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Temperature regime and ice cover dynamics in the coastal regions of the Antarctic Peninsula

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SUMMARY

Climate change affects all regions around the world, but the ice covered areas are particularly vulnerable in this case. The Antarctic ice sheet is the largest single mass of ice on Earth. Melting of ice sheets is dangerous, as it can lead to flooding of low-lying coastal areas and other negative processes. In this study, we use remote sensing methods to analyze the changes in air temperature and its impact on the condition of the ice sheets in the coastal regions of the Antarctic Peninsula. Analysis of space images of the Antarctic Peninsula coast for the period 1985-2020 showed that the ice covered area shrinked, as a result, the length of the coastline expanded, and it became more winding. The length of the coastline has increased by 20-25%. Temperature analysis of the investigated area during 1985-2020 (according to the data provided by the Ukrainian Antarctic Akademik Vernadsky station) showed clearly that the average, maximum, and minimum air temperatures have been trending upwards. The average annual air temperature and the average minimum air temperature increased by 1–1.5 0C, the average maximum air temperature during this period increased by 3.30C. This is a sign that global climate change is also impacting the southernmost regions of Earth.

Keywords: climate change, Remote Sensing, air temperature

Introduction

One of the biggest challenges for humanity in the 21st century is climate change. It affects all regions, but ice sheets are particularly vulnerable to the effects of climate change. "Ice cap" is a powerful regulator of the "ocean-atmosphere" system. It maintains the climate balance on the planet. The melting of Antarctica's ice is dangerous, because the rise of the sea level can lead to flooding of low-lying coastal areas, changes of the temperature of ocean waters and other fluctuations.

Therefore, it is important to analyze the dynamics of changes in the ice sheet of Antarctica's coastal regions in relation to the temperature on the southern continent. This study marks 200 years since the discovery of the Antarctic continent and the 25th anniversary of the Ukrainian Antarctic Akademik Vernadsky station.

Method and Theory

The modern study of the natural environment and resources of Antarctica was started in 1957-1958, when 12 countries decided to begin joint scientific research of the continent. At the same time, an agreement was signed, according to which no country will single-handedly claim the territory of Antarctica, and scientific research will be conducted only for peaceful purposes. This agreement is still valid, but the number of the countries participating in the research has increased to 30. Ukrainian scientists often joined scientific expeditions to Antarctica in Soviet Union times. After the Faraday station complex (belonging to the UK) was transferred to Ukraine and renamed to Akademik Vernadsky station in 1996, Ukraine began its own research of the ice sheet of the continent. Ukrainian researchers contributed to the study of climate conditions of Antarctica: T. Danova (2009, 2011), S. Krakovska (1998, 2017), L. Pysarenko (2017), Y. Lysenko (2010), O. Prokofyeva. (2009), K. Gavryleni (2010) Some of them (S. Krakovska, (2017) worked at Akademik Vernadsky station.

In this paper, we rely on the works of T. Danova, Y. Lysenko. These researchers studied the dynamics of air temperature on the Antarctica coast and its relationship with climate indices in the context of climate change, as well as the impact of temperature changes on the ice cover of the Antarctic Peninsula. The works by S. Krakowska (1998) analyzing temperature extremes at Akademic Vernadsky station were also used. The changes in the ice cover have been monitored for a long time using and various methods have been used - from direct field glaciological and geodetic studies to remote sensing methods (a detailed review is provided, for example, in the work (Marusazh, 2014). One of the most effective methods for quantitative assessments of ice cover is analyzing the data from aerial photographs. This method is successfully used by Ukrainian researchers (Savchyn & Shylo, 2020). For retrospective studies, the limitation of this method is the difference in quality and amount of available photo material during different periods. The same problem appears when analyzing satellite images: the database for previous years is very fragmented and heterogeneous. However, the Landsat series data archive presented in GoogleEartPro allows at least an approximate assessment of the main changes in the coastline of this area.

Resources: to assess temperature changes, we used the following electronic archives of meteorological data: British Antarctic Survey archive, the National Antarctic Scientific Center archive, etc., which contain the data provided by Akademik Vernadsky station (Faraday Station before 1996). The archive data for the period from 1985 to 2020 was analyzed. This period was selected for the study as it covers the first signs of global climate change.

