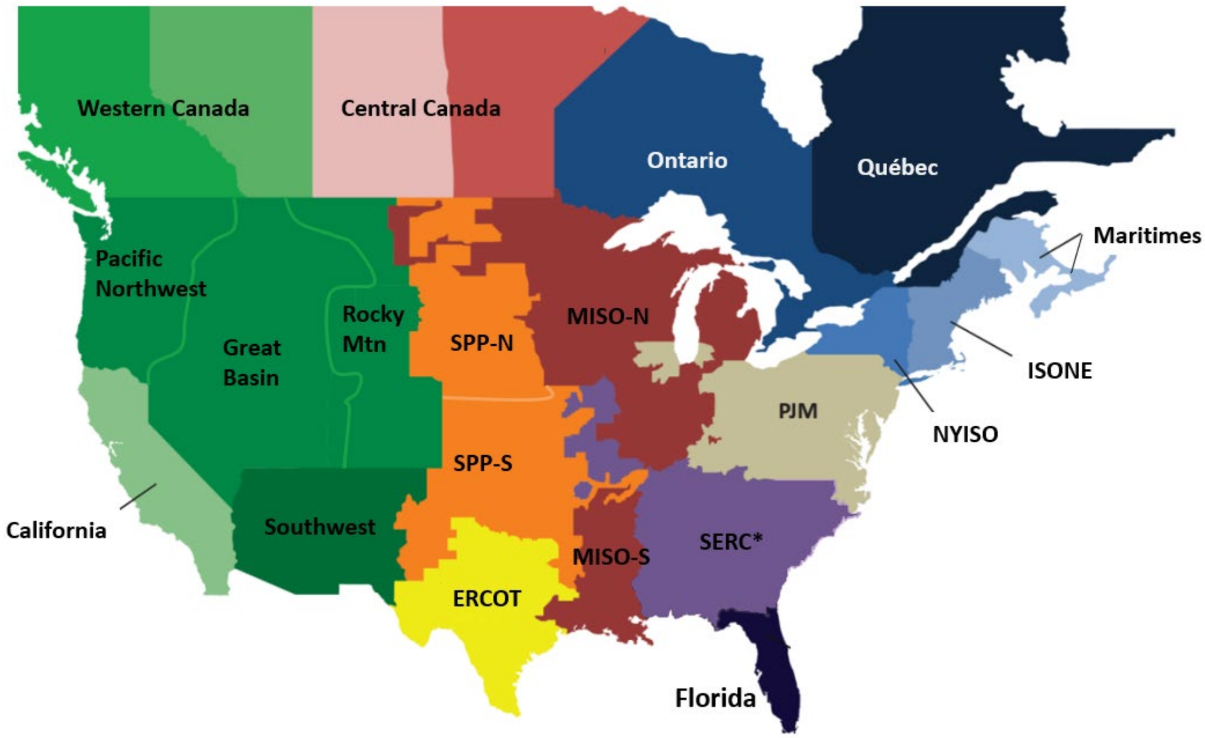
Figure 1: North American Weather Zones for Extreme Weather Events



Event Selection Process

Extreme weather events are defined in this study as extremely hot or cold multi-day events spanning across multiple weather zones. The process to select these extreme events used temperature as the sole defining variable, with emphasis placed on date ranges where multiple weather zones were experiencing historically hot or cold temperatures.

Aggregating balancing authority data to geographical weather zones

Following the topology detailed above, the hourly temperature observations from either the PNNL weather dataset or Canadian weather stations are assigned to weather zones. For each balancing area in the United States, the PNNL data is aggregated from a county-level basis up to the balancing authority based on the population in each county. The balancing authority temperature aggregation was therefore provided in the PNNL dataset.

Additional aggregations were required to develop an average minimum, average, and maximum temperature for zones with multiple balancing authorities in the Northwest, Southwest, and Southeast. In these weather zones, the hourly temperature of each balancing authority was weighted by the 2022 peak load value reported in the EIA Form-861 database. For the Canadian zones, weather station temperature observations were assigned to the nearest population center and weighted by 2021 Census population.

Calculating Three-Day Rolling Average Min/Max Temperatures

Rather than isolating single hours of extreme weather, the rolling 3-day average of minimum and maximum daily temperatures are chosen to represent prolonged periods of extreme weather. The three-day averaging period is centered on every day in the data set (January 1, 1980, to December 31, 2022) and identifies the average minimum and maximum temperature from the day before, day of, and day after. The output of this process develops a dataset of multi-day minimum and maximum temperatures to filter out individual days of extreme heat or cold under the assumption that the power system is more challenged by sustained periods of extreme heat or cold due to cumulative effects on increasing demand and generator outages.

