

# Application of Weather and Other Environmental Inputs in PowerWorld Simulator Version 24

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# Overview

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- The purpose of this presentation is to show the benefits of having weather information become a standard part of power flow analysis and more broadly electric grid planning, and to show how everyone can easily begin using weather data today (at least for North America)
  - The results also apply to related applications such as optimal power flow (OPF), contingency analysis, security-constrained OPF
- This presentation builds on the one I gave in April 2024, covering some of the many recent developments with a tutorial focus
  - A few of the more recent PowerWorld developments are covered, including what is in the newly released Version 24 (March 2025)

# Aside: Upcoming Short Courses

- At Texas A&M in College Station TX in 2025
  - Full details at [epg.engr.tamu.edu/short-courses-main/](http://epg.engr.tamu.edu/short-courses-main/)
  - **Electric Grid Impacts of Geomagnetic Disturbances** (March 18-19)
  - **Primer on the Planning and Operation of Large-Scale Electric Grids** (Sept 9-11)
  - **Fundamentals of Electric Transmission System Planning** (Oct 7-9)
  - **Introduction of Artificial Intelligence in Power Systems** (Nov 4-6)



# Using Weather with PowerWorld Simulator

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- Over the last three years PowerWorld has gained a lot of weather modeling related capability, and is continuing to gain more
- Currently
  - Past, present and future weather data can be loaded into Simulator
    - This can be done using \*.pww, \*.aux, or \*.csv files
    - Hourly past data is available from 1940 to five days behind real time; present data is available from measurements; future is hourly up to 16 days
  - The weather impacts the power system models using PFW (Power Flow Weather or Power Flow Whatever) models; PFW models can be thought of like the stability models: they are applied to power system objects (e.g., a generator or line) and different classes of models can be defined
  - PFW models can be applied automatically in the **Time Step Simulation**, and applied (currently) on demand in the other applications like power flow

# PowerWorld Simulator Version and Build Date

- The weather functionality started being available in Version 23, particularly ones with later build dates, with much more now in 24. Currently available as an add-on included in the base package.
- Much of the weather does not require cases with geographic values, but more can be done when available.
- Since new Version 24 patches are frequently released, what is available depends on the build date; the Simulator version and build date are available by selecting **Window, About**.
- We desire your suggestions on what should be included moving forward.



# The Power Flow and Weather

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- Human activity depends on the weather, and this has always been reflected in the electric load
- Traditionally some power flow parameters have depended on the weather (e.g., line ratings, turbine max MW, line resistance)
- Over the last several decades this dependence has grown substantially with the increase in wind and solar generation
  - They now (all of 2024) provide about 17% of US electric energy; there are times when most of the electricity in regions is supplied by these sources
  - They are extremely dependent on the weather
- Major power system input parameters are now heavily weather dependent (e.g., wind and solar generator Max MW)

# Planning, Weather and Other Resiliency Events

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- As defined by NERC, planning assessment for large-scale grids is, “Documented evaluation of future transmission system performance and corrective action plans to remedy identified deficiencies”
  - Planning is forward looking, leveraging historical information
- Planning can consider timeframes from near real-time to decades
- Weather and other resiliency considerations can include
  - Inputs to set weather dependent power flow values such as wind, solar (irradiation), temperature for transmission line and transfer limits
  - Extreme weather including hurricanes, ice storms, derechos, tornados
  - Other events such as earthquakes, wildfires, geomagnetic disturbances (GMDs), volcanic events, eclipses
  - This are collectively referred to here as Environmental Inputs (ENIs)

# Using Weather and Related Data in the Power Flow

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- To use weather data and other ENIs in the power flow requires
  - The availability of geographic information mapping buses to substations, and then geocoordinates for the substations
    - This is now mostly available for North American grids; PowerWorld has long stored it mostly with the substation records (sometimes the buses)
    - Large-scale synthetic grids with geographic information are also available
  - Convenient access to available ENIs (e.g., weather information) over the footprint of interest
    - For planning often the footprint is large, beyond a single utility
  - The availability of models that represent the impact of weather and other ENIs on electric grid components

# Example Simulator Geographic Displays

- Starting with version 24, external maps can easily be displayed using the right-click menu

51002484	ISO-NE	345.00	1.01440	349.967	14.12			
137417408	ISO-NE	345.00	1.01960	351.762	7.13			
13742355	ISO-NE	345.00	1.02085	352.193	4.29			
137432		02439	353.415	2.79				
1374221		02879	354.932	0.78				
1374081		0245	353.455	0.68				
1374117		0209	351.923	7.15				
25060		01793	349.505	15.01				
1374241		01793	1.021	4.53				
250601		01793	1.003	14.81				
510021		01793	349.548	7.13				
510021		01793	0.998	9.15				
3479		01793	354.861	9.47				
137422		01606	116.847	26.13	5.78	0.84		
1374159		02163	117.48	11.64	12.76	3.47		
137415		01755	117.01	13.22				
137417		03905	119.49	8.12	9.67	3.17		
1374061		03855	119.43	10.69				
1374211		04059	119.668	10.26	3.56	1.00		

Geography page from the substation objects

Substation Information

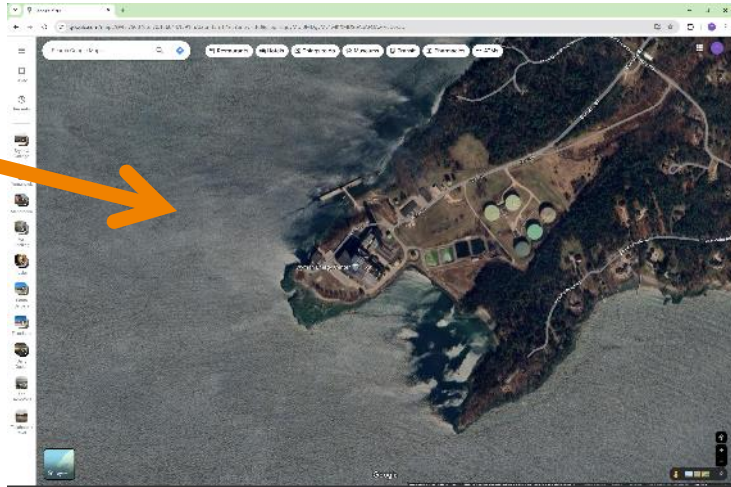
Substation Number: 10019  
 Substation Name: SEQUIM 2  
 Substation ID: 20

Geographic Location

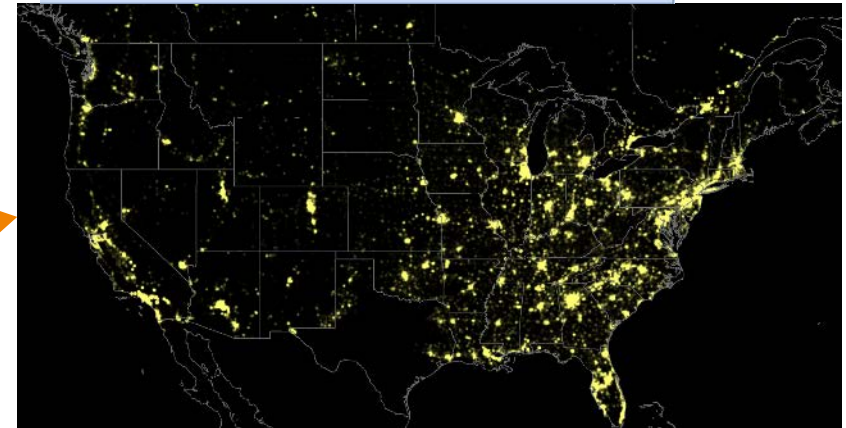
Latitude (degrees): -48.002378584591  
 Longitude (degrees): -123.081742519347

UTM North/South: North  
 UTM Longitude Zone: 10  
 UTM Northing: 5316567.90674376  
 UTM Easting: 493902.656129257

Buttons: Open External Maps, Convert Let/Lon to UTM Coord., Convert UTM to Let/Lon Coord.



Power flow load density contour created leveraging geographic information



# Aside: Rapidly Finding Files Using Simulator

- To quickly find stored files, select **File, General File Browser**

The screenshot shows the File Browser application window. The search path is C:\(C:\). The file list is sorted by extension. The following table represents the data shown in the screenshot:

Extension	Name	Size (KB)	Date Modified	Date Created	Directory	EXE Build Date	Onlines	# of Buses	# of Gen	# of Loads	Gen MW	Gen Mva	Load MW	Load Mvar
PWB	PSC_37Bus(1).pwb	82	9/13/2024 4:23:33 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_10_Planning\PowerWorld Case 23 March 11, 2\	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	\$RTHMMU4.PWB	81	1/23/2025 10:38:35 AM	1/23/2025 1:59:43 PM	C:\Recycle.Bin\5-1-12-1-3489271760-123495824-23	3/23/2024 10:38:35 AM	37	10	26	1450.09	606.9	1420.53	280.73	
PWB	PSC_37Bus_OPF.PWB	85	9/13/2024 4:23:39 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_10_Planning\PowerWorld Case 23 March 11, 2\	3/23/2024 10:38:35 AM	37	9	26	826.19	142.68	813.65	280.73	
PWB	PSC_37Bus_OPF(1).PWB	85	9/13/2024 4:23:39 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_10_Planning\PowerWorld Case 23 March 11, 2\	3/23/2024 10:38:35 AM	37	9	26	826.19	142.68	813.65	280.73	
PWB	PSC_37Bus_EconomicDispatch.PWB	82	9/13/2024 4:23:39 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_10_Planning\PowerWorld Case 23 March 11, 2\	3/23/2024 10:38:35 AM	37	9	26	826.19	142.68	813.65	280.73	
PWB	PSC_37Bus_EconomicDispatch(1).PWB	82	9/13/2024 4:23:39 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_10_Planning\PowerWorld Case 23 March 11, 2\	3/23/2024 10:38:35 AM	37	9	26	826.19	142.68	813.65	280.73	
PWB	B37_Stability.PWB	133	9/13/2024 4:23:41 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_10_Planning\PowerWorld Case 23 October 20, "Problem	3/23/2024 10:38:35 AM	37	9	26	824.86	131.38	813.70	280.73	
PWB	B37_PEAR_PECAN_OverLoad.PWB	82	9/7/2024 9:37:09 AM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_09_Primer\PowerWorld Case 23 October 13, PSC_37B	3/23/2024 10:38:35 AM	37	9	26	825.75	135.28	813.65	280.73	
PWB	B37.PWB	82	9/7/2024 9:37:09 AM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_09_Primer\PowerWorld Case 23 October 13, PSC_37B	3/23/2024 10:38:35 AM	37	9	26	825.40	132.39	813.65	280.73	
PWB	APL_37.PWB	134	9/11/2024 1:04:13 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_09_Primer\PowerWorld Case 24 beta Septem APL_37.p	3/23/2024 10:38:35 AM	37	10	26	1640.06	644.38	1599.55	528.51	
PWB	B37_Stability.PWB	744	4/29/2024 1:10:06 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_09_Primer\PowerWorld Case 24 beta Septem "Problem	3/23/2024 10:38:35 AM	37	9	26	824.96	131.38	813.70	280.73	
PWB	PSC_37Bus_With_April29_METAR_Weather.PWB	5454	4/29/2024 1:10:07 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_24 beta March NorthAm	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	PSC_37Bus_WithExampleWeather_CDT.PWB	5454	4/29/2024 1:10:07 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_24 beta March NorthAm	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	PSC_37Bus_WithExampleWeather.PWB	5454	4/29/2024 1:10:07 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_24 beta March NorthAm	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	PSC_37Bus.pwb	61	4/29/2024 1:10:11 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_22 July 9, 2021 Bus37.pw	3/23/2024 10:38:35 AM	37	9	26	825.81	137.71	813.65	280.73	
PWB	Bus37_Online.PWB	63	4/29/2024 1:10:11 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_22 July 9, 2021 Bus37.pw	3/23/2024 10:38:35 AM	37	9	26	825.81	137.71	813.65	280.73	
PWB	Bus37_LineGDVs.PWB	63	4/29/2024 1:10:11 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_22 July 9, 2021 Bus37.pw	3/23/2024 10:38:35 AM	37	9	26	825.81	137.71	813.65	280.73	
PWB	B37_Stability.PWB	133	4/29/2024 1:10:10 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_22 October 20, "Problem	3/23/2024 10:38:35 AM	37	9	26	824.86	131.38	813.70	280.73	
PWB	PSC_37Bus_VoltageContour.PWB	82	4/29/2024 1:10:04 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_24 beta Febria PSC_37B	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	PSC_37Bus_SwitchedShunts.PWB	82	4/29/2024 1:10:04 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_24 beta Febria PSC_37B	3/23/2024 10:38:35 AM	37	9	26	826.25	176.91	813.63	280.73	
PWB	PSC_37Bus_SVC.PWB	82	4/29/2024 1:10:04 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_24 beta Febria PSC_37B	3/23/2024 10:38:35 AM	37	9	26	826.25	176.91	813.63	280.73	
PWB	PSC_37Bus_Islanded.PWB	77	4/29/2024 1:10:04 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_22 October 13, PSC_37B	3/23/2024 10:38:35 AM	37	9	26	827.60	179.54	813.63	280.73	
PWB	PSC_37Bus.PWB	82	4/29/2024 1:10:04 PM	12/31/1979 11:00:00 PM	C:\Classes\SC_2024_05_PowerWorld\USB\2024_0_24 beta Febria PSC_37B	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	PSC_37Bus_With_April29_METAR_Weather.PWB	744	4/29/2024 12:28:08 PM	4/29/2024 12:28:08 PM	C:\Classes\SC_2024_05_PowerWorld\PowerWork 23 March 11, 2\	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	PSC_37Bus_WithExampleWeather_CDT.PWB	5454	3/30/2024 4:08:57 AM	4/29/2024 9:27:15 AM	C:\Classes\SC_2024_05_PowerWorld\PowerWork 24 beta March NorthAm	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	PSC_37Bus_WithExampleWeather.PWB	5454	3/30/2024 10:10:28 AM	4/29/2024 9:27:15 AM	C:\Classes\SC_2024_05_PowerWorld\PowerWork 24 beta March NorthAm	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	PSC_37Bus.pwb	82	5/19/2024 12:58:16 PM	4/29/2024 9:27:15 AM	C:\Classes\SC_2024_05_PowerWorld\PowerWork 24 beta May 19 PSC_37B	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	
PWB	Bus37_Online.PWB	61	7/11/2021 12:25:46 PM	4/27/2024 10:30:46 AM	C:\Classes\SC_2024_05_PowerWorld\PowerWork 22 July 9, 2021 Bus37.pw	3/23/2024 10:38:35 AM	37	9	26	825.81	137.71	813.65	280.73	
PWB	Bus37_LineGDVs.PWB	63	7/12/2021 3:58:32 PM	4/27/2024 10:30:46 AM	C:\Classes\SC_2024_05_PowerWorld\PowerWork 22 July 9, 2021 Bus37.pw	3/23/2024 10:38:35 AM	37	9	26	825.81	137.71	813.65	280.73	
PWB	SRT9XSRA.PWB	82	9/13/2024 4:23:31 PM	12/31/1979 11:00:00 PM	C:\Recycle.Bin\5-1-12-1-3489271760-123495824-24	3/23/2024 10:38:35 AM	37	9	26	826.20	142.74	813.65	280.73	

Extra information is shown for \*.pwb files, and the right-click menu can be used to open the file

This display can be used to find and open files of any time (e.g., \*.ppt, \*.xls, etc.)

# Availability of Weather Information

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- We started this effort three years back by using historical weather station measurements (mostly identified by their ICAOs [International Civil Aviation Organization], e.g. KLIT, KCLL)
  - We had lots of data, but much of it had missing values; we also only had surface wind values and no direct solar measurements
  - Such measurements at specific locations can still be very useful (e.g., at electrical substations)
- There are many other sources of free weather information, with good coverage provided by *Weather DataSet Needs for Planning and Analyzing Modern Power Systems*, Energy Systems Integration Group (ESIG), October 2023
  - [www.esig.energy/wp-content/uploads/2023/10/ESIG-Weather-Datasets-summary-report-2023.pdf](http://www.esig.energy/wp-content/uploads/2023/10/ESIG-Weather-Datasets-summary-report-2023.pdf)

# ESIG Report (10/2023)

- “These widespread changes lead to the increasing weather-dependence of supply and demand, making power system planning dramatically more complex and requiring much more comprehensive weather data for robust system planning.”
- “The work required to achieve a long-term solution to weather data needs is not trivial, but it is manageable and is much less costly than blindly building trillions of dollars of infrastructure without the basic tools to cost effectively optimize it and assess its reliability.”
- PowerWorld had started working in planning weather integration about a year before the ESIG report appeared, but much progress has been made in the last 18 months

TABLE 2

Summary of Current Power System Modeling Weather Input Data Sources

	Spatial Resolution	Temporal Resolution	Length	Continuously Extended	Correct Variables/ Levels	Coincident and Coherent	Validated/Uncertainty Quantified for Power System Use	Detailed Documentation	Future-Proofed	Availability/Ease of Access	Curation and Advice	Region Covered
MERRA-2 <sup>a</sup>	~60 km	60 min	1980–present	Yes	Yes/No	Yes	No		Probably		Basic	Global
ERA5 <sup>b</sup>	~30 km	60 min	1940–present	Yes	Yes/No	Yes	Some		Yes		Good	Global
HRRR <sup>c</sup>	3 km	15 min	2014–present	Yes	Yes/No	Yes/No	No		Unideal		Basic	U.S.
WIND Toolkit <sup>d</sup>	2 km	5 min	2007–2014	No	Yes/Yes	Yes	Yes		No		Basic	Various
WTK-LED <sup>e</sup>	2 km/4 km	5 min	3 year/20 year	No	Yes/Yes	Yes	Not yet	Not yet	No	Unknown, dataset not yet available		Various
NSRDB <sup>f</sup>	4 km/60 km	30 min	1998–present	Yes	Yes/No	Solar only	Yes		Yes		Basic	Most of globe
CERRA <sup>g</sup>	11 km/5.5 km	60 min	1980–present		No/Yes	No solar	Yes		Possibly		Basic	Europe
CONUS404 <sup>h</sup>	4 km	60 min/15 min (precip)	1980–2020	No	Unknown/Probably	Yes	Not the intended use					Continental U.S.
BARRA <sup>i</sup>	12 km/1.5 km	60 min	1990–2019	No	Yes/Probably	Yes				Fee-based		Australia/New Zealand
Public Observing Networks <sup>j</sup>	Non-uniform, variable density	1 hr or less	Variable	Yes	Yes/No	Mostly	Varies. Not for power systems	Varies	Usually	Usually easy	Varies	Global
Renewable Energy Project Data <sup>k</sup>	Non-uniform, variable density	Usually minutes	Variable but rarely more than 10 years	Varies	Yes/Usually	Yes	Usually	Varies, but usually poor	Varies	Usually poor	Usually none	Very limited
Proprietary Statistically Derived VRE Shapes <sup>l</sup>	Non-uniform, variable density	Usually hourly	Variable. Rarely reliable long records.	Varies	Usually incomplete	No	Partial	See note	No		None	Very limited

■ Fully Met 
 ■ Close to Being Met 
 ■ Partially Met 
 ■ Met in a Very Limited Way 
 ■ Not Met at All 
 ■ Not Enough Info. for Determination

# HICSS 2025 Paper on Power Flow Modeling on Power Flow Weather Modeling

- I have a paper in the 59<sup>th</sup> Hawaii International Conference on System Sciences (HICSS) titled, "Power Flow Modeling of the Impacts of Weather and Other Resiliency Hazards With a Focus on Transmission Planning," available at [overbye.engr.tamu.edu/publications](http://overbye.engr.tamu.edu/publications)

## Power Flow Modeling of the Impacts of Weather and Other Resiliency Hazards With a Focus on Transmission Planning

Authors: [List of authors], Dept. of Electrical and Computer Engineering, Texas A&M University, College Station, TX, USA

Abstract: This paper presents a methodology for modeling weather and other resiliency hazards on power flow modeling. The methodology is based on a combination of weather modeling and power flow modeling. The methodology is applied to a test system to demonstrate its effectiveness.

The impact of the weather on power flow modeling is a critical issue in power system planning. This paper presents a methodology for modeling weather and other resiliency hazards on power flow modeling. The methodology is based on a combination of weather modeling and power flow modeling. The methodology is applied to a test system to demonstrate its effectiveness.

