Study on rainfall over the middle of the Indo-China Peninsula during summer monsoon by producing gauge-calibrated ground-based radar data

MAHAVIK, Nattapon

Chapter 1 Introduction

The Indo-China Peninsula (ICP) is a region affected by the Indian Summer Monsoon (ISM) and the Western North Pacific Summer Monsoon (WNPSM). Southwesterly winds prevail during the ISM in conjunction with short breaks caused by disturbances from the WNPSM. Moreover, the narrow mountain ranges of the ICP have a significant effect on rainfall distribution. A review of existing literature suggests that rainfall over the ICP during the summer monsoon has not been well described because of the lack of rainfall data with sufficient spatiotemporal coverage. In the present study, rainfall over the mid-ICP is examined by producing gauge-calibrated ground-based radar data.

Chapter 2 Production of Gauge-Calibrated Ground-Based Radar Data

This chapter describes the production of a radar rainfall map, which is regarded as providing data with both high spatiotemporal resolution and greater reliability. Although there is a dense network of radars in the mid-ICP, their data are not yet available for public use. In the present study, gauge-calibrated ground-based radar data are produced for the mid-ICP. A simple conversion factor (CF) was calculated to address the difference between the rainfall observed at the gauge and the rainfall converted from radar reflectivity. A calibrated daily accumulated radar rainfall (CDARR) was originally derived for the Vientiane radar (Laos) and used to extract rainfall patterns during the summer monsoons in 2009 and 2010 (described in Chapter 3). The calibrated hourly radar rainfall (CHRR) was originally created during the summer of 2010 by application of a daily CF during the calibration process of three radars: the Vientiane, Phetchabun, and Lamphun radars. Moreover, a radar rainfall composite map was created based on these three radars, which forms the basis for the analysis of diurnal variation presented in Chapter 4. The CHRR is also used in the analysis of orogenic propagating rain systems described in Chapter 5. The conclusions reached following this study are presented in Chapter 6.

Chapter 3 Dominant Rainfall Patterns

This chapter describes the rainfall patterns during the summer monsoons in 2009 and 2010 based on the CDARR of the Vientiane radar. An empirical orthogonal function (EOF) analysis applied to the CDARR revealed that the first three modes explain 40% of the total rainfall variance. The pattern of the first EOF mode was only positive over the radar observation area and the largest value was near the foot of the Annam Range to the east of the radar site. The second EOF mode displayed a dipole pattern that had positive and negative regions in the eastern and western parts of the radar observation area, respectively. The third EOF mode also showed a dipole pattern with positive and negative areas in the southern and northern regions of the observation area, respectively. The composite analysis results suggested that the first EOF mode was possibly produced by a difference in positive vorticity, whereby the difference in the southerly wind component likely caused orographic rainfall in the region to the east of the radar site. In addition, the second and third EOF modes were possibly produced by differences in the westerly and southwesterly wind components, respectively.

Chapter 4 Diurnal Variation of Rainfall over the ICP

This chapter describes the diurnal variation of rainfall from July to September in 2010 based on the CHRR. The number of occurrences of rainfall peaks was examined. Single-peak areas were found over the Chaophraya Basin and the Khorat Plateau connected to the foot of the Annam Range (KPAN). Multiple peaks were located over regions with higher terrain, advancing the understanding of the diurnal variability of rainfall obtained from previous studies based on data from gauges located mainly over the plain. An evening peak in rainfall was observed over the Chaophraya Basin, whereas an early morning peak was observed over the KPAN, which is consistent with the findings of previous studies. The early morning peak in rainfall over the KPAN is a peculiar phenomenon over tropical land, because the dominant pattern of diurnal variability of rainfall in the tropics is a response to solar heating of the ground surface, which leads to the maximum rainfall occurring during the afternoon/evening. The stronger rain intensities were coincident with the times of peak rainfall, implying the occurrence of strong convection. The terrain effect from the mesoscale mountain ranges on rainfall activity was observed over the mid-ICP. This played a significant role in the discontinuity of the times of peak rainfall observed over the Phetchabun and Dong Phraya ranges.

Chapter 5 Orogenic Propagating Rain Systems

This chapter highlights the occurrence of the orogenic propagating rain systems from July to September in 2010 based on the CHRR. We established a method to classify the direction of propagation of rain systems on an hourly basis into propagating regimes: an eastward propagating regime (EPR), westward propagating regime (WPR), and unclassified propagating regime (UPR). The largest number of classified regimes on a specific date was used to represent the propagating direction. Intraseasonal variation of propagating rain days was observed and associated with lower tropospheric wind. Continuous periods of the EPR predominated over the ICP, interspersed by shorter episodes of the WPR. In addition, the EPR occurred most frequently in July and decreased towards the end of the summer, while the WPR occurred most frequently in September. The single-peak areas in the EPR resembled the pattern using all data.

The radar rainfall composite map allowed us to understand that under the EPR, the propagating rain systems over the Chaophraya Basin were unable to cross the narrow Phetchabun and Dong Phraya mountain ranges. In addition, we observed that the phase speeds of the propagating rain systems over the Chaophraya Basin and the KPAN were quite different. The phase speed over the Chaophraya Basin was about 6 m s^{-1}, which was close to the speed of the lower tropospheric wind. However, the phase speed over the KPAN was about 14 m s^{-1}, which was faster than the lower tropospheric wind. The observed phase speeds were consistent with the results from previous studies. However, in contrast to the assumption of a previous study, we found that the direction of propagation of the rain systems over the KPAN did not follow the lower tropospheric wind, which was southwesterly. The rain systems over the KPAN propagated east-southeastward, which in this study were simply called “southeastward” propagating rain systems. The propagating rain systems consisted of individual rain systems with differing lifetimes that were generated at discrete locations. It was found that orographically forced upward vertical motion has shown the relation to rainfall enhancement around the midnight at windward side of Annam range in the north of the KPAN. The convergence has shown the relation to rainfall enhancement over plain of the KPAN at the early morning. The diurnal variation of the local wind circulation might produce cold downslope winds that enhance the early morning rainfall over plain of the KPAN.

Chapter 6 Conclusions

Most countries affected by the Asian monsoon lack high-spatiotemporal-resolution rainfall products. Thus, composite gauge-calibrated ground-based radar data are considered useful for furthering the understanding of the patterns of diurnal variations in rainfall over the ICP. The orography in the mid-ICP has been shown to be significant in the diurnal cycles of rainfall. The application of classification regimes for grouping the propagating rain systems has increased the understanding of rainfall variations in the ICP. Furthermore, our discovery of the southeastward propagating rainfall systems over the KPAN is considered an essential step towards understanding the early morning rainfall that occurs over inlands areas of the ICP.