Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences
Discussions

# First evaluation of the damage related to alluvial events in torrential catchments of Campania (southern Italy), based on a historical database

C.Vennari[1,2], M. Parise[2], N. Santangelo[1] and A. Santo[3]

[1]Department of Earth Sciences, University of Naples Federico II, Largo San Marcellino 10, NA, Italy.
[2] Italian National Research Council, Research Institute for Geo-hydrological Protection, Bari.
[3] Department of Hydraulic, Geotechnical and Environmental Engineering, Applied Geology Division, University of Naples Federico II, Italy.

**Abstract.** This study presents an historical database of alluvial events in torrential catchments of Campania region, southern Italy. Detailed scrutiny and critical analysis of the existing literature, and of the data inventory available, allowed us to build a robust database consisting of about 500 events. Being this study the first step of a longer project, aimed at eventually reaching an hazard analysis, information about time and site of occurrence are known for all the events. The outlet zone of torrential catchments (represented mainly by alluvial fans or fan deltas) are highly urbanized in Campania region, thus collecting information about past events could provide useful information on future events, in terms of damage, and of spatial and temporal occurrence as well. In section 1 we introduce the issue of alluvial events in Italy. Existing database and published studies on hydrogeological events, in particular regarding Campania region, are presented in section 2, where we also discuss the importance of using the historical sources, and their limits and drawbacks. The geological and geomorphological settings of Campania region are introduced in section 3. Then, in section 4, we present our database by illustrating its general structure and the methodology used in collecting information. Statistical and data analysis carried out on the collected data are presented in section 5. Aimed at performing a complete hazard analysis, analysis on rainfall data and the application of numerical models on alluvial events will be the future steps.

## 1. Introduction

Alluvial events in Italy are a frequent natural hazard, due to the peculiar orographic and climatic setting of many sectors of the country. The young orogen (the Apenninic Chain) in the peninsular area is characterized by high relief. In such a setting, torrential stream catchments are one the most widespread landscape unit, characterized by peculiar flood scenarios. During an alluvial event, a torrential stream catchment may be interested by different types of processes, including both fluvial processes (water flood, "debris floods/hyperconcentrated flow" and "debris flow", sensu Costa 1988) and gravity processes (i.e., landslides). As regards the fluvial processes, variations in the flow typology are mainly caused by the concentration of the sediments entrained in the flow. The sediments captured by the stream and transported downvalley generally come from the bed and banks of the torrent, and they may eventually contribute to build alluvial fans or fan deltas, depending on the geographical setting of the catchment (inland or coastal). Although each process has unique diagnostic effects and products, in nature there exists a continuum of flow conditions and sediment concentrations. Identification of the specific hydrological and geomorphic process is thus a central problem for the correct hazard recognition, since each process has different associated hazard characteristics (O'Brien and Julien 1985; Costa 1988; Fema 2000; Jakob 2005). Another important aspect

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

is that in torrential stream catchment a substantial difference of magnitude exists between the low water periods, including a seasonal lack of surface water in ephemeral streams, and flood events capable of heavily rearranging the river-bed topography. The low frequencies of important flow rates might cause the reduction of hazard perception and leads towards an incorrect land use and an unsafe management of the catchment. The collection of historical information of past events must be the starting point to deal with inhabitant security, land planning, and watershed management (D'Agostino, 2013).

Whilst in the Italian Alps, due to their high frequency, these phenomena have been quite well studied (Crosta et al., 2003, 2004; Sosio et al., 2007; Carrara et al., 2008; Simoni et al., 2011; Arattano et al., 2012, 2015; Marchi et al., 2013; Berti et al. 2014; Blahut et al., 2014; Tiranti et al., 2014), in the Apennines they have typically been object of lesser attention, mostly because of the lower recurrence (Sorriso Valvo et al., 1998; Zanchetta et al., 2004a; Santo et al., 2002, 2012, 2015; Cascini et al., 2008a; Santangelo et al., 2011, 2012; Alessio et al, 2013; Antronico et al., 2015a, b).

We focus our attention on torrential stream catchments of Campania region, in the Southern Apennines of Italy, which, during the last decades, has been affected by severe flooding with serious damage and fatalities (Santo et al., 2002, 2012, 2015; Calcaterra et al., 2000, 2003; Del Prete and Mele, 2006; Santangelo et al., 2006, 2011, 2012; Chirico et al., 2012; Alessio et al., 2013).

As the first step in the process of hazard evaluation, we compiled a database with the following main aims: i) to identify over the whole region the most susceptible areas to alluvial events; ii) to discriminate, in the available literature and historical data, alluvial events in torrential stream catchment from flood on large river systems and from gravity processes, such as rapid earth or debris flow (Del Prete et al., 1998; Crosta and Negro, 2003; Guadagno et al., 2003, 2005; Revellino et al., 2004; Zanchetta et al., 2004b; Di Crescenzo and Santo, 2005; Cascini et al., 2008b).

## 2. State of the art

### 2.1 Database on hydrogeological events (floods and landslides)

In any hazard and risk analysis the first step typically consists in collecting information about past events, starting from the concept that past events can provide information on future events, in terms of both spatial and temporal occurrence. Taking into account the loss of memory, it is important to reach the better knowledge possible about where hazardous events occurred in the past, what intensity they had, and what was the frequency of occurrence in the recent history.

Different types of information source can be considered to build a database on floods and debris flows. An high percentage of data and information typically is derived from collection and critical analysis of historical documents. In addition, this part of the work allows to get some hints about past events for which no evidence have been left in the field, or to confirm oral, often not exhaustive, documentary sources.

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

To provide some examples, the CNR IRPI Institute in Turin built a database on landslides, debris flows and stream floods in Northern Italy, collecting hundreds of thousands of records contained in published and unpublished documents and historical reports on natural damaging events over the last 500 years (Tropeano and Turconi, 2004). Further, this work highlighted the importance of using historical documents in the evaluation of natural hazards, as also stated by other authors in different parts of Italy (Calcaterra and Parise, 2001; Gringeri Pantano et al., 2002; Calcaterra et al., 2003). Other studies were focused on the triggering events, by providing a chronological description of 2.256 climatically triggered events in Switzerland, occurred between the years 563 and 1988 (Röthlisberger, 1991).

The AVI project (an Italian acronym for *Aree Vulnerate in Italia*, Areas Affected by Landslides or Floods in Italy) was commissioned by the Minister of Civil Protection to the National Group for Prevention of Hydrogeologic Hazards of the Italian National Research Council (CNR) with the aim to compile an inventory of information on areas historically affected by landslides and floods in Italy (Guzzetti et al., 1994). It is the most complete archive of landslides and floods produced in Italy, and is continuously updated.

In Italy, again, Brunetti et al. (2015), within the framework of a project with the National Department of Civil Protection, analyzed rainfall events that have resulted in shallow failures and debris flows to define national and regional thresholds for the possible occurrence of rainfall-induced shallow landslides and debris flows in the country.

As concerns Campania, several studies have been conducted in order to collect historical information about hydrogeological events. In the majority of the cases these databases refer to landslides or floods, or put together different types of events. In this framework a regional-scale database on alluvial events in torrential catchment does not exist.

The area of Sarno, Quindici and Bracigliano, hit by the catastrophic event on May 5, 1998, was particularly object of detailed studies: Mazzarella and Diodato (2002), on the basis of old documents, collected alluvial events that since 1794 affected the town of Sarno, also including in their work information about rainfall by means of an index of strength (Mazzarella and Diodato, 2002). On the other side of the same mountain, where the village of Quindici is located, Calcaterra et al. (2003) analysed past slope instability by means of historical and geological data to assess the landslide hazard. A careful scrutiny of the historical information was made by the authors, who provided a critical evaluation of the examined sources in order to rank their reliability. Calcaterra et al. (2003) highlighted the importance of combined historical-geological investigations, since only the cross-analysis between historical research and geological, geomorphologic and engineering-geological approaches may help to get a good knowledge on both the spatial and temporal distribution of the events.

Other authors have performed sub-regional or regional studies in Campania on landslides and floods (Migale and Milone 1998; Esposito et al., 2003, Di Crescenzo and Santo, 2005).

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

As regard the alluvial events in the torrential catchments of the region, Alessio et al. (2013) built a database on floods occurred in the Somma-Vesuvius area based on historical (19-20th century) and geomorphological data: they listed 87 flood events, and retrieved spatial and temporal information, hourly and daily rainfall recorded and numbers of victims. In addition, they also calculated geomorphological and planimetric parameters of the catchments affected by the flood events. Further works dealt with the observed or documented damage (Porfido et al., 2013), or with morphological and morphometric parameters aimed at a susceptibility analysis (Santangelo et al., 2012). A geomorphological and morphometric analysis of 102 basin/fan systems, located along the border slopes of the carbonate massifs of Southern Apennines, was carried out by Scorpio (2011). In this study, in order to analyze the susceptibility distribution to alluvial fan flooding in the region, morphometric features of the basin/fan system were used to classify the fans in terms of transport process (debris flow or water flood).

Eventually, many papers are addressed to specific study areas, such as the Teglia catchment (Santo et al., 2015), the Sala Consilina area in the Maddalena Mountain Ridge (Santangelo et al., 2011), and Santa Maria a Vico and Arienzo in the Caserta Mountains (Di Crescenzo et al., 2013). After the November 10, 2009, event in the northern sector of the island of Ischia, Santo et al. (2012) performed a flood hazard, through collection of historical information about landslides and floods (Del Prete and Mele, 2006), combined with geomorphological and rainfall analysis.

Esposito et al. (2011) studied published and unpublished historical sources along the coastal areas of Campania, with greater detail in the Amalfi Coast. In the latter paper the authors also presented a level of quality of the available sources, similarly to what done by Calcaterra and Parise (2001).

### 2.2 Use of historical documents: strengths and weaknesses

Archival and historical data are typically descriptive, written by non-technicians, and rarely they do contain quantitative information on significant elements such as type of process, volume of sediments, runout distance or water height (Stoffel et al., 2013). Nevertheless, they represent an invaluable source of information.

Availability of historical documents, and the possibility to examine them, is a consequence of the history of the country, and of its socio-economic conditions as well. As stated by D'Agostino (2013), a debris flow during wars, famines, or in time of plagues probably does not represent a social priority; thus, the historical analyses could be affected by biases originating from different sensibility to similar events during different historical ages. Obviously, countries of ancient civilization offer a longer period of records, and greater possibilities to find interesting information. At the same way the urbanization history may influence the historical analysis, as a recent urbanized area may records only recent events because there were not witnesses in the past.

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

The quality of historical information is also related to the involved area and the severity of the event. If a heavy event hits only a catchment or municipality, it is likely to have precise temporal and spatial information. On the other hand. if the event affected a larger area, the information will likely be more generic. Figure 1 (modified after D'Agostino, 2013) illustrates the links between the time scale of the event (single, multiple years period, all documentable time) and the scale area involved (single catchment, part of a mountain valley, a region). Depending on both the factors, different levels of historical research have to be developed: specific, medium scale and extended historical research.

Frequently, errors in transcription can result in attributing wrong time of occurrence to an event. It is therefore fundamental to compare all the available information sources. As for location, it may occur that the source reports the locality name of the property being hit, or the name of a street that does not exist anymore, which makes difficult (and sometimes impossible) to exactly locate the site.

As concerns damage to people, in most cases the reported information are very generic, such as "some victims", or in other cases the source provides the total number of victims per event but not for the individual municipalities. The precise estimate of the number of victims is thus not easy. In some cases divergences exist in the numbers of casualties reported by different sources for the same event. The differences can be related to several reasons, including the fact that the exact number is typically available only at the end of the search and rescue operations, from a few days to weeks after the event. During this period, newspapers and even official reports may provide different and changing data (Salvati et al., 2010).

Typically, information sources mainly document the most remarkable events for number of deaths and damages caused. In the last decades, however, with the intensifications of land use, information about smaller events has become available (Stoffel et al., 2013), and might be relevant and useful in order to develop a better hazard assessment.

