Cumulus Activities in Relation to the Mesoscale Convergence Field

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(Manuscript received 22 February 1967, in revised form 24 May 1967)

Abstract

The intimate relation between the activity of the cumulus convections and the mesoscale convergence field is studied over the coastal area of the Japan Sea on January 19, 1965 by using the data of the “Heavy Snow Storm Research Project” which includes the aerial photographic cloud observation and maritime observation in addition to the radar, aerological and surface observations.

The remarkable fact is that the activity of the cumulus is strongly controlled by the mesoscale convergence field, i.e. the well-developed cumuli exist only in the area of convergence of more than $10^{-4}$ sec$^{-1}$.

The roles of the cumulus convection are discussed concerning the dynamical balance of the mesoscale disturbance and mixing effects on the momentum and heat distribution.

1. Introduction

The mesoscale phenomena have long been disregarded as less important entity in the dynamics of the atmospheric motion, even though many authors (e.g. Fujita, 1963 and Newton, 1963) have revealed various kind of interesting structures of mesoscale dynamic systems. In recent years, meteorologists have come to realize the effects of cumulus convection in the large scale atmospheric motion and many efforts have been made to formulate it by parameterization with respect to the characteristic properties of the large scale motion (e.g. Ooyama, 1963). However we know experimentally that the severe convection concentrates in a narrow area such as thunderstorm, heavy rainfall or squall line which are now recognized as the mesoscale disturbances. The observations by meteorological satellites also show that the cloud distribution is not necessarily homogeneous over a wide area but is rather organized into mesoscale patterns (Fritz, 1963).

The mesoscale disturbance has a particular importance in connection with the heavy snowfall along the Japan Sea coastal region of the Japan Islands. It is likely to develop under a very unstably stratified condition within cold vortexes. We think, thus, that one of the important object of the “Heavy Snow Storm Research Project, J.M.A.” is to study the physical link among the synoptic system, mesoscale system and cumulus convection. By using the data of the Project observation, several studies on the aspects of the convective activity with respects to mesoscale and synoptic scale disturbance have been made (Matsumoto and Ninomiya, 1965a and b, 1966, 1967). In the winter of 1965, the third year of the Project observation, the maritime observation at a fixed point was carried out on the “Seifu”, the observation ship belonging to Maizuru Marine Observatory. The area of analysis thus was extended over the coastal sea area.

In this paper, the relation between the cumulus convection and mesoscale convergence field is studied by analysing the synthetic observation data obtained on January 19, 1965. We will also discuss several aspects on the role of the convective motion on the dynamical balance of mesoscale disturbance and on the characteristic temperature field appearing in the lower layers above the condensation level. The network of the aerological and surface stations of the Project observation, the position of the “Seifu” and the
path of the observation flight are presented in Fig. 1.

Fig. 1. The observation network used for the analysis. The black circle, double circle and the thick broken line denote the surface synoptic stations, rawinsonde stations and the path of the observation flight respectively. The polygonal or triangular areas enclosed by thin lines show the network by which divergence and vorticity are calculated.

2. The mesoscale disturbances in the vicinity of the cold dome center

Let us begin with a brief remark on the cold dome and the mesoscale disturbances observed in January 19, 1965. The considerably intense precipitation for the winter time, i.e., about 30 mm in 24 hours, occurred intermittently from the afternoon of January 19, 1965 to the morning of the next day when the cold dome center passed over the Hokuriku District. Since the air temperature was rather high, the precipitation was changed to rain or sleet in the coastal area, but the synoptic structure in this day showed the characteristic situations of the heavy snowfall.

The relationship between the cold dome passage and heavy snowfall has been discussed by many authors (e.g., Fukuda, 1966). Although the cold dome under consideration, similar to the case of January 16, 1965 (Matsumoto, Ninomiya and Akiyama, 1967), is much small as compared with the usual ones, and is detected only by using specially designed 6-hourly aerological observations, it has the typical structure as shown in the vertical cross section along 140°E meridian (Fig. 2). The dome shaped cold air is bounded by a remarkable inversion layer and the funnel-like tropo-

Fig. 2. The vertical cross section along the 140°E meridian at 1500 LST January 19, 1965. The thick and thin lines are the boundary of inversion layer or tropopause and the isotherms. The moist areas in which the humidity exceeds 80% are indicated by stipples.

