The Data Visualization of the Population Density and Nighttime Light Data from 2000 to 2015

1. Dataset:

In this visualization project, the nighttime light data are provided by DMSP OLS. The dataset provided the nighttime light intensity from 1992-2013 annually. The link is at https://eogdata.mines.edu/dmsp/downloadV4composites.html. The dataset is the grid data. The value of each grid is within [0,63]. The 0 means that the region is the dark area. The 63 means that the light reaches maximum possible brightness. The spatial resolution of the nighttime light is about 1 km by 1 km. The dataset covers the global land area and ocean area.

The population data is Gridded Population of the World (GPW), which is provided by NASA. The GPW provides estimates of population density of 2000, 2005, 2010, 2015, and 2020. The link of dataset is at https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-rev11. The population data records the population in each 1 km by 1 km grid. The data only includes the global land area.

Because the amount of dataset is very large, the data will be processed by using the Google Earth Engine (GGE), which is an online cloud platform for geo-computation. The dataset has been stored on the GGE cloud (see https://developers.google.com/earth-engine/datasets/catalog/NOAA_DMSP-OLS_NIGHTTIME_LIGHTS and https://developers.google.com/earth-engine/datasets/catalog/CIESIN_GPWv411_GPW_Population_Density) The data are shown in the Fig. 1.

2. Research Questions:

The nighttime light intensity and population density are import metrics for the urban research. The differences between the metric in the different years and in different regions indicate the spatial and temporal processes of the urban evolution. To investigate the spatial and temporal processes of the urban evolution, researchers need to answer two basic questions: **where and when** city evolves.

The location of the city does not only mean the latitude and longitude coordinate, but also includes the city's boundary. The cities' evolution determines that the administration boundary published by the government cannot describe the boundary of the city properly. For this reason, researchers need to compare the nighttime light intensity and population density in the different boundaries to determine the boundary of the city.

To study the dynamic process of the urban evolution, researchers need to compare the differences of the metric in the different years. The comparison would reveal the speed of urbanization.

3. Design details

The visualization has three parts (See fig 2): two side-by-side windows for spatial data and one panel for charts. The width of window can be adjusted by moving the splitter in the middle horizontally. The

design allows that user visualize two maps layers or one layer. In the two windows mode, user can investigate the same regions by checking the checkbox in the right panel to link the two maps to show the same region. User can also unlink the maps to investigate different regions.

In the area of the side-by-side windows, the project provides three layers to users: 1) hybrid layer, 2) population density layer, and 3) nighttime light layer. The hybrid layer, which combines the population density and the nighttime light layer, is shown as the default layer. If user wants to investigate the population density layer and nighttime light layer individually, they can turn off the hybrid layer and turn on other layers by checking or unchecking the layers in the layer list.

The hybrid layer sets the population density data as the red channel and sets nighttime light data as the green and blue channels. The value range in each color channel is from 0 to 255, which is narrower than the range of population density and wider than the nightlight time density. To visualize most information of the data, the values of population density between 0 and 1000 are projected to 0-255 linearly; and the values of nighttime light intensity between 20 and 60 are projected to 0-255 linearly. If the value from data is less or greater than the assigned range, the value is transfer to 0 or 255 for visualization. In this design, the vibrant city's color is white because the population density and nighttime light values are both high; and the nature reserve's color is black because the population density and nighttime light values are both low. The green area in the map represents that the area has more intense nighttime light and lower population density, which is common in the suburban area of the U.S. The red area represents an area with weaker night light and denser population, which can be found in some developing countries.

The population density layer and nighttime light layer are using discrete single hue palette. The population density layer uses GnBu palette because the population density layer uses the blue and green channel in the hybrid layer. The range from 0 to 1000 is converted to the color from #f7fcf0 to #084081 (the font color is the same color that is used in the project. The grey text highlight color is to highlight the font color). The nighttime light layer uses the red palette because the nighttime layer is red channel in the hybrid layer. The range from 0 to 60 is convert to the color from #fff5f0 to #67000d (the font color is using the same color that is used in the project. The grey text highlight color is to highlight the font color). The opacity of the population density layer and nighttime light layer is set to 0.5 (0 is transparent; and 1 is opaque). The translucence allows users to use base map as their reference.

