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POSSIBILITIES OF LONG-RANGE FORECAST Of WEATHER CONDITIONS OVER THE ANTARCTIC PENINSULA

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Abstract. Developed by us in 1998 the method of long-range weather forecast for the moderate latitudes of Northern hemisphere is based on two-month similarity of atmospheric circulation which is well revealed by the traditional method of analogues of one season. That is why similarity of atmospheric processes in the non-tropical latitudes of Southern hemisphere was also explored by the method of traditional analogue. Similarity between the processes of successive days on the fixed territory taking into account the coincidence of all geographical coordinates allowed to set in Southern hemisphere two-month quasi-periodicity of large-scale and consequently regional atmospheric circulation.

Taking into account found out the period of quasi-periodicity of regional atmospheric circulation of the Antarctic Peninsula near 60 days in a summer period and near 70 days in a winter period the forecast scheme of anomaly of average monthly temperature of air is developed. The forecast scheme of anomaly of average monthly air temperature for the area of Academik Vernadsky Station is developed with monthly earliness with the aim of equations of linear regression. The anomaly of average monthly air temperature of initial month is used in equation of linear regression as prediktor. The estimation of forecast scheme was executed on dependent material of separate years and showed success of the offered method of forecast of average monthly air temperature for Academik Vernadsky Station. For the improvement of estimation of extreme values of temperature above the Antarctic Peninsula and at Academik Vernadsky Station the scheme of long-range forecast of average monthly air temperature was complemented by auxiliary equations, that allow to calculate extreme values. On the whole it is possible to mark that found out atmospheric circulation conformities of near two-month quasi-periodicity for the moderate latitudes of Southern hemisphere can be basis for development of method of long-range forecast of atmospheric circulation and weather conditions for the territory of Antarctic Continent.

Key words: long-range forecast, two-month quasi-periodicity, atmospheric circulation, similarity of atmospheric processes, average monthly temperature, ice cover.

Реферат. Разработанный нами в 1998 г. метод долгосрочного прогноза погоды для умеренных широт Северного полушария основан на двухмесячной аналогичности атмосферной циркуляции, которая хорошо выявляется с помощью традиционного метода аналогов одного сезона. Потому аналогичность атмосферных процессов во внетропических широтах Южного полушария также была исследована с помощью метода традиционного аналога. Аналогичность между процессами последовательных дней на фиксированной территории с учетом совпадения всех географических координат позволила установить в Южном полушарии двухмесячную квазипериодичность крупномасштабной, и следовательно региональной, циркуляции атмосферы.

Учитывая обнаруженный период квазипериодичности региональной атмосферной циркуляции Антарктического полуострова около 60 дней в летний период и около 70 дней в зимний период, разработана прогностическая схема аномалии средней месячной температуры воздуха. Прогностическая схема аномалии средней месячной температуры воздуха для района ст. Ак. Вернадский разработана с месячной заблаговременностью с помощью уравнений линейной регрессии. В качестве предиктора в уравнении линейной регрессии используется аномалия средней месячной температуры воздуха исходного месяца. Оценка прогностической схемы была выполнена на зависимом материале отдельных лет и показала успешность предложенного метода прогноза средней месячной температуры воздуха для ст. Академик Вернадский. Для улучшения оценки экстремальных значений температуры над Антарктическим полуостровом и ст. Академик Вернадский схема долгосрочного прогноза среднемесячной температуры воздуха была дополнена вспомогательными уравнениями, что позволяет вычислять экстремальные значения. В целом можно отметить, что обнаруженные закономерности атмосферной циркуляции около двухмесячной квазипериодичности для умеренных широт Южного полушария могут быть основой для разработки метода долгосрочного прогноза атмосферной циркуляции и погодных условий для территории Антарктиды.

Ключевые слова: долгосрочный прогноз погоды, двухмесячная квазипериодичность, атмосферная циркуляция, аналогичность атмосферных процессов, аномалия среднемесячной температуры, ледовый покров.

1. Introduction

Development the methods of long-term weather forecast is one of the most important and complex problems of meteorological science, taking into account its utmost importance in human's life. Development the long-term weather forecast have begun from the end XIX – beginning XX century when first network of meteorological data has been set up. The basic task in the field of long-term weather forecast was to study general circulation in the atmosphere as the set of large-scale flows in the troposphere and stratosphere.

The most essential results during the early period of research were obtained by Multanovsky, Walker, Baur, Nemayes, Teisserence de Bort [1–4]. The existence of permanent centres of action of the atmosphere (PCA) was revealed on climatological maps of sea level pressure and it was shown, that the large-scale atmospheric circulation and weather settings are determined first of all by intensity of PCA. The state of PCA is used in methods of long-range weather forecast up to now.

