Flood Historical Data for Flood Risk Estimation in Coastal Areas, Eastern Tyrrhenian Sea, Italy

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Abstract

A reconstruction of historical floods occurred along the Amalfi coast, during the last five centuries is presented. The analysis of historical sources allowed to achieve a chronological reconstruction of more than 100 floods, four of which classified as catastrophic events. In this task, the level of information was decisive to carry out space–time identification, estimate the affected area and define the type of damage to the structures, and the environment (e.g. mud flow, debris flow, rock falls, shoreline progradation, fan deltas), which may be relevant for the recognition of similar events within the geologic record. The magnitude of the events was finally estimated, taking into account the size of the areas affected by flooding as well as the type of effects induced on the urban and physical environment and the recurrence intervals.

Keywords

Historical floods • Tyrrhenian sea • Amalfi coast • 1954 flood event

Introduction

The Salerno rocky coast (Campania, Southern Italy) 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, socio-economic costs and modification of the landscape.

A reliable time frequency of the flood recurrence is the most useful tool for flood risk assessment and it requires long time series obtained mostly from historical data. The coast of Salerno province experienced numerous flooding events after heavy thunderstorm, that triggered a series of associated phenomena like intense landslides, inundations, denudation, shoreline progradation, etc.. In this study historical floods since the sixteenth century were analysed in detail to provide a sound basis for reliable risk assessment and a confident land planning on flood-prone areas.

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Geological Setting of the Sorrento Peninsula

The study area is located on the southern slope of the Sorrento Peninsula (Amalfi coast). The peninsula is a major Quaternary morpho-structural unit of the western flank of Southern Apennines and forms a narrow and elevated mountain range (up to 1,444 m) that separates two major embayments of the eastern Tyrrhenian margin, namely the Naples and Salerno Bays (Fig. 1). It is mostly formed by a pile of Mesozoic carbonate rocks, covered by Tertiary to Quaternary siliciclastic and pyroclastic units and is deeply cut by a network of bedrock rivers and channels characterized by relatively small catchment areas and pronounced disequilibrium of the stream profiles. These rivers display flow regimes with a distinct seasonality and a torrential behaviour (Esposito et al. 2004a, b; Budillon et al. 2005; Liquete et al. 2005; Sacchi et al. 2009; Violante et al. 2009). Their source is very high relative to the base level, so that erosion processes proceed relatively rapidly, and tipically create a rugged morphology (Reineck and Singh 1975; Einsele 2000).

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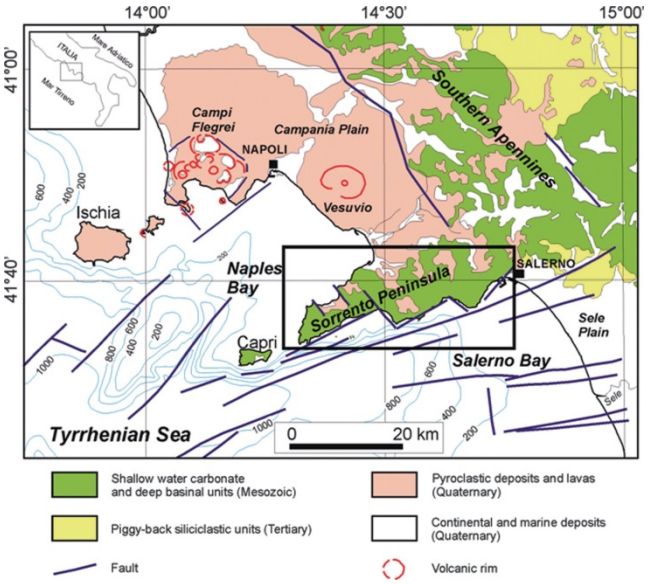

Fig. 1 Tectonic sketch-map of the Campania Apennines and location of the Amalfi coast of the Sorrento Peninsula

Being a horst-like structure in a half-graben basin setting the Sorrento peninsula displays a remarkable asymmetry in the morphology of the two flanks, the southern one (Amalfi coast) being steeper and narrower than the northern one (Sorrento coast). The asymmetry can be also observed offshore, where the narrow continental shelf on the Amalfi side contrasts with a definitely wider shelf in the southern part of the Naples Bay. As a consequence the Amalfi flank of the peninsula is characterized by tectonically uplifted rocky and steep backdrops, deeply incised gorges, and coastal cliffs (Brancaccio et al. 1991).

