ATMOSPHERICS IN THE FAR EAST–II

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Summary

The author made an extensive series of observations of waveform and direction finding of atmospherics, conducted at three observatories in Japan, from 1952 to 1954.

He arranged the obtained results in two parts; in the first he describes in detail the correlation of origins of atmospherics with thunderstorms, showers, snow storms, cumulo-nimbi, cyclones, tropical depressions and storms, typhoons, fronts, troughs in the upper atmosphere, etc.

In the second, he shows the distribution of origins of atmospherics in the Far East as well as in the Western Pacific all the year round, specifically in tropical and subtropical Asia and Australia, the Indonesia Islands, the China Sea including the Philippines etc., and gives a reasonable interpretation of the distribution of origins from meteorological point of view, especially the convergence of air mass in the intertropical and temperate fronts, the orographic lifting and strong insolational heating effects, and so forth.

Résumé

L'auteur a fait les séries d'observation de la forme et la goniométrie des atmosphériques effectuées simultanément aux trois observatoires du Japon de 1952 à 1954.

Il divise les resultats obtenus en deux parties; dans la première partie on rapporte en detail la correlation entre les origines des atmosphériques et les orages, les averses, les tourmentes de neige, les cumulo-nimbus, les cyclones, les cyclones et orages tropicals, les typhons, les fronts, les creux de haute atmosphère, etc.

Dans la deuxième partie, on donne la répartition des origines atmosphériques en Asie et sur l'Océan Pacifique toute l'année, plus particulièrement en Asie et Australie tropicale et subtropicale, Indonésie, les Iles Philippines, la Mer de Chine Orientale et Méridionale, et donne interpretation raisonable sur la répartition des origines des atmosphériques au point de vue météorologique, en particulier de la convergence de la masse d'aire sur les fronts inter-tropicales et tempérés, l'effet de l'ascension orographique de l'aire tropicale ainsi que celui de chauffage fort insolational.

I. Introduction

In the previous paper[1] the author described in detail the extensive observation of atmospherics carried out from 1943 to 1944, and gave a full account of the correlation between atmospherics and weather phenomena, in addition to an explanation of the seasonal variation in distribution of origin of atmospherics in the Far East. At that time he used cathode ray direction finders (C.R.D.F.) and narrow sector goniometers, but the half-power beam width was not sufficiently narrow, *i.e.* 3° for the former and 10° for the latter, neither was the simultaneity of observation at all stations accurate enough to determine satisfactorily the origin of atmospherics from the results, though the stations were widely distributed throughout the Western Pacific. For several years after World War II, the author made fundamental researches to improve observation equipment. He could reach a narrow half-power beam width of 1° for C.R.D.F. with unidirectional characteristics, and could also keep a strict simultaneous observation at every station relying upon JJY, the standard wave emitted by the Radio Regulatory Bureau of Japan.

On account of the remarkable reduction in our territorial range, it is rather difficult to establish widespread observatories, but the highly improved performance of C.R.D.F., the accuracy of simultaneity of observation, and the use of waveform recording equipment have made it possible to determine the waveform of atmospherics having their origins in various kinds of discharge sources, and to investigate their variations with regard to distance and propagation path.

The present paper represnts the results of an extensive series of observations* conducted at Toyokawa, Kikuchi and Akita in Japan, from 1952 to 1954.

This paper is in two parts: the first describes the correlation of atmospherics with weather phenomena referring to meteorological data on the surface of the earth as well as in the upper atmosphere, *i.e.* in 500 mb and 700 mb, as supplied by the Central Meteorological Observatory; the second part covers the seasonal variations of origins of atmospherics in the Far East, interpreted from the meteorological point of view.

II. Correlation of Atmospherics with Weather Phenomena

2.1. Thunderstorms, Showers, Snow Storms and Cumulo-nimbi

As cumulo-nimbi develop, partial discharges within them begin to occur everywhere at random, and shortly after growing into leader strokes followed by main strokes to the earth and sometimes into active partial discharges to other clouds.

Atmospherics emitted from main or partial discharges, neglecting weak high frequency components, have frequencies between 2 and 30 kc/s with predominance around 10 kc/s and durations between 100 and 3,000 μs with predominance around 600–700 μs.[2)]

Those emitted from leader strokes similarly have frequencies between 10 and 60 kc/s with predominance around 20–30 kc/s and durations between 100 and 2,000 μs with predominance around 600–700 μs.[2)]

Showers, being small scale thunderstorms, always emit atmospherics with frequency and duration of the same order, while snow storms emit atmospherics with waveforms more regular than those of thunderstorms, having frequencies between 5 and 30 kc/s with predominance around 6–13 kc/s and durations between 500 and 1,800 μs with predominance around 800 μs.[3)]

* Our network of C.R.D.F., operating at 10 kc/s, consists of Toyokawa (34°50′ N, 137°22′ E), Kikuchi (32°55′ N, 130°50′ E) and Akita (39°43′ N, 140°08′ E) stations. Distance between Kikuchi and Toyokawa is 633 km; between Akita and Toyokawa 597 km and between Akita and Kikuchi 1,126 km. At all stations the waveform observations were made also simultaneously.

Fig. 1 is a weather chart at 1500 JST, 19 September 1952. Origins of atmospherics due to cumulo-nimbi and thunderstorms in the Philippine Islands are indicated by symbol (×). There is also a tropical depression of 1,004 mb north-east of the Philippines. A cold front is in the Kyushu and Formosa districts and origins of atmospherics due to these cumulo-nimbi and showers are observed too.

Fig. 2 is a weather chart at 1500 JST, 14 September 1952 and Fig. 3 one at 1500 JST, 15 September 1952, both of which indicate summer type weather where the wet and warm Ogasawara air mass (mT) prevails.

Origins of atmospherics (×) due to showers and cumulo-nimbi in Formosa in Fig. 2 seem to be partially influenced by a tropical depression of 1,000 mb near Hai Nan Island, and those due to thunderstorms, showers and cumulo-nimbi in Iwoshima in Fig. 3 are of thermal nature.

Fig. 4 is a weather chart at 0900 JST, 17 September 1952, wherein we observe origins of atmospherics due to thunderstorms, showers and cumulo-nimbi in Hachijoshima and Torishima.

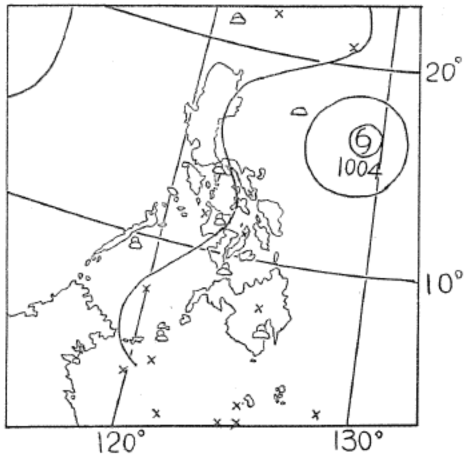

FIG. 1

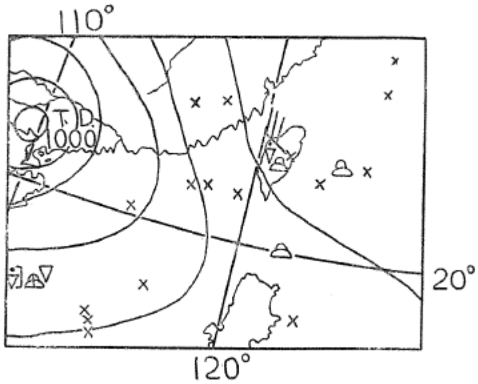

FIG. 2

FIG. 3

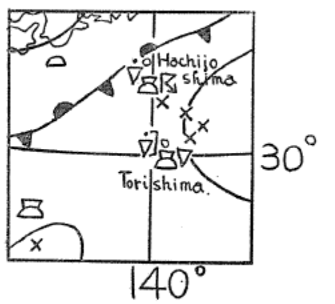

FIG. 4

Fig. 5 is a weather chart at 0300 JST, 16 September 1952. Origins of atmospherics in Iwoshima, Chichishima and Marcus Island are due to thunderstoms and cumulo-nimbi there, but those in Marcus Island are partially influenced by the tropical storm "Olive" of 994 mb in the neighbourhood of Wake Island.

Fig. 6 is a weather chart at 0000 JST, 7 September 1953, and Fig. 7 one at

2100 JST, 8 September 1953, both of which indicate origins of atmospherics (×) due to thunderstorms.

In summer these thunderstorms are always generated in this district owing to a tropical convergence line formed by the mixing of a tropical maritime air mass coming from the Western Pacific and one from the Indian Ocean. Since base lines connecting observatories are too short to determine accurately distant origins such as those in the Philippines, in a radius vector variation of 0.5° in triangulation the distance varies about 200 km. It is inevitable that we cannot obtain in longer distances a strict one to one correspondence between origins of atmospherics and positions of thunderstorms, showers and so forth.

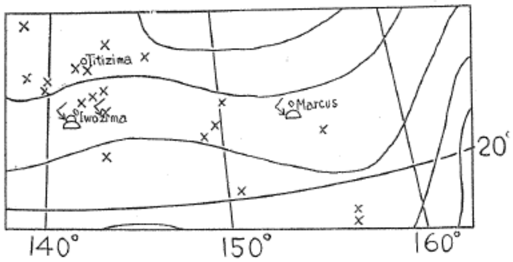

FIG. 5

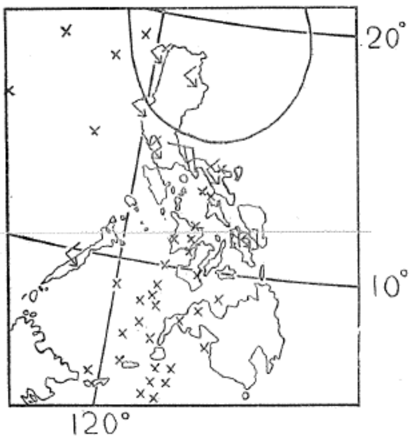

FIG. 6

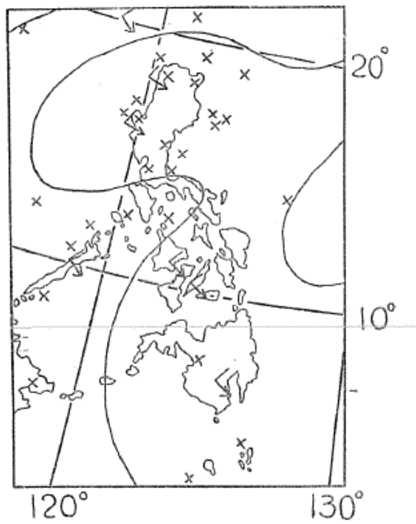

FIG. 7

Fig. 8 is a weather chart at 0900 JST, 22 February 1953. Origins of atmospherics due to snow storms and cumulo-nimbi are distributed along the coast of the Japan Sea and atmospherics due to showers and cumulo-nimbi are on the Pacific, the latter being intimately corrlelated with cold fronts there.

Fig. 9 is a weather chart at 2100 JST, 20 February 1953. Origins of atmospherics due to snow storms and cumulo-nimbi are found in the northern part of Honshu and on Hokkaido. A warm front passes across Honshu, but no origins of atmospherics concerning it are found except those on the Pacific north of the cold front corresponding to showers.

