Examination of the effect of evapotranspiration as an output parameter in SPEI drought index

BIOCLIMATE
Source and Limit of Social Development
6th-9th September 2011
Chateau Topolcianky, Slovakia

Vera Potop[1], Martin Možný[2]

[1]CULS, Department of Agroecology and Biometeorology
[2]Czech Hydrometeorological Institute, Doksany

Abstract. We examined the effects of two different parameterizations of potential evapotranspiration (ET) in calculating water balance as an output parameter into SPEI drought index. The first parameterisation is derived from daily precipitation, saturation vapour pressure, vapour pressure, the vapour pressure deficit and mean air temperature in 2 p.m. local time (AMBAV model). The second parameterisation is based on minimum and maximum air temperature and extraterrestrial radiation (Hargreaves model). Then, we examined this suggestion by running the SPEI model at twice at station for the period 1901-2010. In the first run, SPEI is based on output ET calculated by AMBAV model (ET_{AMBAV}). In the second run, we calculated SPEI time series using Hargreaves approach (ET_H). In order to evaluate effect of ET calculated by 2 methods on SPEI drought index, we have used the following approach: (1) the relationship between monthly potential evapotranspiration estimated by AMBAV and Hargreaves models, (2) correlation of time series of the monthly SPEI parameterisation by ET_{AMBAV} and ET_H, (3) the long-term temporal distributions of ET_{AMBAV} and ET_H, as measured by temporal trend per decades and correlation coefficient of linear trend.

Introduction:

One the decisive factor contributing to the high drought risk in the lowland areas in the Czech Republic is the relatively low precipitation and high potential evapotranspiration (ET), which leads to an insufficient accumulation of moisture in the soil during in the growing season. Evapotranspiration is the most effective climate parameter at mid-latitudes in explaining the intensification of drought conditions (Vicente-Serrano et al., 2010). For the estimation of drought severity, apart from precipitation the inclusion of evapotranspiration gives a more realistic estimate of water deficits. If ET is omitted in this water balance, the severity of drought is underestimated. However, it is widely recognized that ET determines soil moisture variability, and consequently vegetation water content; which, directly affects agricultural droughts commonly recorded using short timescale drought indices. Thus, drought indices that only use evapotranspiration data to monitor agricultural drought are better than precipitation-based drought indices (Možný et al., 2011). In general, methods for estimating ET are based on one or more meteorological elements. Certain of these methods are accurate and reliable; others provide only a rough approximation (Kohut, 2003).

In this study, daily and monthly potential evapotranspiration are integrated to estimate the evaporative power of the atmosphere and to explain effect upon drought conditions.

Materials and methods:

In this paper, we examined the effects of two different parameterizations of potential evapotranspiration (ET) in calculating water balance as output parameter into Standard Precipitation-Evapotranspiration Index (SPEI) (developed by Vicente-Serrano et al., 2010). The SPEI is based on a monthly (or weekly) climatic water balance (precipitation minus evapotranspiration) that is adjusted using a three-parameter log-logistic distribution to take into account common negative values. SPEI index also has capacity to combine impact of temperature and precipitation by estimating changes to potential evapotranspiration during drought.

The first parameterization is derived from daily precipitation (r, mm), saturation vapour pressure (E, hPa), vapour pressure (e, hPa), the vapour pressure deficit (d, hPa) and average air temperature (t, C) in 2 p.m. local time (Agrometeorological Model for Calculating the potential evapotranspiration model (AMBAV); Löpemier, 1994). The second parameterization is based on minimum and maximum air temperature and extraterrestrial radiation (Hargreaves model; Hargreaves and Samani, 1985). The daily total extraterrestrial radiation is calculated theoretically as a function of station latitude, day of the year, solar angle, solar constant and the relative distance of the Earth from the Sun. Then, we examined this suggestion by running the SPEI drought index at twice at each station for the period 1901-2010. In the first run, SPEI is based on output ET calculated by AMBAV model (ET_{AMBAV}). In the second run, we calculated SPEI time series using Hargreaves approach (ET_H).

The comparison of these 2 methods is made on monthly, seasonal and annual bases. In terms of the diagnostic statistic the following measures are given: (1) correlation coefficient (r), (2) coefficient of determination (R in %) and (3) relative root mean square error (RMSE in %).

