

Lidar Remote Sensing in Extreme Climates

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Objective

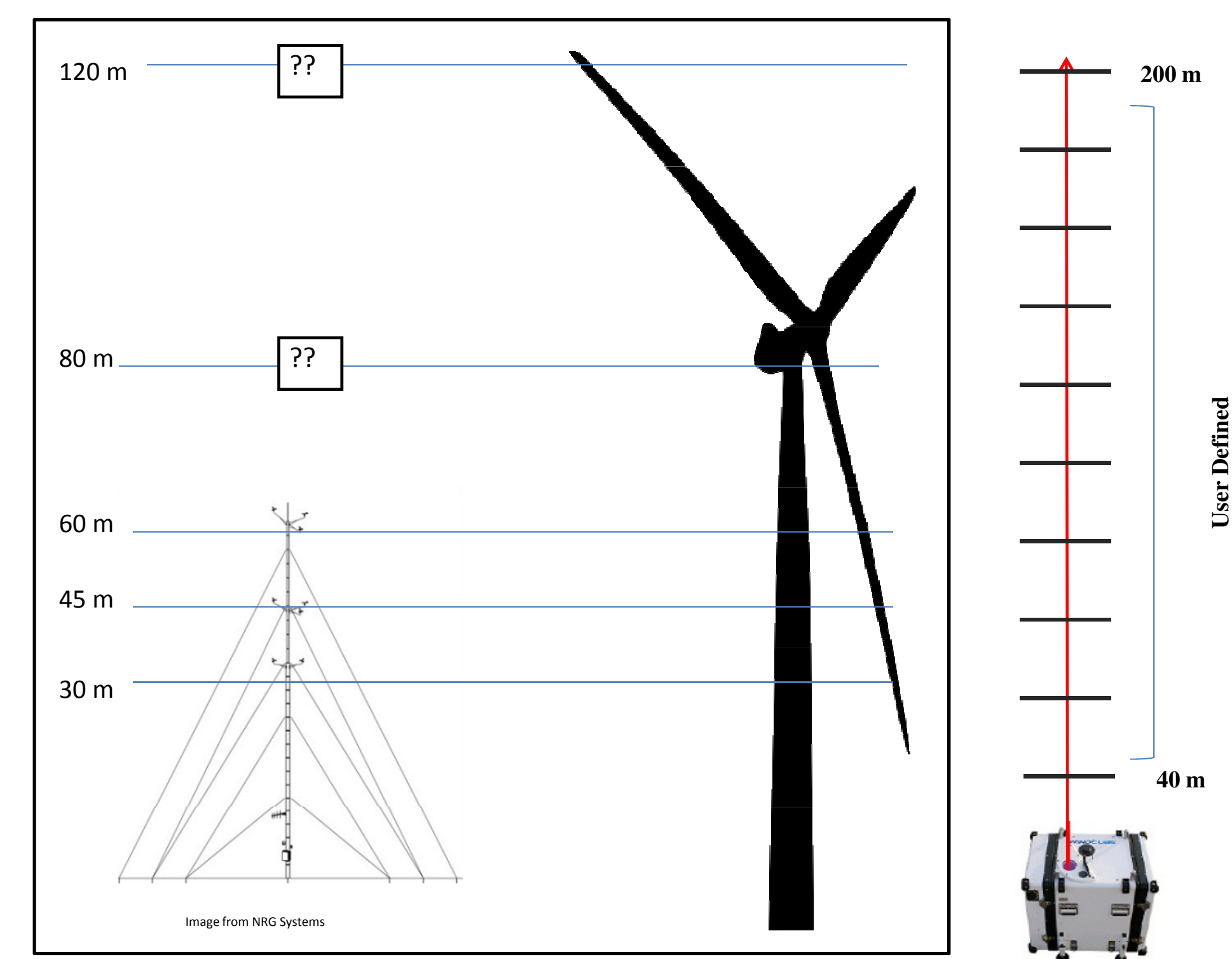
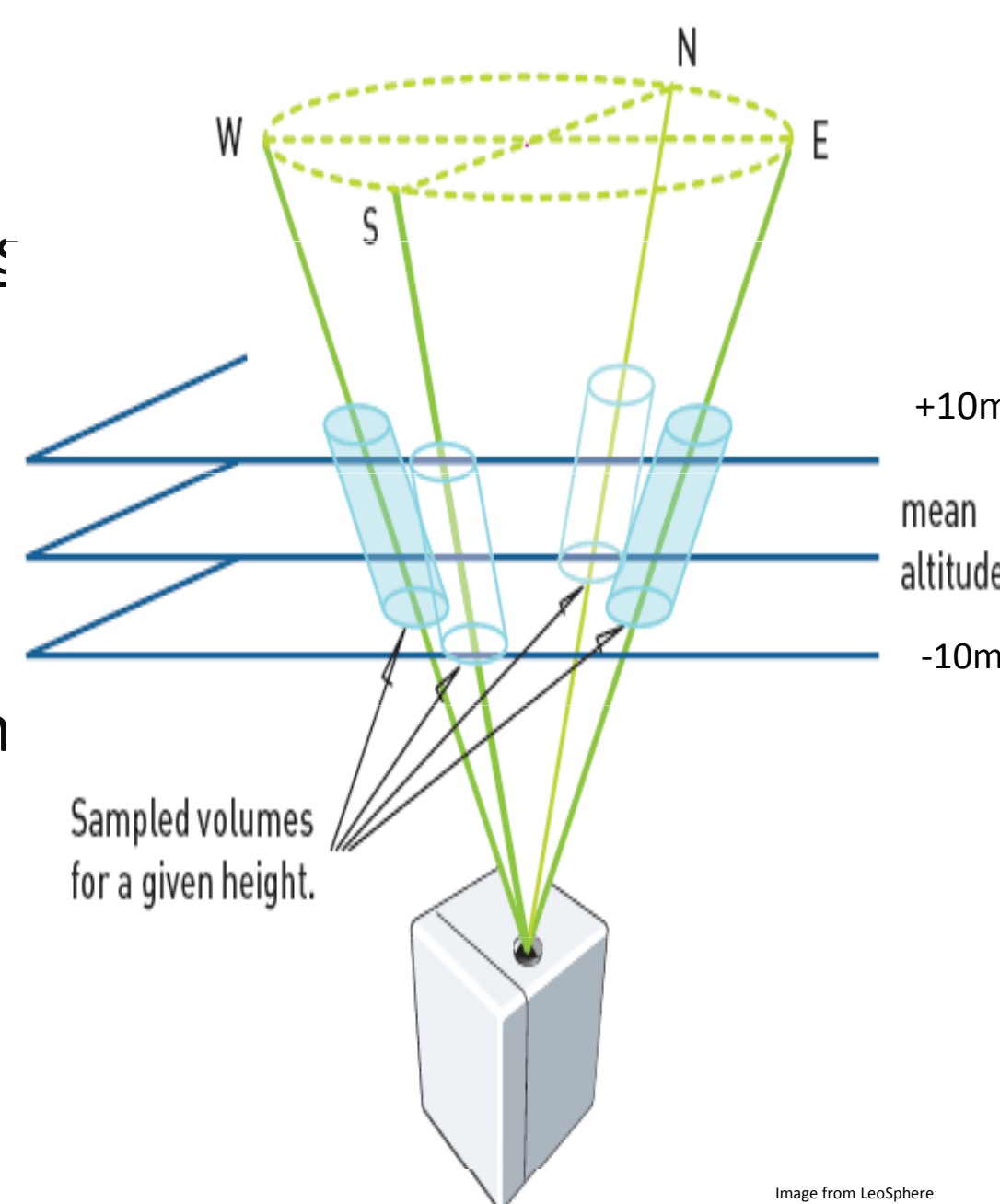
- In order to reduce uncertainty at a project site located in the Canadian Prairies, Lidar was chosen as a tool to
 - Reduce Shear uncertainty
 - Improve wind flow modeling
- The Lidar deployment was used to identify limitations and benefits of Lidar deployment in harsh climates

