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EFFECT OF METEOROLOGICAL EVENTS ON FLOOD OCCURRENCE IN BATMAN, TURKEY

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The purpose of this study is to evaluate the effect of meteorological events on the occurrence of floods in Batman in the southeastern Anatolia Region of Turkey. Batman is an urban area, which has a high risk of floods due to its location along the stream bed of Iluh Creek. No recent flood or torrent event in this area has caused as much damage as that on October 31-November 1, 2006, which caused 10 deaths in the city center in addition to material damage of 15 million Euros. The total amount of precipitation on October 31 is measured as 30 mm with a total of 57 mm precipitation on the next day giving rise to a catastrophic flood occurrence. The daily maximum precipitation of 57 mm is not the highest recorded; a precipitation value of 69.2 mm is measured in April 1999. Intense precipitation in Batman on October 31 and November 1, 2006 fell in these two days of a one-week rainy period. One week of rainfall on the ground causes a decrease in the water absorption capacity of the soil. In such an environment, almost all of the 16 mm rainfall that fell within 15 minutes on October 31 became runoff and led to the flood event. The exceedance probability of this rainfall, with an intensity of 10.6, is 2.43%. In order to determine the effect of meteorological events on the occurrence of such a catastrophe, annual, daily and within-the-day intense rainfalls are analyzed systematically. Besides meteorological conditions, the encroachment of stream beds by urbanization and industry compounds the loss of life and property.

INTRODUCTION

Landslides, floods and torrents that occur after a long and intense precipitation may lead to substantial damages and deaths. Adverse weather conditions and all associated events are defined as hydrological events (Petrucci and Polemio, 2003, 2009; Petrucci et al., 2009). Such events have been frequently encountered in rather larger urban areas in recent years.

Some important problems concerning urban settlements have come about as a result of rapid developments in the Turkish economy and migrations from rural areas towards the city. Among natural disasters in Turkey, floods rank second after earthquakes, which lead to life loss and property. The occurrence and effects of floods in Turkey have increased during recent years and precautions are necessary, which have been presented in various studies (Köse et al., 1991; Yalçinlar, 1995; Ertek, 1995; Koçman et al., 1996; Uzun, 1995; Biricik, 1997; Şahin, 2002; Gürer et al., 2004; Kopar et al., 2005; Turoğlu and Özdemir, 2005; Buldur et al., 2007; Şahinalp, 2007; Sezen et al., 2007).

Floods also occur as serious meteorological catastrophes in central Turkey as well as coastal areas. Heavy downpours and the occupation of stream beds by settlements are among the most effective factors on the flood occurrences. Floods that lead to the maximum probable loss occur mostly at urban areas, where the rate of runoff has increased two to six fold compared to natural surfaces (Şen, 2003).

Batman (long: 38^{o} 40' - 37^{o} 50' North and lat: 41^{o} 10' - 41^{o} 40' East) is located in the Southeastern Anatolia Region (SAR) of Turkey between Mountain Kira and Raman in the southeastern part of Diyarbakir Basin (Figure 1). Batman city is founded on the former meander spur terraces of Batman Creek flowing through the northern side of Bati Raman Mountain in the direction from north to south. Higher terraces are split by Iluh Creek flowing from the east whereas the lower terraces are covered by alluvial fans formed by the same stream (Tonbul and Sunkar, 2008).

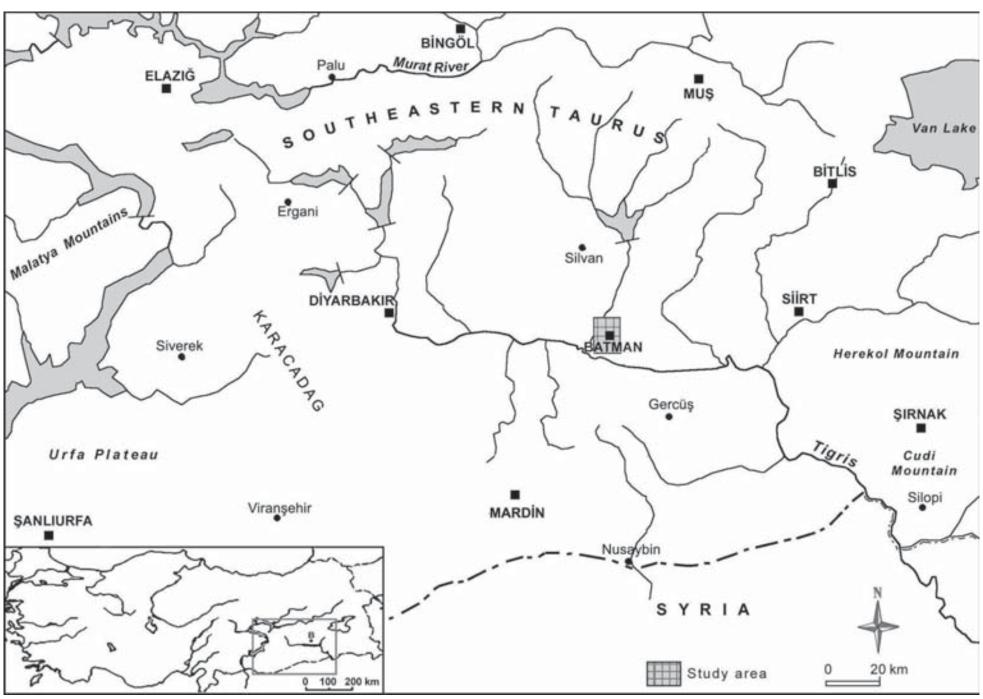

Figure 1. Location map of Batman, Turkey.

Great floods occurred as a result of intense precipitation in the SAR of Turkey in the Autumn, 2006. In this period, 46 people died and 30,975 people were injured (Red Crescent Disaster Report, 2007). Batman city is one of the most affected urban areas throughout the region (Figure 2). The flood of October 31 and November 1, 2006 caused to 11 deaths, including 10 in the city center and 1 in the suburban district of Hasankeyf.

