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Low atmosphere turbulence at Dome C: preliminary results

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Abstract. We discuss the first two months of low altitude atmospheric turbulence at the Antarctic site of Dome C. Using a mini-SODAR, the first 890m of the atmosphere were sampled. It was found that between 9 Feb and 17 Apr 2003, the turbulence was concentrated below a 120m boundary layer that exhibited a clear diurnal cycle. This boundary layer height is less than half as thick as that at the South Pole (270m) as measured by the same instrument. It was also found that for the same period, the ground level wind at Dome C was also half that at the South Pole.

Key words. Site testing – Atmospheric turbulence – Remote Sensing –

1. Introduction

One of the major atmospheric parameters that is important to astronomers is the seeing, which quantifies the loss of resolution of the telescopes due to the atmosphere. This loss is an effect of the optical turbulence that changes the path of light as it travels through the atmosphere. This turbulence is usually located in several different layers of the atmosphere. The first one is within a low altitude boundary layer caused by the thermal interaction between the ground and the atmosphere and the highest one located high in the stratosphere is due to an mixing of the hot air coming from the equatorial region with the cold air coming from the poles.

At the South Pole, the high altitude turbulence was proven to be non-existent (Marks et al. (1999)) due to the extreme latitude of the site. On the other hand, the low altitude turbulence, in this case generated by a strong katabatic wind is very strong and extends up to an average of 270m, giving very poor seeing of 1.8″ (Loewenstein et al (1998) and Travouillon et al (2003)). The Dome C station (Candidi et al. (2003)), however, is located on a local maximum of the Antarctic plateau where we already know the wind is much lower than at the South Pole. We therefore expect that the low atmospherical conditions will be improved when compared to the South Pole. To verify this statement, a SODAR

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Fig. 1. The SODAR antenna installed on top of the AASTINO.

was deployed at Dome C in 2003 as one of the first two instruments of the Automated Astrophysics Site Testing International Observatory (AASTINO, Lawrence et al. (2003)).

2. The instrument

Our SODAR is a PA1 model manufactured by Remtech. This instrument is an acoustic radar that can determine the temperature fluctuation constant C_T^2 by measuring the strength of the echo as the sound is reflected off turbulent cells. It can also determine a three dimensional profile of the wind velocity using two beams oriented at 45° from zenith as well as Doppler shift information. It has a natural range of 900m at 40dB ambient sound level but was manually set to profile the turbulence from 30m to 890m with 30m increments. The data is integrated every 30 minutes in order to obtain an acceptable signal to noise ratio.

The SODAR was installed in the AASTINO during the summer deployment of 2002/2003. The antenna was placed on top of one of the six port-holes available on the roof of the observatory. The bottom of the antenna is in contact with the inside air of the building, keeping the antenna at an acceptable temperature. To isolate the antenna further from the outside temperature, the metallic lining of the antenna was covered by a 5cm tick layer of sterofoam and the top of the antenna by a Goretex material that prevents any precipitation from entering it. The SODAR receiver and control computer are connected to the rest of the observatory's computer network which can be accessed remotely using an Iridium satellite connection. The SODAR data is downloaded daily and made available automatically online to the scientific community.

The preliminary data presented in this paper cover the period between 9 February to 17 April 2003.

3. Results and Discussion

3.1. Wind speeds

On of the most attractive aspects of the Dome C site is the very low wind speed. It is an important criterion for two reasons. First of all, in Antarctica, the wind speed is closely related to the strength of the turbulence (Travouillon et al (2003)). It is therefore expected that the parts of the continent where the katabatic wind is the smallest will have the best low altitude turbulence conditions. Secondly, the wind is an important factor in the choice of the future large telescopes. Their size requires additional constrains such as low seismic activity and wind speed as described by Sarazin et al. (2002).

The first SODAR results show that Dome C wind conditions are greatly improved when compared to the South Pole station. The wind speeds at 30m were taken at Dome C by the SODAR and by balloon launches made by the meteorological team at the South Pole. The results are displayed on Fig. 2 and show that the wind speed at Dome C is half that at the South Pole. With an average so far of $2.9 m.s^{-1}$, we expect that the winter wind conditions will be the best observed when compared to any other site.

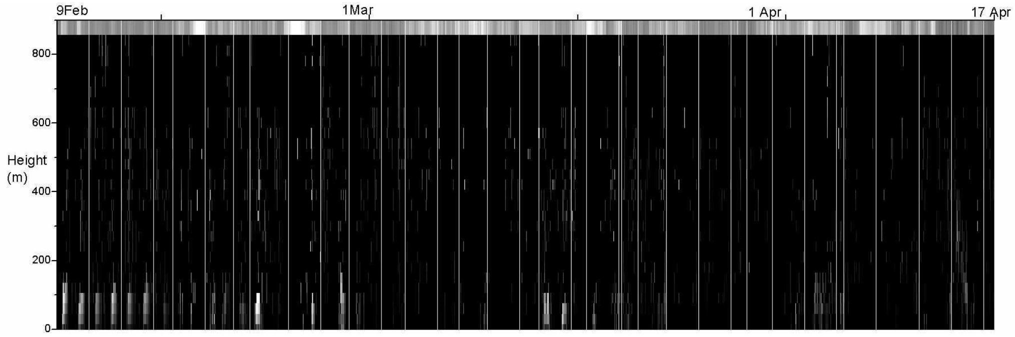

Fig. 3. Grey scale map of the turbulence. A lighter scale corresponds to a higher intensity.

