A case-study of an extreme rainfall event in NW Slovenia

Introduction

On 18 September 2007 heavy precipitation occurred in some parts of western and northern Slovenia. Bands of quasi-stationary convection were responsible for extreme amounts of rain causing destructive river floods and flash flooding in two narrow valleys – Selška dolina (valley) and Kropa. The Bohinj valley was also badly affected. More than 300 mm of rain was measured locally in less than 12 hours. The town of Železniki experienced a huge volume of water as the river Sora, which flows through the town, rose rapidly over a period of 30 minutes to 1 hour. More than 100 cars were swept away and many landslides and debris flows occurred. Heavy precipitation was also observed in some other parts in northern Slovenia, causing landslides and local floods. Six lives were lost and the total damage across all of the affected areas was estimated as around 200 million €.

The orographic characteristics of Slovenia

In Figure 1 the relief map of Slovenia is presented, with some places of interest also indicated. The northwest part of the country is characterised by a region of high mountains – an extension of the Julian Alps with many peaks above 2000 metres. To the southwest lies the lower terrain of the north Italian plain. As a result, the highest precipitation intensities in the mountainous region of NW Slovenia

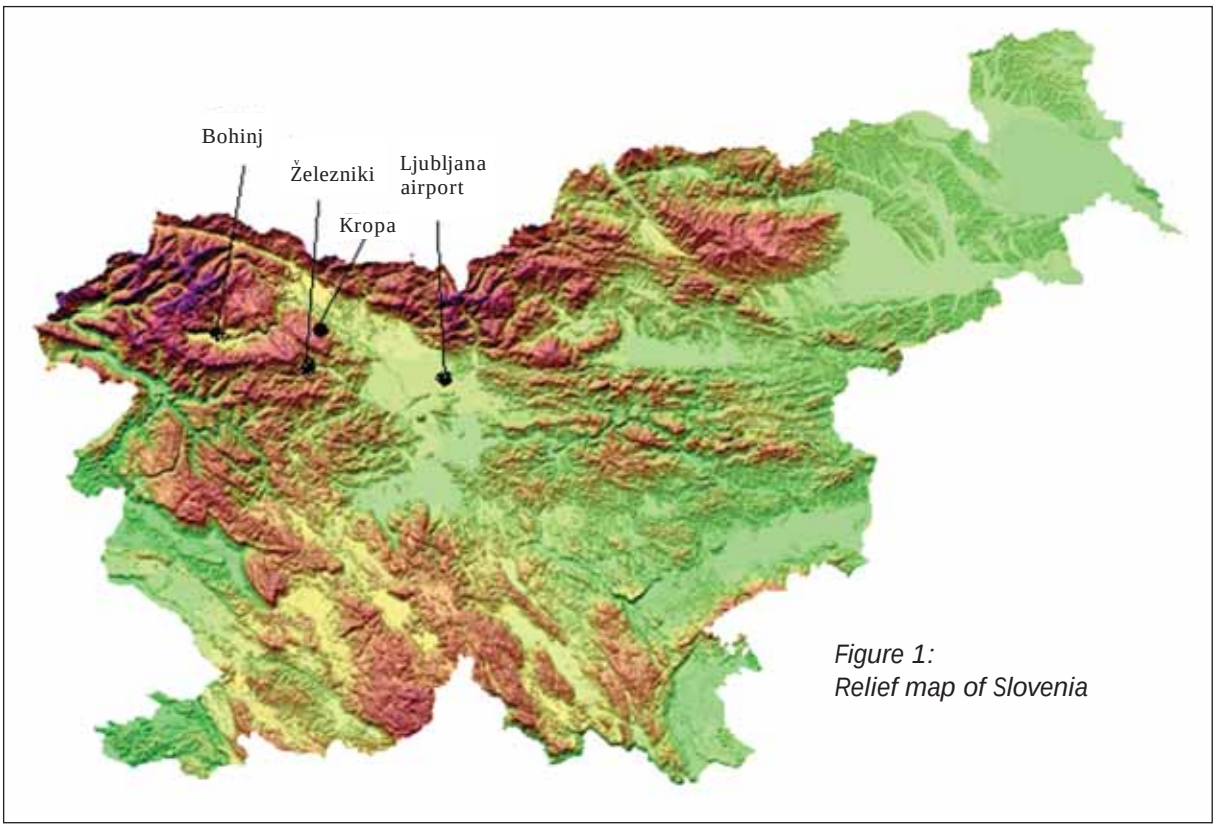


Figure 1: Relief map of Slovenia

tend to occur when moist air approaches on southwesterly winds. The orographic barrier leads to lifting of the airflow and precipitation can be persistent and intensive. In the case of unstable airmasses, the orography can also trigger convection.

