

The Urgent Need for Comprehensive, Curated, Fit-For-Use, Weather and Climate Intelligence to Support the Energy Transition



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IEA Technical Expert Meeting #211
Short-comings and Improvements

April 25, 2024



GridLAB

Meteorology is Becoming Central



RISKS ARE SHIFTING



WEATHER DEPENDENCE AND WEATHER COMPLEXITY
ARE INCREASING



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

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



The Imperative of Quality Weather Data Inputs for use in Power System Planning & Analysis

Main Discussion Points



Ongoing Vision, Leadership, and Coordination

The diagram consists of four horizontal bars of different colors (brown, light blue, orange, and blue) stacked vertically. To the left of each bar is a white circle with a colored outline (brown, light blue, orange, and blue respectively). A thin line connects the circles, starting from the top and ending at the bottom. The text for each point is written in white on its respective bar.

Silos removed. Clear cross-cutting requirements specification

Focus on issues: Validation, UQ, Curation

A Possible Structure for Discussion

• Our Weather “Intelligence” is Inadequate

Producer(s)

Create initial and ongoing gridded archives
Bias correction
Ongoing generic R&D

Gridded Weather Data

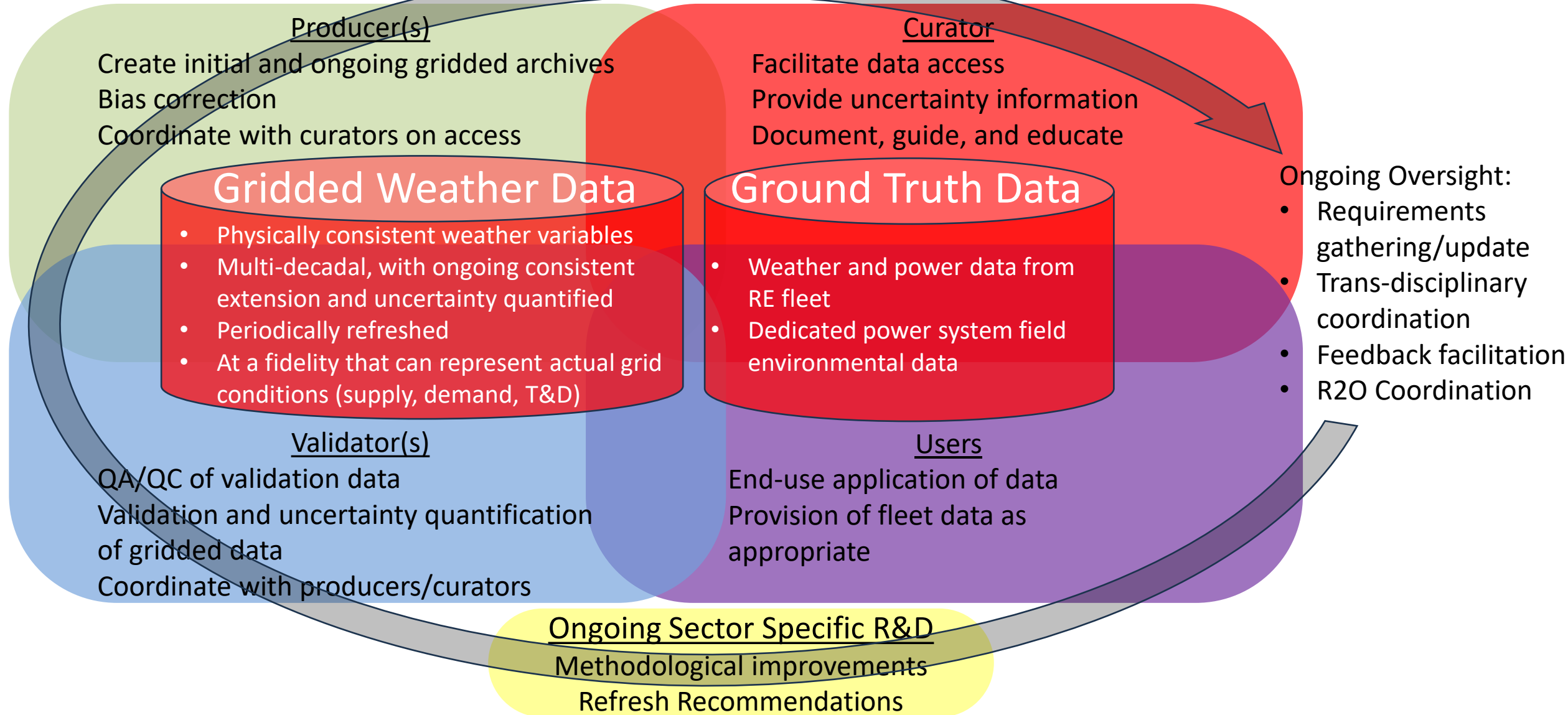
- Physically consistent weather variables
- Multi-decadal, with ongoing consistent extension and uncertainty quantified
- Periodically refreshed
- **Insufficient resolution for general power systems use**

Users

End-use application of data

• We Need Vision, Investment & Leadership

SF Vision For A Holistic Weather Data Support Framework For The Electric System



Requirements: Ongoing Synthesis of Quality Representative Datasets

Representative of
Actual Weather

Coincident, Physically
Consistent Weather
Variables

Sufficient Resolution
(≤ 2 km, ≤ 15 min)

