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Development and Operation of the Winter Maintenance Support System

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Presented by *Naoto TAKAHASHI*
Roberto A. TOKUNAGA
Motoki ASANO
Nobuyoshi ISHIKAWA

-S-I-R-W-E-C-

Outline:

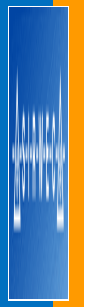
I. Introduction

II. Summary of the System Development

III. System's Composition and Function

IV. State of the System

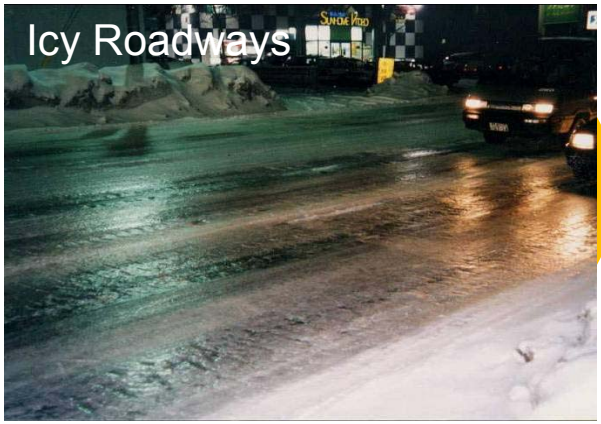
V. Conclusion



INTRODUCTION

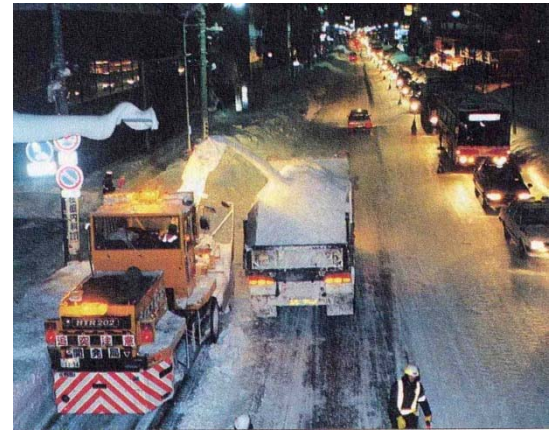
Background:

Roadway conditions during wintertime



To Provide Ever Safer and More Efficient Movement

- Perform various snow and ice control operations



Objective:

Limitation of budgets ✖ High expectation of the public for keeping good roadway condition

Necessary to conduct winter maintenance operations more efficiently

Accurate forecasting of road surface icing is essential to achieve the adequate and appropriate winter maintenance

- It needs developing the approach to predict road icing scientifically
- To start operational work on appropriate timing, it requires providing forecasting information to road authorities as soon as possible

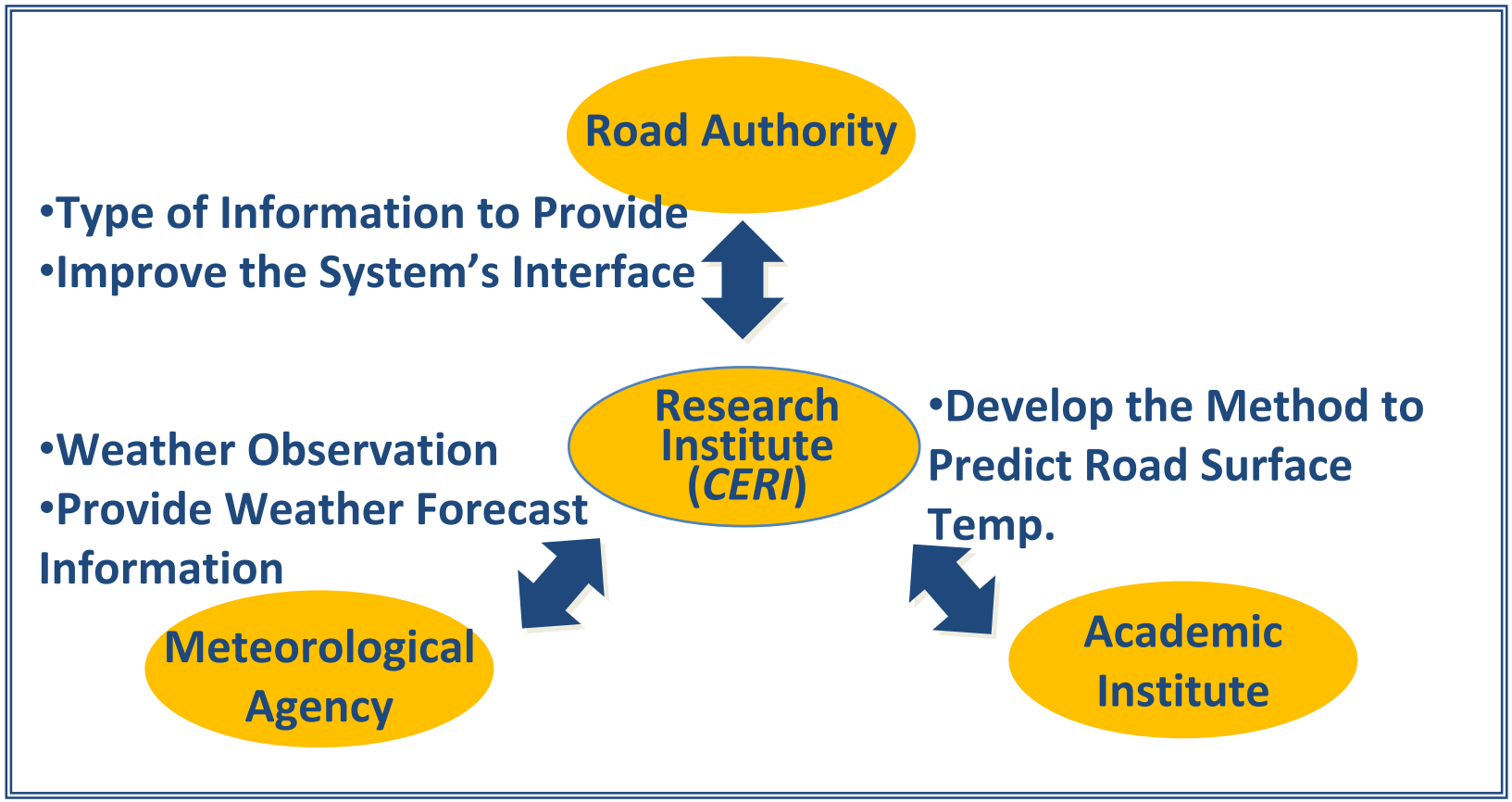
This might lead to more appropriate and more efficient winter maintenance.

