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CLIMATOLOGICAL AND METEOROLOGICAL CHARACTERISTICS OF THE OBSERVATORIO ASTRONOMICO NACIONAL AT SAN PEDRO MARTIR, B. C.

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RESUMEN

Se presenta un reporte "preliminar" de la información climatológica y meteorológica de que disponemos actualmente en el Observatorio Astronómico Nacional de San Pedro Mártir, Baja California. Se hacen sugerencias del tipo de información necesaria para adquirir un mejor conocimiento de la región.

ABSTRACT

We give a "preliminary" report of the climatological and meteorological data at our disposal at the Observatorio Astronómico Nacional in San Pedro Mártir, Baja California. We suggest the kind of information necessary to get a better knowledge of the region.

Key words: METEOROLOGY — SITE TESTING.

I. INTRODUCTION

Through the analysis of meteorological satellite pictures, Mendoza *et al.* (1972) found that the northern part of Baja California is one of the three least cloudy regions in the world. The other two are: the west coast of Africa and a region north of Cerro Tololo in Chile. We also refer to the works of Clapp (1964, 1968), Kornfield and Hasler (1969), and Miller (1971) for other reports and cloud atlasses.

After several prospection trips to the northern part of the peninsula, to evaluate the physical conditions and the logistic problems associated with the development of the observatory (situated at a distance of about 3000 kms from México City), the first meteorological and astronomical observations were started in 1968. Some of the earlier results have been reported by Mendoza (1971, 1973). Our purpose is not to complement earlier works, but mainly to study and analyse the physical conditions that make San Pedro Mártir mountains one of the best sites on the earth for astronomical observations.

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II. CLIMATOLOGICAL CHARACTERISTICS OF SAN PEDRO MARTIR MOUNTAINS

The observatory situated at 31°N is located in the driest zone and within the region of maximum hours of sunshine in North America. According to the climate classification of Koppen as modified by García (1964), the area surrounding the sierra is a semiarid or steppe type and the influence of the altitude makes the climate of the chain of mountains milder. From García and Mosiño (1968), and our own measurements, we can give the following classification: Climate Cs(b')e, sub-humid with winter precipitation, semicold with annual mean temperature of 7.3°C and with mean range of temperature of 10.3°C. The coldest month (March) has an average temperature of −1.5°C, the hottest month (July), a mean temperature of 16.3°C and five months (May through September) with mean temperatures above 10°C.

