VARIJABILNOST PADALINA NA PODRUČJU HRVATSKE S MARITIMNIM PLUVIOMETRIJSKIM REŽIMOM

PRECIPITATION VARIABILITY IN CROATIAN AREAS WITH MARITIME PLUVIOMETRIC REGIME

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Rad se bavi varijabilnošću padalina u dijelu Hrvatske s maritimnim pluviometrijskim režimom. Varijabilnost padalina analizirana je korištenjem godišnjih i mjesečnih vrijednosti srednje relativne varijabilnosti za 18 postaja od 1950. do 2007. godine. Utvrđeno je da godišnja varijabilnost padalina ima relativno veliki raspon – najveću varijabilnost padalina ima postaja Lastovo, a najmanju postaja Parg. U godišnjem hodu varijabilnosti padalina glavni maksimum varijabilnosti je na području sjevernog Jadrana u listopadu, dok se prema jugu maksimum varijabilnost javlja u ljetnim mjesecima – srpnju ili kolovozu. Glavni minimum varijabilnosti u većini postaja s maritimnim pluviometrijskim režimom javlja se u travnju, osim na postajama srednjeg Jadrana, gdje se javlja u studenom. Najmanju varijabilnost padalina ima područje Gorske Hrvatske u gotovo svim mjesecima. Najveće vrijednosti varijabilnosti padalina javljaju se ljeti na području južnog Jadrana. U gotovo svim mjesecima varijabilnost padalina na području Kvarnera je relativno viša u odnosu varijabilnost padalina okolnih postaja.

Ključne riječi: padaline, varijabilnost padalina, maritimni pluviometrijski režim, Primorska Hrvatska, Gorska Hrvatska

The paper deals with the precipitation variability areas of Croatia with pluviometric regime. Precipitation variability was analyzed using yearly and monthly values of the mean relative variability for 18 stations in the period 1950-2007. The research results showed that there is relatively large range of precipitation variability in the researched area. The highest precipitation variability was recorded in Lastovo and the lowest in Parg station. The primary maximum of precipitation variability in the northern Adriatic area is in October, while in the southern part of the Adriatic maximum variability occurs during the summer months - July or August. The minimum variability in most of the stations with maritime pluviometric regime occurs in April, except in the central part of the Adriatic, where it occurs in November. The lowest precipitation variability is in the mountain region of Croatia. The highest values of precipitation variability occur during summer months in the southern part of Adriatic. The values of precipitation variability in the Kvarner region are relatively higher than the variability of the surrounding stations in almost all months.

Keywords: precipitation, precipitation variability, maritime pluviometric regime, Coastal region of Croatia, Mountain region of Croatia

Uvod

Varijabilnost je obilježje svojstveno svakom klimatskom elementu, no neki klimatski elementi, kao što su padaline, imaju izraženu prostornu i vremensku varijabilnost (Jones, 1999.). Varijabilnost padalina dolazi do izražaja zbog važnosti padalina odnosno vode u prostoru. Najbolje se to može vidjeti u aridnim i semiaridnim

Introduction

Variability is a feature of every climate element; however, some of the elements, such as precipitation, feature a more distinct spatial and temporal variability (Jones, 1999). Precipitation variability stands out because of the importance of precipitation, that is, the amount of water in an area. The best example for this are arid and

područjima gdje svaki izostanak padalina ili dugotrajno razdoblje s malim količinama padalina ima izravan utjecaj na vegetaciju i živi svijet, a time i na čovjeka. Hrvatska prima dovoljne količine padalina, pa čak i relativno velike, kao što je to slučaj na području Gorske Hrvatske. Zbog krške podloge prisutne na najvećem dijelu istraživanog područja, dio padalina odlazi u podzemlje te nije dostupan za izravno korištenje.

Razvojem tehnologije ovisnost se društva o padalinama smanjila, ali nije u potpunosti nestala. To se može potvrditi i na području Primorske Hrvatske, pogotovo na njezinu otočnom dijelu, gdje brojne aktivnosti, uključujući i one vezane za turizam, ovise o količini dostupne pitke vode. U slučaju redukcije potrošnje pitke vode, već i najblažeg stupnja, može doći do negodovanja, pa čak i odlaska dijela posjetitelja. Zbog zabrane zalijevanja travnjaka ili cvjetnjaka dolazi do narušavanja estetskog doživljaja turističkih mjesta. Požari, koji u sušnim godinama mogu uzrokovati velike štete, također mogu utjecati na turističku sezonu. Osim ekonomskog utjecaja varijabilnosti padalina, važan je i utjecaj na stanovništvo. Stoga je cilj ovoga članka uputiti na neke zakonitosti raspodjele varijabilnosti padalina na području Hrvatske s maritimnim pluviometrijskim režimom.

Varijabilnost padalina je pojava manje ili veće količine padalina koja padne svake godine, u odnosu na neku srednju vrijednost. Kao srednja vrijednost najčešće se uzima aritmetička sredina ukupne količine padalina tijekom višegodišnjega vremenskog niza.

Varijabilnost padalina u ovom radu analizirana je korištenjem podataka o mjesečnim količinama padalina s 18 postaja na području Hrvatske s maritimnim pluviometrijskim režimom.

Prikazani rezultati dio su šireg istraživanja provedenog u sklopu doktorskog rada *Geografski aspekt razlika u varijabilnosti padalina kontinentskog i maritimnog pluviometrijskog režima u Republici Hrvatskoj* (Maradin, 2011.).

Prethodna istraživanja

Postoji relativno velik broj istraživanja varijabilnosti padalina u svijetu koja su zbog velike prostorne promjenjivosti padalina često regionalnoga karaktera. Posebna se pažnja posvećuje istraživanju varijabilnosti padalina, ali

semiarid areas where any absence of precipitation or long-term periods of minimal precipitation has a direct influence on vegetation and fauna and, hence, on the people. Croatian territory receives sufficient or even relatively high amounts of precipitation, as is the case in Mountain region of Croatia. However, due to the underground drainage system in the karst, which prevails in most of the researched area, a portion of the water is lost in the underground and is not accessible for direct usage.

Technological development has decreased societies' dependence on precipitation, but it has not completely disappeared. This is also the case with the Croatia's coastal region, particularly its islands, where numerous activities, including those related to tourism, depend on the availability of drinking water. Even the smallest degree of drinking water consumption reduction can result in tourists' complaints or even make them leave. Aesthetic perception of the tourist resorts can be disturbed if watering of lawns and flower gardens is prohibited. Fires, which can cause significant damages during dry periods can also influence the tourist season. Furthermore, apart from its economic influence, precipitation variability influence to population is also important. Hence, the aim of this article is to point to certain regularities of precipitation variability distribution in the areas with maritime pluviometric regime in Croatia.

Precipitation variability is the occurrence of a greater or smaller amount of precipitation that falls every year in relation to an average value for a certain period. The average value is usually the arithmetic mean of the precipitation during a certain period.

Precipitation variability in this paper is analysed using the monthly precipitation data from 18 stations in areas with maritime pluviometric regime.

The results were obtained as a part of a wider research conducted within the doctoral thesis *Geographic Aspect of Differences in Precipitation Variability of Continental and Maritime Pluviometric Regimes in the Republic of Croatia* (Maradin, 2011).

Previous researches

There are a relatively great number of precipitation variability researches in the world, which are often of a regional character due to substantial spatial differences in precipitation variability. Special attention has been given to researches of precipitation

i padalina općenito, u onim dijelovima svijeta gdje padalina ima malo ili imaju veliku važnost za život ljudi. Ovdje će biti spomenut samo dio tih istraživanja, pogotovo onih koja se bave utjecajem maritimnosti na varijabilnost padalina.

Varijabilnost padalina na cijeloj Zemlji prvi je istraživao Biel (1929.) te je došao do zaključka da varijabilnost godišnjih količina padalina raste na područjima s malim količinama padalina, i obratno, smanjuje se u krajevima s većim količinama padalina. Varijabilnošću padalina na Zemlji bavio se i Conrad (1941.). On analizira odstupanja relativne promjenjivosti te nalazi da prostor Europe i Sjeverne Amerike u zoni umjerenih i viših geografskih širina ima nešto niže vrijednosti relativne varijabilnosti padalina u odnosu na prosjek, dok područja iznad oceana i obale kontinenata koja se nalaze pod utjecajem hladnih morskih struja imaju visoke vrijednosti relativne varijabilnosti padalina.

Koristeći podatke iz rada Lebedeva i dr. (1979.), koji se odnose na razdoblje od 1931. do 1960. godine, Juras (1995.) je izradio kartu varijabilnosti količina padalina u Europi. Analizirajući varijabilnost padalina na području Europe, Juras (1995.) navodi da su vrijednosti koeficijenta varijacije, u odnosu na druge kontinente, relativno male. Prema jugu kontinenta vrijednosti koeficijenta varijacije rastu, što je posljedica ne toliko manjih prosječnih godišnjih količina padalina koliko izrazito manjeg broja dana s padalinama. Morales (1977.), razmatrajući utjecaj opće cirkulacije atmosfere na varijabilnost padalina, tvrdi da je varijabilnost veća u tropskom i suptropskom pojasu, nego u umjerenim geografskim širinama. Naime na područjima koja zahvaćaju zonalni zapadni vjetrovi, glavni izvor padalina su putujuće ciklone koje se smjenjuju s anticiklonama koje donose stabilnije vrijeme. Ta je izmjena relativno brza i pravilna što uzrokuje manju varijabilnost padalina.

Unatoč brojnim radovima koji se bave obilježjima padalina (Penzar, Penzar, 1979., 1981.; Pandžić, 1988.; Pandžić, Kisegi, 1990.; Gajić-Čapka, 1993.) istraživanja varijabilnosti padalina u Hrvatskoj relativno su rijetka. Margetić (1942.) među prvima proučava promjenjivost padalina na obali te uočava prostornu pravilnost u varijabilnosti padalina. Prema njemu, najveću varijabilnost imaju obalni i otočni dio južne Hrvatske te područja u unutrašnjosti koja su pod maritimnim utjecajem. Penzar (1959.) varijabilnost količine

variability and precipitation in general in those areas of the world where there is a lack of precipitation or where precipitation significantly influences the society. Only a small part of the aforementioned researches is discussed in this work, particularly those that deal with the maritime influence to precipitation variability.

Precipitation variability on the Earth as a whole was first researched by Biel (1929) and he concluded that variability of annual precipitation amount increases in the regions with small amount of precipitation and, vice versa, it decreases in the regions with larger amount of precipitation. Conrad (1941) also studied precipitation variability on Earth. He analysed the deviations in relative variability and found that the regions of Europe and North America in moderate and higher geographic latitudes feature relative precipitation variability values lower than the average, while in the areas above the oceans and continental coasts that are under the influence of cold sea currents higher values of relative precipitation variability were measured.

Juras (1995) has made a map of precipitation variability in Europe using the data from the study of Lebedev et al (1979), which refer to 1931-1960 period. Juras (1995), analysing precipitation variability in Europe, states that values of variation coefficient are relatively small in comparison to other continents. The values of the coefficient are increasing towards the south of Europe, which is less a consequence of lower average annual precipitation amounts than of significantly smaller number of days with precipitation. Morales (1977), researching the influence general circulation of atmosphere has to precipitation variability, states that the variability is higher in tropical and subtropical zones than in moderate latitudes. Namely, the main sources of precipitation in the latitudes affected by western zonal winds are cyclones that interchange with anticyclones that bring a more stable weather. That change is relatively fast and regular, which causes lower precipitation variability.

Precipitation variability researches in Croatia are relatively rare despite numerous studies dealing with precipitation features (Penzar, Penzar, 1979, 1981; Pandžić, 1988; Pandžić and Kisegi, 1990; Gajić-Čapka, 1993). Margetić (1942) was among the first to study precipitation variability in the coastal region of Croatia and noted spatial regularity in precipitation variability. According to him, the greatest variability occurs in coastal and island parts of south Croatia and in continental

padalina određuje korištenjem Schultzeovih koeficijenata koji najveće vrijednosti imaju na otocima sjevernoga Hrvatskog primorja koji nisu najbliži obali, u dijelu Gorskog kotara i u cijeloj Dalmaciji. Penzar naglašava da dobiveni rezultati pokazuju da kontinentalni pluviometrijski režim smanjuje, a maritimni povećava kontraste u godišnjem hodu padalina.

