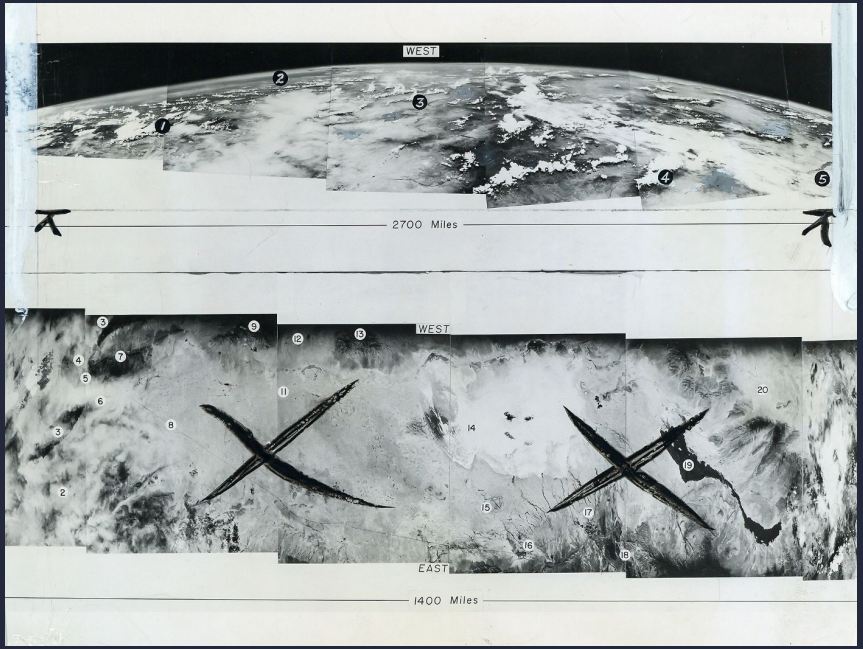
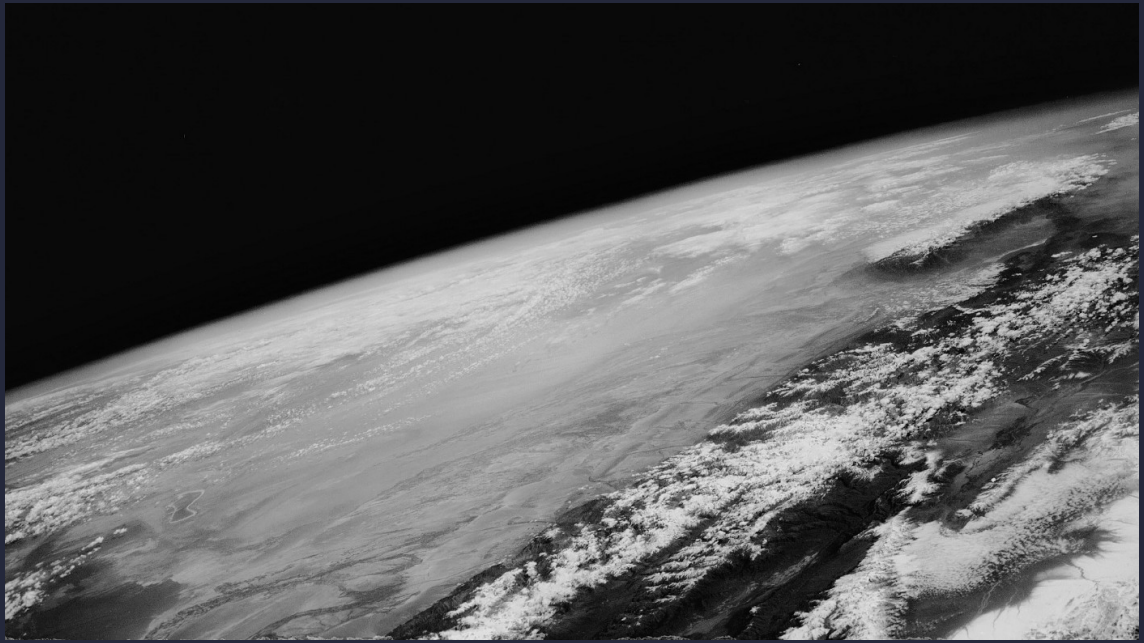
Satellite imagery