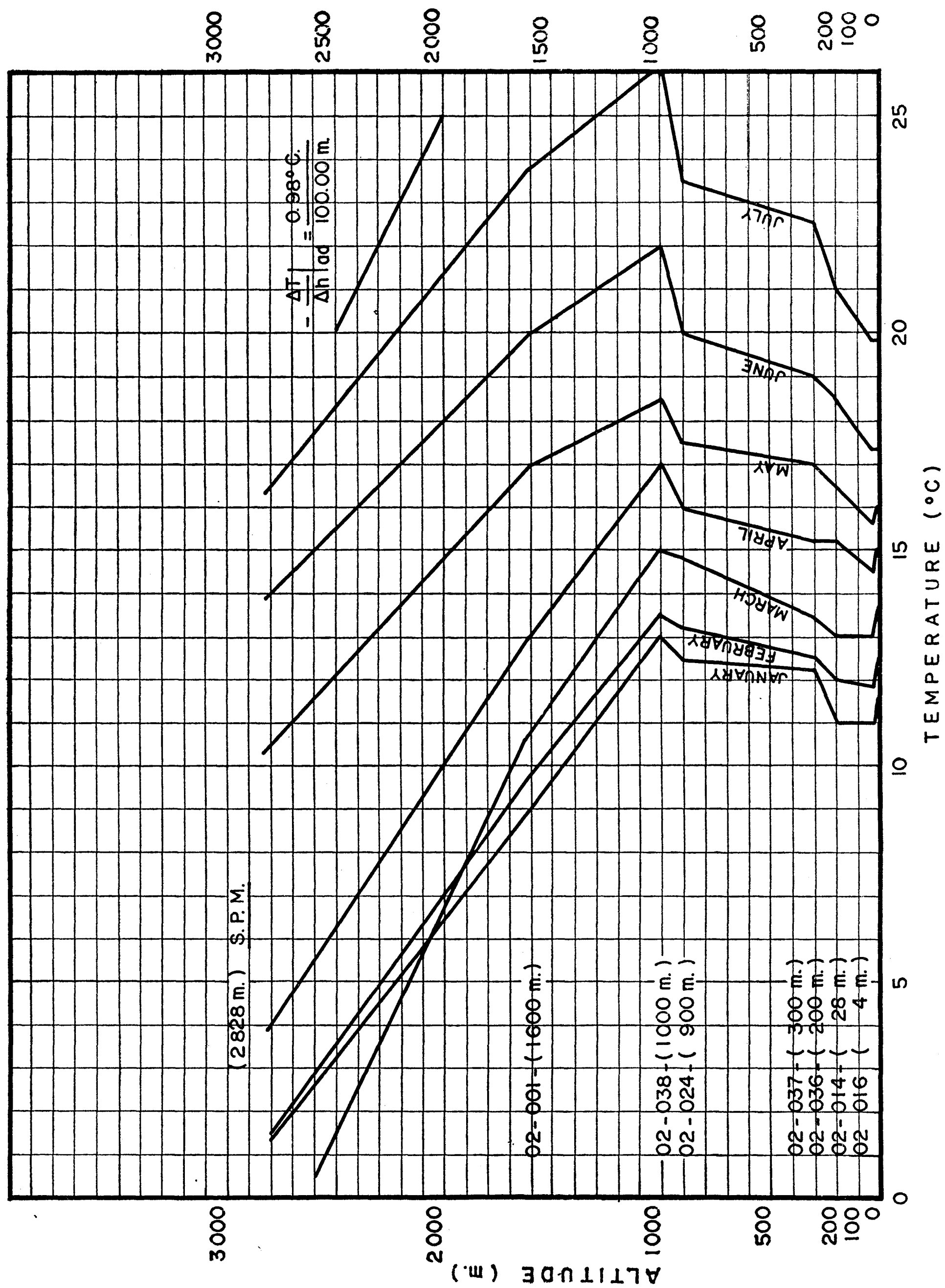

FIG. 1. Vertical gradient of monthly mean temperature at the climatological stations indicated in Table 1.

Figure 1 shows the mean temperature as function of altitude for several climatological stations including the observatory. All these stations are located within a circle of radius less than 100 kms around the observatory and this figure shows very clearly the presence of a well established inversion layer at around 1000 m altitude. Identification of the stations, together with some of its climatological characteristics are given in Table 1, taken from the charts elaborated by CETENAL (1974). The existence of this inversion layer adds to the stability and cleanliness of the higher layers of the atmosphere surrounding the sierra.

At 700 mb pressure level, there is a strong component of the wind coming from the west and southwest and this assures an homogeneous flow over the mountains.

III. METEOROLOGICAL CHARACTERISTICS OF THE NATIONAL ASTRONOMICAL OBSERVATORY

The above mentioned results show the global characteristics of the region, but it is necessary to do measurements "in situ" to determine the quality of the atmosphere over the place. There are basically two types of measurements to be done: meteorological and astronomical measurements. The first ones, besides the most common parameters like a) *temperature,* b) *relative humidity and* c) *atmospheric pressure* are: d) *cloudiness* including the fraction of overcast and type of clouds; e) amount of *precipitation,* and f) *direction and velocity of the wind* at several pressure levels. It is very important to consider the orographic effects and also the wind driven by temperature gradients common to the region. In all these measurements it will be necessary to determine the variations of daily and seasonal type.

