NEXT-GENERATION ACOUSTIC WIND PROFILERS

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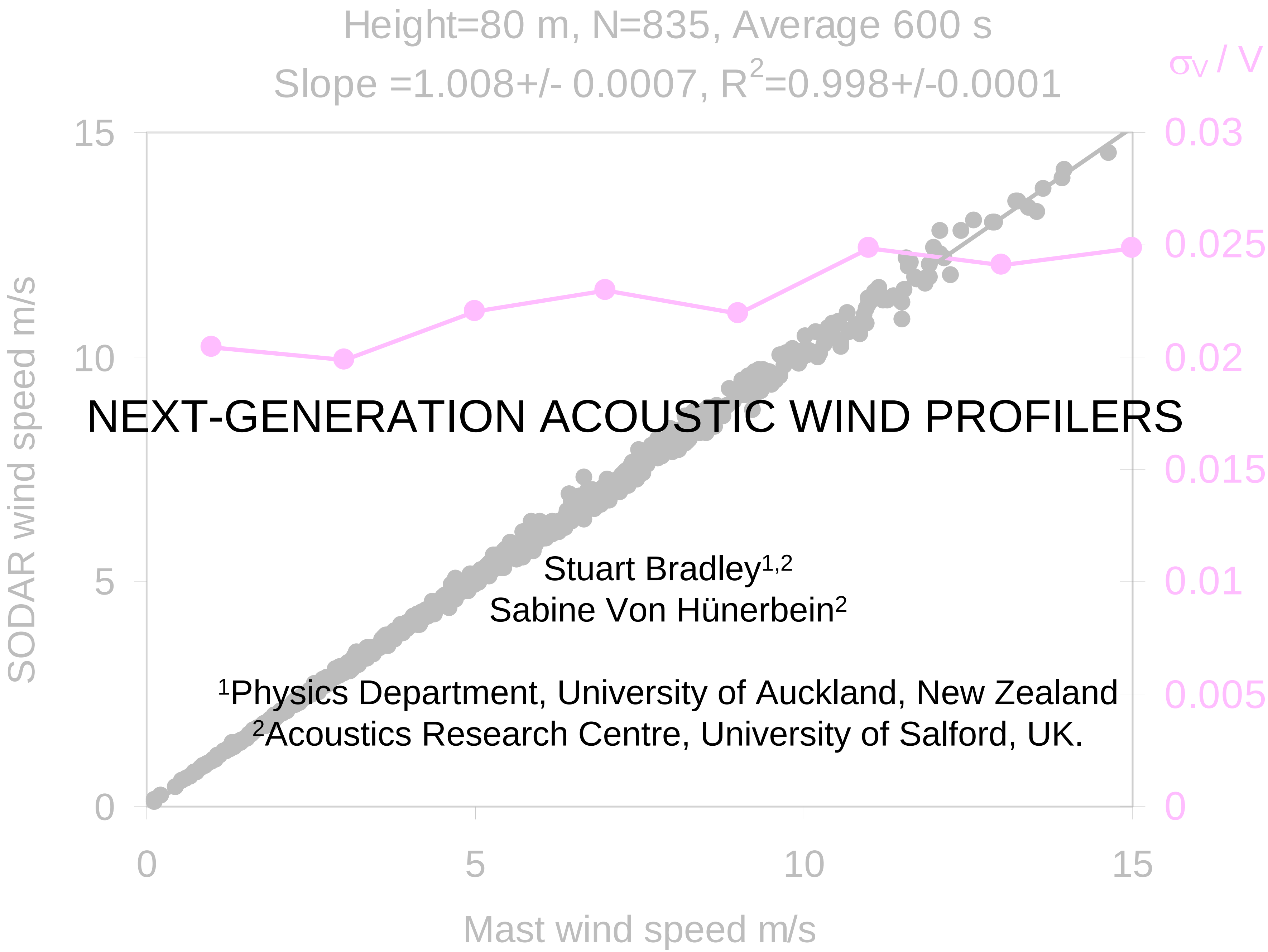

The Two Existing Technologies

LIDAR

- Scatters light from natural particles
- Lowest height ≈ 40m
- Highest reading ≈ 150m
- Averaging time ≈ 10 min
- Cost ≈ €150 k
- Maintenance: currently high, longer term unknown

SODAR

- Scatters sound from turbulent temperature variations
- Lowest height ≈ 10m
- Highest reading ≈ 1000m
- Averaging time ≈ 10 min
- Cost ≈ €35 k
- Maintenance: currently low and well-established