DSIER [/d□ˈza□ər/] — Summer 2025

Julian Hinz

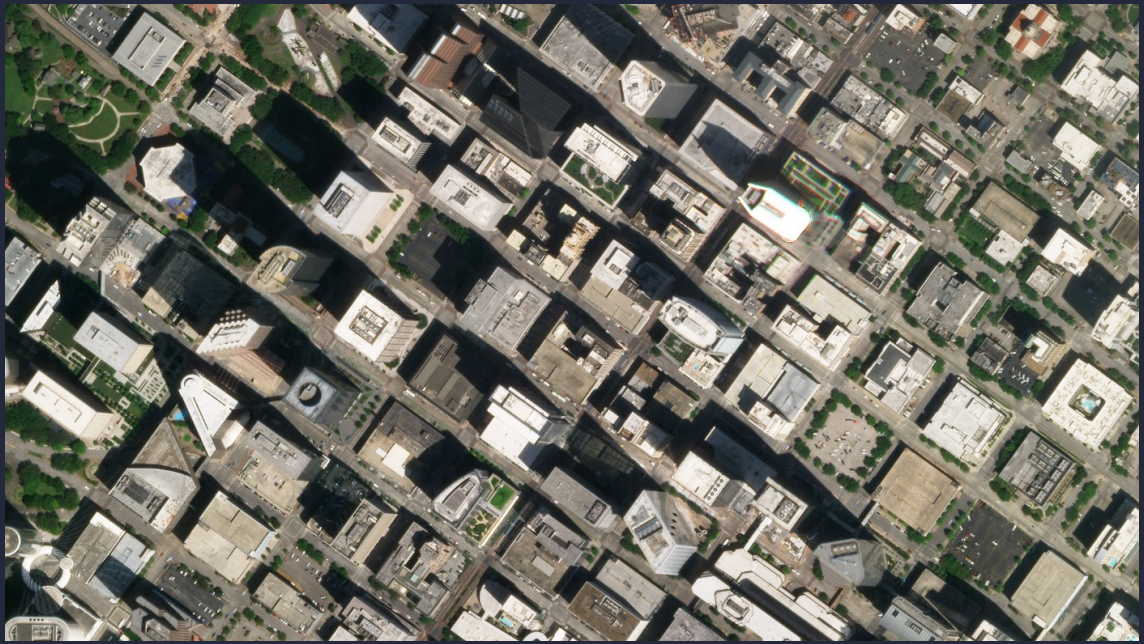
Bielefeld University

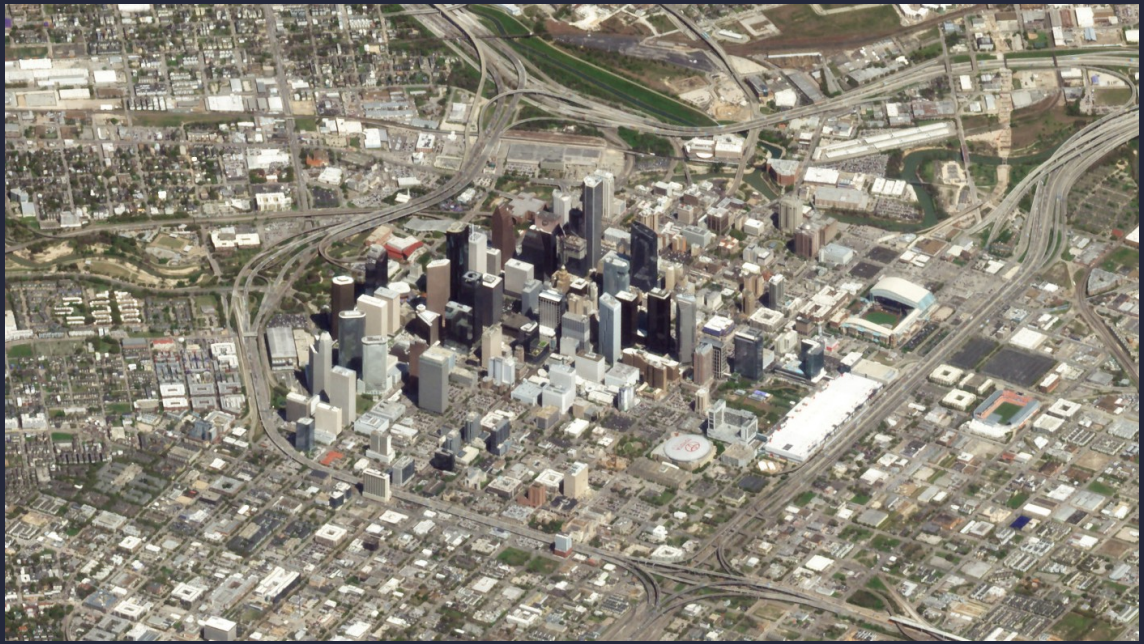

WEST
1
2
3
4
5
2700 Miles
WEST
EAST
1400 Miles

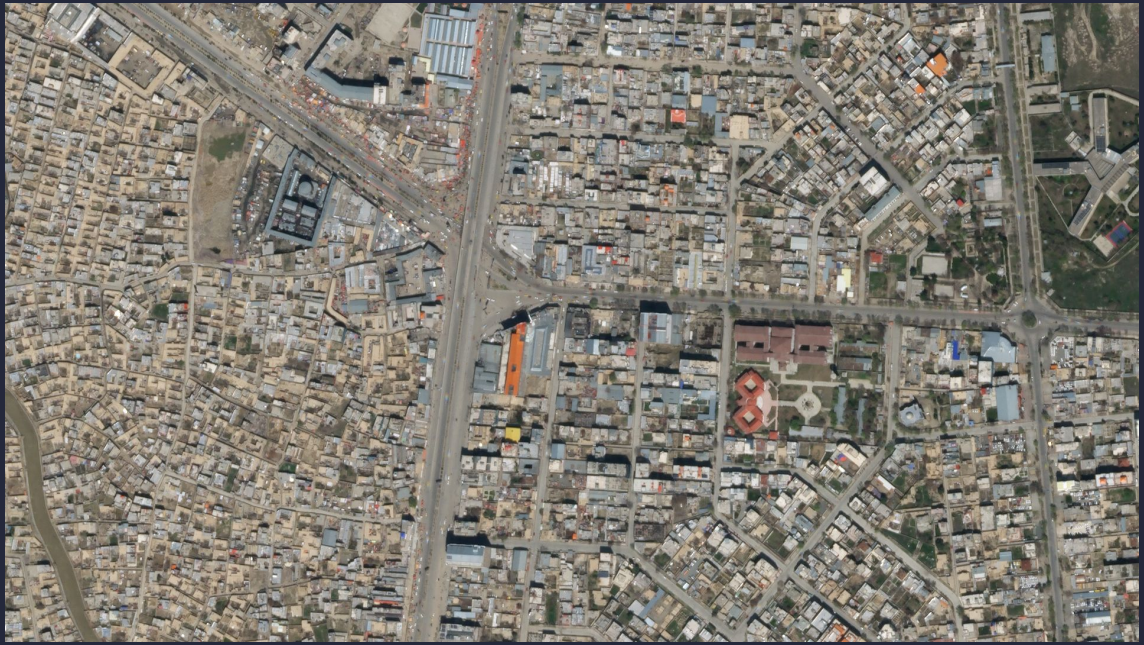


A brief history

- First image from space: Sub-orbital V-2 rocket flight launched by the U.S. on October 24, 1946
- First satellite image: U.S. satellite Explorer 6 on August 14, 1959
- Primary use-case: Spying
- Now: about 1,000 (known) Earth observation satellites in orbit
- Public: Landsat (30m resolution since early 1980s), ESA Sentinel, NASA MODIS (36 spectral bands since 2000), ...
- Private: GeoEye, Maxar, Planet, up to 0.31m spatial resolution








submarine

Use of satellite data in economic analysis

