OPERATIONAL IMAGE-BASED MAPPING IN THE FRANZ JOSEF LAND ARCHIPELAGO

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KEY WORDS: Spaceborne Photograph, SAR Image, Topological Studies, Photogrammetric Mapping, Franz Josef Land, Spirit Leveling, Combined Image-Line Map

ABSTRACT

High-resolution spaceborne photographs, radar imagery and old aerial photographs were successfully used for topological studies and photogrammetric mapping at different scales ranging from 1:600,000 to 1:15,000 in the Franz Josef Land archipelago, Russian High Arctic. Studies have shown significant changes in the region compared to the situation represented in available maps. Ground control data were collected and spirit leveling between old geodetic spots and the current sea level was carried out on several islands during field campaigns in 1994 and 1995. Results of measurements were reduced to the mean sea level of the Barents Sea, as recorded at the Krenkel station, and have clearly shown the subsidence of those islands in the past 40 years. Several combined image-line maps of the archipelago were compiled by means of digital mono- and stereoplotting on a standard PC equipped with a stereoscopic console. The results were obtained with reasonable accuracy and on a time-efficient basis. Some contradictions in existing theories of the arctic geosciences and some surprising findings were revealed in the course of cartographic investigations.

1. INTRODUCTION

Franz Josef Land (FJL) is the northernmost archipelago in the European Arctic which is regarded as a very problematic area for traditional cartography and thus was hitherto poorly mapped. Available topographic and thematic maps containing major spatial information about the whole archipelago were mostly created through materials of the last aerial and geodetic surveys carried out in 1953-1959. How obsolete are those maps and how reliable are those geodetic data today? This question has never been asked before, due, presumably, to the traditional opinion on the High Arctic territories as being among those on the Earth having the slowest rate of topographic changes. Topological studies, that is interpreting the history of a region as indicated by its topography (Webster's encyclopedic dictionary 1996), is a field in which nothing has so far been done in FJL.

Meanwhile, complex cartographic investigations in FJL carried out in 1993-1995 by the Graz University of Technology in association with the Moscow State University of Geodesy and Cartography have revealed drastic topographic changes, having occurred in those lands in the course of the past 40 years, and showed that available topographic maps are neither updated nor accurate (Kostka, Sharov 1996). All obsolete map sheets must be revised on an economical basis by resurvey from automatic polar-orbiting satellites carrying high-resolution instruments, both optical and radar. Apart from the acquisition of suitable spaceborne imagery, two high-level tasks to be solved are:

- determining the modes of environmental changes and providing reliable basic control for operational mapping in the High Arctic;
- developing an effective technique for photogrammetric mapping in these remote areas via spaceborne imagery.

Moreover, Russian topographers have the duty to warn all geoscientists about inaccuracies in the topographic maps of FJL still in use as well as correcting several wrong hypotheses and misinterpretations on current geophysical processes and their environmental impacts on the archipelago.

The present paper describes the results achieved in attempts to solve these tasks. Major attention is paid to the following topics:

- topological studies and analyses of recent natural changes in several coastal areas of FJL by means of comparing historical maps and multitemporal remote sensing data;
- digital mono- and stereoplotting on the basis of Russian spaceborne photographs of high ground resolution on a personal computer (PC) supported by field observations and topographic-geodetic surveys;
- interpretation of current vertical movements in the archipelago and compilation of several image-based maps of FJL at different scales ranging from 1:600,000 to 1:50,000.

This extensive research has resulted in 3 combined image-line maps, 1 basic contour map, 1 sketch map, several geographical discoveries and surprising findings.

2. ON THE TOPOGRAPHY OF FRANZ JOSEF LAND

2.1 Short description

FJL is situated in the northeastern part of the Barents Sea between 79°46'-81°52'N and 44°55'-65°23'E, which is about 800 km from the nearest point on the Eurasian continent. This arctic archipelago includes 191 large and small mountainous islands with a total land area of 16,134 km² and stretches 366 km from west to east and 233 km from south to north. Cape Fligley on Rudolph Island is renowned as the northernmost part of land relating to the "old world" and belonging to the Russian Federation. By decree of the Russian government of 23.04.1994 the whole territory of FJL with the adjoining aquatories - 42,000 square kilometers in total - was proclaimed a national park of federal importance.

FJL has the highest index of glaciation of all Arctic lands: nearly 85% of the land surface is covered by glaciers and the ice shore stretches 2,650 kilometers which is 59.4% of the total coastline (Atlas of the Arctic 1985). The mean ice thickness is estimated as 180 meters. The relief is dominated by typical plateaus with heights ranging from 30 to 500 meters, which are generally covered by glaciers. The glacial topography of numerous ice sheets and domes is mostly homogeneous. This is probably the reason why the locations and values of the maximum heights in FJL are still uncertain. According to the present cartographic knowledge the maximum heights of the archipelago reach 620 m on Wiener Neustadt Island and 606 m in Wilczek Land, Wullerstorf Mountains, but several publications (Grosswald 1973, Barr 1995) give, however without explanation, the highest point as 670 m above sea level in Wilczek Land. There is no agreement on the distribution of depths in straits of the archipelago, either. For instance, the depths in the deepest FJL straits are known to reach 557 m in British Channel, 580 m in Rhodes Channel and 608 m in Backs Channel. Nevertheless, it should be noted that several cartographic sources give a depth of 800 m for the British Channel near Elizabeth Island.

