# MONITORING METHOD OF SPATIAL THERMAL DISTRIBUTION FOR WINTER ROAD MAINTENANCE USING INFRARED THERMOGRAPHY

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**Abstract**

In this study, we evaluated the properties of a road surface in winter, using techniques that previous studies in the field of road pavement have shown to be effective. Specifically, we used infrared (IR) thermography to extract information about the temperature distribution on the road surface, and converted the information obtained from the thermal images into a cross-sectional thermal profile. We used general two-dimensional system to obtain the winter temperature distribution of the road surface in this study. However, owing to specular reflection, the data obtained from these temperatures did not accurately reflect the road surface particle size. Nevertheless, we considered using this property in reverse to analyze the unique properties of winter road surfaces and observe their changes over time. Additionally, in previous investigations of winter road surfaces, a fixed observation point was established and the measurements were taken within a limited range. However, we used thermography to obtain a cross-sectional thermal profile, which, among other advantages, allowed for the analysis of the surrounding frozen environment. Previous studies in the field of road pavement have shown this technique to be effective for evaluating the properties of road surfaces.

## 1. INTRODUCTION

In this study, we evaluated the properties of a road surface in winter, using techniques that previous studies in the field of road pavement have shown to be effective. Specifically, we used infrared (IR) thermography to extract information about the temperature distribution on the road surface, and converted the information obtained from the thermal images into a cross-sectional thermal profile. This made it possible to use methods of numeric analysis (e.g., digital and wavelet filters) to evaluate the properties of the road surface, and also use techniques of statistical analysis to monitor the changes over time.

Previous studies on snow and winter phenomena have used IR light to measure the particle size and specific surface area of piled snow [1] [2]. Other studies have used thermography to explain the formation of water channels and ice plates with snow temperature distributions that cannot be explained in a one-dimensional system [3].

In contrast, we used a very general two-dimensional system to obtain the winter temperature distribution of the road surface in this study. However, owing to specular reflection, the data obtained from these temperatures did not accurately reflect the road surface particle size. Nevertheless, we considered using this property in reverse to analyze the unique properties of winter road surfaces and observe their changes over time. Additionally, in previous investigations of winter road surfaces, a fixed observation point was established and the measurements were taken within a limited range. However, we used thermography to obtain a cross-sectional thermal profile, which, among other advantages, allowed for the analysis of the surrounding frozen environment. Previous studies in the field of road pavement have shown this technique to be effective for evaluating the properties of road surfaces. Moreover, the technique is effective for monitoring road surfaces in winter when the conditions can change over a short period depending on the weather and environmental factors. Figure 1 shows the concept of the study.

## 2. THERMOGRAPHY AND ROAD SURFACE MANAGEMENT

A thermograph is a device for measuring the surface temperature of an object based on the intensity of the IR light sensed in the captured area. It presents the calculated temperature in a visual format.

Because a thermograph can be used for the continuous capture and evaluation of thermal images without making contact with the object, it is effective for use over a wide area. Two variables—the temperature and emissivity of the object surface—are used in the calculation, and these values must be appropriately configured. In particular, it is known that factors such as atmospheric temperature, solar radiation, the distance from the object to be measured, and its surface texture affect the values of these properties. Furthermore, because significant temperature difference between the defective and sound portions of a thermal image is required for thermographic inspection, its application to snow and winter phenomena requires contrast between the undisturbed and characteristic portions.

There have been several reports on the application of thermography to normal road pavements. For example, Reference 4 discusses its application to asphalt cracks and automated data collection [4]. Reference 5 discusses its application to the detection of delamination of airport pavement [5]. However, few studies have directly used it to examine the horizontal winter temperature distribution of road surfaces.

Figures 2–4 show the appearance of various winter road surfaces obtained by thermography. Figure 2 shows an intersection where a road heater has been installed. The high temperature of the pavement immediately above the heating pipe can be observed. Figure 3 compares the interior and exterior of a tunnel along a snow-covered road. The high temperature of the tunnel wall can be observed. Figure 4 shows the two sides of a railroad crossing. The temperature difference between the portions of the road before and after the tracks can be observed.

