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ISOSEISMAL MAP, HUMAN CASUALTY and BUILDING DAMAGE STATISTICS of THE IZMIT EARTHQUAKE of AUGUST 17, 1999

Bülent ÖZMEN[1]

ABSTRACT

A large earthquake occurred in Marmara region of Turkey on August 17, 1999 at 3.02 a.m. on local time. Earthquake parameters were determined by the National Earthquake Network operated by the Earthquake Research Department (ERD) of the General Directorate of Disaster Affairs as magnitude Mw:7.4, epicenter 40.70N latitude, 29.91E longitude and 15.9 kilometers depth. Main schock was about 12 kilometers southeast of the center of Izmit in Kocaeli province.

The main aim of this paper is to find out relation of heavy damage and human casualty and compare the estimation and observed isoseismal maps.

According to Crisis Center of Prime Ministry and General Directorate of Disaster Affairs the earthquake caused the loss of 17127 lives and 43953 injured people and 66441 collapsed and heavily damage, 67242 moderate damage, 80160 slightly damage. Forty-eight percent of total heavy damage has occurred in Kocaeli province, 29 percent in Sakarya province, 14 percent in Yalova province, 5 percent in Bolu province, 5 percent in Istanbul province, 0.04 percent in Bursa province and 0.12 in Eskisehir province. It is the second largest earthquake in Turkey since 1939 Erzincan earthquake (Ms=7.8, 32962 killed) in point of the amount of human loss. This earthquake mainly affected seven provinces.

Isoseismal map has been drawn on the map based on the field observations, preliminary damage evaluation prepared by General Directorate of Disaster Affairs, Ministry of Public Works and Settlement and acceleration records. Seismic intensity was determined X at Gölcük, Çiftlikköy, Adapazarı and Gölyaka districts.

IZMIT EARTHQUAKE

Izmit earthquake occurred at 3.02 a.m. (00:01:39.80 GMT) on local time on August 17, 1999, Tuesday in the densely populated Marmara region of NW Turkey. Earthquake parameters were determined by the National Earthquake Network operated by the Earthquake Research Department (ERD) of the General Directorate of Disaster Affairs as magnitude Mw: 7.4, epicenter 40.70N latitude, 29.91E longitude and 15.9 kilometers depth. Table 1 and Figure 1 compares the locations of epicenters predicted by various institutes.

Maximum intensity observed was assessed to be X according to MSK scale. This earthquake occurred on the western part of the North Anatolian Fault Zone (NAFZ) and caused right-lateral strike-slip movement on the fault. This earthquake is associated

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with a 120-km long surface rupture that extends from southwest of Düzce in the east to near Karamürsel basin in the west.

Table 1: Comparison of earthquake parameters by various institutes

Institute	Date	Latitude	Longitude	Depth	Mw	Md
Disaster Affairs of General Management Earthquake Research Department	17/08/1999 03:01:37 (L.T)	40.70N	29.91E	15.9	7.4	6.7
Boğaziçi University Kandilli Observatory	17/08/1999 03:01.37.6 (L.T)	40.76N	29.97	18		7.4
USGS	17/08/1999 00:01:39.80 (GMT)	40.702	29.987	17	7.4	

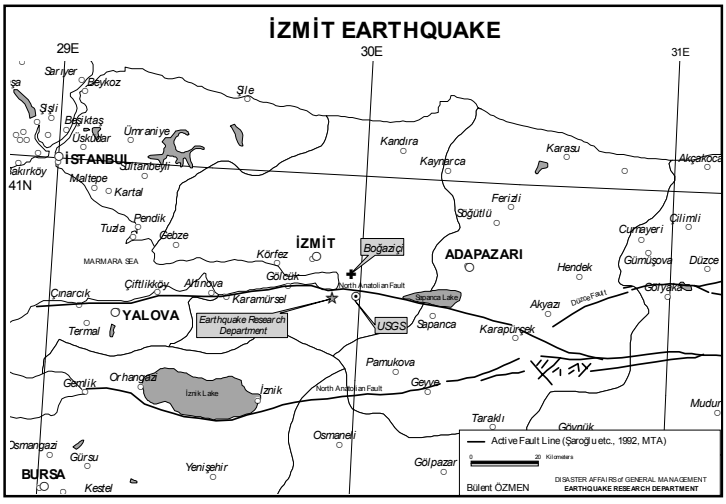

Figure 1 : Compare the location of epicenters predicted by various institutes

Main shock was about 12 kilometers southeast of the center of Izmit in Marmara Region. The maximum horizontal peak ground acceleration of 407 mG was recorded in the Adapazarı station belonging to Strong Ground Motion Network of Earthquake Research Department at 42-km distance from epicenter. Ground motion record nearest to the epicenter was obtained at Izmit station, which is 12-km distance from epicenter. The maximum horizontal peak ground acceleration at Izmit station was 225 mG.

