Lidars – better than metmasts?

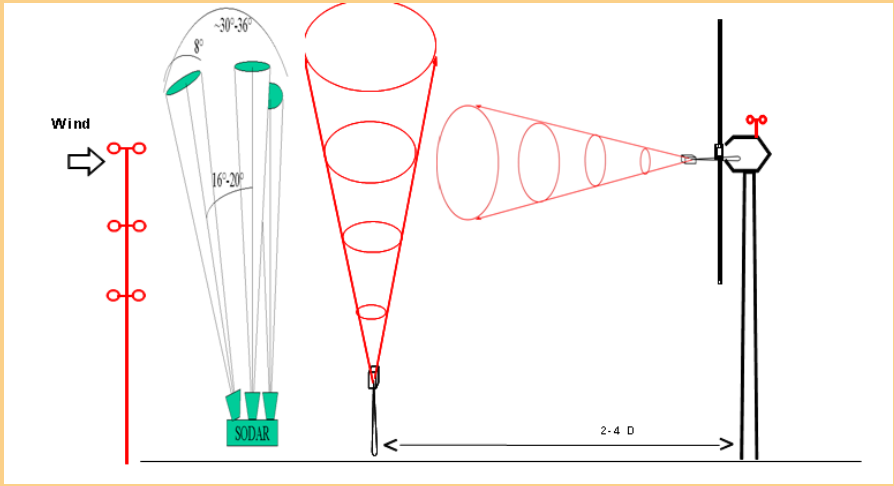
Overview

- WP6 essentials
- Lidar state-of-the-art
- Lidar vs metmast
- Conclusions

WP6 at a glance - topics

SODARs and LIDARs (=Remote Sensing =RS)

Calibration methods
Improvements
Bistatic SODARs
Mast comparisons – flat and complex terrain
Error predictions in complex terrain
Sensing turbulence
Nacelle mounted lidars
Power curve measurements



Introduction of RS to IEC 61400-12
Aerosol statistics

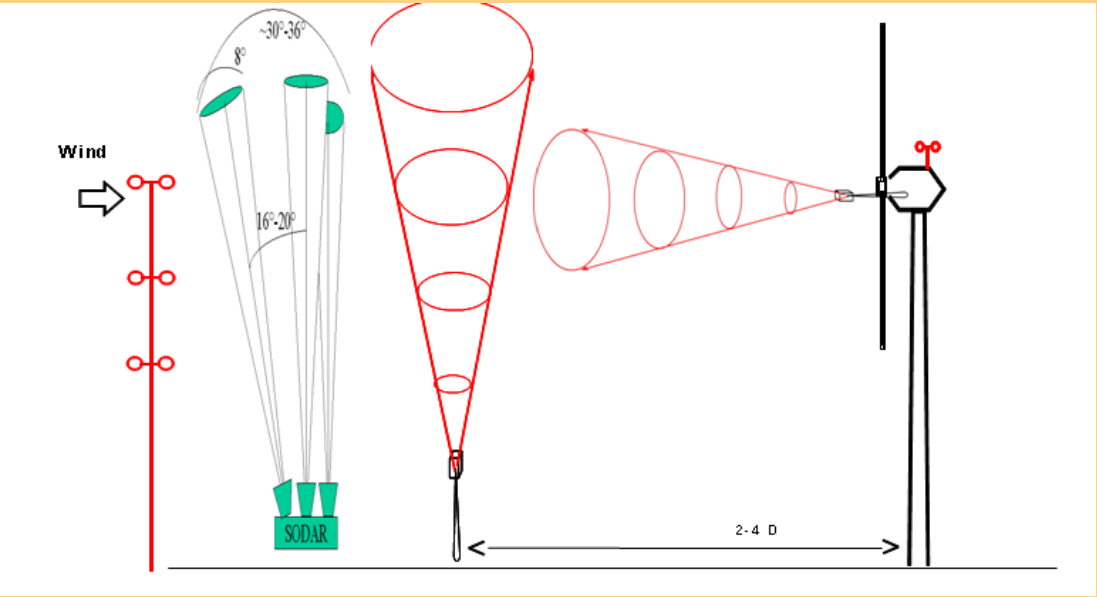
WP6 at a glance - participants

- Risø DTU (WP leader)

- CENER
- CRES

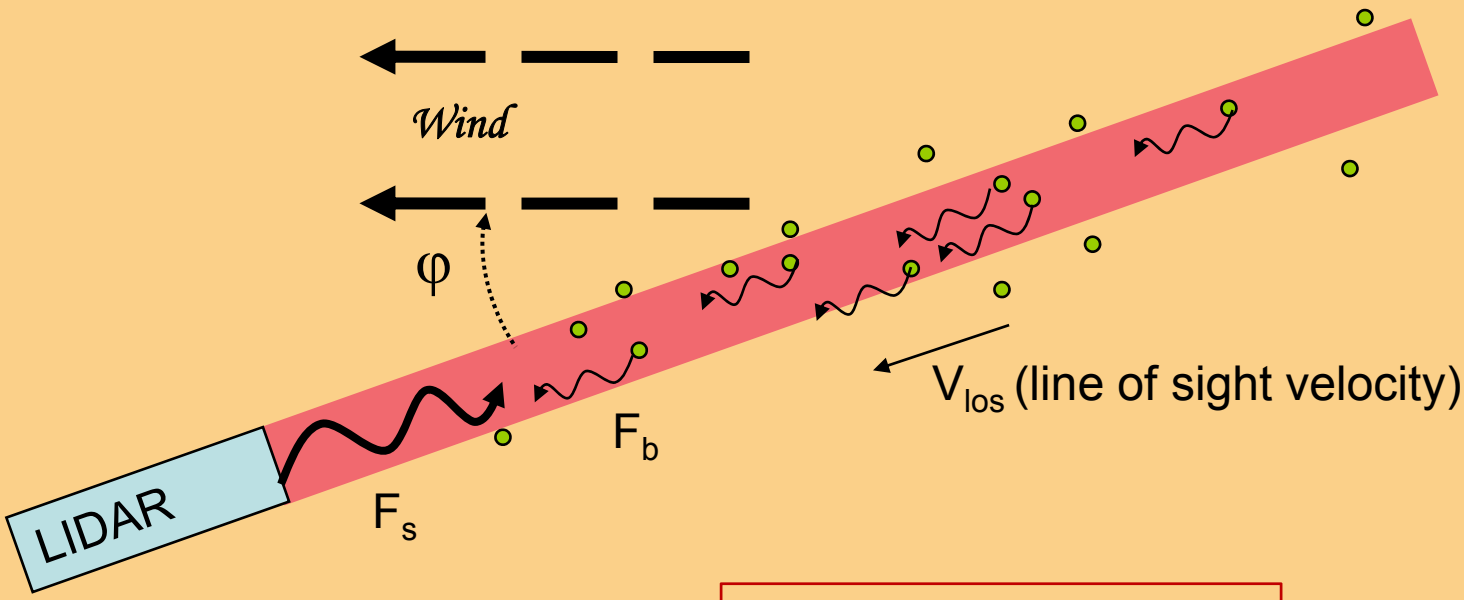
- University of Salford
- University of Auckland

