LIDAR PERFORMANCE IN COMPLEX TERRAIN MODELLED BY WASP ENGINEERING

Ferhat Bingöl
Risø-DTU
Denmark

Jakob Mann
Risø-DTU
Denmark

Dimitri Foussekis
CRES
Greece

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BT4 Remote sensing
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DTU

RISØ

Outline

- LiDARs at Risø and CRES
  (5 minutes)
- WAsP Engineering 2.0
  (5 minutes)
- Greek sites
  (15 minutes)
- Questions
  (0~5 minutes)

-=THIS PRESENTATION INCLUDES 21 SLIDES=-

LiDARs at Risø and CRES

DTU

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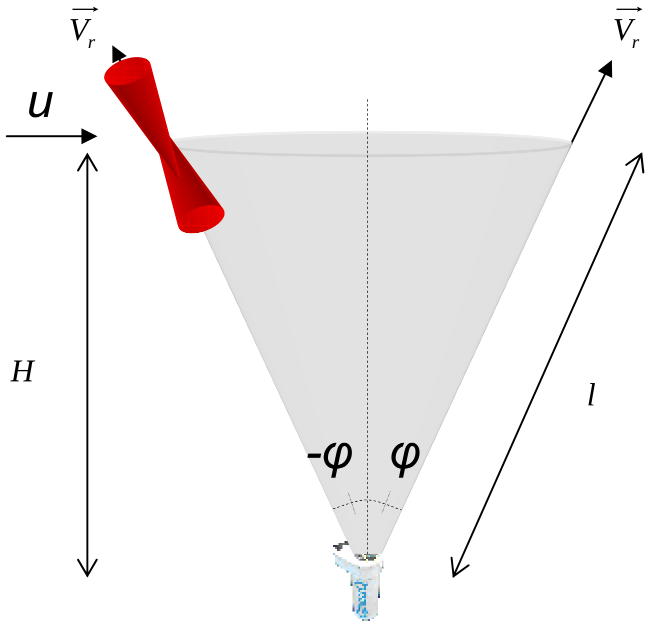
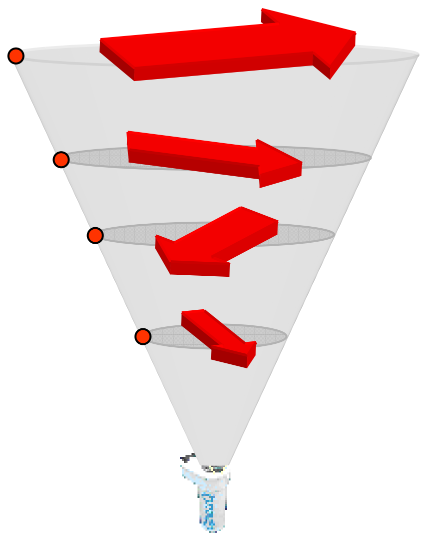
A New Anemometer; QinetiQ ZephIR

Høvsøre

Lavrio

Conical Scanning Mode





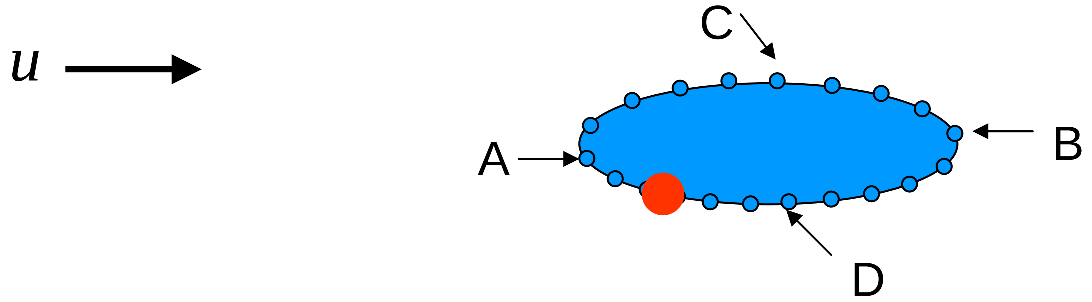
$$v_r = U_h \sin\varphi \cos(\theta - \theta_w) + w\cos\varphi$$

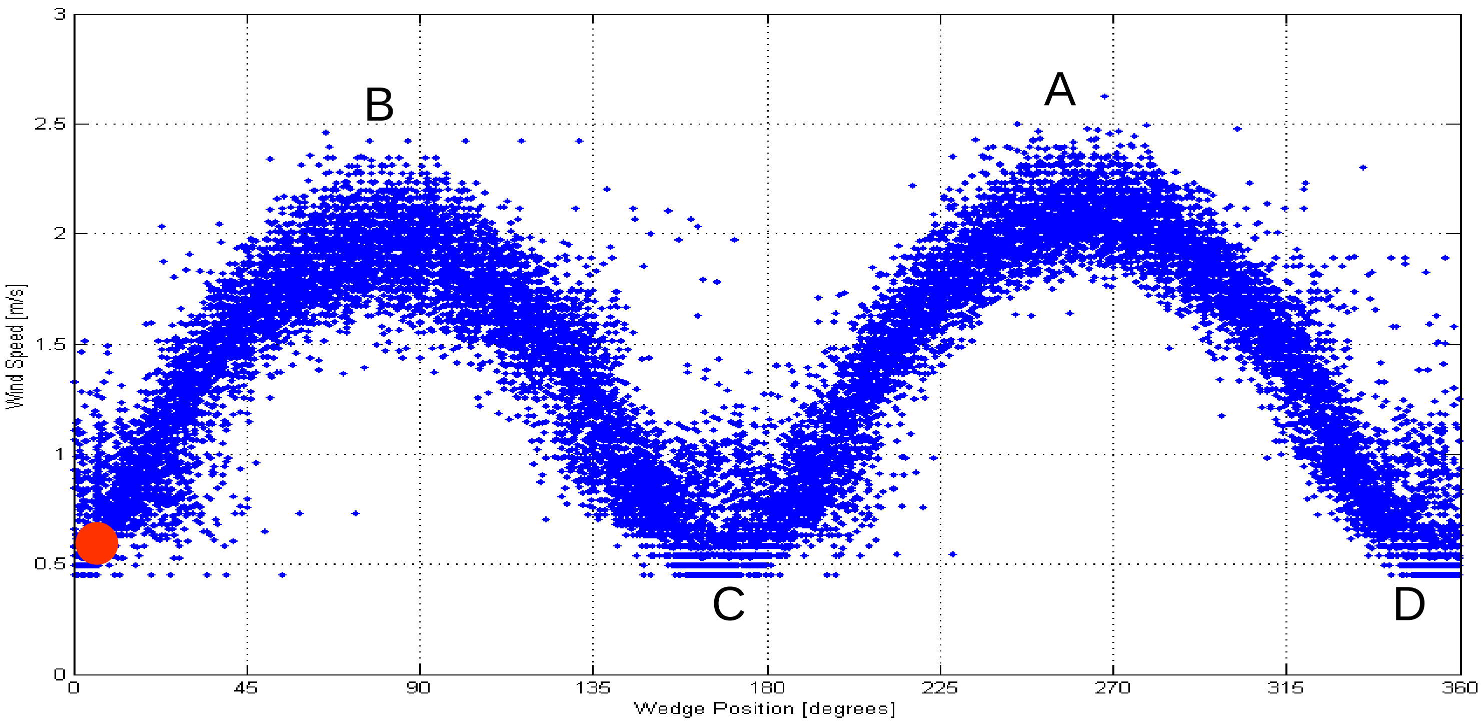
- 1 round = 1 second
- 3 rounds give 1 good data
- It can change focus distance in 1 sec
- φ=30.4º (Azimut angle)
- **θ=[0:π/2]** (scanning angle)