According to Crisis Center of Prime Ministry and General Directorate of Disaster Affairs the earthquake caused the loss of 17127 lives and 43953 injured people and 66441 collapsed and heavily damage, 67242 moderate damage, 80160 slightly damage

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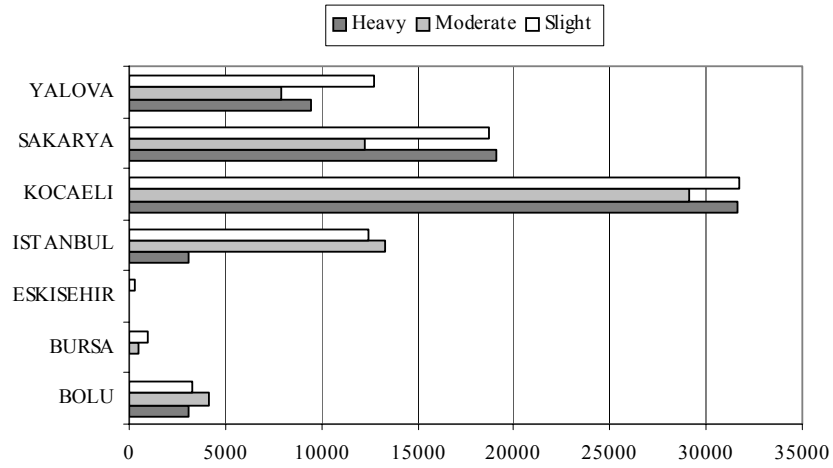
(Table 2). This earthquake mainly affected seven provinces. Forty-eight percent of total heavy damage has occurred in Kocaeli province, 29 percent in Sakarya province, 14 percent in Yalova province, 5 percent in Bolu province, 5 percent in Istanbul province, 0.09 percent in Bursa province and 0.12 in Eskişehir province. Many of the building damage and human casualty occurred in the provinces of Kocaeli, Sakarya and Yalova. It is the second largest earthquake in Turkey since 1939 Erzincan earthquake (Ms=7.8, 32962 killed) in point of the amount of human loss.

Table 2 : Damage assessment

CITY	DAMAGE RESULT					
	HEAVY		MODERATE		SLIGHT	
	HOUSE	SHOP	HOUSE	SHOP	HOUSE	SHOP
BOLU	3095	649	4180	1015	3303	482
BURSA	63	5	434	19	940	68
ESKİŞEHİR	80	19	96	8	314	22
İSTANBUL	3073	532	13339	1999	12455	1239
KOCAELİ	31625	4901	29076	3887	31751	4345
SAKARYA	19043	4068	12200	1963	18712	1675
YALOVA	9462	727	7917	1036	12685	1881
TOTAL	**66441**	**10901**	**67242**	**9927**	**80160**	**9712**



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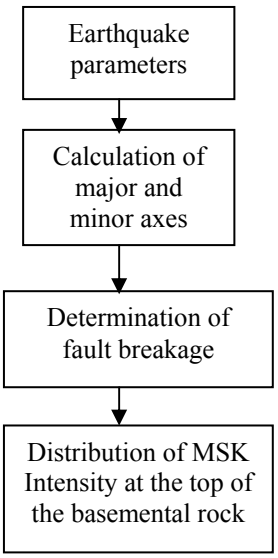
ISOSEISMAL MAP

In this study we prepared two isoseismal maps that are observed and estimated. These maps have been drawn based on MSK Scale that was published by Medvedev, Sponheuer and Karnik in 1964. This scale is of twelve-degrees. Traditionally, Roman numerals have been used to represent intensity values.

Estimated Isoseismal Map

This Map has been drawn on the map using formulas developed by Okada and Geographic Information System Software (Figure 2). Flow of chart estimated isoseismal map is shown in the following.



Main processing flow of the estimated isoseismal map

Firstly, we learned earthquake parameters from seismological division in Earthquake Research Department just after the earthquake. Then, we calculated the lengths of major and minor axes using the following formulas developed by Okada for magnitude 7.3≤ML<7.9.

