National Oceanic and Atmospheric Administration

2015 NOAA SATELLITE CONFERENCE

Preparing for the Future of Environmental Satellites

Greenbelt, Maryland - USA, 27th April - 1st May 2015

UNIVERSIDAD NACIONAL DE ROSARIO

FACULTAD DE CIENCIAS EXACTAS, INGENIERIA Y AGRIMENSURA.

CENTRO DE SENSORES REMOTOS

Night Light Pollution in Large Coastal Urban Areas through Nighttime DMSP Satellite Images.

Principal Investigator: Cotlier, Carlos[(1)] / Co-Investigators: Pacino, Cristina[(2)] – Barparda, Laura[(1)] – Cotlier, Gabriel[(3)] – López, Diego[(1)].

[(1)]Centro Sensores Remotos – Universidad Nacional de Rosario – Argentina, [(2)]CONICET – Universidad Nacional de Rosario – Argentina, [(3)]Technion – Israel Institute of Technology – Israel.

e-mail: csr@fceia.unr.edu.ar

Introduction.

Pollution is detrimental alteration of the natural state of an environment as a result of the introduction of an oblivious agent (pollutant), causing instability, disorder, harm or discomfort to the ecosystem, in a physical or in a living being.

Marine light pollution could be defined as a “degradation of photic habitat by artificial light” (Verheijhen, 1985), disturbing natural organisms behavior when are exposed on wrong place, time and intensity (Marine Pollution Bulletin, 2010).

Coastal urban areas have experienced worldwide a rapid population growth due to global economic development and subject to high anthropogenic pressures that pose a threat to biodiversity and the surrounding ecosystems.

At least 3351 cities worldwide are over the shoreline spreading light over beach and seaboard, 18 of the 20 largest cities from Asia are located on the coast, shoreline or river deltas (Marine Pollution Bulletin, 2010).

Most living organisms are sensitive to natural light quality and intensity changes. For example photosynthetic activity of marine algae and some marine animal species behavior are susceptible to such changes.

Night-time Satellite data have been use on several research subjects related to population and energy consumption (Elvidge et al, 1997), urban area mapping (Imhoff et al, 1997), estimation of worldwide flared gas volumes (Elvidge et al, 2007) and economic development (Sutton et al, 2007).

Regarding ecology and environment subject we could mention forest fire monitoring (Badarinath et al, 2011) and plankton artificial light influence (Kazushi et al, 1997).

In this first stage research we going to focus preliminary, on marine/coastal environments of six cities selected for their distinct urban characteristics and geographic location.

Preliminary research presents a methodology to model “night light pollution” combining satellite imagery with geographic information systems (GIS) and vector shape data, such as bathymetry, coastal boundaries and city limits.

Satellite data products used in this research are produced by the NOAA agency (National Oceanic and Atmospheric Administration), from DMSP-OLS (Defense Meteorological Satellite Program – Operational Line Scanner) instrument from Department of Defense (DoD, EEUU) program run by the Air Force Space and Missile Systems Center (SMC).

Finally, a comparison of data collected and processed in order to initiate the characterization of the phenomenon in the 6 case studies.

Data and Methodology.

DMSP-OLS (Defense Meteorological Satellite Program – Operational Linescan System, EEUU) satellite data was used for night light pollution research. OLS instrument detect emissions in visible near-infrared electromagnetic spectrum region. As an optical satellite depends on weather conditions, therefore a selection process must be done in order to have proper set of data.

DMSP platform have a 830 Km low altitude sun-synchronous near-polar orbit and 101 minutes orbital period. OLS visible and infrared sensors capture data with a 3000km swath, twice a day global coverage. OLS instrument consists of two telescopes and a photomultiplier tube (PMT).

The telescope is sensitive to visible radiation in the range of 0.40 to 1.10 mm (0.58 to 0.91 mm FWHM) and 3.10-5.10 w/cm2sr (watts per cm2 per steradian) and sensitive to infrared radiation from 10.0 to 13.4 m (10.3 to 12.9 m FWHM) and 190 to 310 Kelvin degrees. PMT is sensitive to radiation of 0.47 to 0.95 m (0.51 to 0.86 m FWHM) and 5.10-9.10 w/cm2·sr (watts per cm2 per steradian). Detectors sweep back and forth in a pendulum motion. Analog signal is sampled continuously at a constant rate so that each pixel centers are approximately equidistant at 0.5 km apart.

