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Environmental Regionality in Hokkaido as Revealed by a Multivariate Analysis of Thermal Climatic Elements

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多変量解析法による熱的要素の分析から見た北海道の気候環境の地域特性

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1. Introduction

1. 1 Purposes of the study

Since the climate is the most important factor which produces environmental regionality over the earth surface, regarding the habitat of living things including human beings, various methods and techniques have been developed for assessing the spatial and temporal variations of regional climate. In studying the regional climate two different viewpoints can be applied, i. e., (1) to elucidate and clarify the mean aspects of climatic elements such as annual or monthly mean temperature, and (2) to clarify the daily or hourly variation of climatic elements. It is important to clarify the mean values of climatic elements because such values determine the overall distribution of fauna and flora. It is also important to clarify the variations of each climatic element in time and space because the magnitude and frequency of variations control the activity of living things.

It is necessary to change the viewpoint corresponding to the size of the study area when the climatic regionality is investigated. For example, in a study area of a continental scale the climatic differences between two subregions are clearly marked from the mean values of climatic elements. However, in a smaller study area, such as Hokkaido or smaller, the differences of mean values of climatic elements between the two subregions usually become small. Furthermore, even if the mean values in the two subregions resemble each other, they are not always

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caused by the same synoptic situations. In spite of this fact, the mean values are used generally in the investigation to clarify the climatic regionality regardless of the size of the study area. However, it is necessary to argue the climatic regionality in a smaller area based on the synoptic causes which form the mean values of each climatic element.

From this viewpoint, the study of Sekiguchi (1959) is thought to be very important. He delineated the climatic regions in Japan based on the similarity of the time variation for some climatic elements. However, in his study the synoptic situations causing the variations of climatic elements were not clarified since monthly mean data were used. Although a smaller time scale should be used in the analysis, some probrems are involved, i. e., (1) synoptic situations causing time variations of each climatic element are not clarified when only the correlation is used, (2) plural components which are contained in data can not be distinguished, and (3) differences of regional characteristics of each climatic element become obscure by the background noises peculiar to each station. To overcome these problems another method is required to enhance such studies.

The purpose of this study is to clarify the environmental regionality in Hokkaido from the analysis of day-to-day variation of some thermal climatic elements in relation to synoptic meteorological phenomena. In this study the methods of multivariate analysis, in particular principal component analysis (PCA) and cluster analysis, are used to cope with the problems mentioned above. In the analysis, the relations between some climatic elements are also examined with the time variation of corresponding distribution patterns.

The study area, Hokkaido is selected from the fact that it is considered to be one region from the meso-scale climatic point of view and its size is suitable for examining the applicability of the methods. In the northern regions such as Hokkadio the thermal climatic elements are the most important factor determining the activity of living things. Moreover, within the size of an area such as Hokkaido the elements in question are expected to show clear-cut regionalities both in space and time.

1. 2 Review of previous studies

PCA, which is often called eigenvector analysis or empilical orthogonal function (EOF), plays an important part in this study. It has been used in the meteorological and climatological studies since the mid-1950 s. The main purposes of such studies using PCA are (1) to select the predictors of future climate, (2) to investigate the climatic variation, (3) to clarify the distribution patterns of climatic elements, and (4) to delineate the climatic regions (Table 1).

Generally speaking, most of these are applied to larger scale phenomena (i. e., hemispheric or continental scale in space and annual or monthly in time) in the case of (1), (2) and (3) except for the studies regarding precipitation. It often results that the physical meanings of the distribution patterns become blurred in such cases. Therefore the regional characteristics of climate are not discussed in detail.

In the case of (4), PCA is used to delineate the climatic regions. Momiyama and Mitsudera (1953) used the factor analysis on monthly temperature in Japan for a particular month to delineate climatic regions. However, the physical meaning of each factor was not discussed in detail, hence the climatic regionalities were not clarified and did not reflect the meteorological phenomena. Kojima (1973) showed the climatic divisions of Japan using PCA the connection matrix of some plural

Table 1. Classification of the previous studies using PCA

1) Prediction of future climate

author	element	study area	data
Lorentz (1957)	SLP	North America	once daily (Feb. 1947–1953)
White *et al.* (1958)	SLP	USA	twice daily (Jan. and Feb. 1948–1955)
Glahn (1962)	PRCP (pl.)	Mississippi Delta	hourly (Jun.–Aug. 1957–1959)
Grimmer (1963)	TEMP	Europe	monthly (1881–1960)
Davis (1976)	SST, SLP	mid-latitude North Pacific Ocean	monthly (1947–1974)
Broccoli and Harnack (1981)	SST, SLP	North Pacific Ocean	monthly (1933–1976)

2) Climate variation

author	element	study area	data
Kutzbach (1967)	SLP, TEMP, PRCP	North America	monthly (Jan. 1941–1965)
Sellers (1968)	PRCP	Western USA	monthly (1931–1966)
Kutzbach (1970)	SLP	Northern Hemisphere	monthly (Jan. and Jul. 1899–1969)
Wright (1974)	PRCP	Southwestern Australia	monthly (1876–1970)
Kidson (1975a)	SLP, TEMP, PRCP	both Hemispheres, tropical belt	monthly (1951–1960)
Kidson (1975b)	SLP, TEMP, PRCP	tropical belt	monthly (1951–1960)
Mikami (1975)	TEMP	Japan	monthly (Jul. and Aug. 1901–74)
Trenberth (1975)	SLP, SST	Australasian area	monthly (1959–1972)
Trenberth (1976)	SLP	Australasian area	monthly (1959–1972)
Barnett (1977)	WIND	Pacific Ocean	bimonthly (1950–1972)
Walsh (1977)	TEMP	Arctic region	monthly (1954–1975)
Klugman (1978)	Palmer Drought Index	USA (upper Mid-west)	monthly (1931–1969)
Johnson (1980)	PRCP	Arizona	seasonally (Jun.–Sep. 1927–1976)
Klaus (1980)	PRCP	Southern Sahara	annual (1934–1973)
Andrews and Diaz (1981)	TEMP	Northern Canada	(past 6000 yr)
Enfield (1981)	WIND	Southern tropical Pacific	monthly (1974–1980)
Kitajima (1981)	PRCP 500 mb height	North America	monthly (Jan. and Feb. 1951–1978)
Rogers (1981)	SLP 500 mb height	Northern Hemisphere	seasonally (1946–1977)

Table 1. (Continued)

3) Distribution patterns of climatic elements

author	element	study area	data
Stidd (1967)	PRCP	Nevada	monthly (1953–1963)
Craddock and Flood (1969)	500 mb height	Northern Hemisphere	daily (1965–1967)
Craddock and Flintoff (1970)	1000 mb height, 500 mb height, 1000/500 mb thickness	Northern Hemisphere	daily (1965–1967)
Yamazaki and Kinami (1977)	PRCP	Kanto-Koshin region	daily (Jun.–Oct. 1974)
Hardy (1978)	WIND	San Francisco Bay area	hourly (1973–1974)
Salinger (1980a)	PRCP	New Zealand	monthly (1951–1975)
Salinger (1980b)	TEMP	New Zealand	monthly (1951–1975)
Akiyama (1981)	PRCP	Niigata Prefecture	daily (Jan. and Feb. 1963–1977)
Pittock (1981a)	PRCP	Argentine and Chile	monthly (1931–1960)
Pittock (1981b)	TEMP	Argentine and Chile	monthly (1931–1960)
Wakamatsu and Hatano (1981)	WIND	Kanto district	hourly (Aug. 1978)

4) Climatic regions

Momiyama (1953)	TEMP	Japan	monthly (1901–1940)
Kojima (1973)	pl.	Japan	monthly or yearly (1931–1970)
Barnett (1978)	pl.	Northern Hemisphere	seasonally (1950–1977)
Kishihara (1978)	PRCP (pl.)	Japan	seasonally or yearly (40–80 years, –1958)

5) Others

Walter and Bryson (1966)*	pl.	Madison, Wis.	hourly (Jan. and Jul. 1954–1959)

* weather classification

SLP: sea level pressure. PRCP: precipitation. TEMP: air temperature. SST: sea surface temperature. pl: plural climatic elements or plural characters of each climatic element.

climatic characters, for example mean air temperature during the warm season, maximum depth of snow cover etc.. Kishihara (1978) also made a survey using factor analysis on eight characters of precipitation such as summer or annual amount of precipitation. Although some meanings of the principal components or the factors were shown in the analyses, they were not so clear. Furthermore, the characters were selected subjectively in this method. This fact shows that the results are often influenced by the nature of data. In these cases, the operation of divisions is taken subjectively, especially with respect to the order of the boundaries or grouping.

Another unique method is proposed by Barnett (1978). In his study the regionalities are shown by the key regions which are defined by the connections with principal components for some climatic characters such as preciptation, 700 mb height and so on. However, these characters are also subjectively selected and the boundaries surrounding each region are not clear.

As has been mentioned, a few studies using PCA have been made to clarify the regionality of climates, and some problems remained in those analyses. The important points of these studies itemized in the following. (1) To clarify the distribution patterns for each climatic element with their corresponding synoptic features (physical meanings). (2) To form the climatic region objectively and to show the physical meanings of the boundaries.

It has become clear that there have hitherto been no studies dealing with the climatic elements with regard to the smaller time variations or corresponding synoptic features to clarify the climatic regionality. In view of this, such a detailed study would be required to clarify the environmental regionality in a smaller area.