Significance

- Uncertainty attributed to shear extrapolation and wind flow modeling are major components of project uncertainty.
- Reducing project uncertainty can improve the accuracy and precision of pre construction yield estimates
- Measurement of wind speed at hub height is above the range of typical tilt up meteorological towers
- Lidar is a fast, easy to deploy wind measurement system that measures wind velocity from 40 m to 200 m

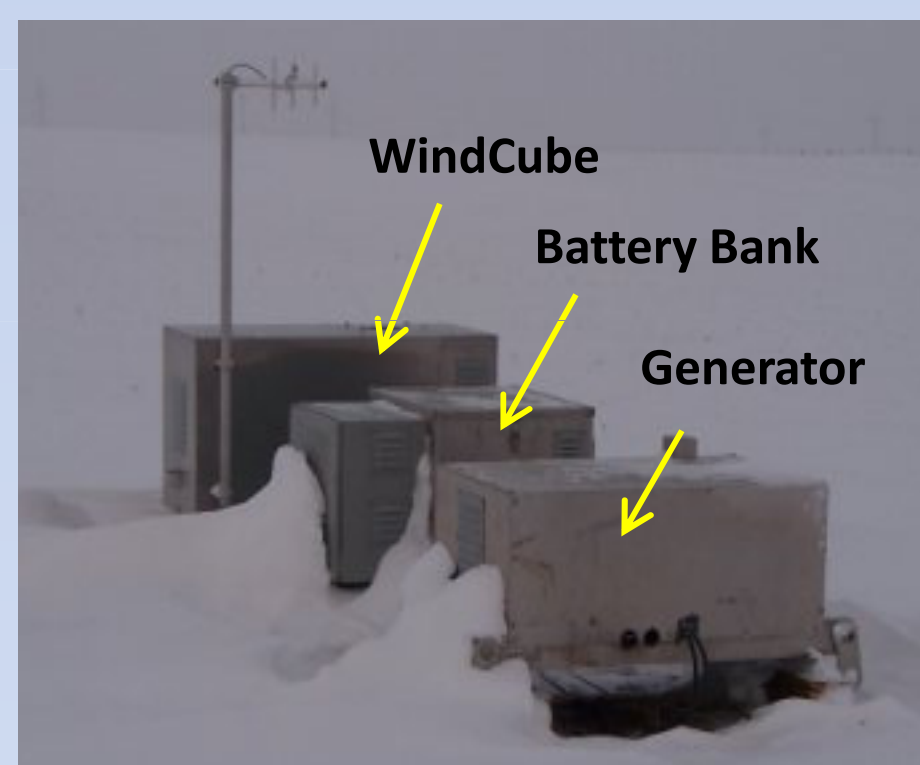
BACKGROUND

- Lidar (Light Detection And Ranging)
- Measures velocity of light scattered from moving particles in the atmosphere to determine the wind velocity profile
- Lidar wind measurements are based on volume averaging from four portions of a 20 meter measurement slice
- WindCube Lidar measures up to 10 heights between 40 m and 200 m
- Particle velocity allows calculation of additional information when compared to anemometer readings such as:
 - Vertical Wind Speed
 - Wind Inclination angle
 - Turbulence Intensity
 - Wind Veer

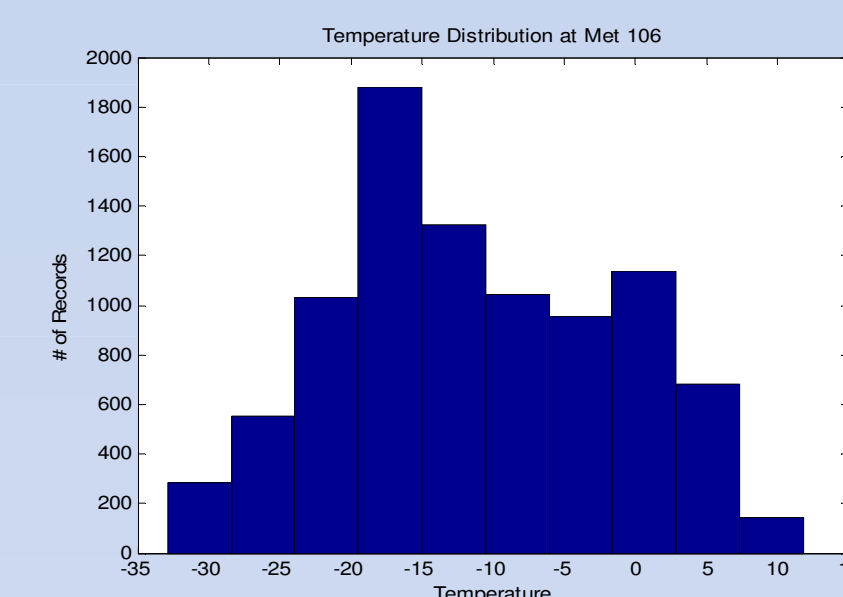


Extreme Condition Deployment

- 92 day deployment from November – February
- Minimum Temperature was -32.9° C
- Anemometer icing 30% for period
- Lidar recovered 42% of the icing data
- 375 W Power draw for heating and Lidar operation



