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# CLIMATE AND WEATHER-RELATED FACTORS LIMITING OUTDOOR ACTIVITIES AND IMPACTING TOURISM: CASE STUDIES IN SLOVENIA

# ANALIZA PODNEBNIH DEJAVNIKOV, KI OMEJUJEJO AKTIVNOSTI NA PROSTEM IN VPLIVAJO NA TURIZEM: PRIMER SLOVENIJE

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## Abstract

Tourism must adapt to climate change while doing its part to help fulfil the Sustainable Development Goals. In scientific literature, climate services for tourism are under-researched. Slovenia (Central Europe), with its diverse climate and topography, was chosen as a case study to investigate climate change's effects on the country as a tourist destination. Using publicly available meteorological data, the Tourism Climate Index and the Holiday Climate Index were estimated. The two indices show a weak relation to the statistical data on overnight stays in selected municipalities for the period 2019-2021. The climate change impact on ski tourism in nine ski areas in Slovenia was estimated using statistically significant negative trends of annual number of days with snow cover. The negative trends were more pronounced for the period 1961-1990 over 1991-2020; 1987 was determined as a turning point in the trend detection. Typical outdoor activities on the Soča River in western Slovenia include rafting and canoe rafting. The trends in river discharges were used to estimate the impact of climate change on the number of navigable days per year and per season (March 15 – October 31), and no clear trends were found in this case study. Further investigations are needed to support tourism adaptation strategies and investigate climate-tourism interaction.

**Keywords:** Climate change, Outdoor activities, Rafting, Slovenia, Snow cover, Tourism, Trends.

## Izvleček

Turizem se mora prilagoditi podnebnim spremembam, medtem ko pomaga pri izpolnjevanju ciljev trajnostnega razvoja. V znanstveni literaturi je ta tematika v povezavi s turizmom premalo raziskana. Kot študija primera je bila izbrana Slovenija (Srednja Evropa) z raznolikim podnebjem in topografijo s ciljem raziskovanja vplivov podnebnih sprememb na turizem v Sloveniji. Na podlagi javno dostopnih meteoroloških podatkov sta bila ocenjena turistični podnebni indeks in počitniški podnebni indeks. Indeksa kažeta šibko povezavo s statističnimi podatki o prenočitvah v izbranih občinah za obdobje 2019–2021. Vpliv podnebnih sprememb na smučarski turizem na devetih smučiščih v Sloveniji smo ocenili s statističnimi analizami letnega

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števila dni s snežno odejo. Negativni trendi letnega števila dni s snežno odejo so bili bolj izraziti v obdobju 1961–1990 kot v obdobju 1991–2020; leto 1987 je bilo prelomno glede na analize trendov. Značilni dejavnosti na prostem na reki Soči v zahodni Sloveniji sta rafting in rafting s kanuji. Trendi pretokov rek so bili uporabljeni za oceno vpliva podnebnih sprememb na število plovnih dni na leto in na sezono (15. marec–31. oktober). Glede na analizo trendov ni bilo zaznanih izrazitih sprememb v številu plovnih dni. Potrebne so nadaljnje raziskave za podporo strategijam prilagajanja turizma na podnebne spremembe in za raziskave interakcij med podnebjem in turizmom.

**Ključne besede:** podnebne spremembe, rafting, športne aktivnosti, Slovenija, snežna odeja, turizem, trendi.

## 1. Introduction

Tourism is one of the world's fastest-growing economic sectors (OECD, 2020), and as such has the potential to contribute directly or indirectly to all of the 17 Sustainable Development Goals (SDG) of the United Nations 2030 Agenda for Sustainable Development. Sustainable tourism is mentioned in SDG #8, #12, and #14. Sustainable tourism, including adventure tourism, is being developed at the same time as radical climate change is occurring, and their mutual relations should be studied (Buckley, 2017). This is especially true in light of the fact that our actions over the past 30 years have not prepared the tourism sector for the next 30 years of accelerating climate change impacts and the transformation to a decarbonized global economy (Scott, 2021).

The availability and use of climate services in the operations and management of tourism is gaining in importance (e.g. Grillakis et al., 2016; Damm et al., 2017; Font Barnet et al., 2021; Mahon et al., 2021; Morin et al., 2021), and there is a growing need for specialized and regionalised climate information products that can bolster climate risk management amongst tourism providers.

In the past, various tourism indices have been developed and proposed to take into account the importance of climate, weather, and extreme weather for tourism (Boqué Ciurana et al., 2022). Two widely used indices are the Tourism Climate Index (TCI) (Mieczkowski, 1985) – integrating climatic variables (i.e. maximum and mean daily temperature, minimum and mean daily relative humidity, precipitation, sunshine, and wind) relevant to tourism into a single index, and the Holiday Climate Index (Scott et al., 2016) – integrating its own set of climatic variables (i.e. daily maximum temperature, mean relative humidity, cloud cover, precipitation, and wind speed) into a single index. The former is one of the most widely applied indices (Scott et al., 2016). The latter was also modified for urban (HCI:Urban) and beach environments (HCI:Beach). A comparison of the indices can also be found in the scientific literature (Rutty et al., 2020; Scott et al., 2016; Yu et al., 2021). Instead of TCI and HCI, other climate indicators can be used, such as, e.g., diurnal temperature range (DTR), although there are few applications found in the literature. The DTR was applied rather as a risk factor for human health (Cheng et al., 2014) and as such it can be used for studying the implications of prolonged heat waves on tourism during the summer. Annual temperature range (ATR) is another weather indicator to be used when studying seasonality and differences between seasons, and it might be rather used for climate change studies.

Apart from general applications of such tourism indices, authors have studied climate and weather-related conditions from the perspective of tourism for specific destinations (Álvarez-Díaz et al., 2010; Boqué Ciurana et al., 2022; Font Barnet et al., 2021; Nižić and Grdić, 2018), or outdoor sport activities such as skiing (Yang and Wan, 2010; Cernaianu and Sobry, 2021; Köberl et al., 2021; Rice et al., 2022; Rujescu, 2022; Scott et al., 2020; Steiger et al., 2019; Steiger and Scott, 2020; Prettenthaler et al; 2022), surfing (Boqué Ciurana et al., 2022; Boqué Ciurana and Aguilar, 2021, 2020), or whitewater rafting (Bowman et al., 2022; Chen et al., 2017; Faria et al., 2022; Polat et al., 2016).

Slovenia, with an tourism sector contributing an estimated ~8.4% (~3.6 billion EUR in 2017 (OECD, 2020; SiStat, 2022)) to the national GDP, is an interesting tourist destination in Central Europe with a diversity of destinations and outdoor activities. It should be noted that tourism's contribution to the national GDP can vary and was estimated to around 10% in 2019 and around 6% in 2021 and it was heavily impacted by COVID-19 situation (WTTC, 2023). As Slovenia is at the crossroads of three different climates (sub-Mediterranean, Alpine, and continental) (Ogrin, 1996), and tourism is an important economic sector, it can serve as a small (area of 20,273 km$^2$; population 2.1 million (SiStat, 2022)) yet relevant case study for an analysis of how climate change can affect tourism using climate and weather-related factors.

A local study was performed by Lotrič et al. (2015a), who surveyed hydrological data relevant for water-related sports activities in Triglav National Park in NW Slovenia, and based on this data estimated how climate change will impact these activities (Lotrič et al., 2015b). When developing a tourist destination, including Slovenia (Dwyer et al., 2012), climate change should be considered. Climate change can be studied from a range of perspectives.

Therefore, the main aim of this case study is to collect and analyse available climate-related data in Slovenia relevant for exploring the relationship between climate and tourism. In order to connect available climate change data with Slovenia as a tourist destination, the following research questions were defined as the basis for this case study:

- Can we estimate to what extent we can expect outdoor activities and outdoor touristic activities in Slovenia to be impacted by current and projected climate change through the end of the 21st century?
- Can we already trace the impact of recent heat waves on the number of tourists looking at the number of overnights stays in selected tourist destinations in Slovenia?
- Can meteorological data in Slovenia confirm the increasing vulnerability of ski areas at middle altitudes as observed in high alpine ski resorts in the Alps?

