Communication strategies to address geo-hydrological risks: the POLARIS web initiative in Italy

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Abstract. Floods and landslides are common phenomena that cause serious damage and pose a severe threat to the population of Italy. The societal and economic impact of floods and landslides in Italy is severe, and strategies to target the mitigation of the effects of these phenomena are needed. In the last few years, the scientific community has started to use web technology to communicate information on geo-hydrological hazards and the associated risks. However, the communication is often targeted to technical experts. In the attempt to communicate to a broader audience relevant information on geo-hydrological hazards with potential human consequences to the population, we designed the POLARIS website. POLARIS publishes accurate information on geo-hydrological risk to the population of Italy, including periodic reports on landslide and flood risk to the population, analyses of specific damaging events, and blog posts on landslide and flood events. By monitoring the access to POLARIS in the 21-month period between January 2014 and October 2015, we found that access increased during particularly damaging geo-hydrological events and immediately after the web site was advertised by press releases. POLARIS demonstrates that the scientific community can implement suitable communication strategies that address different societal audiences, exploiting the role of mass media and social media. The strategies can help multiple audiences understand how risks can be reduced through appropriate measures and behaviors, contributing to increasing the resilience of the population to geo-hydrological risk.

1 Introduction

Geo-hydrological hazards, including floods and landslides, are common geo-hydrological phenomena that cause serious damage and pose severe threats to the population worldwide. Currently, river flooding annually affects 21 million people worldwide, and the estimate is expected to reach 54 million people by 2030 (http://www.wri.org). For landslides, Petley (2012) showed that human losses were considerably higher than had been previously considered. Global costs of geo-hydrological disasters have increased in recent decades and, in future decades, it is expected that the number of people at risk and the occurrence of extreme events will both grow (https://www.ipcc.ch). Integrated risk management involving public authorities, research scientists, companies, and citizens is required to address the interconnectivity between physical infrastructures, economic systems and the role of human factors (Jonkman and Dawson, 2012). The approach should encompass, in a coordinated way, all the necessary activities to maintain a level of security with regard the risk posed by natural hazards (http://www.climchalp.org/) including exchange of information and experience between public bodies, business bodies and citizens.

The availability of detailed and organized information on the geographical and temporal distribution of geo-hydrological events and their consequences, communicated throughout different media channels, is important to implement national communication strategies and preparedness programs. In Italy, detailed information on landslides and floods is available, and catalogues of landslide and flood events with fatalities have been organized and constantly updated (Guzzetti et al., 1994, 2005; Guzzetti and Tonelli, 2004; Salvati et al., 2010, 2012, 2013). For this country, in recent decades, much effort has been exerted to analyse landslide and flood hazards and the associated risk at various geographical scales, from the site specific (local) to the synoptic (national) scale. Despite these efforts, most of these studies remain unknown to the public, that ignores the possible damaging effects that landslides and floods can produce (Salvati et al., 2014). Despite the large number and wide geographical distribution of landslide and flood events, the Italian population receives minimal information and has minimal knowledge on the type, characteristics, frequency, and severity of the harmful events that have occurred in the area where they live, or work. The lack of knowledge is amplified by a weak motivation of the people to be informed and as a consequence they demonstrate weak understanding and perception of geo-hydrological risk (Salvati et al., 2014).

Although, in the last few years, the Italian scientific community has begun to communicate information on geo-hydrological hazards and the associated risks through communication initiatives and thematic websites (http://avi.gndci.cnr.it/; http://sici.irpi.cnr.it/; http://www.isprambiente.gov.it/it/progetti/suolo-e-territorio-1/iffi-inventario-dei-fenomeni-franosi-in-italia; http://www.pcn.minambiente.it/GN/), these often suffer from the lack of effective communication strategies capable of addressing various targets with suitable media. Consequently, the initiatives remain addressed mainly to experts, for specific technical purposes with content and web interfaces that are barely appreciated by a wider audience, and rarely synchronized with social media networks.

Various problems emerged when designing the communication strategy. First, public interest in the issue is important. As Keys (1999) noted, "*It has been apparent for some time that creating community awareness of floods and storms is not easy, (....) Most of the time, people are not particularly interested in them*" (O'Neil, 2004). The core of the problem is to capture public attention and, with long-term actions, familiarise people to the topic. Knowledge-oriented risk communication campaigns on the causes and dynamics of geo-hydrological hazards and their possible consequences to human life, conducted with appropriate frequency, can effectively increase public awareness of geo-hydrological hazards. Second, it is important to find the appropriate mediators to reach the largest number of people. Media represent key mediators of communication between different audiences i.e., the public, scientists, policy-makers, and the operational management (Beck, 1992). They act as *social glue* with respect to the perception and interpretation of natural hazards in heterogeneous societies (Miles and Morse, 2007).

The mission of the POLARIS website is to provide correct and reliable information mainly to media, which will help to further communicate the information to other audiences. In addition, the role of social media should be carefully considered to engage audiences that are typically weakly interested in information on geo-hydrological risk. Thus, efforts were made to improve the link between the POLARIS website and the Facebook page (https://www.facebook.com/CNR.IRPI) of the Istituto di Ricerca per la Protezione Idrogeologica (IRPI, http://www.irpi.cnr.it), of the Italian Consiglio Nazionale delle Ricerche (CNR, http://www.cnr.it), by conveying immediate and concise information on natural disasters using pictures and videos, interspersed with invitations to visit the POLARIS website for detailed information.

Following an overview of the literature on natural hazard's risk communication, in this paper, we describe the website information architecture; we analyse the users' navigation data during the 21-month period since the website was published. Then, we explain possible relations between the maximum access and the context in which they occurred. Finally, we discuss possible future improvement of the site and conclude by summarizing our findings.

2 Background in risk communication and perception

Extensive discussions have been occurred in the past about the most appropriate ways to manage the potential consequences of natural hazards (Scolobig et al. 2015), and governments began to institutionalize disaster risk management processes and practices (McEntire, 2006). More recently, an integrated approach to risk management processes is emerging, encompassing in a coordinated way activities needed to preserve a level of safety with regard the risk posed by natural hazards (http://www.climchalp.org/). Initially associated with environmental management, public health, and emergency management matter, risk communication aims at informing people about a potential hazard and the associated harms (Steelman and McCaffrey, 2012). In the last decade, the relevance of communication is increasing in response to the changes affecting risk governance (Höppner et al., 2010). Accordingly, communication must serve multiple purposes spanning all phases of risk management (Renn 2005) enabling more effective decisions, knowledge-based actions (Höppner et al., 2010), and addressing the exchange of knowledge and attitudes between all the involved actors (i.e., public bodies, private sectors, third sector, citizens). In this context, public participation is crucial, and defined as the co-decision in planning processes designed by others, where the central elements of the participation concept are influence, interaction, and information exchange (Bostenaru, 2004). Starting in the 1990s, extensive public consultation and participation in risk management have focused on re-establishing public trust (Rowe et al., 2004). The appropriate transfer of knowledge between experts and the broader public can be facilitated by effective communication strategies and programs, at national or local level, to align the views of the public with those of the experts (Frewer, 2004). More recently, the increased attention of public institutions to stimulate the participation of citizens in the definition and delivery of public services is leading to the adoption of a citizen-centred risk management approach which takes into account social concerns and the citizens' s perception about risks.