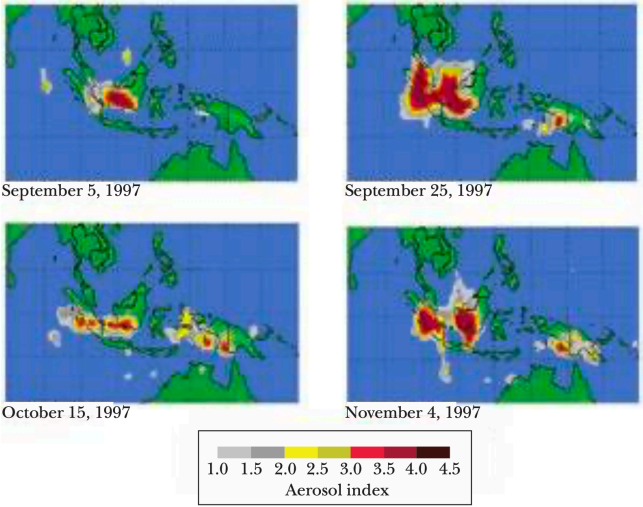
- Night lights, pollution, ...
- Precipitation, wind speed, flooding, topography, ...
- Forest cover, crop choice, agricultural productivity, fish abundance, ...
- Urban development, building type, roads, beach quality, ...

Advantages

Availability and objectivity

- Burgess et al. (2012) study political economy of deforestation
  - → official administrative data may be tainted because of bribing
  - → incentive for misreporting
- Jayachandran (2009) estimate impact of air pollution on infant and fetal mortality
  - → 1997 forest fire caused 16,400 infant and fetal deaths

Aerosol Index of Particulate Air Pollution in Indonesia during Massive Wildfires in 1997



Source: Jayachandran (2006).