For the Southern hemisphere the problem of the long-term forecasts is aggravated by lacking both data and research into large-scale synoptic processes in the Southern hemisphere as well as in the Antarctic peninsula region. Until recently it did not give an opportunity to develop weather forecasts in long lead (month, season). Therefore techniques of the long-term forecasts for the Antarctic peninsula does not exist, despite of its exclusive importance for safe navigation, sea ice forecast, carrying out expeditions and field research, maintaining meteorological services at other Antarctic stations of countries-participants of the Antarctic agreement, and tourism operations.

This paper is devoted to research into the large-scale atmospheric circulation in the Antarctic for detection the basis of long-range forecasting in 1-2 months lead. In this paper transformations in the large-scale atmospheric processes in the Southern hemisphere are firstly obtained which became a basis of the further development the techniques of long-term weather forecast for the Antarctic peninsula region.

2. Materials and method of research

The initial information for research of large-scale atmospheric processes of the Southern hemisphere are the daily fields of sea level pressure (SLP) and geopotential fields at a level 500 гПа between 40-80o S. from a data of the department of climatic researches and long-term weather forecast UHMI , archive of RSHMC (Obninsk) and ERA-40 reanalysis for the period 1980-2008. The archives of fields of pressure are submitted in nodes of the regular grid at a step 2,5o on latitude 0 and longitude 0 and are written down as a matrix:

$$X=\begin{vmatrix} X_1 \\ X_2 \\ \dots \\ \dots \\ X_N \end{vmatrix} = \begin{vmatrix} x_{11} & x_{21} & \dots & x_{i1} & \dots & x_{K\text{-}11} & x_{K1} \\ x_{12} & x_{22} & \dots & x_{i2} & \dots & x_{K\text{-}12} & x_{K2} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ x_{1N} & x_{2N} & \dots & x_{iN} & \dots & x_{K\text{-}1N} & x_{KN} \end{vmatrix}, \; i=1,2,\dots,K, \quad j=1,2,\dots,N \qquad (1)$$

where the elements x_{ij} of the matrix X correspond to meteorological value in *i*-node of a regular geographical grid by a step of 2.5 degrees on latitude and longitude a *j*-field:

$$X_j = \{x_i\}_j = (x_1, x_2, \dots, x_K)_j, \; i=1,2,\dots,K, \qquad (2)$$

where x_i – meteorological value of the elements x_{ij} of the matrix X, K – number of units of a regular grid, N – number of fields in archive.

The method analogue of synoptic processes is as a method of research of large-scale atmospheric circulation used (Мартазинова В.Ф., 1987, Мартазинова В.Ф., 1987). The traditional approach to similar synoptic processes consists in the following: if on some region of a terrestrial surface during some time is marked similar synoptic processes, that was observed in past time in the same territory and in the same calendar terms, then current process will develop similarly. However, such approach, as practice of long-term weather forecast confirms and as shown in (Лоренц Э., 1982), is not justified, and two synoptic processes in 5–7 days become casual in relation to each other. Offered in (Мартазинова В.Ф., 1987, Мартазинова В.Ф., 1987) the new approach to a principle analogue of two synoptic processes removes the traditional requirements of similarity of processes at the same territory in same calendar terms and requires only geometrical similarity of two planetary high-level frontal zones (PHFZ) and fields of pressure at surface of the Earth in the South hemisphere and thus does expand researches of periodicity of atmospheric processes in the time and space for a Southern hemisphere. Such approach has received the name of a method of floating analogue (Мартазинова В.Ф., 1987).

Daily average, maximal, minimal and average monthly temperature of air for Akademik Vernadsky Station during the period 1987–2008 from a data of the Ukrainian Antarctic centre and department of climatic researches UHMI also were used. The archive of temperatures is written down also as a matrix T:

$$T=\left|\begin{array}{cccccc} T_{11} & T_{21} & \dots & T_{m1} & \dots & T_{M1} \\ \hline \dots & \dots & \dots & \dots & \dots & \dots \\ T_{1p} & T_{2p} & \dots & T_{mp} & \dots & T_{Mp} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ T_{1P} & T_{2P} & \dots & T_{mP} & \dots & T_{MP} \end{array}\right|$$

were $m=(1,2,...,M)$, $p=(1,2,...,P)$, $T_{mp} = \{t_i\}_{mp} =(t_1,t_2,...,t_K)_{mp}$ corresponds to a vector of daily temperature of air for m-th year (m=1987 ÷ 2008) p-th month on Akademik Vernadsky Station, P-number of months in one year, K-number of days in one month.