In each map window, there is a dropdown list at the top. By selecting the year in the dropdown list, the data in the map window are switched to the corresponding year. The function provides an opportunity to let user compares the same region in the different year.

The right panel is to show the charts which display the regional temporal trend and histogram quantitatively. After the user creates a polygon in the map window, the two line-charts and two histograms would be added in the right panel area.

The line charts show the temporal trend of population density and nighttime light intensity from 2010 to 2015. The X-axis of the line chart is the years, and the Y-axis is the average population density or the average nighttime light intensity. To compare the difference between different regions, the data from the different windows would be drawn in the same chart. Since the visualization has two map windows, the color of the line is the same color of the corresponding polygons. If the polygon in the left window is

green, the color of the corresponding line is green; and if the polygon in the right window is orange, the color of the corresponding line is orange.

The histogram charts show the distribution of population density and nighttime light. The X-axis of the histogram is the value, and the Y-axis is the frequency. To distinguish the data from left or right window, the color of the bar in the histogram is assigned by using the color of the corresponding polygon. Specifically, the green color represents that the information is from the left window; and orange color represents that the information is from the right window. All the line chats and the histograms have the tiles, so user can tell the content of the charts.

4. Examples of Application

Application 1: where is boundary of the Chicago city in 2015?

The city's boundary is changing all the time, so it **may not be delineated by the government properly. The administration boundary of the Chicago city may underestimate the area of the Chicago city.** A lot of people who lived in the Naperville, Schaumburg, and Evanston etc. commute to the Chicago downtown every weekday. It indicates that the Chicago city's boundary may not only include the Chicago city administration area, but also includes the cities close to the Chicago city. In addition, The Chicago metropolitan boundary, defined by the U.S. Census Bureau, includes several counties, such as DeKalb county, IL and Lake county, IN, where much less people commute to Chicago city than the people lived the county nearby the Chicago city. This indicates that **Chicago metropolitan boundary may overestimate the size of Chicago city.**

To compare the boundaries of the Chicago city administration boundary and Chicago metropolitan boundary, **user can draw the polygons in the side-by-side windows** to compare the histograms of nighttime light intensity and population density.

The histograms are shown in the Fig 3. It showed that the Chicago metropolitan area has many weak nighttime light area and low population cells. All of the cells in the Chicago city administration boundary has high nighttime light intensity. It reveals that the Chicago city administration underestimates the size of Chicago city and Chicago metropolitan area overestimates the size of Chicago city. Further, user can create his own Chicago boundary by drawing a polygon covering cities includes and near the Chicago city. The histogram would show whether the values are clustered at the high values zone.

Application 2: how the city of Beijing, China evolves from 2000 to 2015

During the 2000-2015, **the pace of Beijing's urbanization is very fast**. To investigate this process quantitively, user can use the left window to show the data from the 2000 and use the right window to visualize the data from the 2015 of the Beijing (see Fig 4). The visualization of map shows the difference. User can also draw a polygon, covering Beijing (high nighttime light intensity area), in the right window. The line charts (see Fig 4) show the temporal trends of average population density and nighttime light. It indicates that Beijing has a high utilization speed.

