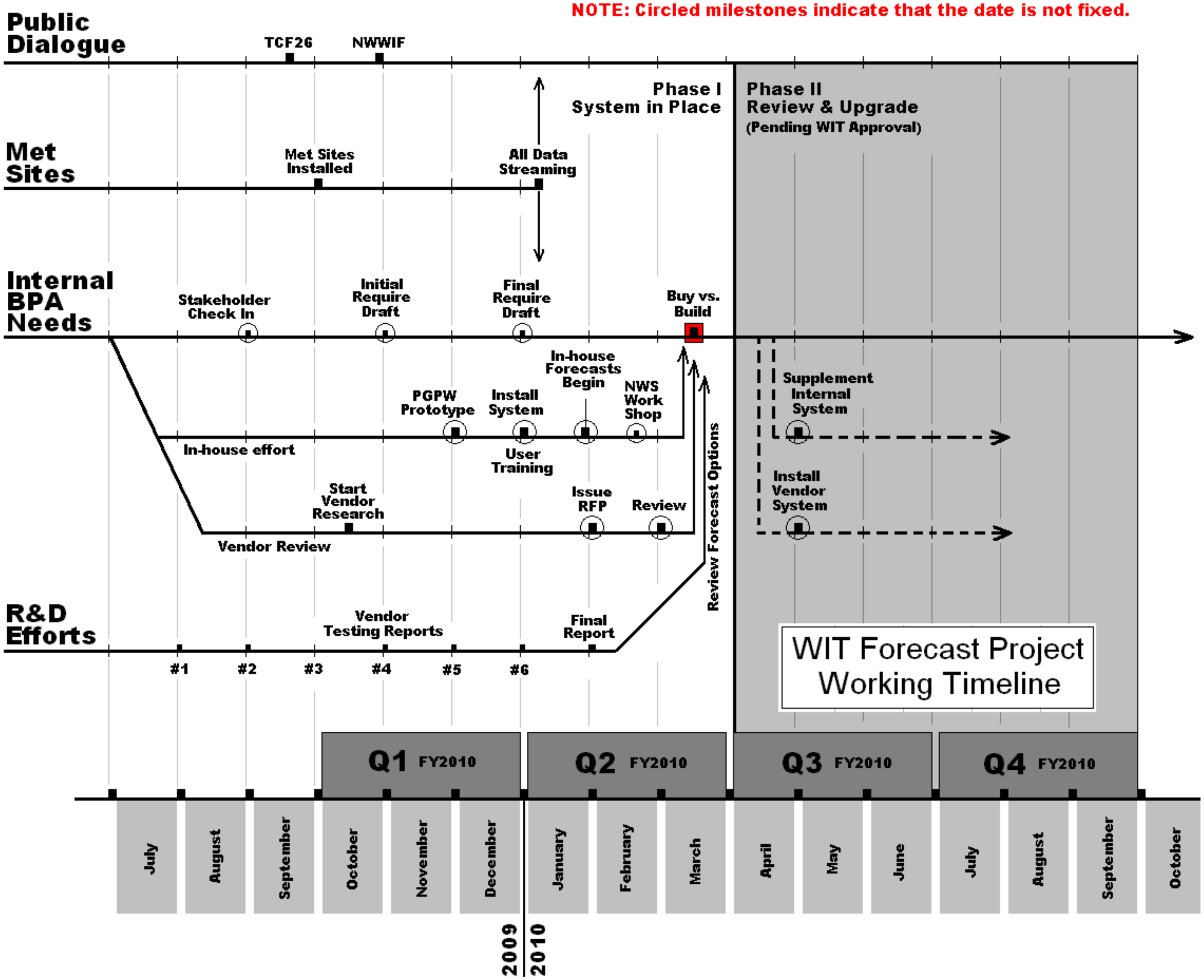
WIT Forecasting Project

Technologies and Techniques

Slides by Matt Neel, Project Manager

Updated: 11/30/09, 10:00AM

Project Timeframe



Forecasting Project Background:

Meteorology and Forecast Creation

Data Collection to Decision Making

Forecasting Background

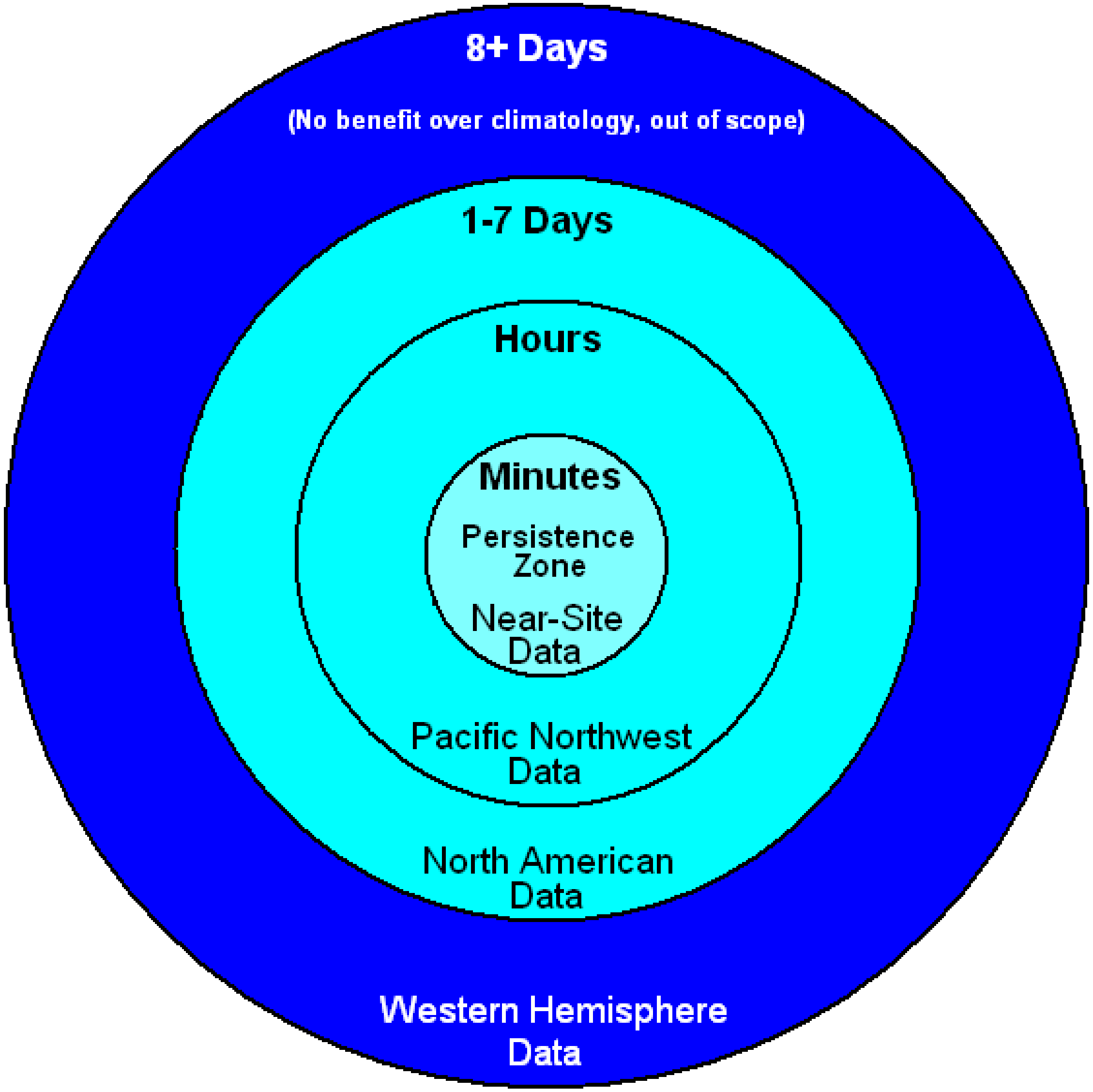
- Wind activity in the Pacific Northwest
  - Local and Vendor perspectives on ramps
- Data types and their benefit
  - Short-term forecasts need data from sources near to the point of interest
  - Long-term forecasts need data from sources far from the point of interest
- The forecasting process
  - General algorithm
  - Sources of error
- Forecast visuals – Raw and Formatted
- Probabilistic Decision Space

Atmospheric Data, Time of Flight and Update Importance

Wind forecasting relies on many different kinds of data sets to make accurate predictions.

In general, shorter-term forecasts require more local data and longer-term require more distant data due to atmospheric time-of-flight

Not all data is updated at the same rate and not every region has data available.

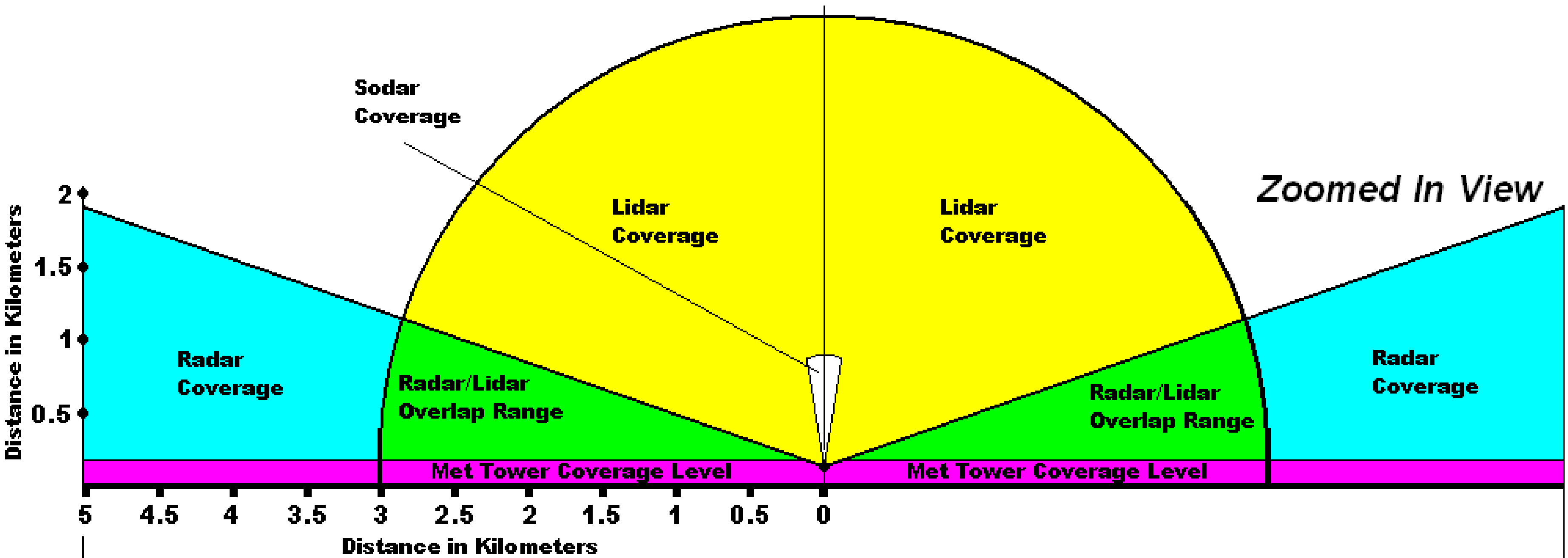


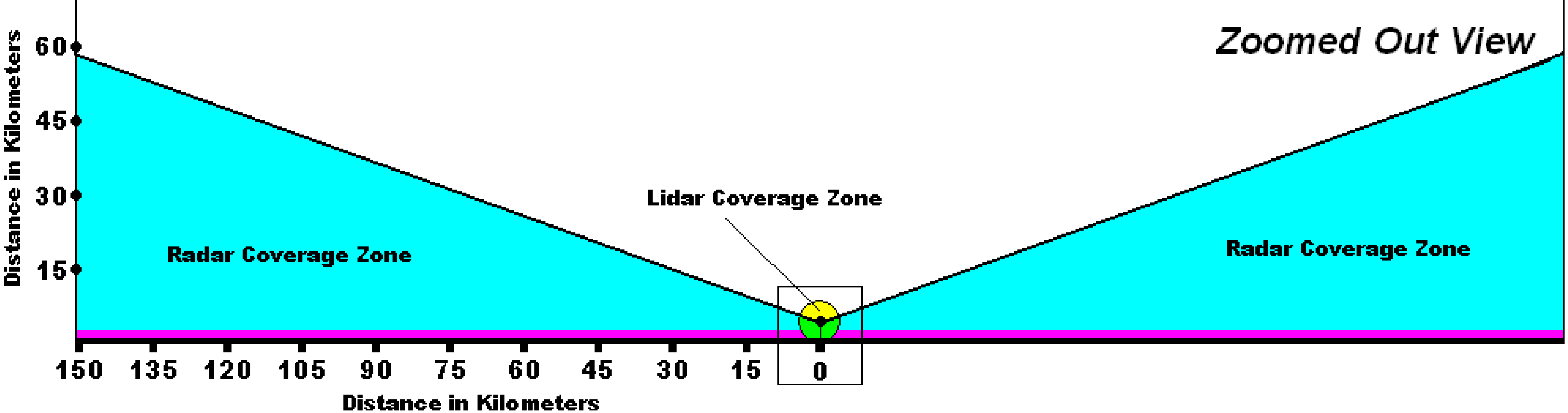
Approximate Comparison: Radar, Sodar, Lidar, Met Sites

