P1.2 ENERGY CONTENT OVER HIGH LATITUDES OF NORTHERN HEMISPHERE

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1. INTRODUCTION

Energetics of the global atmosphere was studied more than 40 years ago by Lorenz (1955). With a focus on the zonally symmetric structure of the global atmosphere, he divided each of available potential energy and kinetic energy into its zonal mean and eddy components. Numerous studies (Otto-Bliesner, 1984; Yu *et al*., 1999; Haimberger and Hantel, 2000) with observational data have estimated the seasonal variation of the atmospheric energetics at northern extratropical latitudes. But observational studies of the seasonal variation of the atmospheric energy at polar latitudes are fewer in number.

In this study, the month-to-month variations of the atmospheric energy during 1980-1993 years are investigated and analysis their connection with the Arctic Oscillation (AO) indices is carried out.

The AO is the leading mode of high-latitude variability in Northern Hemisphere as characterized by the first empirical orthogonal function of mean sea-level pressure (see, Thompson and Wallace, 1998, 2000). In this aspect, the joint analysis for the variations of polar energetics and the AO indices seems interesting.

2. DATA AND METHODS

The GDAAC monthly mean data set of temperature, zonal and meridional winds at 18 pressure levels from 1000 to 20 hPa for 1980-1993 years period was used as initial (Schubert *et al*., 1993).

The offered by Plumb (1983) energy cycle formulation, in which the energy conversions occur as $P_E \to K_E \to K_M \to P_M$, is assumed as a basis. Here,

$$P_E = -\frac{R}{2p}\left(\frac{p}{p_s}\right)^{\kappa}\frac{\overline{\theta'^2}}{\partial\bar{\theta}/\partial p}; \qquad (1)$$

$$K_E = \frac{\overline{u'^2}+\overline{v'^2}}{2}; \qquad (2)$$

$$K_M = \frac{\bar{u}^2+\bar{v}^2}{2}; \qquad (3)$$

$$P_M = c_p\bar{T} - P_E, \qquad (4)$$

P_E is eddy available potential energy, K_E – eddy kinetic energy, K_M – zonal mean kinetic energy, and K_M – zonal mean potential energy. The notations in (1)-(4) are conventional and the concepts of zonal mean value and deviations from it were used:

$$\bar{f} = \frac{1}{L}\int_{-L/2}^{L/2} f dx; \qquad f' = f - \bar{f},$$

where L is length of latitudinal circle.

From (4) it is shown that P_M is mainly determined by the zonal mean air temperature ($c_p\bar{T} \gg P_E$) and therefore the distribution of this energy, in general, is trivial and in this work is not analyzed.

The calculations were carried out for latitudinal belt between 60 N and 90 N.

The monthly mean AO indices were obtained from the NOAA Climate Prediction Centre (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/all_index.html).

3. RESULTS

3.1 *Yearly mean values of energy*

At first consider the mean values of considered energies. Contents of K_M, K_E and P_E over high latitudes of the Northern Hemisphere are 1.17, 0.34 and 1.12 10^6 Jm^{-2} respectively. Fig. 1 shows that the integral values of K_E and K_M content are smoothly poleward decreasing and are almost zero near Northern Pole whereas P_E content has sharp diminution from 3.16 at 62 N to 0.7 10^6 Jm^{-2} at 68 N. Such behavior of the eddy available potential energy is explained by presence of maximum near ground in the zone of Ferrel's cell ascending branch. At the same time, the maximal values of kinetic energy are aroused from the jet stream of high latitudes.

Fig. 2 illustrates such distribution: the main contents of K_M and K_E are concentrate near 300 hPa level in the

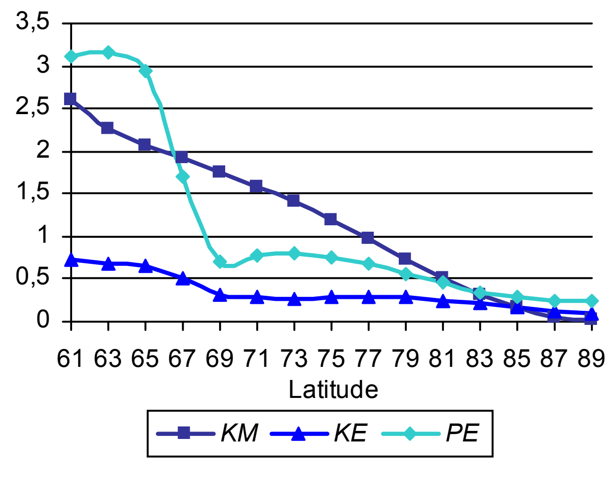

Fig. 1. Latitudinal distributions of the mean values of K_M, K_E and P_E (10^6 Jm^{-2}) for belt between 60 N and 90 N

