Comparison of Lidars, German Test Station for Remote Wind Sensing Devices

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testing- and calibration laboratory with

quality management system according EN ISO/IEC 17025:2005

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for power curve measurements,
wind measurements,
wind resource assessments

for power curve measurements

Contents

- Test Station for remote wind sensing devices
- Presentation of test results of two laser based wind measurement systems (lidar)
- Status and outlook on system integration in wind engineering

Test Station for Remote Wind Sensing Devices near Rysum (North Sea Coast)

- 1. target: test of individual lidar and sodar before field application (analogous to calibration of cup anemometers in wind tunnel)
- 2. target: type specific classification of lidars und sodars (analogous to classification of cup anemometers according to IEC 61400-12-1)
- 135m-Mast provided by Enercon since May 2008, cup anemometers and 3D-sonics at heights 135m, 105m, 71m, 35m
- already 4 Windcubes (lidar) series models tested

LIDAR:
Light Detection And Ranging

ZephIR (Natural Power)

- ZephIR: definition of measurement position by focussing of the laser beam, continuous laser

Windcube (Leosphere)

- Windcube: definition of measurement position by measurement of travel time, pulsed laser

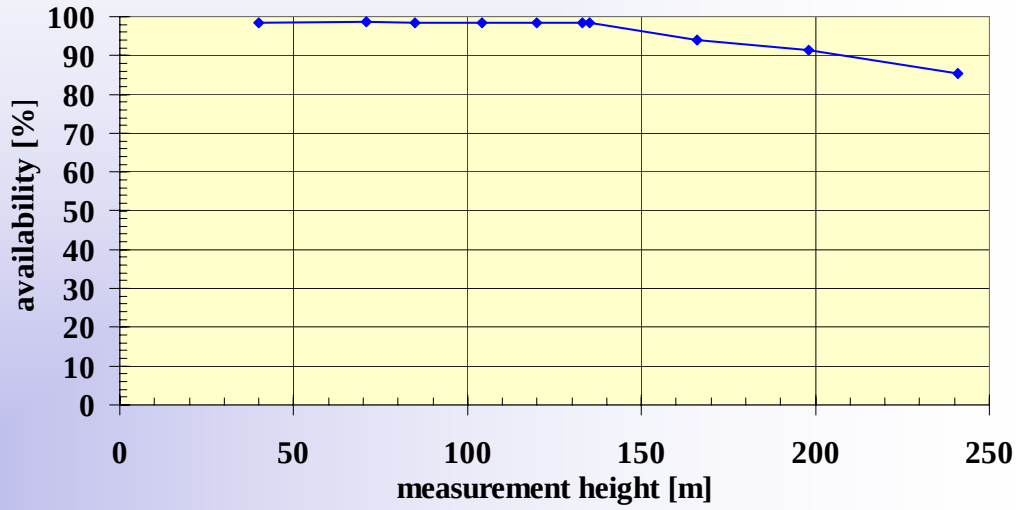
- reflected laser beam has a Doppler-shift in the frequency proportional to the wind speed component in the direction of the laser beam, reflection at particles (aerosols, dust, droplets)
- determination of all 3 wind speed components by rotation of laser beam on a cone

Data Availability

ZephIR

- 65m: 99.7% valid data of horizontal wind speed component
- 124m: 96.1% valid data of horizontal wind speed component

