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Mid-winter thawing in the vicinity of *Arctowski* Station, King George Island

ABSTRACT: Mid-winter rapid rise of temperature in the vicinity of *Arctowski* Station, King George Island (West Antarctica) was studied in 1991. Depending on circumantarctic migration of cyclones, sudden drop in air pressure and foehn-like phenomenon intensified by local topography occurred. Two such events are described on May 13 and June 28, against meteorological conditions during autumn and winter. Extreme intensification of morphogenetic processes caused degradation of a snow cover, immense meltwater discharge, radical transformation of slopes, effective aeolian activity and dynamic modifications in a sea-shore zone.

Key words: Antarctica, South Shetland Islands, maritime, weather conditions, mid-winter thawing.

Introduction

Contemporary development of a polar relief seems to be connected with activity of geomorphic processes during summer. Such observations allow to ascertain constant surface modelling in a "normal" state of atmosphere. Steady ablation of a snow cover and glacier surfaces regularly supply with water to mark effects of these processes. This point of view is relative to gradualism theory, assuming that time alone was necessary to accomplish "a great geologic work" (Sanders 1981). Otherwise it is hard to agree with the afore-cited opinion, having in mind events with traits and dimensions exceeding the average level. Energetic states above mean values exert significantly the image of a polar environment in its inorganic part. It was explained by Wolman and Miller (1960) who presented the process effectiveness. The whole efficiency in a geomorphic system results from magnitude and multiplication of frequency. Basing on dif-

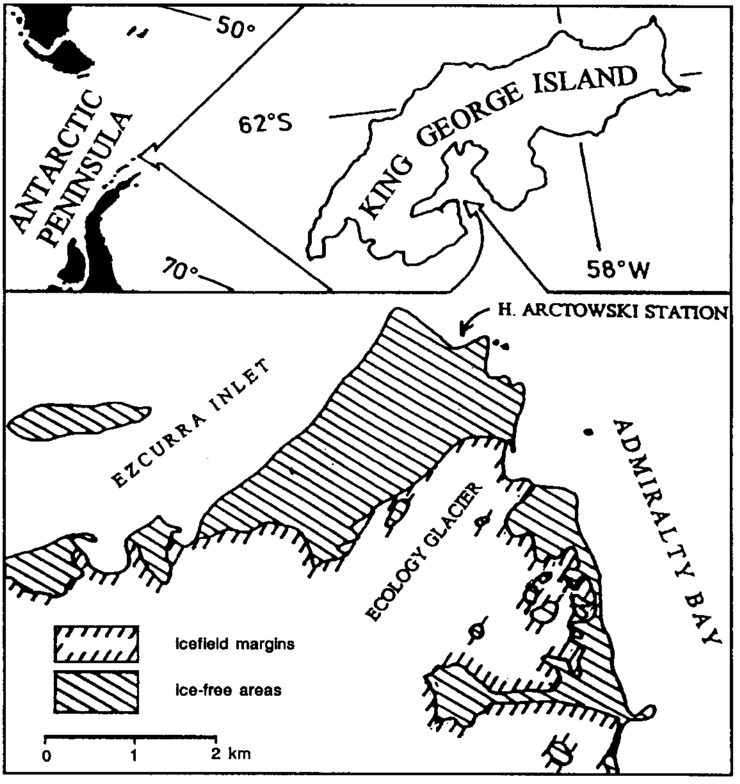

Fig. 1. Location of the study area (detailed map after Battke, 1990).

ferent frequency of events duration, Thornes (1985) denoted that most of the work is done while intensity of the process is a little bit higher than the most frequent one. Morphologic essence of thawings, rain-storms or long-lasting rains was suggested by Klimaszewski (1932), while "...average conditions are working permanently and without breaks".

The author's wintering at the *Arctowski* Station during the 15th Antarctic Expedition organized by the Institute of Ecology, Polish Academy of Sciences, enabled observations of atmospheric conditions during different seasons. Permanent meteorological and hydrological monitoring creates good opportunity to observe and record interaction of processes within a geosystem of maritime Antarctica.

