Application of airborne LiDAR and thermal Infrared technologies for the assessment of human biometeorological conditions in urban areas

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Abstract

The rising global temperature contributes to a strong impact on urban thermal environment and outdoor thermal comfort. Although the existing satellite telemetry methods are convenient to display geographical information. The detail distributions of 3-dimentional radiation properties of the complex urban environment cannot be estimated accurately due to the low resolution and lack of vertical information. Hence, satellite telemetry methods cannot provide enough information concerning biometeorology conditions in urban areas. This research applies an innovative method to observe urban thermal environment by coupled airborne LiDAR and thermal Infrared (TIR) technique combined with synchronous climate measurement in ground level. Banqiao District of New Taipei City, one of the highest developed areas in Taiwan, is selected for the survey area. By combining the airborne LiDAR with thermal image sensors and surface measurements through GPS positioning system, the mean radiant temperature (Tmrt), estimated by various approaches, can be calculated and compared. The results indicated that Tmrt estimated by the LiDAR and TIR are highly in accordance with the value measured in the ground level. Furthermore, the Tmrt and Physiologically Equivalent Temperature (PET) are calculated and displayed as a distribution map. The hotspot of the survey area, which comprised high density building and high amount of anthropogenic heat, can be identified through the map. The analytical result reveal that the use of coupled LiDAR and TIR technology approach will be contributed to understand the urban human biometeorological conditions quickly and accurately.

KET WORD：human biometeorology, LiDAR, thermal Infrared, Physiologically Equivalent Temperature

1. Introduction

LiDAR(light detection and ranging) is a remote sensing technology. By the different laser reflection time, the distance and surface observation can be calculated. The elevation and location of surface points could be identify

clearly positioning by GPS. In terms of the advantage that it can measure the distance by laser in high accuracy rapidly, and observe the surface (DEM) and ground objects (DSM) simultaneously. In the past, airborne LiDAR has been widely used in observing land used changes of a large area, disaster prevention, and terrain exploration. In recent years, the LiDAR technology has become international trends in telemetry observation due to the high resolution.

Airborne thermal image is a surface temperature measured method that could be executing in a wide area it can recorded the thermal infrared information of surface objects, including temperature and thermal inertia. The thermal image is often used to retrieval surface temperature, urban heat island and geothermal exploration. Therefore it is an innovative method to combine both technologies in the assessment of human bio-meteorological with the urban development and surface temperature information.

2. Method

2.1 Study area

Banqiao district (25.0096703°N 121.4590989°E) is the major population and business canter of New Taipei City. The population of the district is about 556,000. And the total area is 23.14 km². The lowest average annual temperature is in January: 15.2 ℃. The highest average annual temperature is in July: 28.3 ℃.Most of the terrain of the district is plain and surrounded by river. River basin area is up to 686 ha. The population density is 24,027 people per square kilometers. (2015.1)

