Freezing Forecast System

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Introduction

The Hokuriku region is situated in the Midwest of Japan overlooking the Japan Sea. With an area of approximately 21,000 km^2 and a population of some 4.8 million the region accounts for 5.6 per cent of the total area, and is inhabited by 3.8 per cent of the tctal population of Japan.

In terms of latitude, the Hokuriku region lies on almost the same latitude as the cities of Washington and Athens. However, in winter, there is a seasonal wind which blows across the Japan Sea from Siberia and, warmed by the Tsushima current, rises loaded with moisture. The subsequent cooling and the topography of the mountain ranges combine to result in a region with one of the highest snowfalls in the world. Indeed, despite a fairly high population density of 228 persons/km^2 the cumulative annual snowfall exceeds 20 m in certain places. In the last few years there has been less snow. Even so, in Jouetsu City in the center of the Hokuriku region (population approx. 130,000) a daily snowfall of 70 cm/day was recorded in February this year (1997).

Even in winter the traffic volume, at 8,200 vehicles/day, is 92 per cent of the volume in summer i.e. only slightly down. For this reason we are called upon by both industry and people going about their daily lives to ensure stable traffic flows in winter, regardless of changes in the weather. Another feature of the Hokuriku region is that there is only a short distance from mountainous parts to coastal areas. There are even several places where the mountains run right down to the

coast. This results in sharp changes in the weather and makes uniform winter road management impossible. For this reason we forecast rainfall volumes and freezing start times for the various districts and carry out snow removal and road surface freezing prevention operations in order to support daily life and industrial activity.

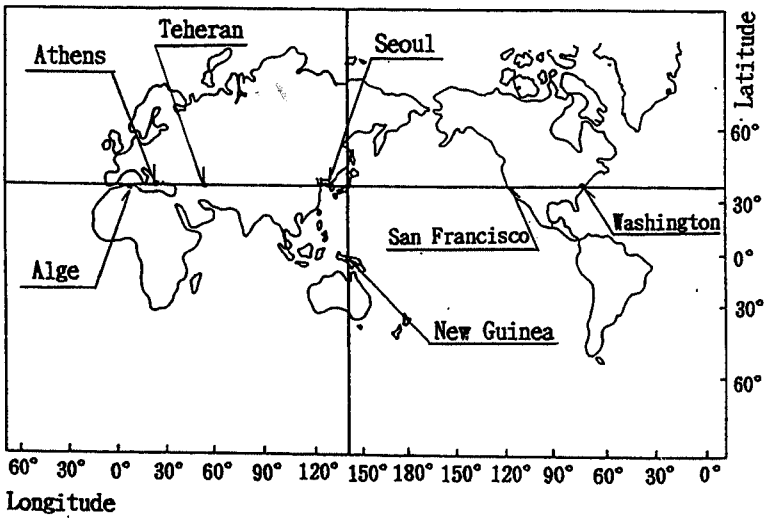


Fig. 1. Hokuriku's position on the world map

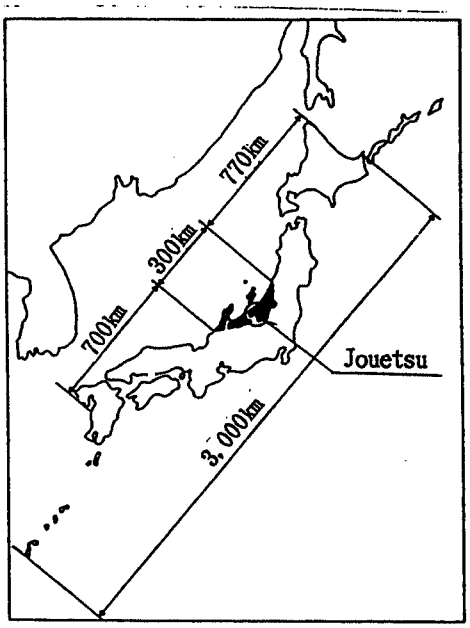


Fig. 2. Hokuriku's position on the map of Japan

1. Outline of freezing forecast system

In making snow removal plans equipment such as snow protection installations and snowplows is important. In addition, in order to remove snow from roads and distribute anti-freezing agents efficiently, weather forecasts concerning how much snow is likely to fall in a particular area at a particular time, whether or not a road is likely to freeze, and other information are also vital.

The road surface freezing and snowfall forecast system is a system which backs up snow removal and anti-freeze distribution operations with systematic information. The system consists of a freezing and snowfall forecast system and a forecast result communication system.

