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# Forecasting State of the Art for Wind Integration


Asian Pacific Partnership Canada Wind Event
Montreal, CA
September 14, 2010

# Wind Power Forecasting: Why is it necessary?

Wind Power Forecasts can be used in order to

- Estimate energy pricing for enhanced market trading
- Enable improved scheduling of other generation
- Optimize plant maintenance schedules
- Comply with existing grid regulations

*… all of which facilitate successful integration of wind generation on regional electric grids.*

# Quantified Value of Forecasting: Generation Scheduling

What is the variable cost reduction to a system operator using wind forecasts?

- Approximately $11 USD / MWh (savings through more efficient scheduling of generation).

| | No Wind Forecast | State-of-the-Art Wind Forecast | Perfect Wind Forecast |
|---|---|---|---|
| Total Cost Reduction | $335 M | $430 M | $456 M |
| Net Benefit | | $95 M | $121 M |
| Wind Generation | | 8,900 GWh | 8,900 GWh |
| Value of Forecast | | $11/MWh | $14/MWh |

*GE-NYSERDA Study for NYISO, 10% Penetration, 2005*

## Forecasts may be centralized or distributed.

| Location | Centralized | Distributed |
|---|---|---|
| Germany | x | Some market trading |
| Denmark | x | |
| Spain | x | x |
| U.S. | x | x |
| Canada | x | x |
| UK | x | x |
| Greece | x | |

*Benefits of Centralization:*

- *Consistency in reporting and formatting*
- *Potentially reduced cost through economies of scale*

*Benefits of Distribution:*

- *Encourages competition amongst vendors – seeks the best forecast at the plant level*
- *Can be better customized for the individual plant owner's needs.*

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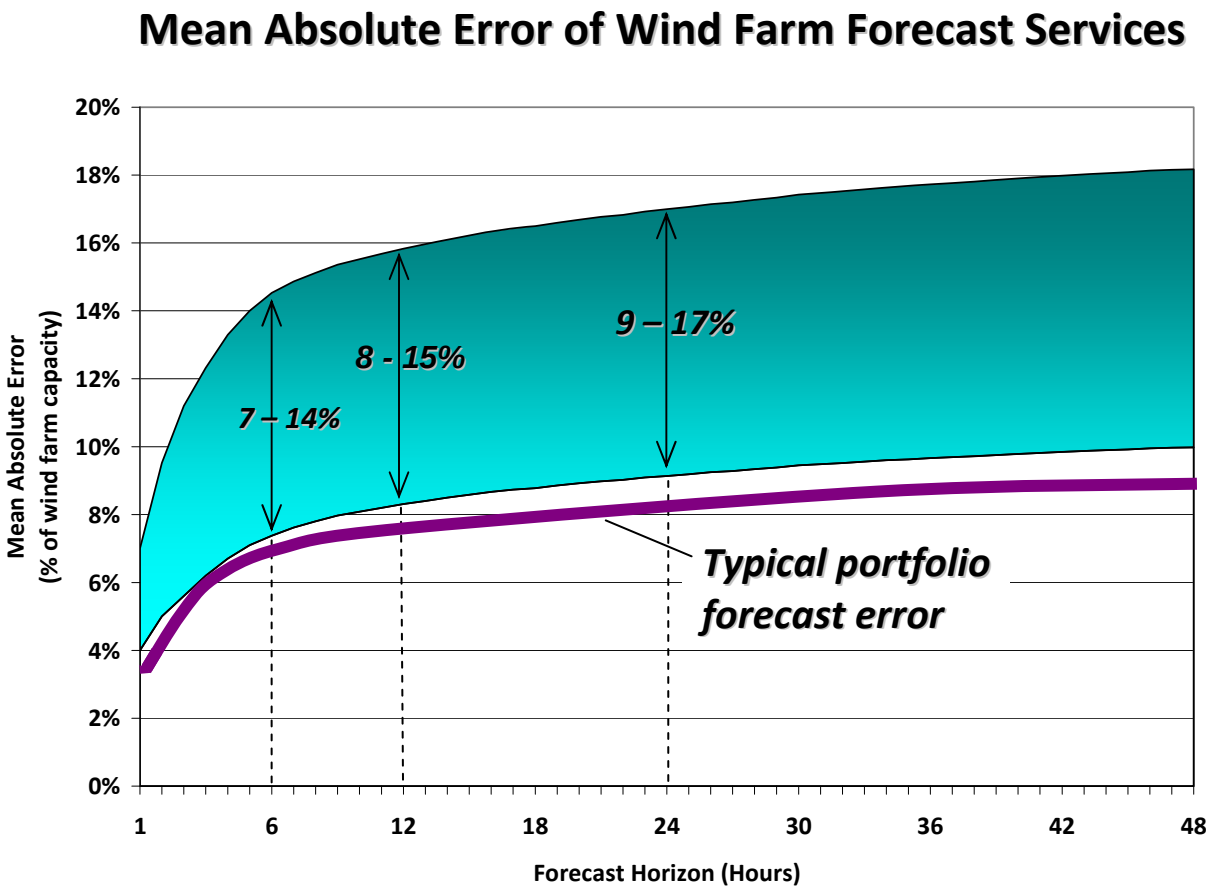
# What is a state-of-the-art wind power forecast?

