Learning Diary

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Preface

This is the learning diary for remote sensing module. Written in Markdown and editable codes.

Introduction

Hello! My name is Yinhao Ren and I am a USS student in CASA. Even though I am familiar with remote sensing somewhat, I haven't done something really fascinating and attractive about this topic. So here I am, looking forword to learn something fun and hope I can pass this module! 

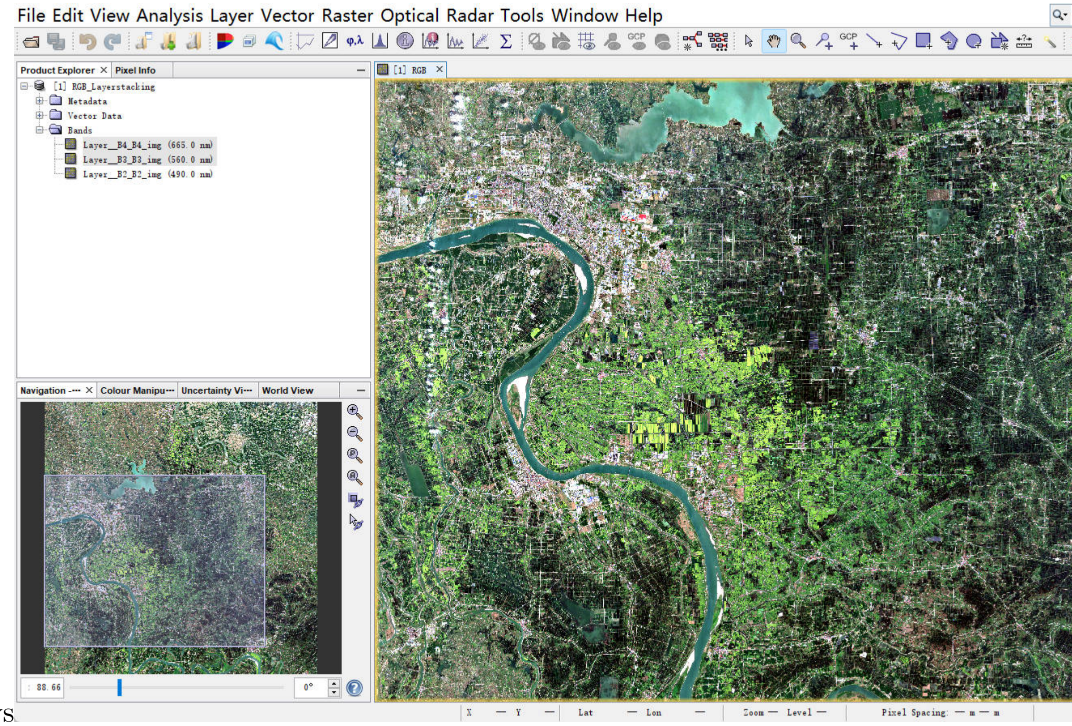
1 An Introduction to Remote Sensing

1.1 Summary

This week the introductory knowledge of remote sensing is mainly introduced in four main aspects. First, the source and application of remote sensing, processing and analyzing data received from satellites, drones, mobile phones, etc., can be applied to decision-making analysis in cities, forests, oceans, etc.; second, the type of sensor, There are two types of sensors, active and passive. The important difference between these two is whether they can send energy independently and get feedback; third, the energy interaction on the earth's surface, such as atmospheric scattering, the existence of electromagnetic waves, etc.; fourth, introduceing four important resolutions, spatial resolution, spectral resolution, time resolution and radiation resolution. For the experimental part of this week, the course learned how to download the Sentinel-2 satellite image and perform basic processing and display functions. After downloading the target satellite image from the open website, we can first open the true color image (RGB three-band) in QGIS. For Sentinel-2 satellite image band description is as follows