## 2. Materials and methods

In order to investigate the effect of climate on tourism and outdoor activities in Slovenia, data from various sources were collected to test the three hypotheses stated in the Introduction. For assessing the dependence between two datasets, we used Pearson correlation coefficient, one of the most frequently applied coefficients (Schober and Schwarte, 2018). Additionally, the coefficient of determination was calculated as the square of the Pearson correlation coefficient based on the two selected variables.

### 2.1. Climate (meteorological) data

The publicly available historical data from the archives of the Slovenian Environment Agency (ARSO) were retrieved. The following datasets were collected:

Daily data (1 Jan. 2019-30 Sept. 2021) about mean, minimum, and maximum air temperature, mean wind speed, mean relative humidity, sunshine duration, daily precipitation and percent of cloudiness for stations shown in Table 1.

Annual data on the number of days with snow cover for 15 selected precipitation-gauging stations in Slovenia, covering the variety of the country's climates as well as a variety of altitudes (coastal area, hilly regions, and mountainous regions). Selected stations are shown in Table 2.

Daily discharge data for the Soča River at the hydrologic gauging station Log Čezsoški (catchment area of 323 km$^2$ and located at 341 m a.s.l.) for the period 1948-2020.

Daily air temperature data and annual number of days with storms for the precipitation station Žaga (located at 353 m a.s.l., latitude = 46.3096 and longitude = 13.4793) for the period 1948-2020.

To investigate changes in the time series, we applied the "trend" package (software R (R Core Team, 2021)), which includes the Pettitt statistical test (Pohlert, 2020). This is a non-parametric test that can be used to detect shifts in the central tendency of a time series (Pohlert, 2020).

We investigated the characteristics of climate conditions in relation to winter sports in Slovenia. The so-called rentability limit of a "100-day season", with a sufficient snow covering at least 30 cm during the period between December 1 and April 15 (Witmer et al., 1986), is frequently used for ski resorts. Since we do not have sufficient data on the number of days when ski resorts in Slovenia produce artificial snow to prolong their own ski seasons, snow cover data as a proxy was used to estimate the climate's suitability for winter sports. Therefore, data on the number of days with snow cover was analysed for selected gauging stations in Slovenia for the period 1961-2020 (Table 2). It is to be said that this is less restrictive than the "100-day season" with at least 30 cm snow cover.

Additionally, we further divided the annual number of snow cover days times the series 1961-2020 into two 30-year periods (1961-1990 and 1991-2020), as defined by the World Meteorological Organization (WMO). Additionally, the complete data set (1961-2020) was tested for the presence of a turning point in a linear trend using the Pettitt test (a statistical significance of 0.05 was used).

### 2.2. Accommodation data

Slovenia is divided into 12 Nomenclature of territorial units for statistics (NUTS) at 3rd level and into 212 municipalities. The accommodation data used within the scope of this study was obtained from the Republic of Slovenia Statistical Office (SURS). The following dataset was used:

Daily data about all overnight stays in all municipalities in Slovenia in the period from January 2019 until June 2021. This data was obtained from SURS and was aggregated to the monthly scale. Special focus was given to municipalities shown in Table 3. As a representative sample, we selected 16 municipalities, having together around 482.500 inhabitants (23% of the Slovenian population) and occupying the area of 3.002 km$^2$ (14.8% of the Slovenian territory. These municipalities were taken from different climate regions of Slovenia, offering different touristic activities (e.g. seaside, city tourism, winter resort, spa resort) and served as a typical sample.

***Table 1:*** *Main characteristics of the selected stations that were used to calculate selected climate indexes.*

***Preglednica 1:*** *Glavne značilnosti izbranih postaj, ki so bile uporabljene za izračun izbranih klimatskih indeksov.*

| Station | Elevation [m ASL] | Latitude | Longitude | Climate |
|---|---|---|---|---|
| Bilje | 55 | 45.8956 | 13.6240 | Mediterranean |
| Bohinjska Češnjica | 596 | 46.2942 | 13.9422 | Mountain |
| Ljubljana | 299 | 46.0655 | 14.5124 | Temperate continental |
| Maribor | 264 | 46.4797 | 15.6818 | Temperate continental |
| Murska Sobota | 187 | 46.6521 | 16.1913 | Temperate continental |
| Novo mesto | 220 | 45.8018 | 15.1773 | Temperate continental |
| Portorož | 2 | 45.4753 | 13.6160 | Mediterranean |
| Šmartno pri Slovenj Gradcu | 452 | 46.4830 | 15.1119 | Mountain |

***Table 2:*** *Main characteristics of the selected stations with snow cover data in the period 1961-2020.*

***Preglednica 2:*** *Glavne značilnosti izbranih postaj, kjer so na voljo podatki o višini snežne odeje za obdobje 1961–2020.*

| Station | Elevation [m asl] | Missing data | Latitude | Longitude | Climate |
|---|---|---|---|---|---|
| Kančevci | 343 | / | 46.7503 | 16.2318 | Temperate continental |
| Kredarica | 2513 | / | 46.3787 | 13.8489 | Mountain |
| Krvavec | 1478 | 1971-1973 | 46.2964 | 14.5201 | Mountain |
| Ljubljana | 299 | / | 46.0655 | 14.5124 | Temperate continental |
| Nova vas na Blokah | 720 | / | 45.7731 | 14.5094 | Temperate continental |
| Postojna | 533 | 1961 | 45.7661 | 14.1932 | Temperate continental |
| Predgrad | 375 | 1987-1988 | 45.5054 | 15.0542 | Temperate continental |
| Rateče | 864 | / | 46.4971 | 13.7129 | Mountain |
| Rut | 695 | 2019-2020 | 46.2049 | 13.8892 | Temperate continental |
| Seča | 2 | / | 45.4939 | 13.6072 | Mediterranean |
| Solčava | 639 | / | 46.4203 | 14.6914 | Mountain |
| Šmartno pri Slovenj Gradcu | 452 | / | 46.4830 | 15.1119 | Mountain |

## 2.3. Tourism indices

As two different climate indices, we have calculated the Holiday Climate Index (HCI) and Tourism Climate Index (TCI) (Scott et al., 2016).

The TCI was the first attempt to develop a numerical index that can be used to quantitatively evaluate a climate's suitability for general tourism activities (Scott et al., 2016). The TCI is composed of five factors: precipitation, mean daily relative humidity, wind, daytime comfort index, and daily comfort index (Scott et al., 2016). This study used the equations and tables shown by Scott et al. (2016) (Scott et al., 2016) to calculate the TCI for several meteorological stations in Slovenia where all the required data was available (daily data from 8 stations as shown in section 2.1., Table 1).

Additionally, we have also calculated the HCI, which was developed to overcome some of the issues related to the TCI (Scott et al., 2016). The HCI is composed of four factors: precipitation, wind, thermal comfort, and aesthetic. Similarly, as in case of the TCI the methodology and factors shown by Scott et al. (2016) were used.

Both TCI and HCI results are a numeric value ranging from 0 to 100, where a value close to 100 indicates ideal conditions and a value close to 0 indicates unfavourable conditions. The numerical values can be related to descriptive rankings that differ between both indices (Scott et al., 2016).

We investigated the relationship between the HCI and TCI indices (for stations shown in Table 1) and the number of overnight stays in various municipalities around the country (Table 3). The HCI and TCI were calculated both at a daily and monthly time scale. For the monthly values, we used the aggregated (mean) daily values. Moreover, we were interested in whether there exists any relationship between the number of overnight stays and climate conditions that can be described using two selected climate indices (i.e. HCI and TCI).

