

# Measurements of the optical seeing isotropy at San Pedro Mártir Observatory

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**Abstract.** We present measurements of optical seeing isotropy carried out at the San Pedro Mártir Observatory, Mexico. The orientation dependence of the seeing is analyzed based on DIMM system measurements in the East-West direction.

## 1. Introduction

The San Pedro Mártir National Astronomical Observatory in Mexico (OAN-SPM) has proven to be an excellent site for astronomy. Survey campaigns at the site have found a mean optical seeing of about 0.7 arc-sec [1-4].

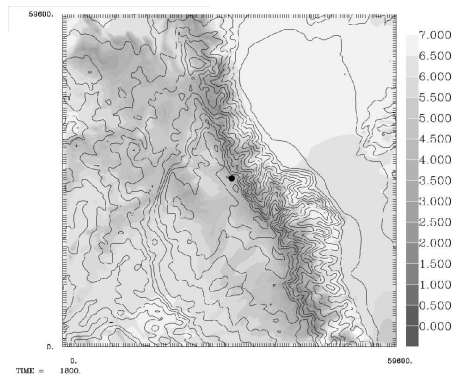
Optical seeing depends on temperature gradient and local terrain structure, among other variables. Sierra San Pedro Mártir, in the Mexican peninsula of Baja California, runs along the NW-SE direction. The West side has a gradual elevation from the Pacific Ocean coast up to an altitude of about 3000 m over the sea level. The summit of the sierra hosts a well populated pine forest. The East side of the sierra has an abrupt decline in altitude ending at a desert at almost sea level (see Figure 1). The East rim of the sierra is the site for the 2.1-m telescope.

Because of the large variations on the surrounding terrain at the 2.1-m telescope, there was a concern on whether optical seeing was dependent on westward/eastward pointing of the telescope. Specifically, the rising thermal currents from the desert (East) were suspected to deteriorate the seeing in that direction relative to the observed seeing in the West direction. There is little variation in the terrain northward-southward of the summit, leading to the expectation that seeing should not vary too much in the N-S direction. This paper presents a study of the seeing isotropy between eastward and westward pointing on the East ridge of the San Pedro Mártir Sierra.

## 2. Observations

Observations were acquired using a two-aperture DIMM from LHESA Electronique described by Vernin & Muñoz-Tuñón[5]. It consists of a 20-cm Schmidt-Cassegrain telescope on a equatorial mount with automatic guiding capabilities, a diaphragm with two 60-mm apertures separated (center-to-center) by 140 mm, an optical wedge in one of the apertures, an intensified CCD camera (LHESAs LH750EIA), and a PC-compatible computer equipped with a frame grabber. An inter-calibration of the OAN-SPM DIMM to the was reported by Núñez et al [6].





**Figure 1.** Topographical map of the San Pedro Mártir Sierra. The dot indicates the location of the OAN-SPM 2.1m telescope [4].



**Figure 2.** The OAN-SPM 2.1-m telescope at the East ridge of the San Pedro Mártir Sierra. The forest (westward) and the desert (eastward) are visible in this picture.

Data from a total of 39 observing nights were collected on 2004 September 09 through November 30 during good weather conditions. Similar air-mass stars in the East and West direction were observed at almost the same time.

### 3. Results

Tables 1 and 2 present the seeing measurements in the East-West direction from 2004 September 14 to September 26: Col. 1 presents the date (month,day), Col. 2 direction (West or East), Col 3 the average seeing (arc-sec), Col. 4 the rms seeing (arc-sec), Col. 5 the median seeing (arc-sec), and Col. 6 the time (minutes).

Table 3 presents the range values of all the measured seeing in the East-West direction during September and October 2004. It presents the seeing range values (column 1), the number of measurements in the range (column 2), and the percentage in that range from of the total seeing measurements (column 3). A large number of measurements (62.49%) have a seeing of less than 1.0 arc-sec.