Coarse-grained coastal alluvial fans confined by narrow valleys at the mouth of the major streams are relatively common in this setting. They are formed by deposition from flash floods, during heavy rain falls.

Methods

Historical records are an important source for the evaluation of flooding episodes caused by torrential or prolonged rainfall and become indispensable to define the quality and completeness of the information needed to outline the trends climatic oscillations and the frequency of extreme events (Agasse 2003; Bayliss and Reed 2001; Barriendos et al. 2003, Porfido et al. 2009, Esposito et al. 2011).

Rich of history, the study area reached its maximum opulence during the Middle Ages, when Amalfi became the first of the Italian Repubbliche Marinare with commercial activities all over the Mediterranean basin and acquired remarkable political influence and military power. A priceless documentary heritage is available for this area, found at the

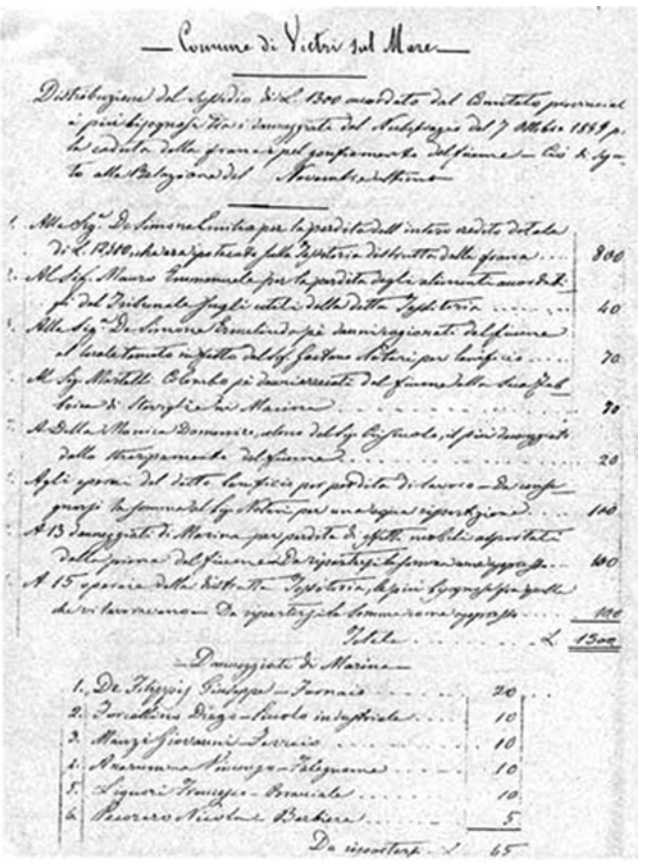

Fig. 2 Archival sources. 7th, October 1899 flooding and government subsidy to the Vietri sul Mare homeless (Prefettura, I Serie, 1899)

State Archives, municipal and ecclesiastical Libraries, public and private cultural associations, local or regional historiography, since the XVI century.

Selected documental sources were collected, including: (1) Administrative documents, consisting of collections written by central/local authorities such as the interior Ministry, the Major, engineering, technical etc. (Fig. 2); (2) Notarial documents, mostly represented by purchase-sale acts, reporting relevant details on pertinent facts and accurate descriptions of localities and events; (Fig. 3); (3) Ecclesial documents, consisting in rich collections of letters, memoirs, chronicles, written by the local ecclesial authorities; (4) Private collections, including letters, memoirs, chronicles, written by noble families, historians, scientists, etc; (5) Bibliographic sources, consisting of texts written by eyewitnesses and specific studies, such as scientific literature and national/local newspapers articles written during or after the event. New sources of information have been identified by analyzing photographs, particularly for the twentieth century, postcards, prints, drawings and art reproductions.

The selected sources were grouped on the basis of the document's intrinsic quality, strictly connected with: (a) source chronologically contemporary with the event; (b) reliability of the writer.

