

AD 662344

SEPTEMBER 1967
Emm 66-86



RESEARCH LIBRARY

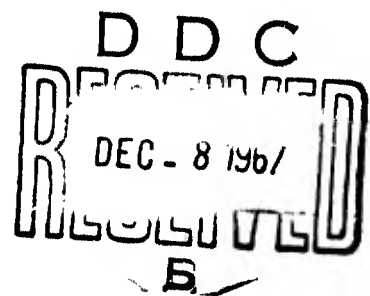
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES

L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

RESEARCH TRANSLATION

**The Relationship Between the Convergence
Belt and Thunderstorm Activities During
Spring in the Warm Region of Fukien**

WANG DE-TSAM



OFFICE OF AEROSPACE RESEARCH
United States Air Force



EMMANUEL COLLEGE
RESEARCH LANGUAGE CENTER
ORIENTAL SCIENCE LIBRARY
400 THE FENWAY
BOSTON, MASSACHUSETTS 02115

TRANSLATION Emm-66-86

THE RELATIONSHIP BETWEEN THE CONVERGENCE BELT
AND THUNDERSTORM ACTIVITIES
DURING SPRING IN THE WARM REGION OF FUKIEN

福建地区春季暖区中的雷暴活动和辐合带的关系

by

Wang De-tsam

王德铨

CH'I-HSIANG HSUEH-PAO

气象学报

(Acta Meteorologica Sinica)

Peking, China

35(3): 316-327, 1965

This translation has been made by the
Oriental Science Library
Research Language Center, Emmanuel College
under Contract AF 19(628)-5073
through the support and sponsorship of the

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
L. G. HANSCOM FIELD
BEDFORD, MASSACHUSETTS

THE RELATIONSHIP BETWEEN THE CONVERGENCE BELT
AND THUNDERSTORM ACTIVITIES
DURING SPRING IN THE WARM REGION OF FUKIEN*

by

Wang De-tsam

ABSTRACT

The findings of this paper reveal that the thunderstorm activities during spring in the warm region of Fukien are closely related to the existence of convergence belts associated with the southerly currents at 850 mb along the south-east coast of China. These activities are often oriented NE - SW or E - W. The convergence belts are an important dynamical feature responsible for the development and realization of thunderstorms within the region under consideration. In the present study, a classification of these convergence belts at 850 mb have been made and their displacements analyzed statistically.

I. INTRODUCTION

The relationship between the existence of convergence belts in the southerly currents over China during warm springs and the occurrence of thunderstorms and rain storms has, in a broad sense, attracted the attention of many practicing forecasters and research meteorologists. Furthermore, such convergence belts have been considered by some writers as the triggering mechanism for the occurrence of thunderstorms in warm regions. However, studies in the past did not adequately explain and substantiate the formation and existence of the convergence belts with actual observations nor did they examine the basic properties of these

* Manuscript received 12 February 1965.

systems in relation to thunderstorm activities. Consequently, it is thought that a deeper meditation on these problems may lead to a better understanding of the characteristic behavior of certain weather systems and the dynamical conditions for the occurrence of thunderstorms in the warm region. This paper represents such an attempt and presents a preliminary analysis of the relationship between the activities of the convergence belts and the development and realization of thunderstorms in the warm region of Fukien during spring.

II. THE EVALUATION OF DIVERGENCE AT 850 MB AND THE RESULTS OF ANALYSIS

The horizontal divergence term on an isobaric surface may be expressed as:

$$D = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}.$$

The divergence field was evaluated from 850-mb contour charts by means of the equivalent finite-difference formula of the foregoing expression at intervals of 220 km over the region bounded by 20°N - 35°N and 110°E - 125°E.

The graphical distribution of divergence was determined by the foregoing method from 15 synoptic samples. These diagrams show a pattern of alternating divergence and convergence zones. In addition to the convergence region associated with the shear line, a narrow but well-defined belt of convergence can also be detected. The calculated distribution of convergence zones is basically concordant with the results of qualitative analyses of upper-air charts.

III. THE CONVERGENCE BELT OF SOUTHERLY CURRENTS AND ITS PROPAGATION

A total of 15 cases of NE - SW (or E - W) oriented thunderstorm activities during spring over the warm region of Fukien has been analyzed*. On one occasion thunderstorms were caused by the poleward displacement of the shear line. There were two cases when thunderstorms did not occur over Foochow though the thundery activities spread in along a SW - NE orientation, almost reaching the extreme south of Foochow. On all other occasions, thunderstorm activities were closely related to the convergence belt of the southerly currents. The synoptic situation favorable for the occurrence of this kind of thunderstorms may be described as follows:

Following an intense southward intrusion of cold air during spring, the frontal surface and the 850-mb shear line tend to disappear after the passage of the latter through Foochow. By this time, a thermal ridge often dominates the Yellow River Basin with the remnant thermal trough just east of 115°E. In general there is no further intrusion of fresh cold air to replace the modified air mass for some time. Furthermore, as its properties undergo further modification over a sea track, the cold high gradually merges with the existing subtropical high to form an intense high cell. Thus an active current of warm southwesterlies gradually becomes established over the southwest of Nanning. Troughs over India, Burma and Southwest China then gradually develop. As a result, souther-

lies become increasingly predominant over the vast region of South and

* In the months of March to June during the period 1957-1960, there were 15 cases of NE - SW (or E - W) oriented thunderstorm activities in the warm region of Fukien. Computations were carried out for 14 cases only because upper-air data were not available in one case.