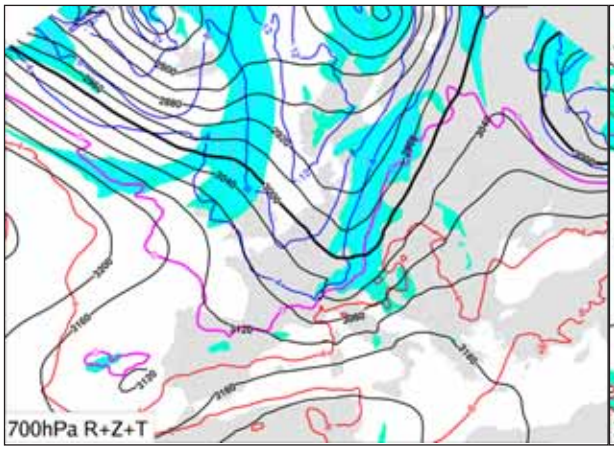


Figure 2a: Analysis of 700hPa height, temperature and relative humidity over Europe (18 Sep.2007 12 UTC)

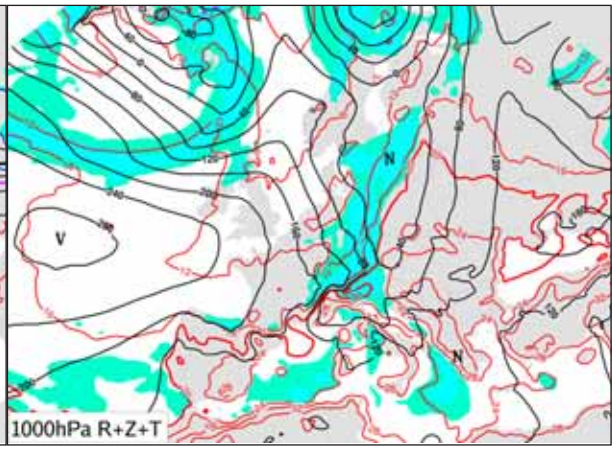


Figure 2b: Analysis of 1000hPa height, temperature and relative humidity over Europe (18 Sep. 2007 12 UTC)

Brief description of the synoptic situation and model behavior for this case

A surface low was present over northern Europe with a cold front approaching the Alps from the northwest. At the same time, an upper trough was moving from west to east with strengthening southwesterly flow over Slovenia, reaching speeds of 20 – 30 m/s above 1500m.

The approaching air mass was very unstable and there was also strong wind shear between the surface and 6000m.

The day before, on 17 September, the limited area models (Aladin/Si, LM of DWD) and the ECMWF global model (all 00 UTC runs) predicted a high amount of precipitation over parts of western Slovenia with values of 100 – 150 mm in 24 hours on 18 September. The forecast maximum was located more to the west towards the border with Italy. The main trend from successive model runs was that predicted precipitation amounts in the region of interest were diminishing. Despite these signals, the meteorologist on duty decided to issue a heavy precipitation warning for the civil protection authorities during the afternoon of 17 September. Following the protocols, a warning is issued when the expected amount of rain exceeds 100 mm in 24 hours in the western part of Slovenia and 50 mm in 24 hours elsewhere. In this case, an extreme weather warning of more than 100 mm of rain in 24 hours was predicted in western parts of Slovenia in the period from 18 September 00 UTC. Local thunderstorms with heavy rain were also mentioned.

Weather developments on 18 September 2007

Outbreaks of rain first occurred in the area of interest between 05:00 and 07:00 local time (UTC +2 hours). A short drier period followed before further rain moved in around 08:00, with a line of thunderstorms passing through between 09:20 and 10:00. Less intense rain occurred over the following 40 minutes but further bands of convection developed and became quasi-stationary across the area of interest between 10:40 and 13:00. As a consequence were many landslides and flash flooding in Kropa valley and in the town of Železniki. During the remainder of the afternoon, further thunderstorms and