Band	Resolution	Central Wavelength	Description
B1	60 m	443 nm	Ultra Blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Visible and Near Infrared (VNIR)
B6	20 m	740 nm	Visible and Near Infrared (VNIR)
B7	20 m	783 nm	Visible and Near Infrared (VNIR)
B8	10 m	842 nm	Visible and Near Infrared (VNIR)
B8a	20 m	865 nm	Visible and Near Infrared (VNIR)
B9	60 m	940 nm	Short Wave Infrared (SWIR)
B10	60 m	1375 nm	Short Wave Infrared (SWIR)
B11	20 m	1610 nm	Short Wave Infrared (SWIR)
B12	20 m	2190 nm	Short Wave Infrared (SWIR)

When we use the Snap software to open an image, we first perform a resampling operation, and then we can use the 432 three bands to perform band fusion to obtain a true color image. A case of a true color image is as follows



can also use Snap to perform image subsetting, scatter plotting comparison and other activities.

1.2 Applications

There are many applications of remote sensing, which are involved in different fields. Peng Chen (2023) used multi-source remote sensing data to effectively detect river water quality, with an accuracy of nearly 90%; Wujian Ye (2022) used remote sensing data combined with deep learning methods to classify and identify pests and diseases in forests, and the recall rate up to 50%. To put it simply, its research is to replace the hysteresis and low resolution of satellite remote sensing with the effectiveness and high resolution of drone remote sensing, it performed data enhancement, labeling, etc. on the images of drones, and finally put them into neural networks abd trained in the network model. Ultimately, they got the corresponding results; Zhou Weimo(2022) used the satellite remote sensing data to predict the yield of wheat at the county level in China with the best R square of 0.79. Most of the methods in these articles are based on satellite or drone remote sensing data as the data source, combined with some typical machine learning algorithms such as random forest, support vector machine, etc. to formulate a model, and finally get the corresponding precision results. I think these methods can effectively overcome difficulties, such as field research, funding, coverage area, etc., and remote sensing images can be used as the basic data source when dealing with large-scale single-type targets.

1.3 Reflection

After reading some relevant literature and understanding research cases, I think that the application of remote sensing in today's society must be deeply integrated with forecasting models to a large extent. An obvious feature of the application of remote sensing is statistical expression based on spatial information, which means models are inseparable. Prediction is an unavoidable topic in industrial applications. Therefore, it is necessary to mine remote sensing prediction models and express the spatiotemporal characteristics of the model through spatial data visualization. In the case studies metioned above, the thematic maps and related reports are the most direct products of remote sensing. However, I think the results can be digitized and informatized, like the results can be made into web pages and apps and processed through some shortcuts, such as QR code or link.

2 Portfolio tools: Xaringan and Quarto

Xaringan Link

https://hairterminator.github.io/

3 Remote sensing data

3.1 Summary

This week's course mainly involves an introduction to remote sensing data and basic processing operations. At present, there are two main types of satellite sensors: whisk broom and push broom. In order to better understand and use satellite image data, the working principles of these two sensors need to be noted:

3.1.1 Whisk Broom Scanners

Whisk broom is sometimes called Spotlight or Across Track Scanners. It uses a "mirror" to reflect light to a detector and uses a "mirror" to move back and forth to collect the value measured from a pixel. Such moving parts are expensive and prone to damage.

All Landsat sensors prior to Landsat 8 were of the whisk-broom type, and the Landsat 8 OLI devices were of the push-broom type.

3.1.2 Push Broom Scanners

Push-brooms, sometimes called along track scanners, use detectors placed perpendicular to the direction of flight of the spacecraft, which collect images one line at a time as the vehicle flies forward (as shown in the figure below) . The signal received by push-broom is stronger than that of whisk-broom, because the time of whisk-broom in one pixel is very long. A certainty with pushbroom is that the detectors may have different sensitivities, which can lead to image streak noise if not calibrated properly.

The current SPOT, IRS, QuickBird, OrbView, IKONOS, Worldview, GeoEYE, and other sensors are all push-broom.

