PART OF DRAFT STRATEGY DOCUMENT

Antarctic Research Strategy for South Africa

DEPARTMENT OF SCIENCE AND TECHNOLOGY

Mission

- To establish a national research programme that will produce maximum human capital, innovation and economic growth

- To increase international profile and influence

- To create a coordinated interactive effort towards public visibility

Vision

- To create a demographically balanced Antarctic research programme that strives for high quality international research, links to other African countries and interdisciplinary research.

Strategic Direction

- Taking advantage of new commercial potentials and research opportunities that involves industry.

- Aim for critical mass of local scientists in the programme from institutions previously not participating in the programme

- Promote fundamental research, which seeks to increase human knowledge and develop multidisciplinary link of basic research to applied knowledge

- Increase human capital

- Develop Research and Development as well as a connectivity programme with industry

1. Previous Research

1.1 Earth Sciences

South African earth science research has been conducted in Western Dronning Maud Land (WDML) since the early 1960's. For logistic reasons, field work has been concentrated on those regions that are within reasonable reach on land from SANAE. These include the nunataks of Ahlmannryggen, Borgmassivet, Kirwanveggen, H.U.Sverdrupfjella and Gjelsvikfjella. Regional mapping in earnest became possible from 1981 when helicopter support became available. Based on the geological maps and limited geophysical data produced in that earlier phase of research, South African geologists played a leading role in recognising and characterising the principal tectonic and stratigraphic units that make up the geology of WDML. Subsequently, since the early 1990's, geological research focussed on specific areas, using specialised manpower and analytical techniques not available to earlier research. This included detailed petrological, structural, geochemical and geochronological studies aimed at reconstructing the tectono-thermal evolution of the various units identified in the previous phase of research.

The rocks exposed in WDML offer insights into the evolution of the Earth's crust for as long as almost three billion years (Fig. 1). An Archaean cratonic fragment, that was most probably linked with the Kaapvaal Craton of South Africa prior to the dispersal of Gondwana some 180 Ma ago, are overlain by late Mesoproterozoic volcano-sedimentary successions derived from a large contemporaneous volcanic arc related to subduction along the craton margin. Remnants of that volcanic arc make up the bulk of a high-grade metamorphic belt (Maud Belt) that stretches for about 1000 km from Heimefrontfjella in the southwest to Gjelsvikfjella in the northeast. Comparative studies on the African continent point to a continuation of that belt into similar high-grade metamorphic belts in South Africa (Namaqua-Natal Belt) and East Africa (Mozambique Belt). Recent geochemical and geochronological studies carried out within SANAP show that a major thermal event, expressed by the outpouring of voluminous flood basalt and hypabyssal intrusion of related mafic dykes and sills, affected the entire subcontinent of southern Africa and WDML around 1110 Ma and a large mantle plume is being held responsible for it.

An earlier phase of high-grade metamorphism, dated between 1090 and 1030 Ma is probably related to continental collision that culminated in the formation of a supercontinent (Rodinia) - a hypothesis that appears to be well established now, although the configuration of that supercontinent, specifically the position of the Maud Belt within it, remains speculative. A second phase of high-grade metamorphism and magmatism affected the belt around 540 Ma when the various continental fragments after the dispersal of Rodinia re-assembled to form another supercontinent (Gondwana). Work carried out over the past few years has shown that the bulk of deformation in the Maud Belt is not related to late Mesoproterozoic continental collision as previously thought, but to Pan-African

tectonism during the collision between East- and West-Gondwana. Locally, intramontane pull-apart basins within the Pan-African orogen were filled with siliciclastic sediment. Otherwise no further sedimentation during the Phanerozoic is recorded in the area.

The break-up of Gondwana around 180 Ma triggered the intrusion of mantle-derived melts into the upper crust, thus leading to the formation of extensive mafic lava flows as well as sills and dykes, features that are dominant in the Vestfjella and southern Kirwanveggen areas. A major crustal discontinuity, interpreted as Pan-African mega-thrust zone, was re-activated at the same time to form a failed rift graben. Alkaline melts ascended along the bounding faults resulting in the development of shallow crustal syenite ring complexes. This large structure was subsequently utilised by ice flow and today represents one of the world's largest glacier systems (Pencksoekket-Jutulstraumen glacier).