***Table 3:*** *Main characteristics of the selected municipalities for which analysis of overnight stays were conducted.*

***Preglednica 3:*** *Glavne značilnosti izbranih občin, kjer so bile izvedene analize o številu prenočitev.*

| Municipality | Area [km$^2$] | Inhabitants | Main tourist activity and characteristics |
|---|---|---|---|
| Bled | 72 | ~8,000 | Natural site with summer and winter peaks in tourist activity |
| Bohinj | 334 | ~5,000 | Natural site with summer and winter peaks in tourist activity |
| Bovec | 367 | ~3,000 | Natural site with summer and winter peaks in tourist activity |
| Celje | 95 | ~49,500 | City municipality |
| Izola | 29 | ~16,500 | Coastal location |
| Koper | 311 | ~52,500 | Coastal location and city municipality |
| Kranjska Gora | 256 | ~5,500 | Natural site with summer and winter peaks in tourist activity |
| Lendava | 123 | ~11,000 | Natural site with summer and winter peaks in tourist activity |
| Ljubljana | 275 | ~276,000 | City municipality |
| Murska Sobota | 64 | ~19,500 | City municipality |
| Nova Gorica | 280 | ~32,000 | City municipality |
| Novo mesto | 236 | ~35,500 | City municipality |
| Piran | 45 | ~17,500 | Coastal location |
| Podčetrtek | 61 | ~3,500 | Thermal water location |
| Rogaška Slatina | 72 | ~11,000 | Thermal water location |
| Tolmin | 382 | ~12,000 | Natural site with summer and winter peaks in tourist activity |

## 3. Results and discussion

### 3.1. Relationship between overnight stays and tourism indices

While dependence between the HCI and TCI was relatively strong at a monthly time scale, the correlation was a bit lower at daily time step (Figure 1). Moreover, the range of values at daily time step was larger compared to monthly data (Figure 1). Similar results were also obtained for other meteorological stations investigated (Table 1). Quite interestingly, in terms of the main descriptive statistics for the calculated TCI and HCI, there were relatively small differences among the meteorological stations (Figure 2). This is especially evident using the daily data, where the 75% percentile value is relatively similar (i.e. around 85) for all stations expect for the Bohinjska Češnjica station. As expected, the highest average values were observed for the Portorož station (i.e. an average HCI of 75 at monthly time scale) since this is a location near the sea, where there are a lot of sunny days and relatively low annual precipitation. As indicated, there were relatively small differences among stations, for example at monthly time step all stations expect Bohinjska Češnjica had an average HCI value over 70. It should be noted that these values correspond to very good conditions for tourism (Scott et al., 2016). In terms of seasonal variations, the largest HCI and TCI values were observed in spring and summer months, while the smallest ones were observed in winter (Figure 3). Almost in all months the conditions can be described as Acceptable (i.e. HCI about 50) and in some months also as Excellent (i.e. HCI about 80) (Figure 3). Hence, general climate conditions for tourism in Slovenia are relatively good throughout the county in almost all seasons.

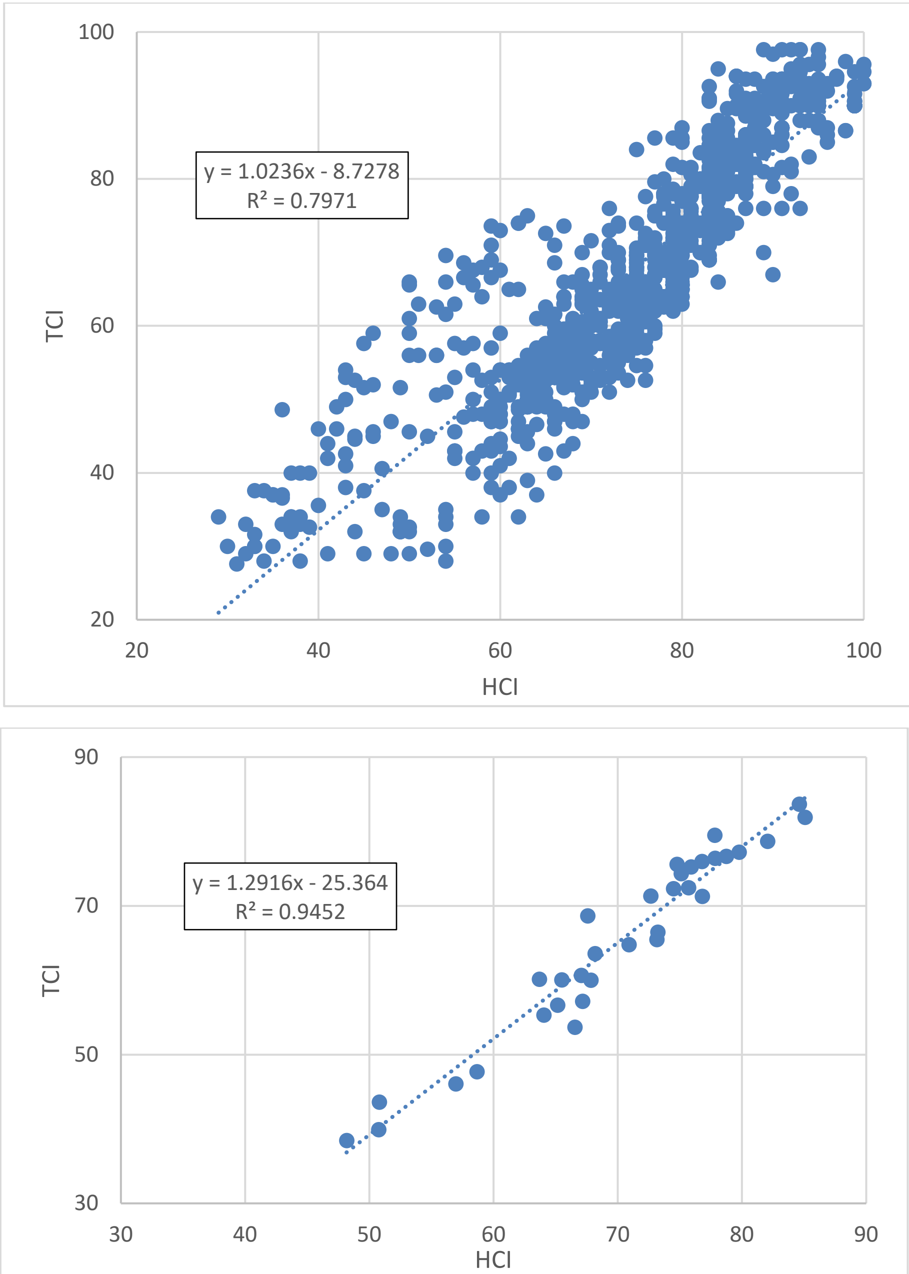


***Figure 1:*** *Comparison between calculated TCI and HCI indices at daily (above) and monthly time scale (below) for the Ljubljana station. Period from 1 Jan. 2019 to 30 Sept. 2021 is shown. In both cases, the best-fit linear trend line and corresponding determination coefficient are shown.*

***Slika 1:*** *Primerjava indeksov TCI in HCI ob uporabi dnevnih (zgoraj) in mesečnih podatkov (spodaj) za postajo Ljubljana. Obdobje od 2019 do 2021. V obeh primerih sta prikazana tudi trendna linija in determinacijski koeficient.*

