Rotor Average wind speed for power curve performance

Ioannis Antoniou (LAC),
Jochen Cleve (LAC),
Apostolos Piperas (LAC)

March 12, 2013

SIEMENS

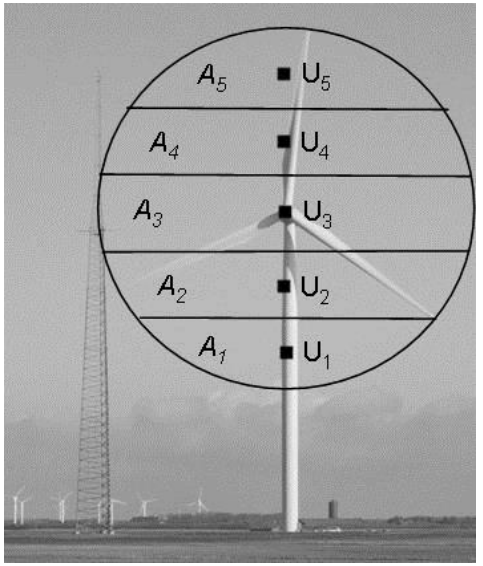
Contents

SIEMENS

- Rotor Average wind speed
- EU flat terrain wind profiles vs. TI
- USA Midwest flat wind profiles vs TI
- Cp vs. TI
- Using the equivalent wind speed in site calibration campaigns: challenges and solutions
- Using the equivalent wind speed in power curve measurement campaigns: looking into the future

SIEMENS

$$V = \sqrt[3]{\frac{1}{A}\int_{H-R}^{H+R}\left(v(z)\cos(\varphi(z))\right)^3 dA}$$