In this research, an area with 1.6 kilometer length and 2.5 kilometer width in Banqiao district was selected to take thermal images, including multiple land use, such as the train station, MRT, the municipal government, shopping center, playground, park, etc. And a 500m*500m area around the Banqiao station was selected as a demonstration area due to the importance of the site.
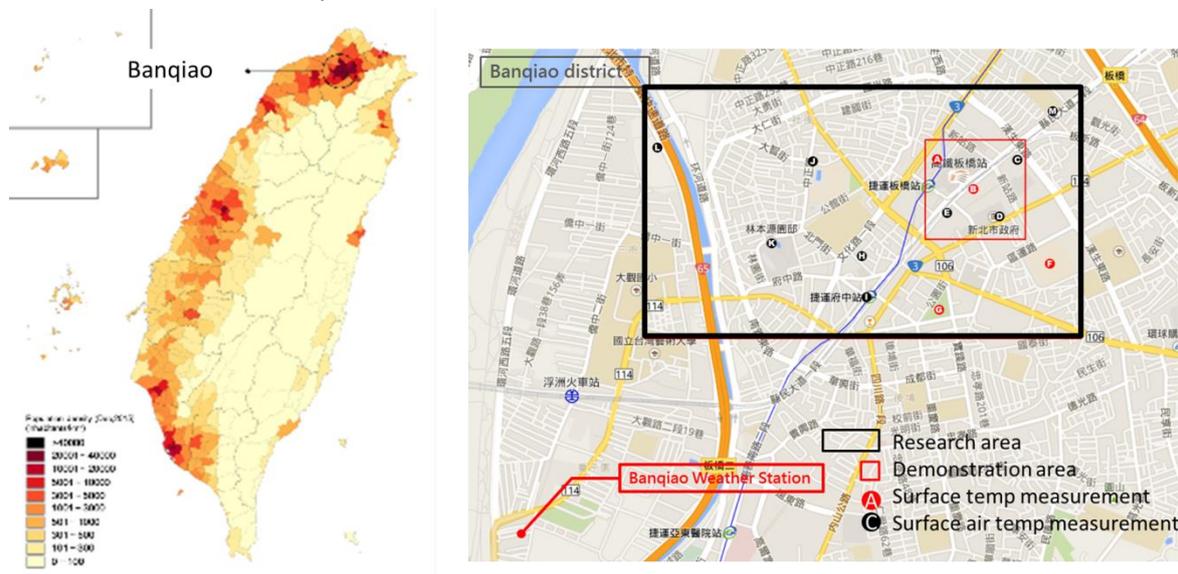

Figure.1 Location of study area and

2.2 Airborne LiDAR and thermal image

Airborne LiDAR sensor was used to create a DSM (Digital Surface Model) in high resolution 1m*1m per pixel with scanning image technique, so that the building heights, building area, form of planting, and tree crown can be obtained. The range of the DSM is between 227.16 and -7.97 in Banqiao, as shown in Figure 2. The resolution of thermal images is 0.5m*0.5m per pixel and with accuracy of 0.05 degrees. The range of the values of thermal images is 66.64 and 17.80.
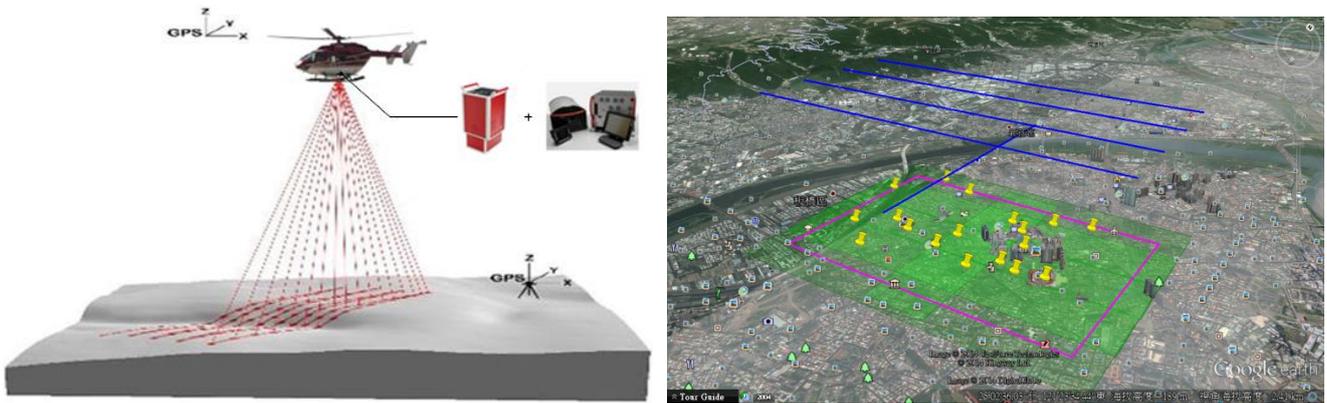
Figure.2 Airborne measurement and route