A careful, unbiased field trial

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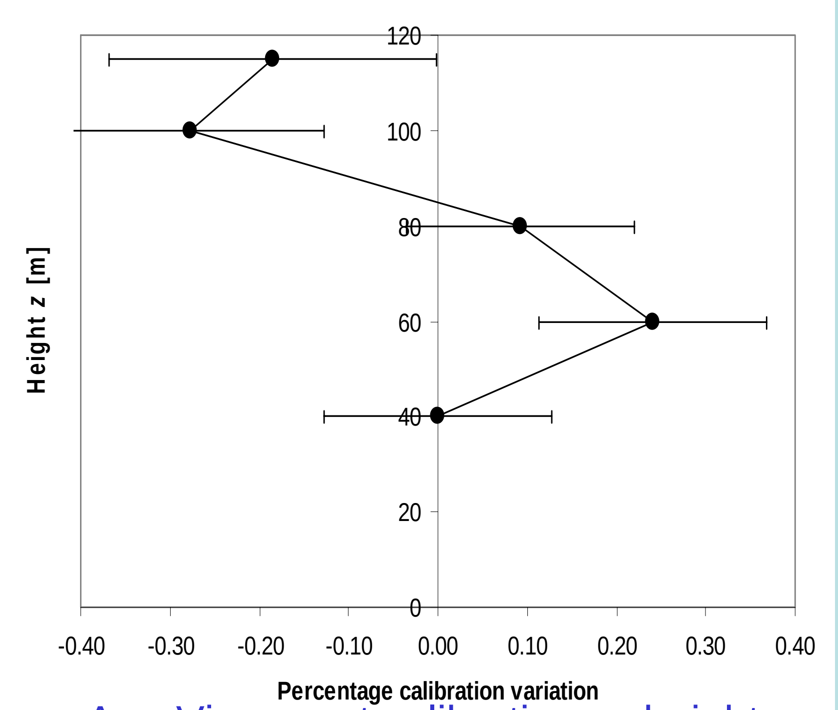
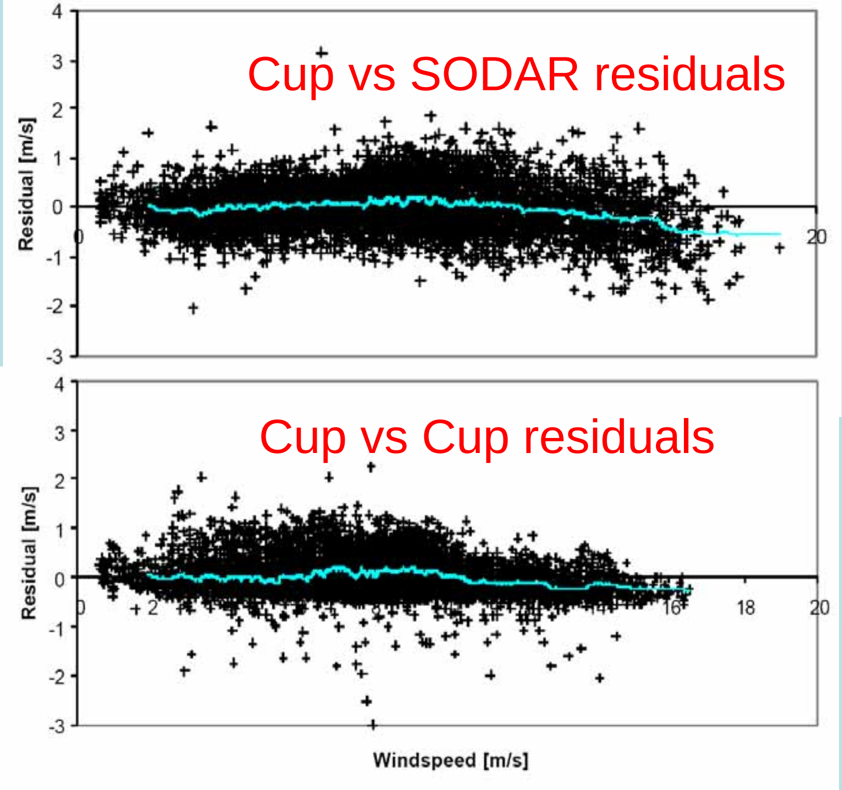
Calibration uncertainty ±0.1%
Variation with height ±0.3%



