Distribution Tendency Of Freezing Index Related To Road Weather In The Northern Districts Of Japan

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1. Introduction

Owing to difficulty of collecting weather data for long period, common freezing index that has been using for road and other constructive design is insufficient because of using short-term data. In consideration of recent road network spread out widely and finely, more accurate freezing index is needed. To this purpose, we treat freezing index derived from long period weather data observed over the half century in the snowy regions in Japan. Besides, recent weather situation is gradually changed, thus the damages due to frost heave action are also changed in the destructions such as paved roads, buried pipes, and various concrete structures.

In this paper, to make more clearer the recent weather situations, long-term data were analyzed using a time series model and a spectral analysis model. Then the regional characteristics of freezing index and their time series tendency will be discussed regarding the distribution law.

2. Analytical Methods of Weather Data

Through the period of December 1950 to March 2001 in every winter season, daily minimum air temperature (T_{min}) was collected whole over the snowy regions, and freezing index (Z_c) of several points was calculated by using Newmann's equation. To all weather data, time series analysis and smoothing method were applied, and then regional characteristics of periodicity of these data were investigated with ARIMA-model. Then the characteristics of distribution of Z_c will be discussed regarding the elevation from the sea level (E_l), maximum freezing index (Z_{max}) and 10-year probability of Z_c (Z_{c10}).

3. Time Series Analysis of Daily Minimum Air Temperature

Figure 1 shows the time series and their spectral analyses of T*min* for three cities, Sapporo in Hokkaido district, Akita in Tohoku district, and Fukui in Hokuriku district. In these figures, solid lines show the smoothing curve of T*min* calculated below. Y-th (Yi) value is decided as follows.

$$Yi = 0.1102(X_{i+2} + X_{i-2}) + 0.2374(X_{i+1} + X_{i-1}) + 0.3048 X_i \qquad (1)$$

Right figures show spectral analyses of T*min* of each left figure. From left figures, we can see that winter temperature is gradually rise up especially after world war Ⅱ. Rising rate of T*min* is larger in the high latitude more than the low latitude, and the steep rising rate were recognized approximately 3 ℃ at Sapporo, 2.5℃ at Akita and 1.5℃ at Fukui within a recent half century. These remarkable winter warming phenomena recognized not only city areas but also isolated areas together.

According to the spectral analyses, most of periodicity peak appeared around the 7 to 9-year and 11- year as is shown in the figures.

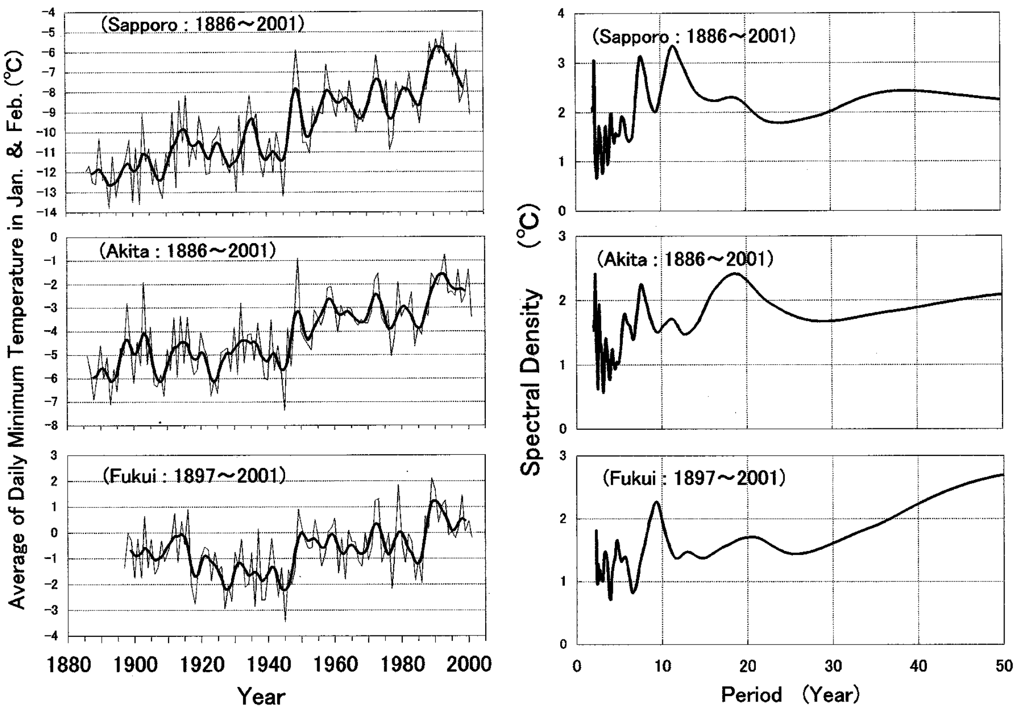

Figure 1. Time series variations of daily minimum temperature (T*min*) in January and February at Sapporo, Akita and Fukui.

