Winter site testing at Dome C, Antarctica: first results

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Abstract: We present site testing results obtained in night-time during the polar winter at Dome C. These results were collected during the first Concordia winterover by A. Agabi. They are based upon seeing and isoplanatic angle monitoring, as well as in-situ balloon measurements of the refractive index structure constant profiles $C_n^2(h)$. The atmosphere is divided into two regions: (i) a 36 m high surface layer responsible for 87% of the turbulence and (ii) a very stable free atmosphere above with a median seeing of 0.36±0.19 arcsec at an elevation of $h = 30$ m. The median seeing measured with a DIMM placed on top of a 8.5 m high tower is 1.3±0.8 arcsec.

1 Introduction

The French and Italian polar station Concordia based at Dome C (75S, 123E) on the Antarctic plateau, has just completed its construction. This location is likely to be one of the best candidates for future installation of a large astronomical observatory. A site testing programme, under the name Concordiastro, has been initiated by our group to characterize this site for high angular resolution astronomy in the visible. Recent results in summer (Aristidi et al., 2005a, 2005b) have shown the potential of this site for solar astronomy with a median seeing of 0.54 arcsec in daytime.

The first winterover has officially started on Feb. 15, 2005. Among the 13 winterers, A. Agabi, the project manager of Concordiastro is spending one year at the site to run our experiments. They consist in

- *in situ* measurements of thermal fluctuations using balloon-borne microthermal sensors (Azouit and Vernin, 2005). The balloon scans the atmosphere between the ground and an altitude of 15–20 km, and sends a value of the refractive index structure constant C_n^2 every 1–2 sec. This corresponds to a vertical resolution between 5 and 10m.
- 3 seeing monitors of DIMM type, as described in Aristidi et al., 2005a. They are located at heights 3.5 m, 8.5 m and 20 m above the snow (the 20 m high one has been set up on the top of the calm building of Concordia on July, 23rd). They give a seeing value every 2 mn. The 3.5 m high monitor can provide as well the isoplanatic angle by changing the pupil mask.

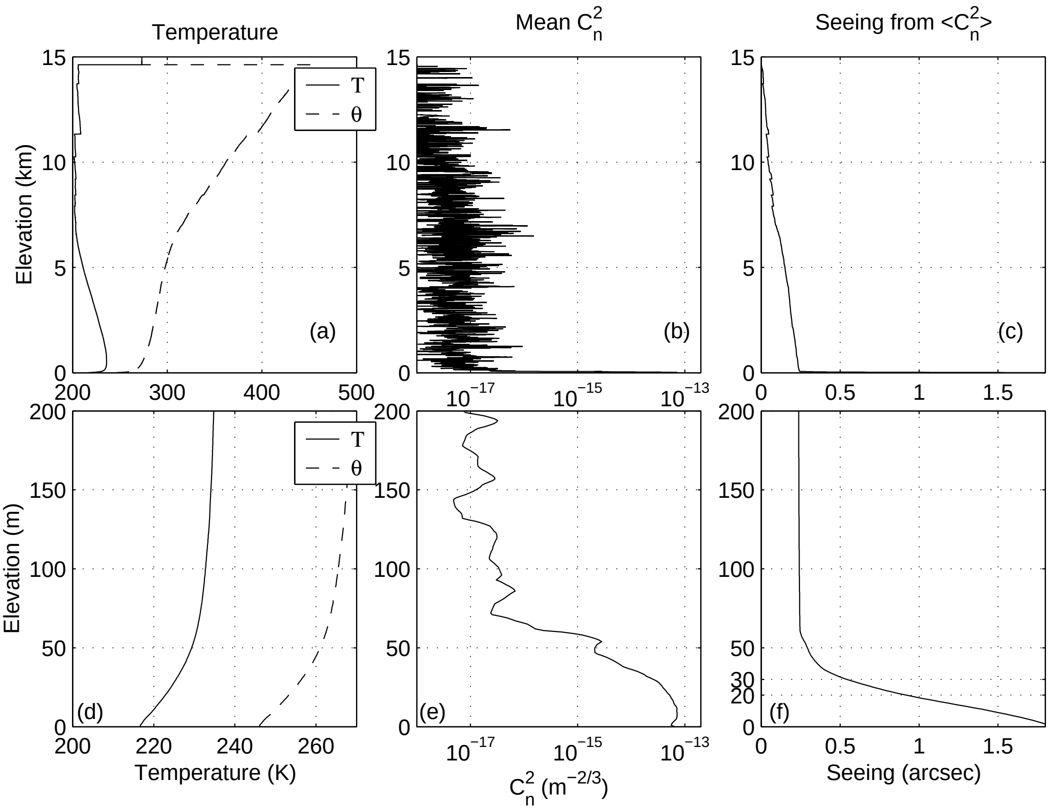

Figure 1: Average vertical profiles of (a) the temperature T and potential temperature θ, (b) the refractive index structure constant C_n^2. Curves (a) and (b) correspond to averages over 16 balloon data between March 15th and August 1st. (c) is the average seeing deduced from individual C_n^2 profiles. Discontinuities in the temperature plot (a) are due to the increasingly insufficient number of flights reaching high altitudes. Plots (d), (e) and (f) show the same quantities on the first 200 m over the ground.

The first results were recently published (Agabi et al., 2005) and we will summarize them here.

2 Results

2.1 Balloon in situ measurements

Balloons launches started on March, 15^{th}. Up to now 16 balloons provided exploitable vertical profiles $C_n^2(h)$. Averaged profiles are shown on fig. 1b. The seeing at a given altitude has been computed from $C_n^2(h)$ profiles (fig. 1c). Largest values are found just above the ground. The remaining of the turbulent energy being well distributed with the altitude. Average C_n^2 profile in the first 200 m is plotted together with the potential temperature gradient $d\theta/dz$ (figure 2). This gradient appears in the definition of the Richardson number that describes the apparition of turbulence. The similarity between the two curves is remarkable.