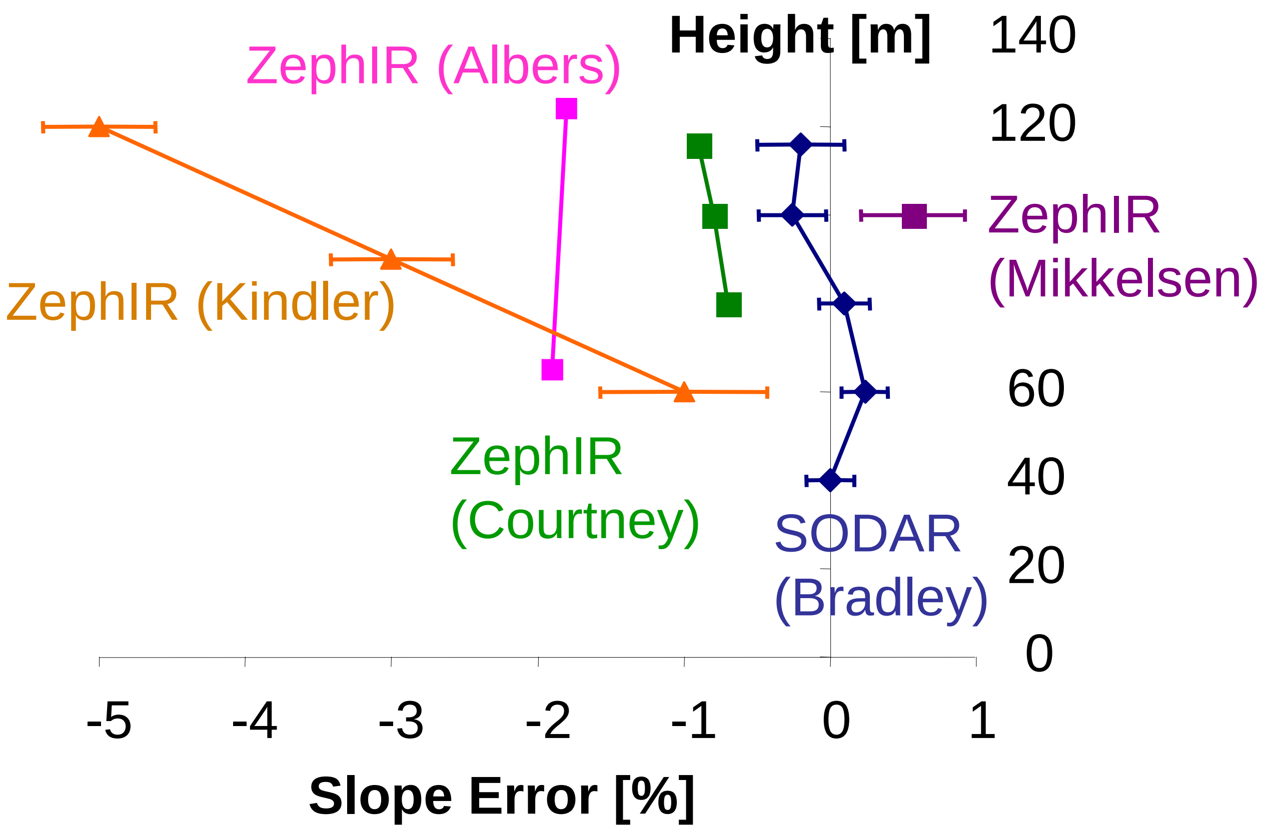
AeroVironment calibration vs height

Cup-cup variation equivalent to SODAR-cup variation



LIDAR vs SODAR Performance?

Difficult to find *independent* comparisons which compare LIDARs and SODARs under similar conditions !



Are Comparisons Reliable?

