



# GLOBE at Night: Using Sky Quality Meters to Measure Sky Brightness



This document includes:

- How to observe with the SQM
  - The SQM, finding latitude and longitude, when to observe, taking and reporting measurements, what do the numbers mean, comparing results
- Demonstrating light pollution
  - Background in light pollution and lighting, materials needed for the shielding demo, doing the shielding demo
- Capstone activities (and resources)
- Addressing multiple measurements

## **CREDITS**

This document on citizen-scientists using Sky Quality Meters to monitor light pollution levels in their community was a collaborative effort between Connie Walker at the [National Optical Astronomy Observatory](#), Chuck Bueter of [nightwise.org](#), Anna Hurst of ASP's [Astronomy from the Ground Up](#) program, Vivian White and Marni Berendsen of ASP's [Night Sky Network](#) and Kim Patten of [the International Dark-Sky Association](#).

## Observations using the Sky Quality Meter (SQM)

The Sky Quality Meters (SQMs) add a new twist to the GLOBE at Night program. They expand the citizen science experience by making it more scientific and more precise. The SQMs allow citizen-scientists to map a city at different locations to identify dark sky oases and even measure changes over time beyond the GLOBE at Night campaign. This document outlines how to make and report SQM observations.

### Important parts of the SQM



The SQM Model

- Push start button here.
- Light enters here.
- Read out numbers here.



The SQM-L Model

### Using the SQM

There are two models of Sky Quality Meters. Information on the newer model, the SQM-L, can be found along with the instruction sheet at <http://unihedron.com/projects/sqm-l/>. Information and the instructions sheet on the older SQM model can be found at <http://unihedron.com/projects/darksky/>.

Both meters are easy to use. The new model (SQM-L) incorporates a lens for collecting more light from a narrower field of view, specifically for city use where surrounding lights or buildings may affect the reading. This narrower field of view is a coned-shaped area in which the detector can "see". The cone is ~20 degrees wide for the SQM-L as opposed to ~84 degrees wide for the SQM. Other differences between the two models include location of the display and the type of push-button. In the SQM-L model, the display is on the same side as a flush-mount push-button, which allows sequential readings to be taken without altering the orientation of the meter. In the SQM model, the display is on the same side as the sensor.

There are five basic steps to participation in GLOBE at Night through SQM measurements.

### 1) Find your latitude and longitude.

There are a few different methods you can choose from:

- Use the interactive latitude/longitude locator available on the “Report” webpage. On it, you may enter a latitude/longitude which creates a corresponding map for verification or find a map of your location from which to get a latitude /longitude.
- Use a GPS unit along with your SQM measurement. Report as many decimal places as the unit provides. OR use a topographic map.
- Visit <http://eo.ucar.edu/geocode/> on-line. Input your location. Or input your city; zoom in/out and pan around until you find your location. Double-click and the latitude and longitude will be displayed.
- Visit <http://world.maporama.com/> and map your street address. Lat/Long coordinates will be displayed under the map.
- Download “Google Earth” at <http://www.earth.google.com>
- Visit <http://www.itouchmap.com/>

### 2) Go outside an hour after sunset until 10 pm.

- Observations should be taken on a clear night when the Moon is not up and when the Sun has set for at least an hour. The Sun and Moon would otherwise contribute to the SQM's sky glow reading.
- Optional - It is best to wait until after astronomical twilight for total natural darkness before taking SQM measurements. To get the times for astronomical twilight for your location as well as Moon phase and Moon rise and set times, see [http://www.sunrisesunset.com/custom\\_srss\\_calendar.asp](http://www.sunrisesunset.com/custom_srss_calendar.asp).)
- The meter is somewhat temperature dependent. Leave the meter outside for at least 5 minutes to reach ambient temperature before taking any measurements.
- Avoid using the SQM or SQM-L near lights like streetlights and in areas that are shaded by trees or buildings. A rule of thumb for the SQM is to be as far from the object as it is high. For streetlights, stand at least 7.5 meters (or 25 feet) away, if possible.