2. Methods

2. 1 Data

The study is based on daily data for 1978-1980. The data of sunshine duration and temperature (i. e., mean air temperature, maximum and minimum air temperature) from approximately 140 stations in Hokkaido were extracted from AMeDAS (Automated Meteorological Data Acquisition System) data which were stored on magnetic tape by the Japan Meteorological Agency. The pressure data was taken from the monthly report of the Japan Meteorological Agency.

The missing data were interpolated from the values of three surrounding stations by the method of Suzuki (1968). The missing ratio of the data for each climatic element are shown in Table 1. Since the missing ratios of the data are all less than 0.8% of the total data, the influence of the interpolated data to the results seem to be ignored in the following analyses. The data for 1978 were mainly used for the analyses, and the results were compared with those of other years to examine the appropriateness of the results.

2. 2 Methods of analysis

With due regard to the problems mentioned in the previous section, the methods in the following are used in order to clarify the environmental regionality in Hokkaido. There are three steps in the analysis of each climatic element. The first step is to extract some dominant distribution patterns of daily variability for each climatic element using PCA. In the second step, the corresponding meteorological phenomena which cause each pattern are investigated. In the third step, the climatic regionalities are clarified by means of cluster analysis from factor loadings. The factor loadings are calculated for each station from each eigenvector obtained from the first step.

In the first step, each datum was converted into a deviation subtracted from the areal mean for each day. This process is used so that a particular component which changes seasonally and does not show the regional difference is removed. Especially in the temperature data, such a component occupies more than 95% of the total variance.

In the second step, from the result of PCA, prevailing days for each pattern are selected as the days when the scores of principal component Z_i exceed the particular values. For all of the prevailing days the synoptic situations which cause the distribution patterns of each climatic element are investigated with reference to the pressure patterns, daily weather maps and the scores of the other principal components including those of other elements. In this investigation the number of cyclones and anticyclones are totalized for each domain with 5° latitude $\times$5° longitude from the daily weather charts at 0900 (JST). These are gathered with the type for each prevailing day. This result becomes one of the fundamental data in the examination of the causes of these patterns.

In the third step, regional characteristics of climate are determined in the following manner. Let l_{ij} be an element of eigenvector representing ith principal component at jth station. The factor loadings f_{ij} are calculated as

$$f_{ij} = A_i \times l_{ij}/S_j \qquad (1)$$

where S_j is the deviation of a climatic element (X_j), and the A_i is the eigenvalue corresponding to the ith principal component. Hence the value of f_{ij} indicates the correlation coefficient between Z_i and X_j. Namely, two stations with similar variations of X have similar values of f. Then the cluster analysis is used with the factor loadings in the n-dimentional space where n equals to the number of factor loadings. In the spaces where the stations with similar variations of X are very closely situated, this method is suitable for organizing groups with same climatic regionality. For the calculation, group average method is used from a viewpoint of resemblance between two groups. At each clustering step, the average of factor loadings is calculated for the combined group. These values show the climatic regionality of the group referring to the phenomena corresponding to Z_i. In each clustering step, the distance is comparatively short when small groups are combined, but becomes long when the combined groups are combined again. Then the distance often abruptly changes at any clustering step. The clustering steps with similar distance are defined as "order" (see Fig. 1). These orders show the grade of each group automatically.

The advantages of the methods applied in this study are summarized as follows. First, the noise of the data, such as the background fluctuation peculiar to each station, is removed and the variation of each climatic element caused by the synoptic phenomena is clearly marked. Second, the regional characteristics of the climate with reference to the corresponding synoptic causes can be clarified by the average values of the factor loadings calculated for each group (region). Third, the grade of each group is formed automatically and the boundaries between two groups are also shown with the physical meanings.

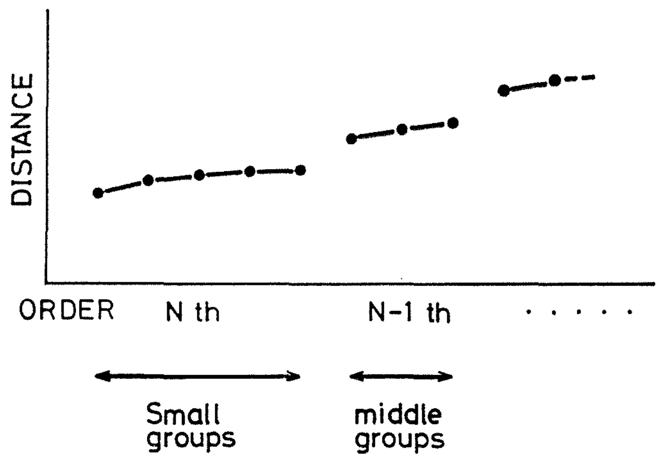

Fig. 1. A schema for the determination of order of clustering regions. See Section 2. 2 for the discussion.

Each climatic element is analysed as shown in Fig. 2, an example for duration of sunshine (DUSS), with consideration to the relation among the other climatic elements. Lastly, the environmental regionality in Hokkaido from the thermal climate is clarified. All the calculations of PCA used in this study depend on the Jacobi method.

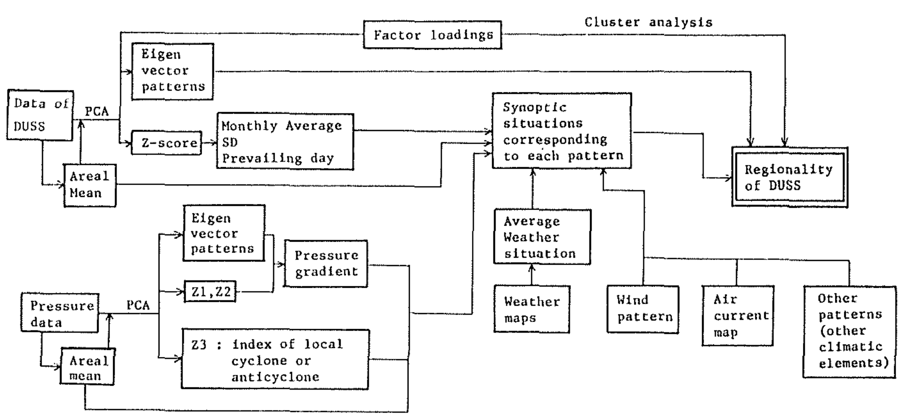

Fig. 2. Flow chart showing the procedures applied in this study, an example for DUSS.

3. Regionality of climatic elements

In this section the regionality (variation type) of thermal climatic elements are clarified using cluster analysis. From the analysis the regions with the same variation types are clarified. Hence, in addition to the description of the features of each region, the physical meanings of the boundary between two regions are discussed. The characteristics of each eigenvector are described minutely in Kato (1983 a).

3. 1 Single climatic element

3. 1. 1 Duration of sunshine (DUSS)

In this case six groups (clustering regions) are formed at the 3rd order. Fig. 3 (a) shows the geographical position of each group. The types of boundary lines shown in the figure correspond to each order. Some of these lines stand for the

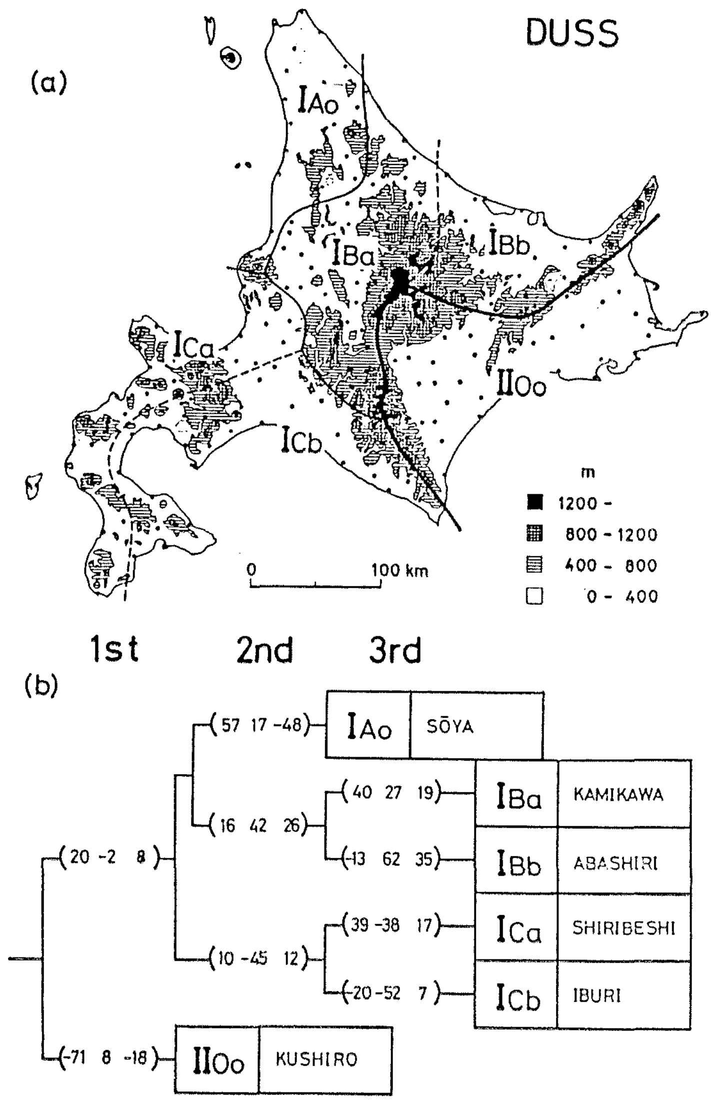

Fig. 3. (a) Regionalization depending upon the clustering of the time variations of duration of sunshine. Boundaries are drawn corresponding to the first order (thick solid line), second order (solid line) and the third order (dashed line) clustering, respectively. (b) Dendrogram of the cluster. The values in the parentheses are the group means of factor loadings (by 100 times) for each station.

transitional zone because these groups are constructed by the clustering method. Each of the groups is named corresponding to all of three orders, [I, II, III, IV], [A, B, C], [a, b], in descending order. If a group does not combine with the other group at a certain order, the character "0" is used at the order. The boxes in the dendrogram of Fig. 3 (b) show the name of each group and its geological name. The values in the parentheses are the group means of the factor loadings (by 100 times) for each station. For each group, one or two factor loadings with great absolute values are selected and are translated into the actual meteorological phenomena through the eigenvector pattern and its feature (Kato, 1983 a). The values of the factor loadings show the main cause of the variation of sunshine duration for each group.

