Mind the Gaps: Weather Data Inputs for Power System Modeling

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Principal and Owner,
Sharply Focused

December 5, 2023

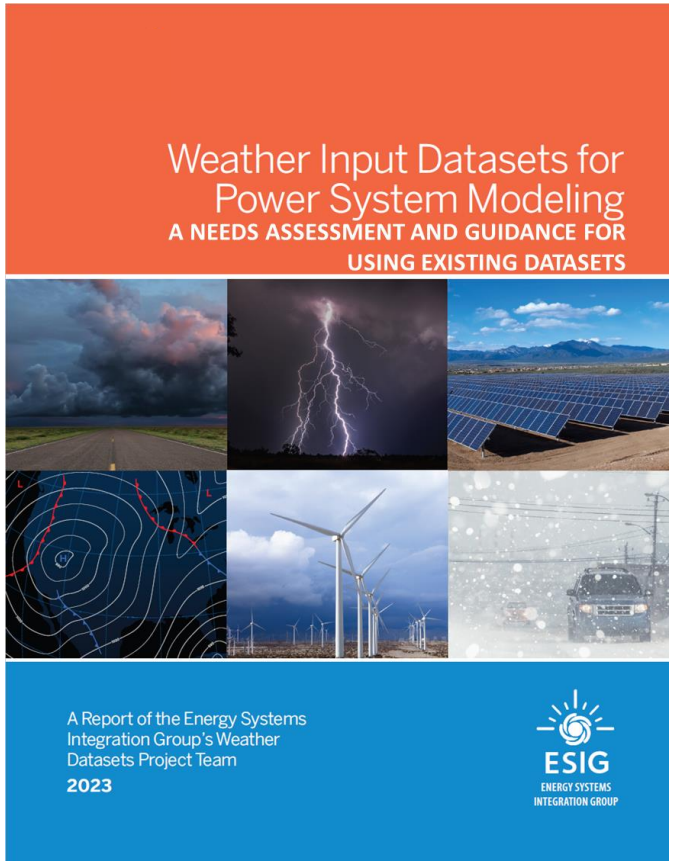
Your assumptions are your windows on the world. Scrub them off every once in a while, or the light won't come in.

Alan Alda, actor, writer and director

Acknowledgements/Disclaimer:

The report and its companion documents were output from the ESIG Weather Inputs Task Force project. I'd like to acknowledge the help of all the members of the task force especially to those contributed to the writing and those who provided deep review and comments.

The project was convened and supported by ESIG. Additional funding was provided by GridLab and Sharply Focused.



[Report Landing Page]
- [Executive Summary]
- [Main Report]
- [Summary Report]
- [Meteorology 101]

While largely objective, some of this presentation represents my own views, some of which may not necessarily be the official views of task force members or member organizations.

Agenda

- **Increasing weather dependence**
- Trans-disciplinary disconnects
- Attributes of the data we need
- Validation: The most critical gap
- What's the current status? Gaps and impacts
- A roadmap to the future

Motivation: The Energy Transition

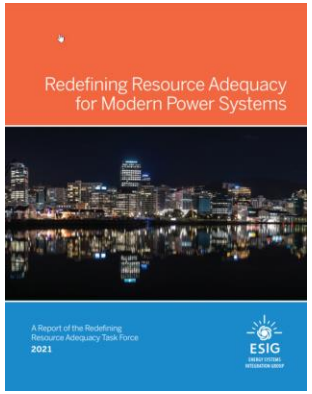
THE ELECTRIC SYSTEM IS CHANGING

…RADICALLY…

AND IS FULL OF UNCERTAINTY

THE SECTOR WILL NEED TO EVOLVE

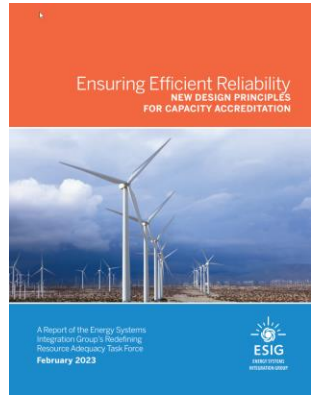
ITS METHODS ACCORDINGLY



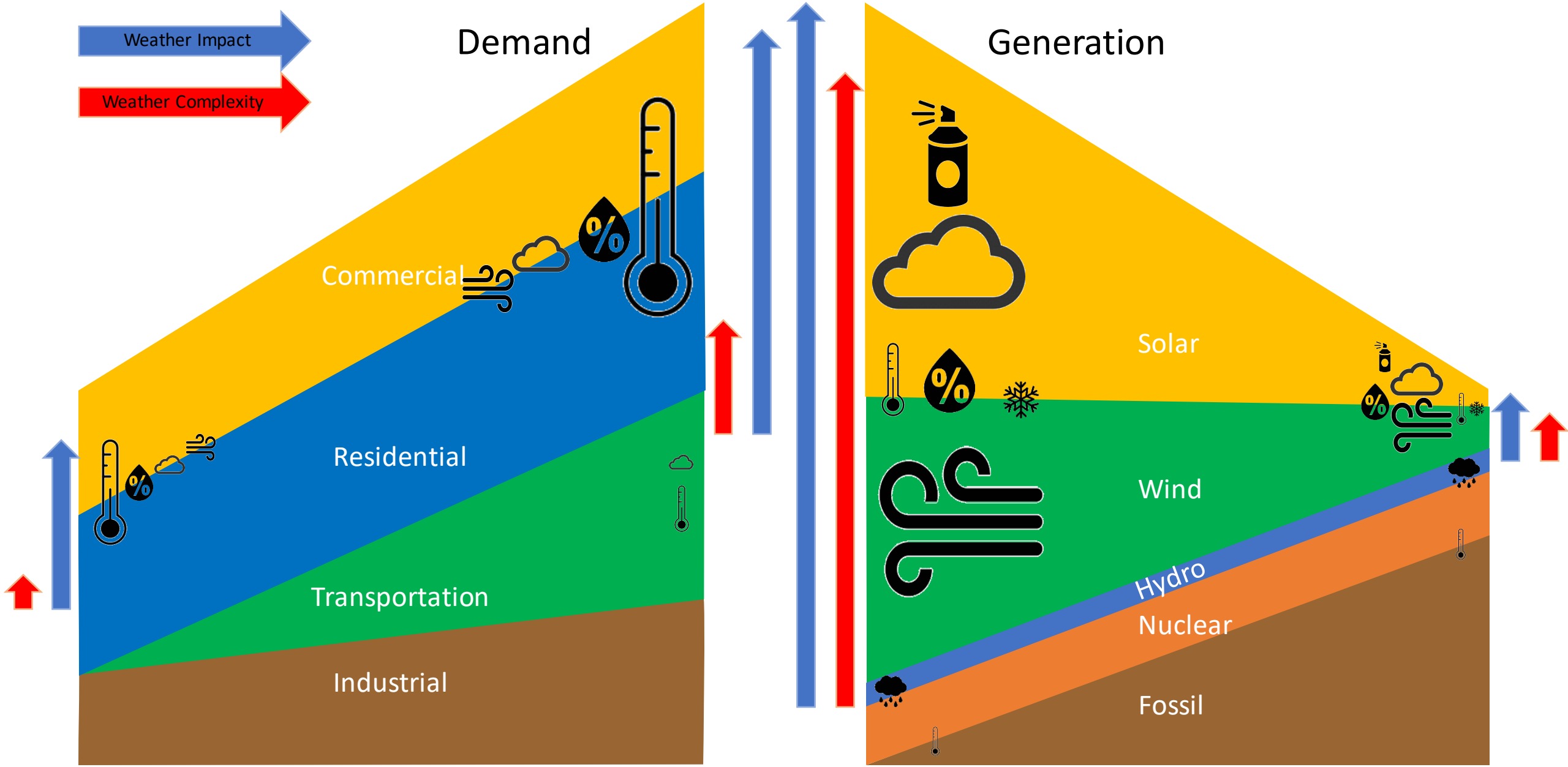
Findings included in seminal consensus-based reports from the ESIG Rethinking Resource Adequacy initiative

The quality of power system studies becomes increasingly dependent on characterization of weather

Methods must evolve to more completely incorporate weather data



The Evolving Weather - Energy Nexus



Meteorology is Becoming Central

Decarbonize by Electrifying Almost Everything

Generate with Zero Carbon Emissions

← Fuel Supply Knowledge Gap →

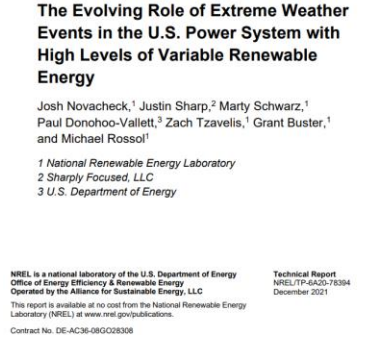
RISKS ARE SHIFTING

WEATHER DEPENDENCE AND WEATHER COMPLEXITY ARE INCREASING

NREL Transforming ENERGY

The Evolving Role of Extreme Weather Events in the U.S. Power System with High Levels of Variable Renewable Energy

(Abstract: https://www.osti.gov/biblio/1837959 | Full Report: https://doi.org/10.2172/1837959)



The Evolving Role of Extreme Weather Events in the U.S. Power System with High Levels of Variable Renewable Energy

Josh Novacheck,[1] Justin Sharp,[2] Marty Schwarz,[1] Paul Donohoo-Vallett,[3] Zach Tzavelis,[1] Grant Buster,[1] and Michael Rossol[1]

1 National Renewable Energy Laboratory
2 Sharply Focused, LLC
3 U.S. Department of Energy

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-6A20-78394
December 2021

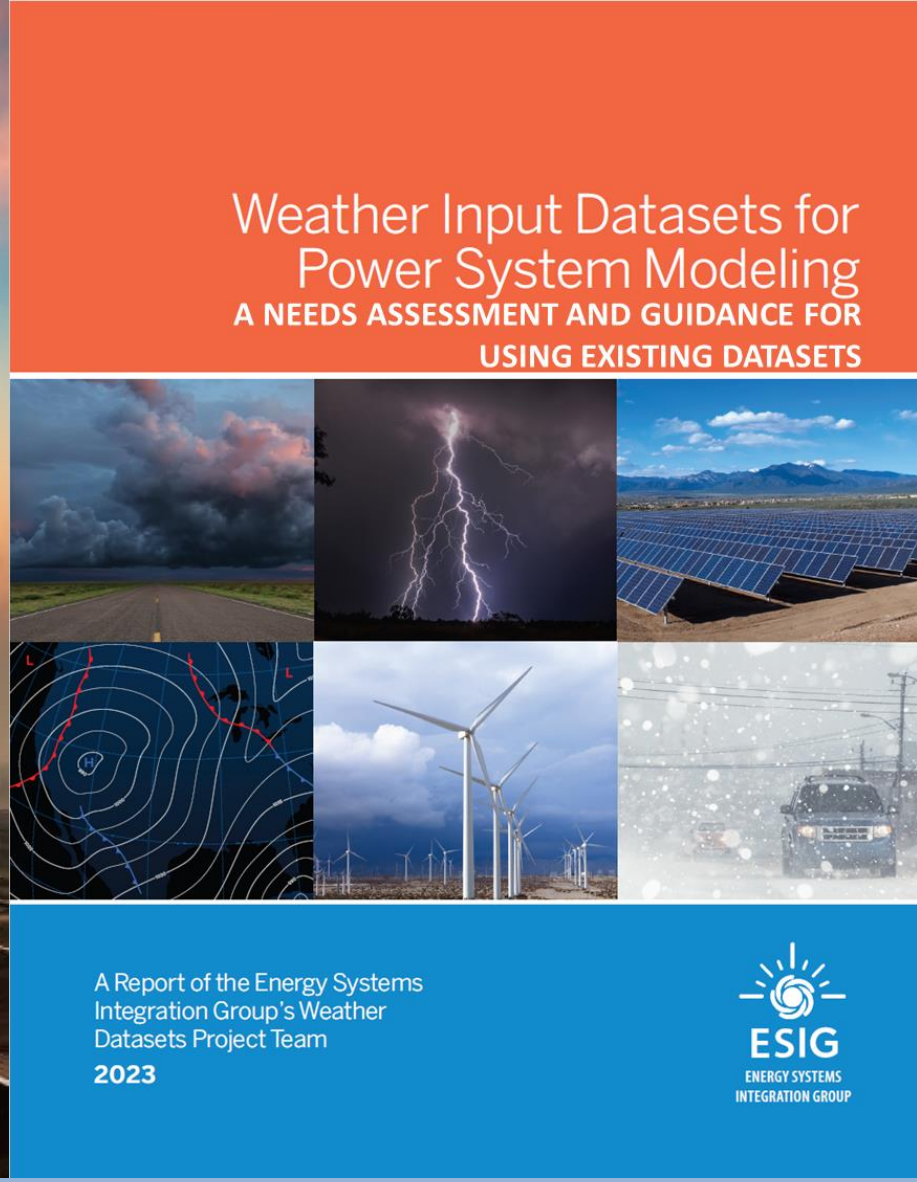
And Yet We Are Largely Flying Blind

(or at a minimum our vision is very limited)

There is an Imperative for Dedicated, Accurate, and Expertly Curated National (and Beyond) Weather Information to Support the Energy Transition!