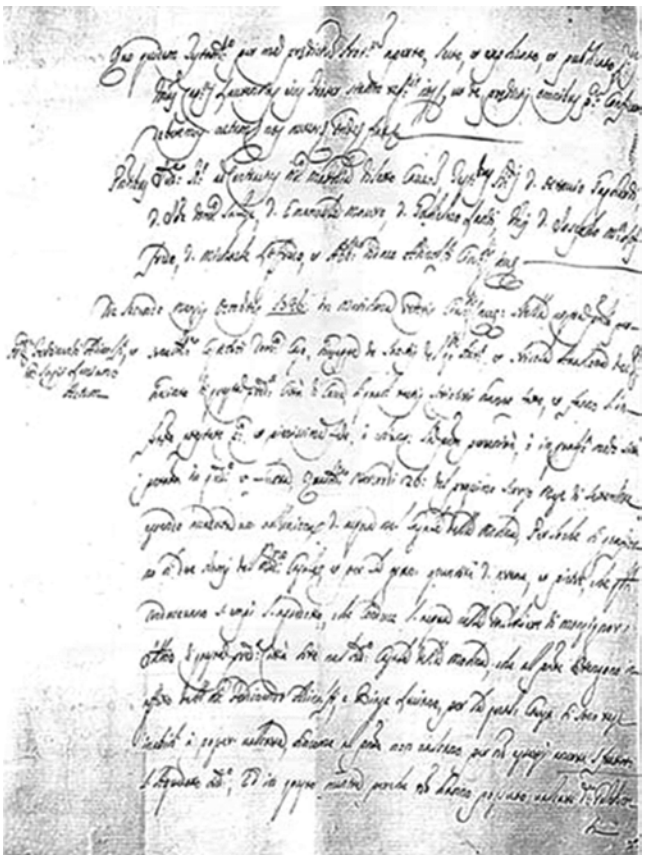

Fig. 3 Archival sources. 25th, January 1736 flooding and destruction along the Bonea Stream in Molina di Vietri sul Mare (Protocolli Notarili, 1736)

Particularly, three types of sources were distinguish as follows:

- Type 1 (highest quality of reference): documentary or bibliographic sources, chronologically contemporary with the event, written by a local or regional administrator, lawyer, historian, parish priest, journalist, scientist, academician or technician.
- Type 2 (medium–high quality of reference): documentary or bibliographic sources, subsequent to the event (from 5 to 50 years), written by a local historian, parish priest, journalist, or scientist or technician.
- Type 3 (medium quality of reference): bibliographic sources, subsequent to the event (over 50 years), written essentially by local literary figures and journalists.

The information obtained from the selected documentary sources were also grouped into three categories taking into account the level of detail of the description:

- Detailed. This category (from technical reports, projects, etc.) gives the precise location of the event, the extent of the flooded area, and the type of flood-induced damage. Occasionally, drawings or photographs of the flood-induced geological effects are also available.
- General. This category gives information on the event type, sometimes the size, and the location of the event.
- Scarce. This category gives very poor information regarding prevalently the flooding date into a generic area of occurrence.

Applying these criteria on the documentary series we were able to classify three different levels of flooding:

1. Minor flood: restricted area of flooding, minor damage to buildings locate adjacent to the river and no serious damage to the population.
2. 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.
3. Major or catastrophic flood: large flooded area, severe damage or complete destruction of infrastructures close to the river, and stretches of roadways eventually swept away.

The informations obtained from the selected documentary sources provide useful information on the dates of meteorological events, flooding duration, river location, description of flood impact on manmade structures and population.

Data Treatment

The systematic search of about 3,500 documents has led to the identification and classification of 136 floods, which affected the whole province of Salerno, specifically the Amalfi coast. Once the analysis of the historical content has been carried out, the towns most frequently hit by floods were identified. Starting from 1581 to 2010 Salerno, Vietri sul mare, Cava de' Tirreni, Amalfi, Majori, Minori, and Atrani were the most damaged. The most intense flooding events occurring along the Amalfi coast which caused extensive inundation, landslides, debris flows and flash floods, shoreline progradation and deaths (Esposito et al. 2002; Esposito et al. 2004; Porfido et al. 2009; Violante 2009).

