National Renewable Energy Laboratory

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WIND POWERING AMERICA

Wind Shear and Resources at Elevated Heights: Indiana and Iowa Case Studies

Dennis Elliott, Marc Schwartz, George Scott - NREL

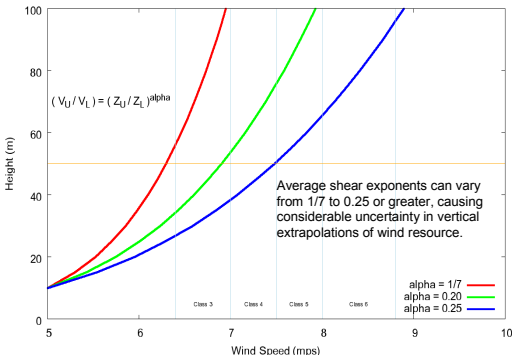
Background

- Considerable uncertainty exists in extrapolating wind resource information typically available from low levels (10–50 m) to turbine hub heights of 80–100 m
- Available wind resource maps for heights of 80–100 m are largely unvalidated
- Tall-tower wind data are needed to examine the wind shear and make more accurate estimates over turbine rotor heights, which may extend well above 100 m

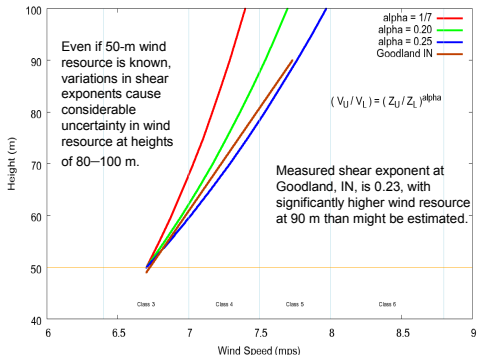
Objectives

- Analyze wind shear and resource characteristics at tall tower sites for some areas of the Great Lakes and Midwest
- Show case studies and comparisons for:
  - Indiana towers located in areas of various surface roughness
  - Iowa towers with heights up to 200+m

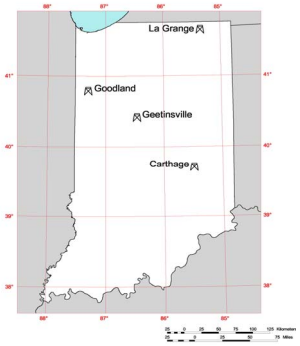
Wind Speed vs. Height for Different Shear Exponents



Wind Speed vs. Height for Different Shear Exponents



Indiana - Tall Towers



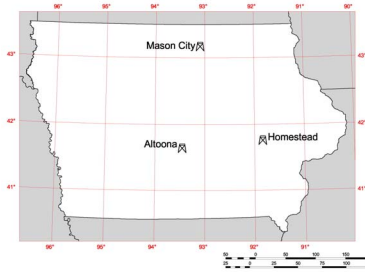
LaGrange, IN – High roughness, prevailing strong winds from S-SW

Geetinsville, IN – Mod/high roughness, prevailing strong winds from S-SW

Goodland, IN – Low roughness, prevailing strong winds from S-SW

Carthage, IN – Low/mod roughness, prevailing strong winds from S-SW

Iowa - Tall Towers



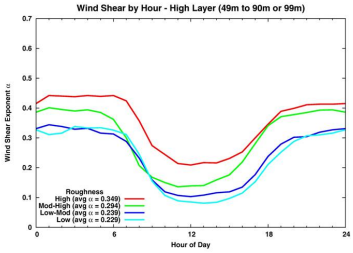
Iowa Analysis

- 3 very tall towers with highest anemometers 193–213 m
- Approximately 9 months data (Dec-Aug) at each tower
- Evaluate wind shear and resource variations by height
- Wind speeds of at least 3 m/s required for shear analysis

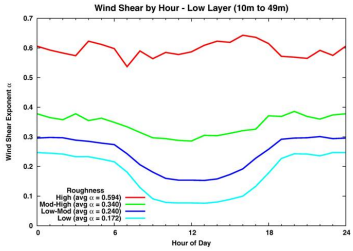
Iowa Analysis Results

- Diurnal variations in average wind speed increase with height
- Differences in average wind speed among towers decreases with height
- Average shear exponent is highest in 100–150 m layer
- Nocturnal shear exponent decreases above 150 m

