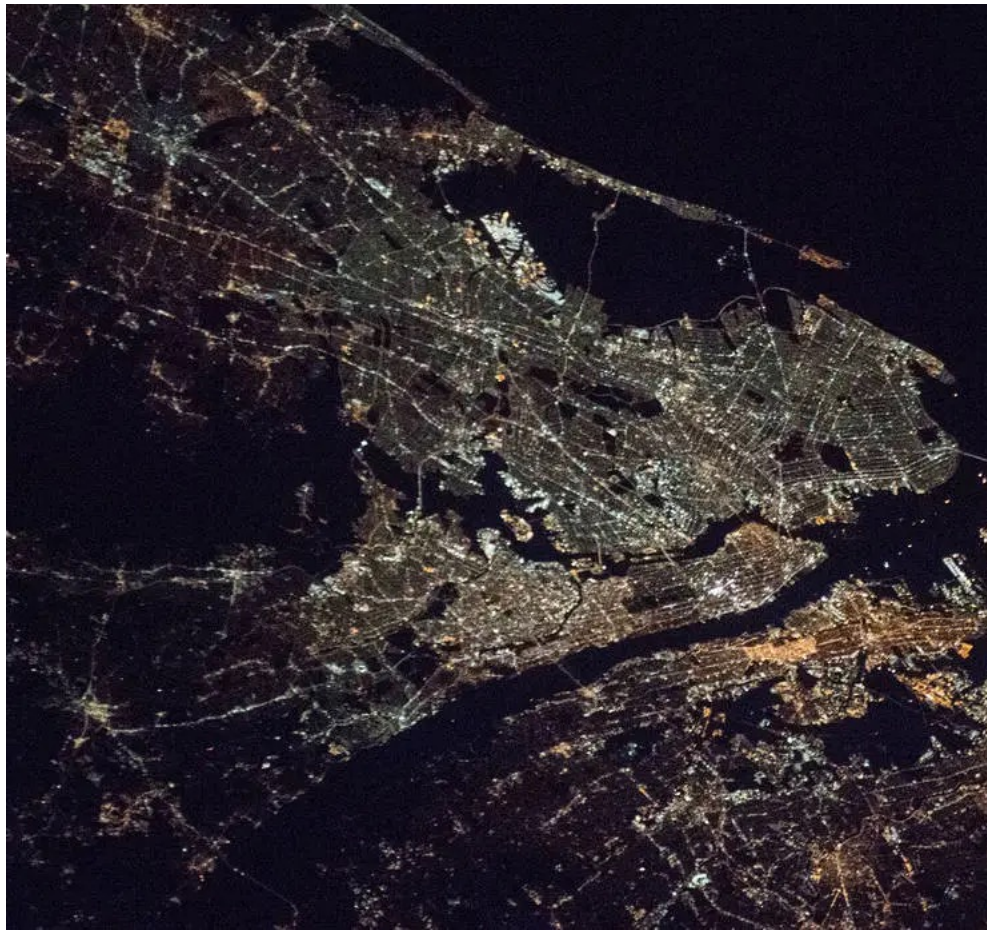
Nighttime Lights for Economic Development

Rob Marty, Data Scientist (DECDI)

Outline

1. Nighttime lights data sources
2. How nighttime lights used in economics / social sciences



Nighttime Lights Data Sources

Nighttime Lights Data Sources

Summary

Original Satellite

- **DMSP-OLS:** 1992 to 2013 (2018)

  US. Air Force

- **VIIRS:** 2012 to present

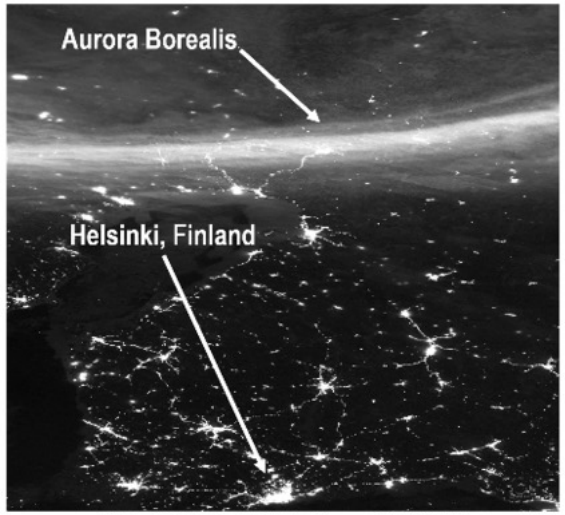
  NOAA in partnership with NASA

Processed Data

Remove effects of moonlight, atmospheric corrections

- **Colorado School of Mines**
  - V1 (Available via GEE)
  - V2 (Not available via GEE)
- **Colorado School of Mines** (available via GEE)
- **NASA Black Marble** (daily available via GEE)

Raw



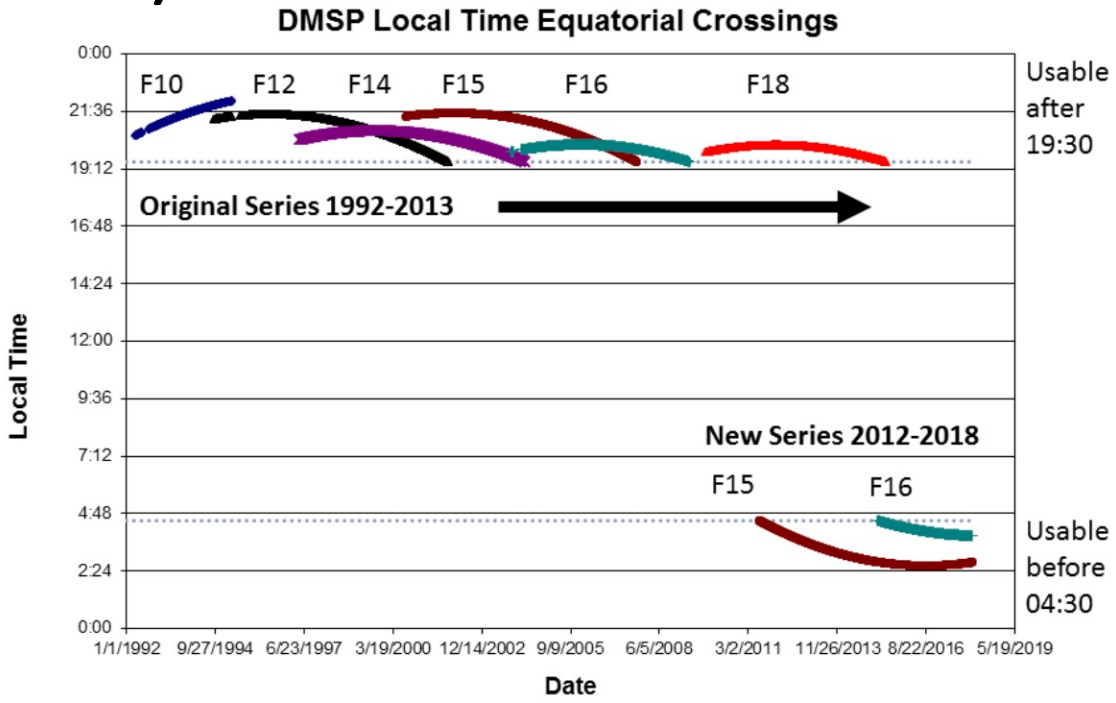
Processed / Corrected

Nighttime Lights Data Sources

Defense Meteorological Satellite Program (DMSP)

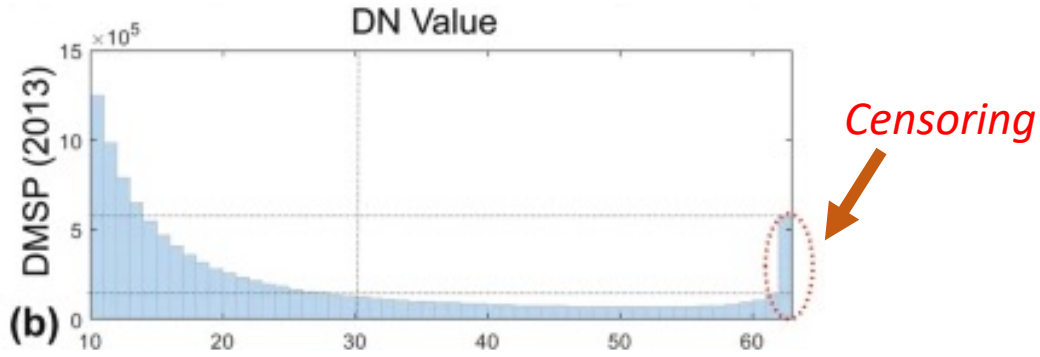
Details

- Original series from 1992-2013; extended to 2018
- Different satellites; requires calibrating across satellites
- Resolution: 30 arc second (~1km at equator)
- Monthly and annual data publicly available
- Unit: Digital Number, integer from 0 – 63; censoring an issue for bright areas



Where to Get Data

- Google Earth Engine
- Colorado School of Mines



Nighttime Lights Data Sources

Visible Infrared Imaging Radiometer Suite (VIIRS)

Details

- 2012 through present
- Resolution: 500 meters
- Daily, monthly, and annual data publicly available

Processed Data

- Colorado School of Mines [GEE]

