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THE CHARACTERISTICS OF THE DISTRIBUTION OF ATMOSPHERICS SOURCES AND THE CONSIDERATION OF THE FIXING ERROR

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Abstract

The monthly distribution of atmospherics sources in the Far East in 1973 was obtained using the triangulation of the three direction finding stations. In general, the dispersive trend in the distribution appears in the region of the continent of China in summer, and in the region of the Pacific Ocean in winter. And the concentrative trend in the distribution appears around the Yangtze River in spring and in autumn. However, it is clear from the directional distribution at Sakushima station that the fixing rate in the region along the baselines is lower than in the other regions because of the distortion caused by the shape of the network. Therefore, the characteristics of the distribution in the region along the baselines can not be obtained accurately.

The calculation of the fixing error by means of computer was carried out under the cónditions due to the measurement accuracy of the direction finder and the arrangement of the three direction finding stations. And also the fixing error was calculated from observational data in 1973 by using the error calculation equation. So that, it is estimated that the fixing error in the region perpendicular to the baselines depends mainly upon the measurement error of the direction finder and the arrangement of the three direction finding stations, and that that in the region along the baselines depends primarily upon the conditions for the fixing of the triangulation and the equation adopted for the error calculation.

1. Introduction

Kamada (1953) previously described the seasonal variations of the arrival direction of atmospherics observed from July 1952 to December 1953. He consequently suggested that the period showing seasonal peculiarities of the sources of atmospherics during one season was about two months. However, he could not distinctly describe the seasonal characteristics of the distribution of atmospherics sources.

Kimpara (1954) previously reported the distribution of atmospherics sources in the Far East obtained in summer and winter 1952-1953, and discussed the relation between the occurrence of atmospherics and the active meteorological phenomena.

A new automatic locating system of atmospherics sources was established in 1968 by using the network of the three direction finding stations, Moshiri, Sakushima and Kagoshima. Since then, improvements of the direction finders (DF) and the data accessing process have been successively made. The observations of the location of atmospherics sources have been made as routine work, and it has become possible to obtain a detailed distribution of atmospherics sources.

In this paper, the authors first describe the monthly distribution of atmospherics sources obtained in 1973, and briefly discuss the locating in the region along the baselines connecting Moshiri, Sakushima and Kagoshima. We will mention in future publications the meteorological interpretation of the distribution of atmospherics sources obtained. Second, we obtain the fixing error both by using computer calculation and by using numerical calculation from the observational data in 1973 and compare the results.

2. The monthly distribution of atmospherics sources.

The location system was already introduced in detail by Iwai et al. (1969). The main amplifiers tuned at the frequency of 8.6kHz, the digital reading circuits and the electronic clocks at the three stations were carefully adjusted just before every observation time. Routine observation was carried out for one week every month. The observing duration is from 10 to 15 minutes every 3 hours from 0h, JST. The sensitivity of the main amplifiers has an important effect on the distance over which atmospherics sources can be detected. In the case of routine observation, it was adjusted so that the number of atmospherics received at the three DF stations became nearly equal. Usually, 40-60 numbers per minute were chosen for locating atmospherics sources in the Far East.

Fig.1 shows the monthly rate of the number of atmospherics fixed to the total number of atmospherics received at Sakushima station. The rate is maximum in September and minimum in January. In general, the rate is high in spring, and it is low in winter. We show the base-lines connecting the three observatories and the name of places in the Far East in Fig.2. Figs.3(a), (b) and (c) show the monthly distribution of atmospherics sources fixed by this location system. The numbers in these figures indicate the total number of atmospherics sources fixed in each region bounded by latitudinal and longitudinal lines at intervals of 5 degrees. We briefly describe the monthly distribu-

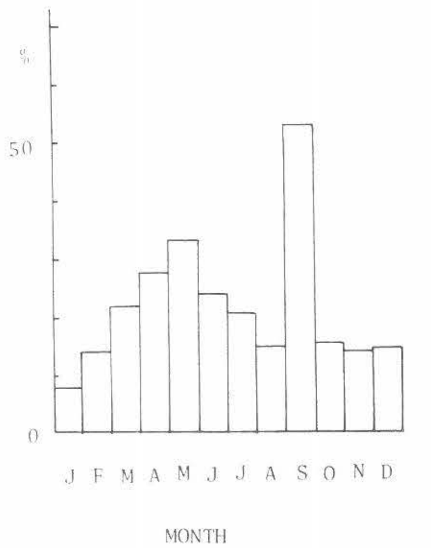


Fig.1 The rate of the number of atmospherics sources fixed to the number of atmospherics received by the DF at Sakushima station.