To analyze the dynamics of the ice cover, data from space optical imaging was used. The northern section of the Antarctic Peninsula was analyzed, which is 7 km afar from Akademik Vernadsky station on Galindez island. The analysis was facilitated by Google Earth Pro resources that provide many opportunities and tools for remote data analysis (Fedoniuk V., Fedoniuk M., Pankevich S., 2013).
Research objectives: 1) to analyze the main meteorological indicators at the Ukrainian Antarctic Akademik Vernadsky station within 1985-2020 in order to detect climate changes; 2) to conduct a

comparative analysis of ice sheet condition around the Ukrainian Antarctic Akademik Vernadsky station using space images.

Results

Using statistical methods to analyze archive meteorological data from 1985-2020, the following parameters of the temperature regime at Akademik Vernadsky station were considered: average annual air temperatures; average minimum temperatures; average maximum temperatures; absolute annual minimum temperature; absolute annual maximum temperature. A number of graphs and charts were created (see figs 1 - 4).

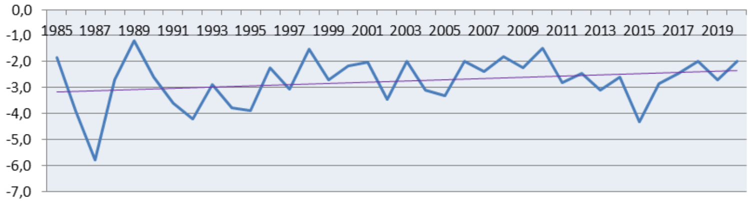

Figure 1 *Average annual air temperature at Akademik Vernadsky Station in 1985-2020*

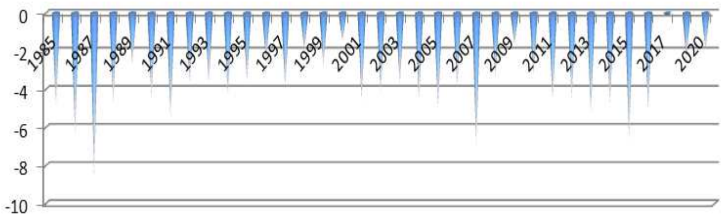

Figure 2 *Average minimum temperature at Akademik Vernadsky Station in 1985-2020*

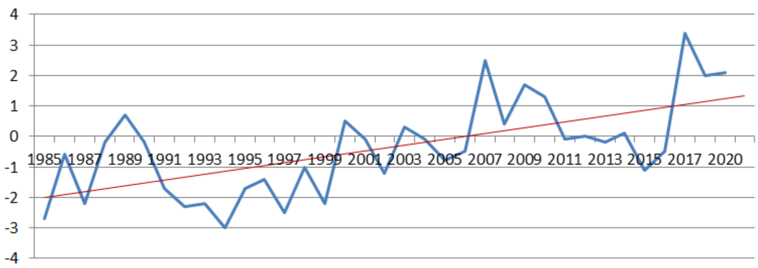

Figure 3 *Average maximum temperature at Akademik Vernadsky Station in 1985-2020*

As we can see in the graphs and charts, all the investigated parameters of the temperature regime at Akademik Vernadsky Station in 1985-2020 were trending upwards, except for the absolute maximum air temperature. The absolute minimum temperature and the average minimum air temperature increased the most: by 10-12^{0}C and by 3.3^{0}C accordingly. The increase in average annual temperatures is more than 1^{0}C and is about to reach the critical mark of 1.5^{0}C according to climate change researchers. During the studied period, most of the average monthly air temperatures (March–November) have upward trends, except for the Antarctic summer months (December–February), when the temperature remains within the average limits or even slightly decreases.

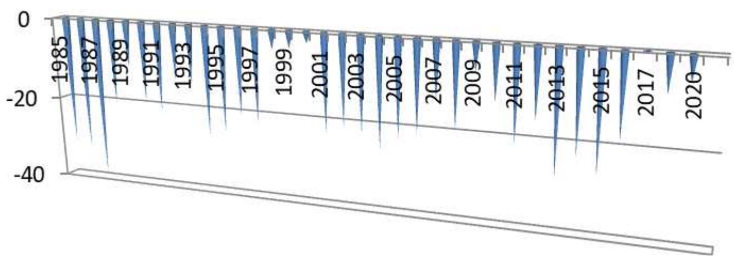

Figure 4 *Absolute minimum temperature at Akademik Vernadsky Station in 1985-2020*

Along with the evaluation of temperature parameters, an analysis of space images of the northern coastal part of the Antarctic Peninsula was carried out (the interval of image selection is 5 years, starting with 1985). The coastline on each image was outlined and its total length was calculated (fig. 5).

