

Night Sky Brightness and Light Pollution in Comunidad de Madrid



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ABSTRACT

Preliminary results of a study of the night sky background brightness around the city of Madrid using Sky Quality Meter (SQM) photometers are presented.

Data-retrieval methodology includes an automatic procedure to measure from a moving vehicle which allows to speed up the data gathering.

The night sky brightness, an astronomical quality parameter that accounts for luminous flux from the sky, is closely related with the light pollution.

The map with the spatial distribution of the night sky brightness around Madrid has been compared to the light pollution as measured with calibrated satellite imagery and nocturnal images taken by astronauts aboard the International Space Station (ISS).

COMUNIDAD DE MADRID

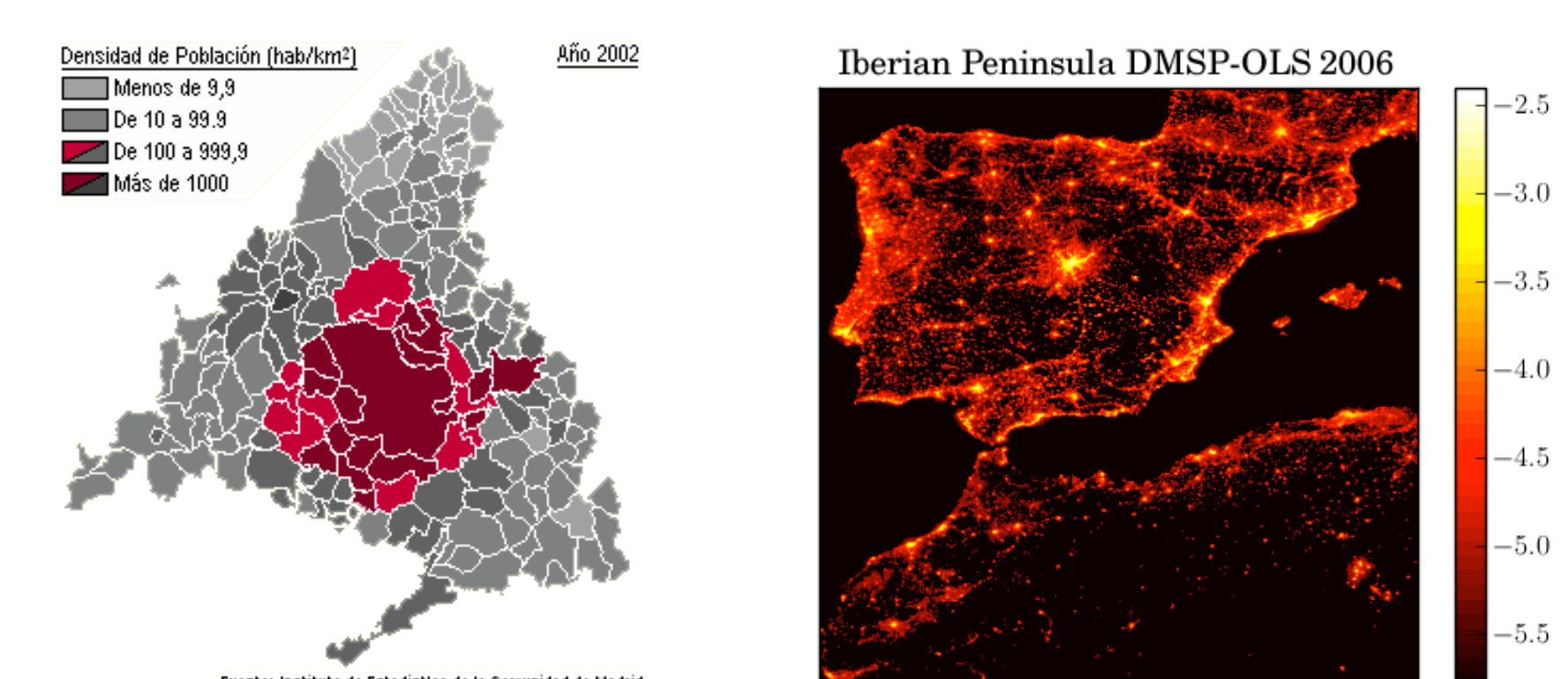


Figure 1: (Left) Population density. (Right) Iberian peninsula and northern Africa imaged with radiance calibrated data from DMSP-OLS satellite. The display scale is logarithmic and coded in units of W/m²/sr/um.

The community of Madrid (Spain) is located at the center of the Iberian Peninsula (Castilian Central Plateau). Its capital is the city of Madrid. It has a population of 6.4 million mostly concentrated within the metropolitan area of Madrid.

OBSERVATIONS

Instrumentation

We are using the Sky Quality Meter (SQM) photometers that have been cross-calibrated to determine zero offsets at the Laboratorio de Investigación Científica Avanzada (LICA) of the UCM. Time and spatial coordinates of the data are obtained with computer linked GPS.



Figure 2: SQM photometer on top of a car.

