Night on Earth: Spatiotemporal Observations of Anthropogenic Processes from Night Lights

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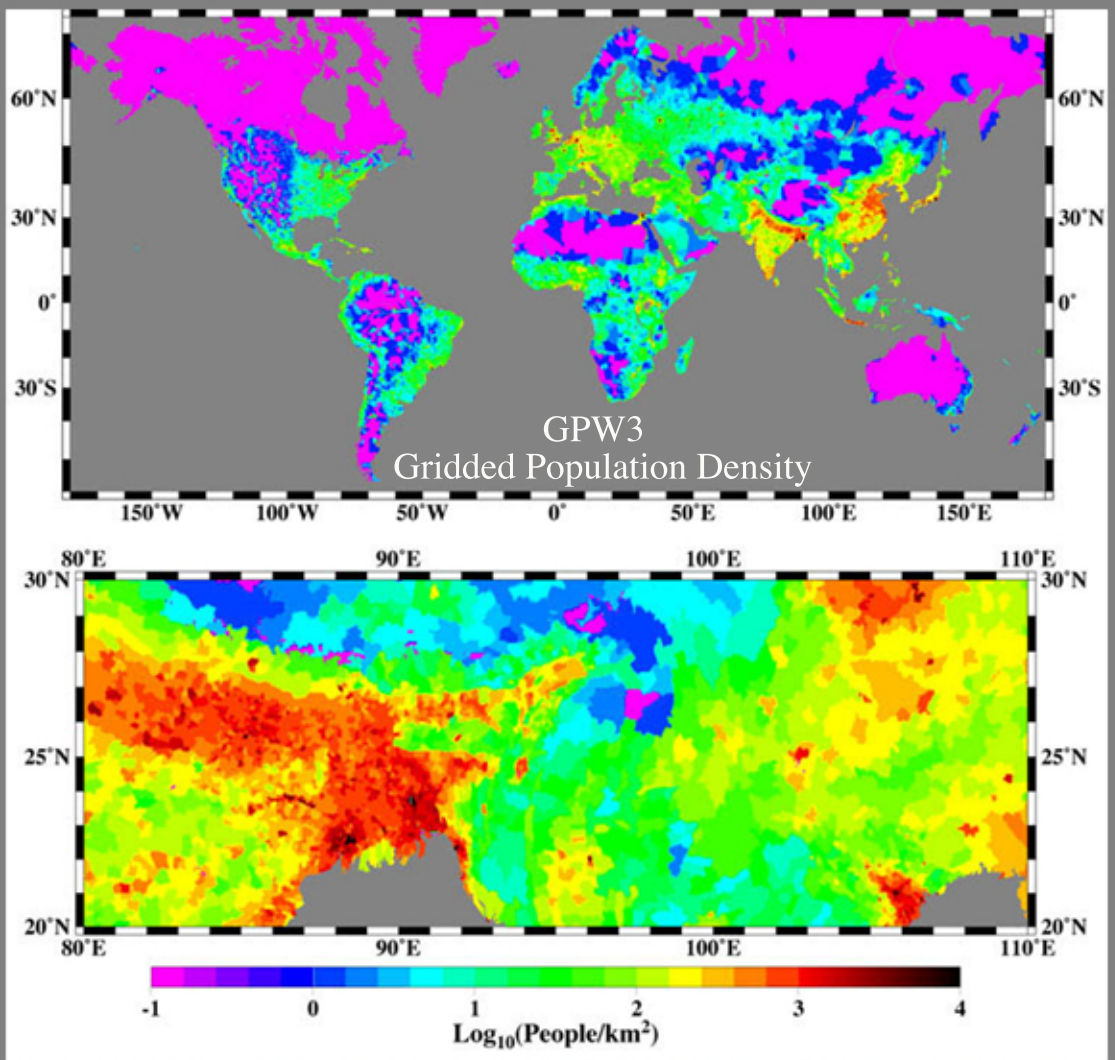
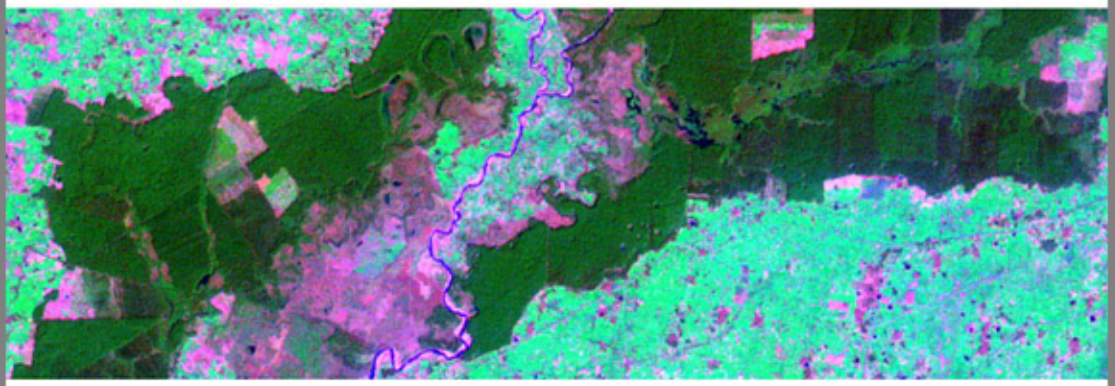
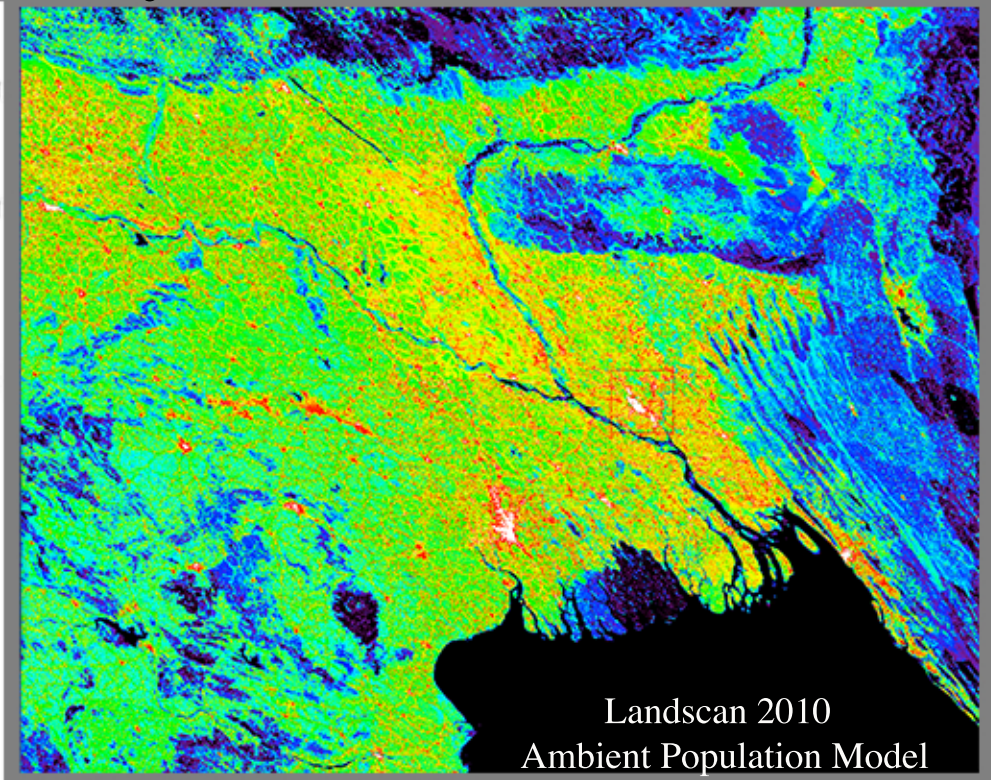
- The paradox of global population distribution
- Challenges of mapping urban land cover and modified landscapes
- Scaling of human setttlements and spatial networks of development
- Multi-temporal evolution of cities and networks
- Night on Earth - A gallery of nocturnal landscapes

Where Is Everyone?







Human population density on Earth's landmasses spans at least 5 orders of magnitude.

