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Polish research on sea and atmosphere physics carried out in West Antarctica, 1977–1990

ABSTRACT: The article presents a review of the researches on sea and atmospheric physics conducted by the Polish expeditions in Antarctica from 1977 to 1990.

Key words: West Antarctica, sea atmosphere, physics.

Introduction

Most researches on sea and atmospheric physics were carried out from 1977 to 1990 at or near *H. Arctowski* Station (King George Island, South Shetland Islands) in West Antarctica: Ezcurra Inlet and Admiralty Bay (Figs 1, 2). Some researches were carried out also in Drake Passage, Bransfield Strait, Scotia Sea and Antarctic parts of the ocean. They included:

- sea dynamics (drift and tidal currents, wave motion, tides and sea level variation);
- sea optics (solar energy inflow into the sea surface, albedo, light attenuation, water transparency);
- biophysics (zooplankton bioluminescence, physical conditions influence on primary bioproduction and migration of krill);
- sea and atmospheric interaction (molecules exchange between sea and atmosphere, wind interaction with sea surface, surface water temperature);
- other fields of physics (*e.g.*, suspension in sea water).

These researches began during the 2nd Antarctic Expedition of the Polish Academy of Sciences to *H. Arctowski* Station. The expedition lasted from 20 December 1977 to 16 March 1978 (Dera 1980). The research was carried out

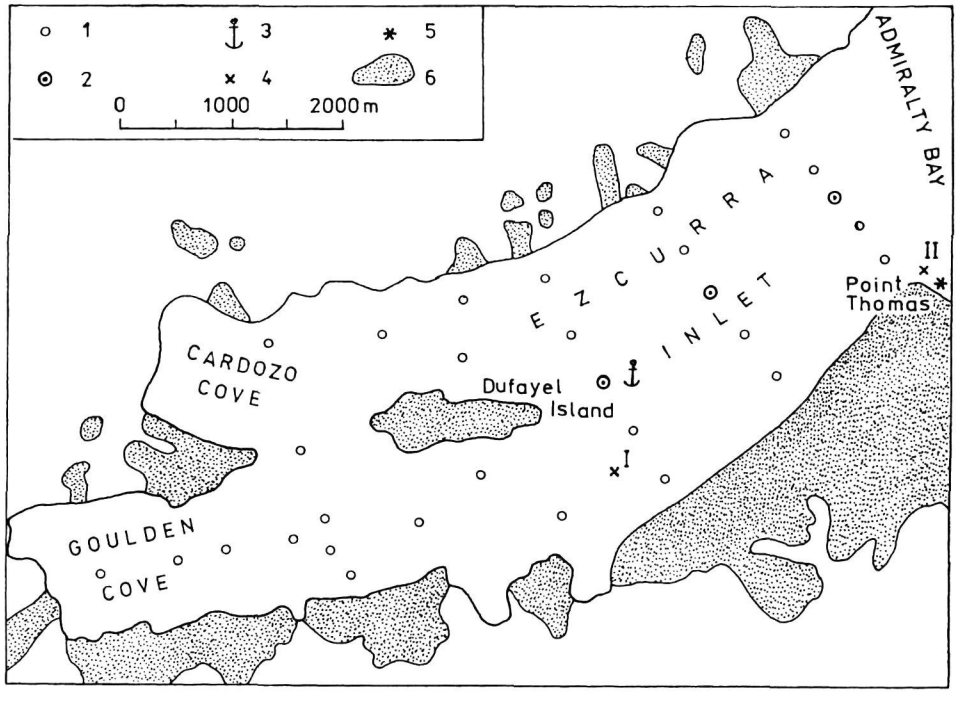

Fig. 1. Ezcurra Inlet, King George Island. Seawater measurement stations: 1 – temperature and suspensions; 2 – suspensions in deep sea; 3 – m/s *Antoni Garnuszewski* anchorage optical and physical properties of seawater; 4 – currents; 5 – sea level.

simultaneously from m/s *Antoni Garnuszewski* and at *H. Arctowski* Station. They included:

1) weather conditions in Ezcurra Inlet (Kowalewski and Wielbińska 1983);
2) mineral suspensions in seawater (Jonasz 1983);
3) direction and velocity exchanges of seawater flows (Catewicz 1983);
4) harmonic analysis of tides (Catewicz and Kowalik 1983);
5) optical properties of water (Olszewski 1983);
6) solar energy inflow into the sea surface and euphotic zone lighting (Woźniak *et al.* 1983);
7) zooplankton bioluminescence (Dera and Węgleńska 1983);
8) primary bioproduction (Hapter *et al.* 1983).