The astronomical measurements are necessary in order to determine a) the *atmospheric absorption* due to the molecules (water vapor principally), dust and suspended particles; b) the *atmospheric scattering,* mainly if one is interested in observing the solar corona; c) the existing *inhomogeneities* of the atmosphere, both in medium and low layers that are strongly affected by the local effects mentioned above, and in higher layers that will be dominated by the global characteristics prevailing over the peninsula.

Since the beginning of the site testing campaign, several meteorological instruments have been working. Unfortunately the actual data only allows us to report preliminary conclusions. It will be necessary to have a longer and more complete series of data in order to obtain a better statistical description of the meteorological characteristics of the observatory.

a) *Temperature*

In Table 2, we give the monthly values of maximum and minimum temperatures for the period 1969-1974. For comparison we also give the values reported by Bücher (1973) for the Pic du Midi Observatory in France and the Izaña Observatory in the Canary Islands.

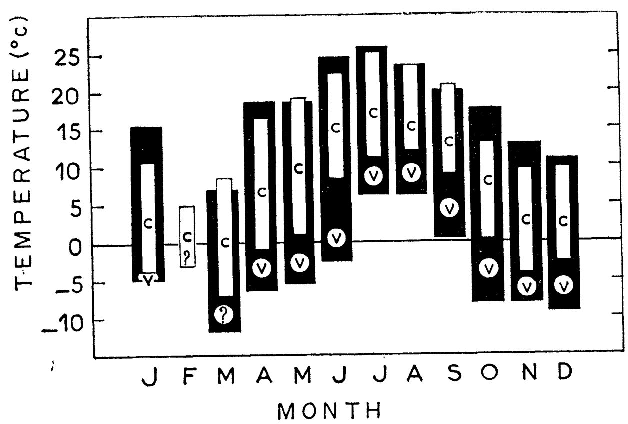

FIG. 2. Monthly mean of maximum and minimum temperatures for the year 1969, for two stations with an altitude difference of 400 m. between them. A comparison between the observed vertical temperature gradient and the adiabatic temperature gradient, shows that the atmosphere around the two stations is stable against convection most of the time.

In Figure 2, we give the mean values of maximum and minimum temperature obtained in 1969 and averaged every five days for two stations situated in the vicinity of the observatory and with an altitude difference of approximately 400 m. This figure demonstrates the existence of a local temperature inversion zone present at night and which ocassionally disappears during the first daytime hours. This effect assures us a cleaner and more stable atmosphere, over the site of the observatory. During daytime, heating may destroy this local inversion layer and may produce forced turbulence. This effect will soon be tested. Of course, the permanence of this phenomenon depends strongly on wind direction and speed, both at night and in the daytime.

TABLE 1

CLIMATOLOGICAL STATIONS AROUND THE OBSERVATORIO ASTRONOMICO NACIONAL *

Station Number	Station Name	Latitude (N)		Longitude (W)		Altitude (m)	Annual Mean Temperature (°C)	Annual Mean Precipitation (mm water)
				PACIFIC SLOPE				
02-016	Vicente Guerrero	30°	43'	116°	0'	4	15.7	142.4
02-014	Las Escobas	30	33	115	57	28	15.5	117.2
02-036	San Telmo	30	58	116	5	200	16.3	166.6
02-037	San Vicente	31	24	116	15	300	17.3	173.0
02-024	La Providencia	31	23	116	4	900	17.9	236.0
02-001	El Alamo	31	36	116	3	1600	15.6	242.6
———	San Pedro Mártir	31	2	115	28	2828	7.3	———
				GULF OF CALIFORNIA SLOPE				
02-032	San Felipe	31	2	114	51	20	24.7	57.7
02-038	Santa Catarina	31	34	115	41	1000	19.2	116.3

* Data from García (1974) and García *et al.* (1974).