## 3. EXPERIMENTAL CONDITIONS

The measurements of this study were taken along a sloping road in Kitami City, Hokkaido, Japan between January 5 and 6, 2013. The road was 6 m wide and 50 m long. We used a portable IR thermograph (FLIR E40) with a measurement wavelength of 7.5–13 μm, component count of 160 × 120 pixels, and temperature resolution of 0.07°C (for a 30°C black body).

Figure 5 shows the weather conditions (temperature and snowfall) at the time of taking the thermal images. At the point “a,” which corresponds to 7 PM (local time) on Jan 5, there had been no snowfall for some time earlier and the area above the tire tracks had frozen. Immediately before point “b,” which corresponds to 10 AM on Jan 6, there had been 3 cm of snowfall and the road was covered with fresh snow, although some parts had been compacted by passing vehicles. The thermal images were taken at the two foregoing times using an emissivity of 0.95.

## 4. EXPERIMENTAL RESULTS AND DISCUSSION

Information about the temperature distribution was extracted from the thermal images. The results of the conversion of the temperature distributions to contours and longitudinal and transverse thermal profiles are shown in Figure 6. The white frame in the figure indicates the part that was analyzed in this study. In Figure 6(a), the temperature of the portions with the frozen tire tracks was lower than that of the peripheral areas, and a large difference between the longitudinal and transverse thermal profiles can be observed. In Figure 6(b), however, the snowfall reduced the difference between the road surface temperatures. Consequently, even in areas where local temperature differences were observed in Figure 6(a), the temperature change in the analyzed area was low.

As the foregoing reveals, the conversion of the thermal images into thermal profiles enables an understanding of the characteristics of local temperature changes. Figure 7 shows the results of the digital signal processing of the longitudinal and transverse thermal profiles. For example, when a low pass filter was applied and a long-wave component was detected, the areas where local temperature differences occurred could be easily identified.

This type of data, when compiled at regular intervals and combined with meteorological data, can be used to determine and monitor areas that freeze easily and are characterized by rapid temperature changes. This information might be effectively used in technology for preventing road disasters.

The relationship between the weather conditions on the frozen slope and the thermal profile data obtained from this study are shown in Figure 8. It can be seen that there was an obvious temperature difference between the frozen and un-frozen parts when the first image was taken (a), and that the temperature difference was less in the image taken after the snowfall (b). In other words, the portions with the frozen tire tracks were more susceptible to rapid temperature changes, and their temperature difference tended to be greater than those of the other areas.

## 5. SUMMARY

Although the data acquired during this study was limited because of the short period, the results suggest that thermography is effective for local monitoring of road surfaces in winter. Because the conversion of the thermal images to longitudinal and transverse thermal profiles enables an analysis similar to those of techniques that previous studies in the field of road pavement have shown to be effective for evaluating the properties of road surfaces, it may also enable new discoveries from previously captured data.