Fig. 3. Surface weather map at 1500 LST January 19, 1965. The hatched area indicates the region where the mesoscale disturbances develop. A wind barb in this map means 10 m·sec⁻¹.
pouse is associated above it. In other words, a cold area is observed at 500~600 mb level and a warm core is analysed at 350~300 mb level above the cold core. Fig. 3 shows a surface weather map at 1500 LST January 19, 1965, when a cyclone is located on the northeastern Japan Sea. Severe phenomena such as thunderstorm or gust are observed towards south of the cyclone center. It is a notable feature that the surface disturbances are observed inside of the polar air bounded by the cold dome boundary layer.

The fluctuations with a period of 2~3 hours are easily recognized on the records of pressure, precipitation and wind at several surface stations (Fig. 4). As discussed in the previous paper (Matsumoto, Ninomiya and Akiyama, 1967), these fluctuations occur with the passage of mesoscale disturbances which develop one after another in the vicinity of the cold dome center. The most remarkable disturbance is the one which passed over Wajima at 1500 LST January 19, and the next is the one which passed at 0000 LST January 20, 1965. Especially during the passage of the former, thunder and lightning were reported, and the strong wind or gust was observed when the latter passed over. Some synoptic meteorologists may understand that the latter is the cold front associated with the cyclone system located over the northeastern Japan Sea and the former is the prefrontal squall line. The horizontal scale and the life-time of the systems mentioned above are, however, much small as compared with these of the synoptic systems. Here we emphasize that a series of the mesoscale disturbances, whose horizontal scale and life-time are 100~200 km and several hours respectively, can be analysed during the process in which a cold-air outbreak is accomplished. The location and the movement of the mesoscale disturbances relative to the cyclone and the cold dome are schematically presented in Fig. 5. The phase velocity of the mesoscale disturbance is 55 km hour⁻¹.

Fig. 4. The time variation of the pressure, temperature, wind, precipitation and weather during 24 hour period from 0900 LST January 19 to 0900 LST January 20, 1965, observed at Wajima, Aikawa and Sakata (see Fig. 1 for their locations).

Fig. 5. Schematic picture showing the relative location of the cold dome, cyclone and mesoscale disturbances. The cold dome boundary at 700 mb surface and the area of cold air associated with the surface cyclone are indicated by a line of small circle and hatches respectively. The areas of mesoscale systems are enclosed by thin solid and/or broken lines. The mesoscale system with black circle and thunder symbol and the system with cross marks and wind flag indicate the mesoscale disturbances which pass over Wajima at 1500 LST January 19 and 0000 LST January 20, 1965 respectively. The area of the convective warming mentioned in section 5 is shown by stipples.
3. Some aspects of cumulus activity in relation to the mesoscale convergence field

In this section, the relation between the activity of the cumulus convection and mesoscale convergence field will be discussed in detail by using the data of the aerial photographic observation of cloud and radar observation. Among a series of the mesoscale disturbances mentioned in section 2, the first and the second system, which passed Wajima at 1500 LST and 1730 LST January 19, 1965 will be discussed here because the observational data are especially abundant for these systems. They are hereafter denoted by system A and system B, respectively (see Fig. 10).

In order to study the field of the mesoscale disturbances selectively, let us apply 2.5 hour running mean to the self-recording materials such as pressure and wind and discuss the deviation fields (Matsumoto and Ninomiya, 1965b). The pressure and wind field thus obtained are shown in Fig. 6.

A remarkable line echo extending from south southwest to north northeast is observed within the system A. The movement of this line echo is schematically shown in Fig. 7a, and the isochrone of the significant weather phenomena such as gust, pressure rise of thunder is presented in Fig. 7b. A typical example of the change of meteorological elements is obtained on the observation ship “Seifu” participating in the project observation and is presented in Fig. 8.

