Climate Variability Of The Discharge Level In The Danube Lower Basin And Teleconnection With NAO

Ileana Mares, Constantin Mares and Petre Stanciu

*National Institute of Hydrology and Water Management,
Bucharest, ROMANIA*

Abstract

The internal structure of monthly time series of the discharge level at Orsova situated in the Danube lower basin for 164 years (1840-2003) has been analyzed. Statistical non-parametric tests (Pettitt and Mann-Kendall) have been applied for the emphasis the climate change points. Also, the signal-to-noise ratio has been estimated for testing the statistical significance of the change points.
By means of power spectra the periodicities from 2 to 40 years have been found. Signal of Quasi-Biennial Oscillation - QBO (about 26 months) is present in the discharge level during the spring and summer time, while periodicity of 40 years appears in autumn months.
Teleconnections between North Atlantic Oscillation (NAO) values and time series of the discharge level at Orsova for the period 1840-2003 were performed. For this period the most significant result is obtained for the NAO index in February and discharge level in April. A positive phase of NAO in February leads to low discharge level in Danube lower basin in April and a negative phase in February favours a high level in April.
Because a change was occurred in the beginning of the 1970s in the North Atlantic Oscillation index, the teleconnection analysis has also been achieved in two separated periods, 1840-1970 and 1971-2003. Taking into account discharge level at Orsova in September as predictand, for the first period NAO in January is a good predictor and for the second period the best predictor is NAO in March.

Keywords: power spectra, extreme events, change points, lagged correlations

Introduction

North Atlantic Oscillation (NAO) is the dominant mode of the winter climate variability in the North Atlantic region. The corresponding index varies from year to year, but also exhibits a tendency to remain in a positive or negative phase for intervals lasting several years. Over the past thirty years, NAO has steadily strengthened, rising from its low index state in the 1960s to a historic maximum in the early 1990s. This trend accounts for a significant portion of the Northern Hemisphere wintertime temperature increase over Eurasia, a major component of the recent warming.
As is shown in the NOAA Office of Global Program, scientists became aware of a connection between variations in temperature at the earth's surface and the strength of the stratospheric winter vortex, located about 60 km above the earth's surface. Changes in the stratospheric circulation can be forced by several different mechanisms including ozone depletion, volcanic dust and CO. Rising CO_2 concentrations cool and strengthen the stratospheric winter vortex translates into stronger surface winds. Enhanced surface westerly winds are consistent with a positive NAO index. These changes, which modulate the temperature over northern Eurasia and America, are sometimes like the Arctic Oscillation.
Relative recently, *Garcia's et al.* (2000) referred many publications related to NAO and its influence on pressure field in Atlantic-European region.

Data used in this study are:

- *Monthly discharge level* at Orsova situated in the Danube lower basin (1840-2003).
- *The NAO values for 1840-2003* are defined as the normalised pressure difference between Ponta Delgata (Azores) and Reykjavik (SW Iceland) according to *Jones et al*. (1997).

- The Palmer Drought Severity Index (PDSI) for the summertime over the 1891-1991 interval, as it was calculated by *Briffa et al.* (1994) defined for 9 regions in Europe (Figure 1).

