Chapter 17
Historical Climatology of Storm Events in the Mediterranean: A Case Study of Damaging Hydrological Events in Calabria, Southern Italy

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Abstract In this chapter, based on the data available in a regional database, some severe damaging hydrogeological events (DHEs) occurred in the last century in Calabria (Italy) have been described in terms of both triggering rain and damaging effects. Among the analyzed cases, there are only three long standing events (1951, 1953 and 1972), while the others are shorter. As far as the triggering rain, the 1951 and 1953 events are still not surpassed, and fortunately it is the same for the number of victims. If we consider the event occurred on 2000 as an exception caused by the negligence of the municipality that allowed a campsite so close to the river, the number of victims per event shows a decreasing trend. This can be a normal evolution which occurs in developed countries, where, because of an improving event management, damage to people tend do decrease and damage to goods to increase. The seasonality is clear: the majority of the events occurred between September and November, which in Calabria are the rainiest months. In terms of damaging phenomena, landslides were always the most frequent type. Greatest damage, especially in terms of victims, was caused by floods, the effects of which were often amplified by sea storms. The interrelations between the different phenomena, as the relationship between floods and landslides carrying debris into the river network and the connection between floods and sea storms, confirm that DHEs have to be studied with a general approach and taking into consideration all the phenomena and their interrelation which can amplify damage and cause cascading effects.

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N. Diodato and G. Bellocchi (eds.), *Storminess and Environmental Change*,
Advances in Natural and Technological Hazards Research 39,
DOI 10.1007/978-94-007-7948-8_17,

17.1 Introduction

Bad weather periods are a source of multiple hazards, because they can trigger several types of damaging phenomena which may cause different types of impacts on several natural and manmade elements in a wide range of circumstances. The whole of all the phenomena triggered by bad weather periods have been defined as Damaging Hydro Geological Events (DHE) (Petrucci and Polemio 2003, 2009).

Phenomena which occur during DHEs can be roughly sorted in some main groups: landslides, floods, erosion processes and sea storms. Each type of phenomenon is characterized by a proper dynamic and, according to the social and economic framework in which it develops, it can cause different impacts. During bad weather periods, all these phenomena occur at the same time (or in a short while), often amplifying damage and hinting emergency management actions. Nevertheless, the studies available in literature tend to analyse each type of phenomenon (and its impact) separately, thus supplying a fragmentary framework of the effects. Major DHEs consist in the simultaneous triggering of different types of phenomena in numerous locations: this can hamper emergency management, especially if management plans are either unavailable or not well defined. Not to mention that, the interaction between damaging phenomena and facilities can cause dangerous "cascading effects" (May 2007), as for example, interruption of roads and power supply, which obstruct both emergency management and post-event recovery.

The occurrence of DHEs depends on the relationships between climatic and geomorphological features that, excluding long-terms effects tied to climatic change, can be considered averagely steady; then, the areas where the combination of these factors is worse (i.e. downpours on river basins characterized by unstable slopes or flash floods) are systematically affected. On the contrary, the damage scenarios of past and future DHEs are not steady: especially in developed countries, modifications of the vulnerable elements distribution can occur within relatively short periods (years). Thus, it is basic to know both the places more frequently affected by past events and damage scenarios characterizing worse cases, in order to learn from past events how to improve preparedness and emergency management actions for future events.

In this paper, basing on the huge amount of data available in a regional database, a catalogue of most recent severe DHEs affecting a Mediterranean region located in southern Italy is presented.

17.2 Damage Data Collection

Newspapers are commonly used to find data on damaging effects of historical DHEs (Rappaport 2000; Agasse 2003; Devoli et al. 2007; Hilker et al. 2009; Kuriakose et al. 2009; Llasat et al. 2009; Maples and Tiefenbacher 2009; Adhikari et al. 2010; FitzGerald et al. 2010), though data can be found in numerous other types of sources (Brázdil et al. 2006; Llasat et al. 2006; Copien et al. 2008; Kirschbaum et al. 2009; Petrucci and Gullà 2010) and actual data availability may vary from a country to another. Limitations of historical data are widely described in literature and concern the completeness of the historical series, the exact localisation in both time and space of the effects, the uncertainty concerning the number of people involved, and the reliability of information sources (Guzzetti 2000; Petrucci and Pasqua 2008, 2009, 2012; Petrucci 2012). Once data have been collected, an Event Database has to be organized. Each record of the DB convert the text gathered from historical sources into a series of fields describing where (municipality and place name, if available), when (year, month, day, hour, if available) and what happened because of rainfall triggered phenomena. The fields concerning what happened describe the type/s of damaging phenomena occurred in a particular location (landslide, flood, sea storm, strong wind, etc.), the damaged elements, the type of damage suffered and, a damage quantification (number of victims, injured, homeless, amount of funds for reconstruction, etc.).

