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ANTARCTIC EXTREMES



Antarctica is a land of surprises. How low are the lowest temperatures ever recorded there? Is there life at -50°C ? Is there anywhere on the continent tourists can actually enjoy swimming?



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Antarctica is an icy continent in the southern hemisphere encompassing an area of over 14 million km². Only 1,500 km of this, along the coasts, consists of rocky oases, whereas the rest, nearly 18,000 km, is ice-covered. The average elevation of the continent is 2000 m above sea level, but the Vostok station lies at 3488 m a.s.l., while the Amundsen–Scott South Pole Station is at 2835 m a.s.l. The continent is surrounded by three oceans with an area of about 50 million km², enwreathing Antarctica inside a convergence line. This Atlantic Convergence marks off an area where highly dense cold surface water pushes under warmer sub-polar water, where there is high baric pressure. The persistent pressure difference, high in the convergence region and low in the divergence zone, closer to the continent, causes a difference in the water level and is the reason why it travels northward away from the continent and returns southward in deeper layers. A current called the West Wind Drift flows to the east around the continent, while near the continental shores the East Wind current flows in the opposite direction.

These phenomena together determine the temperatures in Antarctica. Temperature is important for global physical, chemical and biological processes, and at the physiological and molecular level for liv-

ing organisms. Variations in Antarctic land and water temperatures condition the occurrence of eurythermic organisms (adapted to living in a wide range of temperatures), stenothermic organisms (adapted to smaller temperature fluctuations), or hypostenothermic organisms (adapted to constant temperatures or poorly resistant to fluctuations, as in haibats near the shores of the continent or under the shelf glaciers).

A frigid land of ice?

In 1983 the Vostok station recorded a temperature of -89.2°C , although it is estimated that it may drop there to as low as -96.0°C . The highest temperature ever recorded there was -13.6°C . Recent studies using satellites have shown that with very low humidity and high albedo (with a large share of solar radiation being reflected from the surface), the temperature in the ice cavities of the central Antarctic sometimes drops to -100°C , the lowest temperature recorded on Earth. At the same time, black rocks can grow quite hot in the sunshine. The range of temperature differences is therefore quite vast.

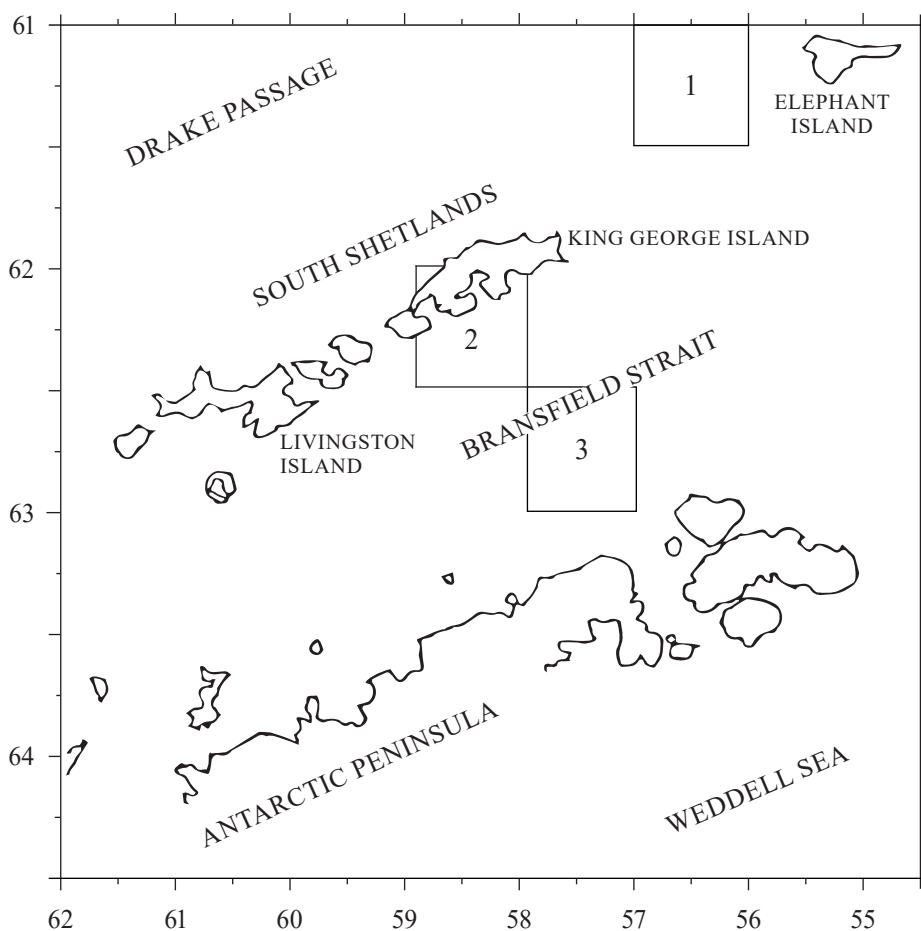
Below the Vostok station, under a layer of ice 4,000 m thick, there is a large lake of the same name, in which fresh water is highly oxidized as a result of the huge pressure and maintains a temperature of -3.0°C . There are many indications that there are microorganisms living in Lake Vostok that have been isolated from the earth's surface for about 0.5 to 1 million years. Bacterial DNA has been found in ice cores.