2.3 Surface measurement

There are 13 measurement points in different land use and land cover in the study area. The data were collected for running the analysis of correlation to correct the surface temperature by airborne thermal images. Measurement data included air temperature; relative humidity, globe temperature, surface temperature and fish eye camera. Points are equipped with the same instrument to the tripod fixed to the ground, measured with 1M height. The wind speed and solar radiation are also observed by the Banqiao weather station near the study area
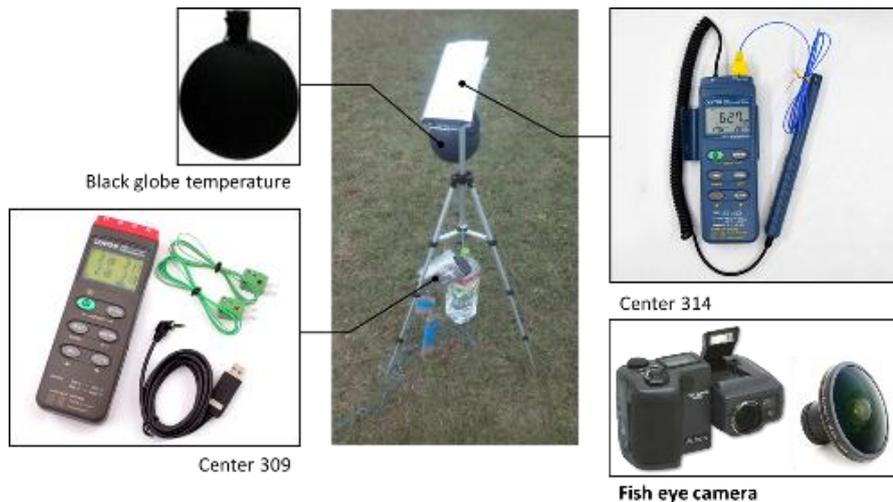

Figure.3 Equipment of surface measurement

2.4 Estimating Method

This research is mainly discussed about the method using airborne LiDAR DSM and thermal images, with information about the surfaces temperature, to estimate the Tmrt. Through a combination of different methods data processing, six different methods were used to estimate Tmrt by the weather forecasting software such as RayMan and SkyHelios in this research. Take the second method as standard, comparing the accuracy with other methods in order to demonstrate the feasibility of the application in the future. First, the measured data includes air temperature, land surface temperature, radiation temperature, relative humidity, and surface temperature. Second, weather station data includes air temperature, and global solar radiation. Third, data from the airborne LiDAR sensors: DSM. Forth, data about sky view factors: fish eye photo, SVF from LiDAR DSM, SVF from model shape file. This research applies six different methods to estimate the Tmrt. As follows:
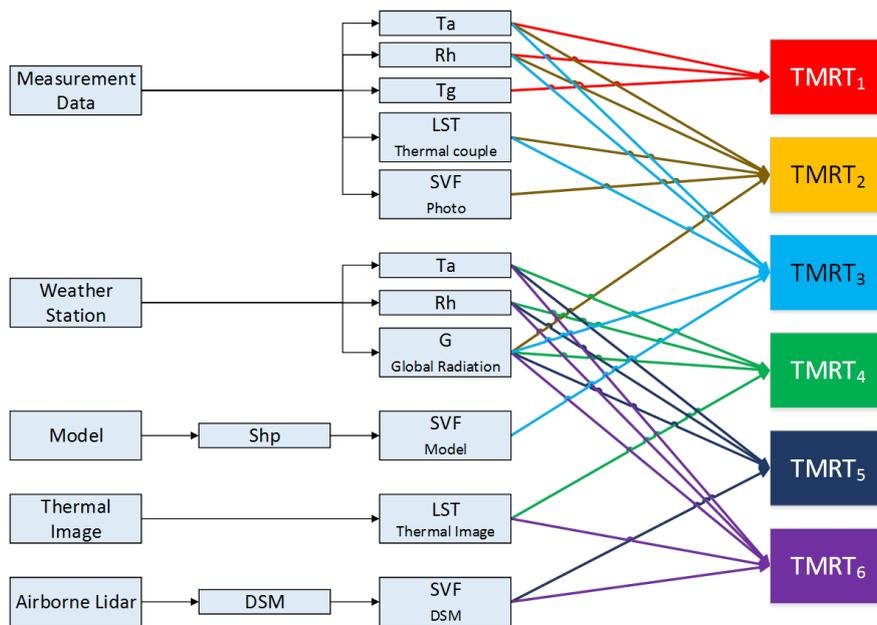
Figure.4 Six Research estimate methods