The aim of this paper is to present a selection of severe DHEs which affected Calabria region (Southern Italy), taking into account that in literature there is a lack of unanimity about criteria to classify event severity, especially because of the habit of analysing the effects of different damaging phenomena separately. Classification of floods severity levels, i.e. are described in Llasat et al. (2005), where "catastrophic flood" is defined as a precipitation episode causing overflowing of banks leading to serious damage or destruction of infrastructure (bridges, mills, walls, and paths), buildings, livestock or crops. Other papers set a magnitude scale of floods, basing on extent of inundated areas, degree of economic damage and number of casualties, made of three (Mudelsee et al. 2006) or five (Copien et al. 2008) levels. Often the number of victims is considered a measure for a catastrophic landslide event and it is used as a proxy for landslide impact, even if this can implies some limitations, especially in the cases of huge and slow landslides causing strong damage but not victims (Guzzetti 2000). Even the severity threshold for an event to be included into international disasters databases can vary greatly. To be included in EMDAT (http://www.emdat.be), i.e., one of the criteria is based on the number of victims (greater than 10), while NATHAN includes all loss events involving natural hazards that have resulted in substantial material or human loss (http://mrnathan.munichre.com), and other international database do not clearly state the selection criteria characterising catastrophic events, as arises from the recent Hazards Loss Dataset Catalogue (Beckman 2009).

Then, taking into account that the selection of severe DHEs among a group of events can be biased by the weight assigned to the different types of damage, the cases analysed in the following have been selected among those during which both landslides and floods caused major destructions of urbanised sectors and serious damage to people.

We selected seven events which have been occurred since 1950, because of the greater data availability for both damage and rain data- starting from the second half of the twentieth century. In the following, after a short introduction of the study area, each selected DHE is briefly described in terms of both phenomena and effects. Finally, a comparison among the selected cases is presented.

17.3 Introduction to the Study Area

Calabria is the southernmost Italian peninsular region having a surface of 15,230 km^2 (Fig. 17.1). The mean altitude is 418 m, and the maximum is 2,266 m. The climate is Mediterranean in the coastal zones, with mild winters, and hot summers characterized by few rain events. The Ionian side, affected by air masses coming from Africa, shows higher temperatures with short and heavy rains; the Tyrrhenian side is influenced by western air masses and has milder temperatures and frequent rain. The average regional annual rainfall is 1,151 mm; heavy rainfall is frequent during autumn and winter, and often triggers DHEs.

The region is made up of crystalline rocks (Palaeozoic – Jurassic), piled during the middle Miocene over carbonate rocks. Neogene flysh fills tectonic depressions. Since the beginning of Quaternary, Calabria has been subjected to still-active uplift. The regional morphology is rugged: only 10 % of territory is plain, while the remaining area shows either hilly or mountainous structure. Administratively, the region is divided into five provinces, further divided in 409 municipalities.

During the second half of the twentieth century, strong changes occurred into the arrangement of population on the regional territory (Table 17.1), either related to the migration of people outside the region, in search of work, or from poor mountain villages to developing coastal towns. In the last 60 years, these features caused important variations in the regional distribution of vulnerable elements, such as urban settlements and communication network, exposed to the effects of damaging hydrogeological events.

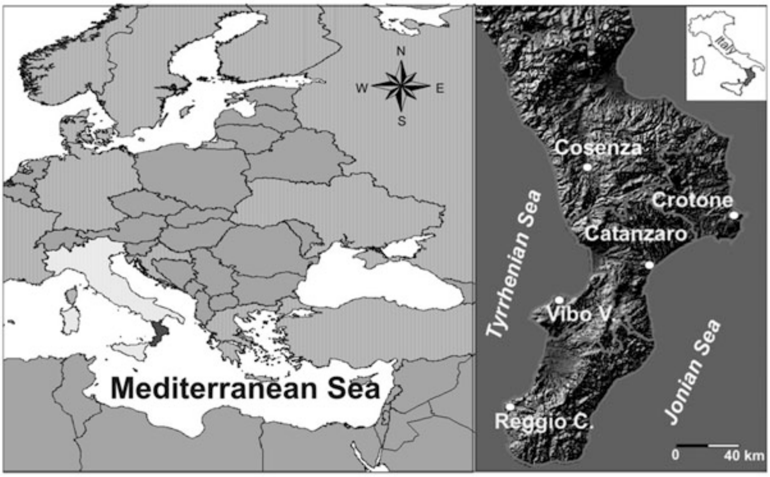


Fig. 17.1 (*Left*) Mediterranean basin: Italy in *white* and Calabria in *black*. (*Right*) shaded relief map of Calabria and province boundaries (Abbreviations: Reggio Calabria = Reggio C.; Vibo Valentia = Vibo V.)