Chronological

Physical Requirements

Covers Multiple
Decades with
Consistent Method

Validated and
Uncertainty
Quantified

Regularly Extended

Periodically Refreshed

Relevance Requirements

Required Attributes of Weather
Inputs for Power Systems Analysis

Expertly Curated

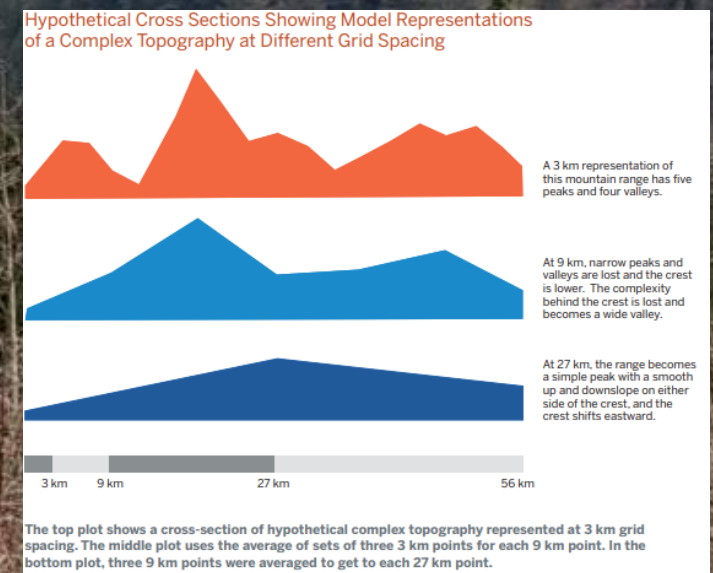
Publicly Available and
Easily Accessible

Transparently
Documented

Usability Requirements

The Imperative of Quality Weather Data Inputs for use in Power System Planning & Analysis

