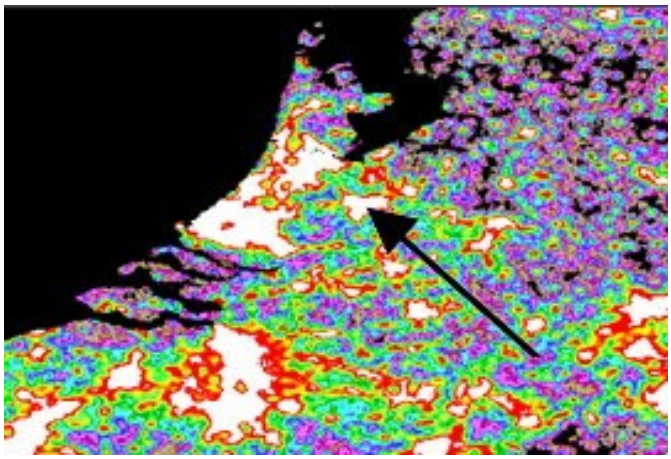
MONITORING

LOCATION

The light meters hang at the side of a houseboat in Utrecht, the Netherlands. Utrecht is a town of about 300.000 inhabitants. With 17 million inhabitants the Netherlands is one of the most lighted parts of the world. The images show the Netherlands and the location of Utrecht in a DMSP map of Holland.



The meters hang at a height of 4 meters, also 4 meters above sea level. One of the meters measures almost the whole sky. Hereunder a picture of what the device 'sees'.

To the right the view of the sky from the measuring location. Most part of the sky is free from obstacles, with a building to the west en high trees in the east.

PURPOSE OF THE MONITORING

Purpose of the monitoring is knowledge about:

1. The variation in night time luminance of the night in the Netherlands. Maps of the night time sky are made when the conditions are ideal with no moon, no clouds etc. How much brighter the sky is in other conditions: rain, snow on the ground, mist we don't know. Monitoring every night during a long time will give an answer to the median and the variation of the night time sky luminance.

2. The long term development of the sky luminance in the Netherlands. Local governments but since shortly also the national government is interested to make a policy about darkness. A lot of initiatives are taken to diminish the light pollution. What is the effect of these efforts?. There was a 3 till 5 % increase in the amount of light pollution. What will it be the next years?

3. The variability of the night sky luminance in different timescales: during each night, during a year. The effect of people going to bed and also atmospheric conditions varying during a night have influence. We donlt know yet what the variability is during a night. In de different seasons effects like Christmas lighting or less people during summertime in the town are possible effects to measure.

MEASURING DARKNESS

The night sky can, just as other surfaces, which gives light be measured in two different ways: the total amount of light and the light from a specific direction. The first is called illuminance and the second luminance. The advantage of illuminance is you measure all the light. The disadvantage is you can never measure only the whole sky; there are always trees or other light sources.
Luminance has the advantage you can measure it well, but it's says nothing about the total light. You want to know how much light is coming from the sky not only in one direction, but from all directions

Illuminance and luminance are exactly defined in respect to the human eye. A well constructed measuring device must follow these sensibilities, otherwise the results are difficult to compare.

SQM-LE

The SQM-LE meter is permanently connected to a laptop. Every 5 minutes it measures the sky. It gives also the temperature. The SQM-LE measures in magnitudes per square arc seconds.
As a measuring device it's a meter between a lux meter and a luminance meter. A normal luminance meter has a much smaller angle. It measures the amount of light of the sky in a angle of 20 degrees.
The SQM-EL is directed directly to the zenit. (point above your head).

