Towards an Antarctic Spatial Data Infrastructure

The SCAR King George Island GIS Project as a model framework
to integrate and redistribute inaccurate and incomplete spatial data

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To my father

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Zusammenfassung

In dieser Arbeit wird das Konzept einer Geodateninfrastruktur auf das Management raumbezogener Daten von King George Island, South Shetland Islands, Antarktis angewandt. Dabei wird überprüft, ob sich Komponenten einer Geodateninfrastruktur auch in einem Umfeld bewähren, in dem mit Blick auf die zu verwaltenden raumbezogenen Daten der Umgang mit unvollständigen und ungenauen Daten im Vordergrund steht.

King George Island ist eines der am dichtesten besiedelten Gebiete der Antarktis. Forschungsstationen von neun verschiedenen Ländern, eine Landebahn auf eisfreiem Grund und reger Tourismus üben einen starken Druck auf die natürlichen Ökosysteme aus. Zwischen den Stationen gibt es wenig Koordination und bisher kaum gemeinsames Umweltmanagement.

Das Scientific Committee on Antarctic Research hat deshalb das King George Island GIS Projekt ins Leben gerufen, um für die Koordination der Aktivitäten auf der Insel eine einheitliche, raumbezogene Datengrundlage zur Verfügung zu stellen. Dafür wurden Daten verschiedenster Provenienz gesammelt und integriert.

Für das Projekt wurden exemplarisch Komponenten entwickelt und getestet, die von SCAR für eine Geodateninfrastruktur Antarktis (AntSDI) benötigt werden. Zu überprüfen war, ob sich diese Bausteine im bezogen auf Datenproduzenten und Datentypen, Nutzer und Anwendungsfälle, sowie die politischen und institutionellen Rahmenbedingungen komplexen Umfeld von King George Island bewähren würden. Denn dann sollten diese Bausteine in ähnlicher Form auch für die gesamte Geodateninfrastruktur Antarktis verwendbar sein.

Zu den auf ISO TC211-Normen und den offenen Spezifikationen des OpenGeospatial Consortium basierende Bausteinen gehört der SCAR Feature Catalogue für eine einheitliche Semantik der Daten, die Definition und Erzeugung von Referenzdatensätzen, ein erweitertes Ortsnamenverzeichnis geeignet als Lagebezug für großmaßstäbige Anwendungen, und nicht zuletzt Geowebdienste für die Darstellung von und für den Zugriff auf die raumbezogenen Daten.

Die KGIS Datenbank konnte im Sinne einer Geodatenstruktur aufgebaut werden, für die semantischen Integration hat sich der SCAR Feature Catalogue gut bewährt, Geodatendienste als Komponenten für eine dienstezentrierten Architektur wurden implementiert, und ein erweiterter Gazetteer mit genauen Positionsangaben und einem semantisch reichen Inhaltsmodell wurde konstruiert.

Diese erste Phase des Projektes war von einer datenzentrierten Sicht geprägt (First Generation SDI) und ist erfolgreich abgeschlossen. In Zukunft werden die Nutzer der Daten und Dienste mehr in den Vordergrund rücken müssen, um die Infrastruktur dynamisch an die Bedürfnisse der Forschung und des Umweltmanagements anpassen zu können (Second Generation SDI).

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Acronyms

AADC	Australian Antarctic Data Centre
ADD	Antarctic Digital Database
AFIM	Antarctic Flight Information Manual
AGDI	Antarctic Geographic Data Integration
AMD	Antarctic Master Directory
AntSDI	AntSDI Antarctic Spatial Data Infrastructure
ASMA	Antarctic Specially Managed Area
ASPA	Antarctic Specially Protected Area
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATCM	Antarctic Treaty Consultative Meeting
ATS	Antarctic Treaty System
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
CD ROM	Compact Disc Read Only Memory
CEMP	CCAMLR Ecosystem Monitoring Program
CEP	Committee on Environmental Protection
CGA	Composite Gazetteer of Antarctica
COMNAP	Committee of Managers of National Antarctic Programmes
DEM	Digital Elevation Model
DIF	Directory Interchange Format
DORIS	Doppler and Ranging Information System
EGGI	Expert Group Geospatial Information
EGM96	NASA GSFC and NIMA Joint Geopotential Model
EUREF	European Reference Frame
GIANT	Geodectic Infrastructure for Antarctica
GML	Geography Mark-up Language
GRS80	Geodetic Reference System
GSDI	Global Spatial Data Infrastructure
GSSG	Geosciences Standing Scientific Group
HSM	Historic Sites and Monuments
IAATO	International Association of Antarctic Tour Operators
IAG	International Association of Geodesy
ICSU	International Council for Science
IERS	International Earth Rotation and Reference Systems Service
IGBP	International Geosphere-Biosphere Programme

INSPIRE	Infrastructure for Spatial Information in Europe
IPY	International Polar Year
ISO	International Organisation for Standardization
ISO/TC211	ISO/ Technical Committee 211
ITRF	International Reference Frame
ITRS	International Reference System
JCADM	SCAR/COMNAP Joint Committee on Antarctic Data Management
KGIS	King George Island GIS Project
LLR	Lunar Laser Ranging
MPA	Multiple-use Planning Area
MSL	Mean Sea Level
PANGAEA	Publishing Network for Geoscientific and Environmental Data
OBIS	Ocean Biogeographic Information System
OGC	Opengeospatial Consortium
RiSCC	Regional Sensitivity to Climate Change
SCAR	Scientific Committee on Antarctic Research
SDI	Spatial Data Infrastructure
SPA	Specially Protected Area
SRA	Specially Reserved Area
SSSI	Site of Special Scientific Interest
UTM	Universal Transverse Mercator
VLBI	Very Long Baseline Intereferometry
WCS	Web Coverage Service
WFS	Web Feature Service
WG GGI	Working Group Geodesy and Geographic Information
WGS 84	World Geodetic System 1984
WMS	Web Map Services

Maps are older than alphabets
(common knowledge)

1 Introduction

1.1 The Need to Provide Frameworks to Integrate and Redistribute Inaccurate and Incomplete Spatial Data

There is a growing understanding that, in a knowledge based society, the effective use of geographic information is of critical importance. Traditionally, the use of geographic information has been viewed as a specialist topic. However, a notable paradigm shift now is underway and spatially referenced information starts to become ubiquitous.

The amount of data being collected is ever increasing and modern information technology facilitates access to large quantities of data. The more data becomes available, the more difficult it gets to extract the important information from these data. It has even been suggested that we are moving into a situation of "being data rich but information poor" (CASSETTARI, 1993). Most of the data being collected has a spatial component. The location of a feature or an event is a potent property when transforming data into information. To know how much of what is where is one of the most powerful tools when trying to understand our environment.

The need to derive relevant information from the wide range of distributed spatially referenced or referenceable resources has led to the demand for frameworks to assist in the discovery, dissemination and exploitation of geospatial data assets. These frameworks must provide for the required policies, enabling technologies, and a basic set of reference data. In 1991 McLaughlin introduced the term National Spatial Data Infrastructure to denote such a framework on the national Canadian level (MCLAUGHLIN, 1991). Since then Spatial Data Infrastructure (SDI) has become a common phrase used at the local, national, regional and global level.

It has been argued that the emergence of SDIs can be considered the major development in the GI community in the last decade (BREGT AND CROMPVOETS, 2005). Considerable amounts of money are being invested in SDI development, and both the political and commercial interest is increasing worldwide. Interestingly though SDIs have not yet become a major research topic (BREGT AND CROMPVOETS, 2005) and many facets of SDIs are not really well understood.

A key asset of an SDI should be the ability to integrate data sets from different origins. One implication of data integration is that the different sources might provide data in different quality. Quality is typically described by accuracy, consistency, resolution, and completeness. Although there is a large body of research on spatial data quality (e.g. GUPTILL AND MORRISON 1996) and on handling uncertainty and imprecision in spatial data analysis (e.g. BEARD, 1989, HUNTER ET AL. 1993, AGUMYA ET AL. 1996, HEUVELINK 1998) and on assessing fitness for use in a decision taking process (DE BRUIN ET AL. 2001) there is not much known on how effective these issues are dealt with in an SDI context.

Spatial, temporal and thematic accuracy and completeness should typically be specified in the metadata of a given data set. Unfortunately it is not straightforward to communicate such information to all potential consumers of the data set. Spatial data often becomes abstracted from the specific application it was produced for. It is passed on to a variety of different user communities and is being used for a range of alternative applications. It can be argued that it is within the responsibility of the consumer of a data set to evaluate its fitness for use for the application at hand. On the other hand it is a design goal of the infrastructure to allow for simple usage of the data. From this point of view it should be avoided to concern the user with details on data handling, all the more if the expected user communities to a large extend are not experts in geographic information.

SDIs provide the means to easily integrate data from a range of distributed sources. But currently we do not have tangible tools that are able to incorporate data quality into the integration process in an automatic way. As a matter of fact in many cases data consumers do not consider data quality issues.

In SDIs established by and sourced from authoritative bodies and targeted at specific user communities with well defined use cases published data often must qualify against strict specifications. Restricting the available data to those that meet certain quality criteria provides for data that is known to be fit for use for the target community and allows for a consistent data integration.

This is not the case with open SDIs where the data producer community is broad and uncontrolled. Some data might be constructed against well defined specifications. These are mainly those data created by administrative institutions. But other data might not need not qualify against strict standards. Yet this is often most valuable data and should equally be included in the spatial data infrastructure.

Consequently such SDIs should be able to handle data that potentially is inaccurate and incomplete. Assuming that such open spatial data infrastructures are targeted at the largest possible user community and that they are often implemented in an environment where funding resources for data management issues are scarce a simple yet robust solution that can communicate inaccuracy or incompleteness at a basic level would be an asset.

1.2 Use Case: Spatial Data from Antarctica

Following a survey conducted in 2001 more than 120 countries have considered SDI initiatives (CROMPVOETS AND BREGT, 2003). These national initiatives are spread across the Americas, Europe, the Asia/Pacific region and Africa. At the supranational level there are regional initiatives such as PCGIAP for the Asia/Pacific region or INSPIRE for Europe. And there is the Global Spatial Data Infrastructure Association which aims at promoting international cooperation and collaboration in support of local, national and international SDI developments. It is just one continent that has been missing on this list until only very recently: Antarctica.

Antarctica is the coldest, driest and most inaccessible continent on earth. The extreme climate, the remoteness and the sparse human presence distinguish the white continent from the rest of the world. Yet it can be argued that there is an urgent need for an Antarctic SDI.

A mix of four main factors pushing the development of SDIs has been identified by BREGT AND CROMPVOETS (2005). These include the need for better data access and sharing of spatial data, technology development and innovation, administrative orders, and the increasing role of spatial data in decision making.

All of these driving forces for SDI development are prevalent for Antarctica. There is a pressing demand for spatially referenced data both within the science and the operations management communities. The necessary internet and communication technology is available to the majority of stakeholders and relevant software can be implemented at affordable costs. Exchange and free access to data is required under the Antarctic Treaty. Spatially referenced data plays a crucial role not only in research programmes but also for environmental management and logistics' operations.

Consequently relevant institutions within the Antarctic community have embarked upon establishing a SDI. The Scientific Committee on Antarctic Research (SCAR) is the principal organisation dealing with Antarctic science. An initiative to setup an Antarctic Spatial Data Infrastructure (AntSDI) has been established in 2004 by SCAR's Expert Group on Geographic Information and is reflected by the Terms of References for that group (SCAR EGGI 2004). The implementation of AntSDI now is part of SCAR's long term strategic plan for 2004-2010 (SCAR 2004b).

When developing AntSDI there is a lot that can be learned from experiences gained from SDI implementation in other regions of the world. Nevertheless one can argue that there are certain facets that are quite distinct to Antarctica, aspects which potentially can become pitfalls on the way to a successful AntSDI.

One aspect is the political setting given by the Antarctic Treaty System and the lack of sovereign territory in Antarctica. This setting has implications mainly on the institutional arrangements for AntSDI.

Another aspects relates to specific properties of the data to be handled by AntSDI and to the Antarctic environment in which these data have been and still are collected. A pre-eminent requirement of AntSDI is to be able to handle spatially inaccurate and incomplete datasets. This relates mainly to legacy data which are an invaluable and often priceless resource for the Antarctic community.

In Antarctica data collection is comparatively expensive due to the remoteness and the harshness of the environment. Budget constraints call for the reuse of legacy data instead of recollection. Even more important legacy data provides a crucial baseline for long term monitoring of environmental changes. Unfortunately in the past attaching accurate positions to observations has been difficult. It is only with the advent of space geodesy and the availability of high resolution remotely sensed imagery that spatial positions can readily be acquired within an adequate accuracy.

Given the environmental conditions and the inaccessibility of many parts of Antarctica it has been, and often still is, difficult to conduct surveys and monitoring programmes with a complete spatial coverage of the region of interest. As a consequence many datasets are spatially incomplete or restricted to rather small, well defined but disperse areas.

Consequently, to leverage the full power of a framework for spatial integration of different datasets an SDI for Antarctic research should be capable of handling data with inaccurate spatial references and incomplete spatial coverage in a simple, consistent and robust way.

1.3 Objective and Outline

The objective of this work is to provide insight into the concepts and technologies of components of a modern SDI and to evaluate how these might be applied to the management of often inexact and fragmentary spatial data. The focus is on implementation and evaluation of a selected subset of relevant open standards and specifications applied to a use case in Antarctica.

The hypothesis is that the concept of an open standards based, service-oriented Spatial Data Infrastructure can successfully be applied to a domain which typically features inaccurate and incomplete spatial data.

The use case and data for the investigation is provided by the SCAR King George Island GIS Project. This project provides spatial framework data for what can be called the most crowded place in Antarctica. The SCAR KGIS Project has to operate in a multi-national and multi-disciplinary environment and integration of legacy data from multiple sources is one of the main aspects of the project work. It provides a well-suited test bed to evaluate the applicability of SDI components in Antarctica.

The measure to verify or discard the hypothesis is to analyse where the implementation of an open standards based spatial data infrastructure can support a more effective operation of existing data sharing policies within the Antarctic community as compared to the 'old style' data distribution of simply passing data sets around.

If an SDI like structure could successfully be implemented for the King George Island GIS project a tangible result of the study would be an operational spatial data management environment for the island – something that has been suggested since the early 1990ties (HARRIS 1991b, HARRIS 1993).

The results of the study hopefully can contribute to implement an SDI for Antarctica which is of use to the wider Antarctic community. A strong motivation for the work is to support the establishment of the Antarctic Spatial Data Infrastructure in a timely manner. In 2007-09 a major science event will take place in Antarctica.

The forthcoming International Polar Year (IPY) 2007-09 is an initiative led by ICSU comprising coordinated, interdisciplinary scientific research and observations in the Earth's polar regions. AntSDI has the potential to supply the adequate means to spatially enable the IPY data and information management in a consistent, robust way to support multi-disciplinary data-mining and analysis and to leave a lasting legacy of benchmark data to monitor environmental change.

As an introduction to SDIs in the following chapter definitions and typologies of SDIs are presented. Open standards are essential for AntSDI. With ISO/TC211 and OGC two standardising bodies at an international level are briefly described. Then the emerging Antarctic Spatial Data Infrastructure is introduced. People and policies play a crucial role for AntSDI. The political environment in which AntSDI has to operate includes the Antarctic Treaty System and SCAR's data management policy. The driving force that establishes AntSDI is the SCAR Expert Group on Geographic Information. Actors within AntSDI are introduced. With already existing building blocks of AntSDI concludes the second chapter.

The third chapter is devoted to the SCAR King George Island GIS project which provides the test bed for implementing components of a Spatial Data Infrastructure for Antarctic data. The specific settings of King George Island are presented, which qualify the KGIS project as a pilot project. The project history, the partners, the workflow and the deliverables are presented. Finally it is elaborated how KGIS can be used as a test bed for AntSDI components.

In the fourth chapter SDI components tested with the KGIS project are discussed. Four main themes are explored in some detail: framework data, place-names, common semantics, and delivery mechanisms and portrayal services. The place-names section plays a pre-eminent role as this has been a first SCAR EGGI endorsed detailed pilot study on the applicability of the SCAR Composite Gazetteer to large scale applications. Each section first presents some background materials for the specific topic. Then relevant existing SCAR policies and enabling technologies are presented. The respective implementation in KGIS is described. Each section concludes with what can be learned from the KGIS case for AntSDI.

The fifth chapter of the book reflects the results of implementing AntSDI components in the KGIS project.

The last chapter provides an outlook on the potential of a successful SDI implementation for the International Polar Year 2007-09 and identifies issues where future research is required.

1.3.1 A Note on Terminology

The terms used for the specific type of data that form an essential part of an SDI include geographic data, spatial data, or geospatial data. In this text the terms spatial and geospatial data are used as synonyms describing data that is referenced to a location on earth. This reference might be described in four dimensions including time. For the term geographic data we follow BERRY (1964) and SINTON (1978) in that geographic data is about space, time, and theme, which is not always the case with spatial data.

2 Setting the Scene: Introducing Spatial Data Infrastructures and AntSDI

2.1 What is an SDI?

Many authors compare spatial data infrastructures (SDI) to any other form of an infrastructure, such as railways, or power lines (PHILLIPS ET AL 1999, GSDI 2004). A basic concept of such an infrastructure is that it provides for members of the relevant community to make use of it. The infrastructure is simply available and taken for granted, although there may be a fee for the right to use it. The users basically do not care how the infrastructure works or who makes it work.

A spatial data infrastructure is “about the facilitation and coordination of the exchange and sharing of spatial data between stakeholders in the spatial community” (CROMPVOETS ET AL., 2004).

There are a number of different definitions of an SDI. Commonly used is the definition referred to in the GSDI Cookbook where the term SDI denotes “the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. The SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general.” (GSDI, 2004, p. 8).

With a strong notion on the term infrastructure the German Federal Mapping Authority defines an SDI as the combination of spatial data, access networks, services and standards. The organisational aspects, though regarded as necessary to set up and maintain the SDI, are not considered part of the infrastructure (BKG, 2003).

GROOT AND MCLAUGHLIN include the organisational aspects and define a Geospatial Data Infrastructure as “the networked geospatial databases and data handling facilities, the complex of institutional, organizational, technological, human, and economic resources which interact with one another and underpin the design, implementation, and maintenance of mechanisms facilitating the sharing, access to, and responsible use of geospatial data at an affordable cost for a specific application domain or enterprise.” (GROOT AND MCLAUGHLIN, 2000, p.5)

RAJABIFARD ET AL suggest a rather broad definition in stating that an SDI is “an initiative which is defined in many different ways, however its common intent is to create an environment in which all stakeholders can cooperate with each other and interact with technology to better achieve their objectives at different political/administrative levels” (RAJABIFARD ET AL., 2003, p. 21). Here the focus is more process-oriented and towards the stakeholders in a spatial data

Figure 2-1: Relations between SDI components. Source: Rajabifard et al 2003, modified.

infrastructure. They then continue in distinguishing two categories of core components in an SDI. The interaction of people and data is identified as one category. The second category are the technological components including access networks, policies and specifications.

This definition suggests that data, services and end-users alone cannot be the sole constituents of an SDI but the concept of an SDI involves also issues related to interoperability, policies and networks. Anyone wishing to make use of the SDI must interact with the technological components and the policies related to the SDI. As a consequence policies and standards do not only contribute to the establishment of an SDI but should be regarded as an essential part of an SDI. They dynamically evolve over time according to the users' needs. This has important implications in terms of community involvement when building and further developing an SDI.

2.2 SDI Typologies and the Role of Open Standards

2.2.1 Hierarchical Levels of SDIs

SDI's can be established at different hierarchical levels. Commonly the levels are structured according to administrative units around which SDIs evolve. Following RAJABIFARD ET AL (2003) this generally leads to six levels of SDIs. The International Global Map project might be regarded as an SDI-like initiative at the global level. Note that there might be more than one global SDI. The European INSPIRE initiative can be considered an SDI initiative at the regional level. A good example for national efforts is the Canadian Geoconnections. Due to its federal structure SDI development in Germany occurs mainly at the state level. The lowest levels are represented by local or corporate SDIs.

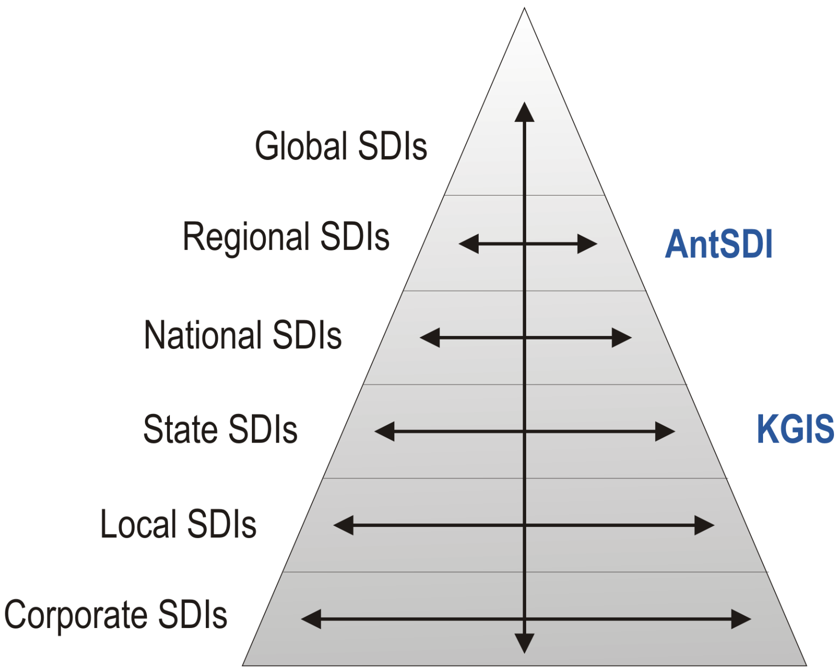

Figure 2-2: Hierarchical levels of SDIs. Source: Rajabifard et al 2003, modified.

Relationships between SDIs at different hierarchical levels include impacts from the top level to the lower level, e.g. in prescribing policies, but also from the lower to the upper level (RAJABIFARD ET AL 2000). Horizontal inter-relationships do also occur, but are less well investigated.

2.2.2 First and Second Generation SDIs

Following RAJABIFARD ET AL (2003) and MASSER (2005) it can be distinguished between first and second generation SDI initiatives. The main difference between the two is the shift from a product-oriented (data-driven) model, to a process-oriented (user-driven) model. This is a useful concept as it helps to analyze the rationale and the motivation of the players involved in an SDI initiative.

The creation of integrated, seamless data-bases was to a large extent the key driver of the first generation, the main actors tended to be national mapping organizations and other data producers.

The transformation into a second generation SDI involves the shift from the data producer's perspective to the data user's perspective. The main driving forces behind those SDIs are data sharing and re-use of data collected by a wide range of institutions for divers purposes.

This change in focus is associated with a shift from the centralized structures typical of first generation SDIs to the paradigm of decentralized and distributed networks of interoperable data and resources.

For the first generation data was the key driver, in the second generation it is the use of the data. This implies the important role of facilitation and coordination in an SDI and the involvement of people. The techno-centric approach of the first generation is replaced by a more socio-technical viewpoint (RAJABIFARD ET AL 2003). Consequently it is increasingly recognized that even if technological barriers would successfully be overcome, the success of the SDI will depend on how well the implementation addresses the respective community barriers.

The technical aspect of second generation SDIs is characterized by a service oriented architecture. A web service is a self-contained, self-describing modular application that can be published, located and dynamically invoked across the internet. A services provides data and processing functionality according to the users needs. A typical example of a spatially enabled web service is a web map services that delivers a spatial and thematic subset of a spatial data set as requested by the user transformed into a spatially referenced image.

2.2.3 The Relevance of Open and Accepted Standards

Standards provide for portability, interoperability, and maintainability (CROSWELL 2000). They allow to move data, software, and applications among multiple computers and operating systems, they ensure the ability to connect to and retrieve information from multiple systems, and they promote long-term and efficient use and upgrading of systems.

GI technology has moved on from monolithic and closed systems to open and interoperable systems with distributed data and functionality. Consequently standardization in the field of Geographic Information has changed its focus from specifying data formats for interchange of spatial data between different systems to specifying interfaces for GI services that provide access to both data and functionality (MCKEE, 2001).

Given the multinational context of SCAR activities the implementation of standards and specifications based on national standards by one single country is not easily acceptable for most other countries. Standards introduced and already approved at an international level are easier to promote within the community and appear less biased in favour of one country.

The maturing of several standards and specification setting processes ensures planning reliability and now paves the way to actually build networks of spatially enabled, distributed data bases, services and applications that draw on such standards. In the field of standardizing Geographic Information technology there are two main organizations at the international level. The ISO Technical Committee 211 and the Open Geospatial Consortium.

2.2.4 The Work of ISO TC211

The International Organisation for Standardisation (ISO) has set up a technical committee concerned with standardization in the field of geographic information, called ISO Technical Committee 211 Geographic Information / Geomatics (ISO/TC211). ISO/TC211 aims to establish a set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. The work includes standards on definition and description of data, data acquisition, processing, analysis, access, presentation and transfer of spatial data in digital form between different systems users and locations.

Members of ISO/TC211 are mainly representatives from national standardization organizations, but include also the Open Geospatial Consortium, international professional bodies such as the International Federation of Surveyors (FIG), the International Cartographic Association (ICA), UN agencies, and sectoral bodies such as the Digital Geographic Information Working Group (DGIWG).

ISO/TC211 follows the rigid ISO scheme in developing standards based on consensus. The work programme of ISO TC211 comprises more than 40 single projects with about 20 standards already published.

SCAR has Liaison status to TC211 to ensure consideration of specific Antarctic concerns and to be able to actively participate in the development of early test bed applications. Relevant ISO TC 211 standards that are being used or are under consideration to establish AntSDI include for example ISO 19110 concerned with a methodology for Feature Cataloguing, ISO 19115 on Metadata, or ISO 19136 on Geography Mark-up Language (GML), an XML dialect to encode spatial data.

2.2.5 The Open Geospatial Consortium

Founded in 1994 the Open Geospatial Consortium (OGC, formerly known as Open GIS Consortium) is an international not-for-profit membership organization with currently 282 members from 32 countries. It comprises 98 members from the academic sector, 113 industry members, and the rest from the governmental sector (ranging from local to international level). The majority of the members originates from North America (136) and Europe (107).

The goal of OGC is "to lead the global development, promotion and harmonization of open standards and architectures that enable the integration of geospatial data and services into user applications and advance the formation of related market opportunities." (OGC 2003a). The work of OGC is targeted at integrating spatial data and geoprocessing into mainstream computing and the wider information infrastructure.

The fundamental concepts around which the OGC specifications evolve are described in the OGC Reference Model (OGC 2003a).

OGC is dedicated to the development of interface specifications that support open access to geographic information and geospatial processing. The Open GIS Consortium develops and provides, through a membership submission and consensus process, implementation-level technical specifications for interfaces to geospatial processes and geospatial information.

OGC interface specifications for web services (e.g. OGC Web Feature Service, OGC Web Map Service) have become widespread and are implemented in many software packages.

2.3 AntSDI: The Emerging Antarctic Spatial Data Infrastructure

People, institutions and policies play an important role within SDIs. In the following the main stakeholders in the emerging Antarctic Spatial Data Infrastructure are introduced.

2.3.1 The Institutional Background

2.3.1.1 The Antarctic Treaty System and the Committee on Environmental Protection

The whole complex of arrangements established to coordinate relations among states with respect to Antarctica is called the Antarctic Treaty System (ATS). The ATS includes the Antarctic Treaty itself, the Protocol on Environmental Protection to the Antarctic Treaty, two separate conventions for the Conservation of Antarctic Seals and on the Conservation of Antarctic Marine Living Resources, and recommendations and measures adopted at meetings of the Antarctic Treaty Parties.

The Antarctic Treaty was established in 1959 and signed by 12 states. Today the Treaty has 29 consultative parties and 20 acceding states. The foremost purpose of the Treaty is to ensure "in the interest of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes". It provides "freedom of scientific investigation in Antarctica" and promotes "international cooperation in scientific investigation in Antarctica", it bans "any measures of a military nature" and prohibits nuclear explosions or nuclear waste disposal (U.S. DEPARTMENT OF STATE, 2002). The Treaty applies to the area south of 60° South.

In Article III of the Antarctic Treaty it is stated explicitly that "Scientific observations and results from Antarctica shall be exchanged and made freely available." (ANTARCTIC TREATY 1959, Article III.1.c).

Environmental protection has always been one of the major topics of cooperation between the Antarctic Treaty members. In 1991 the Protocol on Environmental Protection to the Antarctic Treaty was signed and entered into force in 1998. This protocol to the Antarctic Treaty established the Committee on Environmental Protection (CEP). The functions of the CEP are to provide advice and formulate recommendations to the Antarctic Treaty parties in relation to the Protocol including application and implementation of environmental impact assessment procedures, means to minimise and mitigate environmental impacts, procedures for response actions to environmental emergencies, the operation of the Antarctic Protected Area system, and the collection, archiving, and exchange of information related to environmental protection (ATCPs 1991).

Both the Antarctic Treaty System in general and the CEP might benefit from AntSDI with respect to reporting requirements (inspections of stations, emergencies, etc.) and specifically with respect to the Antarctic Protected Area system. In terms of positions for example many protected areas currently only have a rough description of their limits. AntSDI would support both sound spatial data management as well as spatial information exchange.

2.3.1.2 The Scientific Committee on Antarctic Research

The institutional background for AntSDI is set by the SCAR constitution which calls SCAR member countries to facilitate free and unrestricted access to Antarctic scientific data (SCAR 2004a).

The Scientific Committee on Antarctic Research (SCAR) is the leading independent organization for facilitating and coordinating Antarctic Research. SCAR was formed in 1958 during the International Geophysical Year. It is an interdisciplinary body of the International Council for Science (ICSU). Currently 28 countries are full members and four countries are associate members. Additionally to its primary scientific role, SCAR also provides scientific advice to the Antarctic Treaty Consultative Meetings and other organizations on issues of science and conservation related to the management of Antarctica and the Southern Ocean. In that role, SCAR has made many recommendations which have been included into Antarctic Treaty instruments and into the various international agreements which provide protection for the ecology and environment of Antarctica.

The Antarctic region as defined for the purpose of SCAR includes “Antarctica, its offshore islands, and the surrounding ocean including the Antarctic Circumpolar Current, the northern boundary of which is the Subantarctic Front. Subantarctic islands that lie north of the Subantarctic Front and yet fall into SCAR’s area of interest include Ile Amsterdam, Ile St. Paul, Macquarie Island and Gough Island” (SCAR 2004a).

The SCAR Strategic Plan 2004-21010 states as one of the five main objects that it aims to achieve “to facilitate free and unrestricted access to Antarctic scientific data and information” (SCAR 2004b, p.7). Combining and integrating data sets of different provenience is seen as a potent means to realise the full value of much of the scientific work and SCAR sees its role in adding this value.