3. Result

3.1 DSM and surface temperature information in Banqiao

By combining the DSM and surface temperature with the three-dimensional image, the distribution of temperature is obtained. It is obviously that the hot spots are easily detected in high-density building area, pavement that with lower albedo and the open area which absorb a lot amount of radiation such as commercial district and asphalt road. The parks and other green areas show relatively lower temperature because of the shading factor and high pervious surface.
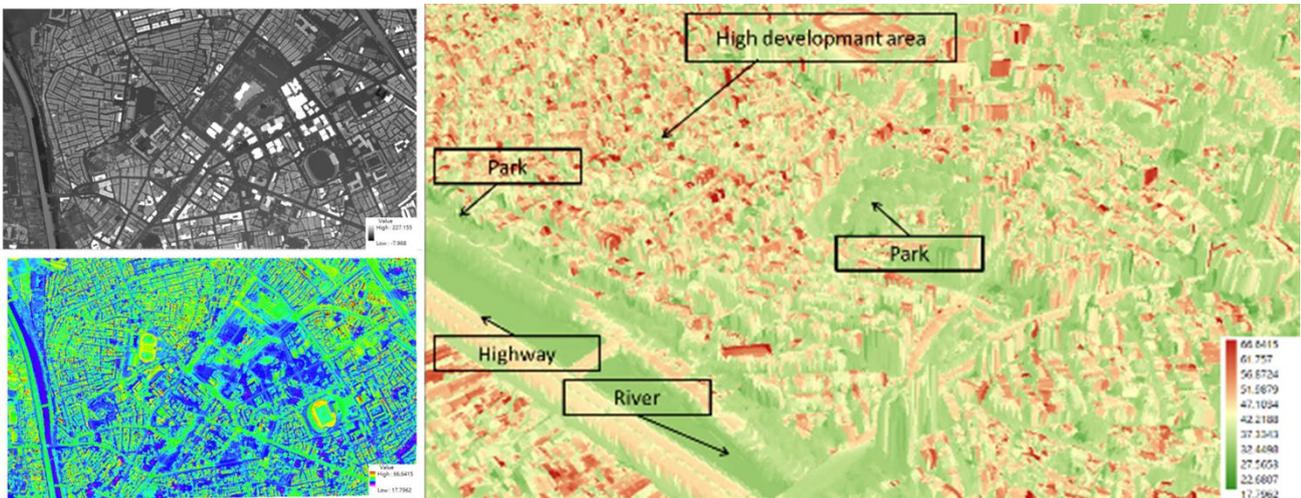

