CMCC – University of Exeter – Met Office

Assessing uncertainties in Climate Models and estimating Future Climate Risks in the Mediterranean region

MEDiterranean CLImate VARiability

(MEDCLIVAR)

Letizia Congedi

contact: letizia.congedi@cmcc.it

Supervisors:

Prof. Matthew Collins, Dr.Debbie Hemming, Prof. Piero Lionello

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Introduction and motivations

The Climate Risk arises from interactions between climate and society. It can be approached considering social aspects by vulnerability assessment and considering climatic aspect by natural hazards assessment, or using a complementary approach, which combine both components. It is important to assess climate variability and change and, subsequently, to identify risks (Jones R et al., 2004). Finally, the knowledge of current climate risks and of the adaptation to those risks provides very useful information to assess future adaptation needs. The risk analysis includes the identification of risk indicators, that are "Indicators of climate variability and change".

In general, many diverse research and policy communities, including those pursuing issues of global environmental change, food security, development assistance and disaster risk, have developed definitions and pre-analytic visions of risk and vulnerability (Birkmann J., 2007). United Nations/International Strategy for Disaster Reduction (UN/ISDR), for example, defines vulnerability as the 'conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards'(UN/ISDR, 2004). According to this definition, the hazard event itself is viewed primarily as external to the system or element at risk, and the term vulnerability describes the conditions of a society or element at risk that also determine the potential or revealed hazard's impact in terms of losses and disruption. Since risk is generally defined as the product of the hazard probability and its consequences, risk can be viewed as a function of the hazard event and the vulnerability of the elements exposed (Birkmann J., 2007). Vulnerability is often viewed as an intrinsic characteristic of a system or element (UN/ISDR, 2004; Cardona, 2004; Wisner, 2002; Thywissen, 2006), although most analysts acknowledge that vulnerability is conditional on a hazard, e.g. with respect to its frequency and severity, or that it is useless to discuss vulnerability independent of its hazard context (Birkmann J., 2007).

The assessment of the consequences of climate change is a key part of climate risk assessment, which is permeated by uncertainty and requires to use specialized methods. The uncertainties affecting climate change effects have biophysical and socioeconomic components. Biophysical uncertainties include interactions between the oceans, atmosphere and biosphere and are partially included directly in climate model results, socioeconomic uncertainties include the dynamics of economy, technology, population and society.

Global Climate Models (GCMs) provide detailed predictions of future climate change, GCMs are not perfect representations of the real world. The size of the grid is limited by the availability of computer resources and the representation of sub-grid scale processes is approximate, and limited by our ability to fully understand and describe climate processes. The consequence of this is that predictions of the future made using climate models are uncertain (Harris G. R. et al, 2010). Projections by global and regional climate model (RCM) simulations are generally consistent with each other at the broad scale (Giorgi F. and Lionello P., 2007) and RCMs are expected to produce more accurate results than GCMs to represent the environmental variables, because of their higher resolution (Lionello P. et al, 2007).

The Objective of this research project is to analyze the techniques for the assessing climate risks and related uncertainties, to adapt them to the needs of the Mediterranean regions in a climate change perspective.

The analysis focuses on the Mediterranean basin and consists of the following points :

- to identify the hazard indicators (daily precipitation);
- to identify the risk indicators (floods);
- to identify the vulnerability indicators (population density, slope of terrains, etc…)
- to develop flood risk maps for the Mediterranean region by using model climate data, risk indicators, vulnerability indicators;
- to discuss the reliability of results.

1. Risk indexes : the EM-DAT database

This research report analysis considers the flood risk in the Mediterranean region in the period from 1970 to 2008 using data describing the damages produced by floods

The EM-DAT database, created by CRED (Centre for Research on the Epidemiology of Disasters), contains records about the disasters caused by the floods used for this study. CRED defines a disaster as "a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering”. For a disaster to be entered into the database, at least one of the following criteria must be fulfilled (Jakubicka T. et al., 2010):

• 10 or more people reported killed;

• 100 or more people reported affected;

• declaration of a state of emergency; and/or

• call for international assistance.

The main objective of the database is to serve the purposes of humanitarian action at national and international levels. It is an initiative aimed to rationalize decision making for disaster preparedness, as well as providing an objective basis for vulnerability assessment and priority setting. EM-DAT database contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies (http://www.emdat.be/).

In the investigated period, the regions affected by flood events are : Albania; Algeria; Austria; Azores; Belarus; Belgium; Bosnia-Hercegovenia; Bulgaria; Canary Is; Croatia; Czech Rep; Czechoslovakia; Egypt; France; Germany; Germany Dem Rep; Germany Fed Rep; Greece; Hungary; Italy; Libyan Arab Jamah; Luxembourg; Macedonia FRY; Malta; Moldova Rep; Montenegro; Morocco; Netherlands; Poland; Portugal; Romania; Russia; Serbia; Serbia Montenegro; Slovakia; Slovenia; Spain; Sudan; Switzerland; Tunisia; Ukraine; Yugoslavia.

For each disaster event, the EM DAT database indicates the geographic area where the disaster occurred, but not the exact location, always. So, in order to associate each flood event with the rainfall event (by using the Instrumental and climate model precipitation daily data), a code has been associated with the type of geographical location, reported by the EM DAT database. This code indicates the degree of uncertainty about the spatial region where the event occurred : “uncertainty 0” is associated with a precise location (single town); “uncertainty 1” is associated with a group of town; “uncertainty 2” is associated with a large area (region); “uncertainty 3” is associated with a group of large regions. In this analysis, emphasis is given to the locations with uncertainty 0, because it's possible associate the flood event with that of precipitation at a point with specific geographical coordinates. The analyzed Mediterranean region covers the area from -10W to 45E in longitude and from 25N to 50N in latitude.

Considering the geographical regions related at each event only, the flood events number for each damaged locations, in the period from 1970 to 2008, is shown in **figure 1**. The regions most affected by floods are: Romania (33 flood events), Algeria (32 flood events), France (31 flood events). The region less affected is Montenegro.

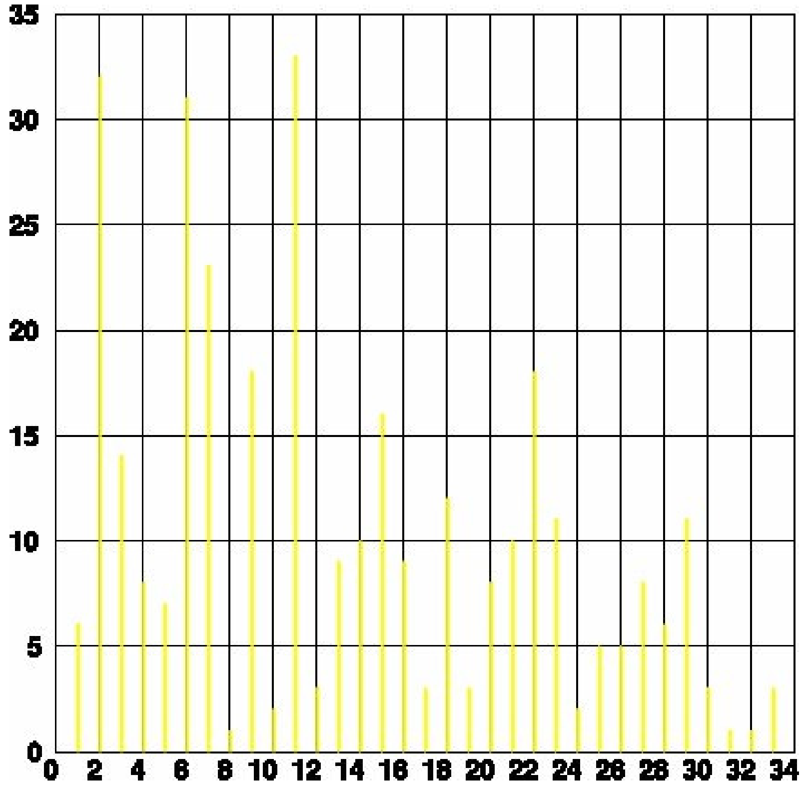


Fig. 1. Number of flood events that occurred in each country of the Mediterranean region in the period from 1970 to 2008. The y axis indicates the number of flood events and x axis the locations where they occurred according to the following table:

1 Albania	12 Russia	23 Hungary
2 Algeria	13 Serbia	24 Luxembourg
3 Austria	14 Slovakia	25 Macedonia
4 Belgium	15 Spain	26 Moldova
5 Egypt	16 Tunisia	27 Portugal
6 France	17 Bosnia	28 Switzerland
7 Italy	18 Bulgaria	29 Ukraine
8 Montenegro	19 Croazia	30 Yugoslavia
9 Morocco	20 Czech Rep	31 Canary Is
10 Poland	21 Germany	32 Czechoslovakia
11 Romania	22 Greece	33 Sudan

In this study, the analyzed flood events were divided into three subtypes, that are the "General Floods", the "Flash floods", the "Floods" :

- the *General Flood* is a gradually rising inland floods (rivers, lakes, groundwater) due to high total depth of rainfall or snowmelt. A general flood is caused when a body of water (river, lake) overflows its normal confines due to rising water levels. The term general flood additionally comprises the accumulation of water on the surface due to long-lasting rainfall (water logging) and the rise of the groundwater table above surface. Furthermore, inundation by melting snow and ice, backwater effects, and special causes such as the outburst of a glacial lake or the breaching of a dam are subsumed under the term general flood. General floods can be expected at certain locations (e.g. along rivers) with a significantly higher probability than at others (http://www.emdat.be/);

- the *Flash Flood* is a rapid inland flood due to intense rainfall. A flash flood describes sudden flooding with short duration. In sloped terrain the water flows rapidly with a high destruction potential. In flat terrain the rainwater cannot infiltrate into the ground or run off (due to small slope) as quickly as it falls. Flash floods typically are associated with thunderstorms. A flash flood can occur at virtually any place (http://www.emdat.be/);
- the *flood* is a significant rise of water level in a stream, lake, reservoir or coastal region (http://www.emdat.be/).

Figures 2, 3 and **4** show the number of floods with uncertainty 0,1,2,3, for the flash flood events (fig.1), general flood events (fig.2) and flood events (fig.3). It's evident that the low number of events occurred on areas very big (with uncertainty 3) in all type of disasters.

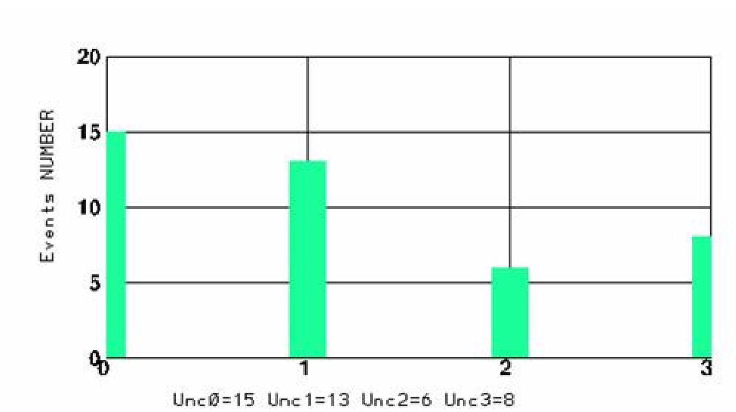


Fig. 2. Number of flash flood events that occurred in the period from 1970 to 2008. The number of flash flood events (y axis) is shown for several uncertainty levels (y axis) : 0, 1, 2, 3.

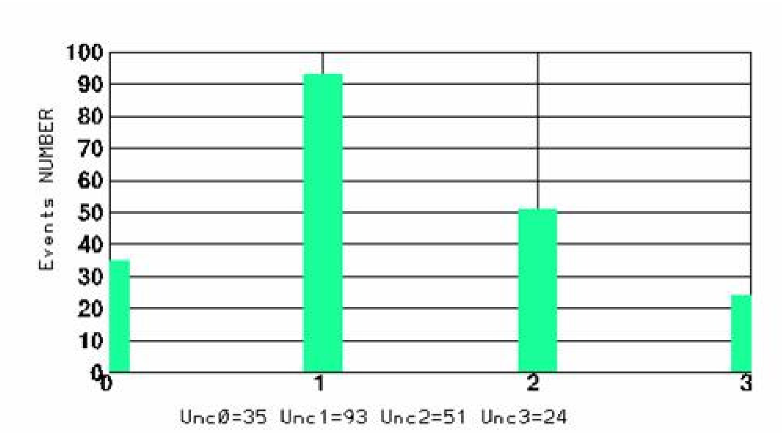


Fig. 3. Number of general flood events that occurred in the period from 1970 to 2008. The number of general flood events (y axis) is shown for several uncertainty levels (x axis) : 0, 1, 2, 3.

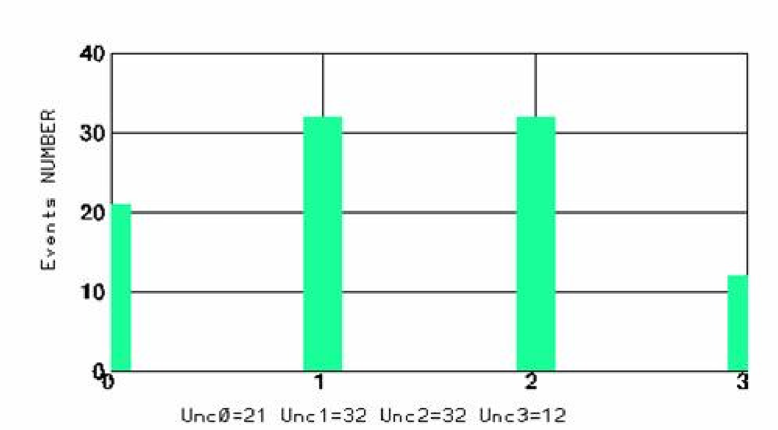


Fig. 4. Number of flood events that occurred in the period from 1970 to 2008. The number of flood events (y axis) is shown for several uncertainty levels (x axis) : 0, 1, 2, 3.

The damages caused by the flood events and analyzed in this report concern the impacts of the disasters (that occur on several sectors, i.e. industry, electricity, communications, cultural infrastructure, transportation, sanitation.) on the infrastructures that were damaged or destroyed, given in absolute values or percentages (houses, bridges, commercial/business structures, roads, schools, hospitals, forests, etc...). In particular, the categories of damage studied are the number of killed peoples, the number of affected peoples (total affected) and the estimated damages (in Million 000'US$). The CRED defines these types of damages in the following way (http://www.emdat.be/) :

- the killed peoples are the persons confirmed as dead and persons missing and presumed dead;

- the total affected indicates the number of peoples requiring immediate assistance during a period of emergency (injured, affected and left homeless); it can also include displaced or evacuated peoples;
- the estimated damage are given in US$ (‘000) and concern the economic impact of a disaster, which usually consists of direct (e.g. damage to infrastructure, crops, housing) and indirect (e.g. loss of revenues, unemployment, market destabilisation) consequences on the local economy.

