Antarctic Science 5 (3): 239–244 (1993)

Review
The SCAR Antarctic digital topographic database

J.W. THOMSON and A.P.R. COOPER

British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, UK

Abstract: The Antarctic digital topographic database is the outcome of a truly international collaborative project between 11 nations. Data capture was co-ordinated in the UK, under the auspices of the Scientific Committee on Antarctic Research (SCAR), during a two-year period. Over 200 maps, at scales ranging from 1:200 000 to 1:5 000 000, were digitized for the project and reference was made to a similar number of satellite images (mostly Landsat photographic products). Editing and harmonization of the data derived from the different sources has produced a seamless map of Antarctica which has the most up-to-date coastline now available. The topographic database created, to be published on one CD-ROM, will form the foundation for future GIS needs in Antarctic research. Products already derived from the database include digital elevation models and customized maps; the latter can be reproduced by research groups to meet their own mapping needs.

Received 17 March 1993, accepted 22 April 1993

Key words: digital elevation model (DEM), GIS, international collaboration, topographic database

Introduction

The design and co-ordination of a topographic database as the foundation for future GIS needs of the international Antarctic community represents a major development in Antarctic mapping. In 1990 a project was proposed, under the auspices of the Scientific Committee on Antarctic Research (SCAR), to create such a topographic database and produce the first seamless digital map of Antarctica (Thomson & Cooper 1992).

The idea for the preparation of a digital map of the world, including Antarctica, was mooted first in 1984 when a joint working group of the International Geographical Union and the International Cartographic Association explored the feasibility of developing a standard global dataset in a topologically structured form, the World Digital Database for Environmental Science (WDDES). In 1987, before the plans of WDDES were finalized, Petroconsultants (CES) Ltd launched MundoCart/CD, the first detailed digital map of the world on one CD-ROM; source maps for Antarctica on this product were at 1:2 500 000 scale. By 1988 the US Defense Mapping Agency had initiated the Digital Chart of the World (DCW), a project which incorporated many of the objectives proposed by the WDDES working group. The DCW, published in 1992 on four CD-ROMs, was derived from 270 1:1 000 000 scale Operational Navigational Charts, augmented by six 1:2 000 000 scale Jet Navigation Charts for coverage of Antarctica (Lang 1992). In 1989 a joint venture between the Scott Polar Research Institute (SPRI) and Petroconsultants (CES) Ltd began work on a digital map of Antarctica for a new edition of the MundoCart product.

Although maps at 1:1 000 000 scale provide an overview of Antarctica on a relatively small number of map sheets (about 80), and are useful, therefore, to programme planners and managers, research scientists frequently require more detailed maps for field work and a higher resolution topographic database as a framework for their data collection and entry. With this in mind the Antarctic Digital Database Project (ADDP) (British Antarctic Survey 1991, Harris 1991) was designed to include cartographic data from maps at scales of 1:200 000 and 1:250 000 for those areas of Antarctica where typically most detail is required, (i.e. in areas of mountainous terrain or coastal regions with exposed rock, such as the Transantarctic Mountains and the Antarctic Peninsula). Maps at scales ranging from 1:500 000 to 1:5 000 000 were used for the rest of the continent (Thomson & Cooper 1992), when no larger-scale maps were available and where lower resolution data were acceptable.

The ADDP proposed in 1990 was a joint venture between the British Antarctic Survey (BAS), SPRI and the World Conservation Monitoring Centre (WCMC), building on the earlier SPRI work. Because maps published by a number of nations active in Antarctic work were to provide the source data for the topographic database, the collaboration of Antarctic mapping agencies in other countries was considered essential and nations were asked to supply their own Antarctic maps in digital form, thus ensuring that the database product would represent a truly international effort. Since many of the maps scheduled for use had been published before satellite imagery was available as a mapping tool, those agencies who so wished had the opportunity to up-date their cartographic data before it was incorporated in the database. The proposal to co-ordinate and produce the ADDP was considered by the SCAR Working

https://doi.org/10.1017/S095410209300032X Published online by Cambridge University Press