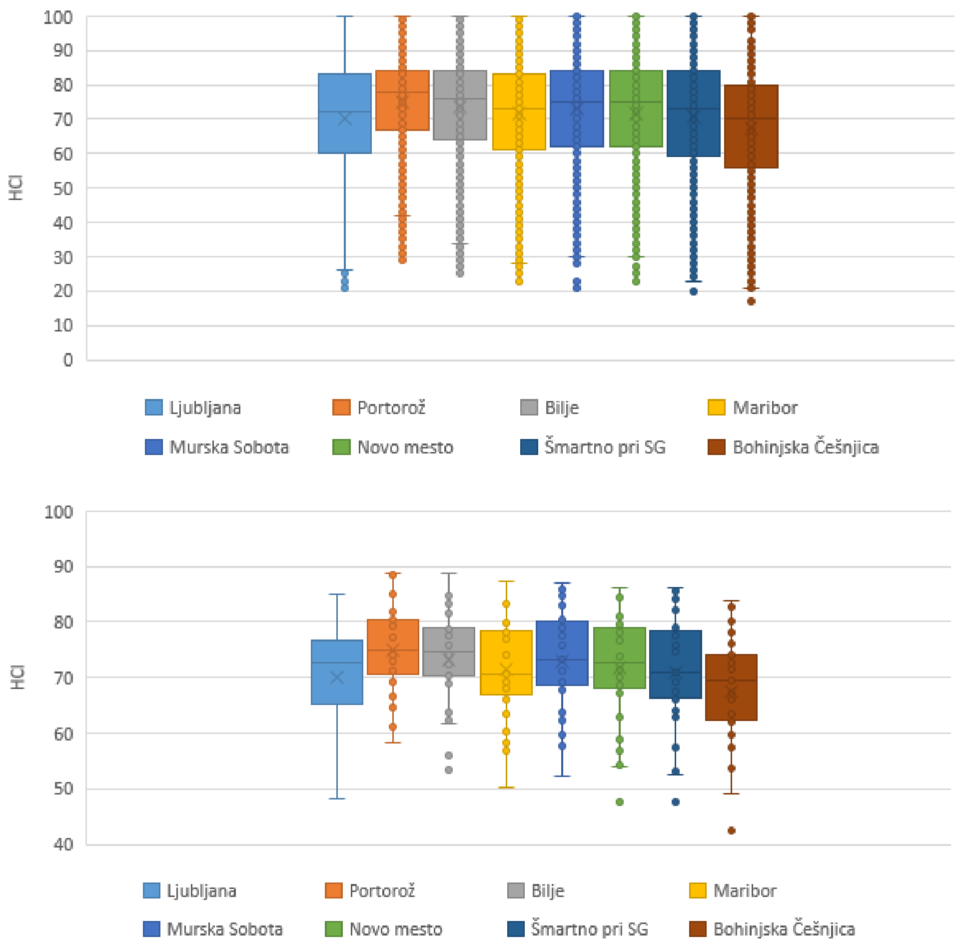


***Figure 2:** Box-plots of HCI values for selected meteorological stations in Slovenia using daily (above) and monthly (below) data.*

***Slika 2:** Okvirji z ročaji na podlagi vrednosti HCI za izbrane meteorološke postaje v Sloveniji z uporabo dnevnih (zgoraj) in mesečnih (spodaj) podatkov.*


***Figure 3:** Seasonal variations in the HCI for the investigation meteorological stations based on the monthly data.*

***Slika 3:** Sezonsko spreminjanje vrednosti HCI za izbrane meteorološke postaje na podlagi mesečnih podatkov.*

Before going into a detailed discussion with regard to the data in Figure 4, it should be stated that COVID-19 had a big impact on the number of overnight stays in spring 2020 and autumn 2020 and winter 2021 (normalized by the number of inhabitants in each municipality in Figure 4) – and the impact was more or less the same for all municipalities in this COVID-19 period, regardless of the weather situation in this period. One can conclude that a pandemic such as COVID-19 has a much more evident impact on tourism as measured by overnight stays than weather variability between seasons or in two consecutive years has.

However, some seasonal variations in Figure 4 can be observed that could be attributed to the climate conditions. There is clearly a much more significant seasonal pattern in the monthly number of overnight stays for various municipalities (Figure 4) compared to the selected seasonal variations in the HCI and TCI. As expected, the dependence between the number of overnight stays and HCI (also TCI) was relatively low (Table 4). The calculated Pearson correlation coefficient was for most stations higher using the monthly data than with daily time step (Table 4). It should be noted that the same values of Pearson correlation coefficient would be obtained even if the data about the number of overnight stays were normalised based on the tourist capacity of specific municipality.

The highest correlation was observed for the Bovec (Figure 5) and Bohinj municipalities, where sports and outdoor activities are the main tourism drivers. On the other hand, the lowest correlation was observed for the Nova Gorica municipality, where the main tourism activity is gambling at casinos. It can be seen that even for the case of the Bovec municipality. where the correlation with the HCI was the strongest, there was a large amount of scatter between the number of overnight stays and HCI, both at daily and monthly time step (Figure 5). Only the Pearson correlation coefficient for the Bovec municipality (at monthly time scale) can be labelled as a moderate correlation, while most of the other values correspond to weak correlation, those lower than 0.1 even to negligible correlation (Table 4) (Schober and Schwarte, 2018).

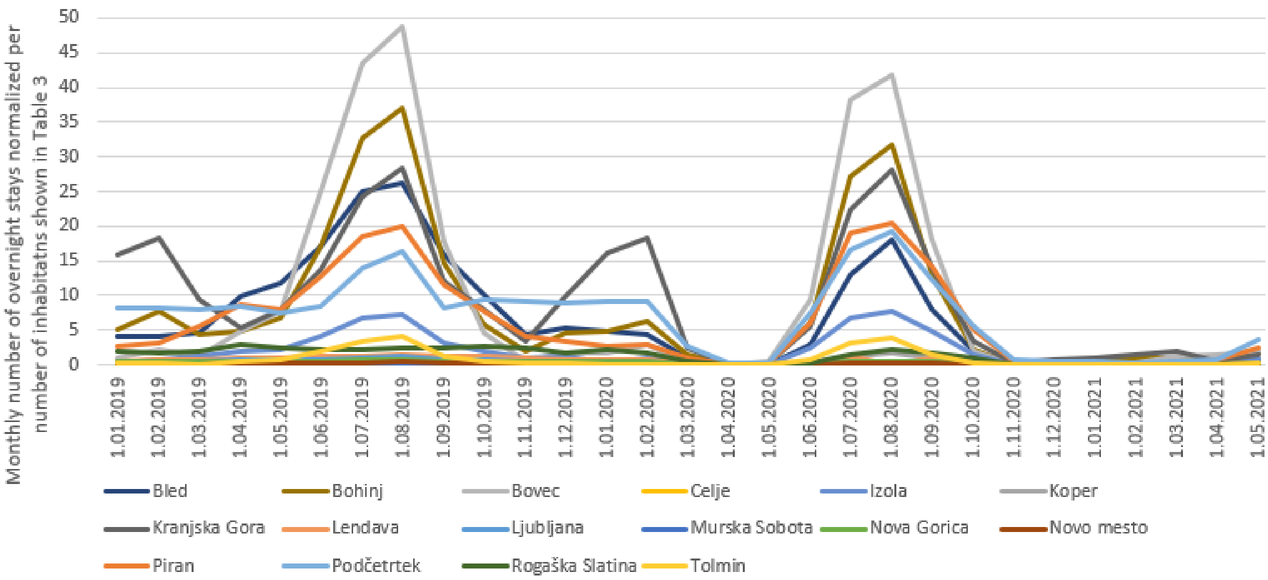


***Figure 4:*** *Seasonal variations in the monthly number of overnight stays in different municipalities (normalized by the number of inhabitants shown in Table 3).*

***Slika 4:*** *Sezonsko spreminjanje števila nočitev za različne občine (normalizirano glede na število prebivalcev občine – preglednica 3).*

Additionally, there was only a weak increase in the number of overnight stays with an increased HCI. Moreover, for municipalities with a lower correlation with the HCI, this increase was even smaller or in some cases the relationship was even negative. Therefore, it is clear that in Slovenia the main tourist activity patterns are not driven by climate conditions, since as indicated these can change on daily or sub-daily basis and long-term weather forecast is still uncertain.

