3rd ARENA Conference: An Astronomical Observatory at CONCORDIA (Dome C, Antarctica)
L. Spinoglio and N. Epchtein (eds)
EAS Publications Series, **40** *(2010) 115-118*

STUDYING THE VERTICAL EXTENT OF THE GROUND LAYER TURBULENCE USING SONIC-ANEMOMETERS

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Abstract. The optical turbulence above Dome C in winter is mainly concentrated in the first tens of meters above the ground. The properties of this so-called surface layer were investigated during the last two winterover by a set of sonics anemometers placed on a 45 m high tower. These anemometers provide measurements of the temperature and the wind speed vector. The sampling rate of 10 Hz allows to derivate the refractive index structure constant C_n^2. We report here the first analysis of these data.

1 Introduction

The development of optical and infrared astronomy at Dome C will largely depend on its potential to achieve high angular resolution beyond the capability of temperate sites where access is easier than Antarctica. The only obstacle to such resolution is a thin ground layer (GL) of optical turbulence caused by a combination of a strong thermal gradient and a sheared katabatic wind. The characterization of the GL, both in terms of intensity and vertical structure, is therefore critical to the determination of methods to compensate its effects (Travouillon *et al.* 2009). So far, our knowledge of the GL comes from several instruments each having specific flaws. Early SODAR measurements, for example, didn't have the vertical resolution to resolve the GL turbulence (Lawrence *et al.* 2004). Balloon-borne microthermal sondes, do have the vertical resolution but lack the temporal resolution necessary to obtain a statistically meaningful data set (Trinquet *et al.* 2008). In situ measurements therefore became a viable option that would attain both temporal and spatial resolutions. The presence of a 30 m tower, which was later risen to 46 m, allowed the possibility of these measurements. Early attempts to

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DOI: 10.1051/eas/1040016

use microthermals sensors at different locations on the tower were later abandoned due to their fragility in the windy and icy conditions.

The alternative to microthermal sensors which uses similar principles to measure optical turbulence without the issue of brittleness is the sonic-anemometer. Introduced in Travouillon (2008), this instrument makes a high speed measurement (20 Hz) of temperature and wind velocity which are processed to obtain a measurement of the optical turbulence parameter C_n^2. Using several sonic-anemometers along the height of the tower allows us to make continuous measurements of the turbulence profiles only limited in vertical resolution by the number of instruments used. The details of the experimental setup are explained in the next section followed by the results obtained so far.

2 Experimental Setup

The sonic-anemometers used for this experiment are modified models Sx from apptech. The modification, which purpose is to operate the units in the low temperatures of the Antarctic plateau, consists of a layer of aerogel which thermally insulates the sensing parts of the instruments as well as a wrap of heating resistance that both warms the unit and protects it from ice formation. This later point is actually critical as the metal radiates more than the surrounding air. It is therefore colder and thus attracts all the humidity from the surrounding air.

At first, in the summer 2006–2007, the tower was 30 m high and 3 anemometers were purchased and placed at heights of 8 m, 16 m and 28 m. The units were operated well during the entire year of 2007 with the exception of the 16 m, which suffered a technical problem which reset its calibration parameters in the second half of the year. For this reason it will be omitted from the results presented here. During this year, a lot was also learned regarding the heating time required to keep the instruments ice-free. A cycle that alternates between heating the instrument and using it for measurements was established that both maximizes the data sampling. During this testing time, we have found that approximately 25% of our data needed to be eliminated due to the effect of the heating. Indeed, no turbulence can be made during the heating period as it affects the local temperature and turbulence measured by the instrument.

In the summer 2007–2008 the tower was risen to 46 m and an additional 3 anemometers were installed on the new section. The heights of the 6 sonics were 8 m, 16 m, 24 m, 31 m, 39 m and 46 m. A limited amount of profiles were gathered in the spring of 2008 due to the complication that the larger setup gave to the electrical load. This data will be still be presented and must be considered as preliminary. We expect that the data gathered in 2009 will be statistically more meaningful and will give us a more accurate picture of the behavior of the GL.

3 Results

Defining the vertical extent of the GL is rather suggestive. First of all the turbulence does not necessarily decrease monotonically with height. A dual-peak GL is

Table 1. Seasonal distribution of the BL height. FA, SL and I correspond to the percentage of the time that the sonic spends respectively in the free atmosphere, the surface layer and in an intermediate state. Data taken in 2007.

Sonic height	8 m			28 m		
	FA	I	SL	FA	I	SL
Summer	8%	68%	24%	16%	59%	25%
Autumn	21%	73%	6%	17%	13%	70%
Winter	42%	42%	14%	21%	5%	77%
Spring	30%	56%	14%	28%	3%	69%

Table 2. Distribution of the BL height in the upper layers in autumn 2008.