Meteorological Technologies

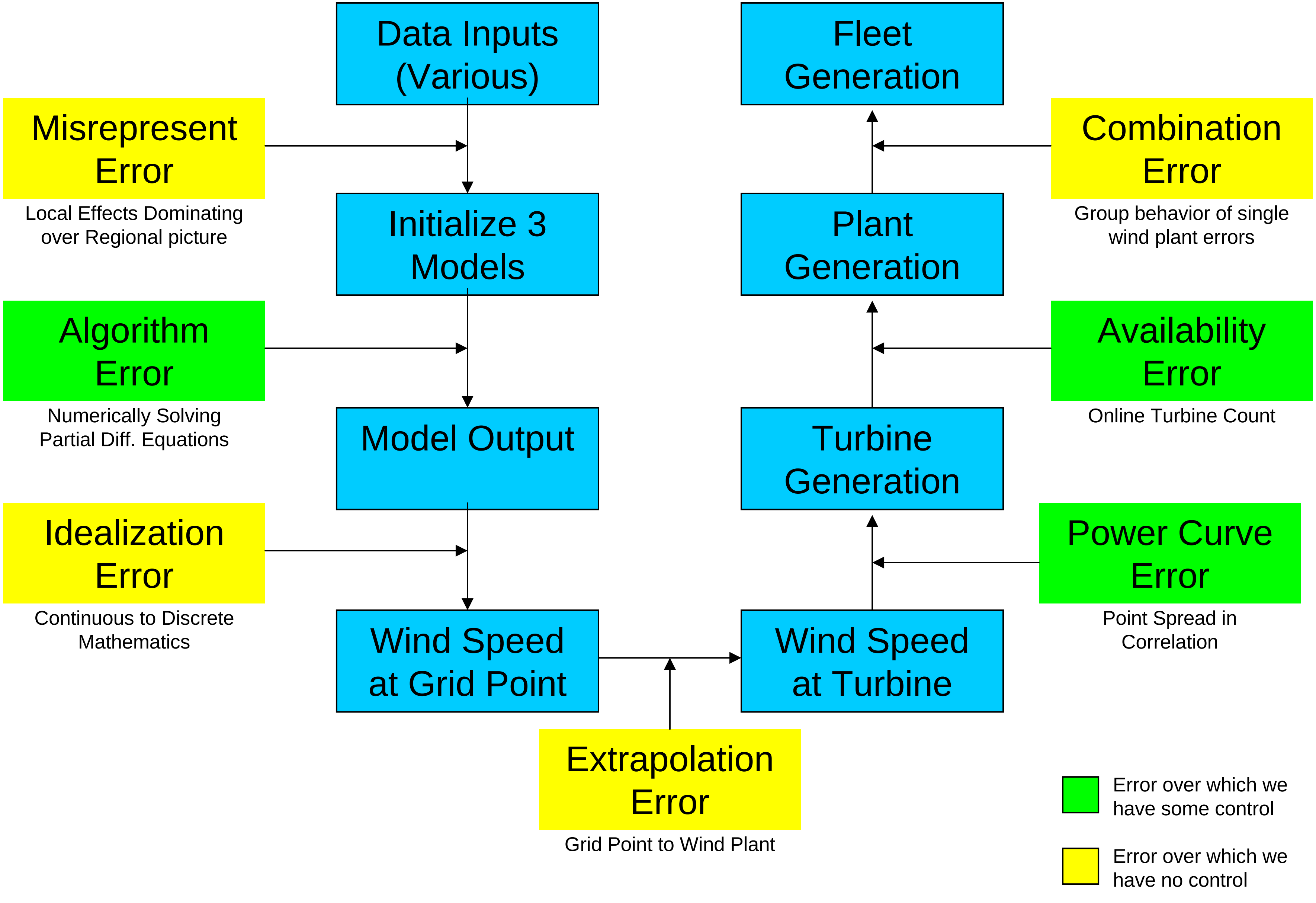
Created by Matt Neel, 7/27/09

(Currently Requires Confirmation)





Wind Energy Forecasting: Process and Error

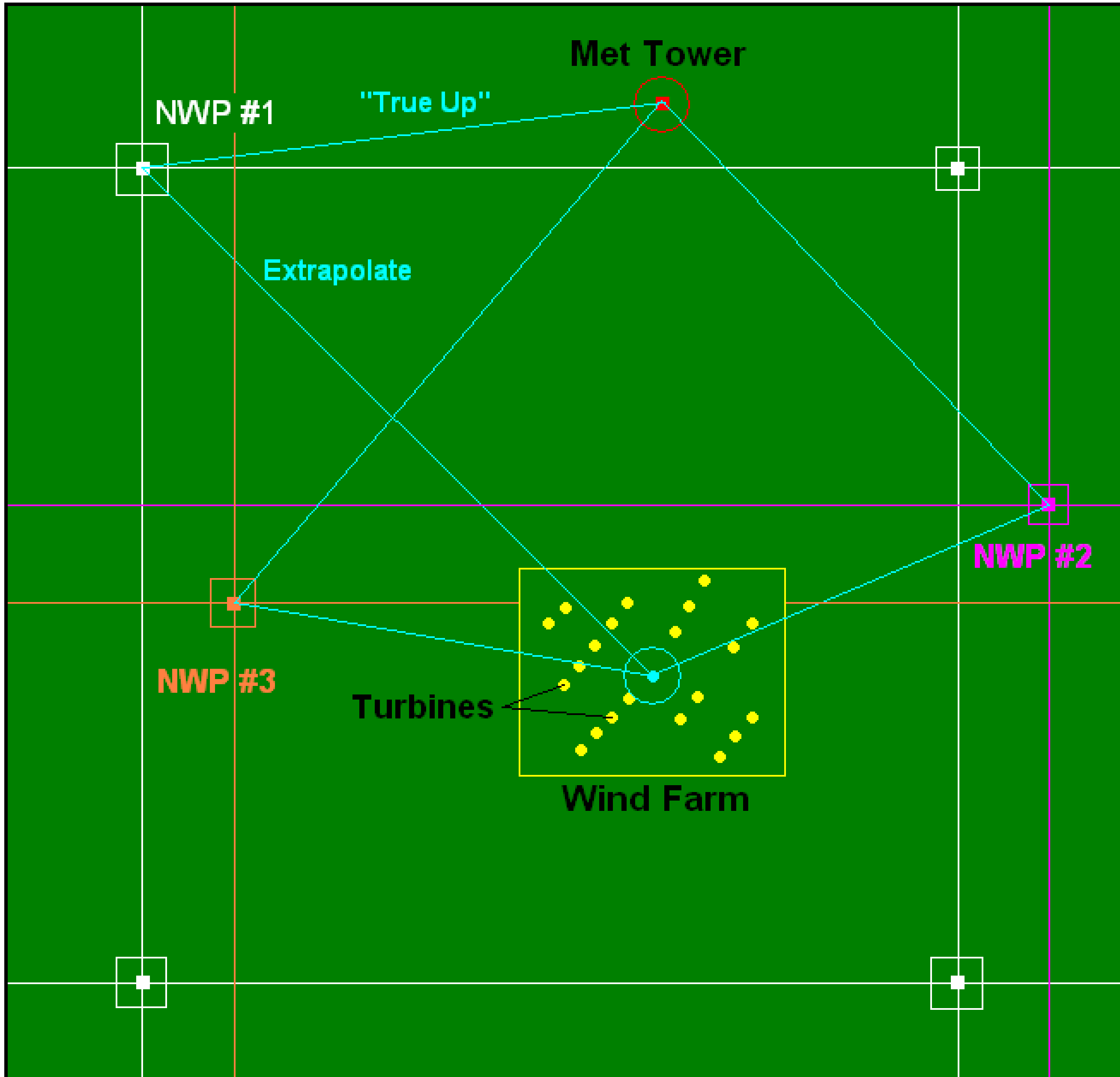


Grid Point Calculations

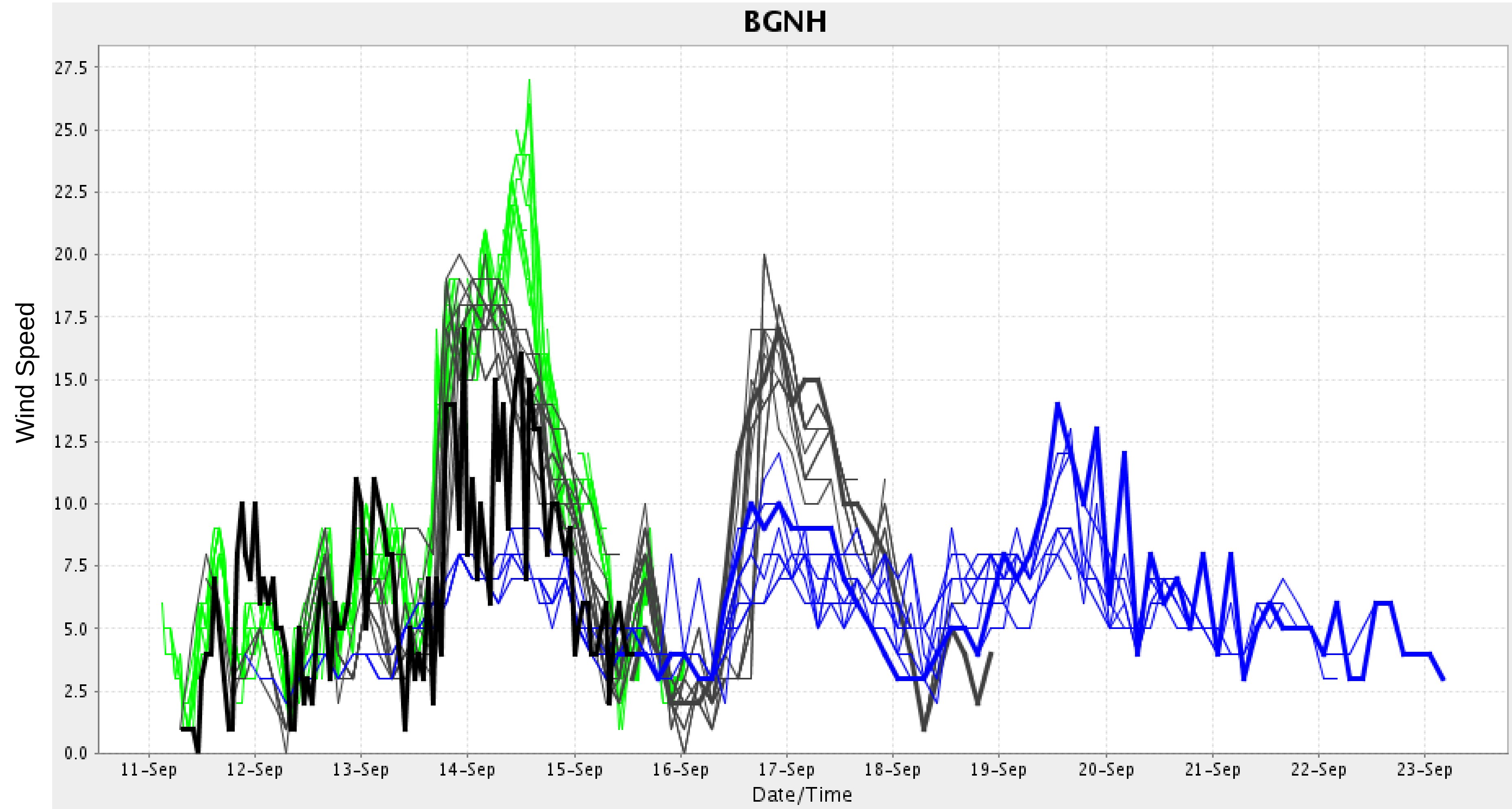
First a wind farm is selected to predict and nearby met towers (if any) are found

The forecaster runs the three NWP models, each having a uniquely sized grid that they superimpose on the earth.