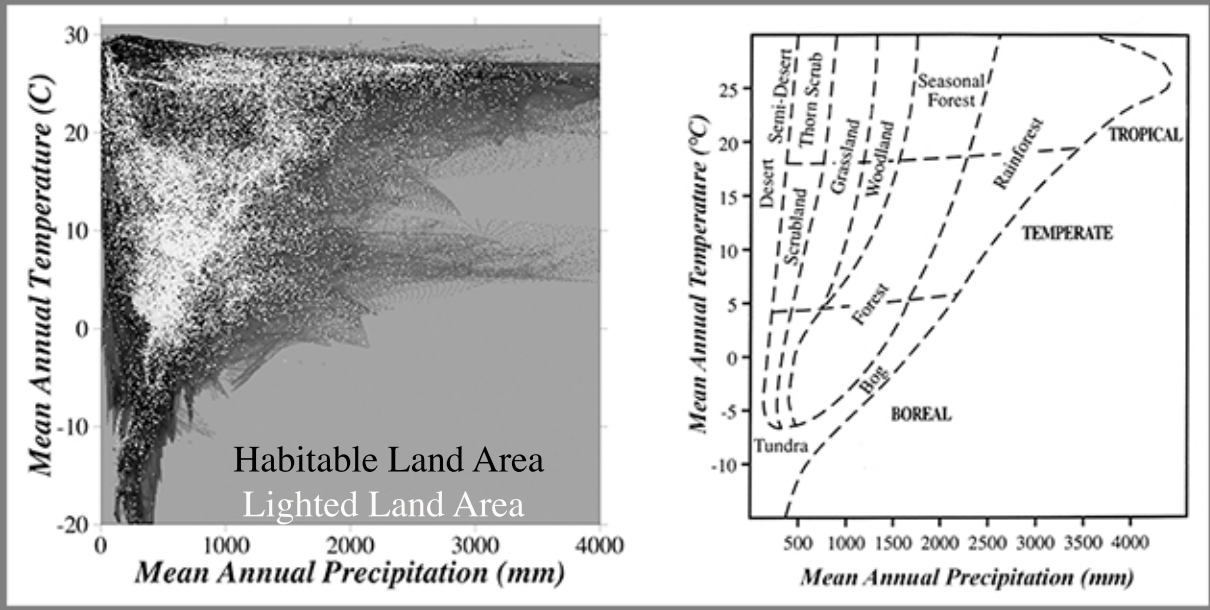
Steep gradients in population density occur on a wide range of spatial scales.

Census data map where people sleep - but are severely limited in accuracy and resolution.

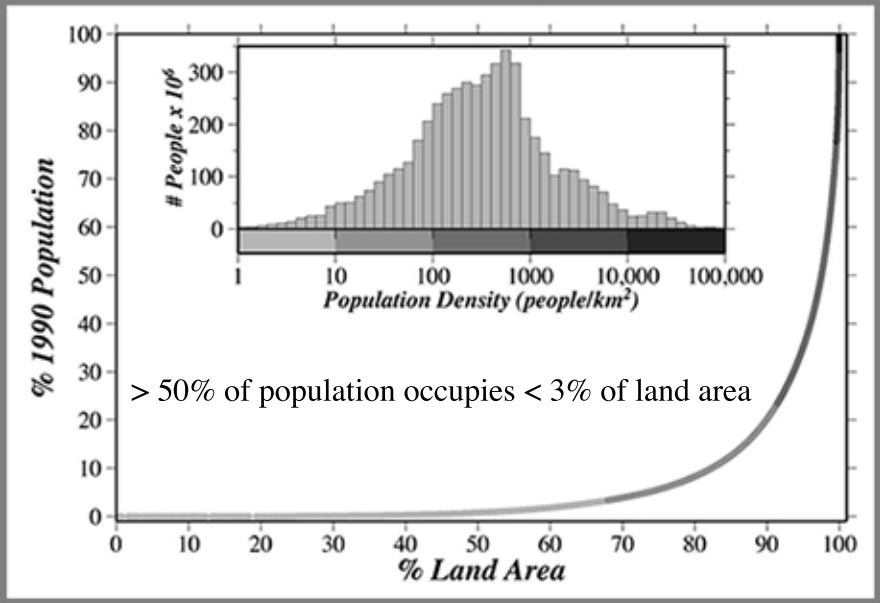
Disaggregated population models assume that population clusters in developed areas - therefore rely on accurate identification of human settlements.

The Paradox

Human population is dispersed across all terrestrial biomes

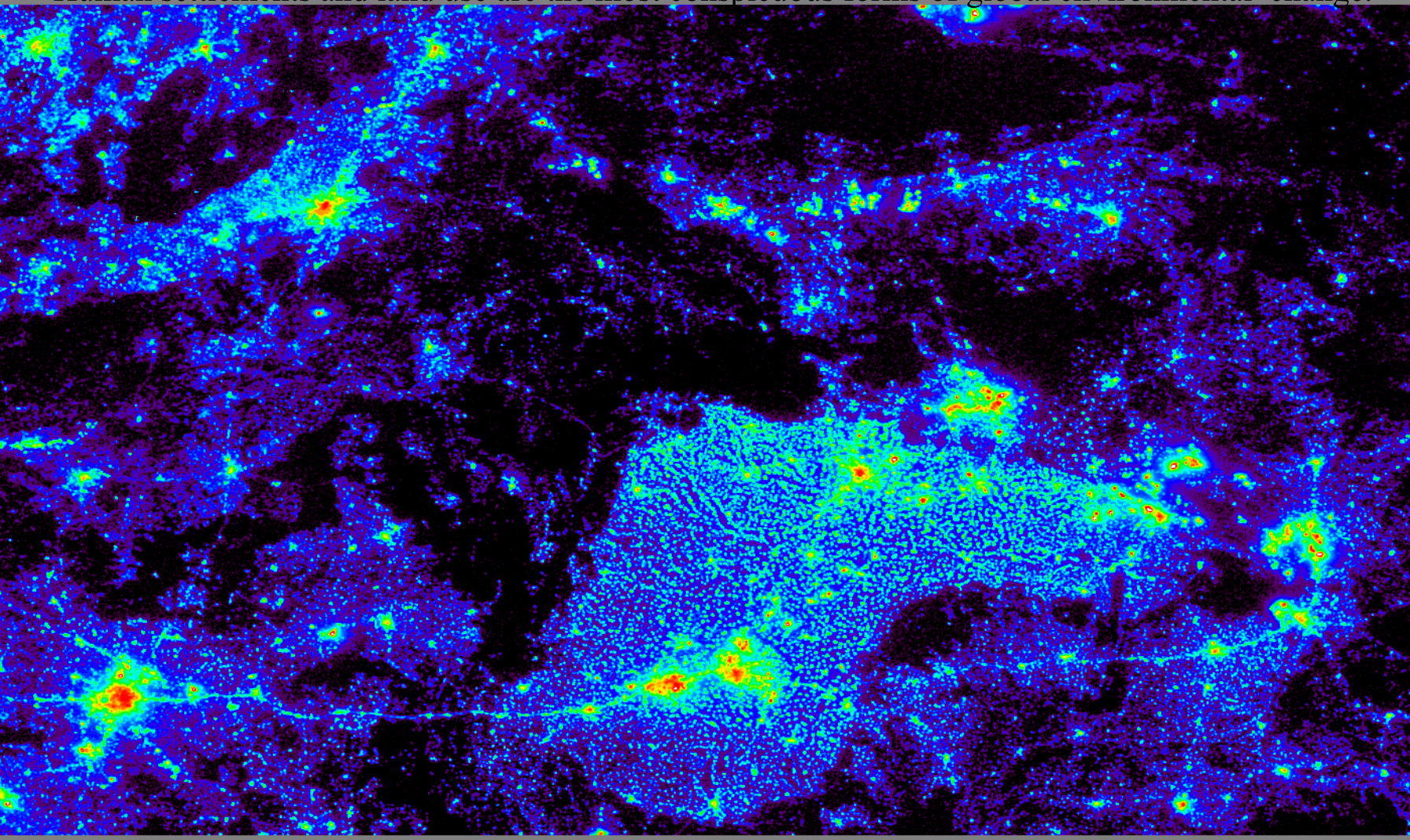


but human population is strongly clustered within biomes.



Small, C., Global Population Distribution and Urban Land Use in Geophysical Parameter Space, *Earth Interactions*,v.8, p.1-18, 2004.

Humans congregate in settlements of widely varying size and connectivity.
Human settlements and land use are the most conspicuous forms of global environmental change.



The structure and evolution of human settlement networks are emergent properties of collective human activity. The consequences of collective human activity define the Anthropocene.

