Investigating Wind Flow properties in Complex Terrain using 3 Lidars and a Meteorological Mast

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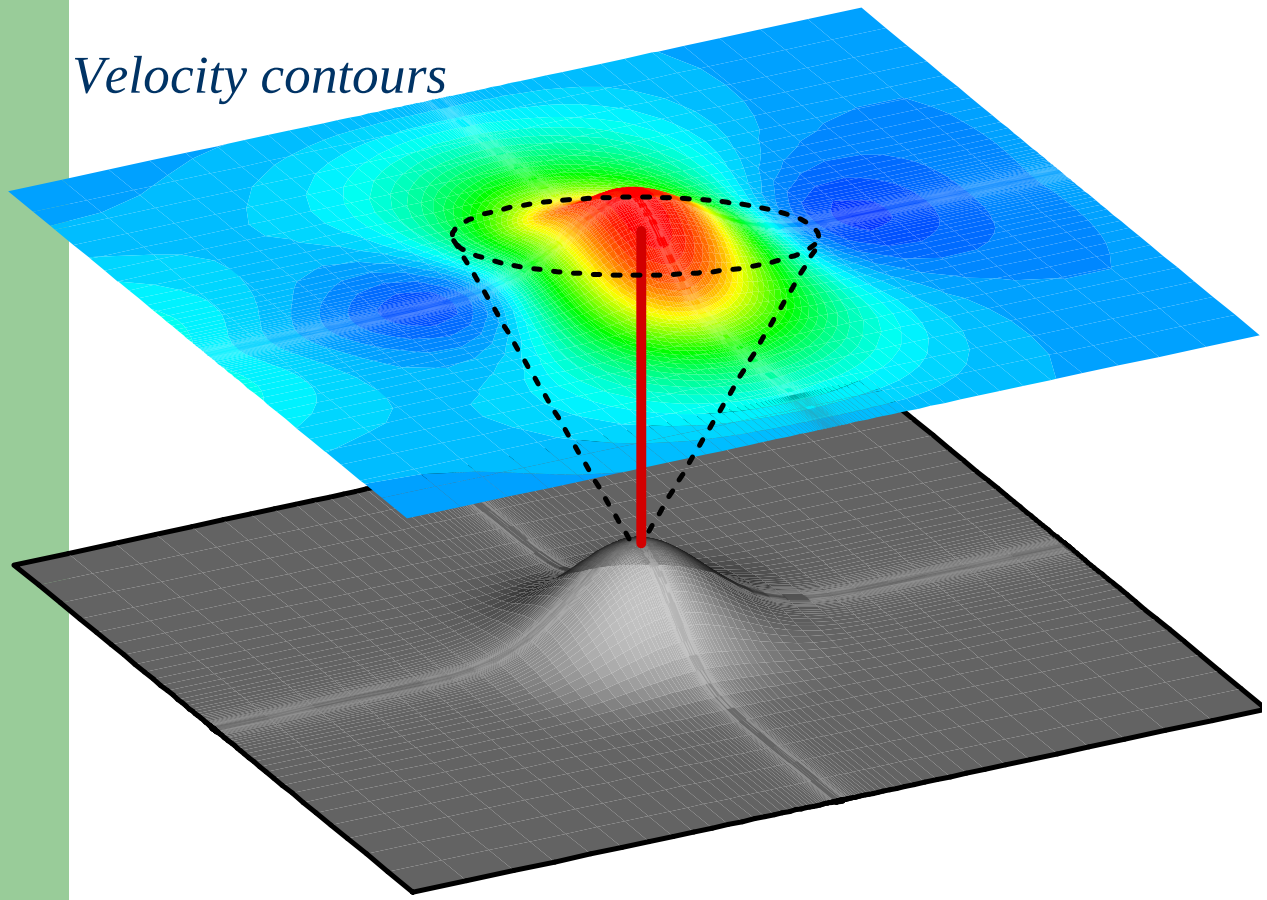
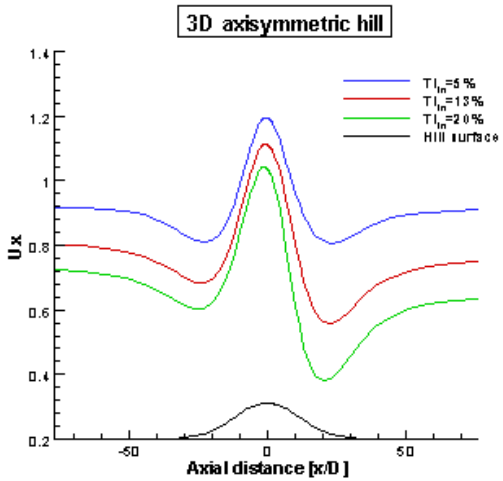
Outline

- Lidars and complex terrain
- Lidars vs Mast's anemometers
- Measuring with a narrower prism (15°)
- Conclusions

Flow over a simple hill

Velocity contours





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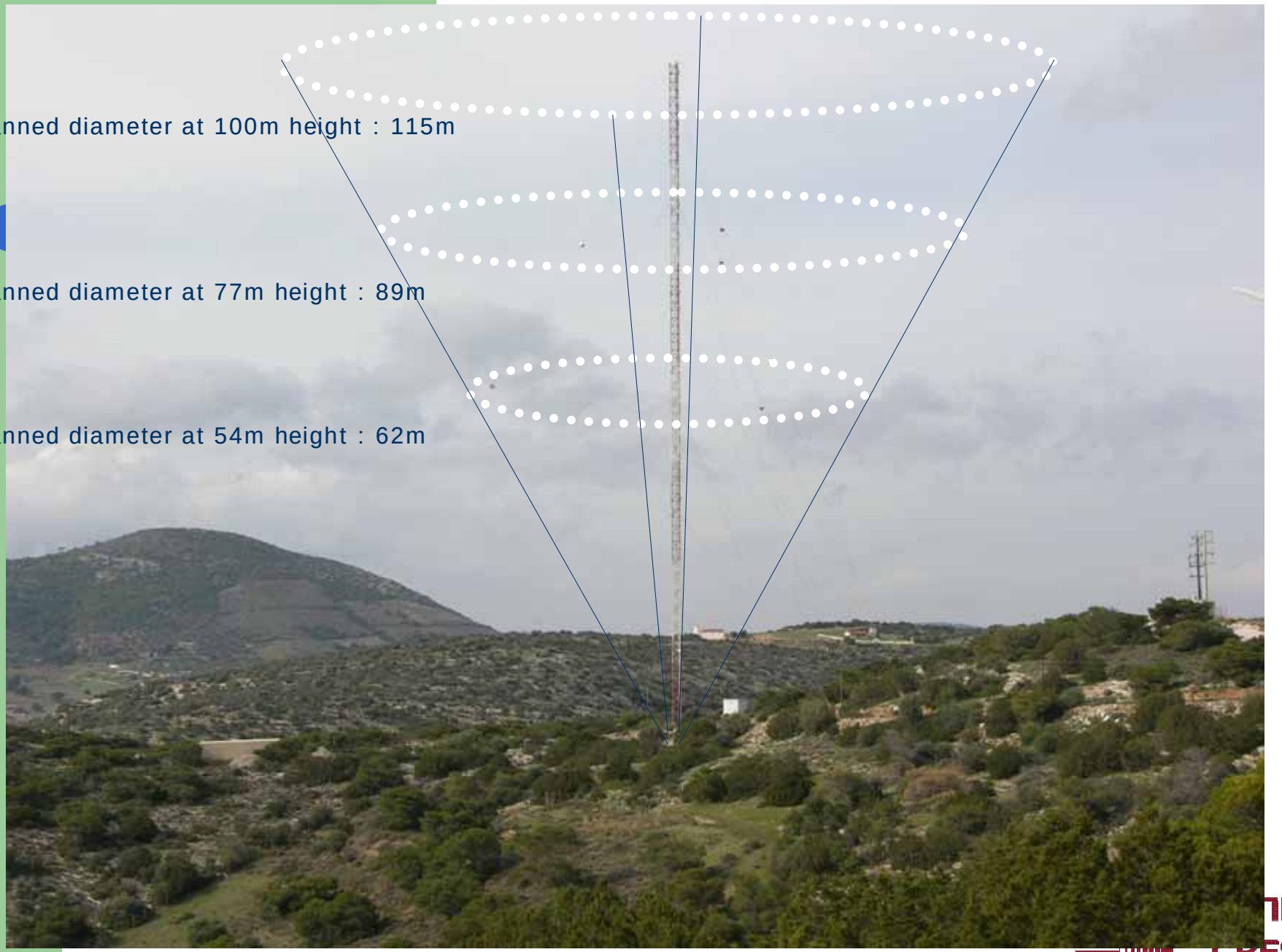
Scanned diameter at 100m height : 115m

Scanned diameter at 77m height : 89m

Scanned diameter at 54m height : 62m



CRES ZephIR

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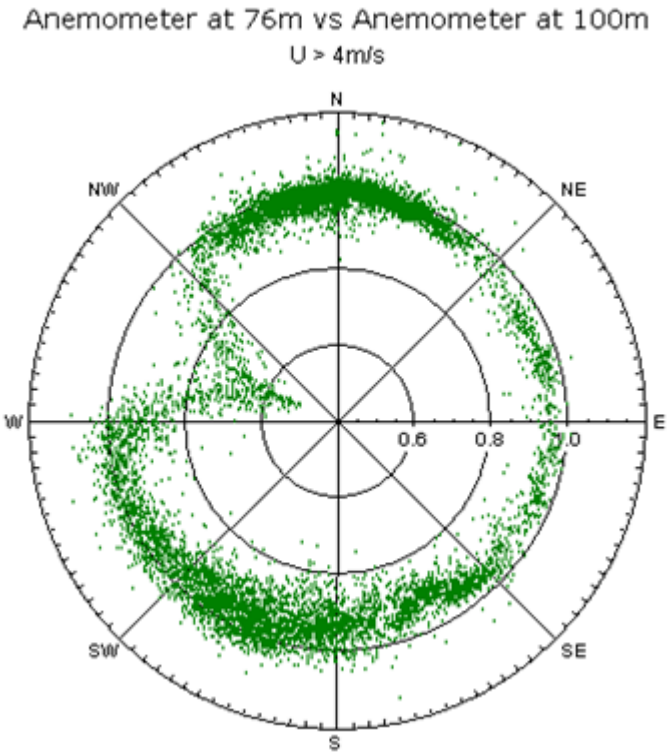
Data filtering



1. Mast tower “shadow”
2. Topography effects (N±40°)
3. Clocks synchronization
4. Sequence of 4 heights, each with ≥140 points (ZephIR)
5. Variance of the Signal broadening $|\Delta\sigma freq|<0.4$ and Carrier to Noise Ratio CNR>-20, for each height (Windcube)