Table 17.1 Comparison between Calabrian population data recorded in 1951 and 2010 (ISTAT 2012)

	Year 1951	Year 2010
Regional Nh	1,995,084	2,011,391
Min Nh (M)	883	291
Max Nh (M)	140,734	186,547
Mean Nh (M)	4,878	4,918
Modal value of Nh (M)	1,604	538
Median of Nh (M)	3,035	2,251
Min PD (M)	8	9
Max PD (M)	1,923	1,868
Mean PD (M)	157	144
Modal value of PD (M)	94	156
Median of PD (M)	121	79

Nh number of inhabitants, (*M*) per municipality, *PD* population density (Inhabitants km^{-2})

The historical researches carried out in recent years allowed us the implementation of an event database, made of about 11,000 records, collecting the effects caused by DHEs which occurred throughout the nineteenth, twentieth and twenty-first centuries (Petrucci et al. 1996, 2008, 2009; Petrucci and Versace 2004, 2005, 2007; Palmieri et al. 2011). Data have been gathered from the historical archive of CNR-IRPI of Cosenza that contains documents coming from different sources (newspapers, scientific articles, technical papers, documents of public works department, etc.).

The selection of the events was performed by examining the database and looking for cases characterised by widespread and serious effects, and for which rainfall data were available.

17.3.1 1951 DHE

Between 16th and 19th October 1951, a major perturbation affected southern Italy, Sicily and Sardinia regions, and devastating precipitation hit the SE sector of Calabria. Rain was exceptional in terms of both intensity and duration: on the S. Cristina rain gauges, 24-h rain was 535 mm, while in 14 gauges daily rainfall reached the maximum historical value (still unsurpassed nowadays), which was more than the double of the average October rain. In 4 days, cumulate rain exceeded 500 mm on a sector of about 850 km^2. Hourly and sub-hourly rains were not systematically collected at that time. Nevertheless, according to the exceptionality of the event, spare values available reported a maximum of 82.2 mm h^{-1} and several cases of about 50 mm h^{-1} (Servizio Idrografico 1951).

Floods and landslides started to manifest since October 16th, causing damage that dramatically increased until the end of the month. Severe flash floods affected the southernmost basins of the region, characterised by steep courses and torrential regimen, typical of the Mediterranean climate. Unfortunately, because of their intermittent regimen, the flow of these rivers was not systematically measured, then, no data about discharges are available. The huge rivers flow, mixed to the debris coming from the numerous landslides triggered by rain and channelled into the river network, became a powerful liquid-solid mass which eroded river beds and destroyed all the settlements and the bridges along the path toward the sea. In several cases, the flow was so large that rivers changed their path, breaking the embankments and flowing into villages located along the river banks. Moreover, heavy rain triggered both shallow and vast deep-seated landslides which affected several villages were people were forced to abandon definitively their houses, strongly damaged or completely destroyed, as in Casalinuovo di Africo (totally abandoned) and in some hamlet of Careri and Caulonia villages.

Twenty-four percent of regional municipalities were affected. The final balance was of 101 victims, 780 broken houses, 4,500 homeless, about 1,700 houses disrupted or heavily damaged, huge damage to agriculture, 26 broken bridges, 77 damaged aqueducts and countless roads interruptions, insomuch as communications between coastal villages were possible only by sea (Botta 1977; Caloiero and Mercuri 1980) (Fig. 17.2).

17.3.2 1953 DHE

Exactly 2 years later, on October 1953, a new devastating event affected almost all the region, and more severely south east Calabria: the cumulate monthly rain reached very high values, even if the most intense rain was recorded in the third decade of October. Seven gauges recorded the maximum value of daily rainfall of their historical series, and 115 mm/h was the maximum value of hourly rain (Stilo gauge).

The rain, very intense between 21st and 22nd, increased river flows causing rapid and highly damaging flash floods. An extraordinary violence characterized the floods of the basins located at the southernmost margin of the region, in Reggio Calabria province (Fig. 17.3).

As a total, 69 % of regional municipalities were damaged. Agriculture, housing, road network and services were severely hit. National government issued a special law dealing with *Provisions for Calabrian sectors affected by recent damaging hydrogeological events* (Law N. 938/1953).

Here, the huge amount of solid transport, strongly fed by landslide debris, carried enormous quantities of mud which roiled the sea for several days. At the same time, violent sea storms obstruct the outflow of rivers, thus prolonging the flood stage and related damaging effects, especially along the coast. On the east coast, the bed of some rivers (Alaco and Gallipari rivers) raised of some meters, because of the huge amount of debris carried.

A river flow measurement is available for a river located on the east coast (Ancinale River); even if this river is outside of the strongest affected area, it recorded an impulsive increasing of its flow that from 21st to 22nd raised from 4 to 106 $m^3\ s^{-1}$ (Servizio Idrografico 1953).