The following figures show the damages caused by the flood events (in the period analyzed) that occurred in the single towns (uncertainty 0) : a total of 70 events. **Figures 5, 6, 7** show the number of killed peoples, the number of affected peoples and the estimated damage, respectively.

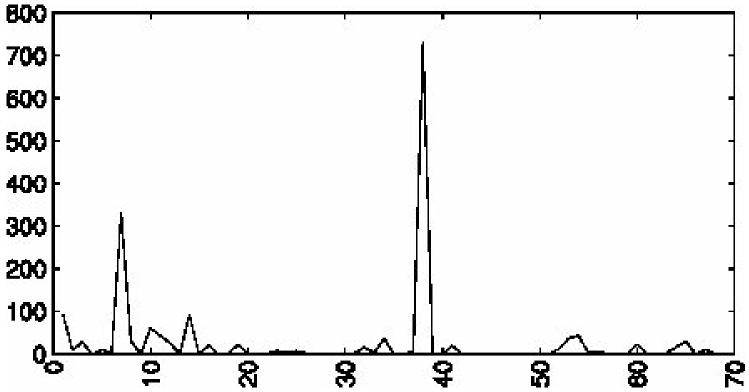


Fig.5. Number of killed peoples (y axis) for each flood event with uncertainty 0 (x axis), in the period 1970-2008.

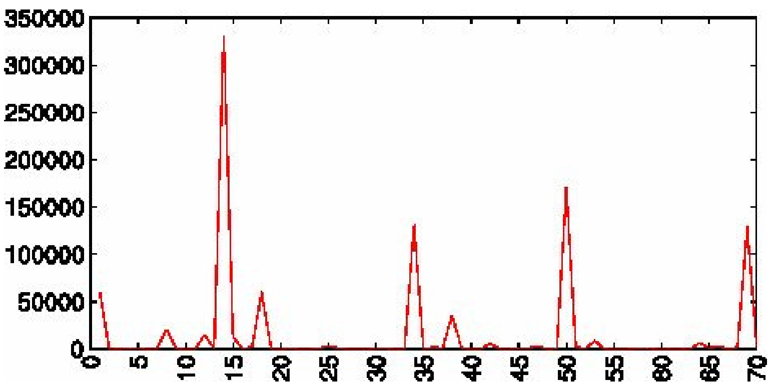


Fig.6. Number of affected peoples (y axis) for each flood event with uncertainty 0 (x axis), in the period 1970-2008.

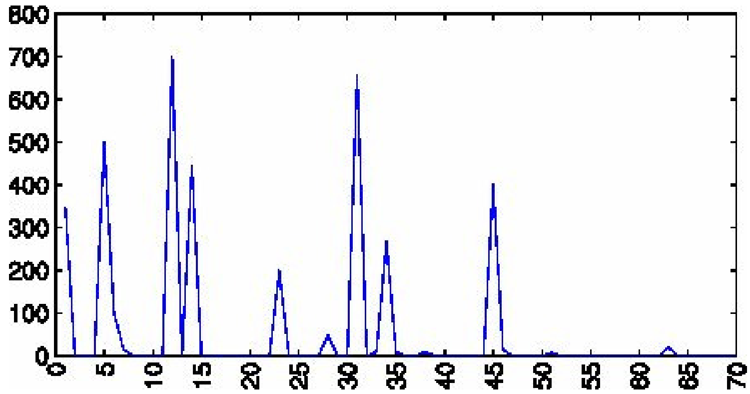


Fig.7. Estimated damage (y axis, in "000"US$) for each flood event with uncertainty 0 (x axis), in the period 1970-2008.

The highest number of killed people is 730 (fig.5) and the flood event (general flood) that has caused it occurred in Morocco (Marrakesh location) in the period from 17/08/1995 to 18/08/1995. Instead a big number of affected peoples (330613) occurred in the summer 2002, from 19 June to 1 July (fig.6) at Stavropol (Russia), by a flash flood. At last, the maximum damage value (700 Million US$) was estimated at Malopolskie (Poland) for the flash flood that occurred from 20/07/2001 to 3/08/2001 (fig.7).

The list of all flood events, that are analyzed in this report, is given in Appendix.

2. Hazard indicator : the daily precipitation (E-OBS and GPCP data)

The daily precipitation values (hazard indicator) have been compared with the damages caused by floods (risk indicators) at single geographical points where the events are occurred in the period 1970-2008. The instrumental E-OBS data and GPCP data were analyzed for this purpose.

The *E-OBS* database was created by ECA&D (European Climate Assessment & Dataset) team and contain gridded daily mean precipitation data, covering the area: 25N-75N x 40W-75E. The original dataset, consisting of spatially irregular meteorological observations (250 stations over the Europe), was interpolated to a regular grid by ECA. The E-OBS data (Version 4.0) used for this report have a spatial resolution 0.25 x 0.25 degree, cover the same spatial domain used to analyze the flood data, in the coordinate box for longitude from -10W to 45E and for latitude from 25N to 50N, and the same studied time period.

The *GPCP* database (Global Precipitation Climatology Project) contains global daily precipitation fields with spatial resolution 2,5 x 2,5 degree and with temporal coverage from 1996 to 2008. The GPCP products include precipitation estimates based on the combination of the satellite measures with the rain gauge measures. The dataset version used for this analysis (1DD v1.1) contains data estimated using the following GPCP components (Xie P. et al., 1996) :

1. GPCP Polar Satellite Precipitation Data Centre - Emission (SSM/I emission estimates);
2. GPCP Polar Satellite Precipitation Data Centre - Scattering (SSM/I scattering estimates);
3. GPCP Geostationary Satellite Precipitation Data Centre (GPI estimates);
4. GPCP Global Precipitation Climatology Centre (rain gauge analyses).

The global spatial grid of the GPCP data was interpolated on the E-OBS spatial grid, (extracted previously), in order to compare the precipitation data on the same geographical domain.

The instrumental data (E-OBS and GPCP) are been used to analyze the daily precipitation values in the point where occurred the disaster, during the flash flood events specially because this type of flooding is due to insensitive rain. Same example are shown following. **Figure 8** shows the daily mean precipitation map, in the period from 19/06/2002 to 1/07/2002 (flood event) over the Mediterranean region, computed by using the E-OBS data. The flood event which occurred in these days over the Russia has been discussed previously (this disaster has caused 330613 affected peoples). The mean precipitation value at Stavropol (flooded location with coordinates lat/lon 45.2/41.58) is about 14 mm/day. The precipitation maximum value (between 80 and 90 mm/day) occurs the day 20 June 2002 (**figure 9**). Precipitation mean (**figure 10**) and maximum (**figure 11**) values similar, but lower than those E-OBS, are calculated by GPCP. Also, both datasets show the precipitation maximum value in the day 20 June.

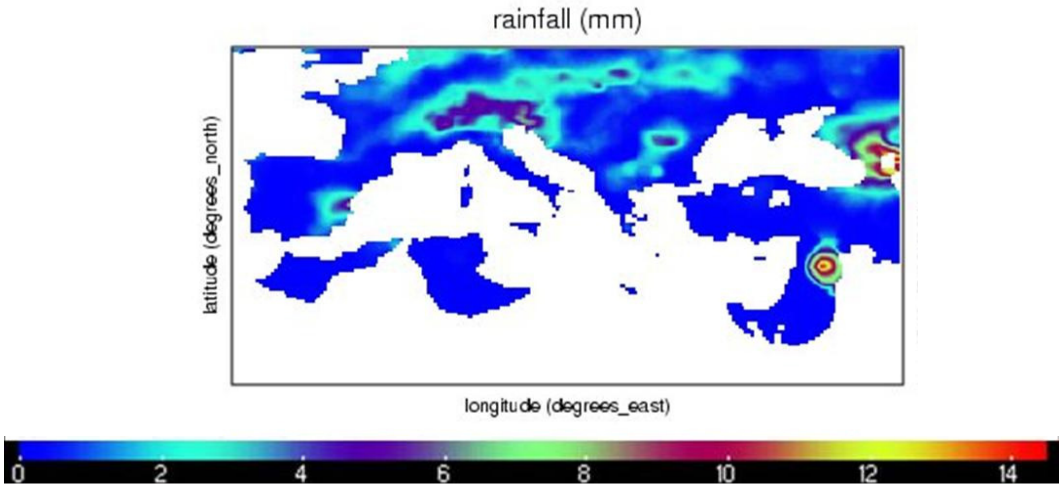


Fig.8. E-OBS daily mean precipitation map (mm/daily) of the Mediterranean region in the flooded period from 19/06/2002 to 1/07/2002m, showing the flood event at Stavropol.

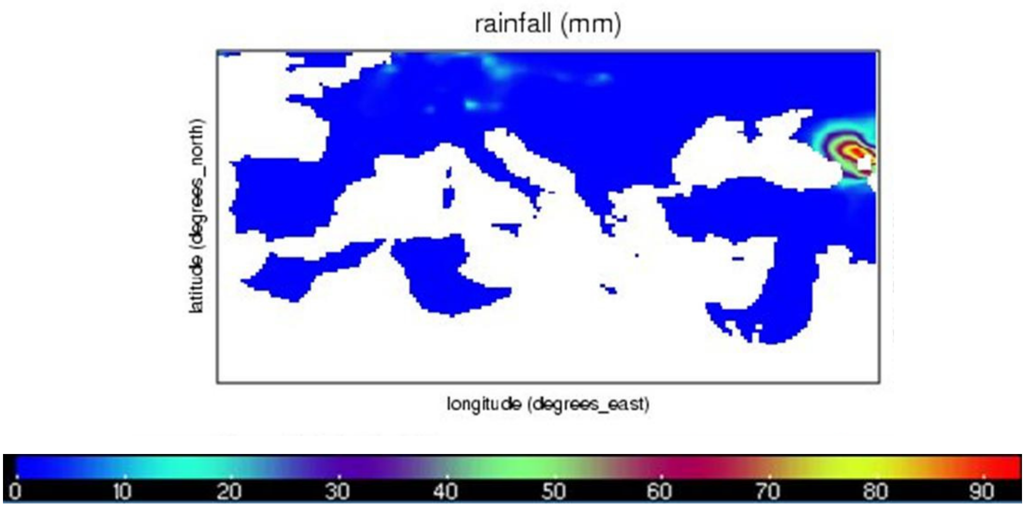


Fig.9. E-OBS daily precipitation map (mm/daily) of the Mediterranean region in the day 20/06/2002, showing the flood event at Stavropol.

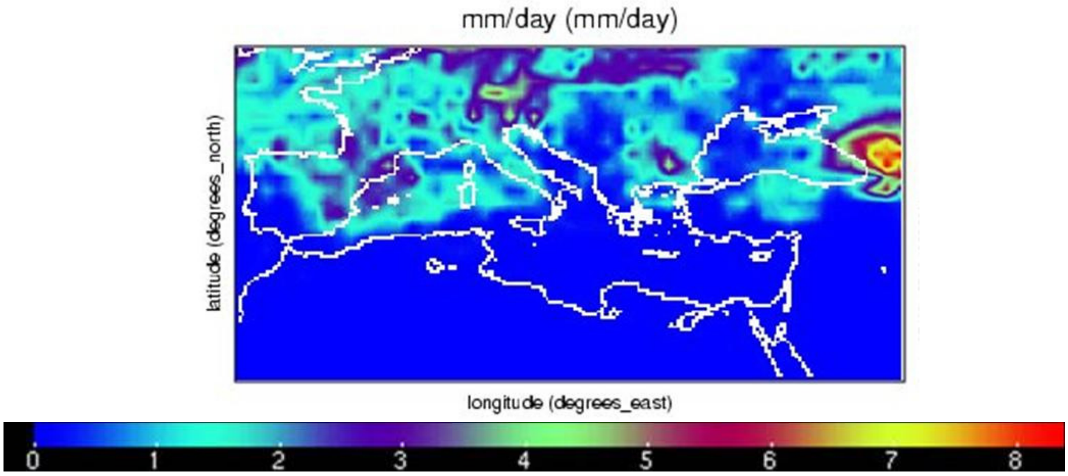


Fig.10. GPCP daily mean precipitation map (mm/daily) of the Mediterranean region in the flooded period from 19/06/2002 to 1/07/2002, showing the flood event at Stavropol.

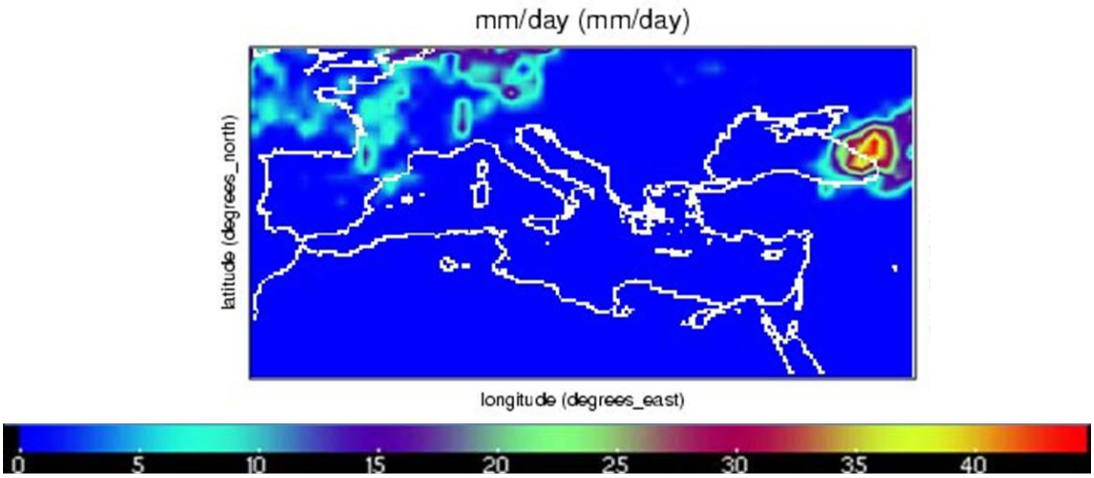


Fig.11. GPCP daily precipitation map (mm/daily) of the Mediterranean region in the day 20/06/2002, showing the flood event at Stavropol.

Instead, the flash flood event that occurred at Malopolskie (Poland), from 20/07/2001 to 3/08/2001, is analyzed in the figure below. **Figure 12** shows the E-OBS daily mean precipitation map of the event over the whole basin. The point of coordinates lat/lon 49.43/20.14 (corresponding to the location where the disaster occurred) gives a precipitation mean value over 10 mm/day and it's confirmed by the GPCP precipitation value, shown in the **figure 14**.