Method

The photometer measures the night sky brightness at zenith from the top of moving vehicle. SQM and GPS readings are recorded with a laptop. The results of every track is archived in a CSV file with brightness data, coordinates and time (one point every 10-15 seconds).

The Sociedad Malagueña de Astronomía has developed a program (Road Runner) that records all the information in one CSV file and creates a KML file on the fly.

DATA & PROCESSING

Data

Sky brightness measurements are obtained during absolutely clear nights (no clouds of any kind) and with no Moon over the horizon. To date we have more than 15,000 points.

SQM magnitudes are transformed to fluxes and averaged in square cells 2 arcmin wide (3,7 km).

Filtering

The SQM data is continuously recorded even inside villages or when the light from lamp posts is contaminating the sky brightness measure. We do not use any kind of light baffle. We filter out spurious data with the information recorded by the observer and that obtained from KML maps. We check visually each track on Google Earth and flag rejected data points.

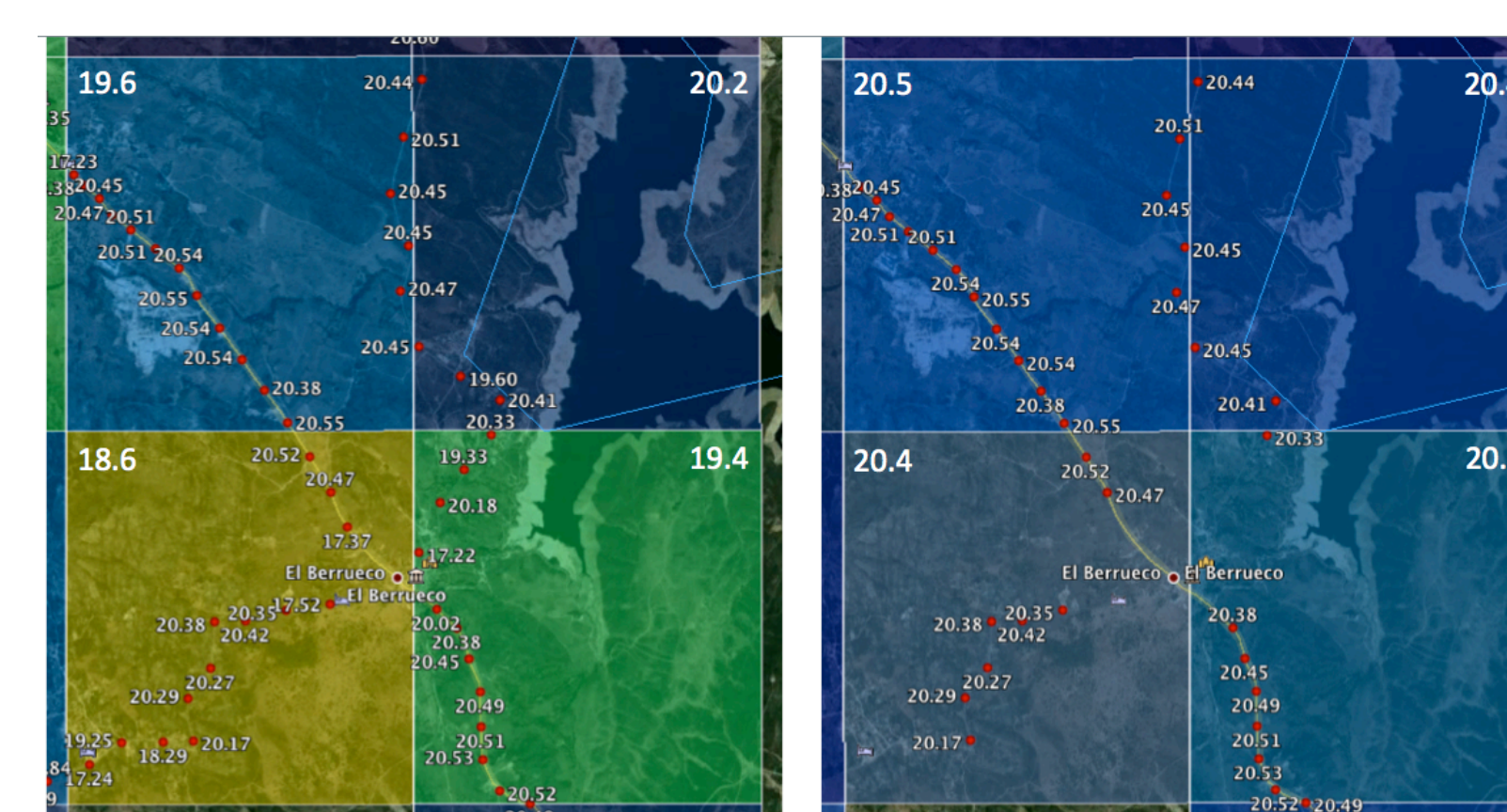


Figure 3: Results around El Berrueco. Average SQM magnitude is labeled in white fonts. (Left) All data points included and (Right) after filtering out points inside the village or near light foci.