Currently, over 300 continental lakes have been discovered, linked by a network of sub-ice rivers with periodic "catastrophic" flows. One of the oddest of these is Don Juan Poland located in the Dry Valleys of Victoria Land. The lake is saline, rich in calcium



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Measurements of sea water temperatures in the South Shetland area were made during the Polish expeditions of the "Professor Siedlecki" ship in three regions: between King George Island and Ivory Island (region 1), in the northern part of Bransfield Strait and Admiralty Bay (region 2), and in the central Bransfield area (region 3) to a depth of 500 m during spring and summer. For region 1 during the studied period, the surface temperature ranged from -1.7 to $+2.0^{\circ}\text{C}$, and at a depth of 500 m from -0.2 to $+1.7^{\circ}\text{C}$. In region 2 the surface temperature ranged from -1.8 to $+1.8^{\circ}\text{C}$, and at 400 m from -1.1 to 0.2°C , while in region 3 on the surface it ranged from -1.7 to 1.4°C , and at a depth of 500 m from -1.0 to -0.5°C . Region 1 on the edge of the shelf and Drake Passage was the warmest. Waters flow into Admiralty Bay from the west and the Drake Passage.

chloride, and so remains liquid even at a temperature of -50°C . Some scientists consider its conditions to resemble those found on Mars.