The precipitation maximum value of the event is registered in day 23/07/2001 by both instrumental measurements (E-OBS and GPCP in the **figures 13** and **15**, respectively). These high values of rain have caused (in the identified spatial area) 27 killed peoples, 15000 affected peoples and 700 Million US$ of damages.

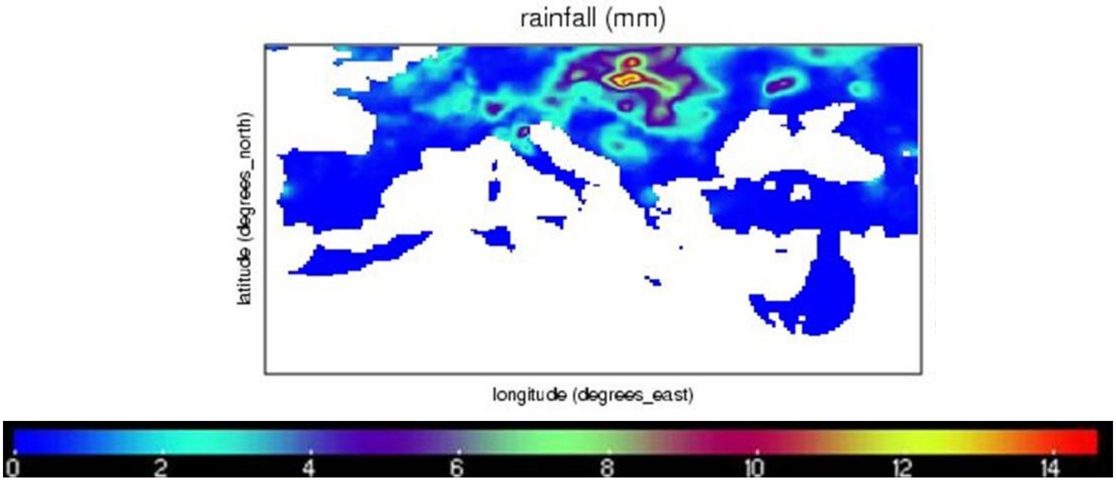


Fig.12. E-OBS daily mean precipitation map (mm/daily) of the Mediterranean region in the flooded period from 20/07/2001 to 3/08/2001, showing the flood event at Malopolskie.

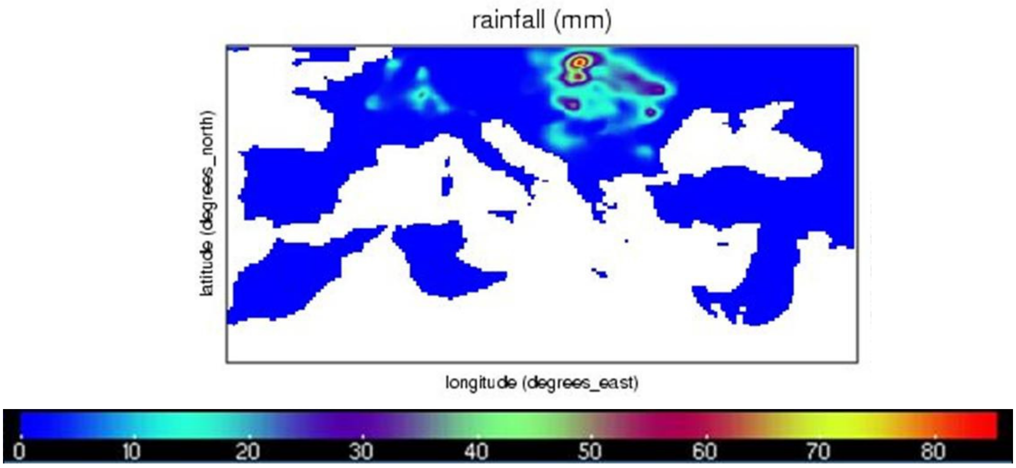


Fig.13. E-OBS daily precipitation map (mm/daily) of the Mediterranean region in the day 23/07/2001, showing the flood event at Malopolskie.

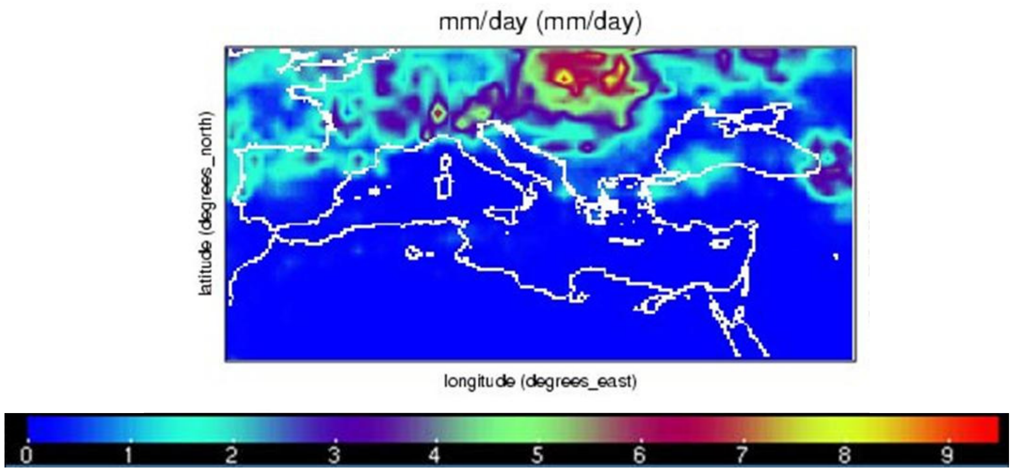


Fig.14. GPCP daily mean precipitation map (mm/daily) of the Mediterranean region in the flooded period from 20/07/2001 to 3/08/2001, showing the flood event at Malopolskie.

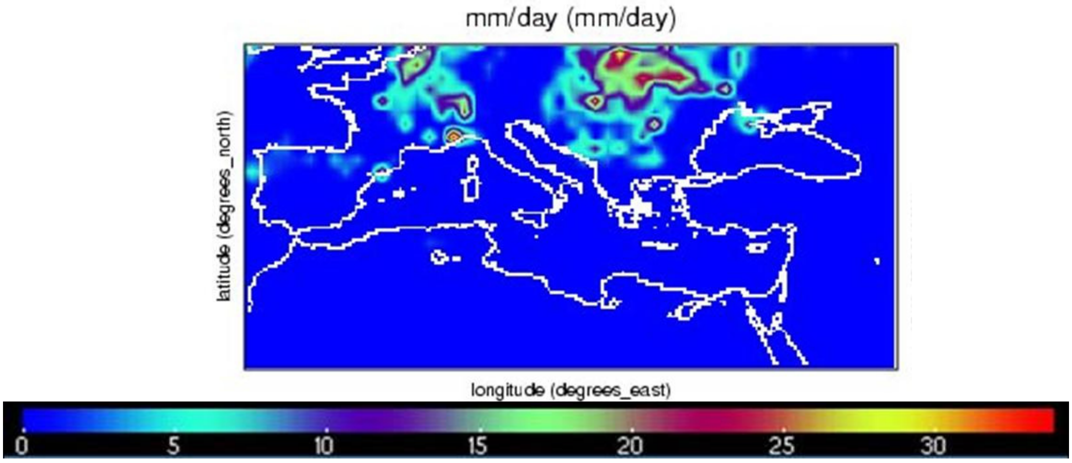


Fig.15. GPCP daily precipitation map (mm/daily) of the Mediterranean region in the day 23/07/2001, showing the flood event at Malopolskie.

2.1 Daily precipitation and risk indicators

It was analyzed the relation between the precipitation instrumental value (E-OBS and GPCP data) and the risk indicator for each location where occur the flash flood, to evaluate the importance of the rain with respect to the reported damage. So, 15 flash floods with uncertainty 0 were taken into account in this analysis. **Figures 16, 17, 18** show the scatter plot of the precipitation maximum and mean values (a and b for every figure**,** respectively), computed in the geographical point where occurred each floods, versus the risk index value (number of killed peoples in fig.16; number of affected peoples in fig.17; damage estimated value in fig.18), during each analyzed flash flood event. The same analysis is carried out by using the E-OBS data and GPCP data. It's evident that there is not a linear relationship between the two compared variables and it applies to all risk indicators. When the precipitation value increases, the damage corresponding value does not increase, necessarily. For few events only, it’s verified by using the precipitation maximum value, particularly. Probably, the damage does not depend on precipitation value only, but by other factors related to the disaster that has affected regions (type of terrains, density population, type of infrastructures and houses, type of the vegetations, etc…), but these factors are not discussed in this section.

At last, considering the number of flood days instead of the risk index value in the scatter plot (**figure 19**), the increasing linear relationship is shown, because the value of rainfall is related to the flooding days number. In every case discussed, the relationships between the risk indicators and the precipitation value show different quite values by using E-OBS data and GPCP data and it is caused by the different characteristics of the two instrumental datasets, such as the different spatial resolution, the different techniques of data assimilation and the different temporal covers.

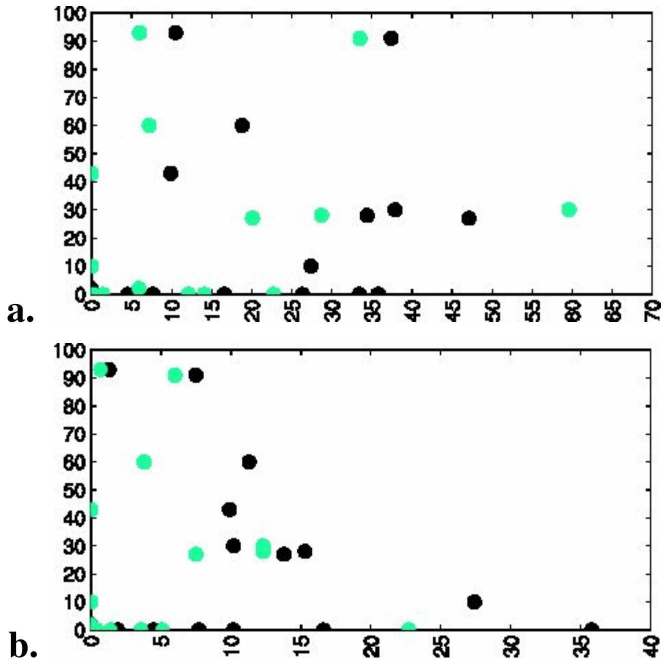


Fig.16. Scatter plot of the precipitation maximum (a) and mean (b) values (x axis, in mm/day) in the flooded geographical location versus the number of killed peoples (y axis), for each flood event. The green dots refer to the GPCP rain value and the black dots refer to the E-EOBS rain value.

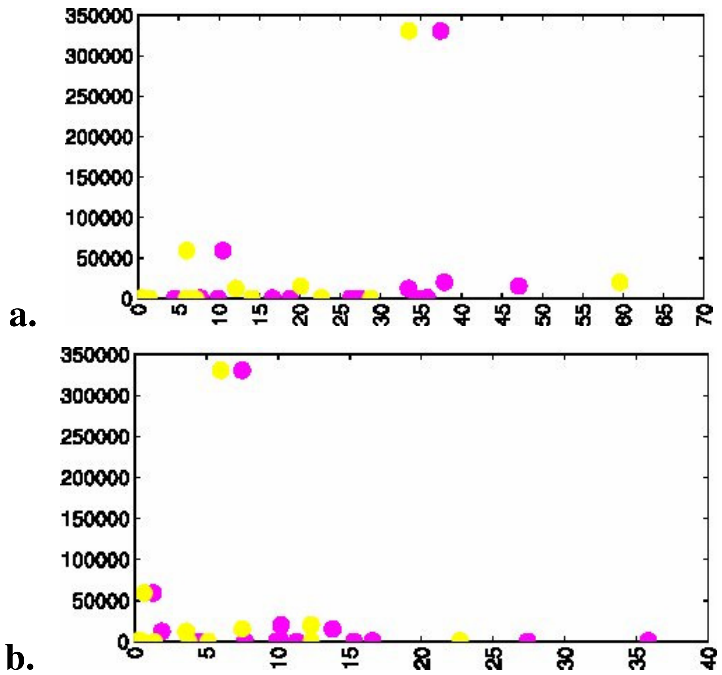


Fig.17. Scatter plot of the precipitation maximum (a) and mean (b) values (x axis, in mm/day) in the flooded geographical location versus the number of affected peoples (y axis), for each flood event. The yellow dots refer to the GPCP rain value and the pink dots refer to the E-EOBS rain value.

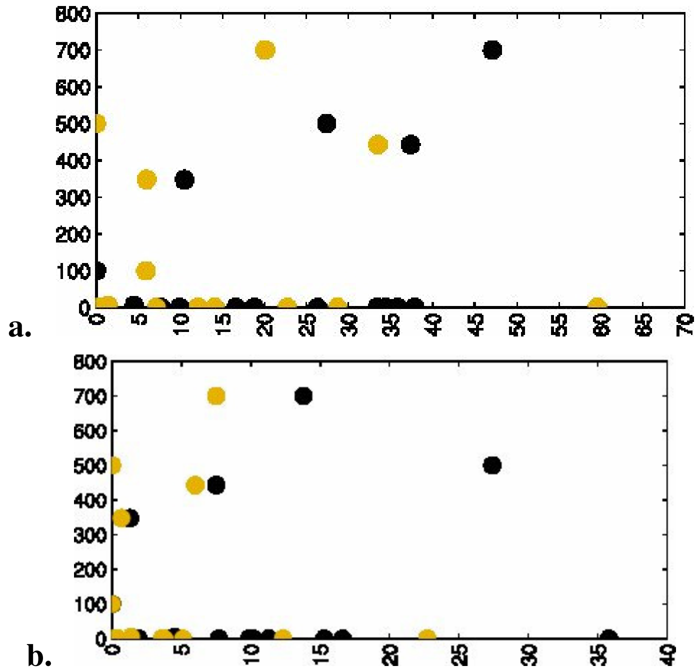
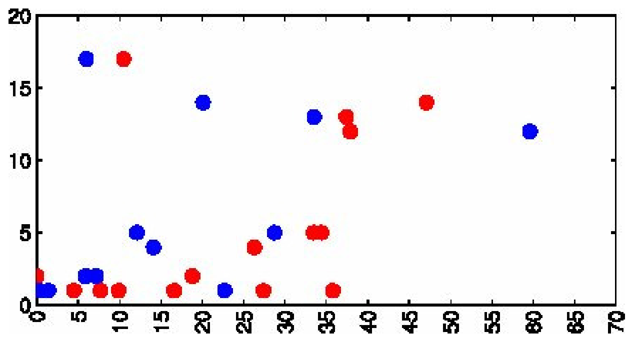
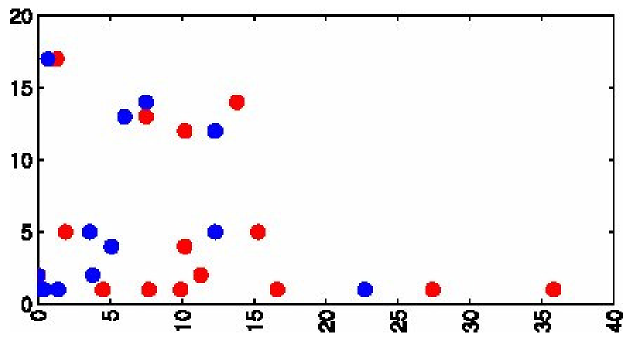


Fig.18. Scatter plot of the precipitation maximum (a) and mean (b) values (x axis, in mm/day) in the flooded geographical location versus the estimated damage (y axis, in Million US$), for each flood event. The brown dots refer to the GPCP rain value and the black dots refer to the E-EOBS rain value.



a.



b.