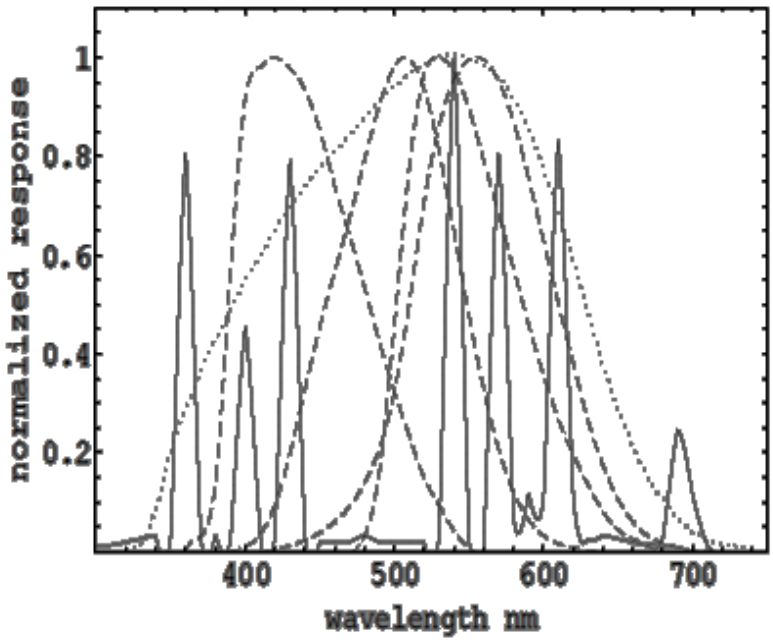


Figure 1 Night sky photometry with sky quality meter, Cinzano 2005.

COLOUR SENSIBILITY

The sensibility of the SQM-LE differs substantially from the human eye. The SQM-EL is the light dotted line, which begins at 320 nm and runs to 700 nm. 320nm is deep in the blue and is not visible for the human eye. The sensibility of the human eye (daylight) is the dashed line to the right.

The sensibility looks like the sensibility of the human eye in the red part of the spectrum but deviates greatly at the green an even more at the blue.

The advantage of the SQM-LE is there are a lot of these apparatuses around the world and the results are well comparable .
The SQM-LE measures in magnitudes per square arc seconds. A sky of around 22 or 23 is the darkest reachable in the whole world. The darkest measurements in Utrecht are around 19. The unit is derived from the old concept magnitude from the Greeks, still used by astronomers.
A sky of magnitude 19 gives as much light per square arc seconds as a star of magnitude 19 .

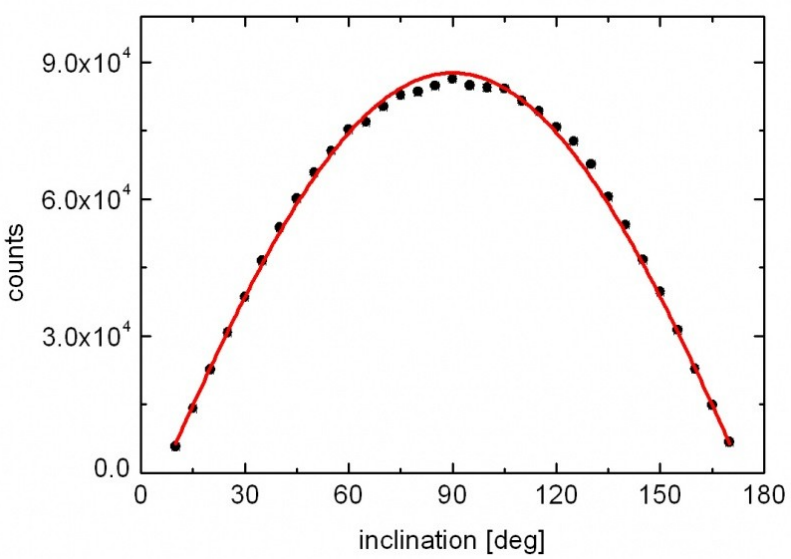
For a more elaborate analysis of the SQM_EL see:

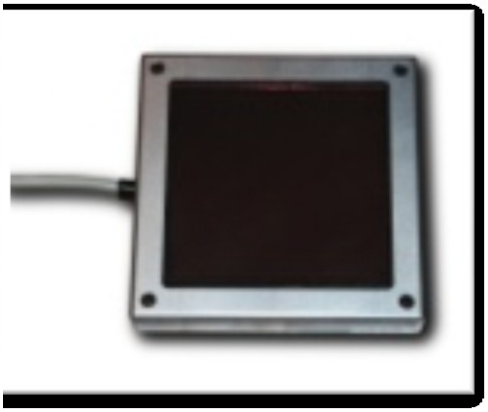
http://www.unihedron.com/projects/darksky/sqmreport_v1p4.pdf.

Lichtmeter Mark 2.3

The Lichtmeter Mark 2.3 is in principle a solar cell in which energy of photons is converted into a current. You don't need electricity for using it and there is only a USB cable into a laptop. Every three minutes a measurement is done in three different channels.

