Remote Sensing Cartography in Antarctic Research

by

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Zusammenfassung:

Nach einleitenden Ausführungen über die Begriffs-Entwicklung gibt der Autor einen Überblick über die Entschleierung der Antarktis mittels Fernerkundung. Nach Darstellung der allgemeinen Grundlagen für die Herstellung und Vervielfältigung von Luft- und Satellitenbildkarten folgen Ausführungen über ein geplantes digitales geokodiertes Informationssystem Antarktis.

Abstract:

After some preliminary remarks on terminological evolution the author gives a general survey of facts and events in the unveiling of the Antarctic. Presentation of the fundamentals of production and reproduction of airphotos and satellite image maps is followed by some explanations on a proposed digital, geo-coded information system Antarctica .

Résumé:

Après quelques remarques préliminaires sur l'évolution terminologique, l'auteur fait un tour d'horizon du dévoilement de l'Antarctique par le moyen de la télédétection. La description des principes fondamentaux en matière de production et reproduction de photographies aériennes et de cartes d'images par satellite est suivie de quelques explications sur le projet d'un système d'information numérique géo-codifié Antarctique .

1. Definitions

Photogrammetry and remote sensing are extremely young sciences in comparison with cartography. The oldest cartographic representation known to us dates back to around 3,800 B.C., and we may assume that the need of man to represent distances and directions, coastlines, the position of settlements, towns, rivers, roads, mountains, etc., i.e. the means of orientation in a region on the earth or in the sky using maps dates back to much earlier than that.

So earth and sky were represented cartographically several thousand years ago and indeed today they are still the most important objects of cartographic representation, although today data from different sciences is represented cartographically, e.g. biological data, such as the map of a human brain.

Cartographic terminology today has replaced the terms earth and sky with planet and space and differentiates accordingly between planetary maps and spatial maps. In addition to cartographic representations of the earth we now have maps of other planets, such as the Earth's moon, Mars, Venus, etc. The "world's horizon", the largest distance measured between another planet and the earth, now extends over approximately 14 thousand million light years, a distance which we can barely imagine. But cartography is not the only science affected by these terminological extensions and the advance of measuring techniques in spatial terms, the development of space programmes has also benefited. Of course, the task of cartography

must be restricted to defining the basic principles of graphic representation or depiction of the results obtained from observation or research in the special branches of science (such as topography, geography, geology, etc.). However, the methods of gleaning this information on the object of representation have, it has been shown, directly influenced map design, production, reproduction and utilization. It can be said in principle that with the first aerial photograph taken from the air (1858) the terms aerial photography and aerial cartography began to evolve, and with the first satellite imagery from space (almost exactly 100 years later, in 1959) the terms satellite photomap and satellite image cartography emerged. The original type of cartography, which is no less important, is often described with the terms linear maps and linear cartography.

The definitive characteristics in gathering information on objects via aerial and satellite photography are twofold: the distance between object and image recording system is often very large and there is no direct contact. Force fields, in particular the electromagnetic field, transfer the information. Since we can now use not only the spectral range visible to us, from about 0.4 µm - 0.7 µm, but also other spectral areas of the electromagnetic wave spectrum, the term photogrammetry emerged around 1866 and the term remote sensing came into use around 1972. Analogously to the cartographic terms mentioned above, the term remote sensing cartography ultimately came into being (see fig. 1).

2. The Unveiling of the Antarctic via Remote Sensing

The first explorers to observe areas of the Antarctic from the air were Robert Falcon Scott, from Britain, and Erich v. Drygalski, from Germany. Both had started on separate Antarctic expeditions in 1901 and both had a captive balloon in their equipment. Scott conducted his balloon ascent on 4 February 1902 near

Whale Bay on the Ross Shelf Ice front and v. Drygalski on 29 March 1902 near Gaussberg mountain. Von Drygalski and some colleagues reached a height of 500 m in the balloon, when Captain H. Ruser and the geologist E. Philippi took photographs from that height of the surrounding area. It has not yet been ascertained whether Scott also took photographs during his ascent. Table 1 shows the use of aerial reconnaissance and photogrammetry in Antarctic research up to 1945. Fig. 2 shows which areas of the Antarctic were covered in this fashion.

