The Galician Night Sky Brightness Monitoring Network

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1. Why monitor the night sky brightness?

Artificial lighting has been a key achievement for the progress of humankind. Like any technological intervention on the environment it has some side effects that must be assessed and minimized for sustainability. One of these side effects is increased skyglow. A non-negligible fraction of the light produced by street lamps is emitted to the atmosphere, directly or after reflections in buildings and pavements, being subsequently scattered by air molecules and aerosols. For a ground-based observer this results in an increase of the brightness of the night sky background.

This phenomenon, one of the most conspicuous manifestations of light pollution, was at first a matter of concern for astronomers and astrophysicists alone, who saw jeopardized the possibility of studying dim celestial objects from observatories located near big cities [1]. Satellite data, especially those provided by the DMSP [2], soon helped to unveil the global dimension of the problem [3]. A growing body of research carried out in the last decades has revealed some of the detrimental effects of artificial light-at-night on individuals, populations and ecosystems, including humans [4], as well as its unwanted consequences in fields so different as the preservation of intangible heritage [5] and atmospheric chemistry [6]. The increased skyglow is strongly amplified in overcast skies by the reflection of light at the cloud cover [7]. The night sky brightness, or rather its change with respect to its expected natural values, is progressively being appraised as a relevant environmental variable, instrumental for understanding the global dynamics of our world at night.

In parallel, the traditional street lights based on incandescence and gas-discharge technologies are being replaced at a fast pace by new solid-state sources. LED lighting is a relatively mature technology with a high potential for achieving substantial reductions in energy consumption, flexibilizing luminaire design and implementing smart control systems. The spectral power distribution of most LEDs used in public lighting applications is however significantly different from that of the traditional lamps, due to its relatively high content of components in the blue region of the spectrum. It is expected that this change in the spectral composition of light may give rise to increased skyglow, as well as to potentially stronger interactions with some biological processes.

All these facts suggest the convenience of measuring the night sky brightness levels in order to keep track of their changes with sufficient time resolution and spatial coverage over extended periods of time. The data thus obtained are expected to be instrumental for validating light pollution propagation models, assessing its evolution and providing scientific and technical support to the current and future public policies aimed at reducing energy consumption and alleviating light pollution.

2. The Galician Night Sky Brightness Monitoring Network

In order to acquire long-term environmental data series that allow to detect these trends the Galician Night Sky Brightness Monitoring Network is being deployed as the result of a joint collaboration between MeteoGalicia, the Galician public meteorological agency [8] and the Wavefront Sensors and Microoptics research group at Universidade de Santiago de Compostela (USC). The Network is based on low-cost luminance meters integrated in several of the automatic wheater stations belonging to MeteoGalicia. Researchers and the public at large can access in real time the sky brightness measurements and relevant meteorological variables. Fourteen measurement sites have been selected for the first phase of deployment, three of which (Santiago de Compostela, Lardeira and O Cebreiro) are already fully operative at the time of writing (February 20, 2014). Once completed, the network is expected to cover a
wide range of environments: urban, suburban and rural areas, from strongly light polluted city centers to natural parks with pristine dark skies, and from coastal regions to the Galician Eastern Mountain ranges.

3. Data acquisition and calibration

The zenithal night sky brightness is measured using SQM-LR detectors [9] working in their native photometric band. The detectors are based on a TSL237 light sensor with temperature compensation, logging data through an RS232 connection. Readings are given in the conventional astrophysical units of magnitudes per squared arcsecond (mag/arcsec²). The raw data are corrected for the transmittance of the protecting glass windows, amounting to an offset of about $-0.1$ mag/arcsec² (Fig. 1a). The detectors are precalibrated from factory, and their readings are claimed to be reproducible to within 0.1 mag/arcsec² rms. Twenty detectors were cross-calibrated taking continuous data streams during the period from June 20 to July 31, 2013, at a single urban site with frequent clouds (Fig. 1b). This provided a wide range of brightness measurements. The results confirmed that the inter-detector variability was well within the expected limits. From these calibration data we defined a synthetic reference detector, to which the readings of any individual detector can be referred for intercomparison.