Challenges of Urban Mapping

Many definitions of urban - Application dependent

Anthropogenic modification of land cover occurs at meter scales - but often necessary to map at global scale.

Modification of land cover takes many forms - at all scales.

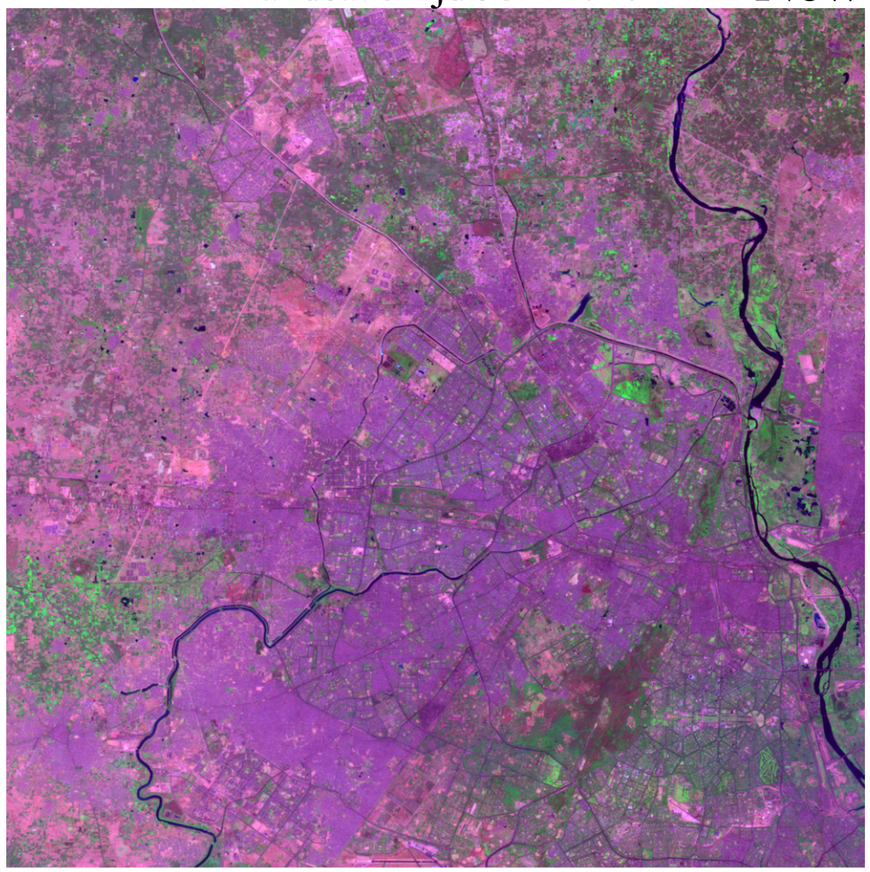
Modification of land cover does not necessarily change the physical properties - natural materials are often used.

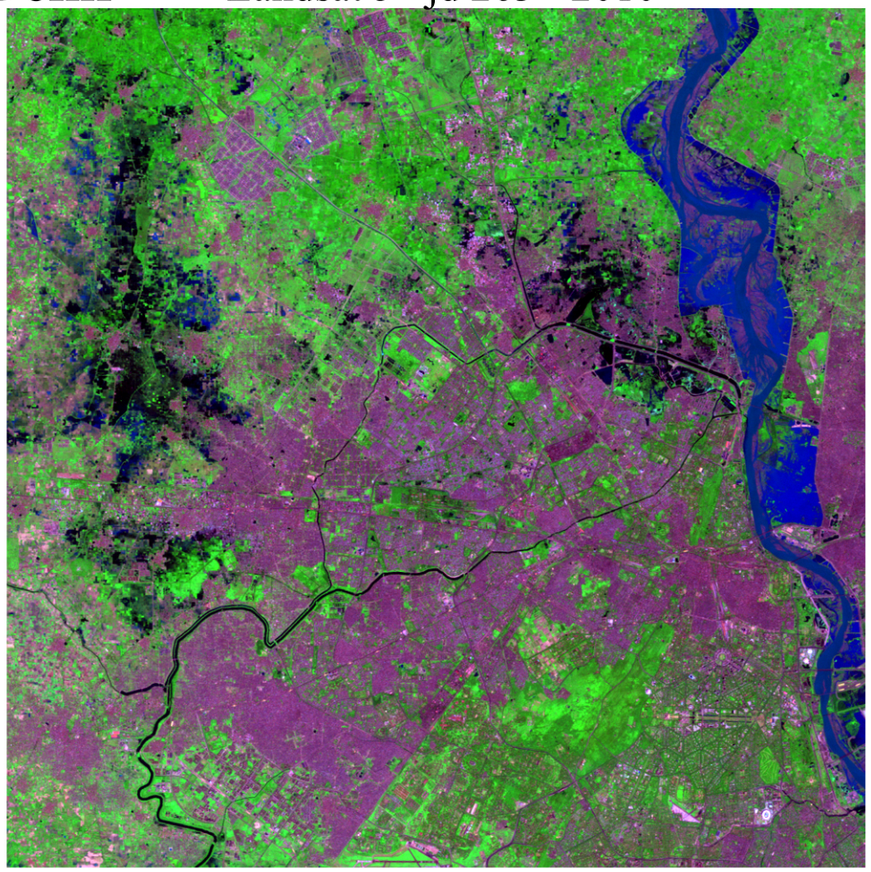
Modification of land cover is rarely spatially contiguous. Generally fractal & not simply connected.