Analysis of air temperature curve recorded in a meteorological observatory at the *Arctowski* Station (meteorological year-books 1978–1991) or at other stations on the South Shetland Islands (Martianov and Rakusa-Suszczewski 1989, Lee, Kim D.H. and Kim Y. 1990) indicates occurrence of morpho-creatively valuable incidents all over the year. In majority, temperatures above 0°C are denoted every month. Changes in mineral substratum depend on much more

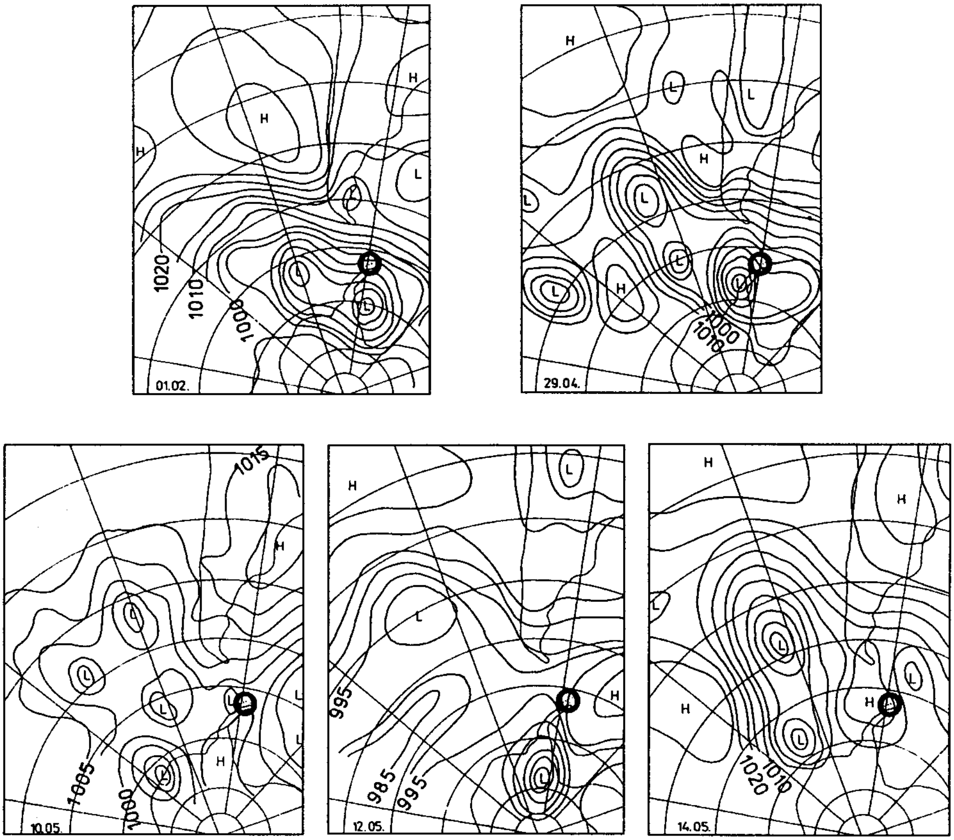

Fig. 2. Maps of air pressure distribution in the South Atlantic on days with selected weather conditions at the *Arctowski* Station in autumn 1991, according to the Chilean Navy Meteorological Survey; isobars in hPa.

agents than a temperature rise itself. Variations of a snow cover thickness, ground freezing depth or occurrence of rainfall are the most valuable reasons for environmental instability.

