NREL
NATIONAL RENEWABLE ENERGY LABORATORY

UWIG Forecasting Workshop — Albany

PIX 17777

UWIG Spring Technical Workshop

Kansas City, Missouri

Debbie Lew

April 15, 2011

NREL/PR-5500-51494

Make Wind like hydro without the fish.

Best Quote

Steve Kropper Wind Pole

What Are Some of the Different Forecasting Approaches?

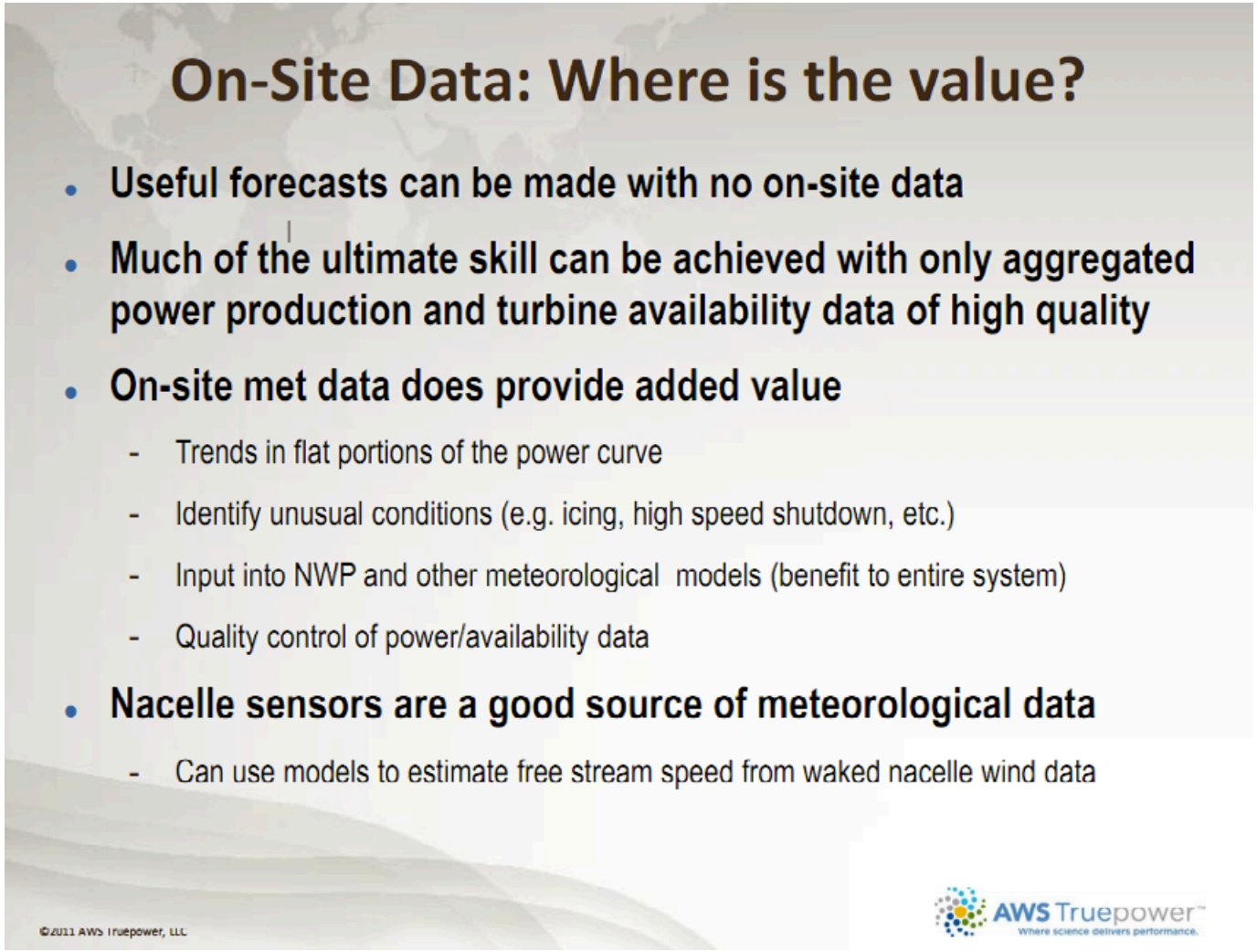
Crummy data		Great data
+ Sophisticated models	Vs.	+ Thin analytics
= Inadequate forecast		= Great forecast?

Windpole

Value of Data

Best resolution to an ongoing debate.

What is the Value of Onsite Data?



What is the Value of Offsite Data?

Off-site Data

- **Many Forms**
  - Other wind farms
  - Existing public and private sites
  - Targeted private networks
- **Highly Variable Value**
  - Depends on objective
    - Lowest MAE or RMSE over all hours?
    - Prediction of ramp events?
  - Depends on weather regime
    - "Measure upstream" concept has inconsistent value
    - Measurements other than near-surface wind may be critical
    - Location and variable selection is critical to obtaining max value
- **Multiple Approaches to Use of Data**
  - Time-lagged variables added to time series models
  - Feature tracking algorithms
  - Initialization of rapid update NWP

AWS Truepower™
Where science delivers performance.

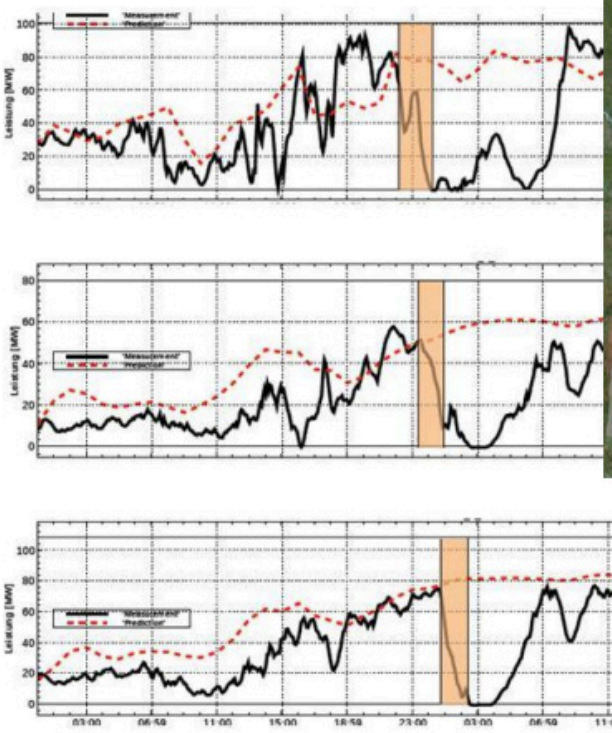
What we learned from MISO / PJM / SPP

Reason for large error

- Icing
- Down regulation by local transmission provider
- Down regulation due to market price
- High wind speed cut off
- Convective weather pattern
- Frontal weather system
- Error does not propagate as the weather does
- Offsite data does not help for two very crucial weather situations
  - Icing
  - Convective weather (day / night pattern)
- For very short term forecast: methodology has to be extremly fast

Can’t I Just Set Up an Upstream Met Tower?

Upstream measurement ?



The propagation direction of the wind speed error is different to the wind direction.

It is necessary to observe the overall “energy weather” situation and not just focussing on the upstream direction.

energy & meteo systems

Conclusion

- Met data can add value
  - Onsite data for icing
  - Regional data for error detection and correction
  - methodology has to be extremly fast

The cost of additional offsite towers does yet not reflect the possible improvement (and its not clear if that ever will).

There are much more promising approaches to improve the forecast using just methodology development with or without using existing met data.

energy & meteo systems

Statistical vs. Atmospheric Modeling Approaches

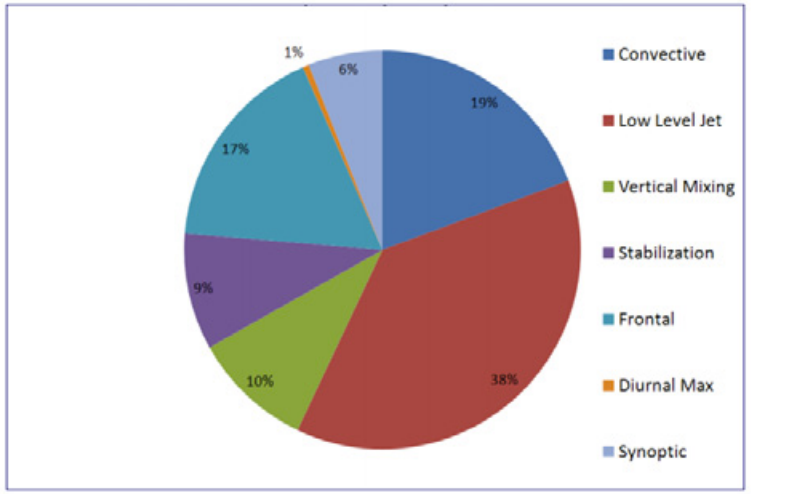
For very short-term forecast: methodology has to extremely fast, so 5 minutes from measurement until delivery of forecast is needed (incl. data transfer, data check, calculation time, and forecast delivery).

