RSrpska, Bosnia and Herzegovina
RHMS Нада Рудан
Nada Rudan@RHMZ.com

Verification of DJF-18 outlook over

The Republika Srpska, Bosnia and Herzegovina

1. SEECOF-18, MedCOF-9 Climate outlook for the 2018 winter season:

Temperature and Precipitation

According to the seasonal forecast based on tercile ranks and climate classification ratings, thermal conditions over the Republika Srpska and Bosnia and Herzegovina for winter 2018 had been described by the following categories: **above** upper tercille over all the Republika Srpska and Bosnia and Herzegovina with probability of **50%** (the portion 2, left).

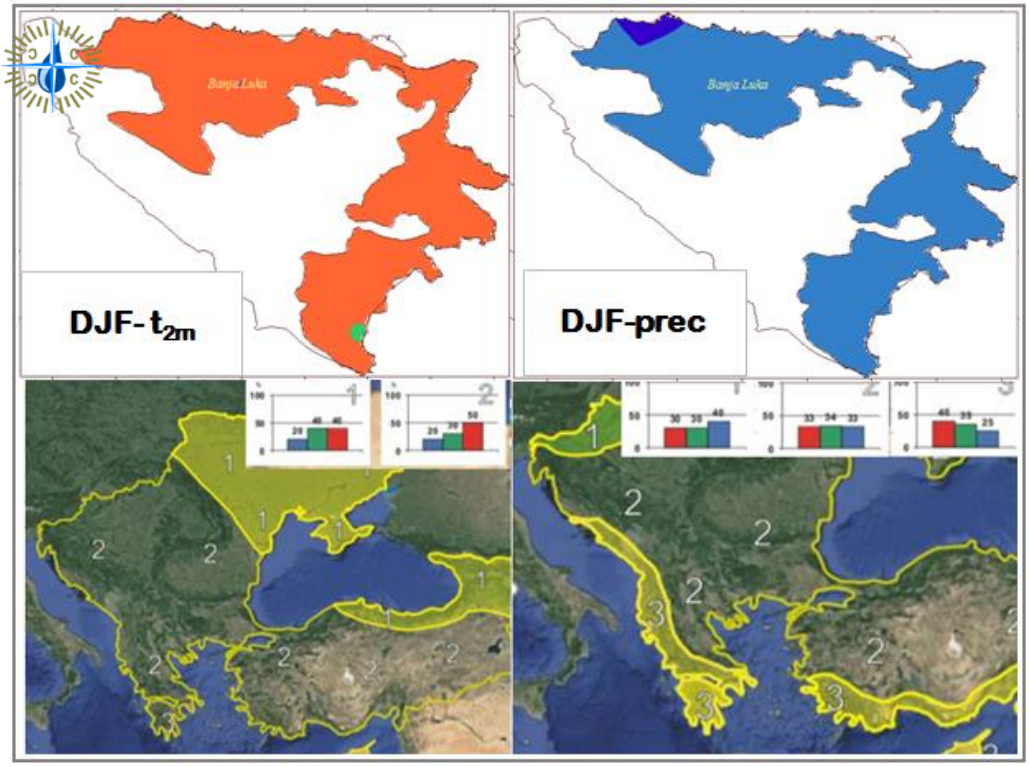


Figure1: Temp (left) and PRC tot (right) DJF18 Outlook

For the southern area, along the coastal region, precipitation amounts had been predicted like below lower tercile value and "no clear signal" for the remaining part of the country (the portions 3 and 2, right).

- ***The Republika Srpska registered warm air thermal conditions and wery wet to extremely wet conditions over the most stations with acumulated snow cover greater than normal;***
- *Precipitation total reached 10th highest over the Southern and 5th max value over the rest in 137 years long data series.*
- *In Banja Luka, acumulated precipitation of 146mm, represents the second highest from 1862 years and differs from the absolute maximum (148mm;1889) just in 2mm.*
- *Snow depth on the end February days reached 2-3 highest value in the north-western part (Krupa na Uni, 96cm).*
- *The last winter season has been 11th warmest over the period 1952-2018 (7th warmest for the 1981-2018)*
- *Temperature, daily max, reached the first lowest value from 1961 (Bijeljina, Banja Luka, Doboj, Sokolac...) on several days from 25-28 feb.*
- *Lowest daily maximums Txn were exceeded* on *26-28 february*

1. Analysis of the 2018 Winter season

Air temperature: *above values of upper tercile*

Table 1. DJF-2018 mean temp statistics over The Republika Srpska (ref 1981-2010)

Station	z (SPI)	NORMSDIST (z) (Percentile)	PercRank (ref1981-2010)	DJF 2018 °C	djf18 anomaly °C (1981-2010)	33,33	50,00	66,67	tercile anom.categ
Бања Лука Banja Luka	1.17	0.88	0.89	3.5	2.0	0.6	2.2	1.3	above
Приједор Prijedor	0.87	0.81	0.81	2.7	1.3	0.5	2.1	0.8	above
Нови Град Novi Grad	0.96	0.83	0.85	2.8	1.6	0.5	1.9	1.1	above
Добој Doboj	1.23	0.89	0.90	3.3	2.0	0.7	2.2	1.0	above
Бијељина Bijeljina	1.13	0.87	0.86	3.6	2.0	0.6	2.2	1.4	above
Соколац Sokolac	1.02	0.85	0.86	-0.8	1.5	-3.0	-1.5	-2.8	above
Билећа Bileca	0.26	0.60	0.64	4.2	0.3	3.3	4.3	4.0	above
Гацко Gacko	0.79	0.79	0.83	0.3	0.8	-1.2	-0.4	-0.5	above
Чемерно Cemerno	0.77	0.78	0.73	-1.4	0.7	-2.7	-1.5	-2.2	above
Требиње Trebinje	0.87	0.81	0.60	6.4	1.0	5.7	6.6	6.2	above
Дрињић Drinic	0.72	0.76	0.75	0.4	1.1	-1.3	-0.2	-0.9	above
Мрк. Г. Mrkonic G.	0.71	0.76	0.76	1.7	1.2	-0.2	1.0	0.3	above
Фоча Foca	1.12	0.87	0.83	2.3	1.5	0.3	1.3	0.7	above

