# Satellite Night Light in Economic Research

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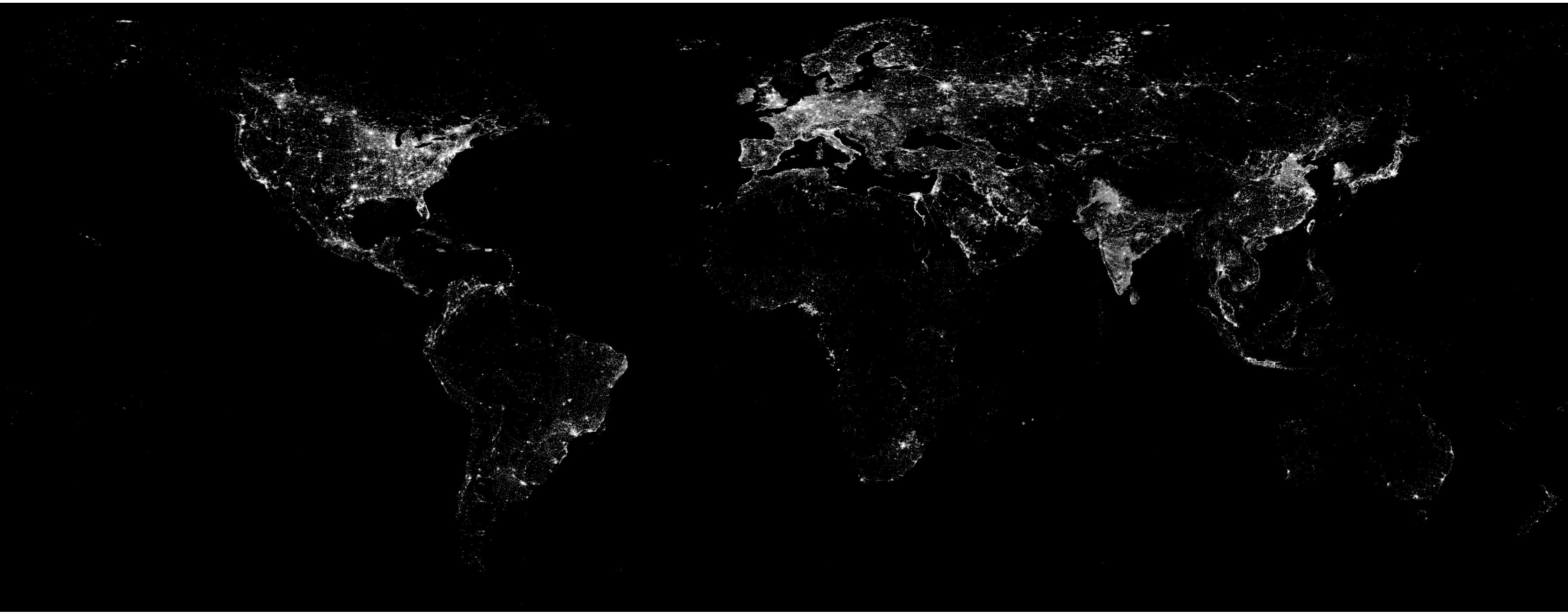
Duke
UNIVERSITY

# Outline

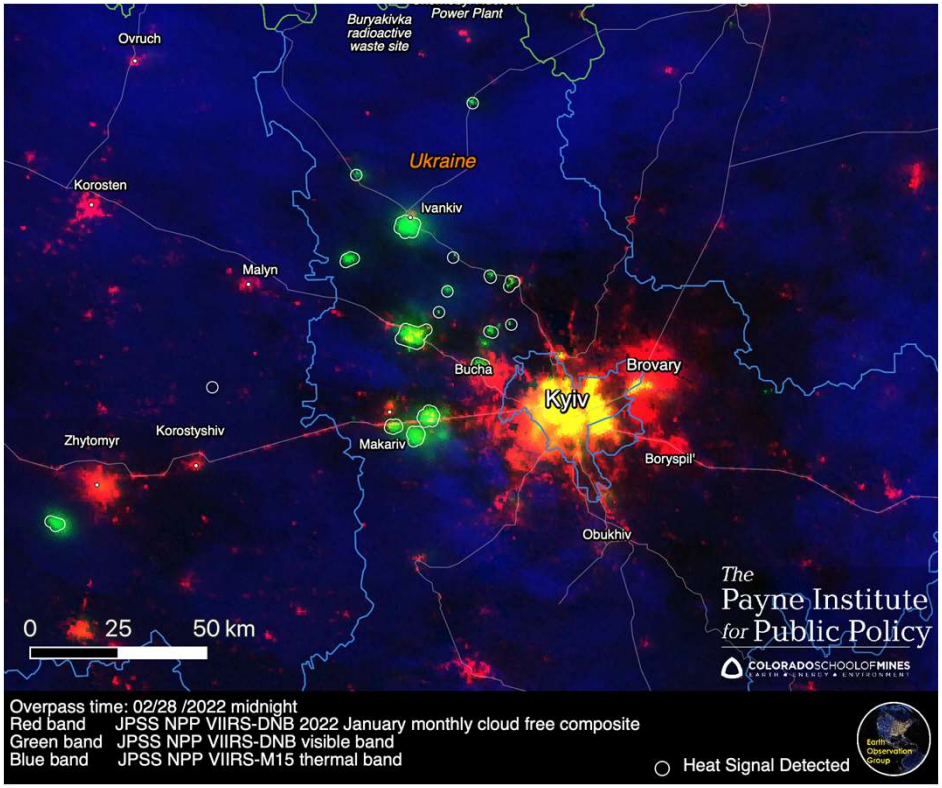
- Data source
- Data description
- Data preprocessing
- Software used for NLD analysis
- NLD in Economic studies
- Related research projects: NLD and Hydro Power Plants (Tajikistan)
- Related research projects: NLD and Health (Kazakhstan)
- Related research projects: NLD analysis of Cities during War (Sri Lanka)
- NLD for Lao PDR



