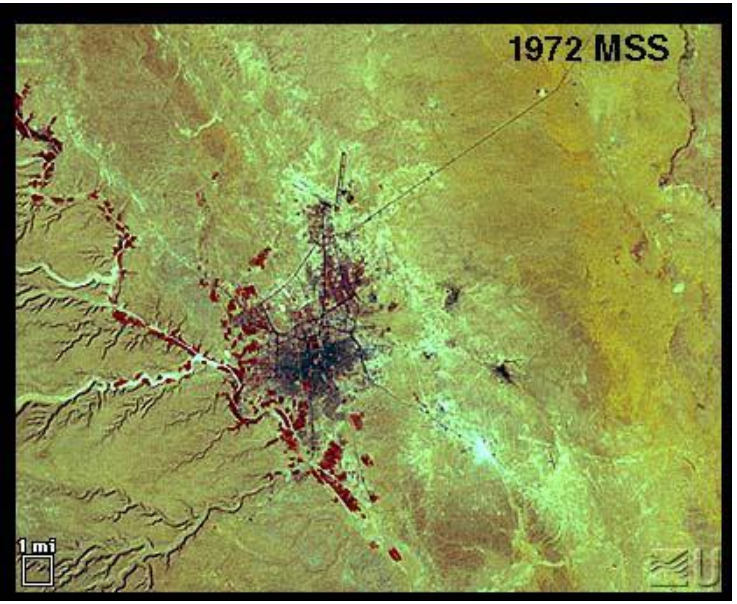
Observing the Human Footprint from Space

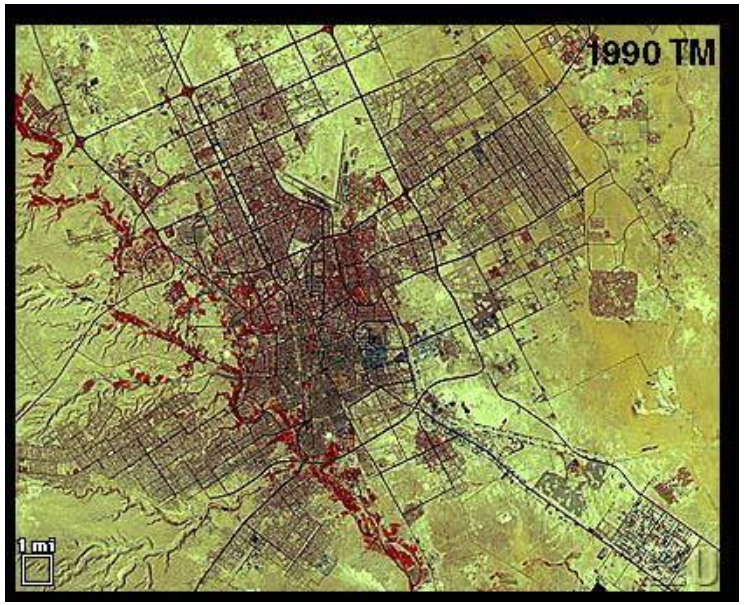
Learning Objectives

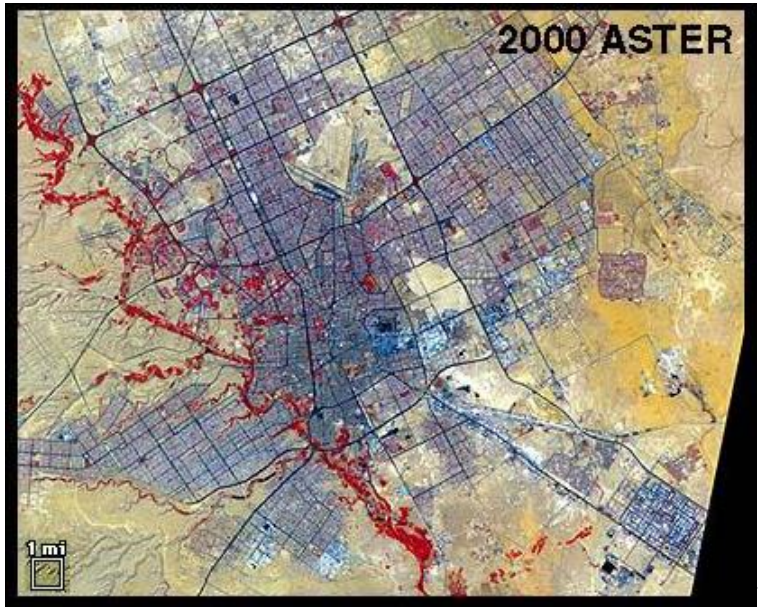
- Human footprint:
  - What is it?
  - Why monitor it?
  - Historical monitoring
  - Remote sensing technologies used to monitor the human footprint
  - Applications/examples

What is human footprint?

- A geographic extent of land under human use
- A measure of how much we are using the Earth's natural resources
- A metric that allows us to calculate human pressure on Earth







Urbanization: Riyadh, Saudi Arabia (Source: NASA)

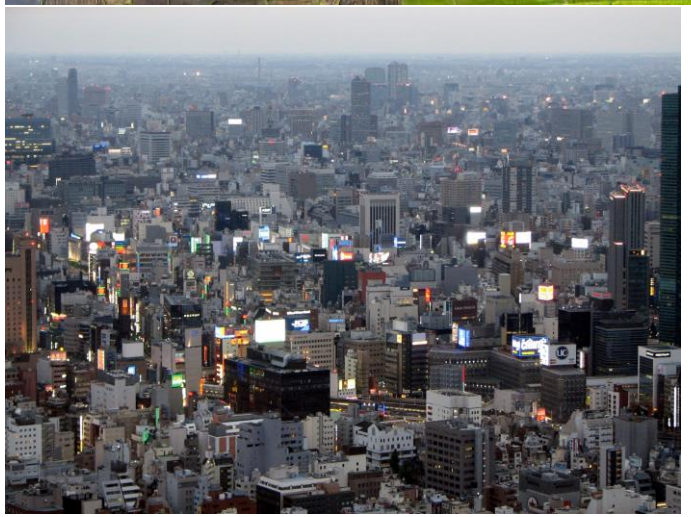
Indicators – How big is our footprint?

