A Basic Study of Short Term Forecasting Methods of Snowfall and Road Surface Temperature Using Intelligent Visibility Meter

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1. Introduction

Snowfall forecasting and road surface temperature forecasting are important subjects to ensure the security of comfortable winter road traffic condition and control management of winter road conditions.

In some conventional methods, the snowfall forecasting methods of 12 hours to 24 hours later have been developed, by the use of correlation between upper-air layer observation and ground snowfall observation.

Owing to make shorter time of forecasting, a forecasting system was developed using radar data. However, the method has some problems in narrowness of forecasting range, in equipment cost and in development cost.

In this research, we aimed to examine the possibility of very short term (to 3 hours later) forecasting of snowfall and road surface temperature by using the observation data of the Intelligent Visibility Meter which has functions to calculate precipitation type and intensity. As a result, we cleared that forecasting precision can be improved by our newly developed method.

2. Character of Intelligent Visibility Meter

2-1 Function of Intelligent Visibility Meter

Intelligent Visibility Meter is composed of optical light source, optical light detector, and control unit. It measures the intensity of forward scattered infrared rays in the atmosphere and converses MOR （Meteorological Optical Range） value.

Furthermore, using the artificial intelligence algorithm, it can observe type and intensity of precipitation.

Major functions of Intelligent Visibility Meter are given as follows;

1) Calculation function of accumulated snow depth.
2) Calculation function of precipitation amount.
3) Calculation function of precipitation intensity.
4) Calculation function of visibility.
5) Calculation function of precipitation classification.

Fig.1 Intelligent Visibility Meter

2-2 Method to distinguish the precipitation type

The precipitation type (in such cases as sleet, rain, snow, etc.) is determined by the relations between ratio of output signal of optical light detector to output signal of static capacity-type rain sensor and air temperature. The schematic diagram is shown in Figure 2.

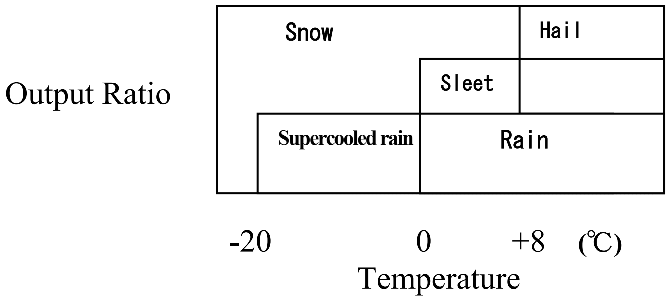

Fig.2 Schematic diagram for precipitation type distinction

2-3 Coding of precipitation type

The precipitation type code is expressed by five digits based on BCD signal, and each digit is set by the number of 1, 2, 4. When precipitation type is obscure, it is set by the number of 0. On the other hand, the weather type code adopts the form of weather code (SYNOP code) by the World Meteorological Organization (WMO) code Table 4680. An example of precipitation type code is shown in Figure 3.

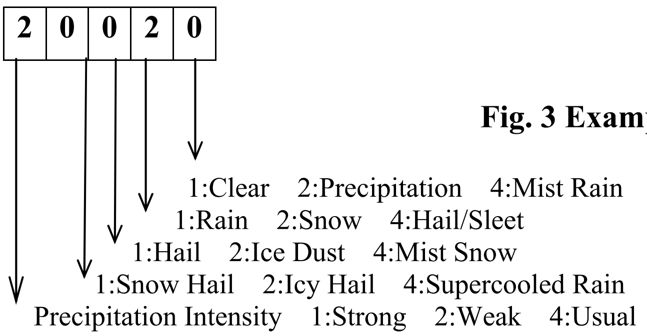

Fig. 3 Example of precipitation type code

2-4 Precipitation intensity

Precipitation intensity classification is made as follows;

1) Strong : more than 8.0 mm /hr
2) Weak : under 2.0 mm /hr
3) Usual : beyond 2.0 and under 8.0 mm /hr

3. Observation point outline

An observation point A (GH=228m) is set on a national road route located in North Latitude 39° 41.8 ' , East Longitude 140° 44.1'.

On the other hand, an observation point B (GH=56m) is an AMeDAS (Automated Meteorological Data Acquisition Systems) observation point of North Latitude 39° 36 ', East Longitude 140° 33.6'. The point B is located in the southwestern direction 15km from the point A. (Figure 4)

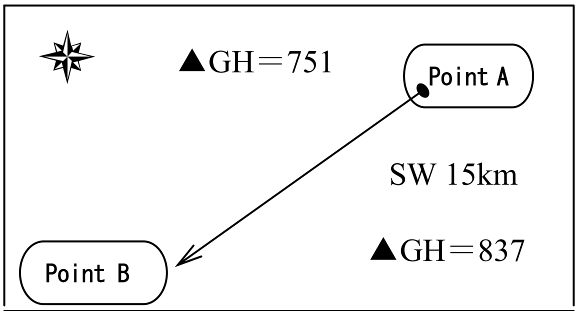

Fig.4 Relation of observation points A and B

The area between the points A and B is a plain part comparatively, and the national route is laid in the SW direction from point A. Along the route hilly areas of about GH=750m to 840m are on both sides. Wind in NNE-ENE direction near point A is browed to SW direction along the national route .