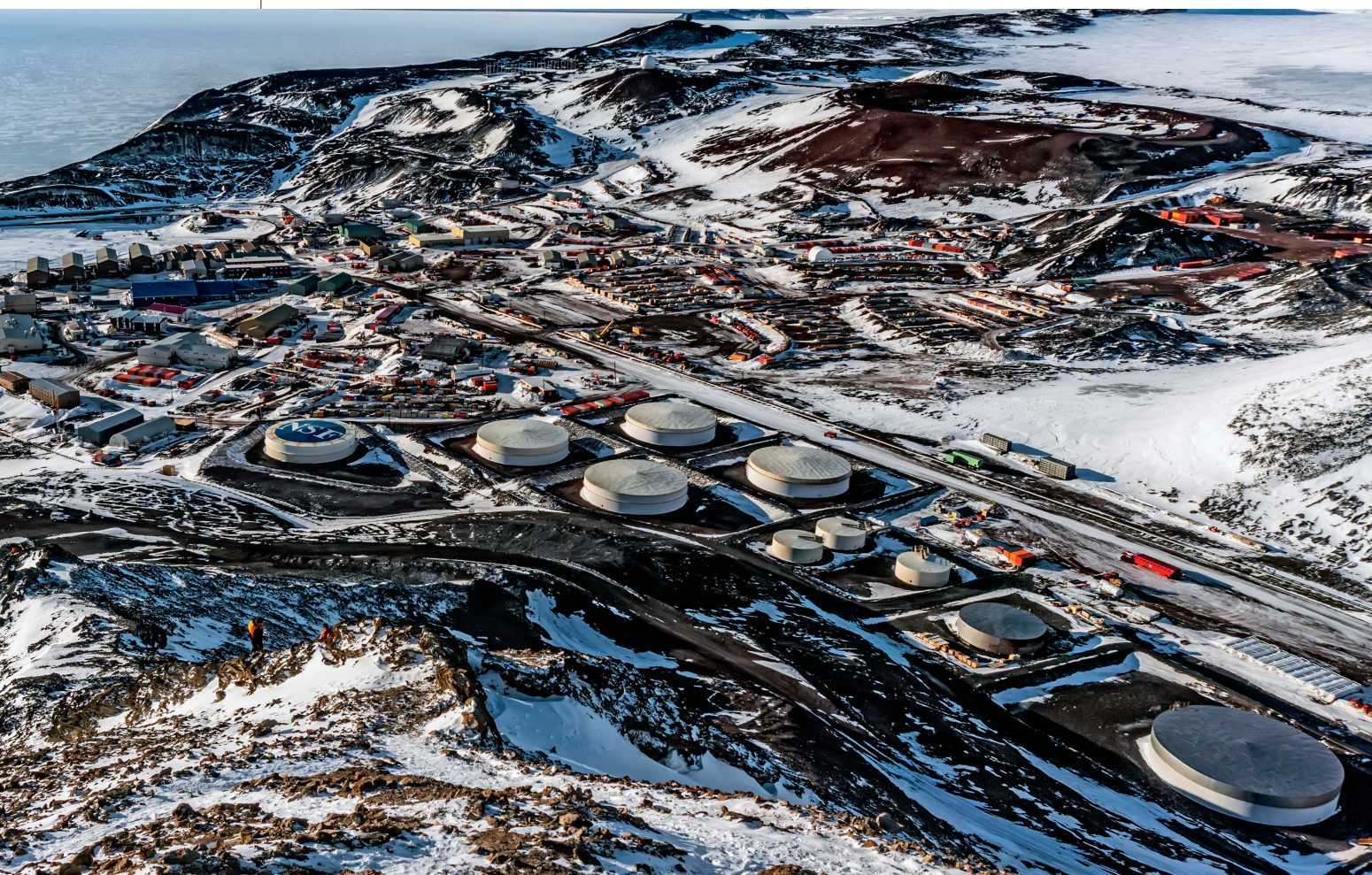
A diverse coastline

The climate of the coastal areas of East Antarctica is determined by the dome of the ice sheet and the proximity of the sea. Negative air temperatures occur there throughout the year, with the annual average being around -11°C near the Molodyozhnaya station, and absolute values ranging from $+9^{\circ}\text{C}$ to -42°C . In the Thala Hills oasis there are about 40 freshwater reservoirs ranging in depth from several cm to 2–3 m covered in ice for 10 months and freezing all the way to the bottom, but in the summer the present author has observed temperatures reaching from 9.2°C in shallow rock pools, to over 20°C . In the summer, the large, 30 m deep Lake Glubokoye thaws at the rocky shore, where temperatures reach 5°C , while at the bottom of the lake the temperature reaches 4°C . Every few years the lake overflows with water, causing a catastrophic outflow to the sea. Cyanobacteria are found in the water, while the fauna includes rotifera, nematodes, and tardigrades. Only two copepod species have been found in the large lakes of the Bunger Oasis. My re-

search conducted on a lake in the Thala Hills oasis in 1969 showed that freezing led to increased water pressure, oxidation, and catastrophic flows, which is similar to the sub-ice lakes discovered deep in the Antarctic continent over the last 20 years.

My research discovered that the sea water temperature at the shore of the Thala Hills oasis in Enderby Land fluctuated from -1.6°C in December 1971 to -0.05°C in January 1972. In winter, temperatures in the littoral zone vary slightly and oscillate around -1.8°C . In winter, baric low pressures are most significant, as they draw in slightly warmer water deeper under the ice surface.

On the opposite side of the continent, in the McMurdo Strait and below the Ross shelf glacier, the waters have a negative temperature and annual fluctuations do not exceed 0.2°C . These, in my view, are hypostenothermic conditions, which affects the organisms living there. Under the shelf glaciers, the water temperature may be lower than -1.9°C , but then its salinity and density increase, which causes it to flow to the bottom of the sea. On the island of Rossa there are also volcanoes, Erebus (3794 m a.s.l.) and Terror, the first of which is active. Such high ice-covered mountains and volcanic activity contribute to the extreme temperature differences in this area. In the ice caves



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McMurdo Station in Antarctica, maintained by the United States.

here, temperatures are close to 0°C , which even promotes the existence of fungi and unique chemolithoautotrophic bacteria that feed on elements found in rocks.