> To improve the use of geospatial information, SCAR aims to encourage the establishment of an Antarctic Spatial Data infrastructure (AntSDI) including fundamental geographic information products and related policies, specifications and enabling technologies.
> […]
> Full implementation of and support for the Antarctic Spatial Data Infrastructure will be essential to ensure the spatial integrity of data collected and to be able to make use of the power of geographic location in data discovery and retrieval, data mining, and data analysis.

Figure 2-3:The role of AntSDI in the Long Term Strategic Plan of SCAR. Source: SCAR 2004b, p. 14.

SCAR holds no data of its own, and it is recognized that one of the most useful services that it can provide to the community is a high level data and information management system to support interdisciplinary research in Antarctica. SCAR has recognized the vital role of spatial location to integrate and communicate science data and information.

Specifically SCAR aims to

- encourage the maximum use of existing data,
- encourage the development and operation of data collection, storage, retrieval and dissemination mechanisms for the common good,
- encourage the community to ensure that these mechanisms are effective. (SCAR 2004b, p. 13).

The scientific business of SCAR is conducted by three Standing Scientific Groups which represent the scientific disciplines active in Antarctic research, namely geosciences, life sciences and physical sciences. Expert Groups within the Standing Scientific Groups address specific research topics.

The Expert Group with the mandate to handle spatial data management issues is the Expert Group on Geospatial Information (EGGI).

EGGI operates in two programmes – Geodesy and Geographic Information. The terms of reference of the Geographic Information programme are (SCAR EGGI 2004):

Understanding that geographic location is a fundamental element for integrating and communicating Antarctic science knowledge, the GI group aims to create an Antarctic spatial data infrastructure (AntSDI) by:

- Providing Antarctic fundamental geographic information products and policies in support
- of science programs
- Integrating and coordinating Antarctic mapping and GIS programs
- Promoting open standards approach to support free and unrestricted data access
- Promoting capacity building within all SCAR nations.

The Geographic Information programme operates a range of Geographic Information projects and the vision is to establish AntSDI.

2.3.2 The Community: Data Users and Producers

2.3.2.1 SCAR

The primarily concern of SCAR is to facilitate scientific work in Antarctica. Consequently the user community consists of researchers from a wide variety of disciplines within life sciences, geosciences and physical sciences. Typical use cases for spatial data are cross-discipline analysis such as feeding grounds of seals compared to sea ice extend. Naturally AntSDI has to deal with a broad user community and a variety of application domains. This has implications for example on a common feature catalogue.

For specific areas of interest framework data such as base topography is produced by organizations with established procedures and well defined standards for mapping. But a characteristic of the user community is that large amounts of data are produced by the scientists themselves - users at the same time are producers as well. As a consequence of having many small groups from entirely different disciplines as data producers there are almost no common standardised procedures on data collection. Although the use of GPS has become prevalent in the last years positional accuracy of data still varies greatly and most often it is not documented.

Increasingly data are re-used by other research groups for entirely different purposes than the producers intention. Data accessibility over the internet here becomes both a blessing and a curse. Fairly often it is difficult or impossible to judge whether available data is fit for the envisaged purpose. Metadata plays a crucial role. Currently the only endorsed metadata standard is the DIF format. As a matter of fact most institutions adhere to a proprietary standard (if at all).

2.3.2.2 ATS / CEP

The Antarctic Treaty System, mainly through the CEP is another potential user of a Spatial Data Infrastructure for Antarctica. Environmental issues being the major concern of the CEP the interests here are for example positioning of boundaries of protected areas or spatially referenced data for environmental impact assessment.

CEP produces no data of its own. Management plans for protected areas, environmental impact assessments, and reporting are provided by the respective member countries. CEP establishes and oversees the procedures related to such activities and is concerned with information exchange on such matters. Consequently CEP potentially has great interest in framework data to which management plans and impact evaluations can be referenced and which allow to index the information it is responsible for based on location.

2.3.2.3 COMNAP

In 1988 The Committee of Managers of National Antarctic Programmes (COMNAP) was established to facilitate liaison between the managers of national agencies responsible for the conduct of logistics operations in support of Antarctic science. COMNAP has its expertise in the realm of operational implementation of activities in Antarctica, safety, technology and information sharing (Fowler, 2000). The membership currently includes twenty-nine countries from the Americas, Africa, Asia, Europe and Oceania.

COMNAP and SCAR are closely connected in a co-operative relationship. This is reflected in biannual coordinated meeting arrangements, in joint task or planning groups and in the joint response or input to the Antarctic Treaty Consultative Meetings (ATCMs) when appropriate. Dealing with the conduct of operations and related information exchange, air safety, waste management, and the like activities of COMNAP members could directly benefit from AntSDI. Benefits might include enhanced information sharing and reporting procedures, immediate access to critical data through web services, or improved reporting e.g. to assess cumulative effects of activities at specific sites.

2.3.2.4 JCADM

The Joint Committee on Antarctic Data Management (JCADM) is a joint committee of SCAR and COMNAP. It was established in 1997. Its purpose is to advise SCAR and COMNAP on the management of Antarctic data. JCADM coordinates the development of the Antarctic Data Directory System, which is composed of the Antarctic Master Directory (AMD), and the National Antarctic Data Centres.

JCADM is neither a potential data producer nor data user. Its involvement with AntSDI lies in the mandate to advise on Antarctic data management. JCADM is able to provide amongst other essential input and guidance related to metadata standards and catalogues.

2.3.2.5 IAATO

The International Association of Antarctic Tour Operators is an industry organization to advocate, promote, and practice safe and environmentally responsible private-sector travel to the Antarctic. The membership comprises ship operators, land-based operators, ship agents, travel agents, one government office and travel companies that charter ships and airplanes from existing operators.

IAATO is an industry group that has resolved to set the highest possible tourism operating standards in its effort to protect Antarctica. This effort is unique, and the challenge to maintain environmentally responsible tourism exists to this extent in no other region of the world. IAATO established procedures and guidelines that should help to ensure safe and environmentally friendly private-sector travel to the Antarctic. These include regulations and restrictions on numbers of people ashore; staff-to-passenger ratios; site-specific and activity-specific guidelines; wildlife watching; pre- and post-visit activity reporting; contingency and emergency medical evacuation plans; and more.

IAATO's potential interest in AntSDI lies in being able to access framework data to reference reporting and statistics to locations.

2.3.3 Building Blocks for AntSDI

AntSDI is not being build from scratch. SCAR EGGI and its predecessors SCAR Working Group Cartography and SCAR Working Group on Geodesy and Geographic Information are concerned with standardizing and making accessible geographic information from Antarctica since 1958.

Projects of the group over the years have produced geographic information resources that are of vital interest to the Antarctic community and that are in wide use since many years. These products form building blocks of AntSDI on a continental scale.

2.3.3.1 The SCAR ADD and other Topographic Datasets

The flagship of the products of EGGI is the Antarctic Digital Database (ADD), a continent wide dataset including the coastline, elevation, and location of stations. The Antarctic Digital Database was created and is managed by the Mapping and Geographic Information Centre of the British Antarctic Survey. The first edition was published in 1993 on CD ROM, the current version is available at http://www.add.scar.org for download on the Internet. The ADD is being transformed to implement the SCAR Feature Catalogue and will be made available as an OGC Web Feature Service. This work is supported by the Cybercartographic Atlas of Antarctica Project of Carleton University, Canada.

There are numerous medium to large scale spatial data bases that cover parts of Antarctica. Many of these databases are available online as downloadable data sets or through online atlases. Examples of online atlases include the USGS Atlas of Antarctic Research (USGS, 2005) or the Australian Antarctic Division Atlas (AADC 2005a). The spatial data from the Australian Antarctic Division already implements the SCAR Feature Catalogue.

2.3.3.2 The SCAR Composite Gazetteer of Antarctica

The standardisation of the Antarctic toponymy is a complex item not easily solved. Antarctica does not fall under the sovereignty of any one nation. There are many national gazetteers for Antarctic place-names. In 1992 the need for a composite gazetteer of Antarctica was recognized by the SCAR Working Group on Geodesy and Geographic Information

In the following years the Composite Gazetteer of Antarctica (CGA) was collated by Italy. The database contains all the place-names officially given to Antarctic (i.e. south of 60° South) geographic features by 23 countries, with the addition of the Antarctic undersea features taken from the General Bathymetric Chart of the Ocean. The database currently includes 35272 official names, corresponding to 17668 geographic features (SCAR, 2005a).

At present the CGA is available as downloadable data base. There is also a web interface that provides for interactive search for place-names and the respective coordinates. The next step in terms of accessibility should be to make the CGA available as a web service for machine to machine communication to provide services for finding place-names in a given area and services for geocoding of named locations.

2.3.3.3 The SCAR Map Catalogue

The SCAR Map Catalogue is a catalogue of Antarctic region maps published by SCAR member countries. The current version is a digital version managed and hosted by the Australian Antarctic Data Centre (AADC 2005b). It lists about 4000 maps. Associated information includes spatial coverage, scale, themes and publication details.

3 The SCAR KGIS Project

3.1 King George Island

3.1.1 General Description

King George Island is the largest island in the South Shetland Islands archipelago. The South Shetlands are situated south of Drake Passage, about 1200 km off Cape Horn, on the northern flank of the Antarctic Peninsula, from which separated by the Bransfield Strait with about 120km distance between the islands and the Antarctic continent.

The island lies in the area covered by the Antarctic Treaty (ANTARCTIC TREATY 1959) and is in the territories claimed by Argentina, Chile and the United Kingdom. However, since the Antarctic Treaty was signed in 1959 all territorial claims have been frozen.

King George Island is situated in maritime Antarctica. The climate is appreciably less severe than further south. Although temperatures fall below 0°C each month, in summer months the average temperature reaches almost 2°C and precipitation often takes the form of rain (BRAUN ET AL 2001a, RAKUSA-SUSZEWSKI 2002, KEJNA 2003). The island is accessible for several summer months even by vessels without ice protection.

King George Island is dominated by a huge ice cap with only 8,5% of the island's surface being ice-free (Tab. 1.1). The coasts of the island are largely formed by ice cliffs. The tectonic settings influence to a great extent the topography of the island and control the location and shape of the ice-fields and of many inlets and coves (TOKARSKI 1987, BIRKENMAJER 1998).

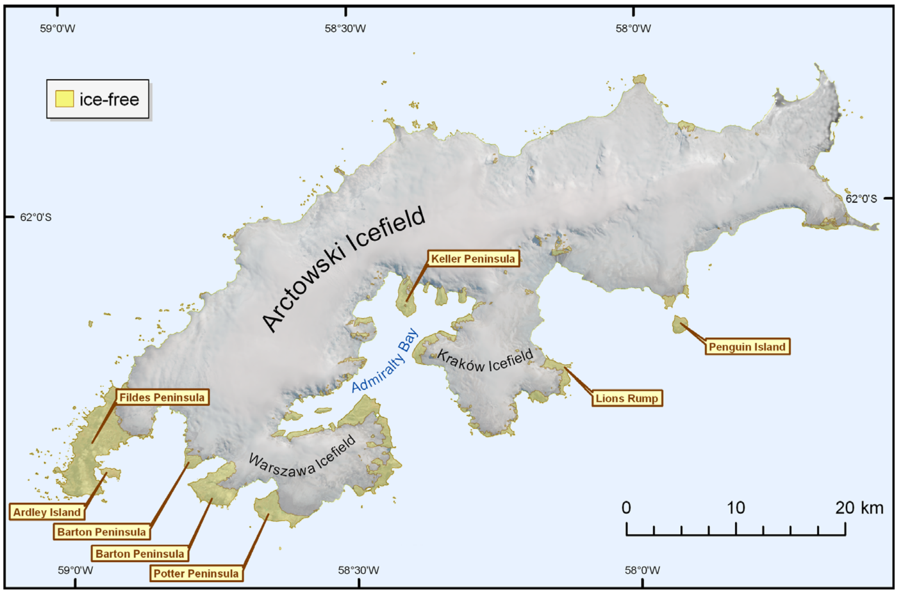

Figure 3-1:Main ice-fields and ice-free areas on King George Island.

The main Arctowski Icefield consists of several unnamed ice domes including the highest point of the island that reaches about 705m a.s.l. The mean ice thickness is about 200m (MACHERET ET AL 1997, MACHERET ET AL 1999, SIMOES ET AL 1999), the maximum measured ice-thickness is almost 400m (PFENDER 1999). The northern slopes of Arctwoski Icefield are gently inclined towards the coast. Steeper outlet glaciers and ice-falls drain into the large, fjord-like Admiralty Bay (about 130km²), one of the three main bays on the South coast. Krakow Icefield (about 75km²) and

Warszawa Icefield (about 70km²) are two minor icefields covering the peninsulas bordering Admiralty Bay. Observations based on remotely sensed data and in situ observations from the last five decades suggest that most glaciers on the island are retreating (e.g. KEJNA ET AL 1998, PARK ET AL 1998, SIMOES ET AL 1999, BIRKENMAJER 2002, BRAUN ET AL 2002, CHUNG ET AL 2004).

Site	Area [km²]
main landmass (total)	1150,4
ice free area (total)	97,7
Fildes Peninsual	29,3
Barton Peninsula	9,5
Potter Peninsula	6,5
Admiralty Bay Western Sh.	12,6
Keller Peninsula	4,1
Lions Rump	2,8
Admiralty Bay Eastern Shore (Vieville Glacier to Wanda Glacier)	2,3
Weaver Peninsula	1,8
Penguin Island	1,7
Ardley Island	1,2

Table 3-1: Areal data for King George Island.

The geomorphology of the ice-free areas of King George Island shows the typical assemblage of periglacial forms including patterned ground, solifluction lobes, and stone stripes (e.g. ZAMORUYEV 1968, BARSCH ET AL 1985, ZHU ET AL 1996, BIRKEMAJER 1997, LOPEZ-MARTINEZ ET AL 2002, DEL VALLE 2004). The active layer is about 0.5m-1.5m on average (e.g. BLUME ET AL. 2002).

The vegetation on the ice-free areas on King George Island can be described as a poorly developed tundra consisting almost entirely of cryptogams with only two native species of vascular plants: Antarctic hairgrass *Deschampsia antarctica* and Antarctic pearlwort *Colobanthus quitensis* (LINDSAY 1971, OCHYRA 1998, HU 1998, OLECH 2002). Mosses predominate in more sheltered areas, lichens in more extreme habitat conditions. Mosses are estimated to be present on King George Island with more than 60 species (OCHYRA 1998), lichens with more than 190 species (OLECH 2000). The introduction of alien vascular plant species to King George Island has been described for Admiralty Bay with recordings of *Poa annua* (OLECH 1996). Some authors suggest that the distribution of *Deschampsia antarctica* is growing due to climate change observed in the area (LEWIS SMITH 2003, GEHRIGHAUSEN ET AL 2003, KIM ET AL 2004).

King George Island features an abundant wildlife. Sea Elephants (*Mirounga leonina*) and fur seals (*Arctocephalus gazella*) use the beaches to haul out, breed and moult. Weddell Seals (*Leptonychotes weddelli*), Crabeater Seals (*Lobodon carcinophaga*), and Leopard Seals (*Hydrurga leptonyx*) can be seen as occasional visitors to the island (e.g. VERGANI ET AL 1990, RAKUSA-SUSZEWSKI 1993B, VERGANI ET AL 2001).

Penguin colonies are populated by Gentoo Penguins (*Pygoscelis papua*), Adélie Penguins (*Pygoscelus adeliea*), and Chinstrap Penguins (*Pygoscelis antarctica*). Flying birds breeding on King George Island include Southern Giant Petrels (*Macronectes giganteus*) and Cape Petrels (*Daption capense*), Wilson's Storm-petrels (*Oceanites oceanicus*) and Black-bellied Storm-petrels (*Fregatta tropica*), Skuas (*Cattharacta spec.*), Shags (*Phalocrocorax [atriceps]*), Kelp Gulls (*Larus Domincanus*), Antarctic Terns (*Sterna vittata*), and Pale-faced Sheathbills (*Chionis alba*) (e.g. KAMENEV 1987, AGUIRRE 1995, HAHN ET AL 1998).

Less obvious to the human eye but present in considerable large numbers are algae, bacteriae, mites and springtails (e.g. BÖLTER 1997, HOGG ET AL 2002).

Compared to Antarctic standards the ecosystems on King George Island are diverse and complex. Terrestrial life concentrates on the ice-free areas. The most productive period is the short summer when light and water is available to plants for growth and reproduction, marine mammals use the beaches to haul-out and reproduce and birds breed and raise their chicks. The spatial and temporal coincidence with human activities bears the potential for conflicting interests on the use of the few ice-free areas.

3.1.2 History of Human Activities on King George Island

King George Island bears a long history of human activities (Headland et al 1985). Based on somewhat dubious discoveries of stone spear heads dating to between 1500 BC and AD 1000 in sea bed fauna and flora samples from Admiralty Bay taken in the 1970ties it was suggested that there had been some pre-historic human presence in the South Shetland Islands. Careful examination of the spear heads indicated that these artefacts had been introduced to the samples subsequent to their collection and the hypothesis of early aboriginal discovery was laid to rest (STEHBERG 1983, STEHBERG ET AL 1983, LEWIS-SMITH ET AL 1987, CAMPBELL 2000).

The first recorded sighting of the island was made by the Englishman William Smith in February 1819, who during a trading voyage from Buenos Aires to Valparaiso was blown far to the south of Cape Horn. In his following journey in October 1819 Smith landed near North Foreland to take possession of the land for King George III after whom he named the island. In February 1820 Edward Bransfield repeated the ceremony at King George Bay (LEE 1913, GOULD 1941, JONES 1975, CAMPBELL 2000).

Following Smith's discovery fur sealers began exploiting at the South Shetlands (JONES 1985A, JONES 9185B, HEADLAND ET AL 1985, LEWIS-SMITH ET AL 1987, STEHBERG ET AL 1983, BERGUNO 1993, STEHBERG ET AL 1995). As there was a strong contest on good sealing beaches much secrecy was about these early commercial activities and not much details of the sealers voyages have survived. Nevertheless, due to the high prices for fur seal skins on the Chinese market the seal stock exploitation begun immediately. In the season 1820-21 there were at least 46 ships around the islands (JONES 1975). By the end of 1822, only three years after the discovery of the island, the fur seal population was almost exterminated (LEWIS-SMITH ET AL 1987) and the sealers' activities ceased. Of these early activities several remnants on King George Island have been described, for example the ruins of stone walls of shelters at Point Hennequin, Admiralty Bay, at Turret Point opposite Penguin Island (LEWIS-SMITH ET AL 1987), and at Suffield Point on Fildes Peninsula (STEHBERG ET AL 1983).

The years from 1843 to 1854 and from 1871 to 1880 saw brief revivals of the seal industry. Although at a comparatively minor level these had a strong impact on the recovery of the fur seal population by further reducing the surviving stock (HEADLAND ET AL 1985). Only since 1970ties the fur seal populations in the South Shetlands have started to recover. Today the numbers are recovering (RAKUSA-SUSZEWSKI 1993B, VALLEJOS ET AL 2000, GOEBEL ET AL 2003, HUCKE-GAETE ET AL 2004) and there is a SCAR recommendation to remove the status of a specially protected species under the Antarctic Treaty System from *Arctocephalus gazella* (ATCM XXVIII 2005g).

In the mid and late 19th century the island has been visited and surveyed by a number of expeditions including Biscoe in 1832, Dumont d'Urville in 1840, and Wilkes in 1839. In March 1874 the German Eduard Dallmann visited the island and left a metal plaque on Potter Peninsula to record his visit. This is now the oldest artefact designated Historic Monument under the Antarctic Treaty.

The next profitable business to take place in the area was the modern whaling industry. In 1906 the floating whaling factory Admiralen, escorted with the whale-catchers Hauken and Ornen arrived at Admiralty Bay on January 28. The Admiralen returned to the Falkland Islands on February 27, 1906. Although in the next season Deception Island became the preferred port for the floating whaling factories Admiralty Bay continued to be an important harbour for whale-catchers. Not only the abundant whale bones found around the beaches of Admiralty Bay that are leftovers of carcases flensed alongside the Admiralen, the harpoons assembled on the beaches and displayed at Arctowski station (KITTEL 2001), or the wooden barrels at Barrell Point, Ezcurra Inlet, but also place-names like Lange Glacier, named after Alexander Lange, manager of the company that operated the Admiralen, Admiralen Peak, and Hauken and Ornen Rocks evoke that epoch. In 1908 the floating factory Telephone sank at the entry of Admiralty Bay. Telephone Rocks and Telephone Point are reminders of that event.

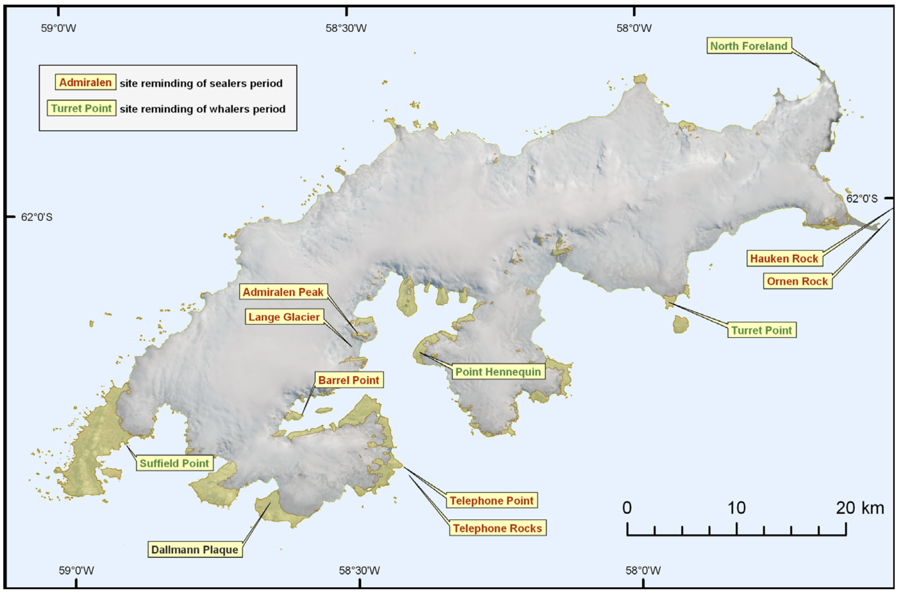

Figure 3-2: Places reminding at the sealers and whalers periods.

The establishment of stations by various nationalities began in January 1947 when Base G, a small hut, was built on Keller Peninsula by the British Falkland Island Dependencies Survey. The base was soon expanded with larger buildings and was then in continual operations until 1961. During the International Geophysical Year 1957/59 several scientific programmes were carried out at Base G including a glaciological survey of the island (NOBLE 1965).

The Argentinean Navy erected a summer hut in the vicinity of Base G in summer 1947-48 and another small hut, named Teniente Jubany, at Potter Cove. In 1981-82 Jubany was enlarged and since then became a constantly operated station. Another Argentinean hut had been constructed on Ardley Island already in 1954. It was called Ardley and later renamed to Refugio Balve. Today there are two additional Argentinean refuges on Potter Peninsula, Refugio Elephante and Refugio Albatros.

The Soviet Union established the Bellingshausen Station on Fildes Peninsula in the summer 1967-68. Since then the station has been continuously manned. In 1972-73 a bunker depot for bulk fuel storage was set up 1.2 km to the North of Bellingshausen Station by the Soviets and a hut to support biological research was erected on the northern coast of Fildes Peninsula.

Chile established Presidente Frei Montalva station in the 1968-69 season. It is situated next to Bellingshausen Staion and has been continuously operated since. In the following years a refuge was erected at the margins of Bellingshausen Ice Dome. Close to Presidente Frei and Bellingshausen a 1,4 km long airstrip on ice-free ground and related operation facilities, called Teniente Rodolfo Marsh, have been constructed by Chile in 1979-80 and have been expanded since to receive larger wheeled aircraft including Hercules C-130 throughout the year (MOP 2005). In the summer 1981-82 a Chilean refuge was built on Ardley Island. In 1994 the Instituto Antartico Chileno opened the Base Cientifica Escudero next to Frei station.

A private expedition from Italy established a refuge, called Giacomo Bove, at Italian Valley in Ezcurra Inlet in 1976. It was occupied in January and February that year, but destroyed in the following summer (ZAVATTI 1976, GORI 2001).

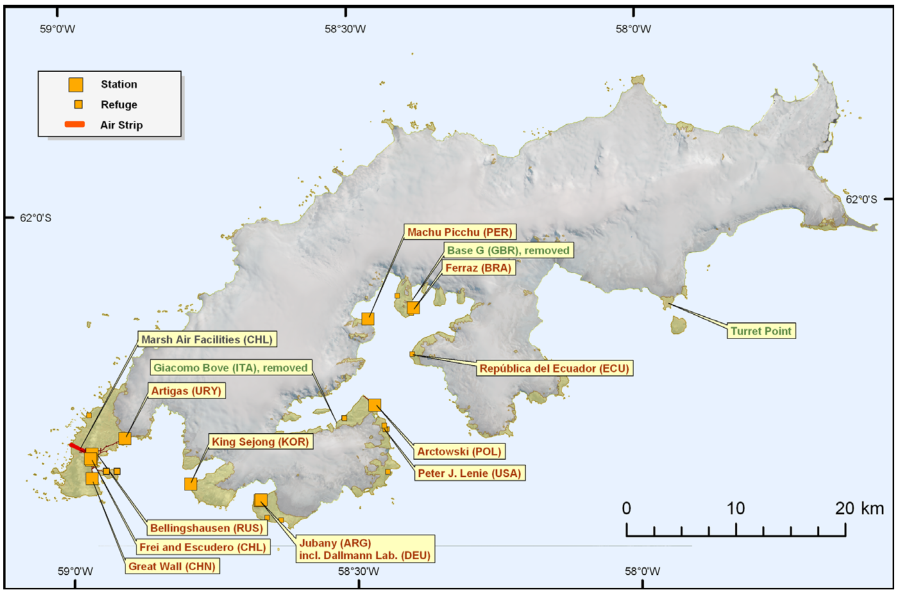

Figure 3-3: Stations and refuges on King George Island.

Near Point Thomas at Admiralty Bay the Polish station Henry Arctowski was set up in February 1977. It has been operating continuously since then (RAKUSA-SUSZEWSKI 1993a). Close to Point Thomas and at other locations in the area there are also removable Polish caravans functioning as summer field laboratories.

In 1978 a US research group established the Peter J. Lenie field station (a.k.a Copacabana) south of Arctowski station. The station has been used since during summer months mainly for a penguin monitoring programme.

In 1984 Brazil established the Commandante Ferraz Station on the Eastern coast of Keller Peninsula, since 1986 it is operated year round. There are two more small Brazilian refuges on Keller Peninsula. The refuge Padre Rambo on Fildes Peninsula had been established by Brazil in December 1985 and was in regular operation until 1990. After deterioration due to weathering the refuge was removed in December 2004 (ATCM XXVIII 2005h).

The Uruguayan Base Científica Antártica Artigas on Fildes Peninsula has been opened in December 1984 and is in continuous operation since. Only three month later in February 1985 China inaugurated the Great Wall Station, located on Fildes Peninsula, too, about 2,5 km south of Bellingshausen, Frei and Escudero stations.

Peru built the Machu Picchu Station at Crépin Point, Admiralty Bay, in 1988. The Station is currently used as summer only station. In the same year South Korea established the King Sejong Station at Barton Peninsula on the western coast of Maxwell Bay, which is operated year round since.

Ecuador has built a refuge at Hennequin Point in 1989, but this refuge has only irregularly been used during summers.

There had been plans by the Czech Republic to set up another station on King George Island. The locality designated for the station was Turret Point (ATCM XXIV 2001). These plans had been withdrawn in favour of a location on James Ross Island (ATCM XXVIII 2005d).

With eight year round stations, the air strip and associated facilities, two summer stations, and a couple of refuges King George Island has occasionally been portrayed as “the most crowded real estate in Antarctica” (P. Cooper). The human impact on the fragile ecosystems has raised concern for many years (e.g. MAY 1989, HARRIS 1991a, OLECH 1996, ASOC UNDATED, ZHAO 2000, ATCM XXVIII 2005a). A joint UK/Germany inspection team under Article VII of the Antarctic Treaty visited the area in 1999. Their report denotes the concentration of facilities on the island as “unique in Antarctica”, considered the impact of human activities in the South Shetland Islands “far greater than elsewhere in Antarctica” and judged the impact of the assemblage of stations around Maxwell Bay “far greater than the combined sum of the actual areas of the stations themselves.” Although it was noted that the co-location of stations provides for substantial advantages in terms of mutual support, including the possibility of shared facilities, they felt that duplication rather than integration of facilities is taking place. The inspection team concluded that “consideration could be given towards further enhancing co-operation” (ATCM XXIII 1999). In order to achieve a coordinated management of facilities and operations a common spatial framework data set is essential.

3.1.3 Tourism

Scientists and station personnel are not the only human visitors to the island. Scientist are largely outnumbered by the tourists visiting King George Island. The island has become a major tourism destination with well over 4000 visitors per year. Tourism is now a major activity in the Antarctic Treaty area and has expanded rapidly in recent years. Most of the tourism is ship based tourism with only short landing trips of the passengers to visit stations or areas with abundant wildlife. Penguin Island e.g. is a favourite tourist destination due to its wildlife (PFEIFFER ET AL. 2003, PFEIFFER ET AL 2004). The stations at Admiralty Bay and Maxwell Bay (including the post office at Frei Station) are often frequented by passengers from cruise-ships (e.g. DONACHIE 1993, IAATO 2005). In the summer 2003/04 Arctowski Station for example has received over 3000 visitors from cruise-ships and more than 2600 passengers landed on Penguin Island (IAATO 2005).

Antarctic land-based tourism is still in its infancy but its potential for rapid growth is recognized and regarded with some concern due to its potential impact on the environment caused by the required permanent infrastructure, additional transport, increased risk of introduction of pathogens, etc. (BAUER 2001, ATCM XXVIII 2005e, ATCM XXVIII 2005f).

King George Island is one of those areas in Antarctica where land-based tourism is already taking place. There are companies offering overnight stays at a hotel in Antarctica (which is part of the facilities of Teniete Marsh airstrip) or to camp and hike in Antarctica (which takes place on Fildes Peninsula). It is not yet clear with which instruments this growing business can be managed under the Antarctic Treaty System (ATCM XXVIII 2005f). But any management plan for such activities will have to include spatial data for example to describe locations of facilities, or to monitor and report activities to assess cumulative effects.

3.1.4 Protected Areas

Human activities and wildlife concentrate on the few ice-free areas, with the highest level of both human and wildlife activities taking place during the short summer. Most of the research and tourism activities are concentrated in the months from December to February. This is also the time for breeding and moulting of many avian and mammalian species. The conflicting interests call for regulations in order to minimize harmful human impact on the natural ecosystems.