Once wind speeds are found at those grid points, the met towers are used as a local check and then the wind speed is extrapolated to the wind plant

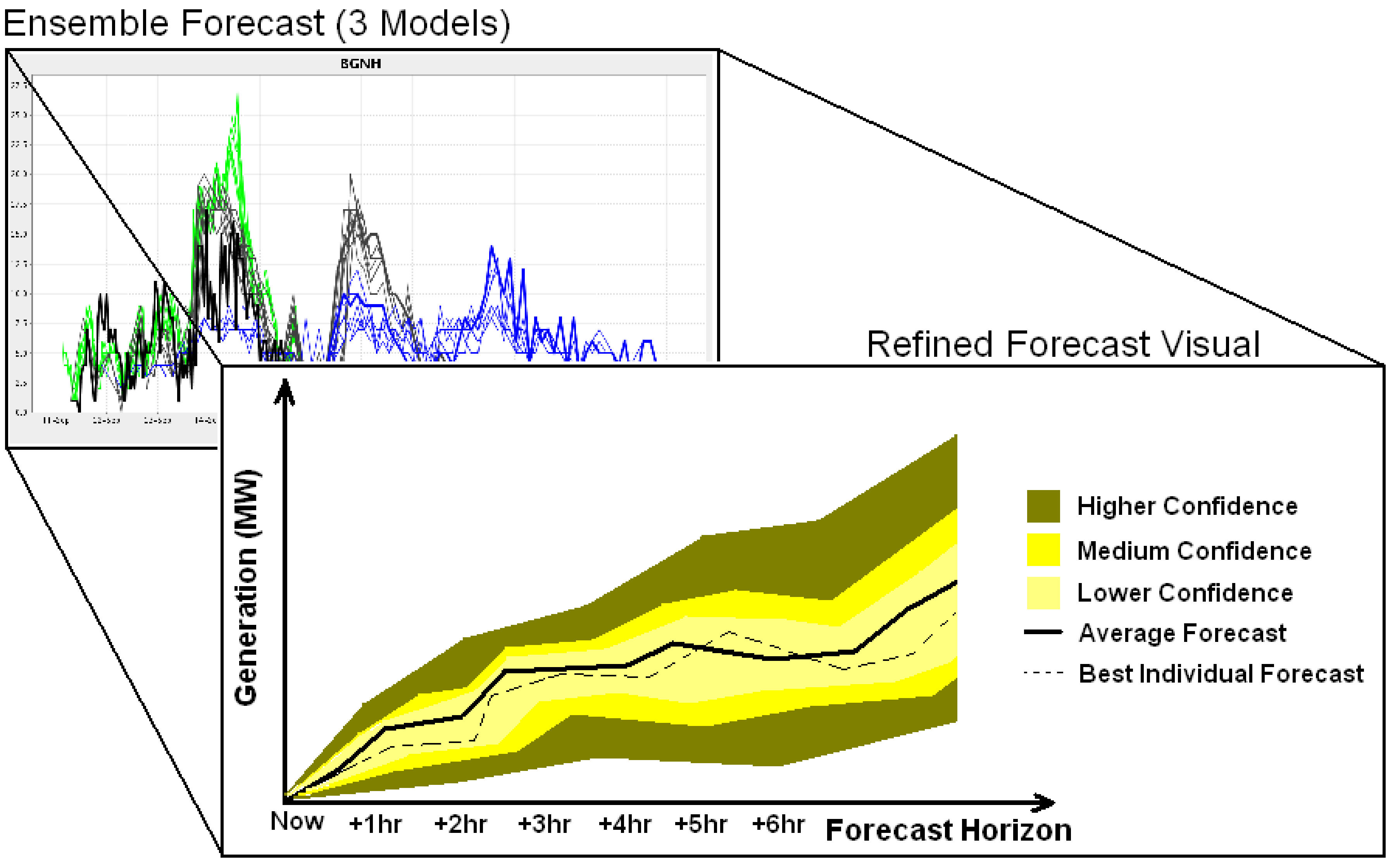


Raw Numerical Forecast (PGPW)

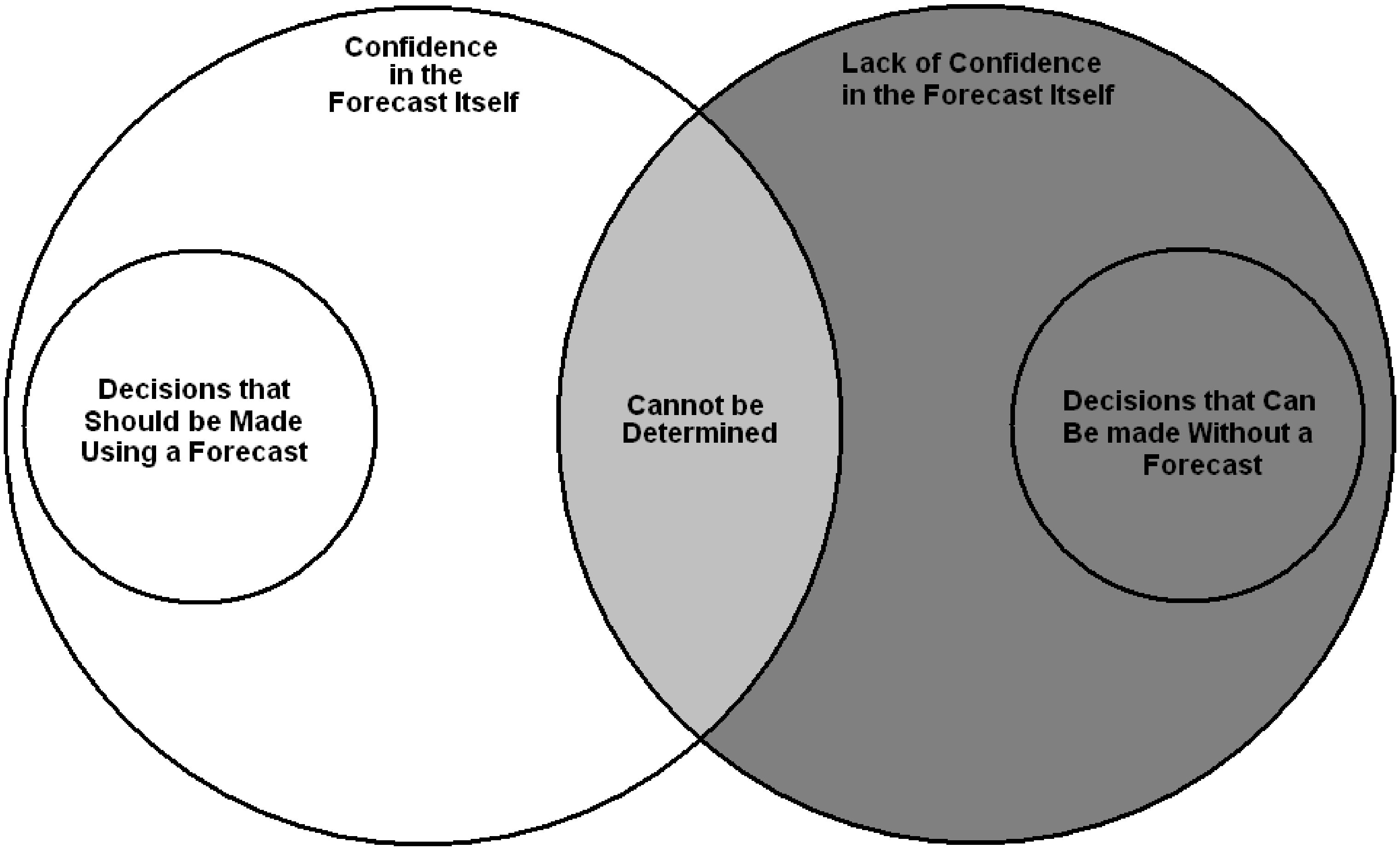


Observed wind speeds (black); RUC Forecast (green);
NAM Forecast (gray); GFS Forecast (blue)

Forecast Translation

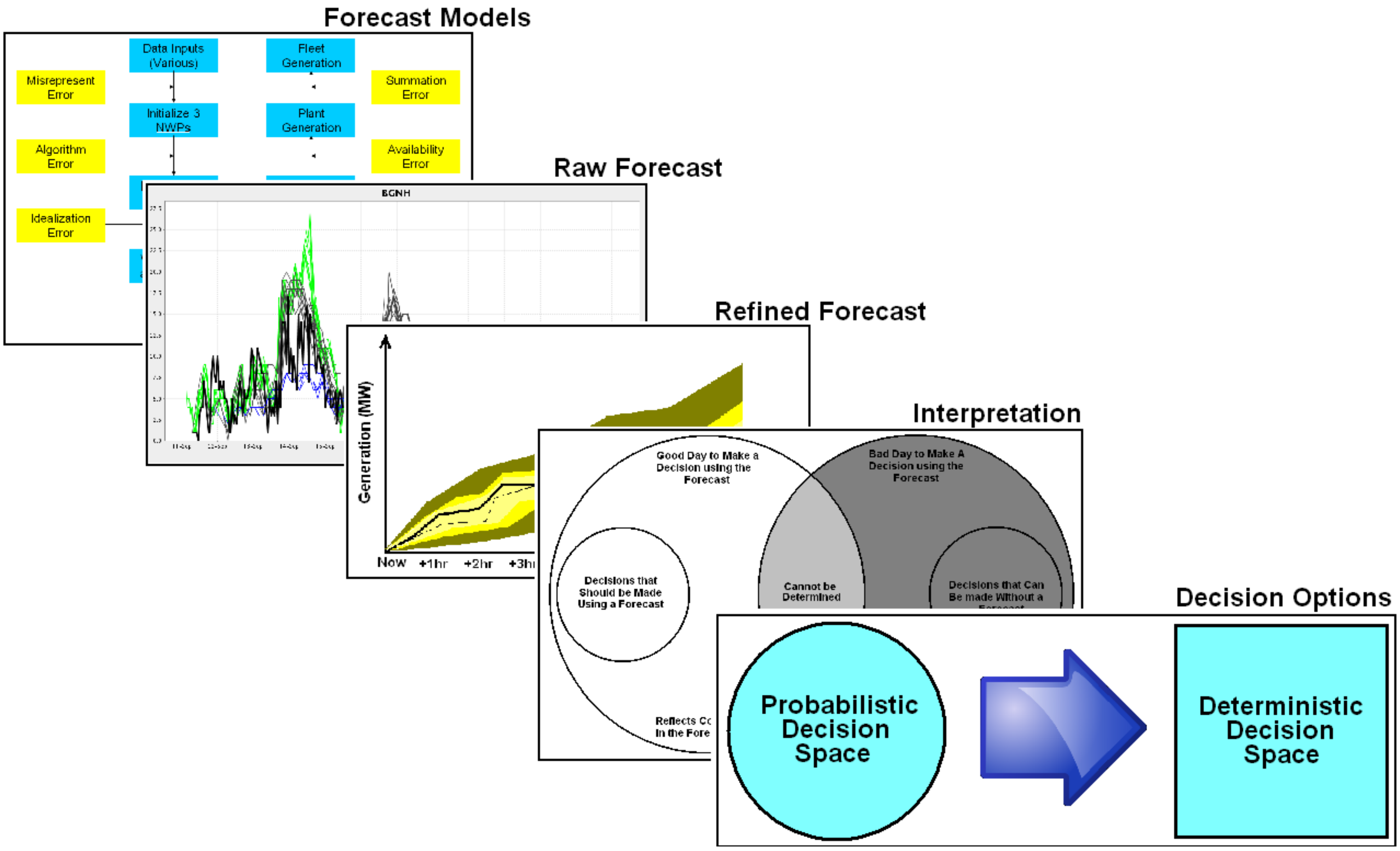


Using the Forecast: Probabilistic Decision Space



Example: "The three NWP models seem to agree with each other today (good day to use forecasts) that there will be only 20% confidence in the wind forecast for the fleet in the next few hours (high uncertainty in the specific forecast)." What would we do with this?

