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SOME ASPECTS OF METEOROLOGY AND CLIMATOLOGY OF THE REGION OF UKRAINIAN ANTARCTIC BASE VERNADSKY

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1. Introduction

The Ukrainian Vernadsky Antarctic base (65°14'S, 64°17'W) is located on Galindez Island, Argentine Islands small archipelago, 8 km from the west coast of the Antarctic Peninsula and some 75 km south of Anvers Island (fig. 1). Another well-known place at nearby Vernadsky is Petermann Island (center of tourist operations), situated 10 km north.

Fig. 1. Antarctic Peninsula
Location of stations

Rys. 1. Półwysep Antarktyczny
Położenie stacji

From 1996, the scientific activity at Vernadsky is taken by Ukrainian Antarctic Center, and meteorology/climatology and glaciology program was initiated and carried out by researchers from Odessa State Environmental University, known as Hydrometeorological Institute before November, 2001. Vernadsky base was formerly known as Faraday (1977-1996) as well as both "Base F" and Argentine Islands, from 1947. Usually Faraday/Vernadsky timeseries are added with measurements made in 1944 –1947 at Port Lockroy (64°8'S, 63°5'W). In total, these uninterrupted records (1944 - till now) are one of the longest in Antarctica.

2. The data used and the purpose of the research

Standard meteorological data of Vernadsky base were used as well as data of the total ozone amount measured by means of Dobson spectrophotometer (∅31). The set of surface synoptic charts of Chilean military service during April, 1997-March, 2001 was used also. The main purpose of research was to find tropospheric synoptic patterns that contribute greatly to changes of weather and climate of the Antarctic Peninsula and, in particular, cause winter cold spells.

3. Results of research

Multi-years' course of the air temperature

Growth of annual Mean Air Temperatures (MAT) is registered by measurements at Vernadsky, being confirmed by the data of other neighboring stations (Kejna 2002). The coldest were 1950s, but with significant year-to-year amplitudes of MAT; during the last decade they were more smoothed (multi-years' trend for Vernadsky is given at Timofeyev (2002)). The most pronounced warming was registered during 1980s and 1990s. During the last years some stabilization in the growth of annual MAT is observed and they are ranged in narrow interval between -1.7 and -3.7°C.

Variability of MAT through Antarctic winter months contributes mainly to annual MAT, so general positive trend at Vernadsky is produced by warmer winter months in the last years. Cold winters had irregular frequency through all the time of observations; the last one was observed in 1987 with MAT of winter months: July – -20.1°C, August – -12.2°C, September – -14.1°C. On the contrary, all following winter months (1988-2002) were in average warmer than -10°C. The frequency of cold or warm winters is therefore an important climatic factor; obviously, various interannual air temperature amplitudes are caused by different circulation in the troposphere.

Types of tropospheric circulation

Clearly outlined eastward air flow exists in the south mid-latitudes and the Antarctic continent is surrounded by the belt of lower pressure with its cyclones. Their tracks are sufficiently consistent to result in a persistent circumpolar expand of low average pressure centred around 60-65°S. Surface weather conditions depend on the track of the individual cyclone or series of cyclones or on the position of higher pressure system. For the Antarctic Peninsula area as well as for the most regions of Antarctica, tracks of cyclones are western or north-western, with different velocity of their displacement, cloud system and other peculiarities (Govorukha i Timofeyev 2002). Types of synoptic tropospheric processes and their regional modifications can be distinguished in dependence on both general shape of pressure fields, tracks of cyclones and on the development of regional circulations.

Considering local weather at Vernadsky, two alternative situations can be picked out: with or without phoen winds, although the frequency of phoens can be insignificant in some months. Phoens are usually form when "north-west" or "west" cyclones migrating from the South-East Pacific cross the Antarctic Peninsula. Rarely, phoens can be observed on the periphery of anticyclones. By measurements at Vernadsky, the majority of monthly maximal temperatures are caused by phoens; significant frequency of phoens can to some degree raise monthly mean temperatures.