BLANK PAGE

East China. During the processes of development and the establishment of these southwesterlies, some form of convergence belt comes into existence. Following the spreading of the southwesterlies over the region and the eastward recession of the Pacific anticyclone, this convergence belt extends northward and gradually moves east or northeastward with further intensification. This is normally known as the east or northeastward spreading of the southerly currents. At this stage another fresh outbreak (southward intrusion) of cold air is developing west of the Yellow River Basin. On the 850-mb chart, a shear line exists south of the Yellow River Basin and remains quasi-stationary or moves slowly southward. The intense outbreak of cold air then brings an end to the activities of the southerly currents associated with weather systems which have dominated the Fukien region for some time.

The flow structure of the convergence belt in the southerlies assumes a definite characteristic form. According to the analysis of 49 case studies from 15 different synoptic processes, the flow patterns of the convergence belt may be classified into five categories as follows:

(a) The D_{NW} type convergence belt: This is the convergence belt between the southwesterlies and the northeasterlies and often occurs behind a small but active dome of cold air. If the small dome of cold air is active before the southward advance of the main cold air stream, a convergence belt usually forms between the intruding northwesterlies and the predominant southeasterlies (Figure 1).

(b) The D_{SE} type convergence belt: This is the convergence belt between the southwesterlies and the southeasterlies and often occurs at

the end of a weak cold air intrusion as a gradual transition to a warm-front type of shear line (Figure 2).

(c) The D_{SW} type convergence belt: This is the convergence belt within the southwesterlies and is characterized by relatively strong speed convergence (Figure 3).

(d) The D_A type convergence belt: This is a convergence zone in the anticyclonic flow. Southwesterlies or south-southwesterlies may prevail behind the convergence line, but the flow configuration is characterized by the presence of anticyclonic curvature and convergence between the wind flow behind the convergence belt and that ahead of it. This type of configuration often occurs when a cold high moves slowly eastward (Figure 4).

(e) The D_C type convergence belt: This is a convergence zone in the cyclonic flow. Southwesterlies or west-southwesterlies may prevail behind the convergence line, and the flow configuration is characterized by the presence of cyclonic curvature and convergence between the wind flow behind the convergence belt and that ahead of it (Figure 5).



Figure 1

The D_{NW} type convergence belt
(1200 GMT 11 May 1957).



Figure 2

The D_{SE} type convergence belt
(1200 GMT 12 May 1957).



Figure 3

The D_{SW} type convergence belt
(1200 GMT 25 June 1958).



Figure 4

The D_A type convergence belt
(0000 GMT 12 April 1960).



Figure 5

The D_C type convergence belt
(0000 GMT 4 April 1958).

TABLE 1

The frequency distribution of the various types
of convergence belts

Type of convergence belt	D_{NW}	D_{SE}	D_{SW}	D_A	D_C	Total
Frequency of occurrence	9	8	19	5	8	49

Table 1 shows that the D_{SW} type convergence belt occurs most frequently. Five of the eight cases of D_{SE} type of convergence belts became warm front type shear-lines.

A statistical survey reveals that a convergence belt usually starts between Canton and Nanning and systematically extends with the south-westerlies generally in a southwest-northeast orientation (11 cases) and occasionally in an east-west orientation (3 cases). The speed of movement of this system varies between about 150 km/12 hr and 600 km/12 hr. The frequency distribution of the speed of propagation of 35 convergence belts in 6 speed ranges is shown in Table 2.

TABLE 2

Speed Fre- quency of occur- rence Type	Speed (km/12 hr)						Total
	100-199	200-299	300-399	400-499	500-599	>600	
D _{NW}	3	2	1	0	0	0	6
D _{SE}	0	1	1	0	1	0	3
D _{SW}	2	3	3	4	2	0	14
D _A	1	2	2	0	0	0	5
D _C	0	1	3	2	0	1	7
Total	6	9	10	6	3	1	35

It is noted from Table 2 that the speed of movement of convergence belts lies between 200 and 400 km/12 hr in 54% of the cases (19/35) and is less than 500 km/12 hr in 89% of the cases (31/35). In other words, convergence belts move with more or less the same speed as the short waves in the westerlies. In general, the D_{NW} and D_A types are relatively slow in movement, the speed being less than 400 km/12 hr. In 83% of the D_{NW} type, the movement is less than 300 km/12 hr.

The present analysis indicates that warm air advection is more intense as the thermal ridge behind a convergence belt becomes more pronounced. As the activities of the cold air ahead of the belt become weaker, the cold high moves eastward more rapidly. The belt then moves faster to follow suit under these conditions but the movement slows down under opposite conditions. This leads to an understanding of the variation of the speed of movement of the various types of convergence belt. The slow movement of the D_{NW} type convergence belt is caused by the activities of a small cold air mass ahead of the system. When the migratory cold high amalgamates with the eastward retreating subtropical high, the northward advance of the D_A type convergence belt also tends to slow down. This is due to the slow weakening of the remnant cold air mass associated with the last intrusion. The relatively rapid movement of the D_{SW} , D_C and D_{SE} types of convergence belts can also be explained by similar reasoning.