This line echo, which closely connected with precipitation, follows the mesoscale low pressure area and precedes the mesoscale high pressure area. This is the characteristic feature of the winter precipitation over the Hokuriku District (Matsumoto, Ninomiya and Akiyama, 1967). Fujita (1959), on the other hand, showed that the precipitation in the warm and/or dry region is found within “mesohigh”. He concluded that the “mesohigh” is resulted from the cooling caused by evaporation from the falling raindrops in the subcloud layer.

The rawinsonde observation at Aikawa at 1500 LST January 19 shows rather dry stratification for the winter season (in winter season, almost saturated moist air is usually...
found in the sub-inversion layer over the warm sea surface). The relative humidity was about 70% in subcloud layer. The cloud base is known to be about 600~800 m above sea level. If the evaporation from the precipitating raindrop and/or snowflake goes on until the air in subcloud layer become saturated, the temperature drop is expected to be about 1.5°C on the ground surface. This estimated value coincides well with the temperature drop observed actually at Aikawa (Fig. 3) and on the ship (Fig. 8). The expected value of the pressure rise caused by this cooling is about 0.3 mb. As the pressure rise observed on the ship is more than 1.0 mb (Fig. 8), the effect of evaporation is not considered to be of primary importance and the mesoscale pressure field shown in Fig. 6 is to be of the substantial character of the mesoscale systems. Therefore the authors (1965b) suggested that these phenomena would be explained by the concept of internal gravity wave which propagates on the cold dome boundary.

The mesoscale convergence field is obtained by using the half-hourly values of 10 minutes mean surface wind data of the polygonal

Fig. 7. Upper figure; The isochrone of the line echo.
Lower figure; The isochrone of mesoscale system analysed by using surface observation.

Fig. 8. The time changes of pressure, temperature and wind (a wind barb means 2 m·sec⁻¹) observed on the ship “Seifu”. The variation of the precipitation intensity and the remarkable weather phenomena are expressed with symbols.

Fig. 9. The thin solid line indicates the convergence calculated by using the wind data at Hekurajima, Wajima, and Seifu. The thick solid line and broken line are the 2.5 hour running mean value of the convergence mentioned above and its deviation from the running mean, respectively.
or triangular networks shown in the station map (Fig. 1). When the scale of the area in which divergence and vorticity is to be calculated is not sufficiently small as compared with the scale of the disturbances under consideration, the estimated values are largely reduced as compared with the true value of the systems. Therefore, when we make the convergence map, the method of reduction which we introduced in the previous paper (1967) is applied.

We mentioned before that the variance of the pressure in mesoscale systems is quite smaller than that of the synoptic systems. On the contrary, the variance of the convergence of mesoscale systems is much larger than that of the large scale motion. As an example, the variation of the 2.5 hours running mean of the convergence obtained by using the triangular network formed by the ship, Hekurajima and Wajima, and the anomaly from it is presented in Fig. 9. The maximum value of anomaly is about $30 \times 10^{-5}$ sec$^{-1}$ while the maximum found in the mean field is less than $8 \times 10^{-5}$ sec$^{-1}$. In other words, the mesoscale disturbance is of primary importance in the convergence field and is related to the cumulus activity as will be discussed hereafter.

It is easily recognized that the convergence area A and B in Fig. 10 move with the same phase velocity as the line echo given in Fig. 5 and mesoscale depressions given in Fig. 6. The sketches of the radar echoes observed by Mt. Yahiko radar at 1500 and 1700 LST January 19, 1965 are shown in Fig. 11.

![Fig. 10. The distribution of the surface wind divergence for 1400, 1500, 1600, 1700 and 1800 LST January 19, 1965. The areas of the convergence are indicated by hatches.](image1)

![Fig. 11. The sketch of the echoes by Mt. Yahiko radar scope at 1500 and 1700 LST January 19, 1965.](image2)