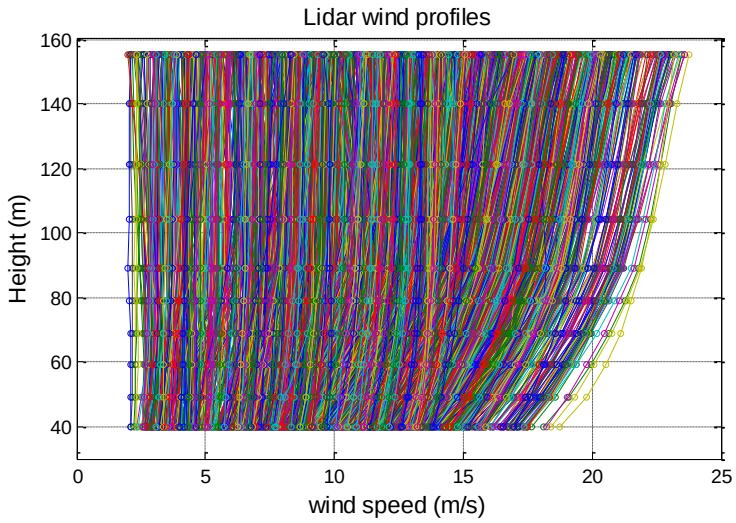


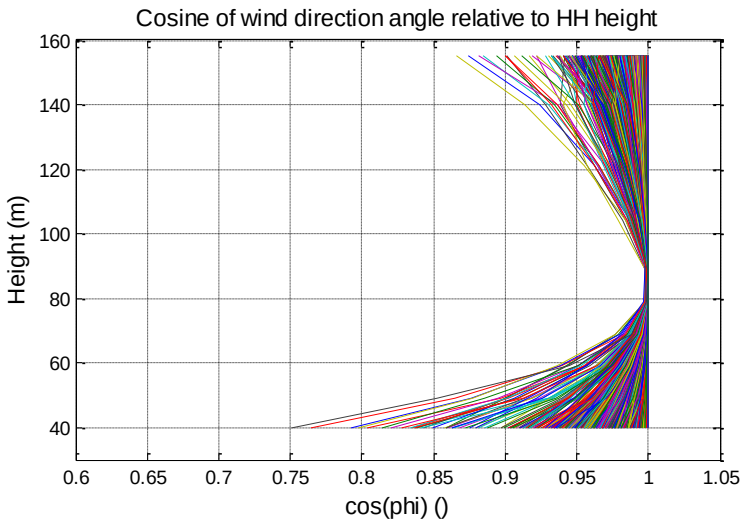
A LIDAR is deployed next to a met mast

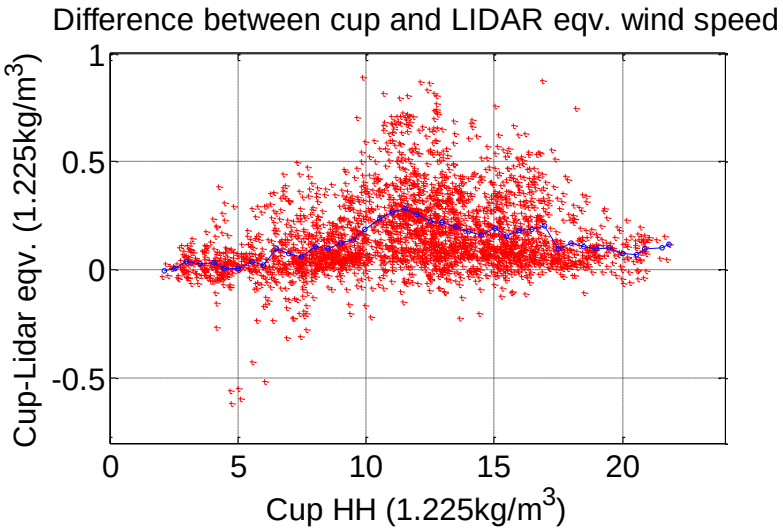
- The LIDAR can measure the wind speed and direction at more heights regularly distributed over the rotor
- The wind speeds at all heights are normalized by dividing with the LIDAR wind speed at hub height.
- The LIDAR wind directions at all heights are subtracted from the direction at hub height (wind veer relative to hub height).
- The normalized LIDAR wind speeds at all heights are multiplied with the cosine of the direction angle relative to hub height
- Subsequently all wind speeds are multiplied with the cup wind speed at hub height.

