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2. ABSTRACT

This report presents a general framework for conducting post flood surveys for collecting data and observations concerning the hydro-morphological response, with the final aim to integrate these data into a coherent methodology for flood hazard assessment. Such actions are particularly important for (small) mountain basins, often lacking adequate monitoring systems. For this, post-flood surveys are important data-collecting strategies which play a critical role in the data gathering of key processes. The complex pattern of an extreme meteorological event and the high spatial variability of the morphological responses require the use of a wide range of measurements and observational methods.

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4. Post-flood survey strategies and structure of event report

High intensity flood events can significantly affect channel morphology, inducing drastic bed level adjustments and/or dramatic planform adjustments in unconfined settings. Several studies have documented morphological changes occurring in response to flood events, and a wide range of responses has been reported (e.g. Lapointe et al., 1998; Magilligan et al., 1998; Fuller, 2008; Arnaud-Fassetta, 2013; Thompson and Croke, 2013). However, few studies provide high quality and quantitative morphological change data related to very infrequent extreme floods.

Predicting the morphological impacts on the fluvial system of high intensity floods in small-medium basins is still challenging due to lack of observations concerning both the hydro-meteorology of these floods (precipitation patterns and flood response) and the morphological response. For this, post-flood surveys are important data-collecting strategies which play a critical role in the data gathering of key processes. The complex pattern of an extreme meteorological event and the high spatial variability of the morphological responses require the use of a wide range of measurements and observational methods. Integrated and interlinked approaches can be the key for a better understanding and prediction of such events and their morphological responses.

A range of methods has been used to analyse the geomorphic responses to large floods. These mainly include: (i) reconstruction of the hydrological event by various sources of data and intensive post-event campaigns (e.g. Gaume et al., 2004; Marchi et al., 2010); (ii) analysis of flood hydraulic variables (e.g. Benito, 1997; Thompson and Croke, 2013); (iii) event landslide mapping and evaluation of coupling/decoupling with the channels (e.g. Guzzetti et al., 2012); (iv) dynamics of large wood (e.g. Lucía et al., 2015); (v) geomorphic and sedimentological analysis of flood deposits (e.g. Wells and Harvey, 1987; Macklin et al., 1992); (vi) quantification of channel changes by field or remotely-sensed data (e.g. Arnaud-Fassetta et al., 2005; Krapesch et al., 2011; Thompson and Croke, 2013) and morphological sediment budgeting (e.g. Fuller, 2008; Milan, 2012; Thompson and Croke, 2013). Notwithstanding this variety of methods and approaches, a general framework for conducting post flood surveys for collecting data and observations concerning the hydro-morphological response and to integrate these data into a coherent methodology for flood hazard assessment is still missing.

4.1 Post event survey of the hydro-morphological response in small- and medium size basins

A range of different approaches and methods can be used for the analysis of geomorphic responses to a flood event. A summary of the spatial scales and methods related to the various components of an overall analysis of the geomorphic response to a flood event is reported in Figure 8, while additional information is also provided in the following sections