If you put garbage in a computer nothing comes out but garbage. But this garbage, having passed through a very expensive machine, is somehow ennobled and none dare criticize it.

Rory Bremner, Scottish Comedian



Mind The Gaps: Weather Data Inputs for Power Systems Modeling

ESIG Webinar | December 5, 2023

It's not just me saying this…

Critical review of renewable generation datasets and their implications for European power system models

Alexander Kies [a,*], Bruno U. Schyska [b], Mariia Bilousova [a,c], Omar El Sayed [a,c], Jakub Jurasz [d], Horst Stoecker [a,c,e]

ABSTRACT

In the process of decarbonization, the global energy mix is shifting from fossil fuels to renewables. To study decarbonization pathways, large-scale energy system models are utilized. These models require accurate data on renewable generation to develop their full potential. Using different data can lead to conflicting results and policy advice. In this work, several datasets that are commonly used to study the transition towards a highly renewable European power system are compared. Significant differences between these datasets are found, resulting in cost-differences of about 10%. These findings indicate that much more attention must be paid to the large uncertainties of the input data.

- Bloomfield *et al* 2016 *Environ. Res. Lett.* "Quantifying the increasing sensitivity of power systems to climate variability"
- Pfenninger 2017 *Appl. Energy* "Dealing with Multiple Decades of Hourly Wind and PV Time Series in Energy Models: A Comparison of Methods to Reduce Time Resolution and the Planning Implications of Inter-Annual Variability"
- Bloomfield *et al* 2018 *Environ. Res. Lett.* "The changing sensitivity of power systems to meteorological drivers: a case study of Great Britain"
- Collins *et al* 2018 *Joule* "Impacts of Inter-Annual Wind and Solar Variations on the European Power System"
- Zeyringer *et al* 2018 *Nat. Energy* "Designing Low-Carbon Power Systems for Great Britain in 2050 That Are Robust to the Spatiotemporal and Inter-Annual Variability of Weather"

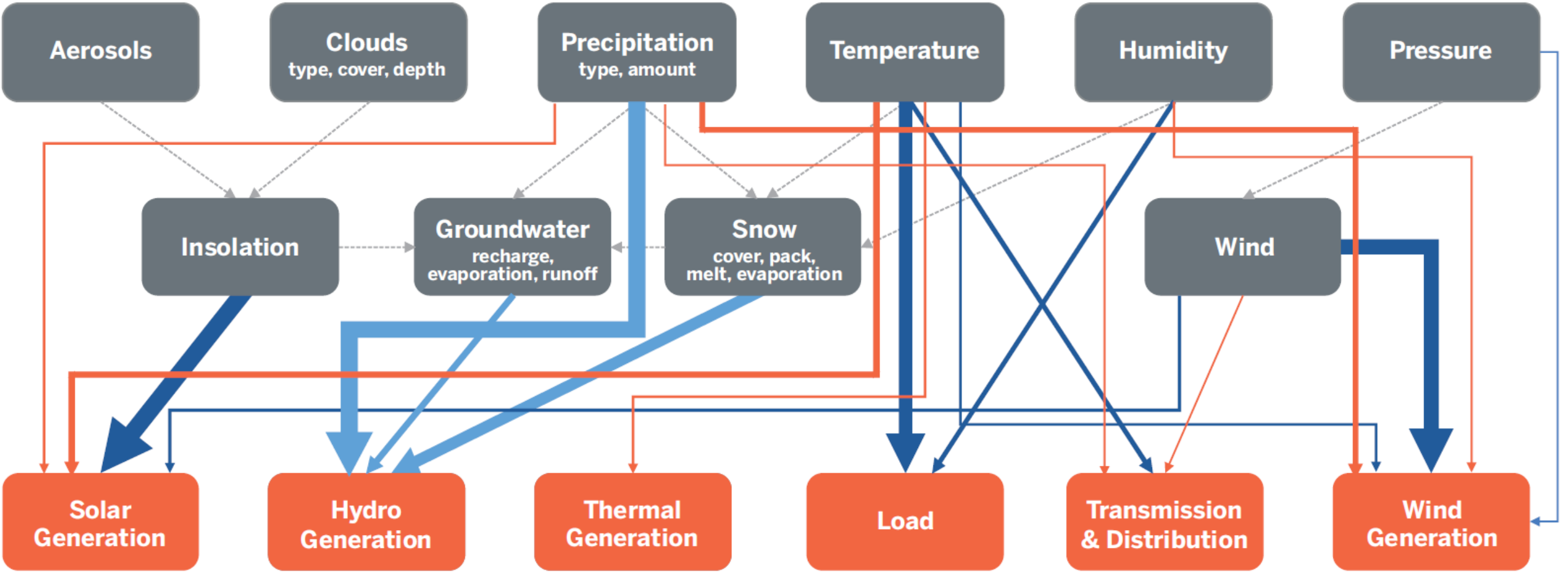
- **Not all shortfalls are alike**… need to characterize size, frequency duration, and timing of events
- **Risk is shifting**… periods of concern longer occur during gross-peak load, need to look across an entire year of operation
- **Weather** is the single most important driver for resource adequacy…
  - Cross-disciplinary power systems and meteorological expertise is necessary
  - We need a North-American Weather Dataset for correlated wind, solar, and load
  - Climate trends should be considered
  - Correlated events are the issue!
- **Resource sharing** is critical, transmission is a capacity resource

Monte Carlo vs. Weather-Synchronized simulation: Weather-Synchronized simulation offers greater transparency and improved treatment of weather correlations, but is limited by data availability. The report explores the benefits and drawbacks of both methods using a deep dive on the No Additions Scenario.

Data needs: Regardless of the RA analysis approach, the availability of more high-resolution hourly power system data as well as information about likely future weather conditions would greatly improve our understanding of RA challenges. In particular, **the expansion of publicly available hourly wind power datasets to more recent years is a high priority**.

ADVANCING RESOURCE ADEQUACY ANALYSIS WITH THE GRIDPATH RA TOOLKIT | **FACT SHEET** | **3**

Electricity System Weather-Dependence



Typical magnitude is approximated by the thickness of the lines.

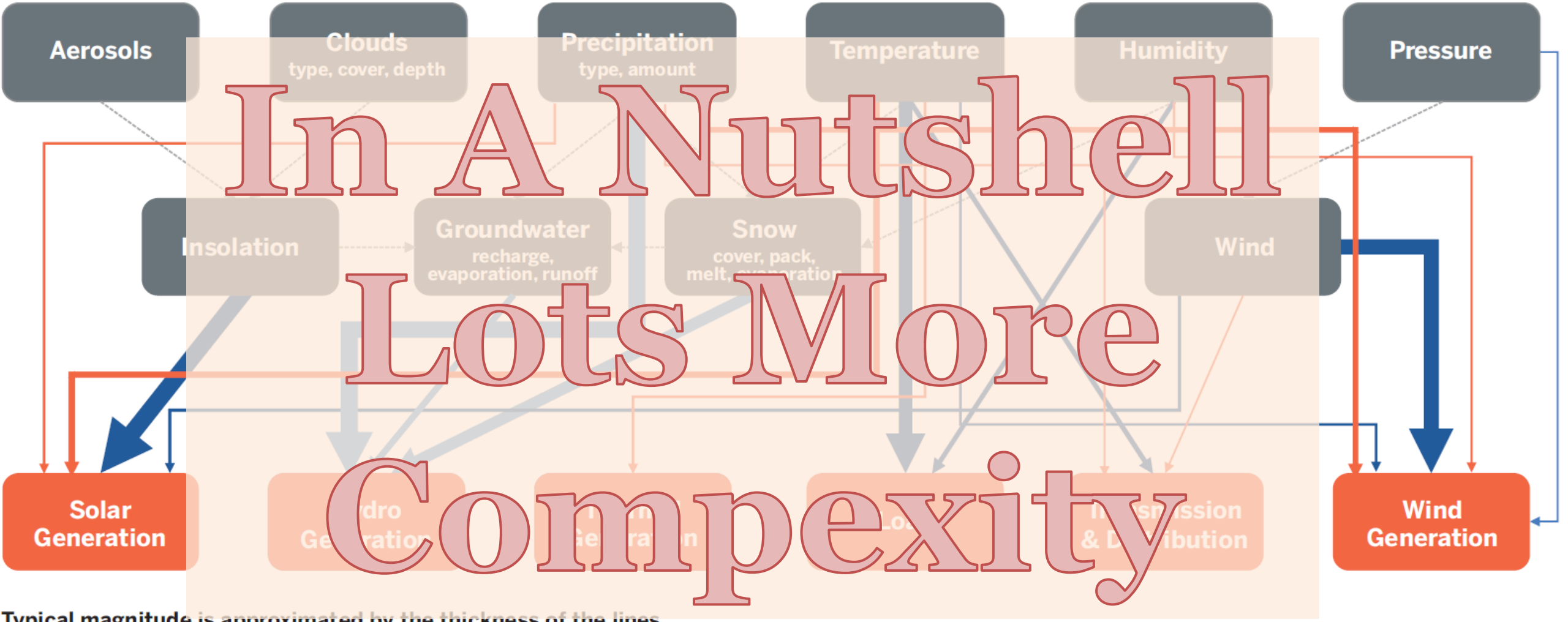
While all environmental variables are interdependent, these are some of the strongest internal links.

Dependence of the electricity system on the climate system.

Strength of dependence is highly variable and depends on asset type and location.

Degree of dependence can be greatly amplified by specific weather and climate conditions.

Electricity System Weather-Dependence

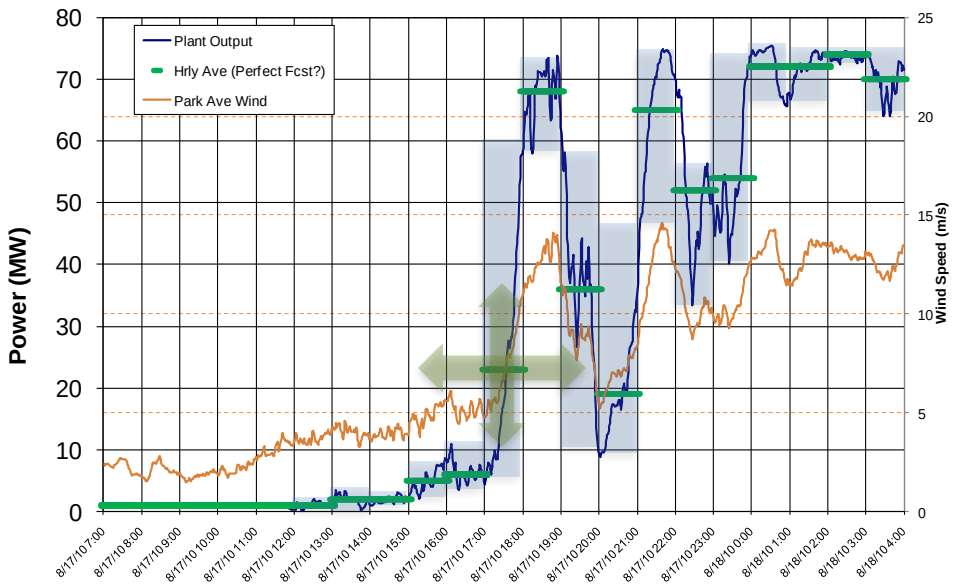


In A Nutshell
Lots More
Compexity

Typical magnitude is approximated by the thickness of the lines.

