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Site-testing results at the Teide Observatory

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Abstract.

There are very few sites in the world that combime both climatological and image quality required conditions for the astronomical observations, such as the heights of Tenerife and La Palma islands, which have therefore attracted the construction of new-generation large telescopes, such as the 10m Gran Telescopio de Canarias (GTC).

To operate technologically and scientifically the Canarian sky, Spain has established the Instituto de Astrofísica de Canarias (IAC). The Observatories of the IAC have become internazionalized through a Agreement on Co-operation in Astrophysics (1979). So far more than thirty scientific institutions from fourteen countries have installed their telescopes and astronomical instrumentation at the Roque de los Muchachos Observatory (ORM, La Palma) and at the Teide Observatory (OT, Tenerife).

The excellent conditions of the IAC's Observatories are protected by a world's first national Law of the Sky, preserving this natural resource from contaminating effects (mainly outdoor lighting).

Comparative statistical results for a long-period database of the Teide Observatory with those obtained at The Roque de los Muchachos Observatory are presented and allow us to confirm the OT as one of the best observatories in the world, with typically sub-arcsecond mean and median seeing values and favourable meteorological conditions.

1. Introduction

Over the last century, several scientific expeditions have corroborated the excellence of the mountain summits of the Canarian Archipelago for astronomical observing, both climatologically and in terms of image quality.

To confirm these results was the main motivation for a collaboration started in 1990 between the Instituto de Astrofísica de Canarias (IAC) and the Department of Astrophysics (DA) of the University of Nice to design and build a differential image motion monitor (DIMM) for measuring the seeing (see scheme, instrumentation annexe and detailed description in Vernin & Muñoz-Tuñón 1995).

This instrument has already been calibrated at Cerro Paranal (Chile) using two other monitors belonging to the European Southern Observatory (ESO).

The first long-range forecast astronomical seeing monitoring at the Canarian observatories was performed at the Teide Observatory (OT) with this instrument. The seeing monitor was installed at ground level near the telescope building, and although local heating disturbances might have affected the measurements compared to the results with the large database we have obtained at the Observatorio del Roque de los Muchachos (ORM), we nevertheless feel that their presentation in this paper is justified.

The statistical behavior of the seeing contributions at Izaña reveal an excellent site, with average values ranging from 0.7 to 1.3 arcseconds.

2. Description of site-testing campaign

Our aim here is to report a representative characterization of the site, by using extensive measurements, analyzing both the climatological and the image quality behavior associated with different sites within the Observatory using meteorological and seeing measurements taken during at least one full year (where possible) in order to study any seasonal dependences, and during full nights in order to characterize the timescale of the variations seeing and their dependence on climatology.

From 1992 November to 1994 May a campaign was undertaken at the Teide Observatory (OT) (Izaña, Tenerife) to probe and test the DA/IAC DIMM. After these tests, the DIMM was transferred to the Roque de los Muchachos Observatory (ORM) on the neighboring island of La Palma to perform a site-testing campaign near the Telescopio Nazionale Galileo (TNG) site. Comparable site-testing campaigns were carried out at the Williams Herschel Telescope (WHT) and as a run-up to preselect two candidate sites for the 10 m Gran Telescopio Canarias (GTC) (Muñoz-Tuñón et al. 1997a).

Although the OT site campaign was performed with the DIMM situated at ground level, with the attendant influence of the surface layer turbulence contribution, the excellent seeing values obtained and reported in this paper are fully comparable with those obtained on La Palma.

Figure 1 shows a contour map of the island of Tenerife from McInnes and Walker (1974) in which the Observatorio del Teide (OT) is located and Figure 2 shows the various sites where the DA/IAC DIMM was installed at the OT. Z0 corresponds to the dome of 1.5 m Carlos Sánchez Telescope (CST), Z1 is the paved entrance to the CST, Z2 depicts an area approximately 20 m SE of the CST, and Z3 is located due south of the CST (near the IAC-80 cm Telescope).