Satellite data used in the present research correspond to a NOAA product called Average Lights x PCT (year 2009), derived from digital number (DN) light detection average of visible nighttime lights without clouds, multiplied by light detection frequency percentage.

This processing creates a product free of clouds, moonlight, sunlight glare, also eliminates potential sources noise removing nightlight ephemeral (like forest fires). PCT image designation indicates Plate Carrée projection (EPSG projection code 4326/WGS84). Pixels coordinates are in latitude and longitude.

As an example images of Barcelona are displayed to illustrate the developed methodology.

A working image subset was defined for each city and applied a projection transformation from Plate Carree (EPSG 4326/WGS84) to UTM projection according each research area spatial location (Figure 1).

Shoreline World Vector layers (National Geospatial-Intelligence Agency – NGA, USA) were used for land/water delimitation.

A mask using shoreline vector layer was created to define each subset marine area. Masks were applied on each cities subset to remain only sea illuminated pixel (Figure 2).

Urban cities vector layers areas were used to define light spill on coastal area and calculate phenomenon affected area. Selection began on seashore (according to normal base line) to zero illumination pixel (DN = 0) over the sea (Figure 2).

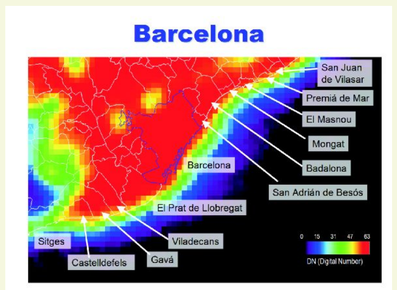


Figure 1

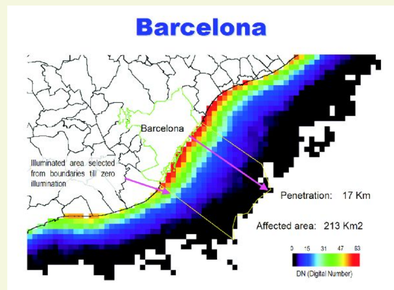


Figure 2

Affected area polygon was created over projected subset whose boundaries are coastline on one side, extension of urban research cities area boundaries and finally zero illumination area limit (Figure 3).

A mask was created with affected vector layer created with each city data from sea illuminated pixels and applied to each DMSP cities image subset, leaving only pixels corresponding to that city. Maximum penetration distance was calculated for each affected area, being maximum distance between coasts and zero pixels sea limit (Figure 3).

Scripps Institute of Oceanography University of California San Diego (http://topex.ucsd.edu/cgi-bin/get_data.cgi) bathymetric data was used to have seafloor topography estimate. Data consist on a 1 minute latitude and longitude grid size. A raster image was created using interpolation (Figure 4).

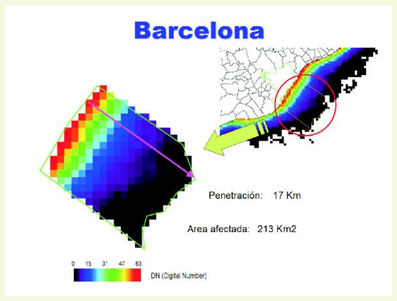


Figure 3

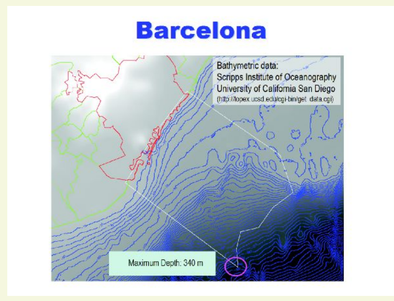


Figure 4

Isobaths (depth contours lines) were created based on bathymetric grid rasterization and overlapped to each cities night lights affected area (Figure 5).