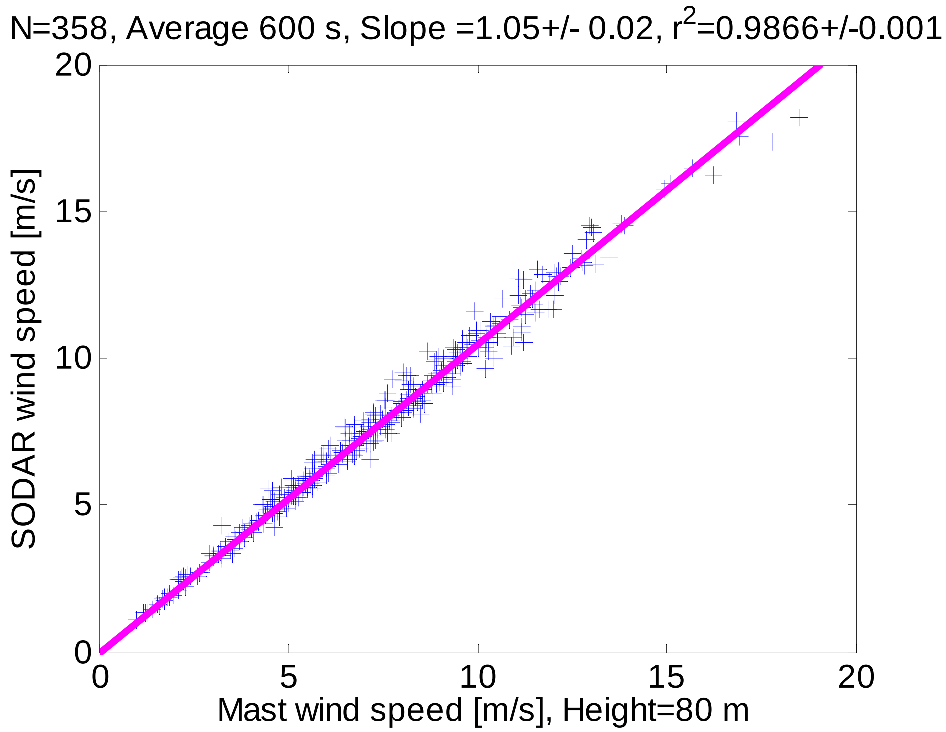
- Many comparisons and field tests are done by companies or institutions which have **major financial commitments** (ownership of instruments, dependency on grants, development contracts, etc), particularly with the more expensive LIDARs. This can mean they concentrate on the product which has the greatest financial impact on *them*

- Many comparisons and field tests **do not give enough statistical information** to allow solid judgement to be made

E. g. Correlation: $\sigma_{R^2} = 2(1- R^2)/N^{1/2}$

R^2	$N = 200$	$N = 400$
0.97	0.9658- 0.9742	0.967- 0.973
0.98	0.9772- 0.9828	0.978- 0.982
0.99	0.9886-0.9914	0.989- 0.991

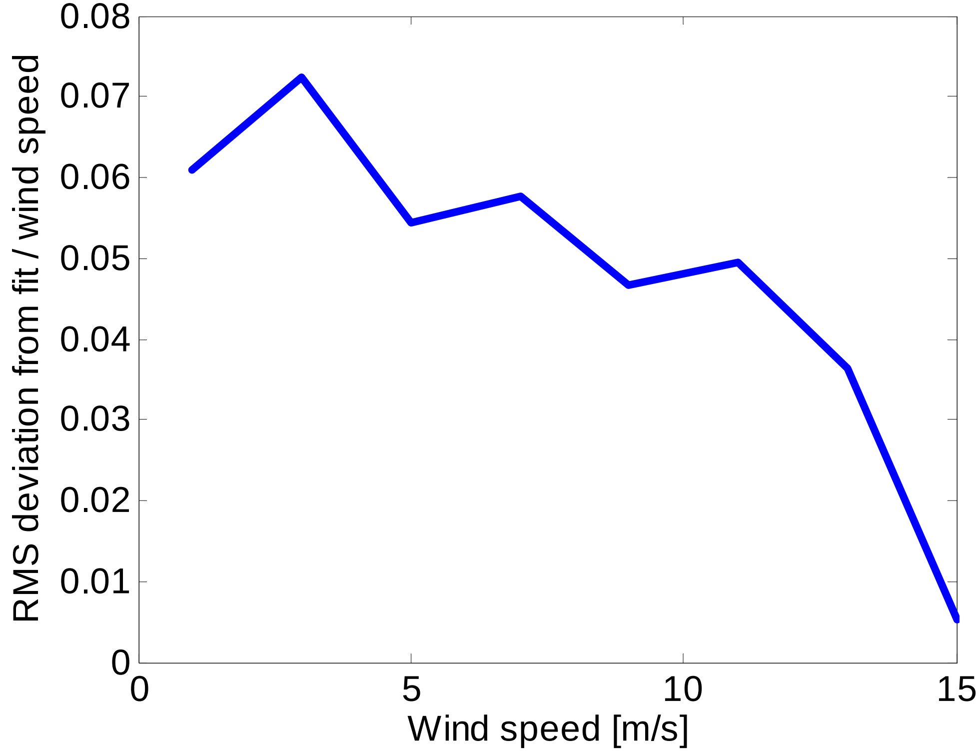
E. g. Typical remote vs mast output



Really important

- Fit a straight line through the origin (why expect non-zero remote wind when actual wind speed is zero ?)
- Number of data points N (affects uncertainties)
- Averaging time
- Height