## 3. Study area

The study area is the Campania region (Southern Italy) extending from the Tyrrhenian Sea to the Southern Apennine Chain for about 13500 kmq. The orographic setting is characterized by the presence of a central mountain ridge made up mainly of Mesozoic carbonates, elongated for more than 200 km in a NW-SE direction, with maximum peaks reaching 2000 meters a.s.l. On the western side the chain is bounded by a deep (up to 2 km) coastal graben originated by Plio-Quaternary extensional tectonics, which were filled by marine/transitional sedimentary successions, and are now occupied by large and flat coastal plains (Ascione et al., 2008). During the late Quaternary a strong volcanic activity was registered in the Campania plain coastal graben with the growth of the Somma-Vesuvius and the Phlegraean Fields volcanoes (Romano et al., 1994). The landscape of the western portion of Campania is thus characterized by a wide flat area with isolated volcanic reliefs and islands. On the eastern side of the region the carbonate ridges pass to hilly landscapes of lower elevation, made up mainly by Miocene and Pliocene flysch successions. In this general orographic setting, torrential stream catchments are a

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

widespread geomorphologic unit along the flanks of the main carbonate ridges, and the slopes of the volcanoes as well, where they have also the higher longitudinal gradients. In the remnant hilly part of the region stream catchments have lower mean longitudinal profiles, and wide alluvial plains linked to perennial river systems prevail. A simplified geological scheme of Campania region is shown in Figure 2.

The general climate is humid temperate with mean annual precipitation ranging from 1000 to 2000 mm. In short, the main situations responsible for abundant rains over the region are generally north-westerly or westerly winds bringing eastward-moving cyclonic depressions. Due to the rugged topography of the region, heavy convective precipitation often results in flash floods, with concomitant widespread floods and landslides.

## 4. Method

### 4.1. Sources used in data collection

The first step of our work was the collection of all available literature and archive data, including those coming by finalized projects like IFFI (*Inventario dei Fenomeni Franosi in Italia* - Inventory of Landslides in Italy, ISPRA-Servizio Geologico d'Italia, 2006), PAI (*Piani Stralcio per l'Assetto Idrogeologico* - River basin plans - Law 267/98) and AVI (*Aree Vulnerate in Italia* - Italian Sites Affected by landslides and floods; Guzzetti et al., 1994). All these data were located as precisely as possible, and included in the web gis database.

The second step involved the critical analysis of each input data aiming at discriminating between alluvial events and landslides, as in many reports these different types of processes are put together under the general classification of "hydrogeological events". In particular, we took into account the following event typologies:

1. Flood events in alluvial plain;
2. Flood events in torrential stream catchment;
3. Landslides;
4. Mixed and/or doubt cases.

All the events that may be easily discriminated based on general description and geographic location were inserted in the database. For the mixed and doubt cases a second analysis was carried out, in order to classify them in one of the four classes, or to definitely exclude them from the database.

Once all the events were grouped in different typologies, we moved to exclude from our analysis the classes 1 and 3, focusing our attention on the class 2, which represented the 56% of the collected data (Fig. 3), and included a list of more than 500 events of alluvial events occurred in torrential stream catchments.

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

### 4.2. Catchment typologies

The torrential stream catchments of Campania most affected by alluvial events in the last decades are mainly located in the carbonate and volcanic settings (Palma et al., 2009; Santangelo et al., 2012; Santo et al., 2012, 2015; Alessio et al., 2013). As regards their geographic location they may have both an inland outlet (generally represented by a fan or by a well defined foothill area; Santangelo et al., 2012), or a coastal outlet, generally represented by a fan delta (Esposito et al., 2011; Santo et al., 2012). They also show similar morphometric conditions (Santangelo, 2012; Alessio et al., 2013) which can be summed up as follows:

- Limited catchment area (from few $km^2$ to 10 $km^2$);
- High relief energy (from hundreds of meters up to 1000 m);
- High slopes gradient (generally greater than 35°);
- High mean gradient of feeder channel (greater than 15°);
- Low concentration time (from 30 minutes to some hours).

As the sediments captured by the stream and transported down-valley generally come from the bed and banks of the torrent, we tried to discriminate among different catchment typologies, basing on the following parameters:

- Bedrock of the catchment (carbonate/volcanic);
- Presence/absence of detrital cover and, in case of presence, its origin (weathered bedrock, soil, pyroclastic cover, etc.);
- Type of outlet zone (alluvial fan or fan delta in coastal area).

Thus, the collected events were eventually grouped, based upon their occurrence in the following five classes:

1. Carbonate catchment with pyroclastic cover;
2. Carbonate catchment without pyroclastic cover;
3. Carbonate catchment with pyroclastic cover and outlet to the sea;
4. Volcanic catchment;
5. Volcanic catchment with outlet to the sea.

### 4.3 Structure of the database, and collected information

The database contains about 500 events and is being continually updated. Each event is identified by an ID, and by the geographical coordinates (events are located by using Google Earth©). The catchment type for each event, according to the five classes defined, is also indicated in the database. Information about time of occurrence is mandatory to include an event in the catalogue. To evaluate the temporal degree of accuracy, five classes were introduced. Undoubtedly, going back to the past the accuracy decreases to the lowest level (annual accuracy). The highest value of temporal accuracy, on the other hand,

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

is assigned when the availability of information on the time of occurrence is complete (hour, day, month and year of occurrence). As concerns the trigger, the rain gauge closest to the site of the event, along with the rainfall data, is also included for the events for which daily or hourly rainfall data were accessible. Particular attention has been given in the catalogue to damage to people and infrastructures. The documented events caused heavy damages to the society, primarily involving buildings, infrastructures and lifelines (roads, pipelines, etc.). Damage to the population includes number of victims, injured, homeless and missing people. In several cases the information source does not allow to quantify damage to people, since the reported information are typically generic, such as "some victims" or “several victims”. Thus, aimed at not loosing any useful data, information about damage are reported also as text, as from the original sources. Further, additional useful information can be included in the field “notes”.

The database is synthetically shown in Table 1, which contains the main information for each event, as date and site of occurrence, damage and victims.

## 5. Data analysis

The database on alluvial events in torrential catchments of Campania contains about 500 events at the time we write (September 2015). The oldest event occurred in 1540, and affected the town of Amalfi. Temporal distribution of the events on the territory (Fig. 4) reveals that most of the municipalities have been affected more than once during the time period covered by the data included in the database (from 1540 to nowadays). Despite there are several catchments with similar geological and geomorphological characteristics, many villages did not record any event, which is probably related to lack of inhabited areas. More than 60% of the events occurred during the last 50 years, but this outcome is likely related to the higher availability of information sources, to the numerous scientific studies carried out in the last decades (mostly as an effect of the Sarno-Quindici catastrophic event in 1998), and to the growing attention toward geological hazards from the society. Five grades of temporal accuracy have been defined in order to classify the different level of knowledge of time of occurrence of the events. Events for which only the year of occurrence is known have a low accuracy, while a high accuracy is assigned when hour, day, month and year of occurrence are known. The histogram in Fig. 5 indicates that most of the collected events have a middle-to-high accuracy, meaning that day, month and year of occurrence are known. The accuracy degree decreases for the oldest events, as well as also for the smaller events.

The recurrence of alluvial events in the same area was also investigated. As shown in Figure 6, among the 86 municipalities that have been damaged by torrential flooding, 16 recorded more than 10 events. At a greater detail 9 out of 16 were located in the outlet zone of coastal carbonate catchments (Sorrento peninsula - Lattari Mts. ridge), whilst the others are in the

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

piedmont areas of inland carbonate massifs (Picentini and Matese Mts.) or in the volcanic area of Somma-Vesuvius. In all these cases the recurrence of the events is very low, ranging from 39 to 3 years, with a mean value of 15(Fig. 7). If only the most damaging events are taken into account the recurrence time increases to 50.

As regards the type of involved catchments, Figure 8 shows the events distribution on the territory, classified according to the aforementioned five classes. Most of the events took place in carbonate catchments with pyroclastic cover, both with and without an outlet to the sea (Figs. 8 and 9a). The widespread presence of carbonate catchments, and the high urbanization as well, affected the information source: as above mentioned, higher urbanization means typically greater availability of data, due to a higher attention toward occurrence of natural hazards. Distinguishing between different catchment types is important in order to discern the different bed and banks materials available, that the surge could entrap and transport downvalley. In a carbonate catchment the surge could take gravel without matrix or with low matrix (Fig. 10a), whilst in carbonate catchments with pyroclastic cover medium and coarse gravels with an high percentage of matrix are available (Fig. 10b). In the volcanic catchments, on the other hand, due to greater erodibility of the material, it is possible to find mainly silts and clays on bed and banks (Fig. 10c).

The monthly distribution of the events is quite variable in the different types of catchments. Figure 9b shows that all the events reach the peak in October, and that Autumn is the season with the highest frequency. After the dry period, heavy rainfall can generate sudden and high discharge, and the water runoff can carry downstream sediments accumulated as a result of the erosion processes.

On the basis of the collected data, in the carbonate catchments with pyroclastic cover the lower number of events is registered in April, or generally during the spring, if there is an outlet to the sea. In the carbonate catchments without cover during the spring season (March-May) there are no events, and the lower number of alluvial events is in January. As regards the volcanic catchments, February and March are the months with the smallest number of events. If the catchment has an outlet to the sea during the spring (March-May) no event has been recorded, and November-December are the months with the lower numbers of events.

As regards damage to people, about 18% of the events caused at least one victim. Figure 11 depicts their distribution in the region. The most dangerous events interested the province of Salerno, affecting the carbonate catchments with pyroclastic cover, both with and without an outlet to the sea. This means that carbonate catchments with pyroclastic cover (class 1) are the most hazardous. All the events with more than 100 victims took place in October; for the most damaging events the total amount of deaths was caused by landslides, debris flows and floods in floodplains. As a consequence, it is not easy to evaluate the victims caused only by alluvial events in torrential catchments. In many situations it was difficult to assign the precise number of casualties, since the information appear to be generic, under forms as "some victims", or "few victims". Further, the attribution of the number of casualties to each municipality was very difficult, since typically the source provides the total number of victims per event, not distinguishing for the different villages. This was the case, for instance,

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016




for the events in 1581 (700-1000 victims), in 1899 (approximately 100 victims), in 1924 (approximately 100 victims), and in 1910 (over 200 victims) that have been the most harmful recorded in the history. Furthermore, as mentioned before, differences in the data reported by different sources for the same event had to be registered.

Taking into account the total amount of collected events, the database contains few cases with injured, homeless and missing people. As regards homeless, for instance, the number is too small when compared with the numbers of events that caused complete disruption of the buildings. This is probably an hint for evaluating that the documented data actually in some ways underrate the reality.

Alluvial events in torrential catchments caused severe damages to the society, primarily involving building, lifelines and infrastructures. In particular, roads and private buildings are the most affected categories. The most dangerous catchments types are carbonate catchments with and without pyroclastic cover. Table 2 reports the category damaged by each event included in the database. In Figure 12 some examples of alluvial events in different torrential catchment types are reported. Frequently they cause severe economic losses to society.

## 6. Final remarks

By analysing the existing literature, we selected alluvial events occurred in torrential catchments of Campania, a land that has repeatedly been affected by severe flooding which caused serious damage and fatalities.

We collected temporal and spatial information on about 500 alluvial events, thus building the first specific database concerning this typology. To this aim, a critical scrutiny of the existing literature was performed, to provide a degree of reliability to the collected information. We also defined the accuracy related to the temporal information available, and for most of the collected events the accuracy resulted to be middle-high, meaning that day, month and year of occurrence are known.

In order to reconstruct flooding scenarios we defined different catchment types on the base of the main geological (bedrock lithology and presence/absence of detrital cover) and geomorphological parameters (type of outlet zone). This differentiation may be useful to understand the type of transported bed load (coarse vs fine grained) and to characterize the deposition area.

We collected also information about damage to people and society. Most of the events took place in carbonate catchments with pyroclastic cover, both with and without an outlet to the sea. Among the 86 municipalities that were damaged by torrential flooding, 16 recorded more than 10 events. In Campania the recurrence time of alluvial events is very low, ranging from few years for damages to buildings and infrastructures up to some decades in the case of events with victims. The widespread presence of carbonate catchments in the region and the high urbanization of the area affected the information

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016




sources, and these represent the main weaknesses of the historical documents. Notwithstanding volcanic areas are densely populated, alluvial events in carbonate catchments with pyroclastic cover caused more damage to people and society than in volcanic catchments.

