Inter-annual and spatial variation of altitudinal increase in rainfall over Mount Inthanon and Mae Chaem Watershed, Northern Thailand

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Abstract:

To understand the inter-annual and spatial variation of altitudinal increase in rainfall amount, duration and intensity over Doi (Mount) Inthanon and Mae Chaem Watershed, Northern Thailand, we have conducted rainfall observations in this area since 1997. Ten years of continuous data for 18 rain gauge stations were accumulated. Altitudinal increases in rainfall were observed for all nine years. Annual rainfall hours also had an altitudinal increase, whereas mean rainfall intensity had no clear altitudinal increase for the nine year period. Not only altitudinal rainfall increase but also inter-annual rainfall fluctuation was determined from the variations of rainfall hours. There was no difference in the intensity of altitudinal increases in rainfall between the western and eastern slopes of Doi Inthanon.

KEYWORDS Rainfall; Altitudinal increase; Inter-annual variation; Mae Chaem Watershed; Doi Inthanon

INTRODUCTION

Mountainous watersheds in the Asian monsoon region have important roles for people living downstream in terms of water resources and natural disaster prevention. Rainfall in mountainous regions is a crucial factor determining the possibility of water resource shortages, flooding, landslides and debris flow. The operational rainfall observation sites were distributed in an easily accessible downstream area; however, a rainfall observation site in a mountainous watershed area was lacking.

We established a rain gauge network in a mountainous watershed in Mae Chaem Watershed, Northern Thailand since September 1997 to understand the spatial and temporal variability of rainfall. Some preliminary results from these observations have been published by Dairaku *et al.* (2000) and Kuraji *et al.* (2001). Dairaku *et al.* (2000) reported the altitudinal increase in rainfall in this watershed using data from 1 June until 23 November, 1998 obtained by 13 rain gauges. Kuraji *et al.* (2001) also examines rainfall in this watershed using data from June 1998 until October 1999. They found that the altitudinal increase in rainfall was obvious in the two wet seasons in 1998 and 1999 with the increment in 1999 being more than 2.5 times greater than in 1998. The altitudinal increase in rainfall was also obvious in the dry season from 1998 to 1999, but the increment was smaller than those in the two wet seasons. It was not the rainfall intensity but the rainfall observed hours which causes the difference of altitudinal increment. Dairaku *et al.* (2004) reported the

Figure 1. Map showing location of rain gauge sites in and around the Mae Chaem watershed. The dark (blue) and bright (yellow) color indicate low and high elevation, respectively.

contribution of rainfall frequency, intensity and duration of several rainfall categories to the rainfall amount in the watershed using data from June to October for 1998 and 1999. However, these reports were based upon less than 2 years data from just 13 rain gauges and the universality and robustness of those findings have not yet been tested.

The objective of this paper is to present new findings that were not shown in previous papers by using 10 years of continuous data collected from 18 rain gauge sites. We sought to present (1) inter-annual fluctuations of rainfall and altitudinal increases in rainfall, and (2) a comparison of altitudinal rainfall increases between east and west slopes of the mountain range.

METHODS

The rainfall observation network was established in the Mae Chaem watershed and on an eastern ridge outside the watershed, in northern Thailand (Figure 1). The highest point of the watershed is Doi (Mount) Inthanon located on the eastern ridge, where No. 7 is located. The network consists of 18 rain gauges (No. 34-

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T: Ota Keiki Co., 20 cm orifice diameter and 0.5 mm per tip) with pulse count time-recording data loggers (KADEC-PLS II: KONA System Co., one second time resolution). We installed two sites in September and seven sites in November 1997; four sites in May 1998; and two sites in November 1999. All 15 sites were located in the Mae Chaem watershed. To compare the east and west sides of the mountain range, two more rain gauges were installed on the east slope of Doi Inthanon in May 2004 (No. 18 and 19) and another rain gauge in November 2005 (No. 17). The locations, names and altitudes of these 18 rain gauge sites are shown in Figure 1 and Table I (Kuraji *et al.*, 2007). The No. 16 site is a river discharge monitoring site and is therefore not shown in Table I. This watershed has been intensively studied in terms of small watershed hydrological modeling studies (Lim *et al.*, 2004, Thanapakpawin *et al.*, 2007, Vongtanaboon *et al.*, 2008).