Calculation of the lengths of major and minor axes

Calculation of the lengths of major and minor axes in MSK intensity X

$$\text{Minor axes length} = 10^{0.58 * M - 3.75} \text{ (km)} = 3 \text{ km}$$

$$\text{Major axes length} = e^{2.91 * M - 17.37} \text{ (km)} = 64 \text{ km}$$

Calculation of the lengths of major and minor axes in MSK intensity IX

$$\text{Minor axes length} = 10^{0.49 * M - 2.77} \text{ (km)} = 7 \text{ km}$$

$$\text{Major axes length} = e^{2.44 * M - 13.43} \text{ (km)} = 102 \text{ km}$$

Calculation of the lengths of major and minor axes in MSK intensity VIII

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Minor axes length = $10^{0.41 * M - 1.85}$ (km) = 15 km
Major axes length = $e^{2.20 * M - 11.32}$ (km) = 143 km

Calculation of the lengths of major and minor axes in MSK intensity VII

Minor axes length = $10^{0.34 * M - 1.03}$ (km) = 31 km
Major axes length = $e^{1.95 * M - 9.20}$ (km) = 187 km

Calculation of the lengths of major and minor axes in MSK intensity VI

Minor axes length = $10^{0.28 * M - 0.28}$ (km) = 62 km
Major axes length = $e^{1.96 * M - 9.10}$ (km) = 222 km

Calculation of the lengths of major and minor axes in MSK intensity V

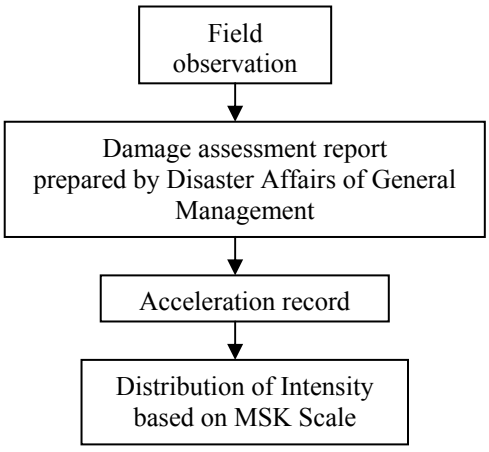
Minor axes length = $10^{0.24 * M + 0.31}$ (km) = 122 km
Major axes length = $e^{1.73 * M - 7.04}$ (km) = 318 km

Later, we generated some ellipse for every intensity along the fault breakage using major and minor axes lengths with buffer zone analysis of Geographic Information System Software.

The estimated isoseismal maps can be used to predict damage and human casualty using the vulnerabilty function just after the earthquake. But we could not any prediction damage for this earthquake due to no detailed database. That`s why we have to obtain a lot of database that needs to calculate the distribution of seismic intensity and predict damage using Geographic Information System (GIS). Briefly, this data can be geology, topographic maps, administrative boundary, settlement places (Province, District, Sub-District, Village), building statistics, roads, bridges, active faults etc. All of maps should be digitezed.

Observed Isoseismal Map

Seismic Intensity map has been drawn on the map based on the field observations, acceleration records and preliminary damage evaluation prepared by General Directorate of Disaster Affairs, Ministry of Public and Settlement (Figure 3). Flow chart of observed isoseismal map is shown in the following.



Main processing flow of the observed isoseismal map

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Total surface area with intensities equal to VI or higher is 49061 square kilometers. 15,090,056 people are living and there are 3,530,304 house at this region. The number of houses have been calculated from population and size of average household. This is shown in Tables 3. This table clarifies that VI intensity zone is of 72 percent of total surface area, VII intensity zone is of 16 percent, VIII intensity zone is of 9 percent, IX intensity zone is of 2 percent and X intensity zone is of 1 percent. Also It is showing us that is living at IV intensity zone of 78 percent of total population, at VII intensity zone of 10 percent, at VIII intensity zone of 4 percent, at IX intensity of 5 percent and at X intensity of 3 percent.

Table 3: Distribution surface area, poopulation and house number as related to isoseismal map

INTENSITY	Area (km^2)	Population(1997)	House Number
VI	35200	11807738	2762044
VII	7955	1521558	355920
VIII	4396	666936	156008
IX	1216	676122	158157
X	294	419699	98175
TOTAL	**49061**	**15090056**	**3530304**

Table 4 shows us the number and percent of heavy, moderate and slight damage at different intensities. These rates can be used for estimating the damage to houses and casualties from MSK Intensity. We can predict damage and casualty using these rates. We think that there is a great deal of similarity in relation to their building quality among other cities in the Turkey.