Max height = 150m

Min height = 10m

Conical Scanning Mode





WAsP Engineering 2.0

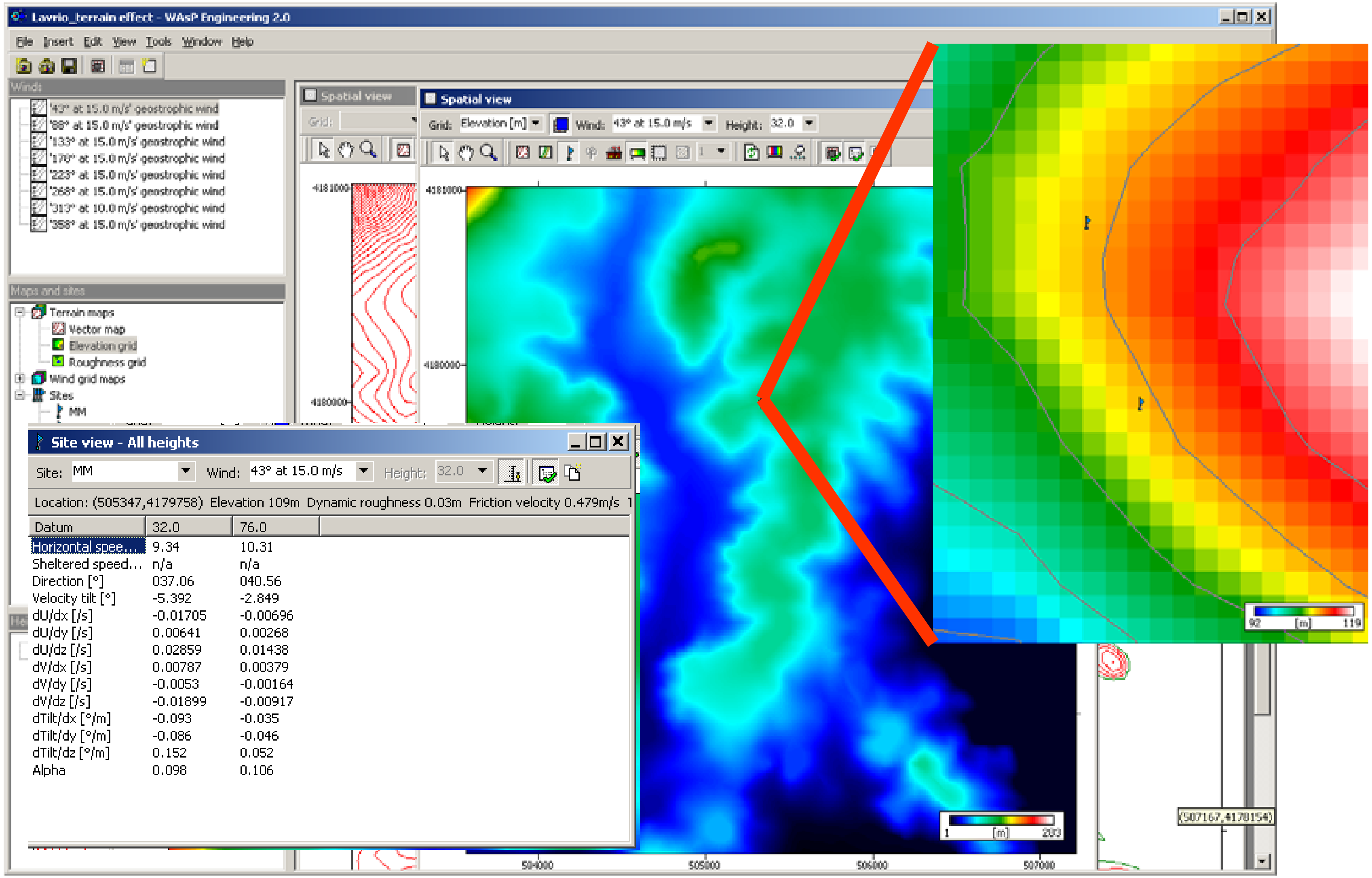
WAsP Engineering (WEng) 2.0

- **WAsP** is the **W**ind Atlas **A**nalysi**s** and Application **P**rogram
  is a PC program for predicting wind climates, wind resources and power productions from wind turbines and wind farms. (http://www.WAsP.dk)

- **WEng** is **W**AsP **Eng**ineering
  is a PC program for the estimation of extreme wind speeds, wind shears, wind profiles and turbulence in complex (and simple) terrain. Version 1.0 was launched in July 2001 and present version is 2.0, originally released in July 2005. (http://http://www.WAsPEngineering.dk/)

- **Official report is**
- *Mann, J.; Ott, S.; Jørgensen, B.H.; Frank, H.P., WAsP engineering 2000. Risø-R-1356(EN) (2002) 90 p.*
  http://www.risoe.dk/rispubl/VEA/ris-r-1356.htm

How to use WEng?



