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ORIGINAL PAPER

Extreme daily precipitation in Belgrade and their links with the prevailing directions of the air trajectories

I. Tošić · M. Unkašević

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Abstract The main goal of this study was to present the statistical analysis of the daily precipitation exceeding 20 mm in Belgrade and their links with the prevailing directions of the air trajectories at 500, 1,500 and 5,000 m. For the extreme precipitation analysis, the generalised extreme value (GEV) distribution and generalised Pareto distribution (GPD) were used. The estimated return levels for 100- and 10-year return periods using GEV and GPD were obtained. Four-day backward trajectory simulations were conducted for days with precipitation exceeding 20 mm to investigate the regional transport of the air moisture towards Belgrade using the hybrid single-particle Lagrangian integrated trajectory model. The air trajectories were classified into 13 trajectory categories by the origin and direction of their approach to Belgrade. Three of the most frequent categories of air flow from south-west, south-east and north-west contributed to more than a half of the observed precipitation. Almost 74.5 % of precipitation totals in Belgrade fell during the warmer part of the year. These were directly connected with the intensive convection of colder and humid, usually maritime, air masses.

1 Introduction

Studies of changes in climate extremes became more prevalent in the second half of the twentieth century since they have severe environmental and socio-economic consequences. In a future warmer climate, the assessment of these changes, particularly of the frequency and intensity of the extreme events producing flood, becomes of great importance. An estimation of the changes in the precipitation extremes in a modified future climate could be helpful for the development of appropriate adaptation and mitigation strategies (Santos et al. 2008).

The list of indices for surface data based on temperature and precipitation were recommended by the Joint Working Group on Climate Change Detection of the World Meteorological Organization–Commission for Climatology and the Research Programme on Climate Variability and Predictability (Peterson et al. 2001) to analyse observed and future changes in weather and climate extremes. Global-scale analyses of these indices were presented by Alexander et al. (2006) and for Europe by Klein Tank and Können (2003).

The most common approach in climate analysis is one in which the extreme quantiles were estimated from a generalised extreme value (GEV) distribution. The use of extreme value theory allows the study of extremes that are rarer than those which can be studied with the descriptive indices (Klein Tank et al. 2009). It was found that the frequency of extremes follows one of three types of distribution: Gumbel, Fréchet or Weibull, i.e. the GEV distribution (Coles 2001; Reiss and Thomas 2001; Beirlant et al. 2004). If daily data are available, the generalised Pareto distribution (GPD) is proposed to be applied. The GPD has been used for the analysis of extreme values in meteorology and hydrology, as well as to damage caused by these events (Katz et al. 2002; Smith 2003; Bordi et al. 2007).

Hellström (2005) pointed out that knowledge of the features of precipitation extremes and their links with the atmospheric conditions could be helpful for the development of more valid future climate change scenarios of the

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Trends in temperature indices over Serbia: relationships to large-scale circulation patterns

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ABSTRACT: In this work, the trends of six climate indices based on the daily maximum and minimum temperatures during the period 1949–2009 at 15 stations distributed across Serbia were analysed. The results showed seasonal changes in the minimum and maximum temperature extremes. An analysis of the extreme temperature indices suggested that the Serbian climate generally tended to become warmer in the last 61 years. The most significant temperature trends were revealed for the summer season.

The influence of large-scale variables on the temperature was examined by means of the empirical orthogonal function and correlation. It was found that the East Atlantic pattern dominated during the winter, spring and summer, while the East Atlantic/West Russia pattern governed during the autumn. In addition, the North Atlantic Oscillation dominated the Serbian extreme temperature variability during the winter.

KEY WORDS daily maximum and minimum temperatures; temperature indices; trends; Serbia; large-scale variables

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1. Introduction

Studies performed on the global scale, based on observational (Easterling *et al.*, 1997) or model data (Intergovernmental Panel on Climate Change-IPCC, 2007), revealed tendencies towards warming, mainly due to increased minimum temperatures. Heino *et al.* (1999) in Finland and Brázdil *et al.* (1996) in Central and Southeast Europe showed that the minimum temperatures had a greater increase than the maximum temperatures on an annual basis. During the 20th century, in most European regions, an increase in the surface air temperature was observed (Brunetti *et al.*, 2000; Houghton *et al.*, 2001). Beniston (2004) found a strong increase in the mean annual minimum temperatures of about 2 °C 100 year^{-1} during the 20th century in Switzerland, while the increase in the mean annual maximum temperatures was much smaller. Goubanova and Li (2006) expected the largest warming of the maximum temperature over Southern Europe for the IPCC-A2 emission scenario.

According to Houghton *et al.* (2001), an increase in the frequency of extreme warm days and a decrease in the frequency of cold nights during the summer were observed over many areas. The number of frost days decreased in many areas of the world (Karl *et al.*, 1999), but many areas of the eastern Mediterranean showed significant increasing trends in the frost day index at the annual scale (Kostopoulou and Jones, 2005). Efthymiadis *et al.* (2011) found decrease of cold extremes (in winter) and the increase of warm/hot extremes (in summer) over the central and eastern Mediterranean. Averaged across the eastern Mediterranean region, Kuglitsch *et al.* (2010) established that, since the 1960s, the hot summer daytime and nighttime temperature have increased by $+0.38 \pm 0.04$ °C decade^{-1} and $+0.30 \pm 0.02$ °C decade^{-1}, respectively.

In Serbia, the extreme temperature increased at Belgrade (Unkašević *et al.*, 2005; Unkašević and Tošić, 2009a). The warmest summers with regards to heat wave duration and severity occurred within the periods 1951–1952, 1987–1998 (especially 1994) and 2000–2007 (Unkašević and Tošić, 2009b). Because the Serbian region is not always covered in European studies, the analysis of temperature tendencies can contribute to better understanding of the temperature changes.

This study focuses on an analysis of the changes and trends in the extreme temperature indices over Serbia, as well as on the connection between the temperature indices and large-scale circulation patterns. The studied indices were selected from the list of climate change indices recommended by the World Meteorological Organization (WMO) – Commission for Climatology and the Research Programme on Climate Variability and Predictability (CLIVAR). The influences of large-scale patterns, such as the North Atlantic Oscillation (NAO), the East Atlantic (EA) and East Atlantic/West Russia (EA–WR) patterns, on the extreme indices were examined by means of the empirical orthogonal function (EOF) and correlation.

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Analysis of wet and dry periods in Serbia

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ABSTRACT: In this study, wet and dry periods were analysed using the Standardized Precipitation Index (SPI) on timescales of 1, 3, 6 and 12 months (SPI1, SPI3, SPI6 and SPI12) at ten stations in Serbia during the period 1949–2011. The onset of severe wetness and drought during the period 1999–2001 was presented. The distributions of the monthly precipitation amounts for each station were modelled by a gamma distribution. The severity and duration of the wet and dry periods were calculated. The generalized Pareto distribution (GPD) was applied to the SPI values for the timescales of 1 and 12 months during the period 1936–2011 in Belgrade. Furthermore, the severity and duration of the wet and dry periods for timescales of 1 and 12 months were analysed using the extreme value theory. Using the time series of the SPI, it was found that the frequency of droughts in the southern part of Serbia was higher than in the other parts of the country. The obtained results indicated that the GPD could be an appropriate distribution for SPI values less than −1 at the 1- and 12-month timescales, and for the severity of the wet and dry periods at the 1-month timescale.

