On Vortical Mesoscale Disturbances Observed During the Period of Heavy Snow or Rain in the Hokuriku District

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Abstract

During the period of heavy and concentrated snow-or rainfall in the Hokuriku District, vortical mesoscale disturbances have often been observed by radar. These vortical disturbances are characterized by a diameter of about 50 to 80 km, which is 100 times as large as that of tornado, and one order of magnitude smaller than that of typhoon, and may be classified as mesocyclone. Radar observations show the remarkable spiral or ring-shaped radar echoes corresponding to vortical disturbances. They usually develop off the coast, move across the plain and disappear in the mountain area of the Hokuriku District, having the lifetime of several hours. Further, it was found that the heavy and concentrated snow-or rainfalls sometimes took place along the track of these vortical disturbances, and that the intensity of precipitation may be estimated by means of wind divergence and the concept of vortical rain like the rain due to typhoon.

1. Introduction

Among synoptic meteorologists, it has been well known that heavy snowfall in the plain area of the Hokuriku District (the Japan Sea coastal region of the central Japan) is closely related to the mesoscale disturbance or small surface cyclone in the vicinity of cold vortex center (e.g. Miyazawa, 1959). Recently radar data at the Hokuriku District have been available and some attempts were made to use them for detailed analyses concerning the mesoscale disturbances over the Japan Sea, where any other kind of observation has scarcely been made. Fukuda (1961) has already pointed out that the bubble-like minor depression appeared over the sea off Hokuriku, and tornado or large water-spout was especially observed over the sea off eastern part of Toyama Prefecture during the period of heavy snowfalls. On the other hand, the author (1966) showed from the detailed radar analysis that a cyclonically rotating system of radar echoes has contributed to the increase of the local concentrated rainfall in the Hokuriku District, and Arakawa (1966) showed that the mesocyclone with hook-shaped echoes was closely related to the rainstorm at Isahaya, the Kyushu District.

Recently, the author found out an interesting and remarkable fact that, during the period of heavy snow-or rainfall, small disturbances like midzet-typhoon with spiral radar echoes have often been formed and developed over the sea off the Hokuriku District, which could be tracked from the sea to the inland, and brought considerable amounts or precipitation. As reported by Fujita (1963), these small disturbances which are found to accompany a definite cyclonic pressure patterns should be called “mesocyclones” whose horizontal dimensions are one order of magnitude smaller than those of ordinary typhoons, which are characterized by the diameter of several hundreds kilometers. These disturbances are designated as “vortical mesoscale disturbance” in this report.

The observational facts indicate that during the period of heavy snow-or rainfall the spiral or ring-shaped echo could be formed under favorable conditions. As the necessary conditions for the initiation of such echoes, we may select the followings: (1) Strong convergence at low levels and divergence at upper levels, which may result in a significant in-
crease of cyclonic vorticity; (2) Much supply of water vapor and sensible heat from the sea surface. These conditions are very similar to those seen with typhoon formation over the tropical maritime region.

The lifetime of the vortical mesoscale disturbance seems to be of the order of several hours. This is pretty long in comparison with the mean life of a thunderstorm cell which is less than one hour. Therefore, it is pointed out that by finding out and tracking the vortical mesoscale disturbance the short range forecasting of heavy precipitation would become possible. In this article, is presented a detailed mesoscale study of the vortical disturbances which appeared in the Hokuriku District recently.

