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論文要約

THESIS OUTLINE

専攻 : Environmental Science and Technology 専攻
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Student's Name

申請学位 (専攻分野) : 博士 (工学)
Academic Degree Requested Doctor of
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要約 (様式自由)
Thesis Outline (free format)

Numerical Study on Lifetime Mechanism and Severe Wind Characteristics of Tornado

To accurately model the tornadic wind field for anti-wind design, a comprehensive understanding to the tornado mechanism and wind characteristics is necessary. Recent approaches including field observations and laboratory models have limitations such as lack of near-ground observations and over-simplified flows. In order to address these limitations, this thesis utilize meteorological model, Weather Research and Forecast with large-eddy simulation implemented (WRFLES), to obtain a realistic tornado process. The tornado case is the 2012 Tsukuba tornado, one of most severe tornadoes ever recorded in Japan. The lifetime mechanism of the tornado is investigated and the resolved tornadic wind features are discussed, whose universality is also demonstrated via a series of parameter tests using an idealized meteorological model, Cloud Model 1 (CM1).

First, the performance of WRFLES in resolving strong wind is validated in a common strong wind condition, typhoon (Chapter 2). The simulated typhoon shows good agreement with several observations. The horizontal roll structures (HRS) are resolved by grids of 250-m horizontal size, while finer-scale turbulence could only be resolved by grids of 50-m horizontal size. How terrain undulation and grid resolution influence the resolved HRS is also investigated.

Then, Chapter 3 investigates the genesis mechanism of the tornado reproduced by WRFLES, concerning the circulation source responsible for the tornadogenesis. Circulation analyses show that the frictional term caused by surface drag is the dominant circulation source. The surface drag generates near-ground crosswise vorticity, which is tilted (or firstly exchanged to streamwise vorticity then tilted) into vertical vorticity when air parcels enter the tornado cyclonically. The rear-flank downdraft (RFD) surge triggers the tornadogenesis by enhancing near-ground convergence.

Chapter 4 investigates the mechanism of maintenance and dissipation (M&D) of the tornado, focusing on the role of RFD in the M&D. How RFD wrapping influences the tornado's intensity is examined from the perspective of circulation import. The intensified RFD is also found playing a crucial role in the vortex replacements between the original tornado and extra vortices (EVs).

Finally, Chapter 5 presents the wind characteristics of the WRFLES-simulated tornado, and validates its universality via a series of parameter tests of different surface drag coefficients using CM1. The WRFLES-simulated tornado exhibits transition from single vortex to vortex ring, and finally to

multi-vortex structures. The temporal peaks of near-ground horizontal velocity could be occasionally caused by gust fronts of RFD outflow, which result in strong low-level jets below 100 m AGL. Among the inflow of tornado, larger wind fluctuation is found on the rear side of the tornado, resulted from the mixing effect of downdraft. In parameter tests, the behavior of RFD, tornadic vortex pattern and turbulence of wind inflow show similarity to the WRFLES-simulated tornado especially in the later life time, partly proving the universality of tornado mechanism and wind features.

The structure of the thesis is summarized below.