The flooding phenomena hit areas spanning from a few km^2 to several hundred km^2, mainly located along rocky coasts and subordinately in the inner part of the Appenines. The inventory of historical flood allowed the definition of the major events that occurred on the Amalfi cioast during last five centuries, including a detailed information of the number of casualties. As regards the sixteenth and seventeenth century, the available data set allowed the identification of five events, among these, the 30th September, 1581 and the 31 August, 1588 has been classified as catastrophic, the first for the extensive damage produced in several localities distributed both on the inland and coast and for extensive inundation (300 victims), high landslide activity and shoreline progradation in Salerno, the second induced

Fig. 4 1954 Flood event: destruction in the Marina di Vietri, at the Bonea stream mouth (Foto Parisio 1954, Col. EPT, Salerno)

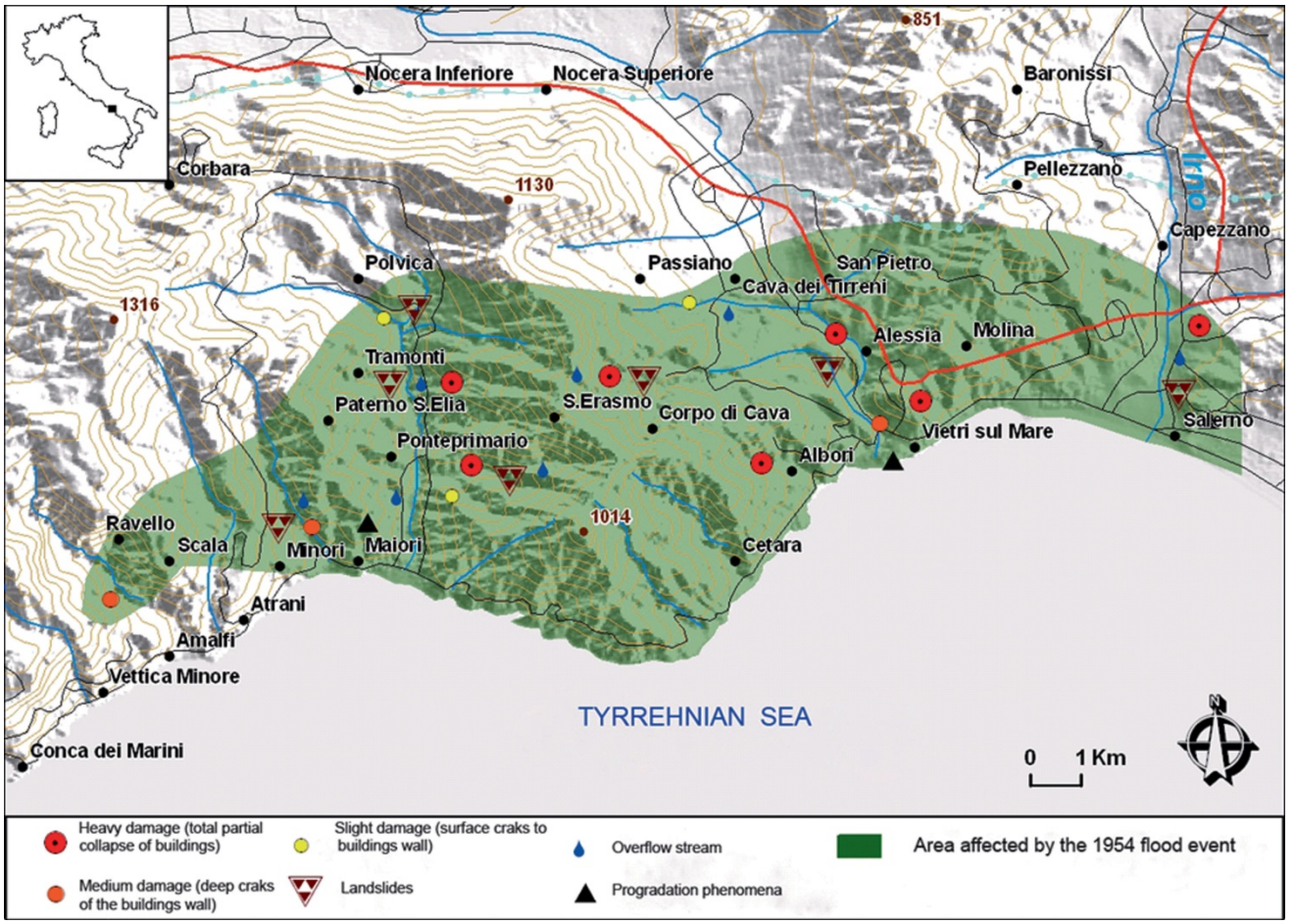

Fig. 5 Damage pattern and geological effects induced by the 1954 flood event between Salerno and Ravello (Salerno province). A catastrophic flood affected 46 villages, causing the collapse of houses. Stream flow and landslides occurred over a wide area extent. Twenty three localities lying along river banks suffered more severe damage (318 victims)

