Forecast of moistening conditions for the warm season in Southwestern Siberia

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The results of search for prognostic relations between characteristics of the South (El Niño) and North Atlantic oscillations and regime of moistening in Tomsk, Omsk, Barnaul, and Kolpashevo during warm seasons are presented.

The problem of long-term weather and climate forecast does not lose its urgency, and attempts to find new predictors for these purposes are still important. The forecast of any meteorological parameter starts from analysis of a synoptic situation on the territory under study and, in the case of a long-term forecast, from analysis of characteristics of the global atmospheric circulation. From these points of view, close attention has been recently paid not only to traditional indices and objects of the global atmospheric circulation (GAC), but also to such phenomena of the ocean–atmosphere interaction as El Niño/Southern Oscillation (ENSO), and the North Atlantic Oscillation (NAO).[1–3]

This paper considers the possibility of using quantitative characteristics of these oscillations in forecasting the moistening regime at the stations in the South of Western Siberia. The Ped's index (S_i), accounting for both the thermal conditions and amount of precipitation at a particular station

$$S_\text{i} = \frac{\Delta T}{\sigma_T} - \frac{\Delta R}{\sigma_R},$$

is taken as an indicator of moistening. Here ΔT and ΔR are temperature and precipitation anomalies for the corresponding period; σ_T and σ_R are their rms deviations. The description of S_i, the calculation technique, and numerical criteria of moistening can be found in Ref. 5.

Thus, the occurrence of periods with an extreme moistening is associated, in the first turn, with certain circulation processes, which can be described, in our opinion, by NAO and ENSO characteristics.

Gilbert Walker, a famous British scientist, introduced the terms NAO and ENSO yet in early twenties of the past century.

Walker called the "Southern Oscillation" one of the atmospheric circulation systems, in which air masses move between the Indonesian equatorial center of low pressure and the subtropical South Pacific High.

Now there exist different methods for calculation of the ENSO intensity, but the most widely used method assumes the use of SOI index, which is determined with the use of normalized anomalies of the sea-level pressure at Tahiti and Darwin (Australia):

$$\delta_{gm} = \left(\frac{P_{gm} - P_\text{m}}{\varepsilon}\right)_\text{Tahiti} - \left(\frac{P_{gm} - P_\text{m}}{\varepsilon}\right)_\text{Darwin},$$

where P_{gm} is the actual pressure, P_m is the many-year mean pressure (norm); g and m are a year and a month, respectively. The SOI index is calculated by the following equation:

$$\text{SOI} = \frac{\delta_{gm}}{\sigma},$$

where σ is the standard deviation of all the δ_{gm} differences.

At negative values of SOI the El Niño phenomenon is formed, and at positive values the La Niña phenomenon is observed.

The term "North Atlantic Oscillation" assumes the change in the pressure field and, as a consequence, in the intensity of the zonal transport over the extratropical zone of North Atlantic. To estimate the NAO strength, Rogers in 1984 proposed to use the difference between seasonal mean values of pressure at stations, situated in the regions of many-year position of the Azores High and the Iceland Low. Quantitatively, the NAO index is defined as a difference between sea-level pressure anomalies, normalized to the standard deviation, between Iceland (usually, Reykjavik or Stykkishylmur) and Azores (Ponta Delgada), or the south of the Iberian Peninsula (Gibraltar or Lisbon) and calculated as

$$\text{NAO} = \frac{\delta_{gm}}{\sigma_\text{m}},$$

where

$$\delta_{gm} = \left(\frac{P^\text{A}_{gm} - P^\text{A}_\text{m}}{\sigma^\text{A}_\text{m}}\right) - \left(\frac{P^\text{I}_{gm} - P^\text{I}_\text{m}}{\sigma^\text{I}_\text{m}}\right).$$

Here P^A_{gm}, P^I_{gm} are the monthly mean pressures at Azores and Iceland, P_m is the many-year mean pressure; the superscripts A and I stand for Azores and Iceland.

