Financing Community Wind

Wind Data and Due Diligence

What is the Project's Capacity Factor?

Community Wind Energy 2006
March 8, 2006

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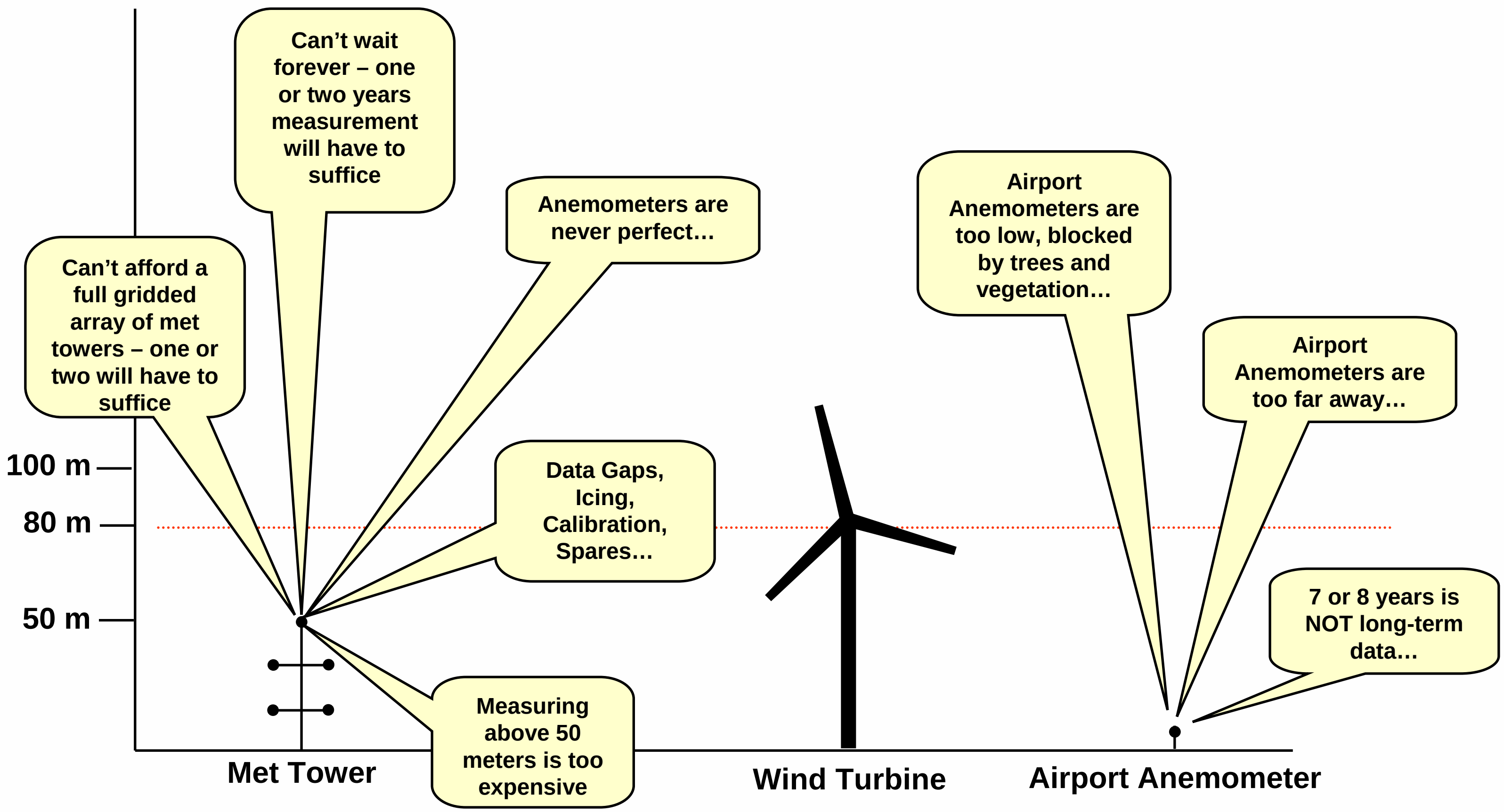
The Need for Wind Assessment

- Location & terrain make big difference
- Power in the wind is proportional to the cube of wind speed, so great value in optimizing location, layout & height
- Many characteristics to consider
  - Shear (speed increase with height)
  - Diurnal & seasonal patterns
  - Long-term interannual variability
- Major planning and financing issue
  - A large investment with a 25-year timeline
  - Variability on many time scales
  - Implications for operations

Predicting Long-term Project Energy



Challenges of distance, height, time & space

Integrated Wind Understanding

Taking advantage of all the available data:

1) Use best available "gridded" archives of real weather data from government agencies
   - *Actual recorded weather data, used to initialize weather forecast models*

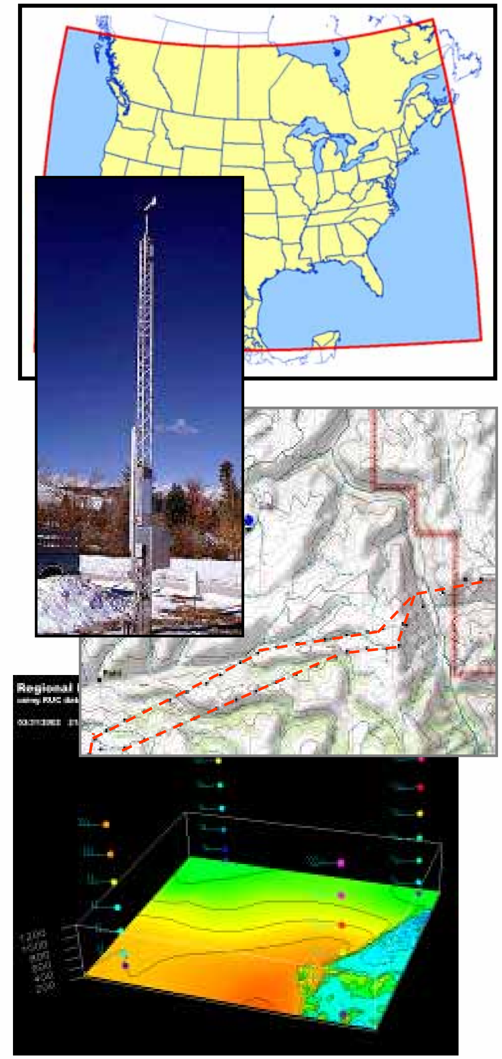
2) Integration of tower data and other on-site measurement points