4． *Zmax* of Tohoku District

Maximum freezing index (*Zmax*) was solved by using the relationship between maximum freezing depth and freezing index. Figure 2 shows the recent 1-decade *Zmax* in Tohoku district, and the distribution law was found as follows.

$$Zmax = a \cdot ln\,(El) + b \qquad (2)$$

In which, *a* and *b* are the regional coefficients as shown in the figures. The same distribution tendency might be introduced for other districts.

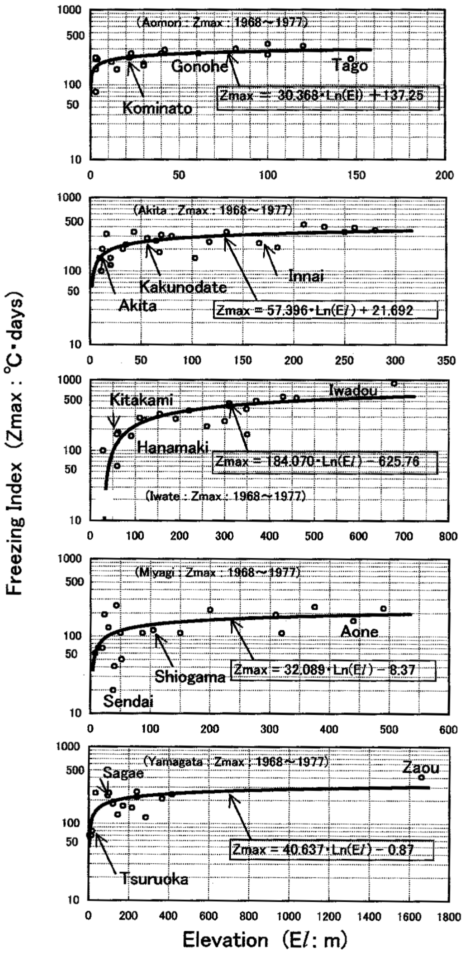

Figure 2 . Distribution law of *Zmax* vs E*l*

5. Distribution of *Zc*$_{10}$

In generally, n-year probability (*Zcn*) of Zc is determined by the following equation.

$$log_{10} Zcn = \sigma \cdot \beta + log_{10} X_0,$$

$$X_0 = log_{10} Xi / k \qquad (3)$$

In which, σ is standard deviation of log_{10} Xi, β is statistic value for *Zcn*, and *k* is sample number. Figure 3 shows the distribution tendency of *Zc*$_{10}$ against the elevation (E*l*) in Hokkaido and Akita prefecture, respectively. The distribution law is same pattern, and Hokkaido is parallel high to Akita prefecture because of its low temperature.

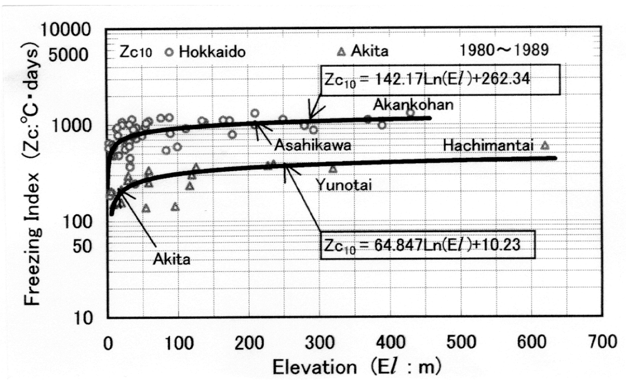

Figure 3. Distribution law of *Zcn* vs E*l*

6. Variations of Z*c*

As is mentioned above, air temperature in winter has been gradually rising up until the present time, therefore, freezing index (Z*c*) is also changed accordance with this phenomenon. Figure 4 (a) shows the time series of Z*c* recorded in January and February for the recent half century in case of Akita and Yokote, Tohoku district. From the latter half of 1970, Z*c* has been decreasing in both cities, and the same tendency was also recognized in other places. Figure 4 (b) shows the spectral analyses by ARIMA-model