  More commonly used; around for longer

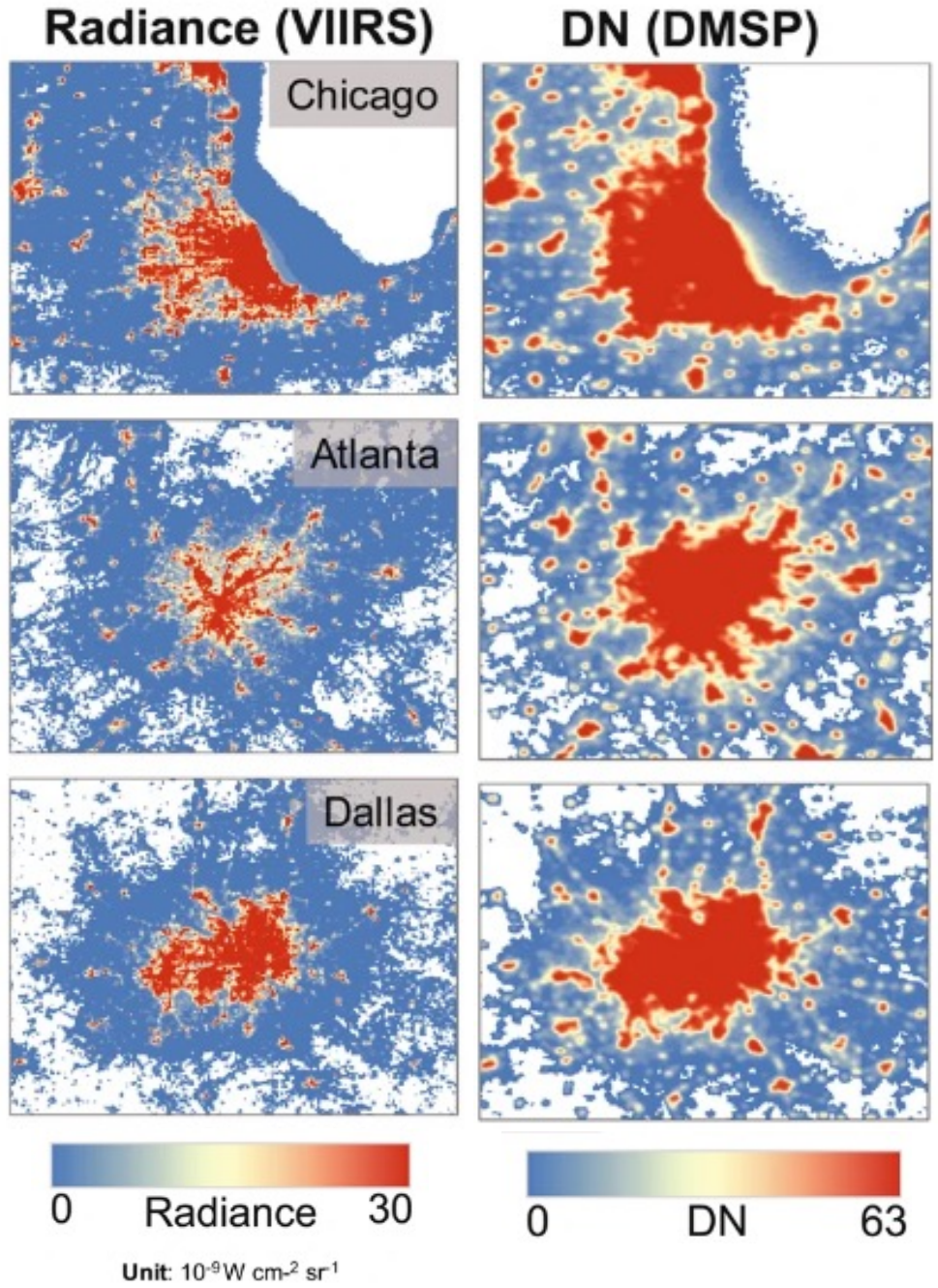
- NASA Black Marble [GEE]

  Released in 2021

DMSP-OLS vs VIIRS

	DMSP	VIIRS
Availability	1992–2013	2012-present
Spatial resolution	30 arc seconds (~1 km)	15 arc seconds (~500 m)
Radiometric resolution	6-bit	12- or 14-bit
Wavelength range	0.4–1.1 μm	0.5–0.89 μm
Units of pixel values	Relative (0–63 scale)	Radiance (nW cm^{-2} sr^{-1})
Overpass time	~19:30	~1:30
On-board calibration	No	Yes
Pixel saturated	Yes	No

Tu et al. (2020)



Li et al. (2020)

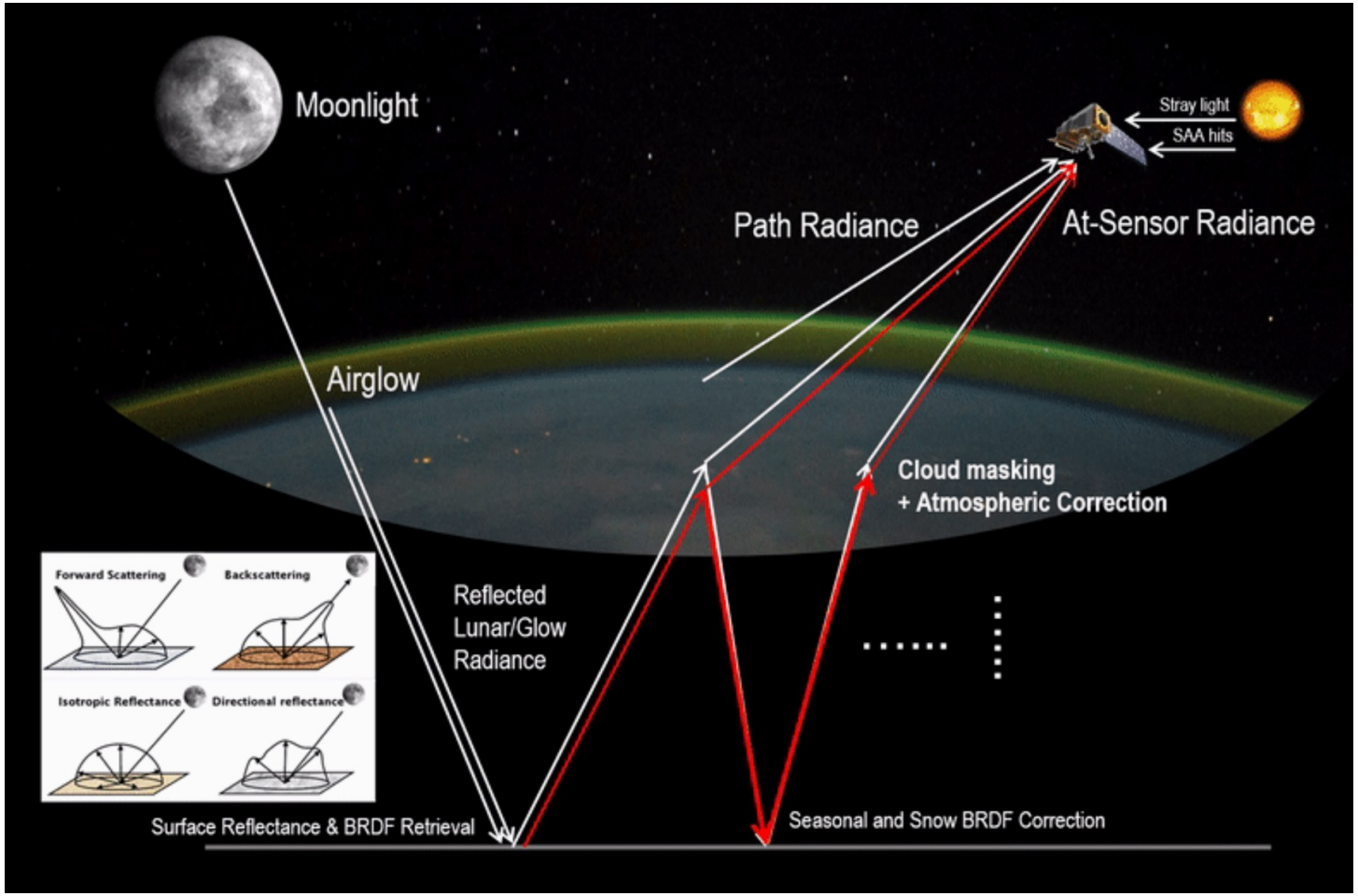
Key advantages of VIIRS

- Higher resolution
- Improved radiometric resolution (captures finer differences in NTL)
- Not saturated (DMSP capped at DN 63)

VIIRS: Colorado School of Mines vs Black Marble

Additional corrections from Black Marble

- **Addresses snowfall**: Snowfall reflects light; estimates snow-free lights
- **Vegetation**: **V**egetation can hide light; less vegetation in winter can result in higher NTL values. Black Marble corrects for vegetation
- Different approach for accounting for **surface reflection** (eg, moon, stars, atmospheric particles) [Bidirectional reflectance distribution function; BRDF]
- In creating monthly/annual data, Black Marble drops daily **outliers** (also done in Colorado School of Mines V2)



For more info, see [The Spatial Edge (Yohan Iddawela)]

[NASA Black Marble]

VIIRS: Colorado School of Mines vs Black Marble

Dealing with stray light: when sunlight hits the satellite

Dealing with Stray Light

- **Colorado School of Mines:** Adjusts for stray light contamination
- **Black Marble:** Drops pixels contaminated by stray light.