According to Ref. 6, at NAO > 0 in winter, as the pressure gradients over North Atlantic intensify,

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cyclones pass over northwestern and northern Europe and Siberia, forming a low-pressure zone, which does not allow invasions from Arctic to penetrate low latitudes and to support, in particular, the Siberian High, thus leading to its weakening. Just this leads to the formation of extremely warm winters in Europe with the large precipitation amount in northwestern Europe, as well as in northern Siberia and in southern regions of Western Siberia, which become open for cyclones from the south when the Siberian High is weak.

At NAO < 0, the zonal flow over North Atlantic weakens, and cyclones follow along southern trajectories, forming positive precipitation anomalies in the southern and southeastern Europe (the so-called Southern and Mediterranean Cyclones). The weaker zonal transport leads to higher occurrence of arctic invasions and to formation of the negative temperature anomaly.

Numerous investigations of NAO and its contribution to the climatic variability indicate its leading role in the mechanism of atmospheric circulation in the Northern Hemisphere.

Figure 1 shows the dynamics of the annual mean values of the SOI and NAO indices (ten times magnified) for the period since 1935 until 1995. This dynamics indicates the growing occurrence of the El Niño phenomenon in the Southern Hemisphere, while since the mid-1950s the positive NAO values prevail in the North Atlantic, that is, we can see the general intensification of the western transport and the prevalence of the related forms of atmospheric circulation.

The initial material for studying relations between ENSO and NAO and the regime of moistening in Western Siberia was the information about the monthly mean temperature and monthly precipitation amounts for 1960–1995 at the stations of Omsk, Barnaul, Tomsk, and Kolpashevo and the monthly mean SOI and NAO indices for this period.[4]

Previously we have revealed that the regimes of moistening in the region under study are related, in some way, to the forms of atmospheric circulation. In the period until 1968, that is, in the epoch of the mixed (B + C) circulation according to the Vangengeim–Girs classification, the increased intensity of atmospheric droughts was observed at all stations in April (Fig. 2) and September, while in May and August the atmospheric moisture content increased. In June and July the moistening was different at these stations, but Tomsk and Kolpashevo, in general, were characterized by intensification of the atmospheric droughts.

In the period since 1969 until 1981, the eastern form was observed, and in this period the intensity of atmospheric droughts decreased at all the stations in April and September and increased in May and August.

In the following period (1982–1990), when the form C prevailed, the tendency to the increasing dryness was observed again, especially, in Tomsk and Kolpashevo (June, July) and to the decreasing dryness in Barnaul and Omsk. Since 1991, the western (W) form prevailed, and there was a tendency to overmoistening of the studied territory in August.

To search for prognostic relations between S_i and the SOI and NAO indices, we used correlation analysis (at the stage of searching for informative predictors) and linear discriminant analysis for constructing the prognostic equations. The informative predictors (that is, monthly mean values of the SOI and NAO index) were searched with a one-year advance time, which was then decreased with a step of one month. As a result, we have separated the periods of occurrence of the Southern and North Atlantic Oscillations, when their influence on the weather conditions in Western Siberia was most probable and the coefficients of correlation with the S_i index were statistically significant. Tables 1 and 2 present the results of the asynchronous correlation analysis.

