Downburst observations
by a high density ground surface observation network (POTEKA)

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Abstract. POTEKA (POint TEnki KAnsoku in Japanese) is a compact weather station that was developed by Meisei Electric Co., Ltd. POTEKA can observe 7 meteorological variables: temperature, pressure, humidity, wind velocity, wind direction, sunshine and rain. About 150 POTEKAs have been installed in Gunma and Saitama prefectures in Japan providing a high density ground surface observation network that has a resolution of approximately 2 km. This network has been recording observations for about five years since 2013, and we have succeeded in observing 11 cases of downbursts and damaging winds, which included five events in the F1 category (Fujita scale). By detailed analysis of the F1 downburst events that were accompanied by substantial damage (particularly the downburst events of August 11, 2013, June 15, 2015 and July 14, 2016), common features of temperature and pressure changes before the F1 downbursts were detected by the POTEKA data nearby.

Keywords: High density observation, Surface observation network, Downburst

1. Introduction

In recent years, global warming and changes in extreme weather events are of great interest to researchers and society. In particular, rapid onset weather events such as localized heavy rainfall, torrential rain, downbursts, and tornadoes are of great concern as they threaten human life and property. Comprehension of the reasons for these localized changes in extreme events is absolutely essential not only for meteorology but also for disaster prevention. However, these changes mostly occur on scales of less than 4 km. Because the installation resolution of the Japan Meteorological Agency's (JMA) Automated Meteorological Data Acquisition System (AMeDAS) is approximately 17 km, it is difficult to examine these changes in detail. For this reason, we have developed a compact weather station (POTEKA). We have realized a high density ground surface observation network with a resolution of approximately 2 km composed of these compact weather stations. The observation network is called the POTEKA NET SYSTEM and has the dual functions of data collection and analysis (Maeda et al. 2014).

After Fujita's investigations of downbursts / microbursts (Fujita 1981), the structures of downbursts have been discussed from Doppler radar observations (e.g., Goff
1976, Wakimoto 1982, Wilson et al. 1984, Klingle et al. 1987, Hjelmfelt 1988, Martner 1997). However, the surface structures of near downbursts are not well known, because of few observational data. Norose et al. (2015) reported the downburst event in Gunma prefecture on August 11, 2013 using the POTEKA data and showed the pressure and temperature fields of downbursts and gust fronts.

In this study, we examined the temporal changes in pressure and temperature associated with F1 downburst events that occurred in the high density ground surface observation network in Gunma and Saitama prefectures (hereinafter, the POTEKA network). This paper summarizes the characteristics of pressure and temperature of near the surface damage of three downbursts.

2. POTEKA weather station

The compact weather station included in the POTEKA weather observation equipment was developed in 2011 according to the concept that they should be compact, light and capable of being installed anywhere. A POTEKA weather station can observe 7

Figure 1. POTEKA weather station and POTEKA weather observation equipment

Figure 2. Several examples of installation locations
variables including temperature, pressure, humidity, wind velocity, wind direction, sunshine and rain. By utilizing the spare channels, a POTEKA weather station can observe other variables such as precipitation. Moreover, temperature, pressure, humidity, wind velocity and precipitation passed the JMA's variable verification test. Photographs of the station and equipment are shown in Fig. 1.

An area of 25 m² (5 m multiplied by 5 m) and an external electric power supply are required for JMA’s AMeDAS, whereas a POTEKA weather station can be installed anywhere such as at a school, a building’s roof or on an electricity pole because of its compact size and solar panel. The installation is straightforward and typically takes less than 1 hour. Several examples are shown in Fig. 2.

3. High density ground surface observation network

POTEKA weather stations, which have been recording observations since 2013, have been installed at about 400 locations in Japan as of December 2017. The number of installations is now increasing steadily. A high density ground surface observation network with a resolution of approximately 4 km has been realized in Iwate, Miyagi, Ibaraki, Gunma, Saitama, Tokyo, Nagano, Shizuoka, Mie, Hyogo, Shimane, Kochi and Oita prefectures in Japan. In particular, a very high density ground surface observation network has been constructed, consisting of around 150 POTEKAs, with a resolution of approximately 2 km over a wide range of about 30 km in the north-south direction and about 60 km in the east-west direction in Gunma and Saitama prefectures.

The plains of Gunma and Saitama prefectures have a cumulonimbus climatological feature that is generated over the surrounding mountains and proceeds over the plains accompanied by the growth in the summer. Moreover, the developing cumulonimbus causes severe gusts such as downbursts and gust fronts frequently. The plains of Gunma and Saitama are characterized by extreme weather changes. The POTEKA network is shown in Fig. 3.

![Figure 3. High density ground surface observation network in Gunma and Saitama (POTEKA network)]
4. POTEKA net system

As soon as a POTEKA weather station is installed and turned on, observations can begin due to the electric power storage of the solar panel and a 3G module built into the electric power supply box. The observation data are transmitted at 1-minute intervals. All POTEKA observation data are accumulated in a cloud server automatically and in real time.