3) Add the best available high-resolution topography and land cover information

4) Properly apply meteorological models and wind field models integrating data over space and time

5) Analyze long-term variation and the financial impact on your specific situation

6) Use wind forecasting to minimize cost and operating impacts & maximize revenues



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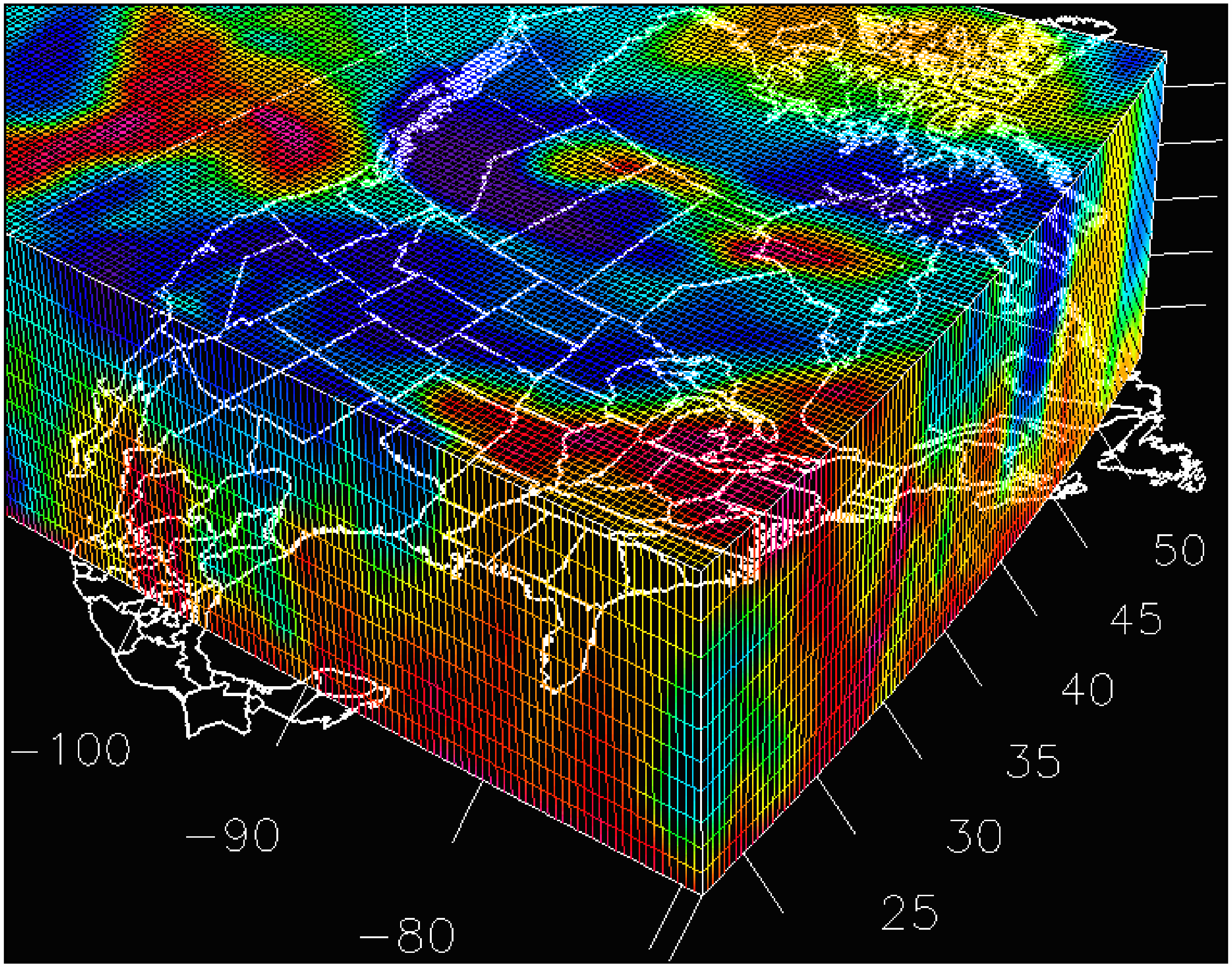
Gridded 3D Weather Data

Integrates all available data sources, from the surface to the upper atmosphere, into a unified and physically consistent state of all grid cells at a given point in time

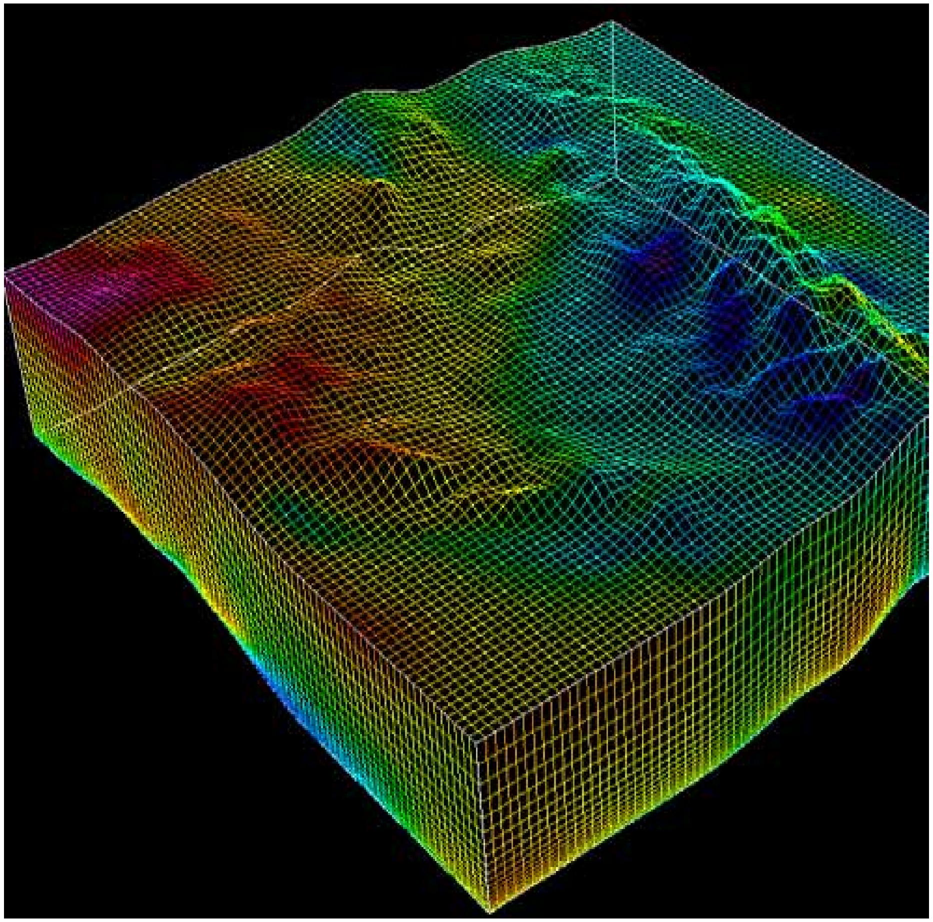
Over 160 weather variables collected from:

- Surface / METAR station data
- Oceanographic buoys
- Ship reports
- Aircraft (over 14,000 ACARS/day)
- NOAA 405 MHz profilers
- Boundary-layer (915 MHz) profilers
- Rawinsondes (balloon soundings)
- Reconnaissance dropwinsonde
- RASS virtual temperatures
- SSM/I precipitable water
- GPS total precipitable water
- GOES precipitable water
- GOES cloud-top pressure
- GOES high-density vis. cloud drift winds
- GOES IR cloud drift winds
- GOES cloud drift winds
- VAD winds from WSR-88D NEXRAD radars



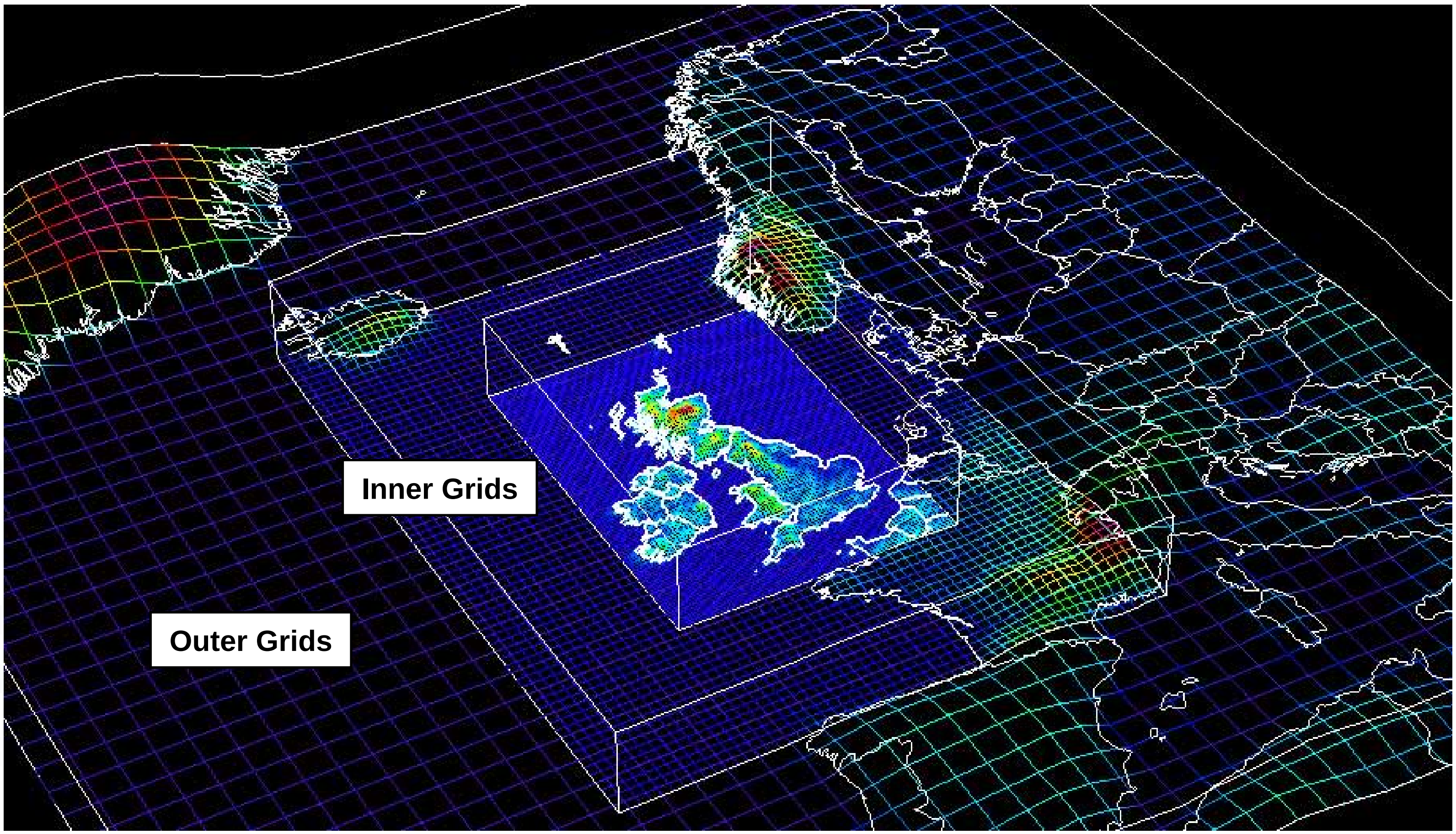
Meteorological Models

- Numerical gridded representation of the laws of physics
  - Conservation relations
    - Mass
    - Energy
    - Momentum
    - Water, etc.
  - Physical processes
    - Radiation
    - Turbulence
    - Soil/ocean interactions, etc.
  - Use lots of fast computers
    - Partial differential equations
    - Gridpoint difference values
    - Step all points through time using very small steps (a few seconds per step)