In order to support road authority's decision with providing accurate forecasting information based on a scientific approach. Developing forecasting method and the ***"Winter Maintenance Support System"*** suitable for Japan's geographical feature, weather and existing snow and ice control activities

SUMMARY OF THE SYSTEM DEVELOPMENT

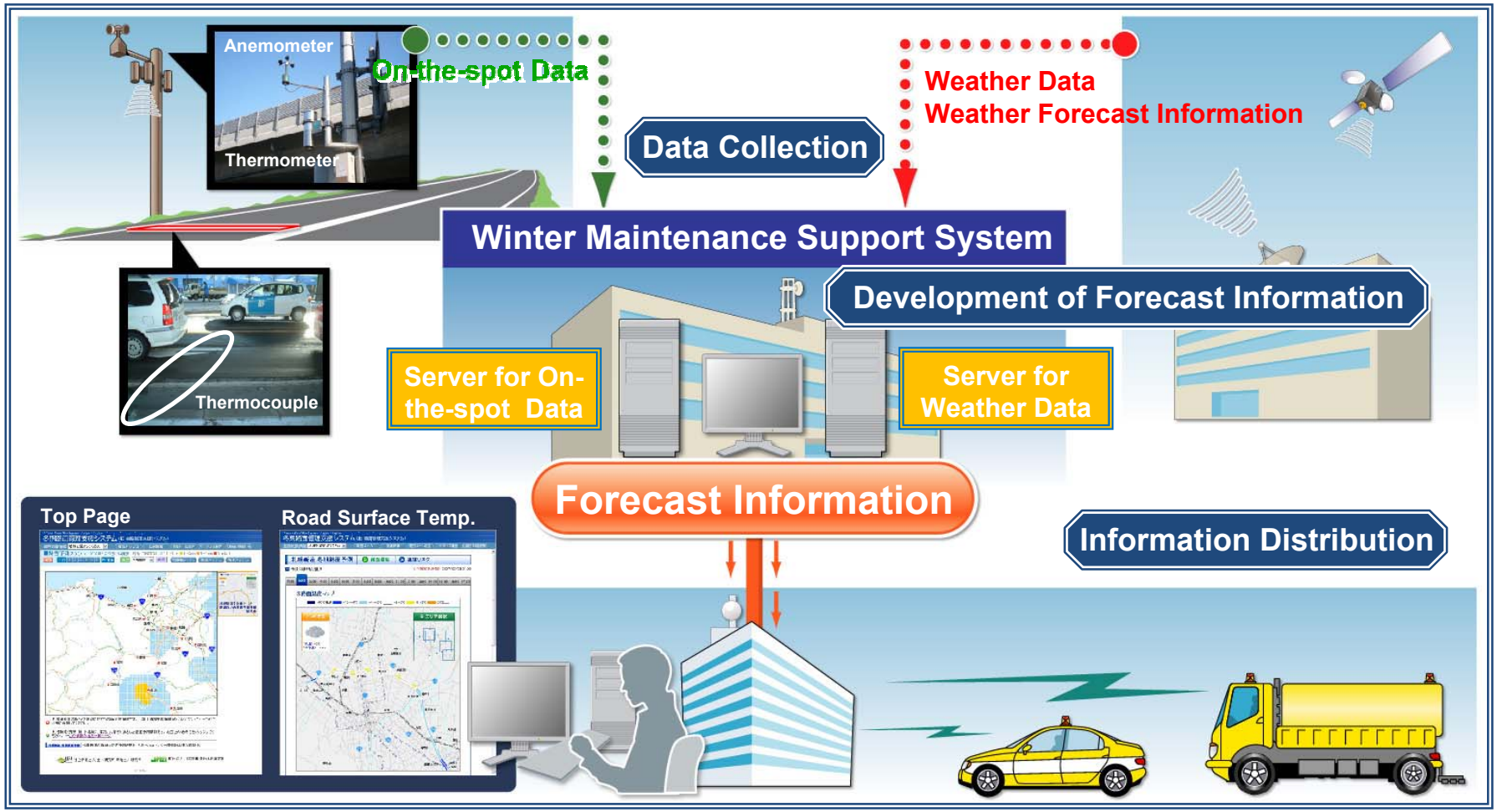
Organization:

The ***Winter Maintenance Support System*** has been developed in cooperation with other relevant organizations.



Summary of the System:

Conceptual Diagram of the System:



Data Collection:

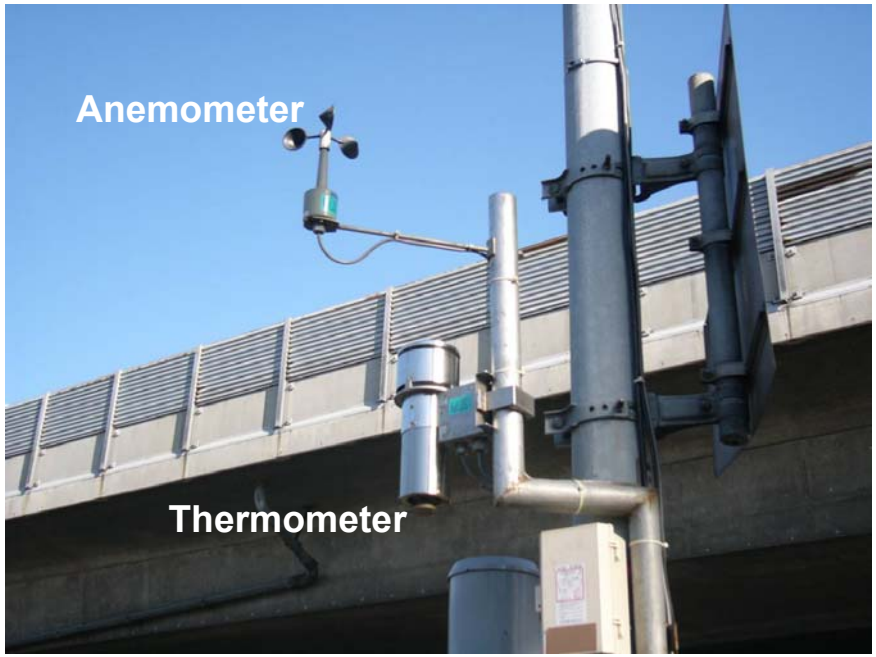
Weather Observation:

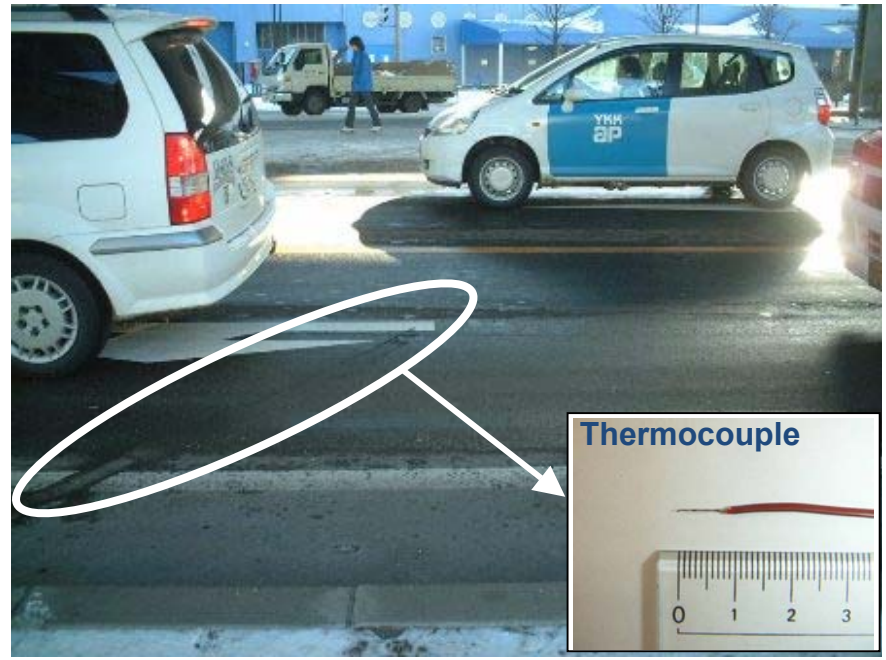
On-the-Spot: Air Temp., Wind Velocity

Meteorological Agency: Solar Radiation, Cloud, Humidity and Weather Forecast

Road-Surface Temp. Observation:

- Trend of Road-Surface Temp.
- Validation





On-the-Spot Observation

Data are concentrated:

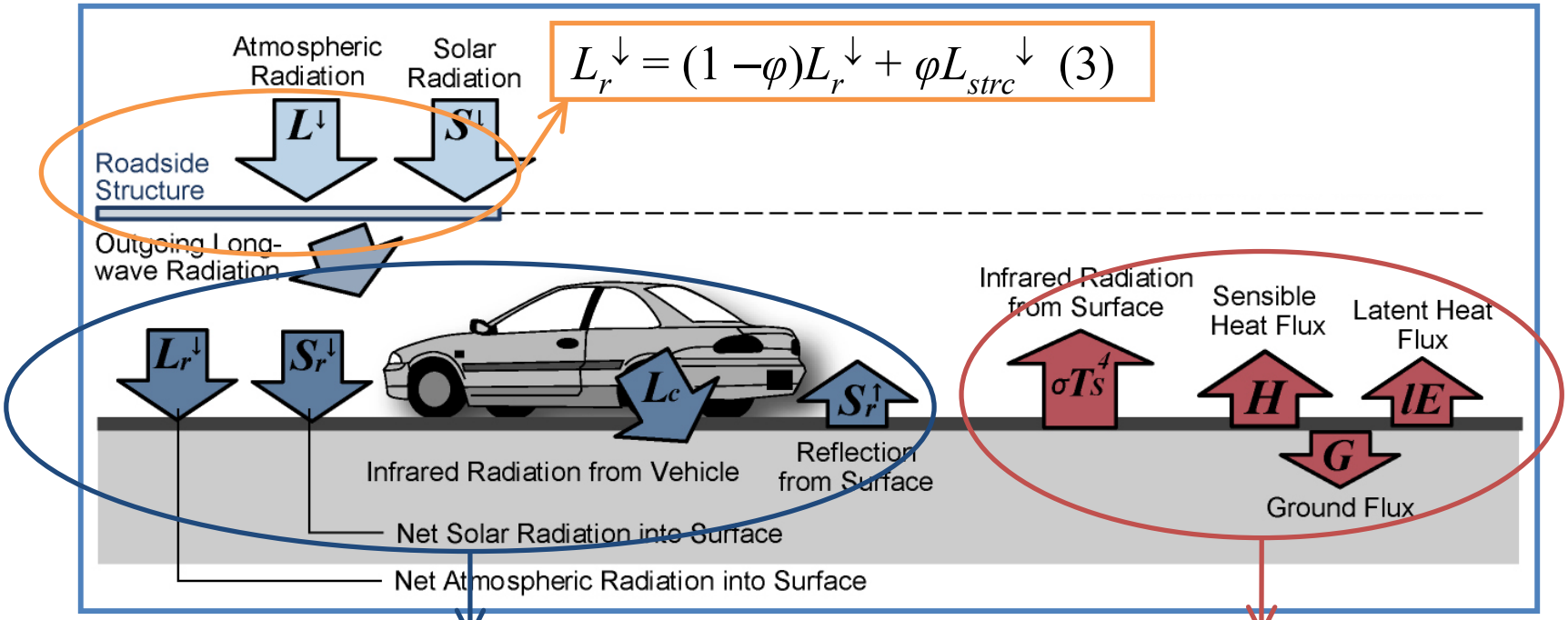
On-the-spot data ~ through the phone line

Data from the meteorological agency ~ through the private

Forecasting Method: *Road Surface Temp.*

Heat Balance Method (derives road surface temp. through analysis of the heat transferred to and from the road surface)

- Consider the Effect of Vehicular Traffic （i.e. infrared radiation from vehicle, radiation shielding by vehicles)
- Consider the Effect of Roadside Structure （i.e. infrared radiation from the structures, radiation shielding by the structures)



$$L_r^{\downarrow} = (1-\varphi)L_r^{\downarrow} + \varphi L_{strc}^{\downarrow} \quad (3)$$

