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On a Supercell Storm in Central Japan

by

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Abstract

A supercell storm which cut a super-long hailswath of about 250 km in Central Japan was analyzed. The characteristic features were : 1) the atmospheric stratification was remarkably unstable in spite of the early time of day, 2) the storm occurrence was related to the "baiu" front, 3) the storm was larger in scale than is usually observed, 4) the storm at the matured stage moved 15° to the right of the mean wind, 5) the translation speed reached 69 km/hr, 6) the duration was extended for as long as 6 hours, and 7) the storm shed large hailstones along the swath.

1. Introduction

The broad path of hail left by a severe storm is called a hailswath. Accrding to an analysis of reports on crop damage (Frisby, 1962), the hailswath from a severe and prolonged storm may be several miles wide and more than 100 miles long in the Great Plains area of the United States of America. Sometimes, the distance may exceed 200 miles. These are suggestive of steady state storms persisting for periods up to 8 hours or longer. Paul (1973) reported a hailswath longer than 30 miles which was created by a supercell hailstorm lasting about 12 hours on the Western prairies of Canada.

In Japan, hailswaths longer than 50 km have rarely been reported, and those less than several tens of kilometers seem to be usual according to the reports on crop damage (e.g., Sakanoue (1969)). Omoto (1970) reported hail damage distribution to be over the major axis of 85 km, but it was not certain whether the elongated damaged area would have been traced by a single storm or one storm system because detailed radar data were not available. So, it might be said that occasionally the area damaged by hail is superimposed by a few hailswaths.

On 19 July 1976, hailfall occurred in an extremely long region over 5 prefectures in Central Japan. The hailfall began in Nagano Prefecture before daybreak, passing Gunma, Saitama, Ibaraki and Chibu Prefectures early in the morning. The region which experienced the hail was about 250 km long and 10 km wide, and hail damage to crops and property was very serious.

In the present paper, the radar analysis of the severe storm which was responsible for

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the destruction is described. In the analysis, the Tokyo radar records from the Japan Meteorological Agency (JMA) were used, together with supplementary data from the Fukui JMA radar.

2. Super-long hailswath

A hail damage survey was carried out by the National Research Center for Dissaster Prevention (NRCDP) for several days immediately after the hail event on 19 July 1976. Interviews with farmers, officials of local governments and persons connected with agricultural insurance bodies were made in order to obtain the general and total situation regarding damage. The NRCDP hailpad network (Seino, 1978 ; Yagi, 1980) hardly detected any evidence of the hailfall (excluding a few observation points situated in its southmost portion) since the hail mostly occurred outside of the network. Fig. 1 shows the hail-damaged regions (Omoto, 1976) estimated from the interviews and Official publications. The stippled area indicates moderate damage and the dark area represents serious damage. The times of occurrence are shown at intervals of 30 minutes by the short straight lines in the figure.

With respect to the long hailfall band including the sporadic part as a whole, the hailfalls began to occur at 0400 hours, Ohmachi, and finished at 0730, Sawara (hail data were not available for the sea, but the examination of the radar records revealed that the storm echo which was identified as responsible for the hailfalls had decayed after leaving the land). The hailfall occurrence, surprisingly, propagated rapidly eastward at 70 km an hour. This is the first point to be noted among the characterisitc features of the hailfall.