The work by South African geologists has been complemented by similar studies carried out largely by German scientists in Heimefrontfjella and Central Dronning Maud Land, but also by geophysical (aeromagnetic) studies by Russian, and more recently also German and British teams. Other earth scientific projects, not directly related to the above topics, were geomorphological studies (geocrygenic landforms and processes) on Marion Island and a geodetic study involving the production of topographic maps from aerial photographs.

The Earth Science Sub-programme within SANAP has contributed significantly to human resource development by training a number of MSc and PhD students, with the current cohort coming exclusively from previously disadvantaged communities. It put South African scientists on the forefront of international research initiatives by integration with various International Geological Correlation Programmes.

A general decline in research funding over the past decade resulted in only two specific earth science projects being currently supported by SANAP. These projects revolve around the distinction between so-called Grenvillian (i.e. ca. 1.0 Ga) and Pan-African (ca. 0.5 Ga) deformation in the high-grade metamorphic northeastern section of the Maud Belt. Detailed geochronological work is under way to resolve this issue that has been a contentious, but for supercontinent reconstructions crucial, question for the past two decades. This work, which is almost completed, is being complemented by a detailed geochemical study on mafic rocks of various ages that aims at constraining the likely tectonic setting of late Mesoproterozoic and Neoproterozoic domains in WDML, as well as assessing the linkage with other magmatic provinces elsewhere in East Antarctica and southern Africa.

The previous 5-year programme (1996-2001) was plagued by a lack of continuity in human resources with several leading scientists having resigned from the programme and some post-graduate students not having completed their work.

This lead not only to a relatively low publication output, with many important results being published only in internal reports, conference abstracts and unpublished theses, but also to a lack of a consolidated data base of previously acquired information. To remedy this situation, an initiative is now under way to compile a comprehensive, GIS data base that will contain all relevant information, satisfy existing commitments to SCAR, and form the foundation for producing comprehensive geological maps of the areas studied by South African geologists in the past.