Makjanić i Volarić (1979.) bave se klimatskim obilježjima otoka Hvara te daju prikaz varijabilnosti padalina analizirajući odnos između razlike najveće i najmanje mjesečne količine padalina i pripadne srednje mjesečne vrijednosti. Najveće vrijednosti tako dobivenih vrijednosti su u ljetnim mjesecima i u listopadu. Juras (1995.) se bavi varijabilnošću količine padalina u Hrvatskoj te zaključuje da postoji velik raspon koeficijenata varijacije. Godišnje vrijednosti koeficijenata varijacije velike su na južnom dijelu jadranske obale i na području Kvarnera. Najmanje vrijednosti su na području Gorskog kotara. Pokazalo se da same vrijednosti pokazatelja varijabilnosti, u ovom slučaju koeficijenata varijacije, ne pružaju dovoljno informacija o razlozima pojave varijabilnosti padalina.

Analizom varijabilnosti količine padalina na hrvatskoj obali bavila se Milković (1998.), koja dobiva najveće vrijednosti koeficijenata varijacije na pučinskim otocima južnog Jadrana, a koje se smanjuju prema unutrašnjosti i prema sjeveru. Postaje s većim srednjim godišnjim količinama padalina obično imaju manje vrijednosti koeficijenata varijacije, no može se dogoditi da imaju i prilično različite vrijednosti, što se može povezati s brojem dana s padalinama. U godišnjem hodu padalina mjesec s najvećom varijabilnosti je listopad. Mjesec s najmanjom varijabilnosti je, u postajama od Rijeke do Splita, travanj, a južnije travanj ili studeni.

Maradin (2008.), koristeći se srednjom relativnom varijabilnosti kao mjerom varijabilnosti padalina, analizira varijabilnost padalina na postajama Crikvenica i Hvar. Usporedbom varijabilnosti padalina u Hvaru i Crikvenici, pokazalo se da je godišnja vrijednost varijabilnosti padalina veća u Crikvenici nego u Hvaru. Mjesečne vrijednosti srednje relativne varijabilnosti podudaraju se u hladnom dijelu godine, kada je varijabilnost tek nešto veća u Crikvenici, dok je u toplom dijelu godine, osim u rujnu, varijabilnost veća u Hvaru.

regions under maritime influence. Penzar (1959) measured precipitation variability using Schultze's coefficients and found the greatest values were measured on northern Croatian littoral islands that are not the ones closest to the coast, in the part of Gorski Kotar and in whole of Dalmatia. Penzar (1959) emphasized his results showed that the contrast in the annual course of precipitation is decreased by continental pluviometric regime, and increased by the maritime regime.

Makjanić and Volarić (1979) have studied climate features of the island of Hvar and provided a review of precipitation variability by analyzing the relationship between the differences in the highest and the lowest monthly precipitation amount and their pertaining mean monthly value. The highest obtained values were measured in the summer months and in October. Juras (1995) studied precipitation quantity variability in Croatia and noticed that there was a great range of variation coefficients. High annual values of variation coefficients were recorded in the southern part of the Adriatic coast and in the Kvarner region. The lowest values were measured in the Gorski Kotar region. The research showed that the values of variability indicators alone, in this case variation coefficients, could not provide enough information about the causes of precipitation variability.

Milković (1998) studied precipitation variability on Croatian coast, and measured the greatest variation coefficients values on the offshore islands in the southern Adriatic. Variation coefficients values are decreasing towards the inland and towards the north. Meteorological stations with higher amounts of annual precipitation usually have lower values of variation coefficients. However, they can also vary in values, which can be linked to number of days with precipitation. In the annual course of precipitation, the month with the greatest precipitation variability is October. The month with the lowest variability in the stations from Rijeka to Split is April and, more to the south, April or November.

Maradin (2008) analysed precipitation variability in Crikvenica and Hvar stations using the mean relative variability as a measure of precipitation variability. He concluded that the annual values of precipitation variability were higher in Crikvenica than in Hvar. Monthly values of mean relative variability coincided in the colder part of the year, with only a slightly greater variability in Crikvenica, while in the warmer part of the year, except for September, the variability was greater in Hvar.

Podaci i metode

Postoje različite metode za određivanje varijabilnosti padalina; od različitih pokazatelja varijabilnosti količine padalina do stohastičkih modela. Sve metode temelje se na načelu da varijabilnost količine padalina određuju odstupanjima padalina od neke vrijednosti, odnosno konstante (Conrad, Pollak, 1950.). Riječ je o mjerama disperzije (Šošić, Serdar, 2002.). Za vrijednost konstante najčešće se uzima aritmetička sredina padalina u nekom razdoblju.

Varijabilnost količine padalina u ovom radu određuje se pomoću srednje apsolutne varijabilnosti padalina. Ona pokazuje prosječnu vrijednost svih odstupanja od srednje vrijednosti, zanemarujući njihove predznake. Izračunava se s pomoću izraza:

$$V_a = \frac{1}{n}\sum_{i=1}^{n}\left|P_i - \overline{P}_g\right|$$

gdje je, Pi vrijednost padalina u i-toj godini promatranog razdoblja, a Pg srednja vrijednost padalina. Kako bi vrijednosti srednje apsolutne varijabilnosti bile usporedive za različite postaje, kao relativni pokazatelj koristi se srednja relativna varijabilnost Vr, koja se računa s pomoću izraza:

$$V_r = \frac{100\overline{V}_a}{\overline{P}_g}\,\%$$

Za analizu prostornih odnosa varijabilnosti padalina bilo je potrebno dobivene vrijednosti varijabilnosti prostorno interpolirati te je dobivena prostorna raspodjela varijabilnosti padalina u pojedinim mjesecima, odnosno godini. Za prostorne interpolacije korišten je program ArcGIS, verzija 9.3. Testirane su brojne metode koje program nudi, a najbolje rezultate dala je metoda Tension Spline. Pri korištenju navedene metode prostorna interpolacija određenog poligona izračunava se na osnovi vrijednosti 12 susjednih postaja. U stranoj literaturi metoda Tension Spline naziva se i *basic minimum curvature technique* ili *thin plate interpolation* (Naoum, Tsanis, 2004.). Pri izradi karata korištenjem Spline Tension metode zanemaren je utjecaj reljefa na varijabilnost padalina. To je učinjeno zbog malog broja korištenih postaja, kao i zbog raspodjele postaja prema nadmorskoj

Data and methods

There are various methods of determining precipitation variability, from numerous precipitation variability indicators to stochastic models. All these methods are based on the assumption that precipitation variability is precipitation deviation from a certain constant (Conrad, Pollak, 1950). In another words, they are measures of dispersion (Šošić, Serdar, 2002). The value of the constant is usually taken to be the arithmetic mean of the precipitation during a certain period.

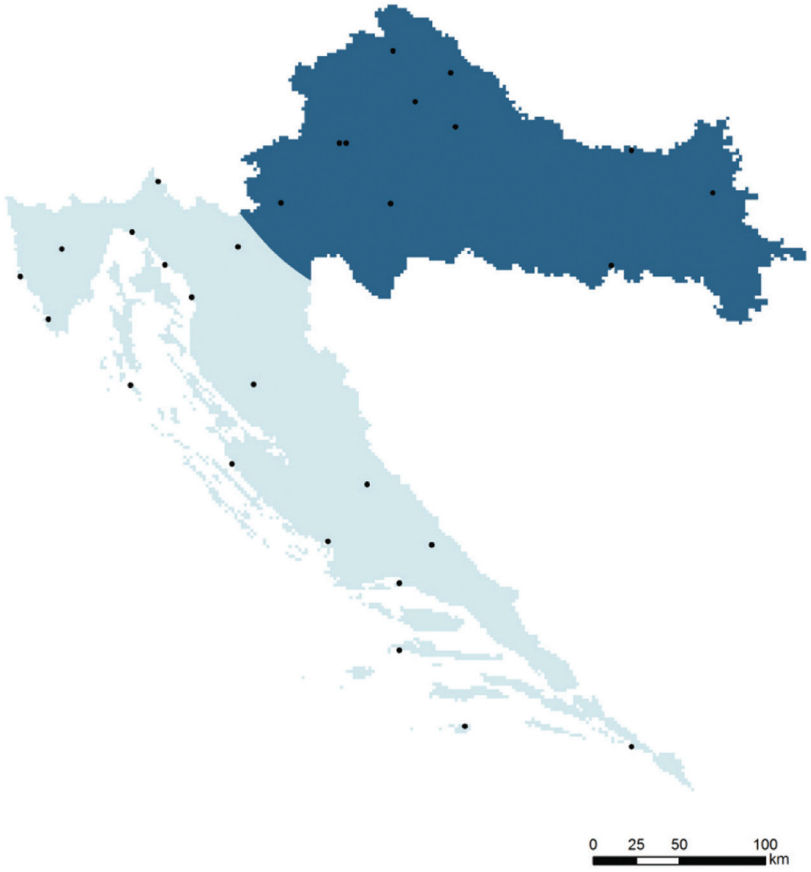
Precipitation variability in this study is determined by using the mean absolute precipitation variability. It is an average value of all the absolute deviations from the mean value. It is calculated by using the formula:

$$V_a = \frac{1}{n}\sum_{i=1}^{n}\left|P_i - \overline{P}_g\right|$$

with P_i being the precipitation value in the i^{-th} year of the researched period, and P_g is the mean value of precipitation. In order to compare precipitation variability for different stations, or for different time series obtained for the same station, the mean relative variability, V_r, is used. It is a relative indicator, and it is being calculated by using the formula:

$$V_r = \frac{100\overline{V}_a}{\overline{P}_g}\,\%$$

In order to conduct spatial analysis of precipitation variability it was necessary to spatially interpolate the calculated values of precipitation variability, resulting in the spatial distribution of precipitation variability for every month separately, and also for the whole year. The software ArcGIS, version 9.3, was used in order to conduct spatial interpolations. The numerous methods that the software provides were tested, and the best results were obtained by the Tension Spline method. Spatial interpolation of a certain polygon using the aforementioned method is calculated based one the values recorded in 12 neighbouring stations. In resource literature the Tension Spline method is also called the *basic minimum curvature technique* or *thin plate interpolation* (Naoum, Tsanis, 2004). In the process of map-making by using the



Slika 1. Područje s kontinentalnim i maritimnim pluviometrijskim režimom u Hrvatskoj
Figure 1 Continental and maritime pluviometric regime area in Croatia

visini. Osim toga, utjecaj reljefa na vrijednosti pokazatelja varijabilnosti manji je nego na vrijednosti srednjih godišnjih količina padalina, zbog čega Juras (1995.) tvrdi da zanemarivanje utjecaja nadmorske visine neće bitno utjecati na prikaz prostorne raspodjele varijabilnosti količine padalina. Da anomalije padalina u odnosu na višegodišnji srednjak uvelike ne ovise reljefu tvrdi i Pandžić (1988.). Naravno, zanemarivanje reljefa se mora uzeti u obzir pri interpretaciji dobivenih podataka o prostornoj raspodjeli varijabilnosti.

Varijabilnost padalina u radu je analizirana korištenjem podataka o mjesečnim količinama padalina na području Hrvatske s maritimnim pluviometrijskim režimom. Područje s maritimnim režimom padalina je ono koje ima veću količinu padalina u zimskoj, tj. hladnoj polovici godine, tj. od listopada do ožujka (Margetić, 1942.; Penzar, 1959.; Šegota, 1986.). U literaturi taj se tip još naziva mediteranski ili suptropski pluviometrijski režim (Penzar, Penzar,

Spline Tension method the influence of relief to precipitation variability is ignored. The reason for this is a small number of weather stations used and inadequate distribution of the stations by altitude. Besides, the influence the relief has on the values of variability indicators is lower than its influence on the values of mean annual precipitation amounts, wherefore Juras (1995) claims that ignoring the influence of altitude would not significantly influence the obtained spatial distribution of precipitation variability. Pandžić (1988) also claims that precipitation anomalies in relation to a certain period average do not mainly depend on the altitude. Neglecting the influence of altitude must be taken into consideration in the process of interpreting the obtained data regarding the spatial distribution of variability.

