A Flexible Method for Identifying Electric Grid Extreme Temperature Events as Per NERC TPL-008

SeungJun Lee, Kseniia Zhgun, Rawand Badawi, Farnaz Safdarian, Thomas J. Overbye
Electrical and Computer Engineering
Texas A&M University, College Station, TX, USA
sl47745@tamu.edu, k_zhgun@tamu.edu, rawand_badawi@tamu.edu,
fsafdarian@tamu.edu, overbye@tamu.edu

Jamie D. Weber
PowerWorld Corporation
Champaign, IL, USA
weber@powerworld.com

***Abstract*—This paper presents a flexible method for determining sets of extreme temperature events for electric grid analysis. The paper is motivated by the new North American Electric Reliability Corporation (NERC) TPL-008-1 Reliability Standard (TPL8) titled "Transmission System Planning Requirements for Extreme Temperature Events." The paper's approach, called the Power Weather Outlier Method (PWOM) starts with hourly historical weather information going back to 1940. Then hourly weighted temperature averages are determined for different parts of large-scale electric grids with the weighting function allowing the inclusion of electric load and/or generation values. Finally, composite averages for various time periods are determined, including for the three-day period specified in TPL8. PWOM is demonstrated on three synthetic electric grids ranging in size from 2000 to 82,000 buses.**

***Index Terms*—electric grid, weather, extreme temperatures, NERC TPL-008, visualization**

I. Introduction

The operation of large-scale electric grids has always been dependent on the weather, with this dependence impacting the generation, load and transmission and distribution systems. However, particularly over the last several decades this dependence has grown in many locations with more weather-dependent renewable generation being deployed. At the same time, society's dependence on a reliable grid has grown as well. Hence there is a need for power system planners to more fully consider the impacts of extreme temperatures with their grid designs.

Specifically in the US, the US Federal Energy Regulatory Commission (FERC) issued Order 896 in June 2023 requiring that the North American Electric Reliability Corporation (NERC) develop new or modified reliability standards concerning transmission planning for extreme heat and cold weather events [1]. This Order notes that since 2011 the US has experienced at least seven major extreme temperature events, with one of these being Winter Storm Uri in February 2021, which severely impacted the Electric Reliability Council of Texas (ERCOT) grid [2].

As a result of the FERC's Order, NERC has recently developed a new Reliability Standard, TPL-008-1, "Transmission System Planning Requirements for Extreme Temperature Events" (TPL8). This standard has an effective date of April 1, 2026 and has eleven specific requirements (R1 to R11), with a phased implementation over four years from the effective date [3]. The first, R1 is for the NERC Planning Coordinators (PCs) to determine which entities are responsible for completing the remaining requirements. R2, which is the motivation for this paper and becomes mandatory in two years, is for each PC to identify the weather zone(s) to which they belong (see Figure 1) and to "identify one common extreme heat benchmark temperature event and one common extreme cold benchmark temperature event for each of its identified zone(s)." R3 to R6, which are also mandatory in two years, are to 1) implement a process for developing benchmark planning cases (R3), 2) use the R3 process to develop the cases and establish normal system conditions (R4), 3) develop steady state voltage limits and post-contingency voltage deviations (R5), and 4) define and document the criteria for the extreme temperature assessment (R6). Then R7 to R11, which are mandatory in four years, are to perform contingency studies and to develop mitigation plans.

The focus of this paper is to present a flexible method that could be used to help identify the extreme heat and cold outlier events in R2 and allows planners to go beyond the specific R2 requirements to identify as many extreme temperature scenarios as desired. The paper is organized as follows. The next section provides additional background information and introduces the paper's flexible method, denoted here as the Power Weather Outlier Method (PWOM). The third section then introduces the test electric grids used in the analysis, while the fourth section presents example results. The last section then provides a summary and presents some future directions. All the results and visualizations in the paper are done using PowerWorld Simulator Version 25 [4], which also contains an implementation of the paper's PWOM. All of the test electric grids and the associated weather data is available for download from the electric grid data repository at [5] and further described in [6].