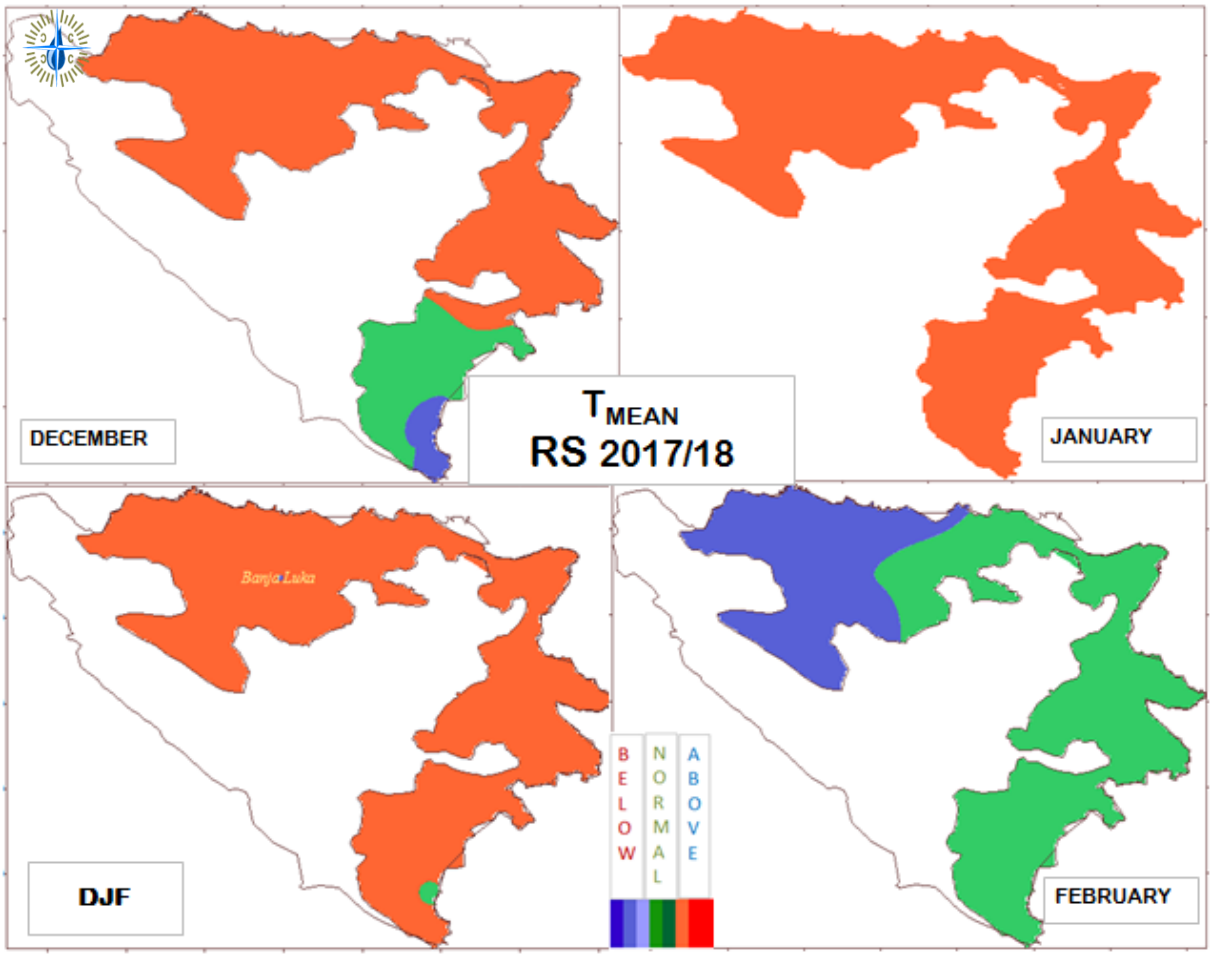


Figure 2:Spatial distribution of Tmean Percentile ranks, based on 1981-2010, over the RS stations for the winter months December (warm, normal to cold in southern), January (warm) February (cold in north-west, normal in the rest of) and for DJF 2018 season (warm)

Mean air temperature, on seasonal scale, throughout RS were above the multi-annual average, relative to its 1981–2010 normal value. Anomalies range from 0,3ºC (Bileca) to 2ºC (Banja Luka, Doboj, Bijeljina), as it is presented at the table 1. Tmean were from -2,7ºC (Sokolac) to +5,8ºC (Trebinje); Banja Luka 0,4ºC; TXx: from 9,8 (Srebrenica) to 17,7 (Ribnik); Banja Luka 14,1ºC; TNn: from -17,4 (Sokolac) to -1,6 (Trebinje); Banja Luka -8,9ºC. *Lowest daily maximums were exceeded* on *26-28 fe*b.