Best Undermining of Own Business Interests
Mark Ahlstrom, Windlogics

Goal is to economically and reliably integrate renewable energy

- Consider the big picture!
- Sure more wind data is helpful. But is it worth it?
- The value of forecasting is driven by market rules and power system operations. Wind forecasting is ONE of the tools to more cost-effectively integrate wind. There may be cheaper, easier ways.

Ramp Events by Type – A Specific Wind Power Plant



Ramp Forecasting

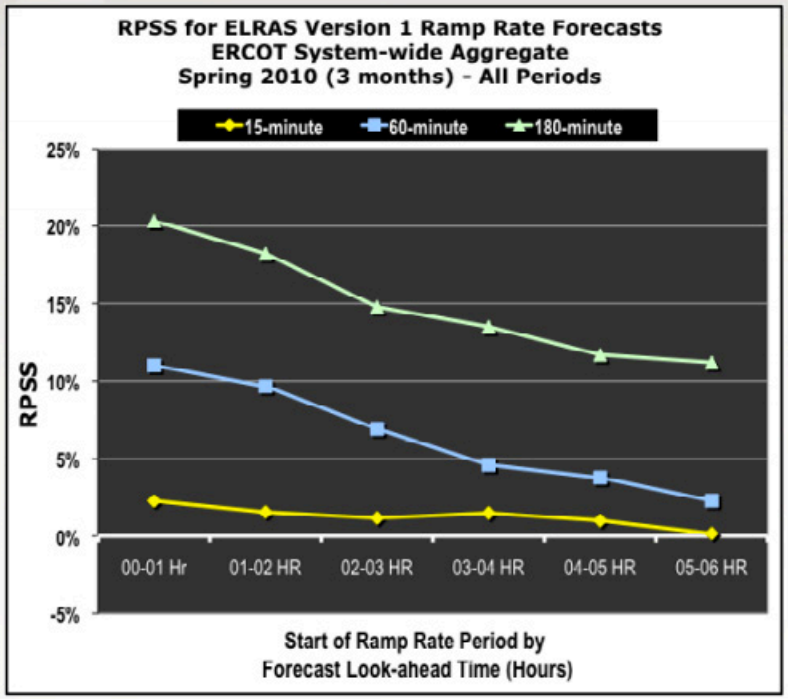
Questions about Ramp Forecasting

- Do we need separate ramp forecasts, or better forecasts?
- Is ramp forecasting more than adding a "MW ramp rate" indicator to a modern forecast with probability distributions?
- Why isn't the ramp risk already reflected in the probability distributions of the wind forecast?
- What does the system operator want? Are they right?
- How does what we do add value? What is the business case?
- How do we promote meaningful progress without creating perceptions that could harm the wind energy market?

WindLogics™

ELRAS Ramp Rate Forecast Performance Initial Evaluation: Spring 2010

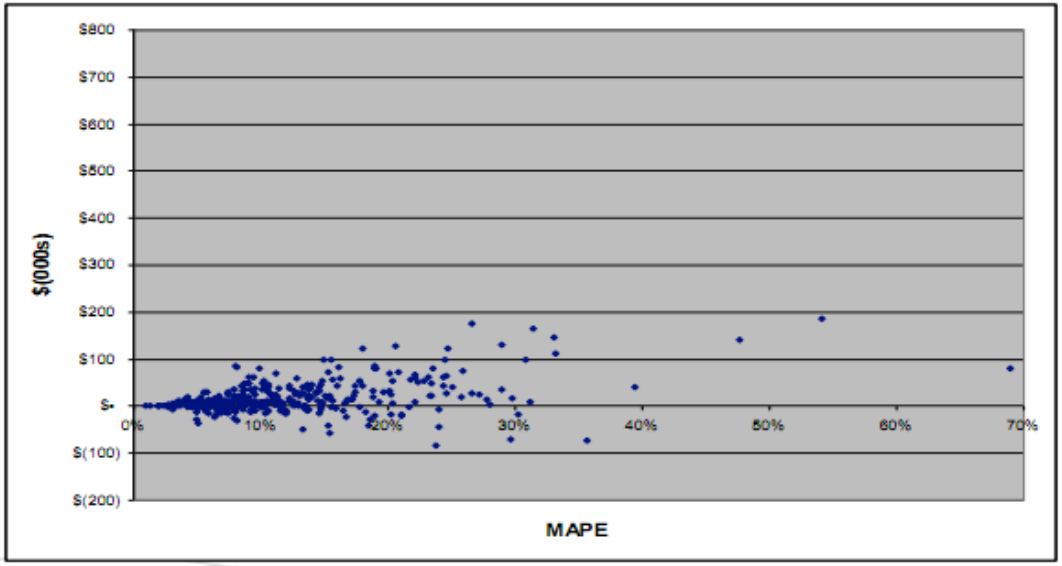
- RPSS calculated for all ramp start periods (beginning every 15 mins) in the sample
  - May be more useful to focus on large ramp rate periods
- Considerable skill for 180-min ramps
- Modest skill for 60-min ramps
- Little skill for 15-min ramps
- Skill decreases with time for 180- and 60-min forecasts
  - Indication that recent info is adding significant value



AWS Truepower™

Case Study: Market Exposure (2010)

- In a 2-day market (eg MISO), day-ahead forecast error manifests in exposure to real-time price. The market punishes errors irrespective of direction.



NSP – 1/1/2010 to 12/31/2010

Mean Absolute Percent Error (MAPE)

2009 = 15.7%

2010 = 12.2%

…$2.5M is savings…

Lessons Learned

- Savings are significant
  - PSCo - $3.1M
    - Highest wind penetration. Flexible system.
  - NSP - $2.5M
  - SPS - $400k
    - Sticky system. Value of better information frequently zero