There is a good correlation between the activities of convergence belts and those of the warm air. This may be illustrated by the structure of the horizontal temperature field in the vicinity of a convergence belt.

An examination of 14 cases in which the convergence belt moves northeastward or eastward shows that the temperature is generally (10 cases) higher to the southwest of the belt than to its northeast. The temperature gradient across the belt varies between 2° and 7°C. In other words, the convergence belt usually lies mainly in the sector of the thermal trough ahead of the thermal ridge. This thermal ridge gradually moves eastward after the east or northeastward displacement of the belt. In three cases, the convergence belt lies mainly in the sector of the thermal trough ahead of the thermal ridge at the initial stage of its appearance. However, after moving northeast or eastward, it lies near or even ahead of the trough-line. On one occasion (27 April 1960) the evidence of the above evolutionary process is insignificant because the convergence belt amalgamates rapidly with an intruding shear-line from the north. It is evident that in general the convergence belt lies mainly in the sector of the trough ahead of the thermal ridge.

The above factual evidence leads to the inference on the mechanism of the convergence belt as follows:

Under the synoptic situation described earlier in this section, the southwesterlies begin to spread northeastward when the warm air becomes active. A belt of convergence with pronounced upcurrent then forms between the intruding warm current and the existing cold air with compensating divergence on both sides. As the deep southwesterlies spread northeastward, the convergence belt tends to move east or northeastward. This completes a synoptic cycle during a typical "warm-wave" period.

A case study of charts depicting the distribution of the temperature field and convergence belts at the 850-mb level indicates that two or three convergence belts may be detected ahead of a thermal ridge within the southwesterlies at this level. Thus a wave-train of these belts propagates northeastward to characterize the pulsational influx of warm air. Such a wave-train may be treated as perturbations in the warm air and is thought to be some kind of inertial gravity waves. The speed of propagation of the wave-train may be expressed as

$$C_r = U + \frac{1}{2\pi} \sqrt{f^2 L^2 + g S L^2}$$

where C_r denotes the propagation speed of the convergence belt, U the mean speed of the basic current in the vicinity of the belt, f the Coriolis parameter, L the horizontal wave-length, L_3 the vertical wave-length and S the stability index which may be expressed as $(\gamma_a - \gamma)/\bar{T}$ where \bar{T} represents the mean temperature, γ_a the adiabatic lapse rate and γ the environmental lapse rate along the vertical.

It is obvious that the propagation speed of a convergence belt increases with the mean speed of the basic current, the horizontal and the vertical wave-length and the environment stability. The dispersion chart of the distribution of horizontal wave-length of these perturbations at 850 mb reveals that the horizontal wave-length varies between 500 and 700 km. This gives propagation speeds of 20 - 40 km/hr by calculation. In general, there is a good agreement between the computed and observed propagation speeds during various phases of the process.

IV. THE PROPAGATION OF CONVERGENCE BELTS
AND THUNDERSTORM ACTIVITIES

In recent years, the importance of low-level convergence on the development of thunderstorms has attracted the attention of many investigators [1, 2]. Under specific conditions of stability and humidity, not only could convergence at middle and low levels serve as an initial impetus to trigger the development of thunderstorms but also bring about sufficient vertical motion to transport water vapor from low to high levels to facilitate the vertical development of cumulonimbus. It was thought that convergence belts at 850 mb could efficiently reflect the intensity of upward motion at the middle and low levels and thus exercise a pronounced influence on the development of thunderstorms.

The analysis of many case studies showed that convergence belts were usually accompanied by unstable weather in its vicinity and that the associated weather moved with these systems. If a convergence belt was located ahead of a "warm moist tongue" or under its control, unstable weather or precipitation would prevail near to this belt. In divergence regions, precipitation was usually absent and the cloud layer broke up and decreased to a very small amount.

The analysis also revealed that before a convergence belt moved into Fukien, stable or unstable weather may occur in the region, but thunderstorms did not usually develop until the belt had entered into the province. This was probably related to the local topography, which is extremely complex and might give rise to strong orographic lifting with relatively intense upward motion below the 850-mb level. The resulting dynamic

conditions would then become more favorable for the development of thunderstorms. However, the orographic effect becomes less pronounced when the scale of the convergence belt grows larger. A statistical survey on the variation of the divergence profile within the convergence belts entering the Fukien region revealed that divergence usually decreased or underwent little change before or after the onset of thunderstorms with only one exception on 7 June 1959. This happened to be the case when no thunderstorms were experienced in Fukien during the passage of a convergence belt. Thus it appears that the effect of a convergence belt on thunderstorm activities is dependent on its life history. Convergence belts of vigorous intensity could easily induce the development of convective currents. However, a discussion on the relationship between convergence belts and thunderstorm activities from this approach would appear immature if it is not substantiated by a portrait of the life history of these features and a detailed study on the relationship between the observed weather and the systematic variation of the divergence field.

For the present investigation, 15 case studies were analyzed. There were 9 cases when thunderstorms spread in from the southwest to the northeast and 3 from west to east. On two occasions, there were no thunderstorms in Fukien during the passage of a convergence belt. The remaining case was associated with the northward displacement of a weakening shear-line; and thunderstorms reached the southern part of Fukien only. Thus thunderstorm activities were closely related to convergence belts, whose eastward and northeastward movements would cause thunderstorms to spread from west to east and from southwest to

northeast respectively. In general, the movements of isobronts basically followed those of the convergence belts. An analysis of the distribution of isobronts in relation to convergence belts revealed that the onset of thunderstorms over an observing station was essentially in phase with the passage of a convergence belt, the difference in timing in individual cases being of the order of a few hours. In other words, the propagation speeds of convergence belts and the accompanying thunderstorms were essentially the same.

