Site Calibration in Complex Terrain

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Overview

- Tony Rovers, Senior Wind Engineer at Meridian Energy.
- Presentation will cover;
  - Mill Creek Project
  - Power performance testing
  - Site calibration and remote sensing application
  - Results from site calibration using sodars
  - Monitoring challenges
  - Recommendations

Mill Creek Wind Farm

- Currently under construction.
- 26x Siemens SWT-2.3MW-82 VS
  - Hub height 68m.
- High average winds and complex terrain environment.
- Site calibration monitoring started in early May 2013 for power performance testing.

- 5 site calibrations completed with mixed results, 1 underway.

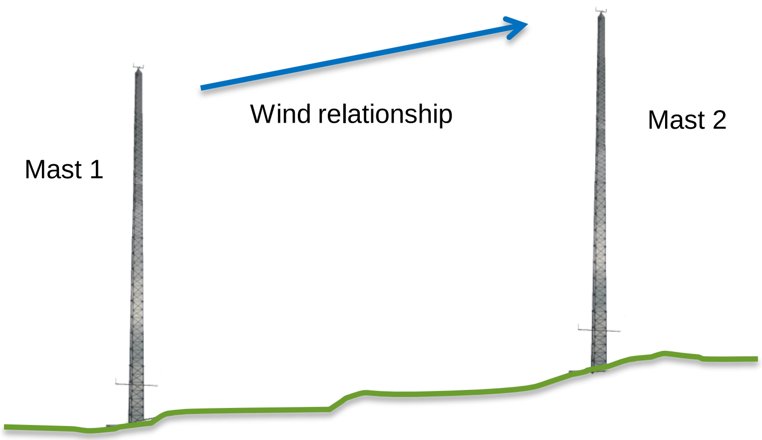
Power Performance

- Power Performance assessment of a wind turbine IEC61400-12-1.
  - Typically to verify turbine power curve under warranty conditions.
- Wind speed measurement reference is used upwind of the turbine and compared with the turbine power output.
- Representative sample of turbines are tested
  - Costly due to a measurement source (i.e. Hub height mast) required for each test turbine.
- No wake from other turbines in the measurement sector
- No formal IEC standard yet for power performance using remote sensing equipment - *currently being investigated*
- At Mill Creek testing is not part of a warranty agreement.

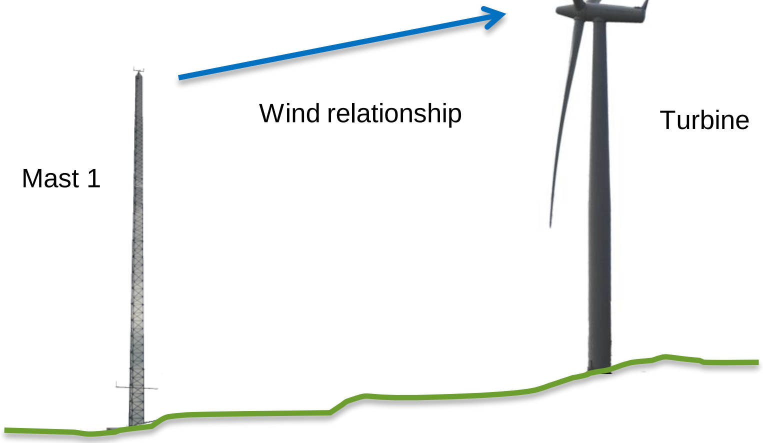
Te Apiti wind farm

Site Calibration Complex Terrain

- Required in complex terrain due to variation in flow between reference and turbine locations.
- Uses a wind measurement at reference location and another at turbine location to determine a wind speed relationship prior to turbine installation
  - Higher cost as two hub height measurement locations required for each turbine to be tested
  - Require approx 2-4 rotor diameters between mast and turbine – 2-2.5 rotor diameters preferred.
- Relationship applied to measured reference wind speed for comparison with turbine power post-installation.