- Vestas
- QinetiQ



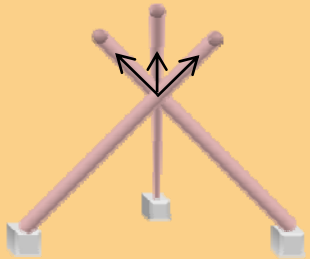
Lidar – state-of-the-art

Basic measuring principle

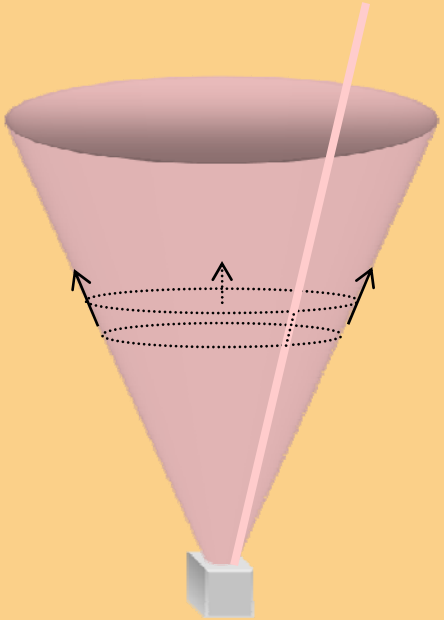


$$F_s - F_b = 2\,V_{los}/\,\lambda$$

Combining line-of-sight speeds to obtain the horizontal wind speed.



Ideal, no assumptions needed



Practical, we need to assume that the flow is homogeneous

Different lidar types

Leosphere WindCube™

Pulsed

Range-gated

Simultaneous heights

Fixed probe-length

Natural Power ZephIR™

Continuous

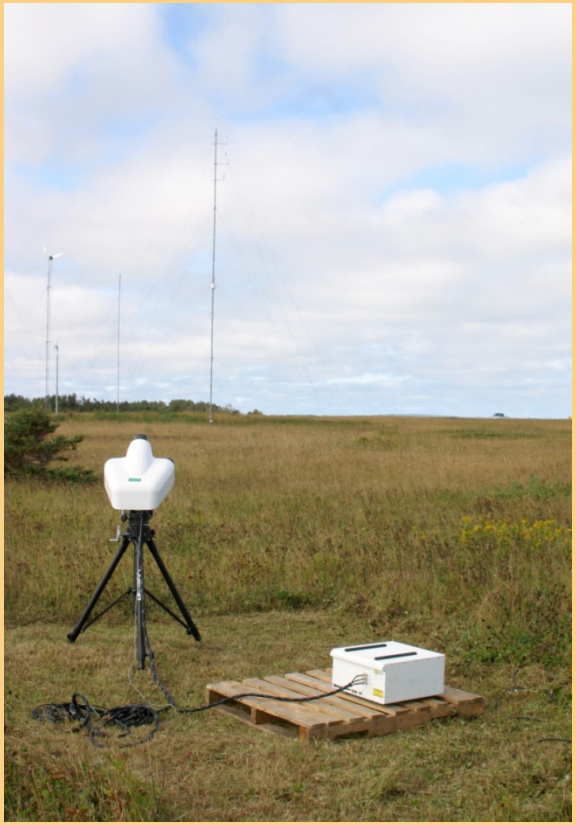
Focused

Sequential heights

Probe-length f(H^2)