It should be emphasized that the disturbances appearing on the radar scope do exist.
only in the mesoscale convergence areas of the order of more than $10^{-4} \text{ sec}^{-1}$ and do not elsewhere. It is easily understood that the strong convergence of the moist air is needed to maintain the cumulus activity. The amount of the horizontal inflow of water vapour in subcloud layer is much larger than that of the outflow caused by the mesoscale vertical motion across the base of the cloud layer. The difference between these amounts over the mesoscale convergence area of $10^{-4} \text{ sec}^{-1}$, which is estimated as much as 10 mm·day$^{-1}$, together with the supply due to the evaporation is to be transferred upward by convective motion (Motsumoto, 1967). The active cumulus convections are thus required over the mesoscale convergence area to balance the water vapour budget. The paper on the quantitative analysis is now being prepared. Asai* shows in his numerical experiment of cellular cumulus convection that, under a certain circumstance, the convection in the convergence area of $10^{-4} \text{ sec}^{-1}$ developed while that in the area of weak convergence of less than $10^{-5} \text{ sec}^{-1}$ did not. Since the convergence in large scale motion is of the order of $10^{-5} \text{ sec}^{-1}$, it seems difficult to suppose that the large scale convergence field controls the cumulus activity directly.

The features of the cloud distribution are also discussed by using the photographic cloud pata obtained on the ship and the aircraft. Fig. 12a is the whole sky photograph taken on the Seifu at 1500 LST, when she is situated at divergence area (see Fig. 10). The cloud amount is 4/10 and small cumuli and alto-cumuli are observed. The whole sky photograph at 1530 LST is presented in Fig. 12b. At this time, the ship is located in the eastern front of the convergence area A whose maximum value is about $-30 \times 10^{-5} \text{ sec}^{-1}$. The bank of cumulonimbi which is approaching to the ship from the direction of west-northwest can be seen in the northwest quadrant of the photograph and the thunder and lightning take place shortly thereafter.

The aerial photographic observation of cloud is carried out along the flight course presented in Fig. 1. A Beachcraft Queenair model 80 was used for the observation flight. The cloud photographs were taken at the altitude of 7500 m above sea level by an aerial camera with super-wide angle lense ($f=152 \text{ mm}$) mounted on the floor of the aircraft and two 35 mm cameras with super-wide angle lense ($f=21 \text{ mm}$) from both side windows. The

* Personal communication.
exposures were made at every 40 sec. simultaneously and thus the cloud height, spacing, etc. are easily calculated by applying the principle of the triangulation.

As seen in Fig. 13, showing the distribution of cloud amount observed during the period from 1323 to 1359 LST, the overcast area with developed cumuli is located around the position where the line echo is observed at 39°N, 136.5°E. While the clear area extends from 137°E to 138°E to the east of the overcast area. The same remarkable arrangement of overcast zone and of the less cloudiness zone was already detected during the flight from 1156 to 1306 LST, and therefore the phase speed and the direction of the movement of these cloud systems are estimated to be 55 km·hour⁻¹ and towards east northeast, respectively. This feature of displacement is exactly the same as that of the radar echo groups and that of mesoscale systems.

The variation of the height of the cloud top along the flight path is presented in Fig. 14. The height of the cumulonimbus or towering cumulus in the overcast area is estimated to

Fig. 13. The distribution of the cloud amount (upper figure) and cloud type (lower figure) observed along the flight path from 1323 LST to 1359 LST January 19, 1965. The radar echo at 1330 LST is also presented in the figure.

Fig. 14. The distribution of the height of the cloud top along the flight path from 1323 LST to 1359 LST January 19, 1965.
be more than 5000 m, while the height of small cumuli which exist in divergence area is at most 1000 m. The broken or overcast area with the moderately developed cumuli whose heights range from 2000 to 3000 m is observed during the flight from 1340 to 1359 LST (see Figs. 13 and 14). This area is characterized by the weak convergence of $-10 \sim -5 \times 10^{-5}$ sec$^{-1}$ as seen in Fig. 10. Thus we arrive at the conclusion that the activity of the cumulus is strongly controlled by the mesoscale convergence field.

The typical examples of these clouds are presented in Figs. 15 and 16. In Fig. 15 are seen the towering cumuli taken by an oblique camera at 1325 LST from the right hand side, which are considered as the characteristic type of the cumulus convection in winter over the mesoscale convergence zone. Fig. 16 shows an example of photographs taken by the vertical camera at 1335 LST, which presents the typical feature of cumuli in the mesoscale divergence zone.*

4. The role of the cumulus convection in the mesoscale dynamical balance

In this section we will discuss the role of the cumulus convection in the dynamical balance of the mesoscale disturbance. We already (1967) pointed out the importance of the apparent irrotational frictional effect caused by the convective motion and that of the twisting terms by evaluating the vorticity and divergence equations for the mesoscale disturbance observed on January 16, 1965.