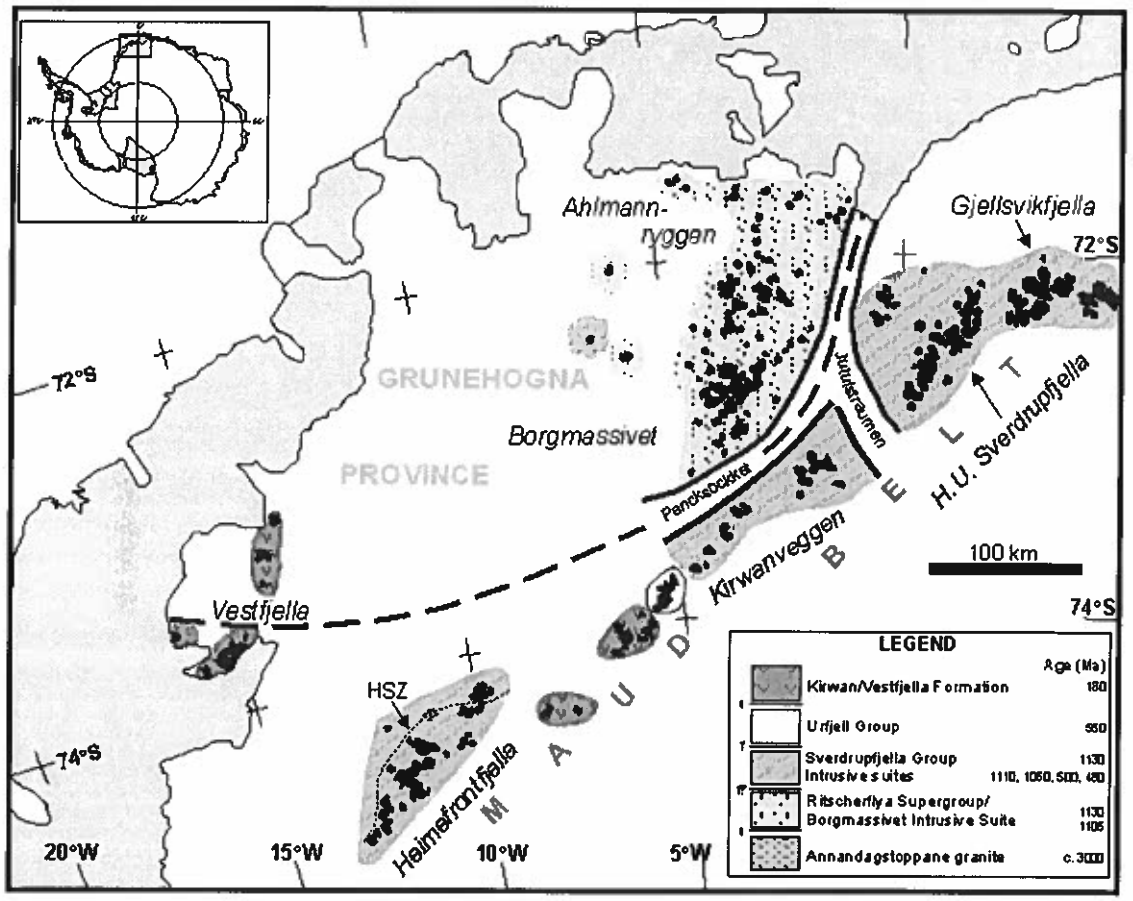

Fig. 1. Main geological units of Western Dronning Maud Land.

1.2 Biological Sciences

The Biological Sciences Programme has been operational largely since the South African Expedition to the Prince Edward Islands in 1965-1966 led by E.M. van Zinderen Bakker. As a consequence of the diversity of life at the Prince Edward Islands, and at Gough Island, much of the research in the biological sciences has been undertaken at the Prince Edward Islands (consistently since the early 1970s), and to a much lesser extent, at Gough Island. Nonetheless, a major, five-year research programme also undertook work at Robertskollen

Nunataks, close to the current SANAE IV station, South Africans have collaborated in the Antarctic Pack Ice Seals programme by censusing and investigating the appropriate species and the appropriate areas, and more recently South African biological researchers have worked with Antarctica New Zealand at Cape Hallett in the Ross Sea area.

Biological research at the Prince Edward Islands has revolved around four key themes. These are the interactions between marine and terrestrial systems, the life histories of key pelagic vertebrates (seals and birds, but also Killer Whales), the structure and functioning of terrestrial ecosystems, and the structure and functioning of the near shore ecosystems. Much of the work on the first two themes has been concerned with understanding the feeding ecology, population dynamics, interactions, and life histories of seabirds (mostly penguins and procellariiforms) and seals (elephant and fur seals). This work has involved a wide variety of approaches, ranging from single species physiological studies, through population monitoring, satellite-based investigations of seabirds and seals at sea, and investigations of food-webs and nutrient flow from pelagic to terrestrial systems. This research naturally led to close interactions with the oceanographic sciences, and indeed many of the key insights regarding seabird foraging and their interactions with pelagic systems have been a consequence of an internationally recognized multi-disciplinary approach to investigating oceanic variability and its impacts on top predators in the pelagic system. At least part of the research has also been driven by South Africa's obligations to the Convention on the Conservation of Antarctic Marine Living Resources, which requires annual censuses of certain species, and reporting in standardized ways of population and diet information, as well as on marine pollution.

Investigations of nutrient transfer to the terrestrial ecosystem naturally meant a focus on the structure and nutrient flux of terrestrial ecosystems, and much of this work was undertaken as a contribution to the International Biome Project. This allowed comparisons with temperate and polar ecosystems in the northern hemisphere that would otherwise not have been possible. Indeed, the integrated ecosystem functioning approach that was a hallmark of the biological sciences programme at that stage led to international acclaim for the work being done especially at Marion Island. The focus on the structure and functioning of ecosystems led naturally to investigations of the life history and physiological of key indigenous species, as well as to a drive to understand which components of the system were indigenous, which had been introduced as a consequence of human activities at the islands, and what the consequences of interactions between these species were likely to be. This research led to an unparalleled knowledge of the biodiversity of the Prince Edward Islands. Indeed, Marion Island is one of the few systems globally (except for species poor Antarctic ones) where virtually all of the terrestrial species (but not at the microbial level) have been documented and described. It also became clear during the course of this work that climates are changing at the island (it was analysis of climate records by biologists that uncovered this trend, rather than analysis by climatologists),

and that interactions between climate change and invasion were likely to have considerable impacts on the local system. Current research is partly exploring this interaction, but this exploration is not fully developed.

The research activity at the Prince Edward Islands has produced a vast body of published work, much of it in the highest quality outlets. A bibliography of research compiled in 1999 (Hänel & Chown 1999, *S. Afr. J. Sci.* **95**, 87-112) indicated that over 30 years, more than 700 research papers, 20 Ph.D. theses, and 25 M.Sc. theses had been produced as a consequence of research at the islands. This body of research is continuing to grow, and is attracting an ever increasing number of historically disadvantaged graduates, and new institutions, to the programme. Presently, the biological research at the Prince Edward Islands concerns population monitoring of seabirds, integrated investigations of marine mammal responses to the pelagic environment, investigations of the systematics, life history, and population and community dynamics of terrestrial plant and animal species, and a large capacity building programme aimed at making a start at understanding the effects of climate change on the island, whilst improving access to the system by historically disadvantaged individuals and institutions.