Fig.19. Scatter plot of the precipitation maximum (a) and mean (b) values (x axis, in mm/day) in the flooded geographical location versus the number of flood days (y axis), for each flood event. The yellow dots refer to the GPCP rain value and the pink dots refer to the E-EOBS rain value.

2.2 Regression analysis

The statistical *coefficient of determination* R^2 is used in this research context in order to evaluate the significance of the relationship between the risk indexes values, that are the "statistical predictands" and the precipitation values, that are the "statistical predictors". The R^2 coefficient was computed for the past variables values, but it's possible to use it in order to forecast the future evolution of the same variable.

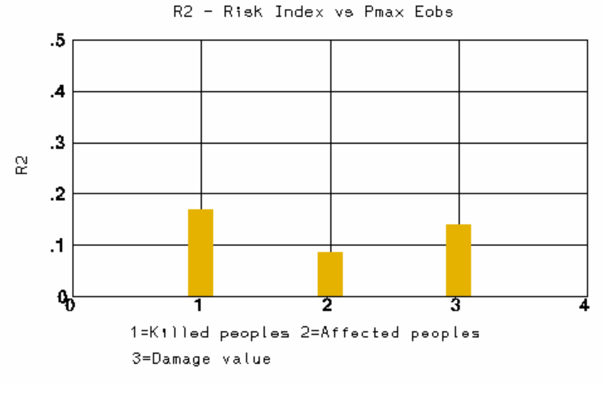
The R^2 value for a *linear regression analysis* is simply the square of the sample correlation coefficient between the outcomes and their predicted values. In general, the R^2 coefficient of determination is a statistical measure of how well the regression line approximates the real data points. This coefficient has values between 0 and 1. An R^2 of 1.0 indicates that the regression line perfectly fits the data (http://en.wikipedia.org/).

Values of R^2 outside the range 0 to 1 can occur in a *multiple regression analysis*. This coefficient is named "adjusted R^2" and is a modification of R^2 that adjusts for the number of explanatory terms in a model. Therefore, the adjusted R^2 can be negative, and will always be less than or equal to R^2 (http://en.wikipedia.org/).

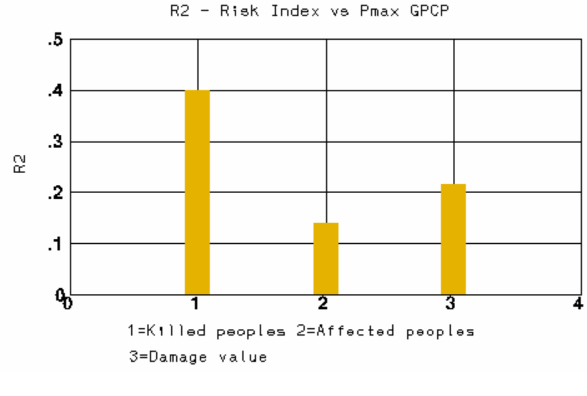
In this study, the R^2 coefficient value has been calculated, for several combinations of predictans variables and predictor variables, or risk index values and precipitation values. The aim is to estimate when the determination coefficient value is big.

Figure 20 shows the R^2 coefficient value (y-axis) computed for a linear regression analysis where the precipitation maximum value is the predictor variable (by using the E.OBS data in fig.20.a and GPCP data in fig.20.b) and the predictand variable is the index of damage (the categories of damage index are given as : 1= number of killed peoples; 2= number of affected peoples; 3= estimated damage, in '000 US$). The higher coefficient values are measured for the categories 1, 3, 2, respectively, for both instrumental data (E-OBS and GPCP). **Figure 21** shows the same results of the figure 20 except than for precipitation mean value (predictor variable). The result of **figure 22** reveals a good relationship between the risk indexes and the number of flood days, by using the killed people value-predictor, especially (R^2 is about 0.6). Instead, **figure 23** shows a coefficient value (for a regression linear, by using the number of flood days and the precipitation instrumental mean values) higher for the GPCP data than the value of E-OBS data.

Finally, the adjusted R^2 value is computed for the multiple regression analysis (**figure 24**), where the risk index (categories 1, 3, 2) is the predictand variable and the maximum precipitation, mean precipitation, number of flooding days values are the predictor variables, together. The results in the fig.24.a (by using E-OBS data) and fig.24.b (by using GPCP data) show that the determination coefficient value is higher in category 1 (by using the number killed peoples), with a R^2 value of 0.5 about.

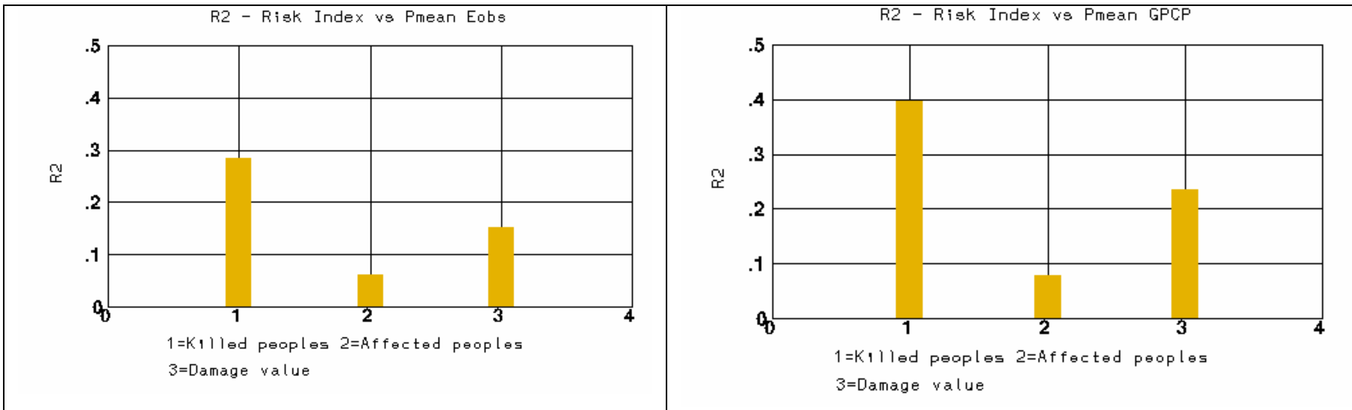


a. E-OBS



b. GPCP

Fig.20. R2 coefficient value (y axis) computed for a linear regression analysis between the E-OBS (a) and GPCP (b) precipitation maximum value-predictor variable (in all locations where occur the flash flood events) and the risk indexes- predictand variable (x axis : 1= number of killed peoples; 2= number of affected peoples; 3= estimated damage, in '000 US$).



a. E-OBS

b. GPCP

Fig.21. R2 coefficient value (y axis) computed for a linear regression analysis between the E-OBS (a) and GPCP (b) precipitation mean value- predictor variable (in all locations where occur the flash flood events) and the risk indexes- predictand variable (x axis : 1= number of killed peoples; 2= number of affected peoples; 3= estimated damage, in '000 US$).

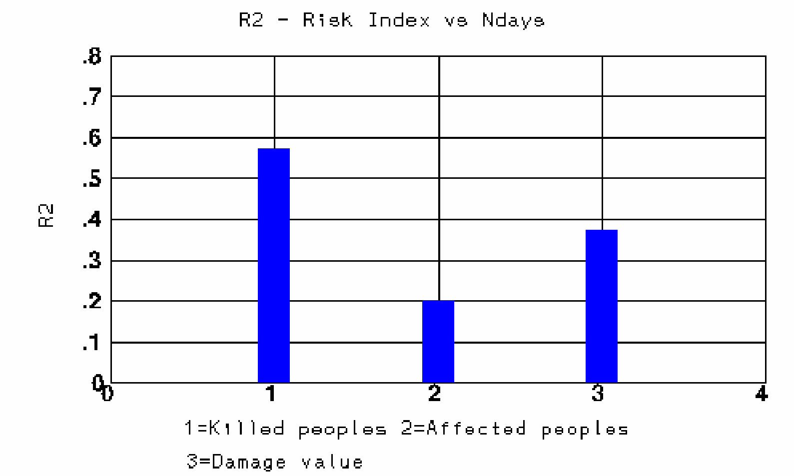


Fig.22. R2 coefficient value (y axis) computed for a linear regression analysis between the number of flooding days- predictor variable and the risk indexes- predictand variable (x axis : 1= number of killed peoples; 2= number of affected peoples; 3= estimated damage, in '000 US$).

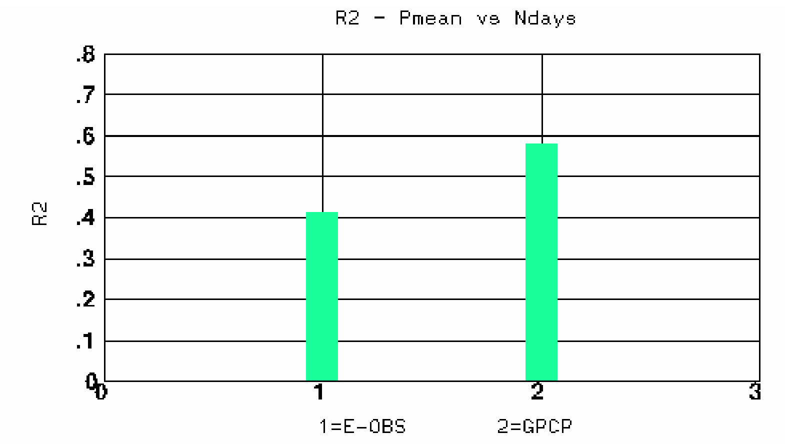


Fig.23. R2 coefficient value (y axis) computed for a linear regression analysis between the precipitation mean value- predictor variable in each flash flood event (x axis : 1= E-OBS rain value; 2= GPCP rain value) and the number of flooding days- predictand variable.

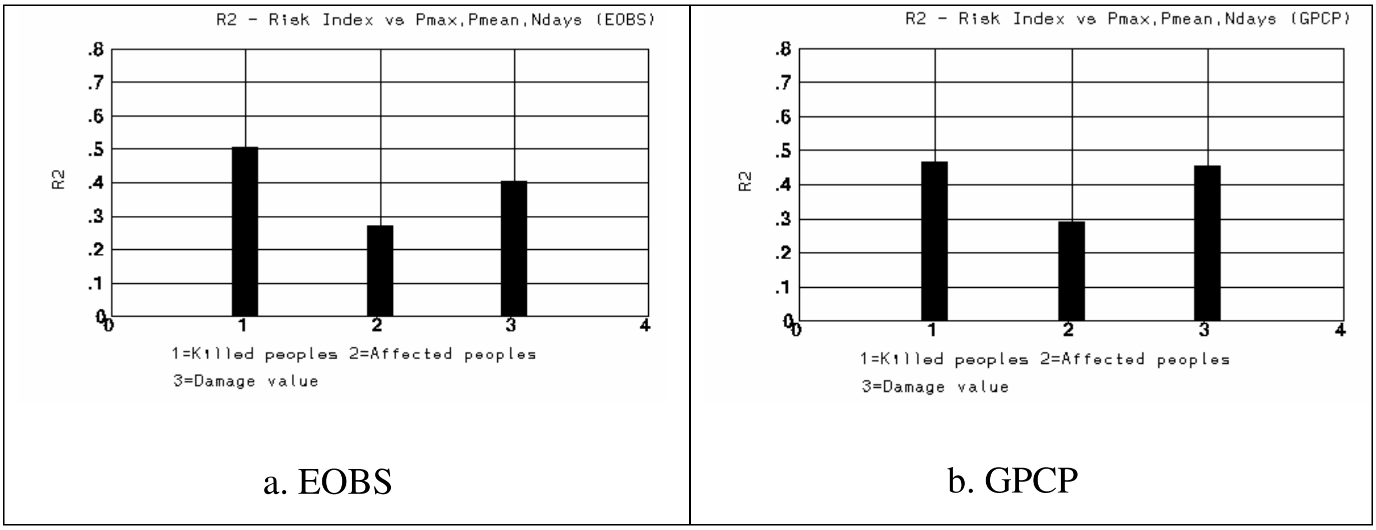


Fig.24. R2 coefficient value (y axis) computed for a multiple regression analysis between the E-OBS (a) and GPCP (b) precipitation mean value- predictor variable, precipitation maximum value-predictor variable, number of flood days- predictor variable and the risk indexes-predictand variable (x axis : 1= number of killed peoples; 2= number of affected peoples; 3= estimated damage, in '000 US$).

3. ENSEMLBES Regional Climate Model data – daily precipitation fields

The daily precipitation data, produced by the simulations of several climate models, are used in this analysis in order to compare it with the instrumental precipitation data (E-OBS and GPCP), that are discussed previously. Data are provided by Regional Climate Models (RCMs) that were used in the ENSEMBLES European project, which is funded by the European Commission (EC) to research climate change and its impacts in Europe. The daily precipitation fields with high spatial resolution (25Km x 25Km) were extracted on the same Mediterranean spatial domain of instrumental data, by analyzing the results on land, only. The RCMs that cover all Mediterranean region were chosen to compute a RCMs ensemble (the grid points that are common to all models are considered, only) for the present period 1970-2008 and for the future period 2021-2050. These are (in brackets the research organization that carried out the simulation is given) :

- RACMO2 (KNMI);
- BCM (METNO);
- REMO (MPI);
- RCA (SMHI).

