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Quantitative method to distinguish flood and flash flood as disasters

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Abstract:

The Civil Defense in Brazil needs to identify and differentiate floods and flash floods for the official registry. This study aims to quantitatively define and differentiate between floods and flash floods. Floods and flash floods are characterized by factors including the speed of water level rise and water flow; the hydrological response time to a rainfall event and the extension of the flood affected area. The hydrological definitions are ambiguous and make it difficult to distinguish between a flood and flash flood event. Even though some papers have mentioned that flash floods occur within 6 hours after an intense rainfall event, there is still certain subjectivity. This study proposes the use of the Operation Efficiency Index (OEI) as a quantitative means to distinguish between a flood and flash flood event. The OEI is defined as the rate of the time of flood concentration (*Tc*) to the operational response time (*To*) in the institution-community system. *Tc* and *To* are associated with environmental and human factors, respectively. When the OEI value is smaller than one, then flash floods occur. Otherwise the event can be defined as a flood.

KEYWORDS flood; flash flood; Operation Efficiency Index

INTRODUCTION

In Brazil, the National, State and Municipal Civil Defenses are governmental organisations responsible for disaster management. One of the most important services of the Civil Defense is the official registry of natural disaster occurrences. As part of this registration process, a damage assessment form (AVADAN) is used to record each natural disaster. According to the Brazilian legislation, the Municipal Commissions of Civil Defense (COMDEC) is responsible for completing the AVADAN form. It can be a good registration method if it is filled out in a correct way for all the types of disasters, because the disasters registry can contribute significantly to the scientific research and the planning that make part of the actions of the pre-event and post-event stages in disaster management.

The first information to be filled out on the AVADAN is the disaster type and its code (CODAR). In the CODAR, the Civil Defense classifies the floods into four types: gradual flood, flash flood, urban pond and coastal flood. Gradual floods and flash floods are the most commonly registered floods. Since each type requires different structural and non-structural measures, it is important to identify which type of flood (i.e. gradual flood or flash flood) has occurred. However, to identify them is not a simple exercise. Georgakakos (1986) commented that there is no sharp distinction between the flood and the flash flood. Due to different perceptions and terminologies used for the floods, there is a difficulty in standardizing the flood categories (Few *et al.*, 2004). The complexities of the floods as natural phenomena generate several definitions both for floods and for flash floods. The characteristics of the floods as disasters still more increase the number of definitions.

The objective of this study is to review various definitions on the flood and the flash flood, and to propose the Operation Efficiency Index (OEI) to quantitatively distinguish between these events. Though floods are typical natural phenomena, the interactions between the flood hazard and the human system result in the flood disasters. The human system is frequently the most important factor in disaster assessment. The proposed distinction method through use of the OEI, considers the human-related factor.

TERMINOLOGY OF FLOODS AND FLASH FLOODS

Floods

According to Few *et al.* (2004), each flood acquires some particular and inherent characteristics of the occurrence locality such as flow velocity and height, duration, and rate of water-level rise. In Table I flood and similar terms are presented with their respective definitions. It is noticed that there is a little variation of definitions of this flood type. Many of them show some common aspects: for example, the flood water usually covers a dry area denominated floodplain and this type of flood is caused by continuing rains. The water-level rising is so slow that it usually occurs in large river catchments, allowing sufficient time for people to be alerted. However, it also occurs in small river catchments, because the main trigger factor is persistent rains. The associated damages are in high totality, because the waters reach great extensions adjacent to the river. Since there is time to alert and consequently time to take people far away from the probable reached areas, the human losses in floods are relatively smaller than in the flash floods.

Flash Floods

Flash floods occur in a sudden, violent and unexpected way, usually in small areas, resulting in a greater danger to life and severe structural damages. They are provoked by intense rainfalls. It must be emphasized that the early warning system is indispensable for the reduction in damages associated with flash floods.