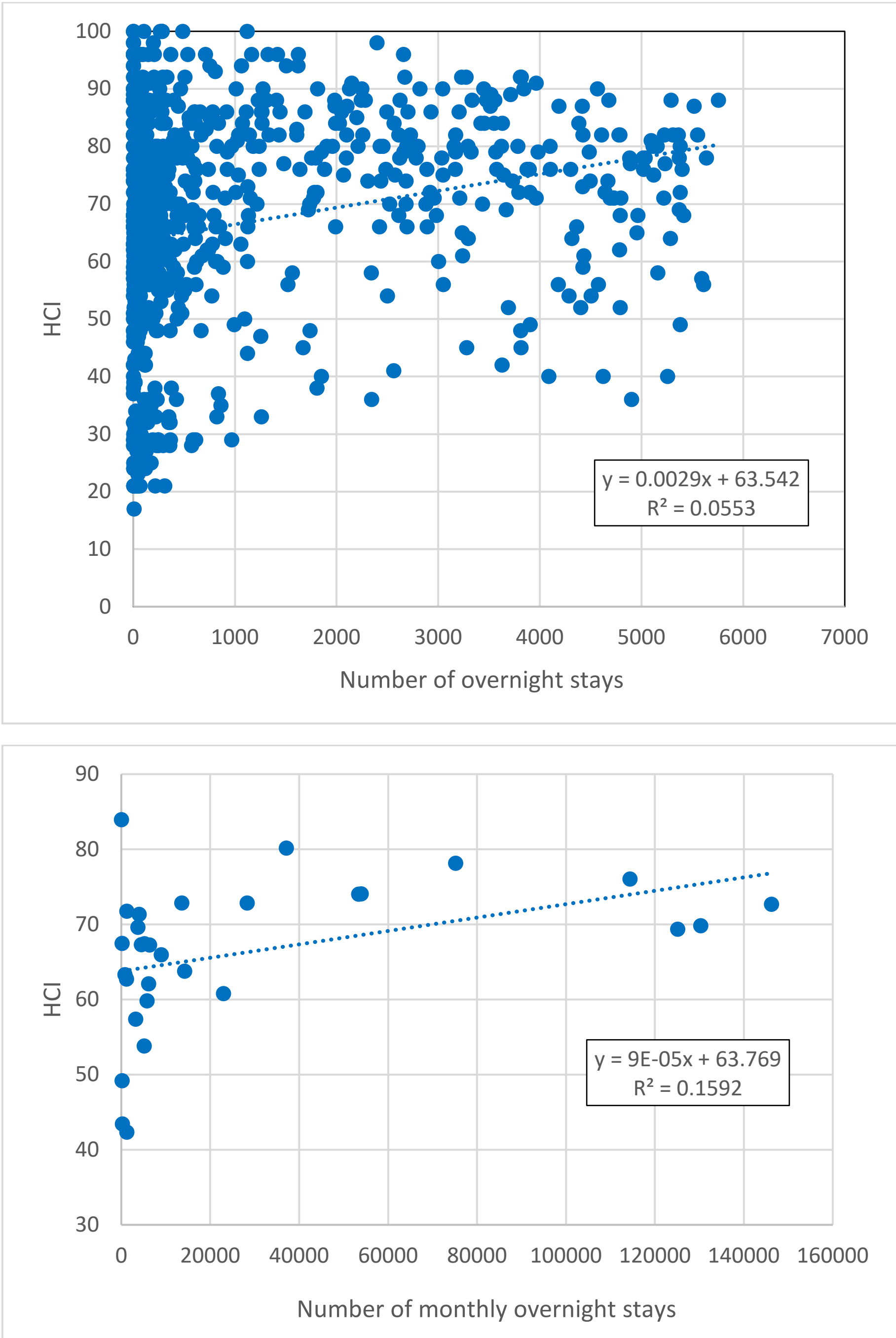


***Figure 5:*** *Relationship between number of overnight stays and HCI at daily (above) and monthly (below) time scale for the Bovec municipality and Bohinjska Češnjica station. In both cases, the best-fit linear trend line and corresponding determination coefficient are shown.*

***Slika 5:*** *Povezava med številom nočitev in HCI (dnevni (zgoraj) in mesečni (spodaj) podatki) za občino Bovec in postajo Bohinjska Češnjica. V obeh primerih sta prikazana tudi trendna linija in determinacijski koeficient.*

***Table 4:*** *Pearson correlation coefficients between number of overnight stays and HCI for daily and monthly data in the analysed 16 Slovenian municipalities.*

***Preglednica 4:*** *Pearsonovi koeficienti korelacije med številom nočitev in indeksom HCI (dnevni in mesečni podatki) za izbranih 16 občin v Sloveniji.*

| Municipality | Daily data | Monthly data | Meteorological station used |
|---|---|---|---|
| Bled | 0.19 | 0.32 | Bohinjska Češnjica |
| Bohinj | 0.22 | 0.37 | Bohinjska Češnjica |
| Bovec | 0.24 | 0.40 | Bohinjska Češnjica |
| Celje | 0.04 | 0.17 | Maribor |
| Izola | 0.17 | 0.29 | Portorož |
| Koper | 0.16 | 0.24 | Portorož |
| Kranjska Gora | 0.18 | 0.29 | Bohinjska Češnjica |
| Lendava | 0.14 | 0.23 | Murska Sobota |
| Ljubljana | 0.10 | 0.14 | Ljubljana |
| Murska Sobota | 0.03 | 0.09 | Murska Sobota |
| Nova Gorica | 0.07 | 0.07 | Bilje |
| Novo mesto | 0.19 | 0.31 | Novo mesto |
| Piran | 0.19 | 0.29 | Portorož |
| Podčetrtek | 0.17 | 0.34 | Maribor |
| Rogaška Slatina | 0.08 | 0.13 | Maribor |
| Tolmin | 0.14 | 0.24 | Bilje |

### 3.2. Changing conditions for winter sports in Slovenia

Figure 6 shows variations in the annual number days with snow cover for the selected stations in Slovenia. Based on the presented results it can be seen that for all analysed stations the number of days with snow cover is slightly decreasing (Table 5).

Based on the conducted test to detect the turning point in the data, it can be seen that for stations that do not have any missing years, the time series have a turning point in a year 1987 (Table 5). In all cases, the results of the applied Pettitt test were statistically significant with the selected significance level of 0.05 (Table 5). The only exception is the highest station at Kredarica (2,513 m ASL), with a turning point in a year 1969 (Table 5).

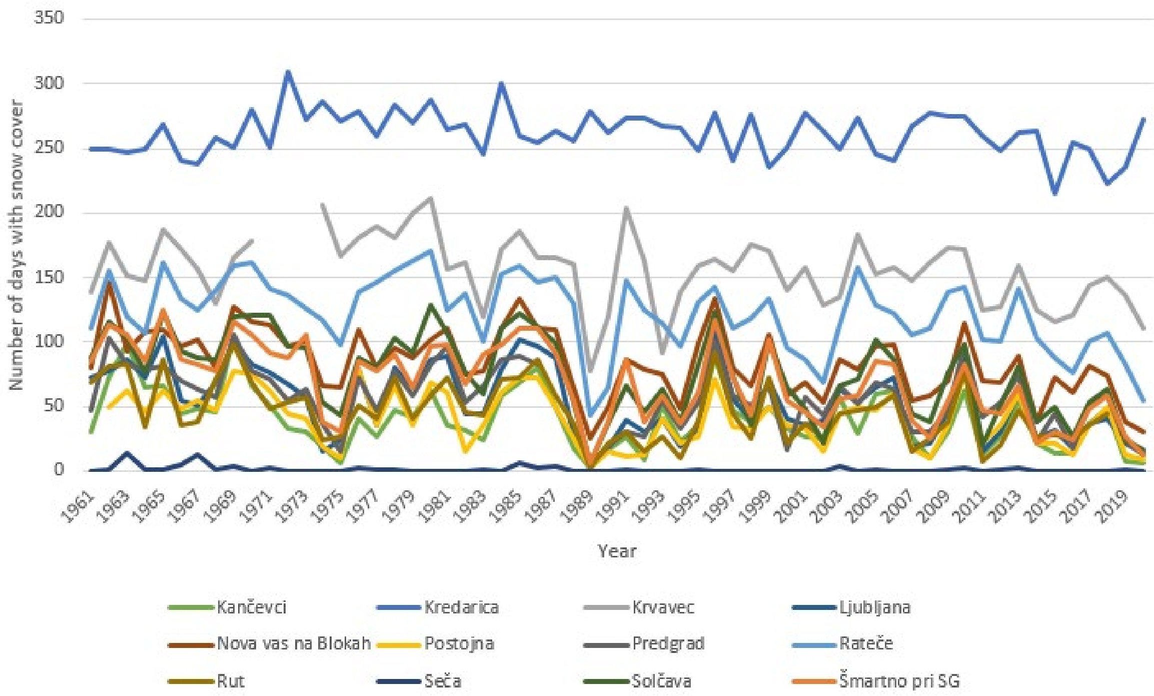


***Figure 6:*** *Variability of the number of days with snow cover in selected stations in Slovenia for the period 1961-2020.*

