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Contents

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Danijela Strle, Matej Ogrin

MATEJ OGRIN

Snow cover may last for months in the Planica Valley.

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Danijela Strle[1], Matej Ogrin[2]

Latent cooling of atmosphere as an indicator of lowered snow line: Case study from Planica and Vrata valleys

ABSTRACT: A lowered snow line in Alpine valleys as a local weather phenomenon often varies from one valley to another. The relief morphology of the valleys and the intensity of precipitation play a crucial role in the variation. In Slovenia certain valleys are more susceptible to this phenomenon than others, one such example being the Planica Valley. This paper examines the occurrence of a lowered snow line in the Planica Valley and the Vrata Valley during the winter seasons of 2015/2016 and 2016/2017. Precipitation events accompanying the occurrence of a lowered snow line were analyzed, and data on temperature and precipitation were included in the analysis. Results showed a striking degree of congruence of the phenomenon in both valleys.

KEY WORDS: lowered snow line, mountain climate, local climate, snow precipitation, Vrata Valley, Planica Valley, Slovenia, geography

Latentno ohlajanje ozračja kot pokazatelj znižane meje sneženja: študija primera iz dolin Planica in Vrata

POVZETEK: Znižana meja sneženja se, kot lokalni vremenski pojav, v alpskih dolinah ne pojavlja povsod v enaki meri. Ključno vlogo imata zaprtost dolinskega reliefa ter intenziteta padavin. Splošno znano v Sloveniji je, da so nekatere doline, kot na primer dolina Planice za ta pojav zelo dovzetne, druge pa manj. V nekaterih dolinah je pojav manj poznan zgolj zaradi tega, ker so neposeljene in pozimi tudi neobljudene. Prispevek govori o analizi pojava znižane meje sneženja v dolini Planice in dolini Vrata v dveh zimskih sezonah 2015/2016 in 2016/2017. Analizirani so bili padavinski dogodki s pojavom znižane meje sneženja, v analizo pa smo vključili temperaturne podatke ter podatke o padavinah. Rezultati so pokazali presenetljivo ujemanje pojava v obeh dolinah.

KLJUČNE BESEDE: znižana meja sneženja, gorsko podnebje, lokalno podnebje, sneg, dolina Vrata, dolina Planica, Slovenija, geografija

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[1] Osredek 12a, SI-1380 Cerknica
danijela.strle@gmail.com (https://orcid.org/0000-0001-8335-2295)

[2] University of Ljubljana, The Faculty of Arts, Ljubljana, Slovenia
matej.ogrin@ff.uni-lj.si (https://orcid.org/0000-0002-4742-3890)

1 Introduction

A lowered snow line is a local climatic occurrence that is especially common in Alpine valleys due to mountainous topography, but can also occur outside of the Alpine valleys and on the lowlands (Jaffe 1967; Steinacker 1983; Strle and Ogrin 2016).

The main reason for cooling of the atmosphere is the melting of snowflakes in the layer with a positive temperature, where latent cooling has an important role (Haby 2015). Minder, Durran and Roe (2011) and Minder (2010) studied the impact of latent cooling on the height of the zero isotherm and snow line with model simulations on the windward side of the mountain. In simulations without calculating the latent cooling, the zero isotherm and snow line were higher. As it approaches the mountain slope, the snow line descends evenly while the zero isotherm descends only near the slope. Cooling of atmosphere due to snow melting can even induce a change in the valley flow (Thériault et al. 2015).

In general, this phenomenon is better known in mountain areas than over low and flat areas: an important scientific record a lowered snow line also comes from an Alpine region. In Innsbruck (elevation 580 m) on 6 June 1956 15 cm of snow fell when the zero isotherm was at an elevation between 1200–1500 m, a day after 27 °C was recorded (Jaffe 1967). A lowered snow line can also appear in open areas, but in such cases winds must be very weak and precipitation strong. In Slovenia such a case was recorded on 18 April 2015 in Logatec (elevation 477 m), when intense and long-lasting precipitation caused an unexpected lowering of the snow line in the Notranjska region of Slovenia when the zero isotherm was at an elevation of around 1000 m (Likar 2015; Slovenian … 2020). Weakening of advection due to mountain relief is not the only reason for a frequent lowered snow line in Alpine valleys. Marwitz (1983; 1987) found that during heavy precipitation the snow line descends considerably lower than in nearby areas with the same air mass. The longer the precipitation lasts, the lower the zero isotherm and the snow line. With increasing precipitation intensity, the lowering of the isotherm and snow line occurs more rapidly (Minder, Durran and Roe 2011). Steinacker (1983) notes that in Alpine valleys the amount of precipitation for cooling the atmosphere is smaller than in open areas due to the »volume effect«. Unterstrasser and Zängl (2006) agree that since the horizontal cross-section of the valley decreases towards the valley bottom, the volume of the air mass below the snow line decreases more rapidly than it does outside valleys. For lowering the zero isotherm to the valley bottom, the initial elevation of the zero isotherm is important. In Alpine valleys the zero isotherm starts to descend much faster if the initial elevation is under the elevation of mountain ridges, which prevents warm air from the surrounding area from entering the area of precipitation and cooling. In extreme cases the thickness of the isotherm layer can reach 3 km (Stewart 1992); however, usually it reaches up to 1 km (Kain, Goss and Baldwin 2000). A typical feature of the lowered snow line phenomenon is significant fluctuation in the snow line within the same air mass and between areas in close proximity. In such cases, often the snow line occurs much lower than predicted (Pehsl 2010). Strle (2018) identified three different types of weather conditions for lowered snow line. These are warm advection, cold advection and cold air lake.

Very little is known about the local climate of Alpine valleys which are uninhabited, such as the Vrata Valley. Although it is well visited in summer, in winter it is virtually devoid of people apart from infrequent mountaineers and climbers. Because it is long (12 km) and impassable in winter, it is one of the less frequently visited Slovenian Alpine valleys in this time of the year. The Planica Valley is also one of the longest in the Slovenian Julian Alps (8 km), but we know more about the local climate there, especially regarding precipitation (Ogrin and Kozamernik 2019; 2020). Precipitation condition in Julian Alps are typical for mountain areas relatively close to the sea with significant precipitation gradients and high precipitation amounts which were discussed already in previous studies (e.g. Ogrin and Ortar 2007; Hrvatin and Zorn 2017)

In Slovenia, a lowered snow line in certain valleys in the Julian Alps was investigated by Strle (2015; 2018) and Strle and Ogrin (2016). Based on a three-year study of the phenomenon, we have obtained a large amount of data, presented in this paper. Research in recent years has provided insight into the magnitude and characteristics of a lowered snow line in some Alpine valleys in the Slovenian part of the Julian Alps.

The aim of this paper is to determine the occurrence of a lowered snow line in the Vrata and the Planica valleys through an analysis of temperature conditions during precipitation events. Our aim was also to analyse similarities and differences in a lowered snow line of the two valleys, which are located near to one another. Since this is also the reason for similar amount and pattern of precipitation the main questions were if lowered snow line occurs at the same time and if the cooling in both valleys is of the same rate. Such detailed questions were not discussed in papers, published so far.

