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SITE TESTING AT SAN PEDRO MÁRTIR

J. Echevarría

Instituto de Astronomía, UNAM, Ciudad Universitaria, México, D.F., México

RESUMEN

En este artículo revisamos el trabajo realizado para medir la turbulencia atmosférica al nivel del suelo en el Observatorio Astronómico Nacional en San Pedro Mártir. Argüimos, basados en resultados más modernos obtenidos a lo largo de más de una década, que la mediana de la *calidad de imagen* es de 0.55 segundos de arco a una altura de 15m. Este análisis comprueba que San Pedro Mártir es uno de los mejores sitios del mundo en cuanto a *calidad de imagen* y probablemente el mejor.

ABSTRACT

In this paper we review the work done to obtain measurements of the atmospheric turbulence at the ground level in the Observatorio Astronómico Nacional at San Pedro Mártir. We argue, from recent results obtained during more than a decade, that the median *seeing* is 0.55 arcsec at a height of 15 m. This analysis confirms that San Pedro Mártir is one of the best ground-based places in the world as far as seeing is concerned and that it is probably the best one.

Key Words: **ATMOSPHERIC EFFECTS — TURBULENCE**

1. INTRODUCTION

In the late sixties the Instituto de Astronomía of the Universidad Nacional Autónoma de México searched for a new observatory site, since the Observatorio Astronómico Nacional, first at Tacubaya, México City and later at Tonantzintla, Puebla, was already inside densely populated areas and therefore highly contaminated. Through satellite photographs, it was found that the northern part of Baja California was one of the three best cloud-free areas in the world. After several meteorological studies, the Observatorio Astronómico Nacional was established at the Sierra of San Pedro Mártir (SPM). It lies within the NE part of the San Pedro Mártir National Park, and it is at the top of a spur arising from the San Felipe desert. At present it has three reflecting telescopes with diameters of 0.84 m, 1.5 m and 2.1 m (see e.g., Moreno-Corral et al. 1994). A number of studies on the climatological properties of this site have been reported, mainly during the first years of operation of SPM (Mendoza 1971, 1973; Walker 1984; Mendoza et al. 1972; Alvarez 1982, Alvarez & Maisterrena 1977; Alvarez & Moreno 1995; and Tapia 1992, 2003). The sky emission at 10 μm has been reported by Westphal (1974), and the atmospheric opacity at 215 GHz has been discussed by Hiriart et al. (1997). Only one old paper on seeing conditions has been reported (Walker 1971).

2. EARLIER SEEING STUDIES

There are only two papers reporting seeing observations. The first is by Mendoza (1971). He reports the combined results of two methods: one using the Danjon telescopes (30 cm and 15 cm), and the Polaris star-trail (15 cm and 16 cm telescopes), at a height of 3.6 m. No details ar given on the number of nights or measurements but only that they were carried out from 1968 to 1971. His results are as follows: seeing greater than 1.5 arcsec 15 percent; seeing less or equal than 1.5 arcsec 85 percent; seeing less then 1.0 arcsec 30 percent. The other paper is by Walker (1971) who, after completing the California Site Survey, explored several sites like Kitt Peak, Flagstaff, Arizona, San Pedro Mártir and Cerro Tololo, Chile, using the Polaris star-trail seeing telescope. The technique was to use trails of Polaris photographed with a six-inch refracting telescope, presumably using one of the instruments used by Mendoza. The observations were carried out from 24 April to 30 July 1970 on the highest point, which is located north-west about 100 m where the 2.1 m telescope is now located. The observations were carried out at the same height of 3.6 m. His results are from 52 nights of data somewhat more elaborated than the previous work and is summarized in his Table VI. His Fig. 6 also plots an histogram of the results. The data is again scarce and distributed in units of arcsec (i.e. less then 1, from 1.1 to 2.0, from 2.1 to 3.0, etc.). No mean or median are given and it would be an overkill to try to do it from the way the data is distributed.

3. RECENT STUDIES

Several recent seeing studies have been carried out since the early seventies: Echevarría et al. (1998; EEA98), Conan et al. (2002; CEA02) and Michel et al. (2003a; 2003b: MEA03).