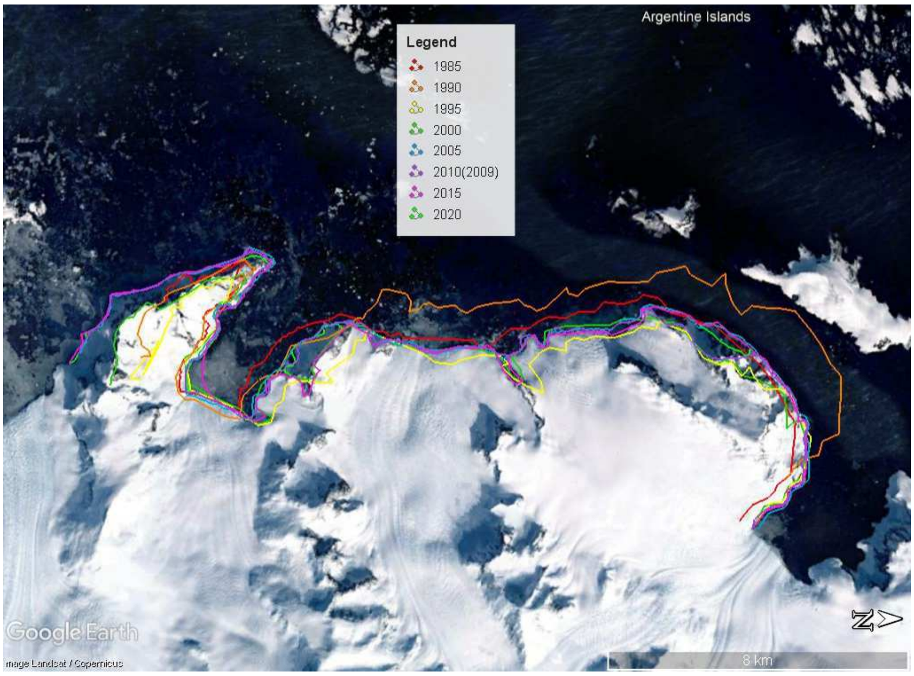

Figure 5. *The change of the Antarctic Peninsula coastline within the studied area in 1985-2020*

Despite the increasing temperature trends, the coastline does not always retreat. In particular, with more intense melting, a larger mass of ice can descend from adjacent glaciers, while significantly exceeding the boundaries of the previous contours.
Table 1 shows the main numerical parameters: the length of the coastline on the selected area of the Antarctic Peninsula coast and the distance from the marker point (this point was an unnamed peak of 515 m) straight to the coast.

Table 1. *Parameters to evealuate the ice cover in coastal areas of the Antarctic Peninsula in 1985-2020*

Year	1985	1990	1995	2000	2005	2010	2015	2020
Distance to the control point from the coast, m	2190	3870	1860	1725	2340	2370	2380	2375
The length of the coastline of the analyzed site, km	32,2	36,3	36,9	36,2	38,4	37,9	39,6	40,2

As illustrated in Table 1, as well as in space images from 1985-2020, during this period, the area covered by the Antarctic Peninsula glacier shrinked. As a result of ice cover and coastal glaciers melting, the contours of the coastline changed, and the coastline "dismembered", becoming more and more winding. The glacier melted and numerous small "fjords" were formed on the coast. In Table 1, we see that the coastline length in the selected area increased from 32.2 to 40.2 km.

Conclusions

Therefore, the study of the ice cover in the northern part of the Antarctic Peninsula using remote sensing showed that ice sheets are gradually shrinking and the ice in the coastal areas of the mainland is melting. This was verified as there is a year over year increase in the length and tortuosity of the coastline on the selected section of the Antarctic Peninsula in 1985 - 2020. The overall increase in the coastline length constitutes 20 - 25%. At the same time, the changes in the ice coverage of the peninsula were not linear and evenly distributed across the coast. In some places, the glacier retreated, and in others, it stepped on the shore. This can be traced by checking the distance from the selected point to the shore (row 1 in

Table 1). In our opinion, this can be explained by the difference in the amount of precipitation, the direction of prevailing winds, and other factors affecting the accumulation and distribution of ice sheets during the studied time period. Melting of ice is consistent with the temperature increase in that area.
In the future studies, it is important to consider not only the coastline, but also the entire adjacent glacial valley, from which ice flows into the sea, and also to evaluate the changes in the area and the ice volume using the data from remote radiometric surveys.

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