***Slika 6:*** *Spremenljivost števila dni s snežno odejo za izbrane postaje na območju Slovenija za obdobje 1961–2020.*

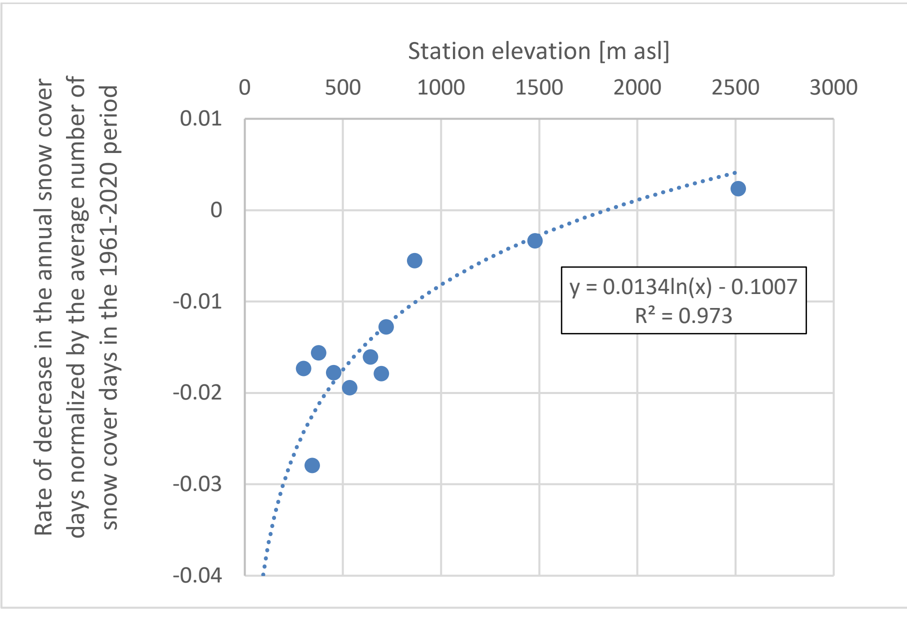


***Figure 7:*** *Changes in the rate of decrease in the annual number of snow cover days normalized by the average number of snow cover days in relationship to station elevation. The logarithmic trend line was added, and the coefficient of determination $R^2$ computed.*

***Slika 7:*** *Intenzivnost sprememb v številu dni s snežno odejo, normalizirana glede na povprečno število dni s snežno odejo v povezavi z nadmorsko višino postaje. Dodana je logaritemska trendna črta s prikazom koeficienta determinacije.*

***Table 5:*** *Main characteristics of the snow cover data for selected stations across Slovenia for the period 1961-2020. A statistical significance of 0.05 was used.*

***Preglednica 5:*** *Glavne značilnosti postaj, kjer se meri višina snežne odeje za obdobje 1961–2020. Stopnja značilnosti 0,05 je bila uporabljena za določitev točke preloma.*

| Station | Mean annual number of snow cover days 1961-2020 (1961-1990; 1991-2020) | Turning point (year)# | Rate of decrease in annual number of snow cover days 1961-2020 (1961-1990; 1991-2020) |
|---|---|---|---|
| Kančevci | 40 (46; 34) | 1987 (Yes) | -0.51 (-1.12; -0.65) |
| Kredarica | 261 (265; 258) | 1969 (No) | -0.19 (0.62; -0.65) |
| Krvavec | 155 (164; 148) | - | -0.59 (-0.52; -1.03) |
| Ljubljana – Bežigrad | 54 (65; 43) | 1987 (Yes) | -0.76 (-0.92; -0.70) |
| Nova vas na Blokah | 85 (95; 74) | 1987 (Yes) | -0.76 (-1.08; -0.97) |
| Postojna | 41 (48; 33) | 1987 (Yes) | -0.48 (-0.78; -0.14) |
| Predgrad | 57 (66; 48) | - | -0.59 (-0.88; -0.41) |
| Rateče | 122 (132; 111) | 1988 (Yes) | -0.76 (-0.68; -1.20) |
| Rut | 46 (55; 37) | - | -0.59 (-0.82; -0.07) |
| Seča | 1 (2; 1) | 1987 (Yes) | -0.05 (-0.11; 0.01) |
| Solčava | 74 (90; 59) | 1987 (Yes) | -1.06 (-1.20; -1.06) |
| Šmartno pri Slovenj Gradcu | 69 (84; 54) | 1987 (Yes) | -1.07 (-1.22; -1.28) |

# … statistically significant

***Table 6:*** *Some statistical data on large ski areas in Slovenia (Adopted from [https://smucisca.delo.si](https://smucisca.delo.si)). The occupancy of the ski area was estimated as a ratio between the ski lifts' capacity and the average daily attendance on ski slopes.*

***Preglednica 6:*** *Nekatere značilnosti večjih smučišč v Sloveniji (povzeto po [https://smucisca.delo.si](https://smucisca.delo.si)). Zasedenost smučišča je bila ocenjena kot razmerje med zmogljivostjo žičnic in povprečno dnevno udeležbo na smučiščih.*

| Ski Area | Ski Area Length (km) | Ski Area (ha) | Elevation (m a.s.l.) | Open 2010/11-2015/16 (days/season) | Occupancy 2010-2016 (1-5) |
|---|---|---|---|---|---|
| Mariborsko Pohorje | 41.5 | 250 | 325 – 1327 | 111 | 1 |
| Kanin – Sella Nevea | 30.0 | 70 | 1140 – 2300 | No data | No data |
| Krvavec | 29.0 | 106 | 1480 – 1971 | 125 | 3 |
| Vogel | 22.0 | 78 | 560 – 1800 | 122 | 3 |
| Kranjska Gora | 20.0 | 130 | 810 – 1295 | 111 | 2 |
| Cerkno | 18.0 | 70 | 800 – 1300 | 91 | 1.5 |

| | | | | | |
|---|---|---|---|---|---|
| Rogla | 13.5 | 100 | 1050 – 1517 | 122 | 4.5 |
| Golte | 12.8 | 50 | 1250 – 1600 | 112 | 4 |
| Stari vrh | 12.0 | 55 | 580 – 1217 | 78 | 5 |

Quite interestingly, the rate of decrease in the annual number of snow cover days in the 1961-1990 period was higher than in the 1991-2020 period (Table 5). Hence, according to analysed data it seems that the decreasing trend in the annual number of snow cover days has become less extreme in the recent three decades (Table 5).

The only positive trend was observed for the Kredarica station at 2,513 m a.s.l. for the period 1961-1990; all other trends were negative, as expected (Table 5). The decrease in the annual number of snow cover days is also more pronounced at medium elevations (300-1000 m a.s.l.) than for the high-altitude stations (Figure 7 and Table 5). The negative trends are also supported by the decrease in the total height of snow cover by 55% in Slovenia for the period 1961-2011 (Bertalanič et al., 2018), and statistically significant negative trends found by the analysis of meteorological data from 25 precipitation gauging stations for the period 1961-2018 in the Mediterranean part of Slovenia (Hrvatin and Zorn, 2022).

Moreover, the climate change simulations run by the Slovenian Environment Agency (ARSO, 2022; Bertalanič et al., 2018) further predict a decrease in the annual number of snow cover days for the entire country. More specifically, according to the RCP 4.5 scenario, the decrease in the annual number of snow cover days is expected to be within the range of 5-35 days for 2041-2070 and 2071-2100 periods compared to the baseline 1981-2010 period (ARSO, 2022; Bertalanič et al., 2018). This decrease is more or less constant throughout the country, while no specific investigation in relation to elevation was conducted (ARSO, 2022; Bertalanič et al., 2018). Meanwhile, for the 2011-2040 period, the predicted decrease is within the range of 5-10 days compared to the baseline period (ARSO, 2022; Bertalanič et al., 2018). However, it should be noted that the analysis conducted by ARSO used the Coupled Model Intercomparison Project (CMIP) CMIP5 and not the latest available version (i.e. CMIP6). The climate patterns and characteristics predicted by the CMIP6 could be to some extent different than the ones simulated by the CMIP5 (Palmer et al., 2021). Such a further analysis using CMIP6 for Slovenia is indeed possible, but not within the more general scope of this paper.

Similarly, a Pan-European study on snow indicators of climate change impact on ski tourism in the 21st century was conducted using the RCP2.6, RCP4.5, and RCP8.5 scenarios (Morin et al., 2021). Within this study, an estimation of the number of days with more than 30 cm of natural snow at 800 m of elevation yielded a negative change from 10 to 25 days for the period 2021-2040 compared to the reference period 1986-2005 for the RCP8.5 in the western part of Slovenia. Also, a climate-related study on ski tourism in neighbouring Austria showed similar results (Steiger and Scott, 2020), as well as for European ski resorts (Masloumidis et al., 2023) and the European Alps in general, where changes are not uniform and depend on altitude, region, and local factors (Marty, 2013).