Advantages

High resolution

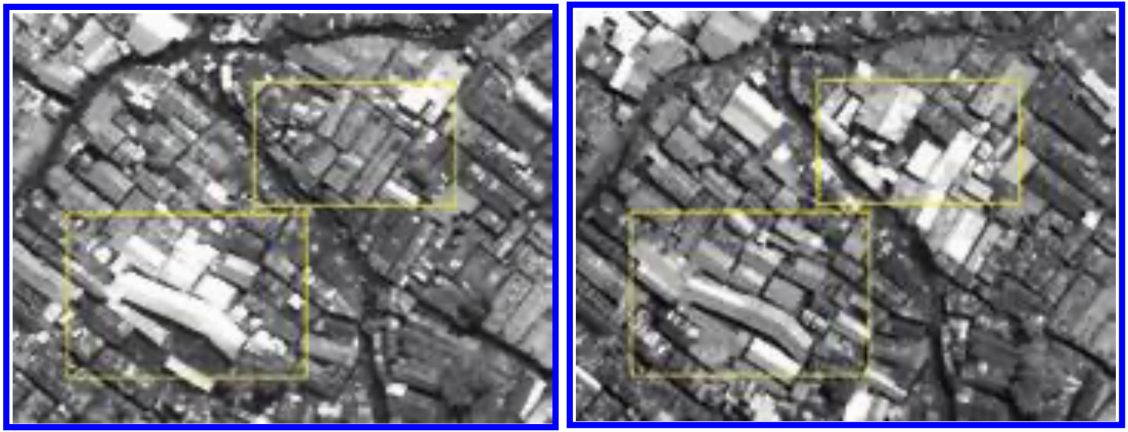
- publicly available satellite imagery has 30-meter-by-30-meter grid cells or better
- private data: better than 0.5m
- Marx, Stoker, and Suri (2015): reflectivity as proxy for dwelling investments in a Nairobi slum

  $\rightarrow$ role of ethnic favoritism in residential markets

- others: count cars in parking lots to estimate retail demand, measure automobile traffic or count crowds at political rallies, ...

A: July 2009

B: August 2012



Source: Marx, Stoker, and Suri (2015).

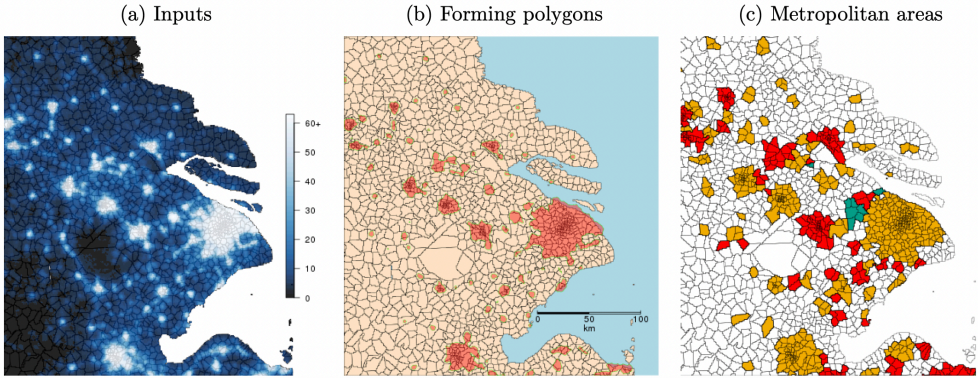
Notes: This is a 50-cm resolution panchromatic image from Kibera, Nairobi. Roofs in the lower left rectangle dulled over time, while those in the upper right rectangle were replaced.

Advantages

Global coverage

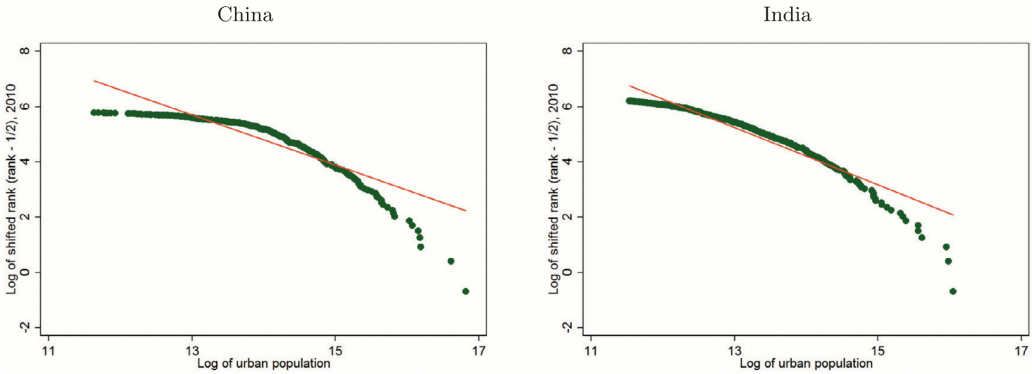
- Henderson, Storeygard, and Weil (2012): nighttime lights a proxy for settlement patterns and wealth at high spatial resolution, globally
- Dingel, Miscio and Davis (2021): For developing countries, lights-based metropolitan populations follow a power law, while administrative units do not

Figure 1: Building metropolitan areas by aggregating smaller units based on lights at night



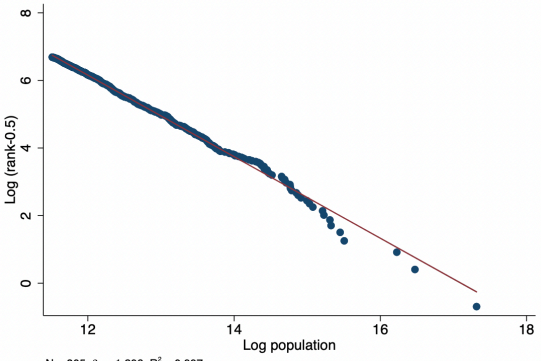
NOTES: This figure illustrates our procedure for combining satellite imagery of lights at night with administrative spatial units to build metropolitan areas. These panels depict a portion of the eastern coast of China in 2000. The administrative spatial units are townships. The polygons in the middle panel are areas of contiguous light brighter than 30. Aggregating the townships that intersect these polygons produces the metropolitan areas depicted in the right panel. Adjacent townships are often assigned to distinct metropolitan areas.