Figure.5 DSM and surface temperature layer and combine image

3.2 Sky view factor distribution

In order to understand the characteristics of high development area, the LiDAR DSM information is used to create thematic layers such as SVF (sky view factor). Which refers to how much sky is shaded by trees or buildings, meaning the proportion of the open area of sky above an area to the overall visual area, in order to evaluate outdoor thermal stress. The results of SVF distribution show that the SVF is higher in surrounding park or tall buildings.
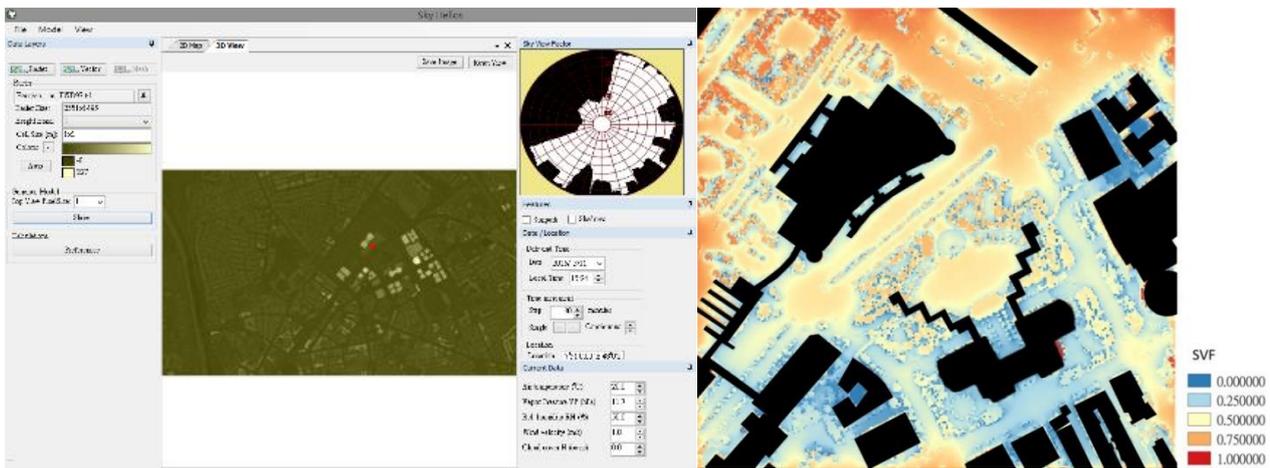
Figure.6 Sky view factor distribution

3.3 Surface temperature correction result

Previous research, the shadow is not as a factor to calibrate the temperature in calculates process. In this study, the DSM files and local geography data like coordinates are import into simulation software to simulate the shadow position at the aerial photograph time. Therefore the surface temperature correction method is conduct in two ways depends on the point is shaded or not, because the shading effect will strongly affect the Tmrt, and the result shows shadow could cool down the land surface very significantly.
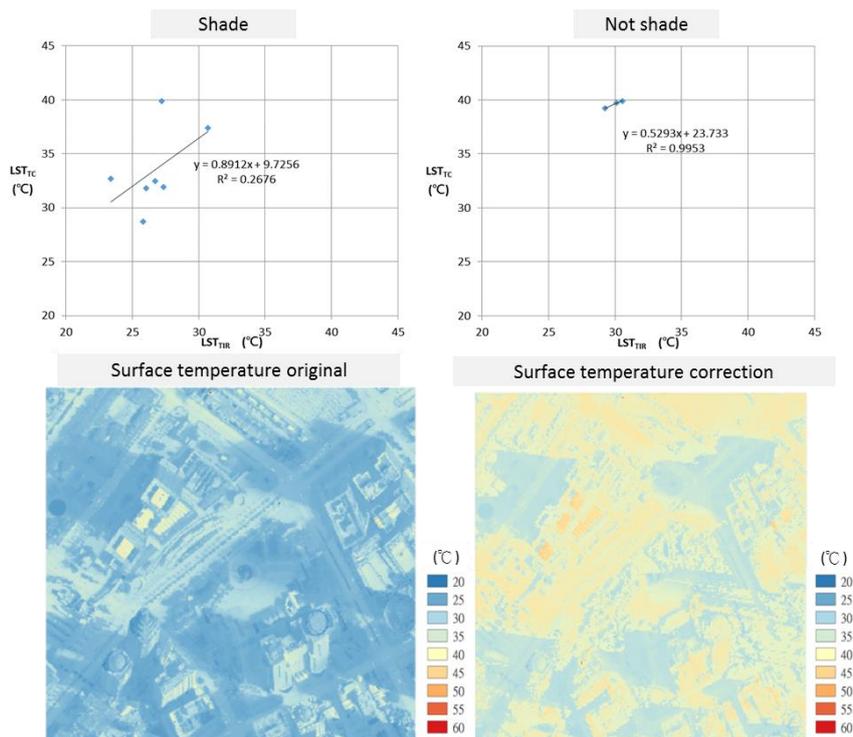