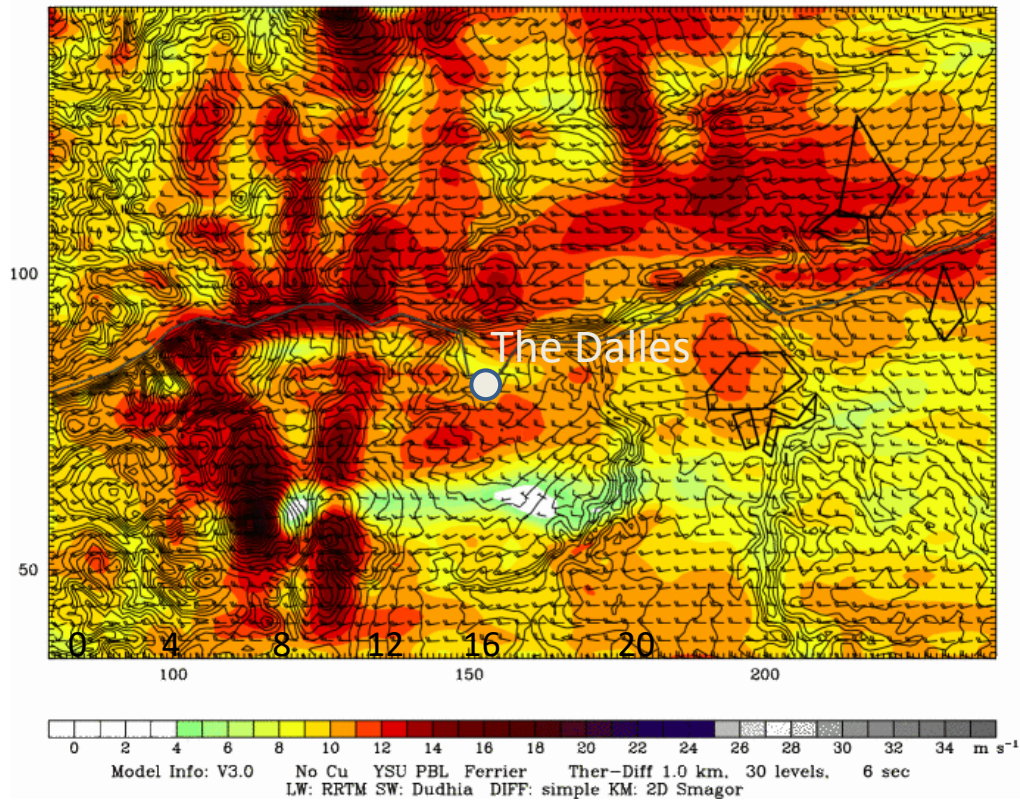




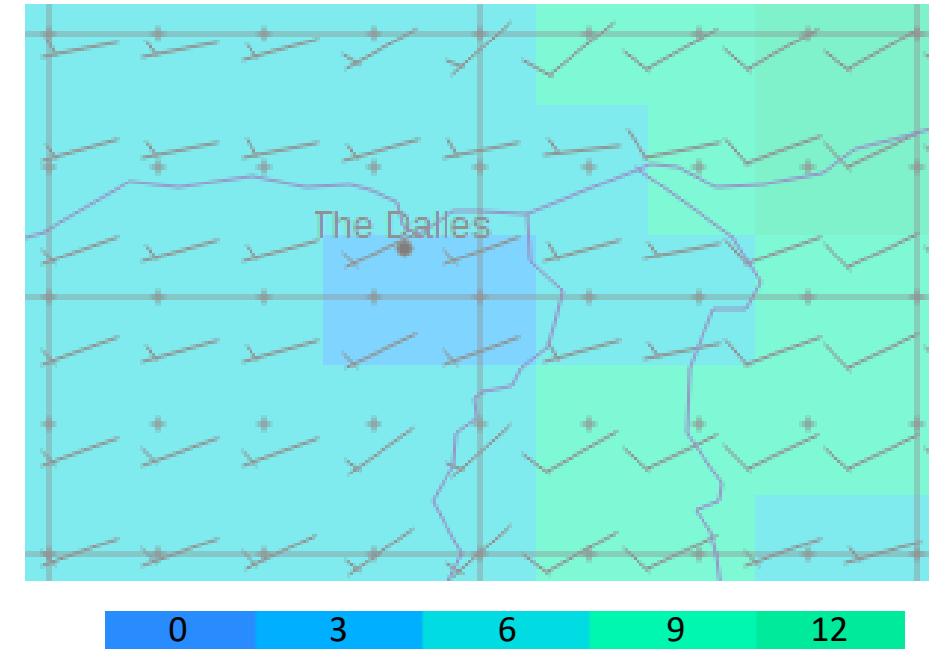
Silos: A Behavioral Gap

- Treating NWP model data as black box data is a recipe for disaster!
- So, is not driving requirements gathering and education from the user side.
- 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.

1km WRF GORGE RESEARCH SIMULATION Init: 1200 UTC Sat 24 Apr 10
Fcst: 9.00 h Valid: 2100 UTC Sat 24 Apr 10 (1400 PDT Sat 24 Apr 10)

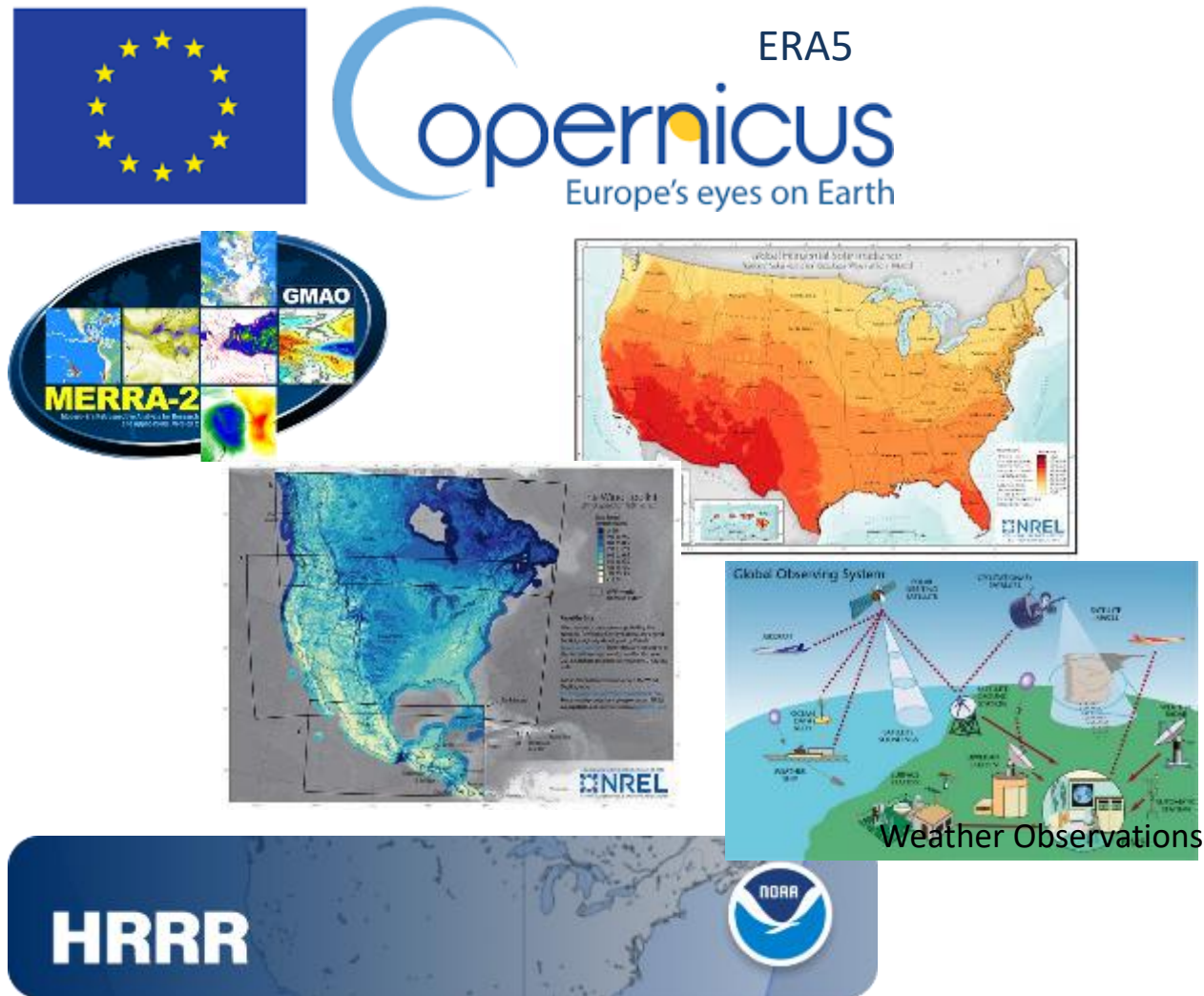


1 km WRF
Forecast and
ERA5
Reanalysis
(~30 km) Valid
Around the
Same Date
and Time



The Imperative of Quality Weather Data Inputs for use in Power System Planning & Analysis

Technical Gaps in Today's Datasets



The data currently available to the sector is not adequate for the task at hand. Datasets have some of the following limitations:

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

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

The Imperative of Quality Weather Data Inputs for use in Power System Planning & Analysis

Validation Requires A Comprehensive Ground Truth Network

- What: Meteorology data, ideally generation and availability data
 - OBSERVATIONAL DATA IS VITAL!!! There's little proprietary value per site but tremendous value if made public across all generators. Untapped!
- Why: To validate synthetic meteorology and generation datasets, quantify their uncertainty, and improve their accuracy
- Who: Industry wide cooperation in data acquisition and sharing
 - Standardized, high quality. Might require legislation/regulation
- When: NOW! ERCOT has shown the way. It can be done. Require as condition of interconnection?

