P5-86 Controllable outflow generator for the experiment of a non-supercell tornado

Yuta Minekawa and Koji Sassa

Kochi University, Akebonocho 2-5-1, Kochi, Japan

1. Introduction

Cold outflows from thunderstorms sometimes become the source of vorticity to generate tornadoes (Fujita 1981). We have employed dry ice mist as outflow in our previous experimental studies to realize tornado-like vortices (Sassa and Takemura 2009). However, the outflow simulated by dry ice mist could not be controlled with respect to its speed and thickness and could not be supplied steadily.

The present study aims to develop a controllable outflow genrator and to clarify the relationship between the horizontal shear and the intensity of non-supercell tornado.

2. Outflow generator and Experiments

The cross section of the outflow generator is shown in Fig. 1. The air supplied from a fan is chilled when it flows through cooling fins. Air temperature can be controlled by changing the voltage to Peltier module, E_p, and the velocity of the outflow is also controllable with the applied voltage to the fan, E_f. In the present study, the height of the outflow, h, was set to 40 mm.

The outflow was visualized by mist supplied from two ultrasonic humidifiers settled upstream of the fan. The horizontal and vertical cross sections of the outflow were illuminated by a laser sheet and were filmed by a hi-speed camera at 1000 fps. Then, we measured the instantaneous velocity fields by using PIV method. Vertical temperature profiles were measured by the array of 16 thermo-couples. Another fan to simulate updraft was settled at the center of the horizontal mixed layer located at the side of the outflow. We made experiments for three conditions of Peltier module operation and four cases of E_f = 5~8 V, totally 12 cases.

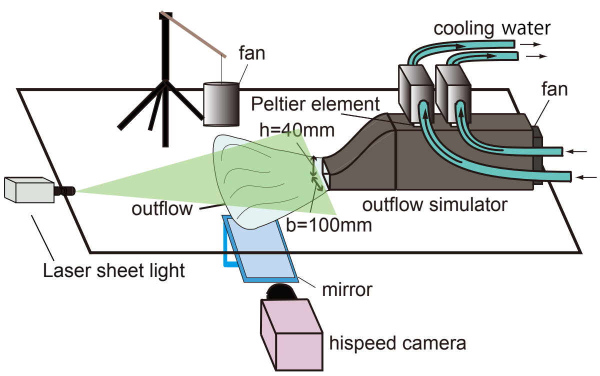

Fig.1 Experimental setup

3. Experimental result

The vertical cross section of outflow is shown in Fig. 2. The mixing layers clearly show the wave pattern due to K-H instability. The vertical profiles of velocity show typical patterns of gravity currents, which is similar to that of the downburst observed by Hjelmfelt (1988) and simulated by Wei-Lian Qu (2009) as shown in Fig. 3. The minimum temperature is observed at the point in which maximum velocity appears. These profiles were kept to be constant for more than 2 hours. The wave due to shear instability is also observed at both sides of the outflow as shown in Fig. 4. The mean shear in the mixing layer increases with E_f as shown in Fig. 5.

When another fan makes updraft above the horizontal shear layer, the tornado-like vortex occurs as shown in Fig. 6. This is because vertical vorticity in the shear layer is enhanced through the stretching mechanism due to the updraft. The instantaneous velocity distribution shown in Fig. 7 is obtained by using PIV

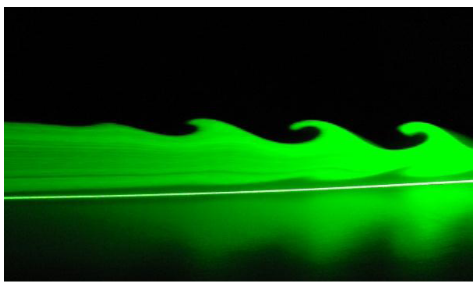

Fig. 2 Side view of outflow (E_p =5V, E_f =8V)