Figure 4. Sample maps of POTEKA data for one observation variable and multiple locations in real time (Top), time series of multiple variables for a single location (Bottom). There are unclear parts because of the hard copies of the actual NET displays.
If the electric storage of the solar panel is fully charged, a POTEKA weather station can operate for several days. Therefore, the observation, transmission and accumulation of data are rarely interrupted. Moreover, a POTEKA weather station includes a data recovery function that is called past compensation. Even if the real time transmission or accumulation is interrupted, if the observations are not interrupted, late transmission or accumulation will be automatically performed after reconnecting. The POTEKA NET SYSTEM is resilient against external disturbances and missing observations are rare.

The observation data transmitted from a POTEKA weather station is accumulated in a leased cloud server. The data accumulated in the cloud server can be utilized from the “POTEKA NET” website. POTEKA NET has several output formats for the data such as maps, contours, graphs and tables. For example, we can check a single observed variable at multiple locations in real time, or multiple variables at a single location for a past time (Fig. 4). POTEKA NET is very useful for several types of weather data analyses. Moreover, POTEKA NET can provide warnings for conditions such as heat waves, heavy rain, and strong wind and this information is provided to relevant parties. The POTEKA NET SYSTEM is shown in Fig. 5.

5. Downburst observations

As discussed in section 3, the plains of Gunma and Saitama prefectures experience severe gusts such as downbursts and gust fronts in the summer. The POTEKA network has succeeded in observing 11 downburst and damaging wind events, which included five in the F1 category (Fujita scale) over about 5 years since 2013. In this section, we introduce the observation results for three particularly severe downburst events that were in the F1 category and were accompanied by substantial damage.

5.1. Downburst on August 11, 2013 (F1)

Because of the high pressure system that developed over the north-western Pacific, August 11, 2013 high temperatures were experienced across Japan. The surface weather chart for this day is shown in Fig. 6. In Gunma and Saitama prefectures, the
maximum daytime temperature was more than 38 °C and a cumulonimbus was developing over the mountains in the west. In the evening, the cumulonimbus that was located to the west of the POTEKA network produced an F1 downburst resulting in damage in Takasaki and Maebashi cities while proceeding to east-northeast. The POTEKA network was able to record detailed observations for the severe downburst (Norose et al. 2015). The observation data of the nearest POTEKA station from the most damaged area is shown in Fig. 7.

Figure 7 shows the observation data at a distance of about 2 km from the most damaged area. A steep pressure jump of 2.6 hPa (from 1004.9 to 1007.5 hPa) over 1 minute
(from 18:12 to 18:13 JST (Japan Standard Time)) was observed. This time was about 2 minutes before (18:13 JST) the time that the damage was reported to have occurred (18:15 JST). Three minutes before (18:10 JST) the steep pressure jump, a steep temperature drop of 2.6 °C (from 30.4 to 27.8 °C) over 1 minute (from 18:09 to 18:10 JST) was observed. Around the same time, a pressure jump of about 1 hPa (from 1004.1 to 1005.1 hPa) over 12 minutes (from 17:55 to 18:07 JST) was observed. In contrast to the temperature, which monotonically decreased, the pressure both increased and decreased complicatedly. Moreover, the POTEKA network could determine the direction the downburst was proceeding in. It was observed that the area of extreme weather changes such as the temperature drop and pressure jump was proceeding from the west to the east-northeast. A contour plot that shows the direction the downburst is travelling in is shown in Fig. 8.

![Contour plot of the conditions proceeding the downburst on Aug 11, 2013](image)

**Figure 8.** Contour plot of the conditions proceeding the downburst on Aug 11, 2013

### 5.2. Downburst on June 15, 2015 (F1)

Because of the colder air at higher altitudes, the atmosphere was unstable over eastern Japan on June 15, 2015. The surface weather chart for this day is shown in Fig. 9. In Gunma prefecture, a cumulonimbus was developing over the mountains in the northwest. In the afternoon, the cumulonimbus that was located to the northwest of the POTEKA network produced an F1 downburst resulting in damage in Maebashi and Iseki cities while proceeding to the southeast. The POTEKA network was able to record detailed observations for the severe downburst. The observation data of the nearest POTEKA station from the most damaged area is shown in Fig. 10.

