

MODERN CLIMATE CHANGE IN SLOVENIA

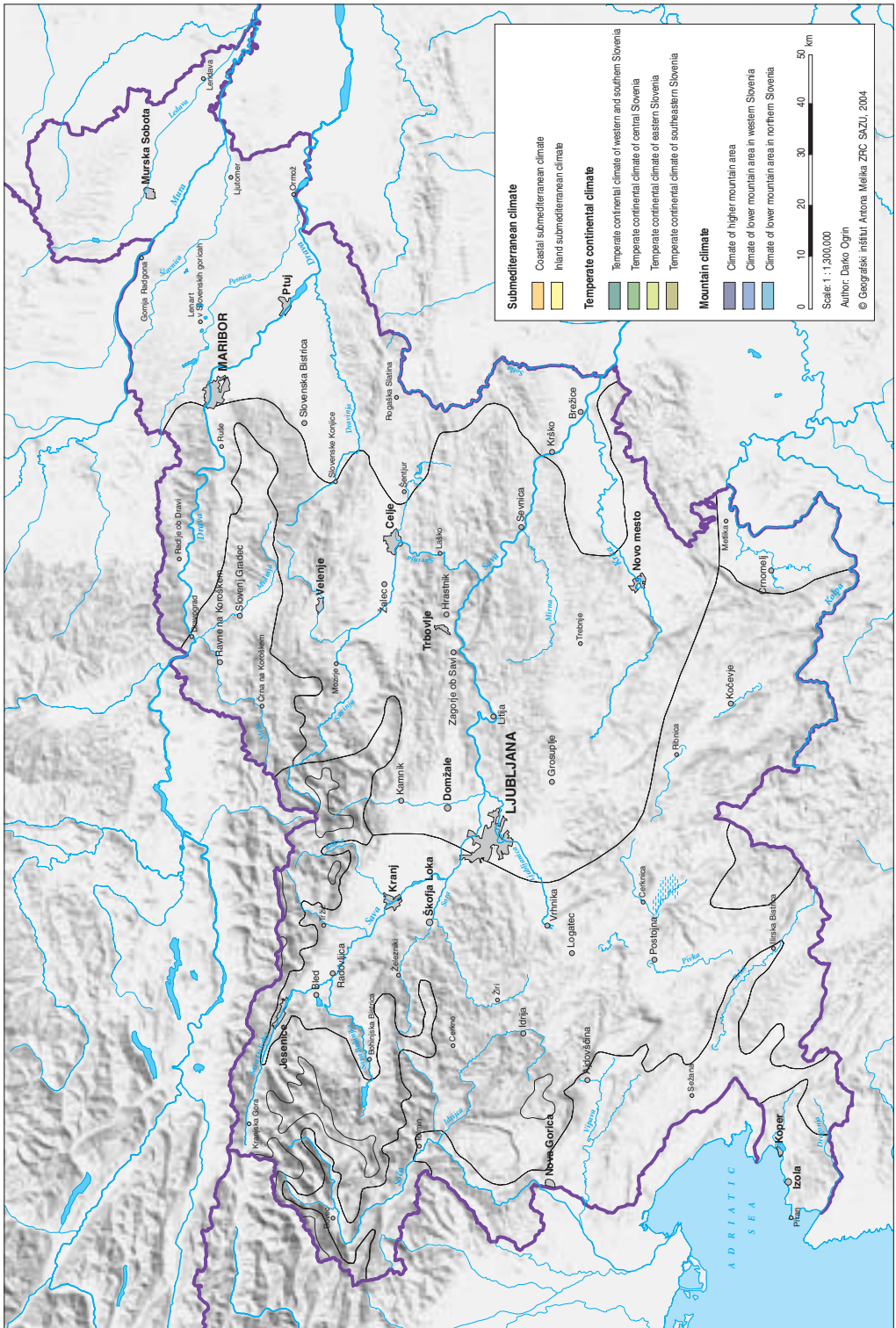
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Basic characteristics of climate in Slovenia

