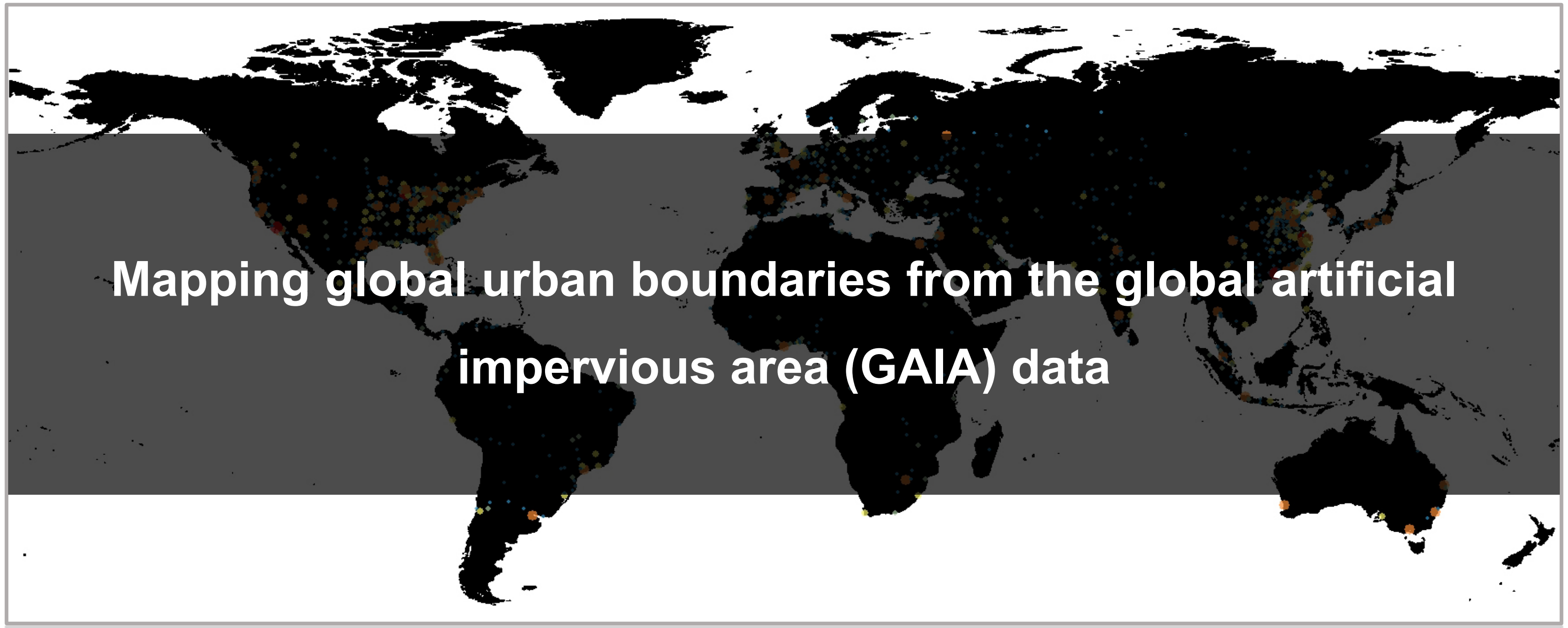
Mapping global urban boundaries from the global artificial impervious area (GAIA) data



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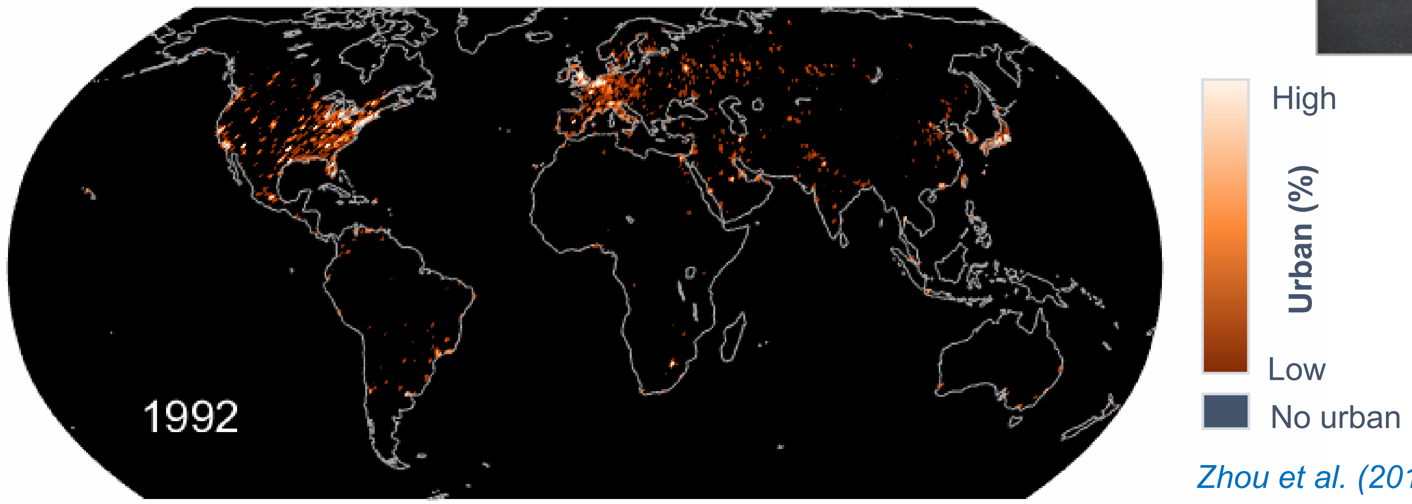
Outline

1. Background

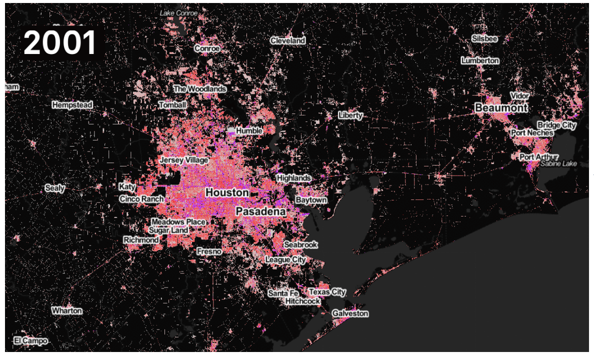
Motivations

- **Current and future urbanization**
  - Urban population 55% today; 70% in 2050; 85% in 2100
- **Role of urban and urbanization**
  - Drivers of development and innovation
  - ~80% GDP; ~70% energy use
- **Dynamics and heterogeneity**
  - An improved understanding of urban environment

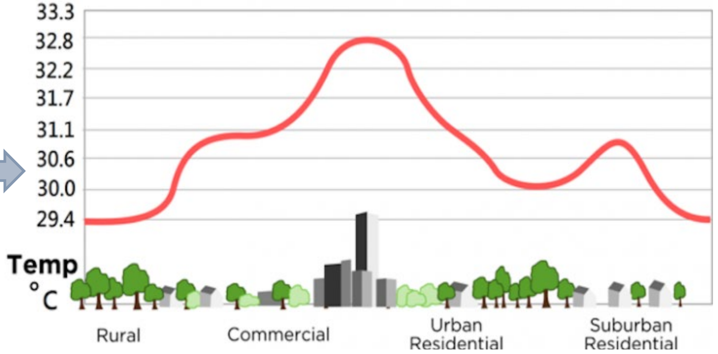


Zhou et al. (2018)

Interactions between urban and natural systems



Urban extent



Urban Heat Island

Vegetation Phenology

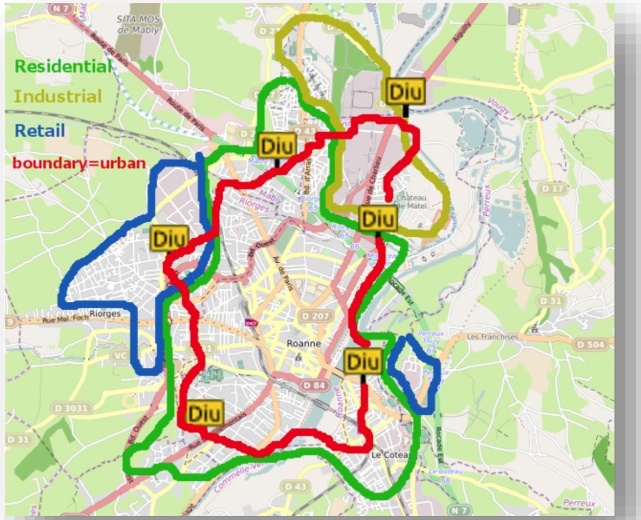
Building Energy Use

Public Health

Emission and Carbon Cycle

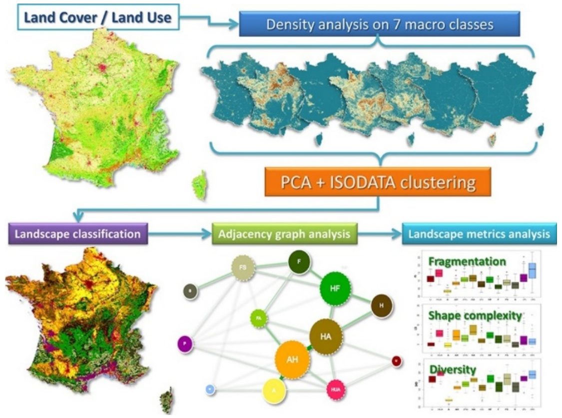
Urban boundary

- ❖ **Basic units for urban studies**
- ❖ **2D urban form**
- ❖ **Dynamics: process of urban expansion**