II. Background and Method

While planning electric grids has always been challenging and weather dependent, over the last decade or two it has become even more difficult. Certainly, a key reason for this in many locations is the decoupling between transmission planning and generation development, with the latter often done by third parties and often involving large amounts of inherently weather dependent renewable generation. At the same time there is a growing focus on electric grid resiliency, to ensure the grid can adequately respond to severe events that often involve weather [7, 8, 9,10]. As noted in [11], "To robustly quantify possible supply/demand combinations in

This material is based upon work supported by the U.S. Department of Energy's Office of Cybersecurity, Energy Security, and Emergency Response under the Energy Delivery and Security Directorate award Number DE-CR0000067. The views expressed herein do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

Copyright ©2026 IEEE. Personal use of this material is permitted. Accepted for the North American Power Symposium (NAPS) 2026, Houghton, MI, October 2026.

future planning scenarios requires long time series of temporally coincident weather variables that accurately describe the weather impacts concurrently affecting the electricity system" and "The need for appropriate weather data to plan for the rapidly increasing weather dependence of both generation and load is becoming acute." Certainly, TPL8 is a solid step in helping to better integrate severe temperature events into electric grid planning.

Associated with TPL8 there is a data set of benchmark temperature events for each of the Figure 1 weather zones, with the top 40 coldest and top 40 hottest given for each in [12], calculated over a 3-day average. Additional information on the technical rationale and justification for TPL8 and details on the development of the weather events are given in [13] and [14]. Specifically, the document mentions as the source the PNNL weather dataset using 43 years of historical hourly meteorology (1980-2022) and 80 years of projected future meteorology [15]. The initial source for the hourly observations is ERA5 [16]. The results were spatially averaged by county and population weighted to the 54 Balancing Authorities in the conterminous US (CONUS).

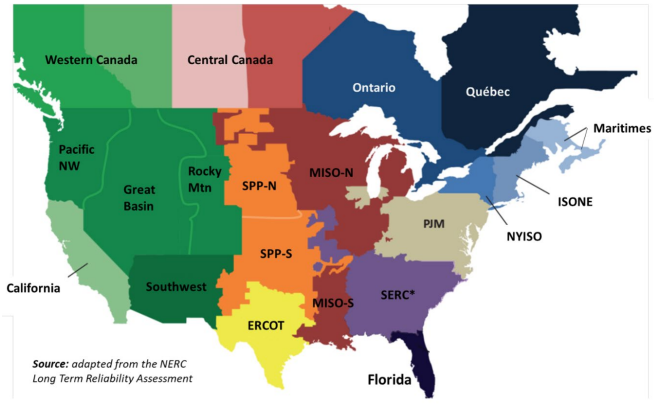

Figure 1: NERC TPL-008-1 Weather Zones (From [17])

This paper's PWOM and results presented here build on this fine prior work in several directions to provide grid planners with additional flexibility. The PWOM then consists of the following. First, the input is a set of historical weather measurements stored in the public PoWer Weather (*.pww) format [18], [19] with a description of the format given at [5]. While the format is general, the historical weather data used here is also the previously mentioned hourly ERA5 [16], which has a native 0.25-degree resolution. The specific weather input files contained data for 38,497 geographic locations covering the footprint shown in Figure 2. For each hour the *.pww files from [5] contain eight weather values for each location including temperature, dew point and wind speed. The website has data files going from 1940 up to the present, with data from 1940 to 2023 used here. An advantage of this *.pww file approach is it allows the spatially varying weather information to be directly integrated into power flow analysis software using the approach of [20] and [19]. It also directly allows for the support of other sources of weather information, with [11] providing a useful summary of available datasets. For this analysis the required *.pww files are downloaded from the website to a local computer, with this being a one-time download.

The second PWOM step is to compute hourly weighted temperature (or other variable) averages for the geographic region of interest. The method provides great flexibility in which locations are included in calculating the average weather values, and also allows for a power system aware approach in determining these values. Recognizing weather occurring in locations with few or no power system components is less important, PWOM allows for the calculation of a weighted average, weighting the weather values by either the amount of load and/or generation at a particular location. Specifically, the weather average can be calculated using a combination of a set of geographic regions along with the location of the load and generation. Examples of this will be shown in Section IV.

This is the most time-consuming portion of PWOM since it requires parsing each of the *.pww files. If the entire Figure 2 footprint is used the required file size is about 230 MB per month. However, usually the entire footprint is not needed, so a step that can save considerable time is to first reduce the size of the input files to just the region of interest. For example, modeling the weather in the ERCOT region reduces the required data by about a factor of 12.

Once the hourly weighted averages are computed the time required to calculate aggregate statistics for any desired time period is trivial with a computation order equal to the total number of hours in the dataset. Thus PWOM allows for quick recalculation of the amount of time included in the averages. While the three days mentioned in TPL8 is certainly an important time period, it can also miss shorter and/or longer periods. This approach allows a planner to interactively determine desired time periods of interest; for example, the coldest hour for the region, or the coldest seven-day period. In keeping with the approach from TPL8 example data, rolling averages can be calculated (i.e., one three-day period might include the first three days, while another includes the second to fourth days). Once periods have been identified PWOM allows the data to be stored in a new *.pww file for subsequent analysis.