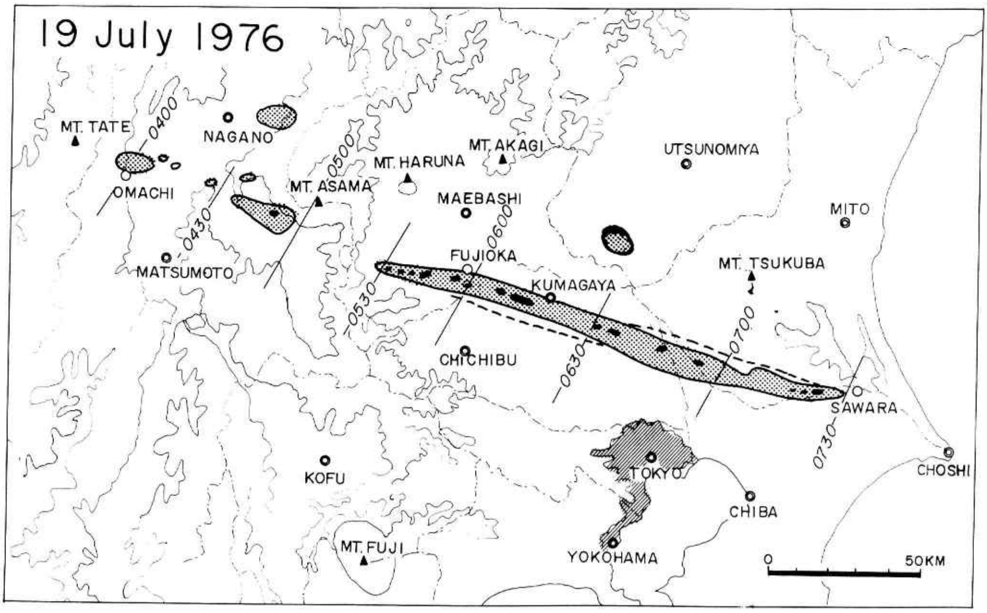

Fig. 1 Super-long hailswath on 19 July 1976 ; stippled areas indicate moderate damage and dark areas present serious damage (after Omoto (1976)).

The second point is that the hailfall occurred during a time when the atmosphere would usually be expected to be stable. The third is that the hailfall occurred in the basins and the plain.

The last and the most remarkable point is the unusual length of the hail-damaged region being over 250 km. Apparently this was the first time in Japan such a super-long hailswath had been recorded.

The size of the hailstones were as large as hen's eggs at maximum in Gunma Prefecture.

3. Meteorological situations

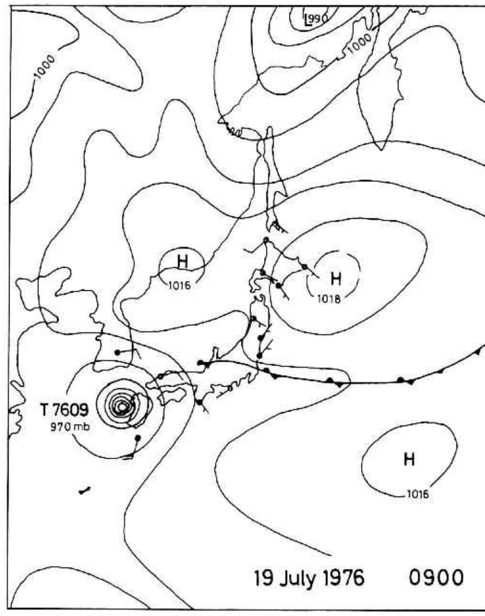

Fig. 2 Surface map, 0900,19 July 1976.

Fig. 2 shows the synoptic surface map at 0900, on 19 July 1976. The "baiu" front had been stationary for two days previously over Central Japan, and the Kanto district had heavy rainfall and hailfall on the 17th and 18th of July. On the 19th of July, the typhoon, #7609 (THERESE), approached northern Kyushu and the anticyclones north of the "baiu" front were enhanced so that the front became active and began to migrate rapidly southward (and finally disappeared over the southern sea, thus ending the rainy season for the year).

Fig. 3 represents the 500 mb map, where the broken lines indicate the isotherms. The cold air mass projected southward over Central Japan. Figs. 4 and 5 are the adiabatic charts at 0440, Wajima (A special time sounding was made due to the approach of the typhoon, #7609.) and at 0900, Tateno, respectively, showing sounding curves for temperature and relative humidity with dry- and wet-adiabats of 300°K. The former sounding corresponds, in time and space, to the early occurrence of the hailfall in Nagano Prefecture, while the latter corresponds to the later occurrence in Chiba Prefecture.

The Showalter stability indexes (SSI's) were -0.3 at 0440, Wajima, and -0.8 at 0900, Tateno, and the temperatures at 500 mb level (T_{500}'s) were -6.3°C at 0440, Wajima, and -9.3°C at 0900, Tateno.

The SSI usually gives an indication of the instability of the atmosphere. This value is derived by assuming appropriate adiabatic ascent of an air parcel, originally at 850 mb, to the 500 mb level and subtracting the temperature (°C) so attained from the 500 mb environment temperature (T_{500}). Cumulonimbus phenomena usually fail to develop for index values greater than $+4$, wheras showers and thunderstorms become increasingly evident as index values decrease from $+4$.

