Climate warming and related phenomena at the region of the Antarctic Peninsula

Vladislav E. Tymofeyev
Ukrainian Research Hydrometeorological Institute
Kiev Prospekt Nauki 37 03028 Ukraine
e-mail:tvvlad@mail.ru

Introduction. As well-known, from 1996 Vernadsky base (65 14'S, 64 17''W) has been continued observations which were commenced at Faraday (Argentine Islands), UK, in 1947. The most important conclusion of meteorological observations is progressive **surface warming** at Vernadsky and other Antarctic Peninsula's and Subantarctic stations.

The aftereffects of climate warming can be found on the state of regional glaciation, sea-ice and environment.

The purpose of the research was to analyse climate variability of the region and to outline possible reasons and aftereffects.

Data used. NCEP/NCAR-Reanalysis (2.5 X 2.5˚ grid), World Center Data (Obninsk, Russia, 5X5˚ grid), surface analysis of Australian weather Bureau and Chilean Military Service.

RESULTS. AIR TEMPERATURE TRENDS. At Vernadsky, the most pronounced surface cooling was observed before 1960s, with following positive air temperature trend (maximum rates were registered during both 1960-1975 and in 1990s (**FIG. 2),** Hence these trends are in general agreement to the Southern Hemisphere's and global temperatures' variability (**FIG. 1**).

Accordingly to conclusions [Martazinova, 2001] global centennial trend of air temperatures can be divided on 3 epochs (cooling before early XX century, "initial" warming during 1900s-1940s, pre-industrial stabilization and following more intensive warming from 1980s).

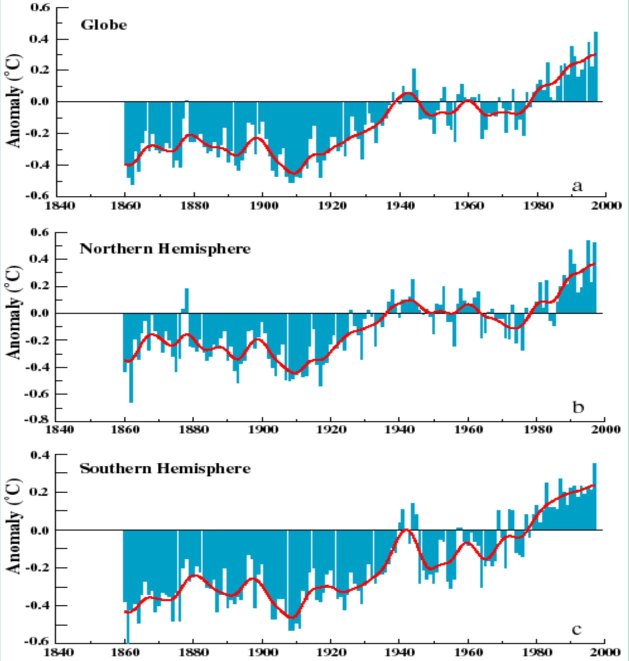


FIG. 1. Annual averages of combined land-air and SST anomalies (blue bars, °C): (a) global, (b) Northern Hemisphere, and (c) Southern Hemisphere. Anomalies are departures from the 1961–90 base period means. Smoothed values (red curve) were obtained using a 13-term Gaussian filter designed to suppress variations on timescales less than 10 yr. (Source: Hadley Centre for Climate Prediction and Research, United Kingdom, and Climatic Research Unit, University of East Anglia, United Kingdom.)

Fig. 1. Air temperature anomalies: Global, Northern Hemisphere and Southern Hemisphere.

During recent years is no significant growth of annual air temperatures is observed.