Windcube

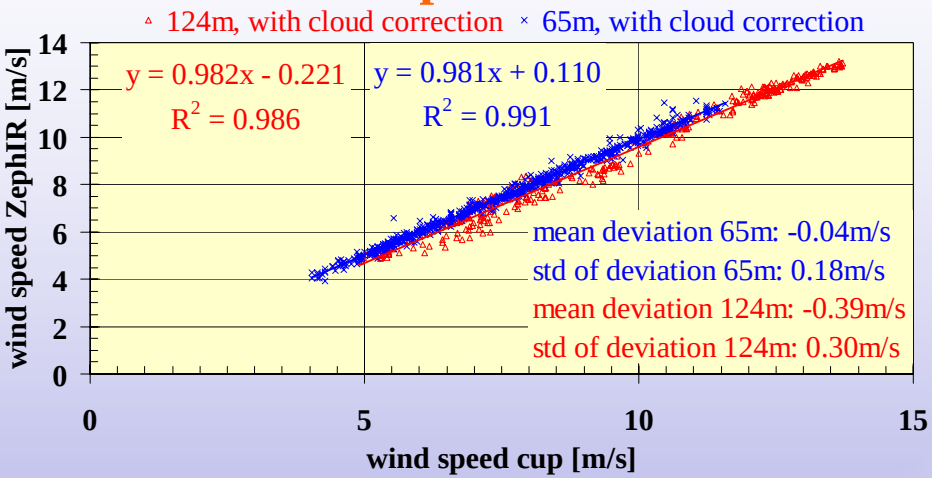


- improved optics in series model has led to increase of availability

- very high rate of valid data, despite partly bad weather like heavy rain, snow, icing conditions
- vertical component invalid at rain, snow etc.

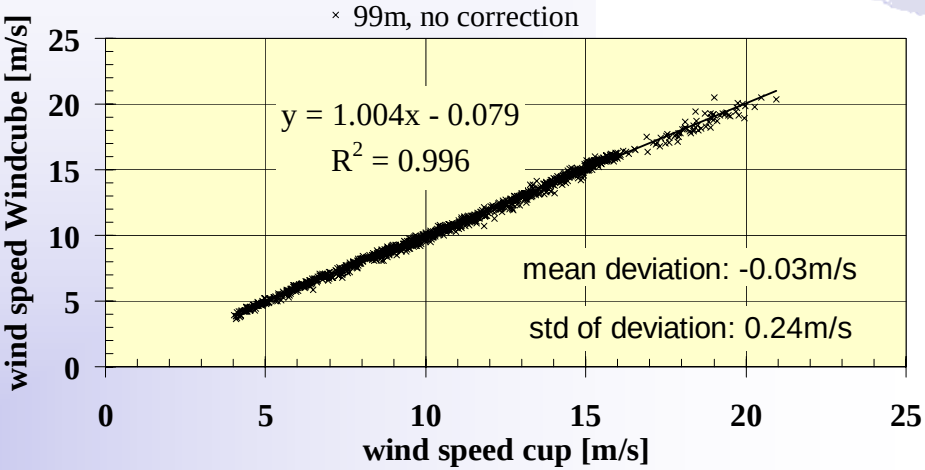
v-horizontal

ZephIR



- High correlation (when cloud correction applied)
- Excellent performance at 65m height (when cloud correction applied)
- Underestimation of wind speeds at 124m height (same slope than at 65m, but different offset), problems at mist

Windcube

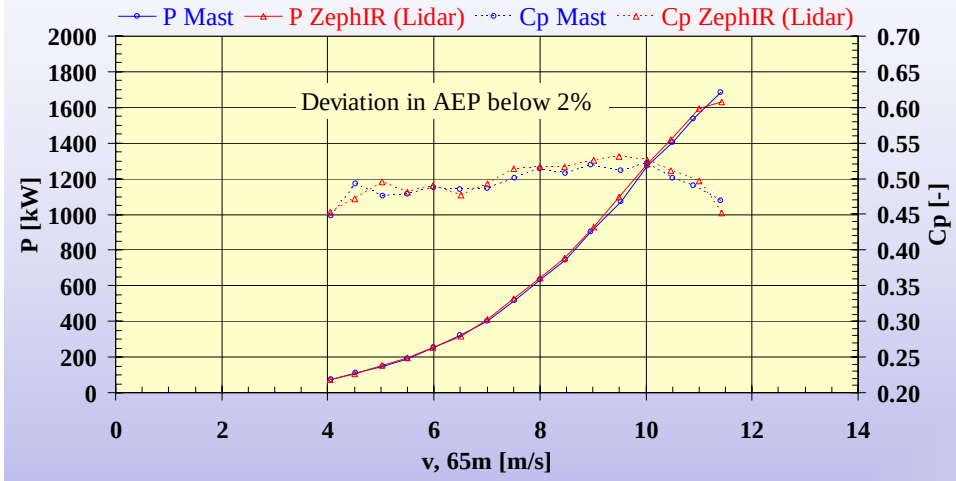


- excellent performance
- no correction (e.g. no cloud correction)
- same accuracy observed in all measurement heights up to 135m

