SOUTH EAST EUROPE
Jointly for our common future

DMCSEE
Drought Management Centre for Southeastern Europe

Programme co-funded by the EUROPEAN UNION

IMPLEMENTATION OF STANDARDIZED PRECIPITATION INDEX - SPI

REPORT

Republic Hydrometeorological Service of Serbia

April 2010

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DMCSEE, WP3 - Activity 3.2.1:

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REPORT

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Abstract

Within Republic Hydrometeorological Service of Serbia, operative procedures for the calculation of some relevant, well known moisture indices were upgraded several years ago. These procedures were mostly developed within the preparation of improved versions of agricultural meteorology bulletins of RHMSS. Procedures for data processing encompass the calculation of *Standardized precipitation index (SPI).* It was shown that the results of operative application of these procedures considerably facilitate monitoring and analyses of moisture conditions. This particularly relates to drought monitoring and assessment of its consequences in the various regions of Serbia. Also, the preparation of mentioned procedures for the calculation of SPI made possible the analyses of moisture conditions during previous decades on the basis of long series of historical data from the territory of Serbia.

Within DMCSEE activities, detailed comparative analysis of values of SPI indices obtained by software provided by EARS and the values obtained by operative RHMSS procedures was made. Some small adaptations, in fact advancements of operative calculation technique dealing with the assessment of rainfall distribution parameters, were done too. So, beginning with 1 January 2010, all SPI operative calculations performed by RHMSS are fully harmonized with the methodology proposed by EARS within the DMCSEE.

Operative procedures carried out in RHMSS comprised regular calculations of standardized precipitation index for 1, 2, 3, 4, 5, 6, 9, 12 and 24 months. Calculations are performed after expiration of each month. Besides this, the calculation of SPI value is made on the basis of precipitation during previous 30, 60 and 90 days and statistical parameters for given part of the year. These are one day step calculations. It is necessary to emphasize that the SPI calibration period currently in use is 1961-2005.

A part of obtained results is accessible and regularly updated on RHMSS Internet presentation (http://www.hidmet.gov.rs/ in the form of maps, graphical and tabular surveys within the section named »Moisture conditions« and agrometeorological bulletins. As more applicable, mostly qualitative assessment of the moisture conditions are presented instead of numerous SPI values.

However, SPI calculations are based on precipitation data daily delivered from 29 stations, which is not particularly large number. Furthermore, full automatization does not exist, so considerable amount of manual work is needed. Finally, the SPI mapping procedures and products are hardly satisfactory. This is the state of affairs at this moment. Issues – scopes mentioned above require particular attention in the forthcoming period.

Description of data

Meteorological network

Meteorological network in Serbia covers an area of over 88,000 square km. There are more than six hundred meteorological stations which are delivering data to Republic Hidrometeorological Service of Serbia on regular basis. Different types of stations exist. Thirty five synoptic stations (including airport meteorological stations) with 24 observations per day have professional observers. All other stations are automatic or involve outsourced collaborators.

Observers on precipitation stations, among other meteorological parameters defined by standard observation programme, measure precipitation once a day. Meteorological diary is sent monthly to RHMSS. Actual data availability delay in practice is at least one to two months. Data arrive in form of written document and they are not ready for instant use. At this moment, a number of active precipitation stations is about 500.

Observers on climatological stations follow the same program regarding the precipitation as their colleagues on precipitation stations, but proceed with additional measurements according to standard programme for this type of station. Considering possible operative use of these data, the situation is quite similar to this which is described above regarding precipitation stations. Climatological station observation programme is currently carried out on 99 locations.

Synoptic stations mainly involve the same procedure as classical climatological stations (some airport meteorological stations are exceptions), but observers do the measuring more frequently during the day. All synoptic stations in Serbia are now in the regime of hourly measuring and hourly reporting via SYNOP bulletins and GTS in real time. Data received via bulletins from 32 synoptic stations are used for operative activities in the field of agricultural meteorology within RHMSS, including monitoring of moisture conditions (See Table on the page 6). Collected data are daily processed, there is no delay.

By the end of 2009, RHMSS completed the network of automatic meteorological stations (AMS). All automatic stations are situated on the locations – meteorological stations under the authority of the Service and with professional employees. Measuring program on these 28 AMSs cover wind speed and direction, air temperature and humidity, precipitation, air pressure, air temperature on 5 cm above the soil, global radiation and soil temperature in the depths of 5, 10, 20, 50 and 100cm. All data from these stations are near-real time available. However, operation of these stations is still in the testing phase – adjustments are carried out, as well as comparative analyses of these data with data obtained by classical measuring on the same location.

Data records

Near–real–time data

Operative SPI calculations are performed on the basis of daily precipitation data regularly submitted from 29 synoptic stations and statistical parameters derived from historical precipitation data. Complete data for the period 1961-2005 exist for the twenty five stations. For the purpose of statistical parameters calculation, previous interpolation of missing data was carried out in case of three of remaining stations. Regional climate model *(Regionalen Klimamodells* on the basis of *FITNAH*) was used.

In case of the station Kopaonik (1710m), only all available original data were used-without interpolation. In practice, SPI values obtained for these four stations without complete series of original data are accepted as approximative. They are considered in spatial analyses, but they are not presented individually.

Classical data

Besides the mentioned stations where Synop reporting exists, there are another 39 climatological stations with data record for the period 1961-2000 and additional 5 for the period 1971-2000. Lists of these stations are given in Tables on the pages 7 and 8.

Among around 500 precipitation stations that are operational today, around 400 stations were functioning during the period 1961-2000, and additional near twenty stations were functioning in the period 1971-2000. The lists of these stations are not attached to this document because of several reasons. The number of these stations is considerable and it is necessary to previously carry out more detailed checking of the real availability of historical data on precipitation from these stations. Also, it is assessed that the expectation that current data from these stations could be included in operative calculation of SPI in nearest future is not real. Unfortunately, actual data availability delay in practice is too big at this moment.

SPI software

Operative SPI calculation in RHMSS is performed by Microsoft Excel sheets and functions. After already mentioned adaptations**,** full harmonization was achieved with the methodology proposed by EARS within the DMCSEE. An example of comparision of SPI values (Appendix I) shows that the differencies betwen calculated values are negligible.

Criteria for quality assessment of moisture conditions on the basis of SPI which was chosen for operative usage in RHMSS are shown in Apendix II, and an examples of moisture condition analyses based on SPI in Appendix III.