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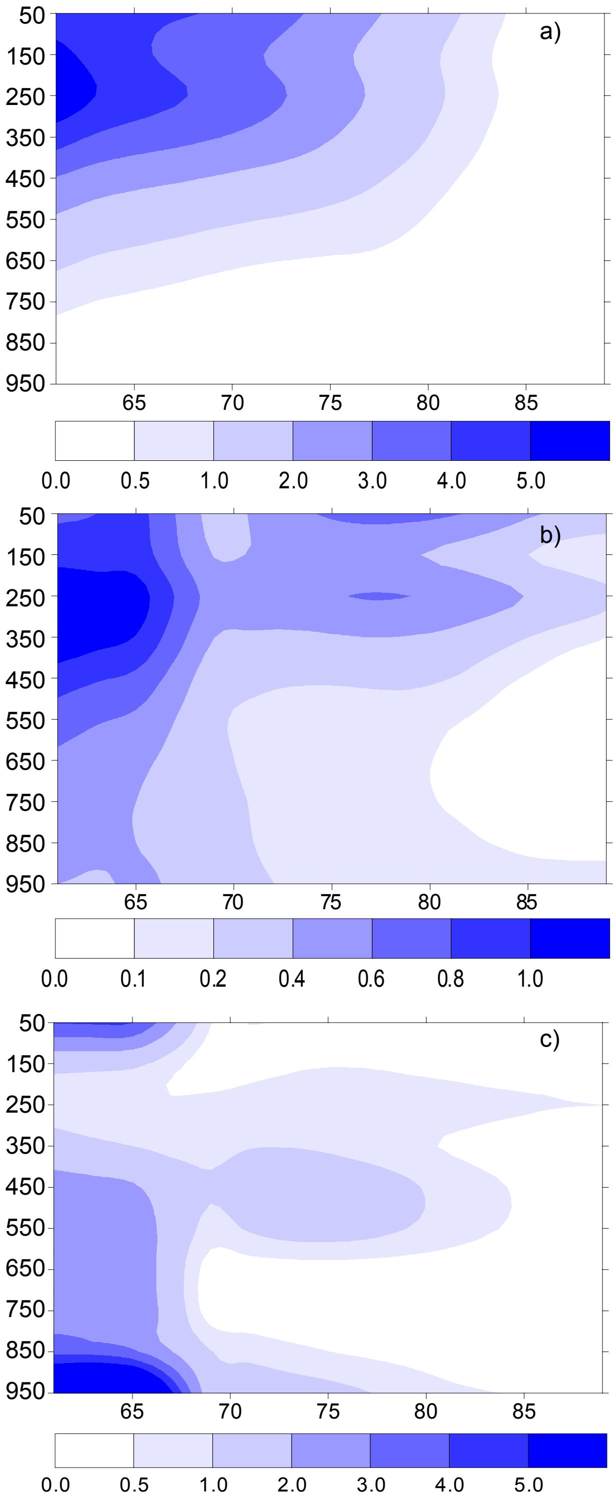

Fig. 2. Vertical cross sections of the yearly mean content of K_M (a), K_E (b) and P_E (c) for Northern polar atmosphere (10^5 Jm^{-2}).

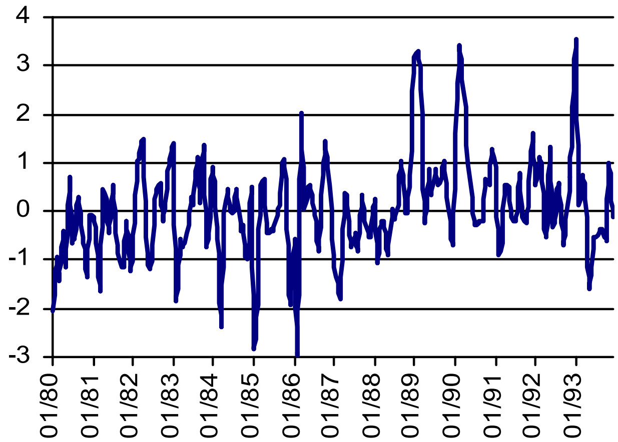

Fig. 3. The Arctic Oscillation indices during 1980-1993 years

60-65 N latitudinal belt (5.78 and 1.22 10^5 Jm^{-2}) but P_E content has two maximums in that region – in the stratosphere (4.09 10^5 Jm^{-2}) and in the boundary layer (10.76 10^5 Jm^{-2}). On this figure the *X* axis is latitude and values on *Y* axis correspond to middles of layers with thick 100 hPa.

As opposed to the tropics (Khokhlov and Glushkov, 2002), in high latitudes maximum values of all energies are observed in one from winter month and then the energy content sharply decrease (Fig. 4).

3.1 *Energetics response on Arctic Oscillation*

The AO is a north-south seesaw of the atmospheric mass between the Arctic region poleward of 60 degree N and the surrounding zonal ring in mid-latitudes. The AO is represented herein by the leading mode (the first empirical orthogonal function) of low-frequency variability of wintertime geopotential between 1000 and 10 hPa. In the middle stratosphere the signature of the AO is a nearly zonally symmetric pattern representing a strong or weak polar vortex (Baldwin and Dunkerton, 1999). Also, Black (2002) has shown that during the Arctic oscillation surface climate variations are directly forced by changes in the strength of the stratospheric polar vortex.

