EXPERIMENTAL SIMULATION FOR EXAMINING FLOW CONDITIONS OF TORNADOGENESIS

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I. INTRODUCTION

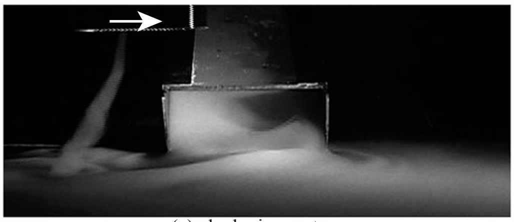
The mechanism of tornadogenesis is still not clear and this fact makes forecast difficult. Recent numerical model enable to simulate the process of tornadogenesis (Noda and Niino 2005). However, its resolution and turbulence model is not enough to simulate the detailed structure of tornadoes. Though laboratory experiments cannot simulate cloud system, we expect that laboratory experiments realizing tornado like vortices under such restricted conditions will clear essential fluid dynamical factors of tornadogenesis. Unfortunately, most of laboratory experiments on tornadoes have focussed to clear the structure of the tornado (Monji 1980). Then, we tried some new experiments simulating the organization process of the tornado like vortex.

II. NONSUPERCELL TORNADO

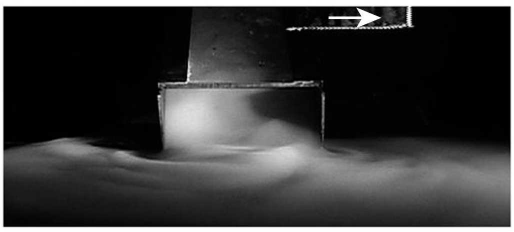
The essential factors of the genesis of the nonsupercell tornado are the updraft due to cumulus and cumulonimbus and the horizontal shear due to the advection of cold air. We realized such situation with a fan making updraft and a gust generator. The gust generator makes cold gust front with mist generated from dry ice.

Examples of resultant tornado like vortex are shown in FIG. 1. The gust flows from back to face of the figure. Then, the shear line in right hand side has cyclonic vorticity and vice versa. FIG. 1(a) shows the clockwise vortex generated through the stretching of the anti-cyclonic vorticity of the horizontal shear. The middle portion of the gust does not have any vertical vorticity and then the tornado like vortex disappears as shown in FIG. 1(b). When the fan moves the right hand side of the gust generator, the gradient of the horizontal shear turns back and the cyclonic tornado like vortex is generated as shown in FIG. 1(c). These facts show that the existence of the horizontal shear near the ground is the most essential factor for the genesis of the nonsupercell tornado. Therefore, the principal generating mechanism of the nonsupercell tornado is 'vortex stretcing'.

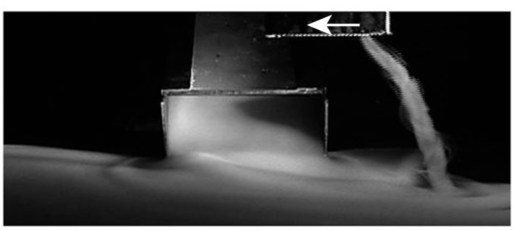
Because the gust simulated with the dry ice mist also has vertical shear, sometimes we can observe the tilting of horizontal vorticity as shown in FIG. 2. But, the tilting of the horizontal vorticity cannot fail to generate counter-rotating vortex pair and they cancel with each other soon. This fact may show that the tilting is not principal mechanism of tornadogenesis.



(a) clockwise vortex



(b) dissipation of vortex



(c) counterclockwise vortex

FIG. 1: Tornado-like vortex generated by the fan moving across the horizontal shear near the floor, arrow denotes the moving direction of the fan.

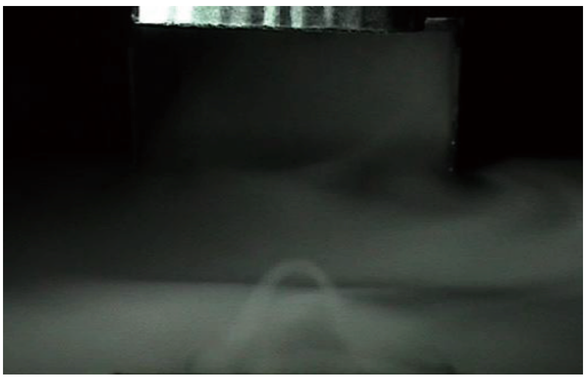


FIG2: Tilting of horizontal vortex inherent in the vertical shear

III. SUPERCELL TORNADO

The essential factors of the genesis of the supercell tornado are the rotating updraft of mesocyclone and the gust front due to rear flank downdraft (Noda and Niino 2005). We made the mesocyclone simulator composed of 24 guide