severe damage to the public and private property and fan delta in the Atrani village.

The eighteenth century was accompanied by 17 events. Among these the 23rd November 1750 has been classified as intermediate flood. The most destructive event occurred on 11 November 1773, classified as a catastrophic on the bases of extensive inundation, high landslides activity and diffuse shoreline progradation (400–450). The nineteenth century was characterized by 44 flood events. The 7th,October 1899 flood event produced a widerspread pattern of

Fig. 6 1954 Flood event: the mouth of the Bonea stream, a few days after the flooding (Foto Parisio 1954, Col. EPT, Salerno)

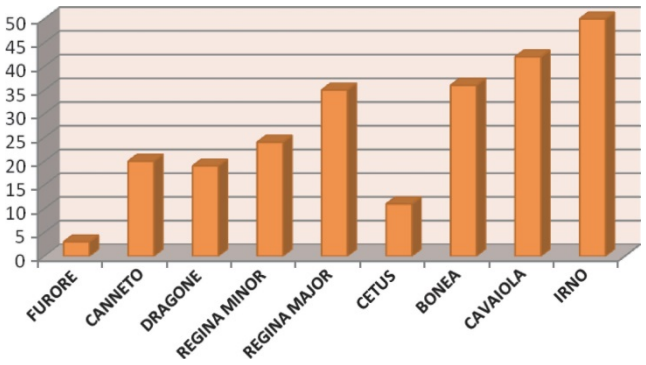

Fig. 7 Floods distribution in the Stream/River basins along the Amalfi coast during the last five centuries

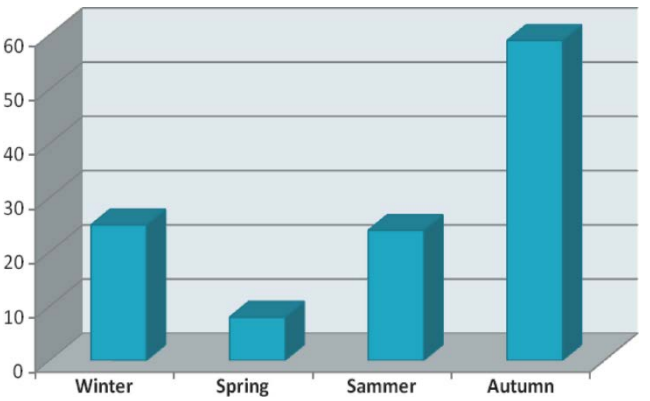

Fig. 8 Seasonal floods distribution along the Amalfi coast (Salerno province)

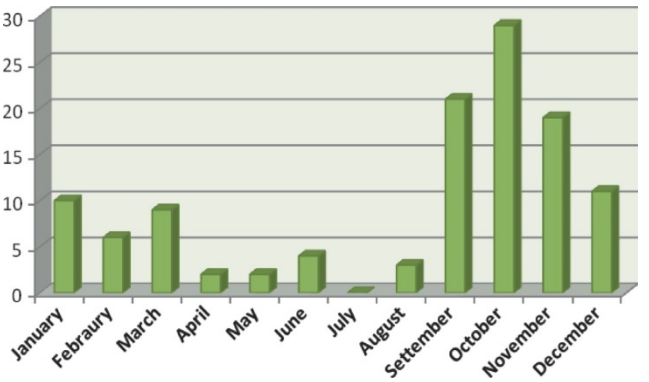

Fig. 9 Monthly floods distribution along the Amalfi coast (Salerno province) AU6

destruction in almost 23 localities (Fumanti et al. 2001), causing massive destruction of thousands of houses, hydraulic mills, aqueducts, main and secondary roads, bridges as well as railways, with 86 deaths.