Newcomers

Gallion



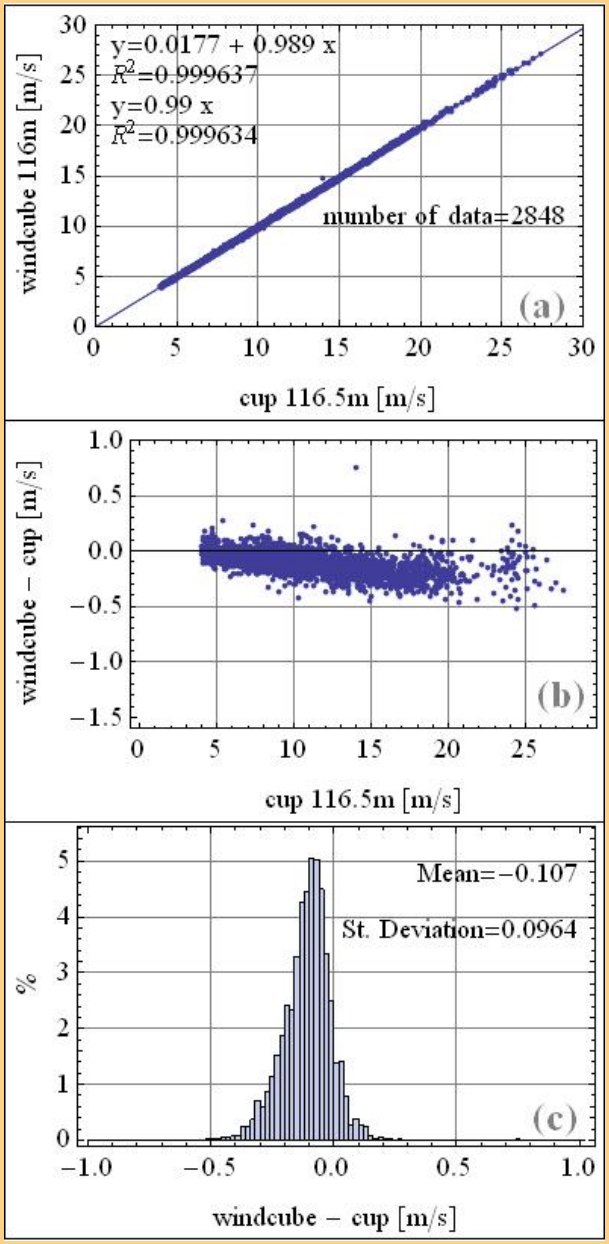
Vindicator

Good lidars are getting accurate - in flat terrain!

Best lidars are within ±1.5% of traceable cup (for the heights we can test).

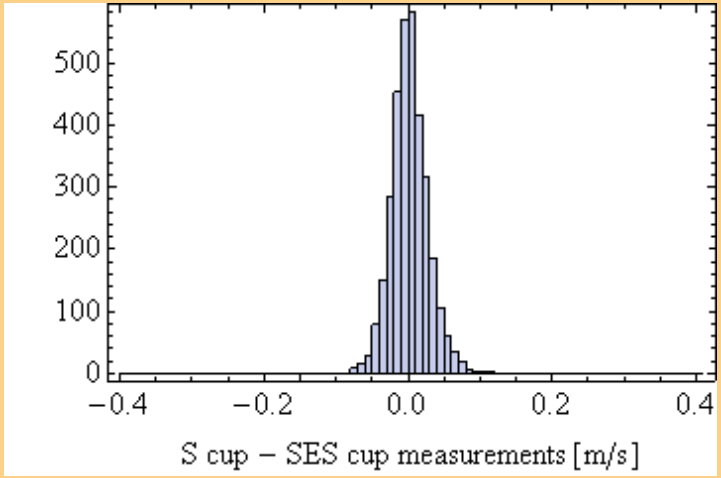
Very low noise

Cup anemometer calibration and cup-mast mounting uncertainties are the limiting constraints for assessing lidar accuracy.