2. Vortical mesoscale disturbances as observed by radar

i) February 2–3, 1965 (snowfall)

On February 2–3, 1965, the plain and mountainous regions in Niigata Prefecture had the largest amount of snowfall during the winter season of the year. As shown in Fig. 1, a well-developed monsoon prevails over the Hokuriku, and the surface pressure field shows a typical winter-type distribution, but at the surface mesomap we can find that the vortical disturbance is concealed in the coastal sea area of the Hokuriku District. This vortical mesoscale disturbance was formed on the sea off Noto peninsula, moved over the southern part of Niigata Prefecture. As shown in Fig. 2, the zone of heavier snowfall extending from southeast to northwest over this region was probably associated with the passage of disturbance. The radar echo associated to the vortical disturbance had a well-defined spiral-like appearance similar to that of typhoon, and persisted for 1.5 hours until it decayed over the mountain area of Niigata Prefecture. In this example, the diameter of the “eye” was about 20 km and the horizontal scale under the influence of this disturbance was about 80 km in diameter.

ii) February 1, 1963 (Snowfall)

On February 1, 1963, the northern plain and mountainous region in Niigata Prefecture had a concentrated snowfall. As shown in Fig. 3, the synoptic pressure pattern is a type of the “Cyclone over the Japan Sea” and vortical
disturbance appeared in the warm sector of the cyclone over the Japan Sea. The author (1961) has already showed that a type of snowfall in the plain of the Hokuriku District, so-called “Sato-yuki” is observed frequently corresponding to the passage of the instability line in the warm sector of cyclone over the Japan Sea, using the special synoptic data. In this example, there is little doubt about the occurrence of the concentrated snowfall corresponding to the passage of vortical disturbance, because the continuous radar data were not available. But we can find out that a typical vortical disturbance which is characterized by a diameter of about 60 km was formed over the sea in the vicinity of Noto peninsula and the Sado Island, as shown in Fig. 4.

Fig. 4. Distribution of snowfall amount (in cm) for 0800–1600 JST 1 and spiral radar echo (shaded area) at 1200 JST 1 February 1963.

i) January 22, 1966 (Snowfall)
On January 22, 1966, the plain region in the Hokuriku District had a heavy snowfall. Especially, the narrow area centering Takada City, Niigata Prefecture, suffered serious damages by the heavy snowfall (Fig. 16). As shown in Fig. 5, a synoptic pattern is the type of those “isobars have a cyclonic curvature over the Japan Sea, so-called Fukurotype” and of “upper cold vortex over the Japan Sea”, which provide the synoptic criteria of heavy snowfall in the plain of the Hokuriku District. In this situation, by using radar observations we found a few of the vortical disturbances, which are difficult to be discerned on synoptic chart (Fig. 16), and, among them, a typical one was formed over the sea off Tango peninsula, moved to ESE wards and struck the coast in the vicinity of Tsuruga City as shown in Fig. 6. It became ill-defined later presumably because of the topographical effect. A remarkable fact is that a sudden pressure fall, change of surface wind direction and burst of snowfall intensity were recorded on its arrival. The scale of the spiral echo, about 70 km in diameter, is somewhat larger than those observed in winters of 1963, and 1965. The lifetime seems to be about 4 hours, which is longer than other examples.

On this day, the other vortical disturbance which was charcterized by a diameter of about 60 km struck Noto peninsula as shown in Fig. 16. The snowfall amounts of 1.2 mm in 10 min were recorded on its arrival at 3 stations of Noto peninsula.

Fig. 5. Surface and 500 mb weather maps at 0900 JST 22 January 1966.

Fig. 6. Distribution of snowfall amount (in cm) for 0900 JST 22-0900 JST 23 January and spiral radar echo (shaded area) at 1054 JST 22 January 1966.

iv) July 18, 1964 (Rainfall)
We had a heavy rainfall on July 18, 1964 over the Hokuriku District. The surface weather map is given in Fig. 3. A pretty narrow area covering Kanazawa and Toyama Cities,
both of which are located on rather flat lands, were subjected to the heavy rainfall and suffered serious damages by flood and landslides. (This heavy rainfall was named as the “San’in-Hokuriku Gou” by JMA). It is seen that the maximum rainfall intensity was observed when the ring-shaped echo passed over the western Hokuriku District (Miyazawa, 1966). The vortical disturbance closely connected with the ring-shaped echo moved across the coastal region, became ill-defined gradually in the mountainous region and contributed to the larger amounts of rainfall at the passage as shown in Figs. 7 and 12. The diameter of the ring-shaped echo was about 25 km.