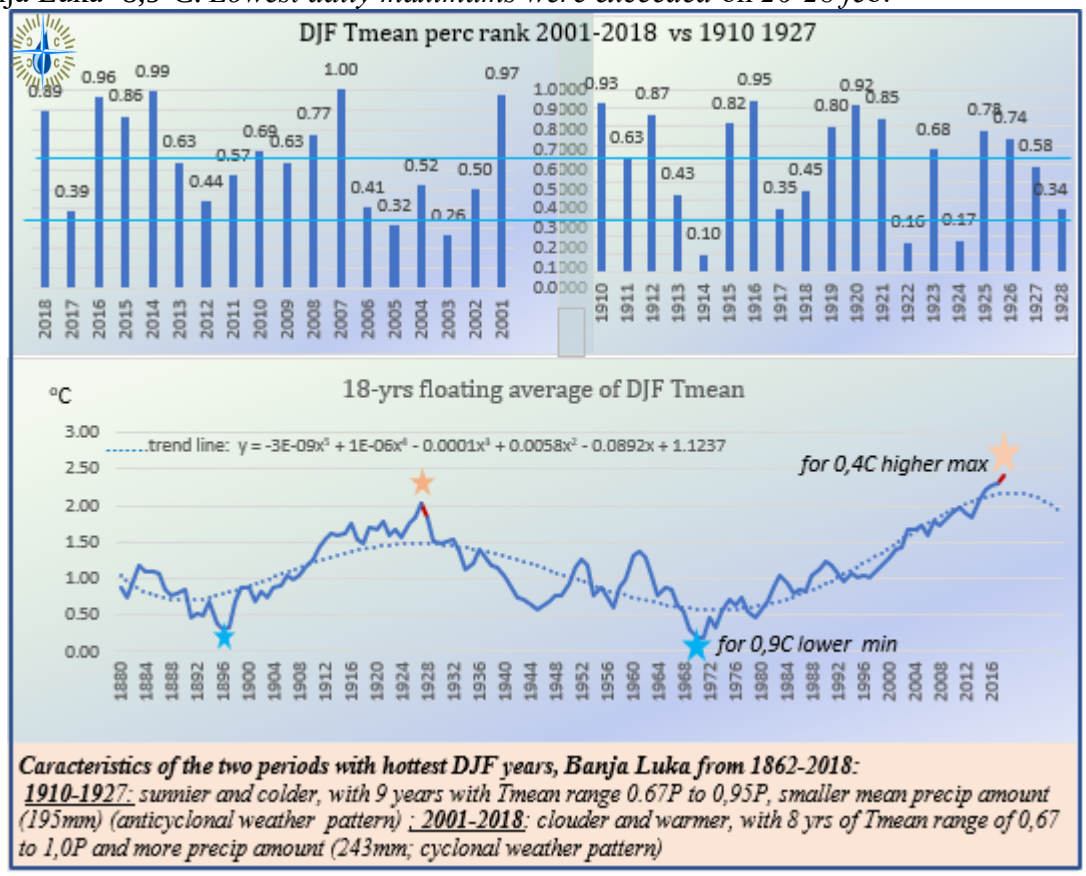


Figure 3 T_{mean} trend in Banja Luka, Rep. Srpska 1861-2018

Fig 3 has shown polynom trend line that fits 18-yrs moving average of *winter* T_{mean} *i*n Banja Luka. It is notable clear long term climate seasonality - with two mins and two maxs over the 137 yrs long period. Graf has shown that *newer minimum (1952-1970 is lower* than the previous one (1879-1897) for -0.9C but the last 18-yrs maximum of Tmean is larger, for 0.4C from the previous maximum of 1908-1926. The 18-year moving average over the period shows that the choice of a linear function to show the trend over the whole data seria of Tmean hides the information of the seasonality (repetition) of warm and cold patterns and that polynom trend line of a second or higher degree is more mimicking empirical (measured value) function.

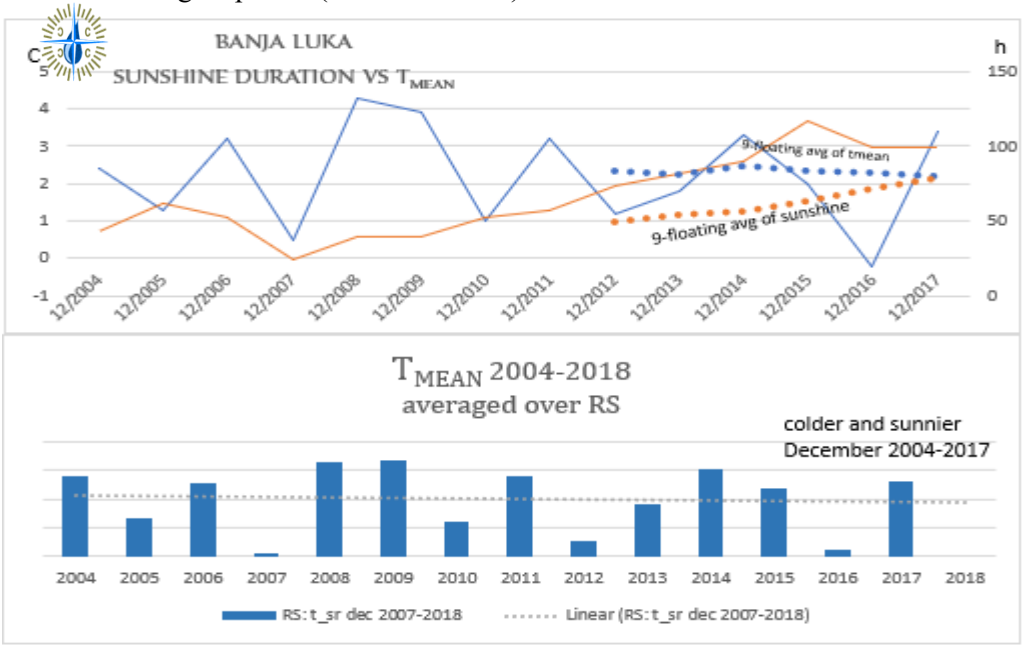


Figure 4: upward tremd of insolation (orange) and slight downward trend of mean temp in Banja Luka in the recent past

According to increasing sunshine duration in winter months during the recent past, and ongoing downward seasonal trend of temperature, extremely cold days and breaking records during this century, early autumn and late spring frost (april/may 2016) and moving the first *averaged date* of snowcover and frost to earlier, the latest one to the later of spring, cooling trend *has been on* and winter weather pattern has lasts longer time.

Analyse of December over the whole period has shown downward Tmean trend with long term increasing Sunshine duration (more sunshine means very cold weather pattern-anticyclone prevailing).

137-yrs weather pattern during January behaves different, warmer and cloudier; 100yrs moving Sunshine average decreases, T_{mean} increases – more cyclone activity. Cyclonic pattern with much snow, followed by strong wind (cyclone type of waether which are replaced by anticyclonal) are registerd during winter 2018 (like the ice days on January (Mrakovica Kozara) and ending February 2018 in Banja Luka, Drinic, Bijeljina, Sokolac, Han Pijesak...) when it was registered the lowest value of daily Tmax in many places *with departure* less than minus two degrees of Celsius (-3,4 Cemerno, -2,8 Sokolac, -2,6 Banja Luka, -4°C Trebinje).