*Site Calibration – **Pre** Install*



*Power Curve test – **Post** Install*

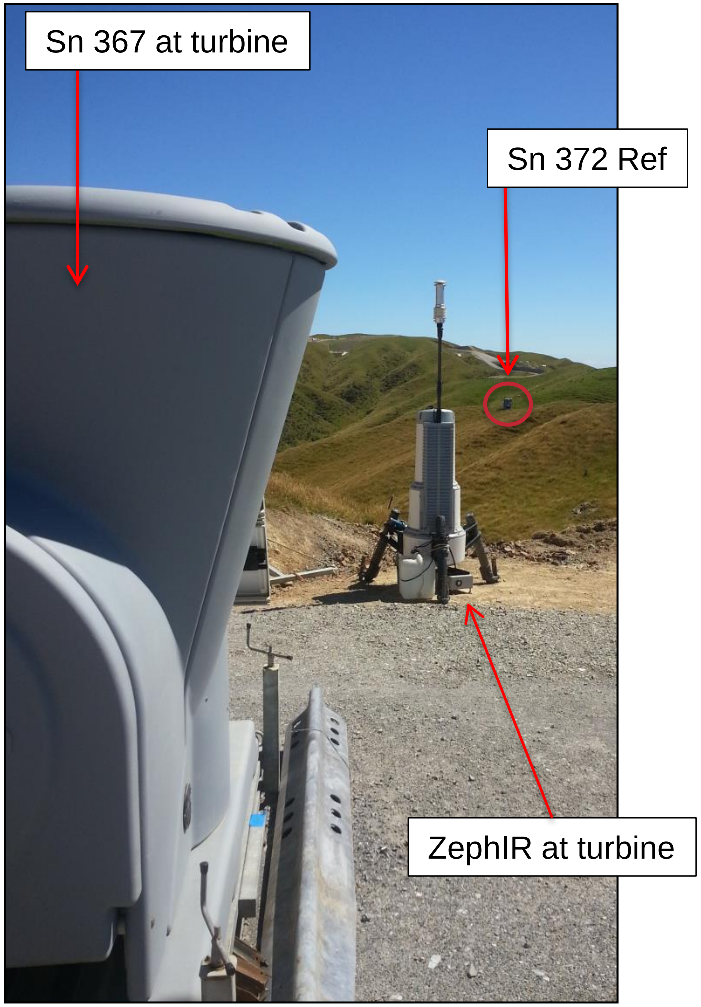
Remote sensing site calibration

Use of remote sensing may provide

- Cost savings due to use of mobile measuring platform.
- Ability to measure at several different locations – more turbines tested.
- Measurements can made prior to heavy equipment and roads on-site.
- Higher hub heights and measurements across the rotor .

However

- More complex measurement and analysis.
- Potentially higher scatter and uncertainty in results dependant on technology, analysis and site conditions.