156, Houston, TX, USA. E-mail: [Email address]

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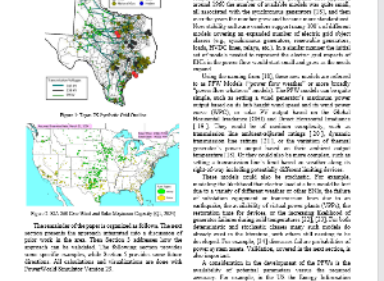


Fig. 1. Location of the test system in the United States.

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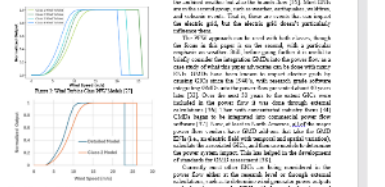


Fig. 2. Impact of weather on power flow modeling.

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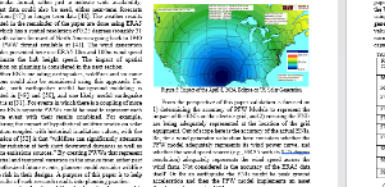


Fig. 3. Location of the test system in the United States.

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158, Houston, TX, USA. E-mail: [Email address]

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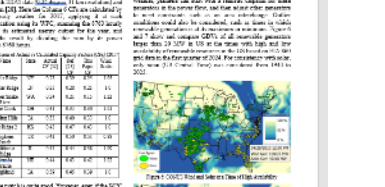


Fig. 4. Location of the test system in the United States.

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159, Houston, TX, USA. E-mail: [Email address]

On a previous paper [1], we presented a methodology for modeling weather and other resiliency hazards on power flow modeling. The methodology is based on a combination of weather modeling and power flow modeling. The methodology is applied to a test system to demonstrate its effectiveness.

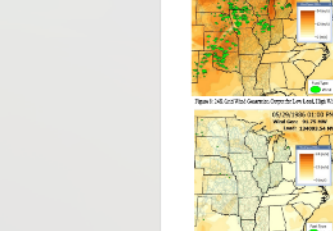


Fig. 5. Location of the test system in the United States.

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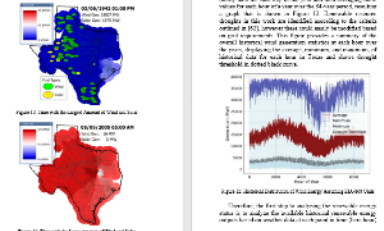


Fig. 6. Impact of weather on power flow modeling.

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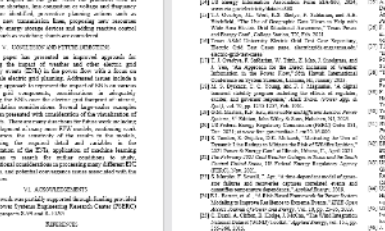


Fig. 7. Location of the test system in the United States.

The impact of the weather on power flow modeling is a critical issue in power system planning. This paper presents a methodology for modeling weather and other resiliency hazards on power flow modeling. The methodology is based on a combination of weather modeling and power flow modeling. The methodology is applied to a test system to demonstrate its effectiveness.

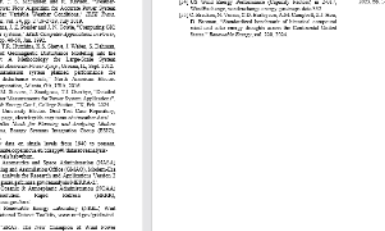


Fig. 8. Impact of weather on power flow modeling.

The impact of the weather on power flow modeling is a critical issue in power system planning. This paper presents a methodology for modeling weather and other resiliency hazards on power flow modeling. The methodology is based on a combination of weather modeling and power flow modeling. The methodology is applied to a test system to demonstrate its effectiveness.



Fig. 9. Location of the test system in the United States.

160, Houston, TX, USA. E-mail: [Email address]

161, Houston, TX, USA. E-mail: [Email address]

162, Houston, TX, USA. E-mail: [Email address]

163, Houston, TX, USA. E-mail: [Email address]

164, Houston, TX, USA. E-mail: [Email address]

165, Houston, TX, USA. E-mail: [Email address]

# Simulator Weather Data Access

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- With respect to weather, PowerWorld's goal is to make it easy to use a wide variety of weather information in all power system planning timeframes, ranging from near real-time to long duration
- We're working on a variety of ways to make weather information available
- The Power Weather (\*.pww) files use a binary format to store weather information and potentially other environmental inputs for a set of time points and a set of locations (e.g., weather stations); the format is relatively general
  - The timepoints can be either uniformly spaced (e.g., hourly) or individually specified (as is the case with forecasts)
  - The weather stations **do not** need to be on a uniform grid

# ERA5

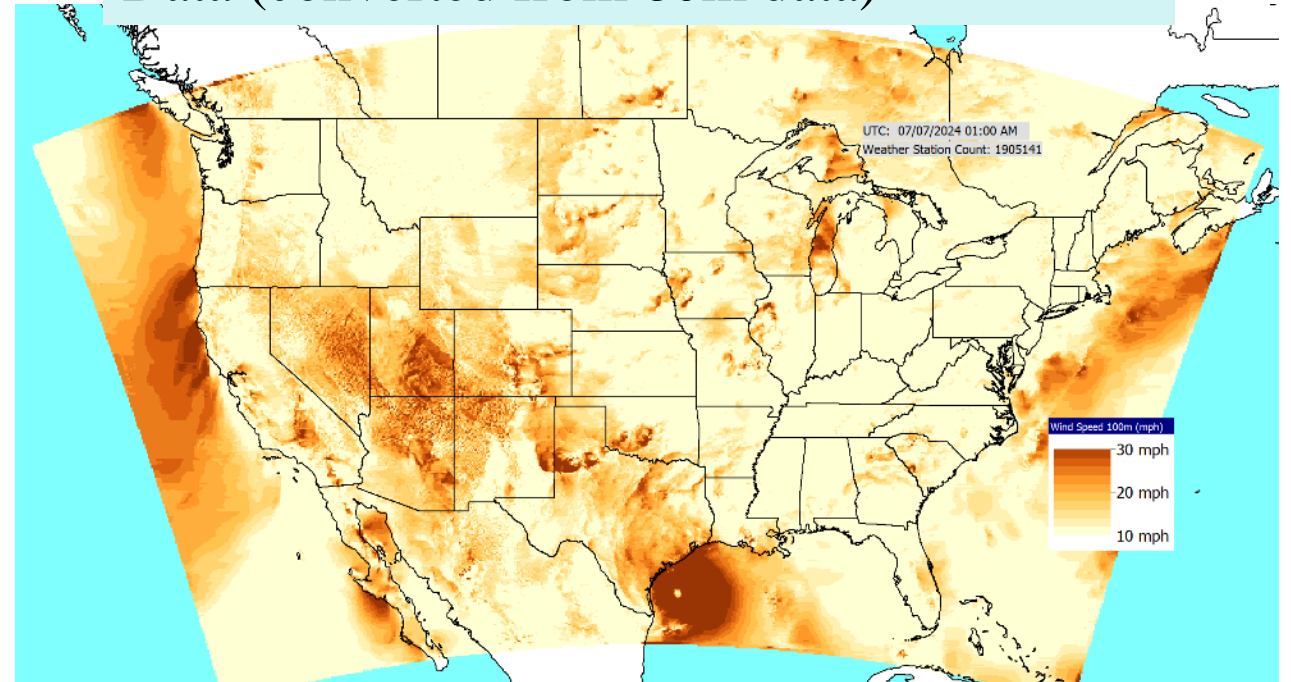
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- One of the datasets we use is ERA5, which is state-of-the art (fifth generation) reanalysis of global climate and weather since 1940
  - It is available hourly on a 0.25 degree grid and includes 10m and 100m wind, and solar global horizontal irradiance and direct horizontal irradiance
  - ERA5 comes from European Centre for Medium-Range Weather Forecasts (ECMWF), (ERA = ECMWF Re-Analysis) with more details on ERA5 available at [rmets.onlinelibrary.wiley.com/doi/10.1002/qj.3803](https://rmets.onlinelibrary.wiley.com/doi/10.1002/qj.3803); available in GRIB and GRIB2
- The ESIG comment on ERA5 is,
  - “However, while ERA5 is unquestionably the best global reanalysis dataset currently available, it is not a panacea. Average validation statistics are very good, but the horizontal grid spacing of 30 km is insufficient to produce detailed meteorological fields present in complex topography, fields that are crucial to resolve for estimating renewable generation in these areas.”

# HRRR

- A second dataset is the HRRR (High-Resolution Rapid Refresh), which is provided by the US National Oceanic and Atmospheric Administration (NOAA)
- HRRR is a 3-km resolution, hourly-updated assimilation/modeling system provided by the NOAA National Center for Environmental Prediction (NCEP)
  - Data is provided on a grid with a total of 1.9 million elements

Simulator Contour of HRRR 100m Wind Data (converted from 80m data)



Ref: [rapidrefresh.noaa.gov/hrrr/](https://rapidrefresh.noaa.gov/hrrr/)

HRRR uses a Lambert Conformal projection (a conic projection)

# Simulator Weather Data Access, cont.

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- Coming soon to a Version 24 patch, Simulator will be able to directly load power system planning related weather information from GRIB or GRIB2 format files
- GRIB (Gridded Binary or General-Regularly-distributed Information in Binary form) is a very common format for the storage and exchange of historical and forecast weather data
  - It is standardized by the World Meteorological Organization (WMO), with GRIB released in 1994 and GRIB2 initially 2003
  - Both GRIB and GRIB2 are widely used, including for the ERA5 and HRRR datasets

# Simulator Weather Data Access, cont.

- Image shows soon to be released functionality to directly load GRIB and GRIB2 data
  - Current HRRR data is available at [www.nco.ncep.noaa.gov/pmb/products/hrrr/](http://www.nco.ncep.noaa.gov/pmb/products/hrrr/)

Weather Related Models and Information

Historical Weather PWW File Directory C:\Classes\SC\_2025\_02\_Planning\PowerWorld Cases\Talk\_17\ Browse... Include Subdirectories

Power Flow Weather (PFW) Models Weather Stations Weather (PWW) File Management Weather (PWW) One Location Weather Statistics Find Outliers Read Grib File

Read GRIB 1 or GRIB 2 File Clear All Data

Setup Weather Using Selected Save Selected in Original GRIB Format

Decode File Messages

None  All  Selected

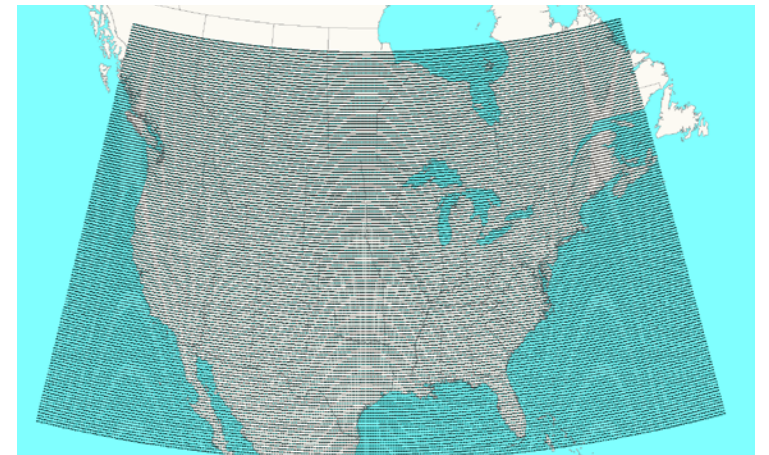
File Summary

First DateTime (JTC) 2025-03-12T00:00Z Minimum Latitude 21.1381 Maximum Grid Points 1905141  
 Last DateTime (JTC) 2025-03-12T00:00Z Maximum Latitude 52.6157  All Grids are the Same  
 Number of Distinct DateTime Values 1 Minimum Longitude -134.0955  
 Number of Unique Parameters 83 Maximum Longitude -60.9172

Selected	Originating Center Number	Originating Center Name	Grid Definition Template String	Product Definition String	Parameter Number	Parameter Category Number	DateTime ISO8601 (JTC)	Count of Values	Average	Minimum	Maximum	Point Count of Parallel or X	Point Count of Meridian or Y	Total Length (Bytes)	Generating Process	Parameter Discipline Name	Parameter Category Name	Data Representation String	Bits per Value
1 NO	7	NCEP	Lambert	Analysis or forecast	0	3	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	2216968	Forecast	Meteorological	Mass	Grid Point Data, Cc	16
2 NO	7	NCEP	Lambert	Analysis or forecast	22	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	13003	Forecast	Meteorological	Moisture	Grid Point Data, Cc	12
3 NO	7	NCEP	Lambert	Analysis or forecast	82	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	1789	Forecast	Meteorological	Moisture	Grid Point Data, Cc	10
4 NO	7	NCEP	Lambert	Analysis or forecast	24	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	101362	Forecast	Meteorological	Moisture	Grid Point Data, Cc	15
5 NO	7	NCEP	Lambert	Analysis or forecast	25	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	13401	Forecast	Meteorological	Moisture	Grid Point Data, Cc	7
6 NO	7	NCEP	Lambert	Analysis or forecast	32	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	7963	Forecast	Meteorological	Moisture	Grid Point Data, Cc	9
7 NO	7	NCEP	Lambert	Analysis or forecast	28	6	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	7993	Forecast	Meteorological	Cloud	Grid Point Data, Cc	9
8 NO	7	NCEP	Lambert	Analysis or forecast	29	6	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	2595	Forecast	Meteorological	Cloud	Grid Point Data, Cc	11
9 NO	7	NCEP	Lambert	Analysis or forecast	100	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	105144	Forecast	Meteorological	Moisture	Grid Point Data, Cc	16
10 NO	7	NCEP	Lambert	Analysis or forecast	193	13	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	571273	Forecast	Meteorological	Unknown 0 13	Grid Point Data, Cc	10
11 NO	7	NCEP	Lambert	Analysis or forecast	192	13	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	308082	Forecast	Meteorological	Unknown 0 13	Grid Point Data, Cc	8
12 NO	7	NCEP	Lambert	Analysis or forecast	32	6	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	60754	Forecast	Meteorological	Cloud	Grid Point Data, Cc	9
13 NO	7	NCEP	Lambert	Analysis or forecast	5	3	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	2277546	Forecast	Meteorological	Mass	Grid Point Data, Cc	17
14 NO	7	NCEP	Lambert	Analysis or forecast	0	0	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	1131690	Forecast	Meteorological	Temperature	Grid Point Data, Cc	9
15 NO	7	NCEP	Lambert	Analysis or forecast	0	0	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	1306105	Forecast	Meteorological	Moisture	Grid Point Data, Cc	11
16 NO	7	NCEP	Lambert	Analysis or forecast	2	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	1111201	Forecast	Meteorological	Momentum	Grid Point Data, Cc	9
17 NO	7	NCEP	Lambert	Analysis or forecast	3	2	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	1068755	Forecast	Meteorological	Momentum	Grid Point Data, Cc	9
18 NO	7	NCEP	Lambert	Analysis or forecast	8	2	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	1001376	Forecast	Meteorological	Momentum	Grid Point Data, Cc	11
19 NO	7	NCEP	Lambert	Analysis or forecast	11	19	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	503809	Forecast	Meteorological	Physical atmosphere	Grid Point Data, Cc	7
20 NO	7	NCEP	Lambert	Analysis or forecast	0	20	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	462533	Forecast	Meteorological	Atmospheric chemi	Grid Point Data, Cc	16
21 NO	7	NCEP	Lambert	Analysis or forecast	0	3	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	2216778	Forecast	Meteorological	Mass	Grid Point Data, Cc	16
22 NO	7	NCEP	Lambert	Analysis or forecast	22	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	14689	Forecast	Meteorological	Moisture	Grid Point Data, Cc	12
23 NO	7	NCEP	Lambert	Analysis or forecast	82	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	527	Forecast	Meteorological	Moisture	Grid Point Data, Cc	8
24 NO	7	NCEP	Lambert	Analysis or forecast	24	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	101598	Forecast	Meteorological	Moisture	Grid Point Data, Cc	15
25 NO	7	NCEP	Lambert	Analysis or forecast	25	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	14368	Forecast	Meteorological	Moisture	Grid Point Data, Cc	7
26 NO	7	NCEP	Lambert	Analysis or forecast	32	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	8426	Forecast	Meteorological	Moisture	Grid Point Data, Cc	10
27 NO	7	NCEP	Lambert	Analysis or forecast	28	6	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	9555	Forecast	Meteorological	Cloud	Grid Point Data, Cc	9
28 NO	7	NCEP	Lambert	Analysis or forecast	29	6	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	269	Forecast	Meteorological	Cloud	Grid Point Data, Cc	8
29 NO	7	NCEP	Lambert	Analysis or forecast	100	1	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	105718	Forecast	Meteorological	Moisture	Grid Point Data, Cc	16
30 NO	7	NCEP	Lambert	Analysis or forecast	193	13	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	534993	Forecast	Meteorological	Unknown 0 13	Grid Point Data, Cc	9
31 NO	7	NCEP	Lambert	Analysis or forecast	192	13	2025-03-12T00:00:00Z	1905141	0.00	0.00	0.00	1799	1059	307631	Forecast	Meteorological	Unknown 0 13	Grid Point Data, Cc	8

# Easy Power Flow Access to ERA5

- ERA5 is available worldwide about five days behind real-time
- We convert it to pww format files, and place it at [electricgrids.engr.tamu.edu/weather-data/](http://electricgrids.engr.tamu.edu/weather-data/)
- Currently we provided data for most of North America and then smaller files for just Texas
  - For each hour the pww files store eight weather values (temperature, dew point, cloud cover percent, wind speed (10m), wind direction (10m), wind speed (100m), global horizontal irradiance, direct horizontal irradiance, wind gusts
  - The North America pww files have 38,497 data points; with 9 values per hour, this is about 247 MB per month, or about 250 GB for the total set
- This data is public so it can be freely used and shared



# Electricgrids.engr.tamu.edu/weather-data/

## Weather Data

This dataset contains historical and forecast weather data for Texas and North America. The historical data starts from 1940 and extends to almost present (5 days from current date). The list of weather values include, temperature, dew point, wind speed, wind direction, wind speed at 100m, cloud cover, global horizontal irradiance, and direct horizontal irradiance for a 0.25 degree latitude and longitude grid across much of North America.

Please contact Thomas Overbye (overbye@tamu.edu) or Farnaz Safdarian (fsafdarian@tamu.edu) for any questions regarding this data.

### [View Available Weather for Download](#)

### [Weather Data Information and PWW Format Description](#)

## References

If you use these datasets in publications, please cite the following papers, and acknowledge the ERA5 data as described below:

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.

F. Safdarian, M. Stevens, J. Snodgrass, T. J. Overbye, "Detailed Hourly Weather Measurements for Power System Applications," 2024 IEEE Texas Power and Energy Conference (TPEC), College Station, TX, Feb. 2024.

Hersbach, H., Bell, B., Berrisford, P., Biavati, G., Horányi, A., Muñoz Sabater, J., Nicolas, J., Peubey, C., Radu, R., Rozum, I., Schepers, D., Simmons, A., Soci, C., Dee, D., Thépaut, J.-N. (2023): ERA5 hourly data on single levels from 1940 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS), DOI: 10.24381/cds.adbb2d47 (Accessed on 23-01-2024)

Please refer to [How to acknowledge, cite and reference data published on the Climate Data Store](#) for complete details on citing the ERA5 data.