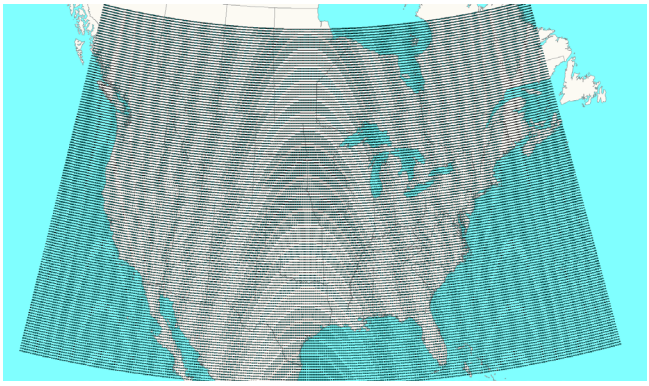

Figure 2: Input Weather Data Geographic Footprint

Finally, in addition to the use of the temperature, PWOM directly supports the calculation of averages based on both

wind chill [21], which takes into account the wind speed at low temperatures, and heat index [22], which takes into account the relative humidity at high temperatures. While temperature is certainly dominant, both wind speed and humidity can play a role in the electric grid's response to extreme conditions [23].

III. Test Electric Grids

Since the PWOM results can be power system dependent, the approach is demonstrated using three larger-scale synthetic electric grids. While PWOM can, of course, be used with actual grids, it is presented here with synthetic grids to allow full public access to the grid models. The first is a 2000-bus, eight-area grid covering the ERCOT geographic footprint [24] and hence corresponds to the yellow weather zone in Figure 1. As modeled it has 1350 bus-level loads with a total of 67 GW, with the geographic distribution of the loads roughly corresponding to the distribution in the actual grid. A visualization of its 500/230/161/115 kV transmission system is shown in Figure 2 with orange used for 500 kV, purple for 230 kV, and gray for 161 and 115 kV lines.

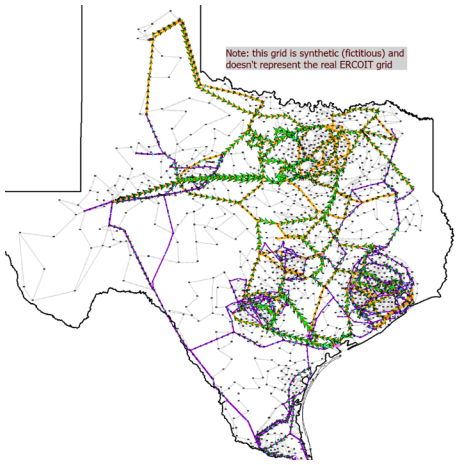

Figure 3: 2000-Bus (2K) Synthetic Grid Oneline Diagram

Since PWOM can calculate weighted averages based on the geographic location and magnitude of the load, Figure 4 visualizes the distribution of the load using the geographic data view (GDV) approach of [25] in which the size of each oval corresponds to the substation load. Each oval's color varies based upon the load's area. In this grid the geographic distribution of the eight areas is roughly proportional to the eight weather zones for the actual ERCOT grid [26]. While GDVs can be useful for showing the precise location of the values, a disadvantage is in dense locations (e.g., large urban regions) there can be significant overlap, causing a visual appearance that can lead to an overestimation of the true value amounts in these dense regions. This can be addressed using a force-based layout algorithm [25], in which overlap can be reduced or eliminated, albeit with some loss of geographic accuracy. The results of this algorithm are shown in Figure 5, which shows the magnitude of the load in the three urban areas (Houston in the Coast Area [magenta], Dallas/Fort Worth in the North Central Area [light blue], and San Antonio/Austin in the South Central Area [dark blue]). From the figures it is apparent most of the load is towards the eastern part of the footprint, but with relatively equal amounts in the north and south. The impact of the weighting approach is demonstrated in the next section.

