Astronomical Site Characterization at the Canarian Observatories

C. Muñoz-Tuñón,1,2 A.M. Varela1,2 and J.A. Castro-Almazán,1,2

1Instituto de Astrofísica de Canarias, E-38200, La Laguna, Spain
2Dept. Astrofísica, Universidad de La Laguna, E-38200, La Laguna, Spain
E-mail: skyteam@iac.es

Abstract. Roque de los Muchachos Observatory (La Palma) and Téide Observatory (Tenerife) are prime astronomical sites, as confirmed by more than 30 years of intensive site-testing campaigns. The IAC has long been aware of the importance of promoting initiatives for the characterization and protection of the Canarian Observatories. For this purpose, in the late ’80s a Sky Team was created to measure the atmospheric parameters relating to astronomical observations, to design and develop new instruments and techniques for astronomical site testing, and to improve and maintain a high level of instrumentation in site characterization. New instruments and techniques are welcomed by the Observatories.

1. Introduction
More than 60 Institutions have facilities at the Canarian Observatories and also contribute to the better characterization of the sites. SUCOSIP1 is the sub-committee that brings together the work carried out by different countries. The most updated databases and models (NCEP/NCAR, WRF, satellites, etc.) are also explored and used [1], [2], [3], [4]. We present a summary of the instruments, results and projects for monitoring the relevant parameters for site characterization: weather conditions, clear/useful time, precipitable water vapor content, sky brightness, image quality and atmospheric turbulence [5], [6], [7] and [8]. The data are also useful for telescope operation, for nightly observing scheduling and forecasting [9], and for feasibility studies for adaptive optics [10], [11], [12], [13].

2. The locations
In Figs 1 and 2 we show the locations at the Roque de los Muchachos (ORM) and at Téide (OT) Observatories where site-testing instruments are currently installed. The Observatories are located in La Palma and Tenerife, respectively (Canary Is., Spain).

3. Seeing
Seeing measurements are taken with instruments based on the Differential Image Motion technique [14]. In Figs 3 and 4 we show the Differential Image Motion Monitors –

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1 The SUb-COMmittee on SIte Properties (SUCOSIP) has been established within the International Scientific Committee (CCI; http://www.iac.es/eno.php?opi=5&lang=en) to guarantee the preservation of the astronomical conditions at the Canarian Observatories. This committee reviews all new developments at an Observatory to evaluate their possible impact on the existing telescopes.
or DIMMs—located at the ORM and the OT. Both are installed on a 5 m tower in order to avoid surface-layer effects. The DIMMs are remotely operated by the IAC Telescopic Operation Technicians (TOTs) and supported by the Instrument Maintenance Department of the IAC.

There are other instruments for seeing monitoring at the ORM belonging to the Telescopio Nazionale Galileo (TNG DIMM) and to the Isaac Newton Group (ING RoboDIMM), shown in Figures 5 and 6 respectively (see Appendix A for a compilation of websites). Systematic comparison among measurements are carried out (see [15] for the last one). Seeing data gathered at the ORM and at the OT (see Fig. 7) are provided in real time in the web page of the Sky Quality Team for the telescopes operation (see Appendix A, web 13). The data are automatically stored for statistical analysis and available upon request.

Figure 1. Map of Roque de los Muchachos Observatory, indicating locations of various instruments routinely operating for site testing.

Figure 2. Map of Teide Observatory, indicating locations of various routinely operating instruments for site testing.

Figure 3. IAC DIMMA at Las Moradas site (ORM), 300 m east of the Gran Telescopio Canarias (GTC). Colour code in Figure 1.

Figure 4. IAC DIMMA at the OT, installed close to the Optical Ground Station (OGS). Colour code in Figure 2.
4. Meteorology
Meteorological parameters are continuously recorded by Automatic Weather Stations (AWSs) belonging to various institutions operating at the Canarian Observatories. The IAC automatic weather stations consist of a metal framework holding the data acquisition unit (DAU), a combined hygrometer and air-temperature sensor, a solarimeter, a surface-wetness probe and a temperature-compensated barometer. A 10 m lattice tower supporting an anemometer and a wind vane is erected near the station. The system is supplied with a solar power generator and a radio communication system. The data logger can be programmed either to take instantaneous data or time-averaged data. Wind speed is measured every 10 s; the average during a minute is the wind speed and the maximum instantaneous measurement during the minute is the gust value. More details in [16].

Real time meteorological parameters provided by different weather stations at the ORM are compiled in a common webpage managed by the Isaac Newton Group (Appendix A, web 5). Weather information at the OT is provided by the IAC (Appendix A, web 7).