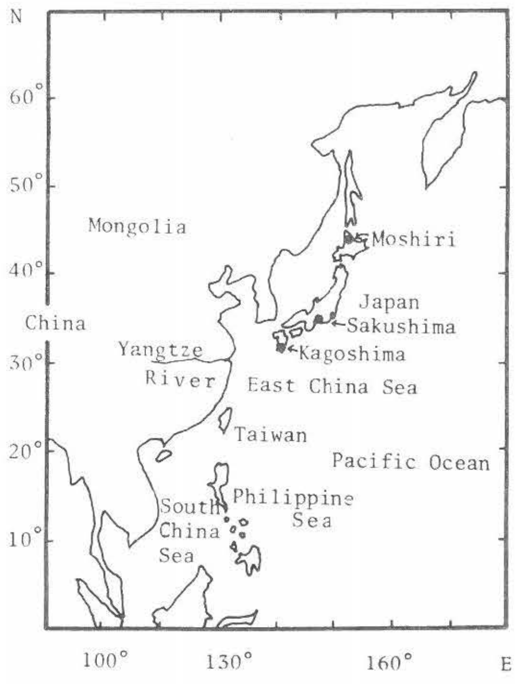


Fig.2 The map of the Far East.

tion of atmospherics sources. In January and February, the dispersive trend of the distribution is found in two regions : south of the Yangtze River and south of the Philippine Sea. In March, April and May, the concentrative trend of the distribution is found in the regions from south of the Yangtze River to the East China Sea, and it seems to move slightly toward the north-east direction from March to May. In June and July, the dispersive trend of the distribution is found over all the continent of China, and in July the trend toward the concentration appears in the region from north of the Yangtze River to the East China Sea. In August and September, the movement of the dispersive distribution from the Philippine Sea to the north-west region of the Pacific Ocean is found. From October to December, the dispersion of the distribution is found over the north-west region of the Pacific Ocean. The observation wasn't carried out continuously, however, the monthly distribution obtained clearly show seasonal peculiarities which roughly correspond to those suggested by Kamada. It is summarized that the dispersive trend in the distribution appears in the region of the continent of China in summer and in the region of the Pacific Ocean in winter. And, the concentrative trend in the distribution appears from the East China Sea along the Yangtze River in spring and autumn.

However, it must be noted that the fixed number in the regions from Taiwan to the Philippines is relatively few. The reason is that the baselines lie in the south-east direction, so that the fixed number in the region along the baselines decreases remarkably. This unavoidable demerit is caused by the shape of the network. Therefore, in order to discuss the distribution of atmospherics sources in this region, it is necessary to take into account the directional distribution of the received atmospherics. So, we use the directional distribution obtained by the uni-directional DF at Sakushima station, situated in the central region among the three stations.

Fig.4 shows the histograms for the arrival direction and for the fixed number of atmospherics observed in 1973. The solid line shows the rate of the number in the azimuthal range of 10 degrees to the total number of the received atmospherics. The dotted line shows the rate of the fixed number to the fixed total number. It is clear from this figure that most of the distant atmospherics occur in the region of the west side seen from Japan, and that the occurrence rate of atmospherics in the region along the baselines, corresponding to the azimuth 200°-240°, is about 33% of the total number. However, the fixing rate in this region is less than about 16% of the total fixed number. A steep cliff in the azimuth of 240° depends on the abovementioned differ-

