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A database on flash flood events in Campania, southern Italy, with an evaluation of their spatial and temporal distribution

Carmela Vennari[1,2], Mario Parise[2], Nicoletta Santangelo[1], and Antonio Santo[3]

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

Correspondence to: Carmela Vennari (c.vennari@ba.irpi.cnr.it)

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Abstract. This study presents an historical database of flash flood events in the Campania region of southern Italy. The study focuses on small catchments characterized by intermittent flow, generally occurring during and after heavy rainstorms, which can be hydrologically defined as small Mediterranean catchments. As the outlet zones of these catchments (consisting mainly of alluvial fans or fan deltas) are highly urbanized in Campania, the population living in the delivery areas is exposed to high risk. 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 from 1540 to 2015, which is continuously updated. Since this study is the first step of a longer project to perform a hazard analysis, information about time and site of occurrence is known for all events. As for the hazard analysis envisaged, collecting information about past events could provide information on future events, in terms of damage and also spatial and temporal occurrence. After introducing the issue of flash floods in Italy we then describe the geological and geomorphological settings of the study area. The database is then presented, illustrating the methodology used in collecting information and its general structure. The collected data are then discussed and the statistical data analysis presented.

1 Introduction

Italy as a country is highly exposed to a variety of geological hazards, whose occurrence reaps heavy casualties every year. In such a context, geohydrological disasters, including all types of slope movements and floods, are undoubtedly among the most frequent, and probably those causing most impact on the built environment. Assessment of the risk related to landslides and floods in Italy, covering the time span from 1850 to 2008, shows that many regions are seriously affected by such geohydrological disasters, with the largest landslide risk in Trentino Alto Adige and Campania and the highest flood risk in Piedmont and Sicily (Salvati et al., 2010). However, discriminating among these different processes, especially in regard to past events, is a difficult task due to the lack of specific terminology and/or to very generic descriptions of the phenomena and their effects (Guzzetti and Tonelli, 2004). This may, as a direct consequence, lead to great uncertainty in the reconstruction of the flood history of a region.

A flash flood is a flood caused by heavy or excessive rainfall in a short period of time. Such floods are localized hydrological phenomena, occurring in small catchments of a few to a few hundred square kilometers, with response times typically being a few hours or less (Borga et al., 2007). Flash floods are typical of small Mediterranean catchments (SMCs) that have three main features: limited water resources, dry summers, and high-intensity rainfall events (Merheb et al., 2016). The Mediterranean climate is associated with intense rainstorms; convective thunderstorms are frequently less than 10–14 km in diameter and result in highly concentrated local rainfall events varying considerably both spatially and temporally (Perrin et al., 2009). In such contexts, after heavy rains, the main stream may trans-

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port down-valley mixtures of water and sediment in varying proportions, which play an important role in the behavior and hazard of the resulting flows. Three types of flows can be differentiated on the basis of the different amount of sediment and of the flow behavior: water flow, hyperconcentrated flow, and debris flow (Pierson and Costa, 1987; Costa, 1988; Komar, 1988; Iverson and Vallance, 2001; Pierson, 2005). During a flash flood the sediments captured by the stream and transported down valley generally derive from the bed and banks of the torrent and may eventually contribute to build alluvial fans or fan deltas. Another important aspect is that in small catchments a substantial difference of magnitude exists between low water periods, with a seasonal lack of surface water within ephemeral streams, and flood events with the power to make substantial changes to riverbed topography (Kirkham et al., 2000; Coe et al., 2003).

Flash floods are a frequent natural hazard in many parts of Europe (Montz and Gruntfest, 2002; Gaume et al., 2009, 2014; Marchi et al., 2010), including Italy. Due to the particular orography and climate of the country, they occur in many different settings, from mountain valleys (Crosta and Frattini, 2004; Tropeano and Turconi, 2004; Gaume et al., 2009) to coastal and inland plains (Esposito et al., 2011; Santangelo et al., 2011; Porfido et al., 2013), in volcanic areas (Alessio et al., 2013), and in semiarid and/or karst environments (Parise, 2003; Cossu et al., 2007; Delle Rose and Parise, 2010). Flash floods generally occur in ungauged watersheds where the lack of information on precipitation and discharge is significant due to the lack of spatially well-distributed rain or flow data. Hence they often remain poorly documented phenomena (Gaume et al., 2009; Ruiz-Villanueva et al., 2010) and, despite their widespread occurrence, they are often described together with landslides and floods in alluvial plains, making it no easy task to distinguish the various processes occurring from documents and reports. This holds especially when examining events occurring at various times in the past in which recorded damage is generally attributed to landslides.

Whilst in the Italian Alps, due to their high frequency, flash floods in small basins have been the subject of detailed studies for many decades (Crosta and Frattini, 2004; Sosio et al., 2007; Carrara et al., 2008; Simoni et al., 2011; Arattano et al., 2012, 2015; Marchi and Tecca, 2013; Berti and Simoni, 2014; Blahut et al., 2014; Tiranti et al., 2014), in the Apennines they have typically been analyzed with less attention (Sorriso Valvo et al., 1998; Zanchetta et al., 2004a; Santo et al., 2002, 2012, 2015; Garfì et al., 2007; Cascini et al., 2008a; Santangelo et al., 2011, 2012; Alessio et al, 2013; Antronico et al., 2015a, b; Scorpio et al., 2016).

The study area of this paper is situated in Campania, in the Southern Apennines of Italy, a region which in recent decades has been affected by severe flash floods with serious damage and fatalities (Calcaterra et al., 2000, 2003; Santo et al., 2002, 2012, 2015; Del Prete and Mele, 2006; Santangelo et al., 2006, 2011, 2012; Chirico et al., 2012; Alessio et al., 2013). The focus of the study consisted of small catchments with intermittent flow, generally occurring during and after heavy rainstorms, which can be hydrologically defined as SMCs. All these basins are smaller than 10 km^2, are characterized by low concentration times (from 30 min to several hours; Santo et al., 2002; Santangelo et al., 2012; Scorpio et al., 2016), and are highly prone to flash flood events. Aiming at collecting all the available information on floods occurring in such catchments, we consulted and scrutinized a variety of sources and scientific papers, with a view to building a reliable catalogue of these events.

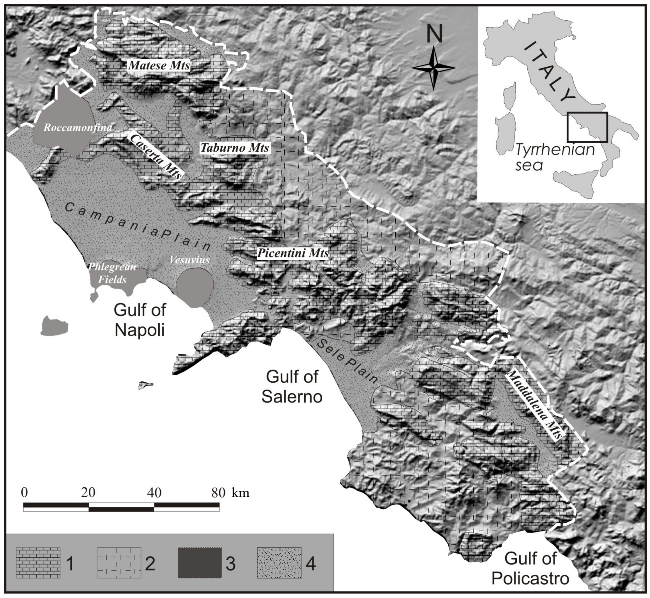

Figure 1. Location and geological setting of the study area. Key: (1) Mesozoic carbonate massifs; (2) Cenozoic hilly terrigenous areas; (3) Quaternary volcanic areas; (4) Quaternary intermountain catchments and coastal plains. The broken line indicates the boundaries of Campania.

As the first step in the process of hazard evaluation, we compiled the database with the following main aims: (i) to identify over the whole region the areas most susceptible to flash floods and (ii) to discriminate whenever possible, in the available literature, flash floods in small catchments from floods in alluvial plains and from gravity processes, such as rapid earth or debris flow (Del Prete et al., 1998; Crosta and Dal Negro, 2003; Guadagno et al., 2003, 2005; Revellino et al., 2004; Zanchetta et al., 2004b; Di Crescenzo and Santo, 2005; Cascini et al., 2008b). Our database is not aimed at a hydrological characterization of the study areas due to lack of hydrological data, especially as concerns the historical events. Nevertheless, given the lack of similar catalogues for the Southern Apennines of Italy, it might be useful in different ways for land use and civil protection planning. In detail, it may help in the selection of sites where monitoring procedures and/or prevention and mitigation works need to be adopted. In this perspective the main users of such data will be local administrators and the civil protection agency.

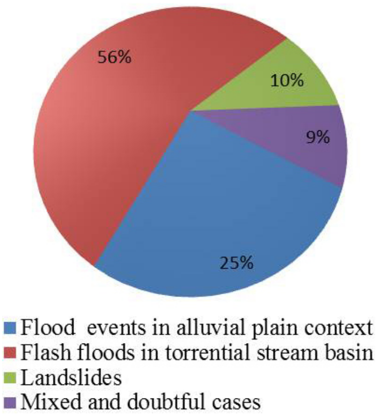

Figure 2. Event types collected while constructing the database.

2 Study area

The region of Campania in southern Italy extends from the Tyrrhenian Sea to the Southern Apennine Chain, covering about 13 500 km^2 (Fig. 1). 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 m a.s.l. (above sea level). On the western side the chain is bounded by a deep (up to 2 km) coastal graben originated by Plio-Quaternary extensional tectonics, which was filled by marine/transitional sedimentary successions and is now occupied by wide flat coastal plains (Ascione et al., 2008). During the late Quaternary strong volcanic activity was registered in the coastal plain with the growth of the Somma–Vesuvius and the Campi Flegrei 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 transition to hilly landscapes of lower elevation, made up mainly of Miocene and Pliocene flysch successions. In this general orographic setting, SMCs are a widespread geomorphic unit along the flanks of the main carbonate ridges, as well as the slopes of the volcanoes, where they have higher longitudinal gradients. In the remaining hilly part of the region, stream catchments present lower mean longitudinal profiles, and wide alluvial plains linked to perennial river systems prevail.