KEY WORDS wet and dry periods; precipitation; Standardized Precipitation Index; generalized Pareto distribution

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1. Introduction

An analysis of precipitation characteristics is a critical component of drought risk assessment. If we wish to compare the climatic conditions of different areas, which often are characterized by different hydrological balances, a standardized variable able to objectively capture the drought condition of a region is required (Bordi and Sutera, 2007). For this purpose, the Standardized Precipitation Index (SPI) appears to be the most powerful index. McKee *et al.* (1993) developed the SPI to quantify precipitation deficits on multiple timescales (3, 6, 12, 24 and 48 months). It is based only on the precipitation field and can be computed on different timescales (Bordi and Sutera, 2007; Bordi *et al.*, 2009). As the index is standardized, wetter-than-normal conditions can also be monitored (Seiler *et al.*, 2002). Positive SPI values indicate greater than median precipitation, and negative values indicate smaller (Bordi and Sutera, 2001). Thus, the SPI seems to be a useful tool for monitoring wetness and drought on multiple timescales (Bordi *et al.*, 2009). The different timescales used for the computation of the SPI reflect the impact of drought on the available water resources; typically, a 3-month timescale is used to characterize meteorological conditions, whereas 12- or 24-month timescales are used to monitor hydrological drought.

Lloyd-Hughes and Saunders (2002) presented multi-temporal climatology for the incidence of 20th century European drought based on monthly SPIs calculated on a 0.5° grid across the whole of Europe for the period 1901–1999. They found the longest droughts in Italy, northwest France and northwest Russia, with typical durations of 40 months. Bordi *et al.* (2004) evaluated the potential predictability of dry and wet spells at two regions in Europe (Sicily and Elba) using the SPI computed on a 24-month timescale. They concluded that there might be a potential for the predictability of dry and wet periods for these two regions. Sienz *et al.* (2007) analysed monthly extremes of dryness and wetness in Iceland based on the SPI. They showed that the SPI extremes are linked to the Europe–Greenland Index describing southwesterly flow anomalies by a dipole and the related geopotential height differences. Mihajlović (2006) analysed the 2003–2004 meteorological drought in the Pannonian part of Croatia (including two stations in Serbia) using the SPI on timescales of 1, 3, 6 and 12 months at 32 stations. He concluded that the SPI on multiple timescales could be used to follow the progression of a drought from its development to its end and could be operationally used to monitor drought conditions in the Pannonian part of Croatia.

In this study, wet and dry conditions in Serbia were assessed through the SPI on 1-, 3- and 6-month timescales, whereas the 12-month timescale is used to investigate hydrological conditions.

This article is organized as follows. In Section 2, the data and methods used are presented. The results are

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Annual and seasonal variability of precipitation and temperatures in Slovenia from 1961 to 2011

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ABSTRACT

Spatial and temporal variability of annual and seasonal (summer and winter) precipitation sums and mean temperatures observed at forty-six stations in Slovenia from 1961 to 2011 were analysed. Principal component analysis (PCA) and a varimax rotation with Kaiser normalization were used to determine the dominant precipitation and temperature patterns in Slovenia. Time series data from the PCA (the principal components, PCs) were used to look for the existence of linear trends and periodicity in the precipitation and temperature data using the Mann–Kendall test and spectral analysis. The relationships between the PCs and circulation patterns, such as the North Atlantic Oscillation (NAO), the East Atlantic (EA) pattern, and the East Atlantic/West Russia (EA/WR) pattern, were also examined.

The first four PCs of precipitation (temperature) contributed from 78.7% in summer to 94.5% in winter (98.4% in winter to 98.5% in summer) of the total variance, and their loadings indicated that the most (least) intensive signal was observed over mountainous northwest Slovenia. A statistically significant decrease of PC1 in annual precipitation and increase in mean annual and both seasonal temperatures was found. Significant relationships existed between annual and winter precipitation in Slovenia and the NAO, and temperature and the East Atlantic pattern from 1961 to 2011. Applying the spectral analysis, periods of 2.4 years in summer precipitation and 2.8 years in winter precipitation series, and 2.1 years in annual temperature (significant at the 5% level of significance) were found in Slovenia.

1. Introduction

Analysing meteorological variables such as precipitation and temperature can provide significant information about the past and future variability of climatic regimes. Detecting oscillations in precipitation and temperature time series yields important information for understanding the climate. These oscillations can be seen as a response of the climate system to either external forcing or feedback processes. Various methods are used to analyse precipitation and temperature variability. Principal component analysis (PCA) is a very useful tool in climate research (Lorenz, 1956; Wilks, 1995).

The temporal evolution of temperatures presents a clear warming pattern worldwide, but the precipitation trend varies from region to region because its changes are more spatially and seasonally variable than temperature ones. Regarding European seasonal warming trends, recent studies reported a very high increase in temperature in central-northern Europe during winter, an overall fast increase in spring and especially summer, and a considerably lower increase in autumn (e.g., Bartolini et al., 2012). It was found that the annual precipitation increases in northern Europe (e.g., Schönwiese and Rapp, 1997) and decreases in southern Europe (e.g., Schönwiese and Rapp, 1997; Brunetti et al., 2000). Some studies have already shown an overall rainfall decrease over the Balkan Peninsula throughout the second half of the twentieth century (Gajić-Čapka, 1994; Tošić et al., 2014).

Interannual precipitation and temperature variations could be caused by the influence of different atmospheric oscillations. Among the several dominant teleconnection patterns of atmospheric variability that have an influence in Europe, four were selected: the North Atlantic Oscillation (NAO), the East Atlantic (EA) pattern, and the East Atlantic/Western Russia (EA/WR) pattern. The NAO has a dominant influence on atmospheric circulation variability in the northern hemisphere (Hurrell, 1995). The positive phase is associated with above-normal precipitation over northern Europe and below-normal rainfall over southern and central Europe. The anomaly centres of the EA pattern are displaced south-eastward to the approximate nodal lines of the NAO (Barnston and Livezey, 1987). The positive phase of the EA is associated with a warm anomaly in Europe. The EA/WR pattern (Barnston and Livezey, 1987) is one of three prominent teleconnection patterns that affect Eurasia throughout the year.

This paper investigates the spatial and temporal variability of the annual precipitation and temperatures in Slovenia. The results of this

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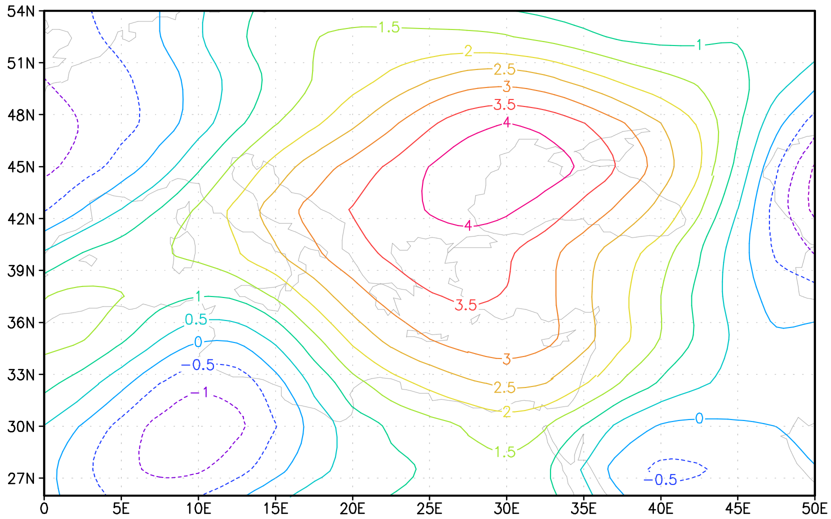

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This textbook presents an extensive collection of solved problems focusing on numerical methods used for the modeling of the atmosphere, following a traditional, Eulerian, grid-point, finite-differencing approach. It covers exercises related to the discrete representation of continuous functions, stability analysis of numerical solutions, time-differencing and linear advection. The most extensive part of the textbook is devoted to horizontal finite-differencing and the behavior of simulated gravity-inertial and Rossby waves on different horizontal distributions of variables. The simulation of nonlinear advection processes is also extensively covered. The textbook concludes with problems related to computationally economical schemes and generalized finite-differencing operators. MATLAB and FORTRAN are used to illustrate how to calculate numerical solutions and visualize the results. Students of meteorology, and experts engaged in the modeling of atmosphere and oceans can benefit from this textbook. In addition, professionals working in other science disciplines that require numerical solving of partial differential equations will find this book to be of interest.