The following institutions were inculued in the above research: Institute of Oceanology of the Polish Academy of Sciences (PAS) at Sopot, Hydroengineering Institute (PAS) in Gdańsk–Oliwa, Institute of Ecology (PAS) in Warsaw, Sea Fisheries Institute in Gdynia, Institute of Telecommunications in Warsaw, Institute of Oceanography, University of Gdańsk and Department of Maritime Physics University of Szczecin.

Atmosphere and sea dynamics

The research on sea and atmosphere physics started during the 2nd Antarctic Expedition of the Polish Academy of Sciences to *Henryk Arctowski* Station (1977/8). The observations (December 1977 – March 1978) included: weather conditions, physico-chemical properties of seawater, suspensions, drift currents and tides, optical and biophysical phenomena (Dera 1980). At Ezcurra Inlet, Admiralty Bay, the atmospheric pressure was 990 mb with variations from 1018 mb on 3 March 1978 to 969.6 mb on 2 February 1978. Based on wind direction and velocity measurements, it was found that the situation and orientation of Ezcurra Inlet, slopes steepness and height of mountains surrounding the fjord, influenced the wind parameters. It was also observed that rapid changes of atmospheric pressure were not always accompanied by the wind and, vice versa, strong wind was often not accompanied by rapid changes of atmospheric pressure. Western wind occurred most often, and eastern wind – most rarely. The temperature of air varied from 0°C to +4°C with maximum of +9.6°C and minimum of -5.8°C. Considerable change in air humidity was observed, the average humidity above fjord being 80%. The foehn phenomena often occurred. The visibility conditions changed much and rain passing to drizzle often appeared. The mean temperature of surface water in Ezcurra Inlet was +1°C, with maximum of +3.4°C in the middle of January (Kowalewski and Wielbińska 1983).

Meteorogical observations and research on physical phenomena in the atmosphere were continued during the next expeditions, until 1990.

Drift currents and tidal currents were measured in Ezcurra Inlet at points I and II (Fig. 1) (Catewicz 1983, Catewicz and Kowalik 1983). Changes of velocity and flow direction at the depth of 20 m and 70 m were measured. At point I, situated deeper inside Ezcurra Inlet, the flows were weaker than at point II situated at the junction of Ezcurra Inlet and Admiralty Bay. The velocity of component currents at the depth of 20 m changed from -10 cm/s to +15 cm/s. At the depth of 70 m, the velocity of component currents changed from -10 cm/s to +10 cm/s. At point II, the velocity of component currents changed more than at point I.

In Admiralty Bay the following component tides occured:

O_1 over a span of T = 25.81 h

K_1 over a span of T = 23.93 h

M_2 over a span of T = 12.42 h

S_2 over a span of T = 12.00 h

Tidal waves which flow from the ocean into the bay generated tidal currents.

Based on harmonic analysis of sea level oscillation (at time of during 29 days) it was found that the main components of tides are M_2, S_2, K_1 and 0_1. The twelve-hour-tides and irregular tides occurred in the bay. In February, the aver-