List of stations

List of stations with near-real-time data delivery – Serbia

Near–real–time data				*Operative SPI calculation*	*AMS existed in addition*
Synoptic stations					
	WMO no.	**name**	**comment**		
1	13067	PALIČ		√	√
2	13160	SOMBOR		√	√
3	13168	NOVI SAD RIMSKI ŠANČEVI		√	√
4	13170	BEČEJ	**Agr. company st.**	√	
5	13173	ZRENJANIN		√	√
6	13174	KIKINDA		√	√
7	13180	BANATSKI KARLOVAC		√	√
8	13183	VRŠAC	**Civil airport st.**	√	
9	13262	LOZNICA		√	√
10	13266	SREMSKA MITROVICA		√	√
11	13269	VALJEVO		√	√
12	13272	BEOGRAD SURČIN	**Civil airport st.**		
13	13274	BEOGRAD OBSERVATORIJA		√	√
14	13278	KRAGUJEVAC		√	√
15	13279	SMEDEREVSKA PALANKA		√	√
16	13285	VELIKO GRADIŠTE		√	√
17	13289	CRNI VRH KOD BORA		√	√
18	13295	NEGOTIN		√	√
19	13367	ZLATIBOR		√	√
20	13369	SJENICA		√	√
21	13370	POŽEGA		√	√
22	13376	KRALJEVO		√	√
23	13378	KOPAONIK		√	√
24	13382	KURŠUMLIJA			√
25	13383	KRUŠEVAC		√	√
26	13384	ĆUPRIJA		√	√
27	13387	NIŠ AERODROM	**Civil airport st.**		
28	13388	NIŠ		√	√
29	13389	LESKOVAC		√	√
30	13392	ZAJEČAR		√	√
31	13397	DIMITROVGRAD		√	√
32	13489	VRANJE		√	√

Active classical stations with time records for 1961- 2000 - Serbia

Synoptic stations		*1961-2000*				
Idmm	**clim. no.**	**name**	Hs	φ	λ	**Start-up**
	674	PALIĆ	102	46° 06'	19° 46'	1945
	1610	SOMBOR	88	45 47	19 05	1949
	1654	NOVI SAD RIMSKI ŠANČEVI	84	45 20	19 52	1948
	1730	BEČEJ	75	45 37	20 04	1945
	1742	ZRENJANIN	80	45 24	20 21	1948
	1712	KIKINDA	81	45 51	20 28	1948
	2631	LOZNICA	121	44 33	19 46	1951
	2603	SREMSKA MITROVICA	81	44 58	19 38	1946
	2655	VALJEVO	176	44 17	19 55	1946
	2712	BEOGRAD OPSERVATORIJA	132	44 48	20 02	1887
	2775	KRAGUJEVAC	197	44 02	20 56	1948
	2755	SMEDEREVSKA PALANKA	122	44 22	20 57	1948
	2813	VELIKO GRADIŠTE	82	44 45	21 31	1945
	2963	NEGOTIN	42	44 14	22 33	1947
	3624	ZLATIBOR	1028	43 44	19 43	1950
	3655	SJENICA	1038	43 16	20 01	1946
	3710	POŽEGA	310	43 50	20 02	1952
	3734	KRALJEVO	215	43 43	20 42	1945
	3861	KURŠUMLIJA	382	43 08	21 16	1951
	3832	KRUŠEVAC	166	43 34	21 21	1946
	3802	ĆUPRIJA	123	43 56	21 22	1946
	3855	NIŠ	201	43 20	21 54	1947
	4805	LESKOVAC	230	42 59	21 57	1948
	3901	ZAJEČAR	144	43 53	22 17	1946
	3974	DIMITROVGRAD	450	43 01	22 45	1947
	4835	VRANJE	432	42 29	21 54	1945
Climate stations						
Idmm	**clim. no.**	**name**	Hs	φ	λ	**Start-up**
	2614	ŠABAC	80	44° 46'	19° 41'	1945
	1700	SENTA	80	45 56	20 05	1945
	1641	BAČ	85	45 24	19 15	1955
	1653	BAČKI PETROVAC	85	45 22	19 34	1948
	2802	BELA CRKVA	90	44 54	21 25	1945
	3801	JAGODINA	115	43 59	21 19	1949
	1602	ALEKSA ŠANTIĆ	120	45 56	19 20	1955
	2723	RADMILOVAC	130	44 45	20 35	1947
	2662	LJUBOVIJA	170	44 11	19 23	1953

Climate stations - *continuation*						
Idmm	**clim. no.**	**name**	Hs	φ	λ	**Start-up**
	3834	ALEKSINAC	180	43 33	21 41	1953
	3735	VRNJAČKA BANJA	235	43 37	20 54	1948
	3810	REKOVAC	251	43 52	21 06	1949
	3863	PROKUPLJE	266	43 14	21 36	1949
	3604	BAJINA BAŠTA	270	43 58	19 34	1956
	4900	VLASOTINCE	271	42 58	22 08	1948
	2652	KRUPANJ	280	44 22	19 23	1958
	3931	KNJAŽEVAC	281	43 34	22 16	1953
	3825	SOKOBANJA	300	43 39	21 51	1946
	2864	ŽAGUBICA	314	44 12	21 47	1946
	4910	PREDEJANE	318	42 50	22 08	1949
	3840	ALEKSANDROVAC	360	43 27	21 04	1946
	2765	ČUMIĆ	366	44 08	20 49	1958
	3963	PIROT	370	43 09	22 36	1947
	3851	BLACE	395	43 18	21 18	1958
	4844	BUJANOVAC	400	42 27	21 47	1948
	4853	PREŠEVO	410	42 18	21 40	1949
	3841	BRUS	440	43 23	21 02	1961
	3731	IVANJICA	465	43 25	20 14	1953
	3972	BABUŠNICA	495	43 04	22 26	1958
	3763	NOVI PAZAR	545	43 08	20 31	1951
	3722	KAONA	570	43 43	20 25	1949
	3842	JASTREBAC	575	43 26	21 23	1947
	2764	RUDNIK PLANINA	700	44 08	20 31	1956
	4942	BOSILJGRAD	730	42 30	22 28	1947
	3765	BLAŽEVO	880	43 14	20 56	1961
	3736	GOČ	990	43 33	20 51	1953
	4773	DRAGAŠ	1060	42 04	20 39	1952
	4922	VLASINA	1260	42 44	22 21	1946
	4815	KUKAVICA	1442	42 39	21 58	1953
Precipitation stations						

Among precipitation stations that are operational today, around 400 were functioning during the period 1961-2000 - according to available evidence

Active classical stations with time records for 1971 - 2000 – Serbia

(only stations in addition to the 1961-2000 list)

Synoptic stations *1971-2000*						
Idmm	**clim. no.**	**name**	Hs	φ	λ	**Start-up**
	1861	VRŠAC	82	45° 09'	21° 19'	1965
	2711	BEOGRAD SURČIN	96	44 49	20 17	1966
	2865	CRNI VRH KOD BORA	1037	44 07	21 57	1966
Climate stations						
Idmm	**clim. no.**	**name**	Hs	φ	λ	**Start-up**
	2871	BAGRDAN (VOJSKA)	113	44° 05'	21° 13'	1969
	3961	BELA PALANKA	291	43 13	22 19	1962
	3744	JOŠANIČKA BANJA	555	43 23	20 45	1965
	4950	TRGOVIŠTE	600	42 22	22 05	1969
	3770	KARAJUKIĆA BUNARI	1165	43 06	20 06	1969
Precipitation stations						
Near twenty today active precipitation stations were functioning in the period 1971-2000 in addition to those which were functioning in the period 1961-2000						