Table I. International sources of map data.

a. Digital contributions

Country	Scale of maps	Number of maps
Australia	1:1 000 000	22
China	1:1000, 1:2000, 1:10 000	4[1]
Germany	1:400 000	Mosaic of 100 satellite images[2]
New Zealand	1:250 000	8 (US)[3]
Norway	1:250 000	32
UK	1:200 000	2 (Russia)
	1:250 000	52
		70 (US)
		2 (Japan)
	1:500 000	3 (US)
	1:1 000 000	13 (Russia)
		2 (US)
	1:1 500 000	1 (Argentina)
	1:2 000 000	1 (Japan)
	1:3 000 000	1
	1:5 000 000	1 (US)

b. Countries permitting digitization of paper maps for the project

Country	Scale of map	Number of maps
Argentina	1:1 500 000	Part of 1 chart
Japan	1:250 000	2
	1:2 000 000	1
Russia	1:200 000	2
	1:1 000 000	13
US	1:250 000	72
	1:1 000 000	2
	1: 5 000 000	1 (minor part)

[1] Data not incorporated in seamless map but available on CD-ROM as a separate dataset.
[2] Provided as vector data interpreted from raster backdrop.
[3] Country of map publisher in parentheses, when different from digitizing nation.

Group on Geodesy and Geographic Information at its meeting in Frankfurt in June 1990. All those nations attending the meeting welcomed and supported the proposal and agreed that the project should be a co-operative venture between the UK consortium and SCAR; the SCAR Executive Committee gave their approval later that same month.

Although several nations expressed a willingness to provide digital data to the project, the bulk of the data capture and data management was undertaken in Cambridge. Such work was labour intensive and beyond the capabilities of existing staff resources at any of the three institutes in Cambridge. External funding was sought by the group whilst work progressed under the sponsorship of BAS. After six months of BAS funding, generous sponsorship was provided by The British Petroleum Company p.l.c. and this enabled the project to proceed to completion during the ensuing 18 months.

International collaboration

Research and development of the Antarctic digital database (ADD) was co-ordinated in the UK but international collaboration was vital to the success of the database production programme for the following reasons:

a) it widened the field of expertise and extent of 'local knowledge' available to the project, thereby improving the currency of the data for different parts of the continent,

b) by spreading the work load (Tables I & II), it enabled completion of the project in a shorter time-frame (two years),

c) it provided a means by which the quality of data incorporated in the database could be validated and enhanced at the time of data entry by the national mapping agencies,

d) international participation avoided duplication of effort amongst the Antarctic community.

Table II. International sources of digital place-names gazetteers.

Country	Number of place-names
Argentina	2910
Australia*	2192
Germany	327
Norway*	1388
Poland	265
UK*	4494
USA*	7809

* Received in time to be incorporated in the place-names hierarchy; other sets of place-names are included on the CD-ROM as separate listings.

The map of Antarctica integrates digital data provided by eight nations (Tables Ia & II) and also data captured in the UK from sources published and provided by four countries (Table Ib). More than 200 maps were converted into digital form by the international team, all being edited and merged in the UK to form the final product, a seamless map of the continent on CD-ROM.

Content of database

Data sources

The principal scales of the maps used for the preparation of the database were 1:250 000, 1:1 000 000 and 1:3 000 000; gaps in the coverage were filled by using a variety of maps at scales of 1:200 000, 1:500 000, 1:2 000 000 and 1:5 000 000. Reference was made to Landsat satellite imagery to improve the coastline, imagery providing a primary source when no suitable maps were available. Indeed, the data provided for the Filchner-Ronne Ice Shelf area was based entirely on linework interpreted from a geocoded raster mosaic of 78 Landsat MSS images (Sievers *et al.* 1989). In spite of the variety of source data, the topographic database has been edited and harmonized to provide a seamless digital map of the entire continent. Harmonization involved checking that features which spanned different map series, and even different map sheets, were consistent both in geometry (edge-matching) and in their attributes. Thus any part

https://doi.org/10.1017/S095410209300032X Published online by Cambridge University Press

of the digital map of Antarctica can be accessed to produce a customized map, the linework within and outside the required map limit being continuous.

