Use of Remote Sensing in Addressing Bias & Uncertainty in Wind Measurements

AWEA Wind Resource & Project Energy Assessment Workshop

Portland, OR, USA, 24&25 Sept. 2008

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Outline

Opportunities for Wind Energy Industry

Value of Remote Sensing

Recent Progress Addressing Usual Concerns

Session Agenda

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Opportunities for Wind Energy Industry

How and when remote sensing is being used?

- Fields of application
  - Wind Resource Assessment ➔ Prelim. siting / Reduce bias-uncertainty
  - Site Suitability ➔ Curtailment issues
  - Project Performance ➔ Understand underperformance
  - Offshore ➔ Reduce cost of WRAP

- Fields of research
  - Wind shear
  - Wind veer
  - Turbulence intensity
  - Flow angle
  - Wake

  } Effect on AEP; Effect on aeroelastic loading; Design improvement; Control algorithm; Simulation refinement; Standard update (power curve/site suitability)

How and when should remote sensing be used ?

Value of Remote Sensing*

North American Consultants – A Survey (Sept. 2008)

- 9 consultants surveyed in US and Canada
- Aggregated results
  - General confidence → Moderate to high
  - Resource assessment → Yes with towers
  - Site calibration → Yes with towers
  - Site suitability → Occasionally
  - Power curve → No

General conclusion

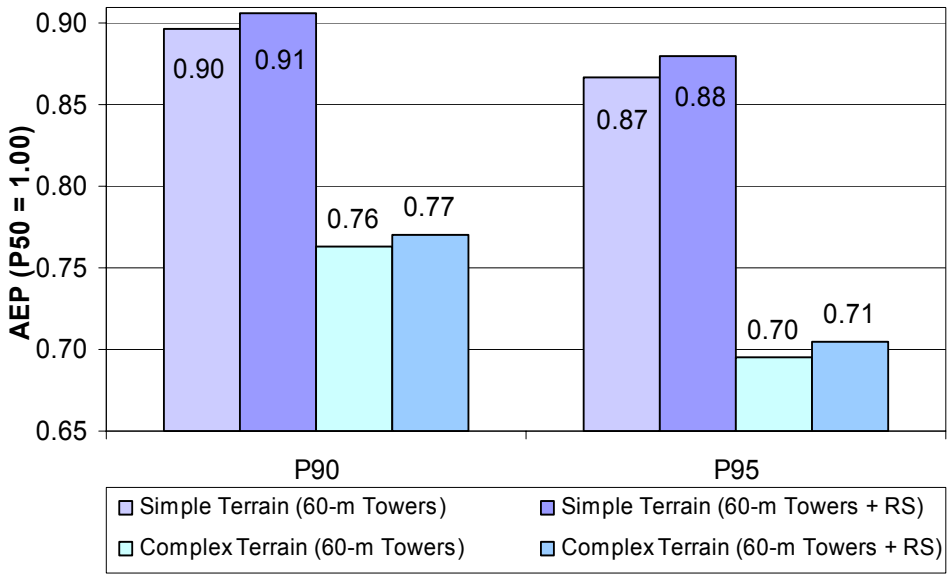
- Remote sensing is offered and increasingly promoted
- Remote sensing is sugested in conjunction with met towers
- Remote sensing is used to reduce uncertainty but not (yet) bias
- Lack of standard impedes full acceptance
- Confidence is still limited due to incomplete understanding of site-specific dependencies

***Onshore only**

Value of Remote Sensing

Case Study: Reducing Vertical Extrapolation Uncertainty

- Typical 100-MW range wind project at CF ~33%



Global uncertainty could be further reduced using site calibration with a mobile remote sensing unit

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Recent Progress Addressing Usual Concerns

Availability: Precipitation / Clear sky / Cold climate

- Evaluation of ZephIR (A. Albers, Windguard, 2006)
- Evaluation of Windcube (A. Albers, Windguard, 2008)
- Commercial lidar profilers for wind energy. A comparative guide (M.Courtney et al., Risoe, EWEC 2008)
- Evaluation of an improved doppler sodar for a wind ramp forecasting system (S. Walker & Ph. Barbour, Bonneville Power Adm./Second Wind Inc., BPA report No. 2008-03, 2008)
- Sodar / Lidar (current workshop)

Summary of Results

- Significant improvement in general availability
- Ongoing studies for longer durations

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Recent Progress Addressing Usual Concerns

Complex Terrain / Flow – Canopy / vegetation

- Accuracy and relevance of pulsed doppler lidar wind profile measurements in complex terrain (R. Parmentier et al., EWEC 2008)
- Laser measurements of flow over a forest (J. Mann et al., IOP 2007)
- Sodar / lidar (current workshop)

Summary of Results

- Better understanding of limitations
- More robust processing algorithms
- CFD models to help understand differences with point measurements

Recent Progress Addressing Usual Concerns

- **Uncertainty & Bias: Vector vs. scalar average, Volume vs. point measurement**
  - Compensation of vector & volume averaging bias in Lidar wind speed measurements (P. Clive, Earth & Env. Sci. 2008)
  - Simulation of turbulence measurements made by a ZephIR Lidar (Dougal McQueen, Meridian, 2008)
  - Evaluation of Windcube (A. Albers, Windguard, 2008)
  - Wind shear proportional errors in the horizontal wind speed sensed by focused, range gated lidars (Lindelöw et al., Earth & Env. Sci. 2008)
  - Maximizing the accuracy of sodar measurements for wind resource assessment (K. Moore & B. Bailey, AWST, 2006)
  - Recommended practices for the use of sodar in wind energy resource assessment (K. Moore et al., IEA, draft ver. 3, 2007)
- **Summary of Results**
  - Simple corrections formulae for volume measurements but not general purpose
  - Sodar/lidar may be within ~2-5% of anemometer mean velocity with "*special care*"
  - Remarkably small standard errors reported for lidar

Recent Progress Addressing Usual Concerns

Other Applications : Power curve

- Evaluation of ZephIR (A. Albers, Windguard, 2006)
- Evaluation of Windcube (A. Albers, Windguard, 2008)
- Remote sensing used for power curves (Wagner et al., Earth & Env. Sci. 2008)
- Turbulence, shear and stability influences on lower boundary-layer profiles (K. Moore et. al., Am. Met. Soc.18th Boundary Layer & Turb. Symposium, Stockholm, 2008)

Summary of Results

- Quantification of AEP bias as compared to IEC standard (anemometer)
- Comparison of uncertainties (lidar vs. anemometer)
- Definition of correction formulae for hub-height velocity to account for shear

Session Agenda

- **Presentation of Recent Validation Campaigns**
  - Sodar
  - Lidar

- **Panel Discussion**
  - Qualitative flow description or quantitative results for the wind project?
  - Best practice and standard?
  - To invest or not to invest in remote sensing?

THANK YOU

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