3. Statistical seeing and climatology results

The useful observing time during the full campaign at the Teide Observatory is consistent with those of Muñoz-Tuñón et al. in 1997b, reaching a 78% useful hours in summer. The DIMM was installed on ground level, then the useful observing time during the winter periods are particularly reduced due to the appearence of frosts. These weather conditions together with the extreme meteorological DIMM operating conditions (when compared with meteorological restrictions allowed on larger telescopes) lead to an underestimated 49% in winter.

The main losses time during the global campaign are associated with natural causes: relative humidity higher than 70% (accounting for 36% of the time lost), greater than 30% cloud cover (36%), winds greater than 15 m s^{-1} (12%). The remaining time lost is associated with the phase of the moon (bright time) and with technical problems and instrument failure (drivers, wiring, computers, mounting and unmounting the DIMM, etc.).

The seeing statistics obtained at the CST (Z0 + Z1 in the map) give mean and median seeing values of order 0.76″ and 0.70″, respectively, as shown in Figure 3, and minimum values reaching 0.2″. Moreover, the mean seeing values closest to the CST (Z2 on the map) and in Z3 are of order 1″ and 1.2″, respectively. The results for the IAC-80 site appear on their face value to be worse than those of CST site; however, it should be borne in mind that the readings were not taken simultaneously and neither do they cover the same time interval. In order to arrive at any firm conclusion regarding the seeing at the two sites, a campaign of simultaneous seeing measurements would be needed.

As expected, during the winter months the number of photometric nights is lower (Guerrero et al. 1998); nevertheless, in the winter of 1992/93 their quality was slightly superior to that obtained during summer 1993. In the summer months seeing dispersion values are smaller and typical mean and median subarcsecond values are obtained. Minima under 0.5″ are usually found, and values greater than 2″ usually occur in isolation.

In Table 1 we summarize the cumulative frequency corresponding to different seeing values classified into three categories: bad seeing corresponds to seeing greater than 2″, good seeing as better than 1″, and finally excellent seeing as smaller than 0.5″.

Table 1. Number of measurements (*Ndata*) and cumulative frequency of seeing at the sites tested Z1: from November 1992 to January 1993; Z2: from February 1993 to May 1993; Z3: from May 1993 to July 1993 and from December 1993 to May 1994.

	Z1	Z2	Z3
Ndata	2228	4556	27611
excellent seeing (< 0.5")	16%	4%	0.3%
good seeing (< 1.0")	85%	57%	43%
bad seeing (> 2.0")	1%	2%	7%

All these values (except those corresponding inside the dome measurements) were measured from the ground are therefore affected by the surface layer turbulence contribution (of order 0.08″; Vernin & Muñoz-Tuñón 1992).

Table 2 shows the total statistical results of the seeing data gathered during different campaigns at several sites at the ORM versus the OT results (at the CST).

Taking into account the SL contribution in the OT database, we may conclude that the mean and median seeing values are quite similar in both observatories, reaching excellent results (smaller than 0.5″) for 16% to 28 % of the time and less that 1″ for 74% to 80% of the time. Bad seeing (greater than 2″) never occurs for more than 5% of the time.

Table 2. Data corresponding to simultaneous seeing measurements at GTC1 and GTC2, the two preselected sites for the GTC-10 m telescope. The data at the TNG and WHT sites are simultaneous but were taken one year before

	GTC1	GTC2	TNG	WHT	CST
Ndata	160119	87978	86385	135332	2228
Min (″).	0.15	0.18	0.17	0.11	0.27
Mean (″)	0.72	0.75	0.76	0.81	0.76
std (″)	0.55	0.40	0.47	0.45	0.27
Median (″)	0.72	0.65	0.64	0.69	0.71
< 0.5″	19%	22%	28%	21%	16%
< 1″	76%	84%	82%	74%	85%
> 2″	5%	2%	3%	3%	1%

GTC2 is the site where the 10 m spanish telescope is being erected (Alvarez et al. 1998 and Muñoz-Tuñón et al. 1997a).

