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Natural hazards in the Mediterranean area (**)

The tentative Table 1 lists the natural phenomena most commonly known and widespread on the Earth's surface and Earth's interior which cause great damage to society.

The table needs quite an extensive explanation.

However not only the explanation will not be complete but I shall consider the Table 1 and its explanation a success if they will help to realize which should be the object of our attention practically and physically (tentatively) and also to recall that in that table there is the matter of many disciplines from seismology, meteorology, volcanology, to sociology, medicine, engineering, to name just a few.

My suggestion is that once one has gone through Table 1 and its tentative explanation, one may start something more complete.

But for the sake of this conference I also think that we must go through this exercise, in order to avoid the painful confusion and waste of time of not knowing what we are saying.

I don't believe that after this discussion this will be quite clear to all, but we have to try.

The discussion begins with the listing on the top of the Table 1, everybody knows what are, floods, avalanches, slides, frost and drought for the frequent description of their effects in news media, the same is true for land and costal erosion caused by rivers, rainfalls and ocean currents.

Pouring is a concentrated rainfall in which the rate of waterfall is of the order of a centimeter per minute, it is generally caused by thunderstorm and hurricanes, and occurs mostly in tropical areas.

A storm surge is an accumulation of water on a coastal area caused by strong

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TABLE 1

Fire	*Hail*	*Flood*	*Lightning*	*Thunder storm*	*Tornado*	*Hurricane*	*Pouring*	*Avalanches*	*Storm surges*	*Erosion*	*Slide*	*Volcanic eruption*	*Earthquake*	*Tsunami*	*Frost*	*Drought*	Reference to cases which cause relevant damage, to average structure and culture
Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Forecast theoretically possible
Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	Operational efficient forecasting system
	hours	days		hours	day	hours	day	day	day	days	days	days		hours	hours		Maximum possible Warning time
Y	Y	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Prevention of phenomenon actually possible
Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Prevention of effect on structures and nature partly possible
		Slide	Fire	Pouring Lightning Tornado Hail Flood	Erosion	Tornado Storm-surge Lightning Flood Slide	Slide Erosion	Erosion Slide	Erosion	Slide	Flood tsunami	Earthquake Slide	Tsunami Slide	Slide		Erosion	Associated natural catastrophes
Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Possible advice to population to prevent and mitigate effects
Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Existing advice to population to prevent and mitigate effects
Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	N	Y	N	N	Areas where the events may occur accurately indicated in forecast
Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Common in Mediterranean countries

persistent winds. We have all seen lightning and hail. Tornadoes, hurricanes and thunderstorms are purely atmospheric phenomena; they are the most confusing terms to most people.

The thunderstorm is generated by temperature imbalances in the atmosphere; it is a violent example of air convenction caused by cooling of the cloud tops and/or warming of the base. At the final stage the cumulo nimbus cloud called thunderstorm may be many km across and often reach 12 km altitude. Most storms are composed of several cells that live perhaps 20 minutes, the storms may last several hours and are accompanied always by lightning and often by heavy precipitation of rain and/or hail. They can also cause flash floods when the rainfall is concentrated in time, rainfalls exceeding 25 cm/hour have been observed and it is not difficult to imagine their direct effect and their capacity to cause flash floods. Thunderstorms are quite common in Mediterranean areas.

But the most destructive child of the thunderstorm is the tornado which consists of a violently rotating column of air descending from a thunderstorm cloud system. They can move at 50 or 100 km/hour or very slowly, the path is from 0.5 to 1.5 km wide and from 5 to 500 km long. The winds of a tornado can reach 300 km/hour velocity. In the United States the tornadoes claim about 100 lives and several hundreds of millions of dollars damage per year. About the same property and culture damage is caused by hail.

But the greatest storm of all is the hurricane: it is formed by a system of spiral clouds and having a definite organized circulation developing over tropical or subtropical waters, covering an area many hundreds of km in diameters and winds of more than 110 km/hour, from which torrential rains fall. The spirals of the hurricane are separated by areas of light or no rain at all. Around the eye of the hurricane, which is free of clouds and has light winds, the wind is the greatest killer; it may gust at 300 km/hour, this in turn causes storm surges, which, together with the wind, cause most of the damage. In 1900 a hurricane in Galveston Texas killed 6000 persons.