Precipitation variability in this study is analysed by using the data regarding monthly precipitation amounts in the maritime pluviometric regime area in Croatia. An area with maritime pluviometric regime is an area that receives greater quantity of

Slika 2. Geografska raspodjela klimatoloških postaja za koje su korišteni podaci o količini padalina u razdoblju od 1950. do 2007. godine
Figure 2 Geographical distribution of climatological stations for which the data in 1950-2007 period were used

1979., 1981.). Prikaz područja s maritimnim pluviometrijskim režimom u Hrvatskoj također je dobiven korištenjem programa ArcGIS (Slika 1.).

Na području s maritimnim pluviometrijskim režimom odabrano je 18 postaja za koje je istraživana varijabilnost padalina (Slika 2.). Razlog relativno malom broju postaja za koje je analizirana varijabilnost padalina je razdoblje za koje je varijabilnost padalina istraživana. Naime unatoč preporuci Svjetske meteorološke organizacije (WMO) o korištenju tridesetogodišnjih razdoblja za analizu klimatskih elemenata i klime u cjelini (WMO, 2010.), suvremena su istraživanja pokazala da za neke dijelove svijeta, kao i za neke klimatske elemente, tridesetogodišnje razdoblje nije dovoljno, već je potrebno uzeti dulje vremensko razdoblje kako bi se dobili relevantni pokazatelji klime. Klimatolozi koji se bave padalinama navode da je na područjima s relativno malom

precipitation in the winter, i.e. the colder half of the year, from October to March (Margetić, 1942; Penzar, 1959; Šegota, 1986). In literature, that type is also called the Mediterranean or subtropical pluviometric regime (Penzar, Penzar, 1979, 1981). An overview of the maritime pluviometric regime area in Croatia is also obtained by using the ArcGIS software (Figure 1).

Within the maritime pluviometric regime area, 18 stations were selected for precipitation variability analysis (Figure 2). The reason for a relatively small number of stations is the period during which precipitation variability was analyzed. Despite the World Meteorological Organization's (WMO) recommendation to use 30-years periods for analyzing the climate elements and the climate as a whole (WMO, 2010), modern researches have showed that for certain parts of the world as well as certain climate elements 30 years is not long enough period. It is necessary to take a longer

količinom padalina za razmatranja potrebno uzeti dulje vremensko razdoblje (Biel, 1944.; Šegota, 1969.; Juras, 1985.). Zbog navedenog, u radu je varijabilnost padalina analizirana za razdoblje od 1950. do 2007. godine.

Obilježja padalina na istraživanom području

Istraživane postaje imaju relativno velik raspon srednje godišnje količine padalina. Najmanje padalina imaju postaje na jadranskoj pučini i otocima, a količina se padalina povećava prema obali, osobito na područjima pod utjecajem reljefa. Najmanje padalina prima postaja Lastovo (668,4 mm), a najviše postaje na području Gorske Hrvatske – Parg (1 842,6 mm) i Ogulin (1 566,2 mm). Pod utjecajem reljefa količina padalina može biti vrlo velika i na postajama na obali (postaje Rijeka i Dubrovnik), dok postaje koje nemaju planinsko zaleđe, kao što su postaje Zadar, Šibenik i Split-Marjan primaju bitno manju količinu padalina. U planinskom pojasu pada najveća količina padalina, s time da je nešto manja u većim konkavnim oblicima reljefa, što najviše dolazi do izražaja u Lici (Pandžić, Likso, 2007.).

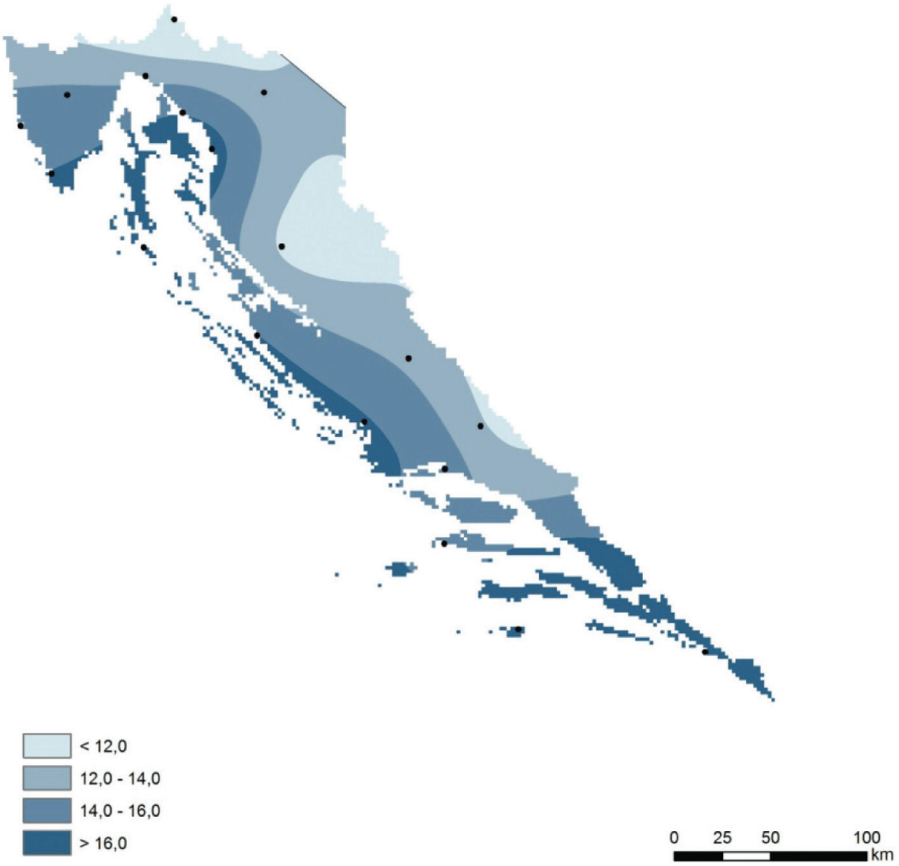
Kako bi se detaljnije mogla objasniti varijabilnost padalina na istraživanom području, potrebno je ukratko spomenuti godišnji hod padalina. Prema tipologiji godišnjeg hoda padalina koju su razradili Penzar i Penzar (1979., 1981.), istraživane postaje imaju tri tipa godišnjeg hoda padalina. Sve postaje imaju tipove padalina u kojima se mjesec s najmanje padalina javlja u toplom dijelu godine. Postaja Lastovo jedina ima tip godišnjeg hoda padalina gdje je najmanje padalina u srpnju, a najviše u prosincu. U postajama Dubrovnik, Hvar, Split-Marjan, Zadar i Mali Lošinj minimum padalina je također u srpnju, dok je maksimum padalina u studenom. U svim ostalim postajama na istraživanom području, koje se uglavnom nalaze sjevernije od spomenutih postaja, javlja se sporedni maksimum padalina u travnju ili svibnju te sporedni minimum u ožujku ili veljači.

period in order to get reliable climate indicators. Climatologists who study precipitation claim that for the regions with relatively small precipitation amounts it is necessary to observe a period longer than 30 years (Biel, 1944; Šegota, 1969; Juras, 1985). Therefore, in this paper the precipitation variability was analysed for the period between 1950 and 2007.

Precipitation features in the research area

The researched stations have a relatively large range of mean annual precipitation amounts. The stations on the Adriatic islands have the lowest amount of precipitation but it increases towards the coast, particularly in the regions that are under the influence of relief. The lowest amount of the precipitation are recorded at Lastovo meteorological station (668.4 mm), and the highest amount at the stations Mountain region of Croatia – Parg (1,842.6 mm) and Ogulin (1,566.2 mm). Precipitation amount can be very high in the coastal stations under the influence of relief (Rijeka and Dubrovnik stations), while stations without the mountainous hinterland (Zadar, Šibenik, Split- Marjan stations) receive a significantly lower precipitation amounts. The highest amount of precipitation is recorded in the mountainous area, and the slightly lower amounts appear in concavely shaped areas, as can best be seen in Lika (Pandžić, Likso, 2007).

In order to explain precipitation variability in the researched area, it is necessary to mention in short the annual course of precipitation. According to the typology of annual course of precipitation developed by Penzar and Penzar (1979-81), there are three types of the annual course of precipitation in the researched stations. Within all the types of precipitation, the month with the lowest precipitation amount occurs in the warm part of the year. Lastovo station is the only station with the annual course of precipitation in which the lowest amount of precipitation occurs in July and the highest in November. In Dubrovnik, Hvar, Split-Marjan, Zadar and Mali Lošinj stations minimum of precipitation occurs also in July, and the maximum also in November. At all other stations in the researched area, which are mostly situated north from the mentioned stations, secondary precipitation maximum occurs in April or May and the secondary minimum occurs in March or February.



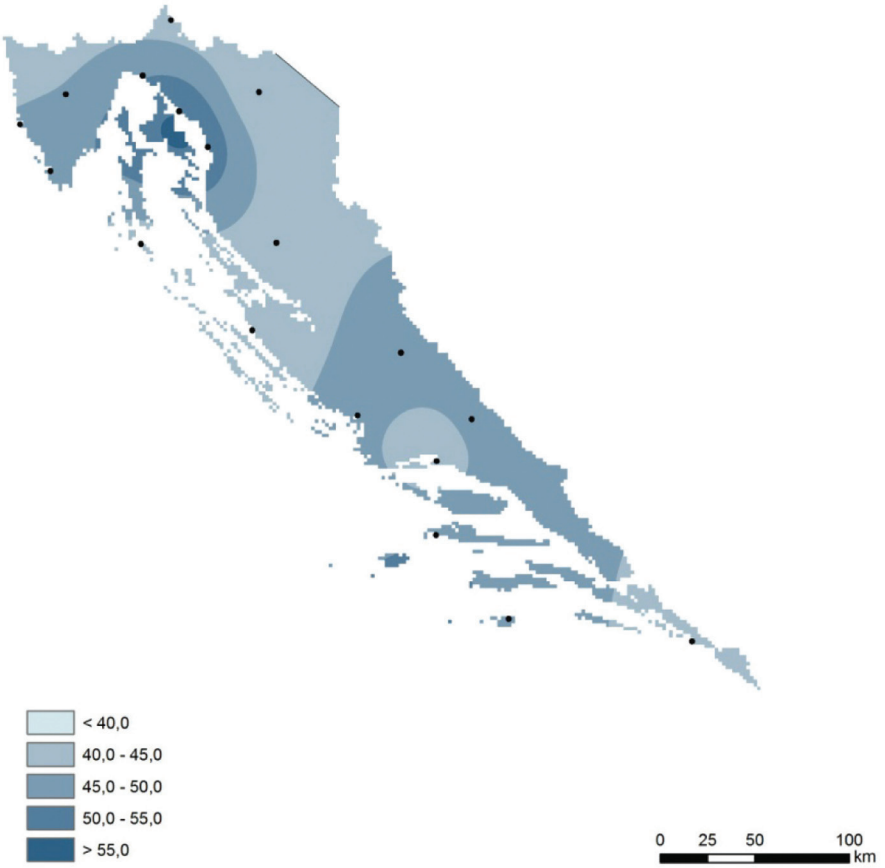
Slika 3. Godišnje vrijednosti varijabilnosti padalina na istraživanom području (%)
Figure 3 Anual values of precipitation variability in researched area (%)

Prostorna raspodjela godišnjih vrijednosti varijabilnosti padalina

Na istraživanom području prisutan je relativno velik raspon varijabilnosti padalina. Postaja s najvećom vrijednosti varijabilnosti je Lastovo (20,6%), a s najmanjom Parg (9,1%). Varijabilnost padalina najmanja je na području Gorske Hrvatske (Slika 3.). Prema obali vrijednosti varijabilnosti padalina se povećavaju. Najveća vrijednost varijabilnosti padalina je na području koje je pod utjecajem suptropskih maksimuma tlaka zraka, zbog čega u ljetnim mjesecima padalina ima malo ili one mogu u potpunosti izostati. Osim na južnom Jadranu varijabilnost padalina velika je i na području Kvarnera. Velike vrijednosti varijabilnosti padalina na području Kvarnera u gotovo svim mjesecima posljedica su raspodjele mora i kopna te dinamike reljefa.

Spatial distribution of annual values of precipitation variability

In the researched area, there is a relatively wide range of precipitation variability. The station with the highest value of precipitation variability is Lastovo (20.6%), and the station with the lowest variability is Parg (9.1%). Precipitation variability is the lowest in the mountain region of Croatia (Figure 3). Toward the coast, the values of precipitation variability are increasing. The highest value of precipitation variability is recorded in the areas under the influence of subtropical air pressure maximums, where there is an only small amount of precipitation in the summer months, or a complete lack of precipitation. Besides the South Adriatic, precipitation variability is also high in the Kvarner region. High values of precipitation variability in the Kvarner region during almost all of the months can be explained by sea and land distribution and terrain dynamics.