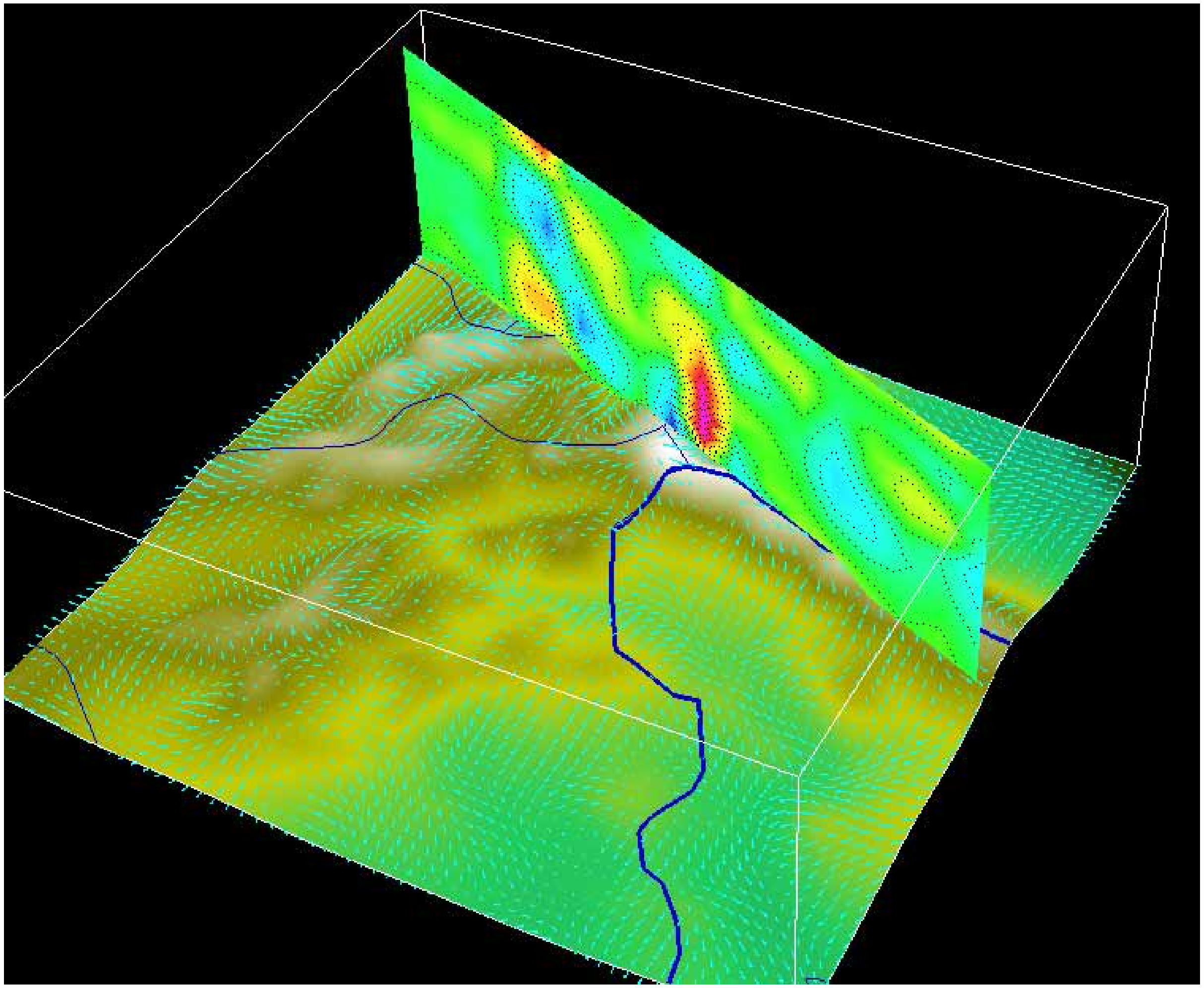


Nesting Modeling Techniques

Modeling "fills the gaps" in both space & time



Understanding of the Entire 3D Space



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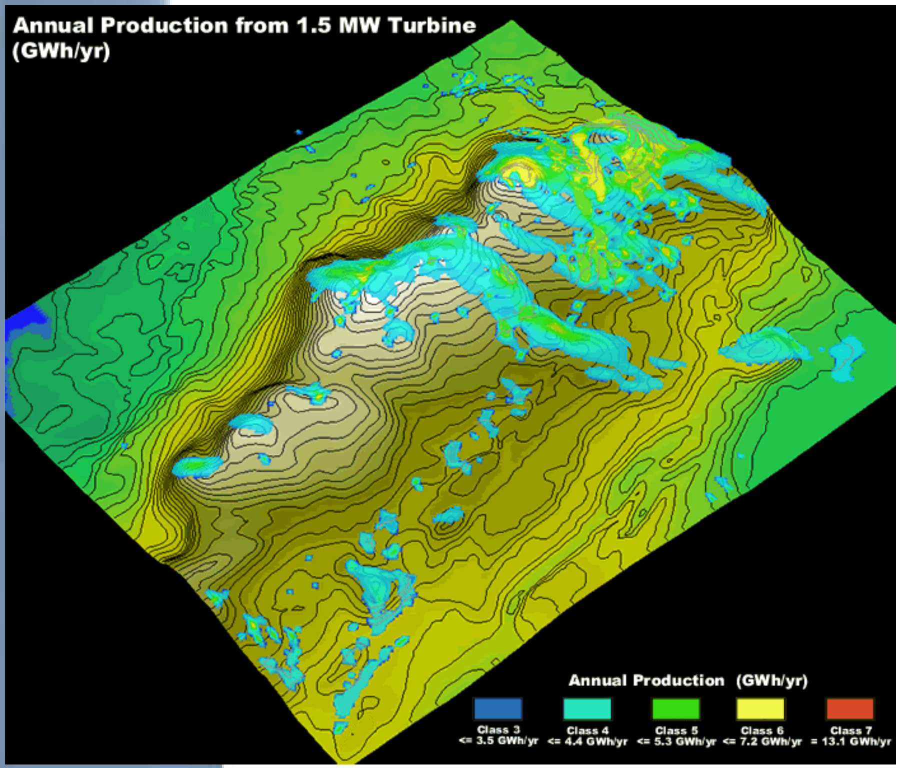
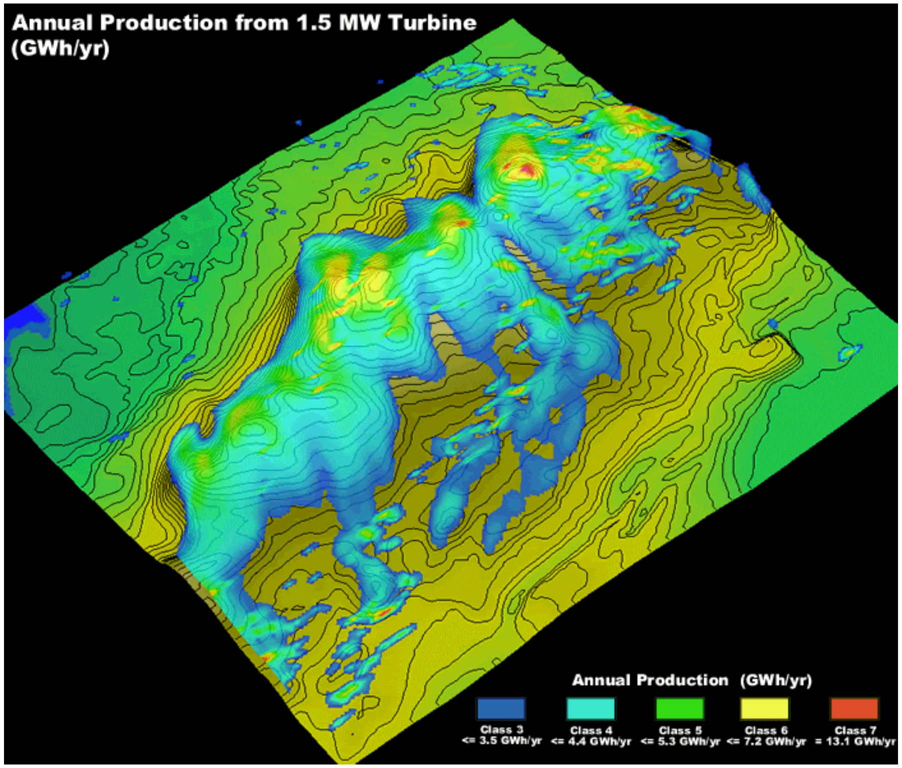
Gross Annual Production

