Measurement of Tsukuba Tornado with particle image velocimetry

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1. Intorduction

Recently everybody having a mobilephone can film tornadoes in high resolution. Tsukuba tornado occurred afternoon at 6 May 2012 was a one of F3 class tornado which is the most violent in Japan. It killed one people and distroyed more than thousand houses. Because the Tsukuba tornado occurred in daytime, many people filmed and/or pictured the Tsukuba tornado from many locations.

The present study aims to examine the feasibility of photogrammetric analysis and to clarify the charactersitics of the Tsukuba tornado.

2. Data Analysis

The time of various movies was fixed by using a frame showing a spark from a power cable cutted by the tornado. Using two movies filmed from different locaions, 3-D locations of the tornado were evaluated. The wind velocity of the tornado was mesured by using the particle image velocimetry (PIV) system. In the present study, we employed 'Flownizer' as the PIV software.

The C-band polarimetric radar in Meteorological Research Institute of JMA also observed the Tsukuba tornado from about 14km south-east.

3. Results

The skelton of the tornado vortex almost inclines north-east, which is the direction of storm motion. However, the skelton meanders as it moves. Such temporal change of 3-D structure of the tornado can be resolved only by stereo-observation of high resollution cameras. The foot of each skelton locates almost on the tornado track estimated from our damage investigation. Some location error may be because the foot of the tornado was hidden by the houces.

The radar PPI scan data shows the outline of funnel cloud or tornado vortex of which axis is shown by a skelton. But the radar data are sparse comparing with the movies of 30 fps in flame rate. Even by a phased array radar, we can get only 1/300 data of the present photographic data.