The regionalities depending on the variations of sunshine duration are described in the following.

IAo ; Japan Sea side type. In winter sunshine duration tends to decreases due to the snow clouds. On the other hand, in summer it increases except for the days with the influence of a cyclone passing through the northern side of Hokkaido.

IBa ; Japan Sea side — Okhotsk Sea side type. Regional characteristics of both IAo and IBb are involved. Since the strength of the winter monsoon or the Okhotsk high governs the extends of the cloud, this area shows the features of a transitional zone.

IBb ; Okhotsk Sea side type. Sunshine duration has a large day-to-day variation in particular during the warm season. It decreases by the influence of the Okhotsk high or the cyclone over the eastern side of Hokkaido.

ICa ; Dōnan — Japan Sea side type. Sunshine duration has a large day-to-day variation during the warm season, but changes in the reverse phase of the variation in IBb. Sunshine duration decreases by the influence of the front or cyclone passing through the southern side of Hokkaido. In addition to these features of Dōnan side the weak characters of IAo are included.

ICb ; Dōnan — Pacific side type. The regional characteristics of Dōnan side is more prominent than those of ICa. The weak features of IIOo are shown because this region is often covered by sea fogs in summer.

IIOo ; Pacific side type. Sunshine duration decreases in summer by the influence of sea fogs or a cyclone passing through the southeastern side. A comparative increases of sunshine duration is seen in winter.

The most notable feature is that the southeastern side of Hokkaido has fairly specific regional properties (variation type) of DUSS in comparison to the other regions. This is caused by the fact that the Hidaka Mountains and the Akan -Shiretoko Mountains play an important role as a boundary of clouds both in winter and summer. These boundaries are clearly marked by the first eigenvector pattern of DUSS.

The boundaries between the northwestern side and the Okhotsk Sea side are not distinct in Fig. 3 (a). This fact indicates that the Kitami Mountains does not act as a clear boundary for the DUSS patterns. However in winter it often acts as a barrier for the snow clouds under some particular general wind directions, and a weak boundary (transitional zone) exists here.

The boundaries of the Hidaka-Yūbari-Mashike Mountains shown here are found in the second eigenvector pattern if the isoplethes are drawn at every 0.01. This line indicates the limit of the cloud regarding the cyclone or the front.

It is worthy of note that both ICa and ICb has the same Dōnan regional characteristics of DUSS and are distinguished by the sub-features of the Japan Sea side and the Pacific side. The boundary between them is very weak or has a character of a transitional zone.

3. 1. 2 Maximum air temperature (MXTP)

Eight clustering regions are formed at the 3rd order in this case. The geographical position of each group and the dendrogram for each order are shown in Fig. 4 (a) and (b), respectively. The regionalities depending on the variation of maximum air temperature are described in the following.

IAo ; Japan Sea side type. Maximum air temperature is suppressed by the wind cooled by the sea when the southwesterly general wind prevails in summer.

IBa ; Western Pacific side type. In summer the maximum air temperature becomes lower by the influence of SST or sea fog under southerly general wind.

IBb ; Eastern Pacific side type. The regionality (variation type) is analogous to that of IBa. Especially the effect of sea fog is very large. Furthermore, the decrease of sunshine duration by the influence of the cyclone passing through the southeastern side causes the decrease of maximum air temperature in summer.

IIAo ; Okhotsk Sea side type. The influence of SST is comparatively small due to the southerly general wind in summer. The Okhotsk high with northeasterly wind reduces the maximum air temperature in early summer.

IIBo ; Kamikawa inland area type. The maximum air temperature rises under the summer pressure pattern (the Ogasawara anticyclone to the southern or the southeastern side with the cyclone to the northern side of Hokkaido).

IICo ; Sorachi inland area type. The influence of the Okhotsk high with cool wind is very small, and the maximum air temperature is comparatively high under this weather system.

IIIOa ; Kushiro inland area type. The maximum air temperature falls according to the decrease of sunshine duration when a cyclone is passing through the southeastern side of Hokkaido in summer. The maximum air temperature rises with a weak surface wind under the southwesterly general wind, but is reduced by the influence of sea under the southeasterly general wind. This area is considered to be the transitional zone from IBb to IIIOb.

IIIOb ; Tokachi inland area type. The maximum air temperature rises when the general wind is southewesterly in summer. Furthermore, the temperature is comparatively high under the influence of the Okhotsk high.

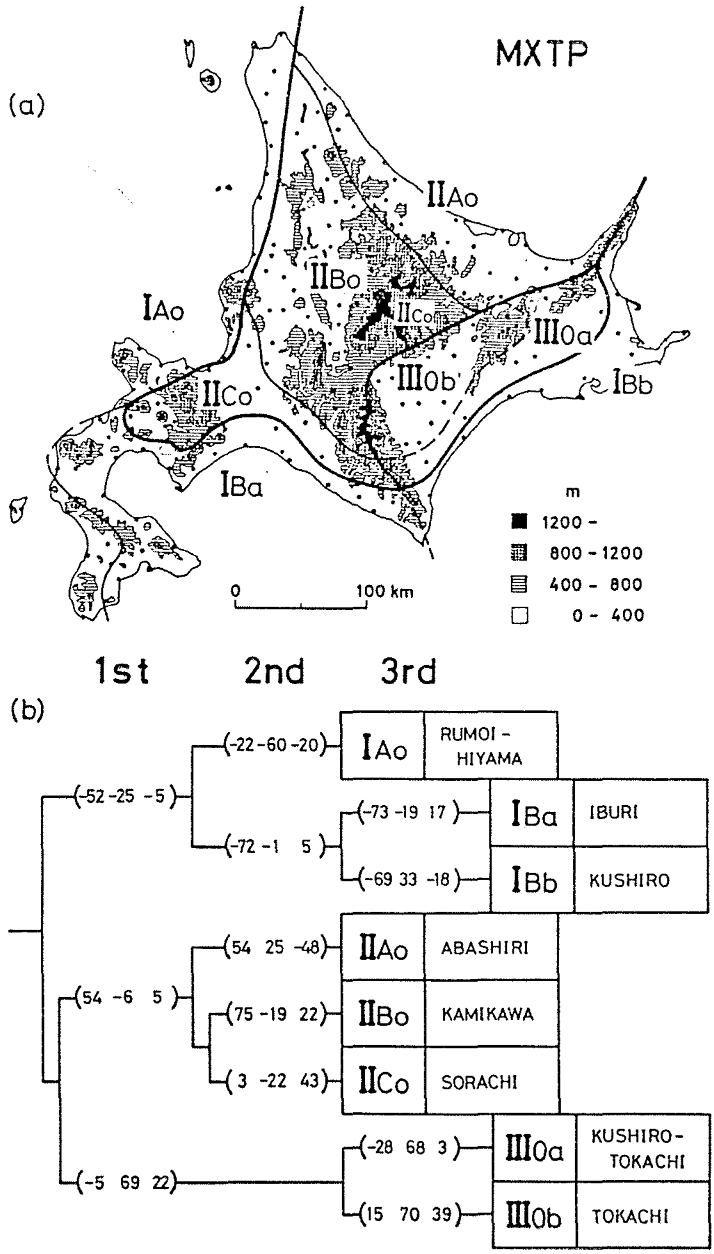

Fig. 4. Same as Fig. 3, except for MXTP.

As for the variation of maximum air temperature, the difference of the regional properties (variation type) between the inland and coastal areas (which corresponds to the first eigenvector pattern) is the primary feature. As is evident from Fig. 4 (a), boundaries parallel to the shore are comparatively clear. These boundaries mainly show the average line of the limit of the influence of the sea.

The boundary along the Hidaka Mountains is clearly marked, but the Akan

-Shiretoko Mountains does not act as a clear boundary. However, the weak boundary is shown along the latter mountains because it acts as a weak boundary in the first eigenvector pattern.

In summer the main direction of general wind is southerly, thus the area of IBa and IBb are always influenced by the SST. On the other hand, the Okhotsk Sea side (IIAo) shows very little effect of the sea on account of this general wind, except under the influence of the Okhotsk high. Furthermore, the western side (IAo) is influenced by the SST under the southwesterly general wind. It is interesting that the coastal area is distinguished by the variations of the maximum air temperature (or corresponding synoptic situations).