- It can be assessed by size of the population
- The amount of human settlements (ex. cities)
- The degree of resource extraction (ex. deforestation, oil/gas, mining)
- The number of products people consume
- The number of cars being driven
  - And how much/often they are driven
- Many more

Why Monitor the Human Footprint?

- The human footprint is a useful tool for:
  - Assessing human impact on the world
    - Environmental
    - Economic
    - Social
- So we can make decisions/planning on:
  - Resource management
  - Land-use planning
    - Ex. Urban planning
  - Conservation focuses

What do you define as “urban”?
What is contributing to the human footprint?



Human Footprint

Definition

- Hard to quantify and define
  - What is an “urban area?”
- Earth observation remote sensing allows us to standardize

Human Footprint

- Measuring the human footprint is difficult because:
  - There are multiple scales to consider
    - Individual, family, city, country, global scales
  - It is constantly changing
  - Hard to find detailed data with global coverage
  - Uncertain definition
    - There is no clear and universally accepted definition

Historical Monitoring of the Human Footprint

- Often quantified with urbanization and population growth
- However, prior to satellites urbanization was often mapped with aerial photography

An aerial view of the now-abandoned town of Bateman, Sask., from the new Howdy McPhail Photograph Collection in University Archives and Special Collections. (Photo: McPhail Fonds, MG 402)

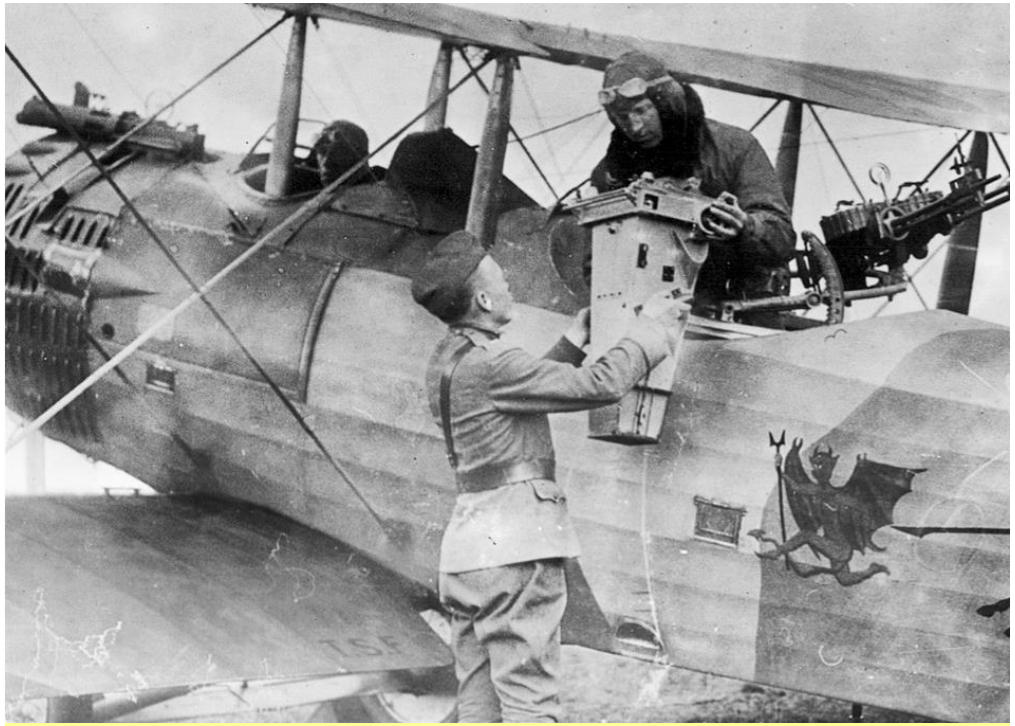
Urban change from aerial photography

- Aerial imagery provide the longest-available record of landscape change (~100 years)
- Early aerial photos are useful for comparative investigation with more recent satellite imagery
- Reveal the historical lay-of-the-land of the present-day cities or transformation rural-urban

Mosaics and mapping
@ US Air Force Langley, VA

Early aerial photography

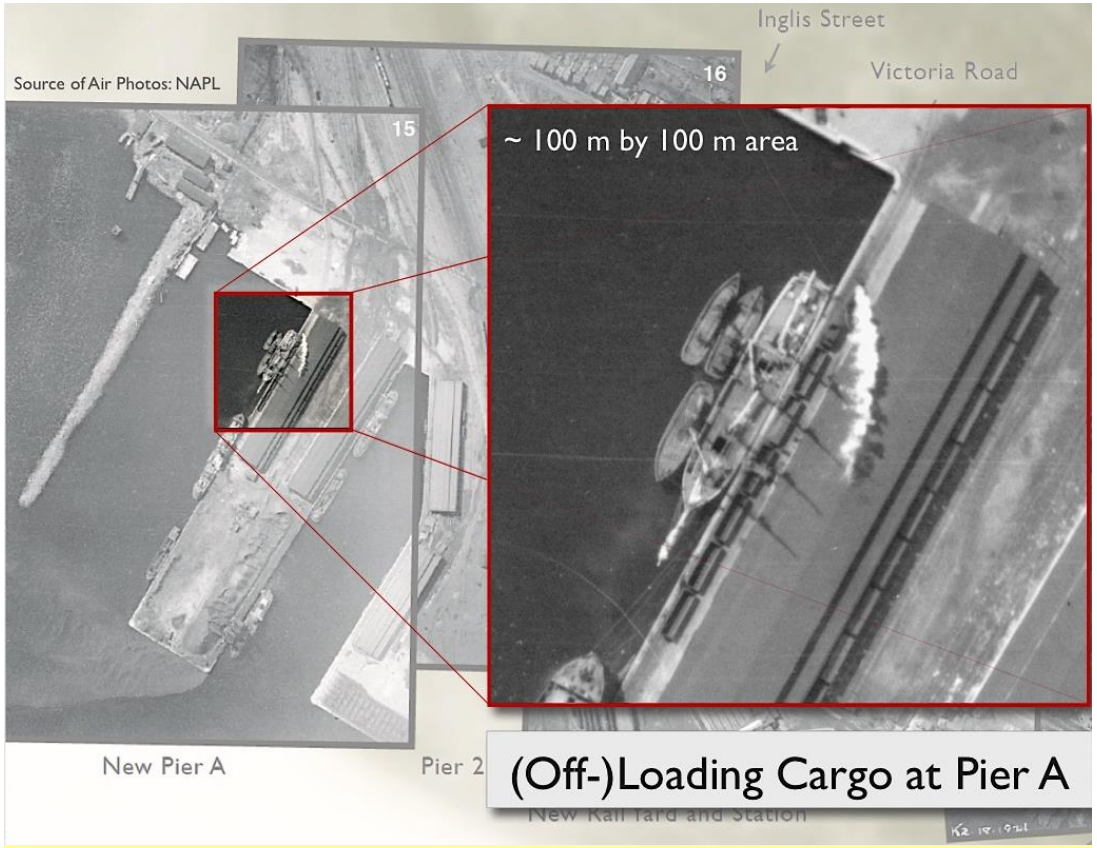
- Aerial photo was the first form of remote sensing used
- During WWI (1914-1918) used for military reconnaissance
- After the war Canada with surplus of planes and camera equipment given by Britain
- Started to be used for civilian applications
  - Surveillance – forest fire detection, fisheries
  - Mapping – urban areas