Besides published paper maps and photographic products of Landsat satellite imagery (mostly MSS scenes), reference was made to scientific papers for detailed information about specific parts of the Antarctic coastline (e.g. Shabtaie & Bentley 1988, Swithinbank 1988, Keys *et al.* 1990). Elevation details for the greater part of the continent were based on an unpublished 1:3 000 000 scale compilation prepared for Drewry (1983), these data being harmonized to larger-scale datasets, particularly over the mountainous regions.

All data capture undertaken in the UK was done manually. Because of time constraints on the project, place-names were entered from gazetteers rather than by linking the names to specially constructed polygons defining mapped features. Thus place-names are located by a single point, defined by geographical co-ordinates; there is no explicit link between a name and its mapped feature. To enable the selection of names in the database according to their size and importance, the place-names were organized in a tree-structured hierarchy using the ORACLE relational database management package. The database entry for each place-name has a reference to a parent name, allowing the spatial extent of a named feature to be determined from the co-ordinates of all the names below it in the hierarchy. Time limitations were such that only those names sent to the UK in digital form could be made available on the CD-ROM (Table II) and only those received early in the project could be incorporated in the hierarchy.

Features included in the database

To a large extent the features recorded in the database are dependent on the amount of detail shown on the original paper maps. Although larger-scale maps generally display more features than smaller-scale maps, the scale of the map is neither a reliable indicator of the range of data to be expected in the database nor of the accuracy of the original material. For example, the 1:250 000 scale maps of Dronning Maud Land and the Transantarctic Mountains, published respectively by Norsk Polarinstitutt, Norway and US Geological Survey, carry a far wider range of features than the BAS unpublished sketch maps at this scale which were used to prepare the database of the Antarctic Peninsula area. Features considered to be relatively ephemeral, such as crevasses, crevasse fields and meltpools on ice shelves, were ignored. This decision was made because not only are they short-lived phenomena but also they have not been plotted on all source maps. Thus their inclusion in some instances and not in others, for lack of data, would have been misleading and might suggest a real absence when this is not so. A grounding line, showing where the continental ice sheets become floating ice shelves, has been interpreted from published maps and satellite imagery wherever necessary. Since many of the maps used for the preparation of the database showed no such interpretation, this is the first time that a continuous coastline has been depicted in such detail for Antarctica.

Table III. Features included in the database at each level of generalization.

Scale	Feature
1:250 000 - 1:1 000 000	Coastal features (grounding line, ice front, ice tongue, coastline*), contours*, glacier margins, glacier flowlines, cliffs*, rock outcrops, moraine*, lakes, islands, ice rumples. Point data: spot heights*, traverses, scientific stations and related cultural information (SSSIs, SPAs, HSMs, SRAs and MPAs).
1:3 000 000	Coastal features (grounding line, ice front, coastline*), contours*, selected flowlines, generalized rock outcrops, selected islands, large lakes. Point data: traverses and scientific stations.
1:10 000 000	Coastal features (grounding line, ice fronts, coastline*), contours*, generalized rock outcrops, selected islands. Point data: scientific stations.
1:30 000 000	Coastal features (grounding line, ice front of major ice shelves, coastline*), large islands, IMW sheet boundaries. No point data.

* Ice and rock features differentiated in database.