The patterns of maximum air temperature in the inland area varies according to the general wind direction. These variations may be well explained by the air current systems. Namely, under the southeasterly or the southwesterly general wind, the surface wind speed decreases and the maximum air temperature rises in IIBo or IIIOb, respectively. On the other hand, in IICo the clear air currents exists under the southeasterly and the southwesterly general wind, but the wind are weak under the influence of the Okhotsk high (northeasterly wind (see Kato, 1983 b)). Especially, the boundary between IIBo and IICo is drawn connected with the first eigenvector pattern. This line also corresponds to the boundary on the pattern of wind speed (Kato, 1982).

The regionalities of maximum air temperature are governed by the wind speed, the effect of the SST and the cloud patterns (DUSS patterns).

3. 1. 3 Minimum air temperature (MNTP)

Seven clustering regions are formed at the 3rd order in this case. The geographical position of each group and the dendrogram for each order are shown in Fig. 5 (a) and (b), respectively. The regionalities depending on the variation of minimum air temperature are described in the following.

IAo ; Okhotsk Sea side — East Pacific side type. In winter the cooling effect is comparatively weak by the influence of the sea. On the other hand, the minimum air temperature is reduced by the influence of the Okhotsk high in summer.

IBo ; Dōnan sea side type. The warming effect of the sea on the minimum air temperature is most notable all over the Hokkaido in winter.

IIOa ; Sōya inland area type. The minimum air temperature is often prevented from decreasing by the influence of snow cloud in winter and by the warm onshore southwesterly wind related to the travelling anticyclone in spring and autumn. The cooling effect of the Okhotsk high is often seen invading here.

IIOb ; Kamikawa inland area type. Minimum air temperature drops by radiation cooling when the pressure gradient is gentle after a winter monsoon. When the general wind direction is westerly in winter, the temperature is comparatively mild due to the snow clouds.

IIIAo ; Sorachi-Shiribeshi inland area type. Spring and autumn show a decline in minimum air temperature by the radiation cooling under the travelling anti-cyclone. The decrease of minimum air temperature is not pronounced in winter compared with the other inland areas.

IIIBa; Tokachi-Abashiri inland area type. When the pressure gradient is gentle in winter, the minimum air temperature falls. Furthermore, under the westerly winter monsoon the minimum air temperature also drops with a weak wind speed. But under the northwesterly general wind it does not drop by the increase of surface wind speed.

IIIBb; East Pacific side type. In winter the temperature is comparatively mild

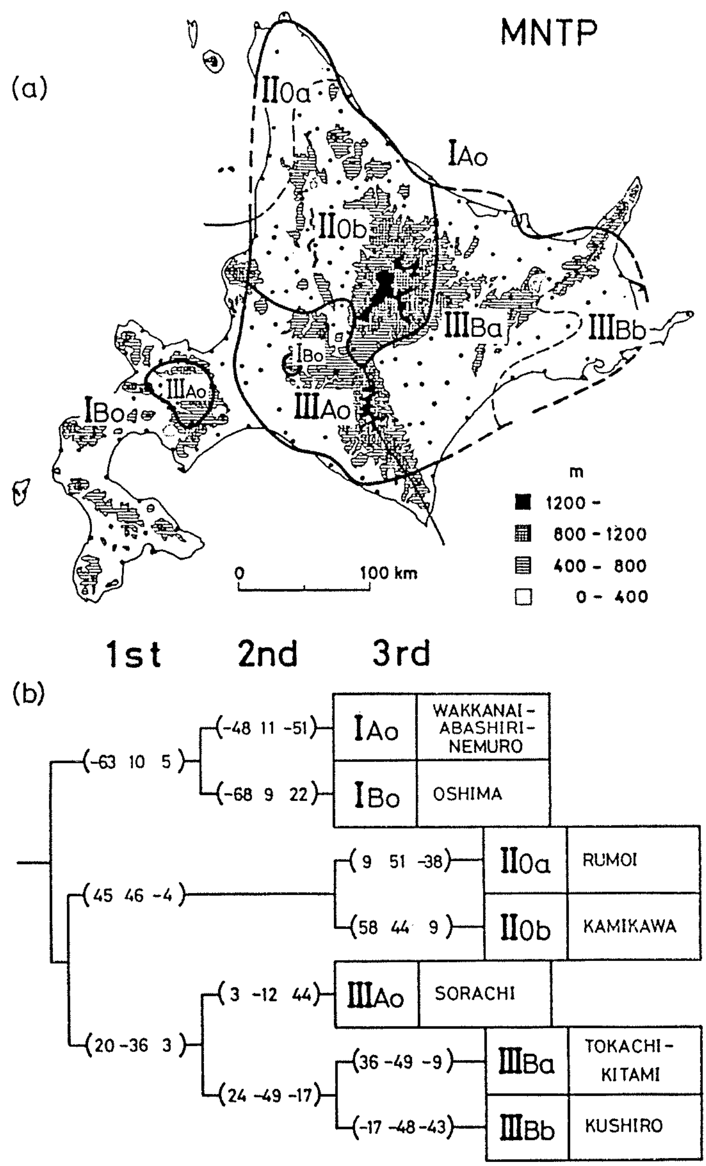

Fig. 5. Same as Fig. 3, except for MNTP.

by the influence of sea or by the wind when the general wind is northwesterly. On the other hand, the temperature tends to become lower under the influence of the Okhotsk high in summer.

Regional characteristics with time variation of minimum air temperature resembles these of maximum air temperature, namely, the inland area is distinguished from the coastal area primarily. However, the clustering regions situated near the sea side are very narrow in shape, and this fact seems to show that the influence of the sea to the MNTP pattern is weaker than that to the MXTP pattern.

Minimum air temperature patterns are more apt to be influenced by the wind than the pattern of maximum air temperature. This tendency is increasingly clear in the inland region. For example, the boundary between the region II and the region III in Fig. 5 (a) is related to the second eigenvector pattern, i. e., the case under the westerly or southwesterly general wind. It is interesting that such a boundary closely resembles that in the pattern of AVWS (daily mean wind speed) (Kato, 1982). Furthermore, the region IIOa is distinguished from IIOb by the feature under the strong southwesterly general wind. IIIBb is also characterized by the northerly wind, whose boundary in inland resembles the isoplethes on the pattern of AVWS ($Z3$) of Kato (1982). The Hidaka Mountains become a weak boundary which distinguishes the air current system in the case of an easterly flow.

The minimum air temperature patterns are mainly controlled by the wind distribution pattern. As a result, the mountains, which govern the sunshine duration patterns, slightly act as boundaries. Fig. 5 (a) results in a resembling pattern to that of AVWS. However, these boundaries are not clear and form the transitional zone.

3. 1. 4 Daily mean air temperature (AVTP)

Seven clustering regions are formed at the 3rd order in this case. The geographical position of each group and the dendrogram for each order are shown in Fig. 6 (a) and (b), respectively. The regionalities depending on the variation of daily mean air temperature are described in the following.

IAa ; Japan Sea side type. In winter the mean air temperature is comparatively mild by the influence of the sea under a westerly general wind. On the other hand, summer is subject to a decline in the maximum air temperature by the onshore wind when the general wind is southwesterly.

IAb ; Okhotsk Sea side type. The effect of the sea on the mean air temperature is smaller than that of any other sea side area. Especially in summer the maximum air temperature is hardly influenced by the sea under the southerly general wind, except for the weather regime with the Okhotsk high when this area continues to have low air temperature throughout the day.

IBa ; Oshima sea side type. The air temperature is the mildest in Hokkaido by the influence of the sea. The annual range of air temperature is small.

IBb ; East Pacific side type. The sea effect is as large as that of IBa. In summer

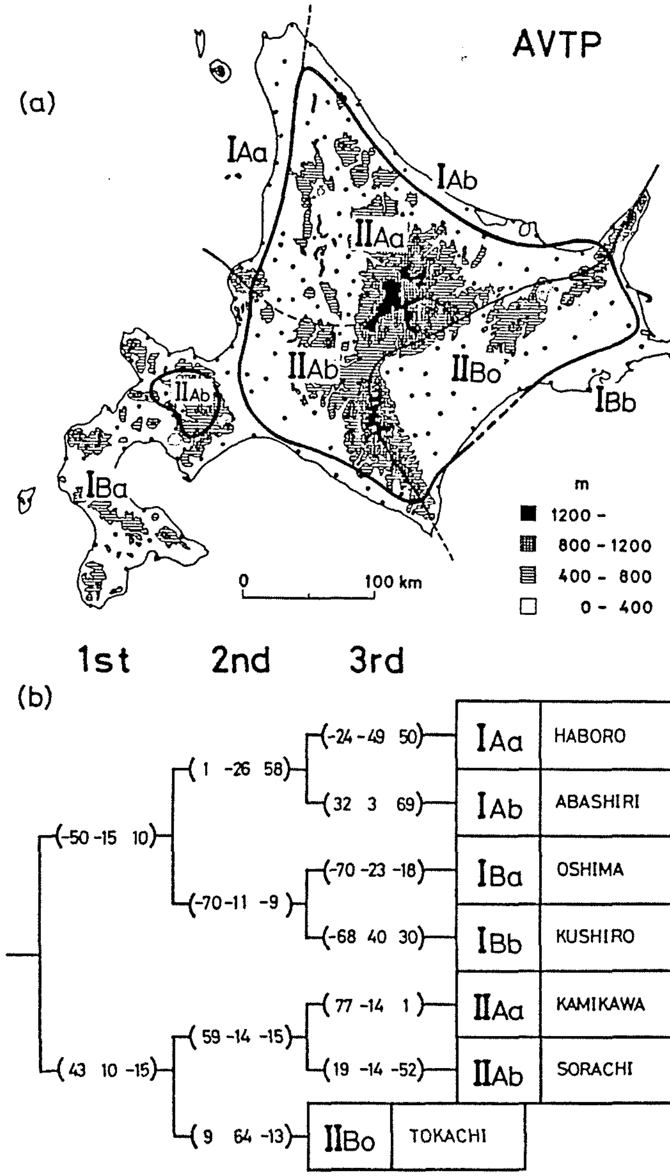

Fig. 6. Same as Fig. 3, except for AVTP.

the maximum air temperature falls by the influence of the sea fog or a cyclone passing through the southeastern side of Hokkaido.