First aerial cameras
@ US Air Force Langley, VA

Characteristics of early aerial images

- Panchromatic (Black and white)
- High spatial resolution (~1m)
- Vertical or oblique
- Individual photographs have limited spatial coverage
  - Need to be mosaicked
- Spatial/temporal coverage depend on needs of original project



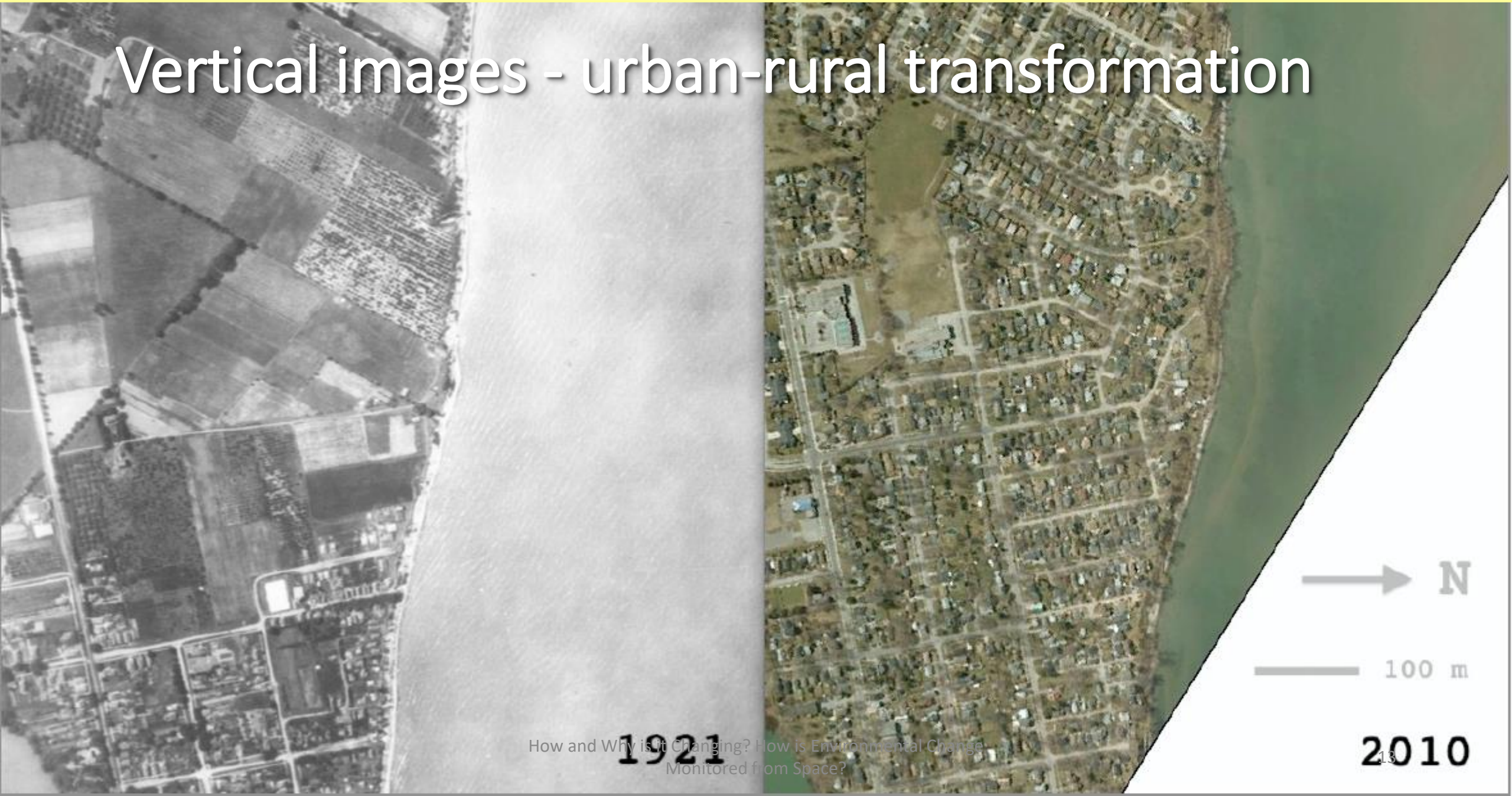
Spatial resolution of an early aerial photo. Halifax, Canada, 1921
@ Dirk Werle

Comparison of 1922 and 1941 aerial photography and modern 2013 Google Earth satellite imagery of London, Ontario
@ Dirk Werle

