EASTERN BLACK SEA FLOODS
METEOROLOGICAL AND HYDROLOGICAL ANALYSIS

ETUDE HYDROLOGIQUE ET METEOROLOGIQUE DES CRUES DANS LE BASSIN DE LA MER NOIRE EN TURQUIE

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Abstract: Totally 54 big and destructive floods have occurred in The Eastern Black Sea Basin of Turkey, between 1956-2005 years, causing 258 death and nearly 500 000 000 US Dollars of damage. In this study, the meteorological and hydrological analysis of these floods is given. General meteorological, topographic and geological properties are firstly introduced. The region is the rainiest one in Turkey. The annual average rainfall height of the region is nearly 1400 mm. Most of the floods have occurred at July, June and August. In these months, the superposition of intensive rainfall with snowmelt of upland areas has caused big floods. Although no increase trend has been observed in the quantity of the floods, especially after 1995, the losses both in life and properties has drastically increased. The measured rainfall data during the floods were compared with the ones previously measured and the return periods (recurrence intervals) were calculated. It was concluded that, especially for the rains which caused significantly damages, the return periods went up to 25 to 100 years, and sometimes probable maximum precipitation values occurred. The return periods of flood discharges were determined and it was concluded that, the return periods went up to 50 to 500 years. A general discussion on the comparison of return periods of rainfall and maximum discharge values of selected 13 floods are also included in the paper. It is concluded that, as a result of inadequate precipitation measuring stations, in most floods there is not a good relationship between the return periods of rainfall and maximum discharge values.

Keywords: Floods, Eastern Black Sea Basin, Hydrological and Meteorological Analysis.

Résumé : Les 54 crues qui se sont produites dans le bassin de La Mer Noire Est de la Turquie, entre 1956-2005, entraînant 258 de pertes humaines et presque 500 millions de USD de dégâts matériels Dans cette étude, nous avons étudié l'analyse météorologique et hydrologique de ces derniers crues avec des propriétés météorologiques, topographiques et géologiques générales dans cette région la plus pluvieuse de la Turquie avec la moyenne de 1400 mm. La plupart des crues se sont produites dans la période du juillet en août pendant laquelle, la superposition des précipitations de fortes intensités avec les fontes de neiges de montagne. Bien qu'aucune tendance d'augmentation n'ait été observée après 1995, les pertes humaines et les dégâts matériels ont augmentées. Les pluies pendant les crues ont été comparées à celles précédentes et les périodes de retour ont été calculées. Donc, les périodes de retour son allé jusqu'à 25 100 ans, et les valeurs maximum parfois probables de précipitation se sont produites. Les périodes de retour des décharges d'inondation ont été déterminées et on l'a conclu que, les périodes de retour sont allées jusqu'à 50 à 500 ans, suivant les périodes de retour des précipitations et des valeurs maximum les 13 crues. Par conclusion, en raison des stations de mesure de précipitation insuffisantes, nous n'avons pas pu élaboré une relation exacte de pluie - débit et de périodes de retours et les valeurs maximum probables.

Mots clés : Crue, Bassin de La Mer Noir, Analyse Hydrologique et Météorologique

INTRODUCTION

Due to geographical location, geology, and topography, Turkey undergoes mainly three different types of natural disasters related to gravity flows; floods, landslides, and snow avalanches. Flooding is second important natural hazard after earthquakes. Devastating flood events have occurred in various river basins of Turkey, especially in recent years. On the average 18 flood events occur in a year and they take about 23 lives. After each flood, the government has paid a large proportion of the damage, in addition to losing significant revenues due to the consequences of economic disruption *(Gürer and Özgüler, 2004)*. According to flood reports prepared by General Directorate of State Hydraulic Works *(DSI, 1970-2005)*, on average 90 million US$ flood damage has occurred per year.