In contrast to any continental area, the standard level, or datum plane, to which all heights or depths are compared in FJL is the mean level of the Barents Sea. The northern Barents Sea level is being recorded since 1957 by tide gauge observations at the Krenkel station, Hayes Island, in the central part of the archipelago. Elevations of the benchmarks NN 1-4 located close to the station above the adopted datum were established in 1956 and 1971 and corrected in 1978. No strong tidal effects are to be observed in FJL. The height of tides in FJL can reach 0.5-0.6 m and even more under heavy winds, but systematic observations show that changes in annual and monthly mean sea level usually do not exceed 20 to 30 cm (Fig 1).

All the components of the topography in FJL are presently undergoing significant changes caused by glacial flow, calving and active marine abrasion of ice shores as well as other coastal processes and recent tectonic movements in the archipelago. Due to difficult access and logistical problems, there are but a few substantial studies of topographic changes in FJL; their terrestrial and temporal coverage is poor thus usually rendering impossible any systematic topological investigation at a regional scale. FJL's terra firma is close to the margin of the Barents Sea continental shelf stretching along the presently active mid-oceanic Hackel spreading ridge system which might strongly affect current geophysical processes in the archipelago. However, neither its geodynamics nor its environmental impact on FJL are completely known or fully understood at present.

A number of indirect studies have been made that attempt to interpret current geodynamics in FJL by means of geomorphological methods, e.g. by comparing the heights of marine terraces with the radiocarbon ages of the organic rests (bones, timbers, molluscan fauna) sampled on the surface of those terraces (Grosswald 1973, Matishov 1993). These studies led to the conclusion that the earth's crust in that area had been subjected to geologically recent uplifts, although the terrace spectra, even of adjacent islands, sometimes were beyond correlation (Lubinsky, personal communication 1995). The hypothesis seemed to be in good correspondence with the "Walbeinhebungstheorie" originating from finds of whale bones on marine terraces of Spitsbergen, and with the theory of glacioisostatic movements in Fennoscandia. Although explorations were performed on several islands in western (Alexandra Land) and central (Bell, Hayes, Hooker islands, etc.) parts of FJL, this hypothesis was later on simply extrapolated to the whole archipelago and even into the present time. The sequential character of movements was never proved, but, nevertheless, the "averaged rates" were published and it was stated that *"the archipelago of Franz Josef Land is now rising by an average rate of 2.5-3 mm per year"* (Naslund 1994, Glazowskiy 1992; cited from Barr 1995). However, many uncertainties still persist in this theory, and the new Russian map (1993) showing contemporary vertical movements of the earth's crust at 1:5,000,000 scale represents FJL as a "white spot" indicating the lack of appropriate data.

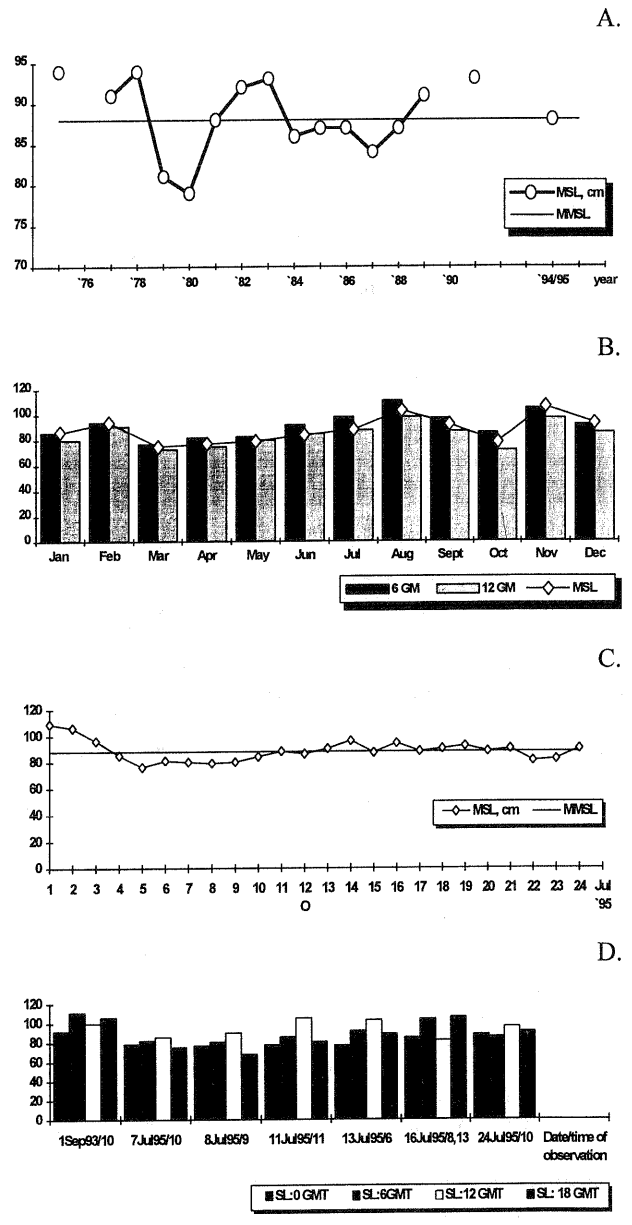


Figure 1. Barents Sea level observed at the Krenkel station, Franz Josef Land: multi-year (MMSL) and annual mean sea level (A); monthly mean sea level observed in 1994/95 at 6 GMT, 12 GMT and averaged (B); averaged sea level during 1-24 July, 1995 (C); current sea level observed on the dates of field observations (D).

