ANALYSIS OF THE HYSTORICAL PRECIPITATION SUMS OF SULINA STATION BY MEANS OF POWER SPECTRA IN RELATION TO SIBIU STATION AND NAO AND SOI INDEXES

P. Paul[1], B. S. David[2]

ABSTRACT

Precipitation is a very variable climatic element. It is highly variable, both temporally and spatially at different scales (inter-annual and intra-annual). The search for cycles in the climatic records can answer some of the complexities of the atmospheric system. This example uses the Sulina precipitation series (1868-2005) and Sibiu (1851-2005) to illustrate the relations of these two stations with each another as well as the influence of NAO and SOI indexes on them.The annual precipitation series of Sulina and Sibiu were analyzed by means of spectral analysis. The power spectra were calculated using the autocorrelation spectral analysis (ASA) and the maximum entropy spectral analysis (MEM). The cycles revealed were compared to other studies illustrating thus the influence of large scale phenomena such as El-Nino Southern Oscillation and North Atlantic Oscillation.

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1. INTRODUCTION

Many authors have analyzed the precipitation patterns in several parts of Europe. Bràdzil (1992) described fluctuations of precipitation in Europe using series of annual areal precipitation sums; Schönwiese et al (1994) gave a general view of the seasonal behavior of precipitation trends in different European countries during 1961-1990 and 1981-1990. Haidu examined the sequential means of the annual rainfall of Europe in the view of climatic jumps (1996), and discussed the credibility of long term trends of the precipitations (2003). For Romania studies were conducted by numerous authors of whom we acknowledge Boroneant C. and Rambu N. (1992), Busuioc Aristita and Von Storch H (1995) who had studied several Romanian precipitation series identifying change points and revealed the NAO influence on the Romanian stations. As far as power spectrum analysis on climatological data is concerned a useful study is that of Ghil and all (2001) who analyzed by means of power spectra the SOI index. The present study is motivated by the above-mentioned attempts and it must be regarded as the first step in a more extended enterprise.

The annual precipitation series of Sulina station (3m, λ= 45°.15' φ= 29°, 67') and Sibiu (416m λ = 47°80' φ = 24°15') were chosen for the period 1868-2005 and 1851-2005 due to their locations Sulina in the south- east of the country bordering the Black Sea and Sibiu in

[1] *Université Louis Pasteur Strasbourg,* paul@equinoxe.u-strasbg.fr
[2] *"Babeş-Bolyai" University, Cluj Napoca,Romania,* bogd_si@yahoo.com

the middle of the country. The stations have also some of the oldest precipitation records in Romania and the changes they had suffered are well documented.

The main aim of this paper is to find the detection of significant cycles in the annual and seasonal precipitation series and find out whether there is an influence of the NAO and ENSO phenomena on the Romanian territory.

2. METHODS AND ANALYSIS.

Since the Sibiu station was considered homogenous the double mass curve was used only on Sulina records to test its homogeneity against the Iasi series (100 m, λ= 47°.17' φ= 27°.63'). An arithmetic plot of the accumulated values of observations of the two stations was paired in time. The relationship remained constant, fact indicated by a straight line (the very slight deviations were regarded as insignificant). Thus we concluded that the data presents no inhomogenities

The spectral analysis is used to analyze cycles of precipitation data. The power spectra of annual anomalies were analyzed using the maximum entropy spectral analysis MEM (Burg, 1978) and the autoccorelation method (ASA). The choice of these two methods was motivated by the fact that there is no best spectral estimate (Tosic & Unkasevic 2005) and thus is advisable to apply several independent procedures.

The ASA Blackmann & Tuckey (1958) is similar to the periodogram. Given a time series {X (t): t = 1, N} the power spectrum

$$\overline{S_x}(f) = \sum_{k=-(N-1)}^{N-1} \varphi_x(k) e^{-2\pi f k}$$

The advantage of the method over the perodogram is that it reduces the estimate's variance and bias and attenuates the leakage effects (Ghill et al, 2002).