Wrong land-use, is an important factor in Turkey when dealing with the flood. Continuous forest cutting to gain new agricultural areas has caused to destroy valuable fertile soil and to increase the sediment loads in the river. The consequences of flooding are strongly influenced by the commercial development and urbanization. The increasing property value has made the flood risk worth taking and has encouraged people to settle in the flood-prone zones despite their known danger. There has been a substantial increase in the construction of asphalt roads, parking lots and pavements in the cities. Insufficient flood control structures and channel improvements in the creeks have further enhanced the flood damage. The capacity of the storm sewers and flood detention structures in the cities is often inadequate to control large floods. These non-meteorological factors aggravate the consequences of the floods to a great extent *(Bacanlı et al, 2003)*.

Very big floods have occurred in The Eastern Black Sea Basin (EBSB) of Turkey, which comprises of 4 provinces; Giresun, Trabzon, Rize and Gümüşhane. In this basin, 54 big floods have taken place between 1956-2005 years, causing 258 death and nearly 500 000 000 US Dollars of damage. The basin is the rainiest one in Turkey. The strata of the basin are generally made of impermeable or semi permeable volcanic rocks. Steep slopes cover great areas, causing to increase of surface runoff velocities *(Üçüncü et al, 1994)*. The measured rainfall height values during the floods were compared with the maximum ones measured previously and it was concluded that, especially for the rains which caused significantly damages, the return periods went up to 25 to 100 years, and sometimes probable maximum precipitation values occurred. Most of the maximum discharges were gauged at gauging stations by using rating curves and some of them were estimated by using the flood marks. The return periods of the discharges were estimated to go up to 50 to 500 years.

THE EASTERN BLACK SEA BASIN

EBSB is located between on the north eastern coast of Turkey, between $40^0 15'$ to $41^0 34'$ north latitudes and $36^0 43'$ to $41^0 35'$ east longitudes (Figure 1). The basin is surrounded by Eastern Black Sea Mountains on the south and Black Sea on the north. Total basin area is 24 077 km^2, yielding 14.9 km^3 water with an average 19.6 lt/sn/km^2 yield. The basin is split by valleys reached from the sea into south zones. The strata of the region are generally made of impermeable or semi permeable volcanic rocks, which prevent the rainfall from percolation and force the water to flow as runoff *(Üçüncü et al, 1994)*.

The Black Sea Coast receives the greatest amount of rainfall. The eastern part of that coast averages 1,400 millimeters of rainfall annually and is the only region of Turkey that receives rainfall throughout the year. The wettest region is the EBSB where annual rainfall can reach 2,200 millimeters. This northern coastal region has a steep and rocky coast, with rivers cascading through gorges of the coastal ranges. A few of the large rivers, those cutting back through the Eastern Black Sea Mountains, have tributaries that flow in broad, elevated basins. Most of the drainage areas of the rivers in the basin are featured by short main courses, their steep slopes and rather dissected with deep valleys and the tributaries have river bed slope bigger than 10 to 20 % at upper reaches. Floods are due to heavy rainfall or to a sudden increase in air temperature, resulting in snow melt in the mountainous parts. The large amount of erosion and debris materials dragged by the flowing water and deposited in the flatter low lying areas *(Gürer and Özgüler, 2004)*. Sudden floods especially at the short main courses are common and these produce widely devastating flash floods, which usually occur more frequently on June, July and August.