2.2 Cartographic summary

The first topographic maps of FJL's central part showed discoveries by the Austrian-Hungarian expedition performed in 1873/74. J. Payer published them in 1874-1877 after having processed the results of a topographic survey performed by means of the classical plane table method. Several subsequent expeditions between 1879 and 1949 (Dutch, English, Norwegian, American, Italian, Russian) explored the whole archipelago and compiled a number of maps based on terrestrial observations and mostly without basic geodetic control. An extensive aerial photographic survey in FJL was performed by Russians in 1952/1953 and repeated over several islands in 1958. 12 astronomic stations provided the horizontal control for aerial surveying. Between 1954 and 1959 extensive geodetic and hydrographic investigations were performed by the N10 expedition of the Hydrographic enterprise of St. Petersburg. The investigations included third-order triangulation and leveling, sea level measurement, bathymetric determinations, etc. and provided the basic control for all presently available topographic maps of FJL.

The large standard map series, which covers the whole area of the archipelago at different scales ranging from 1:1,000,000, 1:500,000, 1:200,000 and 1:100,000 down to 1:50,000 and 1:25,000, was photogrammetrically compiled in the following years. It includes nearly 400 map sheets with standardized information content. The majority of the map sheets were prepared on the basis of the Gauss-Krüger projection and, apart from the geographical coordinates, also contain a geodetic grid. Dimensions of the ellipsoid of Krasovskiy were used. The maps served as a topographic base for the revision of several marine charts, some of which were published in 1961 and 1985. Cartometric investigations of large-scale topographic maps provided valuable spatial information about the glaciological environment of the archipelago, which served as a basis for the Catalogue of Glaciers in FJL (Vinogradov, Psareva 1965). Several topographic and thematic maps are included in the Atlas of the Arctic published in 1985.

These cartographic sources are undoubtedly important for any environmental study in FJL, but their use for precise up-to-date topographic determination is only possible based on a thorough understanding of all natural changes having occurred in the archipelago since the 1950s. Besides, available topographic, marine and thematic maps of the archipelago are dispersed among many national agencies and cannot be readily compiled for analysis. Due to the rapid increase in scientific and economic interests in the region, there is an urgent demand for contemporary, reliable, and inexpensive maps of FJL based on spaceborne imagery. New satellite image maps could assist the appropriate administration and sustainable development of the new national park and could ensure efficient regulation of different activities, including tourism, in that region. in 1987 and 1993 several photographic and radar surveys of the FJL archipelago were performed from space, but no new maps have yet been published by Russian governmental organizations or specialized companies.

2.3 Topographic outline of test area

Several sites situated in coastal areas of large islands in FJL were selected for initial topological studies and field observations. We searched for low-land areas with gentle slopes which are more suitable for coastal studies, since they are easier to access and have already been investigated by several preceding expeditions. In total, 5 key-sites comprising topographic features such as lakes, rivers, hills, capes, glacial fronts, etc. which could be identified on both available maps and remote sensing imagery, were carefully tested both in the field and in the lab.

The central key-site was situated near Cosmic Lake in the eastern coastal area of Hayes Island and included the Krenkel station, one geodetic/navigation signal erected in 1956, tide gauge and two bench marks N2, N4. The second area was chosen 11 km eastwards on Komsomolskiy Island with a geodetic/navigation signal situated 1,200 m from the coast and within direct visibility from the central station. The third test site was located 55 km southwards in the southern part of Hall Island, the first large island of FJL to be mapped relatively accurately 120 years ago. It included Cape Tegetthoff, Lake Cape and the great outlet Sonklar Glacier in between. There is a 40-year-old geodetic pyramid on Lake Cape as well as several lakes, rivers and historical places on both capes. The fourth and fifth test areas both contained several geodetic signals. One was situated 58 km northwestwards, on Ziegler Island (the camp of the Austrian Broadcasting Corporation near Cape Brice) with surrounding areas, while the other was located on the bank of Nillsen Bay (Bell Island), 180 km west of the central station. Several areas on other islands were also investigated, however without basic geodetic control.