During the observation year 1991 at the *Arctowski* Station (Fig. 1), the weather was highly varying. Variations were especially common during the Antarctic autumn and at the beginning of the Antarctic winter (May–July). General atmospheric circulation in the passage between South America and the Antarctic Peninsula results in a constant air flow from the west, undisturbed by large obstacles like the continents. Area of this air-mass translocation includes the Drake Passage, the South Shetland Islands and the Bransfield Strait. According to Kejna (1993), a western advection is decidedly predominant (44% at low pressures and 10.7% at high) for the period 1986–89 in this region. In this westward movement of air masses, both high and low pressure centres participate. Their position is influenced by spreading of a high pressure centre of the

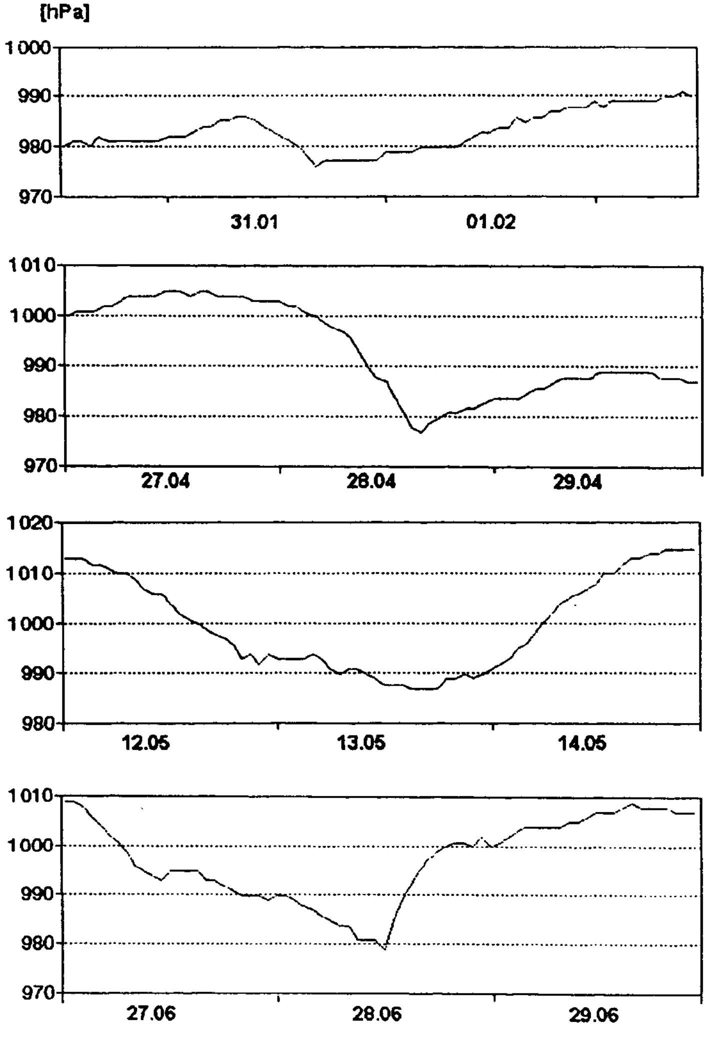

Fig. 3. Air pressure changes at the *Arctowski* Station (*cf.* Fig. 2).

Central Antarctic. Opposite to the scheme presented by Martyn (1985), the axis of migrating cyclones does not go beyond the polar circle only, but can reach almost the latitude of 80°S. This migration of low air pressure centre to the south of the King George Island (Fig. 2) is noted as a pressure drop up to 30 hPa. In a dozen hours or so, occurrence of the foehn phenomenon can be connected with the mentioned air pressure variation (Fig. 3). The foehn speed depends on pressure gradient and distance between the island and a cyclone centre. Typical symptoms of approaching wind are the clouds *Altocumulus lenticularis* and a ridge of foehn clouds.