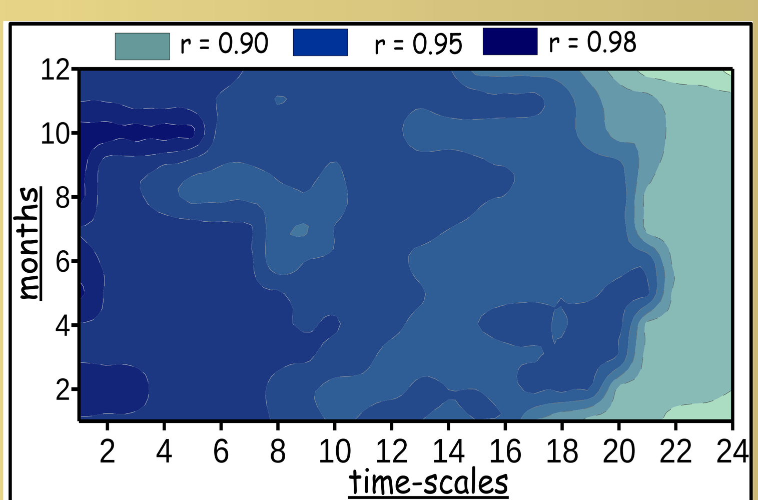

Figure 1.
Correlation coefficient between monthly SPEI parameterisation by ET_{AMBAV} and ET_H at time scales from 1 to 24 months

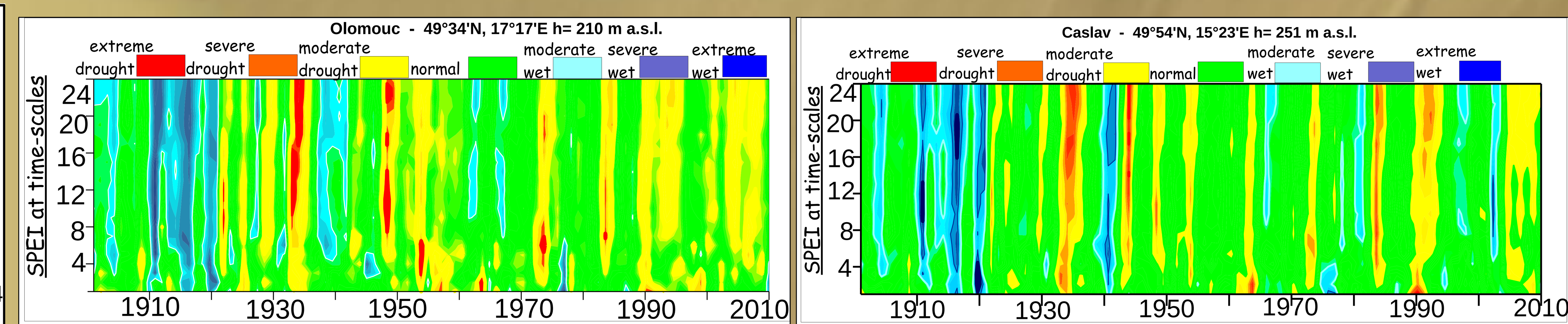

Figure 2.
Secular temporal evolution of the time series of Standard Precipitation-Evapotranspiration Index (SPEI) parameterisation by ET_{AMBAV} at time scales from 1 to 24 months

Table 1.
The relationship between monthly ET estimated by AMBAV and Hargreaves models. α_0 is the intercept; $\beta_1 h$ is slope; r is correlation coefficients; R (%) - coefficient of determination; RMSE (%) - relative root mean square error.

Months	α_0	β_1 h	r	R (%)	RMSE (%)
		ET			
April	48.8	1.08	0.81	80.0	25.9
May	81.4	0.97	0.89	85.1	20.3
June	114.3	0.63	0.52	58.0	90.2
July	98.8	0.86	0.50	51.3	89.0
August	79.7	0.75	0.85	83.3	30.1
September	54.1	0.55	0.75	80.4	32.4

Results and discussion:

In order to evaluate effect of ET calculated by 2 methods on the SPEI drought index, we have used the following approach:
(1) The relationship between monthly potential evapotranspiration estimated by AMBAV and Hargreaves models (Table 1),
(2) Correlation of time series of the monthly SPEI parameterization by ET_{AMBAV} and ET_H (Fig. 1),
(3) The long-term temporal distributions of ET_{AMBAV} and ET_H, as measured by temporal trend per decades and correlation coefficient of linear trend (Table 2).