Research at Gough Island has largely been funded independently (by the U.K. Darwin Initiative and by the U.K. Royal Society for the Protection of Birds). This work has concerned the impacts of fisheries on the seabirds indigenous and endemic to the islands, as well as the substantial impacts invasive species (notably mice) may be having on both seabirds and land birds that nest on Gough Island. The work has also concerned an in-depth investigation into the terrestrial biodiversity of the island (which included capacity building as a major theme), which has revealed substantial impacts of the South African operation, such that there are 71 species of introduced insects, but only a third as many indigenous ones. Most of these invasions have taken place since the establishment of the scientific station in 1956.

Biological research in Antarctica has concerned some work on the abundance of seabirds at sea as part of oceanographic research (especially the BIOMASS programme), and several large-scale censuses of pack ice seals. Terrestrial research was undertaken at Robertskollen and the major theme of this work was understanding the effects of nutrient and water availability on small-scale patterns of diversity. This latter project was not very productive, and suffered from human resources problems throughout much of its history. However, some insight into the biogeography and life history of invertebrates and plants in the region was obtained. It was also concluded that owing to the small amount of biological material available, ongoing work at this site would lead to considerable disturbance. In consequence, at its close, biological research at this site was discontinued.

Smaller biological research programmes in the maritime and continental Antarctic have mostly involved collaborative research on seabird and seal populations with the Swedish and Norwegian Antarctic programmes (including work at Svarthammeren and at Bouvet Island), and on terrestrial systems at Cape Hallett with Antarctica New Zealand. These have been productive, integrated programmes, despite their small size.

1.3 Physical Sciences

The Physical Sciences Programme has operated in Antarctica since the International Geophysical Year in1957. It is the only programme that, of its nature, has demanded a permanent mainland base throughout the year. Other programmes make use of the base for summer expeditions but do not, usually, require overwintering. The programme has involved Potchefstroom University, Rhodes University, The University of Natal, the Hermanus Magnetic Observatory, and Stellenbosch University. The former Weather Bureau was also involved but more with meteorological observations that with student training or research output. It has provided a large number of Masters and PhD graduates and a large publication output which is on record. Over the past five year period, financial constraints have meant that only Potchefstroom University and the University of Natal have remained involved. The thrust has mainly been on studies of the heliosphere, the magnetosphere, and the ionosphere, with some attention being given to the neutral atmosphere.

The focus on geospace is readily justifiable on several grounds. Geospace is the region of space surrounding earth. The orbits of satellites that play crucial roles in the economy are located throughout geospace. Satellites in geospace are of great importance to humankind for communication, navigation, remote sensing and a variety of other purposes. Geospace is a hostile environment for satellites which can be seriously affected by particle radiation. Magnetic storms can cause power outages on the ground. Understanding the solar wind and geospace behaviour has the same importance for satellites as understanding weather does for ships and aeroplanes.

While geospace research is essentially basic rather than applied, an understanding of this region is of considerable importance to the technology on which we depend for a variety of purposes. What, then, is the importance of Antarctica to this region? It arises from the nature of the earth's magnetic field. The geomagnetic field lines that intersect the polar regions stretch far into space. Energetic particles are free to move along these field lines but not across them. Alfvén waves, which are a major mechanism for the transport of energy from one part of geospace to another, travel along field lines and not across them. The effect is that particle and wave phenomena in space map down the field lines onto the upper atmosphere. Study of these effects in the ionosphere and upper atmosphere above Antarctica is analogous to observing a television screen image of activity in deep space. The consequence is that the polar regions are

uniquely important for ground-based studies of geospace. Antarctica is a window into geospace.

Cosmic rays are extremely high energy charged particles that originate both from the sun and from the galaxy. When they impinge on the atmosphere they interact with atmospheric nuclei to produce showers of energetic particles. The latitude at which cosmic rays reach the atmosphere depends on their energy, because of the effect of the magnetic field that screens them from the earth. Only the highest energy particles reach low latitudes. Lower energy particles arrive at the ground in the polar regions. The cosmic ray spectrum can therefore be measured by using chains of detectors over a wide range of latitudes. High latitude stations in the polar regions form an important part of such chains. Events on the sun modulate the intensity of cosmic rays, which therefore contain cyclic dependencies on the 11 and 22 year periods of the sunspot cycle. Useful data require observations over several solar cycles. The modulation may be important for the study of effects on climate.