For flexibility of use, the database available on CD-ROM includes a number of generalized datasets in addition to the seamless map prepared from the basic scale data (that is, at the original scale of the source data). Generalization of the primary dataset was done automatically using two techniques. For rock outcrop and coastlines the vector data were used to create polygons outlining different surface types (ocean, ice shelf, ice sheet or rock), followed by conversion into raster data with a pixel size appropriate to the scale of generalization (e.g. 1500 m for 1:10 000 000). Finally the raster data were converted back into vectors. Generalized contours were created from a digital elevation model. Such generalized datasets enable users to select meaningful displays at scales of 1:1 000 000, 1:3 000 000 and 1:10 000 000; an index map is provided at 1:30 000 000. The range of features included in the database, and the scale at which they can be meaningfully reproduced, are summarized in Table III.

Early products from the ADD

The database described here will be published on one CD-ROM in ARC/INFO format, with polygon topology where appropriate (e.g. rock outcrop). The user's guide supplied with the CD includes a full bibliography of the map sheets and satellite imagery used in the preparation of the ADD.

The ADD is at an early stage in its development and use but a first-generation product has been a detailed digital elevation model (DEM) of Antarctica (front cover and Fig. 1), generated from the coastline and contours in the 1:10 000 000 generalized

https://doi.org/10.1017/S095410209300032X Published online by Cambridge University Press

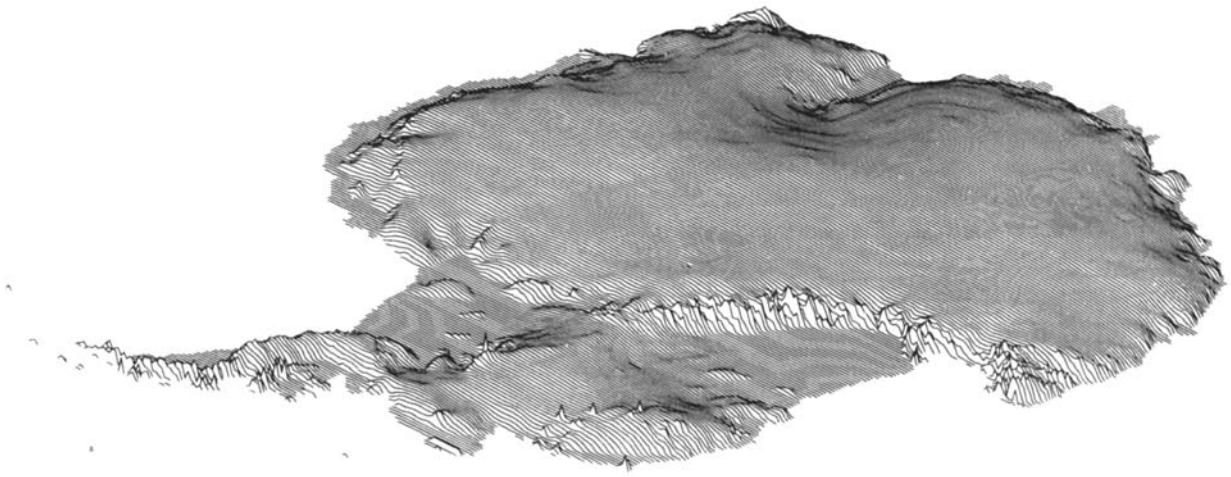


Fig. 1. An isometric view of a wireframe model of Antarctica created from a DEM at 20 km resolution. The viewing direction is from 135°W.

dataset. The contours in regions of very low slope on the East and West Antarctic ice sheets were too widely spaced to provide sufficient elevation information for the DEM and, in these regions, the 500 m contours of the generalized data were supplemented by 100 m contours from the basic scale data. The representation of ice shelves was also problematical as the ADD contours are at intervals of 100 m for the ice sheets and 200–250 m for mountainous regions. Thus ice shelves, which are low-lying features, were without height information. In order to create a good visual effect, ice fronts were set to 50 m above sea-level (asl) and grounding lines to 100 m asl. This crude approximation gives a visually acceptable result and is within the likely known error of the elevation data elsewhere on the ice sheets (Drewry 1983). These data were then used as input to a suite of DEM creation programs (Laser-Scan's DTMCREATE package). This package uses the technique of Delaunay triangulation for interpolation, allowing gridded data to be generated at a range of intervals.