3.1 Validation of the ENSEMBLES RCM data

In order to validate the RCM daily precipitation data, it was computed the bias annual, over the whole Mediterranean region, between the RCM ensemble data and the instrumental data, in the period analyzed for the flood events (1970-2008). **Figure 25** shows the precipitation bias annual maps between RCM ensemble data and E-OBS data (fig. 25.a) and GPCP data (fig. 25.b). The precipitation bias annual values, computed with respect to the E-OBS data and GPCP data, are similar fairly. The positive bias occurs over the geographical areas with complex morphology, such as the mountains and costal regions where the bias annual values exceed the 2500 mm/year. Instead the negative bias values occur over land, mostly. High bias values, in these areas, are justified because the RCMs have difficulty to simulate the local physical effects generated by orography, then the grid points at high levels and on the costal areas where occur land-sea contrasts. Except than these regions morphologically complex, the precipitation annual bias has low values on the Mediterranean domain, so the

RCM ensemble provides a good estimate of the precipitation field by comparing it with the instrumental data.

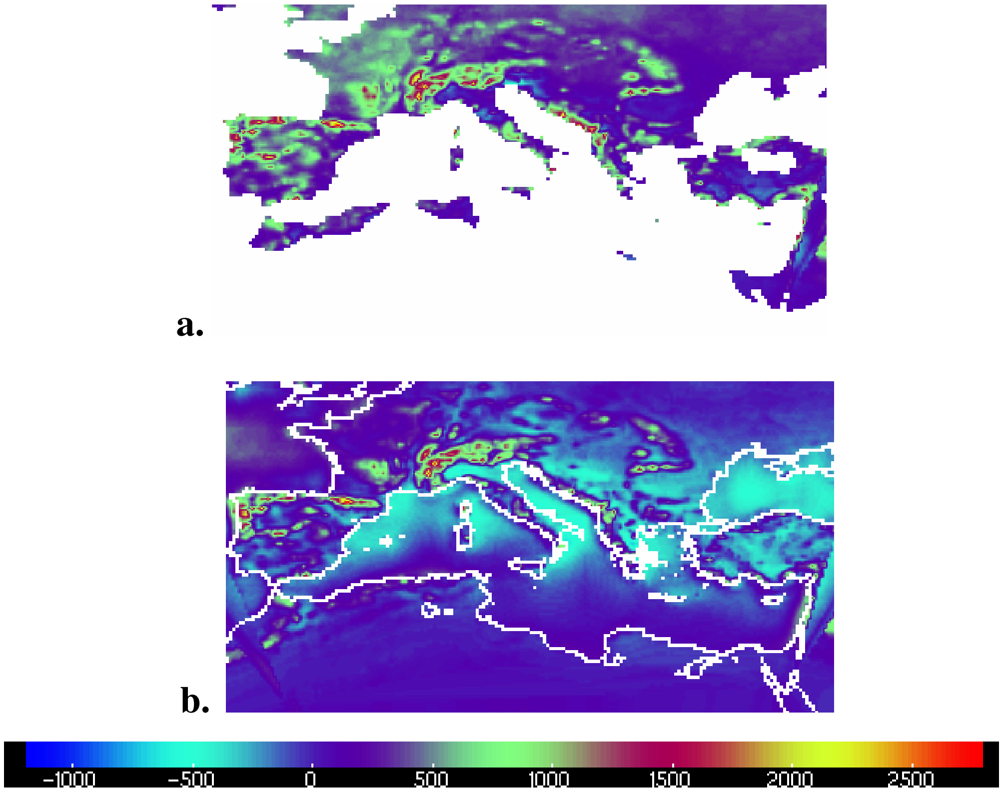


Fig.25. Precipitation bias annual map (mm/year) between RCM data and E-OBS data (a) or GPCP data (b), in the period 1970-2008, over the Mediterranean region.

3.2 Percentile values

The precipitation percentile value at 90^{th} value was calculated, over the whole Mediterranean domain, by using the E-OBS , GPCP, RCM ensemble daily precipitation fields, in the present period 1970-2008 (for the GPCP data, from 1996 to 2008) and in the future period (2021-2050). The percentile is the value below which a specified percentage falls. Then, the 90^{th} percentile is the value (or score) below which 90 percent of the observations may be found. Hence, 90^{th} percentile of daily precipitation can be thought of as the change in the precipitation of the wettest day. **Figure 26** shows the 90^{th} percentile map of daily precipitation in the period 1970-2008 (or 1996-2008, depending on the availability of data) by using the E-OBS data (fig.26.a), GPCP data (fig.26.b) and ENSEMNLES RCM ensemble data (fig26.c), over the Mediterranean region.

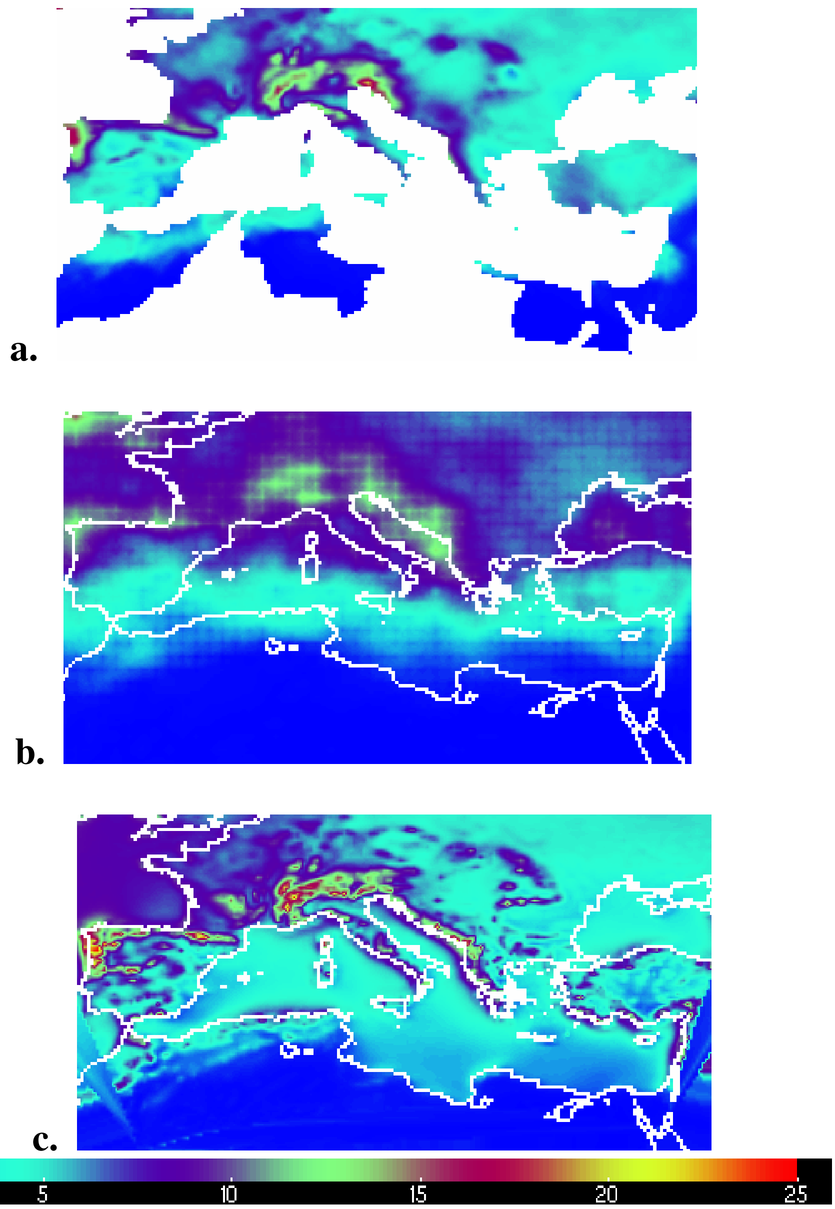


Fig.26. 90th percentile map of daily precipitation (mm) by using the E-OBS data (a-period 1970-2008), GPCP data (b-period 1996-2008) and ENSEMBLES RCM ensemble data (c-period 1970-2008), over the Mediterranean region.

The precipitation percentile 90th values are similar for E-OBS data and RCM ensemble data, mostly (fig.26a,b). Instead, the results for the GPCP data are different than previous, because of the different analyzed period (from 1996 and not from 1970), probably. Considering the whole Mediterranean basin, the precipitation percentile values high are evident over the Alps and the Balkan mountains. In order to evaluate the importance of the flash flood events in the studied geographical location, it was computed the 90th percentile value of daily precipitation for each grid point where occurred the disaster (with uncertainty 0) and in the all temporal period 1970-2008. The results for these 15 disaster events are shown in **figure 27**. For all period analyzed the precipitation daily values, for each locations, are lower than 12mm/day, about. So, the flooding event may be considered unusual, in the locations analyzed.

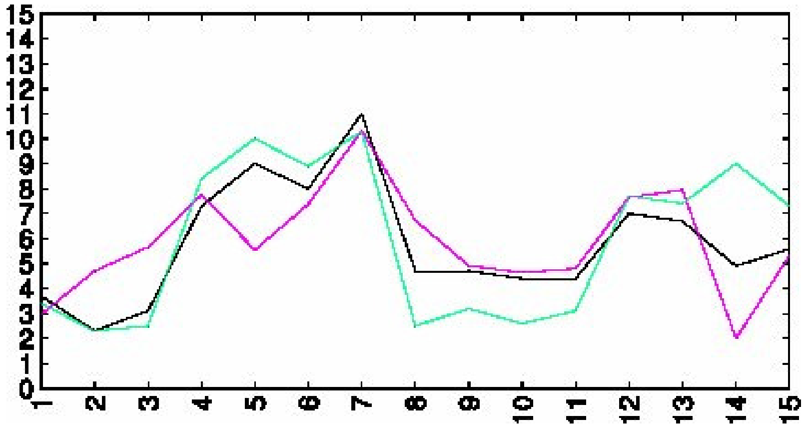


Fig.27. 90th percentile value of daily precipitation (y-axis, in mm), computed for each flash flood events (x-axis, 15 events), for the period 1970-2008. The black line indicates the 90th percentile value by using the E-OBS data; the green line by using the GPCP data; pink line by using RCM ensemble data.

The period from 2021 to 2050 was considered to compare the daily precipitation maximum values in the scenario future with respect to the present period (1970-2008). The annual precipitation anomaly map of the period 2021-2050 with respect to the period 1970-2008, by using the ENSEMBLES RCM ensemble data is shown in **figure 28**. It's evident a heterogeneity of the precipitation values of the signal of climate change, with precipitation negative anomalies over the costal areas specially, opposite anomalies over the Alps and values close to zero in lands.

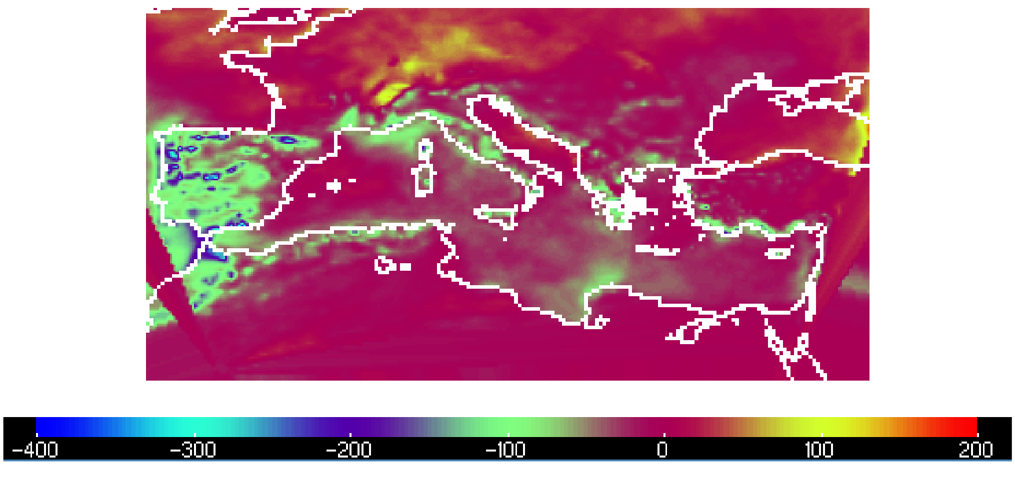


Fig.28. Annual precipitation anomaly map (mm/year) of the period 2021-2050 with respect to the period 1970-2008, by using the ENSEMBLES RCM ensemble data.

The 90th percentile map of daily precipitation, in the period from 2021 to 2050 and by using the RCM ensemble data, is shown in the **figure 29**, also. Instead, the 90th percentile values of daily precipitation in the flooded locations and in the future period (compared with respect to the same percentile values in the past period), by using the ENSEMBLES RCMs ensemble data, are shown in **figure 30**.

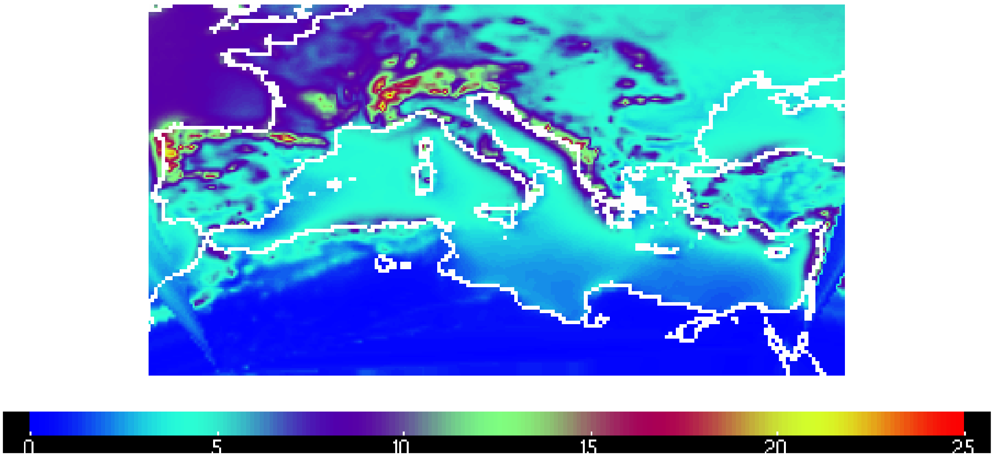


Fig.29. 90th percentile map of daily precipitation (mm) by using the ENSEMBLES RCM ensemble data, in the period from 2021 to 2050, over the Mediterranean region.