An examination of the monthly estimates of the ET_H in comparison with the ET_{AMBAV} estimates shows relatively great differences, especially on June and July (Table 1). Thereby, the correlation (r=0.50-0.52) and determination coefficients (R=51.3-58.0 %) between the 2 estimates in those months are much lower than rest of months. On a monthly RMSE there exists a better agreement during spring (from 20.3 to 25.9 %) and autumn (from 30.1 to 30.1 %) months.

In the Table 2 the trend is the slope of the linear regression, with ET as the dependent variable and time as the independent variable. Table 2 shows that: (1) The ET_{AMBAV} shows the similar decadal tendency as those of the ET_H but are greater in magnitude in most decades. (2) In the period 1991-2000 both runs the ET_{AMBAV} and ET_H estimates gives an increasing trend for annual and all season, but statistical significant are only in spring and summer. The reason is that in most regions of the Czech Republic air temperature has been increasing during recent decades. Contrary, the negative linear slope of trends in ET estimated by AMBAV and Hargreaves models was found in the period 1971-1980.

Graphical examination of the monthly patterns of the correlation coefficients (r) between monthly SPEI parameterization by ET_{AMBAV} and ET_H at various timescales is included in Fig. 1. A strong correlation series was detected between two approaches (r = 0.90 to 0.98), however, few differences was found. Therefore, in this study, we selected ET using the AMBAV approach to calculate SPEI. In Fig. 2 is shown temporal evolution for data series of SPEI parameterization by ET_{AMBAV} at time scales from 1 to 24 months. Drought appears first in the short time scales and if dry conditions persist, the drought develops at longer time scales.

Conclusion:

We can conclude that for all months in the summer half-year, the ET_H method overestimates the ET. This may not be surprising as ET_H uses only temperature as input data, depending the season, other variables like wind speed, humidity and solar radiation may determine the magnitude of ET.

Table 2. Linear slope of (ET, mm yr^{-1}) trends in ET estimated by AMBAV and Hargreaves models. R^2: correlation coefficient of the linear trend; *statistical significant.

	ET_{AMBAVE} Trend	ET_{AMBAVE} R^2	ET_H Trend	ET_H R^2
		1961-1970		
Spring	-0.17	0.09	-1.07	0.05
Summer	1.25	0.08	1.32	0.04
Autumn	-2.02	0.28	-1.26	0.15
Annual	-0.95	0.02	-1.10	0.01
		1971-1980		
Spring	-1.47	0.19	0.87	0.05
Summer	-6.10	0.58*	-2.89	0.14
Autumn	-2.70	0.31*	-0.44	0.02
Annual	-9.89	0.55*	-2.31	0.03
		1981-1990		
Spring	2.09	0.19	2.80	0.14
Summer	0.09	0.01	2.49	0.04
Autumn	-1.50	0.09	-0.63	0.03
Annual	1.76	0.02	4.99	0.06
		1991-2000		
Spring	2.35	0.26*	3.66	0.30
Summer	3.22	0.47*	6.34	0.45*
Autumn	1.26	0.11	3.22	0.10
Annual	1.22	0.20	2.10	0.20
		2001-2010		
Spring	-2.25	0.18	-0.88	0.15
Summer	-5.50	0.19	-0.29	0.10
Autumn	-1.33	0.11	0.20	0.10
Annual	-10.0	0.21	-1.44	0.15

References
Kohut, M., *Selected methods for calculating evaporation and evapotranspiration.* In: workshop „Mikroklima porostů“, Brno, 26. March, 172-186, 2003.
Hargreaves, G.L. and Samani, Z.A., *Reference crop evapotranspiration from temperature*. Applied Engineering in Agriculture, 1985, **1**, 96–99.
Löpemier, F.J., *The calculation of soil moisture and evapotranspiration with agro-meteorological models.* Zeitschrift f. Bewässerungswirtschaft, 1994, 29, 157-167.
Možný, M., Trnka, M., Žalud, Z., Hlavinka, P., Nekovař, J., Potop, V., Virag, M., *Use of a soil moisture network for drought monitoring in the Czech Republic*. Theor Appl Climatol, 2011. DOI 10.1007/s00704-011-0460-6.
Vicente-Serrano, S.M., Beguería, S., López-Moreno, J.I., *A Multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index – SPEI.*Journal of Climate 2010, 23(7), 1696-1718.

Acknowledgements: This research was supported by Research Project MSM No. 6046070901 and OC10010.