In the United States hurricanes are a great danger; NOAA environmental satellites, may give the first clues of the formation of a hurricane; NOAA research planes and hurricane reconnaissance flights by military aircraft assure accurate tracking of the storm as it reaches the North American continent assisted by ocean booys and by ocean-going ships reporting weather conditions and by a network of U.S. National Weather Service high-powered radars. Safety precaution rules have been distributed to the population. Warnings are also issued to the population when a hurricane threatens. Anyway it is important to note that if the authorities make a special recommendation, for instance to evacuate, the final decision is left to the individuals.

Although tornadoes and thunderstorm are short lived phenomena and the most difficult weather phenomena to forecast, it is possible to predict general areas where they are most likely to occur. In the United States this is done by the National Severe Storm Forecast Center in Kansas City Missouri operated by the National Weather Service (an element of NOAA of the US Dept. of Commerce).

The NSSFC meteorologists monitor conditions in the North American atmosphere using surface data from hundreds of sites, radar stations, satellite photos, reports from airplane pilots, and meteorological air profiles. Assembling all this information the area in which a severe storm may occur is forecast. Then a watch bulletin is issued to the public.

The bulletin indicates where a thunderstorm or a tornado may occur and for how long the threat may last. The Warning of the bulletin does not imply that a severe storm will certainly occur or that it may not occur in areas different form those indicated in the bulletin, it is a probabilistic statement and it should be taken with the limitations associated with this type of statement.

In the long run society is almost certainly repaid if all accept the suggestions of the bulletin. This is valid for any forecast of dangerous natural phenomena. You may evacuate once and for nothing but if you and all evacuate all the times when advised to do so, in the long run the number of casualties will certainly be less. The same probabilistic rule applies to property damage.

Through about 360 radio stations in the US the NOAA provides now continuous broadcast of the latest weather information. Taped weather messages are released every four to six minutes, day and night, and are revised every one to three hours. When there is a severe weather threat, the continuous weather forecast is interrupted and substitute special bulletins released. Special receivers are also available which are automatically activated when the special bulletins are released.

A volcano is a system formed by a portion of the Earth's crust containing a chamber of magma, a communication conduct between the chamber and the Earth's surface, and a cone formed by the material erupted through the conduct. The magma is formed by molten rocks (lava), water vapour and gas contained in the lava. When the lava plugs the top of the conducts and the gas and water vapour with their pressure suddenly unplug the conduct, an explosion occurs. Ashes may be thrown in the atmosphere at 10 km height and thousands of km away covering surrounding areas with layers several meters thick as in 79 A.D. in Pompeii killing all who did not evacuate. The gas at very elevated temperature may also kill almost instantly; as in 1902 in the city of St. Pierre, 10 km away from the Volcano of Mount Pelé, when 40,000 died.

Slides of mud are also a threat after the eruption occurs, as in 79 A.D. when Ercolano was literally buried. Sometimes the explosion may occur without the presence of a volcanic conduct as in 1539 in Pozzuoli where in few days a cone 100 m high and 1000 m wide was formed.

An earthquake generally is a sudden release of elastic energy through the slippage on the surfaces of a cut in the Earth's interior called fault. The slippage may be several meters long and the surface of the fault involved in the slip may be 1000 km long and tens of km wide. The energy release causes the propagation of elastic waves in the Earth's surface travelling with a speed of several thousands of km per hour; their destructive portion may last a minute and literally shake everything down with accelerations of more than that of gravity on areas of

TABLE 2

N \ D	0	1	2	3	4	5
8	37 38 55 73 60 110 39* 41* 74* 75* 87* 85* 111*	69				
7	35 69 13 51 52 87 60 12* 56* 87* 71* 72* 81*					
6	56 8 17	36 37 101* 113*	48 86*			
5	25 75 66 83* 76*	65	112*			
4	20 97 3* 40* 82* 84*		24			
3	90*	52		92		
2	62 70 19*	83 44	102 105 78*			
1	86 16 64 104 53* 85* 11*	22 95 18	107			
0	10 49	100 15 47 39*	5 77 25 46 54*	99 101 67 43 84 30*	4 61 21 29 31 33 58 7 91 1* 74* 53*	47 48 50 60 33 2* 3* 62* 41* 100*
	0	1	2	3	4	5

Results of voting for the intersections of the figure.