ERA5 Weather Data > PWW

Show Path

Type | People | Modified | Source

Name ↓

- Texas\_1940-2025
- NorthAmerica\_Forecasts
- NorthAmerica\_1940-2025
- InterestingScenarios

ERA5 Weather Data > PWW > NorthAmerica\_1940-2025

Type | People | Modified | Source

Name ↑

- 3-Month Data\_1940\_2023
- NorthAmerica\_2025
- wind\_gust
- NorthAmerica\_1940s.zip
- NorthAmerica\_1950s.zip
- NorthAmerica\_1960s.zip
- NorthAmerica\_1970s.zip
- NorthAmerica\_1980s.zip
- NorthAmerica\_1990s.zip
- NorthAmerica\_2000s.zip
- NorthAmerica\_2010s.zip
- NorthAmerica\_2020-2023.zip
- NorthAmerica2024\_Q1.pww
- NorthAmerica2024\_Q2.pww
- NorthAmerica2024\_Q3.pww
- NorthAmerica2024\_Q4.pww

Only get the 3-month data if your download speed is slow

Data for current year, updated daily

Historical data; that is, a onetime download; getting a decade took me about 4 minutes

# Viewing Weather for an Hour

- Goto Tools, Weather, Weather Models and Information, Weather Stations Page to view the weather for any valid time

Weather Related Models and Information

Historical Weather PWW File Directory C:\Weather\ Browse...  Include Subdirectories

Power Flow Weather (PFW) Models Weather Stations Weather (PWW) File Management Weather (PWW) One Location Weather Statistics Find Outliers Read Grib File

Weather Date and Time  
Local Date and Time 3/6/2025 12:00:00 AM  
Date and Time (UTC) 2025-03-06T00:00:00Z

Load Weather Obtained from Aviation.Gov (METARS)  
 Update Case to METARS Time  Delete All Existing Stations  
 Add Unknown Stations Load METARS.CACHE.CSV

This data needs to be downloaded outside of Simulator from aviationweather.gov/data/cache/metars.cache.csv

Load Historical Weather from \*.PWW Files  
Desired Date and Hour 3/ 6/2025  
Time Zone to Use  UTC  Local  
Hour 0

Reference Location  
Location Latitude 40.000  
Location Longitude -88.000  
Update All Distances to Reference  
Find Reference Weather Station  
Weather to Aux File  
 Include Data in Aux File

Reduce Number of Weather Stations and Measurements  
Maximum Latitude 37.00  
West Side -107.00 East Side -93.00  
Minimum Latitude 25.50  
Total Weather Stations 38497  
Stations in Region 2679

	Name	Longitude	Latitude	Enabled	Temp F	Temp C	Dew Point F	Dew Point C	Cloud Cover Percent	Wind Speed mph	Wind Speed 100m mph	Direction	Global Horizontal Irradiance W/m <sup>2</sup>	Direct Horizontal Irradiance W/m <sup>2</sup>	Insolation Percent	Place_Name
1	+24.00-060.00/	-60.000000	24.000000	0 YES	74.0	23.3	67.0	19.4	97.0	22.0	25.0	150.0	0.0	0.0	0.0	
2	+24.00-060.25/	-60.250000	24.000000	0 YES	74.0	23.3	67.0	19.4	100.0	24.0	28.0	160.0	0.0	0.0	0.0	
3	+24.00-060.50/	-60.500000	24.000000	0 YES	73.0	22.8	68.0	20.0	99.0	24.0	28.0	175.0	0.0	0.0	0.0	
4	+24.00-060.75/	-60.750000	24.000000	0 YES	72.0	22.2	68.0	20.0	92.0	24.0	27.0	185.0	0.0	0.0	0.0	
5	+24.00-061.00/	-61.000000	24.000000	0 YES	72.0	22.2	68.0	20.0	87.0	23.0	25.0	190.0	0.0	0.0	0.0	
6	+24.00-061.25/	-61.250000	24.000000	0 YES	73.0	22.8	68.0	20.0	83.0	21.0	23.0	190.0	0.0	0.0	0.0	
7	+24.00-061.50/	-61.500000	24.000000	0 YES	74.0	23.3	68.0	20.0	51.0	18.0	20.0	185.0	0.0	0.0	0.0	
8	+24.00-061.75/	-61.750000	24.000000	0 YES	75.0	23.9	67.0	19.4	63.0	13.0	14.0	180.0	0.0	0.0	0.0	
9	+24.00-062.00/	-62.000000	24.000000	0 YES	75.0	23.9	67.0	19.4	74.0	8.0	9.0	175.0	0.0	0.0	0.0	
10	+24.00-062.25/	-62.250000	24.000000	0 YES	75.0	23.9	67.0	19.4	55.0	3.0	3.0	155.0	0.0	0.0	0.0	
11	+24.00-062.50/	-62.500000	24.000000	0 YES	74.0	23.3	68.0	20.0	22.0	4.0	4.0	25.0	0.0	0.0	0.0	
12	+24.00-062.75/	-62.750000	24.000000	0 YES	74.0	23.3	67.0	19.4	6.0	8.0	9.0	10.0	0.0	0.0	0.0	
13	+24.00-063.00/	-63.000000	24.000000	0 YES	75.0	23.9	67.0	19.4	0.0	11.0	12.0	10.0	0.0	0.0	0.0	
14	+24.00-063.25/	-63.250000	24.000000	0 YES	75.0	23.9	66.0	18.9	0.0	12.0	13.0	15.0	0.0	0.0	0.0	
15	+24.00-063.50/	-63.500000	24.000000	0 YES	75.0	23.9	64.0	17.8	0.0	12.0	13.0	20.0	0.0	0.0	0.0	
16	+24.00-063.75/	-63.750000	24.000000	0 YES	75.0	23.9	63.0	17.2	0.0	13.0	14.0	35.0	0.0	0.0	0.0	
17	+24.00-064.00/	-64.000000	24.000000	0 YES	74.0	23.3	63.0	17.2	0.0	13.0	14.0	45.0	0.0	0.0	0.0	
18	+24.00-064.25/	-64.250000	24.000000	0 YES	74.0	23.3	63.0	17.2	0.0	13.0	15.0	50.0	0.0	0.0	0.0	
19	+24.00-064.50/	-64.500000	24.000000	0 YES	74.0	23.3	64.0	17.8	0.0	13.0	14.0	60.0	0.0	0.0	0.0	
20	+24.00-064.75/	-64.750000	24.000000	0 YES	74.0	23.3	64.0	17.8	0.0	13.0	14.0	65.0	0.0	0.0	0.0	
21	+24.00-065.00/	-65.000000	24.000000	0 YES	74.0	23.3	64.0	17.8	0.0	13.0	14.0	70.0	0.0	0.0	0.0	
22	+24.00-065.25/	-65.250000	24.000000	0 YES	74.0	23.3	65.0	18.3	3.0	14.0	15.0	75.0	0.0	0.0	0.0	
23	+24.00-065.50/	-65.500000	24.000000	0 YES	75.0	23.9	65.0	18.3	10.0	14.0	15.0	75.0	0.0	0.0	0.0	
24	+24.00-065.75/	-65.750000	24.000000	0 YES	75.0	23.9	66.0	18.9	20.0	14.0	15.0	80.0	0.0	0.0	0.0	

Directory for pww files

Enter the day and hour; in either Coordinated Universal Time (UTC) or local time

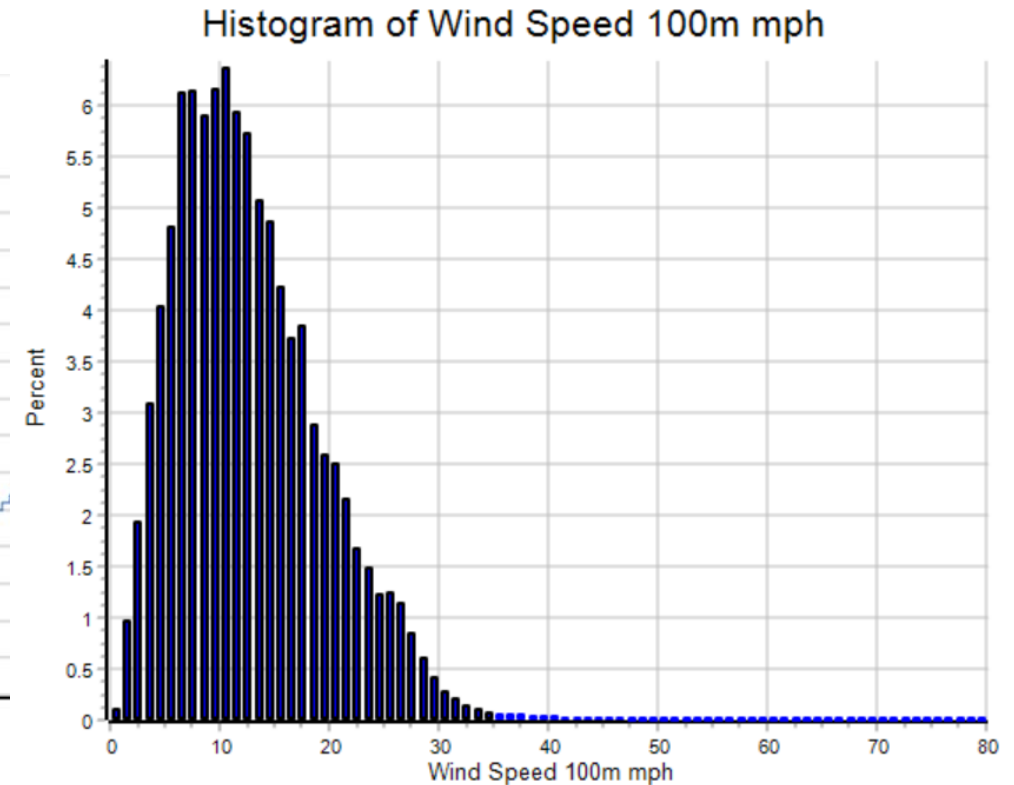
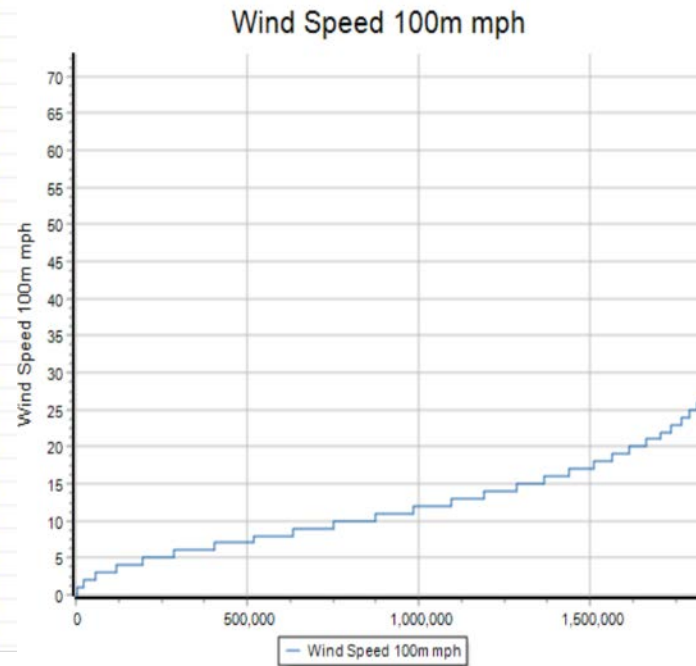
Click **Just Get Weather for Desired Date** to get the weather; it takes about a second

Right-click to see weather station dialog

# Viewing Weather for an Hour, HRRR

- Even the full HRRR data can be viewed this way (1.9 million weather stations!); it can also be sorted or plotted
  - In contrast Excel 2024 maxes out at about 1 million rows and 16,000 columns

1905112	+26.88-094	Name. This is the unique identifier	98	YES	81.0
1905113	+26.80-094	(Key Field) for the WeatherStation	98	YES	80.0
1905114	+26.61-095		98	YES	81.0
1905115	+26.59-095.76/	-95.761499 26.587168	98	YES	81.0
1905116	+26.56-095.94/	-95.939282 26.563589	98	YES	80.0
1905117	+26.56-095.82/	-95.821131 26.561729	98	YES	81.0
1905118	+26.54-095.91/	-95.910254 26.536718	98	YES	80.0
1905119	+27.20-094.74/	-94.735894 27.199874	98	YES	83.0
1905120	+26.86-094.84/	-94.836374 26.858313	98	YES	81.0
1905121	+26.86-094.75/	-94.747467 26.855979	98	YES	82.0
1905122	+26.83-094.84/	-94.837232 26.831875	98	YES	80.0
1905123	+26.83-094.75/	-94.748353 26.829542	98	YES	81.0
1905124	+26.61-095.79/	-95.790496 26.614086	98	YES	81.0
1905125	+26.59-095.88/	-95.879686 26.589097	98	YES	80.0
1905126	+26.59-095.79/	-95.791045 26.587663	98	YES	81.0
1905127	+26.56-095.85/	-95.850668 26.562207	98	YES	81.0
1905128	+26.51-094.82/	-94.817968 26.514034	98	YES	81.0
1905129	+26.49-094.82/	-94.818828 26.487626	98	YES	81.0
1905130	+26.59-095.85/	-95.850139 26.588628	98	YES	81.0
1905131	+26.59-095.82/	-95.820592 26.588150	98	YES	81.0
1905132	+26.56-095.91/	-95.909744 26.563137	98	YES	80.0
1905133	+26.56-095.88/	-95.880206 26.562676	98	YES	80.0
1905134	+26.83-094.78/	-94.777979 26.830328	98	YES	81.0
1905135	+26.86-094.78/	-94.777102 26.856766	98	YES	82.0
1905136	+26.83-094.81/	-94.807605 26.831106	98	YES	81.0
1905137	+26.86-094.81/	-94.806738 26.857544	98	YES	81.0
1905138	+26.51-094.85/	-94.847480 26.514799	98	YES	81.0
1905139	+26.49-094.88/	-94.877835 26.489148	98	YES	82.0
1905140	+28.14-108.49/	108.494895 28.144409	98	YES	71.0
1905141	+26.49-094.85/	-94.848331 26.488392	98	YES	81.0



# Date and Times in Simulator

- In general power flow cases do not need to have an associated date and time, however sometimes these values are useful
- When including weather almost always a date/time is needed, but it may be different from the case date/time
- Values can be seen with **Case Information, Case Description**

Case date/time

Weather date/time

Case Description

24 Optimal Power Flow (OPF), Security Constrained OPF (SCOPF), OPF Reserves, Available Trar

Case Description Case Comments Case Time

Case Time

Set to Present

Case Date Case Local Time Time Zone UTC HR. Offset -5.0

3/13/2025 7:32:02 AM  Offset Is Daylight Time Time Zone CDT

Date and Time in ISO8601 Format 2025-03-13T12:32:02.429Z

Assumed Date (in Case Time Zone) for Determining Inservice Devices

Inservice Date Same as Case Date 3/13/2025

Weather Date/Time

Weather Date/Time (Local) 3/5/2025 7:00:00 PM

Weather Date/Time (ISO8601) 2025-03-06T00:00Z

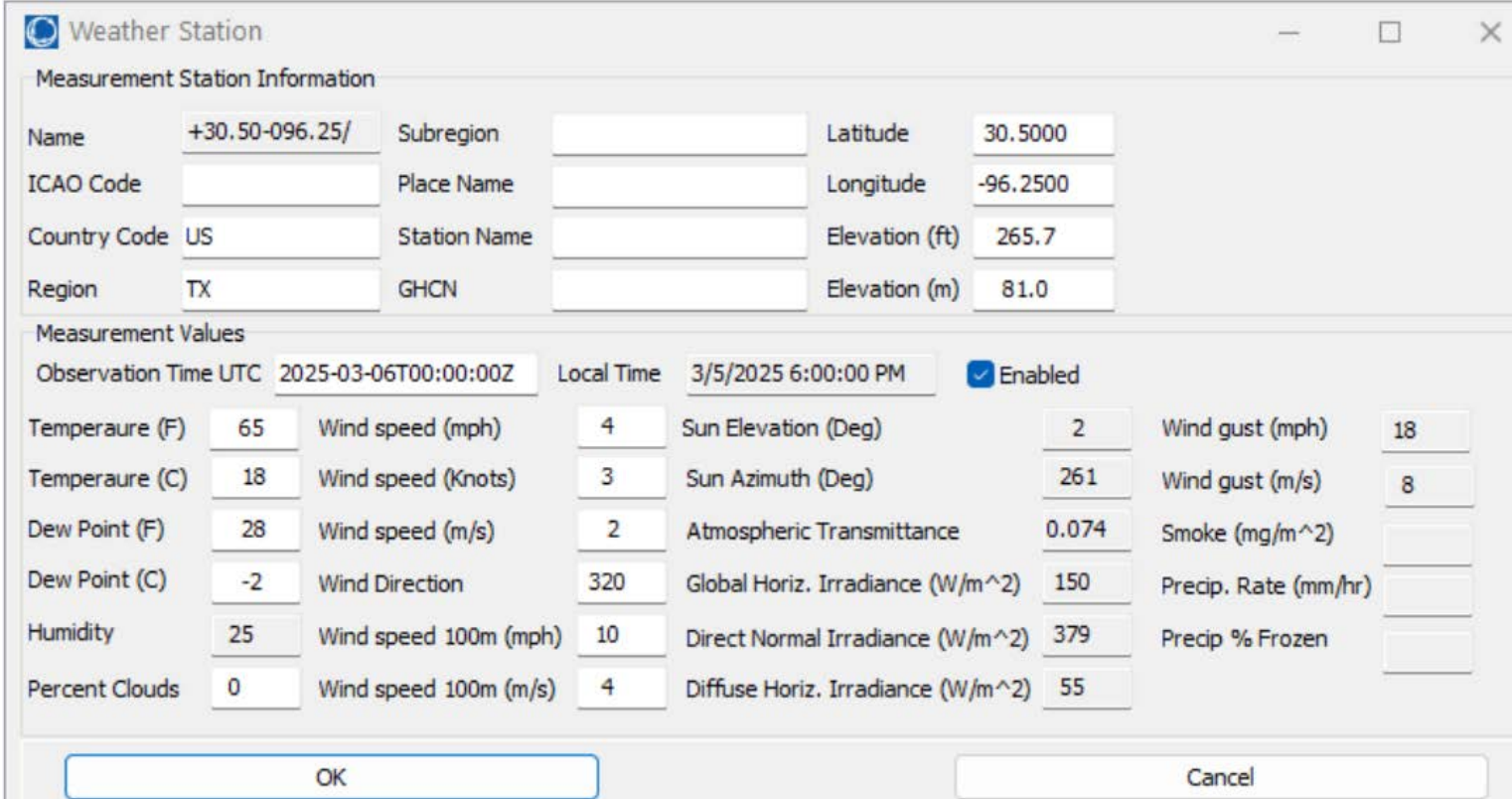
OK Cancel Help

Assumed time zone

Weather date in ISO8601 format

# Simulator Weather Stations

- Simulator uses weather station objects to store the weather data
- A weather station object must have a latitude and longitude; they usually have an elevation, and can have other identifiers
- A weather station may be an actual weather measuring location, but it could also just be a point in a weather model (e.g., ERA5 and HRRR)



The screenshot shows a 'Weather Station' dialog box with two main sections: 'Measurement Station Information' and 'Measurement Values'.