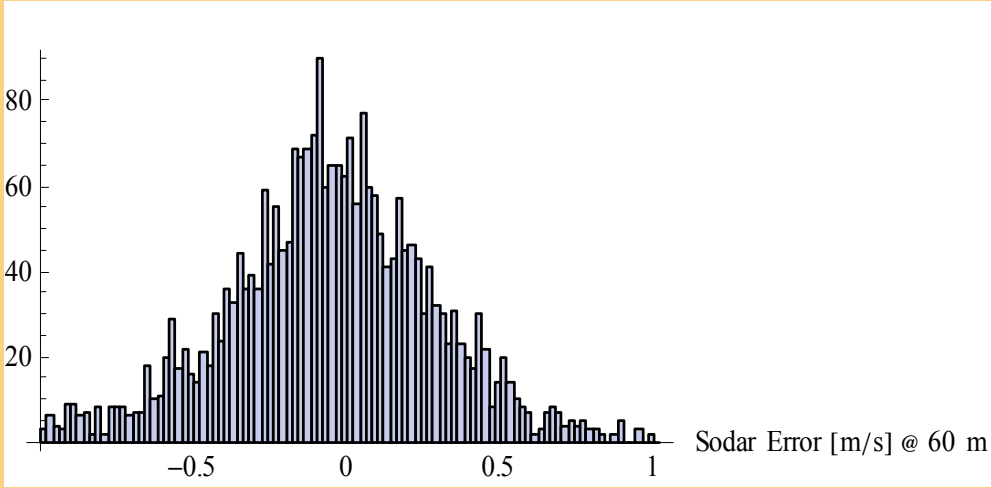


Measurment results for different tested sensors - at 60 m height

Cup to cup

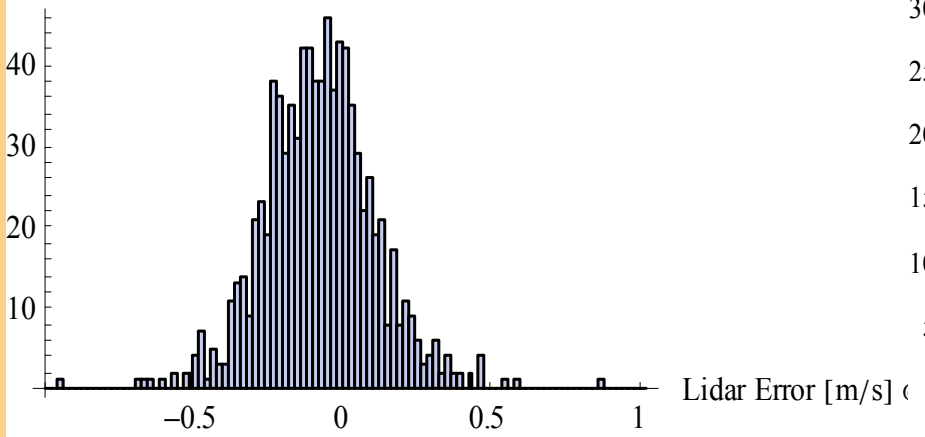


Scintek 2004



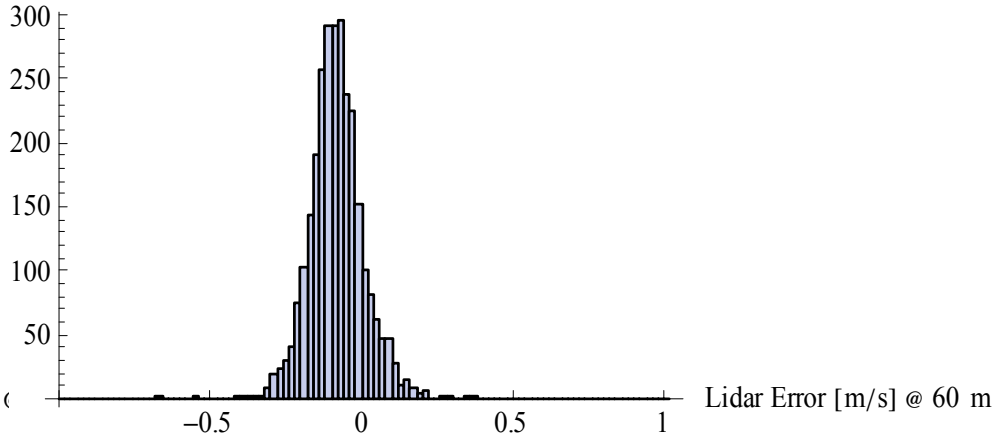
Scintek mean -0.08, STDEV: 0.37

Zephir 2009



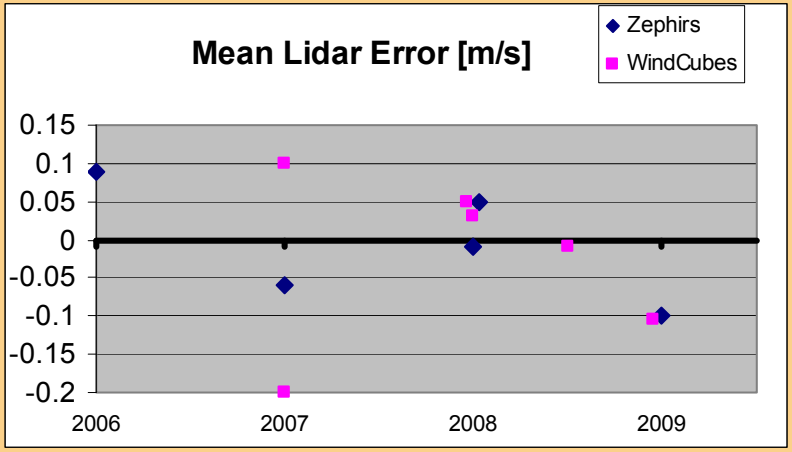
Zephir mean -0.08, STDEV: 0.18

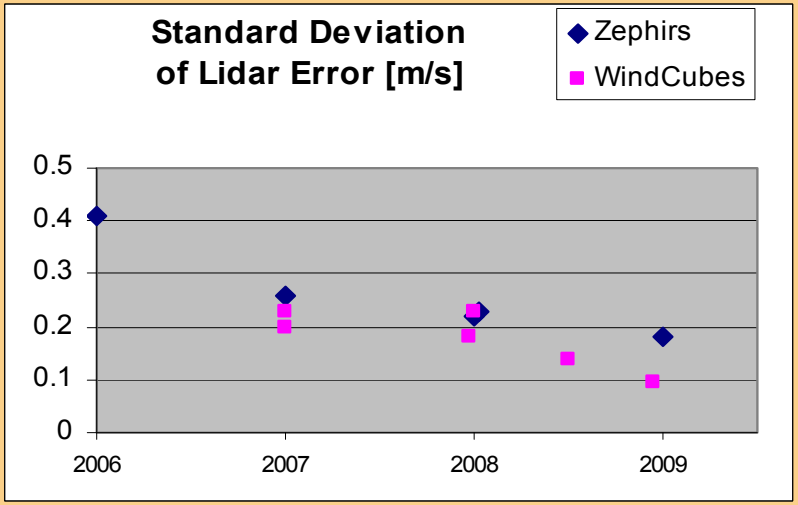
Windcube 2009



WC mean -0.08, STDEV: 0.09

Development of Wind Sensing Lidars





2006: Zephir commercial model introduced. Hardware issues.

2007: Ceilometer installed, screening on clouds: positive bias and σ reduced, availability drops. Leosphere introduces Windcube.

2008: Cloud correction: availability increases. Cone angle accuracy: bias reduced.

2008.5: Cone angle accuracy Estimator improved: nonlinear problems reduced.

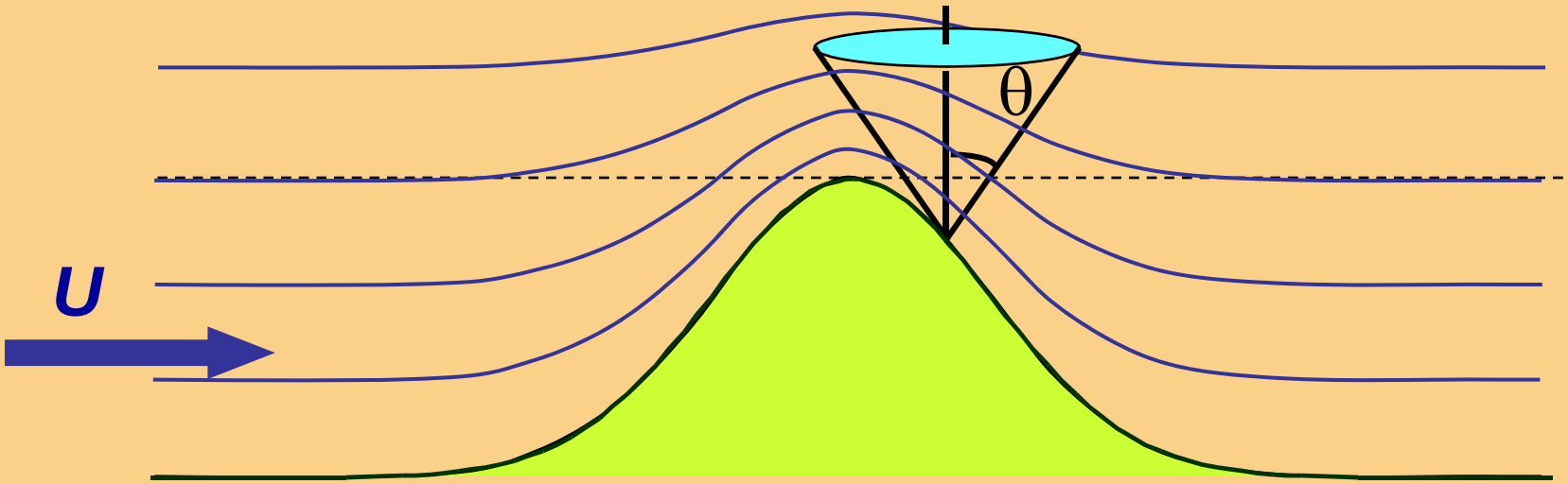
2009: Improved test conditions, lower RIN. Improved test conditions.