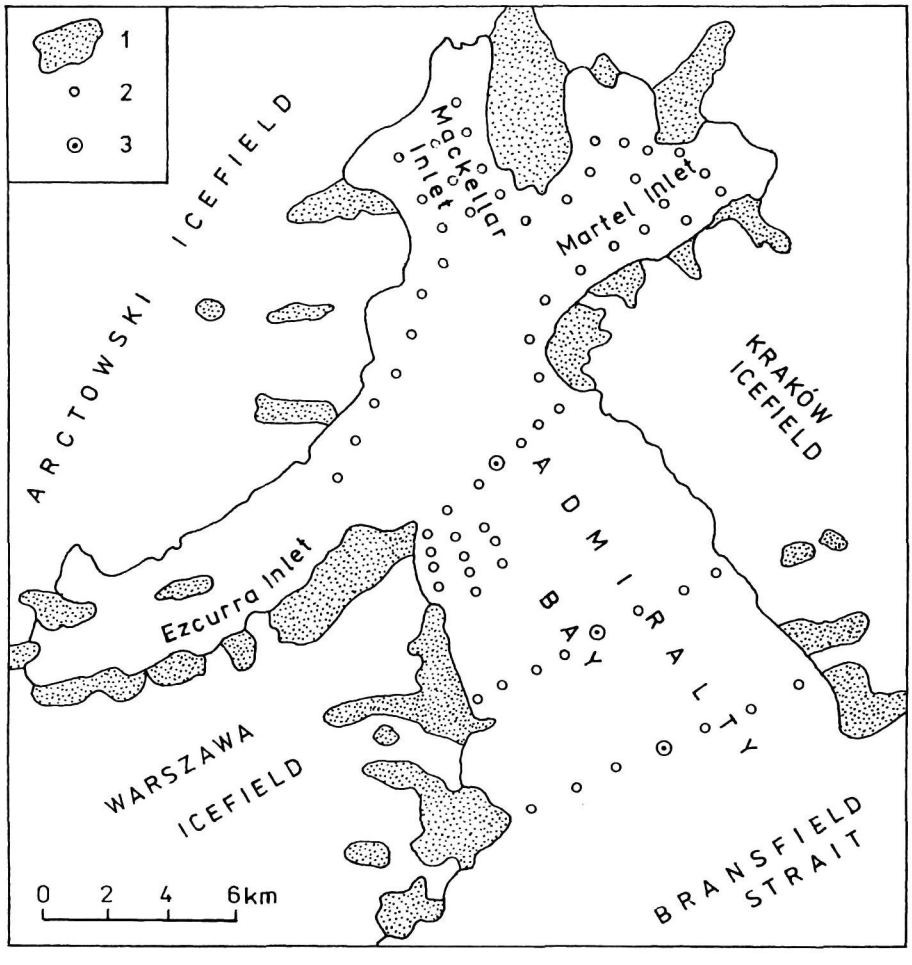

Fig. 2. Admiralty Bay, King George Island. 1 – rock exposures; 2 – measurements of surface water temperature and mineral suspensions; 3 – measurements of suspensions in vertical profiles.

age height of the twelve-hour tides was 158 cm and of the twenty-four-hour tides was 123 cm. In January, the tidal amplitudes were smaller.

A programme devoted to the role of the ocean in generation of climate changes and atmospheric phenomena on the Earth was realised under auspices of the World Meteorogical Organization and the Intergovernmental Oceanographic Commission (Druet and Siwecki 1986a, b). It included southern areas of the Atlantic Ocean, the Indian Ocean, and the Pacific Ocean between the latitudes of 32.5° and 57.5° degree south.

The research on sea dynamics was continued in Ezcurra Inlet and Admiralty Bay (Pruszak 1980). It was found that the flow system occurring in Admiralty Bay was a two-phase-flow system typical for fjords with tides.

From December 1983 to January 1984, the research on water circulation was conducted in Bransfield Strait and adjacent sea areas (Grelowski *et al.* 1986, 1988). After calculating dynamic heights in relation to reference level of 500 mb, a map of geostrophic flows on the surface and expenditure of volume on selected profiles was constructed.

Sea optics and primary bioproduction

During the 2nd Antarctic Expedition (PAS), light attenuation in water and diffusion attenuation of top light were measured (Olszewski 1983), using waves 525 and 425 nm long (December–February) and 525 and 600 nm long (February–March), respectively, on vertical profiles at the depth of 70 m. Temporal runs of 10-day and 40-day values of dispersion albedo for light wave 525 nm were calculated, and the dispersion of albedo dependence on value of the light attenuation coefficient for waves of the same length, and for waves of 425 nm and 600 nm, was established. A high value of light attenuation coefficient in the seawater layer of 24 m thick was found, caused by the presence of suspensions.

Another optical phenomenon, tested from 21 December 1997 to 10 March 1978 was the solar energy inflow into the sea surface in relation to latitude, season of the year, part of the day, optical weather conditions, and specific physical properties of the sea (Woźniak *et al.* 1983). The measurements were carried out for the light wave of 400–700 nm with pyranometer device. The point of measurement was on m/s *Antoni Garnuszewski* in stable position ($\phi = 62°10'$ and $\lambda = 58°32'$ W). Strong temporal changes of weather conditions in the sea, and in the atmosphere, were found. Daily light runs of sea surface within the whole range of spectrum and within the range of 400–700 nm visible light, were made for the depths of 5, 10, 20, 30, 40 and 50 m.

