Introductory Guide to Nighttime Lights

Multi Donor Trust Fund for Sustainable Urban Development

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INTRODUCTORY GUIDE TO
GLOBAL NIGHT TIME LIGHTS (NTL) DATASET
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IN TECHNICAL COLLABORATION WITH ITSQS
OUTLINE

- Why Night Time Lights (NTL)?
- Source Data
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  - DMSP-OLS - Radiance Calibrated
  - Inter-Annual Calibration
- Things to Note About NTL Data
- Potential Applications to Urban and Spatial Studies
- Importance of Triangulation
- General Guidelines for Applying NTL Data to Urban and Spatial Studies
WHY NIGHT TIME LIGHTS?

- It offers a versatile and *global dataset* to social scientists, available at a *relatively fine spatial* resolution.
- It captures a *relative, regional* indicator of urbanization and development in a *cost effective* way.
- It can be used to *map and quantify city and agglomeration extents* for several points in time globally, using locally relevant thresholds of brightness.
- It can be used to identify patterns of *intensive vs. extensive* urban growth.
- It can be used to help construct sub-national level *proxy measures of economic growth and local productivity* in data scarce environments.
SOURCE DATA

- Defense Meteorological Satellite Program (DMSP) – Optical Line Scanner (OLS) database.
  
  http://ngdc.noaa.gov/eog/
  
  http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html
  
  http://ngdc.noaa.gov/eog/dmsp/download_radcal.html
SOURCE DATA – ABOUT THE SATELLITES

- Satellites: Defense Meteorological Satellite Program (DMSP) – 9 satellites (F10 to F18)
- Equipment: Operational Linescan System (OLS) on board 6 DMSP satellites.
- Records visible and near-Infrared emissions from the sun or the moon reflected off clouds and other features.
- Records ground-based sources such as *city lights*, forest fires, gas flares etc. on cloud free nights.
- Light intensity predominantly represents outdoors lights that emanate from infrastructure and economic activities.
- Resolution: 30 arc seconds (~1 km at the equator)
- Global imageries are created by using night time imageries from different nights for different regions of the world, so as to get a cloud free global composite.
TYPES OF DATASETS

- DMSP-OLS - Average Visible, Stable Lights
- DMSP-OLS - Radiance Calibrated (Rad-Cal)
- DMSP OLS – Average Lights X Pct*

*Average Lights x Pct dataset is not relevant to urban spatial studies. The nighttime lights product known as avg_lights_x_pct is derived from the average visible band digital number (DN) of cloud-free light detections multiplied by the percent frequency of light detection.
Average Visible, Stable Lights data created by giving each pixel the average value of pixel values from all cloud free night screens within a given year for a particular location.

Pixel values measure light intensity where 0 indicates the absence of light and 63 is the maximum recorded due to top-coding.

Most commonly used dataset until recently with the release of Radiance Calibrated datasets.

**Advantage:** Consistent time series data available for all years between 1992 - 2013.

**Disadvantage:** Issue of saturation in brightest (core) parts of major cities implies that variation/growth within the core cannot be observed.

Source: CIESIN Thematic Guide to Night-Time Light Remote Sensing and its Applications; Doll, Christopher N.H.
To fix saturation issue, Department of Defense (on request) changed sensor settings on satellites to record greater variation in brightness for some years.

**Advantage:** Larger variation in urban cores implies **better estimates of economic productivity.**

Since DMSP is a constellation of 9 satellites, sensors on board different satellites record light from same sources at different levels of brightness, even within similar time periods.

Different times of data acquisition for satellites lead to systematic fluctuations as well.

In order to ensure cross-dataset and temporal comparability of brightness, NOAA provides ways to standardize measures of brightness over time through inter annual calibration coefficients. However, this inter-annual calibration is not perfect.

http://ngdc.noaa.gov/eog/dmsp/radcal_readme.txt
THINGS TO NOTE ABOUT USING NTL DATA

STRENGTHS
- Free to download
- Easy to use given some GIS expertise.
- Quick and objective methods of urban extents delineation

WEAKNESSES
- Overglow phenomenon can bias results
- Inter annual calibration of lights across time periods is not completely accurate due to sensor characteristics

OPPORTUNITIES
- Global and regional mapping of urbanization
- Ability to evaluate change using time series
- Widely used proxy for economic productivity and growth

THREATS
- Not advisable to use at very low levels of spatial disaggregation – e.g. derivation of city GDP levels
- Data should not be relied upon to derive precise quantitative conclusions at fine spatial scales (e.g. regarding expansion/growth of a given city)
- Unreliable for measuring change for cities smaller than 20 SqKm
Things to Note about Using NTL Data – Overglow Phenomenon

- **Overglow** phenomenon, often also called blooming, refers to dispersion of light due to atmospheric conditions like presence of water vapor, which result in overestimation of total lit area.