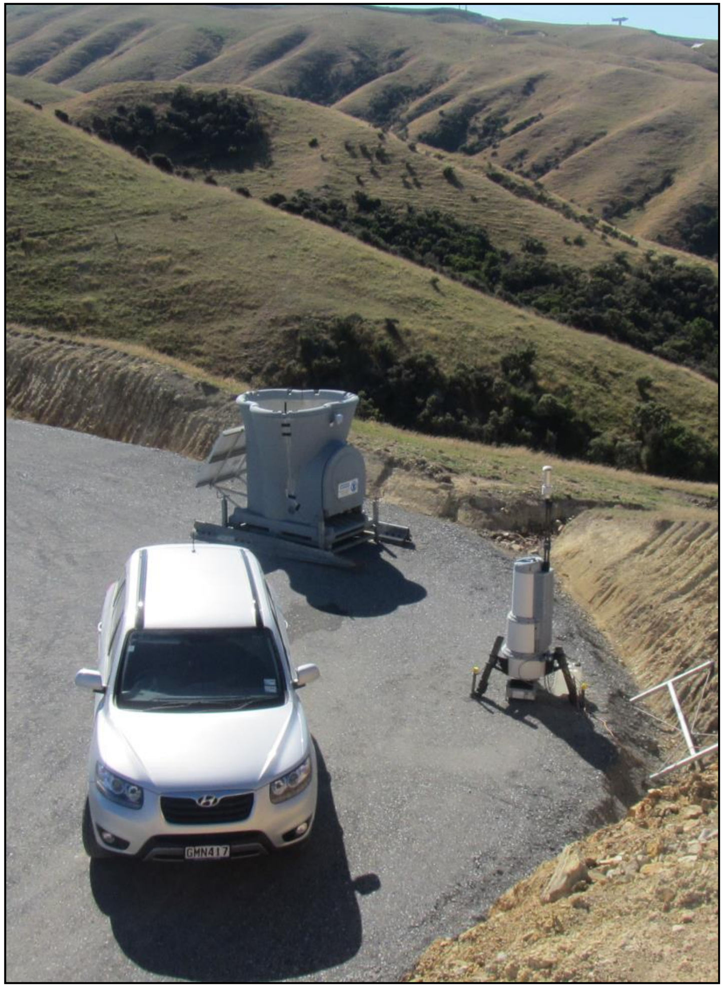


Position 4 test location

Remote sensing site calibration

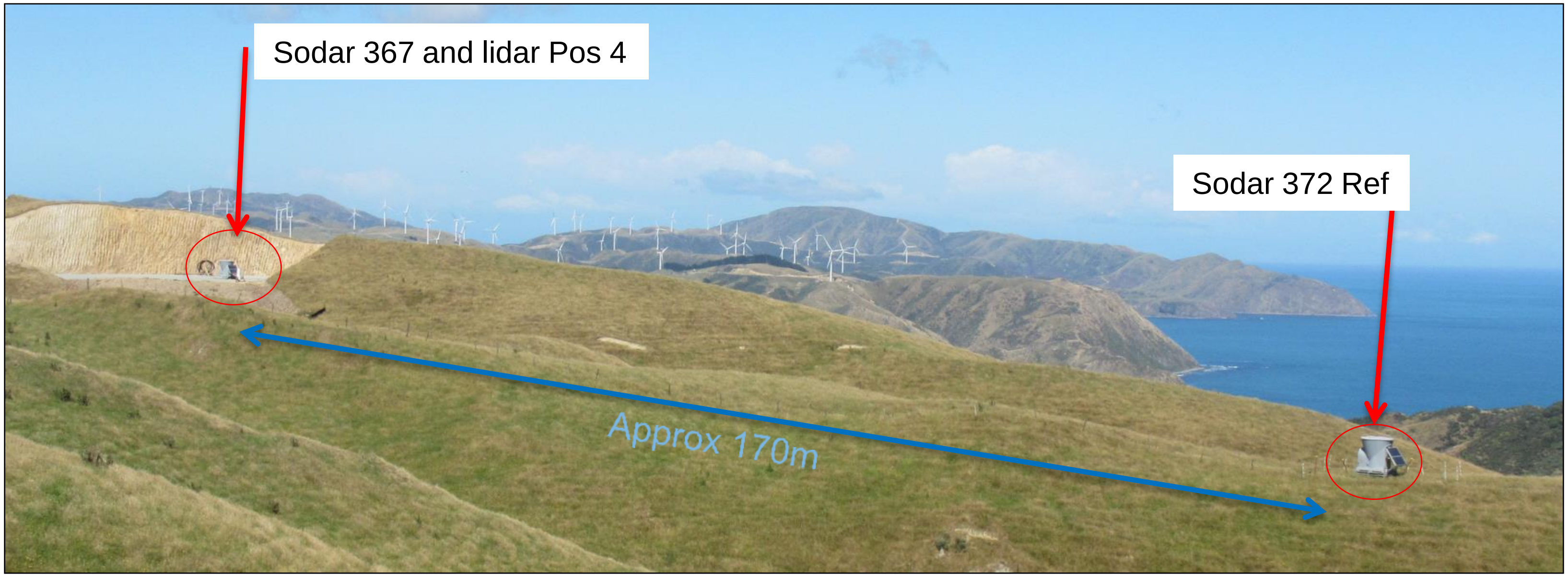
Key considerations

- More data needs to be filtered compared to an anemometer approach e.g. rainfall, background noise, poor data quality/SNR, etc.
  - Results in longer data collection period required.
- Sodar used in this case due to availability of equipment
  - Require synchronisation of sodar units
- Potential to use lidar instead of sodar if available but higher equipment cost
  - Higher data availability and quality expected.
- Complex terrain bias adjustment caused by flow curvature through measurement volume may be required.



Sodar – Synchronisation of Units

- Site calibration – requires two remote sensing units working in tandem.
- Lidars - ZephIR lidars can work in close proximity without interference
- Sodars - Triton sodars however cannot work close together without modification (min of approx 400-500m distance). Potential interference and reduction in quality of the data. Units are to be placed approx 2.0-2.5 rotor diameters apart (approx 170m) as required by IEC standard << 400m.



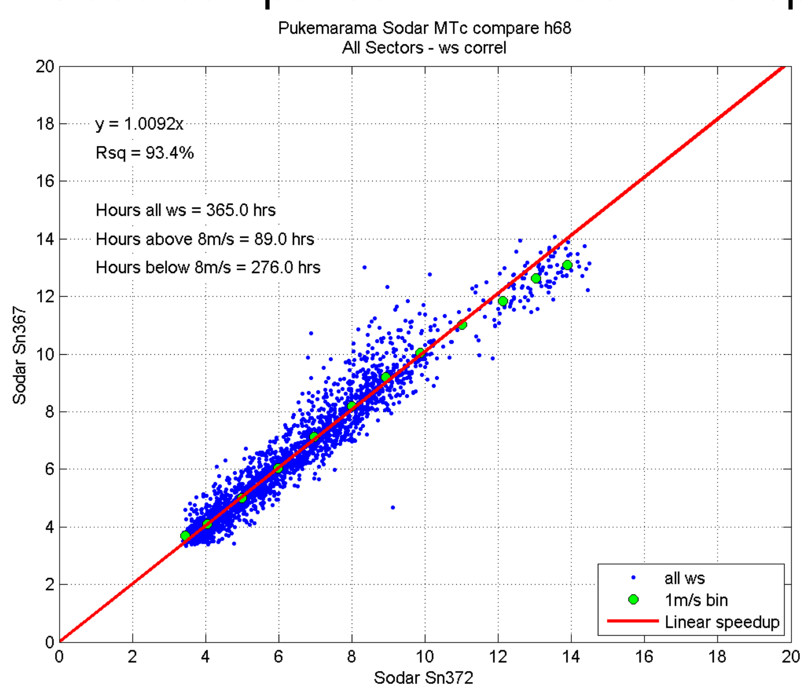
Position 4 site calibration

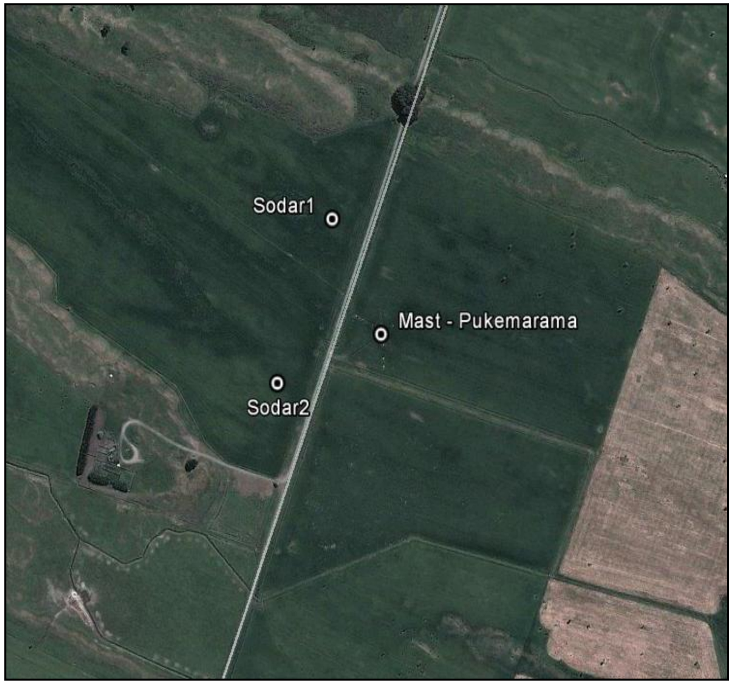
Sodar – Synchronisation of Units

- Solution - set up a communications link between the sodars to stagger the chirps between the two units. Enables measurements to be recorded based exclusively on each emitting unit.
  - Requires a communication package (line-of-sight radio link in this case) and software modification for each unit.
  - Master Unit controls the synchronisation of the Slave Unit.
  - Works over an allowable distance range based on the measurement heights required and the timing between samples.
  - Some potential for variation and slight reduction in sampling for the sodars compared to normal operation.