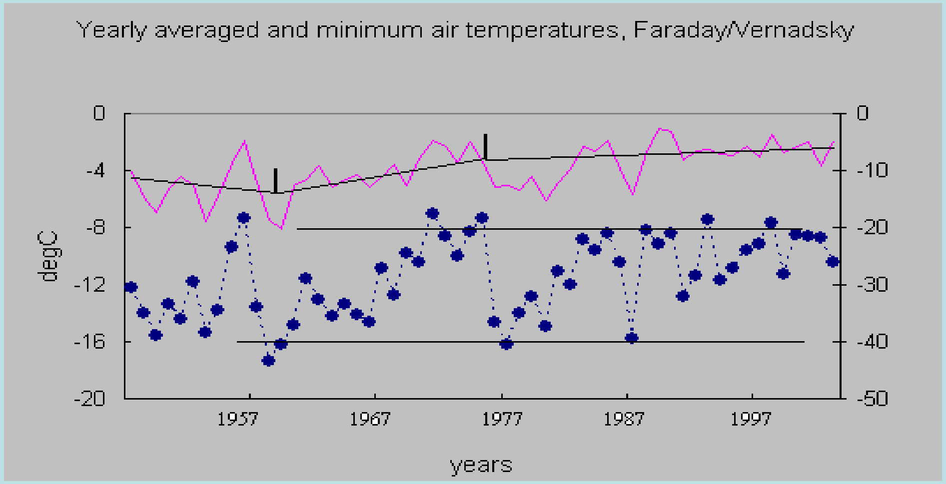
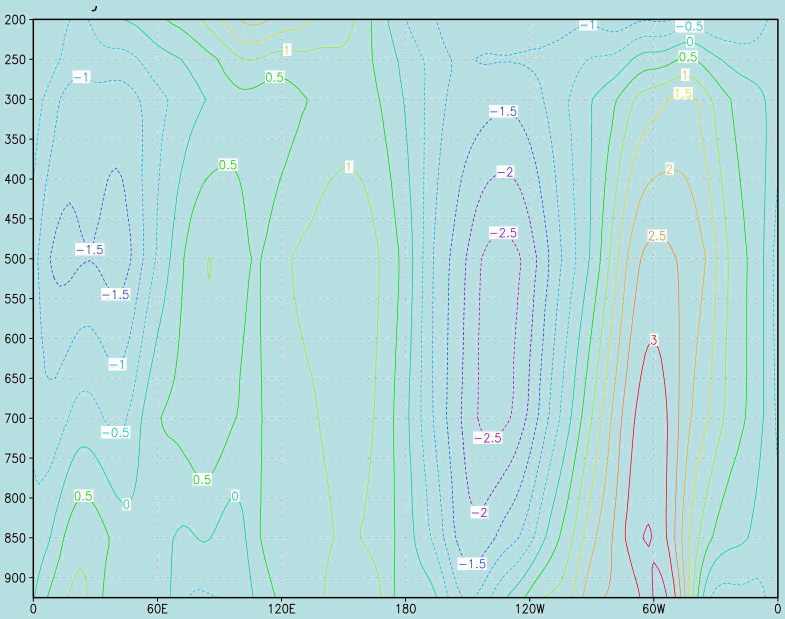


Fig. 2. Climate warming at Vernadsky is accompanying with progressive increase of minimum air surface temperatures (blue dotted line) and more smoothed year-to-the-next their average amplitudes in 1990s.

Winter growth of air temperatures is mainly contributed to total warming; summer warming being significantly less expressed, is the main reason for the recession of local islands’ small glaciers and other changes in environment. At Vernadsky, time interval with daily mean air temperatures exceeding the freezing point is expanded from 1960s covering months December-April from 1995 **(FIG. 3).**

Warming is shown in this region through the all troposphere, decreasing with height, (Fig. 4). Note the cooling area west of 60°W.

(FIG 4. Anomaly of winter temperatures in cross-section of troposphere along 60ºS, 1990s minus 1975 – 1989, NCEP/NCAR Reanalysis.



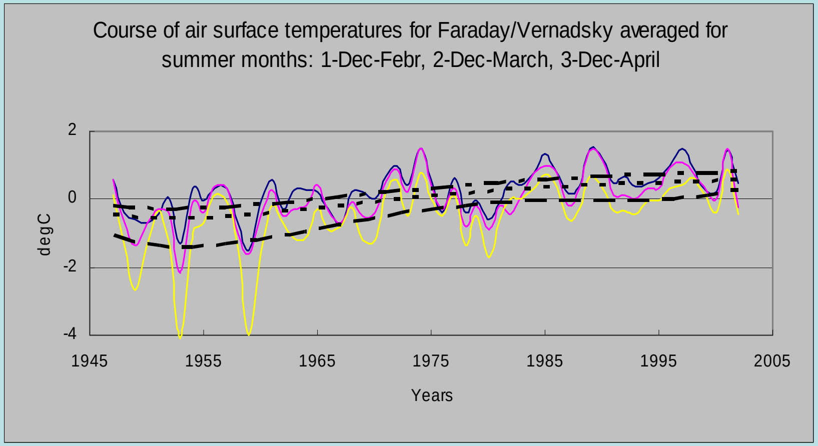
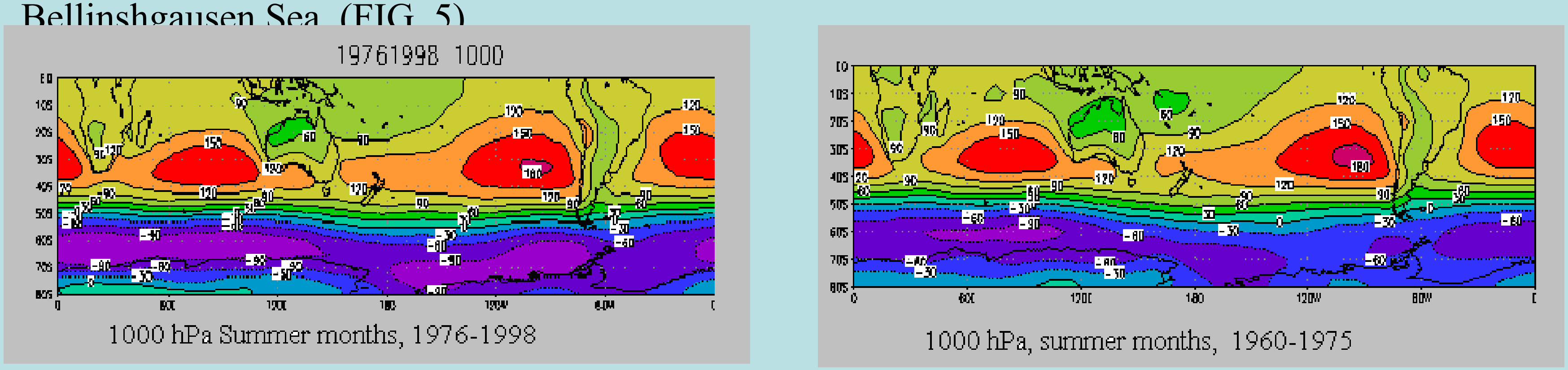