Other classical stations in operative SPI calculation

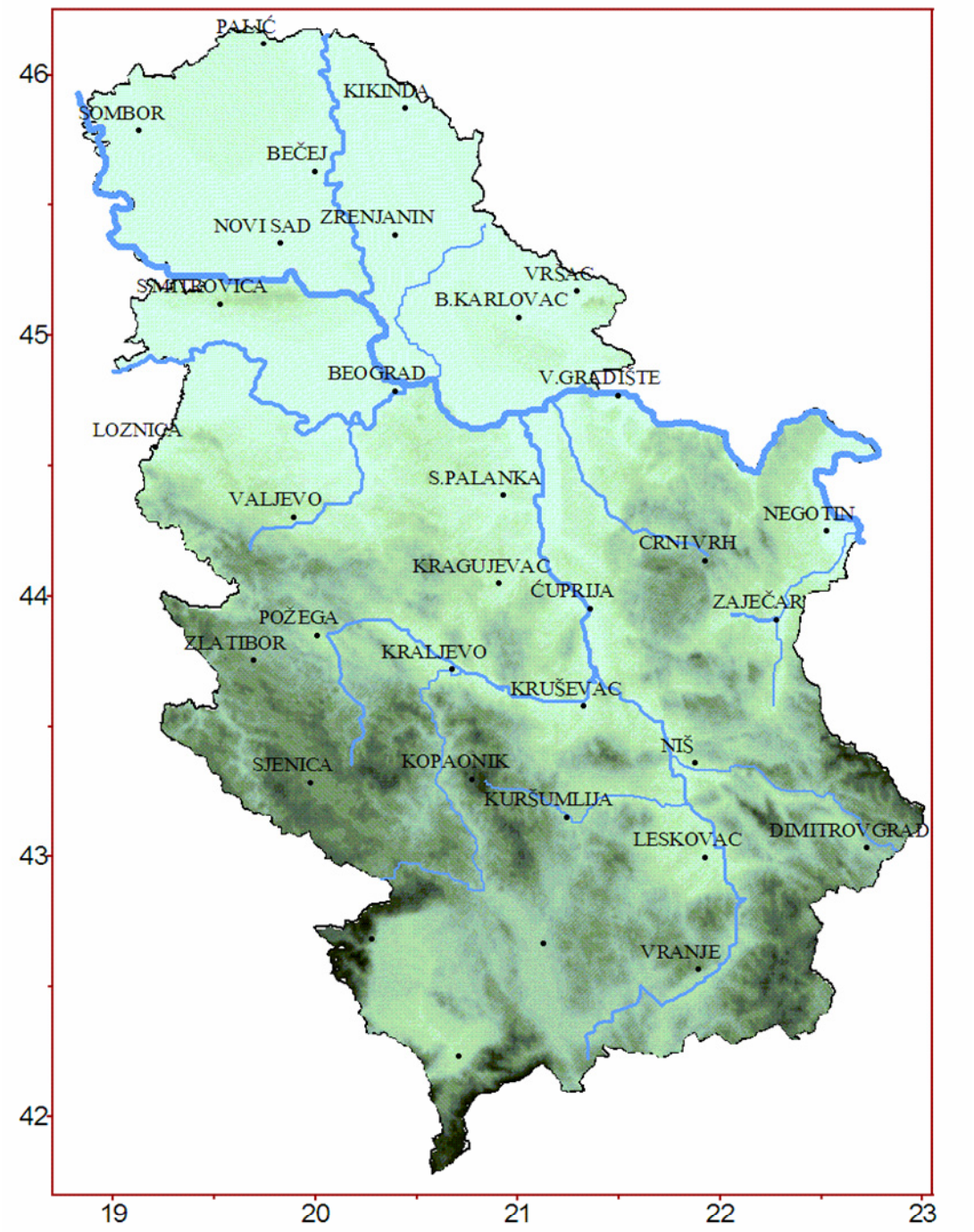
Synoptic stations						
Idmm	**clim. no.**	**name**	Hs	φ	λ	**Start-up / Period**
	1800	BANATSKI KARLOVAC	89	45° 03'	21° 02'	1986
	3755	KOPAONIK	1710	43 17	20 48	1967-73, 1980-

Comment: Respectabe historical meteorological data archive exist for three old synoptic stations on the territory of Autonomous Province Kosovo and Metohija, which is under the administration of UN (see Table below)

Synoptic stations						
Idmm	**WMO no.**	**name**	Hs	φ	λ	**Period**
	473	PEĆ	498	42 40	20 18	1949-1998
	477	PRIZREN	402	42 13	20 44	1949-1998
	481	PRIŠTINA	573	42 39	21 09	1949-1998

Map with stations with operative SPI calculations – Serbia

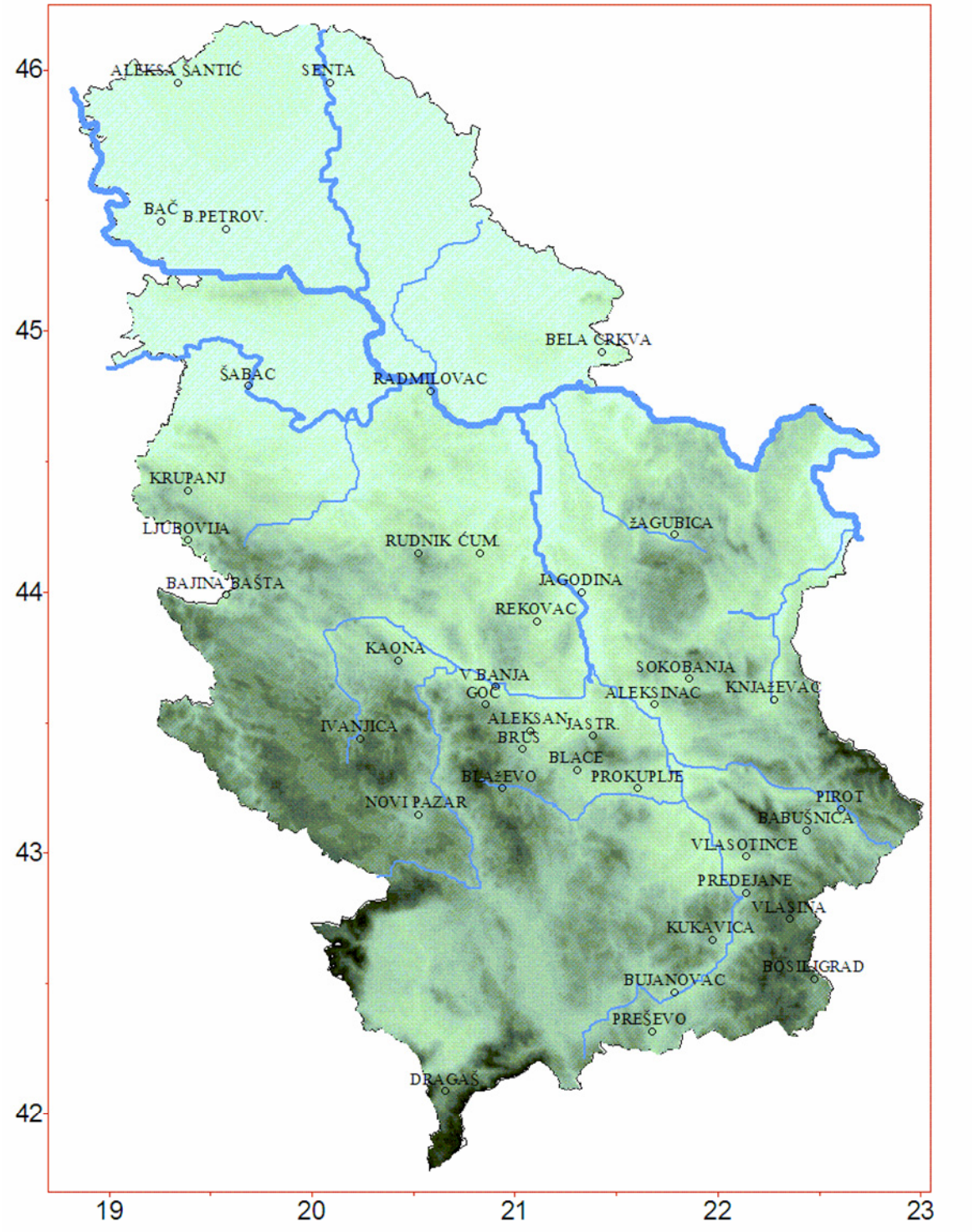
(All are synoptic stations)