Vertical images - Institutional buildings

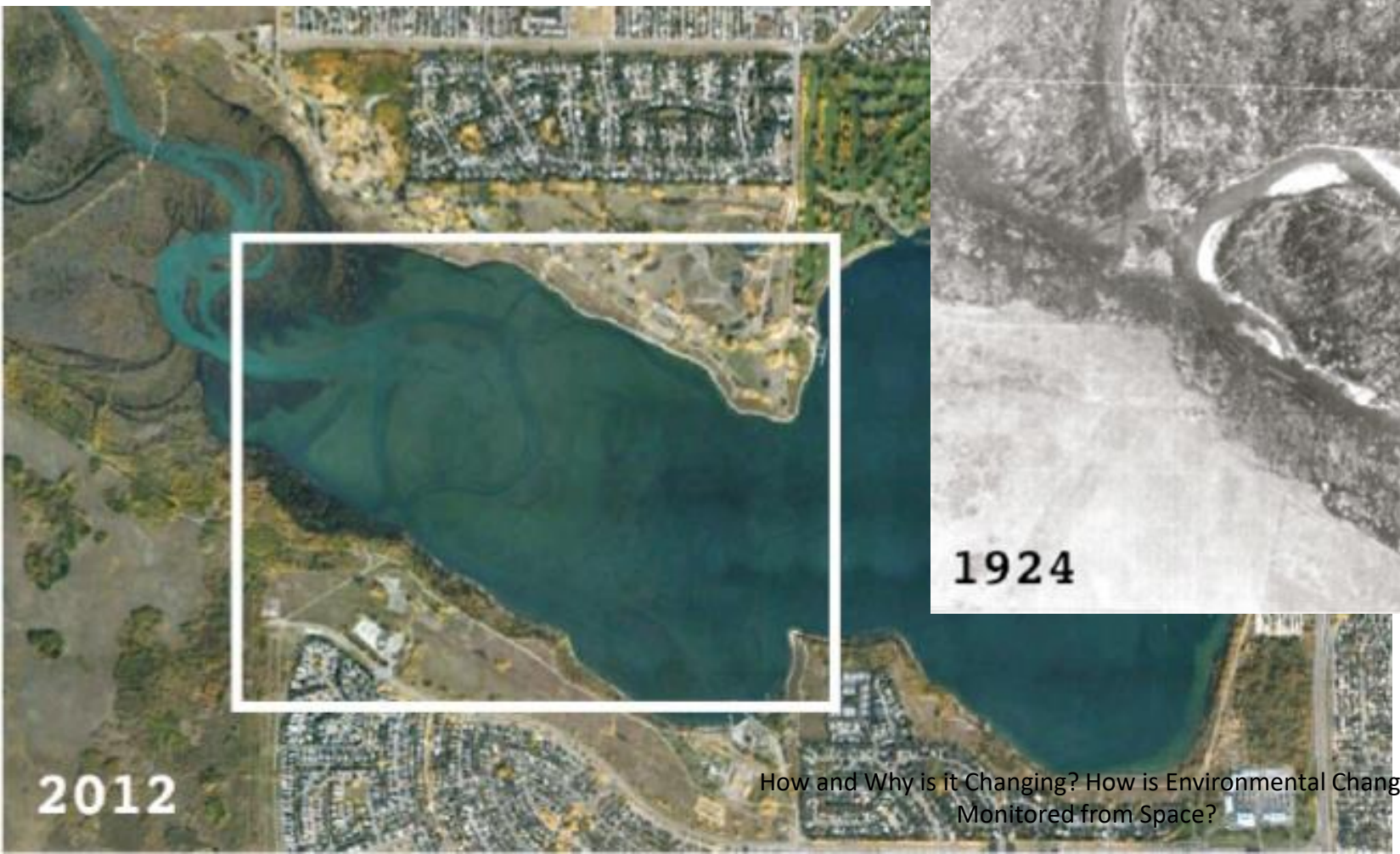
Comparison of 1921 aerial photography and 2010 high-resolution satellite imagery showing Port Dalhousie, Ontario
@ Dirk Werle