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 northwesterly 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 landslides.

The areas most affected by flash floods are the Lattari Mountains (Esposito et al., 2011), the Somma–Vesuvius area

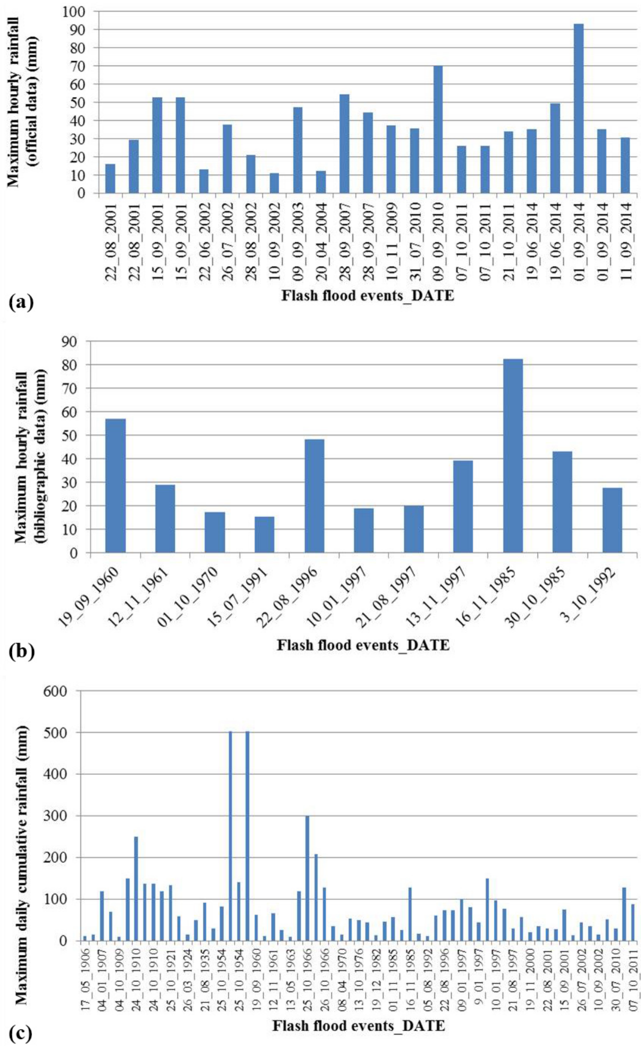

Figure 3. Rainfall data associated to flash floods: **(a)** maximum hourly rainfall (official data from CFDC); **(b)** maximum hourly rainfall (data from the literature); **(c)** maximum daily cumulative rainfall (data from SIMN).

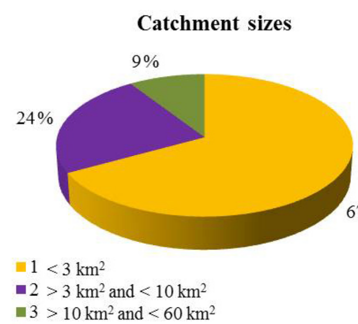

Figure 4. Distribution of flash flood events in the different catchment size classes: (1) $< 3\,km^2$; (2) > 3 and $< 10\,km^2$; (3) > 10 and $< 60\,km^2$.

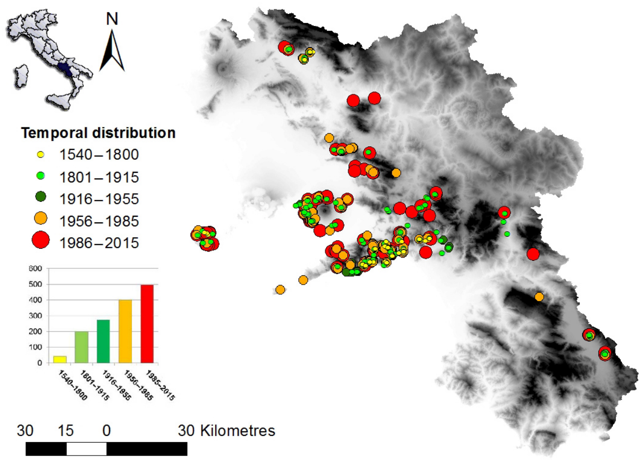

Figure 5. Temporal distribution of alluvial events in Campania. On the left a histogram illustrates their distribution over the time.

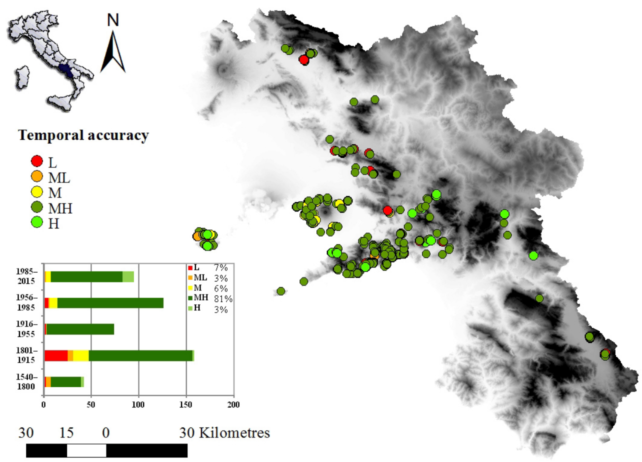

Figure 6. Temporal accuracy distribution of the events collected in Campania. The histogram shows the distribution in five classes of temporal accuracy: low (L), medium-low (ML), medium (M), medium-high (MH), and high (H). The histogram on the left shows the distribution of the accuracy classes in five temporal classes.

and the Island of Ischia (Santo et al., 2012; Alessio et al., 2013), the Picentini Mountains (Chirico et al., 2012; Santangelo et al., 2012; Santo et al., 2015), and the Matese, Caserta, and Maddalena mountain ridges (Santangelo et al., 2011, 2012; Scorpio et al., 2016). Given that the outlet zones of these torrential catchments are often highly urbanized, serious risk to population and settlements exists.

3 Method

3.1 Data collection

The main problem in searching for information about flash floods in Italy is that they are usually grouped with landslides and floods. In most cases the databases refer to landslides or floods or put different types of events together (landslides, flash floods in small catchments, floods in alluvial plains). As before stated, in Campania a regional-scale database on flash floods is not available.

For this reason, first of all we consulted the most complete archive of landslides and floods produced in Italy, the AVI project (an Italian acronym for *Aree Vulnerate in Italia*, areas affected by landslides or floods in Italy). It was commissioned by the Minister for Civil Protection to the National Group for the Prevention of Hydrogeologic Hazards of the Italian National Research Council (CNR) with a view to compile an inventory of information on areas historically affected by landslides and floods in the country (Guzzetti et al., 1994). We scrutinized the AVI archive to extract information about flash floods in small basins in the region. Since the archive is divided into landslides or floods, careful research was essential. Following this scrutiny, we also consulted and critically analyzed the existing literature related to flood events in Campania.

In order to discriminate flash floods from other hydrogeological events, we first adopted a "geographical" approach. Based on the evidence that all the recently occurring and well-documented flash flood events (i.e., with accurate event description and availability of rainfall data; Alessio et al., 2013; Chirico et al., 2012; Santangelo et al., 2011, 2012; Santo et al., 2002, 2012, 2015; Scorpio et al., 2016) affected SMCs, we catalogued all the events recorded in the outlet zone of this kind of hydrographic basin as "flash floods".

According to the above approach we distinguished the following four event types:

– floods in alluvial plains

– flash floods in SMCs

– landslides

– mixed and/or doubtful cases.

All the hydrogeological events that may be easily discriminated, based on general description and geographic location, were included in the database. For mixed and doubtful cases a second analysis was carried out, searching and consulting additional and new sources of information, in the attempt to classify them into one of the four types or to exclude them from the database. Once all the events were grouped into different types, we ruled out classes 1 and 3 for further study and focused on class 2, which represented 56 % of the collected data (Fig. 2). We thus obtained a database of about 500 flash floods occurring in small catchments in Campania (Table 1). Unfortunately, information about damage and rainfall was not available in all cases. That said, the available chronicles and historical descriptions testify to sudden events, lasting just a few hours. Whenever possible, we tried to link the

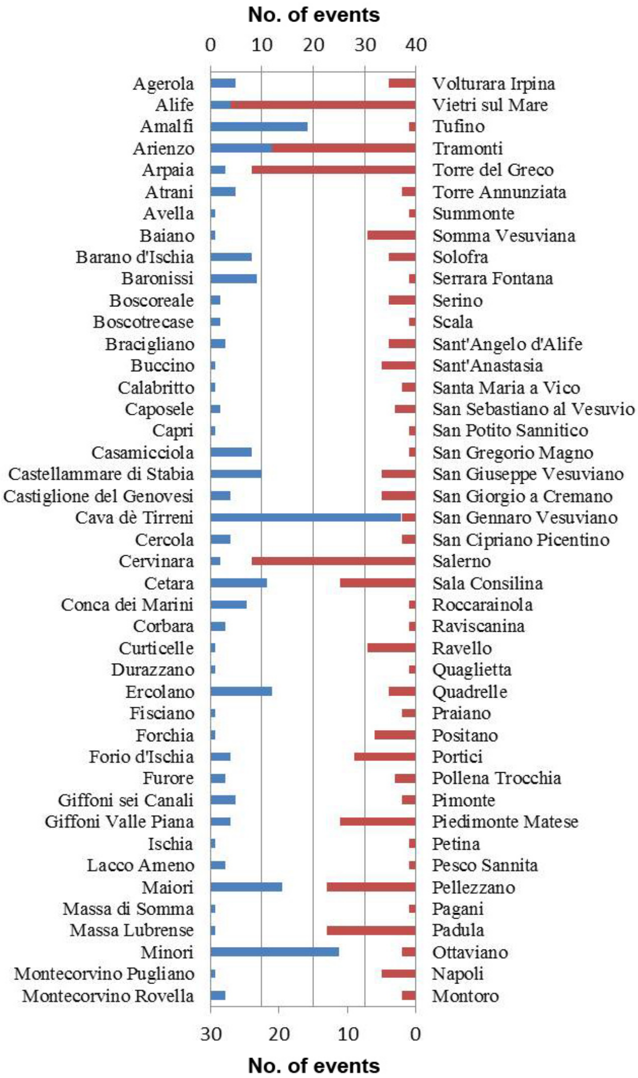

Figure 7. Recurrence of alluvial events in the municipalities.