3. INITIAL TOPOLOGICAL STUDIES: FIRST FINDINGS

In order to determine the amount of environmental changes in FJL and to plan revisionary cartographic work, topological studies have initially been carried out in the lab by comparing spaceborne images with historical/topographic maps and old aerial photographs. The experimental data set included:
- spaceborne stereophotographs obtained on 28.08.1993 at 10.25 GMT over the whole archipelago, except its westernmost part, from Russian "Resource-F1" satellite by KFA-1000 and KATE-200 film cameras at original scales of 1:250,000 and 1:1,250,000 respectively;
- precision imagery obtained by synthetic aperture radar (SAR) from ERS-1 satellite over the western and central part of the archipelago, including 3 scenes taken on 28.08.1993 at 9.20 GMT;
- aerial stereophotographs taken over the third and fourth test sites on 8.08.1953 and 17.08.1953/23.08.1953 by an AFA-TE100 camera at an original scale of 1:30,000.

All images were obtained at the end of the summer melting period under cloud-free conditions and prior to the first snowfalls. All necessary topographic map sheets, the hydrometeorological map (Berliner Wetterkarte) of 28.08.1993, 8.00 GMT, several historical and thematic maps, as well as catalogues of glaciers and geodetic spots in FJL were also at our disposal.

After previous visual comparison several fragments from spaceborne and airborne photographs were digitized and transformed into the common projection as described in Section 5. Appropriate images were overlaid by uniting homologous control points taken inland, and the relative differences in position of "old" and "new" coastlines, glacial fronts and borders were measured. The root mean square error for the planimetric determinations via combinations KFA-1000 +

AFA-TE 100 was within $\pm$ 12 m. Topographic maps were used for the comparison, when aerial photos were not available. The studies have resulted in several interesting findings.

1. The theory of present glacial retreat in FJL first introduced by V. Sukhodrovskiy in 1934 and developed by M.Grosswald in 1973 was proved to be correct in general. We found nearly 50 ice sheets and caps showing drastic withdrawal of their borders (up to several hundreds of meters) during the past 40 years, several of them have totally disappeared. The most significant retreat of glacial termini occurs at fronts of outlet glaciers because of marine abrasion and calving. Thus, big - more than 500 meter long - frontier parts of tidal glaciers on Prince George Land, Jackson, Karl Alexander, McClintock and Salisbury islands were broken off and shorelines have changed significantly. Large tabular icebergs found close to those new glacial fronts indicate that this destruction happened nearly simultaneously in all places, and probably not long ago. The maximum retreat of ice shores was detected to be 2-4 km at Rough Bay on Hall Island. According to our planimetric assessment glacial retreat on Hall Island amounts to 3.2% in the course of the past 40 years.

2. Several new islands attached to the larger lands by glaciers have appeared in FJL due to glacial retreat. So, Littrow Island (65 km²), specified as a peninsula in contemporary maps, was - for the second time after the American Wellman polar expedition - discovered to be separated from Hall Island by the Nordenskjöld Channel (Kostka, Sharov 1996). One new, as yet uncharted islet close to the southern ice shore of Ziegler Island was first discovered in the lab by means of SAR image data, which revealed small terrains free of glacier ice with better contrast, but only if the surrounding water surface is smooth. It was also discovered that Mother-of-pearl Island with a total area of 1.5 km² and a maximum height of 22 m asl, shown on all topographic maps as entirely covered by the ice cap, does not exist any more. We assume it was a temporarily grounded icy island.

3. A very interesting exception to the common glacial retreat in FJL was recognized in spaceborne imagery: the greatest outlet glaciers have advanced offshore by several hundreds of meters. The front of Eastern Glacier at Salisbury Island has flowed about 500 meters into the Rhodes Channel; Impetuous and Famous glaciers in Wilczek Land have advanced by 600 meters in several parts since May 1958. This phenomenon has yet to be explained, but together with other data on glacial dynamics, it supports a hypothesis about the presence of floating or partly grounded ice shelves in the archipelago that has been mistrusted by some explorers until today (Dowdeswell 1994).

4. Ice-free coastal areas also underwent essential changes, especially in the areas with gentle slopes (beaches, low-lands). With the exception of some insignificant advances, which could be caused by fluvioglacial and wave processes, all such areas investigated in the central part of the archipelago have shown a retreat of coastlines. The largest rates of retreat can be observed at the coast of Littrow (between 20 and 80 meters), Komsomolskiy (30-100 m) and Fersman (130-190 m) islands. One example of changing coastlines at Lake Cape is given in Figure 2 showing an "old" aerial photograph with the "new" position of the shoreline overprinted. Such coastal changes could not be explained by occasional variations in the sea level, which was close to the mean value during spaceborne survey (see Figure 1,D - first columns). In satellite images we could not observe any advancement of the delta of the Romantics River, the largest river of the archipelago, with its *delta advancing toward the sea at a rate of 2-3 mm per year* (cited from Barr 1995). Field observations were necessary to interpret all these findings which contradict some existing hypotheses.