Table 4: Number of heavy, moderate and slight damage as related to isoseismal map

Intensity	No. of Heavily damaged house	%	No. of Moderately damaged house	%	No. of Slightly damaged house	%
VI	1111	0.04	6023	0.22	6496	0.24
VII	3241	0.91	9514	2.67	9232	2.59
VIII	4398	2.82	6883	4.41	8289	5.31
IX	24824	15.70	28726	18.16	35977	22.75
X	32458	33.06	15009	15.29	18786	19.14
TOTAL	**66032**		**66155**		**78780**	

Table 5 indicates instrumental places and acceleration records, which were taken one's place in isoseismal map. Average horizontal peak ground acceleration is 62.45 mG at intensity VI, 126 mG at intensity VII, 265 mG at intensity VIII, 299 mG at intensity IX and 407 mG at intensity X.

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Table 5: Instrumental place and acceleration records

Intensity	Instrumental Place	Latitude	Longitude	N-S (mG)	E-W (mG)	Vertical (mG)
VI	Bursa Civil Defense Direct.	40.184	29.131	54.32	45.81	25.73
VI	Ereğli The building of the governer of the district	40.980	27.790	90.36	101.36	56.98
VI	Istanbul Local Office Ministry of Public Works	41.080	29.090	60.67	42.66	36.22
VI	Tekirdağ Local Office Ministry of Public Works	40.979	27.515	32.17	33.45	10.16
VII	Çekmece Nuclear Power Plant	40.970	28.700	118.03	89.61	49.80
VII	Göynük State Hospital	40.396	30.783	137.69	117.90	129.90
VII	Iznik The chief office of the Highways	40.440	29.750	91.89	123.32	82.31
VIII	Gebze Tubitak Marmara Research Center	40.820	29.440	264.82	141.45	198.49
IX	Düzce Meteorological Station	40.844	31.149	314.88	373.76	479.94
IX	Izmit Meteorological Station	40.790	29.960	171.17	224.91	146.39
X	Sakarya Local Office Ministry of Public Works	40.737	30.384	-	407.04	259.00

It is compared the observed and estimated isoseismals at Figure 4. Solid and dotted lines are for the observation and estimated respectively. There are large variations between two maps especially X and IX intensity

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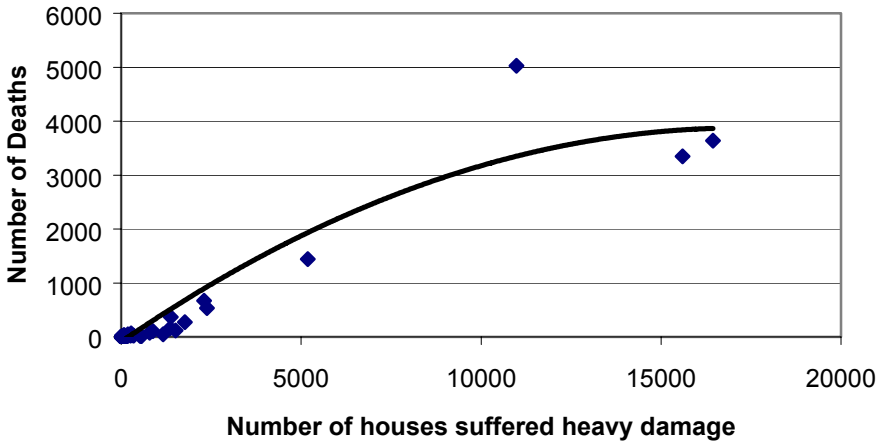

In calculating the fatality rates, secondary effects such as fires, landslides, etc. have not been taken into account. Empirical relations have been developed for city center between fatality and heavy and collapsed houses using the number of heavy damage and death in the city centers.

$D = -1*10^{-5}*H^2 + 0.4595*H - 91.235$
Here:
D : Total number of deaths
H : Total number of collapsed and heavily damaged building

CONCLUSIONS

Seismic intensity was determined X at Gölcük, Çiftlikköy, Adapazarı and Gölyaka districts.

Forty-eight percent of total heavy damage has occurred in Kocaeli province, 29 percent in Sakarya province, 14 percent in Yalova province, 5 percent in Bolu province, 5 percent in Istanbul province, 0.09 percent in Bursa province and 0.12 in Eskişehir province.