Milivoj B. Gavrilov

Milivoj B. Gavrilov, PhD. Professor at the University of Novi Sad, University of Belgrade in Serbia, and University of Skopje in Macedonia. Expert in the numerical modeling of atmosphere and data processing in meteorology, geophysics and business. Author of about 40 papers published in journals, books, and presented during professional meetings.

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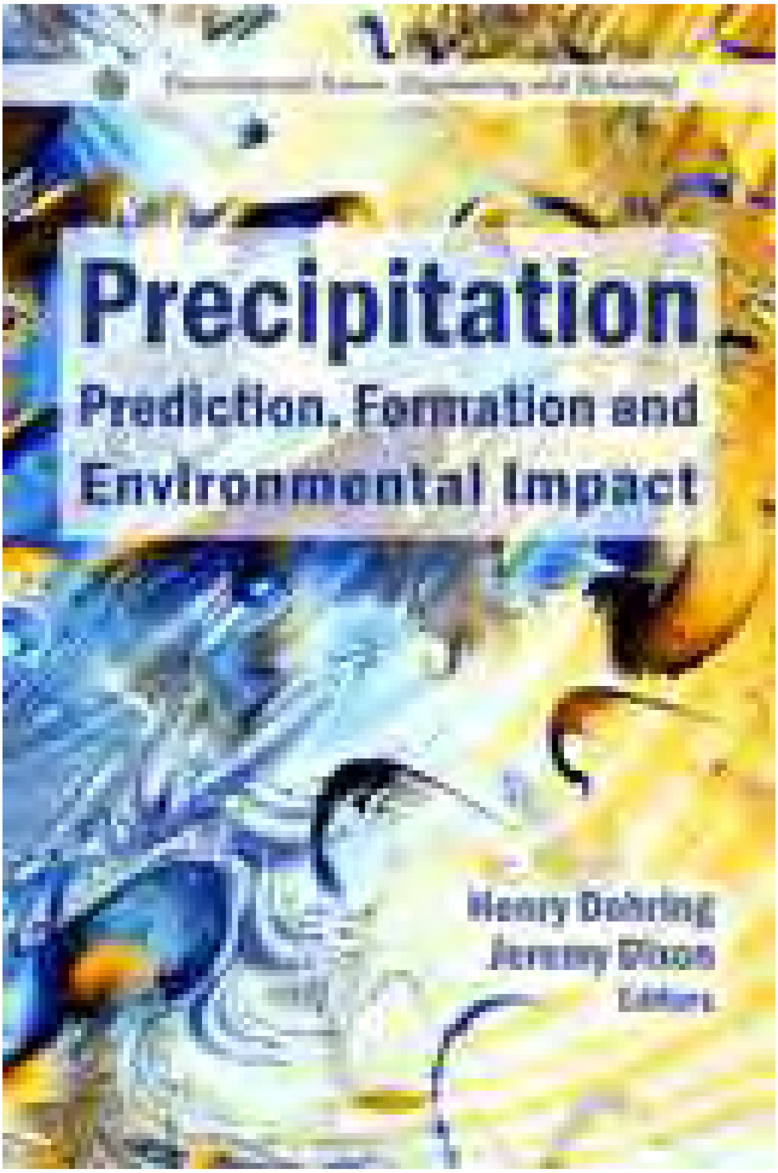
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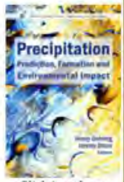
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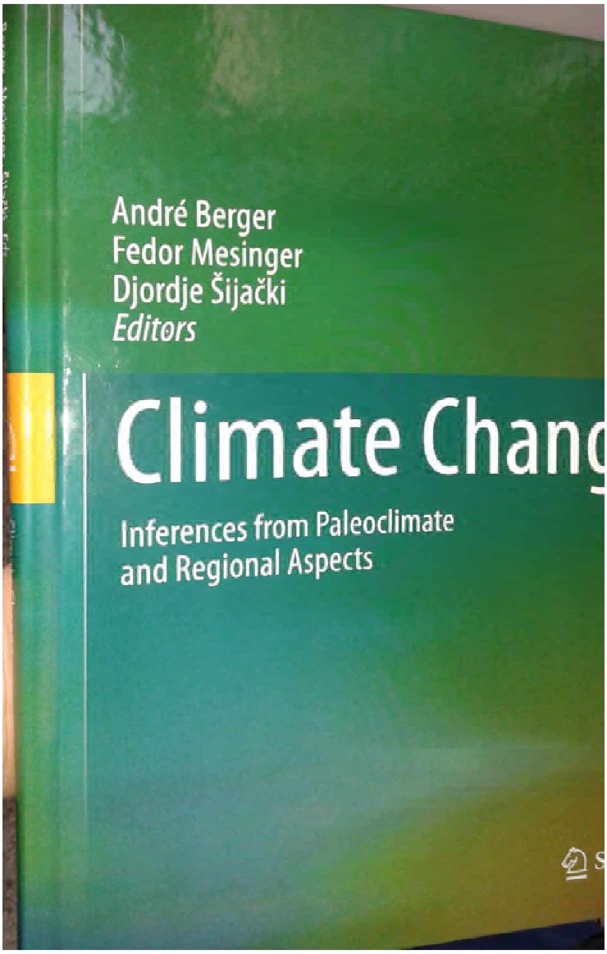
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Source: REGIONAL ENVIRONMENTAL CHANGE Volume: 14 Issue: 5 Special Issue: SI Pages: 1789-1799 DOI: 10.1007/s10113-013-0459-x Published: OCT 2014

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Title: Spatio-temporal patterns of precipitation in Serbia
Author(s): Gocic, M (Gocic, Milan); Trajkovic, S (Trajkovic, Slavisa)
Source: THEORETICAL AND APPLIED CLIMATOLOGY Volume: 117 Issue: 3-4 Pages: 419-431 DOI: 10.1007/s00704-013-1017-7 Published: AUG 2014

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Title: Analysis of precipitation and drought data in Serbia over the period 1980-2010
Author(s): Gocic, M (Gocic, Milan); Trajkovic, S (Trajkovic, Slavisa)
Source: JOURNAL OF HYDROLOGY Volume: 494 Pages: 32-42 DOI: 10.1016/j.jhydrol.2013.04.044 Published: JUN 28 2013

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Title: Mapping average annual precipitation in Serbia (1961-1990) by using regression kriging
Author(s): Bajat, B (Bajat, Branislav); Pejovic, M (Pejovic, Milutin); Lukovic, J (Lukovic, Jelena); Manojlovic, P (Manojlovic, Predrag); Ducic, V (Ducic, Vladan); Mustafic, S (Mustafic, Sanja)
Source: THEORETICAL AND APPLIED CLIMATOLOGY Volume: 112 Issue: 1-2 Pages: 1-13 DOI: 10.1007/s00704-012-0702-2 Published: APR 2013