Vertical images - urban-rural transformation

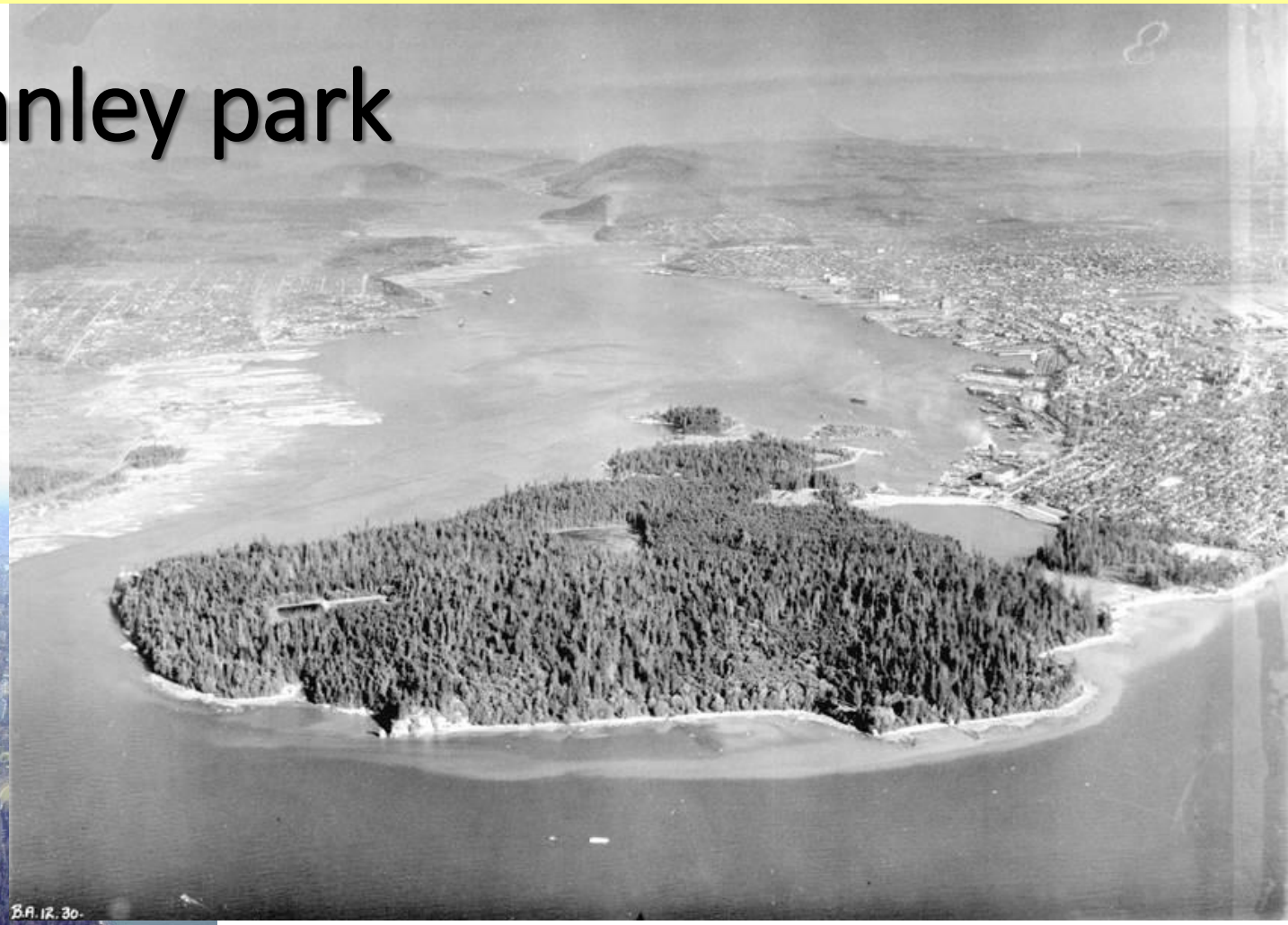


Comparison of 1924 aerial photography and modern 2012 Google Earth satellite imagery of the Elbow River valley and Glenmore Reservoir in Calgary, Alberta
@ Dirk Werle

Vertical images - natural features

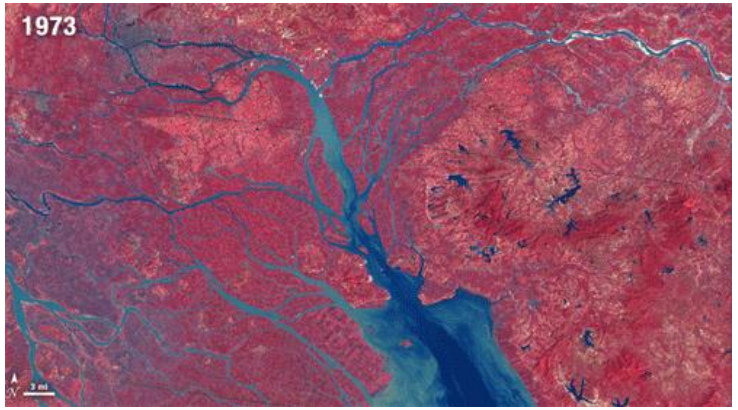


Oblique images - Stanley park



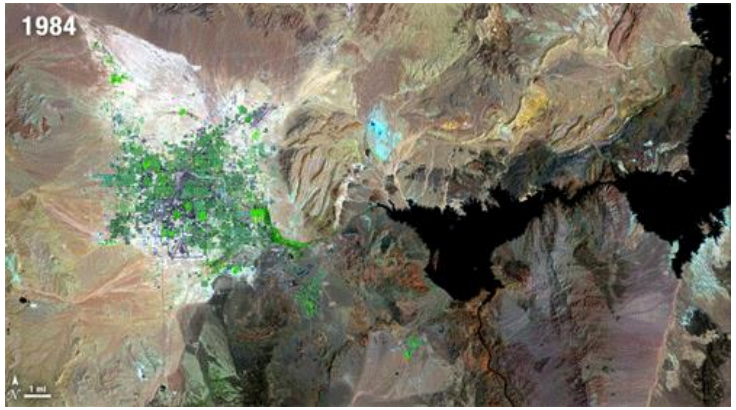
Measuring Human Footprint with Satellites

- True and false colour composites allow us to track urbanization through time
  - Back to the 70s & 80s in the case of Landsat



Zhujiang Delta,
China
1973 - 2003

Dubai
2000 - 2010



Las Vegas
1984 -2011

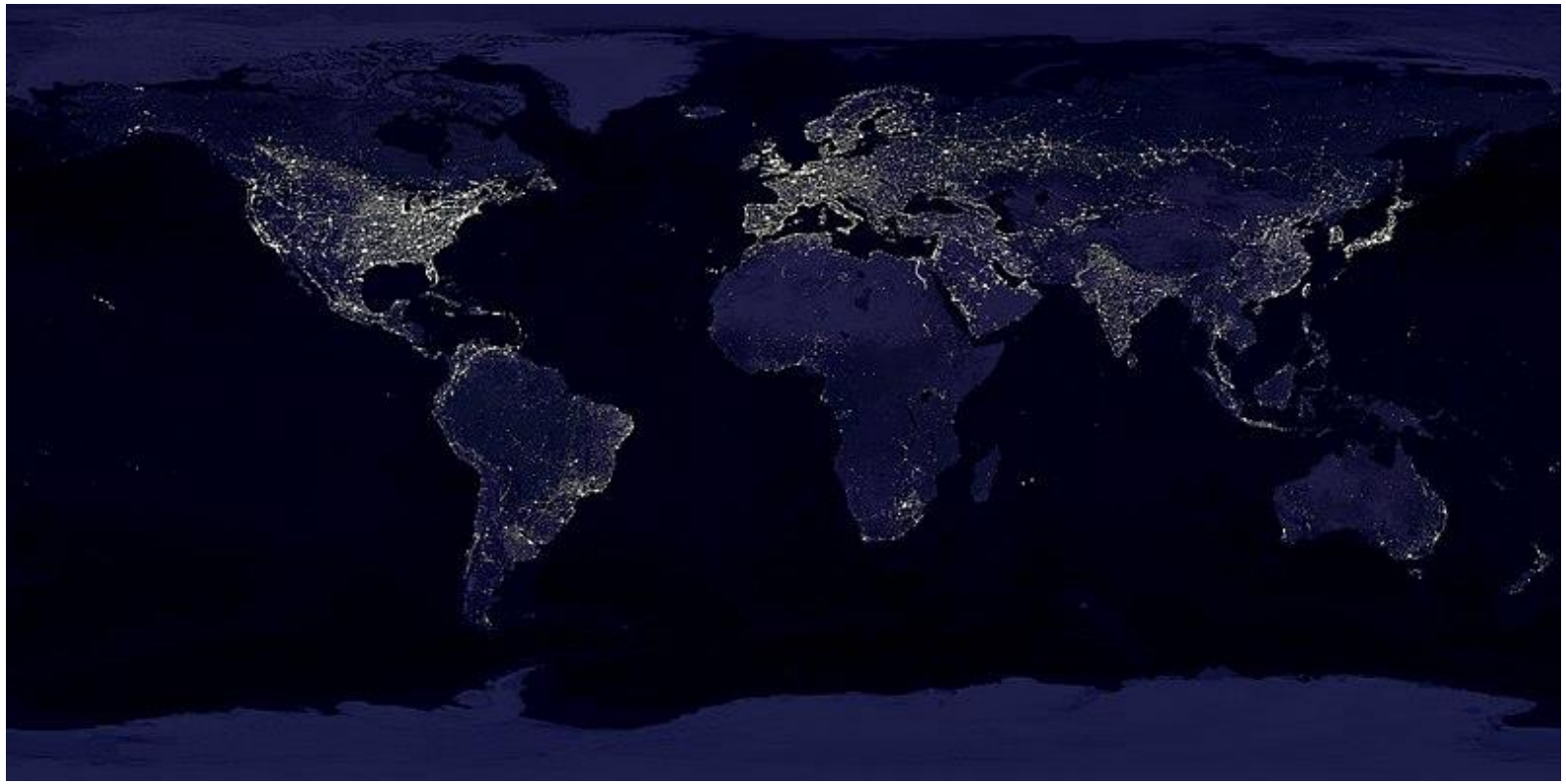
Measuring Human Footprint with Satellites