FIG. 3. Summer warming at Vernadsky.

The warming in this region is thought to be induced somewhat by global anthropogenic agents but in this work we consider the possible contribution of tropospheric circulation change.

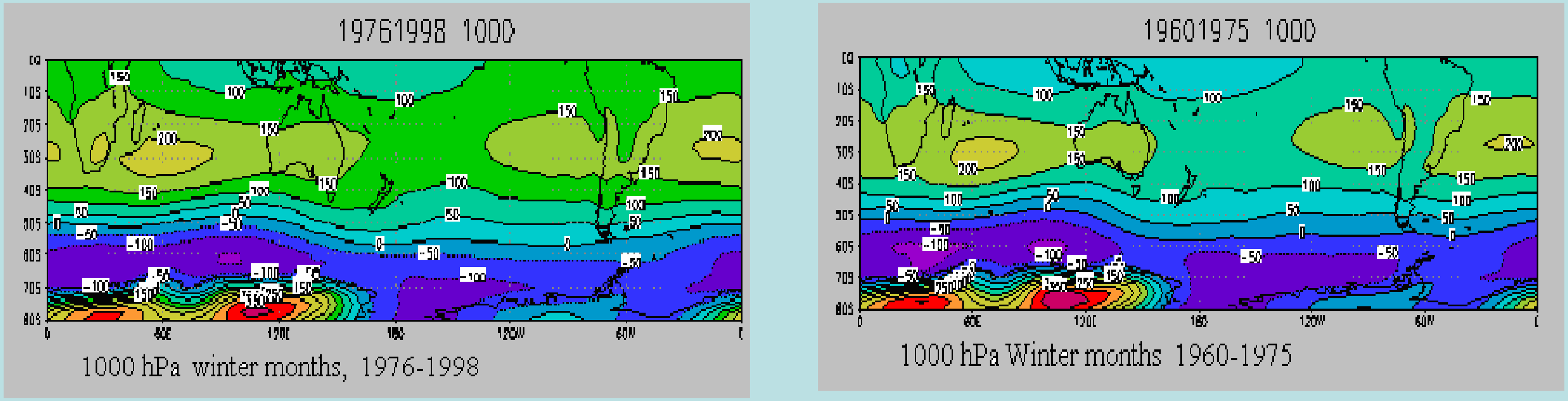
General tropospheric circulation.

Well-outlined zonal currents with significant with pressure gradients in moderate latitudes in the Southern Hemisphere exist, being expressed more than in the Northern Hemisphere. The Antarctic Peninsula lies close to southern margin of lower pressure belt with its strong winds and cyclones. There are small inter-decadal changes in lower atmospheric pressure to last decades of XX century, with some decrease in both summer and winter seasons and so with some deepening of climatic trough over Bellinshgausen Sea. (FIG. 5)



1000 hPa Summer months, 1976-1998

1000 hPa, summer months, 1960-1975



1000 hPa winter months, 1976-1998

1000 hPa Winter months 1960-1975

FIG. 5. Mean geopotential height fields at 1000 hPa (dam) for winter and summer, 1960-1975 and 1976-1998, Southern Hemisphere.

Along with general smoothness of pressure fields, **anomalies** in both atmospheric pressure and H500 hPa are not unheard of here (see also anticyclones' section). E.g., **warm winters** are characterized by strong negative anomalies of pressure close to the Antarctic Peninsula and in south-east sector of Pacific (1998, **Fig. 6**).

Cold winters are characterized by positive anomalies of atmospheric pressure near the Antarctic Peninsula (e.g., 1987), as shown at **FIG 7**. The magnitudes of anomalies are comparable with those in Northern Hemisphere; being often conjugated with them; at **FIG. 7** corresponding positive anomalies are seen at Antarctic Peninsula and close to Aleutian minimum and over Greenland).

Obviously as large-scale governing mechanism of anomalous years is ENSO; the years above were chosen in alternative episodes of ENSO (1987 – cold, 1989 – warm; note different anomalies in east Pacific).

