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 período comprendido entre 1980 y 1995 en San Pedro Mártir, Mauna Kea, en otros observatorios y en algunos 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 más 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, another existing observatories and some 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: SITE-TESTING, ATMOSPHERIC EFFECTS

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 the state-of-the-art analysis and forecast system 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 records per day.

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 lev-
els. 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 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.

In table 3 the corresponding wind velocities obtained from the NCEP reanalysis are shown. The results obtained from the NCEP reanalysis are more accurate for the sites with the extremes 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/](http://www.cdc.noaa.gov/)

REFERENCES

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

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 ±1σ probability points, \( \bar{v} - \sigma_+ = e^{a-b} \) and \( \bar{v} + \sigma_+ = e^{a+b} \).
### TABLE 1

| Sites          | Coordinates          | Costa Rica | SPM | Mauna Kea | Paranal | La Silla | La Palma | Gamsberg | Maidanak |
|----------------|-----------------------|------------|-----|-----------|---------|----------|----------|----------|----------|
| Closest        | Latitud (°N)          | +10.0      | +10.0          | +30.00  | 31.04   | +20.00   | +19.83   | −25.00   | −24.63   |
| Closest        | Longitude (°W)        | −85.0      | −85.0          | −115.00 | −115.46 | −155.00  | −155.47  | −70.00   | −70.40   |

### TABLE 2

| M  | Costa Rica Ave | Costa Rica rms | SPM Ave | SPM rms | Mauna Kea Ave | Mauna Kea rms | Paranal Ave | Paranal rms | La Silla Ave | La Silla rms | La Palma Ave | La Palma rms | Gamsberg Ave | Gamsberg rms | Maidanak Ave | Maidanak 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         |
### TABLE 3
WIND VELOCITY (M/S) 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      |
| 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      | 18.8     | 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 |

### 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**|
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.