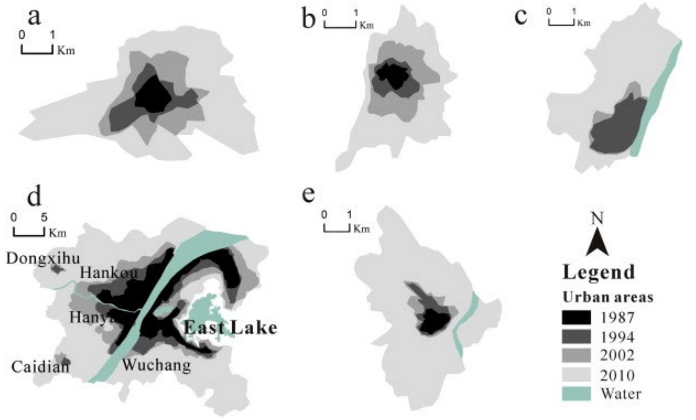


Existing studies

- Density analysis combined with clustering *(Vizzari et al., 2018)*
- Land use entropy model with Kriging interpretation approach *(Hu et al., 2015)*
- Kernel density combining wavelet transform *(Peng et al., 2016)*
- Density of urban infrastructures and population *(US Census Bureau)*
- NTL derived urban boundaries *(Zhou et al., 2018)*



(Vizzari et al., 2018)

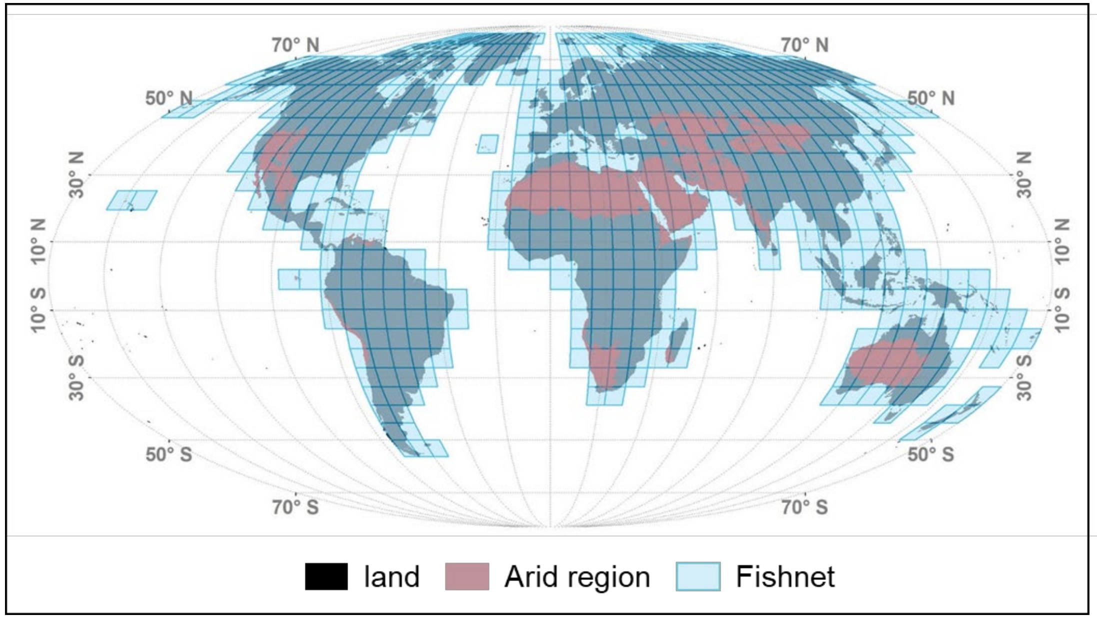


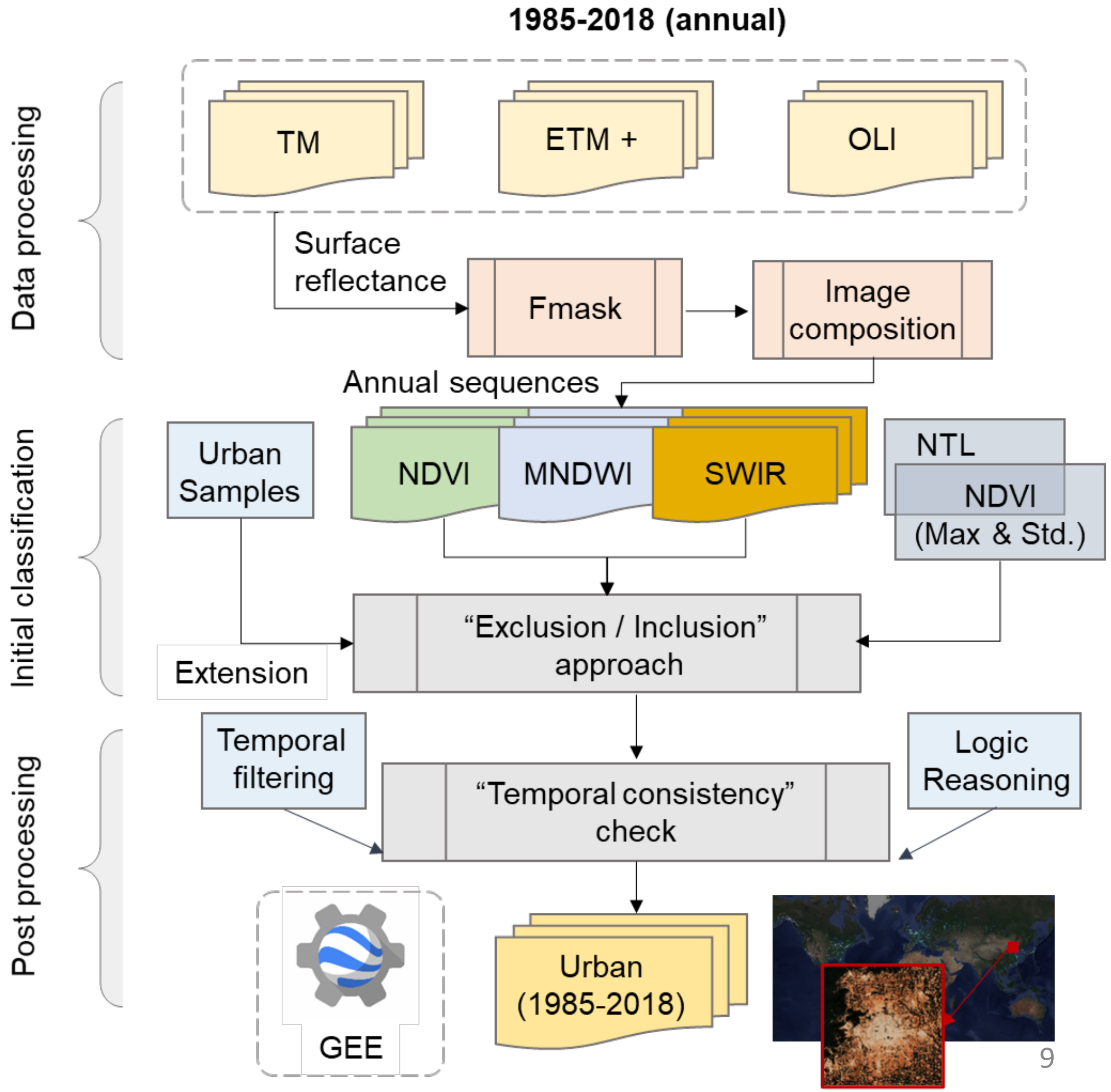
(Hu et al., 2015)

- *Focus on local scale (e.g., city)*
- *Urban-rural transactional regions*

2. The GAIA data

Mapping of global annual urban extent dynamics



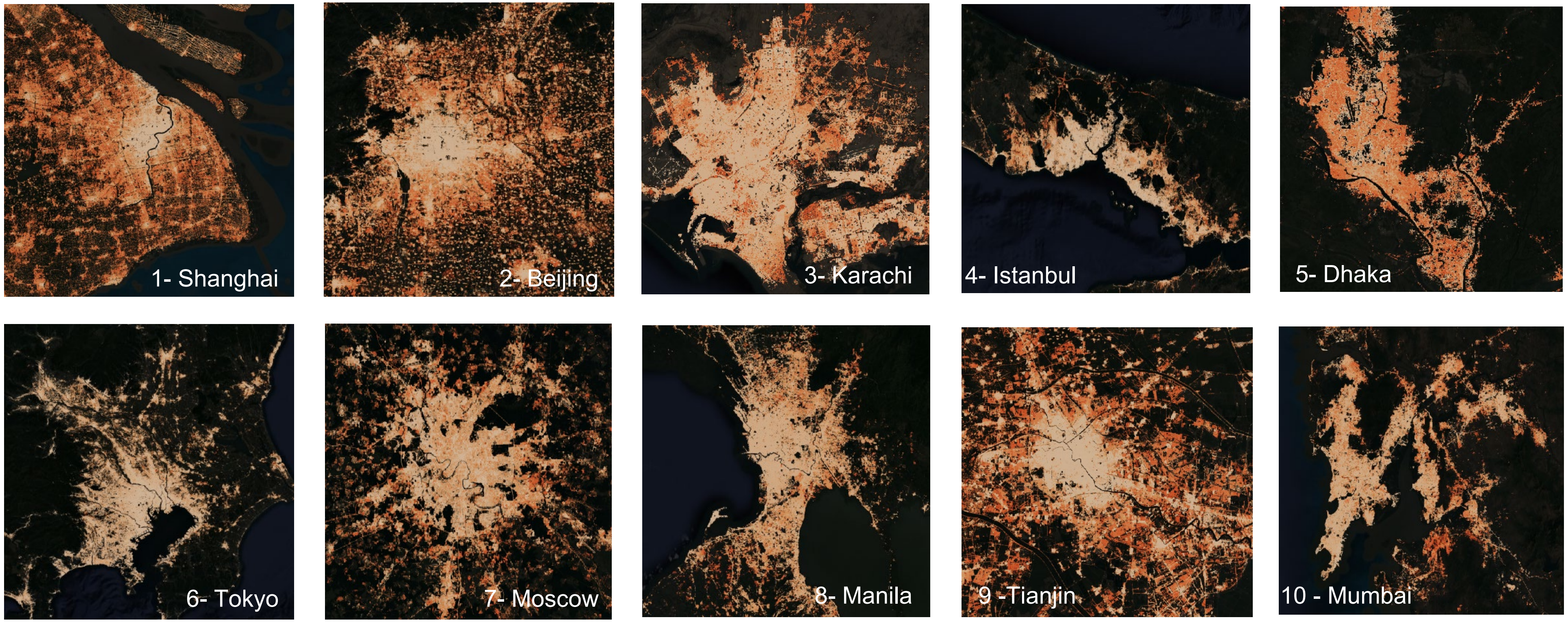


Highlights:

- ❖ All modules complied on GEE
- ❖ Can be updated annually in time
- ❖ Can be applied to other satellite data (e.g., Sentinel)

Gong et al. (2020)

GAIA: Global Annual Impervious Area



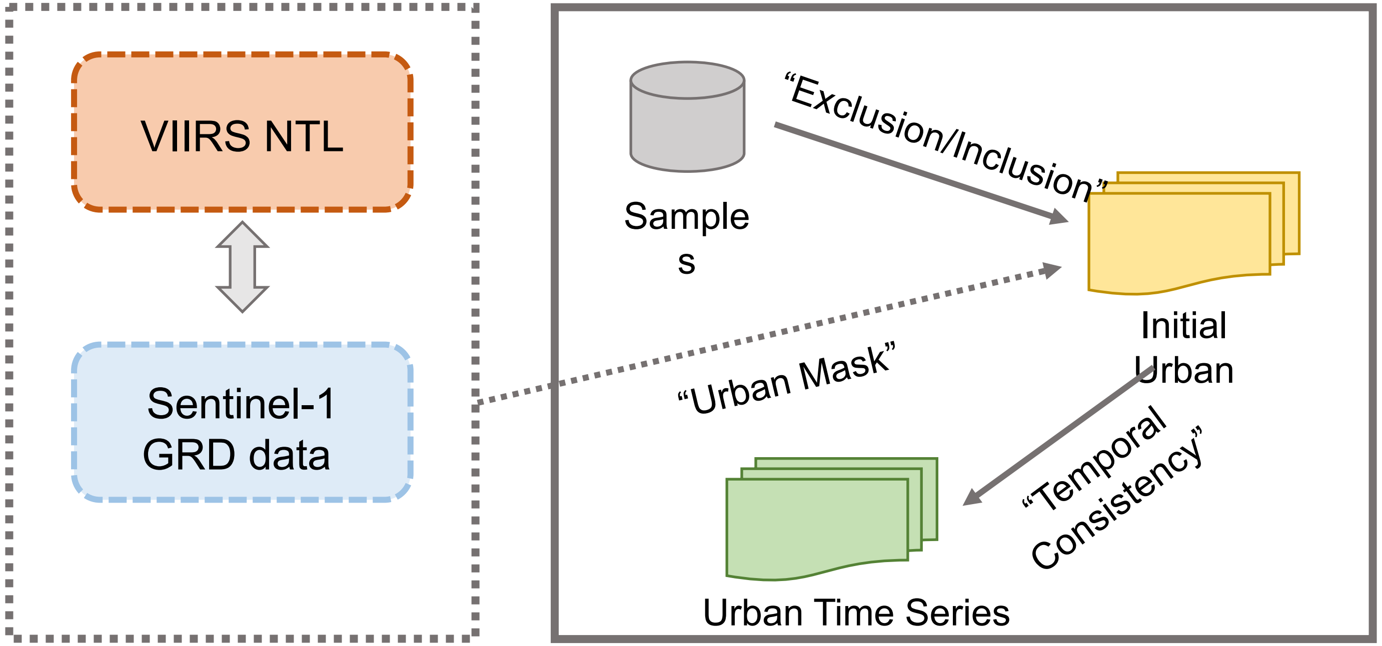
Resolution: 30m

Source: *Tsinghua University*

Gong et al. (2020)

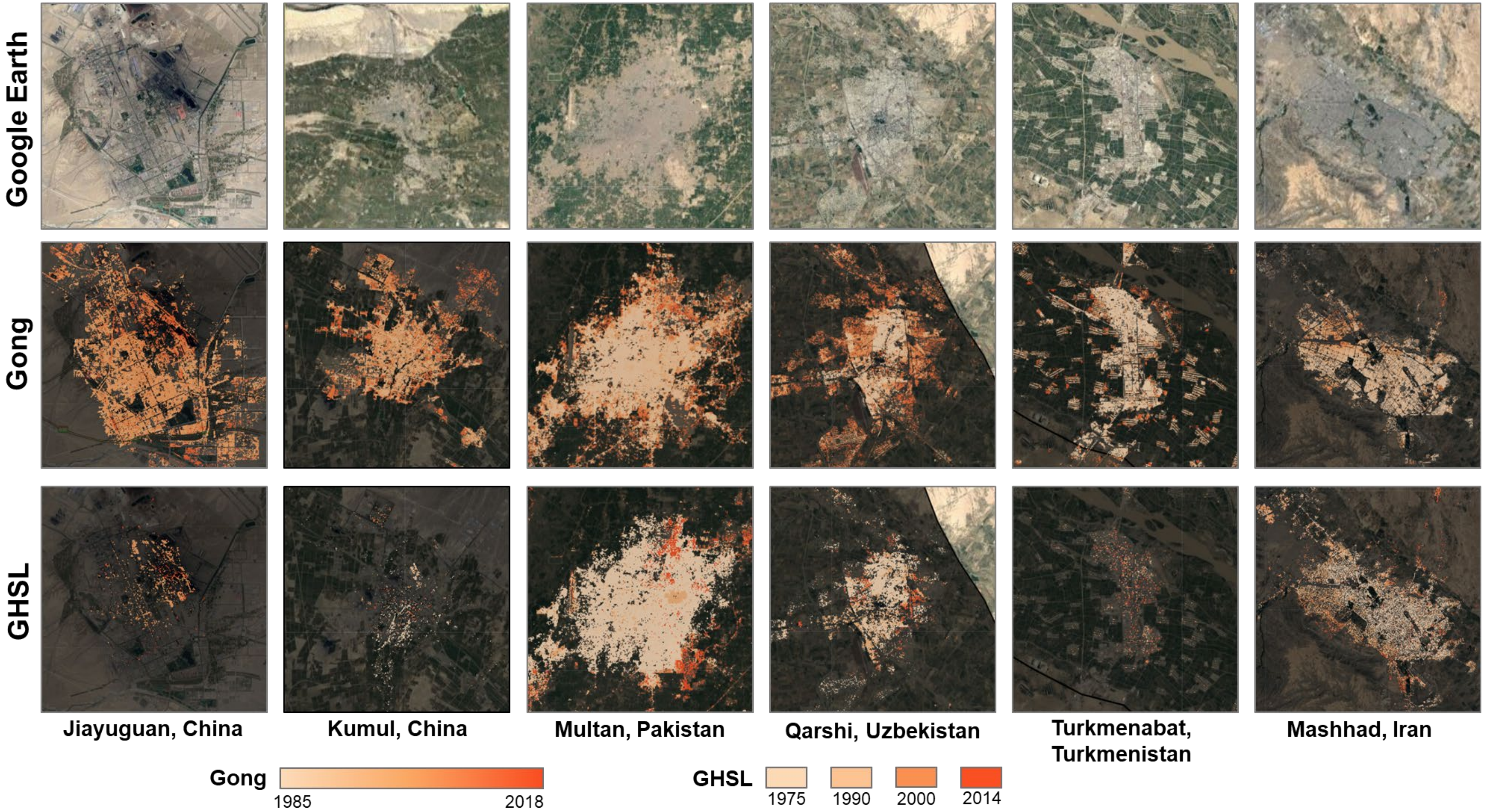
Improved mapping approach in arid areas

- ❖ Primary dataset: Landsat surface reflectance data (i.e., TM, ETM+, and OLI)
- ❖ Ancillary dataset: VIIRS nighttime light (NTL) data & Sentinel-1 GRD data
- ❖ **Key**: introduce a potential urban mask using NTL and Sentinel data



Urban Extent (2018)   Annual Urban Extent Dynamics (1985-2015)