WEng Simulation

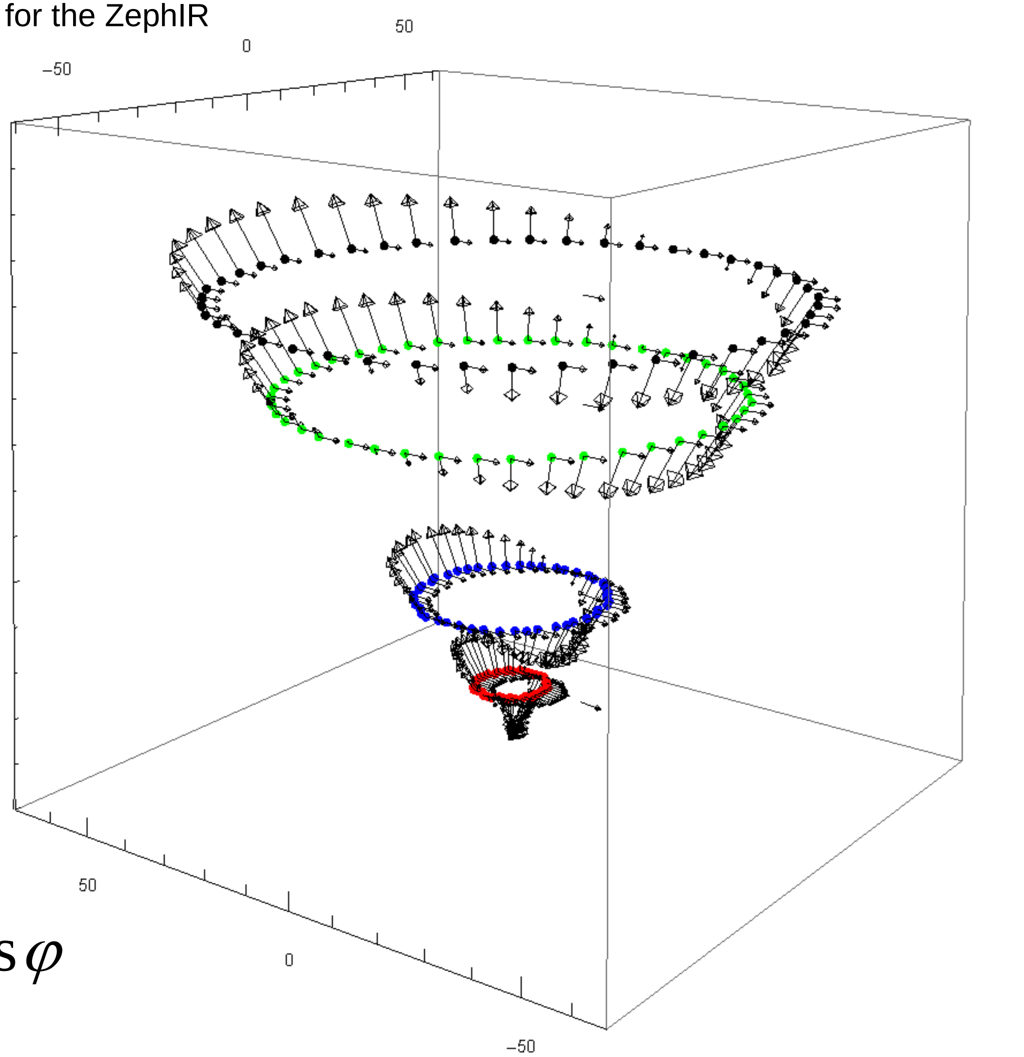
φ :half opening angle of the cone, approximately 30.4º for the ZephIR

θ :geographical angle in which the beam is pointing.

$$\vec{n}(\theta) = \{\sin\theta\sin\varphi, \cos\theta\sin\varphi, \cos\varphi\}$$

The position of the i_{th} measurement point with a geographical angle θ_i on the circle is given by

$$\vec{p}_i = h/\cos\varphi.\vec{n}(\theta_i) + \vec{p}_{LiDAR}$$



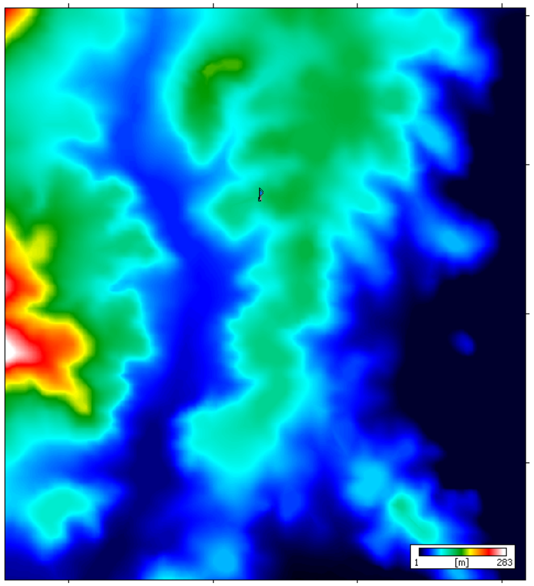
The wind vectors are projected on to laser beam direction by

$$v_r(\theta) = U_h\vec{n}(\theta).\{-\sin\theta_w, -\cos\theta_w, \tan\phi_w\}$$