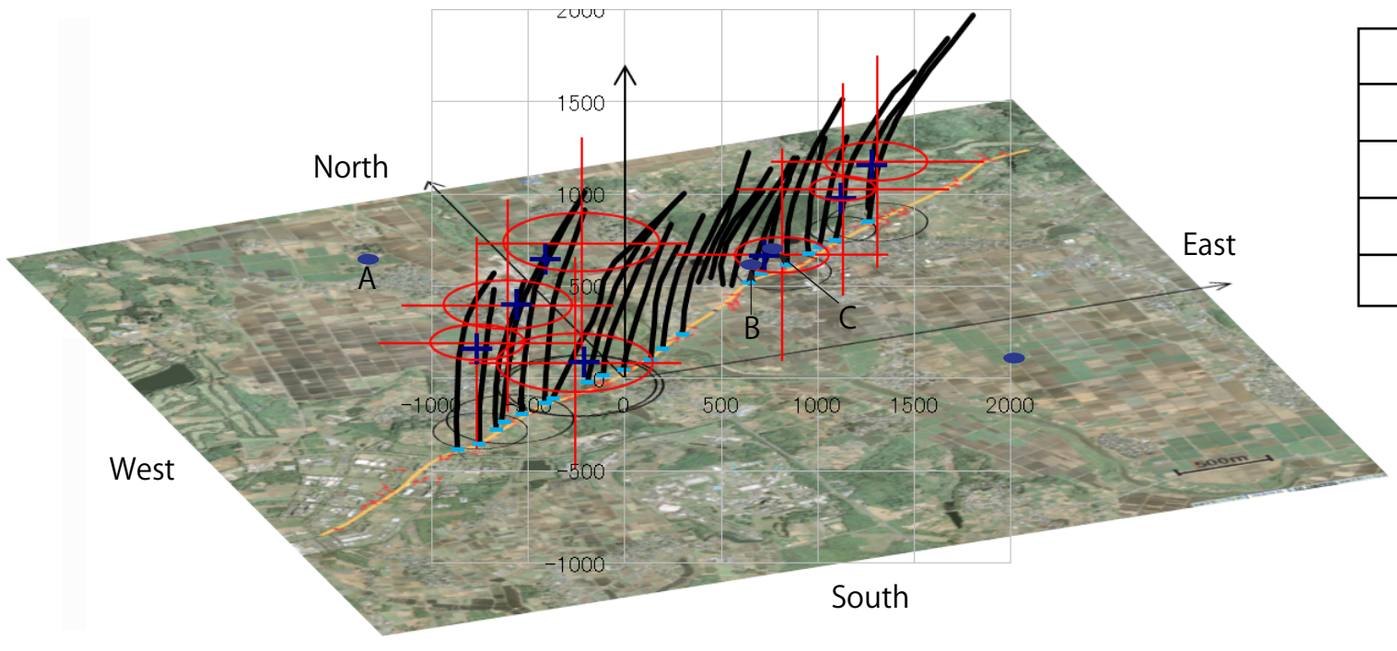


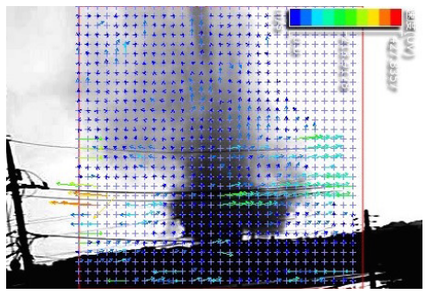
Fig. 1 Track of Tsukuba tornado identified from convergence line, temporal change of skelton of Tsukuba tornado and Horizontal outline of Tsukuba tornado captured by C-band MRI radar. The skeltons are shown every 10 seconds. Dark blue dots show observation locations where Tsukuba tornado was filmed. Red circles show the tornado cores observed by the radar.

Table 1 Comparison of wind velocity

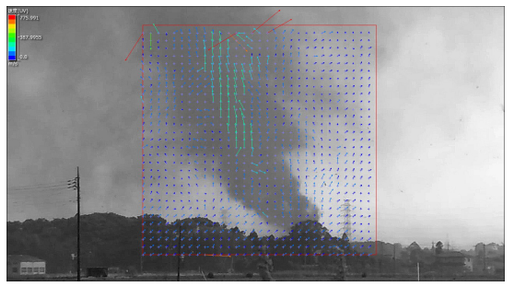
C-band radar	25 m/s
A-point	90 m/s
B-point	--
C-point 1	50 m/s
C-point 2	125 m/s

At present, the particle image velocimetry effectively works only in the case that the debris particles are clearly indetified (e.g. Fig. 2(d)). Therefore, the wind velocity of funnel cloud observed by the C-band radar cannot be compared with that measured by the PIV method. But, the velocity of flying debris can be measured as shown in Figs. 2(a),(c),(d).

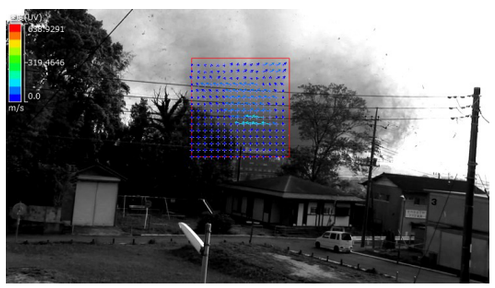
The wind velocities evaluated from the PIV method includes much error, but they shows the values far larger than that obtained from the radar. It is because the control volume of the radar is much larger than that of the PIV method.



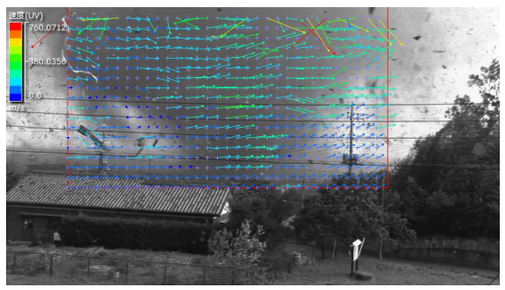
(a) from point B (Mrs. Ito)



(b) from point A (Mrs. Kohigashi)



(c) from point C (Mr. Iida)



(d) from point C (Mr. Iida)

Fig. 2 Examples of results of PIV analysis

4. Conclusions

The present study showed the usefulness of photogrammetric analysis of tornado.

We can get the high resoution data both temporal and spatial comparing with the radar.

Because many cameras was operated in hand, the correction of movementof the frame. At this time, the PIV analysis of tornado movies is difficult. But we believe it one of powerful observation tool for tornado.

Acknowledgement

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