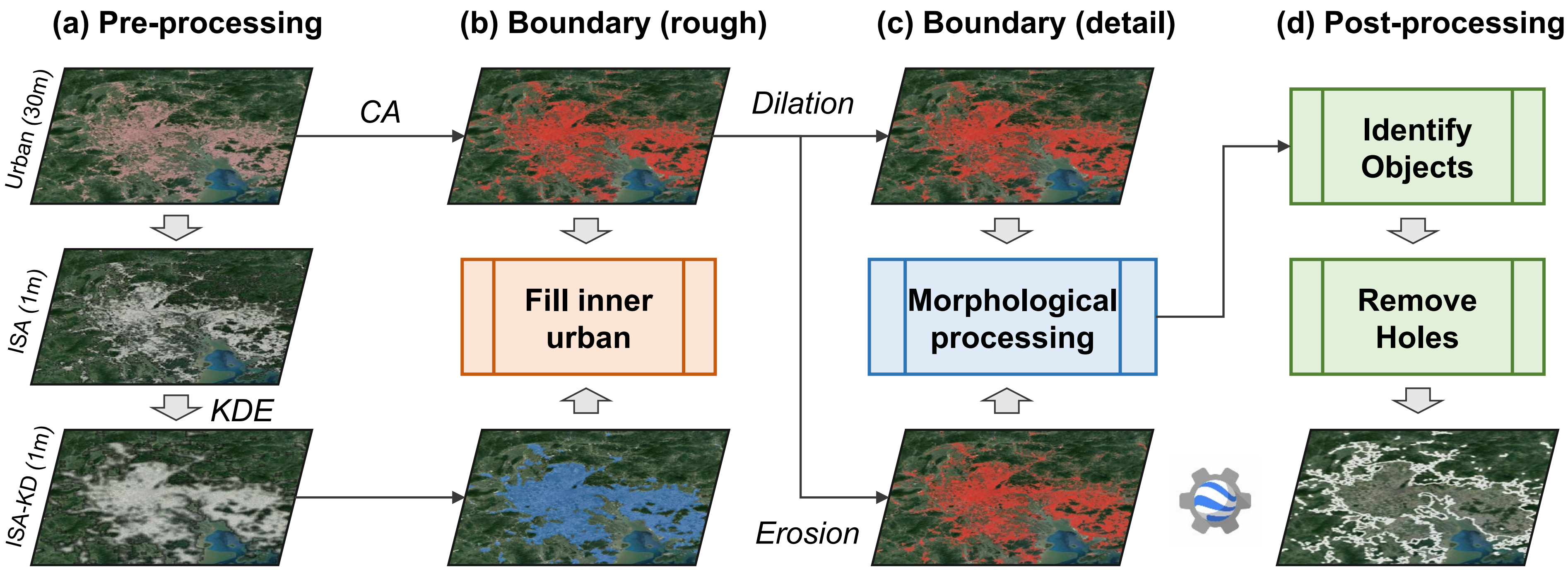
Improved mapping approach in arid areas



3. Urban boundary delineation

Overall framework

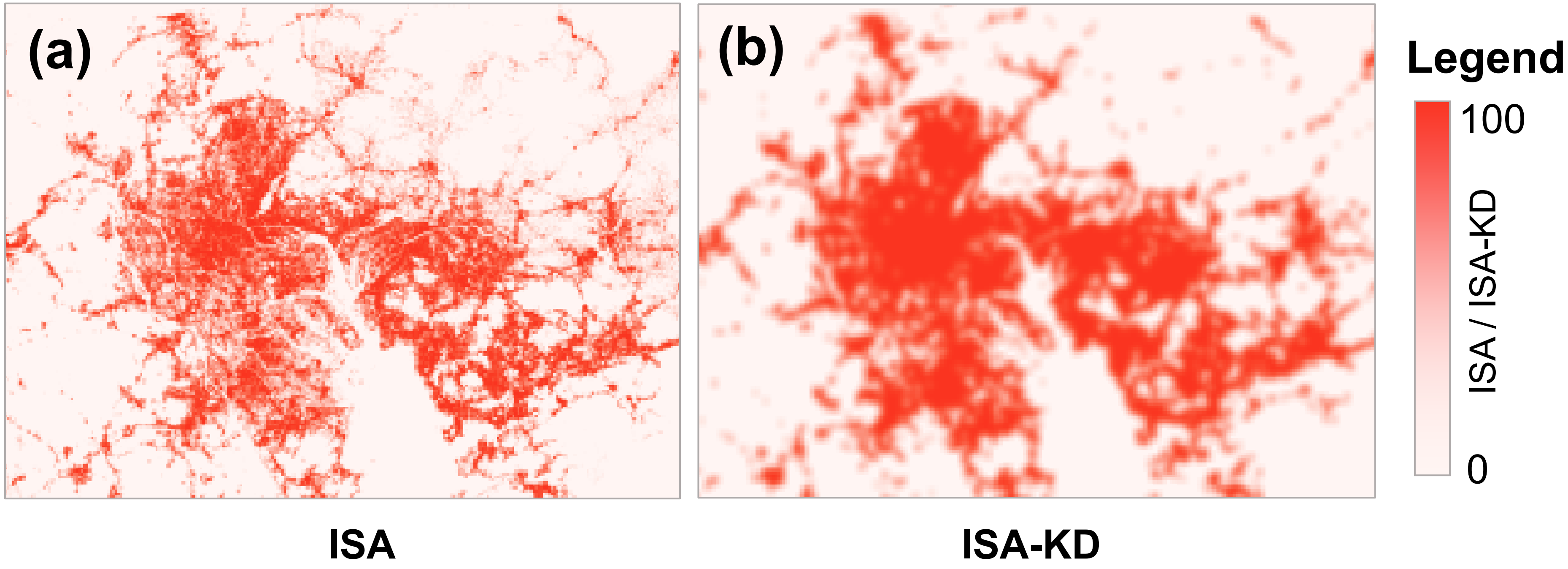
- ❖ **Region: global**
- ❖ **Temporal periods: 1990, 1995, 2000, 2005, 2010, 2018**



Kernel density map

❖ aggregate 30m GAIA data to 1km as the percentage of impervious surface area

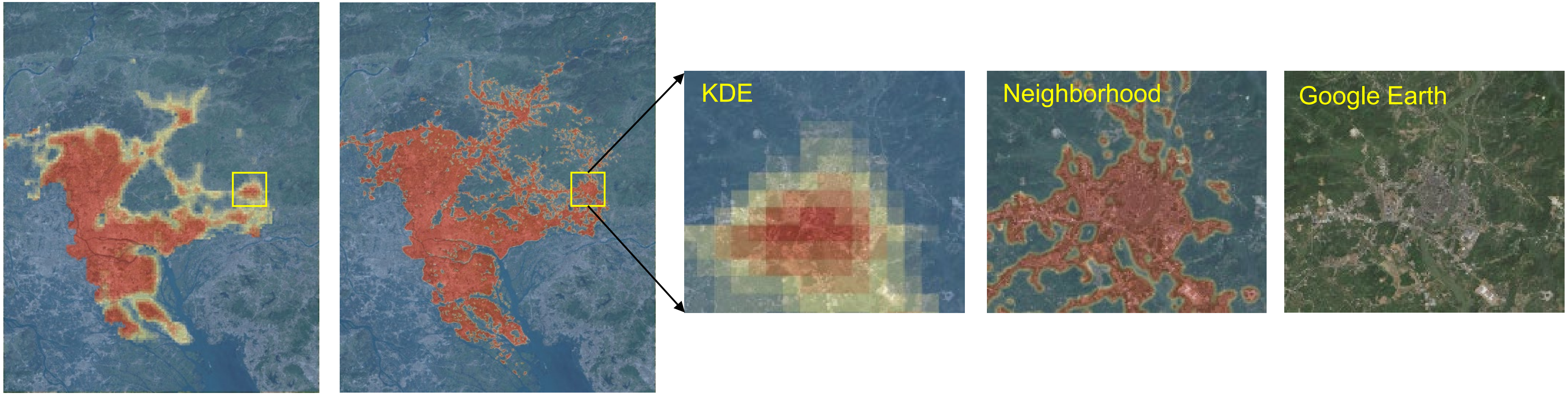
❖ generate the kernel density (KD) map based on the ISA results (bandwidth: 5km)



More smoothed surface in urban domain

Boundary (rough)

- macro-scale (kernel density >20% as urban) (1km)
- micro-scale (neighborhood density; densities larger than 20% as urban; looply run for three times; 11x11 Window ~ 1km) (30m)
- merge derived urban boundaries from these two results



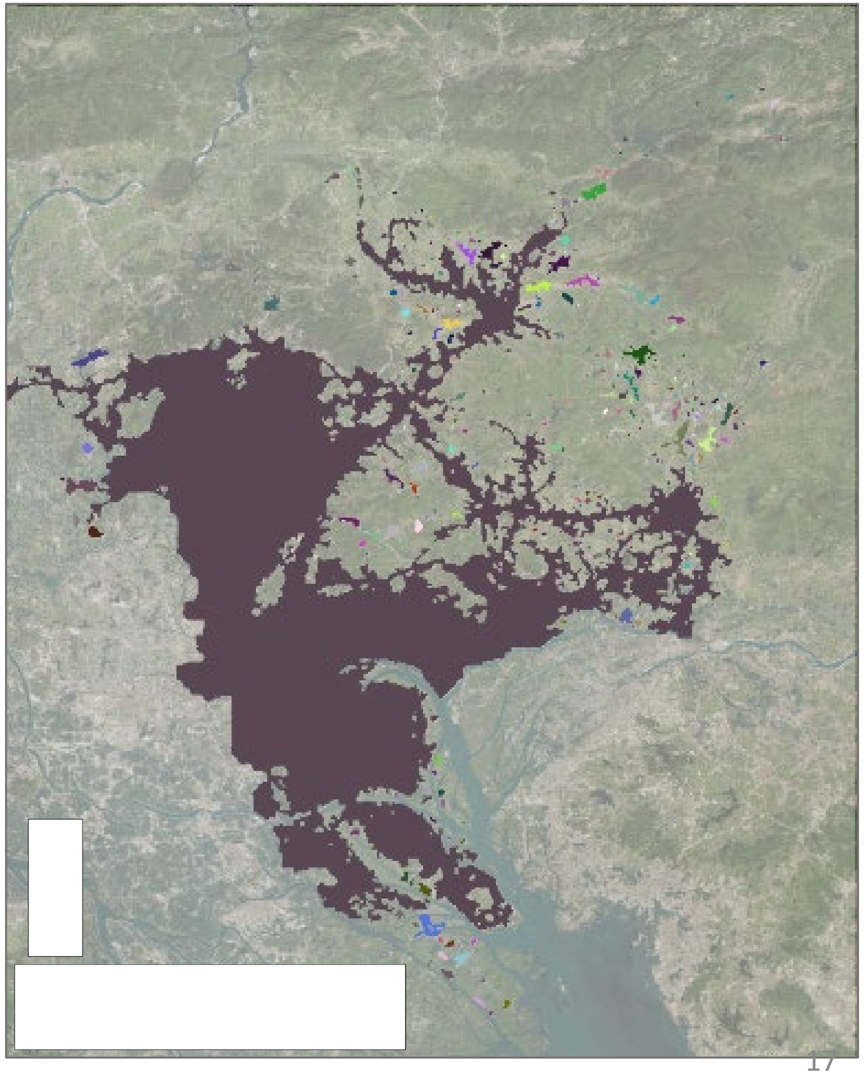
KDE derived result

CA derived result

Boundary (detail) & Post-processing

- ❖ focus on urban fringe areas (using morphological method; 7x7 window);
- ❖ (1) dilation (merge urban pixels if they are close)
- ❖ (2) erosion (erode the dilated regions)