A composite type of convergence belt may take the form of "入". Figure 6 shows its flow pattern and the corresponding distribution of divergence. Figure 6a depicts the position of a convergence belt in relation to the flow configuration and Figure 6b the distribution of divergence computed from the wind field with isopleths in $10^{-6}/\text{sec}$. It was noted that the zone of maximum convergence was located at the "triple-point".



Figure 6

1200 GMT 25 June 1958.

The "入"-type of composite convergence belt was characterized by a central region of intense convergence. The existence of such a region was distinctly observed on three occasions. In each case, an early-hour

isochrone center of thundery activities could be detected during the propagation of the thunderstorms. These centers were found in four cases out of the twelve thundery outbreaks covered by the present study. Of these four cases, three were associated with the "入"-type composite convergence belt. The occurrence of early-hour isochrone centers was governed by many complicated factors. The synoptic situations during the period 25 - 26 May 1959 might be used to illustrate this point.

A "入"-type convergence belt occurred at 0000 GMT on 26 May 1959, following the poleward displacement of the whole system. Figure 7 shows that the early-hour isochrone centers of thunderstorms were closely related to the development of the isobront pattern. In this example, thunderstorms moved poleward from the south, while the frontal system continued to move southward. This indicates that the dynamic conditions for the development of thunderstorms were governed by the convergence belt in the southerlies, which was concordant with the isobront configuration but not related to the existing frontal system.

In the 15 case studies under review, there were three occasions when the passage of a convergence belt over Fukien was not accompanied by thunderstorms. A comprehensive analysis of the relevant upper-air data reveals that each of these three cases was caused by either low humidity or pronounced stability. For example, marked stability occurred during the period 6 - 7 June 1959 and low humidity on 27 April 1960. This shows that although the convergence belt is of paramount importance in producing thunderstorm activities because of the accompanying dynamic conditions, its potentiality cannot be fully realized if favorable instability and humidity

conditions are lacking. In other words, dynamical conditions are necessary but not sufficient to produce thunderstorms if acting alone.

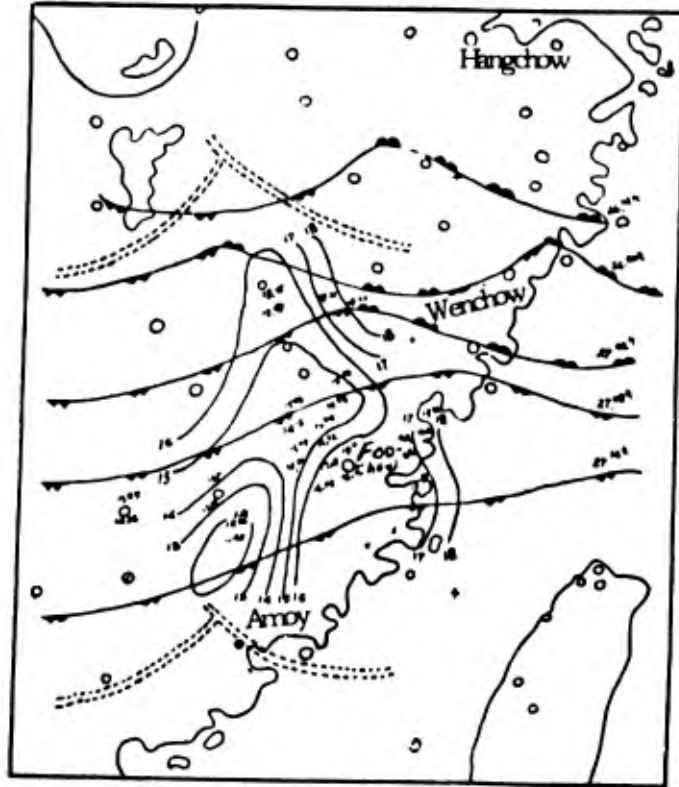


Figure 7

The distribution of isobronts in relation to convergence belts
0000 - 1200 GMT 26 May 1959.

(—— Isobront - - - - Convergence belt)

V. THE CLOUD SYSTEM OF THE CONVERGENCE BELTS

Table 3 shows the time-variation of the cloud system accompanying the passage of convergence belts over Fukien.

It may be noted from the above table that the distribution of clouds ahead of and behind a convergence belt was characterized by regimes of

definite lateral extent. In general terms, the appearance of cumulonimbus might be preceded by cirrus, altocumulus or stratocumulus. In one case, thin cumulus thickened and then developed into cumulonimbus. On another occasion, precipitation was released from broken clouds before the thundery outbreak. Thus the thickening of thin cumulus was not a usual case of development to characterize the change of cloud pattern. The physical explanation for this peculiarity lies in the fact that in addition to the relatively intense convective upward motion brought about by convergence, there is considerable "frontal" uplift resulted from warm air overriding the cold air within the convergence belt. In general, high clouds and medium clouds are observed at some distance ahead of convergence belts, but the horizontal spread of the cloud system is much narrower than in warm fronts. This is probably due to the relatively steep slope of the "surface discontinuity" between the warm and cold air masses with different characteristics. Thus thunderstorms are more likely to occur within convergence belts. However, it seems difficult to arrive at a suitable conclusion at this stage because much has yet to be learned from the vertical structure of these systems.