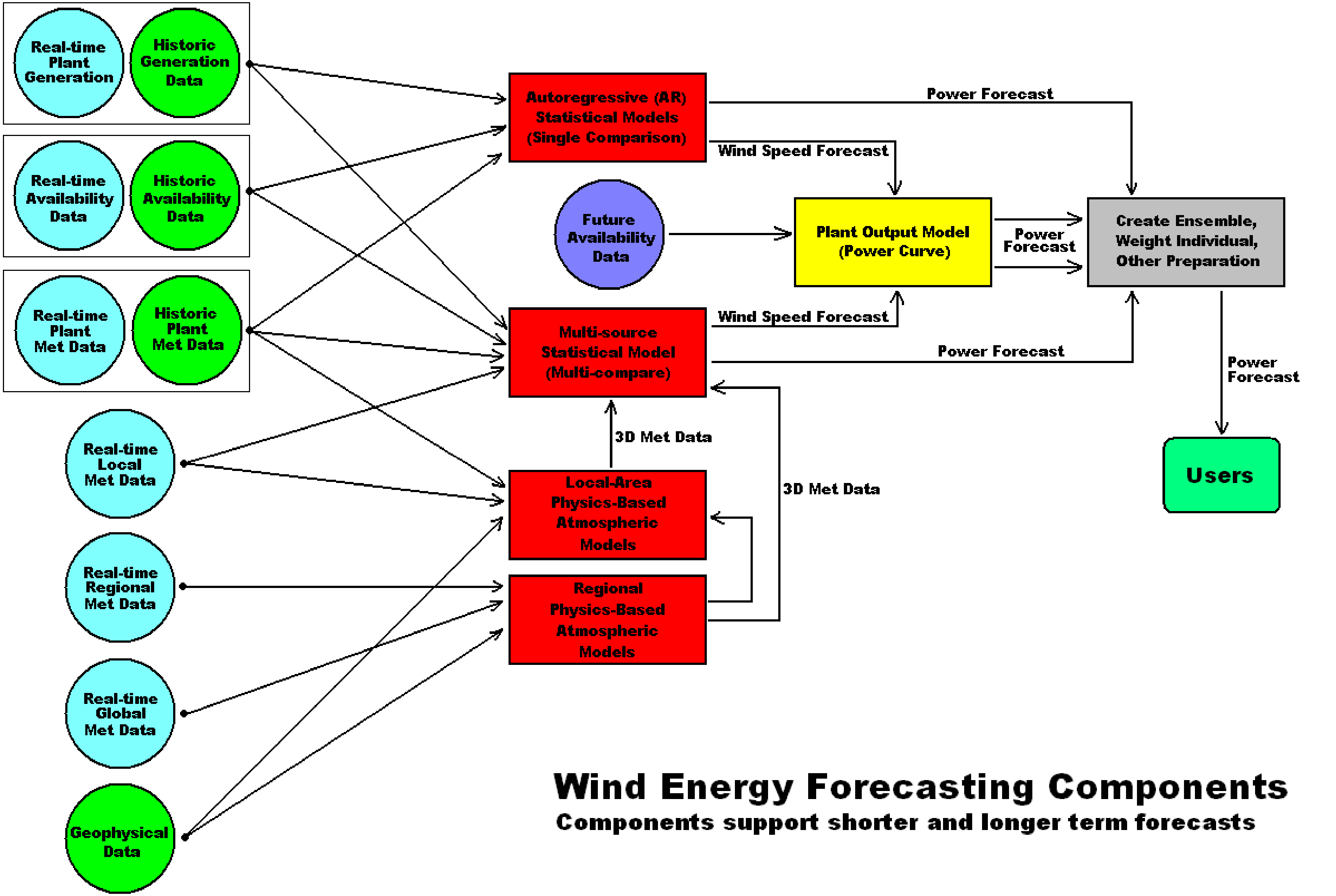
Forecast Process in Review



Forecasting Project Background:

Short-Term Forecasting

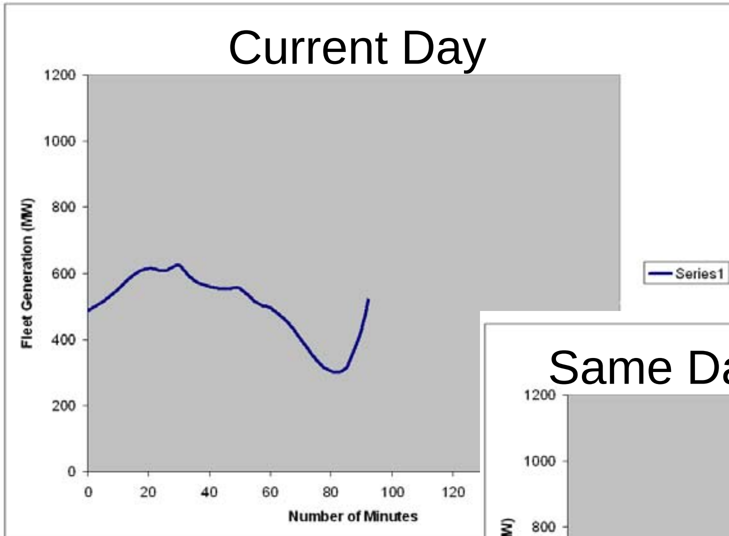
System Components and Results

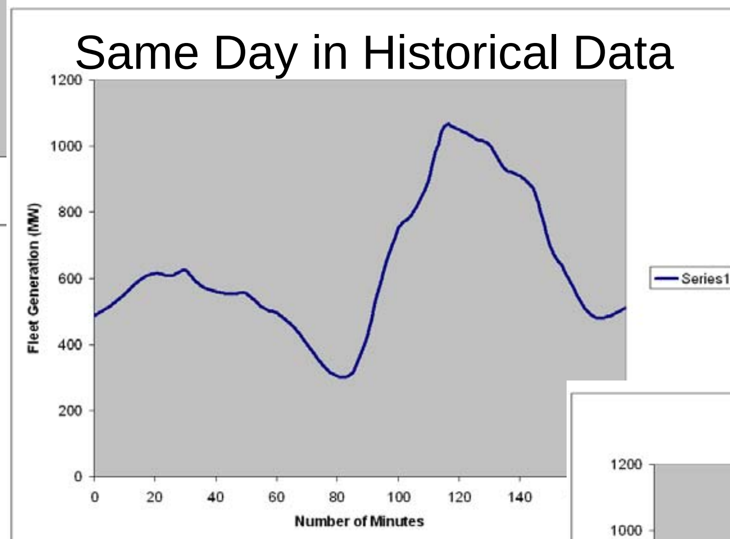


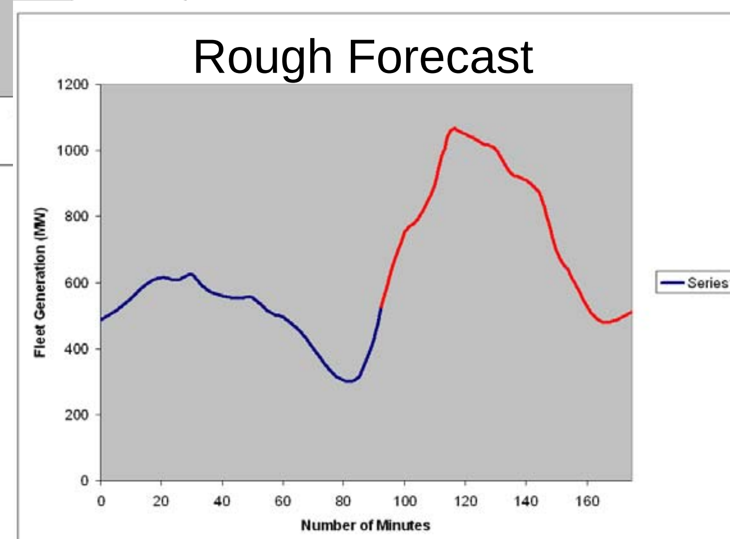
Wind Energy Forecasting Components

Components support shorter and longer term forecasts

Historical Data Matching: Situational Prediction



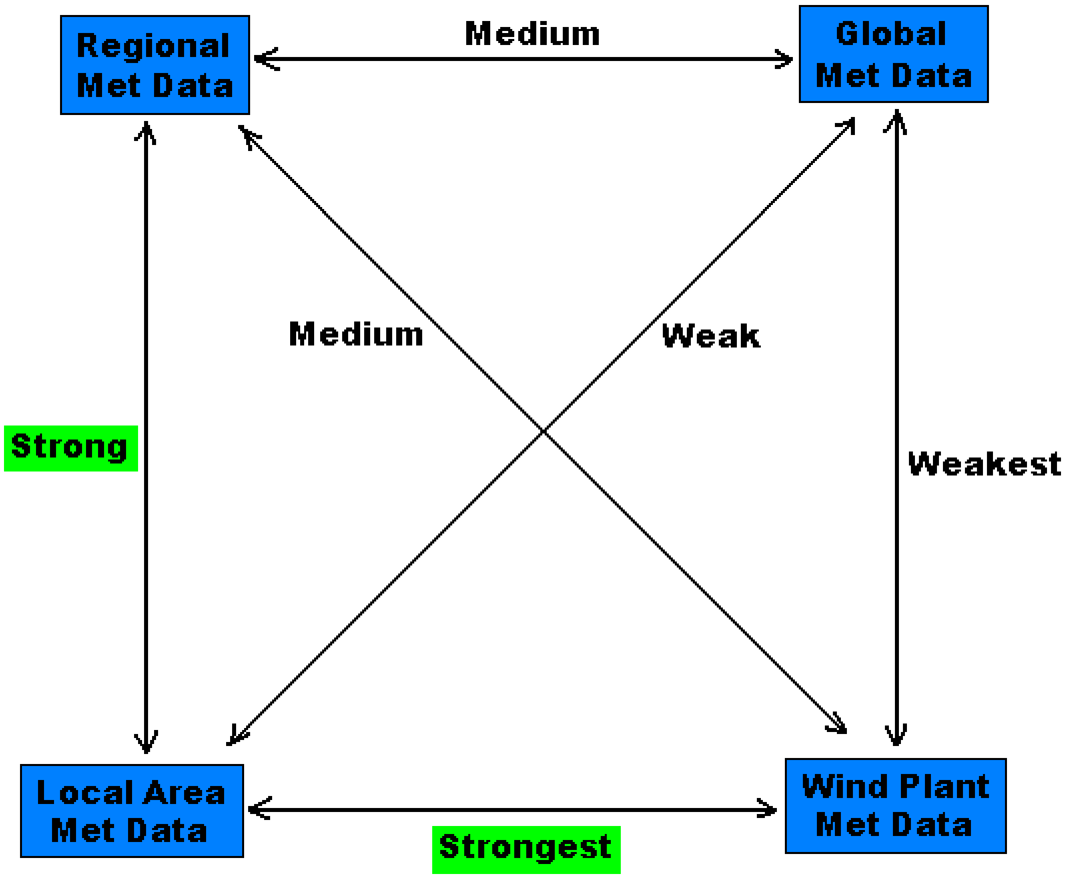




Correlation can be performed with:

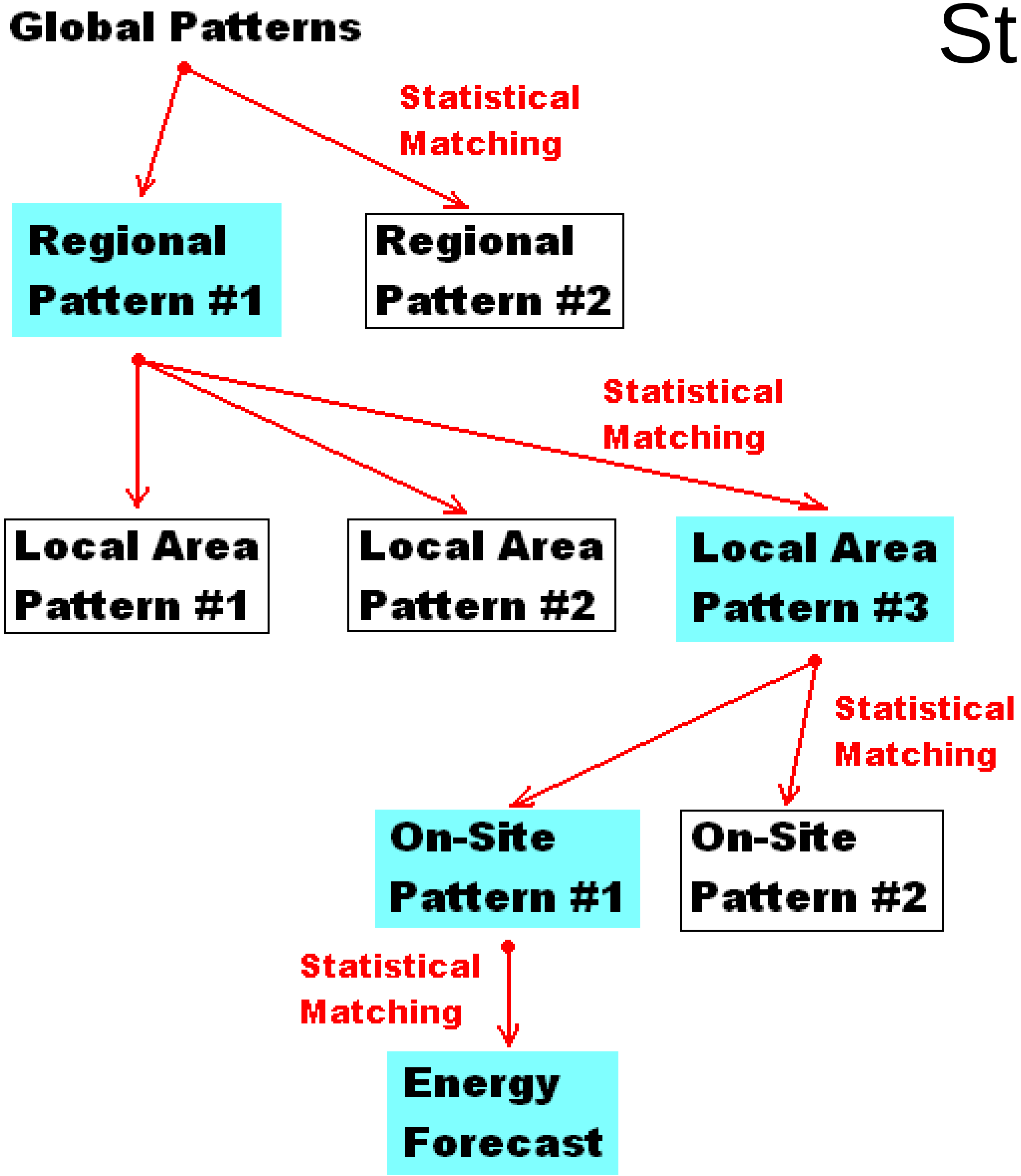
On-site Wind Plant Met Data
Local Met Data
Regional Met Data
Global Data

