MEISEI ECR

No. 26-38

Predictability for extreme weather changes such as a tornado and a downburst utilizing the nowcast data by a high-density ground surface meteorological observation network (POTEKA)

Hisato Iwashita, Meisei Electric Co.,Ltd., 2223 Naganumamachi, Isesaki-shi, Gunma 372-8585, Japan; e-mail: iwashitah@meisei.co.jp

IHI GROUP Realize your dreams

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 rainfalls, torrential rainfalls, downbursts, and tornadoes are of great concern as they threaten human life and property. Comprehension of the reasons for these changes in extreme events is 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 1 to 10 km composed of POTEKA weather stations.

2. POTEKA Weather Station

The compact weather station in the POTEKA weather observation equipment was developed according to the concept that it should be compact, light, and capable of being installed anywhere. A POTEKA weather station can observe 7 variables including temperature, pressure, humidity, wind speed, wind direction, sunshine, and rain. POTEKA weather station can be installed anywhere such as at school, a building's roof or on an electric pole because of its compact size and solar panel.

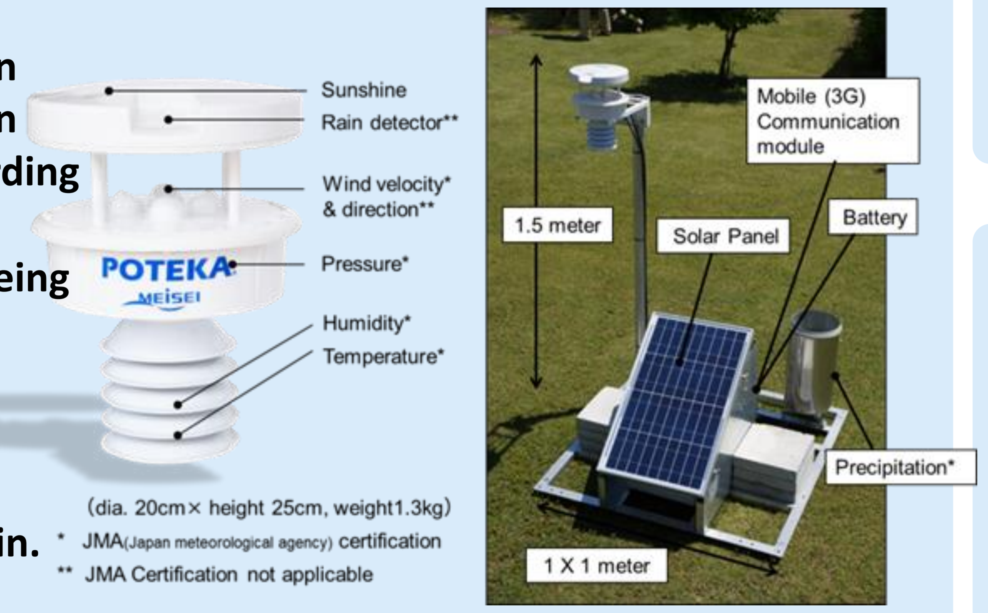

Fig.1 POTEKA weather station and POTEKA weather observation equipment

3. High-Density Ground Surface Observation Network and Gust Observation Results

POTEKA weather stations have been installed at about 800 locations in Japan as of June 2024. In particular, the very high-density ground surface observation network was composed of around 150 POTEKAs, with a resolution of approximately 0.5 to 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 at peak period. 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 a downburst, a gust front, and a tornado frequently. The plains of Gunma and Saitama are characterized by extreme weather changes. We have succeeded in observing 15 damaging wind events, which included five in the F1/JEF1 category (Fujita scale) over about 10 years since 2013. We introduce the observation results for three particularly severe downburst events of August 11, 2013, June 15, 2015, and July 14, 2016.

