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Wind assessment without limits

# New Remote Sensing Tools for Performance Measurement and Optimization of Wind Turbines

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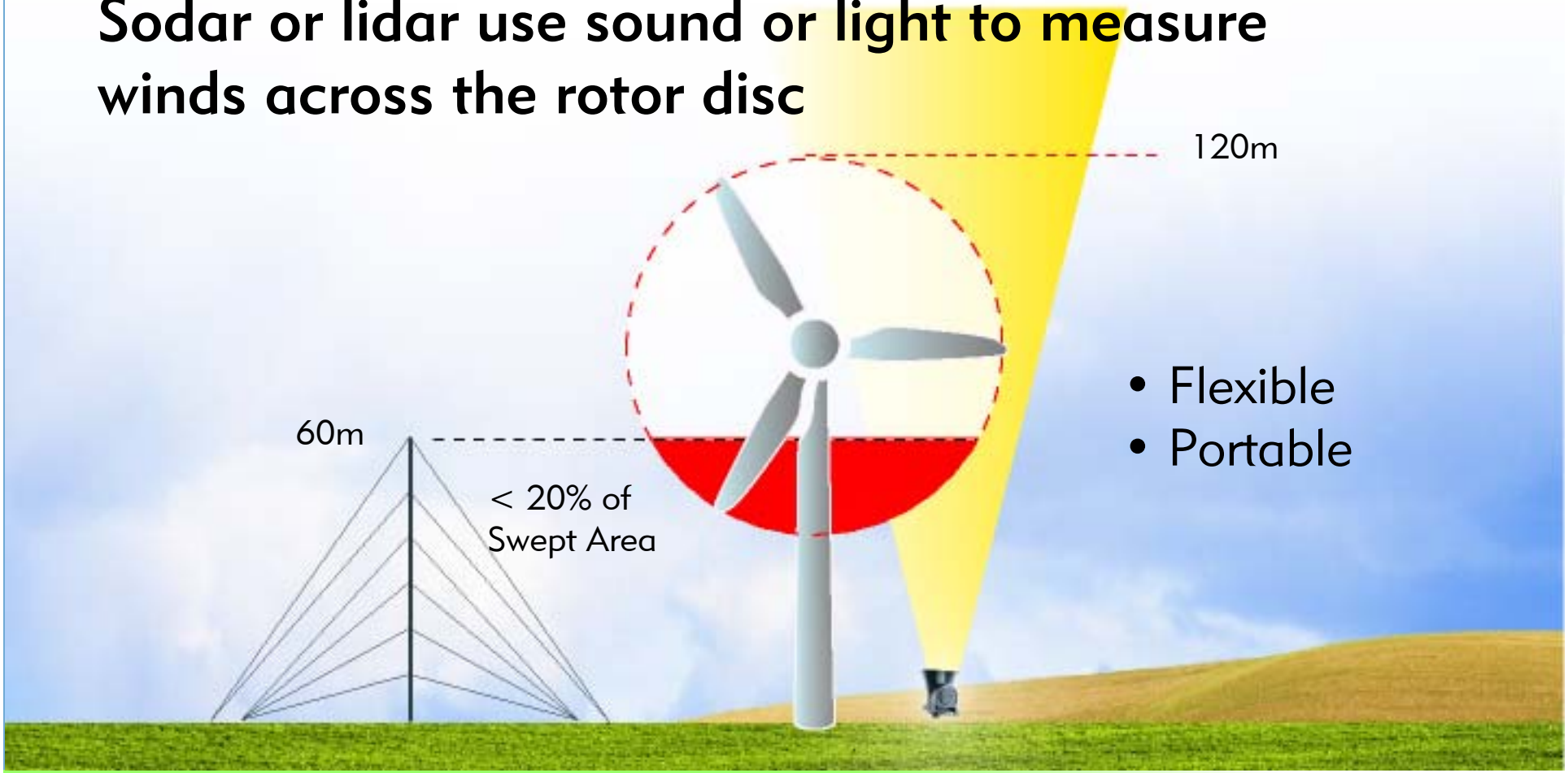
# Remote Sensing

**Sodar or lidar use sound or light to measure winds across the rotor disc**



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# Applications to Management of Wind Turbines

- Power performance measurement across rotor
- Site characterization: shear, veer, unusual effects
- Wakes: direct measurement of wind between rows
- Forecasting