Vindicator and Galion commercial

Mean < ~±0.05 m/s σ ~0.20

Mean < ~±0.05 m/s σ ~0.10

Complex Terrain – errors!



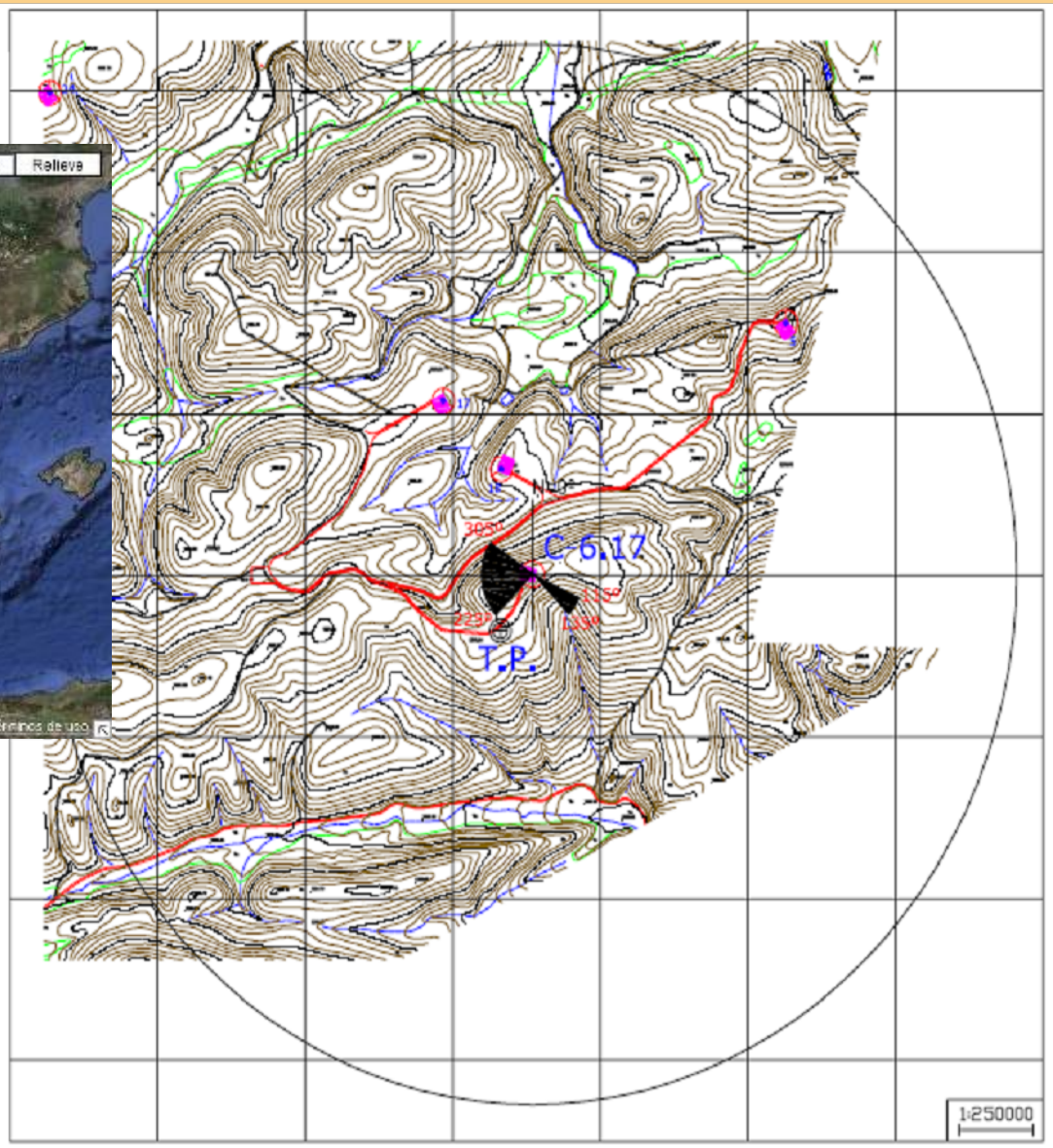
Different parts of cone sample different winds