Caveats

- The final map is built with data taken in different nights with three SQM photometers that have been cross-calibrated to remove zero offsets.
- The SQM band covers Johnson B & V bands. Transformation from SQM magnitudes to astronomical bands depends on the sky color (see Cinzano report "Night Sky Photometry with Sky Quality Meter").
- Sky colour is related with the type of light sources that contribute to light pollution.
- Sky brightness varies during the same night both in colour and intensity.

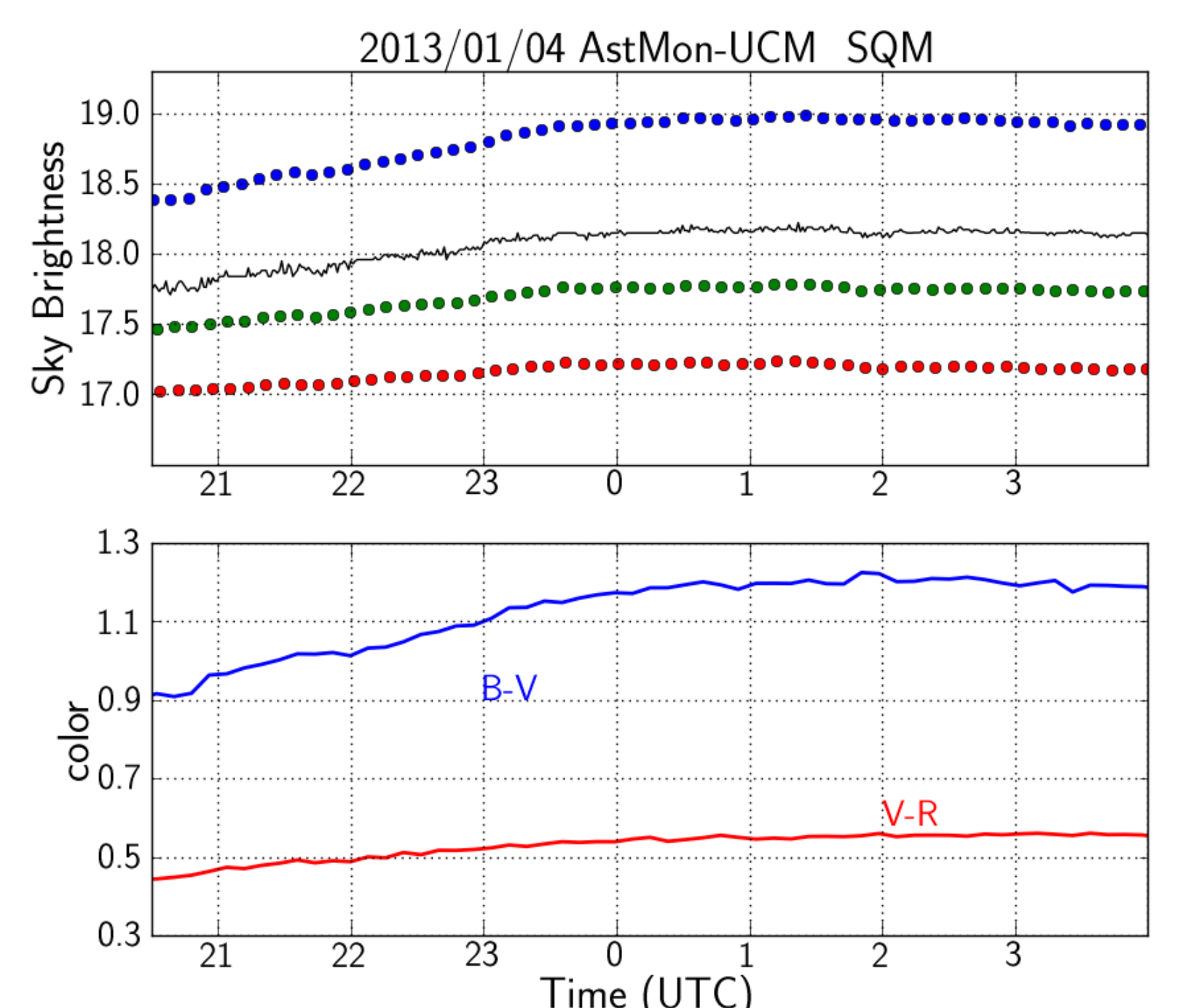


Figure 4: Johnson B, V and R magnitudes around the zenith obtained in Observatorio UCM (blue, green and red points and SQM values (black points) along one clear night. Variation in both quantity and quality of light sources is evident.

