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HIGH ALTITUDE WIND VELOCITY AT SAN PEDRO MÁRTIR AND MAUNA KEA

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RESUMEN

Analizamos el promedio mensual de la velocidad del viento a una altitud aproximada de 12 km sobre el nivel del mar, en el periodo comprendido entre 1980 y 1995 en San Pedro Mártir, Mauna Kea y en otros observatorios y sitios de interés. Comparamos los resultados obtenidos de dos bases de datos, GGUAS y NCEP. Los resultados muestran que San Pedro Mártir y Mauna Kea son comparables y se encuentran entre los lugares mas adecuados para aplicar técnicas que compensan las deformaciones del frente de onda que cambian lentamente.

ABSTRACT

We analyze the monthly average wind velocity at about 12 km above sea level between 1980 to 1995 for San Pedro Mártir, Mauna Kea and other existing observatories and sites of interest. We compare the results obtained from two different data sets, the GGUAS and NCEP. Our results show that San Pedro Mártir and Mauna Kea are comparable and are amongst the most suitable sites to apply slow wavefront corrugation correction techniques.

Key Words: **ATMOSPHERIC EFFECTS — SITE TESTING**

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One of the most important parameters of the potential sites for extremely large telescopes projects, is their suitability for adaptive optics. Sarazin & Tokovinin (2002) have shown that such a suitability is related to the low velocity of upper atmospheric motion, at about 12 km above sea level. Here, we analyse the wind velocity monthly variation over a period of 16 years for San Pedro Mártir (SPM), Mauna Kea and some main observatory sites.

The National Oceanic and Atmospheric Administration (NOAA) in the USA runs several climatological projects. Within the NOAA, the National Climatic Data Center (NCDC) is in charge of managing the resource of global climatological in-situ and remotely sensed data and information. Weather data from the atmosphere are obtained from instrument packages such as radiosondes and rawinsondes carried by weather balloons that transmit the data back to a receiving station on the ground. The upper air data consists of temperature, relative humidity, atmospheric pressure, and wind.

In a similar way the NOAA Climate Diagnostics Center (CDC) goal is to identify the nature and causes for climate variations on time scales ranging from a month to centuries. The CDC NCEP/NCAR (National Center for Environmental Prediction/National Center for Atmospheric Research) Global Reanalysis Project is using state-of-the-art analysis and forecast systems to perform data assimilation using past data from 1948 to the present. The NCEP's role is to use a current and fixed (Jan. 1995) version of a data assimilation and operational forecast model. The task of NCAR is to collect and organize many of the land and marine surface data archives, to provide these to NCEP along with many observed upper and aircraft observations, receive and store the output archives.

The Global Gridded Upper Air Statistics (GGUAS) 1980-1995 Version 1.1 is distributed by the NCDC. The source of the GGUAS data set was the European Centre for Medium-Range Weather Forecasts (ECMWF) 0000Z and 1200Z gridded analyses. The GGUAS data set describes the atmosphere for each month of the year represented on a 2.5 degree global grid at 15 standard pressure levels. We use the monthly average and rms scalar wind velocity at 200 mb (about 12 km above sea level) at the grid point closest to the sites on the basis of two

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TABLE 1

SITES COORDINATES

	Costa Rica		SPM		Mauna Kea		Paranal	
	Closest	real	Closest	real	Closest	real	Closest	real
Latitude	+10.0	+10.0	+30.00	31.04	+20.00	+19.83	−25.00	−24.63
Longitude	−85.0	−85.0	−115.00	−115.46	−155.00	−155.47	−70.00	−70.40
	La Silla		La Palma		Gamsberg		Maidanak	
	Closest	real	Closest	real	Closest	real	Closest	real
Latitute	−30.00	−29.25	+30.00	+28.76	−22.50	−23.34	+40.00	+38.68
Longitude	−70.00	−70.73	−17.50	−17.88	+15.00	+16.23	+65.00	+66.90