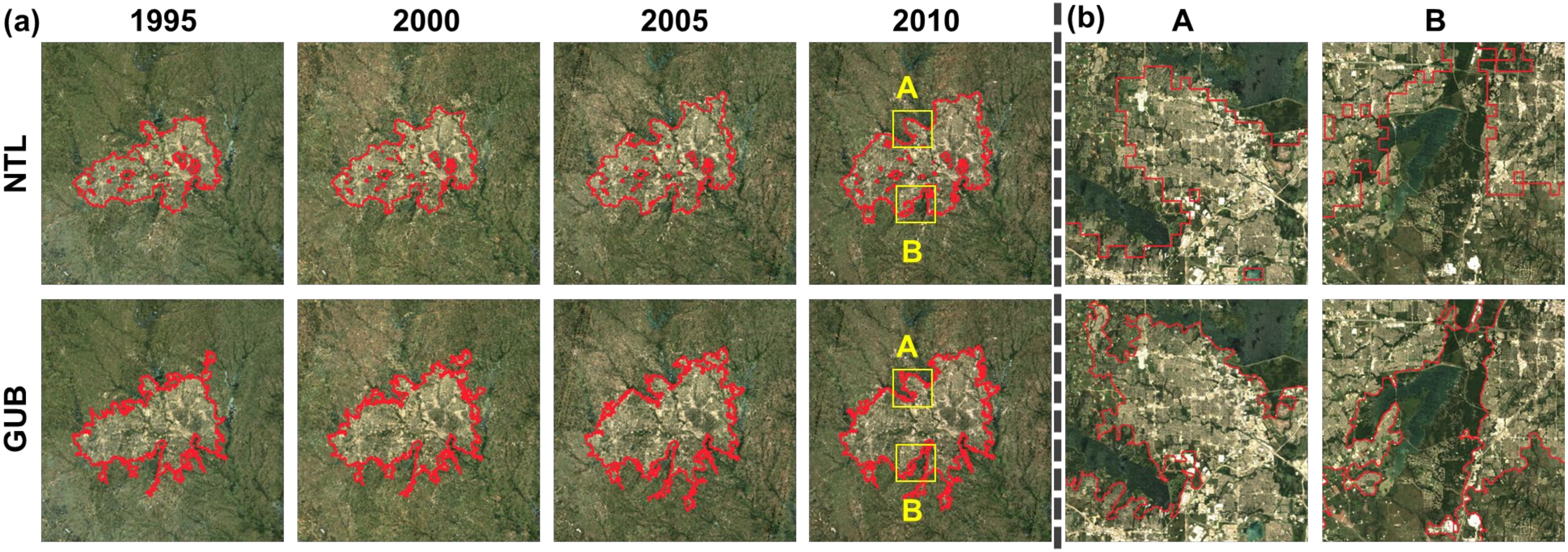
- ❖ identify different objects
- ❖ (1) remove smaller urban clusters (<1km^2)
- ❖ (2) derive the boundary (raster -> shape file)
- ❖ (3) remove small holes



4. Results and discussion

Compare with NTL derived results

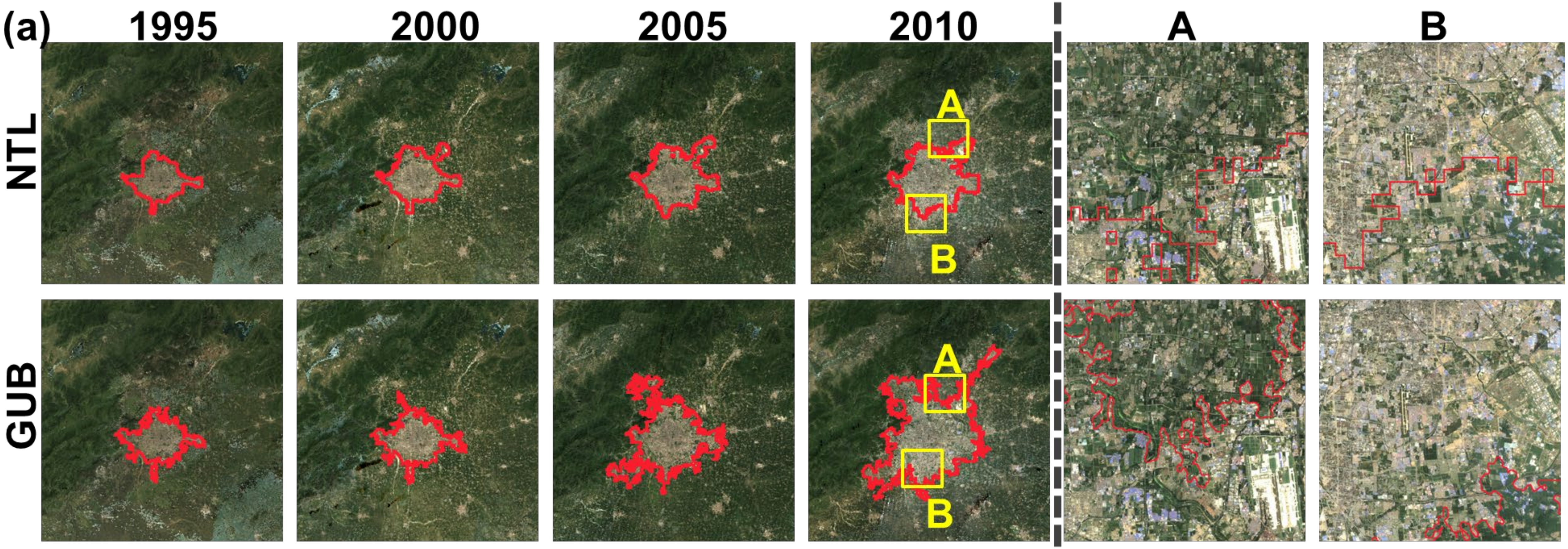
NTL: urban extent map derived from DMSP/OLS NTL data (Zhou et al., 2018)



Dallas, TX, US (150km x 150km) GUB: global urban boundary **More details can be revealed in GUB**

Compare with NTL derived results

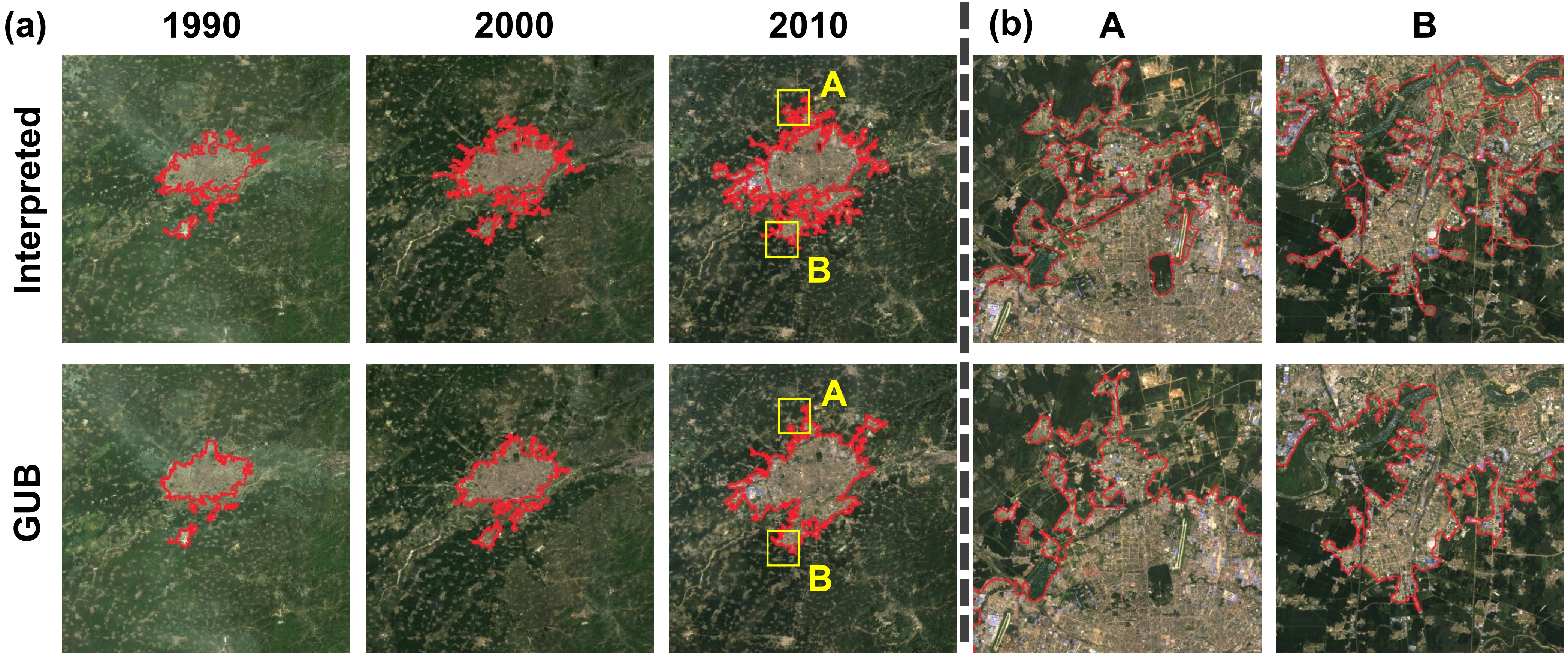
NTL: urban extent map derived from DMSP/OLS NTL data (Zhou et al., 2018)



Beijing, China (150km x 150km) GUB: global urban boundary **More details can be revealed in GUB**

Compare with interpreted results

Interpreted Results: from Landsat images (Wang et al., 2012)

