Variation in Meteorological Variables in Mountainous Regions and Their Effects on Road Surface Temperature Prediction

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INTRODUCTION

Predicting the road surface temperature in a rugged, mountainous environment is challenging due to the sub-regional climate that is contained within a relatively small area. A research project is being conducted in a mountainous region in Japan, in which a road surface temperature prediction model is evaluated. The model utilizes both topographical parameters along the highway and a meteorological forecast at a point location.

The study area is located in the mountainous region of central Japan (approximately 200 kilometers from Tokyo). Figure 1 illustrates the study area and highlights a short stretch of the national highway 17 which is the study segment for the prediction model. It has an elevation difference of 675 meters over a 25-kilometer stretch of the highway. There are several tunnels, snow sheds and snow shelters that protect the highway from natural hazards. Highly rugged, mountainous terrain is assumed to affect the input meteorological variables used for the prediction model.

This study looks into different meteorological input variables in terms of how mountainous terrain affects them, and then it investigates the varying effects that the mountainous terrain exerts on the road surface predicted model.

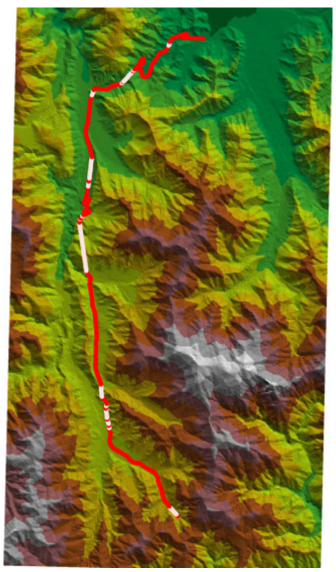

FIGURE 1 Overview of the study area.

TOPOGRAPHIC BOUNDARIES AND THEIR EFFECTS

The placement of road weather information systems (RWIS) in the study area seems to have been decided strategically based on their respective relationships with topographic features of the study area. Location-specific sensors are placed between any topographic boundaries which are demarked by tunnels, snow sheds or snow shelters. These RWIS are actually monitoring the sub-regional climates of the entire study area. This study investigates whether any particular sub-region in the study area has unique characteristics in its measured meteorological variables when they are compared with other sub-regions.

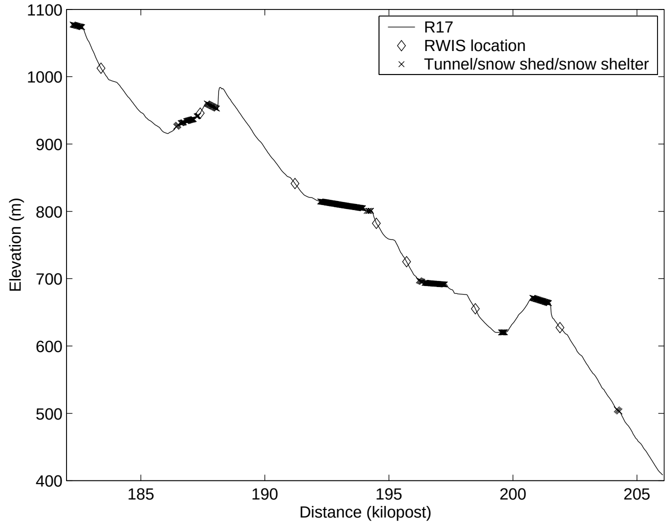

FIGURE 2 RWIS locations with their topographic relationships.

LAPSE RATE

Figure 3 illustrates lapse rates under different meteorological conditions. Data illustrated in the figure is from the RWIS locations represented in Figure 2. The meteorological forecast that is used for the prediction model is from the RWIS location at an even lower elevation, which is located a few kilometers away from the study area. As represented in Figure 2, RWIS are placed in the areas between various topographic boundaries. This study analyzes whether a rugged mountainous area has unique elevation-related characteristics. In other words, it examines what type of relationship exists between meteorological variables and elevation.

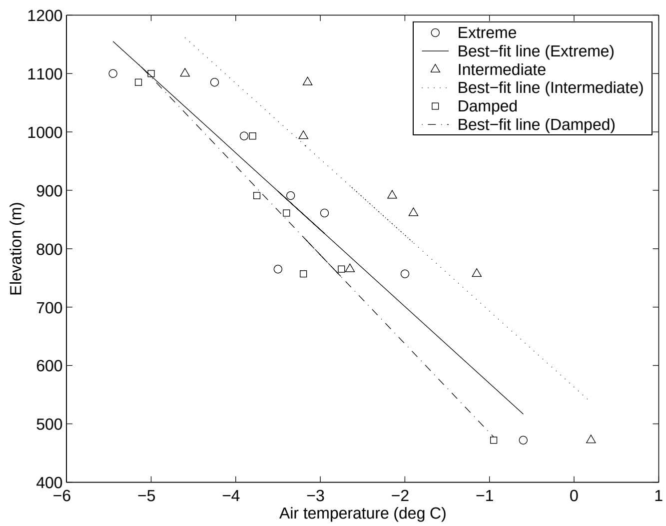

FIGURE 3 Different lapse rates of air temperature.