The Antarctic neutral atmosphere is of global importance for several reasons:

- The discovery of the stratospheric ozone hole in Antarctica is an alarming symptom of humankind's impact on the planet.

- Most of the energy transported from the solar wind to the earth is deposited in the atmosphere in the polar regions.

- There is renewed interest in the relationship between solar-terrestrial physics and climate.

The current research programmes are as follows:

Southern Hemisphere Auroral Radar Experiment (SHARE)

The SHARE radar at SANAE IV is part of the international SuperDARN programme. This is a cooperative international programme involving institutions in USA, UK, Canada, France, Japan, Australia, Italy, and South Africa. There are 15 operational radars, nine in the northern polar regions, five in Antarctica, and one in Tasmania with a field of view in the South Pacific ocean. A sixteenth is under construction for operation from New Zealand. The South African radar began operations in 1997. Its construction was originally jointly funded by the National Environmental Research Council (UK) through the British Antarctic Survey, the National Science Foundation (USA) through the Johns Hopkins University, and the Department of Environment Affairs and Tourism through the University of Potchefstroom (now merged into North West University) and the University of Natal (now merged into the University of KwaZulu-Natal. Operations are the responsibility of these Universities and have been funded by SANAP. The radars are in the forefront of ground-based magnetospheric and ionospheric

research. They are able to observe ionospheric convection in the northern and southern polar caps and provide data for space weather forecasting. They have made major contributions to understanding ULF pulsations. They are also able to make useful observations of meteor trails that allow observations of the upper neutral atmosphere. They are an important integral part of the international programme in space science. In 1998 the SuperDARN programme received a NASA award "in recognition of its contributions to the highly successful exploration of geospace by the Global Geospace Program." The envisioned lifetime over which SuperDARN can continue to make significant contributions to geospace research is at least ten years.

Antarctic Magnetospheric and Ionospheric Ground-based Observations (AMIGO)

This is a cooperative suite of experiments, operated by North West University and the University of KwaZulu-Natal and designed to study the magnetosphere by a variety of techniques. The major instrument is an imaging riometer. There are also magnetometers, and auroral sensors, all operated by North West University. A suite of VLF instruments operated by the University of KwaZulu-Natal is automated and located at SANAE IV, but is not currently funded by SANAP. Satellites and spacecraft provide point observations *in situ*. Ground based arrays are essential for spatial information, and ongoing observations over an extended period of time. The study of geospace requires observations by many different techniques and at many different locations. AMIGO is an important contributor to this effort.

Antarktieke Navorsing oor Kosmiese Strale (ANOKS)

Cosmic rays are extremely energetic particles originating both in the Sun, and in the galaxy. Knowledge of their varying energy spectrum is important for understanding. As they approach the Earth, their trajectories are controlled by the magnetic field in such a way that the lower energy particles strike the Earth near the geomagnetic poles while only the higher energy particles reach lower latitudes. Observations at different latitudes allow information to be found about their energy spectrum. A neutron monitor has been operational at SANAE IV since the earliest expedition. It forms part of a chain through South Africa and extending into Namibia. It offers a nearly continuous data set extending over approximately four solar cycles. This offers good understanding of modulation of cosmic rays by solar activity, providing important insight into the effect on the geospace environment.

1.4 Engineering Sciences

The current involvement of academic engineering science in SANAP dates back to 1999, when Paul van Staden, the last person to fill the position of SANAP mechanical engineer (the post has been vacant 2000), gave a presentation at the University of Stellenbosch about his work. He suggested, based on the pertinent

logistic and otherwise reliance on engineering expertise, e.g. as derived from marine, aeronautics, electronics, mechanical engineering products, that academic engineering sciences has a contribution to make with regards to the technical needs and impact of human activities, as well as opportunities for advancing engineering science per se, in the southern oceans environment and Antarctica.