Primary bioproduction measurements in water units at different depths were taken (Hapter *et al.* 1983). Vertical distribution of daily values of primary production and of chlorophyll a, B concentration in the sea were presented. A dependence of primary production on wholeday-doses of solary radiation energy on the sea surface was established.

Research on zooplankton in Ezcurra Inlet showed that many species react with bioluminescence caused by light impulses of different duration and intensity (Dera and Węgleńska 1983).

Research on sea optics was also conducted in Drake Passage, Bransfield Strait and Scotia Sea (Figs 3, 4). Solar energy inflow in the sea surface and light field in the sea was measured from 24 January to 22 March 1976 (Wensierski and Woźniak 1978). Graphs of dependence of light coefficient on wave length and 24 hrs changes in solar energy inflows into deep sea was presented, and compared to the depth of krill migration.

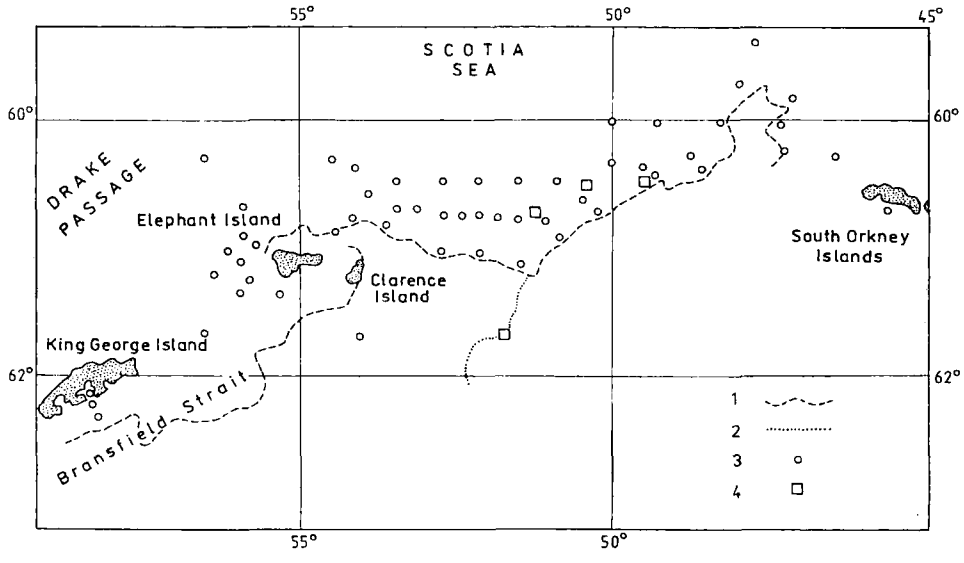

Fig. 3. The areas of Drake Passage, Bransfield Strait and Scotia Sea investigated by the Polish marine expeditions: 1, 2 – edge of sea ice; 3 – seawater stations; 4 – ice stations.

Optical phenomena were investigated within the FIBEX programme in Drake Passage and in the region of South Shetland Islands (Stramski and Montwiłł 1982). Spectral measurements of top light attenuation in the sea within the range of 400–700 nm were also taken.

The sea waters were divided into:

1) clear oceanic waters (including Drake Passage);

2) oceanic waters of medial type;

3) coastal waters at the area of South Shetland Islands.

Distribution of krill and its biomass in Bransfield Strait and Drake Passage (Fig. 3) were examined from 21 December 1983 to 8 January 1984 (Kalinowski *et al.* 1985). Vertical krill migration was investigated using acoustic methods (Godlewska and Klusek 1987, 1991). The Johnson equation modified by Godlewska was used to calculate the krill biomass. The highest concentration of krill, over 1000 units per 1 m^2 were found near Elephant Island and to the north of King George Island. The average concentration of krill in Bransfield Strait was 3.14 units/m^2, and in Drake Passage 4.29 units/m^2.

