# Resource Assessment Overview and MIT Full Breeze Case Study

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Wind Energy Projects in Action

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# Resource Assessment

- Characterize the wind resource at a particular location
- Multi-faceted problem:
  - Speed, direction, shear, veer
  - Temperature
  - Uncertainty: data, model
- Talk focus: wind speed and direction

# Assessment Techniques

- Statistical
  - Measure-Correlate-Predict (MCP)
    - Estimates statistical parameters of wind speed
    - Regression: Linear or more advanced
  - Neural networks
    - Function approximation via learning
  - Kernel density estimation
    - Can treat uncertainty explicitly by generating distributions versus point estimates

# Assessment Techniques

- Physical
  - Computational Fluid Dynamics
  - Model topography and local terrain
  - Combine historical weather patterns with computational model
- Physical and Statistical hybrids
- Ensemble models

# MCP Overview

- Measure: Data at target site
- Retrieve: Long-term data from a reference site (e.g. nearby weather station) with high correlation
- Correlate: Target data with reference data during overlapping time frame
- Predict: Long-term behavior of target site based on long-term behavior of reference

# A Simple Correlation Approach

- Binned linear regression:
  - Estimate parameters $a$ and $b$ such that model equation $\hat{y}(x) = ax + b$ minimizes squared error $|\hat{y} - y|^2$ over training data
  - Binned linear regression creates a separate model for each of a number of wind direction bins
  - Determine approximate linear relationship for each wind direction bin independently

# Measure Correlate Predict

- Alternate methods (Rogers, Manwell, et al, 2005):
  - Monomial regression:

$$y = ax^b$$

$$\Rightarrow \log y = \log a + b \log x$$

  - Two dimensional regression:
    - Given wind vector **x** = (x1, x2) at reference site, determine wind vector **y** = (y1, y2) at target site using matrix-vector equation: **y** = **Ax** + **b**

# Measure Correlate Predict

- Existing methods (cont'd)
  - Variance Ratio method:

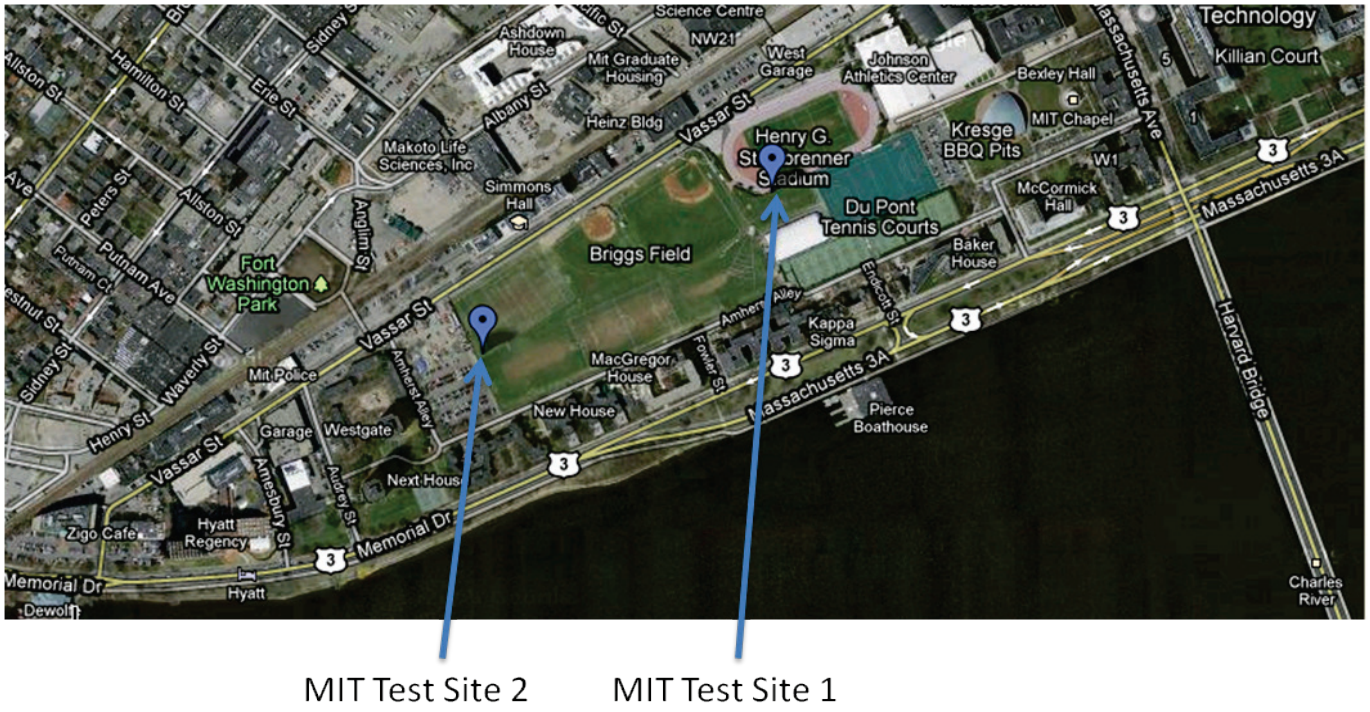
$$y = \mu_y + \frac{\sigma_y}{\sigma_x}\left(x - \mu_x\right)$$