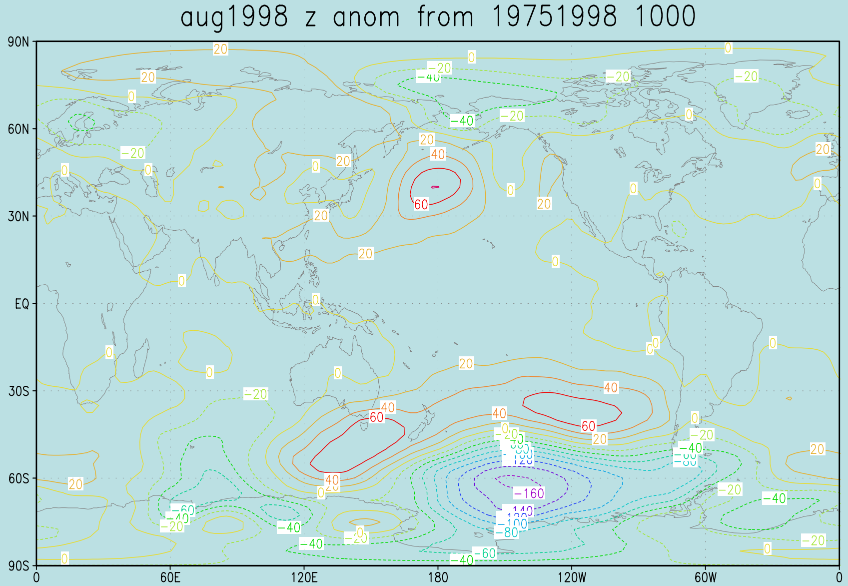


FIG. 6. Global anomalies of atmospheric pressure (hPa) for August, 1998 (warm year)

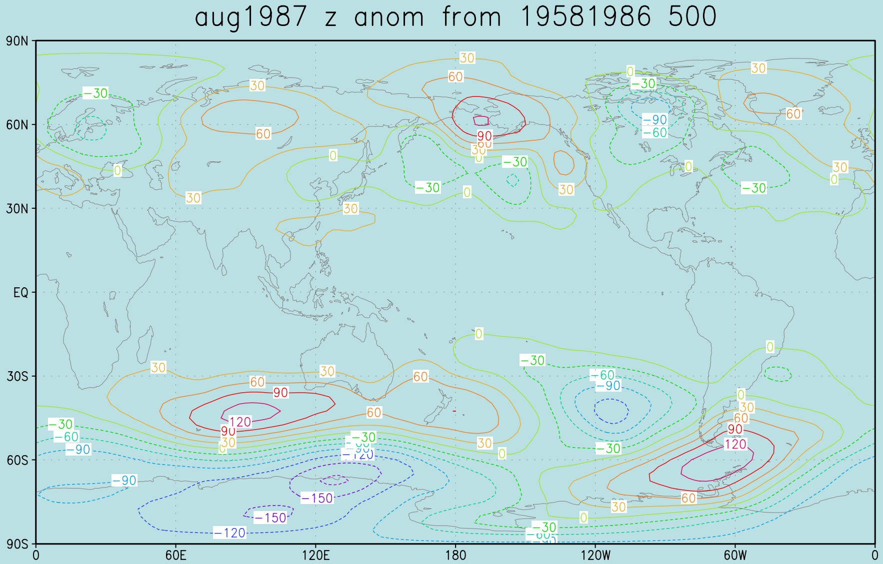


FIG. 7. Global anomalies of atmospheric pressure for August, 1987 (cold year)

Significant year-to-year air temperature oscillations at the Antarctic Peninsula could be explained by different structure of synoptic waves, governing intensity of cold air transport especially in winter. (**FIG**. **8**).

The latter is also known as high-index polarity of Antarctic Oscillation).

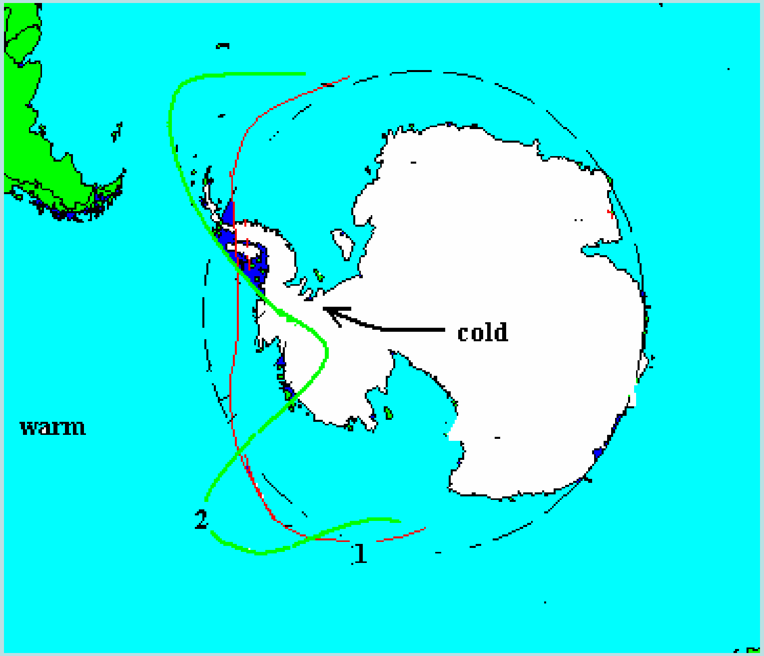


FIG. **8.** Scheme explaining temperature changes at the Antarctic Peninsula. Color lines corresponds to positions of tropospheric wedges or troughs:
1 – in warm years (winters), 2 – in cold years.