$$v_r = U_h \sin\varphi\cos(\theta - \theta_w) + w\cos\varphi$$

Greek Sites

Greek Sites

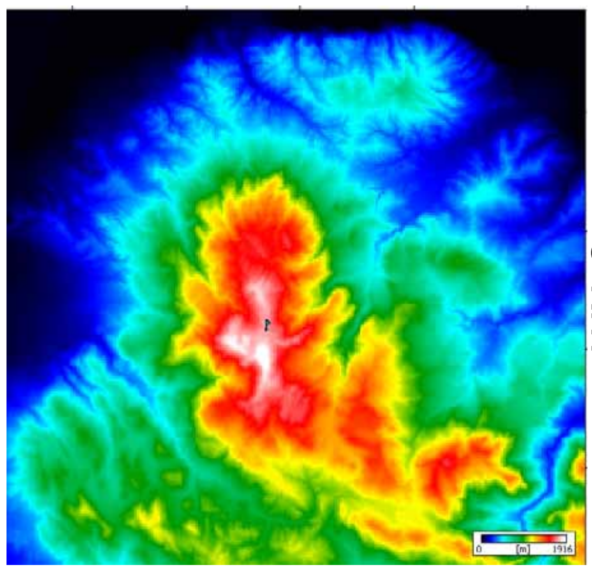


4 km

4 km

Lavrio

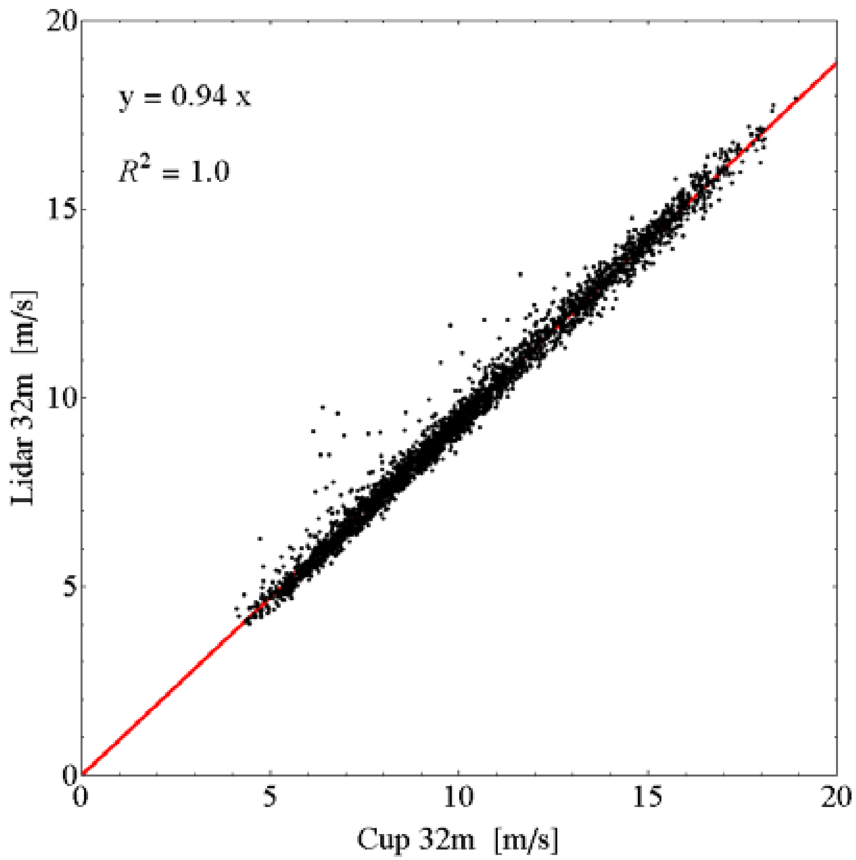