Statistical Correlations: Met Data Regime



Our 14 new met sites support the strong and strongest correlations

Statistical Correlations



One can envision the statistical correlation predictions as organizing major weather patterns on different scales and then determining typical patterns under each category.

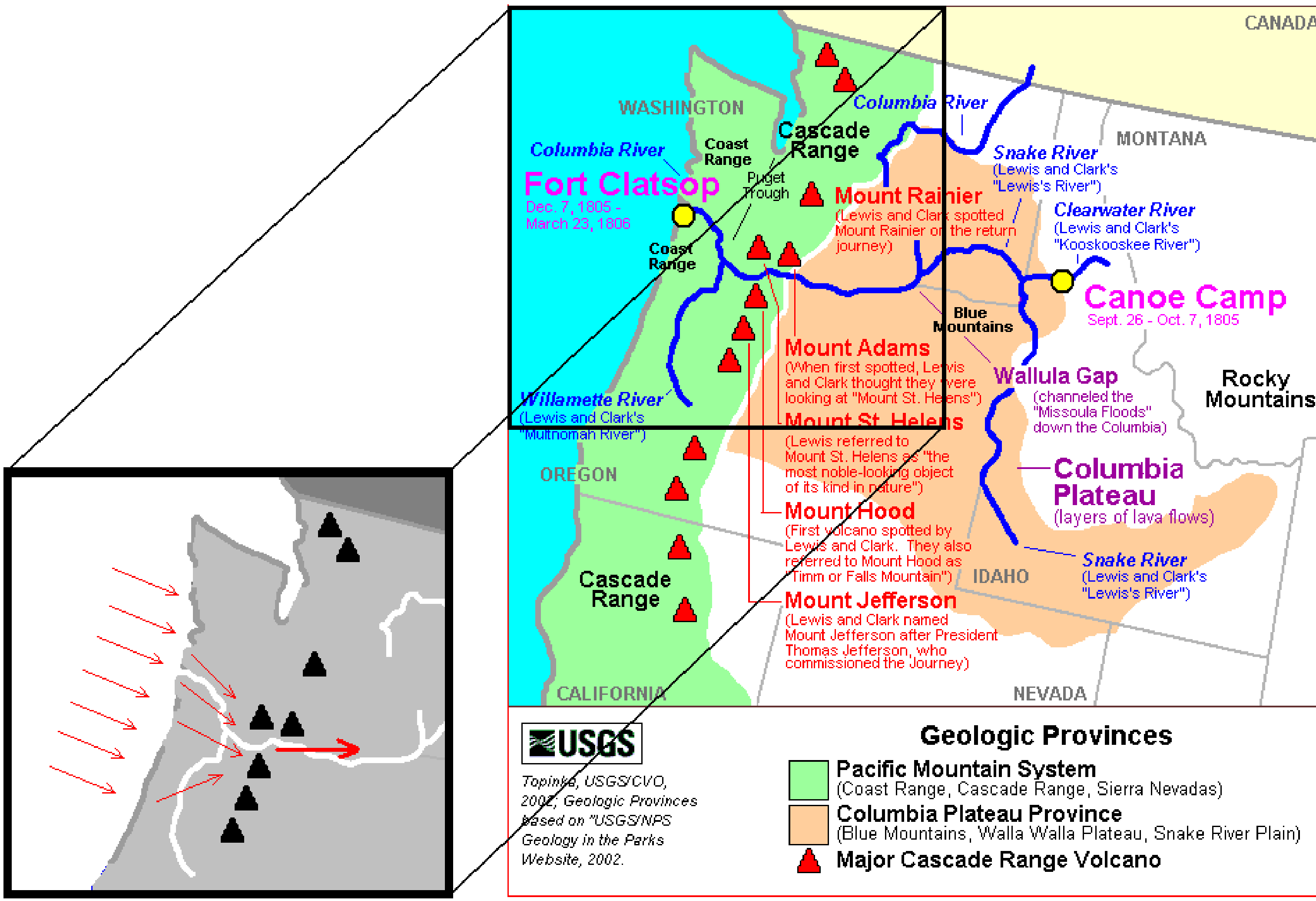
More statistical correlations corresponds with greater forewarning of imminent events

To save computing time, most forecast systems use local area and on-site pattern correlations (not much regional, very little global)

Topographical Contribution: Gap Flow

A common weather pattern is a funneling effect of winds from the ocean (marine push) into the gap (the Columbia gorge) in the Cascade mountain range

Strong data void (Pacific ocean) increases difficulty of predicting incoming fronts.



Forecasting Project Background:

Ramp Forecasting

Probabilistic Forecasting and Decisions

Wind Ramp Sources

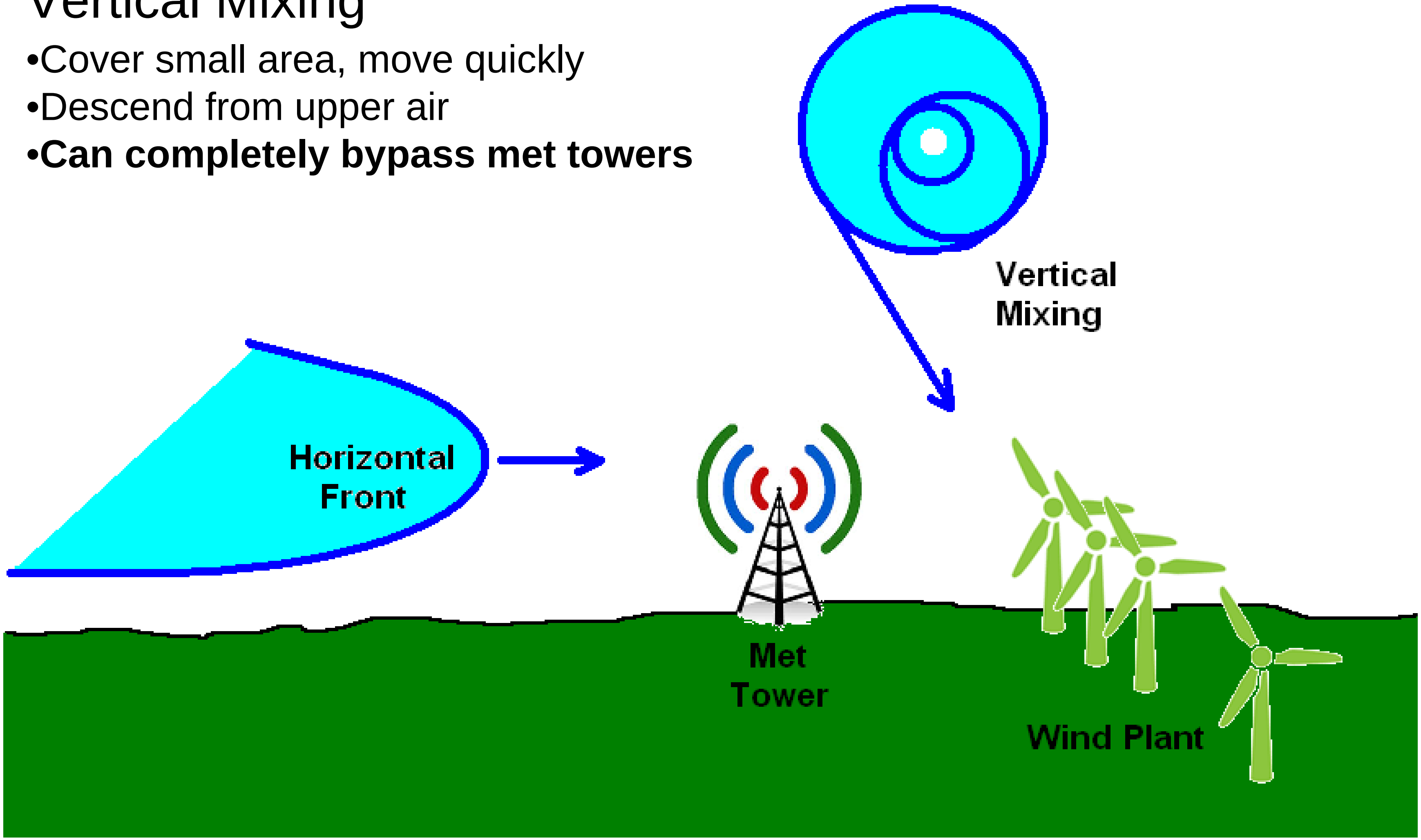
Horizontal Fronts

- Cover large area, move slowly
- Move parallel to the ground
- **Met towers can detect**

Vertical Mixing

- Cover small area, move quickly
- Descend from upper air
- **Can completely bypass met towers**