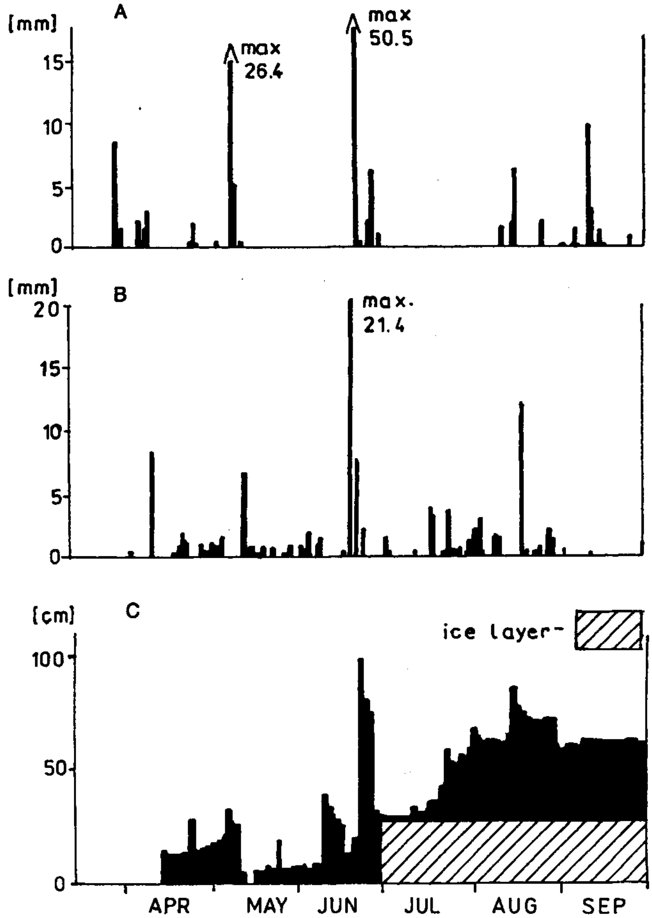

Fig. 4. Rainfall (A), snowfall (B) and snow cover thickness (C) at the *Arctowski* Station in autumn and winter 1991.

High wind speed is additionally accelerated by morphologic conditions in the vicinity of the *Arctowski* Station. Vertical profiles of wind directions at both sides of the ice dome suggested (Bintanja *et al., unpubl.*) its western homogeneity at the windward (western) side. On the other hand, it was transformed at about 350 m a.s.l. at the leeward (eastern) side to the eastern one. These authors suggest presence of the so-called "lee rotor effect", being a kind of circular air movement in a vertical plane, parallel to slope inclination of the ice dome. The present author distinguished a third-order local term due to which, air flow was modelled by high rock and ice shores of the Ezcurra Inlet. Small wind-spouts and decidedly strongest gusts from the north were observed. On the basis of observations in 1978–87 at the *Arctowski* Station, similar relations were described by Kowalski (1985) and Styszyńska (1990, 1994).