**Measurement Station Information:**

Name	+30.50-096.25/	Subregion		Latitude	30.5000
ICAO Code		Place Name		Longitude	-96.2500
Country Code	US	Station Name		Elevation (ft)	265.7
Region	TX	GHCN		Elevation (m)	81.0

**Measurement Values:**

Observation Time UTC: 2025-03-06T00:00:00Z    Local Time: 3/5/2025 6:00:00 PM     Enabled

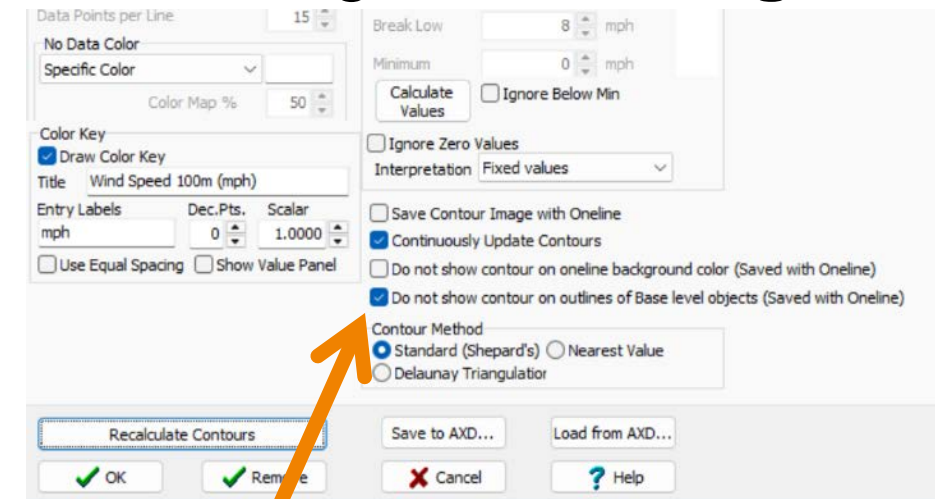
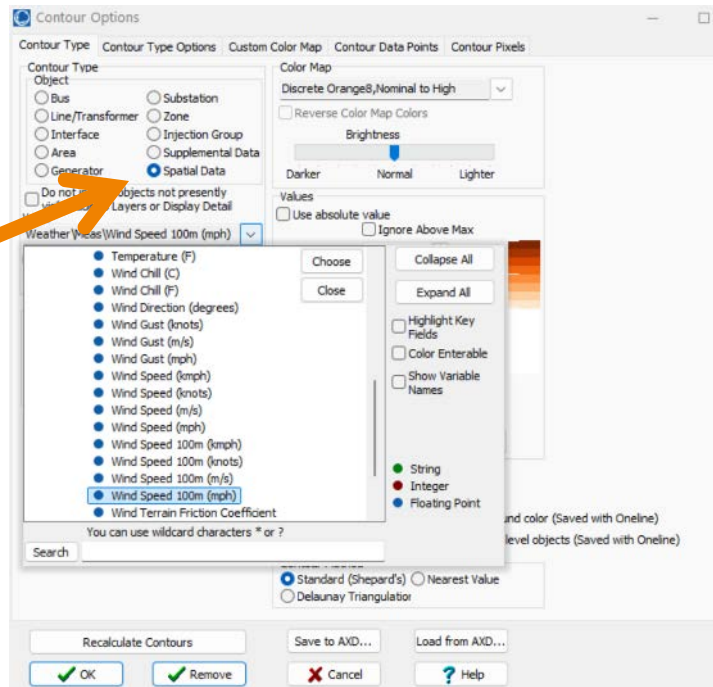
Temperature (F)	65	Wind speed (mph)	4	Sun Elevation (Deg)	2	Wind gust (mph)	18
Temperature (C)	18	Wind speed (Knots)	3	Sun Azimuth (Deg)	261	Wind gust (m/s)	8
Dew Point (F)	28	Wind speed (m/s)	2	Atmospheric Transmittance	0.074	Smoke (mg/m <sup>2</sup> )	
Dew Point (C)	-2	Wind Direction	320	Global Horiz. Irradiance (W/m <sup>2</sup> )	150	Precip. Rate (mm/hr)	
Humidity	25	Wind speed 100m (mph)	10	Direct Normal Irradiance (W/m <sup>2</sup> )	379	Precip % Frozen	
Percent Clouds	0	Wind speed 100m (m/s)	4	Diffuse Horiz. Irradiance (W/m <sup>2</sup> )	55		

Buttons: OK, Cancel

# Visualizing the Weather

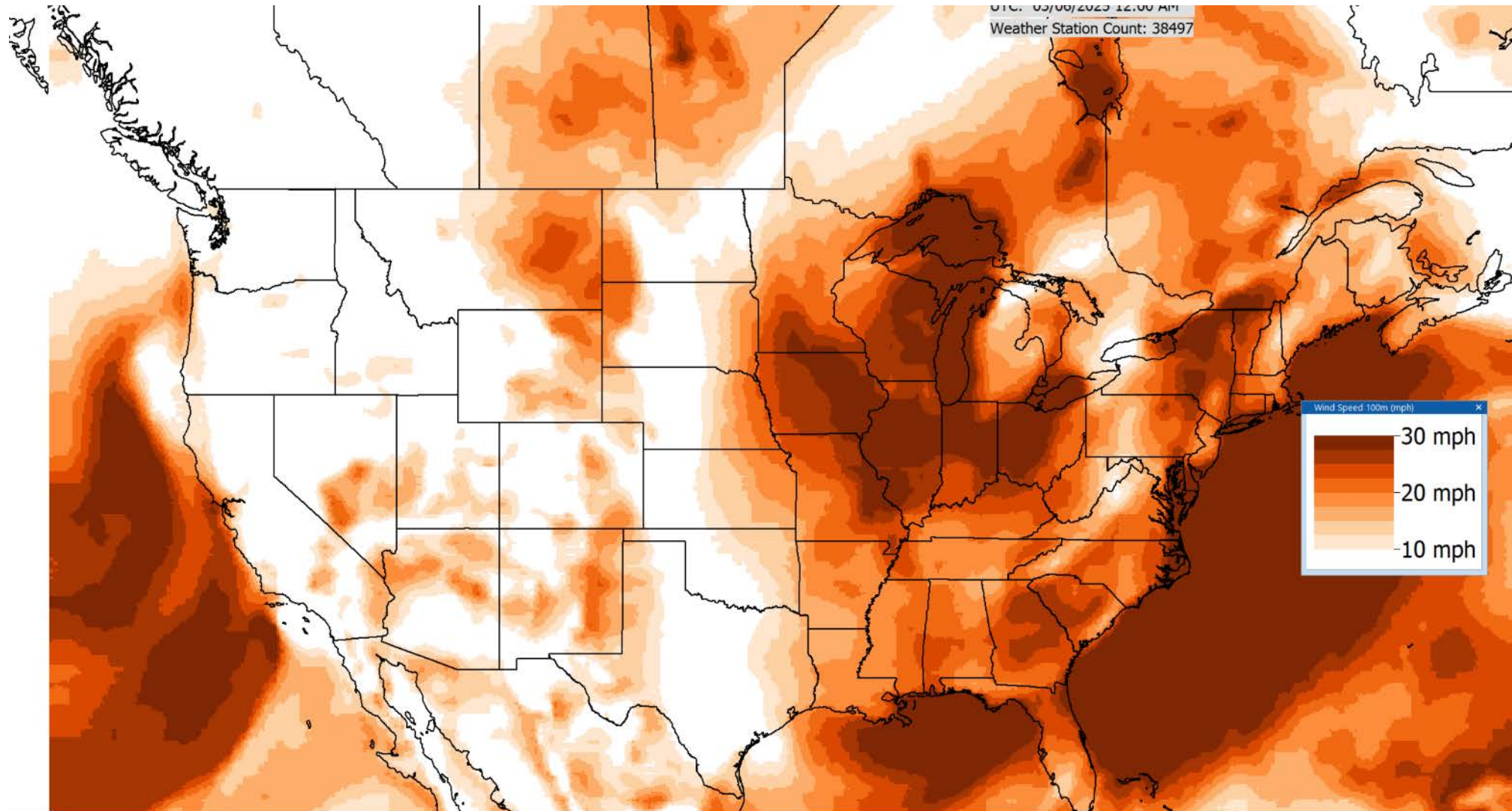
- Weather information can be contoured on a geographic oneline by right-clicking on the oneline background and selecting **Contouring...**

- The weather values can be contoured using the **Spatial Data** object, which does not require objects to actually be on the oneline



Use to select whether the contour is shown on the background, which is often ocean

# Example Contour



# Showing Contour Data Symbols

- Data symbols can be easily added to the contour, and then also easily modified later by just right-clicking on one of them

Contour Options

Contour Type Contour Type Options Custom Color Map Contour Data Points Contour Pixels

Spatial Data Contour Symbol Options

Show Spatial Data Point Symbols  Use Background Fill

Symbol Height 306.511 Fill Color

Automatically Set Height Border Color

Height to Width Ratio 0.500   Show Value in Symbol

Border Pixel Width 1 Value Font Color  Suffix

Max. Symbols to Show 500 Total Digits 4 Prefix

Show Symbols in Top Level Decimal Places 0

Symbol Type

Circle  Rectangle  Triangle

Contour Metrics

Data Point Count 38497 Average 17.2115

Minimum 0 Maximum 57

Contour Resolution

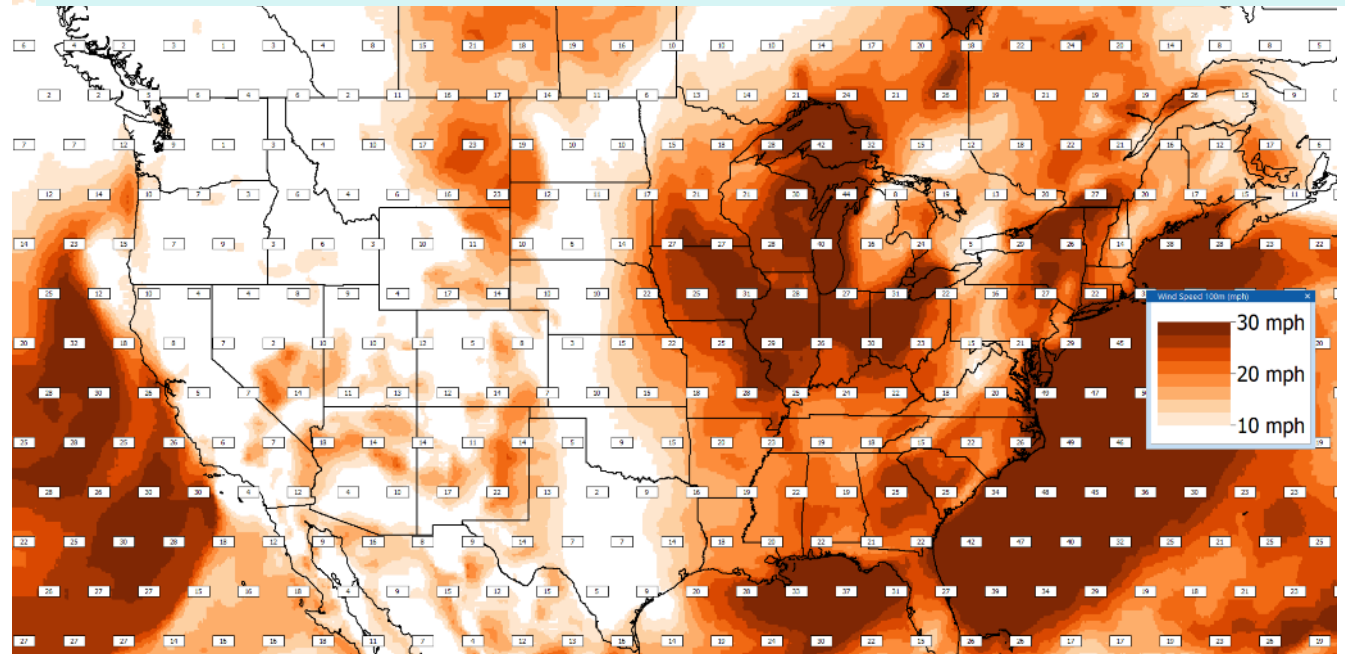
X Resolution 450 Y Resolution 210

Object ID	Value	Pixel Color	X	Y	Latitude	Longitude
1	25.0000		-32148.965	13253.028	24.000	-60.000
2	28.0000		-32282.919	13253.028	24.000	-60.250
3	28.0000		-32416.873	13253.028	24.000	-60.500
4	27.0000		-32550.827	13253.028	24.000	-60.750
5	25.0000		-32684.781	13253.028	24.000	-61.000
6	23.0000		-32818.735	13253.028	24.000	-61.250
7	20.0000		-32952.689	13253.028	24.000	-61.500
8	14.0000		-33086.643	13253.028	24.000	-61.750
9	9.0000		-33220.597	13253.028	24.000	-62.000
10	3.0000		-33354.551	13253.028	24.000	-62.250
11	4.0000		-33488.505	13253.028	24.000	-62.500
12	9.0000		-33622.459	13253.028	24.000	-62.750
13	12.0000		-33756.413	13253.028	24.000	-63.000
14	13.0000		-33890.367	13253.028	24.000	-63.250
15	13.0000		-34024.321	13253.028	24.000	-63.500
16	14.0000		-34158.275	13253.028	24.000	-63.750
17	14.0000		-34292.229	13253.028	24.000	-64.000
18	15.0000		-34426.183	13253.028	24.000	-64.250
19	14.0000		-34560.137	13253.028	24.000	-64.500
20	14.0000		-34694.091	13253.028	24.000	-64.750
21	14.0000		-34828.045	13253.028	24.000	-65.000
22	15.0000		-34961.999	13253.028	24.000	-65.250
23	15.0000		-35095.953	13253.028	24.000	-65.500

Recalculate Contours Save to AXD... Load from AXD...

OK Remove Cancel Help

In Version 24 they can be used with any contour type, not just spatial data ones



# Available ERA5 Fields in Simulator

---

- The ERA5 dataset has hundreds of different values; currently we are using nine of them
  - Surface temperature, surface dew point
  - Wind speed at 10m, wind direction at 10m
  - Wind speed at 100m
  - Wind gusts
  - Total cloud cover (which takes into account all the layers)
  - Total sky direct short-wave (solar) radiation at surface (fdir); used to get the direct horizontal irradiance and the Direct Normal Irradiance (DNI)
  - Surface short-wave (solar) radiation downwards (ssrd); this is used with the direct horizontal irradiance to get the Diffuse Horizontal Irradiance
  - Derived values, like humidity and wind chill, are also available

# Available HRRR Fields in Simulator

---

- Likewise, HRRR has many values; currently we are using 11 of them
  - Surface temperature, surface dew point
  - Wind speed at 10m, wind direction at 10m
  - Wind speed at 80m (converted to 100m when stored)
  - Total cloud cover (which takes into account all the layers)
  - Total sky direct short-wave (solar) radiation at surface (fdir); used to get the direct horizontal irradiance and the Direct Normal Irradiance (DNI)
  - Wind gusts
  - Hourly precipitation (mm/hr)
  - Percent frozen precipitation
  - Vertically-integrated total smoke ( $\text{mg}/\text{m}^2$ )
  - Derived values like humidity are also available

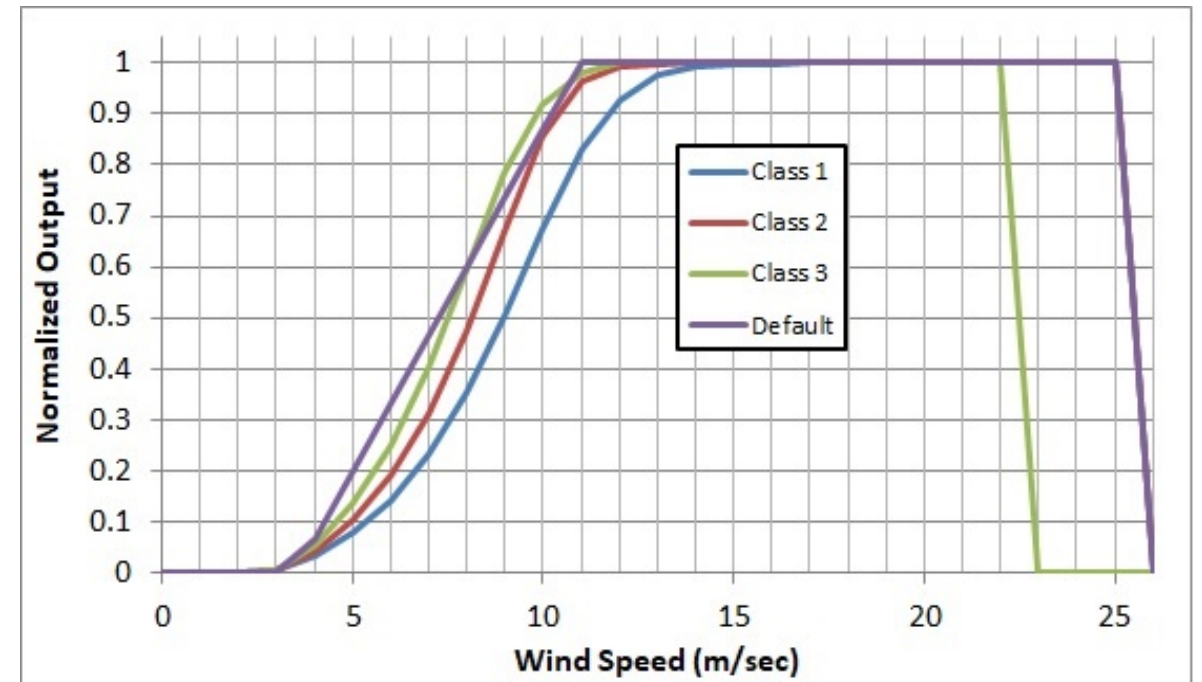
# Models of Grid Weather Impacts

---

- Key focus here isn't weather per se, but modeling the impacts of weather on electric grid components (e.g., generators, lines)
- Certainly, a number of models already exist, and undoubtedly more will be created given that weather data is now conveniently available
- The approach used here for handling a growing list of models is to mimic what has been done with power system stability – start small and expand
  - Early (1960) stability codes just had a handful of models, whereas current codes support many hundreds of different model types
- PowerWorld implements this using PFW Models
  - PFW = Power Flow Weather or Power Flow Whatever models

# Example: Gen MaxMW Wind and Solar

- An example is modeling the impact of wind speed on wind turbine output, or solar irradiation on PV output
  - The image on the right shows several of the generic wind turbine models are based on the turbine classes using data from [a]
  - A simple solar PV model uses either provided solar irradiation or the standard equations for insolation based on location and time of day including cloud cover; this is combined with whether the solar has tracking and, if needed, its tilt and azimuth



[a] C. Draxl, A. Clifton, B. Hodge, J. McCaa, "The Wind Integration National Dataset (WIND) Toolkit," *Applied Energy*, vol. 151, pp. 355-366, 2015.

# Example: Customized Wind Power Curve Model

- Customized wind power curve models can also be defined; this only needs to be done once per wind generator

PFW Models Weather Details Apply Time-Varying Weather to PFW Model Weather Interpolation Details

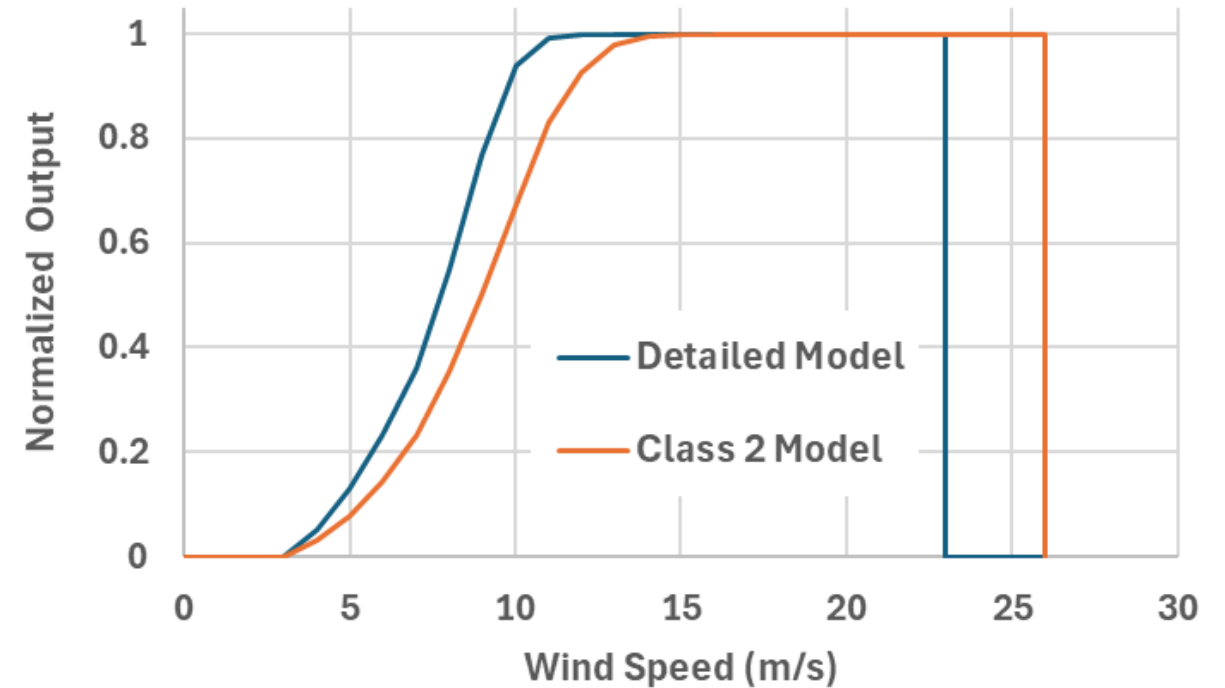
PFW Gen Object

Insert Delete

Type Active - WindGeneral  Active (only one may be active) Set to Defaults

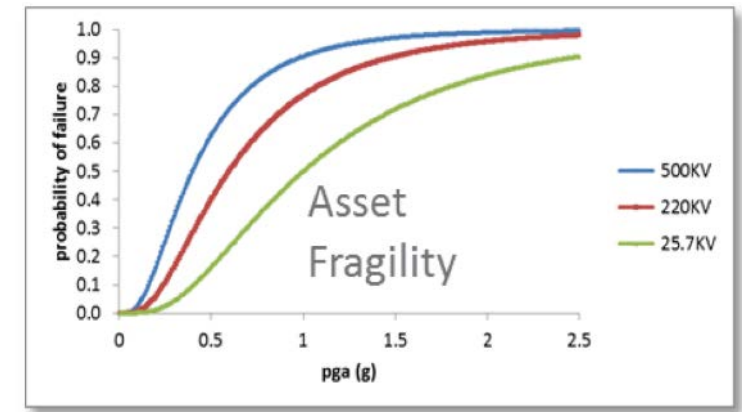
Parameters

Description	Speed1	0.0000	PowerScalar5	0.0500	Speed10
AllowTurnOff	1	PowerScalar1	0.00062	Speed6	5.0000
AllowTurnOn	1	Speed2	1.0000	PowerScalar6	0.1599
MWMax	217.0000	PowerScalar2	0.00062	Speed7	6.0000
HubHeightScalar	1.5000	Speed3	2.0000	PowerScalar7	0.3111
WindSpeedScalar	1.0500	PowerScalar3	0.00062	Speed8	7.0000
HubHeightM	80.1624	Speed4	3.0000	PowerScalar8	0.4988
CutOut1MS	26.0000	PowerScalar4	0.00062	Speed9	8.0000
CutOut2MS	26.0000	Speed5	4.0000	PowerScalar9	0.7154
				Speed14	1



