CAMUS
Zero Carbon Grid Orchestration

# How NODD Weather Forecasts Are Boosting Grid Operations

David Stuebe, Camus Forecast Team Lead | June 24, 2024

ABOUT CAMUS ENERGY

# Grid Orchestration for a 100% Electrified Future

OUR PERSPECTIVE

We leverage deep experience designing & operating **hyperscale, high-reliability software systems** to help utilities build and operate the two-way grid.

Today's speaker

**David Stuebe**

Forecasting Team Lead

WHAT IS GRID ORCHESTRATION?

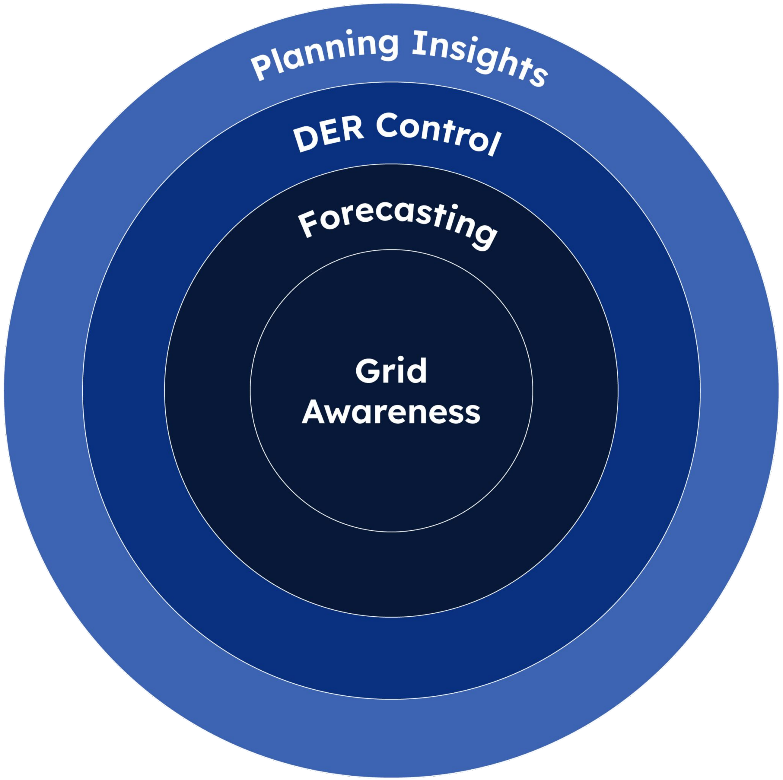
# Visibility and control for a new era of grid management

CAMUS PLATFORM CAPABILITIES

**See real-time and forecasted grid conditions** using data from AMI, GIS, SCADA, and DERMS

**Dispatch DERs with respect for grid constraints,** via an ecosystem of DERMS & aggregator partners

**Incorporate DER flexibility into system planning**, reducing capital investments and lowering rates

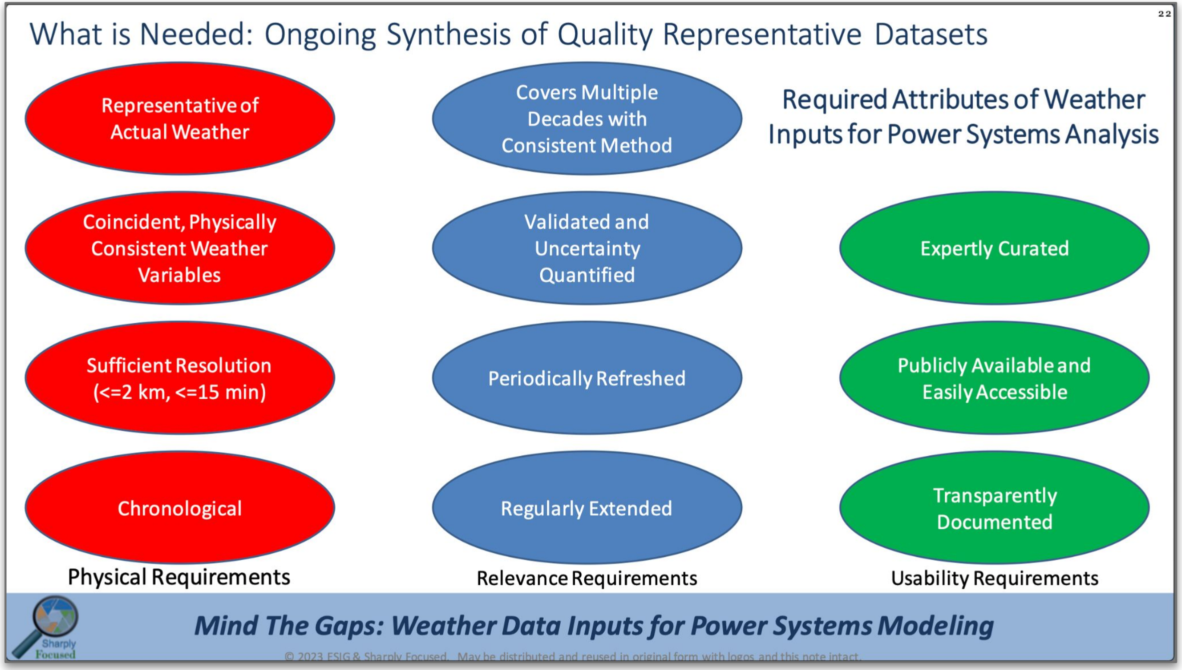


THE CHALLENGE

# Why is working with weather forecast data difficult?

Three challenge areas:

1. **Physical** – do we have the right inputs?
2. **Relevance** – do the time scales match what we need?
3. **Usability** – can we, find, access, and use the data?