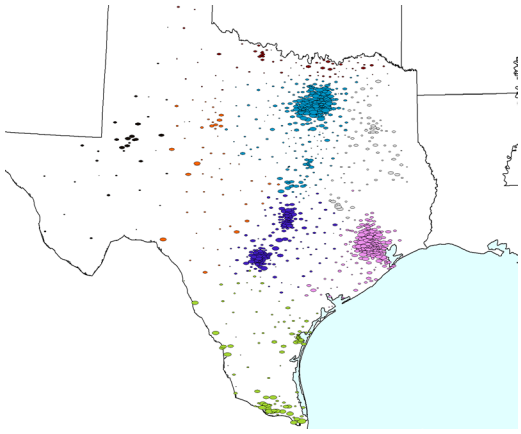

Figure 4: 2K-Grid Load Geographic Data View (GDV)

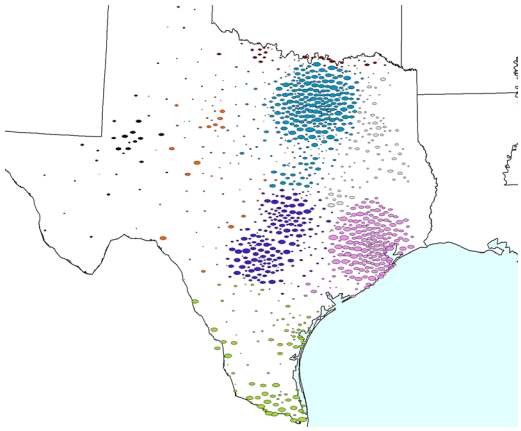

Figure 5: 2K-Grid Load GDV with Force-Based Layout to Remove Overlap

The second synthetic grid example is the one from [27] covering the MISO and SPP geographic footprints (the dark red and orange regions in Figure 1). This grid, which in its final form has 23,600 buses, contains 19 areas, and 11,700 loads with a total load of 104 GW and the load density roughly corresponding to that of the actual grid. Since the example in the next section focuses on the northeast portion of MISO-N (i.e., the US states of Wisconsin [WI] and Michigan [MI]), Figure 5 shows the substation load GDV for the WI (lighter yellow) and MI (blue) areas. In contrast to the previous example, now the vast majority of the load is towards the southern portion of the WI/MI footprint. The last synthetic test grid is the 82,000-bus one presented in [28], with more details given in the next section.

IV. Results

This section presents some PWOM example results, with the twin goals of showing 1) that it can provide near identical outlier weather events identification as the approach of [14]

whose results are given in [12], and 2) that since weather can be quite variable, including outlier events, there could be great benefit in being able to easily consider a wider variety of conditions. While the approach is general for any grid, in the interest of space more detailed results are just presented for the earlier example grids and mostly for cold weather outliers.

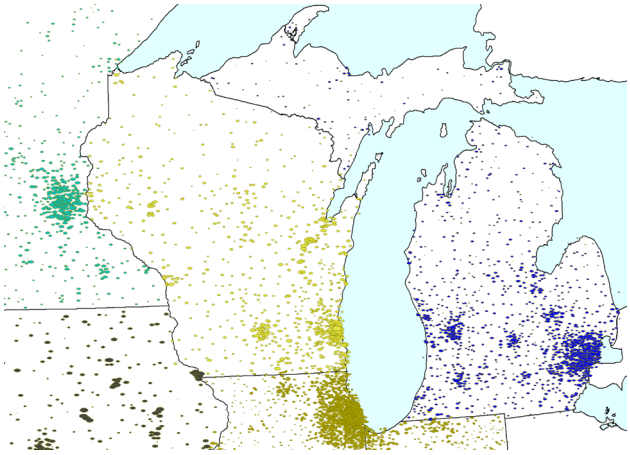

Figure 6: 23,600-Bus Grid Load GDV with Colors Indicating Case Areas

Starting with the ERCOT footprint, the top six coldest three-day periods given in [12] are reproduced in Table 1 with each row showing results for a three-day rolling average period. The first column gives the single date used as the period identifier in [12]; while not explicitly mentioned, this appears to be the middle date in the three-day range. The remaining five columns then give statistics on the daily and three-day temperature values, with the results sorted by the last column. Since the temperature results in [12] are given in Fahrenheit (F), for consistency this unit is used for all results.

Table 1: Top Six 3-Day Coldest Temps. (F) for ERCOT from [12]

Middle Date	Daily Min.	Daily Average	Daily Max.	3-Day Rolling Avg Max	3-Day Rolling Avg Min
12/23/1989	-0.1	10.3	24.7	31.9	6.7
2/15/2021	5.6	13.0	19.0	24.8	8.1
2/16/2021	-0.4	11.1	26.8	26.1	8.7
12/25/1983	4.6	10.2	18.6	24.9	10.6
12/24/1989	11.6	20.3	40.2	40.9	11.3
2/03/2011	8.9	15.4	25.3	26.7	12.2

Results from PWOM for the same footprint over a three-day period are given in Table 2 with the first column also showing the middle date. Since when a date begins depends on the time zone, for consistency all results assume Central Standard Time (CST), which is six hours behind UTC (Coordinated Universal Time). The second and third columns then show the average temperature and wind chill respectively calculated using the PWOM load-weighted approach. That is, each average contains the results for 72 hours with each hourly value a weighted average of the temperature and wind chill at each of the 1350 loads in the 2K grid. The fourth and fifth columns are calculated using the PWOM geographic region approach, and hence are averages of the 855 geographic points within the ERCOT footprint (i.e., based on the ERA5 0.25 degree grid). Results are sorted by the second column.