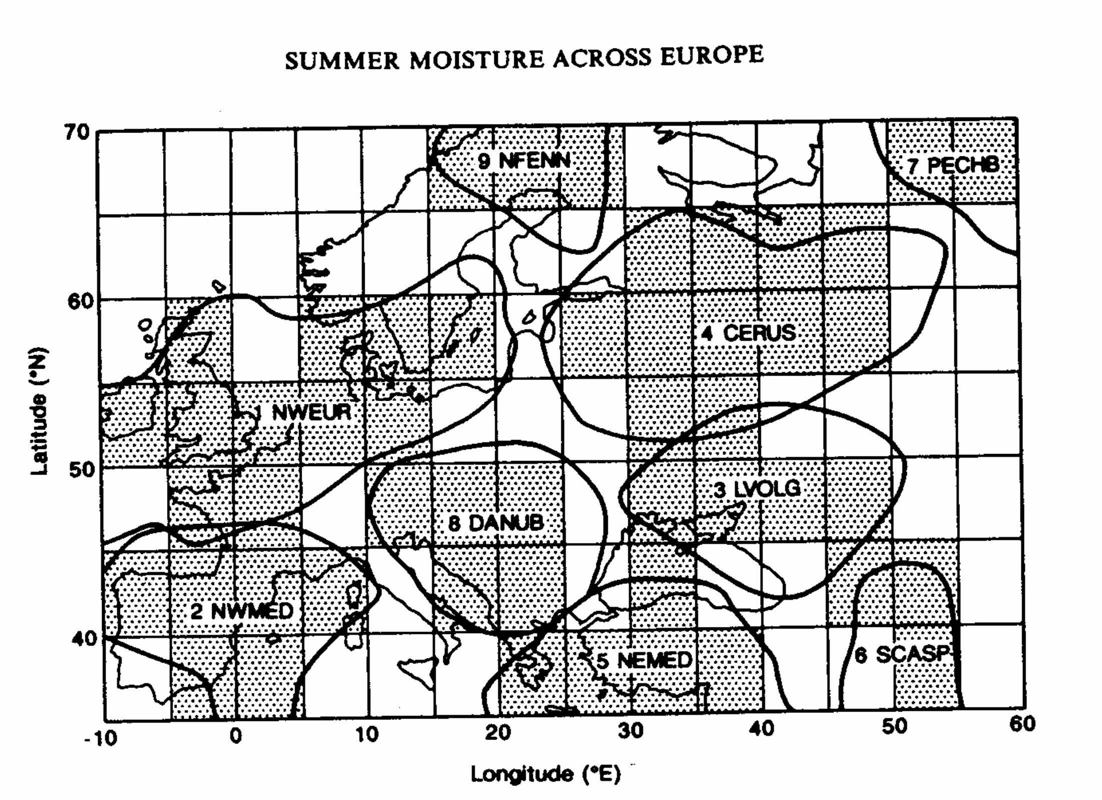

Figure 1. Nine regions of coherent summer moisture variability objectively defined by orthogonal rotation of the principal components of the summer PDSI (after *Briffa et al.*, 1994)

The following nonparametric tests are applied:

- Pettitt to find out the change points;
- Mann-Kendall to test the homogeneity of the series;

The quantification of the change point has been carried out by the estimation of the signal-to-noise ratio (*Mares and Mares*, 1996).
When the series has several change points, the *Sneyers*' (1992) procedure is used for sub-series, consistent with the initial series.
The power spectra are also calculated for estimation the quasi- periodicities in time series of discharge level at Orsova.

The results

Taking into account the value of the signal-to-noise ratio greater than 0.5, as well as the length of the interval (lag≥ 10), the significant climate change points have been obtained (Table 1).
In Table 1, α is the corresponding significance level for the two consecutive series, which is deduced from the standardized statistics; M_1 and M_2, averages of the periods with the length of a lag before the change point and after this point. $R_{S/N}$ represents the signal-to-noise ratio, calculated by means of T-student test.
The best significant result related to the length of the two series which are separated by change point is obtained for summer 1981. Autumn 1942 has the highest value of the signal-noise ratio (0.85). In the both situations the change points make the transition to lower discharge level.

Table 1. Change points in the discharge level (standardised values) at Orsova

	Change - points	Lag	M_1	M_2	$R_{S/N}$	α
Spring	1988	10	0.35	-0.45	0.74	2.10^{-4}
Summer	**1981**	**15**	**0.48**	**-0.46**	**0.59**	**0.03**
Autumn	**1942**	**10**	**0.56**	**-0.74**	**0.85**	**2.10^{-5}**
	1983	10	0.30	-0.44	0.68	0.02
Winter	1984	10	0.67	-0.17	0.73	3.10^{-4}

By means of power spectra we estimated the quasi - periodicities for time series of discharge level at Orsova for every months.
We give a special attention to month of September because in 2003 heat waves which affected many parts of Europe and discharge level in the Danube lower basin was very low (*Mares et al*., 2006).
For September the power spectrum is presented in Figure 2.