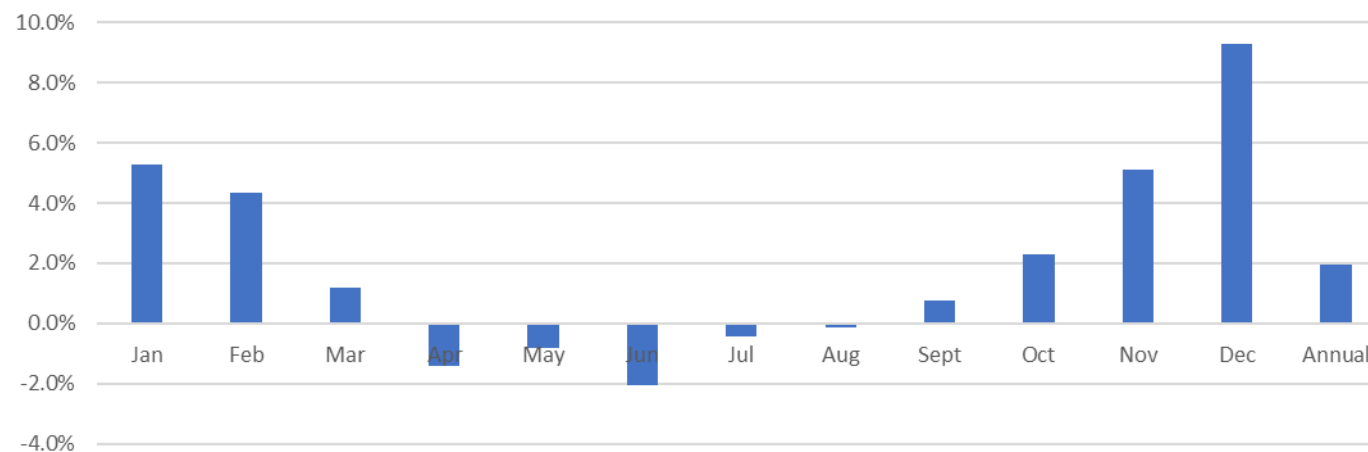


The Imperative of Quality Weather Data Inputs for use in Power System Planning & Analysis

Use Case Specific Validation is Vital

- We must validate according to the use case. E.g. For Resource Adequacy, 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