# Additional PFWs, Including Stochastic Models

- Many different PFW models are possible, and they could certainly be stochastic
- Examples include ambient-adjusted line ratings, dynamic line ratings, thermal generator output variation with temperature, line outage due to wind gusts, asset failure during earthquakes (see figure with pga=Peak Ground Acceleration), incremental impacts of temperature on load, etc.
- Many such models exist in the literature, with others needing to be developed;



# Example: Gen MaxMW PFW Model

- Individual generator PFW models can be entered or viewed using the generator dialog

Generator Information for Present

Bus Number: 57643 Find By Number Status:  Open  Closed View Bus Dialog

Bus Name: Vestas Towers America, Inc Find By Name View Area Dialog

ID: 83 Find ... Energized:  NO (Offline)  YES (Online) View Substation Dialog

Area Name: CS Wind America, Inc. ( Fuel Type: Renew(WIND (Wind)) [PW=12] [E] Unit Type: WT (Wind Turbine) [PW=19] [E]

Labels ...: 57643\_V100 Generator MVA Base: 1.80

Power and Voltage Control Costs OFF Faults Owners, Area, etc. Custom Stability PFWModels, Weather

PFW Models Weather Details Apply Time-Varying Weather to PFW Model Weather Interpolation Details

PFW Gen Object

Insert Delete

Type: Active - WindClass2  Active (only one may be active) Set to Defaults

Parameters

AllowTurnOff	1	HubHeightM	80.0000
AllowTurnOn	1	MWMax	1.8000
HubScalar	1.5000	DefaultWindMS	5.0000

OK Save Save to Aux Cancel Help Print

Generator Information for Present

Bus Number: 56665 Find By Number Status:  Open  Closed View Bus Dialog

Bus Name: Goodhoe Hills Find By Name View Area Dialog

ID: 56 Find ... Energized:  NO (Offline)  YES (Online) View Substation Dialog

Area Name: PacifiCorp (14354) Fuel Type: Renew(WIND (Wind)) [PW=12] [E] Unit Type: WT (Wind Turbine) [PW=19] [E]

Labels ...: 56665\_1 Generator MVA Base: 103.40

Power and Voltage Control Costs OFF Faults Owners, Area, etc. Custom Stability PFWModels, Weather

PFW Models Weather Details Apply Time-Varying Weather to PFW Model Weather Interpolation Details

PFW Gen Object

Insert Delete

Type: WindGeneral  Active (only one may be active) Set to Defaults

Parameters

AllowTurnOff	1	Speed2	3.0000	Speed7	8.0000	Speed12
AllowTurnOn	1	PowerScalar2	0.00500	PowerScalar7	0.5300	PowerScalar12
MWMax	94.0000	Speed3	4.0000	Speed8	9.0000	Speed13
HubScalar	1.5000	PowerScalar3	0.05000	PowerScalar8	0.7400	PowerScalar13
DefaultWindMS	5.0000	Speed4	5.0000	Speed9	10.0000	Speed14
HubHeightM	80.0000	PowerScalar4	0.1200	PowerScalar9	0.8800	PowerScalar14
CutOut1MS	25.0000	Speed5	6.0000	Speed10	11.0000	Speed15
CutOut2MS	25.0000	PowerScalar5	0.2200	PowerScalar10	0.9700	PowerScalar15
Speed1	2.0000	Speed6	7.0000	Speed11	12.0000	Speed16
PowerScalar1	0.00000	PowerScalar6	0.3500	PowerScalar11	1.0000	PowerScalar16

OK Save Save to Aux Cancel Help Print

Generator Information for Present

Bus Number: 20185 Find By Number Status:  Open  Closed View Bus Dialog

Bus Name: Solverde 1 Find By Name View Area Dialog

ID: 59 Find ... Energized:  NO (Offline)  YES (Online) View Substation Dialog

Area Name: AES Distributed Energy Fuel Type: Renew(SUN (Solar)) [PW=10] [E] Unit Type: PV (Photovoltaic) [PW=17] [E]

Labels ...: 60185\_SOLV1 Generator MVA Base: 85.00

Power and Voltage Control Costs OFF Faults Owners, Area, etc. Custom Stability PFWModels, Weather

PFW Models Weather Details Apply Time-Varying Weather to PFW Model Weather Interpolation Details

PFW Gen Object

Insert Delete

Type: Active - SolarPVBasic2  Active (only one may be active) Set to Defaults

Parameters

AllowTurnOff	1
AllowTurnOn	1
Tracking	2
MWMax	81.0000
AzimuthDeg	90.0000
TiltAngleDeg	30.0000
DiffuseFactor	0.1000
DefaultCloud	0.00000

OK Save Save to Aux Cancel Help Print

# Entering Large Number of PFW Models

- A large number of PFW models can be entered by going to the **Weather, Weather Models and Information, PFW Models** page

- The Generator PFW Models list shows all the generators in the case

- Select the desired ones, right-click and select **Insert New PFW Models**

- They can also be added with aux files or by pasting them in

Weather Related Models and Information

Power Flow Weather (PFW) Models Weather Stations Weather (PWW) File Management Weather (PWW) One Location

Power Flow Weather (PFW) Model Options

Update PFW Weather Information and Set Inputs Load PFW Model Aux File

Update PFW Weather Information; Apply to Power System Save All PFW Models in Aux

Restore Design PFW Values PFW Models Applied in Case: NO

Last Action:

Power Flow Model Date and Time

Local Date and Time 12/31/2023

Date and Time (UTC) 2023-12-31T00:00:00Z

Weather Station Summary

Number of Weather Stations 0

Number With at Least Some Valid Values 0

Min Latitude Min Longitude

Max Latitude Max Longitude

PFW Model Summary PFW Models All Generator PFW Models

	Number of Bus	Name of Bus	ID	Status	Gen MW	Min MW	Max MW	Fuel Type	PFW Model Count Active	PFW Model Count Inactive	Active PFW Model(s)	Weather Station	Cust Int 2	Cust Fit
1	55369	Hamakua Energ	38	Closed	0.00	0.00	17.40	WO (Waste/Oth	0	0				
2	6285	North Pole	12	Closed	0.00	0.00	12.00	WO (Waste/Oth	0	0				
3	6285	North Pole	11	Closed	0.00	0.00	53.00	WO (Waste/Oth	0	0				
4	55369	Hamakua Energ	37	Closed	0.00	0.00	21.70	WO (Waste/Oth	0	0				
5	7841	Valdez Cogen	36	Closed	0.00	0.00	5.30	WO (Waste/Oth	0	0				
6	10093	Tesoro Hawaii	82	Closed	0.00	0.00	20.00	WO (Waste/Oth	0	0				
7	55369	Hamakua Energ	36	Closed	0.00	0.00	21.70	WO (Waste/Oth	0	0				
8	56959	Ocotillo Windp	90	Closed	0.00	0.00	58.80	WND (Wind)	1	0	WindClass2			2
9	62562	High Lonesome	31	Closed	0.00	0.00	50.00	WND (Wind)	1	0	WindClass2			2
10	56858	Sagebrush Pow	17	Closed	0.00	0.00	100.70	WND (Wind)	0	0	WindClass2			2
11	58837	Na Pua Makani	169	Closed	0.00	0.00	27.60	WND (Wind)	1	0	WindClass3			3
12	56979	Panther Creek	V 21	Closed	0.00	0.00	231.50	WND (Wind)	1	0	WindClass2			2
13	56544	Windom Wind	F 47	Closed	0.00	0.00	15.60	WND (Wind)	1	0	WindClass2			2
14	56961	Notrees Windp	94	Closed	0.00	0.00	92.50	WND (Wind)	1	0	WindClass2			2
15	65335	Appaloosa Run	61	Closed	0.00	0.00	171.80	WND (Wind)	1	0	WindClass3			3
16	56485	Biglow Canyon	187	Closed	0.00	0.00	161.00	WND (Wind)	1	0	WindClass2			2
17	58594	Steele Flats	Win 66	Closed	0.00	0.00	74.80	WND (Wind)	1	0	WindClass3			3
18	57047	Nobles Wind	Pr 74	Closed	0.00	0.00	200.00	WND (Wind)	1	0	WindClass2			2
19	61638	Turtle Creek	Wir 50	Closed	0.00	0.00	199.20	WND (Wind)	1	0	WindClass3			3
20	63521	CED Mason	City 38	Closed	0.00	0.00	7.90	WND (Wind)	1	0	WindClass2			2
21	61921	Tahoka Wind	95	Closed	0.00	0.00	300.00	WND (Wind)	1	0	WindClass2			2
22	56209	Boeve Windfarr	71	Closed	0.00	0.00	2.00	WND (Wind)	1	0	WindClass3			3
23	62711	Plum Creek	Win 39	Closed	0.00	0.00	230.00	WND (Wind)	1	0	WindClass2			2
24	59493	Prospector	Win 6	Closed	0.00	0.00	10.00	WND (Wind)	1	0	WindClass3			3
25	58830	Cross Winds	Eni 57	Closed	0.00	0.00	44.00	WND (Wind)	1	0	WindClass3			3
26	56974	Wagon Trail	LLC 19	Closed	0.00	0.00	3.30	WND (Wind)	1	0	WindClass2			2
27	60596	Baron Winds	Fa 99	Closed	0.00	0.00	130.00	WND (Wind)	1	0	WindBasic			
28	56538	Loess Hills	40	Closed	0.00	0.00	5.00	WND (Wind)	1	0	WindClass2			2
29	58765	Miami Wind	En 77	Closed	0.00	0.00	288.60	WND (Wind)	1	0	WindClass2			2

# Making it Easy to Get Started: Using EIA-860 Data

---

- To make it easy to get started we've setup copper plate (i.e., no transmission) power flow cases with PFW models based the data provided by the US Energy Information Administration (EIA) in their Form EIA-860 datasets
  - EIA-860 provides data on every generator in the US with 1 MW or more capacity
  - Available at [www.eia.gov/electricity/data/eia860/](http://www.eia.gov/electricity/data/eia860/); it is released yearly with monthly updates available
- We take this data and convert it into a copper plate power flow model, with the resultant cases publicly available at
  - [electricgrids.engr.tamu.edu/eia-860-generator-data-cases/](http://electricgrids.engr.tamu.edu/eia-860-generator-data-cases/)
  - Details on this process are in a 2024 TPEC paper (available as a 2024 paper at [overbye.engr.tamu.edu/publications/](http://overbye.engr.tamu.edu/publications/))

# Example EIA-860 Wind Generator Data

- Right image shows the PFW models to map weather (wind speed) to MW Max
  - From the **Weather, Weather Models and Information** display
- Bottom image shows some EIA-860 wind generators with turbine information

Power Flow Weather (PFW) Models Weather Stations Weather (PWW) File Management Weather (PWW) C

Power Flow Weather (PFW) Model Options

Update PFW Weather Information and Set Inputs Load PFW Model Aux File

Update PFW Weather Information; Apply to Power System Save All PFW Models in Aux

Restore Design PFW Values PFW Models Applied in Case: YES

Last Action:

PFW Model Summary PFW Models All Generator PFW Models

	Model Class	Object Type	Active and Online Count	Active Count	Inactive Count
1	_All Models	_All Models	7540	7640	0
2	Gen MWMax	SolarPVBasic2	6104	6113	0
3	Gen MWMax	WindBasic	30	35	0
4	Gen MWMax	WindClass1	158	168	0
5	Gen MWMax	WindClass2	845	885	0
6	Gen MWMax	WindClass3	374	398	0
7	Gen MWMax	WindClass4	29	41	0

PFW Usage of Model Type WindClass2

Number of Models: 774 (Active: 885, Inactive: 0)

	Number of Bus	ID	Name_Nominal kV of Bus	Area Name of Gen	Model Type	MVA Base	Device Status	Criteria	Model Class	User Specified Weather Station	Input1 Value	Input2 Value	Input3 Value	Input1 Valid	Input2 Valid	Input3 Valid
1	90	0	Snake River_138.0	Nome Joint Utility Systems	WindClass2	0.9	Active		Gen MWMax		1.7882	4.0234		Yes	Yes	No
2	90	99	Snake River_138.0	Nome Joint Utility Systems	WindClass2	0.9	Active		Gen MWMax		1.7882	4.0234		Yes	Yes	No
3	508	86	Lamar Plant_138.0	City of Lamar - (CO)	WindClass2	4.5	Active		Gen MWMax		4.0234	5.3645		Yes	Yes	No
4	508	87	Lamar Plant_138.0	City of Lamar - (CO)	WindClass2	1.5	Active		Gen MWMax		4.0234	5.3645		Yes	Yes	No
5	692	85	Medicine Bow_138.0	SRIV Partnership LLC	WindClass2	4.9	Active		Gen MWMax		8.4938	14.7523		Yes	Yes	No
6	692	86	Medicine Bow_138.0	SRIV Partnership LLC	WindClass2	1.3	Active		Gen MWMax		8.4938	14.7523		Yes	Yes	No
7	944	32	Geneseo_138.0	City of Geneseo - (IL)	WindClass2	1.5	Active		Gen MWMax		4.4704	7.1526		Yes	Yes	No
8	944	33	Geneseo_138.0	City of Geneseo - (IL)	WindClass2	1.5	Active		Gen MWMax		4.4704	7.1526		Yes	Yes	No
9	1172	47	Osage (IA)_138.0	City of Osage - (IA)	WindClass2	1.6	Active		Gen MWMax		3.1293	4.9174		Yes	Yes	No
10	1998	34	Mountain Lake_138.0	City of Mountain Lake - (MN)	WindClass2	1.2	Active		Gen MWMax		2.2352	3.1293		Yes	Yes	No
11	2022	96	Willmar_138.0	Willmar Municipal Utilities	WindClass2	2	Active		Gen MWMax		1.7882	2.2352		Yes	Yes	No
12	2022	97	Willmar_138.0	Willmar Municipal Utilities	WindClass2	2	Active		Gen MWMax		1.7882	2.2352		Yes	Yes	No
13	2024	12	Worthington_138.0	City of Worthington - (MN)	WindClass2	0.9	Active		Gen MWMax		2.2352	4.4704		Yes	Yes	No
14	2024	13	Worthington_138.0	City of Worthington - (MN)	WindClass2	0.9	Active		Gen MWMax		2.2352	4.4704		Yes	Yes	No
15	2024	2	Worthington_138.0	City of Worthington - (MN)	WindClass2	0.9	Active		Gen MWMax		2.2352	4.4704		Yes	Yes	No
16	2024	3	Worthington_138.0	City of Worthington - (MN)	WindClass2	0.9	Active		Gen MWMax		2.2352	4.4704		Yes	Yes	No
17	2024	4	Worthington_138.0	City of Worthington - (MN)	WindClass2	1	Active		Gen MWMax		2.2352	4.4704		Yes	Yes	No
18	2024	5	Worthington_138.0	City of Worthington - (MN)	WindClass2	1	Active		Gen MWMax		2.2352	4.4704		Yes	Yes	No
19	6304	46	Kotzebue Hybrid_138.0	Kotzebue Electric Assn Inc	WindClass2	0.1	Active		Gen MWMax		1.7882	4.0234		Yes	Yes	No
20	6304	47	Kotzebue Hybrid_138.0	Kotzebue Electric Assn Inc	WindClass2	0.1	Active		Gen MWMax		1.7882	4.0234		Yes	Yes	No
21	6304	49	Kotzebue Hybrid_138.0	Kotzebue Electric Assn Inc	WindClass2	0.1	Active		Gen MWMax		1.7882	4.0234		Yes	Yes	No

For the CEII grids we have bus mapping for more than 95% of the generator capacity

# Convenient Access to Wind Turbine Power Curves

- Reference [a], from PNNL, provides good access to power curves for all the wind turbines in CONUS as of end of 2020
- The data they provide can be directly pasted into Simulator