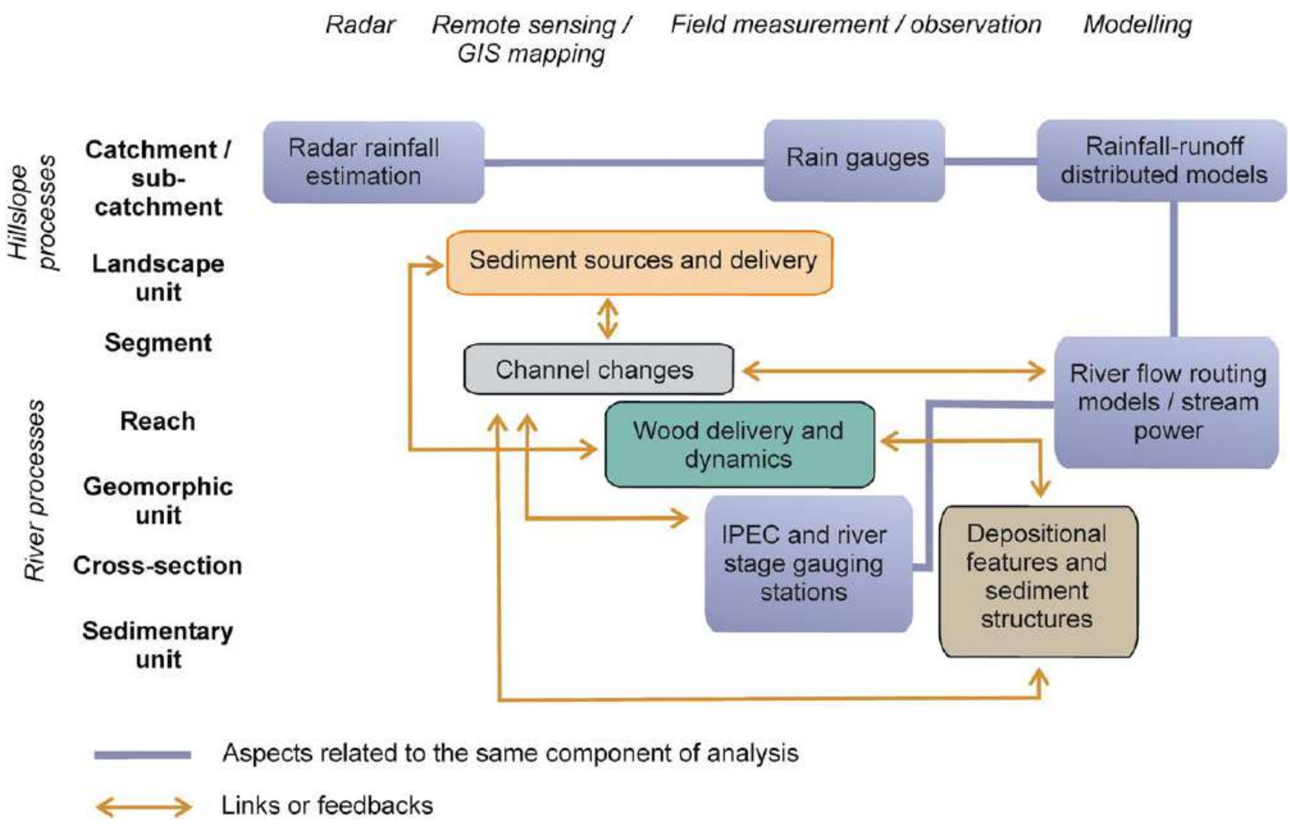

Figure 1: Schematic diagram of spatial scales, approaches, and coupling of process controls on the flood timescale

4.2 Hydrological analysis

As a consequence of the limited spatial and temporal scales, which characterize the flash-flood events, the conventional monitoring networks for rainfall and river discharge are often too sparse for collecting data suitable for the analysis of these events. This has prompted the development of a monitoring strategy that integrates data from hydrometeorological networks with data specifically collected by means of Intensive Post-event Campaigns (IPECs) (Gaume et al., 2004; Borga et al., 2008; Braud et al., 2014). The methodology applied in this study for flood documentation and analysis has been detailed in previous papers (Gaume and Borga, 2008; Marchi et al., 2009). We briefly recall here the main components:

(i) post-flood assessment of peak discharge in ungauged channels through the survey of high water marks in specific river cross sections, and the application of hydraulic equations and models;

(ii) reconstruction of the time evolution of the flood by means of interviewing eyewitnesses and by the collection of documentation (newspapers, reports, videos);

(iii) use of carefully corrected radar rainfall estimates to represent the space–time variability of the triggering rainfall;

(iv) use of distributed hydrological models to evaluate the consistency of rainfall and discharge data.