In normal operation mode the brightness measurements are acquired at a rate of one per minute. These readings are logged and stored off-line for calibration and distribution among interested researchers.

4. Public dissemination of data

According to the public service mission of both MeteoGalicia and the USC, the acquired data are open access. Ten-minute averages of the brightness readings are computed and displayed in real time at the Meteogalicia website. At the time of writing this text the data can be accessed by entering into each station web page, but a dedicated portal is scheduled to be operative soon [10]. Data streams of the last few days can be seen as graphic plots (Fig. 2). Extended period datasets can be downloaded in different file formats together with the meteorological variables of interest. A calibration offset of $-0.1$ mag/arcsec² is applied to all readings before displaying them. One-minute datasets with detailed calibration factors for each detector are available for researchers and the interested public upon request.

![Figure 1](image1.png)  (a) Glass cover of the SQM luminance meters; (b) SQM rack during the calibration tests at MeteoGalicia headquarters.

![Figure 2](image2.png)  SQM data stream available at the MeteoGalicia weather stations webpages
5. First results

During their first months of operation the SQM-LR sensors have provided interesting information regarding the dynamics of the night sky brightness at the three active observation sites. Fig. 3 shows a typical example of the one-minute resolution records along three consecutive moonless nights, taken at the stations of SCQ (Santiago de Compostela, urban, strongly light-polluted skies), LAR (Lardeira, rural site at the Eastern Mountains, dark skies) and CBR (O Cebreiro, rural village with relatively dark-skies).

![Figure 3](image)

**Figure 3** SQM data streams along three consecutive moonless nights at the SCQ, LAR and CBR sites (see text)

The differences between the night sky brightness behavior at these locations can be easily assessed. Fig. 4 shows the histograms of the night sky brightness values corresponding to November 2013 (only values mag>8 are displayed). As expected, darker skies are attained at the rural LAR and CBR sites, being considerably brighter those of SCQ (a town of 100.000 inhabitants). The SCQ records also show a noticeably disperse, bimodal distribution: this is due to the frequent nights with cloud cover and the strong light emissions towards the upper hemisphere at this site. In SCQ the mode of the clear night sky brightness records is about 19 mag/arcsec$^2$. This value reaches 16 mag/arcsec$^2$ in overcast nights, amounting to a 16-fold increase in brightness which is attributable to the enhanced reflection of the urban lights at the base of the clouds.

![Figure 4](image)

**Figure 4** Histogram of the one-minute night sky brightness measurements acquired in Nov. 2013 at the SCQ, CBR and LAR sites.

The effects of the cloud cover can also be assessed by using density plots [10]. These graphics display the frequency of occurrence of different sky brightness values at each hour of the night (Fig. 5). The darker skies at the LAR site are apparent, as well as the bimodal structure of the SCQ pattern.
Figure 5 Night sky brightness density plots (November 2013) of the measuring stations at (a) Santiago de Compostela (SCQ) and (b) Lardeira (LAR). The color bar indicates the absolute frequency of the one-minute readings.

Figure 6 Night sky brightness daily plots with one-minute resolution at (a) SCQ and (b) LAR corresponding to November 2013. The color bar indicates the sky brightness in mag/arcsec².

The time-resolved evolution of the night sky brightness levels at each site may be assessed using daily plots as the ones shown in Fig. 6. Each column of the plot corresponds to a consecutive day, and the values along the column display the one-minute readings. In the relatively cloudless, clear skies of LAR (Fig 6b) the diagonal brightness band produced by the moonlight can be easily noticed. The frequent and irregular clouds at SCQ make the moonlight contribution much less discernible.

6. Conclusions

The night sky brightness is an environmental variable relevant for understanding the global dynamics of our world at night. In order to acquire long-term series of measurements at a representative set of locations, the Galician Night Sky Brightness Monitoring Network is being set up by MeteoGalicia in cooperation with the Wavefront Sensors and Microoptics research group at Universidade de Santiago de Compostela. Ten-minute sky brightness readings are displayed in real time at the MeteoGalicia website and can be accessed and downloaded by researchers and the public at large. One-minute readings are available upon request. The first collected datasets allow to assess the different behavior of the night sky at the three already operative measurement sites.

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References


