FLOOD RISK MANAGEMENT

FLOOD RISK ANALYSIS OF THE POSINA BASIN IN ITALY

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1 INTRODUCTION

In this sub-section (Introduction) the description of the Posina basin is largely taken from the following thesis:

Zviad Ghadua (2014). Probabilistic Flash Flood Guidance based on Bayesian approach, MSc Thesis, UNESCO-IHE.

The Posina river basin (Figure 1) is located in the foothills of Central-Eastern Italian Alps, close toVenice and Padua and has an area of 116 km2. Elevation ranges from 387 m at the outlet to 2232 m at the watershed divides. Posina River is a tributary of Astico River that flows into the Adriatic Sea. Most of the catchment (about 75%) is covered by deciduous forests, especially beeches and hornbeams, thereby saturation-excess is the main rainfall-runoff generation mechanism of the basin. The forest area expanded significantly in the last decades due to land use changes, typically due to abandoning agricultural practices in some areas of the basin. The annual precipitation is estimated to be in the range of 1,600-1,800 mm. Rainfall is concentrated particularly in the spring (April and May) and winter (October and November).The basin is situated in one of Veneto's most rainy areas and is monitored by several meteorological and hydrometric stations.

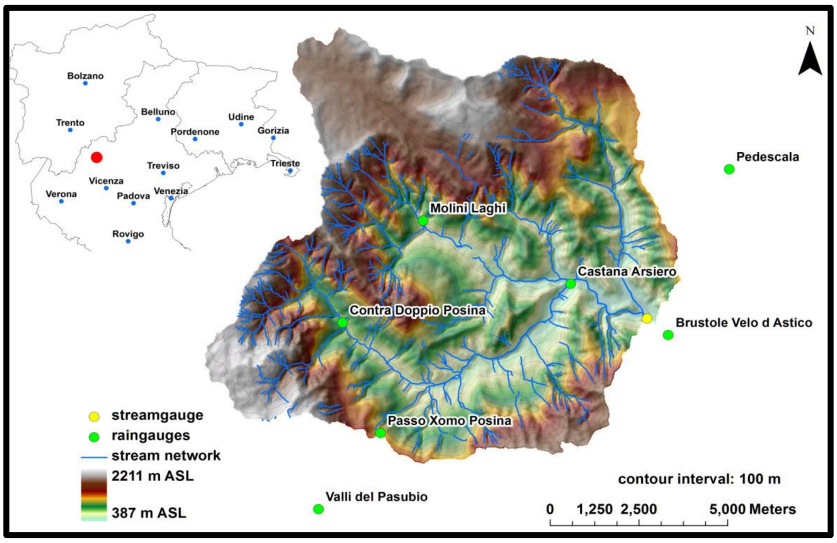

Figure 1 The Posina river basin: the figure illustrates the topography of the basin, the main river network, the location of the raingauges and of the streamgauges, and its position in north-eastern Italy.

The catchment lies inside the coordinates 45.5N and 46.0N and 11E and 11.5E. Within a radius of 12 km from the center of the catchment there is a network of 11 rain gauges reporting hourly rainfall, 7 of which are closer to the catchment, providing representative estimates of the basin-averaged hourly rainfall rates.

Posina suffers from flash floods. The catchment has suffered from numerous floods in the past. For more details on Posina please see the FLOODsite report (referred to on the cover page of this handout and available in the eCampus –Flash floods folder). In Posina the typical rainfall duration leading to flooding is 6 hours. When the river discharge at the outlet is 24 m3/s then inundation begins.

2 CHALLENGES IN FLASH FLOOD FORECASTING (5 POINTS)

Task 1: Briefly explain the challenges to flash flood forecasting in Posina basin (indicative max 200 words).

Answer:

The flash flood forecasting for medium-size mountain basin like Posina Basin, which drains 116Km^2, is driven by the high-level accuracy precipitation and short-time prediction. In other words, the uncertainty in the estimation of rainfall is the biggest challenges leading to forecasting error(*Hill et al.*, 2010).

However, the weather prediction models (such as ECMWF, etc.) have the ambiguous resolution of the rainfall data both at temporal and spatial scale, which are inappropriate for the flash flood forecasting in Posina Basin.

Fortunately, the real-time radar monitoring system and in-situ measurements were set for analysing the real-time rainfall intensities and accumulation amount in Posina. But, the uncertainty in the estimating precipitation intensities enhanced by orographic is needed to solve when collecting data from the radar system(*Borga et al.* (2000)). Meanwhile, in-situ measurements (like 11 rain gauges, etc.) are accurate but do not sufficiently capture situations where spatial variability of precipitation is high(*Hill et al.*, 2010).

On the other hand, the runoff error may occur due to the uncertainty in the estimation of the soil moisture.

To sum up, the flash flood forecasting in Posina basin is no easy and need more technical measurements and methods for solving the challenges and errors.

3 RAINFALL-RUNOFF CURVES (10 POINTS)

TASK2: i) Prepare rainfall-runoff curves for the case without considering the AMC plus for the 3 AMC cases.