4.3-Sediment sources and delivery

Landslide inventory maps (Guzzetti et al., 2012) are the core element in the analysis of sediment entrainment and delivery. The comparison and analysis of pre- and post-event aerial photographs, complemented by field checks, is a valuable approach for the preparation of inventory maps of landslides triggered by the rainstorm, their classification into main typologies, and visual recognition of the linkages with stream channels

The connectivity (or disconnectivity) between sediment sources on the hillslopes (especially landslides) and the channel network is of utmost relevance for the assessment of the geomorphic processes involving the channels. Inventory maps of event landslides and other sediment sources can be crossed with catchment-scale maps of structural connectivity (e.g., Cavalli et al., 2013) to rank the landslides according to their role as sources of sediment delivered to the channels

4.4-Wood transport and deposition

In forested mountain catchments, mass wasting processes and bank erosions cause the input of massive large wood volumes into the channels during flash floods. Such wood material has the potential to obstruct critical channel sections such as bridges, thereby triggering or at least exacerbating inundation processes, as has occurred during many events in the last decades (Comiti et al., 2016). A forensic approach aimed at investigating the origin of recruited wood volumes (e.g., evaluation the relative proportion of wood delivered from hillslopes and from floodplains/islands by delineating source areas through pre- vs post-event orthophotos, integrated by standing forest biomass estimation) has proven to be feasible and highly informative for risk mitigation strategies (Borga et al., 2019). However, in order to estimate a volumetric wood budget at the event scale the quantification and localization of wood volumes deposited along the channels during a given event must be carried out as well, either by means of field surveys or by applying proximal/remote sensing approaches (Lucia et al., 2015). In addition, data of wood removed from channels during emergency and post-emergency operations by civil protection agencies are crucial to obtain reliable wood budget

4.5-Morphological and sedimentological processes and features

Observation and interpretation of geomorphic and sedimentary features and processes conducted after and possibly during the flood event are fundamental to developing a better understanding of the mechanisms responsible for channel changes. To this purpose, post-flood field reconnaissance allows one for the collection of qualitative information on the processes (e.g. sediment transport, bank erosion) responsible for the morphological changes. Sedimentological analysis of flood deposits is performed through the qualitative field characterization of the texture and structure of flood deposits. It is thus possible to interpret the depositional mechanisms and hydraulic conditions responsible for the bed structure, bedforms, and geomorphic units created during the event.

Post-event geomorphological and sedimentological observations permit recognizing the type of flow processes that occurred during a flood in a mountain streams, Different flow processes have different impacts on the channel evolution and require different estimation methods, which makes it critical their proper recognition. While the most common flow process is represented by water floods with suspended load and bedload, in some steep headwater stream, high sediment concentration – resulting from channel and bank erosion or from lateral supplies, can lead to the occurrence of debris floods or even debris flows.

4.6-Morphological channel response

Channel widening is one of the most frequently investigated features when analyzing the channel response to floods (see Ruiz-Villanueva et al., 2023 for a recent meta-analysis). The assessment of channel widening requires a comparison of pre- and post-flood channel planform, derived from topographic surveys or aerial photos. As a consequence, post-flood data acquisition, in addition to the geomorphological and sedimentological observations described in the previous section, must include the collection of aerial imageries (stereopairs of aerial photos and/or orthophotos) that permit determining channel widening and other morphological changes caused by the flood.

The analysis of changes in channel bed elevation (channel bed erosion and within-channel sediment deposition) is more data-demanding than the analysis of channel widening. Pre- and post-flood high-resolution topographic data are necessary for assessing the bed elevation changes: such data usually derive from LiDAR surveys. LiDAR surveys are highly recommended after floods as they permit DEM differencing with pre-flood topographic data if a pre-event LiDAR is available. Regardless of the availability of pre-event LiDAR data, a post-flood LiDAR survey is a highly valuable source of information on the topography shaped by the flood.

For the analysis of channel changes, the investigated streams are generally divided into a series of relatively homogeneous reaches in terms of channel morphology, lateral confinement, hydrology and other characteristics, along which boundary conditions are sufficiently uniform and the river maintains a near-consistent set of process–form interactions (Brierley and Fryirs, 2005; Rinaldi et al., 2013, 2015). This segmentation of the channels permits the collection of homogeneous data that can be used for the analysis of channel changes at the reach scale. Among the methods to recognize the factors controlling channel widening, multiple regression analysis is probably the most common (e.g. Surian et al., 2016).

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