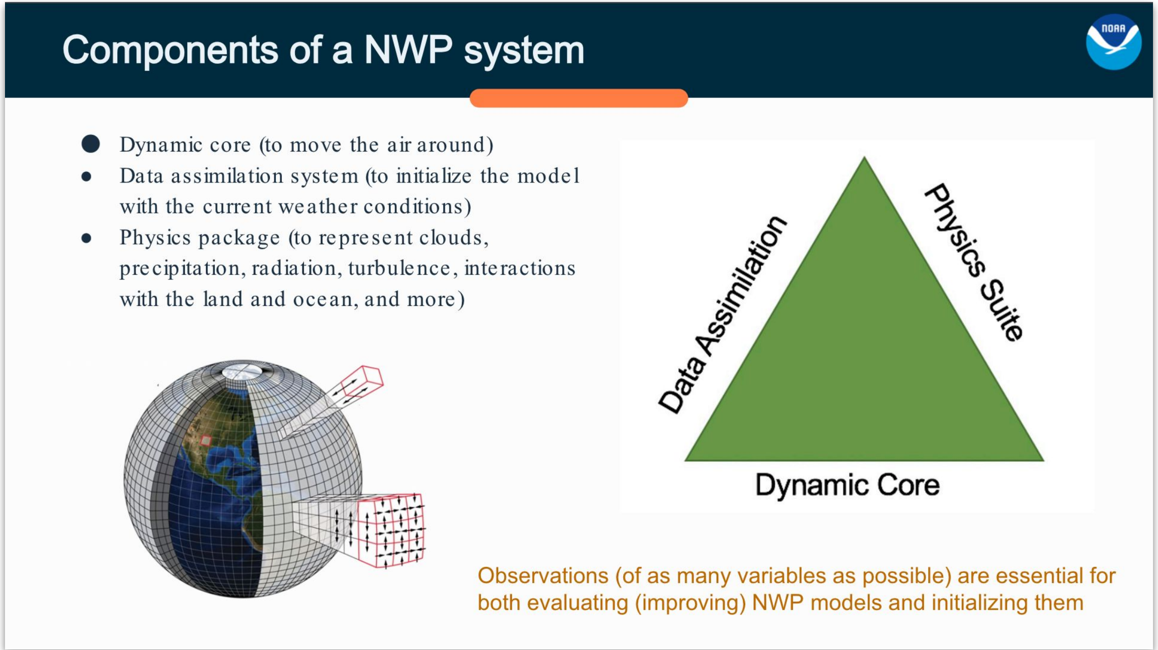



Source: [Weather Data Inputs for Power System Modeling: Mind the Gaps]
December 5, 2023 ESIG Webinar by Justin Sharp

# Discretized model of the atmosphere run on a Supercomputer

Three components:

1. **Data assimilation** - initializes model based on current observations
2. **Dynamic core** - motion & interaction of cell properties, water, heat, etc.)
3. **Physics suite** - approximates smaller factors (e.g. how raindrops form)




Source: NOAA's 3km Rapid Refresh Weather Forecasting Models and Renewable Energy Forecasts January 25, 2024 ESIG Webinar by Dave Turner

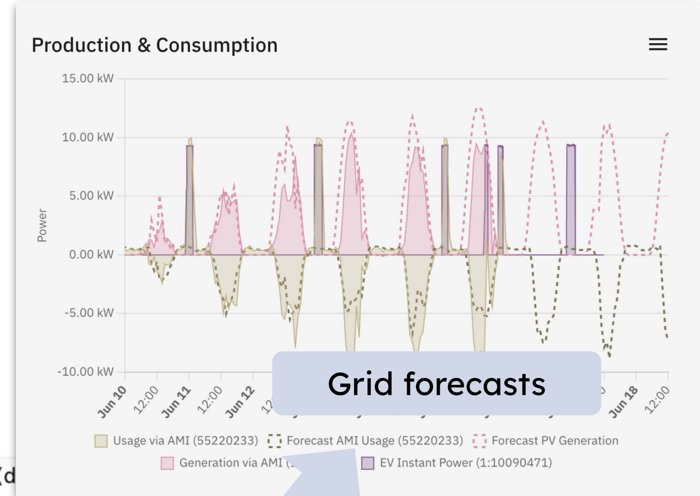
# What are we (Camus) trying to accomplish with weather forecasts?