Risk perception is also important to determine the attitude towards risks and, when information campaigns and risk communication strategies are designed, the public perception should be known (Plapp & Werner, 2006). Risk perception is a subjective assessment of the hazard occurrence’s probability and people’s feelings of the consequences (Posner & Armas 2014). A gap between the public’s perception of their own responsibility, and that of authorities in terms of risk reduction was found by Fernández-Bilbao and Twigger-Ross (2009) who, working in England and Germany, found that the public did not perceive that reducing flood risk was their responsibility. Plattner et al. (2006) highlighted a systematic discrepancy between the individual subjective risk evaluation (perceived), and formal risk evaluation procedures. Similarly, in Italy two national surveys conducted to measure the public perception of landslide and flood risk confirmed that in most of the Italian regions the observed perception of the threat did not match the long-term risk posed by landslides and floods to the population (Salvati et al., 2014).

If it is globally accepted that risk perception has strong implication for the success of risk communication. It is also expected that effective risk communication shapes risk perception (Höppner et al., 2010). There are many studies trying to establish which formats of communication may be most effective (e.g., Faulkner and Ball 2007; Fernandez- Bilbao and Twigger-Ross 2009; Kashefi and Walker 2009; Bier 2001). Three phases of risk communication were identified by Leiss (1996) in the USA, including one-way communication, persuasive communication, and two-way communication. As Höppner et al. (2010) reported, the first is primarily used to convey probabilistic information, educate the public at risk, and to gain consent over risk management practices, whereas the second is thought to change people’s risk related behaviours. In the latter phase, all actors should engage with, and learn from each other (Renn, 2005). Risk communication is a complex activity moving from the one-way distribution of information towards a two-way exchange of knowledge and more participatory approach (Höppner et al., 2010). Despite this latter communication approach seems to be more effective, in the review work conducted by Höppner et al. (2010) between all the communication practices posed by governmental authorities, national and local agencies, the majority resulted one-way efforts, focused solely on improving hazard knowledge or raising risk awareness, mostly regarding flood hazard.

3 Nomenclature

In this work, we adopt the terminology and definitions used in Google Analytics. We use the term *session* to indicate the period of time a user is actively engaged with the POLARIS website. All usage data (screen views, events, ecommerce) are associated to a session. *Users* are people who have had at least one session in the selected date range, including new and returning users. *Pageviews* are the total number of pages viewed, including repeated views of the same page. The *source* is the place users were before viewing a POLARIS website content, including a search engine or another website. *Referral traffic* is Google's method of reporting visitors that arrived at a specific site from sources outside their search engine.

4 POLARIS website

The effectiveness of the POLARIS communication strategy relies on the main assumption that the scientific community can play a key role in increasing awareness (Bier, 2001) of individuals and groups on geo-hydrological hazards, and on the type and extent of the risk posed by geo-hydrological hazards to the population. This role should be attained working in two directions: (i) providing mass media (e.g., journalists) with correct and reliable information, which they can communicate (spread) further to the broader civil society, and (ii) adopting less technical and more widely comprehensible language to better engage citizens. Figure 1 shows the communication flow adopted in POLARIS, where the scientists use different communication approaches to mass media, civil protection and local/regional authorities, and to citizens. In this framework, the media captures information from scientists and uses it for communication purposes.

The scientific and technical content of POLARIS is based on a communication strategy that avoids scientific and technical terminology, in favour of a more widely understandable language. For this purpose, consultants experienced in web-communication strategies on natural hazards, info-graphics, and user experience design were involved in the initiative. The consultants' contribution consisted in arranging the messages using intuitive and engaging web interfaces to display data, graphs, tables, video and in carefully considering usability and accessibility of the website to diversified audiences.

POLARIS is based on a well-defined information architecture encompassing six main sections: (i) Reports, (ii) Are you prepared?, (iii) Events, (iv) Alert Zones, (v) Focus, and (vi) Blog. The sections provide different and complementary information, including: (i) periodical reports with analyses of landslide and flood risk to the population of Italy, (ii) suggestions on suitable behaviours to adopt before, during and after potentially damaging events, (iii) data and synthetic analyses of specific geo-hydrological events with human consequences, (iv) visual information on the morphology, geology, and historical damaging events of the Alert

Zones used by the Italian Civil Protection system for issuing warning on meteorological, hydrological, and geomorphological hazards, (v) detailed analyses of relevant topics or specific events with severe consequences, and (vi) blog-posts on landslide and flood events aimed at encouraging citizens' engagement. Fig. 2 shows the POLARIS home page, with specifically-designed images and graphics to help browse the website.

4.1 Structure of the POLARIS website

The "Reports" section illustrates periodic reports on landslide and flood risk to the population of Italy. Reports are published every six months. The last report is available in two formats: (i) an on-line version, and (i) a standard Adobe® PDF (Portable Document Format) file. The on-line report is directly integrated with the CNR IRPI Spatial Data Infrastructure, SDI (Salvati et al., 2013) where the database is located, and has access to data kept updated regularly. Each report contains the list of landslides and floods that occurred in the period (six months, or a year), with information on the date, location, dead and missing persons, injured people, maps, statistics, and an analysis of the landslide and flood events with direct consequences to the population. Statistics are available for different periods of one, five, and fifty years, enabling comparative analyses of the geographical and temporal variations of geo-hydrological risk in Italy.

The "Events" section publishes information on specific meteorological events in Italy, using text, maps, videos, photographs, and drawings. In this section, specific icons were designed to define the type of the geo-hydrological events. A short text containing information on the sites affected, the damage, and the fatalities or casualties is given, with a map showing the location of landslide and flood that affected the population. The "Focus" section publishes information on specific topics, provides analysis for each Italian region, and offers descriptions of single historical or recent catastrophic geo-hydrological events. The "Events" and "Focus" sections jointly inform the population on the extent and severity of geo-hydrological risk in Italy. They also represent an important source of information and data for the mass media.