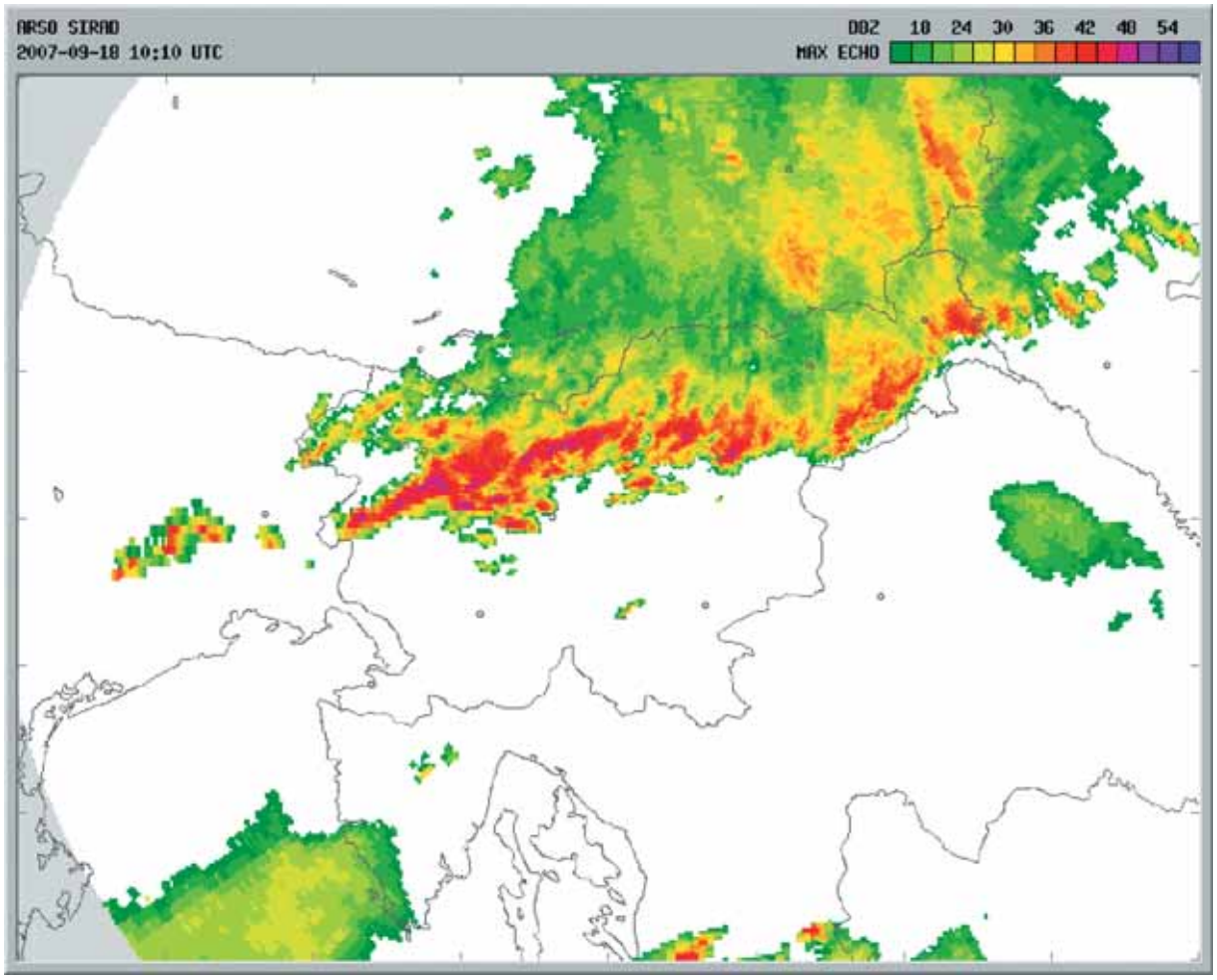


Figure 3: Radar image at 12:10 local time

heavy rain developed across the northern half of the country with the surface cold front clearing during the evening hours. Rain finally ceased at around 22:00 in the worst affected area.

Spatial and temporal distribution of precipitation

Most of the precipitation was recorded in a time period of 6 to 12 hours, within which the greatest return periods were calculated. In some places the return period exceeded 250 years. In Table 1 the highest 6 and 12 hour rainfall accumulations with return periods are presented whilst Table 2 shows some daily (18 Sep. 08:00 – 19 Sep. 08:00) amounts also with return periods.

	Highest 6-hour accumulations		Highest 12-hour accumulations		Daily (24 h) accumulation
Location	Precipitation (mm)	Return period (years)	Precipitation (mm)	Return period (years)	Precipitation (mm)
Lesce	145	> 250	176	> 250	180
Rudno Polje (1250m)	125	10	203	15	214
Ljubljana airport	115	> 250	176	> 250	181
Krvavec (1700m)	91	10	145	20	151
Gorenja vas	43	1	78	5	82

Table 1: The highest 6 and 12-hour precipitation accumulations measured at automatic weather stations with return periods. The data are presented for the affected region.