According to Omoto and Yonetani (1975), it must be probable that hailfalls over the Kanto district will occur for a negative SSI and T_{500} lower than -6°C when Tateno's 0900

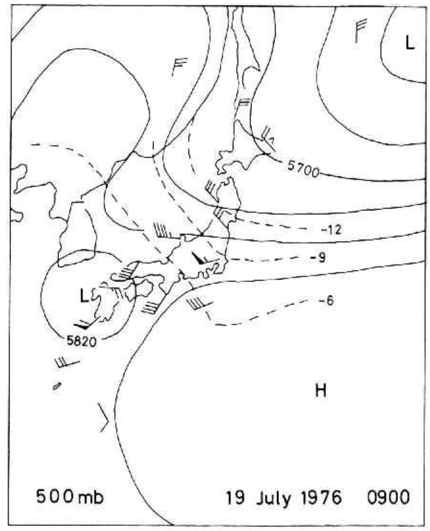

Fig. 3 500 mb map, 0900, 19 July 1976.

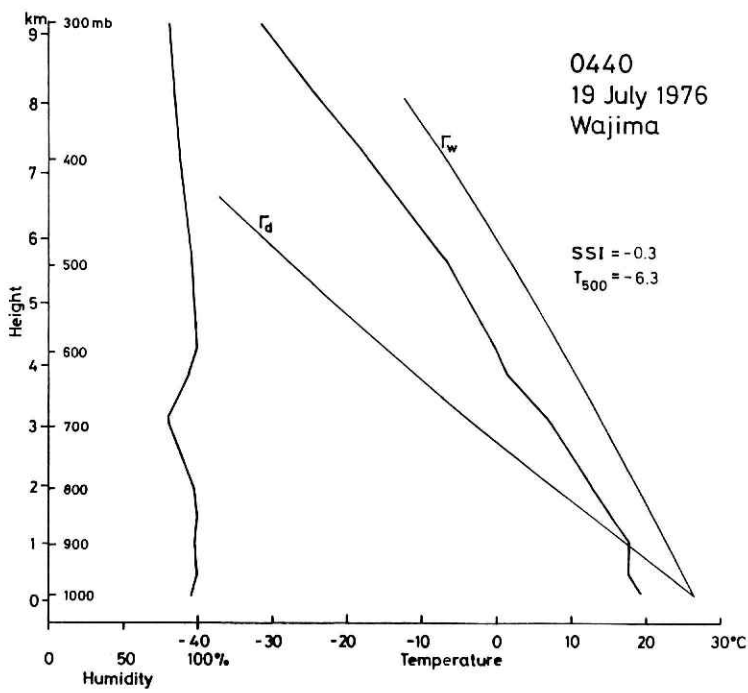

Fig. 4 Soundings at Wajima, 0440, 19 July 1976.

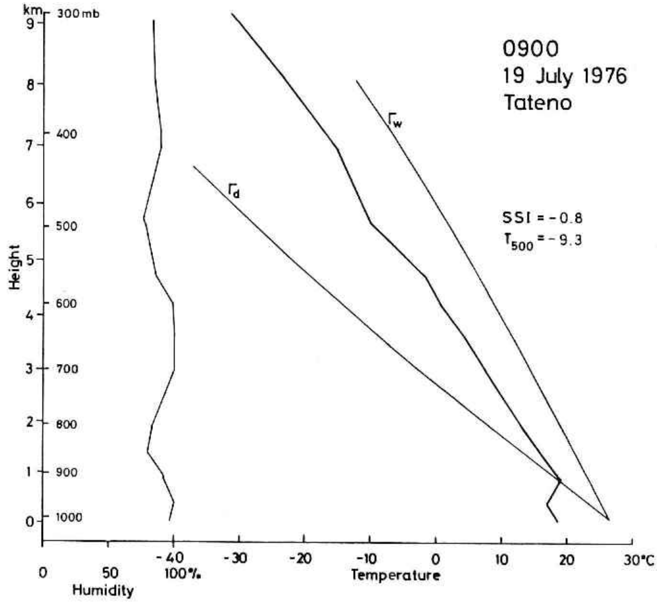

Fig. 5 Soundings at Tateno, 0900, 19 July 1976.

hours sounding is applied. So it should be stated that these SSI's and T_{500}'s in both the upper-air soundings indicated remarkably unstable atmospheric stratifications throughout the occurrence of the hailfalls along the super-long hailswath in spite of the fact that the time period was from dawn to early morning.