The study has also shown that a significant number of catchments were interested by floods with high recurrence time The loss of historical memories of these events is for sure at the origin of an increase in the risk conditions.

The collection of this database represents the first step toward a full hazard analysis; furthermore, by analyzing triggering rainfall events and concentration time, it could also contribute to the development and implementation of specific early warning systems. Eventually, the application of numerical models on torrential floods could be useful to identify the flooded areas depending on the different peak discharge and the different bed material that can be entrained in the flow.

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016




## References

Alessio G., De Falco M., Di Crescenzo G., Nappi, R. and Santo, A.: Flood hazard of the Somma-Vesuvius region based on historical (19-20th century) and geomorphological data, Annals Of Geophysics, Special Issue: Vesuvius monitoring and knowledge 56, 4, S0434, doi:10.4401/ag-6440, 2013.

Antronico, L., Allasia, P., Baldo, M., Greco, R., Robustelli, G. and Sorriso-Valvo, M.: The use of airborne LiDAR data in basin-fan system monitoring: An example from southern Calabria (Italy), in: Engineering Geology for Society and Territory - Volume 2: Landslide Processes, 1 January 2015, 441-444, 2015a.

Antronico, L., Greco, R., and Sorriso-Valvo M.: Recent alluvial fans in Calabria (southern Italy), Journal of Maps, 1-12, doi:10.1080/17445647.2015.1047905, 2015b.

Arattano, M., Cavalli, M., Comiti, F., Coviello, V., Macconi, P., and Marchi, L.: Standardization of methods and procedures for debris flow seismic monitoring, in: Engineering Geology for Society and Territory-Volume 3 , Springer International Publishing, 63-67, 2015.

Arattano, M., Marchi, L., and Cavalli, M.: Analysis of debris-flow recordings in an instrumented basin: confirmations and new findings, Nat. Hazards Earth Syst. Sci., 12, 679-686, doi:10.5194/nhess-12-679-2012, 2012.

Ascione, A., Cinque, A., Miccadei, E., Villani, F., and Berti, C.: The Plio-Quaternary uplift of the Apennine chain: new data from the analysis of topography and river valleys in Central Italy, Geomorphology, 102(1), 105-118, 2008.

Berti, M. and Simoni, A.: DFLOWZ: A free program to evaluate the area potentially inundated by a debris flow, Computers and Geosciences, 67, 14-23, 2014.

Blahut, J., Glade, T., and Sterlacchini, S.: Debris flows risk analysis and direct loss estimation: the case study of Valtellina di Tirano, Italy, Journal of Mountain Science, 11(2), 288-307, 2014.

Brunetti, M.T., Peruccacci, S., Antronico, L.,Bartolini, D., Deganutti, A.M., Gariano, S.L., Iovine, G., Luciani, S., Luino, F., Melillo, M., Palladino, M.R., Parise, M., Rossi, M., Turconi, L., Vennari, C., Vessia, G., Viero, A., and Guzzetti, F.: Catalogue of rainfall events with shallow landslides and new rainfall thresholds in Italy, in: Lollino G., Giordan D., Crosta G.B., Corominas J.,Azzam R.,Wasowski J.,Sciarra N.(Eds.), Springer Special Series: Engineering Geology for Society and Territory.Volume2: Landslide Processes, 1575–1579. http://dx.doi.org/10.1007/978-3-319-09057-3_280, 2015.

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016




Calcaterra, D. and Parise, M.: The contribution of historical information in the assessment of landslide hazard, in: Glade T., Albini P., Frances F. (Eds.) "The Use of Historical Data in Natural Hazard Assessments", Advances in Natural and Technological Hazards Research, 17, Kluwer Academic Publishers, 201-217, 2001.

Calcaterra, D., Parise, M., and Palma, B.: Combining historical and geological data for the assessment of the landslide hazard: a case study from Campania, Italy, Natural Hazards and Earth System Sciences, 3 (1/2), 3-16, 2003.

Calcaterra, D., Parise, M., Palma, B., and Pelella, L.: Multiple debris flows in volcaniclastic materials mantling carbonate slopes, in: Wieczorek, G.F. and Naeser, N.D. (Eds.), Proceedings 2nd International Conference on "Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment", Taiwan, 99-107, 2000.

Calcaterra, D. and Santo, A.: The January 10, 1997 Pozzano landslide, Sorrento Peninsula, Italy. Engineering Geology, 75, 181–200, 2004.

Carrara, A., Crosta, G., and Frattini, P.: Comparing models of debris-flow susceptibility in the alpine environment, Geomorphology, 94, 353–378, 2008.

Cascini, L., Cuomo, S., and Guida, D.: Typical source areas of May 1998 flow-like mass movements in the Campania region, Southern Italy, Source of the Document Engineering Geology, 96 (3-4),107-125, 2008a.

Cascini, L., Ferlisi, S., and Vitolo, E.: Individual and societal risk owing to landslides in the Campania region (Southern Italy), Georisk, 2 (3), 125–140, 2008b.

Chirico, G.B., Di Crescenzo, G., Santangelo, N., Santo, A., and Scorpio V.: Alluvial fan flooding hazard: the study case of Teglia (San Gregorio Magno, Salerno), Rend. Online Soc. Geol. It., 2, 456-458, 2012.

Costa, J.E: Rheologic, Geomorphic and Sedimentologic differentiation of water floods, hyperconcentrated flows, and debris flows, Flood Geomorphology, 113–122, 1988.

Crosta, G.B. and Frattini, P.: Controls on modern Alluvial fan processes in the Central Alps, Nothern Italy, Earth Surf. Proc. Land., 29, 267–293, 2004.

Crosta G.B. and Negro P.D.: Observations and modelling of soil slip-debris flow initiation processes in pyroclastic deposits: The Sarno 1998 event, Natural Hazards and Earth System Sciences, 3 (1-2), 53-69, 2003.

Crosta, G., Cucchiaro, S., and Frattini, P.: Validation of semi-empirical relationships for the definition of debris flow behavior in granular materials, in: Rickenmann D. and Chen C., (eds.), Debris flow hazards mitigation: mechanics, prediction, and assessment, Millpress, Rotterdam, 821–832, 2003.



D'Agostino V.: Assessment of Past Torrential Events Through Historical Sources, in: M. Schneuwly-Bollschweiler et al. (eds.), Dating Torrential Processes on Fans and Cones, Advances in Global Change Research 47,131-146, doi:10.1007/978-94-007-4336-6 20, 2013.

Del Prete, M., Guadagno, F.M., and Hawkins, A.B.: Preliminary report on the landslides of 5 May 1998, Campania, southern Italy, Bulletin of Engineering Geology and the Environment, 57 (2), 113-129, 1998.

Del Prete, S., and Mele, R.: Il contributo delle informazioni storiche per la valutazione della propensione al dissesto nell'Isola d'Ischia (Campania), Rend. Online Soc. Geol. It., 2, 29-47, 2006.

Di Crescenzo, G. and Santo, A.: Debris slides-rapid earth flows in the carbonate massifs of the Campania region (Southern Italy): Morphological and morphometric data for evaluating triggering susceptibility, Geomorphology, 66 (1-4), 255-276, 2005.

Di Crescenzo, G., Liuzza, V., Santangelo, N., Santo, A., and Scorpio, V.: Flood susceptibility assessment in urbanized areas:cases study in Campanian Appennines, Mem. Descr. Carta Geol. d'It. XCIII, 203-218, 2013.

Esposito, E., Porfido, S., Violante, C., and Alaia, F.: Disaster induced by historical floods in a selected coastal area (Southern Italy), in: Proceedings of the Workshop PHEFRA (Palaeofloods, Historical Data and Climatic Variability), edited by: Thorndycraft, V. R., Benito, G., Barriendos, M., and Llasat, M. C., Application in Flood Risk Assessment, Barcelona, Spain, October 2002, 143–148, 2003.

Esposito, G. and Galli, P.: La catastrofe idrogeologica del 1581 nei Monti Picentini (Sa) tra evidenze d'archivio e indagini geomorfologiche, Italian Journal of Quaternary Sciences, 24 (2), 179-189, 2011.

Esposito, E., Porfido, S., Violante, C., Molisso, F., Sacchi, M., Santoro, G., and Spiga, E.: Flood risk estimation through document sources analysis: the case of the Amalfi rocky coast, DTA, 2011.

FEMA: Guidelines for determining flood hazards on alluvial fans, Federal Emergency Management Agency, (http://www.fema.gov/mit/tsd/ft_alfan.htm), 2000.

Gringeri Pantano, F., Nicoletti, P., and Parise, M.: Historical and geological evidence for the seismic origin of newly recognized landslides in south-eastern Sicily, and its significance in terms of hazard, Environmental Management, 29 (1), 116-131, 2002.

Guadagno, F.M., Martino, S., and Mugnozza, G.S.: Influence of man-made cuts on the stability of pyroclastic covers (Campania, southern Italy): A numerical modelling approach, Environmental Geology, 43, 4, 371-384, 2003.



Guadagno, F.M., Forte, R., Revellino, P., Fiorillo, F., and Focareta, M.: Some aspects of the initiation of debris avalanches in the Campania Region: The role of morphological slope discontinuities and the development of failure, Geomorphology, 66 (1-4), 237-254, 2005.

Guzzetti, F., Cardinali, M., and Reichenbach, P.: The AVI Project: a bibliographical and archive inventory of landslides and floods in Italy, Environmental Management, 18, 623–633, 1994.

ISPRA-Servizio Geologico d'Italia: Progetto IFFI (Inventario dei Fenomeni Franosi in Italia), Landslide inventory map of Italy at 1:25,000 scale, ISPRA – Dipartimento Difesa del Suolo-Servizio Geologico d'Italia – Regione Campania, 2006. (http://193.206.192.136/cartanetiffi/).

Jakob, M., Hungr, O. and Jakob, D.M.: Debris-flow hazards and related phenomena, Springer, Berlin, 2005.

Marchi, L. and Tecca, P.R.: Debris-flow monitoring in Italy, in: M. Schneuwly-Bollschweiler et al. (eds.), Dating Torrential Processes on Fans and Cones, Advances in Global Change Research 47,309-318, doi:10.1007/978-94-007-4336-6 20, 2013.

Mazzarella, A. and Diodato, N.: The alluvial events in the last two centuries at Sarno, southern Italy: their classification and power-law time-occurrence, Theoretical and applied climatology, 72(1-2), 75-84, 2002.

Migale, L.S. and Milone, A.: Mud flows in pyroclastic deposits of the Campania, First data from historical research, Rassegna Storica Salernitana, 30, 15 (2), 235-271, 1998.

O'Brien, J.S. and Julien, P.Y.: Physical properties and mechanics of hyperconcentrated sediment flows, in: Proceedings of ASCE specialty conference on the delineation of landsfides, flash floods and debris flow hazards in Utah, Utah Water Research Lab., Univ. of Utah at Logan, Utah, 260–279, 1985.

Palma, B., Calcaterra, D., and Parise M.: Modelli geologici e meccanismi di innesco di frane da scorrimento-colata rapida nei depositi vulcanoclastici della Campania, GEAM-Geoingegneria Ambientale e Mineraria, 126 (1), 21-48, 2009.

Parise, M.: Landslide mapping techniques and their use in the assessment of the landslide hazard, Journal of Physics and Chemistry of the Earth, part C, 26/9, 697-703, 2001.

Porfido, S., Esposito, E., Molisso, F., Sacchi, M., and Violante, C.: Flood Historical Data for Flood Risk Estimation in Coastal Areas, Eastern Tyrrhenian Sea, Italy, in: C. Margottini et al. (eds.), Landslide Science and Practice, 5, Springer-Verlag, Berlin Heidelberg, doi:10.1007/978-3-642-31427-8_13, 2013.

Revellino, P., Hungr, O., Guadagno, F.M., and Evans, S.G.: Velocity and runout simulation of destructive debris flows and debris avalanches in pyroclastic deposits, Campania region, Italy, Environmental Geology, 45 (3), 295-311, 2004.

Romano, P., Santo, A., and Voltaggio, M.: L'evoluzione geomorfologica della pianura del F. Volturno (Campania) durante il tardo Quaternario (Pleistocene medio-superiore - Olocene), Il Quaternario, 7 (1), 41-56, 1994.