IIAa ; Kamikawa inland area type. The maximum air temperature rises under the influence of the Ogasawara anticyclone in summer, and the minimum air temperature falls under a gentle pressure gradient after the winter monsoon. These tendencies are clearly marked and the annual range of temperature is great.

IIAb ; Sorachi inland area type. The regionality (variation type) as an inland area is weaker than that of IIAa. The radiation cooling is notable during the night in spring and autumn under the travelling anticyclone.

IIBo ; Tokachi-Kushiro inland area type. In winter the minimum air temperature drops comparatively with a weak wind under a westerly general wind. The maximum air temperature falls by the sea fog under the southeasterly general wind or by the influence of a cyclone passing through the southeastern side, and it increases under the southwesterly general wind by the Ogasawara anticyclone.

These clustering regions are analogous to those both of MXTP and MNTP in some parts, and the contrast between the inland and the coastal areas is also the primary feature. Furthermore, the boundary between these two areas clearly exists.

Although the IIBo has an inland regionality (variation type), the maximum air temperature which tends to be influenced by the sea in summer distinguishes this area from the other inland areas. IIAb is also characterized with the exception of the fact that the radiation cooling prevails during the night under the travelling anticyclone in spring and autumn.

Some boundaries in Fig. 6 (a) resembles those of MXTP and MNTP (Figs. 4 (a) and 5 (a)) from the position and the significance of them, for example, the Hidaka Mountains provides a comparatively clear boundary. On the other hand, the boundary situated parallel to the east of Kitami Mountains in Fig. 5 (a) disappears in Fig. 6 (a). This is because this boundary is not clear but is merely a transitional zone. In other words this boundary drifts through the day according to the variation of wind system, and becomes increasingly obscure in its position in the daily mean temperature pattern.

3. 1. 5 Discussion and comparison with the previous climatic divisions

In the previous sections it was pointed out that some distribution patterns (or boundaries) of climatic elements resembles those of the other elements. These similarities of boundaries are discussed again corresponding to the weather regimes, and the thermal climatic features are described.

Compared to each clustering regions the most notable boundary exists along the Hidaka Mountains. It plays an important role as a barrier against the low level clouds under a easterly or southeasterly wind. As a result of this, analogous distribution patterns are formed, for example, with DUSS and MXTP.

In the some manner the Akan-Shiretoko Mountains become a barrier of clouds both from the Pacific side and from the Okhotsk Sea side. However, since these mountains are lower than the Hidaka Mountains, the barrier effect against the clouds is weak. In addition, this mountain ranges does not play a role as a boundary in the distribution patterns of minimum temperature. It indicates that this boundary is weak from the viewpoint of the variation of thermal climatic elements.

The boundary line along the Hidaka-Yūbari-Mashike Mountains appears in all figures although it is slightly different from each other in its position. This line has an important meaning as the cloud limit for the pattern of DUSS. It also appears in some temperature patterns. For example, the pattern of MXTP has such a weak boundary, and it often occurs corresponding to this cloud pattern. Furthermore some wind patterns change near this line. Although this line is obscure to some degree in its position, it is an interesting and important boundary.

The other boundary exists along or parallel to the Kitami Mountains. It plays a role as a barrier of snow clouds or winds under the westerly general wind but does not under the northwesterly wind. Furthermore, since these mountains are not high, the wind often flows over or around the north of the mountains. Namely, this boundary has the features of a transitional zone, and its position is not fixed. However this boundary (transitional zone) is important for the temperature patterns, especially in MNTP.

The boundaries which distinguish the inland and the coastal area are clearly shown in the temperature patterns, and they correspond to the average of limit of the influence of the sea. These boundaries exist far from the shore line in the MXTP pattern as compared to the MNTP pattern. It indicates that the sea effect has a stronger invasion in the MXTP pattern than in the MNTP pattern.

The sea effect is comparatively small near the Okhotsk Sea side under the southerly prevailing wind in summer, so this area is distinguished from the other sea side areas. Similarly, the western shore of Hokkaido tends to be influenced by the sea under the southerly or the southwesterly general wind in summer. Hence, the northern Japan Sea side of Hokkaido is characterized especially by such a feature judging from the wind system. The sea effect near the southern coastal area includes the influence of sea fog. Especially this sea fog is heavy in the southeastern coastal area of Hokkaido. The boundary in this area may correspond to the average limit of this fog.

Hence, these features obtained here are compared with the climatic regionalities of some previous studies. Strictly speaking, it can not be discussed in detail because of the difference with 1) the kind of climatic element and 2) the period of the data used in each analysis. As a result, although the minute comparison is not taken here, it is worth while to discuss the climatic regionalities from a different viewpoint. Furthermore, from these discussions the regionalities (variation type of climatic elements) found in this study are examined again.

First, the regional characteristics of sunshine duration (Fig. 3) are compared to the climatic divisions of Sekiguchi (1959) which refers to the percentage of possible sunshine (Fig. 7 (a)). Although the results are very similar to each other, the southwestern side of the Hidaka Mountains is regarded as a transitional zone in his study. This feature is explained by the fact that the clear boundary in each distribution pattern tends to become obscure in the monthly averaged data. It is also due to the fact that the stations are far removed from each other, i. e., the correlation coefficients become small. However, from the viewpoint of daily variation of sunshine duration, the Hidaka Mountains play a role as an important boundary

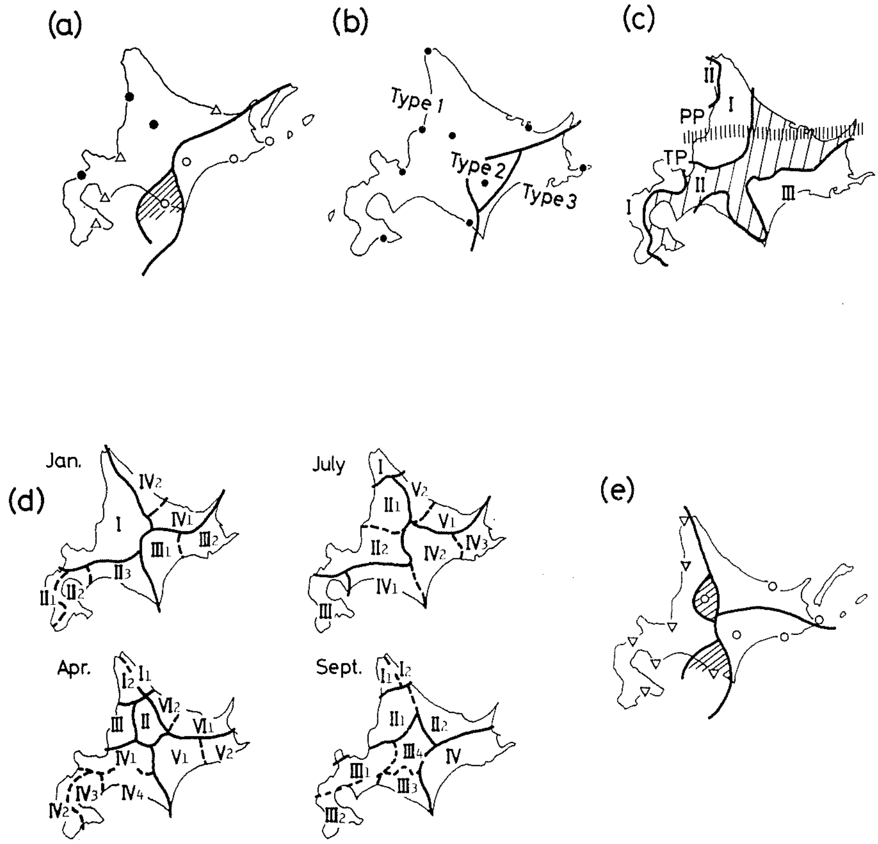

Fig. 7. Climatic divisions of Hokkaido depending on the characteristics of the particular climatic element of (a), (e) Sekiguchi (1959), (b) Hoshino (1970), (c) Suzuki (1962) and (d) Kawamura (1962). See the text for detail.

for the cloud pattern. This is also supported by the climatic divisions by Hoshino (1970) (Fig. 7 (b)) which are based on the use of the entropy of the weather.