On the 70 floods recorded in the twentieth century the most significant occurred in the year, 1924, 1954 and 1966.

The major flooding event was certainly the one that stroke the Amalfi coast on 25 and 26 October 1954 and resulted in more than 300 casualties, 350 injured and 10,000 homeless.

Rainfall lasted about 12 h with a total value of 504 mm and maximum intensity of 150 mm per hour. The most heavily damaged areas included the Bonea torrent (Fig. 4) and Irno river respectively in Vietri sul Mare and Salerno; the Regina Major stream caused also many damages to the village of Maiori. The damage, including destruction of buildings and industries, road, railways and aqueducts. It was estimated in about 35–40 billions of Lira (550 M Euro).

This rainfall event, though of limited extension (Fig. 5), was well recorded because the rain gauge network resolution at that time was quite adequate.

Temporary dams developed at points where the course of the streams narrowed. Marina di Vietri suffered a major flooding that caused a shoreline shift of about 150 m, associated with the formation of a fan-delta at the stream mouth (Fig. 6).

The orographic left of Bonea stream, where both railway and main roads are located, was also affected by severe damage.

Several erosional phenomena including debris flows, solifluction, and denutation occurred along the western side of the S. Liberatore hill, burying and sweeping away large part of communication line. Solifluction and debris flows phenomena were also observed downhill Tresaro, Dragonea and Tresare. These processes released large amounts of material straight into Bonea river bed, reinforcing the overflowing phenomena.

The extreme sensitivity of the Amalfi coast to severe and chatastrophic floodings originates from its peculiar geological and geomorphologic setting and it is clearly evidenced by the high frequency in the recurrence of such events over the last five centuries.

Preliminary analysis indicates that the Irno stream with its 50 events is the river basin with the highest flooding records of the region, followed by the Cavaiola river, 42 events, Bonea, 36 events, Regina Major, 35 events, Regina minor, 24 events, Canneto, 20 events and Dragone with 19 events (Fig. 7).

In particular the Dragone stream basin was the site of the last tragic flood that hit the village of Atrani and caused the death of a young women, on the 10th of September 2010.

These events are mostly concentrated in autumn and winter, with the highest number of floods 59 (51 %) and 25 (21 %) cases respectively (Fig. 8).

Figure 9 shows the number of flood cases occurred monthly: October, with the highest number of events, 29, followed by September with 21 events (18 %) and November with 19 events (16 %) on a total number of 100 flood events considered.

Conclusion

This study shows that historical sources can be an important contribute to improve and evaluation of natural hazards. In particular, this research permitted the recognition of 136 flooding phenomena in the Amalfi Coast, one of the most beautiful coastal location in the world, included in the UNESCO world heritage list since 1997. In this context the level of information is decisive, in fact has been possible to carry out space-time distribution, estimate the affected area and the type of damage to public and private structures, and the geological effects induced.

The Amalfi Coast experienced cartastrophic events both in terms of human and economic losses in 1581 (Castiglione di Giffoni), 1588 (Atrani), 1773 (Cava de' Tirreni), 1899 (Castiglione di Giffoni), 1910 (Cetara), 1924 (Amalfi) and 1954 (Vietri sul Mare - Salerno).

Each of these reported events was triggered by a few days of steady rain followed by several hours of heavy rain. The effects included extensive landslides, significant floods along the streams axes and modifications of the coastline at the mouth of several strams (Irno, Bonea, Dragone etc.).

Such information combined with hydraulic/hydrogeological and economic data may be used for the assessment and reduction of hydrogeological risk in the context of management of coastal area.

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