MAIN RESULTS

Light Pollution comparison

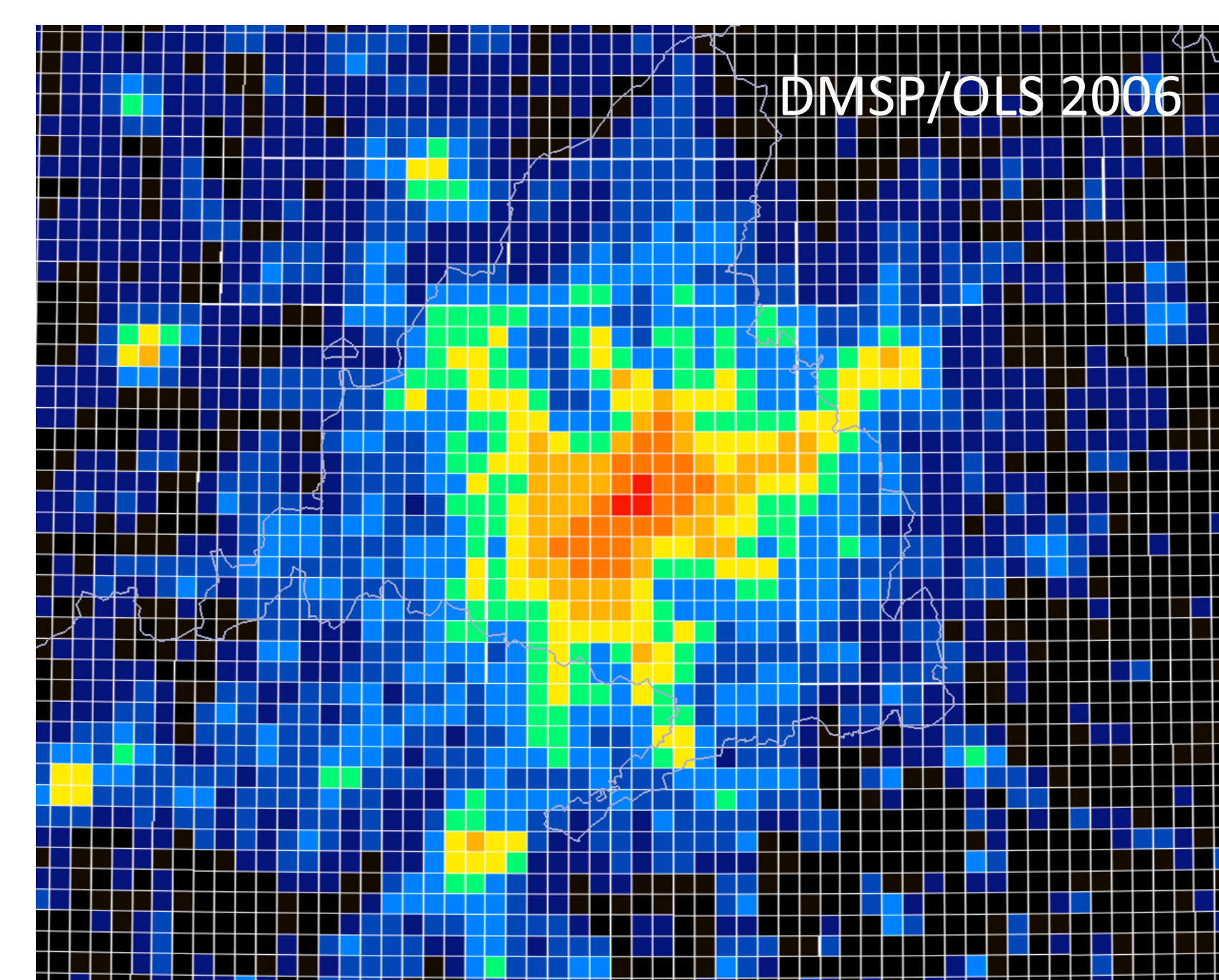


Figure 6: NASA-NOAA DMSP/OLS image with the urban area of Madrid in the middle. To mimic the SQM map, the values are plotted in log scale and the resolution is degraded to cells 2 arcmin wide. The cities of Toledo, Guadalajara, Segovia, Avila, Talavera de la Reina, and Aranjuez clearly stand out.