World War II drastically reduced the amount of research in the Antarctic. The military activities of several German auxiliary cruisers in the Antarctic sea in 1940/41 added to the assumption that German military bases existed in the Antarctic and resulted in British and Australian naval operations, with an inevitable reduction in research. The achievements up to 1945 of geographic reconnaissance and surveying of the Antarctic were considerable, but large-scale, systematic research into the Antarctic did not begin until after World War II with the U.S. Expedition "Operation Highjump" in the austral summer of 1946/47. The expedition consisted of 13 ships, 13 planes and over 4.000 men. On the photogrammetric aerial survey flights aerial photographs were taken covering an area of c. 3.9 million km^2.

The following countries joined in further topographic investigation and surveying of the Antarctic: Australia, Belgium, France, Great Britain, Japan, Norway, Sweden, U.S.A. and U.S.S.R.

The first photographic record of the earth from a space ship, the first satellite photograph, was taken in 1959, but it was not until 1965 that the first special, extensive programme of photographic coverage began with the U.S. GEMINI space programme. Approximately 1000 photographs were taken of the earth at a height of about 300 km.

The LANDSAT space programme began in 1972, and the MSS image data with a pixel size on the ground of 80 m x 80 m aroused the interest of people engaged in Antarctic research. The first satellite photo maps were produced in the USA in 1973 at the 1 : 1,000,000, 1 : 500,000 and 1 : 250,000 scales, followed by further maps in Great Britain, Australia, the Federal Republic of Germany and Japan. A further aid to map production were the AVHRR image data from the NOAA space programme with a pixel size on the ground of approximately 1 km x 1 km, and from 1982 onwards the additional TM image data obtained from the LANDSAT space programme with a pixel size on the ground of 30 x 30 m. HRV image data from the SPOT space programme have been available since 1986. These have the largest resolution in satellite imagery at present, with a pixel size on the ground of 10m x 10 m in the spectrum range 0.5 µm - 0.9 µm. The sensors of the above-mentioned space programmes are passive systems and record so-called optical and - in part - thermal image data. Of the active systems for registering radar image data, the space programmes SIR and ESA-ERS are the most interesting for Antarctic research. SIR-B and SIR-C will be put into a polar orbit, however, the date of the launch is at present unclear. The European satellite ERS-1 will probably be launched in 1991 and will be equipped with an SAR with a pixel size on the ground of approx. 30 x 30 m. Since the sensors mentioned above receive large data stocks, normally real-time reception is required (hence there will be no data storage on board). Therefore, an image data reception station is needed in the Antarctic, if radar image data have to be recorded also locally. This is, without doubt, the goal of many geoscientists who are active in Antarctic research.

3. General Principles of Production and Duplication of Aerial Photomaps and Satellite Image Maps

It is a well-known fact that photogrammetry and remote sensing deal with the reproduction of analog and digital image recordings.

Processing and evaluation of these image recordings depends on the aims of the individual project. The aim is often a rapid flow of data, from recording through processing and evaluation to output; at times a link with other data stocks may be of value. Fig. 3 shows such a data flow system.

4. Digital Geo-Coded Information System Antarctica

All geoscientific research is normally connected to the topography of the particular region of the earth under investigation. Hence, topographic maps (produced from aerial photographs or from satellite imagery) are initially the basis for orientation in the terrain and delimitation of research areas, points of survey, etc. Furthermore, they are a necessary basis for representing the results of geoscientific survey and research in spatial reference to each other, i.e. in thematic maps based on topographic maps.

Repeated areal surveys of a region can be used to extract information on changes in the landscape, such as ice-caps over sea and land, ice flow processes, e.g. the kinematics of shelf ice fronts, etc.