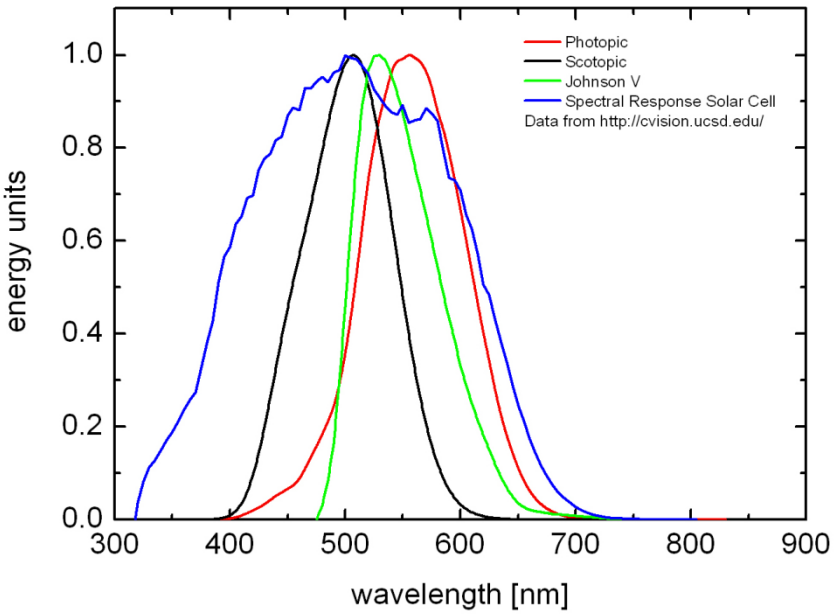
De Lichtmeter Mark 2.3 measures in an angle of almost 180 degrees. The device is rather well calibrated with a cosinus dependency as a lux meter.





Here above is the measuring points and the ideal cosinus. The deviation is minor.

The Lichtmeter Mark 2.3 is also much more sensible for blue then the human eye. Here under is the curve of the Lichtmeter Mark 2.3 compared to the day sensibility of the human eye (Photopic), night sensibility (Scotopic) and the international often used astronomical Johnson V curve.



The sensibility of both devices look alike and this makes the transformation n of the different measurements easier.
The Lichtmeter Mark 2.3 measures not in a unit of light. The device has three sensors, which in essence counts the photons which reaches the cell. As the device in essence a luxmeter the preferable unit is the lux.

For more information look: http://kuffner-sternwarte.at/hms/wiki/index.php5?title=Lightmeter

To make the measurements over a long time reliable every half year both the meters will be calibrated with a real luminance meter and a lux meter (both in possession of Sotto le Stelle). The next calibration will be july 2011.

PROCEDURE

To make the monitoring useful and worth the effort, a protocol is written. Here the description of the procedure.

Night and Astronight

For the measurements of the variation of the night sky luminance we must define what the night is: the night we have defined as the period between sunset and sunrise: altitude sun<0 degrees

For the measurements of the influence of artificial light we must try to get rid of influences by the sun and the moon. We must measure only when both are not contributing. We have chosen as measuring time ‘Astronight': the time of astronomical darkness. Definition of Astronight: Altitude sun<-18 degrees and altitude moon<0 degrees.

At the program Horizons of the Nasa http://ssd.jpl.nasa.gov can the data be downloaded of the height of the moon and sun at a given moment. This is done for the location Utrecht, where the meters are installed for an whole year, every 10 minutes. There are 52.000 data per year which can be processed by Excel.

Especially there are errors at the time of dusk, because the measurements are done every 3 or 5 minutes. As not the mean but the median of the measurements is used as the most important result, this has no influence.

QUANTITIES, UNITS AND CONVERSIONS

The SQM-EL measures in magnitudes. For astronomers this is a normal unit and derived from the unit in which the luminous intensity of stars is measured in. A sky of magnitude 22 is about the darkest measurable in the world. In the Netherlands the values vary between 17 and 21, the lower the value the more light.

To convert the unit magnitude in a unit that's for light engineers well known quantity, candela per square

meter the following formula is used

Or the other way: Magnitude=12,603-2,5*LOG luminance

A better known quantity is the illuminance. This quantity is not well to derive from the luminance. If the sky was everywhere the same brightness, the conversion would be easy: illuminance = pi times luminance.

The sky is at the horizon always brighter then right up (also without light pollution).

Sotto uses the following conversion as rule of thumb:

The value of C lays between 5 and 10 and is uncertain; an issue to investigate.

SQM-LE

The SQM-El measures in the magnitude. The results are also presented in this unity. The normal SQM apparatus, much used in by amateur astronomers gives also measurements in this same unity.

Lichtmeter Mark 2.3

The Lichtmeter Mark 2.3 measures in principle something like the illuminance. There are three sensors which measure different parts of the luminance's. In the beginning all three sensors were used, but Guenther Wuchterl , the developer of the apparatus, uses only the night sensor, which gives the best results as long is sufficient corrected for temperature.