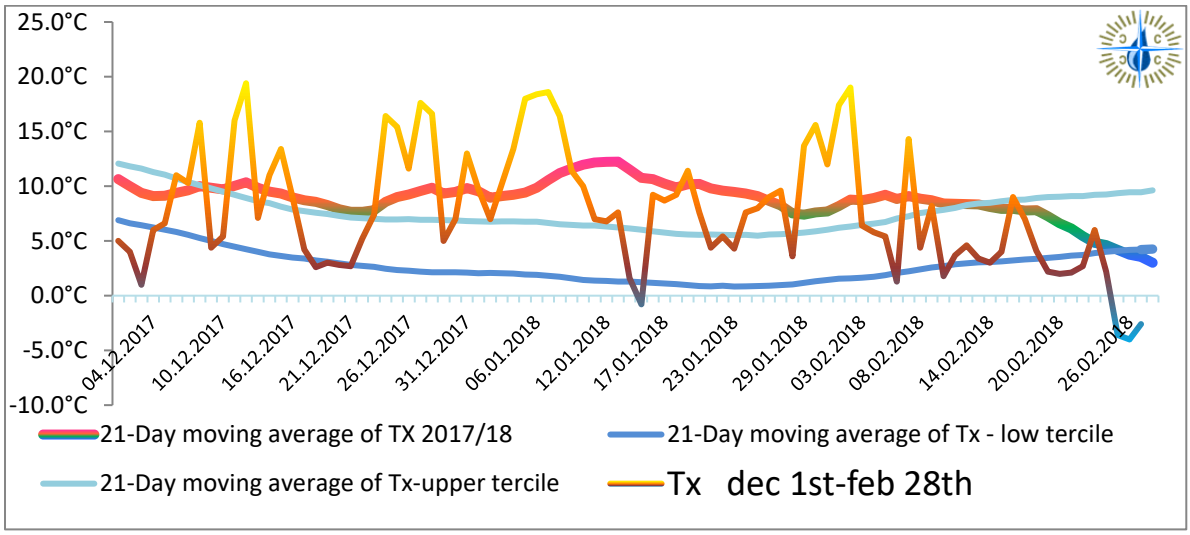
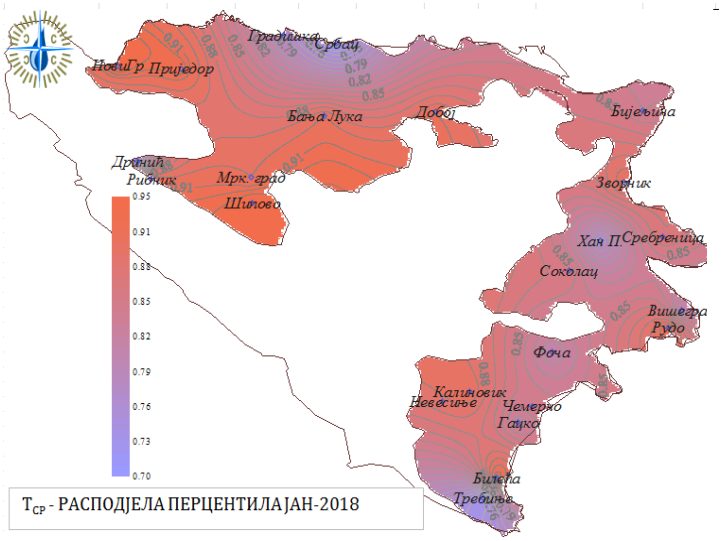


Figure 5: three weeks running means of Tx, lower and upper terciles relative to 1981–2010 and Tx over the *December 1st-February 28th; Bijeljina, RS*

1961-2018 extremes were also recorded with positive departures of 2.3 to 3.6°C, like Bijeljina station on 27 and 28 December 2017 where the highest daily maximum temperature (Txx: 17.6 and 16.6°C) were 2.3 and 3.6°C greater than prevoius maximum (15.3 and 13°C).



According to Januaries 1981-2010 Percentiles ranks, this month is qualified like very warm/extremely warm over the most RS.

Averaged for the recent 12 years period over the territory of the Republic of Srpska, the January day *is colder* (the trend line of Tmean from 2007-2018 has a fall). In this 12-year period, the coldest January day was last year (2017) and it has not been so cold since 1985; The hottest were in 2014, 2007 and 2018.

January 2018 is the fourth warmest in 1951-2018 time span. Last year, 2017 was the fourth coldest in that time spell.

For the 1951-2018 Februaries, the coldest weather pattern was in 1956, 1954, 1965; in the twelve coldest years - three among them of this century. With the average of -3.56C, February 2012 was the fourth coldest.

In February 2018, Kalinovik, Mrkonjić Grad, Drinić, Krupa na Uni, Mrakovica and Han Pijesak had over 15 days with a mean daily temperature below zero. On the coldest February days, the Tmean ranged from -16.1°C in Drinić (Feb. 28, 2018) to -2.5S in Trebinje (Feb. 27 - 2018), where it was the hottest, though below zero. On the hottest day of this month, the Tmean range was +4.2 in Cemerno (Feb 2nd) to +12.4 degrees C in Banja Luka (February 1st). The biggest difference between the hottest and coldest day of February was in Drinic (20 degrees Celsius). With the exception of Trebinje, Bileca and Visegrad, in every place there were less than 5 days with Tmean over 5°C.

Lowest daily maximums Txn were exceeded on ending February (*26-28 fe*b) when Tx of coldest ice day was smaller than previous lowest daily max for negative departure of *-0.8°C to minus 2,4°C* over the *north* of RSrpska (Txn: -5,4°C Banja Luka; -6°C Bijeljina, -9,5 Sokolac; -12,2°C Cemerno), *minus 2.8 to minus 3.4* in the *mountain area* (Sokolac and Cemerno) and up to *minus 4°C in the sothern* places (-0,4 Trebinje, on 27th feb) . Southern area registered breaking Tmin (Trebinje -6,5°C).