- no filtering applied (except of wind direction), i.e. rain data included

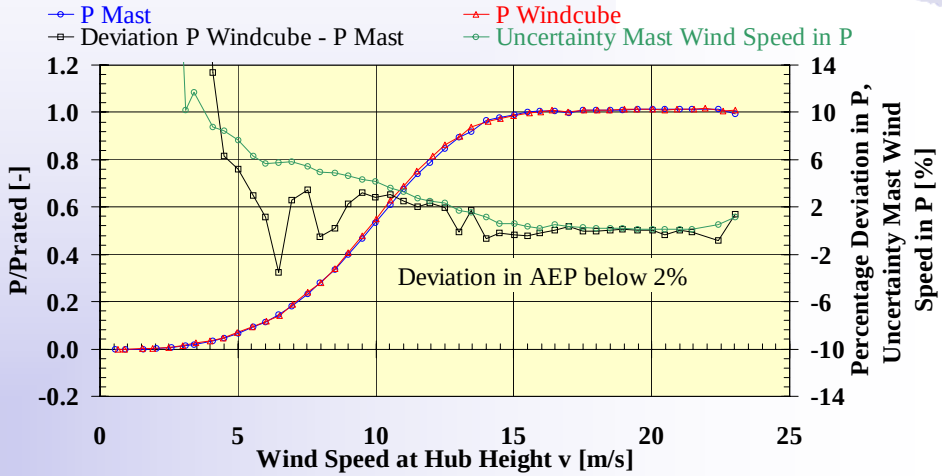
Power Curve Measurements via Lidar

ZephIR



- hub height 65m
- power curve measurement not successful at 124m hub height

Windcube

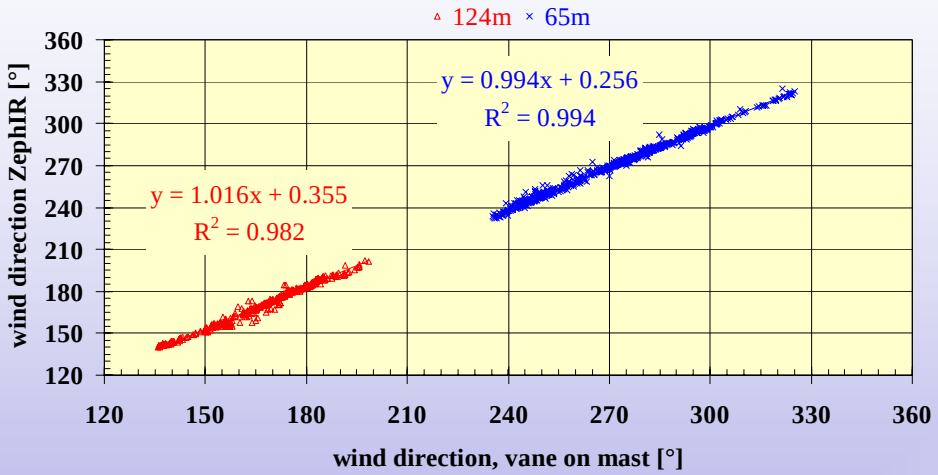


- hub height 99m

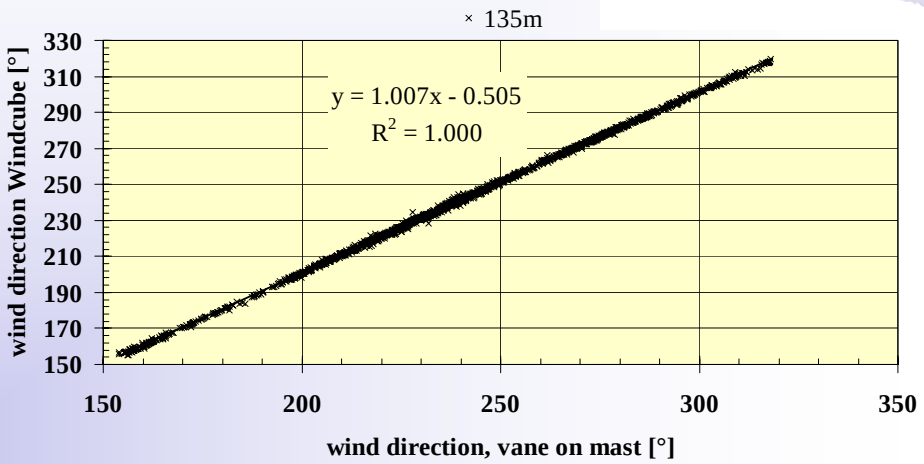