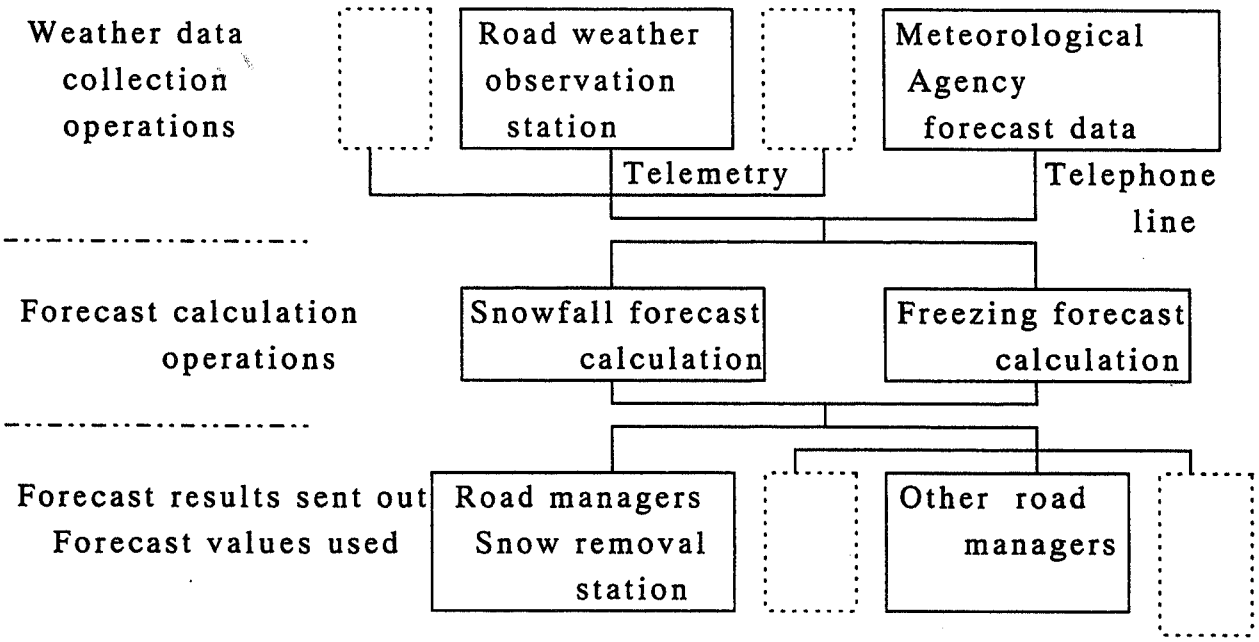
The forecast is made by a statistical method using values from past meteorological observations and results of snowfall and temperature observations.

The forecast uses weather data consisting of ① weather prediction values for the whole of Japan sent out from the Meteorological Agency and ② data observed in real time from various sensors placed along the side of roads by road managers.

The results of the forecast are sent out to road managers and snow removal stations by fax and PC.

The system configuration is as follows :

Freezing forecast system flow chart



2. Weather sensor network and collection of basic data

Data used in forecasts must be available over a wide area around the forecasting base in a short space of time. Data used in the forecast system can be broadly divided into two systems : sensors placed at intervals of 20-30 km along the side of roads by road mangers (temperature, wind direction, wind speed, road temperature, etc.) and data observed by the Meteorological Agency at key points throughout Japan twice a day (at nine o'clock in the morning and at nine o'clock the evening). On the basis of these data the weather situation for the whole of Japan (3-D temperature, wind, pressure, evaporation, etc.) is provided as a numerical weather forecast service.