Record 12 of 22
Title: Complexity analysis of spatial-temporal precipitation system by PCA and SDLE
Author(s): Fan, QB (Fan, Qibin); Wang, YX (Wang, Yanxin); Zhu, L (Zhu, Li)
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Author(s): Shi, P (Shi, Peng); Ma, XX (Ma, Xinxin); Chen, X (Chen, Xi); Qu, SM (Qu, Simin); Zhang, ZC (Zhang, Zhicai)
Source: MATHEMATICAL PROBLEMS IN ENGINEERING Article Number: 929383 DOI: 10.1155/2013/929383 Published: 2013

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Author(s): Ahani, H (Ahani, Hossein); Kherad, M (Kherad, Mehrzad); Kousari, MR (Kousari, Mohammad Reza); Rezaeian-Zadeh, M (Rezaeian-Zadeh, Mehdi); Karampour, MA (Karampour, Mohammad Amin); Ejraee, F (Ejraee, Faezeh); Kamali, S (Kamali, Saeedeh)
Source: THEORETICAL AND APPLIED CLIMATOLOGY Volume: 109 Issue: 3-4 Pages: 361-382 DOI: 10.1007/s00704-011-0572-z Published: AUG 2012

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Title: Mediterranean water resources in a global change scenario
Author(s): Garcia-Ruiz, JM (Garcia-Ruiz, Jose M.); Lopez-Moreno, JI (Ignacio Lopez-Moreno, J.); Vicente-Serrano, SM (Vicente-Serrano, Sergio M.); Lasanta-Martinez, T (Lasanta-Martinez, Teodoro); Begueria, S (Begueria, Santiago)
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Title: Temporal variability of precipitation over Iran: 1966-2005
Author(s): Tabari, H (Tabari, Hossein); Talaee, PH (Talaee, Parisa Hosseinzadeh)
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Author(s): Afzal, M (Afzal, Muhammad); Mansell, MG (Mansell, Martin G.); Gagnon, AS (Gagnon, Alexandre S.)
Edited by: Cornell S; Downy C; Rounsevell M
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Title: Artificial neural network models for forecasting intermittent monthly precipitation in arid regions
Author(s): Dahamsheh, A (Dahamsheh, Ahmad); Aksoy, H (Aksoy, Hafzullah)
Source: METEOROLOGICAL APPLICATIONS Volume: 16 Issue: 3 Pages: 325-337 DOI: 10.1002/met.127 Published: SEP 2009

Record 19 of 22
Title: Spatial variability of monthly and annual rainfall data over Southern Tunisia
Author(s): Ellouze, M (Ellouze, Manel); Azri, C (Azri, Chafai); Abida, H (Abida, Habib)
Source: ATMOSPHERIC RESEARCH Volume: 93 Issue: 4 Pages: 832-839 DOI: 10.1016/j.atmosres.2009.04.005 Published: AUG 2009

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Title: Regionalizing fine time-scale rainfall affected by topography in semi-arid Tunisia
Author(s): Jebari, S (Jebari, Sihem); Berndtsson, R (Berndtsson, Ronny); Uvo, C (Uvo, Cintia); Bahri, A (Bahri, Akissa)
Source: HYDROLOGICAL SCIENCES JOURNAL-JOURNAL DES SCIENCES HYDROLOGIQUES Volume: 52 Issue: 6 Pages: 1199-1215 DOI: 10.1623/hysj.52.6.1199 Published: DEC 2007

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Title: Structural characteristics of annual precipitation data in Jordan
Author(s): Dahamsheh, A (Dahamsheh, A.); Aksoy, H (Aksoy, H.)
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Title: Pattern characteristics of Indian monsoon rainfall using principal component analysis (PCA)
Author(s): Singh, CV (Singh, CV)
Source: ATMOSPHERIC RESEARCH Volume: 79 Issue: 3-4 Pages: 317-326 DOI: 10.1016/j.atmosres.2005.05.006 Published: MAR 2006

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ПОТВРДА

Овим документом потврђујем да је колегеница др Ивана Тошић, ванредни професор Физичког факултет Униерзитета у Београду, била коаутор пленарног предавања „Prevailing winds in Northern Serbia: recent data, geomorphological evidences and numerical simulations" пресентованом на међународној научној конференцији Loess2M - Modelling and Mapping, одржаној је у периоду од 26. до 29. августа 2016. године у Новом Саду. Одржавање овог значајног научног скупа је релизовано је као део активности посвећених обележавању 175-то годишњице од оснивања Српске Академије Наука и Уметности. Ко-оргаанизатори ове научне конфереицније су били: Огранак Српске Академије Наука и Уметности у Новом Саду и Лесна фокус група Интернационалне уније за истраживање квартара (Loess Focus Group of International Union for Quaternary Research). Детаљније информације о овој међународној научној можете наћи на нашем веб сајту: http://www.ogranak.sanu.ac.rs/Skupovi.aspx?arg=2016 .

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СРПСКА АКАДЕМИЈА НАУКА И УМЕТНОСТИ ОГРАНАК САНУ У НОВОМ САДУ · 1841 ·

Geophysical Research Abstracts
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Extreme temperature indices over Serbia

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In this work, the extreme climate indices based on the daily maximum and minimum temperatures during the period 1949–2009 at fifteen stations distributed across Serbia were analyzed. The following temperature indices were considered: cold nights (Tn10), cold days (Tx10), warm nights (Tn90), warm days (Tx90) and frost days (FD). The results showed seasonal changes in the minimum and maximum temperature extremes. The most significant trends of temperature indices were revealed for the summer season. According to the seasonal analysis of five temperature extreme indices, it was found that a warming tendency was dominant. Tendencies significant at the 5 % level were obtained during the spring (Tx10) and summer (Tn10, Tn90 and Tx90). The largest warming tendencies of greater than 1 day per decade were found for Tx90 and Tn90 in the summer. A cooling tendency was revealed only during the autumn for Tx10 and FD, suggesting a rise in the number of cold and frost days.
An analysis of the extreme temperature indices suggested that the Serbian climate generally tended to become warmer in the last 61 years.
To describe the link of the extreme temperature indices with the large-scale atmospheric circulations, indexes of teleconnection patterns, such as the North Atlantic Oscillation (NAO), East Atlantic (EA) and East Atlantic/West Russia (EA–WR) were investigated. It was found that the Tn90 and Tx90 values were highly positively correlated with the EA index during the winter, spring and summer, while Tx10 and Tn10 values were negatively correlated. The Tn10 value probably decreased because of the trend to more positive phases of the EA. Opposite correlations with the EA–WR were found for the Tn10 and Tn90 values in the autumn.