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016




Röthlisberger G.: Chronik der Unwetterschäden in der Schweiz, WSL/FNP Berichte der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft 330, 1–122, 1991.

Salvati, P., Bianchi, C., Rossi, M., and Guzzetti, F.: Societal landslide and flood risk in Italy, Natural Hazards and Earth System Sciences, 10 (3), 465-483, 2010.

Santangelo, N., Santo, A. and Faillace, P.: Valutazione della pericolosità alluvionale delle conoidi del Vallo di Diano (Salerno, Italia meridionale), Il Quaternario Italian Journal of Quaternary Sciences, 19, 3-17, 2006.

Santangelo, N., Santo, A., Di Crescenzo, G., Foscari, G., Liuzza, V., Sciarrotta, S., and Scorpio, V.: Flood susceptibility assessment in a highly urbanized alluvial fan: the case study of Sala Consilina (southern Italy), Natural Hazard and Earth System Science, 11, 2765–2780, 2011.

Santangelo, N., Daunis-i-Estadella, J., Di Crescenzo, G., Di Donato, V., Faillace, P., Martin-Fernandez, J.A., Romano, P., Santo, A., and Scorpio, V.: Topographic predictors of susceptibility to alluvial fan flooding, Southern Apennines, Earth Surf Proc Land, 37, 803–817, doi:10.1002/esp.3197, 2012.

Santo, A., Santangelo, N., Benedice, A. and Iovane F: Pericolosità connessa a processi alluvionali in aree pedemontane: il caso di Castellamare di Stabia in Penisola Sorrentina, Il Quaternario, 15 (1), 23-37, 2002.

Santo, A., Di Crescenzo, G., Del Prete, S., and Di Iorio, L.: The Ischia island flash flood of November 2009 (Italy): Phenomenon analysis and flood hazard, Physics and Chemistry of the Earth, Parts A/B/C, 49, 3-17, 2012.

Santo, A., Santangelo, N., Di Crescenzo, G., Scorpio, V., De Falco, M., and Chirico, G.B.: Flash flood occurrence and magnitude assessment in an alluvial fan context: the October 2011 event in the Southern Apennines, Natural Hazards, 78 (1), 417-442, 2015.

Scorpio, V.: Analisi Geomorfologica dei sistemi bacino-conoide dell'Appennino campano: scenari di suscettibilità alluvionale, PhD Thesis, University of Napoli Federico II, 2011.

Simoni, A., Mammoliti, M., and Berti, M.: Uncertainty of debris flow mobility relationships and its influence on the prediction of inundated areas, Geomorphology, 132 (3-4), 249-259, 2011.

Sorriso-Valvo, M., Antronico, L., and La Pera, E.: Controls on fan morphology in Calabria, southern Italy, Geomorphology, 24, 169–187, 1998.

Sosio R., Crosta G.B., and Frattini P.: Field observations, rheological testing and numerical modelling of a debris-flow event, Earth Surface Processes and Landforms, 32, 2, 290-306, 2007.



Stoffel, M., Schneuwly-Bollschweiler, M., Rudolf-Miklau, F.: Dating Past Events on Fans and Cones– An Introduction, in: M. Schneuwly-Bollschweiler et al. (eds.), Dating Torrential Processes on Fans and Cones, Advances in Global Change Research 47, 1-11, doi:10.1007/978-94-007-4336-6 20, 2013.

Tiranti, D., Cremonini, R., Marco, F., Gaeta, A. R., and Barbero, S.: The DEFENSE (debris Flows triggEred by storms–nowcasting system): An early warning system for torrential processes by radar storm tracking using a Geographic Information System (GIS), Computers & Geosciences, 70, 96-109, 2014.

Tropeano, D., and Turconi, L.: Using historical documents for landslide, debris flow and stream flood prevention. Applications in Northern Italy, Natural Hazards, 31 (3), 663-679, 2004.

Vallario, A.: Il dissesto idrogeologico in Campania, CUEN, 2001.

Zanchetta, G., Sulpizio, R., and Di Vito, M.A.: The role of volcanic activity and climate in alluvial fan growth at volcanic areas: an example from Southern Campania (Italy), Sed Geol, 168, 249–280, 2004a.

Zanchetta, G., Sulpizio, R., Pareschi, M.T., Leoni, F.M., and Santacroce, R.: Document Characteristics of May 5-6, 1998 volcaniclastic debris flows in the Sarno area (Campania, southern Italy): Relationships to structural damage and hazard zonation, Journal of Volcanology and Geothermal Research, 133 (1-4), 377-393, 2004b.

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences
Discussions

**Table**

Table1: N=ID event, Date, Municipality, Locality, D= damage (see table 2), V= number of victim (*=total amount of victims per events in the same date); R=references (see Table 3).

| N | Date | Municipality | locality | D | V | R |
|---|---|---|---|---|---|---|
| 1 | 08/10/1540 | Amalfi | | | | 1 |
| 2 | 1550 | Casamicciola | La Pera quarry, (Ervaniello) | 4 | | 11 |
| 3 | 30/9/1581 | Cava dè Tirreni | | | | 3 |
| 4 | 30/9/1581 | Salerno | | | | 3 |
| 5 | 30/9/1581 | Vietri sul Mare | | | | 3 |
| 6 | 1/10/1581 | Castiglione del Genovesi | | 4,3 | 700-1000* | 8 |
| 7 | 1/10/1581 | Giffoni sei Canali | | 4,3 | 700-1000* | 3; 8 |
| 8 | 1/10/1581 | Piedimonte Matese | | 4, 5 | 400 | 6 |
| 9 | 1/10/1581 | San Cipriano Picentino | | 4,3 | 700-1000* | 8 |
| 10 | 31/8/1588 | Atrani | | | | 3 |
| 11 | 1626 | Salerno | Fusandola | 2. | | 1 |
| 12 | 06/1643 | Casamicciola | Bagni square | 4 | | 11 |
| 13 | 06/1643 | Casamicciola | Piazza La Rita | 4 | | 11 |
| 14 | 20/12/1683 | Maiori | Regina Major catchment | | | 1 |
| 15 | 15/10/1696 | Minori | Regina Minor catchment | | | 1; 2 |
| 16 | 26/9/1728 | Piedimonte Matese | Vallata | 4, 5 | | 6 |
| 17 | 11/11/1773 | Cava dè Tirreni | Passiano | 4 | 400* | 1 |
| 18 | 25/1/1736 | Vietri sul Mare | Bonea catchment | | | 2 |
| 19 | 26/9/1736 | Vietri sul Mare | Bonea catchment | | | 2 |
| 20 | 11/1738 | Vietri sul Mare | Bonea catchment | | | 2 |
| 21 | 3/11/1750 | Salerno | Irno catchment | | | 3 |
| 22 | 3/11/1750 | Vietri sul Mare | | | | 3 |
| 23 | 10/10/1751 | Amalfi | Canneto catchment. (now Grevone) | | | 2 |
| 24 | 1/9/1753 | Amalfi | Loc. Chiorito | | | 1 |
| 25 | 23/1/1757 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 26 | 23/1/1757 | Vietri sul Mare | Bonea catchment | | | 2 |
| 27 | 9/10/1757 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 28 | 25/5/1762 | Cetara | Cetus catchment | | | 3 |
| 29 | 19/1/1764 | Salerno | | | | 2 |
| 30 | 11/1770 | Salerno | Irno catchment | | | 2 |
| 31 | 11/11/1773 | Cava dè Tirreni | | | | 3 |
| 32 | 11/11/1773 | Cetara | | | | 3 |
| 33 | 11/11/1773 | Pellezzano | | | | 3 |
| 34 | 11/11/1773 | Salerno | Loc. Coperchia | 5 | 7 | 3;1 |
| 35 | 11/11/1773 | Tramonti | | | | 3 |
| 36 | 11/11/1773 | Vietri sul Mare | | | | 3 |
| 37 | 20/11/1778 | Alife | | 4 | | 6 |
| 38 | 20/11/1778 | Piedimonte Matese | Loc.Vallata | 4 | | 9 |
| 39 | 2/1780 | Atrani | Dragone catchment | | | 2 |
| 40 | 25/12/1796 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 41 | 25/12/1796 | Salerno | Irno catchment | | | 2 |
| 42 | 25/12/1796 | Vietri sul Mare | Bonea catchment. | | | 2 |
| 43 | 10/1803 | Piedimonte Matese | Loc.Vallata | | | 6 |
| 44 | 21/01/1805 | Solofra | Loc. Caposolofra | 5, 4, 2., 3 | | 15 |
| 45 | 22/1/1805 | Serino | Ribottoli | | 67 | 6 |
| 46 | 9/6/1806 | Sala Consilina | De Petrinisi street | 4, 5 | 30 | 10 |
| 47 | 10/1810 | Piedimonte Matese | Loc.Vallata | | | 9 |
| 48 | 1811 | Arienzo | | 5 | | 6 |
| 49 | 1811 | Santa Maria a Vico | | 5 | | 6 |
| 50 | 21/12/1812 | Positano | Parlati Mt. | 5 | 3 | 1 |
| 51 | 30_31/7/1814 | Bracigliano | | | | 1 |
| 52 | 4 -19/12/1814 | Sala Consilina | Vairo, Marroncelli and Poerio streets | 5 | | 10 |
| 53 | 1814 | Piedimonte Matese | | | | 6 |
| 54 | 12/11/1817 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 55 | 12/11/1817 | Salerno | Irno catchment | | | 2 |
| 56 | 12/11/1817 | Vietri sul Mare | Bonea catchment | | | 2 |
| 57 | 1818 | Cava dè Tirreni | Amalfi coast | | | 2 |
| 58 | 1819 | Cava dè Tirreni | Amalfi coast | | | 2 |
| 59 | 1820 | Cava dè Tirreni | Amalfi coast | | | 2 |
| 60 | 1821 | Salerno | Irno catchment | | | 2 |
| 61 | 6/6/1822 | Sala Consilina | Monteoliveto square, De Petrinis land | 4, 3 | | 10 |
| 62 | 27/10/1822 | Corbara | | | | 1 |
| 63 | 8/11/1822 | Salerno | Road to Vietri | | | 1 |
| 64 | 24/1/1823 | Amalfi | | | | 3 |
| 65 | 24/1/1823 | Bracigliano | | | | 3 |
| 66 | 24/1/1823 | Cava dè Tirreni | | | | 3 |
| 67 | 24/1/1823 | Vietri sul Mare | | | | 3 |
| 68 | 8/10/1823 | Corbara | Main square | | | 1 |
| 69 | 3/10/1824 | Minori | Loc. Torre | | | 1 |
| 70 | 1825 | Cava dè Tirreni | Amalfi coast | | | 2 |
| 71 | 18/6/1827 | Sala Consilina | | 4, 5 | | 6 |
| 72 | 11/7/1829 | Arienzo | | 5 | | 6 |
| 73 | 19/10/1830 | Arienzo | | 5, 1 | | 6 |
| 74 | 16/7/1833 | Arienzo | | | | 6 |
| 75 | 13/9/1834 | Cetara | Cetus catchment | | | 2 |
| 76 | 18/7/1835 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 77 | 18/7/1835 | Conca dei Marini | Irno and Bonea catchment | | | 2 |
| 78 | 18/7/1835 | Salerno | Irno catchment | | | 2 |
| 79 | 27/9/1837 | Salerno | Irno catchment | | | 2 |
| 80 | 27/9/1837 | Vietri sul Mare | Bonea catchment | | | 2 |
| 81 | 27/10/1839 | Padula | | 5 | | 6 |
| 82 | 1/6/1841 | Arienzo | | | | 6 |
| 83 | 20/9/1841 | Piedimonte Matese | Loc. Vallata | 4, 5 | 7* | 6; 9 |
| 84 | 20/9/1841 | San Potito Sannitico | | 4, 5 | 7* | 6; 9 |
| 85 | 7/11/1842 | Serino | Loc. S.Rocco, S.Lucia | | 16 | 6 |
| 86 | 26/10/1843 | Cetara | Cetus catchment | | | 2 |
| 87 | 26/10/1843 | Maiori | Regina Major catchment | | | 2 |
| 88 | 26/10/1843 | Salerno | Irno catchment | | | 2 |
| 89 | 26/10/1843 | Vietri sul Mare | Loc. Molina | | | 1 |
| 90 | 18/3/1845 | Maiori | Regina Major catchment | | | 2 |
| 91 | 18/3/1845 | Vietri sul Mare | Bonea catchment | | | 2 |
| 92 | 1/10/1846 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 93 | 1/10/1846 | Baronissi | Irno catchment | | | 2 |
| 94 | 1/10/1846 | Cetara | Cetus catchment | | | 2 |
| 95 | 1/10/1846 | Fisciano | Canneto, Regina Major, Bonea and Irno catchments | | | 2 |
| 96 | 1/10/1846 | Maiori | Regina Major catchment | | | 2 |
| 97 | 1/10/1846 | Pellezzano | Irno catchment | | | 2 |
| 98 | 31/12/1847 | Amalfi | | | | 2 |
| 99 | 13/9/1851 | Alife | | | | 6 |
| 100 | 13/9/1851 | Piedimonte Matese | | | | 6 |
| 101 | 13/9/1851 | Sant'Angelo d'Alife | | | | 6 |
| 102 | 21/11/1851 | Serino | Loc. S.Lucia, Troiani | 4 | | 6 |
| 103 | 1851 | Padula | | 5 | | 6 |
| 104 | 1851 | Volturara Irpina | | 5 | | 6 |
| 105 | 28/10/1852 | Solofra | | 5, 6, 4 | | 15 |
| 106 | 5/1/1853 | Vietri sul Mare | Bonea catchment. | | | 2 |
| 107 | 20/3/1853 | Volturara Irpina | | | | 6; 9 |
| 108 | 13/9/1857 | Piedimonte Matese | Loc.Vallata | 4, 5 | 90* | 6; 9 |
| 109 | 13/9/1857 | Sant'Angelo d'Alife | Loc. S. Bartolomeo and S. Maria | 4, 5 | 90* | 6; 9 |
| 110 | 1857 | Padula | | 5 | | 6 |
| 111 | 13/6/1858 | Sala Consilina | Indipendenza, Vairo, A. Da Brescia, U. Bossi and C.Battista streets | 4,1, 5 | 18 | 10; 6 |
| 112 | 1859 | Padula | | 4, 5 | | 6 |
| 113 | 8/1866 | Maiori | Loc. Cetraro, road to Tramonti, Regina Major catchment | | | 1,2 |
| 114 | 11/11/1866 | Vietri sul Mare | Bonea catchment | | | 2 |
| 115 | 16/3/1867 | Vietri sul Mare | Bonea catchment | | | 2 |
| 116 | 10/10/1867 | Padula | | 4, 5 | | 6 |
| 117 | 1/4/1875 | Conca dei Marini | Irno catchment. | | | 2 |