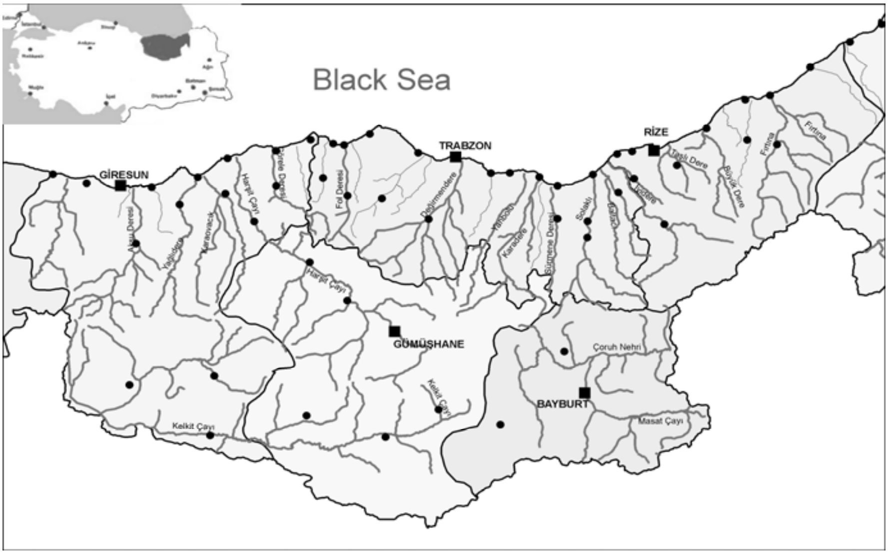

Fig. 1 Location Map of Turkey and EBSB.

During the studied 50 yearly period (1956-2005), totally 54 big floods occurred in the Eastern Black Sea Basin, causing 258 death. On the average 18 flood events occur in a year in Turkey and 1 flood event in the basin, which means that 5 percent of the Turkey's floods have occurred in EBSB. Annual average deaths are 23 and 5 in Turkey and in the basin, respectively; in other words, 22 percent of the deaths have taken place in EBSB. Annual average flood damages are 86 million US$ and 10 million US$ for Turkey and the basin, implying that 12 percent of the flood damages occurred in EBSB.

As previously mentioned, 54 devastating floods occurred in EBSB during the last 50 years. These data are collected by analyzing various flood reports prepared by DSI *(DSI, 1970-2005)*. A brief knowledge of these floods is given in Table 1. In this table, “area” means that the inundated area by flood. The inundated area data before 1970 are not available.

HYDRO-METEOROLOGICAL ANALYSIS OF FLOODS

In this chapter, a hydro meteorological analysis of the EBSB’s floods is presented. Detailed knowledge can be found in Yüksek et al (2006). The data used in this analysis include flood and rainfall data. The flood data were obtained from Annual Flood Reports prepared by DSI *(DSI 1970-2005).* The main data related to the floods are their dates of occurrence (month and day) and peak discharges. Most of the discharges were directly measured at gauging stations. Some of the floods, however, took place at the river sections without gauging stations. The maximum discharge values at these streams were estimated by using flood marks and Manning Formula. In a few big floods, the flood marks were not observed during the floods and the peak discharges were estimated by using rainfall-runoff analysis.

The rainfall data were measured by General Directorate of State Meteorological Works (DMI) at gauging stations. The main problem that arisen in these data was the fact that, many of the stations were equipped by pluviometers, not by pluviographs; which caused some problems at determining the rainfall intensity, the most important meteorological parameter on floods. At these stations, the intensity values were estimated by using pluviometer values at similar and near basins and stations. In the analyses, the maximum annual rainfall height data with various durations (5, 10, 15 and 30 minutes and 1, 2, 3, 4, 5, 6, 8, 12 and 24 hours), prepared by DMI were also used *(DMI, 2001)*

Most of the floods in the EBSB have taken place in three months; June, July and August. 40 floods (74 %) occurred in these months, causing 223 deaths (86 %) and nearly 490 000 000 US $ damage (97 %). In these months, heavy rainfall has been superposed by snow melt, as a result of increase in air temperature, in the mountainous valleys and has resulted in big floods.

It is evident in Table 1 that, although the numbers of floods do not change significantly from 1956 to 2005, both the death and damage figures are going up as the years elapse. In order to get more adequate and reliable opinion about this trend, however, a more sensitive analysis should be carried out. This has been done in a study and the following results are obtained (Yüksek et al, 2006). There are some fluctuations in the numbers of floods, without denoting a time dependent trend. The numbers of death have drastically increased from 1956 to 2005, especially after the greatest flood, which occurred in 20 June 1990. Similar trend is observed in the damages. In brief, even though no increase has been perceived in the numbers of the floods, there is an upward trend in deaths and damages of the floods, especially after 1995.