2 Methods

A characteristic feature of a lowered snow line is that during the precipitation event in the valley it first rains, then an increasingly thick vertical layer of air is gradually formed with a temperature of 0 °C or a few tenths of a degree above 0 °C (Stewart 1992; Kain, Goss and Baldwin 2000; Lackmann et al. 2002; Strle and Ogrin 2016). We therefore analysed temperature conditions during winter precipitation events at different locations and elevations in both valleys. In the temperature analysis from our temperature recording stations we included data obtained in the winters of 2015/2016 and 2016/2017, each from the beginning of December to the end of April. In the Planica Valley, the lowest placed station was Planica 1 at an elevation of 990 m, followed by the Planica 2 station at an elevation of 1200 m, while the highest station was Planica 3 at an elevation of 1390 m (Figure 1). Four stations were set up in the Vrata Valley. The lowest-lying station, Vrata 1, was placed at an elevation of 725 m, followed by the Vrata 2 station at an elevation of 770 m, the Vrata 3 station at an elevation of 940 m, and the highest placed station, Vrata 4, at an elevation of 1115 m (Figure 1).

For an even better understanding of the dynamics of the vertical temperature gradient, we obtained temperature data from the Society for Weather and Climate Research (Archive of the Society … 2017) from the station located on the high mountain plateau of Kriški Podi at an elevation of 2050 m (Figure 1). As precipitation is crucial for the occurrence of a lowered snow line, we also obtained data on precipitation duration and intensity from the ARSO weather stations closest to our measuring spots, collecting data from

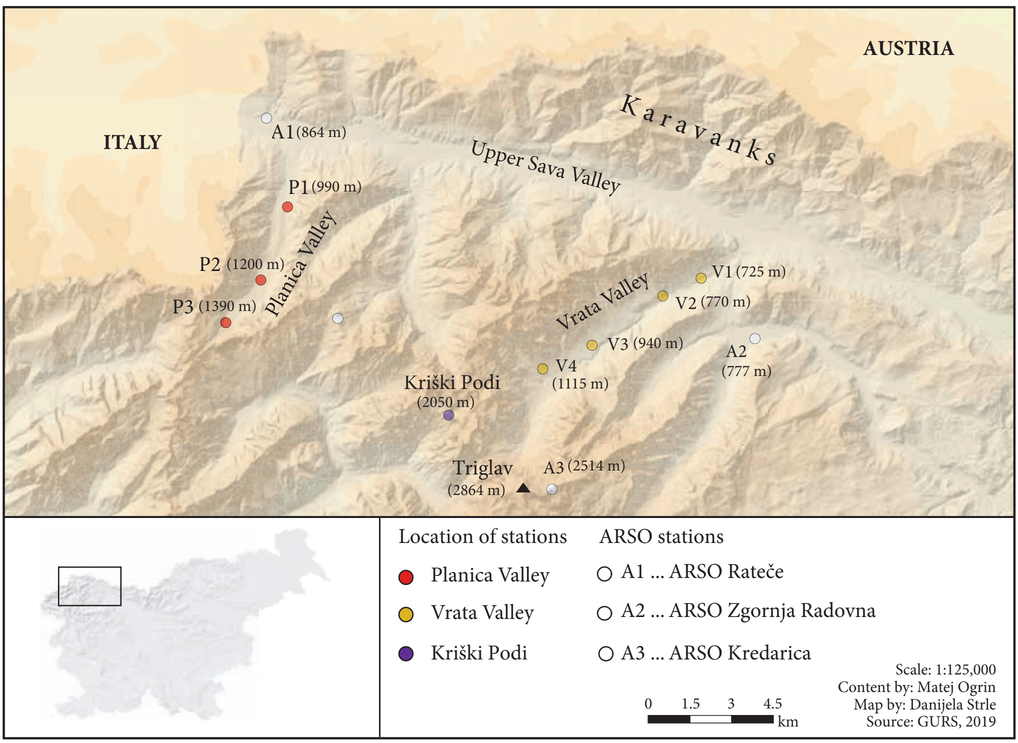

Figure 1: Research area with locations of the measuring stations (see Table 1 for details).

the Rateče and Zgornja Radovna stations. The distance from the Rateče weather station to the nearest station in Planica (P1) was 3.3 km, and it was 7.5 km to the farthest station (P3), while the distance from the Zgornja Radovna weather station to our stations in the Vrata Valley was 2.9 km (V1) and 7.7 km (V4). We did not take data from the ARSO Kredarica high mountain station (2515 m), since the accuracy of precipitation data in winter may be questionable due to the influence of wind (Yang et al. 1994; Førland et al. 1996; Pristov, Pristov and Zupančič 1998; Nešpor and Sevruk 1999; Dolinar, Ovsenik Jeglič and Bertalanič 2006). Precipitation data recorded at ARSO stations only served as a rough estimate of the intensity and duration of precipitation in each valley; we did not compare precipitation intensities in the two valleys.

The temperature was measured using an *iButton* digital thermometer, which was placed in a radiation shield representing an imitation of a Stevenson screen (Vertačnik and Sinjur 2013). The radiation shield protected the digital thermometer from the effects of weather that might influence the accuracy of the data recorded. Digital thermometers in the Planica Valley were set at a resolution of 0.1 °C and the temperature was recorded every 15 minutes. In the Vrata Valley, digital thermometers were set at a resolution of 0.5 °C and the temperature likewise recorded at 15-minute intervals. The reason for the different resolutions is that the Vrata Valley is remote and hard to reach in winter, when there is also a danger of snow avalanches. The measurement period was 85 days for a resolution of 0.5 °C so that we did not need to collect the data as frequently as in the Planica Valley. All measurements were recorded using winter UTC+1 time. Where recorders were set at a resolution of 0.1 °C, one series of measurements lasted 42 days. The radiation shelter on the Kriški Podi Plateau contained a *Madgetech TransiTempII* temperature data logger and was set to a resolution of 0.1 °C, recording data every 15 minutes. It likewise measured temperature using winter UTC+1 time.

Since we were interested only in temperature conditions during times of precipitation, when there is no direct sunlight, the influence of the microlocation on temperature data was negligible, and so we simply attached the temperature recording equipment to the trunks of trees. After completing a series of measurements, we transferred the data from the recorders to a laptop and reset the recorders. Data loss due to *iButton* failure were very few. Only in case of 5 February 2017 we recorded loss of data on station V3, however this did not affect the quality of research.

Table 1: Metadata of measuring stations.

Area	Station	Elevation (m)	Geographical coordinate		Measuring instrument	Measured parameter and measurement interval (min)
			Y (west – east)	X (south – north)		
Planica Valley	Planica 1 (P1)	990	402329	147956	Digital recorder	Temperature; 15
	Planica 2 (P2)	1,200	401370	145330	Digital recorder	Temperature; 15
	Planica 3 (P3)	1,390	400113	143802	Digital recorder	Temperature; 15
	ARSO* Rateče (A1)	864	401574	151142	ARSO	Temperature; 30 Rainfall rate; 30
Vrata Valley	Vrata 1 (V1)	725	417179	145396	Digital recorder	Temperature; 15
	Vrata 2 (V2)	770	415803	144761	Digital recorder	Temperature; 15
	Vrata 3 (V3)	940	413263	142988	Digital recorder	Temperature; 15
	Vrata 4 (V4)	1115	411490	142142	Digital recorder	Temperature; 15
Kredarica	ARSO* Kredarica (A3)	2,514	411822	137823	ARSO	Temperature; 30 Rainfall rate; 30
Radovna Valley	ARSO* Zgornja Radovna	777	419111	143227	ARSO	Temperature; 30 Rainfall rate; 30
Kriški Podi Plateau	Kriški Podi (A2)	2,050	408116	140475	Digital recorder	Temperature; 30 Rainfall rate; 30

*Archive of Slovenian Environment Agency 2020.