Slika 4. Varijabilnost padalina u siječnju (%)
Figure 4 Precipitation variability in January (%)

Prostorna raspodjela mjesečnih vrijednosti varijabilnosti padalina

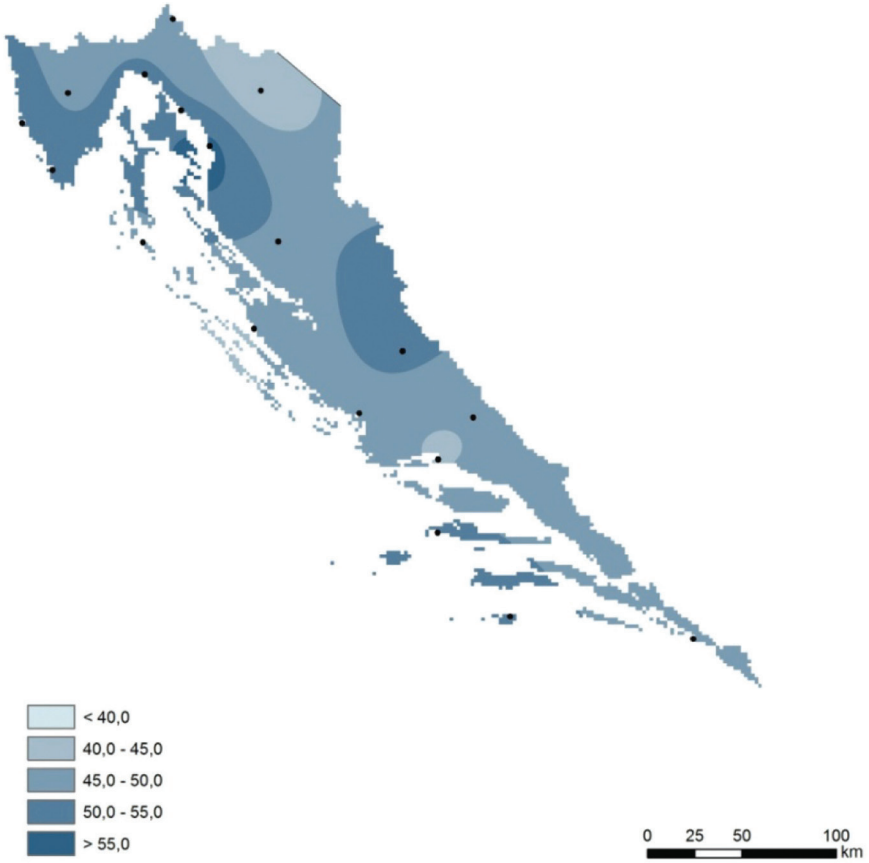
Analiza mjesečnih vrijednosti varijabilnosti padalina, za razliku od godišnjih, bolje upućuje na regionalne razlike u varijabilnosti te na uzroke takvih raspodjela.

U zimskim mjesecima varijabilnost padalina najmanja je na južnom dijelu istraživanog područja, što je posljedica utjecaja ciklonske cirkulacije na postanak padalina u tom dijelu Hrvatske. Varijabilnost padalina mala je i na području Gorske Hrvatske (Slika 4., Slika 5.). Najveću varijabilnost padalina imaju postaje na području Kvarnera i Istre – Senj, Crikvenica, Pazin, Pula i Rijeka. Velika varijabilnost na ovom području može se objasniti utjecajem reljefne raščlanjenosti te odnosa mora i kopna na postanak padalina na području Kvarnera, pogotovo ako se uzme u obzir broj dana s padalinama koji se zimi bitno ne razlikuje u odnosu na ostale postaje na Jadranu. U veljači su vrijednosti varijabilnosti količine padalina nešto veće nego u siječnju (Slika

Spatial distribution of monthly values of precipitation variability

Analysis of monthly precipitation variability values, in contrast to annual values, can more correctly depict regional differences in precipitation variability and their causes.

During the winter months precipitation variability is the lowest in the southern parts of the researched area as a result of cyclonic circulation influence on precipitation formation in that part of Croatia. Precipitation variability is also low in the mountain area (Figure 4, Figure 5). The highest precipitation variability is recorded at the stations in the Kvarner and Istria – Senj, Crikvenica, Pazin, Pula and Rijeka. The relatively high variability in this area can be explained by the influence of terrain dynamics and distribution of land and sea on formation of precipitation in the Kvarner region, particularly if we take into consideration the number of days with precipitation, which in winter does not differ greatly in comparison to other Adriatic stations. Variability of precipitation amounts in



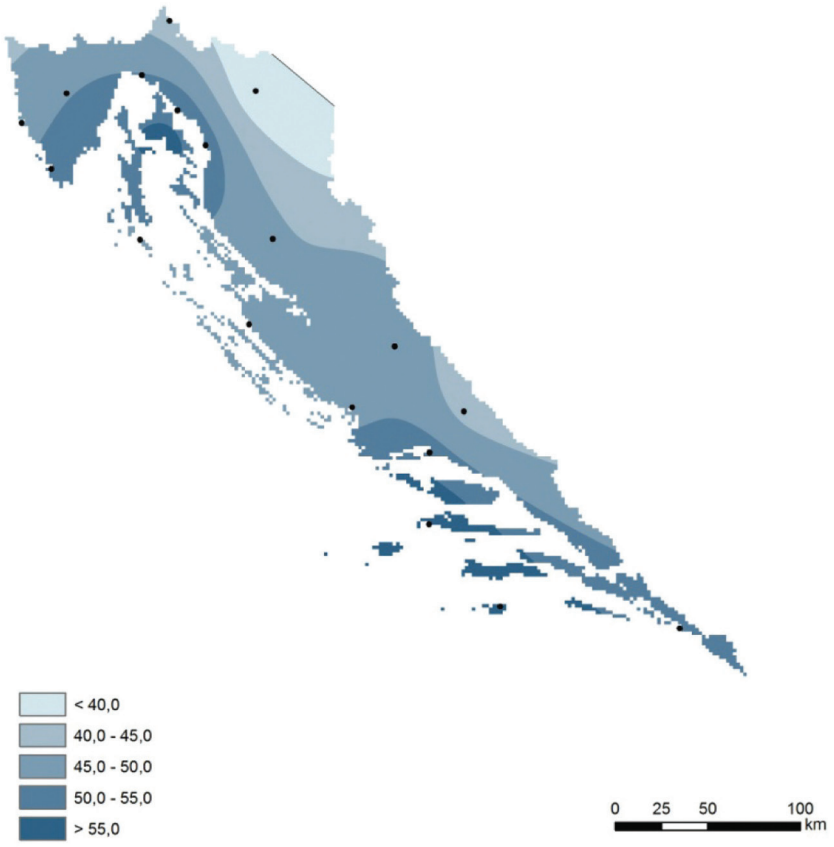
Slika 5. Varijabilnost padalina u veljači (%)
Figure 5 Precipitation variability in February (%)

5.), premda je raspon njihovih vrijednosti i dalje relativno mali. Varijabilnost količine padalina veća od 55% javlja se na području Kvarnera i obalnog dijela Istre i oko postaje Knin. Varijabilnost količine padalina manju od 50% imaju postaje Split-Marjan i Ogulin. Veće vrijednosti varijabilnosti količine padalina u odnosu na siječanj mogu se dijelom objasniti manjim brojem kalendarskih dana u veljači (Juras, 1995.).

Proljeće je godišnje doba s najmanjim vrijednostima varijabilnosti sezonskih količina padalina u Hrvatskoj (Maradin, 2011.), što se može objasniti brojnim izvorima padalina u tom godišnjem dobu. Ipak, postoje razlike između sjevernog i južnog dijela istraživanog područja, gdje je varijabilnost nešto veća. Penzar i Penzar (1979., 1981.) navode da zagrijavanjem kopna koje počinje u ožujku dolazi do smanjivanja padalinskog doprinosa fronti i smanjenja doprinosa ciklona na moru u ukupnoj količini padalina, ali se pojavljuju dva nova izvora padalina – ciklone na kopnu i konvektivne padaline. Velik broj čimbenika koji uzrokuju nastanak padalina

February is slightly higher than in January (Figure 5), although the range of their values is still relatively small. Precipitation variability higher than 55% occurs in the Kvarner, coastal part of Istria, and around Knin. Precipitation variability less than 50% is recorded at the stations Split-Marjan and Ogulin. Higher precipitation variability values than in January can be partially explained by less number of days in February (Juras, 1995).

Spring is the season with the lowest precipitation variability (Maradin, 2011), which can be explained by numerous types of precipitation formation in that part of the year. However, there are differences between northern and southern parts of the researched area, where the variability is slightly higher. Penzar and Penzar (1979, 1981) state that the warming of the land that starts in March leads to a decrease of the precipitation contributed by the fronts and cyclones formed over the sea. However, two new types of precipitation sources occur in that period – land cyclones and convective precipitation. A great number of factors causing precipitation in spring influence lower precipitation variability



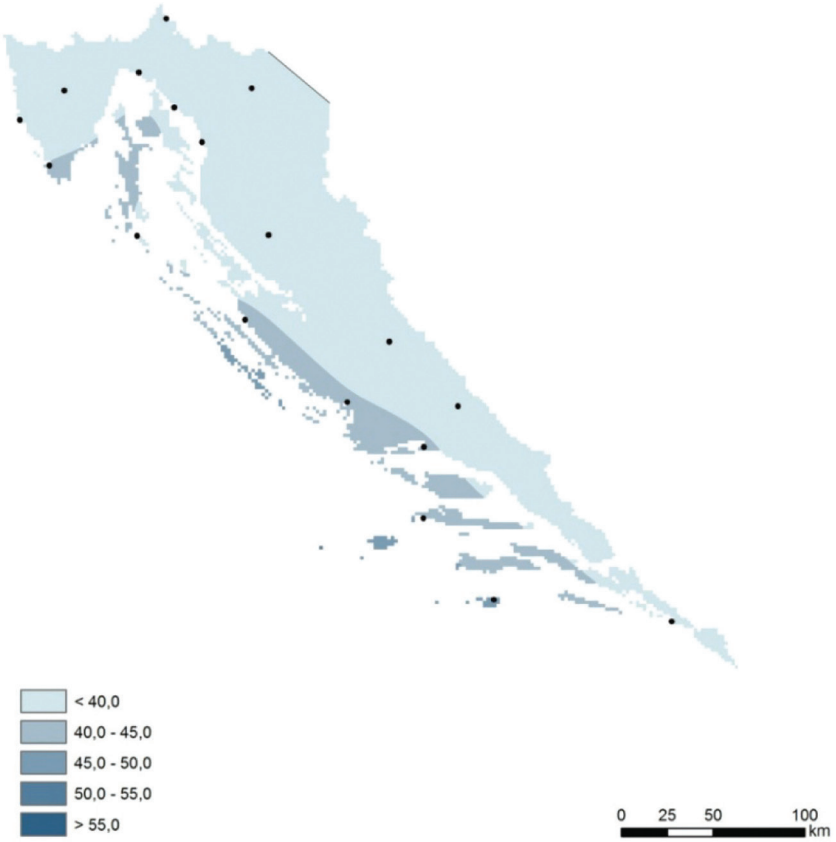
Slika 6. Varijabilnost padalina u ožujku (%)
Figure 6 Precipitation variability in March (%)

u proljeće utječe na manju varijabilnost padalina u tom godišnjem dobu. To potvrđuje i činjenica da se prema jugu smanjuje utjecaj atmosferskih labilnosti i fronti, što uz smanjenje broja ciklona na kopnu smanjuje raznolikost postanka padalina (Penzar, Penzar, 1979., 1981.) i ima za posljedicu veću varijabilnost padalina.

