Studying the relationship between the average velocity of the turbulence and high altitude winds at the Teide Observatory

Universidad de La Laguna

Begoña García-Lorenzo[1], Catalina del Giorgio Castiglione[2], Antonio Eff-Darwich[3], Jesús J. Fuensalida[1]

(1) Instituto de Astrofísica de Canarias, Spain; (2) Dpto. de Astrofísica, Universidad de La Laguna, Spain; (3) Dpto. Edafología y Geología, Universidad La Laguna, Spain

ABSTRACT

The requirements for excellent image quality of current large and future very large telescopes demand a proper knowledge of atmospheric turbulence. Thus several projects are already pursuing this aim. The precise characterization of the turbulence above a particular site requires long-term monitoring. In this sense, due to the lack of long-term information on turbulence, high-altitude winds (in particular winds at the 200-mbar pressure level, V_{200}) have been proposed (Sarazin & Tokovinin 2002, S&T02 hereafter) as a parameter for estimating the total turbulence at a particular site, because records of this parameter exist from several sources. This choice is based on the idea that the greatest source for turbulence generation is related to the highest peak in the vertical wind profile, which is located at the 200-mbar pressure level globally. Moreover, S&T02 found a good correlation between the average velocity of the turbulence, V_0, and V_{200} of the form $V_0 = 0.4*V_{200}$ at the Cerro Pachón and Paranal Observatories in Chile. A linear relationship between V_0 and V_{200} was also found in San Pedro Mártir (Mexico) (Masciadri & Egner 2006, M&E06 hereafter). In this poster, we study the possible connection between V_0 and V_{200} at the Teide Observatory (Spain).

INTRODUCTION

V_{200} is accepted as a parameter for site evaluation based on the good correlation between V_0 and V_{200} found by S&T02 at Paranal+Carro Pachón (Fig. 1a) and M&E06 at San Pedro Mártir (Fig. 1b). García-Lorenzo et al. 2005 shows a high level of agreement between high and low-altitude winds, suggesting a connection between V_0 and V_{200} at five different astronomical sites.

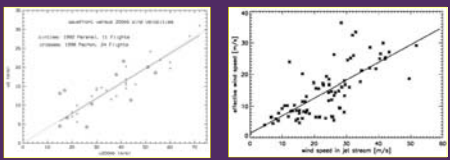
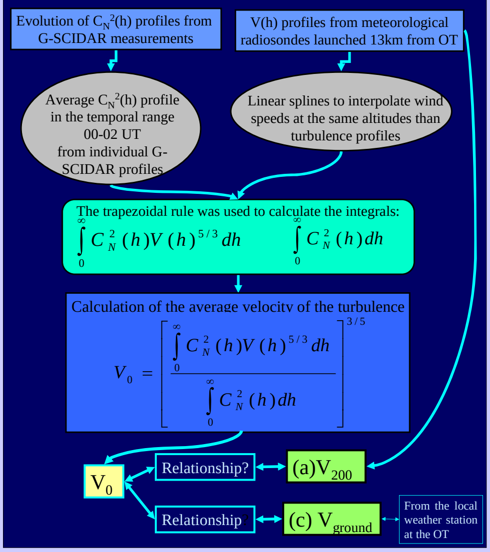


Figure 1: **(a)** Proportionality between V_0 and V_{200} measured over 35 balloon flights at Paranal (crossed circles) and at Pachón (crosses). The line corresponds to $V_0=0.4V_{200}$ (from S&T02). (b) V_0 vs. V_{200} for San Pedro Mártir. The line corresponds to $V_0=0.56V_{200}$ (from M&E06).

Figure 2: Scheme of the procedure followed to study the relation between the average velocity of the turbulence and winds at: (a) 200 mbars pressure level; and (b) the velocity at the ground level, measured by a local weather station next to the TCS where the G-SCIDAR is installed.



THE DATA

The Teide Observatory (OT, table 1), operated by the Instituto de Astrofísica de Canarias, is located on the island of Tenerife (Spain), ~400 km distant from the coast of Morocco. The G-SCIDAR technique (Fuchs, Tallon, & Vernin 1994) is being used to obtain the $C_N^2(h)$ profiles above the OT. The systematic campaigns began in November 2002, with a frequency of ~4-6 nights every month (e.g. García-Lorenzo, Fuensalida & Rodríguez-Hernández 2007).

Table 1: Location of the Teide observatory and the radiosonde station.

	Teide Observatory	Station 60018, Güimar
Latitude (degrees)	28.30 N	28.46 N
Longitude (degrees)	16.51 W	16.27 W
Elevation (m)	2400	105

The wind velocity profiles were retrieved from classical radiosondes for meteorological measurements. These are launched twice daily from Güimar station 60018 (table 1) on the island of Tenerife and about 13 km from OT. The balloons provide measurements at 00UT and 12 UT of V_{200} above this location. We only used the data at 00UT.

Figure 2 shows the basic procedure we have follow to process the $C_N^2(h)$ and V(h) profiles to study the relationship V_0-V_{200}.

We found 95 nights with $C_N^2(h)$ profiles obtained during the corresponding balloon ascent. These nights are distributed from 2003 to 2008 as illustrated in table 2.

Table 2: Number and date of the nights selected for this study.