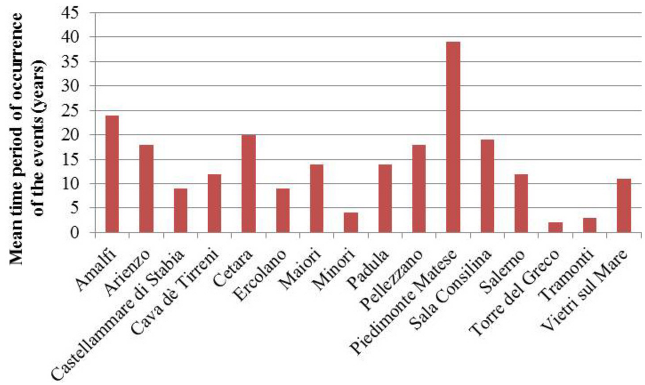

Figure 8. Mean time period of occurrence of the events in the municipalities that have recorded more than 10 events.

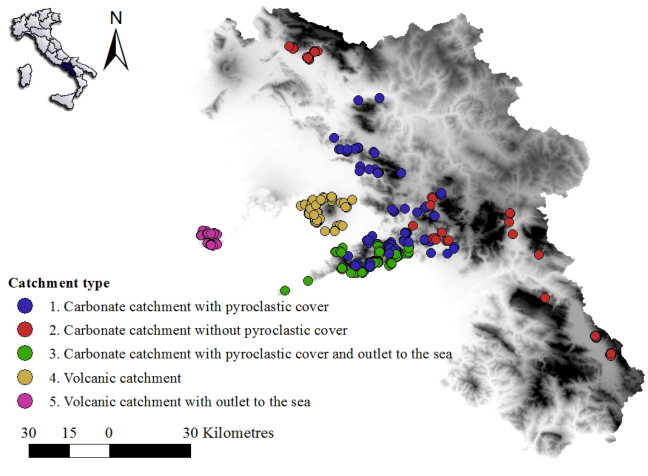

Figure 9. Geographical representation of the events, according to the catchment class.

documented events to hourly rainfall data obtained from the Campania Weather Forecasting Center (CFDC) (Fig. 3a) and rainfall data from the literature (Fig. 3b), obtaining a total record of 34 events. In all cases hourly rainfall values were very close to or greater than 30 mm h^{-1}, and the daily rainfall obtained from the Italian Hydrologic and Oceanographic Service (SIMN) (Fig. 3c) was generally close to or greater than 100 mm. These values are generally associated with high-intensity storms (Santo et al., 2012, 2015) and in the context of small catchments like those under study, characterized by very low concentration times (see Sect. 3.2), may be responsible for flash flood occurrence.

The repetitiveness of flash floods in the same area was also investigated. As shown in Fig. 7, among the 86 municipalities hit, 16 recorded more than 10 events. Nine out of these 16 municipalities were located at the outlet zone of coastal carbonate catchments (Sorrento Peninsula–Lattari ridge), whilst the others are in the piedmont areas of inland carbonate massifs (Picentini and Matese mountains) or in the volcanic area of Mt. Somma–Vesuvius. In all these cases the mean time period of occurrence of the events is very low, ranging from 39 to 3 years, with a mean value of 15 (Fig. 8). If only the most damaging events are taken into account, the mean time period of occurrence increases to 50 years.

3.2 Geomorphological features of the catchments involved

The SMCs in Campania most severely affected by flash floods in recent decades are mainly located in carbonate and volcanic settings (Palma et al., 2009; Santangelo et al., 2012; Santo et al., 2012, 2015; Alessio et al., 2013). Regarding their geographical 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, represented by a fan delta (Esposito et al., 2011; Santo et al., 2012). They also show similar morphometric conditions (Santangelo et

Table 1. N = ID event, date, municipality, location. CE means catchment classes: (1) $< 3\,km^2$; (2) > 3 and $< 10\,km^2$; (3) > 10 and $< 60\,km^2$. D means classes of damaged elements: (1) agricultural land; (2) architectural structures; (3) businesses; (4) private buildings; (5) roads; (6) underground utilities.

N	Date	Municipality	Location	CE	D	V	R	N	Date	Municipality	Location	CE	D	V	R
1	08/10/1540	Amalfi		1			1	56	12/11/1817	Vietri sul Mare	Bonea catchment	2			2
2	1550	Casamicciola	La Pera quarry, (Ervaniello)	1	4		11	57	1818	Cava de' Tirreni	Amalfi coast	1			2
3	30/09/1581	Cava de' Tirreni		1			3	58	1819	Cava de' Tirreni	Amalfi coast	1			2
4	30/09/1581	Salerno		1			3	59	1820	Cava de' Tirreni	Amalfi coast	1			2
5	30/09/1581	Vietri sul Mare		2			3	60	1821	Salerno	Irno catchment	3			2
6	01/10/1581	Castiglione del Genovesi De Petrinis land		1	4, 3	700–1000*	8	61	06/06/1822	Sala Consilina	Monteoliveto square,	2	4, 3		10
7	01/10/1581	Giffoni sei Casali		2	4, 3	700–1000*	3; 8	62	27/10/1822	Corbara					1
8	01/10/1581	Piedimonte Matese		3	4, 5	400	6	63	08/11/1822	Salerno	Road to Vietri				1
9	01/10/1581	San Cipriano Picentino		1	4, 3	700–1000*	8	64	24/01/1823	Amalfi		1			3
10	31/08/1588	Atrani		2			3	65	24/01/1823	Bracigliano		1			3
11	1626	Salerno	Fusandola	1	2		1	66	24/01/1823	Cava de' Tirreni		1			3
12	06/1643	Casamicciola	Bagni square	1	4		11	67	24/01/1823	Vietri sul Mare		2			3
13	06/1643	Casamicciola	Piazza La Rita	1	4		11	68	08/10/1823	Corbara	Main square	1			1
14	20/12/1683	Maiori	Regina Major catchment	3			1	69	03/10/1824	Minori	Loc. Torre	2			1
15	15/10/1696	Minori	Regina Minor catchment	2			1; 2	70	1825	Cava de' Tirreni	Amalfi coast	1			2
16	26/09/1728	Piedimonte Matese	Vallata	3	4, 5		6	71	18/06/1827	Sala Consilina		2	4, 5		6
17	11/11/1773	Cava de' Tirreni	Passiano	1	4	400*	1	72	11/07/1829	Arienzo		1	5		6
18	25/01/1736	Vietri sul Mare	Bonea catchment	2			2	73	19/10/1830	Arienzo		1	5, 1		6
19	26/09/1736	Vietri sul Mare	Bonea catchment	2			2	74	16/07/1833	Arienzo		1			6
20	11/1738	Vietri sul Mare	Bonea catchment	2			2	75	13/09/1834	Cetara	Cetus catchment	1			2
21	03/11/1750	Salerno	Irno catchment	3			3	76	18/07/1835	Cava de' Tirreni	Cavaiola catchment	1			2
22	03/11/1750	Vietri sul Mare		2			3	77	18/07/1835	Conca dei Marini	Irno and Bonea catchment				2
23	10/10/1751	Amalfi	Canneto catchment (now Grevone)	1			2	78	18/07/1835	Salerno	Irno catchment	3			2
24	01/09/1753	Amalfi	Loc. Chiorito	1			1	79	27/09/1837	Salerno	Irno catchment	3			2
25	23/01/1757	Amalfi	Canneto catchment (now Grevone)	1			2	80	27/09/1837	Vietri sul Mare	Bonea catchment	2			2
26	23/01/1757	Vietri sul Mare	Bonea catchment	2			2	81	27/10/1839	Padula		2	5		6
27	09/10/1757	Amalfi	Canneto catchment (now Grevone)	1			2	82	01/06/1841	Arienzo		1			6
28	25/05/1762	Cetara	Cetus catchment	1			3	83	20/09/1841	Piedimonte Matese	Loc. Vallata	3	4, 5	7*	6; 9
29	19/01/1764	Salerno					2	84	20/09/1841	San Potito S.		1	4, 5	7*	6; 9
30	11/1770	Salerno	Irno catchment	3			2	85	07/11/1842	Serino	Loc. S.Rocco, S.Lucia	1		16	6
31	11/11/1773	Cava de' Tirreni		1			3	86	26/10/1843	Cetara	Cetus catchment	1			2
32	11/11/1773	Cetara		1			3	87	26/10/1843	Maiori	Regina Major catchment	3			2
33	11/11/1773	Pellezzano		1			3	88	26/10/1843	Salerno	Irno catchment	3			2
34	11/11/1773	Salerno	Loc. Coperchia	1	5	7	3; 1	89	26/10/1843	Vietri sul Mare	Loc. Molina	2			1
35	11/11/1773	Tramonti		1			3	90	18/03/1845	Maiori	Regina Major catchment	3			2
36	11/11/1773	Vietri sul Mare		2			3	91	18/03/1845	Vietri sul Mare	Bonea catchment	2			2
37	20/11/1778	Alife		2	4		6	92	01/10/1846	Amalfi	Canneto catchment(now Grevone)	1			2
38	20/11/1778	Piedimonte Matese	Loc.Vallata	3	4		9	93	01/10/1846	Baronissi	Irno catchment	1			2
39	02/1780	Atrani	Dragone catchment	2			2	94	01/10/1846	Cetara	Cetus catchment	1			2
40	25/12/1796	Cava de' Tirreni	Cavaiola catchment	1			2	95	01/10/1846	Fisciano and Irno catchments	Canneto, Regina Major, Bonea	2			2
41	25/12/1796	Salerno	Irno catchment	3			2	96	01/10/1846	Maiori	Regina Major catchment	3			2
42	25/12/1796	Vietri sul Mare	Bonea catchment.	2			2	97	01/10/1846	Pellezzano	Irno catchment	1			2
43	10/1803	Piedimonte Matese	Loc.Vallata	3			6	98	31/12/1847	Amalfi		1			2
44	21/01/1805	Solofra	Loc. Caposolofra	2	5, 4, 2, 3		15	99	13/09/1851	Alife		2			6
45	22/01/1805	Serino	Ribottoli	1		67	6	100	13/09/1851	Piedimonte Matese		3			6
46	09/06/1806	Sala Consilina	De Petrinisi street	2	4, 5	30	10	101	13/09/1851	Sant'Angelo d'Alife		2			6
47	10/1810	Piedimonte Matese	Loc.Vallata	3			9	102	21/11/1851	Serino	Loc. S.Lucia, Troiani	1	4		6
48	1811	Arienzo		1	5		6	103	1851	Padula		2	5		6
49	1811	Santa Maria a Vico		1	5		6	104	1851	Volturara Irpina		2	5		6
50	21/12/1812	Positano	Parlati Mt.	1	5	3	1	105	28/10/1852	Solofra		2	5, 6, 4		15
51	30–31/07/1814	Bracigliano		1			1	106	05/01/1853	Vietri sul Mare	Bonea catchment.	2			2
52	04–19/12/1814	Sala Consilina	Vairo, Marroncelli and Poerio street	1	5		10	107	20/03/1853	Volturara Irpina		2			6; 9
53	1814	Piedimonte Matese		3			6	108	13/09/1857	Piedimonte Matese	Loc. Vallata	3	4, 5	90*	6; 9
54	12/11/1817	Cava de' Tirreni	Cavaiola catchment	1			2	109	13/09/1857	Sant'Angelo d'Alife	Loc. S. Bartolomeo and S. Maria	2	4, 5	90*	6; 9
55	12/11/1817	Salerno	Irno catchment	3			2	110	1857	Padula		2	5		6