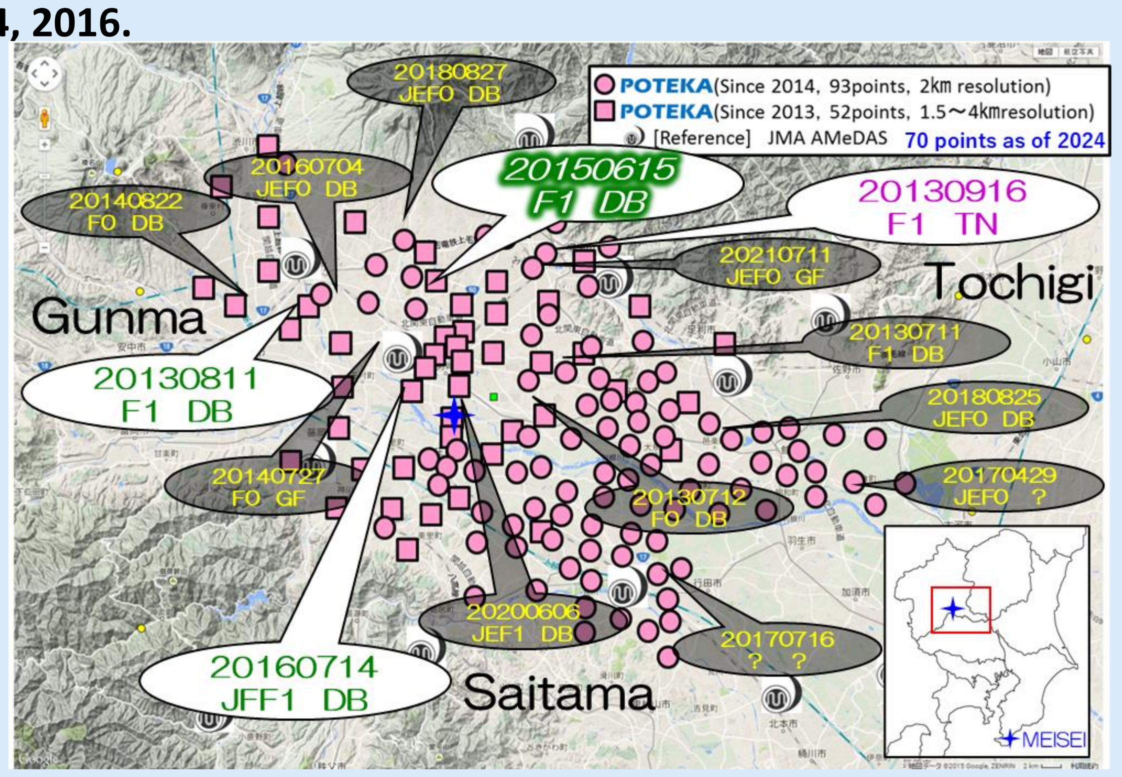

Fig.2 High-density ground surface meteorological observation network in Gunma and Saitama

4. Common Transition of Observation Variables almost just below a Downburst

In these three severe downburst events, the cumulonimbus that was located on the mountains surrounding POTEKA network produced an F1/JEF1 downburst resulting in damage while proceeding over POTEKA network. At a distance of about 1 km from the most damaged area for each event, the four following common characteristics were found.

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.