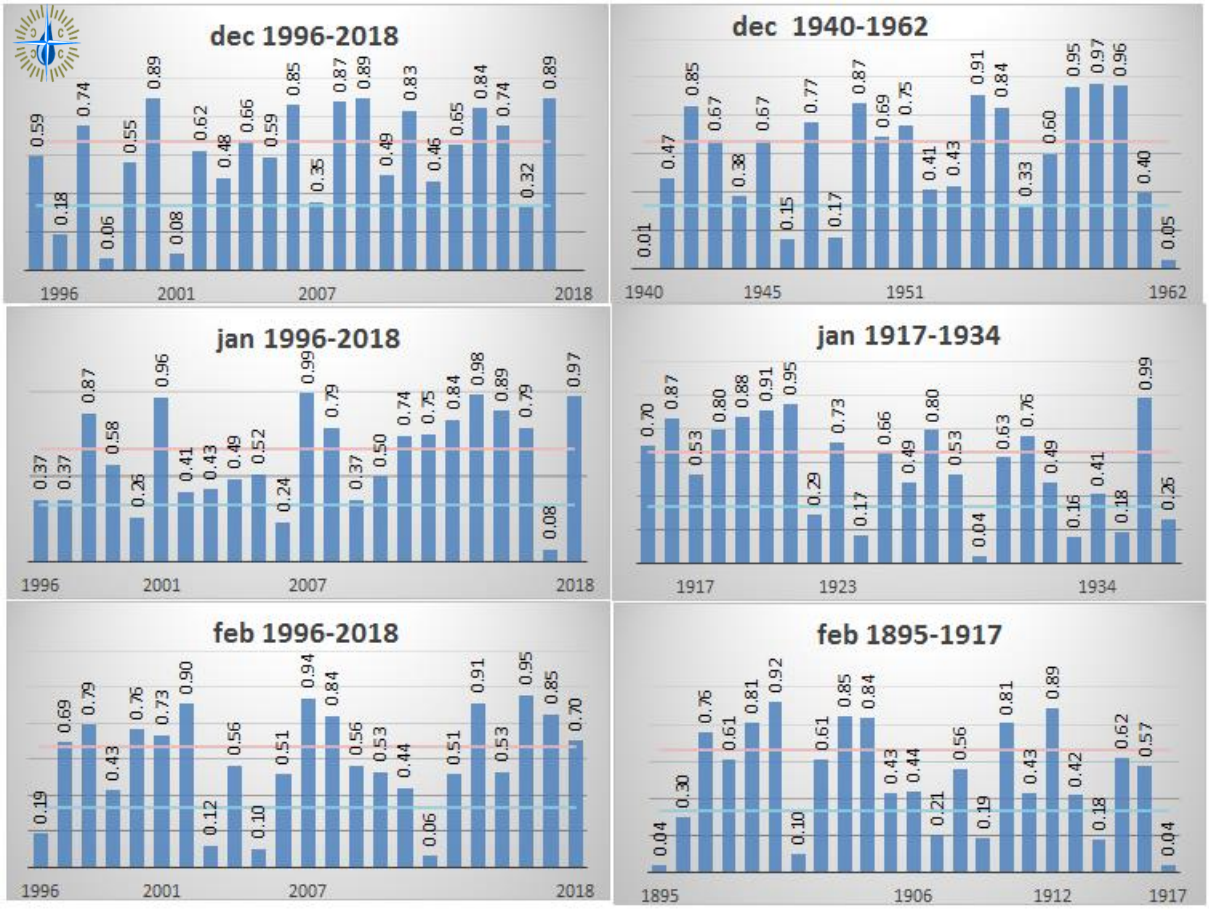


Figure 6: Percentile (according to standardized values) with respect to 1961-2017 in two similar thermal conditions, Banja Luka

The periods of similar thermal conditions *over two decade,* with warm, very warm and extremely warm winter months, are shown in figure 6. Sunshine duration/cloudiness and southern directions of wind influenced those warm climate variability, with return period of 60-100 years. In the period 1940-1962 with

4 years above 0.90th percentile, December, was warmer than in the recent two-decade period of 1996-2018 when percentile ranks were below 0.90P.

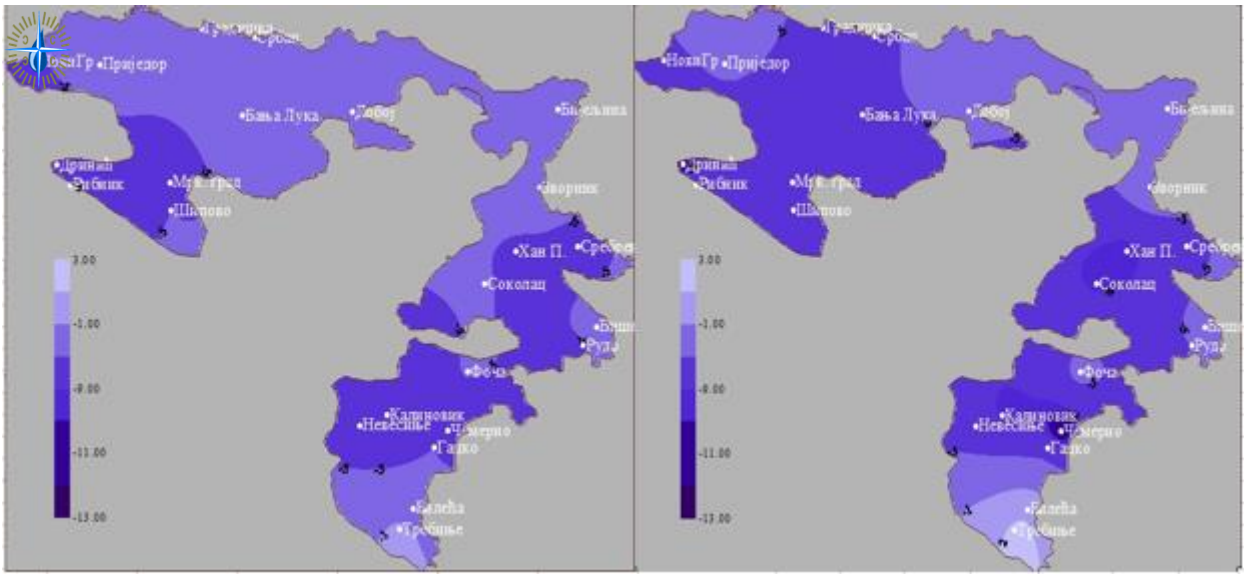
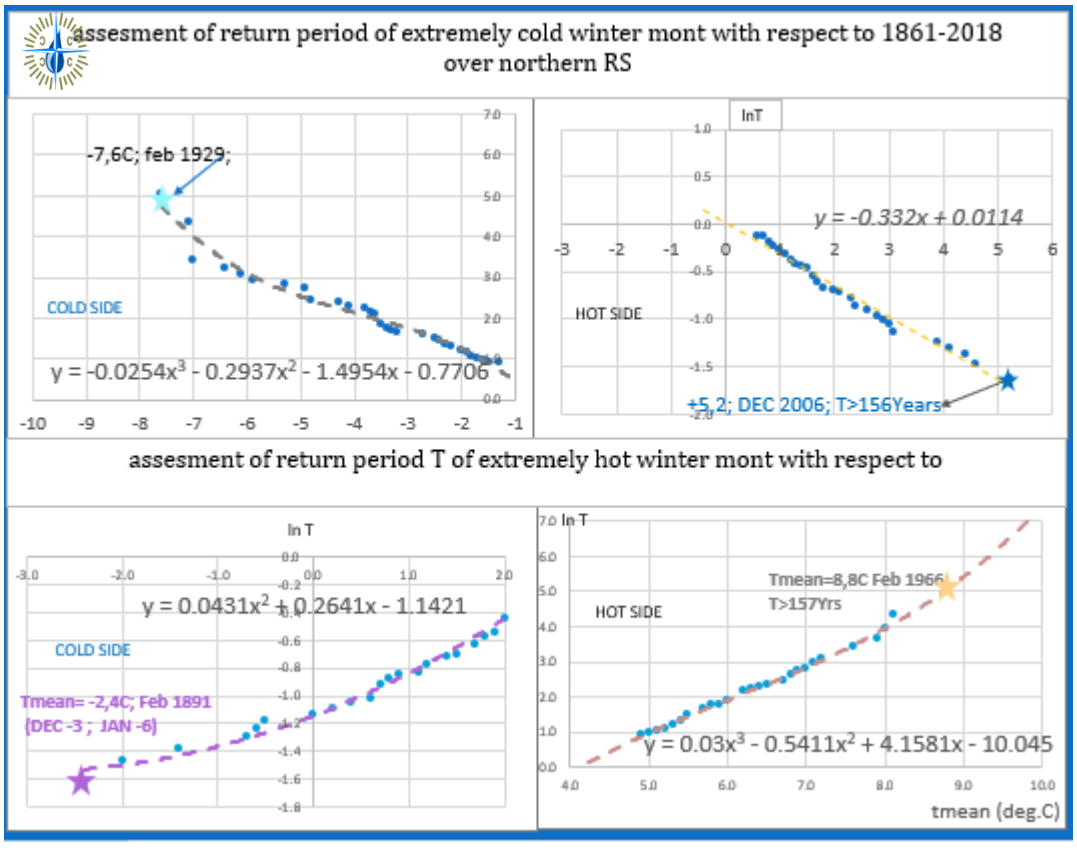