Answer:

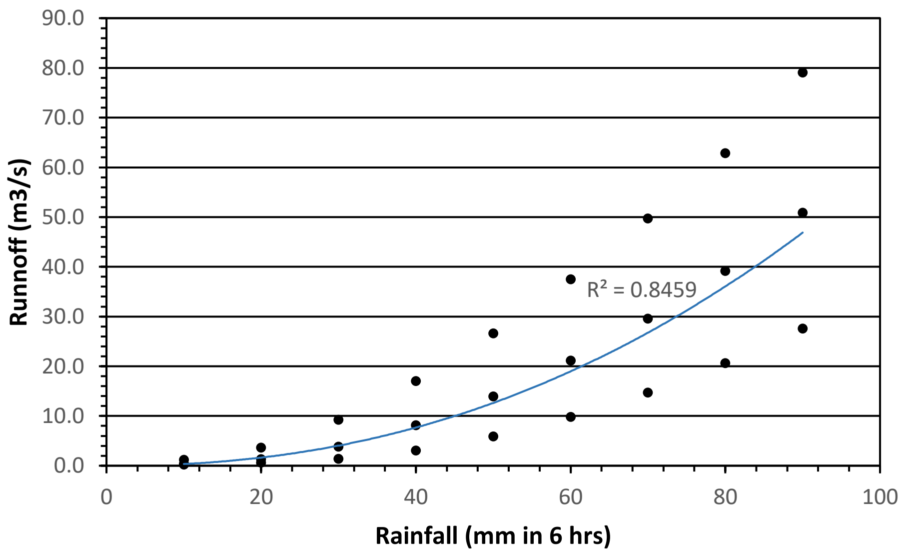

Figure 3.1 Rainfall-Runoff curve without considering the AMC

The rainfall-runoff curve is indicated in figure 3.1, calibrated by the power trend line of the points, and the square of R is 0.8459, which is the highest, compared with other trend lines.

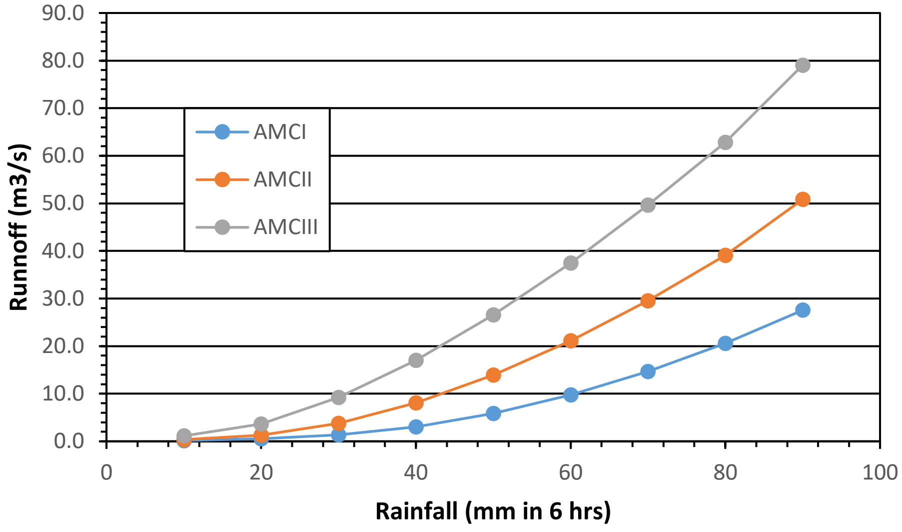

Figure 3.2 Rainfall-Runoff curves with the corresponding AMC

ii) Compute the FFG for the case without considering AMC plus for the 3 AMC cases. Provide brief text – indicative 5 lines – explaining the approach and 4 sets of rainfall-runoff curves showing the FFG values on the charts.

Answer:

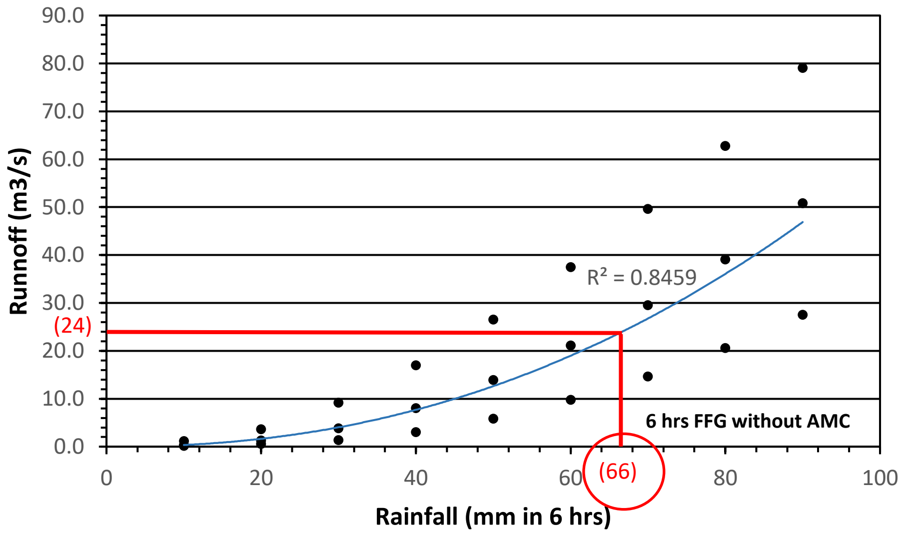

Figure 3.3 6hrs FFG without the considering AMC

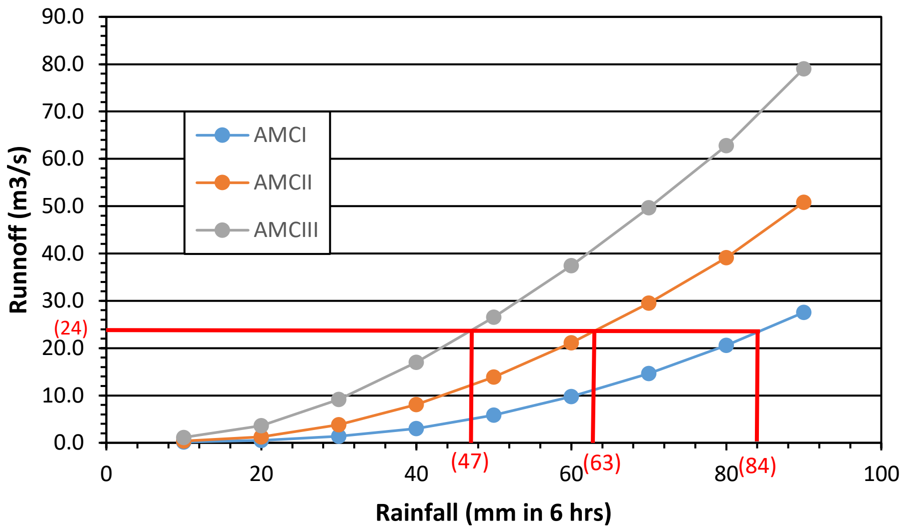

Figure 3.4 6hrs FFG with the corresponding AMC

Table 3.1 Chart of the FFG for case study without considering AMC plus for the 3 AMC cases

	Without AMC	AMCI	AMCII	AMCIII
	mm	mm	mm	mm
FFG	66	84	63	47

Table 3.1 clearly presents the 6hrs flash flood guidance (FFG) for Posina basin without considering AMC plus for the 3 AMC cases. The 6hrs FFG without AMC is 66 mm, as shown in figure 3.3 and figure 3.4 displays that the FFGs for AMCI, AMCII and AMCIII cases are different with 84, 63 and 47 respectively. Interestingly, the threshold rainfall decrease with the increase of the soil moisture as shown in figure 3.4. Because the area with highly wetness condition is easier to saturate and to rapidly deliver water to the stream network, compared with the dry area(*Penna et al.*, 2011). Thus, the threshold rainfall for AMCIII is the smallest, which have a wetter condition. Additionally, the 6hrs FFG without the considering AMC is slightly higher than that for the AMCII case.

The approach of finding the rainfall that causes flooding – flash flood guidance – is easy. First of all, the amount of the runoff to induce flooding during 6 hours of rainfall, called the threshold discharge, is given in the previous introduction, with 24 m3/s. Then, the corresponding rainfall can be computed by different rainfall-runoff curves, as shown in figure 3.3 and 3.4. All results of the 6hrs FFG in Posina Basin are displayed in table 3.1.

4 FORECASTING FLASH FLOODS WITH FFG (30 POINTS)

TASK3: (i) Present Excel plots of comparison of time series: forecasted 6-hourly rainfall data (mm) and the flood forecasts (Flood, No-flood):

- **Consider the three study months separately (number of figures= 3);**
- **Consider 3 AMC cases one by one as the prevailing moisture condition (number of figure per month=1);**
- **Show on the Excel plot forecasts each day: {0,1}where 1 signify flooding;**
- **Show on the Excel plot actual flooding each day {0,1} where 1 signify flooding;**

Forecast lead time = 6 hrs			Flood forecast				
Time	Date and time of model run	Precipitation (accumulation in 6 hrs) (from TIGGE)	Without AMC	AMCI	AMCII	AMCIII	Observed
		mm	{0,1}	{0,1}	{0,1}	{0,1}	{0,1}
6	1/12/2006 0:00	0.0	0	0	0	0	0
30	2/12/2006 0:00	0.0	0	0	0	0	0
54	3/12/2006 0:00	0.0	0	0	0	0	0
78	4/12/2006 0:00	0.5	0	0	0	0	0
102	5/12/2006 0:00	0.0	0	0	0	0	0
126	6/12/2006 0:00	0.6	0	0	0	0	0
150	7/12/2006 0:00	0.4	0	0	0	0	0
174	8/12/2006 0:00	0.2	0	0	0	0	0
198	9/12/2006 0:00	7.0	1	0	1	1	1
222	10/12/2006 0:00	0.0	0	0	0	0	0
246	11/12/2006 0:00	0.0	0	0	0	0	0
270	12/12/2006 0:00	0.0	0	0	0	0	0
294	13/12/2006 0:00	0.0	0	0	0	0	0
318	14/12/2006 0:00	0.0	0	0	0	0	0
342	15/12/2006 0:00	0.0	0	0	0	0	0
366	16/12/2006 0:00	0.0	0	0	0	0	0
390	17/12/2006 0:00	0.2	0	0	0	0	0
414	18/12/2006 0:00	1.9	0	0	0	0	0
438	19/12/2006 0:00	0.0	0	0	0	0	0
462	20/12/2006 0:00	0.0	0	0	0	0	0
486	21/12/2006 0:00	0.0	0	0	0	0	0
510	22/12/2006 0:00	0.0	0	0	0	0	0
534	23/12/2006 0:00	0.0	0	0	0	0	0
558	24/12/2006 0:00	0.0	0	0	0	0	0
582	25/12/2006 0:00	0.0	0	0	0	0	0
606	26/12/2006 0:00	0.0	0	0	0	0	0
630	27/12/2006 0:00	0.0	0	0	0	0	0
654	28/12/2006 0:00	0.0	0	0	0	0	0
678	29/12/2006 0:00	0.0	0	0	0	0	0
702	30/12/2006 0:00	0.0	0	0	0	0	0
726	31/12/2006 0:00	0.0	0	0	0	0	0
	Total	11.0	1.0	0.0	1.0	1.0	1.0