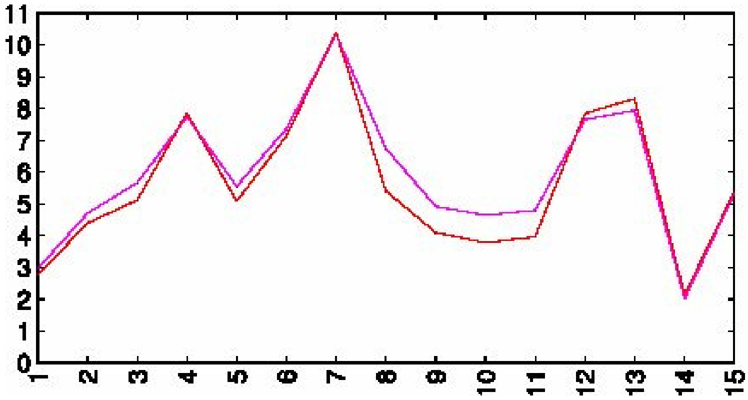


Fig.30. 90th percentile value of daily precipitation (y-axis, in mm), computed for each flooded locations (x-axis, 15 events), for the period 2021-2050 (red line) and the period 1970-2008 (pink line), by using ENSEMBLES RCM ensemble data.

The 90th percentile values of daily precipitation (in the 15 analyzed locations where occurred the flash flood events) in the future period (red line in fig.30) are lower than those in the present climate (pink line in fig.30) and suggest a change in the distribution of precipitation with an increase of moderate precipitation events.

4. Risk maps

In this section some definitions about the “risk maps” are given, with some final examples of the damages maps.

The purpose of flood hazard and flood risk mapping is the geographical identification and illustration of areas at different level of risk from flood hazard (EEA, Report No *4/*2008., 2008).

The flood maps exist in many different forms, but in general it is possible to distinguish between flood hazard and flood risk maps. The hazard maps contain information about the probability and/or magnitude of an event whereas flood risk maps contain additional information about the consequences (EEA, Report No *4/*2008., 2008).

The flood hazard maps shows areas which could be flooded according to three probabilities(low, medium, high)complemented with : type of flood, the flood extent, water depths or water level as appropriate; flow velocity or the relevant water flow direction (EEA, Report No *4/*2008., 2008).

The flood risk maps indicate the potential adverse consequences associated with floods under several probabilities, expressed in term of: indicative number of inhabitants potentially affected; type of economic activity of the area potentially affected; installation which might cause accidental pollution in case of flooding; etc..

The Flood maps are primarily used for :

- flood risk management Strategy (prevention, mitigation);
- land use planning, land management;
- emergency planning;
- public awareness raising;
- private sector.

There are different methods available to quantify the “hazard and risk”, resulting in different types of flood maps (De Moel H. et al., 2009).

The calculation of the flood hazard can be done using methods of varying complexity (Buchele et al., 2006), depending on the amount of data, resources, and time available. While there are different approaches, the conceptual framework behind the calculation of flood hazards is quite general and consists in several steps.

For example, it can be important estimate the discharges for specific return periods. This can be done by using frequency analyses on discharge records and fitting extreme value distributions (Te Linde et al., 2008). When there is no discharge data available but there are precipitation records, runoff coefficients can be to deduce discharge information. To overcome this, flood information (e.g. discharge, precipitation, or flood moments) can be extrapolated by using regionalisation techniques (Merz and Bloschl, 2005). More often however, hydrological models are used to calculate discharges. Such models come in various complexities (Hurkmans et al., 2008), but they all require spatially explicit meteorological (e.g. temperature, precipitation, evaporation, radiation), soil, land cover data as input. This data can be acquired from datasets of interpolated observed data, from re-analysis datasets or from climate models. Major sources of uncertainty with respect to flood hazard mapping include the statistical determination of extreme events from relatively short time series, the spatial extrapolation of data (when used), the DEM, and the presence and/or failure of defence structures. With respect to the DEM, there has been a huge improvement in spatial resolution over the last few decades (De Moel H. et al., 2009).

The most common flood hazard maps are flood extent maps. These are maps displaying the inundated areas of a specific event. This can be a historical event, but also a hypothetical event with a specific return. The extent of a single flood event, or of multiple events, can be depicted and also the extent of historical floods can be shown (De Moel H. et al., 2009).

When flood extents are calculated for specific return periods, the flood depth maps can also easily be calculated. Depicting these water depths on a separate map results in a flood depth map.

In order to get an impression of the over all flood hazard, parameters can instead be aggregated into qualitative classes, resulting in a so-called flood danger map. This is commonly done using matrices or formulas to relate different flood parameters into a single measure for the danger. In such matrices, two axes are used to relate flood parameters (e.g. depth, velocity, return period).

An example of the use of a formula to calculate a measure for the flood danger can be found, where the hazard rating is defined as: depth×(velocity+0.5)+debris factor (Van Alphen, J. and Passchier, R., 2007).

When the information on the consequences of a flood is combined with the hazard information, risk maps can be created. The risk may be calculated as following (EXCIMAP, 2007):

$$Risk = C*Ph$$

where C is the potential adverse consequence and Ph the probability of the hazardous process. Risk is expressed as a potential loss in a particular area within a given period of time (in general one year).

$$C=V*S(mh)*E$$

where V,S and E are the vulnerability parameters:

V=value of the element at risk (in money terms or human life).

S=susceptibility (ranges from 0 to 1).

E=exposure (range from 0 to 1).

The following information can be mapped with regard to flood risks:

1) individual vulnerability parameter "Value" as a direct demand of the flood directive:

- population : number of people, special group, etc..
- economic assets and activity : private property, lifeline, infrastructure, etc..
- environmental issues : installations potentially damaging the environment.

2)Potential adverse consequence (flood damage; loss per unit area)=V*S*E.

3)Risk (loss per unit area in a given period time).

The following figures show the damage risk maps made by using the risk indicators already employed in the previous sections. **Figures 31, 32** and **33** are the damage maps and show the spatial distribution of the risk index values (for each flash flood event with uncertainty 0, in the period 1970-2008) : the map of number of killed peoples (fig.31), the map of affected peoples (fig 32) and the map of the estimated damage, in 000'US$ (fig.33).

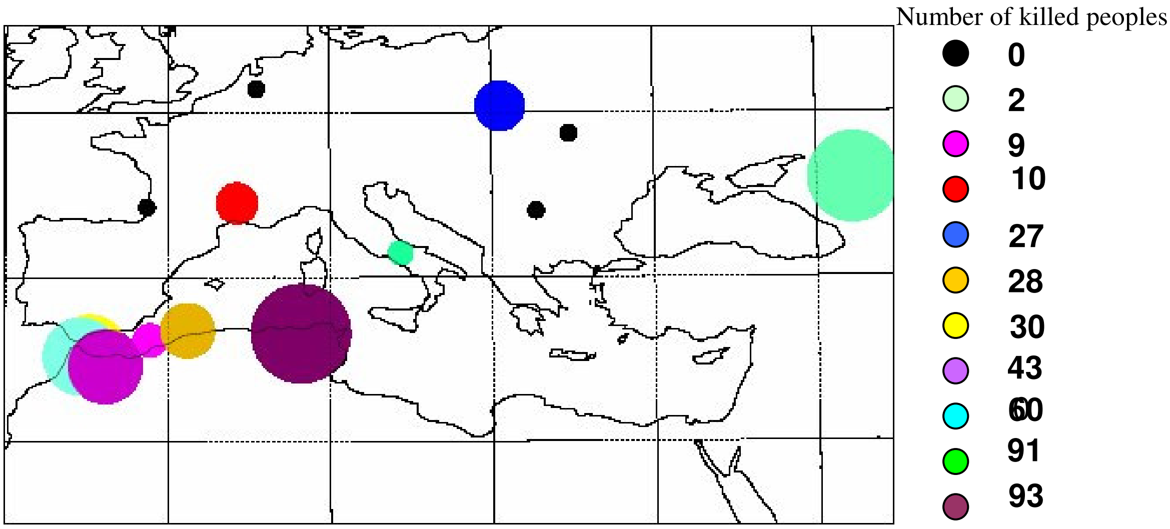


Fig.31. Risk index map with the number of killed peoples at each flooded locations in the period from 1970 to 2008.

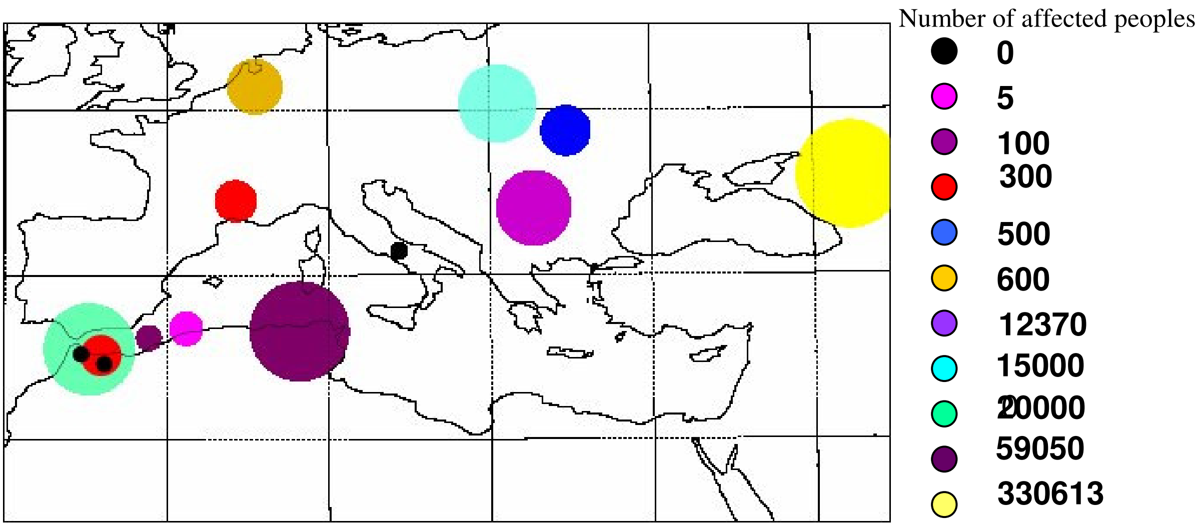


Fig.32. Risk index map with the number of affected peoples at each flooded locations in the period from 1970 to 2008.

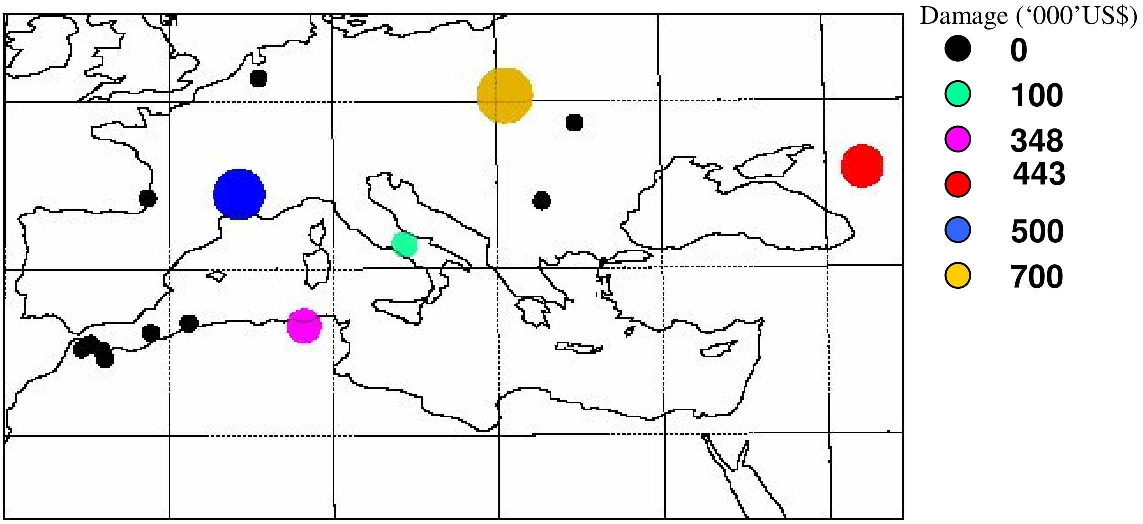


Fig.33. Risk index map with the estimated damage (in 000'US$) at each flooded locations in the period from 1970 to 2008.

5. Conclusions

This report provides some results about the damage caused by floods in locations over the Mediterranean region during the period 1970-2008. Moreover, index risk maps are briefly discussed. Though this study has not reached substantial conclusions yet, because a clear link between daily precipitation amounts and risk indexes has not been identified, it provides some preliminary result and includes a methodological analysis that will be used for the continuation of the research. Several technical, logistical and organizational problems have prevented reaching more comprehensive or conclusive results within the duration of the grant and delayed writing this report. Delays in obtaining permission for the use of appropriate computational resources, impossibility to access to the computer servers of the host institution after the conclusion of the visit (which forced to repeat data analysis procedures). This research is anyhow planned to be continued in the next few months.

Certainly, the analyzed flash flood events consistently present high precipitation values in several data sources and also, simultaneously, recorded damages are significant. Nevertheless, the precipitation quantity (measured during the disaster) is not directly proportional to the quantity of damage caused, as it is shown in the scatter plots of the daily precipitation values against risk indexes). Actually, the type of analyzed risk indexes depend not only on the precipitation values, but also on other important parameters (most of them being independent of the cumulative rainfall in flooded locations). These parameters are vulnerability indexes, which has not been possible analyze during this short project, such as population density; GDP (Gross Domestic Product); APGR (Annual Population Growth Rate); DEM (Digital Elevation Model); slope of flooded terrains; vegetation cover; land use; etc...

For example, it's demonstrated that a low percapita Gross Domestic Product (GDP) (poor nations or least developed countries) and also low density of population (rural areas/regions) characterize countries that are highly vulnerable to and most at risk from floods (UNDP, 2004). In many regions floods occur regularly and catastrophically without significant loss of life, but with very significant loss of property and livelihoods, as in Serbia or Rumania in April 2006 (SCSP, 2006). Many of these local villages suffer extreme poverty and are highly exposed. However, according to this analysis, these areas do not show up as highly vulnerable to floods, since the floods did not cause major fatalities (Birkmann J., 2007). Therefore, there are enormous differences between the flood risk of least developed countries and of highly developed countries (Peduzzi et all., 2005). On the other hand, more in-depth research is needed to examine the various linkages between different forms of development and disaster risk and vulnerability. Especially processes that contribute to higher levels of vulnerability of different social groups or economic sectors require sub-national and local assessment approaches (Birkmann J., 2007). Future developments of this research need to include explicitly all these vulnerability parameters and analyze their modulation of the risk associated with the daily precipitation fields.

Appendix

The following appendix shows the <u>*list of the flood events*</u> analyzed in this research report. For each disaster event, the information shown (discussed in the text) are : the dates (day/month/year) of start and end of the flood (columns 1 and 2); uncertainty value -0,1,2,3 (column 3); number of killed peoples (column 4); number of affected peoples (column 5); estimated of damage in in "000"US$ (column 6); class of flood, denoted by 11= flood, 22 = flash flood, 33= general flood (column 7); flooded country (column 8).