Boom mounted anemometer / Top mounted anemometer

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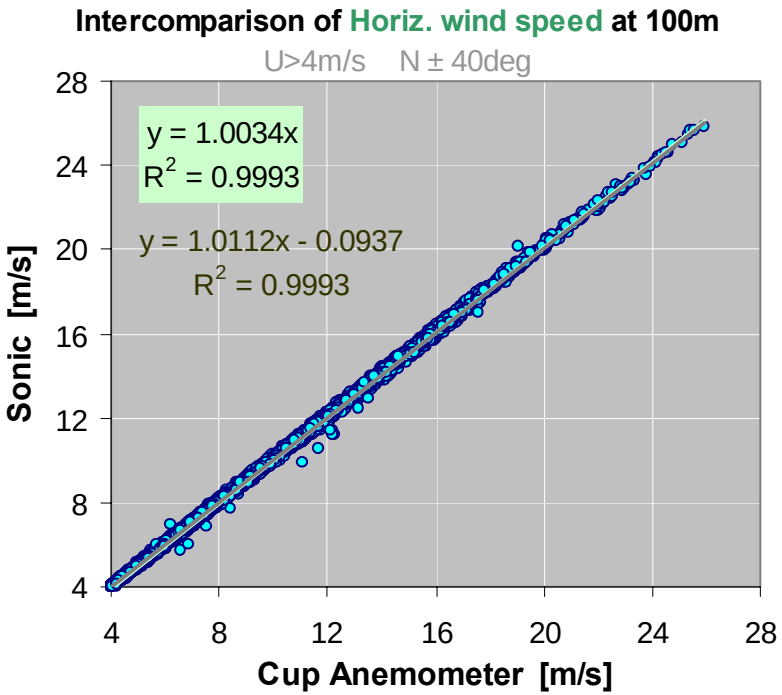
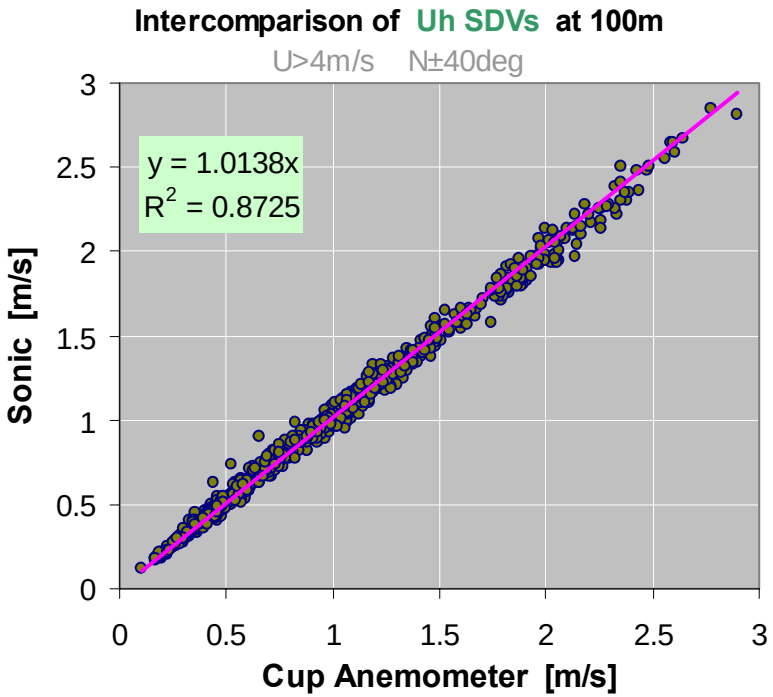
Sonic vs Cup at 100m





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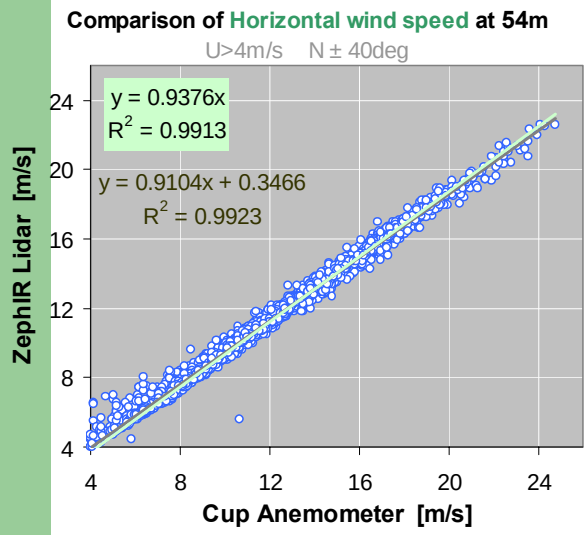
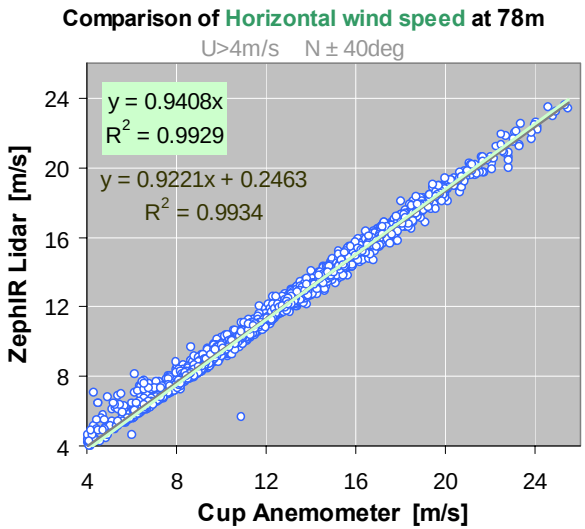
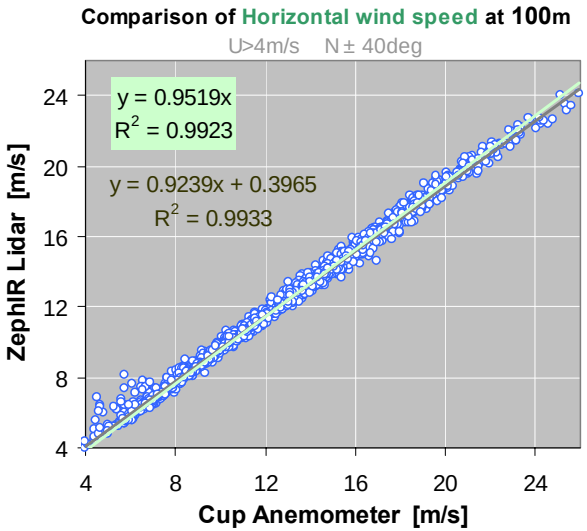
ZephIR vs Cup







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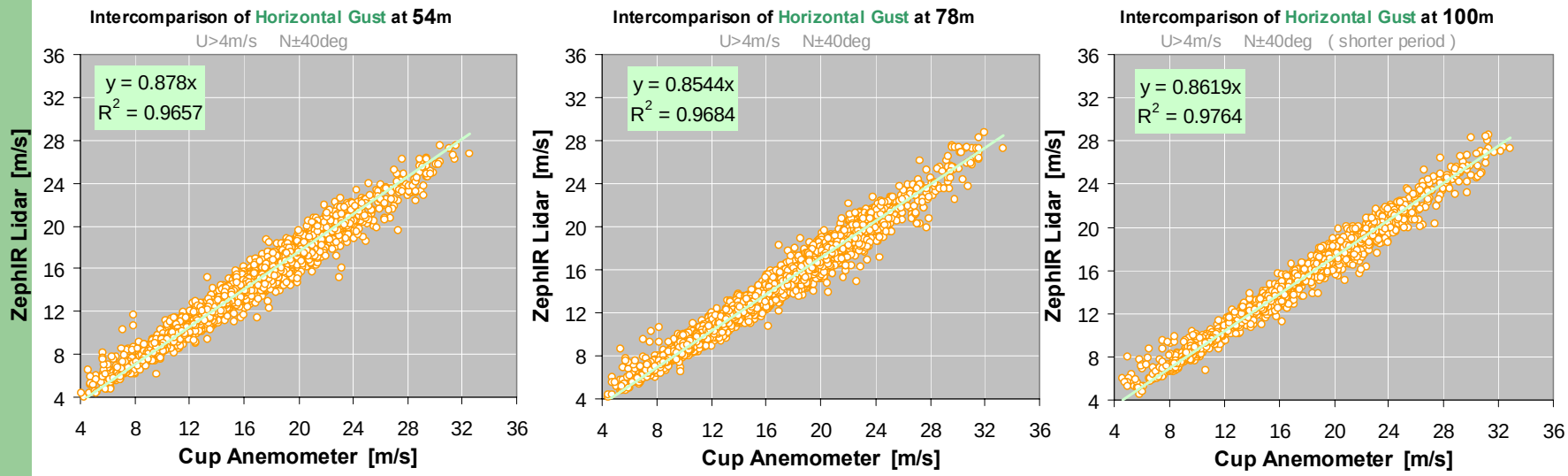
ZephIR vs Cup



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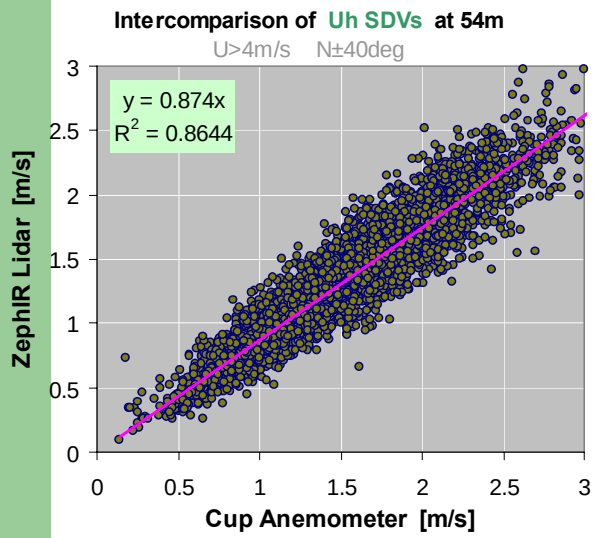
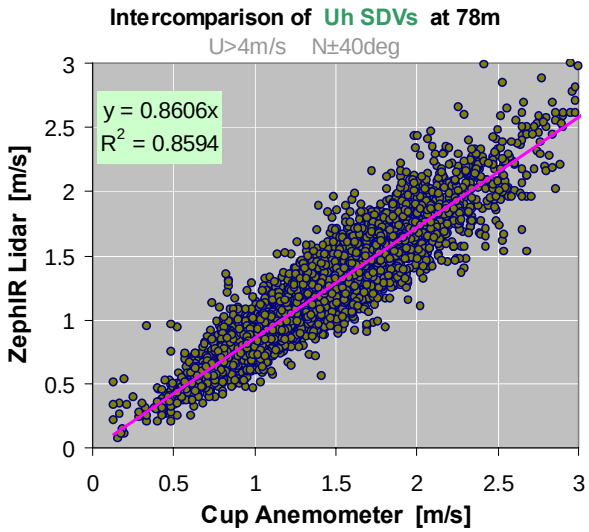
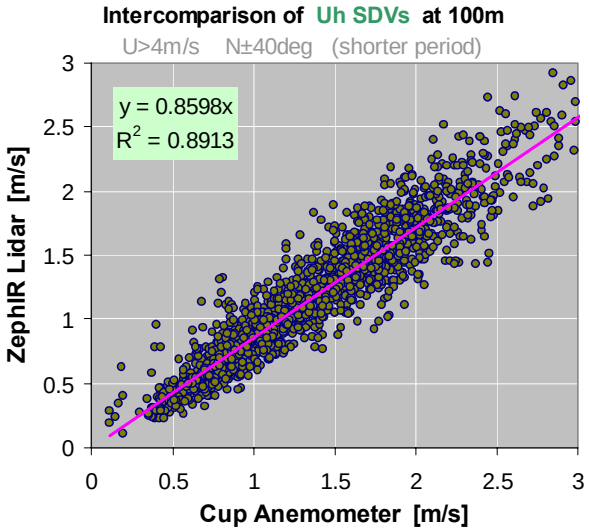
ZephIR vs Cup