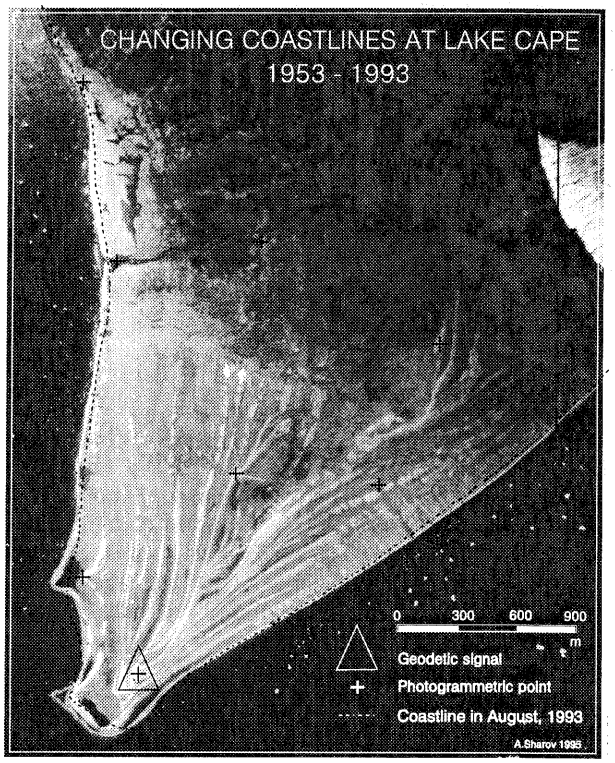


Figure 2. Sketch map showing changes of shorelines at Lake Cape

4. RESULTS OF FIELD OBSERVATIONS

Terrestrial observations and geodetic measurements were carried out during two field campaigns in FJL in August 1994 and July 1995 in order to perform ground control surveys, to check the datum governing the vertical control and to complete obscured areas and phenomena that were not readily understood. A helicopter and motorboat were effectively used to reach distant places of interest, and a number of additional terrestrial and aerial photographs were taken. Some toponymic investigations were performed to verify and present geographic names in the new maps. Specific interpretation of typical sites appearing on aerial and spaceborne images was carried out on 17 large islands of the archipelago. Main emphasis was put on the registration of hydrographic features and areas of pioneer vegetation. In the course of the investigations, we did not find any examples of an increase in the erosion rate testifying to a current uplift in those lands.

Planimetric differential coordinates of 71 ground control points were measured for subsequent mapping by means of two identical "Trimble-Navigation" GPS receivers, and elevations above sea level were determined by "Thommen" and "Avocet" barometric altimeters. The existence of the new small island Malyshok (Midget) in Rhodes Channel very close to the ice shore of Ziegler Island was proved and its coordinates were

measured by GPS as 80°50,201'N and 57°29,513'E. We ought to note that there is a theory about the existence of two small islands near the southern coast of Ziegler Island, which is based on the analysis of aerial photographs (Govorukha, Mikhalenko 1964; cited from Grosswald 1973). We saw only one islet there.

The inspection of the present state of 17 geodetic signals showed that more than half of them do not exist any more, several have been destroyed or are being destroyed by strong winds and other agents. Precision spirit leveling was carried out at Bell, Hall, Hayes, Komsomolskiy and Ziegler islands, and present elevations h_i of 5 geodetic spots and 2 bench marks were measured with relation to the current sea level. Subsequently, corrections were introduced, taking into account the difference ∇_j between the current and multiyear mean levels of the Barents Sea recorded at the tidal station on Hayes Island and calculated on the basis of archival data acquired at the Krenkel station and at the Direction of Hydrometeorological Service, Dikson (Annual data...). Corrected elevations H_i were compared with elevations H_{0i} which had been recorded 40 years before, and differences ΔH_i were calculated in accordance with the following expression

$$\Delta H_i = h_i + \nabla_j - H_{0i}, \text{ where}$$

$$\nabla_j = p_{0j} - \overline{p_{0j}} = p_j + \delta - \overline{p_{0j}},$$

with p_{0j}, $\overline{p_{0j}}$ denoting, respectively, current sea level and multiyear mean sea level, both related to the tidal datum of the tidal station; p_j is the current reading on a tide staff related to the staff 's zero point and δ is a reduction value reducing sea level to the tidal datum. The results of calculations using $\overline{p_{0j}}$ = 0.88 m are given in the table below.

Table. Recent changes in elevations measured in FJL

i	Station	H_{0i}, m est. year	∇_j, m	ΔH_i, m	Wind dir., m/s
1	Ziegler gs *	81.4 1950s	- 0.02	-	Calm
2	Bell g. s. **	17.9 1950s	- 0.07	- 0.06	SW 2
3	Hall/Littr g. s. **	8.6 1950s	+0.17	- 0.69	ENE 3
4	Hayes g. s. *	54.7 1950s	+0.16	- 0.20	NNE 4
5	Komsol. g.s. *	40.2 1950s	- 0.02	- 2.4	E 9
6	Hayes bm N2**	12.0 1969	+0.04	- 0.12	NE 4
7	Hayes bm N4**	4.8 1977	+0.04	- 0.09	Calm

*) single-run; **) double-run.

Measurements were carried out using a N3 precision instrument and a 4-meter leveling rod and were characterized by a maximum section length of 1,200 m and maximum closures of 19 mm. A single error in writing results prevented the calculation of ΔH_i for the geodetic signal on Ziegler Island, where only a single-run was done by leveling. Steady results of measurements at other stations show the present subsidence of the islands and indicate the isocatabatic surface to be tilted from the west to the east, which corresponds to earlier observations. There might be a relationship between these vertical motions and the recent destruction of ice shelves in FJL. Unfortunately, we have no ready mechanism explaining the character of such vertical movements, but, nevertheless, the present results are of fundamental significance and served as an important aid in photogrammetric mapping.