Frequent **topographical modifications** of air currents over Antarctic Peninsula are responsible for lee-side phoen winds formation especially when cyclones pass some north of 65ºS.)

The majority of monthly temperature maxima at Vernadsky are caused by phoen; calculations of surface temperatures on simple adiabatic model showed that monthly averages can be warmed by 0.5 - 1.0ºC when phoens are frequent (FIG. 9).

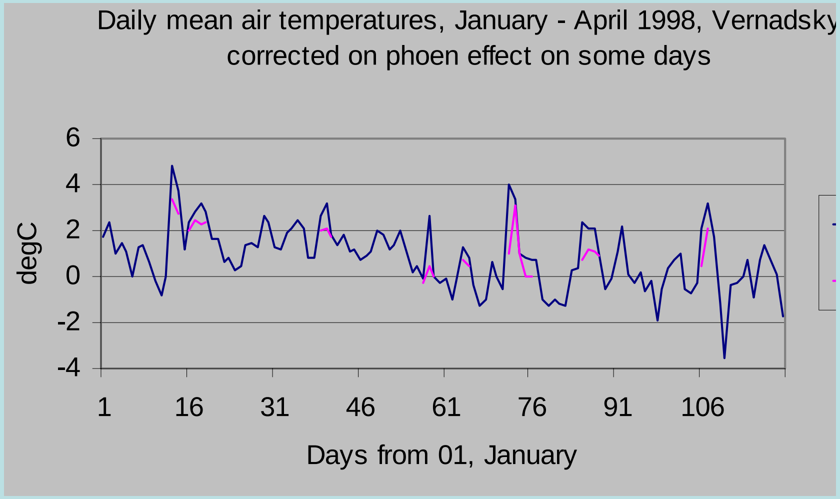


FIG. 9 – Instrumental air temperatures (solid line; re-calculated during PHOENS (broken purple line).

At Vernadsky phoens are developed when westward air stream crosses the Antarctic Peninsula. (FIG. 10).

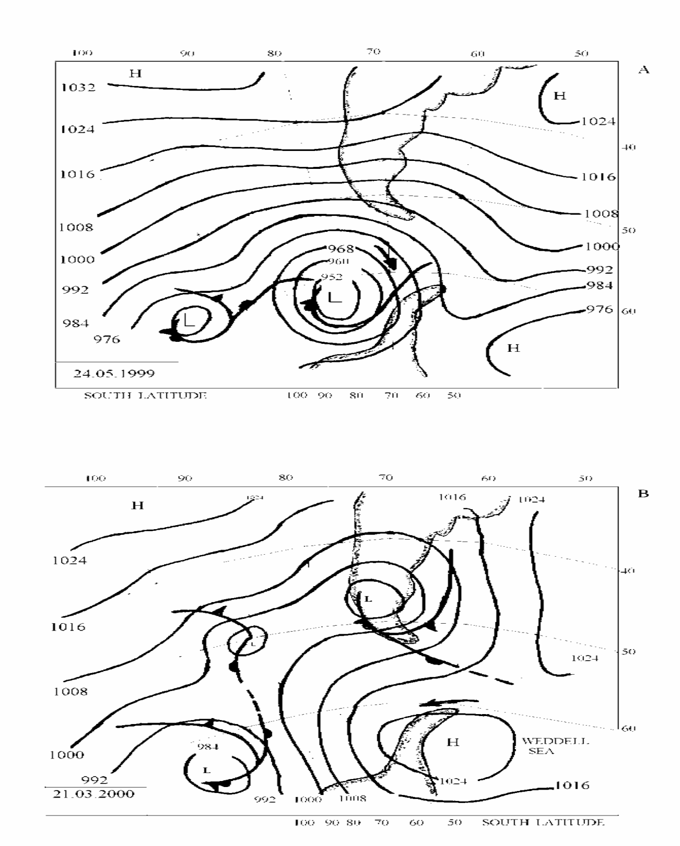


FIG. 10 – Surface analysis in days with phoen effect at Vernadsky: a – 24.05. 1999, b – 21.03. 2000. Isobars through 8 hPa.

Tropospheric cyclones with seasonally changing tracks are responsible for the advection of warm and wet air with quite predictable narrow range of air temperatures. Main paths of synoptic-scale cyclones are shown at **FIG**. 11, they can be divided on 3 groups – **western (1, 2, Fig. 11), north-western (3), south-western (4) .** They also can be divided by their velocity and one of examples can be slowly eastward moving depression with large areas of low pressure having like-blocking character. Migratory cyclones are mostly of dynamic origin, being usually occluded and with significantly lower pressure than in Northern Hemisphere however with lesser temperature contrasts.