Average light density was calculated for each defined affected area, using sum of DMSP subsets DN values and affected area surface (Figure 6, Table I), for cities sea night lights comparison. DN values to radiance passage was performed with the following formula:

$$\text{Radiance} = DN^{3/2} \times 10^{-10}\ W\ cm^{-2}sr^{-1}m^{-1}$$

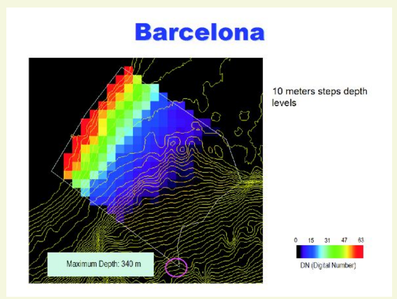


Figure 5

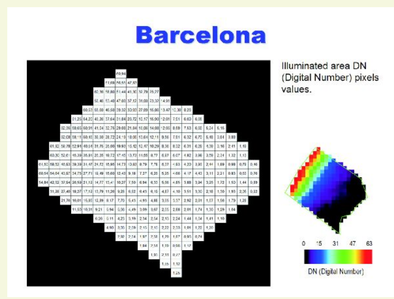


Figure 6

Results.

Table I list collected and processed values from 6 evaluated cities. Average luminance was calculated based on pixels light intensity sum and illuminated surface.

Cities Summary

Luminic Density = DN Total Pixels / Illuminated Area

City	Area (Km2)	Penetration (Km)	Depth (m)	Total Illuminated Area		Luminic Density	
				DN	Radiancia Radiance	DN	Radiancia Radiance
Naples	187	19	375	3450,96	1,98552E-06	18,454E-6	10,618E-15
Athens	152	17,7	95	3836,03	2,39083E-06	25,040E-6	15,729E-15
Buenos Aires	365	25	2	5709,14	2,95301E-06	15,641E-6	8,090E-15
Barcelona	213	17	340	4191,00	2,43122E-06	19,676E-6	11,414E-15
Istanbul	273	23,3	1240	7551,75	4,91549E-06	27,662E-6	18,005E-15
New York – New Jersey	1104	32,3	30	23231,38	15,73014E-06	23,760E-6	14,285E-15

Table I

To analyze relationship between illuminated area and luminance several, gathered and processed data was used on several charts (Charts 1 and 2).

Affected areas statistical values of the 6 cities were plotted across Box Plot charts (Box Plot 1 and 2) with pixels data in DN and radiance. Provides information on the minimum and maximum values, quartiles .

Box Plot shows:

1. Buenos Aires DN pixels have lowest dispersion and small values, indicating that satellite receives little energy in that area, despite being one with large number of outliers. Lower dispersion with low values and the presence of large number of outliers.
2. Istanbul DN pixels have large dispersion, with high values (distribution outliers are not observed). Greater dispersion with high values without the presence of outliers.

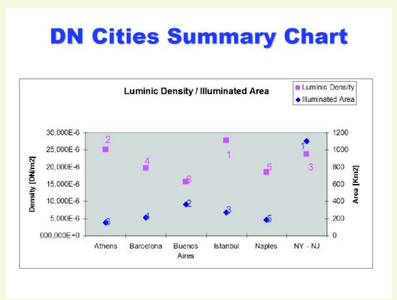


Chart 1

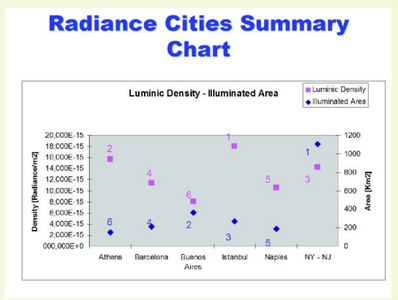
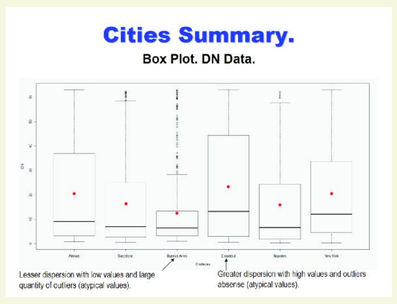
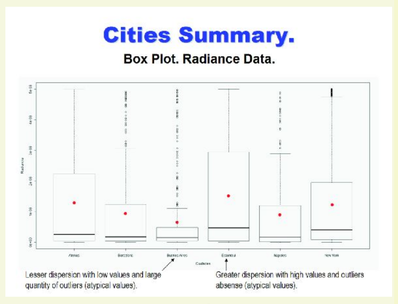


Chart 2



Box Plot 1



Box Plot 2

Discussions and Preliminary Conclusions.