Sodar – Synchronisation of Units

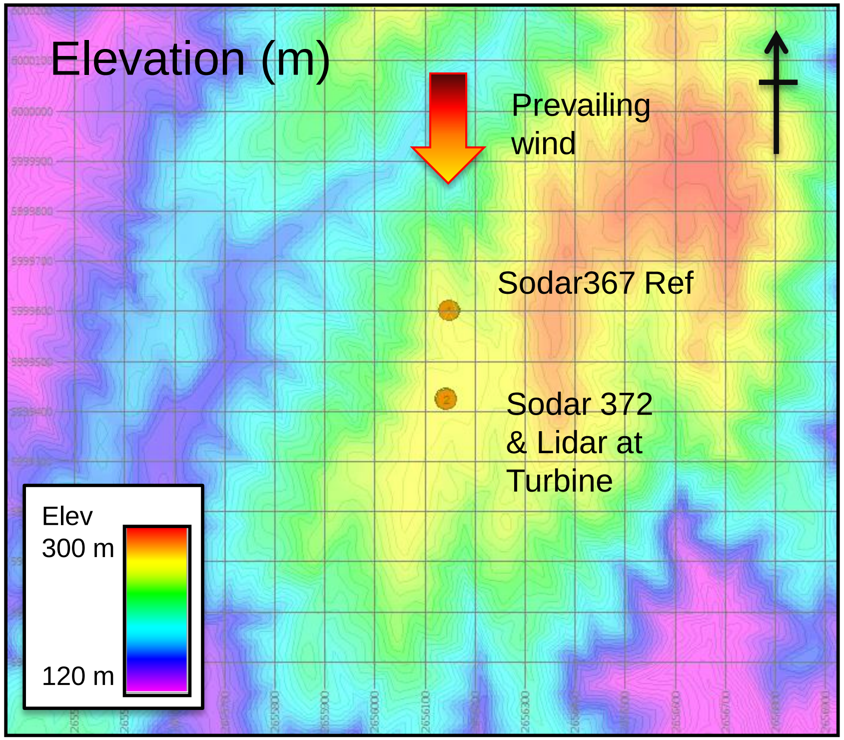
- Testing of prototype modification undertaken in USA and also on a simple terrain low wind site in New Zealand.
  - Testing successful with stable synchronisation between units.
  - Useful comparison between units and also with 80m mast.
  - No noticeable drop in data quality due to two units working in synchronous mode.
  - Test period prior to and after sync modification used for comparison.
  - Good comparison with mast wind speed.





Example A - Position 1

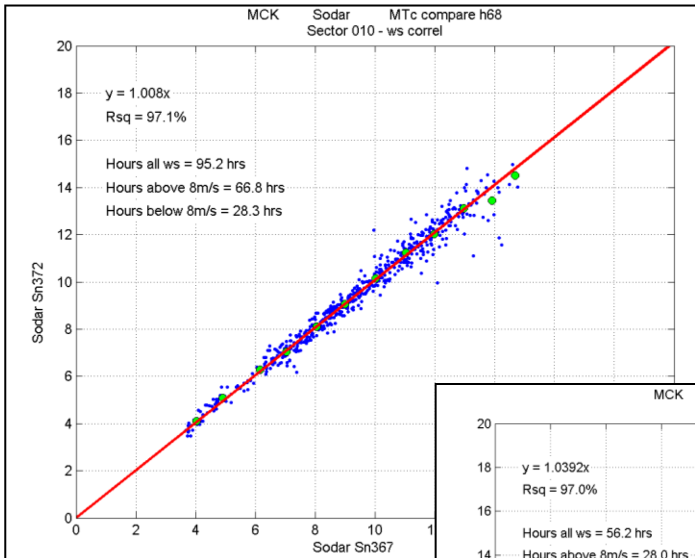
- Units moved to location of first test turbine.
- Complex terrain site with steep valleys.
- Turbine – 68m Hub height 82m rotor diameter.
- Turbine and reference location similar elevations.
- Reference location in prevailing wind direction from turbine.