The Antarctic Treaty System provides for setting aside areas for special protection or management. Formerly there had been adopted five categories of protected areas by the Antarctic Treaty Consultative Parties. These were called Sites of Special Scientific Interest (SSSIs), Specially Protected Areas (SPAs), Specially Reserved Areas (SRAs), Multiple-use Planning areas (MPAs), and Historic Sites and Monuments. Management plans had been required for all categories except for Historic Sites and Monuments. Annex V to the Protocol on Environmental Protection to the Antarctic Treaty (‘Madrid Protocol’), that entered into force in 1998, rationalizes these area designations, and distinguishes more clearly between managed and protected sites (PROTOCOL ON ENVIRONMENTAL PROTECTION 1991). To new categories have been established: Antarctic Specially Managed Areas (ASMAs) and Antarctic Specially Protected Areas (ASPAs). SSSIs and SPAs have been renumbered and designated ASPAs (ATCM XXV 2002). Entry into an ASMA does not require a permit but activities within such an area are directed by a Code of Conduct set out in the respective management plan. To enter an ASPA is prohibited except with a permit issued in accordance with the management plan.

On King George Island there are five sites protected as ASPAs under the Antarctic Treaty system, Admiralty Bay is designated an ASMA, and there are a couple of artefacts listed as Historic Sites and Monuments. An initiative to establish an ASMA for Fildes Peninsula has been started only very recently (ATCM XXVIII 2005a).

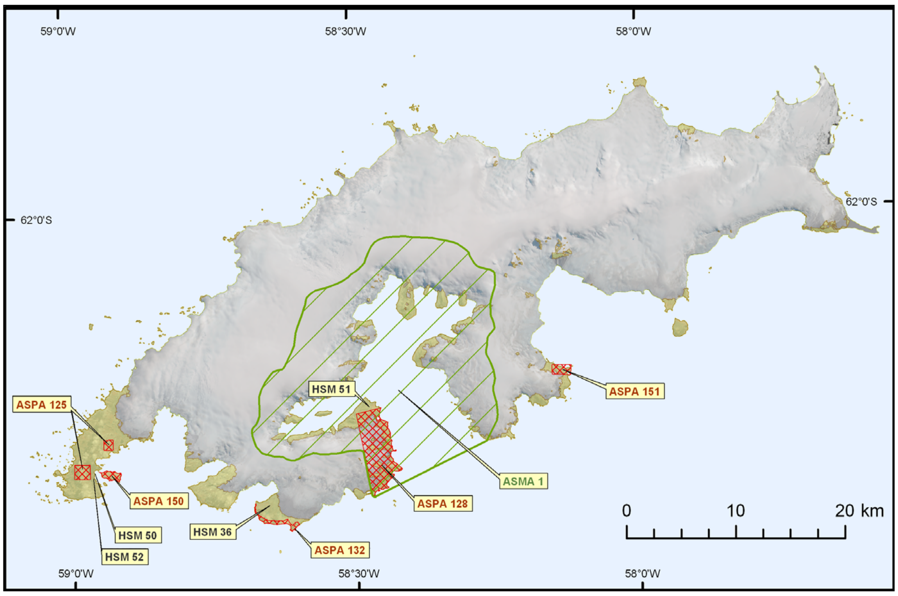

Figure 3-4:Protected and specially managed areas and historic monuments on King George Islands.

On Fildes Peninsula two separate areas form the ASPA 125, which has been established to protect fossil ichnites (ATCM VIII 1975). Parts of the Western shore of Admiralty Bay are under protection as ASPA 128 (CEP III 2000a) because of the diverse avian and mammalian fauna and the locally rich vegetation. ASPA 132 situated on Potter Peninsula protects coastal areas which host important bird colonies, marine mammal breeding areas and a diverse flora. (ATCM XXVIII 2005b). Lions Rump is protected as ASPA 151 for its ecological values. It is regarded as a reference site without human disturbance (CEP III 2000b). A site also protected for its fauna and flora but with about a hundred visitors each summer is Ardley Island, designated ASPA 150 (ATCM XXVIII 2005c).

On Potter Peninsula there is a metal plaque erected by Eduard Dallmann to commemorate the visit of his German expedition on 1 March 1874 on board *Grönland*, the first steamship to reach Antarctica, listed as Historic Site and Monument (HSM No. 36). A plaque mounted on a sea cliff south-west of the Chilean and Russian stations on Fildes Peninsula to commemorate the members of the first Polish Antarctic research expedition which landed there in February 1976 is protected as HSM 50. On a hill south of Arctowski Station is the location of the grave of Wlodzimierz Puchalski, surmounted by an iron cross. He was an artist and producer of documentary films and died in January 1979 whilst working at the Polish station (HSM 51). The monolith erected to honour the establishment of Great Wall Station in February 1985 is protected as HSM 52 (ATCM XXVI 2003).

The management plans require spatial information e.g. to describe locations of protected monuments and the limits of protected areas, specific management zones within ASMAs or ASPAs and to enable consistent reporting of activities to assess cumulative effects.

3.1.5 Research Activities

The ease of access to the island and the available infrastructure favours the conduct of research projects on King George Island.

Early research on King George Island focused on Geology (Ferguson 1921, Tyrell 1921, Tyrell 1945, Fourcade 1960, Hawkes 1961, Orlando 1963, Barton 1965). With the establishment of Base G glaciological investigation started (Hattersley-

SMITH 1951, NOBLE 1965). Scientific activities in Antarctica had been stimulated by the International Geophysical Year in 1957/59, and for example glaciological studies at base G had been promoted by IGY.

Since the 1980ties research activities on King George Island expanded rapidly including a growing number of scientist from countries without an Antarctic tradition hitherto. Although political interests might have guided the establishment of many bases on the island and the scientific output of some of the stations has been questioned (e.g. ATCM XXIII 1999), to many scientists a research project on King George Island has been the entry ticket to the Antarctic community.

Current research subjects include geology, geomorphology, pedology, climatology, meteorology, glaciology, astrophysics, limnology, and marine and terrestrial biology. The Northern Antarctic Peninsula region exhibits one of the world's strongest warming trends in the last decades (e.g. KING ET AL 1997, IPCC 2001, RAU 2004). It has been suggested that retreating glaciers (e.g. PARK ET AL 1998, KEJNA ET AL 1998, BIRKENMAJER 2002, BRAUN ET AL 2002) and changes in the vegetation on King George Island (GEHRIGHAUSEN ET AL 2003) are initiated by the changing climate in the region. The sensitivity of local ecosystems to these changes is currently one of the main research subjects on the island.

Many of these studies incorporate monitoring over longer time periods including an assessment of the spatial location and distribution of indicators under study. Assessing glacier advance or retreat and mapping changes in vegetation distribution are prominent examples. Such long term monitoring requires a topographic framework in which observations can be accurately tied to a location on earth. Modern GPS technology facilitates mapping projects at an appropriate accuracy even for non-specialist and the amount of spatially referenced data produced in research projects is growing rapidly. Spatial location is also a crucial parameter in many multi-disciplinary studies in being the link that relates processes from different domains. A spatial framework data set for King George Island, readily accessible and useable by scientists, thus is an essential requirement.

3.1.6 The Evolving Cartographic Image of King George Island

First charts of the island have been produced from the very beginning of the discovery of the island (e.g. MIERS 1820, SHERRAT 1821, HYDROGRAPHICAL OFFICE 1822, POWELL 1822, WEDDELL 1825, GOULD 1941, ROBERTS 1952, CAMPBELL 2000). Surveying was done from the ships. The interior of the island was not well known until the 20th century.

The French Antarctic expedition led by Charcot (1908-0109) created a detailed chart of Admiralty Bay (BONGRAIN 1914). Between 1930 and 1937 the British RRS Discovery completed an extensive hydrographic survey of the South Shetland Islands including King George Island and since about 1948 charting by a variety of nations has become a continuous operation.

The first comprehensive inland survey started in 1949 from Base G at Keller Peninsula. A British party explored most of the island by foot or by dog team (HATTERSLEY-SMITH 1951).

The age of remote sensing started in the 1950 with airborne sensors. The first aerial survey was completed by Argentina in 1952, followed by Chile in 1954, and the Falkland Islands Dependencies Aerial Survey in the years 1955-56. Since then aerial surveys have been carried out by a variety of countries, including the UK in 1975, Poland in 1978, Chile in 1980, 1983/84 and 2001, Uruguay in 1994, and Brazil/Peru in 2003 (IAU SGM 1995, BRAUN 2001, CISAK 2001, RIVERA MENARES UNDATED, ATCM XXVII 2004).

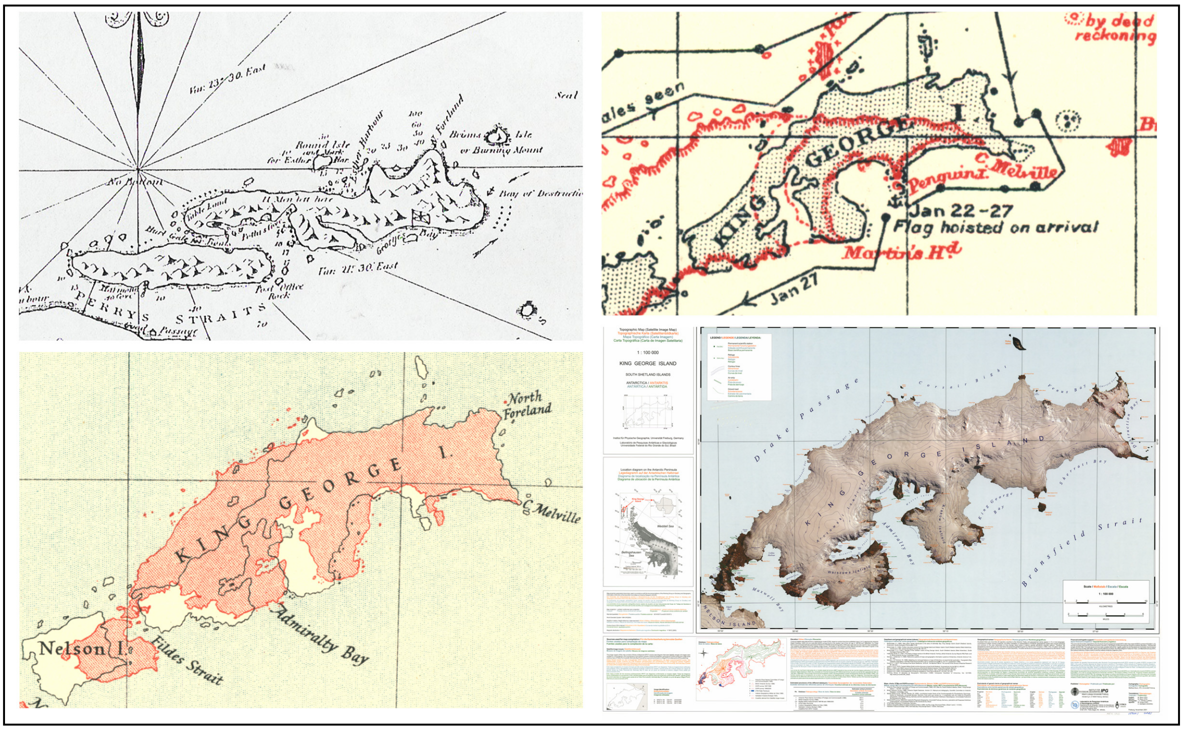

Figure 3-5: The evolving cartographic image of King George Island. Sherrat's map (upper left) dating 1821 is probably the oldest available map showing King George Island in some detail. Bransfield's chart (red overlay upper right) is dating backing to almost the same time. The Discovery charting activities 1935 (red overlay lower left) improved the knowledge about the correct shape of the island substantially, but not much was known about the interior of the island. The first published map covering the entire island and showing inland features in detail is the satellite image map by IPG Freiburg / LaPAG Porto Alegre in 2001 (lower right). Sources: Roberts (1952), Gould (1925), Royal Geographical Society (1936), IPG Freiburg/LaPAG Porto Alegre (2001).

Space-borne imagery is available since the 1960ties starting with declassified Corona data from 1963. Landsat TM, SPOT XS/XI data and ASTER imagery have been used in a variety of applications (e.g. HOCHSCHILDT ET AL 1998, SIMOES ET AL. 1999, BRAUN 2001, BRAUN ET AL 2002, BRAUN ET AL. 2004, VOGT ET AL 2004). Unfortunately the frequent cloud cover over the area severely limits the amount of available space-borne optical imagery and the full potential of space-born stereographic images for DEM construction cannot be leveraged due to the reduced contrast in the snow and ice covered areas.

The polar night and the prevailing cloud cover are of few concern to radar sensors. Cloud penetrating C-Band radar imagery is available from ERS –1, ERS-2, Radarsat, and Envisat and has been used on King George Island e.g. for snow cover analysis (WUNDERLE AT AL. 1994, BRAUN ET AL. 2000) or geomorphological mapping (HOCHSCHILDT ET AL 1998). Application of repeat-pass interferometry for DEM generation is difficult on King George Island due to the fast changing surface properties and the in some parts rather steep topography. Although it is possible to derive glacial velocity fields for some parts of the ice-cap there is currently no accurate DEM from SAR interferometry available. A promising tool in this respect is the forthcoming Terra SAR-X mission in the envisaged tandem configuration.

High resolution optical space-born sensors such as Quickbird or IKONOS are capable of delivering imagery well suited for environmental monitoring applications at the scale of the ice-free areas on King George Island as has been demonstrated with other areas in Antarctica (JEZEK ET AL 1999). But again the amount of available data is severely restricted by cloud cover and the polar night.

Today large scale topographic maps for most of the major ice-free areas are available. A detailed medium scale map for the entire island has been produced (BRAUN ET AL. 2004). Nevertheless the existing information is not always readily discoverable or useable in a digital environment, and there are considerable costs associated with converting available information into a format that can be included in the tools used by scientists or administration personnel. And there is still lack of accurate topographic data for the eastern part of the island.

Table 3-2: List of published large scale topographic maps and charts for King George Island.

Scale	***Name***	***Country, Year of Publication***
1 : 1000	Map of China's Antarctic Great Wall Station Area	China, 1987
1 : 2000	Bellingshausen Station	Russia, 1986
1 : 3000	Bellingshausen. King George Island (Waterloo) [Bellinsgauzen Ostrov King-Dzhorzh (Vaterloo)]	Russia, 1972
1 : 4000	Base Científica Antartica Artigas - Bahía Maxwell [Base Artigas - Maxwell Bay]	Uruguay, 1991
1 : 5000	Cape Lions Rump (King George Bay)	Poland, 1988
1 : 5000	Marian Cove (Bathymetric Map)	South Korea, 1994
1 : 10000	Caletas en Bahia Fildes: Caleta Potter, Caleta Ardley, Caleta Marian [Landing Coves in Fyldes Bay (Bathymetry)]	Chile, 1980
1 : 10000	Islas Shetland del Sur - Isla 25 de Mayo - Caleta Potter	Argentina, 1984
1 : 10000	Topographic Map of Barton Peninsula, King George Island (The King Sejong Station)]	South Korea, 1989
1 : 10000	Fildes Peninsula, King George Island (Sheet 1)	China, 1991
1 : 10000	Fildes Peninsula, King George Island (Sheet 2)	China, 1991
1 : 10000	Isla Rey Jorge - Península Fildes [King George Island - Fildes Peninsula]	Chile, 1996
1 : 10000	Isla Rey Jorge - Península Fildes [King George Island - Fildes Peninsula]	Uruguay, 1997
1 : 12500	Site of Special Scientific Interest No. 8 (SSSI-8) King George Island	Poland, 2002
1 : 20000	Orthophotokarte Fildeshalbinsel (König-Georg-Insel) [Orthophotographic Map Fildes Peninsula (King George Island)]	Germany, 1988
1 : 25000	Bahía Guardia Nacional	Argentina, 1957
1 : 25000	King George Island: Marion Cove and Potter Cove (Hydrographic Chart)	United Kingdom, 1968
1 : 25000	Fildes Peninsula (King George Island) - APC Misc 85	United Kingdom, 1978
1 : 25000	Zatoka Admiralicji (Wyspa Króla Jerzego) [Admiralty Bay (Bahia Lasserre) - King George Island]	Poland, 1980
1 : 30000	Bahia Fildes [Fildes Bay (Bathymetry)]	Chile, 1975
1 : 40000	Bahia Almirantazgo [King George Island: Admiralty Bay (Bathymetry)]	Chile, 1961
1 : 50000	Admiralty Bay (King George Island)	Poland, 1990
1 : 50000	Isla 25 de Mayo - Bahía 25 de Mayo	Argentina, 1957
1 : 50000	King George Island: Admiralty Bay and King George Bay (Hydrographic Chart)	USA, 1965
1 : 50000	Bahia Fildes, Carta Aeronautica [Fildes Bay, Aeronautical Chart]	Chile, 1993
1 : 65000	Zatoka Admiralicji (Wyspa Króla Jerzego) [Admiralty Bay (King George Island)]	Poland, 1990
1 : 100000	King George Island (South Shetland Islands Sheet 1)	United Kingdom, 1968
1 : 100000	King George Island: Admiralty Bay and King George Bay (Hydrographic Chart)	United Kingdom, 1968
1 : 100000	King George Island Topographic Map (Satellite Image Map)	Germany, 2001

3.2 Project Background

Probably nowhere else in Antarctica the need for coordinated approaches in research activities and environmental management is more evident than on King George Island. This is reflected by Scientific Committee on Antarctic Research's (SCAR) recommendation that calls for efforts to integrate scientific objectives and for collaboration among the nations working on the island. The recommendation was first adopted as recommendation SCAR XXVI-6 at the SCAR XXVI Meeting in Tokyo, July 2000, and continued as SCAR XXVII-6. (SCAR 2001, SCAR 2003).

The SCAR King George Island GIS (SCAR KGIS) project provides a fundamental contribution to these endeavours. It is coordinated under the work programme of the SCAR Expert Group Geographic Information (SCAR EGGI). The project makes available an integrated spatial database for use by all countries in multi-disciplinary research applications and environmental management.

The need for geographic information management on King George Island was formulated already in the beginning of the nineties. Coordinated management of geographic information was identified as a vital requirement. The applicability of GIS techniques was demonstrated with some examples and the establishment of a geographic information centre, preferably on the island itself, was proposed (HARRIS 1991b, HARRIS 1993).

In the years to follow many countries active on the island launched projects on geographic data management based on GIS. One of the earliest large-scale data sets published in digital form was provided by China, as an auxiliary data set to the Antarctic Digital Database, Version 1.0 (BAS ET AL 1993) The data covered the Fildes Peninsula, at a scale of 1: 10,000, and the vicinity of the Great Wall Station, at a scale of 1: 1,000 and 1: 2,000, respectively. A Chilean GIS project for the Fildes Peninsula and Ardley Island was established (VILLANUEVA LOPEZ 1993, ATCM XXI 1997, BARRIGA ET AL 2001) and China launched a similar system for the vicinity of Great Wall Station (JIAXIAN ET AL 1997). A project to set up a GIS for the Admiralty Bay ASMA was started by Brazil (SIMOES ET AL 2001, ARIGONY ET AL. 2004). Unfortunately there was only marginal co-ordination between most of these projects. Different standards had been adopted and there was a lot of double production of data sets covering the same areas.

In its 1998-2000 Geographic Information Program SCAR WG GGI established the KGIS project. The project had been proposed already in the 1990ies. Under the co-ordination of Poland the project started in 1998 with a scoping study on available geodetic and map data. A first questionnaire on available data sets was sent out to the relevant countries (CISAK 2001). In 2000 the project co-ordination was transferred to Germany. Since then the project has been coordinated at IPG Universität Freiburg.

Under the 2000-2002 Geographic Information program further key activities have been developed and co-ordination was transferred to Germany. Since then the project has been coordinated at IPG Universität Freiburg. The list of contributing nations was extended to include Argentina, Brazil, China, Chile, Korea, Russia, Poland and Uruguay and opened for further countries interested in participating. Ever since the database has continuously been expanded and a variety of tools to access and make use of the data have been developed.

In 2000 the International GIS Workshop on Antarctic King George Island was hosted at Wuhan University and included six presentations related to specifically to GIS applications for King George Island (GONG 2001). In 2003 the International Antarctic GIS Workshop AntGIS 03 was held at Freiburg University with a session devoted specifically to King George Island (http://www.geographie.uni-freiburg.de/ipg/forschung/ap3/antarctica/antgis_2003/). Wuhan University again hosted the Internationals Antarctic GIS Workshop in 2004 (http://www.geoscience.scar.org/geog/wuhan04/). At this workshop four presentation related to GIS on King George Island have been given.

3.3 Project Partners

Recommendation SCAR XXVIII-6

Concerning the King George Island Geographic Information System (GIS)

Noting SCAR Recommendation XXVI-6 concerning rationalization of scientific activities on King George Island;

Recognising that a Geographic Information System for the whole island has been produced and is now available on the internet;

SCAR recommends that

countries with programme activities on King George Island should make use of this integrated system for science activity, environmental planning and logistic operations; and

National Committees, through their National Programmes, should continue providing spatially referenced data to the Geographic Information System for the mutual benefit of all National Programmes with activities on the island.

Figure 3-6: SCAR Recommendation XXVIII-6 on KGIS project, SCAR XXVIII Bremen 2004.

The SCAR KGIS project is a community effort of nations, institutions, projects, and individuals active on King George Island. It lives on sharing of data produced by many different types of actors such as national mapping agencies, military geographic and geodetic institutions, national Antarctic institutions, national hydrographic institutions, university departments and research groups.

To involve the data user and producer communities considerable effort has been spend on communication and outreach, including the launch of a project web site, lectures and posters at a variety of conferences and institutions. A promotional visit to the Chilean, Russian, Uruguayan, Chinese and South Korean stations on King George Island was possible through the kind support of Instituto Antártico Chileno in 2001. Direct contact with people working on the island proved to be a most efficient way to reach and involve the target community.

Table 3-3: List of project partners that have contributed data to the KGIS data base.

Acronym	*Name*	*City and Country*
DNA-IAA	Dirección Nacional del Antártico - Instituto Antártico Argentino	Buenos Aires / Argentina
FH KA	Fakultät Geoinformationswesen, Hochschule für Technik Karlsruhe (FH)	Karlsruhe / Germany
IAAG	Institut f. Allgemeine und Angewandte Geologie, Universität München	München / Germany
IPG	Institut f. Physische Geographie, Universität Freiburg	Freiburg / Germany
FSU Jena	Institut f. Ökologie, Arbeitsgruppe Polar- und Ornitho-Ökologie, Friedrich-Schiller-Universität Jena	Jena / Germany
INACH	Instituto Antarctico Chileno	Santiago / Chile
IAU	Instituto Antártico Uruguayo / Servício Geográfico Militar	Montevidéo / Uruguay
IGIK	Instytut Geodezji i Kartografii	Warszawa / Poland
IUNG	Instytutu Uprawy Nawozenia i Gleboznawstwa w Pulawach	Pulaway / Poland
KORDI	Korea Ocean Research and Development Institute	Ansan / South Korea
NUPAC/UFRGS	Núcleo de Pesquisas Antárticas e Climaticás, Universidade Federal do Rio Grande do Sul	Porto Alegre / Brasil
SPRI	Scott Polar Research Institute	Cambridge / United Kingdom
AEROGEODEZIJA	State Aerogeodetic Enterprise	St. Petersburg / Russia
DAB PAN	Zak³ad Biologii Antarktyki / Polskiej Akademii Nauk	Warszawa / Poland

3.4 Project Workflow

The KGIS data base holds mainly framework data such as elevation and bathymetry, hydrography, transport and infrastructure, and protected areas and associated information. Source data sets containing this information spatially referenced ranging from paper maps to digital CAD and GIS data have been transformed into a common format, referenced to a common geodetic datum, and mapped to common semantics. Data quality and consistency has been checked and appropriate metadata generated. The integrated data is available on-line.

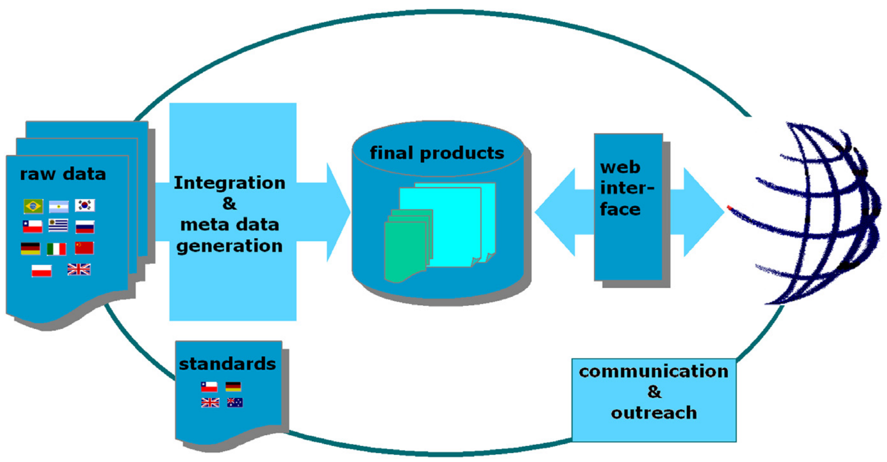

Figure 3-7: KGIS Project Workflow. Source data sets are spatially and semantically integrated following SCAR specifications. The integrated products are accessible on-line.

Most of the source data has been contributed to the project by partner institutions. Own field work includes data collection as part of a joint Brazilian-German Glaciological Expedition to King George Island with the Laboratório de Pesquisas Antárticas e Glaciológicas LAPAG (now Núcleo de Pesquisas Antárticas e Climáticas NUPAC), Universidade Federal do Rio Grande do Sul, Porto Alegre (Simoes et al, 2004) and during the participation in Proyecto 153 “Levantamientos Cartográficos y Sistemas de Información Geograficos de las Islas Shetland del Sur - SIG Fildes” of the Instituto Antártico Chileno INACH in two field season in 1998 and 2001.

Additionally, own data has been derived from the analysis of remotely sensed data sets. SPOT and ASTER imagery has been used to construct the ice-free areas data, large parts of the coastline data, and the glaciological data including glacier catchments and glacier classification. The remotely sensed imagery has also been used to provide for consistent reference data for the eastern part of King George Island.

Raw data provided by a wide variety of institutions has been collected at IPG Freiburg. Data has been accepted in almost any format from paper maps to CAD and GIS digital data sets. These data have been transformed (either by digitizing or by reformatting) to an appropriate digital format, then georeferenced and spatially integrated using WGS84 datum as the common reference system. Semantic integrity has been achieved by mapping to common semantics provided by the SCAR Feature Catalogue. Source and processing of the data has been documented by creating the respective metadata.

3.5 Project Deliverables

3.5.1 Database and Website

The project deliverables are defined in the biennial work programmes for the Geographic Information Programme of the SCAR Working Group on Geodesy and Geographic Information and the SCAR Expert Group on Geographic Information (SCAR WG- GGI 2000, SCAR WG-GGI 2002, SCAR EGGI 2004). The main work package is to integrate and make available the spatial framework data required for research and environmental management on King George Island. Maintenance of a web site to provide background information on the project is also defined as an ongoing activity.

The SCAR KGIS database provides the spatial framework data required in a variety of environmental and scientific applications. The database is implemented using the PostgreSQL/POSTGIS spatially enabled relational database management system (http://postgis.refractions.net) running on a Linux box. PostgreSQL and POSTGIS are both free and open source software products with an active and supportive user community.

The topographic data consists of coastline data, elevation contour lines and elevation raster data sets. The coastline data is classified into rock or ice-cliff coastline in accordance with ground conditions in January 2000. The coastline is modelled as lines carrying the attributes and as polygons to represent islands. Elevation contours are available at 5m, 10m, 25m, 50m, and 100m equidistance, each at an appropriate level of generalization. The raster data sets are obtainable at cell resolution levels of 10 x 10m, 50m x 50m, and 100m x 100m.

The bathymetric data currently covers only Admiralty Bay and Marian Cove. Although there area quite a few hydrographic charts available for the coastal waters surrounding King George Island they do not allow for the construction of a consistent data set. This may change in the near future as there have been a couple of bathymetric surveys around King George Island very recently. The already existing bathymetric data in the KGIS database is made available on request.

The ice-free areas layer shows those regions not covered by glaciers. The data has been updated to reflect the environmental conditions as of January 2000. Ice-free areas are modelled as polygons.

The hydrographic layer consist of water courses and lakes. Watercourses are modelled as lines, lakes as polygons. Depending on the region the data reflect ground conditions between 1984 and 2004.

The glacier layer provides for glacial catchment limits and a classification of the glaciers following the GLIMS (Global Land Ice Measurements from Space) classification scheme (RAU ET AL 2005). This includes information on the glacier type, frontal characteristics, etc.

Man-made structures such as buildings, tanks or pipelines are made available through the station facilities data set. Buildings and tanks are modelled as polygons, pipe lines as lines. Attributes include information about the physical properties of objects such as the material they are made of, on the purpose of the objects, and on ownership at country level. The information has been compiled from published sources such as maps and reports, from own field survey or by personal communication from persons involved in station management or which had been recently working on the island. These attributes are available only for some stations and the currentness of the information cannot always be guaranteed. There is also a data set representing stations and refuges as points. This data set is useful for applications at medium to small scale.

The transportation layer includes roads, paths, and landing areas including helicopter landing pads. These features are modelled as polygons or lines respectively.

The protected areas data set provides for the spatial limits of the protected areas and the locations of the Historic Monuments as listed in the ATCM and CEP documents. The information reflects the status of the respective Management Plans as of the Antarctic Treaty Consultative Meeting ATCM XXVIII and the CEP VII decisions and measures, both June 2005.

The website of the project can be accessed at http://www.kgis.scar.org. It is currently hosted by Institut für Physiche Geographie, Universität Freiburg. The site offers background information on the project and information on ongoing activities. It lists the project partners, describes how to access the SCAR KGIS data, and provides contact information.

3.5.2 Access to Data

The KGIS data can be accessed through a download facility, an interactive online Mapviewer, and as spatially enabled web services with open and well defined interfaces. To make the data discoverable metadata has been published in a relevant catalogue.

The metadata on available KGIS data sets and data access services are described in the Antarctic Master Directory (AMD). The AMD is the SCAR endorsed metadata directory to facilitate discovery of data sets related to Antarctica. The AMD is a portal of the Global Change Master Directory (GCMD). The GCMD is part of CEOS International Directory Network. It is a structured directory which hosts metadata on environmental data sets. It can be searched based on keywords, projects, scientific domains, or by spatial queries. The GCMD also provides for interfaces that allows search engine robots to search and index its contents. Consequently users need not be aware of the KGIS project, nor of SCAR, nor of the AMD but still would be able to discover the project data sets with standard search engines such as Google. The GCMD is accessible online at http://gcmd.nasa.gov, the direct access to the AMD is through http://gcmd.nasa.gov/KeywordSearch/Home.do?Portal=amd&.

The KGIS data is available free for non commercial usage, but SCAR should be acknowledged as source in any derivative work.

Data can be downloaded from the project website as shapefiles, a de facto standard GIS data format (ESRI 1998). Although the format has its limitations (e.g. no topological information can be encoded, the length of fieldnames is restricted, etc.) it was chosen as a flexible and user friendly format. Most commercial and free and open source GIS packages can handle shapefiles directly, so the data can readily be integrated in most applications. Accessing the data download area requires registration. The primary purpose of the user registration is to be able to notify users on updates or corrections of the data.

