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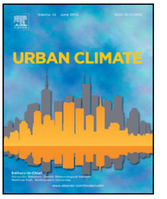

Study of mobile measurements for detailed temperature distribution in a high-density urban area in Tokyo

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Due to the low spatial resolution of measurements from meteorological observation stations, it is difficult to observe urban environmental parameters at a scale relevant to people's daily lives. Mobile measurements can be an effective method of investigating the distribution of environmental conditions in urban areas. However, the effectiveness of mobile measurements is unclear as it is difficult to obtain accurate positioning data for each sample due to Global Positioning System (GPS) errors that may be >20 m in urban areas. We conducted a mobile measurement study during August 25th to 28th, 2015, in Shinjuku, Tokyo, one of the most crowded areas in Japan, to investigate the spatial distribution of air temperature and the range of GPS errors. We equipped bicycles with thermometers and high temporal resolution GPS loggers to measure air temperature and spatial position. The results demonstrated that the range of air temperature variation was almost 2 °C on cloudy days, and that the spatial distribution of air temperature differed for different measurement routes. A spatial resolution in the order of 10^1 m was required to detect locations where the air temperature was locally high, such as near street intersections.

1. Introduction

In recent years, urban environmental issues related to heat and aerial pollutants have become increasingly serious. In Japan, atmospheric properties such as air temperature, wind velocity, and pollutant concentrations are typically measured at meteorological observation stations with a station network spatial resolution of several kilometers. However, heat or atmospheric pollution can have adverse effects on the human body and affect

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people's daily lives at the sub-kilometer scale in urban areas. To overcome this situation, we developed an observation system measuring atmospheric properties continuously at the scale relevant to people's daily lives.

The increasing use of smartphones has led to reduced cost of measurements using these devices. The development of information and communication technology allows for the collection, management, and use of a great variety of data previously unavailable. We presumed it was possible that atmospheric properties could be acquired not only from meteorological observation stations, but also with various types of devices, especially for urban areas (Nuria et al., 2015). However, it is often difficult to unify measurement methods and conditions when using various types of measuring devices.

To overcome this problem, we are focusing on mobile measurement methods, which can be an effective method for addressing insufficient measurement points in urban areas. There are several advantages associated with using mobile measurements. Firstly, we can conduct an observation at any location and over a wide spatial range with one mobile sensor. Secondly, it is possible to reduce the cost related to installing additional observation stations. Finally, by using mobile measurements, we can observe atmospheric properties at a high spatial resolution.

Mobile measurements have been collected using a bicycle in previous studies. For example, Shigeta et al. (2014) observed a cool-island phenomenon around a large green space in Okayama, Japan based on mobile measurements. In a study conducted by the Center for Environmental Science in Saitama (2008), a cool-island phenomenon was observed around a paddy field in Saitama, Japan. Klok et al. (2014) utilized a bus to monitor air temperature, relative humidity, and solar radiation at various locations without incurring the costs of establishing additional measurement stations. There are additional studies that have investigated the spatial distribution of atmospheric properties.

There are two main problems with mobile measurements: (1) obtaining accurate positional data is essential during sampling. However, because building surfaces reflect carrier waves, Global Positioning System (GPS) data collected in urban areas tends to have a large degree of error. (2) There is relatively little published data and discussion regarding mobile measurements methods, such as the sensor lag (Kathrin et al., 2015), and the uncertainties associated with mobile measurements.

In this study, we investigated the range of GPS errors and the spatial distribution of air temperature using mobile measurements in a high-density urban area. This paper presents the results of the mobile measurements carried out in Tokyo during August 25th to 28th, 2015. We also discuss the applicability of mobile measurements to a high-density urban area and the uncertainties associated with reducing the number of samples by using mobile measurements.

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2. Experimental methods

2.1. Instrument specifications

The specifications of the measurement instruments are summarized in Table 1. Fig. 1 depicts the mobile measurement platform used in this study. The concept for the platform was initially described in a document by the Japanese Ministry of the Environment (Ministry of the Environment, 2012). We equipped the bicycles with two platinum resistance thermometers, a temperature logger, and a GPS logger. We used a ventilation shelter and a forced ventilation pipe as shading devices to analyze how different shading devices influenced the data. Additionally, the bicycle was outfitted with a cycle computer to confirm travelling speed, and a time-lapse camera to record experimental conditions. The range of GPS errors differed based on the GPS brand/type. The GPS logger had a measurement accuracy of 2D-RMS 3.0 m (95%). Even though we did not investigate a machine-dependency of GPS errors, the measurement accuracy of our equipment was relatively high compared to current commercial GPS loggers. We installed a GPS logger at a fixed measurement point to observe the measurement accuracy of our equipment. The GPS error analysis is described in Section 4.2.

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