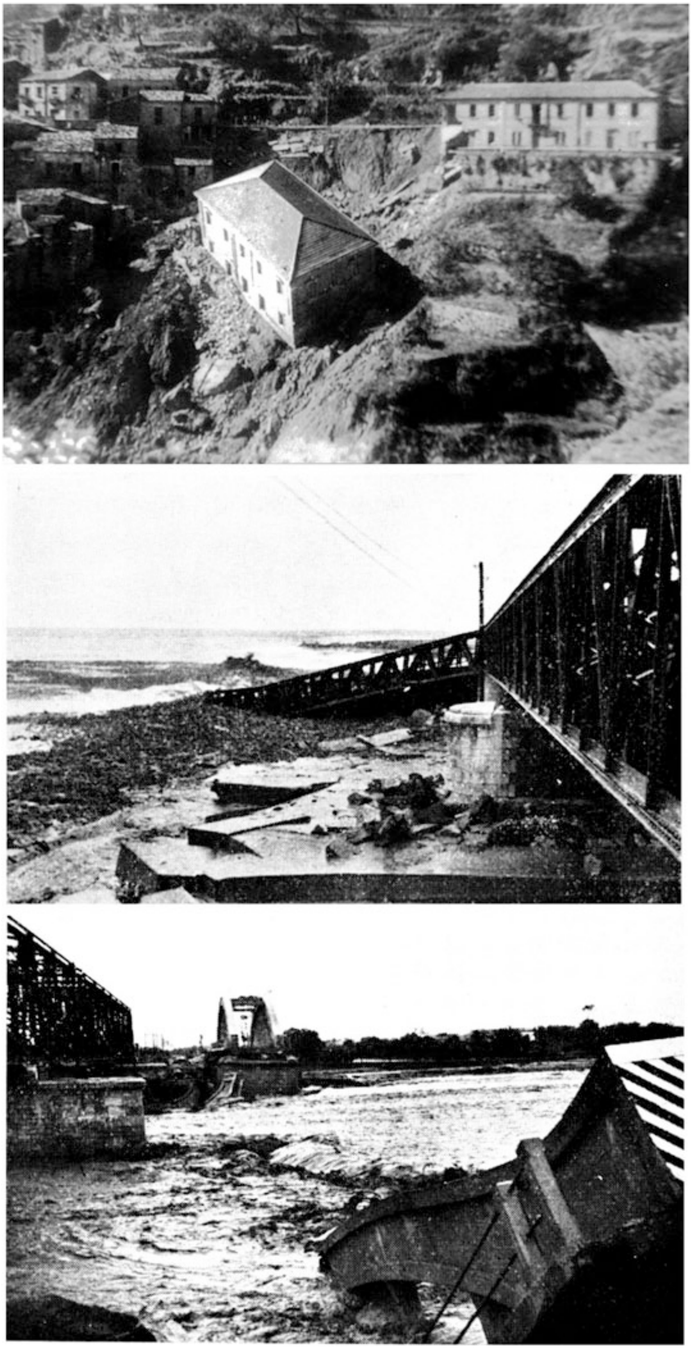


Fig. 17.2 1951 DHE. *Top*, the city-hall of Grotteria village (Reggio C.), moved from the top of a hill because of a landslide (Photo from the archive of the newspaper *L'Unità*). The *middle* and *bottom photos* depict the broken bridges on Bonamico and Careri rivers, respectively, both in Reggio C. province (Photos from Gulli 1952)

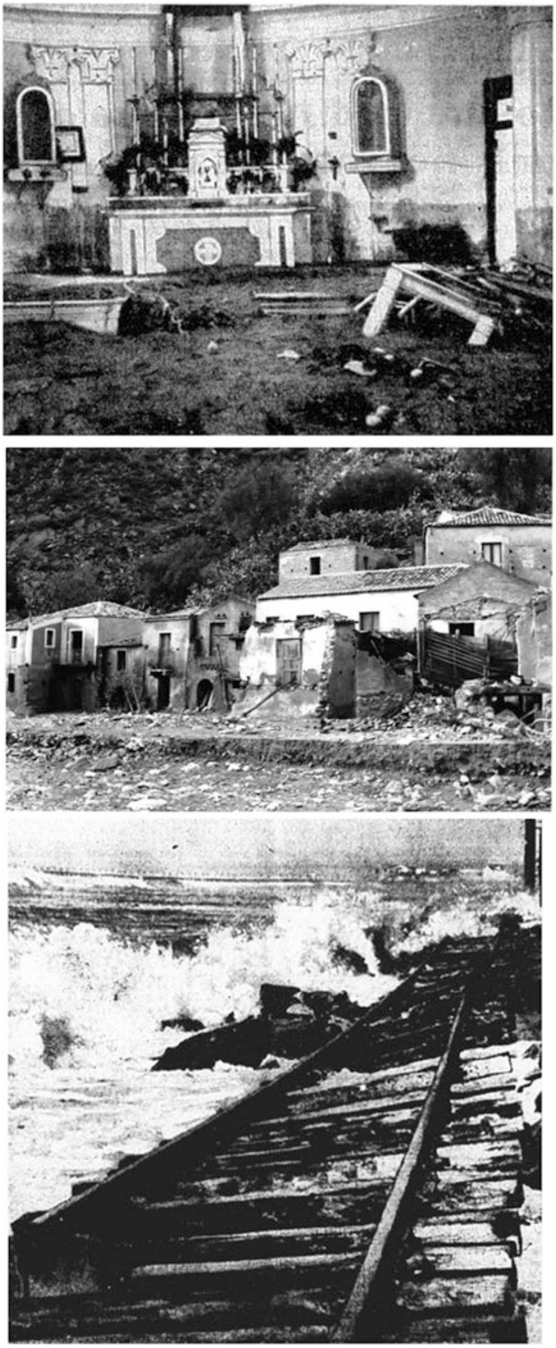


Fig. 17.3 1953 DHE. *Top image*, the church of Oliveto village (Reggio C.) flooded by a torrent: the priest died near the altar (Photo from the archive of the newspaper *La Stampa*). In the *middle*, some houses of Oliveto village located along a river and damaged by the flood (Photo from the archive of the newspaper *L'Unità*). *Bottom*, the railway damaged by sea storms in Reggio C. province (Photo from the archive of the newspaper *La Stampa*).