RESULTS AND DISCUSSION

Inter-annual variation of altitudinal increase in rainfall

Figure 2 shows the relationship between annual rainfall and altitude from 1999 to 2007. Altitudinal increases in rainfall are clearly shown for all years. The

correlation coefficient between annual rainfall and altitude was higher than 0.87 for all years. Annual rain hours also had altitudinal increases (Figure 2). Average rainfall intensity, however, had no altitudinal increase and was almost constant (2–2.5 mm/hour) for all years. These relationships have already been reported by Kuraji *et al.* (2001) using data taken over less than 2 years; the present study confirmed these relationships were universal for 9 years. At site No. 14, average rainfall intensity in 2000 was 3.59 mm/hour, relatively high compared with the values of the other sites and in other years. We investigated and found that high intensity rain events were observed three times in September 2000 at site No. 14. These were 12.5 mm of rain for 8.35 minutes on the 11th, 13.5 mm for 13.1 minutes on the 21st and 34.0 mm for 8.35 minutes on the 24th of September. Except for these events, heavy rainfall events rarely occurred in this watershed during the observation period and at other sites.

Inter-annual fluctuations of rainfall at each site

Figure 2 also shows that annual rainfall, annual rain hours and average rainfall intensity had inter-annual fluctuations. Figure 3 shows inter-annual variations in annual rainfall and annual rain hours at 3 sites (No. 3, 7, and 8) from 1999 to 2007. From Figure 3, it can be seen that rainfall and rain hour had a similar fluctuation pattern. The correlation coefficients between annual rainfall and annual rain hours were greater than 0.59 for all 15 sites in the Mae Chaem watershed. Only one site had a smaller correlation coefficient between inter-annual fluctuation in annual rainfall and that of annual rain hours than that of average rainfall intensity. Not only altitudinal rainfall increase, but also inter-annual fluctuation in rainfall was determined by annual rainfall hours rather than average rainfall intensity.

To understand the influence of rainfall on the inter-annual fluctuation in rainfall, inter-annual variations in annual rainfall and weak rainfall (rainfall intensity less than 5 mm/hour) at 3 sites (No. 3, 7, and 8) from 1998 to 2007 were shown in Figure 4. Dairaku *et al.* (2004) suggest that weak rainfall intensity events contribute to the altitudinal rainfall, and we found here that the inter-annual fluctuation is also influenced by the inter-annual fluctuations of the frequency of weak rainfall intensity events.

Spatial variations of altitudinal increase in rainfall

Figure 5 shows a comparison of altitudinal increases in rainfall (right), annual rainfall hours (center) and

Table I. Station name and altitude (m)

No.	Name	Altitude
1	Wat Chan	990
2	Bo Kaeo	1400
3	Mae Sa	650
4	Mae Yod	1180
5	Mae Ning	1630
6	Mae Jon Luang	1470
7	Doi Inthanon	2565
8	Mae Klang	1540
9	Research Station	1100
10	Mae Chaem POU	490
11	Mae Long	1450
12	Sirikit Plantation	1330
13	Ob Luang	380
14	Huay Bong	810
15	Mae Tho	1250
17	Kloy Mai	670
18	Chom Thong	280
19	Huay Sompoi	1100

Figure 2. Altitudinal increase in annual rainfall (left), annual rainfall hours (center) and average rainfall intensity (right).

Figure 3. Inter-annual variations in annual rainfall (black rectangles, triangles and diamonds) and annual rain hours (white rectangles, triangles and diamonds) at No. 7 (Doi Inthanon), No. 8 (Mae Klang) and No. 3 (Mae Sa) sites.