  - Neural Networks
  - Kernel Density Estimation:
    - Learn joint density estimate from data
    - Explicit treatment of model uncertainty
    - Can be used for forecasting

# Full Breeze Project Overview

- Student-run project to assess the installation of a small wind turbine on campus
- Two potential sites near Briggs athletic field chosen for assessment
- Comparative analysis of wind resource, community and environmental impact, and finance

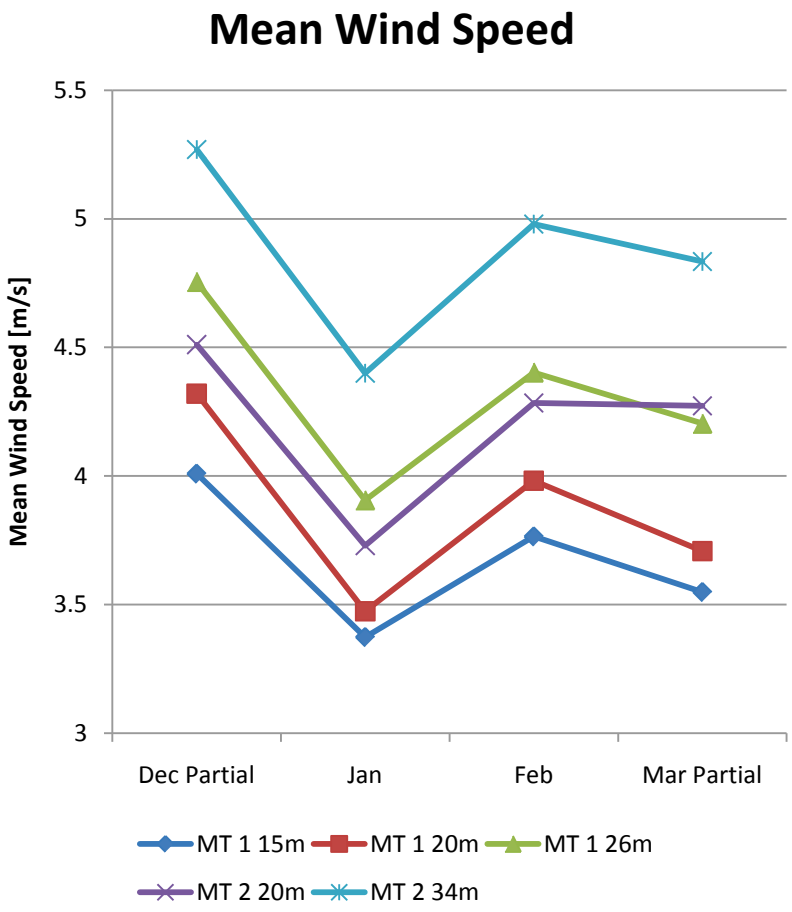
# Full Breeze Test Sites

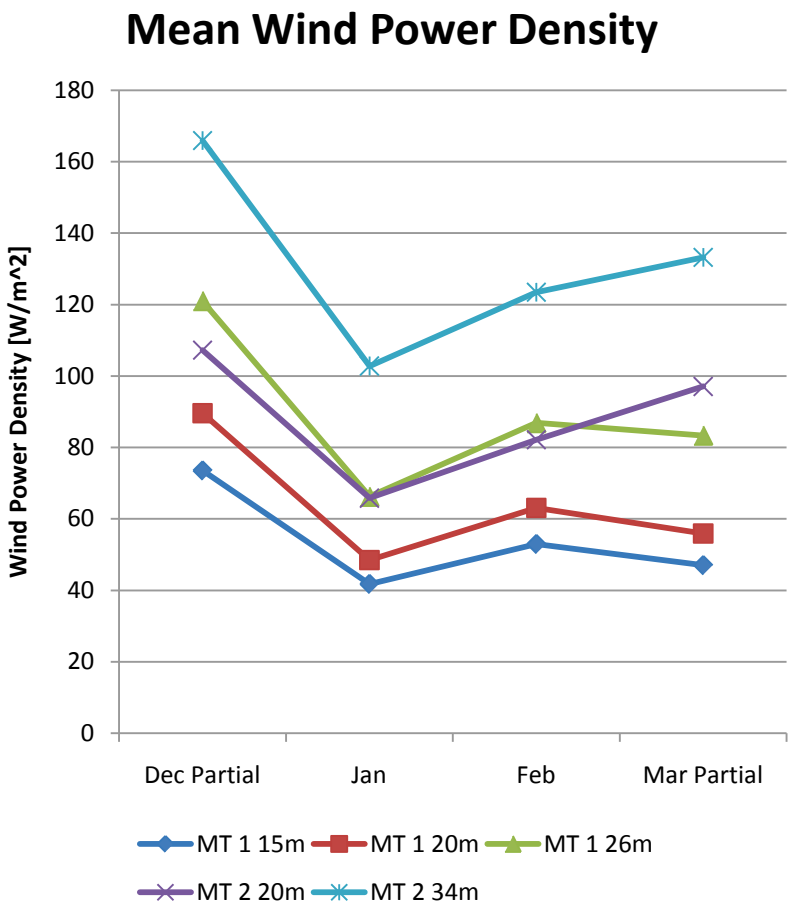



MIT Test Site 2 MIT Test Site 1

- Collected temperature, wind speed, and wind direction at various heights (15 to 34m)

# Comparison of Test Sites



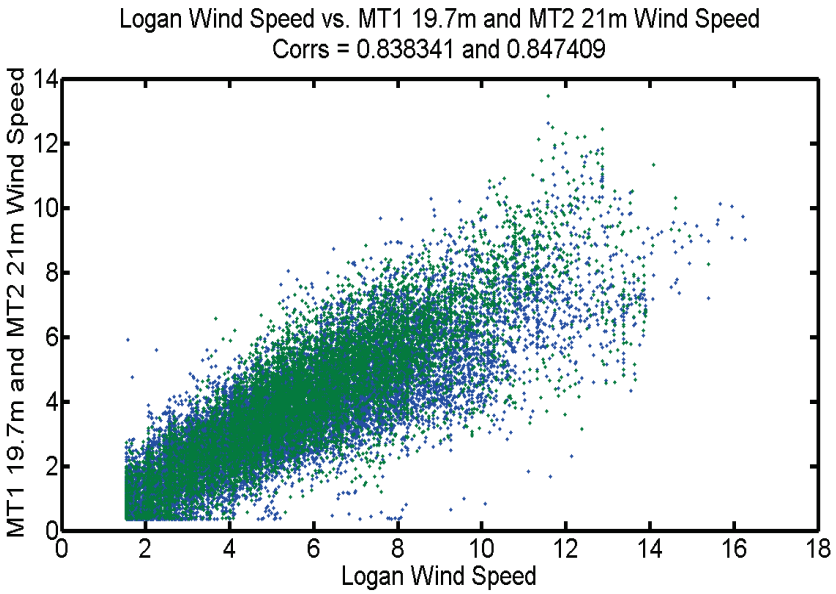
# How to Compare Site 1 to Site 2?

