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A simple method to estimate Atmospheric Stability using Lidar Wind Profiler

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Abstract

This paper proposes a simple method to estimate the atmospheric stability using wind lidar measurements. The method is validated with Obukhov Length (L) and one-year data from Lidar and Sonic anemometer. The results show that the proposed method has a good agreement at stable condition, where it is possible to detect stable condition occurrences within the diurnal and seasonal regime. On the other hand, the method was not accurate for unstable conditions.

Objectives

The wind energy industry has increased the power capacity by developing tall wind turbines reaching up to 200m height. As consequence, the effects of wind shear and turbulence can be significant on power performance, turbine loads and noise at this height. The wind profile variation is influenced by atmospheric stability, which is not an easy parameter to evaluate. In addition, the need for high frequency measurements, in order to calculate turbulent fluxes, are not always available in wind farms. Hence, this paper proposes a simple method to estimate the atmospheric stability using only data from wind profile.

Experiment

This experiment is set in Pedra do Sal Wind Farm, located in the northeast coast of Brazil. One-year of Sonic 3D anemometer (Fig. 01a) and Lidar (Fig. 01b) data was selected, from August 2013 to August 2014. The lidar profiler is installed 300m away from the shoreline (onshore) along with a met mast, 565 m apart.

(a) (b)

Fig. 01: (a) Sonic 3D anemometer and (b) Lidar Wind Profiler at Pedra do Sal.

Methods

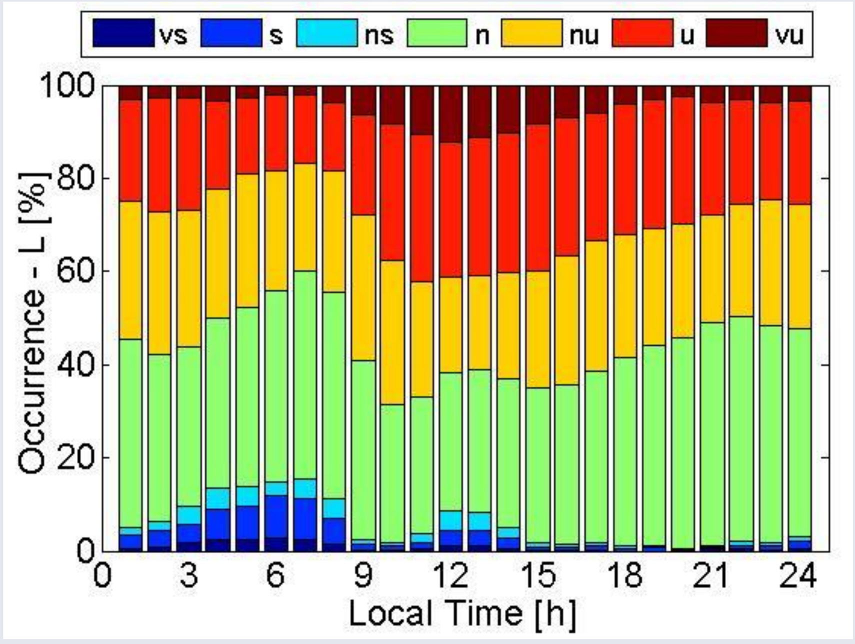
The method is based on Monin-Obukhov Similarity Theory [1], and considered that wind shear from power law and log law have similar dependence with atmospheric stability [2]. Tab. 01 shows the proposed stability classes, which are correlated to Obukhov Length (L) classes suggested by Sathe [3].

Stability Class	Obukhov Length	Wind Shear Profile (Lidar)		
Very Unstable (vu)	-50<L<0	$\frac{\partial\alpha}{\partial z} < 0$	and	$\alpha < 0.052$
Unstable (u)	-200<L<-50	$\frac{\partial\alpha}{\partial z} < 0$	and	$0.052 < \alpha < 0.071$
Near Neutral Unstable (nu)	-500<L<-200	$\frac{\partial\alpha}{\partial z} < 0$	and	$0.071 < \alpha < 0.083$
Neutral (n)	L<-500 or L>500	$\frac{\partial\alpha}{\partial z} < 0$	and	$0.083 < \alpha$
		or		
		$0 < \frac{\partial\alpha}{\partial z} < 0.0012$		
Near Neutral Stable (ns)	200<L<500	$0.0012 < \frac{\partial\alpha}{\partial z} < 0.003$		
Stable (s)	50<L<200	$0.003 < \frac{\partial\alpha}{\partial z} < 0.012$		
Very Stable (vs)	0<L<50	$0.012 < \frac{\partial\alpha}{\partial z}$		