Figure 4. Inter-annual variations in annual rainfall (black rectangles, triangles and diamonds) and weak rainfall (intensity less than 5 mm/hour) (white rectangles, triangles and diamonds) at No. 7 (Doi Inthanon), No. 8 (Mae Klang) and No. 3 (Mae Sa) sites.

average rainfall intensity (right) between the west (site Nos. 6, 8, 10, 12) and the east (site Nos. 17, 18, 19) sides of the mountain range. Because the rain gauges on the east side of the mountain were installed in May 2004, only data from 2005 to 2007 were used. Rainfall at Doi Inthanon (No. 7) is also shown for reference. From Figure 5 we found that there was no clear difference in altitudinal rainfall increase in the annual rainfall and annual rainfall hours between the west and east sides of the Doi Inthanon mountain range. In monsoon regions dominant wind reverses with seasons, and consequently upwind and downwind sides also reverse. As for Doi Inthanon, the eastern slope is the downwind side in summer. Figure 6 is the same as Figure 5 but only for May-June-July (MJJ) rainfall when the predominant wind direction is southwest. From Figure 6 we found that there was no clear decrease in rainfall along the eastern (downwind) side and conclude that no rain

shadow effect appeared around Doi Inthanon during the summer rainy season.

The east side of Doi Inthanon has suffered from a serious water shortage (Walker, 2003) and people believed the area is in the so-called rain shadow of Doi Inthanon. This study shows that there are no differences between the east and west sides of the mountain in terms of rainfall; suggesting there might be another factor affecting the water resources shortage problem, which occurred mainly on the eastern side of the mountain (Kuraji and Kowit, 2000).

CONCLUSION

This study confirmed the universality of previous studies on altitudinal increases in rainfall, rain hours and average rainfall intensity in the Mae Chaem water-

Figure 5. Comparison of altitudinal increases in annual rainfall (left), duration (center) and average rainfall intensity (right) between the west and east slopes of Doi Inthanon. The three sites in the ovals (Nos. 17, 18, 19) are located on the east slope of Doi Inthanon, whereas the other sites (Nos. 6, 7, 8, 10, 12) are located on the west slope of Doi Inthanon. The annual rainfall data at the following stations and years were not recorded and do not appear on the graphs; at Nos. 17 and 18 in 2005, at Nos. 12 and 19 in 2006 and at No. 12 in 2007.

Figure 6. Same as Figure 5 but for May-June-July (MJJ) rainfall.

shed. Ten years of data accumulation enabled us to present the inter-annual fluctuations of rainfall, rain time, average rainfall intensity and altitudinal increases. Although recent advances in rainfall observation through remote sensing systems such as radar or satellite are remarkable, difficulties still remain, especially for mountainous areas with complex topography. A ground based rain gauge network is still essential to study rainfall characteristics in mountainous watersheds.

Natural water-related disasters such as flooding, landslides and debris flows, as well as social conflicts over water resources between upper and lower dwelling inhabitants of a watershed are steadily becoming more serious in South East Asia. One reason the watershed management system of a government might not work effectively to resolve such conflicts is the paucity of hydro-meteorological data for evaluation of heavy rains, water supply, consumption and shortages, due to an insufficient hydro-meteorological observation network. This study shows an example of a dense rain gauge network in a mountainous area where almost no hydro-meteorological information had been available before. Such observation networks will be essential for watershed management to realize disaster mitigation and to resolve social conflicts over water resources in the South East Asian region.

This study focuses on inter-annual variation in altitudinal increase in rainfall but the seasonal variation of altitudinal increase in rainfall is the other important topic that needs to be studied. Okumura *et al.* (2003) examined the diurnal variation in rainfall observed by meteorological radar at Om Koi in Northern Thailand and found the rainfall characteristics were influenced by wind direction, which reverses with monsoonal transition. Synoptic disturbances such as tropical storms may also play a role in the inter-annual fluctuation in rainfall in this region. To carry out such studies we must prepare a combination of observational data (rain gauge network, meteorological radar and satellite) and reanalysis data. The region in this study is one of the possible sites where a combined data set will be available. We expect that much more hydro-meteorological research will be conducted over this site in the near future leading to applications for solving local societal issues.

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