- While all environmental variables are interdependent, these are some of the strongest internal links.
- Dependence of the electricity system on the climate system.
- Strength of dependence is highly variable and depends on asset type and location.
- Degree of dependence can be greatly amplified by specific weather and climate conditions.

Weather Dependence Must Be Managed/Mitigated



Variability and Uncertainty

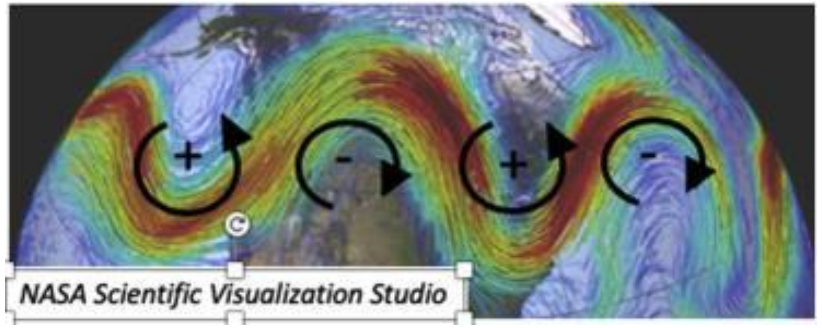
- Mostly due to weather at high RE penetration
- Operational forecasts reduce uncertainty
- Forecasts cannot reduce variability. Planning success depends characterizing and addressing variability ahead of operations.

Ad-hoc Mitigation

- Energy Storage/P2G
- Overbuilding/fossil backup
- Not efficient or cost effective.
- May not meet policy goals.

Informed Mitigation

- Recognizes continental scale
- Builds T&G accordingly
- Requires high-quality, high-resolution, meteorological data
  - Current data is inadequate (pun intended) for the job.



Agenda

- Increasing weather dependence (Almost covered)
- **Trans-disciplinary disconnects**
- Attributes of the data we need
- Validation: The most critical gap
- What's the current status? Gaps and impacts
- A roadmap to the future

- Weather datasets are complex
- They are typically NOT observations
- A trans-disciplinary approach is crucial
  - It needs to be coordinated and managed
  - It cannot be scattershot
  - Knowledge of all the needs, capabilities, and sources is needed

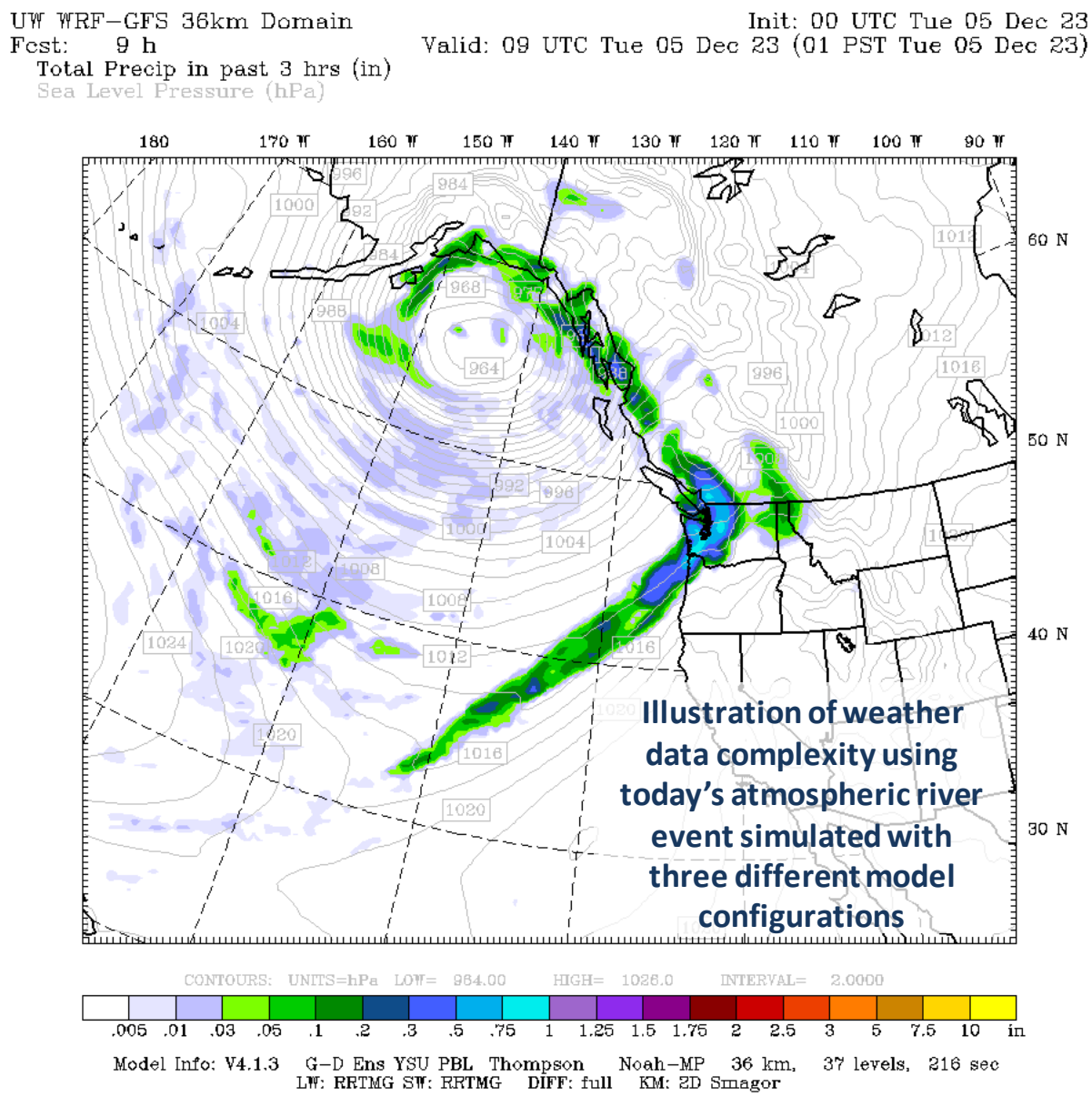


Illustration of weather data complexity using today's atmospheric river event simulated with three different model configurations

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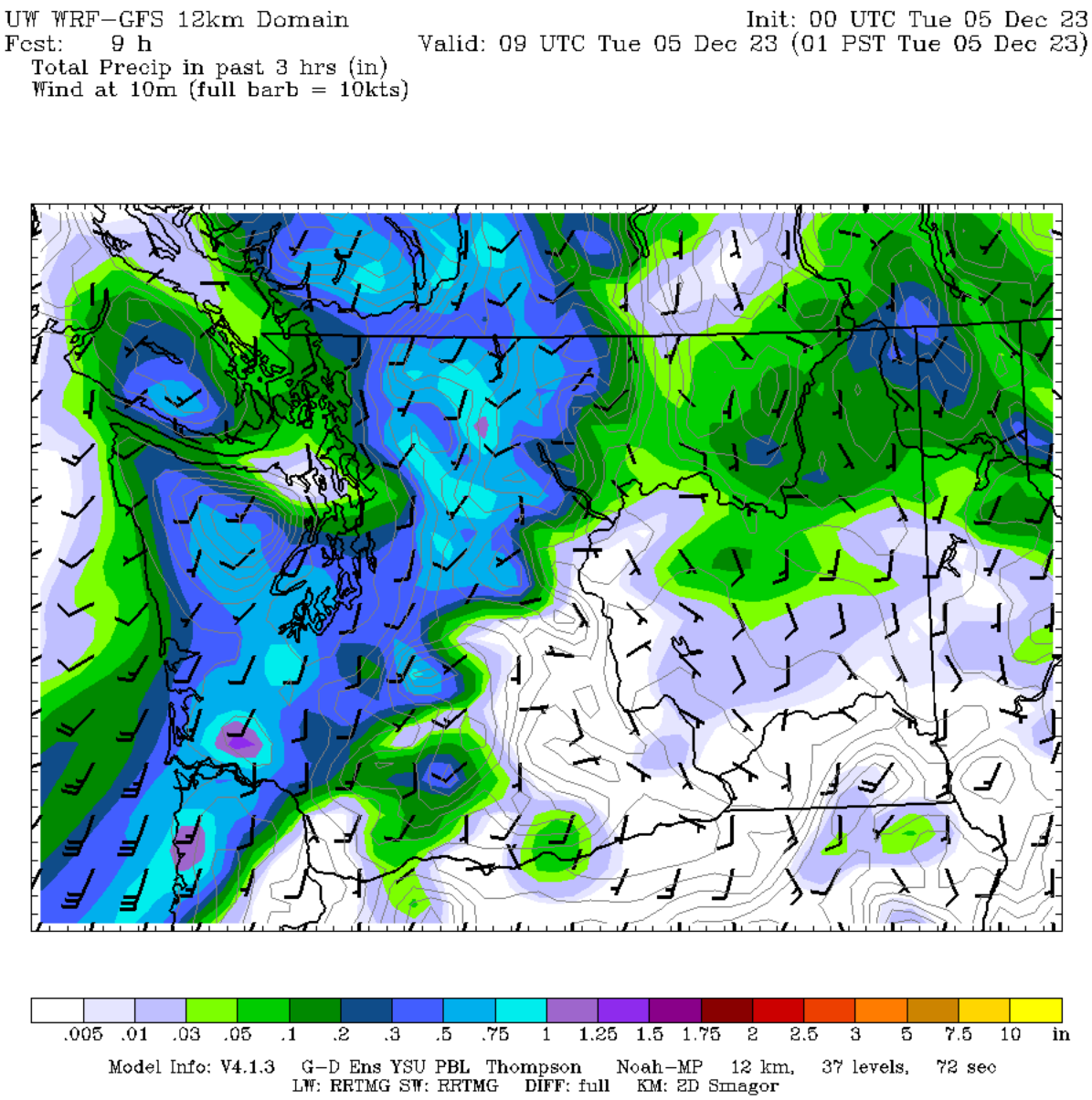

