未來長期氣候變遷對西北太平洋超級颱風個案降水潛在影響之模擬研究

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摘　要

氣候變遷所衍生的極端天氣現象是人類在未來須面對的環境議題之一，未來的災害推估也是學界近期正努力鑽研的一大領域，對西北太平洋區域而言，颱風未來的活動是觀察重點之一，除風力可觀以外，其挾帶的劇烈降水更具破壞力，尤其薩菲爾·辛普森等級C4或C5的強颱更不可言喻。為探討未來暖化下強烈颱風的降水變化，本研究以此為動機，自Thean (2021)選取高解析CReSS模式模擬之三超級颱風個案：梅姬(2010)、海燕(2013)、莫蘭蒂(2016)及其於未來21世紀末RCP 4.5及RCP 8.5情境的實驗結果，加以分析相關降水參數及環流結構上的變異，另使用水收支方程做更進一步的降水定性與定量診斷。

結果指出，三個案在未來情境模擬下，背景水氣增加與垂直次環流上升運動的加強導致颱風劇烈降水皆有顯著成長，在0~400公里半徑範圍內，經全模擬時間平均，三個案在RCP 4.5情境下的降水增幅約為4.63~12.85%，RCP 8.5情境下則增加6.3~29.6%；若縮小至0~200公里半徑，三個案的降水成長更為明顯。各類水象粒子的軸對稱垂直剖面分布也呼應到降水，水氣、降水粒子在內核有顯著增長，而冰相粒子則因溶解層提高，生成高度會些許增加且有總量減少的可能性。

在水收支分析上，考慮不同個案的環流半徑與計算精確度，三個案使用不同半徑與時長進行計算，不過皆有一致的結果：在暖化情境下，密度輻合增強，密度平流加強，粒子絕對溼度時變率亦增加，而整體水收支來源(water source)以水氣的密度輻合為主導；根據此項延伸分析中低層0~5.5公里之可降水量與水平輻合積分，發現儘管三個案於不同暖化情境下誘發降水的偏好不同，部分實驗的降水差異主要來自可降水量的增加，另一部分則對水平輻合變化的敏感度較高，然而兩機制皆會影響未來超級颱風降雨的增加幅度，皆可視為增加降水的充分條件。

關鍵字：氣候變遷、超級颱風、水收支、降水

The Simulation Studies of Potential Influence of Future Long-term Climate Change on Super Typhoon Precipitation Cases in Western North Pacific

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Abstract

The extreme weather under climate change is one of the environmental problems that the humanity will face in the future. In western North Pacific (WNP), typhoons often cause huge damage. In addition to the strong wind, its torrential precipitation is even more destructive, especially for category 4 and 5 super typhoons. To explore the changes in precipitation caused by intense typhoons under future warming scenarios, this study selected three super-typhoon cases from Thean (2021): Megi (2010), Haiyan (2013), and Meranti (2016). This study uses high resolution CReSS model to reproduce these cases and simulate their precipitation at the end of the 21st century under RCP 4.5 and RCP 8.5 warming scenarios combined with CMIP5 data. Following analysis in this research includes the variations of relevant parameters, circulation structures, and water budget.

The results indicate the increase of background moisture and the strengthening of upward motion in the typhoon circulation cause significant increase in precipitation in future scenarios. In radii of 0-400 km, precipitation of these cases has 4.63~12.85% increase under RCP 4.5 scenarios and has 6.3~29.6% increase under RCP 8.5 scenarios. For the inner core of 0-200 km, rainfall in each case has more increase. The radial mean profiles of water hydrometeors also reflect the rainfall distributions: the water vapor and precipitation particles significantly increase in the inner core, and due to the rising of melting layer, there is a possibility that the generation height of ice-phase particles will increase and the quantities will slightly decrease.

As for the water budget, considering different circulation radius and computational accuracy, three cases were calculated with different radii and durations, but all the results are consistent. In the warming future, total water transport would increase, including the enhancement of flux convergence, and absolute humidity change rate; meanwhile, the dominant term of water budget is water vapor density convergence. In addition, by calculating precipitable water (PW) and integrated horizontal convergence (IHC) within the height of 0-5.5 km, this study discovers the attribution inducing precipitation in different experiments is different: rainfall variations in some experiments have more sensitivity to changes of IHC, and some of which have more sensitivity to PW enhancement. Nevertheless, the fact that the increase of future super typhoon rainfall by the interaction between these two mechanisms remains unchanged

Key words: climate change, precipitation, super typhoon, water budget