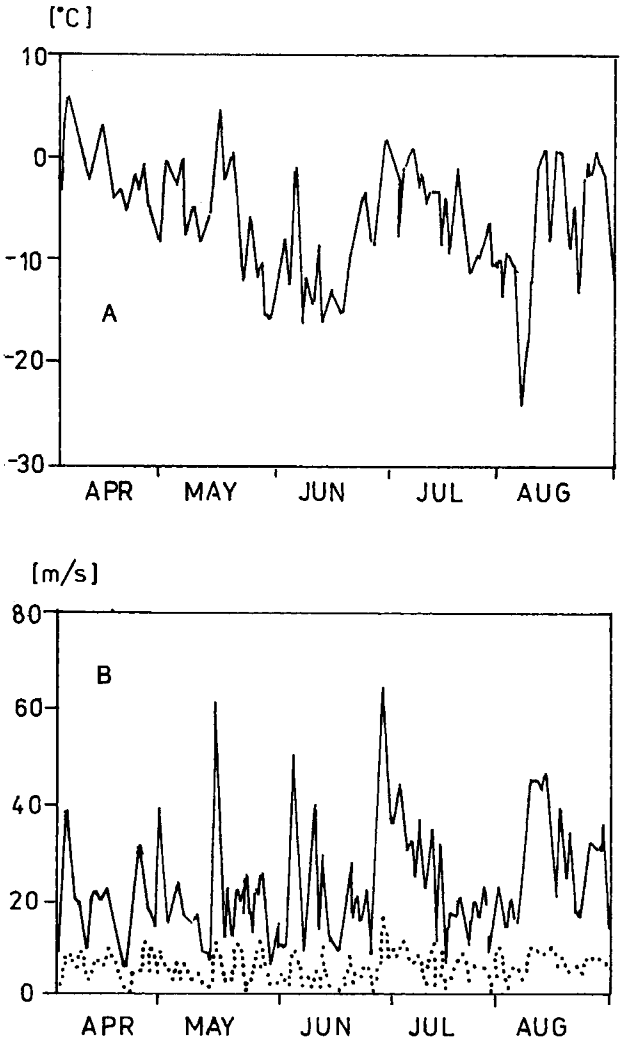

Fig. 5. Daily mean temperatures (A), daily mean (dotted line) and maximum (solid line) wind speed 2 m above the ground (B) during the observation period.

In the described scheme there are three terms, significant for dynamic changes of the landscape. They are: rapid rise of air temperature, high speed of wind and accompanying rainfall, mixed with aerosol of sea water. Detailed analysis was done for two events on May 13 and June 28, when activity of all three agents acted with great effectiveness. As mentioned, temperatures above 0°C occurred during every month in winter. Rise of temperature, following several days with low temperature is very important, what is connected with ground freezing and common occurrence of a snow cover. In 1991, a snow cover appeared relatively late — in the third decade of April (Fig. 4C), but a snowfall

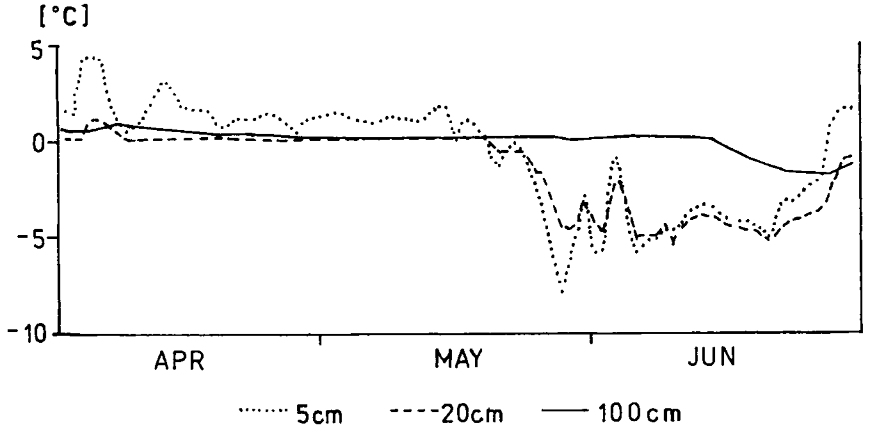

Fig. 6. Daily mean ground temperatures at three depths at the end of autumn 1991.

after a period with air temperature above 0°C caused thermic isolation of a mineral substrate (Fig. 6). On May 13, a transition of temperature was very violent (Fig. 5A) — being almost 15°C, in that 5°C above 0°C. On June 28 a temperature fluctuation was rather small, both in absolute values (10°C) and above 0°C (+2.5°C). During these warmings, a complete ablation of a snow cover was possible. Additionally, a positive reaction of ground temperature was recorded in the whole temperature profile of June.