Table 2: Top 3-Day Coldest Values (F) for ERCOT using PWOM

Middle Date	Avg. Temp (Load)	Avg. Wind Chill (Load)	Avg. Temp (Region)	Avg. Wind Chill (Region)
2/15/2021	19.4	9.3	18.6	8.6
12/23/1989	19.8	11.3	20.9	12.9
12/23/1983	20.1	11.7	23.3	14.6
12/24/1983	20.4	11.5	20.9	12.3
2/01/1951	20.8	11.2	19.6	10.3
1/31/1951	20.9	10.1	19.1	8.5

In comparing the two tables both identify the same three major events (i.e., 1983, 1989 and 2021). PWOM, since it covers more years, also identifies 1951 in the top six. This close match is as expected since both approaches ultimately start from the same ERA5 data. In PWOM the February 2011 event is also found, though it ranked 13th, behind an additional event from 1962.

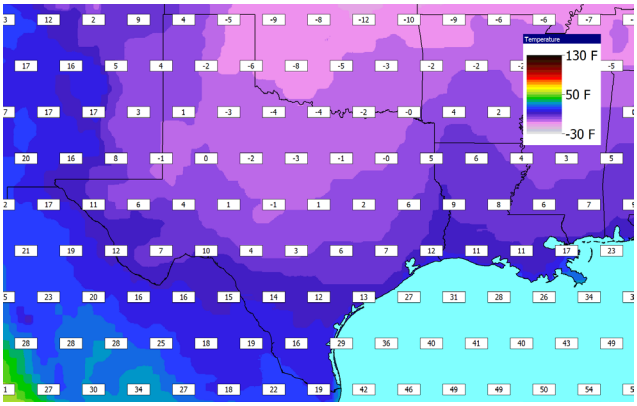

Figure 7: Temperatures on December 23, 1989, 10:00 UTC (4:00 CST)

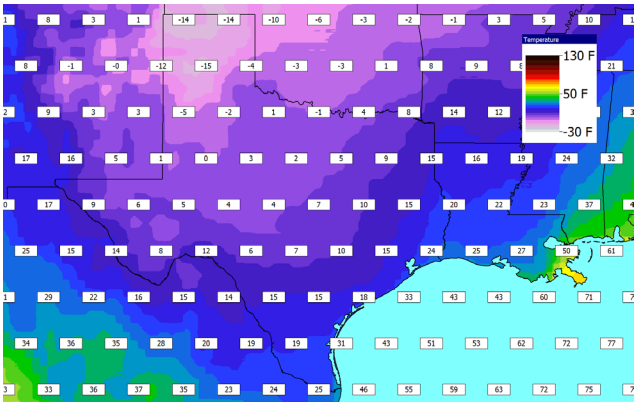

Figure 8: Temperatures on February 15, 2021 14:00 UTC (07:00 CST)

Insight into the importance of the weighting approach and looking at periods beyond just three days can be gained by comparing Figure 7, which shows a color contour of temperatures for the hour with the coldest average temperature in December 1989, with Figure 8, which shows similar data for February 2021. For consistency, the same color scale is used in all the paper's contour figures and the white boxes indicate the temperature (F) at the location. While 2021 is colder using either the load or region weighting over a three

day period, 12/23/1989 actually has the coldest overall hour using the load approach since its coldest temperatures are more pronounced over the portions with the most load (i.e., more towards the eastern part of the footprint as shown in Figure 4 and Figure 5).

Further insight into more localized temperature impacts can be gained by filtering the bus and/or region based weightings. For example, while 12/23/1989 is the overall coldest temperature with the load weighting for the entire grid, other times are colder when considering the loads in just particular areas. For example, the coldest hour for the 2K grid South Central (the dark blue area in Figure 4) and Coast (magenta) areas is 01/31/1949, with its temperature contour shown in Figure 9. While for the entire grid the coldest average temperature on the date is 8.4F (ranking seventh overall), in these areas the cold is more severe (3.8F in South Central and 5.8F in the Coast) even though they are towards the southern part of the 2K grid.