When a lowered snow line occurs, a zone of zero isotherm is established in the valley (Figure 2), so in the analysis of temperatures during precipitation we focused primarily on this phenomenon. We then compared the dynamics of cooling between the two valleys and in this way identified differences and similarities in the occurrence of a lowered snow line.

3 Results

We provide temperature analyses for seven snow events of a lowered snow line in the winter seasons 2015/2016 and 2016/2017 in both valleys and on Kriški Podi (2050 m). Temperature conditions at stations in each valley at roughly the same elevations were analysed. In two cases we refer to temperatures only from higher-lying parts of the valleys and in five cases temperatures from both higher and lower parts. The higher

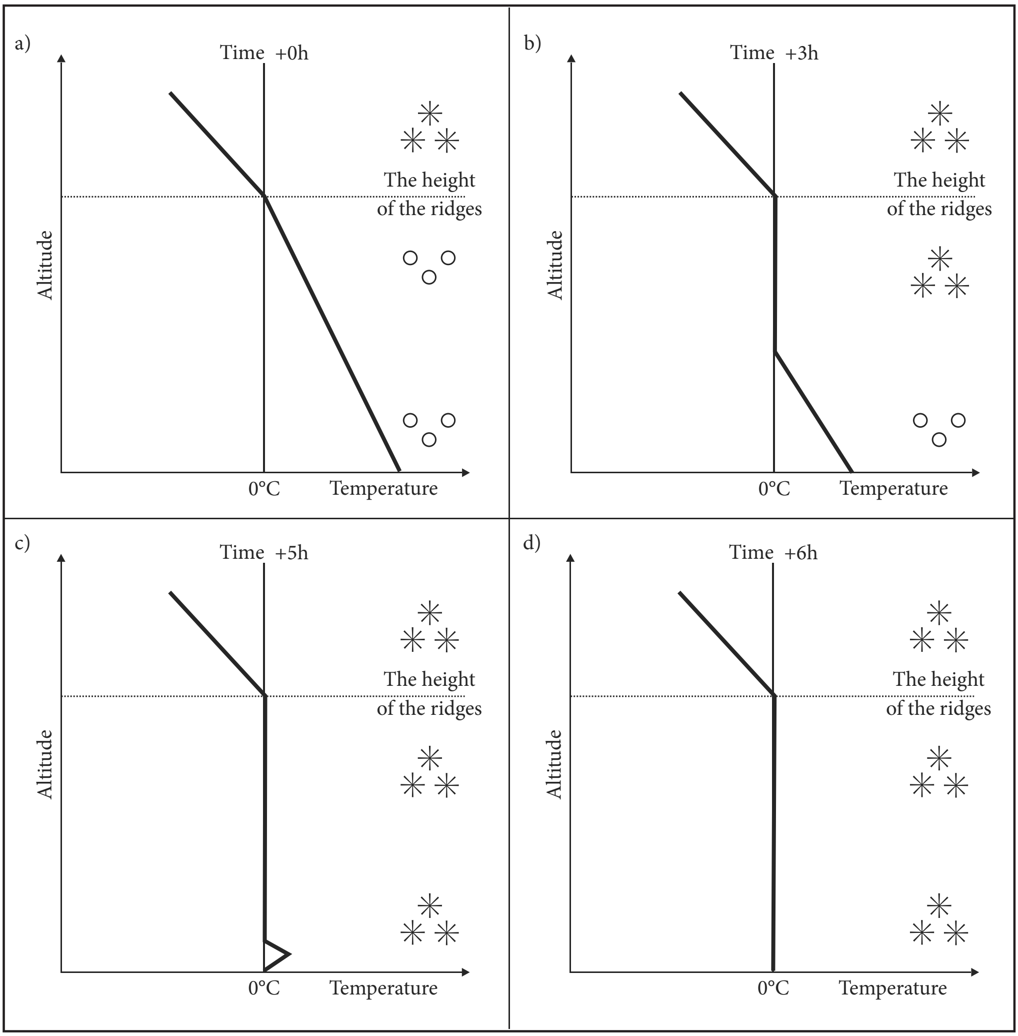

Figure 2: The transition from heavy rain to snow at the surface due to the absorption of latent heat from melting snowflakes (modified after Lackmann et al. 2002, 1018).

stations were Planica 2 (P2, 1200 m) in the Planica Valley and Vrata 4 (V4, 1115 m) in the Vrata Valley, while the lower ones were Planica 1 (P1, 990 m) in the Planica Valley and Vrata 3 (V3, 940 m) in the Vrata Valley.

3.1 Snow event 1: 7–8 February 2016

In the snow event recorded on 7 and 8 February 2016, the temperature congruence in the Vrata and Planica valleys at both elevations was very pronounced, indicating the simultaneous occurrence of a lowered snow line. At higher stations, the cooling in the Vrata Valley was slightly less pronounced or rather took place more slowly than in Planica, and even when the temperature reached its lowest values, the temperature remained a few tenths higher than in the Planica Valley. Pronounced warming at the end of precipitation at higher stations occurred at the same time (Figure 3). At lower-lying stations, the cooling and warming curves were even more closely aligned. Although the cooling started about 90 minutes later in the Vrata Valley, the temperature curves soon merged (Figure 4). The occurrence of a lowered snow line in both valleys took place in a very similar way and almost simultaneously.

3.2 Snow event 2: 9–10 February 2016

The data for the second snow event, which took place on 9 and 10 February 2016, show a strongly congruent cooling and occurrence of a lowered snow line in the two valleys. With the intensification of precipitation, which occurred in the Vrata Valley a little earlier than in the Planica Valley, the atmosphere began to cool, about 45 minutes earlier in Vrata than in Planica. From the temperature on Kriški Podi (2050 m) we see that cold advection started after the lowered snow line effect in both valleys cooled the atmosphere to 0 °C. Due to cold advection, the temperature at both higher stations dropped below 0 °C (to around –2 °C) (Figure 5), while at lower stations it dropped below 0 °C for only a short time, and not lower than –1.5 °C (Figure 6).

3.3 Snow event 3: 28 February–1 March 2016

The case on 28 February –1 March 2016 involved precipitation at intervals and initial warming in both valleys. In the Vrata Valley, at station V4 this was followed by fluctuations in temperature that coincided with the beginning and end of precipitation. When precipitation stopped, the temperature rose to 2 °C or even 3 °C, but when precipitation occurred it cooled to an interval between 0 °C and 0.5 °C. There was hardly any temperature fluctuation in Planica (P2) during precipitation (Figure 7). No fluctuations were recorded at the lower stations in either valley. One exception is the incidence between 11 am and 3 pm on 10 February when the temperature rose by about a degree when the precipitation stopped or lessened. The temperature dynamics at lower-lying stations were quite similar during precipitation (Figure 8).