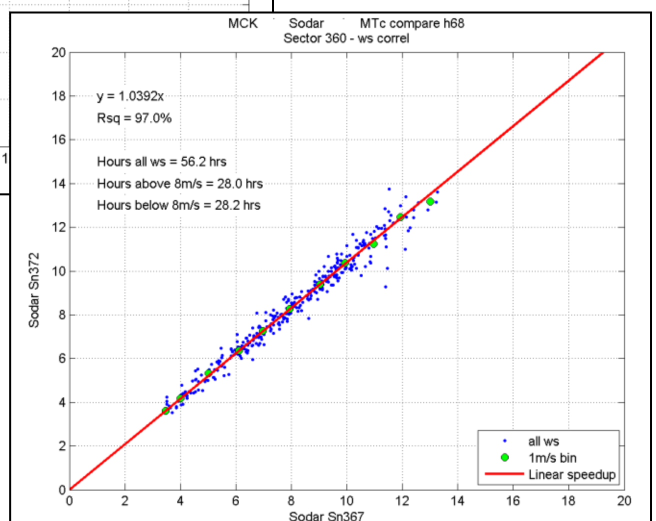


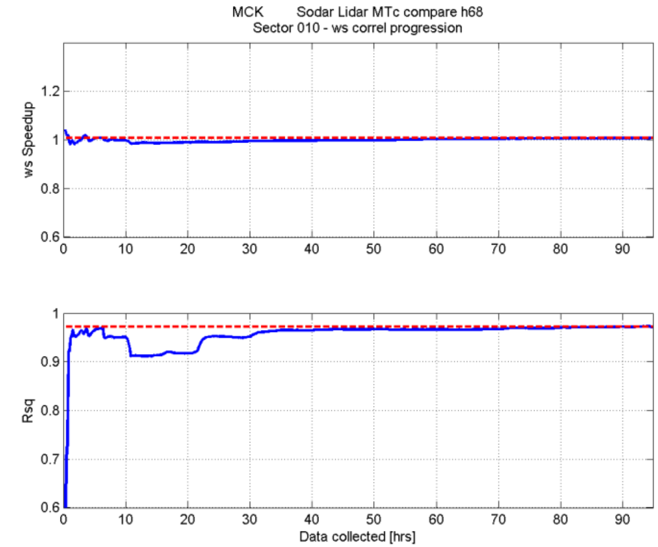
- ZephIR z150 Lidar used for comparison at turbine location
- Complex terrain bias correction calculation using Meteodyn WT
- Data processed into 10 deg sectors
- Based on direction at reference
- Best fit for data tracked
- Ideally at least 24 hours data per sector
    - 6 hours above and below 8m/s

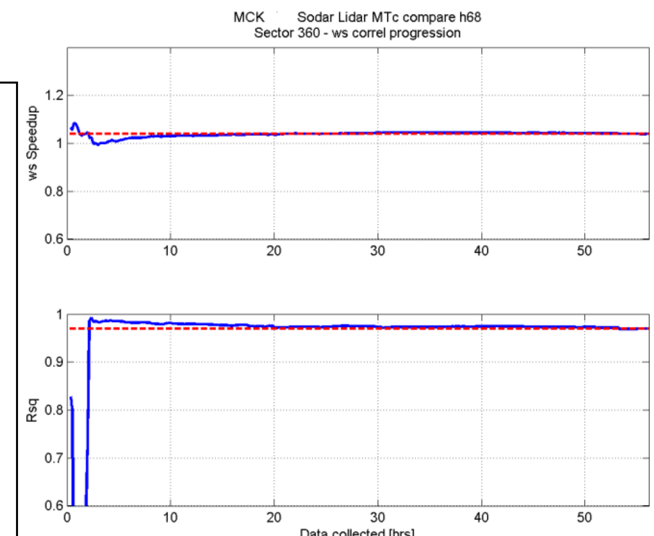
Example A - Position 1

- Good results for prevailing wind direction
- Satisfactory equipment performance
- No construction equipment interference
  - prior to roads and civil works