Bias of WINDTK Derived Generation relative to Actual BPA Generation

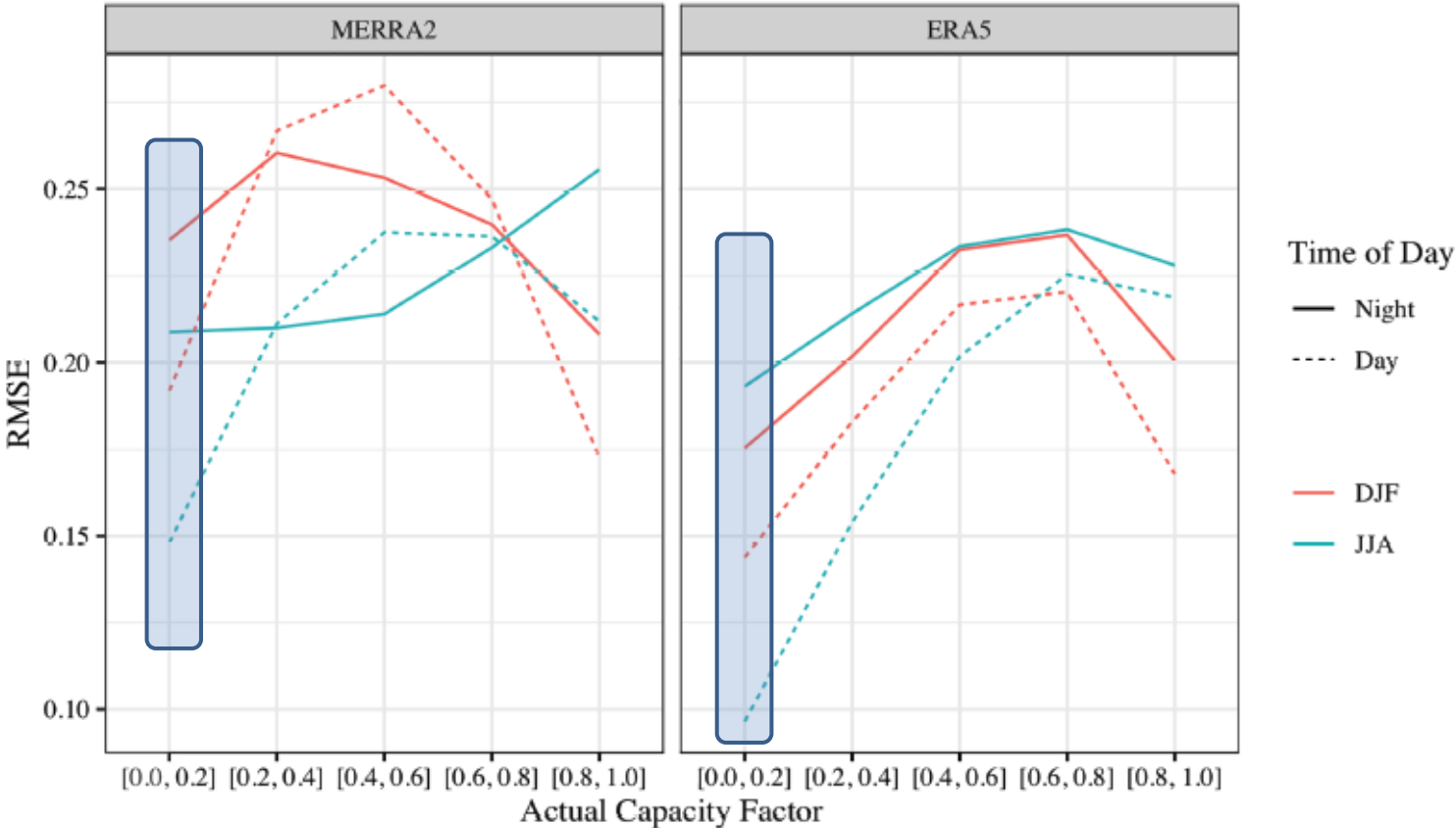


These biased low wind speed events frequently coincide with high load events due to regional mesoscale meteorology

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

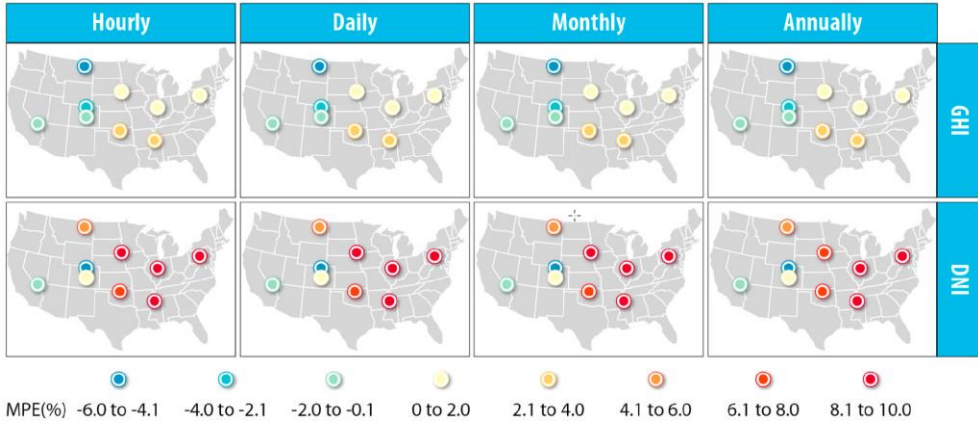


When Validated How Bad Is The Existing Data?



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.

The Imperative of Quality Weather Data Inputs for use in Power System Planning & Analysis



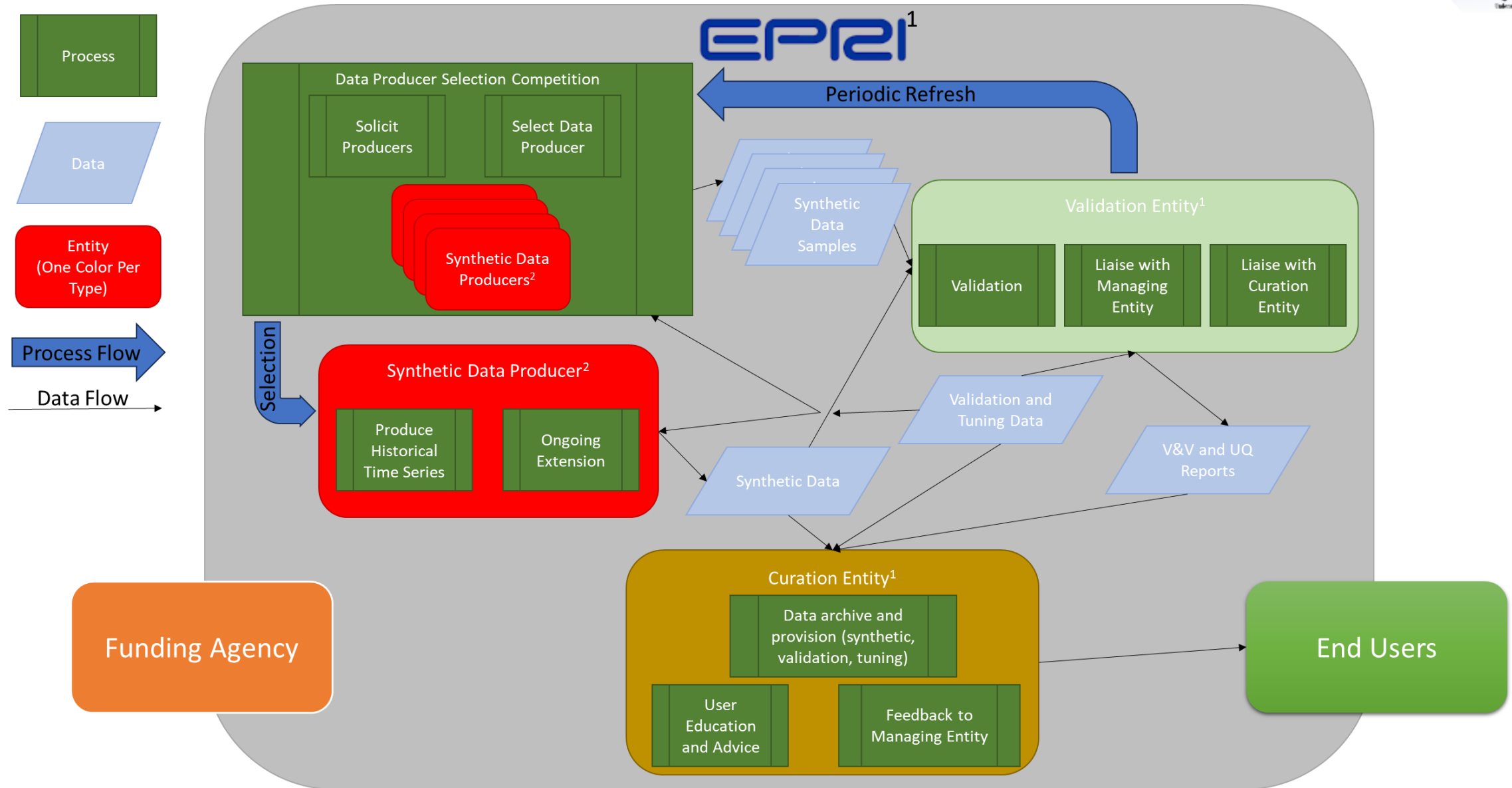
A Closer Look at the Data Available Today

