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Windcube Validation Measurements In Northern Sweden

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Abstract

VTT and Skellefteå Kraft AB organized a measurement campaign in the time period of 24.2.-11.5.2011 at a site in Northern Sweden. This site is located on top of a hill, roughly 500 meters above sea level and it is covered with conifer trees. Also the ground relief at the hilltop is quite unconstant. In the winter season the temperature can change from 0°C down -30°C.

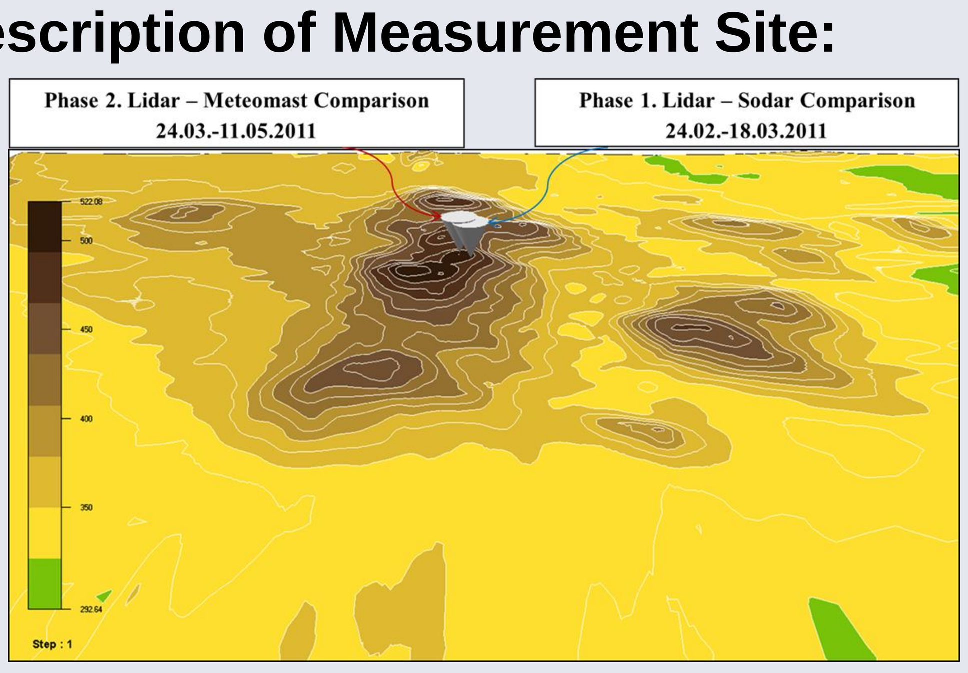
There were three main topics, 1) to investigate how precisely Windcube vs. meteomast data correlate to each another, 2) to analyse and correct the Windcube data which is biased in complex terrain with the WindSim CFD software and with settings which takes also into account atmospheric stability 3) to monitor the Windcube operating performance in cold climate conditions.

From the end of March until mid of May, an obstacle free deployment place for the Windcube was found next to the Skellefteå Kraft AB´s meteomast. With help of this site data, the aim is to be confident with Windcube and meteomast measurements and also investigate how complex terrain and wake effect have an influence on these measurements. At the moment Windcube data can be corrected using WindSim's Remote Sensing Correction tool. Correlation between meteomast data and corrected Windcube data was evaluated.

This winter campaign clearly show how vital it is to understand how cold climate conditions and complex terrain effect have to be taken into account in Remote sensing measurements. Accurate wind resource measurement data enables a more precise estimation for turbines annual energy production.

Objectives

Description of Measurement Site:



- Located on the top of the hill
- 500 m above sea level
- Hilltop is covered with conifer trees
- Ground relief on the site is quite unconstant
- Winter temperature variation:
  from 0 °C down to -30 °C

Main topics of the measurement campaign:

- to monitor Windcube operating performance in arctic conditions
- to investigate the differences between Windcube vs meteomast data
- to analyse and correct the Windcube data which are biased in complex terrain with the Windsim CFD software:
  - with neutral and stable atmospheric settings
  - with forest modelling