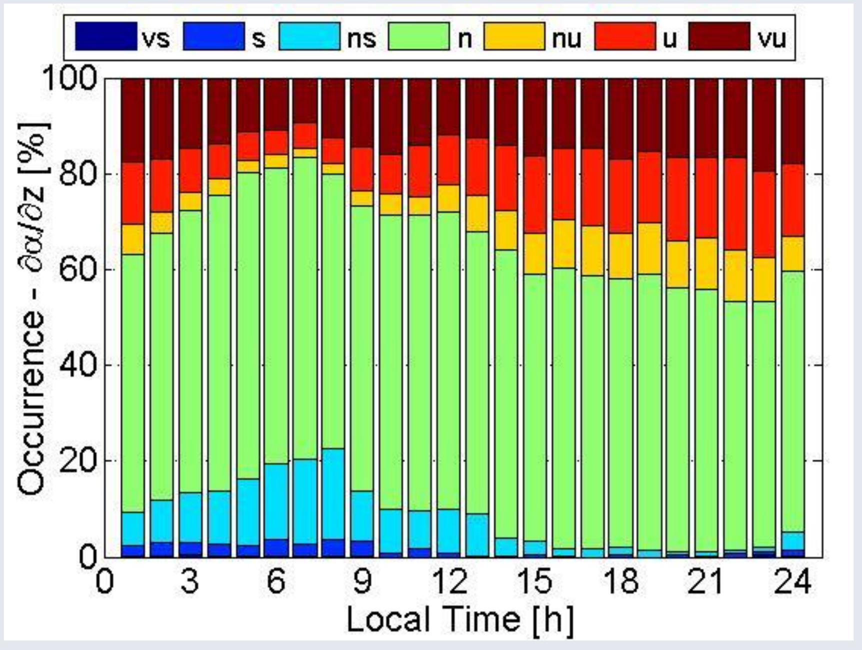
Tab. 01: Atmospheric Stability Classes by Obukhov and wind shear profile (Lidar).

Results

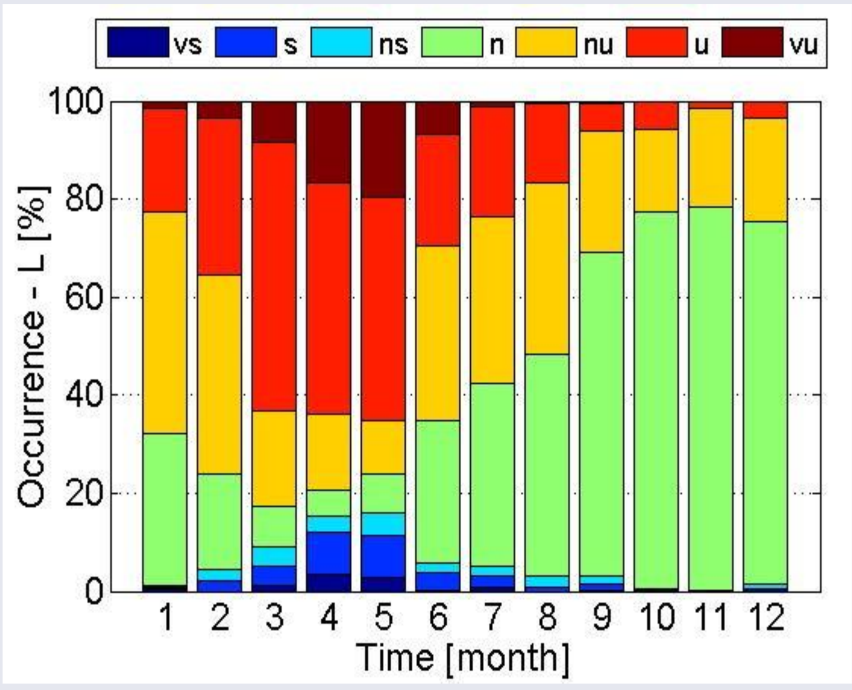
The comparison between Wind Shear Profile and Obukhov Length method presented a good agreement at stable condition. For the diurnal cycle, Fig. 02a and Fig. 02b show that both methods detected stable condition in the morning. For the seasonal regime (Fig. 02c. and Fig. 02d.), stable conditions were verified in autumn (south hemisphere). On the other hand, the unstable conditions were occasionally classified as neutral condition instead, as verified in the first semester of the year (Fig. 02d.).



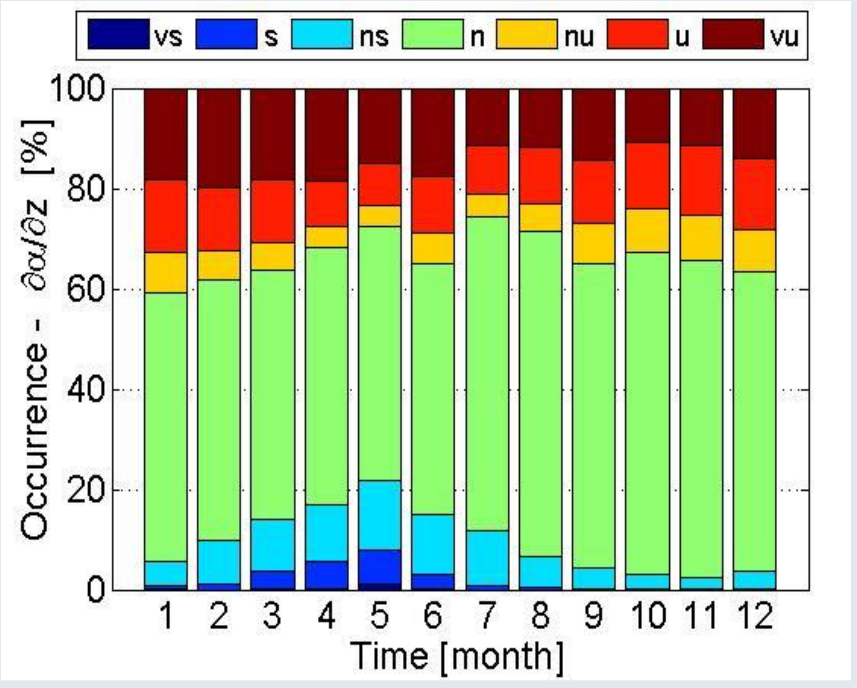
(a)