U odnosu na veljaču, vrijednosti varijabilnosti količine padalina u ožujku na području sjevernog Jadrana približno su iste, dok su na području južnog Jadrana povećane (Slika 6.). To povećanje varijabilnosti na obali može se povezati sa sporednim minimumom u godišnjem hodu padalina koji se u tom mjesecu javlja na području srednjeg i sjevernog Jadrana, kao i velikom međugodišnjom promjenjivošću padalina. Velika količina padalina u ožujku 1964. godine te male količine padalina u istom mjesecu 1973. i 2002. godine na obalnom području Hrvatske, također su utjecale na povećanje vrijednosti varijabilnosti. U travnju većina postaja u Hrvatskoj ima glavni ili sporedni minimum varijabilnosti srednje mjesečne

during that season. This is confirmed by the fact that the influence of atmospheric instability and fronts decreases towards the south, which, along with a number of cyclones over the hinterland, leads to a decrease in precipitation formation (Penzar, Penzar, 1979, 1981) and causes an increase of precipitation variability.

In comparison to February, the values of precipitation variability in March in the Northern Adriatic region are approximately the same, while in the Southern Adriatic region they are increased (Figure 6). The increase in variability in the coastal area can be explained by the secondary minimum in the annual course of precipitation, which occurs in March in the central and northern Adriatic, as well as by greater inter-annual precipitation variability. Large amounts of precipitation in March of 1964 and small amounts of precipitation in March of 1973 and 2002 in the coastal region of Croatia, have also caused increases in values of precipitation variability. In April, at most of the stations in Croatia, a primary or secondary variability



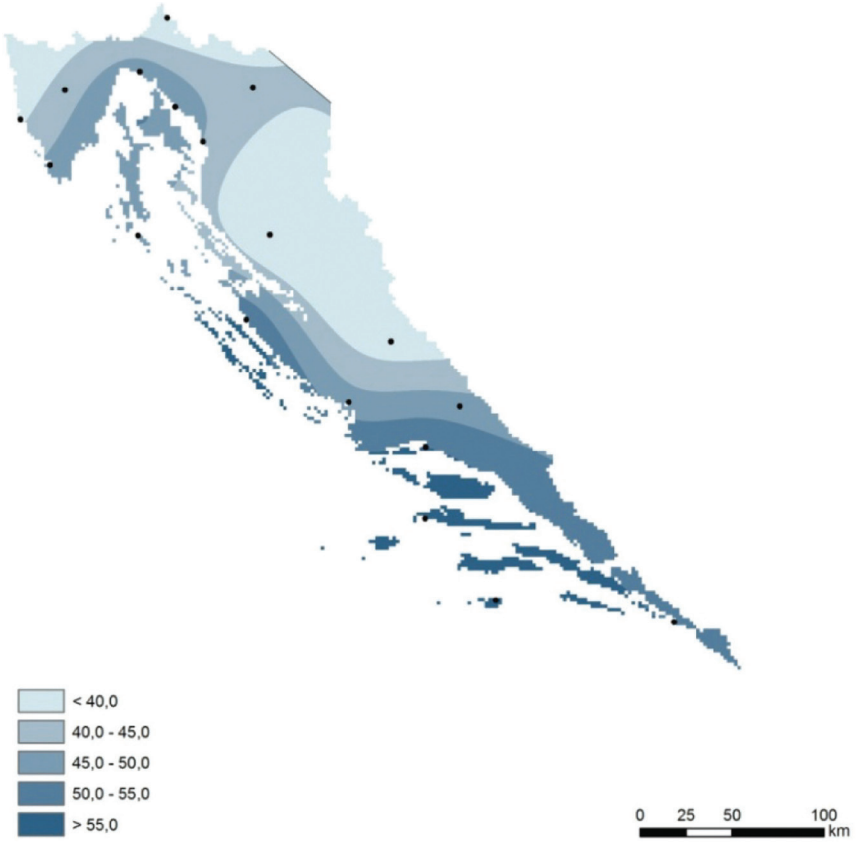
Slika 7. Varijabilnost padalina u travnju (%)
Figure 7 Precipitation variability in April (%)

količine padalina. Ta se činjenica jasno odražava u prostornoj raspodjeli vrijednosti varijabilnosti količine padalina u tom mjesecu (Slika 7.). U travnju vrijednost varijabilnosti količine padalina ni u jednoj postaji nije veća od 45%. Kako se utjecaj ciklona koje s mora dolaze na kopno, a koje su najčešće u travnju (i studenom) (Penzar, Penzar, 1979., 1981.) smanjuje prema jugu, tako je i varijabilnost padalina u postajama južnog Jadrana nešto veća. Veće vrijednosti varijabilnosti količine padalina u nekim postajama na obali mogu se objasniti i manjim brojem dana s padalinama.

Kako se prema ljetu udio padalina koje donose ciklone s mora smanjuje, tako se i varijabilnost količine padalina na obali povećava. Zagrijavanjem kopna i jačanjem utjecaja suptropskih maksimuma tlaka zraka dolazi do smanjenja količine padalina, kao i do smanjenja broja dana s padalinama, što dovodi do povećanja varijabilnosti na južnom Jadranu. Relativno visoke vrijednosti varijabilnosti količine padalina u većem broju postaja na području južnog Jadrana ostaju takve sve do početka jeseni (Juras, 1995.; Milković, 1998.).

minimum of the mean monthly precipitation amounts is recorded. That fact is clearly reflected in spatial distribution of precipitation variability during that month (Figure 7). Precipitation variability in April does not exceed 45% in any of the researched stations. As the influence of cyclones moving from the sea to the land, which are most frequent in April (and November) (Penzar, Penzar, 1979, 1981), decreases towards the south, precipitation variability at the southern Adriatic stations slightly increases. Higher precipitation variability at certain coastal stations can be explained by a smaller number of days with precipitation.

As the share of the precipitation caused by cyclones from the sea decreases, precipitation variability on the coast increases. Warming of the land and strengthening of subtropical air pressure maximum cause an increase in precipitation amounts as well as a decrease in number of days with precipitation, which, consequently, increases variability in the southern Adriatic. Relatively high



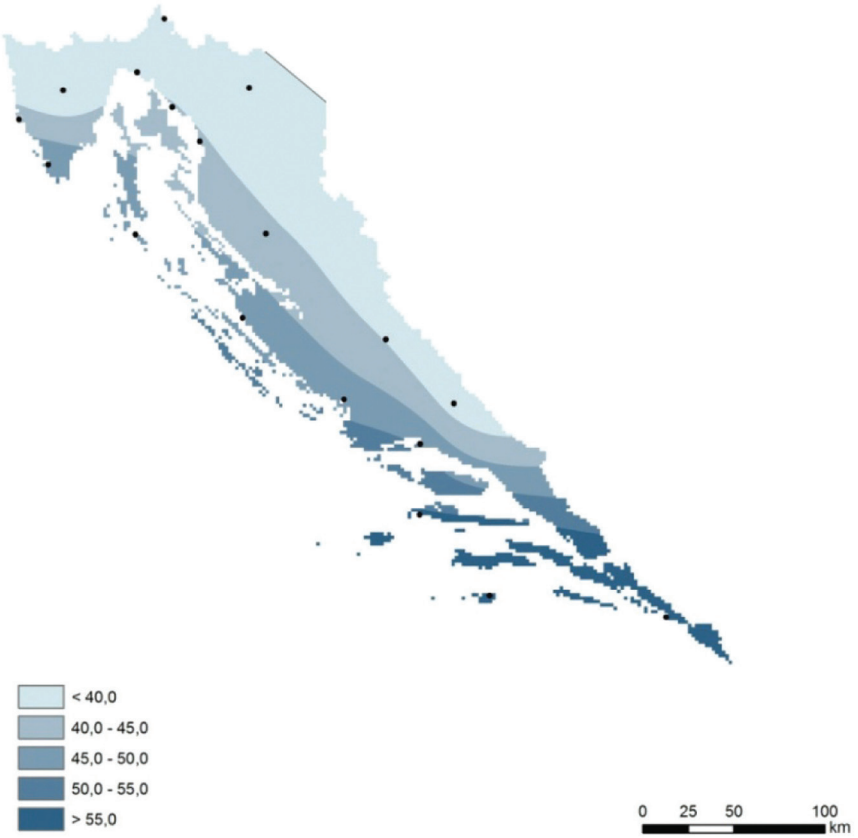
Slika 8. Varijabilnost padalina u svibnju (%)
Figure 8 Precipitation variability in May (%)

Tek u listopadu vrijednosti varijabilnosti na području južnog Jadrana postaju manje od 50%.

Navedena raspodjela varijabilnosti padalina, s većim vrijednostima varijabilnosti na južnom Jadranu, a manjim na sjevernom Jadranu, javlja se već u svibnju (Slika 8.). Najveće vrijednosti varijabilnosti padalina su u obalnom dijelu južne Hrvatske. Najveću varijabilnost ima postaja Lastovo (62,2%). Nešto veće vrijednosti varijabilnosti javljaju se i na području Kvarnera. Najmanje vrijednosti imaju postaje u Gorskoj Hrvatskoj gdje se nalazi postaja s najmanjom varijabilnosti količine padalina, Gospić (33,6%). I u lipnju je varijabilnost padalina veća na području južnog Jadrana (Slika 9.). Naime kako se opća cirkulacija "pomiče za Suncem", tako se i pojas ciklonske aktivnosti povlači na sjever otprilike iznad 50° sjeverne geografske širine, a suptropski pojas visokog tlaka zraka dolazi do naših južnih krajeva (Penzar, Penzar, 1979., 1981.). Osim toga, na području s maritimnim pluviometrijskim režimom u ljetnim je mjesecima količina padalina

values of precipitation variability in the greater number of stations in the South Adriatic region remain such until the beginning of autumn (Juras, 1995; Milković, 1998). Only in October the variability values in the South Adriatic region are under 50%.

The aforementioned precipitation variability distribution, characterised by increased variability values in the South Adriatic, and smaller values in the North Adriatic, occurs already in May (Figure 8). Highest precipitation variability values are measured in the coastal part of southern Croatia. The highest variability is recorded at Lastovo station (62.2%). A slightly higher variability values occur in the Kvarner region as well. The lowest precipitation variability is measured at the stations in the mountain region of Croatia where the station with the lowest variability, Gospić (33.6%), is located. Precipitation variability is higher in the southern Adriatic area in June as well (Figure 9). Namely, as general circulation *follows the sun*, the cyclonic activity zone moves toward the north at



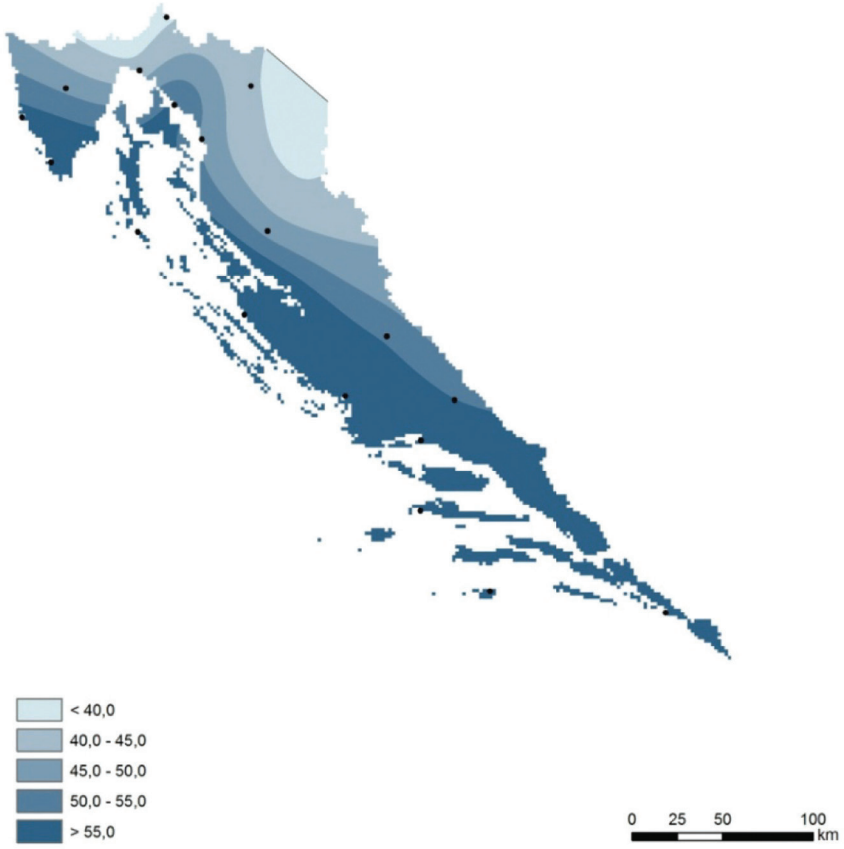
Sika 9. Varijabilnost padalina u lipnju (%)
Figure 9 Precipitation variability in June (%)

vrlo mala. Zato su vrijednosti varijabilnosti količine padalina najveće na jugu, a smanjuju se prema sjeveru kako jača utjecaj ciklonske aktivnosti. Najveće vrijednosti varijabilnosti imaju postaje Lastovo, Dubrovnik i Hvar.