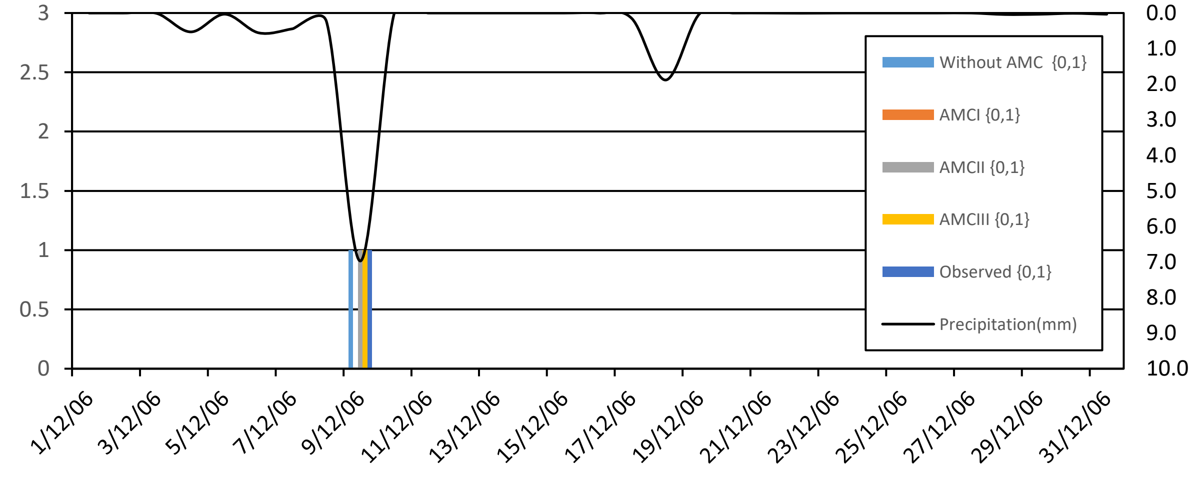

Figure 4.1 Forecasted 6-hourly rainfall data (mm) and the flood forecasts (Flood, No-flood) in Dec. 2006

Forecast lead time = 6 hrs			Flood forecast				
Time	Date and time of model run	Precipitation (accumulation in 6 hrs) (from TIGGE)	Without AMC	AMCI	AMCII	AMCIII	Observed
		mm	{0,1}	{0,1}	{0,1}	{0,1}	{0,1}
6	1/01/2007 0:00	0.2	0	0	0	0	0
30	2/01/2007 0:00	4.5	0	0	0	0	1
54	3/01/2007 0:00	0.0	0	0	0	0	0
78	4/01/2007 0:00	0.0	0	0	0	0	0
102	5/01/2007 0:00	0.0	0	0	0	0	0
126	6/01/2007 0:00	0.0	0	0	0	0	0
150	7/01/2007 0:00	0.0	0	0	0	0	0
174	8/01/2007 0:00	1.1	0	0	0	0	0
198	9/01/2007 0:00	0.0	0	0	0	0	0
222	10/01/2007 0:00	0.0	0	0	0	0	0
246	11/01/2007 0:00	0.1	0	0	0	0	0
270	12/01/2007 0:00	0.0	0	0	0	0	0
294	13/01/2007 0:00	0.0	0	0	0	0	0
318	14/01/2007 0:00	0.0	0	0	0	0	0
342	15/01/2007 0:00	0.1	0	0	0	0	0
366	16/01/2007 0:00	0.0	0	0	0	0	0
390	17/01/2007 0:00	0.1	0	0	0	0	0
414	18/01/2007 0:00	0.0	0	0	0	0	0
438	19/01/2007 0:00	0.0	0	0	0	0	0
462	20/01/2007 0:00	0.0	0	0	0	0	0
486	21/01/2007 0:00	0.1	0	0	0	0	0
510	22/01/2007 0:00	0.1	0	0	0	0	0
534	23/01/2007 0:00	2.4	0	0	0	0	0
558	24/01/2007 0:00	0.0	0	0	0	0	0
582	25/01/2007 0:00	0.0	0	0	0	0	0
606	26/01/2007 0:00	0.1	0	0	0	0	0
630	27/01/2007 0:00	0.0	0	0	0	0	0
654	28/01/2007 0:00	0.0	0	0	0	0	0
678	29/01/2007 0:00	0.0	0	0	0	0	0
702	30/01/2007 0:00	0.0	0	0	0	0	0
726	31/01/2007 0:00	0.0	0	0	0	0	0
	Total	9.1	0.0	0.0	0.0	0.0	1.0

