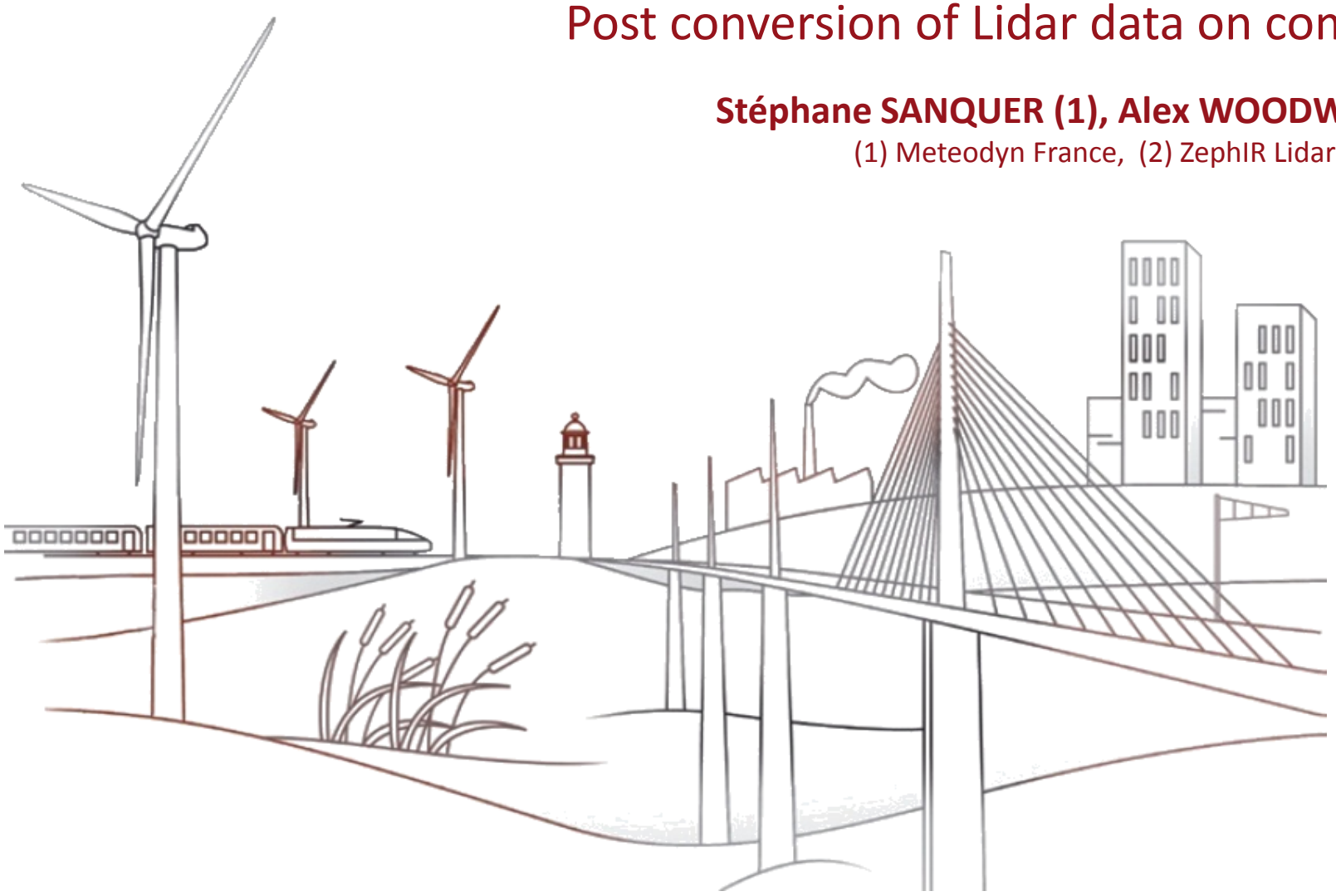
Post conversion of Lidar data on complex terrains