Example: Dimitri Foussekis CRES

$V_{LIDAR} = 0.9995\ V_{MAST} + 0.0194$ in flat terrain

$V_{LIDAR} = 0.8753\ V_{MAST} + 0.4519$ in complex terrain

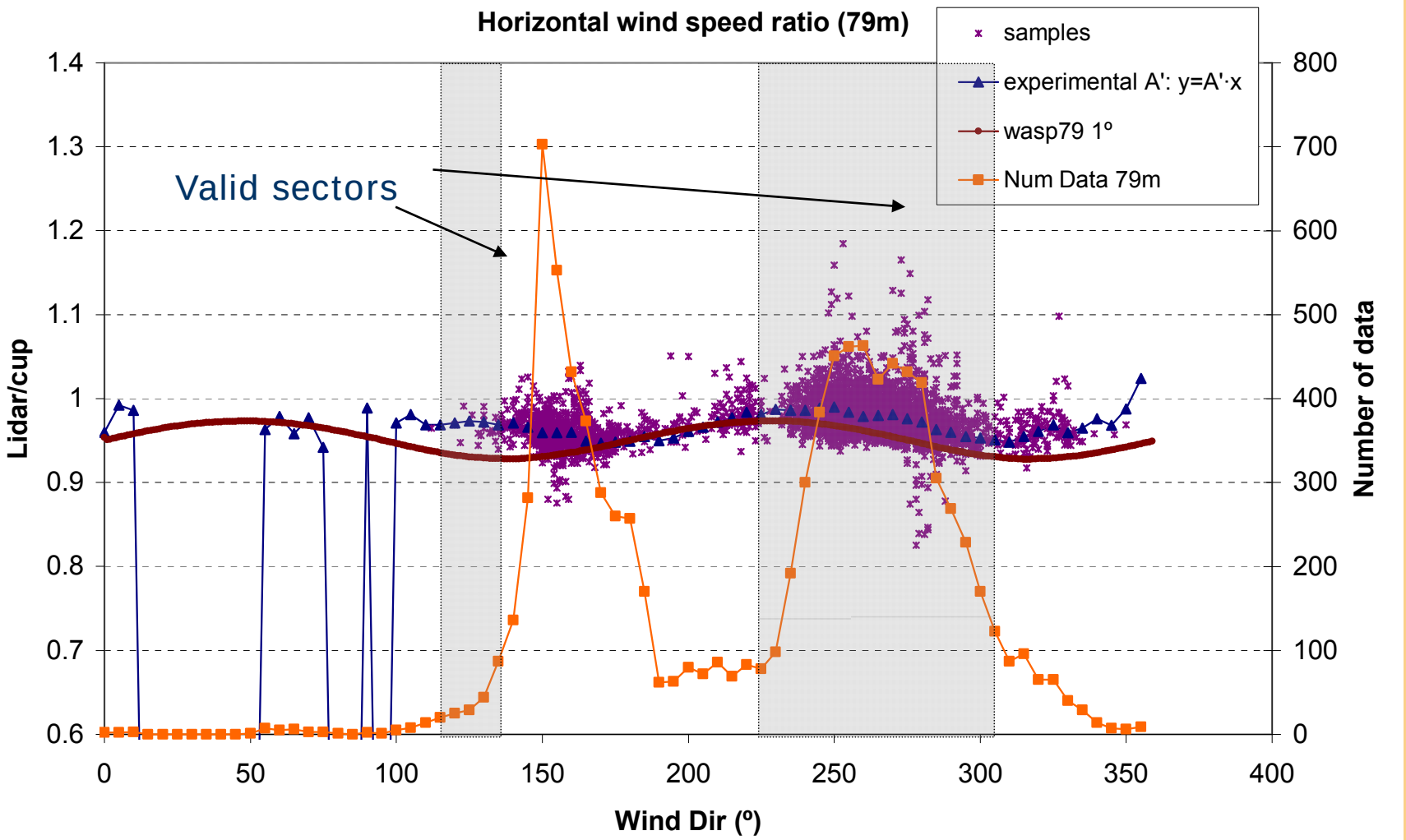
Measurements by CENER



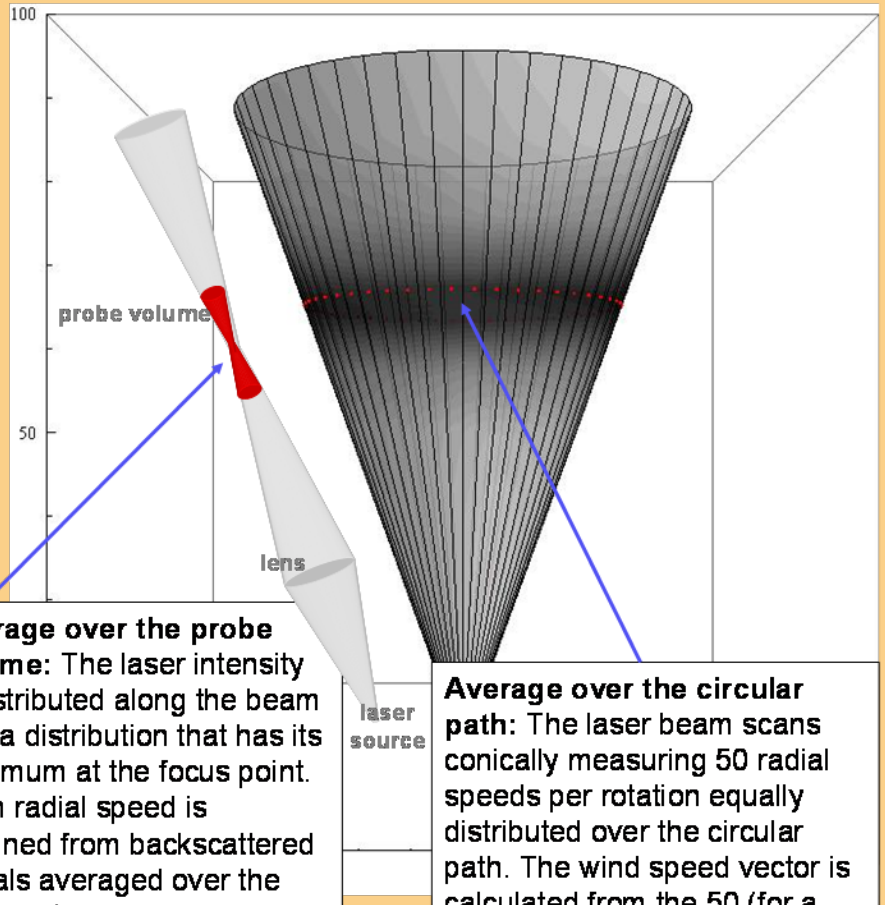
SIXTH FRAMEWORK PROGRAMME


Mast
Lidar

Speed ratios and comparison to WEng