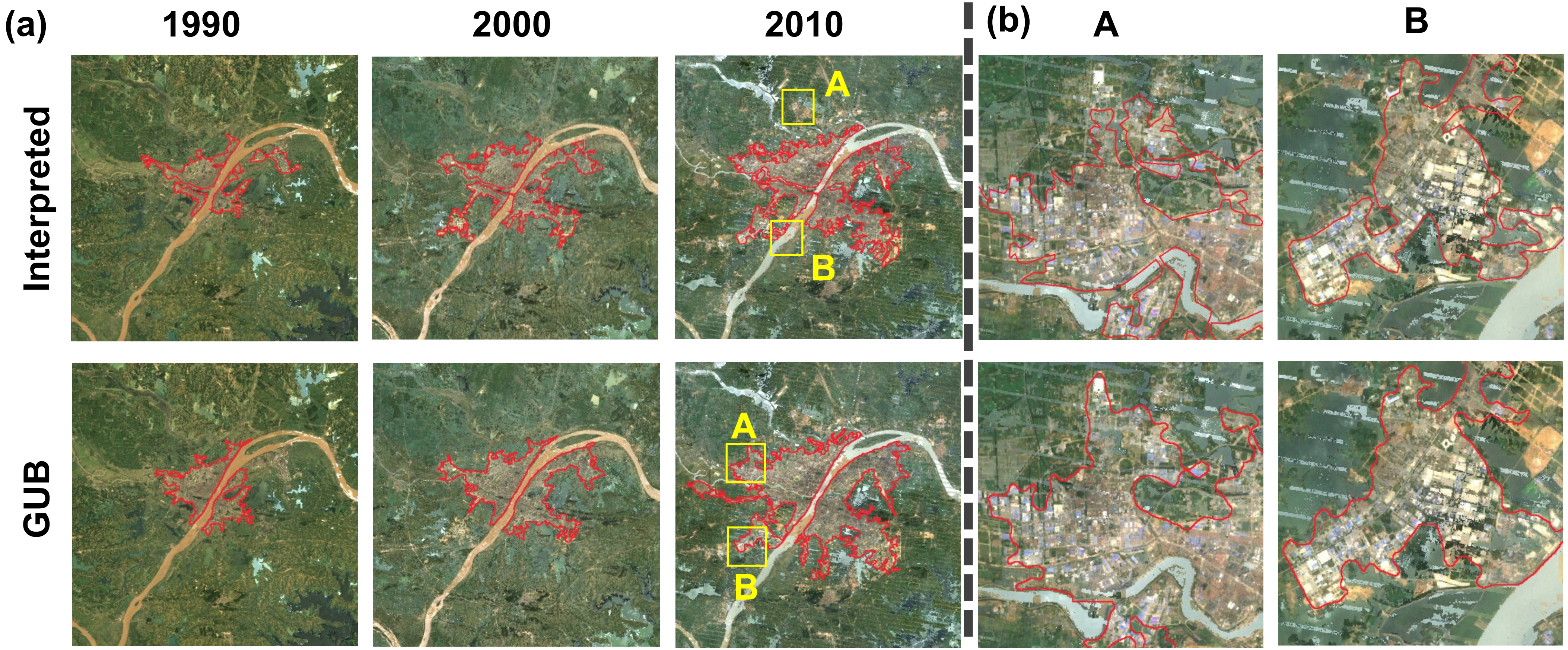


Shenyang, China (60km x 60km)

Good agreement

Compare with interpreted results

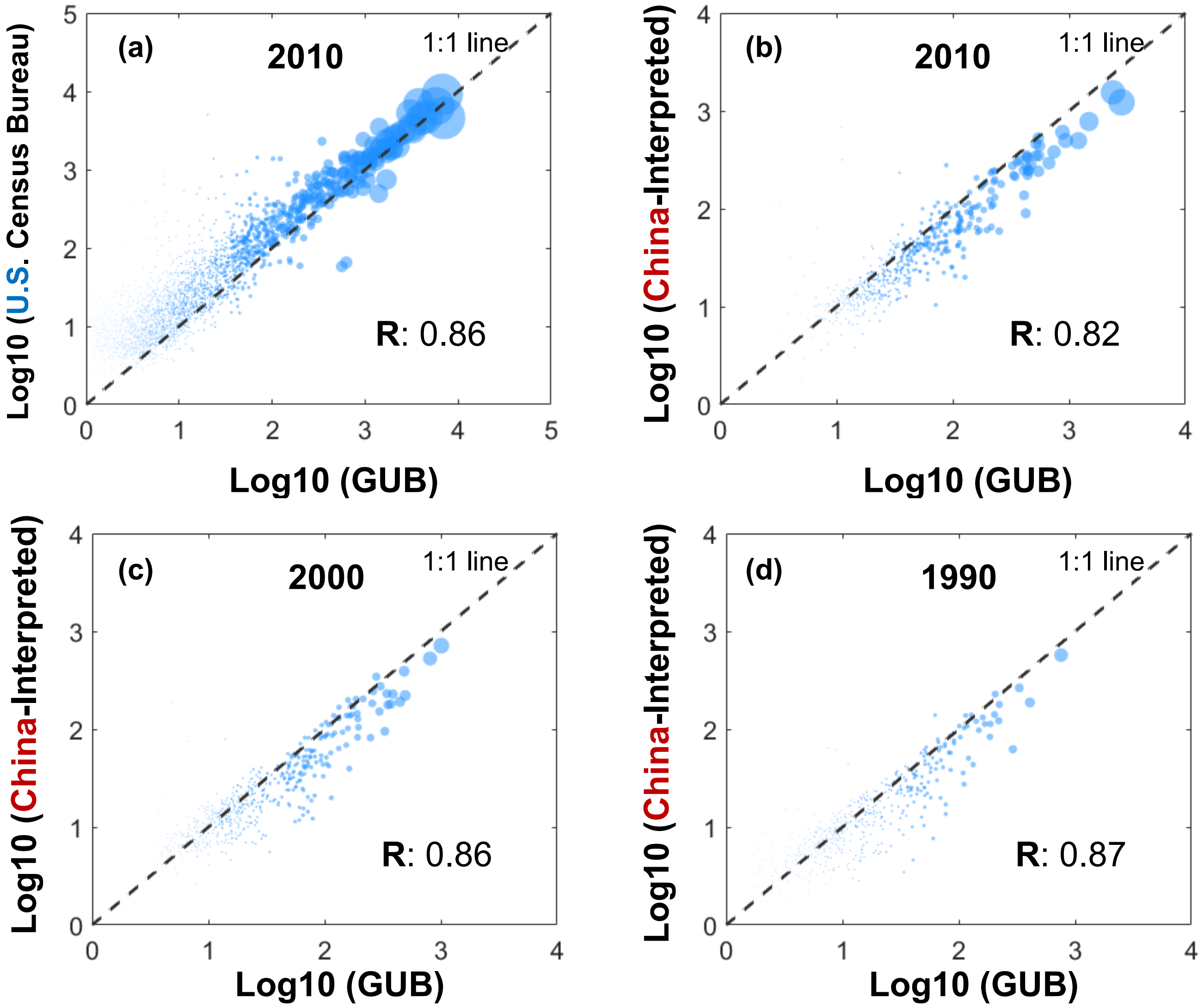
Interpreted Results: from Landsat images (Wang et al., 2012)



Wuhan, China (60km x 60km)

Good agreement

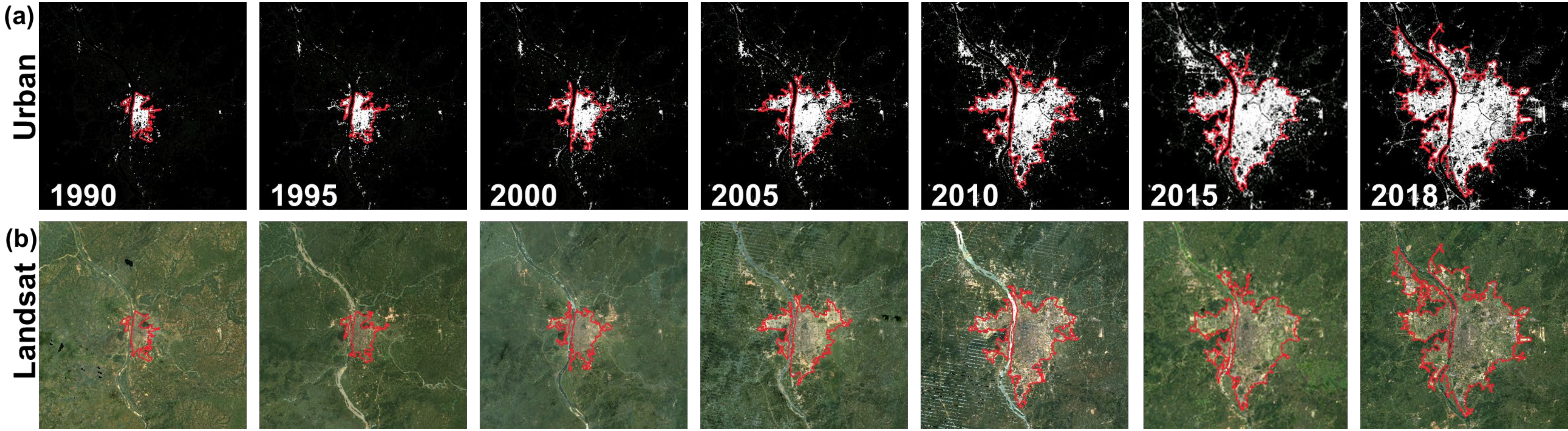
Area comparison at the national scale



- Each dot represent the delineated urban boundary
- In China: slightly overestimated than interpreted results
- In US: slightly underestimated than interpreted results;
- GUB: consistent mapping approach and definitions