Root-mean-square deviation



- Is correlation coefficient R^2 important? (what will you do with it?)
- Are instrument calibration details important? (as long as they are stable)
- The *important parameter* is the **most likely size of wind speed error**

What does the extra €110k buy you ?

A LIDAR has

- A smaller (but heavier) box
- Quiet operation (but with turbine noise and distance from housing, who cares?)
- Marginal increase in R^2 (perhaps)
- Marginally improved accuracy of wind speed ??
- Increased maintenance costs (probably)
- Decreased performance in rain and fog
- Higher power consumption
- No data below 40m or above 150m
- Large height steps (poor vertical resolution)

History and What is Next

- Big advance in SODARs in 1980s with multi-speaker/microphone phased-array technology
- Big advance in LIDARs in 2000s with fibre-based lasers: directly impacting on wind energy
- SODAR developers are only now responding to the impact of LIDARs in wind energy: expectation from new, intense, R&D is another “technology leap”

SNODAR

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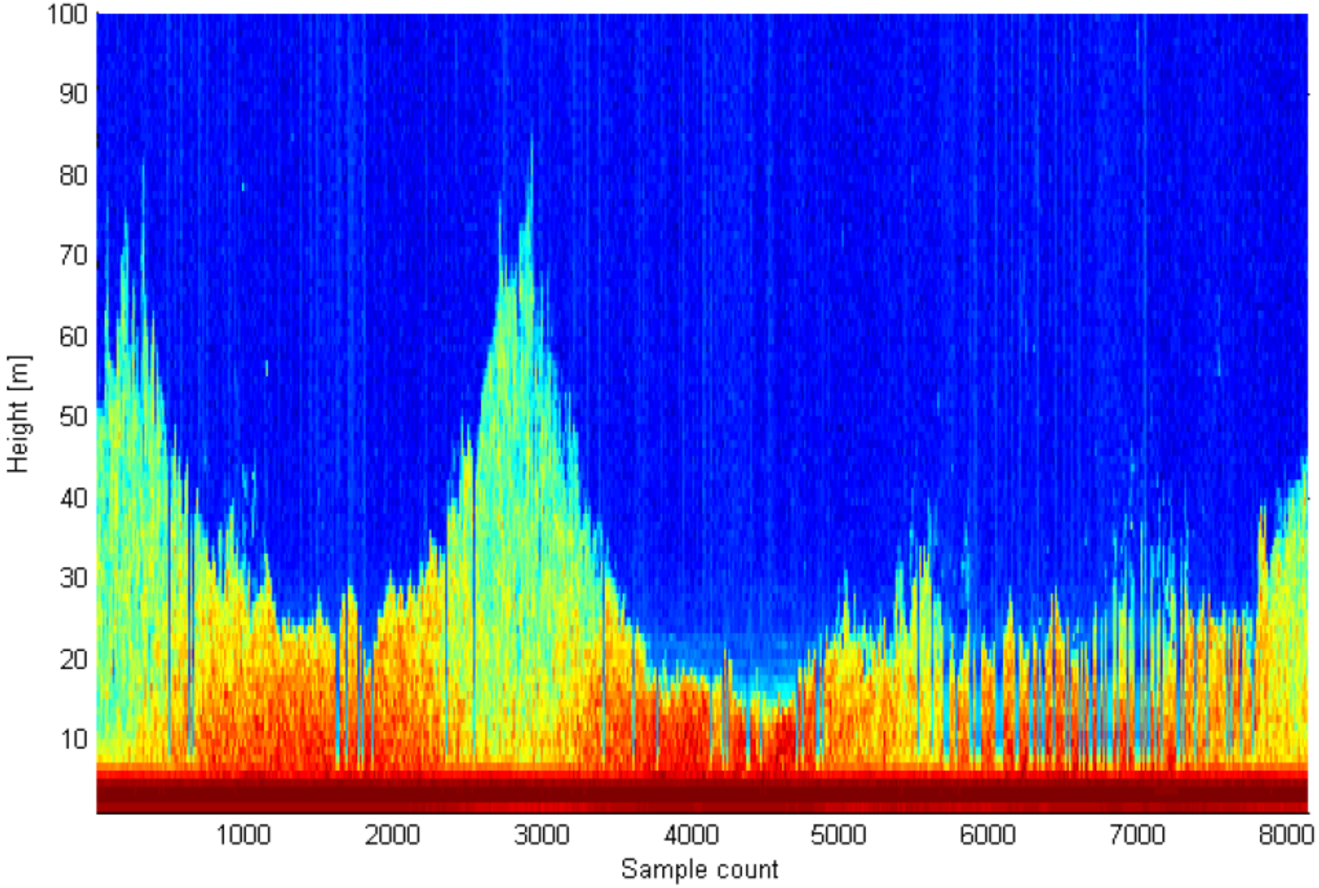
- 1m resolution
- Autonomous operation through Antarctic winter