- This makes brightness threshold determination a very critical aspect of utilizing NTL datasets.

- There is **no single threshold** that would match the urban delineation of all cities since atmospheric conditions and intensities of source lights are different.

Source: CIESIN Thematic Guide to Night-Time Light Remote Sensing and its Applications; Doll, Christopher N.H.
APPLICATIONS TO URBAN AND SPATIAL STUDIES
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- Urban extents estimation.
- Urban and regional growth (intensive vs. extensive patterns of growth).
- Observing regional settlement patterns and urbanization trends based on time-series data.
- Identifying urban agglomerations.
- Developing composite measures of economic productivity.
APPLICATIONS TO URBAN AND SPATIAL STUDIES – URBAN EXTENTS ESTIMATION

Urban Extents

- Urban **footprint** estimation.
- Calculated using thresholds from the Average Digital Number or the Radiance Calibrated datasets.
- Footprint expansion corresponds to extensive growth.

Source: GSURR & ITSQS
Regional and National Growth

- Calculated from temporal analysis of Radiance Calibrated dataset at the national level.

- Intensive growth.
Urban Growth
- Growth within cities.
- Calculated from temporal analysis of Radiance Calibrated dataset that is limited by a city boundary threshold.
- Captures core-periphery growth patterns.

Source: South Asia Urbanization Flagship report.
Urbanization Trends

- Regional settlement patterns from time series data.

- Can be done using ADN or Rad-Cal. However, Rad-Cal is recommended as it better captures intensive growth.

- In this example, ADN was used and therefore we see saturation in the inner city areas. However, it lets us explore national settlement patterns in time periods for which Rad-Cal is unavailable.

Source: GSURR & ITSQS
Agglomeration Economies

- Rapid expansion of urban footprints.
- Observing transformations from independent towns and cities to multi-city agglomerations.
- Spatial expansion of agglomerations to regional mega-agglomerations.
- Shift of economic activity from city core to urban periphery.
- Ribbon developments and corridors of high economic activity.

Source: South Asia Urbanization Flagship report.
Measuring Economic Productivity

- NTL data is a widely used proxy for economic activity.
- Henderson et al. (2012) suggest using NTL in conjunction with traditional economic indicators, that rely on local data, to form more robust composite metrics of economic activity.
- Utilizing only local metrics drawn from national income accounting are susceptible to classical errors.
- Utilizing only NTL introduces errors from biases in imagery from atmospheric conditions etc.
- Combining local data and NTL ensures error reduction in estimating levels of economic activity.

Example of a composite index using NTL: The Prosperity Index

- **Poverty**: Reflects ability to generate widespread prosperity & avoid extreme income deprivation – indicator: % population living on less than $1.25 per day

- **Productivity**: determines long-run competitiveness – indicator: intensity of night-time lights per km²

- **Dynamism**: dynamic areas will achieve greater progress in raising prosperity over time – indicator: GDP growth rate, 1999-2010

Source: South Asia Urbanization Flagship
APPLICATIONS TO URBAN AND SPATIAL STUDIES – ECONOMIC PRODUCTIVITY

Other examples of NTL vs. GDP

Source: Pakistan Urban Sector Assessment, South Asia Urban Unit (GSUUR)

IMPORTANCE OF TRIANGULATION

Why is it important to test feasibility of a region before applying NTL based productivity estimating techniques?

- Capacity of NTL data to measure true luminance varies across countries by climate and aurora activity.
- Measured luminance for same GDP may vary with different compositions of economic activities.
  - Different activities like services vs. manufacturing,
  - Division of economic activity between night and day, and
  - Population density.
- World wide lighting technology may vary over time, which affects relationship between luminance and GDP.
GENERAL GUIDELINES FOR APPLICATION OF NTL TO URBAN STUDIES

SUMMARY

- Best used to draw broad inferences on urbanization trends and spatial growth patterns.
- Best used at regional or national scales.
- City level analyses are possible in cases where adequate data from local sources is available.
- Strongly advised to first test the viability of using NTL through robustness tests with local data prior to drawing micro level conclusions.
- Best used in conjunction with local data to create composite indicators of productivity.
- Important to understand the three types of NTL data and determine which one is the best fit for your analysis.
KEY REFERENCES AND RESOURCES

- http://ngdc.noaa.gov/eog/
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EXTRA SLIDES