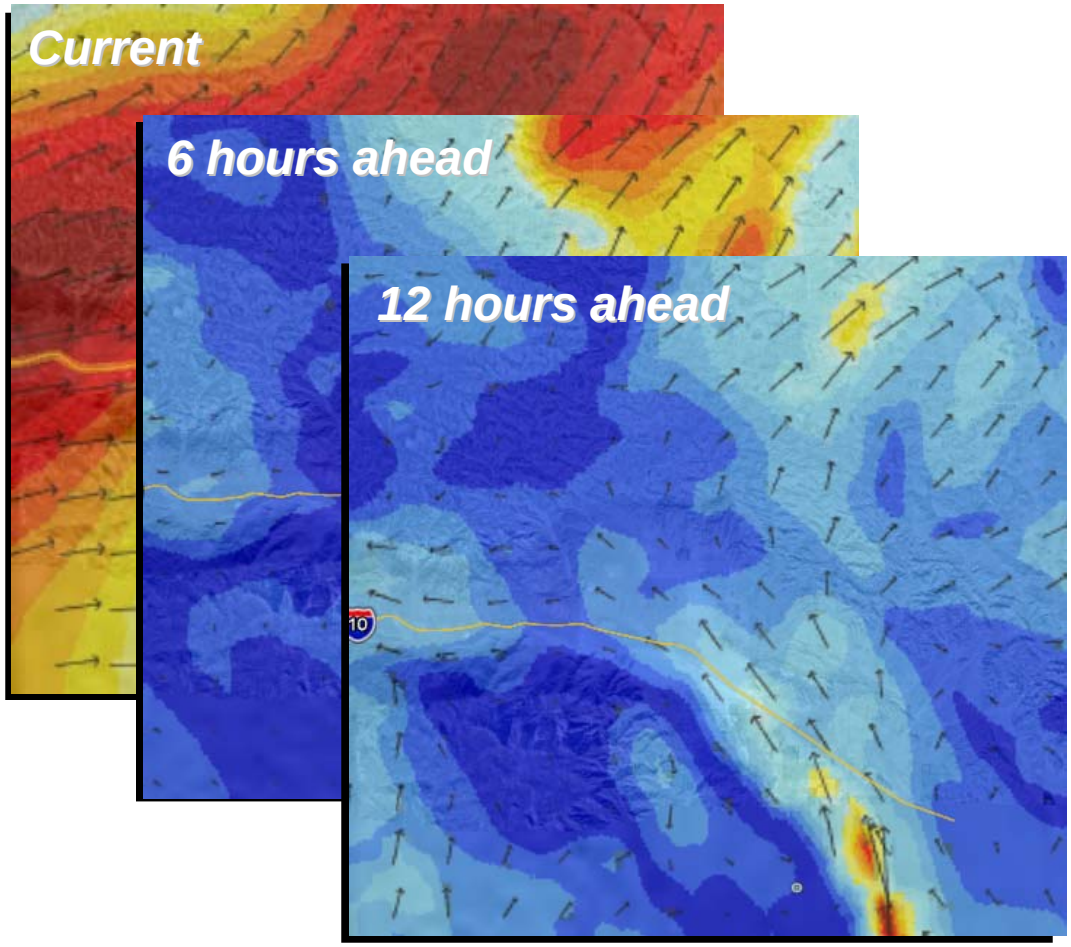



*All mean errors expressed as a percent of rated capacity.*

# Building a wind power forecast…

Numerical Weather Prediction

- Project the boundary layer meteorology: wind speed, direction, temperature, pressure, and humidity
- Coarse-scale model outputs from government centers drive high-resolution mesoscale model.