Conditions around King George Island

The Arctowski station is located on King George Island in the South Shetland Archipelago in West Antarctica. Measurements made at Arctowski station eight times a day by licensed IMGW observers during the years 1978–1987 gave an average air temperature of -18°C for the period, fluctuating in individual years from -0.9°C in 1979 and -0.6°C in 1985, to -2.8°C in 1986. The first meteorological data analysis for this area made by Martianov and myself signaled a trend of increasing temperatures by 0.2°C to 0.6°C compared to previous decades. At the same time, at the Bellingshausen station the average air temperature was -2.4°C . The minimum temperatures were lower at the Arctowski Station (-32.3°C) than at Bellingshausen (-27.4°C), while the maximum temperatures were higher, at $+16.7^{\circ}\text{C}$ and 12.4°C , respectively. The extreme differences in temperatures at the Arctowski

Station cover a span of 49.0°C . Admiralty Bay is surrounded by high hills and open to the south, which means that cold air from the south-east flows in and stays here, and in the summer this region generally experiences western winds (warm and dry); the temperature is also affected by greater sun radiation with fewer clouds than at the Bellingshausen station. Bellingshausen is located on a low peninsula between the Drake Passage and the Bransfield Strait.

The soil temperature at the Arctowski station in the years 1977–1999 was $+0.5^{\circ}\text{C}$ on average, the air temperature -1.6°C . At a depth of 1 cm, the temperature increased at a rate of 0.03°C per year. The highest temperature on the soil surface on a sunny day was 17.8°C , and the lowest in a snowless area was 8.9°C . Negative temperatures (from -0.1°C to -8.0°C) on the surface lasted 192 days, while positive temperatures (from 0.1°C to 16°C) stayed around for 35 days. Shallow reservoirs in South Shetland in the vicinity of the Arctowski station can heat up to 14°C in summer and freeze all the way to the bottom in winter. Many of them receive biogenic salts from nearby penguin colonies, resulting in huge blooms of *Chlorella* algae. The numerous penguin colonies also contribute on

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The Antarctic research stations maintained by various countries.

a small scale to modifying terrestrial temperatures. The water fauna includes rotifera, nematodes, tardigrades, copepods, and fairy shrimps, while land-based fauna includes numerous springtails. High above the station a temperature of 15.2°C was recorded, with 7.0°C near the shore, which points to the stabilizing flow of the water from Admiralty Bay.

The warmest sea waters in the South Shetland area occur locally in the Deception Island caldera, reaching temperatures so warm, thanks to active volcanic activity, that they can actually be enjoyed by tourists bathing in them.

El Niño influence?

Research of the Scripps Institute in California also suggests that the El Niño phenomenon affects the Antarctic ice shelf glaciers, which gain mass on the surface as a result of snowfall, but lose five times more due to ice melting from below. The year 2015 was the warmest for El Niño, which has been shown to affect krill biomass in southern Georgia, and this determines the migration of sea lions to the Antarctic Peninsula and the fluctuations in their numbers in the King George ar-

ea. The differences in the average annual fluctuations observed at the Arctowski station correspond to the five year or close cycles of El Niño. There seems to be a relationship between El Niño and the rise in average temperatures at Arctowski station in 1983, 1987, 1993 and 1998, as well as snowfall. With a general warming trend, as reported in the 2017 International Climate Report, and global temperatures rising by 1.5–1.8°C over the course of a century, temperature differences observed at Arctowski station support conclusions about local climate change in this area. This is important when considering the location of the Arctowski station and plans for its restoration. The problem of rising sea levels and the threat to structures located near the shore of Admiralty Bay is worsening. If sea levels rise by 3 mm per year, while the isostatic emergence of King George Island due to its ice melting, as stated, proceeds at a rate of 7 mm per year, then this process is not a threat. The threat may lie in the changes to the shoreline of Admiralty Bay caused by hydrological factors, such as wind and tidal currents or waves, depending on weather conditions.

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Further reading:

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