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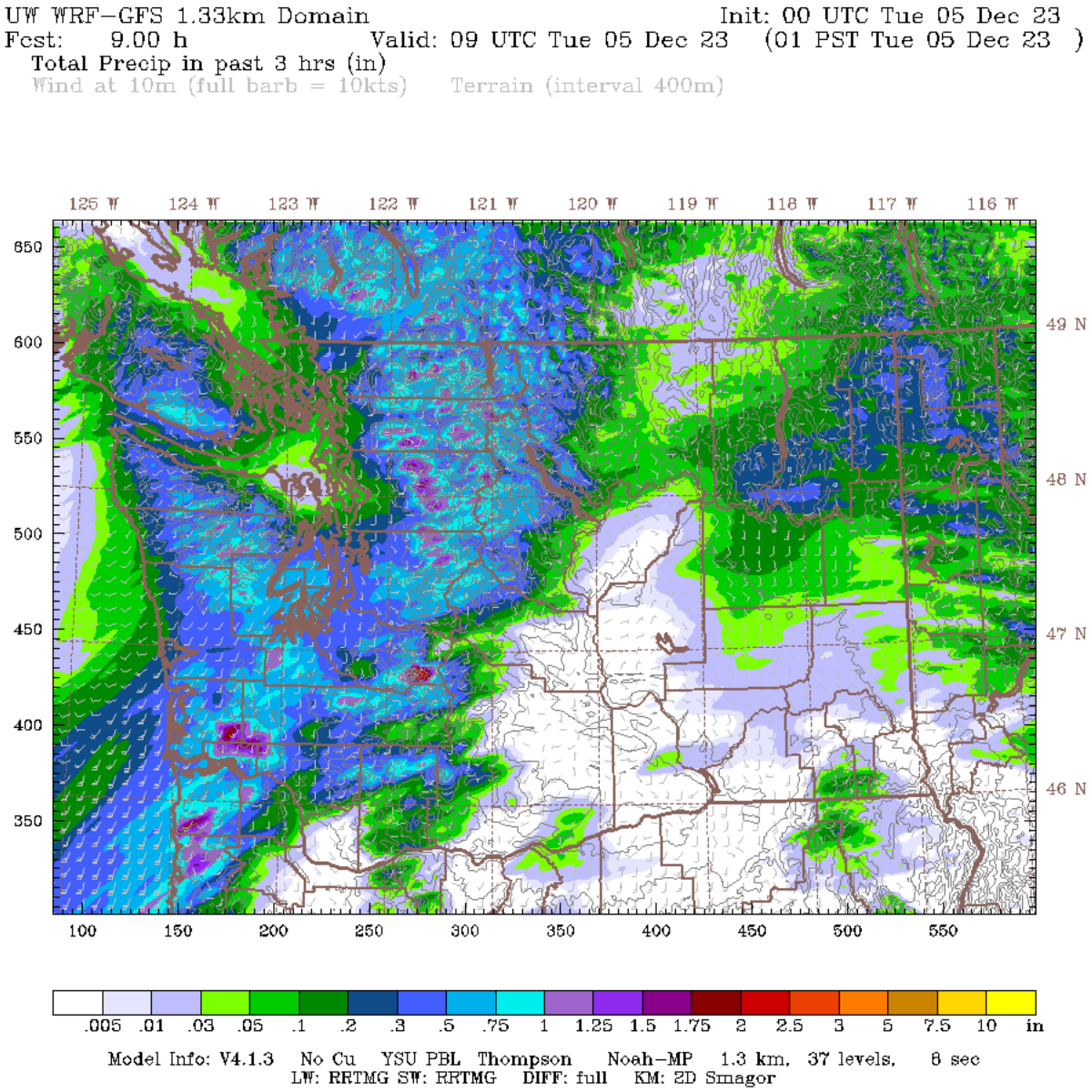
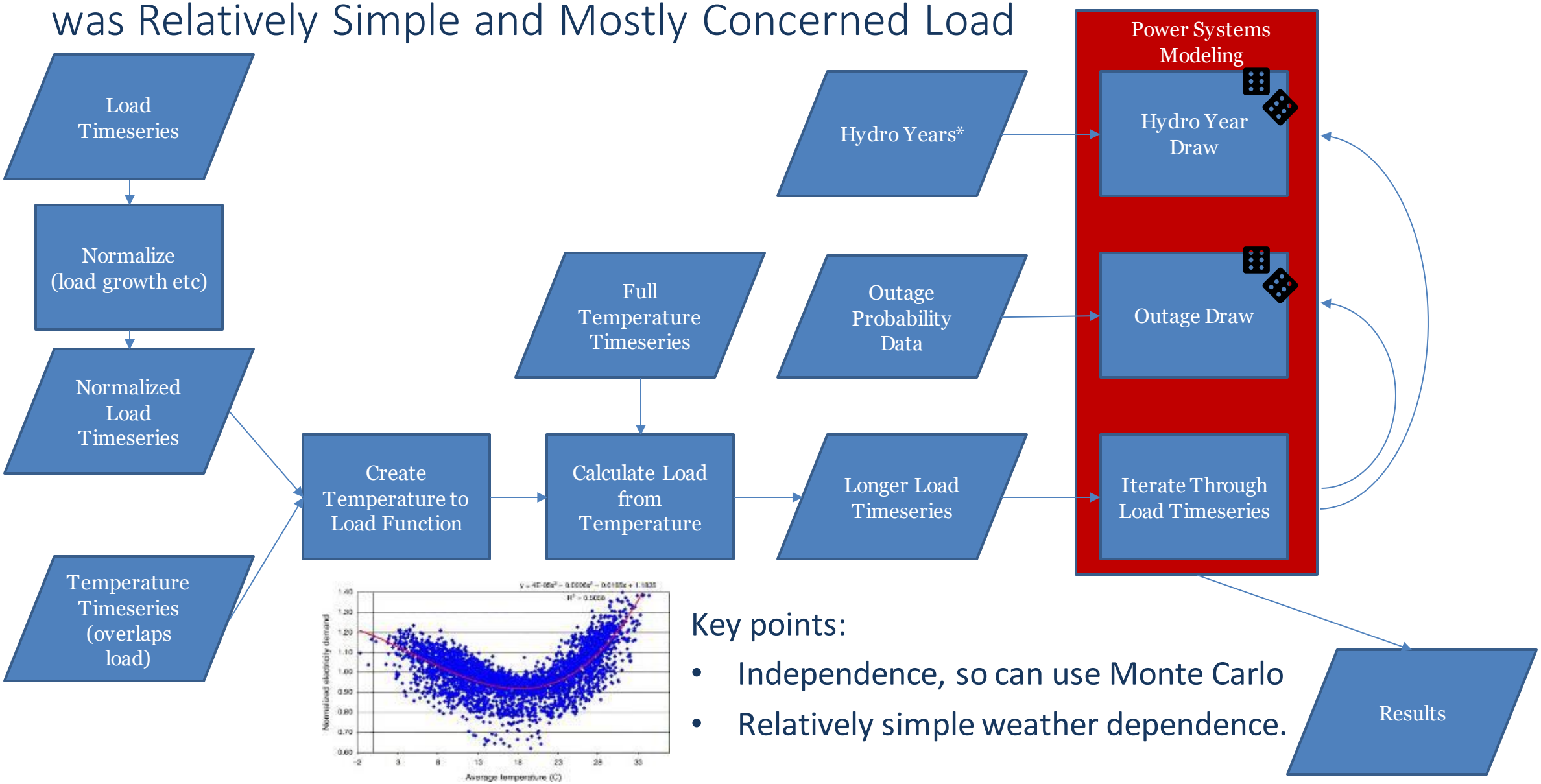


Power System Models Have Always Incorporated Weather but Treatment was Relatively Simple and Mostly Concerned Load

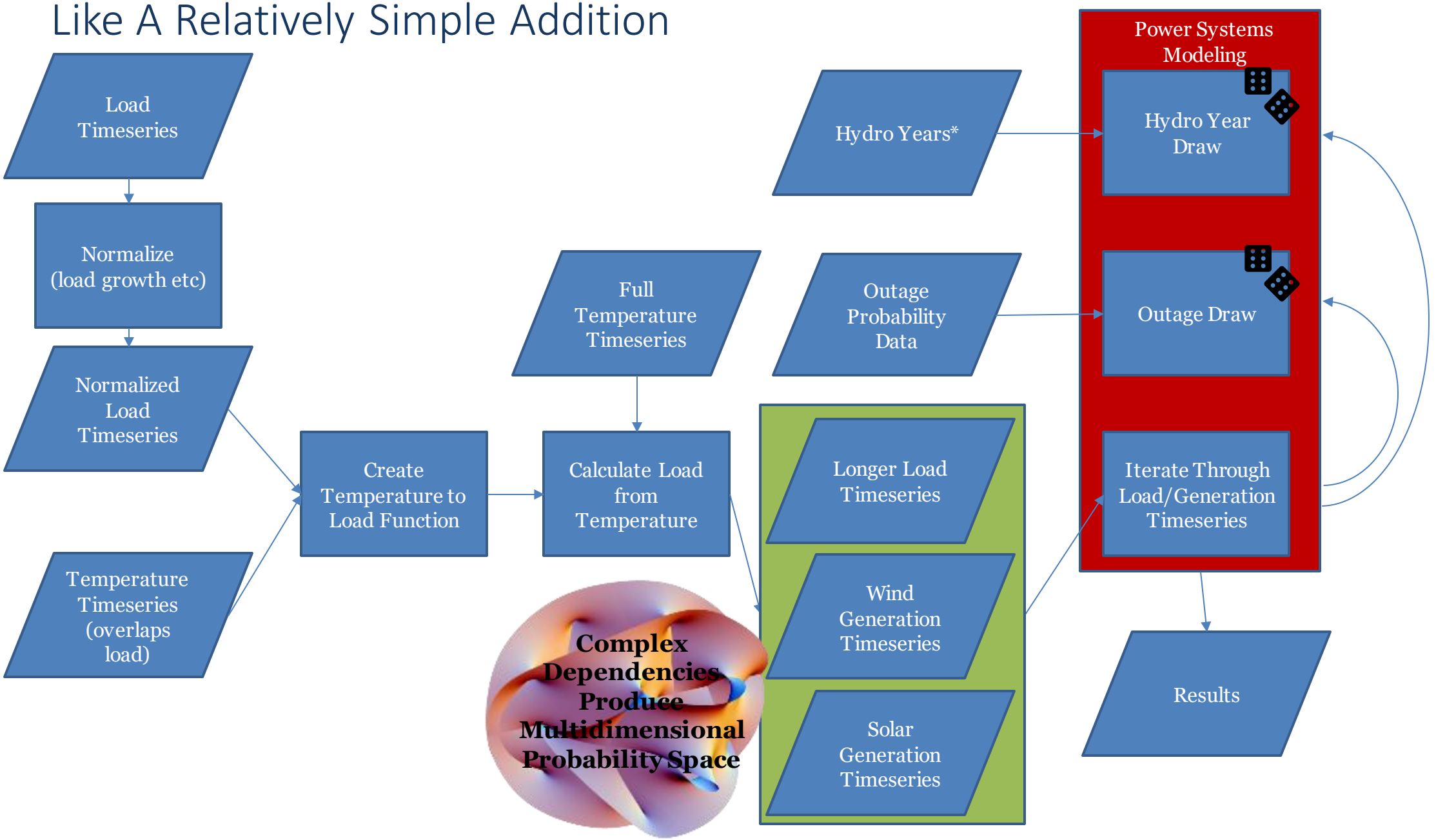


Key points:

- Independence, so can use Monte Carlo
- Relatively simple weather dependence.

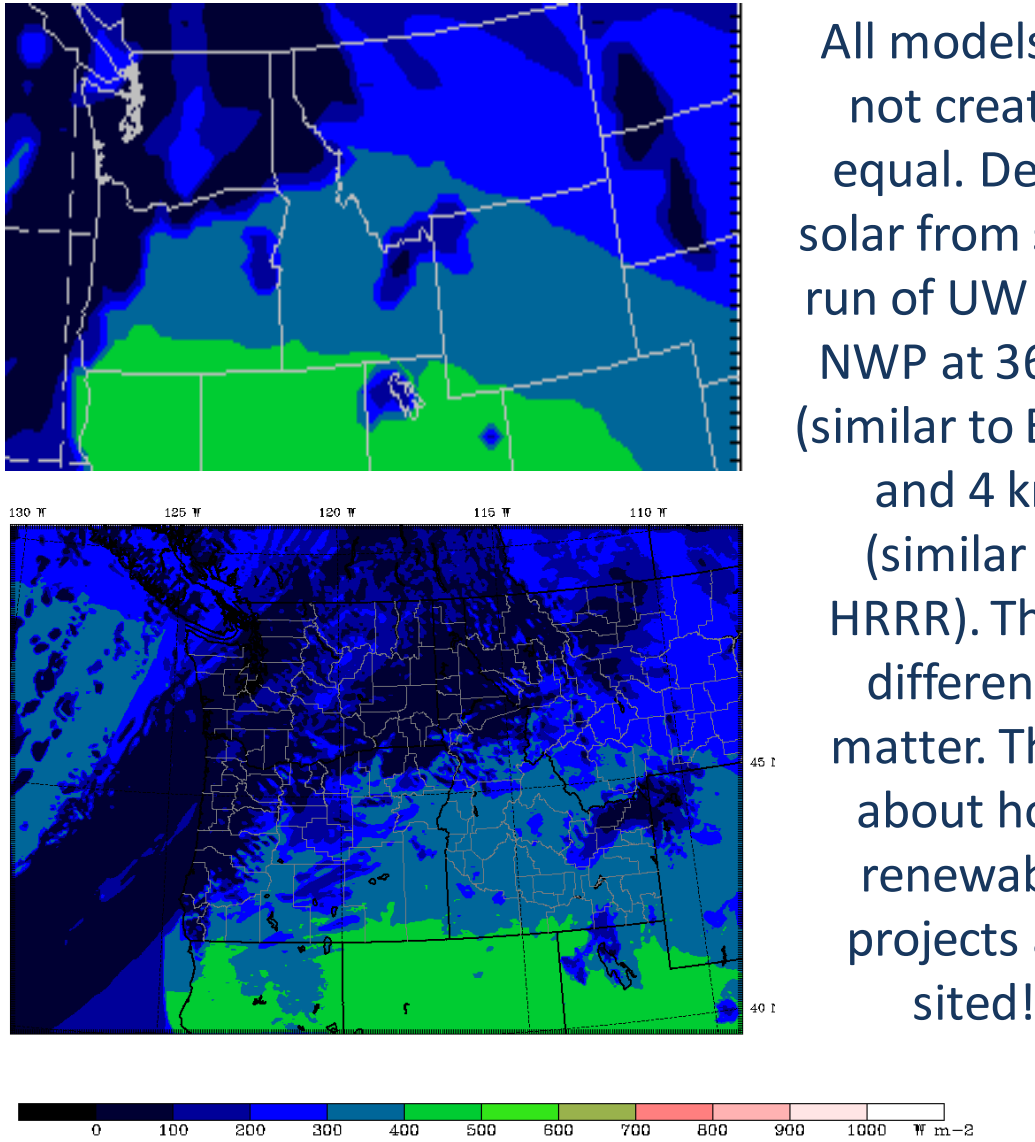
*Hydro years is illustrative only. Can iterate across other constraints. Nesting method can vary.