Prostorni raspored vrijednosti varijabilnosti količine padalina koji se javlja u lipnju vrijedi, uz manje razlike, i za srpanj. U odnosu na lipanj varijabilnost padalina se povećava u većini istraživanih postaja (Slika 10.). Tako se područje s vrijednostima varijabilnosti količine padalina većim od 55%, koje je u lipnju zauzimalo krajnji jug Hrvatske, u srpnju proteže gotovo cijelom obalom, osim dijela Istre i područja oko Rijeke. To je posljedica jačanja utjecaja suptropskih anticiklona. Također, velik broj postaja na Jadranu ima u srpnju minimum u godišnjem hodu količine padalina i godišnjem hodu broja dana s padalinama. Može se dogoditi da padalina u obalnom prostoru u tom mjesecu uopće ne bude (Juras, 1995.). Tako na primjer u srpnju 1988. godine padalina nije bilo ili ih je bilo zanemarivo

above 50° N approximately, and subtropical air pressure maximum moves towards the south of Croatia (Penzar, Penzar, 1979, 1981). Besides that, the precipitation amount in the maritime pluviometric regime area in the summer months is very small. That is the reason why the values of precipitation variability are the highest in the south and decrease towards the north as the influence of cyclonic activity increases. The highest variability values are recorded at Lastovo, Dubrovnik and Hvar stations.

Spatial distribution of precipitation variability which occurs in June is similar to the one in July. In relation to June, precipitation variability increases at the majority of the researched stations (Figure 10). Thus the area with precipitation variability higher than 55%, which covered the southernmost parts of the country in June, stretches over almost the whole of the coast in July, except for some parts of Istria and the area around Rijeka. This is a consequence of an increased influence of subtropical anti-cyclones. In addition, a great



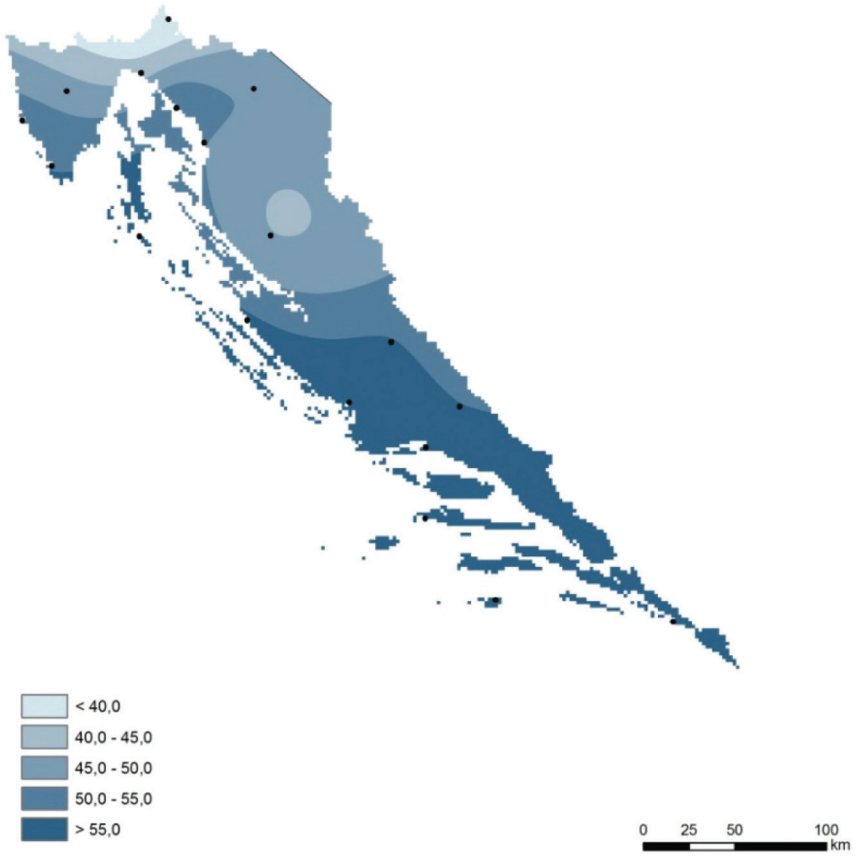
Slika 10. Varijabilnost padalina u srpnju (%)
Figure 10 Precipitation variability in July (%)

malo na postajama Zadar, Šibenik, Lastovo i Hvar. U kolovozu se opći odnosi varijabilnosti količine padalina ne mijenjaju značajnije (Slika 11.). Varijabilnost je i dalje visoka na najvećem dijelu obale, s tim da su na području sjevernog Jadrana vrijednosti varijabilnosti nešto manje. U kolovozu se također može dogoditi da padaline u obalnom dijelu Hrvatske izostanu. Najniže vrijednosti varijabilnosti ima Gorska Hrvatska gdje se nalazi postaja s najmanjom varijabilnosti – Parg.

U rujnu su vrijednosti varijabilnosti padalina velike na obalnom području, a smanjuju se prema unutrašnjosti, pogotovo na području Gorske Hrvatske (Slika 12.). U listopadu dolazi do promjene prostorne raspodjele varijabilnosti padalina, što je posljedica povlačenja suptropskog maksimuma tlaka zraka i jačanja utjecaja ciklonske cirkulacije, što dovodi do povećanja količine padalina na području južnog Jadrana (Penzar, 1959.; Penzar, Penzar, 1979., 1981.). Listopad je mjesec s najvećim vrijednostima varijabilnosti srednje mjesečne količine padalina

number of stations in the Adriatic reach the annual course of precipitation minimum as well as the annual course of number of days with precipitation minimum in July. Sometimes there is no rainfall in the coastal area in July at all (Juras, 1995). Thus, for example, in July of 1988 the stations of Zadar, Šibenik, Lastovo, and Hvar did not record any precipitation at all, or in negligibly small amounts. In August, spatial distribution of precipitation variability does not change significantly (Figure 11). Variability is still high on most of the coast. However, in the North Adriatic region variability values are somewhat lower. In August there can occur an absence of precipitation in the coastal part of Croatia. The lowest variability values are in the mountain region of Croatia where the station with the lowest variability, Parg, is situated.

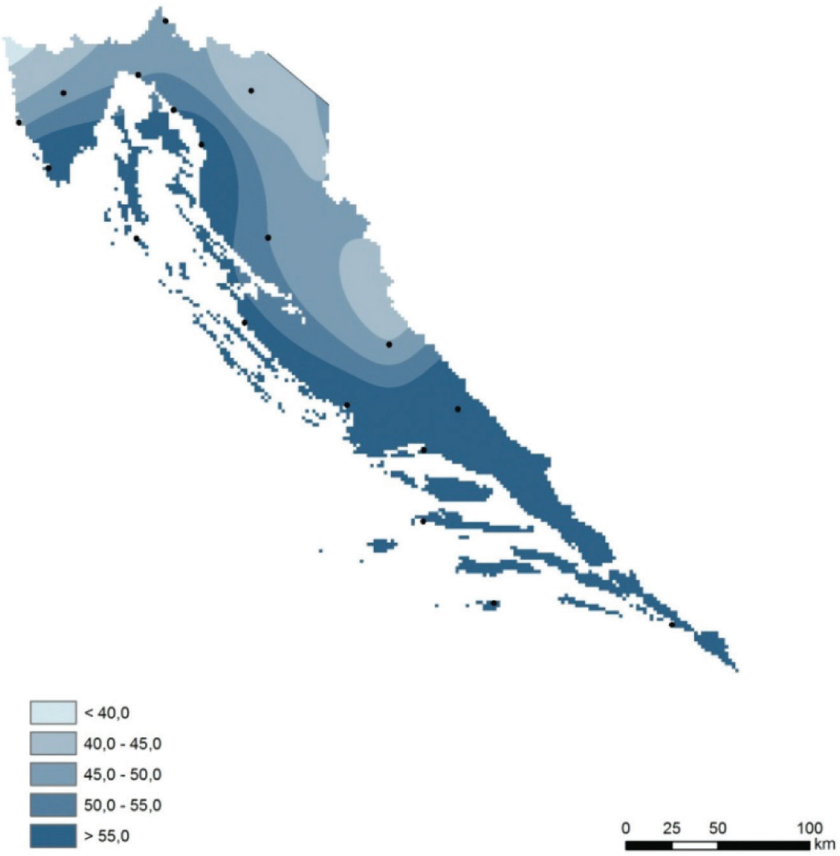
In September, values of precipitation variability are high in the coastal area and decrease towards the inland, particularly in the mountain region of Croatia (Figure 12). October brings a change in spatial distribution of precipitation variability,



Slika 11. Varijabilnost padalina u kolovozu (%)
Figure 11 Precipitation variability in August (%)

na području cijele Hrvatske (Maradin, 2011.). Vrijednost varijabilnosti padalina veću od 55% imaju gotovo sve postaje sjevernog Jadrana (Slik 13.). Varijabilnost je niža na području srednje Dalmacije (postaje Split-Marjan, Sinj i Šibenik) te na području oko postaje Ogulin. Najniža vrijednost varijabilnosti količine padalina je na postaji Split-Marjan, gdje iznosi 49,5%. Visoka varijabilnost količina padalina može se objasniti i činjenicom da se u listopadu u drugoj polovici 20. stoljeća broj dana s tipovima vremena povezanim s većom količinom padalina signifikantno smanjio, a broj dana s tipovima vremena bez padalina signifikantno povećao (Penzar, Penzar, 1979., 1981). To za posljedicu ima smanjenje količine padalina u listopadu u drugoj polovici 20. stoljeća (Penzar, Penzar, 1979., 1981.; Juras, 1985.), koje se može statistički povezati s povećanjem varijabilnosti u tom mjesecu. Visoke vrijednosti varijabilnosti količine padalina posljedica su i izrazito sušnog listopada 1965. godine kada u cijeloj Hrvatskoj gotovo nije bilo padalina, dok su

which is a consequence of subtropical air pressure maximum withdrawal and increased influence of cyclonic circulation, which cause an increase in precipitation amount in the south Adriatic area (Penzar, 1959; Penzar, Penzar, 1979, 1981). October is the month with the highest values of precipitation variability in whole of Croatia (Maradin, 2011). Almost all the stations in the North Adriatic record precipitation variability value higher than 55% (Figure 13). Variability is lower in central Dalmatia (stations Split-Marjan, Sinj and Šibenik) and in the area around the Ogulin station. The lowest variability of precipitation amount is recorded at the Split- Marjan station where it amounts 49.5%. High values of precipitation variability can be explained by the fact that, in the second half of 20th century, the number of days with types of weather linked to increased amounts of precipitation in October significantly decreased, and number of days with types of weather without precipitation significantly increased (Penzar, Penzar, 1979, 1981). Consequently, precipitation



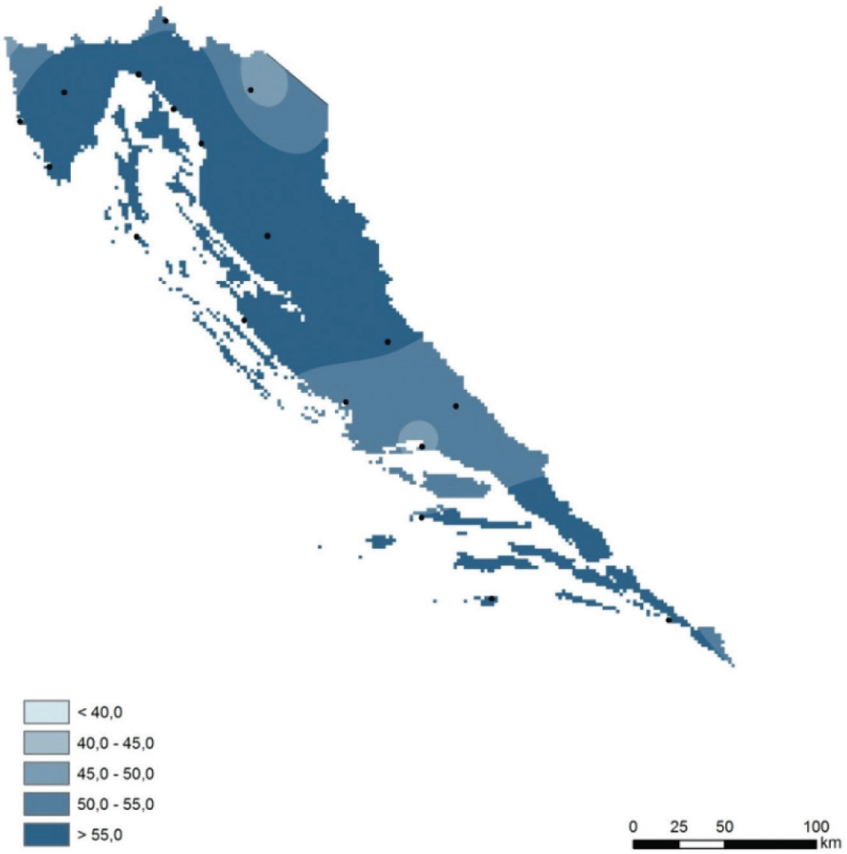
Slika 12. Varijabilnost padalina u rujnu (%)
Figure 12 Precipitation variability in September (%)

prethodne, 1964. godine, u listopadu vrijednosti količine padalina bile u nekim postajama čak i više nego tri puta veće od višegodišnjeg prosjeka (1950. – 2007.).