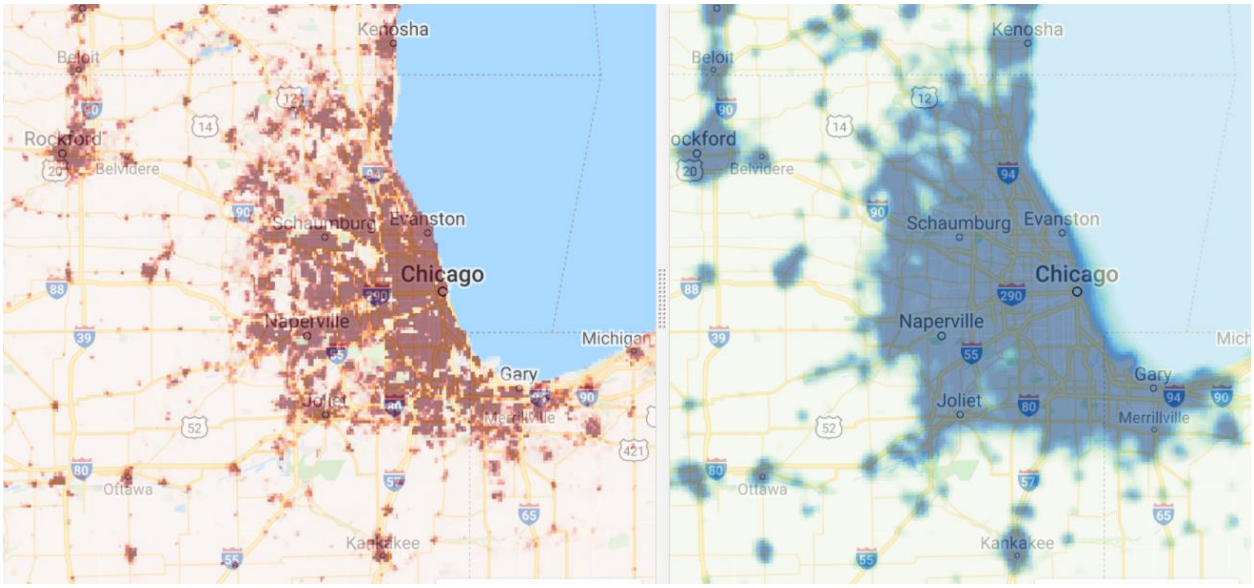

Fig. 1 Left: population density in the Chicago area; Right nighttime light intensity in the Chicago area