SONDE

- Long (several seconds) FM-CW acoustic pulses
- Huge increase in signal strength (30 dB)
- Wind speed estimates every few meters, and every few seconds
- Some remaining technological challenges
- Current work on real-time tracking of aircraft wing-tip vortices (during landing and take-off)

New Acoustic Wind Profilers

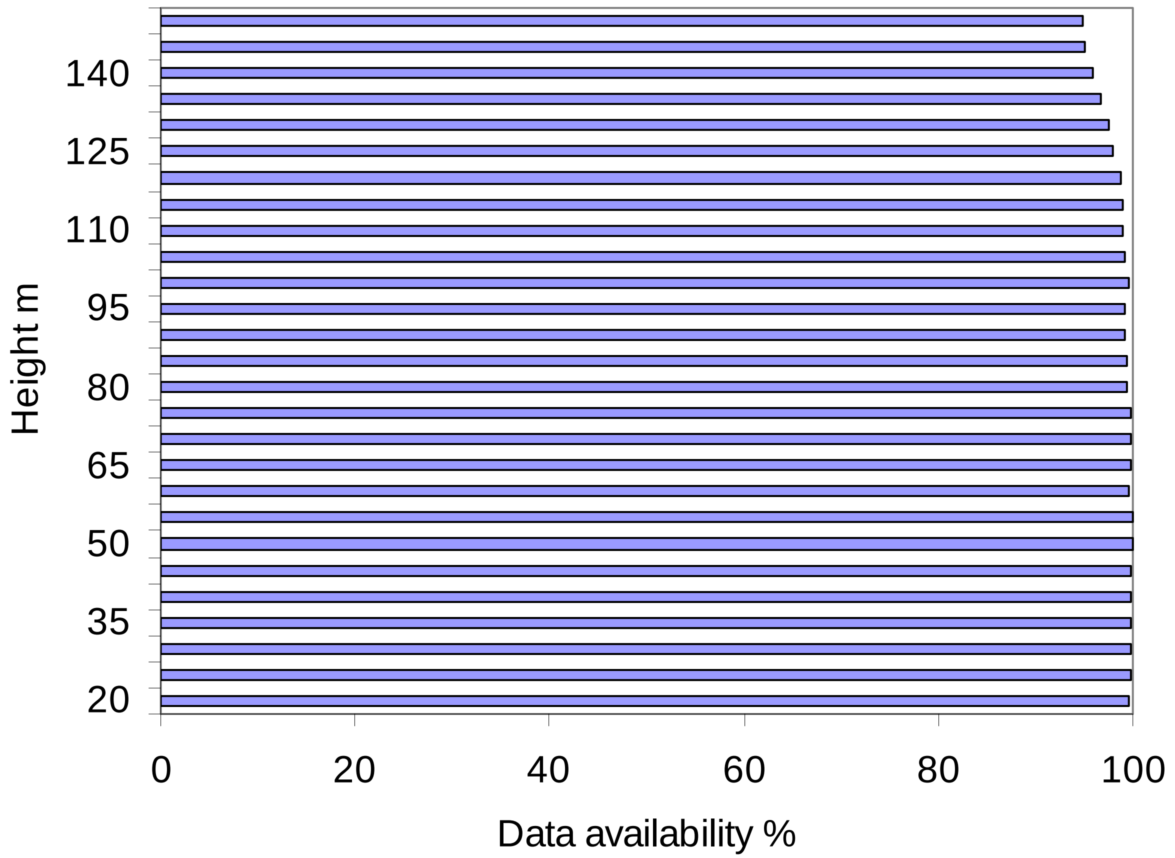
Triton

- Similar acoustic design to long-established ASC (AeroVironment) and ART SODARs
- Solar powered