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Figure 3 shows the seeing variations during the observing runs of September–October 2004. Data points representing westward or eastward telescope pointing are labeled as Forest or Desert, respectively. From Figure 3, it can be notice that seeing is not dependent on a westward versus eastward pointing direction of the telescope. Thus, seeing is isotropic for the OAN-SPM 2.1m telescope at its current location.

### 4. Discussion

Since it has been found the seeing is isotropic at the OAN-SPM 2.1m telescopes site, the variation in quality in seeing must be solely due to local terrain effects and thermal currents produce by differential heating. At the San Pedro Mártir Observatory the prevailing winds come from the Pacific Ocean. Simulation of wind turbulence, showed similar behavior for sites on the East and West side of the sierra [7].

The seeing isotropy between westward and eastward pointing may have the following explanation: since the Sun sets in the West, the mountains shadow the East side of the sierra starting roughly after midday. This will allow the East side to cool down and reach a thermal equilibrium with the atmosphere. (Figure 4). The West side, having a gradual elevation change,

**Table 1.** Measurements of the seeing: forest (West) and desert (East)

Date (mmdd)	direction	Average (")	rms	median (")	time (minutes)
0914	W	0.811	0.183	0.758	40
	E	1.124	0.164	1.115	47
	W	0.781	0.124	0.767	26
	W	0.533	0.058	0.527	16
0915	W	1.145	0.288	1.082	24
	E	0.781	0.082	0.791	10
	W	0.634	0.108	0.613	15
	W	0.477	0.044	0.480	22
	E	0.758	0.087	0.741	27
	W	0.552	0.095	0.541	25
	E	0.387	0.042	0.379	26
	W	0.409	0.042	0.411	26
	E	0.436	0.034	0.436	25
	W	0.741	0.206	0.696	22
	E	0.609	0.073	0.589	18
	W	0.743	0.124	0.729	24
0916	E	0.457	0.039	0.452	20
	W	0.605	0.086	0.597	26
	E	0.441	0.073	0.431	30
	W	0.344	0.043	0.333	27
	E	0.330	0.036	0.326	25
	W	0.689	0.088	0.682	26
	E	0.738	0.095	0.717	14
	W	0.750	0.149	0.723	27
	E	0.967	0.146	0.953	25
	W	0.745	0.106	0.736	25
	E	0.869	0.146	0.842	25
	W	0.639	0.119	0.635	26
0918	W	0.813	0.106	0.802	28
	E	1.126	0.130	1.124	14
	E	1.463	0.225	1.459	27
	W	0.937	0.126	0.953	28
0921	E	1.894	0.536	1.745	27
	E	1.062	0.139	1.068	23
	W	0.981	0.147	0.954	26
	E	1.010	0.354	0.909	27
	W	0.856	0.176	0.811	26
	E	1.135	0.188	1.123	25
	W	0.583	0.097	0.573	23
	E	0.742	0.073	0.745	25
	W	0.879	0.122	0.864	23

## 5. Conclusions

Isotropy of optical seeing in the East-West direction was confirmed at East rim of the San Pedro Mártir sierra. The expectation of having a directional dependence on seeing was motivated