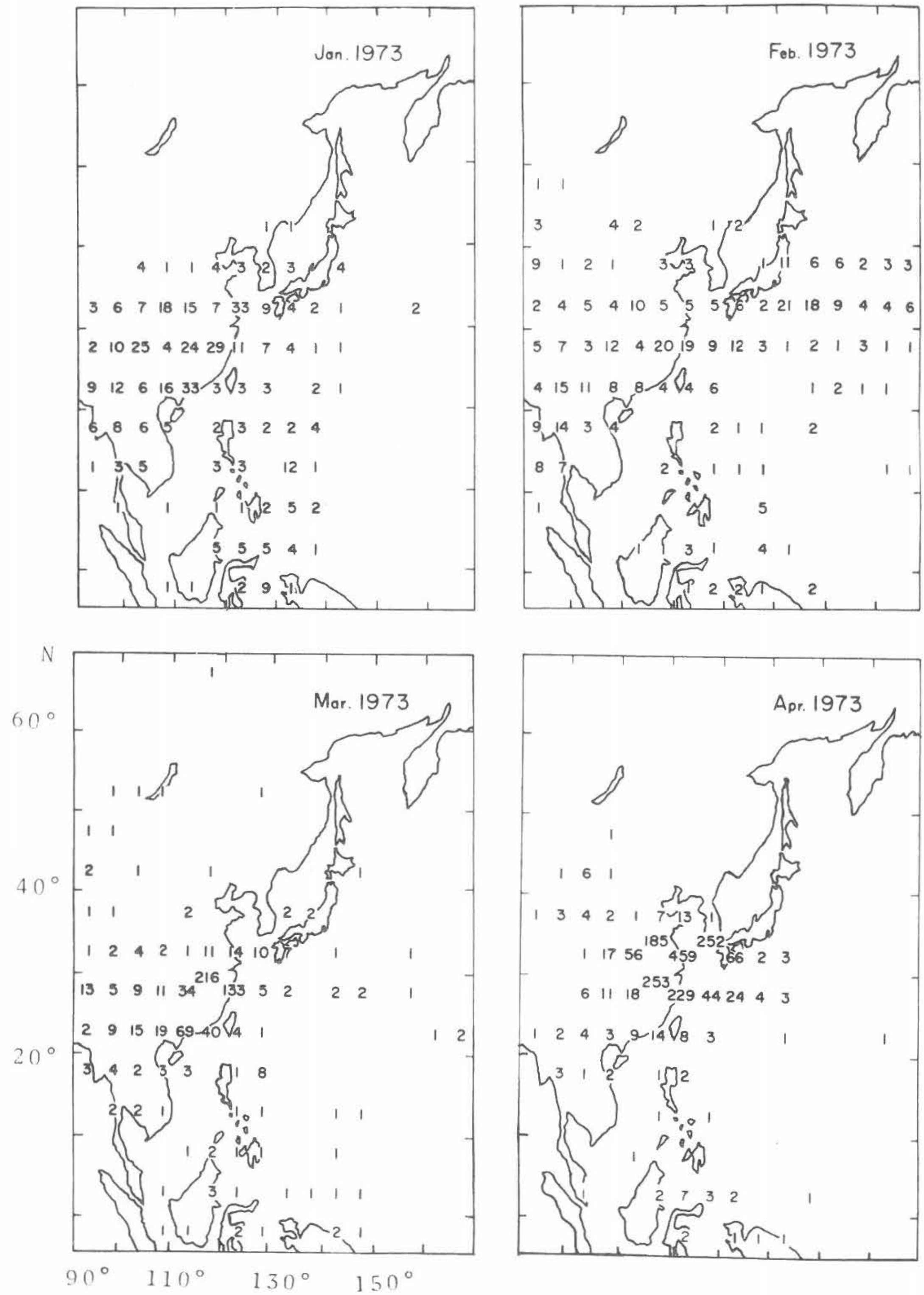


Fig.3(a) The monthly distribution of atmospherics sources.

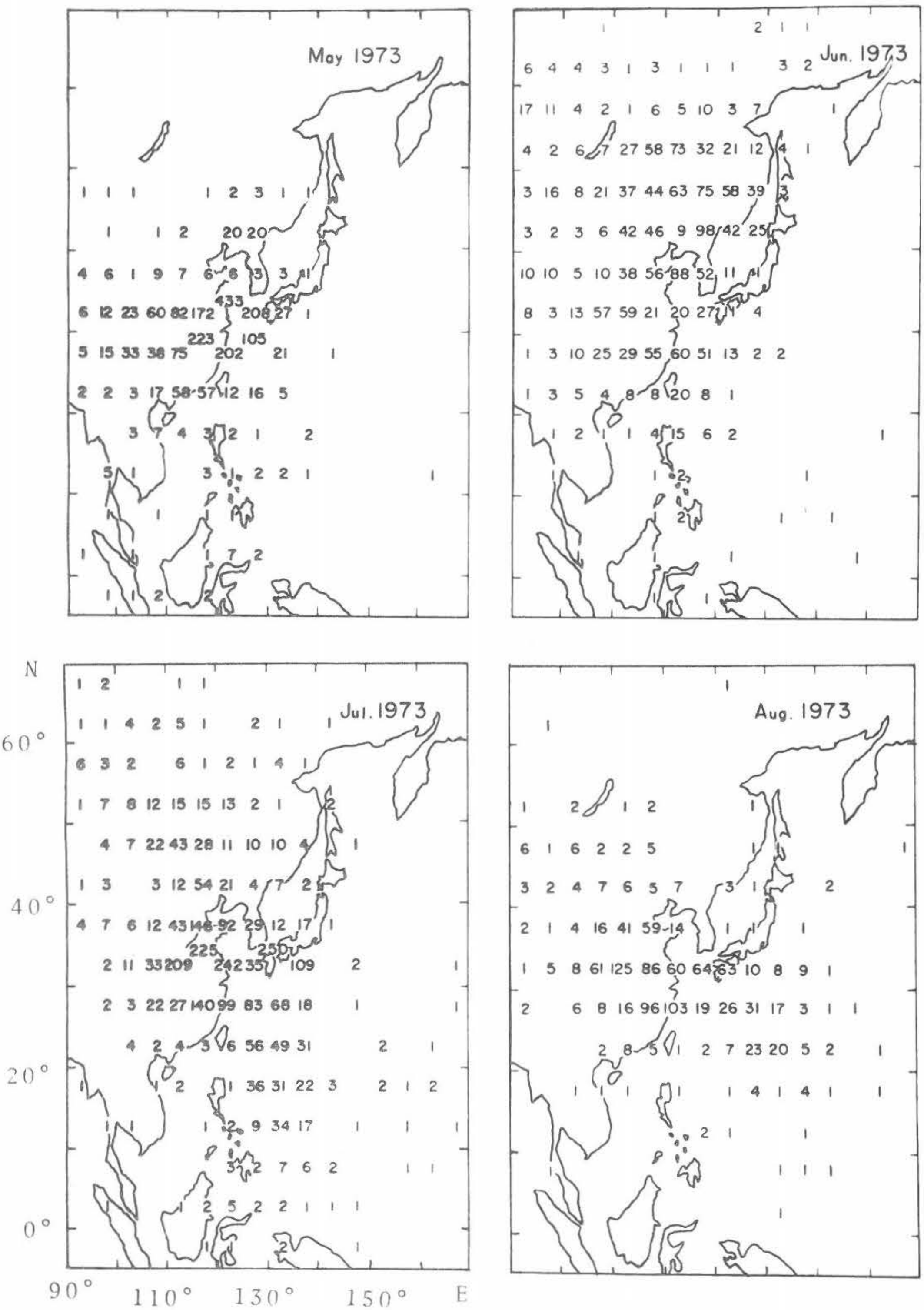


Fig.3(b) The monthly distribution of atmospherics sources.