3.4 Snow event 4: 5 March 2016

In the snow event examined on 5 of March 2016, the temperature trajectories in the Vrata Valley and the Planica Valley largely coincided at both higher and lower-lying stations. At higher stations, we observed brief periods of temperature divergence, when the temperature in Planica rose from 0 °C to about 2 °C with a short-term lessening of precipitation. Something similar occurred at the end of precipitation when the temperature in the Vrata Valley increased by 0.5 °C (Figure 9). There was a difference even before the onset of precipitation when a weak inversion was present in the Planica Valley, which only dissipated through the cooling of the higher layer of air due to melting and warming of the lower layer. A slightly more pronounced inversion layer formed in the Vrata Valley, which also dissipated quickly after precipitation began, and the upper station had the same temperature or was slightly (0.5 °C) cooler (Figure 9; Figure 10).

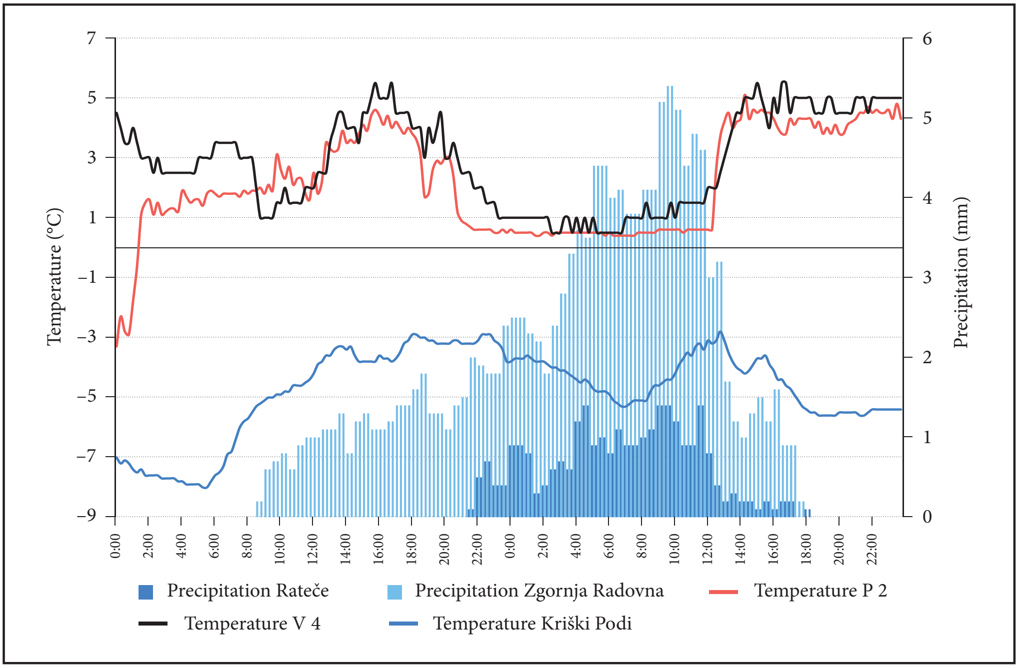

Figure 3: Dynamics of temperature and precipitation on the Kriški Podi Plateau (2050 m) and at higher-lying stations in the Vrata Valley (V4, 1115 m) and the Planica Valley (P2, 1200 m) during an occurrence of a lowered snow line in the night from 7 to 8 February 2016.

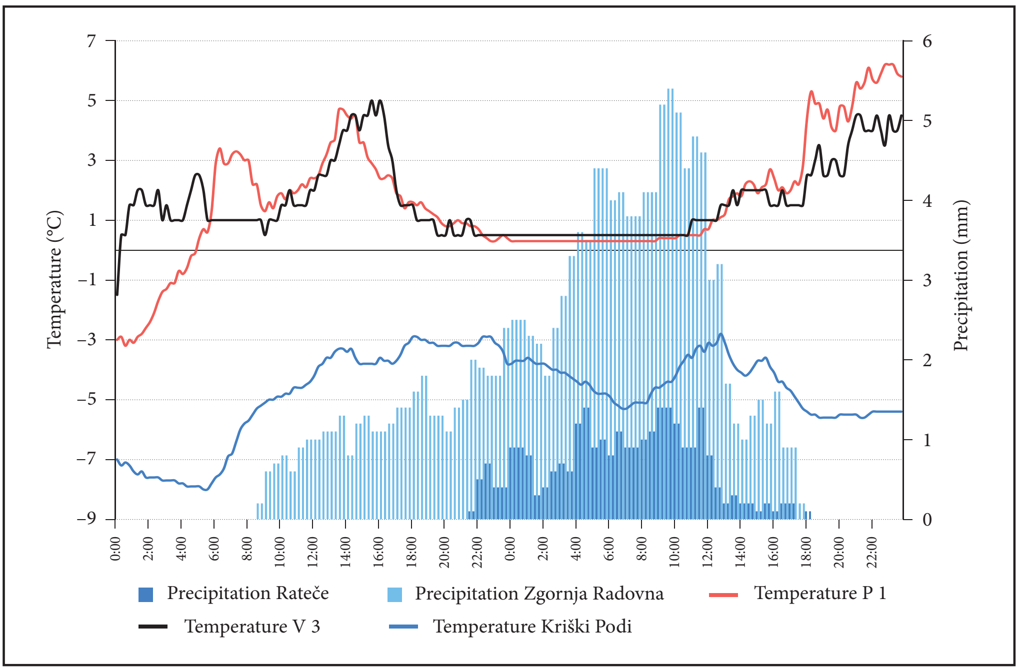

Figure 4: Dynamics of temperature and precipitation on the Kriški Podi Plateau (2050 m) and at lower-lying stations in the Vrata Valley (V3, 940 m) and the Planica Valley (P1, 990 m) during an occurrence of a lowered snow line in the night from 7 to 8 February 2016.

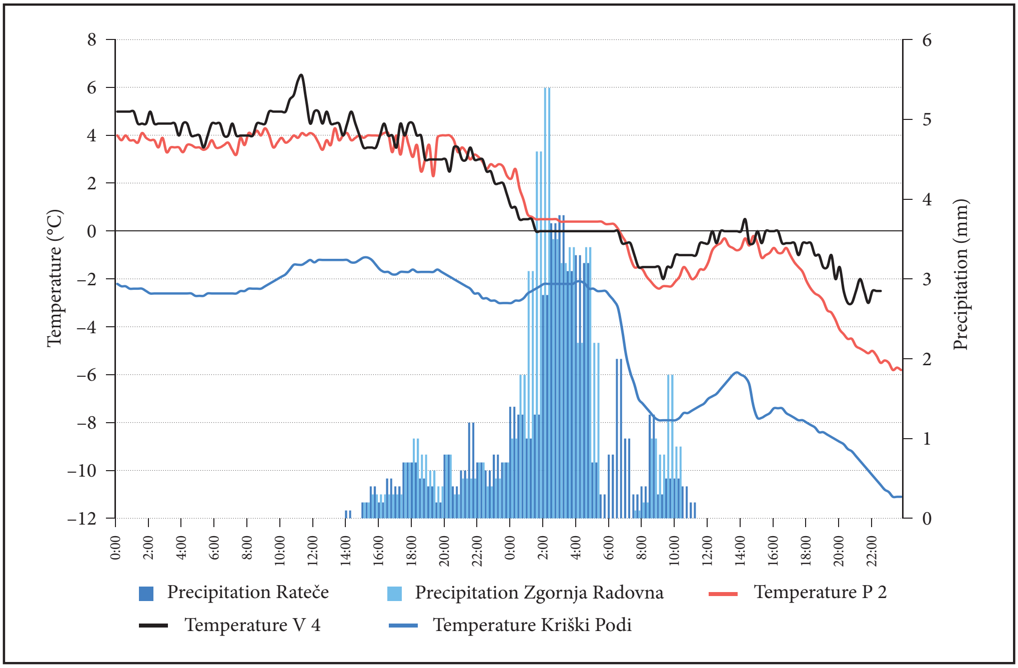

Figure 5: Dynamics of temperature and precipitation on the Kriški Podi Plateau (2050 m) and higher-lying stations in the Vrata Valley (V4, 1115 m) and the Planica Valley (P2, 1200 m) during an occurrence of a lowered snow line in the night from 9 to 10 February 2016.