Production calculation in GWh per year - multiple heights & various turbines
Using hour-by-hour wind/density/shear values & all data sources

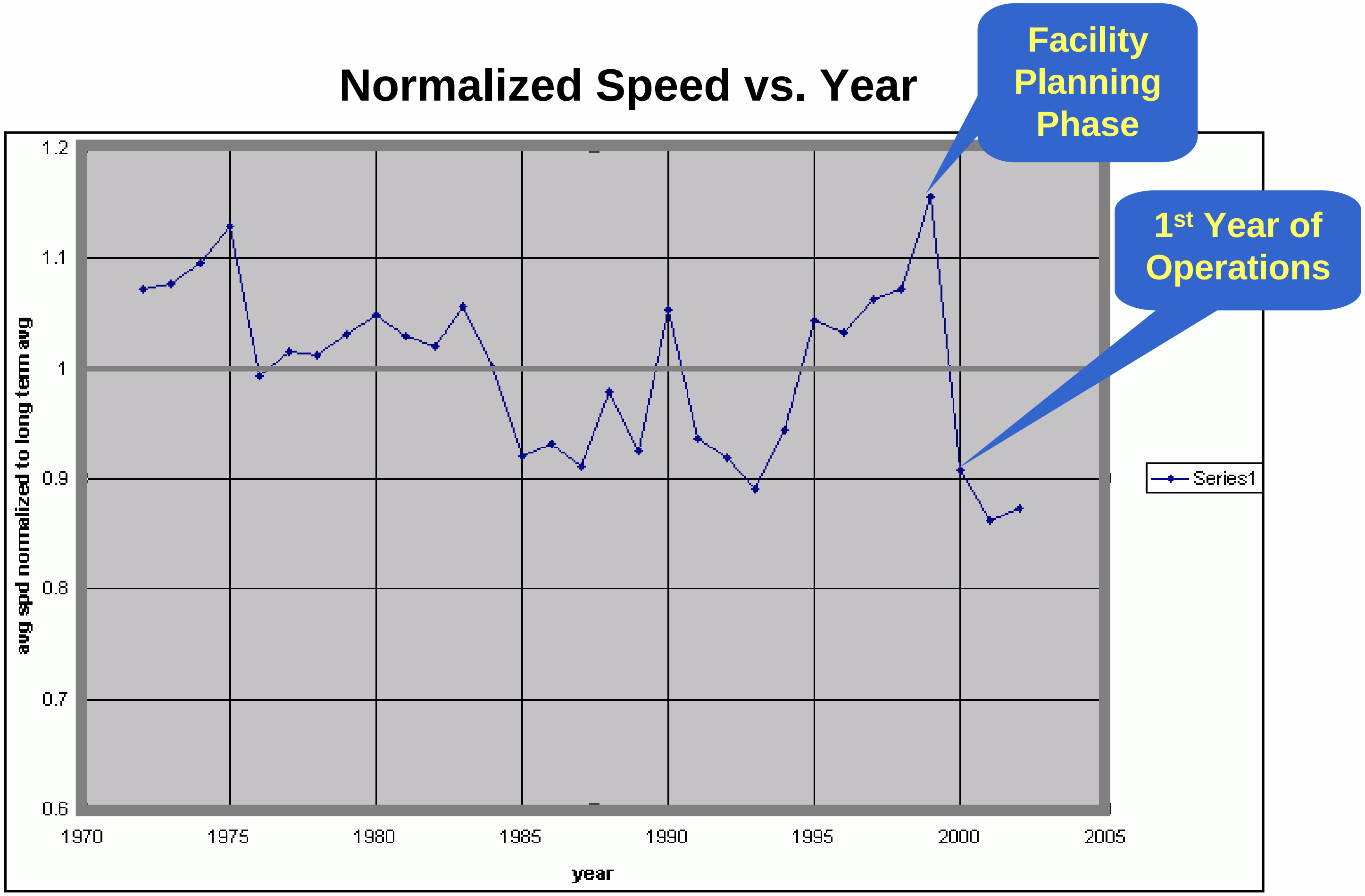


50m Height



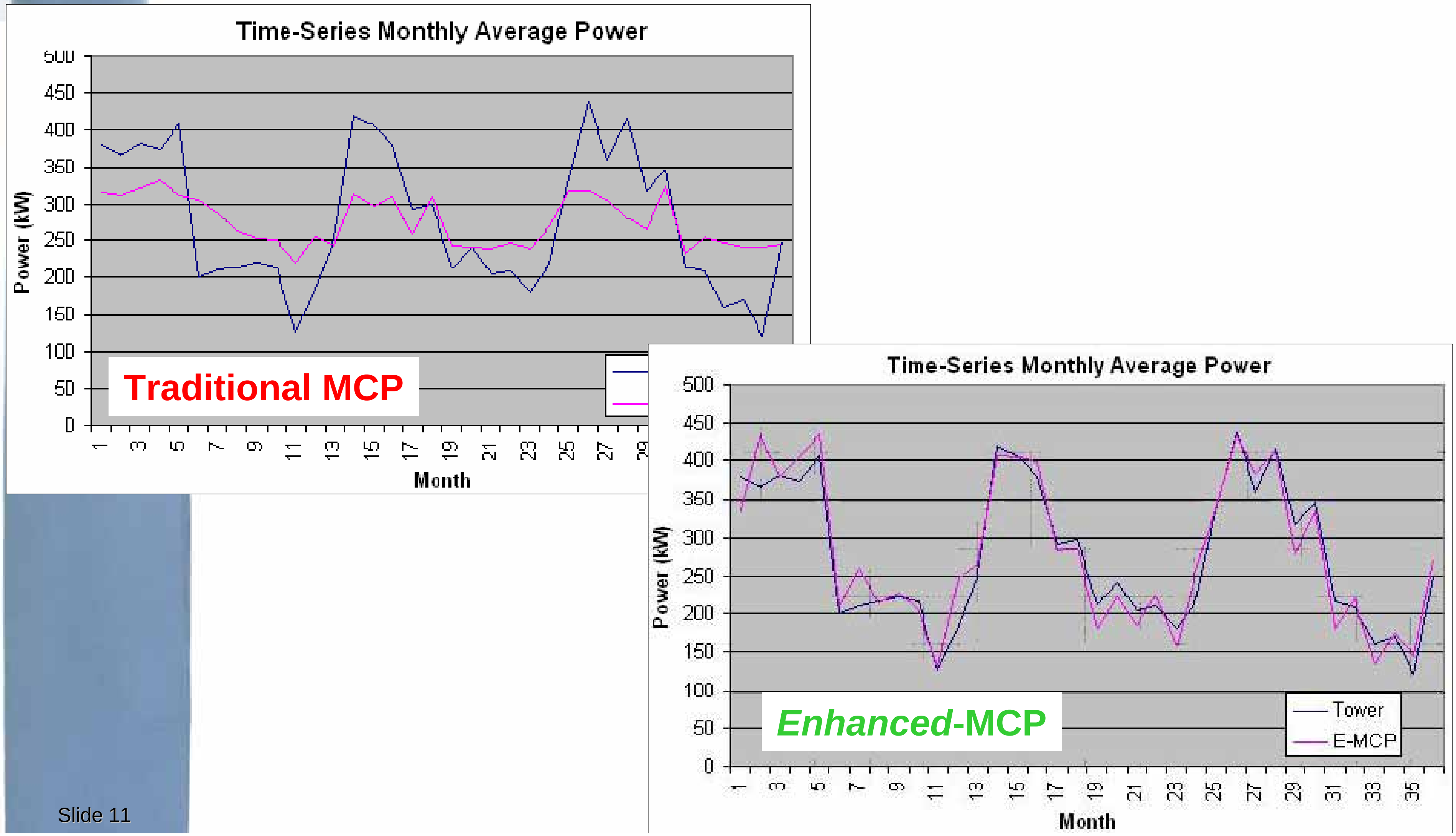
80m Height

Long-term Variability

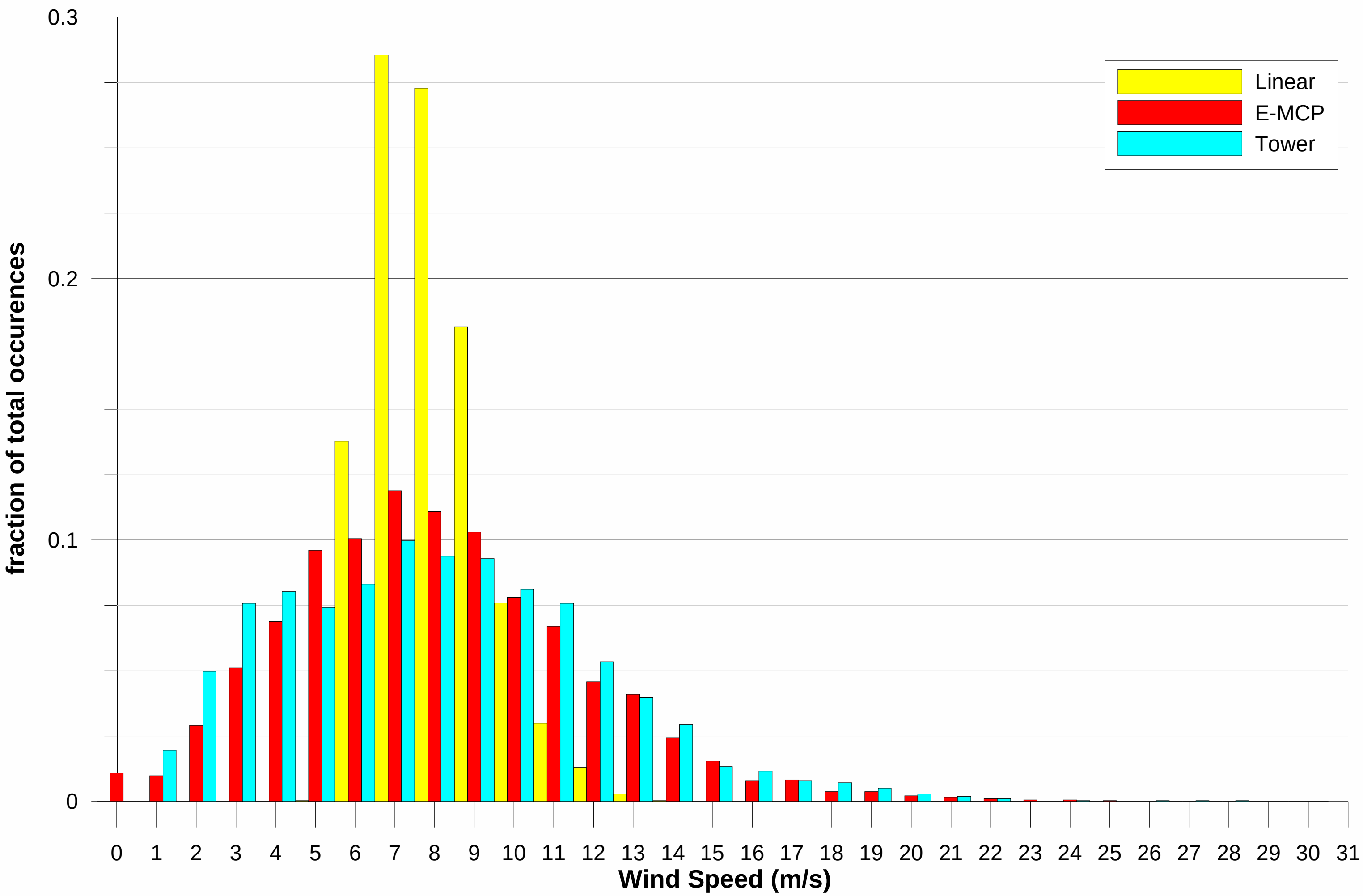


We must extend our understanding to 30 years or more