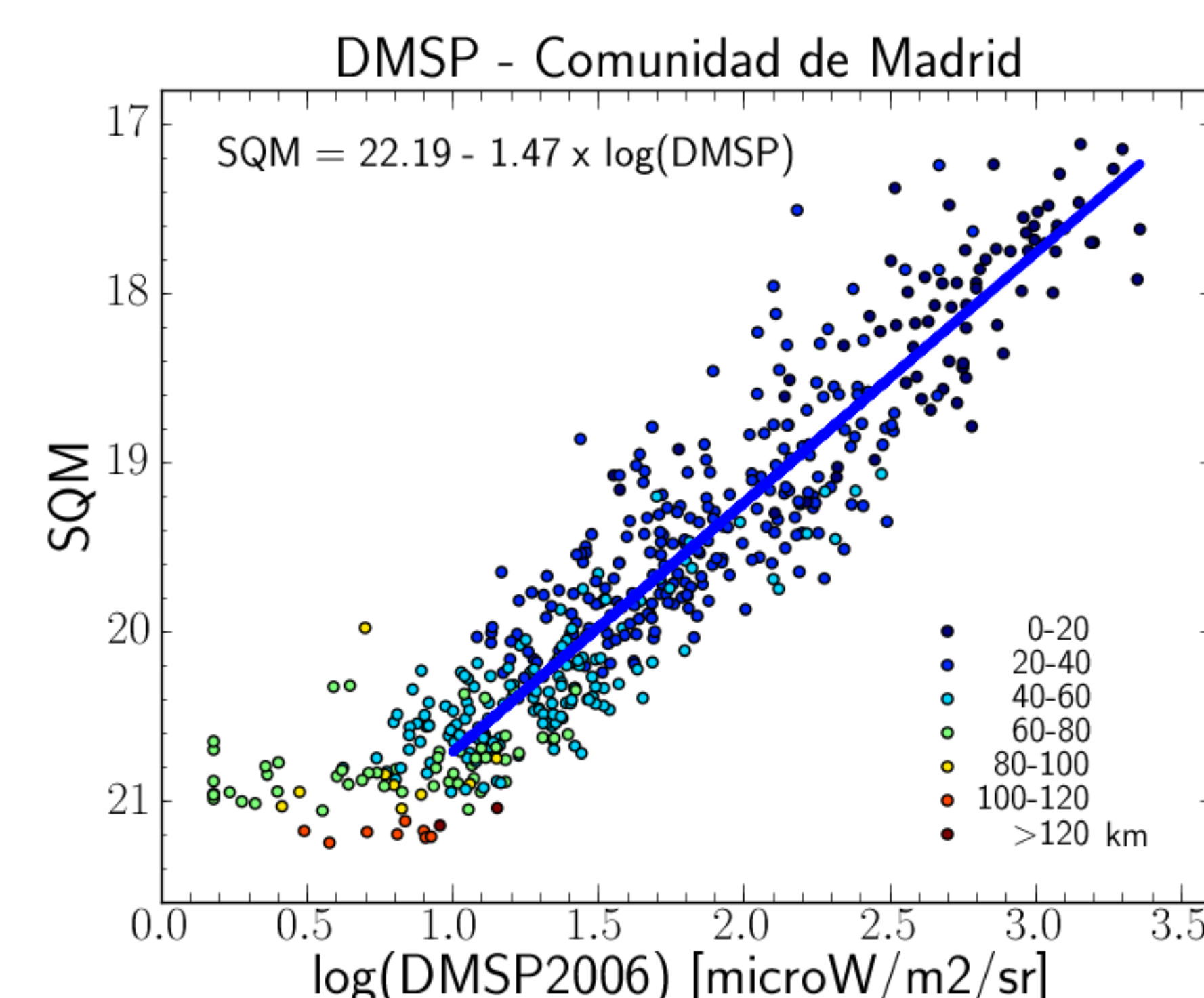
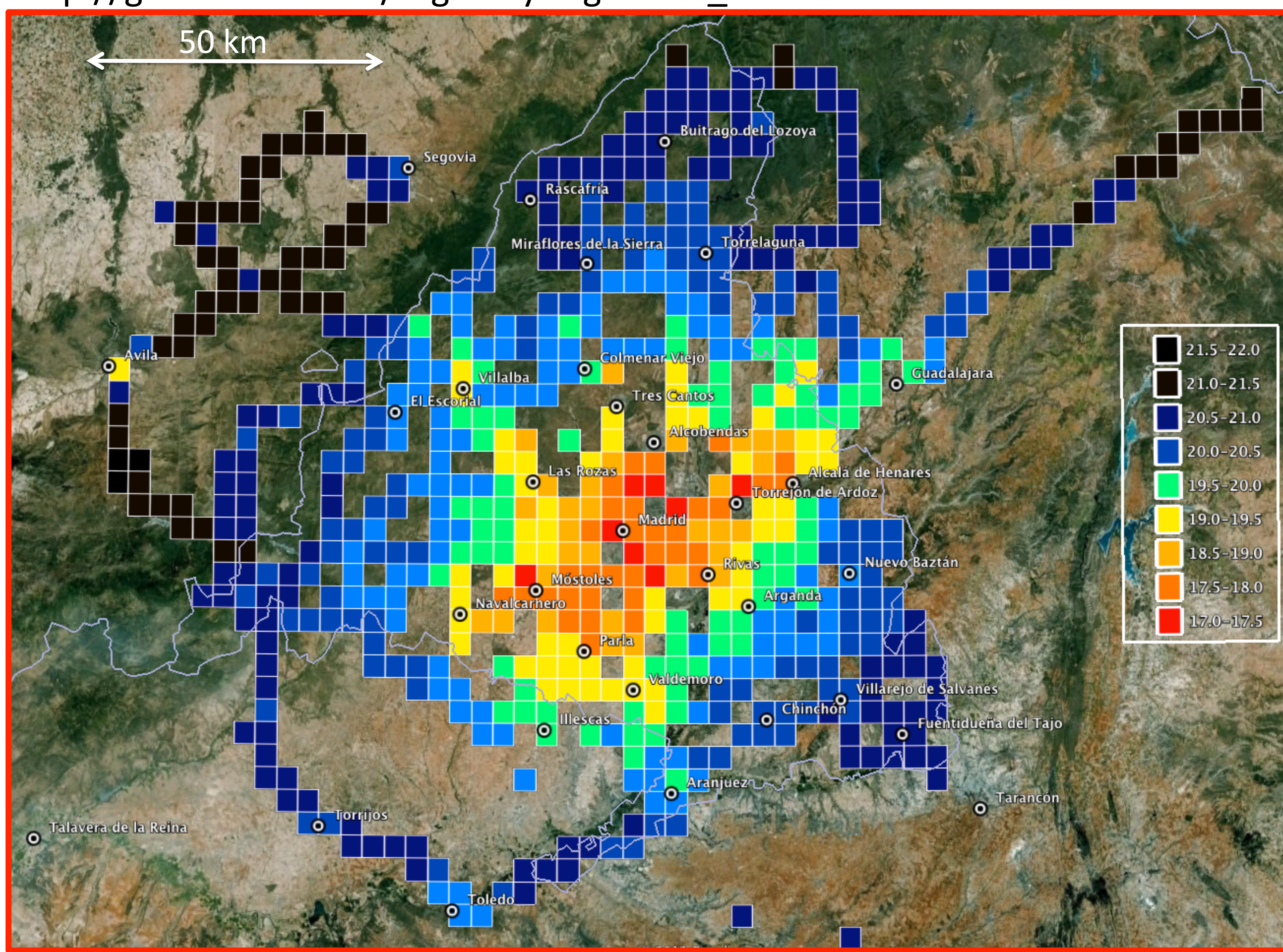