Of the total ice mass on earth, about 9 % is in Greenland, but 90 % in the Antarctic! The maximum thickness of the ice in the Antarctic is over 4,000 m (near the Russian station Vostock). If the ice in the Antarctic melted due to some change in the climate, sea level would rise by about 55 m.

If we look back on the emergence of this continent, we find that initially there was no ice crust, since coal deposits have been found in the Antarctic, about 250 million years old. At that time the continent was probably covered by dense forests of tree-high ferns and horsetails. Over the following millions of years these forests were covered by sediments and were gradually converted into coal.

Without doubt our global climate is influenced by the conditions prevailing in the polar regions, particularly by the behaviour of the inland ice and the shelf ice of the Antarctic.

The Filchner-Ronne Shelf Ice (approx. 500,000 km^2 with flow speeds of up to 3 m per day) together with the adjoining areas to this shelf ice and the Weddell Sea seawards are therefore important research projects of the Federal Republic of Germany, and for this reason are work projects of the Institut für Angewandte Geodäsie in Frankfurt a. M. (IfAG) for the application of photogrammetry and remote sensing.

A very real advantage is when the topographic and thematic map data are available in digital form. Using corresponding data processing programmes, various evaluations, computations, analyses etc. can be carried out very rapidly. But of even greater importance is the possibility to mathematically link various geoscientific data and to analyze their correlation and interrelations very rapidly more accurately than before. In addition, model hypotheses can be tested very quickly and aids to planning and decision-making created in varying forms of representation on a display unit and output in the form of maps, graphs, statistics, etc. For this reason IfAG in Frankfurt/Main has started to establish a digital geo-coded information system "Antarctica" (Geokodiertes Informationssystem Antarktis (GIA).) Fig. 4 shows its structure and goals.

The basis for geocoding is a control point data base, which was begun in 1981 and which comprises more than 230 documented points at present. Control points are points which are easily recognisable in aerial photographs or satellite images, and whose geodetic coordinates are known. For the production of aerial photomaps the necessary densification of the network of control stations is performed by means of aerotriangulation.

A further step in the development of the GIA is the satellite data bank with NOAA (AVHRR) data, begun in 1984, and which now covers the Antarctic region $110^{\circ}W$-0°-$90^{\circ}E$ to the Southern Pole (approx. 5 million km^2).

EOSAT/USA carried out LANDSAT-5 image recordings of about 1,5 million km^2 (76 magnetic tapes) through the period 30 January - 14 March 1986 at the request of IfAG in order to establish a digital satellite image data bank from LANDSAT (MSS) data.

This data bank (with a total of 100 magnetic tapes) will approximately cover the region shown on the 7 sheets of the map 1 : 1,000,000 (fig. 5).

IfAG has laid the foundations for describing future cartographic representations with the establishment of a digital name data base in 1982. It contains over 700 German geographic names; the name data for the neighbouring states, the GDR, Austria and Switzerland were made available from these states.

The orthography is approved by the "Permanent Committee on Geographical Names" (Ständiger Ausschuß für Geographische Namen), initiated by the Federal Minister for the Interior.

The extension of this geo-coded information system "Antarctica" is being furthered at present with the establishment of regional satellite image data bases from the LANDSAT (TM) and SPOT (pan) systems. The data base "Digital Terrain Models" will contain the height measurements from over 100 stereo model measurements chosen from the photogrammetric aerial surveys (with over 7,000 aerial photographs, see fig. 6) conducted by IfAG in the Antarctic in 1983/84 and 1985/86.

One very important and necessary component of the GIA will be the establishment of data bases with geoscientific survey data. This includes the results of geophysical, glaciological, geographical, geological, meterological as well as biological and other research sciences related to terrain and space. The establishment of such data bases will require the assistance of colleagues from the relevant areas of science and will lead to interesting interdisciplinary collaboration.

A digital information system of this type will provide basic prerequisites for extensive scientific model formations.