Landsat 5 jd 93 - 2010

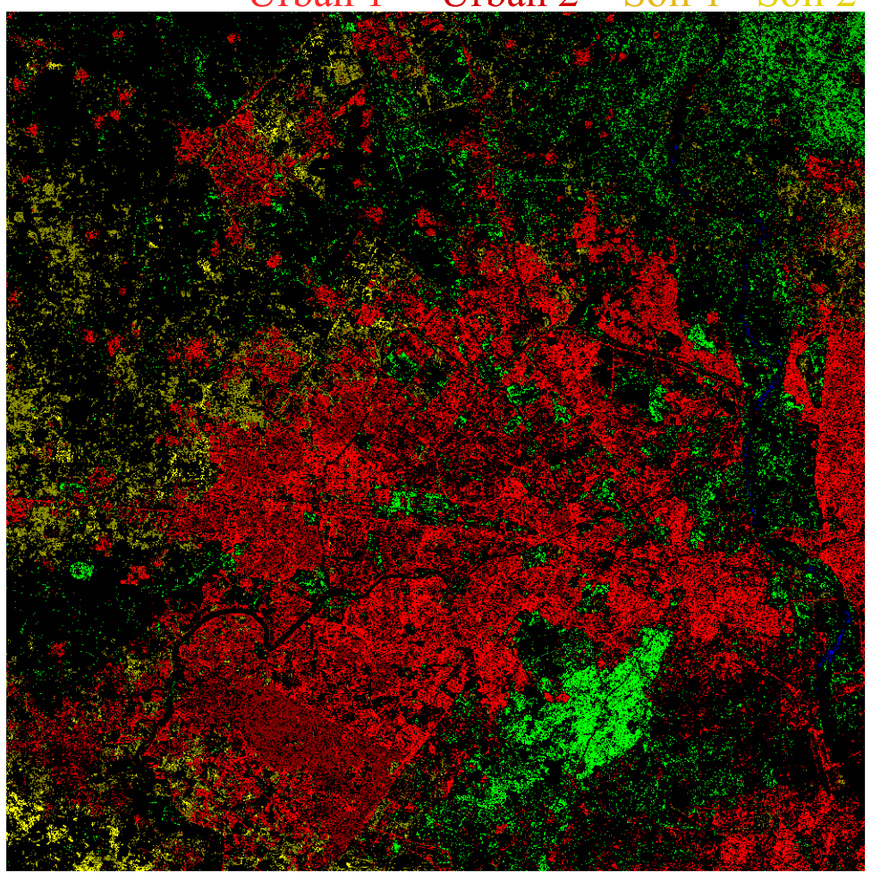
New Delhi

Landsat 5 jd 263 - 2010

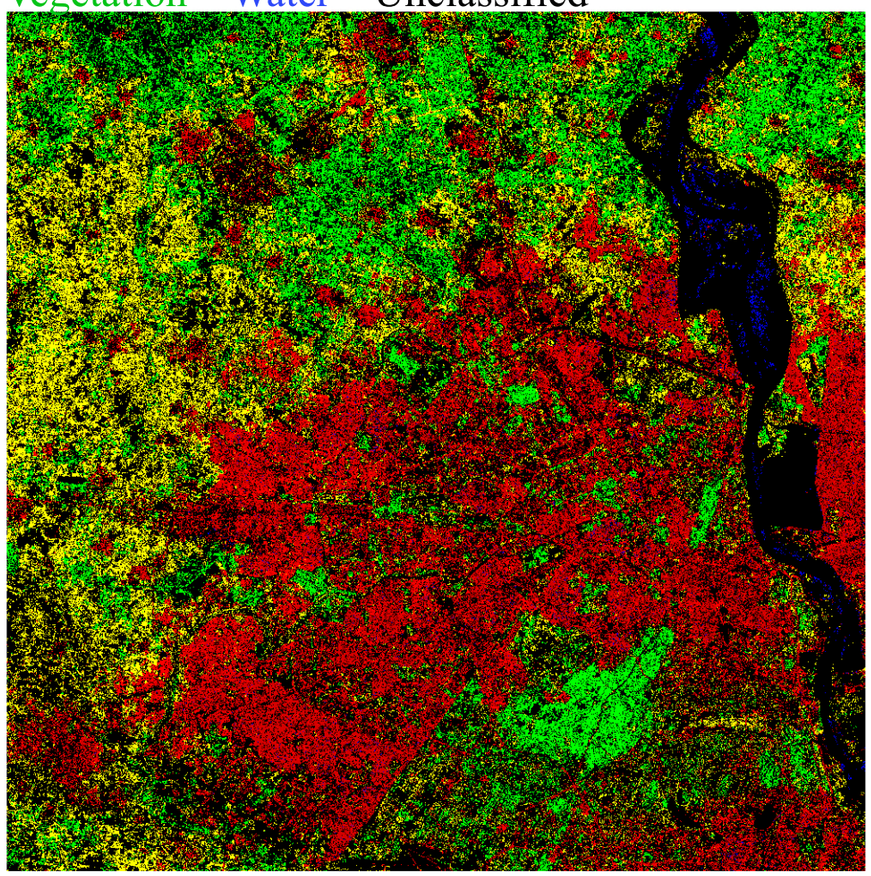




Urban 1 Urban 2 Soil 1 Soil 2



Vegetation Water Unclassified



Strategy

Multi-Sensor - Characterize common *physical properties* of a range of anthropogenic land cover (ALC) and settlement types.

Landsat (reflectance and temperature) ***DMSP-OLS and VIIRS-DNB night light***
MODIS 4 µm radiance ***QuikSCAT microwave backscatter***

Multi-Scale - Characterize ALC and spatial networks of development from village to global scales in diverse environments.

Beijing Cairo Istanbul Mexico Moscow Nairobi New Delhi São Paulo
120 x 120 km^2 sites containing urban, peri-urban, agriculture, forest, desert, etc.

Multi-Temporal - Characterize evolution of ALC using multi-season composites to identify stable physical properties.
Use change in composites to map evolution of ALC from 1990s to 2010s.

Quantify evolution of systems of settlements as spatial networks of development using power law scaling of rank-size distributions.

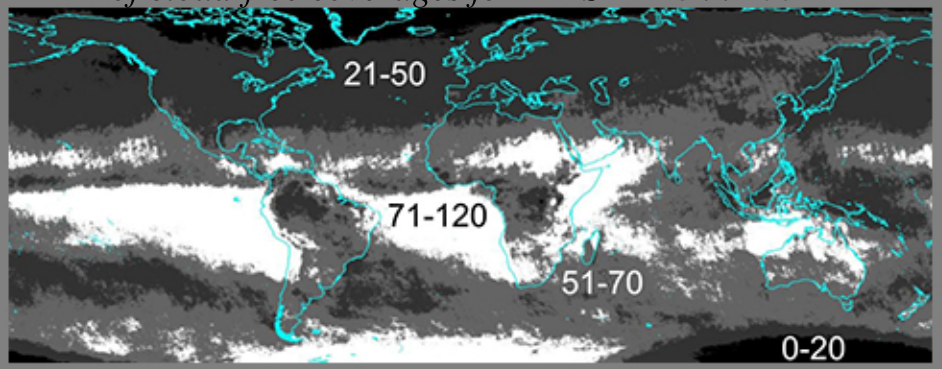
Imaging Night Light from Space

The Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) series of sensors has been imaging night light since the early 1970s. ***5 digital sensors since 1992***

The OLS sensor images VNIR radiance at 2.5 km resolution and 6 bit depth for brightness DN = 0 - 63

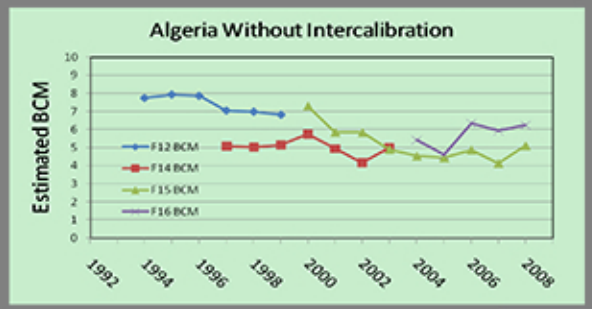
The Earth Observation Group at the National Geophysical Data Center (NGDC) has produced annual composite images of mean cloud-free brightness for each sensor from 1992 to 2010.

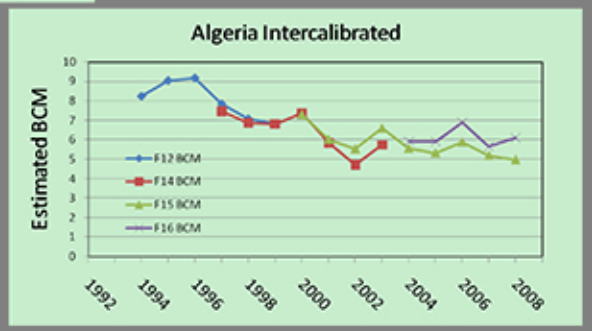
# of cloud-free coverages for DMSP F16 in 2004



Annual mean brightness for DMSP F16 in 2004

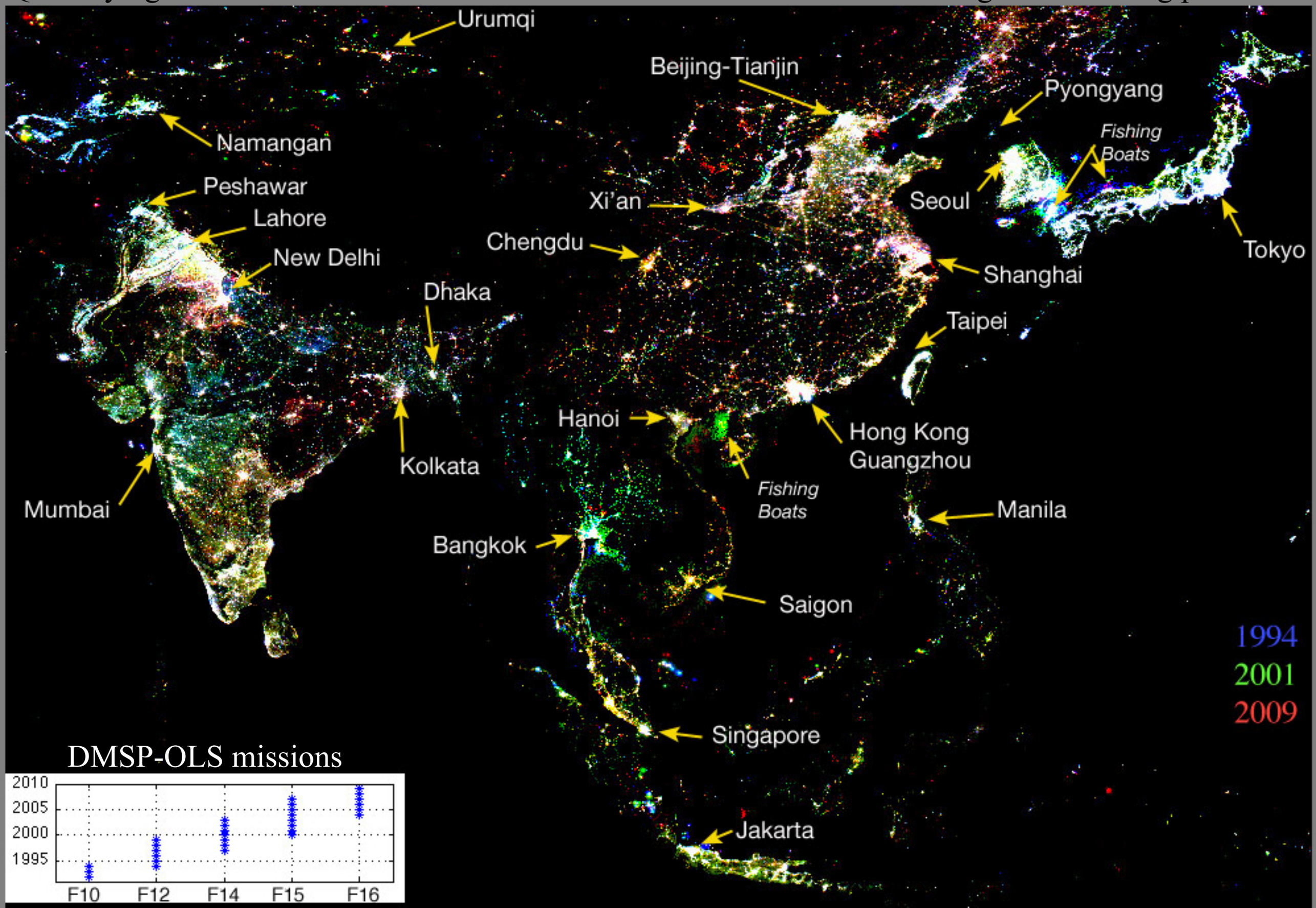
Temporal overlap in satellite missions allows for interannual cross calibration to reduce apparent changes due to sensor degradation and inter-sensor calibration differences.