Value of Forecasting — WWSIS

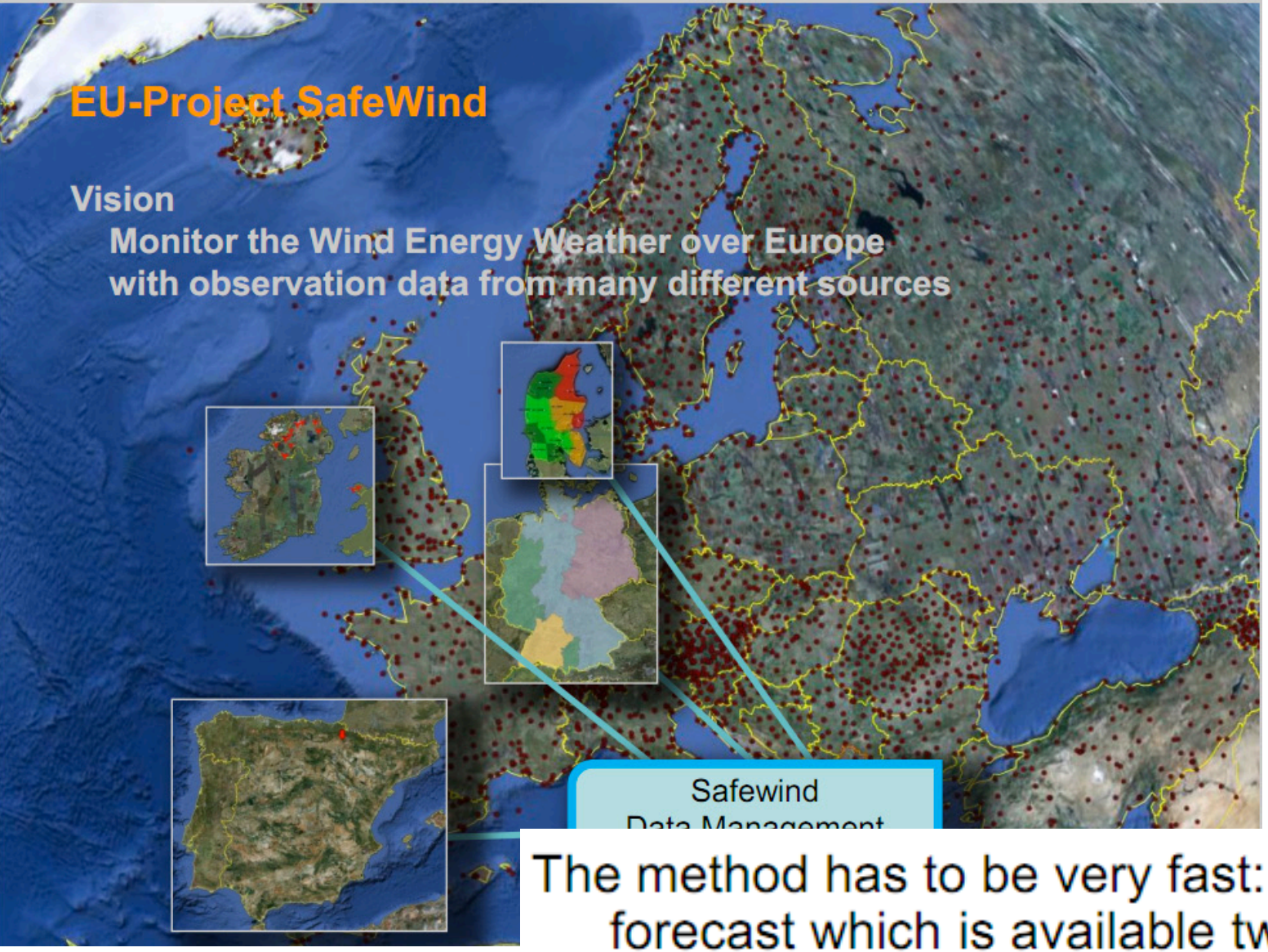
How to Use Probabilistic Forecasts

Probability of what?

- Wind exceeding the dispatch stack range by X MW up, Y MW down?
- Probability that the wind/solar-induced ramp exceeds the ramping capability of the stack? Non-spin availability? How to incorporate that information?
- What data are used to calculate the probabilities?
  - Historical database with artificial intelligence-based classification algorithms?
  - Perturbed forecasts and their relationship to stack?
  - What is long-term implication of a change in the flexibility characteristics of the generation fleet (non-VG)?

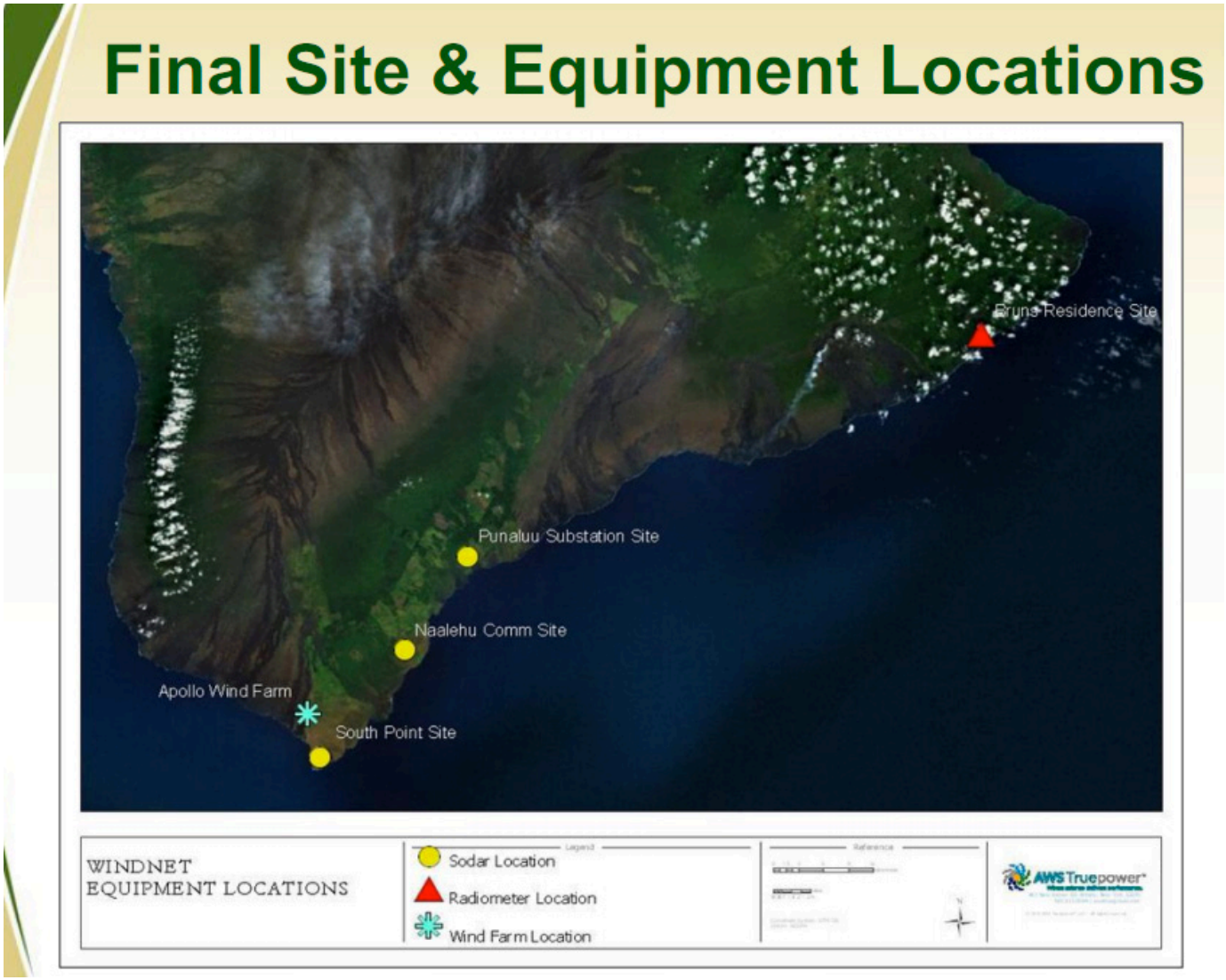
Excitement Over Model Improvements

- DOE/NOAA partnership.
- RR and HRRR model.
- Need for fundamental research to improve NWP models and more observational data to better address what is happening at hub height, rather than present focus on precipitation and temperature at ground level.



The method has to be very fast: A new forecast which is available two hours afte the measurements (e.g. new NWP run) has not much values für very short term forecast !