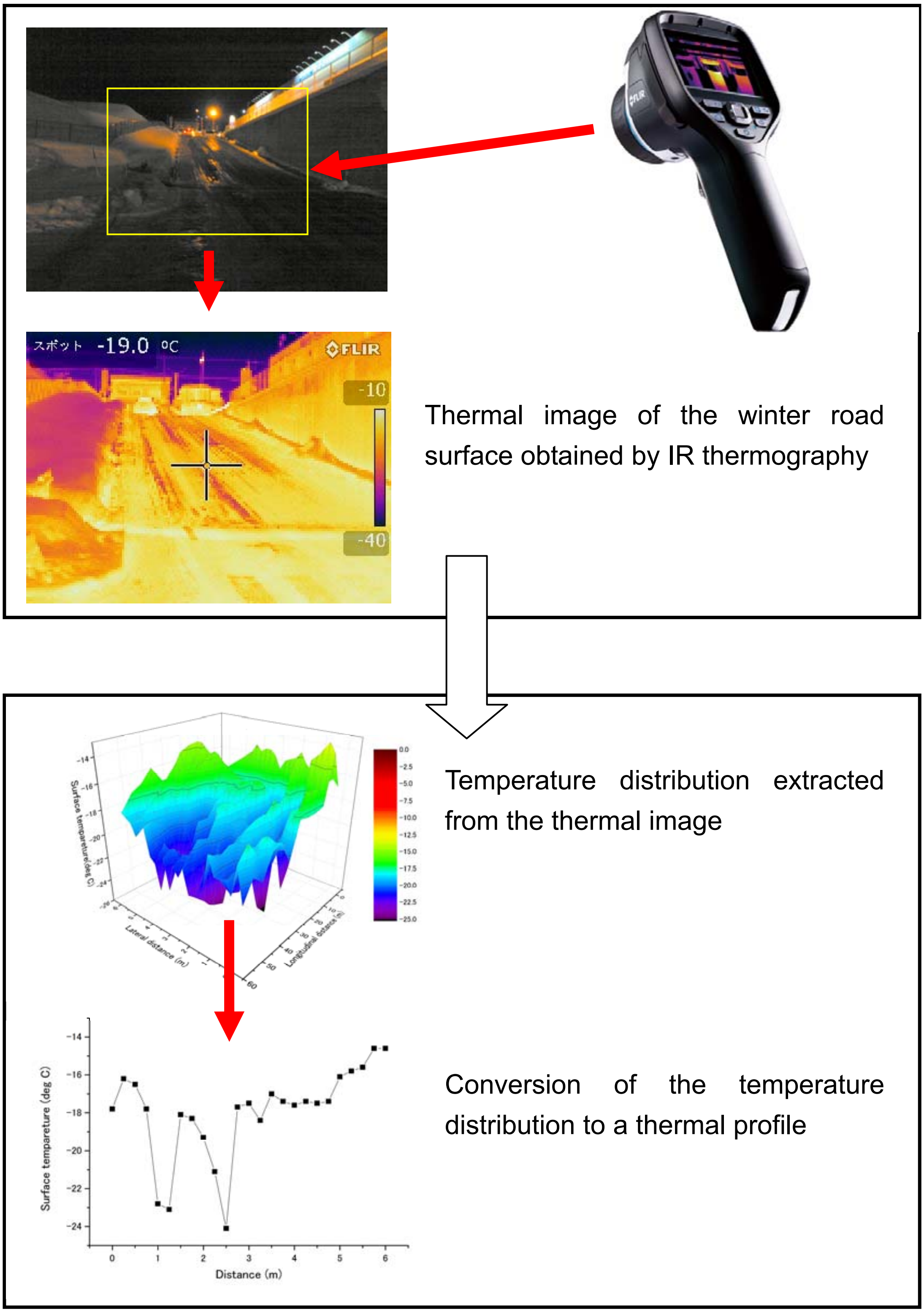



Figure 1 - Concept of the study


Figure 2 - Road intersection with installed heater


Figure 3 - Interior and exterior