(b)



(c)



(d)

Fig. 02: (a) Obukhov and (b) Lidar diurnal atmospheric stability; and (c) Obukhov and (d) Lidar seasonal atmospheric stability regime.

Conclusions

This study can collaborate to understand the variation of wind shear profile according to the atmospheric stability (Fig. 03). Thus, wind energy industry can benefit for best practice in wind resources assessment, power curve, wind forecast, and wake loss effects studies.

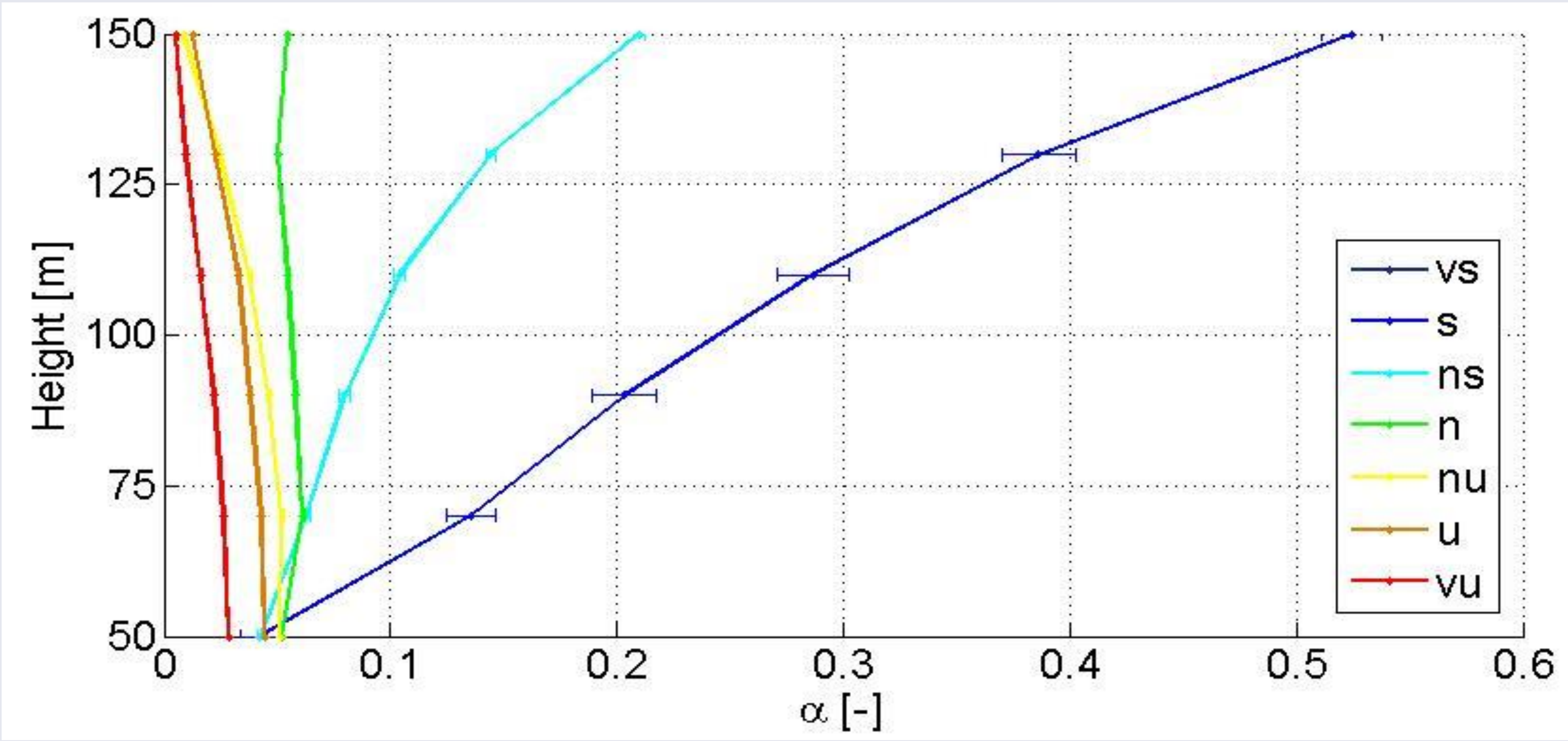


Fig. 03: Average wind shear profile at different atmospheric stability.

Acknowledgements

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