When the European satellite ESA-ERS 1 is launched in 1990 with an image recording system on board, it will then be possible to include a radar data base in the geo-coded information system. However, this does presuppose that radar image data of the Antarctic can be recorded with the obvious requirement of a receiving station in this region.

It is the intention of IfAG to establish such a radar data base for parts of the Antarctic within the framework of the international research project "Polar Ice Sheet".

The subject of "continental drift", closely associated with the name of the German geophysicist Alfred Wegener (1880-1930), who put forward the theory that together all the continents once formed one single continent (Pangaea), is not dealt with here.

The earth took approx. 225 million years to develop from the original continent of Pangaea to the subsequent super continent Gondwana (consisting of Africa, Antarctica, Australia, South America and India) and finally to today's configuration. Instead of "continental drift", we now speak of "plate tectonics" and "geodynamics"...

One of the aims of West German Antarctic research is to illuminate the history of the continent of Antarctica. The geo-coded information system Antarctica can surely make a contribution to this goal.

I am convinced that this geo-coded information system now being established will act as an important aid for scientific model formations. These are the basis for calculating many things and perhaps for forecasts of future developments. At the very least they will contribute to our understanding of natural processes taking place on our planet.

1858 BEGINNING OF AERIAL PHOTOGRAPHY FROM AIRCRAFT

AERIAL IMAGE MAP
AERIAL IMAGE CARTOGRAPHY

AROUND

1866 THE GERMAN GEOGRAPHER L.KERSTEN COINS THE CONCEPT OF PHOTOGRAMMETRY, WHICH IS INTRODUCED TO THE PROFESSIONAL CIRCLES BY A.MEYDENBAUER

1959 BEGINNING OF RECORDING SATELLITE IMAGES FROM SPACECRAFT

SATELLITE IMAGE MAP
SATELLITE IMAGE CARTOGRAPHY

AROUND

1972 THE CONCEPT OF REMOTE SENSING COMES INTO USE

AROUND

1985 INTRODUCTION OF THE CONCEPT OF

REMOTE SENSING CARTOGRAPHY

Fig.1 The Term "Remote Sensing Cartography"