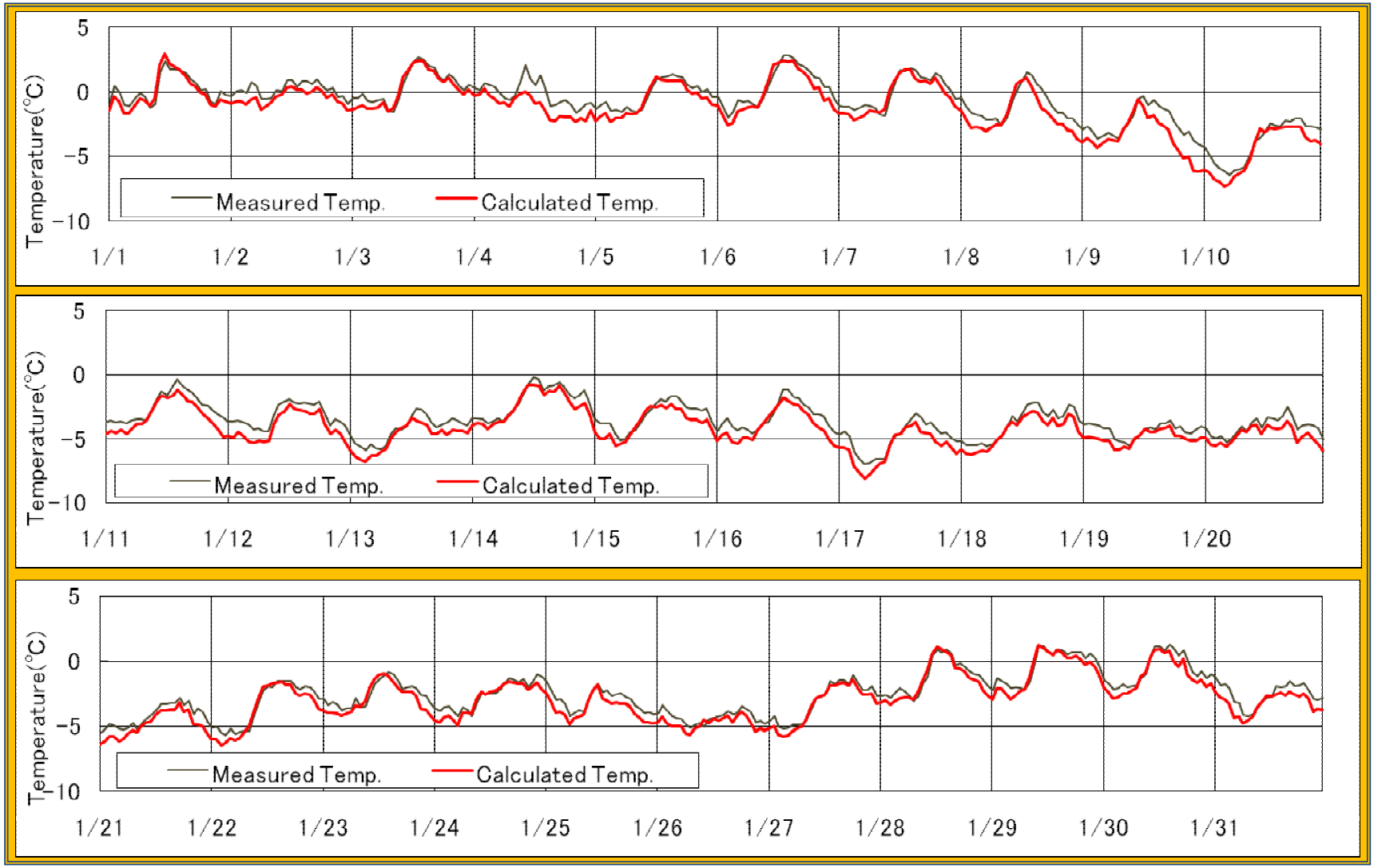
$$R^{\downarrow} = S_r^{\downarrow} - S_r^{\uparrow} + L_r^{\downarrow} + L_c \quad (2)$$

$$R^{\downarrow} = \sigma T_s^4 + H + lE + G \quad (1)$$

Necessary Parameters:

Heat Balance Composition	Parameter	Unit	Value
Radiation Amount $R^{\downarrow}$	Ave. Length of Vehicles d	m	5
	Ave. Speed of Vehicles v	km/h	Intersection: 5 Non-Intersection: 30
	Strength of Scattered-Radiating Light S_s	W/m^2	$Ss = 0.1S^{\downarrow}$ ($S^{\downarrow}$ shows all incoming light)
	Temp. of Vehicle Tv	°C	$T_v = T_a + 20$ (T_a shows temp.)
	Albedo α	–	0.1
Sensible Heat Flux H	Bulk Coefficient C_h	–	0.003
Latent Heat Flux lE	Bulk Coefficient C_e	–	0.003
	Relative Humanity rh_r	–	0.5
	Atmospheric Pressure P	hPa	1000
Ground Flux G	Heat Conductivity k	W/mK	2.1
	Depth Δz	m	0.05

Accuracy of Calculation:



The accuracy of the calculation (RMSE)