We further analysed the nine largest ski areas in Slovenia (all from the global database of ski resorts OpenSkiMap (https://openskimap.org) and their opening days (Table 6). In Slovenia, the total length of ski slopes of all ski areas is easily outnumbered by larger ski areas in the Alps (e.g. St. Anton or Saalbach-Hinterglemm in Austria). Slovenian ski areas' advantages are comparably low daily prices for ski passes and their location close to urban centres (City of Ljubljana and City of Maribor, for example). The annual number of visitors was 1.1 million daily skiers in the season 2014/15 (roughly around 1,100 skiers in around 100 skiing days in a season), nearly 50 times lower than in Austria. The so-called rentability limit of "100-day season" (Witmer et al., 1986) is barely met by the average ski area in Slovenia (Table 6). A study on sustainable tourism in the Alps showed that midaltitude and lower ski areas are highly vulnerable to warm and rainy weather, which tend to increase due to climate change (Alpine Convention, 2013).

But problems with snow conditions in Slovenia at low elevations already occurred in the past, which can also be associated with the results shown in Table 5. For example, the FIS Alpine Ski World Cup in Maribor at Mariborsko Pohorje (Giant Slalom and Slalom for women races since 1970/71) was forced to move 11 times to Kranjska Gora due to bad snow conditions in Maribor on the scheduled dates (but was only cancelled once; in the season 2010/11). The FIS Alpine Ski World Cup in Kranjska Gora (Giant Slalom and Slalom for men races since 1967/68) was cancelled only once, in the season 2019/20. Other important ski events include the FIS Ski Flying & Jumping World Cups, and FIS Ski Flying World Championships in Planica, NW Slovenia. The Planica Valley has a good snow record and, even though the races are scheduled in March, natural snow depots usually have enough snow to optimally prepare large hills for safe flying or jumping. The possibility of using artificial snow in a ski area is very useful for the Krvavec ski area to secure on average 125 skiing days in the period 2010/11 – 2015/16 (Table 6). They have a water reservoir atop Zvoh with a volume of 28,000 $m^3$ (nearly at 2,000 m a.s.l.), filled by water pumped from 522.50 m a.s.l. from the Kokra River. However, it should be noted that in recent decades several ski areas (e.g. Kalič, Kobla, Zatrnik, Zelenica) in Slovenia stopped operating for a variety of reasons (e.g. snow or financial issues).

Due to decreasing trends in the number of days with snow cover for large parts of Slovenia, and the assessed impacts of climate change in Slovenia through the end of the 21st century (ARSO, 2022; Bertalanič et al., 2018), there will be only a few ski areas left in the decades to come – even using artificial snow, as confirmed by a study on 2,234 ski resorts in 28 European countries (François et al., 2023). This trend was also estimated by a Pan-European study on meteorological and snow indicators of climate change impact on ski tourism (Morin et al., 2021). The existing ski areas must immediately increase their efforts to adapt to these new climate factors, to diversify the range of winter sport and leisure activities they offer, and to focus also on the summer season and specific new activities (walking, climbing, horse riding, adrenaline parks, swimming, etc.) to be profitable with the existing infrastructure the whole year around.

### 3.3. Changing conditions for rafting in the Soča River valley

The last case study within this study was selected in the western part of Slovenia, in the Soča River valley. This is also the area with the highest correlation between the number of overnight stays and the climate conditions described by the climate indices (Section 3.1). This alpine valley is an important tourist destination in Slovenia, for both winter and especially summer activities. Among the diverse outdoor activities, such as camping, mountaineering, hiking, parachuting, sky diving, para gliding, and canyoning, also rafting and canoeing are very popular on the Soča River in its upper reaches between Kal-Koritnica and Tolmin.

Previous studies have been conducted in this part of the country related to the tourist activities. For example, a detailed field analysis of rafting (including canoe rafting) activities in the period 2012-2015 was performed by monitoring the Soča River on selected dates (Golja, 2016). The rafting and canoeing activities on the Soča River and its main tributary, the Koritnica River, are defined by the joint municipalities' decree of the three local municipalities: Bovec, Kobarid, and Tolmin (Uradni list Republike Slovenije 71/2014, n.d.). Several aspects of these activities are defined in this document such as the locations to enter the river, reaches where rafting is allowed, operating hours (9am – 6pm resp. 8 pm), period of the year when these activities are allowed (March 15 – October 31). The decree says nothing about the level of river discharge that would restrict rafting, but only says that all users must respect natural conditions and prevailing current conditions in the rafting area. From experiences gained by local guides (Golja, 2016), the Soča River discharges between 10 $m^3/s$ and 50 $m^3/s$ are safe to go rafting. The lower part of the discharge spectrum is preferable for canoe rafting, and its upper part is enjoyed preferably by large rafts. The only river gauging station on the Soča River in the area is Log Čezsoški, where discharge data are available since 1928 (no data are available in the periods 1932-35, 1943-47, and unfortunately also in the period 2014-2015).

The discharge data from the Log Čezsoški gauging station was analysed for the period 1948-2013, and the number of days per year that have preferable discharges between 10 $m^3/s$ and 50 $m^3/s$ are shown in Figure 8. The period was divided into two time series due to a turning point in the linear trend in 1983. The period 1948-1983 experienced a clear negative trend ($n = 36$; $R^2 = 0.5067$), and the period 1984-2013 ($n = 30$; $R^2 = 0.0625$) lacks a clear trend.

The average number of days with discharges between 10 $m^3/s$ and 50 $m^3/s$ for the period 1928-2020 is 252 days, and the standard deviation is 67 days. If we limit these days to navigable days (within the season as defined by the local decree issued by the three municipalities) only, the average for the period 1928-2020 is 173 days, and the standard deviation is 42 days (Figure 8). Looking at the period 1928-2013, and taking into account just navigable days (between March 15 and October 31, and with discharges between 10 $m^3/s$ and 50 $m^3/s$), as shown on Figure 9, no clear trend can be observed in the number of days when such activity is possible. Hence, despite a negative trend in the mean annual and monthly discharge values for most rivers in Slovenia (Bertalanič et al., 2018; Bezak et al., 2016; Cunja et al., 2020; Hrvatin and Zorn, 2022), this has not resulted in a decrease in the number of navigable days for the Soča River. Additionally, the number of navigable days is almost independent of the annual precipitation in this area (Figure 11). Hence, the torrential characteristics of the Soča River actually help it lower the water flow to the range potentially suitable for rafting and canyoning. Moreover, climate change simulations do not predict a significant change in the mean annual discharge values for the Soča River in Slovenia (Bertalanič et al., 2018).

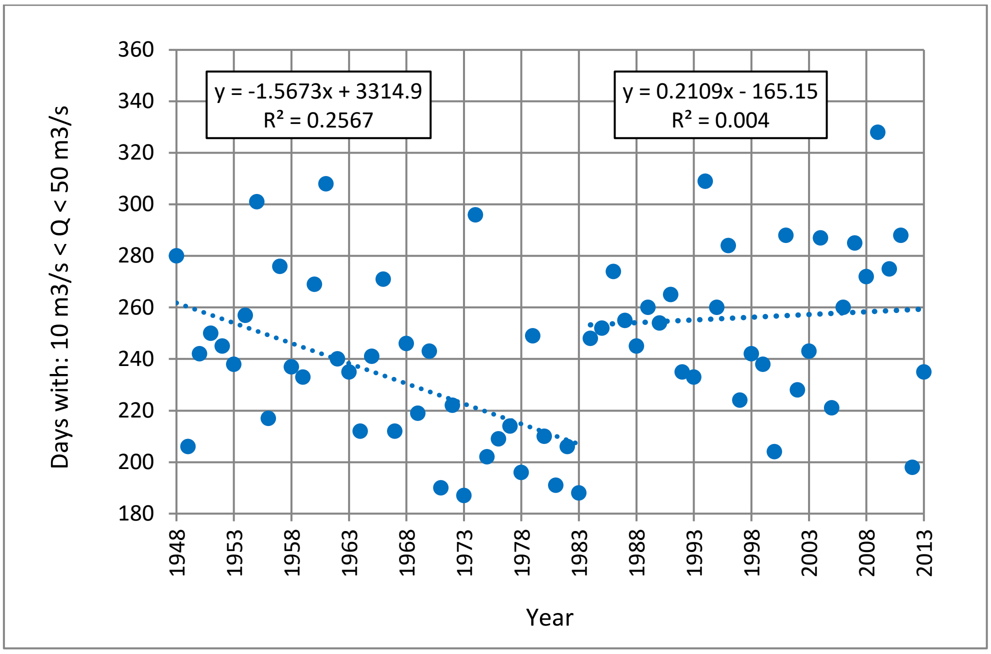


***Figure 8:** The number of days in a year with discharges between 10 $m^3/s$ and 50 $m^3/s$ as measured in the Log Čezsoški gauging station for the period 1948-2013. The time series was divided into 1948-1983 and 1984-2013, and the two trend lines are indicated on the graph.*

