Research on the relationship between the thermal characteristics and the type of land cover in Beijing urban area by ASTER data

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Abstract: The study utilizes remote sensing as the main monitoring means. With different spatial high-resolution, multichannel ASTER remote sensing image as the main information in Beijing city zone; with regional border and statistical data as auxiliary factor a study between the thermal space distribution character and the underground medium is analyzed based on the GIS logical algorithm and synthetic analysis technology. Results show thermal forming mechanism and the rule of distribution is mainly related to the underground medium and the change of the city distribution. Different underground medium has different degree and intensity influence on the thermal space distribution. Furthermore, urban greenbelt and water areas can reduce the thermal effect and large-scale greenbelt creates green island effect. In addition, Road net, residential area, population density, heat resources and so on have some positive effect on the thermal distribution, which increase the local temperature and intensity on the other hand. It is important to study the thermal distribution and its related factors, which contributes to the plan, construction and development of the city.

Keywords: thermal infrared, remote sensing, urban heat island.

1. Introduction

Urban thermal environment has been paid great attentions since British chemist Lake Howard advanced the concept of "urban heat island" in 1833 to describe the phenomenon of temperature in London downtown is higher than suburb[1]. Hereafter, a lot of studies on urban thermal environment have been developed in china and abroad. In recent years, the city heat environment is regarded as a predominant factor to affect the city environment under the background of global warm and urbanization[2]. Sund-borg, Duckworth, Landberg, Jones et al. think that urban heat effect in summer is relevant to urban scale. Japanese scholars show that relationship between urban heat environment and building density is approximately linear. Avissar, Shashua-Bar(1996) and some other scientists also use experience models to analyze and predict the potential influence of urban greenbelt on thermal environment from different viewpoint. There are also some domestic studies on the spatial distribution of urban heat field. Liu Xiaotu et al. analyzed the variation trend of heat field distribution caused by regional characters on the basis of thirty-year data of five counties in south of Jiangsu Province, China. In a word, the study of urban heat field distribution is becoming a hot spot.

Remote sensing is a good information source for the study of urban thermal field. Scientists are applying thermal infrared remote sensing data to study urban thermal field in different ways. In 1997, NASA and EPA launched the urban heat island pilot joint project together, which using remote sensing techniques and field observations to develop the thermal environment study and harness in Los Angeles, Chicago, etc. In 1998, Quattrochi et al. studied the effect of different greenbelt on alleviating city heat effects applying high resolution thermal infrared aerial photos[3].

However, most of the current studies only focused on large scale, i.e., analyzing heat island effect between suburb and urban area. The relationship between heat field distribution and urban land cover is paid little attention. Furthermore, the data sources and study methods used in these studies are also limited.

In this paper, multi-channel, high resolution ASTER images are chosen as a main data source.Under the support of image processing and GIS spatial analyzation techniques, we first produce land classification from ASTER visible and near infrared bands, and retrieve land surface temperature from its thermal infrared bands, then these two products are interpolated and overlaid to study their relationship.

2. Method

1) Temperature and Emissivity separation algorithm

In thermal infrared bands, two parameters, emissivity and temperature, are needed to describe the status of land surface thermal radiation. Therefore for N thermal infrared channels, N observation values are used to estimate N+1 unknown parameters. That is to say, we still need to construct the N+1th equation under some assumption, and then acquire surface temperature and emissivity of the target by solving an equation set. For thermal infrared remote sensing, the separation of temperature and emissivity is a key problem.

According to Planck function and Wien's law, we use TES algorithm(Temperature/Emissivity Seperation) to separate temperature and emissivity[4]. The TES algorithm combines attractive features of three precursors, NEM(Normalized Emission Method), RAT(Ratio Algorithm) and MMD(Min-Max Difference) and with some new features. It is most closely related to the Mean-MMD method. Essentially, TES uses the NEM algorithm to estimate T, from which emissivities are estimated and ratioed to their mean, producing â values. The â spectrum preserves the shape, but not the amplitude, of the actual emissivities. To recover the amplitude, hence, a refined estimate of the temperature, the MMD is calculated and used to predict the minimum emissivity. Basic design of the algorithm is illustrated in Fig. 1.

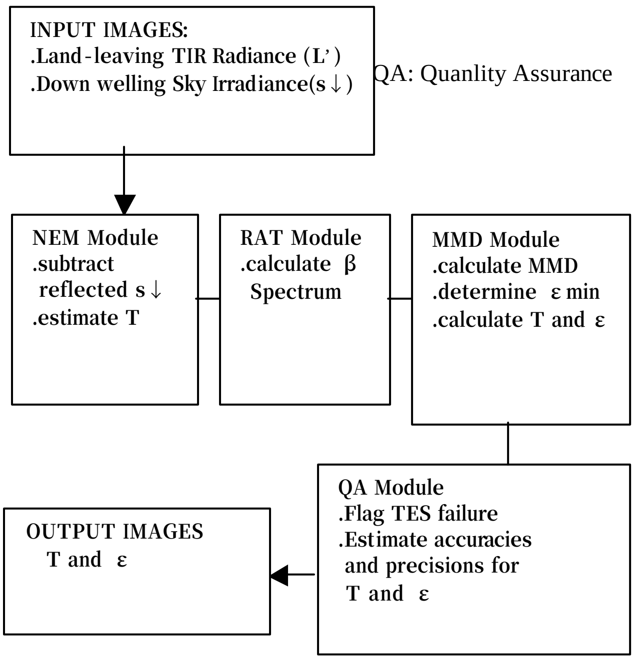

Fig. 1. Basic design of TES algorithm

Studies show that NEM algorithm is very sensible to the initial assumed value for max. When max varied between 0.9 and 1.0, the variation range of inverted temperature is ±4K, and the average variation amplitude of emissivity spectra is 0.06, whereas the temperature variation is only ±0.5K for TES, and emissivity almost leave unchanged. In this experiment, the iteration number for atmosphere download radiation removing process is set to 12, and ratio between atmosphere download radiation and surface radiation is 0.1-0.2. In our works, last temperature and emissivity precisions are 1.0-1.5K and 0.010-0.015 respectively. The result is comparable with Gillespie's, which is ±1.5K for temperature and 0.015 for emissivity.