TABLE 2

MEAN VALUES OF TEMPERATURE *

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Izaña	M	7.4	7.8	9.7	11.1	14.3	18.1	22.5	22.1	18.3	14.1	10.2	7.8	13.6
2367 m														
(1945-1972)	m	0.7	0.6	1.7	2.6	5.2	8.8	13.2	12.9	9.7	6.6	3.5	1.4	5.6
San Pedro Mártir	M	5.0	6.1	4.8	10.3	17.2	22.1	22.1	19.6	18.2	12.8	8.0	7.5	16.3
2882 m	⟨T⟩	1.4	1.5	—1.5	3.9	10.6	13.9	16.3	14.5	13.4	7.9	3.1	2.3	7.3
(1969-1974)	m	—1.6	—2.4	—6.6	—2.3	3.3	6.8	12.2	11.3	8.8	4.0	—0.9	—2.0	—1.5
Pic du Midi	M	—4.3	—4.6	—2.7	—1.2	2.6	6.7	10.4	9.6	7.2	3.4	—1.2	—4.0	1.8
2860 m														
(1945-1972)	m	—9.7	—10.2	—8.5	—7.0	—3.3	0.8	3.9	3.6	1.7	—1.8	—6.4	—9.1	—3.8

* M Maximum Temperature
m Minimum Temperature
⟨T⟩ Mean Temperature

b) *Insolation*

Figure 3 shows a histogram of monthly values of 10 minute periods of clear line of sight (CLOS) between the observer and the sun. The period of observation covers from August 1968 to June 1970. We compare this with similar results at Cerro Tololo, Chile and Mt. Hopkins, Arizona (data from September 1967 to November 1971). Figure 4 also shows the results for two-hour periods of CLOS at sunrise, around noon and before sunset (Meldrud 1974). Cerro Tololo is undoubtedly a privileged place for doing solar observations, although the strong thermal up-draft winds may cause a severe deterioration of the solar image. The other stations show a similar behavior both for short periods (10 minutes) and for long periods (2 hours) of CLOS.

The maximum number of sunshine hours at San Pedro Mártir occurs during morning hours, sometimes extending well into the first afternoon hours. Summer and early autumn are characterized by afternoon showers. Usually clouds disappear before sunset.

TABLE 3

TIME PERCENTAGE FOR WHICH THE SKY BRIGHNESS IS LESS THAN B *

Month	Year	San Pedro Mártir Number of days observed	B < 10 +	B < 50 (%)
May	1973	9	...	14.7
Jun		5	...	2.8
Jul		17	...	29.3
Aug		9	...	28.6
Sep		18	13.6	51.1
Oct		22	11.4	42.6
Nov		7	32.9	59.2
Dec		6	23.1	34.2
Jan	1974	11	36.2	48.0
Feb		5	20.6	41.8
Mar		9	0.0	17.2
Apr		18	5.9	47.3
May		16	4.9	24.6
Jun		14	1.9	14.0
Jul		5	2.0	27.2
Aug		14	6.7	28.2
Sep		9	4.0	30.0
Oct		12	20.6	49.1
Nov		13	19.1	64.3
Dec		6	0.0	44.2

AVERAGES

San Pedro Mártir	1973-1974	12.7	34.9
Climax, Colorado ‡	1970-1971	...	13.8
Grand Mesa, Colorado ‡	1970-1971	...	10.9

* Millionths of the brightness at the center of the sun (normalized to the length of the day)

\+ Time percentage of "coronal sky"

‡ Baur and Curtis (1971)

