Interaction of clouds and fog with the measure of Night Sky Brightness

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Light emitted or reflected up to the sky can interact with clouds or fog changing dramatically the Night Sky Brightness (NSB). The evaluation of NSB can be clearly affected by presence or absence of clouds. This effect is completely depending of the nature of the site: dark site or urban polluted site. But is it possible to develop an inverse procedure to evaluate cloud coverage starting from NSB measurements?

NSB measurements with clouds conditions

NSB and Clouds Data

NSB data coming from Catalan Light Pollution Network

In cooperation with Catalan Service Against Light Pollution we have started a pilot plan of the Xarxa de Contaminació Lumínica de Catalunya (XCLCat) to measure Night Sky Brightness
Each station is based on SQM-L devices, mainly LE (ethernet) but also LU (USB) can be used. All the devices have been intercalibrated to obtain comparable data.

Cloud data from Ceilometers

A ceilometer can provide data of aerosol and clouds with high precision, providing accurate altitude of clouds.Thanks to the cooperation with Meteo Group of the Universitat de Barcelona and Institut de Diagnosi Ambiental i Estudis de l'Aigua (IDAEA-CSIC) we have access to ceilometer data in Barcelona and Montsec.

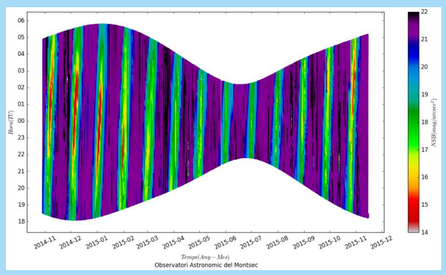

Fig. 1. Sample of NSB data from Montsec (OAdM) station during more than one year

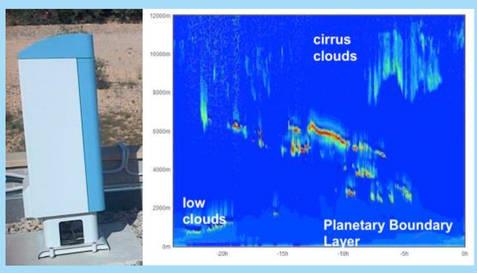

Fig. 2. Ceilometer located in Montsec and sample of data (courtesy of IDAEA-CSIC)

Ampliflying or not the effects of ALAN

In urban areas, like Barcelona, clouds are increasing the NSB in all kind of clouds. Specially low clouds (or fog) are generating the brightest values (around 14 mag/arcsec2)

In natural protected areas, like Montsec, clouds are blocking natural sources of light. Specially low clouds are generating extremely dark values (up to 24 mag/arcsec2). So darkening generated by clouds it is a clear indicator of natural night conditions.

Urban area

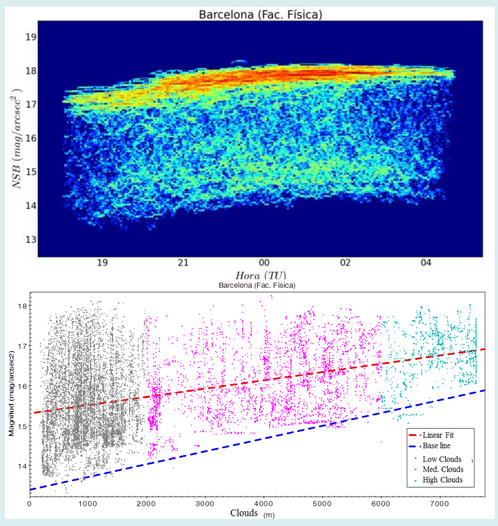

Fig. 3. Clouds are increasing brightness in Barcelona

Natural/Protected area

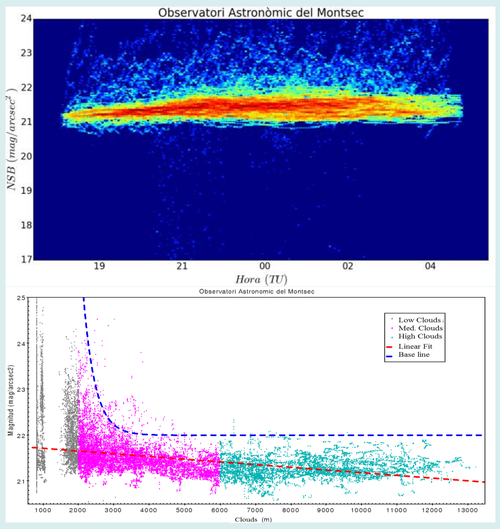

Fig. 4. Clouds are darkening the sky in Montsec

Is it possible to use NSB data to evaluate clouds?