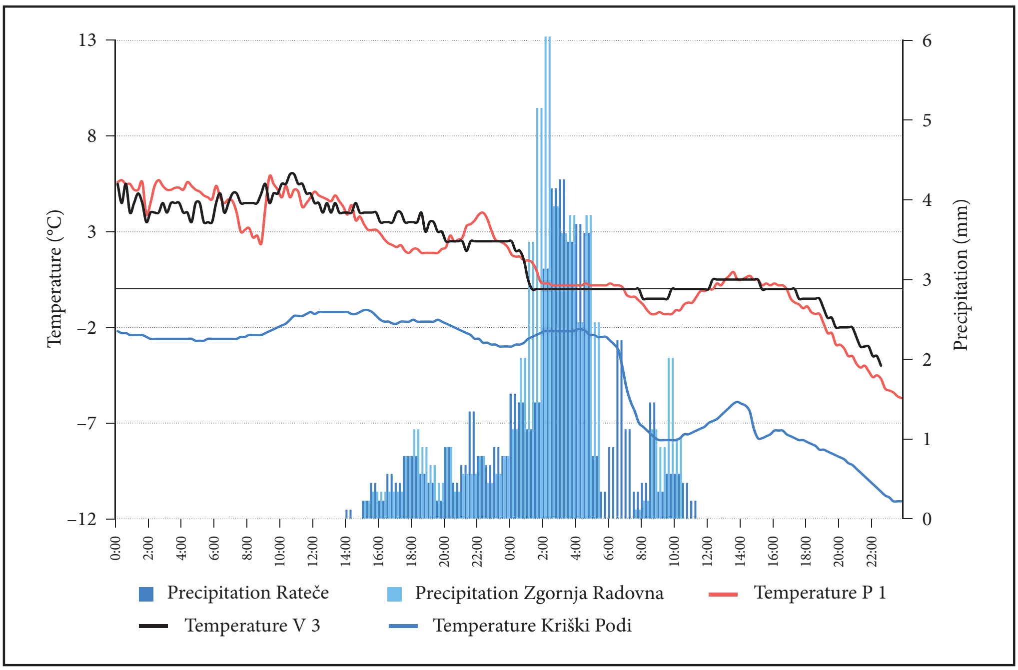

Figure 6: Temperature and precipitation dynamics on the Kriški Podi Plateau (2050 m) and at lower-lying stations in the Vrata Valley (V3, 940 m) and the Planica Valley (P1, 990 m) during an occurrence of a lowered snow line in the night from 9 to 10 February 2016.

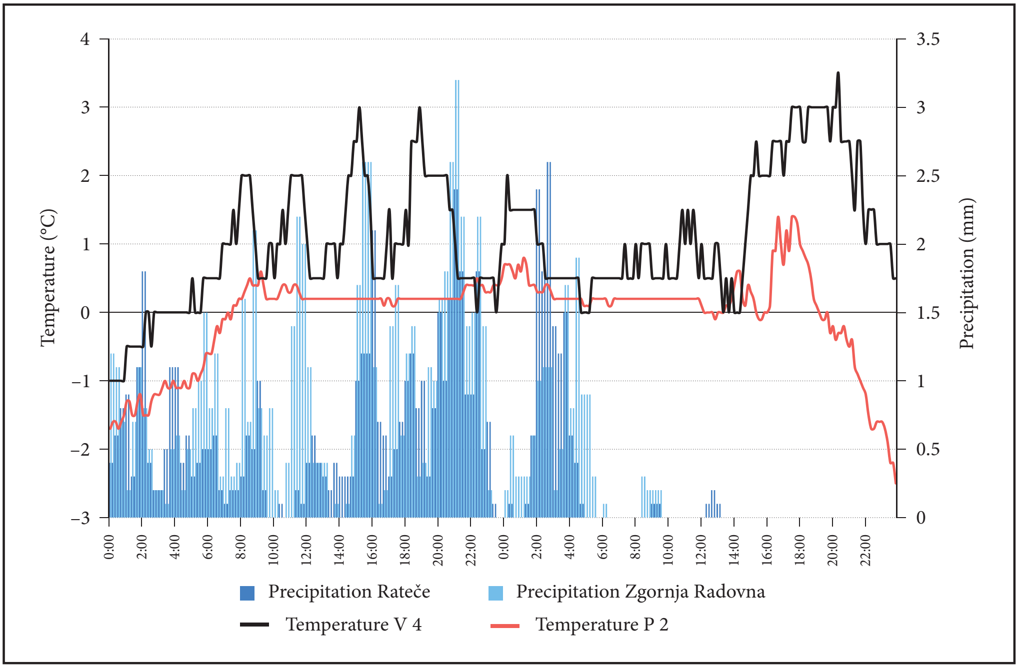

Figure 7: Dynamics of temperature and precipitation at higher-lying stations in the Vrata Valley (V4, 1115 m) and the Planica Valley (P2, 1200 m) during an occurrence of a lowered snow line in the night from 28 February to 1 March 2016.

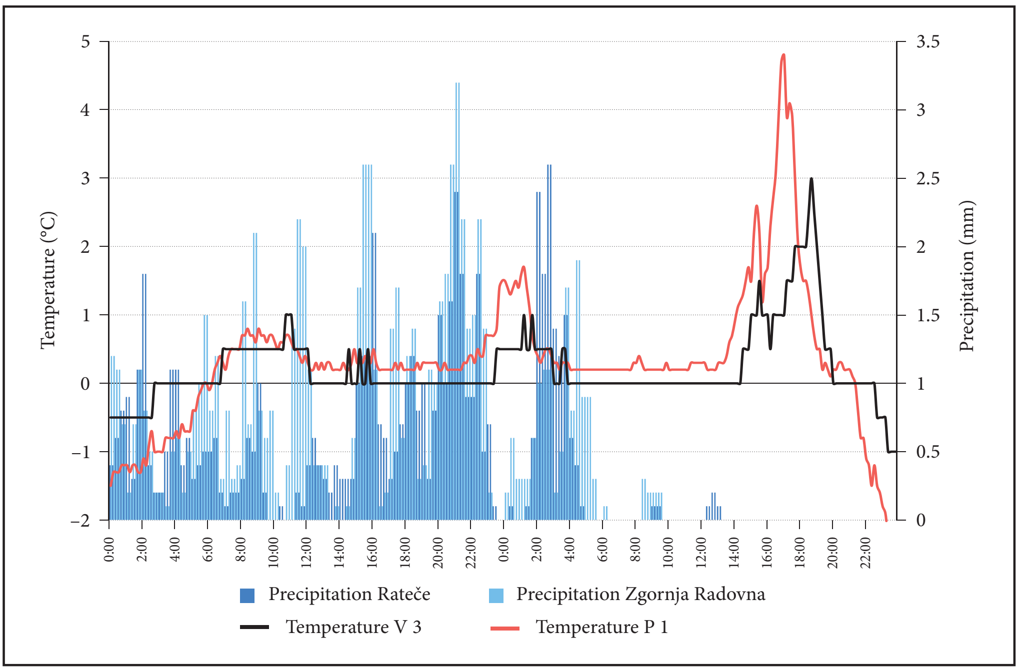

Figure 8: Dynamics of temperature and precipitation at lower-lying stations in the Vrata Valley (V3, 940 m) and the Planica Valley (P1, 990 m) during an occurrence of a lowered snow line in the night from 28 February to 1 March 2016.