Figure 4 shows the cumulative frequency of the seeing data presented in Table 2. Final conclusions concerning the comparative results at the ORM are extensively discussed by Muñoz-Tuñón et al. (1997b), Muñoz-Tuñón et al. (1998), and Mahoney et al. (1998).

Since there were no meteorological data available for the OT itself during the seeing campaign, we have used data kindly supplied by the neighboring Observatorio Meteorológico de Izaña. We now analyze the statistical results for the same period at the OT. Daytime and nighttime are defined from monthly simultaneous solarimeter data obtained at the ORM (Mahoney et al. 1998). The sampling rate is one reading per hour.

3.1. Temperature

There is evidence of the expected seasonal dependence: the typical mean and median daily temperatures ranging from 4 to 6°C increasing to 14 to 16°C during the summer months, where there is also less dispersion in the data. Figure 5 shows the mean, standard deviation, median, and the minimum monthly nocturnal temperatures found at Izaña from 1992 November to 1994 May.

These results are consistent with the seasonal temperature behavior shown in Figure 3 of Mahoney et al. (1998). An important factor determining the stability of observing conditions is the air temperature gradient during the night, which typically results in temperature variations smaller than 2°C.

The monthly air temperature dispersion follows a similar behavior to that observed at the ORM, being generally smaller than 2 or 3°C and reaching $\simeq$5°C in 1992 December.

3.2. Barometric pressure

Figure 6 shows the monthly mean values obtained for the barometric pressure (daytime and nighttime mean differences are smaller than 0.2 mbar).

The monthly barometric pressure profile during the summer (i.e., the maxima pressure difference) can vary by about 4–5 mbar: this value ranges from 6 to 12 mbar during the winter months. Similar behavior is obtained when considering day and night separately. This result is consistent with that obtained at the ORM (Mahoney et al. 1998), and can be explained by the occasional appearance during the winter of cold fronts producing local instabilities in the weather patterns. The lowest mean monthly pressures occur in 1993 February and May. Typical highest mean monthly values are reached in June–July, but can be also be found in winter months.

3.3. Relative humidity

Relative humidity data are recorded only from 1994 January to 1994 May. The monthly mean relative humidity from daytime and nighttime are shown in Figure 7. The relatively small mean values obtained during these months (from 20% in 1994 January to 40% in 1994 April) could be associated with the relatively high mean temperatures obtained in this period compared with that expected for the winter periods (see Mahoney et al. 1998). In general there is a clear correlation between the air temperature and the relative humidity, the latter decreasing this one when the former increases.

3.4. Wind speed and direction

The north-easterly trade-wind scenario at sea level of the Canary islands is dealt by Font Tullot (1956), who describes the predominance at the altitude of Izaña (approximately 2400 m) of north-westerly winds. The reality of the predominant NW winds was also confirmed by Sánchez (1968) in his compilation of 20 years' all-day data from the Observatorio Meteorológico de Izaña. Font Tullot concludes that, although the airflow direction is principally due to strong ground heating and local orography, the local NW flow at Izaña is in fact a little different from the free-air case, especially in the summer months, when the difference in frequency between Izaña and free-air regimes is less than 10%. This result is not at all surprising given that the seaward ridge on which Izaña is situated is steeply inclined with the contours normal to the incident predominant free-air wind.

McInnes & Walker (1974) find the predominant nighttime wind direction at the OT to be from the NW and N octants, followed by the W component, as compared with Fuente Nueva (La Palma) for which they also find a substantial NE component, which, again, is closely related to the local orography. The high peaks on the western islands complicated the air-flow patterns at the Observatory sites (Mahoney et al. 1998). Brandt & Righini (1985) show the windrose obtained from the meteorological station at Izaña from 1921–1950, the W and NW directions being the most frequent.