Fig.2

Flight Reconnaissance and Photogrammetry in Antarctic Research until 1945

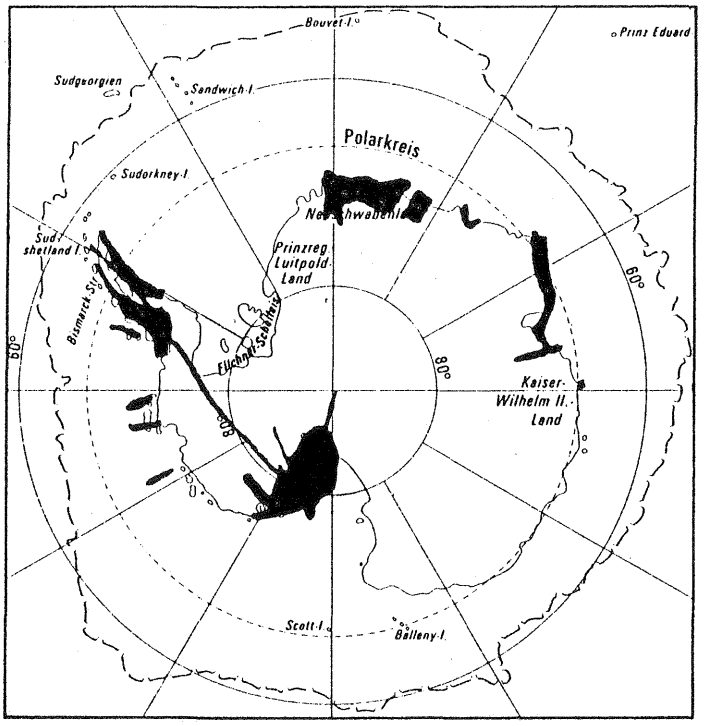

Table 1

Aerial Reconnaisance and Photogrammetry in Antarctic Research until 1945

Time	Country	Exped. Leader	Work/Results
1901 - 1903	Germany	v. Drygalski (1865-1949)	First use of terrestrial photogrammetry. First aerial photographs from a captive balloon at a height of 500 m (29.03.1902) o Gaussberg
1928 - 1930	U.S.A. and Great Britain (Australia)	Wilkins (1888-1958)	First reconnaissance flight in the Antarctic with an aeroplane (on 20.12.1928) o South Shetland Islands to Graham Land and back 1929/30 further reconnaissance flights: o proof that Charcot Land is an island (31.12.192
1928 - 1930	U.S.A.	Byrd (1888-1957)	Reconnaissance flight in Ross Sea area. First return flight to South Pole from Little America station (over 18 hours, 28-29 November 1929)
1929 - 1931	Great Britain Australia New Zealand	Mawson (1882-1958)	1929/30 reconnaissance flight to record coastline of eastern Antarctica (Enderby Land).
1933 - 1935	U.S.A.	Byrd	1934/35 reconnaissance flight over Marie Byrd Land ..., c. 500 000 km² recorded topographically
1933 - 1935	U.S.A.	Ellsworth (1880-1951)	First transantarctic flight from Dundee Island to Little America station (23.11.-04.12.1935), together with pilot Herbert Hollick-Kenyon.
1934 - 1937	Great Britain	Rymill	Reconnaissance flight and survey flight to record coastline of the Antarctic Peninsula (Feb. 1936).
1936/37	Norway	Christensen ( )	Reconnaissance flight and survey flight to record coastline of eastern Antarctica from American Highland to Queen Maud Land.
1938/39	U.S.A.	Ellsworth	Reconnaissance flight over the American Highland (11.01.1939).
1938/39	Germany	Ritscher (1879-1963)	Reconnaissance flight and survey flight over New Swabia (19 January - 5 February 1939), c. 300,000 km² recorded topographically.
1939 - 1941	U.S.A.	Byrd	Reconnaissance flight and survey flight to record coastline of western Antarctica, the ice front of Ross Ice Shelf and parts of Marie Byrd Land.