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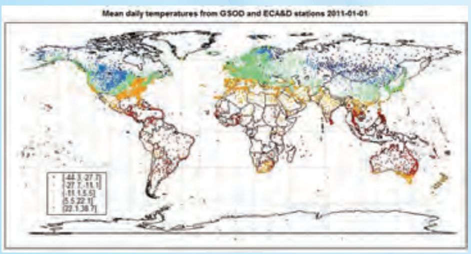

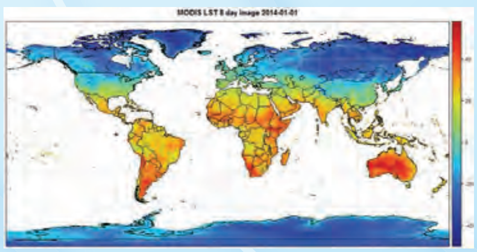

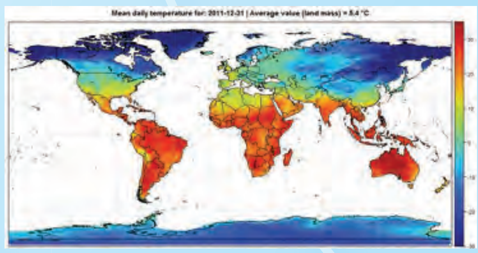

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Future Changes in Drought Characteristics in Serbia

[extended abstact]

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***Abstract*— In this study, possible future changes in drought characteristics in Serbia were analyzed using two drought indices, the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI) on time scale of 12 months.**

Study showed that the SPEI index is more suitable for drought monitoring and projections because it includes evaporative demand. According to the EBU-POM model projections, it is very likely that the drought frequency and its severity will increase in the future.

Keywords*— *drought characteristics; SPI; SPEI; Serbia

I. INTRODUCTION

The most common tools for monitoring drought conditions are drought indices. Most of them are based solely on precipitation, some are based on precipitation and evapotranspiration, while others are related to runoff and vegetation conditions [1]. Some of the drought indices are Palmer Drought Severity Index (PDSI), Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), Crop Moisture Index (CMI), Keetch-Byram Drought Index (KBDI), etc.

Numerous studies used these indices to analyze drought characteristics, e.g. in Turkey [2], Greece [3], Iberian Peninsula [4], Portugal [1], Czech [5], Serbia [6, 7, 8]. These studies are based on observed data sets. In [9], drought statistics based on the PRUDENCE multi-model approach are estimated. According to [9], British Isles would experience more intense short-term droughts but less severe longer duration events. The Mediterranean was identified by [10] as a particularly vulnerable region to global climate change.

In this study, we will analyze the present and future changes in drought characteristics in Serbia using the SPI and SPEI indices estimated from the regional climate model [11, 12, 13].

II. DATA AND METHODOLOGY

A. Data

Observed dataset used for model verification comprises monthly values of air temperature (29 stations) and accumulated precipitation (30 stations) for the period 1961-1990 and 2001-2010. Stations are equally distributed throughout the country. Technical and quality control of these measurements were made by the Republic Hydrometeorological Service of Serbia (RHMSS).

Outputs from the atmosphere-ocean two-way coupled regional climate model, the EBU-POM [11, 12], are used as well. The atmospheric part of the EBU-POM presents Eta/NCEP model and ocean part, Princeton Ocean Model (POM). The atmospheric model was initialized and forced by lateral boundary conditions using fields from the coupled atmosphere-ocean general circulation model SINTEX-G. The atmospheric model domain covers the greater part of European region (Fig. 1) with horizontal resolution of 0.25°. The ocean model horizontal resolution over the Mediterranean was 0.2°.

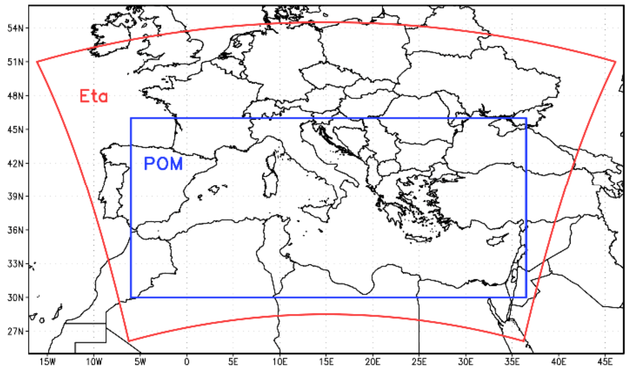

Fig. 1. Domain of the EBU-POM regional climate model

Regional integrations were performed as 30 years' time slices of global model experiments for two periods and climate change scenarios: 1961-1990 – the reference period, and 2071-2100 – projections for the A1B and A2 scenarios. Chosen scenarios are known as 'medium' and 'high' forcing scenarios. For the A1B atmospheric concentrations of CO_2, at the end of 21st century, are ~1.8 and for the A2 ~2.2 times higher than the present value of ~390 ppm.

B. Indices

In this study, we analyzed the main characteristics of drought using the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI) on time scale of 12 months. The 12-month time scale was chosen because it is proven to be relatively good correlated with soil moisture and river discharge. The SPI is a popular index because of its simplicity, only precipitation data are needed. The National Meteorological and Hydrological Services around the world are encouraged to use the SPI in order to characterize meteorological droughts [14]. On the other side, SPEI can account for the possible effects of temperature variability and temperature extremes (through evapotranspiration and the water supply-demand relation) in the context of global warming [11].

Because indices are standardized, comparing climatic conditions of areas with different hydrological regimes is allowed. The strength of the anomaly is classified as set out in Table I [15].

TABLE I. CLASSIFICATION OF INDICES

SPI/SPEI Values	Drought category
< -2.326	Exceptional drought
-2.325 to -1.645	Extreme drought
-1.644 to -1.282	Severe drought
-1.281 to -0.935	Moderate drought
-0.934 to -0.524	Minor drought
-0.525 to 0.524	Near normal

III. RESULTS

Both indices obtained with the observed data sets, mapped using open source SAGA-GIS software and ordinary kriging method, show normal moisture conditions for the period 2001-2010 (Fig. 2).

Looking at the SPI values (Fig. 3), moisture conditions in the period 2071-2100 will be normal with the exception of southwest Serbia and A1B scenario (minor drought). It is in accordance with a more distinct decrease of the precipitation amount in Serbia [12] for A1B (13 mm/season) than for the A2 scenario (6 mm/season). For the period 2071-2100 and both scenarios, significant influence of temperature increase and precipitation decrease is evident on the spatial distribution of SPEI index (Fig. 4). The whole considering area is in the category extreme to exceptional drought.

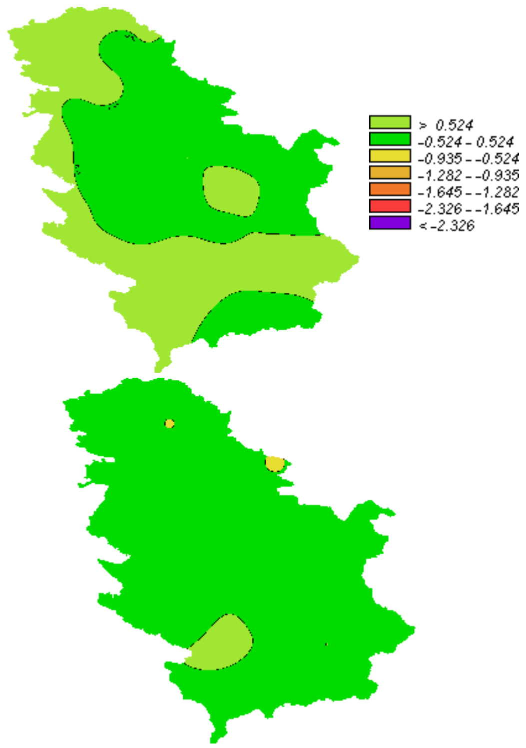

Fig. 2. Spatial distribution of the SPI12 (upper) and SPEI12 (bottom) for the period 2001-2010 based on observational data sets

IV. CONCLUSIONS

The regional climate model EBU-POM reproduces well natural moisture conditions. Study showed that the SPEI index is more suitable for drought monitoring and projections because it includes evaporative demand. According to the EBU-POM model projections and looking at the SPEI values, it is very likely that the drought frequency and its severity will increase in the future, thereby enhancing the associated impacts.