2) Hierarchical mask classification method

Because the surface spectral features are very complicate in a city. It's difficult to discriminate all types by routine classification method. In this paper, we first processed and analyzed ASTER visible and near infrared data, and try to discriminate and classify city targets according to their spectral response feature. Then, the hierarchical mask classification method and layer combination technique are used to separate different types step by step.

The hierarchical mask classification method sequentially extracts information from easy to difficult. Known ground information is introduced during this process. For multi spectral or high spectral classification, regions of interest(ROI) representing different ground types are first found from the image according to field survey. Then, digital features of selected ROIs are evaluated and aiming at different spectral features, different methods are used to extract ground types step by step. At last, class combination technique is applied to get the total classification map. During the classification process, a mask image of subclasses is produced in each step, and the offspring step only process subclass pixels prescribed by the mask image. The process is repeated until all types have been separated successfully. This method is easy to perform. We can discriminate specific spectral difference, while not considering other obvious spectral features which have been separated before.

3. Data and result

A scene of ASTER 1 B image in Beijing is used in our study, which is acquired on June 4th, 2001. Its resolution is 15m in V-NIR bands and 90m in TIR bands. The three V-NIR bands are used for classification and five TIR bands for temperature and emissivity recovery. An elaborate geometry correction is performed using GCPs and Modtran model are applied for initial atmosphere correction.The recovered temperature in Beijing city using TES algorithm is illustrated in Fig. 2.

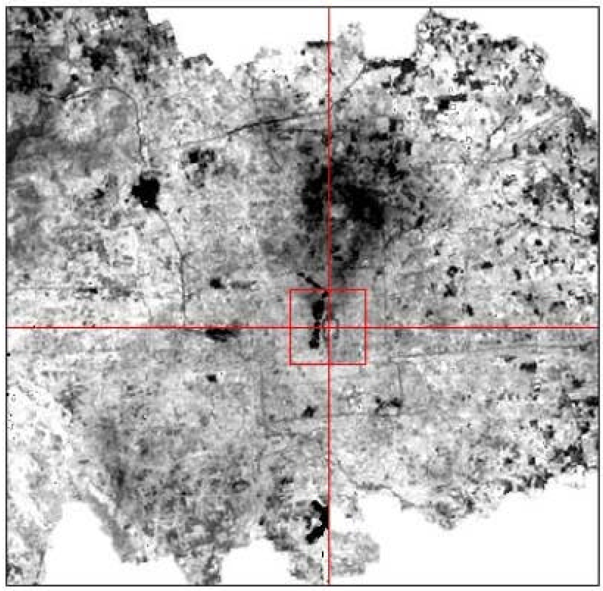

Fig. 2. The land surface temperature distribution of BeiJing

The temperature and land cover data which are synchronistically acquired by remote sensing are helpful to study the relationship between surface thermal field distribution and land cover. Therefore, we can use two perpendicular sections which pass the city center to study the relationship between temperature variation and land cover (Fig.3, Fig.4) . Crown cover fractions in these figures are statistical values of local windows.

From temperature sections and corresponding surface feature, we can see that high temperature regions often connected with density buildings, while low temperature regions often correspond with water body and vegetation. Therefore, to low the city heat island effect down, we must increase waterbody and urban greenbelt area, and control distribution pattern of architecture.

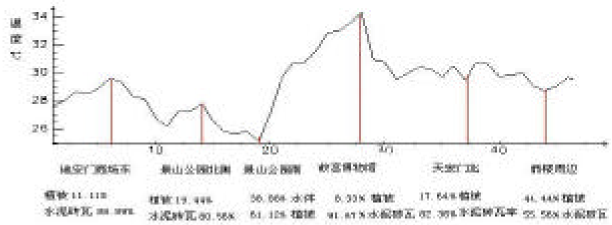

Fig.3. Partial temperature section in N-S direction of Beijing city center

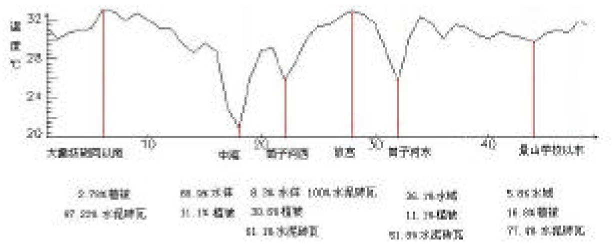

Fig.4. Partial temperature section in W-E direction of Beijing city center

4.Conclutions

Our study shows that Multi-channel, high resolution ASTER data can be effectively applied to study the quantitative relation between city thermal field distribution and land cover. If atmosphere influence can be effectively removed by Modtran 4.0, the temperature and emissivity recovered by ASTER TES algorithm is reasonable and reliable.

Our study also indicates that city thermal environment greatly lies on underground types and their distribution, so, to alleviate city heat island effect, effective measures can include increasing waterbodies and urban greenbelt area, arranging city buildings' allocation reasonably, etc.

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