Different types of pressure fields for the region of the Antarctic Peninsula and adjacent seas are shown in (Kejna 2001, Timofeyev 2002). In general, one can distinguish two types of the low tropospheric pressure fields:

– low-amplitude eastward moving synoptic wave, when eastward moving cyclones or their series are followed by weakly pronounced wedges of higher pressure;
– stationary or slowly drifting larger-amplitude synoptic wave, connected with the intensification of both tropospheric trough with north-west tracks of cyclones, and wedge or anticyclone southward 60°S, that sometimes can be considered as blocking pattern. Blocking processes are not so pronounced and long-lived as in the Northern Hemisphere, but weather conditions caused by them are nearly the same. Sometimes, slowly drifting or quasi-stationary cyclones occupying large area can also have the blocking character.

Blocking processes

The frequency of blocking situations of higher pressure in this region is not significant and they were registered on nearly 7-10% of synoptic charts during April 1997 – March 2001. However, during separate winter months their total duration can reach 25-30% of all the time. Blocking situations usually cause the cold spells at Vernadsky, however their degree depends on the situation of high pressure. The following positions of blocking high are typical: anticyclone over western or central Bellinshgausen Sea (brings in the moderate cooling to the Antarctic Peninsula), anticyclone and blocking wedge over eastern Bellinshgausen Sea but close to the Antarctic Peninsula or above it (brings in the coldest temperatures).

The typical season for blocking is winter, months from June to September. One of the yearly maxima of averaged atmospheric pressure falls to these months, as in September 1997, 1998 and in 1999 (monthly averaged pressure 990.6, 987.5 and 990.5 hPa respectively) as well as in both July (average 1003.4 and maximum 1031.4 hPa) and September 2000 (1001.2 and 1035.8 hPa). The two latter monthly maxima are very high and are comparable with the magnitudes of pressure in centres of subtropical maxima or in anticyclones of temperate latitudes or ever above.

In the first half of September 2000, actual blocking episode was observed during at least 7 days. During 6-11 September 2000, well-developed anticyclone with central closed isobar of 1040 hPa took significant area of the Bellinsghausen Sea. The location of the center of anticyclone on the 7.09.2000 was between 80-90°W, 60°S, its eastern wedge reached Antarctic Peninsula and western one stretched to 120°W (fig. 2). Anticyclone blocked at least two depressions, one located east of South America and another – over South Weddell Sea. In western and south-western winds cooling at

Vernadsky was gradual and not so expressed, in correspondence to slow eastward displacement of the anticyclone, with minimum at Vernadsky -16.8°C.

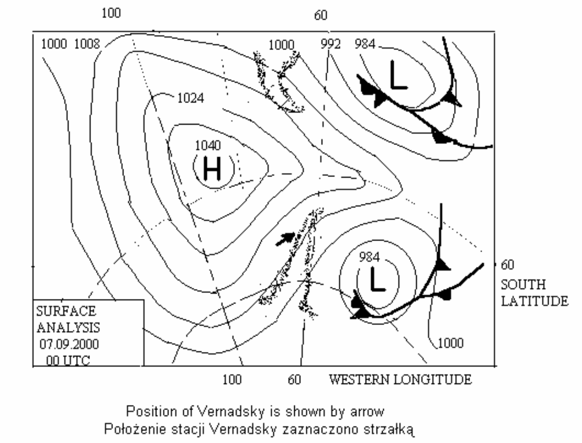

Fig. 2. Surface analysis on the 07.09.2000, isobars through 8 hPa

Rys. 2. Mapa analizy powierzchniowej z 07.09.2000 r., izobary kreślone co 8 hPa

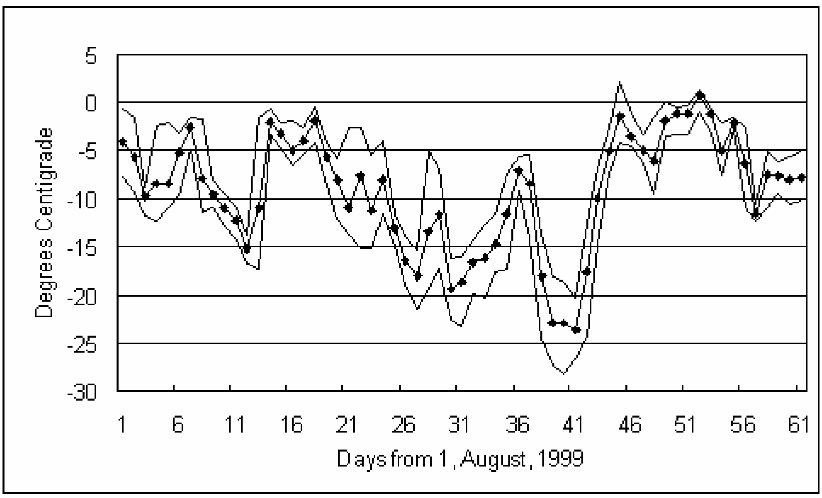

Fig. 3. Course of daily averaged air temperature and extremes at Vernadsky in August – September 1999