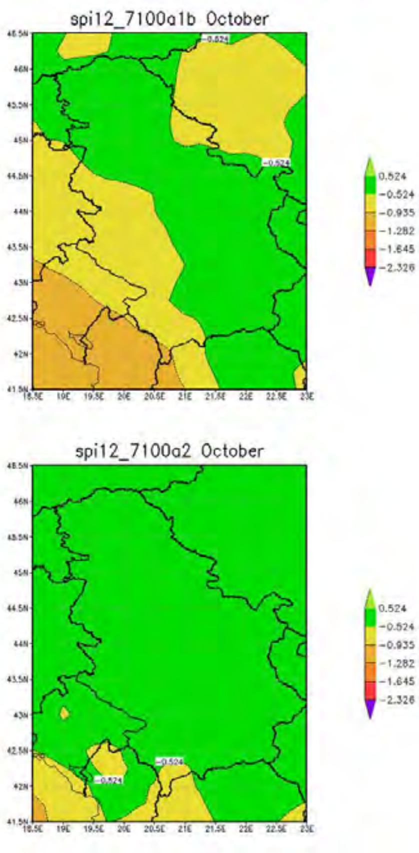

Fig. 3. Spatial distribution of the SPI for the period 2071-2100 and both scenarios A1B and A2 based on the EBU-POM data sets

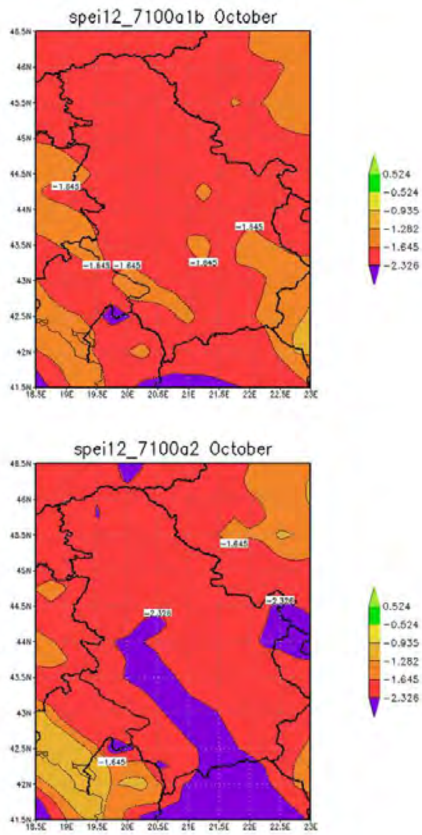

Fig. 4. Spatial distribution of the SPEI for the period 2071-2100 and both scenarios A1B and A2 based on the EBU-POM data sets

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Variability of precipitation in northern Serbia

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Precipitation variability in northern Serbia (Vojvodina) is examined by means of the Empirical Orthogonal Functions (EOF), trend and the spectral analysis. For this purpose, monthly precipitation sums from 92 stations in Vojvodina during the period 1946-2006 were analyzed. It is obtained that the first EOF pattern for the annual and seasonal precipitation is characterized by a homogeneous positive value over the whole region with higher values over the mountains. The first set of EOFs explains from 68.8% (in summer) to 85.4% (in winter) of the total variance. The similarity of EOF1 with the mean field is confirmed.
The time series associated with the first EOF pattern (PC1) reveals decreasing trend in the winter and spring precipitation amounts, and an increase of precipitation during the summer and autumn. All of the analyses conducted were coherent in demonstrating that annual, winter and autumn precipitation in Vojvodina is influenced by the NAO. An intensification of the positive phase of the NAO could be one of the causes of the observed decrease in precipitation in Vojvodina. We did not find significant correlations between this mode and known teleconnection patterns during the summer.
The power spectra of the precipitation PC1 show statistically significant oscillations of 3.3 years during the spring, and about 8.6 and 15 years during the winter. Our findings are consistent with the quasi-periodic oscillations reported in other studies on fluctuations of European precipitation.

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Preliminary results indicate that core REM 3 covers not only Isotope Stage 3 but also the early Glacial (late OIS 5 and OIS 4) and Upper Pleniglacial succession (OIS 2) including the Eltville Tephra layer.

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Prevailing winds in Northern Serbia: recent data, geomorphological evidences and numerical simulations

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The prevailing winds are explored in Northern Serbia, examining the aeolian processes, especially in the southeastern part of the Carpathian (Pannonian) Basin in the area in and around the Banatska Peščara (Deliblato Sands). In this study, four different methodological approaches were used. The first two approaches are based on the identification of prevailing winds using climatological data on winds and synoptic data on atmospheric circulations from the recent period. Geomorphological records and numerical simulation were used as the second two approaches to determine prevailing winds in the past. Recent prevailing winds in Northern Serbia have been encountered mainly in the fourth (270°-360°/00°) and second (90°-180°) quadrants with frequencies of 113.5 and 102.2 days a year, while their frequencies within the area of Banatska Peščara are 106.0 and 121.0 days per year, respectively. The crest directions of the Banatska Peščara dune field confirms that of about 1300 dunes, the vast majority of parabolic dunes (approximately 1200 dunes) show direction of the second quadrant, which is dated to the Early Holocene, while the remaining ones, the so-called, transversal dunes have shifted their direction to the third quadrant. The grain size analyses of loess deposits around the Banatska Peščara shows a main accumulation of aeolian particles from south-east to north-west (prevailing winds from the second quadrant) and probably represent the period between the Last Glacial Maximum (LGM) and the Holocene. Modern wind measurements and geomorphological results showed that the prevailing winds in the recent and past periods were from the same, second, quadrant in and around the Banatska Peščara. These results were confirmed with an explicit numerical simulation of atmospheric circulation that created prevailing winds from the second quadrant in the LGM period.

The phenomenon of prevailing winds in Northern Serbia is the result of the interaction of atmospheric circulation of different scales over the European continent, especially in Southeastern Europe. The main carrier of this interaction is the undulation of the Polar front, which, due to the constant change of form and position, creates distinctive types of weather. Thus, the winds from the second quadrant are most often dry and usually cause weather conditions without precipitation, while winds from the fourth quadrant usually create advection of moist air and precipitation. This alternation of dry and wet winds show a great similarity with the shift of dry and wet monsoons in Asia, but with one difference. Monsoons are replaced every six months, while the dry and moist winds in Northern Serbia alternate many times a year and their total duration amounts to 227.0 days a year in the area of Banatska Peščara.

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Action Links	1	ATMOSRES-D-15-00431	Research Paper	STATISTICAL CHARACTERISATION OF WINTER RAINFALL IN THE ABRUZZO REGION (ITALY) IN RELATION TO THE NORTH ATLANTIC OSCILLATION	Accept	Aug 04, 2015	Aug 05, 2015	Aug 26, 2015	Aug 26, 2015	21		Lorenzo Vergni
Action Links	2	ATMOSRES-D-14-00574R1	Research Paper	Diurnal temperature range trend over North Carolina and the associated mechanisms	Accept	Feb 11, 2015	Feb 11, 2015	Mar 04, 2015	Feb 17, 2015	6		Mohammad Sayemuzzaman, Ph.D.
Action Links	2	ATMOSRES-D-14-00574	Research Paper	Diurnal temperature range trend over North Carolina and the associated mechanisms	Accept	Nov 11, 2014	Nov 14, 2014	Dec 14, 2014	Dec 24, 2014	40		Mohammad Sayemuzzaman, Ph.D.