The distribution of cloud systems associated with the various types of convergence belts showed that the cloud system of the D_{NW} type was somewhat narrow. The passage of the whole system took less than 20 hours. Thunderstorms occurred during the day and the cumulonimbus clouds closely followed the appearance of high and medium clouds. Thus it may be inferred that the slope of the D_{NW} type of convergence belt was relatively steep and that the activities of this type depended on the warm air. On the other hand the cloud system associated with the D_C type convergence belt was rather

broad. Precipitation from scattered clouds often preceded the onset of thunderstorms, which usually occurred at night time and lasted for a short period of about two hours. This suggests that the slope of the D_C type convergence belt was relatively small and that the activities of this type depended less on the warm air. The passage of the D_{SW} and the D_A type of convergence belts was often accompanied by cumulus and intermittent thunderstorms of short duration, but usually more than one thunderstorm was observed in one day. There were two occasions when the passage of a convergence belt over Foochow was not accompanied by thunderstorms. In one case, instability was absent and precipitation was released from scattered clouds only; in the other, only overcast conditions with cumulus at different levels and occasional lightning were experienced because of insufficient moisture in the atmosphere.

The foregoing analysis reveals that convergence belts are somewhat similar to the warm front system. In fact, warm-frontal characteristics were occasionally detected during the propagation and development of convergence belts. In many cases when a convergence belt reached the coast it became a warm front on the weather map. However, they were different in scale, flow structure and the distribution of cloud system. Thus convergence belts seemed to be a characteristic weather system in the warm region prior to the intrusion of a cold front or the formation of a warm front, and only gradually developed warm front features under favorable conditions.

The time of onset of the 12 thundery outbreaks was analyzed as a further attempt to account for the effect of convergence belts on thunderstorm activities from the dynamical viewpoint. In this statistical analysis,

thunderstorms occurring during the period from 1400 GMT to 0200 GMT of the following day were designated as night thunderstorms while those during 0200 GMT to 1400 GMT were classified as day thunderstorms. Table 3 shows that day and night thunderstorms were equally frequent in the twelve case studies in Foochow. There were, however, 65 thunderstorms in the warm region of Foochow in the months of March to June during the period 1957 - 1960, some 25% of which (16 cases) were night thunderstorms. Six (38%) of the night thunderstorms were associated with the passage of convergence belts which propagated from southwest to northeast or along a west-east orientation. In other words, thunderstorms usually occurred during the day in warm regions, because the day-light temperature conditions were more favorable for their development.

The above analysis shows that the convergence belt may serve as one of the dynamical factors to give rise to thunderstorm activities in the warm region. If the instability and humidity conditions are favorable, thunderstorms may accompany the passage of the 850-mb convergence belt.

VI. EXAMPLES

The synoptic situation during the period from 1200 GMT 3 April to 0000 GMT 5 April 1958 associated with the poleward displacement of a convergence belt is used to illustrate some of the above problems.

On 2 April 1958, a mass of cold air moved southward with a cold front passing over Foochow at about 0900 GMT. At 1200 GMT 3 April, the shear-line on the 850-mb chart already reached southern Taiwan.

The Yellow River Basin was then under the influence of a thermal ridge with a thermal trough situated to the east of 115°E . No further fresh supply of cold air was observed. Relatively strong northwesterlies were absent in the coastal regions south of 30°N and the flow configuration was weak and diffused. However, strong southwesterlies of 12 - 14 m/sec prevailed in the region south of Nanning with relatively intense warm air advection. The warm current began to spread further downstream, while winds remained light and variable ahead of the strong intruding southwesterlies. An examination on the temperature field indicates that the 850-mb temperature was 22°C over Haikow and only 15°C over Canton, a difference of as much as 7°C . This shows that the temperature gradient was relatively steep over the region bounded by Nanning, Haikow, Canton and Kweilin.

During the period of vigorous warm air intrusion, upward motion resulted from strong convergence along the discontinuity between the warm and the cold air forming a convergence belt in the southerlies at the 850-mb level. Figure 8 shows the distribution of computed convergence and divergence corresponding to the configuration of a narrow convergence belt with a northwest-southeast orientation. The convergence belt was located near the center of maximum moisture content in the humidity field, and gave rise to a region of showery activities in its vicinity. The 850-mb chart for 0000 GMT 4 April 1958 (Figure 9) shows that the vast region over South and East China was under the influence of the southerlies with wind speed of 12 m/sec near Canton and Ch'angting and 8 m/sec near Kanchow. A temperature difference of 5°C was observed between these stations. The

strong convergence belt subsequently moved to a position near Canton, Kanchow and Swatow. Figure 10 shows that the observed position of this system agreed closely with that determined by the distribution of computed convergence and divergence. The region of showers and thunderstorms associated with the convergence belts was generally located ahead of the thermal trough and in the vicinity of the center of maximum moisture content.