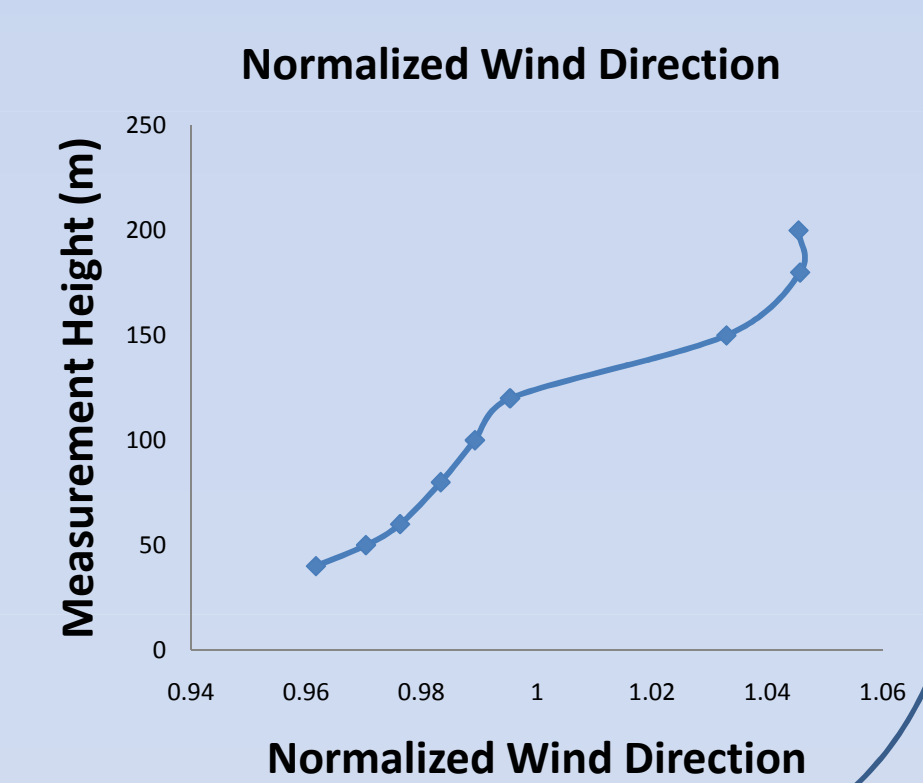
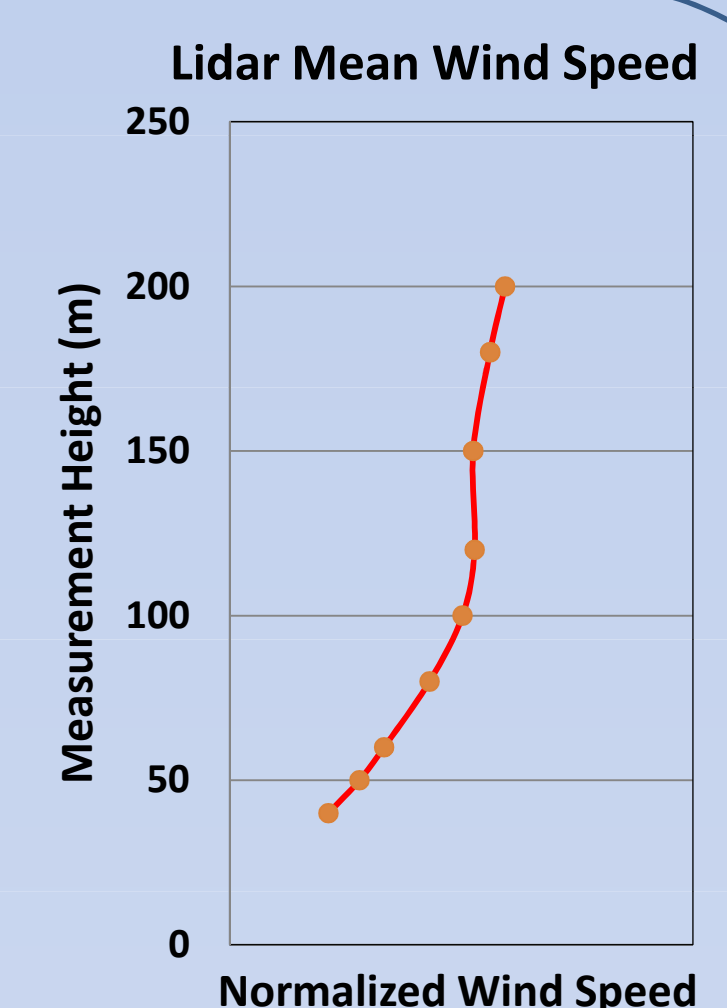
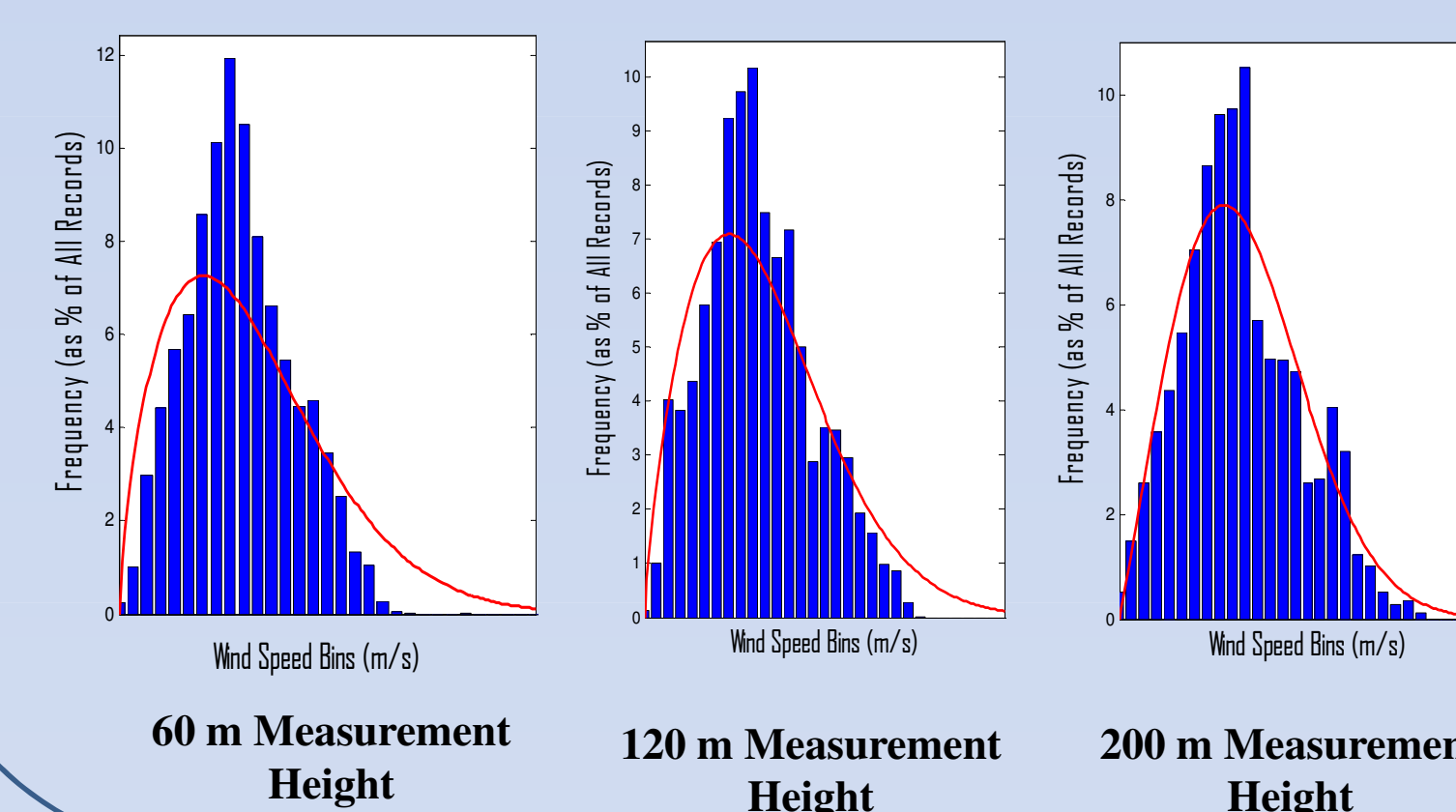
WindCube in Snow Conditions
December 2009



| Weather Type | % Occurance |
|------------------|-------------|
| Freezing Drizzle | 0.9% |
| Freezing Rain | 0.2% |
| Rain | 0.4% |
| Snow | 14.1% |

Wind Distribution and Height

- Wind Distribution varies as a function of height above ground
- Wind Profile generally follows power law throughout rotor path
- Wind Profile diverges from power law profile after 120 m



Operational Experience

- Lidar is power intensive and a dependable power supply is essential
 - GENIVAR has developed a 24 V permanent magnet diesel generator battery bank to provide robust power supply
- Lidar is able to provide wind measurements in conditions when traditional anemometers are unreliable such as icing
- Atmospheric and meteorological conditions can limit Lidar effectiveness
- Siting of Lidar must consider both project considerations and local micro environmental conditions

Conclusions

- Lidar provides a significant amount of additional data not possible with traditional cup anemometry
 - Wind Veer as a function of height
 - Inflow angle and vertical wind speed
 - Turbulence at hub height
 - Wind speed at hub height and throughout rotor path
- Wind shear profiles at project sites can be validated using Lidar wind measurements
- Lidar is still an emerging technology and its strengths and limitations are being explored.