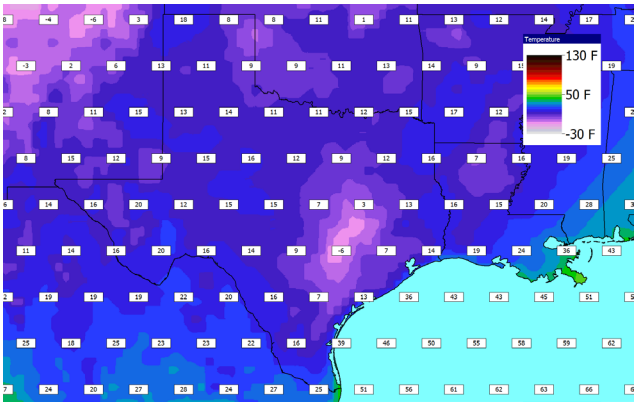

Figure 9: Temperatures on January 31, 1949, 11:00 UTC (04:00 CST)

The second example utilizes the 23.6K grid with a focus on the northeast portion of the grid covering the US states of Michigan and Wisconsin (MI/WI). Again, the first step is a comparison between [12] and PWOM with the former values given in Table 3 and the later in Table 4. As before, the second and third columns in Table 4 give load-weighted results and the fourth and fifth columns treat all values equally. However, now since the comparisons cover different geographic regions (i.e., all of the dark red MISO-N shown in Figure 1 for [12] and just MI/WI for PWOM. Still the match is quite good, with both identifying the January 1994 and February 1996 events; PWOM also finds the 1984 and 1989 events, though they rank somewhat lower.

The MI/WI footprint is chosen here to more clearly illustrate the difference between using the load-weighted and region-weighted approaches. For the 23.6K grid, as shown in Figure 6, most of the load for the MI/WI region is towards the southern portion of the grid and closer to the Great Lakes. This tends to give the load-weighted results consistently warmer temperatures, noted by comparing Columns 2 and 3 with 4 and 5. Then in comparing 1994 with 1996 with the coldest hours in each shown in Figure 10 and Figure 11 respectively, the difference is more pronounced in 1996 because of its larger north-south temperature difference.

Table 3: Top Six 3-Day Coldest Temperatures (F) for MISO-N from [12]

Middle Date	Daily Min.	Daily Max.	3-Day Rolling Avg Max	3-Day Rolling Avg Min
1/19/1994	-30.1	-1.9	-2.7	-25.9
2/03/1996	-26.7	-5.9	-3.8	-24.1
1/20/1984	-23.7	-6.2	-0.3	-23.2
1/18/1994	-29.8	-11.8	-2.9	-23.0
2/02/1996	-22.3	-6.1	-3.2	-21.4
12/22/1989	-22.0	-2.9	0.1	-19.5

Table 4: Top 3-Day Coldest Values (F) for MI/WI using PWOM

Middle Date	Avg. Temp (Load)	Avg. Wind Chill (Load)	Avg. Temp (Region)	Avg. Wind Chill (Region)
2/03/1996	-8.6	-22.4	-14.0	-28.4
1/19/1994	-7.5	-22.7	-11.9	-27.6
2/02/1996	-7.1	-20.9	-13.6	-28.4
1/18/1994	-6.5	-22.9	-11.8	-28.7
1/15/1994	-5.8	-20.4	-10.8	-25.2
1/15/1972	-4.9	-21.2	-8.1	-24.9

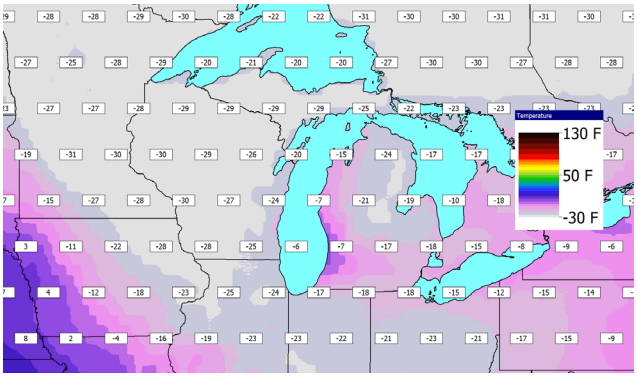

Figure 10: Temperatures on January 19, 1994, 09:00 UTC (03:00 CST)