Panahaiko

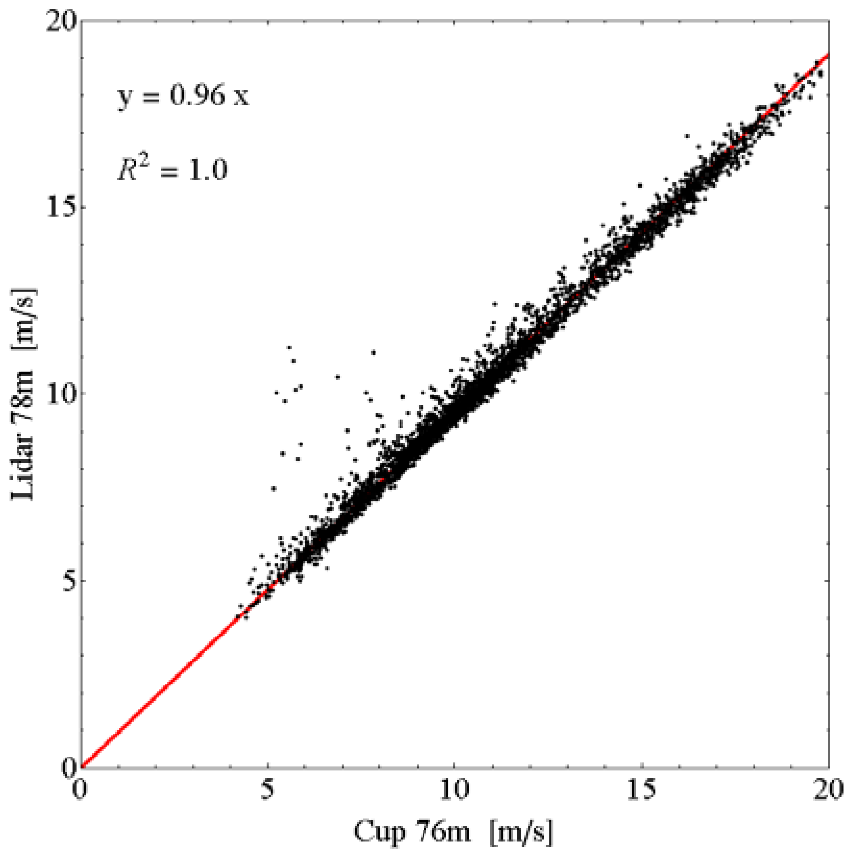


5 km

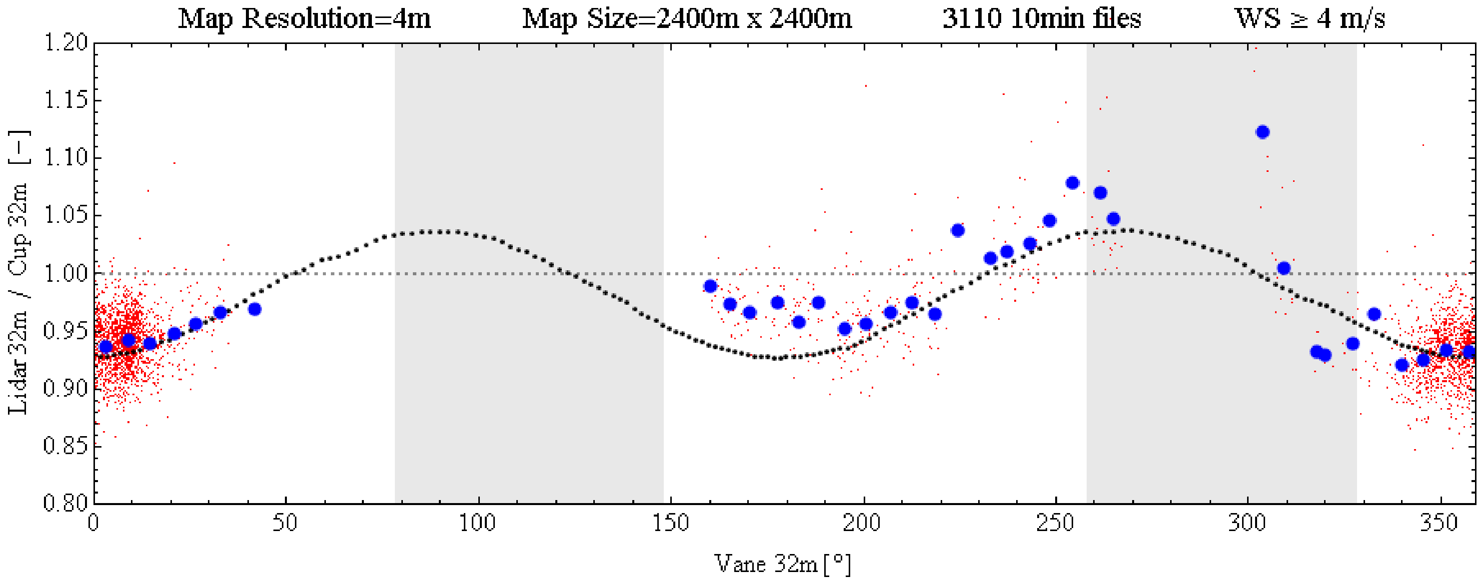
5 km

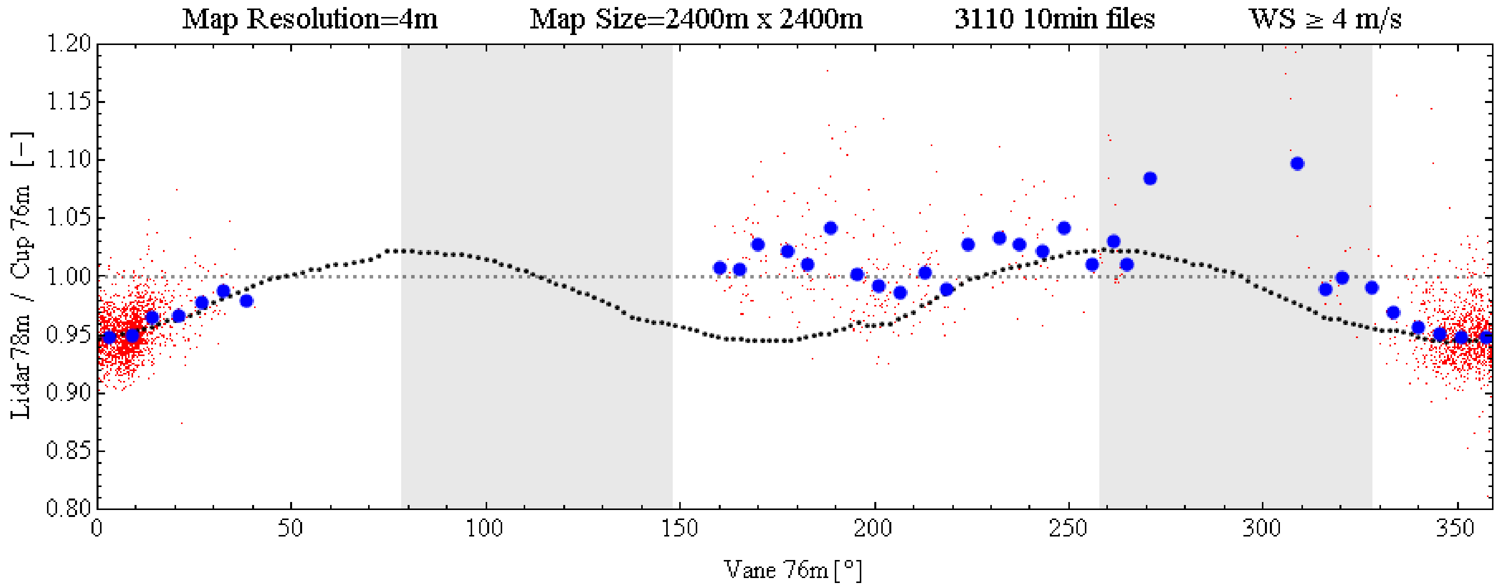
Lavrio


y = 0.94 x
R^2 = 1.0
Lidar 32m [m/s]
Cup 32m [m/s]