The "Alert zones" section provides information for 134 Alert Zones defined by the Italian National Civil Protection system to forecast geo-hydrological hazards, including landslides and floods. The section provides the possibility to query a number of information items, and a sidebar offers access to different thematic layers and maps for each Alert Zone.

The "Are you prepared?" section offers information on suitable (and unsuitable) behaviours to adopt before, during, and after a damaging geo-hydrological event. The suggested elementary behavioural rules may save people's lives.

Finally, the "Blog" section encourages bottom-up participation by users, who can post comments on geo-hydrologic hazards and risks.

In the home page, particular focus is reserved to a section called "It Happened Today" (Italian: *Accadde oggi*), which is a daily register of events in which, for each day of the year, POLARIS publishes a short description of relevant events that adversely impacted the population that specific day. This section is directly linked to the CNR IRPI SDI, which daily automatically relates the event to the exact day.

5 Data

We use Google Analytics to monitor the traffic and performance of the POLARIS website, focusing our analysis on (i) channels used, (ii) number of sessions, (iii) number of users, (iv) users viewing single pages or the entire website, and (v) the geographical distribution of the users. We further monitored POLARIS' Facebook page using "Insight" instrument and particularly the number of "likes" given by users, or the number of users who viewed the posts. We also performed an analysis of the type of posts (containing video, link, images, or text alone) that interested more the users, and their origin.

6 Analysis and results

In this section, we describe the analysis performed to identify possible trends of interest to the POLARIS content, and the dependence between peak access values to the website and possible causes that increased the public interest in the website. We also performed similar analysis for the CNR IRPI Facebook page, which is the Institute's most active social network.

6.1 POLARIS website

The analysis of the data series available from Google Analytics for the period of the website publication, from 16 January 2014 to 15 October 2015, allowed to prepare general statistics summarized in **Table 1**, where we listed the data separately for sessions, users, pageviews, and referrals from social networks. We studied the geographical distribution of the users, and the number of pageviews for each section of the website. Results are shown in Fig 3.

Since POLARIS is published in Italian, it is not surprising that the sessions mainly originate from Italy (91%). Figure 3a shows the geographical distribution of the sessions in Italy. The limited percentage of sessions originating from other nations concentrates in the USA, China, Japan, and Germany. Darker and larger dots in the map show the increasing number of sessions, with few areas where sessions are highly concentrated. The largest number of sessions originate from Umbria, where the main office of CNR IRPI is located. Other areas from where POLARIS was accessed frequently include Rome, where the majority of the government offices are located, Milan (Lombardy), Turin (Piedmont), Genoa (Liguria) and Palermo (Sicily). These cities host institutes and researchers who are interested in geo-hydrological issues. Collectively, they also host 6 million people, 10% of the entire population of Italy.

The pie chart in Fig. 3 shows the number of pageviews for the different sections of the website. Not surprisingly, the home page is the most viewed page, containing, in addition to the navigation menu, the "It Happened Today"

(*Accadde Oggi*) section, which is read by many people, most probably because the content changes daily. The second most viewed section is the Report section, which publishes periodic reports on the risks posed to the Italian population by landslides and floods. This section is updated every six months, and allows to download the reports as PDF files. The "Focus" and "Event" sections have similar access percentages. Their content is simple to read and straightforward to understand thanks to explicative figures and maps. The content differs in the subjects; on the Focus page, we discuss in-depth issues related to geo-hydrological hazards and risks, whereas the Events section is dedicated to the description of specific events that caused damages to the Italian population. The "Alerts Zones" and "Are You Prepared?" sections were not accessed as much as expected, although they both contain relevant information and suggestion to help develop suitable behaviours toward disaster resilience.

Monitoring the number of sessions during the 21 months since the website's publication, it was possible to study their temporal distribution. For the purpose, we normalized the number of sessions per day to the daily average number of sessions in the 21-month period (long-term average, 26.9). Results are shown in Fig. 4, where the ratio in the x-axis represents the daily access number divided by the average access number in the observation period. The grey parts of the line show periods below the long-term average, and the blue parts show periods above the long-term average. Inspection of Fig. 4 reveals that there was an increase in the number of sessions (blue dashed line in Fig. 4) and significant variations in the daily distribution are also evident. We note that in 350 days of 2014, 42 days (12%) were above average and 308 days (88%) were under the average. In the 288 days of 2015 (until 15 October 2015), the trend changed, with 182 days (63.2%) above the long-term average (Table 1).

To investigate the possibility of a repeating pattern or periodic signal in the record, the time series with the number of sessions were analysed using the autocorrelation function (ACF). The ACF measures the degree of correlation between a signal and the signal itself shifted by a given lag, and is defined as:

$$ACF = \frac{1}{n\sigma^2}\sum_{1}^{n-k}(X_i - \bar{x})(X_{i+k} - \bar{x}) \quad \text{eq. (1)}$$

where k is the lag (a day in this case), n is the length of the time series (607 days), σ is the standard deviation of the values (i.e., the standard deviation of the number of sessions), $\bar{x}$ is the average of the values (i.e., the average of the number of sessions), and X_i is a given value of the time series (the value of the number of sessions of the day i). Due to the evident increasing trend (non-stationary) in the average number of sessions during the observation period (dashed line in Fig. 4), data have been detrended. The trend has been defined fitting a curved line (Fig. 5a) obtained applying a kernel smoother based on a normal weight function in a bandwidth of 100 days. Figure 5b shows the coefficients (ACF) calculated per different lag times. The autocorrelation value varies between 1 and -1, and the area between the blue dashed lines represents non-significant autocorrelation values. The analysis revealed that the value of ACF decreases when the lag k (days) increases, and that a marginally significant value of autocorrelation can be observed only for a lag of seven days (a week). However, because the correlation value is not significant at 14 or 21 days, we conclude that the time series of the number of sessions of the POLARIS website does not show evidence of a periodic pattern. The same analysis was performed detrending the data fitting a linear interpolation (dashed line in Fig. 4). Again, the analysis did not reveal a periodic trend.

To gain a better understanding of the temporal distribution of the user access, and to identify peak values, we used the daily number of users and pageviews obtained from Google Analytics. We then related the peak values to several factors, including (i) the occurrence of harmful geo-hydrological events, (ii) the daily early warnings from the Italian National Department of Civil Protection, (iii) the publication of new content in the web site, (iv) the publication of press releases that used our data, and (v) the promotion of the website through media.

