Flood Risk Estimation through Document Sources Analysis: the Case of the Amalfi Rocky Coast

E. Esposito[1], S. Porfido[1], C. Violante[1], F. Molisso[1], M. Sacchi[1], G. Santoro[1], E. Spiga[2]
1, Institute for Coastal Marine Environment, CNR, Napoli, Italy
2, Geologist, ES OR Campania n.85, Avellino, Italy

eliana.esposito@iamc.cnr.it

Abstract

In the last century the Amalfi Coast was affected by numerous severe floods in conjunction with exceptional rainfall that caused major damage in terms of lost lives and economic cost. Historical documentary sources are an important source of information for reconstructing exceptional flood events occurring prior to the instrumental era. Historical analysis also provides an opportunity to extend the time scale window for flood risk studies. To study historical floods we collected all the available information concerning the period between the 16th and the 20th centuries by analysing both published and unpublished sources. The great variety of historical sources made it necessary to formulate an ad hoc scientific procedure that takes into account not only the completeness and reliability of documents related to the period, but also the intrinsic quality of the material. Experience in historical data collection shows that not all documentary sources can provide useful information for flood characterization, but it is necessary to have a selective criteria in order to obtain the best information rather than the best dataset quality.
Analysis of the data in question allowed us to achieve a chronological reconstruction of more than 100 floods. In this task, the level of information was decisive to carry out space–time identification, estimate the affected area and define type of damage to public and private structures, and the geological effects induced.

1 Introduction

The Campania region is particularly subject to the hydrogeologic risk (landslides and flooding), which represents a threat to the natural environment and a persistent menace to urban areas, in terms of human lives and socio-economic costs. A reliable flood record frequency is the most available tool for flood risk assessment and it require long data series obtained mostly from our knowledge about historical events which occurred as far back in time as possible. The format and reliability of historic flood data are likely to be at least as varied as the sources from which they derive. If the collated information is to lead to an improvement in the flood frequency estimates based on relatively short formally gauged records alone, then a rigorous evaluation of the historical data should be undertaken. Without this review it is likely that much spurious information will be included, to the detriment of the estimates produced.

Nevertheless, the use of historical data in the estimation of flooding events have been tested and consolidated during the last decades, giving very important contribution to hazard prevention [12, 2, 8, 15, 9, 13, 14].

The physical landscape of the Amalfi coast, is characterized by steep rocky coast deeply dissected by ephemeral water courses with human activities mainly developed on the narrow stream banks located at the base of steep sided valley, or at the mouth of stream [1]. Such configuration expone this area to a high hydrogeological risk triggered by water events associated with heavy rain [3, 18]. In fact, since historical time, flooding and sliding phenomena have dramatically affected the Amalfi coast, suggesting rapid slope morphodynamics to ascribing to extensive displacement of volcanic (Somma-Vesuvius air-fall deposit) and sedimentary (talus breccia, alluvial and eluvial deposit) covers [7, 10, 16, 17]. These water events also induced severe overflowing of the main streams, resulting in significant damage to property, destruction of roads, bridges, aqueducts, railways and loss of livelihood.

2 Methodology

This study presents a historical reconstruction of the effects of a series of catastrophic floods that occurred along the southern flank of the Sorrento Peninsula (Amalfi coast). The research was based on critical reviews of about 4000 published and unpublished documents since XVI century including above all, technical and administrative documents and projects, memoirs, other public, private and ecclesial documents, contemporary maps and iconographic materials.

To evaluate the intrinsic value of such heterogeneous documents it has been necessary to define a selection criteria in order to obtain the best information versus the best quality of dataset. For this purpose a rigorous methodology of investigation consisting in: a) analysis of historic sources, throughout the completeness and the reliability of the document and b) source classification, based on published and unpublished papers, contemporary (or not) sources, official reports and general public information.

The main groups of sources found in Record Offices and Libraries consist of administrative records (Figure 1), financial reports, law acts, expert investigations, as well as maps, iconographies. and newspapers. This kind of sources provide three levels of information:

- scarce, poor information regarding the occurrence of flood in wide areas and, sometimes, the date of the flooding event;
- general, more accurate information on type, size (sometimes) and location of the event;
- detailed, precise information on location of the event, dimension of the flooded area, level of damages and description of flood-induced geological effects.