Then some climatic divisions depending on the precipitation data are shown as a simple approach. It is interesting that the climatic divisions shown by Suzuki (1962) (Fig. 7 (c)) resembles Fig. 3 (a) (i. e. [PPI] and [TPIII] correspond to IAo and IIOo, respectively). This result also indicates the existence of a transitional zone between them. However, in some parts the boundaries are not similar to each other because of the difference of the data (i. e. cloud pattern and precipitation pattern). Hence, the southern boundary of IAo also seems to be influenced by the topography shown by Kushizaki *et al.* (1965).

The Hidaka Mountains and the Akan-Shiretoko Mountains act as an important boundary of the precipitation, which is analogous to the case of sunshine duration. This feature is also noted by Kawamura (1962) who considered monthly total precipitation ratio to normal (Fig. 7). These boundaries are important from the viewpoint of the distribution pattern of the thermal climatic elements but also of the pluvial climatic elements.

In comparison to the previous study the boundary line along the Hidaka-Yūbari-Mashike Mountains is unique feature. Such a boundary is not shown in the average values of the climatic element because the average values make it obscure by the mixing of some distribution patterns. Furthermore, this boundary does not seem to play a role in producing the precipitation patterns.

The regional characteristics of temperature (Figs. 4 (a), 5 (a) and 6 (a)) are also compared to the climatic divisions of Sekiguchi (1959) which depend on the monthly mean of the daily range of air temperature (Fig. 7 (e)). In his results, the difference of temperature variations between the inland and the coastal area are not found, and the boundaries of the Mountains from Hidaka to Kitami are clearly marked. The difference of the most notable features between Figs. 4 (a), 5 (a) and 6 (a) and Fig. 7 (e) is due not only to the kind of data (i. e. daily range of air temperature in his study) but also to the number of stations and those locations. Namely, the number of stations seems to be too limited to show the inland climatic features. In addition to this the average values (monthly mean) make the temperature difference (correlation coefficients) between two stations small as has been mentioned in Section 1-1. Then it is also explained by the lack of stations why the boundary of Akan-Shiretoko Mountains are not shown in Fig. 7 (e).

General features of the time variation of each climatic element are summarized, especially with respect to the boundaries. Hence, some regionalities of thermal climate could be delineated from the variation pattern of each climatic element. However, the synthetic regionalities of thermal climate should be clarified with a more objective method. Then this clustering method is advanced to use for the plural climatic elements in the following section. The propriety of such results are examined by the comparison with these results obtained here.

3. 2 Plural climatic elements

3. 2. 1 Maximum and minimum air temperatures

To clarify and elucidate the composite regionalities of two climatic elements, the clustering method is used again for the six-dimensional space (i. e. using the first three factor loadings for two climatic elements). Although in this calculation factor loadings of each climatic element are equally weighted, the result is almost the same as that in the case with double weighted to the values for one element in general, except for the orders.

First, MXTP and MNTP are used for example of this analysis. Seven clustering regions are formed at the 3rd order in this case. The geographical position of each group and the dendrogram for each order are shown in Fig. 8 (a) and (b), respectively. Compared Fig. 8 (a) with Figs. 4 (a) and 5 (a), it is noted that the boundaries corresponding to a higher order or the boundaries which are clearly marked with these positions tend to remain in this case. Furthermore, the common boundary line for two elements clearly appeared even if they correspond to a lower order. The regionalities (variation type) of maximum and minimum air temperatures

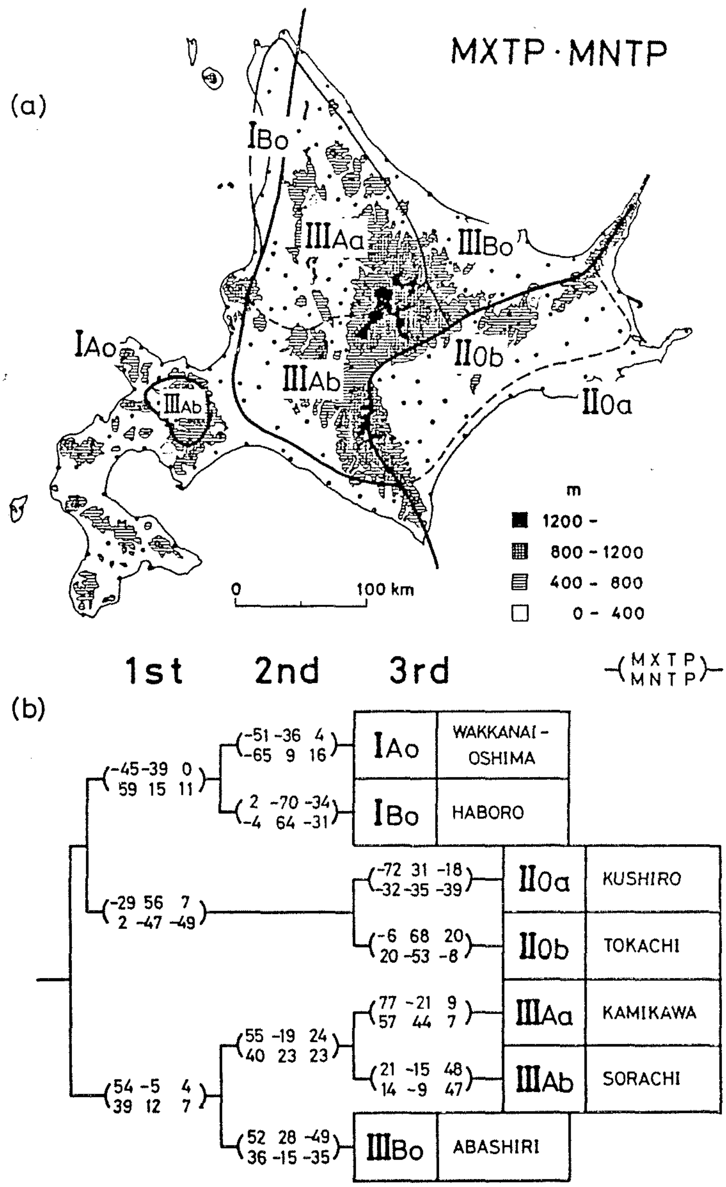

Fig. 8. Same as Fig. 3, except for MXTP and MNTP.

are described in the following.

IAo ; Japan Sea side — Western Pacific side type. Sea effect on the air temperature is strong throughout the year. The annual range of air temperature is the smallest in Hokkaido.

IBo ; North Japan Sea side type. The maximum air temperature tends to fall under the southerly or the southwesterly general wind in summer. The minimum air temperature does not drop by the warm onshore wind or by the snow clouds during winter monsoon. Weak influence of Okhotsk high invades here.

IIOa ; Eastern Pacific side type. In summer the maximum air temperature does not rise on account of the influence of the sea including sea fogs. Cool winds related to the Okhotsk high often invades here.

IIOb ; Tokachi inland area type. The maximum air temperature goes down under the influence of a cyclone passing through the southeastern side of Hokkaido in summer. On the other hand, it rises with the weak surface wind when the general wind is southwesterly. In winter the minimum air temperature drops even if under the influence of a westerly monsoon.

IIIAa ; Kamikawa inland area type. The maximum air temperature rises under the influence of Ogasawara anticyclone. The minimum air temperature drops under a gentle pressure gradient after the winter monsoon.

IIIAb ; Sorachi-Shiribeshi inland area type. The influence of the Okhotsk high on the MXTP is comparatively weak. The minimum air temperature tends to drop during night under the travelling anticyclone in spring and autumn.

IIIBo ; Okhotsk Sea side type. The influence of the sea is weaker than the other sea side areas. In early summer both the maximum and minimum air temperatures go down under the influence of the Okhotsk high with northeasterly cool winds.

In this method the regionalities (variation type) of both the maximum and minimum air temperature are clarified. The order of the boundaries are determined automatically with one or two related climatic elements. In other words, it is unnecessary to select the climatic element for the boundary with considerations to whether it is important or not for the region. It is an advantage of this objective method.

It is noted that Fig. 8 (a) resembles Fig. 6 (a), and the regionalities are also analogous to each other. Therefore, the regionalities of the thermal climatic elements are represented by daily mean air temperature and sunshine duration. The results will be shown in the following section.

3. 2. 2 Duration of sunshine and daily mean air temperature

In order to clarify the regionality (variation type) of thermal climatic elements the data of DUSS and AVTP are analysed. These results were compared with the results which were deduced in section 3-1-e. Eight clustering regions are formed at the third order in this case. The geographical position of each group and the dendrogram for each order are shown in Fig. 9 (a) and (b), respectively. The results are described in the following.