Table 1 Summary of Date, Death and Hazards of the Floods.

No	Date	Death	Area (10^3 m^2)	Damage (US$)	No	Date	Death	Area (10^3 m^2)	Damage (US$)
1	02.09.1956	-	-	1 009 088	28	12.06.1975	-	2125	46 160
2	20.05.1959	13	-	923 036	29	19.05.1977	-	1146	162 420
3	25.08.1959	-	-	2 506 264	30	30.07.1977	6	3470	96 796
4	31.12.1962	-	-	60 207	31	03.01.1979	-	24	30 842
5	02.01.1963	3	-	43 450	32	14.06.1981	-	200	2 547 294
6	08.06.1963	-	-	27 152	33	04.09.1982	-	80	109 149
7	11.06.1963	-	-	461 385	34	19.07.1983	27	2573	2 297 539
8	21.09.1963	2	-	308 181	35	21.07.1983	-	100	321 360
9	04.06.1964	-	-	37 239	36	01.07.1988	-	193	1 580 915
10	25.06.1965	2	-	1 517 660	37	21.07.1988	3	61	251 837
11	05.07.1966	6	-	1 168 007	38	01.08.1988	-	180	358 427
12	04.07.1967	-	-	1 206 243	39	02.08.1988	-	115	67 004
13	17.07.1967		-	179 881	40	27.04.1990	-	158	1456 185
14	27.07.1967	-	-	113 742	41	20.06.1990	57	74 358	347863 008
15	06.08.1967	-	-	51 175	42	31.07.1992	-	-	256 000
16	02.09.1967	-	-	847 623	43	27.06.1994	-	1100	1 273 345
17	09.04.1968	-	-	119 787	44	08.08.1994	-	15	488 111
18	20.04.1968	-	-	621 536	45	06.07.1995	4	170	1 294 650
19	17.07.1971	-	1256	1 021 486	46	31.07.1995	5	670	3 099 304
20	22.06.1972	-	4384	640 068	47	31.08.1995	2	150	3 432 777
21	14.06.1973	-	3610	5 163 450	48	08.08.1998	50	1365	44 479 204
22	07.07.1973	7	-	38 693	49	12.11.2001	10	-	8 346 241
23	14.07.1973	7	5293	41 457	50	24.07.2002	27	-	11 363 317
24	01.06.1974	-	-	5 206	51	10.06.2004	-	-	1 610 383
25	06.06.1974	-	-	514 317	52	02.08.2005	10	-	21 607 143
26	28.07.1974	-	70	44 400	53	21.08.2005	4	-	30 849 624
27	19.08.1974	6	2780	513 966	54	03.10.2005	7	-	150 376
						TOTAL	258	105 646	504 624109

A list of brief properties of the selected 13 devastating floods is given in Table 2. In selecting the flood, the main factor is the magnitude of losses both to life and properties. There is no hydro-meteorological data for the floods of the period of 1956-1969, therefore these floods have not included in the table. In Table 2, the date and the location of the selected floods as well as the losses (to life and property) are presented. The data used in the analysis were collected by using flood reports prepared by State Hydraulic Works (DSI, 1970-2005).

The rainfall heights (R, mm) were analyzed by comparing the measured heights at the same station at other dates and by using the most suitable statistical distribution function, which was determined by chi-square test, the return periods were estimated. Most of the maximum discharges (Q, m^3/s) were gauged at gauging stations by using rating curves and some of them were estimated by using the flood marks. Similar to the rainfall data, the discharges were also compared with the measured data at the same station in other times and the return periods were estimated by using the most suitable statistical distribution function. Log Pearson Type III (LP3) distribution was the most suitable one for both rainfall and discharge values. The other suitable functions were found as Gumbel (G), Two Parameter Gamma (G2P), Two and Three Parameter Log Normal (LN2 and LN3) distributions.