Subordinately parish archives, as well as local libraries, provide important contemporary (or not) documents consisting in memoirs, chronicles, diaries, books and other heterogeneous public, private and ecclesial documents, which often provide useful data to reconstruct the general dynamics of the event (Figure 2). They have been divided into two main groups:

- direct source, including text written by eyewitness, specific studies such as scientific literature and newspaper;

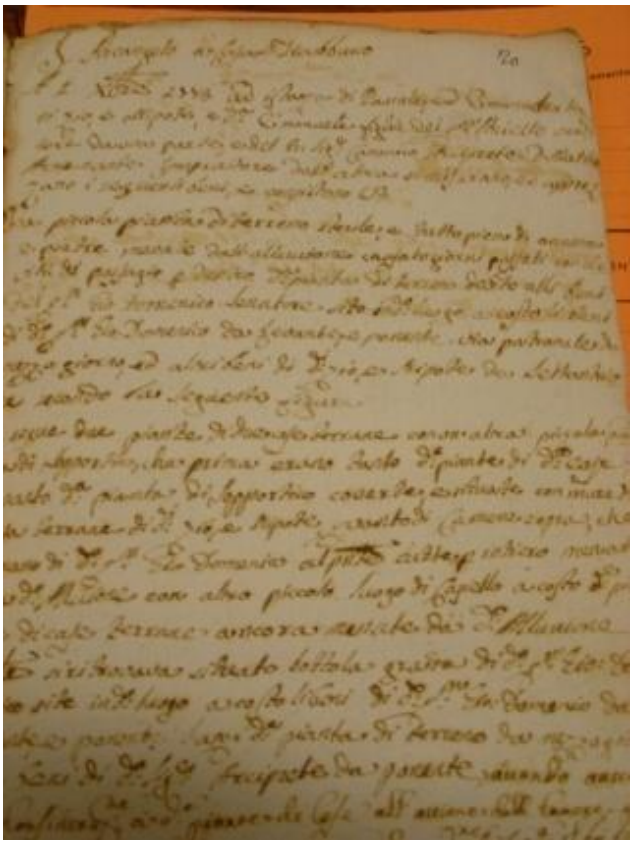

Figure 1: Documentary source related to the 1773 flooding event (Historical Archive, Cava de' Tirreni, Salerno).

- indirect source, including texts written after the event by local authors, scientific literature, chronicles and memoirs.

Another important type of sources is represented by photo, postcard, print, drawing and art reproduction available particularly for the XX century, where is often possible to visualize the effective impact of the disasters (Figure 3). Finally, law acts have not been overlooked, providing them too sometimes useful information on the damage distribution and size of destruction suffered by local communities.

3 Data analysing and chronology of flooding event

The reconstruction of the historical floods chronology comes from numerous and different sources with information of varying quality and completeness. To facilitate cross-referencing between the datasets

Figure 2: Bibliografic document: Map of 1954 flood event drown by Candido from Altavilla Silentina, 1955.

provided by these different sources, the gathered information have been organized in a systematic way producing a specific spreadsheet that include all the available information to give greatest weight of the reliable source, the level of information, location and size of the flood, damage, victim as well as flood-induced geological effects [11]. In particular, data relating to each historic flood have been evaluated according to the completeness of the information and its authenticity. The authenticity weighting has been assessed on the base of such parameters:

1. document chronologically contemporary to the event, wrote by local or regional administrator, lower, historian, parish, journalist, scientist, academician and technician have been classified as highest quality of reference (HQR);
2. document or bibliographic sources, wrote from five until fifty years after the event, by local historian, parish, journalist, sometimes scientist and technician have been considered as medium-high quality of reference (MQR);
3. bibliographic sources, wrote over fifty years from the event by local literary man and journalist, have been classified as medium-scarce quality of reference (SQR).