Figure 7: breaking record of Txn (coldest days in 1961-2018, first lowest T_{maxi} on 26 and 27 Feb 2018 over the most RS stations (Bijeljina on 28.feb minus 6 deg of C)

Breaking 30yrs coldest day record of TXN, with respect to 1981-2010 was happened more frequently during this century on winter's day (like 2001, 2005, 2006, 2007,2009,2010, 2012, 2016, 2018). The coldest first half of February was in 2012 year, with the lowest TXN (1961-2018), during 3-15 ice days in Feb, over the most RS stations.



Figures 8: Estimated return period (Gumbel/Jenkinson) of extremely cold (up) and extremely hot winter months (down) with respect to 1861-2018 over the nortw-west of RS (extreems belong to Februry month excepting hot side of extremely cold event were it is December)

Over the 1961-2018 climatological dataset of in Banja Luka from 28 days of lowest Februaries Tmax, 20 days belong to 1981-2018. In Bijeljina, almost all coldest days in this month are connected to 2000-2018.

The winter season was the 7th warmest 'climatological' winter from 1981 to present. Of the 12 coldest winters, 5 belong to 21century; from 12 warmest ones, 7 belong to this century.
In all three months la Nina related severe weather phenomena (strong wind dust and freezing coldness, heavy rain and snowing, especially during late February, were observed.

The highest maximum of the months were recorded on 12th of December in Zvornik (19,5℃), on 7th of January in Banja Luka (19,3℃) and on 17th February in Bijeljina (19℃).

Precipitation

According to percentile ranks and classification ratings, precipitation amounts for DJF-2018 have been described by the following categories: **extremely wet – close to extremely wet** over the north-western part (Novi Grad, Prijedor, Banja Luka, Krupa na Uni, Mrkonjic Grad, Sipovo, Doboj, some southern high area near Gacko and Cemerno), **very wet** over the wider area of north and east (Srbac, Gradiska, Bijeljina, Han Pijesak, Foca) and **wet** at the remaining part of RS like Drinic, Sokolac, Bileca. Some places over the south, like Trebinje, were in the normal rank.

In the northern area winter 2017/18 was the fiveth-wettest in a series from 1862, with only winters 1970, 1888, 2010 and 2013 being wetter. In December and February above normal precipitation amounts were registered over almost all territoty.

'Climatological winter', averaged over the RS, excluding southern, was ***very*** to **extremely wet** (> 0.98th percentile), with historical floods, caused by melting snow at the begining March, when it was breaking 1947 water level max, near Gradiska (Sava river). It was wet and over the rest, excludeing some portion of the south (Trebinje) and near Sokolac where it was near normal.