**Table 2.** Measurements of seeing: forest (West) and desert (East)

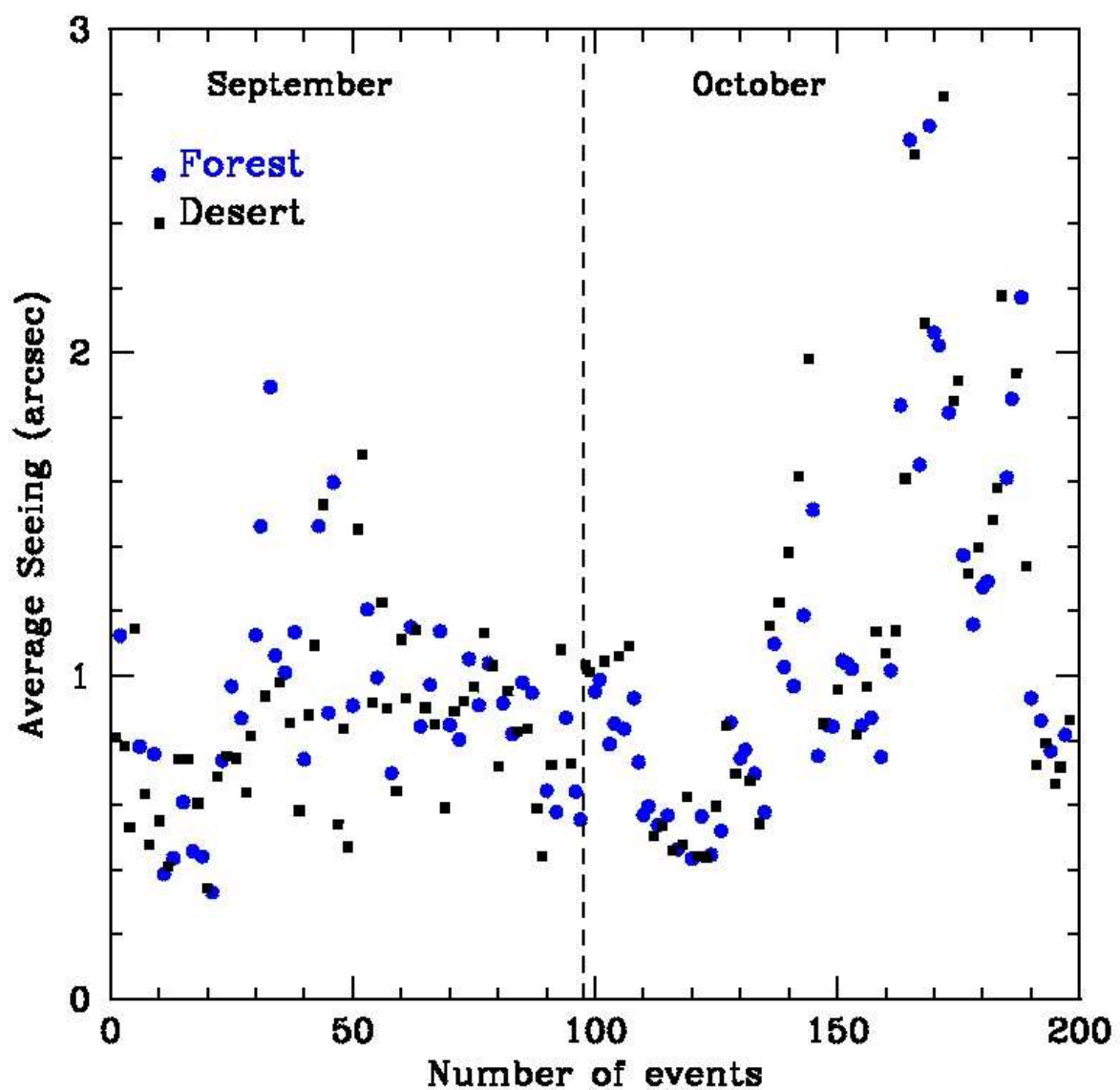
Date (mmdd)	direction	Average (")	rms	median (")	time (minutes)
0922	W	1.095	0.136	1.079	26
	E	1.464	0.303	1.400	22
	W	1.530	0.415	1.455	24
	E	0.885	0.266	0.799	23
	E	1.599	0.261	1.575	13
0923	W	0.540	0.110	0.507	18
	W	0.837	0.553	0.526	28
	W	0.471	0.076	0.464	23
	E	0.908	0.160	0.881	25
0924	W	1.453	0.336	1.469	17
	W	1.683	0.244	1.664	13
	E	1.205	0.163	1.173	24
	W	0.916	0.138	0.888	29
	E	0.994	0.452	0.845	31
	W	1.228	0.177	1.184	14
	W	0.898	0.127	0.869	15
	E	0.698	0.055	0.696	16
	W	0.642	0.060	0.635	17
	W	1.113	0.225	1.164	16
0925	W	0.932	0.241	0.914	17
	E	1.151	0.317	1.082	33
	W	1.142	0.233	1.092	27
	E	0.843	0.152	0.813	26
	W	0.902	0.120	0.879	23
	E	0.972	0.117	0.968	26
	W	0.850	0.145	0.829	22
	E	1.138	0.182	1.087	25
	W	0.592	0.069	0.584	20
	E	0.848	0.110	0.810	26
0926	W	0.891	0.130	0.888	25
	E	0.803	0.050	0.797	17
	W	0.921	0.124	0.903	24
	E	1.052	0.133	1.044	21
	W	0.965	0.093	0.951	24
	E	0.909	0.088	0.895	22
	W	1.134	0.118	1.119	23
	E	1.038	0.136	1.028	22