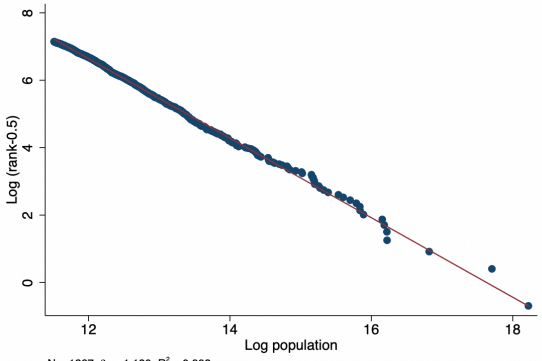
Figure 5: City-size distributions with administrative units, 2010 (Chauvin et al., 2017)



NOTES: These two panels are taken from Figure 2 in Chauvin et al. (2017). The left panel depicts 326 prefecture-level cities in China (slope -0.91, $R^2 = 0.79$). The right panel depicts 495 districts in India (slope -1.03, $R^2 = 0.92$).

Figure 7: China's city-size distribution with night-lights–based units, 2000 and 2010





NOTES: The sample is Chinese metropolitan areas with population greater than 100,000. Metropolitan areas defined by aggregating townships in areas of contiguous night lights with intensity greater than 30. Left panel depicts 2000; right panel 2010.

TECHNICALITIES

Orbits

Geostationary

- directly above a fixed point on the Equator

  $\rightarrow$ continuous observation of same area

- $\approx$ 36,000 kilometers above Earth's surface

  $\rightarrow$ images are relatively low resolution

Orbits

Sun-synchronous

- within 6,000 kilometers and often much more closely
- orbit Earth between 7 and 16 times per day

  → depending on altitude

  → lowest is 282 kilometers with orbital period of 90 minutes
- observe the whole Earth at approximately the same time each day

  → constant solar illumination

Sensors and Bands

- different ranges of electromagnetic spectrum
  - $\rightarrow$ microwaves, infrared, ultraviolet, or visible light
  - $\rightarrow$ human eye: three bands, red, blue, and green
- used to study life cycle in plants, temperature, humidity and precipitation

Processing

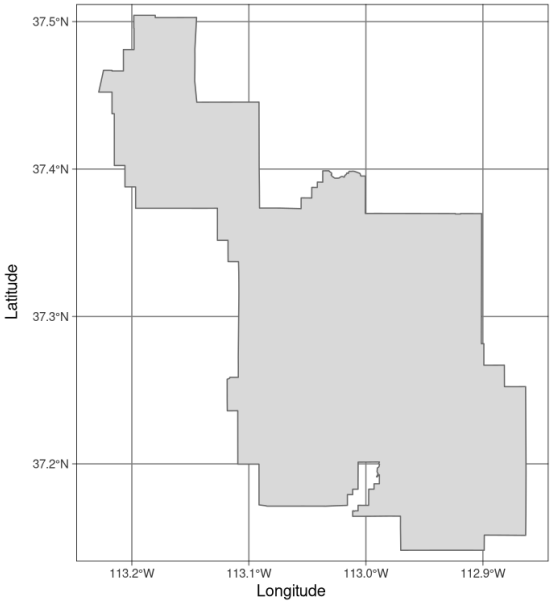
- Removing artefacts (clouds, fires, reflections)
- Adjusting orthorectification (at nadir vs. oblique)
- Projections