AQ500

- Innovative acoustic design (3 dishes, 3 tilted beams, small footprint, reduced diffraction)
- Generally needs additional baffles

Data availability (example from an AQ500)



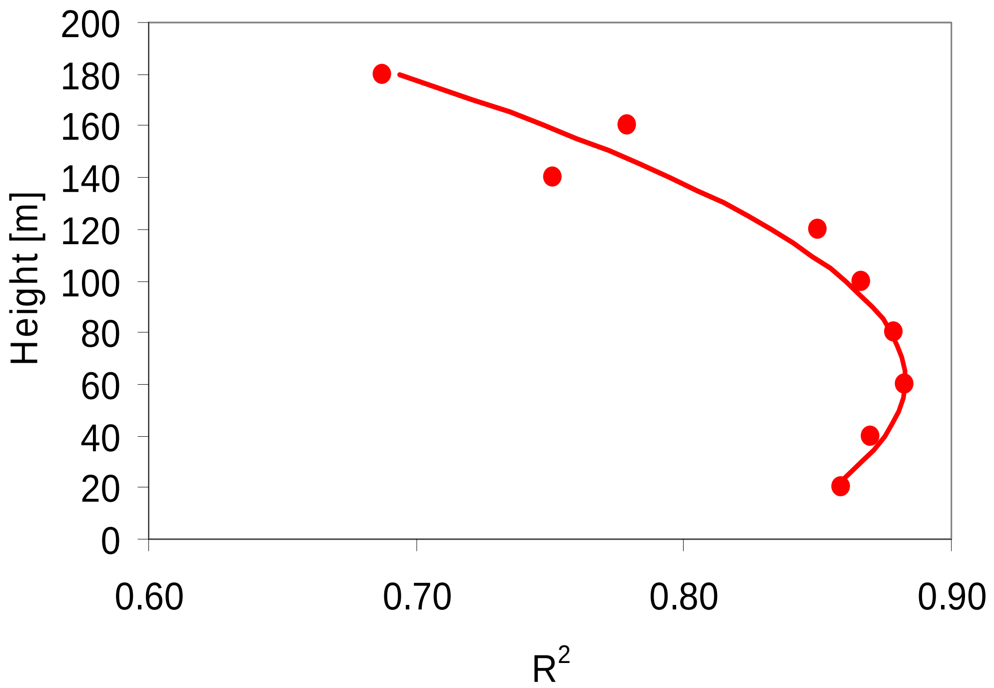
Where will Improvements be Made?

For SODARs:

- Clutter (ability to operate near masts etc, quieter)
- Smart signals (to give shorter averaging times, lower rms errors)
- Lower power
- Compact (smaller footprint)
- Better operation in rain

Acoustic camera picture of diffraction

Beam design



Plot of measured and modelled correlation between winds measured by different beam combinations *on the same 5-beam SODAR*

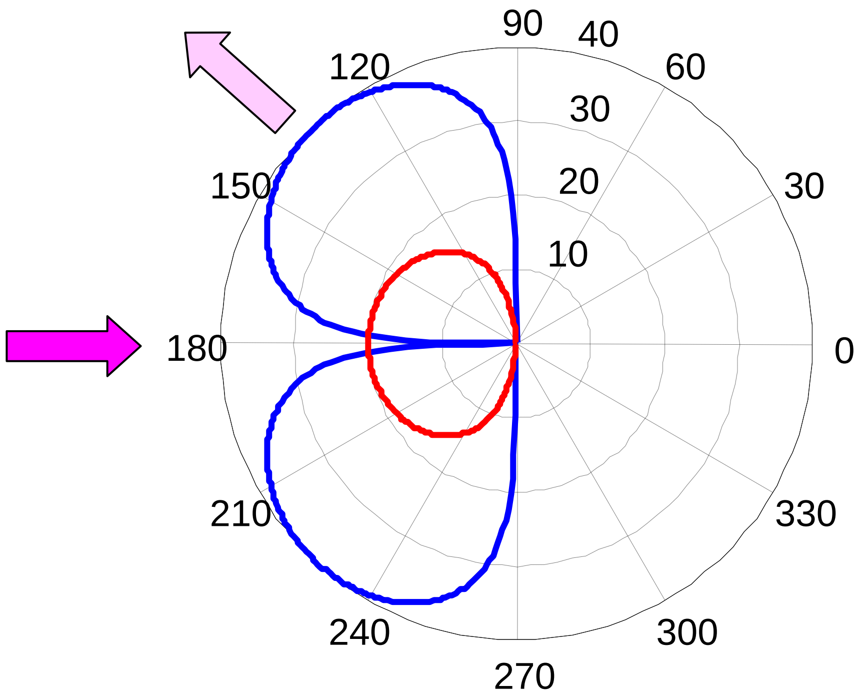
At 60m, the time taken for air to travel from one beam to another (at the wind speed during these measurements) is equal to the time between acoustic pulses