For classification of the annual daily average temperature regimen on the Vernadsky Station of the period 1997–2008 and definition in each class of a temperature mode with the greatest information about class was used a method of "etalons" (Martazinova V., 2005). The etalon of a class determines one annual daily average temperature regimen which has best similarity with the rest yars of set it's the class. The two following criteria of analog are used for this purpose:

1. The criterion of geometrical similarity allows to estimate the coincidence on a sign of anomaly of two curve temperature regimen:

$$\rho = \frac{n_+ - n_-}{n_+ + n_-}, \tag{3}$$

where n_+ – number of days in one year, where the sign of anomalies coincides, n – number of days in which a sign of anomaly is opposite in year. The criterion changes $1 \geq \rho \geq -1$.

2. Criterion of mean square distance η between two curves of temperature regimen:

$$\eta = \sqrt{\frac{1}{K}\sum_{i=1}^{K}(x_{ij} - x_{im})^2}, \tag{4}$$

where x_{ij} and x_{im} – values of temperature of air in i-th day of a curve of temperature regimen j-th and m-th of year of a class.

Such approach to classification allows all variety of curves of temperature regimens to reduce to several basic cases-etalons, which play the important role in formation about climate of Vernadsky station and in construction of a method of long-term weather forecast over Antarctic peninsula.

3. Seasonal character of temperature condition Academik Vernadsky station last decade

For development of the methods of the long-range weather forecast for the Antarctic Peninsula region it is necessary to study present-day regional air temperature regime in all seasons. Daily mean, maximal and minimum air temperatures at Vernadsky station as well as its statistical characteristics during 1997–2008 are shown in table 1. January is a warmest month (T=1.20°C), August is coldest (T=–6.40°C). The smallest variability of air temperature from year to the next is marked in summer (A above 20°C), the largest variability is detected in winter (A above 60°C).

Table 1

Monthly mean and extremal air temperatures, standard deviation (σ), monthly amplitude (A) at Academik Vernadsky base, 1997–2008

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
T^{0}C	1.2	1.1	0.0	-1.4	-2.8	-4.4	-5.4	-6.4	-6.1	-3.5	-1.7	0.0	-2.4
T$_{max}$	2.2	2.3	1.6	0.1	-0.2	-1.1	-2.6	-2.9	-2.5	-1.5	-0.6	1.1	-1.5
T$_{min}$	-0.4	0	-2.2	-2.3	-5.9	-9.3	-8.5	-9.2	-9.1	-6.5	-2.4	-1	-3.5
σ	0.8	0.7	1.0	0.7	1.4	2.1	1.8	1.9	2.1	1.4	0.5	0.6	0.6
A	2.6	2.3	3.8	2.4	5.7	8.2	5.9	6.3	6.6	5	1.8	2.1	4.4

Using method of etalon the classification of air temperature regime during the year by the data of Vernadsky base was carried out and three classes were distinguished (fig.1). The first class of temperature regime comprises majority of years: warm processes in summer with positive anomaly of mean monthly air temperature, by 1–20°C. Cold period is characterized by more significant

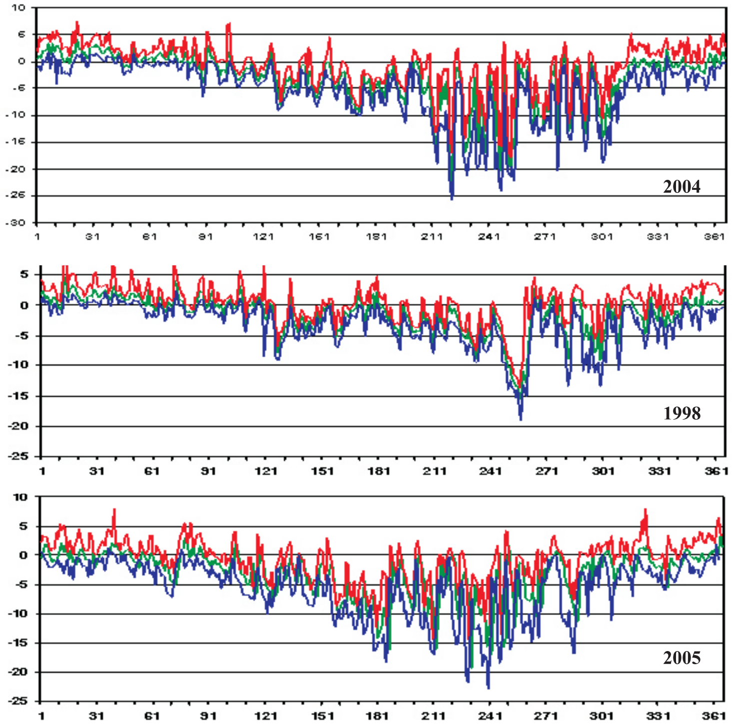

Fig. 1. Types of annual courses of air temperature (modes) at Vernadsky base.

oscillations in daily mean air temperature. Greatest oscillations in the air temperatures from day to the next are marked in winter, reaching 20°C, including sharp cold spells from 00C to as low as –25°C in the nearest 1-2 days (fig.1). The etalon year of the air temperature regime of this class is 2004. The second class of air temperature regime in summer is characterized by the air temperature within the limits of climatological norm, and is characterized by insignificant variability from day to the next during the winter period. As a rule, such winters are warm with air temperature changes from 0°C to –50°. The etalon year of this class of the air temperature regime is 1998 (fig.1). The third type of air temperature regime in winter comprises anomalously cold processes. In summer the nightly air temperatures can fall below –60°C, and fall in daily mean air temperatures as low as to –200° C is marked from the first days of the winter. As an etalon year of this class is the winter of 2005 (fig.1). The lowest air temperatures during this winter were registered about –250°C, and the highest air temperatures during the summer were about 50°C.