At First Glance Adding Wind, Solar and Storage seems Relatively Seems Like A Relatively Simple Addition



Typical Weather Data Sources Used in Power System Modeling

- Load and Hydro
  - Typically, from observations
  - Sometimes from models for consistency
  - Centralized load centers and hydro basins
- Wind and solar
  - Usually, synthetic data from models
  - Better to use observations from renewable energy projects
  - Availability and QA/QC problems
  - What about for future project locations?
  - Rapid variability in time and space
- Different sources are often used
  - e.g. WIND Toolkit for wind, NSRDB for solar, observations for load and hydro

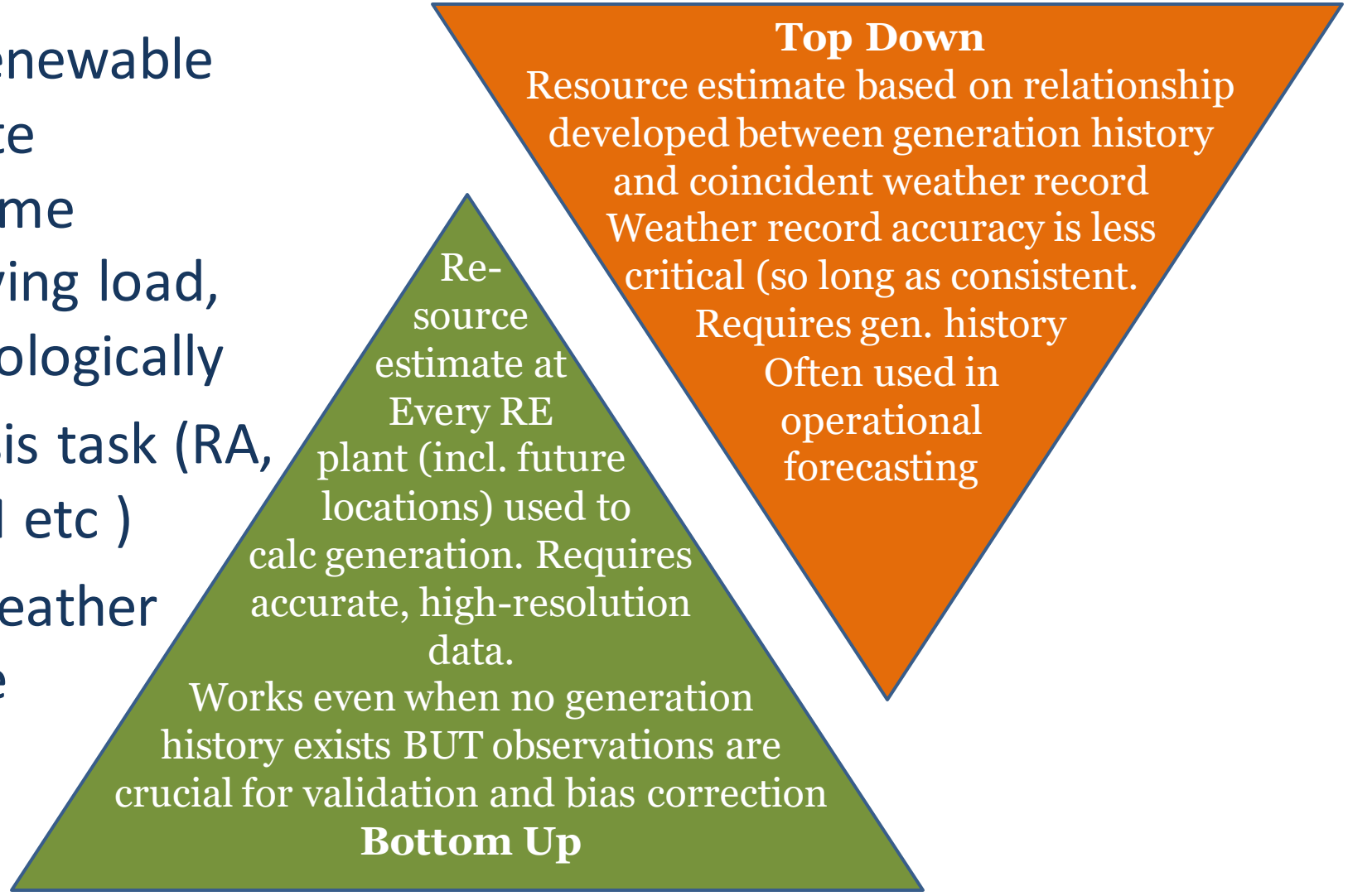


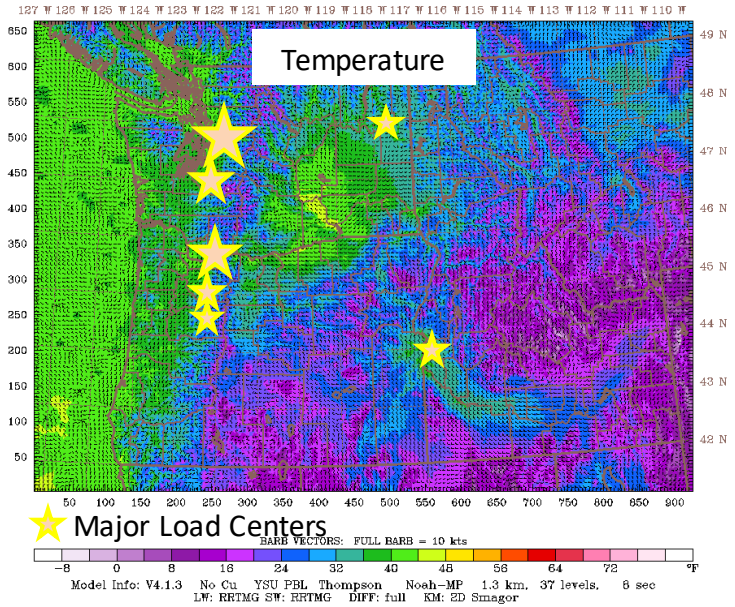
All models are not created equal. Dec 5, solar from same run of UW WRF NWP at 36 km (similar to ERA5) and 4 km (similar to HRRR). These difference matter. Think about how renewable projects are sited!

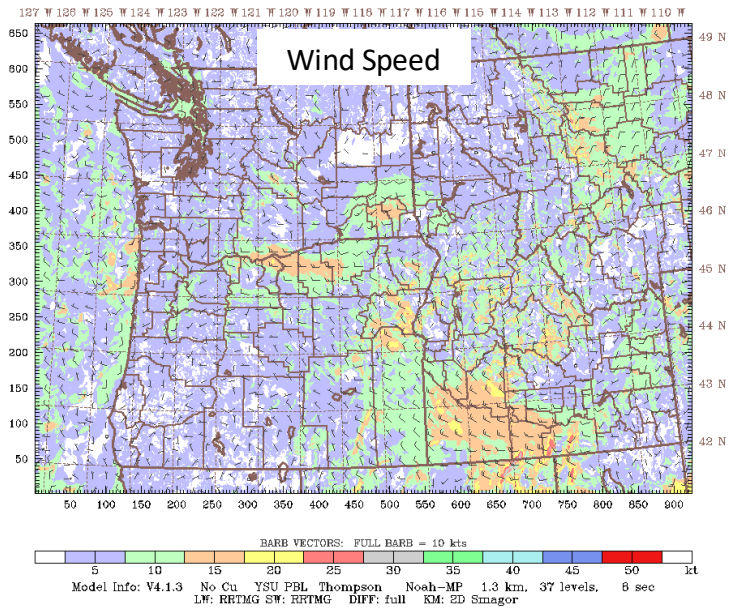
Accurately Modeling Power Systems with Increasing VRE and Storage

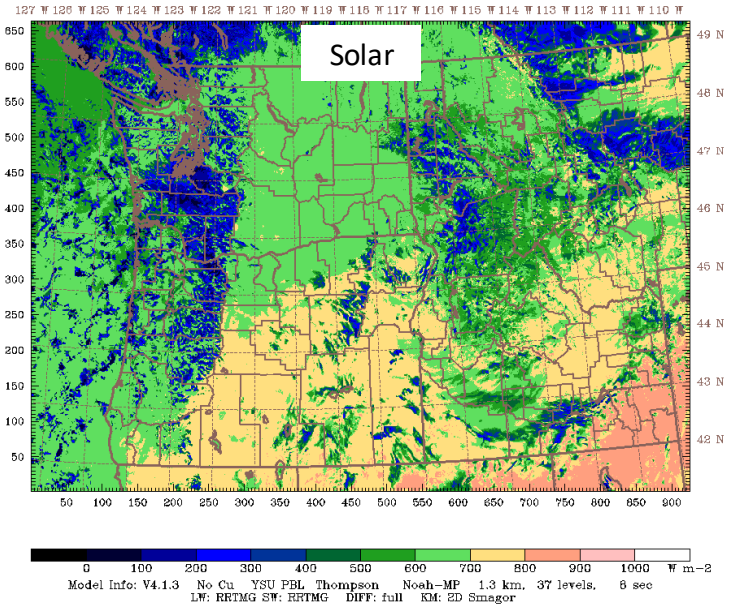
We need to estimate the renewable generation at an appropriate aggregation level for the same weather pattern that is driving load, and we need to do it chronologically

- Details depend on analysis task (RA, Capacity Expansion, PCM etc)
- Consider other G/T&D weather dependent drivers where important









- Power system models have always incorporated weather
  - Treatment mostly concerned with impact of temperature on load, and sampling of hydro years
  - Data needed from urban areas (with plenty of observations), and existing streamflow measurements
- Obs. of weather impacting wind and solar output are not widely available and MUST BE SYNTHESIZED
  - Fields vary rapidly across short distances and times, and are needed for remote areas
  - Data is sparse, has a short history, and where it does exist it is mostly **proprietary**
- The complex interaction between variables impacting load, wind, and solar MUST now be considered, and must be coincident and physically consistent (in time and space),and chronological.
- The interconnectivity in time and space yields complex, yet organized, multi-dimensional probability distributions that must be reasonable for accurate RA assessments.
- DERs/storage and other weather impacts on G,T, and D add more layers of complexity.