An empirical relation between fatality and heavy and collapsed building was derived and was found useful for city center.

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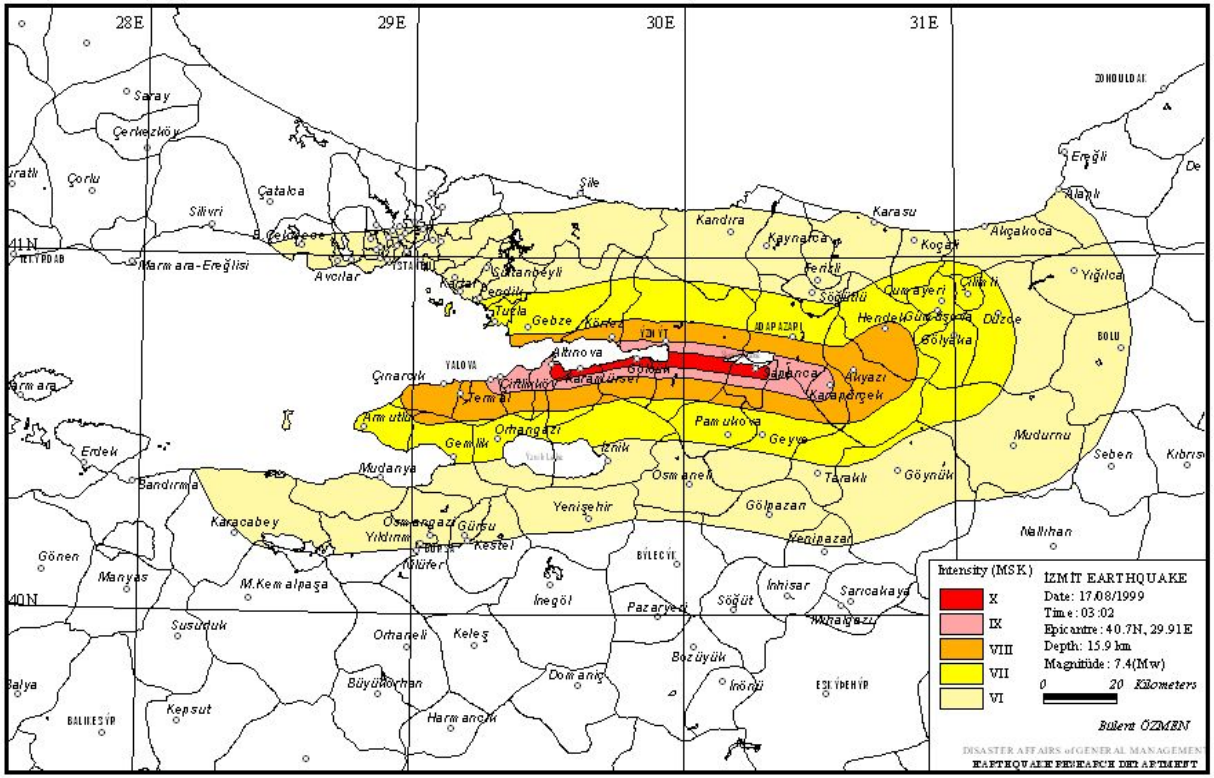

Figure 2 : Estimated Isoseismal map of İzmit Earthquake

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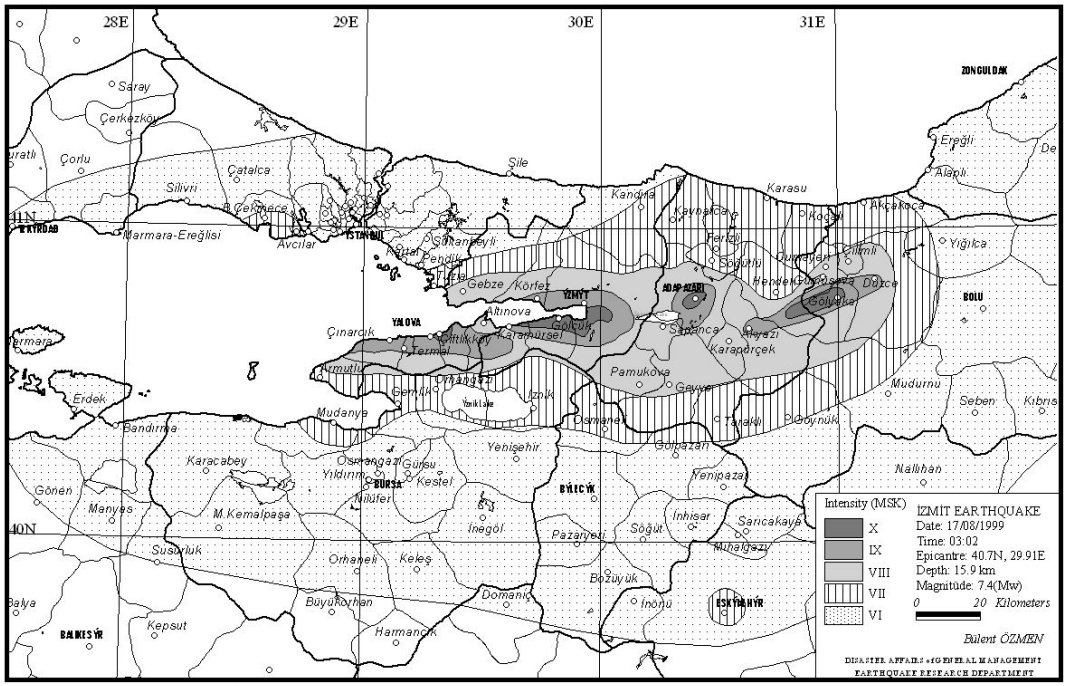

