This paper addresses the use of Geographical Information Systems (GIS) in Polar Science. The Polar Regions represent Earth’s extremes of geography and science. Unlike most other parts of the Earth they are remote, often inaccessible and essentially inhospitable to human life. Relative to other parts of the Earth, much less is known about the origins and natural processes of the Arctic and the Antarctic. Scientific operations and technology for these parts of the world are, therefore, expensive and require major advance planning to ensure maximum use of resources. With the evolution of satellite image technology and application of GIS, the previous barriers to understanding the intricacies of these regions have significantly decreased. As a result our understanding of the Arctic and Antarctica and their effects on Earth’s systems increases daily.

Scientists and their GIS experts are using GIS widely for analysis and presentation of their research findings. Most significantly, GIS provides the means to analyze trends and consolidate many layers of new data from remote sites. This is particularly important in analyzing processes where change can be very slow and sometimes unpredictable, such as glacial activity and ice-sheet flow. It is also important in attempting to understand and even predict atmospheric changes like the annual appearance of the ozone holes at both poles and trends in global warming. It is important in helping Treaty organizations track compliance to eco-system protection measures.

Most of the Polar science research reviewed for this paper does not mention GIS specifically, but rather incorporates its components within the analysis and presentation of data. The consistent incorporation of GIS into the research protocols and analysis suggests that GIS is viewed as an integral part of the research rather than just a new high-tech gadget. The attached annotated bibliography contains a mix of articles about polar science where GIS is specifically featured or is simply part of the work.

- Childers et al. (2001) applied GIS to new aerospatial gravity data in the Arctic Ocean. This data will assist scientists in understanding the origin and evolution of the Arctic Ocean, two remaining uncertainties in the study of the Earth’s plate tectonics. Another group, Guinet et al. (2001), evaluated diving activity and diet of female fur seals in the Antarctic to investigate the effects of changes in the oceanic conditions on distribution and foraging of top marine predators. This study involved fitting the seals with a satellite transmitter and time-depth recorder (TDR).

- The study of glacier composition and activity is very important to understanding atmospheric and climate changes, both past and future. Boulton et al. (1985) produced new DEM maps to evaluate patterns from previous Arctic ice-sheet movement and decay to determine whether there are other ways of modeling ice-sheet behavior. For the Antarctic Ferrigno et al., with the USGS, produced fact sheets detailing recent efforts to provide better coastal-change and glaciological maps. The USGS has a significant collection of maps and data for Antarctica, some for free and some for sale. Working with the British Antarctic Survey (BAS), plans are underway to build a new 24-map series to be georeferenced to a digital mosaic of RADARSAT images with all cartographic data available in the web-accessible USGS Atlas of Antarctic Research.
- The British Antarctic Survey (BAS) is also a major player in the development and maintenance of geospatial data in the Antarctic Digital Database (ADD). This GIS database is used by members of the Scientific Committee on Antarctic Research (SCAR), a scientific consulting arm of the Antarctic Treaty Consultative Meetings. Access by other interested parties is possible through strict licensing agreements. One author from BAS provides an example of the importance of GIS in science where work is being done to show how oceanographic parameters affect the breeding success of squid, which allows for prediction of the success of commercial fisheries the following year. (Cooper, 2003)

- Environmental protection in Antarctica is supported by the CCAMLR Treaty (Convention on the Conservation of Antarctic Marine Living Resources) and the Madrid Protocol, which among other things bans mining for fifty years. Use of GIS is critical as a monitoring tool for scientific data across this large eco-system that the CCAMLR and its scientific committee (CEP) oversees. One author suggests that GIS and better data tracking would help de-politicize much of the decision making process and further legitimize the international standing of the CEP. (Cordonnery, 1998)

- Finally, use of GIS in presenting the effects of pollution and contaminants in the Arctic was used very effectively in two very thorough and detailed sources. The first is a large, colorful book on Arctic Pollution Issues prepared by the Arctic Monitoring and Assessment Programme (AMAP, 1997) in Norway. Nearly every facet of pollution and their affects on humans, plants, animals, land, the atmosphere and marine eco-systems are visually represented using raster or vector maps. The presentation of the data is easily understandable by any interested, non-science-learned reader. The second source is an article by Crane et al. (2000) showing the effects of radionuclide contamination on the Artic. Through colorful raster and vector maps, the authors give a chilling presentation of the extent of contamination from nuclear testing and power plant explosions since the end of World War II.

- Not included in the bibliography are materials and new ideas from the growing number of meetings and symposiums, not yet peer-reviewed, which include GIS and its polar science application as key components. One exception for this paper is the Scientific Committee on Antarctic Research (SCAR) International Workshop held earlier this year.

It is important to note that many individuals and teams across national boundaries and scientific disciplines are thinking of innovative ways to make GIS data more easily gathered and more accessible. Widespread accessibility of scientific data, particularly Polar science data that is currently more sparse than others, will allow faster evolution of answers to key questions and solutions to serious problems. Better and more widespread data will also allow scientists and informed decision-makers to initiate pre-cautionary or remedial measures to protect and restore important Polar eco-systems. And, of equal value, in this writer’s view, is the use of GIS to stir the imagination and interest of average citizens in the Earth’s beautiful, fragile, and important Polar Regions.
Annotated Bibliography

This is an excellent example of the use of GIS in a science related endeavor where GIS is not mentioned, but is consistently applied throughout the volume. This thorough and colorful book on pollution in the Artic is replete with factual data supported by visual depiction of the effects of various contaminants on humans, plants and animals, land, the atmosphere, and marine ecosystems through the use of GIS–based maps. Specific data using charts and maps is provided on persistent organic pollutants (POPs), pesticides, combustion products, radioactive contamination, heavy metal and mineral contamination, and a host of others.