Windroses for the Izaña site (Observatorio Meteorológico de Izaña) for daytime and nighttime separately are shown in Figures 8 and 9, respectively. W and WNW components are similarly predominant in both cases, but during daytime an extra eastern component appears that seems to be associated with an anabatic component. This conclusion is justified by the orographic contours shown in Figure 1: between Izaña ant El Puerto de Güimar, the contours funnel air heated by the Sun upwards toward the Izaña ridge.

We present here a new type of windrose representing mean windspeed in different directions. We conclude that the faster winds (and the highest velocity dispersions) are more frequently associated with southern wind regimes, especially during daytime. The wind is predominantly from the W and WNW for 39.1% of the time, and that the wind speed is lower than 30 km h^{-1} for 54.3% of the time The highest wind-speed frequency occurs for interval from 10 to 19.9 km h^{-1}, a result similar to that obtained at the ORM (Mahoney et al. 1998) and peaks in the W and WNW directions. The values obtained here differ by less than 3% from those published by Sánchez (1968), who based his statistical for the OT on an analysis of 20 years of data. The only discrepancy that we can see is the predominance of winds from the W, against the direction NW found by Sánchez. This might be due to the influence of higher-than-expected temperatures in the winter months in over the last decade, or to orientation errors in the setting up of the respective windvanes at the different sites. The monthly statistics show that the W and WNW components occur with virtually the same frequency during the winter months, in which significant SSE and ESE components (the so-called "southern weather") are also detected.

From March to July (we have no further data for the summer) the W component always dominates over the WNW component and there is a clear predominant presence of trade winds in the other sectors.

We find that there are no signatures of any sort of correlation between seeing values and air temperature, barometric pressure, and relative humidity; nevertheless, there seems to be some sort of correlation between seeing and wind direction at moderate wind speeds (18–36 km h^{-1}), being the northerly wind direction associated with relatively small mean and median seeing seeing values (see Muñoz-Tuñón et al. 1998).

Acknowledgements

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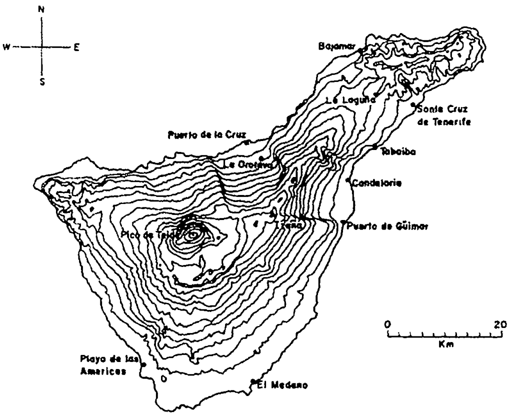

Figure 1. Contour map of the island of Tenerife (from McInnes and Walker 1974).