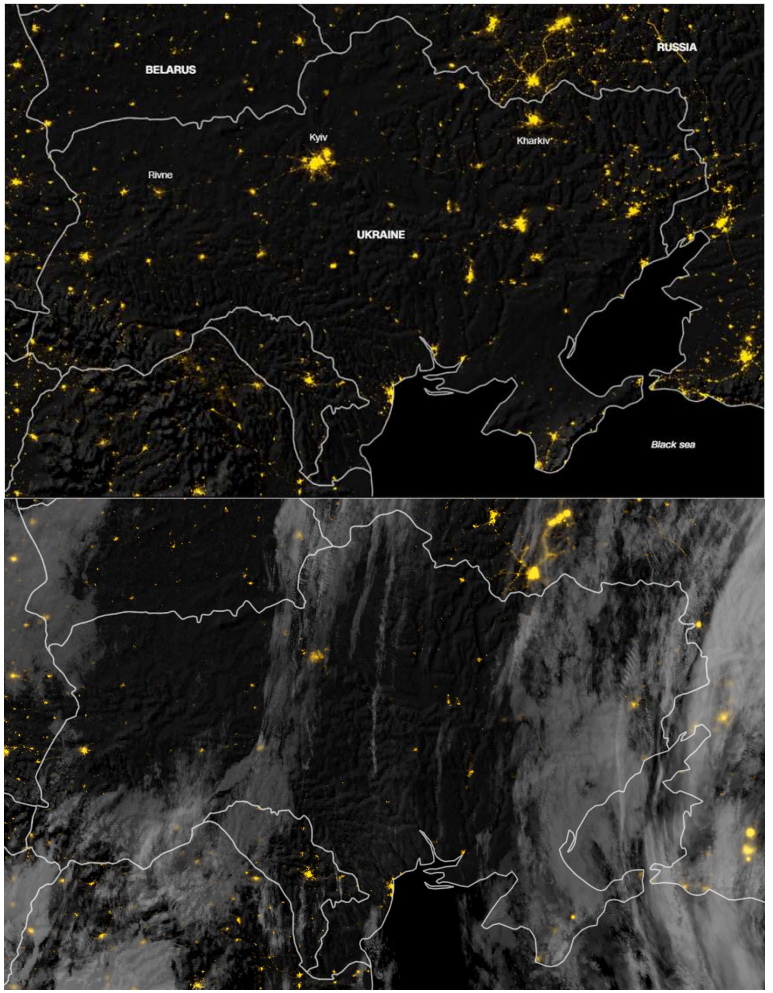
DMSP OLS Night Light Imagery captured by Satellite F18 in 2013

(pre-calibration)

# NLD and conflict zone



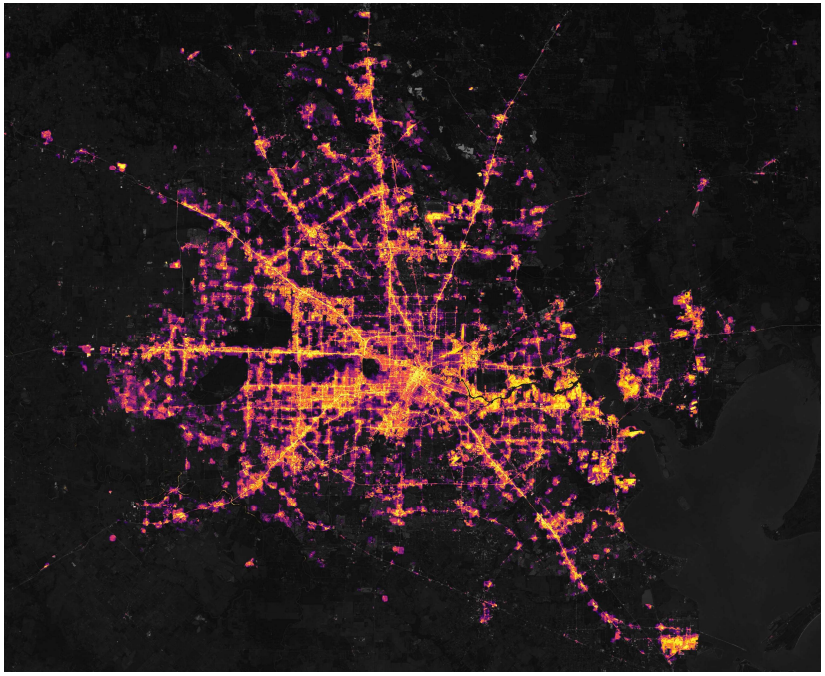

Ukraine on Feb 28, 2022




Ukraine in Jan 2022 and Feb 25, 2022

*Source: Earth Observation Group*

# NLD and disaster impact



Houston, TX on Feb 7, 2021

Houston, TX on Feb 16, 2021

*Source: NASA Earth Observatory*

# NLD source

- Since the 1970s, the U.S. Air Force Defense Meteorological Satellite Program (**DMSP**) has operated satellite sensors capable of detecting visible and near-infrared (VNIR) night light emissions from cities and towns.

- The digitalized version of **DMSP-OLS** Satellite Nighttime Light Data (**NLD**) collected by 5 Satellites is available from **1992**.

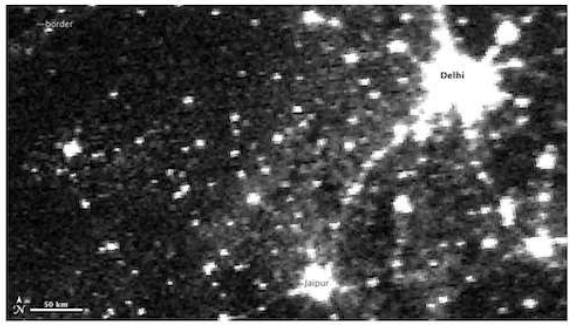
- Since the launch of the latest generation of satellite in **2011**, the Joint Polar-orbiting Satellite System (JPSS), the Visible and Infrared Imaging Suite (**VIIRS**) Day Night Band (**DNB**) on board of JPSS satellites provides higher quality light imaging.