From the perspective of climate units, Slovenia has a warm humid temperate climate like the rest of Europe, with the exception of its mountain regions. It is characteristic of this climate that the average temperatures of the coldest month do not drop below -3°C and that at least four months have an average temperature above 10°C . Relative to precipitation, all seasons receive approximately the same amount with no distinctive dry or wet periods. In a more detailed climate analysis, along with its position in temperate geographical latitudes close to cyclogenetic areas and the considerable height diversity of its surface, the transit character of Slovenia's territory between the Alps and the Dinaric mountains and the Mediterranean and the Pannonian Basin is important. Thus, in spite of its modest geographical size, three types of the climate meet and interweave on Slovene territory: alpine, Mediterranean, and continental (Ogrin 1996). Compared with the standard alpine, Mediterranean, and continental climates, the character of all three climates are not typical due to the intertwinement of their main features, and therefore we often add the prefix »sub-« (submediterranean, subcontinental, subalpine climate). The distinctive transit character of climate types in Slovenia and the variability of



Figure 1: The warm conditions in Slovene Istria, the Vipava Valley, and Goriška Brda in submediterranean Slovenia allow the growing of some southern cultures, including olive trees, a typically Mediterranean culture. Because of one of its northernmost locations in Europe, olive trees are threatened by frosts, which occur on average every twenty years (photography Darko Ogrin).



◀ *Figure 2: Climate divisions in Slovenia.*

the climate make climate classification, establishing borders, and denomination difficult. In general, moving away from the Alps and the High Dinaric plateaus toward the east and northeast, continental climate features grow stronger; toward the south and southwest, Mediterranean features; and with increasing altitudes in the Alps and High Dinaric plateaus, the features of the alpine climate.

Characteristic of the **alpine climate** found in the Julian Alps, the Karavanke Mountains, the Kamniške-Savinjske Alps, the Pohorje mountain range, and the highest parts of the High Dinaric plateaus (Trnovski gozd, Snežnik) is that the average temperature of the coldest month is below -3°C and of the warmest, to the upper tree line (1,900 to 2,000 meters), above 10°C . The upper tree line is the dividing line between the climates of the high and the low mountain worlds. The latter also includes mountain valleys where summer temperatures are on the level of those in continental Slovenia, while due to pronounced temperature inversions, average winter temperatures are below -3°C . Also characteristic of the alpine climate is the least insolation in Slovenia (1,500 to 1,800 hours per year) and a very high level of precipitation (from 1,800 to more than 3,000 mm of precipitation per year).

To the south and southwest of the Alpine-Dinaric barrier, whose relief opens toward the Adriatic Sea, Slovenia has a **submediterranean climate**. Here are the most days with sun (up to 2,350 hours per year), the average temperatures of the coldest month are above the freezing point, and those of the warmest months are higher than 20°C . Due to the retentive action of the sea, temperatures in October are higher than those in April. The precipitation regime is submediterranean with high precipitation in the fall and at the end of spring or beginning of the summer and low precipitation in the winter and summer. The coastal climate variant immediately along the Bay of Trieste has the highest temperatures in Slovenia, and its hinterland variant has somewhat lower temperatures but more precipitation (from 1,200 to 1,600 mm per year).

A **temperate continental climate** is characteristic for the greater part of Slovenia, with the continental character of the climate intensifying toward the northeast. Average January temperatures are between 0°C and -3°C , while July temperatures are between 15°C and 20°C . Due to its location in the western part of the subalpine hills and in the area of the Dinaric barrier (which is why it is often called a »subalpine« climate), the temperate continental climate of southern and western Slovenia is characterized by large precipitation (1,300 to 2,000 mm) with a submediterranean precipitation regime. The temperate continental climate of central Slovenia has a mitigated continental precipitation regime (high precipitation in summer, low in winter) with less precipitation (1,000 to 1,300 mm). In the temperate continental (subpannonian) climate of eastern and southeastern Slovenia, October temperatures in the lowlands are equal to April temperatures while in the hills the April temperatures are higher, the continental precipitation regime is more pronounced, and the annual amount of precipitation (between 800 and 1,000 mm) is the lowest in Slovenia.