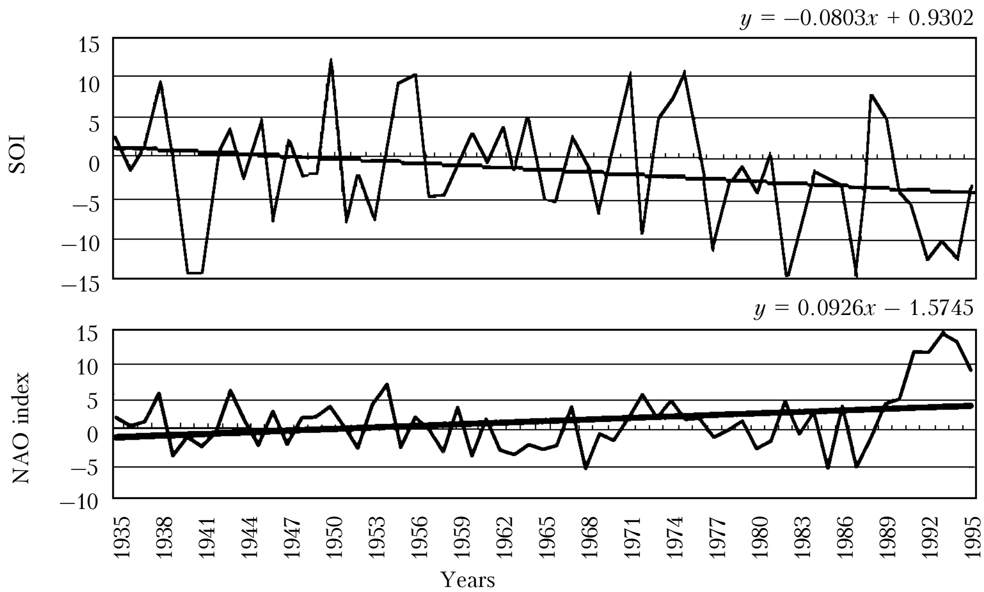

Fig. 1. Dynamics of ENSO and NAO phenomena.

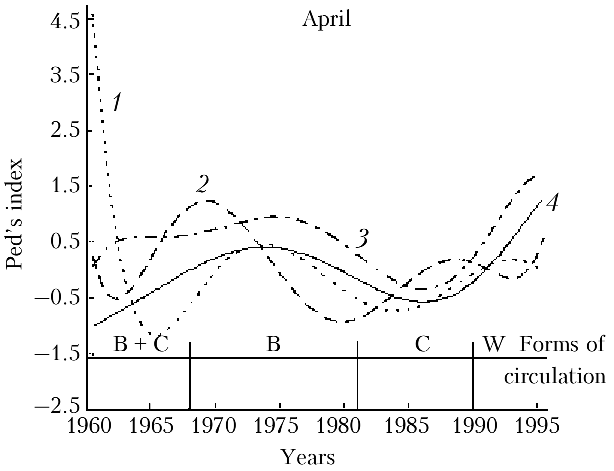

Fig. 2. Dynamics of the Ped's index in April and forms of the atmospheric circulation: Barnaul (*1*), Omsk (*2*), Tomsk (*3*), Kolpashevo (*4*).

It can be seen that the informative indices are mostly SOI for the cold season (November–February) and only for the station in Barnaul the index for July appeared to be significant for moistening in February. The highest coefficients of 0.77 (station in Omsk) and 0.71 (station in Barnaul) are indicative of a rather high level of correlation between SOI and the weather characteristics in the South of Western Siberia.

The North Atlantic Oscillation has a larger number of statistically significant asynchronous correlations with the moistening of the region under study (see Table 2). The highest correlations are observed for the stations in Omsk (–0.73) and Tomsk (–0.69).

At the next stage, we have constructed the separating linear discriminators on the basis of the selected predictors (SOI and NAO indices for November–January) to forecast the class of atmospheric moistening (class "norm" (N) for $-1 \le S_i \le 1$, class "moistening" (M) $S_i < -1$, and class "drought" (D) $S_i > 1$) in the warm half-year by two-month periods: April–May, June–July, August–September, for each of the considered stations. The list of the calculated discriminators with the highest accuracy of forecast for individual classes is presented below.

List of discriminators

Tomsk Station

April–May

$$L(\text{N,D}) = 0.070\text{SOI}_1 + 0.055\text{NAO}_1 + 0.083.$$

Accuracy of the forecast for class "D" – 76.9%; for class "N" – 61.5%; general– 69.2%.

June–July

$$L(\text{N,D}) = -0.022\text{SOI}_1 + 0.015\text{NAO}_1 + 0.004.$$

Accuracy of the forecast for class "D" – 33.3%; "N" – 88.8%; general – 61.1%.

August–September

$$L(\text{N,M}) = 0.005\text{SOI}_1 + 0.044\text{NAO}_1 - 0.025.$$

Accuracy of the forecast for class "M" – 52.9%; "N" – 70.5%; general – 61.7%.