We are unsure as to the prevalence of sources: Horizontal vs. Vertical

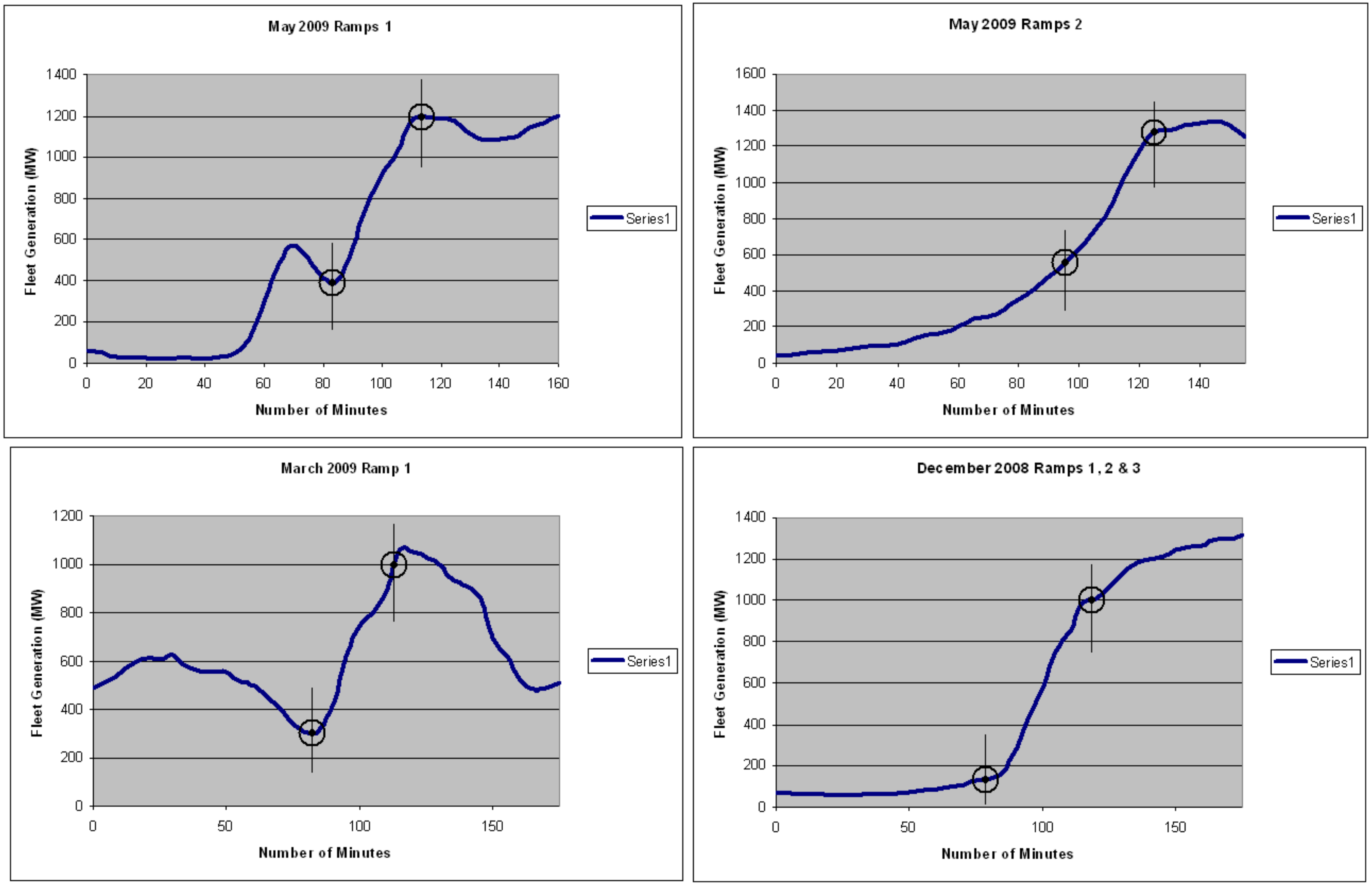


Common Causes of Ramps in the Mid-Columbia Basin

Cause-based Type	Predictability	What data is needed to improve prediction?
Increasing pressure gradient as storm approaches from west	High; small-scale details uncertain	Regional/offshore pressure, wind and temperature data
Decreasing pressure gradient as storm moves away to east	High; small-scale details uncertain	Regional/offshore pressure, wind and temperature data
Cold frontal passage	Moderate; mountains cause complications	Regional/offshore pressure, wind and temperature data
Downward turbulent mixing in rain bands	Very low	Radar and vertical profiles of temperature and wind
Changes in mixing due to changes in low level stability	Low	Vertical profiles of temperature and wind
Mixing out (weakening) of low level jet (morning)	Moderate	Vertical profiles of temperature and wind
Eastward surge of marine air (warm season afternoon-evening)	Moderate / High	Upstream (west) wind data; vertical profiles

Table presented at the recent forecast R&D vendor conference

Wind Ramp Examples (2008-2009)

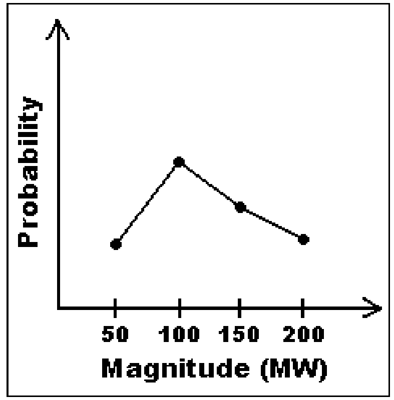


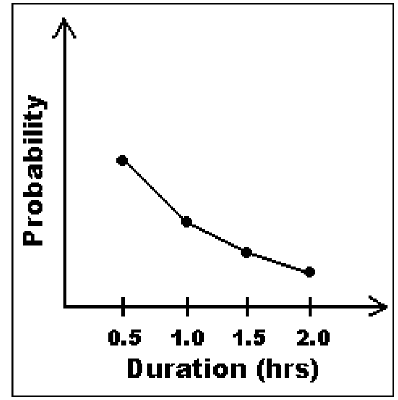
Month	*Ramp #*	*Duration (min)*	*Magnitude (MW)*	*Ramp Rate (MW/min)*
May	1	30	798	26.6
May	2	40	874	21.9
March	1	40	753	18.8
December	1	40	869	21.7

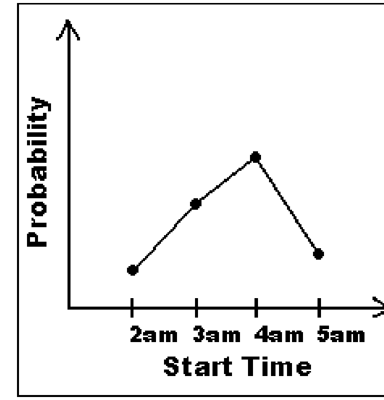
Ramp detection using magnitude thresholds: > 666MW and < -802 MW

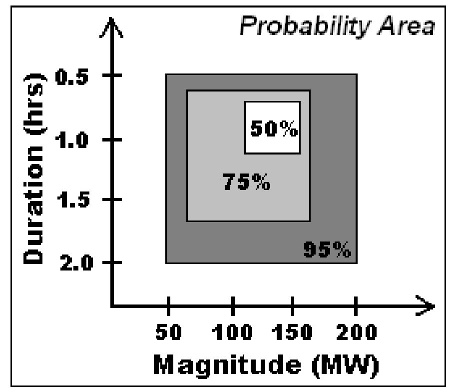
Representation of a ramp probability becomes difficult given the multiple ramp aspects that need to be described, namely:

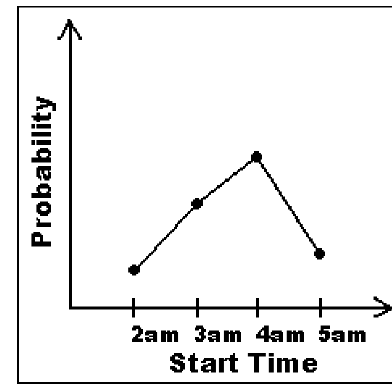
- Magnitude (in MW)
- Duration (ramping time)
- Start Time (local time)



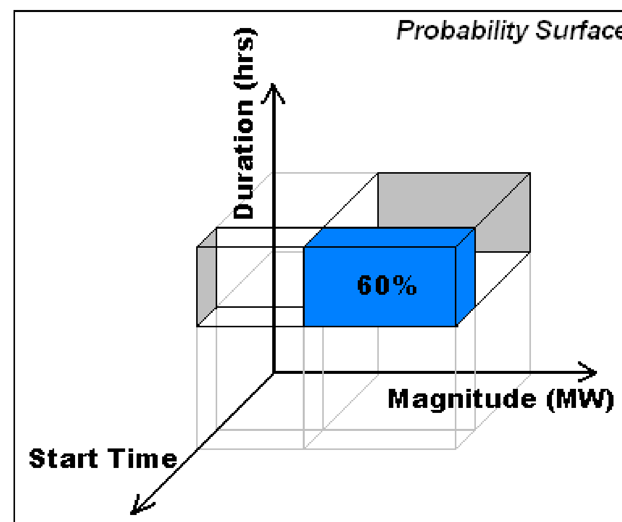








The probabilities can be expressed as three linear plots, a linear and area plot and a 3D surface plot depending on what is useful for decision making



Multiple, Dependent Probabilities

Forecasting Project Background:

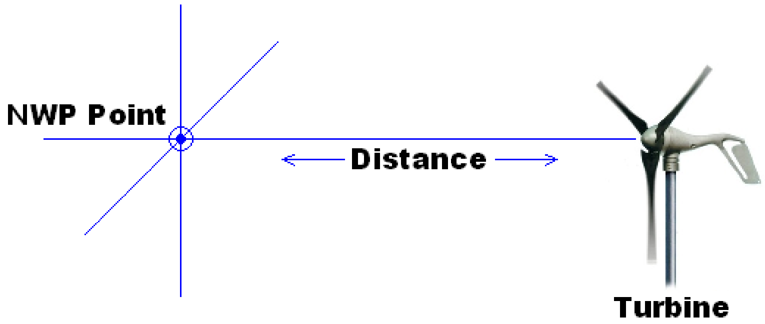
Understanding Forecast Error

Contributions, Standards of Comparison
and an example "perfect" forecast

Forecasting Error Background

- The quality and accuracy of a wind energy forecast often determine its usefulness as well as how sound the methodology was that created it.
- Common error metrics are Root-Mean-Square Error (RMSE), Mean Absolute Error (MAE), Percent better than persistence forecasts and others.
- As an introduction, see the next slide for what happens when there is even a small error in the predicted wind speed at a given point on the earth.