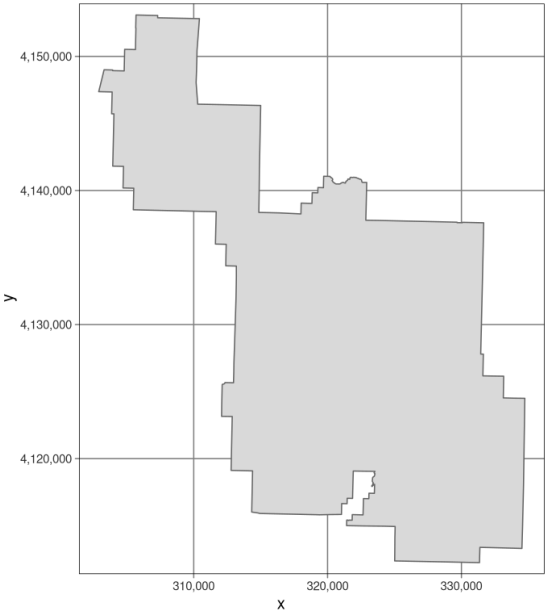
Coordinate Reference Systems

Projections go back and forth between

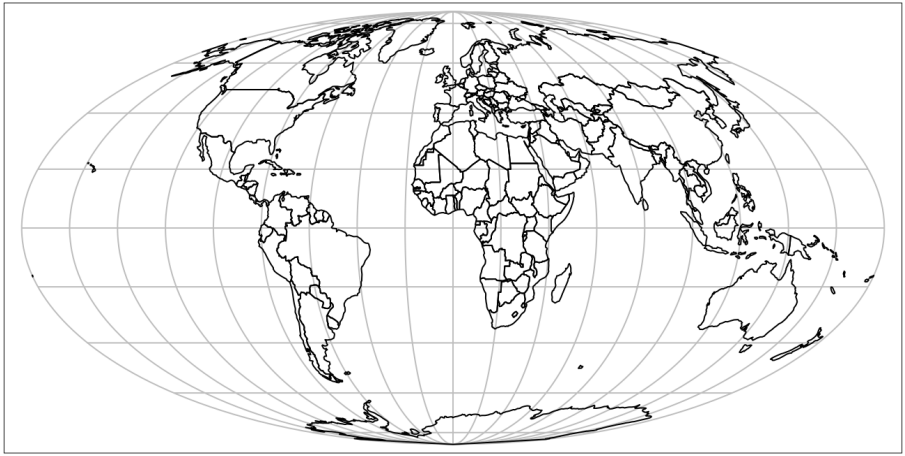
- *ellipsoidal* coordinates — degrees latitude and longitude — pointing to locations on a shape approximating the Earth's shape (an ellipsoid or spheroid)
- *projected* coordinates — coordinates on a flat, two-dimensional coordinate system, used when plotting maps

…what projections? https://www.geo-projections.com

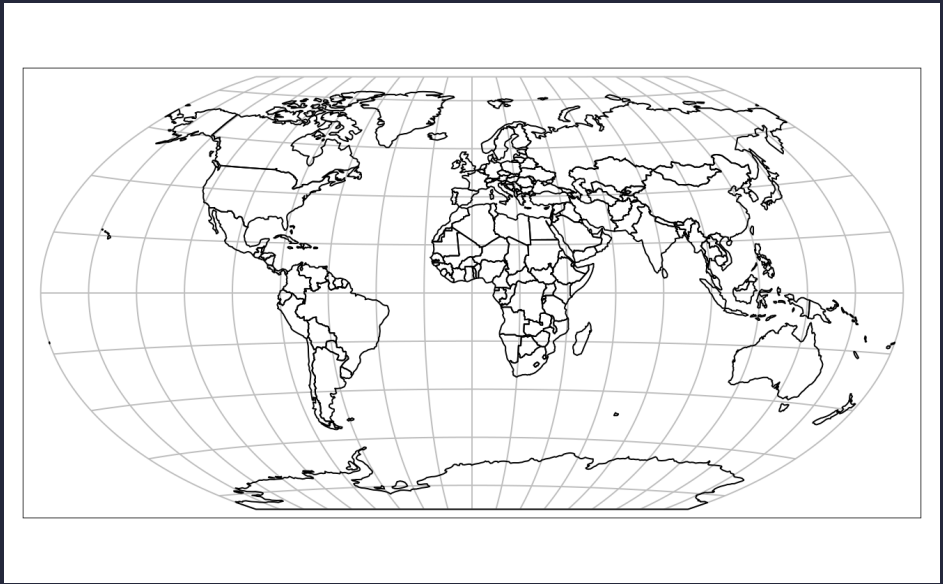

37.5°N
37.4°N
37.3°N
37.2°N
Latitude
113.2°W
113.1°W
113.0°W
112.9°W
Longitude


4,150,000
4,140,000
4,130,000
4,120,000
y
310,000
320,000
330,000
x

Mollweide



Winkel Tripel



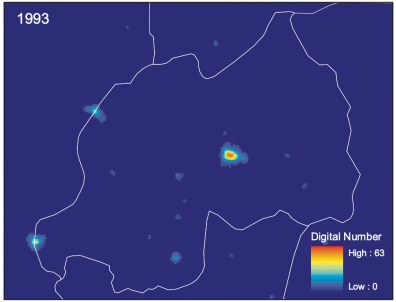
Lambert azimuthal

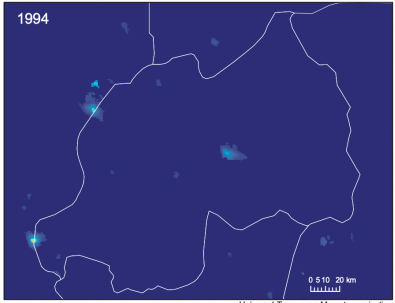
NIGHTLIGHTS

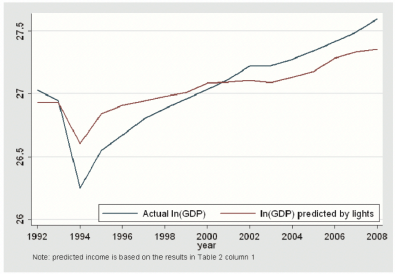
Nightlights and GDP

Henderson, Storeygard, and Weil (2012): “Measuring Economic Growth from Outer Space”