Note: It is expected that station Kuršumlija will be added to the operative calculation SPI scheme very soon, as thirtieth synoptic station.

Map with active climate stations with time records for 1961- 2000

(Stations without SYNOP reporting)



Appendix I: Comparison of SPI values obtained by RHMSS operative calculations and software developed by EARS – an example

Appendix Ia							STATION: VALJEVO				RR 1 month	
1961	22.0	28.6	25.5	43.5	174.5	46.5	92.2	4.6	10.7	8.4	68.2	76.8
1962	45.7	62.0	88.6	72.1	34.5	69.6	47.6	19.5	46.3	47.7	58.3	58.5
1963	92.4	36.1	29.1	88.2	39.9	65.5	64.9	22.9	86.0	7.5	37.1	61.8
1964	4.3	41.0	62.5	65.5	58.0	86.1	110.9	31.1	88.4	77.2	76.8	45.6
1965	31.1	68.1	31.8	65.7	114.5	47.9	82.6	36.4	59.3	1.9	70.1	72.0
1966	70.2	27.8	79.4	85.5	50.7	103.0	125.7	64.4	21.5	59.7	26.7	125.1
1967	35.1	26.9	132.7	58.2	98.2	135.3	75.4	23.9	64.4	19.1	48.8	94.3
1968	91.8	44.2	23.3	23.4	78.7	35.0	86.1	155.1	117.6	25.6	84.0	93.3
1969	30.6	78.4	41.6	39.8	31.9	139.9	85.3	74.0	49.2	7.7	35.2	124.9
1970	55.3	95.5	87.5	80.7	185.3	146.6	96.1	75.7	31.8	89.5	51.8	12.1
1971	32.8	60.5	86.1	60.3	99.5	96.3	77.9	56.4	142.7	35.0	55.7	23.9
1972	9.7	16.3	8.3	66.3	45.9	32.1	193.5	102.7	75.3	110.8	73.3	1.9
1973	21.8	26.1	50.2	104.4	35.3	80.8	98.0	117.8	32.6	41.0	52.4	38.8
1974	50.3	18.8	9.7	80.9	143.5	177.1	42.0	37.5	46.6	175.3	97.4	78.3
1975	31.3	16.9	23.2	42.3	128.9	164.7	112.7	217.8	29.1	103.2	83.6	13.1
1976	112.8	16.4	23.4	72.0	72.5	121.0	89.0	51.2	54.5	10.9	67.3	40.4
1977	52.4	100.4	38.0	85.7	84.3	65.5	96.7	80.5	101.8	18.2	85.7	74.3
1978	26.3	86.0	66.9	40.0	117.3	175.1	43.3	46.7	126.4	18.9	15.2	65.9
1979	79.7	41.6	23.2	64.3	93.9	193.3	69.3	83.6	21.9	74.2	48.8	56.7
1980	82.1	51.3	69.0	49.8	159.0	153.8	76.6	36.6	76.9	61.9	64.2	85.2
1981	52.7	35.9	113.2	68.2	91.8	127.7	20.9	91.0	70.2	51.5	106.3	53.8
1982	32.9	21.6	82.3	50.4	50.3	54.5	140.7	98.1	18.1	80.3	21.2	59.7
1983	28.8	48.4	24.6	51.2	36.6	133.9	90.9	35.2	132.1	43.2	49.3	75.5
1984	84.7	83.9	68.2	59.8	114.6	83.8	76.5	60.2	65.1	28.2	46.4	20.9
1985	57.7	65.0	43.4	106.1	55.4	96.7	9.0	167.4	2.4	28.6	125.3	33.8
1986	57.4	82.1	60.3	73.4	52.4	163.3	117.4	43.5	4.2	58.2	12.1	33.9
1987	107.3	9.0	59.4	59.7	200.8	64.5	36.1	58.3	9.4	47.7	132.2	64.0
1988	54.1	40.6	112.6	44.0	52.6	110.9	6.6	40.0	107.4	26.2	49.4	40.9
1989	7.6	10.8	37.6	52.6	126.7	192.3	19.5	70.6	63.1	54.6	56.7	31.5
1990	14.6	44.0	24.8	49.6	16.5	86.6	17.8	34.7	32.4	35.4	39.2	77.4
1991	28.3	25.3	64.8	97.4	64.6	60.0	96.1	60.5	30.6	105.8	60.4	48.6
1992	22.6	53.5	17.4	48.1	31.5	163.9	28.2	36.0	39.8	118.6	88.8	41.4
1993	42.6	22.6	65.1	34.1	49.1	80.8	53.5	60.8	67.2	8.2	85.7	52.6
1994	65.8	21.9	70.6	69.6	53.5	105.5	82.9	27.7	59.8	51.3	22.1	24.3
1995	93.6	46.7	91.3	72.5	73.4	189.1	58.2	104.6	94.4	1.7	72.9	68.3
1996	32.6	80.6	53.0	56.9	122.3	107.4	28.4	74.0	132.4	44.4	64.8	77.8
1997	35.4	68.1	29.2	58.8	31.6	121.6	177.2	115.8	29.8	157.5	35.1	89.7
1998	80.1	15.2	40.9	33.4	80.2	78.1	50.6	69.2	82.9	117.8	69.3	54.1
1999	39.7	69.6	19.8	72.9	71.3	106.5	212.9	48.8	54.4	35.0	70.9	149.6
2000	32.3	29.4	42.9	35.8	67.6	63.2	34.0	17.8	101.9	16.4	22.7	44.7
2001	55.7	40.7	54.8	127.2	43.4	164.4	84.2	67.1	180.4	19.4	101.0	37.0
2002	28.3	20.1	37.1	84.3	83.7	46.3	75.1	101.4	95.2	137.8	39.7	59.5
2003	59.3	37.7	6.7	15.9	56.6	48.7	92.9	3.2	54.9	166.3	21.6	49.8
2004	81.1	44.2	19.3	92.1	71.5	124.8	67.3	91.3	50.2	47.1	106.5	51.0
2005	34.6	75.3	47.1	56.9	70.9	72.7	122.1	128.9	81.9	27.0	68.5	58.0
2006	41.8	51.0	121.6	77.9	46.4	104.5	35.6	183.4	17.7	27.5	30.6	83.7
2007	53.4	40.6	77.6	7.2	125.0	72.7	22.5	65.4	100.4	119.7	107.5	51.3
2008	36.0	28.2	96.5	46.0	72.9	77.8	72.6	21.9	68.9	22.4	59.7	53.2
61-05												
r1 - ave.	49.1	45.2	50.8	63.5	80.3	106.3	79.2	67.7	65.4	55.6	61.5	58.7
s1	27.3	24.8	30.0	22.7	43.8	46.5	45.2	43.6	40.4	45.7	28.5	29.9