A systematic investigation of historical sources was carried out on published and unpublished documents since 1500.
Results indicates that between 16th and 18th centuries have been analysed more

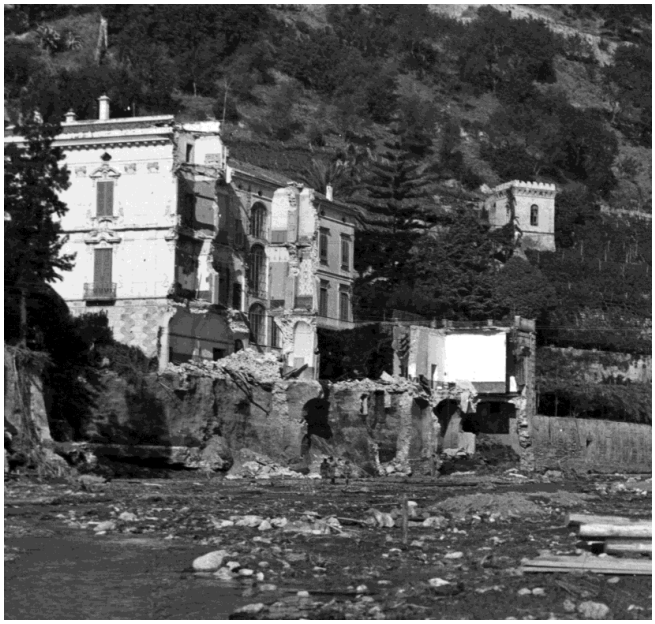

Figure 3: Photographic document: Marina di Vietri (SA) after the 1954 flooding event.

than 1000 sources with HQR, consisting of archival sources (Protocolli Notarili 1581-1798; Regia Udienza dei Principato Citra, 1620-1827; Genio Civile 1783-1901) as well as contemporary bibliographic documents, representing the 63% of the total sources; the MQR is represented by bibliographic sources for the 11% of the total, the last 26% includes bibliographic sources write over 50 years after the events. The highest quality of references (61% of the total) related to the 19th century is constituted by archival sources, (Genio Civile 1783-1901; Atti Demaniali, 1806-1961; Intendenza, 1815-1860; Società Economica, 1856-1960; Atti Prefettura, 1860-1932; Atti del Consiglio Provinciale di Salerno, 1899-1924; Bibliographical Sources, 1709-2004), contemporary national and local newspapers, scientific and tecnical reports for about 1500 sources. Of these only the 4% have been classified as MQR and 35% as SQR. As regards the 20th century most of the fonts (about 1300) have been classified as MQR coming from both archival and bibliographic sources as well as local and national news papers (starting from 1899 to 2000), represented by 55% of the total value, while HQR represented by a huge of documents from archival fonts to scientific and technical reports. Only the 8,5% of the founts have been classified into the third type of sources.

This pooling of data made it possible to determine some of the most relevant flood characteristics, such us magnitude, duration of the event, river location, extension of the basin area, damaged localities, deaths and induced geological effects. In particular the flood magnitude indicates the