Figs. 8, 9, and 10 show the radar photographs of each examples mentioned above. While, we can easily find the rotating character of these vortical disturbances by 16-mm movie of the radar echoes taken at Mt. Yahiko (647 m above sea level) and Tōjinbo (105 m above sea level) in the Hokuriku District.

3. Meso and radar analysis of vortical mesoscale disturbances

On February 2–3, 1965 (case of heavy snowfall) and July 18, 1964 (case of heavy rainfall), we successfully obtained a series of radar pictures taken at Yahiko Station involving the formation and subsequent development of vortical disturbances in the Hokuriku District. Therefore, both examples mentioned above were selected for detailed analysis.

i) Movement of the center of disturbance
As shown in the examples, the detailed tracks of the vortical disturbances indicate the apparent sinusoidal oscillation around the mean path. This feature is very similar to that of
It is of interest to see that the movement of the center of vortical disturbance is quite different from that of the ordinary snow echo cell. The former is characterized by rotating component and the latter by straight translation.

The logarithmic spiral adopted in the study of H. V. Senn and H. W. Hiser (1957) was applied in determining the center position of the spiral-shaped disturbances, and in the case of ring-shaped disturbance the center of the disturbance was determined by geometrical center of the ring-shaped echo. The crossing angles $\alpha$, defined by the angle at which the band intersects with any circle having its center at the disturbance center, were estimated to be about 30° in the case of February 2-3, 1965. This angle was larger than that of ordinary typhoon. Fujihara (1966) obtained about 42° in the case of January 22, 1966. This angle is usually 10–20° in most typhoons. Fujita (1963) showed that an important feature of the precipitation bands of a mesocyclone is the extremely large crossing angle, 45–60°. He considered that it is due to the difference in internal structure between mesocyclones and small hurricanes and that a mesocyclone probably cannot be treated as a small hurricane. It is thus suggested that the large crossing angle of spiral band of the vortical disturbance is an important feature.

With use of a series of radar pictures of February 2–3, 1965, as shown in Fig. 11, the development of the vortical disturbance was investigated. The existence of a vortical disturbance was first seen as a fingered echo which soon curled around the circulation center. To the north of the path of the disturbance, the spiral echo developed gradually and then it became indistinct as hardly detected as it moved in the mountainous region. It was found that the two disturbances, shown in Figs. 2 and 7 moved along the direction about 25° to the right from the direction of 700-mb wind at the nearby rawinsonde station Wajima and the moving velocities were estimated to be 80 km/hr and 66 km/hr, respectively. These are in good agreement with the 700-mb wind speeds at Wajima.

ii) Dissipation of disturbance

Generally, the vortical disturbance may be formed over the sea off coastal region, and then moves to the inland and dissipates gradually at the mountainous region because of the surface friction. According to the synoptic, radar and surface analyses given in the following section, the lifetime of disturbances seems to be about 1.5 to 4 hrs. This value is much larger than the mean lifetime of a thunderstorm cell which is less than 1 hr (Fujita, 1963). The successive positions of the ring-shaped echoes are indicated in Fig. 12 in order to show the dissipation of the vortical disturbance. As the echo moved from the plain to the mountainous region, the diameter of ring-shaped echo decreased. Measurements have shown that the echo diameter which had been about 28 km when echo appeared, decreased to 20 km 30 minutes later and to 16 km 40 minutes later at the mountainous region.

iii) Meso-analysis of disturbance

As the observation network in the coastal region of the Hokuriku District is very coarse,
it is rare to get a chance capable of pursuing the detailed process of the vortical mesoscale disturbance, which is characterized by a diameter of about 50 km. On February 2-3, 1965, fortunately, the data of a relatively dense network was obtained in the coastal region by supplementing 9 railway stations equipped with automatic recording instruments. In Fig. 2 is shown the distribution of the observation stations in the area under consideration. Now let us look at the structure of disturbance which struck the coast line near Kashiwazaki, Niigata Prefecture.

