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Sampling the Ground Layer of the Atmosphere at Dome C using fast Sonic-anemometers

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ABSTRACT

The ground layer turbulence at Dome C is the cause for more than 90% of the total turbulence column. While the height of this layer has been currently measured to be approximately 30m, no long term statistics is available from this part of the atmosphere. In order to plan the construction of future telescope at this site temperature site, temperature, wind speed and turbulence measurements are also necessary. Using fast sonic□anemometers we present, a preliminary set of data covering January to October 2007 sampling these quantities at heights of 8, 16 and 28 meters.

Keywords: atmospheric effects, site testing,

INTRODUCTION

The Antarctic base Dome C has been tested as a potential astronomical site for several years now. It has become well known that the negative aspects of the sites are located in a thin boundary layer, approximately 30m in height. Such conclusion has been drawn from different types of observations using MASS/SODAR [1] and microthermal sensors [2]. Both methods have asserted that above the boundary layer the seeing conditions are the best of any known ground based observatory with a median seeing of approximately 0.3”. This is very promising for a telescope located on a tower above the boundary layer. With the added advantages of low infrared background and continuous observation, such telescope could perform a unique range of sciences only available from space until now. What the two methods haven’t been able to provide, however, is a statistically meaningful estimate of the variations of the boundary layer height as well as temperature and wind measurements within it.

In order to study the extent and variations of the boundary layer, we have installed three sonic-anemometers on a 30m tower. The instruments are modified Sx models from Apptech. They each sample the temperature and wind velocity at a rate of 20Hz and are placed at heights of 8, 16 and 28m. Thanks to the fast readout we can also measure the temperature structure constant C_t^2, which can be integrated to determine the ground layer contribution to the overall seeing. In this paper, we will focus on the temperature and wind velocity results obtained during a time spanning November 2006 to January 2008. Because of the semi constant level of humidity saturation, the instrument is prone to icing. To remediate to this problem, heating coils were wrapped around the instrument to melt the ice forming on the measuring heads of the anemometers and keep the electronics warm. A duty cycle of 1 hour was found to work most of the time. The instrument gets heated 25min with the measurements turned off, then the heaters are turned off and 5 minutes are allowed for the instrument to come to thermal equilibrium with its surrounding before resuming a 30min period of sampling. Occasionally, however, a manual deicing was necessary and led to some periods of a few days without data. We also noted that after such a period, in October 2007, the instrument located at 16m suffered an unknown even which resulted in an offset in its temperature measurements. The temperature data from 16m were therefore omitted from the analysis after this period.

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TEMPERATURES

The time series of temperatures is shown in Fig.1. In summer, the temperature variations are smaller despite the diurnal cycles. The winter temperatures are far more variable spanning 30 degrees in a matter of days. On shorter time scales the temperature variations are all quite significant with swings of 10 degrees observed in a matter of minutes. As seen on Fig.2. the temperature inversion is strong in winter and rarely levels at the 30m level. The strength of the inversion increases as the winter progresses with typical gradients of 10 degrees over the span of the three anemometers. In summer, the presence of the sun breaks the inversion and the temperature gradient oscillates between positive and negative values hence showing a rather flat median profile.

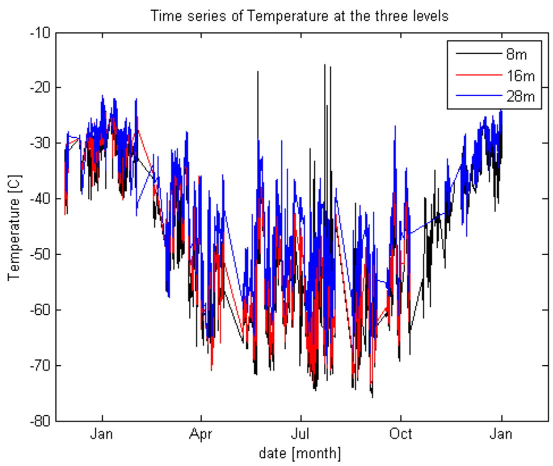

Fig.1. Time series of the temperature measurements taken by the three sonic-anemometers during the year 2007.