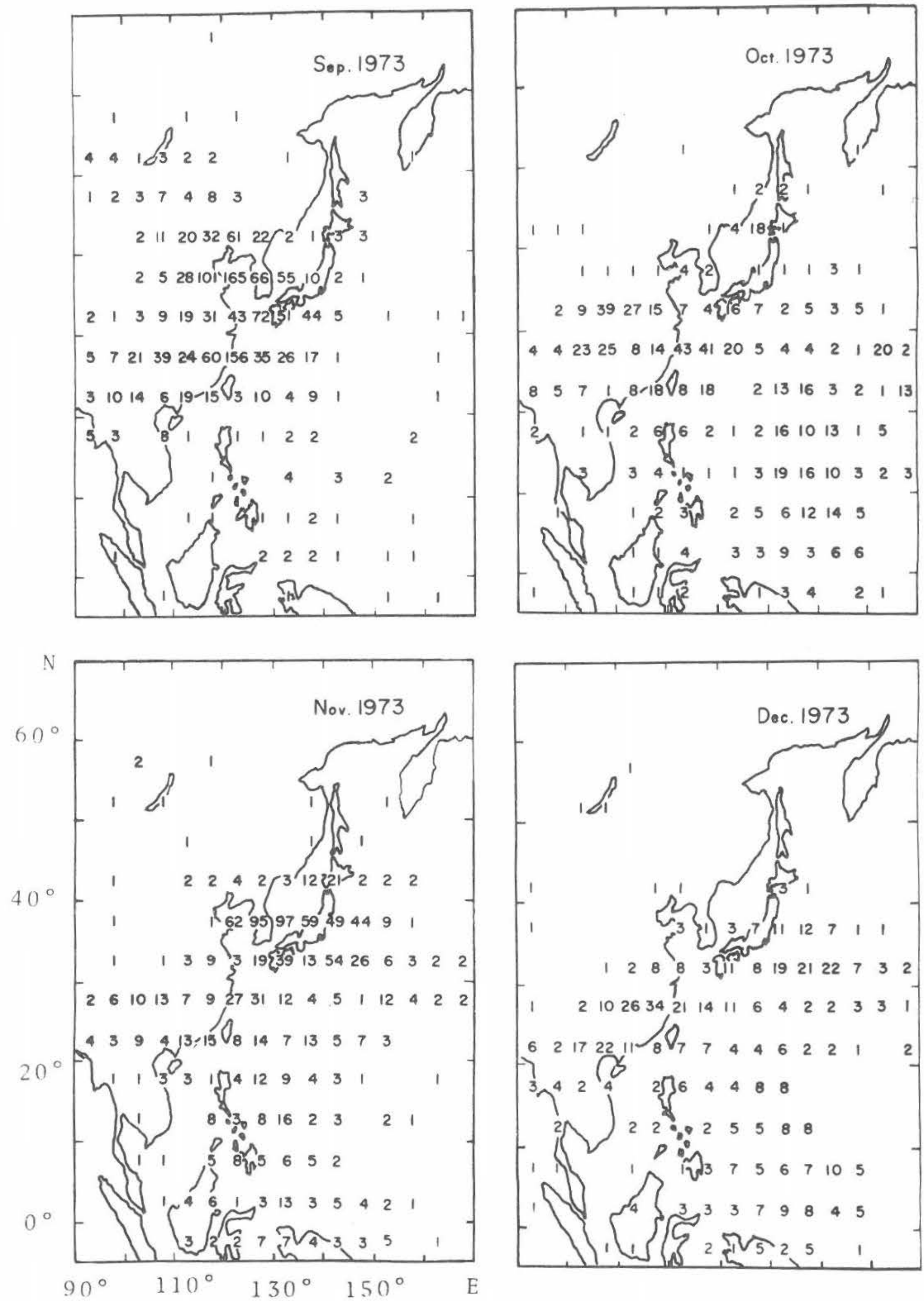


Fig.3(c) The monthly distribution of atmospherics sources.