# NLD specification

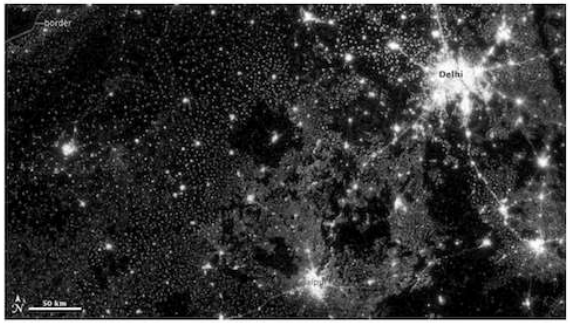
- DMSP-OLS:
  - Monthly and Annual data for period between 1992 and 2013, with an extension series from 2013 – 2021.
  - Image Resolution: 30 arc-second grids (~1km at the Equator)
  - Luminosity is measured in *Digital numbers (DN)* from 0-63
  - Fires, aurora, and background noise are removed
  - Lacks onboard calibration

- VIIRS DNB:
  - Monthly data spanning lights from 2012 to 2020
  - Image Resolution: 15 arc second (~500m at the Equator)
  - Measured in DN from 0-63
  - Fires, aurora, and background noise are removed

DMSP/OLS




VIIRS DNB



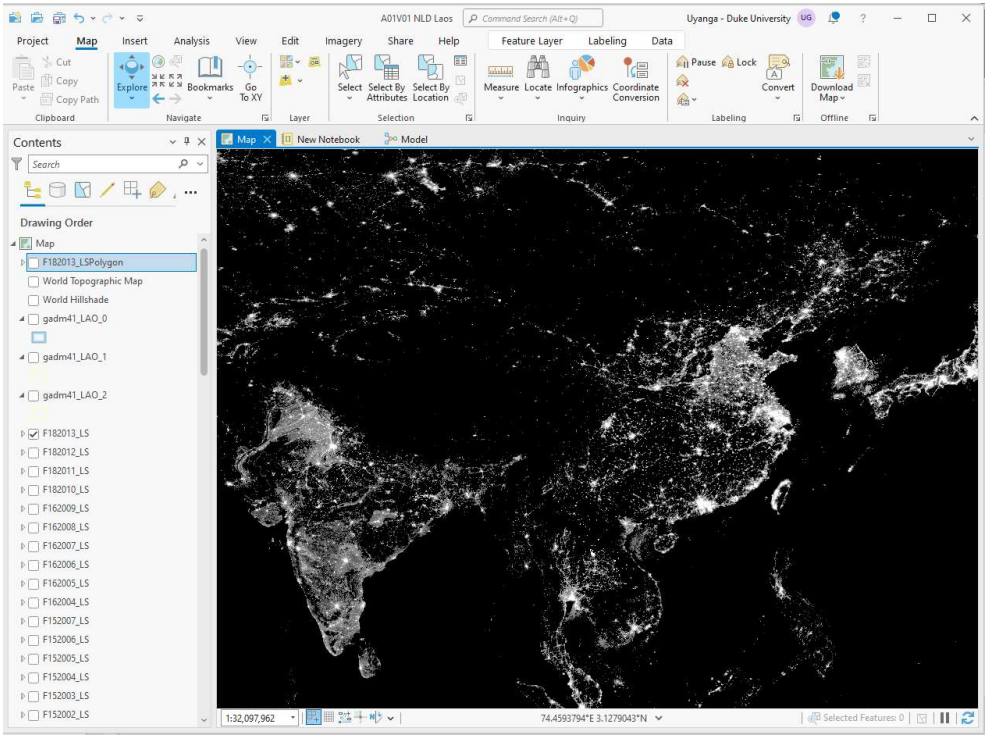
# Software for NLD analysis

For Satellite imagery and NLD processing:

- ArcGIS
  - Desktop and Online versions available
  - Automation using models and Python script
- QGIS
- Google Earth Engine

For NLD processing and analysis:

- Stata
- R
- Python



# NLD preprocessing

- Download NLD and relevant geographical data
  - Shape file of a country with administrative sub-division
  - 2-3 levels of sub-division available at: https://gadm.org/

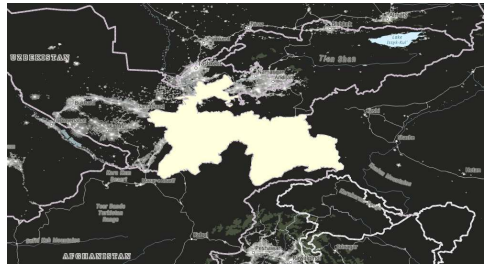
- Remove Gas Flares:
  - Satellite estimates of gas flaring is available at:
  - https://ngdc.noaa.gov/eog/interest/gas_flares_countries_shapefiles.html

- Country or area clipping:
  - NLD map is clipped using country shape file or geo coordinates

Shape file of Tajikistan

*Source: GADM maps and data*

Country clipping Tajikistan



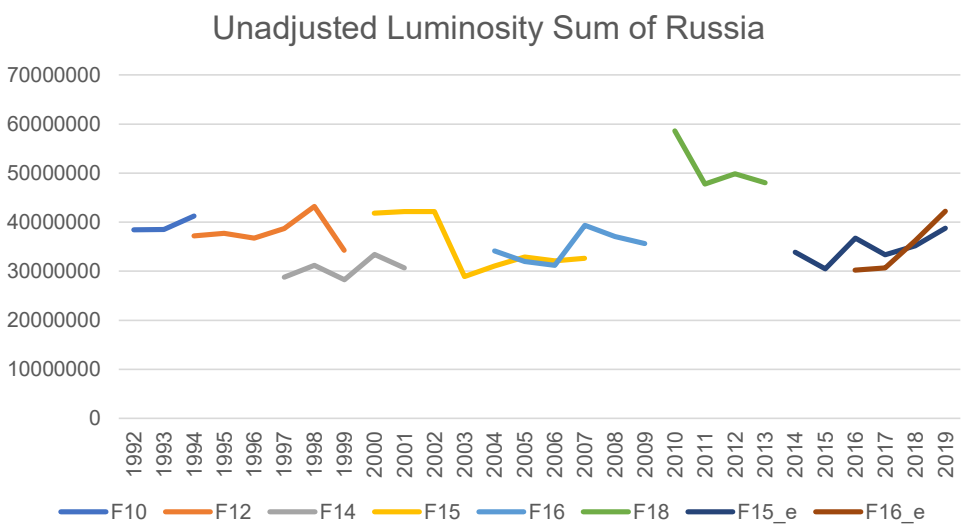
# NLD calibration

- Due to the lack of on-board calibration mechanism, DMSP Nighttime Light product does not report values as radiance, but in digital number.
- The DMSP-OLS satellites F15 and F16 collected pre-dawn data, which was published as Extension series from 2013-2021.
- Therefore, to perform a sensible comparison between images of different years and satellites, an **inter-calibration** of time series data is required.