V = number of victims (* = total number of victims per event on the same date); R = references (see Table 2).

Table 1. Continued.

111	13/06/1858	Sala Consilina	Indipendenza, Vairo, A. Da Brescia, U. Bossi and C. Battista streets	2	4, 1, 5	18	10; 6
112	1859	Padula		2	4, 5		6
113	08/1866	Maiori	Loc. Cetraro, road to Tramonti, Regina Major catchment	1			1, 2
114	11/11/1866	Vietri sul Mare	Bonea catchment	2			2
115	16/03/1867	Vietri sul Mare	Bonea catchment	2			2
116	10/10/1867	Padula		2	4, 5		6
117	01/04/1875	Conca dei Marini		1			2
118	1876	Padula		2	4, 5		6
119	01/02/1878	Conca dei Marini		1			2
120	01/02/1878	Salerno	Irno catchment	3			2
121	17/11/1880	Arienzo		1			9
122	1881	Padula		2	4, 5		6
123	1883	Padula		2	4, 5		6
124	05/02/1885	Amalfi	Canneto catchment (now Grevone)	1			2
125	1891	Tramonti	Regina Major catchment	1			2
126	1896	Baronissi	Irno catchment	1			2
127	1896	Bracigliano	Picentino, Fuorni and Irno catchment	1			2
128	1896	Castiglione del Genovesi	Picentino catchment	1			2
129	1896	Conca dei Marini	Picentino, Fuorni and Irno catchment	1			2
130	1896	Salerno	Irno catchment	3			2
131	07/10/1899	Calabritto		1	4, 3, 5	100*	12
132	07/10/1899	Caposele		1	4, 3, 5	100*	12
133	07/10/1899	Castiglione del Genovesi		1	4, 3, 5	100*	12
134	07/10/1899	Cava de’ Tirreni		1	4, 3, 5	100*	12
135	07/10/1899	Curticelle		1	4, 3, 5	100*	12
136	07/10/1899	Giffoni sei Casali		2	4, 3, 5	100*	12
137	07/10/1899	Giffoni Valle Piana	Secco stream and Colauro street	3	4	3	12
138	07/10/1899	Montecorvino Pugliano		1	4, 3, 5	100*	12
139	07/10/1899	Montecorvino Rovella		1	4, 3, 5	100*	12
140	07/10/1899	Quaglietta			4, 3, 5	100*	12
141	07/10/1899	Salerno	Irno catchment and Rafastia torrent	3	4, 3, 5	100*	12, 5; 1
142	07/10/1899	Vietri sul Mare	Molina di Vietri	2	4, 3, 5	5	12, 2
143	1900	Padula		2	4, 5		6
144	02/1903	Vietri sul Mare	Bonea catchment	2			2
145	1903	Cervinara		2	5		1
146	07/10/1904	Ravello	Dragone catchment	1			2
148	17–18/05/1906	Ercolano		1		2	4
149	01/06/1906	Sant’Anastasia		1			4
150	01/06/1906	Cercola		1			4
151	01/06/1906	Pollena Trocchia		1			4
152	1906	Torre del Greco	Cavallerizzi, XX Settembre and Purgatorio streets, Del Popolo square	1		26	4
153	04/01/1907	Ercolano		1			4
154	24–25/10/1908	Ercolano		1		2	4
155	24–25/10/1908	Portici		1			4
156	24–25/10/1908	San Giorgio a Cremano		1			4
157	24–25/10/1908	Torre del Greco		1			4
158	04/10/1909	Boscotrecase		1			4
160	23/10/1910	Cetara	Cetus catchment, Loc. Utrio and Cappetta, Federico street	1	5, 4	200*	15; 3; 1; 2; 13
161	24/10/1910	Amalfi		1	5	2	3; 1
162	24/10/1910	Barano d’Ischia	Loc. Casabona	1	4, 5		11; 2
163	24–25/10/1910	Boscotrecase		1			4; 2
164	24/10/1910	Casamicciola		1	4, 5	6	11; 2
165	24–25/10/1910	Cercola		1			4; 2
166	24–25/10/1910	Ercolano	Loc. Resina	1			4; 2
167	24/10/1910	Forio d’Ischia	Loc. Monterone	1	4, 5		12; 2
168	24/10/1910	Furore		1	5		3
169	24/10/1910	Ischia		1	5		3; 2
170	24/10/1910	Lacco Ameno		1	4, 5		11; 2
171	24/10/1910	Maiori	Loc. Erchie, S.Nicola and Sovarano	3	5, 4	24	3; 15; 1
172	24/10/1910	Minori		2	5	4	3; 1
173	24–25/10/1910	Pollena Trocchia		1			4
174	24/10/1910	Portici	Giordano street	1			4; 2
175	24/10/1910	Ravello		1	6, 5		3; 1
176	24/10/1910	Salerno	Fusandola stream	1	5		3; 2
177	24–25/10/1910	San Sebastiano al Vesuvio		1			4; 2
178	24–25/10/1910	Sant’Anastasia		1			4
179	24/10/1910	Scala	Loc. Acquabona	1	2		3; 1
180	24/10/1910	Serrara Fontana		1	5		11
181	24–25/10/1910	Somma Vesuviana		1			4
182	24/10/1910	Vietri sul Mare	loc. Molina	2	5	1	3; 1; 2
183	02/01/1911	Cetara	Cetus catchment	1			2
184	02/01/1911	Vietri sul Mare	Bonea catchment	2			2
185	21/09/1911	Boscoreale		2			4
186	21/09/1911	Ercolano	Loc. Resina (Pugliano, Mare, Cortile, Trentola streets)	1		6	4
187	21/09/1911	Ottaviano		1			4
188	21/09/1911	Portici		1			4
189	21/09/1911	San Giuseppe Vesuviano		1			5
190	21/09/1911	Torre del Greco	XX Settembre, Nazionale, Fiorillo and Umberto streets	1			4
191	03/01/1915	Minori	Regina Minor catchment	2			2
192	1915	Alife		2			6
193	06/11/1916	Vietri sul Mare	Bonea catchment	2			2
194	21/09/1921	San Giuseppe Vesuviano		1			4
195	25/10/1921	Ercolano		1			4
196	25/10/1921	Portici		1			4
197	25/10/1921	San Giorgio a Cremano		1			4
198	25/10/1921	Torre del Greco		1			4
199	13/11/1921	Furore		1			2
200	26/03/1924	Agerola		1		100*	3; 8
201	26/03/1924	Amalfi	Loc. Vettica Minore, Baglio	1	2, 5, 4	60	3; 8
202	26/03/1924	Atrani		2		100*	3; 8
203	26/03/1924	Cetara		1		100*	1
204	26/03/1924	Minori		2		100*	3; 8
205	26/03/1924	Positano		1		100*	3; 8
206	26/03/1924	Praiano	Loc. Marina di Praiano	1	4	18	3; 8; 1; 2
207	26/03/1924	Vietri sul Mare	Bonea and Regina Major catchments	2	4	100*	5
208	26/03/1924	Vietri sul Mare		2			3; 8
209	01/10/1927	Sala Consilina		2	4, 5		6
210	01/11/1927	Sala Consilina	Umberto I square	2	4, 5		10

V = number of victims (* = total number of victims per event on the same date); R = references (see Table 2).