Rys. 3. Przebieg średniej dobowej i ekstremalnych wartości temperatury powietrza w okresie sierpień – wrzesień 1999 na stacji Vernadsky

During August-September 1999, several blocking episodes were observed, that resulted in drops of daily averaged air temperatures (fig. 3) on the 9-13 August, 31 August – 4 September and 9-12 September. The latter period was the coldest through the last 7 years of observations at Vernadsky.

The reason of cold spells at the very beginning of September was anticyclone positioned on surface chart over the eastern part of Bellinsghausen Sea on the 1st September 1999 (fig. 4A) with isobars crossing the Antarctic Peninsula from SE to NW. The synoptic analysis on preceding days showed that this anticyclone was formed after intensification and expansion southward of the wedge of the East Pacific subtropical maximum. It is interesting that position of this anticyclone was shifted westward as well as eastward during 28-31 August with weak oscillation of the atmospheric pressure; Vernadsky and western coast of the Peninsula were in south-eastern winds carrying cold air with daily averaged temperatures nearly or under -20°C. This anticyclone somewhat retreated on 6-7 September with some warming (37 and 38th days on fig. 3), but new blocking wedge was set up on 9-12 September (nearly 41st day), carrying the coldest temperatures at Vernadsky in 1999 (-28.6°C, 09 September 1999).

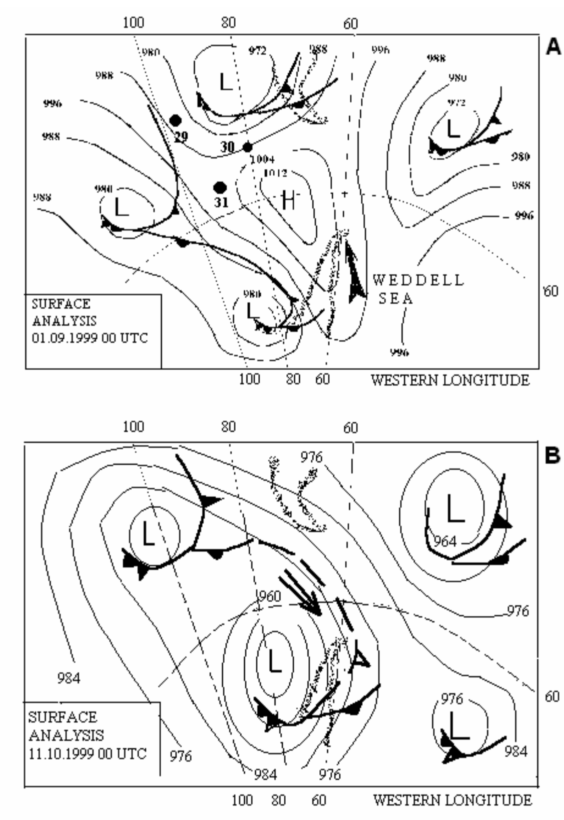

Fig. 4. Surface analysis on the 01.09.1999 (A) and 11.10.1999 (B). On the chart A the positions of the center of anticyclone in preceding days are shown with filled circle and corresponding day of August

Rys. 4. Mapy analizy powierzchniowej z 01.09.1999 (A) i 11.10.1999 (B). Na mapie A kropkami zaznaczono poprzednie pozycje centrum antycyklonu z poprzednich dni sierpnia

The atmospheric pressure can be different in centers of blocking patterns in their top stage of development – in September 2000 it amounted to 1042 hPa in August 13rd 1999, 1025 hPa on the 01st September – 1020 and on 12th September – 1017 hPa, so any conclusion about correlation between the intensity of high pressure and air temperatures it bring in can be made.