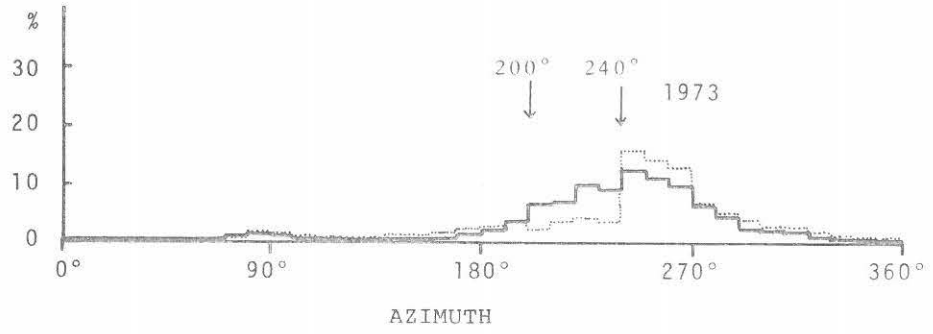


Fig.4 The histograms for the arrival direction (solid line) and for the fixed number (dotted line) of atmospherics observed in 1973.
200° : Direction of the baseline between Moshiri and Sakushima.
240° : Direction of the baseline between Sakushima and Kagoshima.

ence. This difference in the rate of 17% had to be equally allotted to the azimuth except the azimuth 200°-240°. But, 7% of the 17% is equally allotted in the azimuth of 240° to 270°. This may cause the fixing rates in the azimuth of 240° to 270° in March, April and May to appear remarkably higher compared with other months. This is also confirmed from the high concentration of the distribution in the region from south of the Yangtze River to the East China Sea, as shown in Fig. 2. It is suggested that the fixing rate of atmospherics sources in the region along the baselines becomes lower than those in the other regions through the use of this location system, so a larger number of atmospherics than that are fixed is thought to occur in reality.

3. Consideration of the fixing error.

Some kinds of fixing errors are contained for the location of atmospherics sources observed by this system. In order to investigate the fixing error, we first calculate the fixing error under the condition due to the measurement accuracy of DF and the arrangement of the three direction finding stations. Second, we calculate the fixing error with the use of the estimation equation from the observational data in 1973. Then, comparing both the results, we discuss briefly the cause of the fixing error.

3-1. Fixing error with the computer calculation.

Nakai (1957) obtained the 50% probability ellipses in order to estimate the error of position of atmospherics sources, taking the network of the direction finders at Toyokawa, Kumamoto and Akita. And also, he described the contour of the reciprocal of the root-mean-square error in fixing position. He concluded that the error in the region along the baselines was very large, while that in the region perpendicular to the baselines was relatively small. In this section, we calculate the fixing error of atmospherics sources with a different method from that of Nakai, taking the network of the direction finders at Moshiri, Sakushima and Kagoshima. The error obtained by the following method is due to the measurement accuracy of 1 degree of DF and the arrangement of the three direction finding stations, excluding site and propagation errors for direction finding.

The fixing process is described in detail by Iwai et al.(1969). The coordinate of atmospherics sources is determined by the center of gravity of the spherical triangle, called a "cocked hat", formed by the three crossing points. The reading of the bearing angle is digital, and its resolution is 1 degree. We obtain the fixing error of atmospherics sources by computer calculation, using the following method.

Three directional lines (PM, PS and PK) are drawn from the point P, as shown in Fig.5. For example, if the true azimuth of PM is 268.3 degrees, the bearing angle Θ_M obtained by the DF is 268 or 269 degrees. The bearing angle Θ_S and Θ_K are obtained as same way as Θ_M. As a result, eight cocked hats are formed by the triangulation, and eight corresponding fixing points P_1, P_2... P_8 are obtained, so that the number of the mutual distances d_{ij} ($i=1,2,\dots 8$, $i\neq j$) between two points P_i and P_j become 28. We determine the maximum value in all mutual distances d_{ij} as the fixing error at this point. The error is calculated at each intersection point of latitudinal and longitudinal lines at intervals of 5 degrees by using the computer. The calculated results are shown as equi-error curves by making use of interpolation and extrapolation methods, as shown in Fig.6. The dotted curves in this figure