Change of urban boundaries

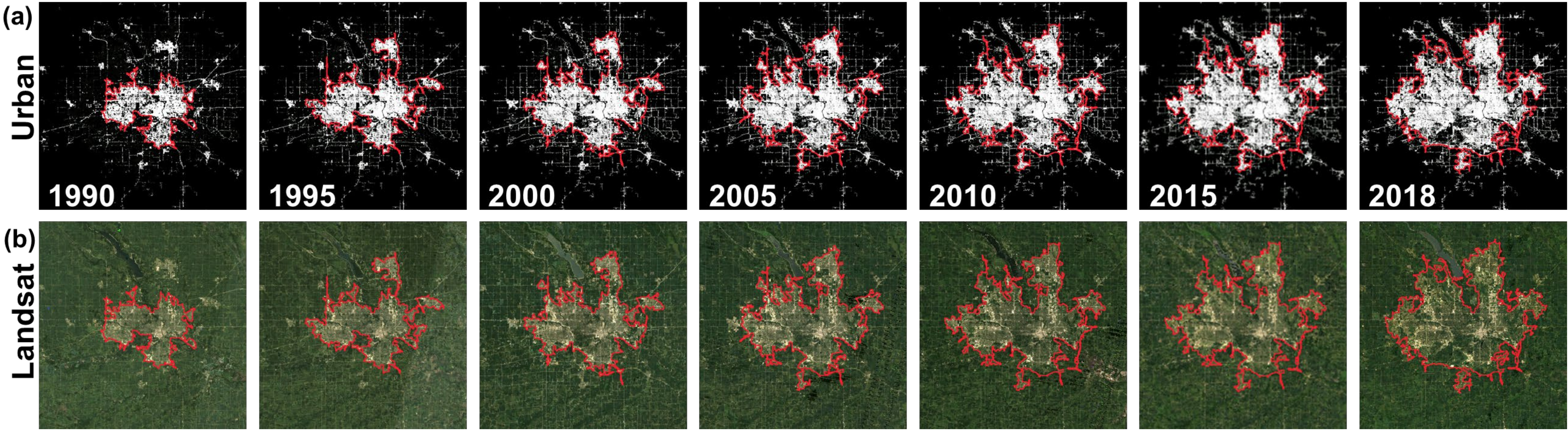
Changsha, China



The mapping approach can well capture the trend of urban extent dynamics

Change of urban boundaries

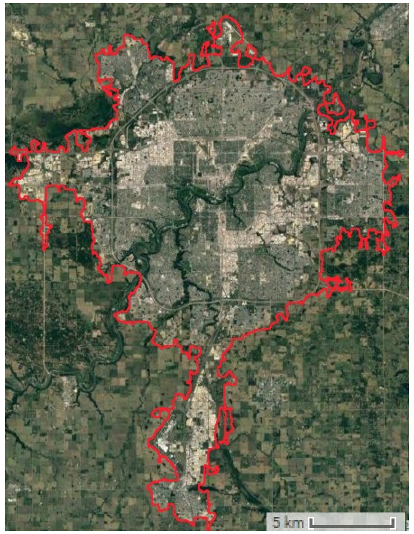
Des Moines, US



The mapping approach can well capture the trend of urban extent dynamics

Urban boundary in different cities

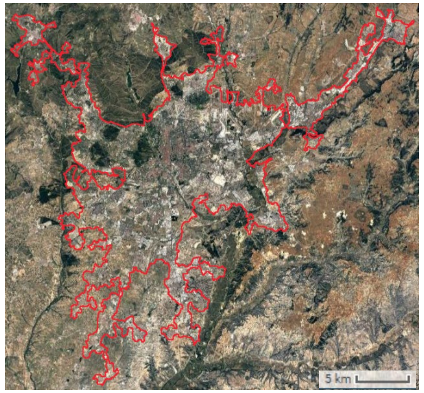
Las Vegas, US



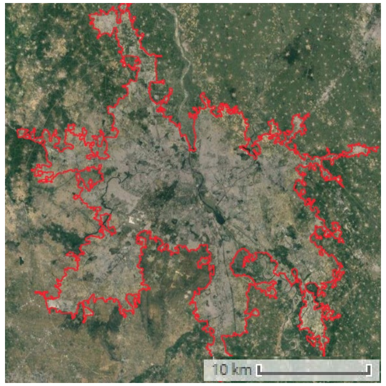
Edmonton, Canada

Buenos Aires, Argentina

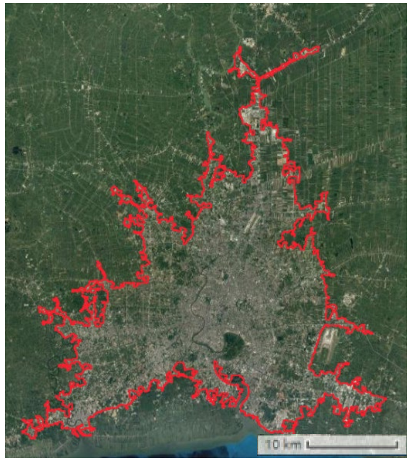
Lagos, Nigeria



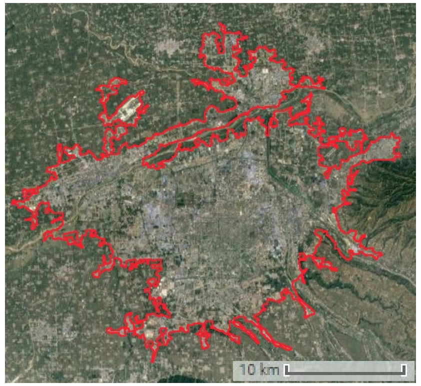
Madrid, Spain



New Delhi, India



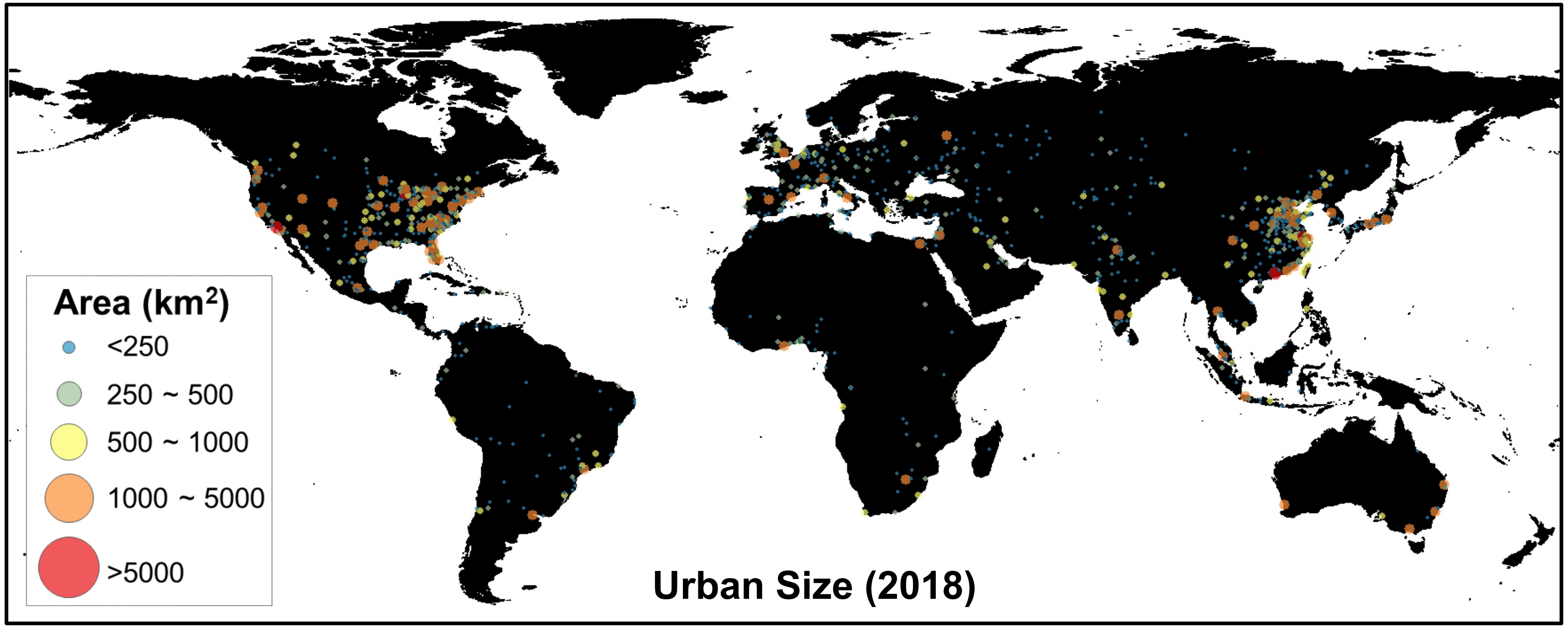
Bangkok, Thailand



Xi’An, China

Underneath: Google Earth High Resolution Image

Global pattern of urban clusters

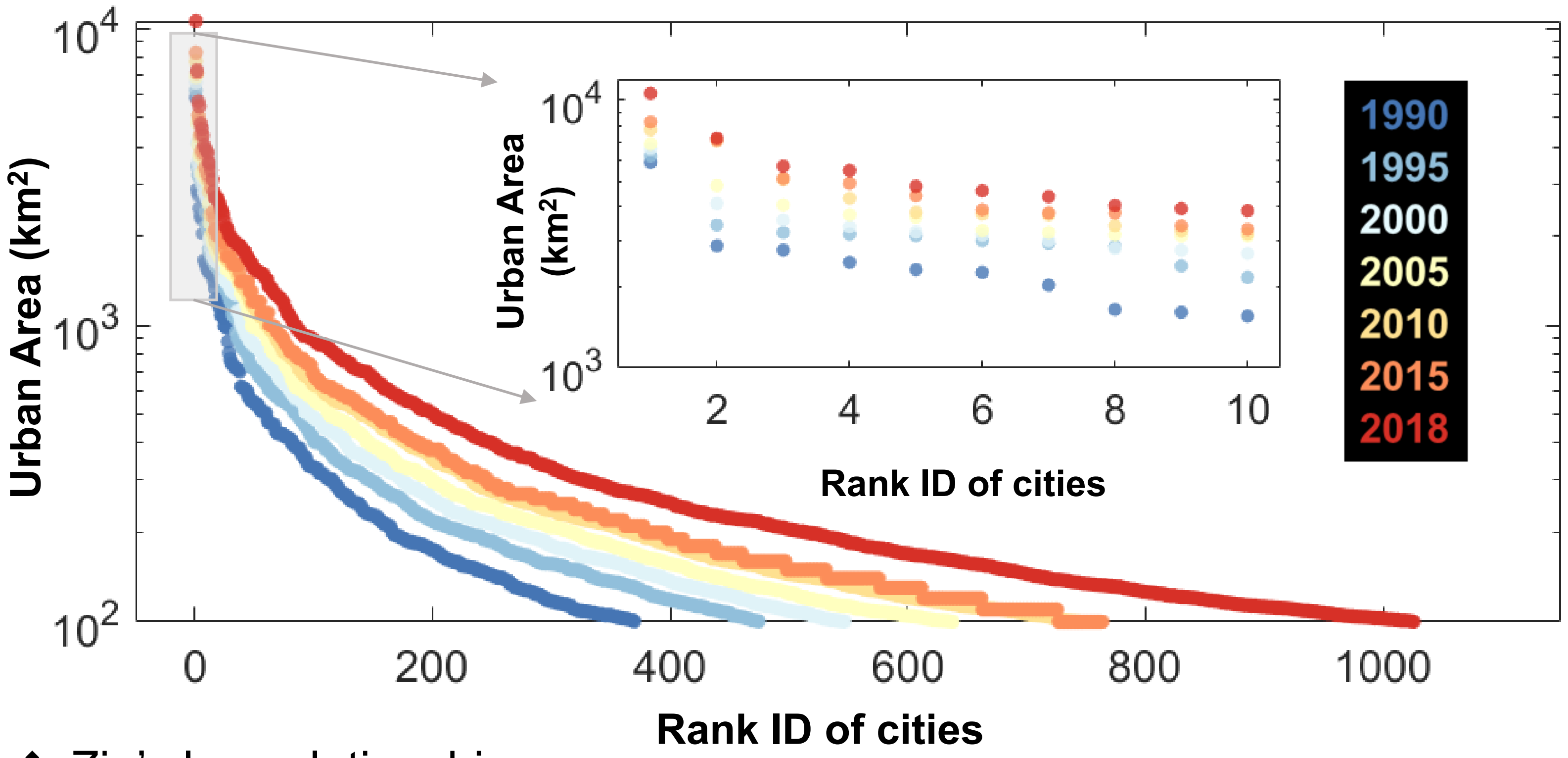


Urban Size: the area of delineated urban clusters

US has larger urban clusters than China

Area – rank relationship