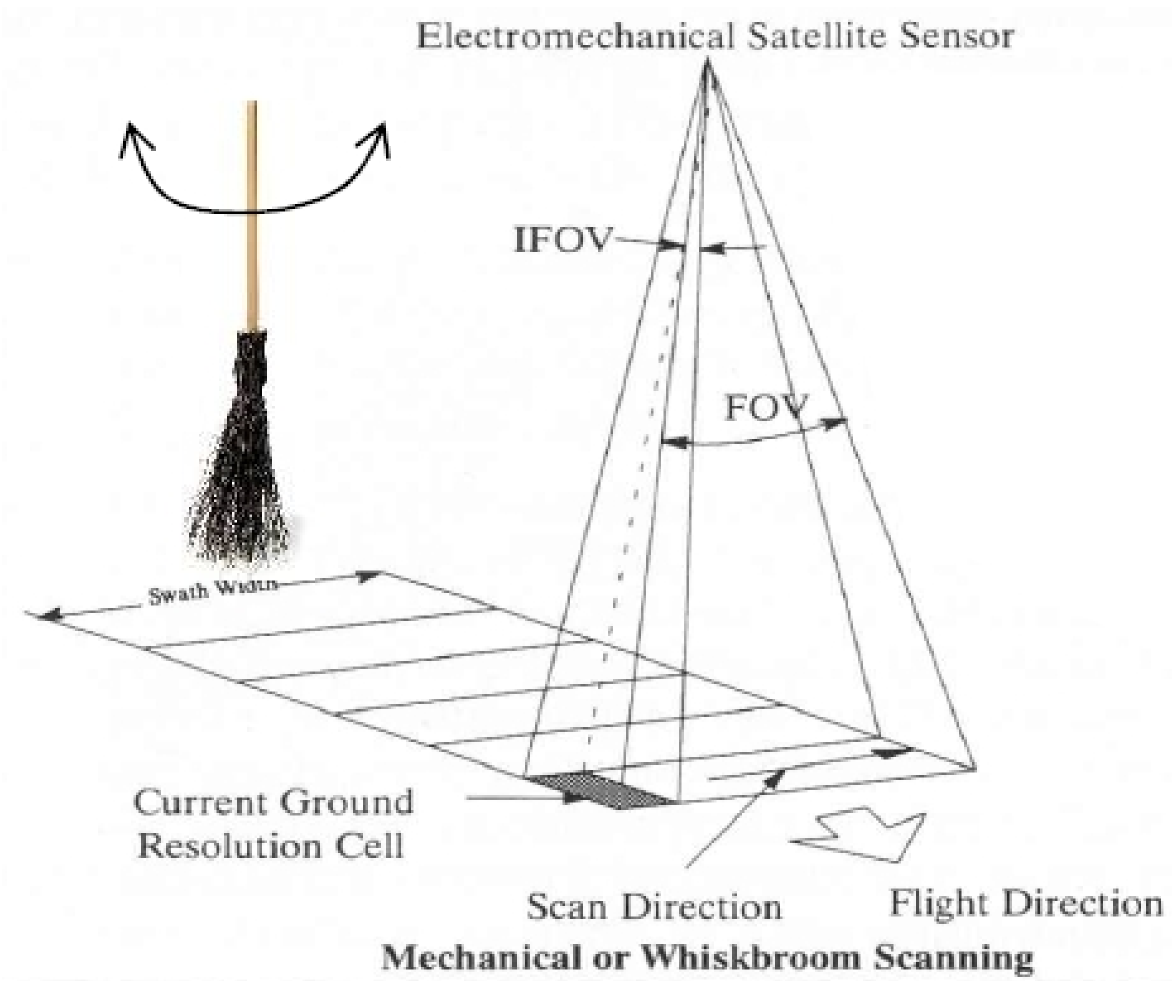


Figure 3.1: Figure 1, The direction of the whisk broom is perpendicular to the flight path, collecting one pixel at a time, and the image comes fromFlorianhillen

