Analysis of the variation of the 0°C isothermal altitude during intense rainfall events

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Objectives and Method

The analysis aims at analysing the evolution of the 0°C isothermal altitude during intense rainfall events. The following steps are followed:

- The rainfall events of around 100 meteorological stations measuring at hourly time step are considered.
- Two meteorological sounding stations launching two weather balloons per day are considered.
- The variation of the 0°C is analysed depending on the rainfall event duration.
- The analysis is carried out distinguishing between winter (December-February) and summer (June-August).

Introduction

In numerous countries of the world (USA, Canada, Sweden, Switzerland,...), the dam safety verifications for extreme floods are realized by referring to the so called Probable Maximum Flood (PMF). According to [1] , the PMF is determined based on the PMP (Probable Maximum Precipitation). The PMF estimation is performed with a hydrological simulation model by routing the PMP. The PMP data is inserted in the routing model as a rainfall event. An assumption on the temperature during the PMP event has to be made. A question raising here, is if the temperature can be assumed to be constant or if its evolution during short intense rainfall events are relevant for the PMF estimation. For this study, the temperature will be referred to as the 0°C isothermal altitude. The analysis of the evolution of the 0°C isothermal altitude during intense rainfall events is aimed here and based on meteorological soundings from the two sounding stations Payerne (CH) and Milan (I).

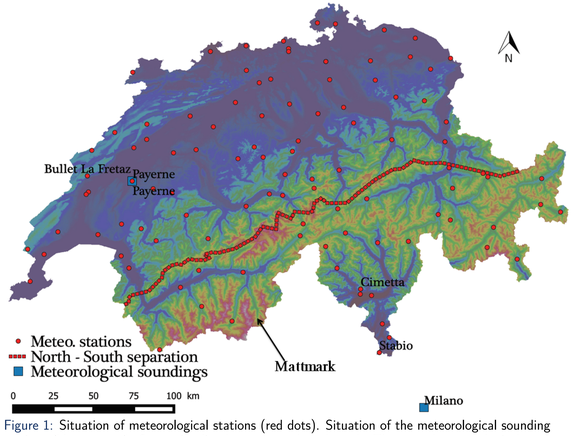

Figure 1: Situation of meteorological stations (red dots). Situation of the meteorological sounding stations (blue squares). Separation line between north and south. The named meteorological stations are used for the validation of the gradient method.

Data

The following data were required to complete the research:

- Hourly rainfall data of 104 meteorological stations from 1981 on.
- Meteorological soundings from 1981 on at two locations (Payerne and Milan).

The data were prepared according to the steps outlined below:

1. Separation of the rainfall data into seasonal datasets.
2. Determination of the measured rainfall events.
3. Only the events with an intensity higher than the 95^{th} quantile are kept.
4. Determination of the 0°C isothermal altitude from the meteorological soundings
5. Attribution of the deduced 0°C isothermal altitude to the beginning and the end of the determined rainfall events according to the separation line shown on Figure 1.
6. Only events with a duration up to 24h are considered.

Methods

The 0°C isothermal altitude H is derived from meteorological soundings by linear interpolation as the temperature is varying linearly until reaching the tropopause, where a thermal inversion is happening. An example of the deduction of the 0°C isothermal altitude H is shown on Figure 2

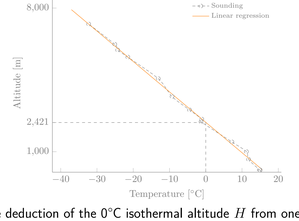

Figure 2: Example of the deduction of the 0°C isothermal altitude H from one mreteorological sounding by linear interpolation.

The variation of the 0°C isothermal altitude H is simply characterized by the difference $\Delta = H_a - H_b$ before and after the rainfall event. The Figure 3

Meteorological soundings

Meteorological soundings are measurements from weather observation balloons filled with helium. At Payerne and Milan, those balloons are launched twice a day (00:00 and 12:00 UTC). They measure air temperature and altitude, but also wind direction and speed, atmospheric pressure, relative air humidity, dew point temperature and ozone concentration and the temperature of the pump.