Fig. 10 is a weather chart at 1500 JST, 17 February 1953. Origins of atmospherics due to cumulo-nimbi are spread over the Philippine Islands. In winter convergence in this district is due to the invasion of a cold air mass (cP) passing over China into the wet and warm air mass (mT) on the East China Sea.

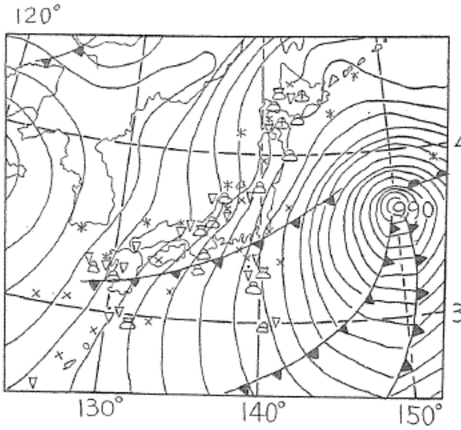

FIG. 8

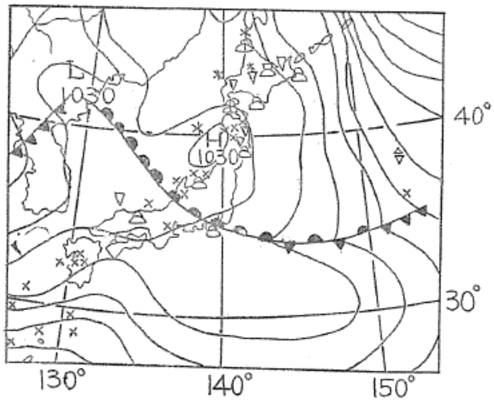

FIG. 9

In the following paragraphs we give many examples of origins of atmospherics distributed in active weather phenomena such as fronts, troughs, depressions, tropical depressions, tropical storms, typhoons, jet streams, etc. and we assume there exist some discharge phenomena similar to thunderstorms, showers and so forth, as symbol of meteorological disturbances found to be fairly coincident with construction of the phenomena.

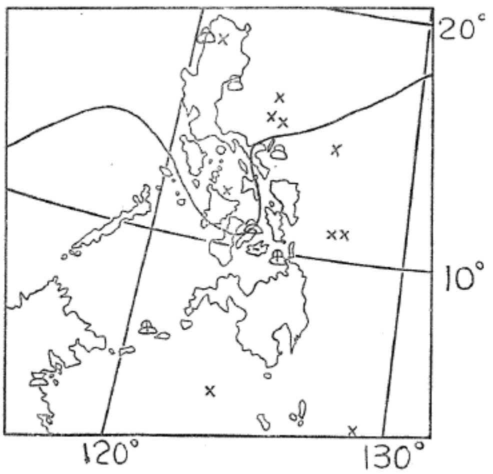

FIG. 10

2.2. Cyclones Accompanied by Fronts

Fig. 11 is a weather chart at 1500 JST, 16 September 1952. An occluded front starts from a cyclon of 1,007 mb

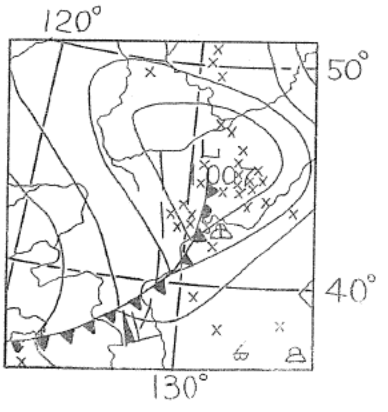

FIG. 11

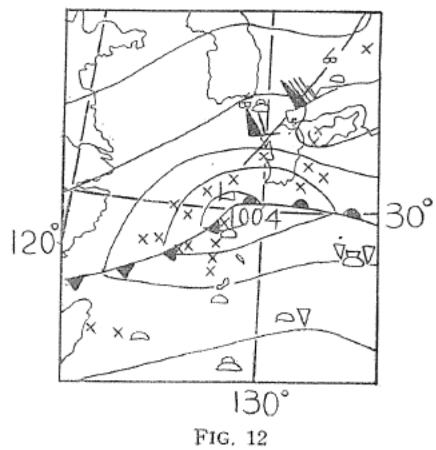

FIG. 12

in Manchuria, and soon changes into a cold front. A trough in 700 mb passes to the west of the cyclone, and there are many origins of atmospherics over convergence regions developed around these phenomena.

Fig. 12 is a weather chart at 1200 JST, 19 September 1952. There is a cyclone of 1,004 mb near the south end of a trough in 700 mb coming from Sakhalin, and a warm front extends eastward and a cold front westward from the cyclone. Origins of atmospherics are scattered along the cold front and the trough, especially near the centre of the cyclone, *i.e.* the convergence region.

Fig. 13 is a weather chart of 0900 JST, 21 September 1952. Origins of atmospherics are spread in the neighbourhood of the centres of cyclones of 1,006 mb and 1,008 mb, respectively, and another group of origins are also found along a trough of 700 mb which passes west of the cyclone of 1,008 mb.

Fig. 14 is a weather chart at 0900 JST, 11 September 1953. Origins of atmospherics are concentrated near the centre of a cyclone of 1,002 mb accompanied by two stationary fronts, the one being extended to the east, the other to the southwest.

Showers and cumulo-nimbi are observed in the neighbourhood of Hachijoshima and Torishima.

There are some other cyclones of lower activity on this stationary front, but it seems that origins are mainly concentrated in cyclones of deep centre.

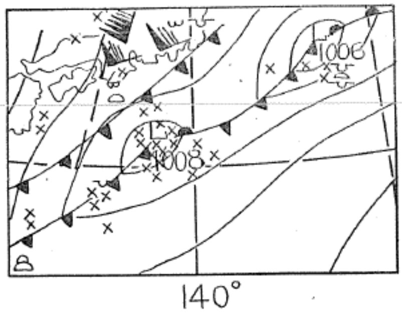

FIG. 13

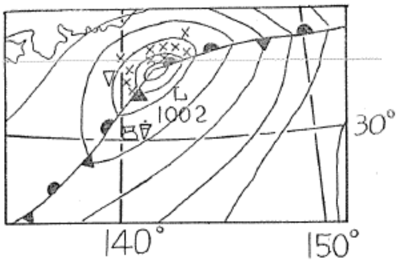

FIG. 14

From these examples we may say that convergence in cyclones is not always sufficiently active to generate electric discharges in the atmosphere, but in some regions cyclones may be remarkably activated by the existence of fronts, troughs, etc. to the extent that they become origins of atmospherics. In fact we very often find many origins concentrated in cyclones of deep centre and very sparsely scattered in cyclones of shallow centre even when they are on the same front.

2.3. Tropical Cyclones

The author described in previous papers several correlations of the distribution of origins of atmospherics with distribution of active regions of Typhoons Kezia[4] and Ruth.[5] Following is a supplement to previous papers, covering studies made thereafter.

Fig. 15 is a weather chart at 0900 JST, 18 September 1952. One group of origins of atmospherics is found on the converging wind line between the eye of Typhoon Olive of 940 mb and the anticyclone to the east, the other group is on the sea between the eye and the stationary front to the north.

Fig. 16 is a weather chart at 0900 JST, 14 September 1952. Origins of atmospherics on the slope of mountains Nan-Shan and Ta-Yu-Shan, and on the coastal line of South China are due to convergence of wet and warm air masses of a tropical depression of 998 mb with the aid of orographic lifting.

Fig. 17 is a weather chart at 0900 JST, 20 September 1952. A tropical depression of 1,004 mb is off the coast of Luzon Island, and many origins of atmospherics are found in nearly symmetrical distribution around its centre.

Fig. 18 is a weather chart at 0900

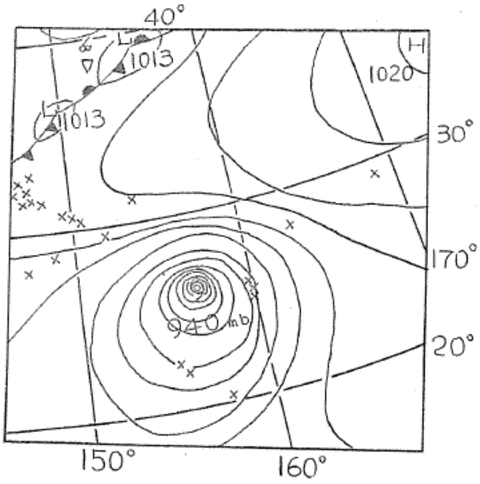

FIG. 15

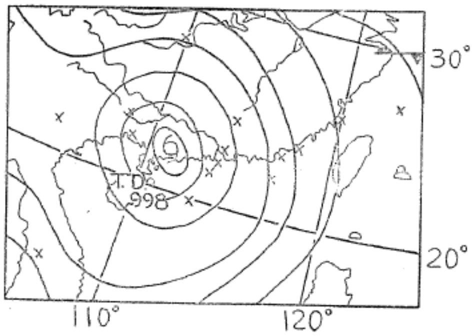

FIG. 16

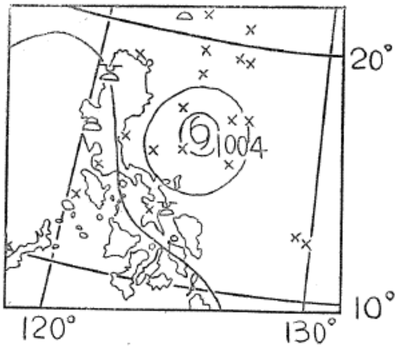

FIG. 17

JST, 8 September 1953. The centre of a tropical depression is at 28° N, 160° E on the Pacific Ocean and a trough in 700 mb passes to the west. Origins of atmospherics are found in the convergence region between the centre of depression and the trough.

Fig. 19 is a weather chart at 0900 JST, 9 September 1953. The centre of a tropical depression is at 30° N, 157° E, from which a tropical front extends eastward, and many origins of atmospherics are found along this front.

Summarizing these results and the observations made in Typhoons Kezia[4] and Ruth,[5] we may conclude that regarding typhoons, tropical storms and depressions, the origins of atmospherics are

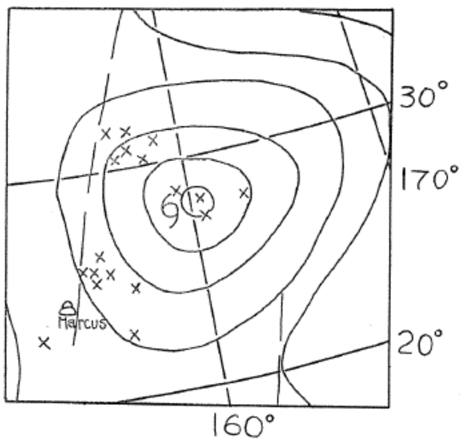

FIG. 18

found in various places, some in the dangerous semi-circle of a typhoon, especially in active zones on the surface of the earth or in the upper atmosphere, some in the converging wind line between the eye and the anticyclone, some on the slopes of mountains with the aide of orographic lifting of wet and warm air mass of the typhoon, some in the converging area between the eye and the fronts or the troughs in the upper atmosphere, some along the tropical fronts extending from the centre, and in other places.