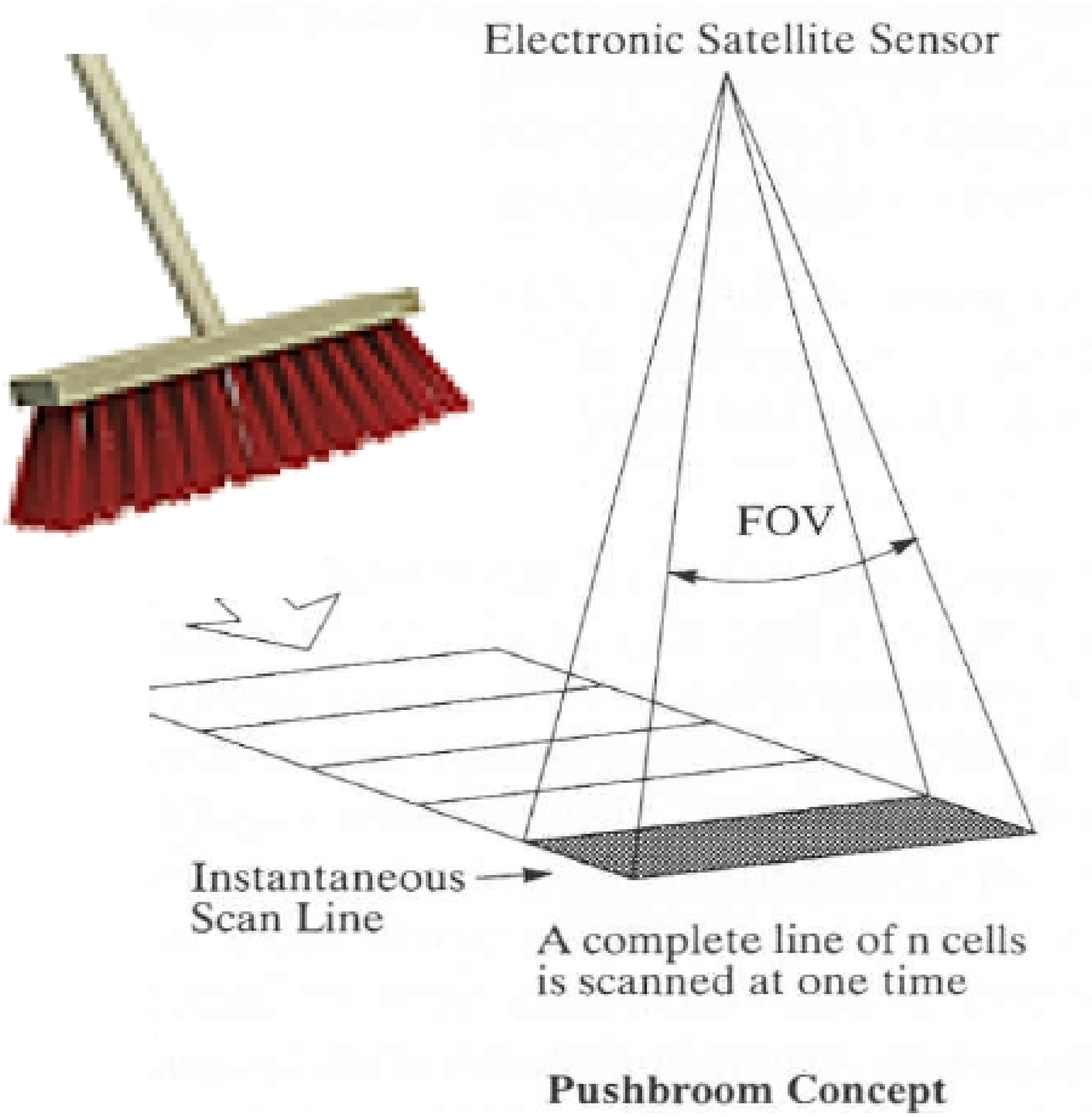


Figure 3.2: Figure 2, the linear array detector moves with the spacecraft to generate continuous image data, similar to pushing a broom forward, the image comes fromFlorianhillen

3.1.3 Image Correction

Remote sensing image correction is divided into geometric correction and radiometric correction. Geometric correction is subdivided into coarse correction, fine correction, hybrid correction, orthorectification, etc. Radiometric correction is divided into radiometric calibration, radiometric correction, atmospheric correction, etc. These concepts are easy to confuse, so we need to understand the purpose and process of each correction. After going through relevant information, I think I can now clearly present each step.