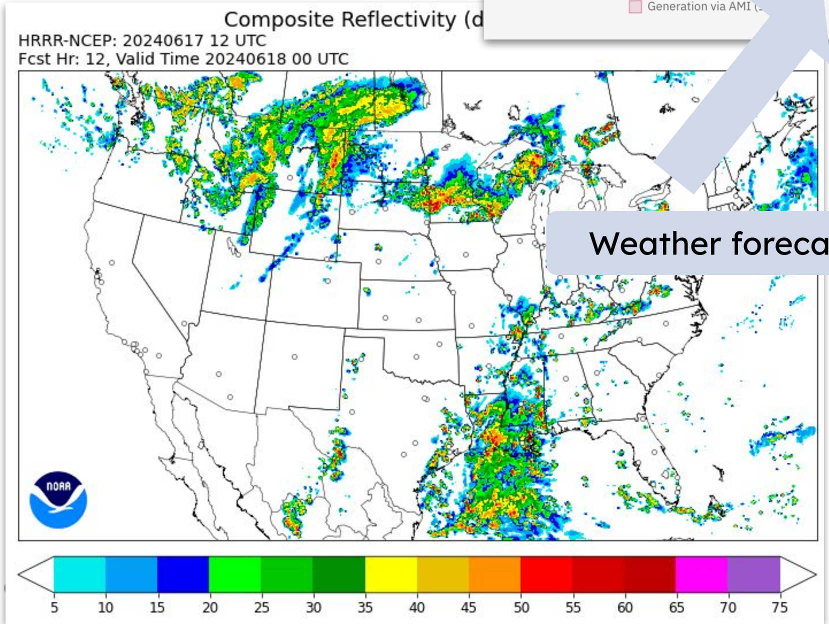
**We're using weather data to create operational forecasts for electric utilities.**

<u>Challenges to overcome:</u>

- Weather forecast data is big and complex
    - Terabytes of data per forecast year
    - Grib2 binary data
- Integrating weather data into machine learning models is complex
    - 100's of meteorological variables
    - Geospatial gridded data

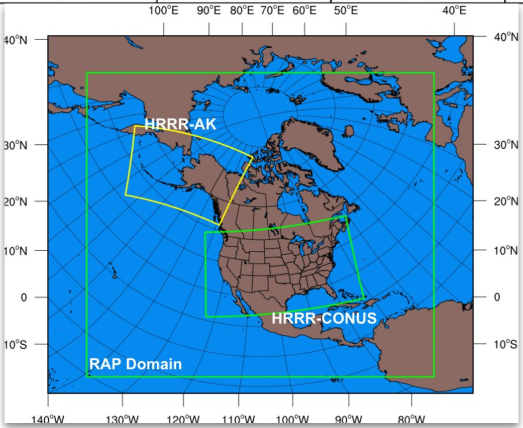
Fortunately, there are many public and private orgs collaborating to help!

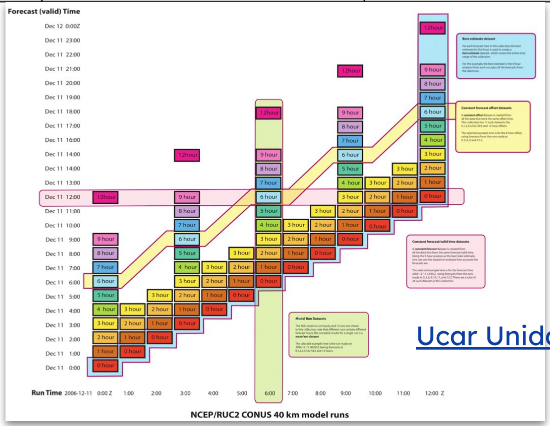


# How do we identify the right weather forecast?

| Model | HRRR V4 (description) | | | GEFS (description) | | | GFS (description) | |
|---|---|---|---|---|---|---|---|---|
| Product | surface (sfc) | | Subhourly (subh) | pgrb2sp25 | pgrb2bp5 | pgrb2ap5 | pgrb2 | |
| Run Schedule | 00, 06, 12, 18 (z) | hourly | hourly | 00, 06, 12, 18 (z) | 00 (z) | 00, 06, 12, 18 (z) | 00, 06, 12, 18 (z) | 00, 06, 12, 18 (z) |
| Forecast Horizon | 0-48 hours* | 0-18 hours | 0-18 hours | 0 - 240 hours | 0 - 840 hours | 0 - 384 hours | 0-120 | 120-384 |
| Spatial coverage | 3km | | | 0.25° | 0.5° | 0.5° | 0.25° | 0.25° |
| Temporal Resolution | 1 hour | 1 hour | 15 min | 3 hour | 3 hour | 3 hour | 1 hour | 3 hour |
| Archive start date | 2020-12-03 (v4) 2018-07-03 (V3) | | | 2020-09-25 ** | | | 2021-03-22 *** | |
| Ensemble | | | | Mean, Control, 30 Perterbation Members, Spread | | | | |
| Status | Till RRFS is operational | | | Operational | | | Operational | |
| GCP Bucket | high-resolution-rapid-refresh | | | gfs-ensemble-forecast-system | | | global-forecast-system | |
| Terabytes/Year | 10.0 | 23.3 | 29.1 | 67.3 | 320.5 | 77.7 | 92.2 | 67.1 |
| Files/Year | 70k | 157k | 157k | 3,737k | 3,270k | 5,980k | 42k | 93k |



