Difficulties in Forecast of Slippery Road Conditions on Packed Snow Surface in Sapporo

Yasuhiko Kajiya, Masao Takeuchi and Kohji Miyashita

Abstract

Mechanical snow removal to keep trafficability has been the major work of the winter road maintenance in Japan. Meanwhile tire changes from studded to 'studless' the road surface management has also been required for safe and smooth traffic. As European countries show the road surface management based on weather forecast is essential to reduce the cost and resources. An ice forecast system from Europe has been introduced and tested comparing the output from the system with observed for 2 winters during 1993-1995 in Sapporo. The results show that the system works well for the ice forecast on bare pavements but there are some difficulties on packed snow conditions. The packed snow formed by heavy traffic during snow fall is difficult to clear away and the packed snow on road is commonly seen in mid winter of Hokkaido Japan. Because of traffic pass and some weather the very slippery road conditions appear frequently with thin liquid water layer on the packed snow surface. The forecast of the slippery conditions on packed snow is required for the road surface management but there are some difficulties to forecast the conditions by the present system.

1. Introduction

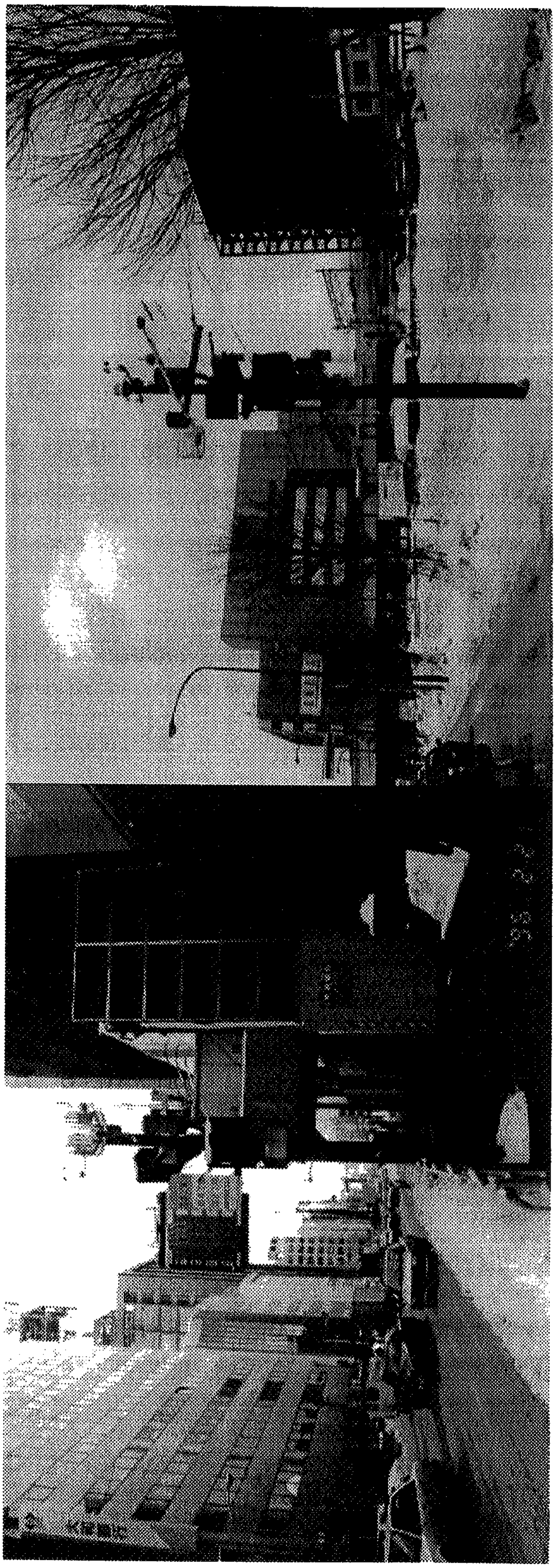
The studded tire scratches the snow surface but the studless tire polishes the surface slippery. Very slippery road has appeared in Sapporo since the use of studded tire has prohibited in 1992. The anti-icing practices have not adopted and packed snow and ice on road has been common in winter. Advanced winter road management has been required for the safe and smooth traffic under the regulation of studded tire. The road surface management based on weather forecast has been operational used in European countries. Vaisala Icecast system was introduced and the validation test of the system was carried out for operational use of it in Sapporo.