3.1.3.1 Geometric Correction

It refers to using a series of mathematical models to correct and eliminate the deformation caused when the geometric position, shape, size, orientation and other characteristics of the objects on the original image are inconsistent with the expression requirements in the reference system. These deformations are often caused by factors such as the deformation of photographic materials, the distortion of the objective lens, atmospheric refraction, the curvature of the earth, the rotation of the earth, and terrain fluctuations.

Geometric correction is the process of eliminating or correcting geometric errors of remote sensing images. The deformation errors of remote sensing images can be roughly divided into two categories: static errors and dynamic errors. Referring to the two error categories, geometric correction is divided into several types: geometric coarse correction, geometric fine correction, hybrid correction and orthorectification. The correction we often refer to is fine correction.

Geometric Coarse Correction: Correction for the cause of distortion. (Distortion causes: distortion of photographic material, distortion of objective lens, curvature of the earth, rotation of the earth)

Geometric fine correction: geometric correction using control points, which uses a mathematical model to approximately describe the geometric distortion process of remote sensing images, and uses some corresponding points between the distorted remote sensing images and the standard map (that is, the control point data pairs) to obtain the geometric distortion model, and then use this model to correct the geometric distortion, which does not consider the cause of the straight distortion.

Hybrid correction: The geometric rough correction and the geometric fine correction are done together, and it often includes the precise ephemeris into the correction model.

Orthorectification generally selects some ground control points on the photo, and uses the digital elevation model (DEM) data within the range of the photo that has been acquired to simultaneously perform tilt correction and projection difference correction on the image, and resample the image into an orthographic image. After mosaicing multiple orthophotos together and performing color balance processing, the images cut out within a certain range are orthophotos.

3.1.3.2 Radiometric Correction

1. Concept

The intensity of radiation entering the sensor is reflected on the image as a brightness value (or gray value). The greater the radiation intensity, the greater the brightness value. This value is mainly affected by two physical quantities: one is the radiation intensity of solar radiation hitting the ground, and the other is the spectral reflectance of ground objects. When the solar radiation is the same, the difference in brightness on the image directly reflects the difference in the reflectivity of the ground. But, in the actual measurement, it is found that the radiation intensity value is also affected by other factors, and this changed part is the part that needs to be corrected, so it is called radiometric distortion.

The causes of radiation distortion are: (1) the error of the sensor itself (2) the influence of the atmosphere on radiation (3) the influence of terrain on radiation (terrain correction)

2. Radiometric correction method

- Histogram minimum value removal method
- Regression analysis method

3. For the cause of radiometric distortion, complete radiation correction includes: radiometric correction, sensor correction, atmospheric correction, terrain correction and sun altitude correction.

DN value (Digital Number): the brightness value of a remote sensing image pixel, and it records the gray value of ground features. Unitless, it is an integer value, and the value is related to the radiation resolution of the sensor, the emissivity of ground objects, the transmittance of the atmosphere, and the scattering rate. It reflects the radiation rate radiance of the surface features

Surface albedo: The ratio of the amount of ground reflected radiation to the amount of incident radiation, which characterizes the ability of the ground to absorb and reflect solar radiation. The greater the reflectivity, the less solar radiation the ground absorbs; the smaller the reflectivity, the more solar radiation the ground absorbs, said: surface albedo

3.1.3.2.1 Radiometric Calibration

Radiation calibration means that when users need to calculate the spectral reflectance or spectral radiance of ground objects, or when they need to compare images acquired by different sensors at different times, they must convert the brightness gray value of the image into absolute radiance. This process is radiometric calibration.