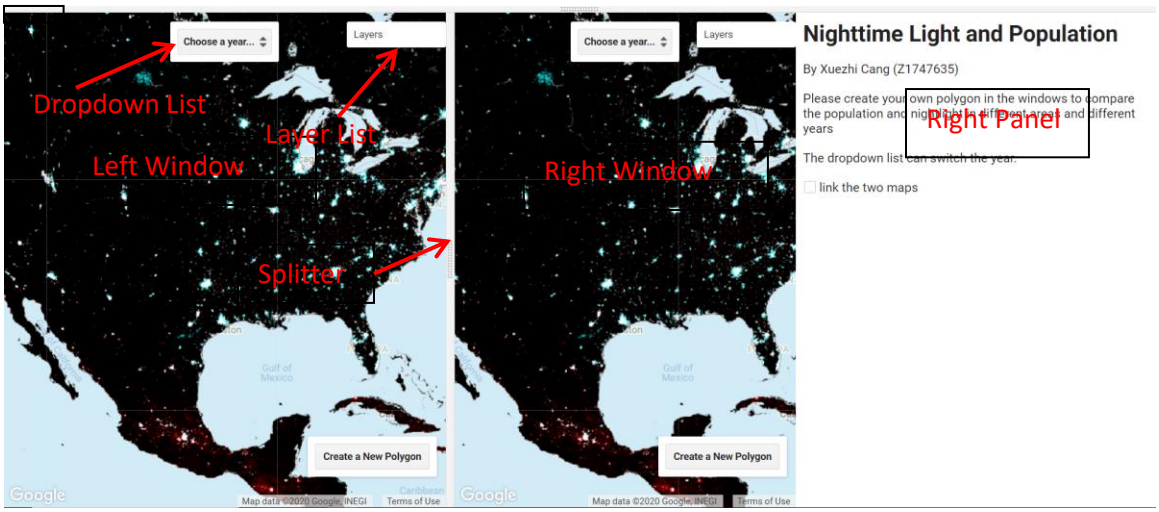

Fig 2 Visualization interface

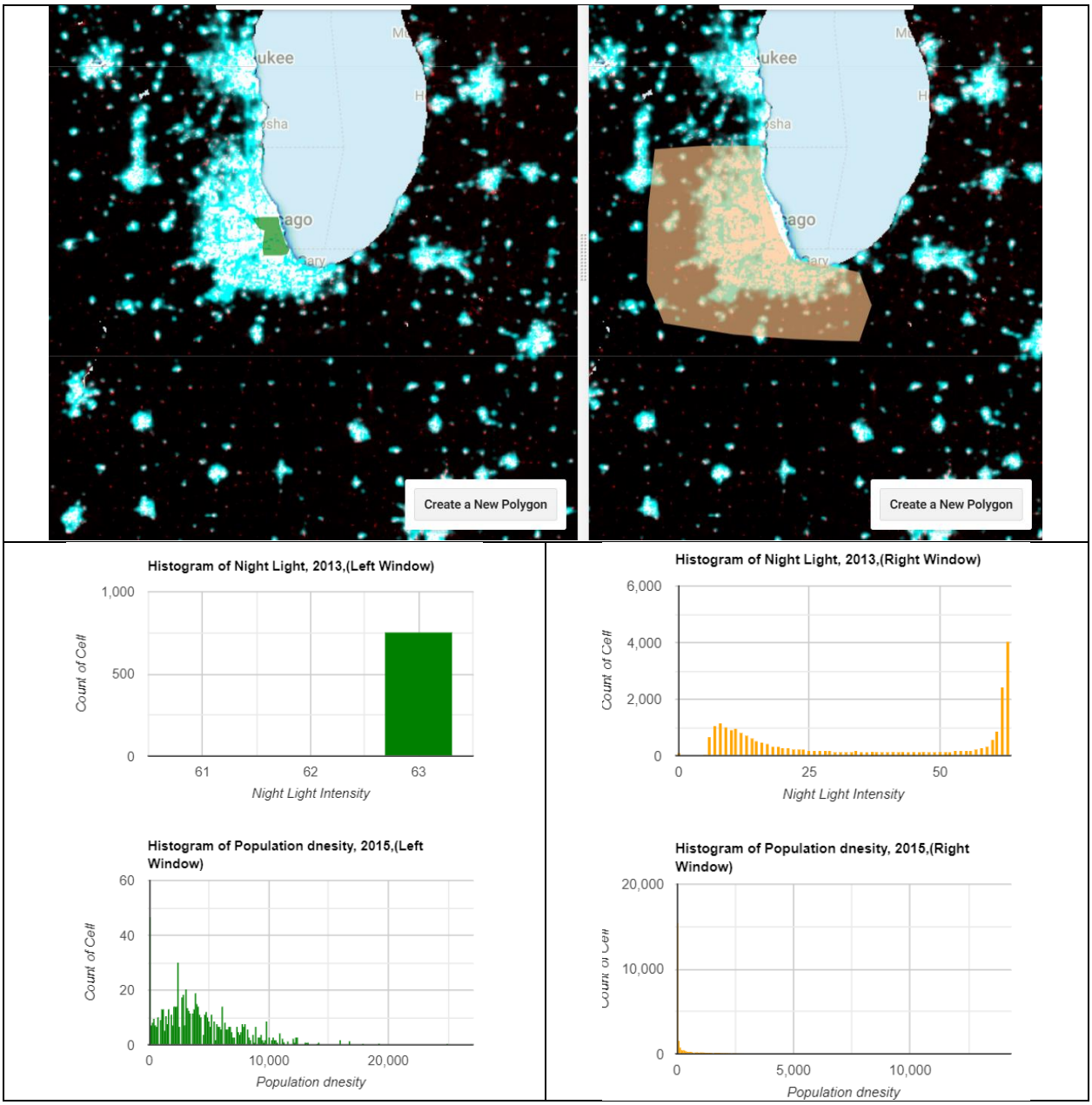

Fig 3 Comparison between the Chicago administration area and the Chicago metropolitan area