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Action Links	2	PALAEO9606	SI: 13_Eurasian Loess records	Moisture sources of the Chinese Loess Plateau during 1979-2009	21 Nov 2016	Under Review		06 Oct 2016	10 Oct 2016	31 Oct 2016	30 Oct 2016	20		Dabang Jiang

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ПОТВРДА

Овим се потврђује да је **др ИВАНА ТОШИЋ**, ванредни професор Физичког факултета Универзитета у Београду, руководила израдом мастер рада УРОША ДАВИДОВИЋА, студента мастер студија смера Метеорологија, под називом „ТРЕНД КЛИМАТСКИХ ИНДЕКСА ТЕМПЕРАТУРЕ И ПАДАВИНА И ПОВЕЗАНОСТ СА СЕВЕРНО-АТЛАНСКОМ ОСЦИЛАЦИЈОМ“.

Проф. др Ивана Тошић је за ментора поменутог мастер рада именована на седници Наставно-научног већа Физичког факултета одржаној 15. јуна 2011. године.

Мастер рад је успешно одбрањен на Физичком факултету 22. јуна 2011. године.

Београд, 13.12.2016.

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ПОТВРДА

Овим се потврђује да је **др ИВАНА ТОШИЋ**, ванредни професор Физичког факултета Универзитета у Београду, руководила израдом мастер рада СУЗАНЕ КНЕЖЕВИЋ, студента мастер студија смера Метеорологија, под називом „УТИЦАЈ ИСТОЧНО-АТЛАНСКЕ ОСЦИЛАЦИЈЕ НА МИНИМАЛНЕ ТЕМПЕРАТУРЕ И ПАДАВИНЕ У БЕОГРАДУ И НИШУ".

Проф. др Ивана Тошић је за ментора поменутог мастер рада именована на седници Наставно-научног већа Физичког факултета одржаној 21. септембра 2011. године.

Мастер рад је успешно одбрањен на Физичком факултету 30. септембра 2011. године.

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Овим се потврђује да је **др ИВАНА ТОШИЋ**, ванредни професор Физичког факултета Универзитета у Београду, руководила израдом мастер рада ПАВЛА АРСЕНОВИЋА, студента мастер студија смера Метеорологија, под називом „СЕЗОНСКА АНАЛИЗА КЛИМЕ ПРИМЕНОМ СЛОЖЕНИХ КЛИМАТСКИХ ИНДЕКСА“.

Проф. др Ивана Тошић је за ментора поменутог мастер рада именована на седници Наставно-научног већа Физичког факултета одржаној 25. септембра 2013. године.

Мастер рад је успешно одбрањен на Физичком факултету 10. октобра 2013. године.

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Овим се потврђује да је **др ИВАНА ТОШИЋ**, ванредни професор Физичког факултета Универзитета у Београду, руководила израдом мастер рада ИЛИЈАНЕ МАСТИЛОВИЋ, студента мастер студија смера Метеорологија, под називом „АНАЛИЗА КЛИМАТОЛОШКИХ НИЗОВА ОСУНЧАВАЊА И ОБЛАЧНОСТИ".

Проф. др Ивана Тошић је за ментора поменутог мастер рада именована на седници Наставно-научног већа Физичког факултета одржаној 25. јуна 2014. године.

Мастер рад је успешно одбрањен на Физичком факултету 19. децембра 2014. године.

Београд, 13.12.2016.

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Овим се потврђује да је **др ИВАНА ТОШИЋ**, ванредни професор Физичког факултета Универзитета у Београду, била члан комисије за одбрану мастер рада ТИЈАНЕ ТАНАСИЈЕВИЋ, студента мастер студија смера Метеорологија, под називом „*ENSO* И ИЗНЕНАДНО СТРАТОСФЕРСКО ЗАГРЕВАЊЕ КАО ИЗВОР ПРЕДИКТАБИЛНОСТИ У ЕВРОАЗИЈИ“.

Проф. др Ивана Тошић је за члана комисије поменутог мастер рада именована на седници Наставно-научног већа Физичког факултета одржаној 21. септембра 2016. године.

Мастер рад је успешно одбрањен на Физичком факултету 30. септембра 2016. године.

Београд, 13.12.2016.

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На основу члана 58. став 1. тачка 23. Статута Грађевинског факултета Универзитета у Београду, Наставно - научно веће Грађевинског факултета Универзитета у Београду, на својој седници одржаној дана 12.09.2013. године, донело је

ОДЛУКУ

Именује се Комисија за оцену и одбрану докторске дисертације **Милана Килибарде, дипл.инж.геод.**,, под насловом:

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у саставу:

1. Др Бранислав Бајат, дипл.инж.геод. ванредни професор Грађевинског факултета у Београду (ментор)
2. Др Владан Дуцић, дипл.геогр., редовни професор Географског факултета у Београду
3.. Др Иван Несторов, дипл.инж.геод., ванредни професор Грађевинског факултета у Београду
4. Др Ивана Тошић, дипл.мат., ванредни професор Физичког факултета у Београду
5. Др Томислав Хенгл, дипл. шум. инж., Wageningen University and Research Centre/ гостујући проф. Грађевинског факултета у Београду

Процедура стицања научног степена доктора наука спровешће се у складу са чланом 123. и 128. Закона о високом образовању ("Службени гласник РС", бр.76/05,100/07-аутентично тумачење, 97/08 и 44/10), а којима је регулисано да лица која су стекла академски назив магистра наука, могу стећи академски назив доктора наука одбраном докторске дисертације, према прописима који су важили до ступања на снагу овог закона, најкасније до краја школске 2015/2016. године.

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Проф. др Душан Најдановић, дипл.инж.грађ.

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- архиви

Дуцић

На седници Наставно-научног већа Географског факултета Универзитета у Београду, одржаној 29. септембра 2009. године, донета је

ОДЛУКА

О именовању Комисије за оцену и одбрану докторске дисертације кандидата мр Горана Анђелковића под насловом: **"ЕКСТРЕМНЕ КЛИМАТСКЕ ПОЈАВЕ У СРБИЈИ"**. Састав Комисије је:

Др Владан Дуцић, ванредни професор Географског факултета
Др Љиљана Гавриловић, редовни професор Географског факултета
Др Милан Радовановић, научни сарадник Географског института "Јован Цвијић" САНУ
Др Ивана Тошић, доцент Физичког факултета

Комисија је дужна да Наставно-научном већу у року од два месеца од дана именовања поднесе реферат о оцени докторске дисертације.

ДЕКАН

Професор др Србољуб Стаменковић

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ГЕОГРАФСКИ ФАКУЛТЕТ
Број 159
Датум: 19. 02. 2014. год.

На седници Наставно-научног већа Географског факултета у Београду, одржаној 13. фебруара 2014. године, донета је

ОДЛУКА

Именовање Комисије за преглед, оцену и одбрану докторске дисертације кандидата мр ДРАГАНА БУРИЋА под називом: **„ДИНАМИКА И МОГУЋИ УЗРОЦИ ТЕМПЕРАТУРНИХ И ПАДАВИНСКИХ ЕКСТРЕМА НА ТЕРИТОРИЈИ ЦРНЕ ГОРЕ У ПЕРИОДУ 1951-2010“.**

Састав Комисије је:

Др Владан Дуцић, редовни професор Географског факултета
Др Горан Анђелковић, доцент Географског факултета
Др Ивана Тошић, ванредни професор Физичког факултета

Комисија је дужна да Наставно-научном већу у року од два месеца од дана именовања поднесе реферат о оцени докторске дисертације.