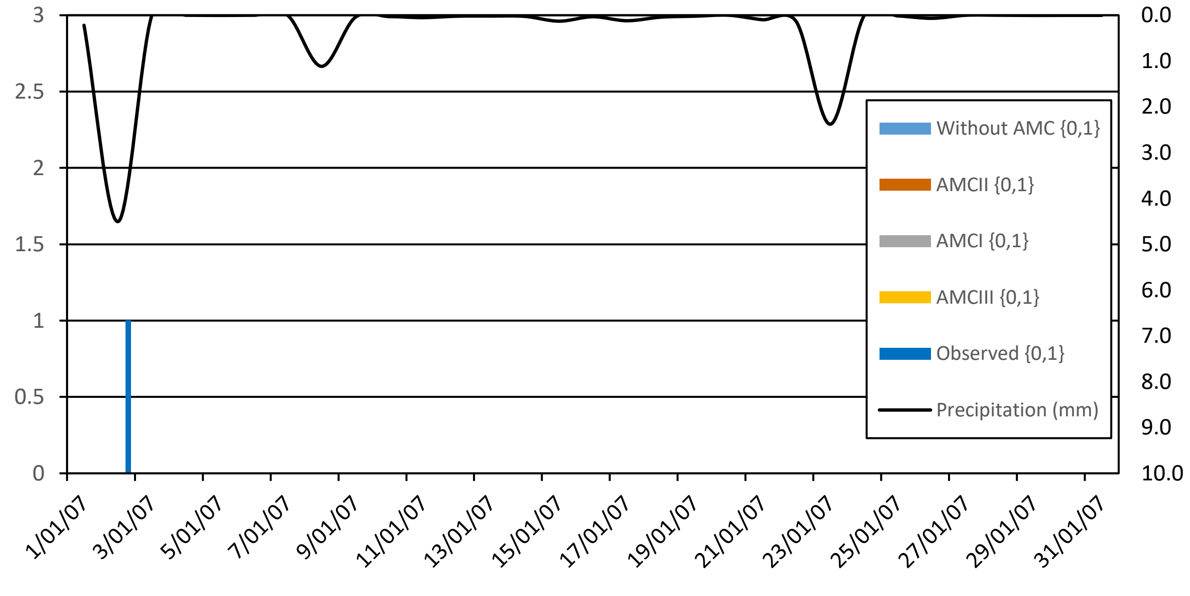

Figure 4.2 Forecasted 6-hourly rainfall data (mm) and the flood forecasts (Flood, No-flood) in Jan. 2007

	Forecast lead time = 6 hrs		Flood forecast				
Time	Date and time of model run	Precipitation (accumulation in 6 hrs) (from TIGGE)	Without AMC	AMCI	AMCII	AMCIII	Observed
		mm	{0,1}	{0,1}	{0,1}	{0,1}	{0,1}
6	1/12/2008 0:00	4.96	0	0	0	1	1
30	2/12/2008 0:00	0.01	0	0	0	0	0
54	3/12/2008 0:00	0.01	0	0	0	0	0
78	4/12/2008 0:00	0.00	0	0	0	0	0
102	5/12/2008 0:00	6.76	1	0	1	1	0
126	6/12/2008 0:00	0.01	0	0	0	0	0
150	7/12/2008 0:00	0.00	0	0	0	0	0
174	8/12/2008 0:00	0.00	0	0	0	0	0
198	9/12/2008 0:00	0.00	0	0	0	0	0
222	10/12/2008 0:00	6.93	1	0	1	1	1
246	11/12/2008 0:00	0.58	0	0	0	0	0
270	12/12/2008 0:00	3.34	0	0	0	0	0
294	13/12/2008 0:00	0.24	0	0	0	0	0
318	14/12/2008 0:00	0.51	0	0	0	0	0
342	15/12/2008 0:00	2.41	0	0	0	0	0
366	16/12/2008 0:00	1.33	0	0	0	0	0
390	17/12/2008 0:00	0.10	0	0	0	0	0
414	18/12/2008 0:00	0.00	0	0	0	0	0
438	19/12/2008 0:00	0.00	0	0	0	0	0
462	20/12/2008 0:00	0.03	0	0	0	0	0
486	21/12/2008 0:00	0.00	0	0	0	0	0
510	22/12/2008 0:00	0.00	0	0	0	0	0
534	23/12/2008 0:00	0.00	0	0	0	0	0
558	24/12/2008 0:00	0.00	0	0	0	0	0
582	25/12/2008 0:00	0.13	0	0	0	0	0
606	26/12/2008 0:00	0.03	0	0	0	0	0
630	27/12/2008 0:00	0.00	0	0	0	0	0
654	28/12/2008 0:00	0.03	0	0	0	0	0
678	29/12/2008 0:00	0.33	0	0	0	0	0
702	30/12/2008 0:00	0.00	0	0	0	0	0
726	31/12/2008 0:00	0.00	0	0	0	0	0
	Total	27.8	2.0	0.0	2.0	3.0	2.0