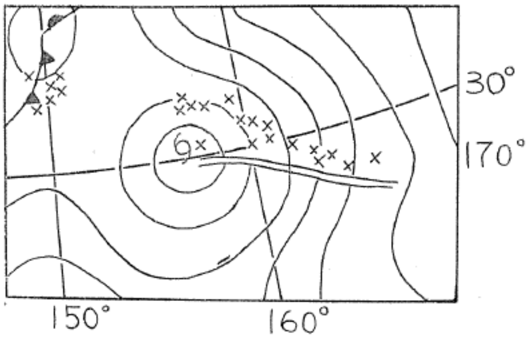

FIG. 19

2.4. Fronts on the Surface of the Earth

Fig. 20 is a weather chart at 0900 JST, 15 September 1952. The pressure distribution is typical summer type, *i.e.* high in the south and low in the north. An anticyclone is on the Ogasawara Island area with its mT air mass prevailing over Japan. As there lies a stationary front south of Japan, the Ogasawara air mass (mT) ascends vigorously above the front and a remarkable convergence is observed along the front. This is the reason many origins of atmospherics are found there.

Fig. 21 is a weather chart at 1500 JST, 19 September 1952. A cold front which starts at the centre of Typhoon Olive going westward along Japan, accompanies a cyclone of 1,002 mb south of Kyushu. A cold front in the chart starting from this cyclone passes by the Ryukyu Islands and goes on to South China. A trough in 700 mb passes through the Japan Sea along Japan and reaches Formosa. The front and the trough energize the convergence region on the East China Sea and origins of atmospherics are found along the front and the trough where showers and cumulo-nimbi are observed.

Fig. 22 is a weather chart at 1500 JST, 9 September 1953. A cold front starting from a cyclone of 1,006 mb in Siberia passes through Manchuria, North China and West China and finally reaches Tibet. It produces some origins of atmospherics on the way which correspond to convergence conditions.

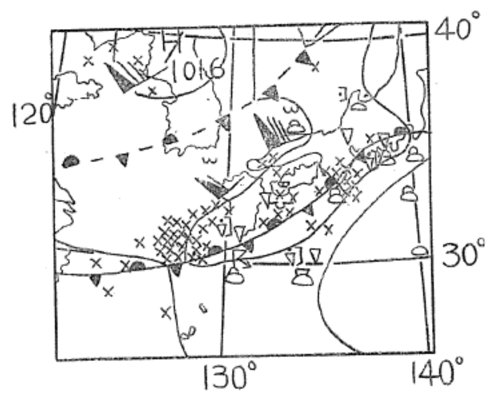

FIG. 20

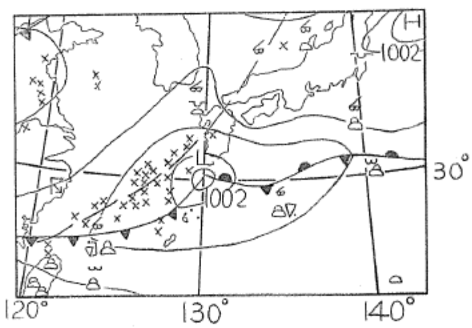

FIG. 21

Fig. 23 is a weather chart at 0900 JST, 15 September 1952. A cold front starting from a cyclone of 1,004 mb in Siberia goes through Taraski Gulf and passes to the west of Hokkaido. This front struck Hokkaido and Sakhalin soon afterwards where it produced thunderstorms. Origins of atmospherics along this cold front are probably due to convergence in the course of generating cumulonimbi.

These examples show that the front on the surface of the earth becomes an important source of atmospherics if it is activated by tropical maritime air flows, troughs in the upper atmosphere, orographic lifting, strong insolational heating on the land, etc., and in such cases thunderstorms, showers, and cumulo-nimbi are generally observed.

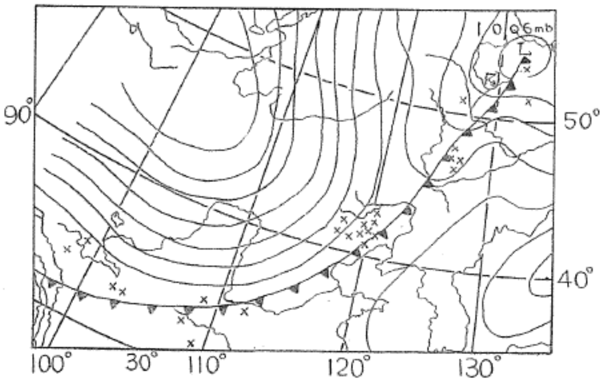

FIG. 22

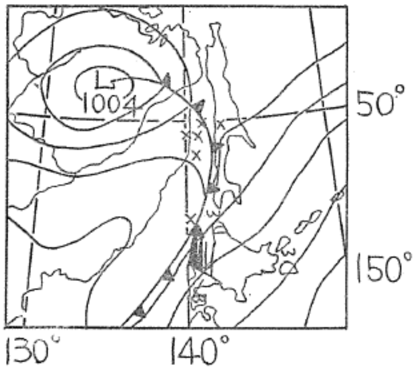

FIG. 23

2.5. Troughs in the Upper Atmosphere

Fig. 24 is a weather chart of upper atmosphere in 700 mb at 1200 JST, 19 February 1953. A trough passes along Japan from Hokkaido to the Ryukyus, and origins of atmospherics are distributed along the trough.

Fig. 25 is a weather chart of upper atmosphere in 700 mb at 0000 JST, 23 February 1953. A trough in 500 mb lies along the south coast of Japan, and another in 700 mb passes to the east coast and reaches a region north of a tropical depression. Origins of atmospherics are distributed along these trough lines, especially in the neighbourhood of a tropical depression at 142° E, 14° N.

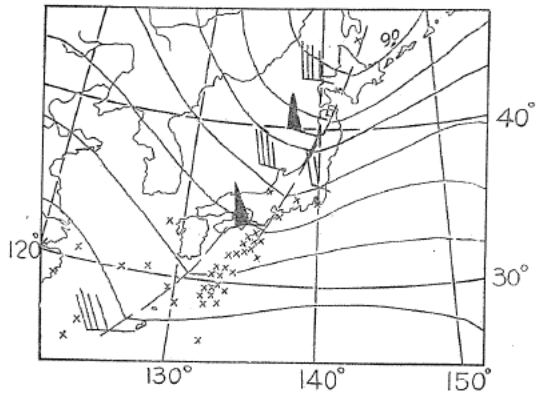

FIG. 24

Fig. 26 is a weather chart of upper atmosphere in 700 mb at 1500 JST, 21

February 1953. Thin lines indicate isothermal lines, and thick lines isobar. We find that there is a tendency for origins of atmospherics to be found not only along a trough line but also, more often, along isothermal lines.

Fig. 27 is a weather chart of upper atmosphere in 700 mb at 1200 JST, 6 September 1953. Trough lines in 500 mb and 700 mb lie on the sea east of the Philippines, and origins of atmospherics are found in this region where a tropical convergence line always prevails. Therefore if this is excited by trough lines, atmospherics are generated.

These examples show that trough

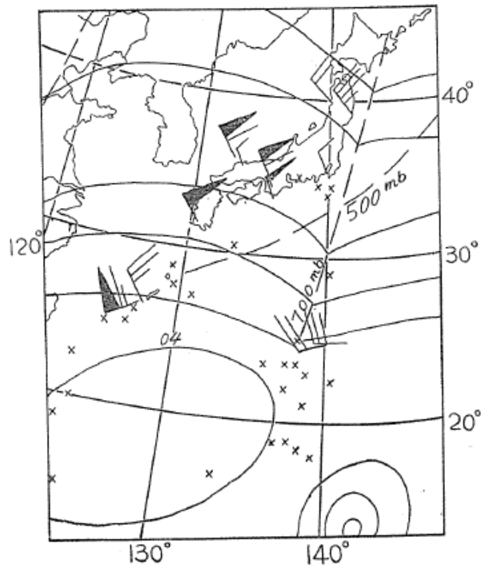

FIG. 25

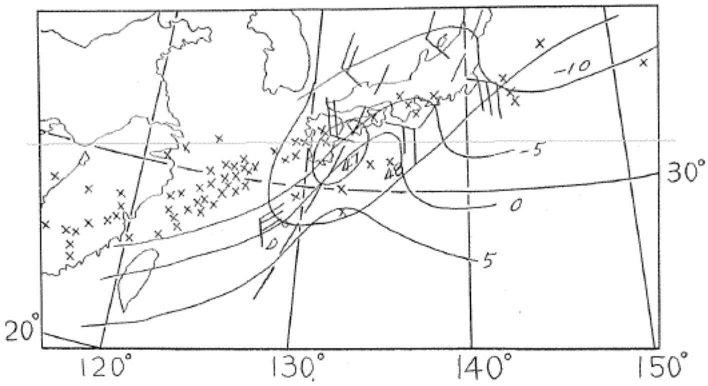

FIG. 26

lines in the upper atmosphere are always accompanied by convergence region and when trough lines are activated by tropical convergence lines in summer or by unstable polar air masses modified by warm sea surfaces in winter, they become origins of atmospherics. In general it is necessary to combine the action of unstable air masses and the convergence of troughs; neither can alone become an origin of atmospherics without the aid of the other.

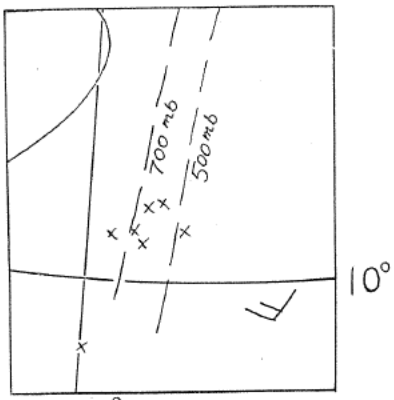

FIG. 27

2.6. Jet Streams in the Upper Atmosphere

The author made previously an extensive study on origins of atmospherics in winter due to jet streams in the upper atmosphere.[6] In this section some supplementary examples and interpretations will be given.

Fig. 28 is a weather chart of upper atmosphere in 700 mb at 1200 JST, 18 February 1953. An anticyclone is in Siberia and strong westerlies flow from the continent to the Pacific. A group of origins of atmospherics is found along a trough in 700 mb, and another group extends itself to the Pacific along the latitude 35° N. The latter group is interpreted as origins due to jet streams in the upper atmosphere.