Figs. 6 and 7 reperesent the wind hodographs and the mean winds from 900 mb up to 200 mb of the same soundings as in Figs. 4 and 5, respectively. The mean wind direction and speed at 0440, Wajima were 273°, 17m/sec, respectively, while at 0900, Tateno, the figures were 266°, 18m/sec, respectively.

4. Results of radar anaysis

The NRCDP radar observation(e.g., Yagi et al. (1976)) in this year had been completed before the hail event in question. So, the radar data used in the present analysis were mainly of Tokyo radar of JMA.

Photos. 1 to 3 reprensent the radar echoes at 0356, 0607 and 0807 hours, respectively. The storm echo which was identified to be responsible for the super-long hailswath is indicated by an arrow in each picture. The storm echo at 0356 hours was located in Nagano Prefecture, at 0607 hours in Saitama Prefecture, and at 0807 hours over the sea immediately after leaving the land. Such radar echo photographs were taken at one to three minute intervals, including a range correction mode, throughout the course of the storm. The very early stage of the storm was examined by analyzing the Fukui JMA radar records.

Figs. 8 to 10 represent the configurations of the radar echoes from 0343 through 0850

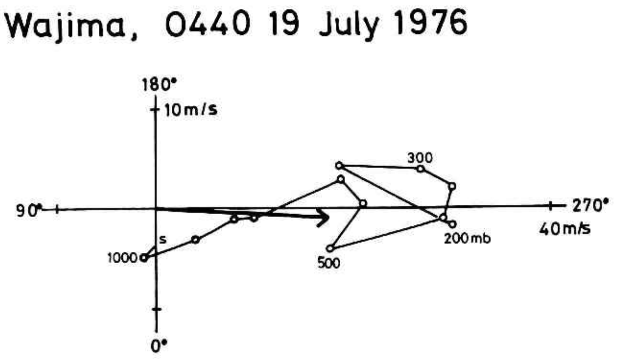

Fig. 6 Upper winds and mean wind at Wajima, 0400, 19 July 1976.

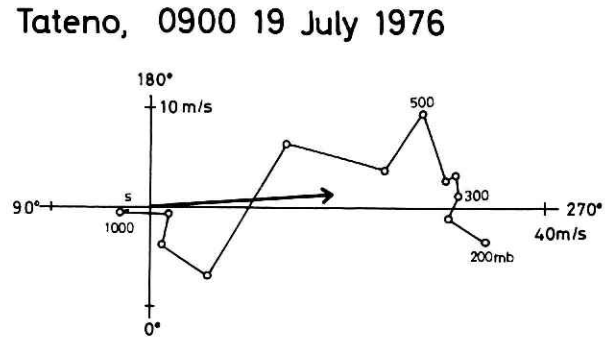

Fig. 7 Same as Fig. 7, but for Tateno, 0900.

hours. The dark parts in each echo represents a "strong" echo. The echo time is marked at the left under the echo group and at the corresponding radar location. The tracings are displace successively toward 180°, to the south, so that sucessive tracings can be readily compared, and in particular the storm echoes in question, which were always situated at the extreme west of the total rainfall echoes, are linked by a broken line.

The first echo of the severe storm which traveled along the super-long hailswath appeared at 0320, southwent of Mt. Tate. In Fig. 8, an 0357, the storm was situated at Ohmachi city with the first hailfall, at 0459, it was at the Ueda basin with the second hailfall, and, at 0523, it had migrated to the Kanto Klain and there it began to shed hailstones over the third and the longest hail-damaged region. Around this time, the storm echo merged with the eastern echo in the "weak" pattern, but as long as it were seen in the "strong" pattern, the echo consistency was clearly followed.

In Fig. 9 from 0550 through 0711, the storm was cutting the long hailswath from Gunma Prefecture to Chiba Prefecture. The serious hail-damaged area within the hailswath occurred intermittently as seen in Fig. 1 ; however, the radar records did not indicate any signs of intensity change or oscillation. Around 0641 in Fig. 9, the storm echo was again separated from other echoes, and began to decay rapidly after the 0711 tracing.