Each type bring in different weather conditions as well as type of cloudiness, precipitation and **total ozone amount**. On approach to the Antarctic Peninsula cyclones usually weakened or segmented but on lee-side they often re-generate.

Seasonally averaged pressure fields show a weakly-developed wedge close to the Antarctic Peninsula (by the data of main gridded analysis, here not shown), so our attention was also paid to anticyclonic processes and their role to climate changes (see below).

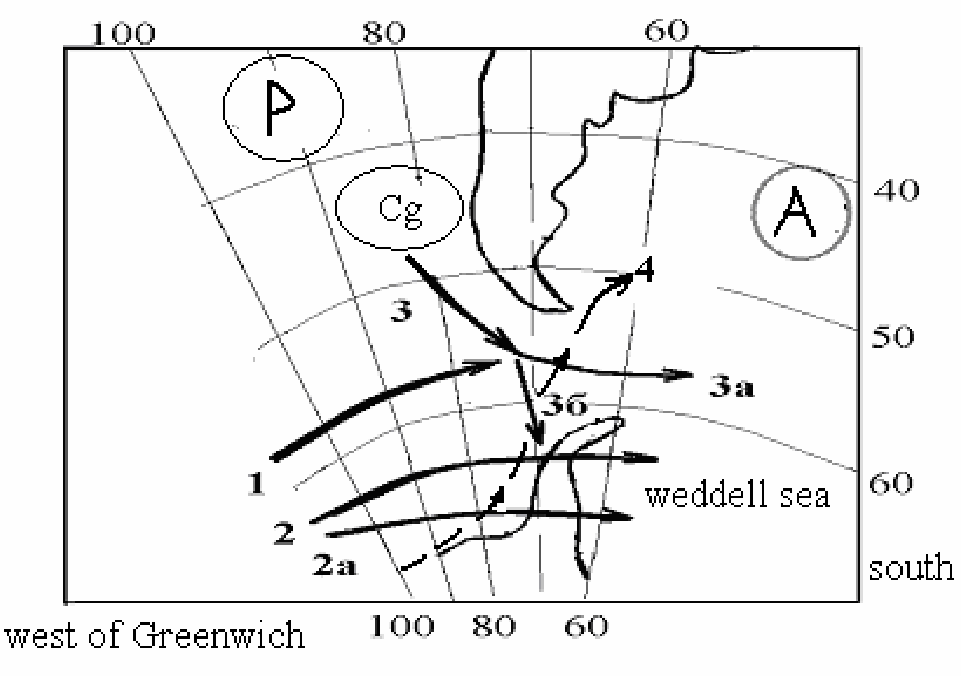


FIG. 11. Main trajectories of cyclones near the Antarctic Peninsula. **P, A** – Pacific and Atlantic subtropical highs, **Cg** – region of moderate-latitude cyclogenesis

Anticyclonic conditions and specifically increased frequency of tropospheric blocking are responsible for separate cold spells as well as cold winters and years in total. Important related phenomena (aftereffects) of blocking were found; they included the formation of solid fast ice in winter and its farther northward expansion in early spring with the delay of the time of the removal of winter ice in Antarctic summer (e.g., in 1999-2000).

Blocking processes of high pressure are not so pronounced and long-lived as in the Northern Hemisphere, but weather conditions caused by them are nearly the same as **deflection of cyclones** form their usual tracks or slowing down their displacement or formation of zones with strong winds (**FIG. 13b**).

At Fig. 13a less-developed wedge is seen west of Antarctic Peninsula, however it cause colder air advection with south-east winds. It was also found that blocks often do not appear on averaged fields made on gridded analysis, or anticyclonic pressure fields are weakly expressed.

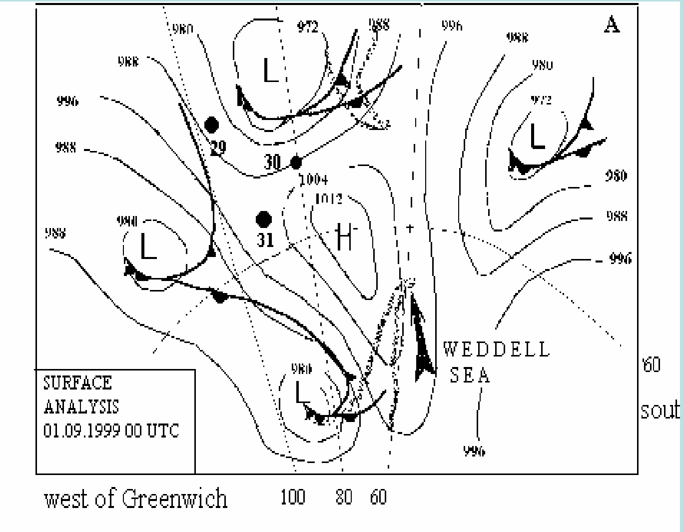


FIG.13a. Blocking anticyclone causing significant cooling at Graham Land with its centers' position in preceding days. Isobars through 8 hPa.