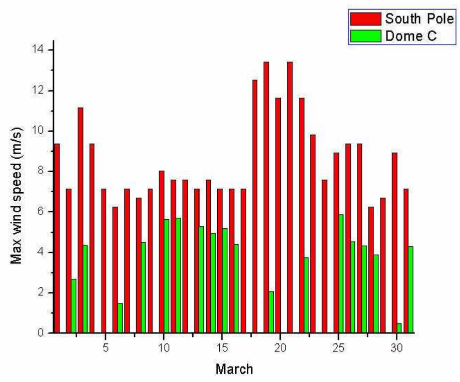

Fig. 2. Average wind speeds taken simultaneously at Dome C and at the South Pole.

3.2. Turbulence

When in 2000 and 2001, the SODAR was run at the South Pole station (Travouillon et al (2003)), it was found that low atmosphere turbulence was very intense and responsible for the poor seeing of the site. However, the most important knowledge about that site acquired by this experiment was the altitude of the boundary layer where all the turbulence was concentrated. Before the SODAR, this information was gathered by Marks et al. (1999) using balloon born microthermal sensors in a total of 15 flights. What the SODAR did was to provide us with a continuous measurement of this information throughout a whole year, adding not only further statistics about the site, but also knowledge of short and long term variations of the turbulence conditions in the low atmosphere.

The average boundary layer height at the South Pole was 270m. This means that a telescope placed above this point will be free of the majority of the seeing. This option cannot be realistically considered and essentially points out one of the main weaknesses of the South Pole observing conditions. Dome C being 400m higher than the South Pole, the expectations were that the ground turbulence would be improved and concentrated into a thinner layer. So far, the results have been positive, confirming the above supposition. We have found that the daily maximum boundary layer height is on average 120m high (see Fig. 4) with large diurnal variations. In agreement with the daytime DIMM measurements taken by Aristidi et al. (2003), the SODAR turbulence profiles shown in Fig 3 show that the turbulence intensity as well as the height of the boundary layer decrease in the beginning of the afternoon when the temperature and wind gradients reach a minimum. During these time, the turbulence falls below the SODAR sensitivity and no useful data can be obtained. This shortcoming is also apparent at night time where the surface inversion layer of 20 to 30m (See Fig. 5) is below the minimum altitude that the SODAR is capable of sampling. We therefore believe that the night time turbulence will likely concentrate in the first 30m of

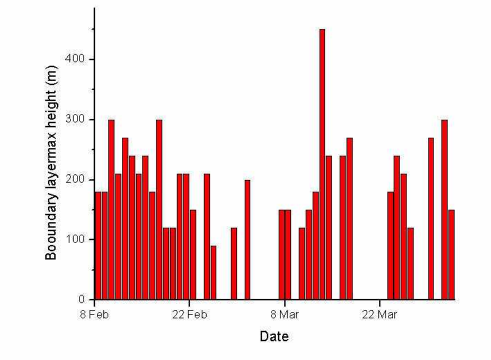

Fig. 4. Histogram of the maximum boundary layer height observed each day

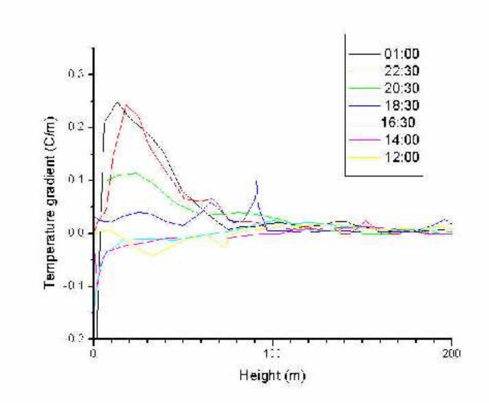

Fig. 5. Temperature gradients at different time of the day. Data taken on the January 25 2003.

the atmosphere and that the integrated total turbulence in the low atmosphere at Dome C will be far less than at the South Pole. This idea will need to be confirmed after a full year of data have been gathered by the instrument.

4. Conclusion

The preliminary results of the SODAR instruments are confirming certain expectations regarding the quality of the low atmosphere conditions at Dome C. The ground wind speeds are amongst the lowest in the world and a factor of two better than at the South Pole. The turbulence results are equally impressive, falling below the SODAR minimum detection threshold at night time.

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