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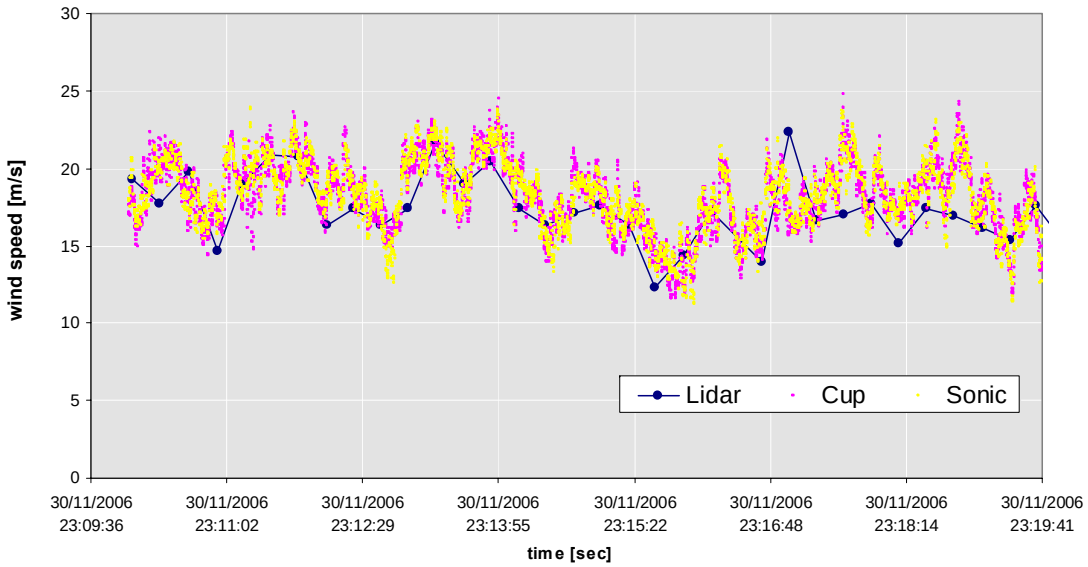
Sampling differences

- Sonic at 4Hz (2400 points / 10min)
- Cup at 1Hz (600 points / 10min)
- Windcube at 0.7 Hz (~400 points / 10min, per height)
- ZephIR at 0.05Hz (~40 points / 10min, per height)



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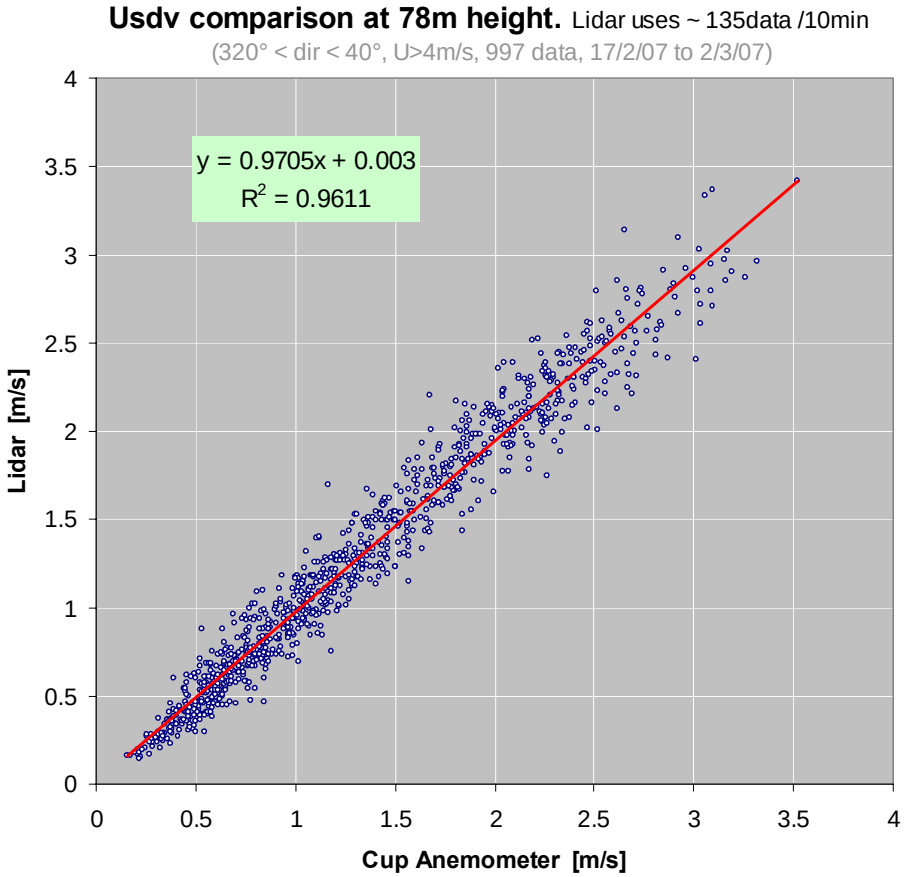
ZephIR “fixed” at 78m



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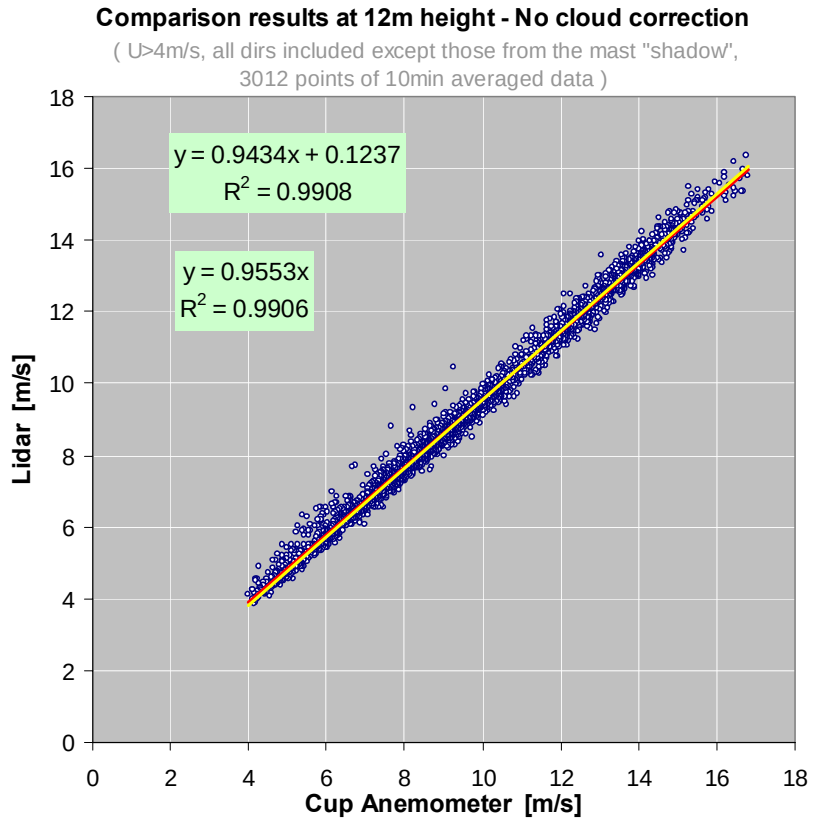
Cup – ZephIR Lidar comparison at 12m height



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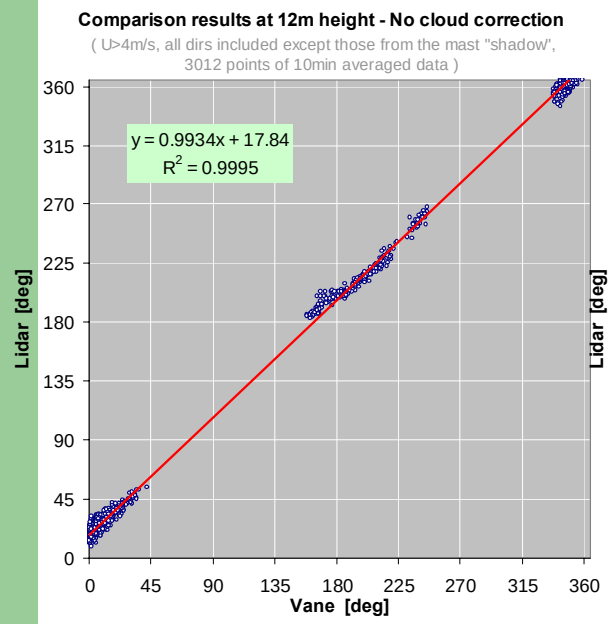
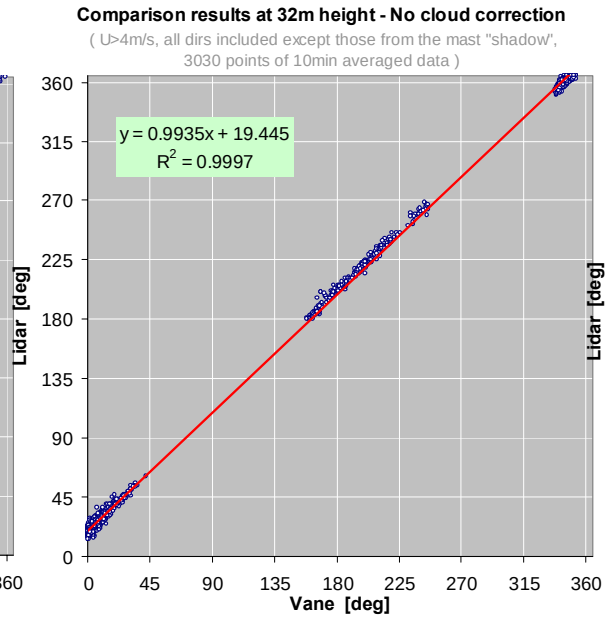
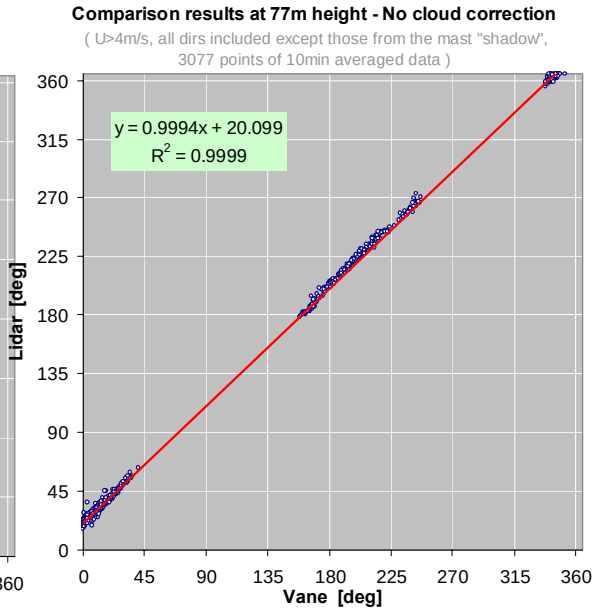
Wind Vane – Lidar comparisons at 12m, 32m and 77m height