Stations	Precipitation amount	Return period (years)
Bukovo	224	25
Cerkno	140	25
Davša	230	250
Kneške Ravne	304	10
Naklo	135	10
Zgornja Sorica	233	50
Zgornje Bitnje	187	100

Table 2: 24 hour precipitation accumulations measured manually at 08:00 on 19 Sep. with estimated return periods. The data are presented for the affected region.

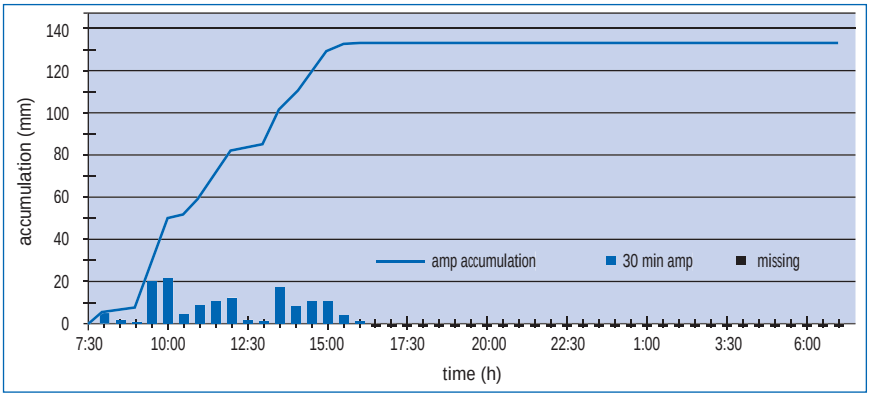
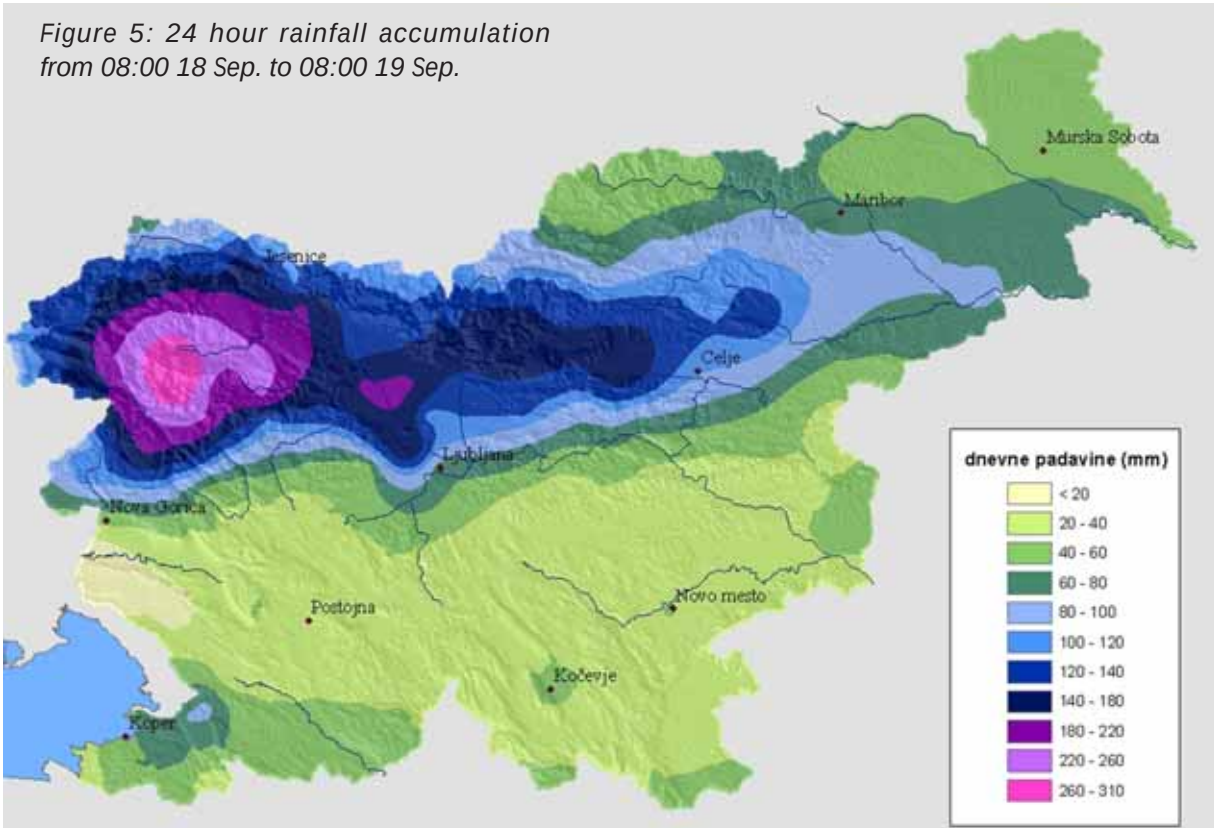