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences
Discussions

| N | Date | Municipality | locality | D | V | R |
|---|---|---|---|---|---|---|
| 118 | 1876 | Padula | | 4, 5 | | 6 |
| 119 | 1/2/1878 | Conca dei Marini | | | | 2 |
| 120 | 1/2/1878 | Salerno | Irno catchment | | | 2 |
| 121 | 17/11/1880 | Arienzo | | | | 9 |
| 122 | 1881 | Padula | | 4, 5 | | 6 |
| 123 | 1883 | Padula | | 4, 5 | | 6 |
| 124 | 5/2/1885 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 125 | 1891 | Tramonti | Regina Major catchment | | | 2 |
| 126 | 1896 | Baronissi | Irno catchment | | | 2 |
| 127 | 1896 | Bracigliano | Picentino, Fuorni and Irno catchment | | | 2 |
| 128 | 1896 | Castiglione del Genovesi | Picentino catchment | | | 2 |
| 129 | 1896 | Conca dei Marini | Picentino, Fuorni and Irno catchment | | | 2 |
| 130 | 1896 | Salerno | Irno catchment | | | 2 |
| | 7/10/1899 | Calabritto | | 4, 3, 5 | 100* | 12 |
| 131 | 7/10/1899 | Caposele | | 4, 3, 5 | 100* | 12 |
| 132 | 7/10/1899 | Castiglione del Genovesi | | 4, 3, 5 | 100* | 12 |
| 133 | 7/10/1899 | Cava dè Tirreni | | 4, 3, 5 | 100* | 12 |
| 134 | 7/10/1899 | Curticelle | | 4, 3, 5 | 100* | 12 |
| 135 | 7/10/1899 | Giffoni sei Canali | | 4, 3, 5 | 100* | 12 |
| 136 | 7/10/1899 | Giffoni Valle Piana | Secco stream and Colauro street | 4 | 3 | 12 |
| 137 | 7/10/1899 | Montecorvino Pugliano | | 4, 3, 5 | 100* | 12 |
| 138 | 7/10/1899 | Montecorvino Rovella | | 4, 3, 5 | 100* | 12 |
| 139 | 7/10/1899 | Quaglietta | | 4, 3, 5 | 100* | 12 |
| 140 | 7/10/1899 | Salerno | Irno catchment and Rafastia torrent | 4, 3, 5 | 100* | 12, 5; 1 |
| 141 | 7/10/1899 | Vietri sul Mare | Molina di Vietri | 4, 3, 5 | 5 | 12,2, |
| 142 | 1900 | Padula | | 4, 5 | | 6 |
| 143 | 02/1903 | Vietri sul Mare | Bonea catchment | | | 2 |
| 144 | 1903 | Cervinara | | 5 | | 1 |
| 145 | 7/10/1904 | Ravello | Dragone catchment | | | 2 |
| | | | | | | |
| 146 | 17-18/05/1906 | Ercolano | | | 2 | 4 |
| 147 | 01/06/1906 | Sant'Anastasia | | | | 4 |
| 148 | 01/06/1906 | Cercola | | | | 4 |
| 149 | 01/06/1906 | Pollena Trocchia | | | | 4 |
| 150 | 1906 | Torre del Greco | Cavallerizzi, XX Settembre and Purgatorio streets, Del Popolo square | | 26 | 4 |
| 151 | 04/01/1907 | Ercolano | | | | 4 |
| 152 | 24-25/10/1908 | Ercolano | | | 2 | 4 |
| 153 | 24-25/10/1908 | Napoli | Loc. Barra | | | 4 |
| 154 | 24-25/10/1908 | Napoli | Loc.San Giovanni a Teduccio | | | 4 |
| 155 | 24-25/10/1908 | Napoli | | | | 4 |
| 156 | 24-25/10/1908 | Portici | | | | 4 |
| 157 | 24-25/10/1908 | San Giorgio a Cremano | | | | 4 |
| 158 | 24-25/10/1908 | Torre del Greco | | | | 4 |
| 159 | 04/10/1909 | Boscotrecase | | | | 4 |
| 160 | 23/10/1910 | Cetara | Cetus catchment, Loc. Utrio and. Cappetta, Federico street | 5, 4 | 200* | 15;3; 1; 2; 13 |
| 161 | 24/10/1910 | Amalfi | | 5 | 2 | 3;1 |
| 162 | 24/10/1910 | Barano d'Ischia | Loc. Casabona | 4,5 | | 11; 2 |
| 163 | 24-25/10/1910 | Boscotrecase | | | | 4; 2 |
| 164 | 24/10/1910 | Casamicciola | | 4,5 | 6 | 11; 2 |
| 165 | 24-25/10/1910 | Cercola | | | | 4; 2 |
| 166 | 24-25/10/1910 | Ercolano | Loc. Resina | | | 4; 2 |
| 167 | 24/10/1910 | Forio d'Ischia | Loc. Monterone | 4,5 | | 12; 2 |
| 168 | 24/10/1910 | Furore | | 5 | | 3 |
| 169 | 24/10/1910 | Ischia | | 5 | | 3;2 |
| 170 | 24/10/1910 | Lacco Ameno | | 4 ,5 | | 11; 2 |
| 171 | 24/10/1910 | Maiori | Loc. Erchie, S.Nicola and Sovarano | 5, 4 | 24 | 3; 15; 1 |
| 172 | 24/10/1910 | Minori | | 5 | 4 | 3; 1 |

| N | Date | Municipality | locality | D | V | R |
|---|---|---|---|---|---|---|
| 173 | 24-25/10/1910 | Pollena Trocchia | | | | 4 |
| 174 | 24/10/1910 | Portici | Giordano street | | | 4; 2 |
| 175 | 24/10/1910 | Ravello | | 6, 5 | | 3; 1 |
| 176 | 24/10/1910 | Salerno | Fusandola stream | 5 | | 3;2 |
| 177 | 24-25/10/1910 | San Sebastiano al Vesuvio | | | | 4; 2 |
| 178 | 24-25/10/1910 | Sant'Anastasia | | | | 4 |
| 179 | 24/10/1910 | Scala | Loc. Acquabona | 2 | | 3; 1 |
| 180 | 24/10/1910 | Serrara Fontana | | 5 | | 11 |
| 181 | 24-25/10/1910 | Somma Vesuviana | | | | 4 |
| 184 | 24/10/1910 | Vietri sul Mare | loc. Molina | 5 | 1 | 3; 1; 2 |
| 185 | 02/01/1911 | Cetara | Cetus catchment | | | 2 |
| 186 | 02/01/1911 | Vietri sul Mare | Bonea catchment | | | 2 |
| 187 | 21/09/1911 | Boscoreale | | | | 4 |
| 188 | 21/09/1911 | Ercolano | Loc. Resina,(Pugliano, Mare, Cortile, Trentola streets) | | 6 | 4 |
| 189 | 21/09/1911 | NA | Loc. San Giovanni a Teduccio | | | 4 |
| 190 | 21/09/1911 | Ottaviano | | | | 4 |
| 191 | 21/09/1911 | Portici | | | | 4 |
| 192 | 21/09/1911 | San Giuseppe Vesuviano | | | | 5 |
| 193 | 21/09/1911 | Torre del Greco | XX Settembre, Nazionale, Fiorillo and Umberto streets | | | 4 |
| 194 | 03/01/1915 | Minori | Regina Minor catchment | | | 2 |
| 195 | 1915 | Alife | | | | 6 |
| 196 | 06/11/1916 | Vietri sul Mare | Bonea catchment | | | 2 |
| 197 | 21/09/1921 | San Giuseppe Vesuviano | | | | 4 |
| 198 | 25/10/1921 | Ercolano | | | | 4 |
| 199 | 25/10/1921 | NA | Loc. Barra | | | 4 |
| 200 | 25/10/1921 | Portici | | | | 4 |
| 201 | 25/10/1921 | San Giorgio a Cremano | | | | 4 |
| 202 | 25/10/1921 | Torre del Greco | | | | 4 |
| 203 | 13/11/1921 | Furore | | | | 2 |
| 204 | 26/03/1924 | Agerola | | | 100* | 3; 8 |
| 205 | 26/03/1924 | Amalfi | Loc. Vettica Minore, Baglio | 2,5 4 | 60 | 3; 8 |
| 206 | 26/03/1924 | Atrani | | | 100* | 3; 8 |
| 207 | 26/03/1924 | Cetara | | | 100* | 1 |
| 211 | 26/03/1924 | Minori | | | 100* | 3; 8 |
| 212 | 26/03/1924 | Positano | | | 100* | 3; 8 |
| 213 | 26/03/1924 | Praiano | Loc. Marina di Praiano | 4 | 18 | 3; 8; 1;2 |
| 214 | 26/03/1924 | Vietri sul Mare | Bonea and Regina Major catchments | 4 | 100* | 5 |
| 215 | 26/03/1924 | Vietri sul Mare | | | | 3; 8 |
| 216 | 01/10/1927 | Sala Consilina | | 4, 5 | | 6 |
| 217 | 01/11/1927 | Sala Consilina | Umberto I square | 4, 5 | | 10 |
| 218 | 21/09/1929 | Giffoni Valle Piana | Picentino catchment | | | 2 |
| 219 | 21/09/1929 | Montecorvino Rovella | | | | 2 |
| 220 | 21/09/1929 | Vietri sul Mare | Bonea catchment | | | 2 |
| 221 | 31/08/1931 | Castellammare di S. | | | 1 | 1 |
| 222 | 01/03/1935 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 223 | 01/03/1935 | Conca dei Marini | | | | 2 |
| 224 | 01/03/1935 | Minori | Regina Minor catchment | | | 2 |
| 225 | 01/03/1935 | Ravello | Dragone catchment | | | 2 |
| 226 | 01/03/1935 | Tramonti | Regina Major catchment | | | 2 |
| 227 | 21/08/1935 | Castellammare di S. | | | | 1 |
| 228 | 1935 | Giffoni Valle Piana | | | | 1 |
| 229 | 14/09/1939 | Amalfi | Canneto catchment.(now Grevone) | | | 2 |
| 230 | 14/09/1939 | Conca dei Marini | Canneto, Regina Major, Irno and Picentino catchments | | | 2 |
| 231 | 14/09/1939 | Maiori | Regina Major catchment | | | 2 |
| 232 | 01/06/1941 | Arienzo | | | | 9 |
| 233 | 18/06/1944 | Minori | Regina Minor catchment | | | 2 |