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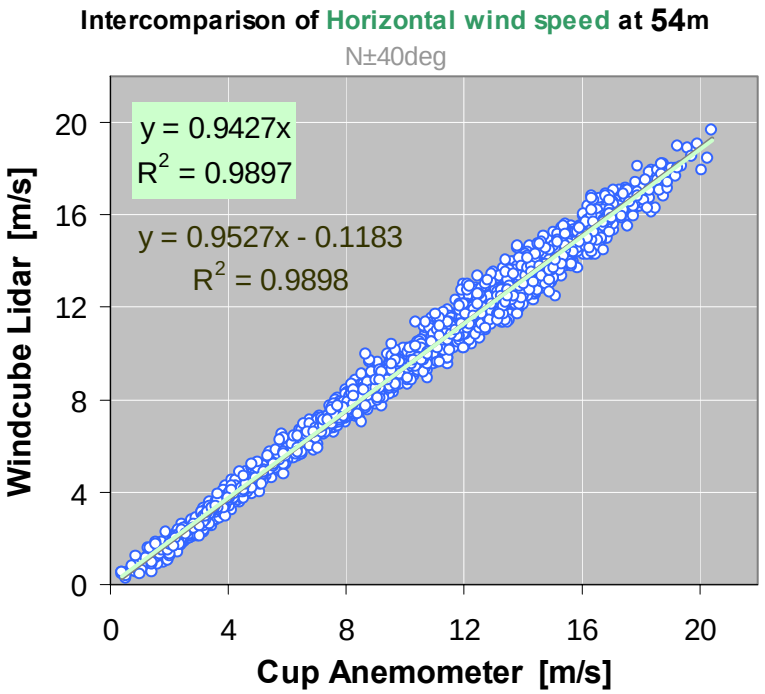
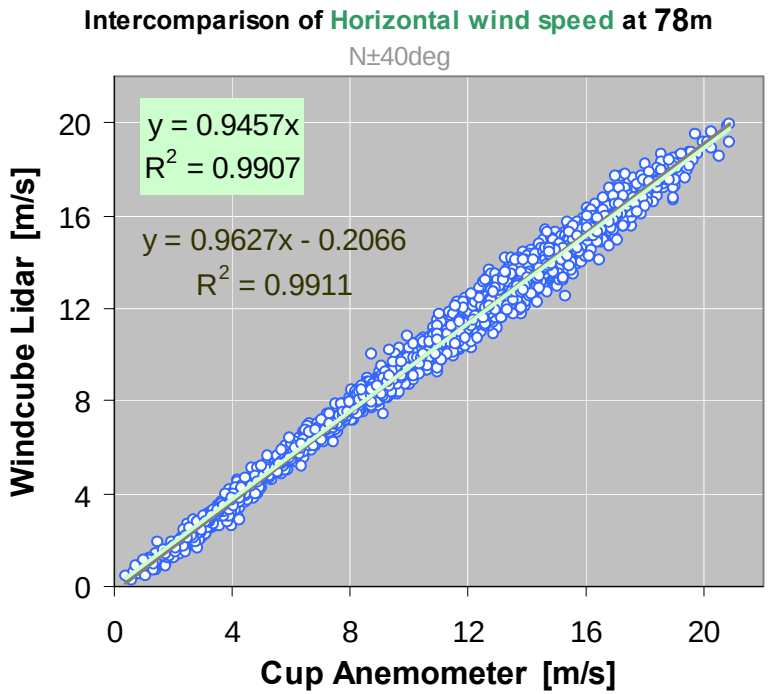
Windcube with 30° prism vs Cup





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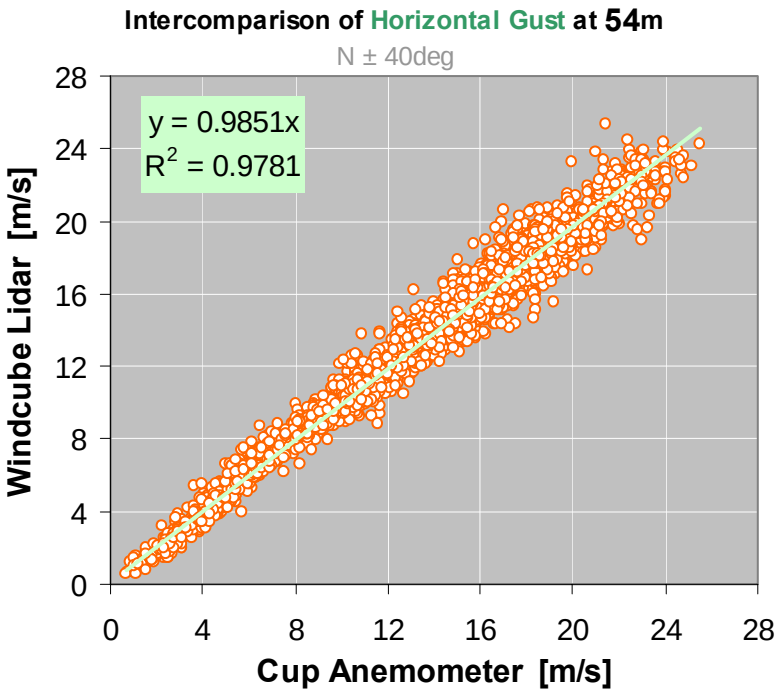

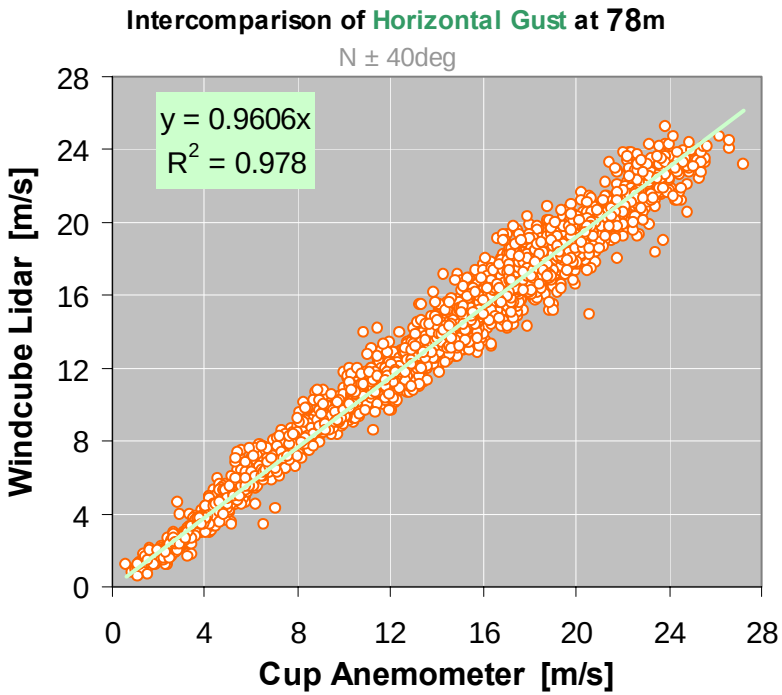

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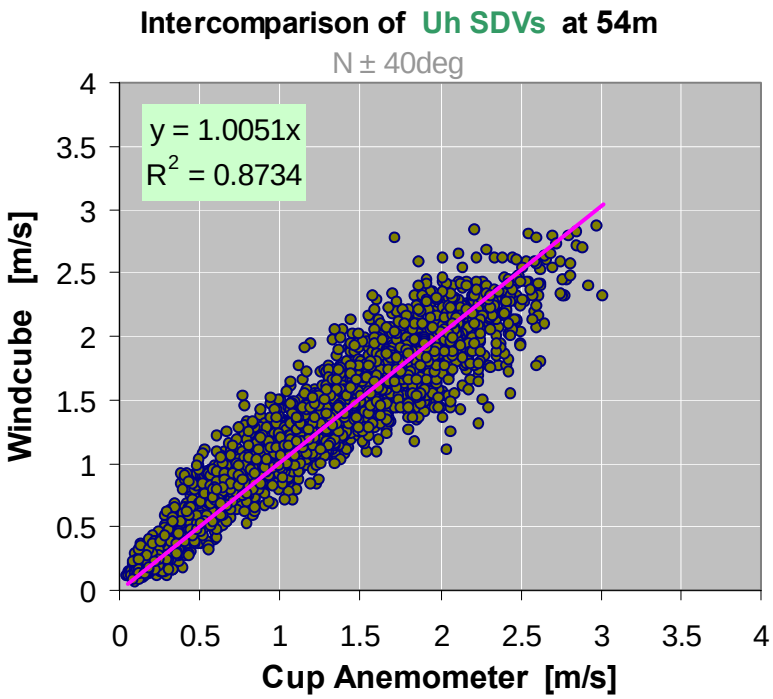
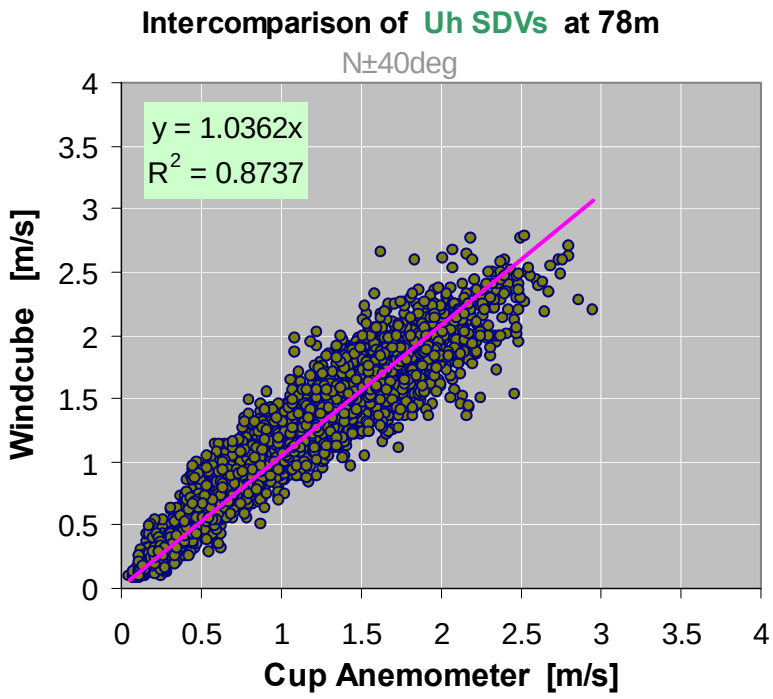
Windcube with 30° prism vs Cup