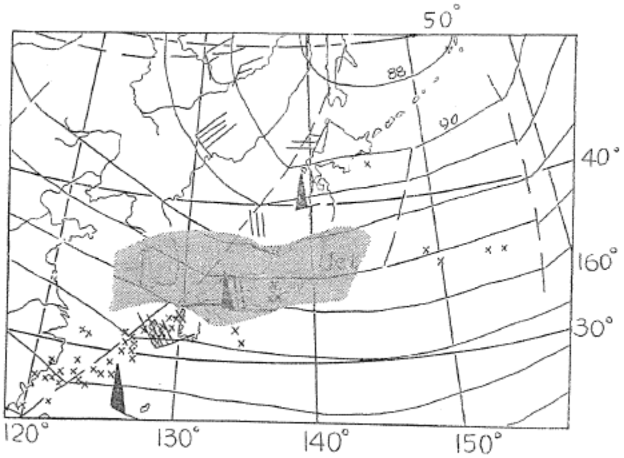

FIG. 28

Fig. 29 is a weather chart of upper atmosphere in 700 mb at 1500 JST, 21 February 1953. An anticyclone is on the Sea of Okhotsk and strong westerlies flow from the continent to the Pacific. A cyclone of 974 mb at 153° E, 39° N is

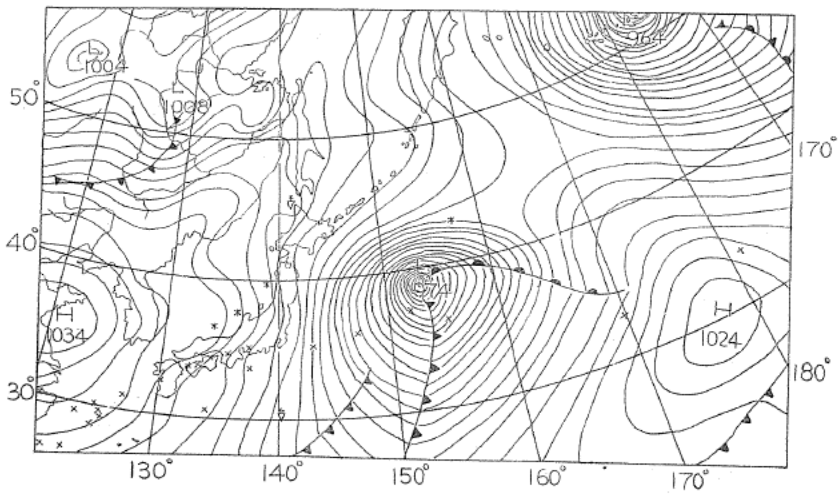

FIG. 29

accompanied by a cold and a warm front. A zonal distribution of origins of atmospherics is found along latitude 35° ± 2° N to longitude 180° E, and is considered due to jet streams in the upper atmosphere.

Although at present it is rather difficult to definitely account for the zonal distribution of origins of atmospherics in winter by jet streams in the upper atmosphere, it is true that many favourable examples have been successively brought out and as yet there appears no other effective interpretation for such zonal distribution.

III. Origins of atmospherics in the Far East[1)7)]

3.1. General Air Flow in the Far East and the Western Pacific[7)]

In accordance with the seasonal variation of the temperature distribution, a deep cold anticyclone is centred above Siberia in winter,* while a heat low forms above northwestern India and secondary heat lows lie over inner China, Mongolia and southern Siberia in summer.*

Above the North Indian Ocean, a dynamic surface anticyclone produces a comparatively high-pressure area in summer, while above the South Indian Ocean the average pressure is high throughout the year.

The North Pacific anticyclone, at times broken into two separate centres in winter, occupies its lowest-latitudinal position in the central portion of the North Pacific. In the South Pacific space, the principal anticyclonic cell dominates most of that oceanic space. To its west a surface heat low is formed in the Australian space.

The period of greatest intensity and magnitude of the North Pacific cell is in summer, while the South Pacific cell is reduced in intensity and is occasionally subject to breakdown and no quasi-permanent cold anticyclones form in Australia.

The immediate result of the creation of a cold anticyclone over the higher latitudes of the Asiatic continent in winter is an outward flow of the cold continental air toward the Pacific Ocean through all of middle-latitudinal and subtropical China.

The reapprearance of the dynamic anticyclonic whirl above India, south and west of the mighty mountain ranges, produces air flow which is basically directed downward with north-westerly to north-easterly velocity components. This outpouring of the subsiding air replaces the Southern Hemisphere air everywhere north of the equator and even invades the Southern Hemisphere to some extent.

The air flow at the lowest southern latitudes is that of a typical monsoon, *i.e.* the easterlies coming from the Northern Hemisphere recurve to the left, following the deflecting force of the Southern Hemisphere and, at southern latitudes greater than 5°, appear as north-westerly to westerly surface winds; it is apparent that at this stage of its development, the air mass is no longer subsident but is convergent and exhibits typical mE† characteristics.

* Winter and summer means those prevailing in the Northern Hemisphere.

† Convergent Tropical Maritime Air on Equatorial Air (mE). The source region of convergent and ascendent maritime equatorial air (mE) consists of the oceanic portion of the zone of general convergence and ascendence called "the intertropical front." Hence in summer the equatorial North Pacific Ocean, the North Indian Ocean, and the Macronesian waters between these two Oceans are source regions of the moist and unstable air mass. In winter the principal source region of mE air moves into the equatorial South Indian Ocean.

The surface flow above the North Pacific on the whole is anticyclonic in winter, with large outbreaks of polar air from the northwest entering the subtropical circulation. South of latitude 20° N the easterly trade winds blow over the entire expanse of Equatorial Pacific Ocean without hindrance from or deflection by any large land mass. South of the equator the easterly surface flow arriving from the Northern Hemisphere turns first into a northerly and then into a north-westerly wind. This deflected flow is most powerful in the area north and east of Australia where the intertropical front reaches the farthermost southern latitudes.

With the advance of the Northern Hemisphere summer, the heat lows in northern Idia and China deepen sufficiently to disrupt the dynamic anticyclonic circulation above South Central Asia and the North Indian Ocean to a considerable depth. Hence the surface circulation above India then becomes cyclonic; that above China at least stagnant. With the breakdown of the anticyclonic circulation and its subsident flow above the North Indian Ocean, the path is then clear for the Southern Hemisphere air to enter deeply into the Northern Hemisphere region, overflowing all of India, the East Indies Archipelago, and most of the southwestern North Pacific.

In the Southern Hemisphere the air flow is characteristically anticyclonic, with easterly winds prevailing at low latitudes south of the equator. The outflow of Southern Hemisphere air crossing the equator undergoes the expected deflection toward the right upon entering the Northern Hemisphere, and therefore is predominantly south-westerly.

The South Pacific space is greatly affected by the inflow of modified south-westerly polar air into the Australian space. Together with the heat low occupying subtropical China, this energetic flow of comparatively cool air is responsible for the inroads which the intertropical front makes into the Northern Hemisphere during the summer. The southerly and south-westerly flow in the China Sea area penetrates the Northern Hemisphere as far as Southern Japan.

3.2. Distribution of origins of atmospherics in the Far East and the Western Pacific.

The following are examples of distribution of origins of atmospherics in the Far East and the Western Pacific which can be explained in detail through meteorological interpretation.

Fig. 30 is a weather chart at 2100 JST, 6 September 1953. Main origins of Atmospherics are observed in 4 districts, *i.e.* (1) the Yantze Valley, (2) the Ganges, Brahmaputra and Irrawaddy Valleys, (3) Malaya and the Indonesia Islands, and (4) the South China Sea and zones along its shore.

In summer the intertropical front lies along the Ganges Valley, across upper Burma, including the Brahmaputra and Irrawaddy Valleys, and continues as a diffused convergence zone through Yünan, the Yantze Valley, the Yellow Sea and southern Japan.

Heavy frontal and orographic disturbance is observed along the western side of Khasi, Arakan (Burma) and Tenasserim (Malaya) mountain ranges when the intertropical front lies to the north of these ranges and the flow of southwesterly equatorial air is forced to ascend along their western slopes.

In tropical and subtropical China, including Yünan and the Yantze Valley, the intertropical front penetrates an area which is already quite active with temperate

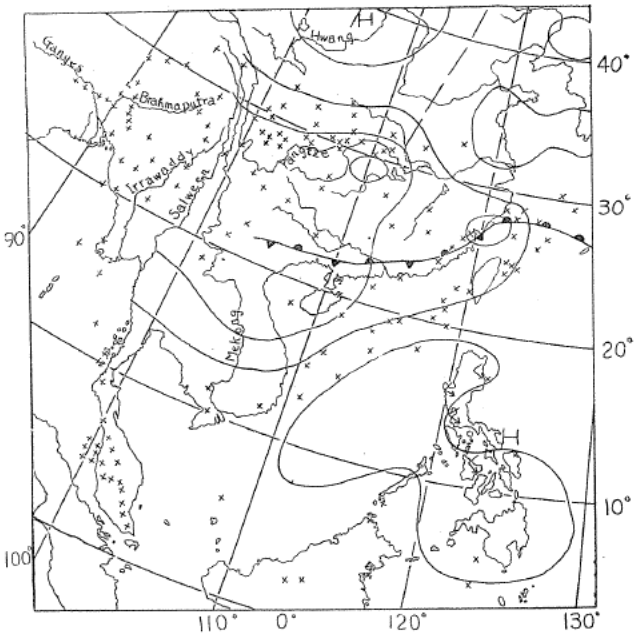

FIG. 30

fronts, tropical squall lines and tropical-front phenomena.

A remarkable discontinuity is also observed in the China Sea area between the deflected South Indian Ocean air mass and the deflected South Pacific trades and Australian air masses (cTs modified into mE air). This discontinuous line is found to be an active intertropical convergence line.

In the Macronesian Waters, including the Indonesia Islands, convergence lines, ranging in intensity from simple squall lines to cyclonic disturbances of hurricane force, develop throughout the entire tropical Indian Ocean area. Even small discontinuities between the various tropical maritime and equatorial air masses involved produce severe frontal phenomena once the tropical convergence sectors have been formed dynamically. Orographic trigger action plays an important part in the formation of these disturbances. Therefore, the most violent and most complicated frontal structures are found in the Macronesian Waters. Each inter-island passage creates its own small air-mass discontinuities and squall lines, depending on the prevailing air flow and the configuration of the terrain.

Fig. 31 is a weather chart at 1500 JST, 21 September 1952. Origins of atmospherics are found in the Philippine Islands, the Ryukyu Islands, Formosa and all over the East and South China Sea. As explained in Fig. 30, these districts are in the heavy tropical convergence zone and so cumulo-nimbi, showers, and thunderstorms are observed everywhere in the region.

Fig. 32 is a weather chart at 1500 JST, 9 September 1953. Origins of atmospherics are distributed on the coast of South China in addition to those on the East and South China Sea, including the Philippine Islands. A cold front coming from a cyclone of 1,008 mb transforms itself at Formosa into a stationary front and invades South China, accompanied by a cyclone of 1,010 mb along the way,

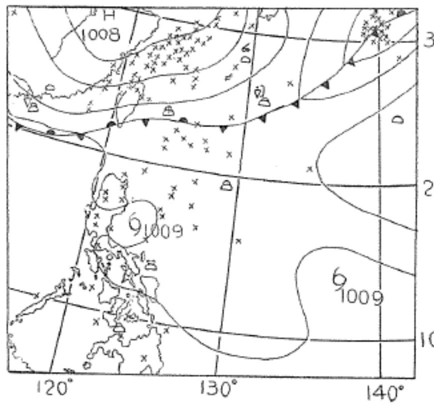

FIG. 31

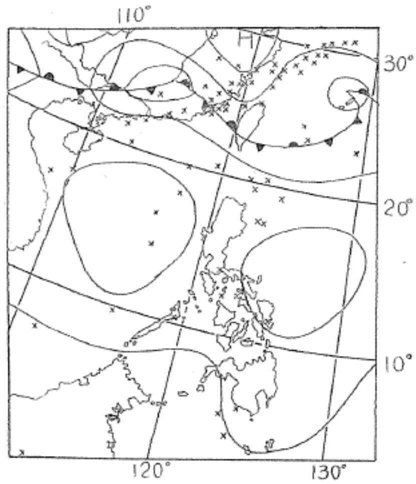

FIG. 32

and the same interpretation as that of Fig. 30 may be made of Fig. 32.