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences
Discussions

| N | Date | Municipality | locality | D | V | R |
|---|---|---|---|---|---|---|
| 234 | 02/10/1945 | Minori | Regina Minor catchment | | | 2 |
| 235 | 02/03/1947 | Minori | Regina Minor catchment | | | 2 |
| 236 | 30/06/1947 | Sala Consilina | Umberto I square | 4, 5 | 1 | 9;10 |
| 237 | 25/10/1947 | Minori | Regina Minor catchment | | | 2 |
| 238 | 23/05/1948 | Minori | Regina Minor catchment | | | 2 |
| 239 | 26/07/1948 | Somma Vesuviana | | 4 | | 4 |
| 240 | 05/09/1948 | Minori | Regina Minor catchment | | | 2 |
| 241 | 02/10/1948 | Alife | Loc. S.Michele | 5 | | 6 |
| 242 | 28/10/1948 | Minori | Regina Minor catchment | | | 2 |
| 243 | 01/10/1949 | Vietri sul Mare | Bonea catchment | | | 2 |
| 244 | 14/08/1950 | Somma Vesuviana | | | | 4 |
| 245 | 02/09/1950 | Somma Vesuviana | | | | 4 |
| 246 | 25/12/1950 | Castellammare di S. | Loc. Pozzano | | | 1 |
| 247 | 21/01/1951 | Minori | Regina Minor catchment | | | 2 |
| 248 | 09/03/1951 | Castellammare di S. | Loc. Pozzano | | | 1 |
| 249 | 09/11/1951 | Giffoni Valle Piana | Picentino catchment | | | 2 |
| 250 | 09/11/1951 | Montecorvino Rovella | | | | 2 |
| 251 | 11/09/1953 | Agerola | | | | 2 |
| 252 | 11/09/1953 | Ravello | Dragone catchment | | | 2 |
| 253 | 1953 | Ravello | Eastern side of Colonna Mt. | | | 1 |
| 254 | 25/10/1954 | Amalfi | Canneto catchment (now Grevone) | | | 3 |
| 255 | 25/10/1954 | Atrani | | | | 3 |
| 256 | 25/10/1954 | Cava dè Tirreni | Loc. Alessia, Marini and Castagneto | | 31 | 3; 1, 18 |
| 257 | 25/10/1954 | Maiori | | | | 3; 1, 18 |
| 258 | 25/10/1954 | Minori | | 2 | | 3; 1, 18 |
| 259 | 25/10/1954 | Positano | | | | 3 |
| 260 | 25/10/1954 | Praiano | Loc. Vettica Maggiore | | | 3 |
| 261 | 25/10/1954 | Salerno | Loc. Fratte,and Canalone | 6, 4, 5 | 205* | 3; 5; 18 |
| 262 | 25/10/1954 | Tramonti | | 5 | | 3; 8; 2; 22 |
| 263 | 25/10/1954 | Vietri sul Mare | Loc. Di Molina and Marina | | | 3, 18 |
| 264 | 05/11/1954 | Ercolano | | | | 4 |
| 265 | 04/02/1955 | San Sebastiano al Vesuvio | | | | 5 |
| 266 | 11/09/1955 | Agerola | | | | 2 |
| 267 | 11/09/1955 | Pellezzano | Irno catchment | | | 2 |
| 268 | 11/09/1955 | Tramonti | Regina Major catchment | | | 2 |
| 269 | 10/01/1956 | San Giuseppe Vesuviano | | | 3 | 4 |
| 270 | 18/11/1956 | Arpaia | | | | 6 |
| 271 | 21/01/1957 | Sant'Anastasia | | | | 5 |
| 272 | 22/10/1957 | Cava dè Tirreni | | | | 2 |
| 273 | 22/10/1957 | Minori | Regina Minor catchment | | | 2 |
| 274 | 22/10/1957 | Tramonti | Regina Major catchment | | | 2 |
| 275 | 30/12/1957 | Cercola | | | 2 | 4 |
| 276 | 19/09/1960 | Ercolano | | | 1 | 4 |
| 277 | 19/09/1960 | Portici | | | | 4 |
| 278 | 07/07/1961 | Torre del Greco | | | 1 | 4 |
| 279 | 12/11/1961 | Torre del Greco | | | 2 | 4 |
| 280 | 27/06/1962 | San Giuseppe Vesuviano | | | | 5 |
| 281 | 16/02/1963 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 282 | 16/02/1963 | Pellezzano | Irno catchment | | | 2 |
| 283 | 16/02/1963 | Petina | | | | 2 |
| 284 | 16/02/1963 | Positano | | | | 2 |
| 285 | 16/02/1963 | Sala Consilina | | 4, 5 | | 6 |
| 286 | 16/02/1963 | Tramonti | Regina Major catchment | | | 2 |
| 287 | 17/02/1963 | Pimonte | | | 4 | 7 |
| 288 | 18/02/1963 | Padula | | 4, 5 | | 6 |
| 289 | 18/02/1963 | Pesco Sannita | | | | 2 |
| 290 | 21/02/1963 | Positano | Loc. Trara Genoino | | | 1 |
| 291 | 13/05/1963 | Sant'Anastasia | | | | 4 |
| 292 | 30/05/1963 | Torre del Greco | | | | 5 |
| 293 | 25/09/1963 | Agerola | | | | 2 |
| 294 | 25/09/1963 | Cava dè Tirreni | | | | 2 |
| 295 | 25/09/1963 | Cetara | Cetus catchment | | | 2 |
| 296 | 25/09/1963 | Minori | | | | 2 |
| 297 | 25/09/1963 | Pagani | | | | 2 |
| 298 | 25/09/1963 | Pellezzano | Irno catchment | | | 2 |
| 299 | 07/10/1963 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 300 | 07/10/1963 | Cetara | Cetus catchment | | | 2 |
| 301 | 07/10/1963 | Maiori | Regina Major catchment | | | 2 |
| 302 | 07/10/1963 | Minori | Regina Minor catchment | | | 2 |
| 303 | 07/10/1963 | Salerno | | | | 1 |
| 304 | 16/12/1963 | Pellezzano | Irno catchment | | | 2 |
| 305 | 16/12/1963 | Tramonti | Regina Major catchment | | | 2 |
| 306 | 13/01/1965 | Torre del Greco | | | | 5 |
| 307 | 06/04/1966 | Torre Annunziata | | | | 5 |
| 308 | 25/10/1966 | Castiglione del Genovesi | | | 1 | 3; 8 |
| 309 | 25/10/1966 | Giffoni sei Canali | Monna Mt. | | 2 | 7; 1 |
| 310 | 26/10/1966 | Alife | | | | 6 |
| 311 | 26/10/1966 | Baronissi | | | | 3 |
| 312 | 26/10/1966 | Cava dè Tirreni | | | | 3 |
| 313 | 26/10/1966 | Piedimonte Matese | Loc. Vallata | | | 6 |
| 314 | 26/10/1966 | Salerno | | | | 3 |
| 315 | 1966 | Ravello | | | | 1 |
| 316 | 09/01/1968 | Salerno | | | | 5 |
| 317 | 17/12/1968 | Padula | | 4, 5 | | 6 |
| 318 | 19/12/1968 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 319 | 19/12/1968 | Tramonti | Regina Major catchment | | | 2 |
| 320 | 1968 | Alife | | | | 6 |
| 321 | 15/03/1969 | Agerola | | | | 1 |
| 322 | 15/03/1969 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 323 | 17/09/1969 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 324 | 22/09/1969 | San Giorgio a Cremano | | | | 1 |
| 325 | 1969 | Arpaia | | | | 5 |
| 326 | 08/04/1970 | Salerno | | 5 | 2 | 1 |
| 327 | 01/10/1970 | Portici | | | 1 | 4 |
| 328 | 01/10/1970 | Torre Annunziata | | | 1 | 4 |
| 329 | 01/10/1970 | Torre del Greco | | | | 4 |
| 330 | 02/10/1970 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 331 | 02/10/1970 | Baronissi | Irno catchment | | | 2 |
| 332 | 02/10/1970 | Minori | | | | 2 |
| 333 | 02/10/1970 | Pellezzano | Irno catchment | | | 2 |
| 334 | 09/12/1970 | Forio d'Ischia | Loc. Montevergine | | | 1 |
| 335 | 25/12/1970 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 336 | 25/12/1970 | Baronissi | Irno catchment | | | 2 |
| 337 | 25/12/1970 | Minori | Regina Minor catchment | | | 2 |
| 338 | 25/12/1970 | Pellezzano | Irno catchment | | | 2 |
| 339 | 1970 | Arienzo | | | | 6 |
| 340 | 19/01/1971 | Torre del Greco | | | | 5 |
| 341 | 21/02/1971 | Castellammare di S. | | 5 | | 1 |
| 342 | 15/10/1971 | Cava dè Tirreni | bacini: Cavaiola | | | 2 |
| 343 | 15/10/1971 | Tramonti | Regina Major catchment | | | 2 |
| 344 | 23/11/1971 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 345 | 23/11/1971 | Minori | Regina Minor catchment | | | 2 |
| 346 | 06/03/1972 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 347 | 06/03/1972 | Tramonti | Regina Major catchment | | | 2 |
| 348 | 27/07/1972 | Piedimonte Matese | Loc. Vallata | 4 | | 6 |
| 349 | 21/10/1972 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 350 | 21/10/1972 | Tramonti | Regina Major catchment | | | 2 |
| 351 | 21/11/1972 | Baronissi | Irno catch | | | 2 |
| 352 | 21/11/1972 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 353 | 21/11/1972 | Pellezzano | Irno catchment | | | 2 |
| 354 | 02/01/1973 | Amalfi | Canneto catchment (now Grevone) | | | 2 |
| 355 | 02/01/1973 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 356 | 02/01/1973 | Maiori | Regina Major catchment | | | 2 |
| 357 | 02/01/1973 | Minori | Regina Minor catchment | | | 2 |
| 358 | 02/01/1973 | Tramonti | Regina Major catchment | | | 2 |
| 359 | 16/02/1973 | Massa Lubrense | S.Costanzo-Mitigliano Mt., Termini | | 10 | 5; 14 |
| 360 | 19/09/1973 | Torre del Greco | | | 2 | 4 |
| 361 | 1973 | Baiano | Loc. Lagno di Trulo | 5 | | 1 |