Black Marble contains many missing values for northern countries from June - August

Black Marble data June 2021

For more info, see [The Spatial Edge (Yohan Iddawela)]

VIIRS: Colorado School of Mines vs Black Marble

Black Marble: Variation from Satellite Angle

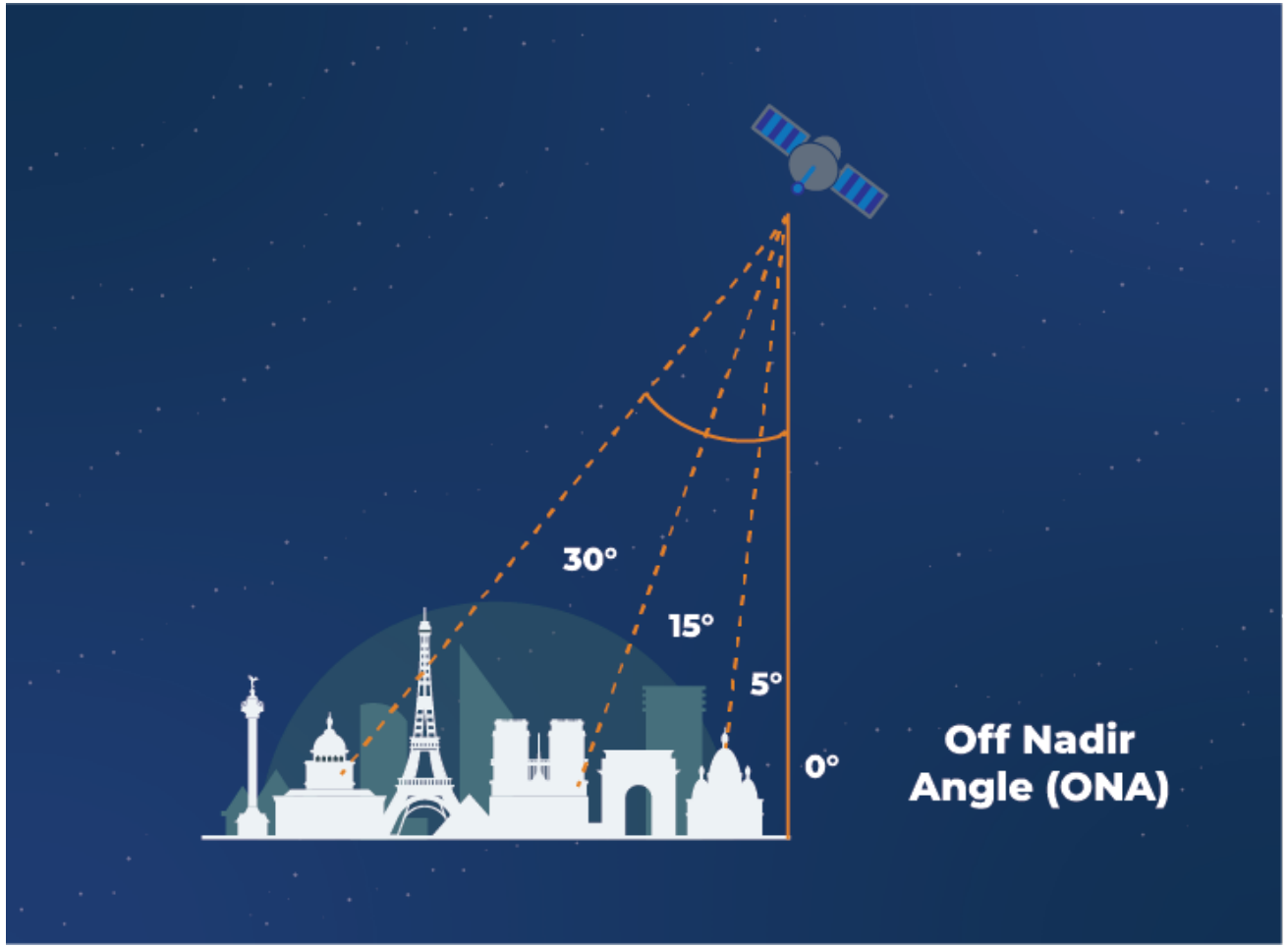
Satellite Angle Differentiation

- **Colorado School of Mines:** No differentiation; single dataset
- **Black Marble:** Provides multiple datasets for annual data:
  - Near-nadir [above]
  - Off-nadir [at angle]
  - Combined / “All Angle”

Near-nadir vs off-nadir

- Near-nadir typically brighter
- In general, off-nadir allows greater coverage for a single image
- Off-nadir captures at angle, which can have advantages for certain applications

Wang et al. (2018): Comparing Dubai and Rome, found that **near-nadir** was brighter but varied more, while **off-nadir** was less bright but varied less



European Space Imaging

For more info, see The Spatial Edge (Yohan Iddawela)

VIIRS: Colorado School of Mines vs Black Marble

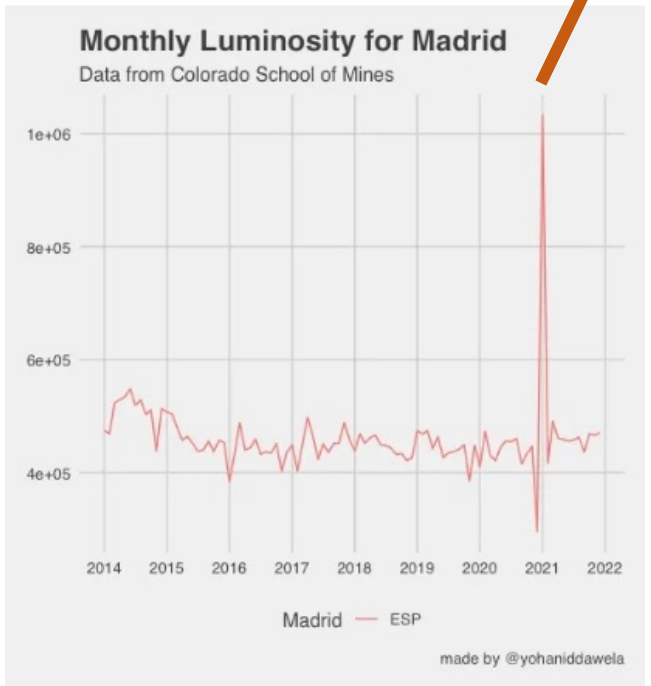
Nighttime light variable options

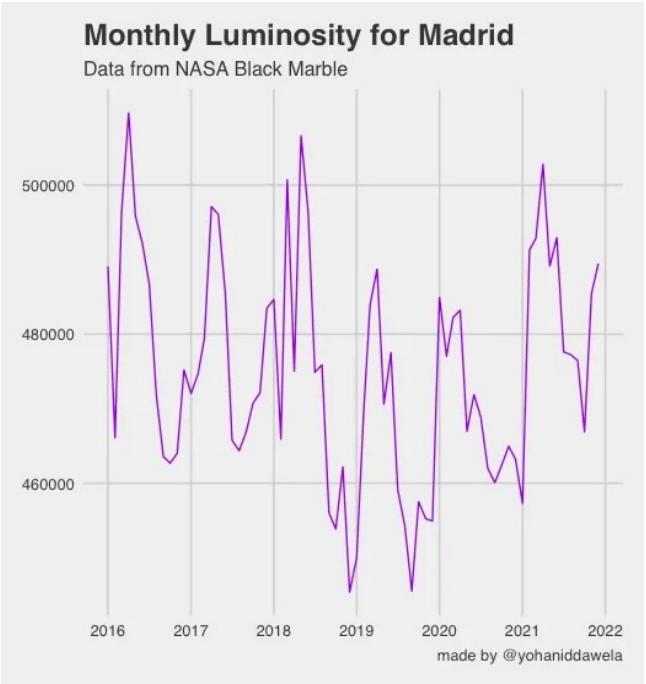
Storm Filomena

Monthly & Annually

Choice: (1) Angle; (2) Snowfall

- AllAngle_Composite_Snow_Covered
- AllAngle_Composite_Snow_Free
- NearNadir_Composite_Snow_Covered
- NearNadir_Composite_Snow_Free
- OffNadir_Composite_Snow_Covered
- OffNadir_Composite_Snow_Free





Source: The Spatial Edge

For more info, see The Spatial Edge (Yohan Iddawela)

VIIRS: Colorado School of Mines vs Black Marble

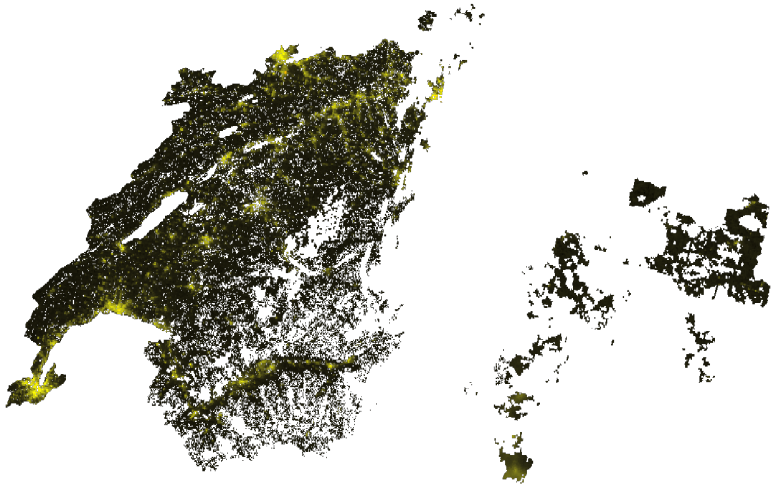
Nighttime light variable options

Corrects for surface reflections

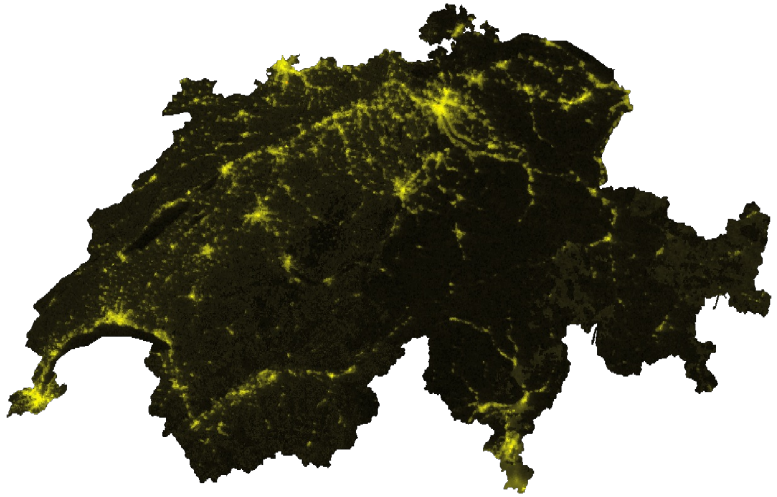
Daily

- **DNB_BRDF-Corrected_NTL:** NTL value for given day
- **Gap_Filled_DNB_BRDF-Corrected_NTL:** Will use latest high quality pixel within 30 days
  - **Latest_High_Quality_Retrieval:** Number of days between day & pixel used