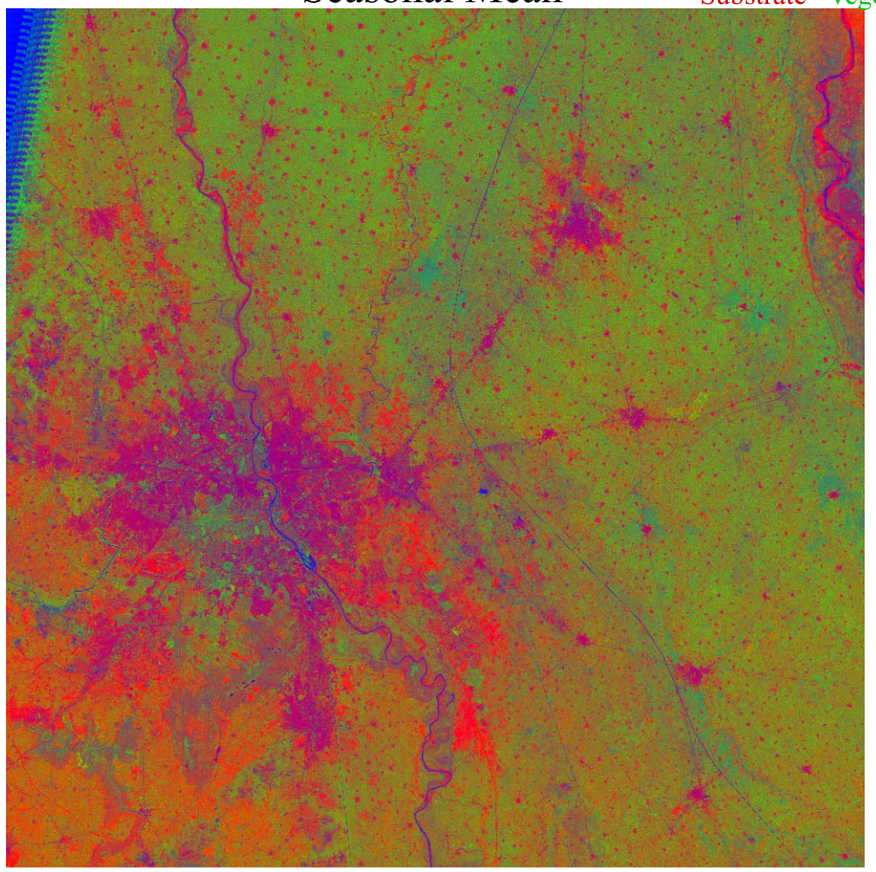
Elvidge, C.D., Ziskin, D., Baugh, K.E., B. T. Tuttle, & Ghosh, T. (2009). A Fifteen Year Record of Global Natural Gas Flaring Derived from Satellite Data. Energies, 2, 595-622.

Interannual changes in night light reflect the evolution of the human settlement network.
Quantifying the structure and evolution of the network informs understanding of the driving processes.