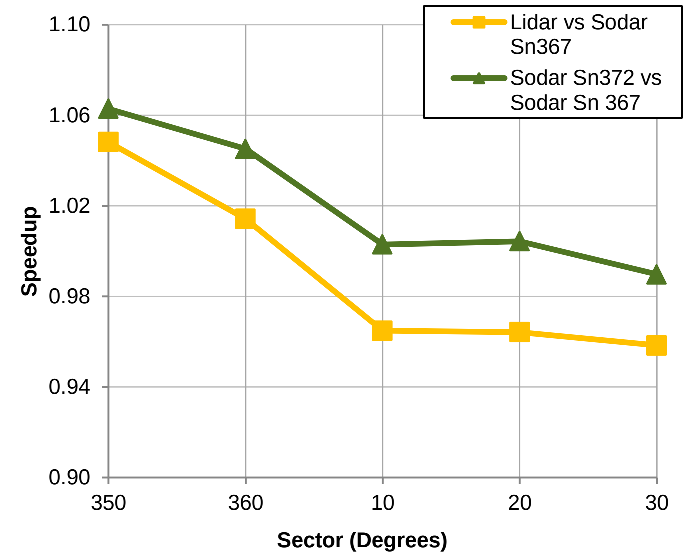


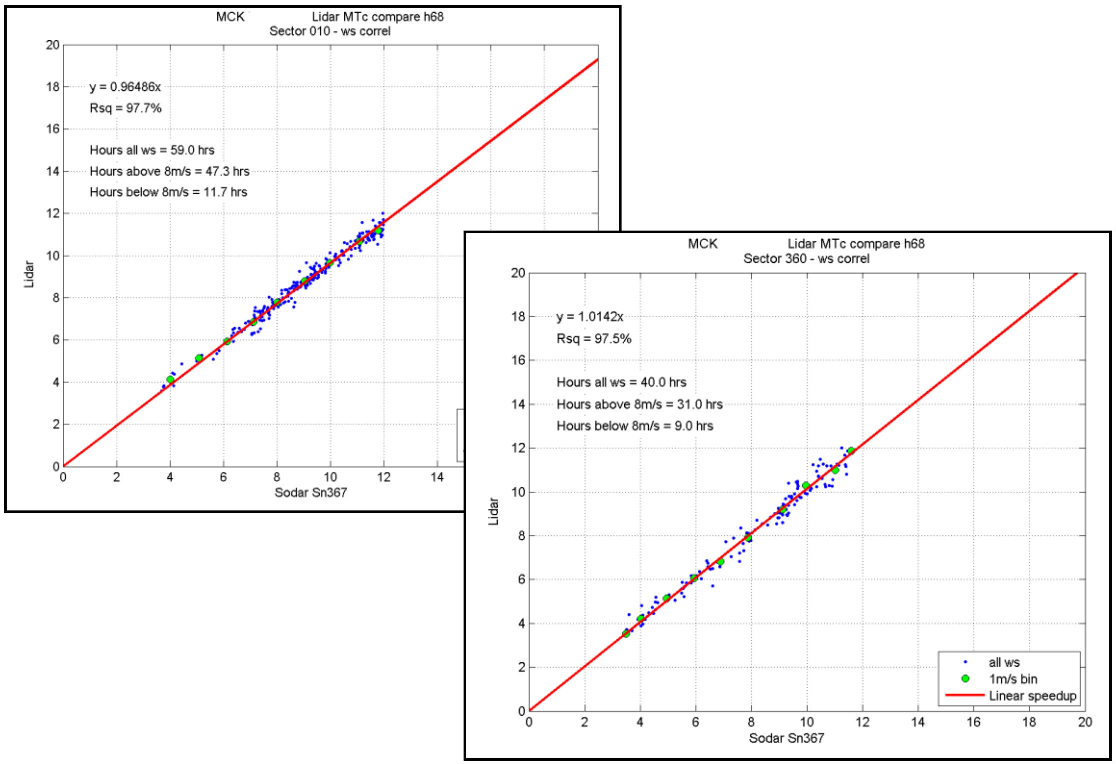


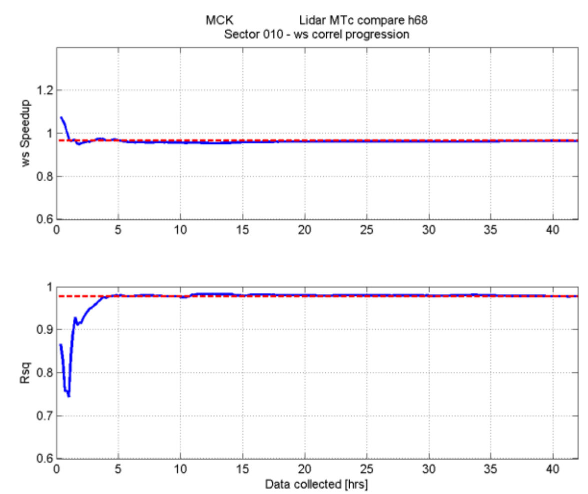


Example A - Position 1 - lidar comparison

- Results for sodar/lidar comparison.
- Similar trends - lidar generally lower speedup.
- Smaller data set - shorter monitoring period.
- Very similar bias correction calculated at adjacent sodar/lidar location.