D: dangerous voting, N non dangerous voting.

The tilda indicates the intersections of second class. The dash indicates intersections of third class. Those with an asterisk against them indicate the intersections which are closer than 35 Km to some of the historical epicenters from the Figure. No special sign indicates intersections of first class (closer than 35 Km to some instrumental epicenter).

hundreds of km in diameter and killing many hundreds of thousands as in 1976 in China.

It is the greatest killer and most destructive of all natural catastrophies.

Methods to forecast earthquakes are under study but the results are not reliable and often still confusing. The problem can be attacked with statistical and probabilistic methods only (Caputo et al. 1979, Caputo et al. 1974).

A Tsunami is a sequence of travelling ocean waves of long length and period depending both on the depth where the wave travels; they are generally generated by earthquake phenomena below or near the ocean flow. In the open ocean the height of the wave may be only a meter, its length more than a hundred km and its speed may exceed 1000 km/hour. As the Tsunami enters the shoaling water of the coast the velocity of the wave decreases and the height increases to tens of meters hitting the coastlines with devastating power. Every coastline of the Pacific will be hit by a Tsunami sooner or later. The same is true for a good part of the Mediterranean coastline.

In the Pacific there is a Tsunami Warning System consisting of a network of tens of seismic and tide stations spread around the Pacific coast. When an earthquake of sufficient magnitude to generate a Tsunami occurs in the Pacific Ocean area the Tsunami Warning System personnel determines the epicenter of the Earthquake. Depending on the location of the epicenter and on the magnitude of the Earthquake a Tsunami watch is issued communicating the information on the Earthquake. Since the information on the Earthquake travels with speed of light, the computation of the epicenter with the proper equipment takes few minutes and the tsunami wave travels with speed of 1000 km/hour in most cases there is plenty of tinse to issue a warning and the expected time of arrival of the Tsunami wave at each location in the Pacific Ocean.