TABLE 2

WIND VELOCITY (M S^{-1}) AT 200 MB OBTAINED FROM THE NOAA GGUAS DATA BASE

M	Costa Rica		SPM		Mauna Kea		Paranal		La Silla		La Palma		Gamsberg		Maidanak	
	Ave	rms	Ave	rms	Ave	rms	Ave	rms	Ave	rms	Ave	rms	Ave	rms	Ave	rms
1	14.2	7.1	33.7	14.7	30.6	11.8	19.5	7.7	27.2	10.0	20.9	10.2	13.6	6.7	28.6	10.2
2	14.1	6.9	37.1	14.7	34.3	11.9	19.3	8.3	24.6	10.4	24.0	10.9	12.2	6.5	27.9	12.5
3	12.5	6.8	39.5	15.6	34.6	13.5	22.0	8.7	26.4	11.3	25.7	13.8	18.5	8.4	27.2	10.6
4	10.8	5.9	31.2	14.6	33.5	14.6	29.7	10.7	31.7	12.8	29.2	13.4	28.7	12.5	24.9	10.0
5	7.8	4.3	27.6	13.7	27.7	13.5	35.5	14.5	36.2	14.3	27.9	12.7	30.2	12.0	26.5	10.6
6	8.1	4.4	21.6	11.0	21.4	11.2	35.6	14.6	36.0	14.1	22.9	10.3	33.0	12.4	30.8	12.3
7	7.6	4.0	11.3	6.9	18.7	8.6	37.4	14.8	37.7	15.6	16.2	8.6	32.1	11.8	27.3	9.7
8	8.1	4.2	12.1	6.4	16.8	7.9	36.2	12.6	38.1	14.4	15.7	8.1	29.9	11.8	28.9	10.4
9	7.6	4.0	19.7	10.2	19.1	8.0	36.6	13.8	36.3	13.8	18.2	9.1	25.6	10.7	30.2	11.0
10	7.8	4.2	27.4	12.0	21.1	9.2	35.8	11.3	39.2	13.1	19.5	10.6	26.6	10.4	25.0	11.9
11	8.3	4.4	30.4	13.8	20.8	10.7	30.9	10.0	34.0	12.8	23.9	11.0	24.0	9.4	28.2	11.1
12	12.2	5.7	32.9	14.0	26.5	11.4	24.5	9.9	27.6	11.7	21.3	11.4	20.9	9.5	27.3	11.3
Ave	**9.9**	5.3	**27.0**	12.6	**25.4**	11.2	**30.3**	11.7	**32.9**	12.9	**22.1**	10.9	**24.6**	10.4	**27.7**	11.0

records per day.

TABLE 4

WIND VELOCITY ANNUAL AVERAGE

Site	GGUAS (m/s)	NCEP (m/s)
SPM	**27.0** ±3.6	**26.5** ±1.7
Mauna Kea	**25.4** ±3.2	**24.3** ±1.3
Paranal	**30.3** ±3.4	**29.3** ±1.4
La Silla	**32.9** ±3.7	**32.4** ±1.5
La Palma	**22.1** ±3.1	**21.4** ±1.3
Gamsberg	**24.6** ±3.0	**23.3** ±1.0
Maidanak	**27.7** ±3.2	**29.1** ±1.5

The CDC Derived NCEP Reanalysis Products include over 80 different variables and several different coordinates systems at 0Z, 6Z, 12Z, and 18Z forecasted values. In particular, the Derived NCEP Pressure Level product provides, the monthly wind speed on a 2.5 degree global grid at 17 pressure levels. We are using the monthly wind velocity at 200 mb on the basis of four records per day between 1980 and 1995 to compare with the GGUAS data for the same period.

The coordinates of the sites included in this analysis are shown in Table 1. Two sets of coordinates are given for each site. The first ones are the actual coordinates used as input to the data basis that correspond to the grid points closest to the geographical coordinates, the latter ones are given as a reference. Costa Rica is included as a tropical place where there is not jet stream.