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column8
17 11 1992	19 11 1992	1	11	35000	7	22	Albania
01 10 2008	17 10 2008	0	93	59050	348	22	Algeria
21 09 2007	24 09 2007	1	18	0	29.5	22	Algeria
13 10 2000	13 10 2000	0	9	5	0	22	Algeria
22 10 2000	25 10 2000	0	28	100	0	22	Algeria
19 06 1996	23 06 1996	2	0	0	5	22	Austria
10 09 2005	11 09 2005	1	0	210	0	22	Belgium
26 08 1971	26 08 1971	0	0	600	0	22	Belgium
13 11 1996	18 11 1996	1	12	260	0	22	Egypt
07 09 2005	09 09 2005	3	1	3000	0	22	France
27 12 2003	03 12 2003	3	9	27000	1500	22	France
25 08 2002	25 08 2002	3	0	800	0	22	France
05 01 2001	07 01 2001	3	0	390	0	22	France
12 11 1999	15 11 1999	3	36	3005	500	22	France
27 01 1996	30 01 1996	1	4	600	6	22	France
03 10 1988	03 10 1988	0	10	300	500	22	France
26 06 2002	09 06 2002	2	0	0	0	22	Italy
14 09 2001	15 09 2001	0	2	0	100	22	Italy
14 10 2000	22 10 2000	3	25	43000	8000	22	Italy
19 06 1996	21 06 1996	1	17	300	32	22	Italy
19 07 1985	19 07 1985	0	329	30	15	22	Italy
26 11 2007	29 11 2007	1	0	1086	0	22	Montenegro
23 10 2008	03 11 2008	0	30	20000	0	22	Morocco
17 11 2003	18 11 2003	1	35	10000	0	22	Morocco
22 10 2000	25 10 2000	0	0	300	0	22	Morocco
28 09 1997	29 09 1997	0	60	0	0	22	Morocco
04 09 1995	04 09 1995	0	43	0	0	22	Morocco
20 07 2001	03 08 2001	0	27	15000	700	22	Poland
12 02 2007	12 02 2007	0	0	500	0	22	Romania
20 06 2006	26 06 2006	3	14	5712	0	22	Romania
27 08 2004	27 08 2004	1	6	14000	0	22	Romania
02 01 2003	02 01 2003	2	3	600	0	22	Romania
19 06 2002	01 07 2002	0	91	330613	443	22	Russia
25 11 2007	29 11 2007	0	0	12370	0	22	Serbia
24 07 2001	31 07 2001	2	1	0	6	22	Slovakia
20 10 2000	26 10 2000	2	8	500	75	22	Spain
02 08 1979	02 08 1979	0	20	50	0	22	Spain
19 10 1973	19 10 1973	1	500	0	400	22	Spain
22 09 2009	23 09 2009	1	17	8	0	22	Tunisia
13 10 2007	16 10 2007	1	16	5000	0	22	Tunisia
30 09 1986	30 09 1986	1	23	2500	0	33	Tunisia
30 11 2005	03 12 2005	1	3	500	0	33	Albania
04 12 2004	08 12 2004	0	0	2500	0.173	33	Albania
21 09 2002	10 10 2002	1	1	66884	17.5	33	Albania
27 12 1995	27 12 1995	1	0	2000	0	33	Albania
24 11 2007	02 12 2007	1	14	1203	0	33	Algeria
12 08 2007	12 08 2007	1	1	102	0	33	Algeria
10 02 2006	15 02 2006	0	1	60000	1.2	33	Algeria
06 03 2005	09 03 2005	1	11	70	0	33	Algeria
14 04 2004	16 04 2004	1	3	27545	0	33	Algeria
15 10 2003	18 10 2003	1	13	0	0	33	Algeria
09 08 2003	11 08 2003	1	13	0	0	33	Algeria
02 04 2003	05 04 2003	1	15	50	0	33	Algeria

09 10 2002	12 10 2002	1	13	4	0	33	Algeria
17 08 2002	28 08 2002	1	29	2301	1.5	33	Algeria
10 11 2001	14 11 2001	1	921	45423	300	33	Algeria
23 04 1996	30 04 1996	1	4	101	0	33	Algeria
21 09 1994	26 09 1994	1	32	1200	0	33	Algeria
19 10 1993	20 10 1993	0	22	16	0	33	Algeria
21 01 1992	29 01 1992	1	21	2258	0.9	33	Algeria
16 07 2009	19 07 2009	0	0	0	0	33	Austria
28 03 2006	17 04 2006	0	0	516	0	33	Austria
21 08 2005	26 08 2005	3	4	0	700	33	Austria
10 07 2005	12 07 2005	1	0	900	0	33	Austria
12 08 2002	20 08 2002	2	9	60000	2400	33	Austria
11 05 1999	30 06 1999	2	3	0	32	33	Austria
08 07 1997	22 07 1997	2	3	0	175	33	Austria
02 08 1991	06 08 1991	1	5	0	82	33	Austria
07 08 1985	07 08 1985	3	12	0	0	33	Austria
18 05 1982	18 05 1982	2	0	0	0	33	Austria
27 01 2002	27 01 2002	2	0	600	0	33	Belgium
20 12 1993	31 12 1993	2	0	0	17	33	Belgium
06 12 2005	09 12 2005	1	0	3100	0	33	Bosnia-Herce
23 03 2004	03 04 2004	1	0	3000	0	33	Bosnia-Herce
06 04 2004	14 04 2004	1	0	275000	0	33	Bosnia-Herce
16 11 2007	21 11 2007	1	2	60	0	33	Bulgaria
04 08 2007	07 08 2007	1	8	10	0	33	Bulgaria
22 05 2007	06 06 2007	1	2	1000	0	33	Bulgaria
07 04 2006	24 05 2006	1	0	0	0	33	Bulgaria
10 04 2006	13 04 2006	2	0	0	0	33	Bulgaria
04 08 2005	11 08 2005	1	7	12000	0	33	Bulgaria
21 09 2005	23 09 2005	0	2	0	0	33	Bulgaria
14 08 2005	26 08 2005	0	7	0	200	33	Bulgaria
02 07 2005	06 07 2005	1	17	200	247	33	Bulgaria
26 05 2005	13 06 2005	1	6	0	10	33	Bulgaria
14 12 1997	16 02 1998	1	0	200	0	33	Bulgaria
04 04 2006	11 05 2006	1	0	0	0	33	Croatia
28 12 2000	30 12 2000	1	0	600	0	33	Croatia
28 03 2006	17 04 2006	1	6	4200	0	33	Czech Rep
17 03 2005	25 03 2005	2	1	0	0	33	Czech Rep
07 08 2002	28 08 2002	1	18	200000	2400	33	Czech Rep
08 03 2000	13 03 2000	2	0	0	80	33	Czech Rep
23 07 1998	27 07 1998	2	6	0	52	33	Czech Rep
02 07 1997	24 07 1997	3	29	102107	1850	33	Czech Rep
10 05 1996	14 05 1996	1	1	60	36	33	Czech Rep
03 03 2002	11 03 2002	0	4	800	0	33	Egypt
20 03 1995	20 03 1995	0	7	3000	0	33	Egypt
02 11 1994	08 11 1994	1	600	160660	140	33	Egypt
15 11 2005	17 11 2005	0	2	1000	0	33	France
01 01 2003	08 01 2003	1	1	0	0	33	France
08 09 2002	12 09 2002	3	23	2500	1990	33	France
07 04 2001	02 05 2001	1	0	7371	0	33	France
21 03 2001	28 03 2001	3	3	8100	132.35	33	France
07 01 1994	12 01 1994	2	10	210	5	33	France
20 12 1993	31 12 1993	2	4	0	600	33	France
27 09 1992	27 09 1992	3	3	0	0	33	France
21 09 1980	21 09 1980	2	6	313	0	33	France
08 07 1977	08 07 1977	2	26	25000	0	33	France
30 09 1958	04 10 1958	3	35	0	0	33	France
09 08 2007	12 08 2007	2	1	0	0	33	Germany
28 03 2006	17 04 2006	2	0	1000	0	33	Germany
21 08 2005	26 08 2005	2	1	0	220	33	Germany
11 05 1999	30 06 1999	2	7	100000	430	33	Germany
07 01 1994	12 01 1994	2	0	0	200	33	Germany
21 12 1993	31 12 1993	3	5	100000	600	33	Germany
26 03 1988	26 03 1988	2	6	3500	0	33	Germany
16 11 2007	02 12 2007	1	2	600	0	33	Greece
21 10 2006	22 10 2006	1	0	90	0	33	Greece
08 10 2006	12 10 2006	1	1	3000	5.659	33	Greece
19 02 2003	19 02 2003	3	0	0	0	33	Greece
02 02 2003	02 02 2003	1	0	0	600	33	Greece
25 01 2003	25 01 2003	1	0	450	0	33	Greece
27 12 2002	27 12 2002	0	0	0	0	33	Greece
06 12 2002	10 12 2002	3	0	0	0	33	Greece
07 11 2002	07 11 2002	2	0	210	0	33	Greece
29 11 2001	29 11 2001	2	0	600	0	33	Greece
24 10 1994	27 10 1994	3	14	1000	437.7	33	Greece
14 08 2005	26 08 2005	0	0	0	48	33	Hungary
17 03 2005	25 03 2005	0	0	0	0	33	Hungary
27 07 2004	02 08 2004	0	0	393	0	33	Hungary

07 08 2002	28 08 2002	1	0	1430	30	33	Hungary
04 03 2001	17 03 2001	2	0	10000	5	33	Hungary
06 04 2000	01 05 2000	2	1	2000	55	33	Hungary
09 07 1999	16 07 1999	2	8	42795	128.4	33	Hungary
21 02 1999	18 03 1999	2	0	90700	165	33	Hungary
04 07 1997	09 08 1997	2	0	0	10	33	Hungary
11 12 2008	15 12 2008	3	3	0	278	33	Italy
29 05 2008	30 05 2008	2	4	0	0	33	Italy
13 11 2004	14 11 2004	2	2	200	0	33	Italy
29 08 2003	31 08 2003	0	2	350	655	33	Italy
25 01 2003	27 01 2003	2	1	1000	150	33	Italy
22 11 2002	03 12 2002	2	2	10000	350	33	Italy
10 09 2000	10 09 2000	0	16	22	0	33	Italy
01 11 1994	10 11 1994	2	68	17300	9300	33	Italy
31 10 1992	31 10 1992	2	0	1000	687.3	33	Italy
28 09 1992	28 09 1992	0	2	0	10	33	Italy
07 10 1970	07 10 1970	0	37	130165	268.3	33	Italy
20 12 1993	31 12 1993	0	0	0	10	33	Luxembourg
04 08 2005	04 08 2005	1	0	2000	0	33	Macedonia FR
04 06 2004	07 06 2004	1	0	100000	3.6	33	Macedonia FR
30 11 2003	30 11 2003	1	0	750	0	33	Macedonia FR
08 01 2003	10 01 2003	1	2	4000	0	33	Macedonia FR
06 12 2002	10 12 2002	0	0	1650	0	33	Macedonia FR
26 07 2008	27 07 2008	2	3	4000	0	33	Moldova Rep
18 08 2005	19 08 2005	1	0	6500	7.752	33	Moldova Rep
24 08 1994	29 08 1994	1	47	25000	300	33	Moldova Rep
26 02 2008	28 02 2008	1	9	0	0	33	Morocco
28 10 2006	29 10 2006	1	0	1000	0	33	Morocco
25 10 2006	27 10 2006	1	11	0	0	33	Morocco
26 05 2006	28 05 2006	0	6	1100	0	33	Morocco
24 11 2002	29 11 2002	1	80	15017	200	33	Morocco
23 12 2001	26 12 2001	1	15	300	2.2	33	Morocco
21 01 1996	01 02 1996	1	25	60000	55	33	Morocco
17 08 1995	18 08 1995	0	730	35000	9	33	Morocco
04 06 2006	06 06 2006	1	0	500	0	33	Poland
18 02 2008	18 02 2008	1	2	110	0	33	Portugal
22 10 2006	08 11 2006	2	0	240	0	33	Portugal
01 01 2003	08 01 2003	2	0	36	0	33	Portugal
26 12 2002	26 12 2002	2	1	60	0	33	Portugal
26 01 2001	29 01 2001	3	6	200	0	33	Portugal
22 12 1996	24 12 1996	2	0	2000	0	33	Portugal
05 09 2007	11 09 2007	1	7	1400	0	33	Romania
25 08 2007	26 08 2007	1	2	1400	0	33	Romania
30 06 2006	03 07 2006	1	30	600	0	33	Romania
19 06 2006	19 06 2006	1	1	600	0	33	Romania
07 04 2006	24 05 2006	1	0	0	0	33	Romania
13 03 2006	07 04 2006	3	6	17071	0	33	Romania
21 09 2005	23 09 2005	1	10	30800	0	33	Romania
14 08 2005	25 08 2005	3	33	2000	313	33	Romania
12 07 2005	28 07 2005	3	24	14669	800	33	Romania
02 07 2005	03 07 2005	1	8	5102	0	33	Romania
21 04 2005	15 05 2005	1	2	3400	200	33	Romania
17 03 2005	25 03 2005	0	2	600	0	33	Romania
28 07 2004	01 08 2004	1	4	14128	0	33	Romania
01 01 2003	08 01 2003	0	0	0	0	33	Romania
06 08 2002	07 08 2002	1	1	301	0.29	33	Romania
19 07 2002	23 07 2002	1	4	4500	0	33	Romania
19 06 2001	22 06 2001	2	7	10803	120	33	Romania
04 03 2001	17 03 2001	3	0	4000	15	33	Romania
05 04 2000	25 04 2000	3	9	60431	100	33	Romania
09 07 1999	16 07 1999	3	15	4362	50	33	Romania
22 06 1999	16 07 1999	2	19	4671	10	33	Romania
15 06 1998	30 06 1998	1	31	12000	150	33	Romania
04 07 1997	09 08 1997	2	20	122320	110	33	Romania
28 12 1995	07 01 1996	3	2	5000	3.4	33	Romania
27 08 1994	28 08 1994	2	2	0	3	33	Romania
29 07 1991	30 07 1991	1	108	15000	50	33	Romania
04 08 2005	04 08 2005	0	19	0	0	33	Russia
04 04 2006	11 05 2006	1	0	35000	0	33	Serbia
21 02 2006	02 03 2006	1	0	1200	0	33	Serbia
20 04 2005	20 04 2005	1	2	3790	0	33	Serbia
28 12 2000	30 12 2000	1	0	2000	0	33	Serbia
05 04 2000	25 04 2000	1	0	4000	0	33	Serbia
28 11 1992	28 11 1992	0	1	6000	0	33	Serbia
04 06 2006	06 06 2006	1	0	100	0	33	Slovakia
28 03 2006	09 05 2006	1	1	0	0	33	Slovakia
17 03 2005	25 03 2005	0	1	0	0	33	Slovakia