Time sections of surface weather elements observed at Kashiwazaki and Takada during the passage of the vortical disturbance are given in Fig. 13. Rather weak wind was observed at Kashiwazaki, which lasted for about 20 minutes around the time when the minimum surface pressure was observed, 0100 JST February 3. Unfortunately, there was no measurement of wind direction. It seems reasonable to expect that there was rather weak wind near the center and strong wind at a distance of about 25 km from the center if a steady movement of the disturbance is assumed. This feature is quite similar to that of the typhoon wind field. The changes in weather elements obtained at the selected stations with passage of the vortical disturbance may be summarized as follows.

i) Takada
Significant changes of wind, temperature, pressure and snowfall intensity were noticed around 0045 JST. There was a sharp increase in wind speed, temperature, snowfall intensity, and clockwise change in wind direction (WSW → NW). The peak gust of WNW 18.9 m/s was recorded at 0045 JST and minimum pressure was recorded at around 0045 JST, when the center of disturbance was located at the nearest distance of about 25 km from Takada Station. This indicates the existence of an intense wind speed at outer core of the disturbance, as mentioned in the previous section. On the other hand, the temperature started to rise rapidly at 0020 JST, and was assumed to have become the maximum value during the time from 0025 to 0105 JST and afterwards it dropped. It was −2.2°C at 0015 JST and −1.4°C at 0040 JST. This temperature rise seems to be due to strong southwesterly flow on the south quadrant of the center. The humidity increased from 0030 JST rapidly; to some extent it was a reflection of the intensity of snowfall. By a recoder of snowfall amount, the snow intensity was measured as about 0.2 mm/15 min at about 0105 JST and snowfall activity was evidently associated with the radar spiral band in the southern section.

ii) Nagaoka
There was a clockwise change in wind direction (NW → N → NNE) with the passage of spiral band. A snowfall intensity of 2 mm/hr (0.3 mm/10 min) was recorded around 0050 JST in a position 45 km northeast of the center, shortly before the disturbance had entered the land. This snowfall activity was evidently associated with the radar spiral band in the northern section. The minimum pressure was recorded around 0105 JST, a little before the center had arrived at the point of minimum distance from the station.

iii) Railway stations
The peak gusts, 20–22 m/s at the coastal region, 15 m/s at the inland, were recorded at 9 railway stations during the passage of disturbance. The barographs have indicated distinct dip-then-rise pattern of 2.0–1.3 mb difference over 50 minutes with the passage of disturbance. On the other hand, the radar has failed the tracking of the disturbance as soon as it entered the mountainous region near Kashiwazaki. However, the available observations at railway stations are sufficient to track it to the mountainous region near Koide (Fig. 2).
As the scale of the disturbance is small and the lack of observation, the analysis is extremely difficult over the sea. However, it would be possible to make extrapolation or interpolation by using the surface self-recording material (Fujita, 1957). Fig. 1 is the surface mesomap thus obtained.

4. Dynamical analysis of vortical mesoscale disturbances

i) Vertical distribution of horizontal divergence and vortical disturbance formation.

The divergence of the upper wind field when the vortical disturbances were observed is shown in Fig. 14. Wajima (600), Akita (582), Sendai (590) and Tateno (646) were selected for computing divergence in the area under consideration. However the area is $7.6 \times 10^4$ km$^2$, which is the same order as that of the aerological network to be used for the discussion of synoptic scale phenomenon. In Fig. 14 the existences of intense convergence at lower levels and divergence at upper levels (400-600 mb) are recognized when the vortical disturbances and associated heavy snowfall are formed. Meanwhile, a thick intense convergence at the lower and middle levels (1000-300 mb) and divergence at the upper level (200 mb) was recognized at 0900 JST 18 July 1964 when the vortical disturbance was formed with heavy rainfall. In this case, Wajima (600), Tateno (646), Shionomisaki (778) and Yonago (744) were selected for the divergence computation and the area is $13.2 \times 10^4$ km$^2$. These networks used in the computation in an adequate scale for the mesoscale phenomenon, but it is verified, though qualitatively, that the vortical disturbances are apt to be formed selectively under the situation where the convergence at lower levels and the divergence at upper levels are established. It is interesting that this vertical distribution seems to be quite similar to the situation concerning the typhoon formation in the Pacific Ocean (Yanai, 1961). In Fig. 14 is shown the mean vertical divergence in the same quadrangle by full line for 37 cases of heavy snowfalls observed in Niigata Prefecture for reference (Fukuhara, 1965).