Figure.7 Two correction equation and the calibration results

3.4 Correlation results

The 4, 5, 6 method is using the LiDAR and thermal image sensors. Comparison of six types of Tmrt estimate method results, the result of the method 6 which combined the airborne LiDAR DSM information and thermal images, is more accurate, as shown in Figure 8. The impact of Tmrt between the radiation and shading is significant. As follows:
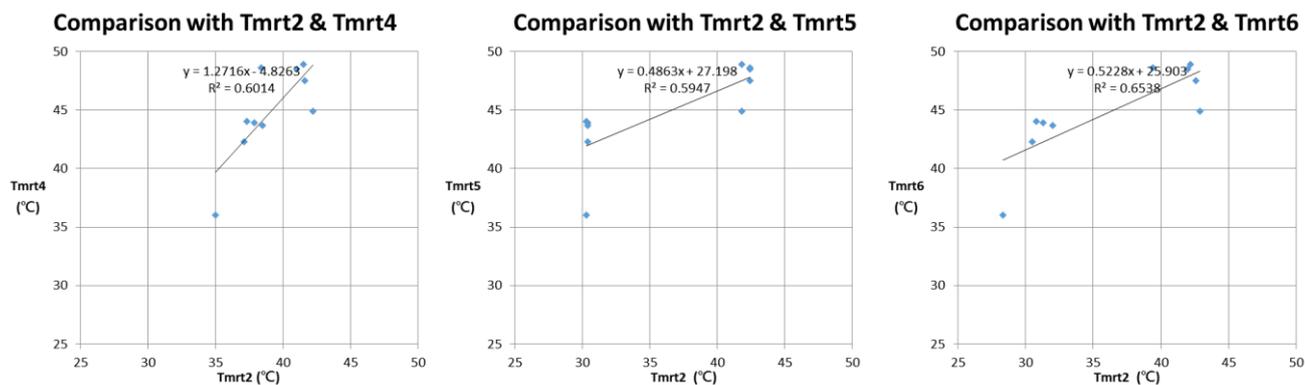
Figure.8 Correlation results of method4, 5, and 6

3.5 Estimate methods result

After the correction of the thermal images, the result of method 4, 5, 6 can be conducted. The influence of land surface temperature is not obvious using method 4, as shown in figure 9 because of the lack of considering with shading effect. Therefore the difference of the temperature in method 4 is not obviously. The impact of the shadow is apparent in method 5. The difference of the Tmrt between the shading areas and non-shading areas is more obviously. In the shading areas the Tmre are lower and in the non-shading areas the Tmrt are higher. In method 6, owing to the method is considered of the shading and surface temperature factors. The Tmrt distribution trend is more close to the measured value.
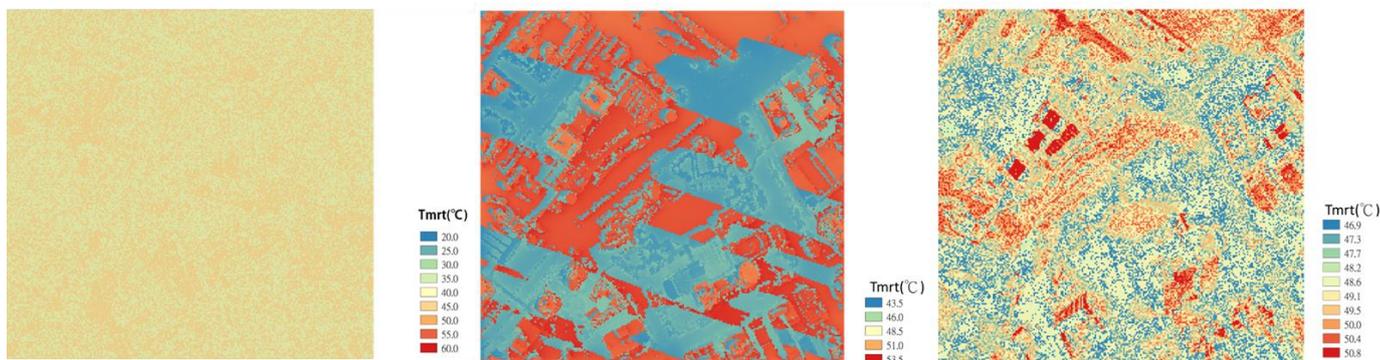

Figure.9 Estimate results of method4, 5, and 6

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