Wind Forecast Errors

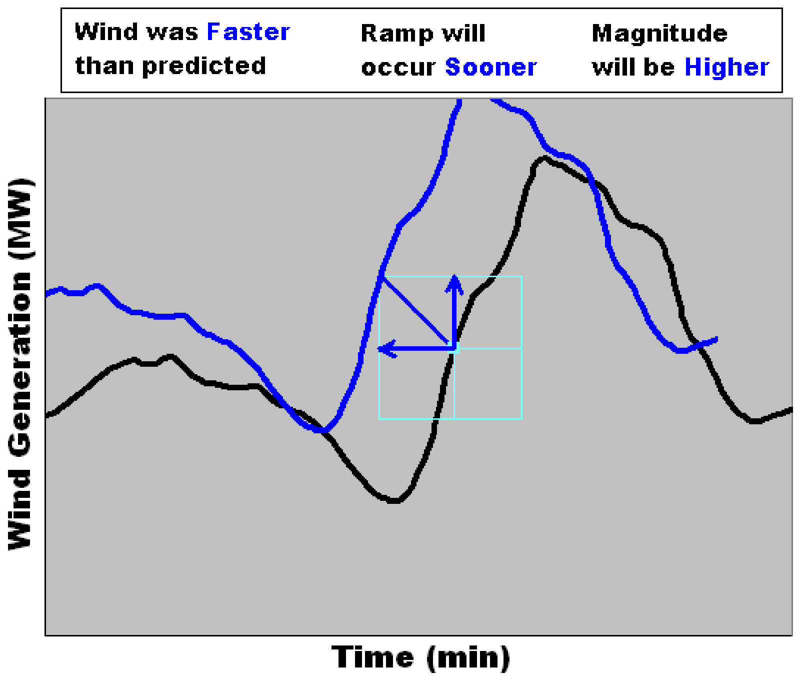


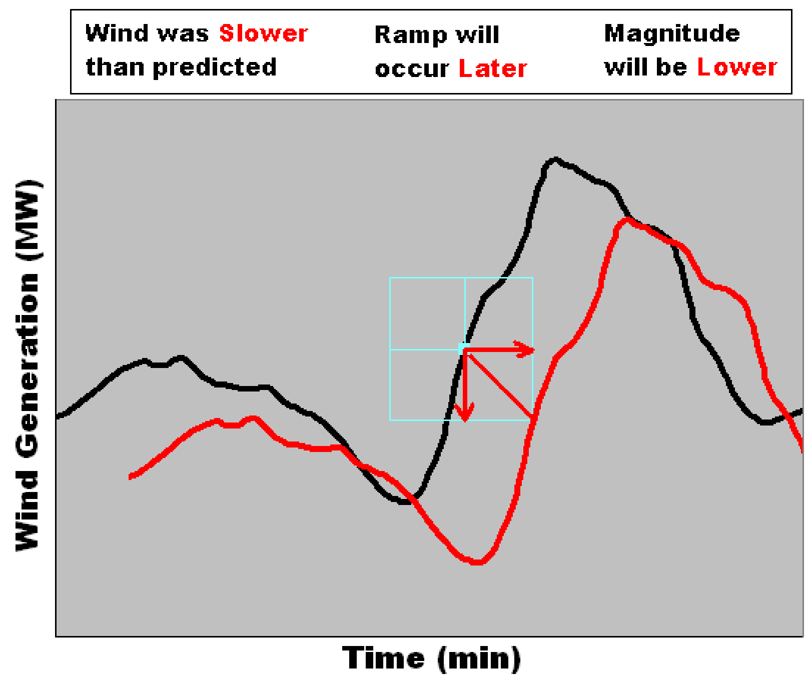
Rate, Distance, Time

$$v = \frac{d}{t}$$

Power Conversion

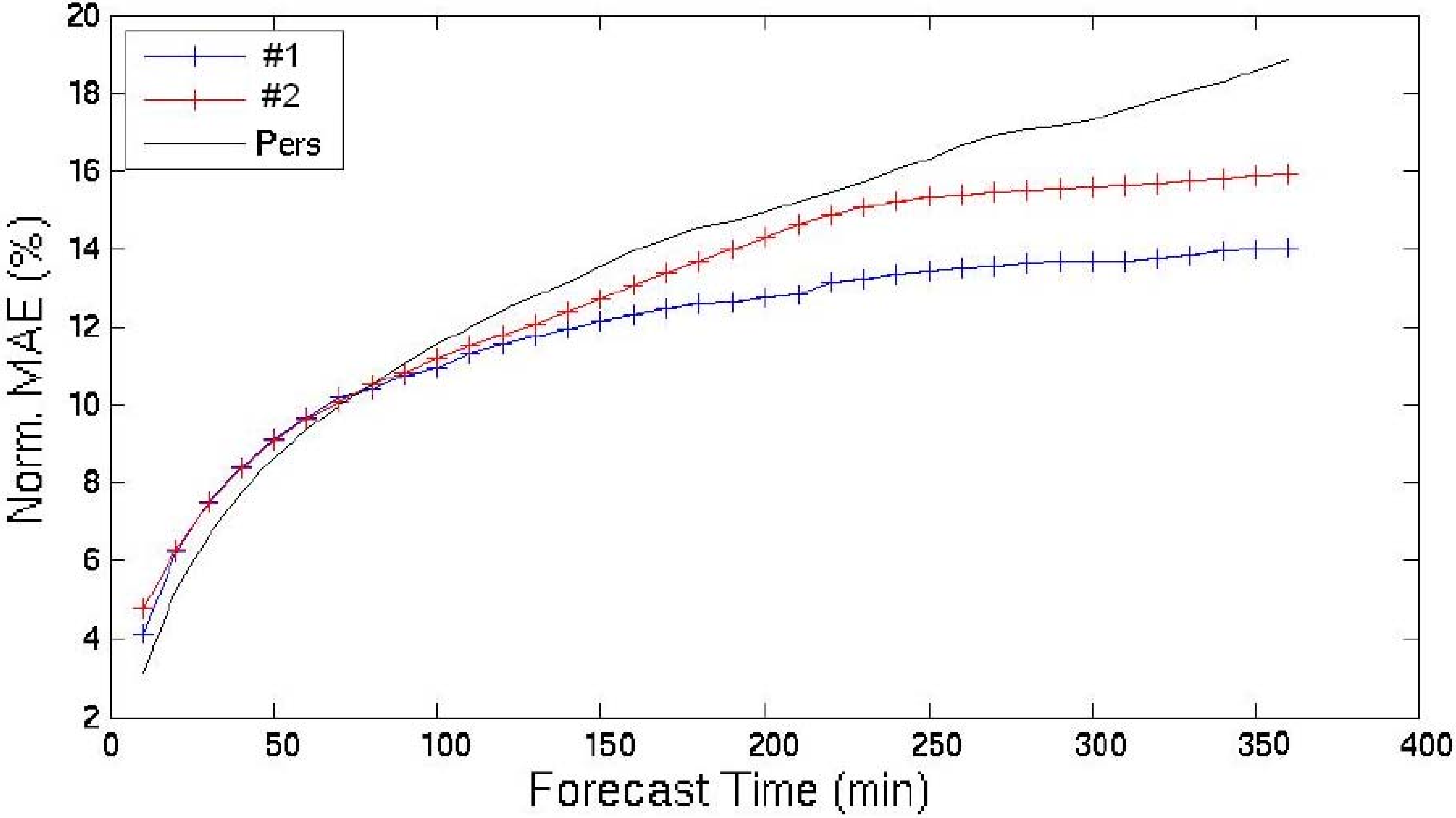
$$P = \alpha \rho A v^3$$





(Black line shows original forecast, red and blue lines show actual)

Wind Energy Forecast Quality: NMAE vs. Forecast Horizon



Forecast Error Example

Forecast Hour	*Goal (%)*	*Current (%)*	*Persistence (%)*
1 hour ahead	3	6	5.5
2 hours ahead	5	8	7.5
3 hours ahead	7	9	9.5
4 hours ahead	9	10	11
5 hours ahead	10	11	12.5
6 hours ahead	10	12	13.5

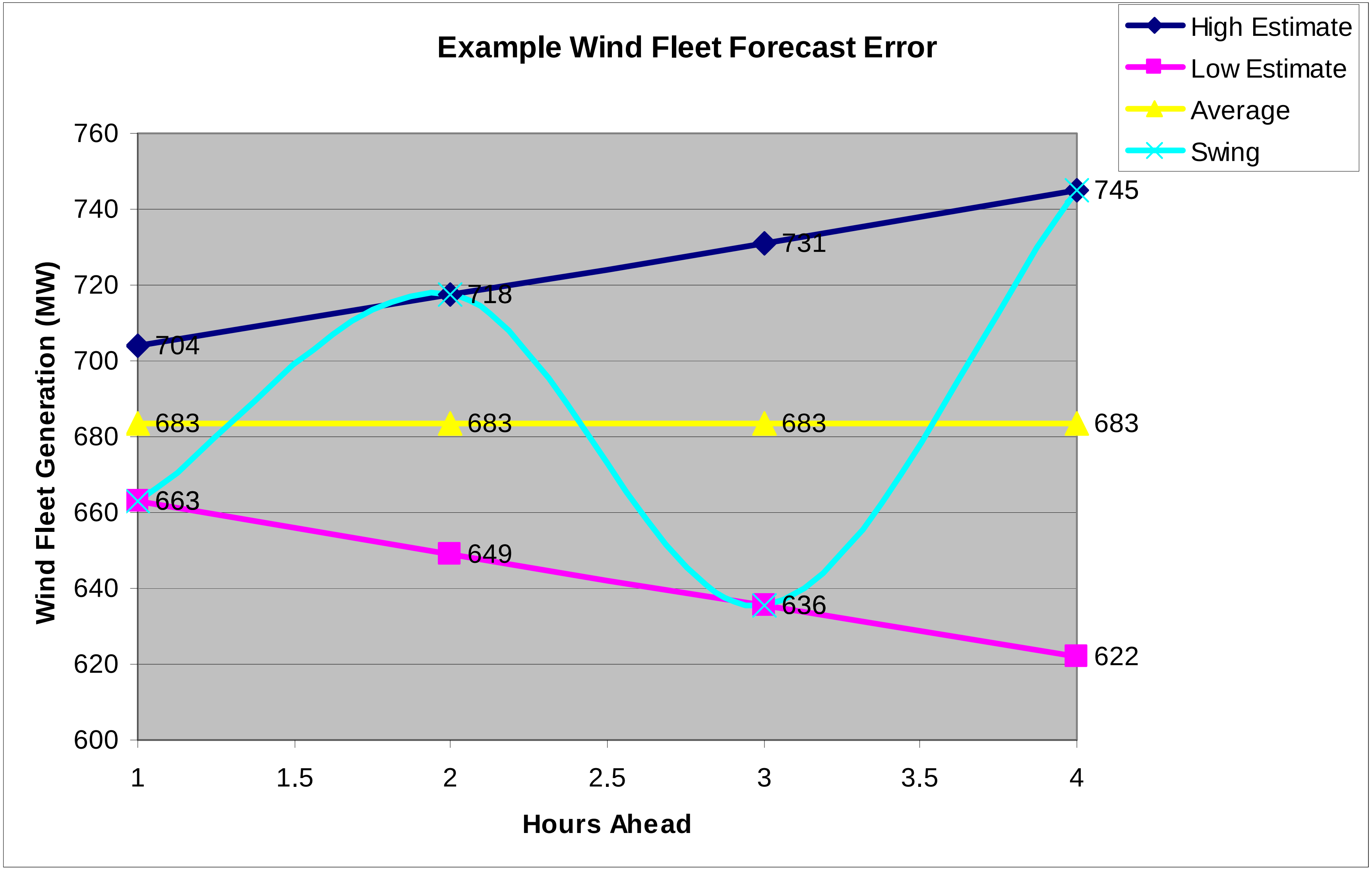
$$\text{Normalized MAE in } \% = \frac{1}{n}\sum_{i=1}^{n}\left|p_i - o_i\right| \times \frac{100}{P_{nameplate}}$$

The above table shows the NMAE “Goal %” for a vendor for a specific wind plant, “Current %” for the vendors’ ability to forecast historically and “Persistence %” using the same historical data

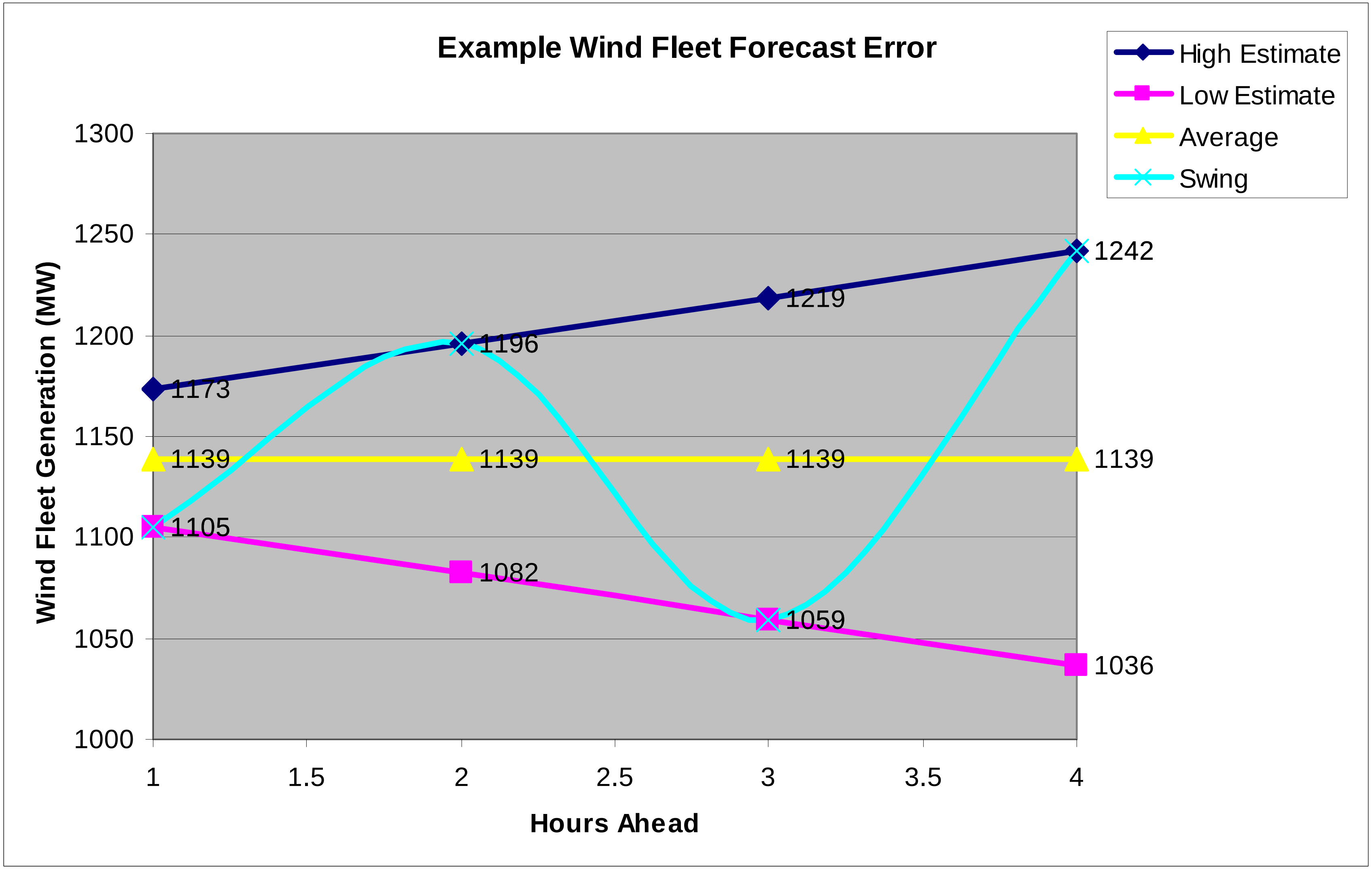
Forecast Error Example

- Begin with the modern wind fleet parameters
- Assume that every wind plant is forecasted to produce 30% (and then 50% on the next slide) of its nameplate for the next four hours
- Apply the 3,5,7,9% NMAE standard to all wind plant forecasts for the next four hours
- Determine highest generation within bounds, lowest generation within bounds, the average and a worst-case generation swing

Wind Fleet Schedule for Next Four Hours: 30% of Nameplate



Wind Fleet Schedule for Next Four Hours: 50% of Nameplate



Error Example Summary

- The swing condition is interesting in that it shows the variation that still occurs even inside a forecast that adhered to a high-quality error standard AND beat persistence.
- In our first example (using 30%), the actual generation might have been anywhere between 622MW and 745MW (123MW variation) four hours ahead of the forecast release. In the 50% example, there was 200MW+ variation at the four hour ahead mark.
- Variation inside a forecast is natural and non-negotiable. A forecast usually only tells us a predicted range of results, not a specific number (without error bars).