Figure 7: Direct comparison of the amount of light detected from space by DMSP/OLS with Night Sky Brightness in cells 2 arcmin wide to minimize the effects of instrument artifacts or PSF. The satellite detects light scattered by the atmosphere and a good relationship is expected.

The points have been color coded with distance to Madrid city center. It is difficult to find dark night skies with brightness over 21 SQM magnitudes inside Comunidad de Madrid.

http://guaix.fis.ucm.es/NightSkyBrightness_Madrid



Work in Progress

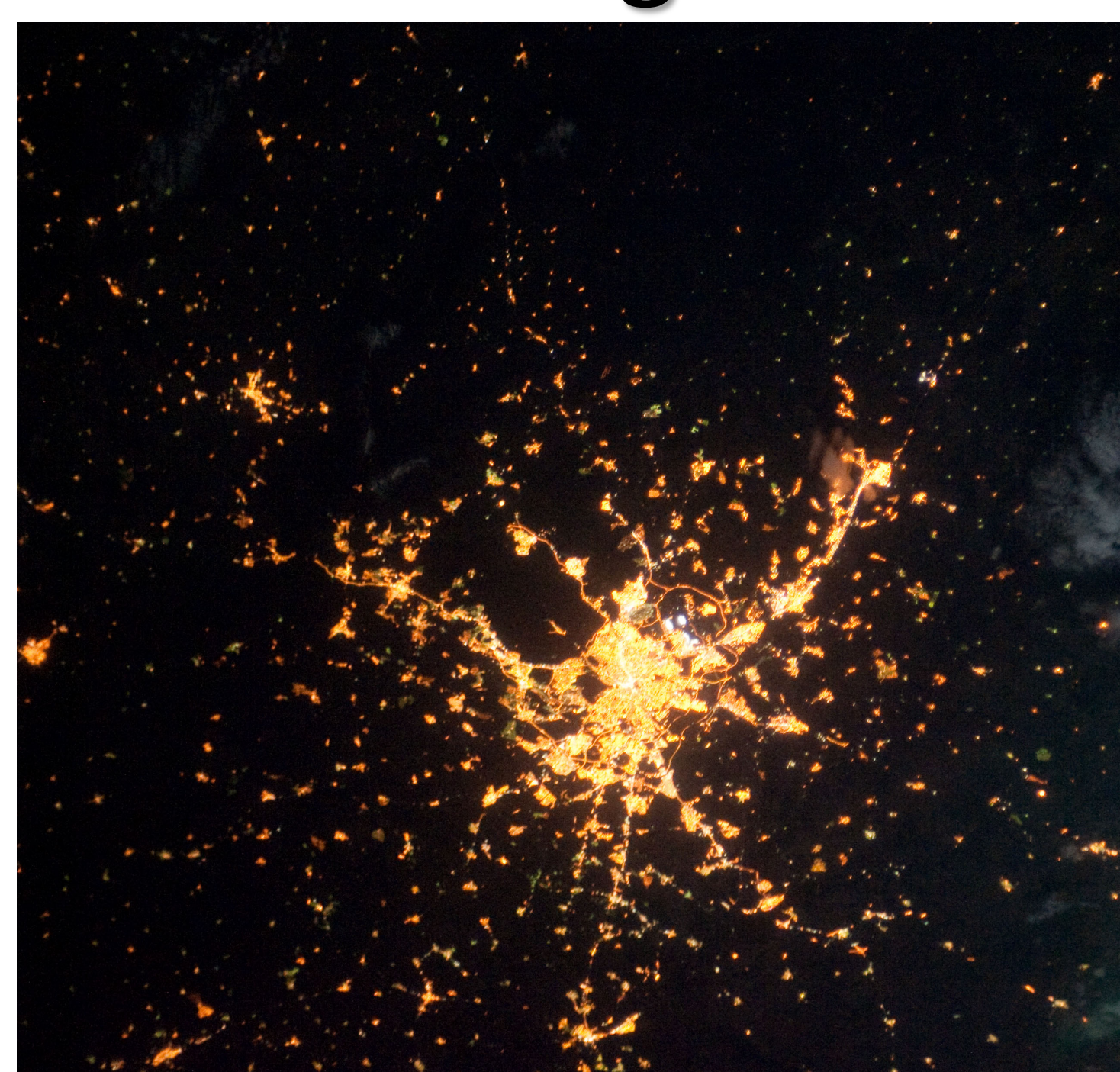


Figure 8: ISS nocturnal picture of Madrid area showing an orange color typical of HPS street lighting lamps. The CMOS detector of the Nikon D3s digital camera used for ISS pictures has three channels (RGB) that can be used to get information of the light sources.

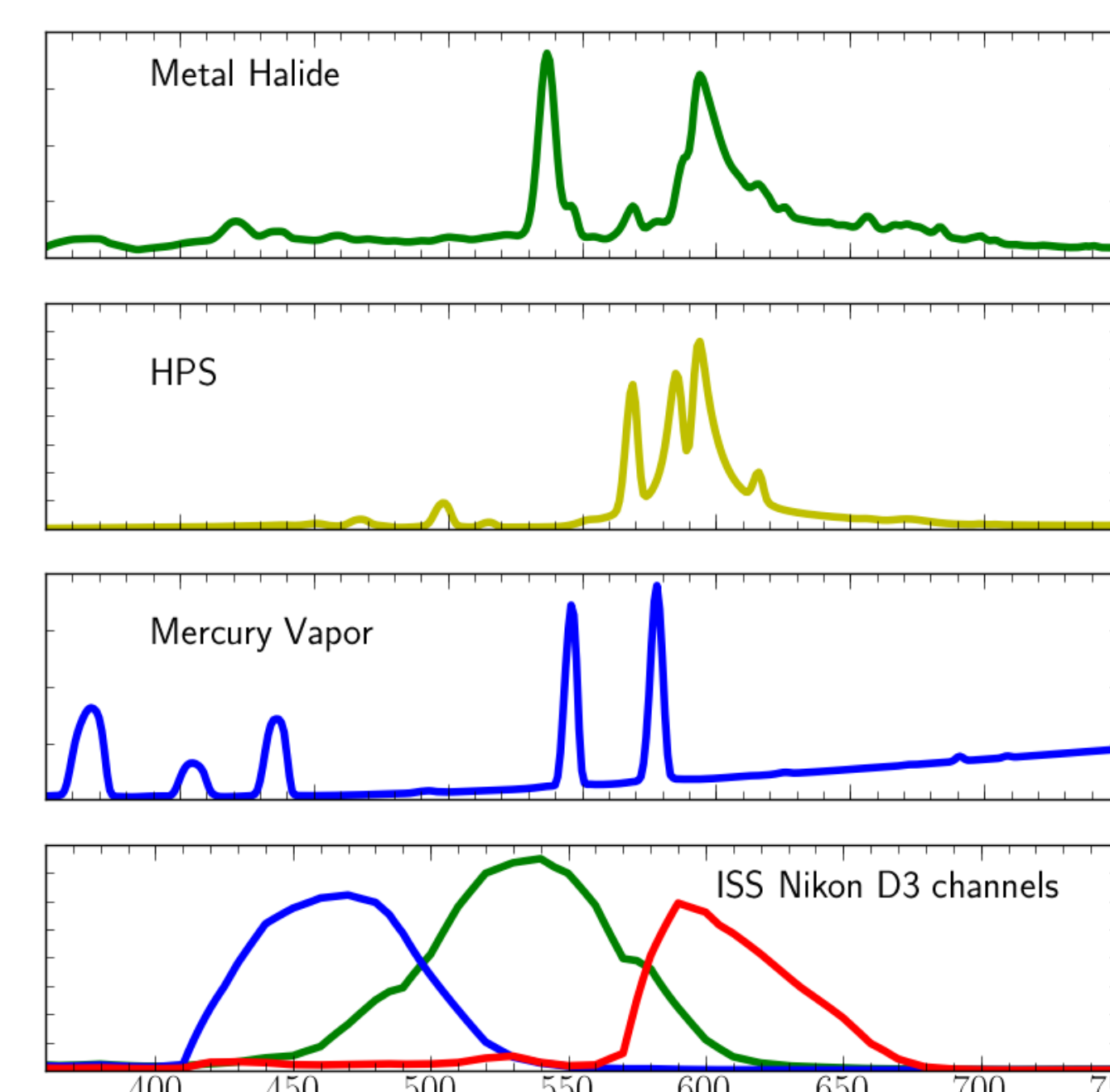


Figure 9: Spectra of lamps used in public lighting and spectral response of a Nikon D3 camera (Laboratorio de Investigación Científica Avanzada, LICA-UCM).