Table 2 shows the results obtained from the GGUAS data base for the sites given in Table 1. The appearance in some sites of large discrepancies between the NOAA NCEP results and previously

TABLE 3

WIND VELOCITY (M S^{-1}) AT 200 MB OBTAINED FROM THE NOAA NCEP DATA BASE

M	Costa Rica		SPM		Mauna Kea		Paranal		La Silla		La Palma		Gamsberg		Maidanak	
	Ave	rms	Ave	rms	Ave	rms	Ave	rms	Ave	rms	Ave	rms	Ave	rms	Ave	rms
1	13.9	3.1	32.2	4.8	29.9	4.9	18.5	2.8	27.2	4.3	20.3	4.0	12.4	2.8	33.2	5.9
2	13.2	2.7	35.8	7.1	32.9	4.4	18.2	3.5	24.1	4.1	24.1	4.4	10.2	2.9	33.1	7.4
3	12.0	3.5	38.4	9.0	33.5	5.4	20.6	3.5	25.9	4.7	25.9	6.2	17.5	3.5	31.1	4.3
4	9.4	2.9	30.2	8.3	32.0	5.9	28.3	3.2	30.6	4.8	29.0	4.8	27.3	4.6	26.5	4.6
5	7.1	1.3	28.7	7.1	25.0	5.7	33.9	5.3	35.6	5.2	27.4	5.4	29.3	2.9	29.3	5.3
6	8.7	2.1	20.9	4.6	20.7	5.3	36.5	6.2	35.1	5.7	21.4	4.2	31.7	4.3	31.5	4.4
7	8.4	2.0	10.5	3.2	18.2	3.3	36.7	6.3	36.9	5.6	15.7	3.9	31.5	4.6	22.2	5.4
8	9.9	2.3	11.9	2.5	15.8	2.2	35.6	5.6	37.4	7.0	14.9	2.5	28.8	4.4	23.6	6.5
9	8.9	1.7	19.7	4.6	18.1	3.3	35.9	7.2	34.8	4.7	17.1	2.7	24.6	2.9	29.4	4.8
10	9.1	1.8	26.8	4.4	19.5	3.3	34.9	3.2	38.2	4.1	18.81	3.8	25.0	2.8	27.4	5.0
11	8.4	2.4	30.4	5.4	20.6	4.6	29.2	3.5	34.0	6.3	21.8	4.2	22.2	3.7	31.0	4.2
12	12.0	2.7	32.1	6.3	25.4	4.8	23.5	3.4	34.0	6.3	20.2	5.3	18.9	2.8	31.3	5.1
Ave	**10.1**	2.4	**26.5**	5.9	**24.3**	4.5	**29.3**	4.7	**32.4**	5.2	**21.4**	4.4	**23.3**	3.6	**29.1**	5.3

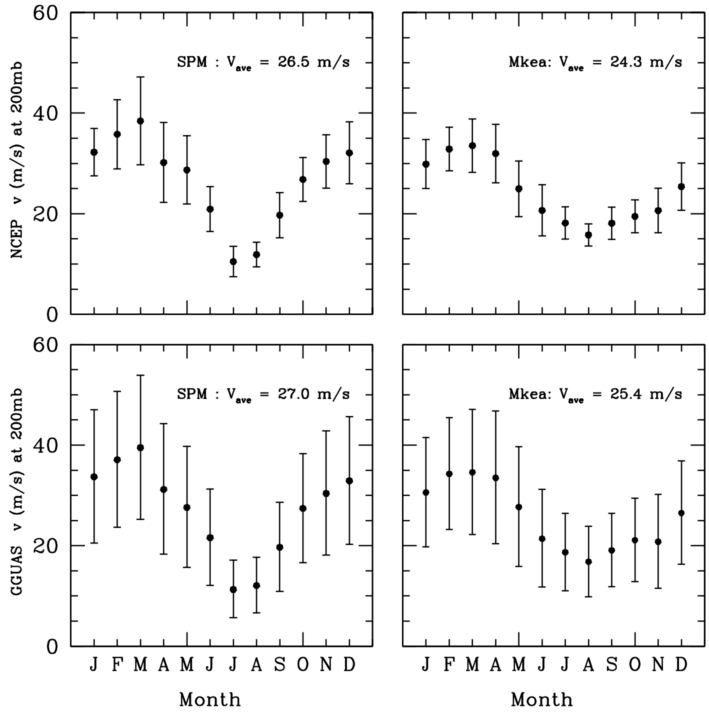

Fig. 1. Monthly average wind speed at 200 mb for SPM and Mauna Kea. The NCEP reanalysis data for both sites are shown in the upper panels. The corresponding GGUAS data are shown in the lower panels. The error bars were calculated assuming a wind log normal distribution as it is explained in the text. For SPM the results obtained from the GGUAS and the NCEP data basis, show the same seasonal trend. Similarly the results for Mauna Kea have the same seasonal trend in the GGUAS and the NCEP data sets. However, the instantaneous wind velocity fluctuations represented by the error bars are less than half for the NCEP than for the GGUAS data. It must be noticed that in July and August the monthly average wind speed is lower in SPM than in Hawaii.