It is interesting to note that the “coreless winter” behavior observed on the Antarctic plateau is clearly noticeable at Dome C in 2007. The july temperatures are warmer than they are at the beginning and the end of the winter period. This effect documented by Neff [3] and Argentini [4] is due to synoptic perturbations which correlate with increase in pressure and a change in wind direction. During this period, however, we did not notice a change in the vertical profile of temperature, nor did the inversion show unusual behavior.

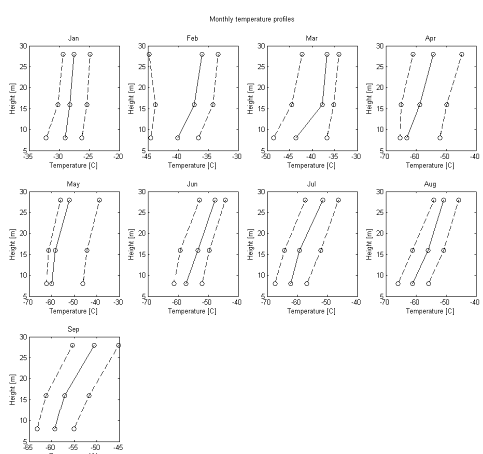

Fig.2. Monthly temperature profiles. The 25%, 50% and 75% percentiles are shown.

WIND VELOCITIES

The wind speed profiles measured by the sonic-anemometers were completed with the wind speed measurements taken at 3m by the Dome C AWS operated by the University of Wisconsin [5] over the same period. The statistics and distribution shown in Fig.3, show a significant increase with height mostly between 3m and 8m which suggest that the 3m wind are significantly slowed by the ground irregularities. With a representative median of 3m/s in 2007, the wind speeds at 3m are lower than they are at temperate sites. At 8m, the wind speeds are in line with the ones measured on Chilean or Hawaiian sites which typically vary between 5 and 7m/s. It is not so much in the median values but in the extreme values that the site shines. The maximum wind speed recorded was 21.2m/s, which is mild comparing with temperate sites. This is an advantage when it comes to observatory construction and observation. The katabatic nature of the wind on the plateau combined with the zero slope of Dome C explains this observation. The monthly profiles shown in Fig.4 show a slight increase in wind speed in winter as well as an increase in their vertical gradient. This effect is even more visible in the weekly median shown in Fig.5 where the AWS data were added. In the early summer 2007, the wind speed profiles were essentially flat. With the decrease of sun elevation the thermal inversion was able to settle and hence favor the pressure driven airflow.

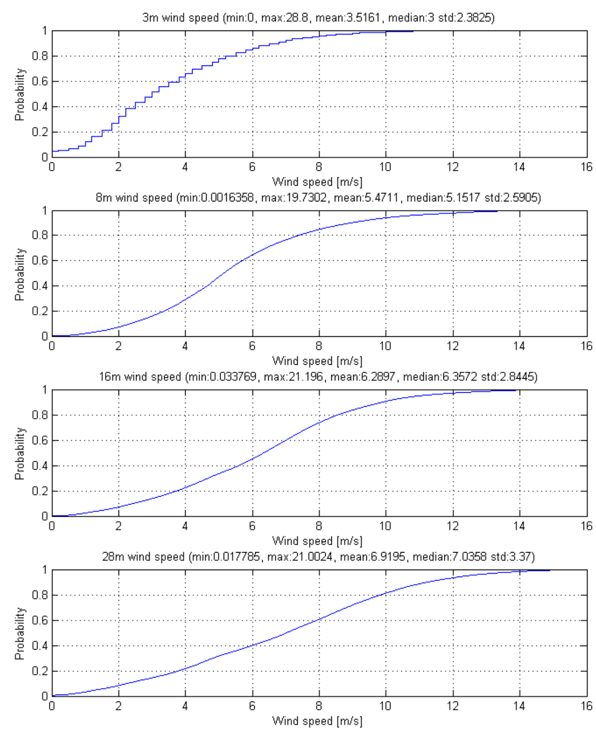

Fig.3. Wind speed distribution at the three sonics levels and at 3m taken by the Dome C AWS over the same period. The full statistics are displayed in the respective titles.