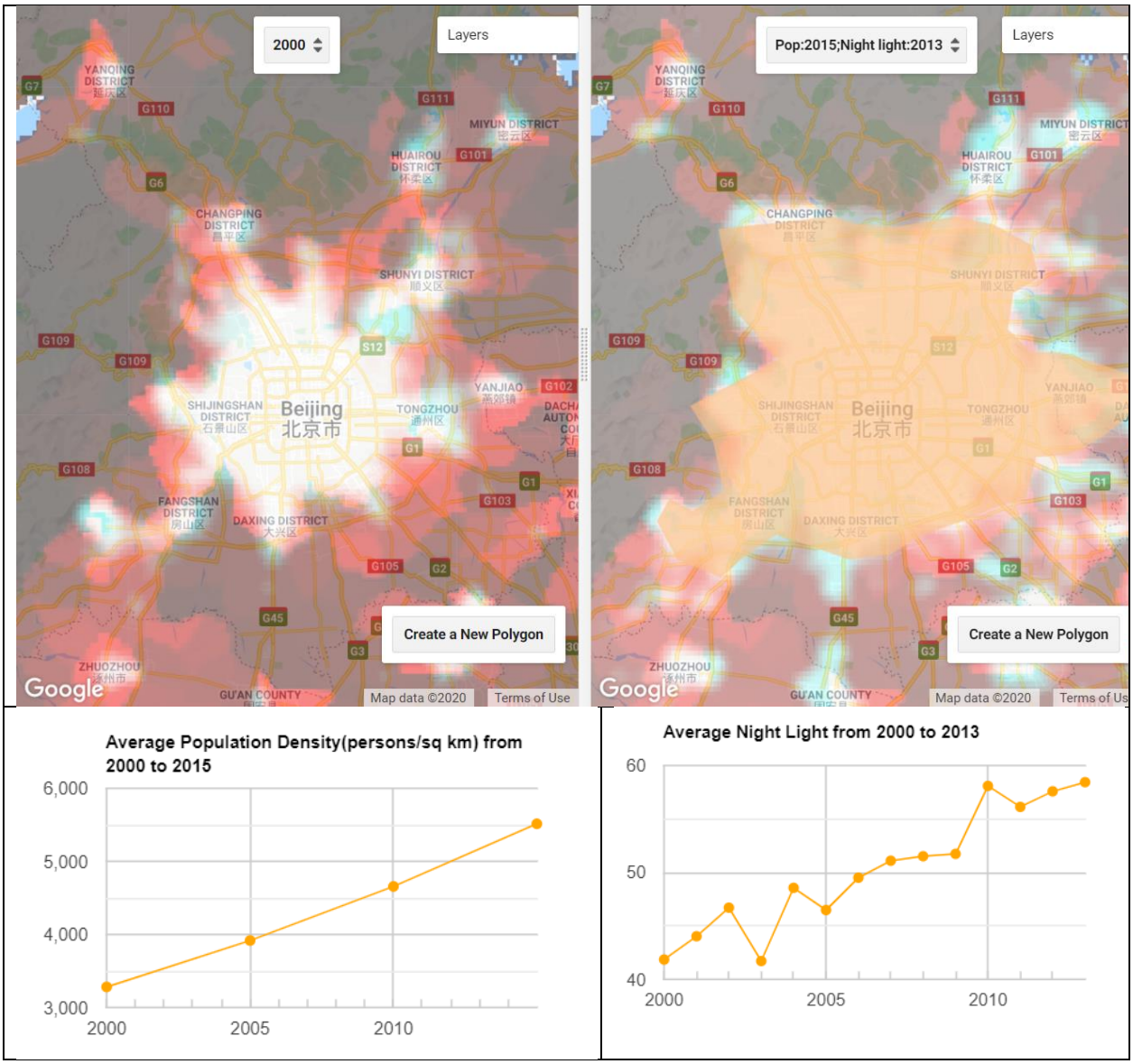

Fig 3 Comparison between the Beijing in 2000 and 2015