Here influence of Arctic Oscillation to seasonal variations of atmospheric energetics is investigated. Indices of the Arctic Oscillation are presented in Fig. 3. This figure shows that since 1980 till 1988 the winter Arctic Oscillation is characterized by negative phase (or small positive) and its maximums were during winters 1984 – 1986. Since 1989 and up to an end of considered period in winter the positive phases were mainly observed and extreme values were registered in winters 1989 – 1990 and 1993.

As large negative values of the AO indices correspond to the rise of pressure in polar vortex during negative phases of the AO the smallest content of KM is observed. On the contrary, when the polar vortex is deepening (the AO indices is positive and maximal) the integral values of KM achieves maximal magnitudes (Fig. 4a).

The similar dependence is not found for eddy kinetic and available potential energies. For example, the maximal KE contents (Fig. 4b) were observed for the small and largest positive AO phase (winter of 1984 and 1989 respectively). Similarly, the greatest PE content

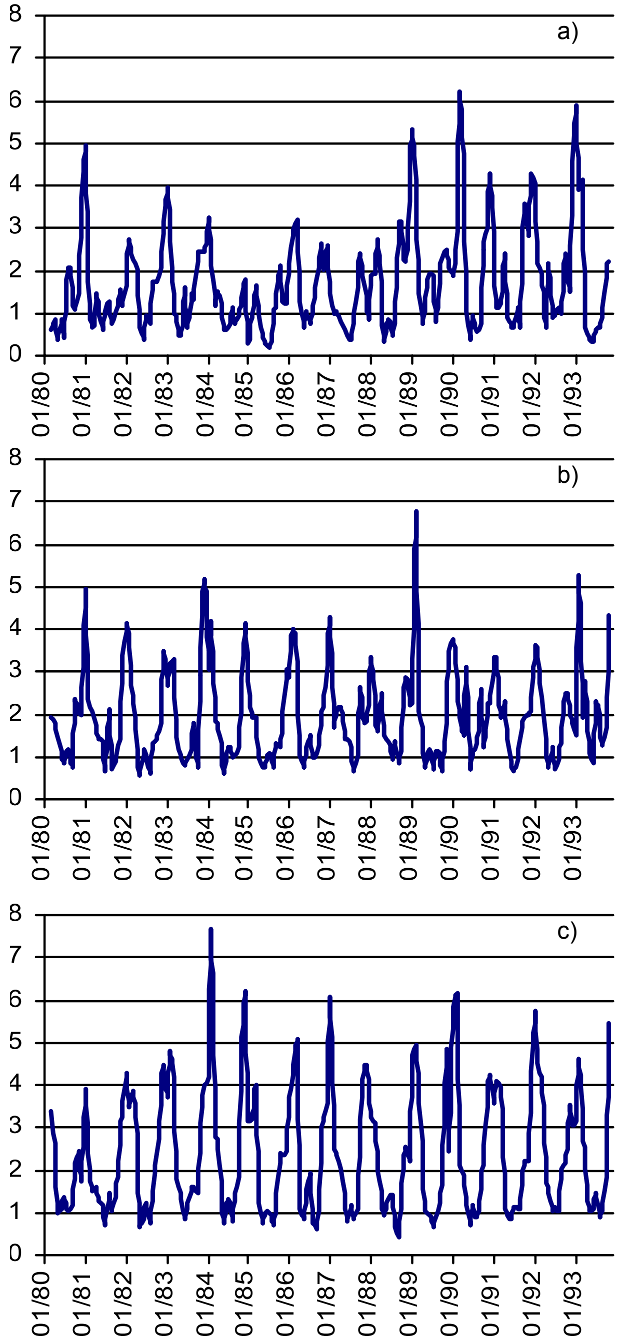

Fig. 4. Month-to-month variations of K_M (a), K_E (b) and P_E (c) (10^6 Jm^{-2}) for belt between 60 N and 90 N during 1980 - 1993 years

(Fig. 4c) was observed in winter 1984. However, here following behavior is found: during years, which are not characterized by the strong positive or negative phases the contents of K_E and P_E are smallest.

It is possible to explain by follows. During strong AO, high latitude westerly wind anomalies extend from the surface well into the stratosphere, achieving largest amplitudes at stratospheric levels (Black, 2002). Otherwise, when the AO is not strong the wind anomaly is poorly evolved too. Therefore, the polar atmosphere is in a condition close to equilibrium and the energy of zonal flow converts less to eddy energy.

CONCLUSIONS

The carried out analysis has shown that some extremes of energy contents are explained by variations of the winter AO indices. At that, the zonal mean kinetic energy is under the greatest influence. The response of eddy kinetic and available potential energies depends on magnitude and spatial distribution of the zonal wind anomalies.

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