Seeing at Cerro Pachon

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This text is a part of the SOAR AO concept document.

The initial specification of the SOAR image quality with and without tip-tilt compensation used a preliminary analysis of the seeing at Cerro Pachon [2], based on DIMM data obtained at both Cerro Tololo and Cerro Pachon sites. The 25% and 75% r_0 values of 30 and 16 cm are given. However, the exposure time of that DIMM was not yet short enough, leading to systematic under-estimation of the atmospheric seeing.

Since then an extensive site surveying campaign was performed at Cerro Pachon under a contract with Gemini. The results are publicly available [3]. On the basis of this Report, Gemini team adopted a model of turbulence vertical distribution and uses it for the modeling of the Gemini-S MCAO. The model corresponds to median seeing of $0.68''$, or $r_0 = 15$ cm (all data here and below are for a wavelength of 0.5 micron). The seeing statistics is based on 44 balloon soundings made in 4 campaigns throughout 1998.

A careful reading of the Report reveals that there is some disagreement in seeing measured by the 3 instruments used in this campaign: balloons, Generalized Scidar (GS) and optical monitor (GSM). During 6 nights in October 1998 when GSM was operational at Cerro Pachon, it measured a seeing of $0.98''$, while balloons gave $0.54''$ – a mismatch of 1.8 times (Table 4.8 of the Report). The disagreement is more for best-seeing profiles and less for worse seeing. The authors of the Report explain this difference by the low altitude of GSM (3 m above ground), while the balloon profiles were integrated from 27 m above the ground. However, the microthermal measurements reported in Table 3.10 *and made during the same period of time* do not support this conjecture: the ground layer between 4 and 27 m contributes a seeing of only $0.12''$. Subtracting this contribution leaves the GSM seeing almost unchanged, $0.97''$. The small contribution of the ground layer to the overall seeing was well documented at other sites (e.g. at Cerro Paranal, [1]) and leaves little doubt.

The GSM seeing data are reliable: the instrument is in perfect agreement with ESO DIMMs both at La Silla and at Paranal, and, in addition, provides two mutually consistent seeing values (one from differential image motion, another from absolute image motion). On the other hand, our re-processing of the balloon profiles for October 1998 (the profiles were kindly provided by the Report authors) have shown that the C_n^2 integrals do depend on the lower integration limit. The balloons were launched from the Gemini site, hence integrating over *all* altitudes is reasonable and gives seeing some 10-20% worse than in the Table 3.7 of the Report. This is not sufficient to explain the whole difference; some of the reasons invoked to explain the divergence between balloons and GS (pp. 93-94 of the Report) must be applicable here as well. The GS gives a seeing worse than balloons by a factor of 1.27 (ratio of average values from Table 4.7), but these data refer to different sites, Tololo and Pachon. The GS and balloon vertical profiles are in reasonable overall agreement with each other at high altitudes

Table 1: Seeing values, arcseconds at 0.5 micron

Hist. level	Balloon	GS (Tololo)	GS (Free atm.)	SOAR model
15%	0.35	0.53	0.34	0.28
50%	0.61	0.75	0.50	0.46
85%	0.95	1.19	0.84	0.77

(the occasional differences up to 10 times, as in Fig. 4.23 of the Report, can be accounted for by the different spatial and temporal sampling of both methods).

The Report does not provide a histogram of balloon seeing data. I constructed such histogram from the 44 data points given in Table 3.6-3.7 of the Report. The seeing at Cerro Tololo and in the free atmosphere (1 km above Tololo) is also given from GS data (Fig. 3.33 b,c of the Report).

The SOAR seeing model is included in the Table, expressed in arcseconds and converted to 15 and 85-percentile levels. The conversion assumes a log-normal seeing distribution of such a width that 25% (75%) seeing are 1.40 times better (worse) than the median, and 15% (85%) are 1.67 times better (worse). This distribution gives a reasonable fit to most seeing data for Tololo/Pachon. It can be seen that SOAR expectation is even better than the free-atmosphere seeing!

Conclusion. As a result of site testing at Pachon, the median seeing is bracketed between $0.61''$ and $0.75''$, with $0.68''$ (as adopted by Gemini) being a reasonable expectation. For 15% of nights we expect a seeing better than $0.41''$ and for 25% – better than $0.49''$. Correcting ground layer alone by adaptive optics may improve the median seeing to $0.50''$ on one half of nights. Some concern about the systematic errors in these data remains and must be removed by long-term DIMM measurements.

The values of seeing given above correspond to the standard atmospheric turbulence spectrum with infinite outer scale. Actual image size in the telescope (even without compensation) will be somewhat smaller due to the outer scale effects (see below).

References

[1] Martin F., Conan R., Tokovinin A., Ziad A., Trinquet H., Borgnino J., Agabi A., Sarazin M. Optical parameters relevant for High Angular Resolution at Paranal from GSM instrument and surface layer contribution. Astron. Astrophys. Suppl. Ser., 2000, V. 144, p. 39-44.

[2] Sebring T., Cecil G., Moretto G., The SOAR telescope project: a four meter telescope focused on image quality. SPIE Proc. (Kona), 1998.

[3] Vernin J., Agabi A., Avila R., Azouit M., Conan R., Martin F., Masciadri E., Sanchez L., and Ziad A., "Gemini site testing campaign. Cerro Pachon and Cerro Tololo," *Gemini RPT-AO-G0094, http://www.gemini.edu/*, 2000.