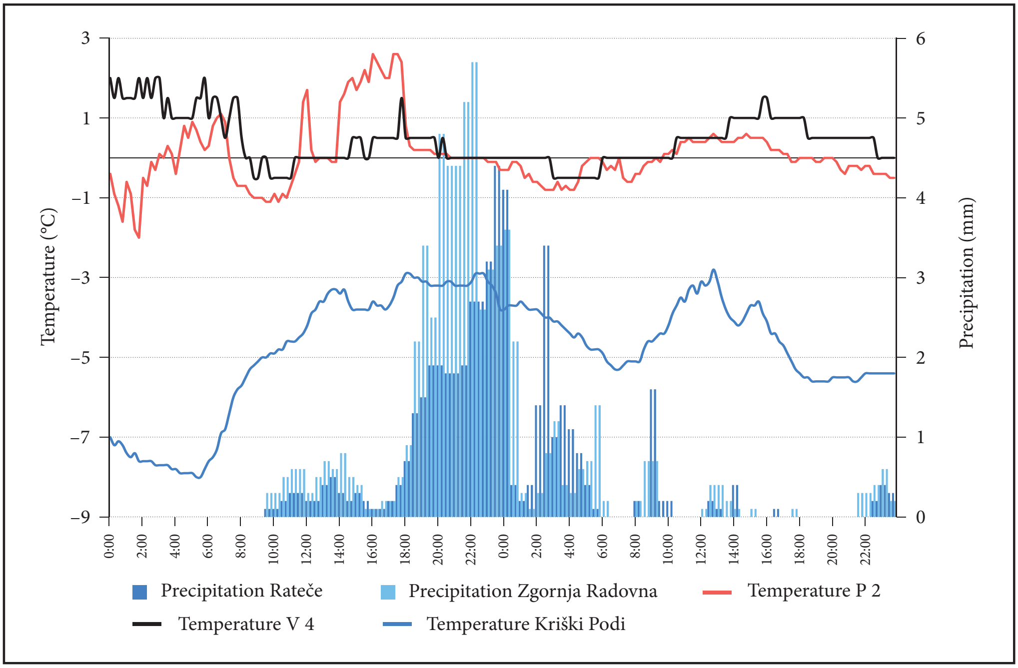

Figure 9: Dynamics of temperature and precipitation on the Kriški Podi Plateau (2050 m) and at higher-lying stations in the Vrata Valley (V4, 1115 m) and the Planica Valley (P2, 1200 m) during an occurrence of a lowered snow line on 5 March 2016.

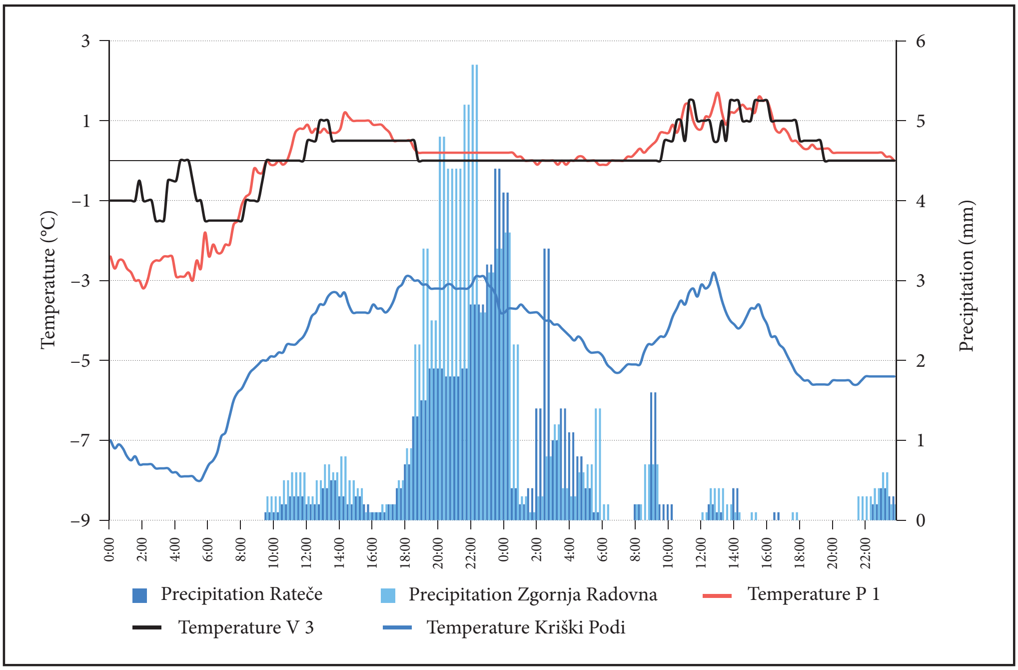

Figure 10: Dynamics of temperature and precipitation on the Kriški Podi Plateau (2050 m) and at lower-lying stations in the Vrata Valley (V3, 940 m) and the Planica Valley (P1, 990 m) during an occurrence of a lowered snow line on 5 March 2016.

3.5 Snow event 5: 5 February 2017

In the snow event on 5 February 2017, for which we have available only data from higher-lying stations, there was noticeable warming in the Planica Valley and the Vrata Valley that coincided with warming on the Kriški Podi Plateau. During the time of precipitation, the temperature in the Planica Valley stayed within an interval between –0.5 °C and +0.5 °C, while in the Vrata Valley the temperature dropped from 2.5 °C to 0.5 °C during precipitation. At the end of precipitation, the temperature in the Vrata Valley rose (to between 2 and 3 °C) while in the Planica Valley it remained at 0 °C. In this case, we do not see a complete congruence since the inversion in the Planica Valley was more pronounced and there was no dissipation. Even so, both temperature curves become closest at the onset of precipitation, as confirmed by the coincidence of a lowered snow line in both valleys (Figure 11).

3.6 Snow event 6: 28 February–1 March 2017

In the sixth snow event, we only have data available for higher-lying stations. The occurrence was recorded on 28 February 2017, when precipitation and a lowered snow line were followed by cold advection. An almost concurrent cooling is seen in both valleys when precipitation occurred, and then cooling stopped at 0 °C (P2) or at 0.5–1 °C (V4). Temperatures dropped below 0 °C only with cooling due to cold advection, which is also visible in the dynamics of temperature on the Kriški Podi Plateau. The cooling was slightly more pronounced in the Planica Valley, although it occurred about two hours later. A temperature of 0 °C was reached in Planica sooner than in the Vrata Valley due likely to the approximately 85 m higher elevation of the Planica station (Figure 12).