The MEM method identifies with the Burg algorithm reveals the frequencies more accurately (Padmanabhan, 1991). Still there is some subjectivity in choosing a filter. In the present study we decided upon the criterion suggested by Ross (1975) and quoted by Tosic & Unkasevic (2005) **N/3,** where N is the length of the series. In such an AR spectral procedure, peaks occur exactly at frequencies corresponding to roots in the AR polynomial.

The general formula of MEM can be described as follows (Ghil and al., 2002):

Given a time series {X (t): t = 1, N} that is assumed to be generated by a wide-sense stationary process with zero mean and variance σ^2, M' + 1 estimated autocorrelation coefficients {Qx(j): j = 0, M'} are computed from it:

$$\mathbf{Qx(j):} = \frac{1}{N+1-j} \sum_{t=1}^{N-j} X(t) X(t+j).$$

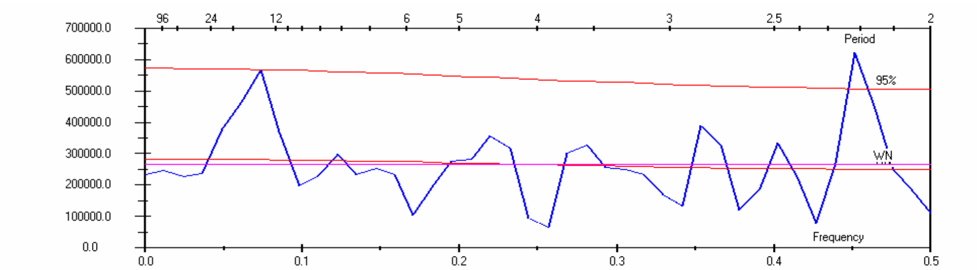
3. RESULTS AND DISCUSSION

The MEM and ASA have been used on the normalized sums of precipitations, which means that the mean value for the entire interval has been subtracted from each annual value and then the residual divided by the standard deviation.

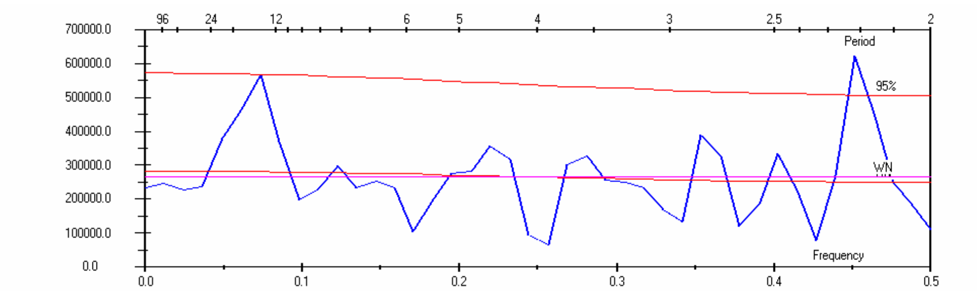
Figures 2 (MEM) and 3 (ASA) show the spectrum of the Sulina and Sibiu series, over 138 and 151 years of records. It can be noticed that there is a general agreement between the two spectral methods. However there are some differences in their spectral resolution and signal detectability. Even so the two methods show nearly identical annual results.

For Sulina two peaks were found: a cycle of 2,2 years at above 95 % level of significance which accounted for up to 5.596 of variance and another one with a periodicity of 13.66 years which explains 4.111 of the variance at. 90% level of significance. Only the cycles revealed by both methods were selected.

For Sibiu ASA method at a level of significance of 95% identified no relevant cycles. Yet at 90 % three were identified: a 2 years cycle (4. 0 variance explained); one of 6- 7 years (4. 1 explained variance) and a 3 years cycle (3.3 variance explained). The MEM method confirmed a cycle of 6, 88 years (9. 6 explained variance) and a biannual one of 2,0 (3.3 explained variance)