The characteristics of the conditions favourable for the formation of vortical disturbance on 22 January 1966 were studied from the synoptic point of view and the distribution of sea surface temperature was examined as a case study. The surface and 500 mb weather map at 0900 JST 22 January 1966 were presented in Fig. 5. The cold vortex which moved southeastward from the East Siberia arrived over the Japan Islands on 22 January. The vertical cross section along the Japan Sea coastal line is shown in Fig. 15. A dome cold air, the center of which is located at 40$^\circ$N, i.e. near Akita (582), appears in the cross-section. The top of the dome reaches 490 mb level (i.e. about 6000 m). A sharp inversion layer is also observed in the lower layer within the cold air. The structure revealed in the cross-section is features commonly observed in any cold vortex (Matsumoto et al, 1965). It should be...
remarked that the vortical disturbances appeared and convective heavy snowfall occurred in the southern part of the cold vortex where a deep unstable layer would be expected.

Furthermore, as one of the Heavy Snow Storm Project observations, the distribution of the sea surface temperature was obtained as given in Fig. 16. The most noticeable feature is that the vortical disturbance seems to be formed at the area of concentration of contour lines of sea surface temperature, indicating the existence of warm current and accordingly a predominant vapor supply (Matsumoto, and Ninomiya, 1966).

![Fig. 16. The distribution of sea surface temperature (in °C) observed from 14 to 27 January 1966. Arrows show the movement of vortical disturbance at 22 January 1966. The snowfall amount (in cm) in the Hokuriku District observed from 0900 JST 22 to 0900 JST 23 is also entered.](image)

It is thus suggested that the combined effects of the intense upper cold air and the heating from the very warm sea surface make the air column unstable when the cold vortex covers the Japan Sea. In this unstable stratified atmosphere the vortical disturbances develop selectively when a condition of low-level convergence and high-level divergence is fulfilled.

ii) Circulation and vorticity around vortical disturbance

Since there is no direct measurement of the wind inside the vortical mesoscale disturbance, the best estimation of the dynamical property should be made indirectly. It is well known that the movements of individual radar echoes are in good agreement with the upper winds at the same level (Tatehira, 1961). Therefore, it would be reasonable to estimate the upper winds with the use of PPI photographs. Using a series of PPI photographs taken with 1.5-degree in elevation angle, the upper winds around the center were obtained for the disturbances of February 3, 1965 and July 18, 1964. Fig. 17 shows the relative wind obtained by subtracting the moving velocity of systems from the estimated wind velocity. The heights of the winds were estimated to be about 2–4 km from the heights of radar beam. A remarkable feature in these figures is the pattern of cyclonic circulation around the center of disturbance. The tangential speed of the air circling around the center has its maximum value at a distance of 25 km and rather weak wind speed is obtained near the center. This facts are in good agreement with the result of meso-analysis mentioned in the foregoing section, although they were derived from the wind field of different levels.

![Fig. 17. Cyclonic wind relative to movement of center of vortical disturbance and relation between tangential speed of circulating parcel and radius. Arrows, numbers in parentheses and shaded area indicate wind vectors, wind speed (in m/s) and spiral band, respectively.](image)

Let us examine the circulation characteristics of these vortical mesoscale disturbances. We express the circulation (C), absolute circulation ($\Gamma_a$) and vorticity of circular vortices (ζ) by

\[ C = 2\pi rv_\theta, \quad \Gamma_a = 2\pi r (v_\theta + \omega r \sin \phi) \]

and

\[ \zeta = 2\pi rv_\theta / \pi r^2, \]

where $v_\theta$ represents the tangential speed around the vortex center.