Floods started to appear to be more severe in Batman after 1970 due to the rapid urban development. Over a short period, this city became a small-scale industrial center in the region with labor migrations from the immediate surroundings due to the establishment of refineries and other petroleum plants. It had also immigrants for security reasons in recent years. The recent rapid development of the city has brought about unguided and unplanned urbanization. The migrant population has promoted illegal settlements in general along the stream beds, and in particular in the stream bed of Iluh Creek that flows through the city. In addition, the channelizing of Iluh Creek was completed in 2005 but it does not have the capacity to carry flood water, because it was built without considering the basin area outside the natural channel bed. These factors led to a doubling of the effect of floods on properties and lives.

In the Batman region summers are considerably hot, whereas winters are relatively warm and rainy. The area remains under the influence of the Basra low pressure center throughout the summer season with dry and hot air masses that prevail in the area. In summer, it is affected by hot and dry winds once the Basra low pressure center expands towards Anatolia. In winter, it remains under the effect of frontal systems from the Central Black Sea in the north, which brings rainfall until April (Atalay and Mortan, 2006). The frontal systems come from the Central Black Sea area from the northwest and start to affect in the autumn season the city, and there is more or less rainfall due to various factors. Polar and tropical borne air masses are effective in the SAR in different periods, and hence the distribution and intensity of climatic elements vary considerably. These air masses are effective on various climatic elements, especially on temperature and precipitation (Gürgen, 2002).

Figure 2. Treatment channel built on the part of Iluh Creek in the city center of Batman (a,b - dwellings built on the former stream bed around the channel were considerably affected by the flood in 2006. c,d - great torrents occurred around the channel after the flood).

A frontal system led to the flood event in Batman on the night of October 31-November 1, 2006. It was formed during the passage of low pressure systems (depression, cyclone) based on a frontal system from the Central Mediterranean. Although such a formation is normally expected, its transition in Turkey may sometimes give rise to more precipitation than usual leading to flood disasters and hazards (Koçman et al., 1996)). Floods in Turkey are not due only on climatic conditions, but also from unplanned settlements and accordingly insufficient infrastructure (Gürer and Özgüler, 2004).

The flood occurrences around Batman in the autumn of 2006 had an unprecedented effect. The most important factors for the occurrence of floods are meteoro–climatologic conditions. Although the catastrophic effects of floods are also associated with geological, geomorphologic, climatic, and hydrographical characteristics, and soil and vegetation properties, as well as human factors, only meteorological factors have been considered in this study.

METHODOLOGY AND DATA

Meteorological data and synoptic maps are employed in the present study in order to describe the effect of meteorological events on the occurrence of floods in and around Batman on October 31-November 1, 2006. Meteorological measurements are obtained from the General Directorate of State Meteorological Services. The data used in the meteorological analysis are precipitation records from Batman Meteorological Station from 1970 to 2006 on monthly and daily minimum and maximum records at standard times. In synoptic evaluations, location maps for 31 October and 1 November 2006 are also employed.

In order to determine the effect of meteorological events on the flood occurrence in Batman, first daily maximum precipitation and then maximum precipitation at standard times are analyzed. For meteorological analyses, primary data are composed of pressure, temperature, humidity of the atmosphere and wind data (Saucier, 2003).

The probability of maximum precipitation leading to flood is calculated according to formulas frequently used for hydrology data and also data with unknown probability distributions. In such sequencing, the number of consecutive maximum precipitation values is sorted from biggest to smallest for n years. According to the sequence number *1, 2, … n* from the biggest to the smallest, the precipitation value corresponding to each number is accepted as the rank of the given maximum precipitation. Using this rank, m, a probability of exceedance (P_{exc}) for each maximum precipitation is attached empirically according to the following formula (Şen, 2009).

$$(P_{exc})_m = m/(n+1) \tag{1}$$

where $(P_{exc})_m$ represents the probability of exceedance with rank, m. In order to find the maximum recurrence intervals of precipitation, the following formula is used for maximum n value,

$$(1/T) = m/(n+1) \tag{2}$$

In order to determine the intensity of precipitation, the formula developed by the General Directorate of Meteorological Services is chosen, where precipitation that leaves a certain amount of water within a certain time is defined as intense precipitation (Kömüşcü et al., 2003).

$$R = \sqrt{5t - \left(\frac{t}{24}\right)^2} \tag{3}$$

where R is the mount of precipitation (mm) and t is its duration

According to this equation, a precipitation of 8.6 mm within 15 minutes is described as intense precipitation. The intensity of precipitation on 31 October 2006 is calculated as 10.6 mm. If this value is compared to the infiltration capacity of the Iluh Creek basin (average 28.9 mm/h) then it is possible to understand that the precipitation exceeded the infiltration capacity of the basin leading to runoff and subsequent flooding.

In order to find the infiltration capacity of Iluh Creek basin, infiltration tests are carried out at different but representative points.

EFFECT OF METEOROLOGICAL CONDITIONS ON THE OCCURRENCE OF FLOODS

The effective precipitation, which leads to flooding in Turkey, has mostly orographic or frontal characters on the Black Sea, Marmara, Aegean and Mediterranean coastlines. Besides frontal, orographic, and convectional precipitations are also effective in the inner and eastern parts of Turkey (Şahin and Sipahioğlu, 2007). The flood occurrences in various seasons across Turkey are based on the above-mentioned precipitation types and other meteorological conditions (Kron, 2002; Kömüşçü et al., 2003; Ceylan et al., 2007)

The prevailing precipitation regime in Batman and its surroundings is distinguished from the Mediterranean precipitation regime, in that more precipitation falls in the spring season due to continental factors. For this reason, the prevailing precipitation regime in the area is called the Delayed Mediterranean Precipitation Regime (Koçman, 1993). Likewise, Sezer (1969) described the precipitation regime in the area as impure or distorted Mediterranean type. On the other hand, Türkeş (1999) analyzed the precipitation data from 91 meteorological stations across Turkey and divided Turkey into seven regions by the precipitation regime. In this classification, the SAR including Batman is located in the Continental Mediterranean Precipitation Regime Region. In the subsequent studies, the Mediterranean and Continental precipitation regime regions are separate from each other. According to the aforementioned study carried out by Türkeş and Tatli (2010), the area of investigation is located in the Continental Eastern and SAR Precipitation Regime Region.