In Fig. 10 for the period 0736 through 0850, the storm moved from Sawara city leaving the land and decayed around 0910 over the sea. After 0730, the storm over the

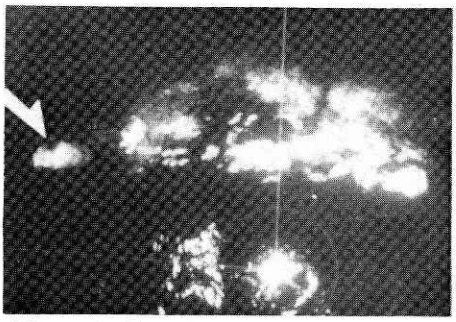

Photo. 1 Severe storm echoes from Tokyo JMA radar at 0356, 19 July 1976.

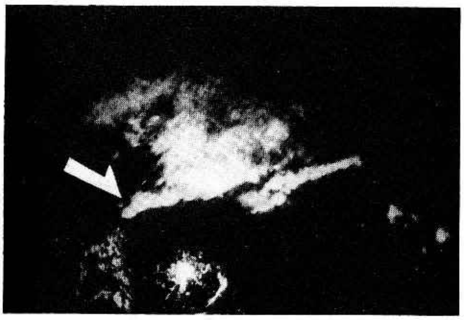

Photo. 2 Same as Photo. 1, but for 0607.

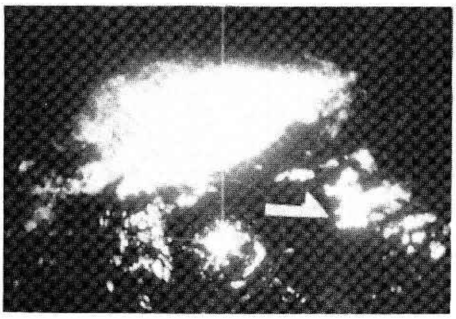

Photo. 3 Same as Photo. 1, but for 0807.

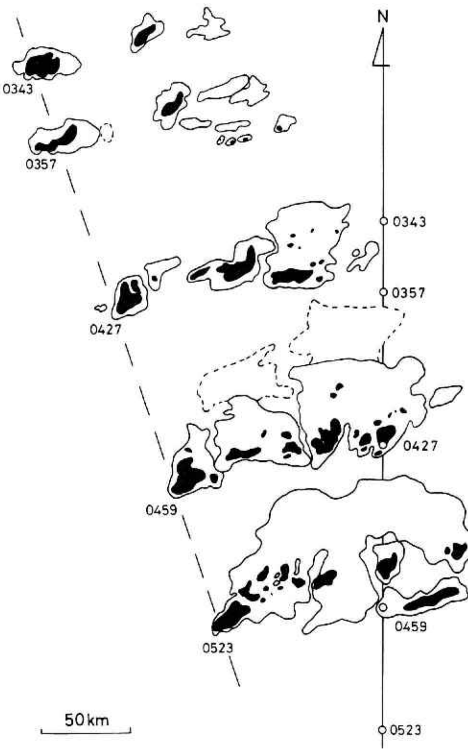

Fig. 8 Configurations of radar echoes during 0343-0523, 19 July 1976. Severe storm being responsible for the superlong hailswath is linked by broken line.

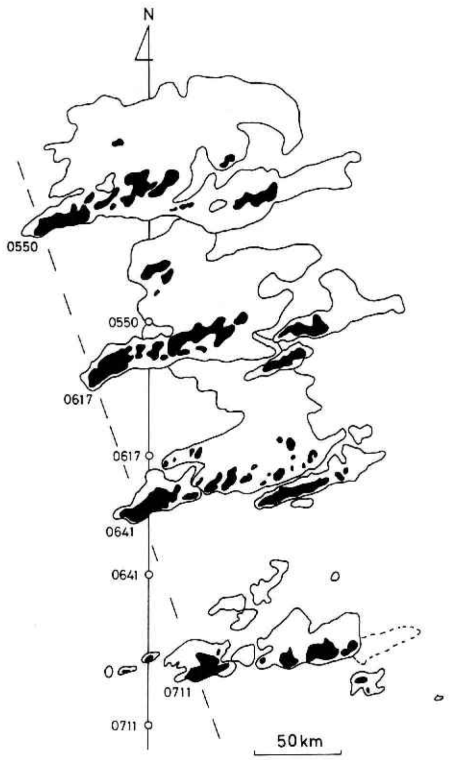

Fig. 9 Same as Fig. 8, but for 0550-0711.