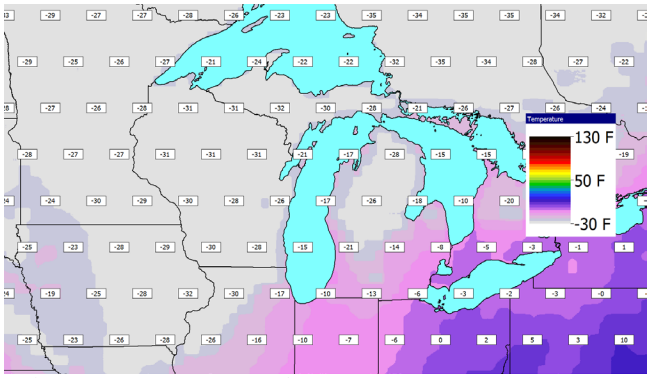

Figure 11: Temperatures on February 3, 1996, 13:00 UTC (07:00 CST)

PWOM can also be used with footprints even larger than the NERC weather zones. The last example is for the 82,000-bus synthetic grid presented [28] covering all of CONUS with the grid divided into three interconnects corresponding to the US portions of the Eastern Interconnect (EI), the WECC and ERCOT. Using the load-weighted approach considering the 72,000 buses in the EI and ERCOT footprints, PWOM identified 12/24/1983 to 12/26/1983 as the coldest three-day period with an average temperature of 10.9 F and wind chill of -1.6 F; the coldest single day is Christmas 1983, with an average temperature of 8.8 F and wind chill of -6.6 F, and the coldest single hour was that same day at 11am UTC (shown in Figure 12) with a temperature of just 1.4 F and wind chill of

-14.2 F. The hottest three day period is 07/21/11 to 07/23/11 with an average temperature of 84.9 F; Figure 13 contours the hottest hour. While not called for by TPL8, such larger events could be useful to study, particularly when combined with other infrastructure models such as the natural gas system.

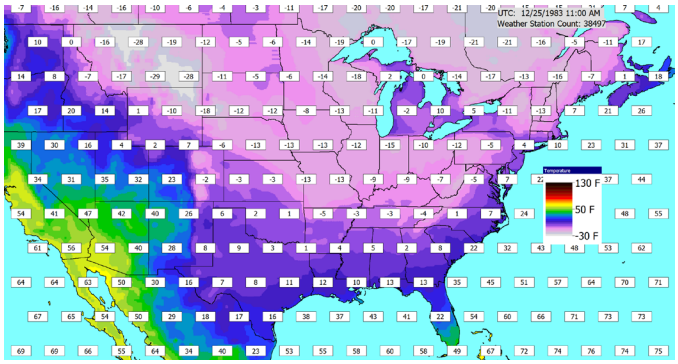

Figure 12: Temperatures on December 25, 1983, 11:00 UTC (04:00 CST)

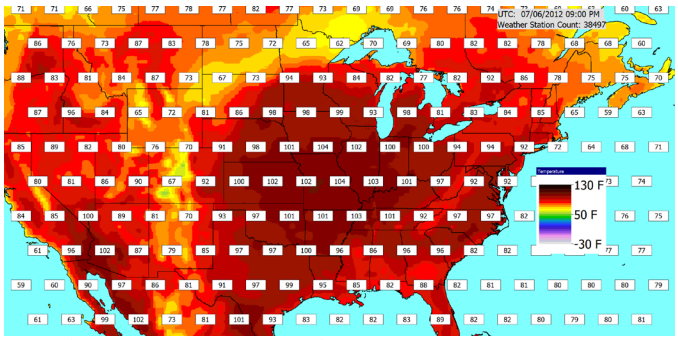

Figure 13: Temperatures on July 6, 2012, 21:00 UTC (15:00 CST)

V. Summary and Future Directions

In summary the paper has presented a technique known as the Power Weather Outlier Method (PWOM) to identify extreme temperature events of varying lengths. Results have shown that PWOM can duplicate and extend the events identified in the new NERC TPL-008-1 Reliability Standard (TPL8). In presenting this method the paper's intent isn't to advocate that TPL8 be modified to include more events, but rather, given the variability of extreme temperature events, to provide power system planners with the ability to easily identify a larger set of events. With this now accomplished future work, already underway, is to provide a method to easily modify power system cases. The anticipated approach is to extend the PFW model approach of [19] to provide more models to represent the incremental changes of temperature variation on electric power systems.

References

[1] US Federal Energy Regulatory Commission Docket No RM22-10-000. Order No. 896, June 15, 2023.

[2] *The February 2021 Cold Weather Outages in Texas and the South Central United States*, FERC, NERC and Regional Entity Staff Report, November 2021.

[3] North American Electric Reliability Corporation (NERC) TPL-008-1 Implementation Plan; www.nerc.com/globalassets/standards/reliability-standards/tpl/2023-07_Final_Ballot_Implementation_Plan_120224.pdf.

[4] PowerWorld Corporation website, powerworld.com; June 2026.