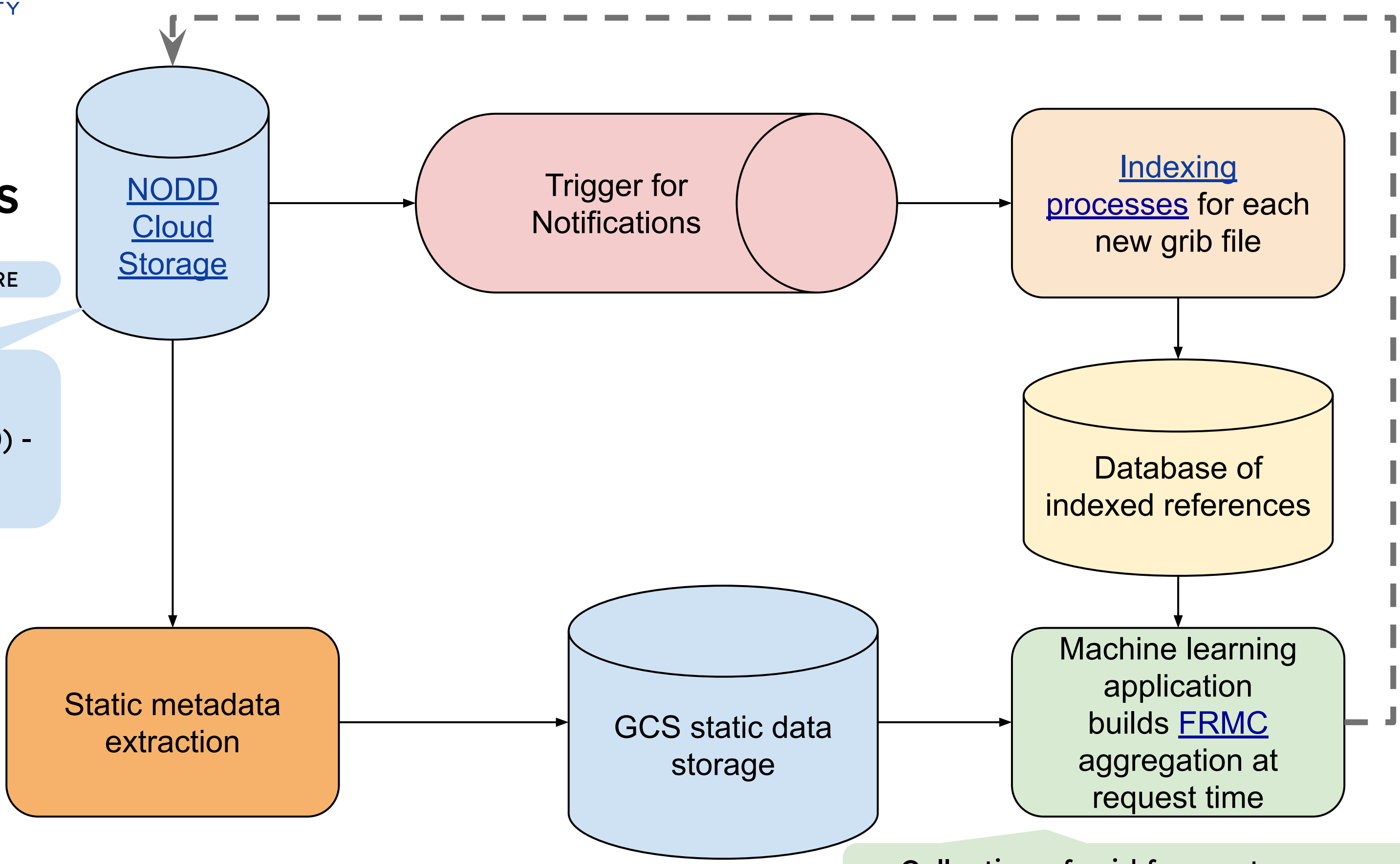

Ucar Unidata FMRC

INCREASING ACCESSIBILITY

# Translating weather to grid forecasts

WE START HERE

Weather forecast archives (since 2020) - zero cost to read!




Collection of grid forecasts across time periods; **easy to access**

# Specific improvements for accessibility

**Big picture:** Grid forecasting is now fast and efficient ($0.02 per meter per year)

100X (!) performance improvement on index ingestion and ML operation!

- We use Xarray DataTree to express grib2 “group” data model for all layers
- Fast & efficient indexing of NODD grib archives using “idx” metadata
- Operational NODD archive index data is stored in a database
- Xarray dataset “kerchunks” are created from index queries for variables and time ranges
- Zarr patch allows fault tolerant & parallel reads for fast & efficient IO

To forecast each individual electric meter for a large investor-owned utility (>1 million meters), it costs $0.02 per meter-year forecast.

**Why is it so economical?** There is a lot we have done in our machine learning too, but an important one = we don’t pay for storing or serving weather data. NODD’s partnership with the cloud providers does this for us.

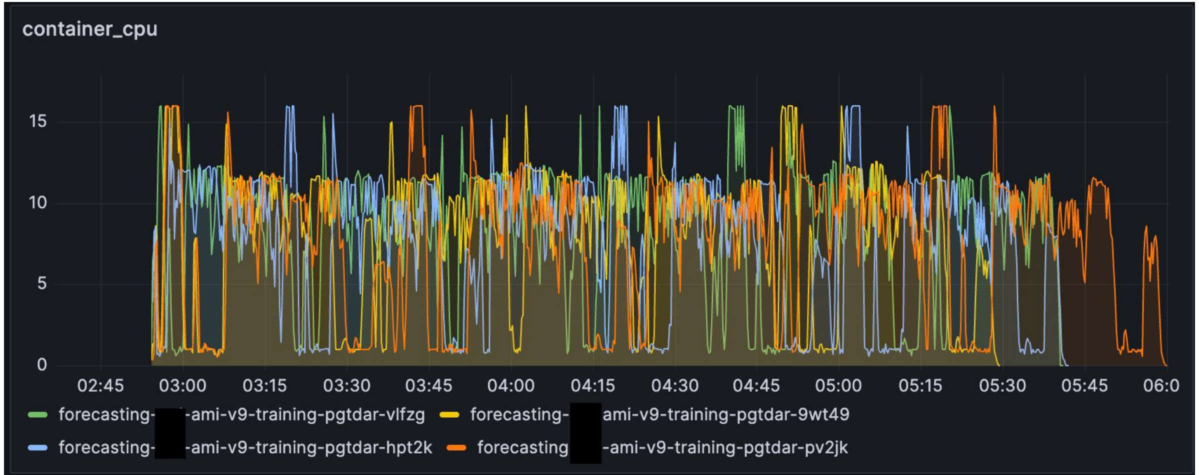
Technical details and source code: [Optimizations for Kerchunk aggregation and Zarr I/O at scale for Machine Learning]