Fig. 33 is a weather chart at 2100 JST, 9 September 1953. Origins of atmospherics are observed in the South China Sea, the Philippine Islands, Indo-China, Siam, Malaya, Borneo, etc. Thunderstorms are indicated by symbol in Palawan Island and Indo-China, and the same interpretation as that of Fig. 30 holds good for Fig. 33.

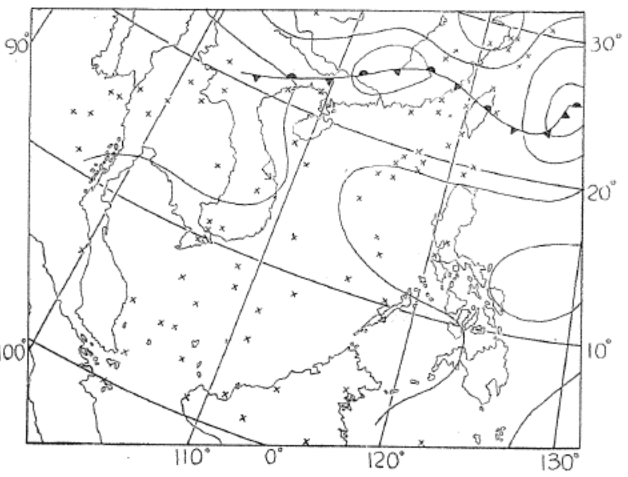

FIG. 33

Fig. 34 is a weather chart at 2100 JST, 7 September 1953. Origins of atmospherics are found in the East and South China Seas, the Philippine Islands, the Ganges, Brahmaputra, Irrawaddy and Mekong Valleys, Sikang inter-mountain area, etc. A stationary front accompanied by a cyclone of 1,006 mb lies in South China and the East China Sea, and the same interpretation as that of Fig. 30 is also true here in Fig. 34.

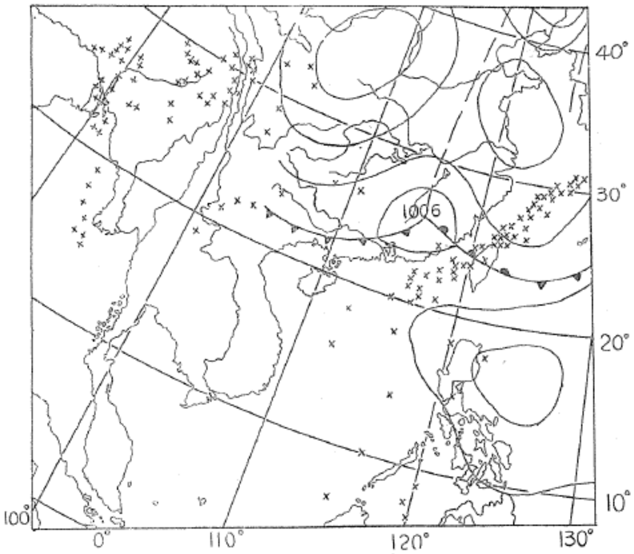

FIG. 34

Fig. 35 is a weather chart at 2100 JST, 21 February 1953. Origins of atmospherics are scattered mainly over the East China Sea but some are found in Japan and South China along a cold front.

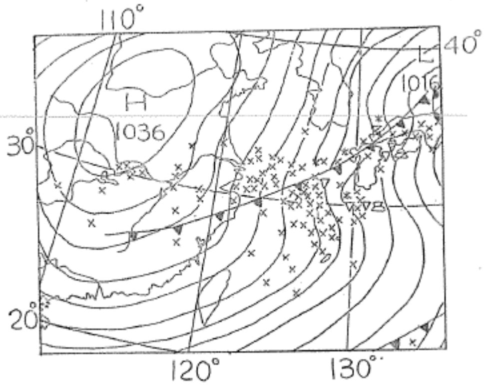

FIG. 35

In winter the primary source region of the polar continental air mass is Siberia. Low temperatures, low moisture content, and vertical stability characterize this air mass in its source region. In its flow towards subtropical and tropical Asia, the polar Siberian air may follow one of four typical trajectories: (1) through inner Mongolia into China; (2) through the highlands of northern China toward the coastal plains; (3) over the Sea of Japan and the Yellow Sea; (4) through the western gap in the Asiatic mountain systems, over Iran, into north-western India.

Upon reaching the truly tropical seas, that is, off the China coast south of Japan, all polar continental air masses, regardless of their intermediate history, are rapidly destabilized and humidified, thereby assuming the general characteristics of tropical maritime air (mT).*

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* Neutral tropical maritime air masses (mT) exist at the western equatorward end of each subtropical anticyclonic cell. The two principal source regions of such air masses affecting Asia and the Indian Ocean are the western North Pacific Ocean and the Indian Ocean proper. The air mass is convectively unstable and, especially in the presence of orographic lifting, will produce heavy thunderstorm clouds and precipitation.

In Fig. 35 an anticyclone is in North China and a cold cP air mass comes into contact with a wet and warm air mass on the East China Sea through (2) and (3) trajectories, and is triggered and heavily activated by the cold front there.

Fig. 36 is a weather chart in the upper atmosphere of 700 mb at 0000 JST, 18 February 1953. Origins of atmospherics are found in the East China Sea along a trough in 700 mb. An anticyclone is in Siberia and a cold cP air mass reaches the East China Sea through (2) and (3) trajectories, and is heavily activated by a trough in 700 mb.

Fig. 37 is a weather chart at 2100 JST, 22 February 1953. Origins of atmospherics are not concentrated over the East China Sea as in Fig. 35 and 36, but they are almost uniformly scattered in South China, Japan and the East China Sea. This is because in this case there are 3 anticyclones of the same strength in China, the Yellow Sea and the Japan Sea, side-by-side, and the characteristic cold cP air flow is too much disturbed to activate the air mass over the East China Sea.

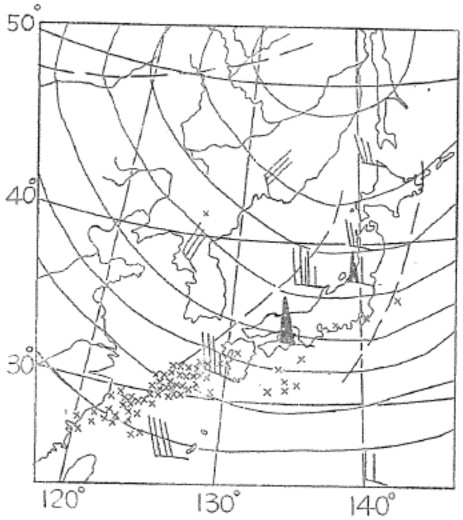

FIG. 36

Fig. 38 is a weather chart at 2100 JST, 23 March 1954. Origins of atmospherics are found in Malaya, Sumatra, Borneo, Siam, Indo-China, South China coast, the Philippine Islands and the South China Sea.

A north-southwestward route of cP air mass through China ends on the South China Sea west of the Philippines. The exposure of this air mass to warm ocean surfaces heats and moistens the air mass surface, converting it rapidly into unstable

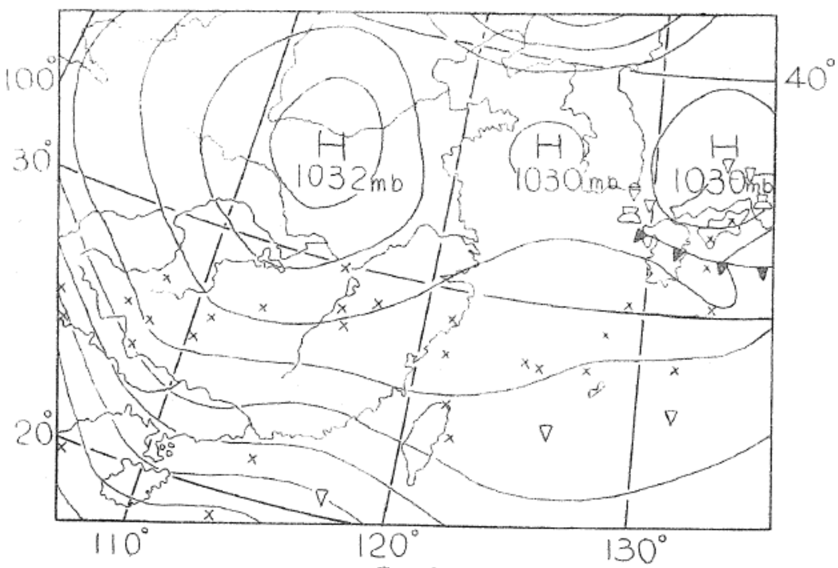

FIG. 37

mT air. This mT air and that of N-E trade wind in the Western Pacific are converged on the South China Sea and are activated by orographic lifting or strong insolational heating in Malaya, Sumatra, Borneo, Indo-China and the Philippines.

Origins of atmospherics in the India-Burma-South China coastal area depend upon the existence of temperate convergence front there throughout the entire year which is ensured by the dynamic convergence between the upper Asiatic anticyclonic cell and the North Pacific anticyclone, and by the temperature and moisture contrast at lower elevations between the Asiatic mainland and the tropical China Sea.

Fig. 39 is a weather chart in the upper atmosphere of 700 mb at 1200 JST, 26 March 1954. Fine lines indicate isothermal lines and heavy lines isobar. Main origins of atmospherics are on the coast of the China Sea along a isothermal line $+6^\circ$ C and others are in Indo-China, Siam, Central China, etc., and the same interpretation for Fig. 30 holds also good for Fig. 39.

Fig. 40 is a weather chart at 2100 JST, 24 March 1954. Origins of atmospherics are found mainly in the Bering Sea. They are considered due to convergence of the warm air mass which flows into the Bering Sea from the Gulf of Alaska and is forced to rise up and over the cold air mass there.