Very high precipitation (Fig. 4A, B) was noted during foehns. A high electric conductivity indicates a significant mineral content in a rainfall. This observation convince about participation of sea water aerosols from the bay. Influence of areosols is decreasing with distance from a shore. Evaluation of pluvial and thermic ablation is very difficult. According to the runoff under, inside and on the surface of snow, measurements were based on water discharge and flow velocity in the Geographers Creek. During the day with maximum flow, water discharges of 300 and 500 l/s occurred, dependent on the regression type (Fig. 7). Estimation was made for the unstable snow/ice channel. In this evaluation, volume of water inside a snow cover was not taken into account. The roughness index in the model was the same as for a mineral channel. Adjustment of the regression curve is more real, accepting a higher value. During the next 24 hours of the lake refilling, water discharge was equal to 227 l/s. This value also significantly exceeds those measured during a summer (Fig. 8).

Nature of aeolian process is marked by boundary values of wind speed (Fig. 5B), being over 40 m/s and reaching a maximum of 61 and 67 m/s. Mean values recorded in 2 minute intervals are between 15 and 20 m/s. These means do not differ at southern winds when the maximum is slightly over 20 m/s. Such difference between winds from opposite directions shows distinctly gustiness of the foehn-like winds.

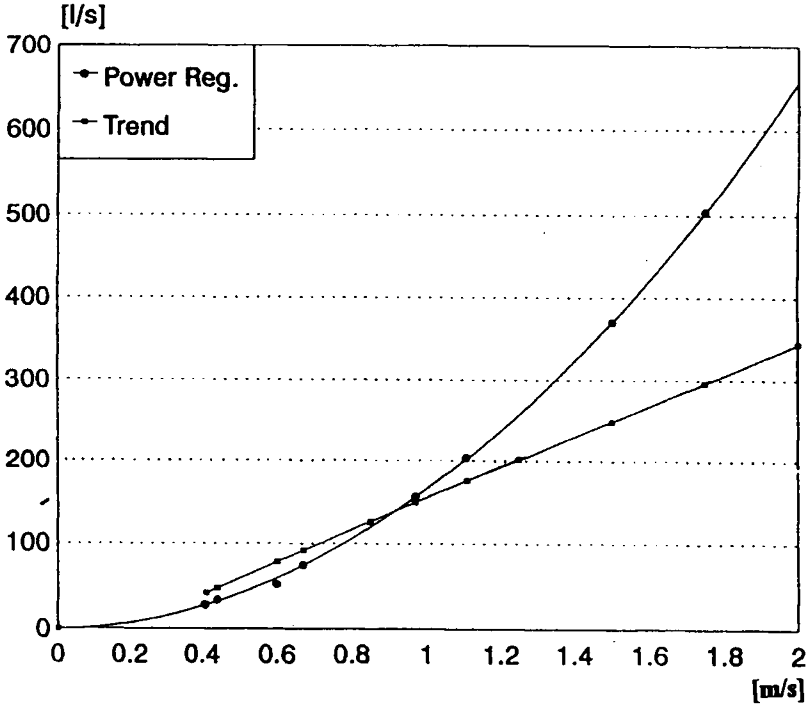

Fig. 7. Relation of water discharge and flow velocity, plotted as linear (trend) and power regression lines at Skamieniały Las Creek, site Limnigraf.

Meteorological conditions described against a topographic situation have significant influence on relief development. They are pointed out as the basis for further studies:

— rapid outflow of water from rainfall and ablation of a snow cover results in active erosion of unfrozen or suddenly thawing ground; unstable substrate facilitates dynamic evolution of incisions on slopes (Pl. 1, Fig. 1; Pl. 1, Fig. 2),

— outflow in marginal zones of glaciers, mainly in lateral situations, causes remodelling of glacier fronts and ice-cored ridges by thermal activity of water accumulated in a snow cover,

— banked up water spreads out of "summer" channels, modelling a ground moraine relief; it leads partly to development of outwash plains, absent at mean and low stages of streams; water under hydrodynamic pressure removes mineral matter from beneath a snow cover and forms therefore niveo-fluvial features (Pl. 2, Fig. 1),

— transformation or complete disappearance of a snow cover, connected with thawing of a frozen ground, allows penetration into the substrate or produces snow-water mixture which freezes into an ice layer (Fig. 4C) that isolates mineral surface from further changes during the ablation season,