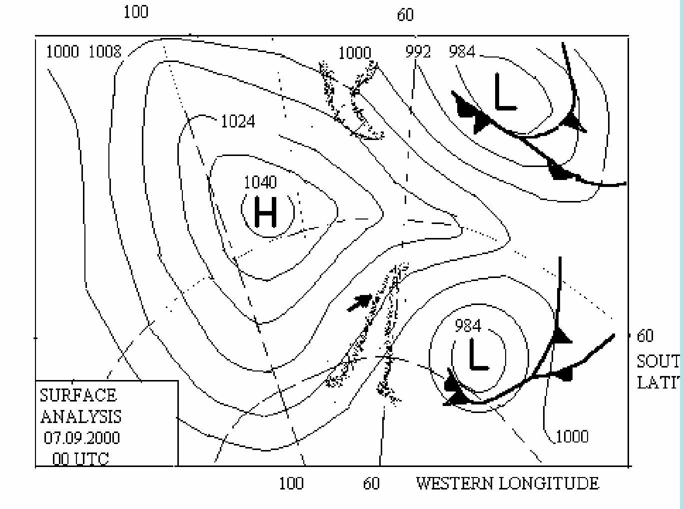


FIG. 13b. Like-Blocking anticyclone with large high pressure area with moderately cold air advection to Antarctic Peninsula (south-west winds).

Changes in Antarctic environment and mostly ecosystems can serve as an indicator of climate change including accelerated reduction of small islands' glaciers; anomalous environmental regimes during summer seasons at Marginal Marine Zone of the Antarctic Peninsula is predominated for the recent years.

First of all it concerns year-to-the-next anomalies of sea surface temperatures (SST) and following differences in the state of environment e.g., changes in krill populations governing in turn by the filling-in of antarctic ecosystems. **Positive anomalies** of SST **(FIG. 14)** cause drops in krill population as well as abundant development of diatoms in early summer (e.g., in 2000 and 2001). By the data of special field trips undertaken from Vernadsky in December, 2000, unusual changes in both color of surface ocean waters and its transparency were recognized to the region of Anvers Island, some 75 km north.

Alternatively, **negative anomalies** in SST during antarctic spring and summer lead to the growth in krill population and better conditions of birds and mammals survival.

Each anomaly in SST have had its own synoptic background. Positive one was developed in weakly expressed pressure fields in early summer. In contrast, the following links between circulation/ environment were found during negative anomaly of SST in 1999:

Stable anticyclonic (blocking) process in winter (especially in August-September) =>
(Formation of solid fast ice) =>
(Its longer deterioration through the 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.)

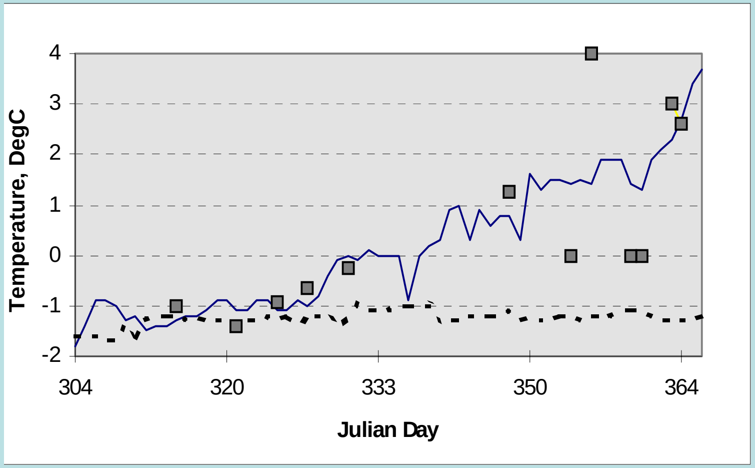


Fig. 14. Sea surface temperatures by the data of Vernadsky Tide Gauge in 2000 (solid line) and in 1999 (dashed line) and by the data of field measurements near Vernadsky base (squares); 300th day = 1st, November.

CONCLUSIONS.

1. Progressive regional low-tropospheric warming at the Antarctic Peninsula region was observed to the turn of millennia, being in general correspondence with global trends. This warming is more expressed in winter but summer warming is mainly contributed to the state of both small islands' glaciers and Antarctic environment.

2. Changes in large-scale tropospheric circulation accompanying (or causing) warming are not easy to find by means of gridded data sets. Inter-decadal changes in upper-tropospheric geopotential fields are not so easy to recognize, although some decrease in averaged pressure is detected by the data of NCEP/NCAR Reanalysis. Anomalies in atmospheric pressure in cold/warm years at the Antarctic Peninsula are better outlined in years with alternative ENSO episodes.