As an example, the mesoscale vorticity map for 1500 LST is presented in Fig. 17. The vertical wind shears at rawinsonde stations are also shown in the figure. The evaluation of the divergence and vorticity equations will be made thereafter along the heavy broken line indicating the path of the successive disturbances.

Fig. 15. The oblique aerial photograph of the developed cumuli taken at 1325 LST January 19, 1965. The top of these cumuli which develop in the mesoscale convergent area reaches up to 5000 m above sea level.

Fig. 16. The vertical aerial photograph of the small cumuli in the mesoscale divergent area taken at 1335 LST January 19, 1965.

Fig. 17. The relation among the vorticity field (thin solid line), divergence field and the vertical wind shear in the lower layer (arrow). The areas of cyclonic and anticyclonic vorticity are indicated by hatches and stipple, respectively. The thick solid line and thick broken line are the isoline of convergence and divergence, respectively.

* Some statistical aspect of cumulus such as spacing, diameter and height will be discussed in future.
The vorticity equation and the divergence equation relevant to the mesoscale system

\[
\frac{\partial \zeta}{\partial t} + V \cdot \nabla \zeta + \omega \frac{\partial \zeta}{\partial t} + \omega_x v_p - \omega_y u_p + (f + \zeta) D
\]

\[
= F_1 - \omega \frac{\partial \zeta}{\partial p}
\]

and

\[
\frac{\partial D}{\partial t} + V \cdot \nabla D + \omega \frac{\partial D}{\partial t} + \omega_x u_p + \omega_y v_p
\]

\[
+ \frac{1}{2} (D^2 + a^2 + b^2 - \zeta^2) + gF^2 z
\]

\[
= F_2 - \omega \frac{\partial D}{\partial p} - \frac{1}{2} D^2
\]

are introduced by the authors in the previous paper (1967), where \( a = u_x - v_y \) and \( b = v_x + u_y \) show deformation, and \( z \) is the height of the 1000 mb surface. All terms on the left side of the equations are concerned with the field of mesoscale system and the terms with prime on the right side represent the effect of convective motion, respectively.

Each term in these equations are evaluated along the heavy broken line in Fig. 17 and are presented in Fig. 18. As for the balance of the divergence equation in particular, the sum of the terms on the left hand side of the equation does not vanish at all and a large residue appears especially within the convergence area as seen in Fig. 18c. In other words, an extraordinarily large hypothetical frictional force is to be introduced to acquire the dynamical balance and it is necessarily of an irrotational character (see also Syono et al. 1959). Thus quite naturally is derived the conclusion that the terms such as \( \omega \frac{\partial D}{\partial p} \) due to the convective motions embeded in this convergent area exert an apparent irrotational frictional effect.

Similar to the case of January 16 the main terms which balance with the local time change of the vorticity \( \partial \zeta / \partial t \) are the twisting terms \( (\omega_x v_p - \omega_y u_p) \) (Fig. 18b). The situation is well understood by looking at the vorticity distribution given in Fig. 17. The strong wind shear at Wajima, which gives rise to the large value of twisting terms to the east of the mesoscale system, owes to the existence of a strong wind speed in the lower troposphere which

![Fig. 18. The distribution of various dynamical quantities along the heavy broken line given in Fig. 17.](image)

(a) The magnitude of divergence (solid line) and vorticity (broken line).

(b) The magnitude of the terms in vorticity equation, \( \partial \zeta / \partial t \) (solid line), \((f + \zeta) D\) (thin broken line) and \((\omega_x v_p - \omega_y u_p)\) (thick broken line).