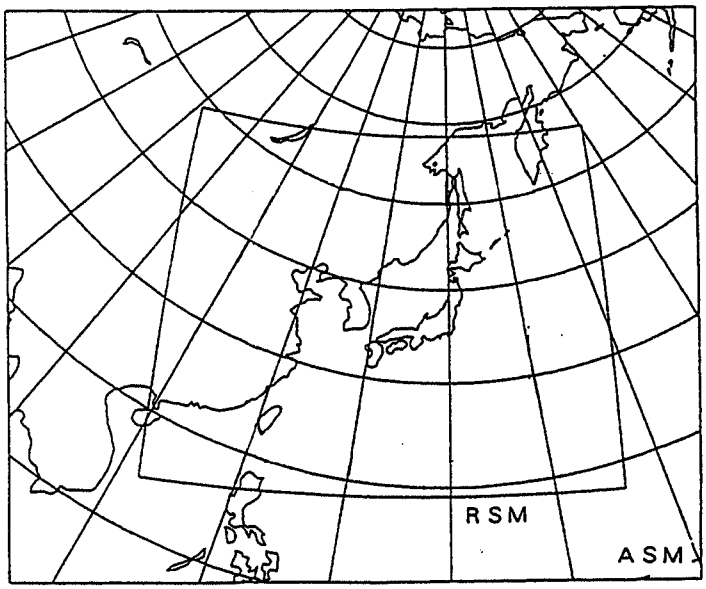


Fig. 3. ASM and new area model in forecast zones

This numerical weather forecast currently uses two models, the Asian model(ASM) and the Japan Zone Model (RSM), as shown in Fig. 3. In our forecast we used the RSM and covered the surrounding sea area including the whole of Japan with a minute 20 km mesh (East-West 15' South-North 12'). In the coastal direction we raised the resolution to 36 classes including 850, 700, 500hPa, and used GPV (Grid Point Value) data which provides a forecast service up to 51 hours ahead.

All these data are available by telephone and we select the data for the point required for the forecast.

Since the most up-to-date data are required for the forecast, data are connected by telephone and telemetry to a PC. Valid points (observation bases) are then extracted from the data to be used for the forecast.

Since topographical factors in the Hokuriku region mean that there are accuracy problems in using the same method we carried out our research on the Jouetsu region, situated roughly in the center of the Hokuriku region, as a case study.

3. Forecast situation and forecast precision

3.1 Road surface freezing forecast

Road surface freezing forecasts predict road surface freezing from the downward trend of road surface temperature, and road surface temperature forecasts are particularly necessary during the time when the air temperature moves from " + " to " − " between evening and morning. For this reason the forecast concentrates on the 16 hours between 5 o'clock in the evening and 8 o'clock the following morning.

In order to forecast the road surface temperature needed for road management the air temperature must first be predicted. The air temperature forecast involves predicting how the present temperature will change. For the change trend we used the GPV land forecast values provided by the Meteorological Agency and made a prediction about road temperature.

To calculate a value for road surface temperature we statistically processed height above sea level and weather data from trends in reflection cooling on the basis of topographical and structural conditions at the site, road position(coast or mountain), and height above sea level, etc.

As shown in the flow chart in Fig. 4, the method predicts how the actual measured data at the site will change by converting the temperature change trend from GPV data into a numerical value.

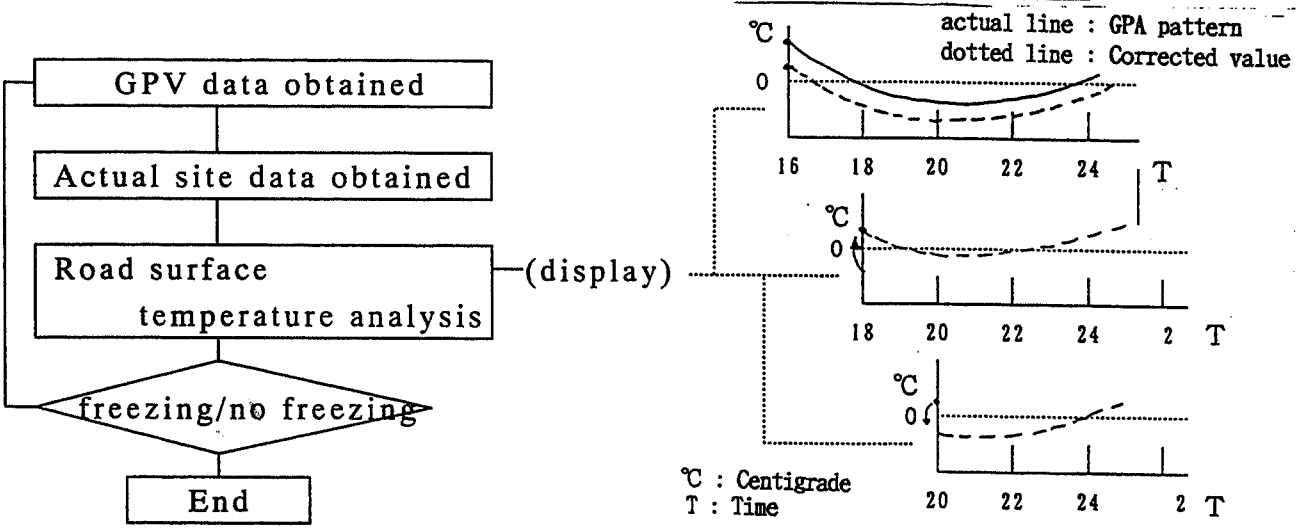


Fig. 4 Road surface temperature prediction flow chart

Since local data is made available every hour, a new forecast result is obtained every hour. In this way the user can obtain the latest forecast values by accessing his server PC every hour.