![Figure 10](image)

**Figure 10** shows the observation data at a distance of about 1 km from the most damaged area. A steep pressure jump of 4.4 hPa (from 1004.7 to 1009.1 hPa) over 4 minutes (from 15:59 to 16:03 JST) was observed. This time was about 2 minutes before (16:03 JST) the time that the damage was reported to have occurred (16:05 JST). About 5 minutes before (15:58 JST) the steep pressure jump, a steep temperature drop of 3.9 °C (from 26.7 to 22.8 °C) over 1 minute (from 15:57 to 15:58 JST) was observed. Around the same time, a pressure jump of about 1 hPa (from 1005.2 to 1006.2 hPa) over 9 minutes
(from 15:47 to 15:56 JST) was observed. Moreover, another station close to the area experiencing the greatest damage observed an even larger temperature drop of 4.7 °C (from 29.4 to 24.7 °C) over 1 minute. In contrast to the temperature, which monotonically decreased, the pressure both increased and decreased complicatedly. Moreover, the POTEKA network could determine the direction the downburst was proceeding in. It was observed that the area of extreme weather changes such as the temperature drop, pressure jump and wind direction rotation was proceeding from the northwest to the southeast. A contour plot that shows the direction the downburst is travelling in is shown in Fig. 11. Figure 12 shows photographs of the damage at the points marked with an X in Fig. 11.
Because of a cold low (cold vortex) over the Japan Sea, the atmosphere was unstable over the whole of Japan on July 14, 2016 (Fig. 13). In Gunma and Saitama prefectures, a cumulonimbus was developing over the mountains in the southwest. In the afternoon, the cumulonimbus was located to the southwest of the POTEKA network produced a JEF1 (Japan Enhanced Fujita scale) downburst resulting in damage in Honjo and Isesaki cities while proceeding to the north-northeast. The POTEKA network was able to record detailed observations for the severe downburst. The observation data of the nearest POTEKA station from the most damaged area is shown in Fig. 14.

Figure 14 shows the observation data at a distance of about 1 km from the most damaged area. A steep pressure jump of 3.8 hPa (from 993.4 to 997.2 hPa) over 5 minutes (from 14:01 to 14:06 JST) was observed. This time was almost the same time (14:06 JST) as the time that the damage was reported to have occurred (14:05 JST). About 9 minutes before (13:57 JST) the steep pressure jump, a steep temperature drop of 2.1 °C (from 30.0
to 27.9 °C) over 1 minute (from 13:56 to 13:57 JST) was observed. Around the same time, a pressure jump of about 1 hPa (from 993.0 to 993.9 hPa) over 9 minutes (from 13:45 to 13:54 JST) was observed. In contrast to the temperature, which monotonically decreased, the pressure both increased and decreased complicatedly. Moreover, the POTEKA network could determine the direction the downburst was proceeding in. It was observed that the area of extreme weather changes such as the temperature drop, pressure jump and wind direction rotation was proceeding from the southwest to the north-northeast. A contour plot that shows the direction the downburst is travelling in is shown in Fig. 15. Figure 16 shows photographs of the damage at the points marked with an X in Fig. 15.
6. Common characteristics of downbursts

Downbursts are typically classified as mesoscale weather events as the scale of a downburst is approximately 4 km. Because the resolution of the JMA's AMeDAS is approximately 17 km, it has been difficult to analyze downburst gusts in detail. However, a high density ground surface observation network with a resolution of approximately 2 km has allowed the analysis of changes in local meteorological conditions just before a downburst and where and how the downburst was generated.

We have identified the four following characteristics before a downburst, according to the POTEKA data near the F1 damage of downbursts.

1) A steep pressure jump of about 3 to 4 hPa is observed at almost the same time as the downburst gust occurrence.
2) About 5 minutes before the steep pressure jump, a steep temperature drop is observed.
3) A pressure jump of about 1 hPa is observed at almost the same time as the steep temperature drop.
4) In contrast to temperature, which monotonically decreases, pressure both increases and decreases complicatedly.
The features 2) and 3) indicate that the passage of gust fronts proceeded to the main downbursts. So, we have found that downbursts on the plains of Gunma and Saitama have three following characteristics in the POTEKA network.

- A steep temperature drop is observed somewhere on the outer line surrounding the network.
- The area experiencing a temperature drop changes with time.
- The damage path follows the path of the area experiencing the temperature drop.

If we follow the path of the area of decreasing temperature, we might be able to predict the occurrence of a downburst gust.

7. Conclusion

The very high density ground surface observation network has been constructed, consisting of around 150 POTEKAs, with a resolution of approximately 2 km over a wide range of about 30 km in the north-south direction and about 60 km in the east-west direction in Gunma and Saitama prefectures. The POTEKA network has succeeded in observing 11 downburst and damaging wind events, which included five in the F1 category over about 5 years since 2013. The nearest POTEKA station from the most damaged area was able to record detailed observations for three particularly severe downburst events that were accompanied by substantial F1 damage. It was observed the extreme weather changes such as the temperature drop and the pressure jump on the damaged area. We have identified the four following common characteristics before F1 downbursts.

1) A steep pressure jump of about 3 to 4 hPa is observed at almost the same time as the downburst gust occurrence.
2) About 5 minutes before the steep pressure jump, a steep temperature drop is observed.
3) A pressure jump of about 1 hPa is observed at almost the same time as the steep temperature drop.
4) In contrast to temperature, which monotonically decreases, pressure both increases and decreases complicatedly.

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