0
5
10
15
20

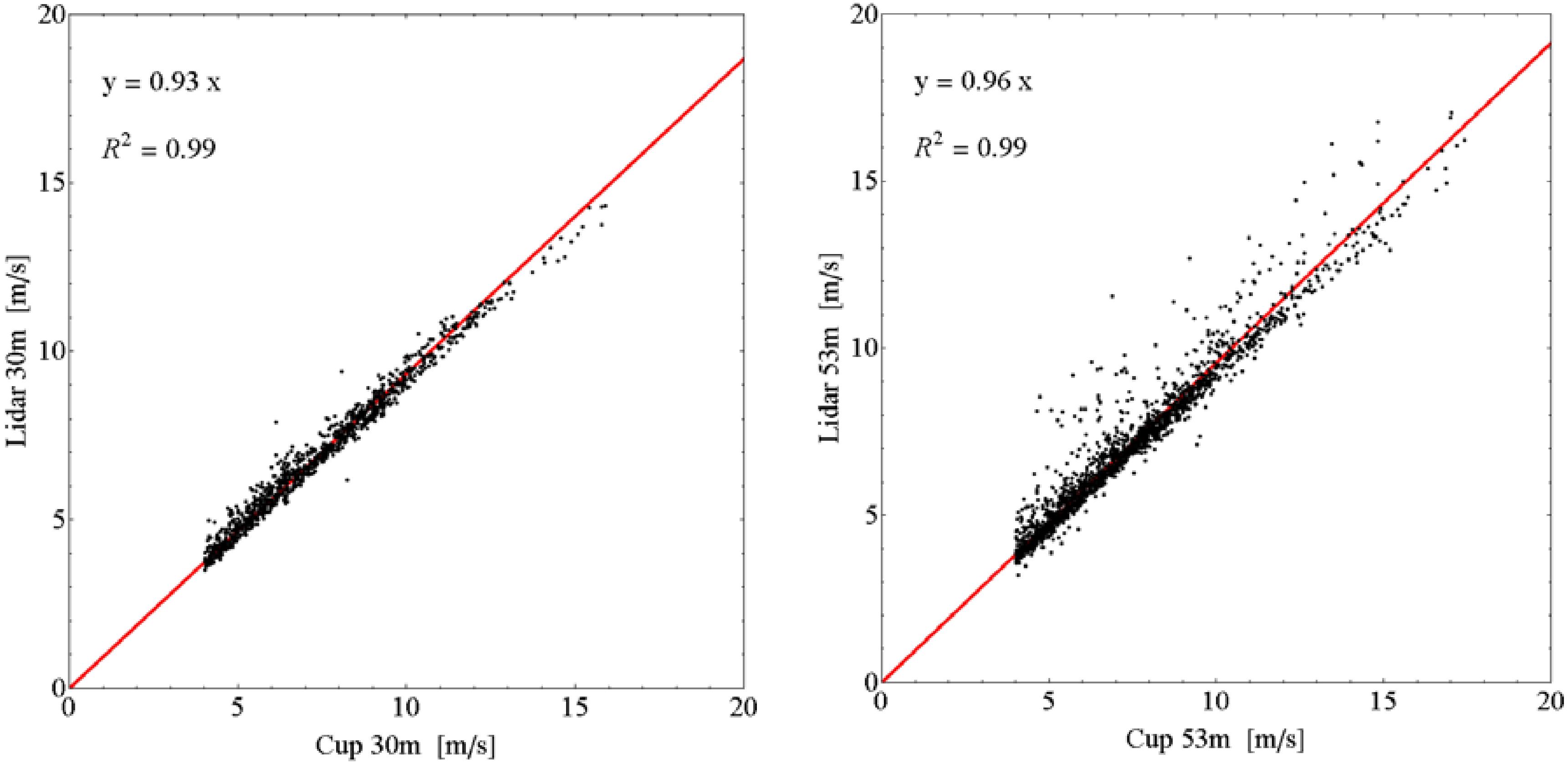

y = 0.96 x
R^2 = 1.0
Lidar 78m [m/s]
Cup 76m [m/s]
0
5
10
15
20

Results; Lavrio



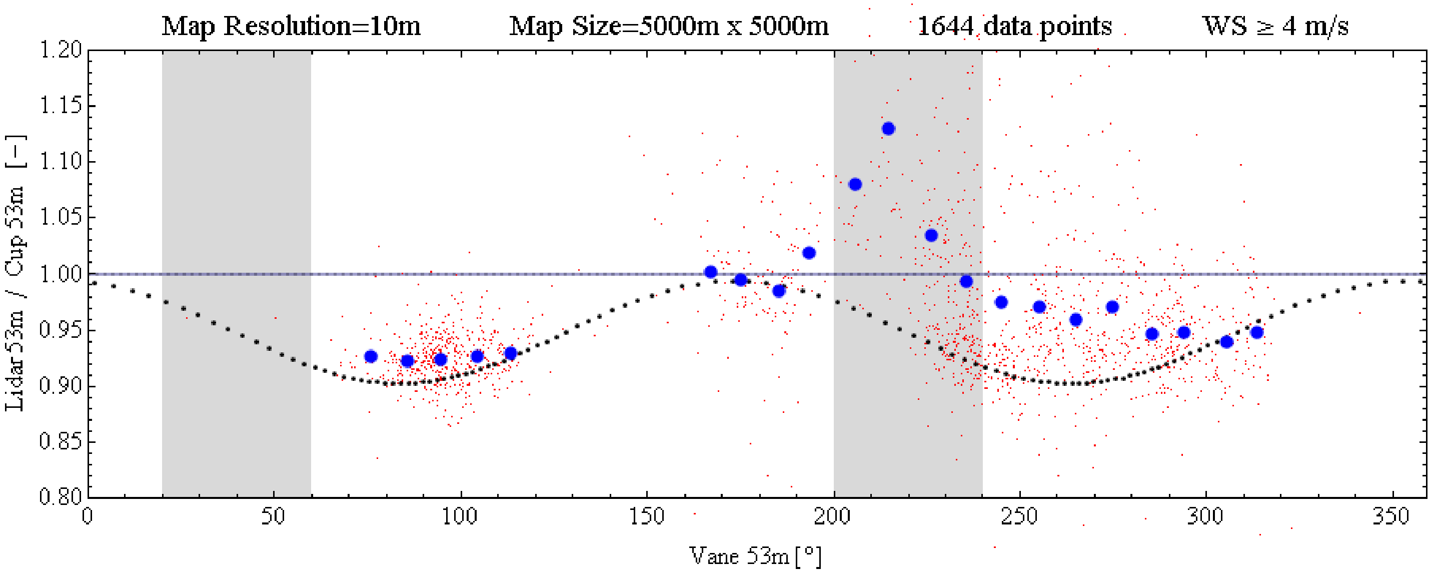