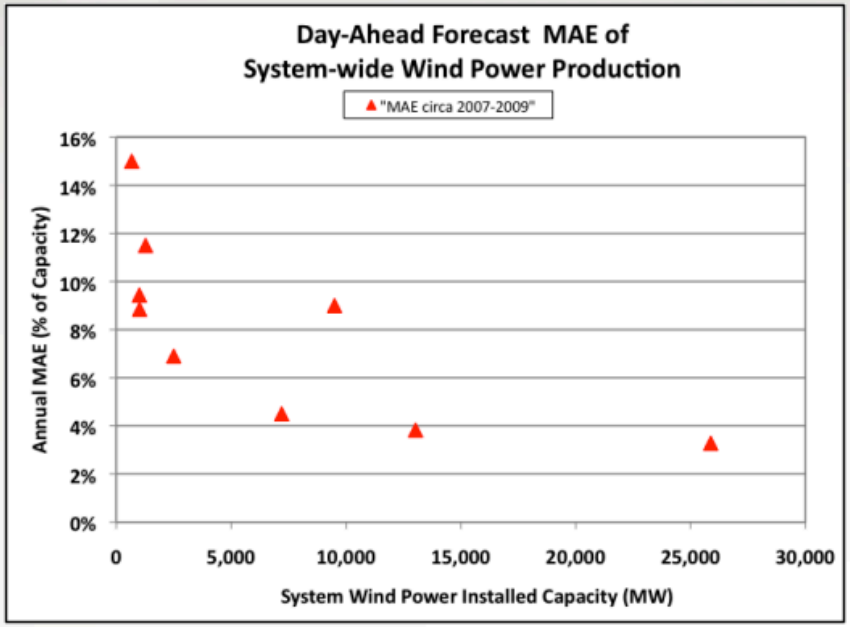
Best Impersonation Attempt



Best Unintended Consequence

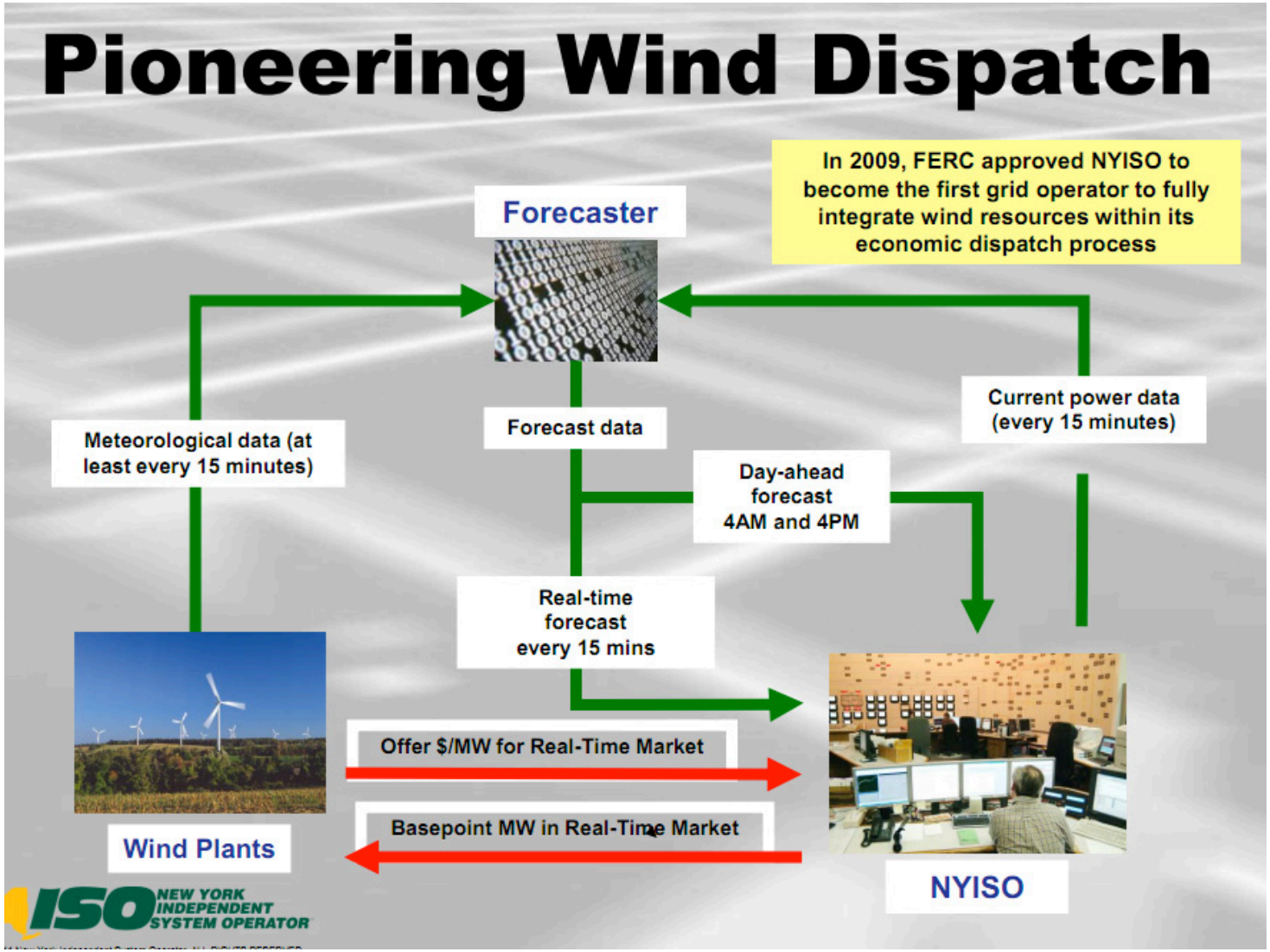
Forecast Performance Examples: Day-ahead MAE for System Aggregates

- MAE significantly correlated to installed capacity
- Diversity factors also play an important role
  - Example: ERCOT has a highly concentrated region of production in west Texas and experiences higher MAE values for the level of installed wind capacity

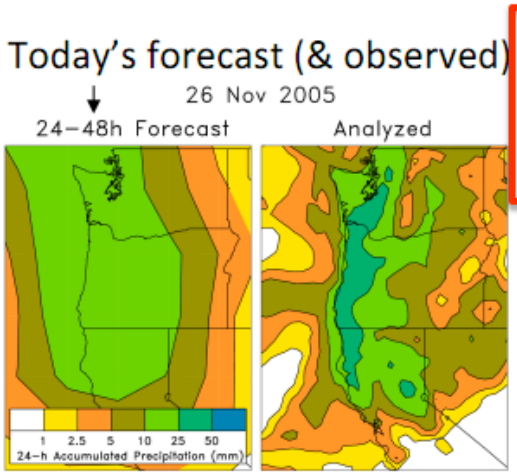


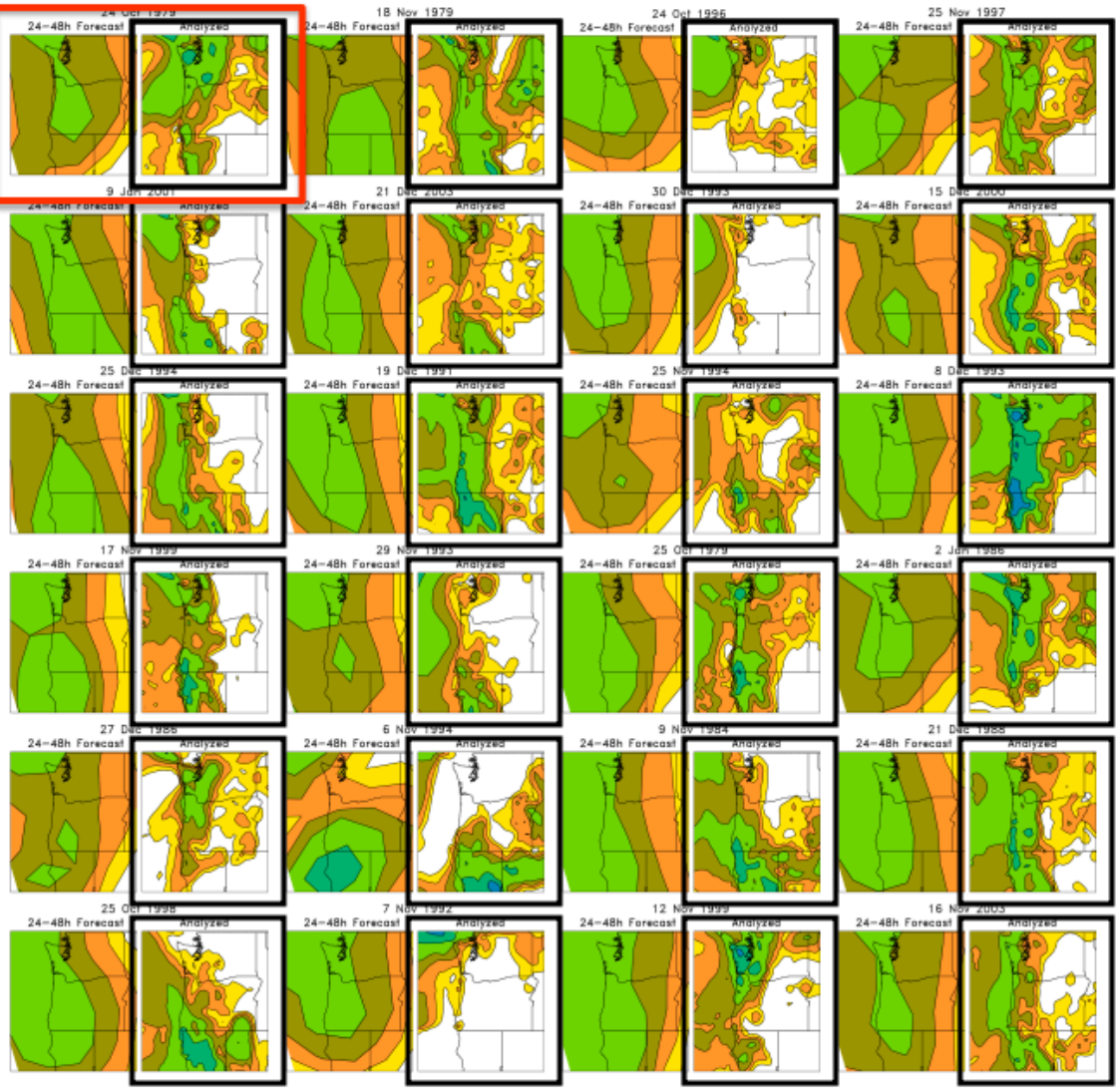
AWS Truepower™
Where science delivers performance.