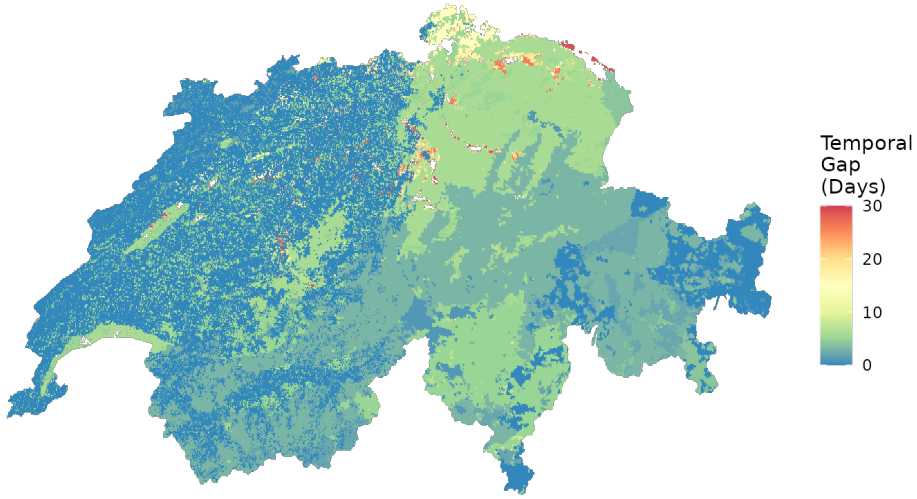
DNB_BRDF-Corrected_NTL



Gap_Filled_DNB_BRDF-Corrected_NTL



Latest_High_Quality_Retrieval



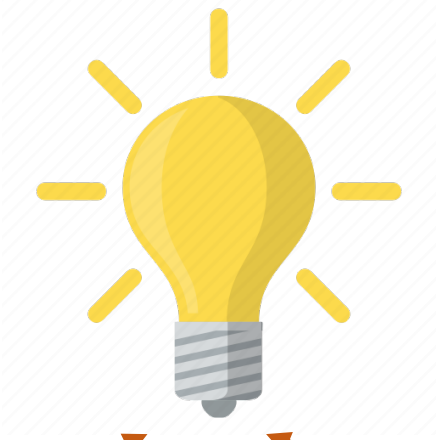
Uses of Nighttime Lights
In Economics & Social Sciences

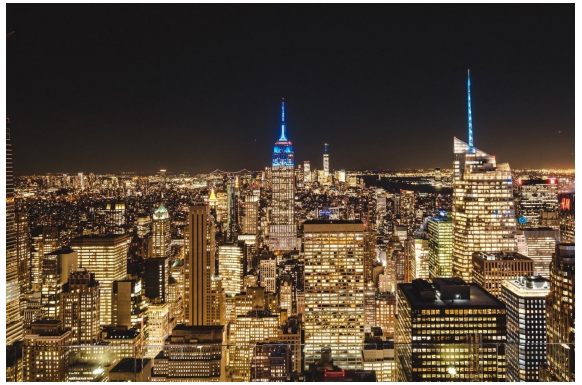
Leveraging nighttime lights requires appreciating what does and does not generate lights

Earth at night (2022)

Human activity & nighttime lights

Many sources of nighttime lights (buildings, gas flaring, traffic, etc).





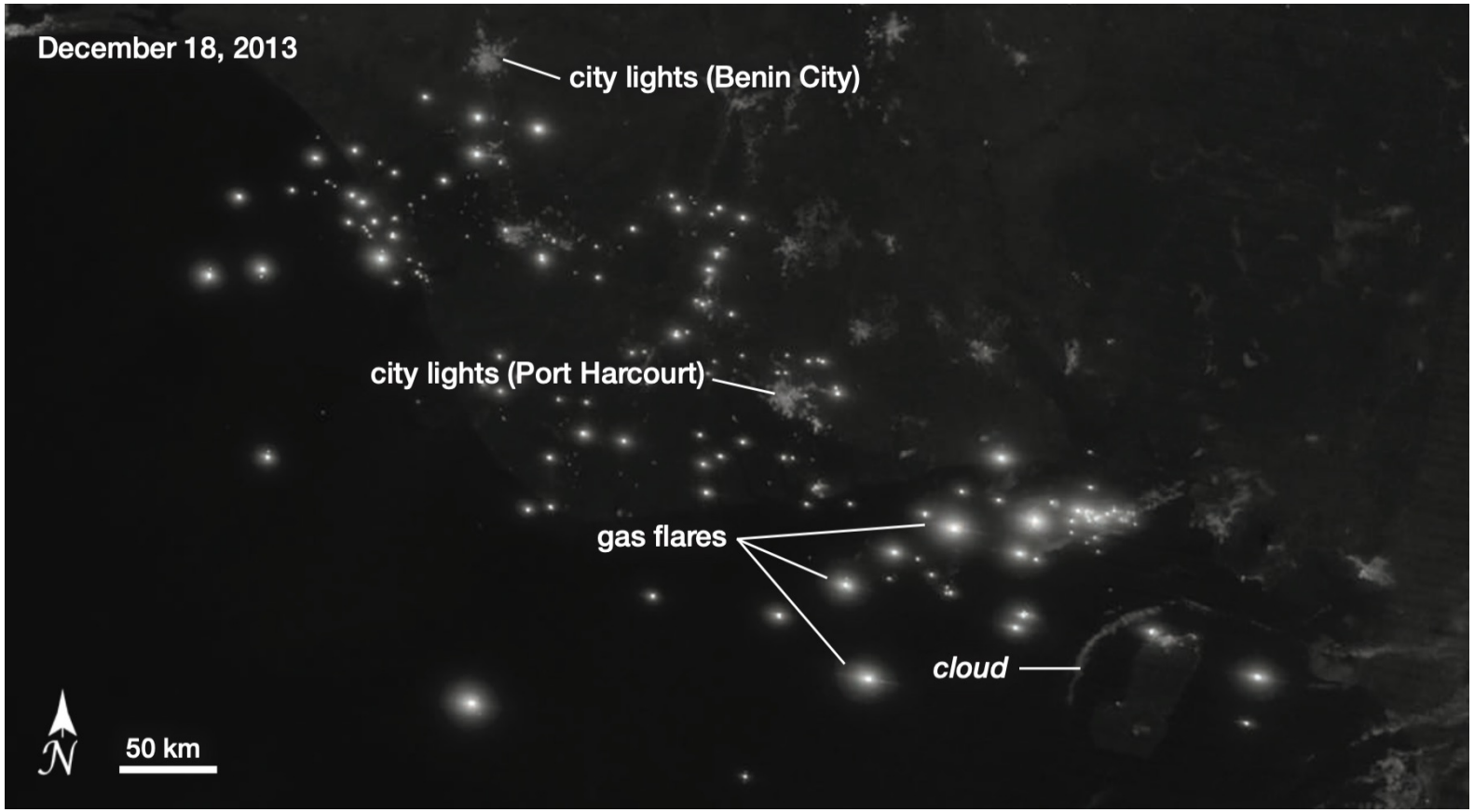
Human activity & nighttime lights

What we can control: What pixels we **include** and **exclude** in spatial aggregations

- Include/exclude gas flaring locations? Do those light contribute to what we're interested in?