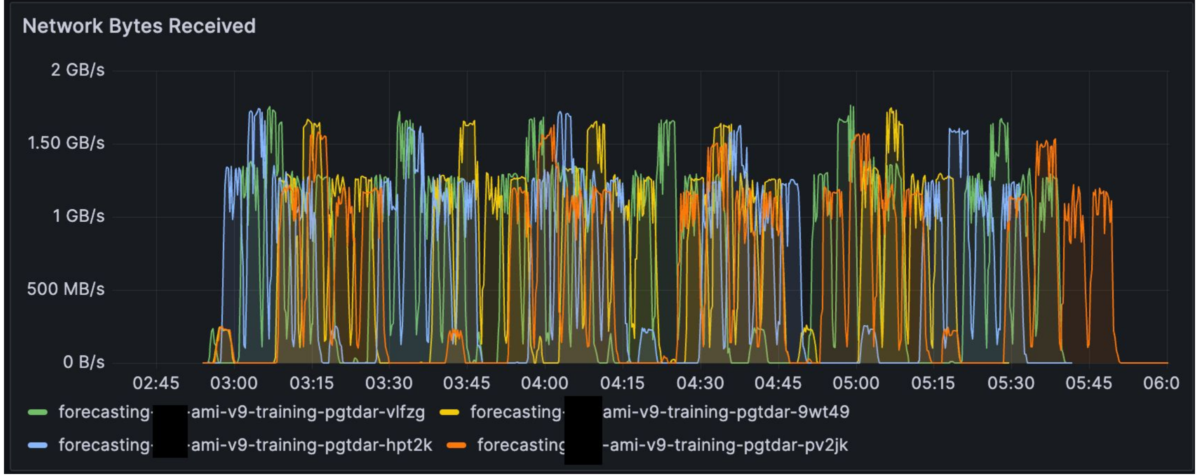
INCREASING ACCESSIBILITY

# Super fast!

Sustained read rates of 1 to 2 Gb/second while training over multiple years.

The parallel processing overhead is much higher for the short prediction tasks. Observed read rates are typically 50-100 Mb/second.



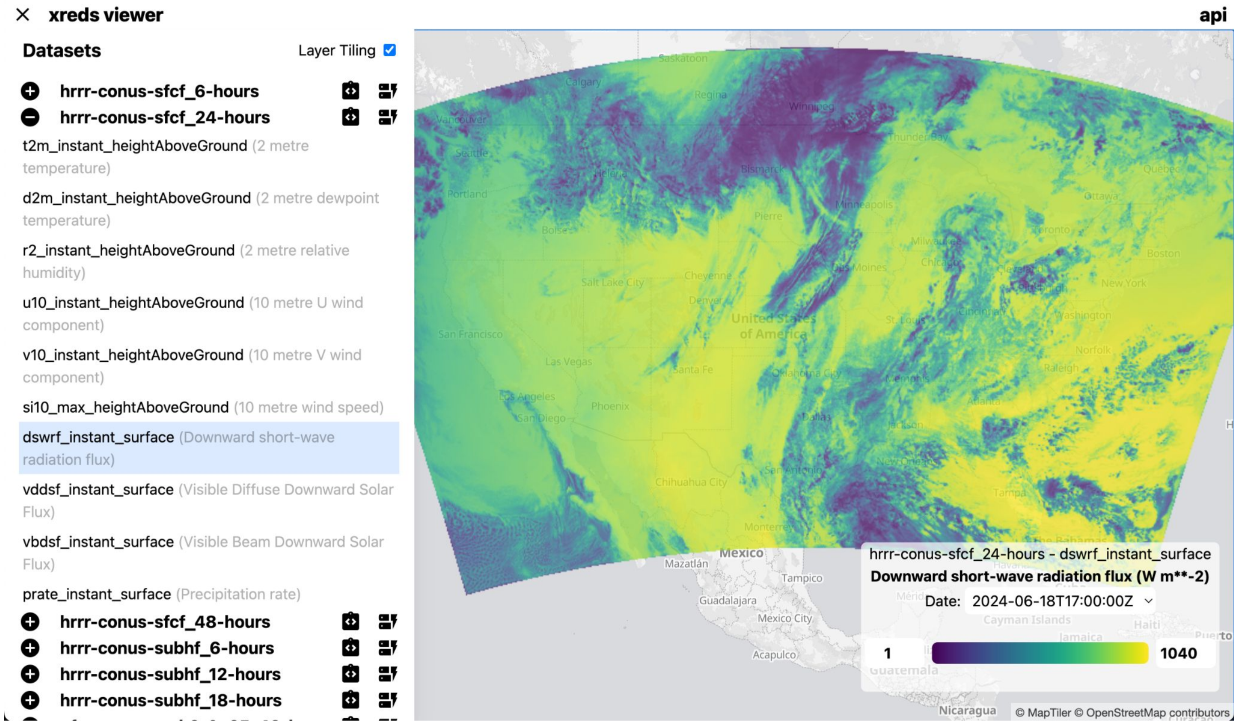



# View data using off the shelf community tools

XPublish is a web services layer for the PyData ecosystem.