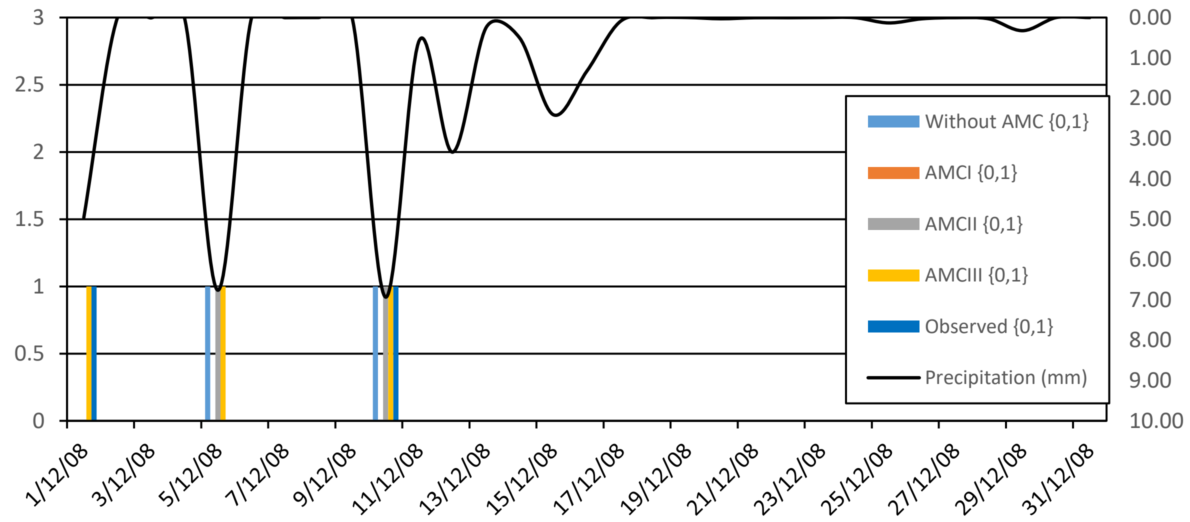

Figure 4.3 Forecasted 6-hourly rainfall data (mm) and the flood forecasts (Flood, No-flood) in Dec. 2008

(ii) Express your opinion about the suitability of the approach (indicative max 100 words)

Answer:

As my opinion, the high-level accuracy precipitation is needed for the 6 hrs flash flood forecast. For example, the inundation did not occur when the forecast rainfall of 6.76 mm on 5th Dec. 2008, because of the uncertainty error in the estimation rainfall from ECMWF with low resolutions. The grid resolution of the model is much larger (approximation 55km*55km), compared with the area of the Posina of 116km^2. Additionally, the threshold discharge before inundation is the same for the whole basin to determine the 6 hrs FFG. It is not useful for larger river basins, which have different threshold discharge of flooding in different rivers. Moreover, the moisture condition should also be similar in the whole area due to the application of only one rainfall-runoff curve for the actual flash flood forecasting.

(iii) Identify one variable which you think mostly determines the accuracy of your forecast (indicative max 2 lines)

Answers:

The estimation of the rainfall is the most significant factor for determining the accuracy of the forecast because the forecast rainfall of 6.76 mm didn't trigger the flash flood on 5th Dec 2008, which may cause by the uncertainty error in the estimation rainfall.

(iv) Provide just ONE suggestion to improve the accuracy of the forecasts (this answer may not be unique) (indicative max 150 words)

Answers:

An important way to improve the accuracy of the forecasts is the reduction of uncertainty error in the estimating rainfall from ECMWF model. It has two ways. One is real-time analysis of the rainfall using in-situ measurement of 11 rain gauges for the correction of the uncertainty errors. Meanwhile, the solution of spatial variability of the precipitation is the interpolation by Thiessen polygon or Inverse Distance Weight (IDW) methods. Another is using the real-time radar system for the correction of the rainfall from ECMWF model, which have been applied in this area to improve the accuracy of the forecasts(*Borga et al.*, 2000).

5 CHECKING ACCURACY OF FORECASTS (15 POINTS)

TASK4: Similar to Table 4 (and 5) and Fig 10 of the paper mentioned above present the accuracy of your forecasts. Provide a brief explanation on the accuracy of the forecasts (indicative max 100 words). Present your findings in the same table and figure for the 3 AMC cases.

Answer：

As the report above, the positive rejection, false alarm, missed alarm and hits were computed for identified the accuracy of the forecasts with AMC plus for the 3 AMC cases, as shown in table 5.1. The positive rejection ratio is same with forecasts without AMC and with AMCIII, AMCII, which account for 95%, and it is smaller than that for the AMCIII case with 96%. Meanwhile, the forecasts using AMCI curve miss all flood events, which missed alarm ratio is 4%. For AMCII cases and without AMC, the missed ratio is lower with 2%. Because they predict two flood events leads to hits ratio of 2%. However, it is a false alarm percentage of 1% in the 6hrs flash flood forecasting, except the forecasting for AMCI case. The percentage of the hits in the flood forecasting for AMCIII cases is the highest, which account for 3%. Thus, the flood forecasting for AMCIII cases is the best, according to table 5.1.

Table 5.1 Contingency table for the flash flood forecasting without AMC plus for the 3 AMC cases. The numbers show the percentage of flood events falling into the four groups positive rejection, false alarm, missed alarm and hits.

Posina	Pos.Rej %	FALSE %	Missed %	Hit %
Without AMC	95	1	2	2
AMCI	96	0	4	0
AMCII	95	1	2	2
AMCIII	95	1	1	3

Figure 5.1 presents the results of POD, FAR and CSI indices for determining the accuracy of the forecasts with different AMCs plus without AMC. The results of the forecast with AMCII and without AMC are same, which is worse than the forecast with AMCIII. POD values analysed in the forecast with AMCII and without AMC were 0.5, which have lower accuracy than those with AMCIII with 0.75. Additionally, the CSI values with AMCIII is the highest, with 0.6, compared with other values, which means that it is high accuracy. However, there are relatively low accuracy of the forecasts with AMCII and without AMC due to FAS values of 0.33, which are bigger than those for AMCIII cases with 0.25.