Appendix Ib						STATION: VALJEVO			Gamma parameters calculation			
1961	3.09	3.35	3.24	3.77	5.16	3.84	4.52	1.53	2.37	2.13	4.22	4.34
1962	3.82	4.13	4.48	4.28	3.54	4.24	3.86	2.97	3.84	3.86	4.07	4.07
1963	4.53	3.59	3.37	4.48	3.69	4.18	4.17	3.13	4.45	2.01	3.61	4.12
1964	1.46	3.71	4.14	4.18	4.06	4.46	4.71	3.44	4.48	4.35	4.34	3.82
1965	3.44	4.22	3.46	4.19	4.74	3.87	4.41	3.59	4.08	0.64	4.25	4.28
1966	4.25	3.33	4.37	4.45	3.93	4.63	4.83	4.17	3.07	4.09	3.28	4.83
1967	3.56	3.29	4.89	4.06	4.59	4.91	4.32	3.17	4.17	2.95	3.89	4.55
1968	4.52	3.79	3.15	3.15	4.37	3.56	4.46	5.04	4.77	3.24	4.43	4.54
1969	3.42	4.36	3.73	3.68	3.46	4.94	4.45	4.30	3.90	2.04	3.56	4.83
1970	4.01	4.56	4.47	4.39	5.22	4.99	4.57	4.33	3.46	4.49	3.95	2.49
1971	3.49	4.10	4.46	4.10	4.60	4.57	4.36	4.03	4.96	3.56	4.02	3.17
1972	2.27	2.79	2.12	4.19	3.83	3.47	5.27	4.63	4.32	4.71	4.29	0.64
1973	3.08	3.26	3.92	4.65	3.56	4.39	4.58	4.77	3.48	3.71	3.96	3.66
1974	3.92	2.93	2.27	4.39	4.97	5.18	3.74	3.62	3.84	5.17	4.58	4.36
1975	3.44	2.83	3.14	3.74	4.86	5.10	4.72	5.38	3.37	4.64	4.43	2.57
1976	4.73	2.80	3.15	4.28	4.28	4.80	4.49	3.94	4.00	2.39	4.21	3.70
1977	3.96	4.61	3.64	4.45	4.43	4.18	4.57	4.39	4.62	2.90	4.45	4.31
1978	3.27	4.45	4.20	3.69	4.76	5.17	3.77	3.84	4.84	2.94	2.72	4.19
1979	4.38	3.73	3.14	4.16	4.54	5.26	4.24	4.43	3.09	4.31	3.89	4.04
1980	4.41	3.94	4.23	3.91	5.07	5.04	4.34	3.60	4.34	4.13	4.16	4.45
1981	3.96	3.58	4.73	4.22	4.52	4.85	3.04	4.51	4.25	3.94	4.67	3.99
1982	3.49	3.07	4.41	3.92	3.92	4.00	4.95	4.59	2.90	4.39	3.05	4.09
1983	3.36	3.88	3.20	3.94	3.60	4.90	4.51	3.56	4.88	3.77	3.90	4.32
1984	4.44	4.43	4.22	4.09	4.74	4.43	4.34	4.10	4.18	3.34	3.84	3.04
1985	4.06	4.17	3.77	4.66	4.01	4.57	2.20	5.12	0.88	3.35	4.83	3.52
1986	4.05	4.41	4.10	4.30	3.96	5.10	4.77	3.77	1.44	4.06	2.49	3.52
1987	4.68	2.20	4.08	4.09	5.30	4.17	3.59	4.07	2.24	3.86	4.88	4.16
1988	3.99	3.70	4.72	3.78	3.96	4.71	1.89	3.69	4.68	3.27	3.90	3.71
1989	2.03	2.38	3.63	3.96	4.84	5.26	2.97	4.26	4.14	4.00	4.04	3.45
1990	2.68	3.78	3.21	3.90	2.80	4.46	2.88	3.55	3.48	3.57	3.67	4.35
1991	3.34	3.23	4.17	4.58	4.17	4.09	4.57	4.10	3.42	4.66	4.10	3.88
1992	3.12	3.98	2.86	3.87	3.45	5.10	3.34	3.58	3.68	4.78	4.49	3.72
1993	3.75	3.12	4.18	3.53	3.89	4.39	3.98	4.11	4.21	2.10	4.45	3.96
1994	4.19	3.09	4.26	4.24	3.98	4.66	4.42	3.32	4.09	3.94	3.10	3.19
1995	4.54	3.84	4.51	4.28	4.30	5.24	4.06	4.65	4.55	0.53	4.29	4.22
1996	3.48	4.39	3.97	4.04	4.81	4.68	3.35	4.30	4.89	3.79	4.17	4.35
1997	3.57	4.22	3.37	4.07	3.45	4.80	5.18	4.75	3.39	5.06	3.56	4.50
1998	4.38	2.72	3.71	3.51	4.38	4.36	3.92	4.24	4.42	4.77	4.24	3.99
1999	3.68	4.24	2.99	4.29	4.27	4.67	5.36	3.89	4.00	3.56	4.26	5.01
2000	3.48	3.38	3.76	3.58	4.21	4.15	3.53	2.88	4.62	2.80	3.12	3.80
2001	4.02	3.71	4.00	4.85	3.77	5.10	4.43	4.21	5.20	2.97	4.62	3.61
2002	3.34	3.00	3.61	4.43	4.43	3.84	4.32	4.62	4.56	4.93	3.68	4.09
2003	4.08	3.63	1.90	2.77	4.04	3.89	4.53	1.16	4.01	5.11	3.07	3.91
2004	4.40	3.79	2.96	4.52	4.27	4.83	4.21	4.51	3.92	3.85	4.67	3.93
2005	3.54	4.32	3.85	4.04	4.26	4.29	4.80	4.86	4.41	3.30	4.23	4.06
2006	3.73	3.93	4.80	4.36	3.84	4.65	3.57	5.21	2.87	3.31	3.42	4.43
2007	3.98	3.70	4.35	1.97	4.83	4.29	3.11	4.18	4.61	4.78	4.68	3.94
2008	3.58	3.34	4.57	3.83	4.29	4.35	4.28	3.09	4.23	3.11	4.09	3.97
61-05												
∑ln(x)	166.70	164.04	167.76	183.68	191.00	205.28	187.50	178.70	175.85	161.94	179.62	175.33
∑ln(x)/N	3.70	3.65	3.73	4.08	4.24	4.56	4.17	3.97	3.91	3.60	3.99	3.90
ln r	3.89	3.81	3.93	4.15	4.39	4.67	4.37	4.21	4.18	4.02	4.12	4.07
A	0.19	0.17	0.20	0.07	0.14	0.10	0.21	0.24	0.27	0.42	0.13	0.18
α	2.81	3.17	2.66	7.32	3.69	4.95	2.59	2.21	1.99	1.34	4.07	3.00
β	17.47	14.29	19.13	8.68	21.79	21.45	30.60	30.61	32.92	41.49	15.11	19.56