- But it can be hard to distinguish/classify urban areas with traditional imagery

The contrast between Warsaw's modern and historic neighborhoods is easily visible by satellite. The new Stadion Narodowy is brilliant white. Śródmieście (Inner City) was rebuilt after World War II and most areas appear beige or gray. But some neighborhoods rebuilt with older-style buildings, such as the red tile and green copper roofs of Stare Miasto (Old Town). (Image courtesy NASA/USGS Landsat.)

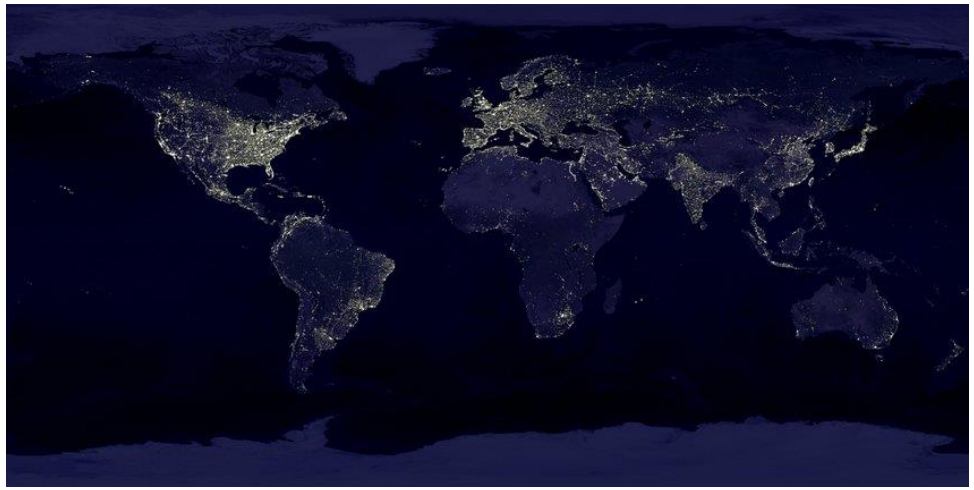
Measuring Human Footprint with Satellites

- Enter night lights



Night Lights Datasets

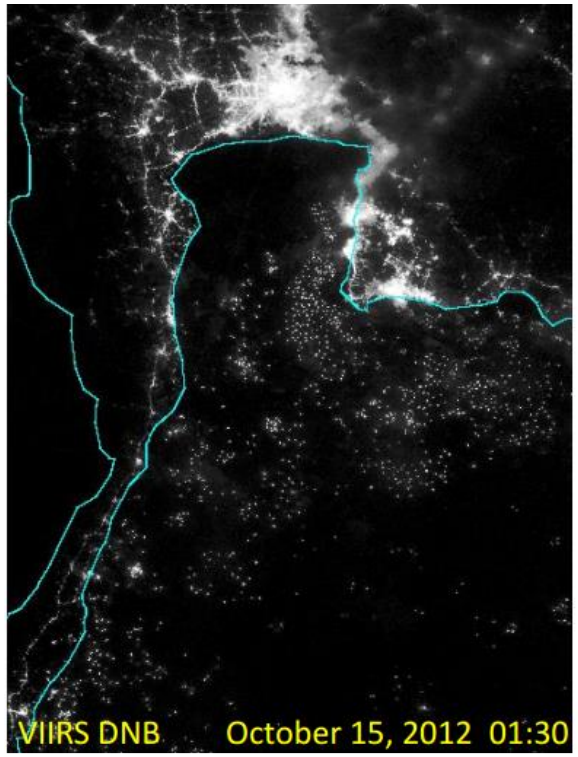
- The Operational Linescan System (OLS) onboard the Defense Meteorological Satellite Program (DMSP)
  - Originally designed to detect clouds at night
    - And aid in meteorological interpretation
  - But also detected city lights, gas flares, and fires
  - Operated from 1992 – 2013
  - Produced the first dataset of night lights from space
  - Measured radiation from 500 – 900nm