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences
Discussions

| N | Date | Municipality | locality | D | V | R |
|---|---|---|---|---|---|---|
| 362 | 21/02/1974 | Capri | Loc. Fuosso Di Marina Grande | | 2 | 5 |
| 363 | 25/09/1974 | Arienzo | | 4 | | 6 |
| 364 | 25/09/1974 | Arpaia | | 4 | | 6 |
| 365 | 25/09/1974 | Forchia | | 4 | | 6 |
| 366 | 03/10/1974 | Arienzo | | | | 6 |
| 367 | 03/10/1974 | Sant'Angelo d'Alife | | | | 6 |
| 368 | 05/10/1974 | Arienzo | | | | 6 |
| 369 | 28/06/1976 | Salerno | Irno catchment | | | 1 |
| 370 | 13/10/1976 | Torre del Greco | | | 1 | 4 |
| 371 | 29/10/1979 | Torre del Greco | Cavallo street | | 2 | 4 |
| 372 | 12/10/1980 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 373 | 12/10/1980 | Maiori | Regina Major catchment | | | 2 |
| 374 | 12/10/1980 | Minori | Regina Minor catchment | | | 2 |
| 375 | 12/10/1980 | Tramonti | Regina Major catchment | | | 2 |
| 376 | 15/10/1980 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 377 | 01/06/1981 | Forio d'Ischia | Paola Poli restaurant | 4 | | 5 |
| 378 | 19/12/1982 | Torre del Greco | Cavallo street | | 2 | 4 |
| 379 | 15/08/1983 | Barano d'Ischia | Scura and Olmitello quarries | | | 15 |
| 380 | 30-31/10/1985 | Ercolano | Palmieri street | | | 4 |
| 381 | 30-31/10/1985 | Ottaviano | Cemetery | | | 4 |
| 382 | 30-31/10/1985 | Portici | Railway | | | 4 |
| 383 | 30-31/10/1985 | San Gennaro Vesuviano | | | | 4 |
| 384 | 30-31/10/1985 | Torre del Greco | Cavallo street | | | 4 |
| 385 | 02/11/1985 | Ercolano | Palmieri street | | 1 | 4 |
| 386 | 16-17/11/1985 | Portici | | | | 4 |
| 387 | 16-17/11/1985 | San Giorgio a Cremano | Tufarelli street | | | 4 |
| 388 | 16-17/11/1985 | Torre del Greco | Cavallo, Novesca and Sant'Elena streets | | | 4 |
| 389 | 17/11/1985 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 390 | 17/11/1985 | Durazzano | Longano Mt. | | | 1 |
| 391 | 17/11/1985 | Maiori | Regina Major catchment | | | 2 |
| 392 | 17/11/1985 | Summonte | | 6, 5 | | 1 |
| 393 | 17/11/1985 | Tramonti | Regina Major catchment | | | 2 |
| 394 | 01/02/1986 | Castellammare di S. | Aragonese Castel | | | 5 |
| 395 | 01/02/1986 | Forio d'Ischia | | | | 5 |
| 396 | 13/03/1986 | Cava dè Tirreni | Loc. Molina | | | 2 |
| 397 | 13/03/1986 | Pellezzano | Irno catchment | | | 2 |
| 398 | 20/07/1986 | Roccarainola | | | | 6 |
| 399 | 24/11/1986 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 400 | 24/11/1986 | Tramonti | Regina Major catchment | | | 2 |
| 401 | 22/02/1987 | Barano d'Ischia | | | | 6 |
| 402 | 16/10/1987 | Baronissi | Irno catchment | | | 2 |
| 403 | 16/10/1987 | Pellezzano | Irno catchment | | | 2 |
| 404 | 10/11/1987 | Cava dè Tirreni | Cavaiolacatchment | | | 2 |
| 405 | 10/11/1987 | Minori | Regina Minor catchment | | | 2 |
| 406 | 10/11/1987 | Positano | | | | 2 |
| 407 | 10/11/1987 | Ravello | | | | 2 |
| 408 | 10/11/1987 | Tramonti | Regina Major catchment | | | 2 |
| 409 | 13/11/1997 | Ercolano | | | | 4 |
| 410 | 15/09/1988 | Baronissi | Irno catchment | | | 2 |
| 411 | 15/09/1988 | Pellezzano | Irno catchment | | | 2 |
| 412 | 15/09/1988 | Tramonti | Regina Major catchment | | | 2 |
| 413 | 15/07/1991 | Torre del Greco | Santa Croce square | | | 4 |
| 414 | 26/03/1992 | Torre del Greco | port | | | 4 |
| 415 | 18/04/1992 | Portici | | | | 4 |
| 416 | 24/06/1992 | Pellezzano | Loc.Cologna | | | 1 |
| 417 | 05/08/1992 | Torre del Greco | | | | 4 |
| 418 | 25/09/1992 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 419 | 25/09/1992 | Tramonti | Regina Major catchment | | | 2 |
| 420 | 3-4/10/1992 | Torre del Greco | Piazza Palomba | | | 4 |
| 421 | 04/10/1992 | Baronissi | Irno catchment | | | 2 |
| 422 | 04/10/1992 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 423 | 20/08/1993 | Serino | Loc. Ribottoli, Puzzillo | | 1 | 6 |
| 424 | 20/08/1993 | Solofra | Loc. Puzzillo | 3 | 1 | 18; 5; 1 |
| 425 | 08/12/1993 | Cava dè Tirreni | Loc. Rotolo | | | 1 |
| 426 | 20/12/1993 | Padula | | 4, 5 | | 9 |
| 427 | 26/12/1993 | Sala Consilina | | 4, 5 | | 6 |
| 428 | 22/08/1996 | Massa di Somma | Paparo street | | | 4 |
| 429 | 22/08/1996 | San Gennaro Vesuviano | | | | 4 |
| 430 | 22/08/1996 | San Giorgio a Cremano | Matteotti street | | | 4 |
| 431 | 22/08/1996 | Torre del Greco | Port, XX Settembre street | | | 4 |
| 432 | 20/09/1996 | Cava dè Tirreni | Cavaiola catchment | | | 2 |
| 433 | 20/09/1996 | Giffoni sei Canali | Picentino catchment | | | 2 |
| 434 | 20/09/1996 | Tramonti | Regina Major catchment | | | 2 |
| 435 | 26/11/1996 | Padula | | 5 | | 6 |
| 436 | 26/11/1996 | Sala Consilina | | 5 | | 6 |
| 437 | 9-10/01/1997 | Casamicciola | loc. Montagnone, Molara, Cantoni, Tresta, Cognola, Campomanno; La Pera, Ervaniello and Puzzillo quarries, , Mt. Tabor, | | | 11 |
| 438 | 09/01/1997 | Castellammare di S. | | | 4 | 5 |
| 439 | 09/01/1997 | Corbara | Chiunzi pass | | | 5 |
| 440 | 9-10/01/1997 | Lacco Ameno | Cito Mt. | | | 11 |
| 441 | 10/01/1997 | Castellammare di S. | Loc. Pozzano | 4, 5 | | 14 |
| 442 | 10/01/1997 | Cava dè Tirreni | Cinque street,SS18, Loc. Avvocatella | | | 1 |
| 443 | 10/01/1997 | Pimonte | Pendolo Mt. | | | 7; 1 |
| 444 | 10/01/1997 | San Cipriano Picentino | Loc. Campigliano | | | 1 |
| 445 | 10/01/1997 | San Giuseppe Vesuviano | | | | 4 |
| 446 | 10/01/1997 | Vietri sul Mare | Loc. Guarno andTresaro | | | 1 |
| 447 | 21/08/1997 | Sant'Anastasia | | | | 4 |
| 448 | 21/08/1997 | Somma Vesuviana | | | | 4 |
| 449 | 13/11/1997 | Boscoreale | Diaz street | | | 4 |
| 450 | 13/11/1997 | Cercola | | | | 4 |
| 451 | 13/11/1997 | San Sebastiano al Vesuvio | | | | 4 |
| 452 | 13/11/1997 | Somma Vesuviana | | | | 4 |
| 453 | 13/11/1997 | Torre del Greco | Beneduce street | | | 4 |
| 454 | 05/05/1998 | Avella | | | | 7 |
| 455 | 05/05/1998 | Montoro | | | 1 | 1 |
| 456 | 24-25/7/1999 | Casamicciola | Loc. Montagnone, Cantoni | 5 | | 11; |
| 457 | 24-25/7/1999 | Lacco Ameno | Ervaniello quarry, La Rita | 5 | | 15 |
| 458 | 15/12/1999 | Cervinara | | | 5 | 5; 6 |
| 459 | 19/11/2000 | Torre del Greco | Loc. Santa Maria La Bruna | | | 4 |
| 460 | 27/12/2000 | Ercolano | Caprile street | | | 4 |
| 461 | 22/08/2001 | Santa Maria a Vico | | | | 6 |
| 462 | 22/08/2001 | Sant'Angelo d'Alife | | 4, 6, 5 | | 16 |
| 463 | 15/09/2001 | Barano d'Ischia | Olmitello quarry | 6 | | 15 |
| 464 | 15/09/2001 | Casamicciola | Loc. La Rita | 4 | 2 | 11 |
| 465 | 22/06/2002 | Raviscanina | | 1 | | 9; 6 |
| 466 | 26/07/2002 | Caposele | | 6., 4 | | 18 |
| 467 | 28/08/2002 | Barano d'Ischia | Scura quarry | | | 15 |
| 468 | 10/09/2002 | Barano d'Ischia | Scura and Petrella quarries | | | 15 |
| 469 | 23_24/09/2002 | Barano d'Ischia | Olmitello quarry | 64 | | 15 |
| 470 | 09/09/2003 | Castellammare di S. | Castel | | | 18 |
| 471 | 20/04/2004 | Cava dè Tirreni | Loc. Badia and Sant'Arcangelo | 5, 4 | | 18 |
| 472 | 28/09/2007 | Montoro | Loc. Frazione Chiusa and Aterrana | 5, 4 | | 18 |
| 473 | 28/09/2007 | Volturara Irpina | rione Candragone | 4, 3 | | 18; 6 |
| 474 | 10/11/2009 | Casamicciola | Bagni square | 4, 5 | 1 | 12 |
| 475 | 30/07/2010 | Somma Vesuviana | | | | 4 |
| 476 | 31/07/2010 | Giffoni sei Canali | Prepezzano stream, Loc.Madonna del Carmine | 5 | | 8 |
| 477 | 09/09/2010 | Atrani | | 5, 4.,1 | 1 | 18 |
| 478 | 07/10/2011 | Buccino | Loc. Teglia | 5, 4 | | 17; 18 |
| 479 | 07/10/2011 | San Gregorio Magno | Loc. Matruro, Teglia | 5 | | 18 |

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

| N | Date | Municipality | locality | D | V | R |
|---|---|---|---|---|---|---|
| 480 | 21/10/2011 | Pollena Trocchia | | | 1 | 4 |
| 481 | 19/06/2014 | Arienzo | Pinazzola street | 5, 4.,3 | | 18 |
| 482 | 19/06/2014 | Tufino | Loc. Icap, Vignola and Ferone, Turati street | 4 | | 18 |
| 483 | 01/09/2014 | Solofra | Loc. Madonna della Neve, Santa Lucia | 5, 4. | | 18 |
| 484 | 01/09/2014 | Volturara Irpina | Rimembranza street | 5,4. | | 18 |
| 485 | 11/09/2014 | Castellammare di S. | Loc. Quisisana | 5 | | 18 |
| 486 | 25/02/2015 | Barano d'Ischia | Loc. Olmitello | | 1 | 18 |
| 487 | 19/09/1943 | Quadrelle | Loc. Mugnano-Quadrelle | | | 18 |
| 488 | 09/09/1973 | Quadrelle | Loc. Mugnano-Quadrelle | | | 18 |
| 489 | 20/08/1997 | Quadrelle | Loc. Mugnano-Quadrelle | | | 18 |
| 490 | 13/11/1997 | Quadrelle | Loc. Mugnano-Quadrelle | | | 18 |

| N | Date | Municipality | locality | D | V | R |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Table 2: Classes of damage caused by events.

| **DAMAGE** | **CLASSES** |
|---|---|
| agricultural lands | 1 |
| architectonical structures | 2 |
| industries | 3 |
| private buildings | 4 |
| roads | 5 |
| underground utilities | 6 |

475

Table3: Classes of sources used.

| **REFERENCES** | **N** |
|---|---|
| Migale and Milone, 1998 | 1 |
| Porfido et al., 2013 | 2 |
| Esposito et al., 2011 | 3 |
| Alessio et al., 2013 | 4 |
| Vallario, 2001 | 5 |
| Santangelo et al., 2012 | 6 |
| Di Crescenzo and Santo, 2005 | 7 |
| Esposito and Galli, 2011 | 8 |
| Scorpio, 2011 | 9 |
| Santangelo et al., 2011 | 10 |
| Santo et al., 2012 | 11 |
| Esposito et al., 2011 | 12 |
| ISPRA-Servizio Geologico d'Italia, 2006 | 13 |
| Calcaterra and Santo, 2004 | 14 |
| Del Prete and Mele, 2006 | 15 |
| Di Crescenzo et al., 2013 | 16 |
| Chirico et al., 2012 | 17 |
| Chronicles | 18 |

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences Discussions

480 **Figures captions**

Figure 1: Relation between area and time scale for the research accuracy, modified after D'Agostino (2013).