2. Winter road conditions in Sapporo

The cumulative depth of winter snow is 5m and the average annual maximum depth of snow cover exceeds 100 cm in Sapporo. Mechanical snow removal has been the major work of the winter road maintenance. Since studded tire prohibited road heatings have been running at main slopes and the using of deicing chemicals has been increasing. However almost every road is covered by packed snow and ice more than 50 % of winter from December to March (Kajiya et al 1993). Packed snow forms during snow fall because of heavy traffic and the weather. Snow removal works are limited by heavy traffic in the daytime and deicing chemicals are not effective in low temperature at night. Occasionally the surfaces of the packed snow melt and freeze to ice at night and the snow and ice conditions remain days to the following snow event. The packed snow polished by traffic wearing 'studless tire' appeared after the prohibit of studded tire. The polished snow of which surface thin water or ice layer on brings especially slippery condition. Deicing chemicals have been used to improve surface conditions mainly on crossroads. The winter road surface condition is variable owing to weather and traffic it is classified 13 states by appearance (Matuzawa et al. 1996).

3. Sensor and System Validation

Vaisala Icecast system has been introduced to test the reliability for operational use in Sapporo. The system is composed with the road weather observation station and the central station. Meteorological and geographical parameters are measured by sensors at the observation station and the system distinguishes 8 states of surface condition with the parameters. The data is transmitted every 10 minute to the central station in Japan Weather Association. The data is analyzed and the state of condition and ice warnings are output at the central station (Haavasoja 1986). The forecast parameters, which include air temperature, dew point, cloud amount and cloud type, are input at the central station to forecast up to 24 hours ahead of the road surface temperature and road condition. Two test sites were selected to compare the effect of different parameters. The main difference of the two is sky view parameter. Site 1 is surrounded by buildings and solar radiation is less than site 2. At site 2 sunlight is shut out by buildings in the morning but exposed in the afternoon. The total solar radiation from December to March is 150 (MJ/m^2) at site 1 and 617 (MJ/m^2) at site 2. The test sites are shown in figure 1. Video camera was used in time lapse mode to monitor and record the visual surface condition. The pictures of the video cameras were used to compare the road condition of distinguished and forecasted by the system. Besides video camera visual observation of the road condition was carried out every morning. The validation was carried out two winters from December to March (1993/1994,1994/1995).