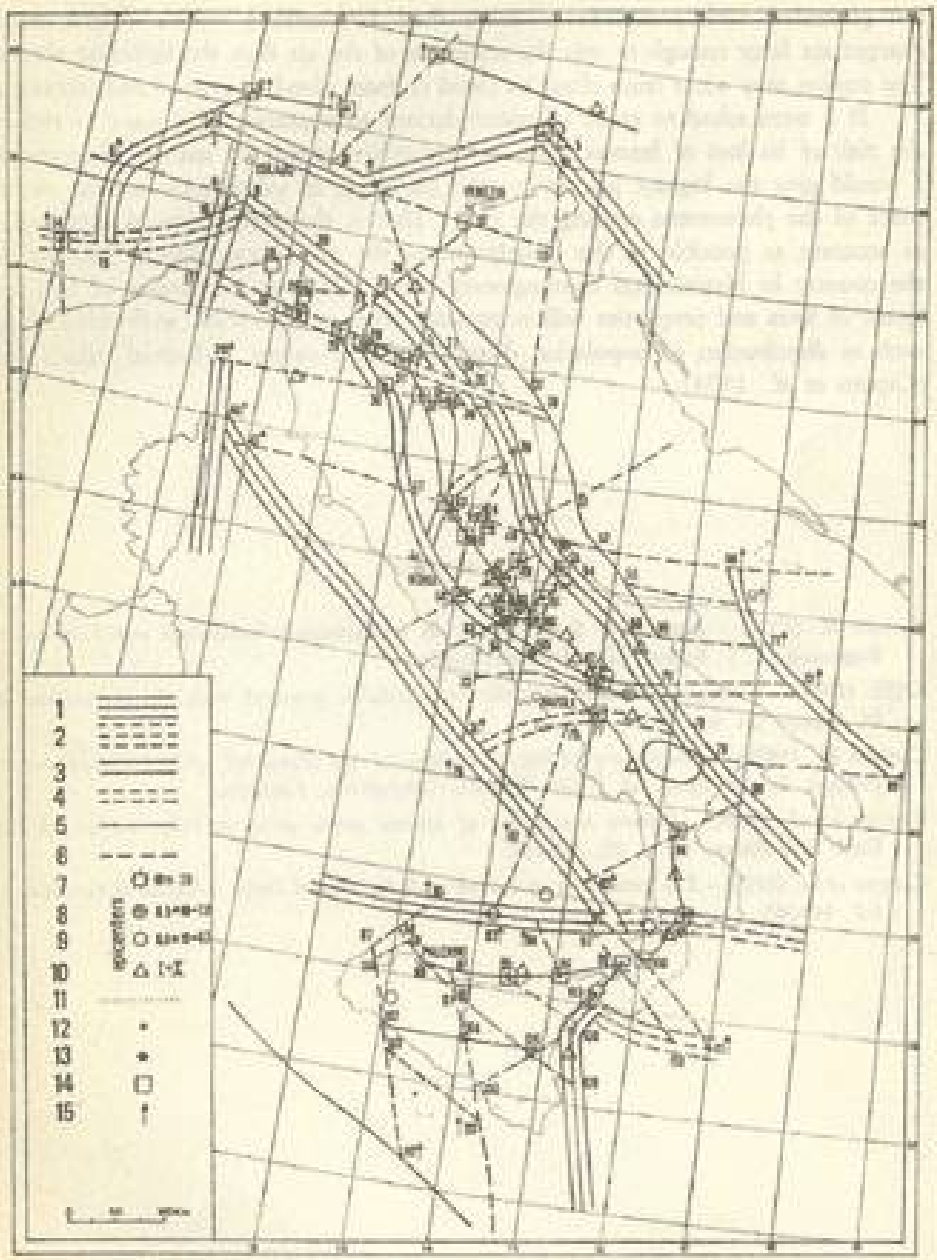
Safety rules have been issued to the public around the Pacific.

This warning system has already saved hundreds of lives and many billions of dollars in property.

In Italy we have just completed the Catalogue of tsunamis of the Italian coast. It was prepared under the auspices of ENEL (1979) with my supervision. A first very tentative analysis of the data presented in the catalogue gives the following formula for the distribution function n(I) of the Tsunamic Intensity I in thousand years (Caputo, 1979)

$$\log n(I) = -0.44\, I + 3.12$$

Now a few words on the weapon of ancient gods: the lighting. When the thunderstorm is growing the interaction between charged particles induces a strong electrical field within the cloud system in which the positive charges are usually in the upper layers of the system, usually frozen, and the negative charges are in the lower part. This in turn induces a strong positive charge on the Earth in an area many km in diameter, in which the positive charges tend to be accumulated on antennas, elevated buildings and trees. The air being a poor conductor prevents the flow of current between the two opposite charges until enormous charges



The Figure shows the results of recognition. The intersections marked with numbers from 1 to 113 are considered for the recognition. The Figure shows also the lineaments of first rank (1, 2), of second rank (3, 4), of third rank (5, 6); it shows also different types of epicenters (7, 8, 9, 10), the full dot (12) indicates intersections recognised as dangerous, the asterisk (13) indicates intersections for which recognition was not possible, the square (14) indicates intersections recognised as dangerous in the experiment future, the arrow (15) indicates intersections not used because they are on the outer boundaries.

are generated with potentials of more than 100 million volts. When these charges are large enough to win the resistence of the air then the lightning occurs. The strokes may occur from cloud to cloud or from cloud to ground and viceversa.

If I were asked to make recommendations to countries who want to reduce the risk of its loss of human lives and properties caused by natural phenomena, I would give the highest priority to the gathering of information on the occurrence of the phenomena causing the risk. That is the compilation of catalogues; as accurate as possible in the description of the phenomena which occurred in the country in historic and contemporary time. Maps and estimates of risk for losses of lives and properties will come later with confrontation with other maps such as distribution of population density, cultural values, industrial values etc. (Caputo *et al.*, 1974).

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