Stéphane SANQUER (1), Alex WOODWARD (2)

(1) Meteodyn France, (2) ZephIR Lidar



Context…

Wind turbines generator higher and higher

⇒ Need Remote Sensing Devices (RSD) precise enough to be compared to standard anemometers

Strong inhomogeneity of wind on complex terrains

⇒ Some discrepancies may appear with standard anemometers

⇒ Post conversion of Lidar data in such situations

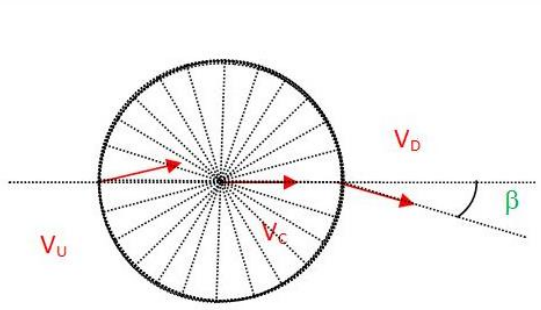
Numerical methodology to give efficient post conversion factor

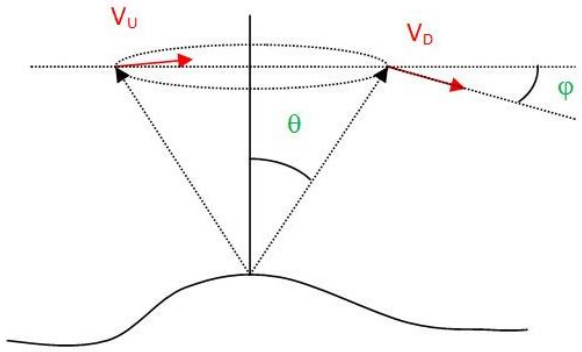
⇒ May we use CFD ?

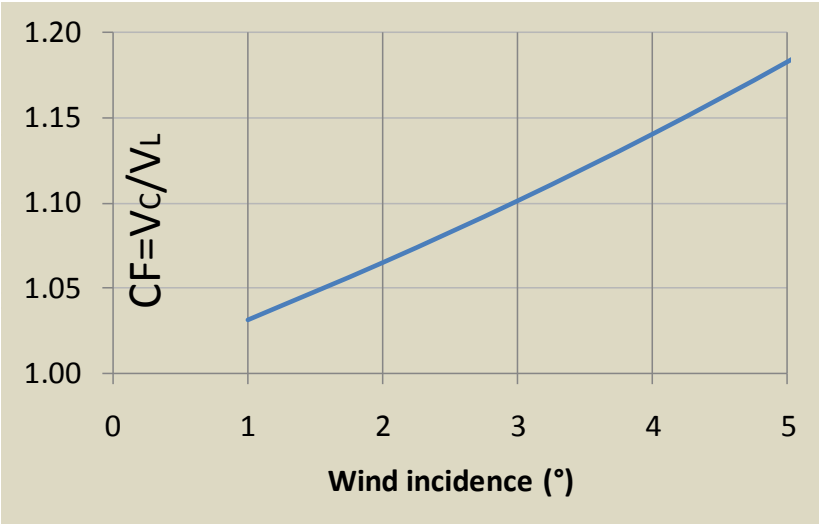
⇒ When should we use the post-conversion : level of terrain complexity ?

Why conversion are needed in complex terrains ?

Velocity vectors aren't be constant across the Lidar scan disk







$$V_L = \frac{V_r(down) - V_r(up)}{2\sin(\theta)} = \frac{\overrightarrow{V_d}.\vec{\imath} - \overrightarrow{V_u}.\vec{\jmath}}{2\sin(\theta)}$$

$$V_L = \frac{1}{2\sin(\theta)}\left(V_d \sin(\theta + \varphi_d) + V_u \sin(\theta - \varphi_u)\right)$$

We need the 3D vectors of the wind upstream and downstream the Lidar scan disk center in order to project them on the beams