Classification of the air temperature regime makes possible to lay basis on the long-range predictability of air temperature at the Vernadsky base:

1. if the winter begins with the lower air temperatures, as in 2005, during a winter period the air temperature within – (20– 25) °C can be expected;
2. if the winter begins with temperatures about 0°C, a steady temperature mode within +5, –5°C to the midwinter is expected. The second half of the winter can have abrupt differences of air temperature or it can continue to oscillate within the limits of temperatures of the first half of the winter;
3. the air temperature in early spring period (September) has the largest variability in the minimal temperatures, and as a rule, the first half of spring can be considered as a continuation of the winter;
4. regardless the type of air temperature changes from day to the next in the winter period, spring air temperatures' amplitudes reaches the maximum in both low and high values;
5. the most complex and spontaneous character of air temperature oscillations is marked in the early spring. Autumn is characterized as the season with smallest oscillations in temperature regime.

4. The two-month quasiperiodicity of atmospheric processes in the Southern Hemisphere and its seasonal position

Stability analysis of the initial geopotential field at 500 hPa level in the Southern Hemisphere during 3 months from day to the next with a time step =1, 2, 3....*K* during the indicated time period can be conducted using the geometric criterion of similarity:

$$\overline{\rho}(\tau) = \frac{1}{K-\tau}\sum_{t=1}^{K-\tau}\rho(t,t+\tau), \qquad (5)$$

where

$$\rho(t,t+\tau) = \frac{n(i,i+\tau)_{+} - n(i,i+\tau)_{-}}{N}, \qquad (6)$$

where *K* is number of geopotential fields in the archive for the period 1997–2006. As noted above, all similarity criteria of atmospheric processes, regardless of the different similarity approaches they represent, are well-correlated in between themselves. Stability of the initial air pressure field within the first days is determined by the value of c> 0.3 and indicates the similarity by the signs of anomalies for up to 60–65% of the given area. This threshold has climatic significance, which is consistent with the atmospheric centers of action in the Southern Hemisphere. In general, the stability of the initial pressure field retains during the first days and further on decreases sharply in all seasons. An increase in $\overline{\ (\ )}$ during the temporal range 55–60 days was noted to be common for all curves in both winter, summer, and in general for the year, which corresponds to a weak similarity in geopotential fields after two months from the initial point. The stability of the initial geopotential fields has a seasonal dependence: winter geopotential fields are much more stable than the summer ones.

The similarity of atmospheric processes in the middle troposphere level in the Southern hemisphere was investigated by the floating analogues method for the three-month interval, as shown in [5] for the Northern Hemisphere. Floating of the current pressure field based on previous fields during the three-month interval was limited by longitude by a $^{0}= 2.5^{0}$ step to the west and east, which was determined by half the distance between the atmospheric centers of action, and with a latitude step of $^{0}= 2.5^{0}$ it did not exceed the distance between winter and summer planetary upper-tropospheric frontal zone (UTFZ) position. At each time step t=1day a maximum similarity matrix of synoptic processes in the Southern Hemisphere (max) was calculated for $\pm\ ^{0}$ и $\pm\ ^{0}$.

$$\rho_{(max)} = \left| \begin{array}{cccc} 1 & \rho_{12(max)} & \rho_{13(max)} & \cdots \rho_{1K(max)} \\ & 1 & \rho_{23(max)} & \cdots \rho_{2K(max)} \\ & & \cdots & \cdots\cdots \\ & & & 1 \end{array} \right|$$

where $_{ij(max)}$ indicates the best measure of similarity of the initial synoptic process with subsequent ones at a time step $j = 1,2,\ldots,K$, day (K corresponds to a three-month interval from the initial day). For example, $_{13(max)}$ shows the best similarity of the pressure field between the first and third days. Also, the geographical location of each maximum similarity is fixed by the coordinates of the analog's offset by $\pm\ ^{0}$ и $\pm\ ^{0}$.

The autocorrelation values (max) analysis showed that the synoptic processes of the Southern hemisphere have a two-month quasiperiodicity likewise to the one observed in the Northern hemisphere. Similar atmospheric processes with a two-month quasiperiodicity have a seasonal shift in latitude and longitude compared to the initial synoptic processes (Table 2).