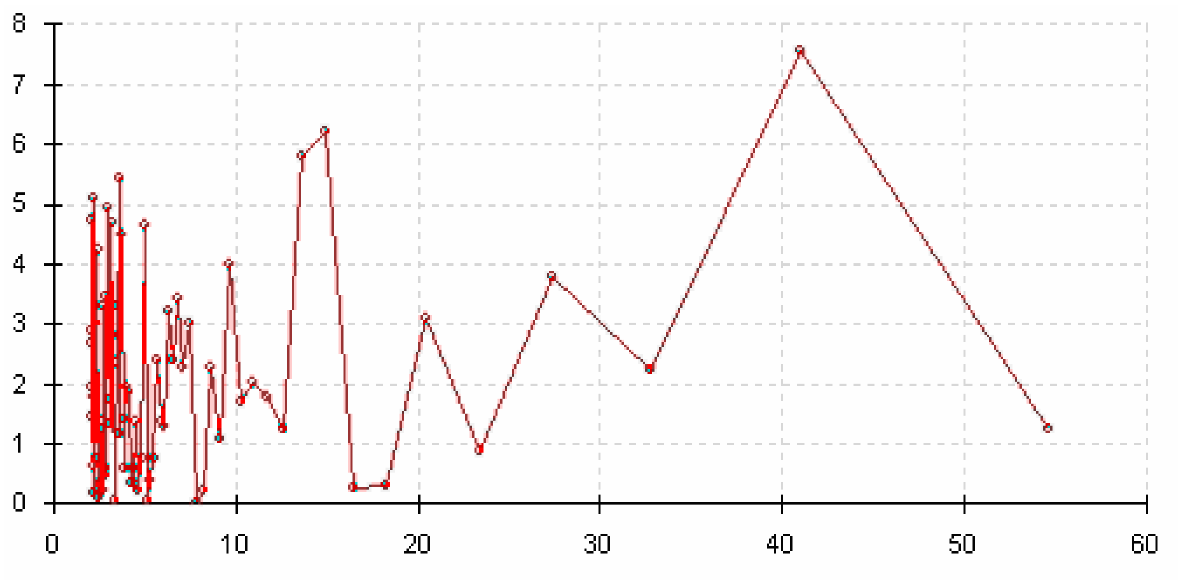

Figure 2. Periods (in years) for the time series of discharge level at Orsova (1840-2003)

From Figure 2 one can see that the most significant period is at the 41 year. A period about 40 year has been also found for October.
Concerning signal of Quasi-Biennial Oscillation - QBO (about 26 months), this was found in the time series of discharge level at Orsova in the months during the spring and summer.
Probable, the QBO signal found in the temperature field (*Mares and Mares*, 2003) especially in the wintertime has an impact with some delay in the hydrological field.
Also a period about 14-15 years is pointed out in Figure 2.

NAO signal

In *Mares et al.* (2002b) the teleconnection between NAO and drought indices were analysed. These indices are Palmer Drought Severity Index (PSDI) defined in 9 regions in Europe (*Briffa et al*., 1994) and an index (EOFDI) defined by *Mares et al*. (2002a) by means of the first principal components of decomposition in empirical orthogonal function of the temperature and precipitation fields in Romania (31 stations).
In *Briffa et al.* (1994) nine regions (Figure 1) of coherent summer moisture variability are objectively defined by orthogonal rotation of the principal components of the summer PDSI. The nine rotated components, which explain 60% of total variability of this data set, represent moisture variability in

north-western Europe (NWEUR), the north-west Mediterranean (NWMED), the lower Volga (LVOLG), central European Russia (CERUS), the north-east Mediterranean (NEMED), the southern Caspian Sea (SCASP), the Pechora Basin (PECHB), the Danube Basin (DANUB), and the northern Fennoscandia (NFENN).

In *Mares et al.* (2002b) the analysis has been carried out for 101 years (1891-1991) and only for Palmer Severity Drought Indices in summer time (June, July and August).
A negative value of PDSI indicates a state of drought. The absolute value of the correlation coefficient must be greater than 0.19 for a 95% confidence level and greater than 0.25 for a 99% confidence level. ROMZ from Table 2 represents the Palmer index for the Romanian territory.

Table 2. The correlation coefficients (r) between NAO and summer Palmer Drought Severity Indices from different regions in Europe. Mon (NAO) - the month for the NAO.

R e g i o n	Mon (NAO)	r	β (%)
NWMED	2	-0.22	95
	3	**-0.31**	**99**
	4	-0.23	95
	10	0.20	95
DANUB	**1**	**-0.24**	**98**
	2	-0.23	95
	3	-0.22	95
ROMZ	**1**	**-0.29**	**99**
	2	0.19	95
	11	0.21	95
NFENN	1	0.19	95
LVOLG	**1**	**-0.26**	**99**
	9	-0.26	99

For the north-western Mediterranean (NWMED) region, the best correlation has been obtained between NAO in March and PDSI in summer. For the Romanian area (ROMZ) Danube basin and lower Volga (LVOLG), NAO in January is the best predictor for the summer PDSI.
In Figure 3 are presented behaviours of the PDSI for all DANUBE basin inn summer and NAO values in January, for the period 1891-1990. The NAO signal on the DANUBE basin has good significance after 1980.