The damage potential of flash floods is confined to the direct neighborhood of the river: the total damage is usually not very extensive although due to the high velocities the individual damage to structures or persons is very large (Plate, 2002). Because flash floods usually affect relatively small areas, losses resulting from them

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Table I. Some terms and definitions of floods

Term	Author	Definition
Flood	Office of Technology Assessment (1980)	An overflow of lands not normally covered by water and that are used or usable by man.
Flood	FEMA (1981)	Flooding results when the flow of water is greater than the normal carrying capacity of a stream, or where coastal waters exceed the normal high tide.
Gradual flood	Castro (1996)	Occur when the waters rise in a slow and previsible way, keeping in this situation for some time, and after that they are drained gradually.
River flood	Kron (2002)	Is the result of intense and/or persistent rain for several days or even weeks over large areas sometimes combined with snowmelt. River floods build up gradually, though sometimes within a short time.
Flood	Dhar and Nandargi (2002)	A flood is defined when at a gauge/discharge (G/D) site the flood waters flow above a certain level which is called danger level (D.L.) or warning level. Danger levels at G/D sites indicate the level above which flood waters will start inundating the areas along the river.
Flood	European Spatial Planning Observation Network (2003)	Flood is a high-water stage in which water overflows its natural or artificial banks onto normally dry land such as a river inundating its floodplain.
Riparian flood	Tucci and Bertoni (2003)	When the precipitation is intense and soil can not infiltrate it, large part of the precipitation flows to the drainage system, getting superior to its natural capacity of the flow. This excess of this volume that can not be drained occupies lowlands, flooding areas very near the rivers.
Flood	National Disaster Education Coalition (2004)	Flooding occurs in known floodplains when prolonged rainfall over several days, intense rainfall over a short period of time, or an ice or debris jam causes a river or stream to overflow and flood the surrounding area.
River flood	Choudhury *et al.* (2004)	River flooding occurs due to heavy monsoon rainfall and melting snow in the upper catchments areas of the major rivers of Bangladesh. Resultant runoff causes these rivers to rise, over-flow their banks, and spread water to floodplain zones.
River flood	Mendiondo (2005)	The overflow of river courses is usually the result of prolonged, copious precipitation over a large area. Usually, a warning can be given a few hours or days beforehand on the basis of flood forecasts.
Flood	NWS/NOAA (2007)	Any high flow, overflow, or inundation by water which causes or threatens damage.

can be overcome by the municipal district. Kelsh (2001) analyzed 22 flash flood cases in USA and showed that the average size of the watersheds for the flash flood events was 46 km^2.

Responsible factors for the short duration of the flash flood include intense rains that persist on an area for a few hours, steep slope, impermeable surfaces, and sudden release of impounded water (Georgakakos, 1986). Hence, particular hydrological characteristics such as small basins, steep slopes and low infiltration capacity combined with a meteorological event contribute to the flash flood formation.

Table II shows some definitions for flash floods, where only three papers (WMO, 1994; NDEC, 2004; NWS/NOAA, 2007) define the flash floods with the value of 6 hours. Georgakakos (1986) adopted 12 hours as the upper bound of the time interval between the time of occurrence of the causative event and the time of occurrence of the flash flood. According to KP. Georgakakos (personal communication), these values (6 and 12 hours) are just empirical. It might be, therefore said that they must be suitable for one local and must not for another one. In other words, it is not simple to determine the critical time for differentiation between floods and flash floods.

OPERATION EFFICIENCY INDEX

Previously, normal floods have been registered as flash floods, and vise verse. This kind of mistake frequently occurs not because of a shortage of knowledge, but because of the complexity of the phenomena and the ambiguous definitions listed in Tables I and II. This situation requires establishing a quantitative method to distinguish the normal (or gradual) flood and the flash flood by reducing the degree of subjectivity. Remembering the description of Georgakakos (1986); "the flash floods require a rapid alarm (early warning) system of the local forecasting center", the present work proposes a quantitative method to identify these two types of floods by use of the Operation Efficiency Index (OEI). This index is defined as:

$$\mathrm{OEI} = \frac{Tc}{To}, \tag{1}$$

where Tc is the time of flood concentration and To is the operational response time in the institution-community system. Tc considers some environmental factors such as precipitation, topography, and land use (McCuen *et al.*, 1984), whereas To is determined by some human factors:

$$To = -Ta + Tt + Tal + Te, \tag{2}$$

Table II. Definitions of flash floods

Term	Author	Definition
Flash flood	IAHS-UNESCO-WMO (1974)	Sudden floods with high peak discharges, produced by severe thunderstorms that are generally of limited areal extent.
Flash flood	Office of Technology Assessment (1980)	A flood that follows the causative event (this might be excessive rains, a dam failure, etc.) within a few hours.
Flash flood	NOAA (1981)	Operationally, flash floods are floods that are short fused and require the issuance of warnings by the local warning and forecast offices rather than by the regional River Forecast Centers.
Flash flood	FEMA (1981)	Flash flooding usually consists of a quick rise in water surface elevation with abnormally high water velocity often creating a 'wall' of water moving down the channel and floodplain.
Flash flood	Georgakakos (1986)	Any flood that occurs at a certain location within a few hours after the causative event (e.g., rainfall, dam break). The time interval of **12 hours** is adopted as the upper bound of the time interval between the time of occurrence of the causative event and the time of occurrence of the flash flood at a certain location.
Flash flood	WMO (1994)	In small catchment, with the time of concentration less than **6 hours**, intense precipitation can generate a flash flood.
Flash flood	Kömüsçü *et al.* (1998)	Are usually produced by intense convective storms which cause very rapid runoff, and the damaging flood usually occurs within hours of the causative rainfall and affects very limited areas.
Flash or Rapid flood	Castro (1996)	Are caused by intense and concentrated rainfall in steep slope regions, and characterized with rapid and violent rising of level of water which flows rapidly.
Flash flood	Doswell (1997)	Flood events where the rising water occurs during or a matter of a few hours after the associated rainfall. If the damaging water level increases occur more than a few hours after the rainfall, the event is considered to be a flood, not a flash flood.
Flash Flood	AMS (2000)	A flash flood is a flood that rises and falls quite rapidly with little or no advance warning, usually the result of intense rainfall over a relatively small area.
Flash flood	Kelsch *et al.* (2001)	Phenomena in which the important hydrologic processes area occurring on the same spatial and temporal scales as the intense precipitation.
Flash flood	Kron (2002)	They are produced by intense rainfall over a small area. Typically, flash floods have an extremely sudden onset.
Flash flood	National Disaster Education Coalition (2004)	Flash floods occur within **6 hours** of a rain event, or after a dam or levee failure, or following a sudden release of water held by an ice or debris jam.
Flash flood	Choudhury *et al.* (2004)	Flash floods are very short-lived floods lasting from several hours to a few days. Water in such flooding rises and falls rapidly.
Flash flood	Mendiondo (2005)	Is a flood event of short duration with a rapidly rising flood wave and a rapidly rising water level. Flash floods are caused by heavy, usually short precipitation, as a torrential rain, in an area that is often very small, typically in conjunction with a thunderstorm.
Flash flood	NWS/NOAA (2007)	A rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within **6 hours** of the causative event (e.g., intense rainfall, dam failure, ice jam).

where Ta is the antecedent time of weather forecasting with high precision; Tt is the transmission time of the forecasting from the forecasting center to the Civil Defence; Tal is the time necessary for the Civil Defence to alert the community; and Te is the time necessary for the communities to move to safe places. Thus, the OEI involves some of the factors that trigger natural disasters (i.e. the environmental and human factors).

Usually $To > 0$, thus in the case where OEI > 1, the flood is defined as "normal" flood, while in the case where OEI < 1, the flood is defined as a "flash" flood. If OEI > 1, there is enough time to save lives (i.e. potentially smaller damages). If OEI < 1, there is a very short time for saving lives (i.e. potentially larger damages). Hence, this index is used to differentiate flood and flash floods as disasters, not as natural phenomenon.

In the study of Marcelino *et al.* (2006) which used the AVADAN data for elaborating a natural disaster risk map of the Santa Catarina State, Brazil, some incorrect registries of normal flood events have been made. For example, the data showed that the state capital, Florianópolis city, has suffered from a high occurrence of gradual floods. Based on Kobiyama *et al.* (2006) which investigated the Tc values for the small experi-

mental catchment in Florianópolis, the values of *Tc* in Florianópolis are about half an hour. There is no system in place to evacuate the population within one hour in this city. It means that OEI is always smaller than one in this city, which automatically indicates that this city has only flash floods. Hence, the normal or gradual floods registered in a certain locality can be considered flash floods if *Tc* values are within a few hours.

CONCLUSION

Not only in Brazil but also in various other countries, the distinction between floods and flash floods is essential for optimal flood disaster management. This work proposes a quantitative method to distinguish between floods and flash floods by using the OEI.

Floods are natural phenomena, and frequently considered as natural disasters. The floods as natural phenomenon are caused only by the environmental factor, whereas the floods as disasters are caused by the environmental and human factors. Therefore the flood disaster analysis must consider human-related factors which are fundamental in disaster occurrence and affect all of their prevention stages (i.e. mitigation, preparedness, response and reconstruction). In this sense, the OEI is coherent, because it considers both environmental and human factors.

For gaining a good mitigation result, it would be ideal that, in terms of the OEI, when floods occur, more lives can be saved compared with flash floods. In this way, at a certain place whose *Tc* value is known, but where an alert system has not been established yet, the OEI use can determine what *Ta* is necessary to transform flash floods to just floods.

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