Table 2

Offset of the two-month similarity of atmospheric processes at the middle troposphere level of the Southern Hemisphere

Current month	Analog -month	Offset	
		$\Delta\varphi^{0}$	$\Delta\lambda^{0}$
March	January	+5	–5
April	February	+5	–5
May	March	+7.5	–7.5
June	April	+5	–10
July	May	0	0
August	June	0	+5
September	July	–5	+10
October	August	–5	+12.5
November	September	–5	+10
December	October	– 5	±10
January	November	–5	–10
February	December	–7.5	–12.5

As seen from Table 2, the similarity of the atmospheric processes in the Southern hemisphere has a seasonal position. This seasonal position is explained by a seasonal pole-equator and land-ocean temperature gradient. For example in summer, when UTFZ in the middle troposphere level is higher than in autumn, the analogues of the summer atmospheric circulation in the hemisphere are to be shifted lower (southward) by –5, –7.5°.

The two-month quasiperiodicity of the atmospheric circulation can be clearly seen from the graphs of daily mean air temperature at Academician Vernadsky base for the winter season (May, June, July and August) of 2007 (Fig. 2, 3). The two-month quasiperiodicity of atmospheric processes of June is noted in May, and the one of August – in July. The similarity in the atmospheric circulation can be seen in the temperature regime in May, July, August in June.

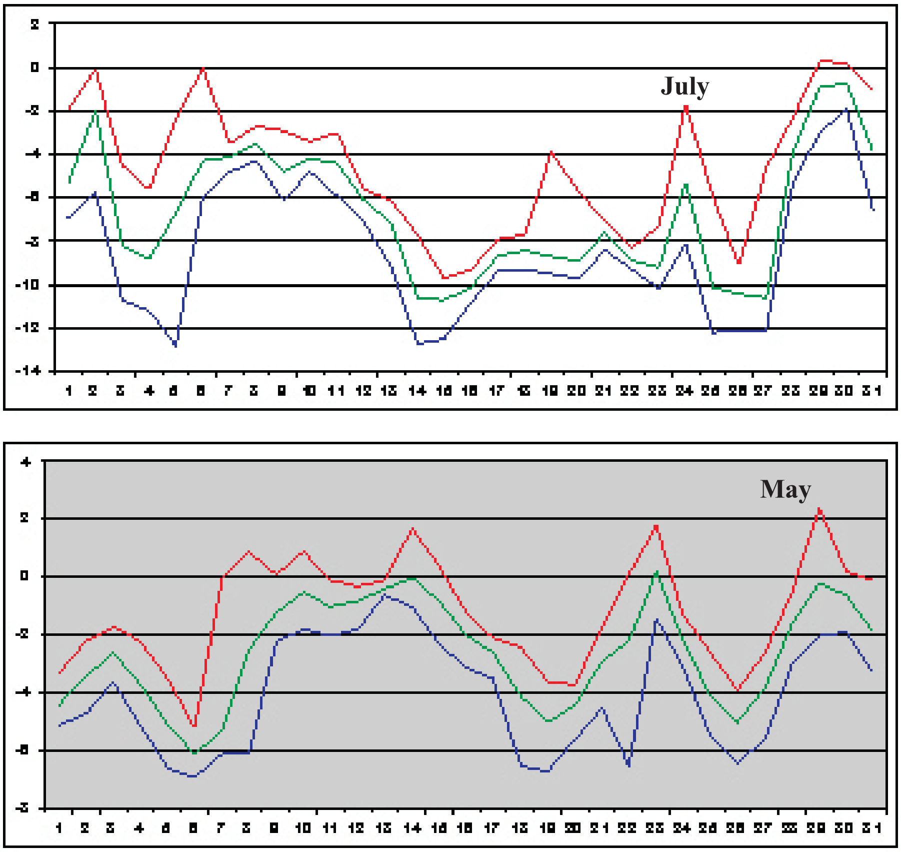

Fig.2. Air temperature regime (daily mean and extremes) at Academician Vernadsky base in July 2007 with a two-month quasiperiodicity in May 2007.

The similarity of temperature in July relative to May 2007, with a slight delay, has high criterion of similarity (= 0.85). Typically, a two-month similarity of the atmospheric circulation in the given season is well evident even with the traditional analog method (Table 2). As a next example of the two-month periodicity of atmospheric processes the air temperature regime at Academician Vernadsky base in August 2007 is shown (Fig. 3).