Figure 6 shows the daily user statistics (Fig. 6a), and a comparison between users and number of pageviews (Fig. 6b), for the 21-month period of website publication, with icons located to identify possible relations. We note how the relation between the peak values and the occurrences of the harmful events until December 2014 became increasingly less relevant since the early months of 2015. In particular, during the period ranging from 15 January to 31 December 2014, the majority of the peaks were registered in the interim of the harmful event occurrences, i.e., on 16-22 January (25 users, 51 sessions, 425 pageviews), when the two Italian regions of Liguria and Emilia Romagna were hit by heavy rain, which caused two fatalities, and a railway interruption to France was caused by a landslide. Similarly, on 6-15 October, an event hit Liguria and other regions in the North of Italy causing four deaths and generating a peak with 44 users, 48 sessions and 115 pageviews. Other correspondences were identified with the icons used to indicate the events, the same as those we used to indicate the type of event (landslide, flood and geo-hydrological events) on the website. Other peak values were related to the publication of new contents. A peak occurred on 15 September 2014 due to a post dedicated to a relevant paper published by the CNR IRPI researchers (38 users, 50 sessions and 110 pageviews); it also occurred on 19 November, due to the publication of the "Are you prepared?" section, explaining how to behave during geo-hydrological events (80 users, 94 sessions and 192 pageviews). The maximum value was registered when the website was promoted through television by a meteorologist during an evening national broadcasting program (338 users, 362 sessions and 951 pageviews).

Another important value corresponds to the press release launch on 13 January 2015, to disseminate the annual report on the geo-hydrological risk to the population; this was prepared for 2014 and available in the Report section (119 users, 141 sessions, 436 pageviews). After these announcements, the site has begun to be consulted by journalists and technicians of different government offices and agencies working on land management. This finding is confirmed by the publication of POLARIS's maps and statistics in national newspapers and in on-line media corresponding to major event occurrences that captured the interest of the public and to the citation of the website URL in reports published by national or regional institutions. The finding means that POLARIS offers quick and easy access to essential information on geo-hydrological hazards and risks.

During 2015, the relation with the occurrence of the events decreased; however, the relation with the publications of new content became more significant. Analysing the sources where the POLARIS traffic originates daily, we found that other peaks were the consequences of the daily activity of users from government offices or agencies. In Fig. 6b, we plotted the users and the pageviews data together. The mean number of pages per user, in the entire period, was 2.5; however, the inspection of Fig. 6b reveals that the variability of this ratio is very large, and days exist when the mean value has been largely exceeded. This result demonstrates that people browse through the site's pages before leaving.

We maintain that the relation to the occurrences of harmful events depends on the new, specific content and the videos that are published during or immediately after harmful events not only on POLARIS but also on the CNR IRPI social network pages from which people can directly access POLARIS.

6.2 CNR IRPI Facebook

Each new content item published on POLARIS was shared via Facebook and Twitter, the two most popular social networks in Italy. We use Facebook and Twitter CNR IRPI accounts to disseminate simple and immediate messages addressing the geo-hydrological hazards. In particular, the objective is to increase the public awareness of the frequency and proximity of the geo-hydrological events and to disseminate media showing hazardous behaviours that pose serious, fatal risks to people.

Analysing the number of referrals from the social networks, corresponding to 14% of the total, we found that the majority (80%) originates from Facebook. The simpler modality of sharing content offered by Facebook with respect to a website makes the publication of links and videos easier. Social media is very widely used when a severe weather condition is occurring. Therefore, it is relevant to compare the number of people who have viewed the content of the CNR IRPI Facebook page with the occurrence of extreme rainfall conditions and or severe warning declarations of the Italian National Department of Civil Protection. For the purpose, we used Facebook statistics because it is the social network from which the majority of the access to POLARIS was registered.

To define the extreme rainfall conditions that occurred in Italy, we exploited an analysis based on hourly rainfall measurements. The analysis was performed in the 84-day period between 1 August and 23 October 2015. We exploited sub-hourly rainfall measurements by more than 2000 rain gauges distributed over the entire Italian territory. According to the method described by Rossi et al. (2015), the empirical cumulative distribution function (ECDF) of the cumulative rainfalls has been modelled for each rain gauge. The function allows the calculation of the non-exceedance probability for any given cumulative rainfall and for a set of predefined durations (3, 6, 12, 24 h), which estimates the non-exceedance probability of the cumulated rainfalls, for each rain gauge. To obtain a continuous representation for the entire Italian territory, the rain gauge data have been interpolated using an inverse distance weighted (IDW) algorithm. This process resulted in a set of four (one for each duration) raster maps that show the non-exceedance probability of the cumulative rainfalls. The maps have been analysed to identify the days when at least 10% of the Italian territory has been interested by a non-exceedance probability of 80%. This probability value corresponds to cumulative rainfall events that can be defined as extreme events and that could have triggered geo-hydrological events.

The results of the analyses showed that, in the considered period, the extreme conditions occurred six times for a duration of 3 h, 12 times for a duration of 6 h, 15 times for a duration of 12 h, and seven times for a duration of 24 h. We plotted these extreme conditions in the daily distribution of Facebook users shown in Fig. 7. We observed that extreme conditions, represented by blue dots on the basis of their duration, occurred on 16 days (19% of the days in the investigated period), grouped into 11 meteorological events that lasted one or more days. In the graph, we plotted with a red icon the days for which it is known that severe warnings of the Italian National Department of Civil Protection were enacted; the days when severe geo-hydrological events occurred are shown in orange in Fig. 7. Analysing the four highest peaks, the first (September 16, 2060 peak value) corresponds to the publication of videos and images regarding the Piacentino (Emilia-Romagna region) flood event of September 13-14, 2015, which caused three deaths and serious damage. The second event on October 6 corresponds to the publication of a re-visit of the Vajont disaster (the most disastrous landslide event that has occurred in Italy) in POLARIS at a date near the event's anniversary; this was immediately shared with Facebook. A few days later, on October 10, the publication of a video showing cars dragged by the water flow caused by heavy rainfall in the Tyrrhenian Messina area (Sicily region) caused a 3916 peak value; finally, the peak of October 21 related to the publication of content that triggered a strong debate. Although the 3-month investigation period is very short, we can observe that, apart the first half of August, there is suitable correspondence with the rainfall extreme conditions and the peak values of Facebook access. In addition, the peak values correspond to the content published and that people shared.