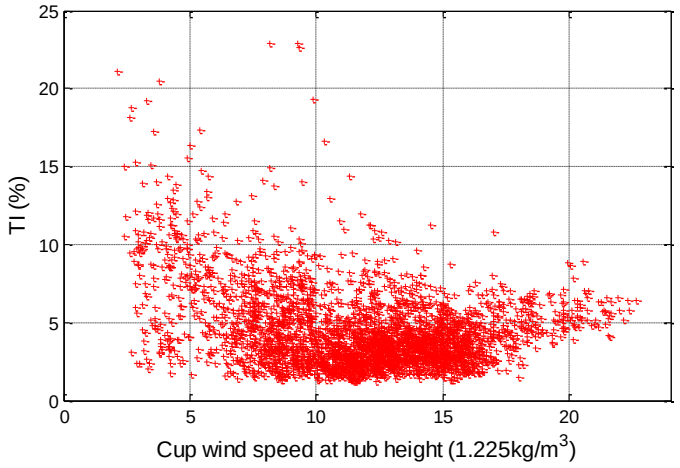
Wind profiles: Flat coastal location

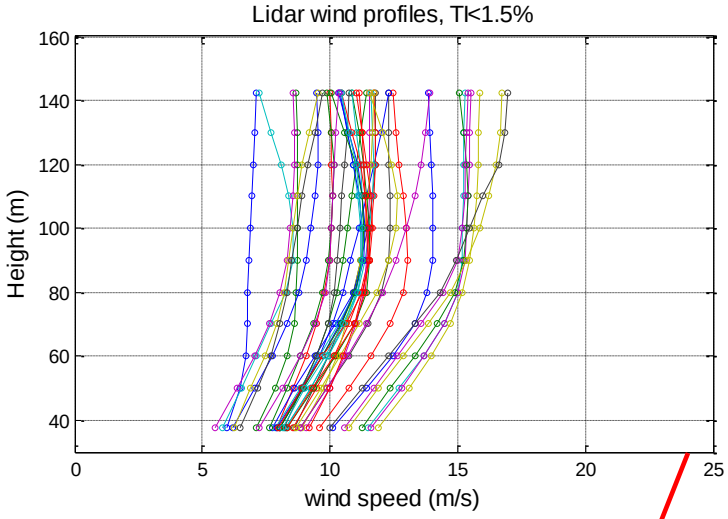
SIEMENS

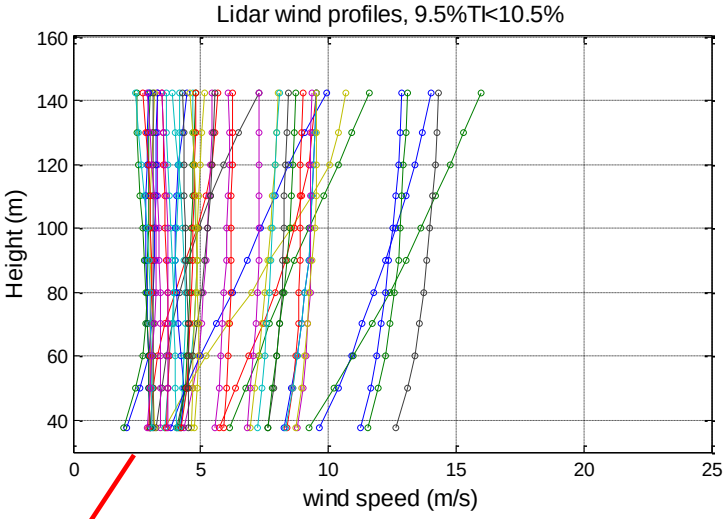






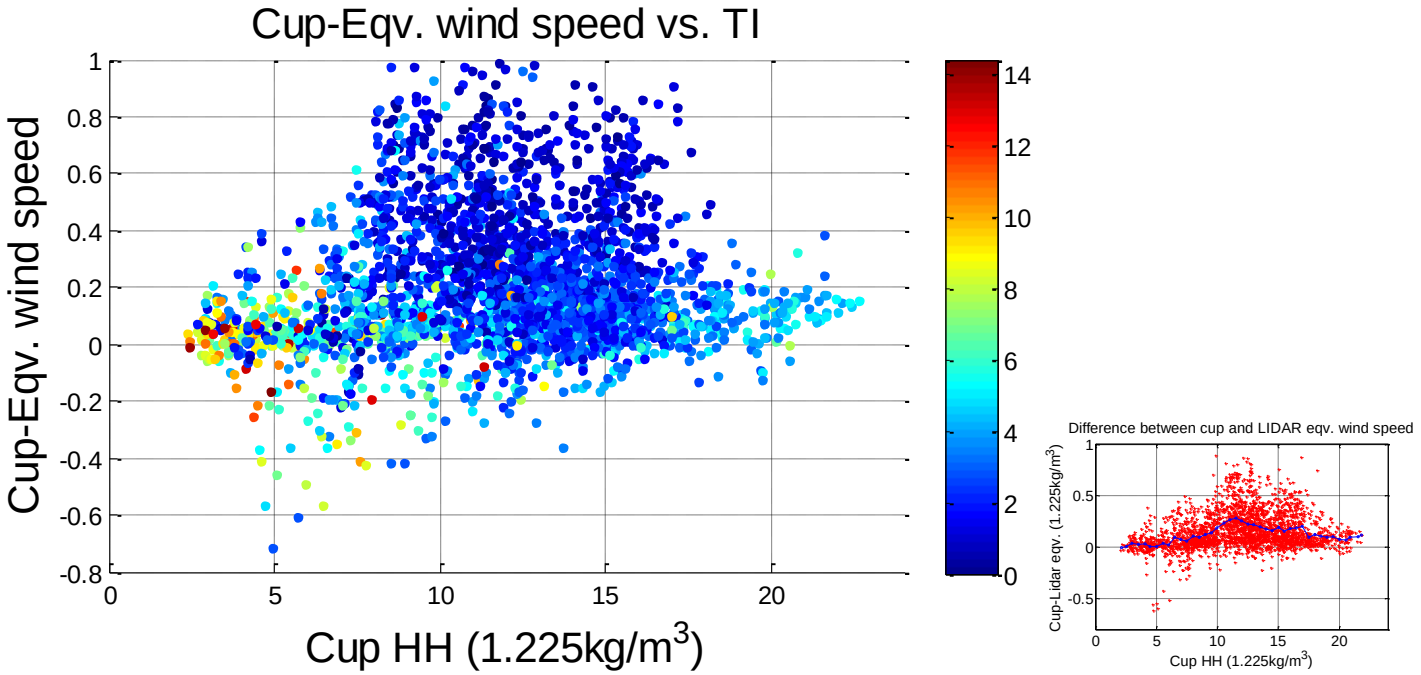




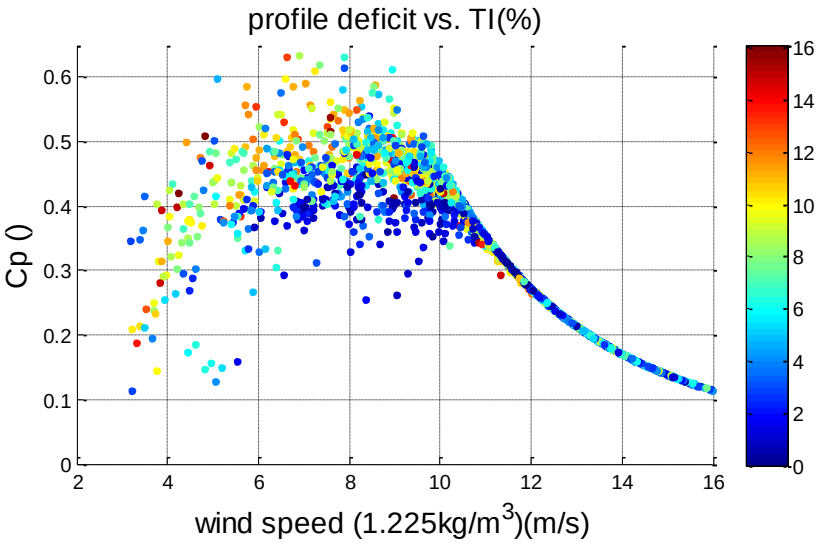


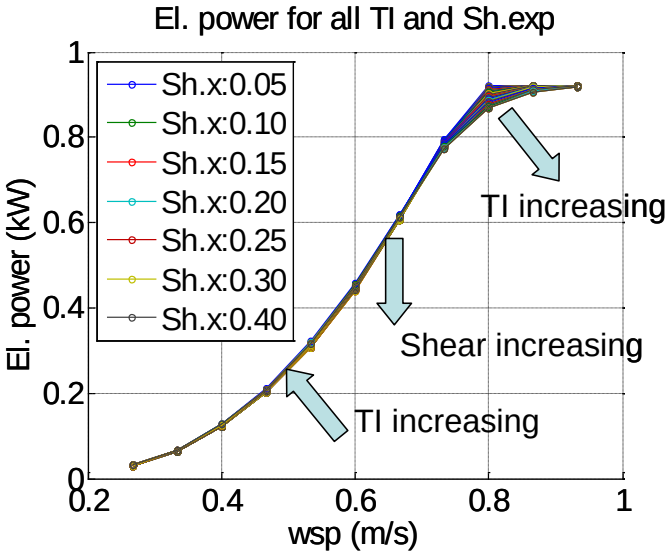
TI (%)	Cup (HH)-Eqv. Wsp (m/s)
TI<1.5%	0.52
1.5%<TI<2.5%	0.42
2.5%<TI<3.5%	0.26
3.5%<TI<4.5%	0.16
4.5%<TI<5.5%	0.13
5.5%<TI<6.5%	0.09
6.5%<TI<7.5%	0.06
7.5%<TI<8.5%	0.04
8.5%<TI<9.5%	0.03
9.5%<TI<10.5%	0.02

- Low TI's are correlated with large variations in the wind profile.
- HIgh TI's are correlated to more uniform profiles
- The HH wind speed is not representative of the wind profile at low TI's.
- It is not precise that w/t under produce at low TI's.



