Analog modeling of dust devil -Study of its growth and dissipation-

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1. The background of this research

The purpose of this research is to search the conditions of the growth and dissipation of the dust devil by analog experiments. For this purpose, we developed an analog model that generates a vertical vortex like dust devil.

Dust devil is a strong vertical vortex that suddenly occurs in the middle of the sunny day. We wondered why such a strong vortex grow up and dissipates suddenly. In the resent years, many numerical studies related to dust devils have been reported. However, while numerical simulation is good at studying the impact of the control parameters to the phenomena, it should approximate fine vortex structure and cannot incorporate fine surface geometries due to the limit of discretization. Therefore, we decided to develop an analog experiment system to generate dust devil in laboratory. We started this research with the hope that we could discover detailed properties of the dust devil that could not be found in the numerical simulations by quantifying the parameters of the dust devil observed under controlled environmental conditions by the analog experiment.

2. Method

By referring to the previous research on the generation mechanism of the dust devil, we created a device that reproduces the environment which generates dust devils.

We made a device that heats the ground surface (water) with a hot plate to generate an ascending air current and rotates a cylindrical wire mesh to give an angular momentum to the inflowing air current. The purpose of heating the water is to generate steam and visualize the dust devil. Furthermore, by applying a sheet-shaped laser beam to this steam, we developed a system to measure the cross section of an vortex quantitatively. Using this system, we measured the diameter of the vortex which was visualized by the sheet-shaped laser in the video image. We measured the change in diameter of the vortex and the temperature distribution inside the vortex with various given angular momentum.

3. Result and discussion

As the ground surface temperature was kept constant and the given angular velocity of the cylinder was increased, the vortex diameter increased. The temperature inside of the vortex was higher than the surrounding, and the temperature difference between them was more significant with smaller vortex diameter was small.

The vertical temperature gradient of the central part was larger when the vortex diameter was large, that is, when the angular momentum was large.

It is suggested that the dust devil plays a certain role in heat transportation and the given angular

momentum should control its efficiency. The reason why the center of the vortex shows higher temperature than the surrounding area is that the hot air near the ground surface is collected by the pressure gradient force in the direction of the center of the vortex, which is the result of the high temperature near the center. However, we have not reached to a clear answer as to why a large centrally oriented pressure gradient force is generated in the early stages of the formation of the vortex.

By conducting quantitative evaluations in the future, we will clarify the mechanism by which the given angular momentum and ground surface temperature affect the scale and structure of the vortex.

By applying the scaling of real whirlwind and experimental equipment using eddy viscosity, we want to find out the conditions critical to the growth and dissipation of the dust devil.

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5. References

・Ito, J., (2017), Formation, Intensification, and Gusty Winds of Dust Devils (Japanese), Wind Engineers, JAWE Vol.42, No.1(No.150)

・Niino, H., (2009), Tornadoes and Dust devils: Current Understandings and Future Subjects (Japanese), 58th National Congress of Theoretical and Applied Mechanics

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