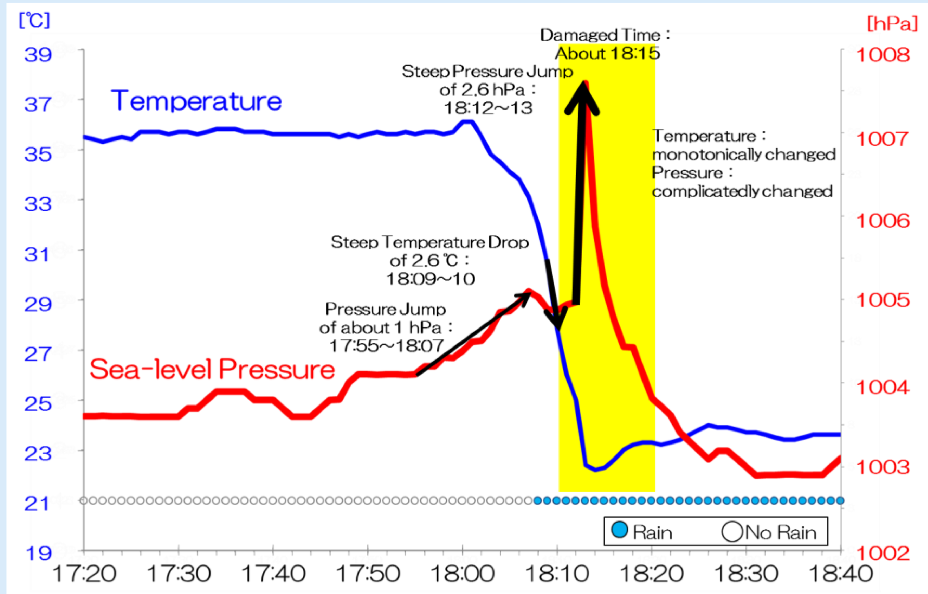

Fig.3-1 August 11, 2013

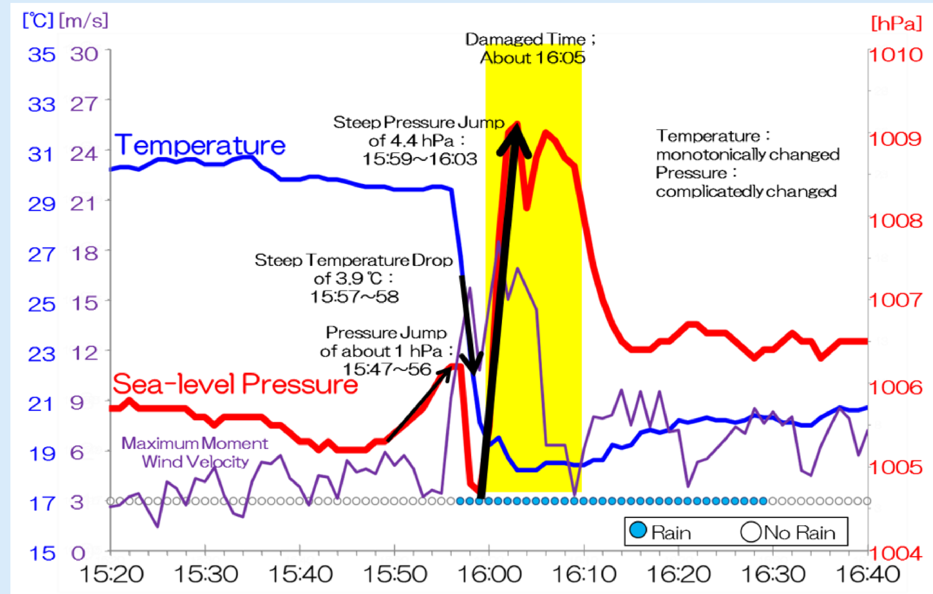

Fig.3-2 June 15, 2015

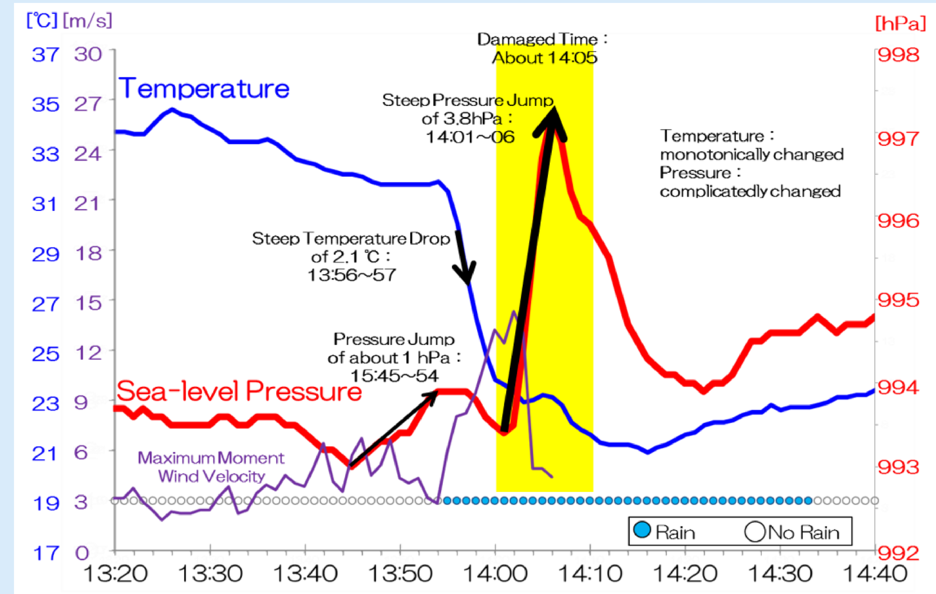

Fig.3-3 July 14, 2016

Observation data from the POTEKA station nearest the most damaged area

5. Common Downburst Proceeding Characteristics

We found that downburst events in Gunma and Saitama plains have the three following common characteristics.

- A steep temperature drop is observed somewhere on the outer line surrounding POTEKA network.
- The temperature drop realm is proceeding over POTEKA network.
- The actual damage occurs in the realm proceeding.