***Slika 8:** Število dni v letu s pretokom med 10 in 50 $m^3/s$ glede na podatke s postaje Log Čezsoški za obdobje 1948–2013. Podatki so razdeljeni v dve podobdobji (1948–1983 in 1984–2013).*

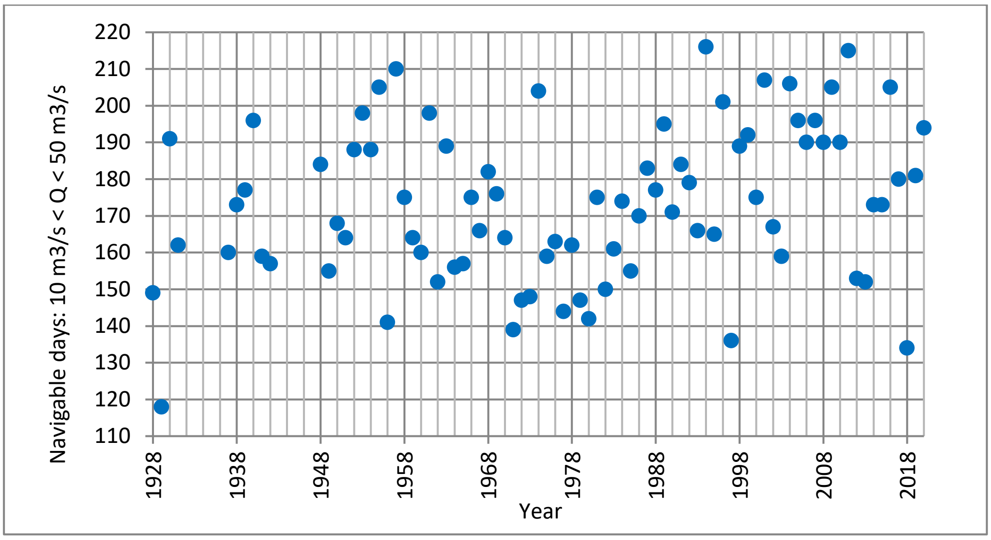


***Figure 9:*** *The number of navigable days (in the period March 15 – October 31) in a year when discharges were between 10 $m^3$/s and 50 $m^3$/s as measured in the Log Čezsoški gauging station for the period 1928-2020. Navigable days are days between March 15 and October 31, if discharge limitations are met.*

***Slika 9:*** *Število plovnih dni (med 15. marcem in 31. oktobrom) s pretokom med 10 in 50 $m^3$/s za obdobje 1928–2020.*

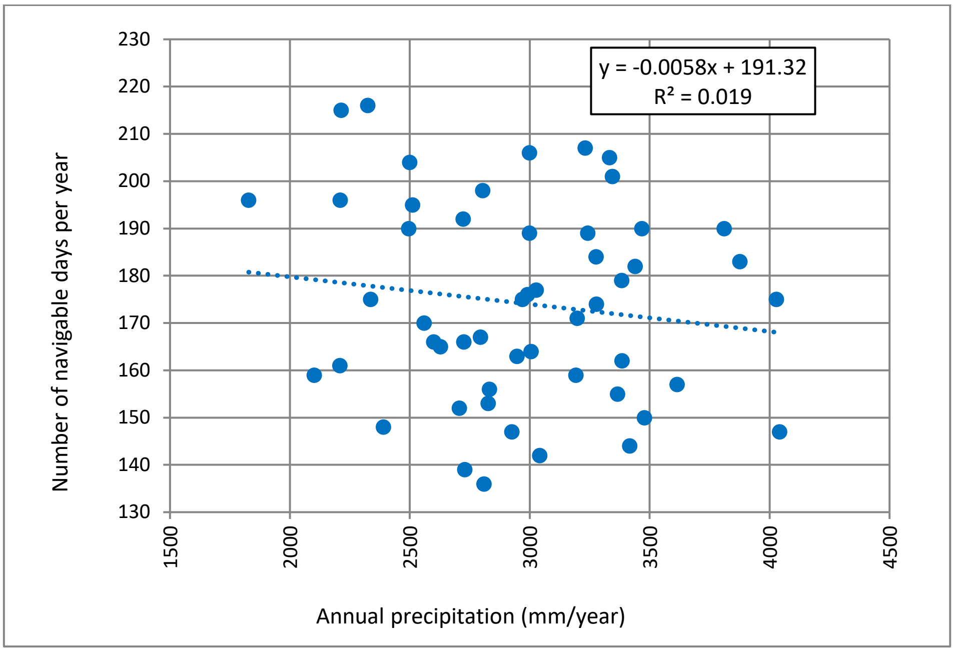


***Figure 10:*** *The number of navigable days per year as the function of annual precipitation in the Žaga gauging station for the period 1961-2012.*

***Slika 10:*** *Povezava med številom plovnih dni in padavinami (postaja Žaga) za obdobje 1961–2012.*

## 4. Conclusions

Based on the presented results about the climate-tourism interaction in Slovenia next conclusions can be made:

– According to the TCI and HCI indices, the climate conditions in Slovenia are almost always described as Acceptable or even Very good, and frequently also as Excellent. It looks like this is the reason why these two climate indices show a weak relationship with the number of overnight stays in Slovenia in this rather short period of analysis. It seems that weather conditions in Slovenia are changing rather quickly and this is clearly not regarded as a driver of tourist activity and frequency in Slovenia. Clear seasonal variations were observed for the aggregated number of overnight stays, while this seasonal variation was much less explicit for the TCI and HCI indices, respectively. Prolonged heat waves might change this impression, but an abundance of water-related and other outdoor activities outside urban areas in rural areas available in Slovenia, along with dense forest cover and hilly and mountain areas, will help attract tourist even during pronounced heat waves – instead of going to more urbanized environments elsewhere.

- The climate conditions for winter tourism (e.g. skiing) in Slovenia have clearly become less suitable in recent decades. However, the decrease in the annual number of snow cover days, which was used as proxy for describing winter tourism activity, is less extreme in the 1991-2020 period compared to the 1961-1990 period. A statistically significant turning point in linear trends in year 1987 was observed for almost all analysed stations in Slovenia. Moreover, the decrease in the annual number of snow cover days was more pronounced at lower and medium elevations compared to high elevations. Hence, this will be soon an issue for the Slovenian ski resorts that are mostly positioned at these elevations. Therefore, additional measures must be taken by the majority of ski resorts in order to adapt to the changing climate, since climate change simulations for Slovenia through the end of the 21st century predict a decreasing trend in the annual number of snow cover days throughout the country. Artificial snowmaking may not be a solution due to rising temperatures.
- Despite negative trends in mean and annual river discharge values for the entire country (especially in summer and spring), the number of navigable days for rafting and canoeing on the Soča River in Slovenia has not been decreasing in recent years. Moreover, compared to the winter tourist activities, the climate change simulations are more favourable for water-related activities since no clear change in the mean annual discharge values is predicted for the Soča River valley in Slovenia.

To sum up, it is clear that climate-tourism interaction in Slovenia is rather complex due to its climatic and topographic diversity, and that further studies are needed to increase our knowledge, especially in light of climate change in the coming years and decades, which will impact some of the tourist activities in Slovenia. Innovative adaptation strategies are needed for tourism and outdoor activities, so they remain attractive for potential tourists even in less favourable climatic and meteorological conditions for outdoor activities.

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