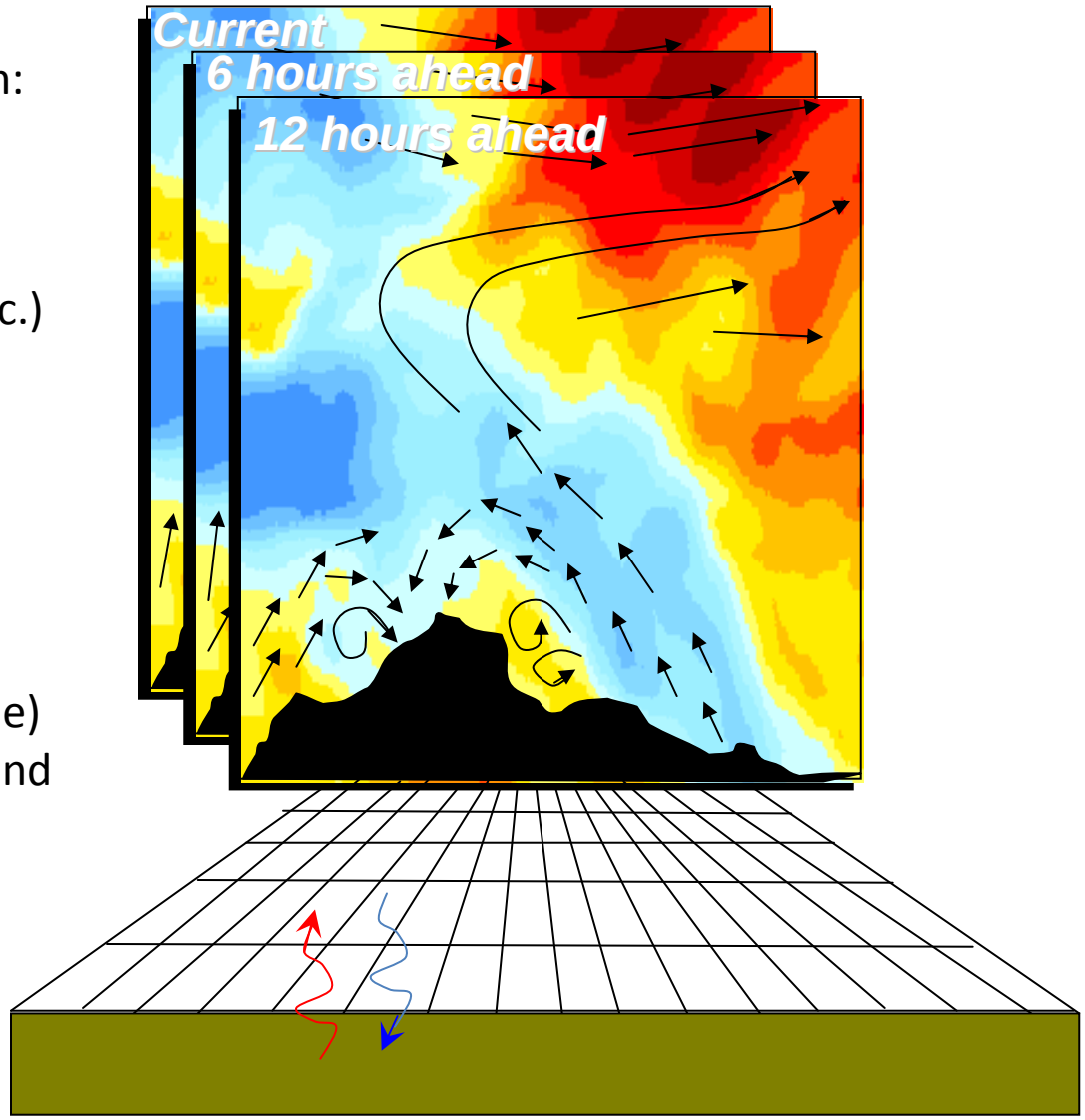


# Building a wind power forecast…

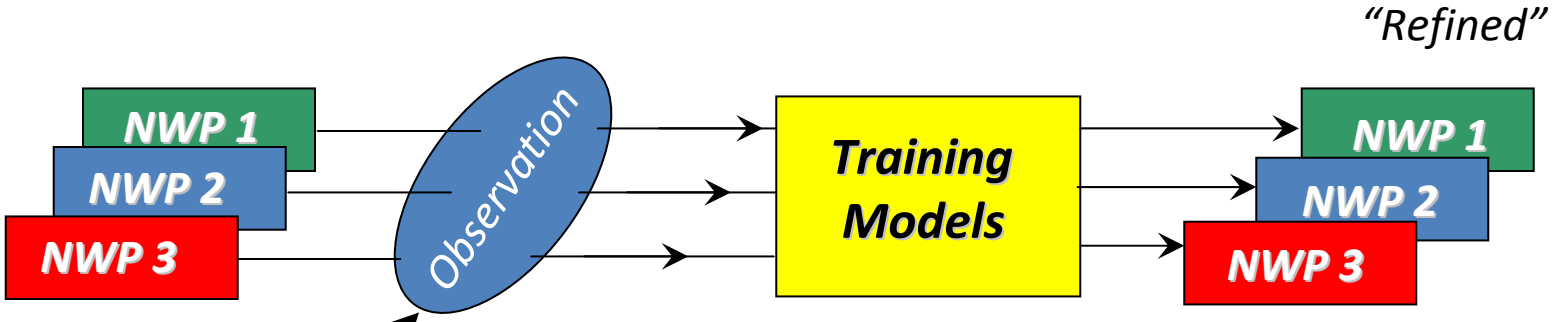
Forecaster's Optimization Problem:

- Realistically simulate:
  - turbulence (topographic, etc.)
  - thermally-driven effects
  - atmospheric stability
  - near surface exchanges
  - wind shear

- Determine:
  - resolution (in space and time)
  - representation of physical and dynamical processes
  - value of observational data