4. Applicability of Intelligent Visibility Meter for short term snowfall forecasting

Weather observation data in the observation point A were gathered during February 28 to March 16, 2001. The data gathered are air temperature, wind direction, wind speed, rainfall, snowfall, accumulated snowdepth, road surface temperature, amount of sunshine, traffic, and Intelligent Visibility Meter data.

Wind direction and wind speed occurrence frequency during the examination period are shown in Figure 5 and Figure 6.

Here, a snowfall forecasting point B is set on the AMeDAS point in the southwestern direction 15km from point A. The relation between the precipitation type code that is observed by Intelligent Visibility Meter at point A, and the snowfall occurrence after 2 to 3 hours at point B were examined.

It can be presumed that the possibility that snowfall occurrence at point A brings snowfall at point B exists when the wind direction at point A is in the NNE-ENE direction. The snow cloud above point A will reach above point B after 2 to 3 hours at wind speed of 1.4 to 2.0 m/sec.

Therefore, data in case of wind speed data at 1.4-2.0 m/sec and wind direction data at NNE-ENE (Case 1) were extracted from the observation data of point A, and the relation between precipitation type code at point A and real snowfall occurrence at point B were analyzed.

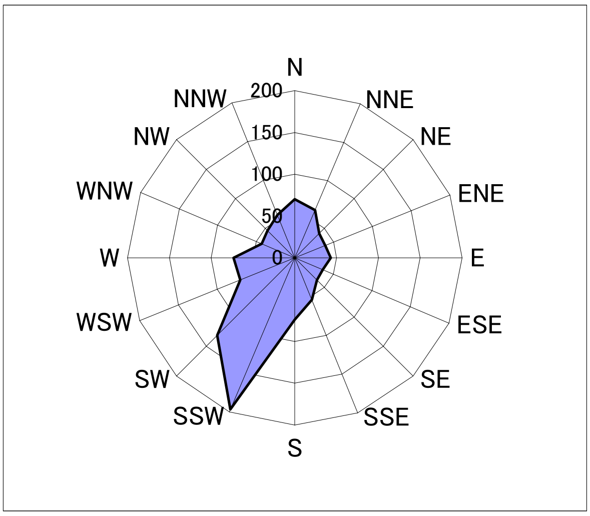

Fig. 5 Wind direction occurrence frequency at Point A

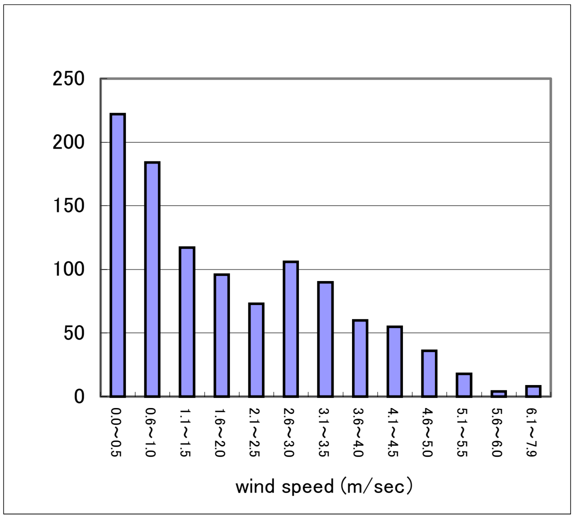

Fig. 6 Wind speed occurrence frequency at Point A

According to the analysis of extracted data, precipitation type codes which bring snowfall at point B were "20020, 20400". Moreover, the codes "20200, 40001" are assumed to be the codes which will not bring snowfall at point B. Hitting ratio is shown in Table 1.

Table 1 Precipitation type code in Case 1

Precipitation type code	Forecast	Hitting Ratio
20020	Snowfall	77.8%
20400		
20200	No Snowfall	73.2%
40001		

On the other hand, under the condition in which wind speed and wind direction do not coincide with the Case 1, the codes which bring snowfall and the codes which do not bring snowfall are shown in Table 2. Hitting ratio at these conditions are shown in the same table.

The snowfall forecasting precision about 74% is achieved by using precipitation type code of Intelligent Visibility Meter as a result of the analysis.