This idea was picked up in 2000, and the heating and ventilation of SANAE IV was the subject of a B.Sc. (Eng.) thesis. This was subsequently followed by two similar theses during 2002 and 2003, which dealt with the energy and waste management at the base respectively. A report with regard to the impact of Diesel engines at SANAP IV was also completed in 2002. These practical projects have served to assess the status quo of some engineering aspects of operations at SANAE IV. In essence consulting reports were produced, which detailed many observations and recommendations, several of which were subsequently acted upon by the Department of Public Works that is responsible for base maintenance. Furthermore, the activities proved to be interesting and motivating to engineering students, emphasising the natural and environmental as opposed to industrial orientated engineering research. Both female engineering students, one Indian, who participated in the SANAE relief voyage of 2001/2, are currently completing their M.Sc. (Eng) (Mechanical Engineering) studies in related topics.

The above work laid the foundations for and spawned several in depth enquiries. The feasibility of wind energy augmentation of the current Diesel base was the subject of an MScEng (Mechanical Engineering) project completed in 2003. This was the first fully funded engineering science SACAR project. Rapidly growing expertise and penetration of wind power generation in the northern hemisphere, coupled with the sensitivity of the natural environment to emissions, motivated this study as well; it returned a favourable recommendation. Excellent support was provided by the engineering section of the Australian Antarctic Division, which in the mean time has three wind turbines operational on the sub-continent. On request, the results of this study (thesis and journal publication) were made available to the Desert Ecological Research Unit of Namibia, Gobabeb, which has received a Danish government grant to erect a wind power system. This work is currently being extended with a SACAR funded study on the use of solar power at SANAE IV. Computer based simulation of particle flow are of general interest to a wide variety of engineering problems. Typically sand drift can be a problem on (South) Africa's coastal and desert roads. The opportunity to investigate the accumulation of snow around the SANAE IV base thus allows seminal work to advance engineering science with regard to the modelling of turbulent particles in suspension significantly. The currently fully funded SACAR Ph.D. (Eng) mechanical engineering project under way is benefiting from significant collaboration with the Building Science Department of the Narvik Institute of Technology, Norway, including co-authorships, mutual visits and exchange of computer codes. Currently an investigation is also underway to

numerically investigate the atmospheric dispersion of light particles over Marion Island in conjunction with a key plant species, and this serves to demonstrate the scope of engineering science opportunities in Southern Oceans and Antarctic research.

1.5 Oceanographic Sciences

The investigations of the vast ocean region south of Africa has been recognised as being of crucial importance to a proper understanding of the weather and climate of southern Africa. It is therefore interesting and instructive to discover that the first observations of this ocean region by the SANAP were measurements of sea surface temperatures by members of the then South African Weather Bureau and that one of the currently most important international projects in the region, the GoodHope programme, is again focussing on air-sea interaction in the region and its effect on climate variability.

South Africans participated in the ISOS (International Southern Ocean Studies) as early as the 1970's, and undertook observation from the old South African supply vessel, the *RSA*, that started establishing the detailed nature and location of oceanic fronts in this part of the world ocean. Only with the acquisition of the research vessel *SA Agulhas*, with sea-going laboratories in the 1980's and totally refurbished in the 1990's, were South African oceanographers fully equipped to carry out oceanographic research of international quality in the Southern Ocean. What has been achieved?

The knowledge of the location and nature of fronts was very poorly known in the region south of Africa, due to a dearth of observations. Over the next 15 years thousands of XBT-measurement and thermosalinograph observations were undertaken in this region and a solid knowledge base built up. These studies also lead to collaboration with biological colleagues in studying the distribution of organisms such as the krill in the international BIOMASS programme. Observations extended from the South Sandwich Islands in the west to Prydz Bay in the east, Antarctica in the south to Tristan da Cunha in the north. Once the general layout of the physical features of this sector of the Southern Ocean had been determined, the next research thrust concentrated on the observed mesoscale features such as eddies. This was done in two ways: first, to investigate eddies at the Subtropical Convergence near South Africa and, second, to study the oceanic environment of the Prince Edward Islands.

The SCARC (Subtropical Convergence and Agulhas Retroflection Cruise) was one of the most successful, multidisciplinary cruises of its kind and was followed by others during which the Subtropical Convergence itself was studied in detail as well as both cyclonic and anti-cyclonic eddies measured in ways not possible before. Much use was made of satellite remote sensing to study the natural behaviour of the fronts and eddies when the ship could not be there, but also in guiding the vessel to the correct location. In this way the heat flux by eddies into the Southern Ocean, across the Subtropical Convergence, was established for

the first time. Observations were also made of the heat and moisture flux from warm eddies to the Subantarctic Atmosphere. It was shown that an astounding 1000 $W.m^{-2}$ could be lost during a severe storm. No observations of this kind had been made in this region before or since.