Numerous landslides damaged road and railway network; on the North-South railway located along the east coast of the region, 20 interruptions occurred because of both landslides and floods.

There is not agreement about the number of victims but according to our data they were 80. Several victims died in shacks realized to shelter people affected by the 1951 event, which were torn down by floods or that collapsed because of rain. Because of damage caused by this event, two villages (Brancaleone Superiore and a Caulonia hamlet) were definitively abandoned.

The American Navy organized the rescue and help operations; evacuees were about 3,500 people and part of them was forced to move to Sicily, thus abandoning forever their home.

17.3.3 1959 DHE

In November 1959, the region was hit by heavy rain clustered in two high-intensity episodes which occurred between 12th and 13th, and 24th and 25th, respectively. The rain started to fall on the south west sector, where high hourly intensities were recorded, as 160 mm h^{-1} and 520 mm 24 h^{-1} (Giffone gauge). At a regional scale, 20 % of the region received more than 100 mm in a day (Caloiero and Mercuri 1980). The first episode mainly affected a wide river basin located on the west regional sector (Mesima River) and its tributaries: here the flow gauge was destroyed by the flood, while water and mud inundated the fields and settlements located on the plain sectors. After this first episode, between 24th and 25th November, about 50 % of the regional territory was affected by more than 100 mm of rain. The higher daily rain reached 280 mm (Trepidò gauge) and it was recorded on central sector, while the highest hourly rain, 147 mm h^{-1}, was recorded on the south west coast (Badolato gauge).

On the south east area, damage was caused by both landslides and rivers overflowing which produced numerous roads and railways interruptions. On the northern sector, in the larger basin of the region (Crati Basin), the river and one of its tributaries overflowed the town of Cosenza by completely destroying the river-side neighbours (Fig. 17.4). On the medium-east sector, river floods and sea storms caused prolonged floods and rivers overflowing, as in the town of Catanzaro, while in the Crotone provinces, damage to industries and bridge collapses were recorded.

As a total, ten victims were deplored, caused by both floods and landslides.

17.3.4 1972 DHE

Between December 1972 and March 1973, a long series of rain events affected different sectors of the region. The most intense rain affected the east sectors of Reggio C. and Catanzaro provinces between 31st December and 3rd January.