Appendix Ic	* "=NORMSINV(GAMMADIST(x,alfa,beta,TRUE))"		STATION: VALJEVO										SPI comparision			
			EXCEL*	DMCSEE	EXCEL*	DMCSEE	EXCEL*	DMCSEE	EXCEL*	DMCSEE	EXCEL*	DMCSEE	EXCEL*	DMCSEE	EXCEL*	DMCSEE
Year	Mon	RR	SPI1	spi1	SPI2	spi2	SPI3	spi3	SPI4	spi4	SPI5	spi5	SPI6	spi6	SPI12	spi12
2004	I	81.1	1.11	1.12	0.62	0.62	-0.31	-0.31	1.45	1.47	1.34	1.35	0.32	0.31	-1.18	-1.21
2004	II	44.2	0.15	0.15	0.85	0.85	0.50	0.50	-0.26	-0.26	1.35	1.35	1.24	1.24	-1.16	-1.16
2004	III	19.3	-1.14	-1.14	-0.72	-0.72	0.11	0.11	-0.06	-0.06	-0.69	-0.69	0.83	0.83	-1.04	-1.04
2004	IV	92.1	1.19	1.19	0.05	0.05	0.03	0.03	0.55	0.55	0.34	0.33	-0.26	-0.26	-0.43	-0.43
2004	V	71.5	-0.04	-0.04	0.51	0.51	-0.09	-0.09	-0.11	-0.11	0.34	0.34	0.20	0.20	-0.26	-0.25
2004	VI	124.8	0.52	0.52	0.26	0.26	0.60	0.60	0.17	0.17	0.15	0.15	0.45	0.45	0.38	0.38
2004	VII	67.3	-0.04	-0.04	0.22	0.22	0.06	0.06	0.41	0.41	0.01	0.01	0.00	0.00	0.16	0.16
2004	VIII	91.3	0.69	0.69	0.32	0.32	0.47	0.47	0.32	0.32	0.57	0.57	0.25	0.25	0.84	0.84
2004	IX	50.2	-0.11	-0.11	0.29	0.29	0.07	0.07	0.26	0.26	0.14	0.14	0.41	0.41	0.80	0.80
2004	X	47.1	0.11	0.11	-0.30	-0.30	0.13	0.13	-0.03	-0.03	0.15	0.15	0.06	0.06	-0.18	-0.18
2004	XI	106.5	1.38	1.38	0.78	0.78	0.45	0.45	0.63	0.63	0.44	0.44	0.56	0.56	0.49	0.49
2004	XII	51.0	-0.04	-0.04	0.94	0.94	0.61	0.61	0.30	0.30	0.54	0.54	0.35	0.34	0.53	0.53
2005	I	34.6	-0.35	-0.35	-0.42	-0.43	0.56	0.57	0.30	0.32	0.04	0.05	0.37	0.36	0.19	0.18
2005	II	75.3	1.17	1.17	0.51	0.51	0.24	0.24	0.97	0.97	0.70	0.70	0.49	0.49	0.43	0.43
2005	III	47.1	0.09	0.09	0.72	0.72	0.34	0.34	0.15	0.15	0.74	0.74	0.58	0.58	0.63	0.63
2005	IV	56.9	-0.17	-0.17	-0.13	-0.13	0.48	0.48	0.18	0.18	0.01	0.01	0.63	0.63	0.39	0.39
2005	V	70.9	-0.06	-0.06	-0.25	-0.25	-0.23	-0.23	0.25	0.25	0.03	0.03	-0.06	-0.06	0.39	0.39
2005	VI	72.7	-0.64	-0.64	-0.58	-0.58	-0.65	-0.65	-0.58	-0.58	-0.18	-0.18	-0.31	-0.31	-0.05	-0.05
2005	VII	122.1	0.95	0.95	0.26	0.26	0.09	0.09	-0.01	-0.01	-0.05	-0.05	0.28	0.28	0.41	0.41
2005	VIII	128.9	1.29	1.29	1.45	1.45	0.93	0.93	0.73	0.73	0.62	0.62	0.55	0.55	0.68	0.68
2005	IX	81.9	0.56	0.56	1.24	1.24	1.52	1.52	1.03	1.03	0.85	0.85	0.75	0.75	0.92	0.92
2005	X	27.0	-0.44	-0.44	-0.07	-0.07	0.74	0.74	1.06	1.06	0.64	0.64	0.52	0.52	0.75	0.75
2005	XI	68.5	0.39	0.38	-0.29	-0.29	0.02	0.02	0.76	0.76	1.07	1.07	0.68	0.68	0.43	0.43
2005	XII	58.0	0.17	0.17	0.26	0.26	-0.33	-0.32	-0.01	-0.01	0.75	0.75	1.05	1.05	0.51	0.51
2006	I	41.8	-0.06	-0.06	-0.06	-0.06	0.06	0.06	-0.44	-0.43	-0.17	-0.16	0.68	0.67	0.58	0.57
2006	II	51.0	0.40	0.40	0.10	0.10	0.05	0.05	0.16	0.16	-0.32	-0.32	-0.07	-0.07	0.40	0.40
2006	III	121.6	1.85	1.85	1.61	1.61	1.25	1.25	1.02	1.02	1.07	1.07	0.66	0.66	0.94	0.94
2006	IV	77.9	0.69	0.69	1.78	1.78	1.64	1.64	1.35	1.35	1.20	1.20	1.24	1.24	1.19	1.19
2006	V	46.4	-0.78	-0.78	-0.33	-0.33	0.88	0.88	0.90	0.90	0.71	0.71	0.64	0.64	0.98	0.98
2006	VI	104.5	0.11	0.11	-0.45	-0.45	-0.21	-0.21	0.65	0.65	0.67	0.67	0.55	0.55	1.22	1.22
2006	VII	35.6	-0.92	-0.92	-0.76	-0.76	-1.13	-1.13	-0.81	-0.81	0.14	0.14	0.20	0.20	0.56	0.56
2006	VIII	183.4	1.98	1.98	1.10	1.10	0.93	0.93	0.48	0.48	0.58	0.58	1.17	1.17	0.94	0.94
2006	IX	17.7	-1.26	-1.26	1.12	1.12	0.44	0.44	0.35	0.35	-0.04	-0.04	0.10	0.10	0.43	0.43
2006	X	27.5	-0.43	-0.43	-1.67	-1.67	0.63	0.63	0.07	0.07	0.04	0.04	-0.30	-0.30	0.43	0.43
2006	XI	30.6	-1.09	-1.09	-1.25	-1.25	-2.25	-2.25	0.22	0.22	-0.30	-0.30	-0.28	-0.28	0.12	0.12
2006	XII	83.7	0.84	0.84	-0.03	-0.03	-0.57	-0.57	-1.45	-1.45	0.50	0.50	-0.02	-0.02	0.35	0.35
2007	I	53.4	0.34	0.35	0.74	0.75	0.04	0.04	-0.44	-0.44	-1.37	-1.39	0.56	0.55	0.45	0.44
2007	II	40.6	0.00	0.00	0.13	0.13	0.54	0.54	-0.04	-0.04	-0.49	-0.49	-1.36	-1.36	0.37	0.37
2007	III	77.6	0.94	0.94	0.63	0.63	0.59	0.59	0.80	0.80	0.36	0.36	-0.05	-0.05	0.01	0.01
2007	IV	7.2	-4.21	-4.21	-0.65	-0.65	-0.63	-0.62	-0.43	-0.43	-0.02	-0.02	-0.49	-0.49	-0.64	-0.64
2007	V	125.0	1.08	1.08	-0.15	-0.15	0.35	0.35	0.25	0.25	0.28	0.28	0.54	0.53	0.09	0.09
2007	VI	72.7	-0.64	-0.64	0.28	0.28	-0.58	-0.58	-0.13	-0.13	-0.17	-0.17	-0.11	-0.11	-0.18	-0.18
2007	VII	22.5	-1.45	-1.45	-1.83	-1.83	-0.58	-0.57	-1.39	-1.39	-0.88	-0.88	-0.86	-0.86	-0.31	-0.31
2007	VIII	65.4	0.18	0.18	-0.90	-0.89	-1.26	-1.26	-0.47	-0.47	-1.10	-1.10	-0.73	-0.73	-1.41	-1.41
2007	IX	100.4	0.88	0.88	0.65	0.65	-0.23	-0.23	-0.63	-0.63	-0.06	-0.06	-0.66	-0.66	-0.66	-0.66
2007	X	119.7	1.29	1.29	1.59	1.59	1.25	1.25	0.55	0.55	0.15	0.15	0.54	0.54	0.14	0.14
2007	XI	107.5	1.40	1.40	1.81	1.81	2.10	2.10	1.62	1.62	0.96	0.96	0.57	0.57	0.71	0.71
2007	XII	51.3	-0.03	-0.03	0.97	0.97	1.71	1.71	2.02	2.02	1.60	1.60	0.87	0.87	0.51	0.51
2008	I	36.0	-0.29	-0.29	-0.38	-0.38	0.62	0.62	1.39	1.41	1.90	1.92	1.52	1.51	0.39	0.38
2008	II	28.2	-0.58	-0.58	-0.71	-0.71	-0.68	-0.68	0.22	0.22	1.08	1.08	1.58	1.58	0.29	0.29
2008	III	96.5	1.36	1.36	0.76	0.76	0.40	0.40	0.21	0.21	0.80	0.80	1.49	1.49	0.43	0.43
2008	IV	46.0	-0.70	-0.70	0.74	0.74	0.32	0.32	0.06	0.06	-0.09	-0.09	0.55	0.55	0.78	0.78
2008	V	72.9	-0.01	-0.01	-0.46	-0.46	0.43	0.43	0.15	0.15	-0.04	-0.04	-0.12	-0.12	0.36	0.36
2008	VI	77.8	-0.51	-0.51	-0.46	-0.46	-0.71	-0.71	0.00	0.00	-0.19	-0.19	-0.31	-0.31	0.40	0.40
2008	VII	72.6	0.07	0.07	-0.55	-0.55	-0.53	-0.53	-0.74	-0.74	-0.10	-0.10	-0.28	-0.28	0.81	0.81
2008	VIII	21.9	-1.17	-1.17	-0.76	-0.76	-1.06	-1.06	-0.99	-0.99	-1.12	-1.12	-0.54	-0.54	0.42	0.42
2008	IX	68.9	0.31	0.31	-0.64	-0.64	-0.61	-0.61	-0.90	-0.90	-0.89	-0.89	-1.04	-1.04	0.15	0.15
2008	X	22.4	-0.61	-0.61	-0.43	-0.43	-1.05	-1.05	-0.95	-0.95	-1.14	-1.14	-1.14	-1.14	-0.69	-0.69
2008	XI	59.7	0.11	0.11	-0.60	-0.60	-0.46	-0.46	-0.97	-0.97	-0.91	-0.91	-1.11	-1.11	-1.05	-1.05
2008	XII	53.2	0.03	0.03	-0.07	-0.07	-0.71	-0.71	-0.56	-0.56	-1.08	-1.08	-0.96	-0.96	-0.99	-0.99