One of the most striking events in the SAR in the meteorological sense is the frequency of precipitation deviations. In this region, the rate of precipitation below or significantly over the average is considerably high. Minimum precipitation may fall to 30% of the annual average. On the other hand, maximum precipitation may sometimes rise to 2 or 3 times over the annual average. Floods after daily precipitation are significantly over the average and downpours occur in summers and they are the primary climatic events leading to loss of life and property in the region (Gürgen, 2002).

The annual average of precipitation in Batman is about 485 mm and its large part has a downpour character. In a broader sense, daily precipitation over an average of 25 mm is regarded as a downpour, whereas precipitation below this value is accepted as normal precipitation in regions where the Mediterranean climate prevails (Dönmez, 1990). Precipitation that leaves a certain amount of water in a certain period of time is defined as intense precipitation, which is caused by medium scale convective systems (Aullo et al., 2002; Delrieu et al., 2005). Heavy downpours in Batman during the Spring and Autumn are effective in flood occurrences. Furthermore, subsequent precipitation may also trigger flooding after heavy downpours.

FINDINGS

Intense Precipitation Floods

Excessive precipitation occurrence around Batman in the evening hours of 31.10.2006 is associated with compression of the frontal system coming from the Mediterranean Sea and the southeastern Taurus Mountains. Although Batman city and its immediate surroundings have a plain structure in terms of geographical formation, it may remain under the orographic influence of the southeastern Taurus Mountains located on the northern side. The aforementioned frontal system that entered the SAR on 25.10.2006 and prevailed for approximately one week gave rise to intense precipitation after one-week compression and fresh breezes.

Examination of the synoptic location map of the SAR for 31 October 2006 indicates excessive precipitation and flood occurrence after a low pressure area shifting towards the east of Iceland under a high pressure center over Eastern Europe. Likewise, a low pressure center over the Central Mediterranean and a high pressure center to the south of the Caspian Sea also played additional significant role (Figure 3a). A polar front over Eastern Europe and a Mediterranean front over the Central Mediterranean formed between these centers.

It is striking that the high pressure center at the south of the Caspian Sea extended towards Anatolia and then the low pressure center coming from the Central Mediterranean moved in a south to north-northeast direction on 31 October 2006 at 2 p.m. local time (Figure 3a). The low pressure center of Central Mediterranean origin rapidly moved in the direction of the high pressure center coming from Western Europe, and passing over the north of Africa, which rose over the high pressure center penetrating into Anatolia like a tongue and hence brought excessive precipitation at the maximum rate with a temperature decrease during the evening hours, and hence the subsequent flooding took place.

The precipitation started at 2 p.m. on October 31, 2006 and reached maximum level once the air masses from the north, become damp, hit and rose over the southeastern Taurus Mountains at around 7 p.m. coupled with the temperature decrease in the evening hours.

The frontal system from the Central Mediterranean led to significant floods in the SAR but lost its effect on November 1, 2006. This situation is clearly observed in the synoptic location map (Figure 3b).

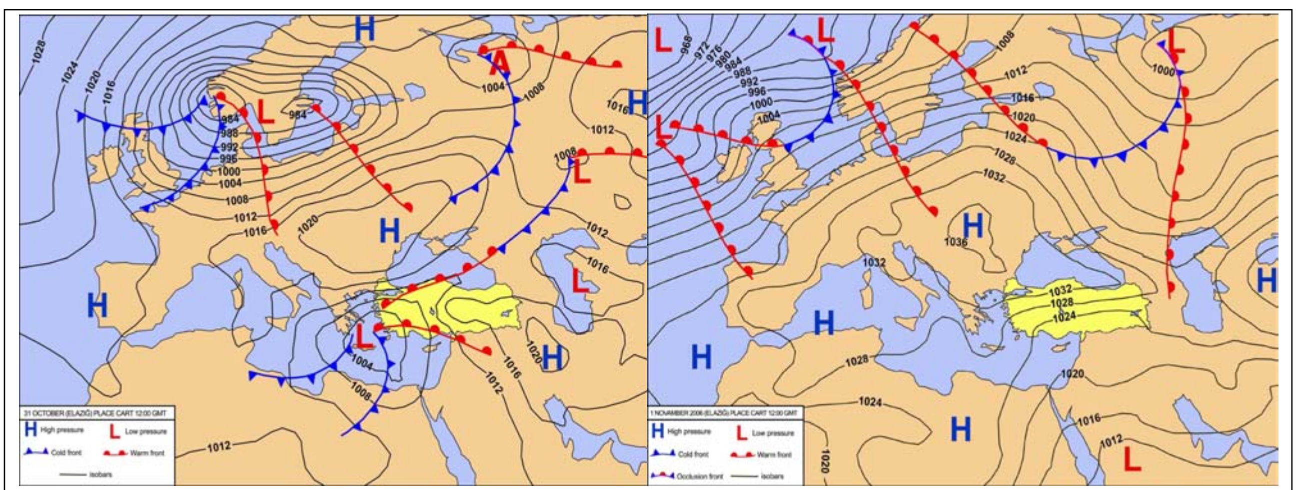

Figure 3. Synoptic location map for 31 October (a)-1 November (b) 2006, 2 pm local time.

Analysis of Daily Maximum Precipitation in Batman (1970-2006)

Evaluation of maximum precipitation causing significant floods in the past revealed that it lasts a short time and is more effective in the occurrence of floods than daily maximum precipitation (Sezer, 1997; Gürgen, 2004; Şahin and Sipahioğlu, 2007; Kömüşçü et al., 2003).

Batman has proximate levels to other provinces in terms of maximum precipitation values in the SAR (Table 1). However, *excessive* downpours as well as topographic structure, ground and vegetation properties are effective in the frequent occurrence of floods (Atalay, 1986; Balci and Öztan, 1987; Cooker and Doornkamp, 1990; Hoşgören, 1992; Strahler and Strahler, 1997; Görcelioğlu, 2003; Turoğlu and Özdemir, 2005).