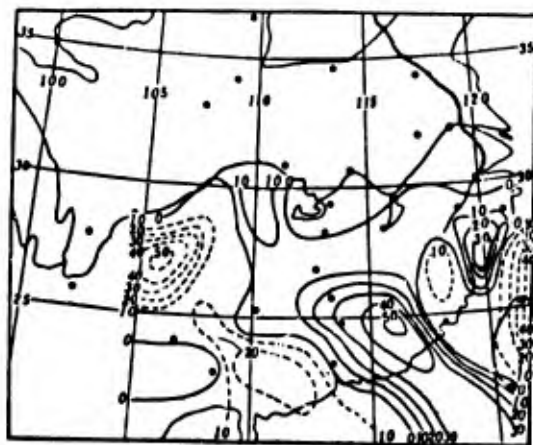


Figure 8

The distribution of 850-mb convergence and divergence
at 1200 GMT 3 April 1958.
(-----Convergence zone ———Divergence zone. Unit: 10^{-6} sec^{-1})

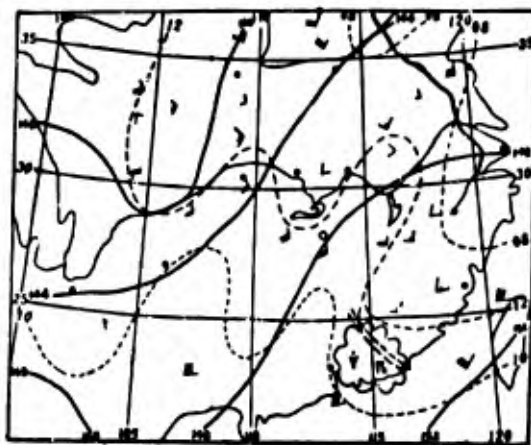


Figure 9

850-mb chart for 0000 GMT 4 April 1958.
(-----Isotherms =====Convergence belt)



Figure 10

The distribution of 850-mb convergence and divergence
at 0000 GMT 4 April 1958.
(-----Convergence zone ———Divergence zone. Unit: 10^{-6}sec^{-1})

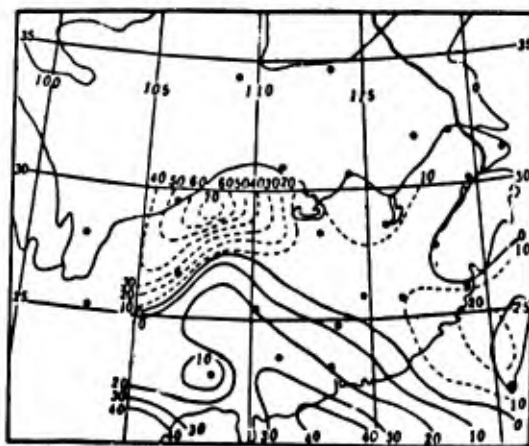


Figure 11

The distribution of 850-mb convergence and divergence
at 1200 GMT 4 April 1958.
(-----Convergence zone ———Divergence zone. Unit: 10^{-6}sec^{-1})

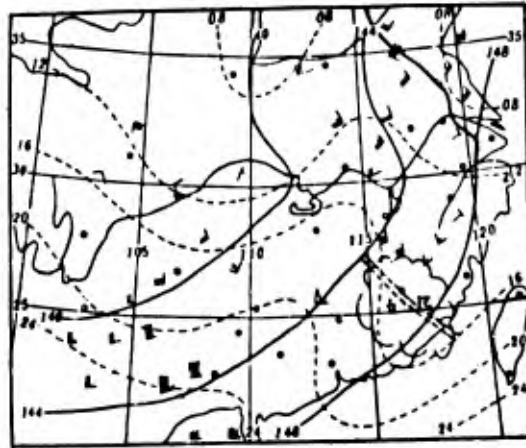


Figure 12

850-mb chart for 1200 GMT 4 April 1958.
(-----Isotherms =====Convergence belt)

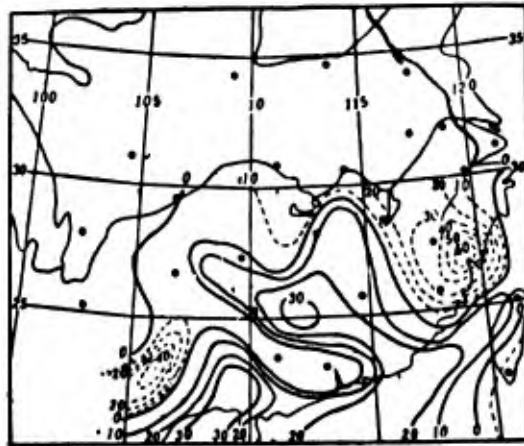


Figure 13

The distribution of 850-mb convergence and divergence
at 0000 GMT 5 April 1958.
(-----Convergence zone ———Divergence zone. Unit: 10^{-6} sec^{-1})

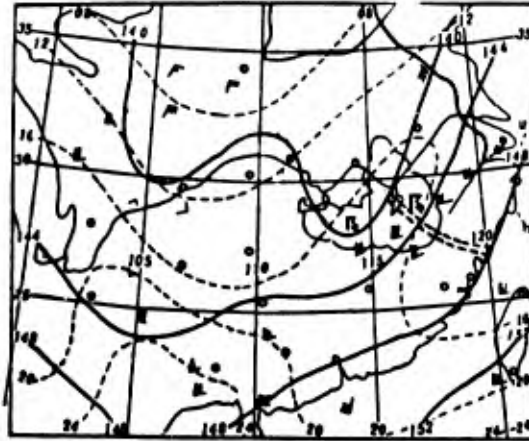


Figure 14

850-mb chart for 0000 GMT 5 April 1958.
(-----Isotherms =====Convergence belt)