The front cover illustration of *Antarctic Science* was created from a DEM of Antarctica at 6 km interval and Fig. 1 was generated from a DEM at 20 km. Triangulation is the most computer-intensive process, but because it is independent of the resolution of the final output, a single triangulation process can be used to generate DEMs at any convenient resolution. The illustration for the front cover was created from the DEM by first generating a hill-shaded view of Antarctica, using Laser-Scan's SLOPES software (Fig. 2). This was combined with the DEM, and a suitable colour scheme devised to allow both hill-shading and elevation to be displayed. On the front cover, the colour gradation from yellow to orange indicates increasing height, with colour changes at 500 m intervals. The hill-shading is superimposed on this to give a three-dimensional impression of the surface. Another version of the hill-shaded model has been used as a backdrop to a 1:10 000 000 scale paper map product derived from the ADD (British Antarctic Survey, 1993).

The digital data of the ADD simplifies the extraction of summary statistics for parameters such as the area of ice sheets, ice shelves and rock outcrop. These statistics are being prepared for a future publication.

GIS applications of the ADD

The ADD can be used to generate customized maps for scientific purposes (Fig. 3). Distribution by SCAR of copies of the CD-ROM to all the national Antarctic mapping centres will enable research groups in many nations to generate maps of Antarctica to suit their own needs. This is a low-level use of the ADD, but one which is of great value to workers in Antarctica, who may otherwise have to refer to several maps at different scales and from different sources for their area of interest. However, it is expected that the true value of the ADD will be in GIS applications. In these, the ADD will provide a uniform, coherent set of base maps for recording or analysing spatial data – an essential prerequisite for GIS. Every point or line in the ADD is coded with its type, source, date, height (if relevant) and other information relevant to data management. There is provision for textual information, such as the name of an expedition in the case of an over-snow traverse. The data are divided into thirteen layers including coast, rock and contours. The ADD holds sufficient information for regions to be divided into basic surface types—rock, lakes, sea, grounded ice and ice shelf. Information is also provided for moraines, although these have been neither uniformly defined nor recorded on all the source maps. The diversity of information in the ADD makes it a valuable resource for many purposes. For example, a biologist might use the basic information provided in the ADD

https://doi.org/10.1017/S095410209300032X Published online by Cambridge University Press