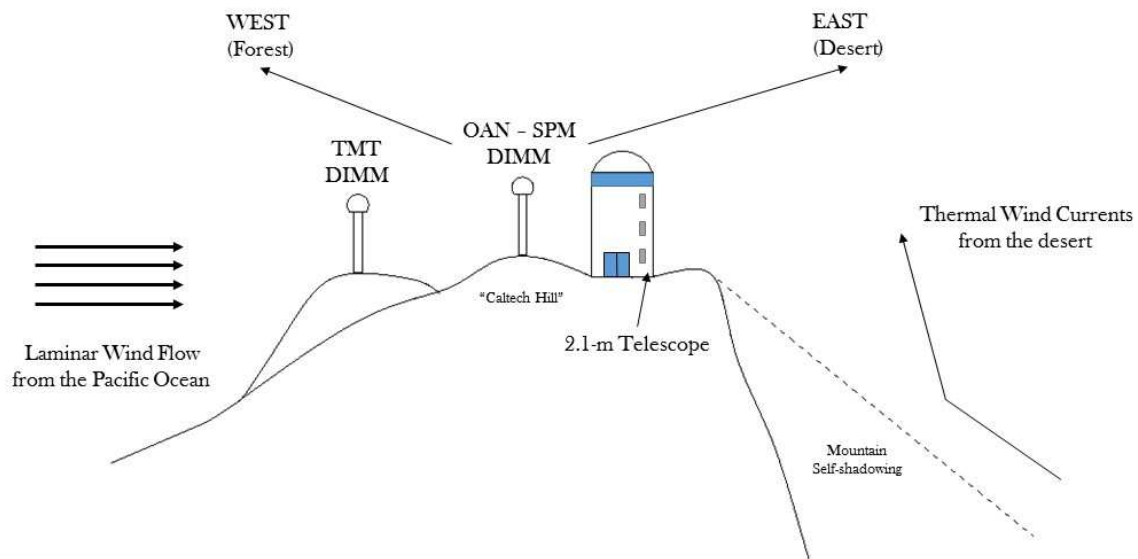
by the large variation in elevation between the eastward and westward directions at the rim site. The isotropy is likely a result of the east side of the mountain being cooling down by self-shadowing and reaching thermal equilibrium with the atmosphere during the afternoon.

Our findings are also supported by over 30 years of observations taken at the 2.1-m telescope near the same location. It has never been a report of seeing variability between eastward and westward pointing from this telescope. However, compared to the 2.1-m telescope observations,

**Table 3.** Measured optical seeing values.

Seeing range (arc-sec)	Measurements	Percentage (%)
Less than 1.0	13538	62.49
Between 1.0 and 5.0	5145	23.75
Larger than 5.0	2982	13.76

**Figure 3.** The variation of seeing over the September and October observing runs. Forest/Desert implies a pointing direction of West/East, respectively.



**Figure 4.** Diagram of the East side of San Pedro Mártir sierra ridge. It schematically shows the position of the Thirty Meter Telescope site survey DIMM (TMT-DIMM), the OAN-SPM DIMM used to made the measurements presented here, and the OAN-SPM 2.1-m telescope.

our seeing measurements were made almost simultaneous in the the E–W direction.

### Acknowledgments

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