The other major effort has gone into studying the oceanic environment of the Prince Edward Islands. This started by a major cruise around the islands, MOES I (Marion Offshore Ecology Study), that showed the unexpected presence of a range of cyclonic and anti-cyclonic eddies near the islands. It suggested that the islands themselves formed an obstacle to a more-or-less laminar flow, creating disturbances in the field leading to a vortex street. A second cruise of this series, the MOES II, again showed the presence of a range of eddies, but not in the pattern of a vortex street at all. This left oceanographers with a challenging puzzle. Subsequent cruises as part of the MIOS and the DEIMEC (Dynamic Eddy Impact on Marion Ecosystem) have resolved the conundrum. SANAP oceanographers have shown that the intense eddies that are advected past the Prince Edward Islands come from a gap in the South-West Indian Ridge whence they move along the inside edge of the ridge towards and past the islands. This gap in the ridge may be a location where the Antarctic Circumpolar Current is constrained, thus facilitating the creation of mesoscale turbulence. This discovery and the elucidation of the underlying mechanism have placed South African physical oceanographers, with their biological colleagues, at the forefront of studies on the influence of eddies on both oceanic and terrestrial ecosystems.

2. Internationally Recognized Research Initiatives

2.1 Earth Sciences

As much of the past and current earth science research within SANAP revolves around questions related to the formation and demise of supercontinents, the various geological units studied in Antarctica must not be seen in isolation but provide an excellent platform for comparison and potential correlation with similar units on other continents, in particular southern and eastern Africa. It is therefore only logical that the geological studies carried out by South African scientists formed an integral part of a number of International Geological Correlation Programmes (IGCP) that are administered by UNESCO. In the past these included the IGCP Projects No. 236, 288, 368, which dealt with Precambrian events in Gondwana continents. The current activities blend perfectly into a further, recently launched IGCP Project No. 478 ("Neoproterozoic to Early Palaeozoic Events in SW-Gondwana") and future earth scientific projects within SANAP could become integral parts of that IGCP Project that will continue until 2007.

Apart from a deeper integration with Inkaba ye Africa, a multi-million Euro project that is planned until at least 2008, unique opportunities exist for South African earth science research in Antarctica to become part of further frontier

international research initiatives. These range from the study of modern sedimentation processes off the shelf around WDML (thus blending into similar studies to be carried out by other nations elsewhere), the drilling of sediments off the coast of WDML (in conjunction with the Ocean Deep Drilling Programme and global palaeoclimate research efforts and in possible collaboration with the Japanese initiative for the International Polar Year) to participation in a potential International Polar Year Project involving a geophysical and geological traverse from WDML into central East Antarctica.

2.2 Biological Sciences

Presently there are two major initiatives in which South African Antarctic Scientists are participating. The first of these is the Antarctic Pack Ice Seals Programme. This programme has as its major goal an understanding of the distribution and abundance of pack ice seals around Antarctica and involves all of the SCAR nations with marine mammal research programmes. Although the programme is nearing completion, South Africa has been a major contributor by way of providing information on seals in its sector of Antarctica.

The Regional Sensitivity to Climate Change (RiSCC) programme of SCAR is a second major programme in which South African scientists are involved. This programme seeks to understand the responses of terrestrial diversity to climate change along a gradient from the high Antarctic to the sub-Antarctic. South Africa has participated in two major RiSCC field seasons, sending scientists to Australia's Heard Island and France's Kerguelen Island, and hosting scientists from the U.K., Norway and Australia at Marion Island. The RiSCC programme of SCAR will be subsumed into a larger programme entitled Evolutionary Biology in Antarctica, that will investigate the responses of marine and terrestrial biodiversity to past and future changes in the environment of Antarctica and its Associated and Dependent Ecosystems.

This focus on biodiversity and ecosystem responses to change will also form a major theme of the life sciences component of the International Polar year (2007/8) and South Africa is in a prime position to make a leading contribution to the IPY via its terrestrial research.