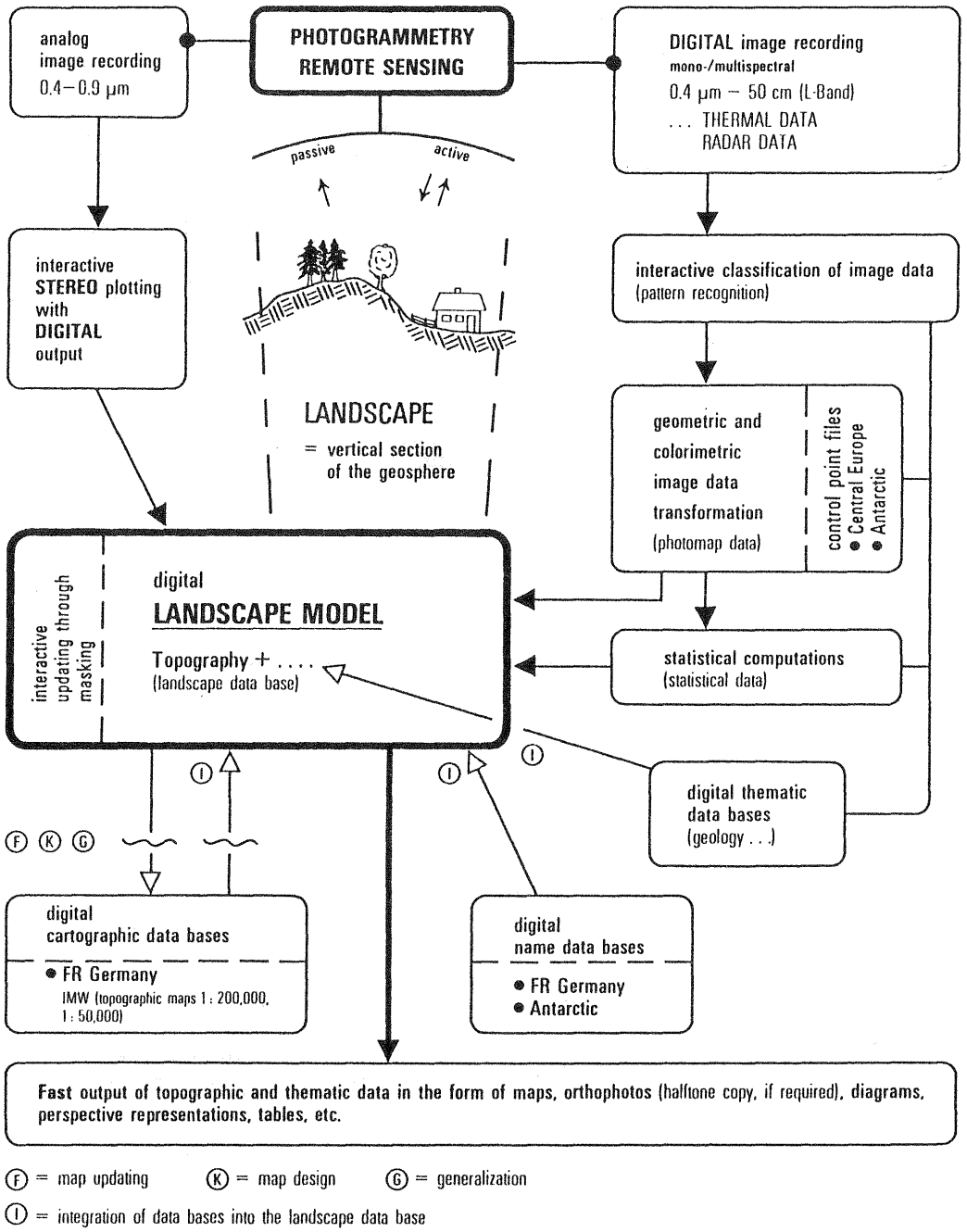

Fig.3 Data flow system

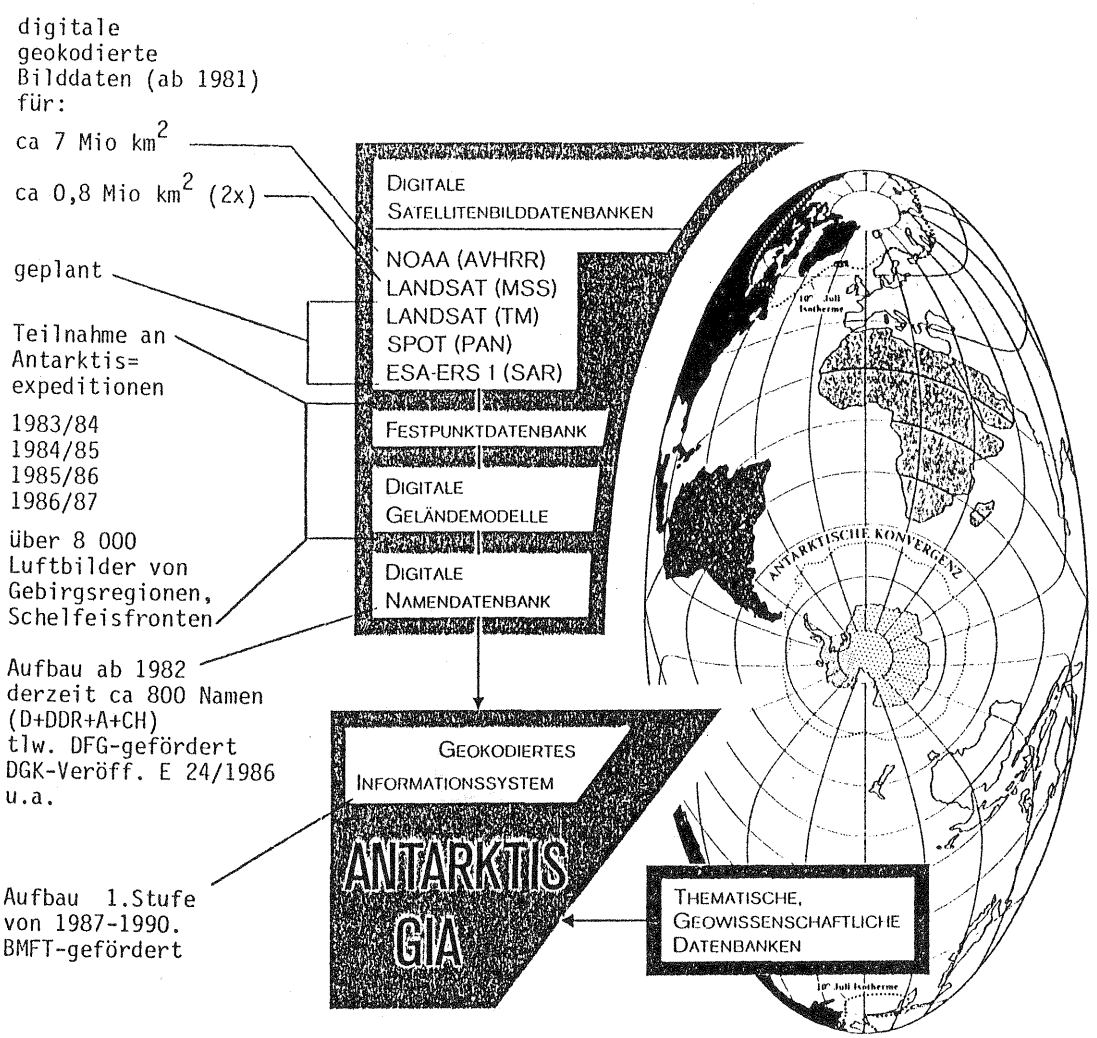

Fig.4 Digital Geocoded Information System of the Antarctic (GIA)