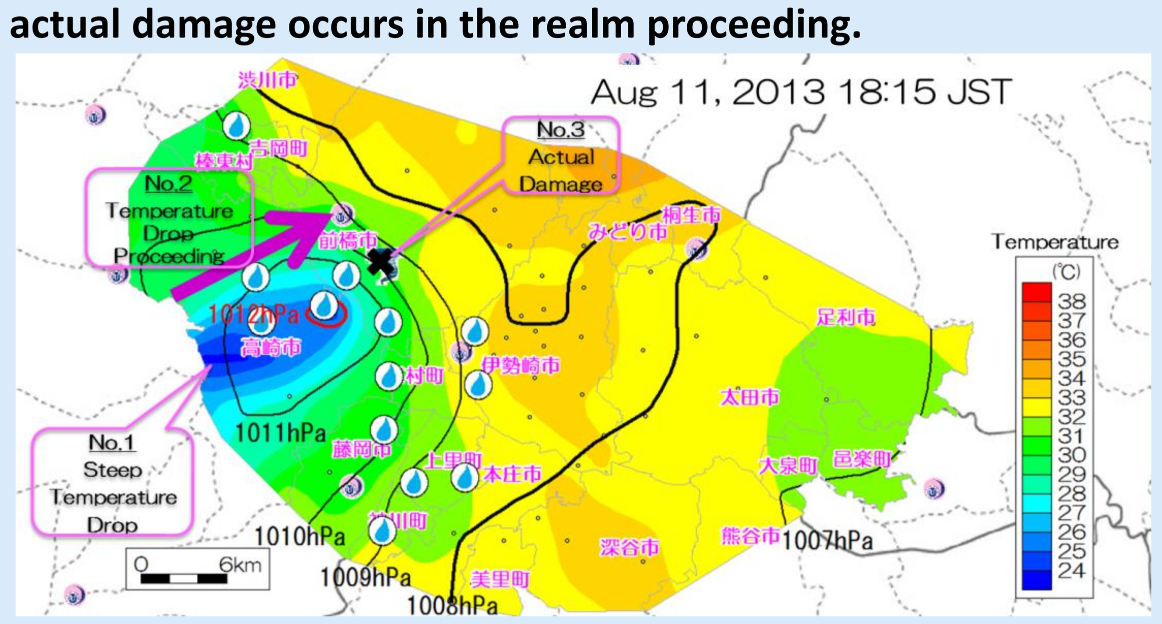

Fig.4-1 August 11, 2013

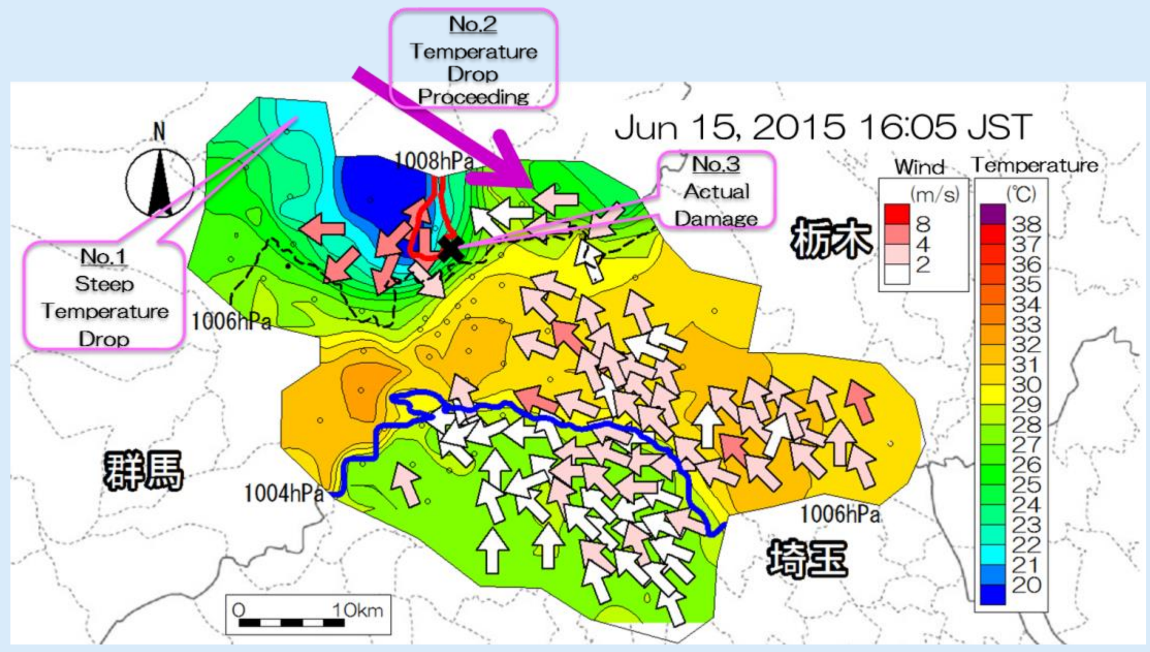

Fig.4-2 June 15, 2015

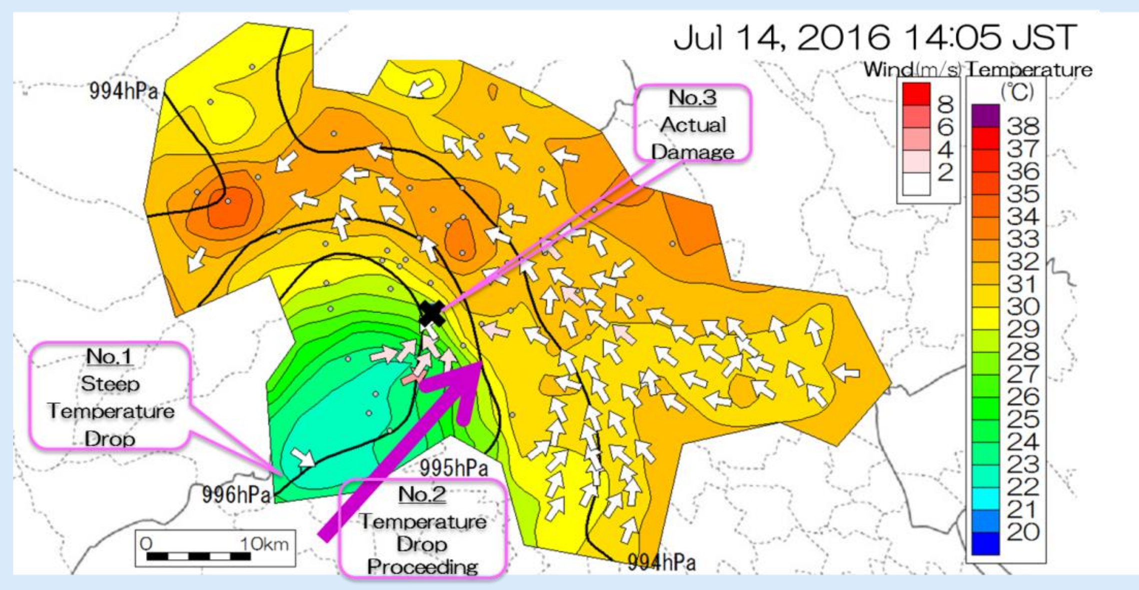

Fig.4-3 July 14, 2016

Contour plot of downburst proceeding

6. Gust Prediction Methodology

According to these common characteristics in section 4 and 5, we conclude that it may be able to predict downburst events from the path of the temperature drop area and from the location of the first point to experience a steep temperature drop. In other words, we considered the potential predictability of downburst events by tracing the location of steep temperature drops from the first observation of a steep temperature drop.

【Procedure of gust prediction methodology】

<Step 1>

The predicted gust area expands up to 10 km around the location at which the first steep temperature drop was first observed (-2 ℃ or less per minute).

<Step 2>

The cumulonimbus velocity is calculated from the distance and observation time between the first drop location and the second drop location at which a small temperature drop of -1 ℃ or less per minute is observed.
⇒ The predicted gust time is then calculated.

<Step 3>

Whenever a small temperature drop of -1 ℃ or less per minute is observed, the cumulonimbus velocity and predicted gust time are modified.

<Step 4>

By distinguishing between the steep temperature drop (-2 ℃ or less per minute) locations and moderate temperature drop (between -1 and -2 ℃ per minute) locations, the predicted gust area is narrowed.

Fig.5 Detailed gust prediction procedures

7. Predicted Results for the Downburst Event on June 15, 2015

The predicted results for the downburst on June 15, 2015 are shown in Fig. 6-1 to 6-7. As shown in Fig. 6-2, about 30 minutes before (15:33 JST) the actual damage occurrence (16:05 JST), the downburst gust prediction methodology could provide advanced warning to actual damage area's people. As shown in Fig. 6-4, about 20 minutes before (15:47 JST) the actual damage occurrence (16:05 JST), the predicted gust time (15:57 to 16:13 JST) was within 10 minutes from the actual damage time (16:05 to 16:15 JST). As Shown in Fig. 6-7, the final predicted gust area (red) included the actual damage area (purple).

If we utilize high-density ground surface observation data, we may be able to realize the gust prediction system of a downburst and a tornado. Moreover, we may be able to predict the occurrence of extreme weather events which threaten human life and property.

