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Orographic effects on heavy rainfall events over northeastern Taiwan during the northeasterly monsoon season

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ABSTRACT

The effects of orographic lifting and blocking on a heavy rainfall event with an accumulation of 631.5 mm on 11 October 2009 over the Lan-Yang Plain (LYP) in northeastern Taiwan during the northeasterly monsoon season were studied by performing observational data analyses and numerical simulations using the Weather Research and Forecasting (WRF) model. The synoptic environment included a low-level easterly wind over the East China Sea and a southeasterly wind over the western North Pacific Ocean which produced convergence areas leading to the heavy rainfall event. The mesoscale features and the orographic lifting and blocking effects on the production and maintenance of the heavy orographic rainfall without the direct influence of the typhoon's circulations during the northeasterly monsoon season in fall were first investigated here. Due to orographic blocking on the prevailing easterly wind over the western LYP, the induced near-surface northeasterly flow containing moist airstream was lifted over the windward (south) side of the LYP and rainfall was enhanced in situ. Meanwhile, the precipitating system was embedded in a weak middle-level flow with the wind reversing its direction over the windward side of the LYP, resulting in a quasi-stationary system over the slope area. Furthermore, the prevailing easterly wind ascended over the coastal slope south of the LYP and enhanced the rainfall there. In addition, the approaching east–west oriented rainband from southeast Taiwan also strengthened the rainfall intensity over northeastern Taiwan. Two sensitivity tests were performed to examine the effect of the orographic lifting of the moist airstream on the production of heavy rainfall. The sensitivity experiment with Taiwan's topography removed (the NT run) shows that the simulated accumulated rainfall over northeastern Taiwan was less than 50 mm in one day, much less than in the control run (CR run). In the NT run, the low-level convergence over northeastern Taiwan produced by the synoptic circulations and the simulated rainband still approaching northeastern Taiwan, are similar to the CR run. Another sensitivity experiment replacing the LYP with a plateau (the PL run) shows that the accumulated daily rainfall over the slope south of the LYP was reduced by ~250 mm compared to the CR run. The reduction of rainfall was caused by lifting relatively less moist air over the slope south of the LYP. These sensitivity tests indicate that the amount of low-level moisture and the orographic effects are equally important for the formation and maintenance of heavy rainfall over northeastern Taiwan under a favorable environment.

1. Introduction

It is well known that orography plays an important role in the formation, enhancement and maintenance of heavy rainfall under different synoptic situations over Taiwan (Lin,

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2007; Yen et al., 2011; Federico et al., 2009; Mastrangelo et al., 2011; Feng and Wang Chen, 2011 among others). In particular, during the Mei-Yu (15 May 15 June) and Post Mei-Yu seasons (∽16 June ∽ 30 June), the rainfall associated with the Mei-Yu front and the embedded mesoscale convective systems (MCSs) was often enhanced dramatically by the Central Mountain Range (CMR) (Lin and Chen, 2002; Chen et al., 2005, 2007a, 2010a, 2010b, 2011; Li et al., 1997, 2011 among others). In October, the northeasterly monsoon prevailing over Taiwan (see Fig. 1a and b for

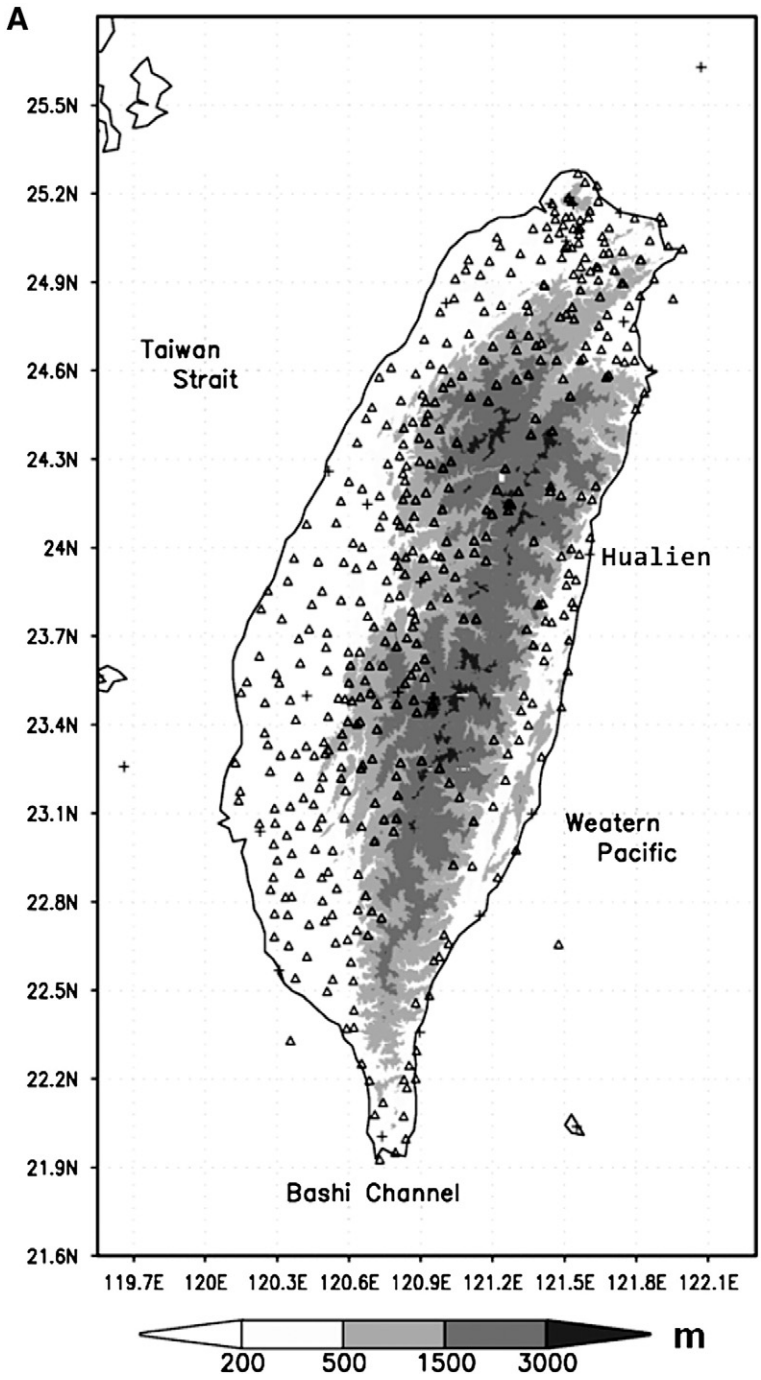

Fig. 1. (A) The topography of Taiwan. The gray scale shows terrain elevations in meters. The triangles and crosses represent the Automatic Rainfall and Meteorological Telemetry System and conventional stations, respectively. (B) Same as (A) but for northeastern Taiwan. The Wu-Fen Shan Doppler radar is indicated by a star symbol. LYP represents Lan-Yang Plain. The locations for conventional station Ilan and Suao are also shown. (C) Same as (B) but for a sensitivity test through the modification of the Lan-Yang Plain (LYP) to a plateau (the PL run).