U studenom su, u odnosu na listopad, vrijednosti varijabilnosti količine padalina manje (Slika 14.). Najveću varijabilnost padalina ima postaja Lastovo (53,3%), a najmanju Ogulin (36,6%). Unutar godišnjeg hoda padalina, u studenom se na sjevernom Jadranu javlja glavni maksimum padalina. Taj maksimum posljedica je povećanja broja čimbenika koji uzrokuju nastanak padalina. U južnoj Hrvatskoj povećava se udio padalina koje donose sredozemne i jadranske ciklone (Penzar, Penzar, 1979., 1981.), zbog čega je varijabilnost količine padalina u tom dijelu Hrvatske manja u odnosu na listopad. Za ciklone koje dolaze sa Sredozemnog mora glavnu navjetrinu predstavljaju obronci Dinarida okrenuti prema jugu i zapadu, te je na tim obroncima i ispred njih jesenski maksimum padalina osobito velik (Penzar,

amounts in October have decreased in second half of 20th century (Penzar, Penzar, 1979, 1981; Juras, 1985), which can be statistically linked to increased variability during that month. High precipitation variability is also a consequence of an extreme draught in October of 1965 when the whole of Croatia was almost totally without precipitation, while in the previous 1964 precipitation amounts in some of the stations were even three times higher than average in 1950-2007 period.

In comparison to October, precipitation variability was smaller in November (Figure 14) The highest precipitation variability was recorded at Lastovo station (53.3%) and the lowest at Ogulin station (36.6%). Within the annual course of precipitation, main maximum of precipitation in the north Adriatic area occurs in November. That maximum is a consequence of a great number of factors that cause precipitation. In the south of Croatia there is an increase in the portion of



Slika 13. Varijabilnost padalina u listopadu (%)
Figure 13 Precipitation variability in October (%)

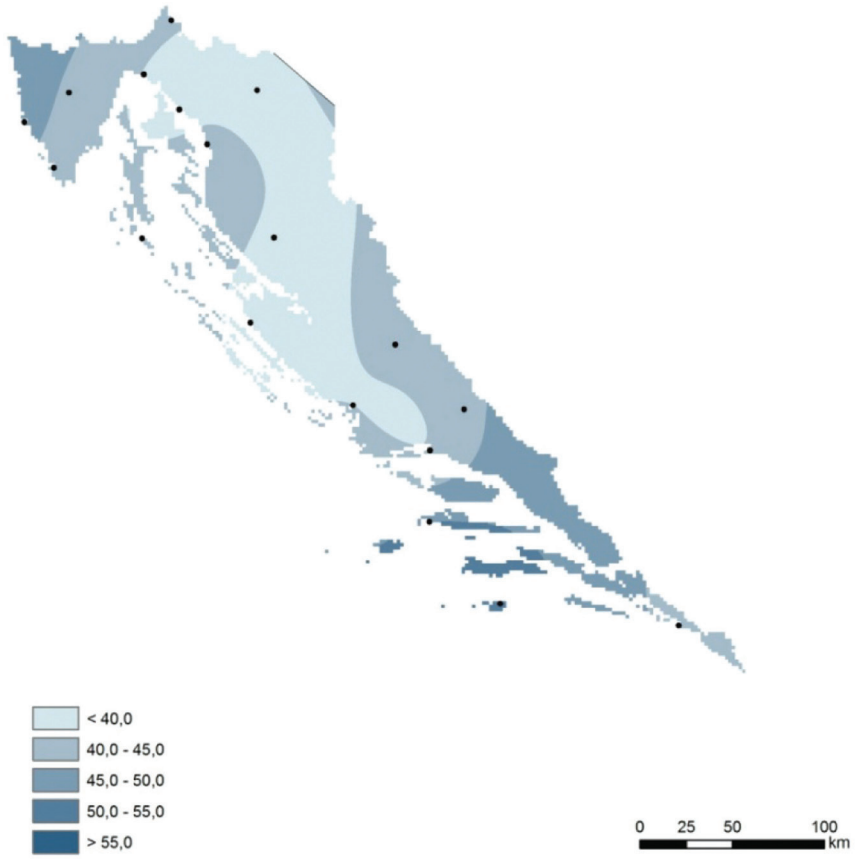
Penzar, 1979., 1981.). Taj maksimum padalina podudara se s niskim vrijednostima varijabilnosti količine padalina na području cijele Gorske Hrvatske. Vrijednosti varijabilnosti količine padalina povećavaju se prema jugu Hrvatske.

U prosincu je varijabilnost padalina na istraživanom području veća nego u studenom. To povećanje najveće je na području srednjeg Jadrana (postaje Zadar, Šibenik, Knin i Sinj) te na nekim otocima (postaje Lastovo i Mali Lošinj), gdje su vrijednosti varijabilnosti veće od 55% (Slika 15.). Najmanje vrijednosti varijabilnosti imaju postaje na Jadranskoj obali (Rovinj, Pula i Dubrovnik). Zanimljivo je spomenuti da je unatoč sličnoj mjesečnoj količini padalina na Hvaru (94,0 mm) i Lastovu (90,5 mm), varijabilnost na te dvije postaje različita. Na Hvaru ona iznosi 49,7%, a na Lastovu 59,3%.

Rezultati istraživanja podudaraju se s rezultatima istraživanja drugih znanstvenika koji se bave

precipitation formed within Mediterranean and Adriatic cyclones (Penzar, Penzar, 1979, 1981), which is the main reason the precipitation variability in that part of Croatia is lower in comparison to October. The main windward side for the cyclones coming from the Mediterranean are the southern and western slopes of the Dinarides, and thus the autumn precipitation maximum is particularly high on those slopes and in front of them (Penzar, Penzar, 1979, 1981). That precipitation maximum coincides with low values of variability in the mountain region of Croatia. Precipitation variability is increasing towards the south of Croatia.

In December, precipitation variability in the researched area was higher than in November. This increase is highest in the central Adriatic region (Zadar, Šibenik and Sinj stations) and on certain islands (Lastovo and Mali Lošinj stations), where the variability is higher than 55% (Figure 15). The lowest variability is recorded at the stations on the Adriatic coast (Rovinj, Pula and

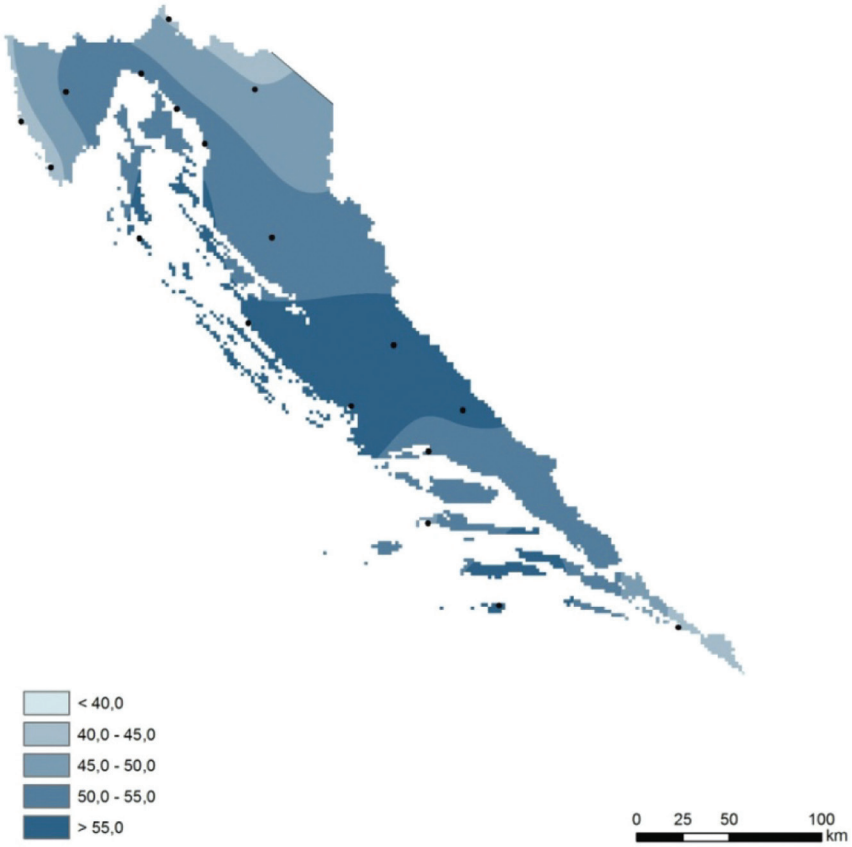


Slika 14. Varijabilnost padalina u studenom (%)
Figure 14 Precipitation variability in November (%)

varijabilnošću padalina (Biel, 1929.; Lebedev i dr., 1979.; Morales, 1979.; Juras; 1995.; Milković, 1998.). Pokazalo se da varijabilnost padalina raste u prostorima s malim količinama padalina, i obratno, smanjuje se u krajevima s većim količinama padalina, kao što je utvrdio i Biel (1929.). Također, Hrvatsku zahvaćaju zonalni zapadni vjetrovi, koji uvjetuju relativno brzu i pravilnu izmjenu putujućih ciklona i anticiklona što uzrokuje manju varijabilnost količina padalina (Morales, 1977.). Stoga ona područja Hrvatske u kojima prevladava zapadno strujanje cijele godine imaju manju varijabilnost padalina u odnosu na područja Hrvatske gdje je u ljetnom dijelu godine izražen utjecaj polja visokog tlaka zraka. Dobivene zakonitosti prostorne raspodjele varijabilnosti padalina odgovaraju zakonitostima koje su utvrđene u drugim radovima (Penzar, 1959.; Juras; 1995.; Milković, 1998.), premda je same vrijednosti često teško uspoređivati zbog različite metodologije istraživanja.

Dubrovnik stations). It is interesting to note that despite similar monthly precipitation amounts in Hvar (94.0 mm) and Lastovo (90.5 mm), the variability at these two stations differs. In Hvar it is 49.7%, and in Lastovo 59.3%.