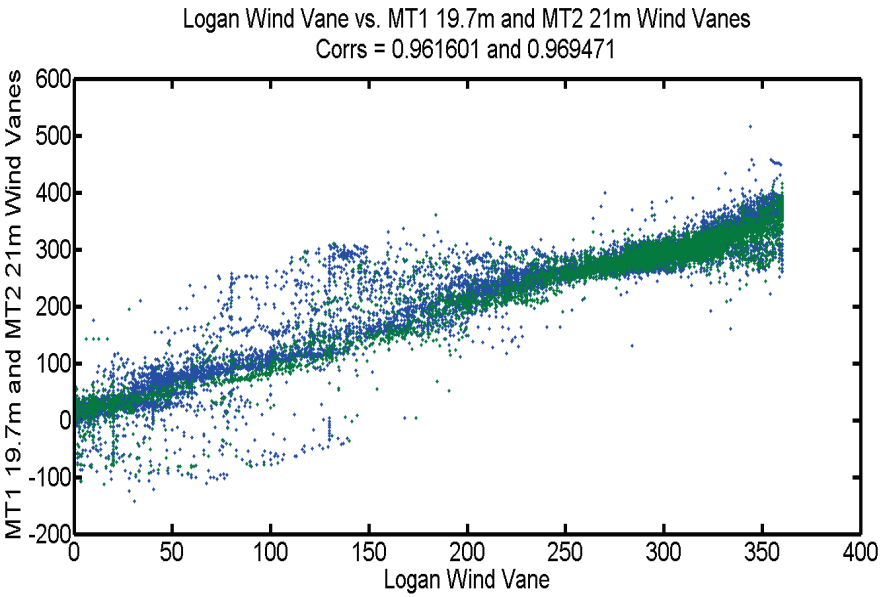
- Wind Shear relates wind speed to altitude:

$$v/v_0 = (h/h_0)^a$$

  - $a$ is the wind shear exponent (depends on surface roughness)
- Speed increases with height
  - Wind power density at Site 1 at 26m appears roughly the same as Site 2 at 20m
  - Site 2 appears to be much stronger than Site 1
  - Is it in the long term?

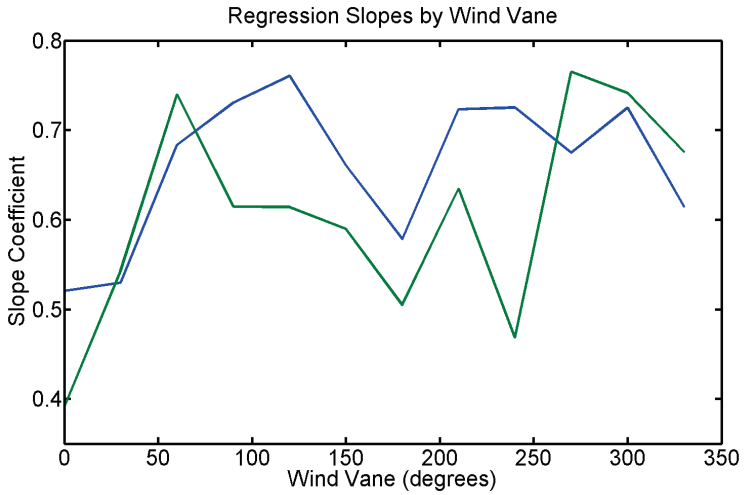
# Test/Reference Site Correlations



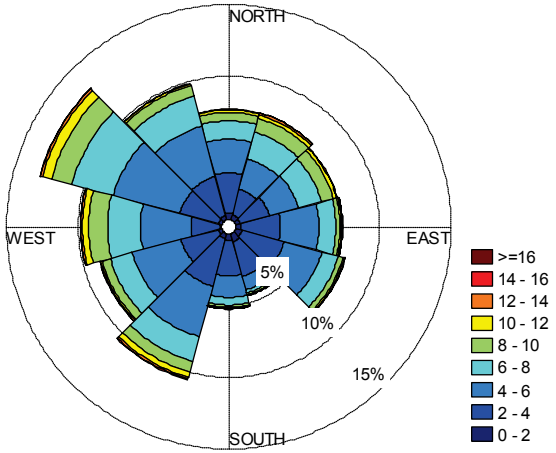




- Logan Airport good candidate for correlation:
  - Over 10 years of data available
  - Pearson's correlation coefficient = Cov(x, y) / (Std(x)Std(y))
    r = 0.84 to 0.85 for wind speed
    r = 0.96 to 0.97 for wind direction (wrapped)