of a tunnel on a snow-covered road


Figure 4 - Two sides of a railroad crossing

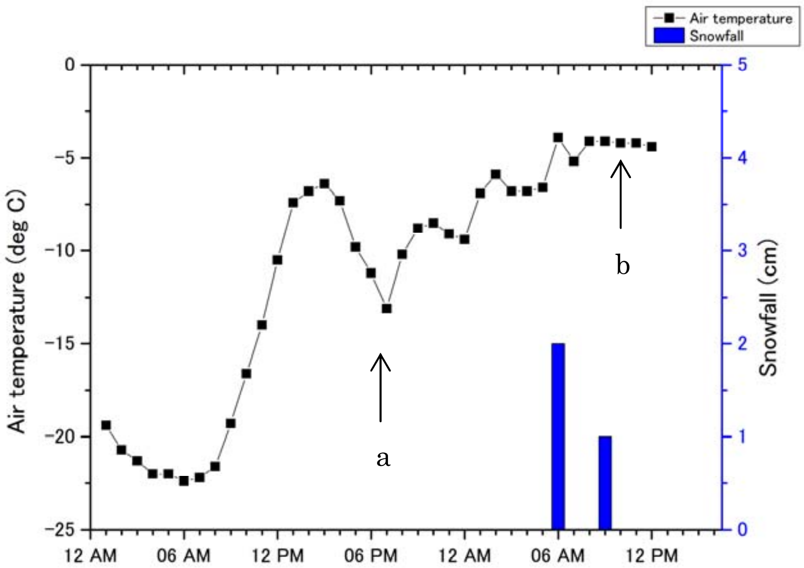
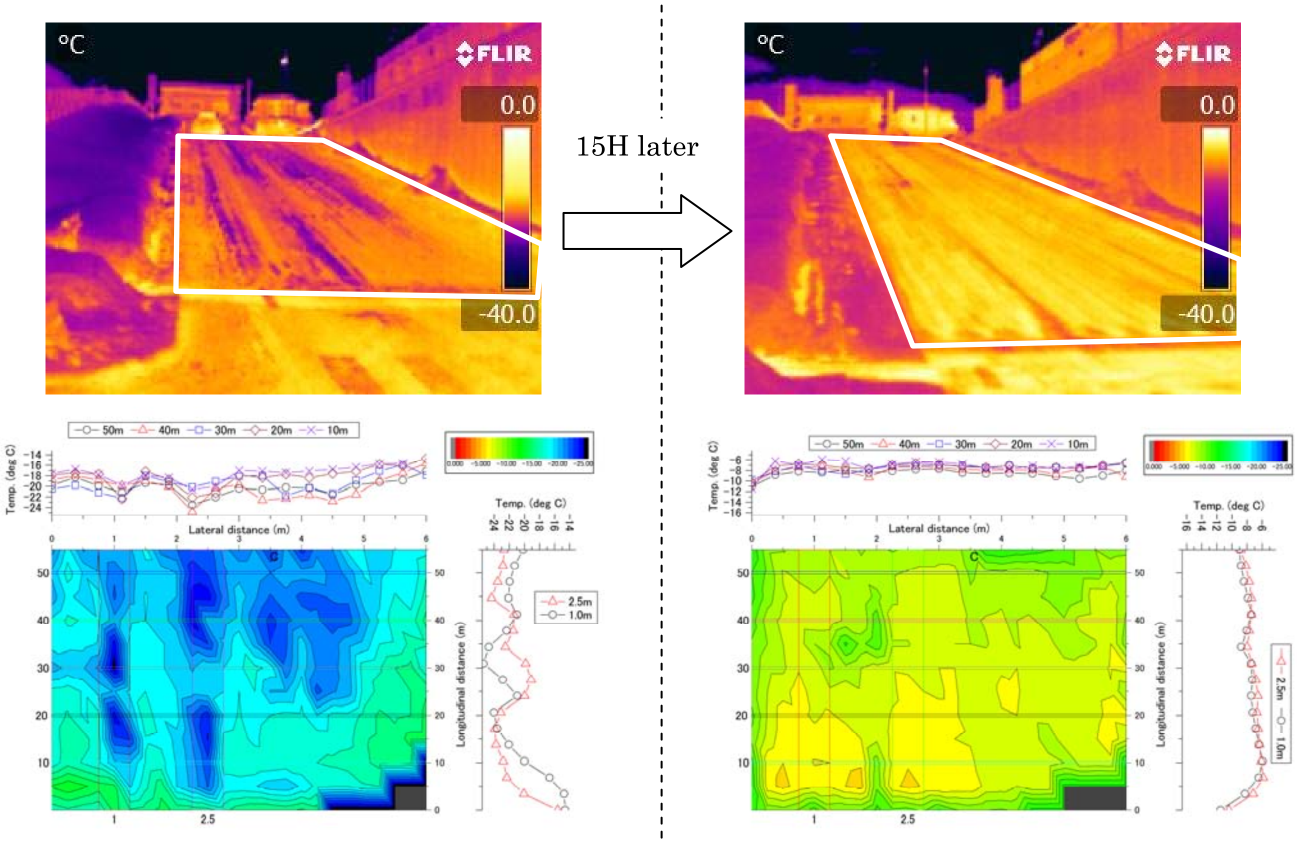