Agenda

- Increasing weather dependence (Almost covered)
- Trans-disciplinary disconnects
- **Attributes of the data we need**
- Validation: The most critical gap
- What's the current status? Gaps and impacts
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What is Needed: Ongoing Synthesis of Quality Representative Datasets

Required Attributes of Weather Inputs for Power Systems Analysis

Physical Requirements	Relevance Requirements	Usability Requirements
Representative of Actual Weather	Covers Multiple Decades with Consistent Method	
Coincident, Physically Consistent Weather Variables	Validated and Uncertainty Quantified	Expertly Curated
Sufficient Resolution (<=2 km, <=15 min)	Periodically Refreshed	Publicly Available and Easily Accessible
Chronological	Regularly Extended	Transparently Documented

The Main Attributes of Time Series Data Necessary to Meet General Power System Modeling Needs

Including the necessary variables	Include the necessary variables at sufficient spatio-temporal resolution and accuracy to reflect actual conditions that define the generation potential at current and future wind/solar sites and temperature at load centers
Covering multiple decades with ongoing extension	Cover multiple decades with consistent methodology and be extended on an ongoing basis to capture the most recent conditions and allow climate trends to be identified
Coincident and physically consistent	Are coincident and physically consistent, in space and time, across weather variables
Validated	Are validated against real conditions with uncertainty quantified
Documented	Are documented transparently and in detail, including limitations and a guide for usage
Periodically refreshed	Are periodically refreshed to account for scientific and technological advancements
Available and accessible	Publicly available, expertly curated, and easily accessible

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

GridLAB

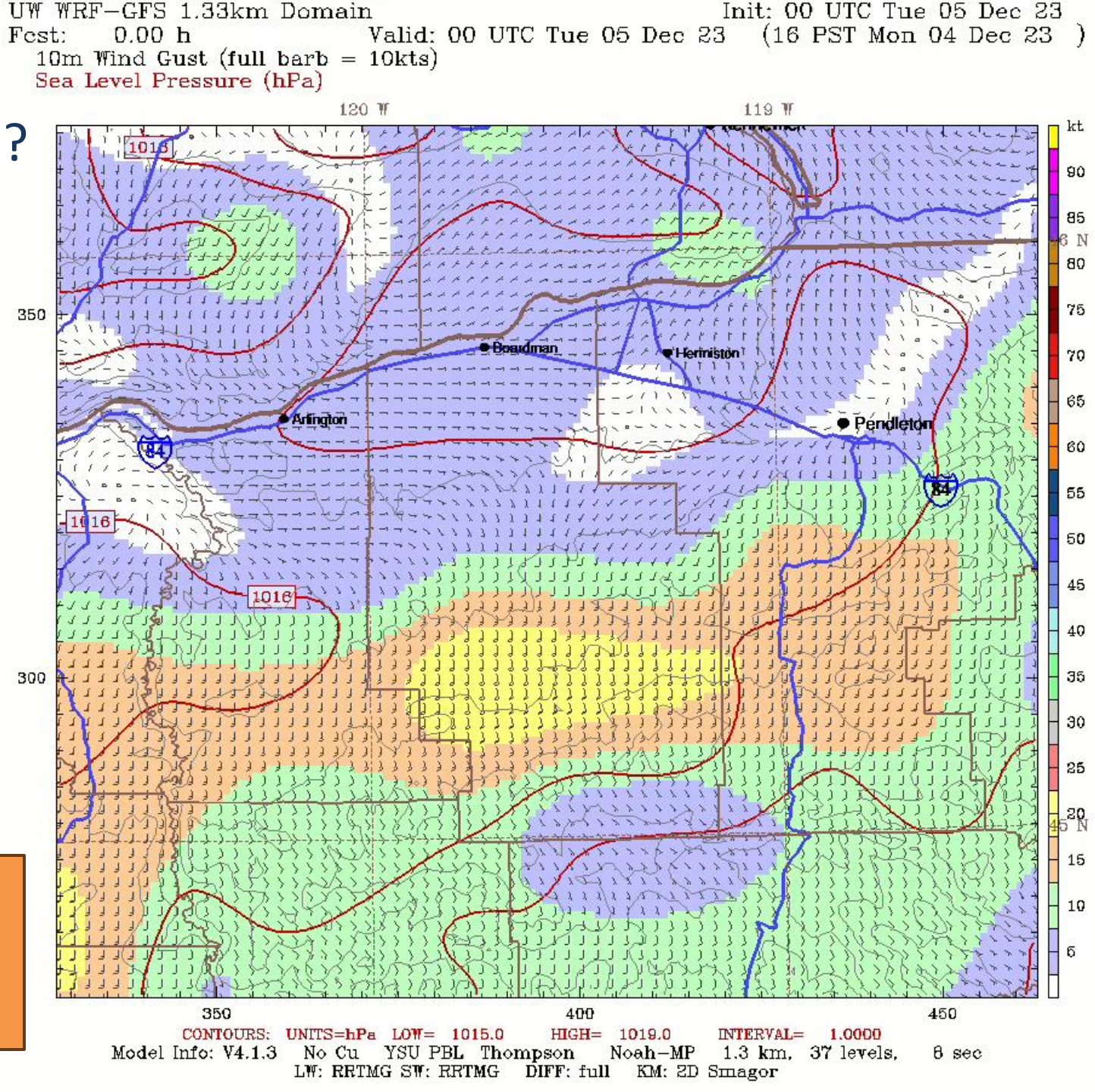
Sharply Focused
Understanding Renewable Resources

Source: Energy Systems Integration Group.

Key Features

- What happens from 4 pm to 5 pm?
  - Did the weather suddenly change?
- Notice the low wind speed and different direction near the river
  - There's a bunch of wind farms there
  - The south wind is creeping in. Why?
- Suddenly tomorrow afternoon it gets windy everywhere. Why?
  - What if the model is wrong?
  - What if the model is often wrong?

While this is a forecast, the same principles are used in data synthesis…and yes, there are NWP weaknesses that correlate with times of RA risk



Don't We Produce This Data and Use it in Operations???

Yes, we do which leads to the radical statement that:

Historical generation estimations used in power system modeling are currently less accurate than operational generation forecasts.

Why? Proprietary plant dataset are available and used for training/validation of operational forecasts, more attention is paid to them and only need data for next few days, versus for the last few decades.

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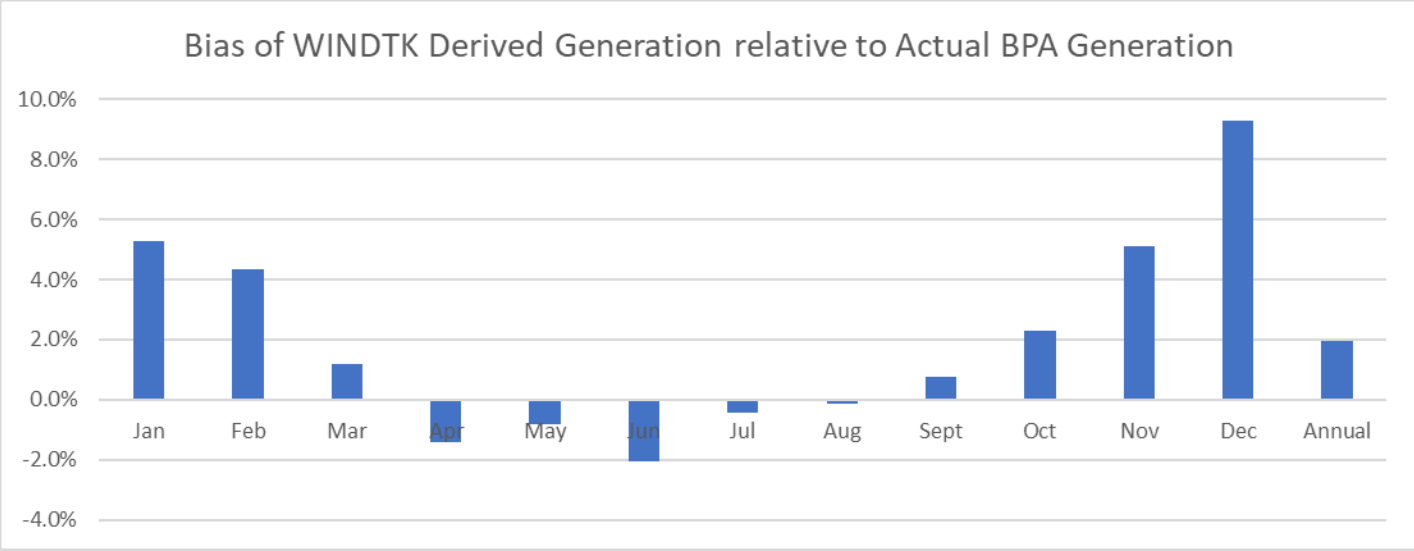
What's Needed: Use Case Specific Validation

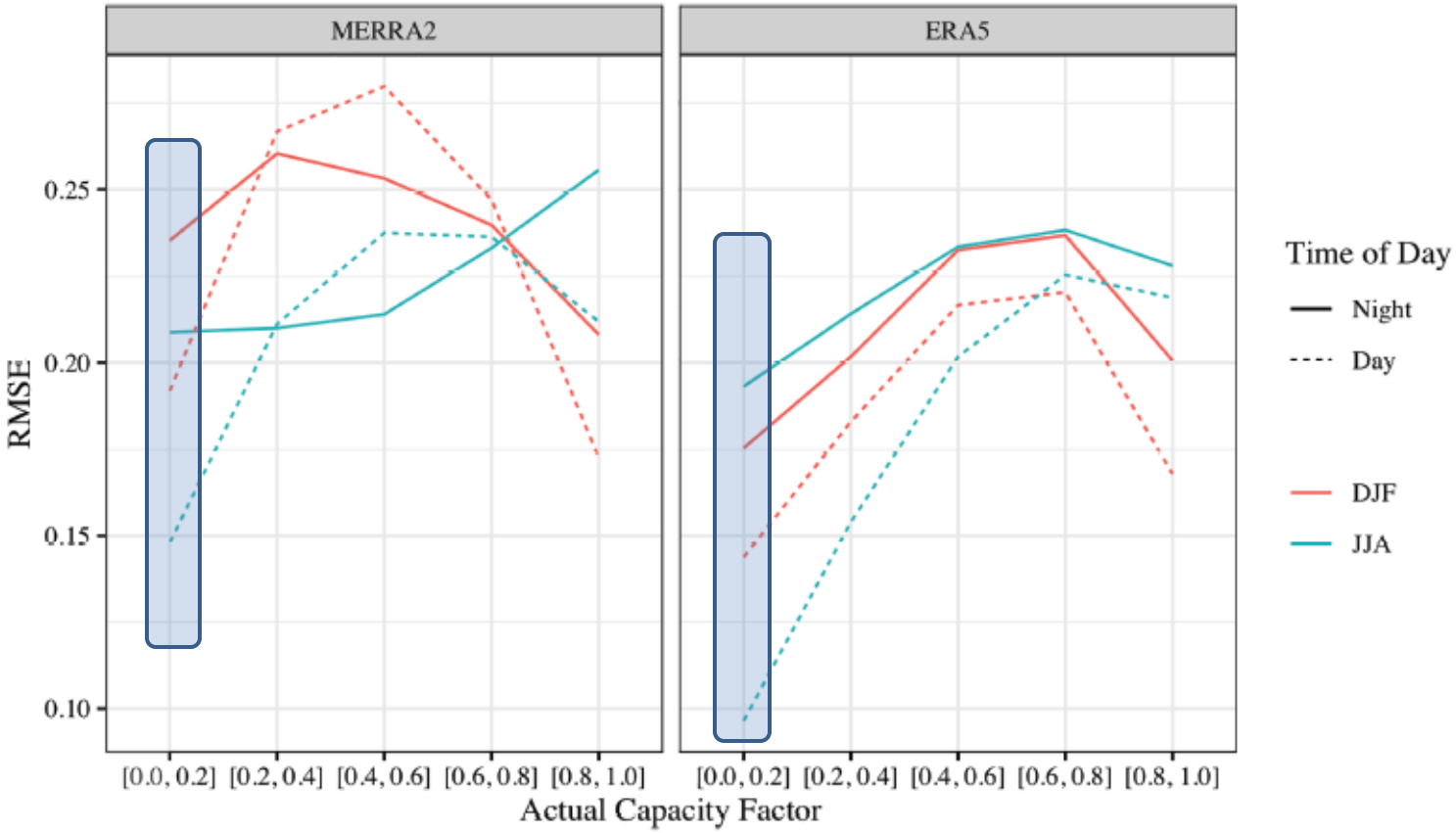
- We must validate according to the use case. E.g. For RA, the distributions, and especially the tails, matter more than the averages
- The distribution of coincident tail events MUST be close to reality
- Example:
  - WINDTK data in the BPA area
  - Wind resource in BPA BA is notoriously difficult to predict with NWP => WFIP2 Project
    - Complex terrain that needs a minimum of 1.33 km resolution to resolve
    - Stable boundary layer issues in the wintertime. => Low wind AND high load