Year	Number of nights	Year	Number of nights
2003	20	2006	11
2004	21	2007	14
2005	23	2008	6

LINEAR RELATIONSHIP between V_0 and V_{200}

After calculation of V_0 following the procedure sketched in figure 2, we compared V_0 with their corresponding V_{200} (figure 4) which it is far from the good correlation V_0-V_{200} found by S&T02 and M&E06 in Paranal-Cerro Pachón and San Pedro Mártir, respectively. The Pearson's correlation coefficient and the best linear fit between V_0 and V_{200} is presented in the following table:

	Pearson's Coef.	Best linear fit
2003	0.19	V_0=0.06V_{200}+7.79
2004	0.74	V_0=0.16V_{200}+6.42
2005	0.61	V_0=0.19V_{200}+5.31
2006	0.75	V_0=0.23V_{200}+3.50
2007	0.69	V_0=0.27V_{200}+5.39
2008	-0.15	V_0=-0.07V_{200}+12.64
Total	0.55	V_0=0.16V_{200}+6.14

Following the same calculation than S&T02 and M&E06, we have forced the best fit of the 95 data to pass through the coordinate origin, obtaining the expression:

V_0=0.456V_{200} for the OT

This approach could induce relative errors ([V_0-(0.456V_{200})/V_0]*100%) of a 25-45%, reaching errors larger than 100% in same cases.

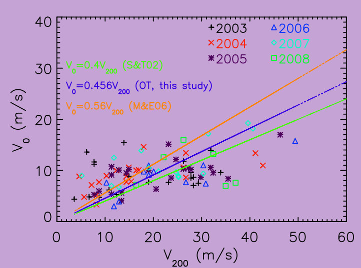


Figure 4: V_{200} as a function of V_0. Different symbols and colours corresponds to data from different years. Blue line corresponds to the best fit passing through the coordinate origin, while green and orange lines are the fits obtained for Paranal and San Pedro Mártir, respectively.

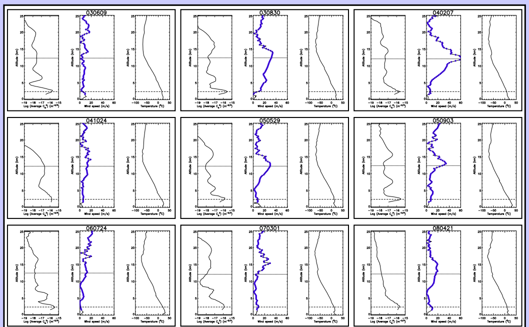


Figure 6: Example of turbulence (C_N^2(h)) and wind velocity (V(h)) profiles used as input data to calculate the average velocity of the turbulence V_0 at the Teide Observatory. Blue dots correspond to the interpolation of V(h) to the grid of C_N^2(h). We have also included the temperature profile for each night.

S&T02 proposed a more general formula to estimate V_0 combining wind velocities from ground and 200 mbar level:

$$V_0 \cong \max(V_{ground}, 0.4V_{200})$$

In the case of the OT, this formula should be written, according to the fit forced to pass through the coordinate origin, as:

$$V_0 \cong \max(2.292V_{ground}, 0.456V_{200})$$

Even using this approach, errors larger than 100% can be reached when estimating V_0, being the mean relative errors of 20-40%.

LINEAR RELATIONSHIP between V_0 and V_{ground}

As suggested by S&T02, and following the procedure sketched in figure 2, we have compared V_0 with the wind velocity at the ground level measured by the weather station placed closer to the Carlos Sánchez telescope, where the G-SCIDAR measurements are carried out. In 10 of the nights selected for this study, this station was down and we do not have local wind measurements. Figure 5 shows the average velocity of the turbulence, V_0 as a function of the wind velocity at the ground, V_{ground}. The Pearson's correlation coefficient and the best linear fit between V_0 and V_{ground} is found in the table below.

	Pearson's Coef.	Best linear fit
2003	0.63	V_0=1.10V_{ground}+5.26
2004	0.46	V_0=1.11V_{ground}+4.61
2005	0.35	V_0=0.76V_{ground}+5.70
2006	0.68	V_0=1.55V_{ground}+1.84
2007	-0.31	V_0=-1.20V_{ground}+17.35
2008	0.70	V_0=1.65V_{ground}+4.59
Total	0.38	V_0=0.83V_{ground}+6.09

Following the same calculation than S&T02 and M&E06 for V_{200}, we have forced the best fit of the 85 data to pass through the coordinate origin, obtaining the expression:

V_0=2.292V_{ground} for the OT

This approach could induce relative errors ([V_0-(2.292V_{ground})/V_0]*100%) of a 20-50%, reaching errors larger than 100% in same cases.

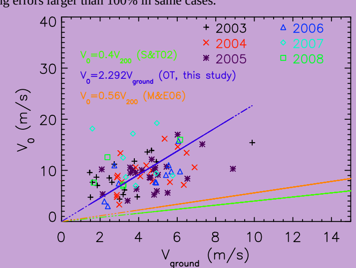


Figure 5: V_0 vs V_{ground}. Different symbols and colours corresponds to data from different years. Blue line corresponds to the best fit passing through the coordinate origin. Green and orange lines are the fits obtained for Paranal and San Pedro Mártir for V_0 vs. V_{200}.

CONCLUSIONS

The linear relation between V_0 and V_{200} is established by the definition of V_0 (see eq. in Fig. 2). This poster shows up the importance of deriving atmospheric turbulence profiles, $C^2_N(h)$, to determine the coefficient of the linear fit connecting V_0 and V_{200}. According to the results of this poster and in agreement with the previous authors, large errors can be induced when estimating V_0 from only V_{200}. Including the wind speed, other factors (e.g. buoyant convection processes, instability phenomena, etc) can be playing an important role to generate turbulence (see Castro-Almazán, García-Lorenzo, & Fuensalida, this conference).

Changes in *wind* regimes (in different seasons, for example) could have an important influence on the *linear coefficient*, taking into account that the approach assumed is based only on the absolute values of the wind, and that we have not yet considered the wind directions.

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