Defining Clear Sky Factors:

Because it is well known that clouds change the measurement of NSB done with SQM, so it could be possible to determine the presence or absences of clouds using SQM measurements.

SQM manufacturer (Unihedron) proposed an experiment called Clear Sky Detection Experiment defining the Clear Sky Factor (CSF). Its experiment only considers to increase CSF when the new measurement is brighter than the previous one. And define their CSF that we will call it here CSF1.

$$CSF = \sum_{i=1}^{10} \|mag(i) - mag(i+1)\| \qquad CSF1 = 2 \times CSF \qquad mag(i+1) < mag(i)$$

New proposals:

Two new proposals are used. A new factor called CSF2 taking into account oscillations in both directions and a quadratic factor called CSF3 to magnify the detection of oscillations.

$$CSF = \sum_{i=1}^{10} \|mag(i) - mag(i+1)\| \qquad CSF3 = \sum_{i=1}^{10} \|mag(i) - mag(i+1)\|^2$$

$$CSF2 = CSF$$

Testing Clear Sky Factors:

Index P is created to evaluate the capacity of separation of samples. It is a ratio of measurements with clouds against total for each CSF interval.

$$P = \frac{N_{cloud}}{N_{total}}$$

Where N_i are measurements with clouds or total

Urban areas

Index P is showing that CSF1 has a strong contaminatin in low values where data with clouds are bad assigned. CSF2 and CSF3 show better performance.

CSF seems a clear possibility to identify clouds

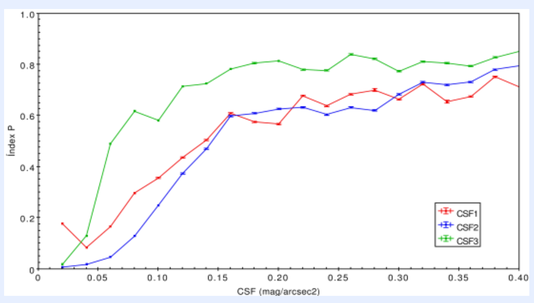

Fig. 5. P-index applied to Barcelona

Protected areas

Index P is showing a capacity of separation but all the CSF have contamination in low values. A possible sample separation could be for CSF around 0.05 mag what is similar to errors of measurements.

CSF seems not very effective in protected areas

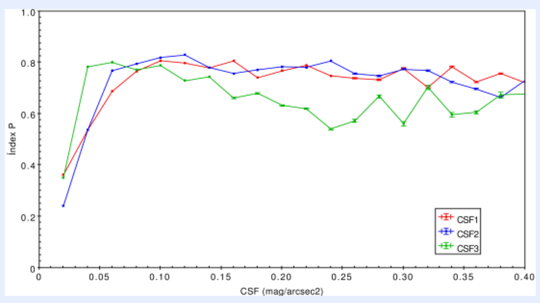

Fig. 6. P-index applied to Montsec

Test Samples:

Using ceilometer data from Barcelona (Univ. Barcelona) and Montsec (IDAEA-CSIC)

We have created for each site five subsamples: w/o clouds, with clouds, low clouds (up to 2km), medium clouds (2 to 6 Km) and high clouds (more than 6 Km).

Clouds data are cross matched with NSB data from Barcelona and two Montsec XCLCat measurement stations (OAdM in the top of the mountain and COU more close to valley)

Mean values of NSB (mag/arcsec2) computed for each sample

	Barcelona	Montsec (OAdM)	Montsec (COU)
Total sample	16.79	21.47	21.38
w/o clouds	17.71	21.44	21.41
With clouds	15.79	21.50	21.36
Low clouds	15.52	21.82	21.52
Medium clouds	16.07	21.50	21.35
High clouds	16.81	21.29	21.26

And using TESS-W clouds sensor?

TESS-W is a simple and compact photometer developed by Stars4ALL H2020 EU project.

It has a NSB detector plus an infrared cloud detector based on difference of temperatures between sky and ground.

If differences are high it means the sky is clear and when difference goes down is because there are clouds. The altitude of clouds is linked to this temperature. Low clouds give lower difference of temperature.

First test using TESS-W located in Montsec shows how darkest values of NSB are directly linked with less difference of temperature (low clouds). The result is clearly compatible with ceilometer previous studies.

Fig. 7. Comparison of NSB measurement and difference of temperatures obtained by TESS-w

More studies with TESS-W on the way…

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