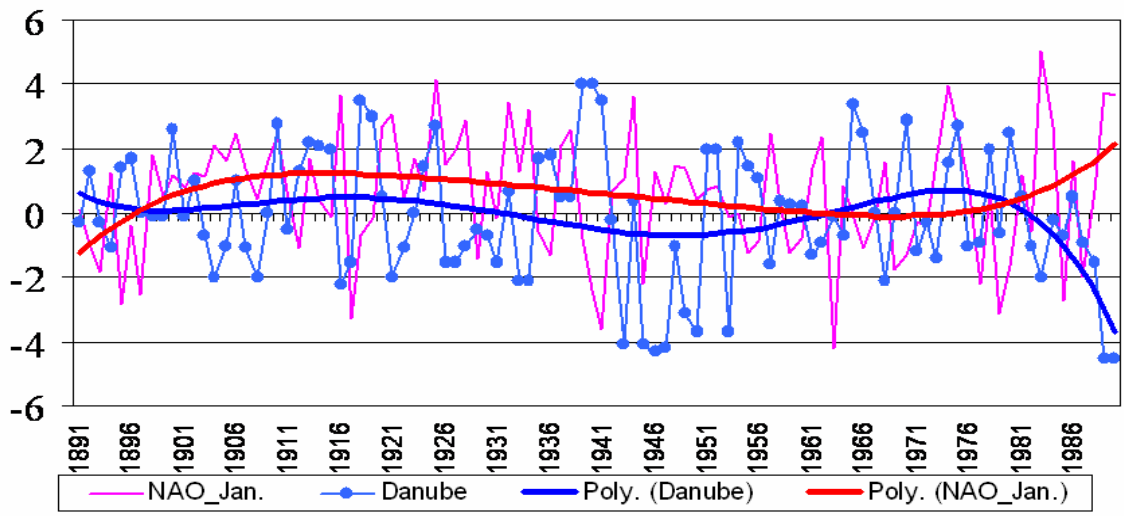

Figure 3. Temporal evolution of NAO (January) and of summer Palmer drought index in Danube Basin (DANUB) for the period 1891-1990

Simultaneously correlation between NAO and EOFDI is presented in Figure 4.

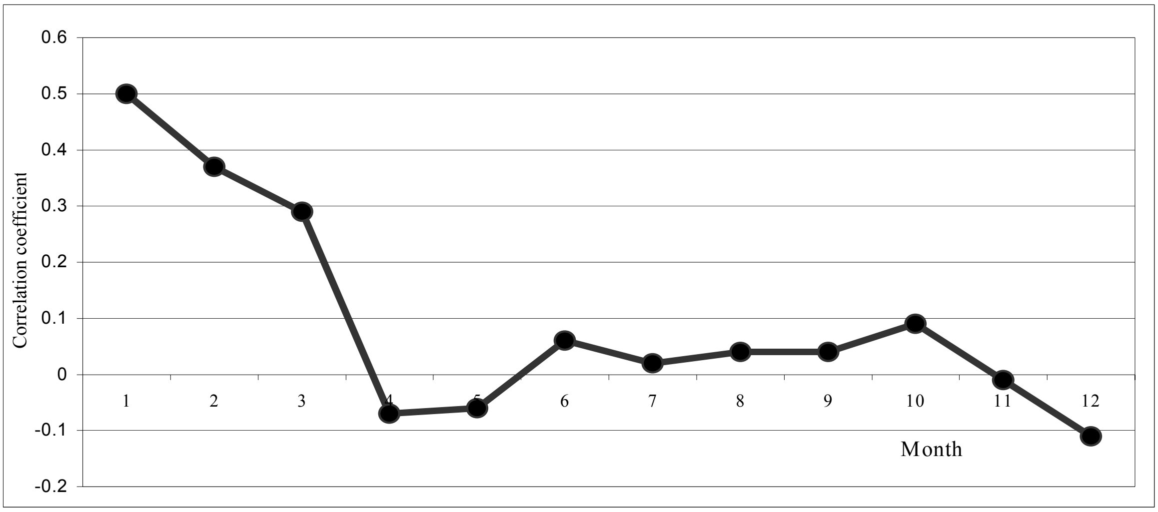

Figure 4. The correlation coefficient between NAO and EOFDI (1951-1997)

Concerning ***the influence of NAO*** on the discharge level of Danube lower basin, the results for Orsova are presented in Table 3 for the period 1840-1999.