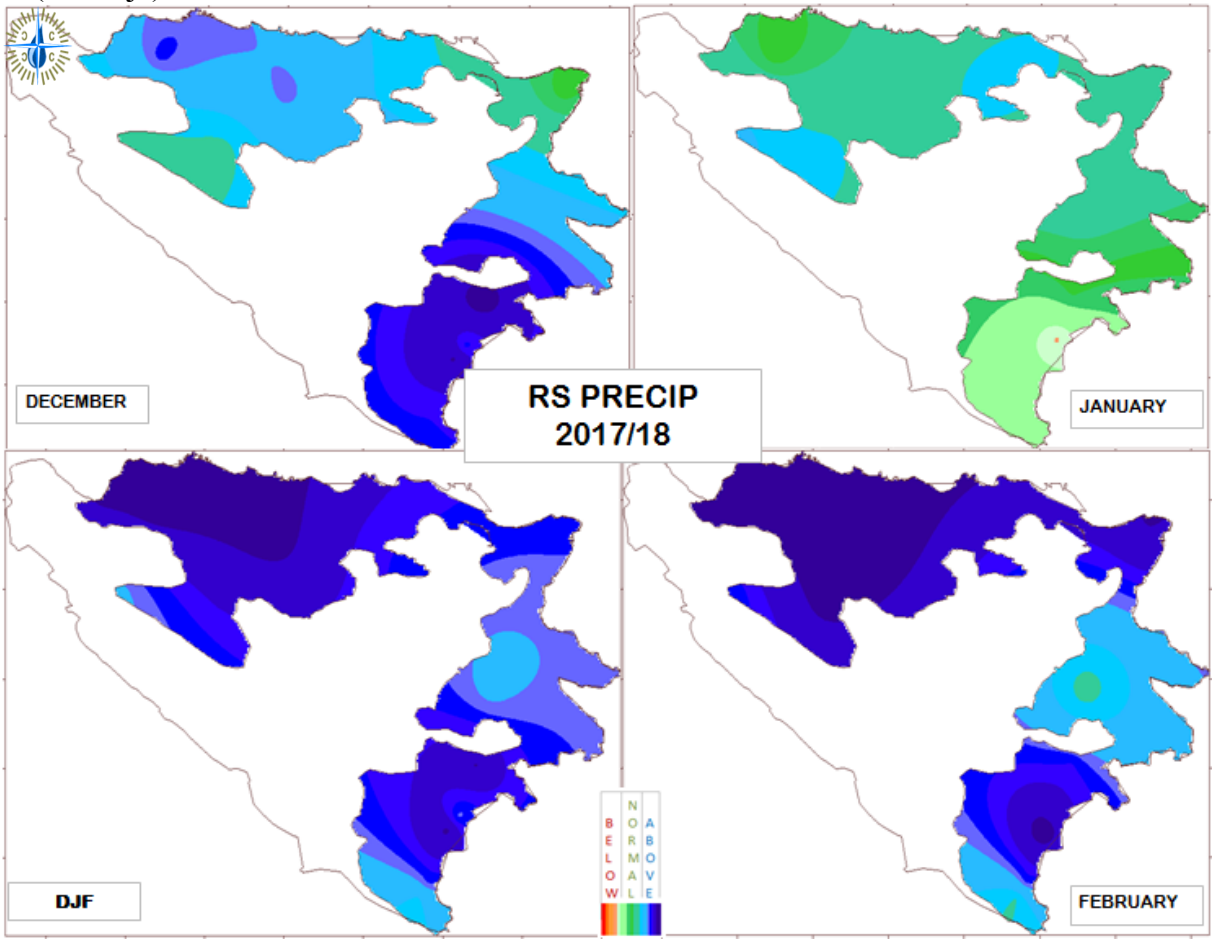


Figure 9: Percentile ranks of precip, based on 1981-2010 over the RS stations for the winter months separately and all the DJF 2018 season

In February it was extremely wet weather conditions over the north-west; trend (suficit) of precipitation, regarding 1981-2010 climatology, range from +45% (Banja Luka) to +103% (Novi Grad)and 138% and Prijedor. Gacko measuerd surplus of +79.8%. Acumulated precipitation of 146mm, has been *the second highest amount over the 137 years in Banja Luka*, and differs from the absolute maximum (148mm;1889) just 2mm. Banja Luka, Novi Grad, Prijedor, Sipovo, Krupa, Gacko and Srbac were *extremely wet*; Mrkonjic Grad and Bijeljina *very wet* (close to extremely wet).

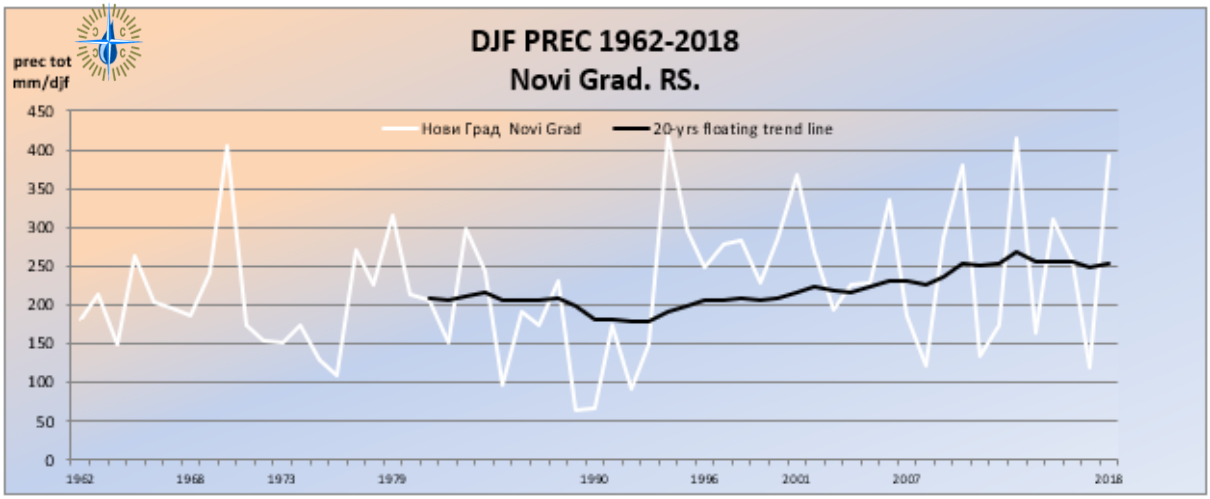


Figure 10: DJF1962-2018 precipitation over the nothwestern RS. Novi Grad have occured increasing 20-yrs DJF trend from 1992

Novi Grad, and many others north western and eastern places, occured increasing 20-yrs moving precipitation trend (from 2008) and this seems to be qualified like climate fluctuation/conditions over the area connected to the seasonal outlook like „no clear signal“ during recent past, that means, dependable of climate like this. The same ocured over the south, but with smaller positive departure.

The graphs have shown increasing 20-yrs floating trend from 2008 in Novi Grad (same over the rest of RS). The similar increasing precipitation has occured in the southern - this winter precipitation total belongs to wet category in average (10th highest amount per DJF season). Precipitation regime is significantly different over the south regarding the amount of precipitation and the pattern over the year, so this area had a signal of smaller amount and that was good.

Table 2. driest and wettest 12 of the DJF 1962-2018, The Republika Srpska

FJD 1961-2018 RS southern

Driest 12	90	153	172	180	245	253	267	295	307	336	361	366
	1992	1975	1990	1993	2002	1989	2017	1976	1998	1985	2008	1962
Wettest 12	742	745	749	759	769	781	797	816	831	882	894	1045
	1979	1969	2018	1965	1996	1986	1963	1970	2009	2013	1977	2010

FJD 1961-2018 RS northern

Driest 12	73	77	106	111	126	127	128	130	131	138	140	147
	1989	1990	1992	1975	1972	1985	1976	2008	1993	1973	2017	2014
Wettest 12	276	277	281	290	291	298	298	303	352	400	401	410
	1979	1977	1983	2006	1965	1969	1994	2015	2018	2010	2013	1970

At the northern, eastern and midle area, from the twelve highest DJF precip amount in the 1981-2018, five have been in this century, 2018 is third highest; 2010 and 2013 are the years connected to secondary maximum with difference just one millimeter.