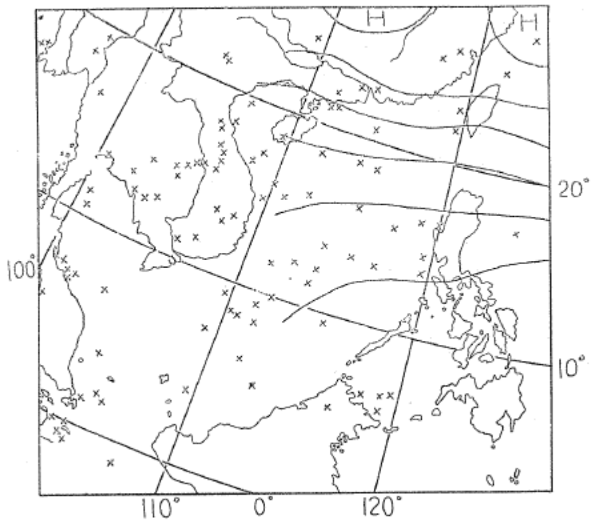

FIG. 38

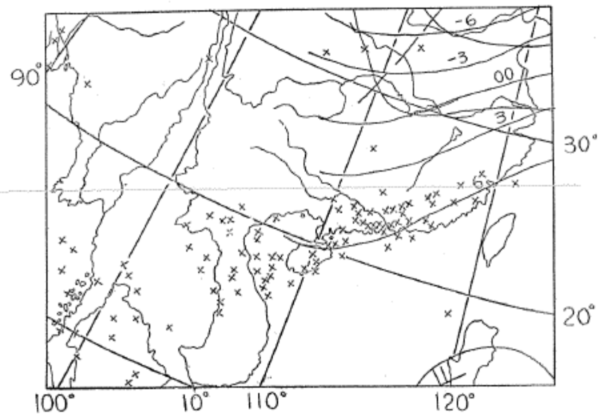

FIG. 39

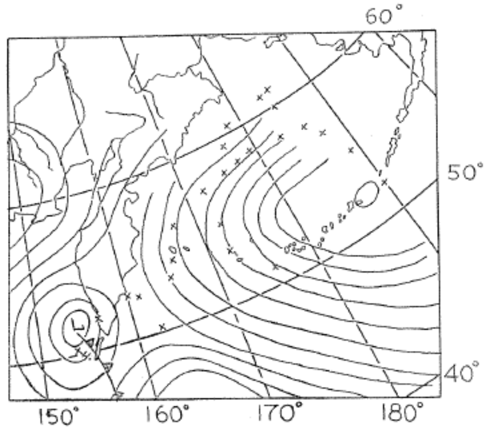

FIG. 40

Fig. 41 shows the distribution of origins of atmospherics in the Far East in September 1953 for the daytime. They are found in Manchuria, Hopeh, Shantung, the Yantze, Mekong, Irrawaddy and Brahmaputra Valleys, Siam, Indo-China, Malaya, Borneo, Sumatra, the Philippine Islands, the Archipelagoes in the Equatorial Pacific, the East and South China Seas, the Western Pacific and the Bering Sea. The interpretation of the majority of origins of atmospherics has already been made in the preceding examples excepting those in the archipelagoes in the Equatorial Pacific, which are explained as follows.

In summer the intertropical front follows the west coast of Central America to about latitude 15° N, passes just south of the Revilla-Gigedo Islands, reaches latitude 2° N near longitude 160° E, recurves toward the north-west and north, sweeps between the islands of Guam and Yap, crosses the Ryukyu Islands and other southernmost islands of Japan including Kyushu, then crosses the Yellow Sea or the Korea Strait and enters the Asiatic continent, where it loses most of its sharpness and assumes the character of a transition boundary.

Orographic obstacles in the path of the intertropical front, however, have a very marked trigger action on the ascendent and unstable air near the front. Such islands as Palmyra and Fanning are often the scenes of violent squalls and convergence clouds, while the frontal weather in adjacent oceanic areas is by comparison very mild. Because of the similarity in the two converging air masses the frontal discontinuity surface is nearly vertical. Within the frontal zone, however, narrow tongues of air underrun and overrun each other, producing extraordinary cloud formations such as towering cumulo-nimbus clouds under an altocumulus deck.

In India the continued sharp convergence and cyclonic shear along the intertropical front between the north-easters and the south-westerly monsoon in the Ganges Valley and the Bay of Bengal form frequent frontal-wave disturbances which move westward through the valley. These disturbances, although of limited dimensions, are accompanied by heavy precipitation, thunderstorms, atmospherics, and icing within the Cb clouds. The usual path of these intertropicalfront disturbances originates at the estuary of the Ganges and Brahmaputra Rivers, and continues west into Raiputana and Sind.

The influence of orographic lifting on the already convergent air masses is very marked in India. For example, both orographic and frontal weather are quite severe along the Western Ghats, while the region on the eastern slopes lies in rain shadow, mainly because of the orographic descent (although the less convergent characteristics of the southerly air mass are an important accessory influence). The arc form distribution of origins concentrated on the western boundary and the liner distribution on the southern indicate the limit of map available for triangulation and means that they belong to origins in some districts further away in these directions from observatories. For example, origins found off the coast of Calcutta in the Bay of Bengal may be attributed to thunderstorms in the Western Ghats.

Fig. 42 is the distribution of origins of atmospherics in the Far East in September 1953 during the nighttime. They are found in Hopeh, the Yantze, Mekong, Irrawaddy and Brahmaputra Valleys, Siam, Indo-China, Malaya, Sumatra, Java, Borneo, the Philippines, South China, the East and South China Seas, the North Pacific, etc. General features are almost the same as in the preceding example except that those origins in the archipelagoes in the equatorial Pacific, *i.e.* in com-

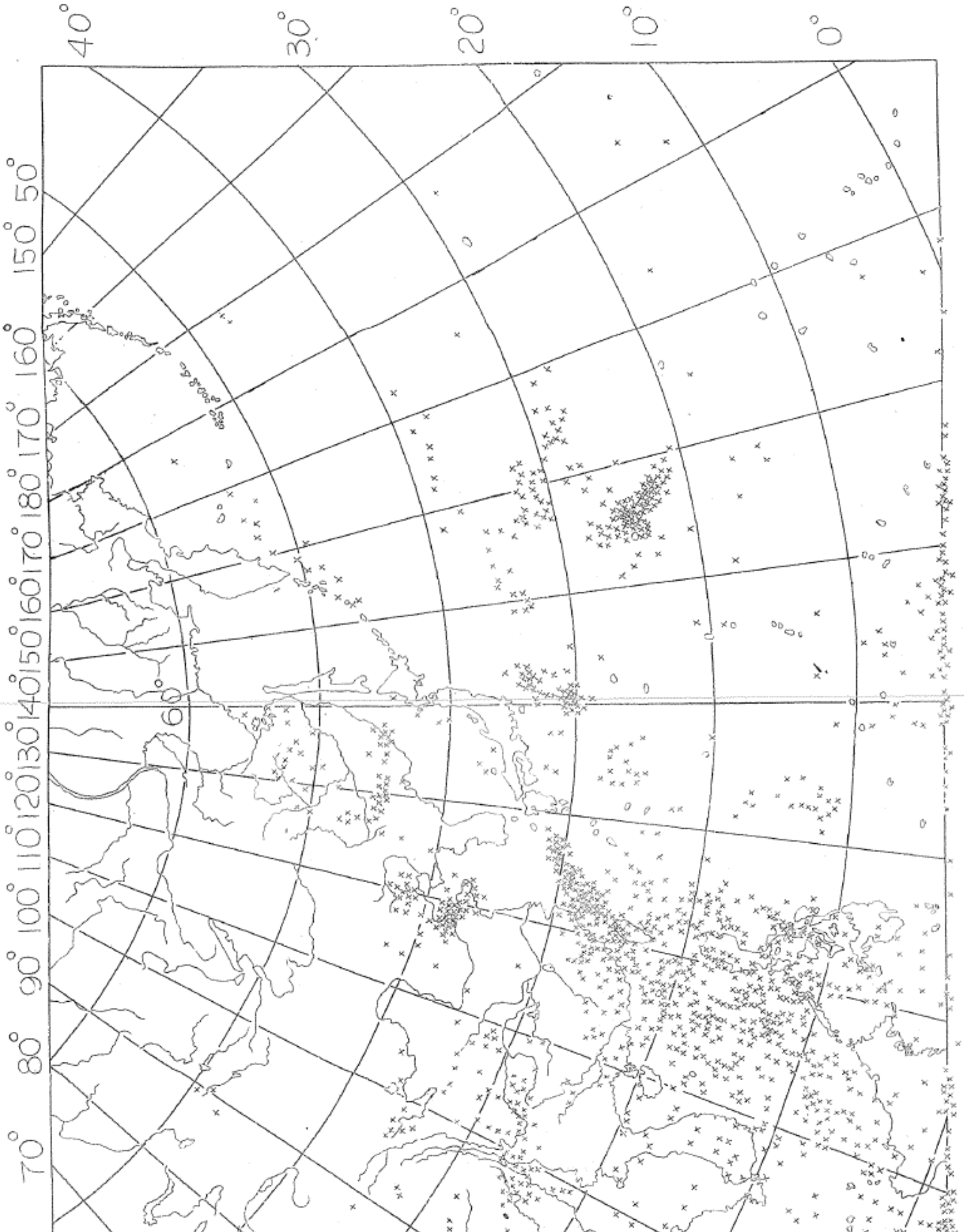
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FIG. 41

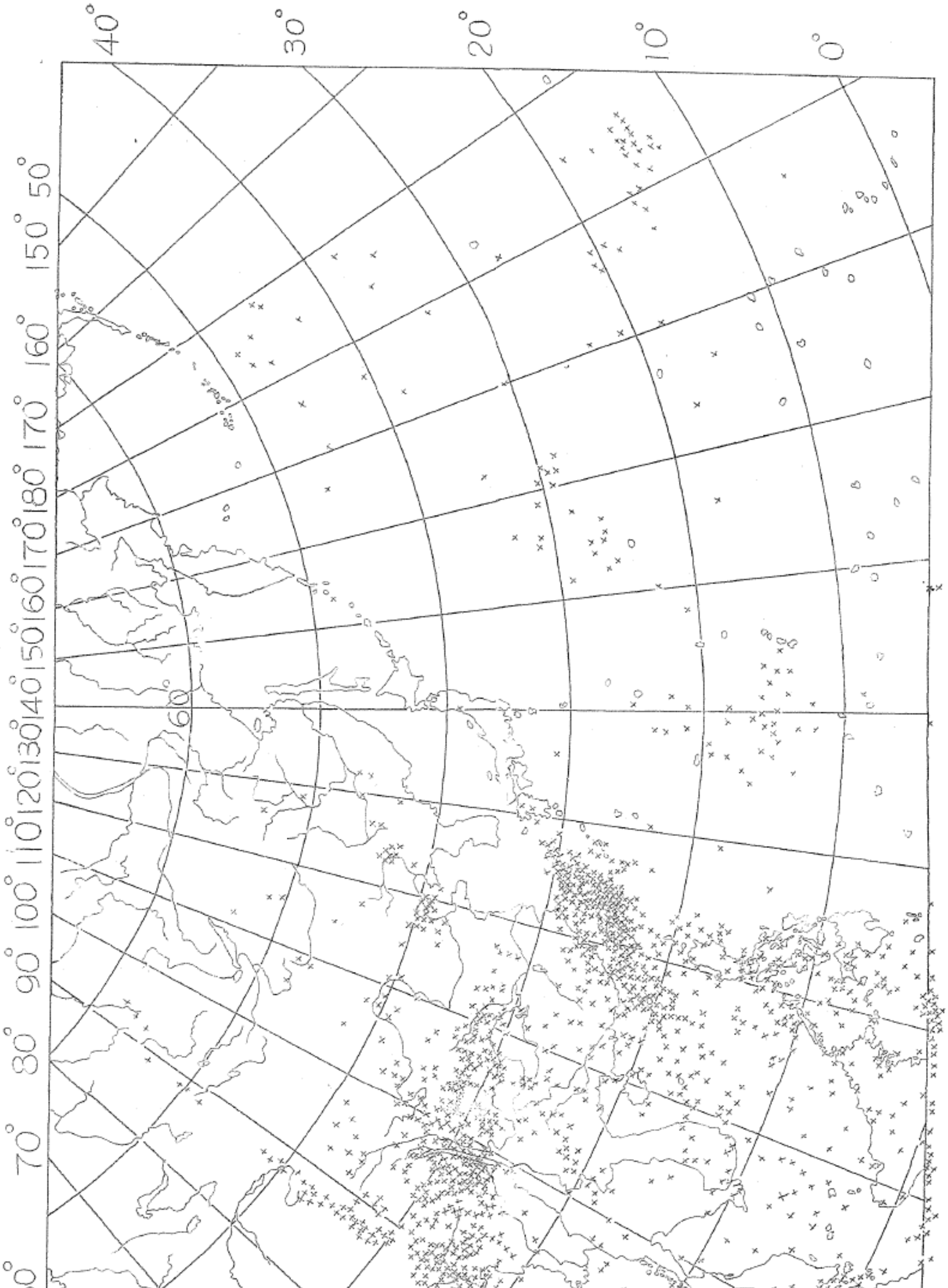
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FIG. 42

parison with the distribution in the daytime, are very sparsely scattered in the archipelagoes in equatorial zone at night. It is very likely that in these small islands the strong insolational heating effect predominates over the orographic lifting.