The results of the study correspond to the results of other researchers that have studied precipitation variability (Biel, 1929; Lebedev et al., 1979; Morales, 1979; Juras, 1995; Milković, 1998). The results show that precipitation variability increases in the regions with low precipitation amounts and, vice versa, it decreases in the regions with higher precipitation amounts, as determined by Biel (1929). In addition, Croatia is under the influence of west zonal winds responsible for relatively quick and regular alterations of cyclones and anticyclones, which causes lower precipitation variability (Morales, 1977). That is the reason why Croatian regions in which western atmospheric circulation dominates during the whole year have



Slika 15. Varijabilnost padalina u prosincu (%)
Figure 15 Precipitation variability in December (%)

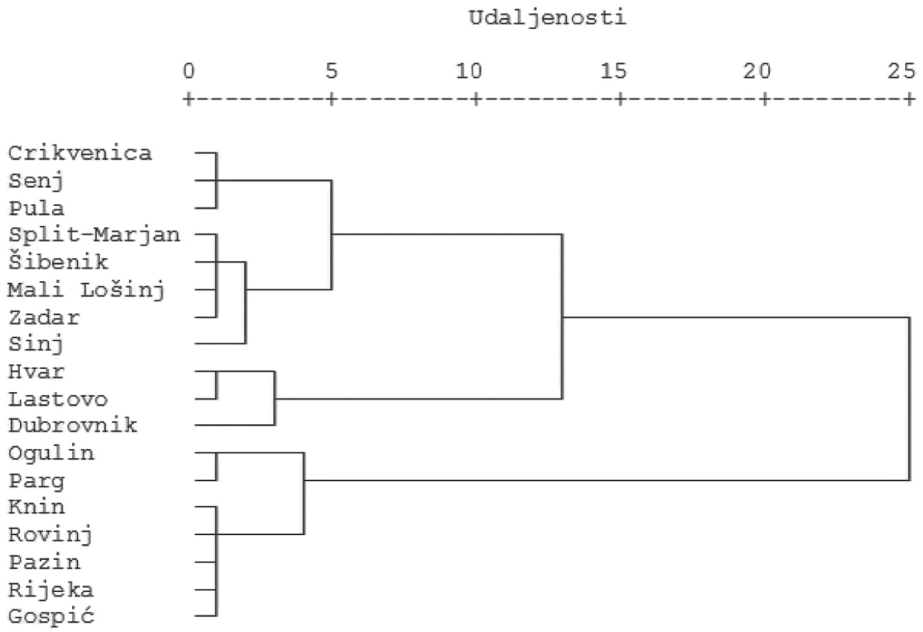
Prostorne razlike u godišnjem hodu varijabilnosti padalina

Kako bi se bolje mogle uočiti prostorne razlike u varijabilnosti padalina, analizirane su razlike između godišnjeg hoda padalina na istraživanom području. U tu svrhu primijenjena je klaster analiza kojom se varijable razvrstavaju u manje skupine ili klastere. Kako je za klaster analizu korišten mali broj postaja, nemoguće je izdvajati tipove varijabilnosti padalina u istraživanom području, ali dobiveni rezultati mogu uputiti na prostorne razlike. Provedene su različite metode hijerarhijske klaster analize, a najbolje je rezultate dala Wardova metoda s kvadriranim euklidskim udaljenostima. Iz klaster dendrograma vidljivo je da se 18 istraživanih postaja na osnovi godišnjeg hoda varijabilnosti padalina može razvrstati u tri klastera (Slika 16.).

lower precipitation variability in comparison to the regions under the influence of the subtropical high air pressure field in the summer part of the year. Regularities in spatial distribution of precipitation variability correspond to regularities established in other studies (Penzar, 1959; Juras; 1995; Milković, 1998), although the results are often not suitable for comparison because of the different methodology used.

Spatial differences in the annual course of precipitation variability

In order to gain more insight into spatial regularities in precipitation variability, the differences in annual courses of precipitation in the researched area were analysed. For that purpose a cluster analysis, which involves grouping variables into smaller groups or clusters, was conducted. Since



Slika 16. Dendrogram klaster analize za 18 klimatoloških postaja
Figure 16 Dendrogram of cluster analysis for 18 climatological stations

Prvi klaster čini sedam postaja – Gospić, Knin, Ogulin, Parg, Pazin, Rijeka i Rovinj. U većini navedenih postaja glavni je maksimum varijabilnosti padalina u listopadu, a sporedni u zimskim mjesecima, najčešće u veljači. Glavni je minimum u travnju, a sporedni u lipnju ili studenom. Drugi klaster čini osam postaja – Crikvenica, Mali Lošinj, Pula, Senj, Sinj, Split-Marjan, Šibenik i Zadar. Na većini tih postaja glavni je maksimum varijabilnosti u srpnju, kolovozu ili rujnu, a sporedni je u prosincu. Glavni je minimum varijabilnosti u studenom, a sporedni u travnju. Unutar ovoga klastera izdvajaju se tri najsjevernije postaje Crikvenica, Pula i Senj. Premda imaju sličan godišnji hod varijabilnosti količine padalina, na postajama koje su smještene južnije taj se hod ipak ponešto razlikuje. Na navedenim je postajama glavni maksimum varijabilnosti u listopadu, a sporedni u veljači. Na postajama Pula i Senj glavni je minimum varijabilnosti u travnju, a sporedni u studenom. Navedene postaje imaju obilježja varijabilnosti padalina slična prethodnom klasteru te predstavljaju svojevrsno prijelazno područje. Treći klaster čine tri najjužnije postaje – Dubrovnik, Hvar i Lastovo. Na navedenim postajama glavni se maksimum varijabilnosti javlja u srpnju ili kolovozu, a sporedni u ožujku.

a small number of stations were used for cluster analysis it was impossible to clearly distinguish types of annual course of precipitation variability in the researched area. However, the obtained results can point to spatial differences. Different methods of hierarchic cluster analysis were conducted but the best results were obtained by Ward's method with squared Euclidian distances. The cluster dendrogram suggests that the eighteen researched stations can be grouped into three clusters based on annual course of precipitation variability (Figure 16).

The first cluster consists of seven stations - Gospić, Knin, Ogulin, Parg, Pazin, Rijeka, and Rovinj. In the majority of these stations, the main variability maximum is in October and the secondary is during the winter months, usually in February. The primary minimum is in April, and the secondary is in June or November. The second cluster consists of eight stations – Crikvenica, Mali Lošinj, Pula, Senj, Sinj, Split-Marjan, Šibenik, and Zadar. In most of these stations, the primary variability maximum occurs in July, August or September, and the secondary in December. The primary variability minimum occurs in November, and the secondary in April. Within this cluster, the three stations located farthest to the north, Crikvenica, Pula and Senj, stand out. Although

Glavni se minimum varijabilnosti padalina javlja u travnju, a sporedni u siječnju.

Provedena analiza pokazala je razlike u prostornom rasporedu varijabilnosti padalina. Dobiveni rezultati mogu biti temelj za analize koje se bave gospodarenjem vodom. Posebno to dolazi do izražaja ako se uzme u obzir velika varijabilnost padalina u mjesecima s relativno malim količinama padalina u nekim postajama na istraživanom području.

Zaključak

Područje s maritimnim pluviometrijskim režimom ima relativno veliki raspon količine padalina. Najmanje padalina imaju postaje na jadranskoj pučini i otocima, a količina se povećava prema obali, osobito pod utjecajem reljefa. Slično godišnjem hodu količine padalina, istraživano područje ima i relativno velik raspon varijabilnosti padalina. Postaja s najvećom vrijednosti varijabilnosti je Lastovo (20,6%), a s najmanjom Parg (9,1%). Varijabilnost padalina najmanja je na području Gorske Hrvatske. Prema obali vrijednost varijabilnosti padalina se povećava.

Klaster analiza godišnjeg hoda varijabilnosti padalina pokazala je da se postaje prema navedenom obilježju mogu svrstati u tri skupine. Prvu čine postaje Gorske Hrvatske i krajnjeg sjevera istraživanog područja, gdje se glavni maksimum varijabilnosti padalina javlja u listopadu, a sporedni u zimskim mjesecima, najčešće u veljači. Glavni je minimum u travnju, a sporedni u lipnju ili studenom. Drugu skupinu čini osam postaja – Crikvenica, Mali Lošinj, Pula, Senj, Sinj, Split-Marjan, Šibenik i Zadar. Na većini navedenih postaja, glavni maksimum varijabilnosti je u srpnju, kolovozu ili rujnu, a sporedni u prosincu. Glavni minimum varijabilnosti je u studenom, a sporedni u travnju. Najjužnije područje Jadrana glavni maksimum varijabilnosti ima u srpnju ili kolovozu, a sporedni u ožujku. Glavni se minimum varijabilnosti padalina u tom području javlja u travnju, a sporedni u siječnju.

Analiza mjesečnih vrijednosti pokazala je da na varijabilnost padalina velik utjecaj ima postanak padalina. Mjeseci s najmanjom varijabilnosti najčešće su oni mjeseci u kojima postoji velik broj čimbenika koji uzrokuju postanak padalina. Također, područja koja su pod utjecajem ciklonske cirkulacije imaju manju varijabilnost jer je ova cirkulacija povezana s relativno

these three stations record similar annual course of precipitation variability, in the stations located more to the south annual course is, nevertheless, somewhat different. In the aforementioned stations, the main variability maximum occurs in October, and the secondary in February. As for the stations in Pula and Senj, the main variability maximum is recorded in April, and secondary in November. Precipitation variability features at those stations is similar to the previous cluster and they represent a kind of a transitional area. The third cluster consists of three southernmost stations – Dubrovnik, Hvar and Lastovo. At those stations the main variability maximum occurs in July or August, and the secondary in March. The main variability minimum occurs in April, and the secondary in January.

The conducted analysis demonstrates the differences in spatial distribution of precipitation variability. Its results can be used as a basis for analyses that deal with water management, particularly if we take into consideration high precipitation variability in the months with relatively low precipitation at some of the stations in the researched area.

Conclusion

Maritime pluviometric regime area features a relatively large range of precipitation amounts. The lowest amount of precipitation is recorded at the stations located on the Adriatic islands and the amounts increase towards the coast, particularly under the influence of the relief. Similar to the annual course of precipitation amounts, the researched area records a relatively wide range of precipitation variability, the station with the highest precipitation variability being Lastovo (20.6%), and the one with the lowest variability Parg (9.1%). Precipitation variability is the lowest in the mountain region of Croatia. Towards the coast the precipitation variability increases.

Cluster analysis of annual course of precipitation variability demonstrated that the stations, according to the stated feature, could be classified into three groups. The first group consists of the stations in the mountain region of Croatia and the northern part of the research area where the primary variability maximum occurs in October and the secondary in winter months, most often in February. The primary minimum occurs in April, and the secondary in June or November. The second group consists of eight stations – Crikvenica, Mali Lošinj, Pula, Senj, Sinj,

učestalim padalinama. Zbog toga su vrijednosti varijabilnosti padalina na području sjevernog Jadrana gotovo cijele godine niže, osim u zimskim mjesecima kada je zbog ciklona koje dolaze sa Sredozemlja minimum varijabilnosti padalina na području južnog Jadrana. Na području Kvarnera varijabilnost padalina povećana je cijele godine, što se najvjerojatnije može povezati s utjecajem raspodjele mora i kopna te dinamike reljefa na postanak padalina.

Osim količine padalina, zbog velike prostorne i vremenske promjenjivosti, varijabilnost padalina bitna je za gospodarenje vodom u prostoru. Posebno to dolazi do izražaja na obalnim područjima s relativno malim količinama padalina. Suše, redukcije potrošnje pitke vode, požari te njihov utjecaj na turizam i poljoprivredu samo su neki primjeri važnosti poznavanja varijabilnosti padalina kao bitne klimatološke komponente upravljanja prostorom. Navedeni argumenti upućuju na nužnost daljnjih istraživanja varijabilnosti padalina, na manjim područjima i na većem broju istraživanih postaja.

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Split-Marjan, Šibenik, and Zadar. At the majority of them the main variability maximum is recorded in July, August or September, and the secondary in December. The main variability minimum occurs in November, and the secondary in April. The southernmost part of the Adriatic records the primary variability maximum in July or August and the secondary in March. The primary precipitation variability minimum in that area is recorded in April and the secondary in January.

The analysis of monthly values showed that precipitation variability is greatly influenced by types of precipitation formation. The months with the lowest variability are most often the months in which a large number of factors influence formation of the precipitation. Moreover, the areas under the influence of cyclonic circulation record the lowest precipitation variability since this circulation is connected to relatively frequent precipitation. That is why the precipitation variability in the north Adriatic area are lower during the whole year, except in the winter months, when minimum variability occurs in the southern parts of the Adriatic due to cyclones moving from the Mediterranean. In addition, in the Kvarner region, the precipitation variability is increased throughout the year, which is most probably connected to the influence the distribution of the land and sea and terrain dynamics have on formation of precipitation.

Along with precipitation amounts, precipitation variability is also important for water management in the area because of its wide spatial and temporal variability. It is particularly important in the coastal regions with relatively small amounts of precipitation. Draughts, drinking water reductions, fires and their influence on tourism and agriculture are just some of the examples that point to the importance of precipitation variability as a significant component of space management. The arguments stated in the paper point to the necessity of further precipitation variability researches on smaller areas and with a larger number of stations included.

Note

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