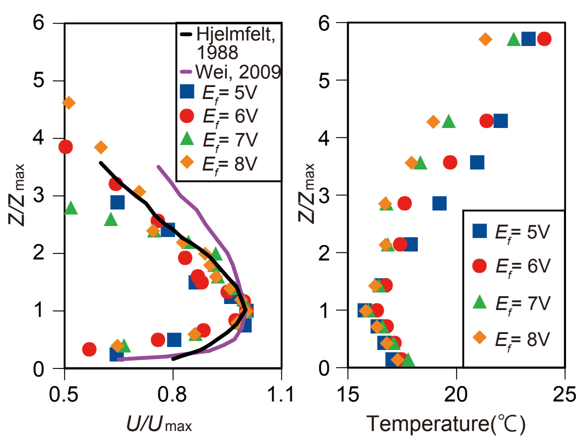

Fig. 3 Velocity and temperature profiles of simulated outflows

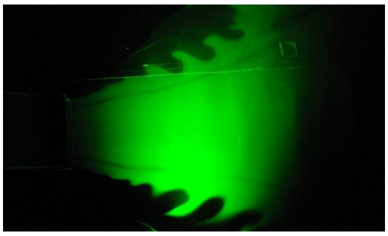

Fig. 4 Plan view of outflow (E_p =5V, Ef=8V)

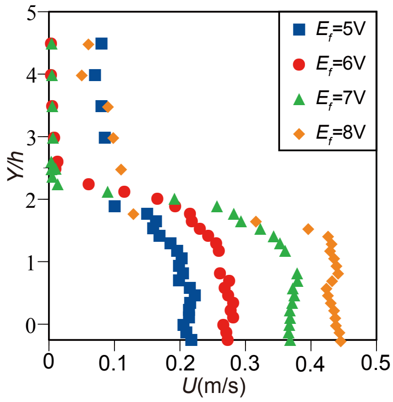

Fig. 5 Horizontal velocity distributions at X/h=3.75 (E_p=5V)

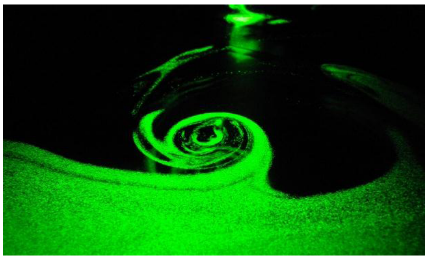

Fig. 6 Plan view of tornado-like vortex (E_p =0V, Ef=6V)

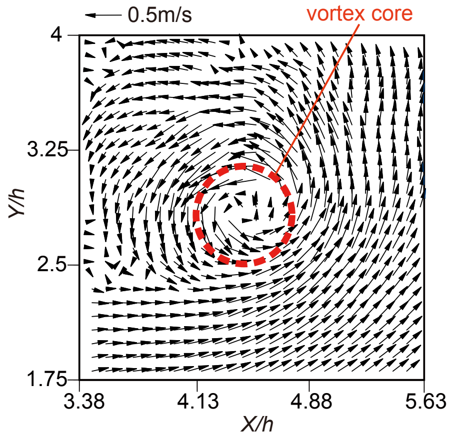

Fig. 7 Velocity field of a tornado-like vortex at Z/h =0.25 (E_p =5V, Ef=8V)

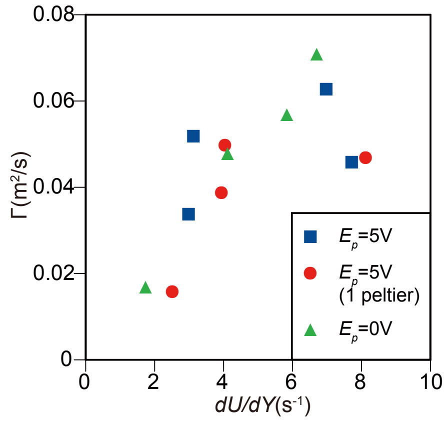

Fig. 8 The circulation vs. horizontal shear

analysis. The circulation of the tornado-like vortex is calculated in the dashed circle.

The circulation increases with the horizontal shear of the shear layer, but the tornado-like vortices blows out due to too large horizontal velocity of outflow as shown in Fig. 8. The cold outflow can make tornado-like vortex stronger than the neutral outflow.

4. Conclusion

We confirmed that our outflow generator is controllable and can simulate the actual outflow. The tornado-like vortex becomes stronger with the shear of the outflow.

Further experiments will show the condition of the non-supercell tornado outbreak.

Acknowledgment

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References

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