Treat Wind Like Other Generators



An example of a statistical correction technique using those reforecasts



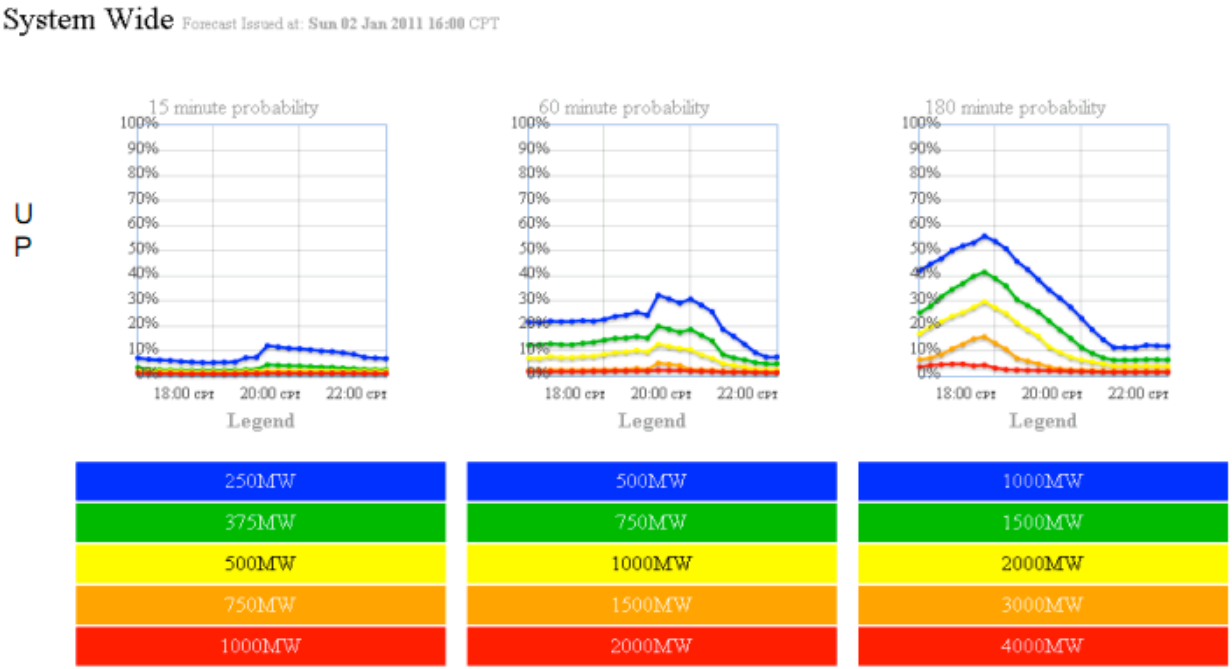


For each pair (e.g. red box), on the left are old forecasts that are somewhat similar to this day's ensemble-mean forecast. The boxed data on the right, the analyzed precipitation for the same dates as the chosen analog forecasts, can be used to statistically adjust and downscale the forecast.

Analog approaches like this may be particularly useful for hydrologic ensemble applications, where an ensemble of weather realizations is needed as inputs to a hydrologic ensemble streamflow system.

Ramp Forecasts

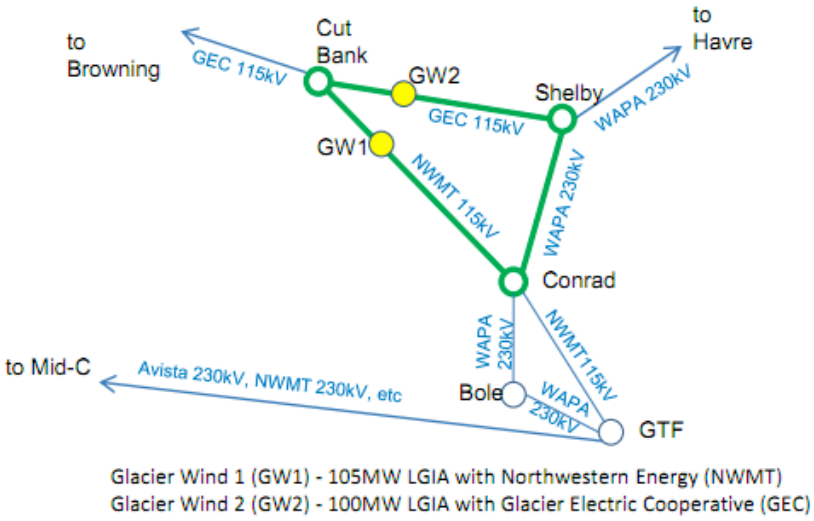
ELRAS



- **Provides the probability of wind power output ramp events of various MW changes over various time frames**
  - The far right graph shows that there is a 30% chance of the wind output changing by 2000 MW or more between 18:00 and 21:00
- **Provides information for wind output increases and decreased separately**
- **Information is provided on both the system level and by region within ERCOT**
- **Can be used is parallel with Operating Day Reliability Unit Commitment (RUC) study results**

Most Challenging Job

NaturEner Power Watch, LLC – Montana



Glacier Wind 1 (GW1) - 105MW LGIA with Northwestern Energy (NWMT)
Glacier Wind 2 (GW2) - 100MW LGIA with Glacier Electric Cooperative (GEC)

- ✓ Firm Bi-Directional Transmission on Glacier Electric Cooperative Line
- ✓ Regulating and Contingency Reserves Inbound, Firm Point-to-Point Transmission to GW1-GW2
- ✓ GW2's integration required LAPS with NWMT, GEC, and WAPA
- ✓ Operations from San Francisco, Trading from Vancouver (MSCG), Balancing from Houston (CECD), and ancillary products and transmission within WECC

NaturEner

Metrics

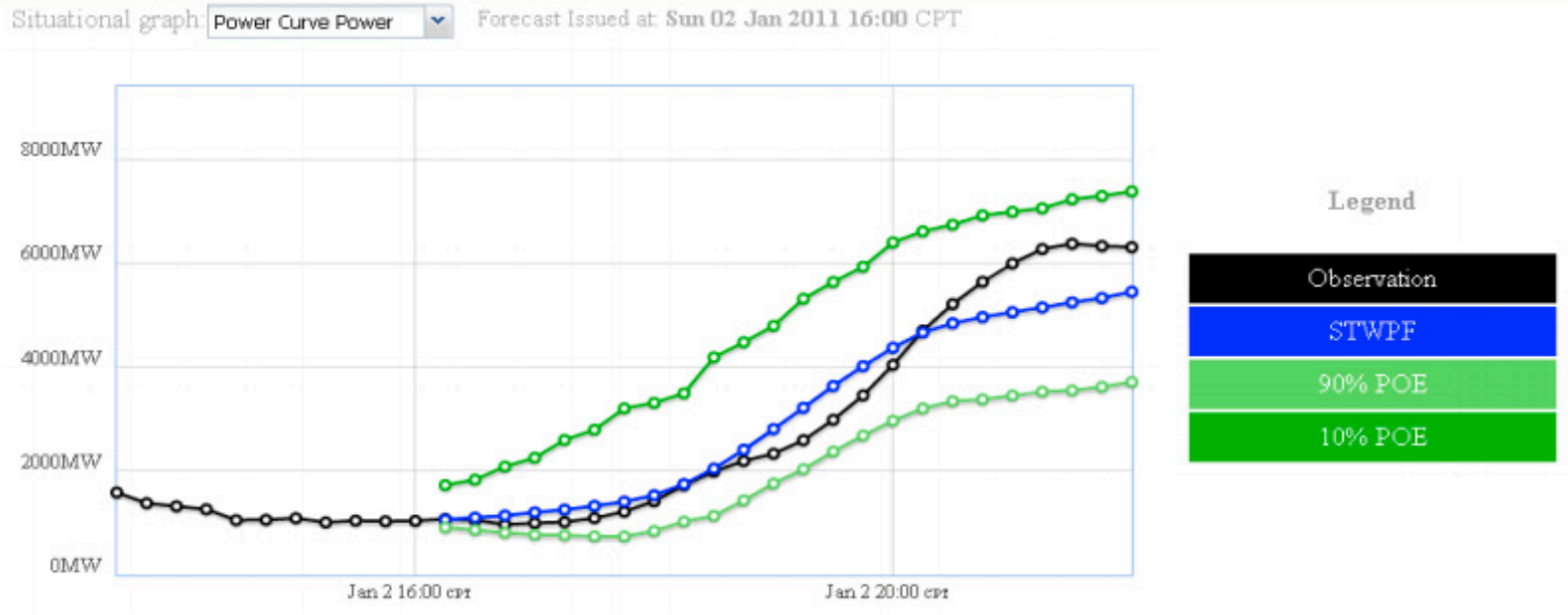
Comparison to Existing Metrics

- If the forecast was improved in exactly the right way, MAE would improve along with ramp metrics.
  - In practice, we don't necessarily see this.
  - Error during constant periods is increased.
  - Ramp events aren't frequent enough to dominate the average error.
- The best forecast may not have the best MAE or RSME.