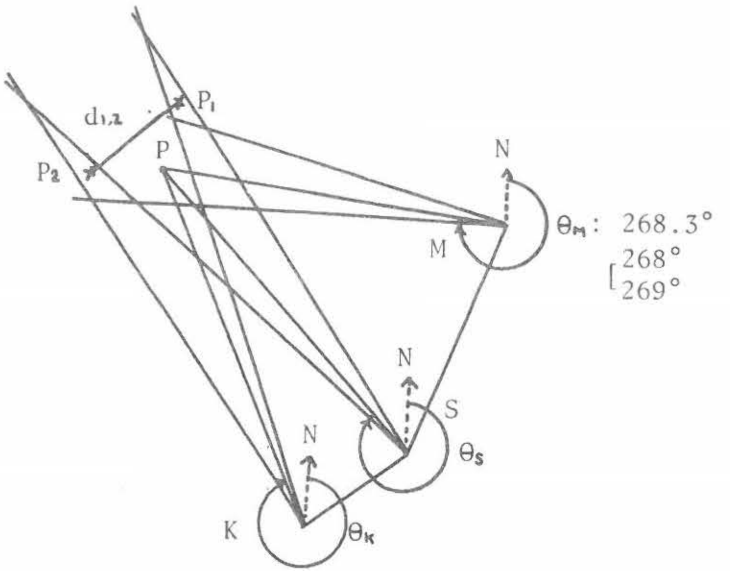
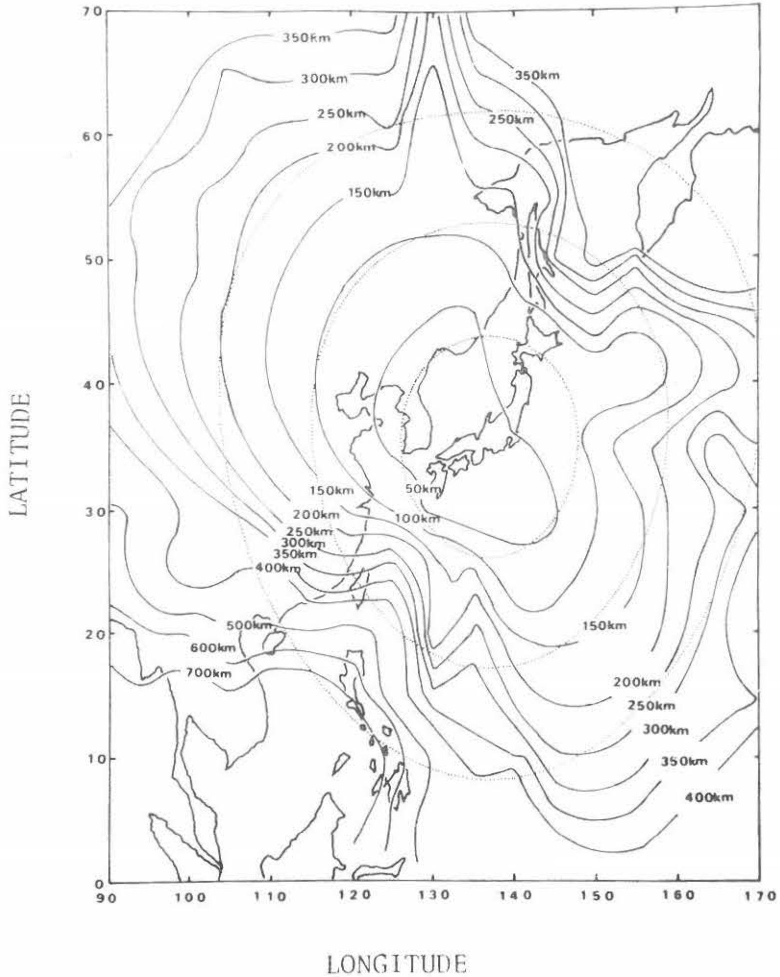


Fig.5 The method of the error calculation

Fig.6 The contour of the equi-error curves obtatined by the computer caluculation.



indicate the equi-distance at intervals of 1000Km from Sakushima station. It is clear from this figure that the error is relatively larger in the region along the baselines, while that it is relatively smaller in the region perpendicular to the baselines. For example, the error in Taiwan which is situated about 2000Km from Sakushima station is about 400Km, while that at latitude 50°N and longitude 120°E in the continent of China is about 100Km. It is also clear from this figure that the curves in the continent of China are smooth except in the region around latitude 60°N and longitude 130°E, while several convex and concave curves are seen in the region of the Pacific Ocean.

3-2. Fixing error calculated from the observational data.

The coordinates of atmospherics sources obtained from the fixing calculation is indicated in latitude and longitude, and the values of symbols shown in Fig.7 are also indicated. We calculate the fixing error with the use of these symbols. As to the estimation of the error of locating by the triangulation method, it is basically considered that the smaller the dimensions of the cocked hat are, the smaller the fixing error becomes. Now, as a standard to consider the fixing error, we assume the following equation.

$$E={}^{1}/_{3}\ [\ G_M\times{}^{1}/_{2}DAN(M)+G_S\times{}^{1}/_{2}DAN(S)+G_K\times{}^{1}/_{2}DAN(K)\ ]$$

where G_M, G_S and G_K : distance from the station indicated in subscript to the center of gravity of the spherical triangle.

DAN(M), DAN(S) and DAN(K) : angle between the bearing measured at the station in subscript and the bearing angle seen from this station to the crossing point fixed by bearing angles at the two other stations.

Each item approximately means the deviation from the line connected between the center of gravity and the station indicated in the round bracket, if the value of DAN is small. We use in this paper the mean value of the three items in order to compare with the error curves obtained by computer calculation. The value calculated from the above equation is not the absolute error, but the relative error to consider the cause of the fixing error. We calculate the value of error using the above equation for all atmospherics sources fixed, and then obtain the mean value for each region bounded by latitudinal and longitudinal lines at intervals of 5 degrees. The mean values are drawn as equi-

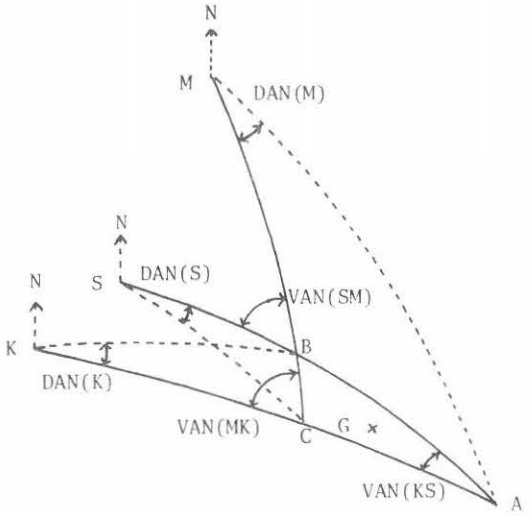


Fig.7 Symbols given by the triangulation method

error curves by making use of interpolation and extrapolation methods, and are shown in Fig.8 and Fig.9. Fig.8 shows the error curves for the data observed in the daytime, and Fig.9 shows those for data observed at night.