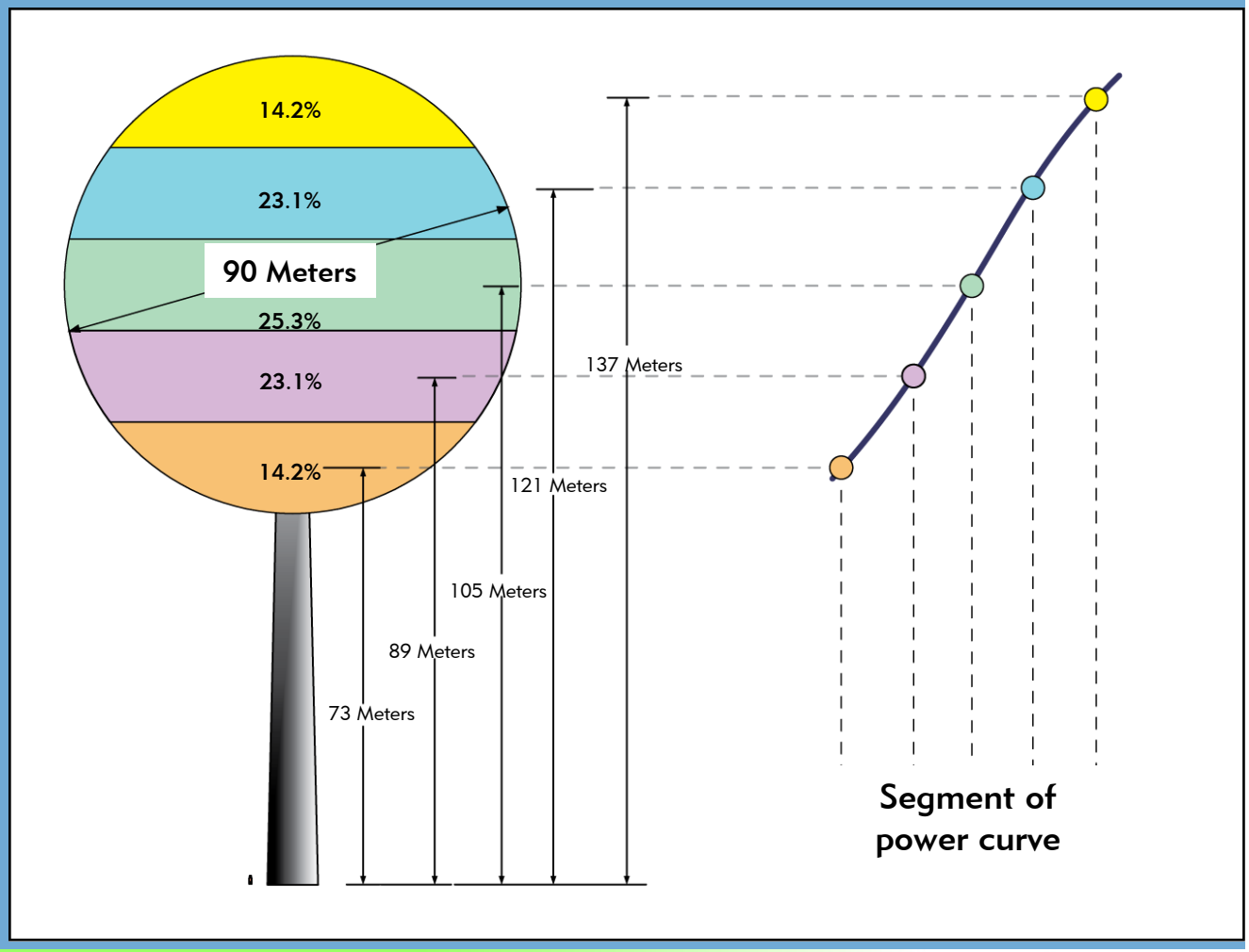
# Power Performance

## Current Methods

- Formal studies use IEC 1400-12: Costly, difficult to place met towers, single hub-height measurement.
- SCADA typically uses nacelle anemometers: Distorted by flow around nacelle, not very accurate.
- Could use reference met towers: Only a few per site - difficult and costly to place, costly to maintain