We take $r=14$ km, $v_\theta=7$ m/s on the distur-
bance of February 3, 1965, and then we obtain

\[ C = 61.4 \times 10^6 \text{ cm}^2 \text{ sec}^{-1}, \quad \Gamma \approx 67 \times 10^6 \text{ cm}^2 \text{ sec}^{-1}, \]

and

\[ \zeta \approx 10^{-3} \text{ sec}^{-1}. \]

Fujita (1965) showed that the circulation around the tornadoes seems to be of the order of \(10^8\) cm\(^2\) sec\(^{-1}\). Therefore, the circulation around the vortical mesoscale disturbance is about 100 times larger than that of a tornado. Referring to the kinematic diagram of cyclonic circulation systems ranging from tornado to frontal cyclone proposed by Fujita (1965), a hurricane with a radius of several hundred kilometers is characterized by an absolute circulation of about \(500 \times 10^8\) cm\(^2\) sec\(^{-1}\), which is 100 times larger than that of a tornado. From these values it is recognized that the characteristic dimension of circulation of vortical mesoscale disturbance ranges between those of tornado and typhoon.

From the wind data estimated at about 10-km intervals given in Fig. 17, the distribution of velocity divergence at 7.5-km grid points was calculated by applying interpolation of the wind data and assuming the weak wind near the center as shown Fig. 18. In the case of the heavy snowfall (Fig. 18a), we notice that the spiral bands correspond to the convergence zones qualitatively. In the case of heavy rainfall (Fig. 18b), the maximum convergence zone is located to the north of the path and the zone corresponds to the maximum rainfall zone. Therefore, it is pointed out from these results that the convergence, spiral band and maximum rainfall area are obviously inter-related.

As seen in Fig. 12, we can find at three stations (A, B, C) where the vortical disturbance passed, that there were significant changes in rainfall intensity corresponding to the passage of disturbance. On the other hand, as shown in Fig. 16, the strong snowfall of 1.2 mm in 10-min was observed at Wajima when the disturbance passed through Noto peninsula. Summarizing the observational facts mentioned above, the precipitation related to the vortical mesoscale disturbance can be estimated roughly from the divergence around the center based on the conception of the vortical rain.

As a first approximation, the convergence was assumed to have a linear decrease with height to the levels of non-divergence which are at 700 mb and 500 mb in the cases of heavy snowfall and heavy rainfall, respectively. The assumption is believed to be much realistic of atmosphere. Under this circumstance, the intensities of precipitation were estimated by using the so-called condensation function \( F \). In case of heavy rainfall, the estimated rainfall intensity was about 10 mm in 10-min. This is almost equivalent to the observed value, when the value of divergence is assumed to be \(-10 \times 10^{-4}\) sec\(^{-1}\) at 700 mb. In case of heavy snowfall, estimated snowfall intensity was about 2 mm in 10-min, when the value of divergence is assumed to be \(-5 \times 10^{-4}\) sec\(^{-1}\) at 800 mb.

Finally, let us consider the vortical rain around the disturbance for reference (Syôno, and Kasahara, 1953).

The vortical rainfall intensity, \( W(r) \), is written as follows
\[ W(r) = A \cdot \frac{\zeta_v(r)}{\sqrt{f + \zeta_v(r)}} \]

and
\[ A = \frac{\bar{q} \sqrt{\nu}}{2} \cdot \frac{\sin 2\phi}{\cos \left( \phi + \frac{\pi}{4} \right)}; \quad \zeta_v = \frac{1}{r} \left[ \frac{A(r)v}{\Delta r} \right] \]