Fig. 43 is the distribution of origins of atmospherics in the Far East in March, 1954 during the daytime. They are found in Japan, South China, Indo-China, Siam, Malaya, Sumatra, Borneo, the Philippines, the Yantze, Irrawaddy and Mekong Valleys, the Bering Sea, the East and South China Seas, the North Pacific, the Kurile Islands, the archipelagoes in the Equatorial Pacific, etc. The arc form distribution of origins concentrated on the eastern and western boundaries as well as the linear distribution on the southern boundary indicates the limit of map available for triangulation, as in the preceding case.

Fig. 44 is the distribution of origins of atmospherics in the Far East in March 1954 in the nighttime. They are found in Japan, South China, Indo-China, Siam, Tsinghai, Sikang, Yünan, Burma, Malaya, Sumatra, Borneo, the Philippines, the Yantze and Irrawaddy Valleys, the East and South China Seas, the Bering Sea, the North Pacific, etc. but not in the archipelagoes as in the Equatorial Pacific in the daytime. This is considered due to predominance of the insolational heating effect over the orographic lifting in the archipelagoes.

Origins in the Yantze Valley are caused by the temperate front waves formed in the Chinese Lake Basin (Yantze Kiang region). Despite the participation of modified polar air in their formation they are characterized here as temperate because the dynamic convergence taking place between the two neighbouring anticyclonic cells (during periods of slow circulation) gives the most logical explanation for their formation. The frontal waves developing in the Lake Basin region, in contrast to the China Sea temperate-front cyclones, move at a comparatively rapid rate toward the east, and rarely occlude before leaving the continent. Recent investigations show that the majority of temperate-front depressions appearing in southern China in winter (January to April) form over the Lake Basin south of the middle Yangtze, and a minority are attributed to temperate-front disturbances from India, known as the south-westerly depression.

Fig. 45 is the distribution of origins of atmospherics in the Far East in February 1953 in the daytime. They are found in Japan, Siberia, Sakhalin, South China, Siam, Indo-China, Malaya, Burma, Sumatra, Borneo, the Philippines, Java, Celebes, New Guinea, the northern part of Australia supposedly from the direction, Sea of Okhotsk, the East and South China Seas, the North Pacific, the archipelagoes in the Equatorial Pacific, etc.

In winter (November to April) the intertropical front is displaced into the Southern Hemisphere. The intertropical-front phenomena then develop in the Southern Hemisphere in a pattern similar to that described for Northern Hemisphere during the summer season. The southernmost latitudes reached by the intertropical front, however, usually do not exceed 5° S. Only above Australia does the intertropical front reach farther south, extending at times over the northern districts of New South Wales. The outflow of subsident Northern-Hemisphere air, under the influence of the left-hand deflecting force of the Southern Hemisphere, becomes a north-westerly monsoon flow. The easterly winds equatorwards of the now powerful and steady anticyclonic belt of the South Indian Ocean provide the opposite air flow on the southern side of the front and the

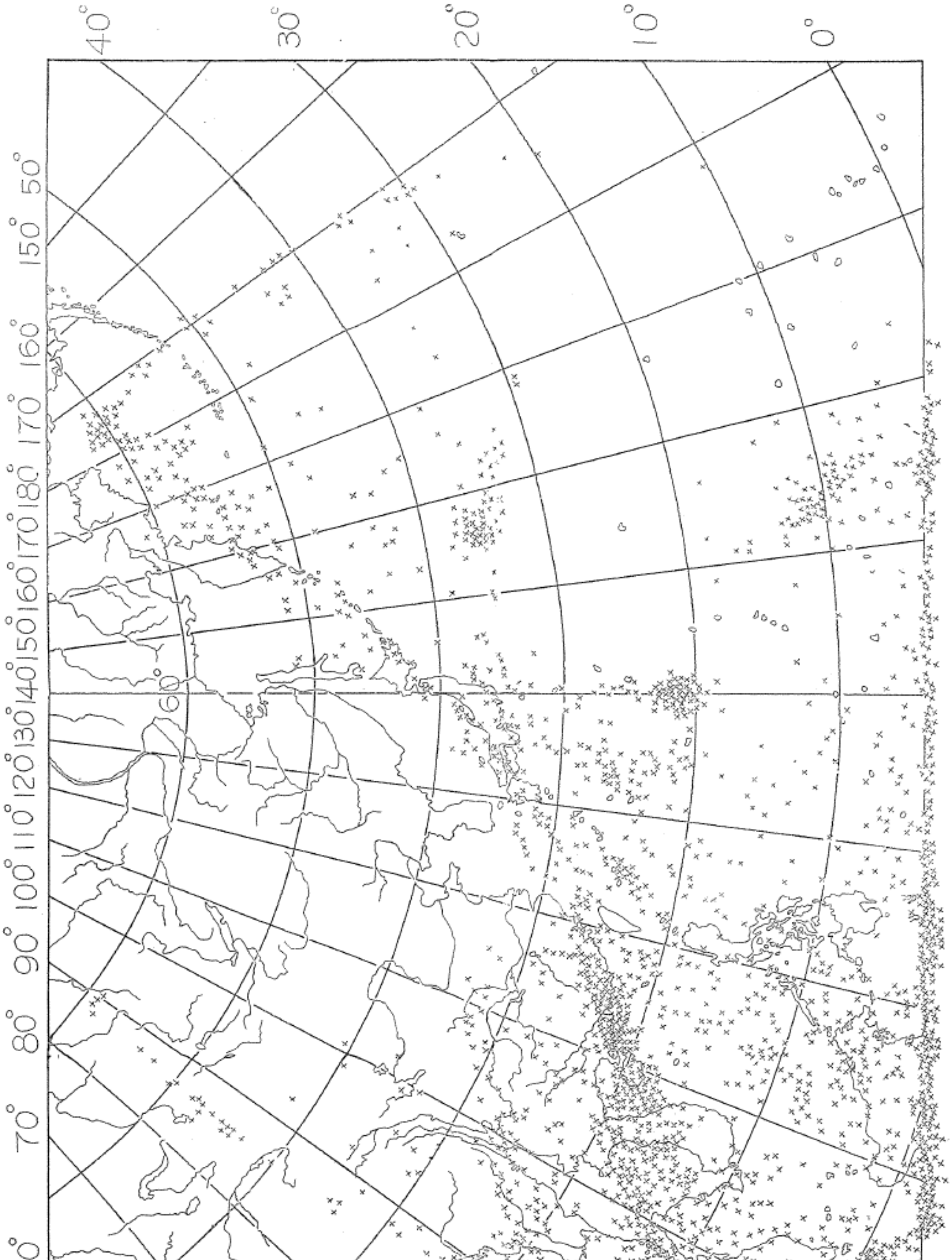
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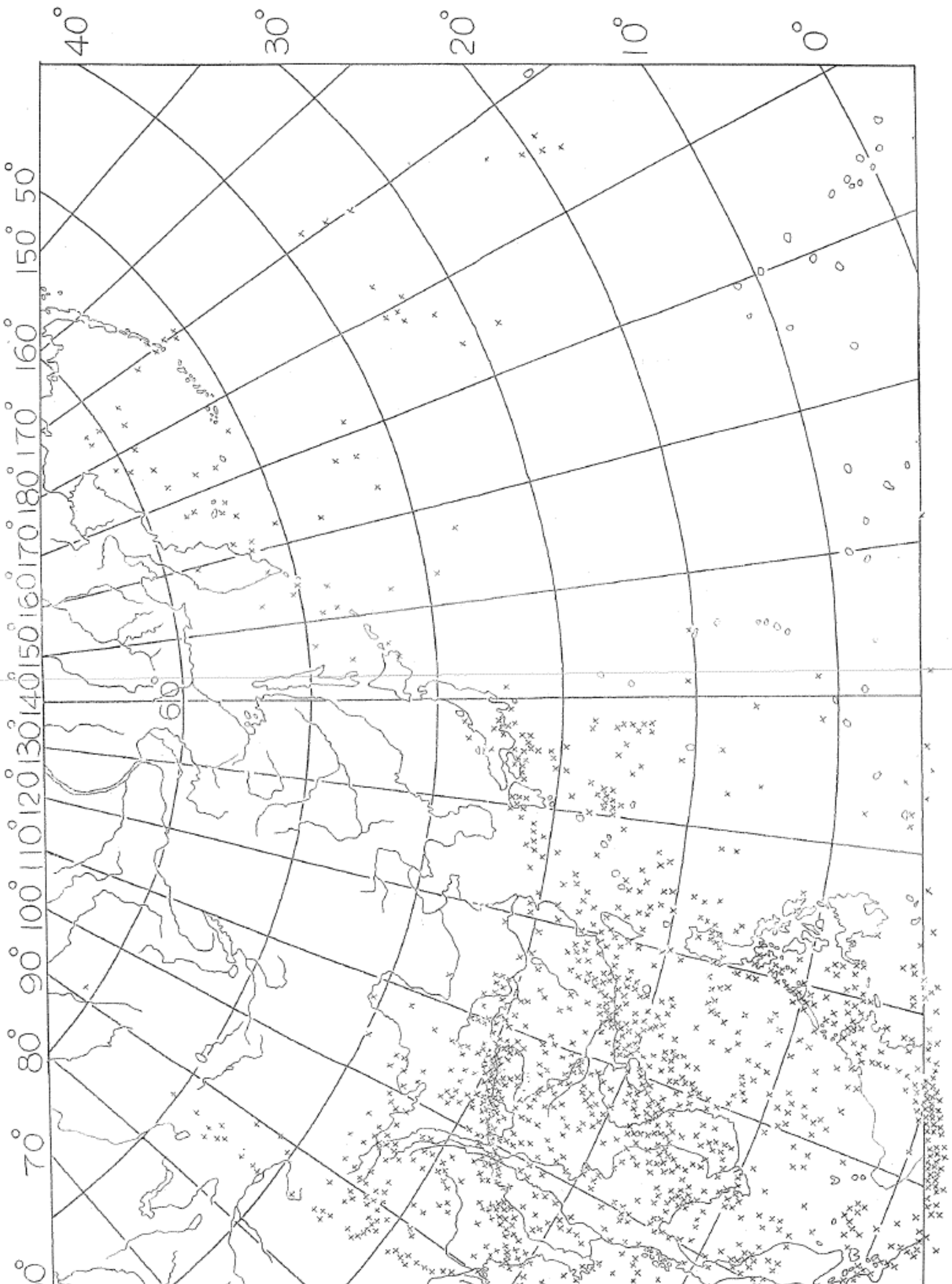
FIG. 43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FG. 44