Regarding the event in this study, the air mass hitting and rising over the southeastern Taurus Mountains brought a precipitation of 57 mm into the area on the last day of the same week. However, the maximum precipitation of 57 mm measured on 1 November 2006, one day after the flood event, is not the highest value recorded (1970-2006). A daily maximum precipitation of about 69 mm in April 1999 is the highest during record period (Figure 4). The total amount of precipitation in Batman on the day of flood occurrence (October 31) is about 30 mm. More than half of the daily maximum precipitation values in the recorded period exceeded this value. Although daily maximum precipitation is effective in the occurrence of floods, it may not always lead to floods. This indicates that precipitation within a certain time rather than daily maximum precipitation is more effective on the flood occurrence in Batman.

It can be seen from Table 2 that daily maximum precipitation values are higher than monthly average precipitation in some months (Figure 5). The highest value of maximum precipitation is measured in the Spring months, whereas the lowest value appears in the Summer months.

Table 1. Maximum Precipitation Values SAR by month (1970-2006)

Provinces	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Batman	40.2	37.3	42	69.2	63.4	20.4	4	4.4	13.8	36.2	57	41.8
Diyarbakır	52.2	48.5	71.6	63.2	44.1	28.5	3.1	3.8	20.0	44.0	43.4	51.0
Mardin	140.0	145.9	65.4	112.2	57	35.8	5.0	2.3	10.8	81.9	83.0	94.0
Siirt	51.9	53.2	51.2	71.4	68.1	16.7	22.2	12.2	14.2	65.6	57.4	50.1
Şırnak	50.2	48.7	42.3	53.1	49.5	12.1	38.4	1.8	10.5	52.2	58.5	91.4

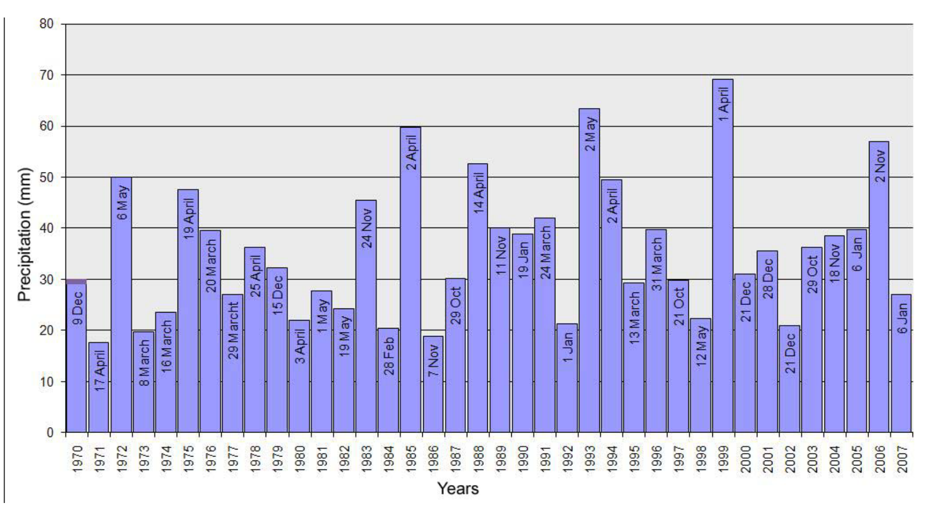

Figure 4. Daily maximum precipitation in Batman by year (1970-2007).

Among the daily maximum precipitation for Batman according to long-term records (1970-2006), the exceedance probability of the maximum precipitation of 57 mm on 31 October to 1 November 2006 is about 9.75%. Although this percentage is not so high, it represents a strong risk in terms of floods.

Although maximum precipitation in Batman appears in April or May, floods in Autumn are more effective with sudden downpours, vegetation, and overall land use. Downpours in April and May have convectional character due to temperature increase, while in October, November and March they are based on the displacement of warm and cold fronts.

In Batman and its surroundings, the number of rainy days (84.8) is limited and in accordance with the character of the Mediterranean precipitation regime. However, the amount of daily precipitation contributes to the intensity of precipitation. The difference between the amount of precipitation and the number of rainy days indicates that a large part of the precipitation falls as downpours (Table 3).

Table 2. Values of daily maximum precipitation in Batman by month (1970-2006).

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum Precipitation	40.2	37.3	42	69.2	63.4	20.4	4	4.4	13.8	36.2	57	41.8
Average Precipitation	58.6	68.6	80.6	70.5	40.4	7.4	0.3	0.4	2.6	28.1	56.3	70.9

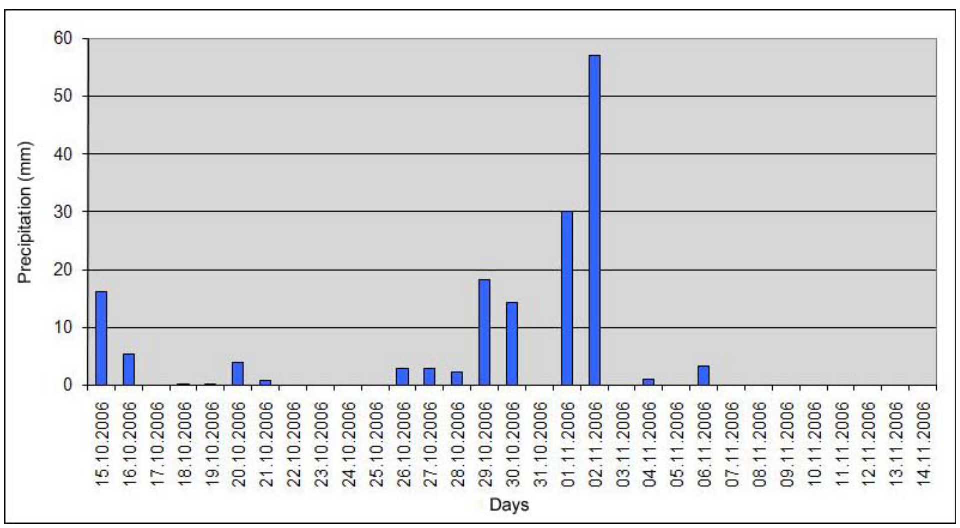

Figure 5. Long-term (1970-2006) monthly total precipitation and daily total precipitation in Batman. It is noted that the daily maximum precipitation rate in the spring season in which flood and torrent events occur is higher than monthly average values.