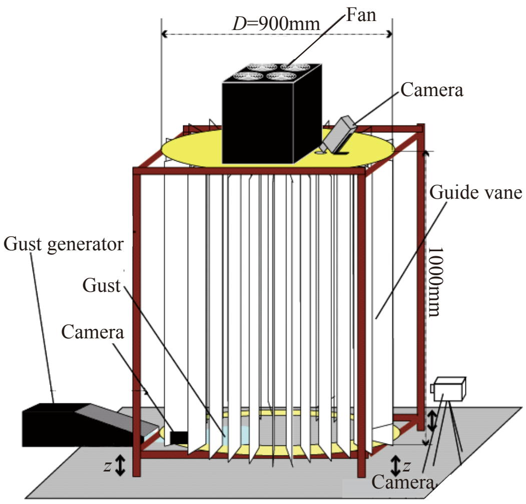


FIG. 3: Mesocyclone simulator and Gust generator

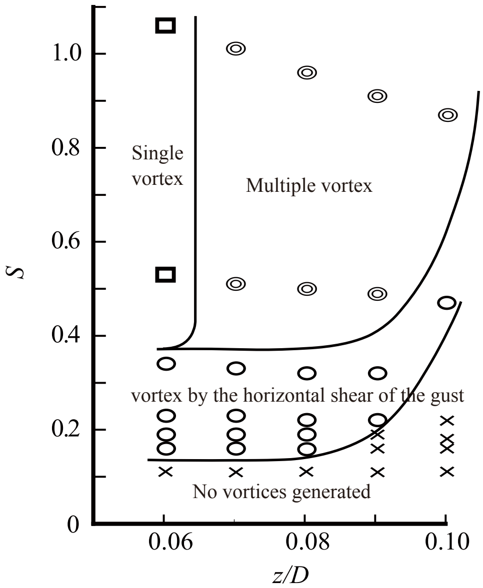


FIG. 4: Four patterns of flow fields realized by our simulator

vanes and axial fans as shown in FIG. 3. Though it is similar to conventional tornado simulators, our system has open space under it. The gust generator simulates the rear flank downdraft. We made flow visualization at various heights of open space, *z*, and at various attack angles of vanes.

We observed four different flow patterns as shown in FIG. 4. These patterns depend on the normalized height, *z/D*, and swirl ratio, *S*. The case of single vortex may similar to that in the conventional tornado simulator, because open space is very narrow. In the most case, the tornado like vortex is generated from the horizontal shear of the gust through the vortex stretching mechanism in spite of the rotation of upper mesocyclone. When the open space is wide, the tornado like vortex cannot be generated even at high swirl ratio. These facts show that the intensity and the height of mesocyclone affect the genesis of supercell tornado.

FIG. 5 shows the multiple vortex realized in our simulator. The suction vortices twining around the main vortex from the shear line of the gust shown in FIG. 5 is observed by Doppler radar by (Wurman 2002) and the counter rotating vortex is also observed actually by (Bluestein et al. 2007). These facts show our simulator reproduces actual flow field under the supercell well. We expect that the result shown in FIG. 4 is helpful to make tornado alert system in the future.

IV. REFERENCES

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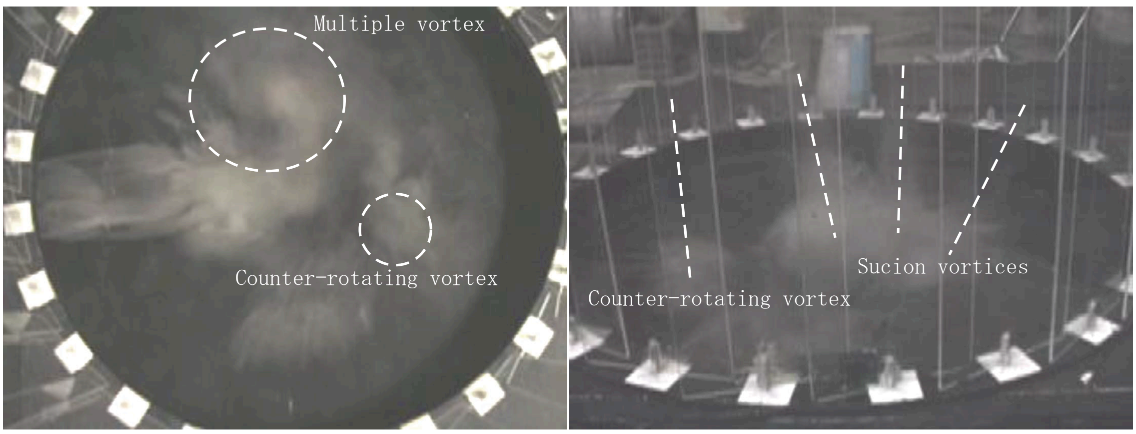

(a) plan view (b) side view

FIG. 5: Multiple vortex and counter-rotating vortex realized under the mesocyclone simulator