Consequently, the 6hrs FFG with the AMCIII is selected for the forecast because it has higher accuracy, compared with other FFGs.

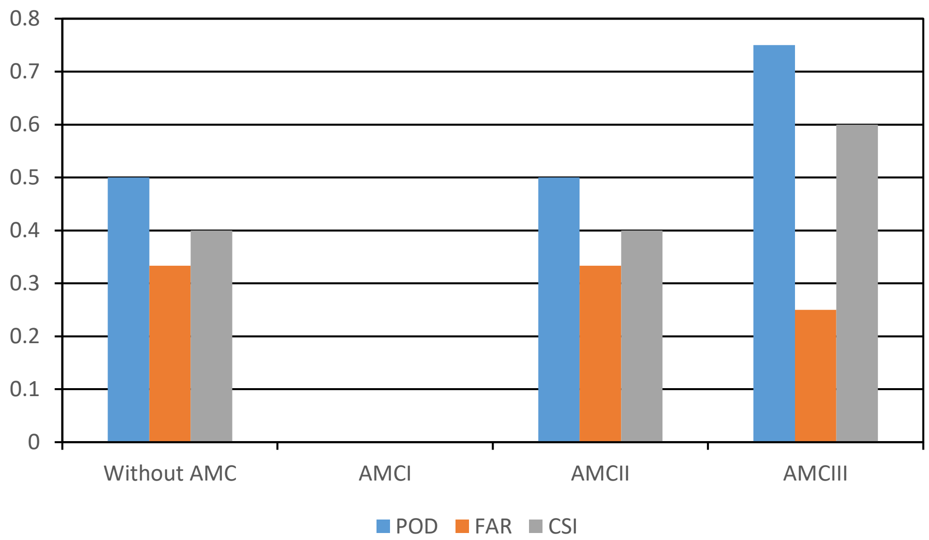

Figure 5.1. Performance coefficients assessed comparing simulated and observed flood extent forecasted by different 6 hrs FFG determined without AMC plus for the 3 AMC cases.

6 RAINFALL TRIGGERING INDEX (RTI) (20 POINTS)

TASK5: (i) Find the daily measured rainfall data of Posina (generated data). Using the rainfall forecast and measured rainfall data compute RTI for each day of the study period. Present your results in a table for the following dates:

-09/12/06 -02/01/07 -01/12/08 -05/12/08 -10/12/08

In the same table present the FFG values (for 3 AMC cases). Present also whether there was actually a flood or not. No explanation or description of the procedure followed is needed.

					FFG based forecast			
	Measured rainfall	Forecast rainfall	Rt	RTI	AMC1	AMC2	AMC3	Observed (flood/ no-flood)
	mm	mm	mm	mm	{0,1}	{0,1}	{0,1}	{0,1}
09/12/06	0.2	7.0	0.5	7.5	0	1	1	1
02/01/07	0.2	4.5	0.0	4.5	0	0	0	1
01/12/08	6.7	5.0	0.6	5.6	0	0	1	1
05/12/08	0.0	6.8	0.0	6.8	0	1	1	0
10/12/08	0.0	6.9	0.0	6.9	0	1	1	1

(ii) If you have to decide on a RTI value as a threshold for flash floods in Posina what value you will choose. Provide your explanation (indicative max 200 words).

Answers:

The RTI value I will choose as a threshold for flash floods in Posina is 5.6 mm. There are several reasons. First of all, according to the measured rainfall using rain gauges, there may have a flood event due to the observed rainfall of 6.7 mm on 1st Dec 2008. But, measured rainfall of 0.2 mm on 2nd Jan 2007 is hard to prove the occurrence of a flood event. Thus, the RTI value of 4.5 mm is inappropriate as the threshold; otherwise, there has more information to the correction of the estimating rainfall. Secondly, other RTI values of 7.5 mm, 6.8mm and 6.9mm respectively, obviously indicate the occurrence of a flash flood, which the 6hurs FFG can also detect easily. Therefore, they are inappropriate as the threshold too. Finally, the RTI value of 5.6 mm on 1st Dec 2008 is much larger than the forecast rainfall, while the RTI value of 4.5 mm is approximate as same as the forecast rainfall on 2nd Jan 2007, which means the Rt value is zero. In other words, RTI values are the correction forecast rainfall, which the RTI value on 1st Dec 2008 as the threshold is higher accuracy for flash floods forecasting, successfully predicting three flood events and one false alarm.

7 DEVELOPING A COMMUNITY BASED FLASH FLOOD AWARENESS SYSTEM (20 POINTS)

TASK6: (i) In the following some components of a community based flash flood risk reduction system are listed. Please present a block diagram of a conceptual framework of a community based flash flood risk reduction system using the items listed below. Provide connection arrows among the block items. You may add items. It is also possible to use the same item more than one time. Please note that there
may not be a unique answer.
- Developing a gauging network
- Crowdsourcing for augmenting data collection
- Forecasting - Warning - Awareness
- Monitoring (by volunteers)
- Gathering of historical data
- Risk assessment - Resilience
- Understanding the flooding process
- Risk reduction - Dissemination