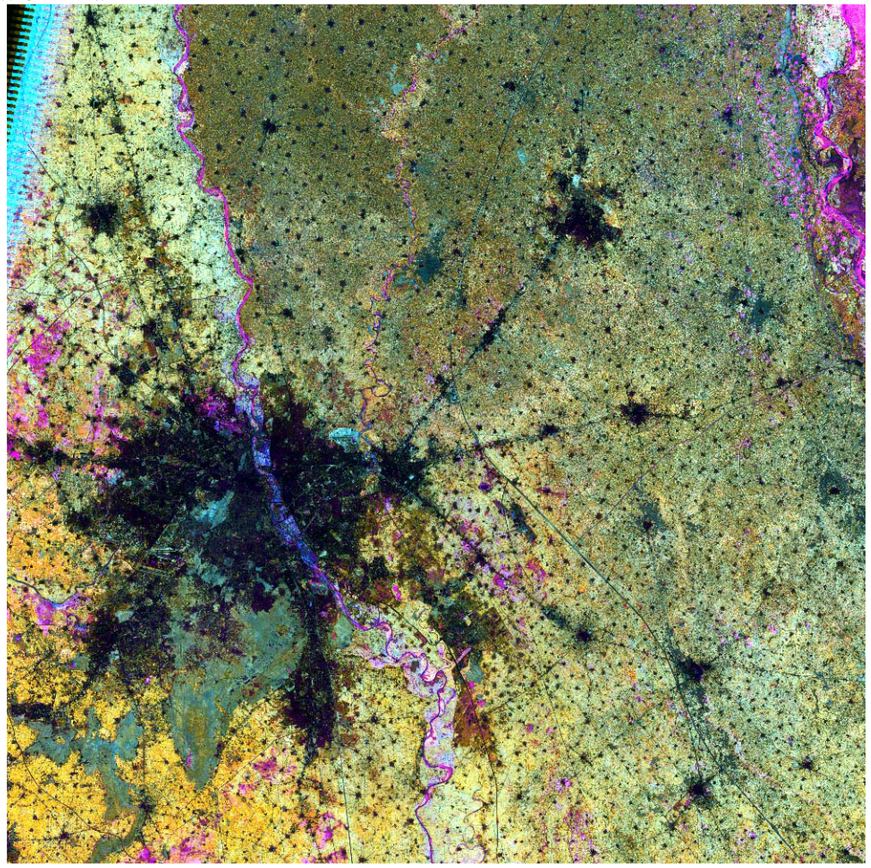


Seasonal Mean

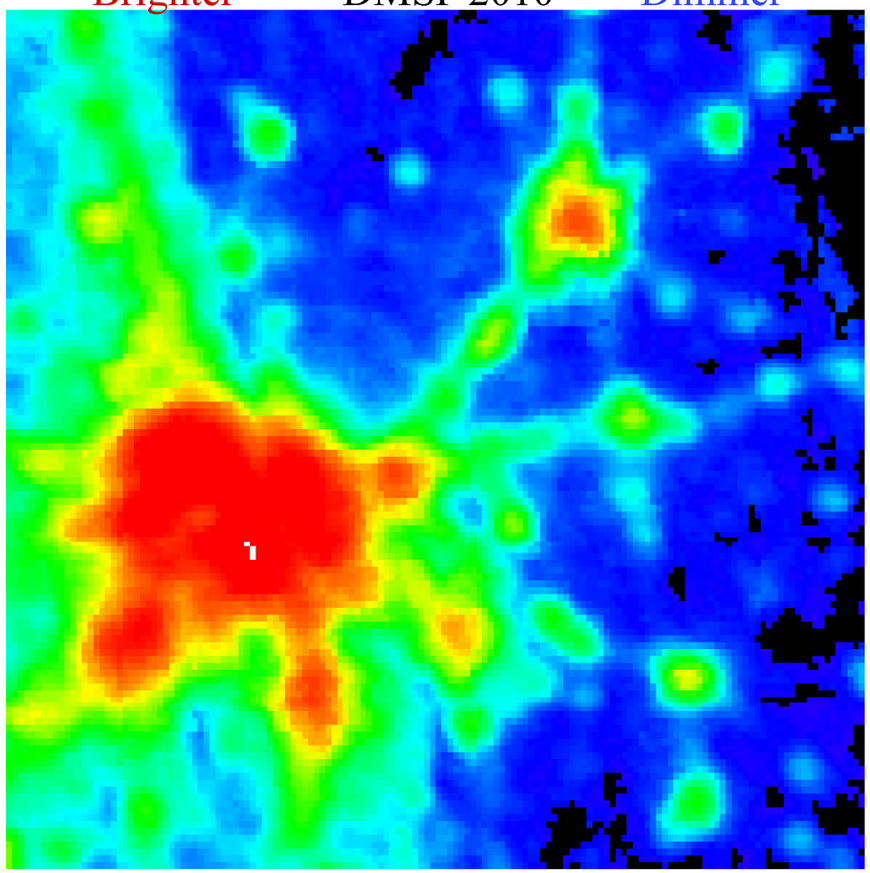
Substrate Vegetation Dark



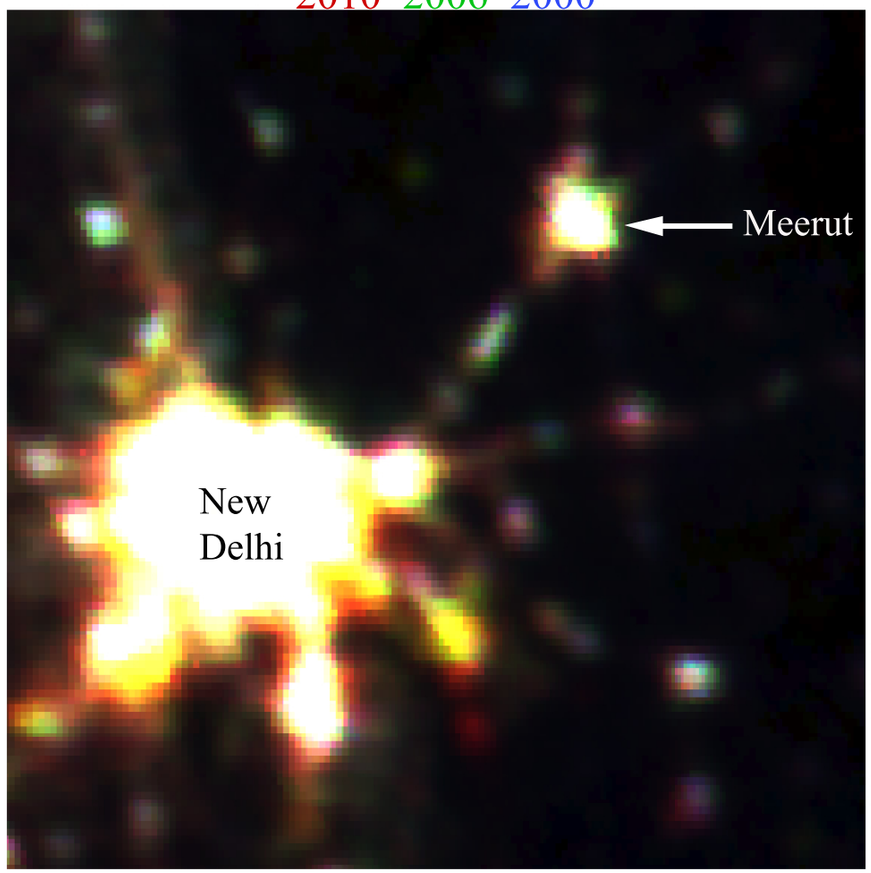
Seasonal Standard Deviation



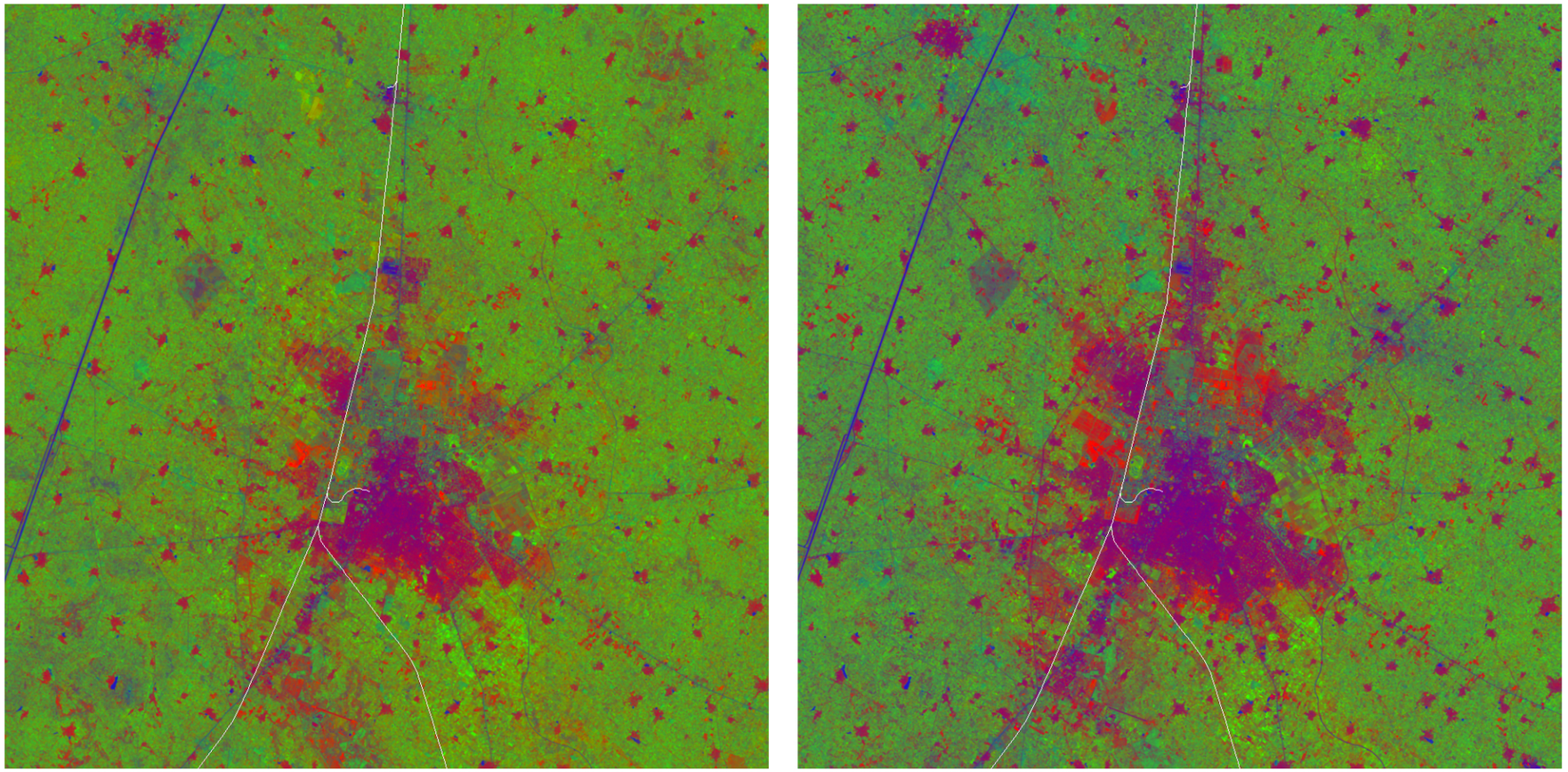
Brighter DMSP 2010 Dimmer



2010 2006 2000