Large Cup(HH)-Eqv. Wind speed differences occur at low turbulence intensities



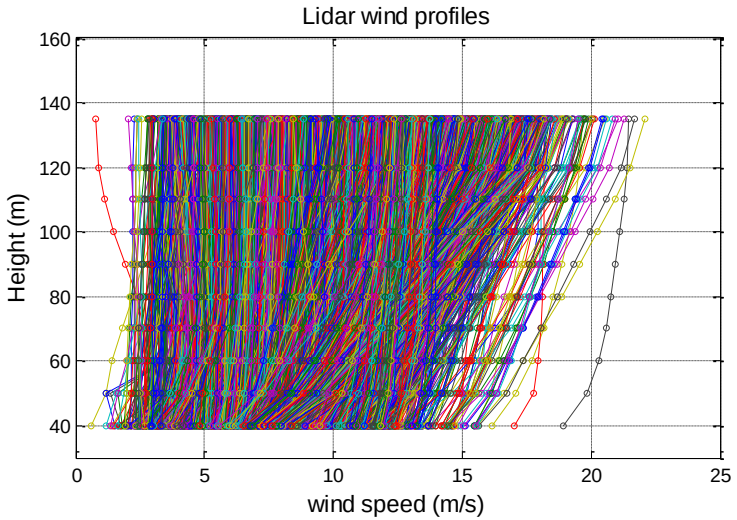


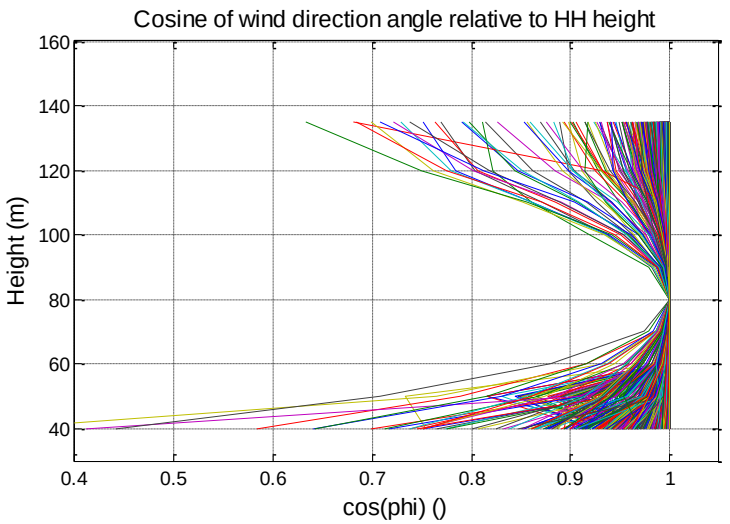
- Low Cp values seem to correlate with low Ti values in the linear part of the power function (flat part of the Cp curve)
- In the linear part of the power function, Cp is mostly influenced by the wind speed over the rotor disk and less by variations in turbulence.
- The use of the equivalent wind speed should be preferred relative to filtering low TI data.

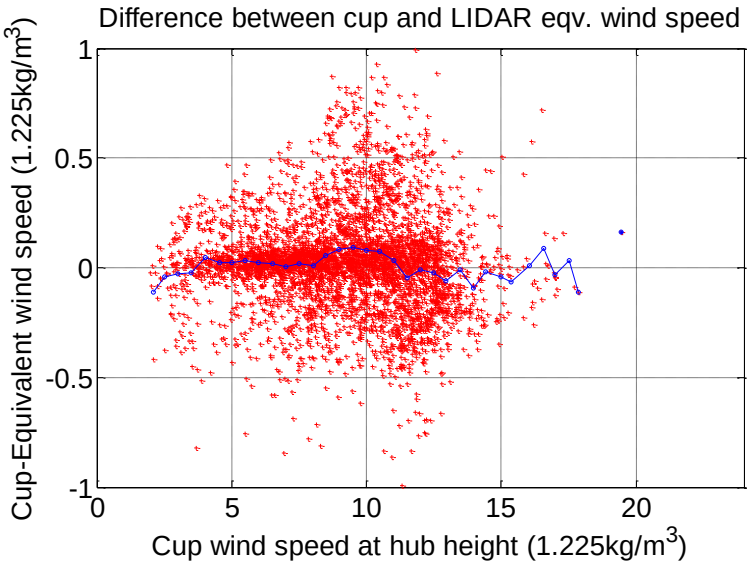
- In the above example: $AEP_{(TI>5\%)}$-$AEP_{(all\ TI's)}$=+3%