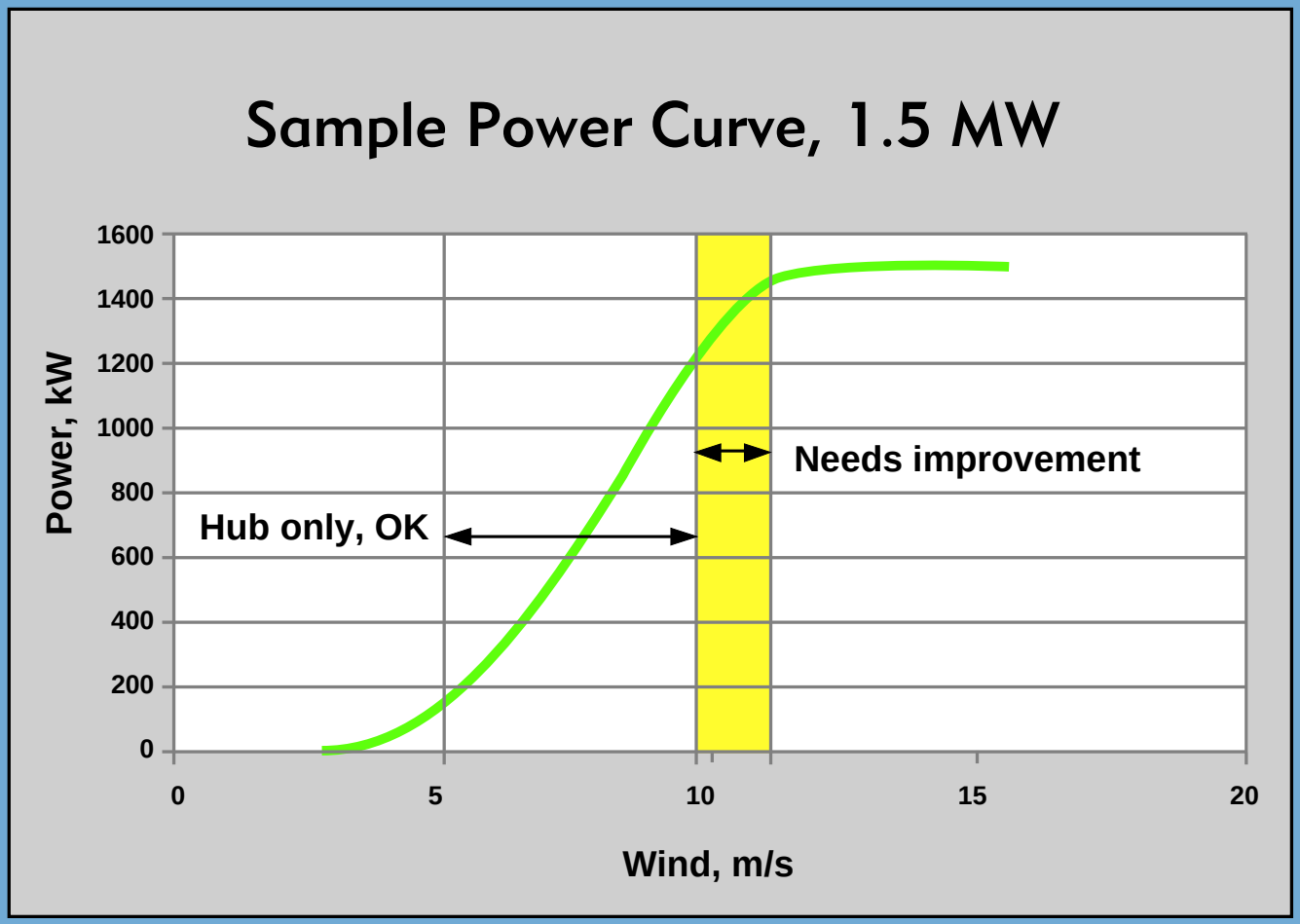
# Integrated Rotor Measurement

**Consider the rotor disc in five horizontal segments…**




Following a paper at 14th International Symposium for Advancement of Boundary Later Remote Sensing (ISARS 2008) by Wagner, Jørgensen, Larsen, Antoniou, and Thesbjerg (Risø, Siemens, and Vestas)