2000 Meerut 2010

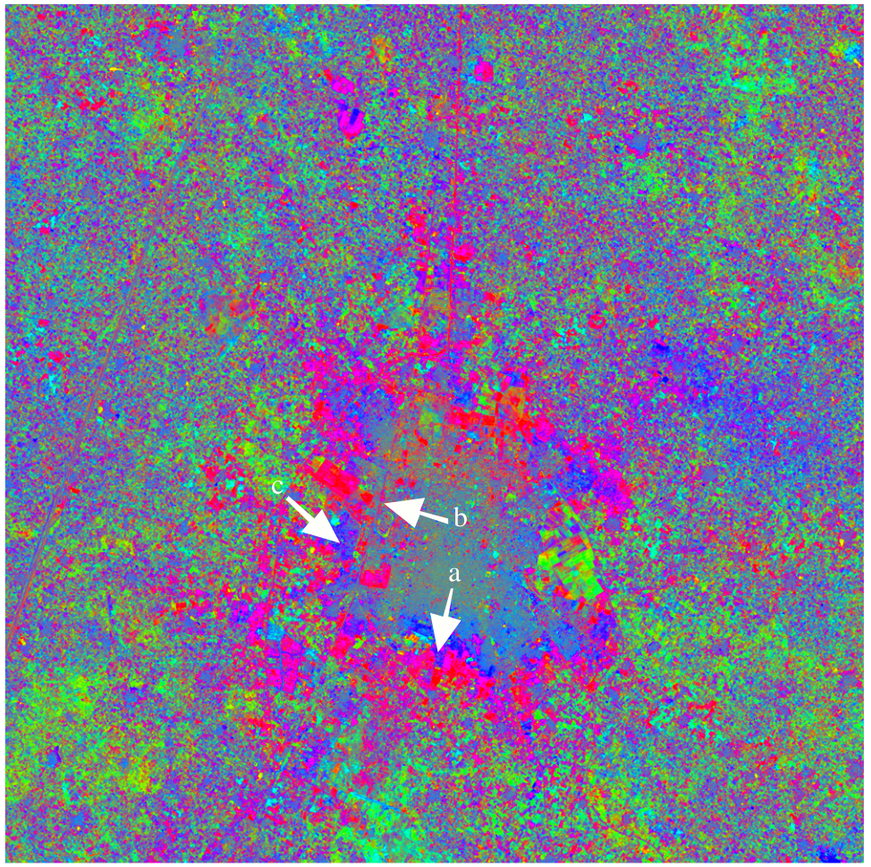


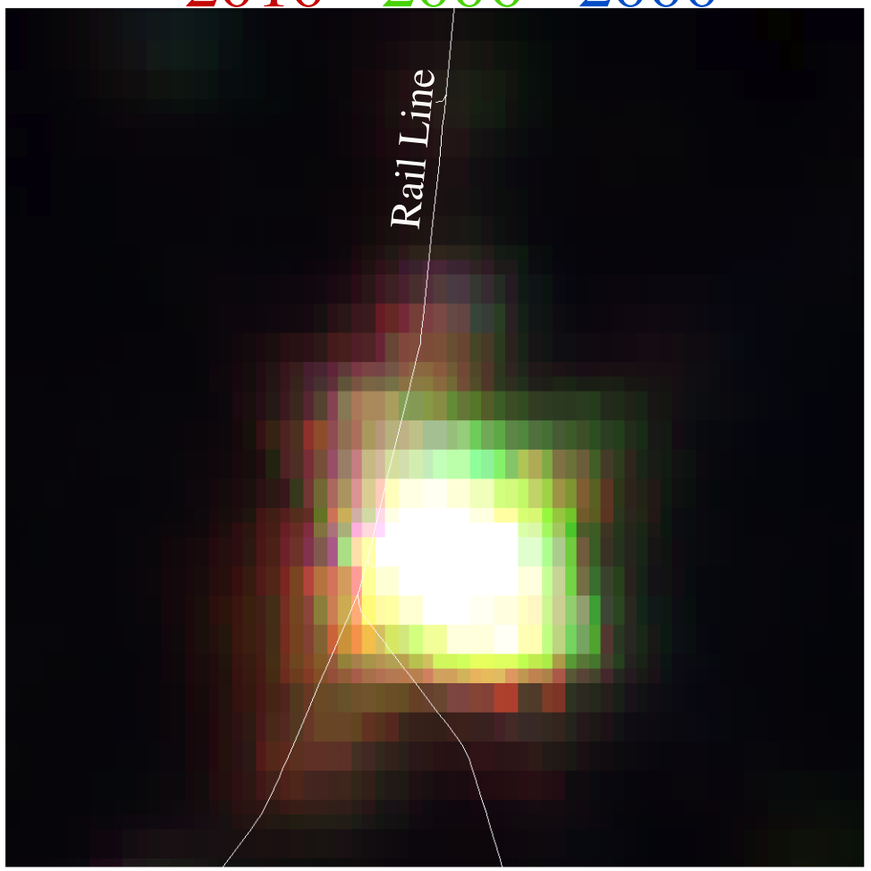
Substrate Vegetation Dark

δS δV δD

Scale: 30x30 km

2010 2006 2000





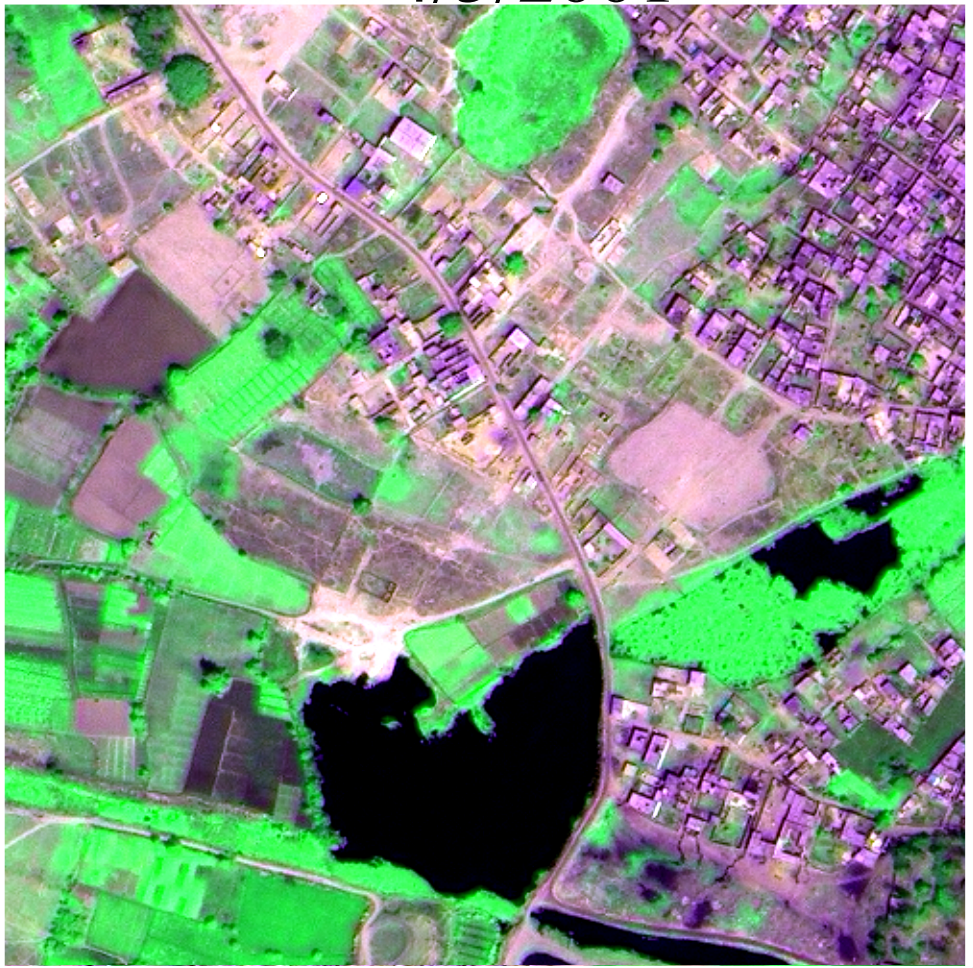
4/5/2001
a
2/3/2010
b

4/5/2001 a 2/3/2010

4/5/2001