Table 1. Continued.

211	21/09/1929	Giffoni Valle Piana	Picentino catchment	3			2
212	21/09/1929	Montecorvino Rovella		1			2
213	21/09/1929	Vietri sul Mare	Bonea catchment	2			2
214	31/08/1931	Castellammare di S.		1		1	1
215	01/03/1935	Cava de' Tirreni	Cavaiola catchment	1			2
216	01/03/1935	Conca dei Marini		1			2
217	01/03/1935	Minori	Regina Minor catchment	2			2
218	01/03/1935	Ravello	Dragone catchment	1			2
219	01/03/1935	Tramonti	Regina Major catchment	1			2
220	21/08/1935	Castellammare di S.		1			1
221	1935	Giffoni Valle Piana		3			1
222	14/09/1939	Amalfi	Canneto catchment (now Grevone)	1			2
223	14/09/1939	Conca dei Marini	Canneto	1			2
224	14/09/1939	Maiori	Regina Major catchment	3			2
225	01/06/1941	Arienzo		1			9
226	18/06/1944	Minori	Regina Minor catchment	2			2
227	02/10/1945	Minori	Regina Minor catchment	2			2
228	02/03/1947	Minori	Regina Minor catchment	2			2
229	30/06/1947	Sala Consilina	Umberto I square	2	4, 5	1	9; 10
230	25/10/1947	Minori	Regina Minor catchment	2			2
231	23/05/1948	Minori	Regina Minor catchment	2			2
232	26/07/1948	Somma Vesuviana		1	4		4
233	05/09/1948	Minori	Regina Minor catchment	2			2
234	02/10/1948	Alife	Loc. S.Michele	2	5		6
235	28/10/1948	Minori	Regina Minor catchment	2			2
236	01/10/1949	Vietri sul Mare	Bonea catchment	2			2
237	14/08/1950	Somma Vesuviana		1			4
238	02/09/1950	Somma Vesuviana		1			4
239	25/12/1950	Castellammare di S.	Loc. Pozzano	1			1
240	21/01/1951	Minori	Regina Minor catchment	2			2
241	09/03/1951	Castellammare di S.	Loc. Pozzano	1			1
242	09/11/1951	Giffoni Valle Piana	Picentino catchment	3			2
243	09/11/1951	Montecorvino Rovella		1			2
244	11/09/1953	Agerola		1			2
245	11/09/1953	Ravello	Dragone catchment	1			2
246	1953	Ravello	Eastern side of Colonna Mt.	1			1
247	25/10/1954	Amalfi	Canneto catchment (now Grevone)	2			3
248	25/10/1954	Atrani		2			3
249	25/10/1954	Cava de' Tirreni	Loc. Alessia, Marini and Castagneto	1		31	3; 1, 18
250	25/10/1954	Maiori		3			3; 1, 18
251	25/10/1954	Minori		2	2		3; 1, 18
252	25/10/1954	Positano		1			3
253	25/10/1954	Praiano	Loc. Vettica Maggiore	1			3
254	25/10/1954	Salerno	Loc. Fratte, and Canalone	3	6, 4, 5	205*	3; 5; 18
255	25/10/1954	Tramonti		1	5		3; 8; 2; 22
256	25/10/1954	Vietri sul Mare	Loc. Di Molina and Marina	2			3, 18
257	05/11/1954	Ercolano		1			4
258	04/02/1955	San Sebastiano al Vesuvio		1			5
259	11/09/1955	Agerola		1			2
260	11/09/1955	Pellezzano	Irno catchment	1			2
261	11/09/1955	Tramonti	Regina Major catchment	1			2
262	10/01/1956	San Giuseppe Vesuviano		1		3	4
263	18/11/1956	Arpaia		1			6
264	21/01/1957	Sant'Anastasia		1			5
265	22/10/1957	Cava de' Tirreni		1			2
266	22/10/1957	Minori	Regina Minor catchment	2			2
267	22/10/1957	Tramonti	Regina Major catchment	1			2
268	30/12/1957	Cercola		1		2	4
269	19/09/1960	Ercolano		1		1	4
270	19/09/1960	Portici		1			4
271	07/07/1961	Torre del Greco		1		1	4
272	12/11/1961	Torre del Greco		1		2	4
273	27/06/1962	San Giuseppe Vesuviano		1			5
274	16/02/1963	Cava de' Tirreni	Cavaiola catchment	1			2
275	16/02/1963	Pellezzano	Irno catchment	1			2
276	16/02/1963	Petina		1			2
277	16/02/1963	Positano		1			2
278	16/02/1963	Sala Consilina		2	4, 5		6
279	16/02/1963	Tramonti	Regina Major catchment	1			2
280	18/02/1963	Padula		2	4, 5		6
281	21/02/1963	Positano	Loc. Trara Genoino	1			1
282	13/05/1963	Sant'Anastasia		1			4
283	30/05/1963	Torre del Greco		1			5
284	25/09/1963	Agerola		1			2
285	25/09/1963	Cava de' Tirreni		1			2
286	25/09/1963	Cetara	Cetus catchment	1			2
287	25/09/1963	Minori		2			2
288	25/09/1963	Pellezzano	Irno catchment	1			2
289	07/10/1963	Amalfi	Canneto catchment (now Grevone)	1			2
290	07/10/1963	Cetara	Cetus catchment	1			2
291	07/10/1963	Maiori	Regina Major catchment	3			2
292	07/10/1963	Minori	Regina Minor catchment	2			2
293	07/10/1963	Salerno					1
294	16/12/1963	Pellezzano	Irno catchment	1			2
295	16/12/1963	Tramonti	Regina Major catchment	1			2
296	13/01/1965	Torre del Greco		1			5
297	06/04/1966	Torre Annunziata		1			5
298	25/10/1966	Castiglione del Genovesi		1		1	3; 8
299	25/10/1966	Giffoni sei Casali	Monna Mt.	2		2	7; 1
300	26/10/1966	Alife		2			6
301	26/10/1966	Baronissi		1			3
302	26/10/1966	Cava de' Tirreni		1			3
303	26/10/1966	Piedimonte Matese	Loc. Vallata	3			6
304	26/10/1966	Salerno					3
305	1966	Ravello		1			1
306	09/01/1968	Salerno					5
307	17/12/1968	Padula		2	4, 5		6
308	19/12/1968	Amalfi	Canneto catchment (now Grevone)	1			2
309	19/12/1968	Tramonti	Regina Major catchment	1			2
310	1968	Alife		2			6
311	15/03/1969	Agerola		1			1
312	15/03/1969	Cava de' Tirreni	Cavaiola catchment	1			2
313	17/09/1969	Cava de' Tirreni	Cavaiola catchment	1			2
314	22/09/1969	San Giorgio a Cremano		1			1
315	1969	Arpaia		1			5
316	08/04/1970	Salerno			5	2	1
317	01/10/1970	Portici		1		1	4
318	01/10/1970	Torre Annunziata		1		1	4
319	01/10/1970	Torre del Greco		1			4
320	02/10/1970	Amalfi	Canneto catchment (now Grevone)	1			2
321	02/10/1970	Baronissi	Irno catchment	1			2
322	02/10/1970	Minori		2			2
323	02/10/1970	Pellezzano	Irno catchment	1			2
324	09/12/1970	Forio d'Ischia	Loc. Montevergine	1			1
325	25/12/1970	Amalfi	Canneto catchment (now Grevone)	1			2
326	25/12/1970	Baronissi	Irno catchment	1			2
327	25/12/1970	Minori	Regina Minor catchment	2			2
328	25/12/1970	Pellezzano	Irno catchment	1			2
329	1970	Arienzo		1			6
330	19/01/1971	Torre del Greco		1			5
331	21/02/1971	Castellammare di S.		1	5		1
332	15/10/1971	Cava de' Tirreni	Cavaiola catchment	1			2

V = number of victims (* = total number of victims per event on the same date); R = references (see Table 2).

Table 1. Continued.