Table 3. Total number of rainy days per month (1970-2006).

Precipitation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1-25	399	373	407	404	280	182	15	13	34	212	285	368
25-50	4	6	12	11	4	0	0	0	0	5	11	12
50>	0	0	0	3	2	0	0	0	0	0	1	0
Total	403	379	419	418	286	182	15	13	34	217	297	380

It has been stated that vegetation and land use are also effective in the relatively higher risk of flood occurrences due to downpours in the Autumn despite the abundance of precipitation in the Spring, where although the soil is saturated the runoff time of is delayed, as this season coincides with the foliation and growth periods of steppe-type vegetation. Consequently, the stream flow is delayed and part of the precipitation is absorbed by plants (Sunkar and Tonbul, 2009). However, in the Autumn crops are harvested and steppe–type vegetation fades away, thus the runoff rate increases.

Daily Maximum Precipitation

The precipitation causing to flood event in Batman on October 31-November 1, 2006 is evaluated in two different ways. Firstly, according to daily maximum precipitation and secondly, according to maximum precipitation within the day. Within the context of maximum precipitation, the highest precipitation values are observed at standard times.

According to daily precipitation values towards the end of October and beginning of November 2006, effective precipitation fell for one week in the period with flood occurrences (Figure 6). The precipitation started in the last week of October and reached maximum level on the first day of November. Rainfalls at maximum levels are considerably effective in the flood occurrence on October 31-November 1, 2006. Before the flooding took place, the infiltration of rainfalls through the ground causes a decrease in the water absorption capacity of soil

The amount of precipitation in Batman at standard times in 2006 within a period of 15 minutes is the highest value measured in the observation period (Table 4). According to the results of probability calculations, the exceedance probability of higher precipitation values is low, whereas that of lower precipitation values is high (Table 4).

The same table shows the rank, probability and recurrence intervals of maximum precipitation at standard times in Batman Meteorology Station. The values in the probability column give the equality to or exceedance of maximum precipitation. The exceedance probability of 16 mm precipitation in Batman within 15 minutes in 2006 is about 2.43%.

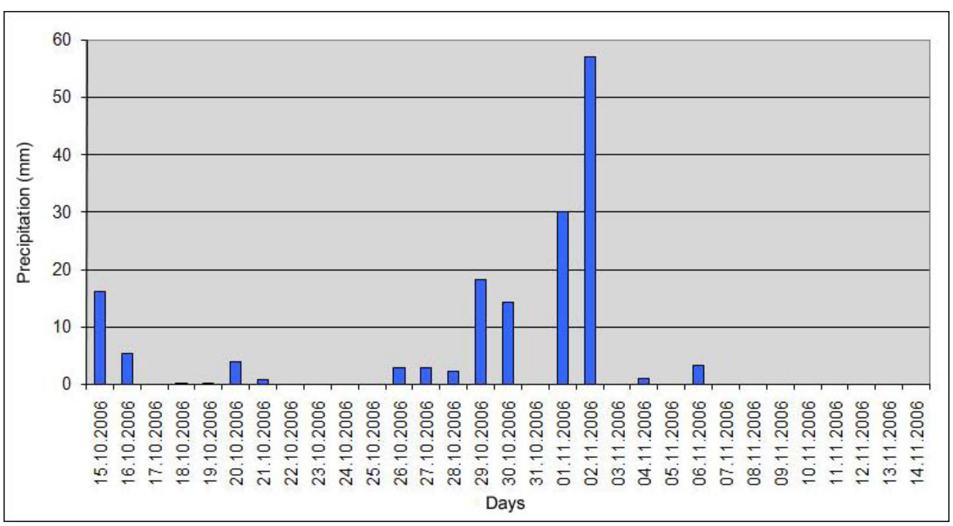

Figure 6. Daily precipitation values for Batman in the one-month period (The absence of precipitation on October 31 when the flood disaster occurred is due to the meteorological recording system. Measurements are made from 7 am, 2 pm, 2 pm, 9 pm, and 9 pm, 7 am. Those for 9 pm-7 am are recorded the following day).

Table 4. Highest precipitation values observed at standard times in Batman meteorology station and realization probabilities.