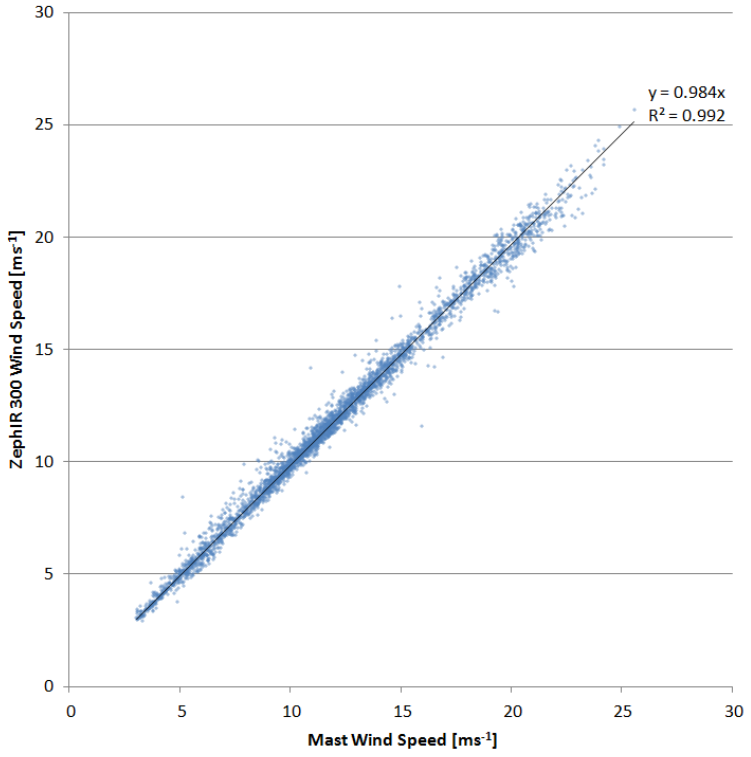
Interpretation of site complexity

	Class 0 z0 < 0.01 m	Class 1 z0 in [0.01m;0.05m]	Class 2 z0 in [0.05m; 0.4m]	Class 3 z0>0.4m
Flat and low roughness	simple	simple		
Hilly . hill height <100 m . slope in [5°, 10°]	moderately complex	moderately complex	moderately complex	complex
Vegetated flat sites canopy height in [5m, 10m]		moderately complex	moderately complex	
Mountains without forest with slope > 10°	complex	complex	complex	
Flat with Forests canopy height >10m				complex
Mountains and forests				highly complex

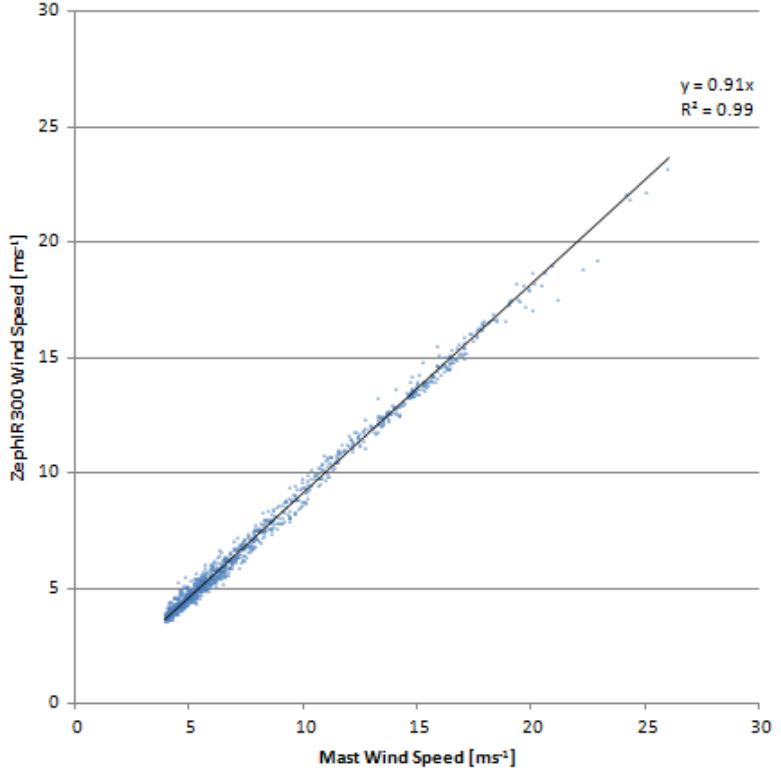
F. Bingöl (2009) : Complex terrain and wind Lidars – Risoe-PhD