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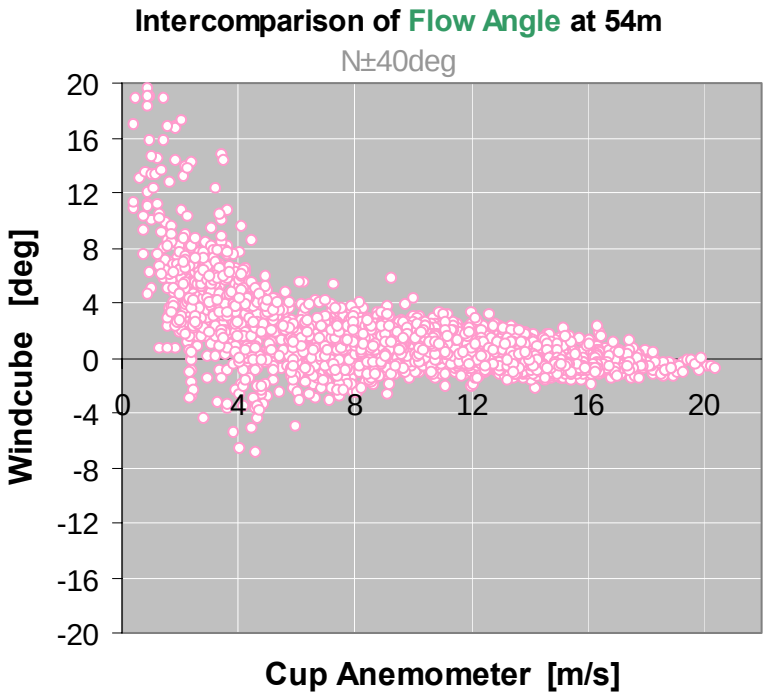
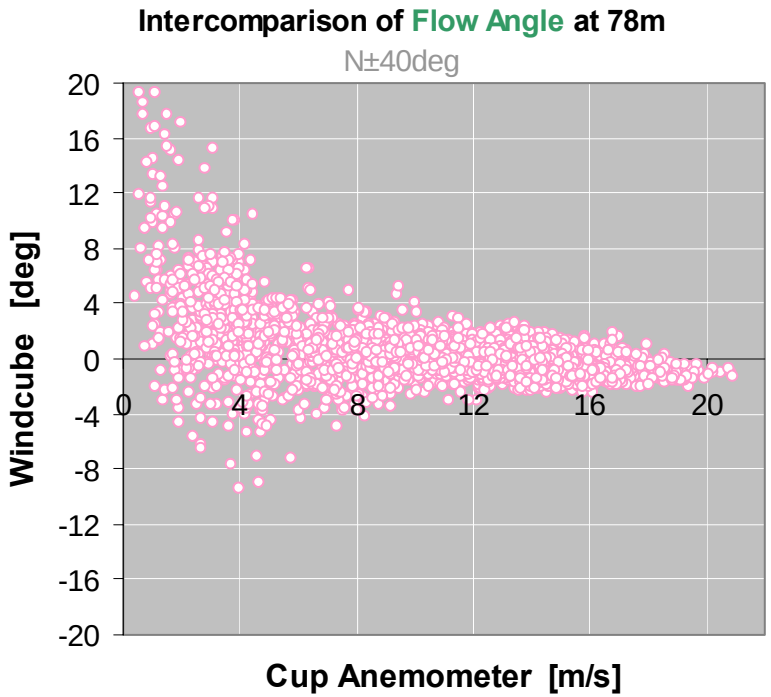
Windcube with 30° prism vs Cup





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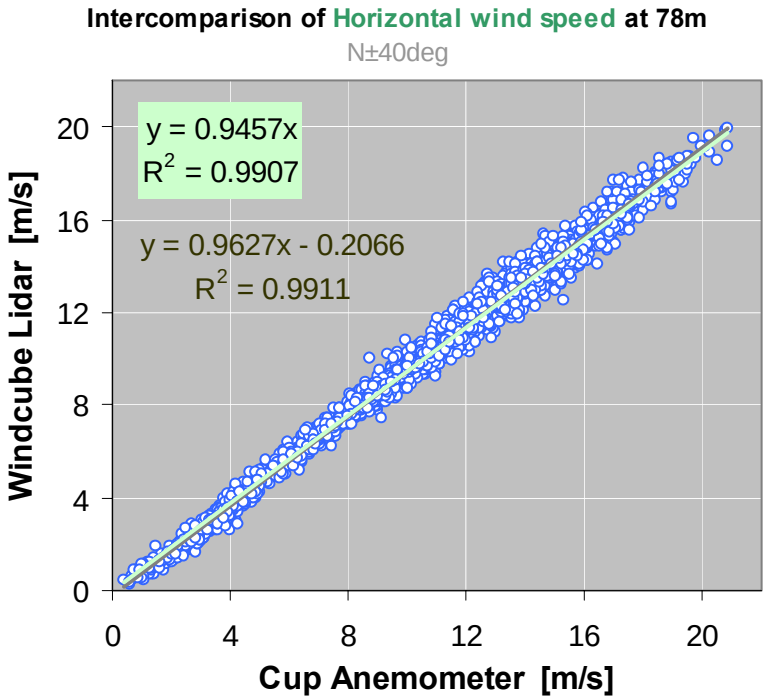
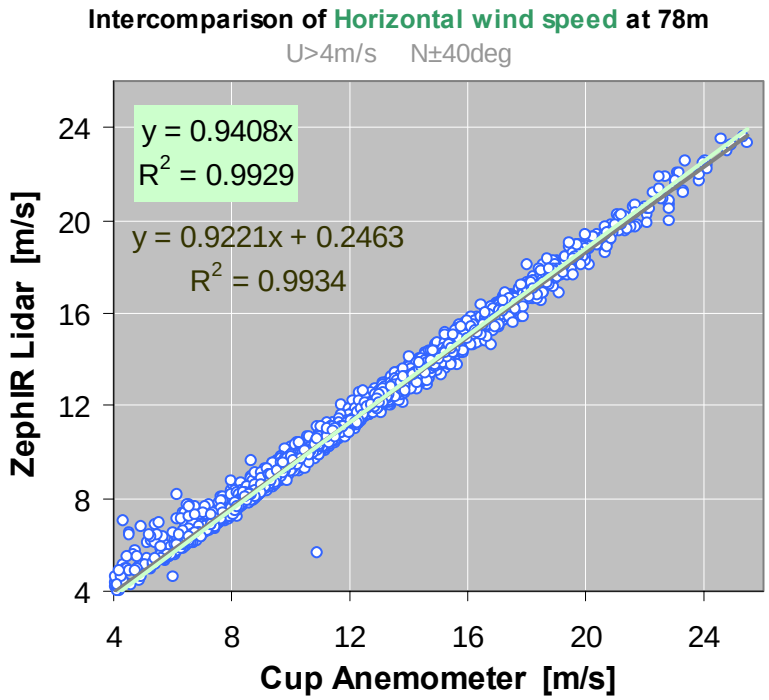
Windcube (30°) and ZephIR vs Cup at 78m





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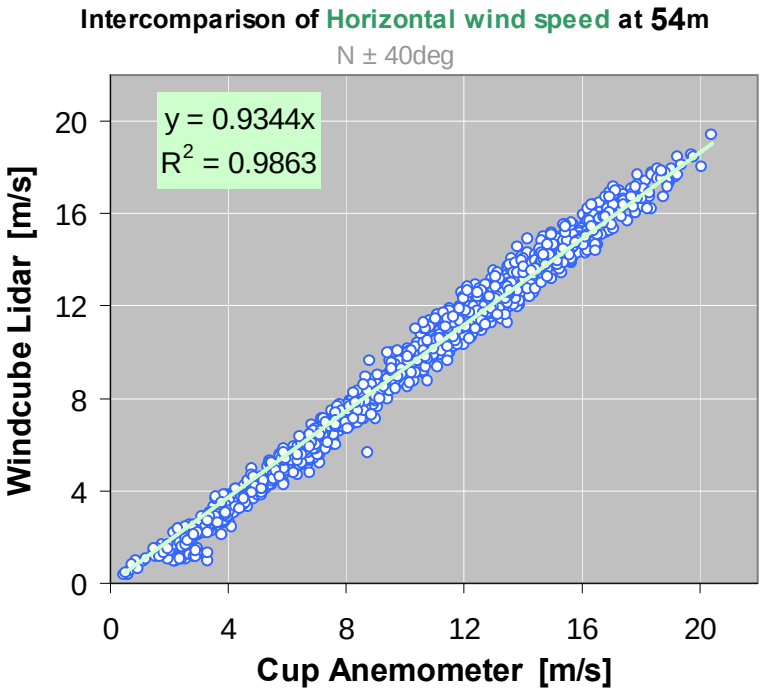
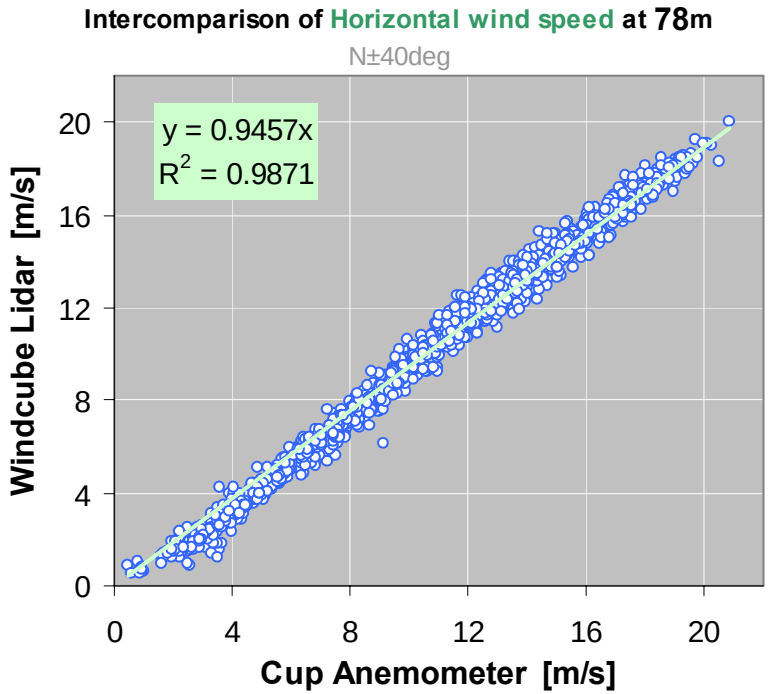
Windcube with 15° prism vs Cup