The Lichtmeter Mark 2.3 is now calibrated with the next formula:

$$X = c (b (a \exp (n(1+d*T)/a) - 1) + n)$$

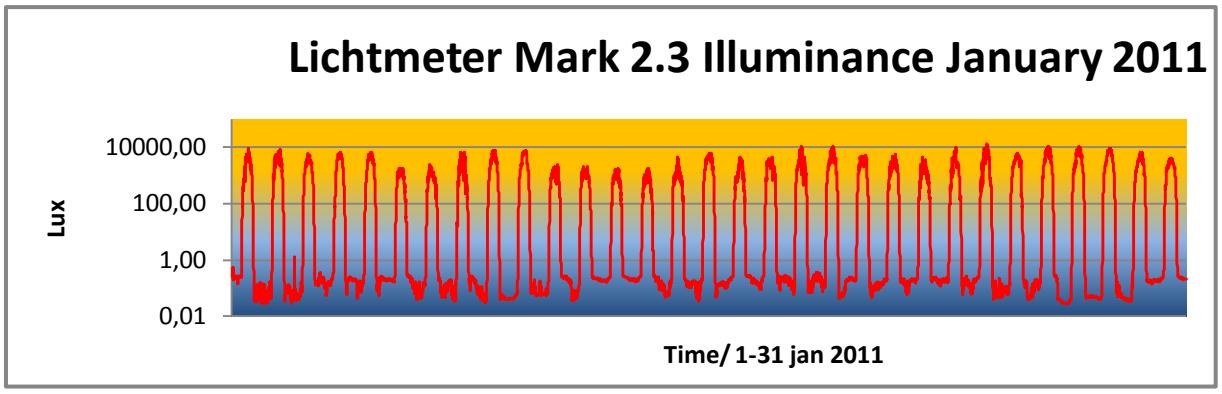
with
n . . .counts (sensor 1 output)

T . . .sensor-temperature in °C

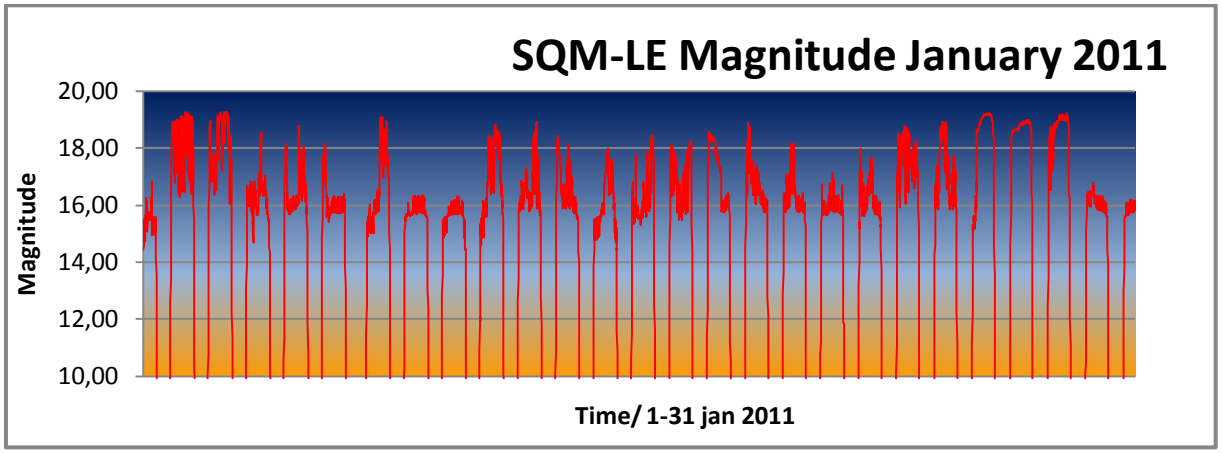
X . . .horizontal illumination [Lux])

[a,b,c,d = 1.16538e+05, 4.18392e-03, 3.40829e-07, 4.95388e-03 [Lux]]