333	15/10/1971	Tramonti	Regina Major catchment	1			2	394	10/11/1987	Positano		1			2
334	23/11/1971	Amalfi	Canneto catchment (now Grevone)	1			2	395	10/11/1987	Ravello		1			2
335	23/11/1971	Minori	Regina Minor catchment	2			2	396	10/11/1987	Tramonti	Regina Major catchment	1			2
336	06/03/1972	Cava de' Tirreni	Cavaiola catchment	1			2	397	13/11/1997	Ercolano					4
337	06/03/1972	Tramonti	Regina Major catchment	1			2	398	15/09/1988	Baronissi	Irno catchment	1			2
338	27/07/1972	Piedimonte Matese	Loc. Vallata	3	4		6	399	15/09/1988	Pellezzano	Irno catchment	1			2
339	21/10/1972	Cava de' Tirreni	Cavaiola catchment	1			2	400	15/09/1988	Tramonti	Regina Major catchment	1			2
340	21/10/1972	Tramonti	Regina Major catchment	1			2	401	15/07/1991	Torre del Greco	Santa Croce square	1			4
341	21/11/1972	Baronissi	Irno catch	1			2	402	26/03/1992	Torre del Greco	port	1			4
342	21/11/1972	Cava de' Tirreni	Cavaiola catchment	1			2	403	18/04/1992	Portici		1			4
343	21/11/1972	Pellezzano	Irno catchment	1			2	404	24/06/1992	Pellezzano	Loc.Cologna	1			1
344	02/01/1973	Amalfi	Canneto catchment (now Grevone)	1			2	405	05/08/1992	Torre del Greco		1			4
345	02/01/1973	Cava de' Tirreni	Cavaiola catchment	1			2	406	25/09/1992	Cava de' Tirreni	Cavaiola catchment	1			2
346	02/01/1973	Maiori	Regina Major catchment	3			2	407	25/09/1992	Tramonti	Regina Major catchment	1			2
347	02/01/1973	Minori	Regina Minor catchment	2			2	408	03–04/10/1992	Torre del Greco	Piazza Palomba	1			4
348	02/01/1973	Tramonti	Regina Major catchment	1			2	409	04/10/1992	Baronissi	Irno catchment	1			2
349	19/09/1973	Torre del Greco		1		2	4	410	04/10/1992	Cava de' Tirreni	Cavaiola catchment	1			2
350	1973	Baiano	Loc. Lagno di Trulo	1	5		1	411	20/08/1993	Serino	Loc. Ribottoli, Puzzillo	1		1	6
351	25/09/1974	Arienzo		1	4		6	412	20/08/1993	Solofra	Loc. Puzzillo	2	3	1	18; 5; 1
352	25/09/1974	Arpaia		1	4		6	413	08/12/1993	Cava de' Tirreni	Loc. Rotolo	1			1
353	25/09/1974	Forchia		1	4		6	414	20/12/1993	Padula		2	4, 5		9
354	03/10/1974	Arienzo		1			6	415	26/12/1993	Sala Consilina		2	4, 5		6
355	03/10/1974	Sant'Angelo d'Alife		2			6	416	22/08/1996	Massa di Somma	Paparo street	1			4
356	05/10/1974	Arienzo		1			6	417	22/08/1996	San Gennaro Vesuviano		1			4
357	28/06/1976	Salerno	Irno catchment	3			1	418	22/08/1996	San Giorgio a Cremano	Matteotti street	1			4
358	13/10/1976	Torre del Greco		1		1	4	419	22/08/1996	Torre del Greco	Port, XX Settembre street	1			4
359	29/10/1979	Torre del Greco	Cavallo street	1		2	4	420	20/09/1996	Cava de' Tirreni	Cavaiola catchment	1			2
360	12/10/1980	Cava de' Tirreni	Cavaiola catchment	1			2	421	20/09/1996	Giffoni sei Casali	Picentino catchment	3			2
361	12/10/1980	Maiori	Regina Major catchment	3			2	422	20/09/1996	Tramonti	Regina Major catchment	1			2
362	12/10/1980	Minori	Regina Minor catchment	2			2	423	26/11/1996	Padula		2	5		6
363	12/10/1980	Tramonti	Regina Major catchment	1			2	424	26/11/1996	Sala Consilina		2	5		6
364	15/10/1980	Cava de' Tirreni	Cavaiola catchment	1			2	425	09–10/01/1997	Casamicciola	loc. Montagnone, Molara, Cantoni, Tresta, Cognola, Campomanno; La Pera, Ervaniello and Puzzillo quarries, Mt. Taburno,	1			11
365	01/06/1981	Forio d'Ischia	Paola Poli restaurant	1	4		5	426	09/01/1997	Castellammare di S.		1		4	5
366	19/12/1982	Torre del Greco	Cavallo street	1		2	4	427	09/01/1997	Corbara	Chiunzi pass	1			5
367	15/08/1983	Barano d'Ischia	Scura and Olmitello quarries	1			15	428	09–10/01/1997	Lacco Ameno	Cito Mt.	1			11
368	30–31/10/1985	Ercolano	Palmieri street	1			4	429	10/01/1997	Castellammare di S.	Loc. Pozzano	1	4, 5		14
369	30–31/10/1985	Ottaviano	Cemetery	1			4	430	10/01/1997	Cava de' Tirreni	Cinque street,SS18, Loc. Avvocatella	1			1
370	30–31/10/1985	Portici	Railway	1			4	431	10/01/1997	San Cipriano Picentino	Loc. Campigliano	1			1
371	30–31/10/1985	San Gennaro Vesuviano		1			4	432	10/01/1997	San Giuseppe Vesuviano		1			4
372	30–31/10/1985	Torre del Greco	Cavallo street	1			4	433	10/01/1997	Vietri sul Mare	Loc. Guarno and Tresaro	2			1
373	02/11/1985	Ercolano	Palmieri street			1	4	434	21/08/1997	Sant'Anastasia		1			4
374	16-17/11/1985	Portici		1			4	435	21/08/1997	Somma Vesuviana		1			4
375	16–17/11/1985	San Giorgio a Cremano	Tufarelli street	1			4	436	13/11/1997	Boscoreale	Diaz street	1			4
376	16–17/11/1985	Torre del Greco	Cavallo, Novesca, Sant'Elena streets	1			4	437	13/11/1997	Cercola		1			4
377	17/11/1985	Cava de' Tirreni	Cavaiola catchment	1			2	438	13/11/1997	San Sebastiano al Vesuvio		1			4
378	17/11/1985	Durazzano	Longano Mt.	1			1	439	13/11/1997	Somma Vesuviana		1			4
379	17/11/1985	Maiori	Regina Major catchment	3			2	440	13/11/1997	Torre del Greco	Beneduce street	1			4
380	17/11/1985	Summonte		1	6, 5		1	441	05/05/1998	Avella		3			7
381	17/11/1985	Tramonti	Regina Major catchment	1			2	442	05/05/1998	Montoro		1		1	1
382	01/02/1986	Castellammare di S.	Aragonese Castel	1			5	443	24–25/7/1999	Casamicciola	Loc. Montagnone, Cantoni	1	5		11;
383	01/02/1986	Forio d'Ischia		1			5	444	24–25/7/1999	Lacco Ameno	Ervaniello quarry, La Rita		5		15
384	13/03/1986	Cava de' Tirreni	Loc. Molina	1			2	445	15/12/1999	Cervinara		2		5	5; 6
385	13/03/1986	Pellezzano	Irno catchment	1			2	446	19/11/2000	Torre del Greco	Loc. Santa Maria La Bruna	1			4
386	20/07/1986	Roccarainola		1			6	447	27/12/2000	Ercolano	Caprile street	1			4
387	24/11/1986	Cava de' Tirreni	Cavaiola catchment	1			2	448	22/08/2001	Santa Maria a Vico		1			6
388	24/11/1986	Tramonti	Regina Major catchment	1			2	449	22/08/2001	Sant'Angelo d'Alife		2	4, 6, 5		16
389	22/02/1987	Barano d'Ischia		1			6	450	15/09/2001	Barano d'Ischia	Olmitello quarry	1	6		15
390	16/10/1987	Baronissi	Irno catchment	1			2	451	15/09/2001	Casamicciola	Loc. La Rita	1	4	2	11
391	16/10/1987	Pellezzano	Irno catchment	1			2	452	22/06/2002	Raviscanina		1	1		9; 6
392	09/11/1987	Castellammare di S.		1			18	453	26/07/2002	Caposele		1	6, 4		18
393	10/11/1987	Minori	Regina Minor catchment	2			2	454	28/08/2002	Barano d'Ischia	Scura quarry	1			15

V = number of victims (* = total number of victims per event on the same date); R = references (see Table 2).

Table 1. Continued.

455	10/09/2002	Barano d'Ischia	Scura and Petrella quarries	1			15
456	23–24/09/2002	Barano d'Ischia	Olmitello quarry	1	64		15
457	09/09/2003	Castellammare di S.	Castel	1			18
458	20/04/2004	Cava de' Tirreni	Loc. Badia and Sant'Arcangelo	1	5, 4		18
459	28/09/2007	Montoro	Loc. Frazione Chiusa and Aterrana	1	5, 4		18
460	28/09/2007	Volturara Irpina	Loc. Candragone	2	4, 3		18; 6
461	10/11/2009	Casamicciola	Bagni square	1	4, 5	1	12
462	30/07/2010	Somma Vesuviana		1			4
463	31/07/2010	Giffoni sei Casali	Prepezzano stream, Loc. Madonna del Carmine	3	5		8
464	09/09/2010	Atrani		2	5, 4, 1	1	18
465	07/10/2011	Buccino	Loc. Teglia	2	5, 4		17; 18
466	07/10/2011	San Gregorio Magno	Loc. Matruro, Teglia	3	5		18
467	21/10/2011	Pollena Trocchia		1		1	4
468	19/06/2014	Arienzo	Pinazzola street	1	5, 4, 3		18
469	19/06/2014	Tufino	Loc. Icap, Vignola and Ferone, Turati street	1	4		18
470	01/09/2014	Solofra	Loc. Madonna della Neve, Santa Lucia	2	5, 4.		18
471	01/09/2014	Volturara Irpina	Rimembranza street	2	5, 4		18
472	11/09/2014	Castellammare di S.	Loc. Quisisana	1	5		18
473	25/02/2015	Barano d'Ischia	Loc. Olmitello	1		1	18
474	19/09/1943	Quadrelle	Loc. Mugnano-Quadrelle	2			18
475	09/09/1973	Quadrelle	Loc. Mugnano-Quadrelle	2			18
476	20/08/1997	Quadrelle	Loc. Mugnano-Quadrelle	2			18
478	13/11/1997	Quadrelle	Loc. Mugnano-Quadrelle	2			18

V = number of victims (* = total number of victims per event on the same date); R = references (see Table 2).

al., 2012; Alessio et al., 2013), which can be summed up as follows:

- limited catchment area (from a few km^2 to $10\,km^2$)
- high relief energy (from hundreds of meters up to 1000 m)
- high slope gradient (generally greater than 35°)
- high mean gradient of feeder channel (greater than 15°)
- low concentration time (from 30 min to a few 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 types, based on the following parameters:

- bedrock of the catchment (carbonate/volcanic);
- presence/absence of detrital cover and, if present, 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 into the following five classes:

- carbonate catchment with pyroclastic cover
- carbonate catchment without pyroclastic cover
- carbonate catchment with pyroclastic cover and outlet to the sea
- volcanic catchment
- volcanic catchment with outlet to the sea.