## Building a wind power forecast…




*Multiple solutions desired*

*Adequate feedback of observational data essential -*

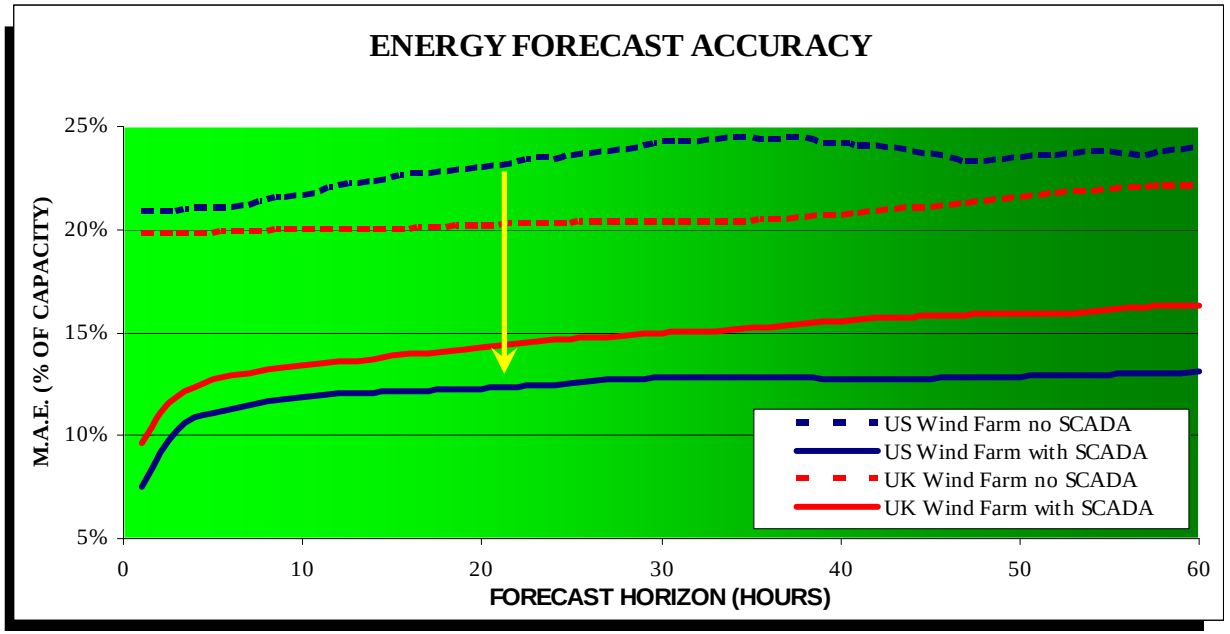
*Common "training" models used:*

- *AR(MA)*
- *neural net*
- *Support Vector Machines*

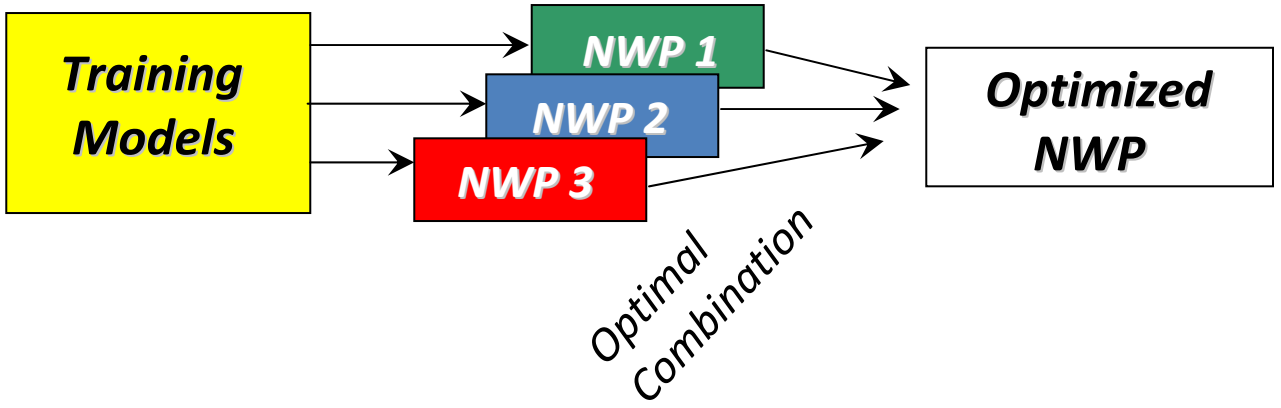
*Missing and/or erroneous data presents a challenge to the forecaster.*