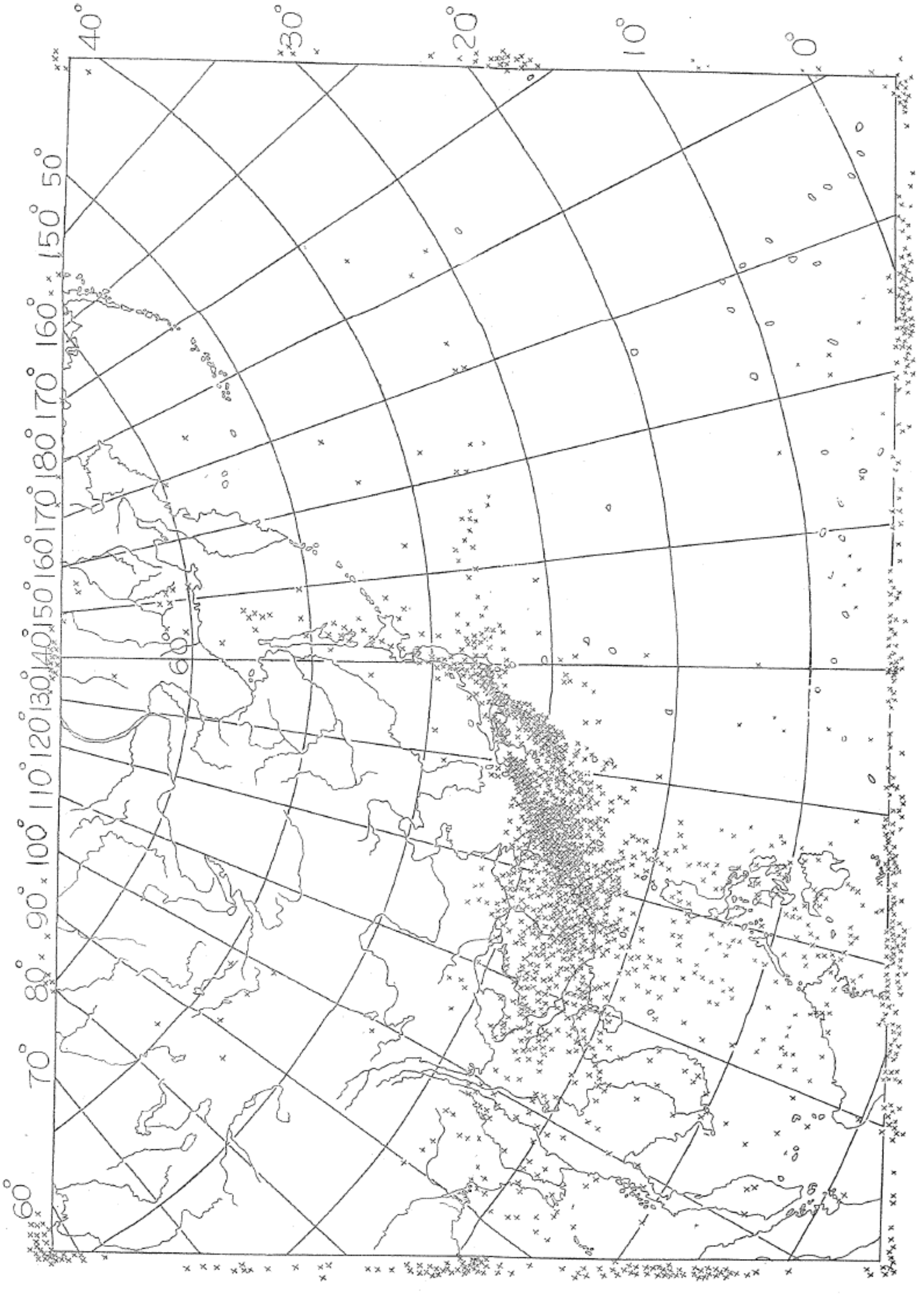

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FIG. 45

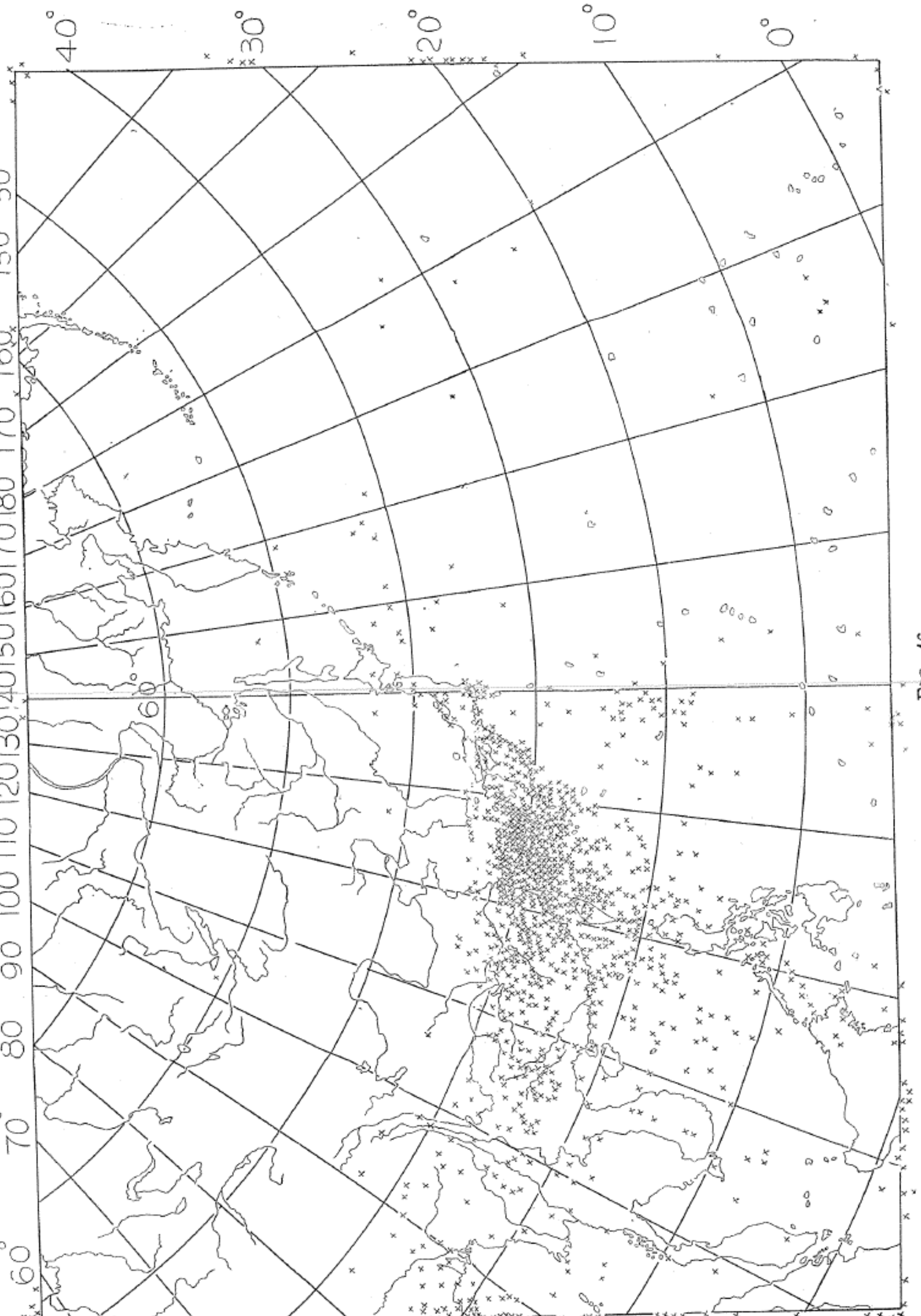
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FIG. 46

necessary cyclonic shear for the formation of frontal waves. The relatively high average latitude of these disturbances is the principal cause for the high intensity of most intertropical-front disturbances in the equatorial South Indian Ocean.

Fig. 46 is the distribution of origins of atmospherics in the Far East in February 1953 in the nighttime. They are found in Japan, South China, Yünan, Indo-China, Siam, Burma, India, the Philippines, Malaya, Sumatra, Borneo, the Yantze, Mekong, Irrawaddy, Brahmaputra and Ganges Valleys, the East and South China Seas, the North Pacific, etc., but not in the archipelagoes in the Equatorial Pacific, as in the daytime. This is probably because the insolational heating effect predominates over the orographic lifting.

IV. Conclusion

4.1. Correlation of Atmospherics with Weather Phenomena

The atmospherics are radio waves emitted from discharges in the atmosphere, accompanied by thunderstorms, showers, snow storms and developed cumulo-nimbi; therefore origins of atmospherics coincide very well with districts occupied by these phenomena, so long as the ratio of the base line between observatories to the distance between origins and observatories is reasonable.

Cyclones also become origins provided they are deepened by fronts, troughs or other stimulating agents, while in tropical stroms, depressions or typhoons, origins are found in many different ways, *i.e.* in dangerous semi-circle or active regions, in the converging wind line between the eye and the anticyclone, in orographic lifting areas, in converging areas between the eye and fronts or troughs, along the tropical front extending from the centre, etc. Troughs or fronts become origins when they are activated by strong insolational heating, orographic lifting, invasion of wet and warm air masses, etc.

All these phenomena are always accompanied by thunderstorms, showers, cumulo-nimbi, etc. when they are observed as origins.

4.2. Distribution of atmospherics in the Far East and the Western Pacific

In summer, origins of atmospherics are distributed (1) in tropical and subtropical Asia, especially in valleys with large rivers and mountenous districts, passed by intertropical front, (2) on the tropical convergence line of the China Sea, *i.e.* the confluence region of two mE air flow coming from the Western Pacific and the Indian Ocean, (3) in orographic lifting regions in the Indonesia Islands and Malaya, and (4) in the strong insolational heating regions in archipelagoes in the Equatorial Pacific.

In winter also (1) in tropical and subtropical Asia, especially in valleys with large rivers, passed by the activated temperate front, (2) in the northern part of Australia passed by the intertropical front, (3) on the China Sea where the cold cP air mass invades under the warm mE, (4) in orographic lifting regions in the Indonesia Islands including New Guinea, and (5) in the strong insolational heating regions in archipelagoes in the Equatorial Pacific.

V. Acknowledgements

The investigations herein described are part of a study programme of work of the Research Institute of Atmospherics, Nagoya University, performed by almost all members. Facilities for carrying out observations and arranging information were provided by the Radio Regulatory Bureau, our collegues including Miss Y. Kimura, assistant, and Mr. U. Imura of Nagoya Meteorological Observatory. Their full cooperation in this work is acknowledged.

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