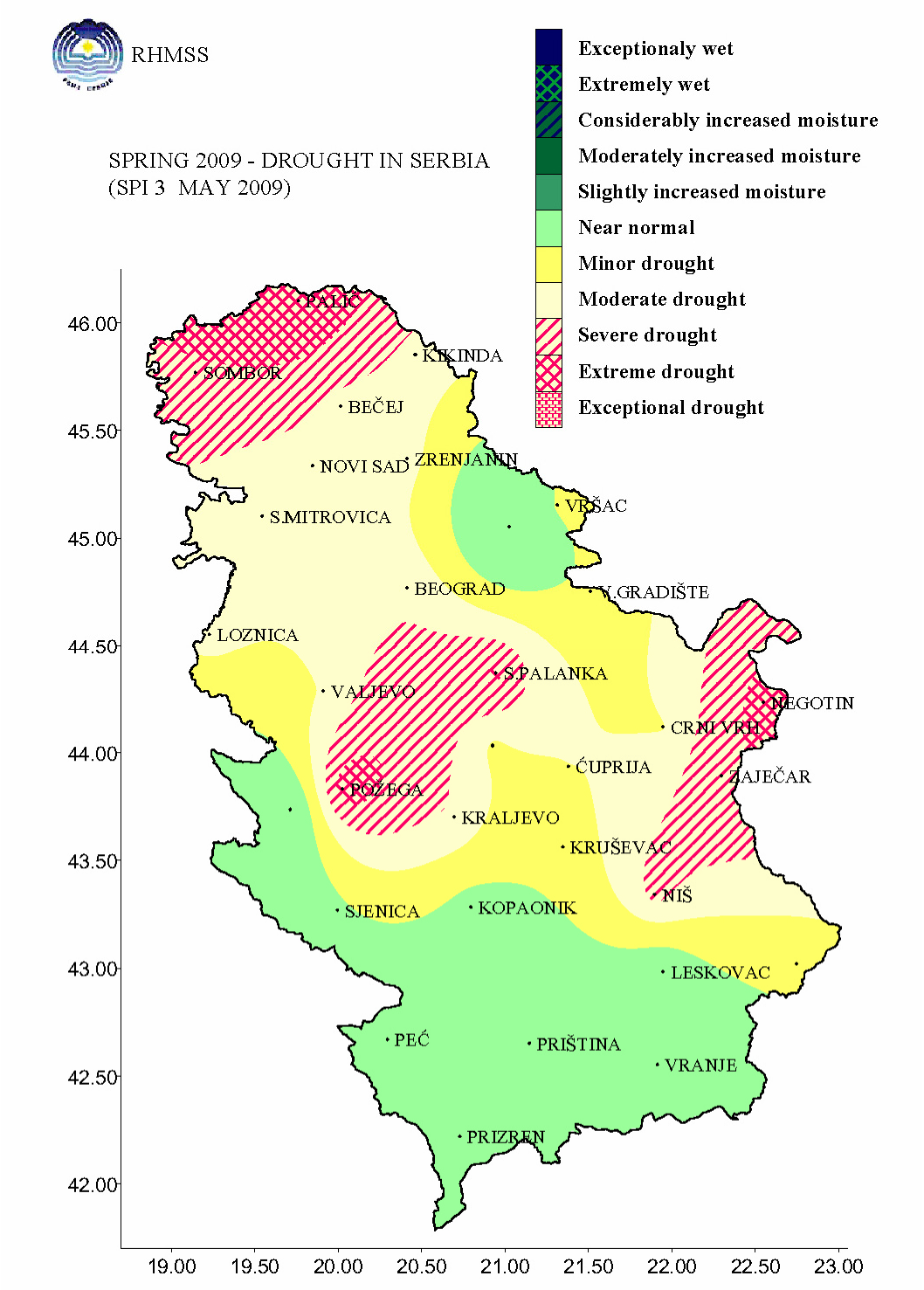
Appendix II: Criteria for quality assessment of moisture conditions on the basis of SPI which was chosen for operative usage in RHMSS