Selecting and Ranking Extreme Weather Events by Severity

Once 3-day average temperatures were calculated for every day, the forty coldest minimum values and forty warmest maximum values were isolated and ranked for each zone, with rank 1 illustrating the most extreme event. To avoid overlap of events within the same period, any ranked weather events within one week of another would be removed in favor of the most extreme event. For example, if a zone's seventh- and tenth-most extreme event occur within a 7-day period, only the day with the seventh-most extreme event would remain in the event database. As a result, some zones may have a discontinuous ranked list given the removal of "duplicate" events.

A similar one-week overlap method was developed to group contemporaneous extreme weather events amongst weather zones. First, all event dates were expanded to have a one-week "overlap period" centered on each date. Then, beginning with the earliest event date, all events that share at least one day of their overlap periods with the selected event date's overlap period, will be grouped together. The final event date range will take the earliest and latest dates of all grouped event overlap periods.

The design of the distinct event date ranges encourages multiple weather zones to share extreme weather events over the course of a one- to two-week event period. To graphically represent the shared extreme events, all event ranges are listed with the affected zones' ranks in west-to-east order. A final shortlist of extreme weather events was developed across all zones. This list included the top one and two most extreme events, done separately for heat and cold periods. Events that included at least three zones experience a top five event simultaneous was also included. For example, if PJM, NYISO, and ISONE all experienced a top five extreme event, but it was not a top one or two event for any zone in isolation, the event was included in the final shortlist.

Results

The result tables show the filtered list of event date ranges with the event ranks for each affected zone; a lower rank represents a more extreme event and is shaded darker.

Cold Events

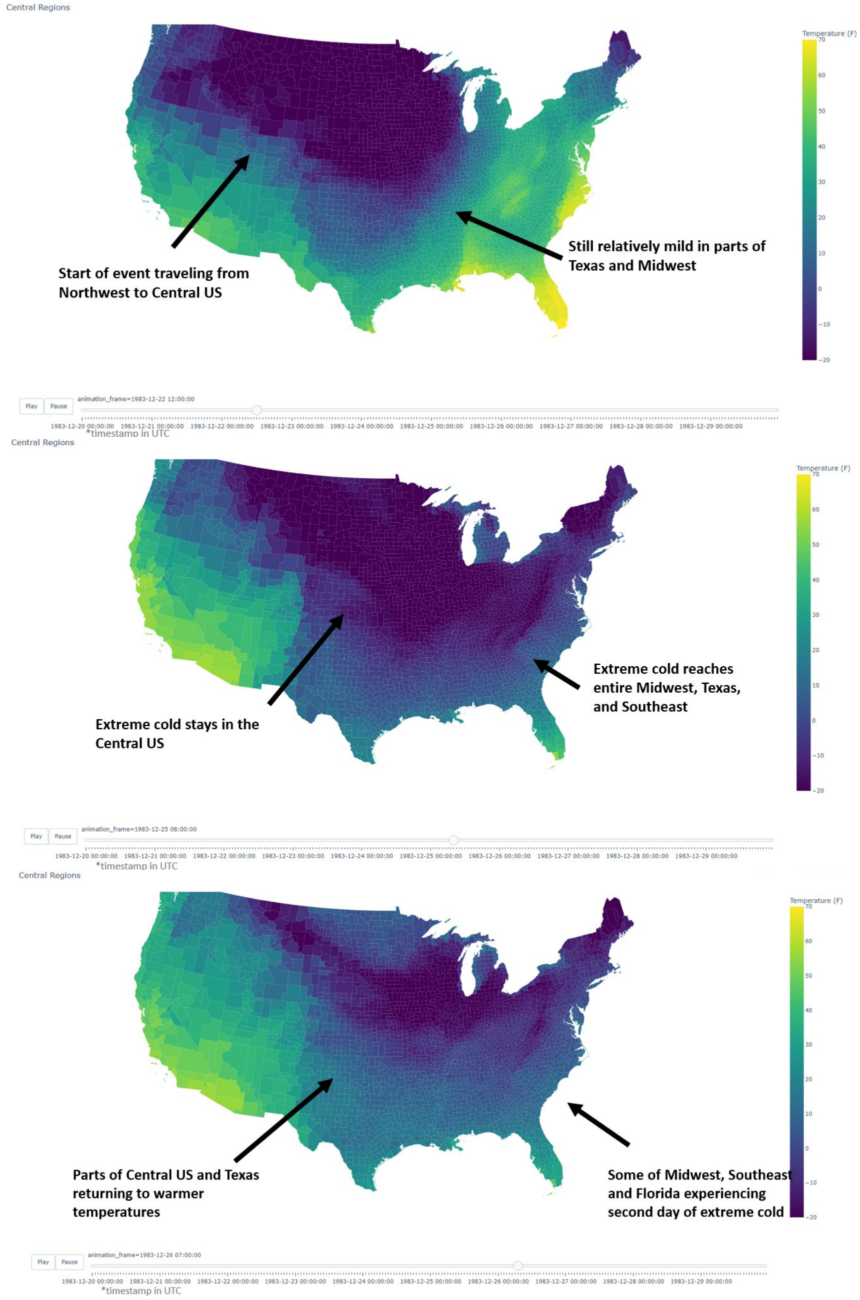
The cold events demonstrate more concentrated events among nearby zones, with the most extreme temperature event occurring December 20^{th} to December 29^{th}, 1983. The event uniquely spanned across the conterminous United States and yielded top ten coldest 3-day average minimum temperatures in 10 different weather zones.