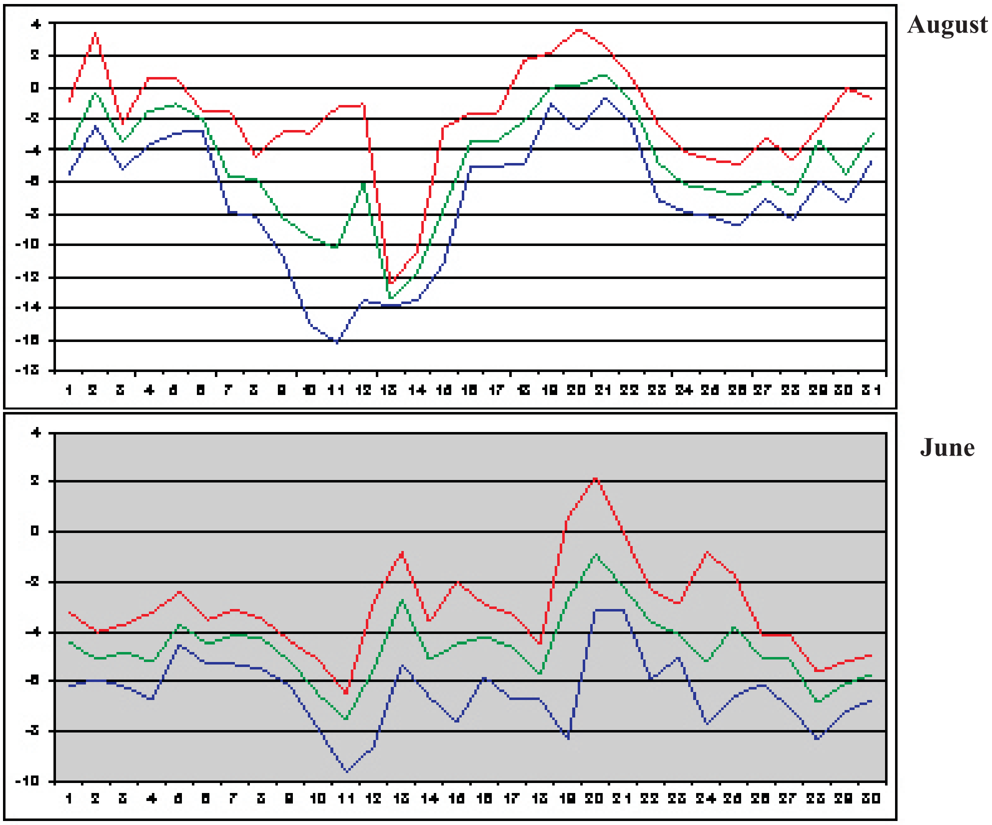

Fig. 3. Air temperature regime (daily mean and extremes) at Academician Vernadsky base in August 2007 with a two-month quasiperiodicity in June 2007.

Similarity in the air temperature regime in June and May is high with a weak lag with the criterion of similarity =0,80. The detected two-month quasiperiodicity of atmospheric processes is essential for developing a method of long-term weather forecasting and provides great opportunities for long-term detailed weather forecasts with monthly advance. Knowing the nature of the changes in the atmospheric processes in advance for the month one can recognize which changes in the air temperature can be expected in the next 40 days in the Southern Hemisphere, possibly including an opportunity to predict the ice cover in the sea around the Antarctic Peninsula. For these calculations, the model of circulation THREETOX complemented by model of the dynamics-thermodynamics of ice [16, 17] is used.

5. The model of formation of ice cover

To describe the processes of formation of ice cover the circulation model THREETOX [16], is used, that is supplemented by a model of the dynamics-thermodynamics of ice [17]. The circulation model is a hydrostatic model with free surface, the equations are written in the orthogonal curvilinear system of horizontal coordinates and in the mixed-sigma vertical coordinate system. Turbulent mixing is parameterized using exchange coefficients and turbulence model. Ice dynamic model describes the thermodynamics of ice, rheology of ice sheet, mass balance, the ice concentration and stresses.

Formation of ice cover in the shelf areas of the antarctic aeas, for example, in Weddell Sea, begins with the formation of ice at negative temperature of air. The cause of the formation of frazil ice is super-cooling the inner layers of the water column, whereas the ice has not formed on the surface. In most models, this process is not described and it is assumed that the entire frazil ice immediately gets on the surface, where a young ice is formed. But for the modeling of the shelf convection it is necessary a more detailed description of this process, because the formation of ice resulted not only in the release of brine, which increases density but also in the entrainment of the suspended sediments [18, 19]. These processes can make a significant contribution to the maintenance of near-bottom gravity currents, contributing to the formation of Antarctic Bottom Water (ABW).