- Equation for calibration from Elvidge et al. (2009):

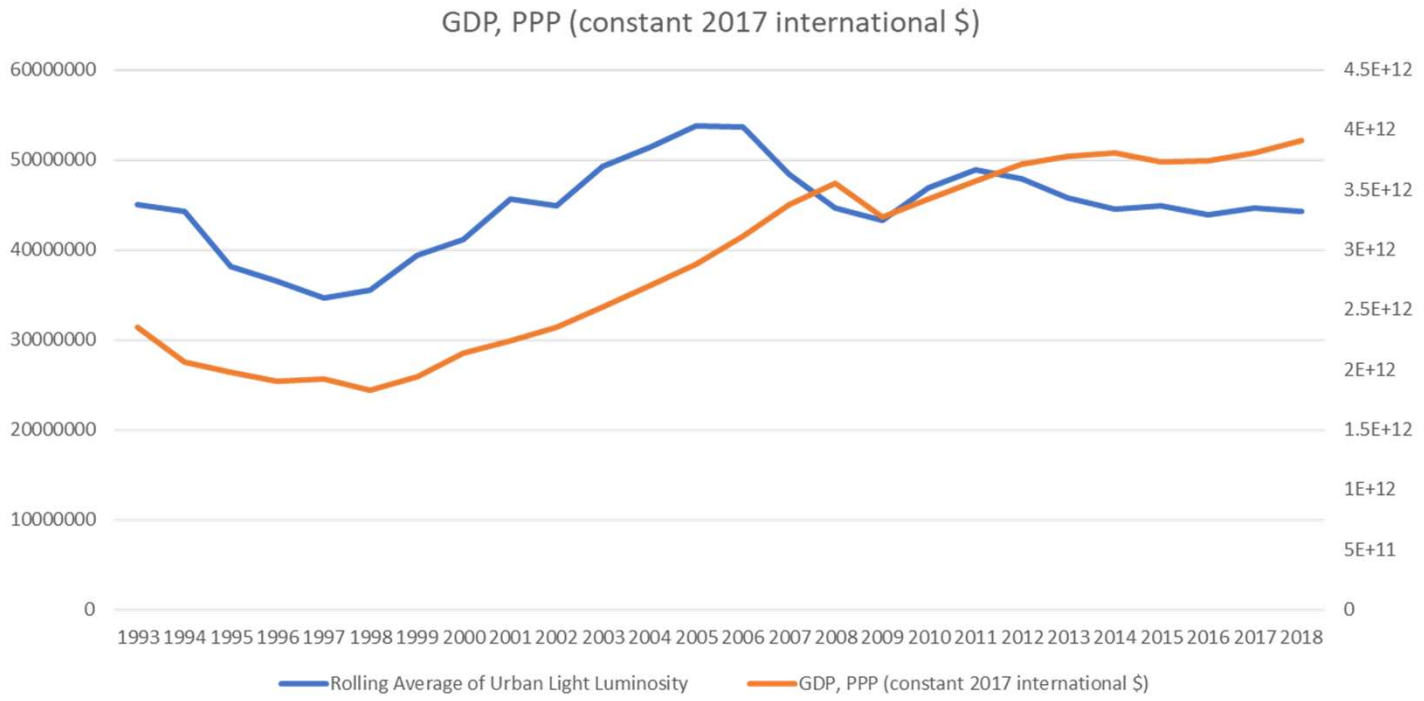
$$DN_{adjusted} = C_0 + C_1 \times DN + C_2 \times DN^2$$

# NLD calibration, 2




- This figure shows the sum of unadjusted night light luminosity of Russia from 1992 to 2019 collected by different satellites
- **Significant discrepancies** in collecting data for different satellites

# NLD Russia after satellite calibration



# NLD preprocessing

- Create Grid:
  - To get the most accurate data create grid that aligns with pixel size

- Export statistical values associated with light:
  - Digital Number values on pixel level
  - Zonal Statistics using sum, mean, min, max, standard deviation values

F142001ZonalSt_TJ_calVar2 - A01V04 NLD - ArcGIS Pro

F142001ZonalSt_TJ_calVar2

Field: Add Calculate | Selection: Select By Attributes Zoom To Switch Clear Delete Copy | Rows: Insert

| | OID | NAME_2 | ZONE_CODE | COUNT | AREA | MIN | MAX | RANGE | MEAN | STD | SUM | MEDIAN | PCT90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | Fayzobod | 1 | 1173 | 0.081458 | 0 | 14.046 | 14.046 | 1.776161 | 3.209182 | 2083.436894 | 0 | 7.401 |
| 2 | 1 | Hissor | 2 | 1237 | 0.085903 | 0 | 31.280998 | 31.280998 | 5.719858 | 6.652156 | 7075.463778 | 6.018 | 16.578001 |
| 3 | 2 | Jirgatol | 3 | 7058 | 0.490139 | 0 | 8.766 | 8.766 | 0.079763 | 0.737877 | 562.967969 | 0 | 0 |
| 4 | 3 | Nurobod | 4 | 1546 | 0.107361 | 0 | 7.401 | 7.401 | 0.752389 | 2.028315 | 1163.192932 | 0 | 6.018 |
| 5 | 4 | Rasht | 5 | 6988 | 0.485278 | 0 | 10.113 | 10.113 | 0.264827 | 1.294885 | 1850.609899 | 0 | 0 |
| 6 | 5 | Roghun | 6 | 1291 | 0.089653 | 0 | 11.441999 | 11.441999 | 1.255306 | 2.708176 | 1620.599915 | 0 | 6.018 |
| 7 | 6 | Rudaki | 7 | 2959 | 0.205486 | 0 | 56.121002 | 56.121002 | 6.551863 | 12.937862 | 19386.962898 | 0 | 22.593 |

Zonal Statistics of Tajikistan

# NLD in Economic studies

- NLD provides insights into the social, economic, and cultural patterns, including electrification, migration, activity in conflict areas and war zones, extreme weather effects, and urban/rural development.
- Urbanization process
  - Mellander et al. (2015) use nighttime light (NTL) data in Sweden and conclude that NTL data could be an excellent indicator of the urbanization process in OECD countries
- Population
  - Huang et al. (2016) states nighttime light data are significantly related to the urban populations, especially in countries with an ongoing urbanization process and a considerable inflow of city population.
- Gross Domestic Product (GDP)
  - Chen and Nordhaus (2001) state that the luminosity could work as a good proxy of economic output for low income countries, especially for those with poorly statistical systems, while for other countries, the approximation is relatively limited.
- Social epidemiology
  - Impact and spread of Covid
  - Consequences of environmental disasters (Hurricane Katrina, Semipalatinsk polygon radiation)
- Other economic and social indicators
  - population mobility
  - electricity consumption