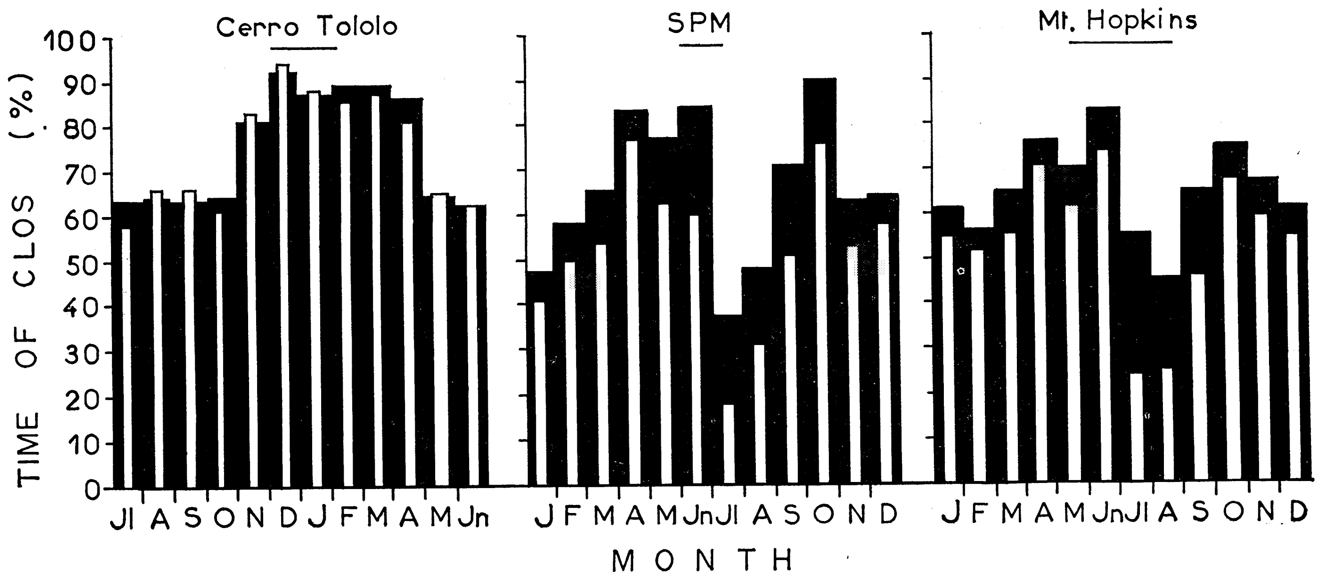

FIG. 3. Insolation time (percentage). 10 minute time periods of clear line of sight (CLOS) between the observer and the sun for three stations as indicated. Cerro Tololo, Chile (Nov. 1967 to Nov. 1971); Mt. Hopkins, Arizona (Sept. 1967 to Nov. 1971); San Pedro Mártir, Baja California (Aug. 1968 to June 1970). Black is used for the morning, white for the afternoon.

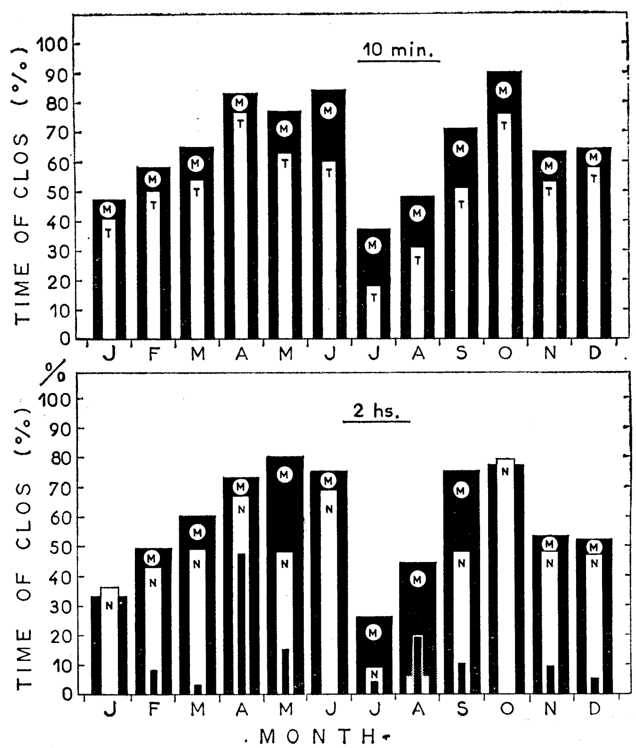

FIG. 4. Insolation time (percentage) for San Pedro Mártir. a) 10 minute periods of CLOS. Black for morning hours, white for the afternoon. b) Two hour periods ofcontinuous CLOS. M = two hour periods after sunrise. N = Two hour periods around noon. T = two hour periodsbefore sunset.