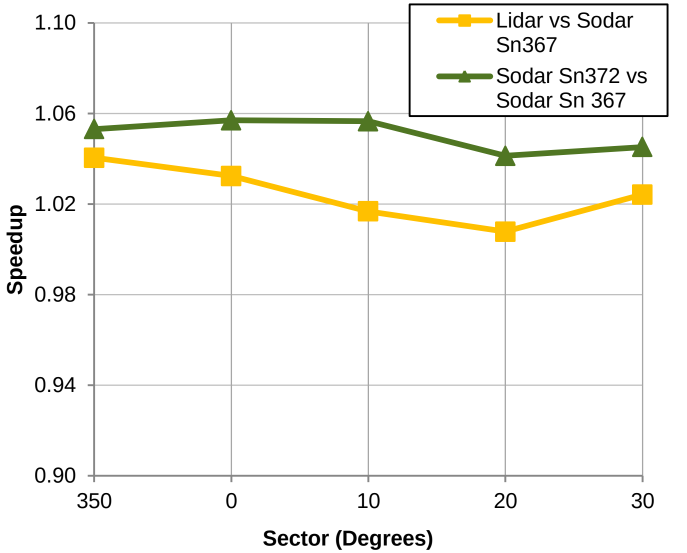


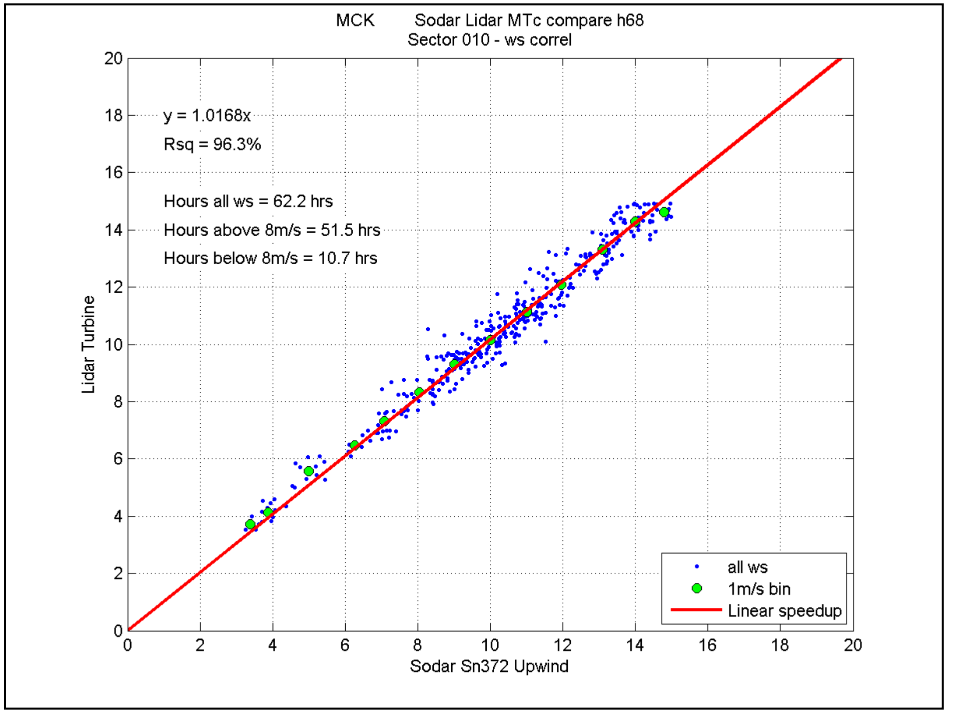


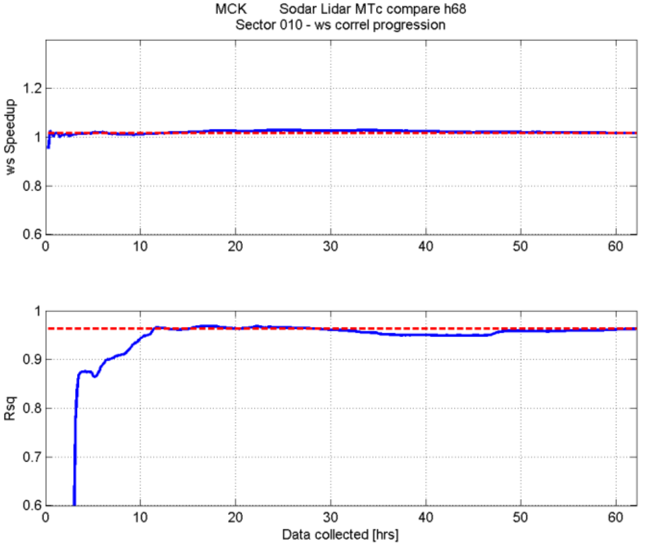


Example B - Position 4 - lidar comparison

- Results for sodar/lidar comparison.
- Similar trends - lidar generally lower speedup.
- Smaller data set - shorter monitoring period.
- Very similar bias correction calculated at adjacent sodar/lidar location.