Figures 1 and 2 shows:

1. Buenos Aires city has the smallest average luminance with an important light pollution affected area. Could be awarded to geography on which city is located, with a river (freshwater and very low depth) in its waterfront instead open sea.
2. Istanbul followed by Athens and New York/New Jersey have the highest average luminance but emphasizing that New York/New Jersey area is extensive, nearly 4 times bigger than Buenos Aires area (second in illuminated area size). These circumstances also merit further analysis of the geographical location of these cities.

To complement data and available information preliminary analysis, following subjects will be analyzed:

3. Geographic and oceanographic waterfront and surrounding features of analyzed cities.
4. Impacts of light pollution on coastal living organism's behavior, analysis could provide new considerations for urban coastal centers expansion and planning.
5. More efficient illumination systems possible use that could reduce light ocean pollution phenomena.

References.

[1] VERHEIJEN F.J. (1985). Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causations, remedies. Experimental Biology. Vol. 44, 1–18.

[2] EDITORIAL (2010). Light pollution in the sea. Marine Pollution Bulletin. Vol. 60, 1383–1385.

[3] MAZOR T., LEVIN N., POSSINGHAM H. P., LEVY Y., ROCCHINI D., RICHARDSON A., KARK S. (2013). Can satellite-based night lights be used for conservation? The case of nesting sea turtles in the Mediterranean. Biological Conservation 159 (2013) 63-72.

[4] ELVIDGE, C.D., BAUGH, K.E., KIHN, E.A., KROEHL, H.W, DAVIS, E.R, DAVIS, C. (1997). Relation between satellite observed visible - near infrared emissions, population, and energy consumption. International Journal of Remote Sensing. Vol. 18, 1373–1379.

[5] IMHOFF, M.L., LAWRENCE, W.T., STUTZER, D.C. Y ELVIDGE, C.D. (1997). A Technique for Using Composite DMSP/OLS 'City Lights' Satellite Data to Accurately Map Urban Areas. Remote Sensing of Environment. Vol. 61, pag. 361–370.

[6] SUTTON, P.C. (2003). A scale-adjusted measure of “Urban sprawl” using nighttime satellite imagery. Remote Sensing of Environment. Vol. 86, Num. 3, 353–369.

[7] ELVIDGE C.D., ERWIN E.H., BAUGH K.E., TUTTLE B.T., HOWARD A.T., PACK D.W., MILESI C. (2007). Satellite data estimate worldwide flared gas volumes. Oil and Gas Journal. 50–58.

[8] SUTTON P.C., ELVIDGE C.D., GHOSH T. (2007), Estimation of gross domestic product at sub-national scales using nighttime satellite imagery. International Journal of Ecological Economics and Statistics. Vol. 8 (SO7), 5–21

[9] BADARINATH K.V.S, SHARMA A.R., KHAROL S.K. (2011). Forest fire monitoring and burnt area mapping using satellite data: a study over the forest region of Kerala State, India. International Journal of Remote Sensing. Vol. 32, Num. 1, pag. 85–102.

[10] KAZUSHI O., MASAYUKI S. Nighttime Emergence Patterns of Planktonic and Benthic Crustaceans in a Shallow Subtidal Environment. (1997) Journal of Oceanography. Vol. 53, 611–621.

[11] RODRIGUES P., AUBRECHT C., GIL A., LONGCORE T., ELVIDGE C. (2012). Remote Sensing to map influence of light pollution on Cory´s shearwater in Sao Miguel Island, Azores Archipielago. Springer. DOI 10.1007/s10344-011-0555-5.

[12] EUROPEAN PETROLEUM SURVEY GROUP. (2012). EPSG, Geodetic Parameter Dataset version 8.1. Coordinate Reference System. http://www.epsg.org.

[13] ELVIDGE C.D., BAUGH K.E., DIETZ J.B., BLAND T., SUTTON P.C., KROEHL H.W. (1999). Radiance Calibration of DMSP-OLS Low-Light Imaging Data of Human Settlements. Remote Sensing of Environment. Vol. 68, 77–88.