- deviations smaller than uncertainty of cup anemometer

Wind Direction

ZephIR



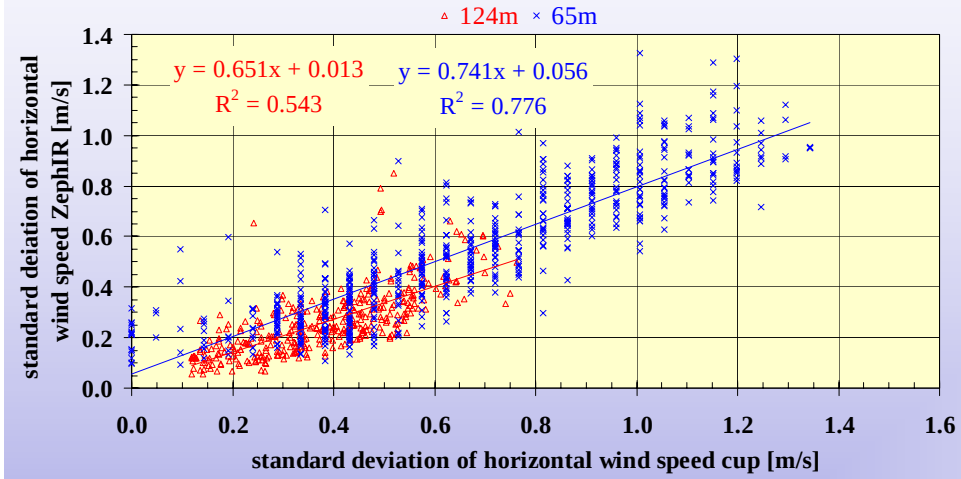
Windcube



- At single 3-second averages the detected direction is switched around
  - good statistics of 10-minute averages

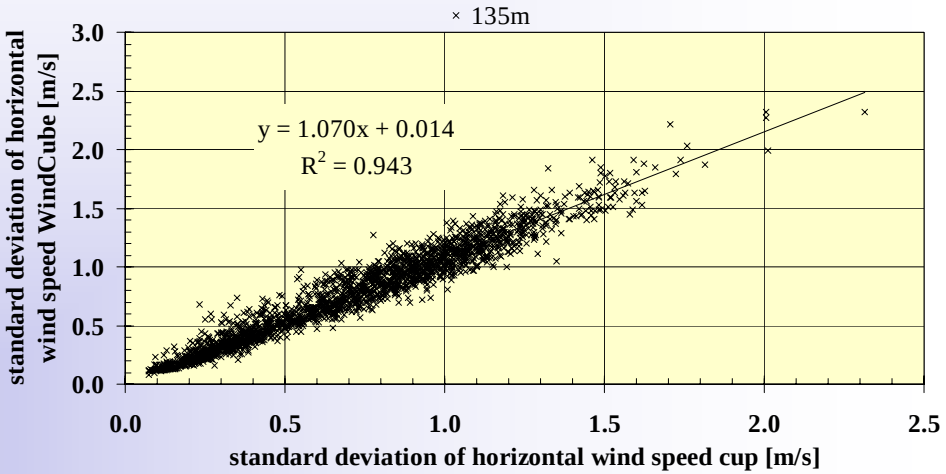
Standard Deviation of Horizontal Wind Speed Component