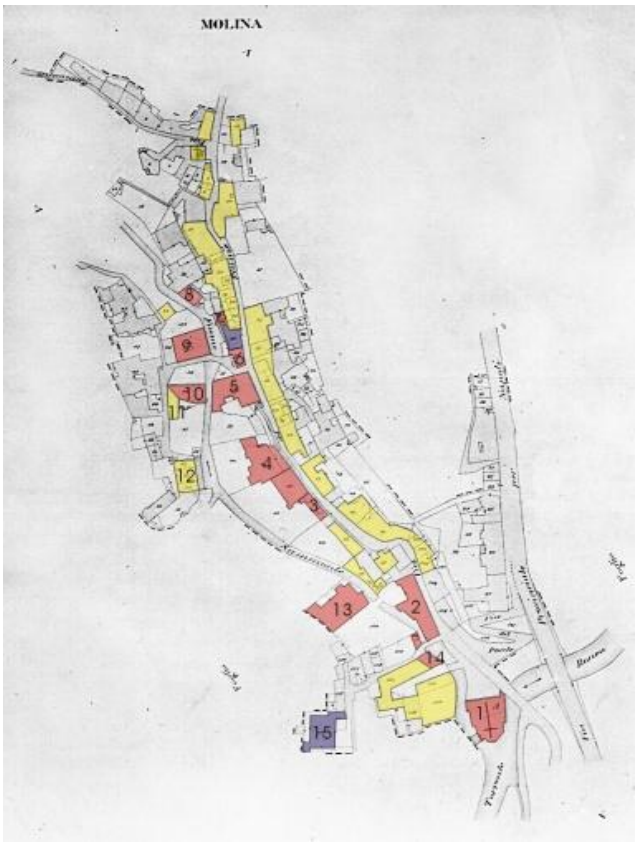

Figure 4: Detailed reconstruction of damage suffered after 1954 flooding event in locality Molina di Vietri (Esposito, 2004).

size of the past flood event based on degree of damage to both buildings and infrastructures, extent of the flooded area, loss of lives and time recurrence.
According to Dartmouth Flood Observatory, three different level of severity class have been recognized:

- Class I – (small flood): restricted area of flooding, minor damage to buildings located adjacent to the river and no serious damage to the population. Overflows depend on the river bed obstruction and on the embankment conditions. Recurrence interval $<$20 years.
- Class II – (intermediate flood): large area of flooding, severe damage and partial destruction to buildings located adjacent to or along the river. Infrastructures are destroyed along several hundred metres. Other damage is caused by the overflow with its heavy sediment transport. Bankfull discharge is exceeded in several places. Recurrence interval $<$100 years.
- Class III – (catastrophic or large flood):

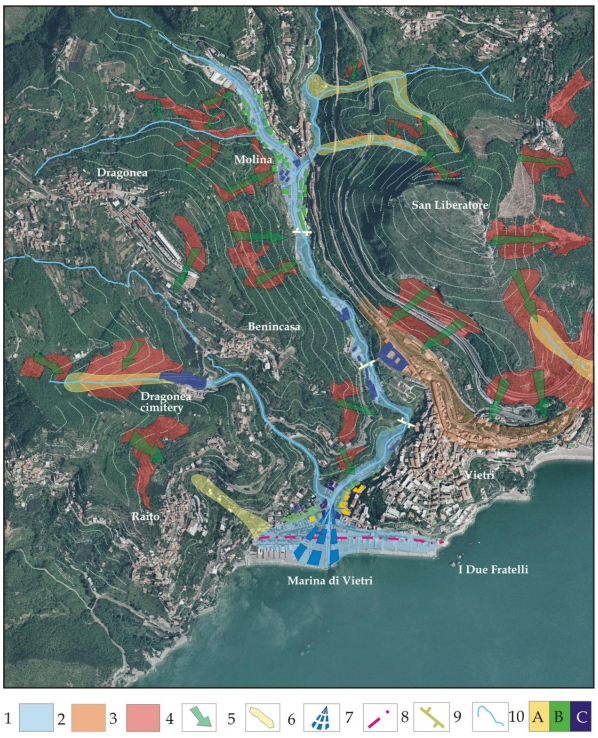

Figure 5: Geological effects and damage pattern induced by the 1954 flood event. (1) Overflowing area, (2) mud deposits, (3) evidence of past denudation, (4) landslide phenomena, (5) channelled debris flow, (6) alluvial fan, (7) shoreline before 1954 event, (8) temporary dam, (9) drainage network, (10) damage categories: (A) heavy, (B) medium, (C) light [5].

large area of flooding, severe damage or complete destruction of infrastructures close to the river, and stretches of roadways may be swept away. Overflowing affects also zones far from the river bed. Large morphological changes with river bed changes are also possible. Recurrence interval $>$100 years.