XReds is a configuration based webmap service gui frontend.

Accessibility beyond the ML models - visual exploration using standard webmap services.



# An open-source stack for weather data

CAMUS

Machine Learning Forecasts for Grid Operators

Fsspec & Kerchunk

scikit learn

XPublish

CFGrib

Zarr

xarray

NumPy

Open Source Python Data Science Tools

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

NOAA Open Data Dissemination

Microsoft Azure

Google Cloud

aws

Cloud Services

# Who helps us make the available data operational for utilities?

Xarray Zarr Fsspec Kerchunk Xpublish

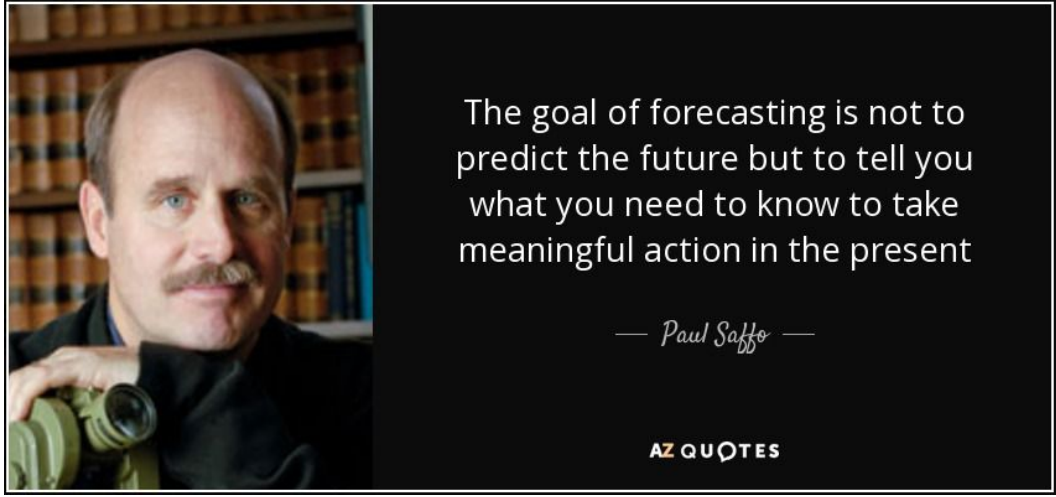
ECMWF

NOAA Open Data Dissemination

SO WHAT?

# How utilities use forecasts

**Distribution system operators need foresight to operate their grid** – the urgency only increases with more DERs making prediction more complex.




Let's briefly highlight **two utility use cases** for operational weather forecasts:

1. **Peak demand reduction** (e.g. demand response)
2. **Flexible interconnection** (generation) / **flexible service connection** (loads)

# Managing peaks can save millions of $

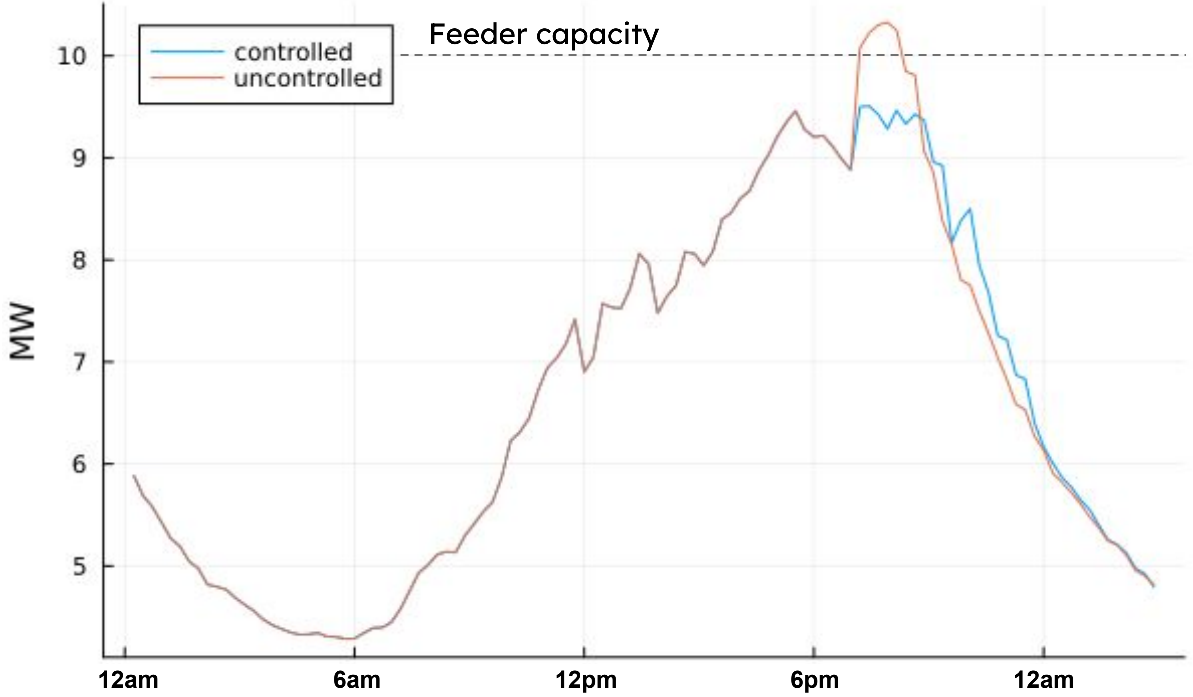
The grid **must be ready** to serve maximum demand at any time.