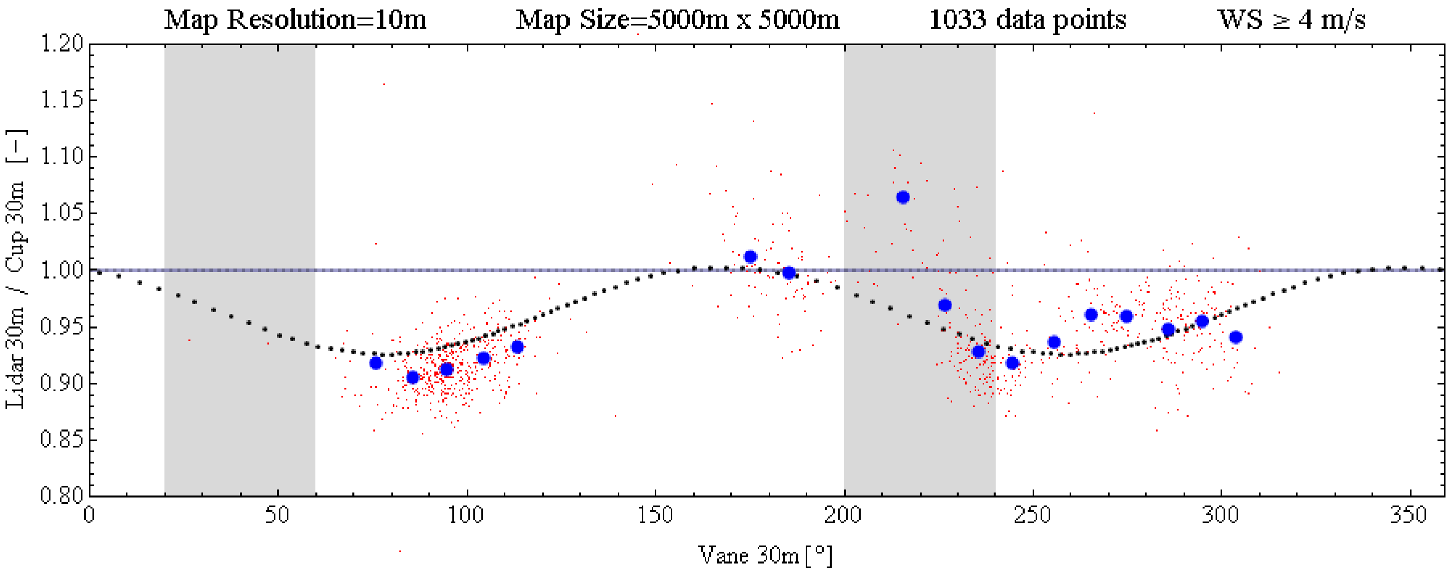
Panahaiko



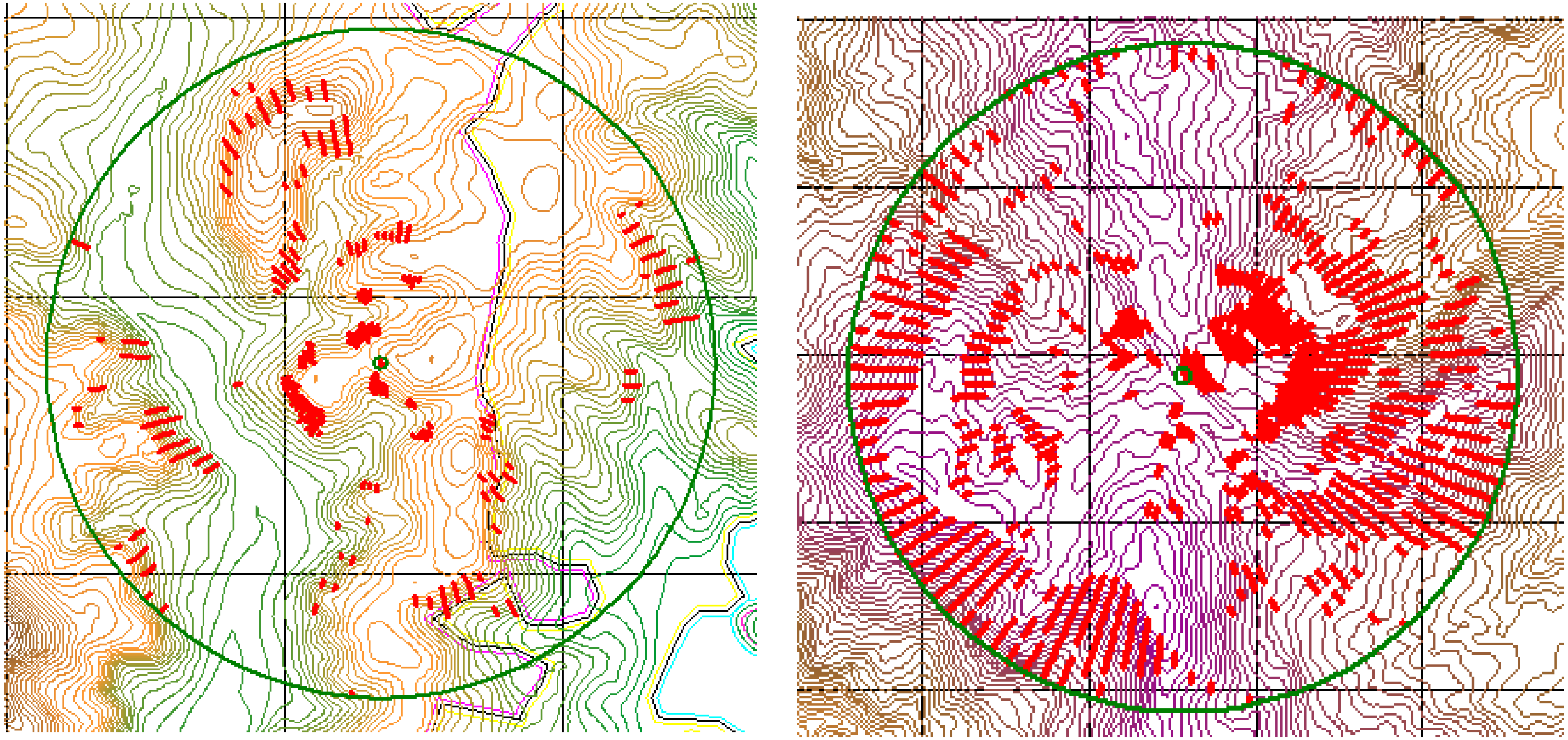
y = 0.93 x
R^2 = 0.99
Lidar 30m [m/s]
Cup 30m [m/s]
0
5
10
15
20
y = 0.96 x
R^2 = 0.99
Lidar 53m [m/s]
Cup 53m [m/s]