7 Discussion

In Polaris we mean risk communication as a two-way exchange of related information and knowledge on natural hazards and associated risk for the population. The Blog section of the website is mainly encouraging bottom-up feedback through visitors' s comments. The link to Facebook stimulates more feedback from citizens who upload pictures and make post on Facebook. This means that participation, whose central elements are influence, interaction and information exchange (Bostenaru, 2004), is mainly facilitated by the link with Facebook. However, the website Blog section remains less active than we expected, for at least two reasons: first, in Italy, the perception of geo-hydrological hazards is still very weak, people show less interested toward these geo-hydrological events than to other natural hazards such as, seismic risk (Salvati et al., 2014). Second, people do not know how a geo-hydrological event can hit them. People are interested to actively participate through the blog section mainly when a particularly disastrous event is occurring, and in such a case, by simply uploading videos and pictures rather than asking for explanation or advices. This means that, despite many institutions are making efforts to increase the public understanding of geo-hydrological risk through nationwide awareness campaigns (e.g. I do not risk, http://iononrischio.protezionecivile.it/), people still ignore how a large part of the Italian territory suffers of geo-hydrological risk. Such an underestimation of the possible risks, the high confidence in the local administrators towards which citizens delegate their personal safeness are all factors that impede an effective risk communication.

It is important to highlights that Polaris offers a knowledge-oriented risk communication which tends to operate continuously and does not regard the warning messages released in the event of a disaster. The communication efforts seeks to change the people's attitudes to the geo-hydrological hazard that they may have encountered giving many examples of what had happened before. People will not react to risk warnings if foregoing communication has not motivated and prepared them.

For this purpose, we are going to evolve the Blog section of Polaris which is the most relevant for stimulating public participation at any moment. In particular, we plan to integrate other relevant social media, such as Instagram and Pinterest, stimulating the sharing of images and videos and the associated tags and comments. For encourage more resilient behaviours during the occurrences of hazardous events, we would stimulate the usage of video through the YouTube and Vimeo channels that we can comment for feedback and/or advices. Finally, we are going to create new synergies with the "I do not risk" campaign and website of the Italian Department of Civil Protection, which will increase traffic, information exchange and, as such, strengthen the risk perception by the Italian population.

8 Concluding remarks

The analysis we conducted in the 21 months after publication of the POLARIS website allowed the following considerations. The geographical distribution of people interested in the published topics is widespread throughout Italy, with a few geographical areas in which sessions are highly concentrated. After the home page, the most viewed website section is the Report, followed by the Focus and Events sections. In a period shorter than two years, the number of sessions has generally increased; however, we observed that, in 2015, the most significant positive step occurred. The analysis of the time series, performed to identify possible periodical signals in the daily distribution of sessions, did not highlight any relevant information.

Monitoring the access of users to the POLARIS website and the number of pageviews during its publication period from 16 January 2014 to15 October 2015, we noticed that, frequently, the peak values correspond to the occurrence of particularly damaging geo-hydrological events. However, inspection of the daily statistics available for CNR IRPI Facebook demonstrated that a correspondence exists between the extreme rainfall events and the number of people who have viewed the content Facebook page. This finding was expected because CNR IRPI Facebook page's objective is to capture the attention of the public at large by proposing content that satisfies their curiosity and their immediate interest during extreme events, which increases the number of followers. Because the Facebook page is linked to POLARIS, an increase in Facebook followers can trigger a gradual increase in the number of people interested in more structured and specialized content and data on geo-hydrological topics such as those published on POLARIS. Similarly, the specificity, scientifically based, of the POLARIS content, which is focused on geo-hydrological hazard and risk, became a source of information for journalists and media operators. The growth of user access when media operators publicized the website, suggested that we enhance our collaboration with scientific journalists by linking traditional (e.g., television) and social media to further enlarge the awareness of the website, and to better explain to users how to exploit the website information.

The POLARIS initiative demonstrates how the scientific community can implement different communication strategies to enhance an effective process that helps different audiences to understand (i) how risks associated with geo-hydrological hazards are estimated and (ii) how risks can be reduced by increasing knowledge to the population.

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9 References

Beck, U.: Risk Society: Towards a New Modernity, Published in association with Theory, Culture & Society, SAGE Publication, 260 pp., 1992.

Bier V.M.: On the state of the art: risk communication to the public, Reliab. Eng. Syst. safe., 71, 139-150, doi:10.1016/S0951-8320(00)00090-9, 2001.

Bostenaru Dan, M.D.: Review of retrofit strategies decision system in historic perspective, Nat. Hazards Earth Syst. Sci., 4, 449–462, doi:10.5194/nhess-4-449-2004, 2004.

Faulkner, H. and Ball D.: Environmental hazards and risk communication, Environmental Hazards, 7, 71-78, doi: 10.1016/j.envhaz.2007.08.002, 2007.

Fernández-Bilbao A. and Twigger-Ross C.: Improving Response, Recovery and Resilience, Improving Institutional and Social Responses to Flooding, Science Report SC060019, Work Package 2, Environment Agency, Bristol, 134 pp., 2009.

Frewer, L.: The public and effective risk communication, Toxicol. Lett., 149, 391-397, doi:10.1016/j.toxlet.2003.12.049, 2004.

Jonkman S.N. and Dawson R.: Issues and Challenges in Flood Risk Management - Editorial for the Special Issue on Flood Risk Management, Water, 4, 785-792, doi:10.3390/w4040785, 2012.

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, doi: 10.1007/BF02400865, 1994.

Guzzetti, F., Stark C.P., and Salvati, P.: Evaluation of flood and landslide risk to the population of Italy. Environ. Manage., 36, 15-36, doi:10.1007/s00267-003-0257-1, 2005.

Höppner, C., Bründl, M., and Buchecker, M.: Risk communication and natural hazards. WP5 Report, Swiss Federal Research Institute WSL, available at: http://caphaz-net.org/outcomes-results/CapHaz-Net_WP5_Risk-Communication.pdf, 2010.

Höppner, C., Whittle R., Bründl, M., and Buchecker M.: Linking social capacities and risk communication in Europe: a gap between theory and practice? Nat. Hazards, 64, 1753-1778, doi: 10.1007/s11069-012-0356-5, 2012.

Kashefi, E. and Walker, G.: How the Public and Professional Partners Make Sense of Information About Risk and Uncertainty - Literature Review, Science Project SC070060, Environment Agency, Bristol, 2009.

Leiss, W.: Three phases in the evolution of risk communication practice, Ann. Am. Acad. Polit. Soc. Sci., 545, 85-94, doi: 10.1177/0002716296545001009, 1996.