### 3) Take a measurement.

- Point the SQM or SQM-L directly overhead (at the zenith). The meter should be held above head level so that shadows or reflections from your body do not interfere with the reading. Keep it steady.
- Press the start button once to take a reading. The SQM will beep each second while it is accumulating photons (light particles). The beeping will stop once the display reading is ready to be viewed. Under urban skies, a reading will be displayed almost immediately. Under the very darkest skies, the meter may take up to a minute to complete its measurement.
- **You must also take and submit an unaided-eye observation toward Orion for each SQM or SQM-L measurement submitted.**
- (Optional:) Press the start button a second time. The temperature in C° and then F° is displayed. Then the model number of your meter (1.17) and the serial number are displayed.

#### 4) Report your measurement.

- Measurements can be submitted on-line at <http://www.globe.gov/GaN/report.html> during the campaign and up to a week afterward.
- The observation date, the local time, the latitude and longitude, the SQM reading and the SQM serial number are to be filled out on-line. Remember to enter your unaided-eye Orion observation for each SQM or SQM-L measurement you took.
- For multiple measurements, see the section entitled “A Data Template for Multiple SQM Measurements”.

Observation Date: \*

Local Observation Time (HH:MM): \* 6 : 0 PM

Latitude:\* 0.0000000 Longitude:\* 0.0000000

Country and State:\*

Comments on location:

Your nighttime sky:\*

Orion Stars Not Visible  Magnitude 1 Chart  Magnitude 2 Chart  Magnitude 3 Chart

Magnitude 4 Chart  Magnitude 5 Chart  Magnitude 6 Chart  Magnitude 7 Chart

Optional reading from the Unihedron Sky Quality Meter:

Optional serial number from the Unihedron Sky Quality Meter:

Estimate the cloud cover in the sky:\*

Clear  Clusters cover 1/4 of sky  Clusters over 1/2 of sky  Clusters cover more than 1/2 of sky

- Paper versions of the observation forms as well as additional information are always available in either the downloadable Teacher or Family Packets at <http://www.globe.gov/GaN/observe.html>

#### 5) Compare your observation to thousands around the world.

- Find the results from past campaigns here: <http://www.globe.gov/globeatnight/analyze.html>

## What do the numbers mean?

The SQM or SQM-L measures how much light strikes the sensor. The meter then converts that amount of light into units of magnitudes per square arc-second. The larger the number read on the meter display, the darker the sky. A meter reading of 21.00 would indicate a very dark site, while a reading of 16.00 would indicate a light polluted sky. For more information on the meaning of the units used by the SQM, see: <http://www.nightwise.org/magnitudes.htm>



To compare the SQM measurement with the corresponding magnitude chart chose for the unaided-eye observation, go to <http://members.c solutions.net/fisherka/astronote/plan/tlmnelm/html/NELM2BCalc.html>. You will see an input box labeled "NELM". That is where you put the number for the magnitude chart you chose (e.g., the limiting magnitude). Click on "Calculate" and a value for the SQM measurement (labeled "MPSAS") will appear in the input box to the right. Similarly, on the next line, you see an input box labeled "MPSAS". That is where you put the value for the SQM measurement. Click on "Calculate" and the limiting magnitude will appear in the input box to the right. How well do the values calculated compare to the values observed or measured?

Typically in a city, limiting magnitudes observed have values of 3 or 4. These correspond to SQM measurements of 16.88 magnitudes per square arcsecond or 18.04 magnitudes per square arcsecond. Most people cannot see beyond a limiting magnitude of 6 which corresponds to ~ 21 magnitudes per square arcsecond and a truly dark site.

## Demonstrating Light Pollution and Shielding

This demonstration will illustrate the effects of lighting on our view of the night sky. It will also demonstrate how shielding can reduce light pollution while making the lighting more effective. All demo materials are off-the shelf items. They are also provided in the

Dark Skies Education Kit. This demonstration is adapted from an activity on the Paper Plate Education website: <http://analyzer.depaul.edu/paperplate/lights.htm>.