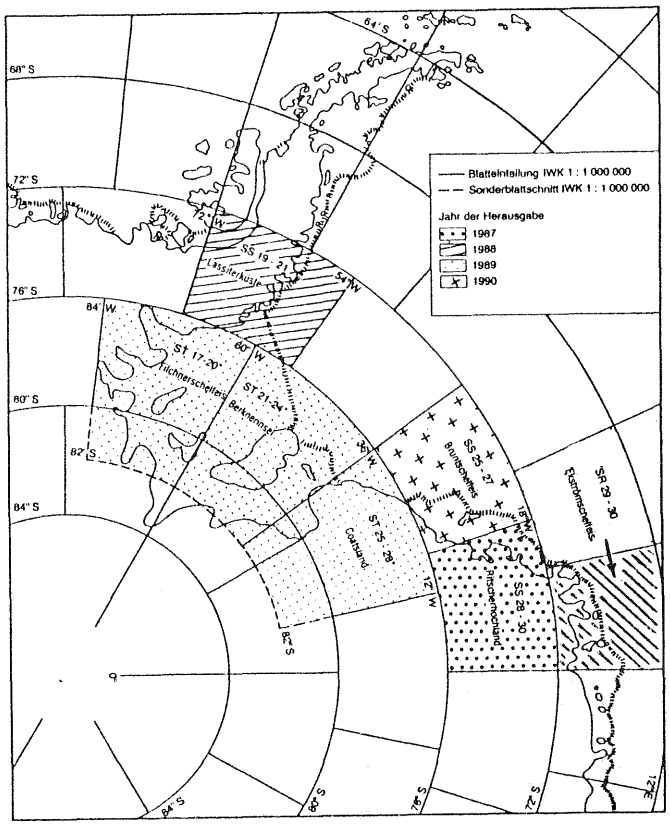

Fig. 5

Production Program
Satellite Photo
Maps 1:1,000,000

Fig.6

Photogrammetric
Photo Flights
by the
Antarctic
Expeditions of
1983/84, 1985/86
and 1986/87