# Building a wind power forecast…

*Effect of Reliable Feedback*

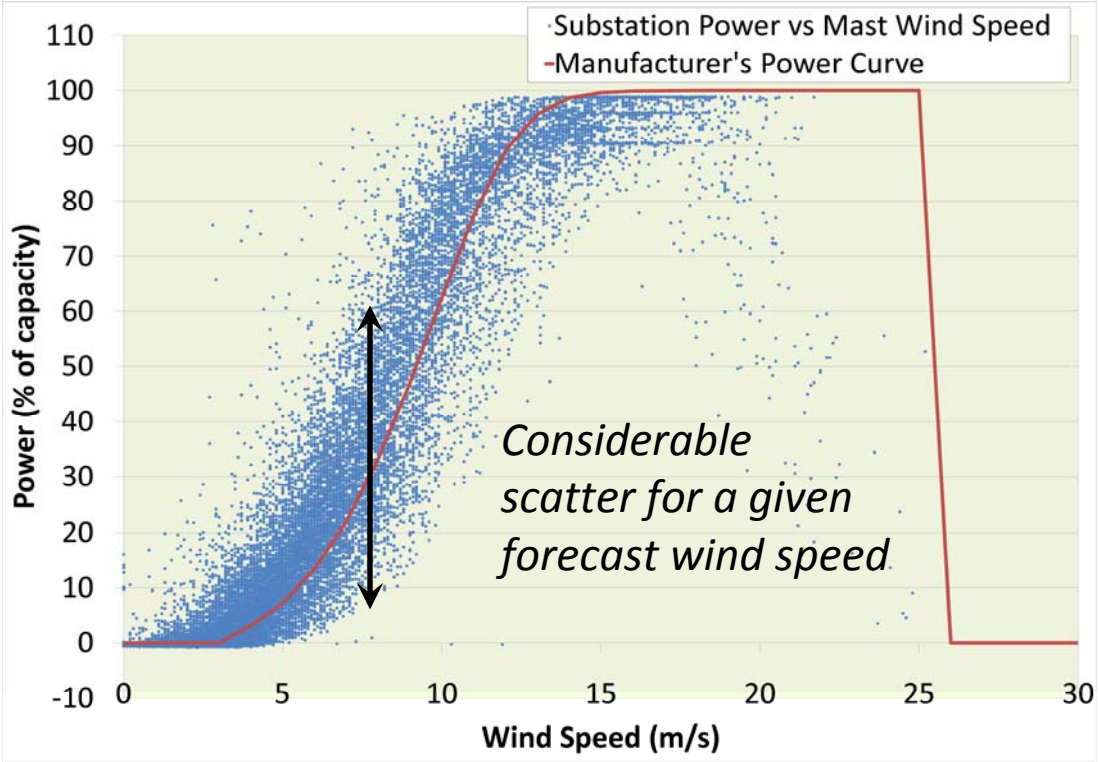



*Error statistics averaged over 1 year of simulation.*



# Building a wind power forecast…

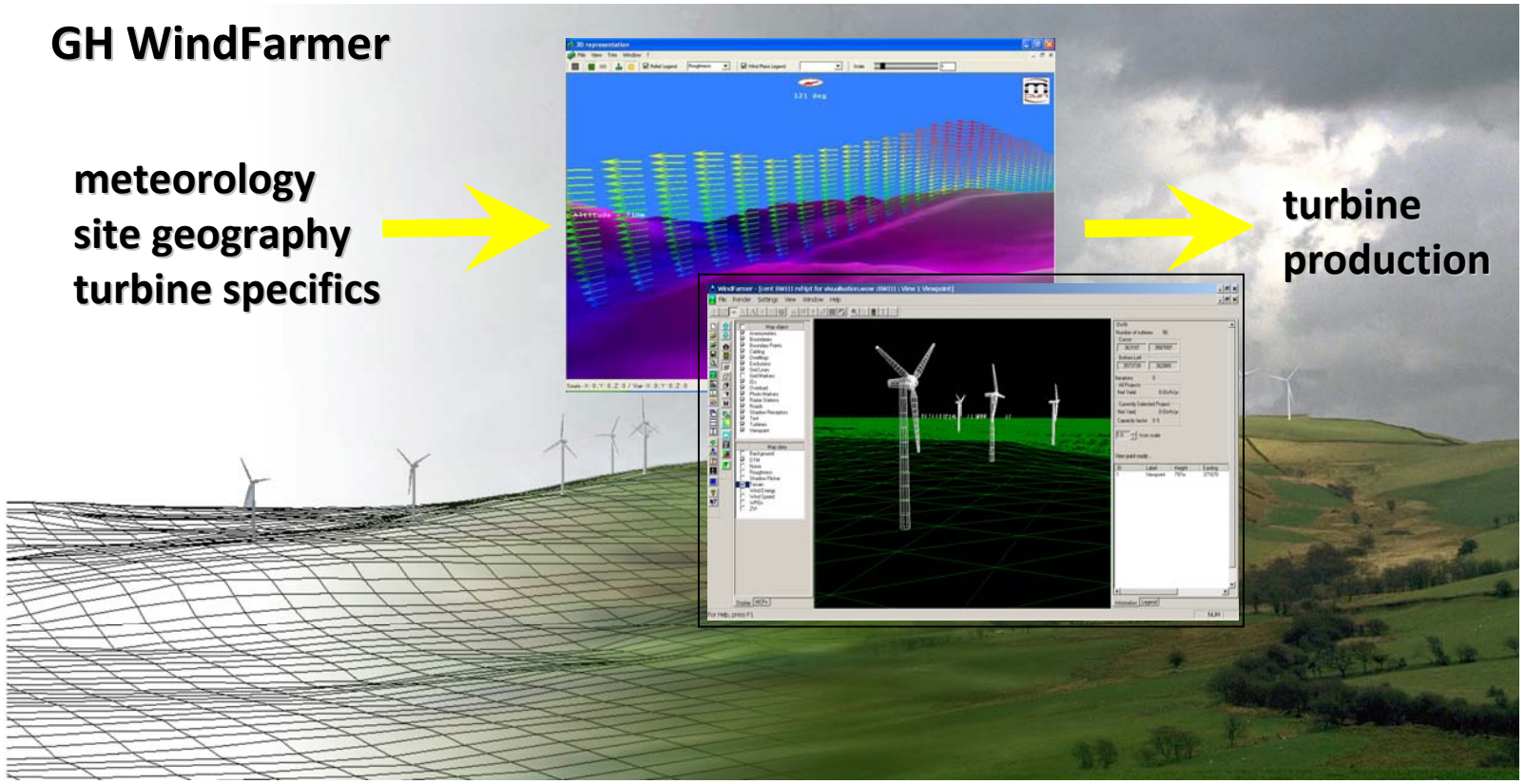
*It is possible to produce a wind power forecast with the optimal NWP and a scaled turbine manufacturer's power curve, but …*




*10-minute values over 6 months*

*one can produce a better forecast with a detailed wind farm power model.*

# Building a wind power forecast…




***industry standard tool for wind farm design, flow simulation, and optimization***

***digitally models each wind farm***

- **wake simulation**
- **flow channeling**
- **turbulence**

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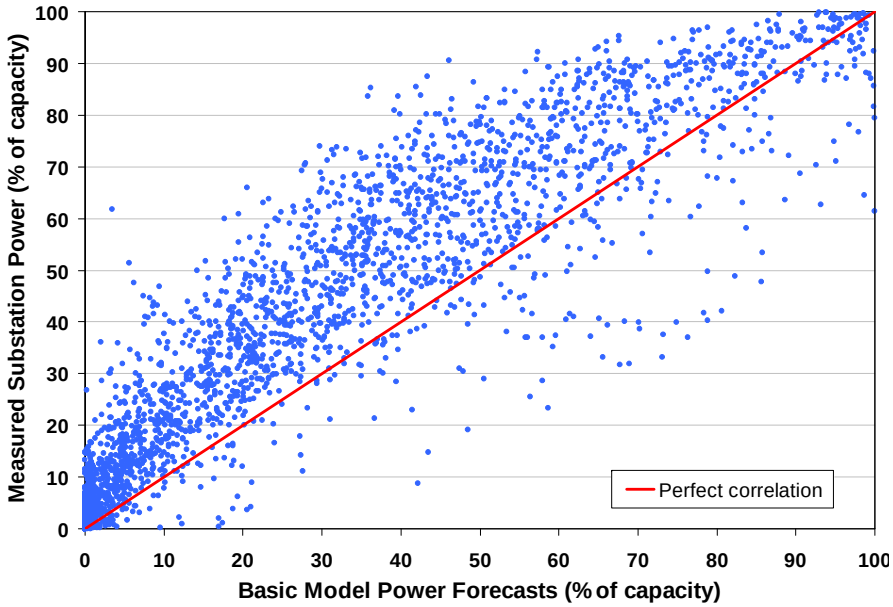
# Building a wind power forecast…