Table 3. The most significant correlation coefficients (R) between NAO and discharge level of Danube at Orsova for the period 160 years.

Mon (NAO)	1	1	1	**2**	10	12
Mon (ORS)	2	3	4	**4**	11	1
R	-0.29	-0.35	-0.34	**- 0.40**	-0.34	-0.30

From Table 3 one can see that the NAO in February is a good predictor for the discharge level of Danube at Orsova in April.

The mechanism responsible for some delay in the NAO impact on the precipitation in Europe are poorly understood, the springtime response to NAO in January may be due to the snow cover state in wintertime (*Kaczmarek*, 2000). For the other lags it is very difficult to explain the complex interaction between components of land-atmosphere-ocean system.

The graphical representation of the NAO in February and the discharge level (standardised) of Danube at Orsova in April is presented in Figure 5 but only the interval 1951-1999.

The above result was obtained for the period 1840-1999, but because a change was occurred in the beginning of the 1970s in the North Atlantic Oscillation index (*Beniston*, 2005), the teleconnection analysis has also been achieved in two separated periods, 1840-1970 and 1971-2003.

Taking into account discharge level at Orsova in September as predictand, for the first period NAO in January is a good predictor (Figure 6) and for the second period the best predictor is NAO in March (Figure 7).

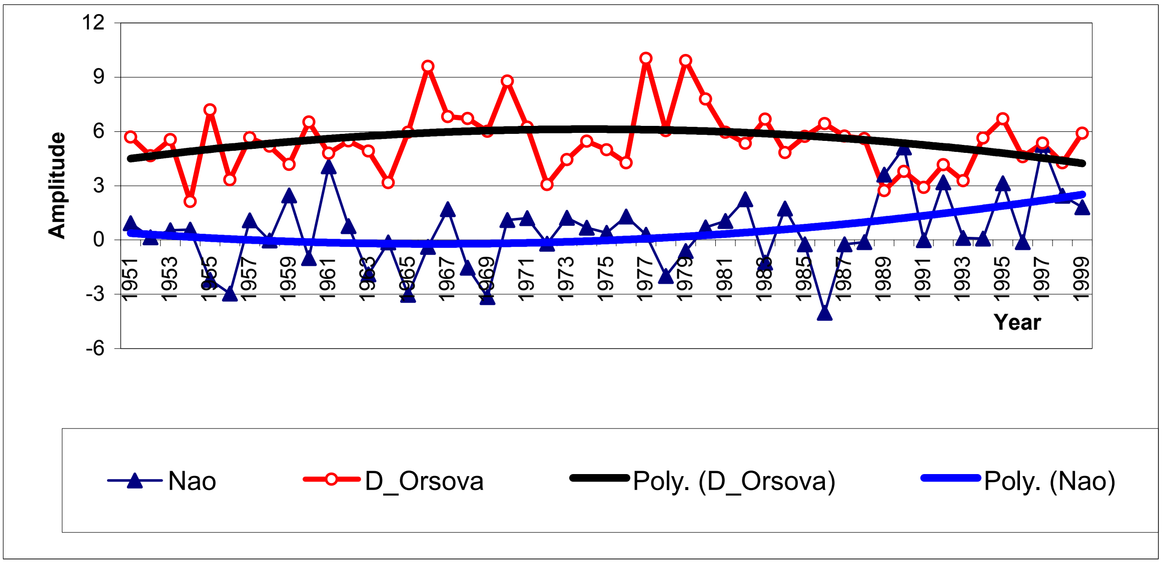

Figure 5. Teleconection between NAO time series in Februarie and Orsova discharge in April