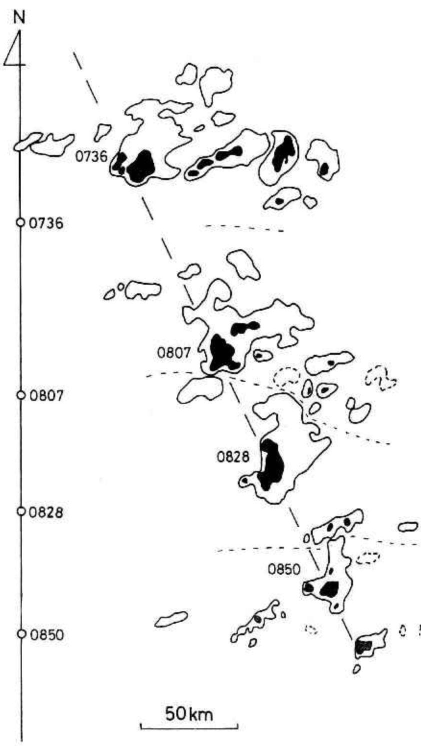

Fig. 10 Same as Fig. 8, but for 0736-0850.

land was no longer accompanied by hailfall.

The trajectory of the severe storm and the storm echoes at the indicated times were superimposed on the topographical map as shown in Fig. 11. The contour lines are 100m, 1000 m and 2000 m above mean sea level. The Tone River which is the biggest river in the Kanto district is illustrated in the figure too.

The radar analysis of the sever storm which cut the superlong hailswath in Fig. 1 produced the following resuts: The storm was noted to persist as long as 6 hours. The matured size of the storm exceeded 30 km in the major axis. The speed of the storm movement reached 69 km/hr, which was the same as the propagation speed of the hail occurrence derived from the hail damage survey. The direction of the storm movement during the major span of the storm history was 285°, along an almost straight line. The severe storm was found to be a single steady convective system.

Echoes other than this long-lasting storm echo did not survive more than one to two hours, although some of them were accompanied with hailfall which occurred north to the super-long hailswath as seen in Fig. 1.

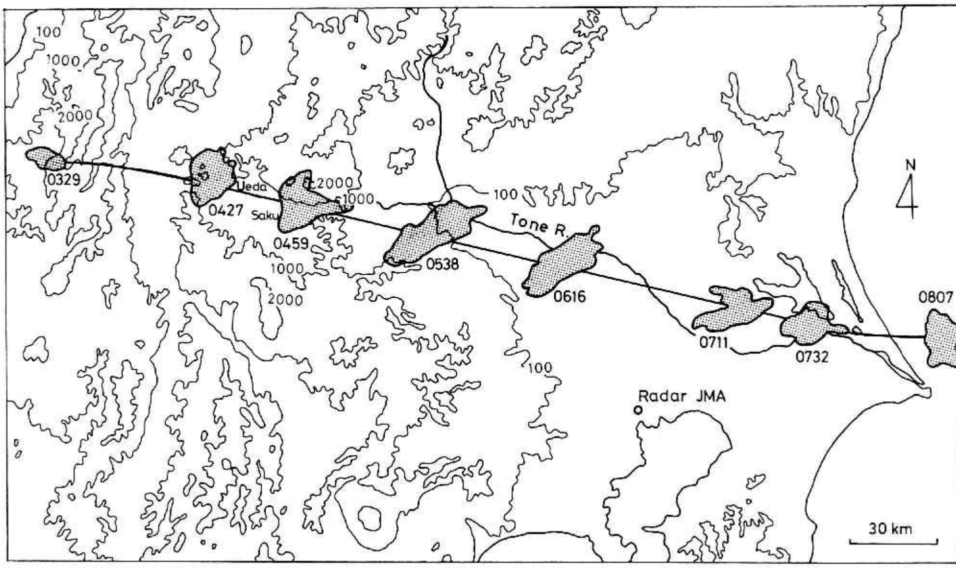

Fig. 11 Topography and superimposed trajectory of the severe storm which cut the super-long hailswath on 19 July 1976.