Figure 2. Location and geological setting of the study areas. Key: 1) Mesozoic carbonate massifs; 2) Cenozoic hilly terrigenous areas; 3) Quaternary volcanic areas; 4) Quaternary intermountain catchments and coastal plains. The broken line indicates the boundaries of Campania region.

485 Figure 3: Event typologies collected during the database building.

Figure 4: Temporal distribution of alluvial events in Campania.

Figure 5: Temporal accuracy distribution of the collected events in Campania. The histogram shows the distribution in five classes of temporal accuracy: L low, ML Middle-Low, M Middle, MH Middle-High, H High.

Figure 6: Recurrence of alluvial events in the municipalities.

490 Figure 7: Recurrence time of the events in the municipalities that have recorded more than 10events.

Figure 8: Representation of the events on the territory, according to the catchment class.

Figure 9: a) percentage of events in each catchment class; b). monthly distributions of the events in the different catchment classes. Catchment classes: 1) Carbonate catchment with pyroclastic cover, 2) Carbonate catchment without pyroclastic cover, 3) Carbonate catchment with pyroclastic cover and outlet to the sea, 4) Volcanic catchment, 5)
495 Volcanic catchment with outlet to the sea.

Figure 10: Different grain size deposits for the different catchment classes: a) Solopaca 2015, carbonate gravels and blocks (class 2); b) Atrani 2010, gravel and sands (classes 1 and 3); c) Casamicciola 2009: sands, silt and clay (classes 4 and 5).

Figure 11: Distribution of victims recorded in the territory.

500 Figure 12: Typical examples of damage caused by alluvial events: a) Casamicciola, November 10, 2009; b) Buccino-Teglia, October 7, 2011; c) Arienzo, June 6, 2014; d) Solofra, September 1, 2014.

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences
Discussions

**Figures**

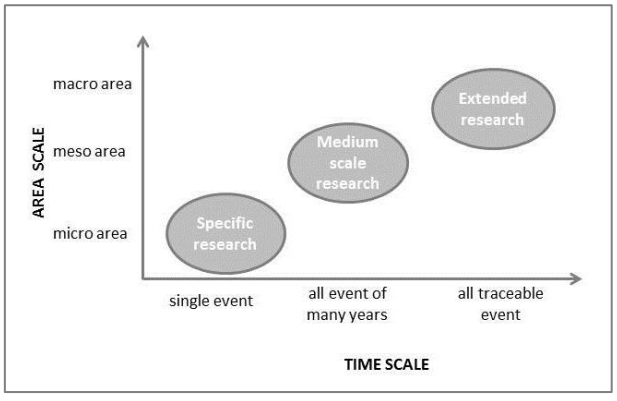



**fig01**

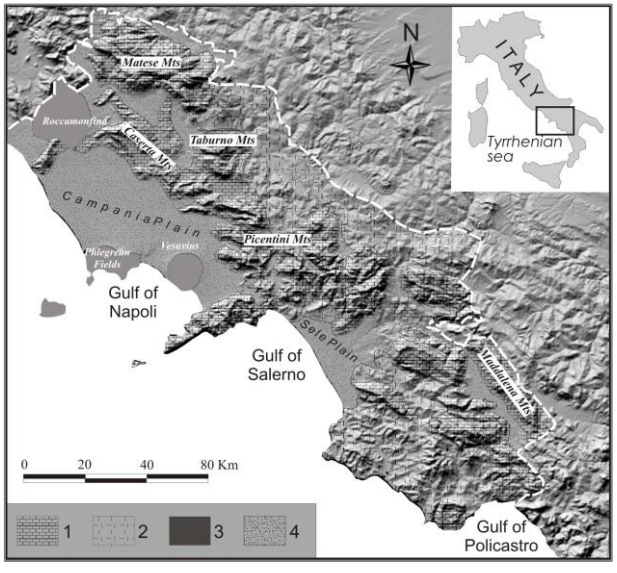



**fig02**

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016



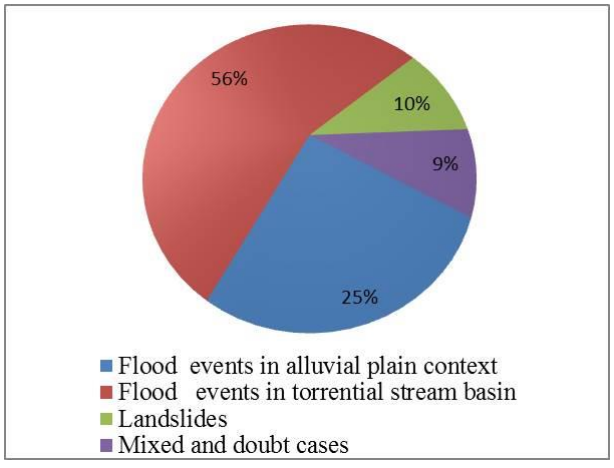




**fig03**

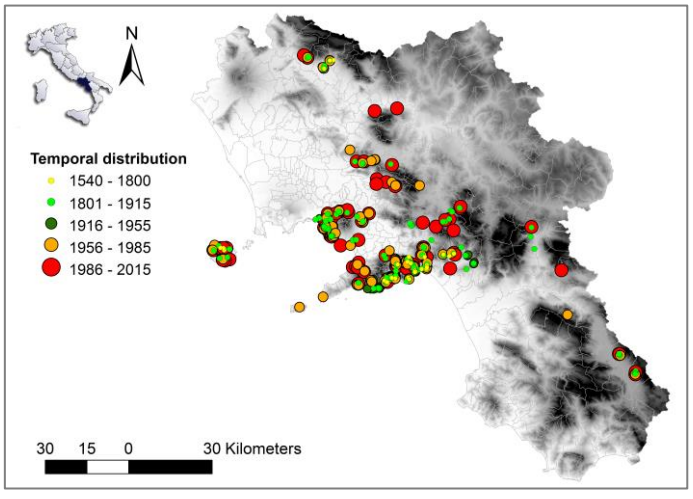



**fig04**

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences
Discussions

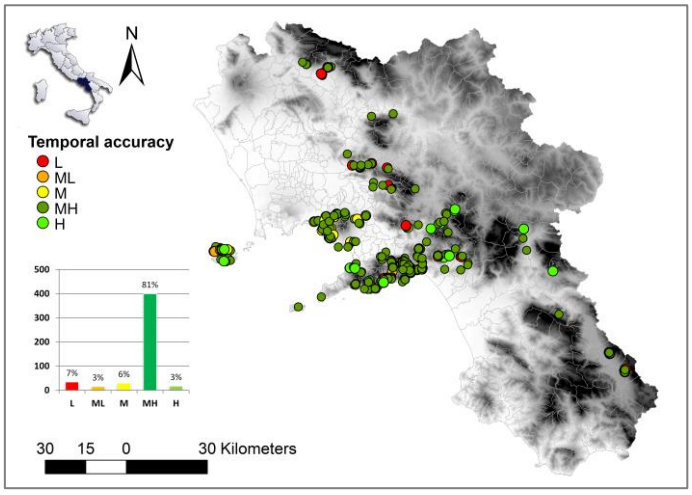



**fig05**

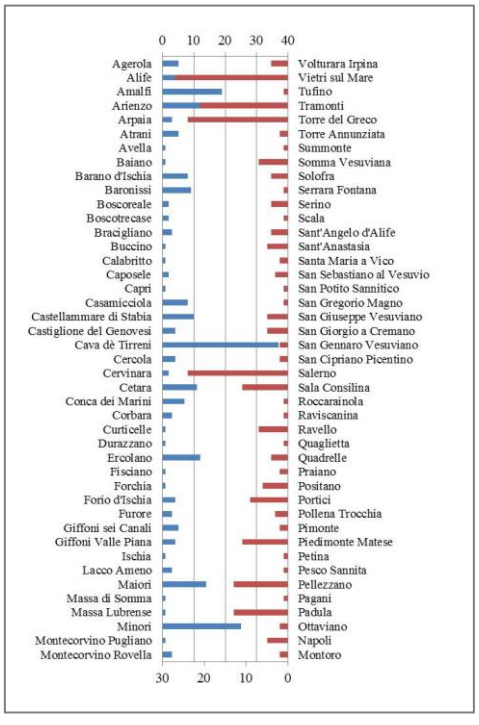



**fig06**

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences
Discussions

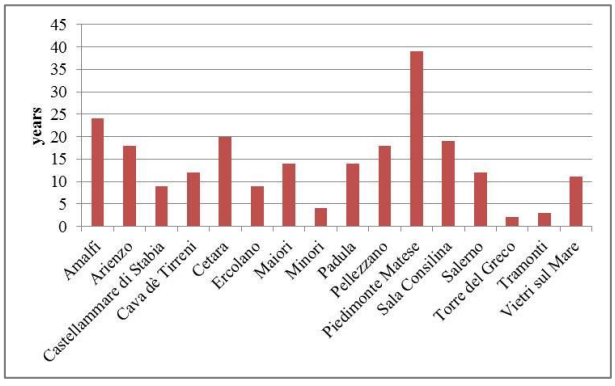



**fig07**

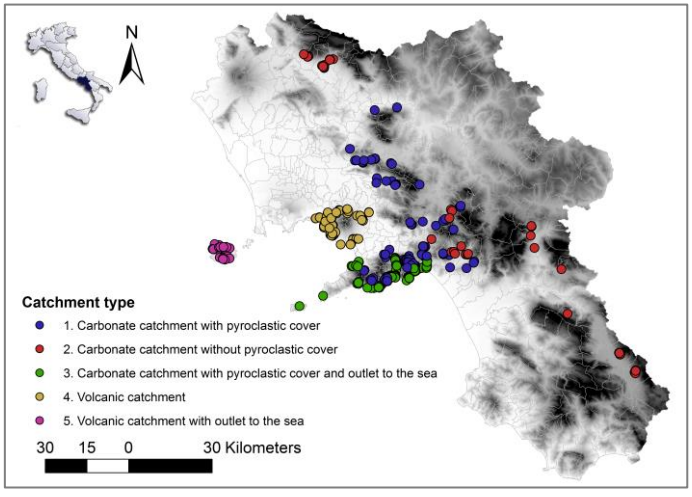



**fig08**

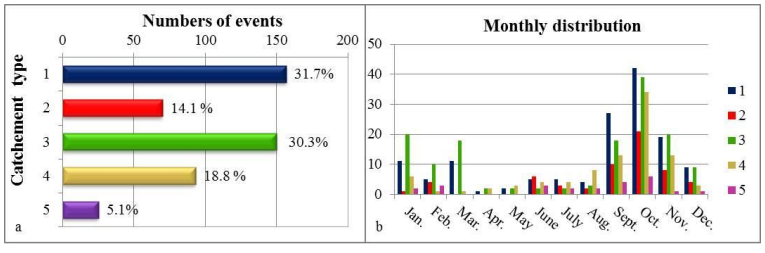



**fig09**

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016

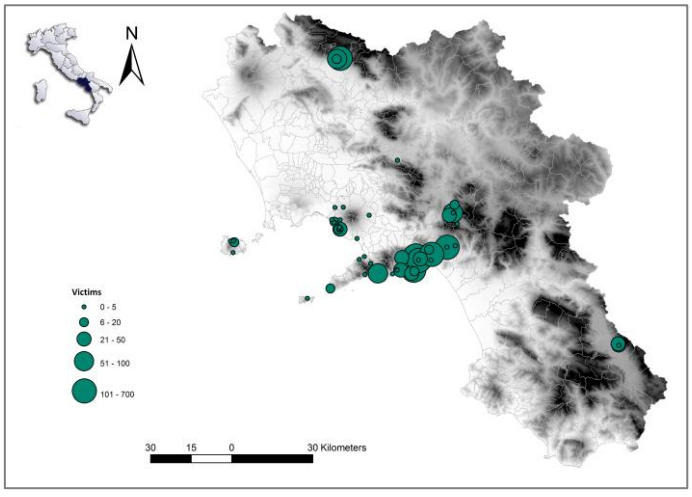




**fig10**

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2015-355, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 19 January 2016


Natural Hazards and Earth System Sciences
Discussions




525 **Fig11**


**Fig12**