Nenciu Posner C. and Armas I.: Conceptual approaches concerning risk, vulnerability and adaptation, Riscuri şi Catastrofe, 15(2), 7-24, 2014

McEntire D.: Disaster Response and Recovery: Strategies and Tactics for Resilience. Wiley, Hoboken, 2006.

Miles, B. and Morse S.: The role of news media in natural disaster risk and recovery, Ecol. Econ., 63, 365-373, doi:10.1016/j.ecolecon.2006.08.007, 2007.

O'Neill, P.: Developing a risk communication model to encourage community safety from natural hazard, available at: http://www.ses.nsw.gov.au/content/documents/pdf/research-papers/42904/Developing_a_risk_communication_model.pdf, 2004.

Pearce, L.D.R.: An Integrated Approach For Community Hazard, Impact, Risk and Vulnerability Analysis: HIRV. PhD thesis, Univ. of British Columbia, Vancouver, B.C., Canada, 2000.

Petley, D.: Global patterns of loss of life from landslides, Geology, 40(10), 927-930, doi: 10.1130/G33217.1 , 2012.

Plapp T., and Werner U.: Understanding risk perception from natural hazard: Example from Germany, in: Risk21 - Coping with Risks due to Natural Hazards in the 21st Century, Ammann W., Dannenmann S., Vulliet L. (eds.), Taylor and Francis, London, 101- 108, 2006.

Plattner Th., Plapp T., Hebel B.: Integrating public risk perception into formal natural hazard risk assessment, Nat. Hazards Earth Syst. Sci., 6, 471–483, doi:10.5194/nhess-6-471-2006, 2006.

Renn, O., White paper on Risk Governance: Towards an integrative approach, International risk governance council, Geneva, 2005

Rossi, M. Torri, D., and Santi, E.: Bias in topographic thresholds for gully heads. Nat. Hazards, 79, Supplement 1, 51–69, doi: 10.1007/s11069-015-1701-2, 2015.

Rowe, G. and. Frewer L.J.: A Typology of Public Engagement Mechanisms. Sci. Technol. Hum. Val., 30(2), 251-290, doi: 10.1177/0162243904271724, 2005.

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.

Salvati, P., Bianchi, C., Rossi, M., and Guzzetti F.: Flood Risk in Italy, in: Changes of flood risk in Europe, Kundzewicz, Z. (ed.), IAHS Special Publication 10, IAHS Press, UK, 277-292, 2012, available at http://www.iahs.info/bluebooks/SP010.pdf, 2012.

Salvati P., Marchesini I., Balducci V., Bianchi C., Guzzetti F.: A New Digital Catalogue of Harmful Landslides and Floods in Italy, in: Landslide Science and Practice, Proceedings of the Second World Landslide Forum, Rome, 19-25 September 2011, edited by Margottini C., Canuti P., and Sassa K. (eds.), Vol. 3: Spatial Analysis and Modelling, 409-414, ISBN: 978-3-642-31309-7, 2013.

Salvati, P., Bianchi, C., Fiorucci F., Giostrella P., Marchesini I. and Guzzetti F.: Perception of Flood and Landslide Risk in Italy: a Preliminary Analysis. Nat. Hazards Earth Syst. Sci., 14, 2589-2603, doi: 10.5194/nhess-14-2589-2014, 2014.

Scolobig A., Prior T., Schroter D., Jorin J., and Patt A.: Towards people-cantered approaches for effective disaster risk management: Balancing rhetoric with reality, International Journal for Disaster Risk Reduction, 12: 202-212, doi: 10.1016/j.ijdrr.2015.01.006, 2015.

Steelman T.A. and McCaffrey S.: Best practices in risk and crisis communication: Implications for natural hazards management, Nat. Hazards, 65, 683-705, doi: 10.1007/s11069-012-0386-z, 2013.

Vasterman, P., Yzermans C. J., and Dirkzwager A.: The role of the media and media hypes in the aftermath of disasters, Epidemiol. Rev., 27, 107-114, doi: 10.1093/epirev/mxi002, 2005.

Figure captions

Figure 1. The POLARIS communication flow.

Figure 2. The POLARIS Home Page (http://polaris.irpi.cnr.it). Violet boxes show English translation of original Italian text.

Figure 3. General statistics from Google Analytics for the 638-day period from 16 January 2014 to 15 October 2015. (a) map showing the geographical distribution of the sessions in Italy. (b) Pie chart shows number of pageviews for different sections of the website.

Figure 4. Daily average access number to the POLARIS website in the 638-day period from 16 January 2014 to 15 October 2015.

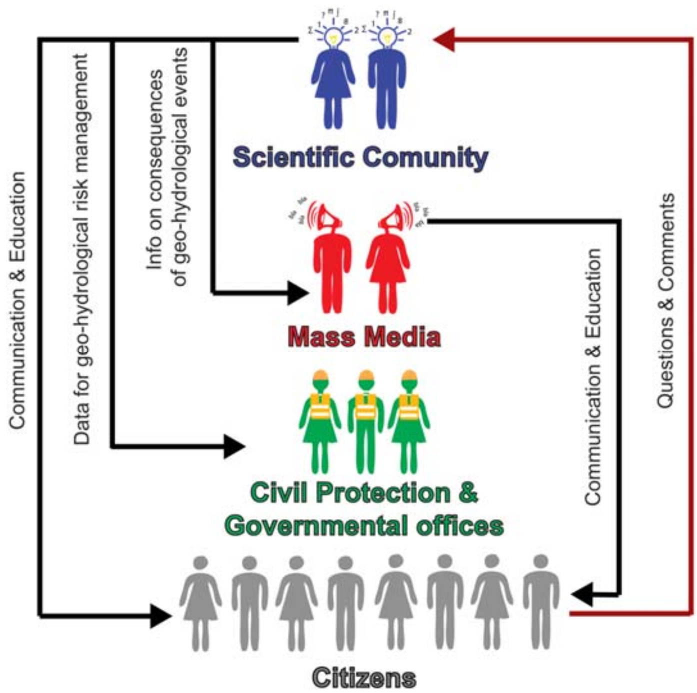
Figure 5. (a) Plot shows the original data (points) and the line (violet line) describing its trend. (b) Chart shows Autocorrelation Coefficient Function (ACF) calculated using the time series of the number of sessions of the POLARIS website.

Figure 6. (a) Daily number of users of the POLARIS web site in the 638-day period from 16 January 2014 to 15 October 2015. (b) Daily number of pageviews (violet line) and users (blue line) in the same period.

Figure 7. Number of unique Facebook page users. Days with extreme rainfall conditions are marked by blue dots, days with the major geo-hydrological events are marked by orange diamonds, and days with severe warning declarations are marked by red dots.