GenM	Max_Wind	General	Label (for use in input)	AllowTurn	Turn	Device	Sta	MW	Max	HubHeight	Power-Speed Curve	plant_cod	plant_cod	generator	lat	lon	ba	nerc	regio	state	system_cz	wind_farm	wind_farm	wind_turbi	wind_turbi	wind_turbi	wind_turbi	wind_resoi	wind_resoi	wind_resoi	wind_farm	turb_generat	adjus
508_T4	1	1	Active	1.5	79.97952	[0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.25, 3	508	508_1	T4	38.03333	-102.538	PSCO	WECC	CO	1500	[0]	[0]	79.97952	[0.0, 0.0, 0.0]	[0.0, 0.25,	82.5	0.14	0.1	0	0	15							
508_T1-T3	1	1	Active	4.5	79.97952	[0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.25, 3	508	508_T1-T3		38.03333	-102.538	PSCO	WECC	CO	4500	[0, 660.0,	[0, 0, 660.0,	79.97952	[0.0, 0.0, 0.0]	[0.0, 0.25,	82.5	0.14	0.1	0	0	15							
692_10	1	1	Active	4.9	49.9872	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	692	692	10	41.83528	-106.243	WAUW	WECC	WY	4900	[0, 376.0,	[0, 0, 0, 0,	49.9872	[0, 0, 0, 0,	[0.0, 0.506	47	0.14	0.1	0	0	15							
692_11	1	1	Active	1.3	49.9872	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	692	692_1	11	41.83528	-106.243	WAUW	WECC	WY	1300	[0, 336.0,	[0, 0]	49.9872	[0, 0, 0, 0,	[0.0, 0.506	42	0.14	0.1	0	0	15							
944_10	1	1	Active	1.5	60.96	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	944	944	10	41.45149	-90.1485	MISO	MRO	IL	1500	[0]	[0]	60.96	[0, 0, 0, 0,	[0.0, 0.506	77	0.14	0.1	0	0	15							
944_11	1	1	Active	1.5	60.96	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	944	944_1	11	41.45149	-90.1485	MISO	MRO	IL	1500	[0]	[0]	60.96	[0, 0, 0, 0,	[0.0, 0.506	77	0.14	0.1	0	0	15							
1172_W1	1	1	Active	1.6	79.248	[0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.25, 3	1172	1172_W1		43.27972	-92.8106	MISO	MRO	IA	1600	[0]	[0]	79.248	[0.0, 0.0, 0.0]	[0.0, 0.25,	77	0.14	0.1	0	0	15							
1998_8	1	1	Active	1.2	74.9808	[3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5	1998	1998	8	43.9405	-94.9434	MISO	MRO	MN	1200	[0]	[0]	74.9808	[0.0, 0.0, 0.0]	[3.0, 3.5, 4	64	0.14	0.1	0	0	15							
2022_WTG4	1	1	Active	2	79.97952	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	2022	2022_1	WTG4	45.12171	-95.0532	MISO	MRO	MN	2000	[0]	[0]	79.97952	[0, 0, 0, 0,	[0.0, 0.506	80	0.14	0.1	0	0	15							
2022_WTG3	1	1	Active	2	79.97952	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	2022	2022	WTG3	45.12171	-95.0532	MISO	MRO	MN	2000	[0]	[0]	79.97952	[0, 0, 0, 0,	[0.0, 0.506	80	0.14	0.1	0	0	15							
2024_9	1	1	Active	0.9	73.152	[2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0,	2024	2024_5	9	43.63349	-95.6092	MISO	MRO	MN	900	[0]	[0]	73.152	[2.96, 4.48]	[2.5, 3.0, 3	52.2	0.14	0.1	0	0	15							
2024_8	1	1	Active	0.9	73.152	[2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0,	2024	2024_4	8	43.63349	-95.6092	MISO	MRO	MN	900	[0]	[0]	73.152	[2.96, 4.48]	[2.5, 3.0, 3	52.2	0.14	0.1	0	0	15							
2024_12	1	1	Active	1	73.152	[3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5	2024	2024_2	12	43.63349	-95.6092	MISO	MRO	MN	1000	[0]	[0]	73.152	[0.0, 0.0, 0.0]	[3.0, 3.5, 4	54	0.14	0.1	0	0	15							
2024_10	1	1	Active	0.9	73.152	[2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0,	2024	2024	10	43.63349	-95.6092	MISO	MRO	MN	900	[0]	[0]	73.152	[2.96, 4.48]	[2.5, 3.0, 3	52.2	0.14	0.1	0	0	15							
2024_11	1	1	Active	0.9	73.152	[2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0,	2024	2024_1	11	43.63349	-95.6092	MISO	MRO	MN	900	[0]	[0]	73.152	[2.96, 4.48]	[2.5, 3.0, 3	52.2	0.14	0.1	0	0	15							
2024_13	1	1	Active	1	73.152	[3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5	2024	2024_3	13	43.63349	-95.6092	MISO	MRO	MN	1000	[0]	[0]	73.152	[0.0, 0.0, 0.0]	[3.0, 3.5, 4	54	0.14	0.1	0	0	15							
2240_CTNWD	1	1	Active	40.9	89.916	[3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5	2240	2240	CTNWD	41.4281	-96.4623	SWPP	MRO	NE	40900	[0, 564.0,	[0, 0, 0, 0,	89.916	[0.0, 0.0, 0.0]	[3.0, 3.5, 4	70.5	0.14	0.1	0	0	15							
7381_1	1	1	Active	6	40.2336	[0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.25, 3	7381	7381	1	42.8625	-72.9628	ISNE	NPCC	VT	6000	[0, 320.0,	[0, 0, 0, 0,	40.2336	[0.0, 0.0, 0.0]	[0.0, 0.25,	40	0.14	0.1	0	0	15							
7501_2	1	1	Active	3	70.104	[4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0,	7501	7501	2	42.4789	-71.9	ISNE	NPCC	MA	3000	[0, 616.0,	[0, 0]	70.104	[54.0, 141.	[4.0, 5.0, 6	77	0.14	0.1	0	0	15							
7526_2	1	1	Active	24	79.97952	[0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.25, 3	7526	7526	2	38.11642	-121.769	CISO	WECC	CA	24000	[0, 720.0,	[0, 0, 0, 0,	79.97952	[0.0, 0.0, 0.0]	[0.0, 0.25,	90	0.14	0.1	0	0	15							
7526_2B	1	1	Active	63	79.97952	[0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.25, 3	7526	7526_1	2B	38.11642	-121.769	CISO	WECC	CA	63000	[0, 720.0,	[0, 0, 0, 0,	79.97952	[0.0, 0.0, 0.0]	[0.0, 0.25,	90	0.14	0.1	0	0	15							
7526_3	1	1	Active	128	79.97952	[0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.25, 3	7526	7526_2	3	38.11642	-121.769	CISO	WECC	CA	128000	[0, 720.0,	[0, 0, 0, 0,	79.97952	[0.0, 0.0, 0.0]	[0.0, 0.25,	90	0.14	0.1	0	0	15							
7526_1	1	1	Active	13.2	54.864	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	7526	7526_3	1	38.11642	-121.769	CISO	WECC	CA	13200	[0, 376.0,	[0, 0, 0, 0,	54.864	[0, 0, 0, 0,	[0.0, 0.506	47	0.14	0.1	0	0	15							
7771_3	1	1	Active	1.5	61.47816	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	7771	7771	3	42.82579	-99.7775	SWPP	MRO	NE	1500	[0]	[0]	61.47816	[0, 0, 0, 0,	[0.0, 0.506	77	0.14	0.1	0	0	15							
7771_4	1	1	Active	1.5	61.47816	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	7771	7771_1	4	42.82579	-99.7775	SWPP	MRO	NE	1500	[0]	[0]	61.47816	[0, 0, 0, 0,	[0.0, 0.506	77	0.14	0.1	0	0	15							
7855_8	1	1	Active	0.7	54.864	[3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.	7855	7855	8	46.895	-96.7347	SWPP	MRO	MN	700	[0]	[0]	54.864	[4.4, 16.68]	[3.5, 4.0, 4	48.2	0.14	0.1	0	0	15							
7855_9	1	1	Active	0.7	54.864	[3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.	7855	7855_1	9	46.895	-96.7347	SWPP	MRO	MN	700	[0]	[0]	54.864	[4.4, 16.68]	[3.5, 4.0, 4	48.2	0.14	0.1	0	0	15							
7886_1	1	1	Active	11	64.9224	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	7886	7886	1	44.6694	-87.6333	MISO	MRO	WI	11000	[0, 376.0,	[0, 0, 0, 0,	64.9224	[0, 0, 0, 0,	[0.0, 0.506	47	0.14	0.1	0	0	15							
7927_1	1	1	Active	0.6	64.9224	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	7927	7927	1	36.12099	-84.3387	TVA	SERC	TN	600	[0]	[0]	64.9224	[0, 0, 0, 0,	[0.0, 0.506	47	0.14	0.1	0	0	15							
7927_2	1	1	Active	0.6	64.9224	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	7927	7927_1	2	36.12099	-84.3387	TVA	SERC	TN	600	[0]	[0]	64.9224	[0, 0, 0, 0,	[0.0, 0.506	47	0.14	0.1	0	0	15							
7927_3	1	1	Active	0.6	64.9224	[0.0, 0.5063291139240507, 1.0126582278481013, 1.51898734177215,	7927	7927_2	3	36.12099	-84.3387	TVA	SERC	TN	600	[0]	[0]	64.9224	[0, 0, 0, 0,	[0.0, 0.506	47	0.14	0.1	0	0	15							

[a] C. Bracken, S. Underwood, A. Campbell, T.B. Thurber, N. Voisin, Hourly wind and solar generation profiles for every EIA 2020 plant in the CONUS, 2023, [dx.doi.org/10.5281/zenodo.7901615](https://dx.doi.org/10.5281/zenodo.7901615)

# Pasting in the Wind Power Curves

- Select all the data on the previous slide data in Excel, and copy it
- In Simulator open **Tools, Weather, Weather Models and Information**; select the PFW Model Summary page, and right-click on the WindGeneral object type

Weather Related Models and information

Historical Weather PWW File Directory C:\Projects\_2024\ERAS\_HistoricalWeatherData\CONUS\_ByYear\

Power Flow Weather (PFW) Models Weather Stations Weather (PWW) File Management Weather (PWW) One Location Weather Statistics Find Outlets

Power Flow Weather (PFW) Model Options

Update PFW Weather Information and Set Inputs Load PFW Model Aux File

Update PFW Weather Information; Apply to Power System Save All PFW Models in Aux

Restore Design PFW Values PFW Models Applied in Case: NO

Last Action:

Power Flow Model Date and Time

Local Date and Time 12/25/2022 6:00:00 PM

Date and Time (UTC) 2022-12-25T18:00:00Z

Weather Date and Time

Local Date and Time 1/28/2024 1:32:31 PM

Date and Time (UTC) 2024-01-28T13:32:31Z

PFW Model Summary PFW Models All Generator PFW Models

Show Only PFW Models in Use

	Model Class	Object Type	Active and Online Count	Active Count	Inactive Count
1	All Models	All Models	6222	6222	0
2	Gen MWMax	SolarPVBasic1	0	0	0
3	Gen MWMax	SolarPVBasic2	6222	6222	0
4	Gen MWMax	TemperatureBasic1	0	0	0
5	Gen MWMax	WindBasic	0	0	0
6	Gen MWMax	WindClass1	0	0	0
7	Gen MWMax	WindClass2	0	0	0
8	Gen MWMax	WindClass3	0	0	0
9	Gen MWMax	WindClass4	0	0	0
10	Gen MWMax	WindGeneral	0	0	0
11	Gen MWMaxMin	GenMWMaxMinXY	0	0	0

PFW Usage of Model Type WindGeneral

Close

Active and Online Active Inactive

Number of Models 0 0 0

Records Geo Set Columns

Number of Bus	ID	Name_Nominal	Area Name of Gen	Model Type	MVA Base	Device Status	Criteria	Model Class	User Specified	Input1 Value	Input2 Value	Input3 Value
1	60619	96 Rush Creek Wir	Public Service	WindGener	600	Active		Gen MWMa:				
2	63578	11 Sagamore Wind	Southwestern	WindGener	522	Active		Gen MWMa:				
3	62952	51 Cheyenne Ridg	Public Service	WindGener	498.4	Active		Gen MWMa:				
4	57501	58 Rolling Hills Wi	MidAmerican	WindGener	484.2	Active		Gen MWMa:				
5	59247	50 Hale Communit	Southwestern	WindGener	478	Active		Gen MWMa:				
6	57787	81 Flat Ridge 2 Wi	AE Power Sen	WindGener	470.4	Active		Gen MWMa:				
7	62587	45 Mesquite Star_	Mesquite Star	WindGener	418.9	Active		Gen MWMa:				
8	58695	6 Grande Prairie	BHE Renewab	WindGener	400	Active		Gen MWMa:				
9	62563	15 High Prairie Wi	Union Electric	WindGener	400	Active		Gen MWMa:				
10	61077	30 Orient Wind Fa	MidAmerican	WindGener	398.8	Active		Gen MWMa:				
11	63389	91 Jordan Creek W	Jordan Creek	WindGener	398.6	Active		Gen MWMa:				
12	61402	85 Foard City Win	Foard City Wi	WindGener	352.8	Active		Gen MWMa:				
13	63114	15 Mohave Count; Mohave	Cour	WindGener	350	Active		Gen MWMa:				
14	57195	93 Lower Snake Ri	Puget Sound	WindGener	342.7	Active		Gen MWMa:				
15	59292	85 Rattlesnake Cre	Rattlesnake C	WindGener	318.1	Active		Gen MWMa:				
16	61343	89 Karankawa Wir	Avangrid Ren	WindGener	307.1	Active		Gen MWMa:				
17	63327	20 Diamond Sprin	Allete Clean E	WindGener	303.5	Active		Gen MWMa:				
18	62038	9 Santa Rita East_	Inenergy Ser	WindGener	302.4	Active		Gen MWMa:				
19	57449	94 Blue Creek Win	Avangrid Ren	WindGener	302	Active		Gen MWMa:				

Transient Stability Usage of Model Type

Close

Active and Online Active Inactive

Number of Models 0 0

Records Geo Set Columns

Number of Bus	ID	Name_Nominal	Area Name of Gen	Model Type	MVA B	Device Status	Criteria	Model Class	User Specified	Input1
1	60619	96 Rush Creek Wir	Public Service	WindGener	600	Active		Gen MWMa:		
2	63578	11 Sagamore Wind	Southwestern	WindGener	522	Active		Gen MWMa:		
3	62952	51 Cheyenne Ridg	Public Service	WindGener	498.4	Active		Gen MWMa:		
4	57501	58 Rolling Hills Wi	MidAmerican	WindGener	484.2	Active		Gen MWMa:		
5	59247	50 Hale Communit	Southwestern	WindGener	478	Active		Gen MWMa:		
6	57787	81 Flat Ridge 2 Wi	AE Power Sen	WindGener	470.4	Active		Gen MWMa:		
7	62587	45 Mesquite Star_	Mesquite Star	WindGener	418.9	Active		Gen MWMa:		
8	58695	6 Grande Prairie	BHE Renewab	WindGener	400	Active		Gen MWMa:		
9	62563	15 High Prairie Wi	Union Electric	WindGener	400	Active		Gen MWMa:		
10	61077	30 Orient Wind Fa	MidAmerican	WindGener	398.8	Active		Gen MWMa:		
11	63389	91 Jordan Creek W	Jordan Creek	WindGener	398.6	Active		Gen MWMa:		
12	61402	85 Foard City Win	Foard City Wi	WindGener	352.8	Active		Gen MWMa:		
13	63114	15 Mohave Count; Mohave	Cour	WindGener	350	Active		Gen MWMa:		
14	57195	93 Lower Snake Ri	Puget Sound	WindGener	342.7	Active		Gen MWMa:		
15	59292	85 Rattlesnake Cre	Rattlesnake C	WindGener	318.1	Active		Gen MWMa:		
16	61343	89 Karankawa Wir	Avangrid Ren	WindGener	307.1	Active		Gen MWMa:		
17	63327	20 Diamond Sprin	Allete Clean E	WindGener	303.5	Active		Gen MWMa:		
18	62038	9 Santa Rita East_	Inenergy Ser	WindGener	302.4	Active		Gen MWMa:		
19	57449	94 Blue Creek Win	Avangrid Ren	WindGener	302	Active		Gen MWMa:		

# One Wind Turbine Example, Full CONUS Wind/Solar

The below display shows the wind (green) and solar (yellow) installed capacity; applying the weather modifies these

Generator Information for Present

Bus Number: 60619  
 ID: 96  
 Bus Name: Rush Creek Wind  
 Area Name: Public Service Co of Colorado (:)  
 Labels ...: 60619\_GEN1  
 Generator MVA Base: 600.00

Status:  Open  Closed  
 Energized:  NO (Offline)  YES (Online)

Fuel Type: Renew(WND (Wind)) [PW=12] [t]  
 Unit Type: WT (Wind Turbine) [PW=19] [E]

Power and Voltage Control Costs OPF Faults Owners, Area, etc. Custom Stability PFWModels, Weather

PFW Models Weather Details Apply Time-Varying Weather to PFW Model Weather Interpolation Details

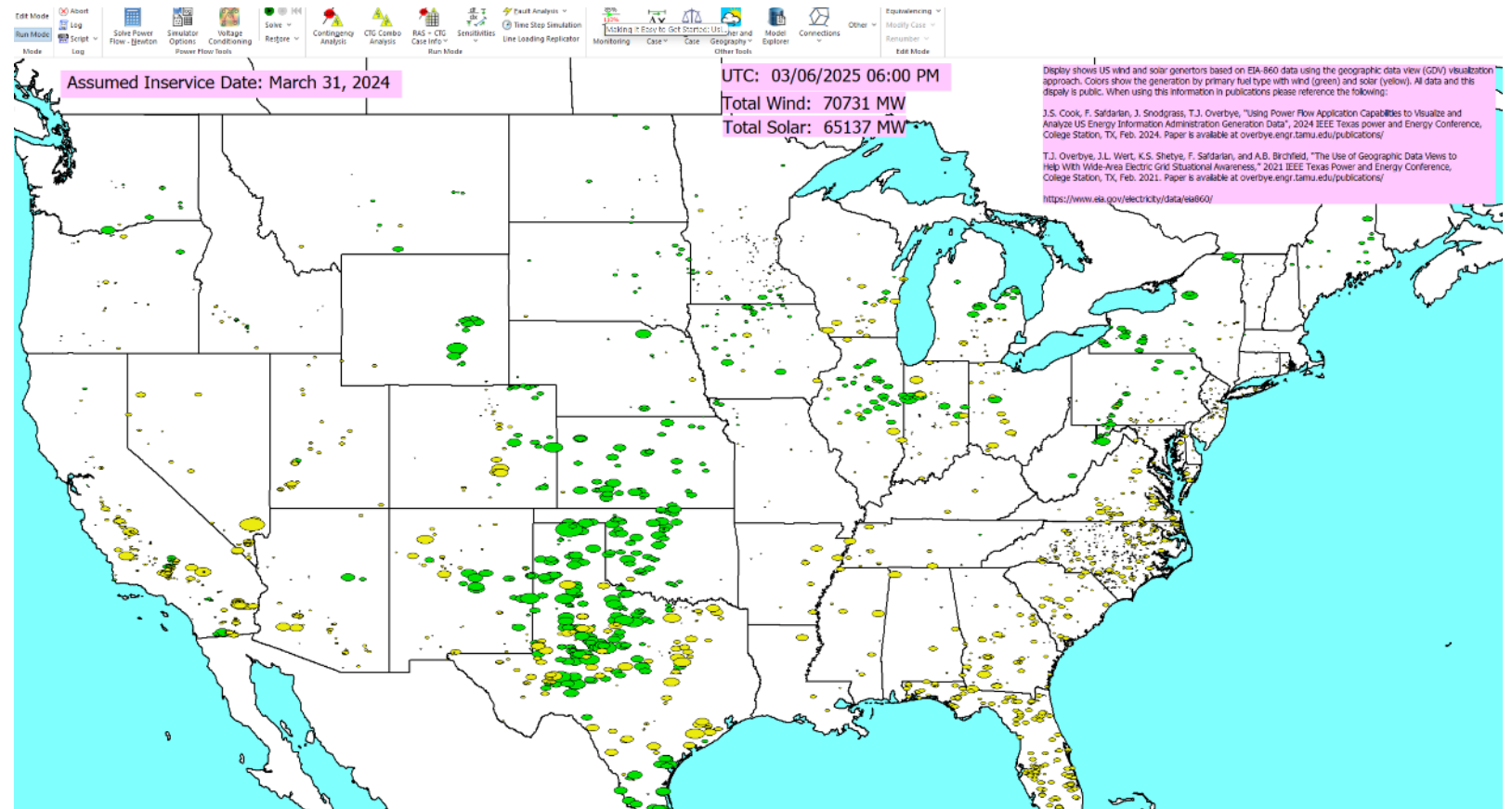
PFW Gen Object

Insert Delete

Type: Active - WindGeneral  Active (only one may be active) Set to Defaults

Parameters			
Speed1	3.0000	PowerScalar5	0.2317
Speed2	3.0015	PowerScalar6	0.3587
Speed3	3.9970	PowerScalar7	0.5503
Speed4	5.0074	PowerScalar8	0.7693
Speed5	6.0030	PowerScalar9	0.9386
Speed6	6.9985	PowerScalar10	0.9905
Speed7	8.0089	PowerScalar11	0.9989
Speed8	9.0045	PowerScalar12	0.9989
Speed9	10.0000	PowerScalar13	0.9989
Speed10	11.0104	PowerScalar14	
Speed11	12.0059	PowerScalar15	
Speed12	13.0015	PowerScalar16	
Speed13	14.0119	PowerScalar17	
Speed14	15.0074	PowerScalar18	
Speed15		PowerScalar19	
Speed16		PowerScalar20	
Speed17		PowerScalar21	
Speed18		PowerScalar22	