When precipitation ended, the temperatures rose by 2–3 °C (Figure 12). In this case as well the occurrence of a lowered snow line largely coincided in the two valleys, and cooling was more pronounced in the Planica Valley by about one degree, but this difference could be attributed to the 85 m higher elevation of the station (Figure 1).

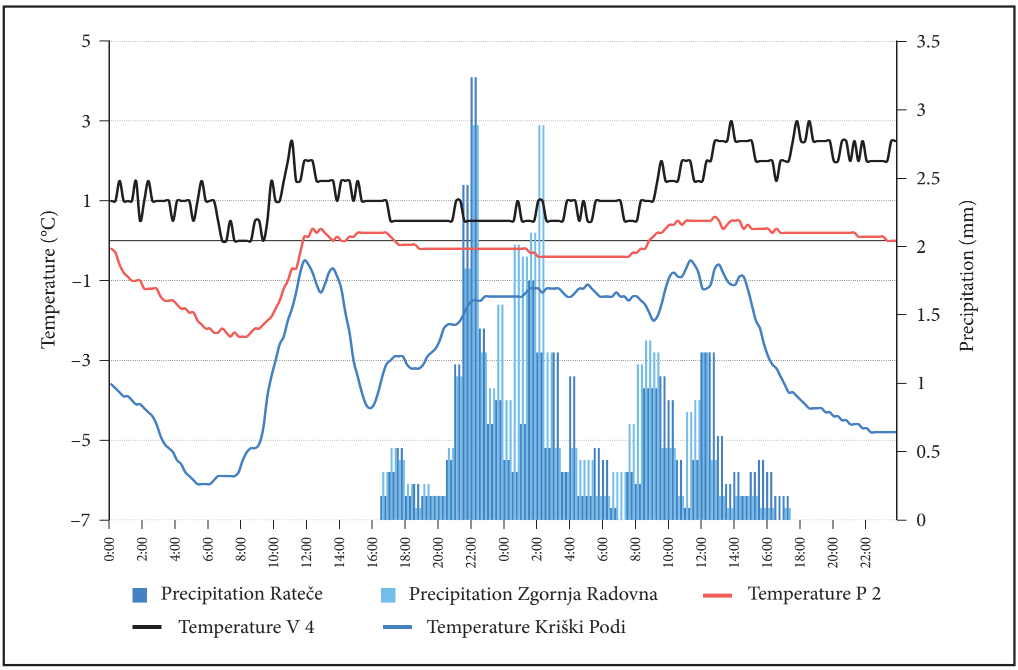

Figure 11: Dynamics of temperature and precipitation on the Kriški Podi Plateau (2050 m) and at higher-lying stations in the Vrata Valley (V4, 1115 m) and the Planica Valley (P2, 1200 m) during an occurrence of a lowered snow line on 5 February 2017.

3.7 Snow event 7: 4–5 March 2017

An analysis of snow event 7, recorded on the evening of 4 March 2017, shows temperature dynamics is similar to previous cases. Cooling was slightly more pronounced in the Planica Valley, but the temperature difference was less than one degree (Figure 13).

4 Discussion

Determination of a lowered snow line through an analysis of temperature profiles during precipitation events has proven to be very useful. An analysis of temperature distribution with elevation within the valley system shows very clearly whether or not the effect of a lowered snow line has occurred. The phenomenon of a lowered snow line in Slovenia is best known in the Upper Sava Valley and partly in Bohinj because these areas are inhabited. There are also weather stations of the Slovenian Environment Agency (ARSO) in Rateče and Bohinj, and both areas are host to visitors in winter. It is difficult to obtain meteorological observation data from remote and inaccessible valleys, since these are uninhabited and do not have permanent automatic weather stations and cameras. In our study, temperature conditions were determined in a relatively simple way in two valleys, which also enables research on the prevalence of the phenomenon and its dependence on other factors, for example, valley morphology and orientation. In our study, it also turned out that the phenomenon in valleys that are sufficiently close to one another and similarly closed to the advection of wind is quite similar but not entirely identical. To completely exclude temperature differences due to elevation, it would be even better if the stations were set up at exactly the same elevation. We also noticed, that in the case of no wind and the effect of a lowered snow line, differences in elevation of up to about 50 m do not have a significant effect on temperature, but when advection is present in dry air, the difference in elevation can also mean a temperature difference of up to 0.5 °C, whereas during advection in saturated air these differences are smaller and amount to about 0.3 °C.

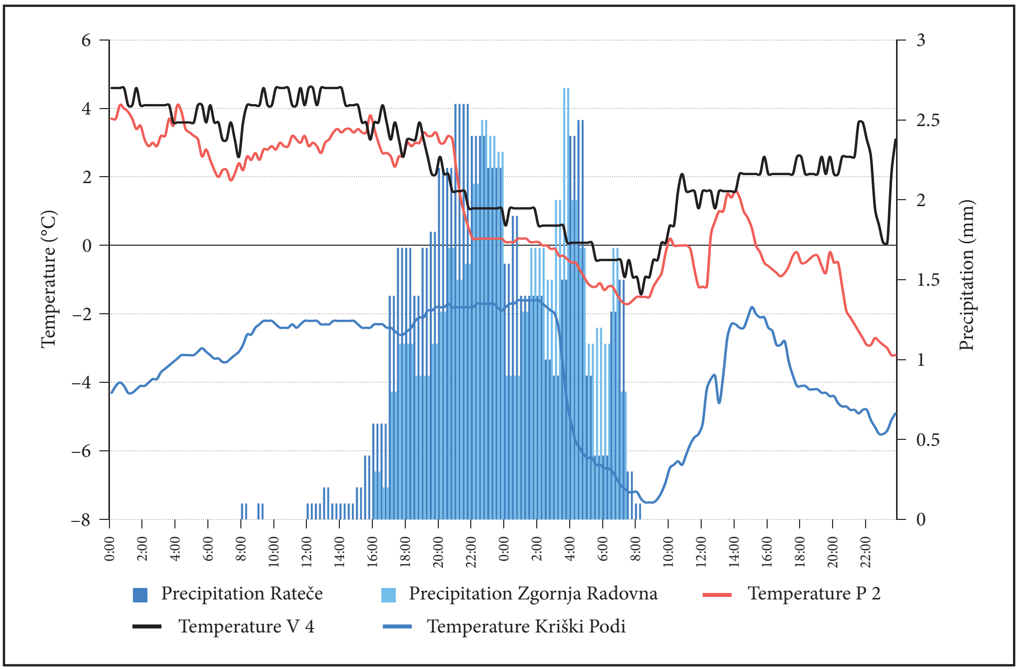

Figure 12: Dynamics of temperature and precipitation on the Kriški Podi Plateau (2050 m) and at higher-lying stations in the Vrata Valley (V4, 1115 m) and the Planica Valley (P2, 1200 m) during an occurrence of a lowered snow line in the night from 28 February to 1 March 2017.