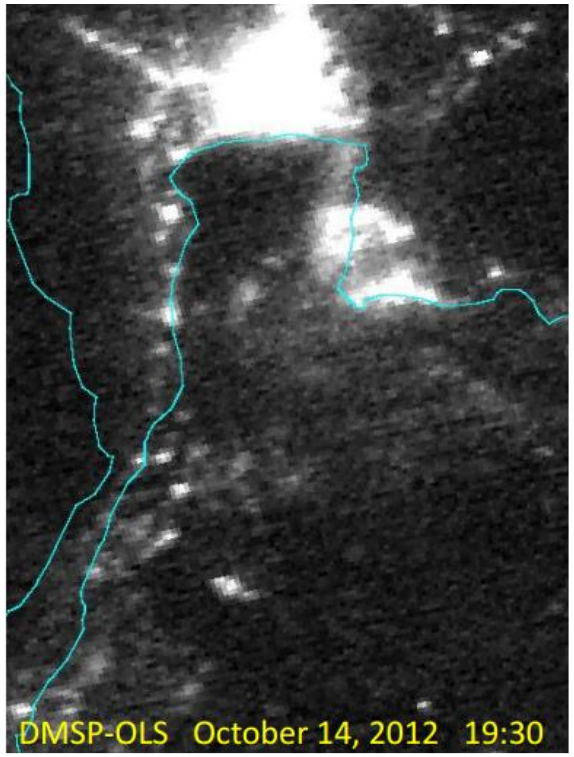


Night Lights Datasets

- DMSP-OLS limitations:
  - Coarse spatial resolution (~2.7 km)
  - Low sensitivity
    - Saturation on bright pixels (e.g. city centers)
    - Limited low light detection capability (ex. rural areas)
  - Limited spectral resolution
  - No in-flight calibration

Detailed review: Table 1 in Elvidge et al., 2013

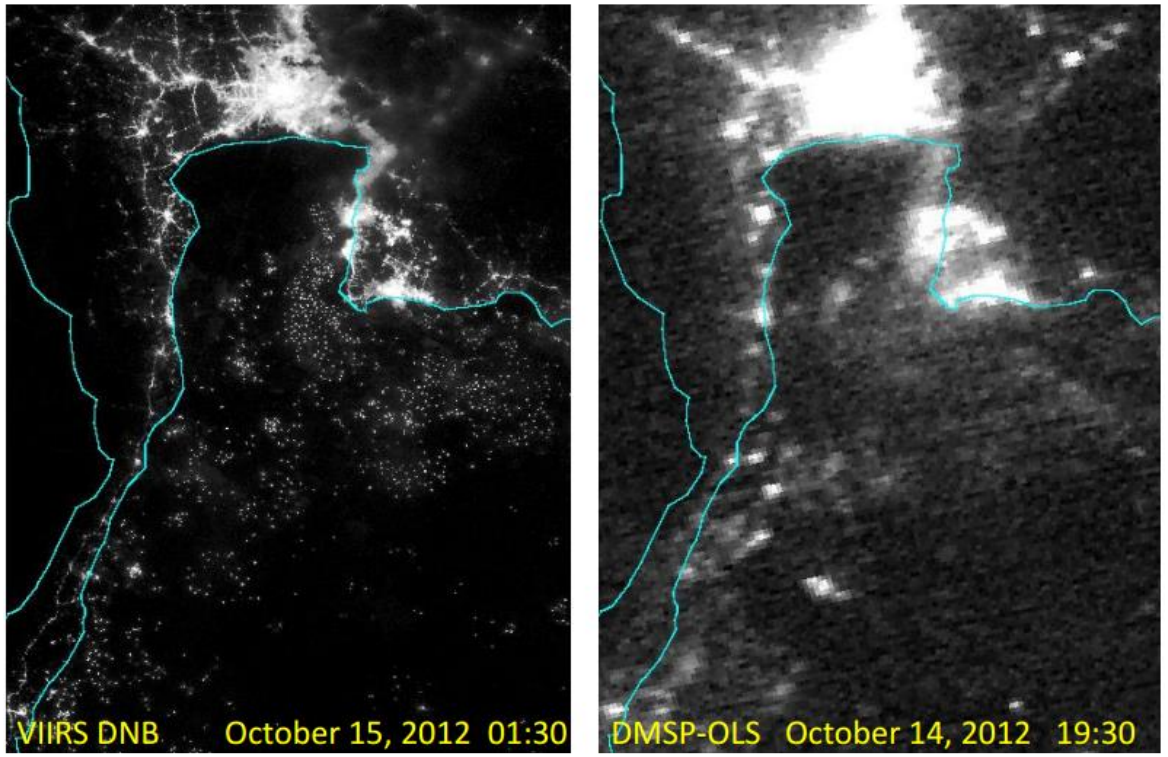




Night Lights Datasets

- The Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the joint NASA/NOAA Suomi National Polar-orbiting Partnership (Suomi NPP)
  - Provides global daily measurements of night lights data since 2011
  - Improvements include:
    - Higher spatial resolution
      - 375 – 750m
    - Daily temporal resolution
      - More complete global coverage
    - Improved sensitivity
      - Can measure very bright and minimally bright lights better
    - More spectral resolution
    - In flight calibration