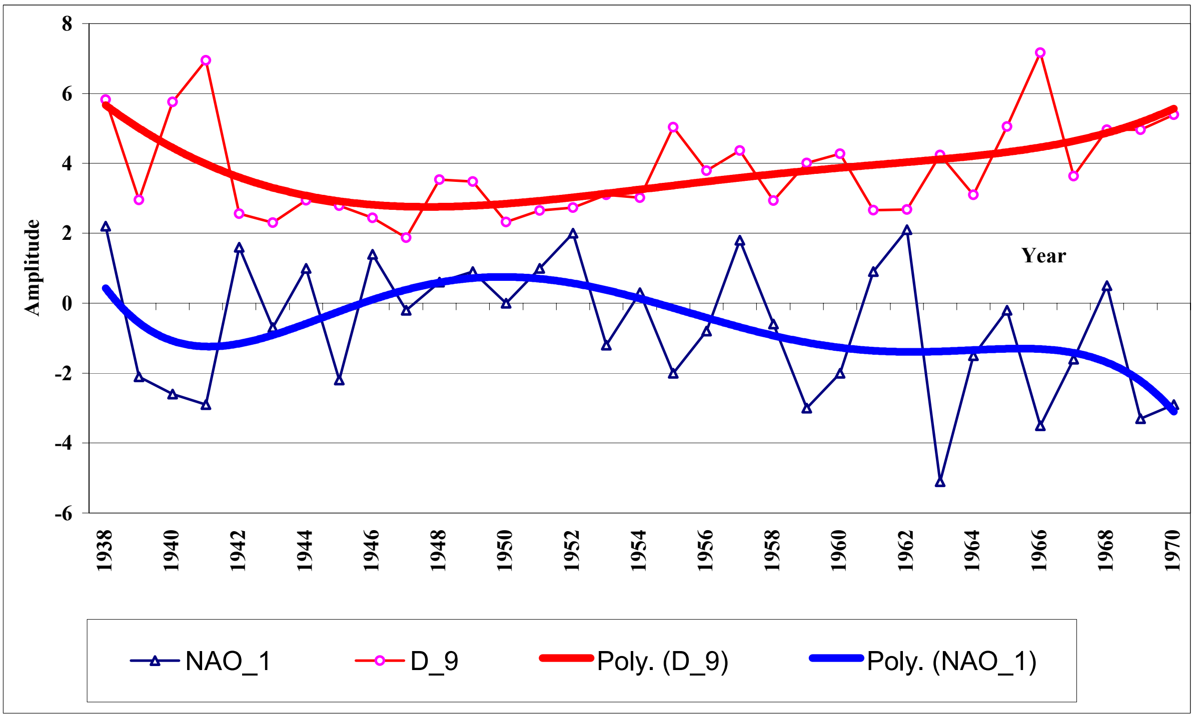

Figure 6. Teleconnection between Orsova descharge in September and NAO in January