(c) The magnitude of the terms in divergence equation, \( \partial D / \partial t \) (thick solid line), \( F^2 g z \) (thick broken line), \( \omega \frac{\partial D}{\partial p} \) (thin solid line), \( \omega_x u_p + \omega_y v_p \) (thin broken line) and the sum of these terms (thin dotted line with cross marks).
amounts to 16 m·sec⁻¹ at 500 m above sea level. It is interesting to find out that the strong wind in the lower layer is located within a limited area of the mesoscale disturbance. Such a circumstance is often observed in the mesoscale disturbances and we can quote the case of January 16, 1965 and another example of January 20, 1965.*

Let us now discuss the physical relation between the strong wind in lower layers and the convective activity. Taking into consideration the homogenizing effect of convective activity on the physical properties such as momentum it is easily supposed that the vertical wind profile within the region of active convections differs from that in its environment if the general field has a strong wind shear. Several studies show remarkably uniform wind distributions in a well organized convection (see also Fujita and Arnold, 1963 and Newton, 1966). The vertical profiles of the horizontal wind speed of Wajima and Aikawa at 1500 LST January 19, are presented in Fig. 19. The interesting fact recognized in the profile of Wajima is the almost uniform wind speed of 16~20 m·sec⁻¹ in the thick layer from 0.5 to 5 km above sea level and the existence of strong wind shear in the lowermost layer from the earth’s surface to 0.5 km and in the higher layer above 5 km, while the wind speed at Aikawa increases almost linearly with height. It should be mentioned that, at the observation time 1500 LST, Wajima is covered by the mesoscale convective system but Aikawa is not. Similar uniformity in the wind field was analysed for the winter monsoon situation over the warm Japan Sea surface where cumulus convection develops in the lower layer bounded by the well defined inversion (Matsumoto and Ninomiya, 1967a). In other words, relatively strong wind, as compared with the general field, is found in the lower part of the convective layer and the relatively weak wind in its upper part.**

The dynamical aspect of the role of cumulus convection will be summarized as follows. The active cumulus convections are localized selectively in the mesoscale convergence area. The convective mixing there makes the wind speed uniform and the strong wind is likely to be built up in the lower levels of a deep convective layer. The strong vertical wind shear thus appearing on the bottom of this convective layer could be transformed into the vertical vorticity through the effect of twisting terms. The fact that the vorticity distribution is of smaller scale and seems to be subordinative to the convergence field would be attributed to the mechanism mentioned above. On the other hand, the characteristic wind profile in the convective area may provide a favorable condition to the propagation of mesoscale convergence field under consideration. Concerning the vertical distribution of mesoscale divergence field, the authors (1967) have ever shown an interesting structure that the divergent field is analysed in the upper levels of convective layer as well as the convergent field in the lower levels and is obviously related to wind profile mentioned above,

5. The convective warming in the lower troposphere associated with the mesoscale disturbances

In this section, the thermodynamic aspects

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* Reported at the general meeting of Japan Meteorological Society of Oct. 1966 held in Sapporo.
** Recently the discussion on the momentum exchange associated with the cumulus draft in the hurricane has been made by Gray (1967).
of the mesoscale convective system will be discussed briefly. The sensible and latent heat transport and the release of the latent heat owing to the convective motion are the important physical processes in the large scale motion.

![Image: The vertical cross section along the Japan Sea coastal line at 1500 LST, January 19, 1965.](image)

In Fig. 20 is presented the vertical cross section along the Japan Sea coastal line at 1500 LST January 19, 1965. A remarkable fact is the existence of the warm air around 850 mb level over Wajima. This warm area is found under the swelling inversion layer, the southern extension of the cold dome boundary and shows up a remarkably concentrated smaller scale distribution on the 850 mb weather map. It might be a questioned that this warm air should be ascribed to the advection of the south westerly current which characterized the warm sector field. To answer this question, the trajectory of the air parcel at 850 mb surface and the movement of the warm core should be compared. Actually it is found that the substantial displacement and the phase propagation are different each other. As the area of warm air is located in the vicinity of the cold dome center where the mesoscale disturbances are likely to develop, it would be naturally supposed that the most important physical factor is the warming due to the release of the latent heat associated with the condensation process of the cumulus activity. The location of the warm core relative to the cold dome is schematically presented in Fig. 5.