5. PHOTOGRAMMETRIC MAPPING ON PC

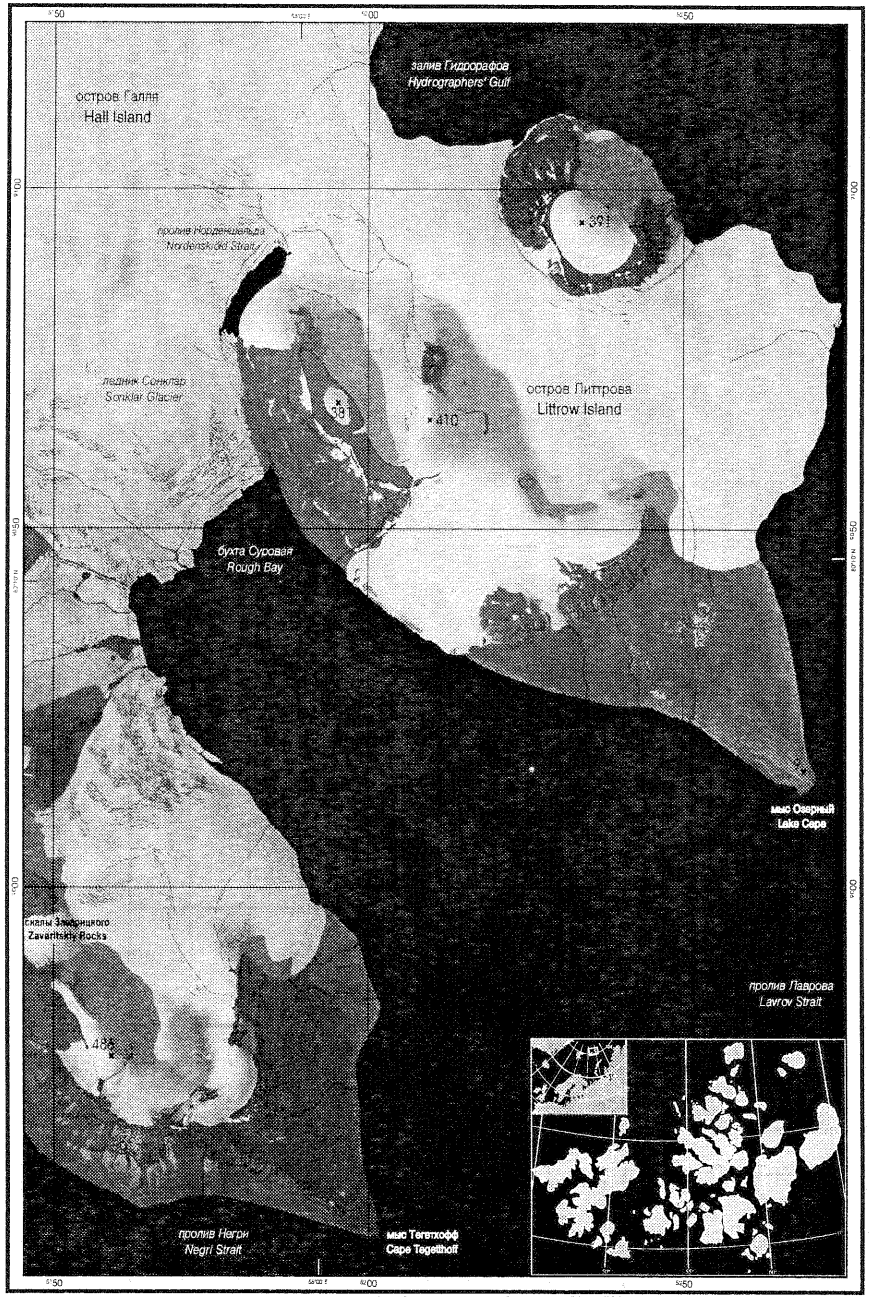
Satellite image maps presenting all surface details in their real appearance with the addition of conventional graphic elements are ideal for depicting high arctic areas, where natural features are predominant, complicated socio-economic objects are scarce, the relief is mostly homogeneous, and vegetation cover is negligible. They can be produced relatively quickly and at low cost, if done on a standard PC.

5.1 Digital mono- and stereoplotting

Image mapping of FJL was performed with reasonable accuracy and within a relatively short period of time at the Department of Remote Sensing, Image Processing and Cartography, TU Graz, by means of digital mono- and stereoplotting on the PC-based photogrammetric microstation. Fragments from spaceborne and aerial photographs were initially digitized with different spatial resolutions and were enhanced to a similar extent so as to provide comparable scales and interpretabilities of input data. Thus, spaceborne KATE-200 images digitized with a spatial resolution of 1250 DPI have a ground resolution of 25 m, which is the same as that of SAR digital imagery. Digitizing of spaceborne KFA-1000 images with 2500 DPI and aerial photographs with 300 DPI also provided digital data suitable for joint analysis. The image set was subjected to further geometric homogenization by means of image rectification and by reducing all image fragments to the normal case using "DVR", "ERDAS", and "PHOTOMOD" softwares.