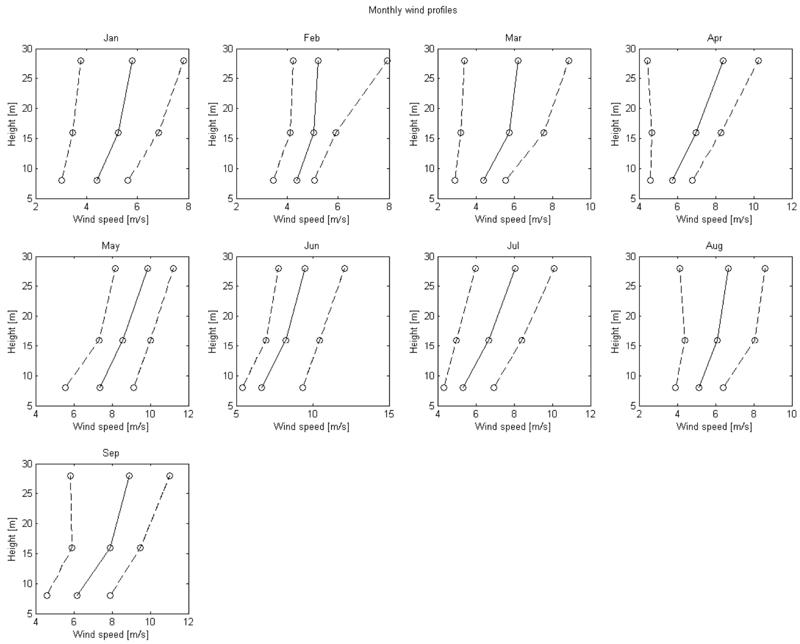

Fig.4. Monthly Wind speed profiles. The 25%, 50% and 75% percentiles are shown.

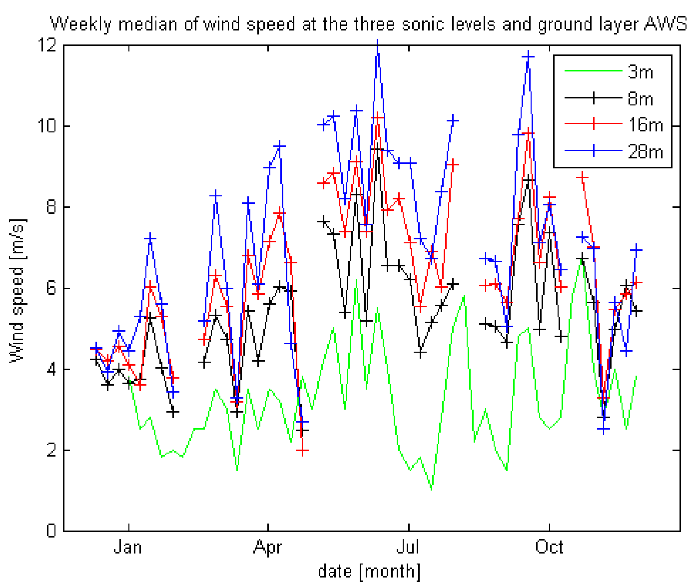

Fig.5. Weekly median wind speed using the 3 anemometers and the 3m AWS.

CONCLUSION

The weather conditions in the boundary layer at Dome C show some challenge for future observatories. In addition to the well known turbulence, the temperature variations can decisively hinder operation. And this also adds to a saturated humidity that needs to be addressed. These issues are good reasons to locate the telescope safely above the boundary layer, hence avoiding turbulence and temperature gradient problems. However, this means putting the telescope in higher wind speeds and therefore adjusting designs accordingly. In order to complete this study, the tower was extended in the summer of 2008 to 45m and three additional sonic-anemometers were used to sample the extra height. This will enable us to determine the optimum height for the construction of a telescope, where it will always be above the turbulence boundary layer.

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