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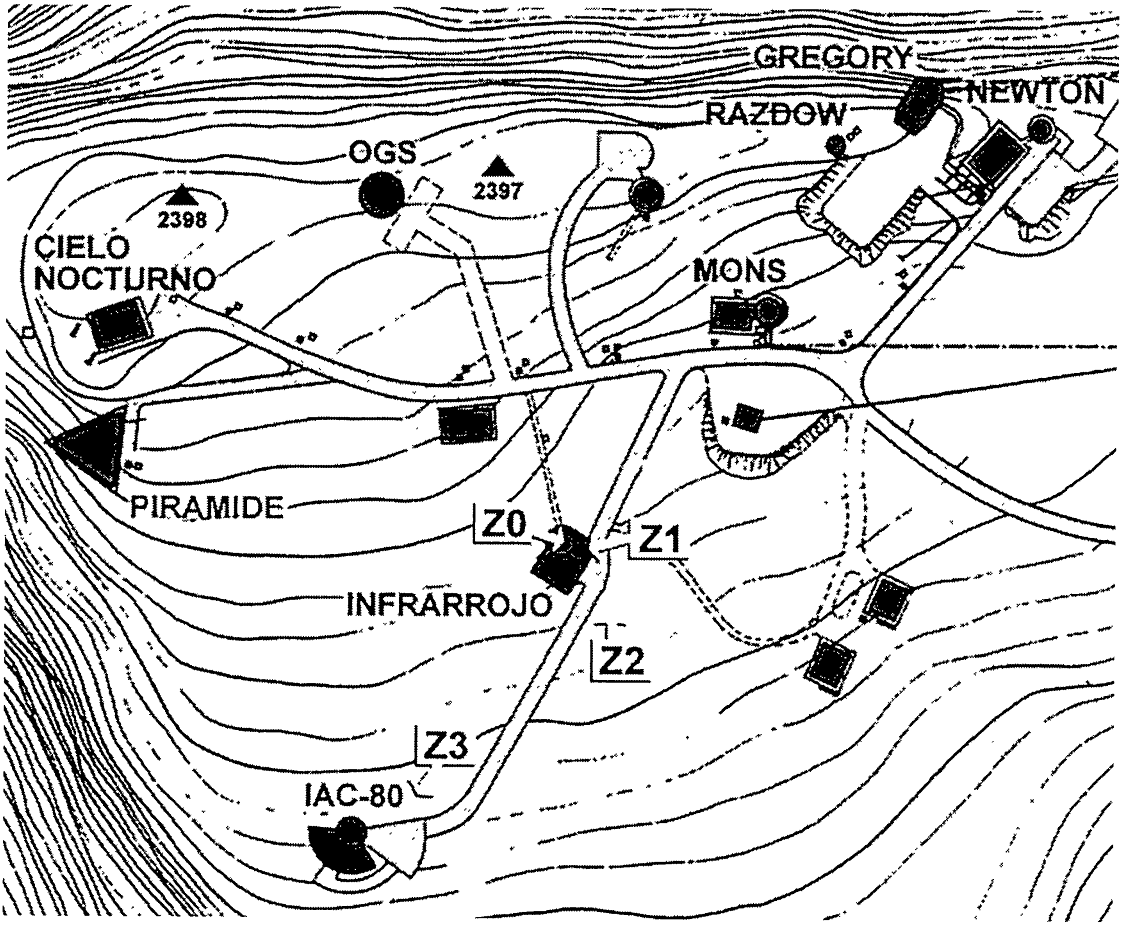

Figure 2. Map of the OT, showing the different sites where the site-testing campaign was performed.

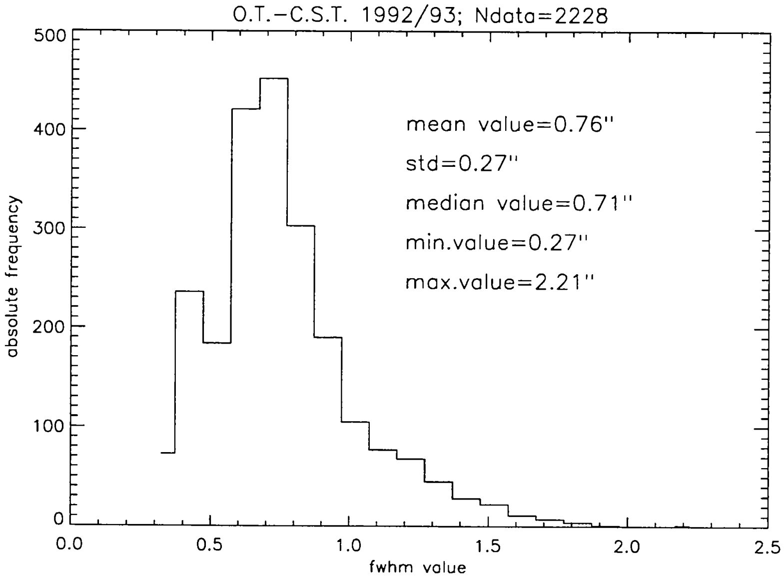

Figure 3. Distribution function of seeing corresponding to the CST location.