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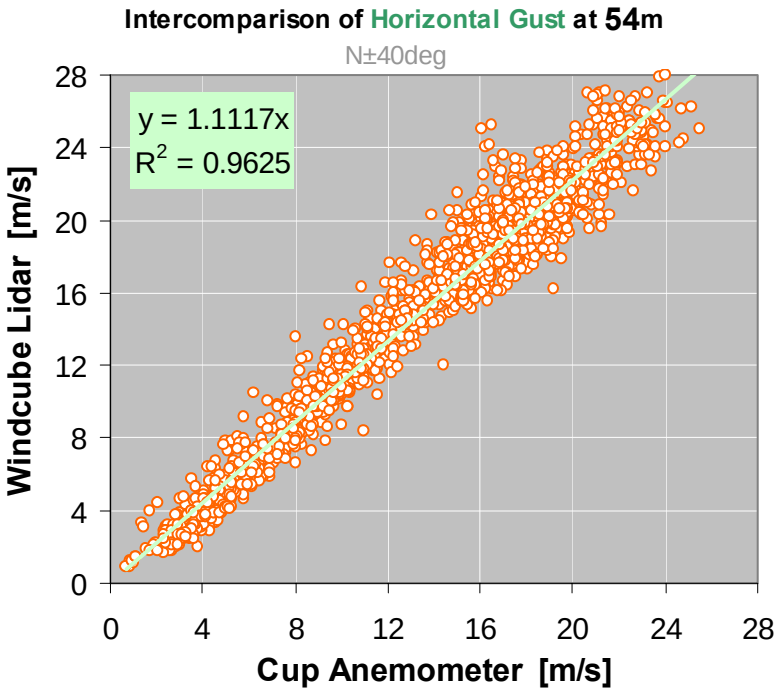
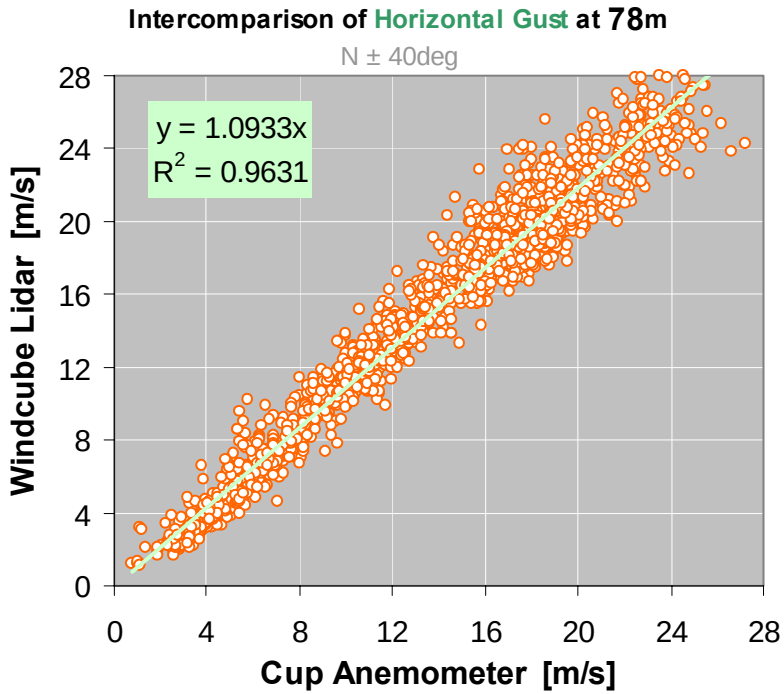
Windcube with 15° prism vs Cup





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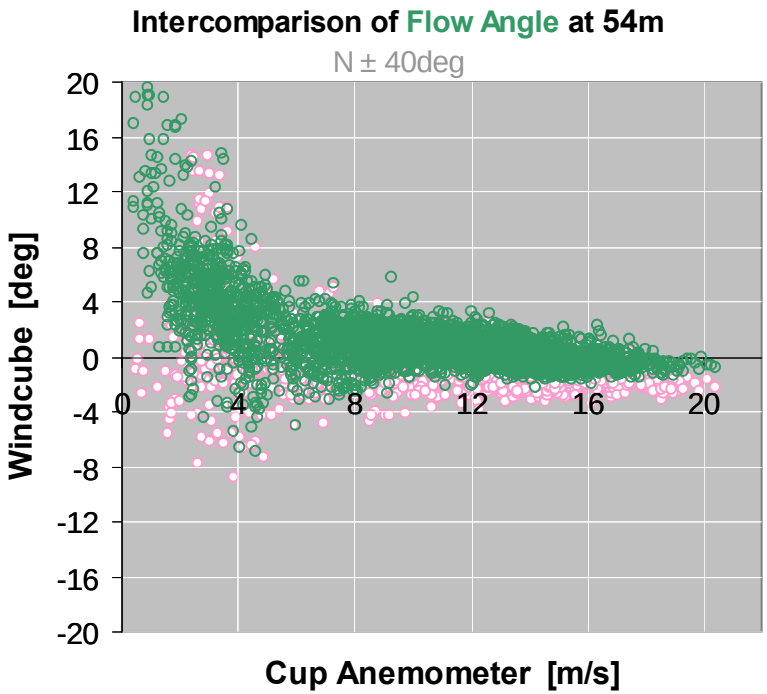
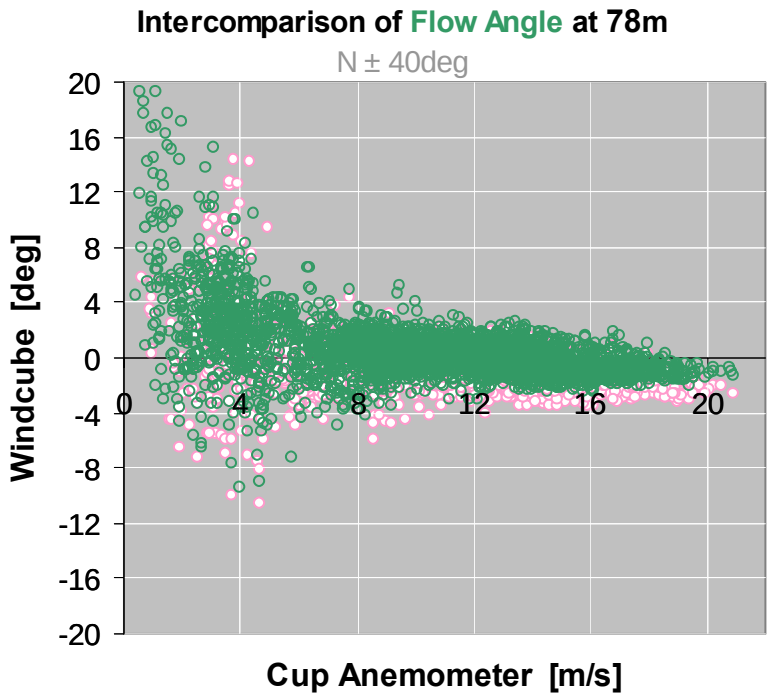
Windcube with 15° prism vs Cup





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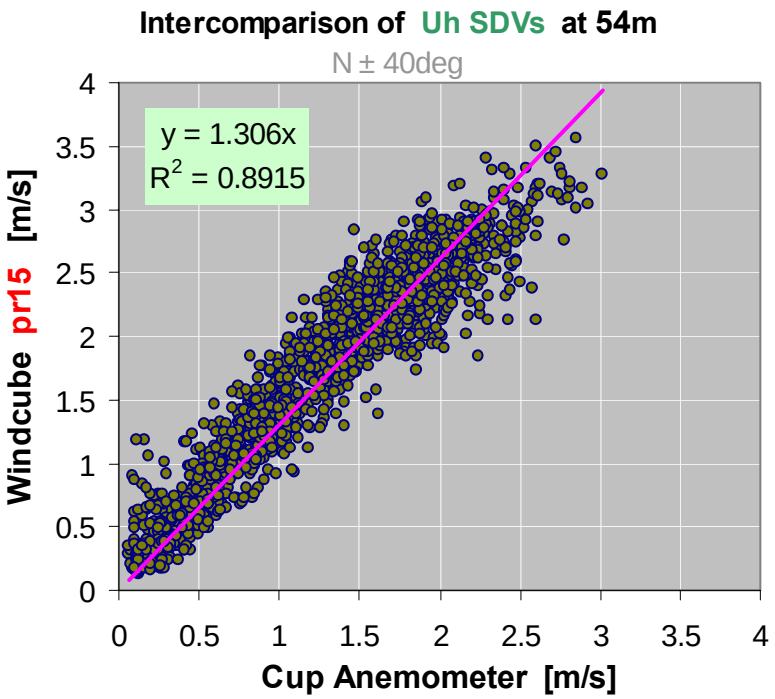
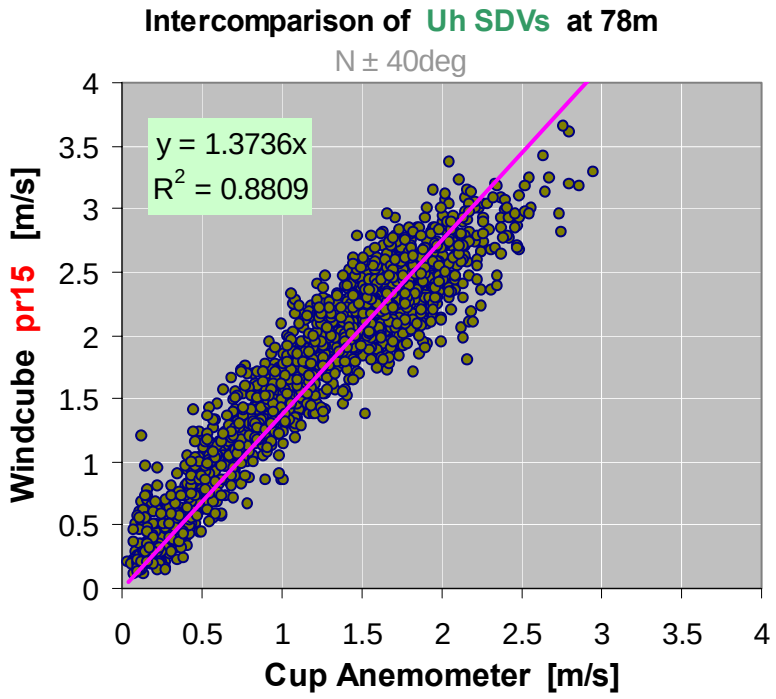
Windcube with 15° prism vs Cup





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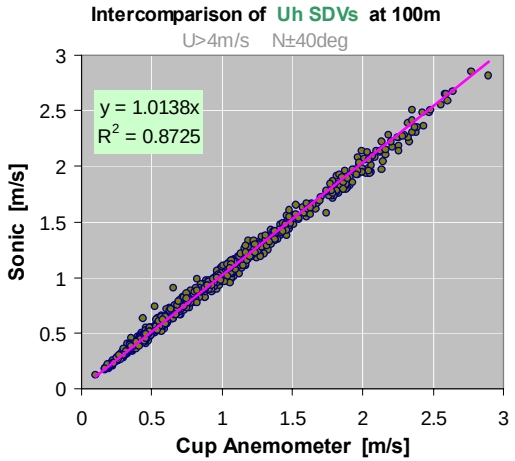
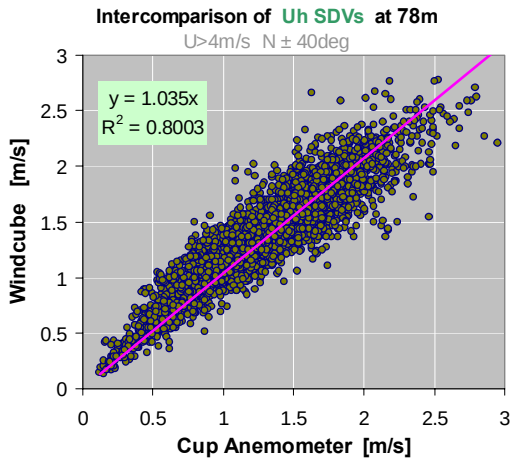
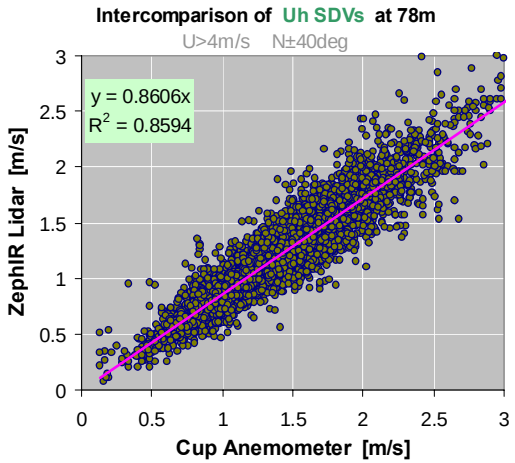
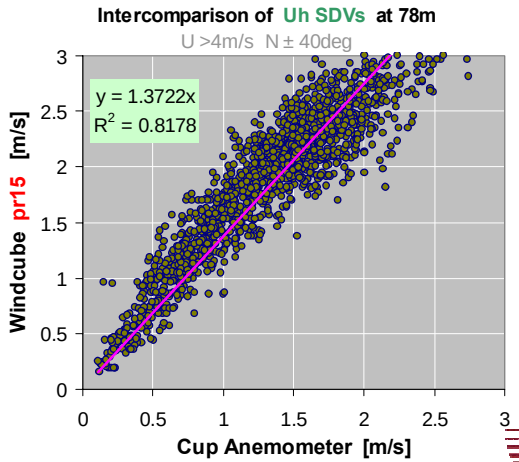
SDV of Horizontal wind speed at 78m