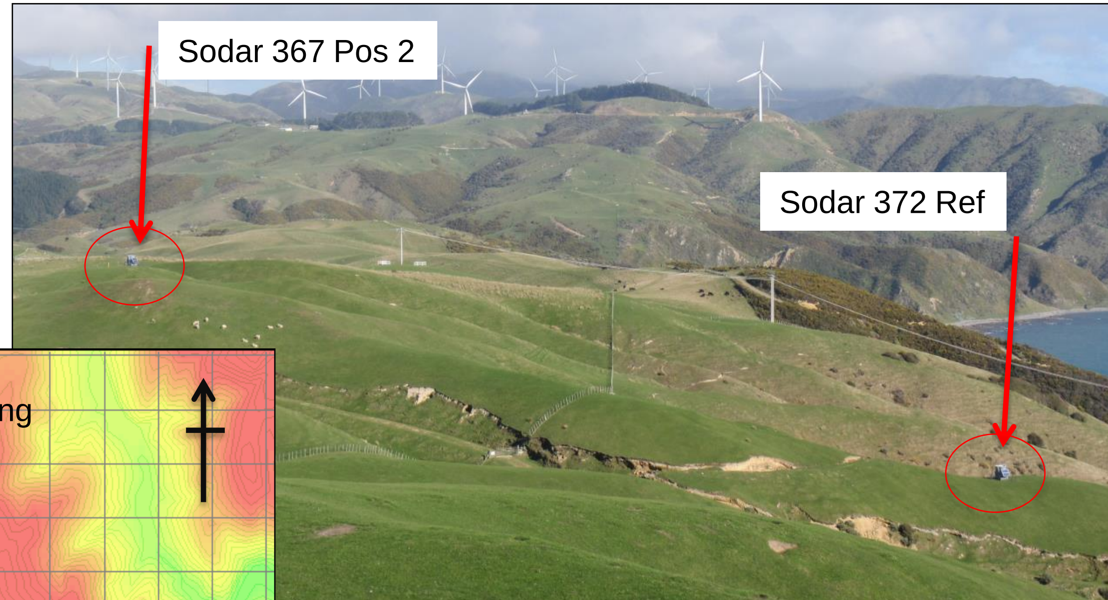


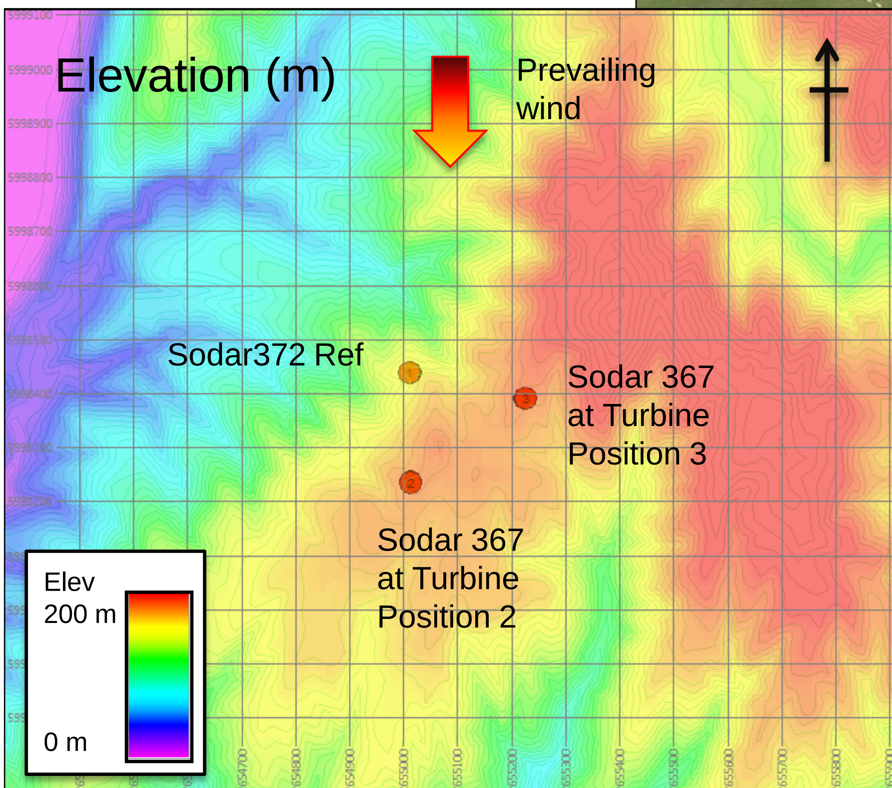




Example C - Position 3

- Two turbine locations
- One reference location
- Complex terrain

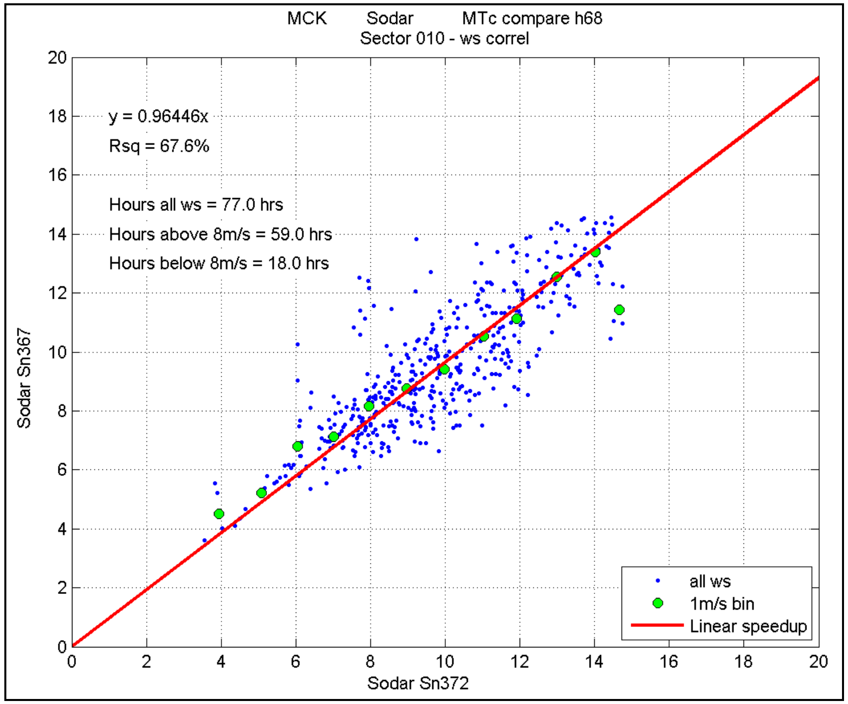


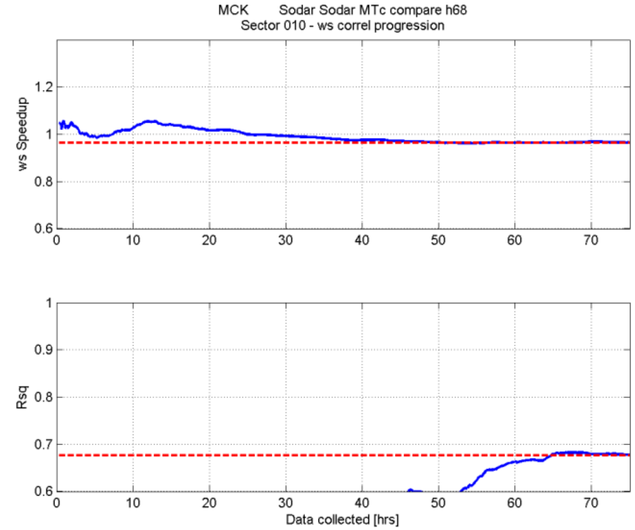


- Greater variation in terrain
- Construction equipment in use
  - Greater impact on Pos 3
- Line of sight issues
  - Impact on radio transmission for Pos 3

Example C - Position 3

- Position 3 poor results
- Poor correlation
- Poor convergence to best fit
- Not suitable for use
  - Poor measurement result





Site Calibration - Challenges

Siting

- Complex terrain – strong wind climate.
- Site access, wake free and location.
- Equipment placement prior civil works vs. final turbine location and elevation.
- Timing of testing,
  - Prior to site civil works, during, after civil works complete.

Equipment

- Thorough testing and rugged design for high wind environment required.
- Spares required for rapid repairs during site calibration phase.

Environment

- High winds – can damage equipment and reduce data availability for sodar.
- Equipment - damage due to animals/stock. Fence required but will increase noise around sodar in high wind conditions.

Recommendations

- Align sodar so main beams are not aligned with other sodars or turbine location.
- Sodars need to be located to minimise wind noise around the unit.
  - Sheltered location vs turbine position and ideal reference location.
  - Minimise or remove fencing, no tight wires or straps.

Lidar generator trailer

- Co-ordination with construction programme at an early stage to minimise nearby construction noise.
- Using two lidars may also be an option.
  - High wind data availability
  - Not dependant on background noise at turbine location.
- Further analysis of data sets required for confirmation of calibration results – Preliminary results show suitable results at 4 out of 5 locations so far!