These biased low wind speed events frequently coincide with high load events due to regional mesoscale meteorology



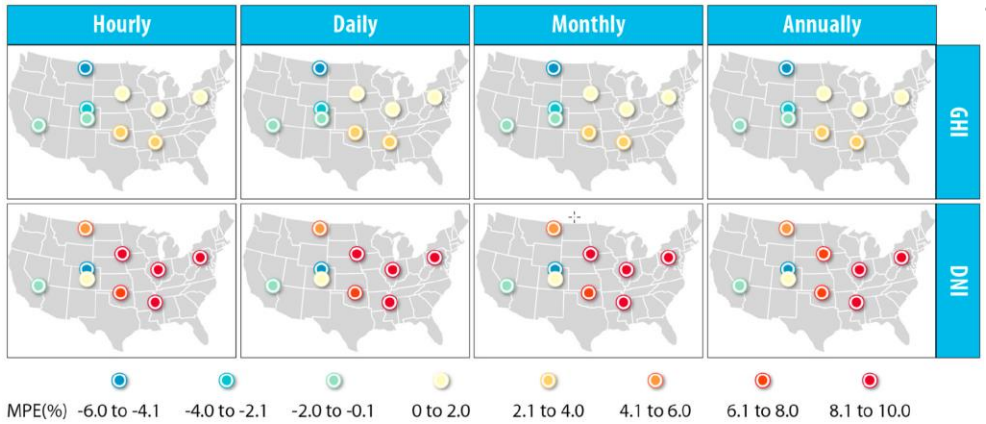
Tail event deviations can be >7x.
e.g. BA wide generation of 3% and model-based estimates of 23%!

When Validated How Bad Is The Existing Data?



Average RMSE as a function of recorded CF bins for winter and summer divided into nighttime (8–1 h before sunrise) and daytime (1–8 h after sunrise) averaged across over 100 ERCOT windfarms over 7-years.

Figure: Davidson & Millstein (2022): Limitations of reanalysis data for wind power applications



NSRDB validated* against a handful (literally) of observations, because there simply aren't many quality surface solar measurements available. Note mean percentage error is significant on an hourly and even daily basis, especially for DNI. Despite not being created for this purpose, NSRDB is broadly used as the solar insolation input to estimate solar generation for PS modeling, generally without reference to data input uncertainty

*Sengupta et al (2018): The National Solar Radiation Data Base (NSRDB); Renewable and Sustainable Energy Reviews. *(Figure from paper)*

Note the errors at low CF's (boxed). These matter the most for resource adequacy studies.

What is Needed: Comprehensive Industry Wide Data Transparency and Sharing

- What: Meteorology data, generation data, availability data
  - Little proprietary value per site but a tremendous untapped asset if made public across all generators
- Why: To validate synthetic meteorology and generation datasets, quantify their uncertainty, and improve their accuracy
- ERCOT is leading the way. Others should follow ASAP
  - Might require legislation/regulation.

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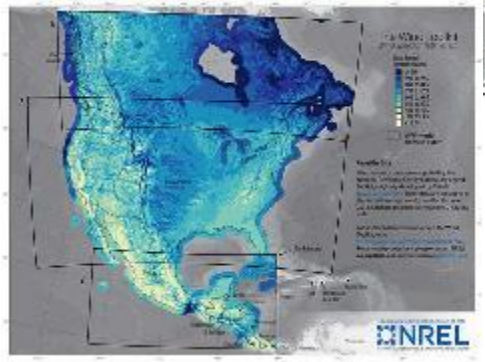
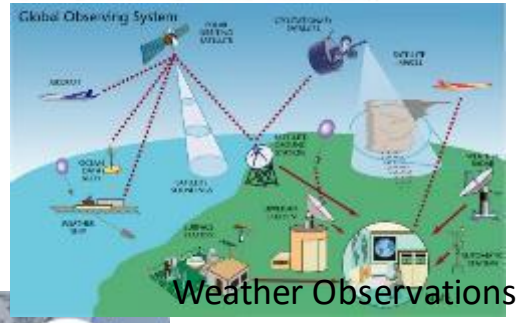
What About The Data Available Today?

ERA5

Copernicus
Europe's eyes on Earth

GMAO
MERRA-2





Weather Observations

HRRR

The data currently available to the sector (on left) is not adequate for the task at hand. Main issues are one or more of the following:

- Insufficient spatial or temporal resolution
- Insufficient time history
- Insufficient validation
- Distributions don't match reality, especially for extreme events
- Sometimes proprietary and opaque
- Not coincident or physically consistent
- Archaic or not extended to present date
- Non-static modeling platforms

Why does it matter?

- You can't correctly predict the wind and solar generation if the weather data isn't good. Sometimes, you'll be WAY off.
- Load estimation is also more difficult

A Closer Look at the Data Available Today

- Observations:
  - Closest representation of truth
  - Too sparse, and requires rigorous QC
  - And/Or Proprietary
- ERA5 (~30 km) (and MERRA2, ~60 km):
  - Longest, most complete consistent time series
  - Easy to use
  - Too low resolution for generation estimates
- WIND TK (2 km, 5 min/hourly):
  - Resolves most physical phenomena
  - Includes forecast database
  - Some temporal seams
  - Outdated model, esp. not great for solar
  - Only 2007-2013 using same set up. 2014 available using different configuration.
- NSRDB (4 km, 30 min):
  - Based on satellite observations and a physics based model
  - Continuous and consistent since 1998
  - Not originally designed for integration studies
  - Non-solar fields are misleading interpolations of MERRA2
- HRRR (3 km, 15 min):
  - Resolves most physical phenomena
  - Data from operational forecast archive
  - Model configuration inconsistent in time
- Data from proprietary models:
  - Opaque and often unscientific in basis

Common Issue: Lack of validation and examination of use case applicability

General Issues with Today's Methodologies

- Provided for offline reference reading!
- Model data (even reanalysis data) is NOT the same as observations
  - Ability to represent features is limited by resolution.
  - LARGE deviations can exist between model data and reality
  - Models have limitations and weaknesses. These are understood by NWP experts but not by general data users
- Model data is being used as a black box
  - Gridded data is easily accessible and easy to use
  - Therefore, it is very attractive to data hungry users
  - But see bullet#1…users must understand the limitations and the impacts on downstream results
- Lack of validation:
  - Model data contains many (often millions) of data points.
  - There is very little validation of any of these points
  - Mostly because there are few observations available (but see below)
  - Validations are not targeted to RA needs (e.g. low resource periods)
- Lack of observations for validation, bias correction and generation estimation
  - Model data MUST be validated, and uncertainty quantified
  - Models will always be imperfect. Ground truth allows sophisticated bias correction to be applied
  - Generation data allows sophisticated models to be used to estimate generation time series from past met. Data
  - **The rapid build out of wind and solar means this data <u>is</u> available. But it is currently proprietary. This <u>must</u> change.**

A Quick Word About Climate Change

- It isn't the focus here, but it is important
- Getting our house in order to address climate ***variability*** is the #1 priority
- By doing that in an ongoing fashion we implicitly begin to address climate trends
- We also begin to validate and quantify the uncertainty of climate change models
- While large, I believe the impact of climate change is second order compared to the massive impact of increased weather dependency and the need to properly quantify climate variability in this context

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[a]	~60 km	60 min	1980–present	Yes	Yes/No	Yes	No		Probably		Basic	Global
ERA5[b]	~30 km	60 min	1940–present	Yes	Yes/No	Yes	Some		Yes		Good	Global
HRRR[c]	3 km	15 min	2014–present	Yes	Yes/No	Yes/No	No		Unideal		Basic	U.S.
WIND Toolkit[d]	2 km	5 min	2007–2014	No	Yes/Yes	Yes	Yes		No		Basic	Various
WTK-LED[e]	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[f]	4 km/ 60 km	30 min	1998–present	Yes	Yes/No	Solar only	Yes		Yes		Basic	Most of globe
CERRA[g]	11 km/5.5 km	60 min	1980–present		No/Yes	No solar	Yes		Possibly		Basic	Europe
CONUS404[h]	4 km	60 min/ 15 min (precip)	1980–2020	No	Unknown/ Probably	Yes	Not the intended use					Continental U.S.
BARRA[i]	12 km/ 1.5 km	60 min	1990–2019	No	Yes/ Probably	Yes				Fee-based		Australia/ New Zealand
Public Observing Networks[j]	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[k]	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[l]	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

Summary of the most applicable datasets globally that are (or can be) used to provide weather inputs for power system analysis tasks, especially for providing estimate of site-level generation, and concurrent weather-driven load and generation outage risks. The degree to which the needs of each column heading are met is estimated with color coding. See documentation for each dataset for all details. Footnotes on next page. P76, main report.

Source: Energy Systems Integration Group

a MERRA-2. The resolution of MERRA-2 (Modern-Era Retrospective Analysis for Research and Applications) is typically insufficient for weather input use in power system analysis.

b ECMWF (European Center for Medium-Range Weather Forecasting) Reanalysis v5. ERA5 has insufficient resolution to diagnose regional or local weather, yet it is widely used for power system analysis.

c High-Resolution Rapid Refresh (HRRR). The HRRR is an operational model and therefore configured to balance accuracy with speed. It undergoes regular configuration updates, so model skill is changing in time. Occasionally, major updates may occur that can create step changes in model biases.

d Wind Integration National Dataset Toolkit. The years 2007 through 2013 cover the U.S., and 2014 uses a different configuration that includes Mexico and Canada.

e WTK-LED (WIND (Wind Integration National Dataset) Toolkit Long-term Ensemble Dataset) is still in production, and there is little current documentation. There are three years at 2 km, and 20 years at 4 km that are downscaled to 2 km with the machine learning GAN (generative adversarial network) approach. In addition, one year of ensemble data is being produced to aid in quantifying uncertainty.

f NSRDB (National Solar Radiation Database). Irradiance resolution is 4 km. Other variables are interpolated from MERRA-2 data using an unvalidated method. These data are generally not appropriate as weather inputs to power system analysis, forcing NSRDB to be used in combination with other datasets, which creates consistency issues.

g CERRA (Copernicus Regional Reanalysis for Europe). Ensembles at 11 km. Does not include all weather variables.

h CONUS404. A 4 km, long-term regional hydroclimate reanalysis over the conterminous United States (CONUS), 1979–2020. Developed by the U.S. Geological Survey to assess hydrological climatology, but may be useful to repurpose for power system analysis.

i Bureau's Atmospheric High-Resolution Regional Reanalysis for Australia. A 12 km reanalysis with 1.5 km domains over four cities in Australia.

j Many public observing networks exist with variable density, quality, and applicability.