North areas: from 12 wettest DJFs from 1861, six belong to 1981-2018 period, and there is no one among driest from 1981 onwards.

Table 3. DJF-2018 Precip statistics over The Republika Srpska (ref 1981-2010

Station	z (SPI)	NORMSDIST (z) (percentile)	PercRank (ref1981-2010)	DJF 2018 (mm)	DJF 2018 prec % (ref1981-2010)	suf/def %	33,33	66,67	50,00	tercile anom.categ
Бања Лука Banja Luka	1.94	**0.97**	0.98	**368**	164	64.4	209	250	232	above
Приједор Prijedor	2.72	**1.00**	1.00	**380**	188	88	175	228	208	above
Нови Град Novi Grad	1.87	**0.97**	0.98	**392**	174	74	190	272	228	above
Добој Doboj	1.16	**0.88**	0.97	**259**	136	36	175	217	195	above
Бијељина Bijeljina	1.01	**0.84**	0.86	**212**	132	32	140	182	161	above
Соколац Sokolac	0.79	**0.79**	0.81	**230**	131	31	150	207	179	above
Билећа Bileca	1.02	**0.85**	0.90	**685**	144	44	384	550	502	above
Гацко Gacko	1.89	**0.97**	0.97	**922**	190	90	381	573	472	above
Чемерно Cemerno	0.96	**0.83**	0.84	**702**	142	42	381	615	488	above
Требиње Trebinje	0.54	**0.71**	0.67	**689**	122	22	460	681	568	above
Дринић Drinic	0.87	**0.81**	0.83	**496**	137	37	296	429	403	above
Мркоњић Г. mrkonic c.	1.30	**0.90**	0.92	**369**	140	40	236	292	277	above
Фоча Foca	1.70	**0.96**	0.94	**343**	182	82	150	173	163	above

Historical data series for the winter months of the1882-2018 for Banja Luka has shown upward trend; acumulated precepitation for december-february was in *extreem* category (0.98P) - **fourth highest over 137 years!**

driest 12	119	113	109	109	107	97	89	83	79	68	62	60
	1972	1883	1976	1992	1903	1925	1989	1894	1890	1990	1885	1949
wettest 12	457	457	414	368	356	345	335	328	326	315	314	310
	1970	1888	2010	2018	2013	1907	1915	1960	1983	1981	1936	1994

From 12 wettest DJFs from 1861, six belong to 1981-2018 period, and there is no one among driest from 1981 onwards. Treating the whole period with measurements, the range of „normal“ DJF precipitation fall in **178-237mm** range**.** For the 1981-2010 climatology, the normal range is **209-250mm.** Climatology statistics of lower and upper tercile differ because of *increasing trend* of *winter* precipitation; *arithmetical mean* value moved to larger values of the corresponding percentile, and for the 1981-2010 reference it is not at median (0.5^{th} P) but around 0.6th percentile. Increasing trend of precipitation and temperature according to higher percentile value of arithmetical mean ie their larger terciles categories value of 30-yrs normal that seems to be too short to present real state of empiric distribution of percentiles and theirs corresponding return period. Gumbel theory of extremes fit better to „percentile rank“ over the whole data period of measurements – the return period of extreme events significantly failed with the percentile based on standardized index (normalized values) and short period of reference**.**

1. **High impact events:**

-- Huge snow depth caused floods during melting in March over western Sava River Basin.

(Gradiska, 1947 water level max had broken 2018)

--Ending February was extremely cold / *lowest* daily Tmax record

2.Verification of the SEECOF-18 & MedCOF-9 climate outlook for the 2018 winter

Country	Seasonal temperature (DJF)		Seasonal precipitation (DJF)	
	Observed	SEECOF16, MedCOF-6 climate outlook	Observed	SEECOF16, MedCOF-6 climate outlook
The Republika Srpska - Bosnia and Herzegovina	*Above upper tercile* ***Tmean**: from -1,6 Han Pijsak to 6,4 Trebinje;)* ***Tmax**: from 10°C (Gacko) to 19,5°C (Zvornok;)* ***Tmin:** from -19,9°C in Drinic to -6,5°C in Trebinje;* *(0,76 – 0,89P Warm)*		*Above upper tercile* ***precip total** from 192mm (Srbac) to 922mm (Gacko).* (0.7 to 1P Very vet to extremely wet)	No signal (means usual climate conditions would prevail)

The outlook for DJF 2018 for both elements, mean temperature and precipitation had been correct, even for the precipitation was *no signal (no unusual decadal drivers, excepting February and strenghtened La Nina).*

Bearing in mind increasing precipitation trend as the nearest climate variability, over the whole teritory, especialy over the north-western areas, precipitation forecast was correct - for it favoured ***climate conditions*** over the wide MedCof&SEECOF area, dependable on *precipitation regime* on decadal or longer time scale.

Mean temperature for the Republika Srpska is calculated from three time measurements (Tmean1) according standard formula { TG14 =(t07+t14+t21+t21) ¼}. DJF anomaly: + 1,29°C for RS in average. It is important to mention that Tmean2, calculated from Tmax and Tmin { TG5= (Tmax+Tmin)* ½ } **significantly difers** at daily scale (up to 5deg C, depending to amplitude) and much less, but significantly also, at montly level (gives greater values as ending results on monthly or annual levels) and one shouldn't be replaces by another. Actually, when it is colder in the evening, Tmean2 is warmer up to 6 degrees.*

This is to say that, according to Tmean2 it has been less cold when it is too cold but much warmer when it is very hot.

***For example, in Banja Luka monthly Tmean2 in December is greater 0,71degC from Tmean1**; on daily scale, December 9th Tmean2 differs up to +6,3 °C (T07=0,7°C; T14=0,9°C; T21=-1°C; TMIN=-1°C; TMAX=6,2°C).*

According to RHMS Banja Luka, Tmean is always presented like Tmean1 (TG14).