The swelling of the inversion layer could again be regarded as the result of convective activity. The authors (1967a) already pointed out in the analysis of the inversion layer which develops under the winter monsoon situation that the rises of inversion are found above the groups of the active convectons. The cold air underneath the upheaven inversion layer would be explained by the overshoot of the convective upward motions.

Similar, but more remarkable warming at the bottom of a single huge cumulonimbus and the cooling at its top is analysed by Fujita and Byers (1960). The thermal structure of the warm core of the tropical cyclone (Yanai, 1961) can also be referred to as the analogous situation.

If our implication is correct, the convective warming might appear under most of the cold domes because the mesoscale disturbances usually develop in the vicinity of the cold dome center. In order to make the validity of our supposition clear, it is needed to study many other cases and it will be reported in the separated paper (Matsumoto and Ninomiya, 1967b).

6. **Concluding remarks**

This work, the first step in understanding the relation between the mesoscale disturbance and the convective motion, could not be made without the data of synthetic observation which is carried out by the Heavy Snow Storm Research Project, J.M.A.

The important informations obtained by making the synoptic and dynamic analysis on the heavy snowfall in January 19, 1965 are summarized as follows.

1. The cumulus activity and the mesoscale convergence field is closely interrelated. Namely the active cumulus convections whose top exceeds 5000 m exist only in the mesoscale convergence zone of the order of $10^{-4}$ sec$^{-1}$.

2. As for the role of the convection in the balance of the mesoscale disturbance, it is concluded that the strong wind in lower layer formed by the convective mixing causes the increase of vorticity of the mesoscale
system through the work of the twisting terms. The strong wind is also favorable to maintain the convergence of the mesoscale system.

3. The warming in the lower troposphere and the swelling of inversion layer is observed associated with the mesoscale disturbance and are supposed to be caused by the release of latent heat.

Acknowledgments

The authors express their hearty thanks to Dr. K. Takahashi for his encouragement, and to the members of the Heavy Snow Storm Project for their discussions and participation in the project observation. Thanks are also due to Mr. H. Ino, Maizuru Marine Observatory, Mr. T. Kawamoto, Wajima Observatory and Mr. K. Ishiyama, Sakata Observatory who collected invaluable data for us.

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積雲対流と中規模擾乱にともなう収束域との関係

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冬期日本海域を寒冷渦が通過すると、北陸地方に強い降雪の事象は多くの解析によって知られている。しかしながら、降雪は総観規模に対応する様な広い地域内で一様におこるわけではなく、寒冷渦中心附近で発達するいくつかの中規模擾乱にともなっておこっていることが知られてきた。この報告では1965年1月19日に北陸地方を通過した中規模擾乱を、航空写真観測、定点海上気象観測、レーダー観測などを含む、北陸豪雪特別観測の資料をもとに、大規模擾乱、中規模擾乱および積雲対流の相互関係においての解析を行なった。その主要な結果は次の様に要約される。

1. 寒冷渦中心附近に、いくつかの中規模擾乱（その水平スケールは100 km、ライフタイムは数時間）が発達する。

2. 雲頂が5000 m以上に達する活発な積雲対流は中規模擾乱にともなう10^{-4} sec^{-1}以上の強い収束域にのみ存在する。これに対して弱い収束域あるいは発散域内では高さ1000 m程度の小さな積雲がまばらに存在するにすぎない。これらの事実は積雲対流の活動が中規模収束域によって直接的に支配されている事を示している。

3. 中規模収束域では密な対流活動の混合作用によって、厚い気層内にほぼ一定の風速が現出する。したがって一般場に比較して下層に強風が、上空で弱い風速が現出される。この下層の強風は、地表から500 mまでの層内でのシアーニーを増し、立上がりの頂の関係を通して中規模擾乱の温度場をつくる。また前述した風速の垂直分布は擾乱の収束場を前進させるのに好都合である。

4. 中規模擾乱にともなう対流活動による潜熱放出によるものとおもわれる温度域が800〜850 mbにあらわれ、同時におその上方では逆転層が盛上ることが認められる。

5. 海上積雲対流、中規模擾乱の解析には、航空機による観測、定点海上気象観測などがレーダー観測とならんで必要不可欠のものであることがわかった。本研究は気象研究所北陸豪雪特別研究の一部をなすものである。