# Issues With Single Hub Height Measurement



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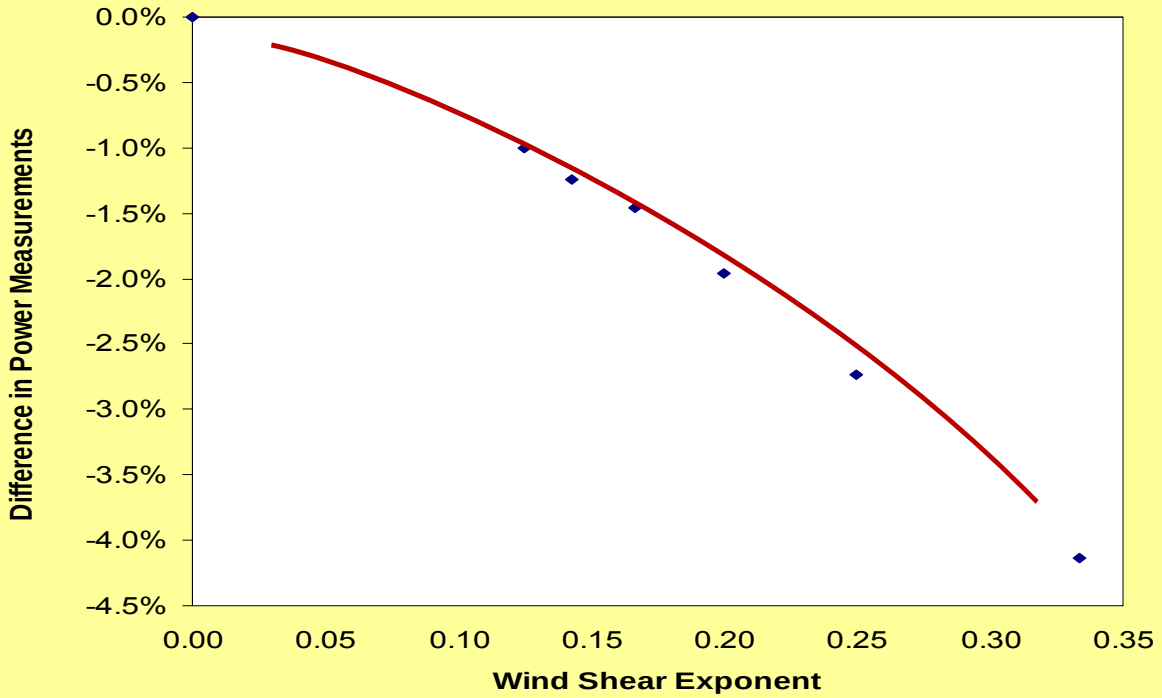
# Hub Height vs. Integrated Rotor Measurement

**Integrated Method Predicts Less Power at 10-11 m/s (Power Curve "Knee"), for 1.5 MW Turbine**




The greater the wind shear, the greater the difference in power predictions between the two methods.