4 Results

The database contains about 500 events (Table 1) and is being continually updated. Each event is identified by an ID and by its geographical coordinates (events are located with Google Earth©). In order to include an event in our database, knowledge of its location and its temporal occurrence was essential. The events were located as points, usually at the fan apex or where the main damage was recorded. The catchments were catalogued according to their size (column CE in Table 1) and, as shown in Fig. 4, 67 % of the events in question affected catchments smaller than $3\,km^2$, while 91 % of the catchments were smaller than $10\,km^2$. Particular attention was given in the database to damage type (column D

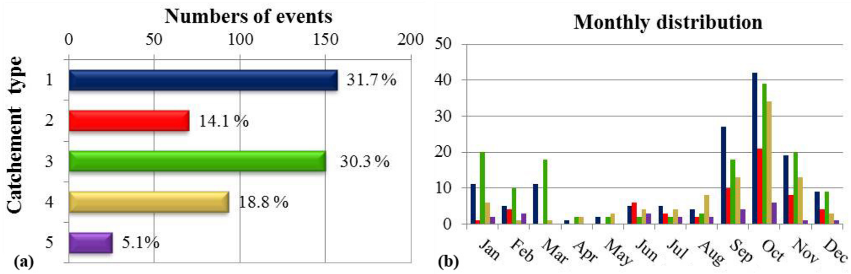

Figure 10. Number **(a)** and monthly distribution **(b)** of flash floods events for the different classes of catchments. Catchment class key: (1) carbonate catchment with pyroclastic cover; (2) carbonate catchment without pyroclastic cover; (3) carbonate catchment with pyroclastic cover and outlet to the sea; (4) volcanic catchment; (5) volcanic catchment with outlet to the sea.

Table 2. References used in Table 1 (R column).

References	No.
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
Newspapers	18

in Table 1) and to the presence of victims, if reported (column V in Table 1). The documented events caused serious social damage, primarily involving buildings, infrastructures, and lifelines (roads, pipelines, etc.). Damage to the population includes the number of victims, injured, homeless, and missing people. In several cases the information source does not allow casualties to be quantified with precision, since the information reported is typically generic, such as "some victims" or "several victims". Thus, in order not to loose any useful data, information about damage is also reported as text, as in the sources. Further, additional useful information can be included in the field notes.

The information thereby gathered may be useful to depict a regional scenario on the spatial and temporal distribution of flash floods in Campania. The oldest event occurred in 1540 in the town of Amalfi. The temporal distribution of the events in the region (Fig. 5) reveals that most of the municipalities have been affected by flash floods more than once during the time period covered by the database. Although there are several catchments with similar geological and geomorphological characteristics, many villages have no event recorded, probably related to the absence of inhabited areas. More than 60 % of the events have occurred during the last 50 years, a finding which is probably related to the greater availability of information sources in recent times, the numerous scientific studies carried out in the last few decades and the growing attention to geological hazards. Five degrees of temporal accuracy were used to classify the different levels of knowledge for time 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. 6 indicates that most of the events in question have a medium-to-high accuracy, meaning that day, month, and year of occurrence are known. The accuracy degree declines, as expected, for the oldest events.

Regarding the geomorphological features of the catchments involved, Fig. 9 shows the regional distribution of events, classified according to the five classes mentioned above. Most of the events took place in carbonate catchments with pyroclastic cover, both with and without an outlet to the sea (Figs. 9 and 10a). The widespread presence of carbonate catchments, as well as the high urbanization, affected the information source: as mentioned above, intense urbanization typically means greater availability of data, due to higher attention towards the damage generated by natural hazards. Distinguishing between different catchment types is important in order to discern the different bed and bank materials available which the flow could entrap and transport down valley. In a typical carbonate catchment the surge could generally take gravels without or with a low content of matrix (Fig. 11a); in carbonate catchments with pyroclastic cover, however, medium and coarse gravels with a high percentage of matrix are expected to be available (Fig. 11b). Further, in pure volcanic catchments, due to greater erodibility of the material, mainly silts and clays can be found (Fig. 11c). The mean time period of occurrence of the events in each catchment type ranges from 3 to 35 years. Carbonate catchments

Figure 11. 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).

with pyroclastic cover, both with and without an outlet to the sea, show a mean time period of occurrence of 6 years, which becomes 10 years for carbonate catchments without pyroclastic cover. Regarding the volcanic catchments, which in general present a lower number of events, the mean time period of occurrence is 35 years at Ischia and 3 years for the area surrounding Mt. Somma–Vesuvius.

The monthly distribution of flash flood events is quite variable in the different types of catchments. Figure 10b shows that all the events peak in October, with autumn being the season with the highest frequency. After the dry period, heavy rainfall can generate sudden high discharge, and runoff can carry downstream sediments accumulating as a result of the erosion processes. Locally, this could also be related to

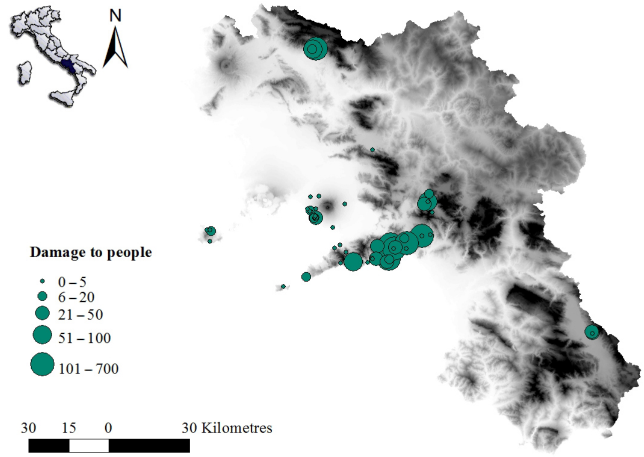

Figure 12. Distribution of victims recorded in the territory.

occurrence of wildfires during the dry season (Calcaterra et al., 2007a, b).

On the basis of the collected data, in the carbonate catchments with pyroclastic cover the lowest number of events is recorded in April, or generally during the spring, if there is an outlet to the sea. In the carbonate catchments without cover during spring (March–May) there are no events, and the lowest number of alluvial events is in January. In volcanic catchments, February and March are the months with the smallest number of events. For catchments with an outlet to the sea, during the spring (March–May) no event was recorded, and November–December are the months with the fewest events.

Regarding damage to people, in most cases the reported information is very generic, or in other cases the source provides the total number of victims per event but not for the individual municipalities. A 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 could be due 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 severe events in terms of the number of deaths and damage caused.

About 18 % of the events in the database caused at least one victim. Figure 12 depicts their distribution in the region. The most dangerous events hit 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; further, for the most damaging events the total number of deaths was also caused by landslides. Hence it is not easy to evaluate the victims caused only by flash

Figure 13. Typical examples of damage caused by alluvial events: **(a)** Casamicciola, 10 November 2009; **(b)** Buccino-Teglia, 7 October 2011; **(c)** Arienzo, 6 June 2014; **(d)** Solofra, 1 September 2014.

flood events in small catchments. Further, attribution of the number of casualties to each municipality was very difficult, since the source typically provides the total number of victims per event, not distinguishing the different villages. This applies, for instance, to the events in 1581 (700–1000 victims), in 1899 (approximately 100 victims), in 1924 (approximately 100 victims), and in 1910 (over 200 victims) which were the most devastating in recorded history.

The mean time period of occurrence for the events with more or less than 100 victims is very different: 62 years for the events with more than 100 victims and only 3 years for all the other events.

Taking into account the total number of events, the database contains few cases with injured, homeless and missing people. With regard to the homeless, for instance, the number is too small when compared with the numbers of events that caused complete destruction of the buildings. This suggests that the documented data in some ways underestimate reality.

The flash floods documented caused severe social damage, primarily involving buildings, lifelines and infrastructures. In particular, roads and private buildings were the most severely affected categories. In this regard, the most dangerous catchment types are carbonate catchments with and without pyroclastic cover. The damaged elements by each event are reported in classes in the database. In Fig. 13 some examples of damage produced by flash floods are shown.

5 Final remarks

Through an analysis of the existing literature, we focused on flash flood events in Campania, a region that has repeatedly been affected by severe flooding causing serious damage and fatalities. We collected temporal and spatial information on about 500 flash floods, thus building the first specific database concerning this type of geological hazard in the region. For this purpose, a critical scrutiny of the existing literature was performed to provide a degree of reliability for the collected information. We also defined the accuracy related to the temporal information available, and for most of the events accuracy proved to be medium to high, meaning that day, month and year of occurrence of the single event are known.

In order to reconstruct flood scenarios, we classified different catchment types on the basis 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 also collected information about damage to people and society, which occurred as a consequence of flash floods. 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 mean occurrence interval of floods is very low, ranging from a few years for damage 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 intense urbanization of the area affected the information sources, and these represent the main weaknesses of the historical documents. Although the volcanic areas in Campania are densely populated, the alluvial events in carbonate catchments with pyroclastic cover caused more damage to people and society than those occurring in volcanic catchments. The study also showed that a significant number of catchments were affected by floods with high mean time period of occurrence of the events. The loss of historical memories of these events certainly lies at the origin of an increase in the risk conditions.

Such a database may be useful in different ways for land use and civil protection planning. First of all, it may help to locate the areas more susceptible to flash floods all over the region. Secondly, it may facilitate local authorities in charge of land management to select sites where monitoring procedures and/or prevention and mitigation works need to be adopted. In this perspective the main users of the database will be local administrators and the civil protection agency.