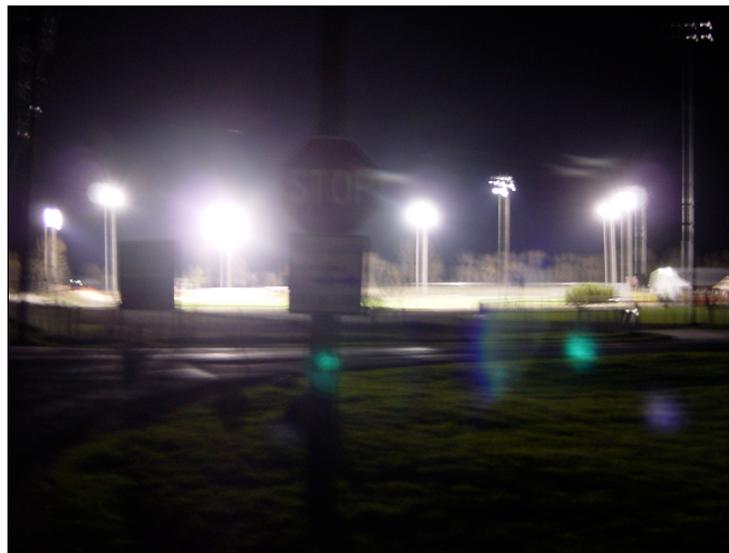
## Materials

- Two “mini-lights” (such as a mini-flashlight or Maglight)
- Cardboard cube planetarium (with a small hole on one side for a mini-light and with pinhole “stars” on the opposite side)
- PVC cap or other items to act as shields
- White surface on which to do the demo or a city mat (as in the kit)
- Optional – picture book with landscapes or city scenes, such as “There Once Was A Sky Full of Stars” by Bob Crelin
- Optional – props like 1.5 inch figures of people and match box cars

## Background – Light Pollution

There are three main types of light pollution:

- *Glare* is too much background light. Can you see the stop sign or read the sign below it in this image?



- *Light trespass* is light that spills into an area where it is unwanted. Would you be able to sleep if your bedroom window faced this neighbor's light?



- *Sky glow* is lots of light scattering off particles in the air, giving the appearance of a glowing sky. Do you see any stars in this image?



These images, as well as others illustrating the effects of different types of lighting, can be found on the Nightwise website: <http://www.nightwise.org/examples.htm>

More background on light pollution can be found on the GLOBE at Night website:  
[http://www.globe.gov/GaN/learn\\_light.html](http://www.globe.gov/GaN/learn_light.html)

## Background – Lighting

Quality lighting should:

- Maximize the desired effects:
  - Good vision
  - Good night ambiance
- Minimize the adverse effects:
  - Energy waste
  - Glare
  - Light trespass
  - Sky glow

Keys to quality lighting:

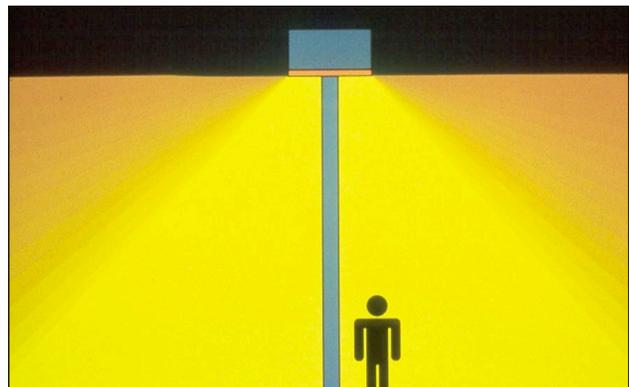
- See the effect, not the source.
- Shine the light down.
- No glare.
- Light only where and when needed.
- Don't over-light.
- Use energy efficient sources.

*Shielding* can maximize the desired effects of lighting by controlling the light output and minimizing the glare, light trespass, and light that travels straight up, as illustrated below.