Comparing the curves in Fig.8 and Fig.9, on the whole, the error curve of 200Km at night is more snakelike than the one of in the daytime, and it comes near to the Japanese Islands except in the region along the baselines, that is, the error is larger at night than in the daytime.

Observing the error curves in the continent of China, a loop of the error curve of 100Km is found in the region of latitude 40°-50°N and longitude 105°E in the daytime, but it is found to move near latitude 40°N and longitude 110°E at night. The error curves more than the value of 200Km are found in the region of the latitude 45°-50°N and longitude 120°-125°E at night. This is probably caused by the fact that the number fixed in this region is very low. The error curves more than 300Km are found in the region of latitude 30°N and longitude 110°E in the daytime, but they are not found at night.

observing the error curves in the region of the Pacific Ocean, the error curve of 100Km is found in the region of latitude 25°N and longitude 160°E in the daytime, but the error of the small error is not found at night. The error curves of 200Km with long bootlike shape are found in the south region far from Japan in the daytime and at night too.

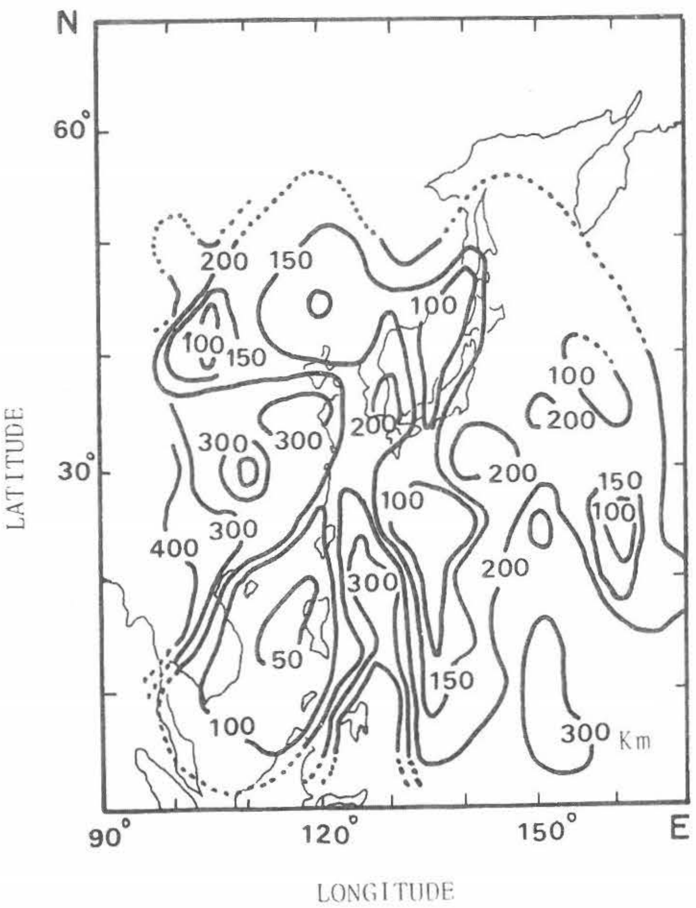


Fig.8 The contour of the equi-error curves (daytime).