- 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



A First Draft Proposal for Discussion with Potential Partners and Funders



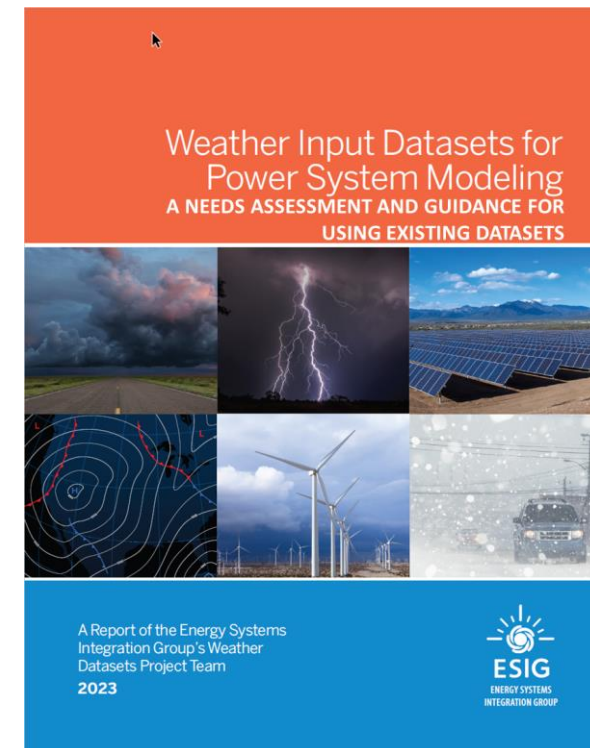
¹May all be the same organization. ² Should *not* be the same organization; creates a conflict of interest.



THANK YOU

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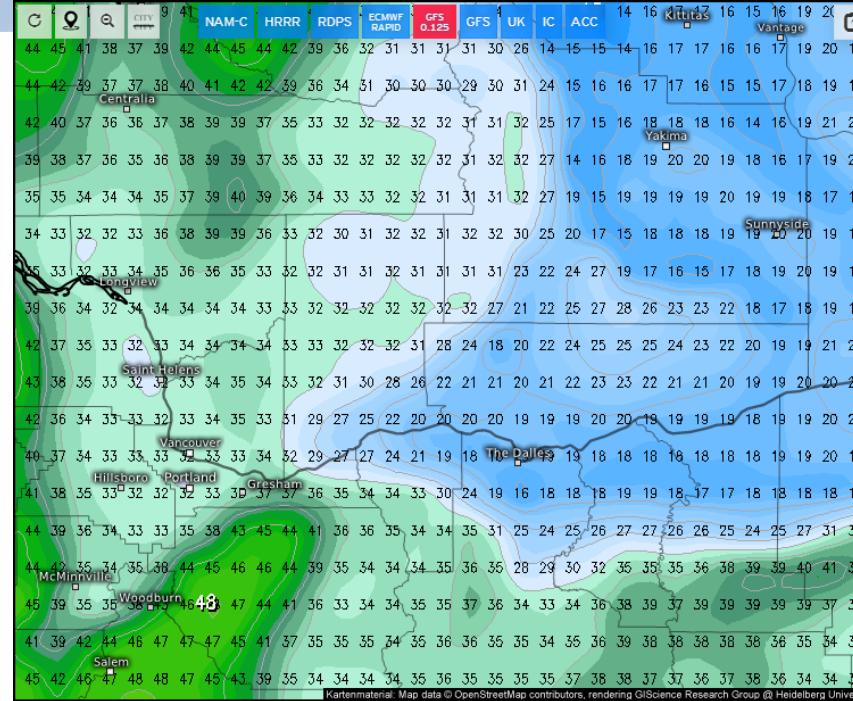


[Weather Input Datasets for
Power System Planning](#)