Observation	Maximum Precipitation at Standard Times (mm)					Rank	Gradational Maximum Precipitation (mm)					Prob. %	Recurrence
Year	5 min	10 min	15 min	30 min	24		5	10	15	30	24		
2008	2.7	5.1	7.4	9.0	21.4	1	9.7	12.8	16.0	21.9	69.2	2.43	41.00
2007	3.1	3.7	4.7	5.3	27.0	2	9.5	12.5	15.6	20.8	63.4	4.87	20.50
2006	6.6	8.7	16	19.2	57.0	3	9.3	10.7	14.8	20.7	59.8	7.31	13.66
2005	1.5	2.2	2.9	4.1	39.8	4	8.2	10.0	13.4	19.2	57.0	9.75	10.25
2004	3.3	3.8	5.1	9.6	40.2	5	7.6	9.9	12.9	17.0	52.6	12.19	8.20
2003	8.2	12.8	14.8	20.8	36.2	6	7.4	9.7	12.3	14.6	50.0	14.63	6.83
2002	4.1	4.8	5.7	10.3	36.6	7	7.0	9.1	11.5	14.3	49.4	17.07	5.85
2001	2.3	3.9	4.8	6.4	35.6	8	6.7	9.0	10.1	13.7	47.5	17.51	5.12
2000	3.8	4.7	5.2	5.8	22.0	9	6.6	8.9	10.1	12.6	45.5	21.95	4.55
1999	1.4	2.1	2.9	3.9	69.2	10	6.1	8.7	10.0	12.1	42.0	24.39	4.10
1998	4.4	8.3	10.1	10.2	25.2	11	6.0	8.6	10.0	12.0	40.1	26.82	3.72
1997	6.1	8.6	10.0	12.1	29.8	12	5.6	8.3	9.9	11.6	39.8	29.26	3.41
1996	1.4	2.9	4.3	7.2	39.7	13	5.4	8.0	9.5	10.8	39.7	31.17	3.15
1995	4.1	4.8	6.2	8.1	31.6	14	5.3	7.4	9.5	10.3	39.5	34.14	2.92
1994	5.4	7.0	9.5	14.3	65.5	15	5.0	7.3	8.1	10.2	38.9	36.58	2.73
1993	3.1	4.7	6.7	8.1	63.4	16	5.0	7.0	7.8	10.2	38.5	39.02	2.56
1992	4.5	7.4	7.8	12.6	21.5	17	4.5	5.7	7.4	9.8	37.1	41.46	2.41
1991	9.3	9.9	10.1	10.8	42.0	18	4.4	5.6	6.9	9.6	36.3	43.90	2.27
1990	5.0	8.9	11.5	12.0	38.9	19	4.3	5.4	6.7	9.1	36.2	46.34	2.15
1989	5.6	9.0	12.3	20.7	40.1	20	4.1	5.1	6.2	9.0	35.6	48.78	2.05
1988	1.5	3.5	4.0	5.4	52.6	21	4.1	5.1	6.2	8.1	33.1	51.21	1.95
1987	1.6	2.7	3.8	5.9	30.1	22	4.0	4.8	5.8	8.1	31.0	53.65	1.86
1986	3.1	4.4	6.2	7.9	18.9	23	3.8	4.8	5.8	8.0	30.1	56.09	1.78
1985	2.8	5.1	5.1	6.5	60.6	24	3.6	4.8	5.7	7.9	29.8	58.53	1.70
1984	2.0	2.5	2.6	3.1	20.4	25	3.3	4.7	5.2	7.2	29.2	60.97	1.64
1983	4.0	4.8	4.8	5.2	45.5	26	3.1	4.7	5.2	6.7	29.1	63.41	1.57
1982	9.7	12.5	13.4	21.9	24.3	27	3.1	4.4	5.1	6.5	28.6	65.85	1.51
1981	5.3	5.7	5.8	5.9	33.1	28	3.1	3.9	5.1	6.4	27.1	68.29	1.46
1980	7.0	8.0	9.5	9.8	22.5	29	3.0	3.8	5.0	6.4	27.0	70.73	1.41
1979	6.0	9.1	10.0	11.6	37.1	30	2.8	3.8	4.8	6.4	24.3	73.17	1.36
1978	3.0	3.3	3.9	8.0	36.3	31	2.7	3.7	4.8	5.9	23.5	75.60	1.32
1977	9.5	10.0	12.9	14.6	27.6	32	2.7	3.5	4.7	5.9	22.4	78.04	1.28
1976	4.3	5.4	5.8	6.4	39.5	33	2.3	3.5	4.3	5.8	21.9	80.48	1.24
1975	5.0	5.6	6.9	10.2	47.5	34	2.0	3.3	4.0	5.4	21.5	82.92	1.20
1974	6.7	7.3	8.1	9.1	23.5	35	1.6	2.9	3.9	5.3	21.4	85.36	1.17
1973	1.2	1.6	2.0	2.8	19.8	36	1.5	2.7	3.8	5.2	20.4	87.80	1.13
1972	7.4	9.2	9.9	13.7	50.0	37	1.5	2.5	2.9	4.1	20.4	90.24	1.10
1971	2.7	3.5	5.2	6.7	17.7	38	1.4	2.2	2.9	3.9	19.8	92.68	1.07
1970	3.6	3.8	5.0	6.4	29.1	39	1.4	2.1	2.6	3.1	18.9	95.12	1.05
1969	7.6	10.7	15.6	17.0	28.6	40	1.2	1.6	2.0	2.8	17.7	97.56	1.02

In trend analyses, a high correlation and a positive significant association are found between the maximum precipitation observed in Batman in standard times of 15 minutes and 24 hours. As the amount of the precipitation measured in 15 minutes increases, the maximum precipitation in 24 hours also increases (Figure 7). This situation is similar to the event of deviation from normal for maximum precipitation in 15 minutes and 24 hours. That is, the trend analyses are in parallel with probability distributions (Figure 8). In this case, the amount of maximum precipitation over Batman in 15 minutes is of high importance.

According to quadratic trend analyses, which are widely used in variable data analyses and predictions, maximum precipitation over Batman in 24 hours tended to decrease, while maximum precipitation in 15 minutes showed increase (Figure 9).

The most important factor affecting the flood event in Batman on October 31 - November 1, 2006 is downpours of short duration storms. According to pluviograph records at the Batman Meteorology Station, three intense downpours occurred on October 31 and the other two on November 1 (Figures 10 and 11).

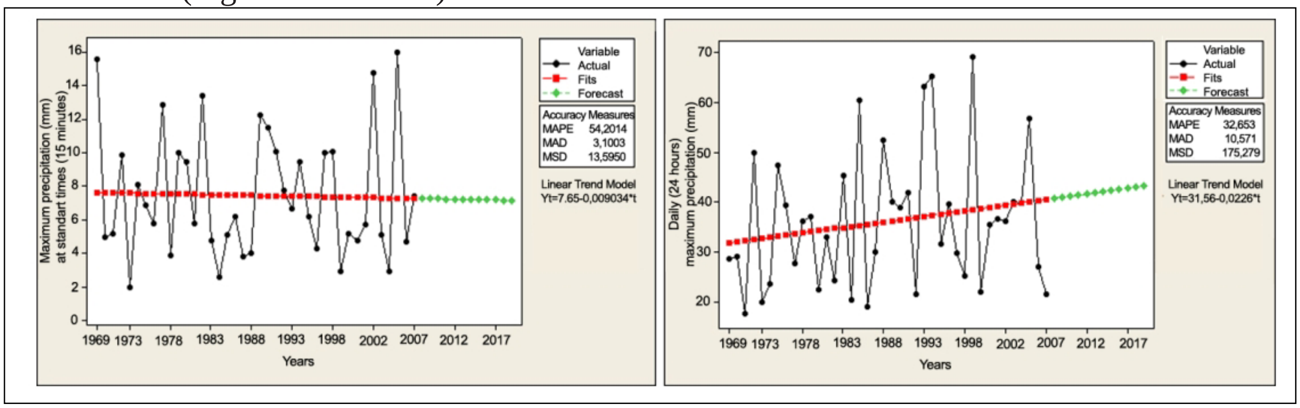

Figure 7. Trend analyses of maximum precipitation observed in Batman in Standard times of 15 minutes and 24 hours.