- long-run lights-GDP relationship has correlation coefficient of 0.53
- long-run lights-GDP elasticity of 0.28 to 0.32
  $\rightarrow$ no evidence of non-linearity or asymmetry between increases and decreases
- under a range of assumptions about measurement error: structural elasticity of lights growth with respect to GDP growth of between 1.0 and 1.7







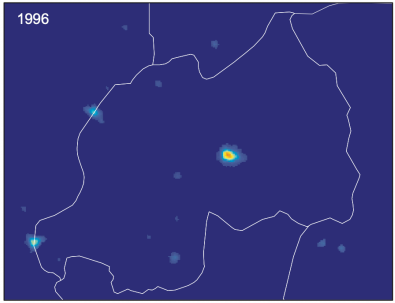
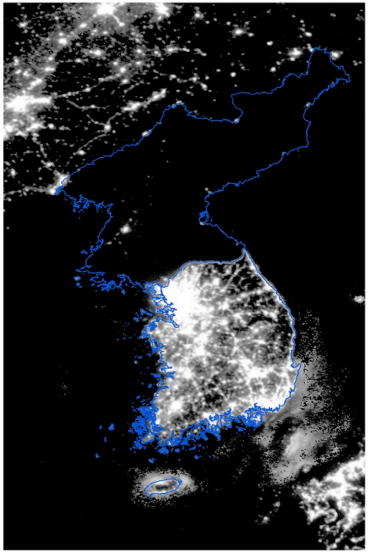


Figure 4: Genocide event: Rwanda

Many nightlight papers

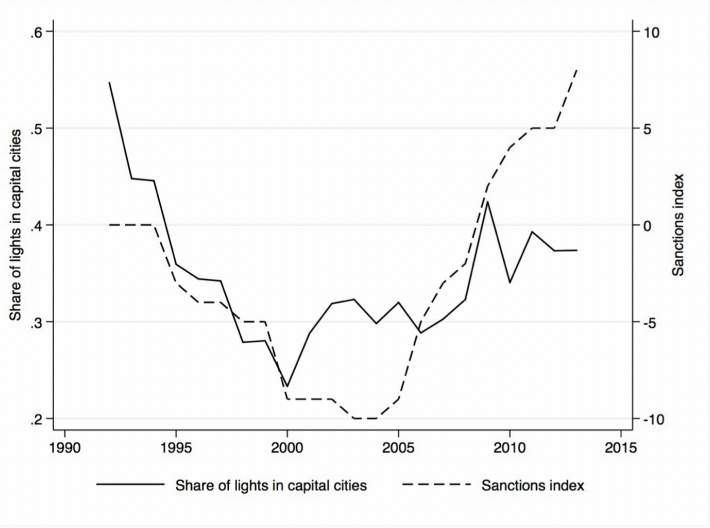
- Hodler and Raschky (2014): Regional favoritism
  → Stronger growth in origin region of ruler
- Bluhm and Krause (2022): Top lights - Bright cities and their contribution to economic development
  → Top-coding leads to underestimating growth of African cities
- Lee (2016): International isolation and regional inequality: Evidence from sanctions on North Korea
  → has also used the night lights data to estimate economic activity in North Korea, whose government produces no credible economic statistics

Figure 5. Satellite Image of the Korean Peninsula in 2010.



Notes: The above map covers the area between 123 and 131 degrees longitude, and 32 and 44 degrees latitude. The bright area in the middle of North Korea is the Pyongyang, the capital city, region.

Figure 7. Share of lights in the capital cities and the sanctions index



Notes: The solid line represents the sum of all lights (digital numbers) in Pyongyang and province capitals divided by total lights (digital numbers) in North Korea. The dashed line presents the sanctions index from Figure 1.

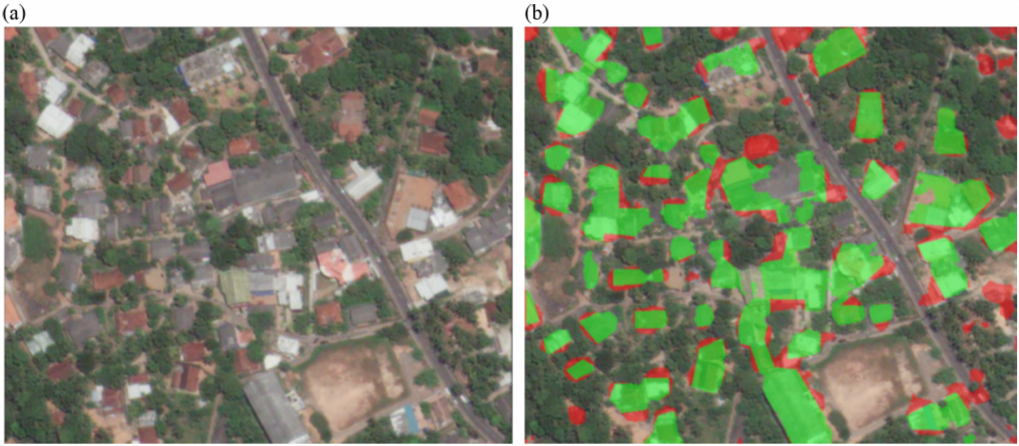
VISIBLE SPECTRUM

Papers

- von Carnap (2022): Remotely-sensed market activity as a short-run economic indicator in rural areas of developing countries
- Engstrom et al. (2022): Poverty from Space - Using High Resolution Satellite Imagery for Estimating Economic Well-being