*Unshielded fixture*



*Shielded fixture*

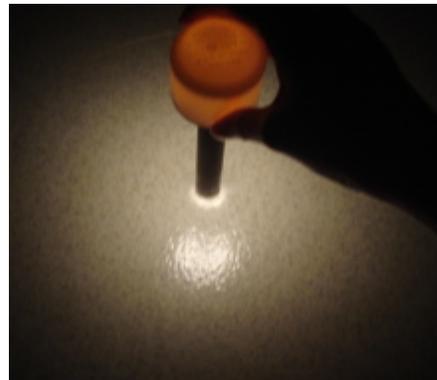
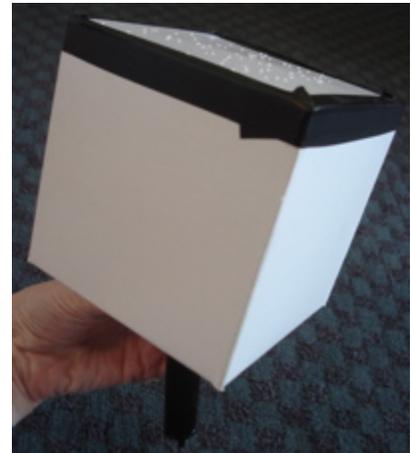


## Doing the Shielding Demonstration

- Make sure you are in a very dark room with a low ceiling. Set up the activity on a table with a white surface.
- If you'd like to include a landscape or city scene as part of the demo, prop open a book to the page with that as a background illustration.



- Unscrew the reflectors from both “mini-lights” and turn on one of them (“candle mode”). You can use the reflector ends as a base to stand the lights on the table.
- Place the bulb top of the “mini-light” barely into the big hole at the bottom of the cardboard cube “mini-planetarium”.
- With the room lights off, project the “stars” from the cardboard cube onto the ceiling. Observe how many stars you can see and how bright they appear.
- Using the second “mini-light” as a “street light”, place it on the table (in front of the landscape if you are using it) and turn it on.
- What do you notice about the number of stars?
- Now place the PVC cap (or another shield) above the second mini-light to represent a shielded streetlight.
- What differences do you notice with and without the shield? How is your view of the stars affected? How does the lighting of the area directly under the lamp change?



## Wrap Up

With your audience/students/family members/other citizen-scientists, discuss your observations and the benefits of shielded lighting. Note that shielded lighting improves our view of the stars (reduces sky glow). It is also safer and more energy efficient, since it directs light down to the ground, where we want lighting, rather than up into the sky. This improves the quality of life for people, animals, and plants, saves money and energy, and preserves our beautiful dark skies.

## Capstone activities

For capstone activities, interested citizen-scientists may choose to expand the SQM measurements beyond the campaign period. There are different types of SQM measurements one can take during the rest of the year—from grid surveys of one's town on one night (repeatable every month), to seasonal surveys, to surveys every hour over a night at one or more location, to surveys of 8 cardinal directions along one's horizon (concurrent with regular SQM measurements or measurements at different angles along one's meridian).

Another type of capstone activity encompasses the analysis of the maps. Analysis of the maps could include a comparison with other data sets such as the last couple of years of SQM data and the limiting-magnitude unaided-eye observations, population density, satellite data on nighttime lights (top view looking down versus the SQM's bottom view looking up) and regional environmental concerns (e.g., sea turtles in Florida). GLOBE at Night will endeavor to place the first four of those data sets on-line. The Map Viewer on the GLOBE at Night results webpage enables the citizen-scientist to zoom into an area of interest using these data sets.

Other capstone activities involve citizen-scientists meeting with their local officials to increase their awareness of dark skies preservation issues and to promote the use of compliant fixtures and shielding. For more information on these types of activities, visit the International Dark-Sky Association at <http://www.darksky.org>. You may also want to encourage others to take part in citizen science projects to measure light pollution (see resources below) by writing letters to the local newspaper, government, and businesses to encourage the installation of shielded lighting in their community.