By reducing peak demand, costs are lowered via:

- Less peak-cost generation purchased
- Avoided transmission and distribution upgrades

**Accurate forecasting is required to reduce peaks.**

## Example of Peak Reduction via DER Control



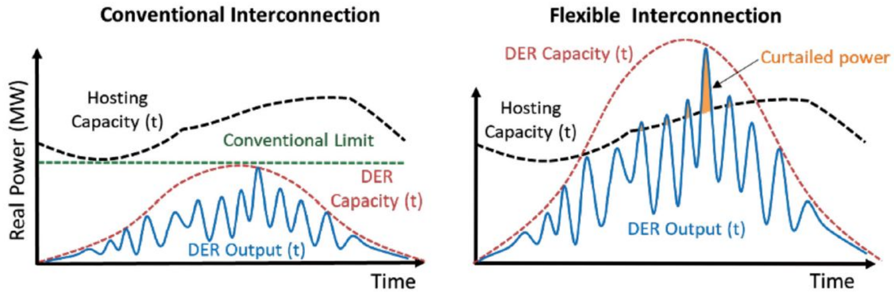
USE CASE #2: FLEXIBLE INTERCONNECTION

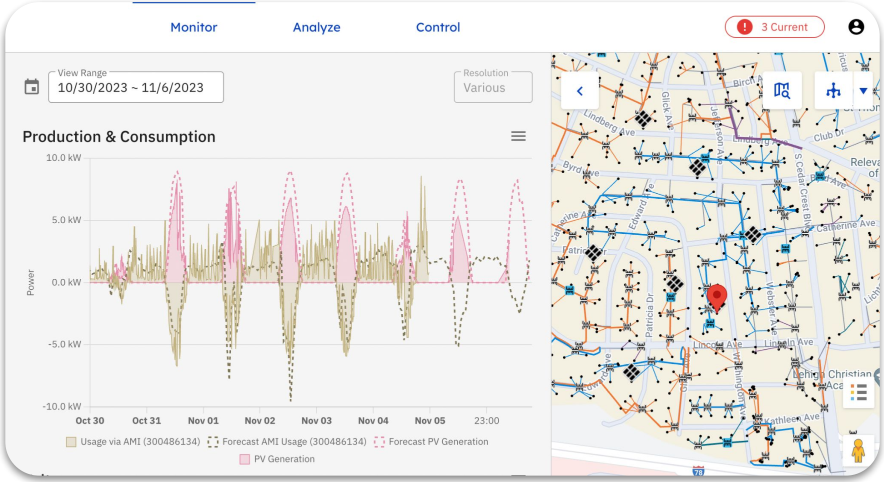
# Customers and regulators want faster interconnections

**Goal:** Enable increased utilization of existing infrastructure and **accelerate interconnection** of more DERs

How it works:

1. Use GIS/connectivity, conductor attributes, & asset ratings to establish system models
2. Train machine learning models to **predict outputs at the meter-level**, then aggregate
3. Evaluate network at min/max DER dispatch
4. Generate “operating envelopes” and manage devices to avoid voltage/loading violations



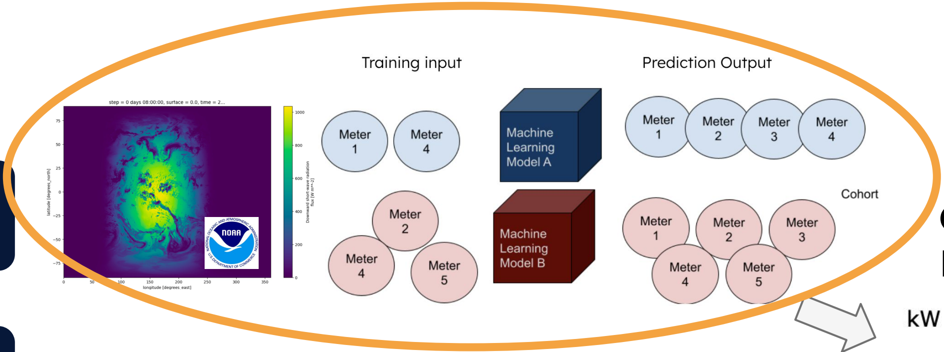
# Forecasting is an essential enabler for flexible interconnections