OK Save Save to Aux Cancel Help Print



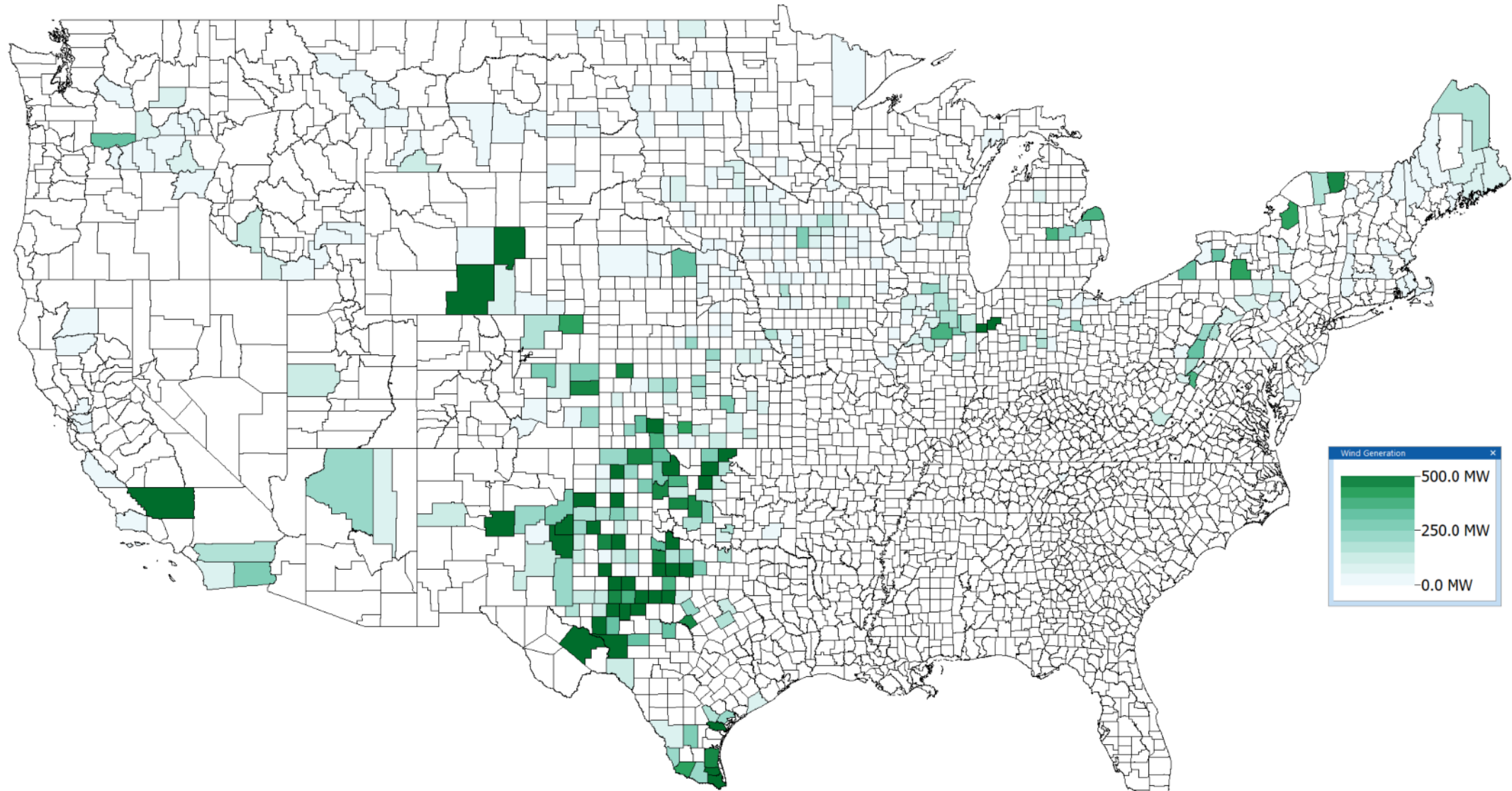
# Aside: Geographic Regions in Simulator Version 24

- New with version 24, Simulator can directly model geographic regions, including showing a summary and details on the buses in regions; results can also be visualized
- The functionality is available by selecting **Tools, Weather and Geography, Regions**
- Regions can be either stored in aux files, imported using shape files, or setup manually

	Name, Class	Name, Proper	Name, Proper 2	Geography Point Count	Geography Subgroup Count	Latitude, Minimum	Latitude, Maximum	Longitude, Min	Longitude, Max	# of Buses	Gen MW	Gen MW Wind	Gen Mvar	Load MW	Load Mvar	Shunt MW	Shunt Mvar
1	48	Nolan		39	1	32.081	32.525	-100.665	-100.147	15	2250.96	2080.515	0.00				
2	35	Torrance		78	1	34.260	35.042	-106.471	-105.290	10	1793.73	1756.200	0.00				
3	06	Kern		240	1	34.791	35.798	-120.194	-117.616	247	3652.17	1753.117	0.00				
4	48	Taylor		54	1	32.081	32.523	-100.152	-99.630	8	1441.41	1441.413	0.00				
5	48	Hansford		25	1	36.055	36.500	-101.624	-101.085	5	1220.80	1220.800	0.00				
6	20	Ford		56	1	37.467	37.914	-100.227	-99.556	7	1180.80	1180.800	0.00				
7	56	Converse		123	1	42.289	43.500	-106.078	-104.892	9	1147.76	1147.757	0.00				
8	48	Crockett		900	1	30.287	31.087	-102.391	-100.961	3	1024.50	1024.500	0.00				
9	48	Sterling		31	1	31.556	32.087	-101.268	-100.822	5	1145.59	1018.200	0.00				
10	48	Scurry		42	1	32.525	32.970	-101.175	-100.656	14	1482.36	990.700	0.00				
11	48	Oldham		32	1	35.183	35.628	-103.043	-102.163	6	964.38	964.377	0.00				
12	48	Floyd		38	1	33.830	34.313	-101.565	-101.041	6	957.19	957.194	0.00				
13	56	Carbon		70	1	40.999	42.434	-107.930	-106.068	15	926.36	926.363	0.00				
14	40	Garfield		96	1	36.164	36.594	-98.105	-97.461	7	892.71	882.705	0.00				
15	48	Carson		32	1	35.182	35.625	-101.623	-101.086	11	850.22	850.224	0.00				
16	18	Benton		44	1	40.476	40.737	-87.527	-87.094	5	828.58	828.584	0.00				

Shows the wind generation by county

# Aside: Geographic Regions Showing Wind Generation by County



# Mapping Weather to the Electric Grid Components

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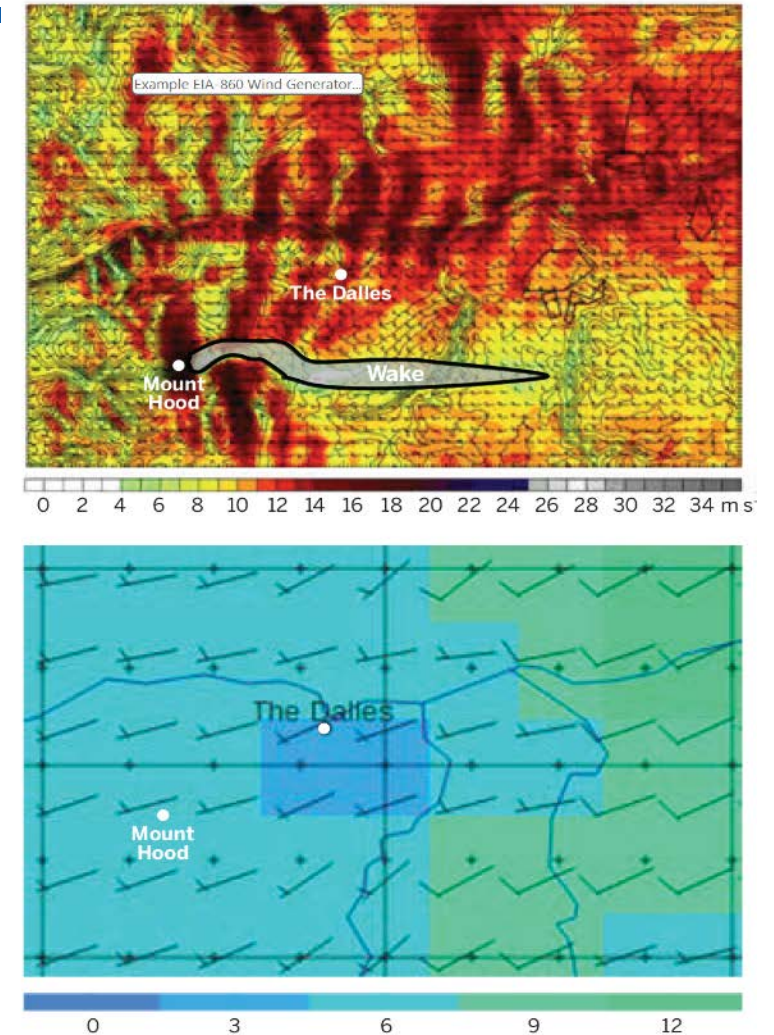
- While the newer weather datasets have lots of points, there is still usually at least some distance between power grid components and the nearest weather measurement, requiring interpolation
- There is no single best algorithm for doing the needed 2D scattered data interpolation, but there are a number of good and fast algorithms (grid-based, closest neighbor, Delaunay Triangulation, Shepherd's)
  - Since the weather values have an associated elevation, if the power grid component's elevation (or profile for a line) is known this could be considered
- If high resolution is needed, then HRRR data can be quite useful

# Dealing with Local Terrain

- In some situations, particularly wind, the local terrain variation can be significant, meaning that by themselves datasets like ERA5 may not be sufficient
  - High resolution datasets like HRRR can certainly help in these situations
- It is important to keep in mind the ultimate goal of using weather in planning; often quite acceptable results can be obtained including compensation terms in the PFW models that only need to be set once

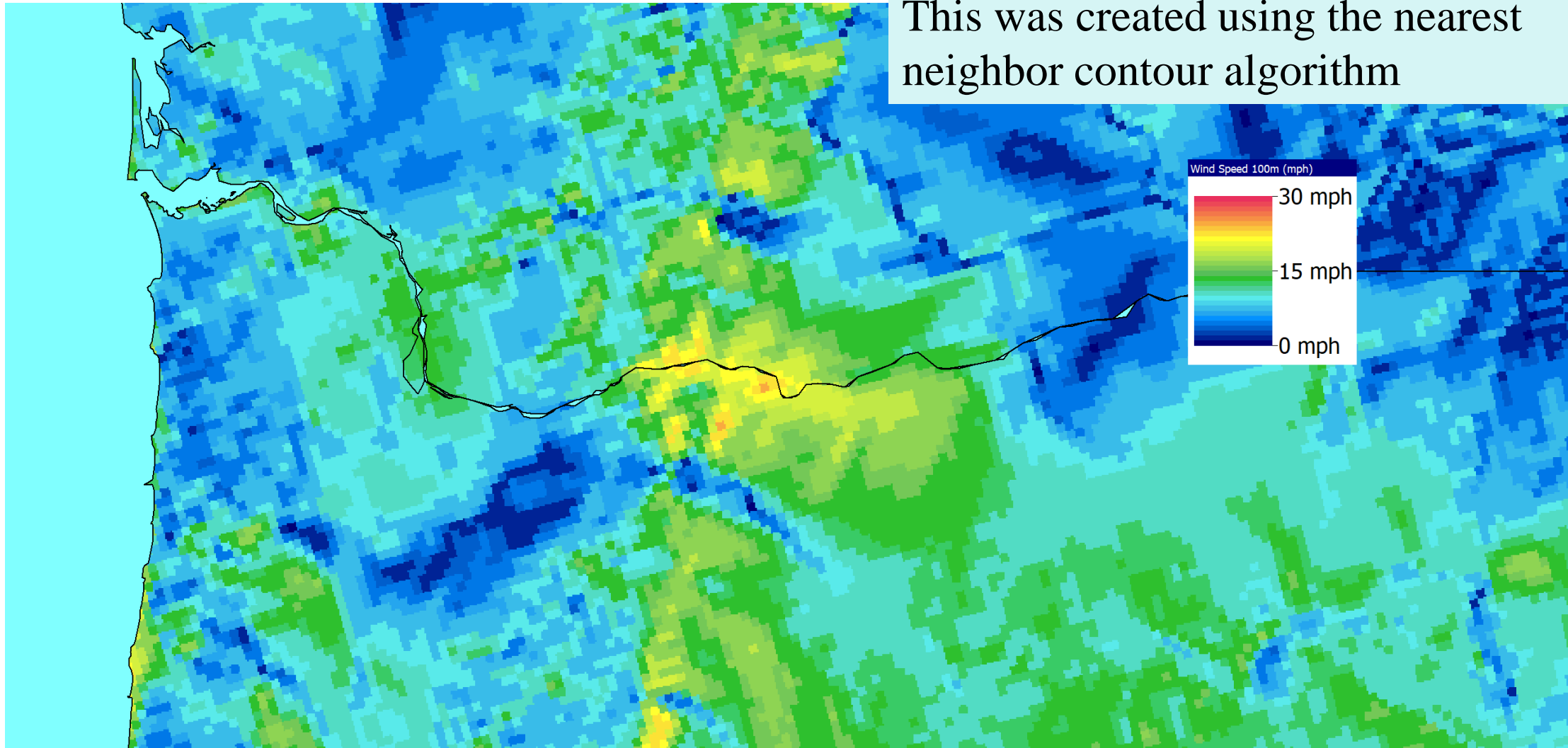
FIGURE 5

Wakes and Waves Observable in a 1 km, But Not 30 km, Simulation of the Columbia Gorge in the U.S. Pacific Northwest



The output from a 1 km Weather Research and Forecasting (WRF) simulation (top) clearly shows mountain wake and wave activity to the east of Mount Hood, whereas the output from the 30 km ERA5 dataset (bottom) for the same hour in April 2010 does not show this activity.

# Simulator HRRR 100m Wind Contour Columbia River



# Reducing the Geographic Footprint

- Using data for all of North America is not usually recommended
  - Smaller footprints use less memory, down quicker and require less computation
  - We are supplying data more most of North America to make sure all data is available for subsequent reduction

- PowerWorld has a tool to make it easy to reduce the footprint by specifying a new geographic rectangle
- **At Tools, Weather, Weather Models and Information on the Weather PWW File Management page**

The screenshot shows the 'Weather PWW File Management' tool interface. The 'Reduce Geographic Size' section is active, with the following settings:

- Minimum Latitude: 25.50
- Maximum Latitude: 37.00
- Minimum Longitude: -107.00
- Maximum Longitude: -93.00
- Output Dir.: (Browse...)
- File Prefix: (empty)
- Do File Reduction: (button)
- Status: (button)

The 'Consolidate Selected PWW Files' section has the following settings:

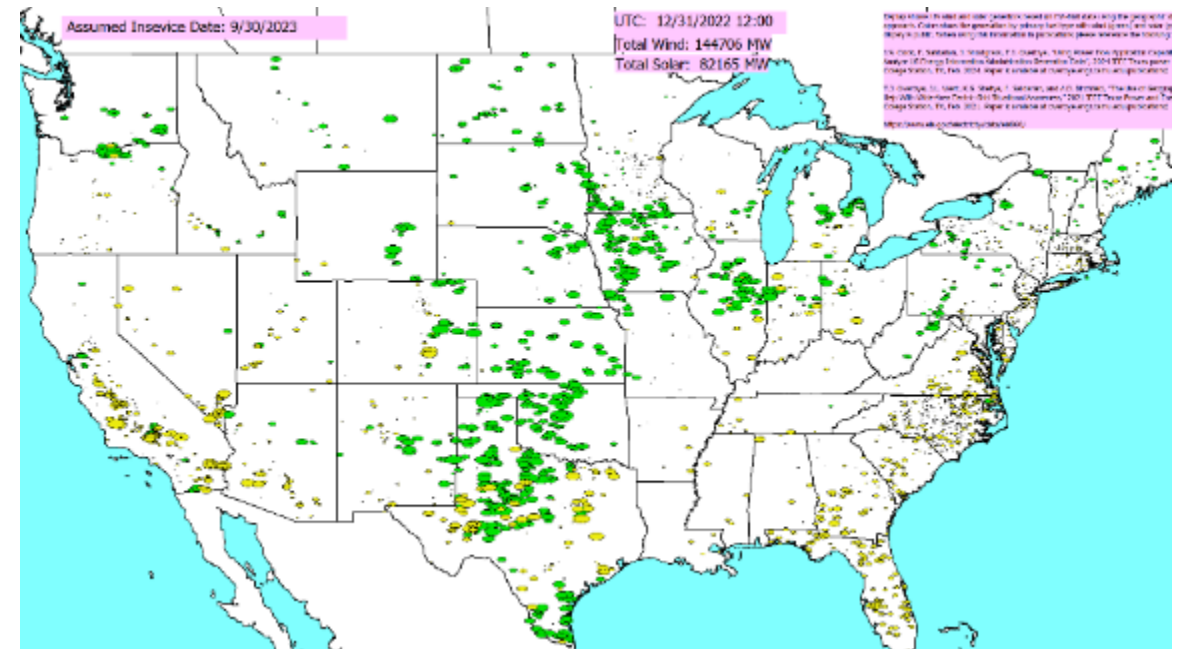
- Consolidate By: Quarter (selected)
- Output Directory for Consolidated PWW File: (empty)
- File Prefix: (empty)
- Update Historical Weather Directory to: (checkbox checked)
- Do File Consolidation: (button)
- Cancel Consol: (button)
- Status: (button)

The 'PWW File Information' table is displayed below the configuration:

	FileName without Path	First Date/Tim	Last Date/Time	Date Count	Date Range Type	File Selected	Minimum Latitude	Maximum Latitude	Minimum Longitude	Maximum Longitude	File Size (MB)	Date File Modified
1	CONUS1940	01/01/1940, 00:00	12/31/1940, 23:00	366	Year	NO	24.50	49.00	-125.00	-66.50	1559.9796	06/04/2024, 15:11
2	CONUS1941	01/01/1941, 00:00	12/31/1941, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:12
3	CONUS1942	01/01/1942, 00:00	12/31/1942, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:14
4	CONUS1943	01/01/1943, 00:00	12/31/1943, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:16
5	CONUS1944	01/01/1944, 00:00	12/31/1944, 23:00	366	Year	NO	24.50	49.00	-125.00	-66.50	1559.9796	06/04/2024, 15:17
6	CONUS1945	01/01/1945, 00:00	12/31/1945, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:19
7	CONUS1946	01/01/1946, 00:00	12/31/1946, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:20
8	CONUS1947	01/01/1947, 00:00	12/31/1947, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:22
9	CONUS1948	01/01/1948, 00:00	12/31/1948, 23:00	366	Year	NO	24.50	49.00	-125.00	-66.50	1559.9796	06/04/2024, 15:24
10	CONUS1949	01/01/1949, 00:00	12/31/1949, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:25
11	CONUS1950	01/01/1950, 00:00	12/31/1950, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:27
12	CONUS1951	01/01/1951, 00:00	12/31/1951, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:28
13	CONUS1952	01/01/1952, 00:00	12/31/1952, 23:00	366	Year	NO	24.50	49.00	-125.00	-66.50	1559.9796	06/04/2024, 15:30
14	CONUS1953	01/01/1953, 00:00	12/31/1953, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:31
15	CONUS1954	01/01/1954, 00:00	12/31/1954, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:33
16	CONUS1955	01/01/1955, 00:00	12/31/1955, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:35
17	CONUS1956	01/01/1956, 00:00	12/31/1956, 23:00	366	Year	NO	24.50	49.00	-125.00	-66.50	1559.9796	06/04/2024, 15:36
18	CONUS1957	01/01/1957, 00:00	12/31/1957, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:38
19	CONUS1958	01/01/1958, 00:00	12/31/1958, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:39
20	CONUS1959	01/01/1959, 00:00	12/31/1959, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:41
21	CONUS1960	01/01/1960, 00:00	12/31/1960, 23:00	366	Year	NO	24.50	49.00	-125.00	-66.50	1559.9796	06/04/2024, 15:43
22	CONUS1961	01/01/1961, 00:00	12/31/1961, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:44
23	CONUS1962	01/01/1962, 00:00	12/31/1962, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:46
24	CONUS1963	01/01/1963, 00:00	12/31/1963, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:47
25	CONUS1964	01/01/1964, 00:00	12/31/1964, 23:00	366	Year	NO	24.50	49.00	-125.00	-66.50	1559.9796	06/04/2024, 15:49
26	CONUS1965	01/01/1965, 00:00	12/31/1965, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:50
27	CONUS1966	01/01/1966, 00:00	12/31/1966, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:52
28	CONUS1967	01/01/1967, 00:00	12/31/1967, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:54
29	CONUS1968	01/01/1968, 00:00	12/31/1968, 23:00	366	Year	NO	24.50	49.00	-125.00	-66.50	1559.9796	06/04/2024, 15:55
30	CONUS1969	01/01/1969, 00:00	12/31/1969, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:57
31	CONUS1970	01/01/1970, 00:00	12/31/1970, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 15:58
32	CONUS1971	01/01/1971, 00:00	12/31/1971, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 16:00
33	CONUS1972	01/01/1972, 00:00	12/31/1972, 23:00	366	Year	NO	24.50	49.00	-125.00	-66.50	1559.9796	06/04/2024, 16:02
34	CONUS1973	01/01/1973, 00:00	12/31/1973, 23:00	365	Year	NO	24.50	49.00	-125.00	-66.50	1555.7197	06/04/2024, 16:03

# Applying the Weather

- Weather can be applied to a power flow case using the pww files in multiple ways
  - At a specified point in time
  - As a summary of a large amount of weather at a single location (e.g., a generator) or at a few locations (a transmission line)
  - As a time series, sequentially solving lots of different time points
- The next few slides give an overview of these, showing the changes in the wind and solar outputs