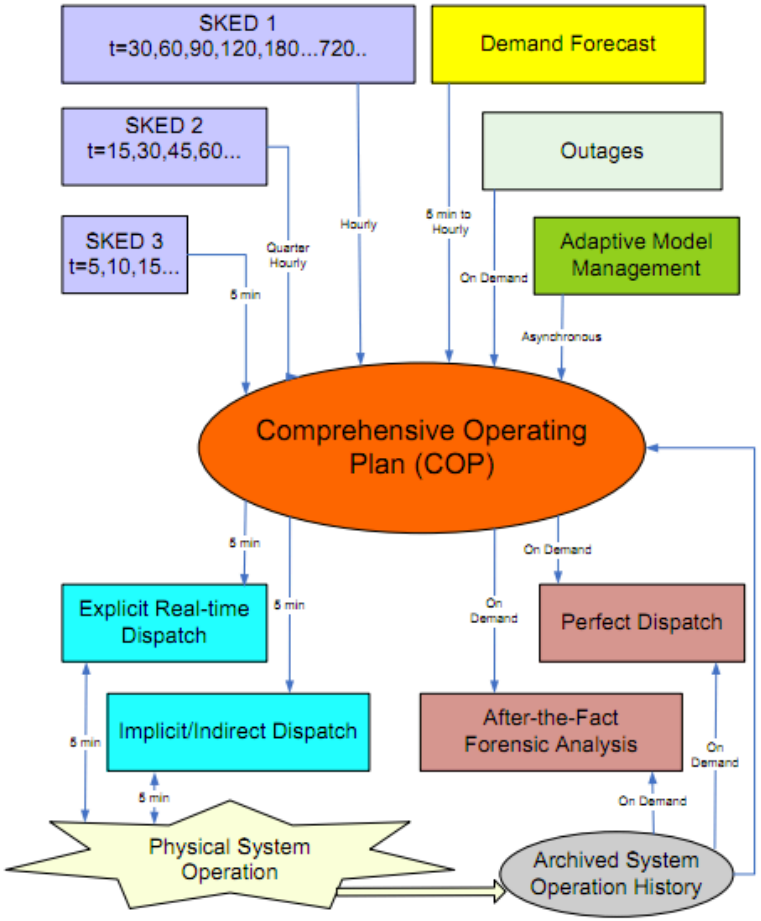
NaturEner

Probabilistic Tools

ELRAS (cont.)



Smart Dispatch Solution Overview



Generation Control Applications (GCA)

- Multi-stage (SKEDs) robust dispatch, scheduling and commitment coordinated via COP
- Holistic forward-looking view of system conditions

After-the-fact Analysis (AFA)

- Performance benchmarking against Perfect Dispatch (PD)
- Root-cause analysis
- Simulation & impact analysis

Net Demand Forecast

- More accurate forecasting and uncertainty modeling of load, renewable generations and demand response.
- Integration of multiple forecasts

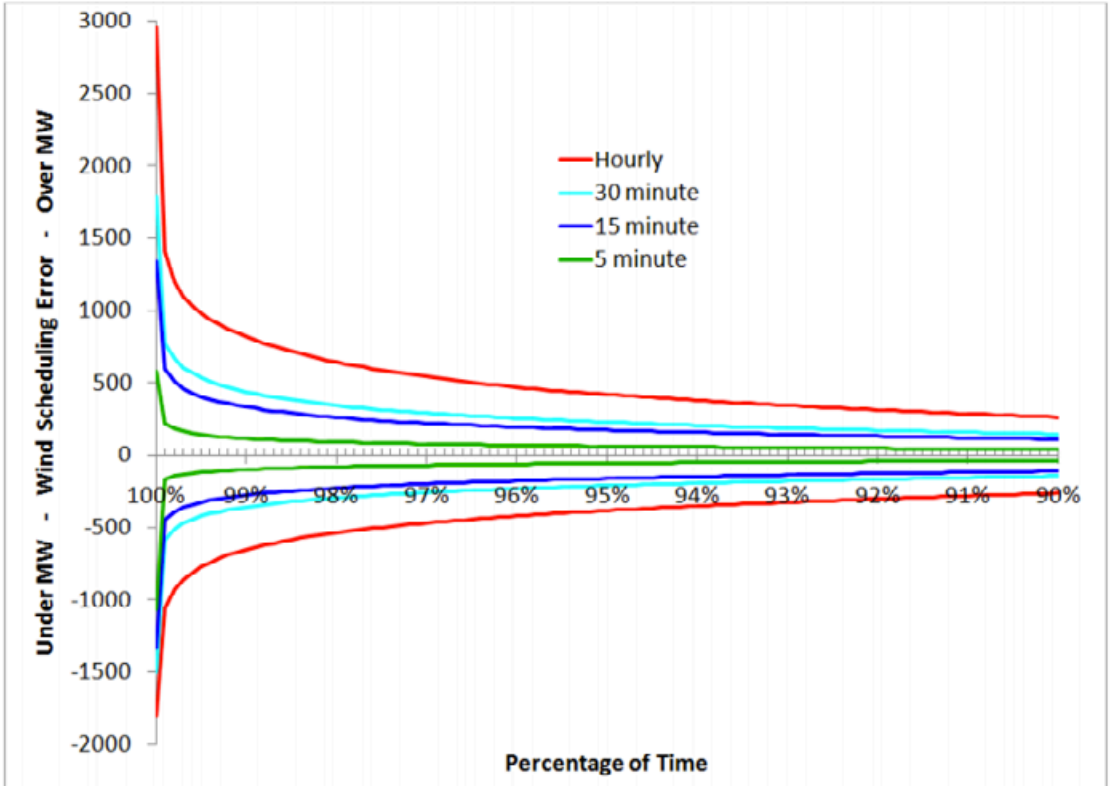
Adaptive Model Management

- Constraint management
- Generator Performance

GRID | ALSTOM

Improved forecasts improve market efficiency for all market participants Shorter intervals = reduced forecast errors.

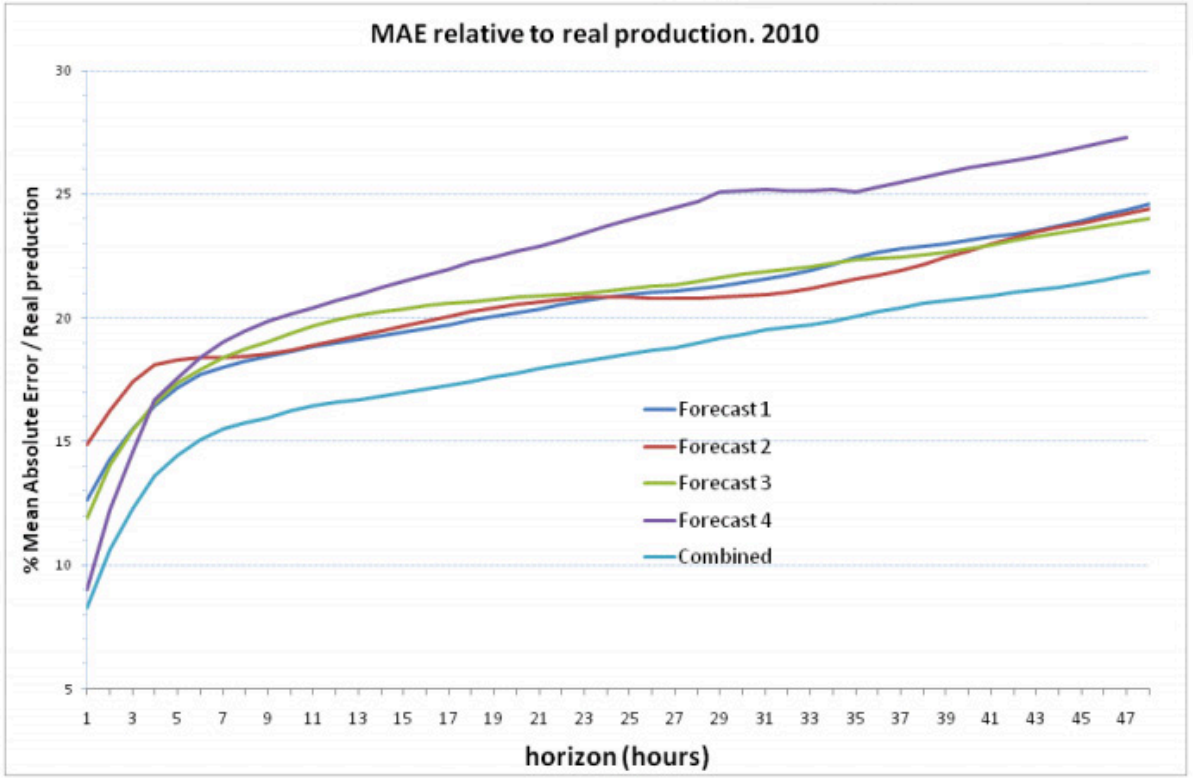
Reduced Scheduling Errors For Both Frequent and Rare Events