IOo ; North Japan Sea side type. The duration of sunshine decreases by the snow clouds in winter. It increases in summer except for the days with influence of a cyclone passing through the northern side. In winter the mean air temperature is comparatively mild by the influence of sea under the westerly general wind. On the other hand, summer is subject to decline in a maximum

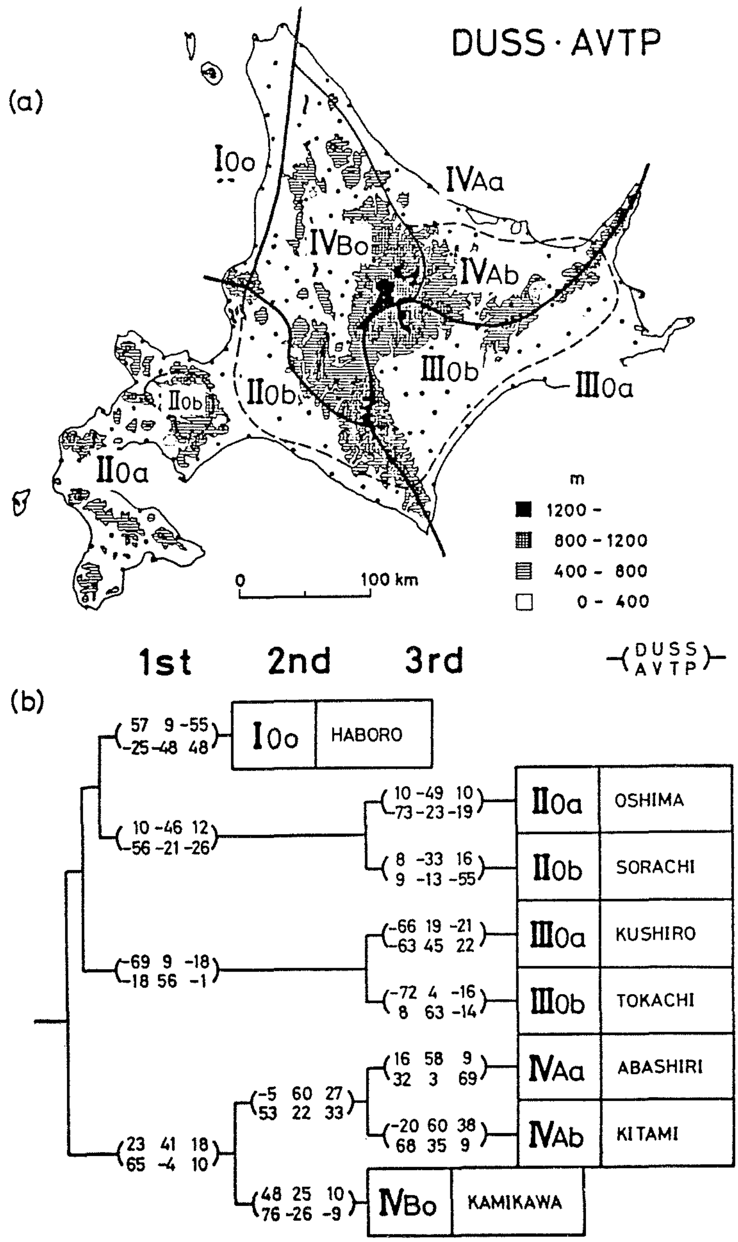

Fig. 9. Same as Fig. 3, except for DUSS and AVTP.

air temperature by the onshore wind when the general wind is southerly or southwesterly. The influence of the Okhotsk high often invades here.

IIOa ; Oshima sea side type. The sunshine duration has a large day-to-day variation during the warm season. It decreases by the front or a cyclone passing through the southern side of Hokkaido. The air temperature is the mildest in Hokkaido by the influence of the sea. The annual range of air temperature is small.

IIOb; Sorachi-Shiribeshi inland area type. The variation of sunshine duration is analogous to that of IIOa, but is weak. The inland characteristics of the air temperature variation type is weaker than those of the other inland areas. The radiation cooling during the night under the travelling anticyclone is notable in spring and autumn.

IIIOa; Eastern Pacific side type. The sunshine duration decreases in summer under the influence of sea fogs or cyclones passing through the southeastern side of Hokkaido. As a result, the maximum air temperature goes down during that season. In winter the sunshine duration shows a comparative increase.

IIIOb; Tokachi inland area type. The variation of sunshine duration is about the same as that of IIIOa. In winter the minimum air temperature shows a comparative drop in relation to the weak surface wind even under the westerly general wind. The maximum air temperature goes down by the sea fog with a southeasterly wind or under the influence of a cyclone passing through the southeastern side and increases in relation to the weak wind under the southwesterly general wind by the travelling anticyclone or the Ogasawara anticyclone.

IVAa; Okhotsk Sea side type. The sunshine duration has a large day-to-day variation especially during the warm season, but changes with a reverse phase of the variation in IIOa. It decreases by the influence of the Okhotsk high or the cyclone on the eastern side of Hokkaido. The effect of the sea on the air temperature is smaller than that of any other coastal areas. Especially in summer, the maximum air temperature is hardly influenced by the sea under the southerly general wind, except under the influence of the Okhotsk high when this area continues to have low temperature throughout the day.

IVAb; Abashiri inland area type. Variation of sunshine duration is about the same as that of IVAa. The maximum air temperature goes up under the influence of the Ogasawara anticyclone in summer, and the minimum air temperature goes down under the gentle pressure gradient after the winter monsoon. The inland regionality (variation type) of air temperature is notable. Annual range of the air temperature is fairly large.

IVBo; Kamikawa inland area type. The variation of air temperature is analogous to that of IVAb, but it is stronger here. The duration of sunshine decreases by the influence of snow clouds under a winter monsoon. The minimum air temperature does not drop by clouds or by wind during such a weather condition.

These results mainly reflect the regionalities (boundaries) which are deduced in section 3-1-e. Furthermore, the order of the boundary is clearly formed in this case. The high ordered boundaries have an important physical meaning both for the sunshine duration and daily mean air temperature.

As is evident from the Fig. 9 (b), the group named IV is primarily distinguished from the other regions. This is the region characterized by the extreme variation of air temperature, referred to as the inland climate. The southern or southwestern boundaries of this region are related with the patterns both of DUSS and AVTP, and the western boundary is related with the pattern of AVTP. The inland area of region IV is divided into IVAb and IVBo by the difference of the influence of the winter monsoon. Namely, the minimum air temperature of IVAb tends to decrease with cloudless and weak surface wind even under the westerly monsoon.

IIIOb and IIOb, which also have inland features but are noted to be weak. The former region is characterized by a feature of low maximum air temperature related to the decrease of sunshine duration in summer, and the latter by the feature of minimum air temperature drop in spring and autumn under a travelling anticyclone. The latter region is situated on an airway. Hence, the wind weakens the inland climatic features of IIOb.

With regard to the coastal area, IVAa is distinguished from other coastal areas by a comparatively weak sea effect except under the influence of the Okhotsk high. Furthermore, IOo is a region which is under the influence of the Okhotsk high and has a sea effect which acts when the general wind direction is southwesterly (strictly speaking, from S to SW) in summer. IIIOa is mainly characterized by the influence of sea fog. Generally speaking, these boundaries near the coast are formed related to the maximum air temperature patterns.

As was mentioned above, the regionalities for the variation of the thermal climatic elements are clearly marked in Fig. 9. Furthermore the boundaries were also examined with these physical meanings. These results also show that these methods can be applied to the case with plural climatic elements. In this case, it has the advantage that the important boundaries for each climatic element or the common boundaries for some climatic elements are automatically selected and clearly marked.

3. 2. 3 Comparison with the previous climatic divisions

In comparison with the previous climatic divisions, the boundaries parallel to the shorelines are emphasized in this study corresponding to the primary features of air temperature patterns. It is interesting that this feature resembles that described by Uchijima (1962) which depends on the summation water temperature and aridity index (Fig. 10 (a)). It is also suggested that the boundaries parallel to the shoreline play an important role for the thermal climate from the fact that the region [A] is distinguished from the region [B] by the summation water temperature (3000°C) in Fig. 10 (a).

The Hidaka Mountains and the Akan-Shiretoko Mountains are important boundaries from the synthetic point of view (Saito, 1967 ; Yoshino, 1980) (Fig. 10 (b), (c)). However, in contrast, Fukui (1929) divided Hokkaido into two areas, i. e. Oshima Peninsula and the main part (northeastern part) of Hokkaido, by a line drawn with special regard to air temperature. The monthly mean air temperature in the former region falls below zero for less than three months. In this study, from a viewpoint of variation of temperature, Oshima Peninsula is regarded as the

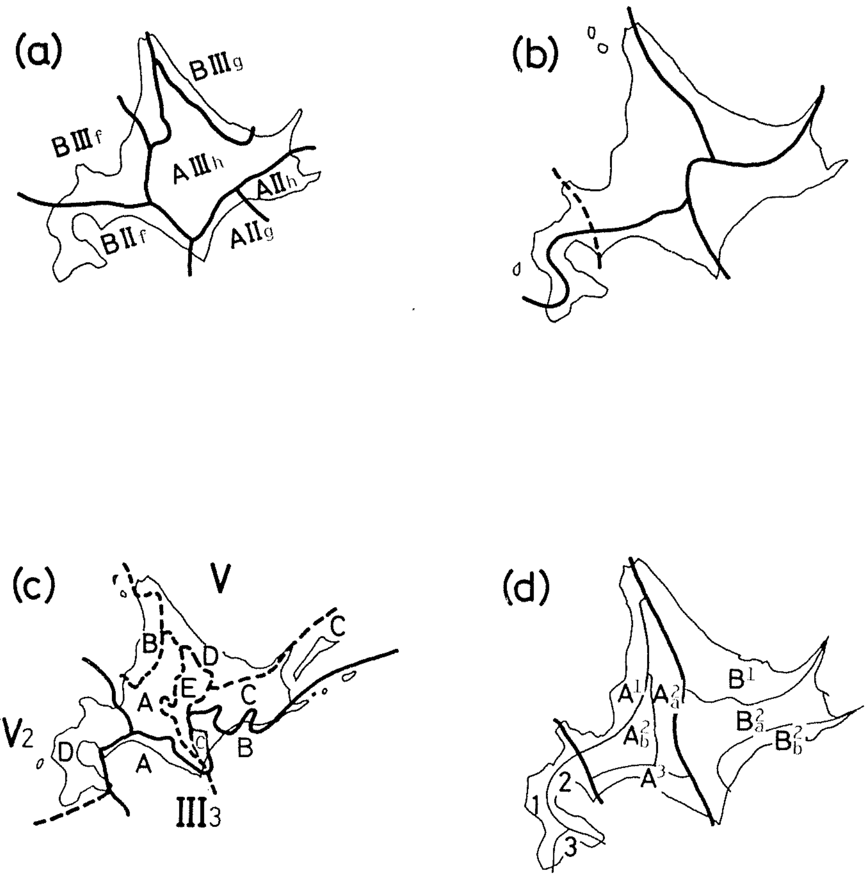

Fig. 10. Climatic divisions of Hokkaido from the synthetic point of view of (a) Uchijima (1962), (b) Saito *et al.* (1967), (c) Yoshino (1980) and (d) Fukui (1929). See the text for detail.

same as the coastal regions of Ishikari and Hidaka district in general. Furthermore, regional characteristics around Shiribeshi Mountains are similar to those of the inland regions of Sorachi and Ishikari districts. It is an interesting feature noted in this study.