The integrated KGIS products are available as OGC web services, too. These can be directly plugged in into OGC enabled client applications, without the need to download, convert or reproject datasets. The standardized OGC interfaces allows standard GIS packages that are implementing OGC interfaces to directly connect to the KGIS database. Suitable client products include commercial off-the shelf software such as ESRI's ArcGIS ™ or Intergraph's GeoMedia ™, or free and open source products such as uDIG (http://udig.refractions.net).

Two different data services are provided, a Web Map Service (OGC WMS) that provides functionality for portrayal and delivers georeferenced map images of the data to the client, and a Web Feature Service (OGC WFS) that provides the data as discrete features including their attributes encoded in GML. The WMS is build using the UMN Mapserver software that also powers the interactive Mapviewer (http://mapserver.gis.umn.edu/). The WFS is implemented with GeoServer, a free and open source Java product that is the OGC reference implementation for WFS (http://geoserver.sourceforge.net/).

The connection information required by the client is available from the project website. The services and associated information are also registered as data services in the Antarctic Master directory.

For users that are only interested into browsing the map layers and querying the data or to produce customizable maps for their respective area of interest the interactive KGIS Mapviewer has been developed (http://www.kgis.scar.org/mapviewer/). This access tool can be used online within any reasonable recent browser and without technical expert knowledge in geographic information handling.

It is build on the free and open UMN Mapserver software. On the server side the required functionality has been programmed using php and the php/Mapscript scripting language access to the UMN Mapserver API, on the client side additional functionality has been implemented with JavaScript to facilitate direct interaction in the client.

The KGIS Mapviewer allows to select specific thematic layers such as elevation or station facilities. It also features an orthorectified SPOT satellite image as backdrop. This data can not be included in the downloadable KGIS data due to copyright restrictions but is very useful in the Mapviewer for illustrative purposes.

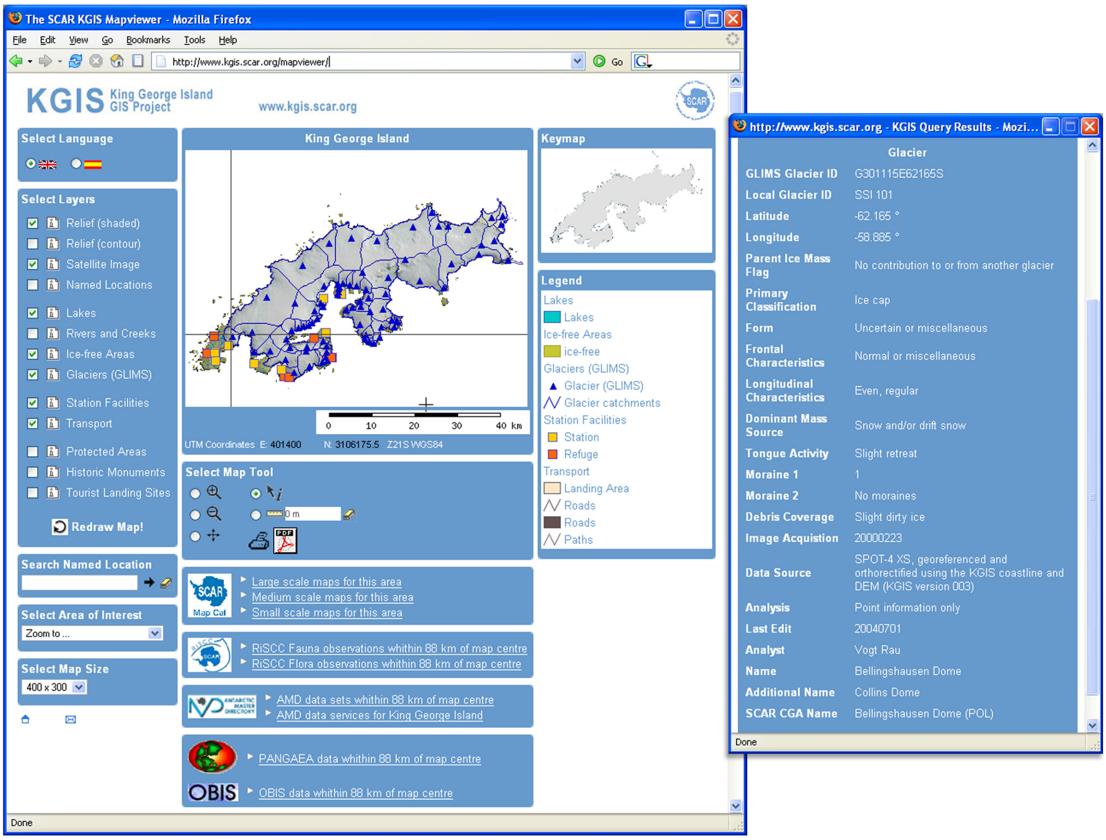

Figure 3-8: The interactive KGIS Mapviewer: The KGIS Mapviewer allows navigation based on place-names, selection of themes of interest, query of feature attributes and creation of customized maps in pdf format. The interactive map can also be used to spatially query external databases.

The viewer provides for zoom and pan functionality, direct navigation to predefined target areas (e.g. Fildes Peninsula), and navigation based on place-names. The place-name navigation is powered by the KGIS gazetteer described in more detail in Chapter 4. UTM coordinates for any specific location can be read directly from the display and a measurement tool to assess distances is available, too.

To get information on an object of interest the user can point to the respective feature with the query tool and the available information for the feature is retrieved from the database and displayed in a separate window. Where available the semantics of the attributes are described in more detail based on the definitions from the SCAR Feature Catalogue. The user can access this information by moving the mouse over the respective attribute displayed in the query-results window. A fly-out window displays the appropriate definition.

Customizable maps can be designed in an interactive fashion by selecting the content and the area to be displayed. Optionally a latitude-longitude or a UTM grid can be chosen as an overlay. The Mapviewer then creates a pdf document containing the map in a resolution suitable for high quality print-out.

The KGIS Mapviewer not only allows for portrayal and query of the KGIS database. It can also be used as a portal to spatially query against external data bases for data on King George Island. External databases include the SCAR Map Catalogue and the SCAR Riscc Biodiversity Database, the Antarctic Master Directory described above, the PANGEA System and OBIS. The SCAR Riscc (Regional Sensitivity to Climate Change) Biodiversity database provides fauna and flora observations mainly from terrestrial and limnetic ecosystems. The Biodiversity database and the SCAR Map Catalogue are both hosted at the Australian Antarctic Data Centre. OBIS (Ocean Biogeographic Information System) is the information component of the Census of Marine Live Initiative and serves data on marine species. It is managed by Rutgers University, New Jersey. PANGEA (Publishing Network for Geoscientific and Environmental Data) is a public digital library for georeferenced science data with special emphasis on environmental, marine and geological research. It is jointly operated by Alfred-Wegener-Institute für Polar- und Meeresforschung and Marum Center for Marine Environmental Sciences.

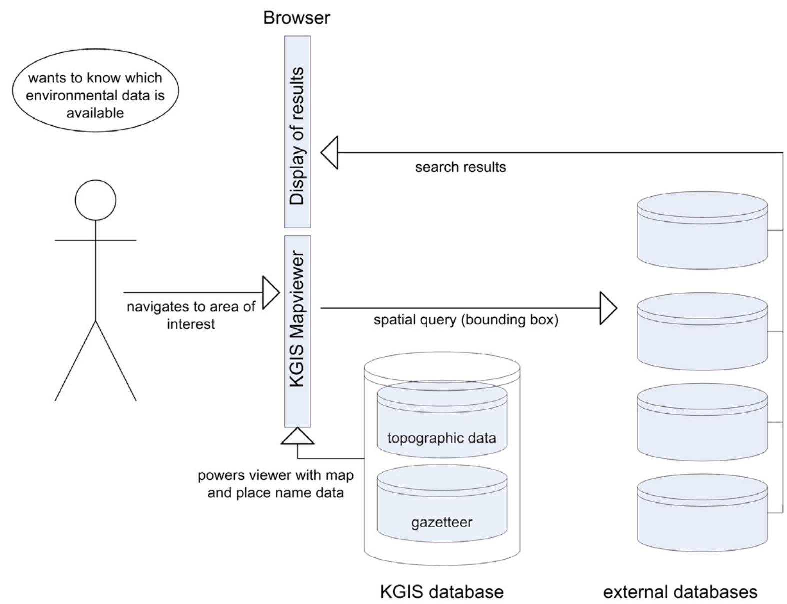

Figure 3-9: The KGIS Mapviewer as a tool to spatially query external data bases.

To query one of these resources for data from King George Island it is simply required to zoom into the area of interest and to select the appropriate link for the respective database. Information on available datasets for the area will then be displayed in a separate window.

3.6 The SCAR KGIS Project as a Model for an Antarctic SDI?

The KGIS project aims at spatially enabling research activities and environmental management to the widest extent possible. It involves the producers of spatial data and aims at a broad user community. There are certain institutional arrangements, rules and policies on which the project workflow is based. It has evolved over time according to the users' needs and with the advance of technology. To a certain extent the KGIS project including the data base and access mechanisms can be considered implementing components of a Spatial Data Infrastructure for King George Island.

King George Island is not representative for Antarctica. The combination of the many bases, the plethora of scientific and operational activities, the diverse fauna and flora, and the tourism activities render it unique in Antarctica.

However, the settings of the project provide for many facets typical to data and information management in Antarctic.

The community involved in the KGIS project comprises:

- a multitude of nationalities
- different cultures
- at least eight different languages
- diverse administrative structures
- groups with different financial resources
- various levels of information technology infrastructures

A wide range of activities takes place on the island:

- a plethora of scientific activities in a variety of disciplines
- a large amount of logistic operations producing considerable land-based and air traffic
- a high number of station personnel on duty and also for recreational purposes interacts with the environment
- different flavours of tourism, including the evolving business of land-based tourism

The island features:

- a diverse physical environment including extensive ice-covered areas and a number of larger ice-free areas
- a diverse fauna and flora
- an extensive set of building structures and associated facilities
- a representative selection of transport infrastructure including fixed wing air transport facilities and gravel roads
- different categories of protected areas including ASPAs and an ASMA

In an international and complex context the KGIS project has to support a wide range of use cases that potentially can develop in any given part of Antarctica. McMurdo for example is even more populated, but there is less potential for international conflict. The Larseman Hills area in East Antarctica features international cooperation, but the scale of scientific and tourism activity is different. Livingston Island, also part of the South Shetlands, features comparable environmental settings, but there is considerable less human presence.

The wide range of activities on King George Island to a large extent provide for the potential uses cases for an Antarctic Spatial Data Infrastructure. As a coordinated effort of countries from South America, Asia, and Europe KGIS has to cope with issues of international and intercultural cooperation that might also evolve in an Antarctic Spatial Data Infrastructure targeting the international SCAR community. The physical, man-made and administrative features present on King George Island to a wide range cover the types of features present in Antarctica.

Consequently the KGIS project can be considered a well-suited test bed to develop, implement and test components that might be re-useable in the emerging Antarctic Spatial Data Infrastructure.

4 SDI Components Developed and Implemented for KGIS

This chapter discusses products and specifications that have been developed within the KGIS project activities and which can be regarded as SDI components. Each component is introduced by providing the required background information. Then existing policies, mainly SCAR policies, for the respective component are presented. Following is a section describing the implementation for the KGIS project. Finally for each component conclusions for an Antarctic Spatial Data Infrastructure are discussed.

The components include

- geodetic reference
- framework data
- place-names
- common semantics: a feature catalogue
- metadata
- data access and portrayal services

First geodetic reference and the geodetic infrastructure on King George Island is discussed. In the following section the construction of a consistent set of framework data for King George Island is explained. The resulting data base is one of the more tangible products of the study. Also a tangible result is a new gazetteer for King George island with accurate positions for the named locations. The establishment of the gazetteer is discussed in greater detail. This was a SCAR WG GGI endorsed pilot study to assess the applicability of the SCAR Composite Gazetteer of Antarctica for large scale applications. Semantic integration of the data has been based on the SCAR Feature Catalogue. The SCAR Feature Catalogue is being developed mainly by the Australian Antarctic Data Centre, KGIS contributions to the further development of the contents are presented following the place-names section. Finally the implementation of data access and data portrayal services with open, well defined interfaces is described. These services make the data accessible in a service oriented Spatial Data Infrastructure.

4.1 Geodetic Reference System

4.1.1 Background

Any spatial data infrastructure must be built on a solid positional foundation (MANNING ET AL 2003). A uniform geodetic infrastructure on a single, well-defined datum would best support this requirement. Building spatial data sets of different data on mixed geodetic datums introduces inhomogeneities and uncertainty. To people not from geodesy or geography disciplines describing positions merely by geographic coordinates seems to be adequate. This approach often leads to confusion because people are not aware of the importance of geodetic datums. When integrating data from different sources or when working with legacy data sets this often is a pre-eminent problem.

Any method of position referencing using a coordinate system is dependent upon the ellipsoid and datum used to model the Earth. A datum defines the position of the origin, scale, and the orientation of a coordinate system. A geodetic datum is describing the relationship of a 2- or 3- dimensional coordinate system to the Earth. It may include the definition of an ellipsoid as a simple mathematical model of the Earth. (ISO/TC-211 2005).

A coordinate system which is related to the Earth by a geodetic datum is called a geodetic coordinate reference system (ISO/TC-211 2005).

Where the geodetic datums of geodetic coordinate reference systems vary, transformations are used to bring together data based on individual geodetic datums. Applicable methods include simple block or origin shifts, ellipsoid change (Molodensky), the 7-parameter similarity transformation (Helmert) , and grid based methods. The required parameters for the transformation have to be developed by comparing positions of well defined points known in the different datums (e.g. HOOIJBERG 1997).

Transformations between coordinate reference systems based on different datums always are only approximations. The accuracy of such an approximation depends on the number, distribution and quality of the common points and on the location of the points to be transformed relative to the reference points used to derive the transformation parameters.

Two types of datums can be distinguished, global and local datums. A local datum is specifically designed for a certain geographic area of use. It generally includes the latitude and longitude of an initial point, the direction to some other reference point, and an ellipsoid that is a best fit to the surface of the earth in that geographic area. It is realised by a reference network of benchmark points with known positions in the respective datum.

A global datum is a datum that is a best fit on global scale. Well known global datums include WGS72 or WGS84, the latter being explained in more detail below.

When choosing a positional framework for an SDI it seems reasonable to adopt one single global reference frame and datum for the entire SDI. However, there are a number of reasons why this is neither feasible nor desirable for regional or global SDIs. First of all, such a reference framework would have to be dynamic to provide for high accuracy. If global coordinate reference systems are used even for local applications, it is important to realise that in a global coordinate system the ground on which we stand is constantly moving under the fixed coordinate system due to plate tectonics. Global reference systems usually are defined stationary with respect to the average of all these motions. Consequently positions in such a reference system are in motion relative to any particular region. King George Island for example moves with a speed of about 1,5 cm per year relative to the ITRF2000 described below (value calculated from the ITRF2000 stations on King George Island using the ITRF online service).

Geodetic networks provide for the physical links to a coordinate system. Although this has dramatically changed with satellite positioning technologies, the principle remains that the primary reference is what gives access to geodetic coordinates. Geodetic ground marks which constitute the realization of a reference system historically were considered positions that are fixed on the surface of the earth. But the advances in measuring positions and the better understanding of the movements of the Earth's crust lead to the development of dynamic datums. These have time varying components such as a velocity model, which describes the changes of the coordinates of the ground marks with time. Consequently coordinates in such a reference system are four-dimensional, because they must include a time stamp, called epoch.

Handling of such a reference framework would impose increased operational complexity. It would be much simpler to realize reference systems on a well defined local geodetic infrastructure and to relate these reference frames to a global reference frame. This would allow for well defined transformations from one reference frame to another (MANNING ET AL 2003).

The International Terrestrial Reference Frame (ITRF) is the global reference frame that realizes the International Terrestrial Reference System (ITRS). ITRS is the state of the art global reference system. ITRS consists of a set of prescriptions and conventions together with the modelling necessary to define origin, scale, orientation and time evolution of a Conventional Terrestrial Reference System. The system is realized by the ITRF based on estimated coordinates and velocities of a set of some two hundred stations observed by VLBI, LLR, GPS, SLR, and DORIS. These are published in a series of epoch determinations, the latest one being ITRF2000. In the last years, some countries and regions have been converting to datums based on the ITRF. An example of such a datum is the European Terrestrial Reference Frame 1989 (EUREF89), which realizes the European Terrestrial Reference System, was defined identical with the ITRS at Epoch 1989.0. and is stable with regard to the Eurasian plate, but drifting under ITRF with known parameters.

IAG recommends that the GRS80 be the geodetic reference system to be used by international organizations (MORITZ 1980). It is a system without any realizations. It is useful e.g. to convert ITRF Cartesian coordinates to latitude / longitude values.

The reference system widely used for navigation and mapping with GPS is the World Geodetic System 1984 (WGS84). The WGS84 consists of a global geocentric reference frame and collection of models. This reference frame was defined by the United States National Imagery and Mapping Agency (NIMA, 2000).

WGS 84 has evolved significantly since its creation in the mid-1980s. First realizations have been based on the U.S. Navy Navigation Satellite System, commonly known as DOPPLER Transit, and provided station coordinates with accuracies of about one meter. More recent realizations of WGS84 have been based on GPS data, such as WGS84(G730) or WGS84(G873). These newer WGS84 realizations are coincident with ITRF at about 10cm level. Where necessary, ITRF positions can be re-labelled as WGS84, without loss of accuracy.

The WGS84 ellipsoid and the GRS80 ellipsoid can be regarded identical, the only difference being the way certain parameters are defined.

Until 1 May 2000, WGS84 point positions recorded by a single GPS receiver may have had a positional error of up to 100 metres due to the degradation of the signal by the US Department of Defense (“Selective Availability”). However, on 1 May 2000, Selective Availability was removed from GPS, so that WGS84 point positions obtained by a single GPS receiver now have a positional error of about

10-20 metres (at 95% confidence level). Better relative accuracy can be obtained by using differential techniques, but the resulting absolute positions still depend on the position and datum of the base station.

With appropriate geodetic GPS observations and post-processing, ITRF positions may be obtained anywhere with an accuracy of a few centimetres. Although the post-processing required to obtain such positions involves substantial expertise and is fairly comprehensive, on-line services are available on the Internet, which allow suitable GPS data to be uploaded and processed and the ITRF positions returned (e.g. GEOSCIENCE AUSTRALIA 2005). Consequently it is reasonably simple to establish an accurate ITRF based datum by observing with geodetic GPS receivers on key sites in the survey network; computing the ITRF positions; and then propagating these positions through the network by readjustment.

Horizontal and vertical positioning is traditionally separated. Heights and depths are measured along the direction of gravity and related to vertical reference surfaces based on the geoid, an equipotential surface of the Earth's gravity field. The zero surface to which elevations or heights are referred is called a vertical datum. Traditionally, surveyors have tried to simplify the task by using the mean sea level as the definition of zero elevation, because the sea surface is available worldwide. The mean sea level (MSL) is determined by continuously measuring the tidal rise and fall of the ocean at tide gauge stations. The MSL measured at a tide gauge station can then be defined as the zero elevation for a local or regional area.

Height should not be referred to as a coordinate. It is more like a physical quantity, because it is defined above a physically defined, irregular surface. Treating height as the vertical coordinate z additionally to the horizontal coordinates x and y is a good approximation of physical reality in smaller areas, but it becomes quickly invalid over larger areas.

The vertical accuracy of geospatial information and resulting map products depends on how the elevations were compiled. If the elevations are based on first order geodetic levelling, the control heights should be very accurate, probably good to centimetres with respect to 'local mean sea level'. A height bias in the local mean sea level would be the major potential error source.

If no levelling data are available for vertical control, elevations can be estimated from GPS measurements and a geoid height derived from a geoid model. For mapping purposes, the orthometric heights (height above the geoid) are substituted for elevations above mean sea level.

A precise geoid model is very important to increase the accuracy of height coordinate systems. The GPS measured ellipsoid height alone provides the geometric information of the position, but does not give orthometric height because it tells nothing about the gravity field. Different geoid models will yield different orthometric heights for a point, even though the GPS determined ellipsoid height might be very accurate. Consequently orthometric height calculated from GPS measurement should never be given without also stating the geoid model used.

The lack of gravity information severely constrains an accurate definition of the geoid in Antarctica, especially across the inland of the continent.

The Earth Gravitational Model 1996 (EGM96) provides a geoid with an accuracy of ±0.5 - ±1.0 m worldwide. Although limited by the amount of data used in the Antarctic region, a grid of separation values from EGM96 to the WGS84 reference ellipsoid is provided by the United States National Geospatial-Intelligence Agency. It can be accessed as an online service at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/intpt.htm. For King George Island the separation is calculated to be about 22m, depending on the location on the island.

4.1.2 Policies

Since SCAR was formed in 1958 there has been substantial international cooperation in Antarctic Geodesy. The SCAR Geodetic Infrastructure for Antarctica (GIANT) program was established in 1992 and has become the coordinating program for all SCAR Antarctic geodesy (MANNING, 2005).

Within the GIANT programme a number of permanent GPS receivers have been installed in Antarctica. This fiducial network of GPS points, augmented by Very Long Baseline Interferometry (VLBI) and other techniques, forms the basis for an integrated geodetic infrastructure in Antarctica.

Data from continuous GPS sites in Antarctica were used in ITRF 2000 primary determinations (Altamimi 2001) and ITRF 2000 positions of the included stations can be calculated for any desired epoch from the ITRF website (http://itrf.ensg.ign.fr/).

The permanent sites provide a stable platform for combining measurements from summer campaigns coordinated under the SCAR Epoch Crustal Movements programme, densifying the ITRF network across Antarctica. The Epoch surveys have been processed by DIETRICH ET AL (2001) as densification of the global reference frame. The result is a network of officially published IERS coordinates (with velocities) for Antarctic rock sites.

> *“That members adopt the International Terrestrial Reference Frame 2000 (ITRF2000) at an epoch of 2000.0 together with the GRS80 ellipsoid, as the geodetic datum for all Antarctic activities.”*

Figure 4-1: SCAR GSSG Standing Resolution on Geodetic Infrastructure

To facilitate the use of spatial data for all applications the use of ITRF was proposed in 2000 to the SCAR Working Group on Geodesy and Geographic Information (MANNING 2000). At SCAR XXVII in Shanghai, 2002, the standing resolution on geodetic datum was updated accordingly.

4.1.3 Enabling Technologies

Nowadays positioning is available through GPS, both for high precise geodetic work as well as for mapping that requires less accurate positioning. ITRF2000 stations allow to link local geodetic networks to the global ITRF2000 reference frame.

Many scientists have started to use GPS as auxiliary tool for data acquisition in the field, e.g. to map nest sites, vegetation patches, morphological forms, or glacier boundaries. Simple GPS measurements yield WGS84 coordinates with a positional accuracy not better than 10m. Using differential GPS with a reference station on a well known point the positional accuracy can significantly be enhanced and depends largely on the accuracy of the reference station's coordinates.

4.1.4 KGIS Implementation

King George Island is an example of diverse local datums. A number of nations had established geodetic datums for geodetic networks, in the early years based on Doppler or Astronomic fixes (e.g. XU 1990, SLEDZINSKI 2001). Many postions of reference points have subsequently been established or improved using GPS (e.g. IAU-SGM 1995, SEKOWSKI, 2001, BARRIGA et al 2001). In some cases the networks with different datums overlap, giving rise to conflicting and confusing

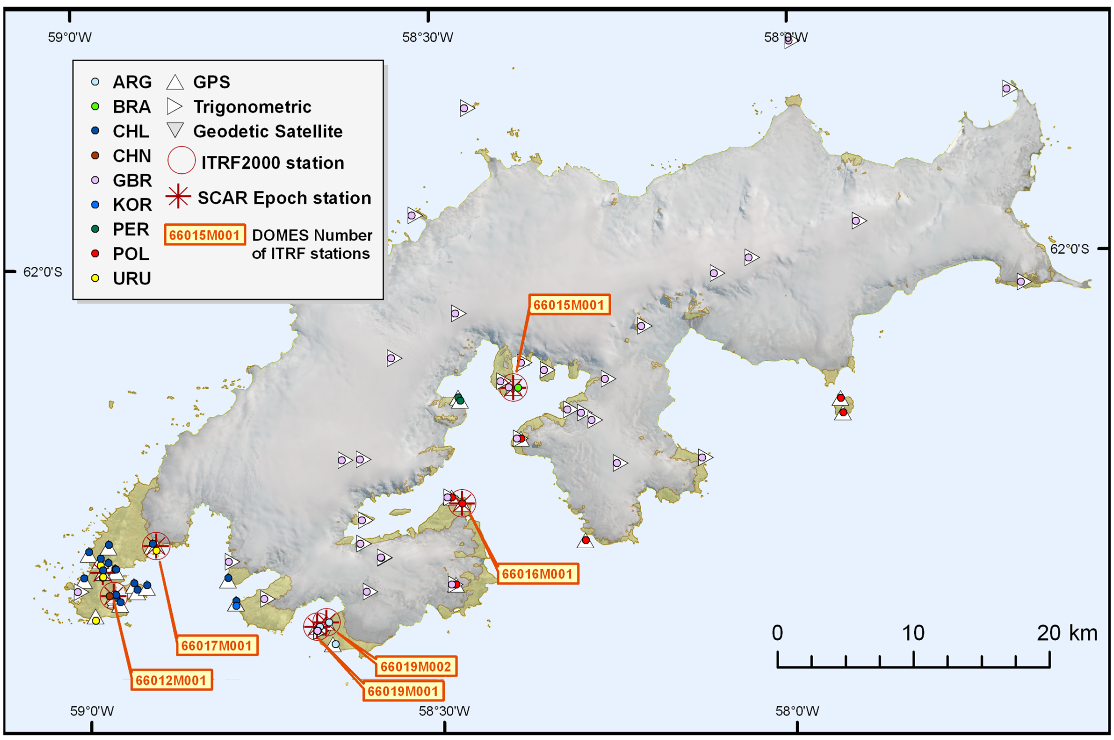

Figure 4-2: Geodetic networks on King George Island. Six stations are included in the primary ITRF2000 solution.

positions for the same points.

The situation has recently been considerably improved as six stations on King George Island are included in the ITRF 2000, which can be used as reference stations for applications that require high absolute positional accuracy. ITRF2000 coordinates for these stations can be calculated for any given epoch online from the ITRF service at http://itrf.ensg.ign.fr/.

The information on geodetic reference points provided to the KGIS project with the questionnaire in 1999 (CISAK, 2001) has been updated with more recent information from websites and reports. The location of the sites is provided in the KGIS Mapviewer as layer Geodetic Networks. Points can be queried to get information on the methods used to establish the positions. Links to published and online resources that provide additional information are also displayed.

There are also a number of sites on King George Island that have taken part in the SCAR Epoch campaigns. These data are available online from the SCAR Epoch data base hosted at IPG TU Dresden (http://www.tu-dresden.de/ipg/service/scargps/database.html). For these sites direct links to the Epoch data base are provided, too.

With respect to legacy data made available to KGIS in most cases it was not possible to establish useful transformation parameters to WGS84 or ITRF2000. Given the relative accuracy and consistency of such data sets co-registering to a spatially consistent control data set was considered accurate enough to allow for integration of such data sets. For details refer to chapter 4.2.

For the eastern parts and along the northern coast of the island reliable control data is still lacking to the KGIS project. If such data would be taken and made available for sites that can be identified in satellite imagery it would be an extremely useful contribution to ameliorate the accuracy of the topographic framework for King George Island. Candidate areas for surveys include Cape Melville and North Foreland, and along the Northern coast False Round Point, Pottinger Point, or Davey Point.

4.1.5 Conclusion for AntSDI

ITRS and the current realization ITRF2000 provide for a consistent global geocentric reference frame. A number of Antarctic GPS stations are included in the ITRF2000.

To limit the number of individual datums being used across Antarctica and to avoid the use of a dynamic system of datums, the SCAR GSSG standing resolution on the use of ITRF2000 (at an epoch of 2000.0) as an Antarctic datum for the geodetic infrastructure and as the basis for spatial data should be followed when establishing or re-assessing geodetic networks.

Information on ITRF stations in Antarctica should be made readily available. The SCAR Geodetic control data base seems the obvious choice to store and provide this information.

It is suggest this data base be made available as an OGC WMS and WFS service to become a more useful resource within AntSDI. Institutions might wish to make available information on geodetic control individually. Preferably they might use OGC interfaces too, using the semantics for geodetic control as defined in the SCAR Feature Catalogue.

In the SCAR Feature Catalogue the feature type Geodetic Control might be modified to cater for such applications. Respective optional properties for the feature type might be defined, such as SCAR Epoch Labels, DOMES numbers, or an ITRF2000 flag to make ITRF stations easily discoverable.

Users should be aware of the limitations of GPS, specifically when simpler handheld devices are used that do not allow for differential GPS. It should be better communicated to non-geodesist users of GPS which require high accuracy absolute position data how they best acquire these. A consolidated “geodesy for the laymen” information page on best practises with higher accuracy GPS measurements accessible on the web might be helpful.

4.2 Framework data

4.2.1 Background

The need to enable the sharing of spatial data is at the heart of the SDI concept (GROOT ET AL 2000). This raises the question as to which extent data collected for one application can be used in another context. Obviously some data are more shareable than others and are being collected with a very broad audience in mind from the start.

Following a survey conducted by Onsrud in 1999 (data depicted in GROOT ET AL 2000, p. 9) on 23 countries the majority considered the following data to be relevant to a broad user community and essential for inclusion in the respective national SDIs:

- Geodetic control
- Land surface elevation / topographic data
- Digital imagery
- Administrative Boundaries
- Cadastral / land ownership
- Transportation/roads
- Hydrography
- Land use / land cover

These are the traditional base map themes in use by national mapping authorities in many countries. They are required in many application domains and provide also the key to integrate other, more specialized thematic data. The establishment of base data themes, variously known as fundamental, core, reference, foundation, or framework data has been described as a practice in many initiatives as a central part of creating an SDI, yet there is no common agreement which themes are to be regarded as base themes.

The terms used to denote the set of base data differ slightly in their meaning. The two concepts of core data (needed in most applications) and reference data (used to spatially integrate other data) for example are rather different perspectives (LUZET ET AL 2004).

In the following data of high re-use potential that is relevant to most users of the SDI is called framework data. This includes both the flavour of reference data as well as that of core data.

In the beginning of the work of ISOTC211 there has been no ISO standard that defines what base layers are.

Several national projects have been undertaken to define and build standardised framework data content and/or encoding. An example is the Master Map of the Ordnance Survey in the UK (OS 2005). The specifications of Global Map can be regarded as a definition of framework data at the global level (ISCGM 2000, MARUYAMA ET AL 2005).

4.2.2 Policies

No definition or formal specification exists of what should be considered framework data for Antarctica. Two projects of the SCAR WG-GGI can be considered closely related to the issue of framework data: The initiative Antarctic Geographic Data Integration AGDI (running from 1996 to 2000) and the Antarctic Digital Database (ADD).