To properly describe the formation of frazil ice, the equations model the hydrodynamics of the ocean [16], in accordance with [18, 19], supplemented by distributed sources:

$$\frac{dT}{dt} = \frac{\partial}{\partial z}\left(\left(\nu_t' + \nu_f'\right)\frac{\partial T}{\partial z}\right) + \frac{\partial}{\partial x}\left(K_n\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_n\frac{\partial T}{\partial y}\right) + \frac{1}{\rho_0 c_p}\frac{\partial I}{\partial z} + G_T \qquad (7)$$

$$\frac{dS}{dt} = \frac{\partial}{\partial z}\left(\left(\nu_t' + \nu_f'\right)\frac{\partial S}{\partial z}\right) + \frac{\partial}{\partial x}\left(K_n\frac{\partial S}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_n\frac{\partial S}{\partial y}\right) + G_S \qquad (8)$$

where t is time; $'_t$ is the coefficient of vertical diffusion; $'_f$ is background value of vertical diffusion coefficient, K_n is the coefficient of horizontal diffusion, $_0$ is a undisturbed density of water, c_p water heat capacity, *I(z)* is a flux of penetrating solar radiation, T is a water temperature, S is salinity, G_T and G_S are distributed sources for te mperature and salinity, respectively.

Introduce one more of advective- diffusion equation, which describes the transport of frazil ice within the aquatic environment:

$$\frac{dC_i}{dt} = \frac{\partial}{\partial z}\left(\left(\nu_t' + \nu_f'\right)\frac{\partial C_i}{\partial z}\right) - w_i\frac{\partial C_i}{\partial z} + \frac{\partial}{\partial x}\left(K_n\frac{\partial C_i}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_n\frac{\partial C_i}{\partial y}\right) + G_i \qquad (9)$$

where C_i is volumetric concentration of ice; G_i is a distributed source of the ice, W_i is a speed of lifting of ice on the surface of water.

Distributed sources for temperature, salinity, and ice in the water column depend on the freezing and melting of ice crystals. It is assumed that volume changes are controlled by the ice flow of heat from the already existing ice crystals in the water column and change of the heat balance leads to a change in their volume of ice by the crystallization or melting. Salinity varies in accordance with the influx of salt particles during freezing or fresh water during their melting.

The flow of heat from the ice crystals in the surrounding water is:

$$Q_i = Nuk_w\left(T_i - T\right)/2\,r \qquad (10)$$

where Nu 6 is the Nusselt number; k_w is a thermal conductivity at the boundary of the ice-water; T_i is a the temperature of the crystal ice; r is the ice crystal radius. The temperature of ice crystals is assumed equal to the freezing temperature of ice and depends on the temperature of the surrounding water and salinity.

Heat flow equation for the temperature of water is described as:

$$G_T = \frac{aC_iQ_i}{c_p\rho} \qquad (11)$$

where a is the ratio of surface area to volume of the crystal ice, for a sphere $a \quad 3/r$, for a cylinder or disk $a \quad 2/r$.

Increased salinity due to crystallization or water desalination due to melting is described as:

$$G_i = \frac{aSC_iQ_i}{L_i\rho} \tag{12}$$

where L_i is the latent heat of crystallization of pure ice.

The boundary conditions for the equation of the concentration of frazil ice are:

at bottom $\frac{\partial C_i}{\partial z} = 0$ and at surface $\nu'_t \frac{\partial C_i}{\partial z} = W_{FR}$,

where W_{FR} is prescribed.

This model of frazil ice complements the equations of dynamic-thermodynamics of the ice cover [17] by an explicit description of the processes of formation of young ice.

6. Scheme of the long-range forecast of anomaly mean monthly temperature of air for the Academik Vernadsky Station in the cold and warm periods of year.

On the basis of revealed we two-month quasi-periodicity of atmospheric circulation above a Southern hemisphere and, hence, above the Antarctic peninsula, developed forecasting scheme of anomaly of mean monthly temperature of air with monthly earliness. In given article the developed scheme of the forecast for area of the Vernadsky Station with the help of the equations of linear regression is resulted:

$$\Delta T_{t+2} = \alpha\Delta T_{t+b}, \tag{13}$$

where T_t is predictor, which corresponds to value of anomaly of mean monthly temperature of air at the moment of forming of the forecast, T_{t+2} – is forecast value of anomaly of mean monthly temperature in the second month from initial T_t. The equation of linear regression was received by a method of the least squares:

$$\sum_{i=1}^{n} (\Delta T''_i - \Delta T_i)^2 = min, \tag{14}$$

where T''_i – actual value, T_i – forecast value T_{t+2} for i month, n – quantity of the designed forecasts. Then:

$$\partial \sum_{i=1}^{n} (\Delta T''_i - \alpha\Delta T_i - b)^2 / \partial\alpha = 0, \tag{15}$$

$$\partial \sum_{i=1}^{n} (\Delta T''_i - \alpha\Delta T_i - b)^2 / \partial b = 0, \tag{16}$$

