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西南季風氣流與颱風路徑對颱風離陸後台灣降雨之影響

Influence of Southwest Monsoon Flow and Typhoon Track on Taiwan Rainfall during the Exit Phase

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摘要

本研究探討西南季風氣流對颱風離陸後台灣降雨的影響。定義西行颱風離陸後階段（exit phase）為颱風中心離開台灣陸地起至中心距最近海岸線為 100 km 的時段，並選取路徑穿越台灣北（路徑 N）、中（路徑 C）、及南（路徑 S）的颱風個案進行統計。將過去 57 年分為前 30 年（1960-1989，P1）和後 30 年（1987-2016，P2），台灣 21 個長期觀測人工測站的時雨量資料顯示 P2 相較 P1 具有颱風降雨量(~60%)和降雨強度(~30%)的年代際增加，且路徑 C 颱風個數也具有年代際增加的現象。使用 JRA-55 再分析資料進行計算，台灣西南外海局地之西南季風水氣通量（southwest monsoon water vapor flux，SWF）在路徑 C 期間比路徑 N 期間大。本研究顯示 SWF 的增加會造成降雨強度的增加，而 SWF 增強與颱風延時增加的合成作用會導致離陸後降雨量的增加。莫拉克颱風（2009）分類上屬於路徑 C，其離陸後具有極緩慢的移行速度及破紀錄降雨量，本研究選定此個案進行數值模式模擬實驗和位渦趨勢診斷分析，以了解颱風離陸後造成延時增加的動力過程。颱風環流和西南季風氣流交互作用下，於台灣海峽形成之不對稱對流是導致颱風減速的原因，雨帶內由後造型對流機制形成新對流胞及對流胞的碰撞合併。在西行颱風離陸後階段，SWF 增強和颱風延時增加可用以解釋颱風降雨量的年代際增加遠多於降雨強度增加的現象。

另一方面，通過台灣東側太平洋面的北行颱風也有機會與西南氣流交互作用並造成南台灣的強降雨。北行颱風可強化副熱帶高壓西側的重力位高度梯度，增強的南風軸向西南延伸，具有大氣長河的特徵。在沒有其它強綜觀天氣系統的條件下，颱風的南側環流會在其北行過程中增強 SWF（$R=0.76$），並將旺盛的水氣傳入台灣。根據所有地面測站的時雨量資料，2000-2016 年 18 個颱風中有 10（13）個滿足南台灣豪雨（大雨）標準。其中，谷超颱風（2012）北行的過程中，泰利颱風（2012）於南海上形成並逐漸北行接近台灣，造成 SWF 更為增強及降雨延時的增加。本研究透過數值模式模擬實驗和片段位渦反演診斷，以釐清泰利颱風如何影響此階段的台灣南部降雨。研究顯示減弱的颱風渦旋具有較快的移速，台灣南部沿岸輻合減少使得地形上的降雨減少，降雨位置東

移至海面上。北行颱風期間，南海上颱風的位置及環流範圍主宰輻合發生的位置，並進而影響台灣南部的降雨。

關鍵字：颱風降雨、年代際變化、西南季風、非絕熱、颱風移速減慢、西行颱風、北行颱風

Abstract

This thesis studies the influence of southwest monsoon flow on rainfall after typhoon centers leave Taiwan. For westward-moving typhoons, exit phase is defined as the time interval when a typhoon center leaves the Taiwan coast to 100 km away from the nearest coastline. Typhoons move across Taiwan through its northern (track N), central (track C), or southern (track S) part are selected for a statistical study. Taiwan hourly rainfall data of 21 surface gauge stations from the past 57 years are divided into two periods: 1960-1989 (P1) and 1987-2016 (P2). From P1 to P2, there are decadal increases of rainfall (~60%) and rainfall intensity (~30%, mm h^{-1}) in the exit phase. There is also a decadal increase of the track-C typhoons. The southwest monsoon water vapor flux (SWF) in a local region southwest of Taiwan, as computed from the JRA-55 dataset, is substantially larger in the track-C typhoons than that in the track-N typhoons. Our analysis indicates that the increase of SWF leads to the increase of rainfall intensity. Moreover, both the enhanced SWF and the prolonged duration time contribute to the increased rainfall in the exit phase. Typhoon Morakot (2009), a track-C typhoon with extremely slow speed in the exit phase, produced the record-breaking rainfall. Model experiments and potential vorticity tendency diagnosis of Typhoon Morakot are used to understand the dynamics of increased duration time. The slowdown of typhoon motion is shown to be due to the asymmetric convection in the Taiwan Strait, which is produced by the interaction between typhoon circulation and southwest monsoon flow. The enhanced SWF and the prolonged duration time may explain the observed fact that the decadal rainfall increase is much larger than that of rainfall intensity in the exit phase of westward-moving typhoons.

On the other hand, northward-moving typhoons across east of Taiwan on the Pacific Ocean may produce extreme rainfall in southern Taiwan. Northward-moving typhoons may strengthen the western ridge of subtropical high, and the sustainable southwesterly moisture flux has the characteristic of atmospheric river. Without other strong synoptic-scale forcing near Taiwan,

SWF is enhanced by the south side of norward-moving typhoon circulation (R = 0.76) and transports strong moisture into Taiwan. Hourly rainfall data of all surface gauge stations indicates 10 (13) of 18 typhoons produced extremely heavy (heavy) rainfall in southern Taiwan during 2000-2016. Typhoon Guchol (2012) moved northward with Typhoon Talim (2012) in South China Sea, contributed strengthened SWF and prolonged rainfall period. Model experiments and piecewise potential vorticity inversion diagnostics are used to investigate how Typhoon Talim affected rainfall. The weaker typhoon with faster moving speed shows decreased convergence along southwest coast of Taiwan and produces the rainfall more east to the ocean. During the period of a northward-moving typhoon, the position of another typhoon circulation in South China Sea dominates the position of convergence, and affects the rainfall in southern Taiwan.

Key Words: typhoon rainfall, decadal variation, southwest monsoon, diabatic heating, slow translation speed, westward-moving typhoon, northward-moving typhoon