Under these results, the following cold events are recommended for the TPL-008-1 Benchmark Temperature Event Library:

- 12/17/1990 – 1/2/1991 for the Western U.S. and Western part of Canada
  - 12/21 for Pacific NW
  - 12/22 for Rocky Mountain, Great Basin, California
  - 12/23 for Southwest
  - 12/29 for Western Canada
- 12/19/1989 – 12/27/1989 for Central and Southeast U.S. and Central part of Canada
  - 12/23 for Central Canada
  - 12/24 for Central US
  - 12/25 for Texas, ERCOT, Midwest, Southeast
  - 12/26 for Florida
- 1/13/1994 – 1/29/1994 for the Northeast U.S. and Canada
  - 1/16 for New England, Ontario, Quebec and Maritimes
  - 1/20 for Central Atlantic, New York

It is important to note that these weather events do not affect all zones simultaneously, but instead move across the continent in predictable patterns. This has important implications for power system operations and reliability as load and generator availability may be affected in different zones in different times. An example of this is from the 1983 event shown geographically in Figure 2. In this example, the worst case does not occur at the same time in each zone and ideally multiple time periods should be assessed by the planning coordinators.

Figure 2: Snippets of Animated Weather Event Temperature Map



Heat Events

The heat events used are more numerous and disparate from one another. In other words, while extreme cold events tend to affect large geographies simultaneously, heat events can be more localized. The unconcentrated nature of heat events makes selecting the most extreme event more ambiguous.

Under these results, the following heat events are recommended for the NERC TPL-008-1 Benchmark Temperature Event Library:

- 7/13/2006 – 7/26/2006 for the Western U.S. and Western part of Canada
  - 7/16 for Rocky Mountain, Great Basin
  - 7/22 for Western Canada, Pacific NW
  - 7/23 for California, Southwest
- 6/21/2012 – 7/9/2012 for Central and Southeast U.S. and Central part of Canada
  - 6/26 for Texas ERCOT
  - 6/28 for Central Canada, Central US
  - 6/30 for Southeast, Florida
  - 7/5 for Midwest
- 7/16/2021 – 7/25/2021 for the Northeast U.S. and Eastern part of Canada
  - 7/21 for Central Atlantic, Ontario, Quebec and Maritimes
  - 7/22 for New York, New England

Recommendations

The results of this study should inform planning coordinators of potential dates of when to study power system conditions under extreme weather scenarios. While the final selection of event date ranges aligns with historical records of extreme weather, a few recommendations and considerations should be made before proceeding with this study's results.

- Planning coordinators should assess the entire list of distinct events shown and determine which events were the most extreme for their jurisdiction along with neighboring areas.
- Modeled temperature data provides widespread consistency of weather data across many years and many zones. Observed temperature data can recognizably vary from modeled values due to the variety of observation methods at individual weather stations. The temperatures derived from the PNNL dataset for the extreme weather event selection can be provided, but actual temperature values used in planning scenarios may need to be derived from observed weather records for local consistency.
- While temperature is a strong indicator of extreme weather events, it is not the only indicator available in historical weather data sets. The inclusion of other weather variables such as humidity and wind speed could further quantify the severity of extreme weather events.
- Care should be taken when developing wind, solar, and generator de-rates or outage assumptions in the planning cases, using meteorological information to dispatch.
- Exceptions need to be accounted for – including HVDC and switchable units.

TPL-008-1 ERO Enterprise Benchmark Weather Event Development and Maintenance Process Document Version History			
Version	**Date**	**Owner**	**Change tracking**
1	TBD	Standards Staff	Initial Version