ZephIR



- underestimation of turbulence due to spatial averaging and 3s-averaging (cup-anemometer: 1s-averaging)

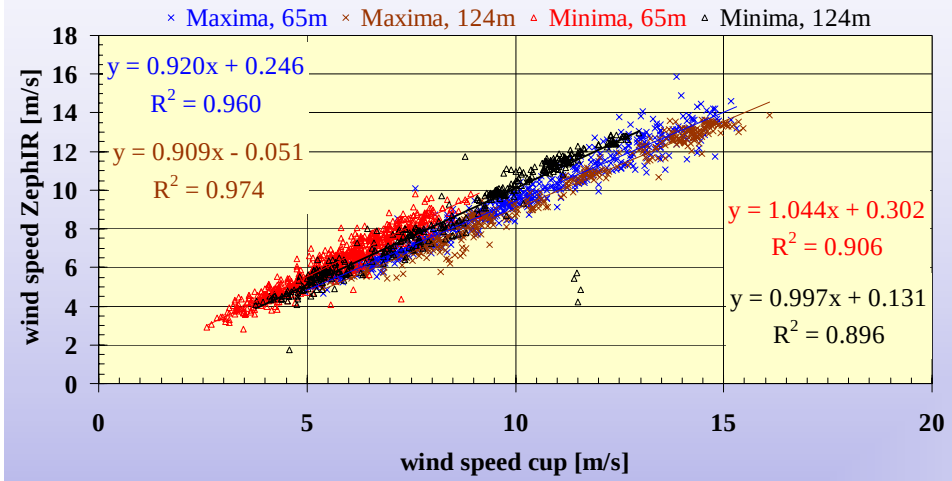
Windcube



- turbulence tracked astonishing well, despite different measurement principles of lidar and cup anemometer
- small improvement gained by reduction of scanning cycle from 8s (prototype) to 6s or 4s (series model)

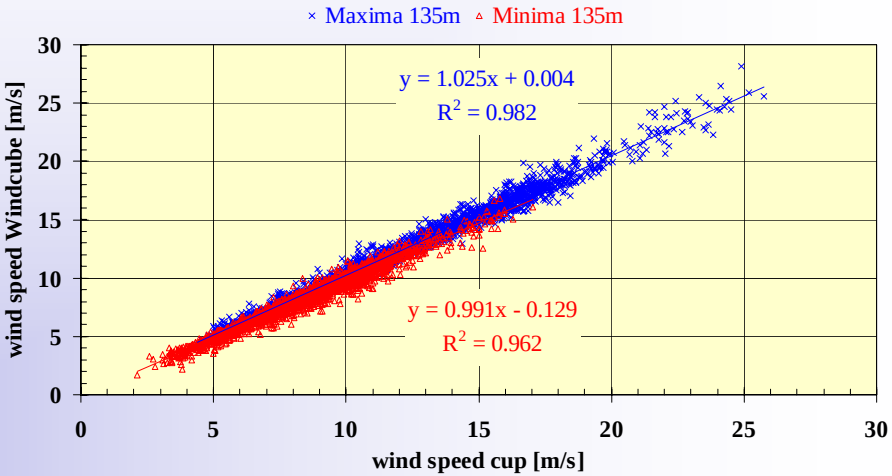
Extreme Values of Horizontal Wind Speed Component

ZephIR



- maxima are underestimated, minima are overestimated
- underestimation of extreme values due to spatial averaging and 3s-averaging (cup-anemometer: 1s-averaging)