site1

site2

Figure 1. Observation Stations

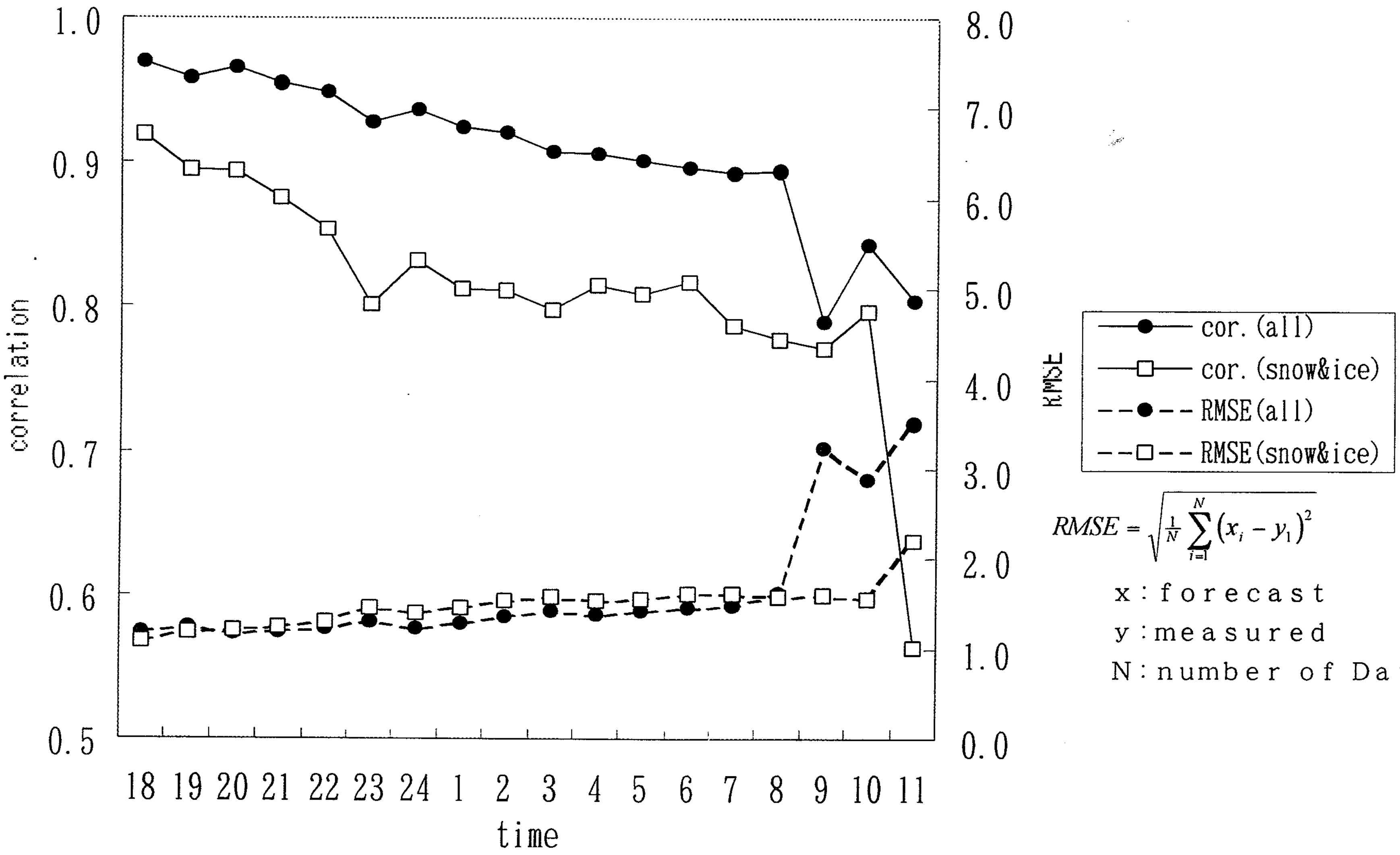
3.1 Road Surface Temperature

The surface temperature forecasted by using weather forecast data (cloud amount, cloud type and precipitation) was compared by actual measured at the stations as real time test. Retrospective verification was tested using actual measured data to eliminate forecast errors. The performance is examined by correlation coefficient and 'root mean square error(RMSE)' every hour for all the days in the test period. The correlation and the RMSE at site 1 are plotted of real-time test in Figure 2 and retrospective in figure 3. The RMSE shows that the errors range from 1.2 to 1.4° C in real-time tests at night time. Large errors appeared after sunrise. The errors are 0.5° C smaller in retrospective verification before sunrise. Packed snow condition is prevailing in Sapporo. The influence of packed snow condition for the forecast is also plotted as the same way in the figures. Initial packed snow condition was picked out in the figure. The errors in packed snow condition are a little larger at night time but smaller at day time comparing with in overall condition. The influence of packed snow is small except at day time. The influence of solar radiation is less in packed snow condition. These results suggest that there is influence of solar radiation in the large errors at day time. Heat from traffic is also considerable (Matuzawa et al. 1995) at busy traffic hour. The influence of solar radiation is expected to improve but not so fatal for operational use since road maintenance works are decided by the condition of early in the morning. As a whole the performance of forecast for road surface temperature is acceptable for operational use.

4.1 Road Condition

4.1.1 Sensor

The sensor was tested comparing with the condition measured by the sensor and visual observation every morning in winter 1994/1995. The condition is classified into 3 types, snow and ice, wet and dry. The accuracy is shown as accordance ratio including both sites for each condition in table 1. The TR (treatment) appeared frequently for each condition as errors especially in snow and ice condition. The accuracy excluded the case of TR is also tabulated in the table. The TR in snow and ice tends to appear under the condition of higher temperature and less precipitation. Chemicals were used in 86.5%(64/74) of the case (TR). The sensor seems to have responded sensitive for chemicals. The improvement of TR is required for operational use.