AGDI's goal was to provide a set of base data integrated at the continental level with a 5km resolution (JOHNSTONE 2000). Seven data sets were identified as fundamental layers:

- Coastline
- Bathymetry
- Surface elevation
- Ice bed elevation
- Features
- Names
- Remote sensing

The project produced specifications (JOHNSTONE 1999) and a data library accessible at http://www.geoscience.scar.org/geog/agdi/intro.htm, but lack of resources prevented from creating the integrated products, the product component had to be suspended at SCAR XXVI 2000 and the project put on hold.

Within the AGDI specifications the layer Features had been defined rather open as to be “a database of features in Antarctica including ice features, rock features, built features and administrative boundaries” (JOHNSTONE 1999).

The ADD has been structured into 14 layers:

- Cliff
- Coast
- Contour
- Elevation
- Fauna
- Flowline
- Glacier Margin
- Human
- Ice dome
- Lakes
- Moraine
- Rock
- Streams
- Traverse

The specifications for the layers are very much scale depended and targeted at small scales. Fauna and Human for example allow only for point representations and there is no concept on how to model features such as roads.

The above examples indicate that framework data for Antarctica differ from what generally might be considered framework data in other regions of the world. The cryosphere plays a prominent role and man made features and administrative objects are of minor importance.

4.2.3 Enabling Technologies

4.2.4 KGIS Implementation

In both SCAR examples described above specifications have been developed particularly for small scale application. The KGIS database on the contrary is applicable to large and medium scale applications. Furthermore ice-free areas play a major role for human activities and are expected to be of interest to a large part of the user community. Given the number of permanent stations, the road network, or the facilities for air transport such man-made structures cannot be neglected. There are not many types of administrative boundaries in Antarctica, but limits of protected areas have to be considered in every activity on the ground. Consequently the following layers have been identified as required framework data for King George Island:

- Geodetic control
- Elevation
- Coastline
- Surface hydrography
- Ice-free areas
- Station facilities
- Transport
- Administrative boundaries
- Orthoimagery.

In the following first the rationale for choosing a specific theme as framework data for King George Island is given, followed by a description on how the data set has been produced. The Geodetic control layer has already been described in the previous chapter.

4.2.4.1 Elevation

Elevation data is defined here as surface elevation. It qualifies both as topographic reference as well as core data providing ground detail required in most applications. Bedrock elevation, though available for parts of King George Island (PFENDER 1999), is considered to be of rather specific interest to the glaciological community.

Elevation data has been compiled from many sources. A first version of a digital topographic data base has already been produced before the start of the KGIS project (BRAUN ET AL 2001b). The pool of source data used has substantially been expanded since, but the methodology for integration has remained principally the same.

New data has been included mainly for the ice-free areas such as Fildes Peninsula (IGM-INACH 1996), Weaver Peninsula and Barton Peninsula (KORDI 1990), Potter Peninsula (DNA IAA-IAAG 2002), the Western shore of Admiralty

Bay (Pudelko 2003), Lions Rump (BATTKE ET AL 1988), Penguin Island (PAC 1995, BATTKE ET AL 2000) and Turret Point (BATTKE ET AL 2000). Most of the ice-free areas where scientific activities are taking place are now covered by high resolution topographic data captured at scale 1:10 000 or better with the exception of the Machu Picchu area, Keller Peninsula and the Eastern shore of Admiralty Bay. It is expected that topographic data derived from the Brazil-Peru activities (ATCM 2004) will fill this gap in the near future. New data for ice-covered areas has been included for Bellingshausen Dome, a.k.a Collins Dome (SERVICIO GEOGRÁFICO MILITAR 1993).

Input data comprises contour line data and point elevation data. Data formats include GIS data files referenced to a coordinate system including a datum, CAD data files with a coordinate system but without a geodetic datum, and paper maps. When necessary the data has been digitized or reformatted.

First the data has been ranked according to accuracy. Where data sets overlap the more accurate source has been used and the less accurate has been discarded.

As common reference system WGS84 datum has been chosen on the grounds that a considerable amount of the data sets already has been referenced to WGS84 and that most users would work with WGS84. The accuracy of the data does not require the use of highly accurate, time-dependent ITRF coordinates.

Where information on the datum used has been available data has been transformed from that datum to WGS84 using the Helmert Transformation and parameters as provided with ArcGIS 8.3 and 9.0. In cases where no datum has been assigned to a map or where no transformation parameters had been available the data was co-registered to existing georeferenced data by rubber-sheeting.

A continuous gridded Digital Elevation Model (DEM) was generated from contour lines and single spot heights using the Topo To Raster Tool of ESRI's ArcGIS ™, (which is the ArcGIS implementation of the former Arc/INFO TOPOGRID module). The ANUDEM algorithm implemented in the tool uses an iterative finite difference interpolation technique and is optimised to have the computational efficiency of local interpolation methods, such as inverse distance weighted interpolation, without losing the surface continuity of global interpolation techniques like splines or kriging (HUTCHINSON 1989, HUTCHINSON 2000). The algorithm is specifically designed to integrate different data types into the DEM generation and is able to include information on lakes and watercourses to produce hydrological correct DEMs.

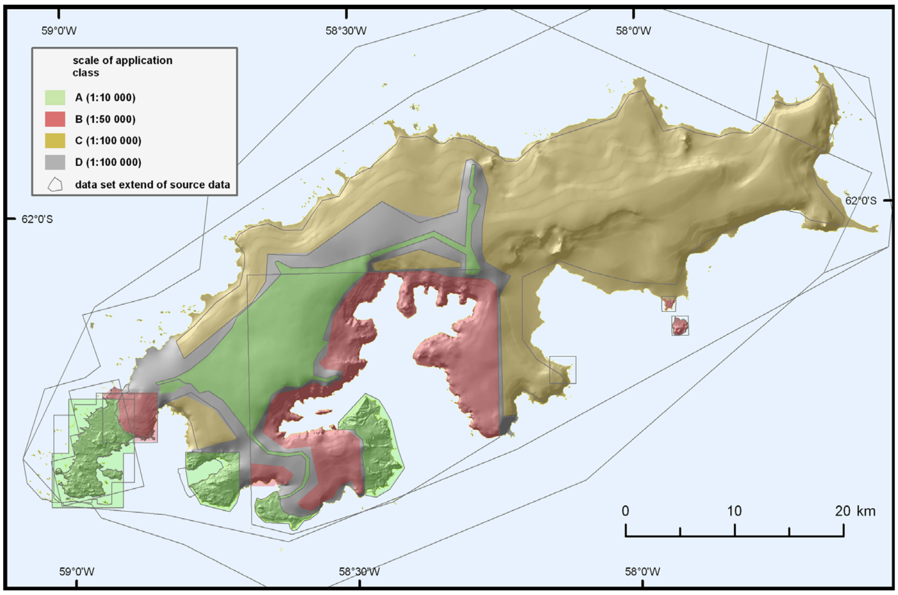

Figure 4-3: Source data and positional accuracy for elevation layer. For explanations refer to the text.

Subsequently from this DEM consistent elevation contours have been derived.

The level of accuracy of the DEM and consequently the range of applications varies across the island. Detailed information on the source data and on the horizontal and vertical accuracy is documented with the metadata. To allow a broad user community quick assessment of available data and its potential usefulness for an envisaged application, the DEM data has been classified into accuracy classes based on the horizontal and vertical accuracy of the source data. Thus a preliminary fit for purpose assessment is possible without consulting the metadata in detail.

Four classes are distinguished. Class A refers to data suitable for large scale applications up to a scale of about 1:10 000. This is a typical working scale for applications situated in one of the ice-free areas. Data with a horizontal and vertical accuracy of 5m or better is assigned to this class. Characteristically this comprises areas with source data stemming from DGPS field measurements or from data derived from aerial photogrammetry. Class B data should generally not be used at large scales as the positional accuracy does not lend to studies at that scale. The horizontal and vertical positional accuracy of the class members is about 30m. For most applications it can be considered appropriate for work up to a scale of about 1:50 000. The class typically includes legacy data based on pre-DPS surveys. Class C targets at working scales of 1:100 000 and smaller. Data from this class is suitable usually for studies at the scale of the entire island, such as ice sheet modelling. The horizontal accuracy is about 100m, the vertical accuracy about 50m. Class D follows the same specifications, except for the origin of the data. This class comprises only interpolated data and is not directly based on source data. The positional accuracy is considered to be the same as class C.

The extend of the areas covered by the respective source data is provided as polygons. This facilitates quick access to information on spatial coverage of the source data.

4.2.4.2 Coastline

Coastline data has specific aspects in Antarctica compared to other regions of the world. Large parts of the coastline are formed by ice-cliffs, as a consequence the location of the coastline may vary considerably over time. With ice shelves there are actually two coastlines. The ice-front limits the area of navigable waters, the grounding line where the ice starts to float describes the limit of the ocean water body. On King George Island the temporal aspect of the coastline is of major interest to scientific activities. It is being regarded as an indicator of climate change and has a strong influence on ecosystems.

For the construction of the coastline data it was distinguished between coastline segments in ice-free areas and coastline segments formed by ice due to the pronounced temporal component of the ice coastline position. For the non-ice parts available high resolution data has been used where available. Basically the same source data sets have been included as for the elevation. This results in a accurate and detailed coastline for most of the major ice-free areas.

Wherever the coast is formed by ice the position of the coastline (defined here as the limit of navigable water) has been derived from the most recent available remotely sensed image. For large parts of the island this was a SPOT image dating February 2000, for some parts an ASTER scene from November 2001 was used. Details on image processing and accuracy are provided below in the section on orthoimagery.

The ice cap of King George Island does not nourish large ice-sheets, but there are some tidewater glaciers (e.g. BRAUN ET AL 2002). No information on the position of the grounding lines of such glaciers has been available.

4.2.4.3 Surface Hydrography

Surface hydrographic data includes both lakes and streams and is of relevance to a broad scientific community, for the planning and conduct of operations and to environmental management. There is a pronounced temporal aspect with this data, as melt water is the pre-dominant source for surface water leading to high seasonal and interannual variability in available surface water.

Most of the data has been derived from the high resolution data covering ice-free areas as described above. Additional sources have been used where these sources showed features not present in the data sets used for the elevation. Where spatially overlapping sources with the same level of positional accuracy shows different features, the data set was constructed as a super set of all features present in the source data. This has happened .e.g. on Fildes Peninsula with the hydrographic layer being a combination of data contained in the Chilean, Uruguayan, Chinese and German data sets.

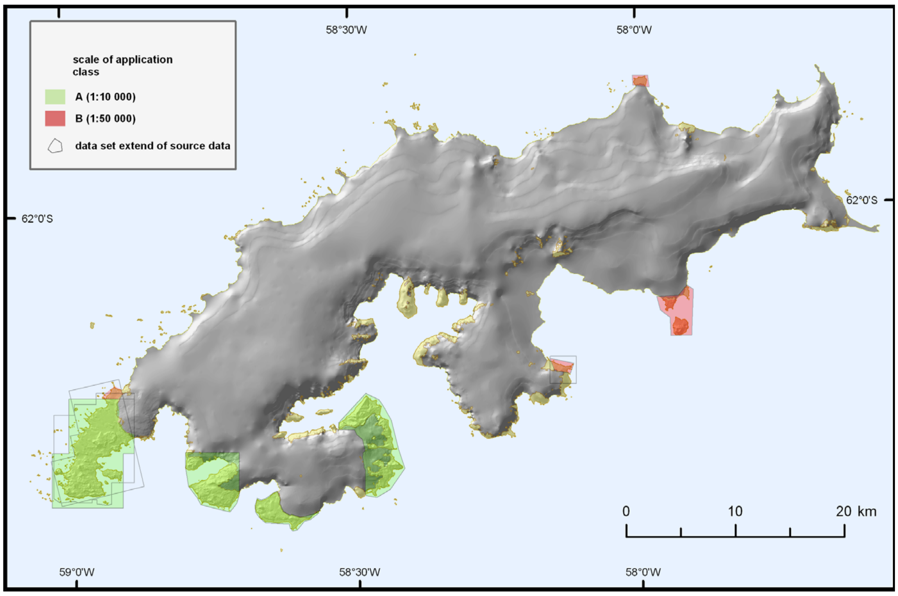

Figure 4-4: Source data and positional accuracy for surface hydrography layer. For details refer to the text.

Aditional data includes the Orthophotokarte Fildeshalbinsel 1:20 000 produced by FH Karlsruhe (FH KARLSRUHE 1988) published in MÄUSBACHER (1991), the Uruguayan Fildes Peninsula Map 1:10 000 (INSTITUTO ANTÁRCTICO URUGUAYO 1997), the geomorphological map of Barton and Weaver Peninsulas (LOPÉZ-MARTINÉZ ET AL 2002), the Lions Rump 1:5 000 map (BATTKE ET AL 1988), the Turret Point and Penguin Island sketch map (BATTKE AND PUDELKO, 2000), a sketch map in BIRKENMAJER (1995) for the Three Sisters Point area. For lakes at False Round Point the orthorectified SPOT image February 2000 has been used although the resolution of the image clearly limits the accuracy of the derived lake boundaries.

4.2.4.4 Ice-free Areas

Land use / land-cover has been identified as part of many framework content models and considerable efforts are being made to standardize respective classifications on a global level (e.g. the IGBP Land Cover Classification used with Global Map). In Antarctica the basic land-cover classification reduces to two classes, ice-covered and ice-free with generally only very minor areas being ice-free. Consequently it is convenient to have a data set consisting only of the ice-free areas instead of a land-cover dataset. This concept is very similar to the rock layer in the ADD. This data set is of general interest for science, operations, and environmental management.

Due to the fast changing extent of glaciers the ice-free area has been mostly derived from the SPOT image February 2000 being the latest available source. The data set was constructed by visual interpretation of the orthorectified satellite image. For the Northern coast, the Eastern part of the island, the surroundings of Krakow Peninsula and the nunataks this is the first consistent data set containing this information for the entire island.

4.2.4.5 Station Facilities

Information on station facilities is mainly required for reference purposes, for operations, and for environmental management. For reference purposes the geometry of the facilities, i.e. the ground plan of buildings and other structures is sufficient. This data was mostly accessible from the available sources.

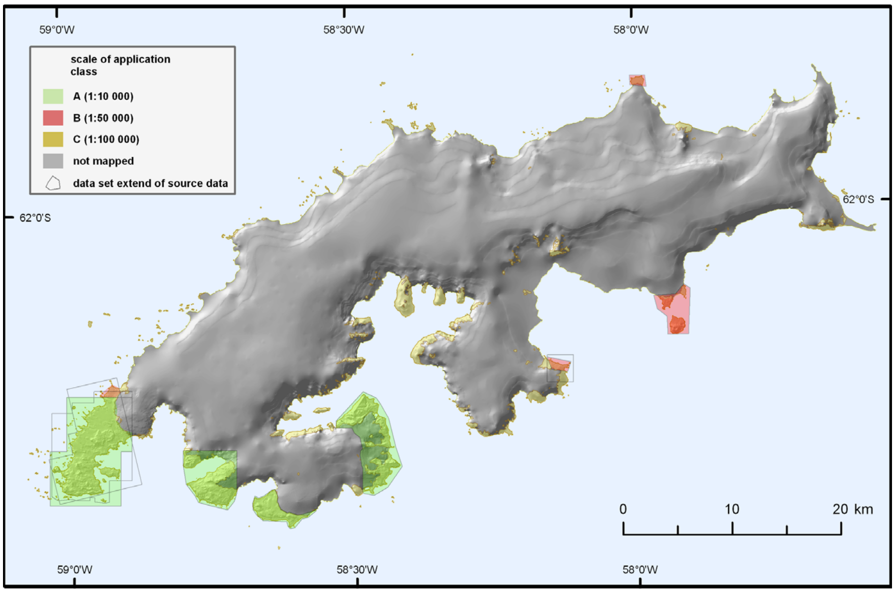

Figure 4-5:Mapping extent of source data and positional accuracy for infrastructure and transportation layers. For details refer to the text.

For operations and environmental management information on status, purpose of use, etc. is essential. Although regarded as required, to collect this information and to keep it up-to-date has been almost impossible. Partly because the institution responsible in managing the facilities have not shown great interest in making available the data, partly because a lack of resources prevented from keeping it up-to-date.

For the Great Wall Station information provided on a detailed Chinese map has been used (CHINARE 1987), this information potentially is outdated. For the Chilean and Russian facilities data collected during field work in 2001 has been used. This information is not complete and potentially already outdated. For Artigas the information was derived from the Uruguayan chart Base Científica Antarctica Artigas (SERVICIO DE OCEANOGRAFÍA, HIDROGRAFÍA Y METEOROLOGÍA DE LA ARMADA E INSTITUTO ANTÁRTICO URUGUAYO 1991). For King Sejong Station, Jubany, Arctowski and Ferraz no attribute information was available.

4.2.4.6 Transport

Information on roads and paths and on facilities for air transport are required both for general reference but also for operations and environmental management. This information has been derived from the available maps and field work mentioned above. Unlike most other areas in Antarctica Fildes Peninsula features an extensive network of gravel roads.

4.2.4.7 Administrative Boundaries

Essentially there are few types of administrative boundaries relevant to the international Antarctic community. One is the limit of the area covered by the Antarctic Treaty itself, i.e. 60°S. Additionally there are the boundaries of areas set aside for protection or management under the Antarctic Treaty System and limits of any subsidiary zones within these areas. Mainly these are Antarctic Specially Protected Areas and Antarctic Specially Managed Areas, additionally Seal Reserves under the Convention on the Conservation of Antarctic Seals, and CCAMLR Environmental Monitoring Program (CEMP) sites.

There might be more administrative boundaries around stations such as no-go zones or a border that defines the area around a base that is not to be left without permission of the station commander. Such limits are only relevant to the respective station personnel, not to staff of other stations.

For the protected areas the spatial limits have been derived from the management plans. In some cases this is straight forward as the limits are defined by natural features. The limit of the ASPA Ardley Island is the coastline of the island (ATCM XXVIII 2005c). The limit of the ASPA in Admiralty Bay is defined by prominent natural features and straight lines connecting these.

For the ASPA on Potter Peninsula the limit towards the land has been derived from the map annexed to the Management Plan (ATCM XXVIII 2005b), which was accurately enough and which presumably had been designed using the same topographic source data that was made available by Argentina to the KGIS project (DNA-IAA IAAG 2002).

For Lions Rump the coordinates given in the Management Plan have been used. Although these are probably not very accurate, in practical terms they are sufficient. Lions Rump is remote from any base, there are no occasional visitors. Any person entering the ASPA would go purposely to that area and would need a permit.

Establishing accurate spatial limits for ASPA 125 on Fildes Peninsula has not been possible. The sketch map given in the management plan is only a imprecise sketch (ATCM VIII 1975).

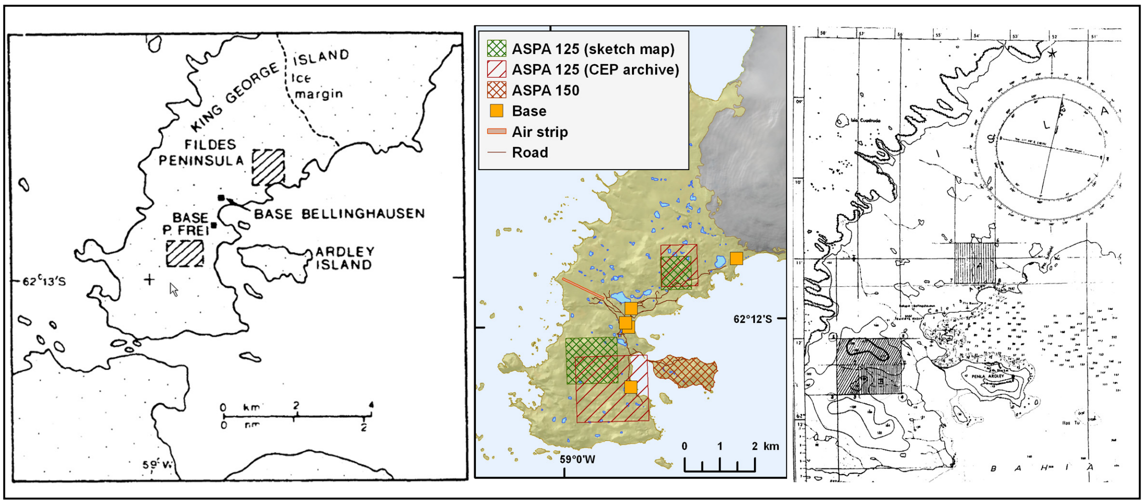

Figure 4-6: Inaccurately defined boundaries of ASPA 125 on Fildes Peninsula. The sketch map to the left is the map as provided with the management plan. The map in the middle shows the boundaries established from the coordinates listed in the CEP Protected Areas Archive with an arbitrarily assigned WGS84 datum (in red) and the coordinates established from the unpublished sketch map to the right (in green). For details see text. Source: ATCM VIII 1975, CEP 2005, INACH (unpublished).

The coordinates listed in CEP Antarctica Protected Area Information Archive (http://www.cep.aq/apa/aspa/index.html) are given without any associated datum (CEP 2005). Based on these coordinates with an WGS84 datum arbitrarily assigned one of the two areas would actually extend into the sea, which is in contradiction to the sketch map provided with the original management plan. Obviously WGS84 could not have been used when the limits were defined originally, but it has not been possible to unambiguously identify the datum initially used.

The geometry of the ASPA 125 as provided with the KGIS data has been established from an unpublished sketch map presumably drawn by the late V. Villanueva when the limits of the ASPA have been defined originally (INACH, unpublished).

The two areas of ASPA 125 are easily entered by visitors as they are located close to the stations on Fildes Peninsula. The values that are protected by the ASPA have already been damaged to a great part by people not aware of the ASPA or not respecting the limits of the ASPA. The lack of tangible natural or clearly marked borders of the ASPA is further complicating the situation.

4.2.4.8 Orthoimagery

Ortorectified imagery is helpful for informative purposes and can be used to derive information for areas not covered by other surveys. The KGIS coastline for example was mainly derived from space-borne orthoimagery. For the ice-free areas orthoimagery with a spatial resolution better than one meter would be suitable for detailed mapping of surface hydrography, transportation infrastructure or even vegetation. This resolution can be achieved by aerial surveys. With the advent of high resolution satellites such as Quickbird or Ikonos it is also possible to acquire imagery from space with a ground resolution of about 1 m. Unfortunately, currently there are no cloud- and snow-free images from the Quickbird or Ikonos archives available for King George Island. To cover the entire island with orthoimagery a SPOT XI scene acquired 23 February 2000 was used. This image shows almost all of the island with only very minor cloud coverage on Fildes Peninsula, Potter Peninsula and an area on the Northern shore.

The image was orthorectified using Erdas IMAGINE 8.4's SPOT Sensor Model implementation, the KGIS DEM and 42 ground control points. The ground control includes points on Fildes, Weaver, Barton and Potter Peninsulas, from the Admiralty Bay area, from Penguin Island and from Stigant point on the Northern coast. The Stigant Point control data was measured during the field campaign in 1997/98 (BRAUN ET AL 2001b), the Admiralty Bay ground control was acquired in 2001 and has been kindly provided by Braun and Pichlmaier (PERS. COMMUN.). It must be noted that there is a lack of reliable ground control for the eastern part of the island. Error assessment with independent control points yielded an RMS error of 0,84 pixels, that is about 17m.

4.2.5 Conclusions for AntSDI

With respect to large scale data a core set of fundamental data layers has been identified which is of potential use to a wide community. Institutions might be encouraged to prioritise making available such data within the Antarctic Spatial Data Infrastructure.

The SCAR Feature Catalogue is capable of supplying the semantics of features comprising the framework data. The experience gained from the diverse source data provided by a multitude of institutions suggests that mapping from private data models to the community model defined by the SCAR Feature Catalogue should be feasible with most data resources. To ensures semantic interoperability within the Antarctic Spatial Data Infrastructure data providers should publicly make available their data using the SCAR Feature Catalogue feature types.

An orthorectified satellite image is provided as orthoimagery background layer. The imagery has great value in providing ground detail and reference for many applications. For large scale applications focussing on the ice-free areas its value is somewhat limited due to the spatial resolution. Existing airborne or high resolution space-borne orthoimagery which provides for the required information should be made publicly available and accessible in georeferenced digital format to the greatest extent possible.

Selected framework data layers are within the responsibility of other domains external to the SCAR community. SCAR EGGI should liaise with the Committee on Environmental Protection (CEP) on issues related to the Antarctic Treaty Protected Area System and with COMNAP on framework data closely related to operations and facility management.

Boundaries of ASPAs and ASMAs are essential framework data within AntSDI. The boundary delineation of protected sites forms the basis of legal enforcement. Currently the black-and white print of a map constitutes the legally binding document on positioning. But such documents are not very accessible in an Spatial Data Infrastructure.

In the annex on map production to the Guide to the Preparation of Management Plans for Antarctic Specially Areas (CEP 1998) it is recognized that some of the original positioning of protected areas is highly suspect. An example of corrupted positioning has been described above with the example of ASPA 125. In the CEP Guide advice is given on how to establish more precise positions for ASPA boundaries (note that the text is not very precise on geodetic reference and might be clarified with respect to the difference of spheroid and reference framework).

For sites where the positioning has been reassessed using GPS the boundary geometry should be made accessible by AntSDI compliant web services for easy integration in spatially enabled applications.

EGGI might communicate the benefits of such services to CEP. The amount of data that actually must be served being very limited it seems reasonable that an appropriate institution can be identified which is able to provide the required infrastructure to CEP. For a start the data might be served for informative purposes only. On the long run the digital version of the boundary geometries may potentially acquire the same legal status as the black-and white map published in an approved management plan.

Framework data related to station facilities and transport is in the domain of COMNAP. Currently COMNAP provides on its website only point representations of the location of stations. For large scale applications in research and environmental management more detailed geometries and a selected set of properties for facilities and transportation infrastructure are required. This data should be managed by the operators of the respective stations and facilities.

EGGI might discuss with COMNAP which would be the minimum set of properties for facilities and transportation that can be made available by the parties. COMNAP might consider to spatially enable its Exchange of Information by including spatially referenced geometries in the reports. Candidate features include buildings and refuges, tanks, pipelines, and aerials.

The same principles applies to transport infrastructure. Noting the liability issues involved, it is suggested that COMNAP might evaluate if spatially referenced data on transportation, such as e.g. the location of helipads or landing strips from the Antarctic Flight Information Manual AFIM, might be made publicly available within AntSDI for reference purposes.

4.3 Place-names

4.3.1 Background

Place-names are the favoured method of referring to a geographic location in human discourse, much more intuitive to use than for example geographic coordinates.

A place can be defined as a socio-cultural expression designating a location, which is typically described in natural language by a place-name (HILL, 2004). A list of place-names is commonly referred to as a gazetteer. A more rigorous definition that emphasizes the link of places to the spatial location is given by ISO 19112:2003 in defining a gazetteer as a „directory of instances of a class or classes of features containing some information regarding position“ (ISO 2003, p. 2) and further describing it as "a directory of geographic identifiers describing location instances" (ISO 2003a, p. 5). The identifier for a place need not be a name. There are many other types of geographic identifiers such as postal codes or street addresses. The positional information can be descriptive, but also a coordinate reference.

Places can be defined in space by an associated geometry. Lakes might by characterized by polygons, rivers by lines, or a sampling site by a point. Encoding of these geometries with geographic coordinates allows places to be represented by the appropriate footprints in a well defined reference system. The coordinate representations of named places are the key to spatially enabling resources. These representations link the textual domain with the spatial domain in a consistent and persistent way (REID ET AL., 2004).

Due to this linking capability in a modern IT environment gazetteers become powerful information tools. Gazetteers for example play a crucial role in establishing spatially enabled digital libraries (HILL, 2004). Gazetteers allow for intuitive navigation in spatially enabled data bases, geocoding of data that has no explicit coordinate representation of its location, and geoparsing. Geoparsing refers to the capability to process a textual document and identify key words and phrases that have a spatial context. A geoparser service works with two sources of information: a textual source (e.g., a scientific publication) and a reserved vocabulary (i.e. the list of place-names). The parser returns all occurrences of any word of the reserved vocabulary in the text source. Each occasion establishes a link between the source and the location associated with the reserved word. A gazetteer can thus support geographic translation and geographic indexing within resources, both of which enhance the capacity to use location as a key search parameter.

A typical use case where gazetteers ad value to other services are metadata catalogues. Metadata often include a point or polygon representation of the data footprint defined in geographic coordinates. The user searching the metadata catalogue would describe his area of interest using a place-name. A gazetteer service then could translate the place-name into a geometry which can be used to query against the geometries stored in the metadata records. Unfortunately, most of the publicly available gazetteer data currently are able to support this level of functionality only to a limited degree.

Although the spatial extent of a geographic feature representing a place is a key element it is often approximate or ill-defined. Geometries can be fuzzy and might change over time. It seems easier to derive and to handle generalized footprints such as a simple point that represents the approximate centre of a feature. Unfortunately this then wouldn't tell about the real spatial extension of the feature and wouldn't allow for operations such as 'contains' or 'overlaps'. Point representation of locations prevails in most gazetteers, but it is not well understood how this generalization affects information representation and retrieval. The development of spatially enabled ranking methods for georeferenced resources is a current research topic (e.g. JANÉE ET AL. 2004, VAN KREVELD ET AL., 2004).

It is desirable to supply more precise footprint geometries to a location. Digital gazetteers easily provide for the possibilities to hold not only point, but also more complex representations of a place, such as lines or polygons. Practically the feasibility of such an approach depends on the types of features that should be represented and on the available source data for such geometries. Within reasonably accurate limits the two-dimensional extend of a lake feature might be stored as a polygon geometry. On the other hand it is generally not possible to unequivocally establish such a polygon footprint for less clearly delimitable features such as a seaway passage.

Most gazetteers have been established by toponymic authorities whose primary purpose is to disambiguate one named place from another. To this end, general point locations for named places usually are sufficient.

4.3.2 Policies: The SCAR CGA

On behalf of SCAR the Italian Antarctic Program is maintaining the SCAR Composite Gazetteer of Antarctica (SCAR CGA). The SCAR CGA is a compilation of Antarctic place-names (i.e. south of 60° South) which are officially recognized by a SCAR member country (SCAR 1998, SCAR 2004c, SCAR 2005). The SCAR CGA contains more than 35 000 place-names referring to more than 17 500 different features. Each place-name entry in the SCAR CGA is associated with a reference number for the feature being named, the country that has provided the name, geographic coordinates of the point representation of the footprint of the named feature, a class attribute indicating the geographic nature of the feature, and in many cases a description of the feature and/or the name.