Figure 4: Accumulated precipitation in Suha

The intensity of rainfall can also be seen graphically in Figure 4 (below). The station is located in Suha, some 20km downstream from the worst affected town of Železniki. Rainfall intensities upstream of Železniki were estimated to have been even greater.

Figure 5 (below) shows the spatial distribution of rainfall accumulations in the 24 hour period from 08:00 on 18 Sep. 08:00 to 08:00 on 19 Sep. Note that more than 100 mm of rain was measured across the northern half of the country except in the lowlands of NE Slovenia. Peaks of more than 200 mm appeared in the region of the Julian Alps, where amounts of more than 300 mm were measured in some places.

Figure 5: 24 hour rainfall accumulation from 08:00 18 Sep. to 08:00 19 Sep.



The impact of heavy precipitation in Selška dolina (valley)

The worst affected place was the town of Železniki, a rural community with 7000 inhabitants situated in Selška dolina (valley). It is estimated that almost half of the population were affected by the rising floodwaters. The river Sora flows through the town and has many tributaries upstream that flow down steep terrain. Due to heavy rainfall in that region during morning between 09:00 and 10:00, the rivers and torrents began to rise. Intense rainfall continued and between 13:00 and 14:00, the discharge rates of the river Sora upstream of Železniki increased dramatically. The river burst its banks within 30 minutes. In Železniki the peak was reached at 14:00 when the water level was 370 cm above normal with a discharge rate of around 170 m^3/s. This represents a discharge rate with a return period of 50 to 100 years. The river was in a state of severe flood for only 1 to 2 hours and subsided very rapidly. Figure 6 shows the discharge of the Sora at the flow gauge in Suha, 20km downstream of Železniki.

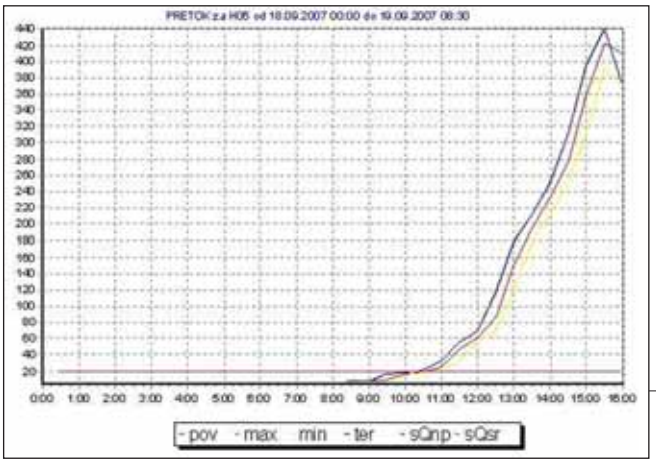


Figure 6: Discharge of the river Sora at Suha on 18 Sep.

The speed at which river levels rose and discharge rates were exceptional. The re-sulting floodwaters caused a lot of damage to buildings, factories, traffic routes and the local infrastructure and also resulted in the loss of personal belongings. The estimated damage in Železniki alone was around 70 million €. The reason for such a destructive situation was due to the intensity of rainfall over a very complex terrain, with rapidly responding river systems.

Was there any pressure on the forecaster?

The answer to this question is partly yes and partly no. First of all, the forecaster reacted correctly on 17 September when the warning was issued and sent to the civil protection authorities 20 hours before the event. Of course, the extreme rainfall amounts were underestimated but locally heavy rain was forecasted for western parts of Slovenia. A post-event analysis of the situation has showed that with existing tools, the prediction of the exact location and duration of the heavy precipitation was not possible. As a result there was no blame on the forecaster and in this case no pressure was applied. However, a week after the event another active frontal system was forecast to affect the same region. The pressure rose from day to day, particularly with increased interest from the media who wanted to

Figure 7: Destruction in Železniki from floodwaters.