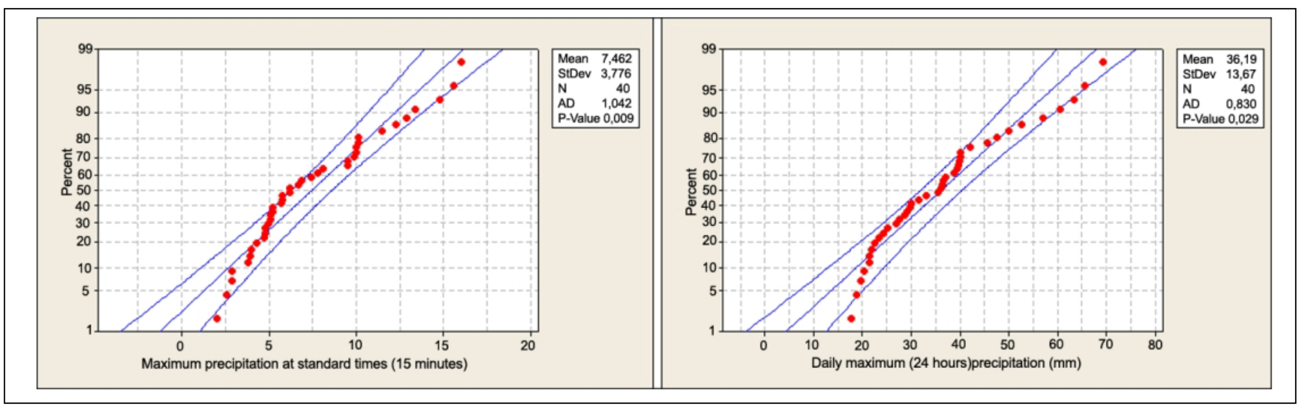

Figure 8. Probability distributions of maximum precipitation observed in Batman in Standard times of 15 minutes and 24 hours.

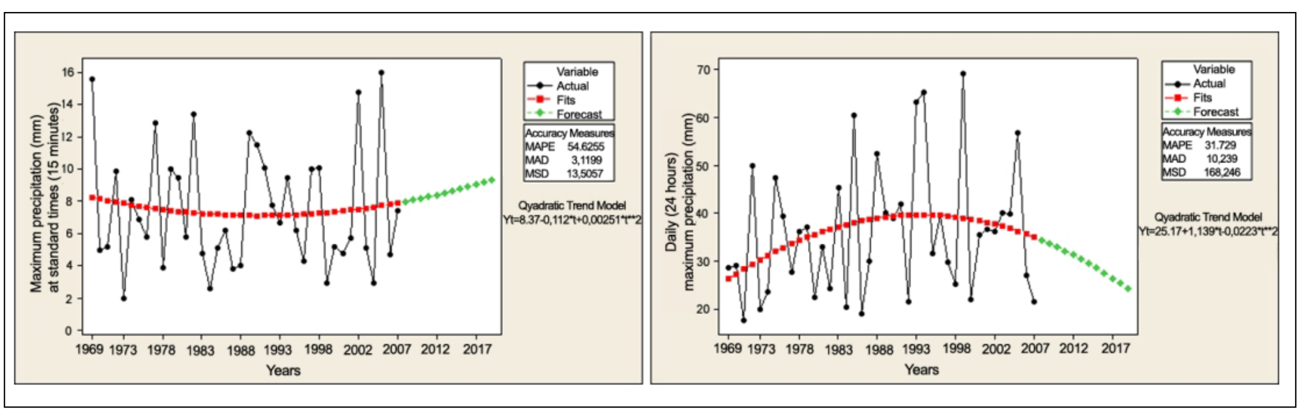

Figure 9. Quadratic trend analyses of maximum precipitation observed in Batman in Standard times of 15 minutes and 24 hours.

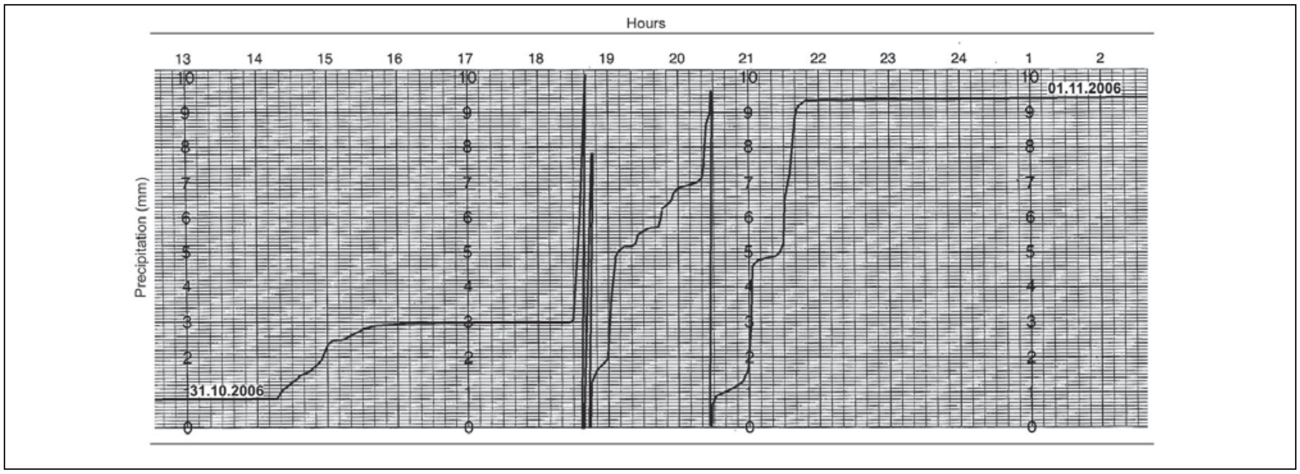

Figure 10. Pluviograph data for October 31, 2006 obtained from Batman Meteorology Station. (16 mm of the 30 mm precipitation on October 31 fell within 15 minute, the remainder fell in the next few hours.)