INPUTS

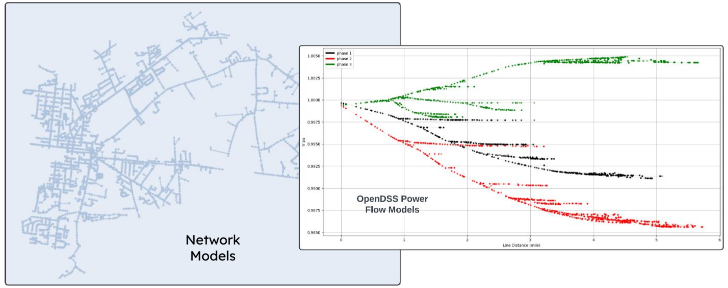
**AMI**

**GIS & Connectivity**

**SCADA**

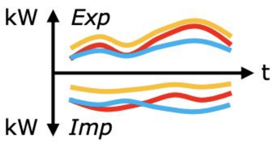



**System Models**




OUTPUTS

**Operating Envelopes**




DEVICE CONTROL

**DRMS & DERMS**

**DER Aggregators (Non-Utility VPPs & Fleets)**

**FTM Resources**

# There's much more to do; here are ideas for how to get involved!

1. Support NOAA to improve data and data accessibility
   - NOAA Open Data Dissemination
   - NOAA Center for Environmental Prediction
   - US Integrated Ocean Observing System

2. Engage with existing solution providers for off the shelf solutions
   - Camus Energy
   - RPS
   - EarthMover
   - OpenMeteo
   - Anaconda

Camus source code is available in the RPS/IOOS Nextgen DMAC Github repo

3. Engage with organizations to support further development of these tools
   - Energy Systems Integration Group
   - Pangeo Discourse
   - Earth Science Information Partners
   - OpenClimateFix
   - Numfocus

4. Get your hands dirty by developing new features to advance the capabilities
   - zarr-python
   - light-speed-io
   - Kerchunk
   - VirtualiZarr
   - Xpublish
   - Xreds

CAMUS

Zero Carbon Grid Orchestration

THANKS!

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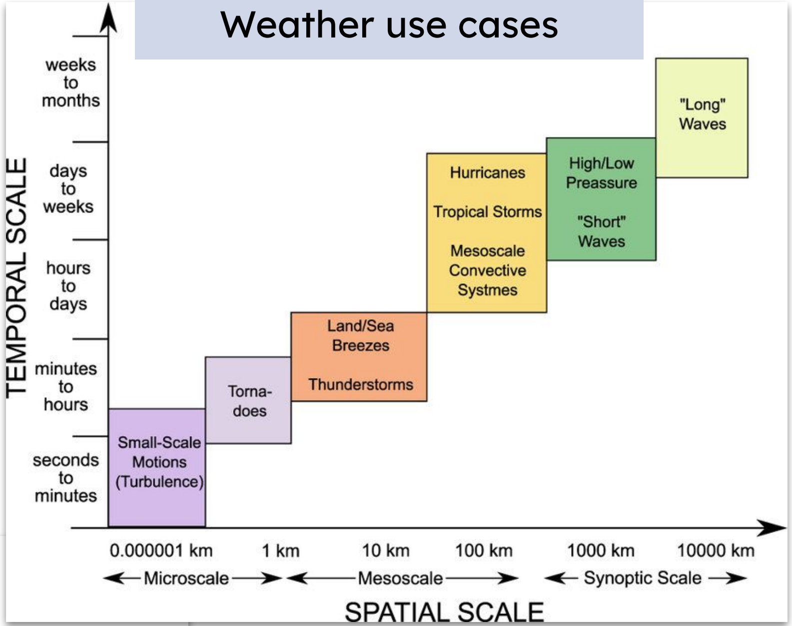
CURATING DATA

# Time scales matter!

**Selecting the right data depends on the use case** you want to serve. For utility operations, time scales can range from milliseconds to decades across different use cases.

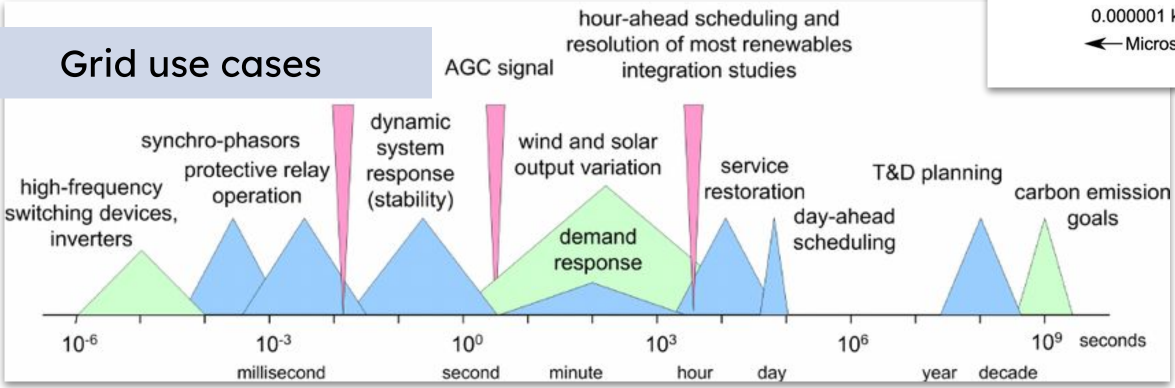
A common tradeoff: **time vs. spatial resolution**

## Weather use cases




Brisch, Jonathan & Kantz, Holger. (2019). Power law error growth in multi-hierarchical chaotic systems -- a dynamical mechanism for finite prediction horizon. New Journal of Physics. 21. 10.1088/1367-2630/ab3b4c.

## Grid use cases




Meier, Alexandra. (2011). Integration of renewable generation in California: Coordination challenges in time and space. IEEE. 10.1109/EPQU.2011.6128888.