EXPLANATION OF THE MOISTURE CONDITIONS CATEGORIES		
Moisture conditions	Value	
Exceptional drought	**SPI ≤ -2.326**	
Extreme drought	**-2.326 < SPI ≤ -1.645**	
Severe drought	**-1.645 < SPI ≤ -1.282**	
Moderate drought	**-1.282 < SPI ≤ -0.935**	
Minor drought	**-0.935 < SPI ≤ -0.524**	Usual moisture conditions
Near normal	**-0.524 < SPI < +0.524**	
Slightly increased moisture	**+0.524 ≤ SPI < +0.935**	
Moderately increased moisture	**+0.935 ≤ SPI < +1.282**	
Considerably increased moisture	**+1.282 ≤ SPI < +1.645**	
Extremely wet	**+1.645 ≤SPI < +2.326**	
Exceptionally wet	**SPI ≥ +2.326**	

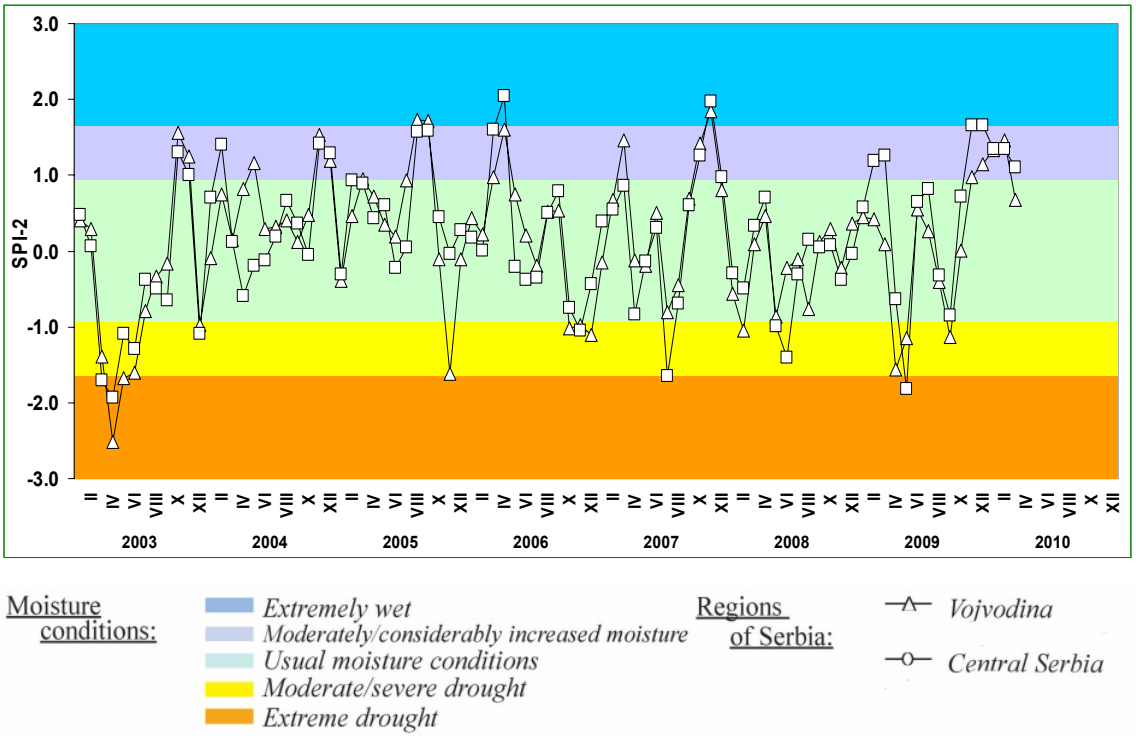
Note: Criteria were defined only on the basis of SPI probability distribution - precipitation probability distribution in the last instance. They are not defined by cause/effect analysis, that is, index calibration according to the recorded consequences. However, even such criteria might help. Usually there is a significant correlation between the magnitude and duration of precipitation regime anomaly and detrimental consequences in agriculture, water management, etc.

MOISTURE CONDITION CATEGORIES OCCURRENCE PROBABILITY		
Moisture conditions	Probability	
Exceptional drought	**1%**	
Extreme drought	**4%**	
Severe drought	**5%**	
Moderate drought	**7.5%**	
Minor drought	**12.5%**	Usual moisture conditions 65%
Near normal	**40%**	
Slightly increased moisture	**12.5%**	
Moderately increased moisture	**7.5%**	
Considerably increased moisture	**5%**	
Extremely wet	**4%**	
Exceptionally wet	**1%**	

Appendix III: Examples of drought analyses on the basis of SPI



Moisture condition changes in two regions of Serbia on the basis of two month SPI calculated for successive months starting with year 2003 up to March 2010



Six month SPI for September might be use as the indicator of prevailing moisture conditions during vegetation period. Vojvodina Province, 1961-2009