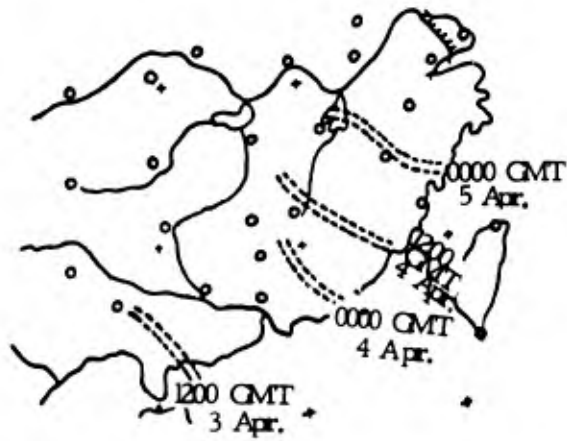


Figure 15

The movement of the 850-mb convergence belt during the period
from 1200 GMT 3 April to 0000 GMT 5 April 1958.

The distribution of convergence and divergence at 1200 GMT 4 April 1958 (Figure 11) shows that on this chart the convergence belt had moved to the region of Kanchow north of Amoy. By this time the southerlies dominated South, East and a great part of North China. Strong to gale force southwest winds prevailed to the southwest of Kanchow with wind speed reaching 18 - 22 m/sec, while the wind speed in the vicinity of Chien-ou was 6 m/sec only (Figure 12). The distribution of showers and thunderstorms was almost "ideal" with respect to the convergence belt. Perhaps, it would be worthwhile to mention here that by this time the Yellow River Basin gradually came under the control of the thermal trough, and began to brew another fresh outbreak of cold air. The corresponding shear-lines near Chungking about 30°N then started to move slowly southward. Figure 13 shows that by 0000 GMT 5 April 1958, the convergence belt had moved to Nanchang and to the northeast of Foochow. The flow configuration of the wind field indicates that the speed of the southwesterlies to the southwest of the convergence belt reached 20 - 28 m/sec, while the wind speed ahead of it was 8 m/sec and 16 m/sec. Thunderstorms dominated a large area near the convergence belt (Figure 14). With the major trough continuing its eastward displacement, the northern shear-line had already approached the Changsha and Chihchiang region while the surface cold front reached Nanchang and Huangshan. By 1200 GMT 6 April 1958, the cold front had already passed Foochow, and the activities of the convergence belt ended along the southeast coast to complete the synoptic cycle.

Figure 15 shows the movement of the 850-mb convergence belt and Figure 16 the continuity positions of the 1480-gpm contour at 850 mb. These figures serve to indicate the mode of the systematic displacement of the convergence belt to the northeast. The belt belonged to D_{SE} , D_C and D_{SW} types at various phases and its movement was relatively fast with an average speed of 350 km/12 hr. During the northeastward displacement of this system, the continental cold high gradually moved eastward into the adjacent seas and amalgamated with the subtropical high forming an intense high cell with a poleward displacement. The synoptic process of the northeastward displacement of the convergence belt and the regime of unstable weather followed the advance of strong westerlies associated with the thermal ridge.

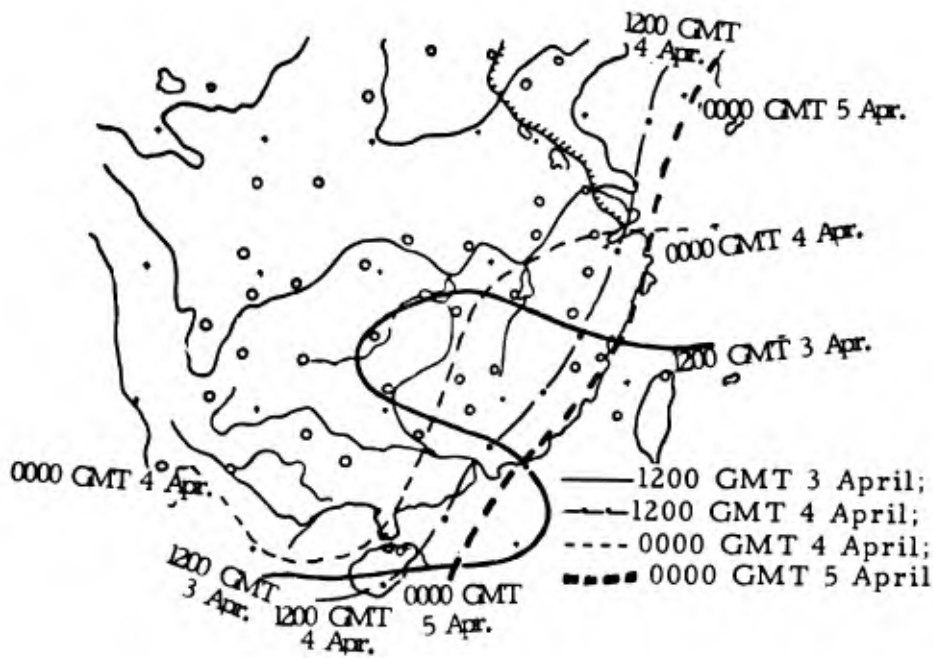


Figure 16

Continuity chart for the 1480-gpm contour at 850 mb during the period from 1200 GMT 3 April to 0000 GMT 5 April 1958.