  $\rightarrow$ Combining nightlight data with visible spectrum imagery to predict poverty

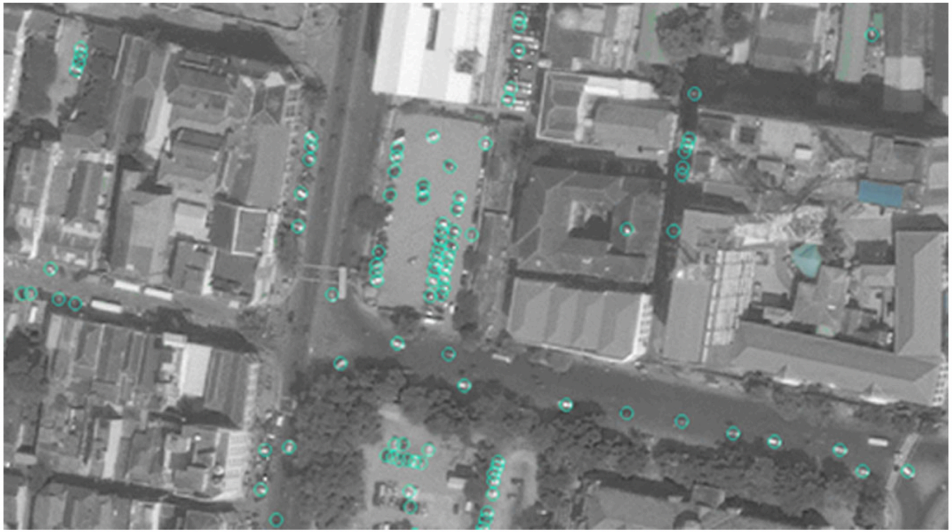
Figure 3. Example Developed Area (Buildings) Classification. (a) Raw satellite imagery. (b) Satellite imagery overlaid with building classification



Source: Digital Global.

Note: Areas in green show are true positive building classifications. Images in red are false positives: erroneously classified areas as buildings.

Figure 4. Example Car Classification



Source: Digital Globe.
Note: Cars identified by convolutional neural network shown in blue.

Tongaren, Kenya on Fri, Oct 3, 2019

Tongaren, Kenya on Thu, Nov 22, 2020

Source: Google Earth Archive


planet.
2021.08.04
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Median composite of all days ⇒ ∼ non-market day

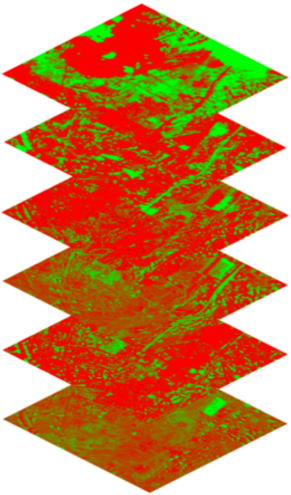
⇒

Key assumption I: Markets take place on <4 days/week more

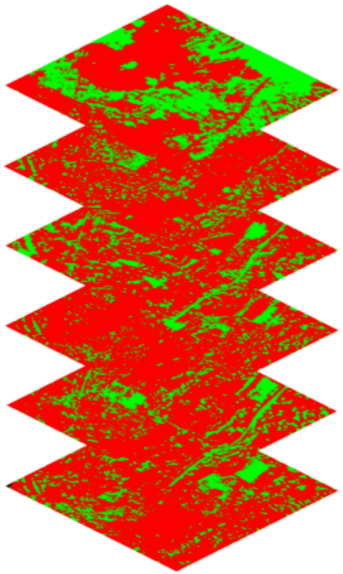
⇒ median composite will look like a non-market day

$-$

$=$



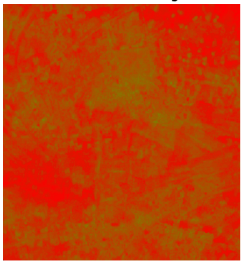
$P_{p,t}$ $-$ P_p^{ref} $= \Delta_{p,t}$



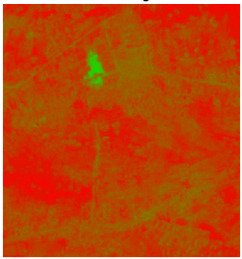
$\Rightarrow$

$\Rightarrow$

Thursdays



Fridays



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