Examples of MCP Research – Time Series

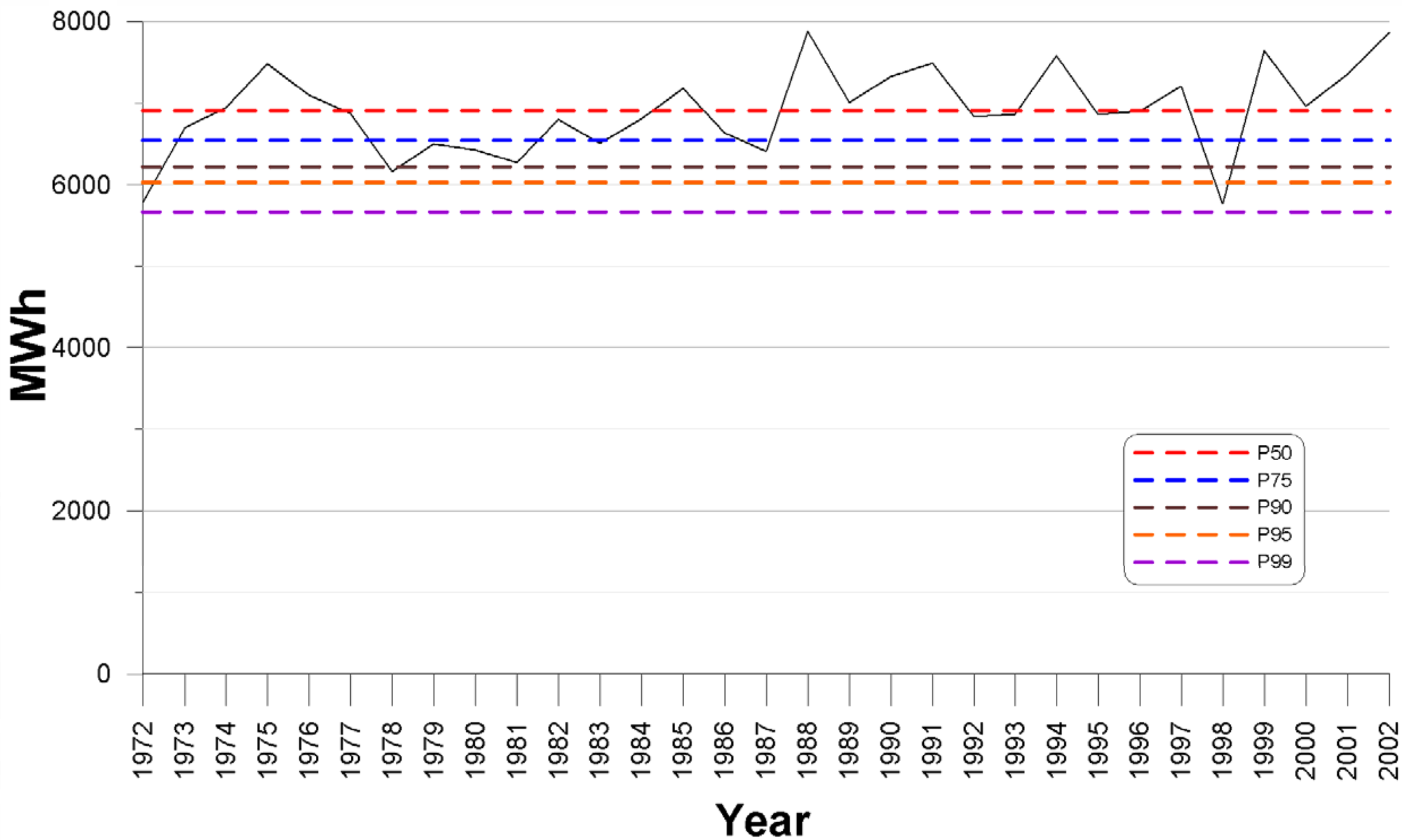


Examples of MCP Research – Distribution



Annual Historical Energy

(Wind Data 1972–2002)



Goal – Accurate Predictive Intervals

Speed	Gross Capacity Factor (Vestas V80 1.8 Class 1A)
7.78 m/s	41.47 %

Table 1. Forty-year mean quantities at 67 m AGL

Speed Standard Deviation (% of period mean)	Gross CF Standard Deviation (Vestas V80 1.8 Class 1A) (% of period mean)
3.95%	7.26%

Table 2. Forty-year standard deviations of annual-average quantities at 67 m AGL

Speed				Gross Capacity Factor (Vestas V80 1.8 Class 1A)			
P75	**P90**	**P95**	**P99**	**P75**	**P90**	**P95**	**P99**
7.57	7.37	7.26	7.02	39.40	37.50	36.34	34.08