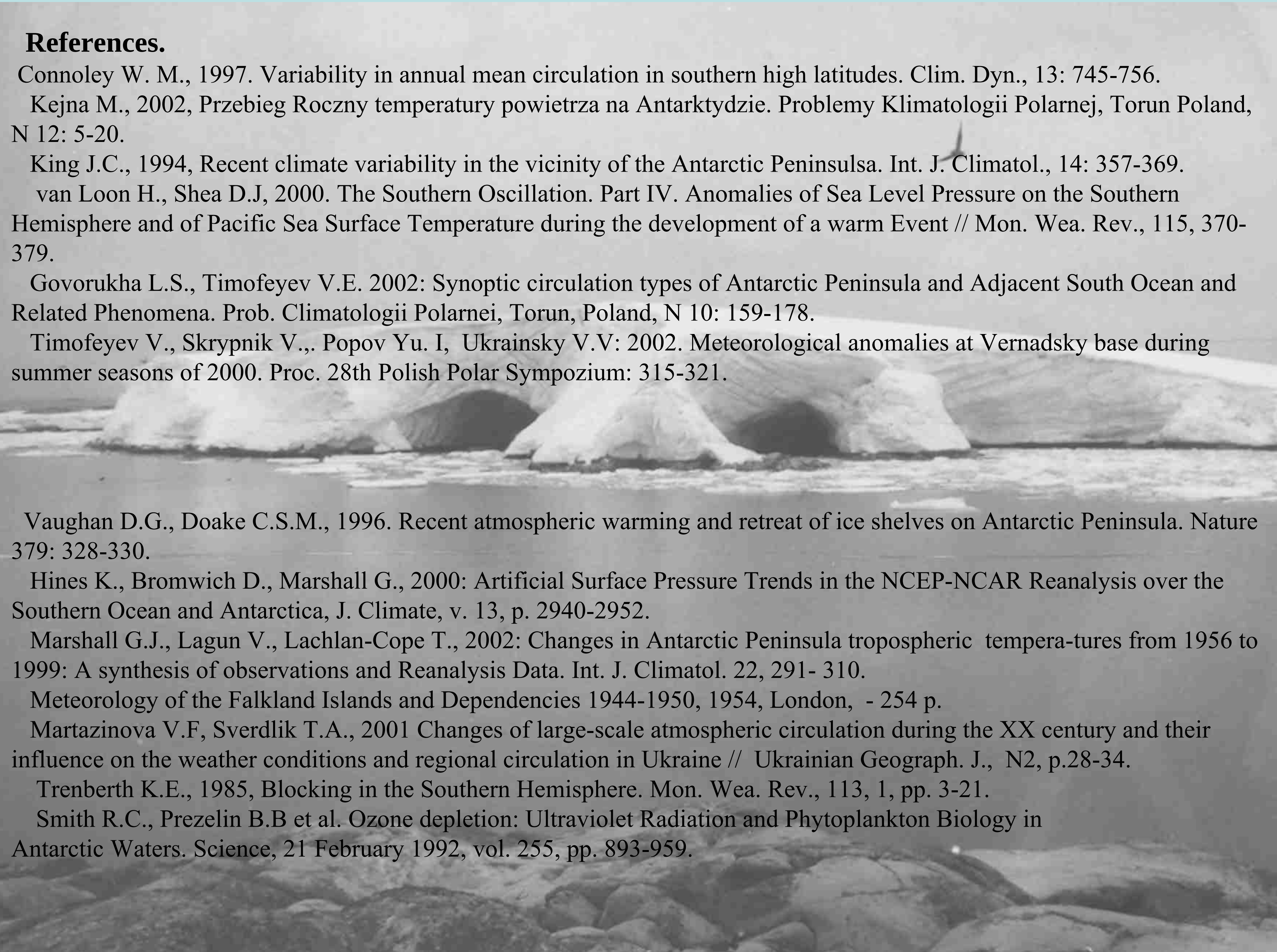
3. The analysis of daily synoptic charts also shows significant differences in circulation between warm and cold years (winters). Tropospheric cyclones with seasonally changing tracks are responsible for the advection of warm and wet air to this region with quite predictable narrow range of air temperatures.

The greatest contribution to air temperatures' cooling on Antarctic Peninsula brings in wedges or anticyclones, especially blocking episodes with highest degree of meridionality and coldest air advection from Antarctic continent.

Warming at the region of Antarctic Peninsula could be explained by its marginal position at low pressure belt, that governs the intensity of cyclones and cut off frequent advection of colder air along with decreasing in meridionality. However intensification of anticyclogenesis, especially anticyclonic blocking conditions lead to coldest air advection from the Antarctic continent.

4. Blocking wedges and like-blocking cyclones are found to be a synoptic background of the atmospheric ozone depletion during the timing of ozone hole as well as in non-ozone hole months.

5. A number of anomalous phenomena grew in the recent years' transitive periods between winter and Antarctic summer, under obvious influence of climatic changes. Firstly, it concerns summer anomalies of sea surface temperatures and related changes in Antarctic ecosystems in Marginal Ice Zone of the Antarctic Peninsula. Synoptic variability on both seasonal and year-to-the-next scales could define changes in sea-ice and environment.



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