Differences between RSD and mast data depends on complexity

ZephIR 300 vs. Mast: Site 3 - Complex Terrain with Forestry Pre-CFD Conversion



ZephIR 300 vs. Mast: Site 4 - Heavily Complex Terrain Pre-CFD conversion



Purposes…

Assessing differences between ZephIR 300 and mast data in various complexity classes

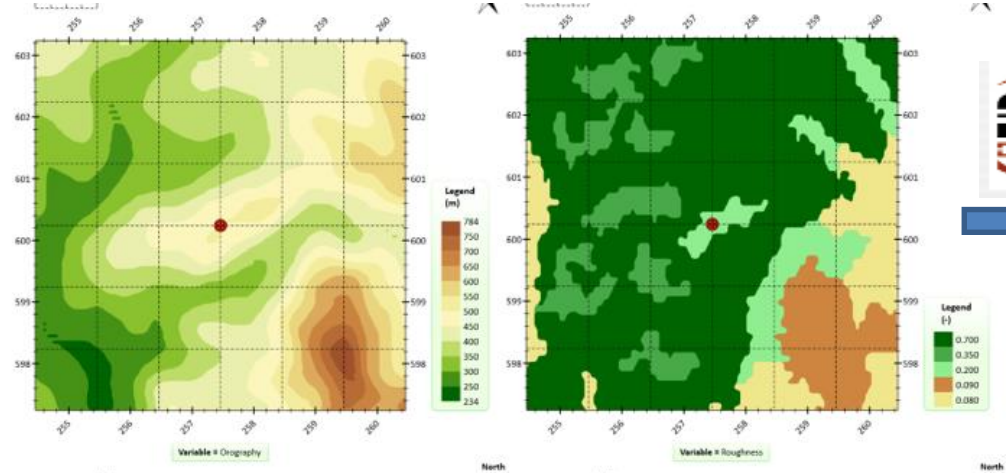
Highlighting the categories where CFD conversion is needed

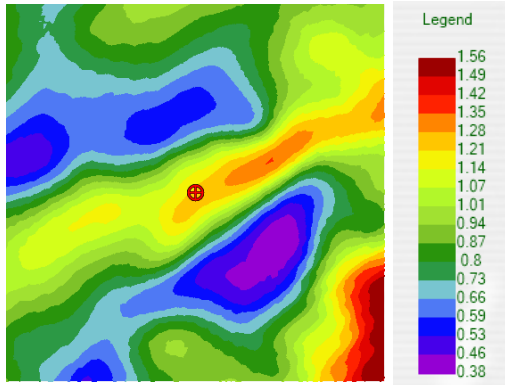
Providing an efficient methodology for conversion of Lidar data on complex terrains

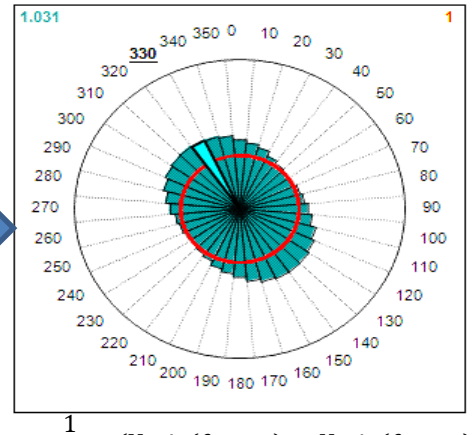
Computations of 8 sites : from the simplest to the highest complex