Table 3. Predictive intervals for speed and gross capacity factor at 67 m AGL

Gross Energy to Net Energy

1) **Start with a gross energy value (P50, P90, etc.)**
   - **Predictive intervals (P90, etc.) are statistically derived directly from the long-term variability of the project site at hub height**
   - **Predictive intervals are NOT confidence intervals**
   - **A long-term time series of energy data at hub height, generated with best available data & practices, is a very powerful tool… consider combinations of projects, etc.**

2) **Subtract other net losses for a net energy value**

3) **What about uncertainty & confidence intervals?**

Net Project Losses

- Other project losses, usually linear in nature and related to the project design and turbines:
  - Wake and array losses……….3-7% typical, less for single row or small project
  - Turbine availability…………….3% typical, negotiable in turbine agreement
  - Turbine power curve…………..2% typical, negotiable in turbine agreement
  - Electrical losses………………..2-3% typical, based on design & current levels
  - Parasitic/icing losses………….1-2% typical, site & turbine/technology dependent

- Other items that apply to some projects:
  - Wind sector management…………………if needed on project, perhaps 1%
  - Substation maintenance/downtime……..on remote feeders, perhaps ½%
  - High wind hysteresis………………………for high wind sites, frequent cutouts

- Bottom line:
  - Total net losses of 9% – 15%
  - Turbine layout has the biggest impact on this value, and accuracy of wake/array losses depends on accuracy of long-term wind data

Uncertainty & Confidence Intervals

- **"Uncertainty" is not a statistical term, and real samples for calculating the distributions are usually lacking, but there are other "uncertainties" that may impact financial risk**
  - **Example where we have some samples: anemometer uncertainty**
    - **New, calibrated #40 anemometers have relative uncertainty in wind speed of ~1.6%**
    - **Concerns about time (e.g., bearing wear), installation (booms, vane alignment), data quality (missing data), calibrated vs uncalibrated anemometers, etc.**
    - **Errors are magnified if used for shear to hub height & power calculations**
  - **Examples where site-specific data is limited:**
    - **Depending on approach, could also adjust for "uncertainty" in the methods, data or model for power curve, wake losses, hub height values, long-term normalization, etc.**
    - **It is very difficult to calculate actual values, so rules of thumb are traditionally used**
- **Investing in best practices will allow the bankers to use modest uncertainty assumptions and to give you financing at better values**

Financial Risk is the Bottom Line

- **Improved understanding of wind resource and variability has great value**
- **Need integrating approaches that unify all data and reduce the risk inherent in single-point data sources**
  - Meteorological Towers
  - Modeling
  - Statistics
- **The goals:**
  - Accurate results based on scientific and statistical methods
  - Consistent ways to view risk and compare projects
  - Take wind plants into the mainstream of power generation projects in terms of process, financing, operations and utility perception

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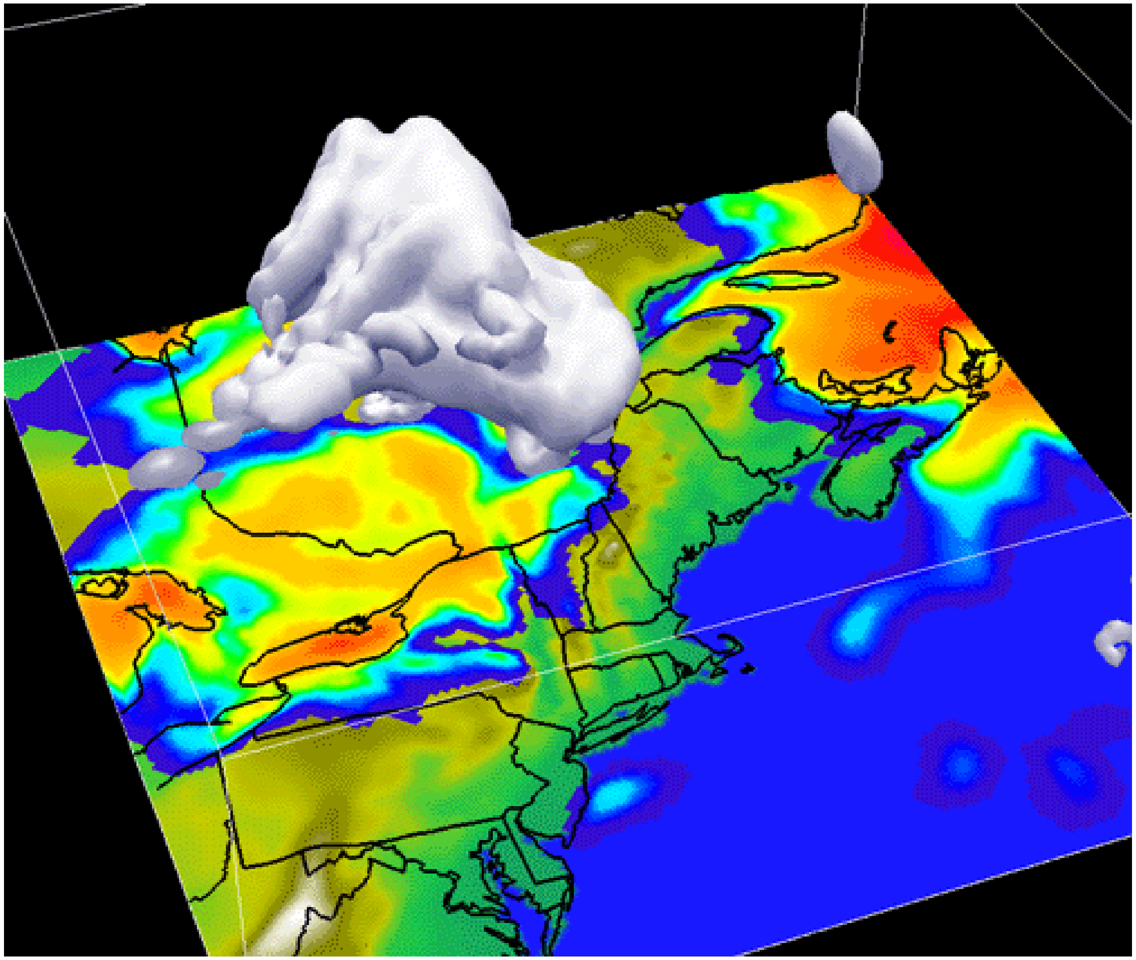
Time series showing forecast with wind speed and cloud cover



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