approximately 1.2 degree Celsius

Forecasting Method: *Surface Condition*

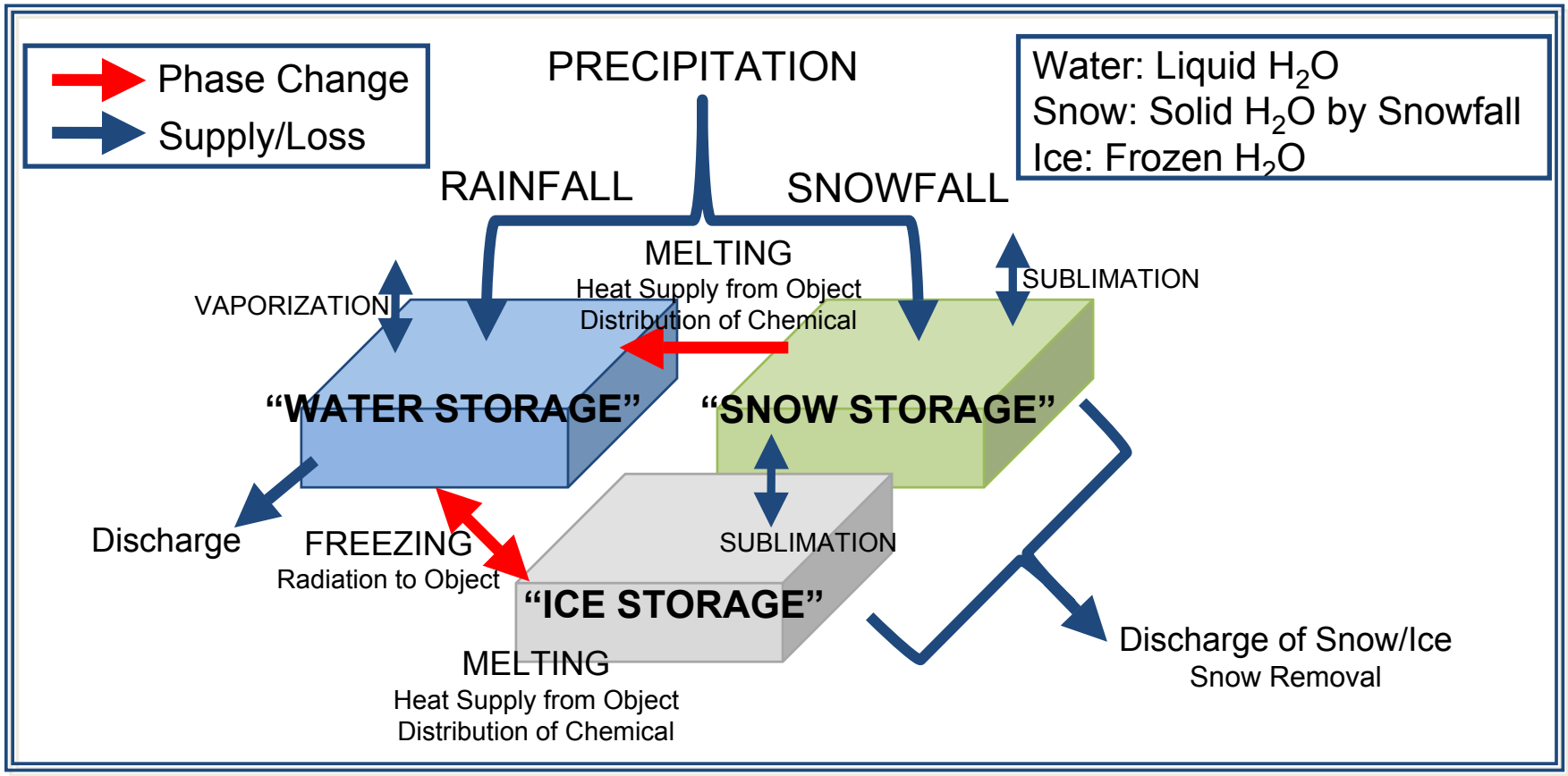
Supply/Loss
Phase Change
} of Water

Water, Snow and Ice Storage

"Road Icing Risk"

High Risk : icy
Moderate Risk : snow or slush
Low Risk : wet or dry

Accuracy ≈70%



Road Surface Condition: Basic Equations

$$\frac{dq_{water}}{dt} = -\tau \cdot \ q_{water} + \frac{M}{L} - \frac{lE}{L_{evap}} + \Pr ec_{water}$$

q_{water}= accumulated water level,
τ= drainage coefficient (0~1),
M= melting (if positive value)/freezing (if negative value) heat transfer,
L= latent heat,
L_{evap}= enthalpy of vaporization,
$Prec_{water}$= rainfall.

$$\frac{dq_{snow}}{dt} = -A\frac{M}{L} - B\frac{lE}{L_{subl}} - \Gamma \cdot \ rm \cdot \frac{q_{snow}}{q_{snow} + q_{ice}} + \Pr ec_{snow}$$

$$\frac{dq_{ice}}{dt} = -(1-A)\frac{M}{L} - (1-B)\frac{lE}{L_{subl}} - \Gamma \cdot \ rm \cdot \frac{q_{ice}}{q_{snow} + q_{ice}}$$

q_{snow}= accumulated level of snow,
L_{subl}= latent heat of sublimation,
rm= snow removal,
$Prec_{snow}$= snowfall, and
A, B, Γ: 0, 1 flags are:

$$A = \begin{cases} 1, & q_{snow} > 0 \quad and \quad M > 0 \\ 0 \end{cases} \qquad B = \begin{cases} 1, & q_{snow} > 0 \\ 0 \end{cases} \qquad \Gamma = \begin{cases} 1, & rm > 0 \\ 0 \end{cases}$$

Process of System Development and Operation:

DATE	ACTION
2004	- Selected a case study route - Began to observe weather and road surface temp. - Developed the model to predict road surface temperature - Evaluated in model verification
Dec. 2005	- Began to operate the system experimentally (Provide text-based information: 1 point)
Feb. 2006	- Displayed the predicted result with the graph - Added the points to predict road condition (1 points to 5 points)
Dec. 2006	- Started the experimental operation of the system with the same interface as the 2005/06 version - Added the study route to predict road condition
Feb. 2007	- Integrated with the existing system used by road authority - Began to provide the route information for the case study route
Dec. 2007	- Started the experimental operation of the system with the same interface as the 2006/07 version - Added the study route to predict road condition
Feb. 2008	- Improved the interface of the map (zooming, dragging) - Added the study route to provide the route information

Discussion with Road Authority:

The system's improvement has been performed from the early stage of the system development since a scheme and an interface desirable for road authority were unknown in advance.

Repeating discussion with road authority and contractors

- Operation cycle/time
- Contents
- Interface
- Operationality etc.