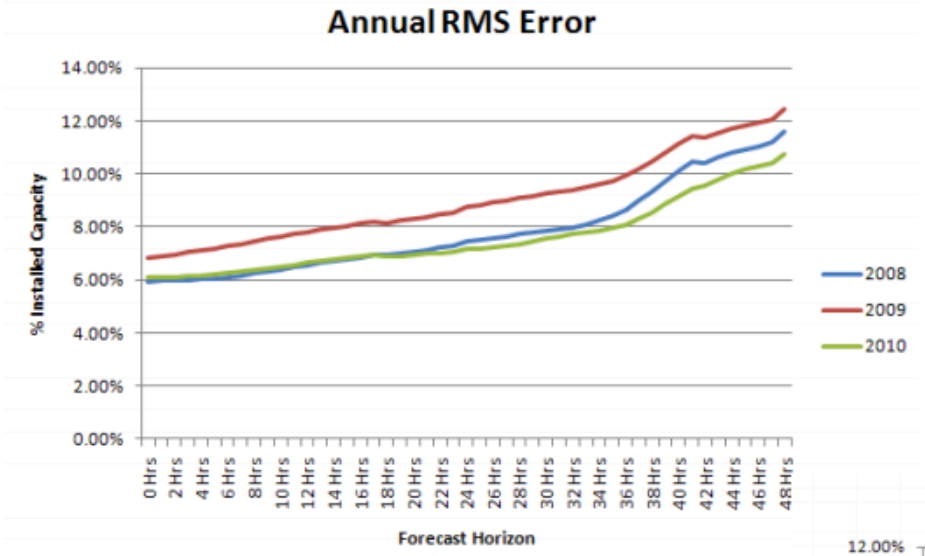
RED ELÉCTRICA DE ESPAÑA

Combination module (IV)

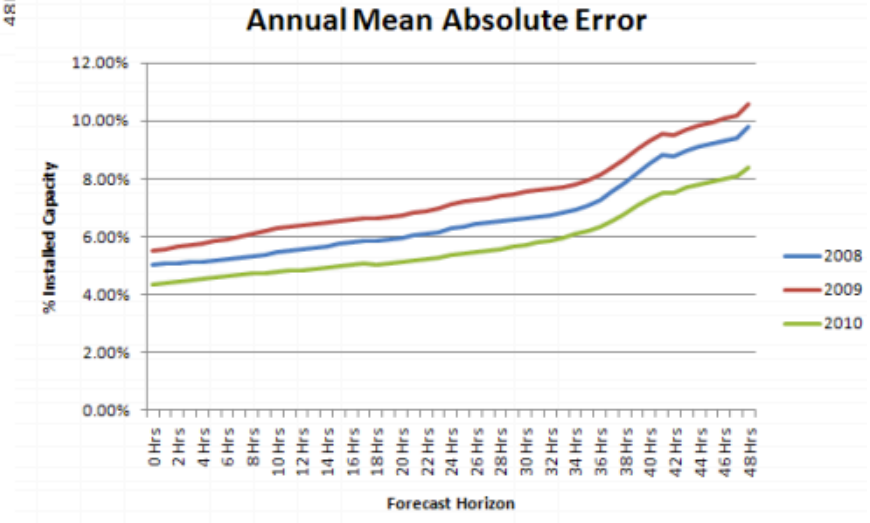
- The final combination tends to be better or equal than the best predictor for each hour

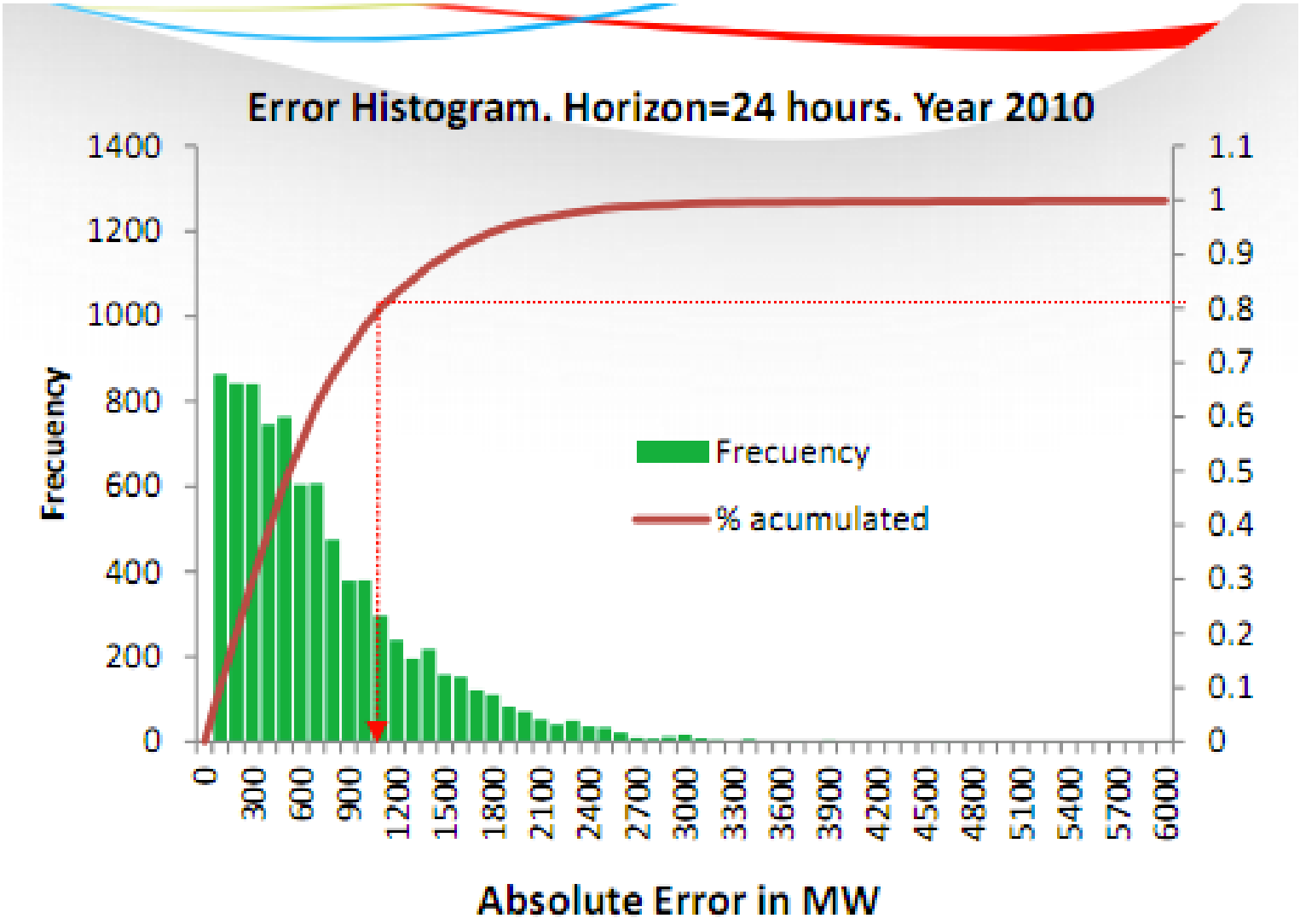


Wind Power Forecast Applications in EirGrid - Analysis



RMSE forecast error
MAE forecast error




Error Histogram. Horizon=24 hours. Year 2010
Frecuency
Frecuency
% acumulated
1400
1200
1000
800
600
400
200
0
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
4800
5100
5400
5700
6000
Absolute Error in MW

How are Utilities Using the Forecasts?