In the following, very brief analysis of the selected floods is given, according to the number of the flood given in Table 1. In the analysis, a relationship was researched between the return periods of observed rainfall and maximum discharge (Q) values (T_R and T_Q, respectively). The measured rainfall values were compared with maximum daily rainfall values as well as with maximum annual values with various durations (t=5, 10, 15 and 30 minutes, 1, 2, 3, 4, 5, 6, 8, 12 and 18 hours), in order to estimate their return periods.

Flood 1: The return period of the maximum discharge is nearly 100 years (T_Q=100 years). The rainfall values with short durations (10 to 30 minutes) have nearly 5 years return periods (T_R=5 years). It is highly probable that, the rainfall values that could not be measured at gauging stations caused big floods. Flood 2: T_Q values were nearly 500 years near Pazar. The T_R was about 25 to 100 years for R values with 1 to 12 hours in Pazar. This implies that, intensive rainfall have caused devastating discharges. Flood 3: T_Q=500 years, however T_R=5 years, which means that, the unmeasured rainfall caused big floods. Flood 4: There is a near relationship between T_Q=200 years and T_R=100 years in Ardeşen. Flood 5: T_Q=20 to150 years, no intensive rainfall has been measured, which means that the unmeasured rainfalls have become important for causing floods. Flood 6: This was the most devastating flood which affected nearly 10 000 km^2 area. The most intensive rainfall occurred in Kürtün-Doğankent-Tonya, with T_R values 50 to 500 years, causing great discharges with return periods up to 500 years. Flood 7: In Erenköy and Çataldere Streams, T_Q=100 to 250 years. However, there was no precipitation station near these streams. In Rize, T_R=10 years for t=1 to 3 hours rainfalls, which were supposed to cause flood. Flood 8: The intensive rainfalls near Pazar, with 1 to 12 hours durations and 25 to 50 years return period caused floods with 100 to 500 years return periods. Flood 9: This was a local flood which was focused at Beşköy Town. The main reason for the deaths and hazards was land slide that took place immediately after the flood. No precipitation and discharge data exist for Beşköy. Flood 10: T_R for 24 hourly rainfalls was 5 years, which could not explain the big discharges with 500 years return period. It is highly probable that, the unmeasured rainfalls with shorter durations have caused big floods. Flood 11, 12 and 13: The rainfall data for short durations are not available. The measured rainfall values (T_R=1 year), can not cause big discharges with 100 to 500 years return periods.

Table 2. Rainfall and Discharge Values of Selected Big Floods.

No	Date	Location of Flood	Death	Hazard ($)	Rainfall (24 Hours)			Discharge		
					Station	Height (mm)	T (year)	Station	Disch. (m^3/s)	T (year)
1	14.07.1973	Kalkandere, Güneysu (Rize)	7	45 650	Rize	26.7	0.5	Taşlıdere	242	100
					Çayeli	50.3	1			
					Of	26.3	0.5			
2	30.07.1977	Fındıklı, Ardeşen, Pazar, Çayeli, İyidere, Merkez (Rize) Tonya (Trabzon)	6	106 725	Tonya	52.4	10	Abuçağlayan	151	10
								Hemşin	535	500
					Ardeşen	96.7	2	Büyükdere	225	25
								İyidere	1200	500
					Çayeli	89.3	1	Baltacı	432	500
								Manahoz	79	5
3	19.07.1983	Pazar, Fındıklı (Rize)	27	-	Çamlıhemşin	64.9	2	Abuçağlayan	651	500
					Arhavi	132.4	5	Hemşin	590	500
4	21.07.1988	Ardeşen, Pazar, Çayeli (Rize)	3	370 220	Pazar	118.0	5	Ardeşen	42	200
					Ardeşen	180.2	100	Hemşin	260	5
					Fındıklı	64.3	1			
5	27.04.1990	Maçka, Çaykara, Araklı, Merkez (Trabzon), Torul (Gümüşhane), Yusufeli, Ardanuç, Şavşat, Merkez (Artvin)	-	274 235	Gümüşhane	15.3	1	Değirmendere	182	20
								Karadere	150	15
					Araklı	40.7	1	Solaklı Deresi	185	150
								Harşit	150	5
6	20.06.1990	Maçka, Akçaabat, Çarşıbaşı, Vakfıkebir, Tonya,Of Şalpazarı, Merkez (Trabzon) Doğankent, Tirebolu, Yağlıdere, Espiye, Keşap, Dereli, Bulancak,Merkez (Giresun), Torul, Merkez (Gümüşhane)	57	378 693 785	Giresun	24.1	1	Galyandere	157	500
					Tamdere	48.3	5	Esiroğlu	647	500
					Doğankent	138.4	50	Cücenköprü	280	500
					Kürtün	138.7	500	Torul	700	200
					Vakfıkebir	112.1	10	Eymür	2457	500
					Tonya	127.8	500	Kürtün	2016	500
					Trabzon	64.8	5	Derecik	194	500
7	06.07.1995	Çaykara, Dernekpazarı, Of (Trabzon), Güneysu (Rize)	4	1 390 900	Çaykara	20.4	1	Solaklı	183	20
								Manahoz	180	10
					Rize	40.8	1	Erenköy	107	100
								Çataldere	72	250