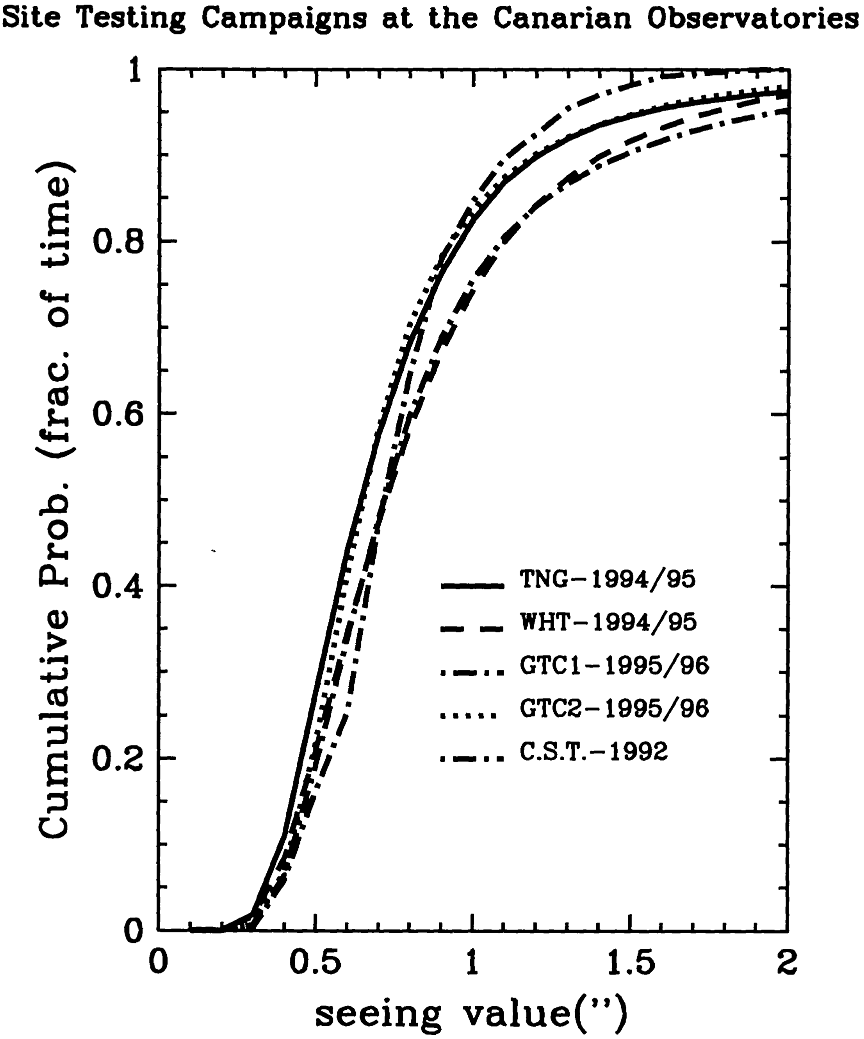

Figure 4. Cumulative probability plot of seeing values obtained for all data gathered at the GTC1, GTC2, WHT and TNG sites versus the CST and CST+CST site. This last telescope is located at the OT, and the others at the ORM. The number of data is indicated in Table 2.