27 07 2004	02 08 2004	1	1	230	0	33	Slovakia
16 08 2002	18 08 2002	0	0	0	3	33	Slovakia
22 06 1999	01 07 1999	2	2	36148	113.3	33	Slovakia
20 07 1998	24 07 1998	1	54	11667	45	33	Slovakia
04 07 1997	09 08 1997	2	0	0	60	33	Slovakia
19 08 2005	24 08 2005	2	0	0	5	33	Slovenia
12 10 2007	18 10 2007	1	3	3600	0	33	Spain
23 05 2007	26 05 2007	0	1	550	400	33	Spain
03 04 2007	05 04 2007	3	1	280	0	33	Spain
22 10 2006	08 11 2006	3	0	0	0	33	Spain
27 03 2004	28 03 2004	0	0	600	14.285	33	Spain
28 09 1997	01 10 1997	1	5	400	0	33	Spain
22 12 1996	24 12 1996	1	1	4000	576.6	33	Spain
04 11 1987	04 11 1987	1	5	2000	1283	33	Spain
08 08 2007	12 08 2007	2	1	101	350	33	Switzerland
26 07 2006	27 07 2006	0	0	3000	0	33	Switzerland
21 08 2005	26 08 2005	1	6	2500	2100	33	Switzerland
11 05 1999	30 06 1999	2	3	0	330	33	Switzerland
16 09 2003	18 09 2003	1	4	0	0	33	Tunisia
14 01 2003	16 01 2003	1	8	27000	0	33	Tunisia
20 01 1990	01 02 1990	1	37	152000	242.8	33	Tunisia
26 07 2008	27 07 2008	1	38	224725	1000	33	Ukraine
07 04 2006	24 05 2006	0	0	0	0	33	Ukraine
12 03 2003	12 03 2003	0	0	600	0	33	Ukraine
04 03 2001	17 03 2001	3	9	300000	15	33	Ukraine
08 11 1998	08 11 1998	1	18	24570	1.259	33	Ukraine
04 07 1997	09 08 1997	2	0	0	17	33	Ukraine
03 04 1996	10 04 1996	1	0	10000	0	33	Ukraine
29 06 1995	29 06 1995	0	0	170000	0	33	Ukraine
20 12 1993	24 12 1993	2	5	25000	159	33	Ukraine
25 07 1993	12 08 1993	1	4	300000	80	33	Ukraine
30 10 1990	30 10 1990	2	0	0	766.1	33	Yugoslavia
09 05 1965	09 05 1965	2	3	95000	347	11	Yugoslavia
20 09 1995	20 09 1995	1	4	1500	0	11	Albania
21 03 2007	23 03 2007	1	15	0	0	11	Algeria
18 06 2005	20 06 2005	0	1	1750	7.256	11	Algeria
13 11 2004	14 11 2004	2	19	20	0	11	Algeria
07 12 2002	07 12 2002	1	6	0	0	11	Algeria
17 08 2000	17 08 2000	1	0	100	0	11	Algeria
06 08 2000	06 08 2000	1	7	0	0	11	Algeria
14 01 1999	14 01 1999	0	12	702	0	11	Algeria
02 08 1997	02 08 1997	2	4	3000	0	11	Algeria
09 01 1985	09 01 1985	2	26	15000	0	11	Algeria
10 11 1982	10 11 1982	0	37	8514	0	11	Algeria
04 09 1981	04 09 1981	0	43	50	0	11	Algeria
31 03 1974	31 03 1974	1	11	20000	30	11	Algeria
27 06 1995	27 06 1995	0	2	0	0.2	11	Austria
22 09 1983	22 09 1983	2	0	0	0	11	Austria
13 10 1980	13 10 1980	2	0	0	0	11	Austria
26 08 2002	26 08 2002	1	0	600	0	11	Belgium
11 02 2002	11 02 2002	2	0	1200	0	11	Belgium
24 08 1987	24 08 1987	2	0	0	0	11	Belgium
14 05 1906	14 05 1906	0	6	0	0	11	Belgium
10 08 2002	11 08 2002	1	1	0	1	11	Bulgaria
20 11 2001	20 11 2001	2	7	300	0	11	Canary Is
06 09 2001	06 09 2001	1	0	1200	0	11	Croatia
30 06 2006	30 06 2006	0	0	115	0	11	Czech Rep
24 05 1987	24 05 1987	2	0	0	1	11	Czechoslovak
20 12 2002	20 12 2002	1	14	70	0	11	Egypt
18 10 1997	20 10 1997	2	4	0	1	11	Egypt
20 02 1975	20 02 1975	2	15	0	0	11	Egypt
08 07 2001	08 07 2001	2	0	300	0	11	France
04 07 2001	04 07 2001	3	0	721	0	11	France
13 12 2000	13 12 2000	3	0	600	0	11	France
02 12 2000	02 12 2000	2	0	600	0	11	France
10 07 2000	10 07 2000	1	1	600	0	11	France
10 06 2000	10 06 2000	3	1	200	0	11	France
18 01 1999	18 01 1999	0	0	1100	0	11	France
03 01 1996	03 01 1996	1	0	780	0	11	France
05 11 1994	05 11 1994	3	3	0	95	11	France
27 06 1994	27 06 1994	0	0	200	0	11	France
14 07 1987	14 07 1987	0	23	0	0	11	France
28 05 1983	28 05 1983	2	0	3500	0	11	France
20 12 1981	20 12 1981	3	0	0	0	11	France
11 08 2002	20 08 2002	3	27	330108	11600	11	Germany
28 08 1992	30 08 1992	1	0	0	30.1	11	Germany
31 05 1983	31 05 1983	1	0	12	0	11	Germany

13 12 2002	13 12 2002	1	0	180	0	11	Greece
19 11 2000	19 11 2000	1	1	6000	0	11	Greece
31 10 2000	31 10 2000	2	0	600	0	11	Greece
03 02 1998	03 02 1998	2	3	900	0	11	Greece
12 01 1997	13 01 1997	1	9	0	160	11	Greece
20 11 1979	20 11 1979	2	15	0	0	11	Greece
01 10 1977	30 11 1977	1	27	1600	28	11	Greece
14 05 1996	14 05 1996	0	0	200	0	11	Hungary
01 05 1970	30 06 1970	2	300	0	85	11	Hungary
12 07 2008	12 07 2008	1	2	300	0	11	Italy
04 08 2002	14 08 2002	3	0	20	296	11	Italy
20 11 2000	20 11 2000	3	5	2000	50	11	Italy
20 09 2000	20 09 2000	1	0	1000	0	11	Italy
09 10 1996	09 10 1996	0	0	200	0	11	Italy
02 02 1986	02 02 1986	0	2	0	20	11	Italy
02 11 1968	02 11 1968	3	72	3000	0	11	Italy
13 04 1983	13 04 1983	2	0	0	0	11	Luxembourg
15 03 1999	15 03 1999	3	0	1713	4	11	Moldova Rep
06 07 1997	29 07 1997	2	9	2244	50	11	Moldova Rep
22 12 2000	22 12 2000	1	6	650	0	11	Morocco
01 04 1995	01 04 1995	2	18	3000	0	11	Morocco
25 10 1979	25 10 1979	0	16	6292	0	11	Morocco
21 04 1975	21 04 1975	2	10	12000	0	11	Morocco
22 01 1970	22 01 1970	2	11	266444	30	11	Morocco
04 08 1977	04 08 1977	2	0	1000	0	11	Poland
18 11 1983	18 11 1983	1	19	2000	95	11	Portugal
29 12 1981	29 12 1981	0	30	900	0	11	Portugal
07 08 2007	07 08 2007	1	3	960	0	11	Romania
13 03 1984	13 03 1984	2	0	2000	0	11	Romania
11 05 1970	11 05 1970	2	215	238755	500	11	Romania
18 09 2000	18 09 2000	2	0	1320	0	11	Russia
11 06 2002	11 06 2002	0	0	2400	0	11	Serbia
28 12 1999	28 12 1999	1	0	330	0	11	Serbia
10 06 2000	10 06 2000	2	16	500	0	11	Spain
10 10 1994	10 10 1994	0	10	0	0	11	Spain
01 11 1983	01 11 1983	0	0	1600	0	11	Spain
25 08 1983	25 08 1983	1	45	506000	3900	11	Spain
19 10 1982	19 10 1982	1	43	226600	630	11	Spain
03 08 2002	03 08 2002	1	0	100000	0	11	Sudan
13 09 1994	13 09 1994	1	8	5965	0	11	Sudan
15 08 1983	15 08 1983	0	0	130000	0	11	Sudan
17 08 1997	17 08 1997	1	0	0	68.5	11	Switzerland
16 05 1983	16 05 1983	1	0	0	0	11	Switzerland
28 10 1982	28 10 1982	3	117	30000	90	11	Tunisia
06 03 1979	06 03 1979	0	0	750	0	11	Tunisia
21 03 1973	21 03 1973	2	52	41000	5	11	Tunisia
28 02 2005	28 02 2005	1	0	8340	0	11	Ukraine
23 03 1981	23 03 1981	2	70	0	0	11	Yugoslavia

Bibliography

- ✓ Birkmann, J., 2007 : Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications. Environmental Hazards, 7, 20–31, Elsevier.
- ✓ Buchele, B., Kreibich, H., Kron, A., Thieken, A., Ihringer, J., Oberle, P., Merz, B., Nestmann, F., 2006 : Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks, Nat. Hazards Earth Syst. Sci., 6, 485–503, 2006. http://www.nat-hazards-earth-syst-sci.net/6/485/2006/.
- ✓ Cardona, O.D., 2004 : The need for rethinking the concepts of vulnerability and risk from a holistic perspective: a necessary review and criticism for effective risk management. In: Bankoff, G., Frerks, G., Hilhorst, D. (Eds.), Mapping Vulnerability: Disasters, Development and People. Earthscan Publishers, London.
- ✓ De Moel, H., Van Alphen,, J., Aerts, J. C. J. H. , 2009 : Flood maps in Europe – methods, availability and use. Nat. Hazards Earth Syst. Sci., 9, 289–301.
- ✓ EEA (European Environment Agency) : Impacts of Europe's changing climate - 2008 indicator-based assessment, 2008. Report No *4/*2008. ISBN 978-92-9167-372-8.
- ✓ EXCIMAP, 2007 : Handbook on good practices for flood mapping in Europe, European exchange circle on flood mapping, available at: http://ec.europa.eu/environment/water/flood risk/flood atlas/index.htm.
- ✓ Giorgi, F., Lionello, P., 2007 : Climate Change Projections for the Mediterranean Region Global and Planetary Change; doi:10.1016/j.gloplacha.2007.09.005.
- ✓ Harris, G. R., Collins, M., Sexton, D. M. H., Murphy, J. M., Booth, B. B. B., 2010 : Probabilistic Projections for 21st Century European Climate, in press.
- ✓ Hurkmans, R. T. W. L., de Moel, H., Aerts, J. C. J. H., Troch, P. A., 2008 : Water balance versus land surface model in the simulation of Rhine river discharges, Water Resour. Res., 44, W01418, doi:10.1029/2007WR006168.
- ✓ Jakubicka T., Vos, F., Phalkey, R., Marx, M., , 2010 : Health impacts of floods in Europe: data gaps and information needs from a spatial perspective. Report - MICRODIS project, funded by the European Commission under the Sixth Framework Programme, Belgium.
- ✓ Jones, R., Mearns, L. O., 2004 : Assessing future climate risks. Chapter 5 in Lim, B., I. Carter and Huq, S., UNDP Adaption Policy Framework.

- ✓ Lionello, P., Boldrin, U., Giorgi, F., 2007 : Future changes in cyclone climatology over Europe as inferred from a regional climate simulation; Clim.Dyn; DOI 10.1007/s00382-007-0315-0.
- ✓ Merz, R., Bloschl, G., 2005 : Flood frequency regionalisation-spatial proximity vs. catchment attributes, J. Hydrol., 302, 283–306.
- ✓ Peduzzi, P., Dao, H., Herold, C., 2005 : Mapping disastrous natural hazards using global datasets. Natural Hazards 35 (2), 265–289.
- ✓ Special Coordinator of the Stability Pact for South Eastern Europe (SCSP), 2006 : Report on April 2006 floods in South Eastern Europe. Available at: /http://www.reliefweb.int/rw/RWB.NSF/db900SID/VBO6Q4GZJ?OpenDocument&rc=4&cc=rou.
- ✓ Te Linde, A. H., Aerts, J. C. J. H., Van den Hurk, B., 2008 : Effects of flood control measures and climate change in the Rhine basin, in: Proceedings of the 4th International Symposium on Flood Defence, Toronto, Canada, 6-5-2008, 118/1-9.
- ✓ Thywissen, K., 2006 : Core terminology of disaster reduction: a comparative glossary. In: Birkmann, J. (Ed.), Measuring Vulnerability to Natural Hazards—Towards Disaster Resilient Societies. UNUPress, Tokyo, New York, Paris.
- ✓ United Nations Development Programme (UNDP), 2004 : Reducing disaster risk. A challenge for development. A Global Report, UNDP—Bureau for Crisis Prevention and Recovery (BRCP), New York. Available at /http://www.undp.org/bcpr/disred/rdr.htm.
- ✓ United Nations International Strategy for Disaster Reduction (UN/ISDR), 2004 : Living with Risk. A Global Review of Disaster Reduction Initiatives. 2004 version. UN Publications, Geneva.
- ✓ Van Alphen, J., Passchier, R., 2007 : Atlas of Flood Maps, examples from 19 European countries, USA and Japen, Ministry of Transport, Public Works and Water Management, The Hague, Netherlands, prepared for EXCIMAP, available at: http://ec.europa.eu/environment/water/flood risk/flood atlas/index.htm.
- ✓ Wisner, B., 2002 : Who? What? Where? When? in an emergency: notes on possible indicators of vulnerability and resilience: by phase of the disaster management cycle and social actor. In: Plate, E. (Ed.), Environment and Human Security: Contributions to a Workshop in Bonn, 23–25 October 2002, Germany, pp. 12/7–12/14.
- ✓ Xie, P., Arkin, P.A., 1996 : Analysis of global monthly precipitation using gauge observations, satellite estimates, and numerical model predictions. J. Climate, 9, 840-858.

Web Sites :

http://en.wikipedia.org/

http://www.emdat.be/