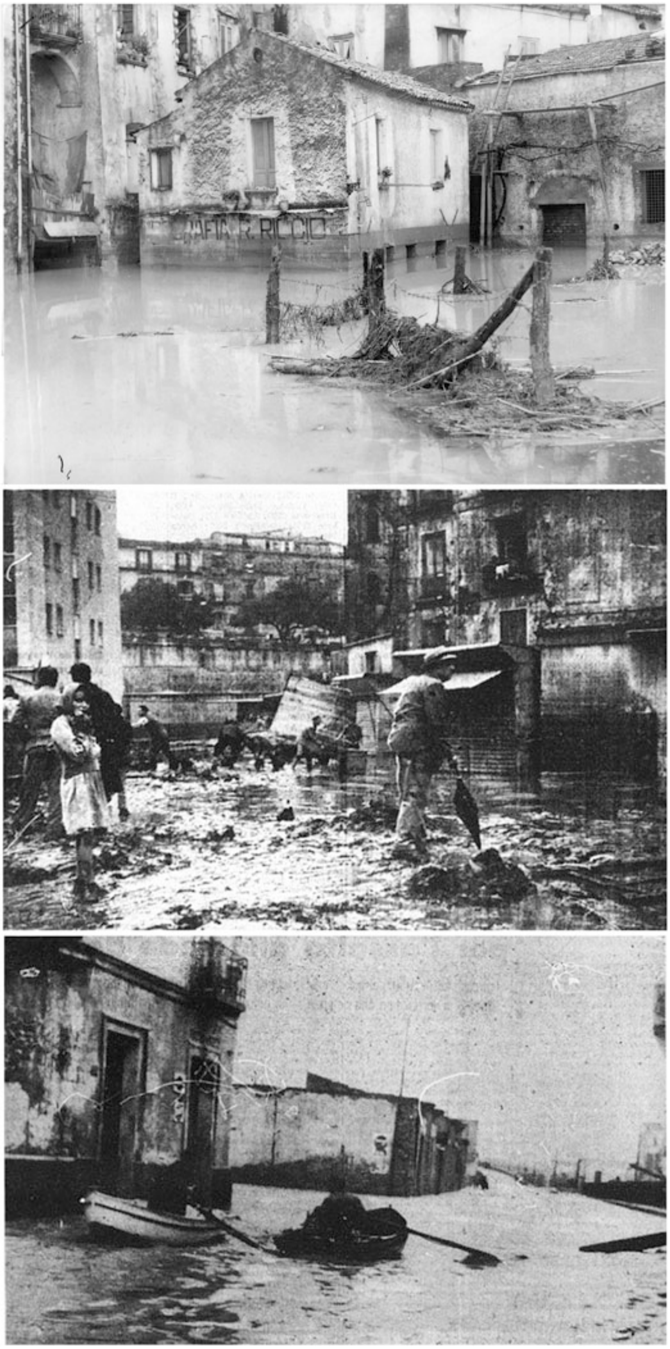


Fig. 17.4 1959 DHE. *Top* and *middle images*: flood in Cosenza town (*top*, photo from Petrucci et al. 2009; *middle*, photo from the archive of the newspaper *La Stampa*). *Bottom*: Catanzaro town flooded (Photo from the archive of the newspaper *La Stampa*)

Daily rain reached highest values on January the 2nd: 433.4 and 420 mm (Palermiti and Pietracupa gauges, respectively).

Since high saturation level was reached because of the previous rain, this downpour caused the overflow of rivers located on the east sector, where violent sea storms further obstructed the flow of rivers into the sea. In the meanwhile, huge landslides were triggered, as the one that blocked the Bonamico River, in the Reggio C. province, creating a temporary lake which threatened a village on the riverside. The lake was artificially drained without causing further damage (Fig. 17.5).

Huge damage affected communication network, with more than 30 road interruption and eight bridges collapsed (Petrucci et al. 1996).

In the Reggio C. province, after this event two hamlets were completely abandoned (Roghudi Vecchio and Grappedà di Careri). Out of the six victims, three died because of landslides and three drowned in a river, after falling with their car from a broken bridge.

Moreover, after this paroxysmal phase, rain continued to affect the region until the beginning of April: the latest intense episode touched the extreme north-east sector, the driest of the region. Here, some large landslides were triggered: among the most damaging, the one which deformed the railway and the coastal state road on a front of 600 m, blocking north-south traffic for 20 days, and the other one that destroyed the cemetery of Oriolo Village and blocked a river valley creating a temporary lake.

17.3.5 1996 DHE: Crotone, East Calabria

October 1996 marks the date of that we call the Crotone DHE: the rain caused moderate damage all around the region but the epicenter of the event was a very narrow zone around Crotone town, on the east sector. It has been claimed that two anomalous sub synoptic-scale cyclones, which had no resemblance with any typical mid-latitude event, developed between October 3rd and 10th over the western-central Mediterranean and triggered the event (Reale and Atlas 2001).

In the first 2 weeks of the month, the rain affected the small river basins of the area, and probably almost saturated their terrains; then on October 14th a further downpour affected the area, with rain intensities in 24 h from 125.6 mm (Brasimato gauge) to 147.2 mm (S. Anna Gauge).

This rain caused impressive floods of the two basins passing thorough Crotone town (Esaro and Passovecchio Rivers) (Fig. 17.6).

Water overflowed and invaded industries, shops, ground floor of the riverside buildings – especially in the Gabelluccia and Fondo Gesù neighborhoods – swept away cars and destroyed a bridge in the town. In some neighborhoods, the overflowed water almost reached the height of 4 m.

Six people died killed by the flood: two of them have never been found.

Fig. 17.5 1973 DHE. *Top left*: the Bonamico landslide lake (Delfino 2004); *top right*: the bridge on S. Agata river (Reggio C.). *Middle image*: the railway bridge on Corace river (*white arrow*). *Bottom image*: the Simeri coastal village threatened by Simeri river) (the last three photos were publisher in Giangrossi 1973)

Fig. 17.6 Crotone DHE. *Top* and *middle photos*, Crotone town after the flood and a broken bridge. *Bottom image*: damage in Cosenza province (Cerisano village)

17.3.6 2000 DHE: Soverato, South-East Calabria

Even during this event, the strongest damage was quite localized, and mainly affected south east sector. The remaining of the region recorded damage to urban settlements, agriculture and commerce, and several road interruptions, as on the north east sector, where the flood of Fiumarella River destroyed about 200 m of the north-south railways.

Rain was starting from 8th September and the highest intensity, 300 mm 24 h^{-1}, was recorded in the Palermiti gauge, near Soverato village. Actually, the name of the event came from this last village: the campsite “Le Giare”, located in this municipality just along Beltrame River, was the epicenter of damage. Along this river, some 10 km upward the campsite, debris and logs created a sort of temporary plug to river flow. Then, the power of the flood broken this barrier and transported downstream all the debris forming the plug. At five in the morning of 10th, Beltrame River overflowed and completely swept the campsite, where a group of 62 people (handicapped and their helpers) were having a vacation. The enormous expanse of water and mud around the camp site obstructed rescue operations: 13 people died.

Southward of this area, in the south-east sector of Reggio C. province, severe effects of urban flooding affected road network, private houses and commercial activities (Fig. 17.7). In Roccella village, more than 100 houses were evacuated because inundated by rivers outflowing, and more than 100 cars and numerous dustbins were carried by the water flowing along the urban streets until the sea.