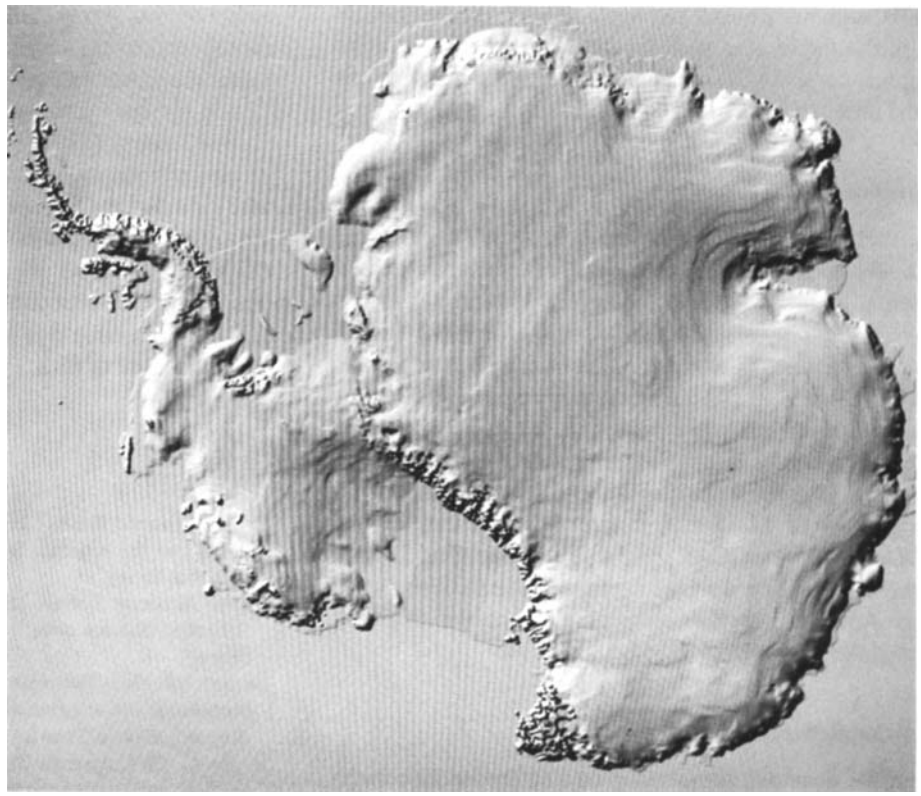


Fig. 2. A hill-shaded image of Antarctica derived from a DEM at 6 km resolution.

to investigate and evaluate habitats for living organisms, and a geologist to plot field observations. This basic capability is greatly extended by using the GIS to link topographic data with other data held in external databases. In the cases mentioned above, the biologist might refer to data on species abundances, and the geologist to a database of previous observations within an area of interest.

Future development of the ADD

The current version of the ADD, while a great advance on previous work, has some important deficiencies. The most obvious missing datasets are bathymetry and sub-glacial topography. Thus the ADD has no data from below sea level or below the ice surface—a decision enforced by the restricted time frame of the project. Except for four sample datasets contributed by China, there are no data at a scale larger than 1:200 000. It is envisaged that enhancement of the database will proceed under the auspices of SCAR and its Working Group on Geodesy and Geographic Information, with BAS continuing to play a co-ordinating role for capture of new data and maintenance of the original database. Newly published maps, as well as those at larger scales (≥1:25 000), will be digitized for the new phase of the project and harmonized with the existing data. Other features to be added should include, but not be limited to: bathymetry (south of 60°S), maps of subantarctic islands, sub-ice topography, sea surface temperature, accumulation and temperature data for the ice cap, geological data, distribution of

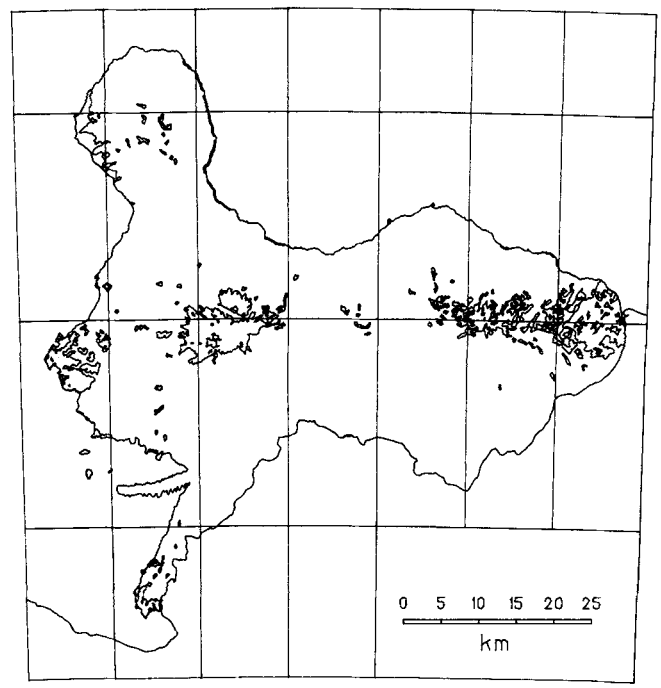


Fig. 3. A customized map of Ross Island (77°30'S, 177°E) derived from the ADD at 1:1 000 000 scale. Only grounding line, ice fronts and rock outcrops are shown on this plot.

https://doi.org/10.1017/S095410209300032X Published online by Cambridge University Press

fauna and flora. BAS hope to be able to release new versions of the ADD, with bathymetry and other additional data, on CD-ROM in the future. As with the current version, the future development of the ADD will depend heavily on contributions from the international Antarctic community.