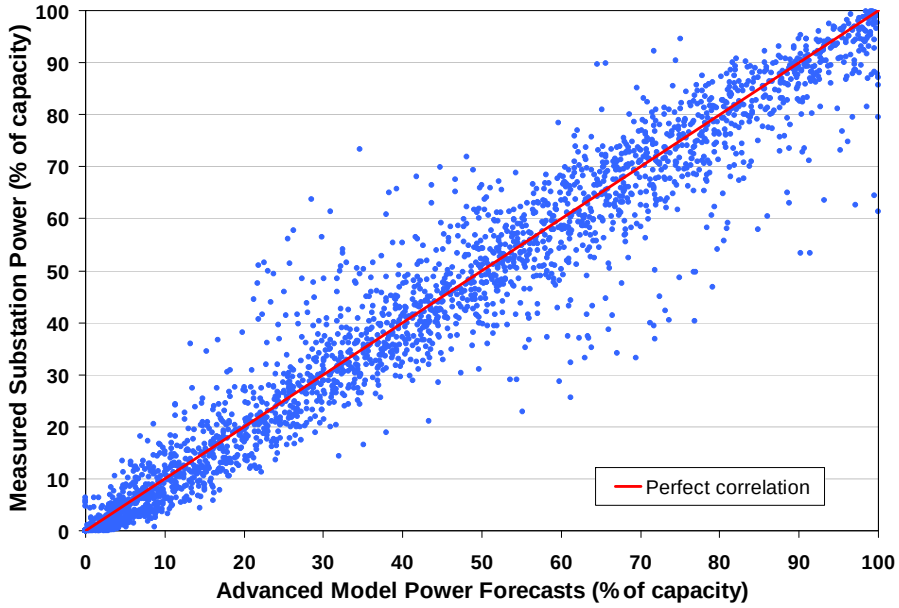
*Basic Model*




*MAE ~ 11.6% of Capacity*

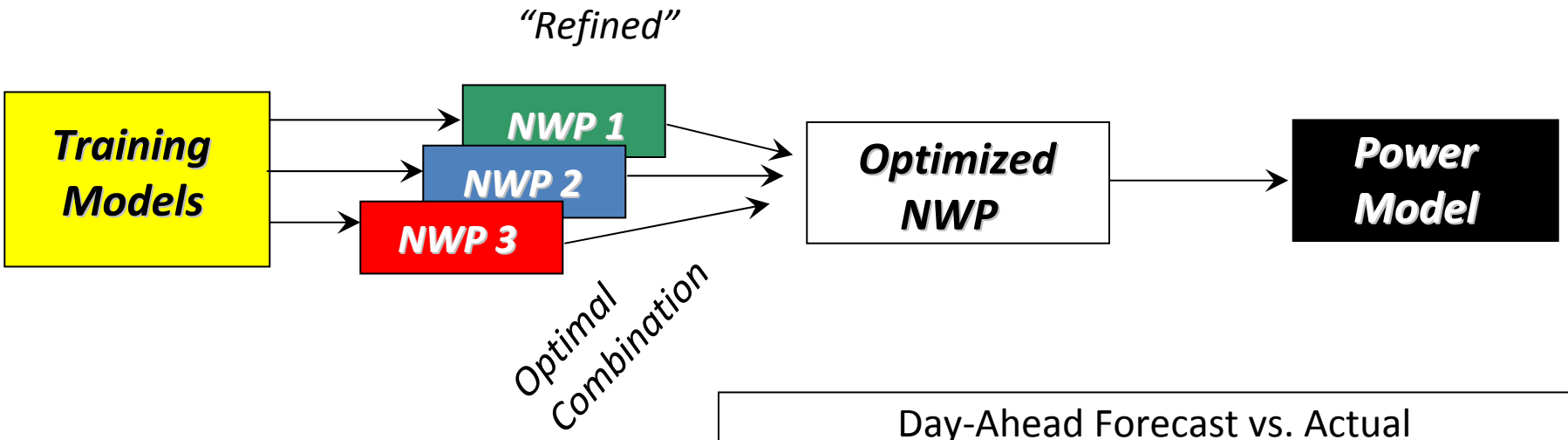
*MAE ~ 4.6% of Capacity*

***Advanced Model***

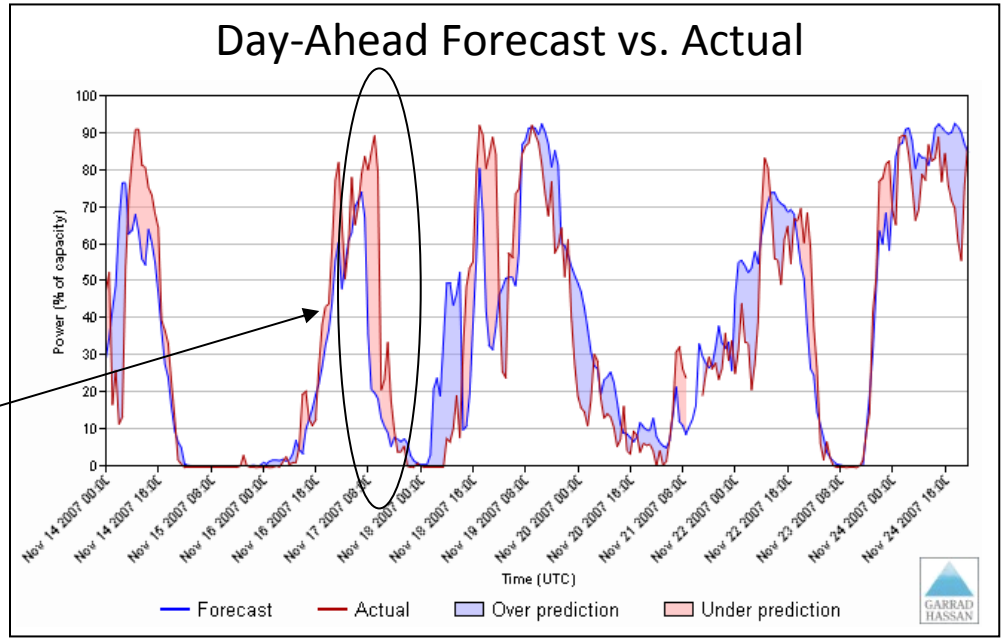



*4 Month sample shown*

## Building a wind power forecast…

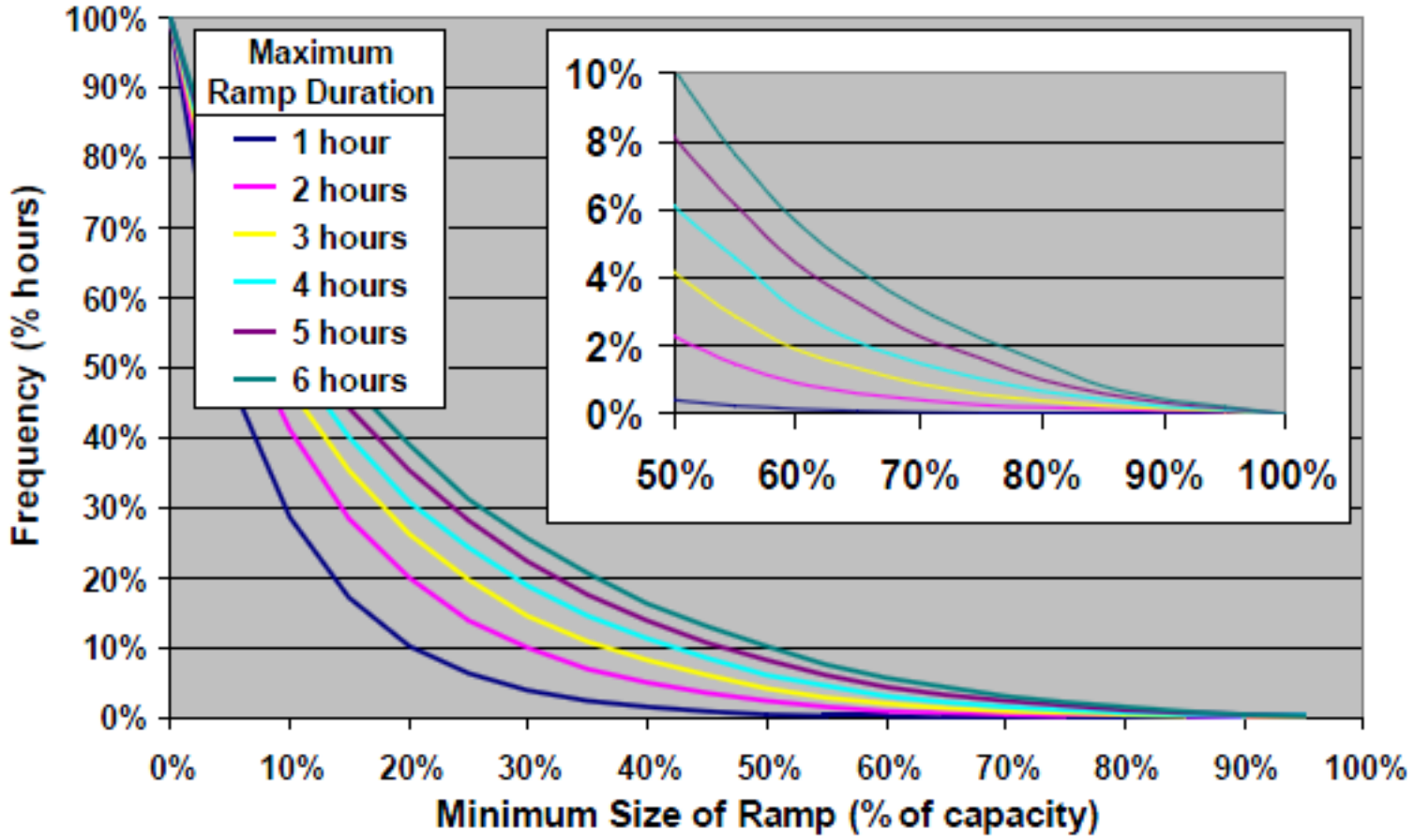