6 Data availability

The database was built for the author's PhD project; we have chosen to make it public with this publication. Any additional information about data sets can be provided by the authors.

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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, Ann. Geophys.-Italy, 56, 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: Eng. Geol. for Society and Territory – Volume 2: Landslide Processes, 441–444, 2015a.

Antronico, L., Greco, R., and Sorriso-Valvo, M.: Recent alluvial fans in Calabria (southern Italy), J. Maps, 3, 1–12, doi:10.1080/17445647.2015.1047905, 2015b.

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.

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

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, 105–118, 2008.

Berti, M. and Simoni, A.: DFLOWZ: A free program to evaluate the area potentially inundated by a debris flow, Comput. Geosci., 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, J. Mt. Sci., 11, 288–307, 2014.

Borga, M., Boscolo, P., Zanon, F., and Sangati, M.: Hydrometeorological analysis of the 29 August 2003 flash flood in the Eastern Italian Alps, J. Hydrometeorol., 8, 1049–1067, 2007.

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

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

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, Nat. Hazards Earth Syst. Sci., 3, 3–16, doi:10.5194/nhess-3-3-2003, 2003.

Calcaterra, D., Coppin, D., de Vita, S., Di Vito, M. A., Orsi, G., Palma, B., and Parise, M.: Slope processes in weathered volcaniclastic deposits within the city of Naples: the Camaldoli Hill case, Geomorphology, 87, 132–157, 2007a.

Calcaterra, D., Parise, M., Strumia, S., and Mazzella, E.: Relations between fire, vegetation and landslides in the heavily populated metropolitan area of Naples, Italy, edited by: Schaefer, V. R., Schuster, R. L., and Turner, A. K., in: Proceedings 1st North American Landslide Conference, Vail (Colorado), 3–8 June 2007, AEG Special Publ., 23, 1448–1461, 2007b.

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, Eng. Geol., 96, 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, 125–140, 2008b.

CFDC (Centro Funzionale Decentrato della Campania): Centro Funzionale per la previsione meteorologica e il monitoraggio meteoidropluviometrico e delle frane, available at: http://centrofunzionale.regione.campania.it/, last access: 23 November 2016.

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.

Coe, J. A., Godt, J. W., Parise, M., and Moscariello, A.: Estimating debris-flow probability using fan stratigraphy, historic records, and drainage-basin morphology, Interstate 70 highway corridor, central Colorado, U.S.A., in: Proc. 3rd International Conference on Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment, Davos (Switzerland), 2, 1085–1096, 2003.

Cossu, A., De Waele, J., and Di Gregorio, F.: Coastal karst geomorphosites at risk? A case study: the floods of 6–11 december 2004 in central-east Sardinia, in: Natural and Anthropogenic Hazards in Karst Areas: Recognition, Analysis, and Mitigation, edited by: Parise, M. and Gunn, J., Geological Society of London, special publ. 279, 85–95, 2007.

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

Crosta, G. B. and Dal Negro, P.: Observations and modelling of soil slip-debris flow initiation processes in pyroclastic deposits: the Sarno 1998 event, Nat. Hazards Earth Syst. Sci., 3, 53–69, doi:10.5194/nhess-3-53-2003, 2003.

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

Delle Rose, M. and Parise, M.: Water management in the karst of Apulia, southern Italy, in: Proc. Int. Interdisc. Conf. "Sustainability of the karst environment. Dinaric karst and other karst regions", IHP-UNESCO, Series on Groundwater, 2, 33–40, 2010.

Del Prete, M., Guadagno, F. M., and Hawkins, A. B.: Preliminary report on the landslides of 5 May 1998, Campania, southern Italy, Bull. Eng. Geol. Environ., 57, 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, 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 Apennines, Mem. Descr. Carta Geol. It., 93, 203–218, 2013.

Esposito, G. and Galli, P.: La catastrofe idrogeologica del 1581 nei Monti Picentini (Sa) tra evidenze d'archivio e indagini geomorfologiche, Ital. J. Quat. Sci., 24, 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.

Garfi, G., Bruno, D., Calcaterra, D., and Parise, M.: Fan morphodynamics and slope instability in the Mucone River basin (Sila Massif, southern Italy): significance of weathering and role of land use changes, Catena, 69, 181–196, 2007.

Gaume, E., Bain, V., Bernardara, P., Newinger, O., Barbuc, M., Bateman, A., Blaškovičová, L., Blöschl, G., Borga, M., Dumitrescu A., Daliakopoulos, I., Garcia, J., Irimescu, A., Kohnova, S., Koutroulis, A., Marchi, L., Matreata, S., Medina, V., Preciso, E., Sempere-Torres, D., Stancalie, G., Szolgay, J., Ioannis Tsanis, I., Velasco, D., and Viglione, D.: A compilation of data on European flash floods, J. Hydrol., 367, 70–78, 2009.

Gaume, E., Grunfest, E., Naulin, J.-P., Payrastre, O., and Vannier, O.: Social and hydrological responses to extrem precipitations: an interdisciplinary strategy for postflood investigation, Weather Clim. Soc., 6, 135–153, 2014.

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, Environ. Geol., 43, 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, 237–254, 2005.

Guzzetti, F. and Tonelli, G.: Information system on hydrological and geomorphological catastrophes in Italy (SICI): a tool for managing landslide and flood hazards, Nat. Hazards Earth Syst. Sci., 4, 213–232, doi:10.5194/nhess-4-213-2004, 2004.

Guzzetti, F., Cardinali, M., and Reichenbach, P.: The AVI Project: a bibliographical and archive inventory of landslides and floods in Italy, Environ. Manage., 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, available at http://193.206.192.136/cartanetiffi/ (last access: 23 November 2016), 2006.

Iverson, R. M. and Vallance, J. W.: New views of granular mass flows, Geology, 29, 115–118, 2001.

Kirkham, R. M., Parise, M., and Cannon, S. H.: Geology of the 1994 South Canyon fire area, and a geomorphic analysis of the September 1, 1994 debris flows, south flank of Storm King Mountain, Glenwood Springs, Colorado, Colorado Geological Survey Special Publication, 46, 39 pp., 2000.

Komar, P. D.: Sediment transport by floods, in: Flood geomorphology, edited by: Baker, V. R., Kochel, R. C., and Patton, P. C., Wiley-INterscience, New York, 97–111, 1988.

Marchi, L. and Tecca, P. R.: Debris-flow monitoring in Italy, edited by: Schneuwly-Bollschweiler M., Stoffel M., and Rudolf-Miklau F., in: Dating Torrential Processes on Fans and Cones, Adv. Glob. Change Res., 47, 309–318, doi:10.1007/978-94-007-4336-620, 2013.

Marchi, L., Borga, M., Preciso, E., and Gaume, E.: Characterisation of selected extreme flash floods in Europe and implications for flood risk management, J. Hydrol., 394, 118–133, 2010.

Merheb, M., Moussa, R., Abdallah, C., Colin, F., Perrin, C., and Baghdadi, N.: Hydrological response characteristics of Mediterranean catchments at different time scales: a meta-analysis, Hydrolog. Sci. J., 61, 2520–2539, doi:10.1080/02626667.2016.114017, 2016.

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

Montz, B. E. and Gruntfest, E.: Flash flood mitigation: Recommendations for research and applications, Environ. Haz., 4, 15–22, 2002.

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, 126, 21–48, 2009.

Parise, M.: Flood history in the karst environment of Castellana-Grotte (Apulia, southern Italy), Nat. Hazards Earth Syst. Sci., 3, 593–604, doi:10.5194/nhess-3-593-2003, 2003.

Perrin, J. L. and Tournoud, M. G.: Hydrological processes controlling flow generation in a small Mediterranean catchment under karstic influence, Hydrolog. Sci. J., 54, 1125–1140, 2009.

Pierson, T. C.: Distinguishing between debris flows and floods from field evidence in small watersheds (No. 2004-3142), US Geological Survey, 4 pp., 2005.

Pierson, T. C. and Costa, J. E: A rheologic classification of subaerial sediment-water flows, in: Geological Society of America Reviews in Eng. Geol., 7, 1–12, 1987.

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, edited by: Margottini, C., Canuti, P., and Sassa, K., 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, Environ. Geol., 45, 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, 41–56, 1994.

Ruiz-Villanueva, V., Díez-Herrero, A., Stoffel, M., Bollschweiler, M., Bodoque, J. M., and Ballesteros, J. A.: Dendrogeomorphic analysis of flash floods in a small ungauged mountain catchment (Central Spain), Geomorphology, 118, 383–392, 2010.

Salvati, P., Bianchi, C., Rossi, M., and Guzzetti, F.: Societal landslide and flood risk in Italy, Nat. Hazards Earth Syst. Sci., 10, 465–483, doi:10.5194/nhess-10-465-2010, 2010.

Santangelo, N., Santo, A. and Faillace, P.: Valutazione della pericolosità alluvionale delle conoidi del Vallo di Diano (Salerno, Italia meridionale), IJQS, 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), Nat. Hazards Earth Syst. Sci., 11, 2765–2780, doi:10.5194/nhess-11-2765-2011, 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, 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, Phys. Chem. Earth, 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, Nat. Hazards, 78, 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.

SIMN (Servizio Idrografico e Mareografico Nazionale): 1919–1996, Hydrological Annals, Part I, Naples, available at http://centrofunzionale.regione.campania.it/index.php/documenti/annali, last access: 23 November 2016.

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

SorrisoValvo, 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 Surf. Proc. Land., 32, 290–306, 2007.

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), Comput. Geosci., 70, 96–109, 2014.

Tropeano, D. and Turconi, L.: Using historical documents for landslide, debris flow and stream flood prevention, Applications in Northern Italy, Nat. Hazards, 31, 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, J. Volcanol. Geoth. Res., 133, 377–393, 2004b.