EEA98 report observations with two different monitors and a Micro Temperture Array tower. The two seeing monitors used by these authors were the Site Testing Telescope (STT) from Steward Observatory, designed to observe Polaris. The second one is the Carnegie Monitor (CM) which can observe and track any star. The Micro-Thermal Array (MTA) consisted of five pairs of platinum detectors to measure temperature differences located at different heights, from 4 to 28 m. They concluded that the median seeing is 0.61 arcsec with a first quartile of 0.50 arcsec. The MTA measurements, which ran for more than a year, clearly showed that the local seeing decreases substantially by 0.1 arcsec at a height of 15 m. A seasonal variation was also detected with better median values for spring (0.58 arcsec) and summer (0.58 arcsec) and lower values for autumn (0.68 arcsec) and winter (0.69 arcsec). The STT observations cover 386 nights spanning a three year period (March 29, 1992 to August 1994); the CM observations were conducted for 114 nights (from September 3 1992 to August 10 1993); and the MTA observations were carried out for 90 nights in two different periods (April 16 to May 17 and June 18 to August 23 1992).

The second recent study by CEA02, although mainly devoted to measure the wavefront outer scale, included ground-based seeing measurements with the DIMM monitor of the San Pedro Mártir Observatory. This was acquired after the campaign of EA98. They report observations during 38 nights from different epochs: 7-22 May, 9 and 29 October, 1-14 December 2000 and 6-11 October 2001. The telescope was located at the CM tower for most of the observations, except in May and October 2000 were the monitor was 2 m above the ground. In their paper they found a bimodal distribution during their December 2000 campaign with peaks centered at 0.50 and 0.75 arcsec, and an overall seeing median of 0.77 arc sec including all observations.

The third study by MEA03 was conducted with the same DIMM monitor during 105 nights spanning almost a three year period (August 19 2000 to May 30 2003). The monitor was located at the CM tower at a height of 8.3 m. These authors reported a median of 0.62 arcsec and a first quartile of 0.49 arcsec. This work includes seven nights also reported by CEA02, which were compatible with the instrument setup and reduction method. MEA03 also analyze the seasonal behavior of the data and finds somewhat similar results to EA98. They found the following median values: spring 0.61, summer 0.54, autumn 0.61 and winter 0.70. The authors point out that the lack of evenly distribution of points argues in favor of taking a mean of the four seasons, and this is the value that they quote in their abstract. However the overall distribution of the 112 nights yield a median of 0.59 arcsec and a first quartile of 0.47 arcsec.

4. DISCUSSION

It is clear that the recent seeing campaigns put San Pedro Mártir Observatory among the best sites in the world in terms of seeing quality. The similarity of results even from such different monitors as the STT, CM and DIMM yield similar results. We are tempted, therefore, to attempt to produce a median seeing value which takes into account the total number of observed nights. Strictly speaking, this is questionable, but could give us another insight into the quality of the site. Therefore, instead of quoting values of the different campaigns we add the total number of observed nights weighted in a reasonable way.

TABLE 1

CORRECT SEEING SAMPLES FOR A HEIGHT OF 15 METERS

First Quartile	Median	No. of Nights	Median at 15m height	Sample
0.45	0.58	144	0.53	CM,STT
0.51	0.62	329	0.54	STT
0.52	0.70	42	0.65	CM
0.46	0.59	112	0.54	DIMM
0.50	0.61	597	0.55	Total

We have separated the data in four samples: a) nights observed simultaneously with the STT and CM, b) the remaining STT nights, c) the remaining CM nights, and d) the DIMM nights. In Table 1 we present the median and first quartile for the four samples, the number of nights and a weight associated primarily with the number of observed nights. In the last column we have used the MTA observations to correct the sample to a height of 15 m, which is the height where we should have a substantial improvement in the local seeing and a height at which we expect to place a new-generation telescope.

Not surprisingly the final result is the same as EEA98's, although now the predicted seeing at 15 m height is better balanced with the other campaigns. Still, a value of 0.55 arsec at 15 m is an extremely good result and we conclude the the San Pedro Mártir is indeed the best place in the world in terms of seeing. This can be confirmed by comparing Table 3 of MEA03, which includes the most comprehensive list of DIMM campaigns for 17 sites around the globe.

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Juan Echevarría: Instituto de Astronomía, UNAM, Apartado Postal 70-264, 04510 México, D.F., México (jer@astroscu.unam.mx).