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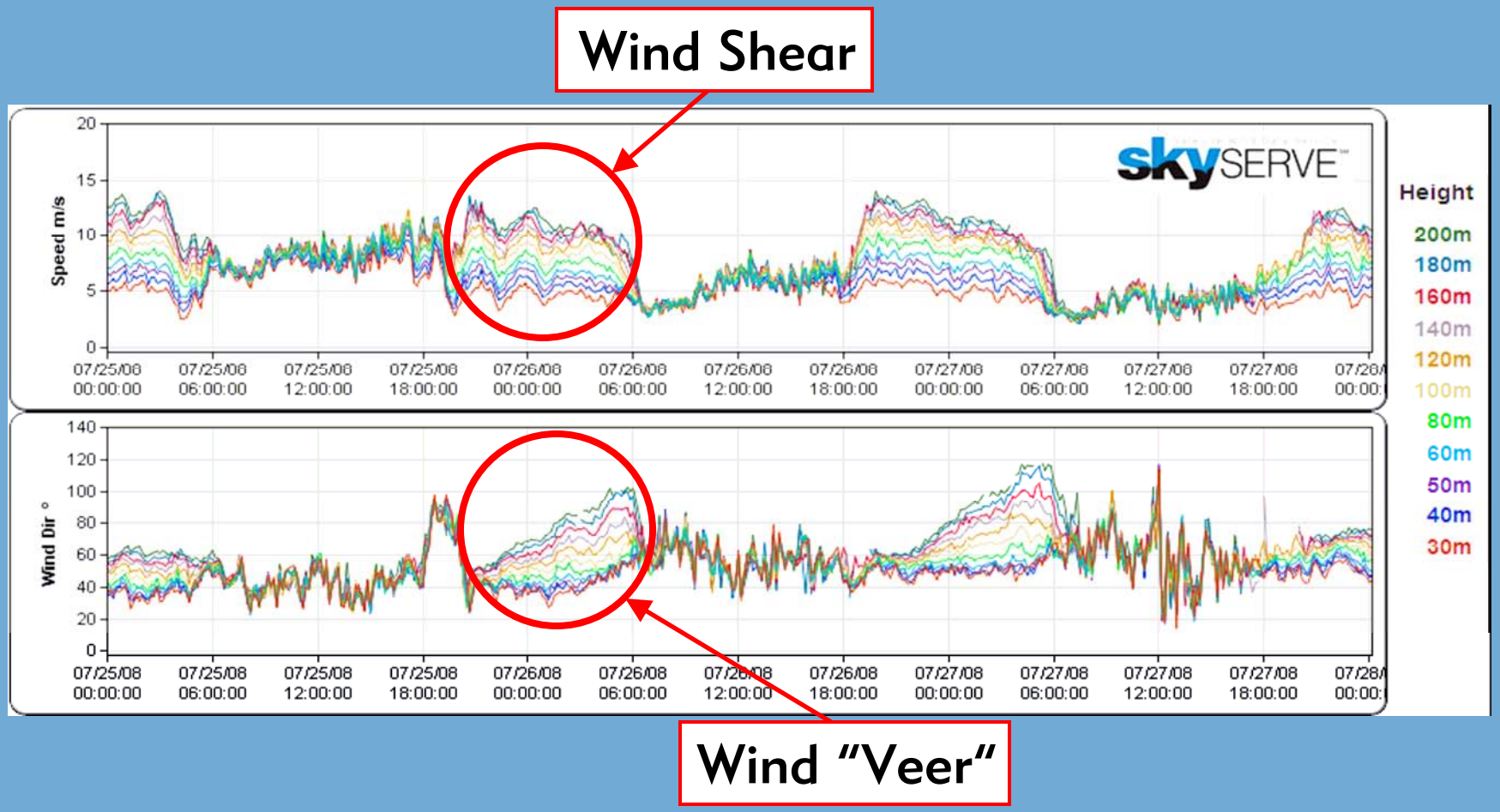
# Examples of Anomalous Winds



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# Wind Shear Exponent Comparison

- **Tower exponent found using data from two heights**
- **Triton exponent found using data from 50 m to 120 m:**
  - Plot: $\log(U_z/U_{zr})$ vs $\log(z/z_r)$
  - Slope of best fit = Alpha

| Site | Tower Heights | Triton **Overall** | Tower **Overall** | Triton ☼ **DayTime** | Tower ☼ **DayTime** | Triton ☾ **NightTime** | Tower ☾ **NightTime** |
|---|---|---|---|---|---|---|---|
| California | 58 / 33 | 0.11 | 0.15 | 0.05 | 0.09 | 0.16 | 0.20 |
| Kansas | 60 / 45 | 0.20 | 0.13 | 0.08 | 0.01 | 0.32 | 0.24 |
| Mass. | 60 / 40 | 0.36 | 0.45 | 0.23 | 0.32 | 0.52 | 0.63 |
| Colorado | 58 / 40 | 0.19 | 0.15 | 0.05 | 0.06 | 0.25 | 0.24 |
| BAO | 100 / 50 | 0.13 | 0.16 | 0.09 | 0.11 | 0.17 | 0.20 |
| NREL | 80 / 50 | 0.06 | 0.09 | 0.04 | 0.06 | 0.09 | 0.12 |
| Wash. | 60 / 40 | 0.09 | 0.11 | 0.04 | 0.08 | 0.15 | 0.15 |
| | | | | | | | |
| **Average** | | **0.16** | **0.17** | **0.08** | **0.10** | **0.24** | **0.25** |

# Final Thoughts: Better Shear/Veer Data…

**Better shear/veer data will allow operators and turbine suppliers to optimize turbines.**

- Wind shear causes cyclic flapping loads. May affect hub and tower bolt P/M schedule.
- Veer might cause sub-optimum yaw error. What are the effects on the turbine rotor?
- Wind conditions can be measured to better understand how to adjust turbine controls to avoid blade/tower strikes.

# Final Thoughts: Improved Measurements…

**Improved measurements can make it possible to create an accurate site model and better forecasts.**

- Model can be used with SCADA data to better understand under-performers.
- Better forecasts with strategically placed remote sensing gear.