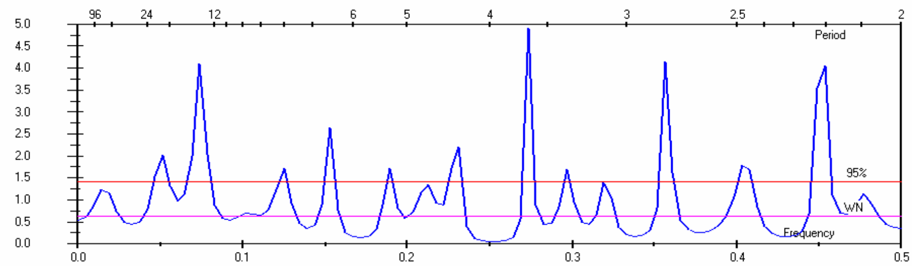


Sulina ASA

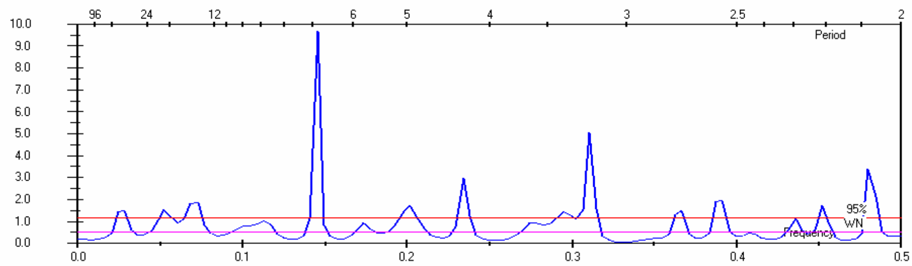


Sibiu ASA

Figure 1. ***The ASA power spectra for the annual sums of Sulina (a) and Sibiu (b)***



a) Sulina MEM



b) Sibiu MEM

Figure 2. ***The MEM power spectra for annual sums of Sulina (a) and Sibiu (b)***

Three cycles were identified a Quasi Biannual Oscillation (QBO), a medium –wave oscillation cycle observed at annual with a periodicity of about 14 years and a 6-7 years cycle.

These relevant cycles detected in this study usually agree with results obtained for other studies of Europe. Bràdzil et al. (1985) founded cycles with lengths of 2-5 years and 10 -16 years for the annual precipitation totals over Central Europe. Maheras and Vafianidis (1991) detected the QBO for Sofia (Bulgaria) and Thessaloniki (Greece). Cycles of medium waves were identified for Serbia and Montenegro as dominant in winter the seasonal precipitation over 1951-2002 and a QBO for the third part of the same season by Tosik (2004). For the station of Belgrade the same oscillations were identified by Tosic & Unkasevic (2005).

According to Reed et al (1961) QBO is one of the most important components of short term climate fluctuations, and can be found in the zonal wind and temperature of the tropical stratosphere. Lamb (1972) and Tosic & Unkasevic (2005) noted that QBO is related to the Southern Oscillation, which is the strength of subtropical height belt in both northern and southern hemisphere. Many studies have shown that there may be two fundamental time-scales in the inter-annual variability of the monsoon- ocean – atmosphere system: a QBO cycle associated with the tropical biannual oscillation and a cycle of 4-6 years associated with the ENSO phenomena.

The correlation among Sulina and Sibiu and the NAO and SOI indexes was investigated and 95% significant correlations were found as presented in Table 1:

The correlation between Sulina and Sibiu stations and NAO and SOI indexes

Table 1

		SOI	SULINA	SIBIU	NAO
SOI	Pearson Correlation	1	-,127	-,221*	-,156
	Sig. (2-tailed)		,162	,014	,084
	N	123	123	123	123
SULINA	Pearson Correlation	-,127	1	,250**	-,260**
	Sig. (2-tailed)	,162		,005	,004
	N	123	123	123	123
SIBIU	Pearson Correlation	-,221*	,250**	1	-,172
	Sig. (2-tailed)	,014	,005		,058
	N	123	123	123	123
NAO	Pearson Correlation	-,156	-,260**	-,172	1
	Sig. (2-tailed)	,084	,004	,058	
	N	123	123	123	123

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

CONCLUSIONS:

The findings from this paper are consistent with phenomena identified over Europe.

Therefore concluding we can say that three cycles were identified a Quasi Biannual Oscillation (QBO), a medium –wave oscillation cycle observed at annual with a periodicity of about 14 years and a 6-7 years cycle.

They appear to be related somehow to the ENSO and NAO phenomena although their connection is not quite clear. Negative correlations between Sulina and NAO and between Sibiu and SOI have been identified.

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