In Antarctica issues related to place-names have the potential to provoke considerable debate amongst the members of the Antarctic Treaty System and SCAR due to the historical and political implications of the place-names (CERVELLATI ET AL, 2000). There is no single toponymic authority under the Antarctic Treaty System. Many countries have their own Antarctic naming authorities which have responsibility for their territorial claims or areas of national activities in Antarctica, and some countries lack any formal mechanism to establish Antarctic place-names. Geographical names appear in at least 17 languages and five scripts (SIEVERS AND THOMSON, 1995). Multiple names for one feature are common (e.g. HATTERSLEY-SMITH AND THOMSON 1988, SIEVERS AND THOMSON 1995, CERVELLATI ET AL. 2000, VOGT 2004). This has led to a situation where "the potential for at best confusion, and at worst disaster, is obvious" (CERVELLATI ET AL., 2000, p.11).

When establishing the SCAR CGA the goal was to provide a compilation of the Antarctic place-names that have been recognized by national naming authorities to serve as the primary reference of existing place-names. The footprint of the named feature is represented by a point. The point coordinates generally are recorded with a precision to the minute and without an associated geodetic datum.

The feature type of a named feature, in the SCAR CGA terminology called class, has been derived from the generic part of the feature's name in order to help understanding the geographic nature of a feature. It is solely meant to aid in arranging and interpreting the gazetteer data and it is explicitly stated that users should be cautious in relying on the class attributes for other purposes (CERVELLATI ET AL, 2000).

The main design aspect of the SCAR CGA is that only names approved by national bodies be included and that the authority of contributing sources be respected. The data supplied by the respective bodies is used as provided, without changes to the content or correction of errors unless advised by the relevant authority. Great care is taken to deal with the political sensitivities of Antarctic place-names and no priority on which name or spelling to be used is implicated.

Recommendation SCAR XXVIII–1 - *Concerning Antarctic place-names*

Noting that the SCAR Composite Gazetteer of Antarctica (CGA), comprising toponymic data from SCAR member countries, the International Hydrographic Organization (IHO) and the International Oceanographic Commission (IOC), contains around 34,165 entries for 17,097 features, with about 10% of features having two or more entirely different names,

Noting also the need for greater accuracy of the coordinates and applying the principle of 'one name per feature' for both scientific clarity and operational safety

SCAR *recommends* that National Committees, directly or through their national Antarctic naming authority:

1. refer to the CGA in considering all proposals for new place-names;
2. avoid adding new place-names to features already named;
3. submit all new approved place-names and their coordinates to the SCAR Expert Group on Geospatial Information for inclusion in the CGA;
4. ensure that all existing toponymic data are provided to the Expert Group on Geospatial Information for inclusion in the CGA.

Figure 4-7 Recommendation concerning Antarctic place-names, SCAR XXVIII, Bremen, 2004.

National naming authorities are asked to provide relevant data in a timely manner in order to keep the Composite Gazetteer up-to-date.

This policy is backed by a number of SCAR resolutions starting with Recommendation SCAR XXIV - 5 (Cambridge, 1996), followed by Recommendations SCAR XXV-7 (Concepción 1998), SCAR XXVI-2 (Tokyo 2000), SCAR XXVII-1 (Shanghai 2002), SCAR and XXVIII–1 (Bremen 2004).

Noteworthy is that the most recent recommendation SCAR XXVIII-1 for the first time reflects the use of the CGA not only as the primary resource to disambiguate Antarctic place-names but also as a resource for geocoding features by "noting also the need for greater accuracy of the coordinates".

In terms of large scale applications for various reasons many coordinates listed in the SCAR CGA can be regarded as only approximate. In case of multiple names for one feature often coordinates for the very same feature but originating from different countries vary considerably. This is not only confusing but can be dangerous in case of Search and Rescue activities.

Reasons for inaccurate and/or varying coordinates include:

- There is no geodetic datum assigned to the geographic coordinates in the SCAR CGA
- The named feature has some spatial extent, consequently there is no clearly defined location for the reference point of the place-name
- The feature's shape and/or extend has changed over time
- Many coordinates are only registered with a precision of one minute, and for large scale applications this precision is insufficient
- The method with which the coordinates have been recorded is inaccurate
- Typos or other errors in the source gazetteer or in the SCAR CGA

Currently there is a printed version of the SCAR CGA (SCAR 1998, SCAR 2004c) and an on-line accessible and searchable database that is quarterly updated (SCAR 2005).

In order to fully utilize the potential of the gazetteer within the emerging Antarctic Spatial Data Infrastructure it would be an asset if it were a resource with consistent and accurate content that is able to provide the required services through well defined open interfaces.

4.3.3 Enabling Technologies

Today many gazetteers are available online, prominent examples include the Alexandria Digitial Library Gazetteer (http://www.alexandria.ucsb.edu/gazetteer) or the Getty Thesaurus of Geographic Names (http://www.getty.edu/research/conducting_research/vocabularies/tgn/). Although these gazetteers can be used online they cannot be readily included in a SDI as long as they do not conform to common models for content and structure and are not exposed through standardized and open interfaces that support the functionality required within an SDI.

Following HILL AND GOODCHILD (2000) two different models of gazetteers can be distinguished, the metadata model and the hierarchical thesaurus model. The metadata model is more focused on properties of the entries, of particular importance is the location of a place-name. The thesaurus model is directed towards the explicit description of hierarchical relationships of place-names. Recently these to categories have been link both in conceptual as well as in technical terms. A good example for this is ISO 19112:2003.

A solid fundament that enables gazetteers to readily power standards based service interfaces is a well defined and commonly accepted conceptual gazetteer model. ISO TC211 has worked on a standard to provide such a model.

ISO 19112:2003 provides a general model for spatial referencing by geographic identifiers (indirect referencing), where a spatial reference is not defined by coordinates, but by a relationship to a location defined by a geographic feature that is identified by a geographic identifier. Usually the relationship is that of 'containment within', but could also be a more complex one build on properties such as 'adjacent' or 'at a distance and bearing of'. Geographic identifiers are defined as the "spatial reference in the form of a label or a code that identifies a location" (ISO 2003a).

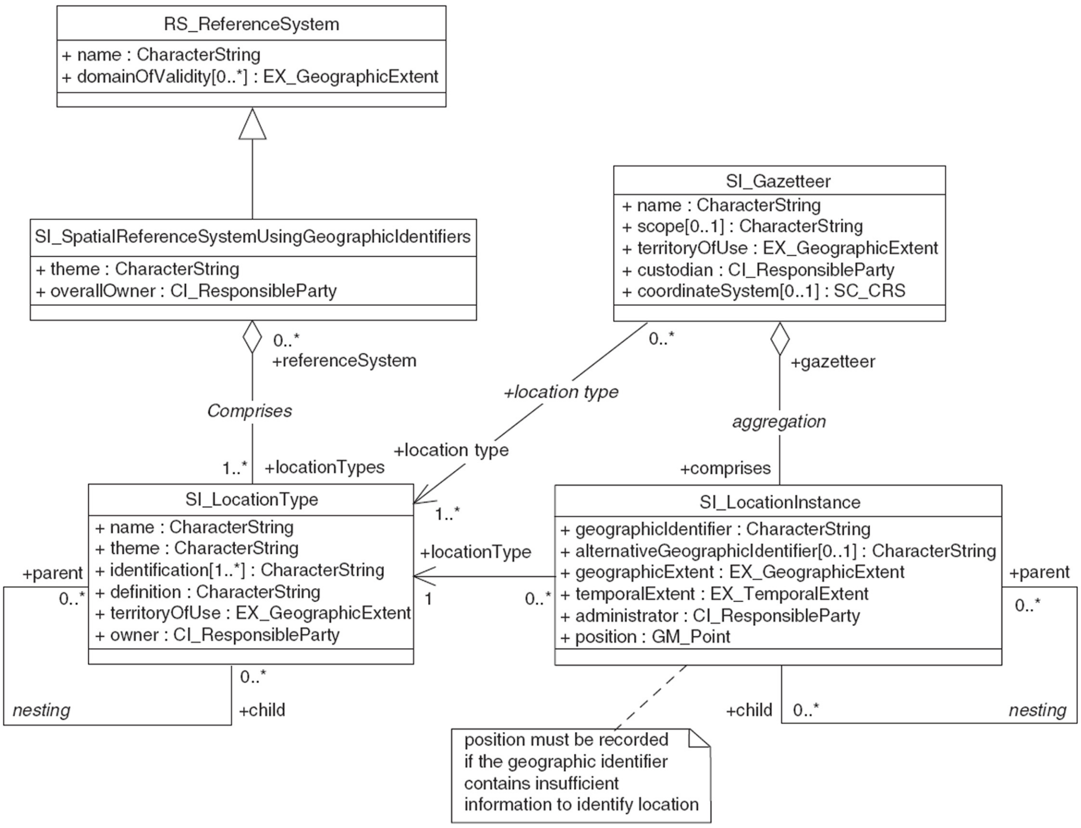

Figure 4-8: Conceptual model of spatial referencing by geographic identifiers. Source: ISO 2003a, p. 7.

The standard aims at enabling the consistent construction of gazetteers. It covers the definition and recording of the referencing feature. The components of a spatial reference system using geographic identifiers and the essential components of a gazetteer are defined.

In the conceptual model the class SI_LocationInstance represents a gazetteer entry. The gazetteer SI_Gazetteer is an aggregation of SI_LocationInstance and has a name, optionally a scope, a territory of use (class EX_GeographicExtent defined in the Extent package of ISO 19115), a custodian (class

CI_ResponsibleParty defined in the Citation package of ISO 19115) and an optional coordinate system (class SC_CRS defined in the Extent package of ISO 19111). The location instances might have properties such as identifiers or descriptions of the spatial and temporal extent and it is possible to defined hierarchical relationships between location instances.

The conceptual model also provides for a spatial reference system using geographic identifiers. Location instances of a gazetteer might be related to location types of such a reference system. The parent/child associations allow for the construction of hierarchical or network-type like structures within the reference system. With the inclusion of location types the semantic information content of the gazetteer can be enriched which for example allows for more powerful search strategies applied to the gazetteer.

Influenced by ISO 19112 and relevant work from the digital library community that is more focused on gazetteer content standards OGC has published a discussion paper on gazetteer services (ATKINSON AND FITZKE, 2002). It builds on OGC specifications such as the OGC Filter Encoding (VRETANOS, 2005) for syntactical interoperability and draws from ISO standards such as ISO 19115 for semantic interoperability. The abstract model to be implemented by the service has been derived from an earlier draft of ISO19112 (ISO/TC211 2001). The proposed OGC Gazetteer Service WFS-G is a specialization of the OGC Web Feature Service 1.0.0 specification (VRETANOS, 2002).

One of the major differences between the WFS-G and the generic WFS is that the gazetteer service must only return features of the defined type SI_LocationInstance, or SI_LocationInstanceBrief, or a type derived from these. This streamlines the coding of clients because of the a-priori knowledge of the structure of the features. SI_LocationInstance implements the SI_LocationInstance model from the ISO19112 draft.

To take advantage of the thesaurus aspect of a gazetteer it is suggested to extend the WFS GetFeature operation by mechanisms to recursively retrieve child, parent, or related features of a given feature.

Although an open standards based interoperable core gazetteer service would be an important asset within SDIs and spatially enabled digital libraries and would be able to add value to other services, the proposed OGC Gazetteer service WFS-G so far has not been adopted as an OGC specification. This might be due to consistency problems with the then evolving base specifications such as GML or WFS. Nevertheless there are some examples where gazetteer services build on the WFS-G discussion paper have been implemented (e.g. FITZKE, 2005).

4.3.4 KGIS Implementation

There are ca. 1020 officially recognized place-names for King George Island registered in the SCAR CGA (SCAR 2005). These names refer to ca. 560 different geographic features. Nine countries (ARG, CHL, CHN, DEU, GBR, POL, RUS, URY, USA) have submitted names for places on King George Island to the CGA. Many places are named by two or more countries. Sometimes the names differ only by the generic part of the name (e.g. Punta Thomas vs. Point Thomas), sometimes the same geographic feature has been given entirely different names by different countries (e.g. Admiralty Bay vs. Bahía Lasserre). Multi-naming is common especially in areas used by many countries, e.g. on Fildes Peninsula or in Admiralty Bay. About 35% of the named features have more than one name assigned. In addition to the officially registered names there are many more unofficial names used in maps, charts, or publications.

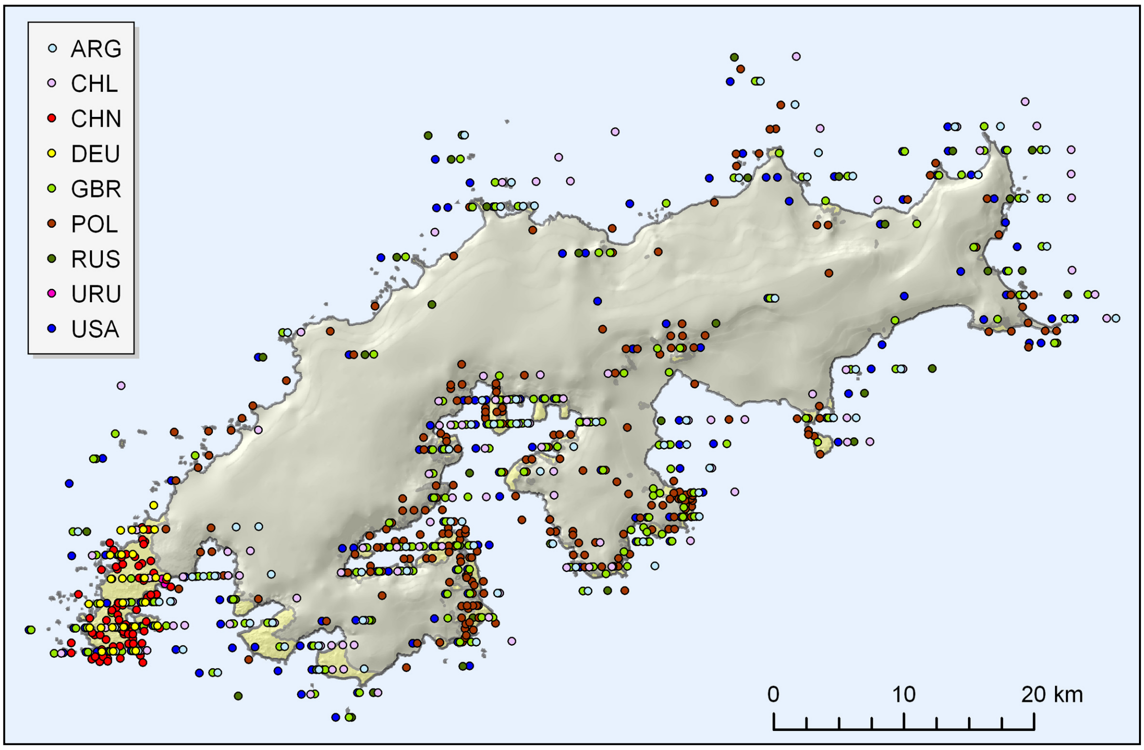

Figure 4-9: Named places on King George Island as listed in the SCAR CGA. Note the concentration of named features on Fildes Peninsula (lower left, ca. 260 names) and in Admiralty Bay (central bay, ca. 360 names).

In a pilot study the SCAR KGIS topographic data has been used to develop a methodology to solve the "One pair of coordinates per SCAR CGA feature" problem inherent to the SCAR CGA and to relocate the place-names to less imprecise and more consistent positions. Using the KGIS data and high resolution satellite images a dataset has been constructed with new, unique and in many cases more accurate coordinates for each SCAR CGA feature on King George Island. The data set also provides a reviewed classification of the locations, parent-child relationships between locations and a hierarchy for portrayal purposes. In the following this dataset is referred to as the KGIS Gazetteer.

It has to be noted that although developed based on the SCAR KGIS project data this gazetteer is not an officially endorsed gazetteer. It should be regarded as a result of a pilot study to demonstrate that it is technically feasible to improve the spatial accuracy and to enrich the semantic content of the SCAR CGA data and to show the benefits of more consistent toponymic data. Historical or political considerations have been explicitly excluded from the study and where coordinates for a place have been used as listed by a source country this does not imply any precedence or priority for the place-name from the respective country.

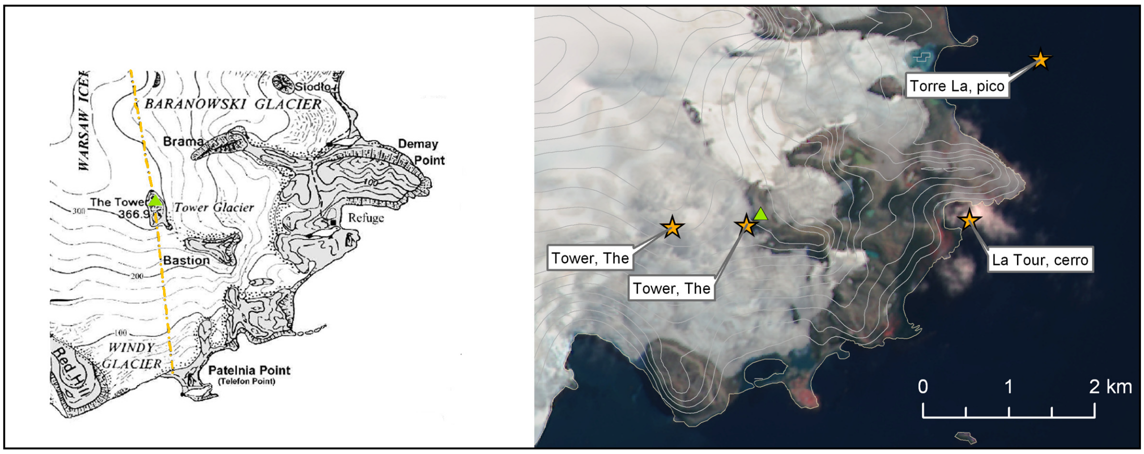

Figure 4-10: An example for multiple coordinates for one feature. The named feature is a mountain that is used in the description of the limits of ASPA 128 as shown in the left part of the figure. The yellow stars indicate the locations of that feature based on the coordinates given in the SCAR CGA, the green triangle shows the true location. Note how the features Tower and Bastion, shown in the map as nunataks, now form a ridge; note also the retreat of Windy, Tower and Baranowski Glaciers. Source left part: Management Plan SSSI 8, modified, right part backdrop ortho-rectified SPOT satellite image 2000-02-23.

Two steps must be performed to apply a single and accurate position to a named place: identification and positioning. Before being able to assign more precise coordinates to a named feature the feature must be unambiguously identified. Mapping a list of place-names to a detailed set of geographic features is often not as simple as it seems. Descriptions and sketch maps are not always unambiguous. Inconsistencies between descriptions of older place-names and the more recent control data set might sometimes reflect the changes in the dynamic glacial and peri-glacial environment. Natural phenomena, e.g. ice dammed lakes or melt water streams, used in verbal descriptions or in sketch maps might have changed size or shape or might have disappeared. Sometimes the control data set shows more features of a given type than the sketch map or the description. This might happen due to an imprecise description or to newly evolved features.

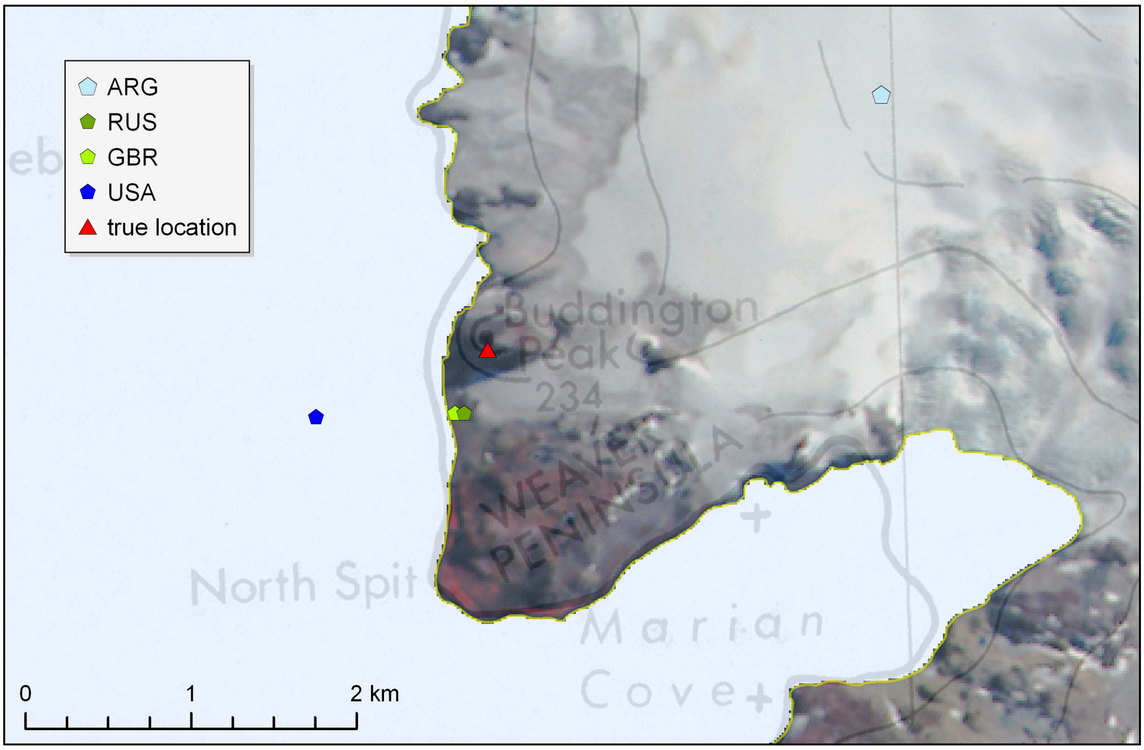

Figure 4-11 Identifying feature 1996 (Buddington Peak / Monte Gomez) using the orthorectified satellite image and a co-registered British map. The new location is marked by the red triangle, the varying SCAR CGA locations for feature 1996 as submitted to the SCAR CGA by four different countries are indicated by the other markers.

Maps, sketches and gazetteer descriptions from the respective naming countries that show or describe locations of place-names have been carefully used and cross checked with other available sources to resolve any ambiguity in feature identification. In conflicting cases precedence was given first to the national gazetteer information, then to sketch maps devoted to place-names, then to other sources such as published maps. The table below shows the source data used for this task. The auxiliary maps and sketches have been georeferenced by co-registration to the KGIS data. Although co-registered sketch maps do not provide for accurate positions they have helped in feature identification.

used for place-names from this country	used for identification (I) / location (L)	Data source
all	L	SCAR King George Island GIS Project topographic data as of 2004-04-01.
all	I/L	orthorectified SPOT XS image, Acquisition date 2000-02-03, the image was orthorectified using the KGIS DEM (50m resolution) as of 2004-04-01 by IPG Uni Freiburg.
all where applicabale	I	Place-name description in the SCAR Composite Gazetteer of Antarctica as of 2005-07-01.
ARG	I/L	Potter Peninsula, 1:10 000, Instituto Antartico Argentino and IAAG Uni Munich, 2003.
CHL	I/L	Isla Rey Jorge - Peninsula Fildes, Instituto Geografico Militar and Instituto Antartico Chileno, 1996.
DEU	I	Orthophotokarte Fildeshalbinsel, König Georg Insel, 1:20 000, Heidelberger Geographische Arbeiten 89, 1991.
DEU	I	Institut für Physische Geographie der Freien Universität Berlin (unpublished): Schreiben vom 11. März 1985 (Stäblein) an den Ständigen Ausschuß für Geographische Namen (StAGN); Liste neuer topographischer Namen im Bereich der Fildes Peninsula (King George Island, South Shetland Islands, Antarktika), erhoben bei Expeditionen unter der Leitung des Geographischen Instituts der Universität Heidelberg (Barsch) und des Geomorphologischen Laboratoriums der Freien Universität Berlin (Stäblein) 1982-1985., incl. sketch maps.
GBR	I	Antarctic Place-names Committee, Foreign and Commonwealth Office: British Antarctic Territory, South Shetland Islands, Sheet 1 King George Island, APC Misc 64,1:100 000, 10th Edition, 1986.
GBR	I	Antarctic Place-names Committee, Foreign and Commonwealth Office: British Antarctic Territory, South Shetland Islands, Admiralty Bay, APC Misc 67, 1: 50 000, 4th Edition, 1986.
GBR	I	Antarctic Place-names Committee, Foreign and Commonwealth Office: British Antarctic Territory, South Shetland Islands, Fildes Peninsula Misc 85, 4th Edition, 1:25 000, 1978.
POL	I	Cape Lions Rump, 1:5 000, Battke, Z. and J. Czisak, Polish Academy Of Sciences, 1988.
POL	I/L	Site of Special Scientific Interest No. 8, 1:12 500, IUNG Pulawy, 2002.
POL		Zatoka Admiralicji, 1:25 000, Furmanczyk, K. and A. Marsz, Polish Academy Of Sciences, 1980.
POL	I	Birkenmajer, Quaternary geology at Arctowski Station, King George Island, South Shetland Islands (Anatrctica), Studia Geologica Polonia, 110, 1997, pp 7-26, p 92.
POL	I	Birkenmajer, Geology of the northern coast of King George Island, South Shetland Islands (West Antarctica), Studia Geologica Polonia, 110, 1997, pp 7-26, p 15ff.
POL	I	Birkenmajer, K., Basal and intraformational unconformities in Lower Oligocene glacigenic deposits (Polonez Cove Formation), King George Island, South Shetland Islands (West Antartcica), Studia Geologica Polonia, 107, 1995, pp 99-129, p 103.
POL	I	Birkenmajer, K., Quaternary Geology at Lions Rump (SSSI No. 34), King George Island, South Shetland Islands (West Antarctica), Bulletin of the Polish Academy of Siences, Earth Siences, 42/3, 1984, pp 207-211, p 208.
POL	I	Paulo, A. et A.K. Tokarski, Geology of the Turret Point – Three Sisters Point Area, King George Island (South Shetland Islands, Antarctica), Studia Geologica Polonia, 1982, pp 81-103, p 83.
URU	I/L	Isla Rey Jorge - Peninsula Fildes, Instituto Antartico Uruguayo, 1997.

Table 4-1: Sources used for feature identification.

Once the feature is unequivocally identified it is possible to assign a precise reference point to the named place. To relocate the reference point for the named feature to a unique and accurate position the SCAR KGIS topographic data base, an orthorectified SPOT satellite image (dated 2000-02-23) and occasionally additional maps have been used. Each feature is represented by a point. Obviously there are some feature classes which provide for an intuitive position for the point, such as the very top of a mountain feature. With lake features the centre point was used. With watercourses the point has been set close to the shore but with a reasonable distance inland. The inland point location accommodates for changes in the coastline and the fact that on many beaches watercourses join and constitute a braided river system. In a similar fashion the points representing glaciers have been set close to the glacier front on the centre line of the glacier but far enough upstream to consider potential glacier retreat. For less clearly defined features such as a seaway passage or a valley the point was set somewhat arbitrarily in the guesstimated centre of the feature. Whenever an already existing position from the CGA was reasonably close to the above described positions these already existing coordinates have been used. In most cases this happened with more recent place-names of which the coordinates are listed with a better precision than to the minute. Presumably such coordinates have been collected by GPS.

Using the above described procedure of careful identification and relocation it was possible to identify and locate 92% places, that is 511 out of the 560 named features. The review of the SCAR CGA content proved the excellent work of the compilers in feature identification and classification.

When compiling the SCAR CGA incorrect feature identification resulted in two types of error. One category comprises names where it was not recognized that different names describe the same feature. The other category consists of names assigned to one feature although naming different features.

In ca. 24 cases names from different countries describing the same feature have been allocated different SCAR CGA reference numbers. For example Lago Uruguay (URU, SCAR CGA 15226) refers to the same feature as Profound Lake (GBR/USA, SCAR CGA 11650), and Kiteschbach (DEU, SCAR CGA 7586) is the same feature as Station Creek (GBR/USA, SCAR CGA 13954).

In one case names assigned to one SCAR CGA reference number (SCAR CGA 4167) actually name different features. See-Elefanten-Bucht (DEU) is a cove located at Fildes Peninsula, whereas Elephant Seal Cove (POL) is located at Turret Point. Note that the translation of See-Elefanten-Bucht yields Elephant Seal Cove – a striking example where uncoordinated naming can become really confusing.

Four features have changed their geographic nature due to ice retreat, one feature has completely disappeared. An example is the feature SCAR CGA 1130 which formerly was a small cape that due to ice retreat has become an island. It is called Bell Point by the UK, USA and Russia, whereas the Polish name is Bell Island. In the SCAR CGA (SCAR 2005) the class assigned is 8 (Capes and coastal projections).

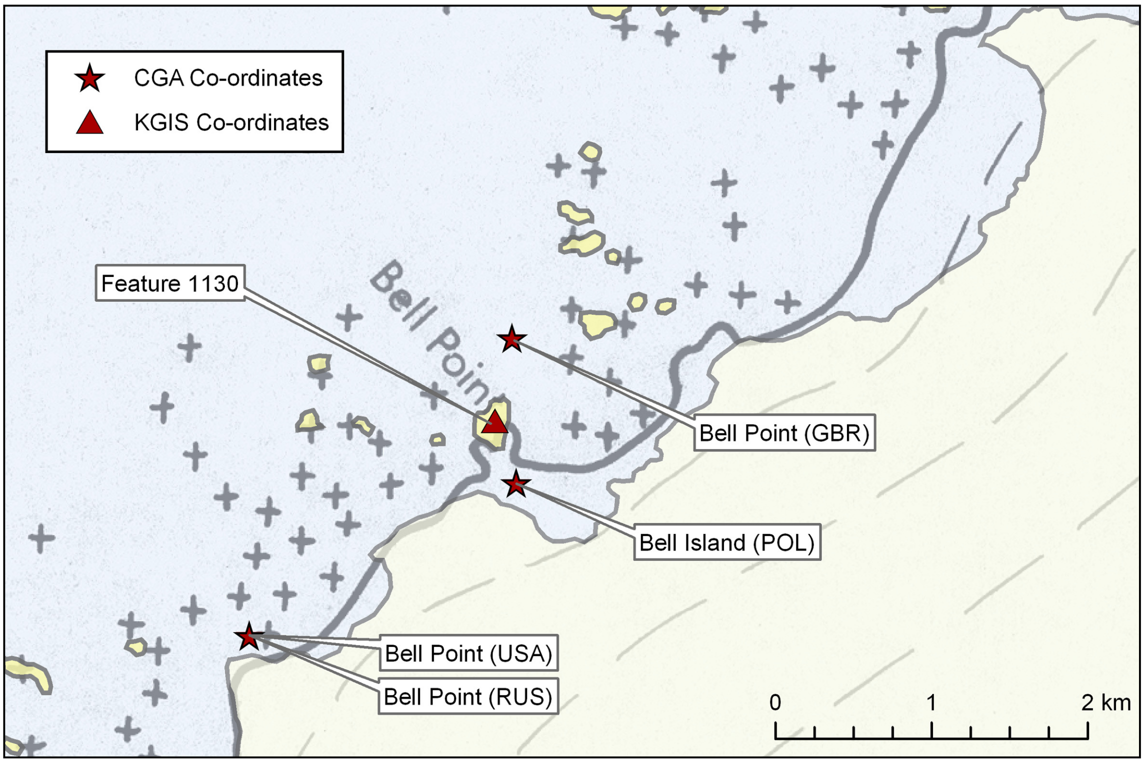

Figure 4-12: Feature 1130 has changed its geographic nature from a small cape to an island: The figure presents the coast line (thick line) as shown in the place-name sketch map (UK APC Misc64, 1986) overlaid on the SCAR KGIS coast line (thin line). Stars indicate feature coordinates as listed in the SCAR CGA, the triangle indicates the new single position for the feature as used in the KGIS Gazetteer. Note: the sketch map is only approximately co-registered to the KGIS data for informative purposes.