17.3.7 2006 DHE: Vibo Valentia, Mid-West Calabria

Another localized event occurred in July 2006: it is an anomalous period for DHE occurrence in Calabria, as far as July is the driest month almost everywhere in the region. Actually the event was caused by a very intense downpour affecting a restricted regional sector on the mid-west coast, even if rain and related damage also affected some spare municipalities on the north east coast. The epicenter of rain was the town of Vibo Valentia: here, rain intensity was 200 mm/5 h, while the monthly average of July, for this gauge is 17 mm.

This intense rainfall triggered several debris flows along the slopes which rapidly conveyed a huge amount of debris into the river network where flash floods were starting. The solid/liquid mixture which originated had a volume exceeding the capability of both small and large bridges of the area. Then, all the torrent and rivers went out of their beds, especially in the places where bridges acted as a bottle neck to the river flow. At the end of this short event, a wide urbanized area along the coast was completely inundated by mud, and mud plumes in the sea marked the river mouths for several days. Similar plumes were also detected at the end of roads developing perpendicular to the coast: this happened because these roads behaved as rivers, by conveying the mixture of mud and water to the sea (Fig. 17.8).

Fig. 17.7 Soverato DHE. *Top*: the camping where victims occurred (From: http://www.strill.it/index.php?option=com_content&task=view&id). *Middle* and *bottom images*: rivers overflowing in Locri (Reggio C.)

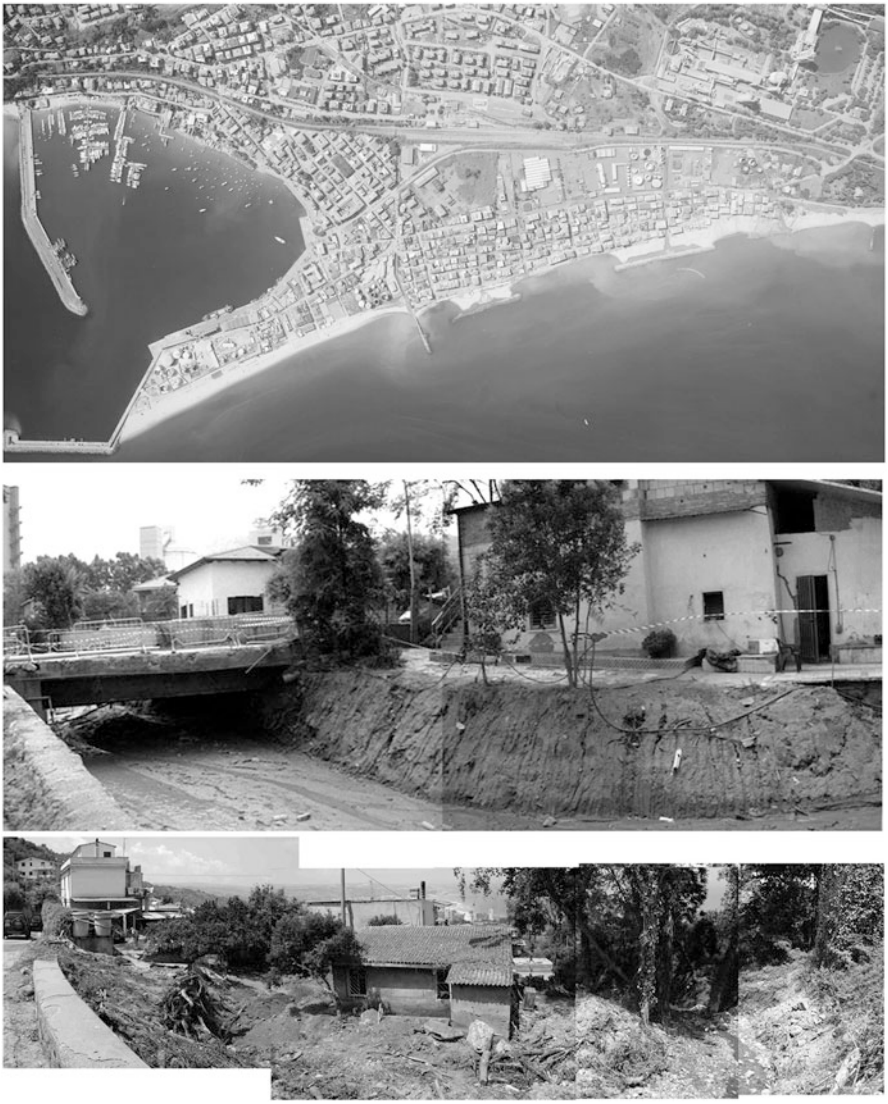
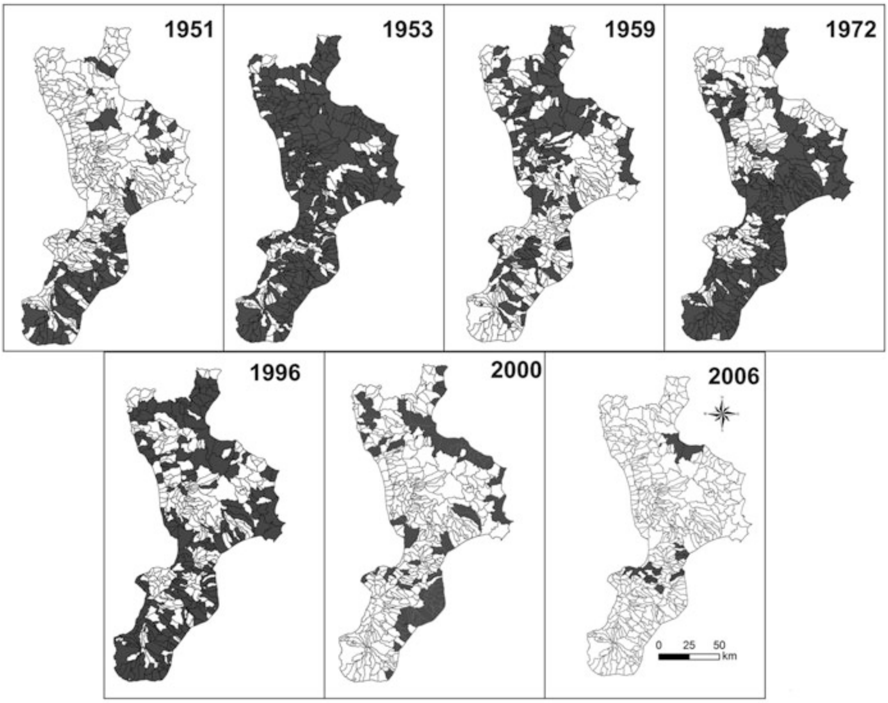