Kolpashevo Station

April–May

$$L(\text{N,D}) = 0.038\text{SOI}_{12} - 0.011\text{NAO}_{12} - 0.014.$$

Accuracy of the forecast for class "D" – 76.4%; "N" – 70.5%; general – 73.5%.

June–July

$$L(\text{N,M}) = 0.005\text{SOI}_{12} - 0.08\text{NAO}_1 + 0.037.$$

Accuracy of the forecast for class "M" – 75.0%; "N" – 62.5%; general – 68.7%.

Omsk Station

April–May

$$L(\text{N,M}) = 0.034\text{SOI}_1 + 0.0135\text{NAO}_1 - 0.024.$$

Accuracy of the forecast for class "M" – 69.2%; "N" – less than 50%.

Table 1. Coefficients of significant correlation between the Ped's index and SOI

SOI		Omsk				Tomsk		Kolpashevo			Barnaul				
	Month	Ped's index													
		Month													
		4	7	8	9	8	9	7	8	9	2	6	7	9	11
La Niña	1		0.66					0.62					0.71		0.44
	2		0.38			0.37							0.34		–0.6
	3									0.58					
	4						–0.4								
	7										–0.4				
	11	0.42	0.77		0.71								0.67		
	12	0.39	0.59		0.46	0.34			0.39				0.53		
El Niño	1		–0.53					–0.54		–0.41		–0.33		–0.37	
	2		–0.33							–0.45				–0.4	
	3			–0.34											
	4						0.62								
	7										0.37				
	11		–0.41	–0.52											
	12			–0.44		–0.37			–0.33				–0.4		

Table 2. Coefficients of significant correlation between the Ped's index and NAO index

NAO index	Month	Omsk								Tomsk					Kolpashevo								Barnaul								
		Ped's index																													
		Month																													
		1	2	3	5	7	8	10	11	4	5	6	7	8	1	2	3	4	5	7	10	11	1	2	3	4	5	6	10	11	12
Positive index	1									0.42	0.44		0.39	0.45					0.33						0.34	0.44					
	2										0.64								0.45							0.58					
	3	0.42	0.49		0.34	0.44													0.33							0.34					
	4										0.36										0.46										
	7																									0.49					
	8	0.37	0.61					0.5			0.39															0.39					
	9																										0.39	0.33			
	10																											–0.37			
	11				–0.47													–0.34													
	12																–0.35											0.39			
Negative index	1									0.44				0.44			0.34		0.33						0.34						
	2													0.46																	
	3	–0.33	–0.39			–0.53	–0.44								–0.34	–0.46				–0.53			–0.34	–0.4	–0.37						0.35
	4																				–0.59								–0.57		–0.4
	6								0.45													0.41									
	7																													0.34	
	8		–0.39	–0.73				0.44	–0.33							–0.39						–0.34							–0.44	–0.34	–0.33
	9										–0.48																				
	10	–0.45								0.48					–0.43								–0.4	–0.33	0.33				–0.42		
	11				–0.39					0.51																					
	12									–0.39	–0.31	–0.69	–0.56	–0.6																	

Barnaul Station
April–May

$$L(\mathrm{N,D}) = 0.005\mathrm{SOI}_1 + 0.009\mathrm{NAO}_1 + 0.035.$$

Accuracy of the forecast for class "D" – 73.3%; "N" – 73.3%; general – 73.3%.

For the function $L(\mathrm{N, D})$, at $L > 0$ the drought is forecasted, and $L < 0$ corresponds to the class "norm." For the function $L(\mathrm{N, M})$, $L > 0$ corresponds to the class "norm," and $L < 0$ corresponds to "moistening." The subscript of the predictors indicates a month, this predictor corresponds to. The order of using the obtained functions for the forecast at each station and each two-month period is the following. The discriminator between the classes "N" and "D" is calculated, and if the result points to the occurrence of the class "D," then the calculation is completed with the forecast of droughty conditions. If the result is indicative of the class "N," then the next discriminator between the classes "N" and "M" is calculated. The result obtained in this case is final.

In conclusion, it should be noted that the relations obtained can be recommended for use if the forecast services have the corresponding initial information about the state of the GAC objects considered in this study.

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