Orography | Roughness | CFD | Conversion Factor

Moderately complex

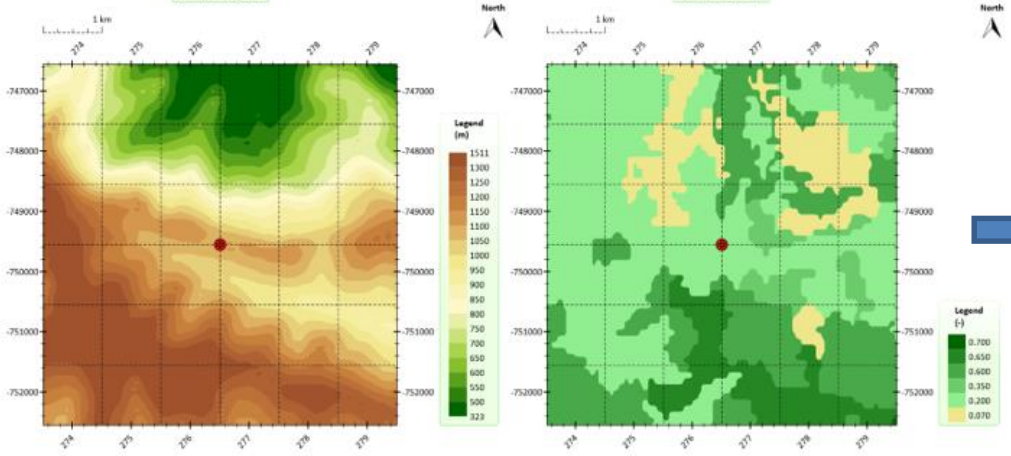


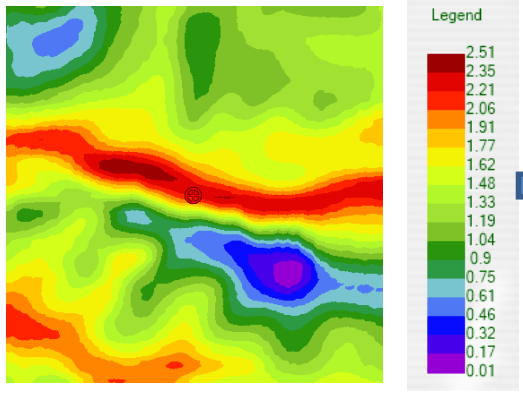


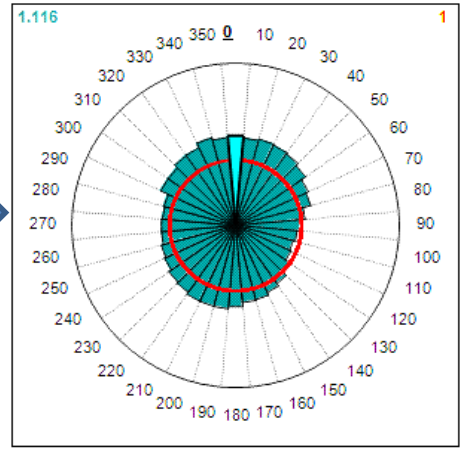


$$V_L = \frac{1}{2\sin(\theta)}(V_d \sin(\theta + \varphi_d) + V_u \sin(\theta - \varphi_u))$$