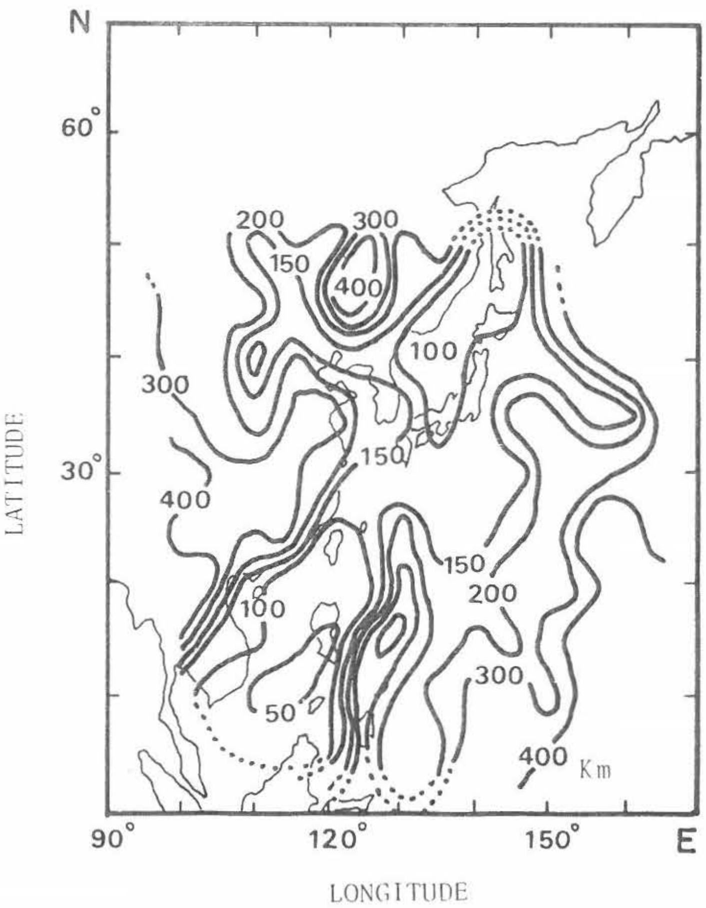


Fig.9 The contour of the equi-error curves (night).

These differnces seem to depend upon the error of the measurement of the bearing angle. It is suggested that the propagation error mainly affect the fixing error at night.

Comparing the error curves in the region along the baselines in the daytime with those at night, both patterns are considerably similar. Namely, in the daytime and at night too, the error curves of 50Km are found to the west side of the Philippines, while that of 400Km is found in the east side of the Philippines. Judging from the principle of the triangulation method, the error in the region along the baselines had to be relatively large. However, the error in the west side of the Philippines is very small. The reason for this is considered to be as follows. As described above, the measurement resolution of the bearing angle is 1 degree, so that the fixed number in the region along the baselines becomes few, which is due to the restriction of the shape of the cocked hats formed. Two typical cocked hats formed in this region are shown in Fig.10. In the west side of the Philippines, the shape of most of the cocked hats is near flat, and the length of the base is relatively small. Cocked hats with the long bases can not be formed. Therefore, the value of the error calculated from above equation become very much smaller. While, the cocked hats formed are very large in the

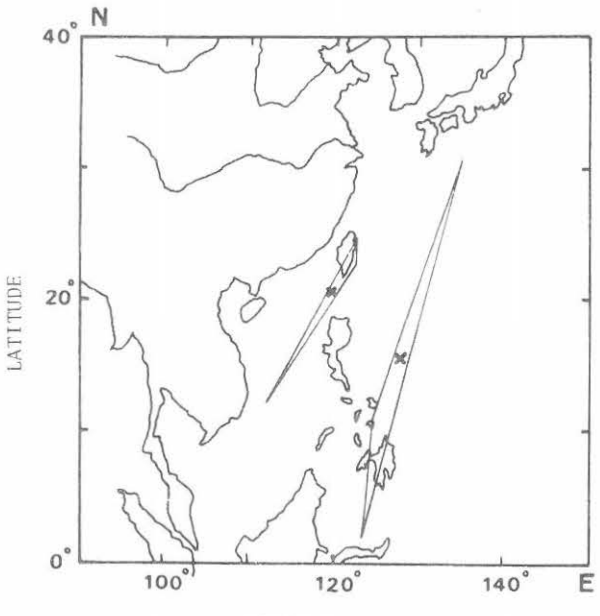


Fig.10 Two typical shape of the cocked hats of the direction along the basalines around the Philippines.

east of the Philippines, and so the error becomes relatively larger. It is summarized that the patterns in the daytime and at night in the region along the baselines distinctly depend upon the above equation.

Finally, we compare the patterns of Fig.6 and Fig.8. The two patterns are not similar on the whole. Observing in detail, the error curves of 150Km and 200Km in Fig.6 and those in Fig.8 have similar trends in the region perpendicular to the baselines, and some loops are found in and out of the curves of 200Km in Fig.8. It is suggested from these results that the fixing error from the observational data is due not only to the instrumental error and the arrangement of the DF stations but also to site and propagation errors, except in the region along the baselines.

The remarkable difference between Fig.6 and Fig.8 is found in the region along the baselines. For example, the curves of 200Km is drawn from the East China Sea to the Philippine Sea in Fig.6, while it extends to the South China Sea in Fig.8. This difference is mainly caused by the condition for the fixing of the triangulation in this region and the equation used in the error calculation, as discussed above.

4. Concluding remarks and future problems.

It is clear that the distribution of atmospherics sources in the Far East have seasonal peculiarities. However, the fixing rate in the region along the baselines becomes lower than that in the other regions because of the distortion caused by the shape of the three stations DF network. Therefore, we can not accurately describe the characteristics of the distribution in the region along the baselines.

It is confirmed from the computer error calculation and from the error calculated from the observational data that the fixing error in the region perpendicular to the baselines mainly depends upon the measurement error of the DF and the arrangement of the three DF stations, and that that in the region along the baselines depends upon the condition for the fixing of the triangulation and the equation adopted in the error calculation.

In order to solve these problems, a detailed investigation of site and propagation errors is necessary. And the development of the GDD* method and others is necessary. The observational plan for locating using a fourth station far from the Japanese Islands must be also carried out, in the future.

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* GDD is the difference between the group delay times of the spectral components at two frequencies that can be chosen in the lower VLF range (5 to 10KHz).