What nighttime light ignores

- Sources of activity that don't generate light (e.g., agriculture and forestry)



Earth at night (2022)

Nighttime lights & economic activity

Earth at night (2022)

Nighttime lights & economic activity

- Many studies documenting link between nighttime lights and economic activity
- Allows analyzing economic activity sub-nationally
- Martinez (2022) compares growth rate in NTL & GDP across countries; less free countries had larger discrepancies

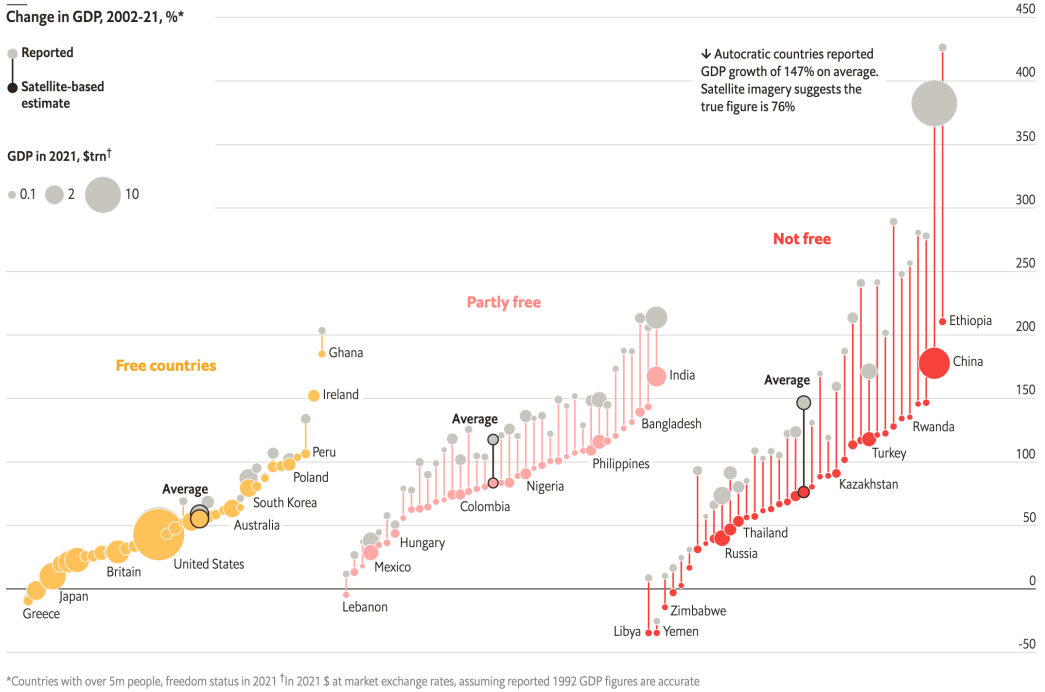
Measuring Economic Growth from Outer Space†

By J. Vernon Henderson, Adam Storeygard, and David N. Weil*

Graphic detail | Shining light on lies

A study of lights at night suggests dictators lie about economic growth

Satellite data hints at the scale of their deception



*Countries with over 5m people, freedom status in 2021 †In 2021 $ at market exchange rates, assuming reported 1992 GDP figures are accurate

How do nighttime lights capture economic activity?

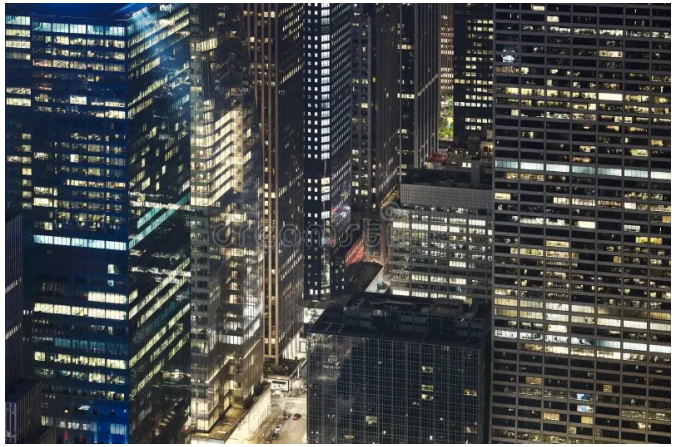
Argues that service sector produce less lights (e.g., compared to manufacturing); elasticity of lights to GDP declines as income rises / country moves to service sector

"[N]ight-time lights do provide a robust indicator of such activity albeit the relationship seems to be statistically stronger for developing economies than developed ones. ***In the developed economies the services sector, which are less reliant on physical infrastructure,*** *account for a greater proportion of overall economic output and artificial light generation might exhibit decreasing elasticity of demand as income levels rise."*

—Mellander et al., 2015

How do nighttime lights capture economic activity?

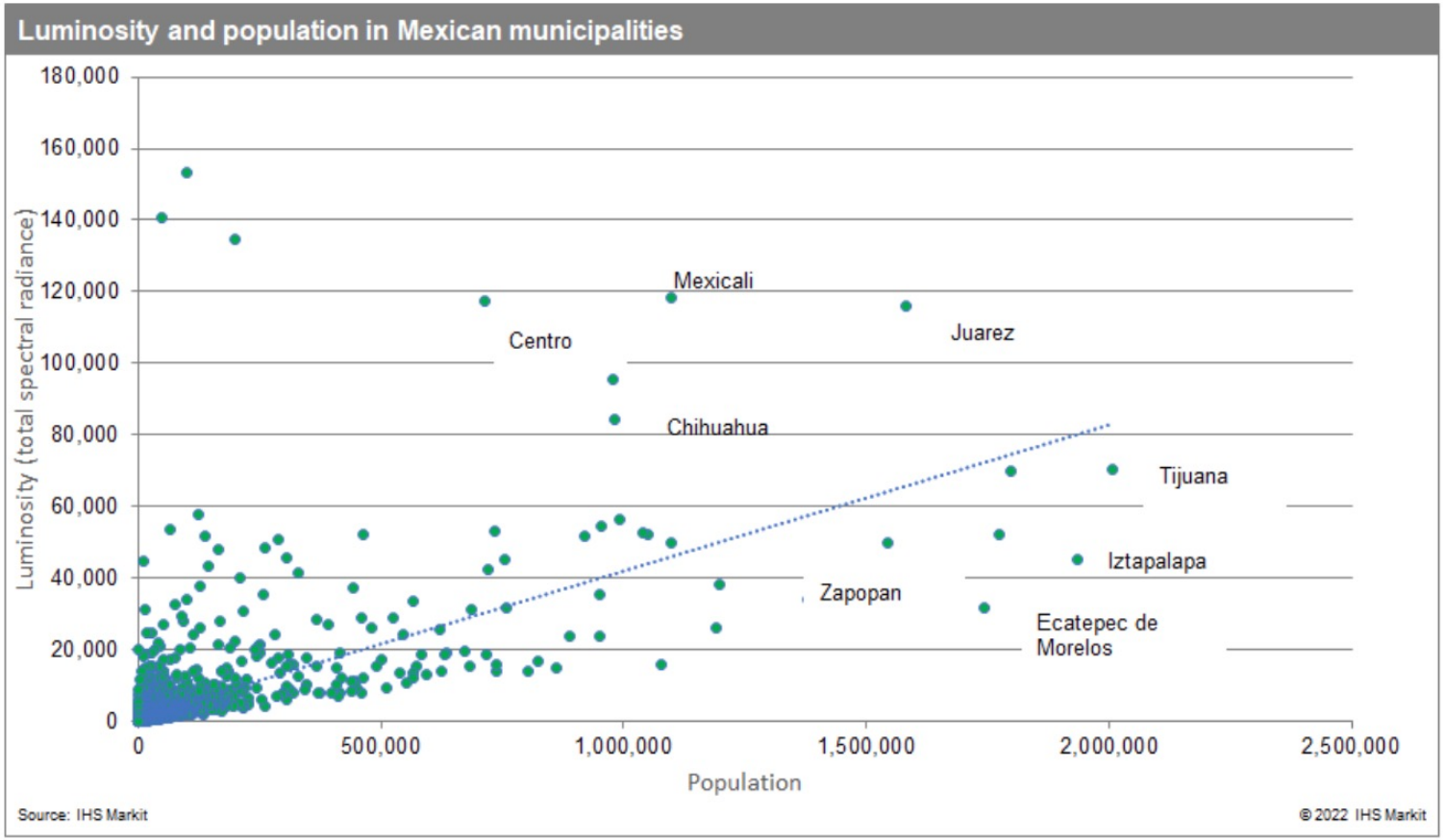
- Using firm level data in Sweden, shows NTL strongly associated with population & establishment density; weaker association with wages. NTL may be particularly good indicator of degree of urbanization. (Mellander et al., 2015).
- Nighttime lights may not explain value-added from agriculture & forestry (Keola et al. 2015).



How do nighttime lights capture economic activity?

Analysis of Mexican municipalities (article from [Hugo Foster & Marie Lechler, 2022])

- More luminosity than expected given population in **key border crossing locations with large cargo infrastructure & manufacturing activities**
- Strong NTL in key supply chain & industry nodes, such as ports & oil/gas facilities
- Less luminosity than expected given population in poorer locations