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published data based on GGUAS statistics (Sarazin, 2000; Sarazin, 2002) led to a revision of the latter and the discovery of a bug in the query script. The GGUAS statistics presented here thus supersede all previously published data.

The corresponding wind velocities obtained from the NCEP re-analysis are shown in Table 3. The first column indicates the month number. For each site two values are reported. First, the wind velocity obtained by averaging the monthly values over the 16 years period. Second, the instantaneous rms fluctuations around the average. For the whole period, the annual average and the quadratic average of the monthly rms values are included. The latter represents a typical fluctuation of the wind speed velocity. It must be noticed that the rms fluctuations are larger for the GGUAS data than for the NCEP reanalysis data by a factor larger than 2.

Table 4 shows a summary of the wind velocity yearly average obtained with the GGUAS and the NCEP data sets. Here we include the error in the annual average determination, given by the annual rms fluctuations divided by $\sqrt{N}$ where N is equal to 12.

Figure 1 is a plot of the monthly average wind speed at 200 mb for SPM (left) and Mauna Kea (right). In the upper panels the NCEP reanalysis data are shown for both sites with the corresponding GGUAS data in the lower panels. The error bars were calculated assuming a wind log normal distribution:

$$p(v)dv = \frac{1}{b\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\left(\frac{\ln v - a}{b}\right)^2\right\} \frac{dv}{v} \quad . \quad (1)$$

The mean wind speed is here equal to $\bar{v} = e^{a+b^2}$ and asymmetrical error bars can be constructed from the positions of the $\pm 1\sigma$ probability points, $\bar{v} - \sigma_- = e^{a-b}$ and $\bar{v} + \sigma_- = e^{a+b}$ (where the cumulative probabilities are p=0.843 and p=0.1587).

The monthly average wind velocity obtained with the GGUAS and NCEP reanalysis data sets show the same seasonal trend for SPM and Mauna Kea. Nevertheless, the instantaneous fluctuations are larger, more than a factor of two, for the GGUAS than for the NCEP data. In fact, the results in Table 4 show that with the GGUAS data, the yearly average wind velocities obtained for all the sites are comparable within 3σ. If we consider the results from the NCEP reanalysis for the sites with the extreme values, La Silla and La Palma, the difference in the annual wind velocity is larger that 5.5σ. Therefore, to compare sites is more accurate to use the results obtained from the NCEP reanalysis data set.

The wind velocity annual average for SPM is 1.2σ, 1.6σ, 2.6σ below Maidanak, Paranal and La Silla respectively. On the other hand, SPM is 1σ, 1.2σ, 2.1σ above Mauna Kea, Gamsberg and La Palma respectively. For Mauna Kea, the annual average wind velocity is 2.4σ, 2.6σ, 4.1σ below Maidanak, Paranal and La Silla respectively. In contrast, Mauna Kea is 1.6σ, 1.8σ above Gamsberg and La Palma respectively, giving a statistically tangible site ranking. Nevertheless, a deeper and fairer comparison would require a monthly based data analysis. For instance, the monthly average wind speed at SPM in July and August is lower than at Mauna Kea and La Palma.

We have analysed the seasonal variations of the monthly average wind velocity over a 16 year period for some of the main observatory sites in the world by using data from GGUAS and the NCEP reanalysis data sets. We conclude that the data obtained from the NCEP reanalysis are more accurate for the determination of the monthly average wind velocity at 200 mb. Using these data we have shown that SPM and Mauna Kea are amongst the best observatory sites suitable for Adaptive Optics techniques.

NCEP Reanalysis data provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, USA, from their Web site at `http://www.cdc.noaa.gov/`.

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