When closely compared, the Kitami Mountains also form a notable boundary in the previous studies. Namely, the Okhotsk Sea side (IVAa and IVAb shown in Fig. 9 (a)) is clearly marked in the previous studies (Fig. 10 (b), (c) and (d)). However in general, the low ordered boundaries clarified in this study are different from those of other studies.

It is stressed that this study adds the following new knowledge to the climatic regionalities of Hokkaido at a lower ordered division : namely Kitami Basin and the inland part of Ishikari-Sorachi Lowland are distinguished from other regions. Furthermore, it was also revealed first that the characters of regional climate surrounding the Shiribeshi Mountains are the same as those of the inland part of the Ishikari-Sorachi Lowland.

From the comparison, it is suggested that the high ordered boundaries in this analysis often resemble those of the previous work, but the low ordered boundaries do not. Namely, the new knowledge of the climatic regionalities of Hokkaido in this study is revealed clearly in the subdivided regions. It is suggested that this method is useful in order to clarify the climatic regionality of such a spatial scale as Hokkaido in detail. Thus the results of this study may be used not only to clarify the physical meanings of the boundaries of the other work but also to divide each region.

4. Conclusions

In order to clarify or otherwise elucidate the environmental regionality in Hokkaido, the day-to-day variation of some thermal climatic elements are analysed in relation to synoptic meteorological phenomena. The thermal climatic elements are the most important factors determining the activity of the living things in the northern regions such as Hokkaido. Moreover, within this size of an area such as Hokkaido these elements are expected to show a clear-cut regionalities both in space and time.

The methods rely on both principal component analysis (PCA) and cluster analysis using factor loadings. The factor loadings correspond to the correlation coefficient between the principal component and the climatic element for each station, and show the connection between them. Each datum was converted into a deviation subtracted from the areal mean for each day.

The advantage of the methods applied in this study are summarized as follows : Firstly, the background noise of the data, such as fluctuations peculiar to each station, is removed and the varation of each climatic element caused by the synoptic phenomena is clearly marked. Secondly, the regional characteristics of climate with reference to the corresponding synoptic causes can be clarified by the average values of the factor loadings calculated for each group (region). Thirdly, the grade of each group is formed automatically and the boundaries are also shown with the corresponding physical meanings.

The four regions with different time variation type of sunshine duration are distinguished. Especially, the southeastern side of Hokkaido has fairly specific regionalities in comparison with the other regions. The boundaries between the regions are comparatively clear.

As for the temporal variation of air temperature the difference of the regional characteristics between the inland and the coastal areas is the primary feature. The distribution patterns of maximum air temperature are governed by the patterns of sunshine duration, wind speed and the influence of the sea. The coastal zone is divided into four subregions by the variation types of the maximum air temperature with the intensity of sea effect. The boundaries along the mountains are clearly marked in the maximum air temperature patterns controlled by the sunshine duration. On the other hand, the boundaries in the minimum air temperature patterns become obscure in general since the regional characteristics of minimum air temperature are controlled mainly by the wind distribution pattern. However, some boundaries such as Kitami Mountains exist although they show the features of transitional zones. The patterns of daily mean air temperature are always related with one or more patterns of maximum and minimum air temperatures and show the mean features of such patterns.

These results often show that a pattern of sunshine duration and a corresponding pattern of air temperature prevail at the same time, e. g., under an Ogasawara anticyclone. But, in general, including these cases, each climatic element does not have a distribution pattern resembling the others with regard to synoptic scale phenomenon. It is because that the pattern of air temperature is influenced not only by sunshine duration but also by wind and sea surface temperatures.

To clarify the thermal climatic regionalities caused by plural climatic elements, the clustering method is used again for two climatic elements, i. e. sunshine duration and daily mean air temperature. As a result, four inland regions and four coastal regions are distinguished at the third order of the clustering step. Especially, the boundaries running parallel to the shoreline is notable in this study. Hidaka Mountains and Akan-Shiretoko Mountains are important boundaries from a viewpoint of variation of thermal climatic elements. In contrast, Oshima Peninsula is preferably separated from the main part (northeastern part) of Hokkaido by the line of Hidaka-Yūbari-Mashike Mountains.

It is stressed that this study adds the following new knowledge to the climatic regionalities of Hokkaido at lower ordered divisions ; — namely, Kitami Basin and the inland part of Ishikari-Sorachi Lowlands are distinguished from the other regions. Furthermore, it is also revealed first that the characters of regional climate around Shiribeshi Mountains are the same as those of the inland parts of Ishikari-Sorachi Lowlands.

Although these analyses mainly depend on the data of one whole year, comparatively clear climatic regionalities were obtained. However, the data covering a long time should be analysed if these results are to be compared with the climatic regions from the average data in detail.

Since the data used here are transformed into a deviation from the areal mean, these results can not be compared to the climatic features of the other areas. For such a comparison other analysis must be done again on a large area including these smaller areas. Furthermore, although the relative difference of variation pattern of climatic elements between the regions are clarified by this method, the absolute values of such elements are not shown in the analysis. Then it is necessary to add the areal means of climatic elements to the results. These are the drawbacks of these methods. However, these methods are useful to clarify the regionalities of some climatic elements in a small area. It is the merit of these methods that the regionalities (variation types) of plural climatic elements are delineated objectively in relation to the synoptic causes (meteorological phenomena). Hereafter these methods may be applied to other regions, and the propriety of the results should also be examined with the applicability to the smaller or larger region, or to other fairly different climatic regions such as the tropics.

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Summary

In order to clarify the environmental regionality in Hokkaido, some thermal climatic elements at about 140 sites are analysed with time variation (day-to-day variation) in relation to synoptic meteorological phenomena. Both principal component analysis and cluster analysis using factor loadings are applied.

The four regions with different time variation types of sunshine duration are distinguished. Especially, the southeastern side of Hokkaido has fairly specific regionalities in comparison with the other regions. The boundaries between the regions are comparatively clear.

As for the temporal variation of air temperature, the difference of the regional characteristics between the inland and the coastal areas is the primary feature. The distribution patterns of maximum air temperature are governed by the patterns of sunshine duration, wind speed and the influence of the sea. The coastal zone is divided into four subregions by the variation types of the maximum air temperature with the intensity of sea effect. The boundaries along the mountains are clearly marked in the maximum air temperature patterns controlled by the sunshine duration. On the other hand, the boundaries in the minimum air temperature patterns become obscure in general since the regional characteristics of minimum air temperature are controlled mainly by the wind distribution pattern. However, some boundaries such as Kitami Mountains exist although they show the features of transitional zone. The patterns of daily mean air temperature are always concerned with one or more patterns of maximum and minimum air

temperatures and show the mean features of such patterns.

These results often show that a pattern of sunshine duration and a corresponding pattern of air temperature prevail at the same time, e. g., under an Ogasawara anticyclone. But, in general, including these cases, each climatic element does not have a distribution pattern resembling the other with regard to synoptic scale phenomenon. It is because that the patterns of air temperature are influenced not only by sunshine duration but also by wind and sea surface temperature.

To clarify the thermal climatic regionalities caused by plural climatic elements, the clustering method is used again for two climatic elements, i. e. sunshine duration and daily mean air temperature. As a result, four inland regions and four coastal regions are distinguished at the third order of the clustering step. Especially the boundaries running parallel to the shoreline are notable in this study. Hidaka Mountains and Akan-Shiretoko Mountains are important boundaries from a viewpoint of variation of thermal climatic elements. In contrast, Oshima Peninsula is preferably separated from the main part (northeastern part) of Hokkaido by the line of Hidaka-Yūbari-Mashike Mountains.

It is stressed that this study adds the following new knowledge to the climatic regionalities of Hokkaido at lower ordered division ; — namely, Kitami Basin and the inland part of Ishikari-Sorachi Lowlands are distinguished from the other regions. Furthermore, it is also revealed first that the characters of regional climate around Shiribeshi Mountains are the same as those of the inland parts of Ishikari-Sorachi Lowland.