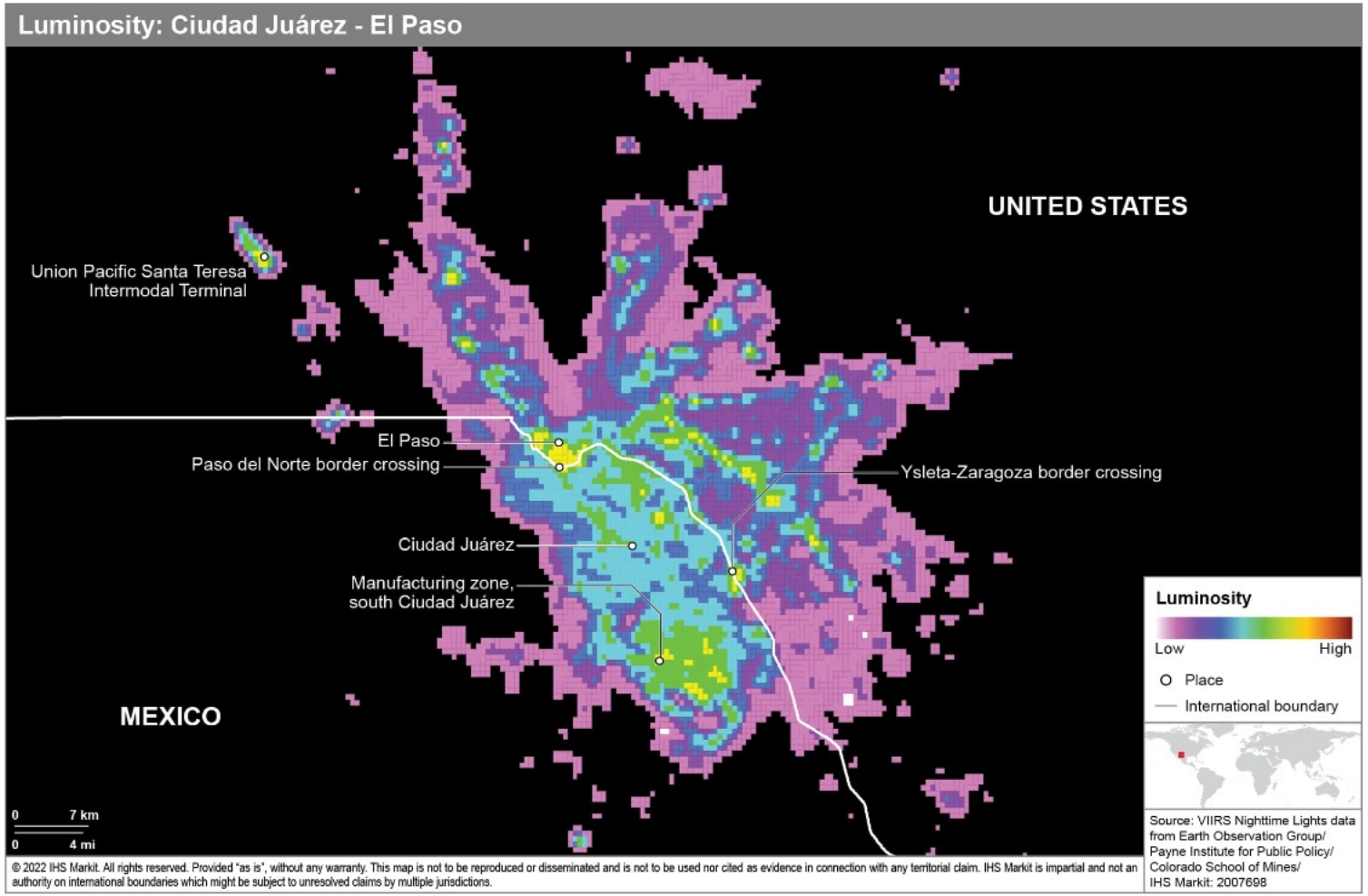


How do nighttime lights capture economic activity?

Analysis of Mexican municipalities (article from [Hugo Foster & Marie Lechler, 2022]())

Within Juarez-El Paso, more nighttime lights

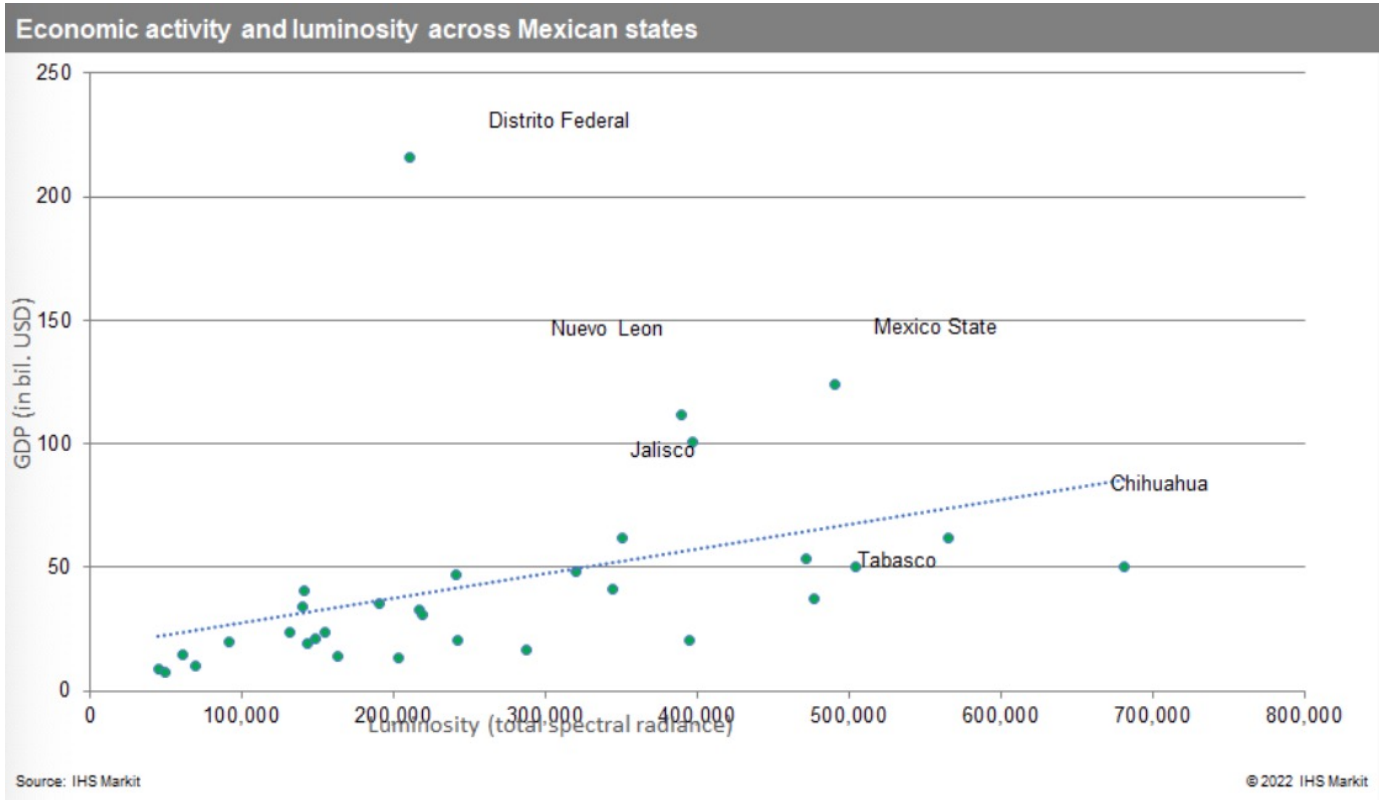
- Around border crossings
- Transportation terminals
- Manufacturing sites



How do nighttime lights capture economic activity?

Analysis of Mexican municipalities (article from [Hugo Foster & Marie Lechler, 2022](#))

- States with more NTL tend to have higher economic output
- Mexico City (Distrito Federal) is outlier; high NTL within cities can be generated by assets with varying relevance to economic activity: factories, stadiums, housing
- ***"Luminosity data is less likely to be useful where local economies are based around service industries that emit less light compared to manufacturing"***

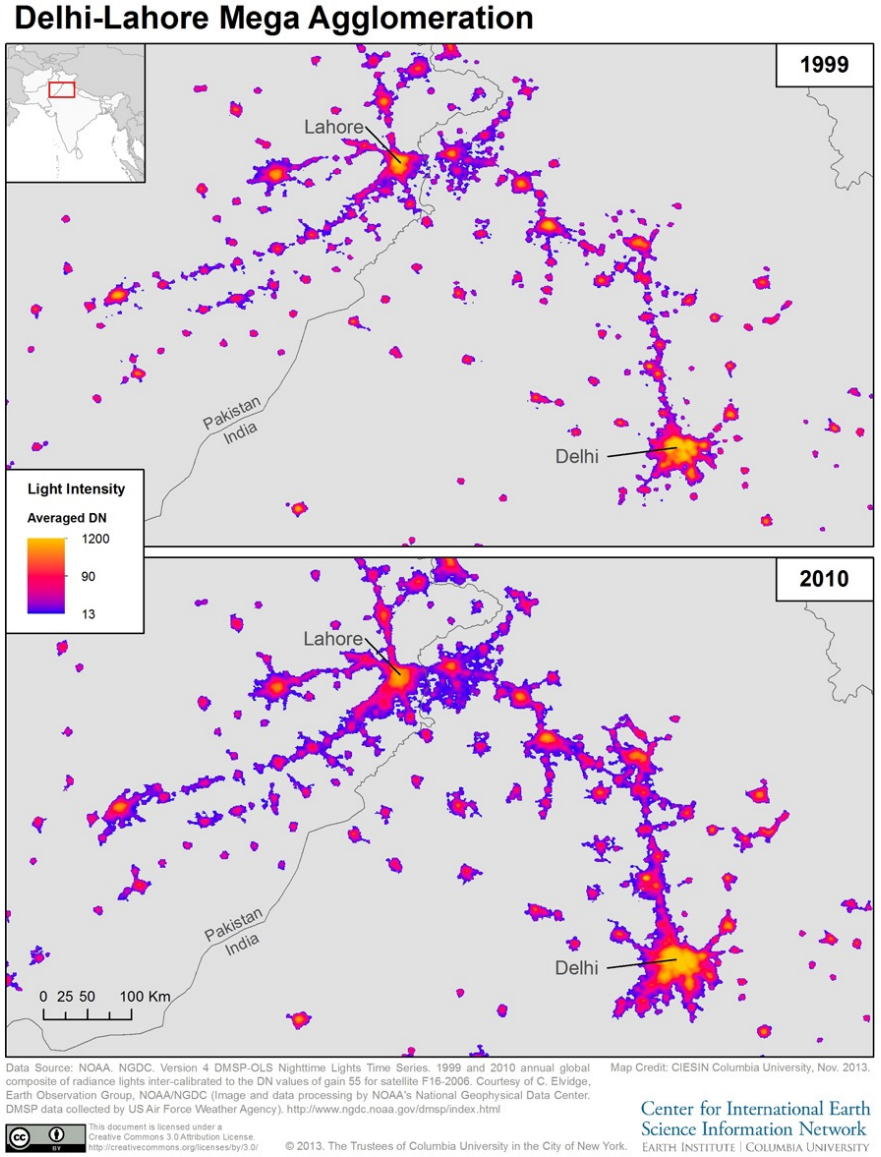


Other applications of nighttime lights

Earth at night (2022)