3.2 Road surface freezing forecast accuracy

Inspections were carried out at points on coastal sections of trunk roads around Jouetsu, namely "Sekikawa Ohashi Bridge" and "Himekawa Ohashi Bridge;" and "Myoko Ohashi Bridge" and "Yashiro Ohashi Bridge" inland. Inspections were based on observation results from sensors (temperature, road temperature, freezing detector) placed on top of the various bridges.

Results of the forecast are shown in Table 1. After one hour the coefficient of correlation was 0.97, with a standard error of 0.7 representing a high degree of accuracy. However, the coefficient of correlation for the forecast 16 hours later
was 0.8 or less with a standard error of nearly 2.0 i.e. accuracy had fallen.

Consequently, a valid system is one which sends actual road temperatures obtained from telemetry to a PC in real time and corrects forecast values.

Table 1. Correlation analysis results for GPV land temperature forecast data and site data

	after 1 hour	after 2 hours	after 3 hours	after 16 hours
Coefficient of correlation	0.97	0.93	0.90	0.78
Standard error	0.70	1.05	1.25	1.73

Inspection results from 1994 data
(1995 inspection results are more or less the same)

3.3 Snowfall forecast

In winter road surface management, information on what time freezing will begin and when snow will start to fall is most important. Snowfall is also an important item since snowfall causes a road surface situation to change rapidly and is strongly linked to freezing predictions.

Below is an outline of our snowfall forecast method.

For basic snowfall data we used the GPV upper air data (850,700,500hPa) provided as a service every three hours by the Meteorological Agency. We compiled a forecast method using 9 points (9 grids) of GPV upper air data for the site on which we wishes to make a prediction.

The forecast method was based on the relationship between GPV data (16 elements x 9 points x 2 hours) and the actual measurement data (snowdrift depth of total snowdrift data) for two years, 1994 and 1995.

The forecast, as shown in the flow chart, predicts snowfall amount (cm/hr) on the basis of the 2-group distinguishing method and the heavy recurrence method.

GPV data was received automatically every 3 hours from NTT and, using a system which outputs forecast results, snowfall strength every 3 hours between 15:00 and 09:00 was calculated and provided as a service in combination with the freezing forecast.

3.4 Inspection of snowfall forecast accuracy

For the inspection of the snowfall forecast value and the actual measurement value we made an internal inspection of the 1995 actual values and showed an example of the results in Table 2. The accuracy rate for snowfall/no snowfall every 3 hours was about 70 per cent in one section during January and February, but the rate for the whole period was 80 per cent or above.

Table 2. Rate of accuracy for snowfall forecast (1995/12- 1996/3)

Month/hours	15:00 -18:00	18:00 -21:00	21:00 -24:00	00:00 -03:00	03:00 -06:00	06:00 -09:00
December	81.3	80.0	86.7	92.6	86.7	86.7
January	79.3	72.4	71.4	96.4	72.4	89.7
February	82.1	82.1	77.8	81.5	84.6	96.3
March	80.0	90.0	100.0	95.0	90.5	100.0
Whole Period	80.6	80.4	82.2	91.0	82.4	93.5

4. Use in Road surface management

Forecast results are sent in the evening of the same day to snow removal stations and the director, on the basis of these results, gives instructions for sending out snowplows and operating personnel. Moreover, when long-term operations are predicted he can arrange for extra personnel to be on standby.

A forecast for the week ahead is also made at the weekend and this is used even while road surface anti-freeze agents are being prepared and machines maintained.

However, local directors get things ready early so that they have time to spare and cannot see the result correlation. This winter we plan to prepare a research format before the event and analyze its usefulness.

Efficient road surface management is possible by establishing before the event, on the basis of forecast results, the right time to spread anti-freeze agents on roads.

5. Information provision system

Forecast results begin each day at 16:00 and at 16:30 they are sent by fax or e-mail to other road managers(prefecture, city, town, village).

In providing forecasts, road managers share forecast details and data about the actual situation in order to improve the contents of the forecast.

6. Future developments

On this occasion we used the Jouetsu area of the Hokuriku region as a case study, but for other areas too, by combining weather sensor data and GPV data, it is possible to forecast freezing with a good degree of accuracy. Discussions are underway in various districts.

In future the system will have to be improved by raising the accuracy in terms of time of issue and amount of information (lowest temperature, snowfall amount, etc.)

At present the forecast service is provided to road managers. However, provision to general road users is likely to come to pass after discussions about improvements in legal system conditions.