	FA	I	SL
31 m	14%	17%	69%
39 m	20%	21%	59%
46 m	24%	37%	39%

often observed as the the top of the GL is associated with a strong shear. Also defining the height of GL depends on what level of turbulence gradient one considers as being the boundary between the GL and the free atmosphere (FA). To solve this dilemma, we use the method proposed in Aristidi *et al.* (2009) which consists in deducing the time a given anemometer spends within the GL by fitting three Gaussian fits to the distribution of the turbulence that it measured. The argument is that the FA and the GL have different distributions due to the different nature of how they form turbulence. The third fit corresponds to an intermediate case that corresponds to the time spent at the boundary between the GL and the FA. Figure 1 presents two examples of such fits, one where all three components are visibly obvious and one where the GL is so dominant that only one distribution is visible.

The results of the 2007 data are summarized in Table 1, broken down in seasons. In summer, it is not surprising that the 28 m anemometers spend a large amount of time in an intermediate state as the diurnal variations have huge effects on the GL seeing. As night sets, the boundary layer becomes more defined and the same anemometer spends the majority of the time still within the GL. In the peak of the winter, the GL is above 28 m 77% of the time. This is more than previously expected. Using the 2008, as illustrated in Table 2, we see that the GL runs out of momentum, but still represents 40% of the statistics at 46 m. The 2008 data, however, has only a limited amount of data mainly corresponding to the autumn season. It is is expected, extrapolating the temporal evolution of the 2007 data, that this number will decrease in the peak of winter and that the GL will spend less than 30% of the time above 46 m.

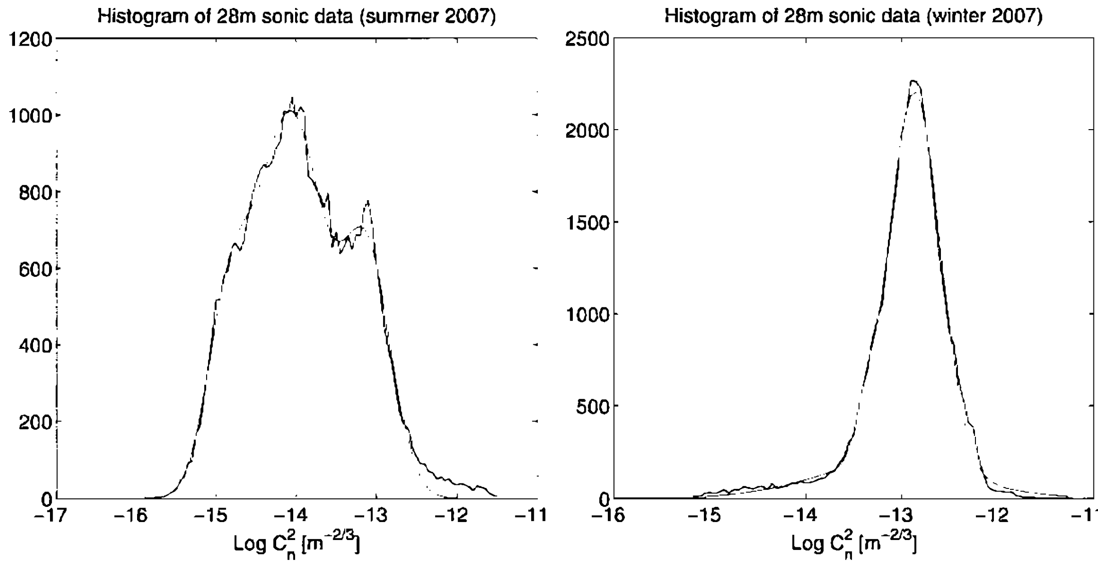

Fig. 1. Distribution of the optical turbulence at 28 m in summer (left) and in winter (right). The line corresponds to a triple Gaussian fit.

3.1 Conclusions

Although preliminary, the data presented here indicate that the the GL is quite variable and can be considered to be still significant at a height of 46 m. More statistically viable results should be available in 2009 when all 6 anemometers will be operating throughout the entire year. The variability of the GL height suggests that removing the GL turbulence may be easier using a GLAO system, which is relatively insensitive to the exact vertical extent of the turbulence rather than setting a telescope on top of a tower which will be fixed and hence see it performance very greatly.

References

Aristidi, E., *et al.*, 2009, A&A, 499, 955

Lawrence, J.S., Ashley, M.C.B., Tokovinin, A., & Travouillon, T., 2004, Nature, 431, 278

Travouillon, T., Jolissaint, L., Ashley, M.C.B., Lawrence, J.S, & Storey, J.W.V., 2009, PASP, 121, 668

Travouillon, T., *et al.*, 2008, SPIE, 7012, 70124B-5

Trinquet, H., *et al.*, 2008, PASP, 120, 203