ДЕКАН ФАКУЛТЕТА

Др Дејан Филиповић, редовни професор

Република Србија
МИНИСТАРСТВО ПРОСВЕТЕ,
НАУКЕ И ТЕХНОЛОШКОГ РАЗВОЈА
Број: 451-03-2411/2016-14/1
Датум: 14.11.2016. године
Београд
Немањина 22-26

Физички факултет Универзитета у Београду
- проф. др Ивана Тошић-

11000 Београд
Студентски трг 12

Предмет: Одлука Министарства просвете, науке и технолошког развоја о одређивању новог руководиоца Пројекта ев. бр. ОИ 176013;

Поводом образложеног захтева руководилаца реализатора истраживања Пројекта ОИ 176013, на основу члана 2. Анекса уговора о реализацији пројекта ОИ у текућем циклусу истраживања отпочетог 01.01.2011. године, министар просвете, науке и технолошког развоја доноси одлуку о одређивању проф. др Иване Тошић, Физички факултет, Универзитета у Београду, као руководиоца Пројекта ОИ 176013 „Метеоролошки екстреми и климатске промене у Србији".
Ова одлука заједно са захтевом НИО-Физичког факултета, Универзитета у Београду, за замену руководиоца Пројекта (због одласка у пензију претходног руководиоца), саставни је део Анекса VI основног уговора о реализацији Пројекта ОИ у периоду јул-децембар 2016. године, у циклусу истраживања од 01.01.2011 до 31.12.2016. године.

МИНИСТАР

Младен Шарчевић

МЕТЕОРОЛОШКО ДРУШТВО СРБИЈЕ
11000 Београд, Булевар Ослобођења бр.8
E-mail: meteo.org@gmail.com

Број:02/16
Датум:12.12.2016. године

П О Т В Р Д А

да је **Ивана Тошић**, ванредни професор Физичког факултета Универзитета у Београду, активан члан Метеоролошког друштва Србије, струковног удружења грађана.

Председник УО Метеоролошког
Друштва Србије

Зоран Цуцинић дипл.мет.

УНИВЕРЗИТЕТ У БЕОГРАДУ
ФИЗИЧКИ ФАКУЛТЕТ
Бр. 492/2
20. 11. 2012 год.
БЕОГРАД, СТУДЕНТСКИ ТРГ 12-16
П. ФАХ 44

УНИВЕРЗИТЕТ У БЕОГРАДУ
ФИЗИЧКИ ФАКУЛТЕТ
САВЕТ ФАКУЛТЕТА
Б е о г р а д
08. новембар 2012. године

На основу члана 53. Закона о високом образовању («Сл. гласник Републике Србије» број 76/05, аутентично тумачење 100/07, 97/08, 44/10 и 93/12), Савет Физичког факултета на својој конститутивној седници одржаној 08. новембра 2012. године, донео је следећу,

О Д Л У К У

Верификују се мандати чланова Савета Физичког факултета, за мандатни период од три године од 2012. до 2015. године и то:

Из реда наставника и сарадника Физичког Факултета - Изабрани од стране ННВ-а на седницама одржаним 23. маја и 20. јуна 2012.

1. Проф. др Буквић Срђану,
2. Проф. др Радовановић Воји,
3. Проф. др Вуковић Татјани,
4. Проф. др Јелезовић Хаџић Сунчици,
5. Проф. др Гошић Ивани,
6. Доц. др Димитријевић Марији,
7. Доц. др Ђурђевић Владимиру,
8. Доц. др Касалица Бећку,
9. Доц. др Попарић Горану,
10. Доц. др Спасојевић Ђорђу,
11. др Малетић Славици,
12. др Латас Душку,
13. др Сарван Мирјани.

Из реда АНН особља Факултета – изабрани 21. маја 2012.

1. Митровић Слађани
2. Перковић Младену

Из реда студената Факултета – верификован мандат 22. децембра 2011. године за мандатни период од годину дана:

1. Прлина Игору,
2. Лончар Марку ,
3. Влаисављевић Марку,
4. Кретић Јулијани

Влада Републике Србије, као оснивач није доставила Физичком факултету имена лица именованих за представнике оснивача, за чланство у Савету Физичког факултета.

Верификацијом мандата, стиче се својство члана Савета, а тиме и право и дужност учешћа у раду Савета.

Председница Савета Физичког факултета
од 2009. до 2012. године

Проф. др Маја Бурић

Maja Burić

Република Србија Универзитет у Београду - Физички факултет Београд

УНИВЕРЗИТЕТ У БЕОГРАДУ
ФИЗИЧКИ ФАКУЛТЕТ
САВЕТ ФАКУЛТЕТА
Б е о г р а д
24. децембар 2009. године

На основу члана 53. Закона о високом образовању «Сл. гласник Републике Србије» број 76/05, Савет Физичког факултета на својој седници одржаној 24. децембра 2009. године, једногласно је донео следећу,

О Д Л У К У

Верификују се мандати чланова Савета Физичког факултета Универзитета у Београду, за мандатни период од три године од 2009. до 2012. године и то:

Из реда наставника и сарадника Факултета – изабрани на седници Наставно-научног већа Факултета одржаној 20. маја 2009. године:

1. др Драгомир Крпић, редовни професор
2. др Маја Бурић, редовни професор
3. др Сунчица Елезовић Хаџић, ванредни професор
4. др Мићо Митровић, ванредни професор
5. др Божидар Николић, доцент
6. др Ивана Тошић, доцент
7. др Андријана Жекић, доцент
8. др Иван Белча, доцент
9. др Братислав Обрадовић, доцент
10. мр Мирјана Сарван, асистент
11. мр Душко Латас, асистент
12. мр Владимир Ђурђевић, асистент
13. мр Зорица Поповић, асистент

Из реда АТП особља Факултета – изабрани на састанку запослених радника Факултета одржаном 01. јуна 2009. године:

1. Марица Огњановић
2. Зоран Бокор

Из реда студената Факултета – изабрани на седници Студентског парламента одржаној 22. октобра 2009. године:

1. Јелена Пешић
2. Марко Лончар
3. Марко Влаисављевић
4. Јелена Пајовић

Влада Републике Србије, као оснивач није именовала своје представнике за чланове Савета.

Верификацијом мандата, стиче се својство члана Савета, а тиме и право и дужност учешћа у раду Савета.

Председник Савета Факултета
од 2006. до 2009. године
Проф. др Драгомир Крпић

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На основу члана 162. Статута Физичког факултета Универзитета у Београду, Научно-наставно веће Физичког факултета на својој седници одржаној 27. марта 2013. године донело је

О Д Л У К У

За руководиоце смерова основних и мастер студија за акредитацију Физичког факултета ИМЕНУЈУ СЕ:

- проф. др Јаблан Дојчиловић за студијски програм Општа физика
- проф. др Воја Радовановић за студијски програм Теоријска и експериментална физика
- проф. др Иван Белча за студијски програм Примењена и компјутерска физика
- проф. др Ивана Тошић за студијски програм Метеорологија

Именовани руководиоци смерова уједно ће чинити и колегијум Комисије за проверу и унапређење квалитета наставе.

Београд, 28.3.2013.

ДЕКАН ФИЗИЧКОГ ФАКУЛТЕТА

Проф. др Јаблан Дојчиловић