The systematic search for historic sources has led to the identification and classification of 106 floods, which affected the whole province of Salerno, and specifically the Amalfi coast (Table 1and Table 2). The most intense events classified with a Magnitude III, occurred in 1581, 1773, 1899, 1954. A widespread pattern of destruction characterized these events: serious damage to buildings and to industries, together with destruction of roads, bridges, aqueducts, railways etc. The cultural heritage also suffered great damage. In addition, all these events caused a large number of victims. Also extensive environmental effects such as landslide, overflowing, change of

Date			TR	IL	Location	Magnitude
30	09	1581	1,3	a	Salerno, Cava T., Vietri M., Castiglione G., Giffoni C., Giffoni V. P.	III
31	08	1588	1,3	b	Atrani	II
03	11	1750	1	b	Vietri M., Salerno	II
19	01	1764	1,3	b	Naples and Salerno province	II
11	11	1773	1,2,3	a	Salerno, Coperchia, Cava T., Vietri M., Tramonti, Cetara, Nocera, Mercato S. S.	III
24	01	1823	1	a	Amalfi, Maiori, Cetara, Cava T., Nocera, Vietri M., Salerno, Bracigliano	II
7	10	1899	1,2,3	a	Castiglione G., Giffoni C., Giffoni V.P., Montecorvino R., Montecorvino P. Vietri M., Cava T., Salerno, Caposele, Calabritto, Quaglietta, Pontecagnano, Battipaglia	III
24	10	1910	1,2,3	a	Ravello, Tramonti, Furore, Amalfi, Scala, Cetara, Maiori, Minori, Vietri M., Salerno, Ischia	II
26	03	1924	1,2,3	a	Positano, Agerola, Vettica M., Praiano, Amalfi, Atrani, Furore, Minori, Maiori, Vietri M., Salerno	II
25	10	1954	1,2	a	Positano, Vettica M., Praiano, Amalfi, Atrani, Minori, Tramonti, Maiori, Vietri M., Cava T., Nocera, Salerno	III
26	10	1966	1,2	a	Giffoni, Salerno, Cava T., Baronissi,	II

References: (1) highest quality of reference; (2) medium-high quality of reference; (3) medium quality of reference; (IL) Information levels: (a) detailed level; (b) general level - (c) scarce level; Magnitude: Class II (intermediate flood); Class III (catastrophic or large flood).

Table 1: Major floods identified on the basis of the available sources occurred since XVI century along the Amalfi coast (Modified from [11]).

coastline, characterized these events.
The large availability of data led us to reconstruct in detail the pattern of damage (Figure 4), as well as the geological induced effect (Figure 5) for some flooding events [6, 4, 17].

4 Conclusion

A systematic investigation of historical sources was carried out analysing both published and unpublished sources since XVI century. The great variety of historical sources made it necessary to formulate an ad hoc scientific procedure that would above all take into consideration the document's intrinsic quality in order to minimize spurious data.
In this task, the level of information was decisive: we were able to carry out space-time identification, estimate the area affected, the type of damage to public and private structures, and the geological effects induced. On the basis of the size of the areas hit by flooding, the type of effects induced on the urban and physical environment and the recurrence intervals, we estimated the magnitude of the events. The latter measure is undoubtedly fundamental for hydrogeological risk assessment and for estimating the return times of extreme events in the area.