Conclusions

The value of multilateral international collaboration on a large project such as the ADDP is considerable since it has enabled completion of the work in a timely fashion and it has also improved the quality of the final product. Furthermore, the fact that the data were provided by an international group led the UK consortium to ask SCAR to be the copyright holder of the database, thus ensuring free access to the database for the Antarctic community. It is hoped that the success of the ADDP, and of other Antarctic scientific datasets such as the Biological Invesitgations of Marine Antarctic Systems and Stocks (BIOMASS) and the SCAR Antarctic Seismic Data Library System (SDLS) will encourage further multilateral collaboration amongst Antarctic scientists and enable the creation of a fully integrated Antarctic GIS for the benefit of all.

Acknowledgements

Without the generous sponsorship of The British Petroleum Company p.l.c. for the UK-based work, and the support and co-operation of many international colleagues in the Antarctic mapping community, the ADDP could never have achieved its objective in the given time frame. The sponsorship and encouragement of the Director, BAS is gratefully acknowledged as also is the advice and support given to the UK team by the members of the ADDP Steering Committee.

There is insufficient space to thank all those individuals who worked on and for the database during the ADDP but special mention should be made of Ms E.M.R. Edwards (WCMC) who was the principal digitizer of source material in the UK and editor of files during the final harmonization, Mrs S.R. Jordan (BAS) who, as principal editor of digital data, did much of the research and interpretation of satellite imagery, Mrs A. Roberts (BAS) for her work on the place-names hierarchy and Dr C. Swithinbank (SPRI) for his expert advice and interpretation of satellite imagery of the Antarctic coastline. Thanks are due also to M. Adam, J. Rhind and I. Barnes (WCMC), who shared data management duties with APRC, K.G. Newport (SPRI) for digitizing many of the US 1:250 000 scale maps of the Transantarctic Mountains, and A.J. Fox (BAS) for joining the UK team at a late stage in the project to help with editing and harmonization of files.

References

British Antarctic Survey. 1991. *Antarctica: an environmental database.* Leaflet on the Antarctic Digital Database Project. Cambridge: British Antarctic Survey.

British Antarctic Survey. 1993. *Antarctica - a topographic database,* 1:10 000 000 scale map, BAS (Misc) 7. Cambridge: British Antarctic Survey.

Drewry, D.J. 1983. The surface of the Antarctic Ice Sheet. *In* Drewry, D.J. *ed, Antarctica: Glaciological and Geophysical Folio,* Cambridge: Scott Polar Research Institute, Sheet 2.

Harris, C. 1991. Antarctic Digital Database Project: a new tool for Antarctic environmental science and management. *Polar Record*, **27**, 260-261.

Keys, H.J.R., Jacobs, S.S. & Barnett, D. 1990. The calving and drift of iceberg B-9 in the Ross Sea, Antarctica. *Antarctic Science*, **2**, 243-257.

Lang, L. 1992. Digital chart of the world becoming a reality. *GIS Europe*, **1**, 58-60.

Shabtaie, S. & Bentley, C.R. 1988. Ice-thickness map of the West Antarctic ice streams by radar sounding. *Annals of Glaciology*, **11**, 126-136.

Sievers, J., Grindel, A. & Meier, W. 1989. Digital satellite image mapping of Antarctica. *Polarforschung*, **59**, 25-33.

Swithinbank, C. 1988. Satellite image atlas of glaciers of the world: Antarctica. *US Geological Survey Professional Paper*, **1386-B**, 278 pp.

Thomson, J.W. & Cooper, A.P.R. 1992. A digital map of Antarctica. *Mapping Awareness*, **6**, 21-25.

https://doi.org/10.1017/S095410209300032X Published online by Cambridge University Press