Figure 3 : Isoseismal map of İzmit Earthquake

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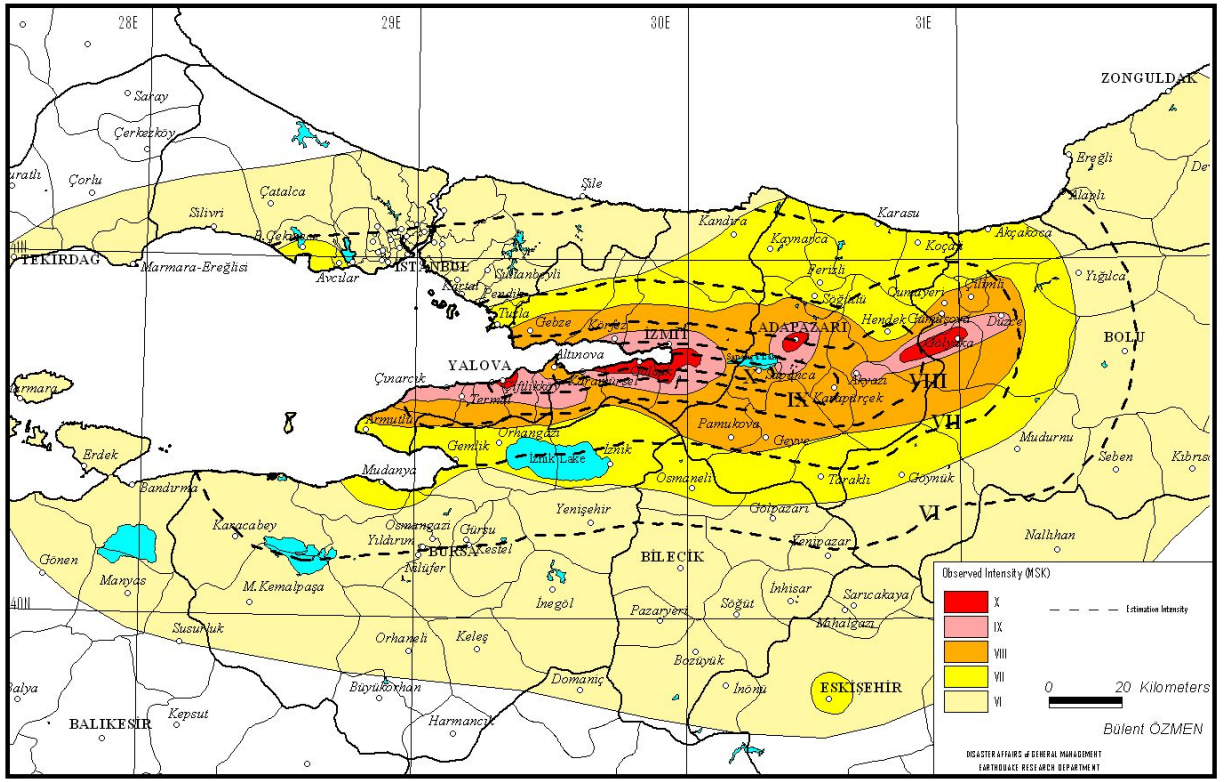

Figure 4 : Compare the estimated and observed isoseismal map

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