# Binned Linear Regression Results



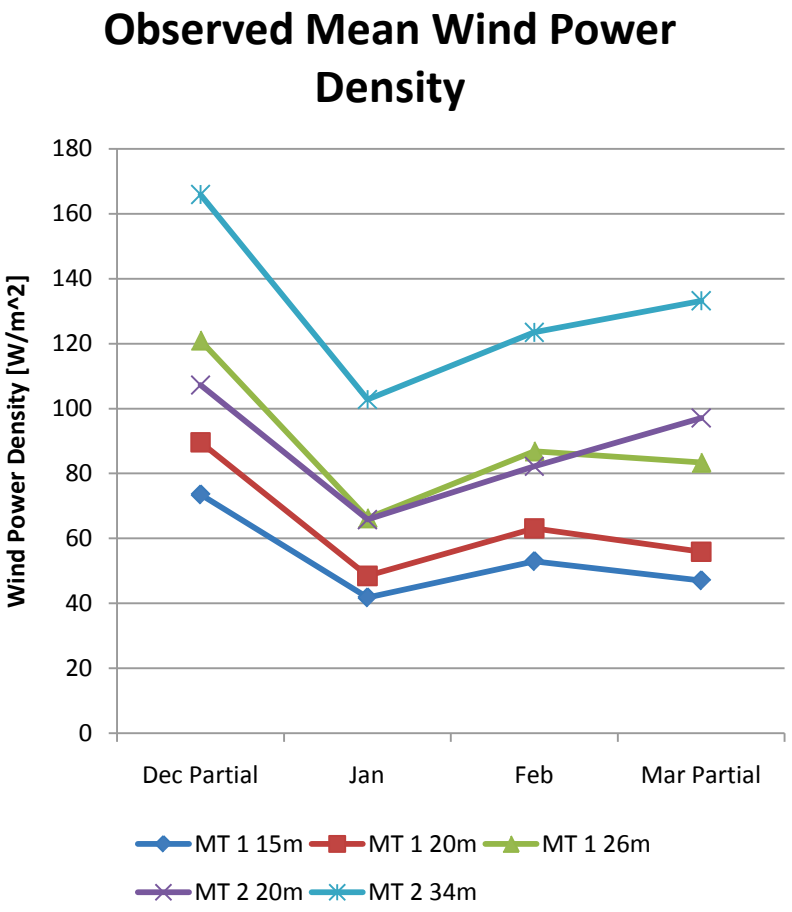

Blue – Met Tower 1 Green – Met Tower 2

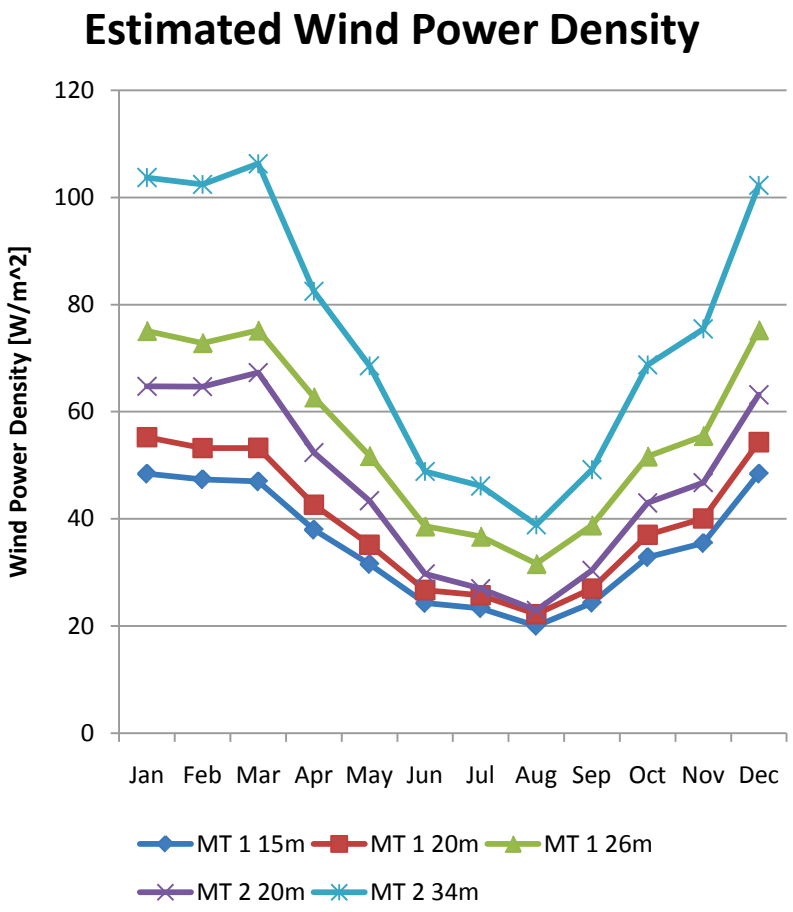



Logan Wind Rose

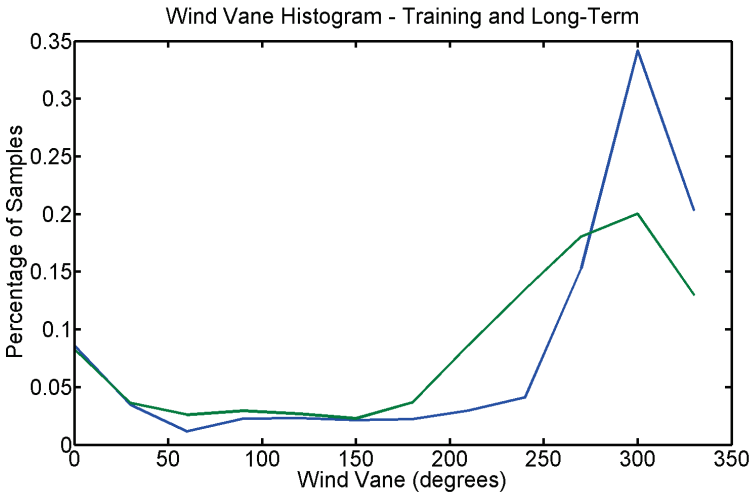
- Regression slopes *a* (from $y = ax + b$) on left
- Met Tower 1 out performs Met Tower 2 under most prevailing wind directions
- Winds often come from 270 to 330 range, shifting overall advantage to Met Tower 2

# MCP Results: Observations to Estimations

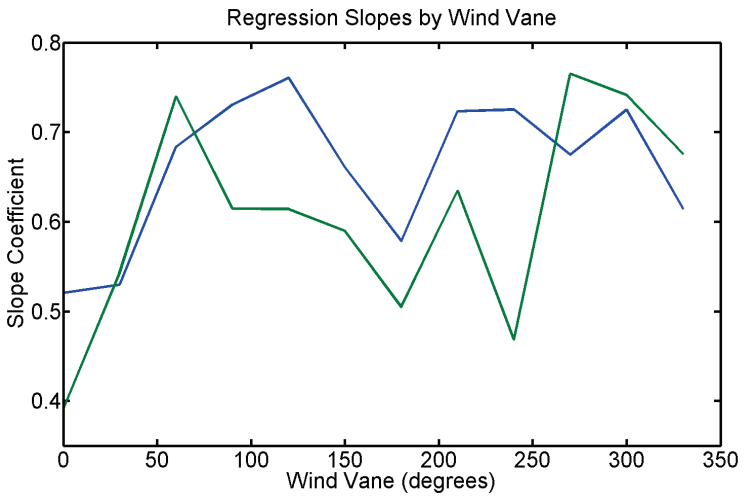


# Why the Divergence?




Blue – Observed Green – Long-Term Trend




Blue – Met Tower 1 Green – Met Tower 2

- Long-term wind direction distribution more spread out
- Site 2 still better than Site 1, but not by as much as observed during data gathering period

# More Information

- Visit http://windenergy.mit.edu for much more information on Project Full Breeze, the MIT Wind Energy Group, and Wind Energy Projects in Action (WEPA)
- Visit http://people.csail.mit.edu/cychan/ for more on my research in wind energy and computer science
- Thanks!