$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - y_1)^2}$$

x : forecast
y : measured
N : number of Date

Figure 2. Realtime comparison of road surface temparature (site1. Des. /94-Mar. -95)

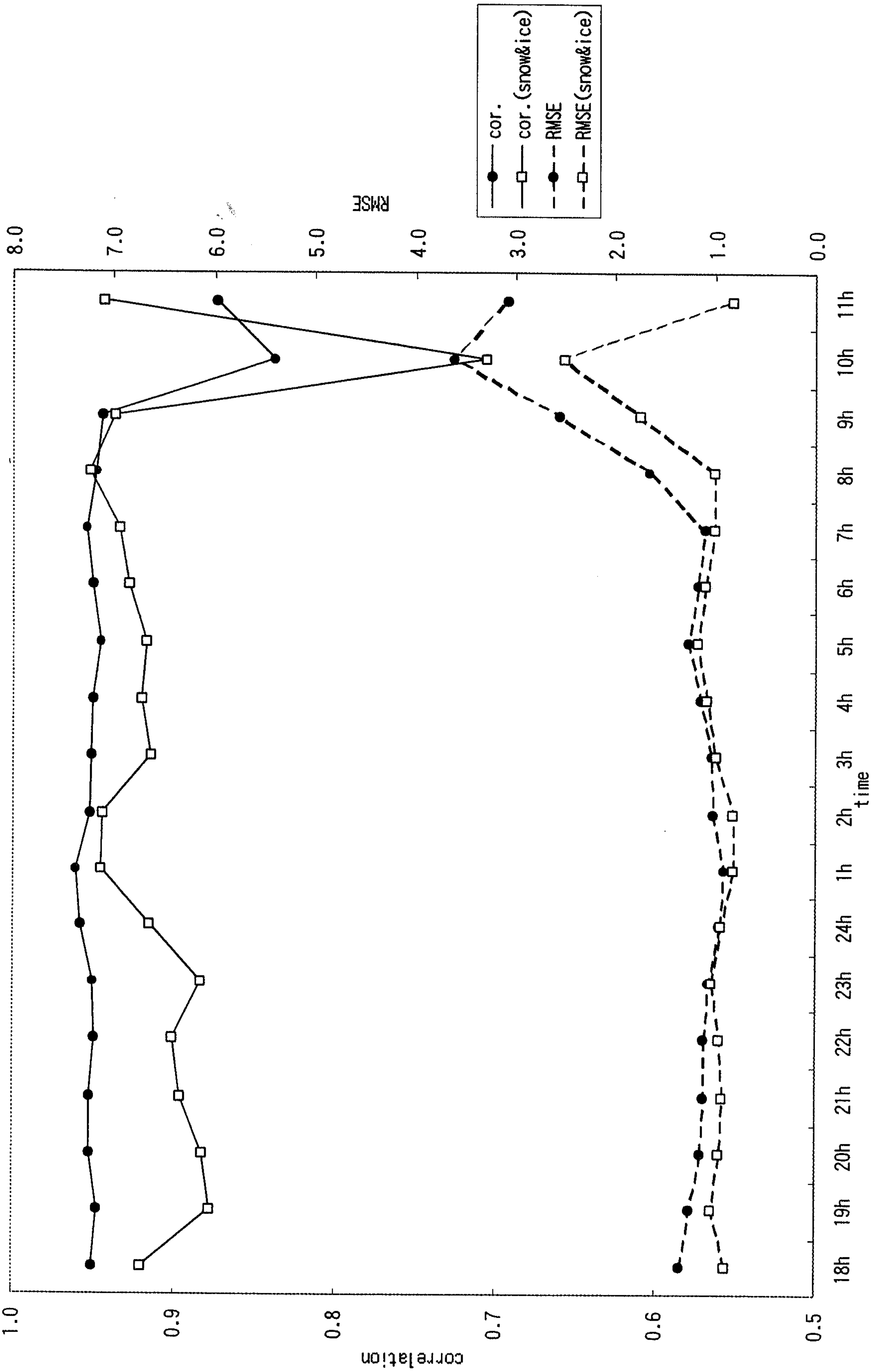


Figure3. Retrospective comparison of road surface temparature (site1. Des. /94-Mar. -95)