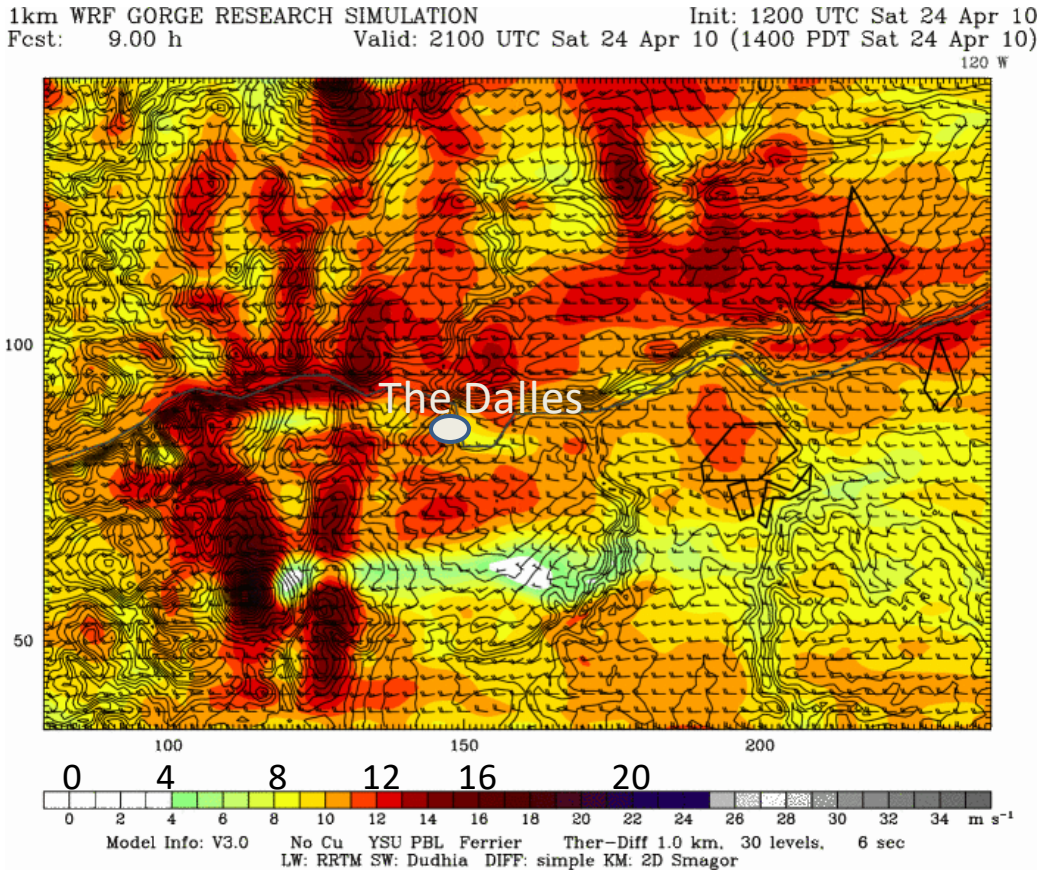
k Observed data from renewable energy facilities is of course applicable to variable renewable energy, but quality varies from site to site and is typically proprietary. Data across the upper portion of the rotor sweep is often not measured.

l Often used proprietary data. The same shape is often assumed across broad areas. Validations are not rigorous, and methodologies are usually not fully documented in a transparent way. Output usually includes only a single weather variable.

Agenda

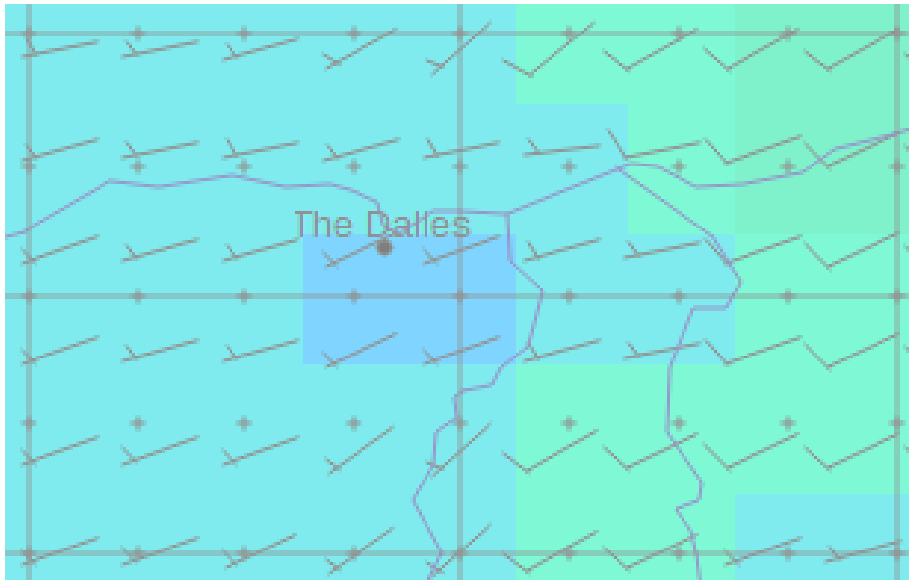
- Increasing weather dependence (Almost covered)
- Trans-disciplinary disconnects
- Attributes of the data we need
- Validation: The most critical gap
- What's the current status? Gaps and impacts
- **A roadmap to the future**

What is Needed: Behavioral Change and Trans-disciplinary Coordination



- Treating NWP model data as black box data is a recipe for disaster!
- Both meteorology and power systems are complicated. Let's stop assuming we understand each other's specialties and work more closely to meet each other's needs.

1 km WRF Forecast and ERA5 Reanalysis (~30 km) Valid Around the Same Date and Time



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How Do We Get To What We Need?

- Power systems experts need to working with NWP experts to ensure there is crystal clear requirements specifications. Meteorologists must be transparent about what is and is not possible
- Three routes. Analyze cost benefit FIRST before expending large amount of effort.
- All require a comprehensive set of observations from industry. Start with ERCOT if we can't get them anywhere else.
  - Reanalysis + obs + machine learning (cheapest, my gut tells me it will be insufficient)
  - Moderate resolution NWP + GAN Downscaling (promising but needs validation)
  - High resolution NWP (will definitely work but still won't be perfect)

How Much Will It Cost/How Long Will It Take?

Rough ballpark estimates for 1-km CONUS dataset back to 1990 based on polling vendors specializing in high volume NWP work

- Compute costs: Initial: $8-15 M. Ongoing $1-2 M/yr including storage
- People: Initial history: $1-2 M. Ongoing NWP: $300-500K/yr. Validation, dissemination, curation: $400-700K/yr
- Total for 1990-2035: $30-55M
- Includes overhead, but not profit.
- Probably conservative but detailed analysis is needed.
- Time: Six months on CPU for first 33 yrs. 1 ½ year project

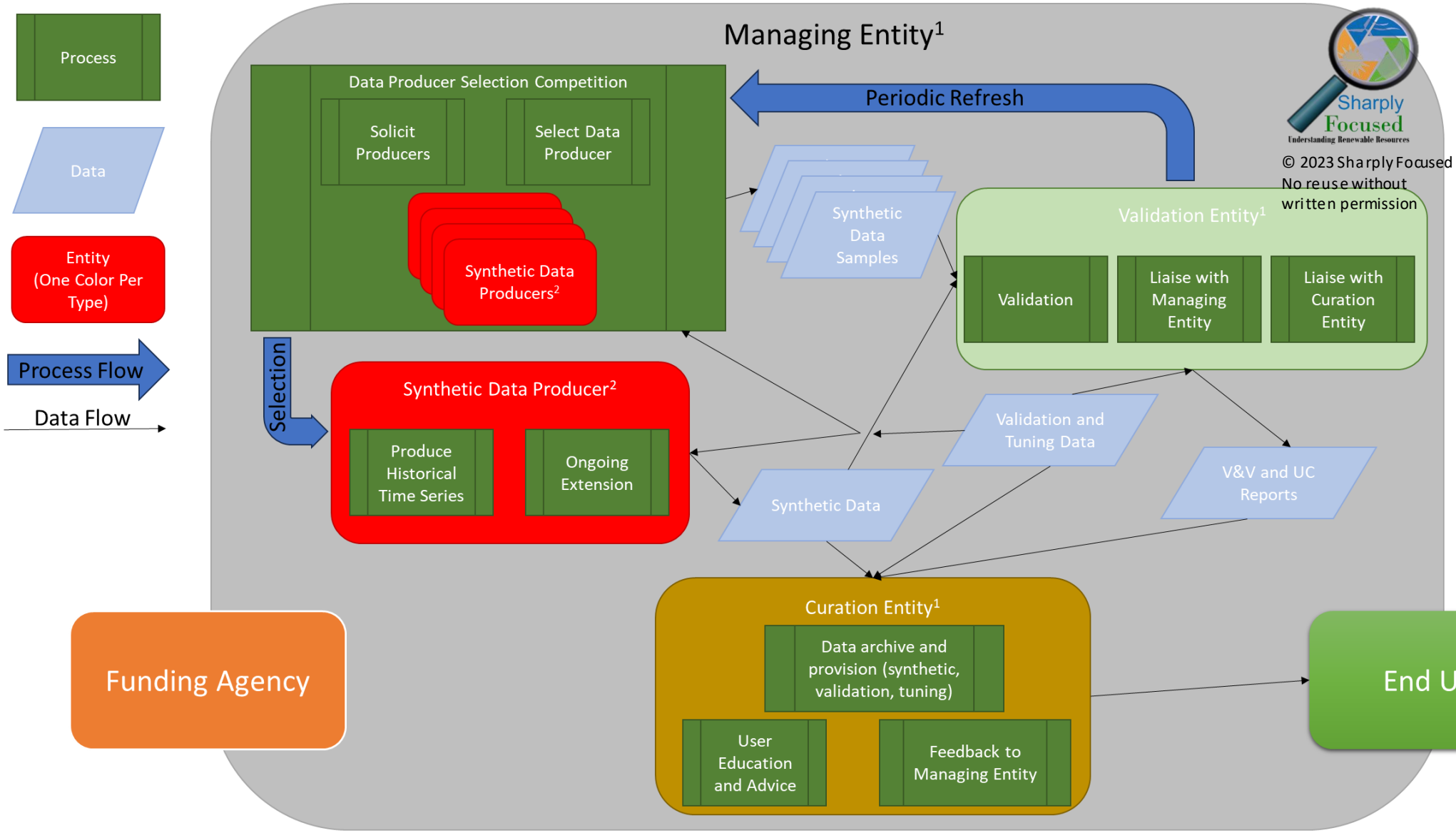
OR

Investment to decarbonize the grid by 2035: $330-740B[1]

Less than 0.01% and the potential cost of **flying blind** is…???

[1] NREL 2022: https://www.energy.gov/eere/articles/nrel-study-identifies-opportunities-and-challenges-achieving-us-transformational-goal

A First Draft Proposal for Discussion with Potential Partners and Funders



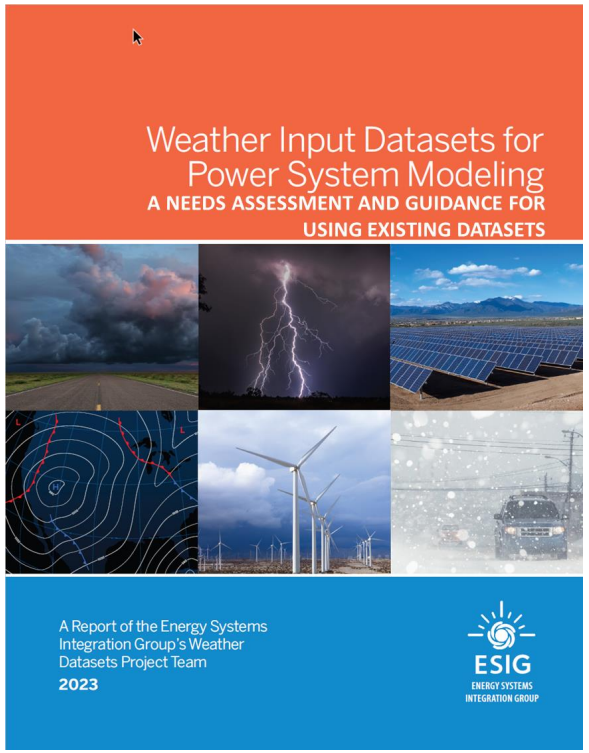
A comprehensive, well thought out, and properly funded strategy is needed. The current scattershot uncoordinated approach is wasteful and is not working.

I want to play major role in moving this ball forward and recognize that I can't do it alone.

I encourage advocates, funding entities (e.g. DOE), and partners like labs, NOAA, EPRI and private weather vendors to connect to discuss.

[1]May all be the same organization. [2] Should *not* be the same organization; creates a conflict of interest.

THANK YOU



Weather Input Datasets for Power System Planning

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