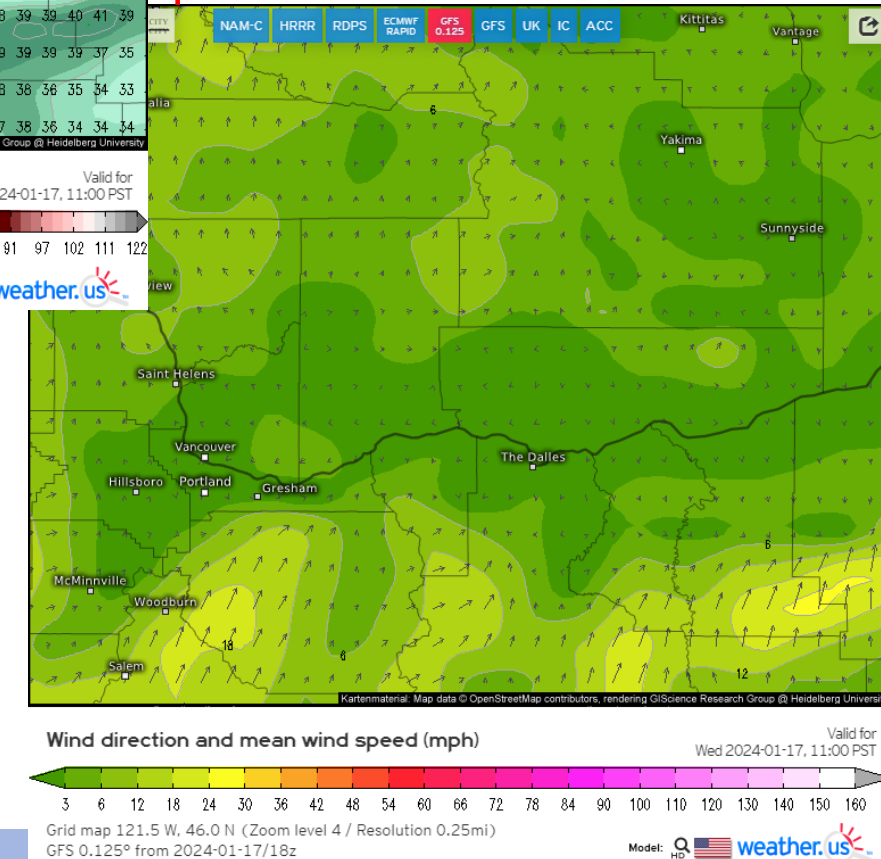
**Scan for report
landing page**

- Modern weather datasets are increasingly complex
- They are typically NOT observations
- Let's illustrate this with very different model views of the same time in the historic January 2024 event
- The point: it's complicated
 - 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

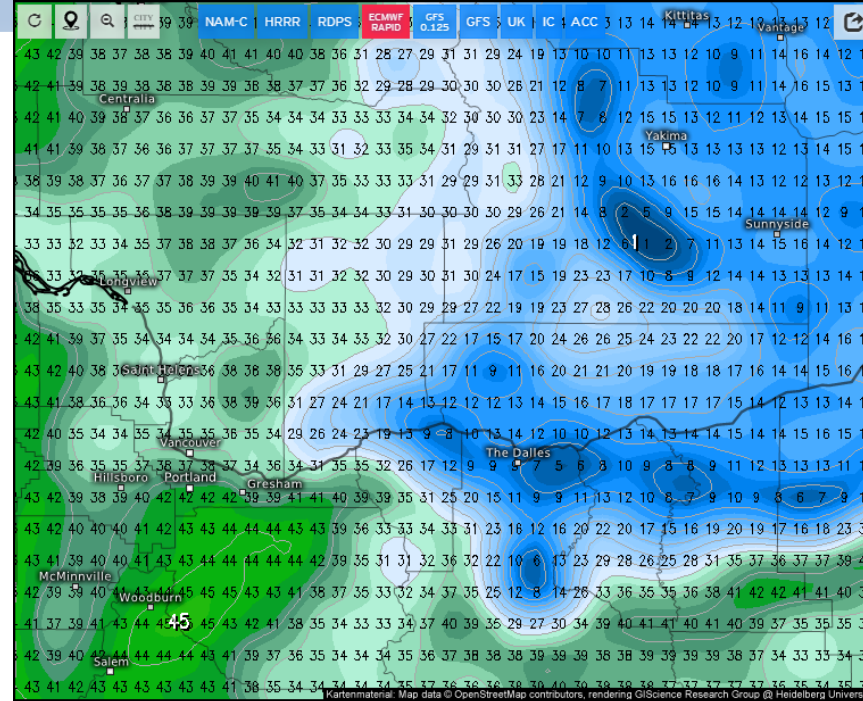


NOAA/NCEP GFS Model
0.125 degree
~13-km Grid Spacing
(>twice ERA5 resolution)

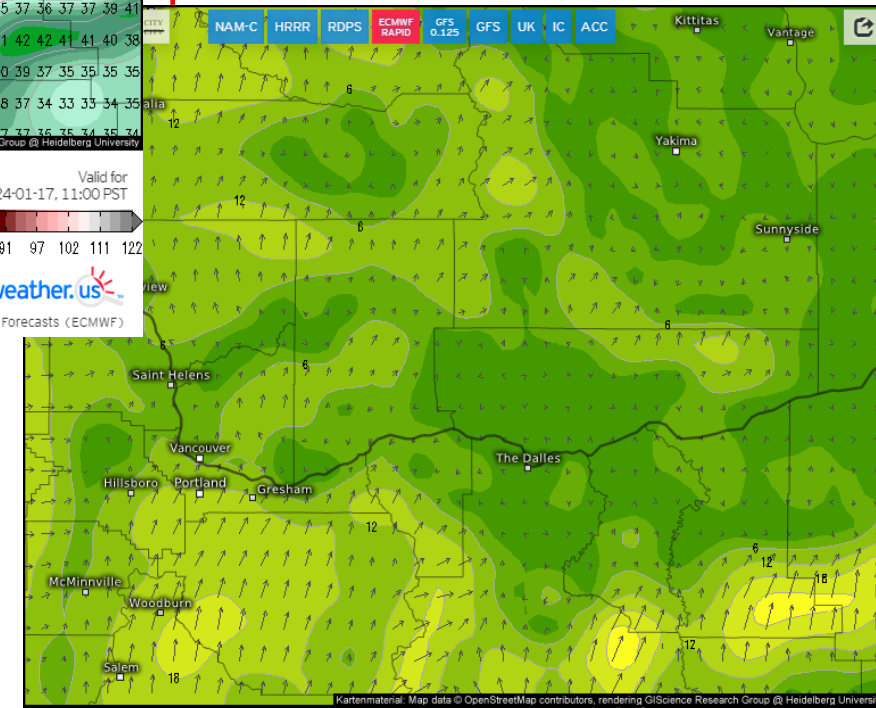
All 1-hr Forecasts
Valid 11 PST, 20240117
Differences in resolution of topography and the features driven by it, and in the model assimilation methods have profound effects