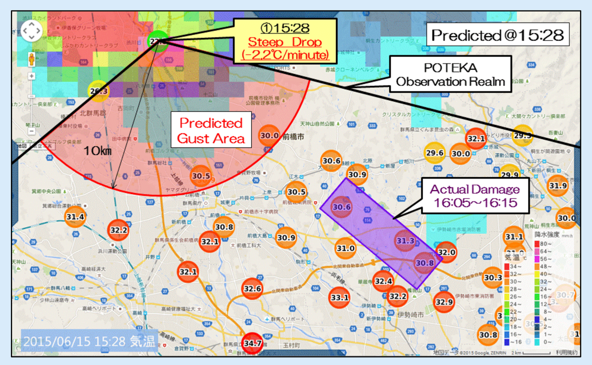

Fig.6-1 Predicted result at 15:28

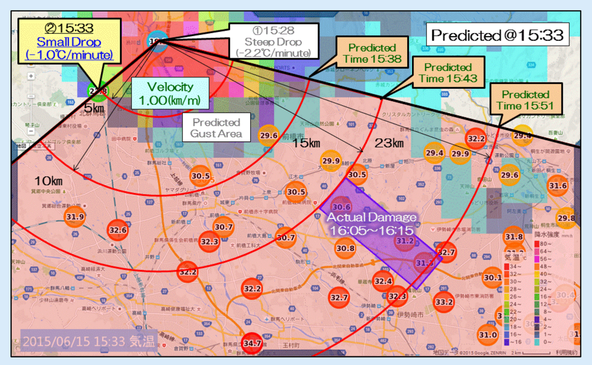

Fig.6-2 Predicted result at 15:33

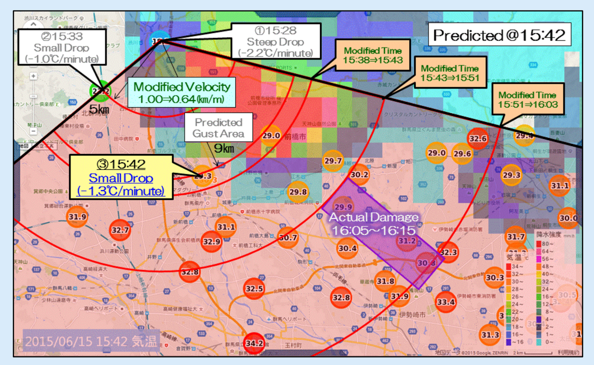

Fig.6-3 Predicted result at 15:42

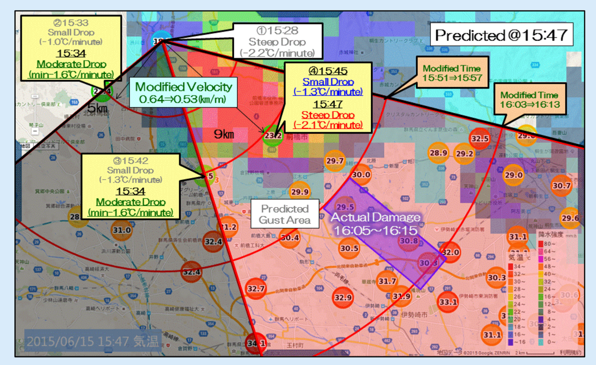

Fig.6-4 Predicted result at 15:47

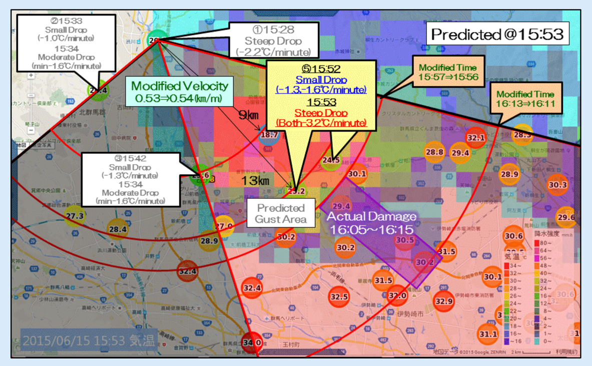

Fig.6-5 Predicted result at 15:53

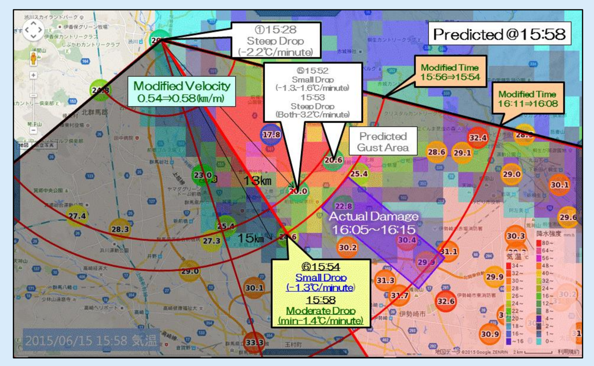

Fig.6-6 Predicted result at 15:58

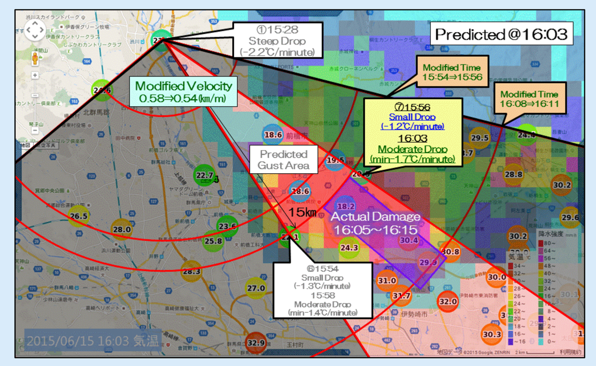

Fig.6-7 Final result at 16:03