2003 年 6 月 8 日夏威夷瓦胡島龍捲風狀渦旋事件的數值研究

A Numerical Study of the Tornado-Like Vortex Event over Oahu, Hawaii, on 8 June 2003

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摘 要

在這項研究中，我們再次探討了2003年6月瓦胡島中部的一次強降雨事件，期間發生了一場罕見的弱龍捲風。我們使用數值模型分析了導致龍捲風形成的氣象條件。此前關於此事件的研究使用1.5公里網格的數值模型分析了半乾旱地區的對流觸發。與之不同的是，我們使用超高解析度模型來模擬龍捲風狀渦旋的形成和移動。40米的適當網格尺寸，結合大渦流模擬方法，成功地再現了弱渦旋事件。儘管在龍捲風的確切位置上存在細微差異，但該模擬促進了對渦旋初始形成和向下游移動的詳細分析，證明了該模型的有效性。我們的結果表明，龍捲風事件受到瓦胡島當地海陸風、熱力觸發的對流系統和地形之間相互作用的影響。由於海陸風和對流系統的下沉氣流，在地面附近形成了一個弱渦旋。隨後，通過上下層的耦合效應，進入的對流系統產生了吸力效應，增強了上層的下沉氣流。這個過程使得龍捲風渦旋從頂部連接到底部。我們的研究結果可能有助於改進數值天氣預報模型，並幫助預報員預測熱帶島嶼上類似的天氣事件。

關鍵字：自下而上耦合，弱島嶼龍捲風，超高解析度

Abstract

In this study, we revisit a heavy rainfall event over central Oahu in June 2003, during which a rare weak tornado occurred. We used a numerical model to analyze the meteorological conditions that led to the formation of the tornado. Previous studies on this event have analyzed convection initiation over the semiarid region using a numerical model with 1.5-km grids. By contrast, we used an ultra-high-resolution model to simulate the formation and movement of the tornado-like vortex. An appropriate grid size of 40 m, coupled with the large-eddy simulation method, successfully reproduced the weak vortex event. This simulation facilitated a detailed analysis of the vortex's initialization and downstream movement, demonstrating the model's effectiveness despite minor discrepancies in the tornado's exact location. Our results indicated that the tornado event was influenced by the interactions among Oahu's local land and sea breeze, thermally induced convective systems, and topography. A weak vortex formed near the ground due to downdrafts from the land-sea breeze and convective systems. Subsequently, through the coupling effect of the upper and lower layers, the incoming convective system exerted a suction effect that enhanced the upper-level downdrafts. This process allowed the tornado vortex to connect from the top to the

bottom. Our findings may help improve numerical weather prediction models and assist forecasters in predicting similar weather events over tropical islands.

Key words : bottom-up coupling, weak island tornadoes, ultra-high resolution