Detailed review: Table 1 in Elvidge et al., 2013

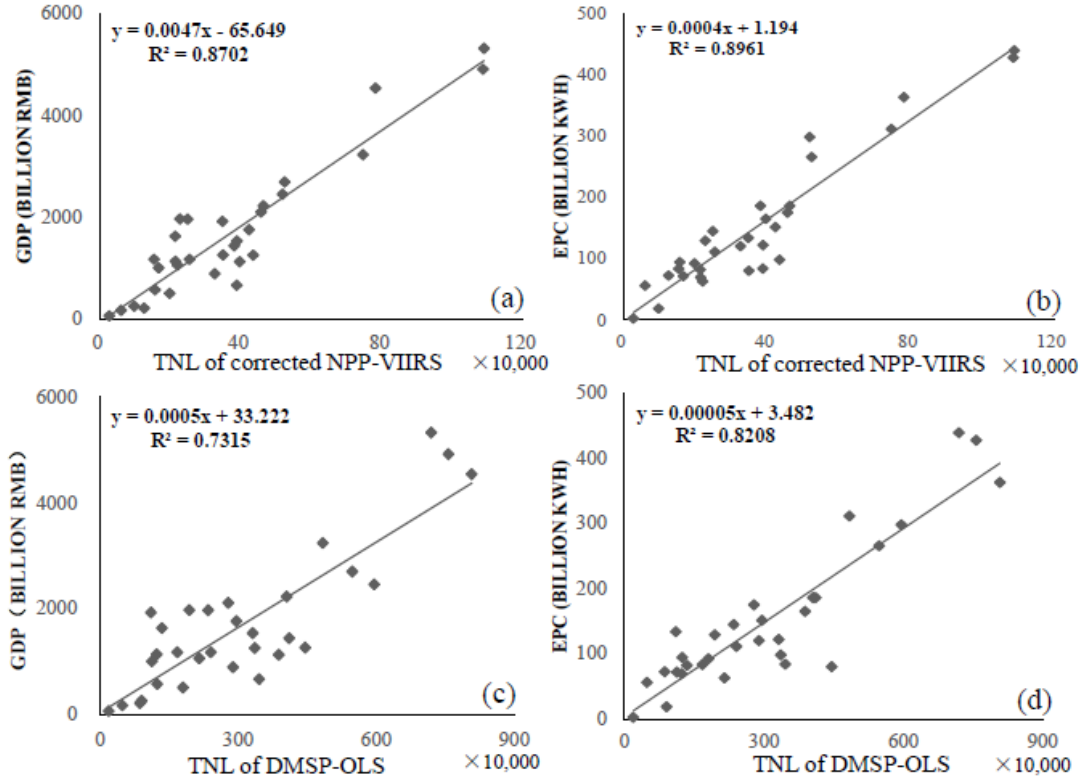



NASA

How nighttime lights measures the human footprint?

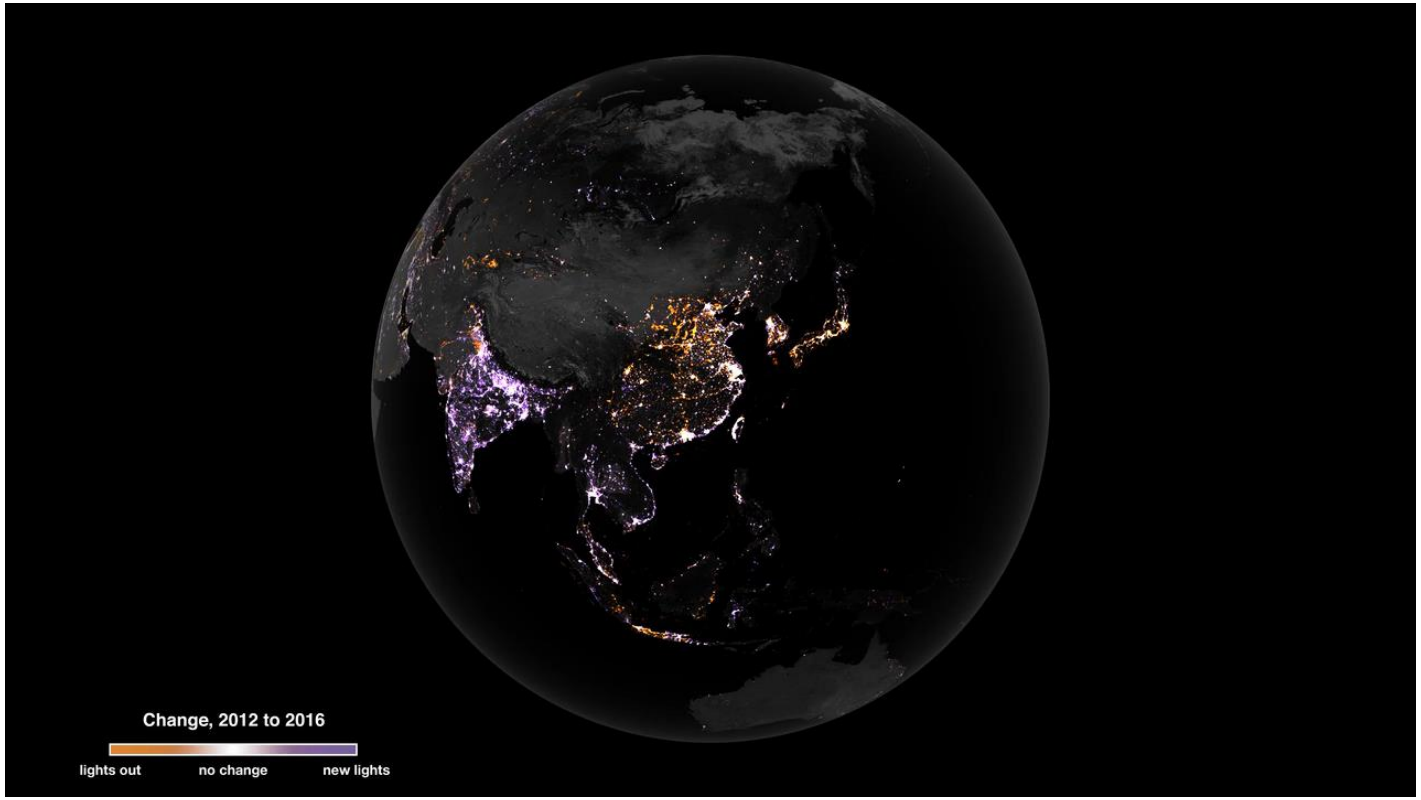
Given their high correlation to human activities, both DMPS-OLS and VIIRS images have been widely used for measuring:

- Population
- Energy consumption
- Economic activities (e.g. GDP)
- Urban extent
- Gas flaring volume
- CO2 emissions



Changing Night Lights

- Allow us to measure how the human footprint is changing
  - Urbanization
  - Energy consumption
  - Socioeconomics
  - Culture
  - Population



Measuring the Human Footprint

Aerial Imagery

- High spatial resolution
- Manual interpretation
  - Mosaics
  - Classification
- Inefficient data collection
  - Have to fly planes
- Costly
- Low temporal resolution
- Historical data (back to 1920s)

Satellite Data (VIIRS & DMSP-OLS)

Depending on the dataset:

- Standardized data
  - Consistent definition of human footprint
- Efficient data collection
  - And processing/analysis
- Coverage
- Resolutions
  - Spatial
  - Temporal
  - Spectral

Important Topics

- Why is night lights data advantageous (compared to daytime satellite imagery) when trying to map urban areas?
- What are some examples of metrics that night lights data from space can be related to?
- Why is the standardized nature of satellite data particularly helpful for measuring the human footprint?
- Describe a situation where satellite data alone may not be applicable for measuring change in the human footprint, and you may have to incorporate the use of aerial imagery?