- *Training algorithms and combination generally act to reduce mean forecast error*
- *Optimization challenge is how to deal with large, rapid fluctuations*



# Building a wind power forecast…

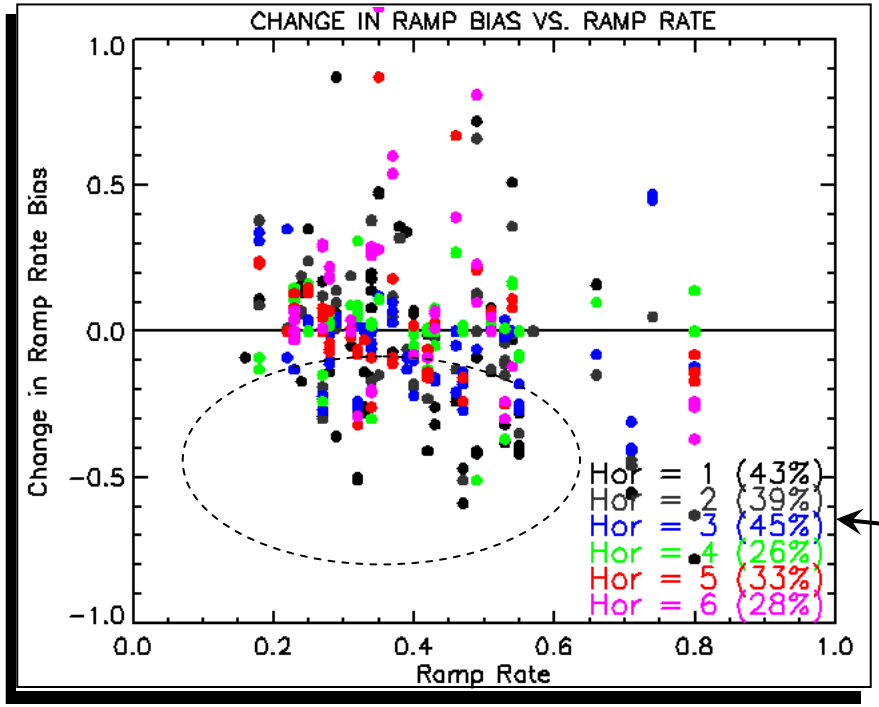
***Ramp event:*** *a change in power greater than or equal to* ***50%*** *capacity over a duration of no greater than* ***4*** *hours.*