Sea-atmosphere interaction

Marigenic molecules exchange on the sea-atmosphere interface was investigated from 10 January to 20 March 1981 at the *H. Arctowski* Station (Garbalew-

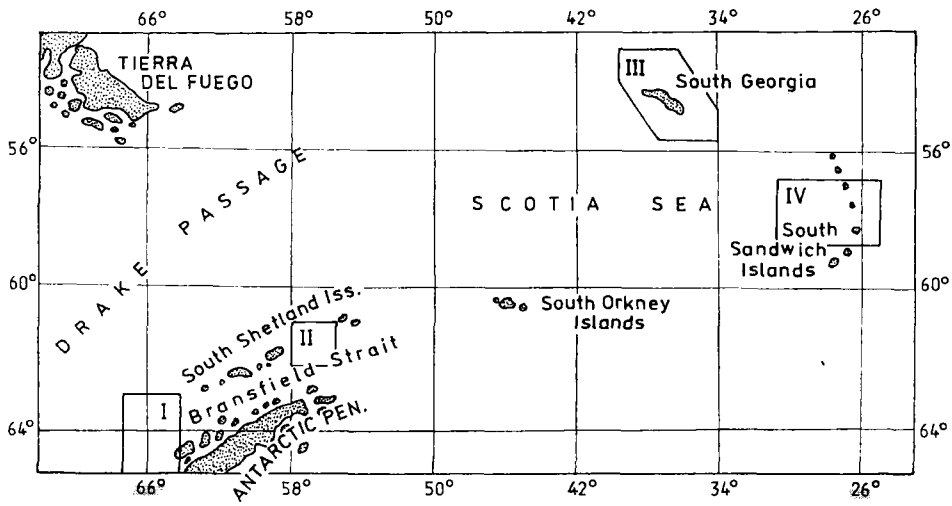

Fig. 4. Areas of research by the Polish marine expeditions: I – north-west Bransfield Strait; II – between King George Island and Elephant Island; III – South Georgia; IV – South Sandwich Islands.

ski and Marks 1983, 1985). A high concentration of marigenic molecules, on an average less than 5 μm in diameter, was found in the air above sea surface. Measurements of short-term changes in concentration of molecules in suspension with water and sea salt crystals were taken at vertical profiles. A dependence of marigenic molecules number and their volume concentration on wind velocity was stated.

Suspensions in seawater

From 20 December 1977 to 10 March, 1978, suspensions in seawater of Ezcurra Inlet and Bransfield Strait were tested (Jonasz 1983). The samples of water were drawn from the depth of 1 to 80 m, and the Coulter Counter was used. The largest concentration of suspensions was observed at the depth of 10 m.

The studies were continued in Admiralty Bay from December 1978 to February 1979 (Pęcherzewski 1980). The suspension concentration varied from 2.8 mg/l to 182.6 mg/l. The maximum concentration of suspensions was found at the depth of 10 to 50 m.

The research was continued from January 1989 to March 1990 during the voyage across the Atlantic Ocean to the *H. Arctowski* Station. They included concentration, dispersal distributions, propagation and time and spatial modifications of mineral suspensions (Gurgul 1993, Gurgul *et al.* 1993a–c). The re-

search included also the Ezcurra Inlet and Admiralty Bay waters (Gurgul 1993; Gurgul *et al.* 1992, 1993c). Concentration and dispersal distribution of the suspensions in ice of Ecology Glacier were also studied (Gurgul *et al.* 1995, 1996a, b).

Temperature and salinity of seawater

From 30 October to 3 November 1986 Grelowski and Wojewódzki (1988) carried out measurements on salinity, temperature and density of seawater in the Scotia Sea. The STD diagrams were made of the oceanic front in this sea. The graphs of isoline T°C, S‰, SIGMAT, O_2 [cm^3/dm^3] and CHL.a [mg/m^3] (Rakusa-Suszczewski 1988) were made for seawater around King George Island and Elephant Island.

From January 1988 to March, 1990, temperature of the surface water was measured almost every day in Ezcurra Inlet and Admiralty Bay (Gurgul *et al.* 1994, 1996b). The highest average temperature of seawater in Ezcurra Inlet (+2.5°C) was noticed on 6 January 1990, the lowest (-1,2°C) in November. The temperature of surface water depended on: melting of glaciers and growlers, weather conditions and the air temperature. The maximum temperature of seawater was +3°C (on 3 January, 1990) in the area between Dufayel Island and southern coast of Ezcurra Inlet.

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