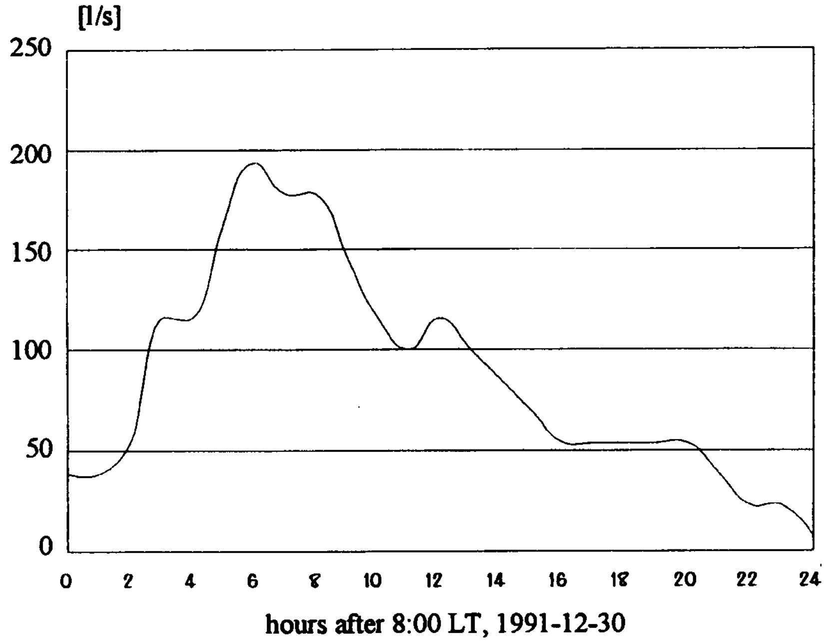

Fig. 8. Water discharge measured during 24 hours in summer 1991 at Skamieniały Las Creek, site Limnigraf.

— fast movement of air mass accelerates ablation of a snow cover by evaporation and removes snow particles out of their original location on flat surfaces *e.g.* on glaciers; this low rate of snow accumulation is valuable in glacier mass balance,

— on snow-free surfaces the conditions are favourable for effective aeolian processes transporting coarse material (gravel), mobile mainly in a beach zone,

— fresh incisions are formed on a beach what basicly changes a scheme of hydrographic network (Pl. 2, Fig. 2),

— dynamics of the sea/land contact zone during strong storms, with participation of sea and glacier ice is a separate problem.

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Streszczenie

W 1991 roku prowadzono obserwacje gwałtownych ociepleń śródzimowych w okolicach stacji im. H. Arctowskiego na Wyspie Króla Jerzego, Szetlandy Południowe (fig. 1). Zależnie od okołoantarktycznej migracji niżów barycznych (fig. 2), dochodzi do gwałtownych spadków ciśnienia atmosferycznego (fig. 3) i fenu wzmocnionego warunkami lokalnymi. Opisano dwa takie zdarzenia (13 maja i 28 czerwca) na tle warunków meteorologicznych notowanych w okresie jesienno-zimowym (fig. 4–6). Ekstremalne nasilenie procesów morfogenetycznych objawia się degradacją pokrywy śnieżnej, bardzo wysokimi -niespotykanymi latem wartościami przepływu wód pochodzących z ablacji śnieżnej i lodowcowej (fig. 7–8), istotnym przeobrażaniem powierzchni stokowych (pl. 1), efektywną eolizacją i dynamiką przekształceń rzeźby w strefie brzegu morskiego (pl. 2).

1. Effect of rapid flow on slopes: development of fresh incisions and outflow cones (May 1991).
2. Remnants of outflow cone deposition at foot of a slope from the upper picture.

1. Ephemeral feature of niveo-fluvial deposition.
2. Incut of a stream across a storm ridge. Blocks of lake ice are visible.