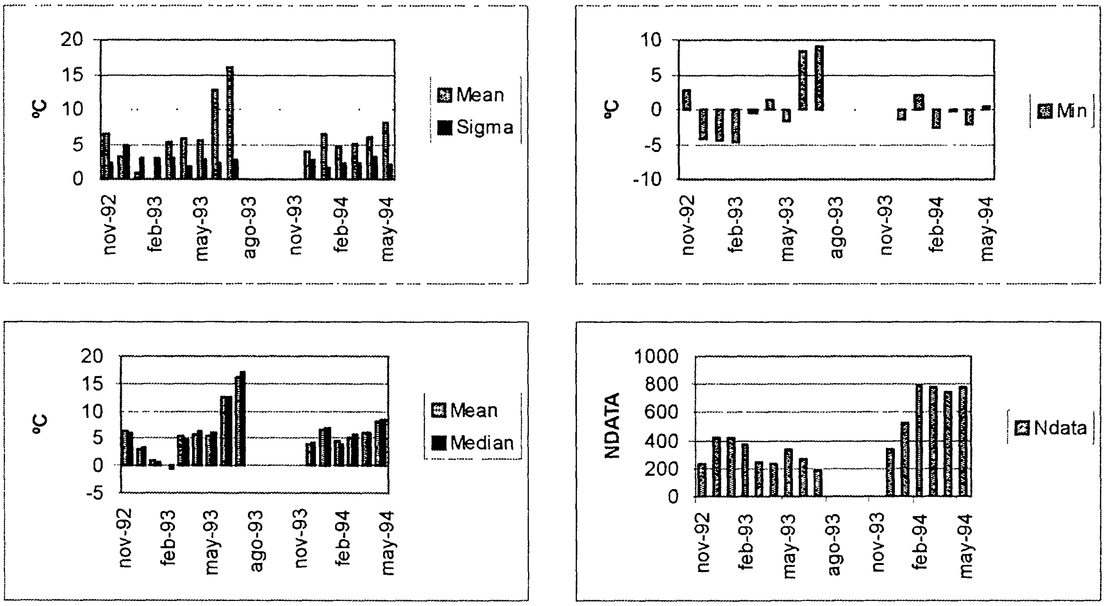

Figure 5. Mean, median, minimum, and r.m.s. air temperature, and number of readings for each month at the Observatorio Meteorológico de Izaña (nighttime).

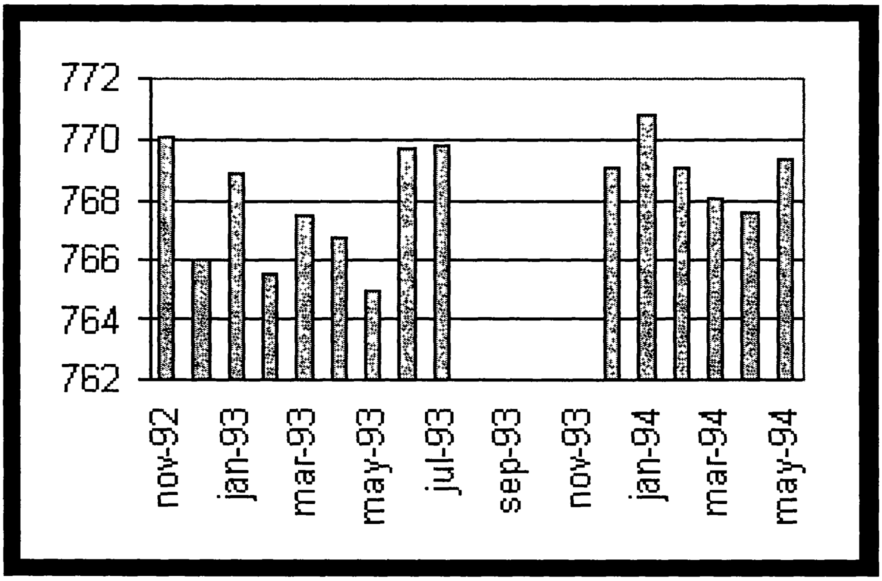

Figure 6. Mean values obtained for the barometric pressure (daytime and nighttime mean values differ by less than 0.02 mbar).