3.1.3.2.2 Atmospheric Correction

1. Concept

The purpose of atmospheric correction is to eliminate the influence of factors such as atmosphere and light on the reflection of ground objects, obtain real physical model parameters such as surface reflectance, radiation, and surface temperature, and use them to eliminate water vapor, oxygen, carbon dioxide, methane, and ozone in the atmosphere. In most cases, atmospheric correction is also the process of inverting the true reflectance of ground objects.

2. Classification Method

- Absolute atmospheric correction methods: MORTRAN model, LOWTRAN model, ACTOR model and 6S model based on radiative transfer
- Relative atmospheric correction methods: Statistical-based invariant target method, histogram matching method.

3.2 Application

Yuanyuan Pan(2018) aimed at the lack of research on the atmospheric correction of Sentinel-2A satellites, selected three types of ground objects, forests, water bodies, and urban buildings as the research objects, and analyzed the changes in reflectance before and after atmospheric correction of the Sentinel-2A single-band channel; at the same time, Landsat- 8, Gaofen-1 (GF-1) were used as auxiliary data, and the research was carried out from three aspects: the reflectance curve of homogeneous pixel after atmospheric correction of three sensors, and the change of vegetation index before and after atmospheric correction. The results showed that: 1) After atmospheric correction of Sentinel-2A, the reflectance of the visible light channel becomes smaller, and the longer the wavelength is, the less significant the effect of atmospheric correction is; the reflectivity of near-infrared and short-wave infrared increases. 2) After atmospheric correction, the three data sources The spectral curves of the same species tend to be consistent, and the Sentinel-2A water body and vegetation spectral curves can better reflect the characteristics of the ground features. 3) Compared with Landsat-8, Sentinel-2A, GF-1WFV1 atmospheric correction The NDVI of forest land increases significantly , Sentinel-2A high vegetation coverage area increased, low vegetation coverage area decreased, which can best reflect the vegetation characteristics; Sentinel-2A NDWI change is not as significant as

Landsat-8 NDWI change. Chen Ling (2020) used the FLAASH module of ENVI software to perform atmospheric correction on Worldview3, and took the uninhabited area of Lop Nur, Xinjiang as an example, using the ASD measured spectral data of typical saline-alkali land and diorite in this area to evlauate the data before and after atmospheric correction of Worldview3. First, she converted the DN value of Worldview3 into radiance and apparent reflectance, and used the FLAASH module to perform atmospheric correction; then, she calculated the radiation brightness and apparent value, and resampled the measured saline-alkali land and diorite spectral data to the corresponding bands of Worldview3; finally, the results were qualitatively analyzed and compared quantitatively. The research showed that it is feasible to use the FLAASH module to perform atmospheric correction on Worldview3 data. The measured spectra of typical ground objects and reflection spectra obtained after atmospheric correction have a high degree of agreement, with the highest correlation coefficient reaching 0.80. It can be seen that there are many articles on the research on atmospheric correction. The reason is that atmospheric correction is one of the important steps in the preprocessing of hyperspectral remote sensing images, and its accuracy determines the degree of hyperspectral remote sensing application to a certain extent. The above two studies have considered the atmospheric correction process of different data sources, and proved the indispensability of atmospheric correction through experiments.

3.3 Reflection

The difference between ortho-rectification and general geometric correction confused me at first, but after consulting relevant information, I found that the main difference is whether the digital elevation model is added. Because orthorectification is a kind of geometric correction, it corrects the image of pixel displacement caused by terrain fluctuations and sensor errors, and requires elevation points or DEM. At the same time, I realized the importance of remote sensing image correction, because without the correction process, the subsequent processing and analysis would be completely futile, and it is not an exaggeration to say that it is the cornerstone of the remote sensing field. Therefore, a calibrated image is one of the most important requirements for remote sensing image processing and analysis. However, in the face of correction, there are many methods to choose. Selecting an appropriate correction model combined with image features and performing appropriate parameter adjustments also need to be considered when we deal with the problem.

3.4 Reference

Zhuo Kong, Haitao Yang, Fengjie Zheng(2022). Research progress on atmospheric correction of hyperspectral remote sensing images. Remote sensing of natural resources,2022,34(4):1-10. DOI:10.6046/zrzyyg.2021371.