During the period from 1200 GMT 4 April to 0000 GMT 5 April 1958, a convergence belt passed over Foochow and there were thunderstorm activities in the Fukien region spreading in from southwest to northeast. Figure 17 represents an isobront analysis in connection with this thundery outbreak together with the positions of the convergence belt at 1200 GMT 4 April and 0000 GMT 5 April 1958. It may be noted that the direction and the speed of movement of the convergence belt were in general concordant with those of the isobronts. The onset of thunderstorms over each observing station was almost synchronized with the time of passage of the convergence belt. This shows that the thunderstorms under consideration were closely related to the dynamical action of the convergence belt.

Table 3 shows that the passage of a D_C -type convergence belt over Foochow was characterized by a broad horizontal zone of clouds. There were short durations of thunderstorms during the night and each thunderstorm was preceded and followed by continuous precipitation from broken clouds. It was also noted that there was little thundery activity before the entry of the convergence belt into Fukien and it was only after the passage of this system into the province that systematic thunderstorm activities were observed.

Since the convergence belt in this example belongs to the D_C -type, it could be easily mistaken as a warm-front type of shear-line. As mentioned in the previous sections the occurrence of such a belt was in most cases associated with speed convergence in the southwesterly current alone. The synoptic situation during the period from 0000 GMT 12 March to

0000 GMT 14 March 1958 was an example of this type. The intrusion of a small mass of cold air at 0000 GMT 13 March gave rise to the formation of a D_{NW} -type of convergence belt, and affected its propagation velocity to a great extent. However, its northeastward displacement was not held up completely because the intruding cold air was relatively weak. Following the weakening of the cold air, the convergence belt resumed its northeastward displacement. By 0000 GMT 14 March 1958, the belt became a warm-front type shear-line with a poleward advancement and its activities came to an end. From 1200 GMT 13 March to 0000 GMT 14 March 1958, the northeastward movement of a convergence belt over Foochow brought thunderstorms to the Fukien region which spread from southwest to northeast.

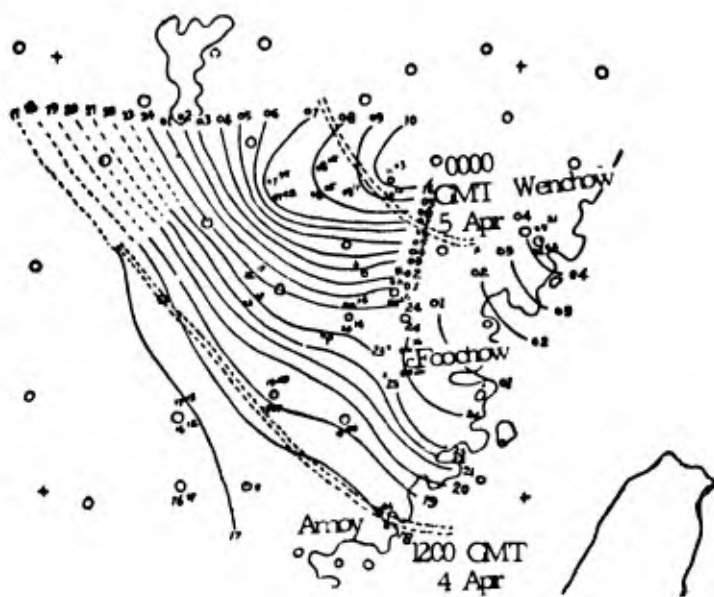


Figure 17

Isobront pattern and positions of the convergence belts in connection with thunderstorms during the period from 1200 GMT 4 April to 0000 GMT 5 April 1958.

VII. CONCLUSION

Owing to the various limitations, it is not possible to carry out the present investigation on convergence belts to such a degree of refinement as we would wish to. In such a study there are many difficult problems to be solved and the following points are but a few particularly important ones:

(a) A certain degree of inaccuracy in the evaluation of divergence is inevitable because of the inadequacy in the method of calculation, instrumental errors and insufficient density of the observing network.

(b) The time step of the finite-difference approximation may be too long to reveal the fine structure of the evolution of the convergence centers and the movement of the convergence belt.

(c) This paper only presents the distribution of horizontal divergence computed at the 850-mb level, but no attempt has been made to evaluate the vertical velocity by integration along the vertical. Hence it was not possible to analyze the individual cases of thunderstorms which occurred in divergence areas at the 850-mb level.

(d) Despite the enormous amount of computation made in the present study, this paper does not sufficiently cover the interaction and the relationship between the large-scale synoptic features and the small systems.

(e) A further detailed investigation is needed to deal with the structure and the life history of convergence belts.

ACKNOWLEDGMENT

This paper was prepared under the supervision of Chang Chen-yüeh.

LITERATURE CITED

1. Kenneth, L. P. and J. London. "The low-level jet as related to nocturnal thunderstorms over Midwest United States," Journal of Applied Meteorology, 1(1), 1962.
2. House, D. C. "The divergence equation as related to severe thunderstorm forecasting," Bulletin of the American Meteorological Society, 42(12), 1961.

352-cth-8/66