c) *Sky Brightness*

In Table 3 we show the values obtained during 1973 and 1974 with a sky brightness photometer developed and installed by HAO of Boulder, Colorado, in a cooperative project. We compare these values with those reported by Baur and Curtis (1971) for two other stations. These measurements give us an indication of the conditions of San Pedro Mártir for doing solar coronal observations. In the column indicated by (+), we have the monthly time percentage of "Coronal Sky" in which we expect to be able to observe the solar corona. The number of days observed each month is also given in the table. Most of the months are well represented except probably June and December 1973 and February, July and December, 1974. This report gives and indication that autumn and winter seem to be adequate for doing solar corona observations.

TABLE 4

TIME PERCENTAGE FOR WHICH THE IR SKY NOISE (10μ) IS SMALLER THAN ($R \times 10^{-7}$ WATTS CM^{-2} $STERAD^{-1}$)

Month	Year	$R < 1$	$1 < R < 5$	$5 < R$	$R < 1$	$1 < R < 5$	$5 < R$	$R < 1$	$1 < R < 5$	$5 < R$
	1971	Between	4:00 and	12:00	Between	12:00 and	20:00	Between	20:00 and	4:00
Sep		0%	31%	69%	7%	16%	77%	5%	51%	45%
Oct		25	20	55	12	41	47	19	19	62
Nov		5	10	85	16	3	81	21	18	61
Dic		2	1	97	8	2	90	6	2	92
	1972									
Jan		12	7	81	9	9	83	6	7	87
Feb		49	17	34	27	45	28	43	13	44
Mar		9	4	87	6	5	89	11	2	87
Apr		22	12	66	12	19	69	38	6	56
May		38	30	32	10	35	55	48	16	35
Jun		13	44	43	4	37	59	25	53	23
Average		18	18	65	11	21	68	22	19	59

TABLE 5

AMOUNT OF PRECIPITABLE WATER

Station	Period	Number of Observ.	Mean (mm of Water)
White Mountain	Jul 71-Jun 72	104/154	1.6
San Pedro Mártir	Sep 71-Jun 72	178/245	3.3
Tenerife	May 70-Jun 71	426/801	3.5

d) *Infrared absorption and precipitable water vapor*

During 1971 and 1972 Westphal (1974) conducted and IR sky noise survey in the 10μ band. He investigated simultaneously the following places: Palomar Mountain in California; Kitt Peak and Mt. Lemmon in Arizona; McDonald Observatory in Texas; Mauna Kea in Hawaii; Cerro Tololo in Chile, and San Pedro Mártir in Baja California, México. Figure 5 shows some of the results obtained from this comparative study. In Table 4 we give the percentage of time for which the sky noise in San Pedro Mártir is smaller than the indicated values.

Figura 6 shows a histogram of the amount of precipitable water vapor for San Pedro Mártir as compared with White Mountain in California and with the Izaña Observatory in the Canary Islands.

For this experiment, the ratio of the atmospheric transmission in the regions at 1.65μ and 1.87μ using the sun as an extraterrestrial source and normalizing for the air mass, was computed. For the Izaña Observatory in Tenerife, we refer to the experiment reported by Sánchez Magro *et al.* (1971).