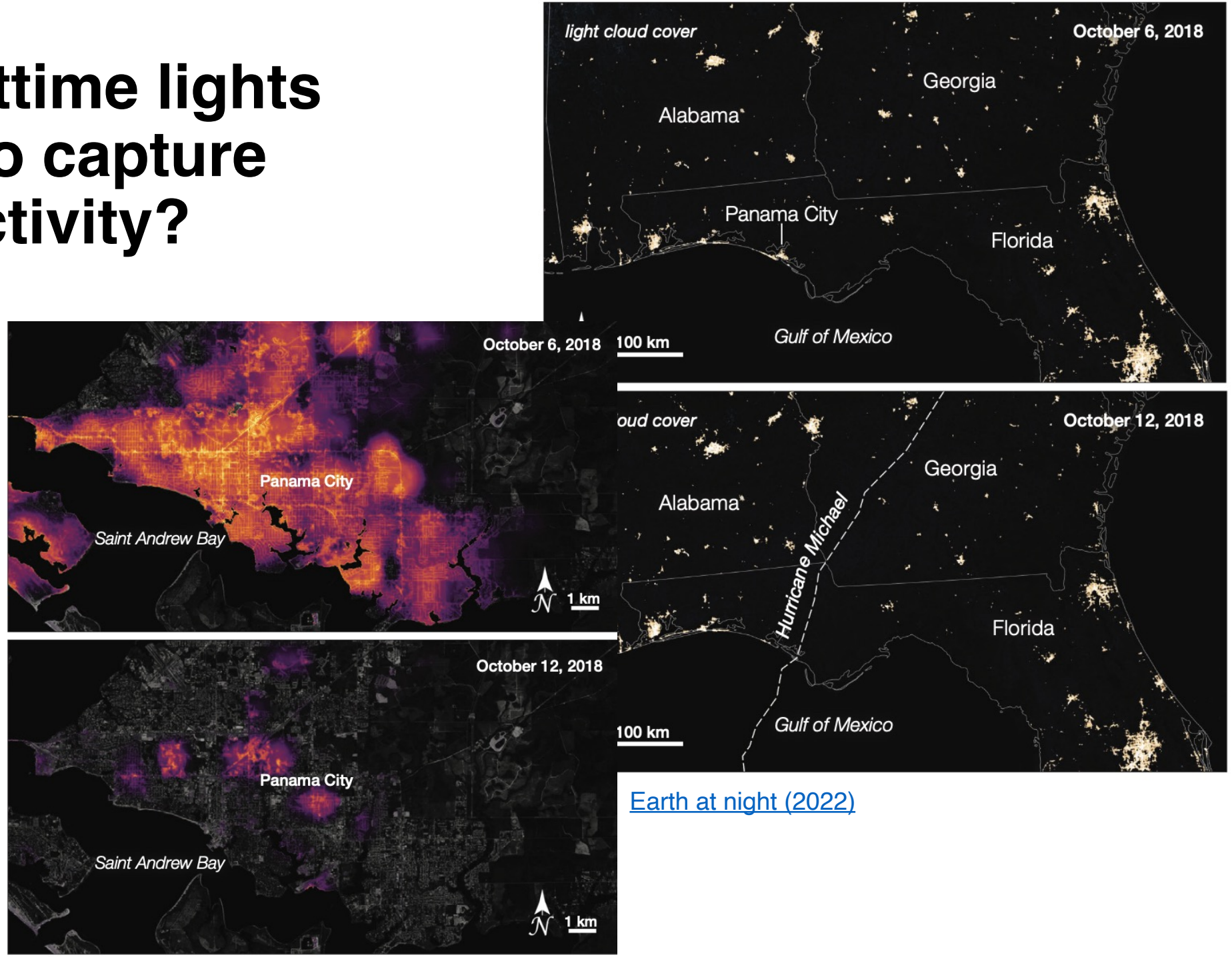
How has nighttime lights been used to capture human activity?

- Identify extents of urban areas [here]
- Estimate urban population size and density [here]
- Measure electricity use, energy consumption, and GHG emissions [here]
- Estimating offshore oil production [here]
- Proxy for economic activity / GDP [here and here]
  - Natural disaster, conflict, etc damages [here, here]
  - Impact of infrastructure / policies (eg, roads) [here, here, here]



How has nighttime lights been used to capture human activity?

Impact of Hurricane Michael

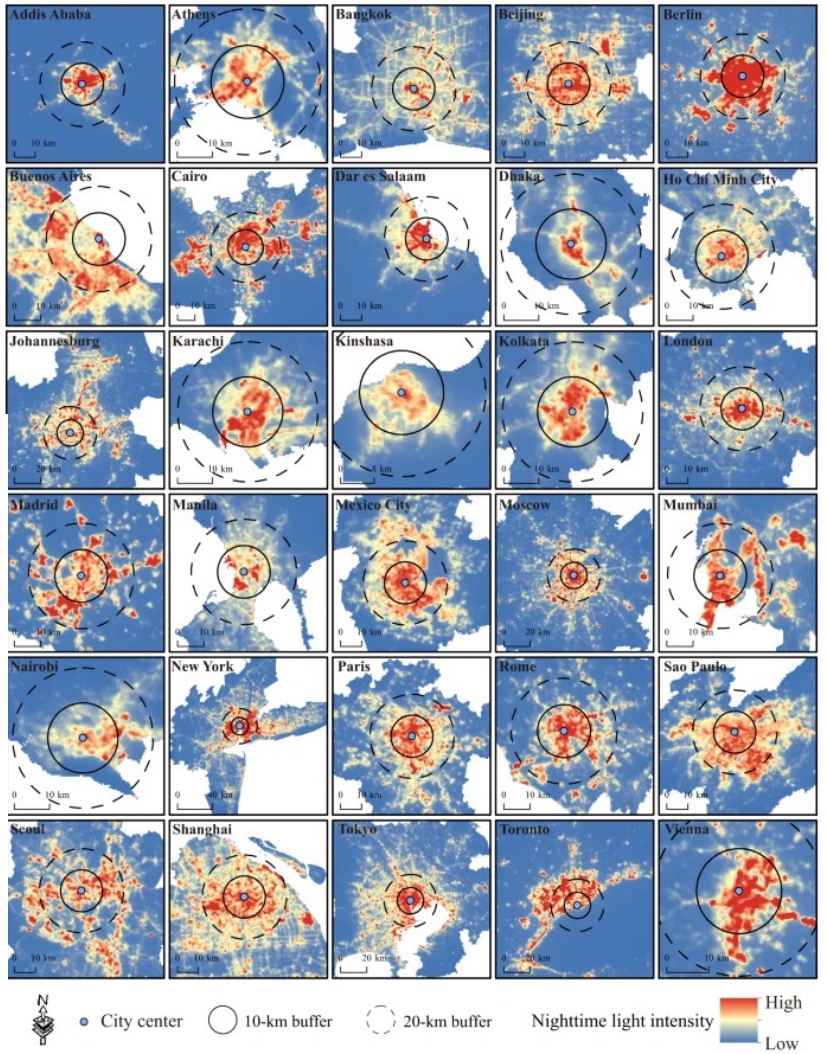


[Earth at night (2022)]

How has nighttime lights been used to capture human activity?

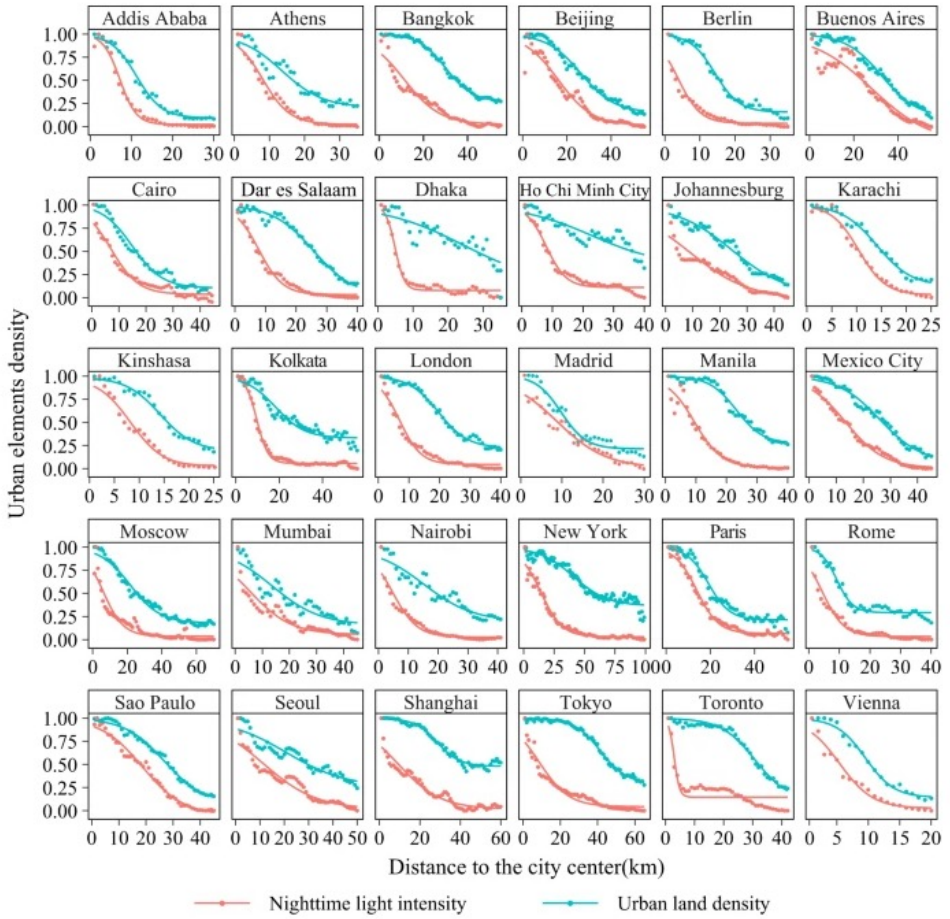
Spatial Agglomeration of Cities

Fig. 4: Spatial distribution of nighttime light of 30 global megacities in 2020.