Fig. 17.8 Vibo Valentia DHE. At the *top*, air photo of Vibo harbor area where the turbidity of the sea and the mud in the urbanized area are represented by light *grey* tones. *Middle* and *bottom images*, debris dropped by floods

Damage to road network, cars, private buildings, industries and commerce was very high because of the high urbanization degree of the affected area. There were four victims: one person because of lightning and three people were swept away by a torrent, one of these was a newborn baby.

17.4 Discussions and Conclusions

In this chapter, some of the severest damaging hydrogeological events occurred in the last century in Calabria have been described. They are different in terms of both triggering rain, and damaging effects. Among the analyzed cases, there are three long standing events (1951, 1953 and 1972) which affected wide regional sectors, as summarized by the IDA (Index of Damaged Area) that is the percentage of regional area on which some type of damage was recorded (Fig. 17.9). The remaining events



N.	Year	From		To		D (days)	IDA (%)	F	L	Sf	Ss	W	Victims
1	1951	Oct	7	Oct	24	18	25.10	40	42	18	0	1	101
2	1953	Oct	21	Nov	13	23	81.13	29	41	27	1	2	80
3	1959	Nov	20	Nov	26	7	40.94	27	38	30	3	1	7
4	1972	Dec	15	Mar	7	80	60.25	21	44	24	5	5	6
5	1996	Oct	3	Oct	14	12	54.74	15	54	26	2	4	6
6	2000	Sep	7	Sep	13	7	24.90	18	38	34	10	0	13
7	2006	Jul	3	Jul	4	2	3.82	45	30	25	0	0	4

Fig. 17.9 The maps represent the municipalities affected by damage during the analyzed events. In the table, main features of the analyzed DHEs. N: identification number of the event; Year: year of occurrence; From: day and month the first damage was noticed; To: day and month the last damage was noticed; D (days): duration of the event; IDA (%): Index of Damaged Area F, L, Sf, Ss and W: number of Floods, Landslides, Secondary floods, Sea storm, and Wind damage expressed as percentage of the total number of phenomena that occurred during the analyzed DHE; Victims: number of fatalities caused by the event

are shorter, even if only for Vibo Valentia event the value of IDA is very low. This event, actually, can be considered as an anomalous case because it happened in the summer and was the result of rain centered on a small territorial sector.

As far as the amount of triggering rain, the 1951 and 1953 events are still not surpassed, and fortunately it is the same for the number of victims. If we consider the Soverato event an exception, caused by the negligence of the municipality that allowed a campsite so close to the river, the number of victims per event shows a decreasing trend. This can be a normal evolution which occurs in developed countries, where, because of an improved event management (in terms of defensive works, improved constructions standards and people more conscious behavior) the damage to people tend do decrease and damage to goods to increase.

The seasonality of the events is clear: the majority of rains occurred between September and November, which are the rainiest months in Calabria. In terms of damaging phenomena, landslides were always the most frequent type. Greatest damage, especially in terms of victims, was caused by floods, the effects of which were often amplified by sea storms.

The high interrelations between the different types of phenomena, as the relationship between floods and landslides carrying debris into the river network and the connection between floods and sea storms, confirm that DHEs have to be studied with a general approach and taking into consideration all the types of phenomena and their interrelation which can amplify damage and cause dangerous cascading effects.

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