YuanYuan Pan, Changchun Li(2018). Atmospheric correction method and correction effect of Sentinel-2A satellite. Information of Remote Sensing,2018,33(5):41-48. DOI:10.3969/j.issn.1000-3177.2018.05.007.

4 Policy

4.1 Summary

The urban heat island effect means that the overall or partial temperature of an urban area is higher than that of the surrounding area. The urban area with a higher temperature is surrounded or partially surrounded by suburbs with a lower temperature, just like an island protruding from the sea. Since this type of island represents a high-temperature urban area, that's why it's called the urban heat island effect. Wuhan, the largest city in central China, is located in the northern subtropical zone, with the Yangtze River and Han River running through it. Like other large cities in China, Wuhan has experienced rapid development and urbanization over the past few decades. The city's temperature changes are well represented in the central region of China. The latest research shows that the intensity of Wuhan's "urban heat island" has accelerated in recent years. According to recent data, the urban heat island effect has made the average temperature in central Wuhan 1.8-2.0°C higher than that in distant urban areas. In summer, the temperature in some parts of the central urban area is sometimes even 5.9°C higher than that in distant urban areas. In response to this situation, Wuhan has formulated a series of policies to reduce the impact of the urban heat island effect. One of them is the "Wuhan Lake Protection Regulations", which elaborated on the protection methods of lakes and set severe punishment standards for behaviors that destroy lake ecology.

4.2 Application

In order to better protect the lake ecology of Wuhan and punish those with behaviors that destroy the ecology, we can use some methods to monitor which lakes are shrinking in size, and then go to the field to investigate the causes of lake destruction. There are many data source for us to choose from, including Landsat MSS, ETM+, TM, Landsat 8, GF1-WFV, GF6-WFV and other multi-source satellite image data (Jianwei Ma, 2017).

Remote sensing data processing method: using remote sensing processing software to perform geometric correction, georeferencing and other preprocessing on Landsat series and GF series satellite data; then combining different bands of images to obtain Wuhan Normalized Difference Water Index (NDWI), which is calculated as follows:

$$NDWI = \frac{\rho_{\mathrm{Green}} - \rho_{\mathrm{NIR}}}{\rho_{\mathrm{Green}} + \rho_{\mathrm{NIR}}}$$

Figure 4.1: NDWI calculating formula

Then Convert the result raster images into vector graphics, calculate the lake water area in different years, and establish a spatial database of lakes in Wuhan. The proposed results are as follows:

when we get outputs like this, we can pay much attention to those lakes shrinking fast to corrospond to the action of protecting the lake of Wuhan. By doing this, city can acquire better absorting-heat ablity and Ultimately, it is benifitial to the decrease of UHI.

4.3 Refelection

At the policy level, although ensuring the integrity of the lake can meet the mitigation needs of urban heat island, population growth and urbanization will conflict with it. The process of urban development and expansion will definitely affect the ecology of the lake. In this process, increased competition for land from humans and waters is an urgent concern for authorities. In terms of research methods, when the research area is large, the single threshold method is often not effective in extracting small water bodies. And the post-processing workload is heavy because the pixel-based water body extraction is prone to “salt and pepper” phenomenon and the extracted patterns are too fragmented. Therefore, it may be considered to use the object-oriented segmentation of water body extraction algorithm to perform multi-scale segmentation of the image, since it fully considers the characteristics of the spectrum and shape of the ground objects, and it can divide the entire image into numerous homogeneous patches, which can effectively avoid the “salt and pepper phenomenon”. Ultimately, the extraction result is more complete, and the extraction of small water bodies is more effective.

4.4 Reference

Jianwei Ma, Shifeng Huang, Zongnan Xu. Satellite remote sensing of lake area in Wuhan from 1973 to 2015. Journal of Hydraulic Engineering,2017,48(8):903-913. DOI:10.13243/j.cnki.slxb.20170097.