8	31.08.1995	Çayeli (Rize)	2	368 800	Pazar	147	10	Aşıklar	112	10
								Büyükdere	696	70
								Şairler	123	100
								Güneysu	341	25
								Melyat	276	500
								Hemşin	550	70
								Işıklar	106	70
								Cano	390	150
9	07-08.08.1998	Köprübaşı, Sürmene, Of, Hayrat, Dernekpazarı, Çaykara (Trabzon) Kalkandere, İyidere, İkizdere (Rize)	50	43 421 900	Rize	45,5	1	Maki	195	500
								Yanbolu	54	5
								Baltacı	95	25
10	11-12.11.2001	Çayeli, Güneysu, Pazar, Ardeşen, Çamlıhemşin, Fındıklı (Rize)	10	8 147 850	Pazar	100	5	Abuçağlayan	109	5
								Hemşin	171	500
								Hala	164	25
								Salarha	124	5
								Fırtına	233	10
11	23-24.07.2002	Merkez, Güneysu, Çayeli (Rize)	27	11 093 200	Rize	42	1	Salarha	80	1
								Şenöz	57	5
								Salarha	175	10
								Şairler	130	100
								Aşıklar	100	70
								Güneysu	450	500
12	02.08.2005	İkizdere (Rize) , Hayrat, Of, Çaykara (Trabzon)	10	21 093 520	Fırtına	80		Sürmene	190	500
								Solaklı	200	50
								Maki	200	500
								Baltacı	400	500
13	21.08.2005	Of (Trabzon), Güneysu, Çayeli, Hemşin, Ardeşen (Rize)	4	30 116 300				Solaklı	30	1
								Güneysu	200	
								Büyükdere	250	
								Hemşin	260	500
								Hala	156	25
								Fırtına	700	100
TOTAL			**207**	**495 123 085**						

CONCLUSIONS

In this study, a general review on meteorological and hydrological analysis of the floods occurred in the Eastern Black Sea Region of Turkey during the period of 1956-2005 years is given. The observed flood discharge and precipitation data are compared with the measured data at the same stations in other times. It was concluded that, especially for the rainfalls which caused significantly damages, the return periods went up to 25 to 100 years, and sometimes probable maximum precipitation values occurred. The return periods of flood discharges were determined as to go up to 50 to 500 years. Most of the floods occurred in June, July and August. Although no increase trend was observed in the quantity of the floods, the losses both in life and properties drastically increased, especially after 1990.By analyzing the return periods of rainfall values and maximum discharges of selected 13 big floods, it was concluded that, in general there was not a good relationship between the return periods of rainfall and discharge values. The main reason for this difference was supposed to be inadequate precipitation measuring stations, which in turn caused incorrect or inadequate measuring of height and especially intensity of the rainfall. In order to reach better hydro-meteorological analysis of the floods, the EBSB should be equipped with more rainfall gauging stations with pluviographs.

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