These conditions are reduced to system of the equations:

$$\sum_{i=1}^{n} \Delta T''_i \, \Delta T_i = \alpha \sum_{i=1}^{n} \Delta T_i^2 + b \sum_{i=1}^{n} \Delta T_i \tag{17}$$

$$\sum_{i=1}^{n} \Delta T''_i = \alpha \sum_{i=1}^{n} \Delta T_i + nb, \tag{18}$$

Whence

$$b = 1/n \sum_{i=1}^{n} \Delta T''_i - \alpha/n \sum_{i=1}^{n} \Delta T_i\,, \tag{19}$$

$$\alpha = n \sum_{i=1}^{n} \Delta T''_i \, \Delta T_i - \sum_{i=1}^{n} \Delta T_i \sum_{i=1}^{n} \Delta T''_i \,/ n \sum_{i=1}^{n} \Delta T_i^2 - \left(\sum_{i=1}^{n} \Delta T_i\right)^2 \tag{20}$$

Calculate forecast scheme are various for warm and cold half-year at the expense of various variability of temperature of air from day to day in each half-year. Received forecast scheme of the forecast of anomaly of temperature of air in the second month from initial in the cold period has the equation of regression:

$$\Delta T_{t+2} = \alpha \Delta T_t + b = 2.4\, \Delta T_t - 1.57, \tag{21}$$

where as predictor T_t the anomaly of mean monthly temperature of air of initial month in the cold period (April – September) is used. Temperature of air in the cold period has the large variability from day to day, thus the value of anomalies can reach critical value and consequently in the forecast equation (21) coefficients (a) and (b) on absolute value above than values of warm half-year:

$$\Delta T_{t+2} = \alpha \Delta T_t + b = 0.71\, \Delta T_t + 0.57. \tag{22}$$

As predictor ΔTt of the equation (22) the anomaly of mean monthly temperature of air of month of the warm period (October – March) is used. Temperature of air in the warm period has small variability, therefore the coefficients of the equation (22) are close to zero.

The estimation of forecast schemes was carried out on a dependent and independent material of separate years and months of the cold and warm periods. It was got at verification of method, that the sign of anomaly on the second month from initial is forecast successfully, with probability about 70% in a cold period and 75% exceeds in a warm period. It is necessary to note, that the values of anomaly of temperature close to 1°C are predicted successfully in a range of a mistake ±0.5°C, but the given method has bad predictability for values of large anomalies from 2–4°C and by that lowers an estimation of success of a method of the forecast.

Taking into account, that the forecast of extreme values of temperature has large practical preciousness and that the quantity of extreme values is increased to the cold period, and the offered method does not allow successfully to predict extremeness, the scheme of the long-range forecast of mean monthly temperature of air above the Antarctic peninsula and Academician Vernadsky Station was complemented by the auxiliary equations with the help of an average square of a difference between forecast and actual temperature. Residual dispersion $D=\sigma^2-\sigma^2_T$ (where σ^2 – dispersion of forecast temperature, σ^2_T – dispersion of actual temperature) shows, that than more considerable D, the more mistake of extreme anomaly of temperature. In view of particularity σ^2/σ^2_T the equations of linear regression allowing to calculate of extreme values ΔT_{t+2} were constructed:

$$\Delta T_{t+2} = \varepsilon(\alpha\Delta T_t + b) \qquad (23)$$

where predictor T_t remains former, ε is a coefficient of extremeness, expected on a formula:

$$\varepsilon = \sqrt{\frac{\sum_{k=1}^{N}\Delta T_{kp}^2}{\sum_{k=1}^{N}\Delta \hat{T}_{kp}^2}}, \qquad (24)$$

where ΔT_{kp} – actual anomaly of mean monthly temperature of air in the second month from initial at station from sample of volume N; $\Delta\hat{T}_{kp}$ – forecasting anomaly of mean monthly temperature of air in the second month from initial same sample. The coefficient of extremeness is removed by the lack of the linear equation consisting that all forecast magnitude change near the norm.

However this improvement of a prediction of extremeness of values is reached by its some deterioration for small deviations ΔT_{t+2}. The offered method allows to predict extreme values of anomaly of mean monthly temperature of air ΔT_{t+2} with anticipation for a month.

Conclusions

As a whole it is possible to note, that the method of the long-range forecast of anomaly of mean monthly temperature of air for the Antarctic Heninsula is created. The revealed spatiotemporal two-monthly quasi-periodical mechanism of atmospheric circulation of the Southern hemisphere in a basis of the method, offered in the given job, the long-range forecast of temperature of air above the Antarctic peninsula. The estimation of success offered of the forecast scheme in the warm and cold periods has shown good justification in a mark of anomaly of mean monthly temperature. The calculate scheme of the forecast is prepared for operative job. With the help of law of atmospheric processes on a Southern hemisphere further is planned to proceed to development of the detailed long-range weather forecast – the periods of sharp changes of pressure, temperature and strong precipitation inside of forecasting month with monthly earliness.

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