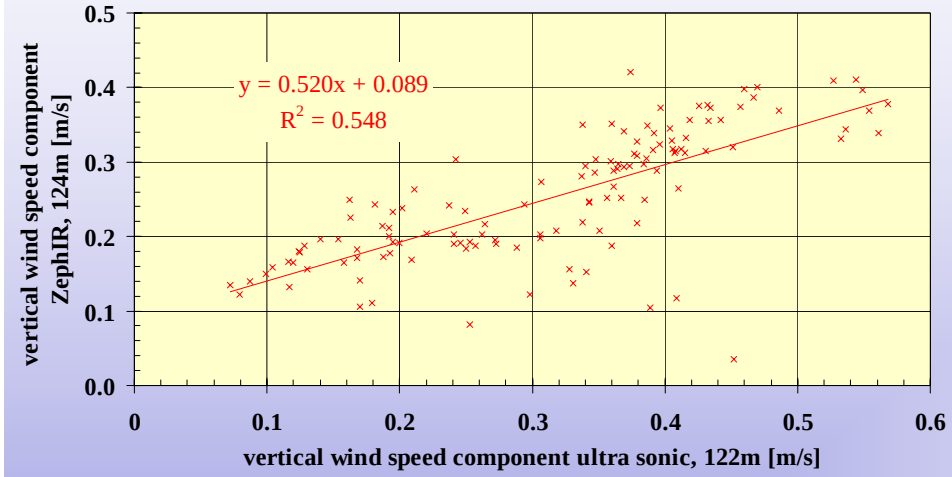
Windcube



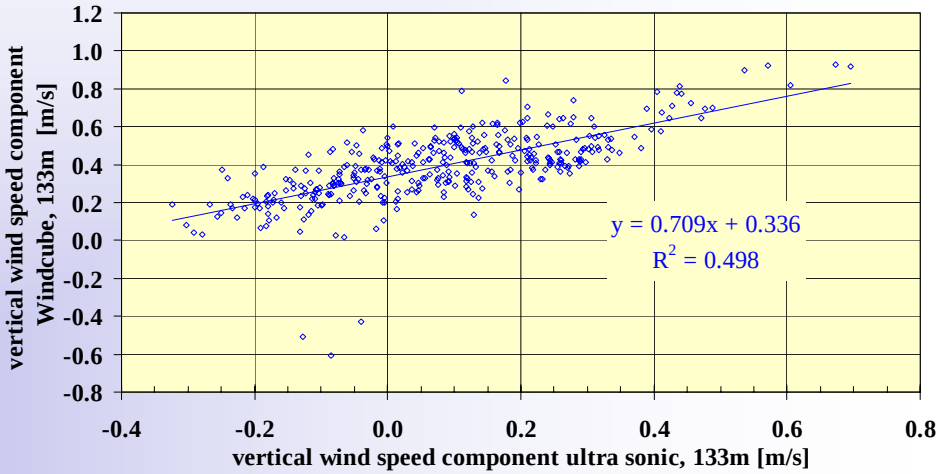
- Maxima/Minima only slightly overestimated/underestimated
- Extreme values tracked astonishing well, despite different measurement principles of lidar and cup anemometer
- small improvement gained by reduction of scanning cycle from 8s (prototype) to 6s or 4s