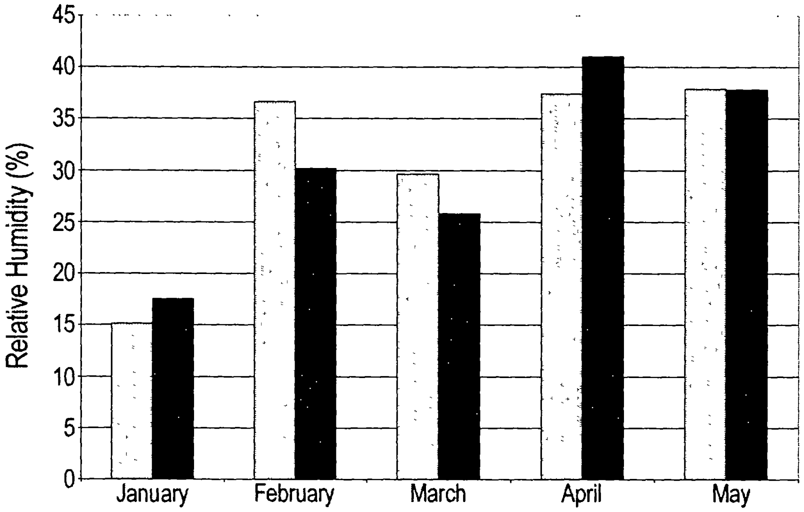

Figure 7. Monthly mean relative humidity from January to May 1994. Light-shaded and dark-shaded bars correspond to daytime and nighttime respectively.

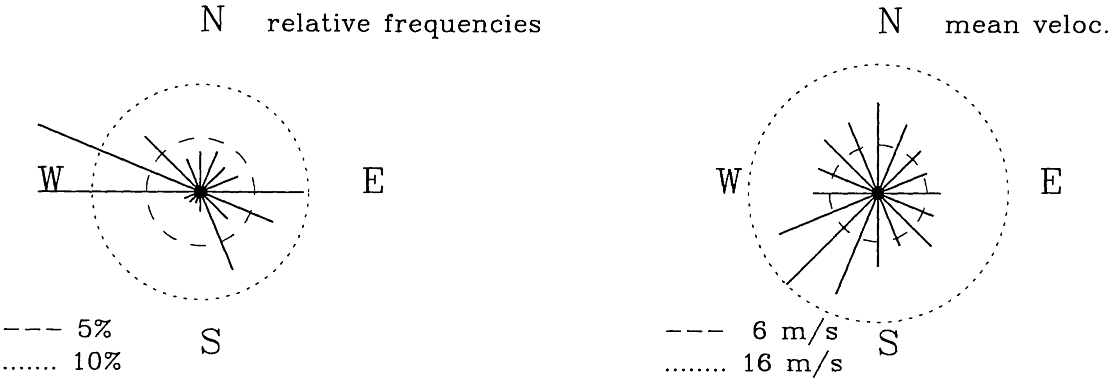

Figure 8. Daytime windroses for 1992 November to 1994 May.

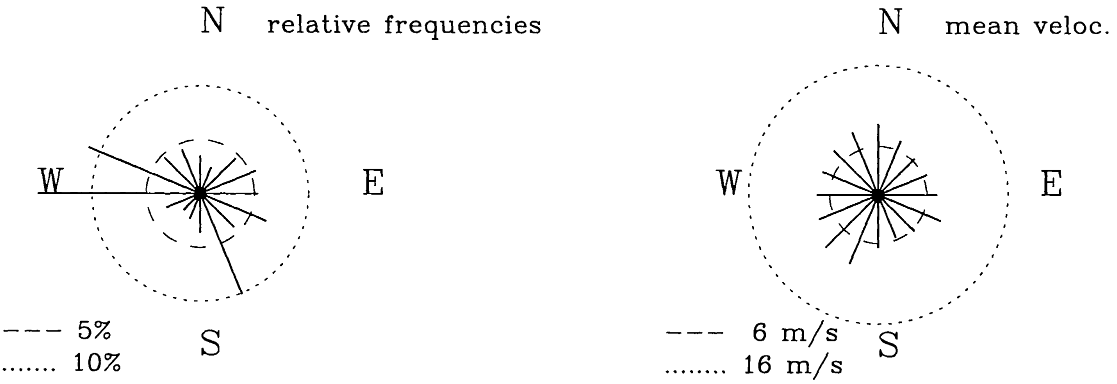

Figure 9. Nocturnal windroses for the period from 1992 November to 1994 May.