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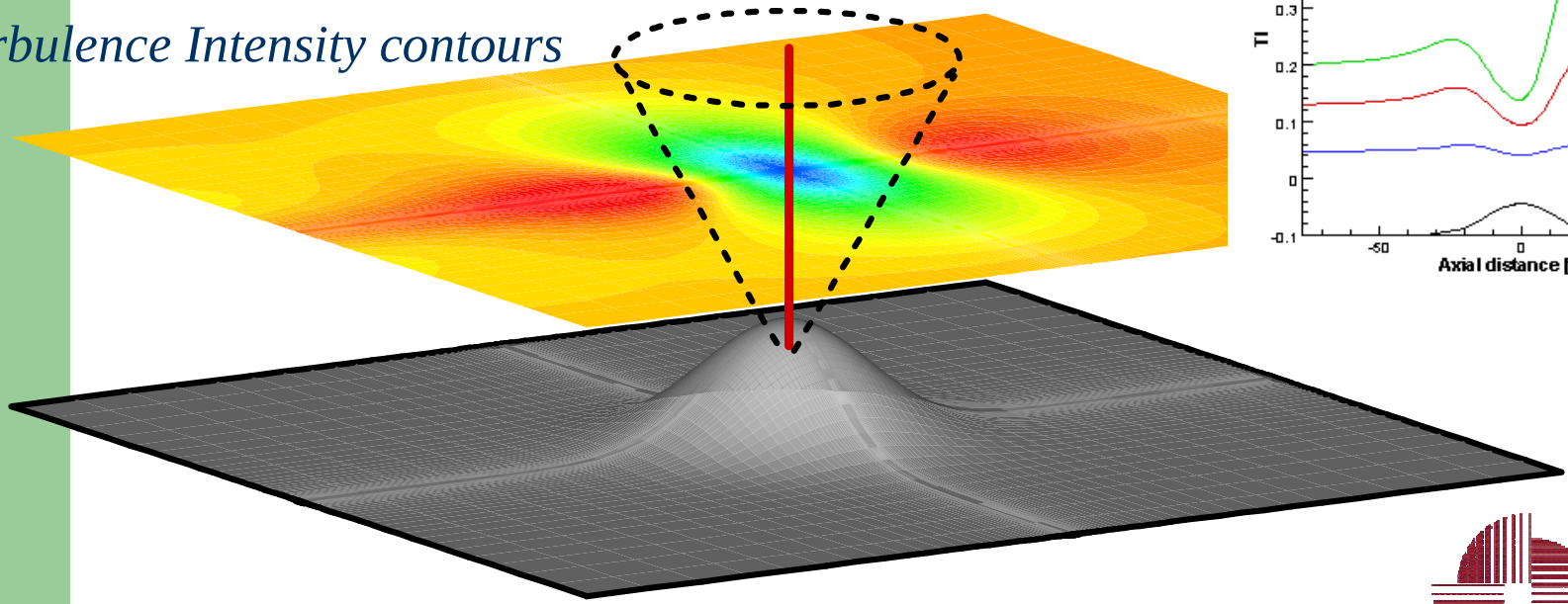
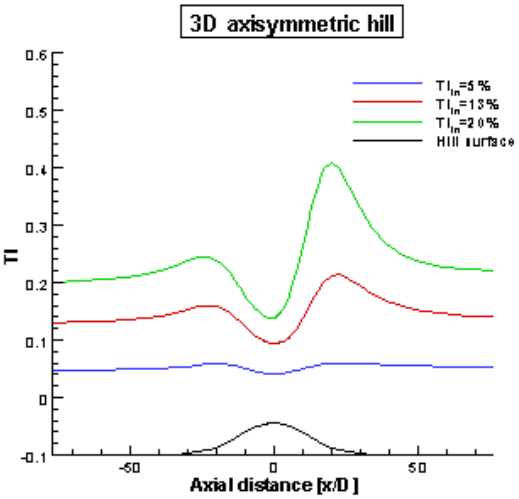
Flow over a Gaussian hill

Turbulence Intensity contours





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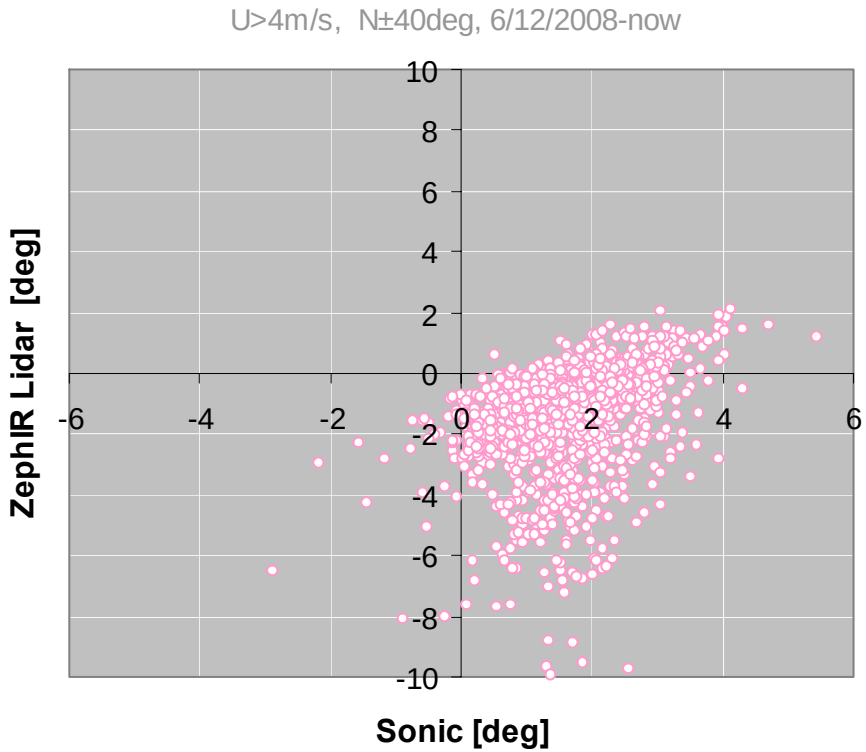
Flow Angle: ZephIR vs Sonic at 100m



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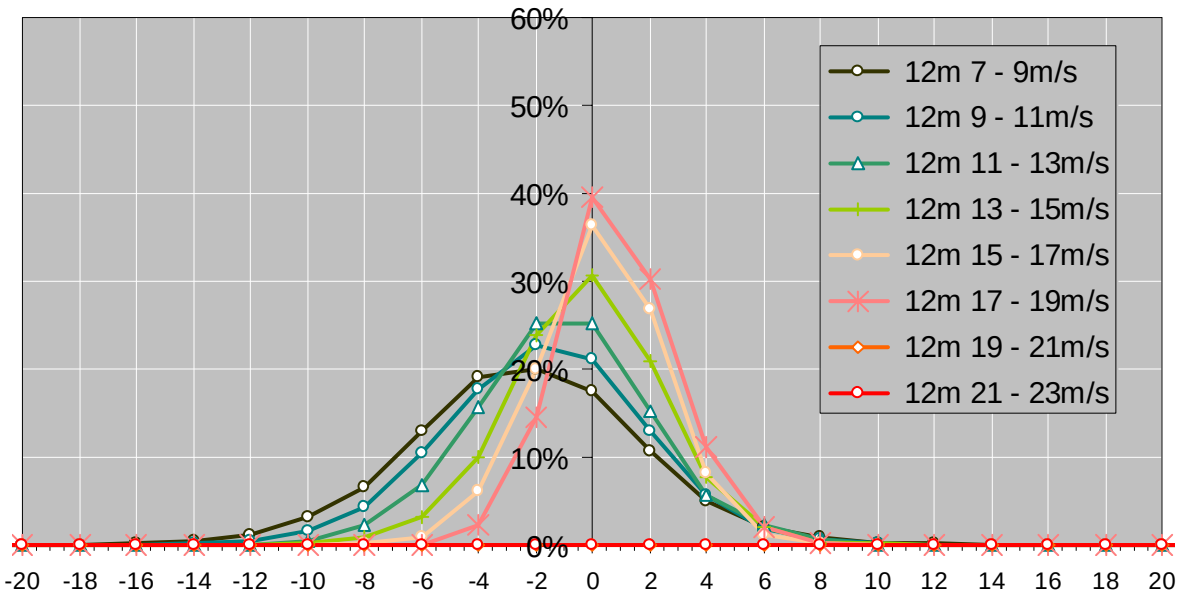
ZephIR: Flow inclination angle at 12m height



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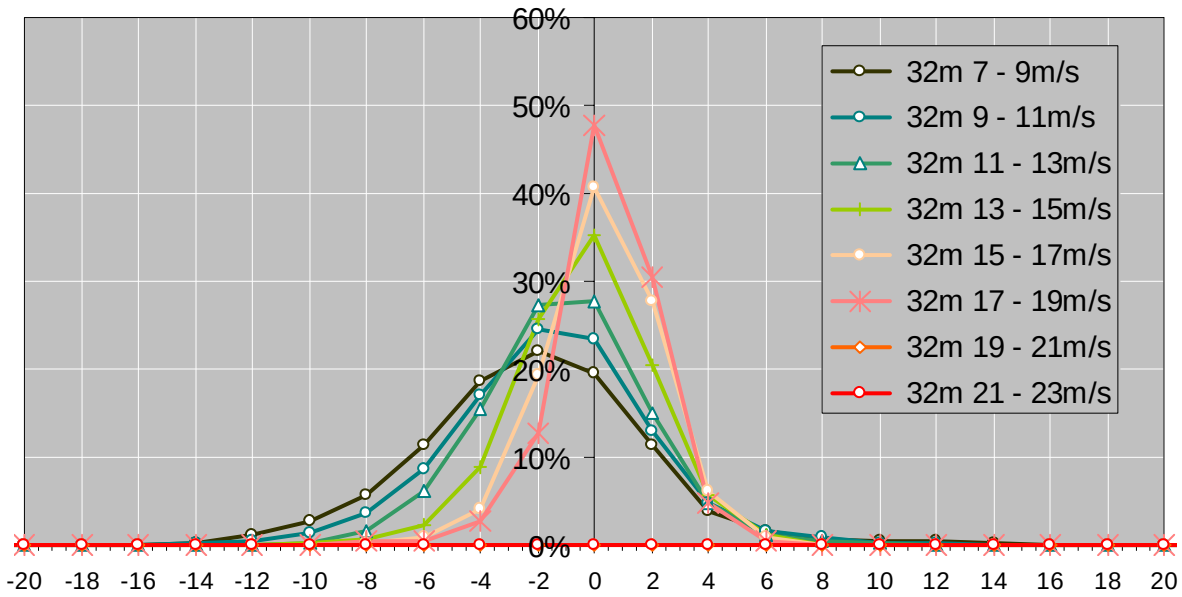
ZephIR: Flow inclination angle at 32m height