METEOROLOGICAL FORECAST VARIABLES

Figure 4 shows the differences in any two given consecutive air temperature forecasts. Every 12 hours, hourly values of meteorological variables are forecasted for the next 48 hours. The first 12 hours of a forecast are compared with the corresponding hours of the previous forecast. In this way, it is possible to determine the efficiency of the forecast in general over a certain period of time.

For the period of time plotted in Figure 4, an input meteorological variable appears to be relatively unbiased, whereas its variance increases dramatically at certain time periods. The meteorological forecast is an important set of input variables for the prediction model; thus, it is clear that the meteorological forecast affects the resulting road surface temperature predictions. This issue becomes even more complicated when it is concerned with the nature of mountainous topography. A meteorological forecast is for a fixed point or an area. Therefore, this study analyzes the effects of variability in the input meteorological forecast variables. Specifically, it questions how a meteorological forecast for one point location could represent other areas that are separated by topographic boundaries even if they are located in a relatively small area.

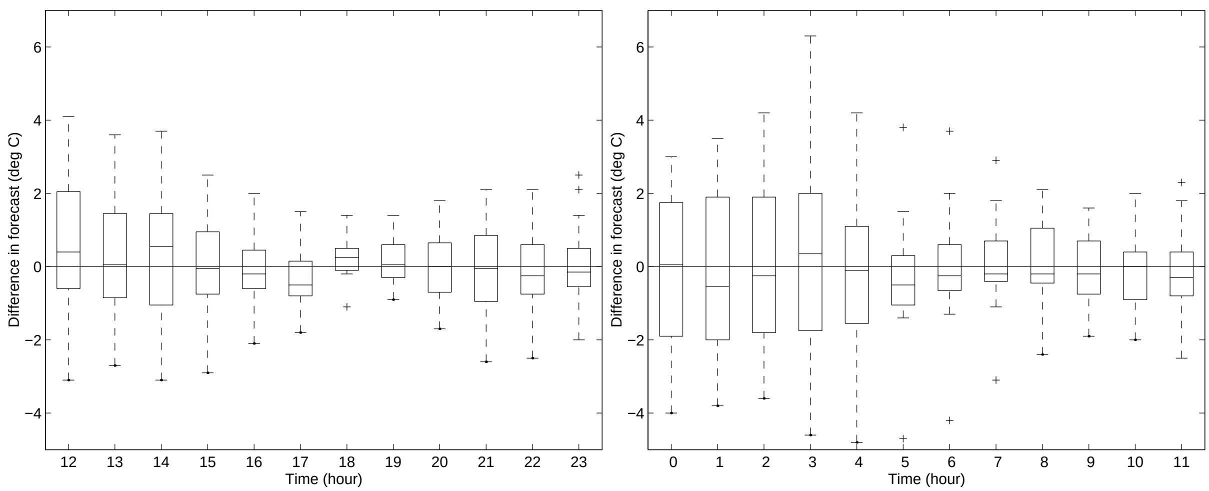

FIGURE 4 Data dispersion in input variable.

FREEZE-AND-MELT CYCLE AND TIME OF THE YEAR

Another important issue is how often road surface repeats a freeze-and-melt cycle. Figure 5 illustrates the median diurnal trends in air and road surface temperatures at a point location in the study area. During the winter season, it is not rare that road surface temperature goes through a diurnal (or even more frequent) freeze-and-melt cycle, while air temperature may not reach the melting point.

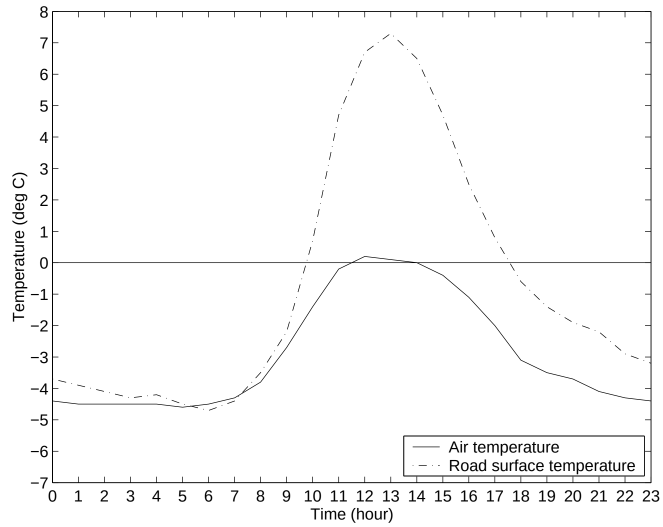

FIGURE 5 Mean monthly diurnal patterns for air and road surface temperatures.

This study examines how often a freeze-and-melt cycle takes place at particular RWIS locations that have road surface temperature sensors, and it compares the result with actual road freezing (with moisture) detected at the same site with road surface condition sensors.

PROPOSED STUDY

The road surface temperature prediction model will be run based on a set of meteorological forecast variables. Moreover, as part of the study, the actual road surface temperature will be measured with a vehicle equipped with an infrared thermometer multiple times during the winter season, and this is going to be a supplemental dataset to evaluate the prediction model itself. Topography and elevation-induced effects are identified and investigated, and results of the predictions will be compared with an analysis of the meteorological forecast and RWIS-providing actual meteorological data. The results of this study will be presented at the SIRWEC meeting.