Several fragments from KATE-200 photographs were combined in an image mosaic, and photo coordinates were transformed into the Gauss-Krüger coordinate system with a reference to the available topographic maps. Two small fragments from quick looks of LANDSAT and SPOT imagery were included in the mosaicking to cover some blank spots. The planimetric accuracy of this controlled mosaic covering the whole FJL archipelago is characterized by an rmse value of $\pm$ 125 m, which was checked with ground control data by an independent expert.

Digital stereoplotting was performed using "DVP" and "PHOTOMOD" softwares. Several aerial stereopairs and only one stereomodel from the KFA-1000 photographs were needed to cover the Hall Island test area, and one stereomodel from KATE-200 imagery was used for digital terrain modeling of the central part of FJL (Ziegler Island). Once the stereomodels had been set in place and oriented, precise three-dimensional measurements of topographic features were made, followed by computer-assisted drawings. Contouring in glacial areas combined with local interpretation of both optical and radar imagery did not bring about the essential difficulties we had expected and actually was even more convenient than contouring in rocky areas affected by shadows. 3 DTMs and



Земля Франца-Иосифа, Русская Арктика **Franz Josef Land Archipelago, Russian Arctic**

остров ГАЛЛЯ - мыс ТЕГЕТХОФФ
Hall Island - Cape Tegetthoff

	I Official Russian: Cyrillic	II Russian: internationally transliterated	III English equivalent	IV German equivalent	V Original name form	VI Firstly named by	VII Original name given after
1	остров Галлия	ostrov Gallja	Hall Island	Hallinsel	Hall Insel	Austro-Hungarian Payer - Weyprecht expedition 1872-1874	Charles Francis Hall
2	залив Гидрографов	zaliv Gidrografov	Hydrographers' Gulf	Hydrographen-golf	залив Гидрографов	Federal Marine Research Institute Project 1957 of the U.S.S.R	Soviet hydrographers
3	скалы Заварицкого	skaly Zavarickogo	Zavaritskiy Rocks	Sawarizkifelsen	скалы Заварицкого	Federal Marine Research Institute Project 1957 of the U.S.S.R	A.N. Zavarickij
4	пролив Лаврова	proliv Lavrova	Lavrov Strait	Lawrowstraße	пролив Лаврова	Federal Marine Research Institute Project 1957 of the U.S.S.R	A.M. Lavrov
5	остров Литтрова	ostrov Littrova	Littrow Island	Littrowinsel	Kap McClintock	Austro-Hungarian Payer - Weyprecht expedition 1872-1874	Sir Francis Leopold MacClintock
6	пролив Негри	proliv Negri	Negri Strait	Negristraße	Negri Fjord	Austro-Hungarian Payer - Weyprecht expedition 1872-1874	Cristoforo Negri
7	пролив Нордешельда	proliv Norden el'da	Nordenskiöld Strait	Nordenskiöld-straße	Nordenskiöld-Fjord	Austro-Hungarian Payer - Weyprecht expedition 1872-1874	Adolf Erich Nordenskiöld
8	мыс Озерный	mys Ozernyj	Lake Cape	Seenkap	мыс Озерный	Federal Marine Research Institute Project 1957 of the U.S.S.R	Small lakes behind the cape
9	ледник Сонклар	lednik Sonklar	Sonklar Glacier	Sonklargletscher	Sonklar-Gletscher	Austro-Hungarian Payer - Weyprecht expedition 1872-1874	Karl Sonklar, Edler von Innstätten
10	бухта Суровая	buhta Surovaja	Rough Bay	Rauhe Bucht	бухта Суровая	Federal Marine Research Institute Project 1957 of the U.S.S.R	Rough weather conditions
11	мыс Тегетхофф	mys Tegethoff	Cape Tegetthoff	Kap Tegetthoff	Kap Tegetthoff	Austro-Hungarian Payer - Weyprecht expedition 1872-1874	Wilhelm von Tegetthoff

Легенда **Legend**

Береговая линия / Coastal line
Ледники, Границы ледников / Glaciers, glacial borders
Ледниковые трещины / Crevasses
Реки / Rivers
Озера / Lakes
Скалы / Rocks
Морены / Moraines
Растительность / Vegetation
410 Отметки высот / Heights

Описание карты

Использована система координат Гаусса-Крюгера русских топографических карт 1:100 000 (1956) и 1:200 000 (1971)

Использованные изображения: КАФА-1000 космические фотографии NN 17706, 17707, полученные 28го Августа, 1993 в оригинальном масштабе 1:250 000 и при наземном разрешении 5 м (Госцентр "Природа")

Полевые наблюдения, дешифрирование, трансформирование и стереофотограмметрическая обработка изображений: А. Шаров, Москва