Trends of climate change in the last 150 years

In Slovenia and its immediate vicinity, there are two meteorological stations in Ljubljana and Trieste that have been operating without interruption for more than 150 years. The Trieste station began working in 1841, and the Ljubljana station in 1851. With the data from Ljubljana, we can illustrate the changes in the temperate continental climate of central Slovenia, and with the data from Trieste, the changes in the submediterranean climate of southwestern Slovenia. The locations and instrumentation of the two stations have changed numerous times throughout their history, and therefore the homogeneity of their data set is somewhat questionable. This is particularly true for Ljubljana, where after World War II the station was moved to the outskirts of the city, which by the end of the 20th century had become

part of the consolidated urban complex. Given that the data was never corrected, the data for Ljubljana, especially with regard to establishing the changes in the air temperature, represents a mix of the influence of the local urban climate and the general trends of climate change. The data set for Trieste, where the station was also moved several times but never out of the city limits, is more homogeneous. Furthermore, the temperature data was also corrected so that it corresponds to the measurements it would have had if the station had been operating the entire time at its current location in the center of the city not far from the sea.

Below we present the main trends in the changing of annual and seasonal temperatures and precipitation. The general course of temperatures between the two stations coincides, somewhat less for the course of precipitation, with the difference that the variability for Ljubljana is larger. At both stations, the temperatures indicate a general trend of increase, particularly for the winter temperatures. In the last 150 years in Ljubljana, the average annual temperature rose by 1.4° (trend: $1\text{ K}/100\text{ years}$), which is more than the standard deviation for annual temperatures, while in Trieste, which is under the climatic influence of the sea, only by 0.4° (trend: $0.2\text{ K}/100\text{ years}$). In the last 150 years, winters in Ljubljana warmed by 2.5° ($1.6\text{ K}/100\text{ years}$), and in Trieste by 1.1° ($0.7\text{ K}/100\text{ years}$). In both cases, a pronounced warming trend in all seasons except fall has been evident in the last decade. A negative trend appears only in the summer temperatures of Trieste ($-0.2\text{ K}/100\text{ years}$), mostly due to the above-average warm summers at the beginning of the operation of this station and the relatively cooler summers in the second half of the 20th century until the 1980's. Since 1980, the summers have also begun to become warmer.