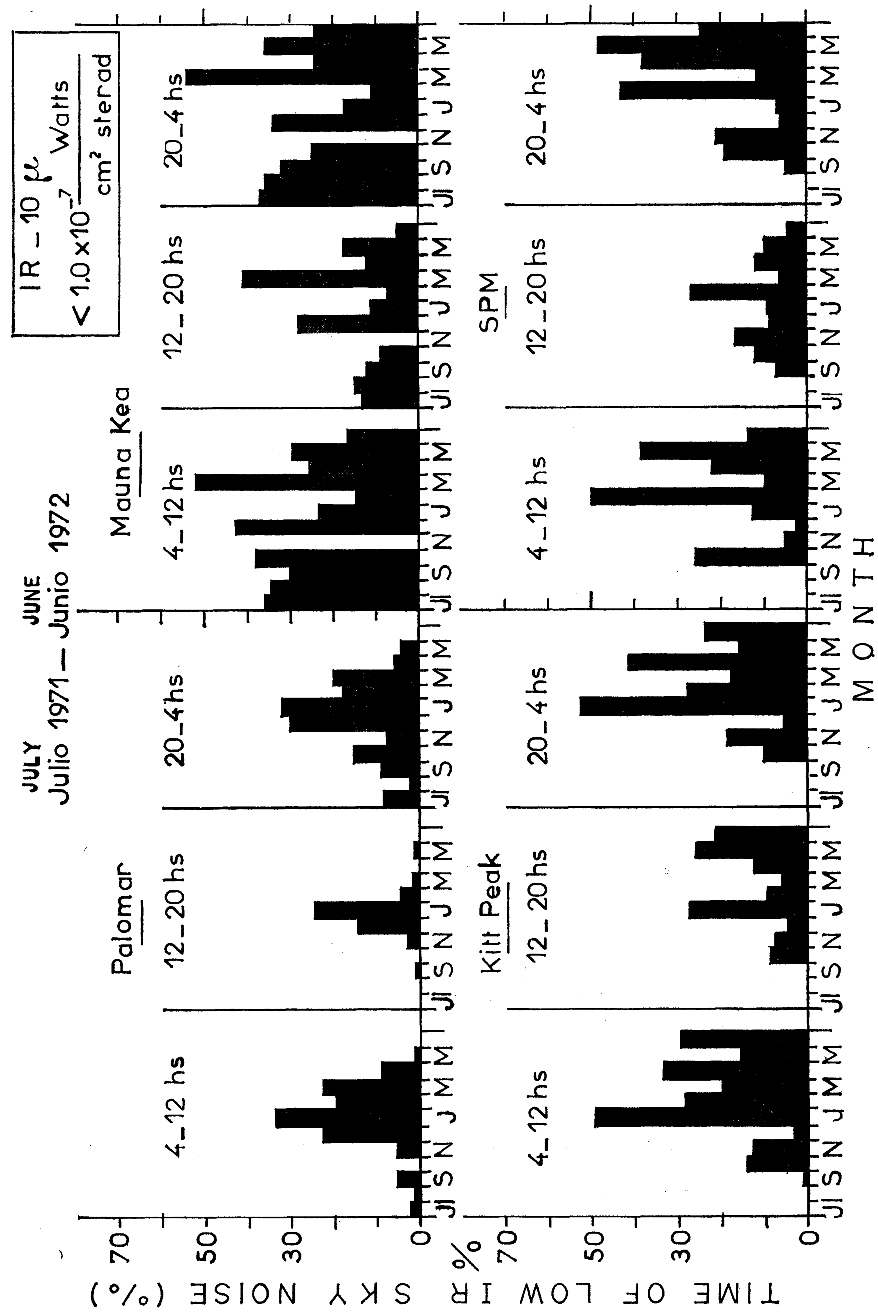

FIG. 5. Time percentage for which the IR Sky Noise (10μ) is smaller than 1.0×10^{-7} watts cm^{-2} $sterad^{-1}$. 8 hour periods as indicated (July 1971 to June 1972). See also table 4.