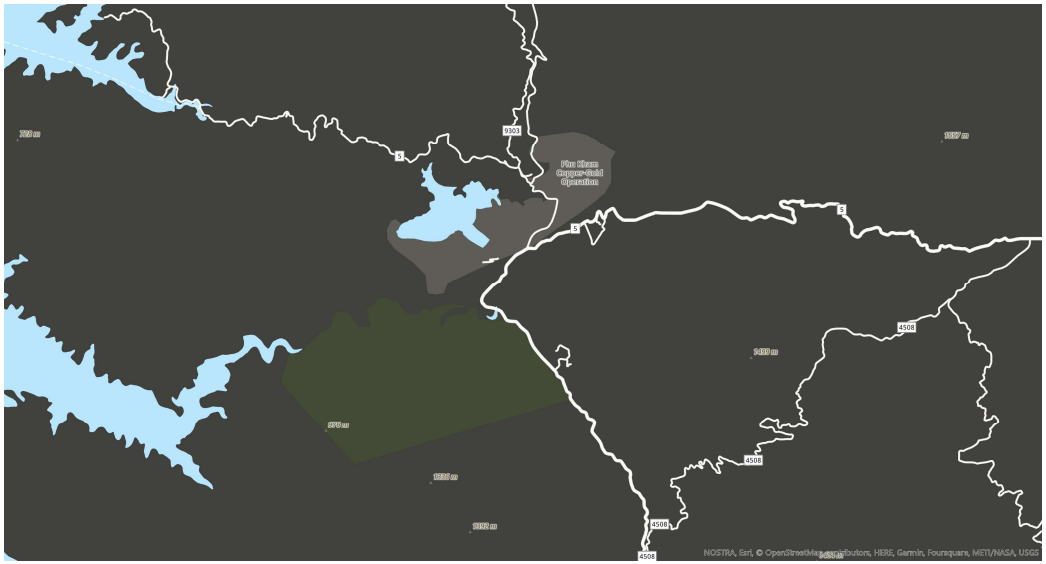
# NLD for Lao PDR

Laos F121992

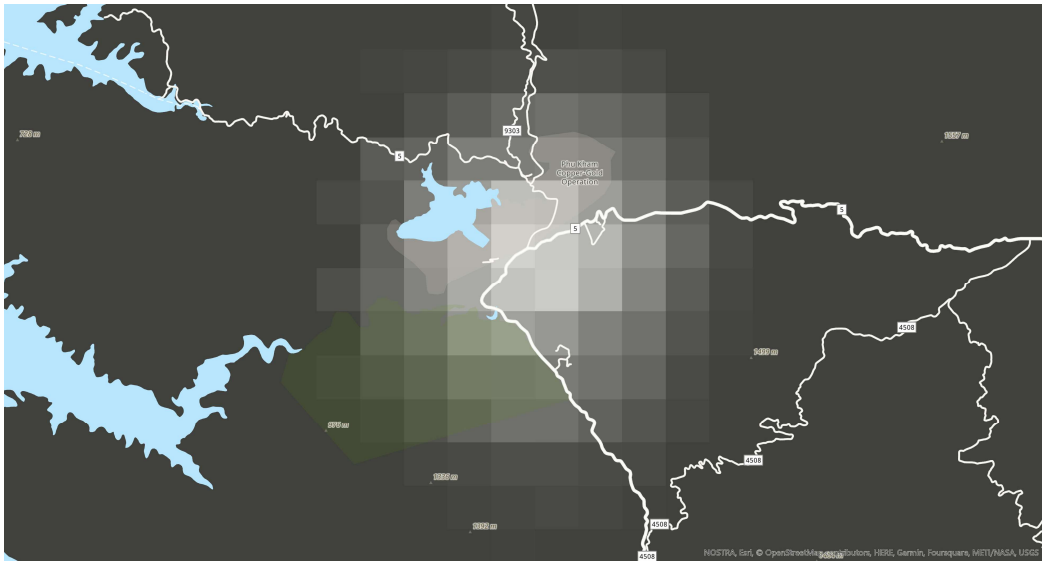
Laos F142000

Laos F182013

# NLD for Lao PDR: opening a mining region



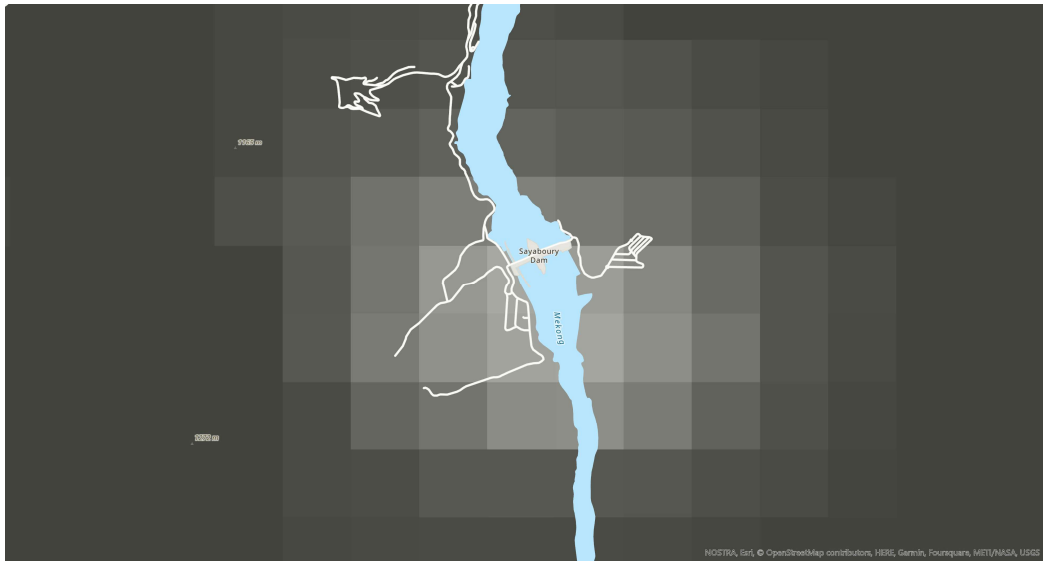
Phu Kham Gold-Copper Operation F162005



Phu Kham Gold-Copper Operation F162021

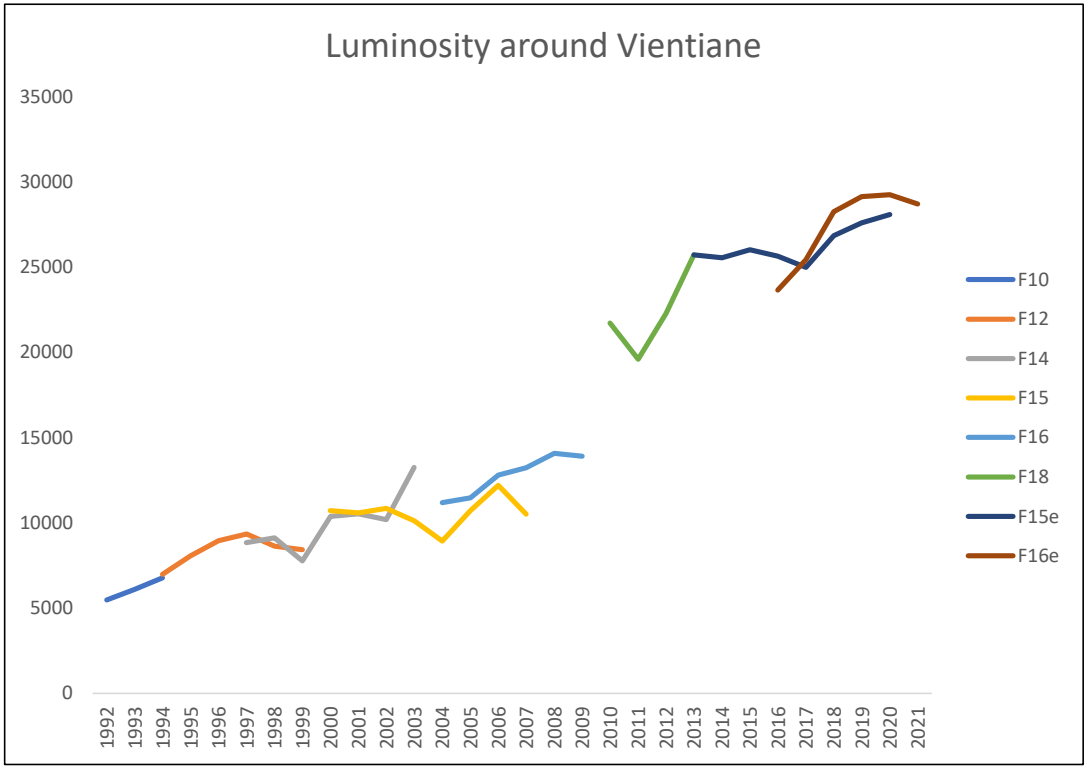
# NLD for Lao PDR: power-generating dam

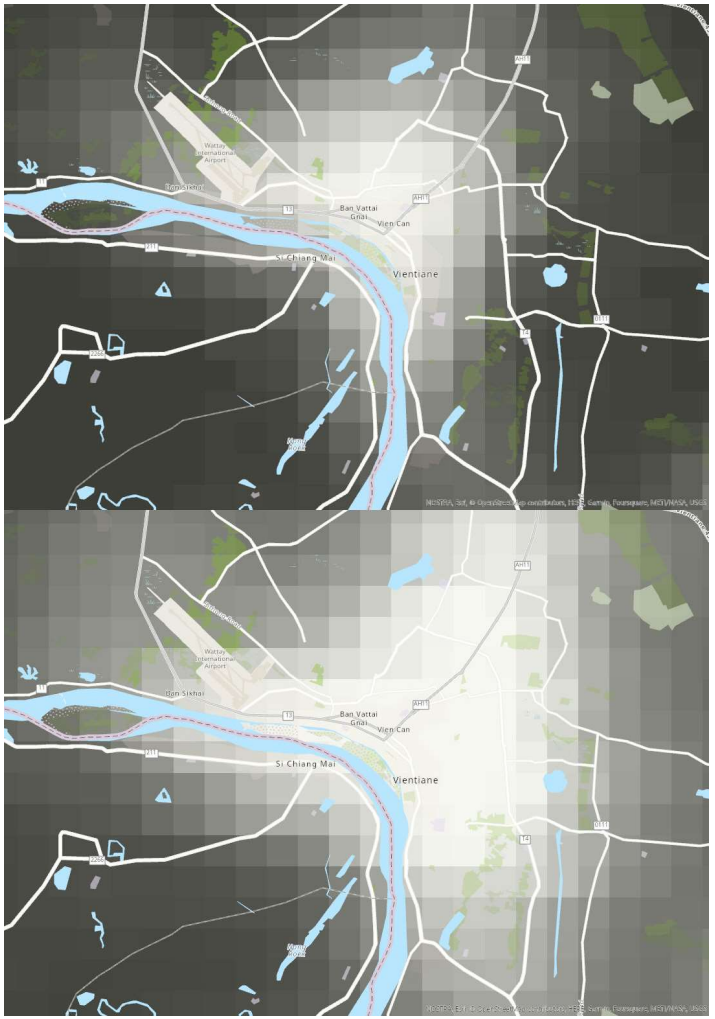