	Statistics	Number
Sessions	Total	17,159
	Daily average	26.9
	Average duration	00:02:38
	Days above average (2014)	42 (12%)
	Days above average (2015)	182 (63.2%)
Users	Total	11,529
	Daily average	23.3
	Days above average (2014)	37 (10.6%)
	Days above average (2015)	180 (62.5%)
Pageviews	Total	44,032
	Daily average	69
	Average per session	2.6
	Days above average (2014)	68 (19.4%)
	Days above average (2015)	165 (57.3%)
	Home page	14,284
	Report section	5976
	Focus section	5509
	Significant Event section	5489
	Blog section	2550
	Alert Zones section	2108
	Are You Prepared? section	1894
Referrals	Total from Social Network	2394
	Facebook	1917 (80%)
	Twitter	430 (18%)
	Other Social Networks	47 (2%)

Table 1: **POLARIS website general statistic for sessions, users, pageviews, and referrals from social networks, calculated using Google Analytics data.**



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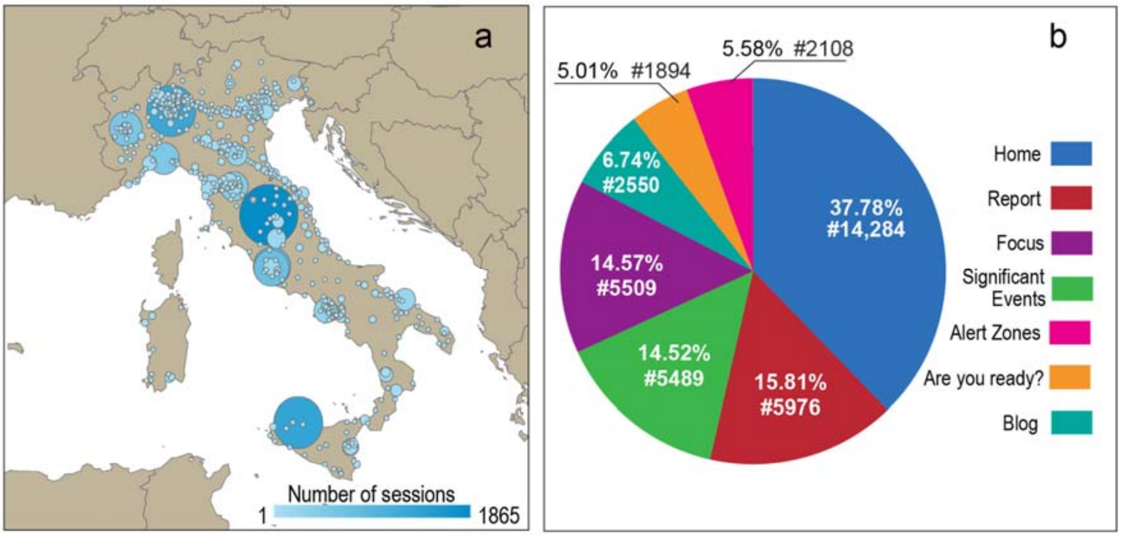

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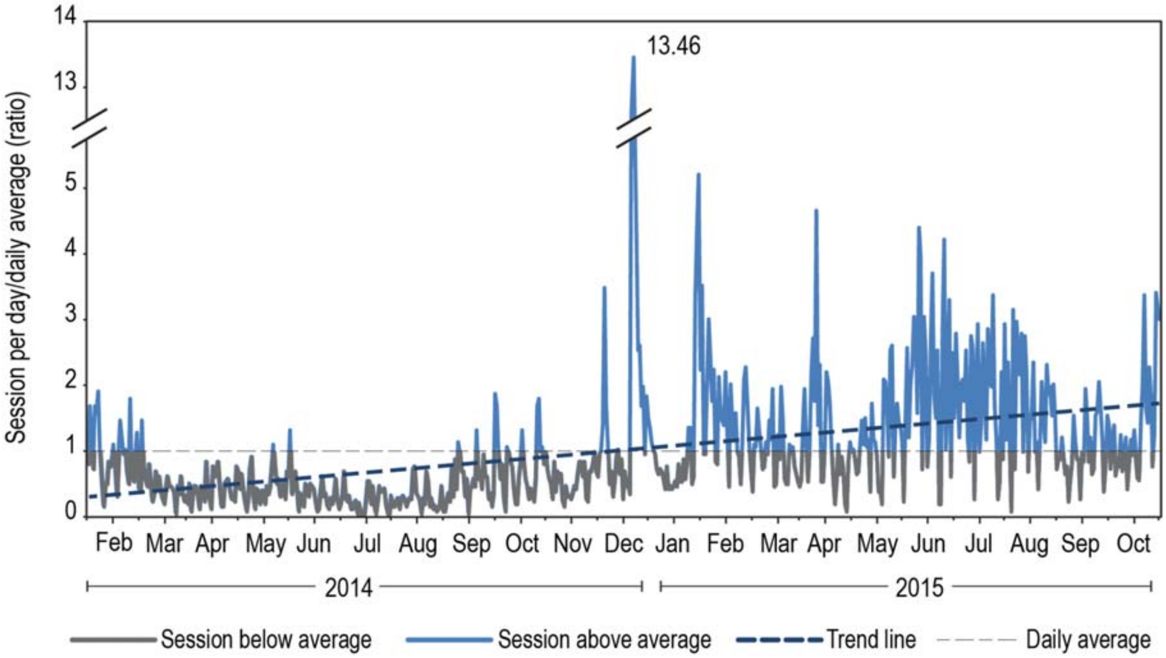

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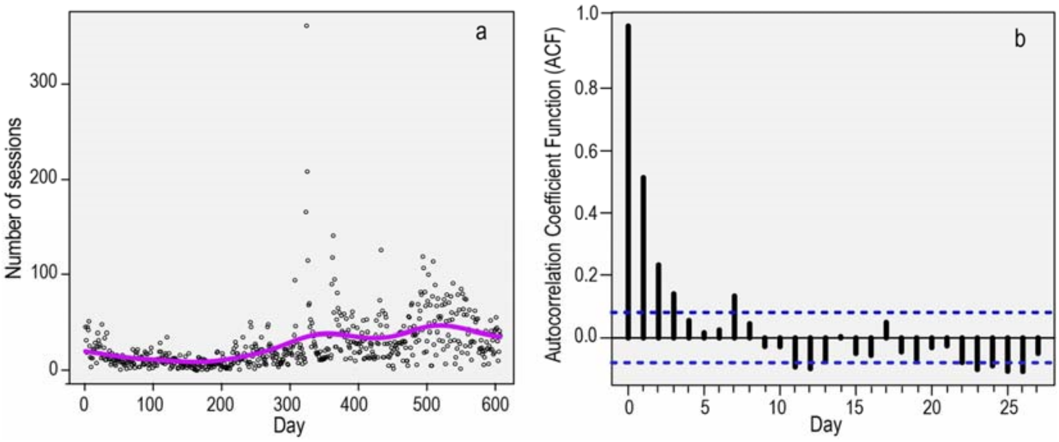