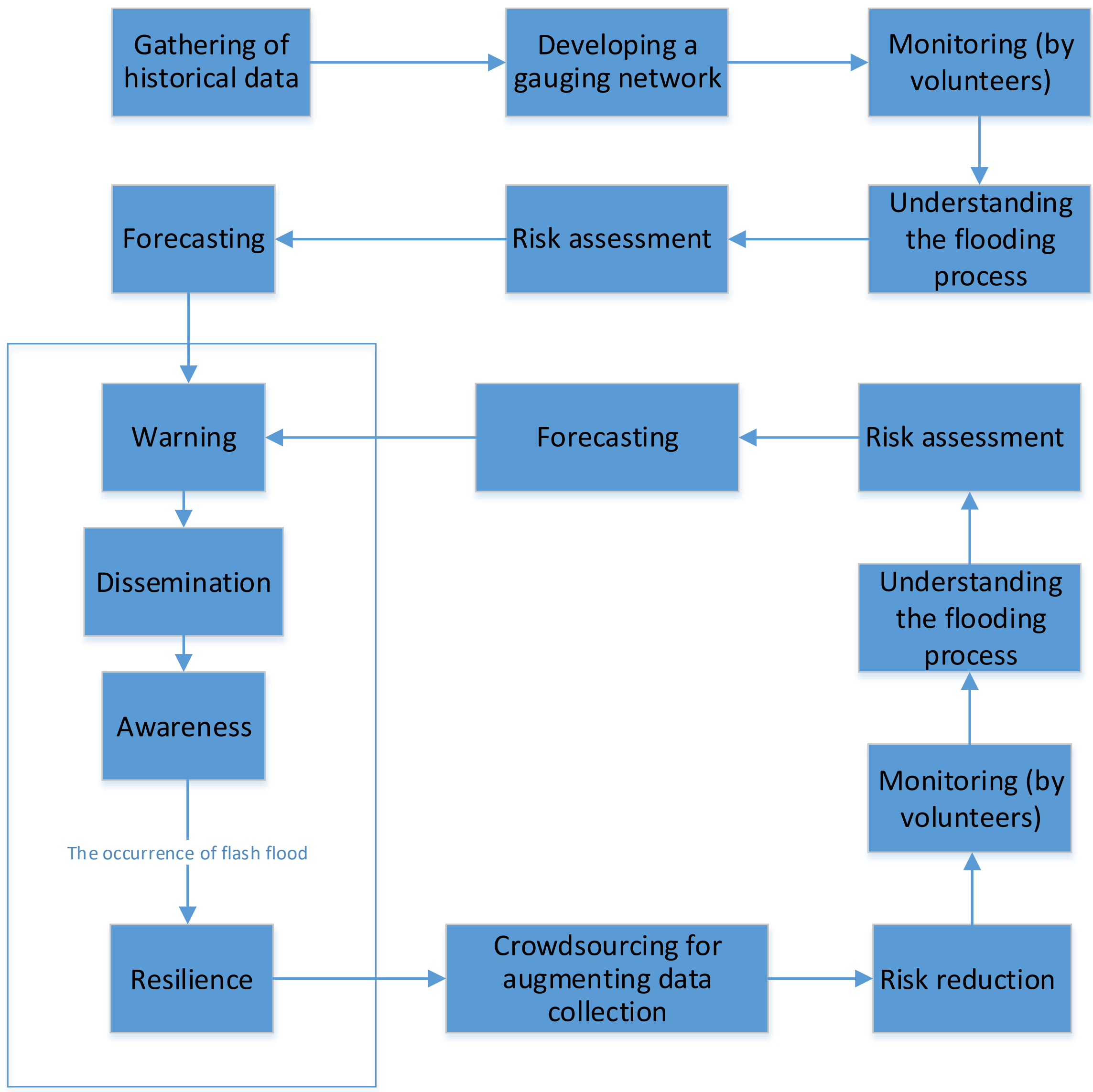

Figure 7.1 Diagram of the community-based flash flood risk reduction system

(ii) Describe in indicative 200 words how this system will reduce risk and bring resilience.

The diagram indicates the flash flood risk reduction system. First of all, Gathering of the historical data in Posina is needed for the analysis of the flooding process. Then, it is necessary to develop a gauging network and to collect the data in order to risk assessment. After that, according to the weather prediction model, the flash flood is forecasted, and then, people in high-risk areas is warned and evacuated. After the flash flood, the build should be reconstruction, and the flood area is needed to clean-up. Meanwhile, crowdsourcing is for augmenting data collection to understand flash flood process. It could be used to determine the measurements of risk reduction. Therefore, the reevaluation of risk assessment is done after finishing the operation of the risk reduction, according to the monitoring data by volunteers. Next, the system forecasts a new flash flood and warns people. Last but not least, the community organize recovery, provide relief and adjust the measurement of risk reduction. To sum up, this system continuously collects data to improve monitoring accuracy and adjust flood control measures and ultimately achieves precise flash flood control.

References:

Borga, M., et al. (2000), On the use of real - time radar rainfall estimates for flood prediction in mountainous basins, *Journal of Geophysical Research: Atmospheres*, *105*(D2), 2269-2280.

Hill, C., et al. (2010), Flash flood early warning system reference guide, *University Corporation for Atmospheric Research: Boulder, CO, USA*.

Penna, D., et al. (2011), The influence of soil moisture on threshold runoff generation processes in an alpine headwater catchment, *Hydrology and Earth System Sciences*, *15*(3), 689-702.