5. Considerations and concluding remarks

According to the radar analysis, the severe storm which was identified as having cut the super-long hailswath in Fig. 1 moved at the speed of 69 km/hr, as fast as the propagation speed of the hail occurrence along the hailswath. Compared with the usual storm speed, this speed is a distinctive feature. Yagi et al. (1976) and Yagi (1979) tracked 128 severe storms (including hailstorms) in the northern Kanto district by the NRCDP radar and obtained their average migration speed, which was about 21 km/hr. In fact, there were few storms reported as having traveled at a speed higher than 30 to 40 km/hr. In the case of the sever storm in question, it has been pointed out that the mean winds which ranged from 900 mb up to 200 mb at Wajima and Tateno were great enough to drive the storm at that high speed ; they exceeded 60 km/hr as shown in Figs. 6 and 7.

The direction of movement during the major span of the storm history was 285°. This movement occurred along an almost straight line, deviating 15° to the right of the mean wind (regarded as 270°) shown in Figs. 6 and 7. However, in the very early stages the direction of mevement was 275°, while at the time of decay, it was 265°. These directions were, respectively, coincident with the corresponding mean winds (273° at 0440, Wajima and 265° at 0900, Tateno). Therefore, the total trajectory was revealed to be a very elongated reverse S-shape which had shortly curved at the both ends of the major straight track ; the storm moved more nearly with the mean wind very early and very late in its life when it was relatively small, but up to 15° to right of the mean wind while it was most strongly developed.

The long duration and straight trajectory of the storm on 19 July 1976 seems to be a somewhat strange feature in Japan where the topographical condition are relatively complicated. Due to the influence of mountains, in general, severe storms occasionally change their routes and migrate or stop and gradually decay (e.g., Kitaoka(1950), Asada, Yamakawa and Kasuga (1966) and Omoto (1968)).

Fig. 12 demonstrates the free passage of the storm over the mountainous regions. The storm echoes at the indicated times are superimposed on the topographical map. The contour lines are 100 m, 1000 m and 2000 m above mean sea level. It is noted in the figure that the straight trajectory line happens to be situated over a basin (Ueda and Saku, around 0430) and a valley (south to Mt. Asama, around 0500), that is, the storm could, by chance, pass through the basins and the valley and not be so seriously obstructed. After the free passage over the western mountainous regions, the storm moved over the Kanto plain, running approximately along the Tone River. Such an accidental path for the storm appears to be one of the possible causes for the long duration.

Finally, the characteristic storm features analyzed are arranged as follows: 1) the atmospheric stratification was remarkably unstable in spite of early time of day, 2) the storm occurrence was related to the "baiu" front, 3) the storm was larger in scale than is usually observed, 4) the storm at the matured stage moved 15° to the right of the mean wind, 5) the translation speed reached 69 km/hr, 6) the duration was extended for as long as 6 hours, and 7) the storm shed large hailstones along the super-long hailswath. Due to these features, the severe storms along the super-long hailswath over Central Japan on 19 July 1976 in thought to have been the single convective system termed a "supercell storm".

Newton (1967) described in his review based on analytical investigations which included those of Browning and Ludlam (1960), Browning (1964) and Newton and Fankhauser (1964) that some large severe storms maintain circulations lasting several hours, and these storms, rather than being multicellular, are dominated by a single "supercell" of great size and intensity with hail and tornadoes.

In fact a tatsumaki (tornado) was reported in Gunma Prefecture early in the morning 19 July 1976, the day of the hail.

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日本列島中央部に発生したスーパーセルストームについて

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要旨

日本列島中央部において約250kmにわたる非常に長い降雹域をもたらしたスーパーセルストームのレーダーエコー解析を行った．その顕著な特徴は，

1) 早朝にもかかわらず大気成層が非常に不安定であった．
2) ストームは梅雨前線に伴って発生した．
3) ストームの大きさは通常観測される対流セルより大きかった．
4) 盛熟期のストームは大気平均風から15°右へ偏って移動した．
5) 移動速度は毎時69kmに達した．
6) 持続時間は6時間もの長きにわたった．
7) ストームは降雹域にそって，場所によっては鶏卵大に及ぶ，大きな雹を降らせた．

などであった．

＊第1研究部異常気候防災研究室