TABLE 6

SUMMARY OF RESULTS

POSITION OF THE TELESCOPE *

31° 02′ 38″ N

115° 27′ 47″ W

CLOUDLESS NIGHTS (Annual Percentage) +

Photometric Nights 63%

Spectroscopic Nights 91%

ATMOSPHERIC TURBULENCE DURING THE NIGHT +

Quality of the image		
	$Q > 1''.5$	15%
	$Q < 1''.5$	85%
	$Q < 1''.0$	30%

AVERAGE CHARACTERISTICS

	Period of Measurement	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar
		INSOLATION ‡			
	Aug 68-Jun 70	72%	43%	68%	53%
		PRECIPITABLE WATER VAPOR (Time Percentage) §			
$H_2O > 3$ mm		44%	89%	27%	23%
$H_2O < 3$ mm	Sep 71-Jun 72	56%	11%	73%	77%
$H_2O < 2$ mm		20%	....	33%	19%
		RELATIVE HUMIDITY ‖			
Night		40%	55%	49%	52%
	May 68-Jun 69				
Day		42%	56%	38%	54%
		WIND VELOCITY ‖			
Night	May 68-Jun 69	5m/s	3m/s	5m/s	8m/s
Day		3m/s	2m/s	3m/s	7m/s

* From CETENAL (1974)

\+ Mendoza (1971)

‡ Meldrud (1974)

§ Westphal (1974)

‖ This paper

Finally in Table 6, we summarize the results obtained from other measurements. As reported by Mendoza (1971) about 30% of the night-time observations are expected to have an image quality better than 1.0 second of arc. We have to consider that this value was obtained with a small size telescope and it gives only an "indication" of the quality of the image that may be expected on large instruments. It is expected to have about 230 cloudless nights per year and of the order of 330 spectroscopic nights. More than 50% of the daytime is cloudless. The precipitable water vapor content is low; autumn is apparently the driest season. Wind speed is relatively strong as expected for the altitude of the observatory.

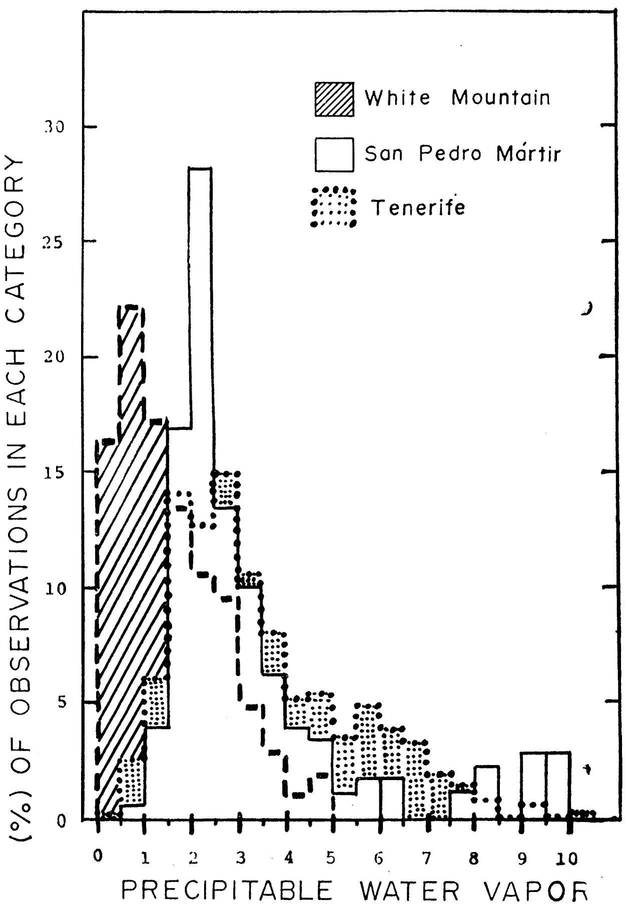

Fig. 6. Histogram of the precipitable water vapor in San Pedro Mártir, Baja California, as compared to other stations. Details of observations are given in Table 5.

Although we want to emphasize the preliminary nature of the results obtained from this analysis, we can be confident of the future of the observatory. Several years of astronomical observations have already confirmed the good quality of the site. The acquisition of data has been possible thanks to the work and effort of a great variety of persons: technicians and astronomers that have worked at the Observatorio Astronómico Nacional for several years and in different epochs.

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