forecast	measured	Des.	Jan.	Feb.	Mar.	total	
snow	snow	8	24	9	2	43	
	wet	0	0	0	1	1	
	dry	0	2	0	0	2	
	TR	11	8	6	1	26	
	—				2	2	
	total	19	34	15	6	74	
accordance ratio		42.1	70.6	60.0	33.3	58.1	
%		(100)	(92.3)	(100)	(40.0)	(90.0)	(exclude TR)

forecast	measured	Des.	Jan.	Feb.	Mar.	total	
snow&ice	s&i	12	29	11	2	54	
	wet	1	0	0	1	2	
	dry	1	2	0	0	3	
	TR	26	21	8	3	59	
	—	0	0	0	4	2	
	total	40	52	19	10	121	
accordance ratio		30.0	55.8	57.9	20.0	43.8	
%		(85.7)	(93.5)	(100)	(28.5)	(87.1)	(exclude TR)

forecast	measured	Des.	Jan.	Feb.	Mar.	total	
dry	dry	6	0	12	33	51	
	wet	2	0	1	4	7	
	snow	0	0	1	0	1	
	TR	4	0	5	0	9	
	—	0	0	0	2	2	
	total	12	0	19	39	70	
accordance ratio		50.0		63.2	84.6	72.9	
%		(75.0)		(85.7)	(84.6)	(83.6)	(exclude TR)

forecast	measured	Des.	Jan.	Feb.	Mar.	total	
wet	wet	10	9	9	9	37	
	dry	0	0	0	2	2	
	snow	0	0	4	1	5	
	TR	0	1	5	1	7	
	—	0	0	0	0	0	
	total	10	10	18	13	51	
accordance ratio		100	90	50	69.2	72.5	
%		(100)	(100)	(69.2)	(75.0)	(84.1)	(exclude TR)

Table 1. Comparison of measurement by the sensor with observation

4.1.2 Forecast of Road Condition

Real time and retrospective tests were carried out for the verification of road condition. Road condition forecasted by the model was compared with measured by video camera. Road condition is classified into 3 type as the case of sensor test. Results of the validation are summarized in Table 2. The accuracy is shown as accordance ratio with observed and forecasted snow & ice condition. Table 3. shows the case that snow & ice appeared under dry or wet forecasted. The accordance ratio is acceptable but the later case is required to improve for operational use.

5. Conclusion

The validation of Icecast system shows that the road surface temperature forecast is acceptable but road condition forecast is not as well forecasted as expected. Weather and road condition are different especially heavy snow and prevailing packed snow road in Sapporo from European countries where the system works well. The different snow condition was thought to make road condition forecast difficult in Sapporo. The influence of snow condition was very little on the forecast of road surface temperature, however the errors of road condition forecast tend to appeared more frequently in initial snow and ice conditions. The sensor error seems to be influenced by snow and ice conditions. Since the function of the system is unknown black box for us there is a limit to examine the difficulties in road condition forecast.

6. References

Haavasoja, T.(1986). Remote sensing of road condition, Vaisara News, 108:3-6

Matuzawa M., Kajikawa, Y., and Takagi, H.(1996).Evaluation of winter road conditions based on sevice level classification by the appearance.Proc.39th.Annual Meeting Hokkaido Dev. Bureau.69-76.

	local time	18	21	24	03	06	09	11	average
site 1	real time	65	75	72	68	68	59	55	67
	retrospective	76	72	78	74	69	62	54	69
site 2	real time	61	70	72	66	60	54	35	61
	retrosoective	69	75	75	71	65	51	38	64

Table 2. Accordance ratio of snow & ice condition (%)

	local time	18	21	24	03	06	09	11	average
site 1	real time	26	32	35	39	31	19	9	26
	retrospective	23	32	33	31	28	10	6	24
site 2	real time	16	22	26	33	28	14	4	19
	retrosoective	15	20	21	20	11	7	3	14

Table 3. Ratio of snow & ice observed during dry or wet forecasted (%)

Yasuhiko Kajiya, Civil Engineering Research Institute, Hokkaido Development Bureau, Hiragishi Toyohira-ku Sapporo 062 Japan

Masao Takeuchi and Kohji Miyashita, Japan Weather Association Hokkaido Head Office, N4 W23 Chuo-ku Sapporo 064 Japan