State of Snow and Ice Control Operation

- Schedule and cycle of daily operation
- Goal on operational performance
- Point and section where should be noticed as icy roadway
- Important point and section for anti-icing treatment
- Amount of anti-icing materials and their proper use

Item, Contents and Interface

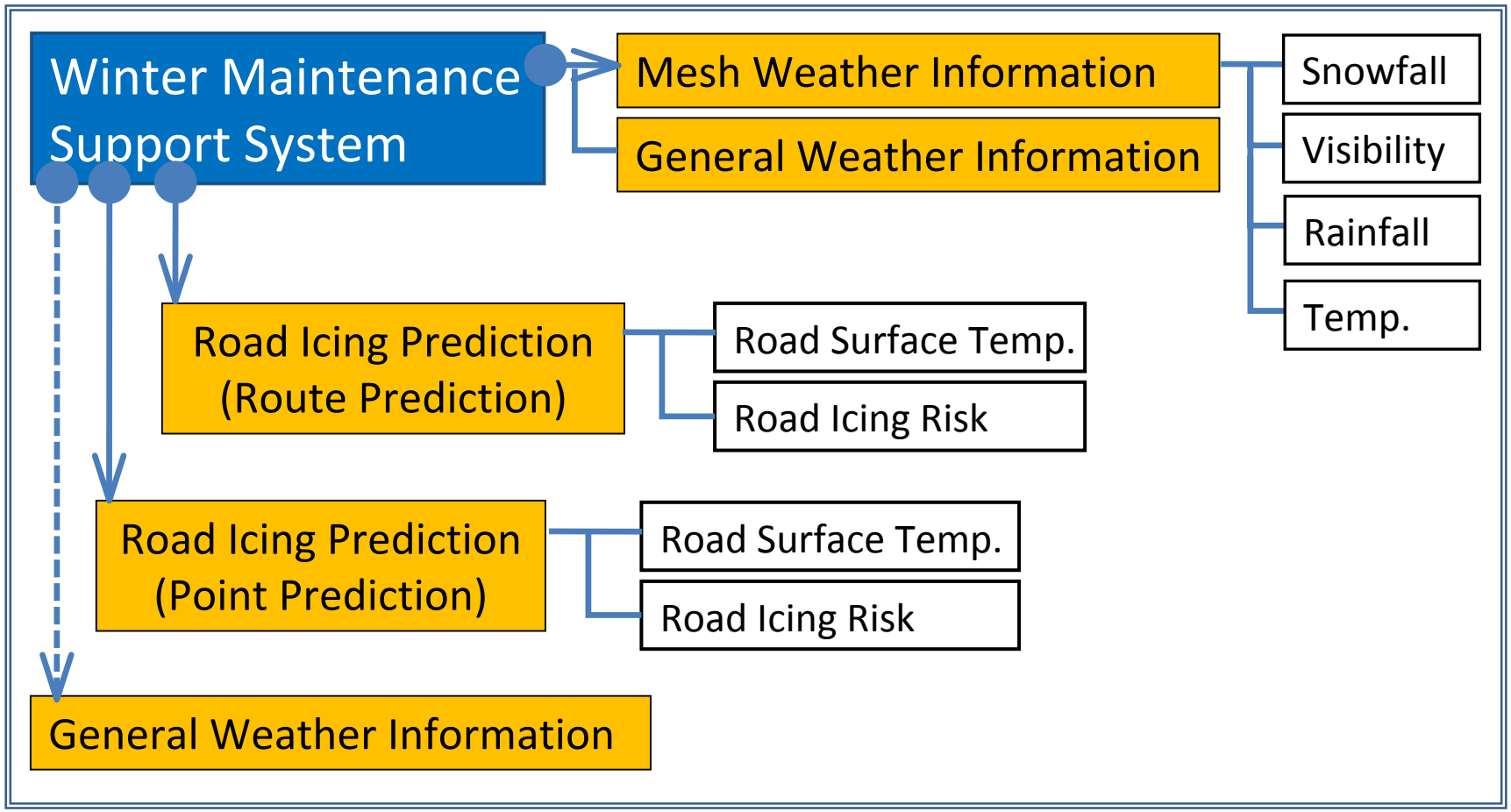
- Appropriate forecast time to provide information?
- Necessary items for information service?
- Suitable classifications for winter road conditions?
- Appropriate display and description on top screen
- Amount of Information displayed on one screen
- Size of screen showing predicted condition at specific point
- Permissible frequency of click
- How to display route prediction
- Request for the existing screen and information
- Request for long-term improvement

SYSTEM'S COMPOSITION AND FUNCTION

Scheme of the System:

The information is roughly classified into two categories;

- ✓ Mesh weather information
- ✓ Road-surface icing information



Top Page and Mesh Weather Information Screen:

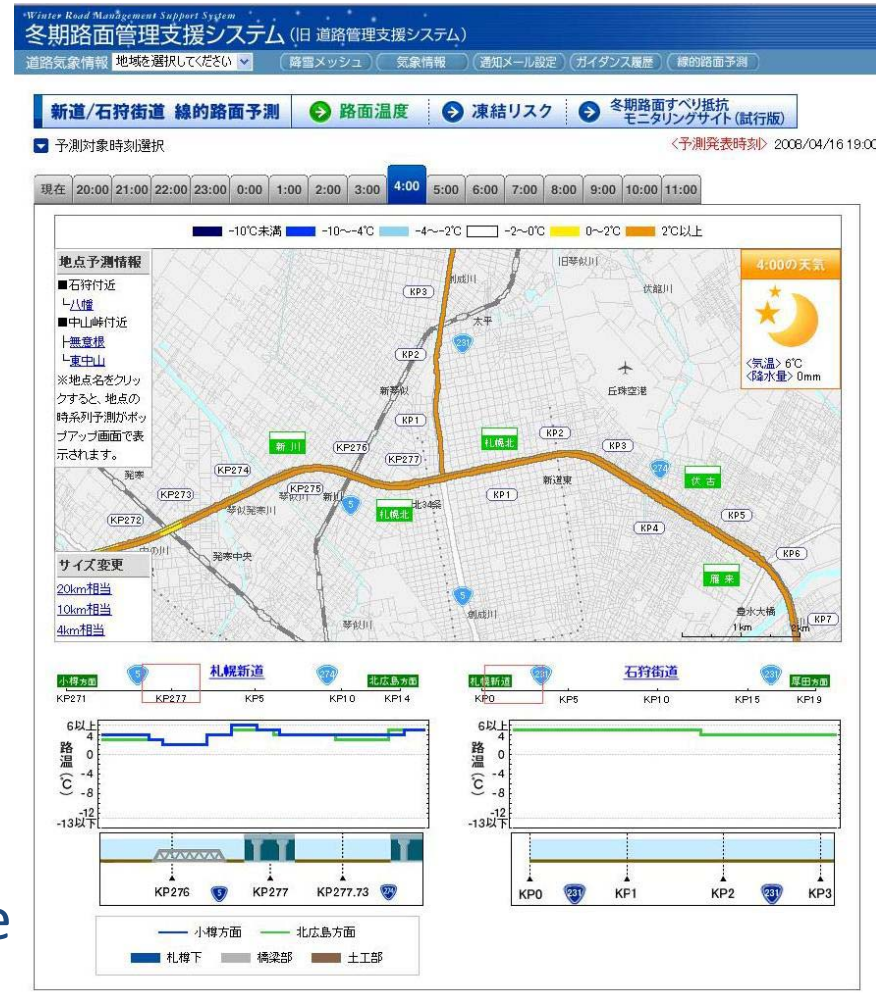
- Integrated with the road authority's existing system according to the opinion from road authority
- Integration is completed to put information together with utilizing the top page of the existing system
- The top page serves forecast information and past data including snowfall, visual range, rain and temp.
- The size of mesh is 1 Km^2
- The information is classified into 5 steps on the basis of the value referred to when road authority works