Another month with frequent blocking is March when usually the second yearly wave of atmospheric pressure is observed, with a bit lower monthly average (1001 hPa) and maximum (1018.2 hPa) in 2000. Blocking pattern was responsible for slight cooling just above freezing point but more important was the reduction in total ozone amount (TOA) during March 2000 as non ozone-hole month. It can be clearly seen from fig. 5, where temporal course of TOA with drop to the end of March 2000 is shown (minimum daily average 217 Dobson Units (DU) on the 30 March, just before the retreat of the anticyclone). Remember, during the ozone-hole (September – November) daily averaged TOA amounted to 150-230 DU at Vernadsky so the reduction in TOA in March 2000 to such low levels that are peculiar to the ozone-hole period can be explained only such a peculiarity in tropospheric circulation as blocking anticyclone.

Clear settled weather dominates during blocking processes of high pressure; only radiation fogs in surface layer can interrupt good conditions; usual precipitation are absent excluding diamond dust in low temperatures. There can be 3 or 4 consecutive clear days during blocking processes so they make a "breakthrough" in the total cloudy regime, with average cloudiness of 6/8 and 8/8 for Vernadsky.

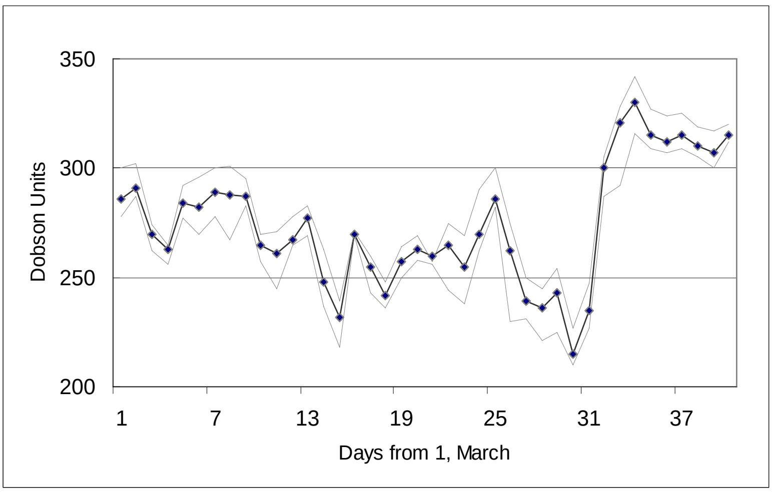

Fig. 5. Course of daily averaged and extremes total ozone amount at Vernadsky in 1 March – 10 April 2000

Rys. 5. Przebieg średnich i ekstremalnych dobowych wartości ozonu na stacji Vernadsky
w okresie od 1 marca do 10 kwietnia 2000 r.

The example of the like-blocking low can be cyclone that crossed the Bellingshausen Sea and the Antarctic Peninsula 11-20 October 1999 (fig. 4B). This cyclone brought in very low pressure at Vernadsky (937.2 hPa) but without strong winds and snowfalls. As the main important thing was the preservation of the low magnitudes of the total ozone amount within this cyclone, that are characteristic to the ozone-hole season. Alternatively, it is well-known that intensive cyclones was slowly moving and nearly filling-in without strong meridional circulation at the upper troposphere, that provide poleward transport of ozone-rich air.

4. Discussion

The role of blocking processes in the formation the weather is obvious and is discussed early [Trenberth 1996]; their increased frequency or prolonged duration in the Northern Hemisphere lead to anomalies in seasonally averaged air temperature or to the formation of other anomalous phenomena like droughts, forest fires etc.

Accordingly to the Atmospheric Model Intercomparison Project (1996), the actual blocking episode is registered in the case when calculated indices of blocking are maintained during at least 5 days with only one non-blocked day but with two successive blocked days. In our research, we hadn't calculate any indices but took into account duration of the process or displacement of the wedge or anticyclone. Blocking situations were distinguished in cases when center of anticyclone or axis of the wedge took nearly the same position at least 3 consecutive days or they drifted westward and then eastward. In this sense, the process in 9-13 September 1999 is actual blocking one, being at least 3 days quasi-stationary nearly Antarctic Peninsula, that corresponds to 3 days with lowest temperatures in fig. 3 (39-41 days).

Prolonged blocking situations contribute to records in monthly averaged atmospheric pressure and create significant contrast to average pressure fields that show a trough over the Bellinsghausen Sea (Monthly Climate Bulletin 1992, Atlas Antarktiki 1967).

Sometimes blocking episodes cause not only cold spells in winters but have related climatic importance with environmental aftereffects. For example, the following links between circulation/ environment were found (at the example of processes in 1999):

anticyclonic (blocking) processes in August-September)
⇒ formation of solid fast ice
⇒ its longer deterioration through the Antarctic spring/summer
⇒ cooler both surface waters and air temperatures in summer (and less rates of ablation)
⇒ abundant krill
⇒ better conditions for breeding of birds and mammals.