Included clusters: urban area > 1000 km^2



- ❖ Zip's law relationship
- ❖ From 1990 to 2018, increased number of large urban clusters
- ❖ Same rand order with notably increased urban areas over past decades

Ratio: ISA / Urban Area

US – Dallas (150km x 150km)

Google Earth Image

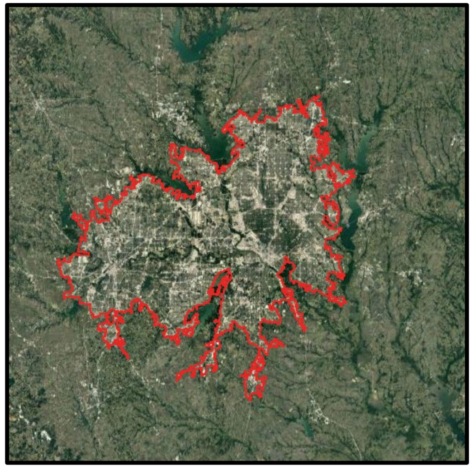
3002 km2

ISA map

3988 km2

Urban Boundary (before remove small holes)

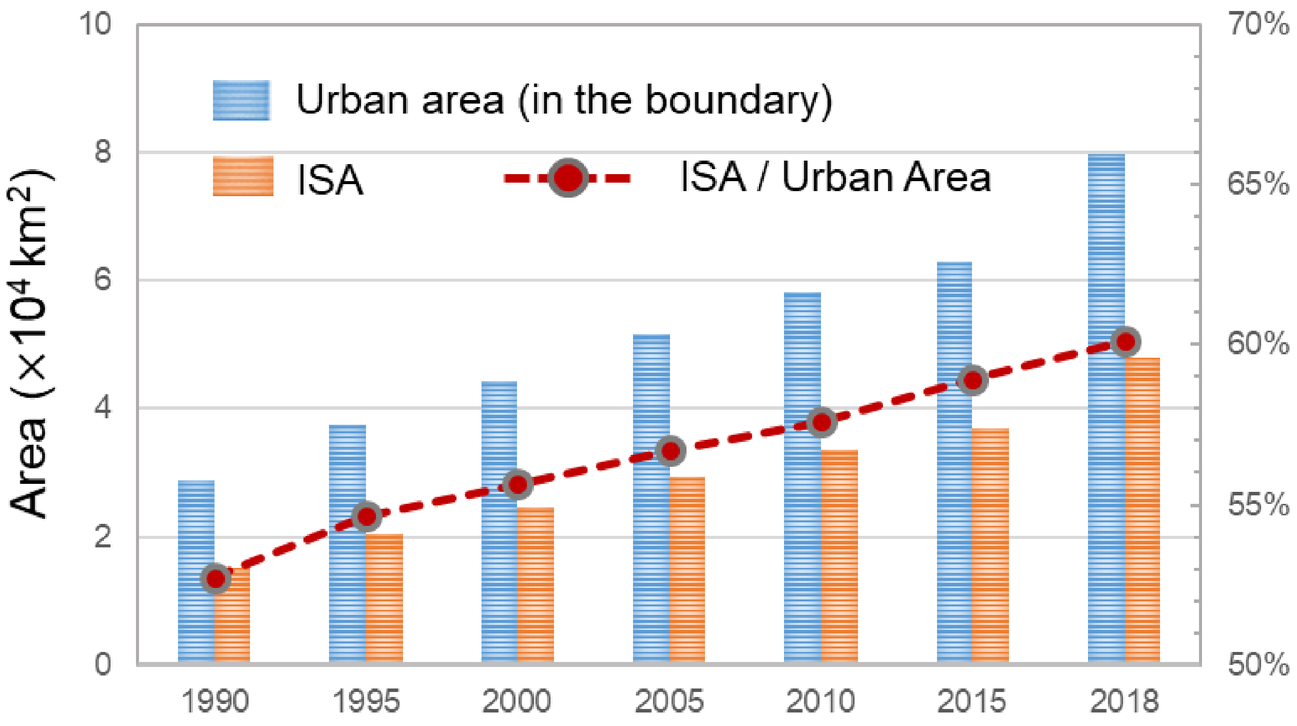
4309 km2

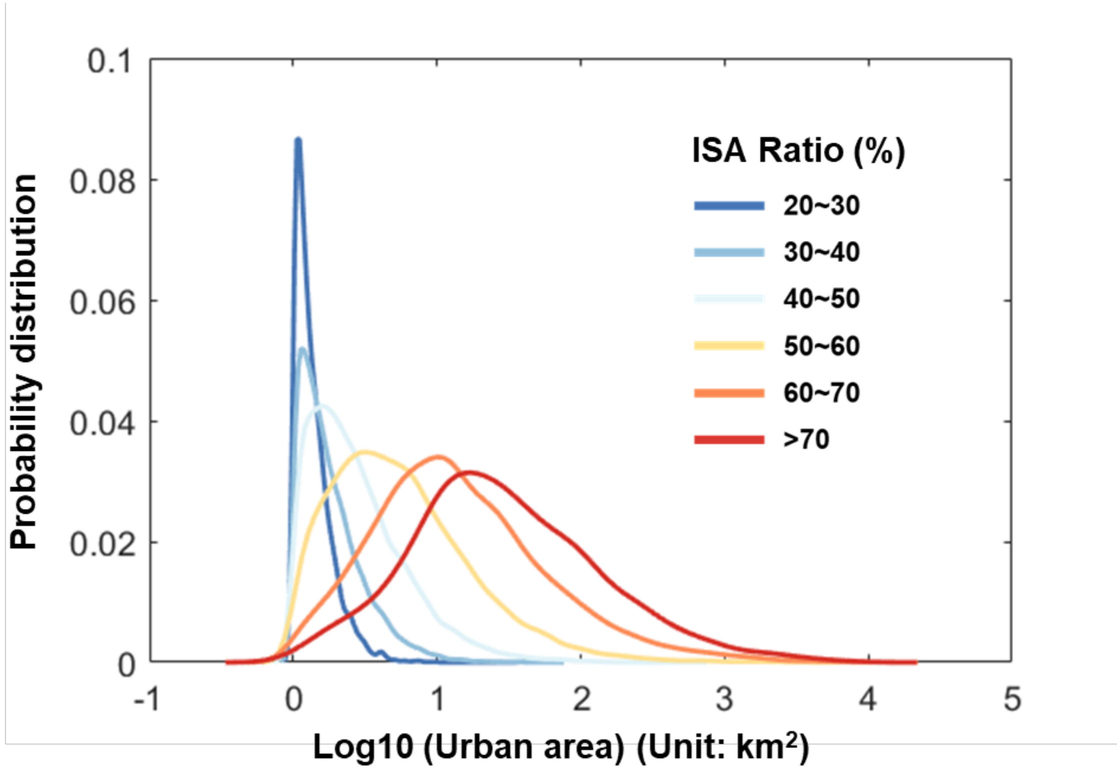


Urban Boundary (after remove small holes)

Ratio: ISA / Urban Area = 69%

Ratio: ISA / Urban Area





- ❖ Ratio: ISA/Urban, from 53% to 60%, showing a consistent increasing trend from 1990 to 2018.
- ❖ Low ISA ratio: smaller urban cluster; Larger ISA ratio: larger urban clusters

5. Summary

Summary

- ❖ Long term and fine resolution urban clusters
- ❖ The delineated boundary agrees well with the urban extent
- ❖ Serve as basic spatial unit and support for global studies

Thank You