Sayaboury Dam F182010




Sayaboury Dam F162021

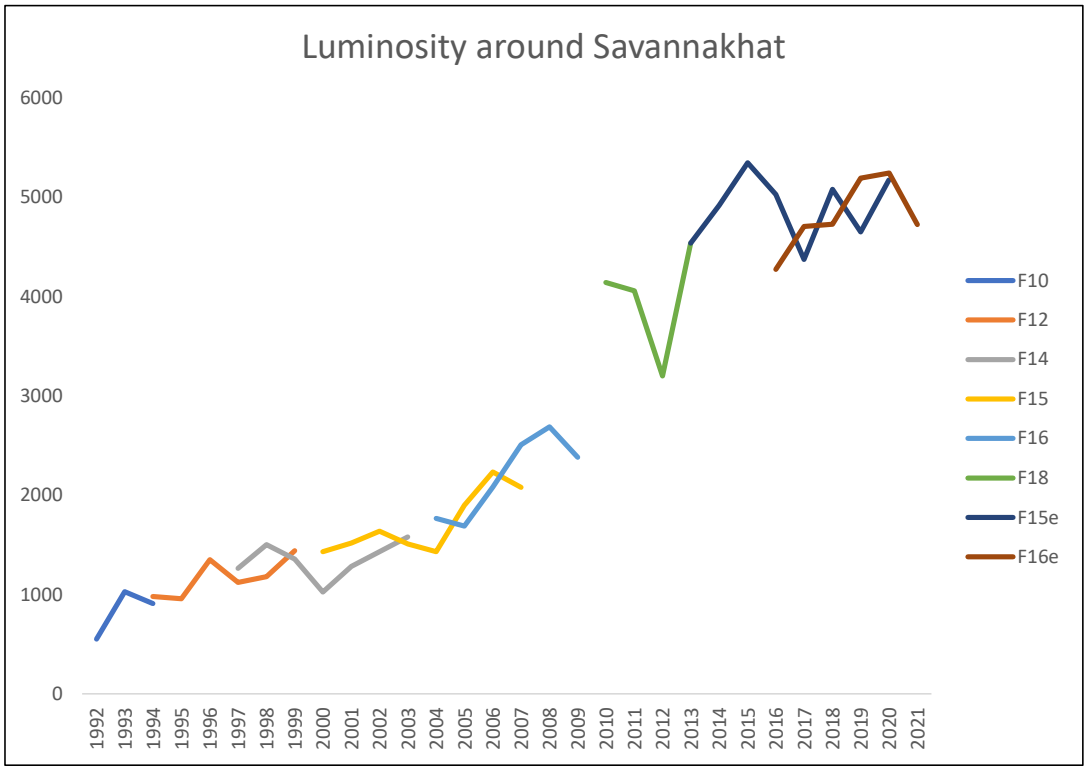
# NLD for Lao PDR: major cities




F101992 & F162021

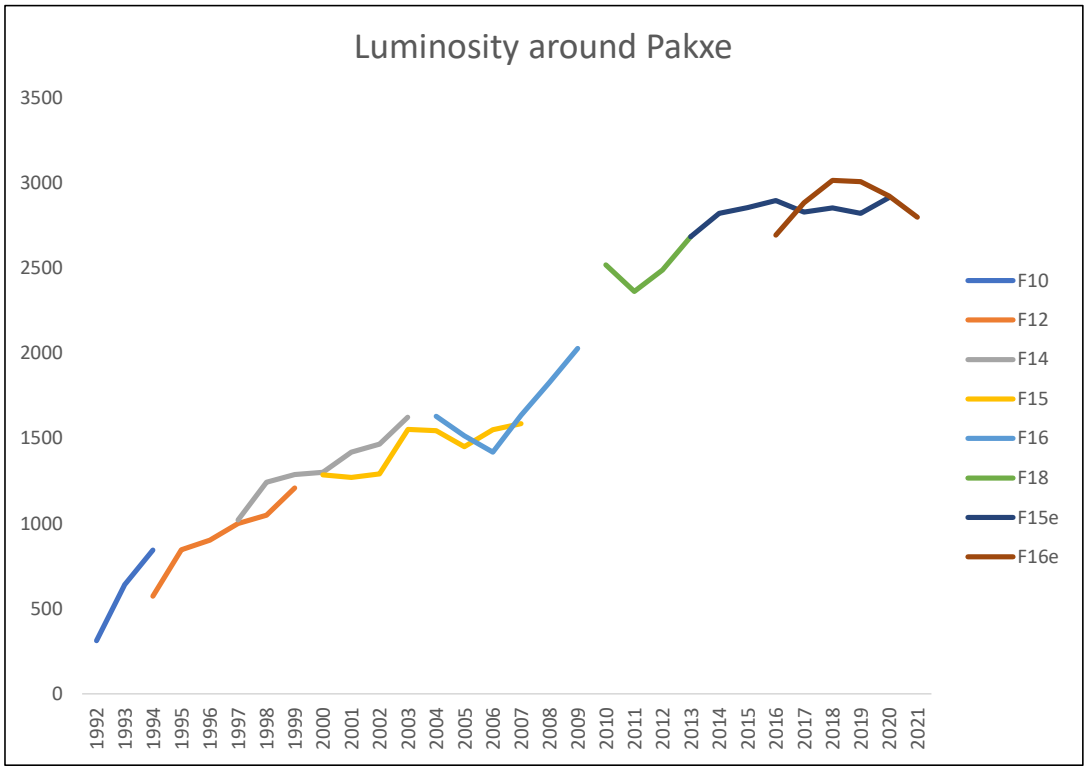
# NLD for Lao PDR: major cities

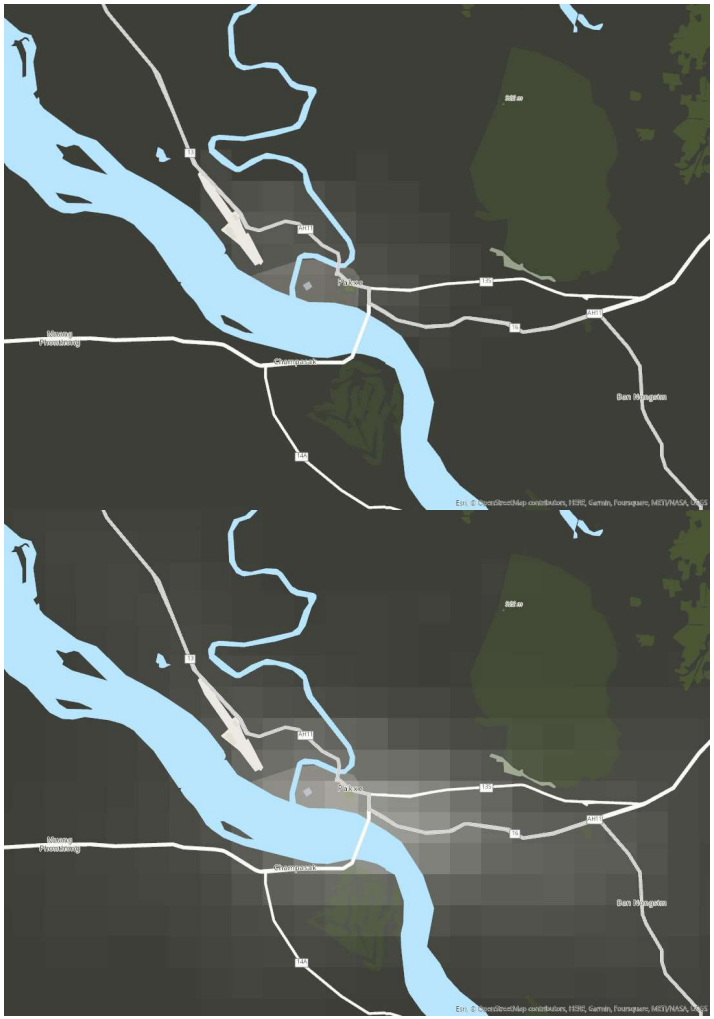




F101992 & F162021

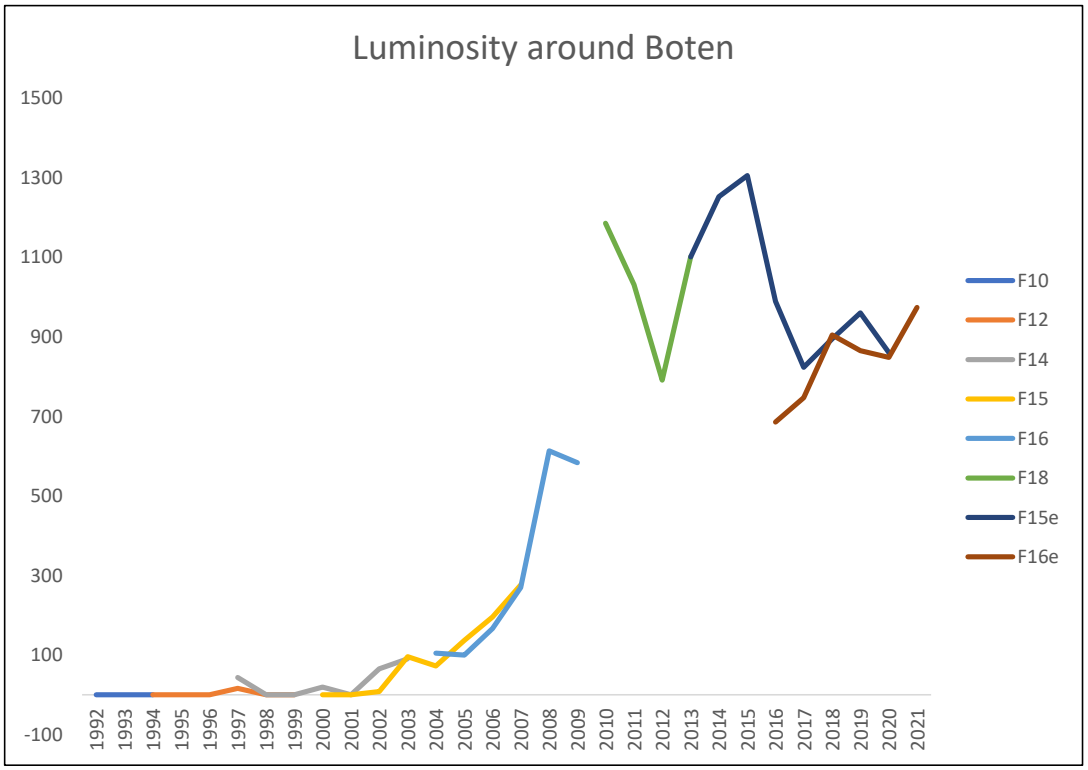
# NLD for Lao PDR: major cities



F101992 & F162021