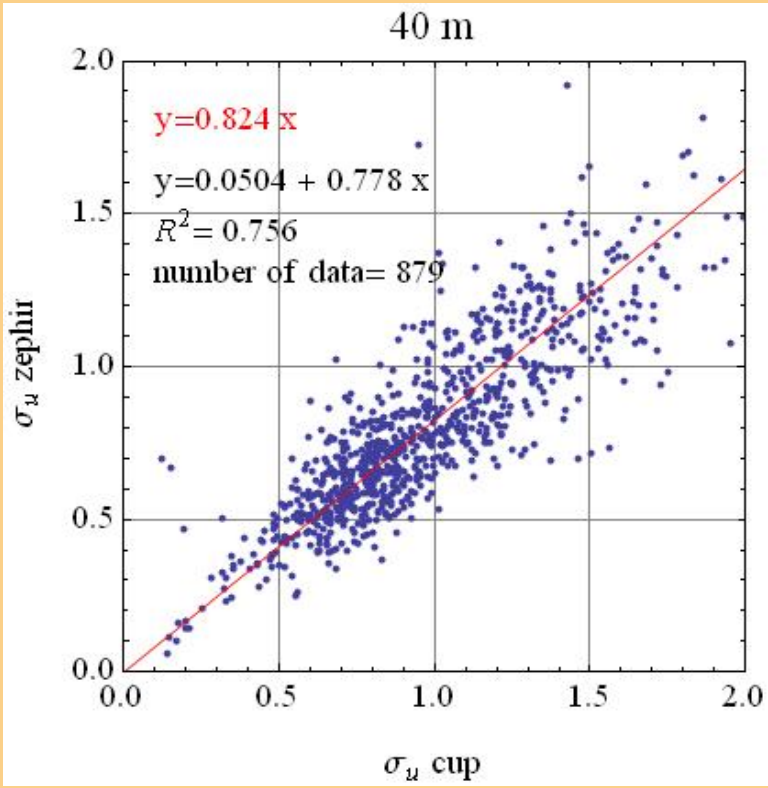


Turbulence sensed by a lidar – spatial attenuation

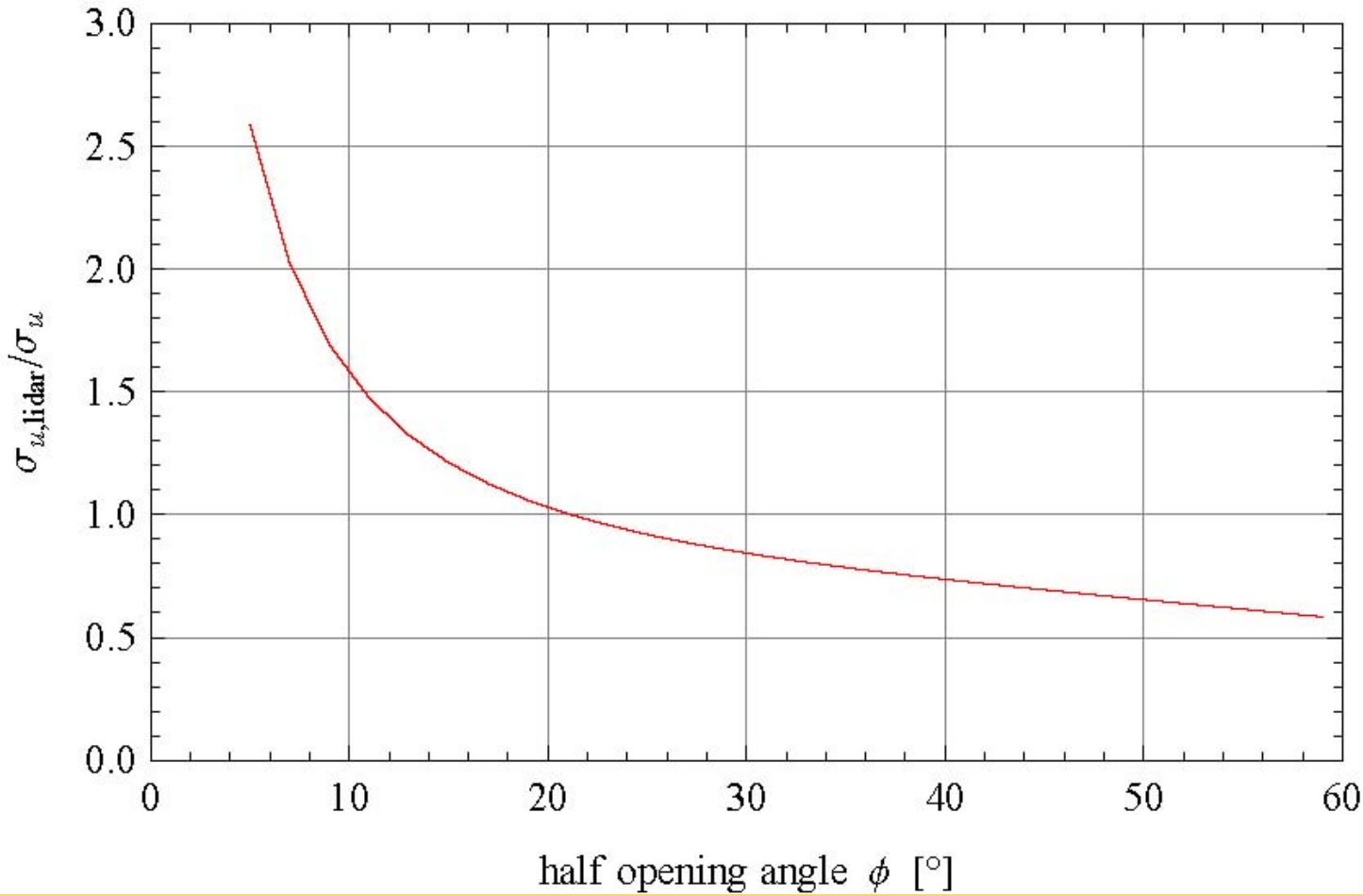


Average over the probe volume: The laser intensity is distributed along the beam with a distribution that has its maximum at the focus point. Each radial speed is obtained from backscattered signals averaged over the probe volume.