5. Precipitable Water Vapour content
Precipitable Water Vapour (PWV) content is crucial for infrared atmospheric characterization, and also for for the operational use of the CanaryCam instrument at GTC, and for optimizing queue-scheduled observations. The PWV monitoring is based on GPS data processing from a permanent GPS installation [17]. An estimation process is run every 30 minutes using fixed orbits to produce the latest PWV estimation for the ORM. The real-time data are published on the Sky Quality Team website (Appendix A, web 16) and the interface is in Figure 8. The PWV monitor has been extended to the OT and is going to be released briefly.

6. Sky brightness
One of the most damaging effects for astronomy is brightness or glare in the night sky caused by artificial light reflecting off gases and particles in the air. The Sky Quality Protection Technical Office (OTPC) was set up by the IAC in January 1992 to provide advice on the application
Figure 7. Webpage of the on-line seeing data retrieved at the Canarian Observatories by the DIMMAs (Appendix A, webs 14 and 15). The upper plot shows the seeing values in UT, while the lower plot shows the histogram of the seeing values for that night.

Figure 8. Webpage showing the on-line precipitable water vapour content gathered at the Canarian Observatories (Appendix A, webs 16 and 17).

of the Sky Law (Law 31/1988), which protects the astronomical quality of observatories in the Canaries from light pollution, radioelectric and atmospheric pollution and aviation routes (see Appendix A, web 8). The OTPC also develops important tasks concerning the application of the law and advising in the implementations of lights in the cities of the Islands [18].

ASTMON (All-Sky Transmission Monitor) and SQM (Sky Quality Meter) are the most recommended instruments for monitoring the sky brightness. Fig. 9 shows the ASTMON located at the OT. Software to provide the clear night fraction is in preparation in collaboration between IAC, Complutense University of Madrid and GTC. SQM at the ORM and at the OT provide on-line data through the IAC’s webpage (Appendix A, webs 9 and 10).

7. Atmospheric extinction

Sky transparency is a key parameter, as it defines the quality of the photometry to be acquired in astronomical observations. Extinction is associated with the absorption/scattering of incoming photons by the atmosphere of the Earth and is characterized by the extinction coefficient, K. Sources of sky transparency degradation are clouds (water vapour) and aerosols (dust particles included). This coefficient is wavelength-dependent and can be determined by making observations of a star at different airmasses ([2] and [19]). The Carlsberg Meridian Telescope (CMT, formerly the Carlsberg Automatic Meridian Circle), a 17.8 cm diameter telescope, started operations in 1984 May and has since then provided continuous automated measurements of atmosphere extinction (see Fig. 10). the longest and most complete and homogeneous in situ database available for any observatory. Relative monthly frequency of weather downtime at the CMT from the log for 5 yr compared with that of the WHT for 18 yr is shown in Fig. 11. The
average monthly weather downtime estimated from the CMT data log is 20.7%, in reasonable agreement with earlier studies [20]. Monthly $K_V$ medians are shown in Figure 12.

**Figure 11.** Relative monthly frequency of weather downtime at the CMT from the log for 5 yr compared with that of the WHT for 18 yr.

**Figure 12.** Monthly $K_V$ medians for 20 years. The solid line joins the median $K_V$ for each month [19].

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Appendix A. Miscellaneous compilation of webs

[1] Telescopio Nazionale Galileo Galilei
www.tng.iac.es

[2] Weather and seeing panel
.../weather

[3] Isaac Newton Group of Telescopes
www.ing.iac.es

[4] Weather and seeing panel
catserver.ing.iac.es/weather

[5] Weather site view
.../index.php?view=site

[6] Instituto de Astrofísica de Canarias
www.iac.es

[7] Weather panel for OT
.../telescopes/tiempo/weather.html

[8] Sky Quality Protection Technical Office
.../servicios.php?op1=28&lang=en

[9] Sky Quality Monitor at ORM
.../telescopios/pages/es/inicio/meteo/sqm-orm.php

[10] Sky Quality Monitor at OT
.../telescopios/pages/es/inicio/meteo/sqm-ot.php

[11] Canarian Observatories Updates
CUps – electronic journal

[12] IAC site characterization (Sky Team)
www.iac.es/site-testing

[13] Real time panel
.../realtime

[14] DIMM at ORM
.../DIMMA_ORM

[15] DIMM at OT
.../DIMMA_OT

[16] PWV Monitor at ORM
.../PWV_ORM

[17] PWV Monitor at OT
.../PWV_OT

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