Date			TR	IL	Location
20	12	1683	3	b	Maiori
15	10	1696	3	b	Minori
09	11	1735	1	b	Cetara, Cava T., Salerno, Vietri M.
25	01	1736	1	b	Vietri M.
26	09	1736	1	b	Vietri M.
	11	1738	1	b	Vietri M.
10	10	1751	1,2	b	Amalfi
01	09	1753	1,2	c	Amalfi
23	01	1757	1	a	Vietri M.
09	10	1757	1,2	a	Amalfi
25	05	1762	2	a	Cetara
	11	1770	1	b	Salerno
	02	1780	1	b	Atrani
25	12	1796	1	a	Cava T.,Vietri M., Salerno
12	11	1817	1	a	Cava T., Vietri M., Salerno
	12	1822	1	b	Salerno,Vietri M.
13	09	1834	1	b	Cetara
18	07	1835	1	b	Conca marina, Salerno, Cava T.
27	09	1837	1	b	Salerno,Vietri M.
01	01	1841	1	c	Salerno province
26	10	1843	3	b	Cetara, Maiori, Vietri M., Salerno
18	03	1845	3	b	Maiori, Vietri M.
05	01	1853	1	b	Vietri M.
11	10	1866	1	b	Vietri M.
	08	1866	3	a	Tramonti
11	11	1866	1	a	Vietri M.
16	03	1867	1	b	Vietri M., Salerno
12	11	1868	1	b	Salerno
01	04	1875	1	b	Conca M, Salerno
	12	1875	3	c	Salerno province
01	02	1878	1	a	Conca M.
	11	1881	3	c	Salerno province
15	09	1882	1	b	Salerno
05	02	1885	1	b	Amalfi
		1891	3	b	Tramonti
		1896	3	b	Conca M., Castiglione G., Baronissi, Bracigliano, Salerno
		1898	3	c	Salerno province
		1899	3	b	Conca M.
	02	1903	1	b	Vietri M.
07	10	1904	2	b	Ravello
23	06	1905	3	c	Salerno province
01	09	1905	3	c	Salerno province
11	12	1908	3	c	Salerno province
02	01	1911	1	a	Cetara, Vietri M., Salerno
21	09	1912	1	c	Salerno province
03	01	1915	2	a	Minori
06	11	1916	1	b	Vietri M.
13	11	1921	1	a	Furore, Salerno
21	09	1929	2	b	Salerno province Montecorvino R., Giffoni, Vietri sul M.
01	03	1935	2,3	b	Conca M., Minori, Tramonti, Ravello, Cava T.
18	11	1935	2	b	Salerno, Vietri M.
14	09	1939	1,2	b	Conca M., Amalfi, Maiori, Salerno, Pontecagnano
		1940	3	c	Salerno province
18	06	1944	2	b	Minori
09	12	1946	2	b	Minori
02	03	1947	2	b	Minori
25	10	1947	2	b	Minori
23	05	1948	2	b	Minori
05	09	1948	2	b	Minori
28	10	1948	2	b	Minori
01	10	1949	1,2	b	Praiano, Maiori, Vietri M., Salerno, Giffoni
21	01	1951	2	b	Minori
09	11	1951	1,2	b	Montecorvino R., Giffoni
11	09	1953	2,3	b	Agerola, Ravello, Salerno
11	09	1955	2	b	Tramonti, Agerola, Pellezzano
22	10	1957	2	b	Tramonti, Minori, Cava T.
	03	1960	2	c	Salerno province
16	02	1963	2	b	Tramonti, Cava T., Pellezzano
25	09	1963	2	b	Cetara, Minori, Cava T., Pellezzano
08	10	1963	1, 2	b	Amalfi, Cetara, Cava T., Salerno
16	12	1963	1,2	b	Tramonti, Pellezzano
09	01	1968	2	c	Salerno province
19	12	1968	1,2	b	Amalfi, Tramonti
15	03	1969	2	b	Agerola, Cava T.
02	10	1970	1,2	b	Salerno, Pellezzano, Baronissi, Giffoni
25	12	1970	1,2	b	Amalfi, Minori, Baronissi, Pellezzano
15	10	1971	1,2	b	Tramonti, Cava T.
23	11	1971	1,2	b	Amalfi, Minori
06	03	1972	1,2	b	Tramonti, Cava T.
21	10	1972	1,2	b	Tramonti, Cava T.
21	11	1972	1,2	b	Cava T., Baronissi, Pellezzano
02	01	1973	1,2	b	Amalfi,Tramonti, Minori, Maiori, Cava T.
28	06	1976	2	b	Salerno
09	04	1978	2	c	Salerno province
12	10	1980	1,2	b	Tramonti, Minori, Maiori, Cava T.
15	11	1980	2	b	Cava T.
17	11	1985	1,2	b	Tramonti, Maiori, Cava T., Salerno
13	03	1986	1,2	b	Cava T., Pellezzano, Pontecagnano
24	11	1986	1,2	b	Tramonti, Cava T.
16	10	1987	1,2	b	Baronissi, Pellezzano
10	11	1987	1,2	b	Positano,Ravello,Tramonti,Minori,Cava T.
15	09	1988	1,2	b	Tramonti, Pellezzano, Baronissi, Salerno
25	09	1992	1,2	b	Tramonti, Cava T., Salerno
04	10	1992	1,2	b	Cava T., Baronissi, Salerno
20	09	1996	1,2	b	Tramonti, Cava T., Salerno, Giffoni

References: (1) highest quality of reference; (2) medium-high quality of reference; (3) medium quality of reference;
(IL) Information levels: (a) detailed level; (b) general level
(c) scarce level.