The shape of this curve is a measure of the spatial correlation for wind

Bistatic SODARs

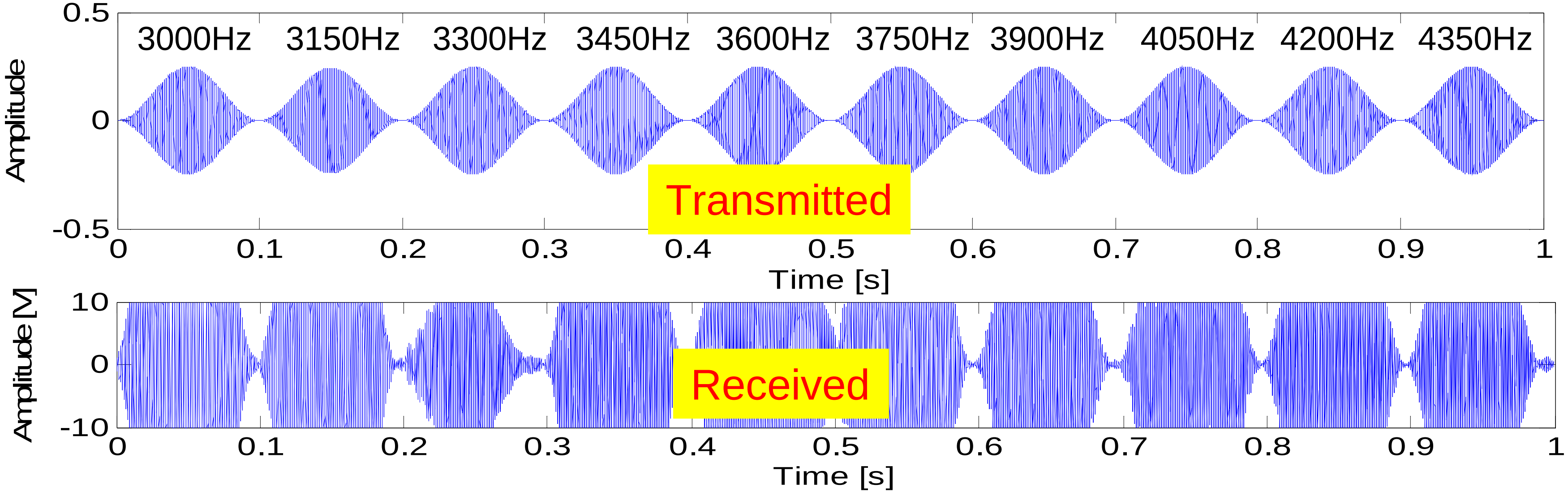
- Useful to separate transmitter and receiver ('bistatic') so that turbulent velocity fluctuations are also measured

- The 'break-even' angle is about 11°: this would require separating the transmitter and receiver by about 20m



Power dB.
Blue=velocity fluctuations,
Red=temperature fluctuations

“Piccolo” Bi-Static + Smart signals



- Continuous cycle step-chirp
- Unfortunately, the *direct* signal saturated all channels so all useful data is lost during those periods (it needs acoustic baffles)
- However, beam-forming for z = 32m, picks up the gaps at 0.3s, 0.4s, …,0.9s. Adding resulting power spectra gives 8 dB improvement for SNR of the 3000 Hz signal. This is a very useful increase!

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The Next-Generation SODARs

- Will look different (smaller, new acoustic design)
- Will be quiet, except when alongside
- Will sound different (smart signals)
- Will be solar-powered
- Will clearly surpass current LIDAR performance

Summary

- Next-generation SODARs, with very superior performance will emerge in the next 2-3 years
- The design challenges are ***not*** extreme
- In an increasingly recession and risk-averse financial environment, the business case for SODARs is strong