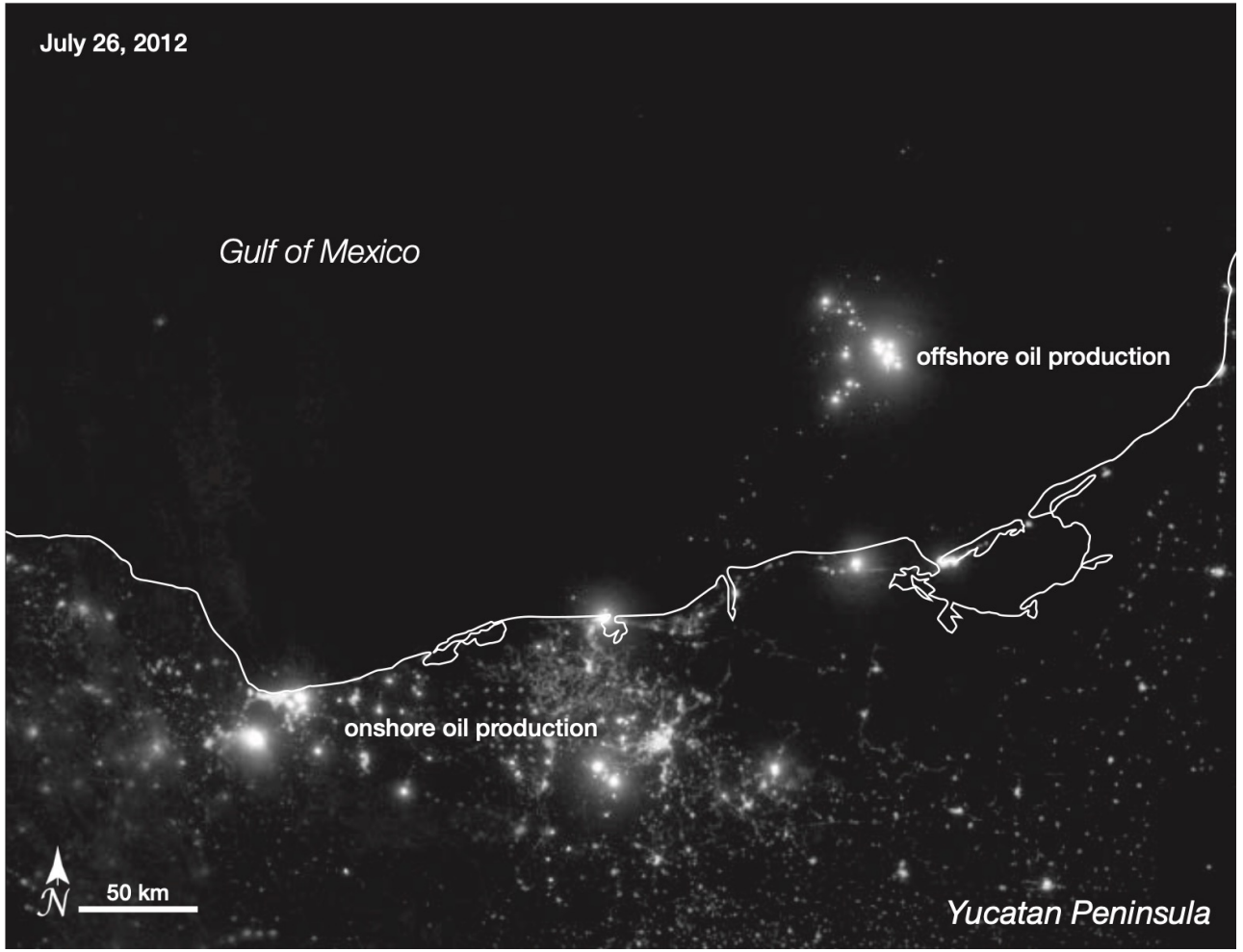
Zheng et al. (2023)

Fig. 5: Spatial gradients of urban land density and nighttime light intensity.



How has nighttime lights been used to capture human activity?

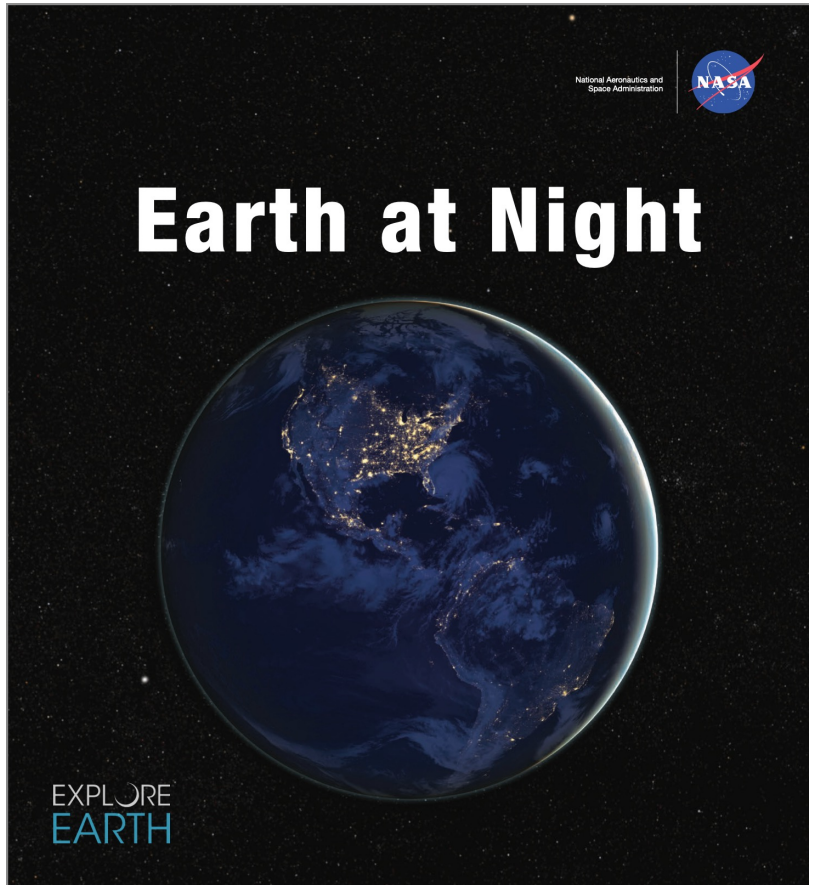
Oil Production



Earth at night (2022)

Other resources for examples of use of nighttime lights

Earth at Night (2022):
Examples across variety of sectors



World Bank Data Lab:
Support using nighttime lights for many WB teams

red-sea-monitoring Public
Data and analytics to support monitoring of changes in Red Sea maritime traffic
Jupyter Notebook ☆ 0 MPL-2.0 0 5 2 Updated 16 hours ago

syria-economic-monitor Public
Support for the Syria Economic Monitor
Jupyter Notebook ☆ 8 MPL-2.0 3 12 4 Updated 16 hours ago

myanmar-economic-monitor Public
Resources to support the Myanmar Economic Monitor
Jupyter Notebook ☆ 0 MPL-2.0 0 5 1 Updated 16 hours ago

lebanon-economic-monitor Public
Understanding Lebanon's Economy through Alternative Data
Jupyter Notebook ☆ 0 MPL-2.0 3 9 2 Updated 16 hours ago

niger-economic-monitoring Public
Niger Economic Monitoring
Jupyter Notebook ☆ 1 MPL-2.0 1 6 (1 issue needs help) 2 Updated

turkiye-earthquake-impact Public
Türkiye Earthquake Impact
Jupyter Notebook ☆ 1 MPL-2.0 1 1 1 Updated 16 hours ago

gaza-israel-conflict-impact-analysis Public
Gaza-Israel 2023 Conflict Impact Analysis
Jupyter Notebook ☆ 3 MPL-2.0 4 2 1 Updated 16 hours ago

Main Takeaways

Nighttime lights data sources

- **Two sources of raw data:** DMSP-OLS and VIIRS. VIIRS goes until present and is better in many ways (eg, more granular)
- **Two sources of processed VIIRS data:** Colorado School of Mines & Black Marble.
  - Black Marble is more recent & makes additional corrections (snow, vegetation)
  - Black Marble provides additional choice on NTL variable
    - Daily: Gap filled vs not gap filled.
    - Monthly/Annually: Angle & snow correction

Applications of nighttime lights

- Wide of use nighttime lights in social science research, from GDP to urbanization
- Key to think about what does and does not contribute to NTL (eg, manufacturing vs service sector; agriculture and forestry)
- With nighttime lights, we can control which pixels we use to spatially aggregate. Do we exclude gas flaring locations? Do we only include lights in city boundaries?

Thank You

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