Figure 5 - Weather conditions (temperature and snowfall)
at the time the thermal images were taken




(a) (b)

Figure 6 - Results of conversion of the thermal images to thermal profiles; (a) frozen road surface, (b) after 3 cm of snowfall

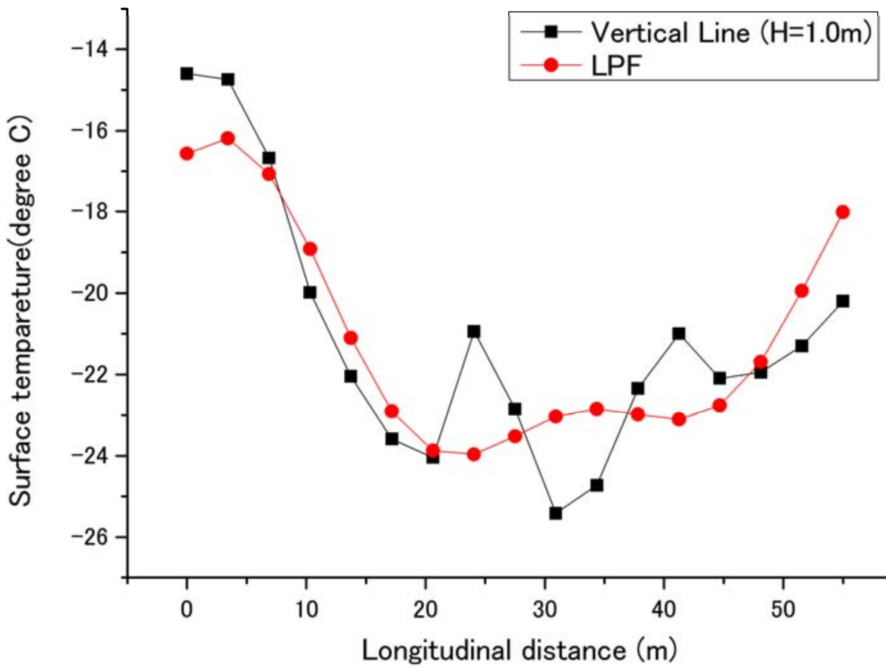



Figure 7 - Results of low-pass filtering of the thermal profile data

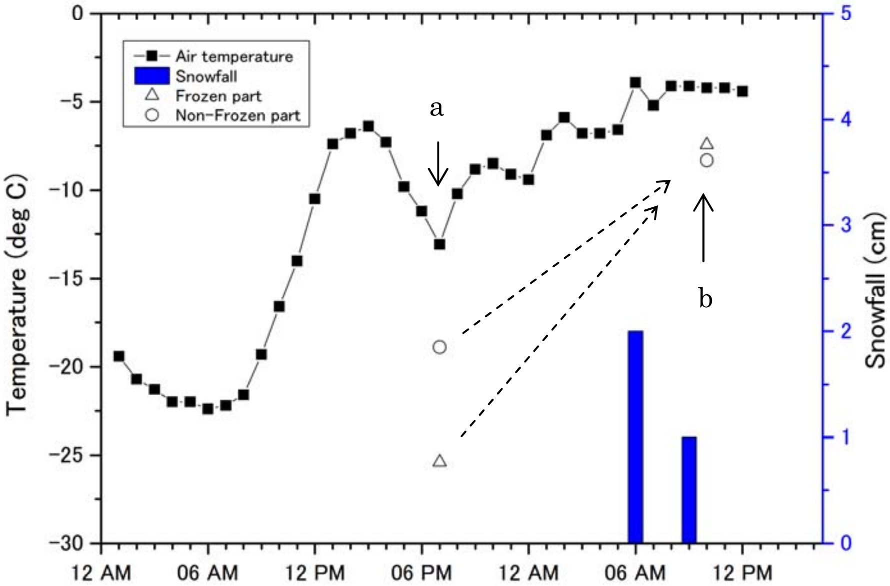



Figure 8 - Relationship between the weather conditions and the thermal profile data

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