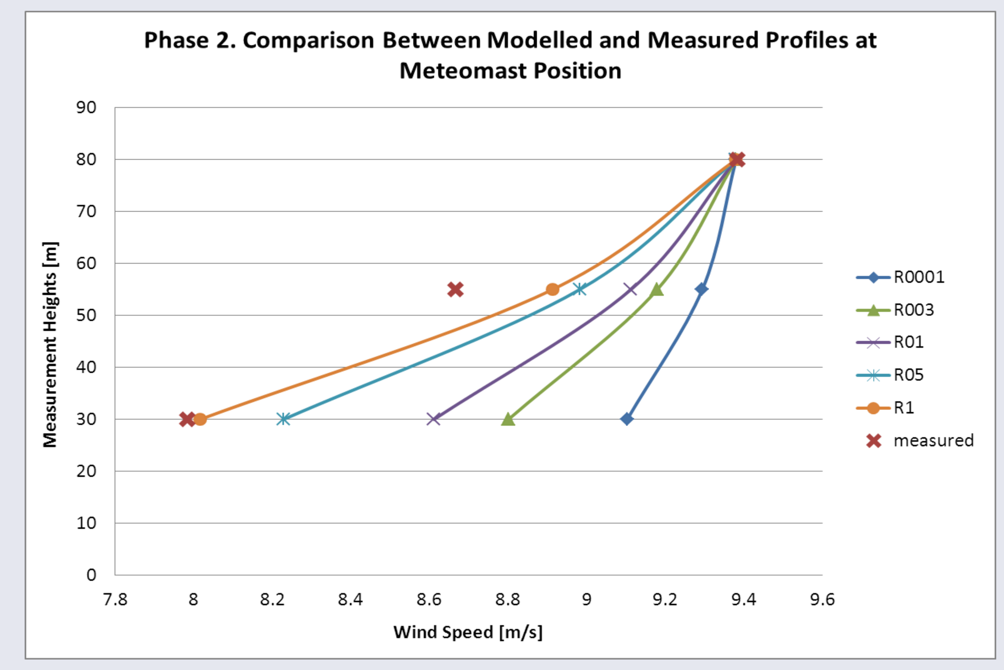
Methods

Data Analysis:

- To quantify the difference between lidar & meteomast measurements in complex terrain due to the flow disuniformity
- CFD based remote sensing correction can help to minimize the biased horizontal wind speed values between lidar & meteomast measurements
- Therefore it was important to carry out sensitivity study to find optimum simulation parameters for lidar data correction
- Eight simulations with different simulation settings were carried out:
  - Different roughness values: R0.001, R0.03, R0.1, R0.5 & R1.0
  - Before using the Remote Sensing Correction Tool, we estimated which roughness value describes well snow and forest conditions
  - In the modelling part also the atmospheric conditions took into account: Forest/Neutral, Forest/Stable & Snow/Stable

Results

Sensitivity Study – Modelling with Roughness Values



- Beginning of campaign forest was covered with snow
- End of the campaign there was only forest
- Roughness value R1 reach the closest the measured lidar wind data
- Modelling the influence of the terrain only using the roughness height was not satisfactory, [Table 2.]

CFD Based Remote Sensing Correction

Sensitivity Study – Definition of the Atmospheric Modelling Parameters: [1;2]

- Roughness Value = 0.8
- Input data for the Monin-Obukhov Lenght calculation = Windcube data
- Calculated average of the Monin-Obukhov Length Value ~ 29

Table 1. Distribution of the atmosphere conditions during the winter measurement campaign 2011 in Northern Sweden [1;2]

Stability class	Count of Stability Group	Stability Group
A=1	1.16 %	Extremely unstable conditions
B=2	4.08 %	Moderately unstable conditions
C=3	12.17 %	Slightly unstable conditions
D=4	29.76 %	Neutral conditions
E=5	28.86 %	Slightly stable conditions
F=6	23.96 %	Moderately stable conditions

Summary of the Sensitivity Study, Data Correction & Modelling

Table 2. Summary of the comparison of correlation between corrected Windcube data and meteomast data, first part where roughness height and neutral atmospheric conditions are used and second part where forest modelling and stable atmospheric conditions are taken into account

Phase2	Speed Lidar 80m = A * (Speed Mast 80m) + B						Error on Vertical Extrapolation
	Measured		Roughness		Corrected (Lidar)		
	A	B	Z0 (m)	type	A	B	[From 80m to 55m] [%]
	0.9518	0.0724	0.001	Snow	0.9139	0.2822	-7.2
			0.03		0.9920	-0.0172	-5.9
			0.1	↓	0.9905	-0.0190	-5.1
			0.5		0.9871	-0.0262	-3.6
			1.0	Forest	0.9869	0.0267	-3
	Speed Lidar 80m = A * (Speed Mast 80m) + B						Error on Vertical Extrapolation
			Advanced Modelling Conditions		Corrected (Lidar)		
					A	B	[From 80m to 55m] [%]
	Modelled		Forest / Neutral Atmosphere		1.0014	-0.0107	0.4
			Forest / Stable Atmosphere		0.9917	-0.0106	5.6
			Snow / Stable Atmosphere		1.0276	-0.011	1.3

Conclusions

Based on this case study our first conclusion is:

- The Lidar campaign completed in Northern Sweden with some challenges
  - Tough deploying conditions: Lidar started tilting,due to melting snow
  - Low data availability during the winter storms
  - Lidar indicated 5 % lower values compared to the mast measurements
- With CFD simulations it is possible to reduce the 5 % error into 1 %

→ It is important to plan where to deploy the Windcube to optimize the data quality

Future:

- This data analysis and CFD modelling procedure shows that lidar measurements can be used for the wind resource assessment purposes also in the complex terrain regions when data correction, roughness and atmosphere conditions are taken into account
- It would be also interesting to study the Lidar correction also with Wasp engineering software and see the difference between these two simulation software

References

1. Thomas P. (1986) – Stability classification by acoustic remote sensing. Atmospheric Research 20, pp. 165-172
2. Castellani, F., Vignaroli, A. & Piccioni, E. Numerical and Experimental Methods for wind shear investigations and power curve site-specific adjustment