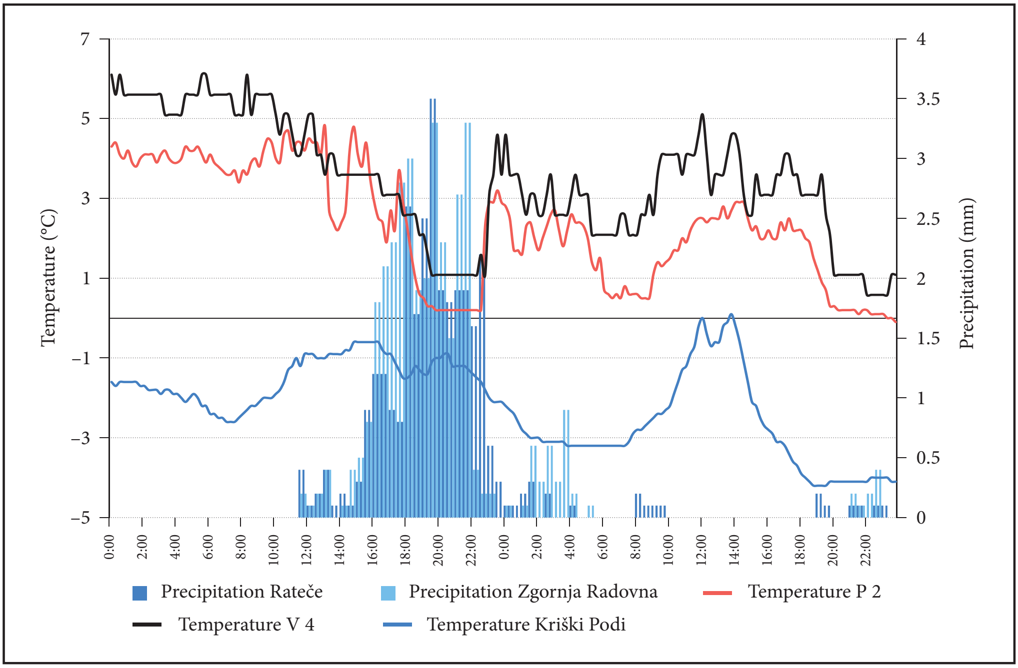

Figure 13: Dynamics of temperature and precipitation on the Kriški Podi Plateau (2050 m) and at higher-lying stations in the Vrata Valley (V4, 1115 m) and the Planica Valley (P2, 1200 m) during an occurrence of a lowered snow line in the night from 4 to 5 March 2017.

The analysis of temperature conditions during a lowered snow line occurrence in the Vrata Valley and the Planica Valley showed considerable coincidence in the two valleys during the period of measurement. Comparison of temperatures at two elevations in the two valleys also showed a slight divergence of temperatures, with slightly more pronounced cooling observed in the Planica Valley in five of the nine instances (taking into account both the higher and lower stations). In calm atmosphere condition this is due to a more pronounced inversion. In the case of cold advection, part of this difference can be explained by the difference in elevation, since the higher station in Planica (P2) was located about 85 m higher and the lower station in Planica (P1) about 50 m higher than the corresponding stations in the Vrata Valley. The difference in the resolution of the measurements should also be taken into account: the thermometers in Planica were set to a resolution of 0.1 °C and in Vrata to 0.5 °C. The lower resolution and consequently longer period of measurements in the Vrata Valley was, as discussed in section 2, due to the remoteness of the valley and safety concerns.

The proximity of the valleys to one another plays an important role, but it is not the only factor contributing to similar intensity of a lowered snow line, nor it is a decisive one. The elevation of the surrounding mountains is also a contributing factor in the occurrence of a lowered snow line due to weakening of advection. Minder, Durran and Roe (2011) with model simulations showed that at higher wind speed, lowering of the snow line weakens. Simulations also showed that weakening of advection could also be the result of the blocking effect of relief, which is often the case in mountainous areas. An effect similar to weakening of advection due to blocking by mountains also occurs in deep and closed Alpine valleys. The ridges above the valleys protect them against strong winds, which also explains why a lowered snow line appears more often and more intensively in Alpine valleys (Unterstrasser and Zängl 2006). The importance of weak advection was also confirmed by Kain, Goss and Baldwin (2000). As in the Planica Valley, the Vrata Valley is also surrounded by high ridges over 2000 m in elevation at the valley head. In particular, the northern side surrounding the valley rises above 1900 m at the entrance to the valley with the slopes of Vrtaško Sleme (2076 m) and Vrtaški Vrh (1898 m) and then rapidly exceeds 2000 m. At the southern edge of the valley, the slopes rise more gradually, reaching 2000 m only with the slopes of the summit Nad Kuhinjo Špica

(2266 m). The ridges are high enough to protect both valleys often from strong advection. On the other hand, the elevation of the ridges is also important for the air temperature at the upper boundary of the valley, where precipitation enters the valley system and where advection begins to weaken. The head of the Vrata Valley, which is surrounded by the highest mountains in Slovenia (for example, the north wall of Triglav with the Triglav massif (2864 m) and Škrlatica (2740 m) especially weakens advection in the valley from north, south and west, and the narrow passage by way of Luknja Saddle (1758 m) does not have a significant effect in these cases. The Vrata and Planica valleys are quite similar with respect to the closed-in nature of the valley heads and so a lowered snow line occurrence is primarily influenced by this feature of the valley heads of both valleys. In both valleys precipitation increases towards the head of the valley significantly and this is also an important factor for lowered snow line.

Kain, Goss and Baldwin (2000) cited steady or moderate intensity of precipitation for at least several hours as an important factor for lowered snow line and this is the case in our study. In the same study Kain, Goss and Baldwin (2000) cited surface temperatures close to freezing point at the beginning of precipitation also as an important factor. Measurements in our study indicate, that occurrence of lowered snow line in Vrata and Planica valleys is rarely connected with cold air pool at the bottom of the valley. However, if cold air pool is formed prior the precipitation and it does not dissipate when precipitation starts, snow line lowers even faster.

In a study of latent cooling effect in the south Alpine Toce valley Zängl (2007) argues that cooling by evaporating cloud water also influences temperature, especially if valley atmosphere continues to be subsaturated due to down valley wind. If snow melts already above the valley, the contribution of evaporating cloud water to cooling can be of major importance. In our case we know, that falling snowflakes melted in the valley system, but we did not have wind data to observe any downwinds.

The location north of the main Julian Alps massif also plays an important role, contributing to the attenuation of southern winds in the lower layers of the atmosphere. An analysis of snow conditions in both valleys would certainly contribute to a better understanding of the intensity of the occurrence, but we do not have this data.

5 Conclusion

Through an analysis of temperature conditions during precipitation events we identified cases of a lowered snow line in the Vrata and Planica valleys. Since many Alpine valleys are remote and without systematic meteorological monitoring, this method proved to be useful and representative. We can conclude that in both valleys lowered snow line occurs practically at the same time which is a result of similar influence of topography. In both valleys south and west advection are often disturbed or weakened due to mountain topography while the precipitation gradients increase precipitation in heads of the valley significantly (in Planica for factor 1,8) (Ogrin and Kozamernik, 2019) The strong temporal coincidence of the latent cooling of the valley atmosphere during precipitation, as well as very similar temperature conditions, suggest similar snow conditions; however, snow conditions were not discussed since snow data were not available.

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