Road Icing Prediction Screen:

- Moves to the top screen of road icing prediction (route prediction) by clicking a map of the top page or the window beside the map.
- “Route prediction” corresponds to advanced operation such as “spot spraying”
- Two kinds of information
  - Road surface temp.
  - Icing risk information

Road Surface Temp.:

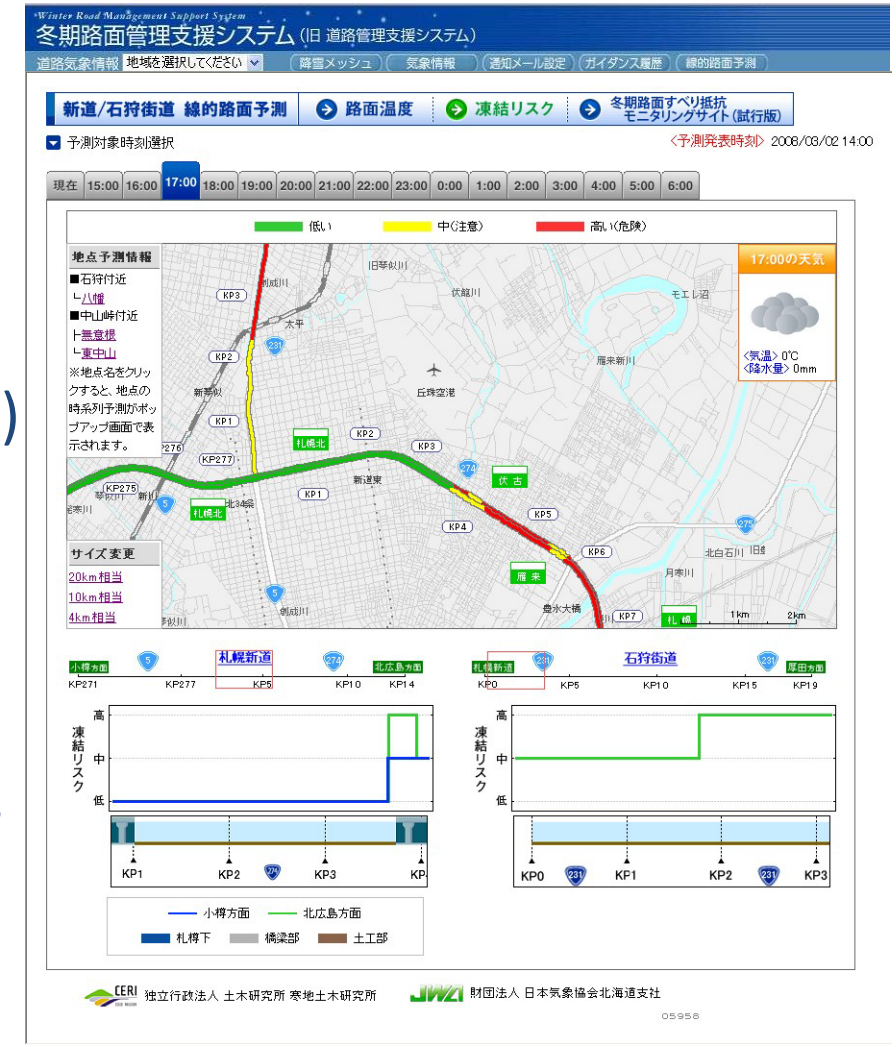
- Road surface temp. is divided into 5 levels in addition to one with 2 degrees Celsius or more
- Indicating 16-hour forecast
- Zoom operation in three steps
- Dragging the map in the window
- Weather information (pictogram, air temp. and precipitation) on the small window



Road Icing Prediction Screen:

Road Icing Risk:

- " Road Icing Risk" is displayed into 3 levels due to road authority's opinion;
  - High Risk (icy)
  - Moderate Risk (snow or slush)
  - Low Risk (wet or dry)
- Indicating 16-hour forecast
- Zoom operation in three steps
- Dragging the map in the window
- Weather information (pictogram, air temp. and precipitation) on the small window