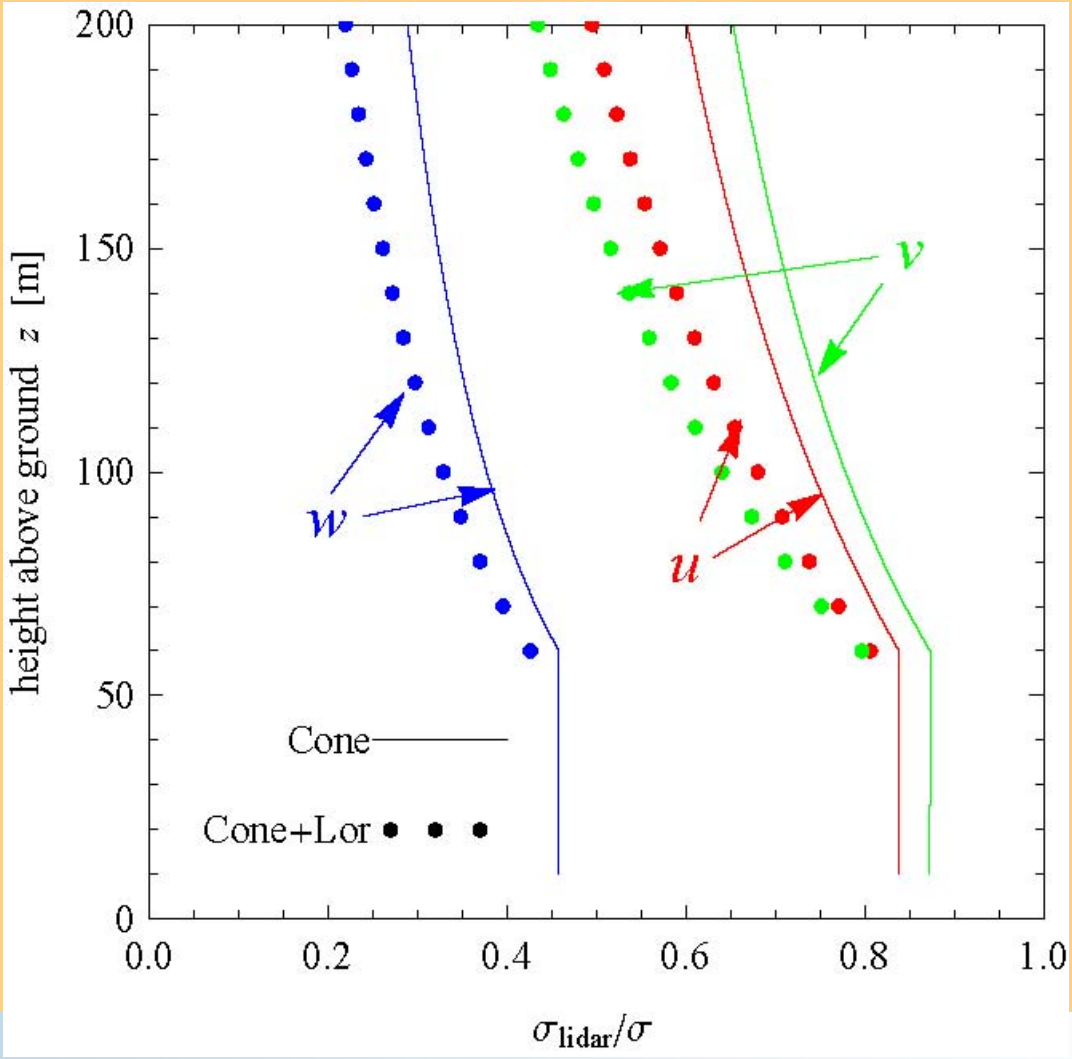
Average over the circular path: The laser beam scans conically measuring 50 radial speeds per rotation equally distributed over the circular path. The wind speed vector is calculated from the 50 (for a lidar scanning for 1second, 150 if it scans for 3 seconds) radial speeds.



The horizontal variance 'seen' by the lidar depends on the cone angle.



The ratio also varies with height



Lidar vs metmast - accuracy

- Whilst we 'calibrate' lidars using cups, we can never do better than the cup accuracy.

- Many mast measurements are not particularly good
  - Mast shadow and flow distortion
  - Bad calibrations

- Even in complex terrain, cup and lidar errors may well be comparable.

- Lidar verification requirements are driving improvements in cup calibration and mounting techniques.

Lidar vs metmast - price

• Assuming lidars can be used many times, their economics appear promising, especially for replacing high masts.

•There are also 'hidden/forgotten' lidar costs

- Power supply
- Maintenance
- Repairs! (renting might be attractive)

• Well conducted lidar resource measurements should reduce the AEP uncertainty, giving more subtle economic benefits.

Lidars vs metmast - reliability

- No contest!
- Lidars improving but there is still a way to go.

Lidars – wish list

- Traceable accuracy (coming) but preferably without using cups (?).

- Lower price

- Higher reliability

- Lower power consumption (autonomous systems)

Lidars – better than metmasts?

- Accuracy 1-1 (2-1 if shear is important)
- Economics 1-1
- Reliability 0-1
- Flexibility/discretion 1-0

Thanks for listening!

mike@risoe.dtu.dk