Vertical Wind Speed Component

ZephIR

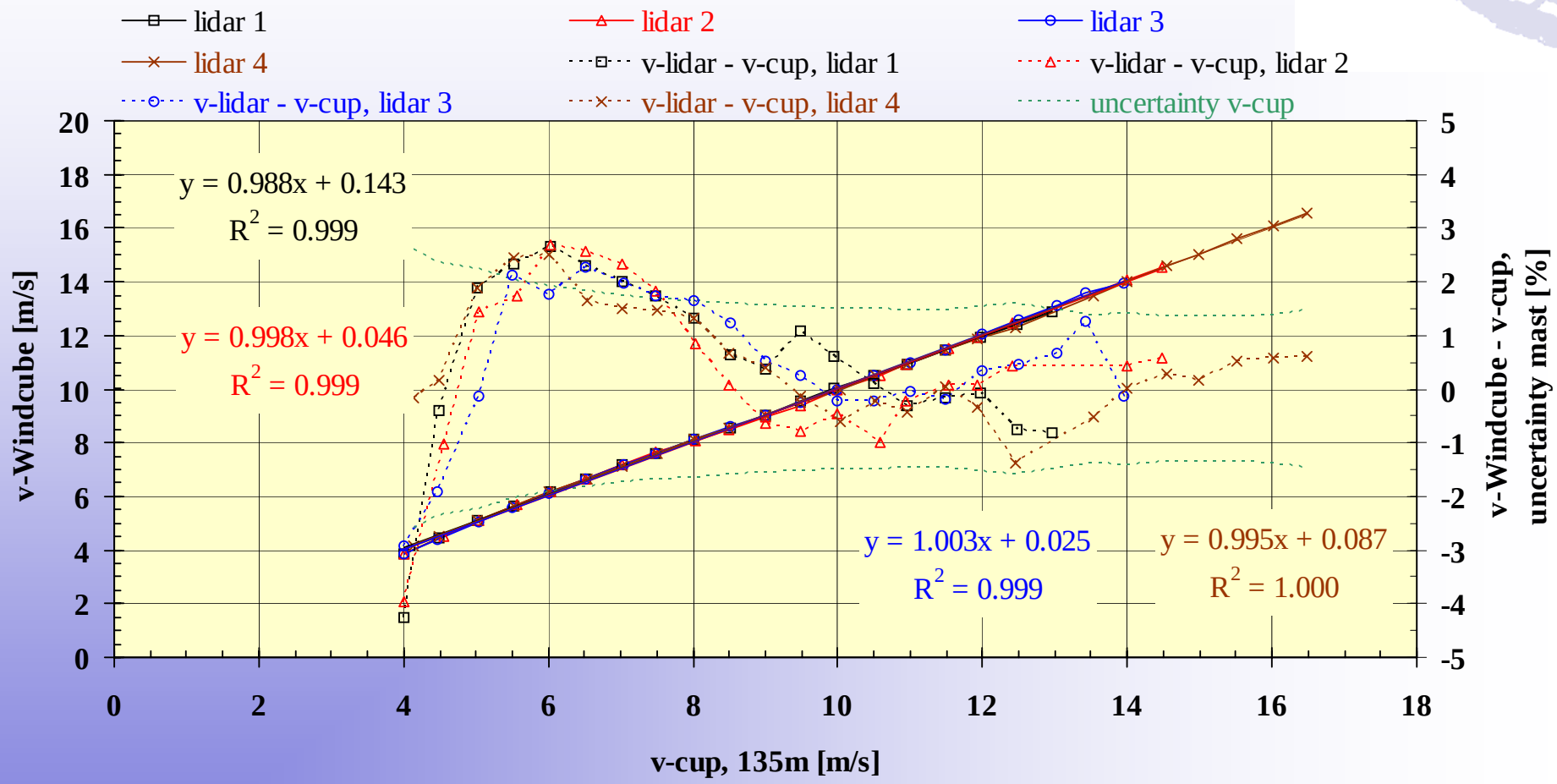


Windcube



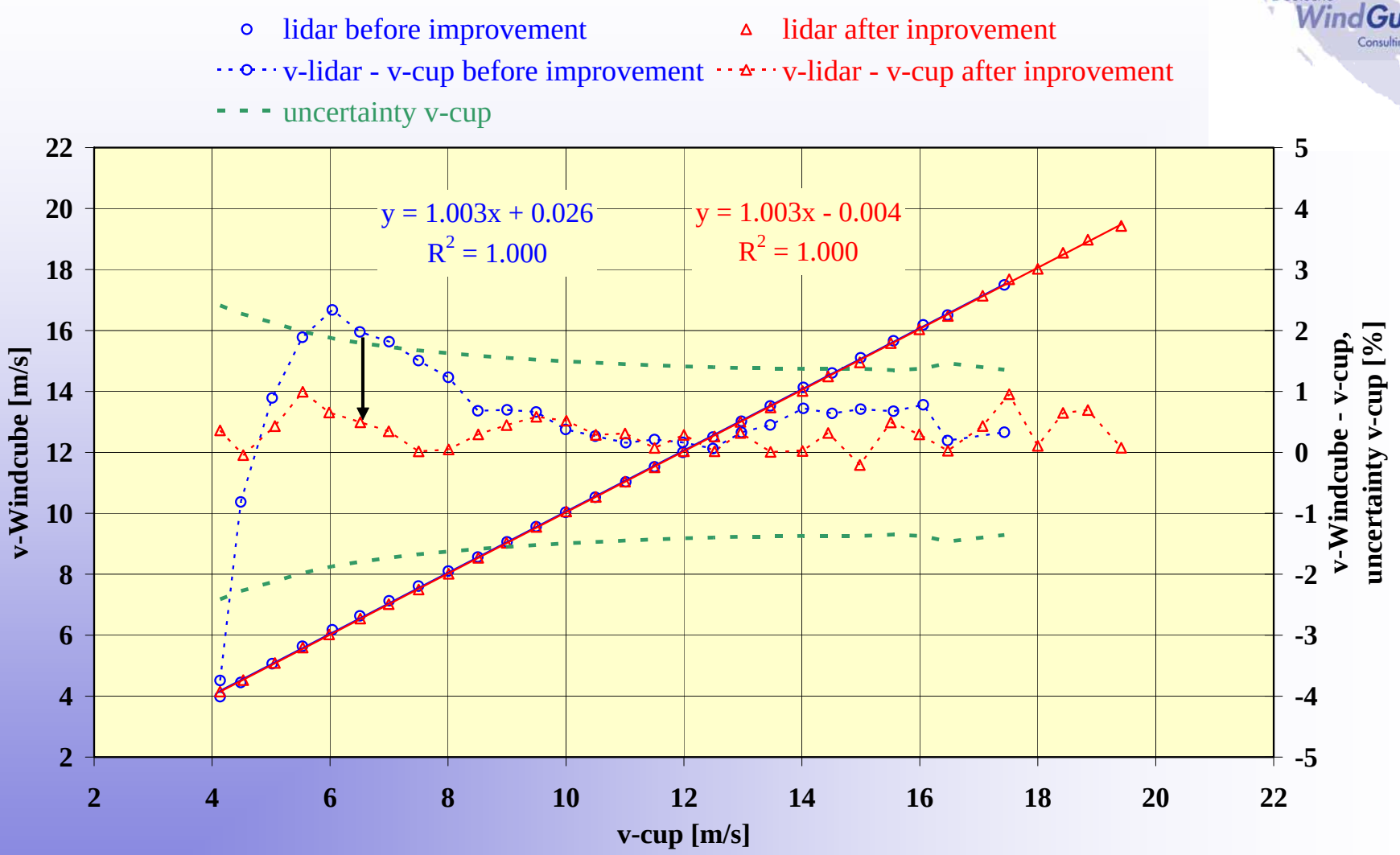
- poor correlation
- vertical wind speed evaluation by lidar requires improvements

Comparison of 4 Windcubes (horizontal wind speed component)



- Identical properties, good reproducibility
- S-shape of deviation between lidar and cup due to problem of spectrum analysis in first software version

Improvement of Spectrum Analysis at Windcube



- Test of new software version with improved spectrum analysis
- Improved accuracy over entire wind speed range

Overview Comparison ZephIR and Windcube

ZephIR

- high availability of valid data
- very accurate at lower measurement heights
- at larger measurement heights tendency to underestimation of wind speeds, increasing with vertical wind shear
- problematic at low mist
- Cloud correction required (improvement under test)
- turbulence intensity and extreme values are underestimated
- room for improvement by further data correction and filtering

Windcube

- high availability up to 200m measurement height
- very accurate
- turbulence intensity and extreme values are measured astonishingly well

- accurate wind direction measurement
- vertical wind speed component not accurate (improvement needed)
- accuracy in complex terrain needs further investigation