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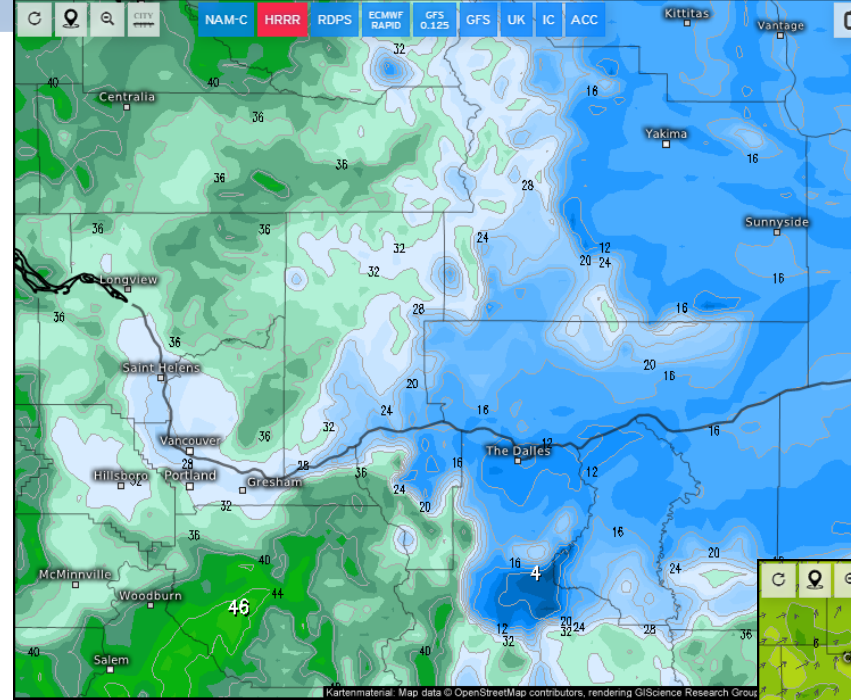


ECWMF IFS Model
~8-km Grid Spacing



All 1-hr Forecasts
Valid 11 PST, 20240117
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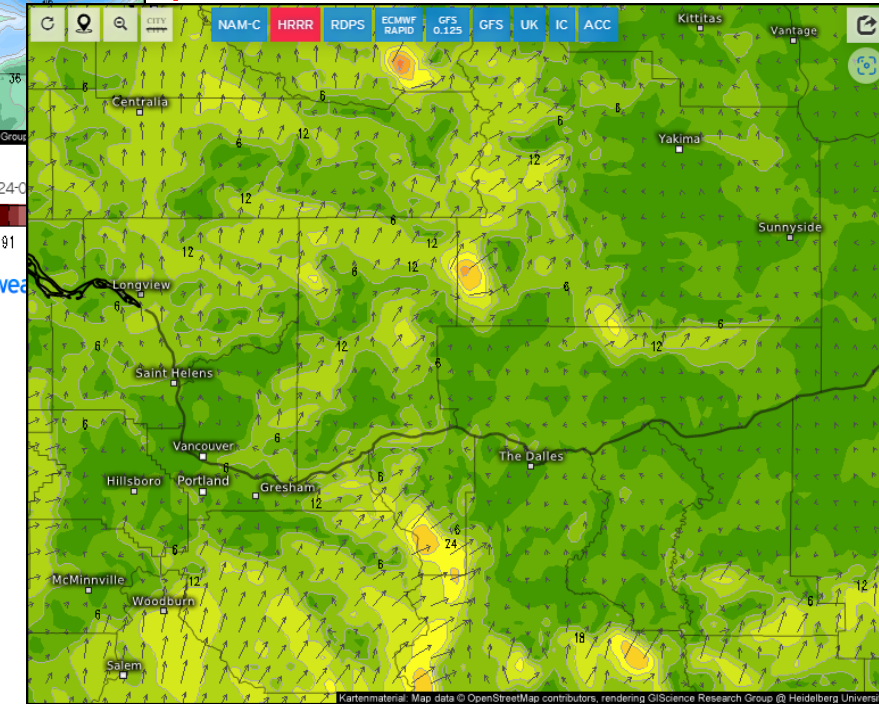
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Temperature (°F)
 -33 -22 -17 -11 -6 0 5 10 16 21 27 32 37 43 48 54 59 64 70 75 81 86 91
 Grid map 121.5 W, 46.0 N (Zoom level 4 / Resolution 0.25mi)
 HRRR (18 hours) from 2024-01-17/18z

NOAA/NCEP HRRR
 3-km Grid Spacing
 Begins to resolve the
 Columbia Gorge.

All 1-hr Forecasts
 Valid 11 PST, 20240117
 Differences in resolution of
 topography and the features
 driven by it, and in the model
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 profound effects



Wind direction and mean wind speed (mph)
 3 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 100 110 120 130 140 150 160
 Grid map 121.5 W, 46.0 N (Zoom level 4 / Resolution 0.25mi)
 HRRR (18 hours) from 2024-01-17/18z