*Distribution from multiple wind plant locations over 1 year.*

## Building a wind power forecast…

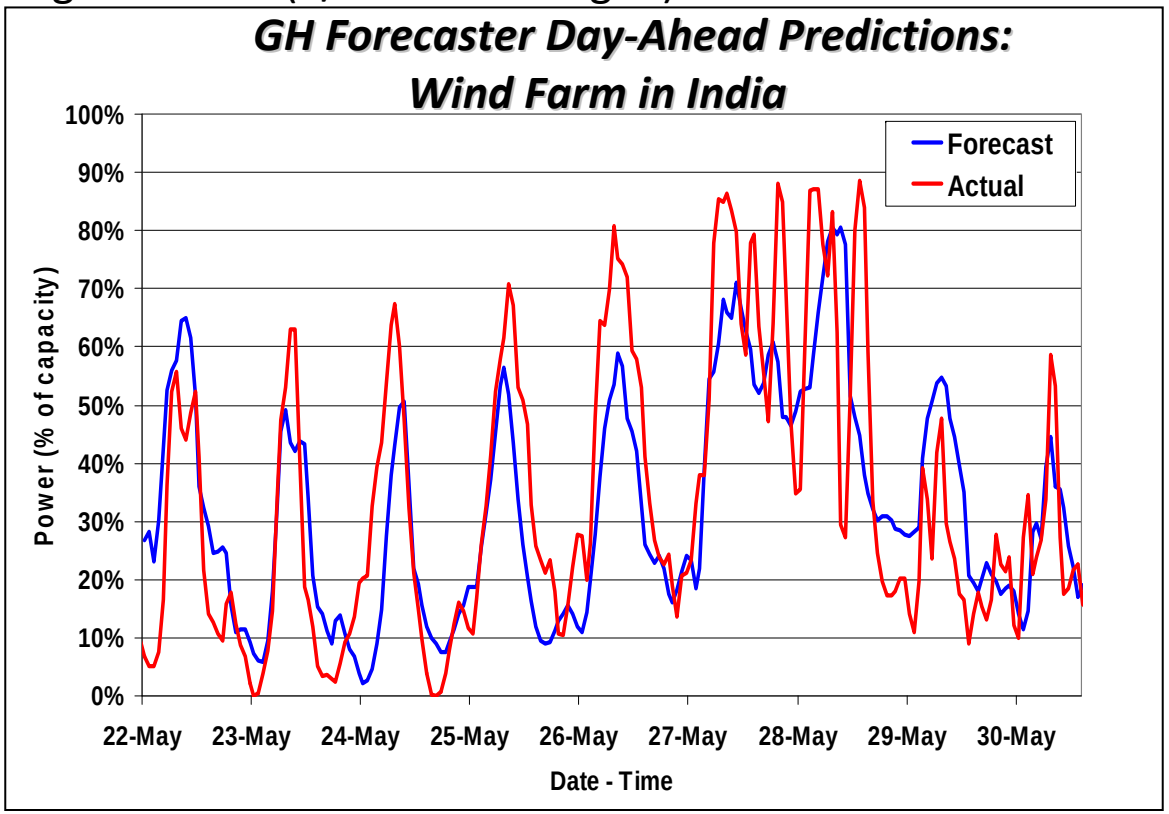
- *No standard metric for evaluating forecast ramp performance*
- *Ramps not forecast can result in curtailment (up) or scrambling to fill shortfall with costly reserves (down).*
- *Perhaps more detrimental: misforecasting the ramp direction*




- *Pacific Northwest study showed that use of upwind measurement tower can reduce forecast error of upramps at short horizons*
- *Over 1 year period, as many as 40% of forecasted ramps showed reduced error in ramp rate, magnitude when upwind data is used intelligently.*

# Meeting the needs of the Asian-Pacific Wind Sector

- Penetration of wind in countries like India starting to impact grid operations significantly.
- New sites in India require forecasts with penalties levied on production outside a margin of error (+/- 30% actual gen).
- Complex meteorology, highly seasonal weather regime, monsoonal inter-actions with complicated topo-graphy (Tibetan P., Himalayas) present challenges for wind forecasting.



## Summary

- Wind Forecasting proves its value for efficient system operations that promote successful wind integration.
- State-of-the-art forecasts rely on high quality observational data, knowledge of how best to tune weather and power models for a local wind regime.
- An advanced power model is generally preferred over a power curve – reduces mean error.
- Ramps are particular challenges – no well-defined way to optimize for predicting; Upwind observations show some benefits. No standard way to evaluate ramp forecasts. Advances being made for probabilistic ramp prediction.
- Increased wind penetration in emerging markets (e.g., India, China) now significantly impacting grid operations – grid codes reflect this and incentivize high quality wind forecasts.