Highly complex



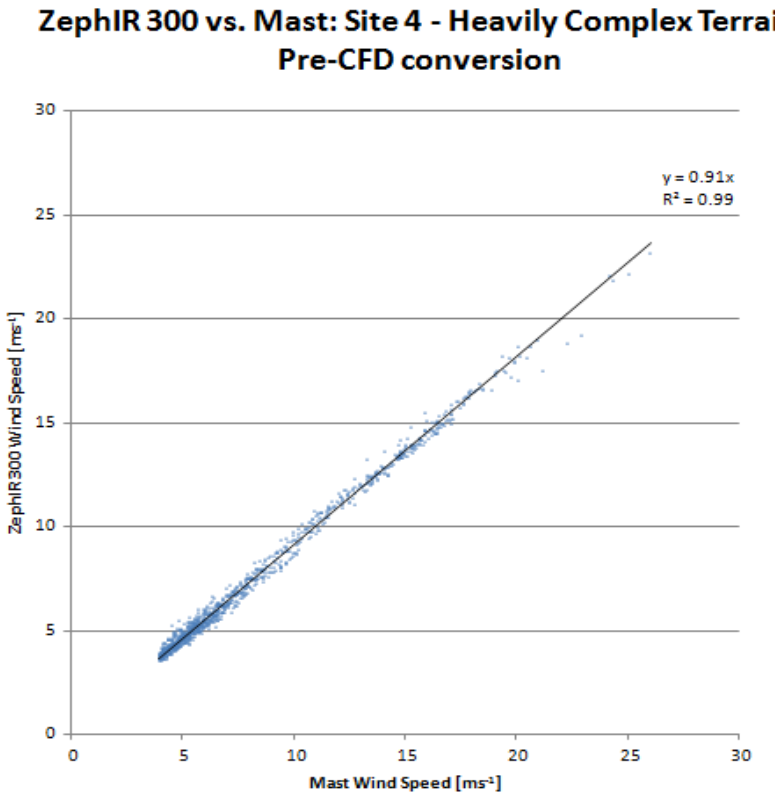


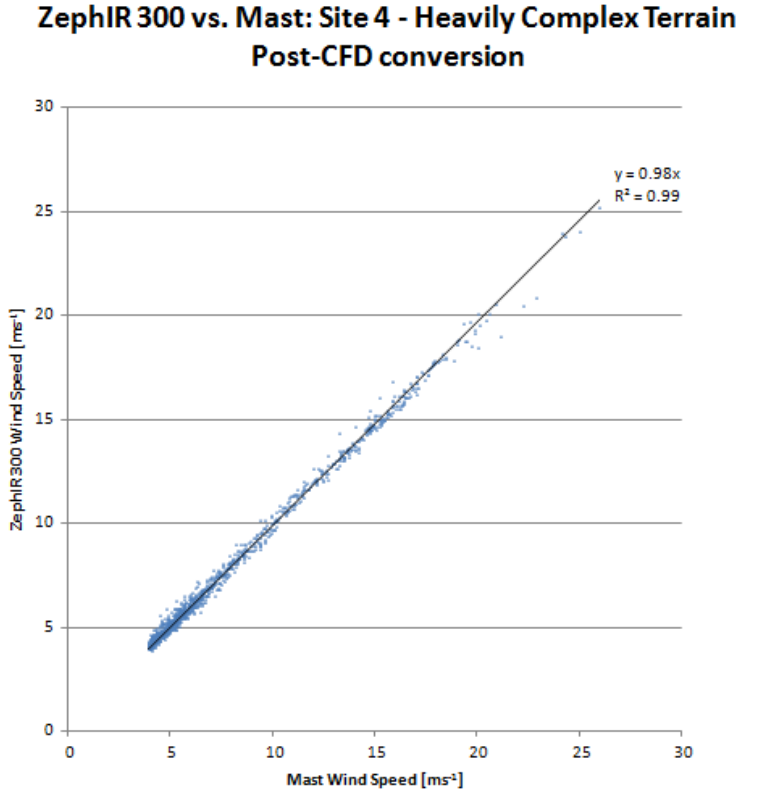


Top: Moderately complex with forestry (site n°3) – Bottom: highly complex (site n°4)

At each time step, by using the conversion factor (depends on the wind incidence)