Value Provided by Forecast

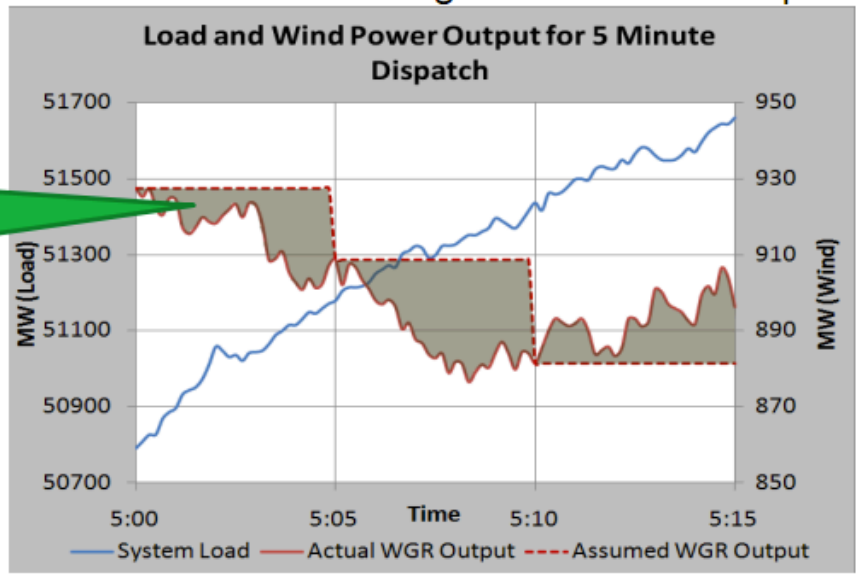
- Many time frames of value
  - Outage Coordination – 24-72 hours in advance
  - Transmission Security Planning Day Ahead studies
    - Share forecasts with PJM to develop study models more accurately
    - Working with SPP to do the same
  - Day Ahead Reliability Assessment unit commitments
  - Intra Day Reliability Assessment unit commitments
  - Reliability Coordinators
    - Congestion Management
    - Manual curtailments and releasing curtailments
    - Unit Commitments – both to commit and not to commit

MidwestISO
Energizing the Heartland

Long-term

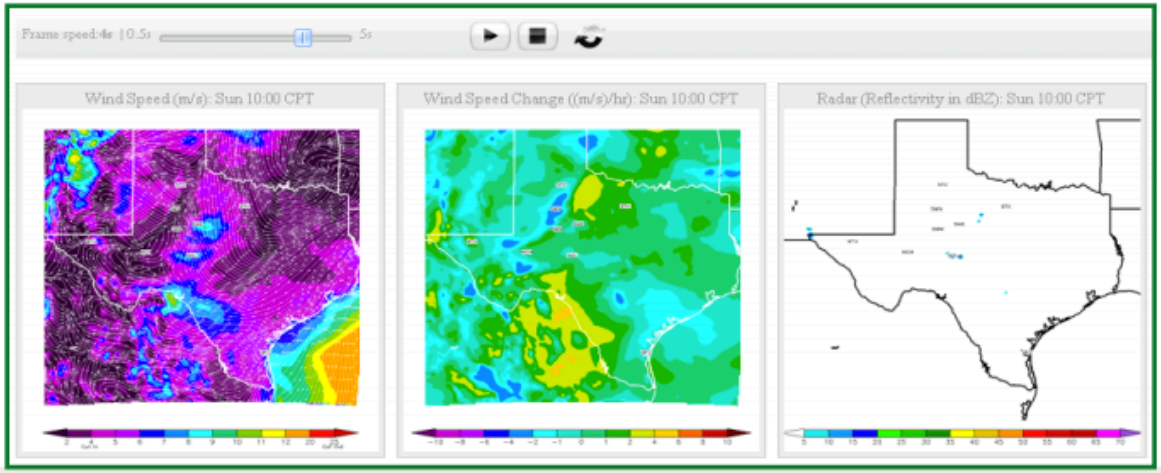
- **ERCOT re-dispatches Generation Resources every 5 minutes**
- **Power output persistence is assumed for "uncurtailed" WGRs**
  - This means that changes that occur in WGR power output within the 5 minute dispatch periods need to be covered by Regulation Service in order to retain load-generation balance
  - Historical, observed 5 minute changes in wind generation are used to the determine the amount of Regulation Service to procure

Energy from Regulation needed to maintain load-generation balance



Short-term

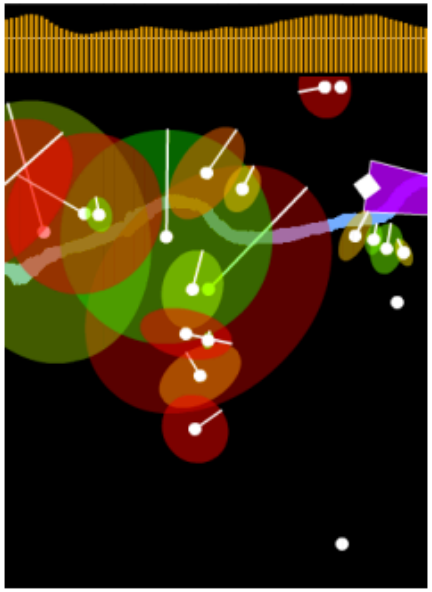
- **As the Operators enter the Operating Day, they are able to execute hourly RUC studies**
  - The Operators would like to wait as close to real-time as possible to commit a Resource
  - When development is completed, ERAT will also be run in the Operating Day
- **The Operator is also able to begin using the ERCOT Large Ramp Alert System (ELRAS)**
  - ELRAS provides probabilistic forecast information for the next 6 hours
  - The displays include animated graphics of weather conditions



Wind Power Forecasting and **State Awareness**

- Install 14 new BPA owned anemometers
  - Publicly posted data
    - http://transmission.bpa.gov/Business/Operations/Wind/MetData.aspx
  - Develop public visualization animation
    - http://www.bpa.gov/go/windsocks
  - Develop iCRS multi dimensional data visualization
    - Generation Maps

```
Date/Time (UTC),Barometric Pressure (INHG),Rela
01/09/2011 23:45:00,27.020,101.7,27.5,243.3,15.
01/09/2011 23:50:00,27.024,101.8,27.5,243.2,14.
01/09/2011 23:55:00,27.025,101.7,27.5,242.6,14.
01/10/2011 00:00:00,27.026,101.7,27.5,243.9,13.
01/10/2011 00:05:00,27.027,101.8,27.5,243.1,14.
01/10/2011 00:10:00,27.030,101.7,27.5,243.4,12.
01/10/2011 00:15:00,27.032,101.7,27.6,241.8,12.
01/10/2011 00:20:00,27.032,101.7,27.5,245.4,11.
01/10/2011 00:25:00,27.036,101.7,27.5,246.1,11.
01/10/2011 00:30:00,27.035,101.6,27.4,244.5,12.
01/10/2011 00:35:00,27.036,101.6,27.3,244.9,13.
01/10/2011 00:40:00,27.036,101.5,27.1,239.8,11.
01/10/2011 00:45:00,27.036,101.5,27.0,248.0,12.
01/10/2011 00:50:00,27.036,101.5,26.9,246.9,10.
01/10/2011 00:55:00,27.034,101.5,26.8,244.9,11.
01/10/2011 01:00:00,27.031,101.4,26.8,248.2,10.
```



What Are the Challenges?

Forecasting Challenges

- New projects
  - Accuracy during construction/commissioning
  - When to include in MISO Wide forecast
  - Accurate tracking of commercial operation
- Forecast skewed by manual curtailments
  - Curtailment info must be fed back to forecast
  - Wind information lost during curtailments
- Severe weather (icing, high speed cutout, cold weather)
- Generator Operator reductions due to prices

MidwestISO
Energizing the Heartland