# NLD for Lao PDR: railway

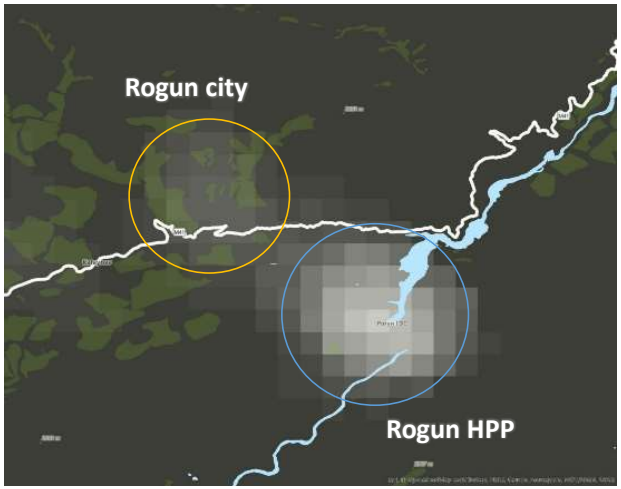




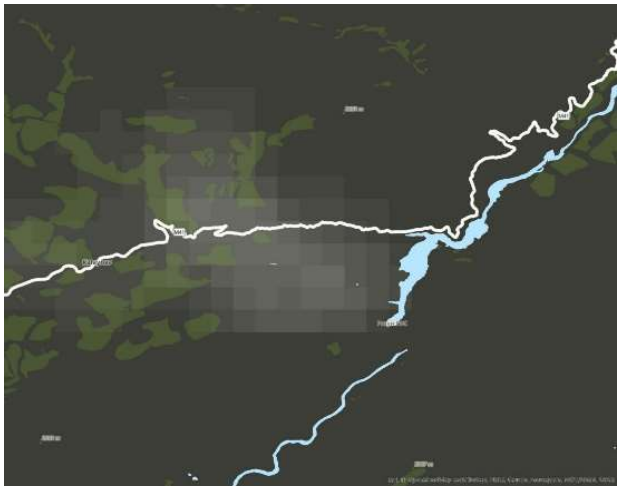
F142003 & F162021

# Research project: Rogun hydro plant, Tajikistan

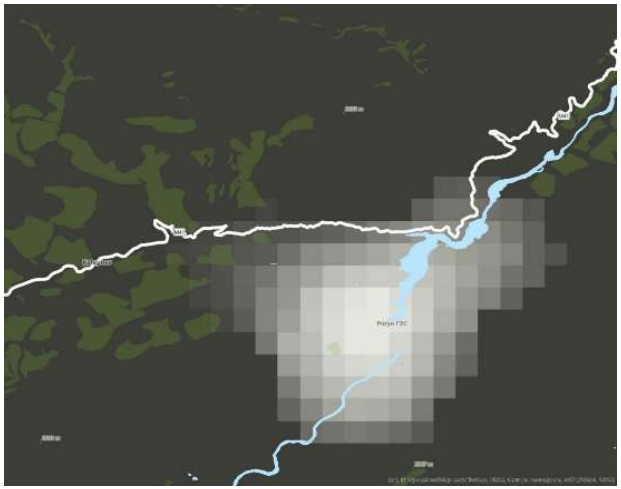
Rogun City, Tajikistan F10-1992




Rogun City, Tajikistan F10-1993



Rogun City, Tajikistan F16-2021



NLD images reflect the timeline of Rogun Hydro Power Plant (HPP) constuction:

- 1976 – construction of Rogun HPP starts
- 1991-1992 – construction stalled with collapse of USSR
- 2008 – construction was resumed after several attempts
- 2018-2019 – Hydro Power Plant was commissioned

# Reference and data source

- NLD DMSP-OLS: https://eogdata.mines.edu/products/dmsp/
- NLD VIIRS DNB: https://eogdata.mines.edu/products/vnl/
- Gas Flaring: https://ngdc.noaa.gov/eog/interest/gas_flares_countries_shapefiles.html
- Country Shape File: https://gadm.org/