RSD data are Post-converted





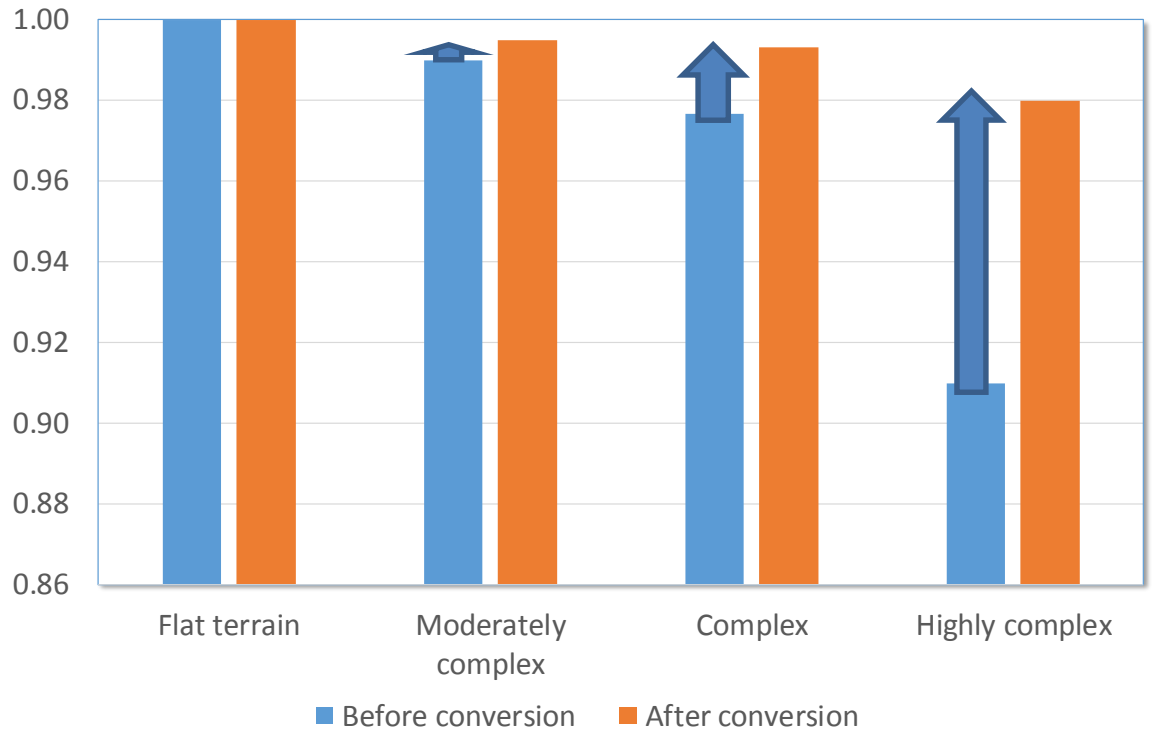
Correlation factor R^2 unchanged – Linear regression factor increased close to unity

Post-conversion of Lidar data

Site Configuration	Height (m)	Forest	Before conversion		After Conversion	
			Correlation factor R^2	Linear regression factor	Correlation factor R^2	Linear regression factor
1- Flat terrain	70	No	1.00	1.00	1.00	1.00
2- Moderately complex	61	No	0.99	0.99	0.99	0.99
3- Complex	80	Yes	0.99	0.98	0.99	0.98
4 - Highly complex	45	Yes	0.99	0.91	1.00	0.98
5 - Complex	80	Yes	0.97	0.97	0.97	1.00
6 - Complex	80	No	0.99	0.98	0.99	1.00
7 - Moderately complex	50	No	0.99	0.99	0.99	1.00
8 - Complex	44	No	0.99	0.98	0.99	1.00

Linear regression factor

U_{Lidar} vs U_{Mast}



Conclusions

Applying CFD conversion to data from RSD in complex terrain improves the agreement between wind speed measurements from RSD and masts

CFD post conversion needed for complex and extremely complex terrain.

Same effect of terrain than forest on the linear regression factor (0.97). Conversion improve the factor close to unity (0.99)

After correction for highly complex site, the factor is 0.98. Method of post conversion depends on the ability of CFD to accurately predict the flow deviation over the ground.