Figure 4.2: Distribution of water area across years

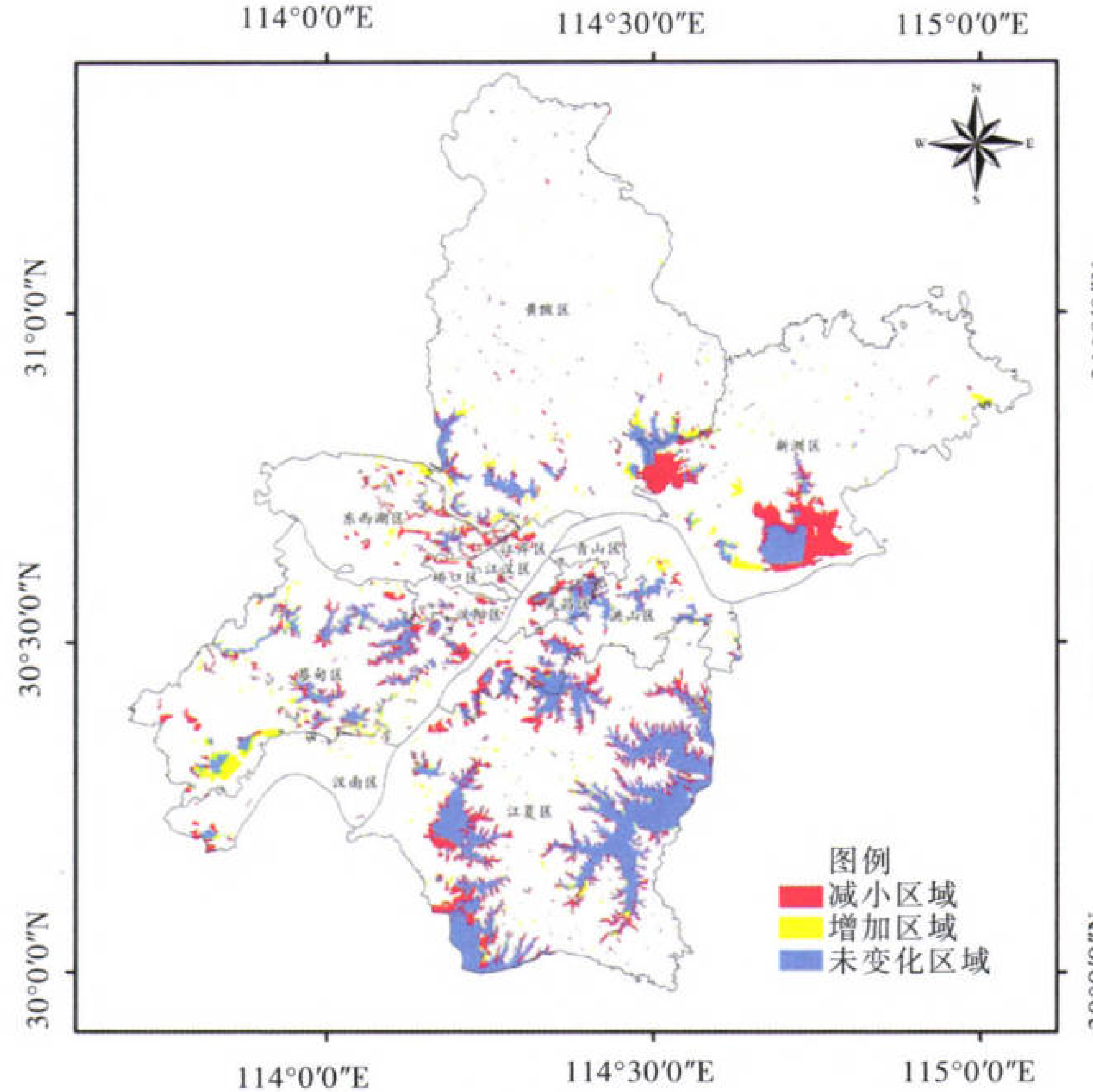


Figure 4.3: Change of distribution of water area in Wuhan. Red legend means diappearing area, yeallow means increased area and blue means non-changed

5 An introduction to Google Earth Engine