## On-line Resources

- GLOBE at Night - <http://www.globe.gov/GaN/>
- IYA Dark Skies Awareness Cornerstone Project – <http://www.darkskiesawareness.org>
- International Dark Sky Association - <http://www.darksky.org/>
- Nightwise - <http://www.nightwise.org/>
- Earth Hour - <http://www.earthhour.org>
- Let There Be Night – <http://www.lettherebenight.org>
- National Park Service Dark Sky Team - <http://www2.nature.nps.gov/air/lightscapes/>

## A Data Sheet for Multiple Measurements

**For 500 measurements** or more, a data sheet as an excel spreadsheet is available for either Orion data and/or SQM data. Download the excel file from: [GaN\\_DataSheet.xls](#). Once you have entered your measurements and other parameters, send the excel file to [cwalker@noao.edu](mailto:cwalker@noao.edu) by April 7, 2009.

For less than 500 measurements, you may use the excel spreadsheet or the pdf file to record data, but you must **submit the data yourself by individual entry on-line** using the report page at <http://www.globe.gov/GaN/report.html>. Download the excel file from [GaN\\_DataSheet.xls](#) or the pdf file from [GaN\\_DataSheet.pdf](#).

Here is an explanation of the columns in the data sheet. **Do not fill in the “Tempid” or the “Submitdtm” columns.** Columns to fill in include the latitude, the longitude, the observation date and local time, the magnitude chart # for the unaided eye observation toward Orion, and the cloud cover estimate. The optional columns include the comments columns, the SQM measurement, and the SQM serial number. However, we are hoping you will have SQM measurements to submit. (Helpful notes: you must submit **an Orion observation for every SQM measurement** submitted. Also, citizen-scientists can use the tool on the on-line report form to get the latitude and longitude of their observations. Be careful when using the “-“ and “+” signs in the latitude and longitude entries.) An example of a data entry is given below.

### **Key to the Columns for the Excel or PDF Data Sheet:**

- Latitude in Decimal Degrees (-DD.DDDDDD or +DD.DDDDDD to denote South or Northern Hemisphere, respectively) (Notice up to 6 decimal places after the “.”)
- Longitude in Decimal Degrees (-DDD.DDDDDD or +DDD.DDDDDD to denote West or East of Greenwich, England, respectively)
- Observation Date in month with the format “MM”, day with the format “DD”, year with the format “YYYY” (MM/DD/YYYY) plus Local Time (HH:MM) [PM]
- Magnitude Chart for unaided-eye observation toward Orion (using magnitude chart designations “1” through “7”; see [www.globe.gov/globeatnight](http://www.globe.gov/globeatnight))
- Cloud Cover expressed as either “0” for a clear sky or “1/4”, “1/2” or “3/4” for ¼, ½ or ¾ or more of the sky with cloud cover, respectively.
- Comments on Sky Conditions (optional)
- Comments on Location (optional)
- SQM Reading in Magnitude per Square Arcsecond with the format “XX.XX”
- SQM Serial # (e.g., four digits) (optional, but preferred)

On the first page of either the excel file or the pdf file:

Tempid	Latitude (in decimal degrees, DD.DDDDDD)	Longitude (in decimal degrees, DDD.DDDDDD)	Observation Date (MM/DD/YY) and Local Observation Time (HH:MM)	MAGNITUDE CHART for unaided-eye observation toward Orion	Cloud Cover Estimate (0 for clear or clouds over 1/4, 1/2 or 3/4 of sky)	Comments on Sky Conditions
	32.32125	-110.88630	3/16/09 8:00	4	0	perfectly clear; no moon

On the second page of either the excel file or the pdf file:

Comments on Location	Country	Submitdtm	Sky Quality Meter Reading	Sky Quality Meter Serial #
an empty lot about 300 feet from any lights	USA		18.81	1337

**Note:** This entire page is available for download as a [pdf](#).

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### QUESTIONS?

Email Connie Walker at [cwalker@noao.edu](mailto:cwalker@noao.edu).

Happy star-hunting!