a

2/3/2010



b

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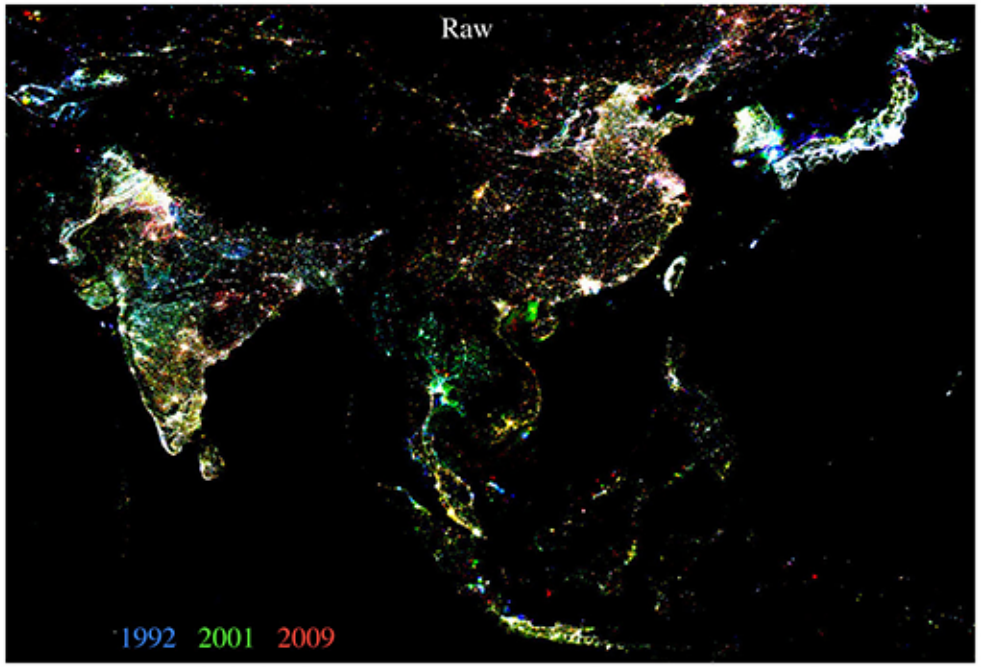
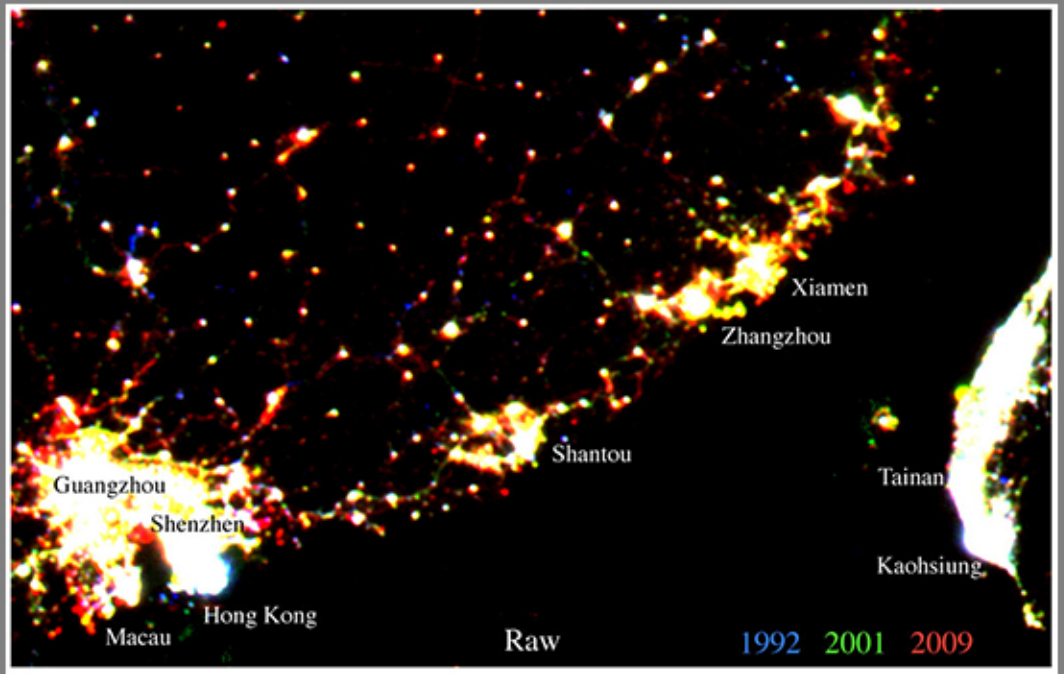
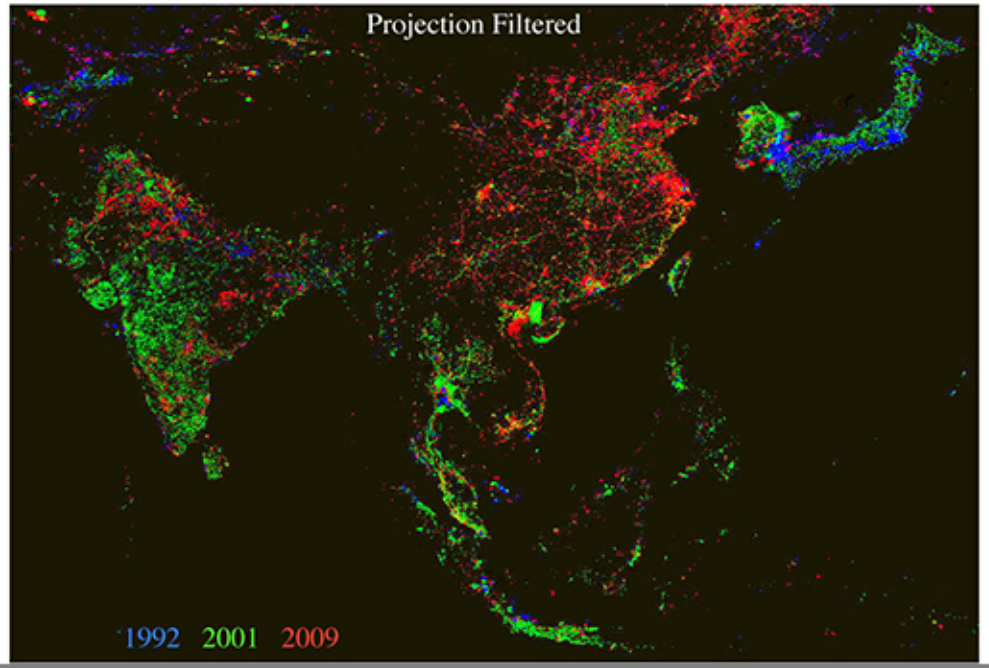
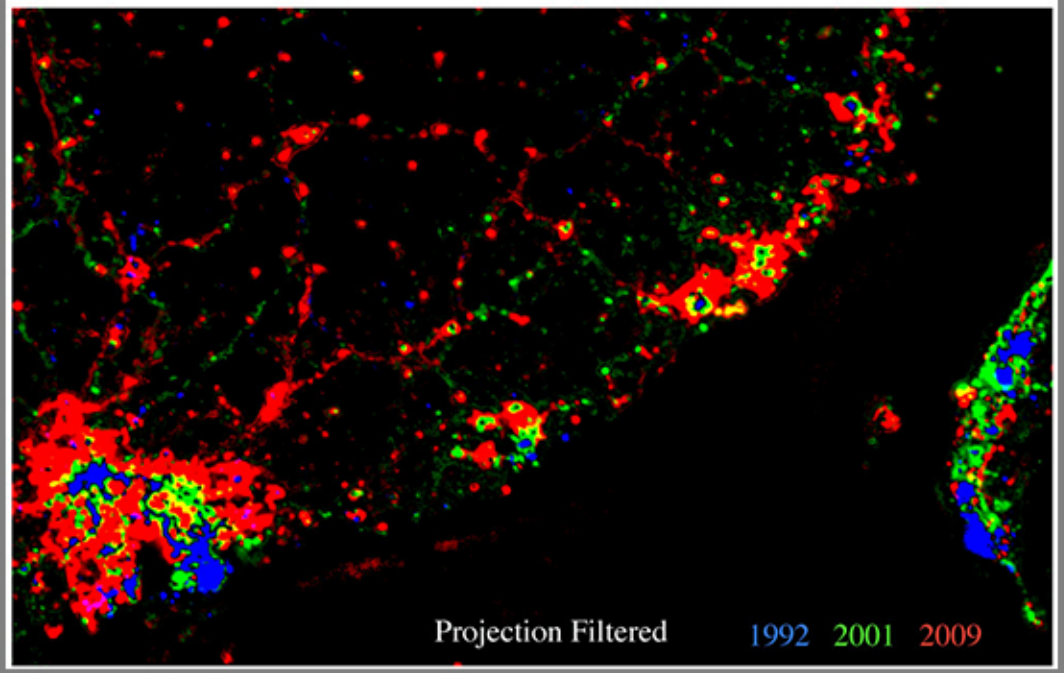
2/3/2010

Decadal Change of Asia Night Light