Table 2: Minor floods identified on the basis of the available sources occurred since XVI century along the Amalfi coast. All the event have been classify as small flood, Magnitude I (Modified from [11]).

References

[1] L. Brancaccio. Genesi e caratteri delle forme costiere nella Penisola Sorrentina. *Bollettino della Società dei Naturalisti in Napoli*, 77:247–274, 1968.

[2] R. Brazdil, r R. Glase, C. Pfister, J. M. Antoine, M. Barriendos, et al. Flood events of selected rivers of Europe in the Sixteenth Century. *Climatic Change*, 43:239–285, 1999.

[3] P. Budetta, D. Calcaterra, and A. Santo. Engineering-geological zoning of potentially unstable rock slopes in Sorrentine Peninsula (Southern Italy). pp. 2119–2126, 1994.

[4] E. Esposito, S. Porfido, and C. Violante. Reconstruction and recurrence of flood-induced geological effects: the Vietri sul Mare case history (Amalfi coast, Southern Italy). *AGI Fast Slope Movements Prediction and Prevention for Risk Mitigation*, 1:169– 172, 2003.

[5] E. Esposito, S. Porfido, and C. Violante. Il nubifragio dell'ottobre 1954 a Vietri sul Mare-Costa di Amalfi Salerno. *CNR GNDCI*, (2870):1–381, 2004.

[6] E. Esposito, S. Porfido, C. Violante, and F. Alaia. Disaster induced by historical floods in a selected coastal area (Southern Italy). *Thorndycraft V.R., Palaeofloods, Historical data and climatic variability: Applications in flood risk assessment. Proceedings of the PHEFRA International Workshop*, pp. 143–148, 2003.

[7] E. Esposito, S. Porfido, C. Violante, C. Biscarini, et al. Water events and historical flood recurrences in the Vietri sul Mare coastal area (Costiera Amalfitana, southern Italy). *Proceedings of the UNESCO/IAHS/IWHA Symposium on The Basis of Civilization - Water Science?*, 286:95–106, 2004.

[8] T. Glade, P. Albini, and F. Francès. The use of historical data in natural hazard assessments. 2001.

[9] F. Guzzetti and G. Tonelli. SICI: an information system on historical landslides and floods in Italy. *Natural Hazards and Earth System Sciences*, 4(2):213–232, 2004.

[10] F. Molisso, E. Esposito, D. Insinga, C. Lubritto, et al. Facies analysis of flood dominated fan-deltas off Amalfi coast, Eastern Tyrrhenian Sea. *This volume*, 2010.

[11] S. Porfido, E. Esposito, F. Alaia, F. Molisso, and M. Sacchi. The use of documentary sources for reconstructing flood chronologies on the Amalfi Coast (southern Italy). *Geol. Soc. of London*, 322:173–187, 2009.

[12] AVI Project. http://avi.gndci.pg.cnr.it/welcome_en.htm. 1989.

[13] IFFI Project. http://www.mais.sinanet.apat.it/cartanetiffi/default_nosso.asp. 2004.

[14] SICI Project. http://sici.irpi.cnr.it/index.htm. 2009.

[15] V.T. Thorndycraft, G. Benito, M. Barriendos, and M.C. Llasat. Palaeofloods, Historical data and climatic variability: Applications in flood risk assessment. *Proceedings of the PHEFRA International Workshop*, pp. 1–378, 2003.

[16] C. Violante. Geohazard in rocky coastal areas. *Geological Society of London*, 322:1–210, 2009.

[17] C. Violante. Rocky coast: geological constraints for hazard assessment. *Geological Society of London*, 322:1–32, 2009.

[18] C. Violante, C. Biscarini, E. Esposito, F. Molisso, et al. The consequences of hydrologic events on steep coastal watersheds: the Costa d'Amalfi, eastern Tyrrhenian sea. *IAHS*, 327:102–113, 2009.