Географические названия: Й. Брой, Вена и Т. Верещака, Москва

Картографическая идея: Р. Костка, Грац

Картографическое черчение: Х. Кроттендорфер, Вена

Картографический дизайн: Т. Хсу, Вена

Цифровая картография, обработка изображений и подготовка к изданию: Х. Байсманн и Р. Хенгсбергер, Вена

Сотрудничество

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Map Specifications

Cartographic references: Gauss-Kriger coordinate system of the Russian topographic maps 1:100 000 (1956) and 1:200 000 (1971)

Image source: KFA-1000 spaceborne photographs NN 17706, 17707 from 28th August 1993 at 1:250 000 original scale and mean ground resolution of 5 m ("Priroda" State Center)

Field observation, interpretation, geometric rectification and photogrammetric stereoplotting by A. Sharov, Moscow

Geographical names by J. Breu and T. Verestchaka, Vienna and Moscow

Cartographic concept by R. Kostka, Graz

Cartographic drawing by H. Krottendorfer, Vienna

Cartographic design: Ch. Hsu, Vienna

Digital cartography, image processing and preparation for publishing: H. Beissmann and R. Hengsberger, Vienna

Cooperation

Moscow State University of Geodesy and Cartography (Rector: Prof. V. Savinykh, Faculty of Applied Cosmonautics: Dean V. Malinnikov, Cartographic Faculty: Dean T. Nyrtsova)

Institute of Applied Geodesy and Photogrammetry, Department 271/3, Graz University of Technology (Head: Prof. G. Brandstätter)

Institute of Cartography, Austrian Academy of Sciences (Director: Dr. H. Beisamann)

Масштаб 1 : 50 000 **Scale 1 : 50 000**

0 500 1000 1500 2000 2500 m

Figure 3. One of final cartographic products

several orthoimages were created in semi-automatic mode and represented in both graphic and realistic halftone forms. The relatively small area of the islands, the low elevations, the dense net of reliable ground control points and permanent referencing to the sea level, which is well defined by the ice floes, improve the accuracy of stereoplotting and the final products.

5.2 Final cartographic products

Several image maps of FJL were completed, edited and printed during the period of 1994-1996. All maps are presented in Gauss-Krüger projection with necessary toponyms. Dimensions of the ellipsoid of Krasovskiy were used, and elevations of photogrammetric points are given with respect to the current level of the Barents Sea. The graphical precision of the printed maps is usually between 0.2 and 0.5 mm at publication scale.

A combined image-line map covering the whole FJL archipelago generated by means of monoplotting on the basis of KATE-200 photographs was printed in four colors at 1:600,000 scale. The map is generally designed for touristic purposes; its legend includes islands, glaciers, ice-free areas, spot elevations and the most interesting historical and touristic spots. It contains 221 geographic names, both Russian and English, of all large islands, straits and bays, capes and scientific stations. There are several pages of text attached describing the high arctic environment in FJL and the history of its exploration.

A satellite basic contour map of Ziegler Island with surrounding areas in the central part of FJL was printed in six colours at 1:100,000 scale with a contour interval of 50 meters. Different kinds of shorelines are presented: ice-free and icy shores, precipitous and sloping, steady and changing banks. All elevations given were compiled photogrammetrically and checked via ground control. The elevation accuracy is characterized by the rmse of $\pm$ 17.5 meters. A new kind of combined image-line map was created by overlaying the digital contour map of Ziegler Island on a digital fragment of an ERS-1 radar image, which was appropriately transformed beforehand. The advantage of such an approach is that thematic glaciological information about the distribution of different glacial zones, which can be distinguished in SAR imagery, can be combined with conventional topographic information. The combined map is printed at 1:200,000 scale in order to diminish inaccuracies arising from the overlay procedure.

A combined image-line map of Hall Island-Cape Tegetthoff was prepared at 1:50,000 scale on the basis of KFA-1000 stereophotographs with a ground resolution of 5 meters. Apart from the tick marks of normal geographic coordinates the map also features a geodetic grid. The image map covers an area of 17x13 square kilometers and reveals the beautiful nature of that site in ten colors. The original size of the map sheet is 640x465 mm^2. A small-size black-and-white copy of this map is given in Figure 3. Several sketch maps were drafted for the same test area by means of comparison between aerial and spaceborne photographs in order to show the drastic retreat of glacial borders and essential changes in shorelines which have occurred in the course of the past 40 years. One of them printed at original scale of 1:15,000 has already been shown in Figure 1.

CONCLUSIONS

A wide range of useful features as well as the attractive appearance, cost-efficiency and up-to-detains of our satellite image maps make them an ideal basis for scientific and administrative activities in the FJL archipelago. Obviously, PC-based mapping technology can not compete with a complex cartographic/photogrammetric workstation, but its cost efficiency, relative simplicity and rapid access to results ensure the popularity of such approach among the broad research community. Further terrestrial topographic investigations using mobile devices for accurate 3-dimensional positioning are needed in order to verify our determinations and to extrapolate them over the whole archipelago. Nevertheless, the present results are of fundamental significance and could serve as an important aid in the photogrammetric mapping of the whole Russian Arctic territory at 1:200,000 scale to be carried out in the scope of the New State Cartographic Program.

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