In the British sketch map published in 1986 (UK APC Misc64, 1986) the feature is shown as a small cape. Due to ice retreat it has become an island as can be seen on a satellite image acquired in 2000 from which the KGIS coastline data in this area is derived. Figure 4-12 shows both the coordinate variations for the gazetteer entries from the different countries and an overlay of the KGIS data with an approximately co-registered British sketch map. The ice-cliff front has retreated leaving Bell Point as an island.

Although the case study proved that in most cases it is a straightforward process to identify and relocate features given appropriate reference data is available there are some general problems to be noted.

Fuzzy boundaries of certain feature types make for somewhat arbitrary point positions. This is a known problem that is inherent to such feature types and the concept of a point representation.

In some cases the control data do not allow for a unique feature identification. Typically this has happened when the exact summit location of a mountain feature was not resolved in the topographic data and not clearly identifiable in the imagery. Occasionally this has also happened with coastal features such as cliffs and points where the recent coastline doesn’t show any clearly distinguishable such feature. This might be due to the fact that a cliff might be visible when looking from a boat towards the coast but that cliff might not be recognizable when looking from above. It is also possible that the coastline has changed such that the feature has disappeared, e.g. a once protruding ice-cliff forming a cape has been subject to glacial retreat and the cape-like shape has been destroyed. In few cases the description of the feature was unclear and there was no other source available.

In the KGIS topographic data base the more precision positioning of the place-names greatly simplified identification of named instances of respective feature types such as lakes or watercourses. All the named instances of lakes, watercourses, glaciers, and infrastructure facilities have been semi-automatically attributed with the SCAR CGA reference number to enable linking a feature to the place-name(s). In the interactive KGIS Mapviewer for example a query against a feature instance of these types returns all of the associated SCAR CGA names.

A review of the class attribute of the SCAR CGA based on external data sets such as descriptions, maps and imagery has been performed. None of the national Antarctic gazetteers supplied to the CGA included any reference to the type of feature named. The feature type given in the CGA was derived from the generic part of the name by the compilers of the SCAR CGA (Cervellati et al. 2000). When mapping place-names to feature types one has to be aware of the fact that geographic names can be poor indicators of feature type, since any name can be given to any feature. Often the generic part of the name does not reflect the authoritative definition of the respective feature type. This problem has been described for other gazetteers as well (Hill et al., 1999).

Additionally the classification scheme is not easily applied in a consistent way. Some classes used in the SCAR CGA show a lot of separation from other types; for example, the generic mappings for inland water features (class 11) or islands (class 5) do not show any overlap with other feature types. Other categories, however, are difficult to separate; namely the elevated features (classes 2a-f) have many generic mappings in common. When a category is very broad, it potentially becomes a dumping ground for a wide range of feature types not otherwise categorized.

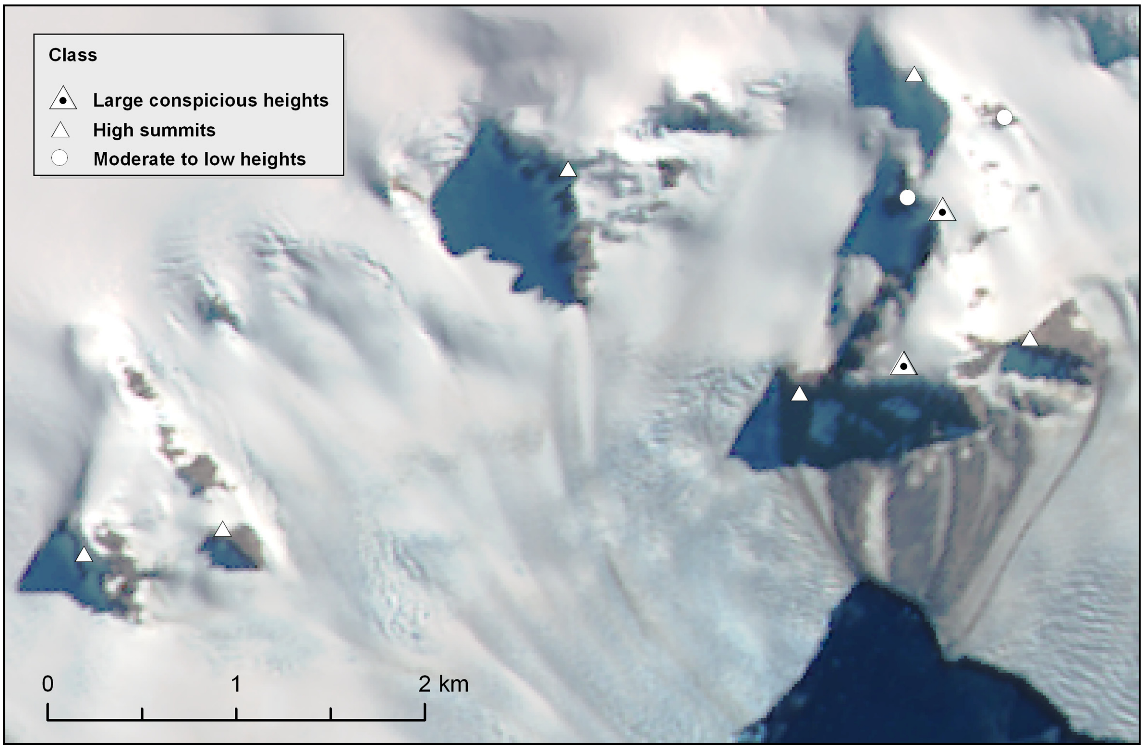

Figure 4-13: Ambiguities in feature classification due to overlapping classes: Named elevated features in the Arctowski Mountains as classified in the SCAR CGA. Although features are not easily identified in the image it is even more difficult to unambiguously decide on the appropriate class. The class boundary between moderate and high is fuzzy and classes 'Large conspiciuos heights' and 'High summits' semantically do overlap. Backdrop is an ortho-rectified SPOT satellite image.

The classification of the named places based on the generic term of the place-names has led to misclassification of only ca. 16 features (ca. 27 names). An example of erroneous mapping from the generic term to the feature type is the place Süd-Passage (DEU, SCAR CGA 14203) which was classified as a sea access feature where in fact it denotes a broad mountain pass. The main problem with the classification lies rather in a consistent mapping to feature classes that overlap, such as the elevated feature classes high summits (2d) versus large conspicuous heights (2a).

The conceptual model of ISO 19112:2003 allows to establish parent-child relations between locations. These relationships enable semantically richer searches based on the thesaurus concept of broader and narrower term. In the KGIS Gazetteer data set parent-child relationships have been assigned to the places according to their spatial location and extent. For a given feature multiple relations of the same type have been allowed, for example a bay could be both a child of the land mass it is projecting into and a child of the larger water body it is part of. Admiralty Bay is for example both a child of Bransfield Strait and of King George Island. Theoretically additional relationship types could be defined, such as 'adjacent to' or 'overlapping with'. This would open interesting possibilities for advanced searches but was considered beyond the scope of this study.

Additionally to the parent-child relationships hierarchical levels of locations have been introduced as an attribute that provides for automated label selection for portrayal. An approach to construct a hierarchy for Antarctic place-names has already been described (BAS ET AL. 1993, ROBERTS ET AL. 1994, COOPER AND FRETWELL 2003). The hierarchy introduced in that study was mainly meant to serve cartographic purposes. The hierarchical level of a location was derived implicitly from the parent-child relationship tree. Unfortunately names are unevenly distributed throughout Antarctica. To arrive at consistent hierarchical levels without breaking the parent-child relations artificial objects as place holders in the hierarchy had to be introduced.

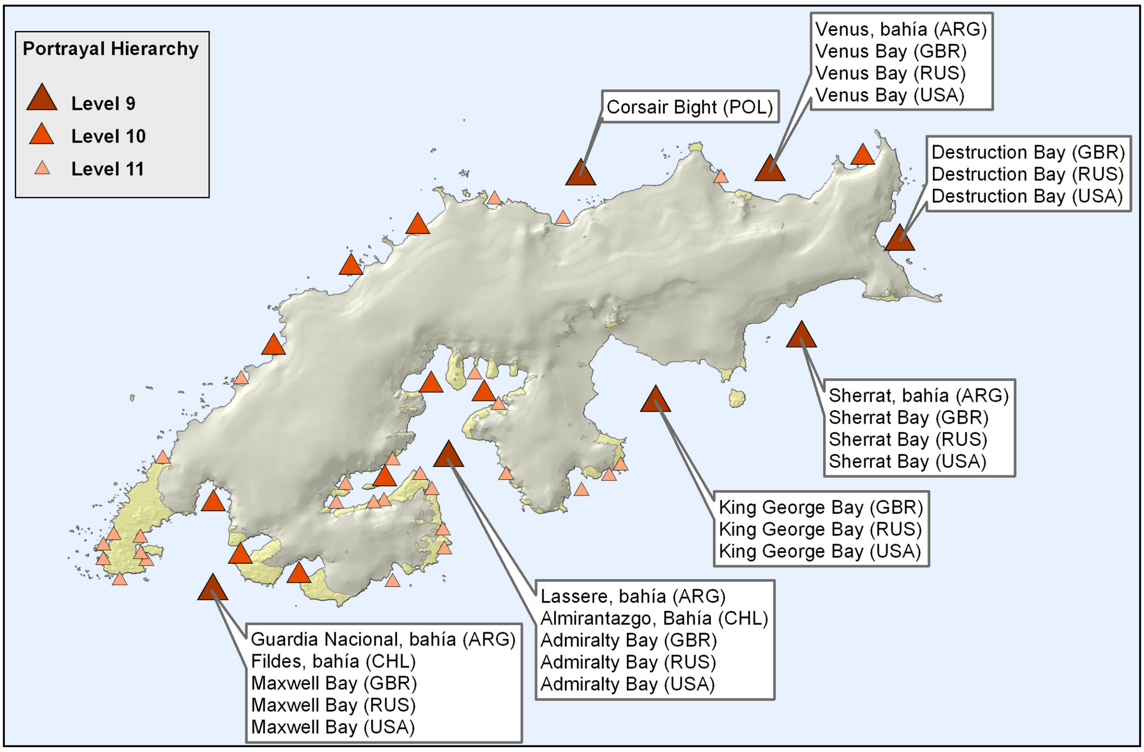

Figure 4-14: Hierarchical levels for label display: For clarity only the cove and harbour features are displayed and only the top level has been chosen for labelling.

For the KGIS Gazetteer the parent-child relationship has been split from the location hierarchy for cartographic display. The portrayal hierarchy is considered a separate concept from the parent-child relations and as such a location property in its own right. For example both the small Wesele Cove (ca. 0,58 km²) and the large fjord-like Admiralty Bay (ca. 133 km²) are direct children of the Bransfield Strait. Nevertheless they have been assigned different hierarchical levels. This avoids the introduction of artificial place holders into the gazetteer. At the same time this is a very flexible approach which can accommodate for the variety of aspects relevant in the label selection process, which not necessarily are reflected in a parent-child hierarchy or the size of a feature. Names describing the location of some human activity might be an example for such features. To fit into the bigger picture of the whole continent hierarchical levels have been chosen following the schema proposed in BAS ET AL (1993) and ROBERTS ET AL (1994) resulting in four levels applied to the places on King George Island.

For each identified named SCAR CGA feature on King George Island the KGIS Gazetteer now provides:

- as identifier of the location the SCAR CGA reference number
- a pair of unique and accurate coordinates
- a reviewed class attribute
- a hierarchy-level attribute for automated label selection for portrayal
- parent-child relationship(s) with other locations
- information on the data source(s) used to identify the feature
- information on the data source(s) used to derive the unique and more accurate coordinates for the reference point

The reference number in the KGIS Gazetteer can be used as a pointer to the respective SCAR CGA entry or in case of multi-naming to the respective SCAR CGA entries with the related description(s) and coordinates. This structure is consistent with the general SCAR feature model as specified in the SCAR Feature Catalogue which allows a feature to have more than one geometry. In this case we would have the original SCAR CGA coordinates as additional geometries.

The data set constructed in the pilot study is available through an OGC WFS interface that can be plugged in into other OGC compliant client applications. The KGIS WFS service provides a feature type Place-name that delivers features with the KGIS Gazetteer location point position as geometry and all associated SCAR CGA place-names and respective source countries as attributes. This allows the end user to select which name (or names) to use. Note that this is not yet a full WFS-G implementation as the thesaurus filter capabilities are not fully supported yet.

While keeping the existing SCAR CGA content untouched the external KGIS Gazetteer with the SCAR CGA Reference Number as identifier allows to provide accurate and unique coordinates per SCAR CGA feature. Additionally it supplies a reviewed classification attribute that not only relies on the generic term mapping but is derived from additional data, namely maps and imagery. It also includes relationships between locations that provide for enhanced search capabilities. A hierarchy of place-names applicable in label selection for display purposes is introduced.

The current solution works fine in terms of technical implementation and can be plugged in transparently in applications to provide the SCAR CGA data with more precise positions. In the KGIS Mapviewer for example it enhances the navigation by place-name functionality. In case of multi-naming it uses the related term capability of the thesaurus model to be able to display all alternative SCAR CGA names for a given feature.

The drawback of this approach is that the KGIS Gazetteer currently is no formally recognized gazetteer. In terms of institutional policies it remains questionable if this approach is sufficient for the future development of the SCAR CGA. It is an open discussion how such more accurate and unique coordinates can be incorporated in the SCAR CGA or at least be formally related to it.

4.3.5 Conclusions for AntSDI

The SCAR Composite Gazetteer of Antarctica (CGA) is a priceless resource for named locations in Antarctica and a crucial component of the emerging spatial data infrastructure for Antarctica. SCAR has continuously recognized the importance of the integrity of the gazetteer content in SCAR resolutions since the first publication of the SCAR CGA.

The case study on the SCAR CGA content for King George Island suggests that with improvements to the content of the gazetteer the SCAR CGA can be enabled to better power capable gazetteer services.

In case of multi-naming the coordinates associated with the different names for the same feature most often do vary. Additionally, in terms of large scale applications many coordinates for place-names can be regarded as only approximate.

To ensure consistency of the SCAR CGA and to tap its full potential for a spatial data infrastructure it is suggested the coordinates associated with the place-names be reviewed and more precise coordinates be established. The KGIS Gazetteer pilot study shows that this is feasible in areas for which a firm topographic reference dataset including imagery is available. In cases where multi-naming occurs with more precise coordinates the “One pair of coordinates per SCAR CGA feature” issue can be resolved as well.

International co-operation for such gazetteer projects would be beneficial. Access to required control data would be facilitated and input from affected countries be ensured. SCAR might consider establishing a policy to stimulate and endorse such coordinated projects. It might be useful to start with such projects in focal areas of human activities and areas where multi-naming is common. SCAR might identify such high priority areas.

When establishing new positions for the reference point it is absolutely crucial to record metadata on the control data used for both feature identification and feature relocation. The metadata allows interested parties including national place-name authorities to evaluate the relocation. SCAR might consider setting up reporting requirements and a quality control scheme.

SCAR should start a discussion on a policy to formally register the more accurate and unique coordinates in the SCAR CGA. There is potential for considerable debates on such projects. Issues include the historical and political implications of the place-names, liability, a feasible way to achieve results in a timely manner, and the resourcing of the work.

One approach could be to suggest each country to modify their national gazetteers for Antarctic place-names accordingly with the new coordinates and then to formally resubmit those place-names including the modified coordinates to the SCAR CGA. It can be questioned if this approach is acceptable. The positions given in the gazetteers are part of the definitions of the place-names and consequently this would require national naming authorities to accept gazetteer content imposed by external entities.

An alternative approach could be to include the new and more precise coordinates in the SCAR CGA as an additional geometry for the respective feature. This would be consistent with the SCAR CGA policy to respect the naming authorities. The advantage would be that gazetteer data as supplied by national authorities could rest unmodified. The current gazetteer content model can accommodate for such an approach. The new data can be considered a source gazetteer data set in its own right, providing as place-names simply the SCAR reference numbers. The source naming authority could then be the project that provided the coordinates or SCAR itself. On the other hand this would require some sort of SCAR endorsement for the additional coordinates potentially including issues such as selection of appropriate data sets, quality control, and liability.

A third alternative could be to simply provide guidelines for the establishment of informal gazetteers that can link SCAR CGA features within specific areas to new, unique and more accurate coordinates. Even though not formally recognized or endorsed such gazetteers could be useful products in terms of gazetteer services and could leverage the full potential of the SCAR CGA for the respective areas by improving geocoding applications. Currently the KGIS gazetteer is such a product. While this approach would circumnavigate the political issues related to the SCAR CGA, on the long run it seems to be less favourable as it might lead to conflicting gazetteers for an area.

Apart from the issues described above there are further topics which do not bear the political and institutional implications described above.

Currently coordinates in the SCAR CGA do not have an associated geodetic datum and for most legacy data in the SCAR CGA it will not be possible to reconstruct this information. Nevertheless, to provide for a more precise spatial reference it is suggested that all new coordinates included in the SCAR CGA have assigned a geodetic datum. It is suggested that the SCAR CGA content model be extend to provide for the means to record this information.

There is a temporal dimension to the names as well. This is common with many gazetteers as features might change their name and extent through the course of history. In the case of Antarctica there is an additional component due to the changing physical environment. Currently the SCAR CGA structure allows to record temporal information only in a limited way by including it in the description attribute. The case study indicates that it might be useful to extend the content model of the SCAR CGA to allow for a temporal extend attribute. This is consistent with the ISO 19112:2003 conceptual model for a gazetteer (ISO 2003a) and would allow for automated processing of temporal attributes in gazetteer applications.

In terms of semantic content of the SCAR CGA the pilot study suggests that it seems difficult to apply the SCAR CGA feature classification in a consistent way. The generic term mappings often are the easiest accessible source of information on which type a named feature belongs too. The cost associated with reassessing each feature might favour the generic term mapping as a practical approach. The feature type can be derived from the name itself and without the need to consult other sources. When place-name positions are reassessed the feature has to be identified in additional sources other then the gazetteer, for example a satellite image or a detailed map. At this stage a more precise classification of the feature might happen at minimal extra cost.

To this end it might be well worth considering establishing a modified list of classes for the SCAR CGA based on the feature types and definitions of the SCAR Feature Catalogue. This would enhance interoperability of gazetteer based applications and other data bases as they would share common semantics.

Using the SCAR CGA reference number as an attribute for feature instances in topographic databases facilitates harvesting of polygonal or line footprints from GIS datasets to enrich gazetteer footprints. For example a lake feature that bears one or multiple names listed in the CGA might carry the attribute of the SCAR CGA reference number. This enables populating the geographic extent attribute of a location instance in an automated way. At the same time this allows to relate all names listed in the SCAR CGA to the respective feature without having to assign priority to a specific name. It might then be left to the end user of the data to decide on which name to use e.g. for display purposes thus circumventing the name selection problem common with printed maps (SIEVERS AND THOMSON, 1995). The SCAR Feature Catalogue already provides for such an approach of linking the gazetteer and other databases by listing the SCAR Reference Number as an attribute for all feature types which can be named.

Relationships between locations improve the search capability of a gazetteer. Introducing a parent-child relationship would enrich the semantic content of the SCAR CGA and greatly enhance search capabilities by allowing to search following the broader and narrower term concept of the thesaurus model. Parent-child relationships between location instances are in accordance with ISO19112:2003.

The use of the gazetteer data in portrayal web services such as a WMS calls for the ability of automated label selection. This can be achieved by introducing a hierarchy of identifiers for display purposes. When reviewing the named locations in a specific area such a hierarchy might be developed. To ensure consistency amongst such hierarchies a well defined set of hierarchical levels would be required. It is suggested to establish guidelines on how to establish such hierarchies including definitions for the respective levels.

Based on the pilot study for King George Island enhancements to the content and structure of the SCAR CGA have been suggested. Most of the suggestions can be implemented respecting the authority of contributing national naming authorities, i.e. without changes to the provided content unless advised by the relevant authority. The changes do not judge on the source content, but add functionality for efficient and automated processing of the SCAR CGA in spatially enabled web services.

4.4 Common Semantics: Implementing the SCAR Feature Catalogue

The SCAR Feature Catalogue is being developed as part of the SCAR EGGI project SCAR Spatial Data Model under the coordination of Australia. The Australian Antarctic Data Centre (AADC) is hosting the technical infrastructure to provide the Feature Catalogue online and also has to a great extent developed the content of the Feature Catalogue. By kind invitation of the Australian Antarctic Division it was possible to work with the AADC staff and to jointly further develop the contents of the SCAR Feature Catalogue based on experience from the KGIS project.

In the following the concept of feature catalogues is introduced, the relevant ISO standard ISO 19110 is presented, and relevant SCAR policies are described. The section on KGIS implementation provides examples of semantic integration of source data by mapping the data models of the source data sets to the feature types of the SCAR Feature Catalogue. A short description of the integration of the Feature Catalogue into the technical infrastructure of KGIS and on how the semantics of the data are communicated to the users is provided, too. The final section concludes with some recommendations for the further development of the SCAR Feature Catalogue based on the KGIS experience.

4.4.1 Background

“Geographic features are real world phenomena associated with a location relative to the Earth, about which data are collected, maintained, and disseminated. Feature catalogues are defining the types of features, attributes, their operations, and relationships represented in spatial data from a specific domain. Feature catalogues are vital to turning data into usable information. Feature catalogues enable the dissemination, sharing, and use of spatial data through providing a better understanding of the content and meaning of the data” (ISO1910:2005a).

As long as suppliers and users of geographic data don’t have a common understanding of the kinds of real world phenomena represented by the data, users will be unable to judge whether the data supplied are fit for their purpose.

ISO/TC211 has developed ISO 19110:2005 Methodology for Feature Cataloguing to provide a standardized framework to organize and report the classification of real world phenomena. A catalogue of feature types presents the specific abstraction of the real world applicable to a given domain in a form understandable and accessible to users of the data. The requirements of particular applications imply the way real world objects are grouped into feature types. The feature catalogue defines the meaning of the feature types and their associated attributes, operations and associations. It provides the common semantics that allow users to understand the meaning of the data.

The conceptual model shows that a feature catalogue consists of features at the type level, which are characterized by properties. These properties might include attributes, associations and operations. Each feature type must have a name, optionally a code, alias names and a definition. Properties must have a name, optionally a definition; attributes specifically might also carry a code, the associated unit of measurement, in case of domains with listed values the list of values and their meaning, and the data type.

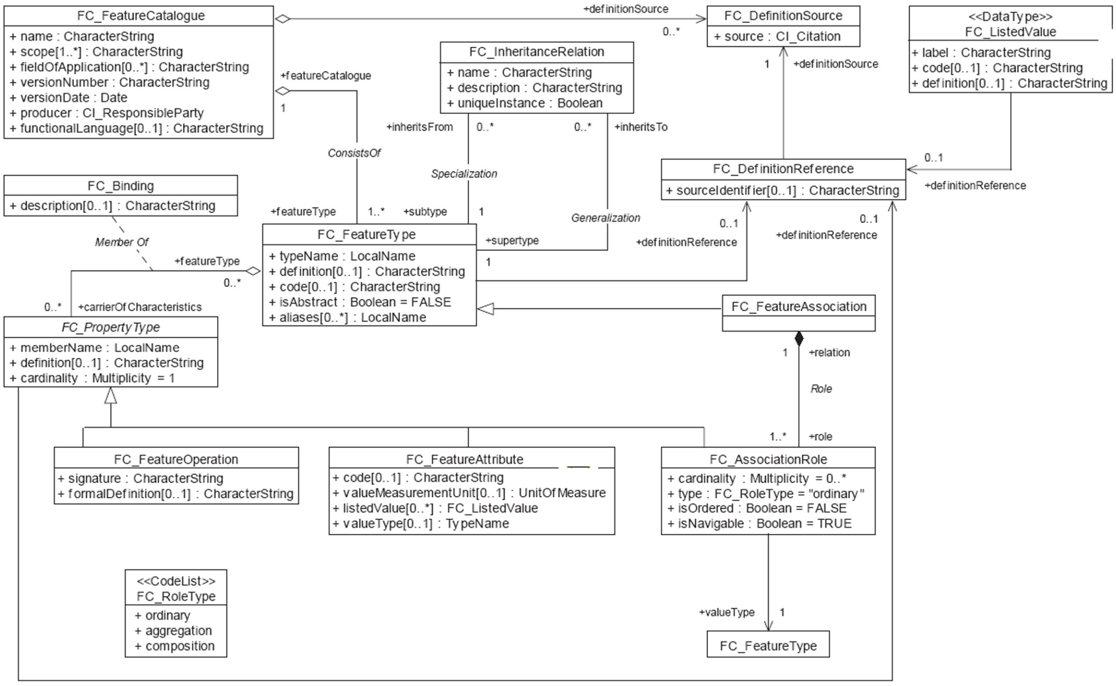

Figure 4-15: ISO 19110 - The conceptual model of a feature catalogue. Source: ISO/TC211 2004a, p.28.

Given the variety of institutions and scientific communities that either provide or use Antarctic spatial data the necessity of an accepted set of definitions of feature types is obvious. To standardize the representation of geographic features is a long standing effort within SCAR (e.g. BERGE ET AL 1996). Major efforts of the former SCAR WGGI have produced a draft feature coding system that can be regarded as a first step towards a feature catalogue. The symbol dictionary (THOMSON 2000) was derived mainly from experience gained from static, analogue (i.e. paper) maps and was targeted at the production of these kinds of maps.

The increasing ease of data sharing in electronic form across the internet urged a revamping of the WGGI project to establish a dictionary suitable for digital spatial data. Important design principles from the very beginning have been compliance to emerging ISO standards and an object oriented approach that allows the SCAR Feature Catalogue to be flexible enough to cater to existing spatial data structures.

The SCAR Feature Catalogue is based on ISO 19110:2005 Methodology for Feature Cataloguing (ISO 2005a, note that the development of the SCAR Feature Catalogue has been based on the Final Draft Standard of ISO19110 (ISO/TC-211 2004a).

It has to provide the means for semantic interoperability within the emerging Antarctic Spatial Data Infrastructure. An extensive set of feature types and mandatory attributes have been specified The catalogue currently describes approximately 400 feature types with their definitions and attributes. The catalogue is accessible online at http://www.aad.gov.au/default.asp?casid=14645 through a searchable web interface.

Given the broad information community it applies to and the wide variety of application domains the catalogue has a flat structure with no build in hierarchies to provide maximum flexibility.

One of the basic principles in constructing the SCAR Feature Catalogue is to rely on definitions from the relevant scientific and non scientific information communities. Using the definitions from accepted sources within the respective communities is regarded as key to the successful implementation. For example names of plants or animals are referenced from the SCAR RiSCC taxonomy (http://www-aadc.aad.gov.au/biodiversity/default.asp). Definitions of glaciological features follow the glacier classification manual developed within the Global Land Ice Measurements from Space Programme (RAU ET AL 2005), one of the major international glaciological projects.

At present the Feature Catalogue does not include association relationships between features nor operations on features. These might develop as the catalogue evolves.

The SCAR Feature Catalogue now is a living document accessible on the web (http://www-aadc.aad.gov.au/gis/model/). SCAR GIG members and interested scientific communities are encouraged to comment on and contribute to the SCAR Feature Catalogue development.

4.4.2 Policies

The SCAR Feature Catalogue is developed and released in increments to allow for insight during the development process. At the same time it incorporates feedback from scientists of the various disciplines to adjust the range of features with which the reality is modelled to the scientific needs.

A rigid policy on updates of the feature catalogue has not yet been established.

A translated version of the SCAR Feature Catalogue in Spanish language has been produced by Chile. This is very useful in terms of communicating the semantics of data to the large Spanish speaking (i.e. mainly South American) part of the community. Given the regular updates of the content it remains an open question how the resources required for maintaining translated versions can be secured.

4.4.3 Enabling Technology

The SCAR Feature Catalogue is available online through a searchable web interface. It can also be downloaded as a Microsoft Access™ data base. This facilitates setting up a local copy of the catalogue within the environment of the respective data base that is powered by the SCAR Feature Catalogue. Currently there are no standardised encoding schemes or access service interfaces defined for feature catalogues.

4.4.4 KGIS Implementation

The Australian Antarctic Division, the coordinating institution and driving force for the SCAR Spatial Data Model Project, can be considered to represent that type of institutions which have almost complete control on the production of Antarctic data sets they are responsible for.

In the KGIS project the challenge is to handle data sets that come from a broad diversity of institutions and there has been almost no control on the production of data sets included in the KGIS data base. The SCAR community comprises a mixture of both, the large national Antarctic Institutions with well established information technology and data management infrastructures and a plethora of smaller institutions and research groups with a wide range of technical and financial capabilities and often less well defined data management policies. The Feature Catalogue should accommodate for both complimentary views on spatial data management.

To take into account the variety of data users and producers and the consequential diversity of data structures SCAR WGGI considered the experience stemming from the SCAR KGIS project an essential input to the development of the SCAR Feature catalogue. The Feature Catalogue has been implemented with the KGIS data base. Modifications and amendments developed during the implementation have been provided as feed back to the SCAR Feature Catalogue. The results of the joint work with Australia were presented at SCAR XVII, Shanghai, 2002 (Brolsma et al., 2002).

The SCAR KGIS data base is implemented as a spatially enabled relational data base. The feature catalogue is implemented such that each feature type is modelled as a feature class in its own right, i.e. each feature type lives in its own table. For features that can be represented by multiple geometries (e.g. as points or polygons) the table can hold different geometries. Attributes fields with listed values hold the codes for these values.

A local copy of the feature catalogue is stored in the database. Codes and short names of the Feature Catalogue are used as keys linking the data tables to the Feature Catalogue. This allows to easily update the local copy of the Feature Catalogue when a new version becomes available. It is also readily possible to use the Spanish version of the SCAR Feature Catalogue to communicate the verbose semantics in an additional language.

Views linking the data tables with the feature catalogue provide for a verbose presentation of feature attributes and attribute values to the public. This is used for example with the WFS service to produce GML property names and values in accordance with the feature catalogue.