We found a ground seeing, above ground and up to 15–20 km, of 1.9±0.5 arcsec, and a 36±10 m thick surface layer accounting for 87% of the turbulent energy. The seeing above this surface layer is 0.36±0.19 arcsec. Other parameters deduced from individual profiles are summarized in table 1. Isoplanatic angle θ_0 and coherence time τ_0 correspond to the adaptive

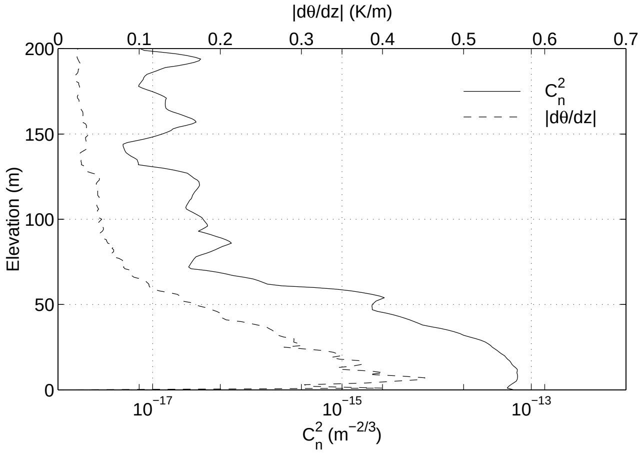

Figure 2: Average vertical profiles of C_n^2 and of the potential temperature gradient $d\theta/dz$ in the first 200 m above ground.

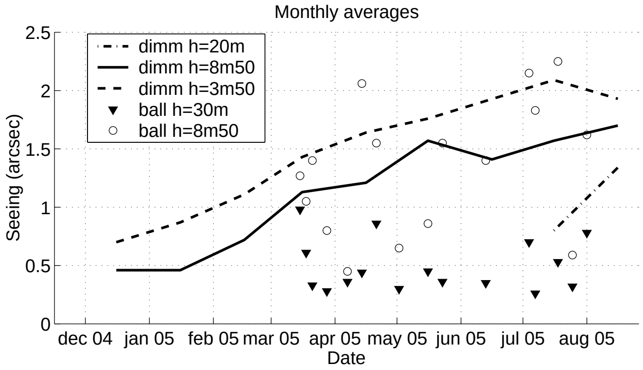

Figure 3: Monthly averaged ground seeing from the monitors located at elevations 3.5 m, 8.5 m, and 20 m. Individual points are ballon-based estimations at 8.5 m and 30 m.

optics definition (eq. 7 and 9 of Marks et al. , 1999). All values compued above the surface layer are in remarkable agreement with measurements reported by Lawrence et al. (2004). θ_0 appears to be smaller than the summer median value of 6.8 arcsec, though the surface layer is of little influence on it. High altitude strong winds (up to 30 m/s at h=16km) have indeed been observed in May and June (Agabi et al. , 2005).

2.2 Seeing and isoplanatic angle monitorings

The seeing data taken into account in this paper have been collected during the period March 1st – August 23th , 2005. The seeing statistics provided in Table 1 stands for the monitor located on the platform (elevation h = 8.5 m). The “ground” seeing monitor at h = 3.5 m has also been running during the same period of time, while the “roof” monitor at h = 20 m provides data since July, 23rd. Figure 3 shows, for the 3 monitors, the monthly averaged seeing evolution during the transition from summer to winter. Both seeings follow the same positive trend. Isoplanatic angle data are available since May, 19th and statistics are displayed on table 1. Here again, data from the monitor are compatible with data from the ballon C_n^2 profiles. θ_0 appears to be similar to South Pole value of 3.23 arcsec (Marks et al. , 1999).

Balloon data

	ϵ ($''$)	θ_0 ($''$)	τ_0 (ms)
$h \geq 8.5$ m	1.4±0.6	4.7±2.6	2.9±7.0
$h \geq 30$ m	0.36±0.19	4.7±2.6	8.6±7.1

Monitors data

$h \geq 8.5$ m	ϵ ($''$)	θ_0 ($''$)
Median	1.3±0.8	2.7±1.6
Min/Max	0.12/3.37	0.43/10.91
Ndata	36127	9501

Table 1: Median optical parameters from the DIMM and the balloons. The uncertainties are standard deviations of the values.

3 Conclusion

The situation at Dome C appears to be similar at South Pole (Marks et al. , 1999): a poor ground seeing mainly due to a strongly turbulent boundary layer and an excellent free atmosphere seeing of 0.35 arcsec. The big difference is the height of the boundary layer : 220 m at South Pole and 36 m at Dome C. We could imagine 30 m high structures to put telescope onto, and benefit from the excellent free atmosphere seeing. This is not an insurmountable problem: existing telescopes are often elevated (ESO 3.6m at La Silla is at 30 m, CFHT at Mauna Kea is at 28 m). The properties of the boundary layer need to be investigated carefully. A dedicated experiment with micro-thermal sensors on the 32 m-high American tower is foreseen for the second winterover.

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References

Agabi A., Aristidi E., Azouit M. et al., 2005, PASP, submitted
Aristidi E., Agabi A., Fossat E. et al., 2005a, A& A, in press
Aristidi E., Agabi A., Azouit M. et al., 2005b, A&A, 430, 739
Azouit M., Vernin J., 2005, PASP 117, 536
Lawrence J., Ashley M., Tokovinin A.A., Travouillon T., 2004, Nature 431, 278
Marks R., Vernin J., Azouit M., et al., 1999, A&AS, 134, 161