As prognostic prognostic indicator for the formation of blocking can be northward expansion of the continental wedge over Antarctic Peninsula provided that another wedge of subtropical maxima is expanded south of 60°S. It is obvious also that the cooling of the lower troposphere above the icy and snow-covered Antarctic Peninsula is additional factor for the formation and maintenance of higher pressure. Concerning indices, it is available to calculate them meridionally between operating bases, e.g., one index between Rothera (UK, 68°S, 68°W) and any station at King George Island, and another one farther north, between the latter and extremity of the South America.

5. Conclusions

Regional warming at the Antarctic Peninsula region was intensified to the turn of millenia, but it was nearly stopped in the last years. The warming was caused mainly by warmer winters during two last decades. Large amplitudes of annually averaged air temperature can occur from one year to the next, being connected with irregular frequency of cold winters.

Separate cold spells and cold winters on the whole are usually caused by greater frequency of anticyclonic (blocking) processes which have not only climatic importance but environmental after-effects. It is despite that their frequency is less than a number of cyclones.

The typical region of blocking is the Bellingshausen Sea and the Antarctic Peninsula itself; the maximum pressure at centers of blocking patterns (up to 1040 hPa) comparable with that in anticyclones of moderate latitudes of the Northern Hemisphere. There is no clear correlation with atmospheric pressure and the degree of cooling at Vernadsky; the coldest spells are connected with blocking wedge or anticyclone with sharply shaped isobars crossing the Antarctic Peninsula with south-eastern winds at stations. Decline in the total ozone amount in non-ozone hole months to the magnitudes that are peculiar to the ozone hole season is another important after effect of blocking.

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NIEKTÓRE ASPEKTY METEOROLOGII I KLIMATOLOGII REJONU UKRAIŃSKIEJ STACJI ANTARKTYCZNEJ „VERNADSKY"

Streszczenie

Ukraińska Stacja Antarktyczna „Vernadsky" (65°14'S, 64°17'W) usytuowana jest na Galindez Island w archipelagu Argentine Islands, około 8 km od zachodnich wybrzeży Półwyspu Antarktycznego. Od 1996 roku stacja pracuje pod obecną nazwą, poprzednio jako angielska stacja Faraday (1977–1996) i Base F (Argentine Island) od 1947 roku, co daje jeden z najdłuższych ciągów obserwacyjnych w Antarktyce.

Na stacji obserwowany jest wzrost wartości średniej rocznej temperatury powietrza (MAT). Najchłodniejsze były lata 50.te, największe ocieplenie rejestrowano w dekadzie lat 1980–1990. W ostatnich latach

obserwuje się pewną stabilizację wzrostu temperatury średniej rocznej, która lokuje się w wąskim przedziale od -1.7° do -3.7°C. Zmienność średniej rocznej wynika głównie ze zmienności temperatury miesięcy zimowych. Obserwowany dodatni trend temperatury jest wynikiem cieplejszych zim w ostatnich latach. Zimy surowe występują nieregularnie, ostatnią notowano w 1987 roku. W okresie 1988–2002 nie odnotowano średniej miesięcznej temperatury powietrza niższej niż -10°C.

Lokalne warunki stacji Vernadsky wpływają na dużą częstość sytuacji z efektami fenowymi, które występują głównie podczas przemieszczania się cyklonów z NW lub W. Większość przypadków temperatur maksymalnych na stacji notowana jest w takich właśnie przypadkach.

Sytuacje synoptyczne z blokadą wysokiego ciśnienia występujące w ostatnich dwóch latach stanowiły 7–10%, w niektórych miesiącach zimowych osiągając znaczącą frekwencję (25–30%). Przykład sytuacji z wyżem blokującym przedstawia rysunek 2. W takich warunkach (rys. 3 i 4A) na stacji obserwuje się zazwyczaj znaczące, kilkudniowe spadki temperatury powietrza.

Sytuacje blokadowe często występują również w marcu. W marcu 2000 roku w takich warunkach obserwowano znaczący spadek ilości ozonu (rys. 5), nieomal do poziomu charakterystycznego dla końca zimy.

Tłumaczenie – Grzegorz Kruszewski