The authors discuss construction of a high spatial resolution DEM of the Austfonna area in the Arctic using a shape-from-shading algorithm. They apply a shape-from-shading model to satellite imagery with +/- accuracy of 0.8° to create the new DEMs. Other techniques for refinement, such as using a second winter visible image acquired at a different time of day, are discussed. The authors propose that production of Arctic ice cap and ice sheet DEMs would be best achieved using InSAR, however, should that technique fail, the shape-from-shading method provides a potential alternative.

The authors provide detailed discussion about glacial geologic theory in terms of ice-sheet behavior. After determining and evaluating patterns from previous ice-sheet movement and decay, a suggestion is made that “views of ice-sheet behavior based on high latitude models may be inappropriate to the dynamically more active mid-latitude ice sheets based in large part on deformable sediment beds.” This means that there a new ways of looking at old data with the use of more sophisticated mapping techniques. Of particular interest is a georeferenced map of previous Arctic ice-sheets with a legend showing Lambert Conformal Conic Projection and standard parallel coordinates.

The authors provide results of a detailed study that will assist scientists in understanding the origin and evolution of the Arctic Ocean, two of the largest remaining uncertainties in plate tectonics. The Arctic Gravity Project spearheaded by the International Association of Geodesy and NIMA has two significant data sets to assist in understanding magnetic fields of the Arctic Ocean. Satellite altimeter data from European Space Agency’s Earth Remote Sensing (ERS) – 1 and –2 are compared with U.S. Naval Research Laboratory (NRL) aerophysical data. The authors determined that the accuracy and compatibility of the data are very favorable and include excellent color maps based on these data.

The British Antarctic Survey is a major player in the development and maintenance of geospatial data in the Antarctic Digital Database (ADD). http://www.nerc-bas.ac.uk/public/magic/add_home.html The author provides an excellent overview of how GIS
works in this difficult, geographically vast environment. Of particular importance is the use of GIS in science where, for example, work is being done to show how oceanographic parameters affect the breeding success of squid, which allows for prediction of the success of commercial fisheries in the following year.

Cordonnery, L. 1998. "Environmental Protection in Antarctica: Drawing Lessons from the CCAMLR Model for the Implementation of the Madrid Protocol," ODIL 29: 125-146. This paper is a known critique by students of international marine environmental protection treaties. In it the author provides a thorough analysis of the problems with the current CCAMLR Treaty (Convention on the Conservation of Antarctic Marine Living Resources) and the subsequent Madrid Protocol, which sets up further protection measures including a ban on mining for fifty years. Of particular importance is the recommendation that the Committee on Environmental Protection (CEP), defined under the Protocol, adopt GIS as a key tool to support and improve decision-making and monitoring of the wider part of the ecosystem with better scientific data. Better data tracking would help in de-politicizing much of the decision-making process and further legitimize the international standing of the CEP.

Crane, K., J. Galasso, and C. Brown. 2000. Northern Ocean Inventories of Radionuclide Contamination: GIS Efforts to Determine Past and Present State of Environment in and Adjacent to the Arctic. Marine Pollution Bulletin 40 (10): 853-868. This is an excellent and frightening article showing the contamination effects of nuclear testing and power plant explosions through release and migration of radionuclides in the oceans, rivers, sediments, plants and animals of the Arctic region and adjacent points. Radionuclides are the radiation emitters that in part comprise the 200 other deadly fission products of these disasters. Very detailed and colorful GIS maps are included showing key contamination points in the Arctic region.

Ferrigno, J.F., R.S. Williams, Jr., and J.W. Thomson. Coastal-change and glaciological maps of the Antarctic Peninsula. USGS Fact Sheet 017-02. http://pubs.usgs.gov/fs/fs17-02/fs017-02.html The authors describe current and planned USGS maps for Antarctica. This is good news to many constituents. The BAS (British Antarctic Survey) has used a georeferenced digital image mosaic from LandSat Thematic Mapper images prepared in Germany as an image-map base. A new 24-map series (I-2600) will be georeferenced to a digital mosaic of RADARSAT images with all cartographic data available in the web-accessible USGS Atlas of Antarctic Research. Additionally, new coastline information will be incorporated into the Scientific Committee on Antarctic Research Digital Database (ADD). The article also provides links to USGS fact sheets relevant to the subject.

Guinet, C., L. Dubroca, M.A. Lea, and S. Goldsworthy. 2001. Spatial distribution of foraging in female Antarctic fur seals in relation to oceanographic variables: a scale-dependent approach using geographic information systems. Marine Ecology Progress Series 219: 251-264. The authors were able to show the applicability of GIS in investigating the effects of changes in the oceanographic conditions on the at-sea distribution and foraging efficiency of top marine predators, in this case using female Antarctic fur seals. Distribution of diving activity for 11 fur seal females equipped with a satellite unit and a TDR was recorded. Diet of these seals was also recorded using other means. Using GIS, the authors concluded that foraging activity of marine predators can be closely related to environmental variables and abundance of fish, and suggested that lactating fur seals can be used with some confidence as indicators of the
distribution of their prey. This success opens the door for other similar uses of GIS technology in scientific research.


At its second international GIS workshop in April 2003, the Scientific Committee on Antarctic Research (SCAR), a scientific consulting arm of the Antarctic Treaty Consultative Meetings, reviewed papers from GIS users including scientists and data model and database development experts. The common thread was a strong interest in the advancement of science in Antarctica. While the papers are not yet peer-reviewed, they do provide a view to current thinking and research in the field. A common theme appears to be the continuing need to build usable and easily accessible GIS data for Antarctica. The SCAR homepage is http://www.scar.org/