Results; Panahaiko



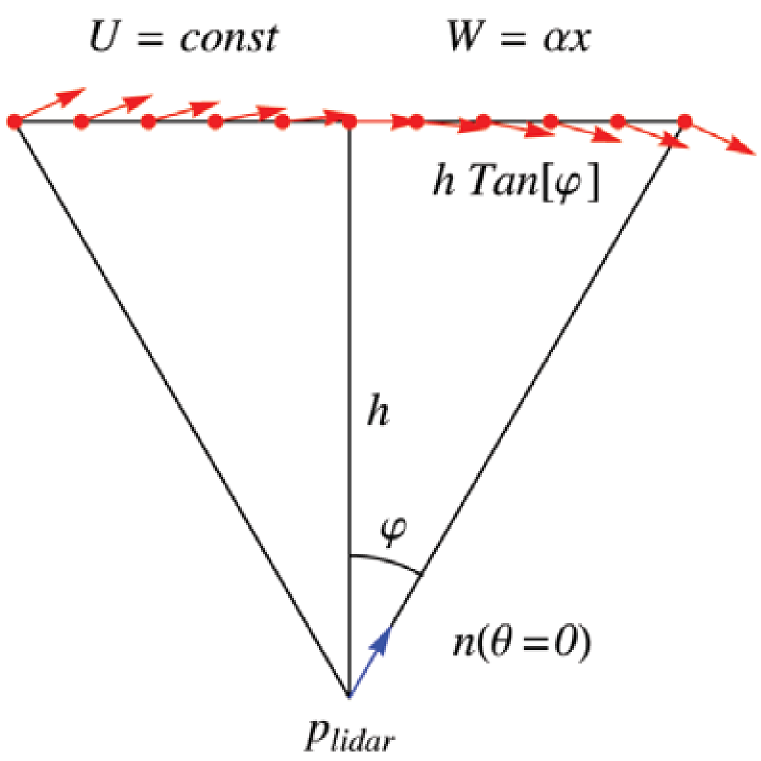


The limit of WEng in complex terrain



LiDAR position RIX values for both sites.
(Left) Lavrio, (Right) Panahaiko. Total RIX values are ~10% and ~25% respectively.

Conical Scanning in non-homogeneous flow



$$v_{up} = (-\sin\varphi, \cos\varphi)\cdot(U, -h\alpha\tan\varphi)$$
$$= -U\sin\varphi - h\alpha\sin\varphi$$
$$= -(U + h\alpha)\sin\varphi$$

$$v_{down} = (\sin\varphi, \cos\varphi)\cdot(U, h\alpha\tan\varphi)$$
$$= U\sin\varphi + h\alpha\sin\varphi$$
$$= (U + h\alpha)\sin\varphi$$

Does NOT depend on φ ⇨ $$U_{lidar} = \frac{v_{down} - v_{up}}{2\sin\varphi} = U + h\alpha$$

Conclusion

- We have shown that in complex terrain of the type commonly used for wind turbine parks, errors in the horizontal wind speed as measured by a conically scanning LiDAR can be of the order of 3-7%. We find that the calculations with WAsP Engineering model match the experiment except for some sectors where the terrain is particularly steep.

- Resolution and map sizes are advised.

- Therefore we can say "LiDAR complex terrain performance can be modeled with WAsP Engineering with limitations".

- The operation explained here is converted into a WAsP Engineering Script where users can try. (http://www.wasp.dk)

References

•Modeling conically scanning LiDAR error in complex terrain with WAsP Engineering
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Risø DTU Report, Risø National Laboratory, Roskilde, Denmark November 2008

•David A. Smith, Michael Harris, Adrian S. Coffey, Torben Mikkelsen, Hans E. Jørgensen, Jakob Mann, and Régis Danielian. Wind LiDAR evaluation at the Danish wind test site Høvsøre. Wind Energy, 9(1–2):87–93, 2006.

•Jørgensen, H.; Mikkelsen, T.; Mann, J.; Bryce, D.; Coffy, A.; Harris, M.; and Smith, D. "Site Wind Field Determination Using a CW Doppler LiDAR - Comparison with Cup Anemometers at Risø." Proc. EWEA Special Topic Conference: The Science of Making Torque from Wind; April 19-21, 2004, Delft, The Netherlands. pp.261-266.

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•Mortensen, N.G., A.J. Bowen and I. Antoniou (2006). "Improving WAsP predictions in (too) complex terrain" Proceedings of the 2006 European Wind Energy Conference and Exhibition, Athens, Greece, February 27 to March 2.

Thank You !

Ferhat Bingöl

ferhat.bingoel@risoe.dk