Results

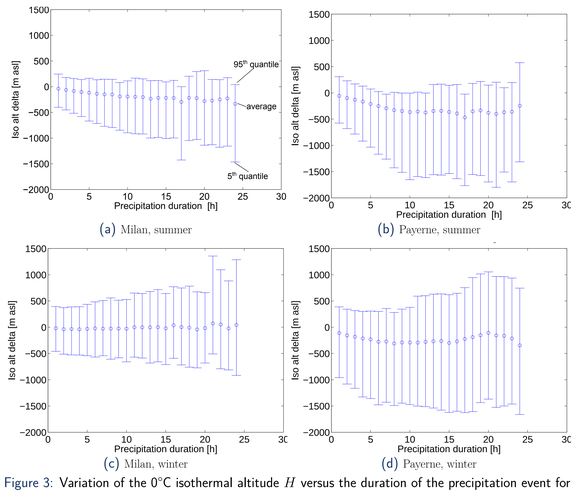

Figure 3: Variation of the 0°C isothermal altitude H versus the duration of the precipitation event for summer and winter related to the meteorological soundings of Milan and Payerne

Result discussion

The graphs from Figure 3 show that, during rainfall events happening in summer, the 0°C isothermal altitude H tends to decrease. The variation of H is more pronounced when the duration of the rainfall event is long. During summer, the average decrease of H stabilises at an event duration of about 10h.

Furthermore, Figure 3 shows that the decrease of H during intense rainfall events is clearer during summer. In winter, the average decrease of H is less pronounced. For Milan (Figure 3c) a relation between the average decrease and the event duration is not recognizable.

The interval between the 95^{th} and 5^{th} quantile show a greater variation range in winter than in summer. In particular, during winter the possibility of an increase of H during the precipitation event is more likely to happen as it can be deduced from the 95^{th} quantile on Figures 3c and 3d.

When comparing Figures 3a and 3c with Figures 3b and 3d, it is apparent that the variation of H is higher for the northern part of Switzerland (cf separation line on Figure 1) than in the south.

The influence of the results presented before is tested here by performing a PMP-PMF simulation for a Swiss alpine basin, i.e. Mattmark dam catchment.

Relevance of the results for PMF estimations

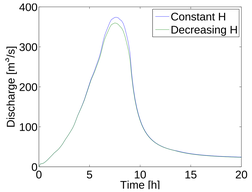

Figure 4: PMF hydrographs from a 9h PMP under constant and decreasing isothermal conditions.

The lowest point of the basin is situated at 2174 m a.s.l. . The highest point The Mattmark dam catchment (38 km^2 and 28% glacier cover) is situated at around 4000 m a.s.l. . The situation of the dam is indicated on Figure 1.

For this study, a 9h PMP is routed under summer conditions through the catchment using the GSM-Socont hydrological model ([2];[3];[4]) developed for alpine catchments with glacier cover. The initial 0°C isothermal altitude is admitted to be at 4698 m a.s.l. . This value has been determined in an earlier study and indicates that no solid precipitation is occurring on the catchment. According to Figure 3a, the 0°C isothermal altitude H can fall about 1000 m below its initial value. A linear decrease of H is assumed. The PMF hydrographs shown on Figure 4 show that the influence of the isothermal altitude variation is small.

Conclusion

This analysis showed that the 0°C isothermal altitude is decreasing in most cases during short intense rainfall events, especially in summer. The trend for the winter season is only perceivable for the soundings from Payerne. When PMP-PMF simulations are performed and the initial 0°C isothermal altitude is set to be higher than the highest point of the catchment, the evolution of the 0°C isothermal altitude is very small. It is reasonable to assume a constant 0°C isothermal altitude; it is more secure for the design and the variation of the discharge is probably too small to be reliable compared to the sources of uncertainty when PMF estimations are performed.

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