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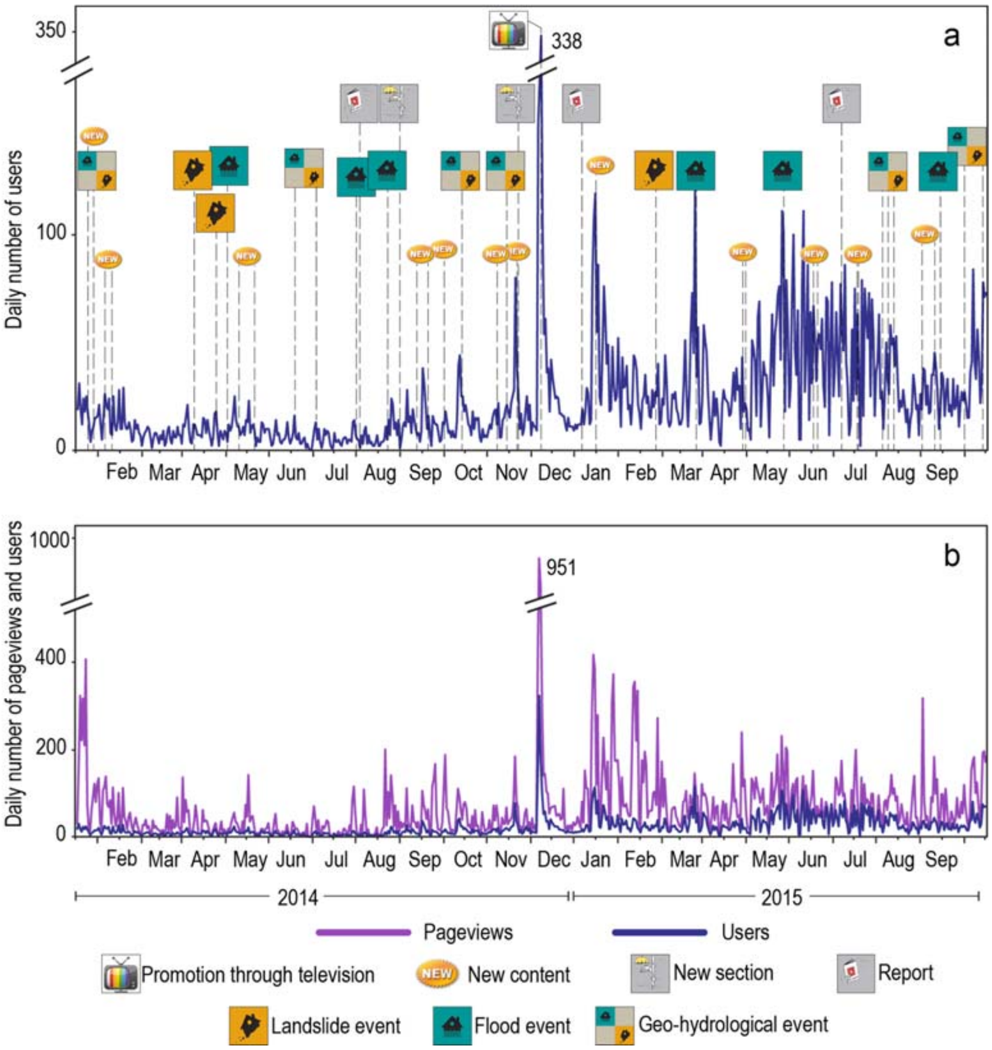

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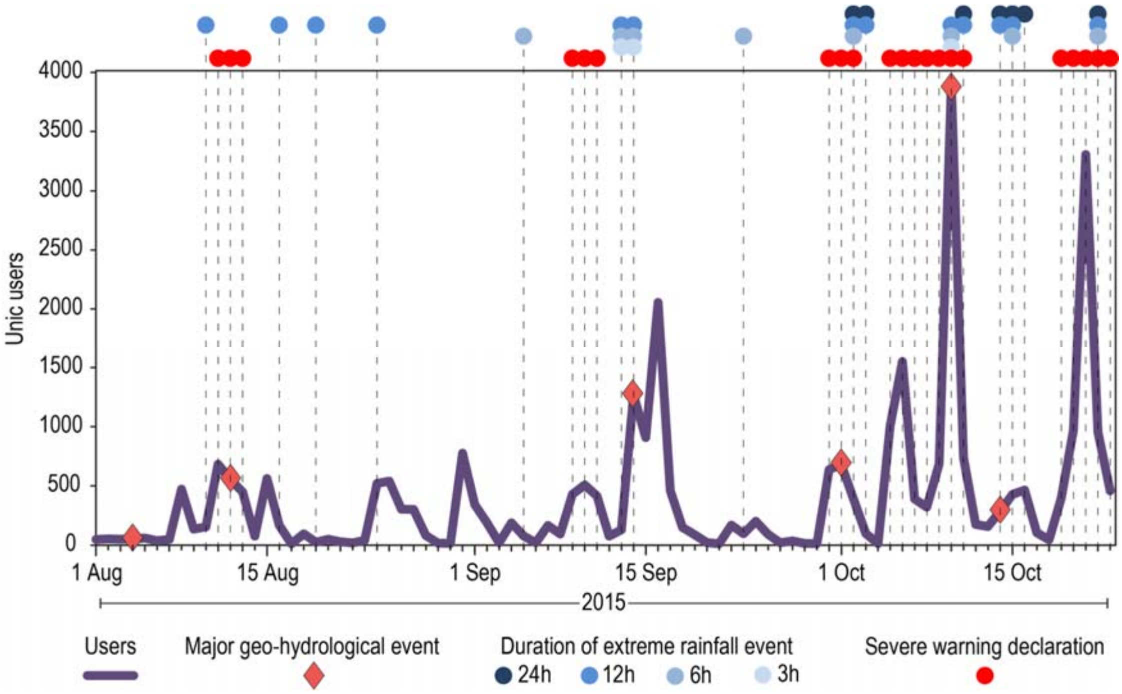

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