Recent Example Forecasts

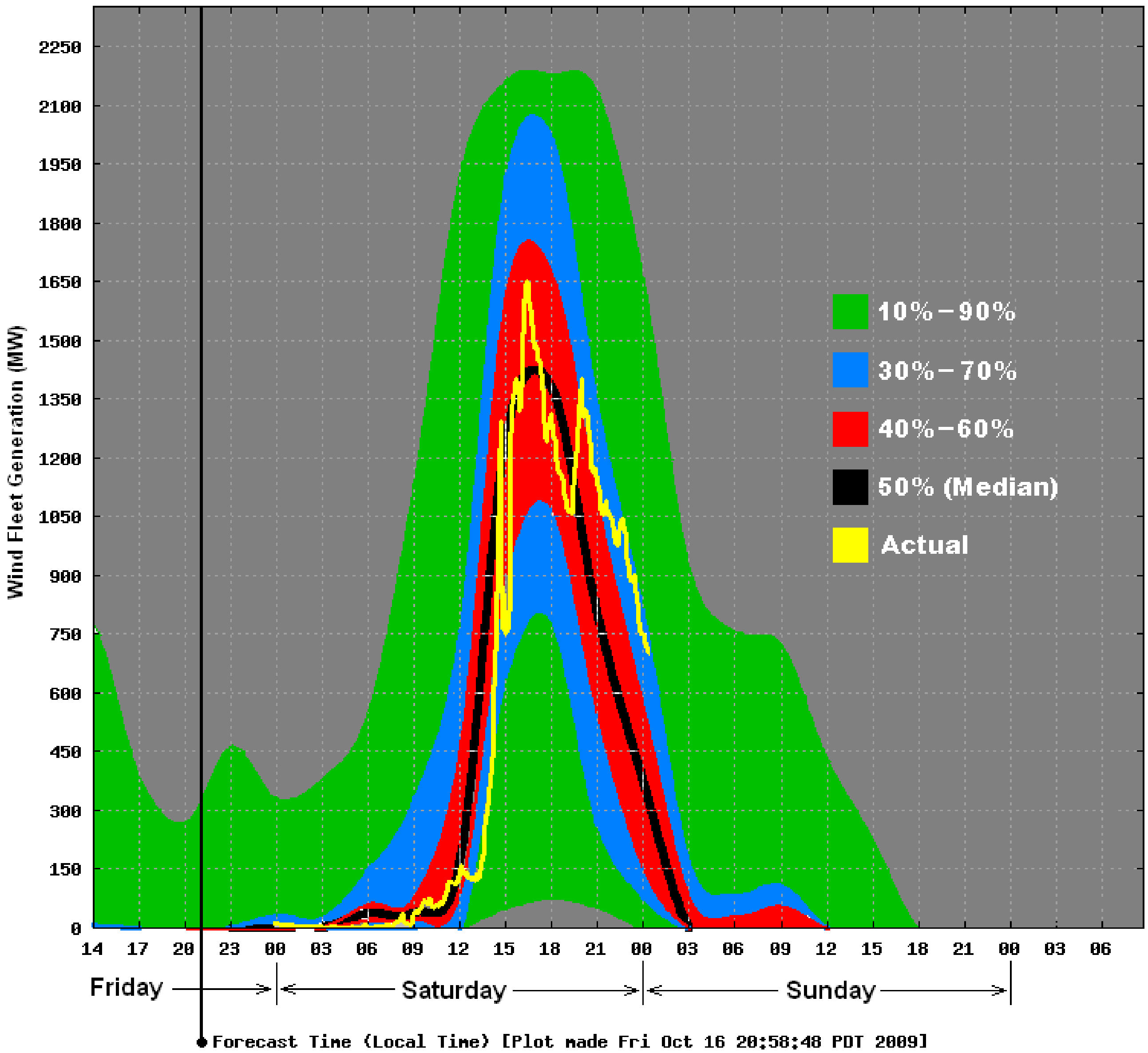
Trial Forecasts Produced by PGPW
for Discussion Purposes Only

Recent Ramp Forecasts

- Example forecasts created by David Bright
- Single Forecast – Ramp of 10/17/09
- Single Forecast – Ramps of 10/29/09 to 11/01/09
- Single Forecast – Ramps of 11/4/09 to 11/7/09 (circulated to PGSD on afternoon of 11/4/09)
- Day-ahead portion of the forecast is fairly strong in regard to timing and magnitude.
- Many more modifications and refinements can be applied. These were wind fleet generation forecasts whereas the prototype system creates plant-level forecasts and then aggregates them into the wind fleet.

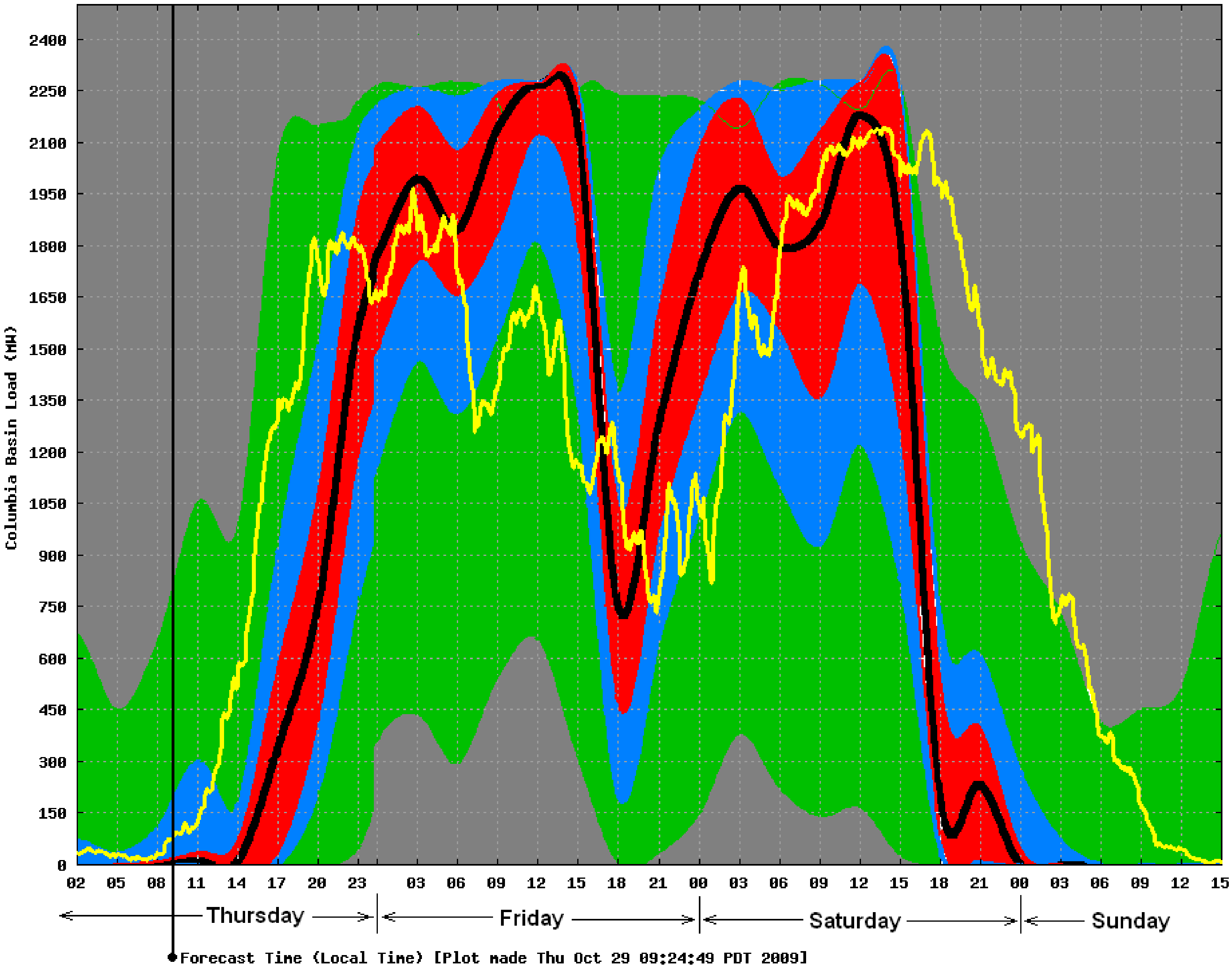
Ramp Prediction Analysis

72 Hour Ahead Forecast that Covered the Wind Ramp of 10/17/09 (1pm)
(Ramp occurred 17 hours after forecast was made)

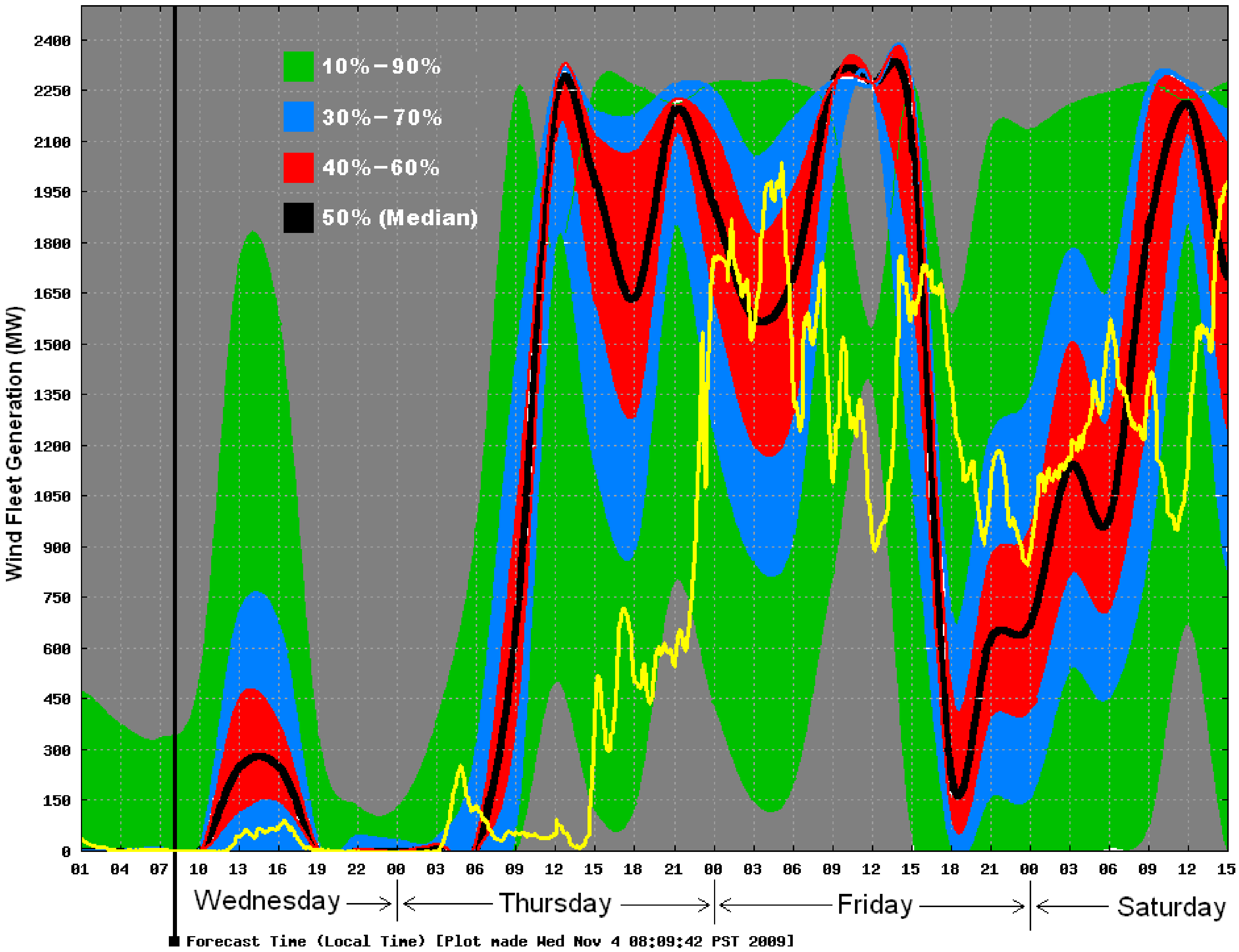


Ramp Prediction Analysis

(Covering multiple ramps from 10/29/09 to 11/01/09)



Wind Ramp Forecast for 11/4/09 through 11/7/09 (Rough Estimate)



Thank you!