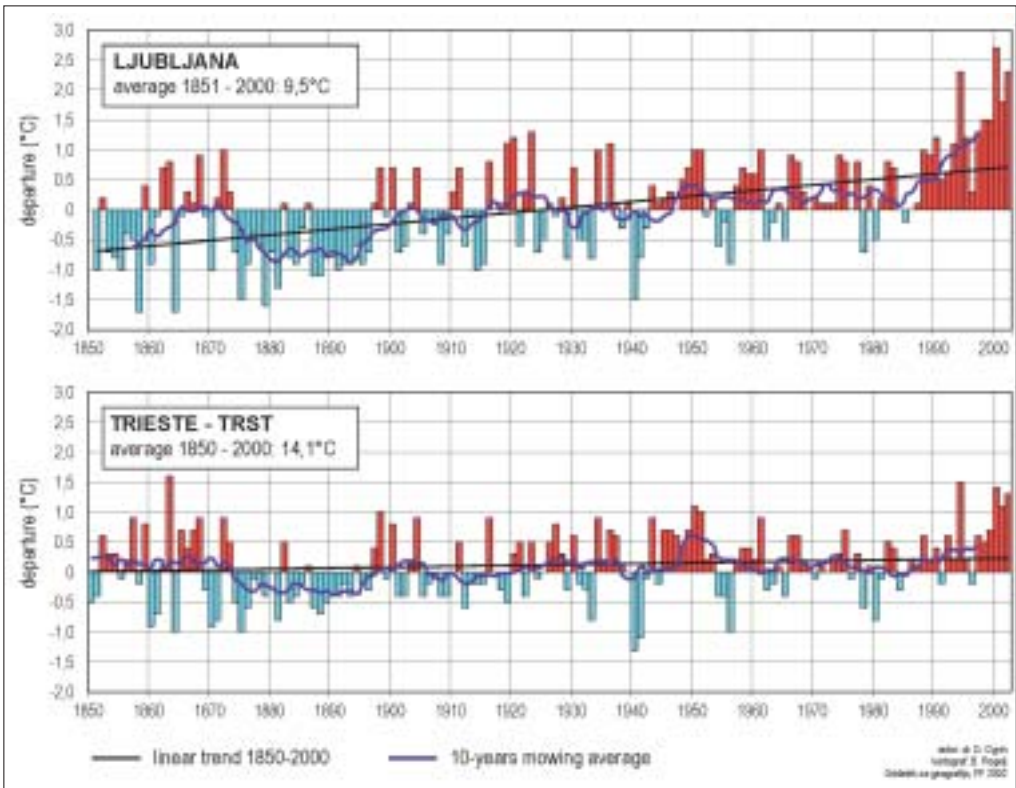


Figure 3: Average deviation and the trend of average annual temperatures in Ljubljana and Trieste between 1850 and 2002.



Figure 4: Free-growing palm in the center of Ljubljana. Will conditions for growing of thermophilic plants and cultures improve in central Slovenia due to the predicted climate change in the 21st century and the increasingly higher temperatures? (photography Darko Ogrin).

Average seasonal relative variability of precipitation at both stations is between 30% and 40%, and annually 17% (Ljubljana) or 20% (Trieste). At both stations, a lowering trend in the annual amount of precipitation is evident (Trieste: -80 mm/100 years; Ljubljana: -36 mm/100 years), largely due to the drop in the amount of precipitation in the fall (Ljubljana: -38 mm/100 years; Trieste: -44 mm/100 years). The drop in fall precipitation in the second half of the 20th century in Ljubljana brought about a change in the precipitation regime. The submediterranean regime with its primary climax in the fall was replaced by the subcontinental regime that has its climax of precipitation in the summer months. In Trieste, the summer and spring precipitation has also decreased along with the fall precipitation, while the winter precipitation shows no trend. In Ljubljana, spring precipitation has also decreased along with the fall precipitation, but summer and winter precipitation has increased slightly. It is interesting that in the last fifteen years, in Ljubljana and in Trieste, the fall precipitation has started to strengthen, which if this trend continues heralds another change of the precipitation regime in Ljubljana.

It is characteristic for the last fifteen years that temperatures in Slovenia have increased significantly. Average annual temperatures in all Slovene regions are 0.5° to 1° higher than the average temperatures between 1961 and 1990, the winters are 1° warmer, and the summers 1° to 1.5° warmer. The year 2000 was even the warmest since systematic measurements have been taken. Temperatures in the interior of Slovenia are becoming ever more similar to those in submediterranean Slovenia, where the warming trends are less pronounced. There have been no major changes in the quantity of precipitation, but the greater intensity of downpours and a lower number of days with fog and of days with snow blanket were found, which causes problems for lower-lying ski areas. Due to high summer temperatures and the irregularity of precipitation, considerable damage has been caused in the last decade by frequent droughts, which along submediterranean and subpannonian Slovenia, have also encompassed central Slovenia where they do not normally occur.

Although regional scenarios of future climate change are even less reliable than global ones, a forecast for Slovenia of the climate in the 21st century has been elaborated that considers the changes in the general circulation of atmosphere and previous trends in climate elements (Kajfež - Bogataj 2001). More reliable is the forecast of temperatures, which should increase by $1^{\circ} \pm 0.5^{\circ}$ by 2025, and in the long term by $2^{\circ} \pm 1^{\circ}$ by 2075. The forecast of precipitation is less reliable. The forecast also predicts more intensive warming in the cold half of the year, smaller daily temperature spans, fewer days with a snow blanket, more intensive precipitation and a changed precipitation regime, and more frequent and more intensive extreme weather events such as droughts, floods, and thunderstorms. It is expected that the negative consequences of climate change will nullify the positive effects linked to the prolongation of the vegetation period, the improvement of conditions for growing thermophilic plants, and the increase in the choice of plant cultures at higher sites.

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