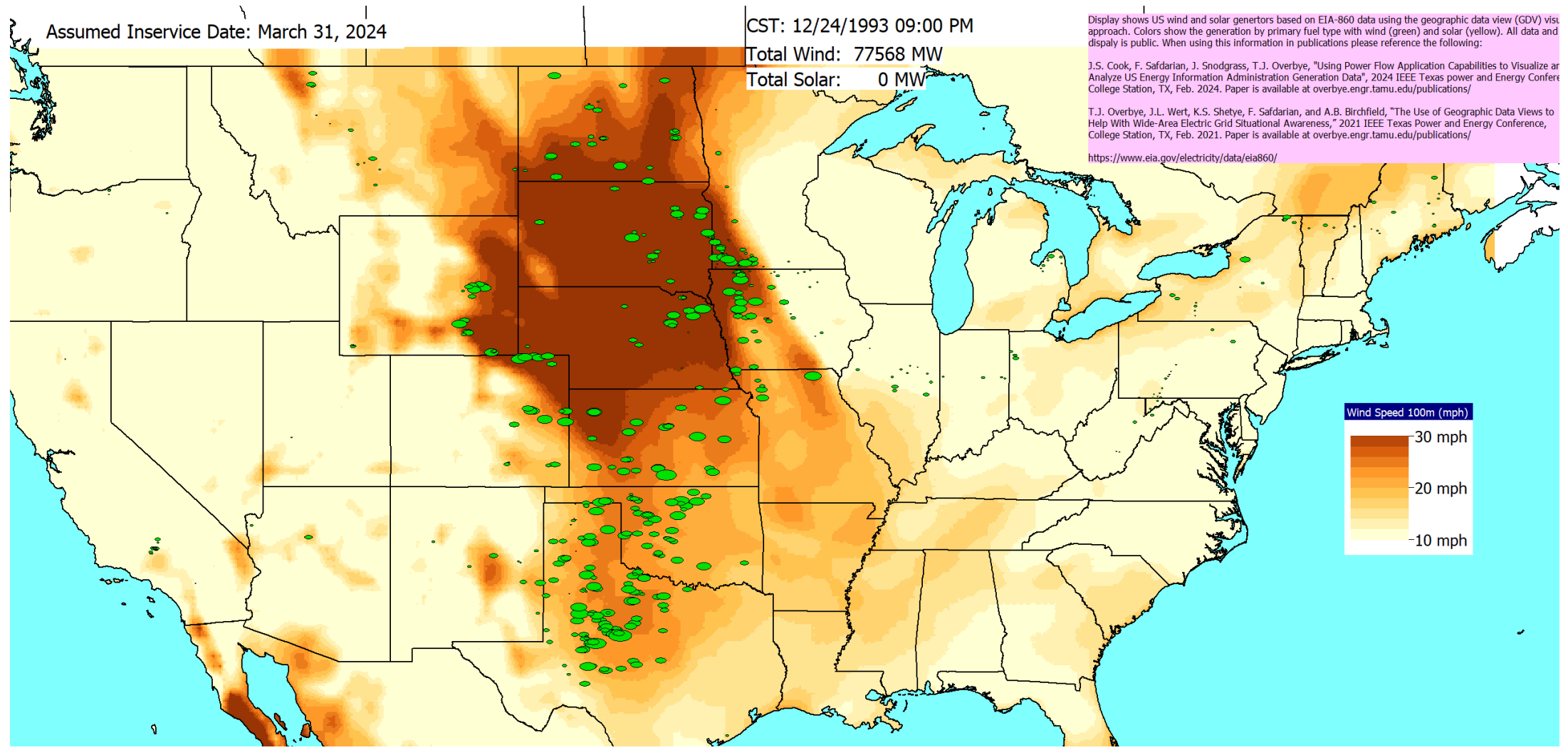
# Applying Weather for a Single Time Point

- With the provided pww files, any time going back to 1940 can be simulated. The pww files are designed for quick searching, and for providing direct access to all the data for a particular time.
- Getting the access to the weather for all of North America with ERA5 takes about a second; optionally the weather can also be applied to the power flow
- Once applied the power flow (and other applications) can be solved as normal
- Restore values at the end

Name	Longitude	Latitude	Enabled	Temp F	Temp C	Dew Point F	Dew Point C	Cloud Cover Percent	Wind Speed mph	Wind Speed 100m mph	Wind Direction	Global Horizontal Irradiance W/m <sup>2</sup>	Direct Horizontal Irradiance W/m <sup>2</sup>	Insolation Percent	Place_No
1	-24.50-067.00	-66.500000	24.500000	0	YES	77.0	25.0	69.0	20.6	14.0	12.0	130.0	0.0	0.0	0.0
2	-24.50-067.75	-66.750000	24.500000	0	YES	77.0	25.0	69.0	20.6	12.0	12.0	150.0	0.0	0.0	0.0
3	-24.50-067.00	-67.000000	24.500000	0	YES	77.0	25.0	70.0	21.1	9.0	13.0	160.0	0.0	0.0	0.0
4	-24.50-067.25	-67.250000	24.500000	0	YES	77.0	25.0	70.0	21.1	17.0	13.0	160.0	0.0	0.0	0.0
5	-24.50-067.50	-67.500000	24.500000	0	YES	77.0	25.0	70.0	21.1	21.0	14.0	170.0	0.0	0.0	0.0
6	-24.50-067.75	-67.750000	24.500000	0	YES	77.0	25.0	71.0	21.7	14.0	14.0	135.0	0.0	0.0	0.0
7	-24.50-068.00	-68.000000	24.500000	0	YES	77.0	25.0	71.0	21.7	13.0	14.0	170.0	0.0	0.0	0.0
8	-24.50-068.25	-68.250000	24.500000	0	YES	77.0	25.0	71.0	21.7	26.0	14.0	170.0	0.0	0.0	0.0
9	-24.50-068.50	-68.500000	24.500000	0	YES	77.0	25.0	71.0	21.7	27.0	14.0	170.0	0.0	0.0	0.0
10	-24.50-068.75	-68.750000	24.500000	0	YES	77.0	25.0	71.0	21.7	26.0	14.0	170.0	0.0	0.0	0.0
11	-24.50-069.00	-69.000000	24.500000	0	YES	77.0	25.0	71.0	21.7	48.0	14.0	170.0	0.0	0.0	0.0
12	-24.50-069.25	-69.250000	24.500000	0	YES	77.0	25.0	71.0	21.7	47.0	14.0	170.0	0.0	0.0	0.0
13	-24.50-069.50	-69.500000	24.500000	0	YES	77.0	25.0	71.0	21.7	40.0	13.0	170.0	0.0	0.0	0.0
14	-24.50-069.75	-69.750000	24.500000	0	YES	77.0	25.0	71.0	21.7	38.0	13.0	160.0	0.0	0.0	0.0
15	-24.50-070.00	-70.000000	24.500000	0	YES	77.0	25.0	71.0	21.7	36.0	13.0	160.0	0.0	0.0	0.0
16	-24.50-070.25	-70.250000	24.500000	0	YES	77.0	25.0	72.0	22.2	35.0	13.0	160.0	0.0	0.0	0.0
17	-24.50-070.50	-70.500000	24.500000	0	YES	77.0	25.0	72.0	22.2	36.0	13.0	160.0	0.0	0.0	0.0
18	-24.50-070.75	-70.750000	24.500000	0	YES	77.0	25.0	72.0	22.2	33.0	13.0	160.0	0.0	0.0	0.0
19	-24.50-071.00	-71.000000	24.500000	0	YES	77.0	25.0	72.0	22.2	44.0	12.0	150.0	0.0	0.0	0.0
20	-24.50-071.25	-71.250000	24.500000	0	YES	77.0	25.0	72.0	22.2	52.0	12.0	150.0	0.0	0.0	0.0

# Visualization of Weather from 12/24/1993

Historical weather is being applied to 2024 wind and solar generation



# Simulating Large Amounts of Weather Information

- To easily view and simulate many time values, the pww files can be loaded into the Time Step simulation (**Tools, Time Step Simulation**)
  - Select **Read PWW File** to load the desired file

Allows a weather location to be easily located (Seattle here)

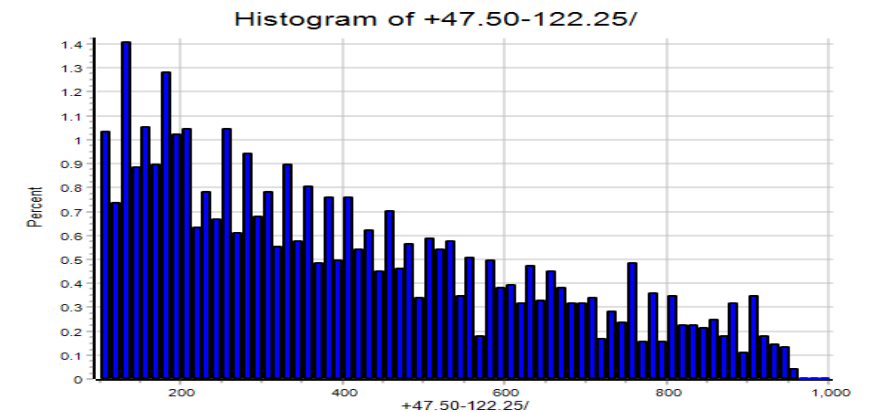
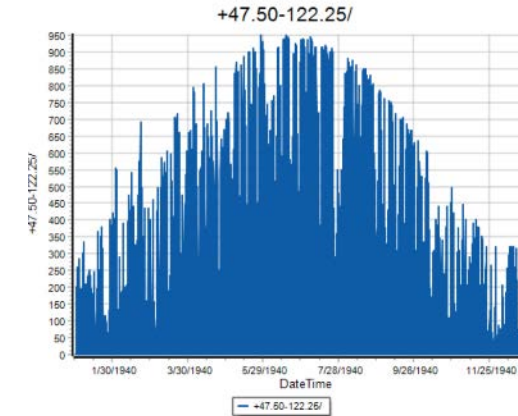
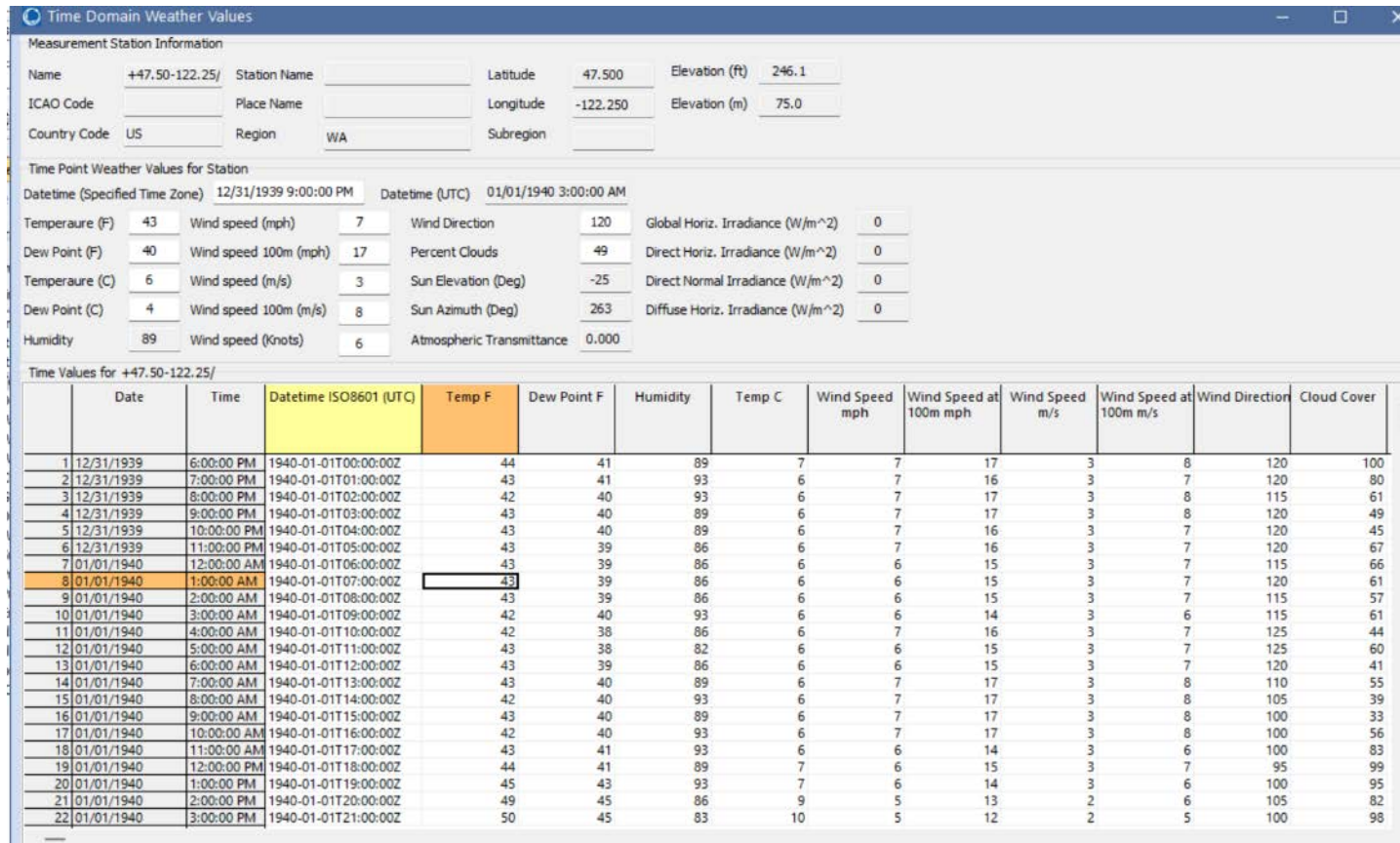
Like any Simulator case information grid, the data can be easily plotted and exported

The screenshot shows the 'Time Step Simulation' interface. The 'Read PWW File' button is highlighted with an orange arrow. Below it, the 'Find Column by Location' section shows latitude (47.50) and longitude (-122.25) for Seattle. The data table below shows the following columns: Datetime (ISO8601 (UTC)), Date, Time, and various weather parameters (Temperature, Dew Point, Wind Speed, Wind Direction, Wind Speed at 100m, Cloud Cover, Global Irradiance, Direct Irradiance, Wind Gust, Smoke, Precipitation Rate). The table contains 34 rows of data, starting from 1940-01-01T00:00:00Z at 6:00:00 PM and ending at 1940-01-02T09:00:00Z at 3:00:00 AM.

	Datetime (ISO8601 (UTC))	Date	Time	+47.50-118.50/	+47.50-118.75/	+47.50-119.00/	+47.50-119.25/	+47.50-119.50/	+47.50-119.75/	+47.50-120.00/	+47.50-120.25/	+47.50-120.50/
1	1940-01-01T00:00:00Z	12/31/1939	6:00:00 PM	32	33	32	31	30	29	30	29	28
2	1940-01-01T01:00:00Z	12/31/1939	7:00:00 PM	32	33	32	31	30	29	30	29	28
3	1940-01-01T02:00:00Z	12/31/1939	8:00:00 PM	32	32	32	31	29	29	29	29	28
4	1940-01-01T03:00:00Z	12/31/1939	9:00:00 PM	32	32	31	30	29	29	29	29	28
5	1940-01-01T04:00:00Z	12/31/1939	10:00:00 PM	32	32	31	30	29	28	29	29	28
6	1940-01-01T05:00:00Z	12/31/1939	11:00:00 PM	31	32	31	30	29	28	28	29	28
7	1940-01-01T06:00:00Z	01/01/1940	12:00:00 AM	31	32	31	30	28	27	28	28	28
8	1940-01-01T07:00:00Z	01/01/1940	1:00:00 AM	31	31	30	29	27	27	27	28	28
9	1940-01-01T08:00:00Z	01/01/1940	2:00:00 AM	30	30	29	27	24	23	26	26	26
10	1940-01-01T09:00:00Z	01/01/1940	3:00:00 AM	29	30	28	26	24	23	26	26	26
11	1940-01-01T10:00:00Z	01/01/1940	4:00:00 AM	30	30	29	28	25	24	25	26	26
12	1940-01-01T11:00:00Z	01/01/1940	5:00:00 AM	30	30	28	27	23	22	24	26	26
13	1940-01-01T12:00:00Z	01/01/1940	6:00:00 AM	31	31	29	27	24	22	25	25	26
14	1940-01-01T13:00:00Z	01/01/1940	7:00:00 AM	30	31	29	27	24	23	25	26	26
15	1940-01-01T14:00:00Z	01/01/1940	8:00:00 AM	31	31	30	28	25	24	25	27	27
16	1940-01-01T15:00:00Z	01/01/1940	9:00:00 AM	31	31	29	27	24	23	26	26	26
17	1940-01-01T16:00:00Z	01/01/1940	10:00:00 AM	30	30	28	26	24	24	26	27	27
18	1940-01-01T17:00:00Z	01/01/1940	11:00:00 AM	31	31	28	27	24	24	26	26	26
19	1940-01-01T18:00:00Z	01/01/1940	12:00:00 PM	32	32	30	28	26	25	26	27	27
20	1940-01-01T19:00:00Z	01/01/1940	1:00:00 PM	34	33	31	30	28	27	28	29	29
21	1940-01-01T20:00:00Z	01/01/1940	2:00:00 PM	36	36	33	32	30	29	30	30	29
22	1940-01-01T21:00:00Z	01/01/1940	3:00:00 PM	35	35	33	31	29	29	29	29	28
23	1940-01-01T22:00:00Z	01/01/1940	4:00:00 PM	37	37	34	33	31	28	29	28	28
24	1940-01-01T23:00:00Z	01/01/1940	5:00:00 PM	36	36	33	31	30	29	29	28	28
25	1940-01-02T00:00:00Z	01/01/1940	6:00:00 PM	36	37	34	33	31	30	29	30	29
26	1940-01-02T01:00:00Z	01/01/1940	7:00:00 PM	35	36	34	33	31	30	30	30	29
27	1940-01-02T02:00:00Z	01/01/1940	8:00:00 PM	34	35	33	31	30	29	29	30	29
28	1940-01-02T03:00:00Z	01/01/1940	9:00:00 PM	34	35	33	31	30	30	30	30	29
29	1940-01-02T04:00:00Z	01/01/1940	10:00:00 PM	34	35	33	32	31	31	31	31	29
30	1940-01-02T05:00:00Z	01/01/1940	11:00:00 PM	34	35	34	33	32	32	32	30	29
31	1940-01-02T06:00:00Z	01/02/1940	12:00:00 AM	33	34	33	33	32	31	31	31	29
32	1940-01-02T07:00:00Z	01/02/1940	1:00:00 AM	34	35	34	33	33	32	33	31	30
33	1940-01-02T08:00:00Z	01/02/1940	2:00:00 AM	35	36	34	34	33	33	33	32	30
34	1940-01-02T09:00:00Z	01/02/1940	3:00:00 AM	35	36	34	34	33	33	33	31	29

# Seeing All Weather Data for a Location

- To see all the weather data for a location, just right-click on the column and select **Show Dialog with All Times for Location**



# Availability of Forecasted Weather Information

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- Forecasted weather information is also available from a variety of sources; here we use the free forecasts provided by US National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP) NCEP Central Operations
  - [nco.ncep.noaa.gov/pmb/products/gfs/](http://nco.ncep.noaa.gov/pmb/products/gfs/)
  - Specifically we're using the 0.25 degree resolution GFS results, which provide four global forecasts per day going out for 16 days (hourly for the first five days, then every three hours)
  - Forecasts are also pww files, so all of the existing tools can be used, though the forecasts do not have the solar irradiance values
- We hope to soon get access to longer-term forecasts

# Some Potential Additional Models

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- With weather information a part of the power flow a wide variety of additional power flow model enhancements become possible. Some examples are given below, recognizing that many are already done using external analysis
  - Transmission line limits that depend on temperature, wind and insolation along the right-of-way; working with industry we already have some quite sophisticated models
  - Transformer limits
  - Load models (recognizing that the load depends on many factors, initial models could be linearizations about a specified value)
  - Line resistance (though this would be more complex since it is operating point dependent)
  - Etc.

# Future Directions

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- There are many future directions to pursue
  - A number of models that relate weather to electric grid values already exist, but many more certainly need to be developed
  - Integration of weather into tools such as contingency analysis; better tools for dealing with stochastic models
  - Support for more weather types, greater integration of reading primary sources such as GRIB and GRIB2 files
  - Determining the required level of weather details; higher resolution datasets are available; also other potentially severe resiliency events
  - More validation!!
  - Increased automation of the updating process; maybe more footprints
  - Machine learning applications given lots of potential operating points

# Thank You! Questions?

Recent papers are at [overbye.engr.tamu.edu/publications/](http://overbye.engr.tamu.edu/publications/) For questions afterwards email at [overbye@tamu.edu](mailto:overbye@tamu.edu) or [overbye@powerworld.com](mailto:overbye@powerworld.com)