Spectral signatures from the NOAA lighting spectral library from Kruse & Elvidge, 2010.

Sky Brightness Map

Figure 5: Night Sky Brightness map. The survey is still in progress. Main villages and cities are labeled. The magnitudes are displayed in the SQM band which comprises the Johnson B and V astronomical photometric bands.

Madrid urban area is the main source of light pollution in the center of the Iberian peninsula. Its effect extends radially but not symmetrically. The glare of Madrid's lights is easily visible from a distance of 150 km in North East direction.

The brightness of the night sky reaches values near those of natural skies at different distances from Madrid city center depending on the orography. We have measured dark sky values (SQM=21.5) at 76 km West and 85 km North West in places at the other side of Guadarrama mountain range.

We intend to set a network of photometers in fixed locations to study the daily and long term evolution of the night sky brightness.

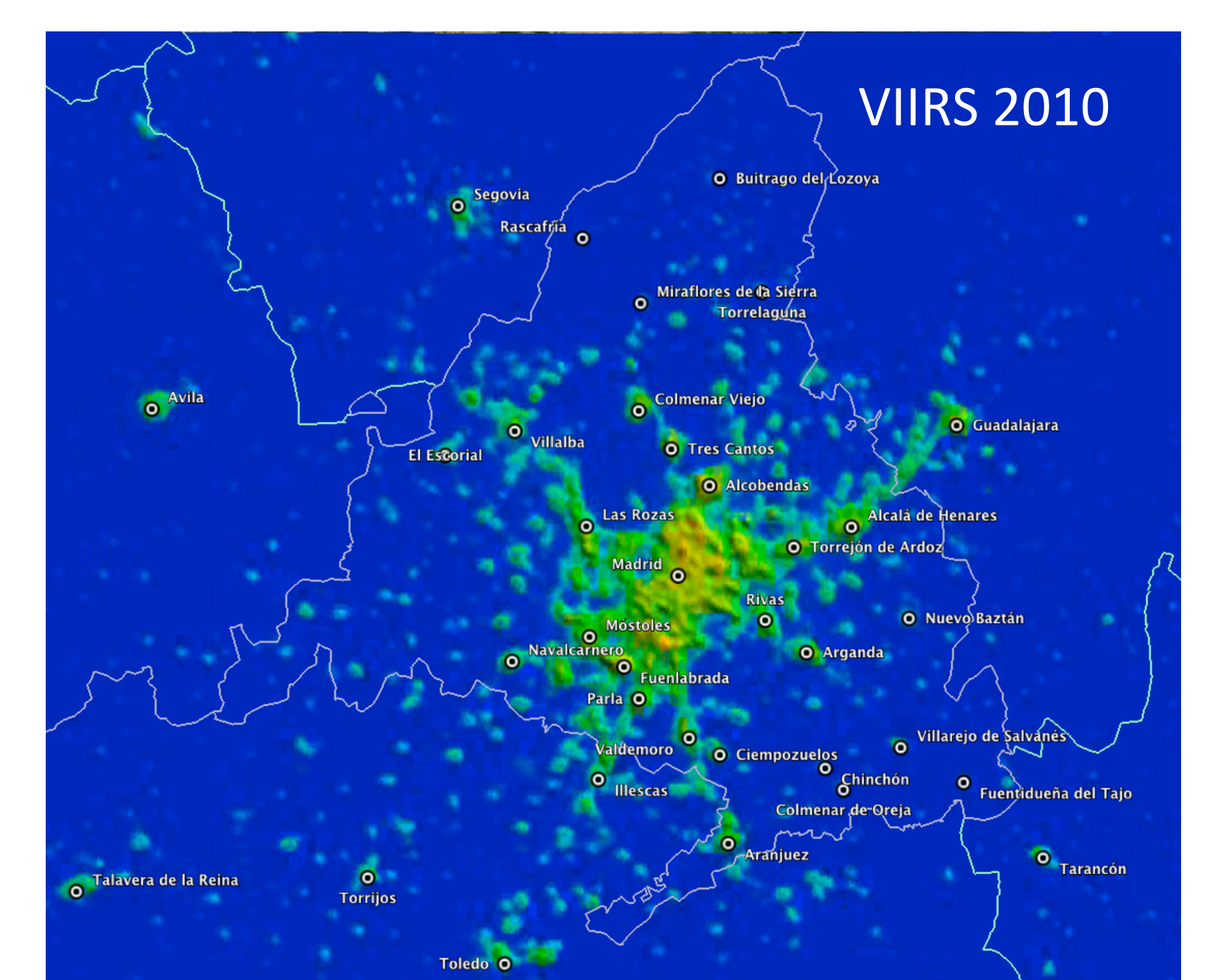


Figure 10: New satellite NASA-NOAA SUOMI NPP VIIRS-DNB images have better spatial resolution than previous DMSP/OLS data.

We are working with this data to compare Night Sky Brightness and Light Pollution using models of the artificial sky radiance as ILLUMINA.