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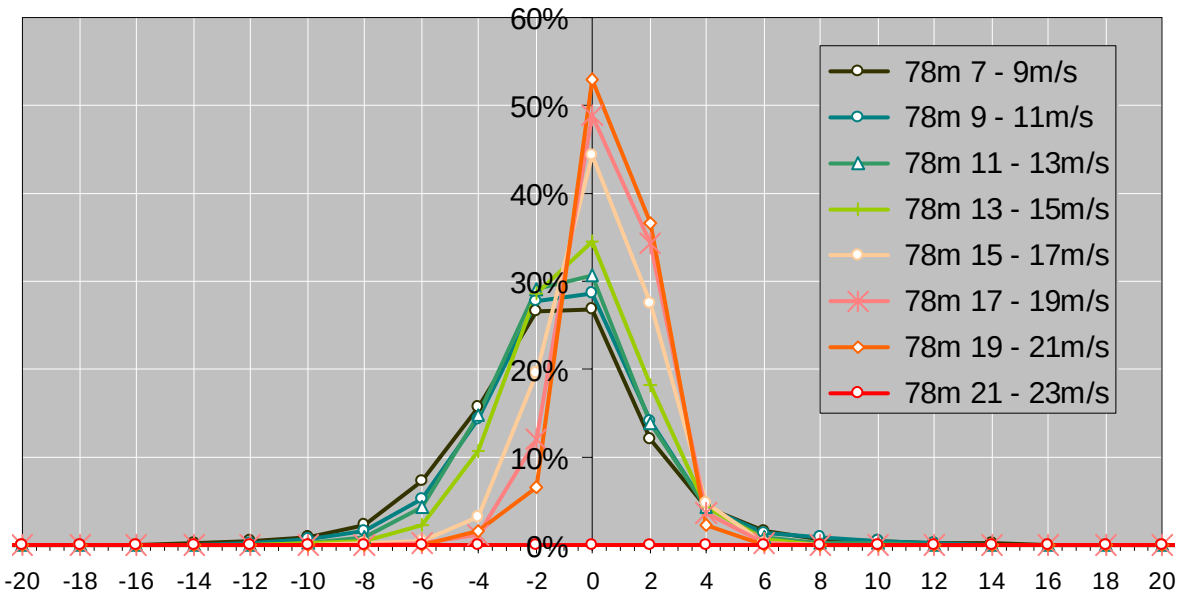
ZephIR: Flow inclination angle at 78m height



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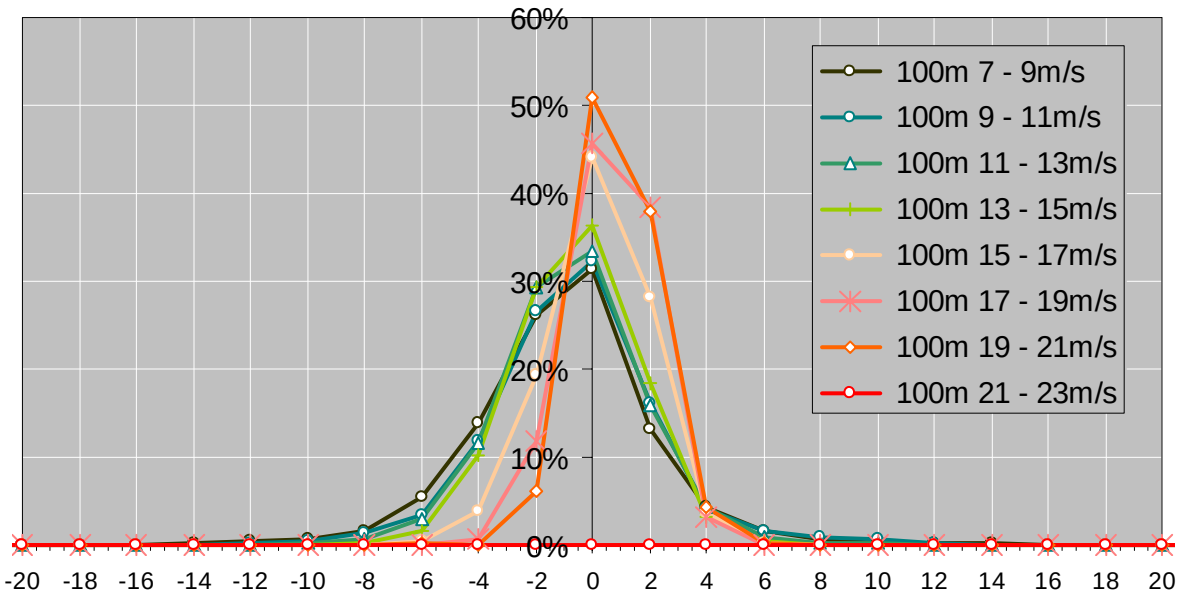
ZephIR: Flow inclination angle at 100m height



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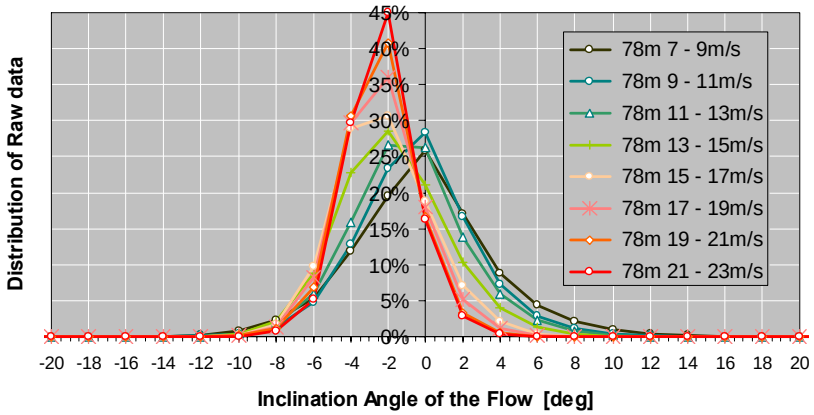
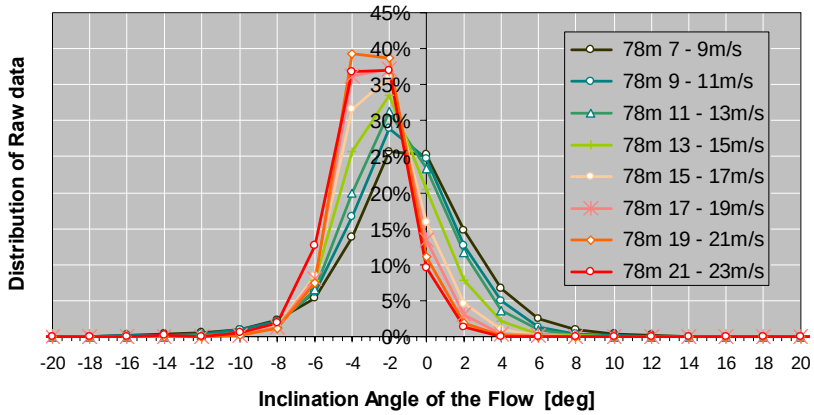
Flow Inclination angle at 80m

Windcube (30°)



ZephIR



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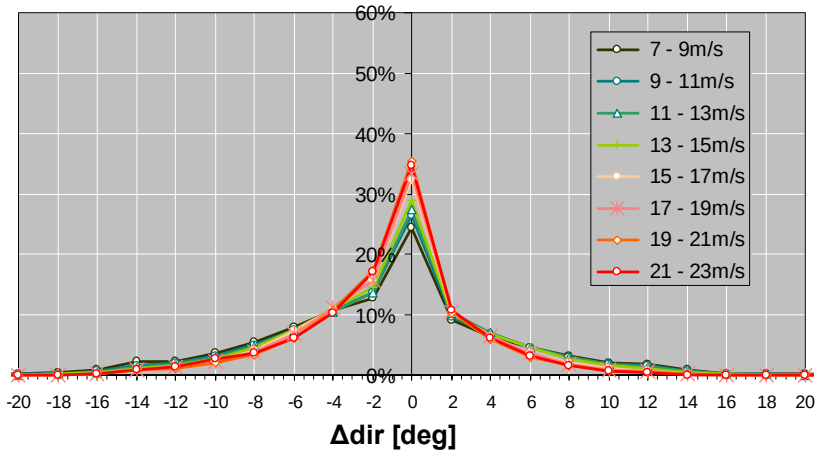
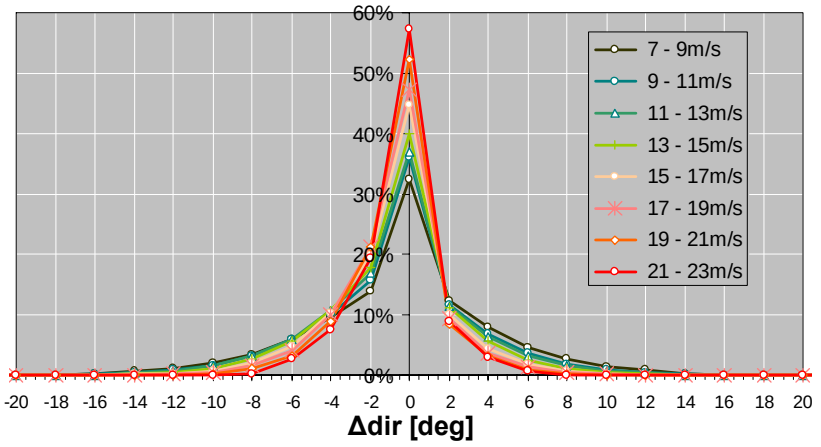
Windcube: Wind direction variation per height

Distribution of instantaneous wind direction changes per height, using all the raw data (1.5sec).

Dir78m – Dir100m



Dir120m – Dir100m



Wind vanes: Cannot avoid small misalignments between heights

Lidar: No misalignment error between heights

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Conclusions

- *Confirmation of the ~6% velocity deficit measured by all Lidars compared to Cups and Sonics from 12m to 100m.*
- *Impressive wind speed correlation to cup anemometers.*
- *Lidar's T.I. is marked by the spatial character of the measurement and may not be directly comparable to that of Cup anemometers.*
- *New results for narrower angle cones (15° prism). Further analysis of inst. radial velocities is needed to confirm the SDVs increase.*
- *Lidars may sense more representatively the wind flow over the rotor of a multi-MW WT, operating in complex terrain. Revision of the ref. wind speed is recommended, for more accurate Power Performance evaluation.*
- *New ideas (algorithms, alternative scanning modes, new prisms,…) are necessary to further improve the accuracy of Lidars* ***in complex terrain.***