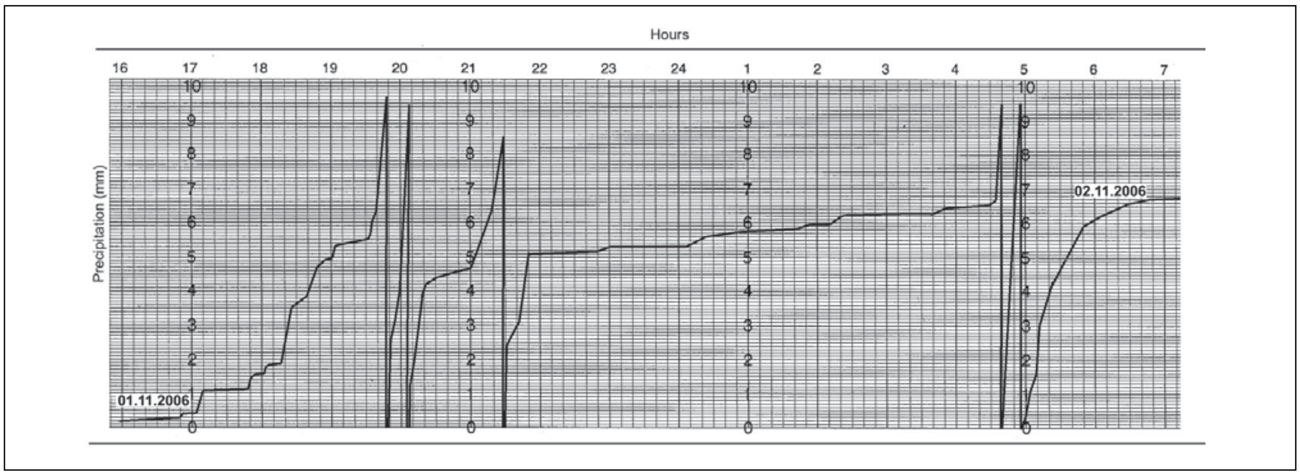

Figure 11. Pluviograph data for November 1-2, 2006 from Batman Meteorology Station.

A total of 16 mm of precipitation occurred within 15 minutes from 6.30 p.m. to 6.45 p.m. on October 31, 2006. It started the runoff and caused catastrophic flooding in the city center from 9 p.m. to 9.30 p.m. As the time of maximum precipitation on November 1 and 2 is extended, its intensity was lower compared to the precipitation on October 31. A precipitation of 18 mm within 40 minutes occurred on November 1, and 15 mm fell within approximately 40 minutes on November 2. A large part of the precipitation on these dates started the runoff but did not cause as great a flooding as on October 31.

The intensity of the precipitation in Batman within 15 minutes on October 31, 2006 is extremely high. The three great precipitation events within 30 hours on October 31 and November 1-2 indicate that the risk of flooding is very high in this area.

DISCUSSION AND CONCLUSIONS

The flood events in Batman on October 31-November 1, 2006 are due to the over passing of low pressure and frontal systems from the Central Mediterranean.

The risk of flooding in any region is not based only on intense precipitation. Geological-geomorphologic characteristics, soil and vegetation properties and human activities can all have negative effects in vulnerable regions in terms of floods. As Batman city is located on or near floodplains, it has high risk of flooding. The flood occurrence on the date in question can also be attributed to this factor. In the process of city expansion and development, Iluh Creek and its branches should be cleared of settlements and industrial plants.

The last catastrophic flood in Batman was at 9 p.m. – 9.30 p.m. on October 31, 2006. The flooding on this date resulted in a total of 11 deaths, including 10 in the city center and 1 in the district of Hasankeyf, and great loss of property.

The total amount of precipitation on the day when the flood event occurred is recorded as 30 mm, which is not considered with high risk in terms of floodings. However, 16 mm of the 30 mm precipitation fell within 15 minutes and the remaining amount after this intense precipitation. Due to the ground being saturated in the previous days, thus reducing the infiltration capacity, and due to the lithologic, morphologic, and hydrographic structures of the soil, all the precipitation became runoff in a short period of time and caused flooding in the city center. It is noted that no flooding occurred in 1982 despite the high intensity of precipitation within 5 and 10 minute intervals. This indicates that intense precipitation in low amounts is not sufficient to cause flooding.

Flood events occurred in the city center after the precipitation of 57 mm on November 1, 2006. However, this precipitation did not cause as large a flood as the precipitation of October 31. As one could not have been able to obtain pluviograph data in the previous study (Sunkar and Tonbul, 2009), it is stated that the flood event occurred after the precipitation of 57 mm. However, after evaluation of the pluviograph data, it is found that the catastrophic flooding occurred on 31 October 2006 with 30 mm of precipitation. Türkoðlu (2009) analyzed flood events in the SAR in the Autumn of 2006 according to maximum daily precipitation in this period and associated the flood event in Batman with the precipitation of 57 mm. It is true that flooding also occurred on the day when the precipitation of 57 mm fell, however, the flood event at catastrophic level occurred on the previous day. No great flooding occurred on another occasion, when a maximum precipitation of 69.2 mm fell in April 1999 (Figure 4). This indicates that intense precipitation lasting for a short time within the day is more effective for flood occurrence in Batman. At the same time, it is seen that the occurrence of a precipitation event prior to intense precipitation is also important. In this respect, intense precipitation within the day rather than daily maximum precipitation should be analyzed to describe floods.

According to the probability calculations, the recurrence frequency of daily maximum precipitation in Batman is low. However, the total maximum precipitation occurrence probability on the day, when the flooding occurred is considerably high. Overall, the highest value at standard times (15 minutes) from 1970 to 2008 occurred in 2006.

It is strongly advised that in order to eliminate the risk of further flooding in the Batman city center, the creeks in the city center should be reevaluated for their flood risk considering basin extent and maximum flow rates. In addition, where satellite towns may be established in the surrounding areas, thorough studies of flood risk should be conducted.

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