[5] Texas A&M University Electric Grid Test Case Repository; https://electricgrids.engr.tamu.edu/; access June 2026.

[6] S. Kunkolienkar, F. Safdarian, J. Snodgrass, A. Birchfield, T. Overbye, "A Description of the Texas A&M University Electric Grid Test Case Repository for Power System Studies", 2024 IEEE Texas Power and Energy Conference (TPEC), College Station, TX, Feb. 2024.

[7] *Analytic Research Foundations for the Next-Generation Electric Grid*, The National Academies Press, Washington, DC, 2016.

[8] *Enhancing the Resilience of the Nation's Electricity System*, The National Academies Press, Washington, DC, 2017.

[9] T.J. Overbye, K.R. Davis, A.B. Birchfield, "The Electric Grid and Severe Resiliency Events," *The Bridge*, U.S. National Academy of Engineering, vol. 53, Summer 2023, pp. 73-79.

[10] H. Huang et. al., "Toward Resilient Modern Power Systems: From Single Domain to Cross-Domain Resilience Enhancement", *Proceedings of IEEE*, vol. 112, no. 4, April 2024.

[11] *Weather DataSet Needs for Planning and Analyzing Modern Power Systems*, Energy Systems Integration Group (ESIG), October 2023.

[12] NERC TPL-008-1 Benchmark Temperature Events, April 2025; online at www.nerc.com/globalassets/standards/reliability-standards/tpl/TPL-008-1_Benchmark_Temperature_Events_April_2025.pdf.

[13] NERC, "Technical Rationale and Justification for TPL-008-1", December 2024.

[14] NERC, "ERO Enterprise Process for TPL-008-1 Benchmark Weather Event Development and Maintenance," December 2024.

[15] C. Burleyson, T. Thurber, C. Vernon, "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.

[16] H. Hersbach, et. al., "The ERA5 global reanalysis," *Quarterly Journal of the Royal Meteorological Society*, vol. 146, no. 730, pp. 1999–2049, 2020. [Online]. Available: https://doi.org/10.1002/qj.3803.

[17] NERC TPL-008 Data Library, www.nerc.com/globalassets/standards/projects/2023-07/tpl-008_data_library_read_me.pdf.

[18] F. Safdarian, M. Stevens, J. Snodgrass, T.J. Overbye, "Detailed Hourly Weather Measurements for Power System Applications", Texas Power & Energy Conf., College Station, TX, Feb. 2024.

[19] F. Safdarian, J. Cook, K. Zhgun, T.J. Overbye, J. Snodgrass, "Power Flow Modeling of the Impacts of Weather and Other Resiliency Hazards with a Focus on Transmission Planning," 58th Hawaii International Conference on System Sciences, Waikoloa, HI, January 2025.

[20] T. J. Overbye, F. Safdarian, W. Trinh, Z. Mao, J. Snodgrass, and J. Yeo, "An Approach for the Direct Inclusion of Weather Information in the Power Flow," Proc. 56th Hawaii International Conference on System Sciences (HICSS), January 2023.

[21] US National Weather Service, "Understanding Wind Chill," https://www.weather.gov/safety/cold-wind-chill-chart.

[22] US National Weather Service, "What is the Heat Index," www.weather.gov/ama/heatindex.

[23] F. Zhong, "How electric load responds to temperature and weather variables in Texas," Energy Economics, May 2026.

[24] A.B. Birchfield, K.M. Gegner, T. Xu, K.S. Shetye, and T.J. Overbye, "Statistical Considerations in the Creation of Realistic Synthetic Power Grids for Geomagnetic Disturbance Studies," *IEEE Transactions on Power Systems*, vol. 32, pp. 1502-1510, Mar. 2017.

[25] T.J. Overbye, J.L. Wert, K.S. Shetye, F. Safdarian, and A.B. Birchfield, "The Use of Geographic Data Views to Help with Wide-Area Electric Grid Situational Awareness," 2021 IEEE Texas Power and Energy Conference, College Station, TX, Feb. 2021.

[26] ERCOT Zones, ercot.com/gridmktinfo/dashboards/weatherforecast

[27] F. Safdarian, A. Birchfield, K. Shetye, and T.J. Overbye, "Additional Insights in Creating Large-Scale, High-Quality Synthetic Grids: A Case Study," Kansas Power and Energy Conference (KPEC), Apr. 2021.

[28] T.J. Overbye, J. Wert, K. Shetye, F. Safdarian, and A. Birchfield, "Delaunay Triangulation Based Wide-Area Visualization of Electric Transmission Grids," Kansas Power & Energy Conference, Apr. 2021.