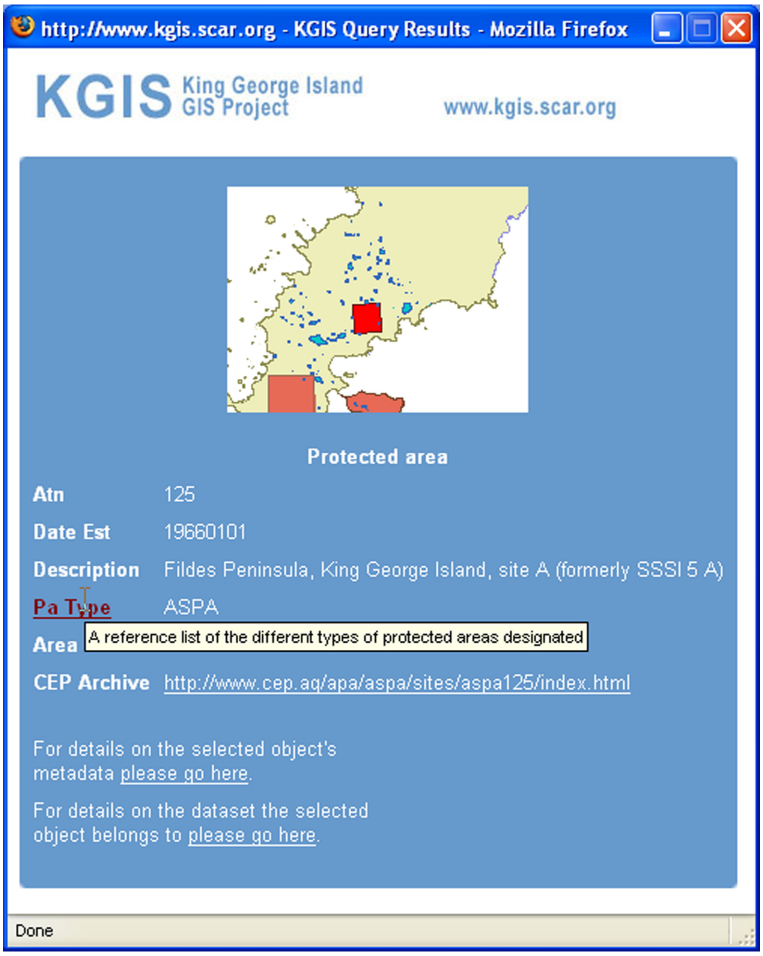

Figure 4-16: Using the Feature Catalogue to communicate the meaning of the data: In the KGIS Mapviewer users can access definitions of feature, attribute and attribute values by simply pointing to the respective term. A fly-out window displays the respective definition pulled from the SCAR Feature Catalogue.

Another application that relies heavily on the local copy of the Feature Catalogue is the SCAR KGIS Mapviewer, that pulls definitions for features and attributes from the catalogue tables.

Moving the mouse cursor over the name of a feature, an attribute or an attribute value name triggers a fly-out window to appear that displays the verbose definition of the respective term (Fig. 4-16). Depending on the language the user has selected for the viewer the names and definitions are presented either in Spanish or English. This makes the meaning of the data readily visible to the consumer of the data.

To establish consistent semantics in the integrated KGIS database the contents of each source data set have been carefully mapped to feature types from the Feature Catalogue. Where necessary the SCAR Feature Catalogue contents have been extended or modified during the joint work with AADC to allow for consistent mapping.

Depending on the data set mapping occurred at different levels. In some cases a one to one mapping from a data set layer to a SCAR Feature Type was possible. In this case only the attributes of the source data had to be mapped to the appropriate properties of the SCAR feature.

With some data sets, mainly data provided in CAD formats, the mapping occurred at the feature level. An example would be a data set with a layer man-made structures. This layer had to be mapped at the feature instance level to e.g. building, tank, pipline, bunding, etc. The workflow then involved extensive consultation of additional information to identify the correct feature type.

4.4.5 Conclusions for AntSDI

The usefulness of any information is reduced when the meaning is unclear, especially across different application domains.

Under the SCAR Spatial Data Model project coordinated by the Australian Antarctic Division the SCAR Feature Catalogue is being developed to support common semantics for Antarctic spatial data. The Feature Catalogue thus facilitates sharing of spatially referenced data and information not only within the SCAR community but also with external user groups such as CEP or COMNAP.

The successful implementation of the SCAR Feature Catalogue in the KGIS data base suggest that it is possible to map a wide variety of data structures present in the Antarctic community to the feature types listed in the feature catalogue. This does not necessarily require to restructure a data base scheme that is used in any given institution. It is merely required to develop a consistent mapping of the private schema to a public schema in accordance with the feature catalogue to be able to present data with semantics consistent with other resources within the Antarctic Spatial Data Infrastructure.

It has to be noted that using the semantics of the Feature Catalogue will not automatically result in interoperability between applications. With respect to syntactic interoperability an encoding schema for the feature types would have to be developed. In the context of a service oriented architecture build on OGC-and ISO standards this should by a GML application schema.

It may also be used as a standard framework within which to harmonize semantics of overlapping domains. It can for example help to bridge the gaps in the terminology used in specific scientific disciplines or to CEP and COMANP terminology by either providing for consistent mappings of terms used or by direct inclusion of the required feature types.

However, in situations where classifications of features differ, the SCAR feature Catalogue may at least serve to clarify the differences and thereby help to avoid the errors that would result from ignoring them.

An example is provided by in the annex on map production to the Guide to the Preparation of Management Plans for Antarctic Specially Areas (CEP 1998). There is a list of features to be considered for inclusion on maps of protected areas. The list gives an indication of what features are important from the environmental management view point. The list is rather extensive, but only few features are not yet present in the SCAR Feature Catalogue. Specifically approach routes for boat and aircraft are currently not listed in the Feature Catalogue and should be included. Few features have overlapping semantics which cannot easily be mapped one to one to a feature type from the SCAR Feature Catalogue.

In the further development of the Feature Catalogue liaison with CEP, COMNAP and the different scientific communities might be enhanced to ensure a complete and consistent classification of features for the Antarctic Community.

Having the SCAR Feature Type Catalogue as a living document on the web supports the need for easy access, and allows for rapid update of enhancements and amendments. A fast changing document on the other hand prevents from implementing the Feature Catalogue in applications as it is not always possible to keep track with the updates.

Currently the development of the Feature Catalogue is driven by a few groups in a rather informal way. To institutionalize the update and amendment of the Feature Catalogue a policy on versioning needs to be established.

This policy should rationalize the workflow from suggestions of changes and peer review of suggested changes to finally adopt or dismiss the changes. The review board might include members from different user groups such as scientists, operation managers and environmental managers.

Releasing versions shouldn't occur too often. One version per year might be a reasonable interval.

When changing definitions or bindings of attributes or attribute listed values care should be taken to ensure backward compatibility as much as possible and reasonable.

When deleting feature types, attributes, or attribute listed values 'deprecated' for the deleted object might be used at least for one or two years.

4.5 Metadata

4.5.1 Background

Typically spatial data is used by many people other than the data producer. To understand and to be able to make proper use of the data the user needs to be provided with documentation on the data. This documentation is generally referred to as metadata.

Metadata allows the producer to characterize the spatial data properly. It facilitates the management and organization of data. It permits the user to determine if data is of use to the envisaged application. It enables the user to make use of the data in the most efficient way. It facilitates data discovery, retrieval, and re-use.

Metadata standards are helpful in documenting data in a consistent way. For spatial data a variety of metadata standards is in use. The Dublin Core standard is mainly used in the library domain and not specifically developed for spatial data. There are standards at the national level such as the Content Standard for Digital Geospatial Metadata (CSDGM) of the US Federal Geographic Data Committee (FGDC).

At the international level ISO/TC211 has developed two standards that relate to metadata: 19115:2003 Geographic Information – Metadata (ISO 2003b) for spatial data and 19119:2005 Geographic Information – Services (ISO 2005b). ISO 19119 includes specifications to describe spatially enabled services. ISO 19115 provides for the documentation of spatial (and non-spatial) data sets.

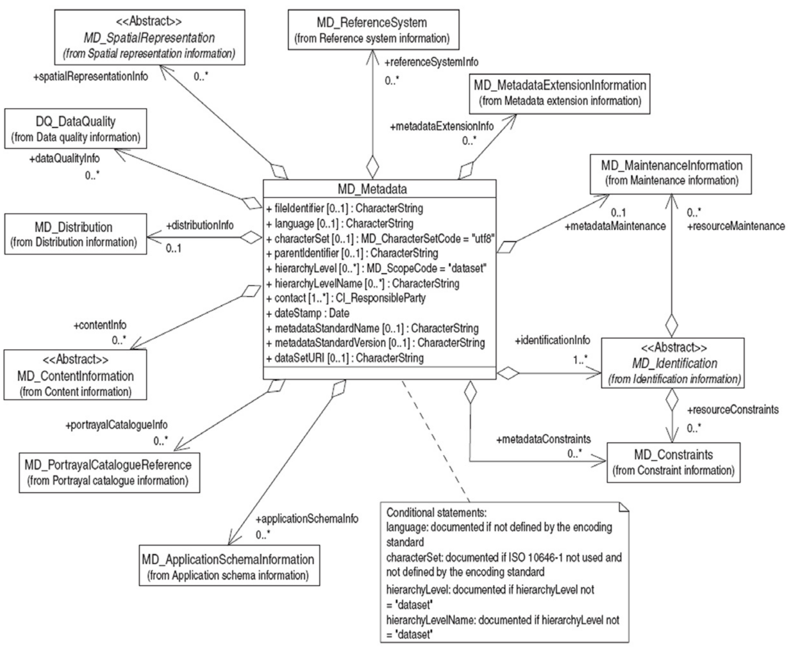

Figure 4-17: The classes that in aggregate form the class MD_Metadata of ISO19115. Source: ISO/TC211 (2003), p 19.

With ISO 19115 the TC211 has developed an extensive standard for describing data. The standard lists eleven classes which in aggregate form the MD_Metadata class. The classes allow to record identification of the dataset, information on data quality, distribution of the dataset, the spatial and temporal extent, access constraints, and the like. The standard describes the content and definitions of metadata elements, their data types, and their inherent dependencies. In total the standard lists almost 300 elements that can be used to document various aspects of the data. The standard provides also for a formal way to specify additional elements.

The standard is one of the core standards of the ISO 19100 family of standards. Elements of this standard are reused in other standards.

The standard can be applied to any granularity of data. It can be used to document metadata at the level of data series, at the level of data sets and at the level of feature types and instances. It allows for linked hierarchies in order to minimize duplication of metadata elements

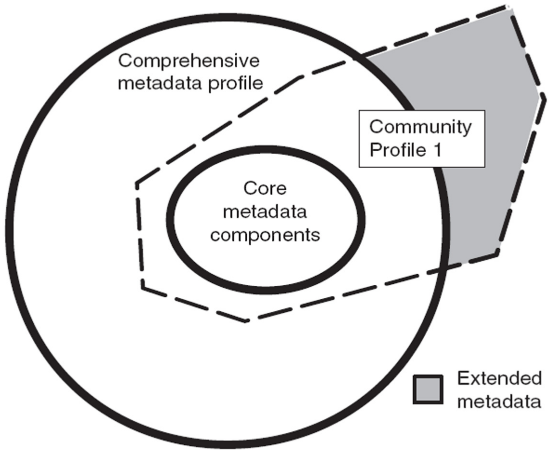

Figure 4-18: Metadata community profile. The inner circle contains the mandatory core elements from ISO19115. In the profile optional elements of the comprehensive metadata profile are included. Additionally the profile contains a set of metadata extensions specified according to the rules for extension. Source: ISO/TC211 2003, p. 107.

Only a core set of the metadata elements is mandatory. Consequently, in order to arrive at a useful set of metadata elements an application profile for a specific community can be developed. The extension profile must include the core set of metadata elements as specified in ISO 19115, it can declare a selected set of the optional elements listed in ISO 19115 mandatory, and add additional elements according to the rules for extensions as described in the standard.

Within the project ISO 19139 Geographic information - Metadata - XML schema implementation the TC211 is developing a XML encoding schema for ISO 19115 (ISO/TC211 2004b). With this Technical Standard it should be possible to encode the ISO 19115 elements in a consistent way to allow for automated processing with software tools. Once this specification is published it is expected that ISO 19115 community profiles and associated ISO 19139 profiles will evolve as useful tools in an automated processing environment.

Within the SCAR community JCADM has the mandate to advise on data management. JCADM has established the Antarctic Master Directory (AMD), which is the SCAR endorsed metadata catalogue for Antarctic data. The AMD is a directory that contains data set and service descriptions including descriptions of spatial data sets. The AMD is currently hosted by the Global Change Master Directory (GCMD) and is accessible through its own portal at http://gcmd.nasa.gov/KeywordSearch/Home.do?Portal=amd.

For the GCMD and consequently for the AMD the Directory Interchange Format (DIF) and the Service Entry Resource Format (SERF) are the standards to be used to describe data sets and services. DIF and SERF are considered to provide that set of attributes that are instrumental in helping users to determine if a data set meets their qualifications. Consequently DIF and SERF standardize metadata that is mainly suitable for data discovery and retrieval. DIF and SERF are less comprehensive than ISO 19115. The capability to document for example the lineage of a data set is somewhat limited.

The success of the AMD depends on the commitment of data managers and producers, i.e. in many cases the scientists themselves, to produce metadata records. Although Antarctic research scientist are the major beneficiaries of such metadata they have not been very successful as originators of this metadata.

4.5.2 Policies

JCADM has established the Antarctic Master Directory as the central metadata catalogue for Antarctic Science data. The AMD is a suitable catalogue for data discovery. SCAR member countries should encourage scientists to publish metadata on their data, including spatial data, in the AMD, either through their respective National Antarctic Data Centres or directly to the AMD.

No decision if and how ISO 19115 and the forthcoming ISO 19139 might be applied in Antarctic Data Management has yet been taken.

4.5.3 Enabling Technologies

To publish DIF or SERF records the GCMD provides for tools that help in creation of the metadata, the simplest being a browser based web interface to manually fill in the DIF or SERF fields in order to create a valid record.

Many GIS software packages provide for tools to create metadata records that follow ISO 19115 from a spatial data set in a semi-automatic way. As the encoding of such records is not yet standardized it is not necessarily straightforward to parse an ISO 19115 record created with one application with another application.

4.5.4 SCAR KGIS Implementation

Within KGIS metadata plays a crucial role in order to keep track of the source data used to create the integrated products and to document the process steps to transform the source data to the final products. With this respect metadata records are used to assist in managing the data base.

Metadata about the KGIS data base has been published to the AMD, both as DIF records for the downloadable data and as SERF records for the access and portrayal services. Here metadata has been produced to allow for discovery of the data set.

Within the KGIS project the ArcGIS Metadata Editor based on the Draft Standard of ISO 19115 was used to document metadata for the source data and the integrated data sets. The metadata is encoded in XML. However, with ISO 19139 not yet published it is currently not possible to encode 19115 elements in XML according to a common standardized schema. Common sense has driven the selection of required metadata elements and it is expected that with the advent of ISO 19139 and of profiles derived from it the mapping from the now existing XML records to a more interoperable schema should be straight forward.

4.5.5 Conclusions for AntSDI

Metadata needs to be made available in order to help users identify and locate relevant datasets. The AMD is an appropriate, established and SCAR endorsed metadata catalogue for data discovery. Building on this, AntSDI would require that framework datasets and the other spatial datasets as well as services that provide those data are documented in the AMD and that the metadata is kept up to date.

AMD is a powerful tool to advertise the existence of data sets and services. Its ability to be harvested by internet search engines increases the potential user community dramatically. Users need not be aware of the AMD or of SCAR activities to discover the data.

Additionally through its web portal the AMD presents the metadata records accessible in a structured form and searchable by discipline, keywords, or location.

Through the programming interface the AMD can be searched by other spatially enabled tools as has been demonstrated with the KGIS Mapvierwer. Spatially enabled portals and online mapviewers within AntSDI might include similar functionality in order to make AMD content readily available to the users in a spatial context.

The GCMD currently does not provide for an OGC Catalogue Services interface which would allow for catalogue services to discover data or services within the AMD through a well defined open standards based interface. JCADM might consider the usefulness of such an interface and evaluate the possibilities to establish such an interface in order to make AntSDI data sets and services discoverable with clients that implement OGC Catalogue Services.

ISO 19139 will soon provide the means to consistent encoding of ISO 19115 community profiles. EGGI might consult with JCADM in order to identify a suitable profile or to establish a SCAR ISO 19115 profile and an associated XML schema based on 19139. This would allow to provide more comprehensive metadata records with spatial data sets from Antarctica. Such a profile might enable to convey information on accuracy and completeness in a standardized and interoperable way.

4.6 Data access and Portrayal Services

4.6.1 Background

OGC has specified three services that are considered useful in the AntSDI environment for data access and portrayal. These are the Web Map Service (OGC WMS), the Web Feature Service (OGC WFS) and the Web Coverage Service (OGC WCS).

The WMS serves a georeferenced image of spatial data according to the user's request. The current version is WMS version 1.1.1 (OGC 2002a). The WFS delivers discrete features modelled as vectors including the attributes and encoded in GML. The most recent version published is version 1.1 (OGC 2005a). The WCS serves continuous data where a position in a spatio-temporal domain is associated to a record of values of defined data types, including raster data. The current version is WCS 1.0 (OGC 2003b).

Additional relevant specifications include the Filter Encoding (OGC 2005b), which provides the ability to express predicates in XML, a functionality very useful with WFS, and SLD, the Styled Layer Descriptor (OGC 2002b). The SLD is an encoding for how the WMS specification can be extended to allow user-defined symbolization of data.

Web map services are used for portrayal of spatial data. A map server provides a visual representation of the data, not the data itself. The intention is to portray spatial information easily for most users, requiring only map reading skills. Applications include the presentation of general purpose maps to show locations and geographic backdrops, as well as more sophisticated and interactive mapping tools. Web mapping services are often used to assist in spatially enabled search systems, showing extent and geographic context of data against map reference data.

Map services that provide OGC interfaces are called OGC WMS (note that there are other map services). An OGC WMS can potentially deliver images in various formats including PNG or JPEG, it might also provide a representation of the data in the SVG vector format. The service is simple yet powerful. A client can request maps from different servers and construct an overlay image. Servers might be cascading, that is a server might request the data it provides from another server. Additional functionality that allows the client to interact with the server to request specific portrayal of the data is provided by Styled Layer Descriptor enabled WMS.

Typical clients include Desktop GIS that implement a WMS interface. Clients are also available on the internet as applications that run in a browser.

Web Feature Services provide discrete features encoded in GML. There are two categories of WFS. A basic WFS supports read access by the client to the underlying data store. A Transactional WFS supports also write access. A WFS client may analyze, visualize or process the retrieved data.

4.6.2 Policies

AntSDI is build on open standards interfaces and consequently supports OGC WMS, OGC WFS and OGC WCS services.

A projection commonly used with Antarctica at medium and small scales is the Polar Stereographic Projection as specified for the ADD (BAS ET AL 1993). Where applicable services should be able to serve data in this projection.

A service advertises the spatial reference system of the data served in order to allow the client correct overlay of different data sets. A convenient way and a de facto standard to exchange information on projections and reference systems is using the codes from the EPSG Geodetic Parameters Dataset (OGP 2005).

A set of projection parameters for the portrayal of data in the Lambert Conformal Projection based on the recommendations of SIEVERS AND BENNAT (1989) has been promoted into the EPSG data base, too. Since Version 6.7, released 29 May 2005, the EPSG Geodetic Parameters Dataset includes these projections. The projections can be used as a common set of projections for portrayal at medium scale. Where applicable services should be able to advertise the relevant ones of these projections in order to facilitate interoperability.

4.6.3 Enabling Technology

On the server side there is a wide variety of products to set up a WMS server and some software packages to set up a WFS server. Most of the server applications can connect to the standard data stores used in spatial data management.

4.6.4 KGIS Implementation

For the KGIS data base both a WMS service and a WFS service have been set up based on free and open source products. The system runs on Linux. The data store at the back end is provided by the PostgreSQL/POSTGIS free and open source relational data base management system. The WMS server is setup using the UMN Mapserver software as described in Chapter 3. The WFS server is implemented with GeoServer, a free and open source java tool, that is the OGC reference implementation of the WFS 1.0 specification.

The connection strings to the services are advertised on the KGIS project web site and SERF entries for the services have been published in the Antarctic Master Directory.

Projection	*Datum*	*EPSG Code*
UTM zone 21S	*WGS 84*	*32721*
Antarctic Polar Stereographic (as used in the SCAR ADD)	*WGS 84*	*3031*
SCAR IMW SP21-22 (Lambert Conformal Conic)	*WGS 84*	*3205*
Geodetic Lat Lon	*WGS 84*	*4326*

Table 4-2: Projections served by the KGIS WMS and WFS services.

For the WFS data layers representing framework data have been selected. The data is served using the feature type attributes and names from the SCAR Feature Catalogue (Fig. 4-19). Layers served by the WFS include:

- Contour_025
- Island
- Coastline
- Icefree
- Waterstorage
- Watercourse
- Place-name

The WMS and the WFS services are able to serve data in the projections as listed in Tab. 4-2.

The WMS layers served are the same as provided with the interactive KGIS Mapviewer. For each feature type they also include the map extent and the scale of application class layers to provide the user with readily accessible information on incomplete or inaccurate data. The data is portrayed in same style as depicted in Figs. 4-3 – 4-5. In case this information might alert the user to consult the respective metadata record in order to judge if the data is fit-for-purpose.

4.6.5 Conclusions for AntSDI

Implementation of the OGC Web Map Services for the KGIS project have been straight forward. Users' feedback has helped to improve the service and indicates that WMS services are useful to those that are aware its functionality.

Inspection of the web servers log file indicates that currently the WMS interface is used by significantly less users than the interactive, browser based KGIS Mapviewer. However, the usage patterns point out that these few users heavily make use of the service.

From this evidence it might be concluded that it is rather a lack of awareness of the potential use of WMS than a lack of functionality.

AntSDI should promote within the non-GI-expert user community how WMS services can interact with many commercial and free software tools. The benefit of easy integration with own data might be demonstrated by providing real world examples from a scientists perspective.

There are many products on the market which allow to set up a WMS server including commercial GIS server software and free and open source software. AntSDI should encourage institutions to establish such servers. To this end it would be helpful if the AntSDI website would provide a cookbook which includes specific aspects of serving spatial data from Antarctica, namely setting up the required projections.

The WFS service has been used only very rarely. But these statistic are of less value as currently there is a lack of wide spread client software. WFS is a rather new technology not yet well established in the GI user community - let alone in the wider scientific community. However, with more clients available and growing into a more widespread and known tool WFS is much more powerful than a WMS in being able to serve the actual data, not just a portrait.


```
<wfs:FeatureCollection xsi:schemaLocation="http://www.scar.org/antsdi
http://www.kgis.scar.org:7070/geoserver/wfs/DescribeFeatureType?typeName=SCAR:Watercourse
http://www.opengis.net/wfs
http://www.kgis.scar.org:7070/geoserver/data/capabilities/wfs/1.0.0/WFS-basic.xsd">
 - <gml:boundedBy>
   - <gml:Box srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
     - <gml:coordinates decimal="." cs="," ts=" ">
         -58.53153229,-62.18001556 -58.52173996,-62.17812729
       </gml:coordinates>
     </gml:Box>
   </gml:boundedBy>
 - <gml:featureMember>
   - <SCAR:Watercourse fid="Watercourse.169031">
     - <SCAR:Geometry>
       - <gml:MultiLineString srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
         - <gml:lineStringMember>
           - <gml:LineString>
             - <gml:coordinates decimal="." cs="," ts=" ">
                 -58.52174016,-62.17822641 -58.5223968,-62.17814863 -58.522726,-62.17812737
                 -58.52298242,-62.17815984 -58.52341104,-62.17823893 -58.52371595,-62.17829733
                 -58.52414324,-62.17834997 -58.52470978,-62.17835697 -58.52484271,-62.17837315
                 -58.52508071,-62.17841463 -58.52548216,-62.17851607 -58.52602441,-62.17860272
                 -58.52664122,-62.17867091 -58.5269154,-62.17868112 -58.52742447,-62.1786711
                 -58.52763352,-62.17869967 -58.52798693,-62.17878399 -58.52822872,-62.17890041
                 -58.52839418,-62.17900003 -58.52841682,-62.17907476 -58.52844526,-62.17926411
                 -58.52853504,-62.17936015 -58.52872834,-62.17945065 -58.52917044,-62.17960896
                 -58.52951354,-62.17967575 -58.529838,-62.17974715 -58.53016314,-62.17983177
                 -58.53056328,-62.17990675 -58.53117137,-62.17998824 -58.53153134,-62.18001514
               </gml:coordinates>
             </gml:LineString>
           </gml:lineStringMember>
         </gml:MultiLineString>
       </SCAR:Geometry>
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       <SCAR:Watercourse_type>Creek</SCAR:Watercourse_type>
       <SCAR:Origin>Unknown</SCAR:Origin>
       <SCAR:Kind>Natural</SCAR:Kind>
       <SCAR:Certainty>Definite</SCAR:Certainty>
       <SCAR:Length>588.338685971</SCAR:Length>
       <SCAR:Dataset_Id>10014</SCAR:Dataset_Id>
       <SCAR:Q_Info>10014</SCAR:Q_Info>
     </SCAR:Watercourse>
   </gml:featureMember>
</wfs:FeatureCollection>
```


Figure 4-19: Chunk of GML as served by the KGIS WFS describing a lake feature

A GML application schema for consistent GML encoding of the SCAR Feature Catalogue is urgently required. Development of such a schema might be prioritized.

WCS has not been implemented in the KGIS project due to the lack of stable server software. This might change in the near future. WCS might then be used within KGIS to serve the digital terrain model. Potentially WCS is of great value to the scientific community. Many models need raster data input, which can be provided by WCS. Such a service can remove the burden of data transformation and ingestion from the data consumer.

With the mapping extent layer and the scale of application class layer a simple and robust tool can be implemented to communicate positional accuracy and spatial coverage of data to the consumer of the service. These layers make potentially inaccurate data or incomplete coverage much more visible to the user than the information hidden in the metadata record. The ScaleHint element of the OGC WMS specification, designed to provide similar information, has not been useful in this context . It is an optional element that is not consistently interpreted in various client software and led to rather misleading and confusing behaviour on the client side.

5 Results

5.1 Lessons learnt: KGIS as an SDI for King George Island?

Within the SCAR KGIS project components which are considered essential for an SDI have been developed. A discussion of how this has been achieved and what might be concluded from the KGIS case for AntSDI has been presented in detail in the respective subsections of the previous chapter.

A set of core data has been identified as framework data that is required by many users. Most layers of the integrated framework data have been constructed and are now available for King George Island as the SCAR KGIS data base.

A new Gazetteer for King George Island has been established which features more precise coordinates for the places listed in the SCAR CGA. A hierarchy of place-names has been implemented to enable thesaurus like queries against the gazetteer.

The SCAR Feature Catalogue has been used to integrate data from diverse sources. Based on the use cases in the data integration process contributions have been made to the further development of the Feature Catalogue.

An interactive Mapviewer has been developed as a tool to access the data in a way which requires only map reading skills but no expert knowledge in spatial data handling. This service widely used. The Mapviewer serves also as a spatially enabled query tool against external data bases.

Services for portrayal and for data access through machine to machine communication based on open standards have been setup. The data can be accessed with WMS clients for map portray of the data. A WFS interface allows to retrieve features with their properties encoded I GML. These services are now in use by data consumers.

Following the SDI definition of Rajabifard et al (2003) and the scheme depicted in Fig. 2-1 KGIS might be regarded as an SDI. Standards and policies have been used, data has been produced and published an is in use now. Interaction with people took place mainly on the data producer's side.

In the hierarchy developed by Rajabifard et al (2003) and depicted in Fig. 2-2 KGIS can be regarded as an SDI like initiative at an intermediate level, whereas AntSDI would be grouped into the regional level. Interactions with initiatives at the lower level have already taken place (e.g. with the ASMA Admiralty Bay GIS) and might continue. AntSDI specifications such as the Feature Catalogue promote the integration of various levels.

Recalling the classification in first and second generation SDIs the KGIS Project as it has functioned in the past years has to be classified into the first generation. The view was product oriented, most involvement was on the data producers site, and the amount of interaction with the user community had been limited.

Now that for King George Island the framework data is available onto which other data can be referenced it is time to shift project activities from the data producers perspective to the users viewpoint. Capacity and community building to facilitate exchange of further data can be identified as the priority for the future of the project.

5.2 Lessons learnt: implications for AntSDI

The SCAR Feature Catalogue has proven its applicability to provide for common semantics. The importance of this document for AntSDI cannot be underestimated. However, to the further development an update policy has to be agreed upon. In order to promote technical interoperability a GML application schema needs to be derived from the Feature Catalogue to provide for consistent encoding of features.

The SCAR Composite Gazetteer is an invaluable resource for the AntSDI user community. However, for large scale applications coordinates have to be reassessed. It has been demonstrated that it is feasible to improve the positional information significantly. Yet it is unclear how these improved coordinates can be incorporated in the CGA.

Boundaries of protected areas are crucial framework data. Entry into an ASPA is prohibited without permission. Currently paper sketch maps describe the position of the limits of the ASPA. It is suggested EGGI consult with CEP to evaluate if boundaries can be made available as digital spatial data.

It is recognized that data and reporting related to facilities management and to air transport infrastructure is in the domain of COMNAP. However, making available a restricted set of information on facilities, including the geometries would be an asset in AntSDI.

Metadata has not been studied in detailed, partly due to the lack of tangible standards. With the forthcoming publication of ISO 19139 rapid development of community profiles is to be expected. JCADM in consultation with EGGI might provide for guidance on how to establish an ISO 19139 profile for data in the SCAR domain.

Layers identified as framework data should be prioritized for publication in areas where they are not yet publicly available. Where georeferenced orthoimagery is available, it is suggested these should be made available as WMS service.

OGC services have been proven to be easily implemented. Users are just starting to use these functionalities. Data providers might be encouraged to set up OGC services. The increasing number of available tools implementing OGC interfaces suggests that the service based architecture should be established and that users will increasingly start to use these functionality.

5.3 Handling incomplete and inaccurate spatial data in an SDI

The constructing of the framework data sets included the integration of incomplete and inaccurate spatial data sets. Care has been taken to document source data appropriately.

Within an environment where machine to machine communication through web services occurs there is great potential for misuse of data because the limitations of a given data set are not recognized by the user.

The ScaleHint property mechanism foreseen by the WMS standard cannot be usefully implemented as it is only specified as a recommendation and is implemented in serves and clients in various ways.

However, to make the user aware of the limitations of the data it is necessary to make information on fit-for-use readily visible to the user to alert him on possible misuse. A simple yet robust method applied with the data access and data portrayal tools is to supply a graphical representation of the likely useful scales of applications and the extents of mapped and unmapped areas. Three classes have been defined which allow the user to quickly assess if there are potential problems with the data.

6 Outlook: AntSDI and IPY

The coming IPY in 2007/09 will feature a boost of scientific activity in Antarctica An unpreceded amount of spatially referenced data from Antarctic will be collected in the field. It should be the concern of SCAR to advice on sound management of these data.

AntSDI is capable of providing the required infrastructure for spatial data management. To emerge into a successful tool it is required that the user community becomes more involved. Capacity workshops within the user communities, including the different scientific groups and research programmes might be useful tools.

It will be interesting to see if the AntSDI initiative manages to proceed from a currently mainly producers driven SDI into an infrastructure that is used and driven by the wider Antarctic community including scientist, environmental managers, operations managers, and even the tourism industry.

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