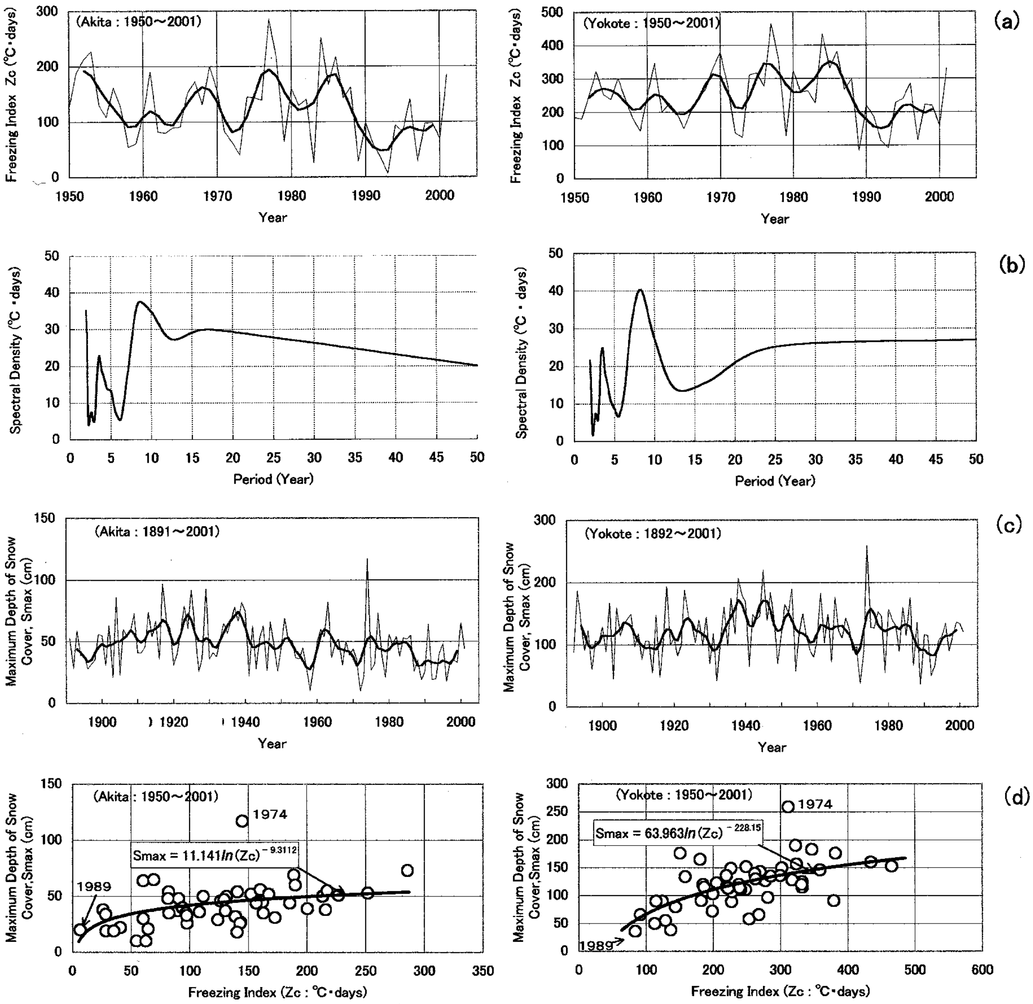

Figure 4. Time series analyses (a) and spectral density (b) of Z*c*, time series analyses of S*max* (c), and the relationship between Z*c* and S*max* (d).

for each Z*c*. Spectral peak appeared around 8-year, and the results correspond to the

T*min* spectral peaks as was already shown in Figure 1. For comparison with snow cover depth, time series data of the maximum depth of snow cover (S*max*) from the beginning of observation to 2001 are drawn in the Figure 4 (c). As is seen from the figure, the largest value was recorded in 1974, however, S*max* is getting decreasing in recent years, and the tendency is very similar to *Zc* variations. Thus the relationship between *Zc* and S*max* was found as is shown below in the Figure 4 (d).

$$Smax = 11.41\ ln \cdot Zc^{-9.3112} \quad \text{for Akita, and } Smax = 63.96\ ln \cdot Zc^{-228.15} \text{ for Yokote} \quad (4)$$

In which, the values of 1974 are out of ordinary due to the insulation of heavy snow that has an warming effect for road ground.

7. Distribution of *Zc* in 2001

In January and February of 2001, we have experienced fairy sever cold winter at several points. According to the weather records, it appeared mainly in the northern part of Japan. Figure 5 shows an example of distribution map of *Zc* of Akita prefecture observed in January and February of 2001. These scores were in generally large 1.5 times compare with recent years, and roughly responded to Zc_{10}. Large *Zc* appeared remarkably in the inland basin and hill sites.

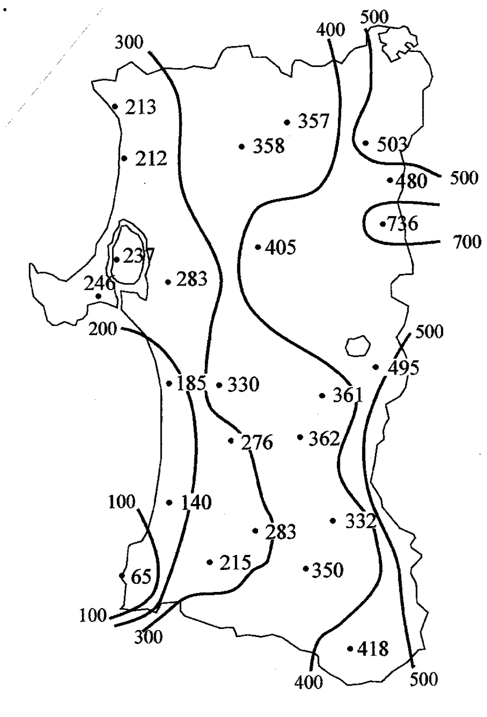

Figure 5. Distribution map of *Zc* in 2001.

8. Concluding Remarks

Using long period weather records in winter, average of daily minimum air temperature (T*min*), freezing index (*Zc*), 10-year probability of *Zc* (Zc_{10}), and one decade maximum *Zc* (*Zmax*) were discussed with elevation from the sea level (E*l*) and maximum depth of snow cover (S*max*). Numerical equations were found between these parameters, and all relationships presented in this paper are all new results, therefore, these analytical data might be useful for road constructive works as new information.