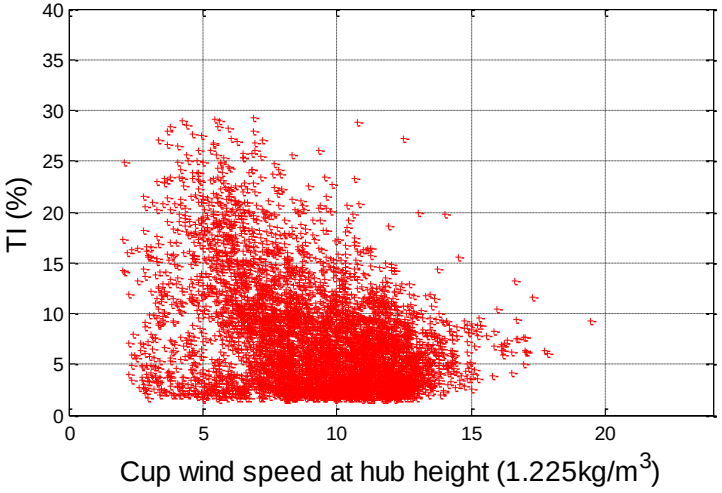
Wind profiles: Flat Midwest USA

SIEMENS



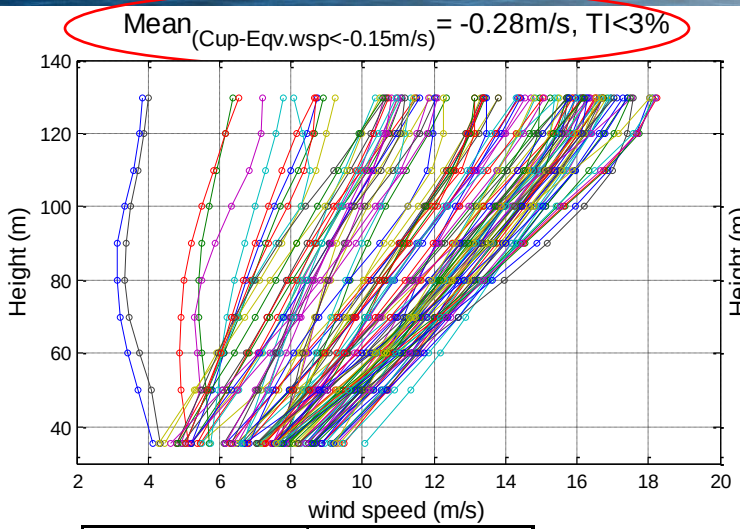


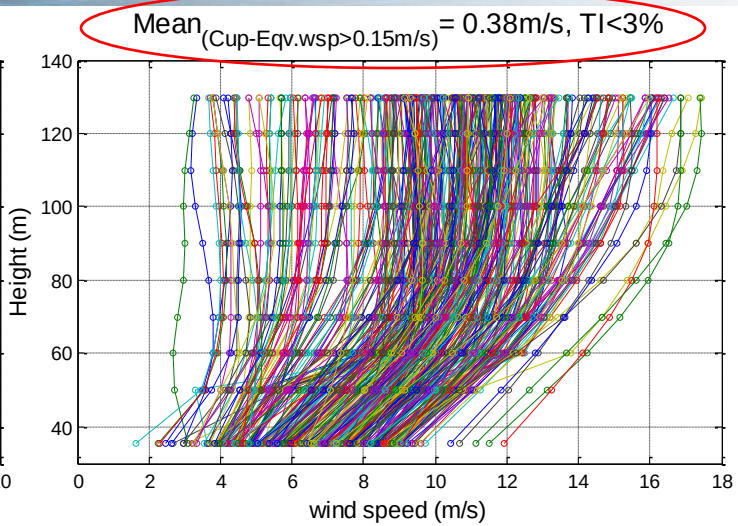




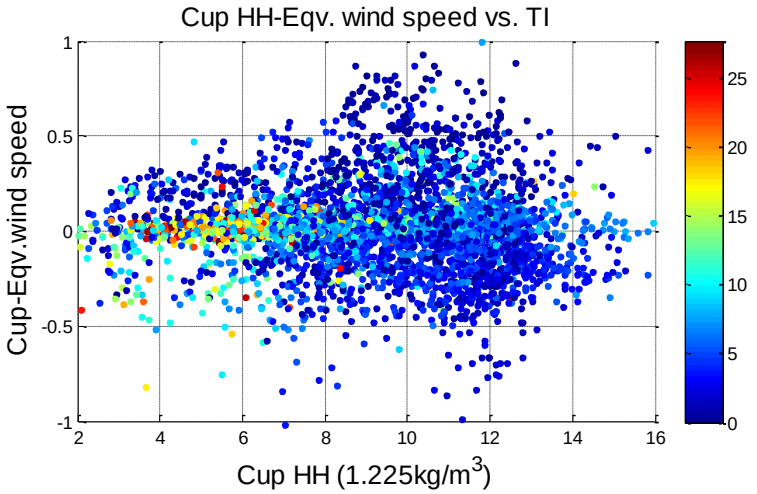
Wind profiles: Flat Midwest USA

SIEMENS



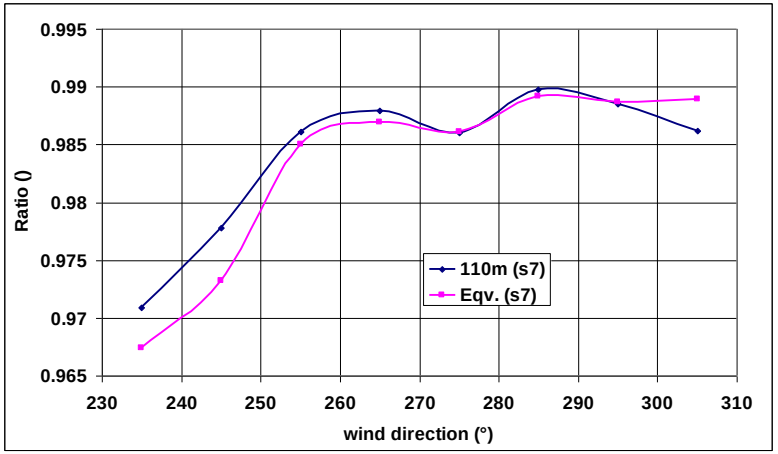


TI(%)	C(HH)-Eqv.Wsp (m/s)
TI<2%	0.29
2%<TI<3%	0.12
3%<TI<4%	0.02
4%<TI<5%	-0.04
5%<TI<6%	-0.04
6%<TI</%	-0.04
7%<TI<8%	0
8%<TI<9%	0.02
9%<TI<10%	0.03
10%<TI<11%	0.04
11%<TI<12%	0.03
12%<TI<13%	0.02



- TI can be used as proxy for atmospheric stability, still it is a rather coarse estimator.
- Wind profiles may form differently under stable conditions; the issue remains: The HH wind speed does not describe accurately the wind profile.

- Lidar 1:1 comparison.
- Site calibration.
- 1:1 post-calibration and lidar vs. cup calibration.
- Next step a combined (?) report:
  - IEC power function vs. HH wind speed.
  - Annex to the report: power function vs. equivalent wind speed (help make the eqv. wind speed better known and more accepted).



Conclusions

SIEMENS

- Low TI allows for wind profiles with irregular shear which are the main reason of the large deviations between the equivalent wind speed and the HH wind speed.
- The discrepancy can be resolved by either filtering low TI values or by representing the power function vs. the equivalent wind speed.
- The broader use of remote sensing devices may contribute in reducing both the time, costs and the uncertainties in the wind speed measurements.
- A frame which will allow the broader use of the equivalent wind speed is urgently needed.