Wind Shear by Hour - High Layer (49m to 90m or 99m)



Wind Shear by Hour - Low Layer (10m to 49m)



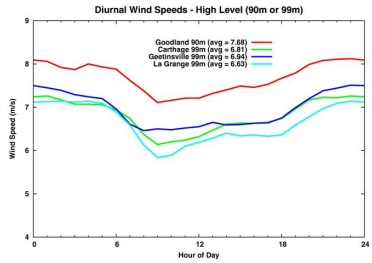
Indiana Analysis

- 4 tall towers in areas with different categories of surface roughness
- Highest anemometers 90-100m
- Approximately one year of data at each tower
- Evaluate wind shear variations by roughness category and height
- Wind speeds of at least 3 m/s required for shear analysis

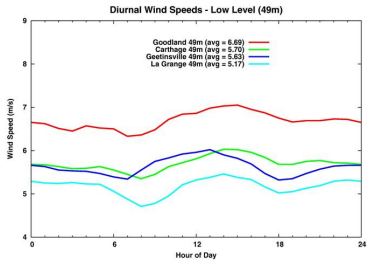
Indiana Analysis Results

- Notable variations in average shear exponent with highest shear found at towers with highest roughness
- Roughness effects on shear extend well above 50m and are apparent in both daytime mixed and nighttime stable layers
- Differences in average wind speed among towers decreases with height

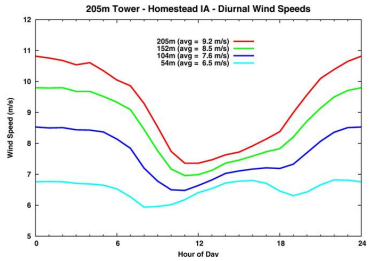
Diurnal Wind Speeds - High Level (90m or 99m)



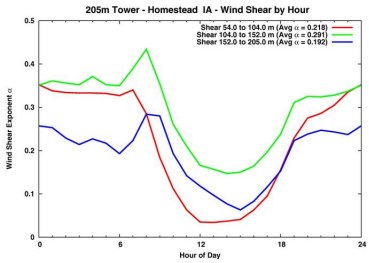
Diurnal Wind Speeds - Low Level (49m)



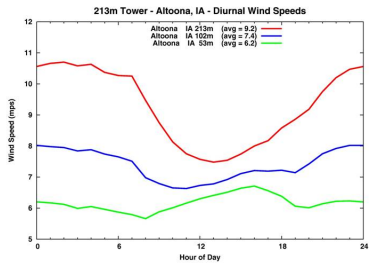
205m Tower - Homestead IA - Diurnal Wind Speeds



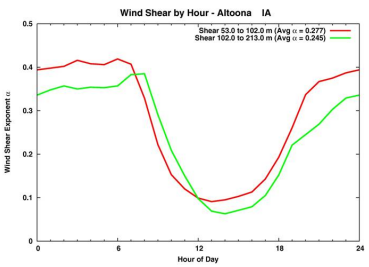
205m Tower - Homestead IA - Wind Shear by Hour



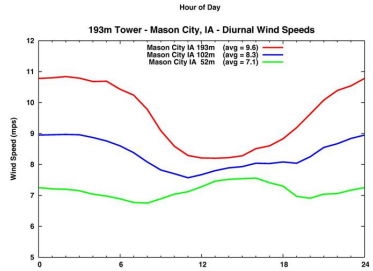
213m Tower - Altoona, IA - Diurnal Wind Speeds



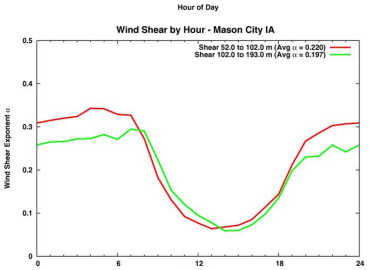
Wind Shear by Hour - Altoona IA



193m Tower - Mason City, IA - Diurnal Wind Speeds



Wind Shear by Hour - Mason City IA



Conclusions

- Surface roughness effects on wind shear and resource at turbine hub heights can be significant
- Wind shear exponents at heights of 100–150 m can exceed those at heights of 50–100 m
- Diurnal variations of wind speed increase with height above 50 m
- Average wind resource variability among stations decreases with height

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