UNDERSTANDING THE RESULTS



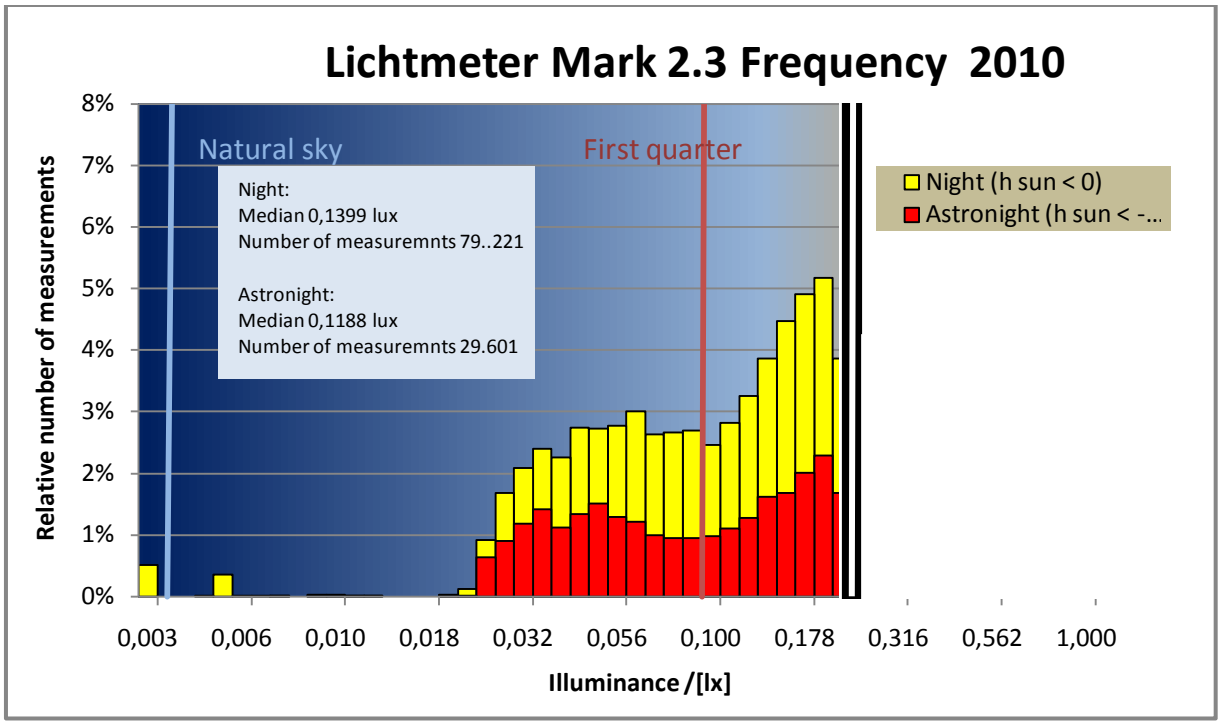
In the graphic above are the measurements of one month of the Lichtmeter Mark 3.2. The nights are visible by the low values and the days as the high values at the top. In January the sun does not come high and the highest values are around 10.000 lux; in the summer this can be 10 times higher. You can see also the nights are longer then the days.



The graphic of the SQM-El over the same month looks like this. The nights are the values around 18 and 19. The apparatus does not measure during the day. it switches off around magnitude 6, which is as the sun is a few degrees above the horizon.

You can see that at the half of the month, the moon was full and there was also some snow in the beginning of the month, which gives low values at night (high illuminances).

At the end of the month especially 27 January, you can see the graphic is very smooth at night, a night without clouds which the light from the ground strongly reflect, which result in higher light values (low magnitude).



This is the graphic to analyze the data. it is done in concurrence with some other people in the world, which do the same measurements. It's is a graphic which gives the frequency of the different light values over the course of the time, in this graphic the whole of the year 2010.

As you can see in the text box there were 79.221 measurements done in 2010 during the night and 29.601 during Astronight.

Horizontal is the lux value from, at the left the low values and at the right the high values (around dusk).

The lowest values lay around 0,02 lux, which is the darkest value happening in Utrecht. The yellow boxes at 0,004 lux are measurements of snow covering the sensor.

The highest values are around 0,2 lux which is around the same as during full moon, which is given as the white line. The median lies at 0,1399 lux which is something lighter than first quarter of the moon.

A really black night you can't find in Utrecht, as the value would be around 0,004 lux, which you can see as the blue vertical line which gives the natural unpolluted night sky.

The median for Astronight lays at 0,1188 lux. This is more or less the same value as first quarter. The light pollution in Utrecht gives somewhat the same amount of light as the first quarter.

The graphic above is of the Lichtmeter Mark 2.3. A comparable graphic is done for the measurements of the SQM-EL. The values are in magnitude but the results are at the same way presented.

In the course of 2011 a further analysis will be conducted of the data collected so far during the years 2009 and 2010.