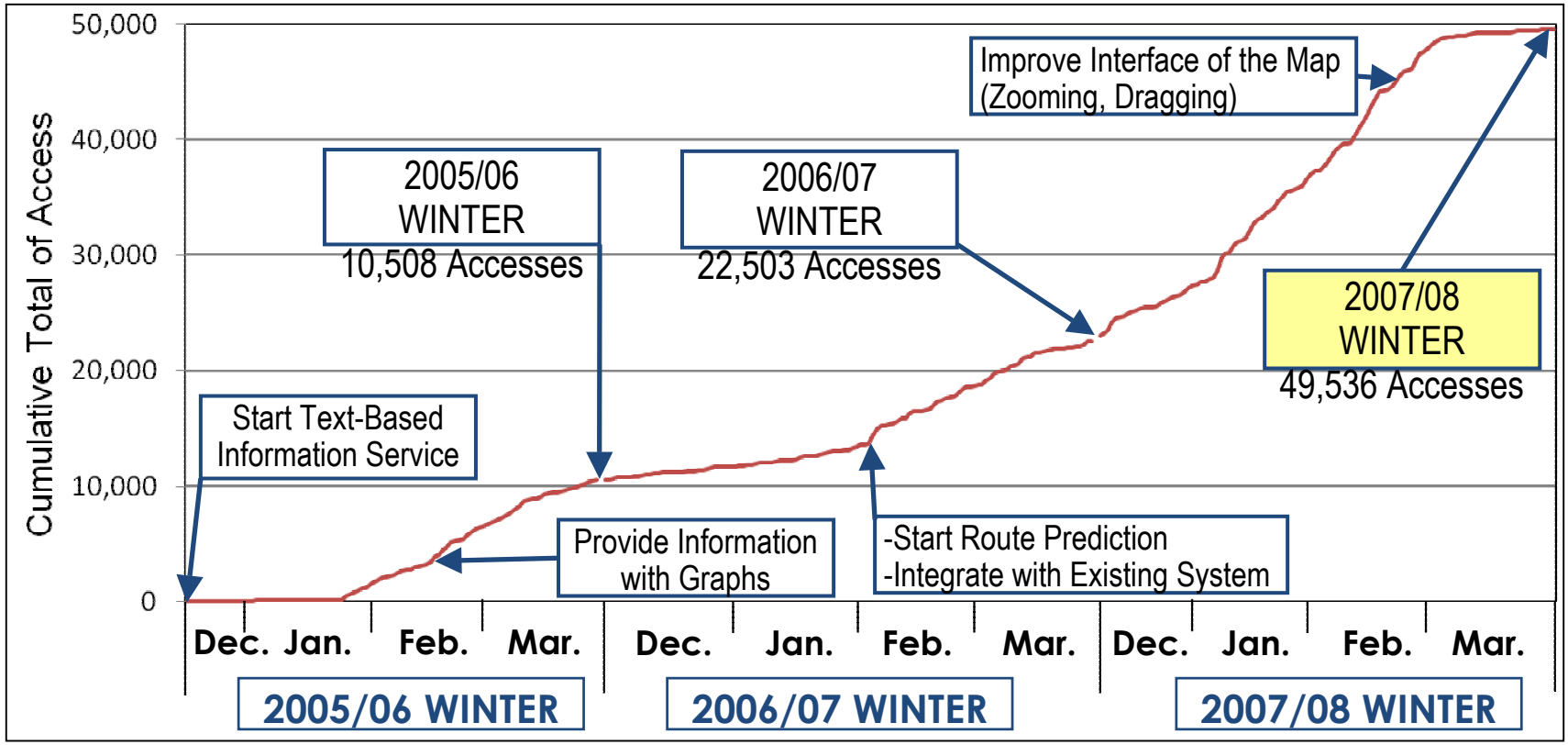
STATE OF THE SYSTEM

Comments on the use of the System:

- ***State of Confirmation***
  - Check the information on the system for every hour when the weather is unstable, especially from 5 p.m. to 8 a.m.
  - Check the information 2 to 3 times a day when the weather is stable.
  - When considering operation plan at night, often confirm the information if evening temperature is less than +1 degree Celsius.
  - Not use the system the other way around as fixing the operational system at the time of storm.
- ***Practical Use for Snow and Ice Control Operation***
  - Use as reference of anti-icing activity.
  - Utilize as a factor which determines time to go on patrol.
- ***Expectation and Direction of Future Improvement***
  - Being desirable for the predicted value of road surface condition after treatment to change by distributing of anti-icing material.
  - Since accountability is further required for operational activities from now on, use positively as reliable source in that case.

Number of Access to the System:

- Started experimental operation in Dec. 2005
- Number of access steadily increased after the end of Jan. 2006.
- Number of access significantly increased in Feb. 2007 after integrated with the existing system and started route prediction
- Number of access reached up to almost 50,000 at the end of Mar. 2008



CONCLUSION

Conclusions & Future Theme:

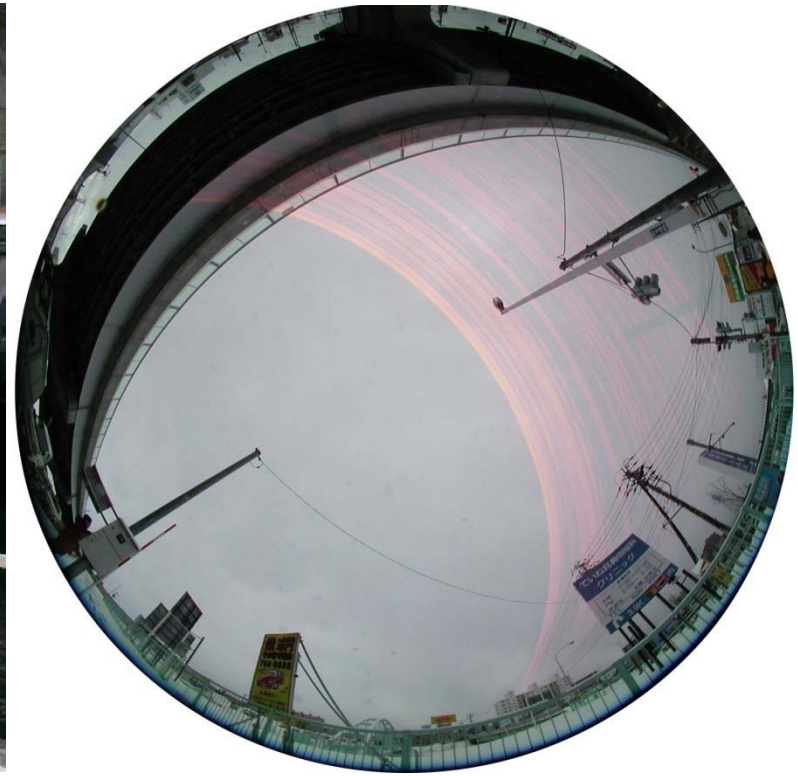
- ***"Winter Maintenance Support System"*** supports road authority's decision-making for snow and ice control operation.
- We would like to improve the system more useful and reliable for road authority
  - *Improve prediction accuracy*
  - *Extend target route*
  - *Utilize Geographical Information System (GIS)*
  - *Add a function which presents proposed measures*

Thank you for your attention!

Naoto TAKAHASHI,
Civil Engineering Research Institute for cold region
-S-I-R-W-E-C-
takahashi-n24k@ceri.go.jp

Measuring Rate of Shielding :

- The rate of shielding was calculated by taking a picture of the sky using a fisheye lens.



Measuring Longwave Radiation:

- Longwave radiation levels were measured by installing a longwave radiation sensor at the study point
- Longwave radiation level data was collected for duration of 45 days from January 25th to March 10th of 2006.

Accuracy of Longwave Radiation Level:

Before Modification: Values calculated by basic model, not taking into account surrounding environment.

After Modification: Values calculated by revised model, which takes into account surrounding environment.

The basic model produced an RMSE of 39.5W/m^2, while the revised model had an RMSE of only 17.8W/m^2