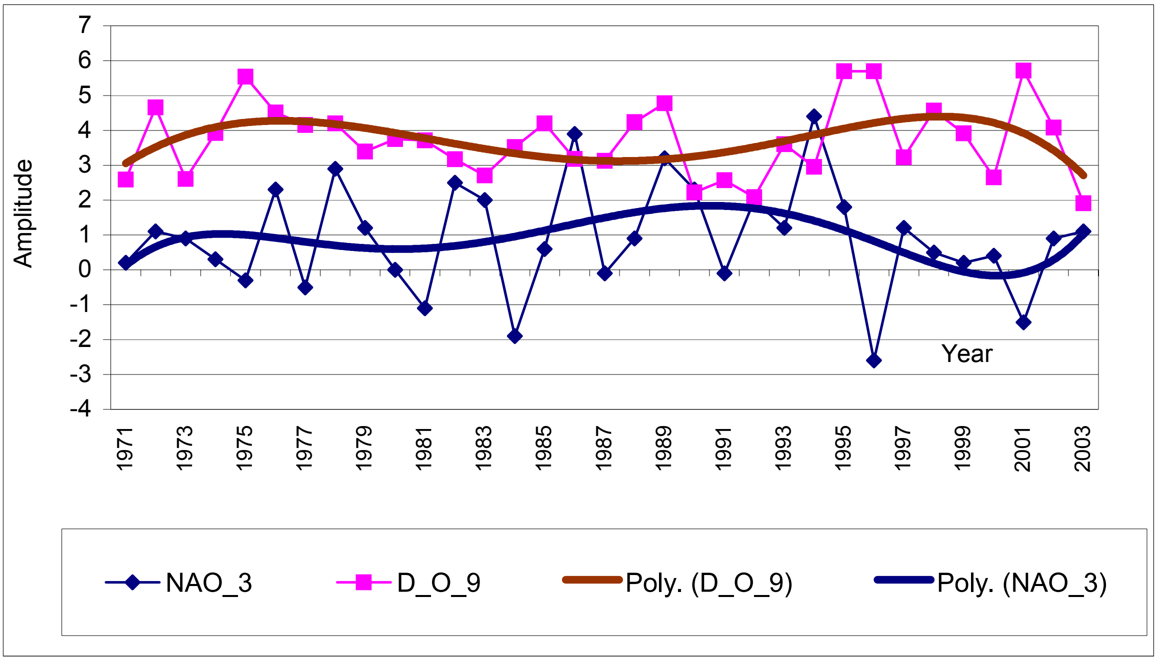

Figure 7. Teleconnection between Orsova descharge in September and NAO in March

Also the signals of ENSO (El Nino – Southern Oscillation) in climate variability in Romania were tested in *Mares et al.* (2002a)

Conclusions

- The most significant change point in the seasonal values of discharge level in the Danube lower basin is in the summer 1981, and this point makes the transition to a lower levels.
- Signal of Quasi-Biennial Oscillation - QBO (about 26 months), was found in the time series of discharge level at Orsova in the months during the spring and summer.
- A period of about 40 year (with high level of significance) was estimated in discharge level at Orsova in the months of autumn time.
- NAO in January influences the behavior of summer PDSI in the Danube Basin.
- NAO in February has a significant signal in the time series of discharge level in April for Danube lower basin.
- Taking into account discharge level at Orsova in September as predictand, for the period before 1970, NAO in January is a good predictor and for the period after 1970 the best predictor is NAO in March.
- For all situations a positive NAO determines a negative value of PDSI, namely a drier state and reverse or a lower level of discharge.

References

Beniston, M., 2005: Warm winter spells in the Swiss Alps: Strong heat waves in a cold season ? A study focusing on climate observations at the Saentis high mountain site. *Geophys. Res. Lett.*, 32, Lo1812, doi:10.1029/2004GL021478.

Briffa, K.R, P.D.Jones and M.Hulme, 1994: Summer moisture variability across Europe, 1892 - 1991 : An analysis based on Palmer drought severity index. *Int.J. Climatol.*, 14, 475-506.

Garcia, R., D. Gallego, E. Hernandez, A.Marcias, L. Gimeno and P. Ribera, 2000: Precipitation in the Canary Islands: reconstruction and major influences. *International Workshop on Climatic Change: Implications for the Hydrological Cycle and for water Management*, Wengen, Switzerland, September 27-29, 2000.

Jones, P.D. T. Jonsson and D. Wheeler, 1997 : Extension to the North Atlantic Oscillation using early instrumental pressure observations from Gibraltar AND South-West Iceland. *Int. J. Climatol.* 17,1433-1450.

Kaczmarek, Z., 2000: Impact of North Atlantic Oscillations on river discharges in Europe. *International Workshop on Climatic Change: Implications for the Hydrological Cycle and for water Management*, Wengen, Switzerland, September 27-29, 2000.

Mares, Ileana and C. Mares, 1996: The analysis of climate variability at local and regional scales in the global warming context. *World Resource Review*, **8**.4.2, 440 - 447.

Mareş C., Mares Ileana, and Mihaela Mihailescu, **2002a:** Testing of NAO and ENSO signals in the precipitation field in Europe. In Beniston, M (ed), Climatic Change: Implications for the Hydrological Cycle and for Water Management. *Advances in Global Change Research*, **10**, *Kluwer Academic Publications*, Dordrecht and Boston, 113-121, ISBN 1-4020-0444-3.

Mareş Ileana, C. Mareş and Mihaela Mihăilescu, **2002b:** NAO impact on the summer moisture variability across Europe*. Physics and chemistry of the Earth*, 27, 2002, 1013-1017, ISSN 1474-7065.

Mares C. and Ileana Mares, 2003: Improvement of Long-Range Forecasting by EEOF Extrapolation using an AR-MEM Model. *Weather and Forecasting,* **18**, 311-324, ISSN 1520-0434.

Mares C., Antoaneta Stanciu and Ileana Mares, 2006: On the Possible Causes of the Severe Droughts in the Danube lower Basin In 2003. *BALWOIS 2006 Conference.*

Sneyers, R., 1992 : On the use of statistical analysis for the objective determination of climate change. *Meteor. Zietschrift,N.F.1,* 247-256.