This means that the very short term snowfall forecasting of the specific area can be achieved from the ground observation value with Intelligent Visibility Meter without using upper air layer observation data. Therefore, Intelligent Visibility Meter has an applicability to snowfall forecasting at the correlation point.

Though pressed snow type road surface condition and frozen type road surface condition bring extremely big difficulties in winter road service, measuring instrument and methods are not established as for the detection or forecasting for these road surface conditions.

One of the causes of this problem is that short term snowfall forecasting method for a specific area is not established. Therefore, forecasting for pressed snow type road surface condition is difficult.

Intelligent Visibility Meter brings the high possibility for snowfall forecasting methods as a new forecasting method using precipitation type code.

Table-2 Precipitation type code under conditions not coincide with Case 1

<table>
<tr><th>Precipitation type code</th><th>Forecast</th><th>Occurrence sample number</th><th>Hitting ratio</th></tr>
<tr><td>20020</td><td rowspan="5">Snowfall</td><td>89</td><td rowspan="5">76.1%</td></tr>
<tr><td>20400</td><td>17</td></tr>
<tr><td>10020</td><td>2</td></tr>
<tr><td>20200</td><td>2</td></tr>
<tr><td>40020</td><td>7</td></tr>
<tr><td>20002</td><td rowspan="8">No Snowfall</td><td>3</td><td rowspan="8">73.8%</td></tr>
<tr><td>20010</td><td>9</td></tr>
<tr><td>20004</td><td>6</td></tr>
<tr><td>20040</td><td>1</td></tr>
<tr><td>40001</td><td>221</td></tr>
<tr><td>40004</td><td>3</td></tr>
<tr><td>40010</td><td>6</td></tr>
<tr><td>40002</td><td>1</td></tr>
</table>

5. Road surface temperature forecasting by precipitation type code

The classifications of precipitation type code using Intelligent Visibility Meter are separated from every alike group as Table 3. Multiple regression analysis in which the object variable is road surface temperature of 3 hours future at point A was carried out for the period 28 February to 16 March, 2001. The explanation variables in this analysis are air temperature, 1 to 3 hours former road surface temperature, ground temperature, traffic, amount of sunshine, wind direction, and wind speed.

As a result of the analysis, the multiple correlation coefficient $r = 0.88$ is got for the case of un-classified data. On the other hand, better result beyond $r = 0.88$ was recognized for the case except the Visibility classification "20020", "20040+20200" .

The sense of paying attention to initial road surface condition and amount of sunshine, further analysis of 20040+20200 group was carried out. The category was classified as follows;

1) Observation data that the amount of sunshine is 0.1 ($MJ/m^2 \cdot hr$) above in the initial road surface "Frozen"
2) Observation data that the amount of sunshine is 0.1 ($MJ/m^2 \cdot hr$) above in the initial road surface "Except Frozen"
3) Observation data that the amount of sunshine is 0.0 ($MJ/m^2 \cdot hr$) in the initial road surface "Frozen"
4) Observation data that the amount of sunshine is 0.0 ($MJ/m^2 \cdot hr$) in the initial road surface "Except Frozen".

Multiple regression analysis result by above classification is shown in Table 4.

Table-3 Road temperature forecasting by Visibility classification and Multiple correlation coefficient

Precipitation type code	Sample number analyzed	Multiple correlation Coefficient
Un-classified	951	0.88
10020	5	0.98
20002+20004	22	0.93
20010	12	0.93
20020	288	0.86
20040+20200	13	0.87
20400	53	0.94
40001	531	0.88
40004+40010＋40002	27	0.98

Table-4 Road temperature forecasting using initial road surface condition and amount of sunshine in case of precipitation type code 20020

Category	Sample number analyzed	Multiple correlation coefficient
Amount of sunshine is 0.1 ($MJ/m^2 \cdot hr$) above in initial road surface "frozen"	11	0.83
Amount of sunshine is 0.1 ($MJ/m^2 \cdot hr$) above in initial road surface "Except Frozen"	80	0.92
Amount of sunshine is 0.0 ($MJ/m^2 \cdot hr$) in initial road surface "Frozen"	54	0.92
Amount of sunshine is 0.0 ($MJ/m^2 \cdot hr$) in initial road surface "Except Frozen"	143	0.96

It exceeds original precision except for the analysis of category 1), and this high forecasting precision suggests the possibility that forecasting can be improved largely by using precipitation type code, initial road surface condition and amount of sunshine.

6. Summary

Pattern analysis of road surface temperature has been studied as one of road surface temperature forecasting methods in various fields. However, a plenty of accumulation of the resemblance pattern is necessary for the improvement of precision.

Our newly developed methods using precipitation type code is thought to be of great possibility for road surface temperature forecasting analysis in the future.