Where \( \bar{q} \) is the mean absolute humidity, \( \zeta_v \), the vorticity of surface wind, \( \phi \) and \( \nu \) are the angles between the surface wind and isobar, and eddy viscosity, respectively. Since the order of the coriolis force is one order magnitude smaller compared with the centrifugal force within 20 km from the center of disturbance, which is computed from the surface wind, it is impossible to estimate the vortical rain near the center of the circulation. Here, it would be reasonable to assume as follows; \( \nu = 3 \times 10^6 \text{ cm}^2 \text{ sec}^{-1} \), \( \phi = 30^\circ \) (Kawamoto, 1956) and \( \bar{q} = 2.1 \text{ gr/m}^3 \) (case of heavy snowfall). \( \zeta_v \) is estimated from the recording wind data at the station through which the disturbance passed. In case of heavy snowfall, a comparison between the estimated and observed snowfall intensities can not be treated in details for the lack of the observed value near the path of the vortical disturbance, but the observed snowfall intensity of 0.2 mm in 1.5 min at Takada, which is at 25 km to the south of the disturbance center, is almost equivalent to the estimated value of 0.3 mm in 10 min, when the value of vorticity is assumed to be \( 5 \times 10^{-4} \text{ sec}^{-1} \).

The quantitative estimations tried here are based on many assumptions. In order to discuss more decisively, we have to investigate the other effects such as dynamical and orographical precipitation, and so on. Although the results obtained here may not be complete, it may be suggested that the variations of concentrated local rain-and snowfall within a short time are closely related to the passage of the vortical mesoscale disturbance, because the intensities of precipitation due to both of topographical and dynamical effects are not expected to be so large.

5. Concluding remarks

The results of the mesoscale and radar analyses are summarized as follows:

1) During the period of heavy snow-or rainfall in the Hokuriku District, the vortical mesoscale disturbances like the midzet-typhoon with the spiral and/or ring-shaped echoes have been formed occasionally and brought the violent phenomena such as sudden changes of intensity of precipitation, pressure and wind, etc. They persisted for several hours while moving across the Hokuriku District.

2) The horizontal diameters of the vortical disturbances are about 50 to 80 km which are one order of magnitude smaller than that of a regular typhoon and also the diameters of “eye” region are about 20 km.

3) The mesoscale disturbance will develop through an unstable density stratification, especially when combined with the characteristic distribution of divergence (low-level convergence and high-level divergence). This seems to have cyclonic circulation sense.

4) The vortical disturbance moves in the direction about 25° to the right from the 700-mb wind direction with the same velocity to the 700-mb wind in the vicinity of the disturbance.

5) The precipitation related to the vortical disturbance seems to be due mainly to the vortical effect, which is estimated roughly by means of wind divergence and the theory of the vortical rain.

Recent cloud photographs from satellites also reveal the existence of large numbers of mesoscale cloud circulation. These informations would be of great help to making clear the mechanism of the vortical disturbance. In order to throw light on the forecasting of the concentrated heavy snow-or rainfall shown here, the many cases of vortical mesoscale disturbances should be analyzed, and the detailed mechanisms of initiation and development should be studied in future.

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References


北陸地方の集中豪雪雪時における中規模のうず性じょう乱について

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北陸地方の集中豪雪雪時に、水平規模 50～80 km のうず性のじょう乱がレーダー解析などによって認められることがある。これらは、直径数 100 km の台風と数 100 m 以下の竜巻の中間の規模をもち、低気圧性循環をもつことからメソサイクロンとして分類される。

中規模のうず性じょう乱は、明瞭なスパイラルバンドまたはリング状エコーを示し、既状の中心域の直径は約 20 km 程度である。じょう乱は北陸沿岸域で発生し、しばしば 700 mb の風に流され、平野部を通って山地で消滅し、寿命は数時間以内と考えられる。じょう乱の通過によって、局所の短時間の降雨雨雪強度、地上風、地上気圧などの急変をもたらすが、特に強雨雪にはうず性降雨も卓越しているようである。なお、この種のじょう乱の発生について、2, 3 の検討が加えられた。