2.3 Physical Sciences

The SHARE radar programme is part of SuperDARN, an International Radar Network for Studying the Earth's Upper Atmosphere, Ionosphere, and Connection into Space. The programme is operated under a Council consisting of the Principal Investigators. The SHARE PI serves on the Council. Participating countries are USA, Canada, UK, France, Italy, Japan, Australia, and South Africa. SuperDARN is part of the NASA global geoscience mission. SuperDARN has established itself in the forefront of ground based systems for studying magnetospheric convection, ULF pulsations, internal atmospheric gravity waves, and properties of the ionospheric plasma. It is a key participant in the global effort to understand space weather. Although its prime objective is to study the

magnetosphere and ionosphere, it is also capable of observing neutral atmosphere dynamics through the observation of meteor trails. As a consequence SuperDARN data is routinely supplied to the TIMED satellite programme. The TIMED satellite aims to understand how energy is deposited into the mesosphere and lower thermosphere on a global basis and to study the impact of this deposition on MLT global dynamics. The National Science Foundation Program on Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) has agreed to co-sponsor a number of ground-based investigations including SuperDARN that provide additional data to support the TIMED mission.

2.4 Engineering Sciences

At present the projects being addressed by the Engineering Sciences are very much a function of problems highlighted by the Madrid Protocol (on Environmental Protection) to the Antarctic Treaty as well as by the Committee of Managers of National Antarctic Programmes (COMNAP). Typically these international initiatives are concerned with reducing the impacts of humans on the Antarctic environment and improving accessibility to the continent by science and logistic staff.

2.5 Oceanographic sciences

One of the most important new international efforts will be to study climate change and climate variability in the Southern Ocean. The Ocean Climatology Research Group of Professor Lutjeharms' at UCT has recently shown that sea surface temperatures at Marion Island have risen by 1.4 ° C over a period of 50 years. Further studies using long records are continuing. Such records are difficult to achieve.

A major new initiative to make a contribution to appropriate time series has therefore been the GoodHope expeditions in which the ocean between Africa and Antarctica is being monitored on a regular basis. This is too great an effort for South Africa to carry out on its own and colleagues from at least 8 countries are involved. This points to serious problem in the oceanic component of the SANAP.

Currently the *SA Agulhas* is the only vessel on which sea-going oceanography students are being trained in South Africa. This is an innovative and productive teaching effort that is of enormous benefit in training the next generation of physical and biological oceanographers. However, the SANAP only pays 7 % of the research costs involved in the physical oceanography programme it calls its own. No dedicated ship's time is available to attract young oceanographers to cutting edge research projects and no salaries are paid to home-based personnel. This makes the SANAP participation in the exiting new international programmes in the Southern Ocean increasingly hazardous. Nonetheless, there are many such programmes, including the joint SCAR/SCOR/IOC project on climatic variability and the contributions of the Southern Ocean to this variability

and its change through time; as well as several ongoing initiatives such as ICEFISH and ANDEEP which are exploring patterns of regional biodiversity variation across the Southern Ocean.

3. Frontier Research Projects: A Preamble

Before developing key research themes for ARESSA, it is essential to recognize several key factors that are likely to impinge on South Africa's ability to develop a programme that will maximize the production of new knowledge and human capital, increase global visibility and competitiveness of Antarctic Research, and enhance the national and international visibility of South African Antarctic Research.

- Large, integrated science projects are likely to provide one of the most suitable vehicles for addressing the Mission and Vision of the ARESSA, and will mean ready linkages with international programmes which have a similar, broad-scale approach.

- Integrated programmes mean that researchers new to the subtleties of Antarctic research and logistics are provided with the necessary guidance to ensure that their work has every chance of success.

- Innovative research is not only done in the context of large-scale programmes. Individual researchers, working alone, can make substantive contributions, and room must be made for them in the Antarctic Programme.

- Innovation means that secure projects focussing on the main research themes cannot be the only ones that are supported. Rather, a small portion of support should also be set aside for innovative, incubator projects that are high risk.

- South African Antarctic Research has traditionally focussed on work at South African stations and using South African shipping infrastructure. Much can be gained by encouraging broader interactions with the Polar community such that work is done from other stations and using the infrastructure across the region that is supported by all of the SCAR members.

- There is an urgent need for South Africa to contribute to the development of and to participate in the International Polar Year (IPY 2007/2008). This can most usefully be done through participation via SCAR and via IPY itself. In developing the research themes below, cognisance has been taken of the major role that South African researchers could potentially play in the IPY.

- For innovative, large-scale, integrated frontier research projects to succeed, there must be adequate advance planning, with appropriate lead in times and exit strategies. These lead in times are essential not only in the context of doing the work, but also ensuring that there is logistic buy-in both locally and from partners abroad.

- Whilst Antarctic Research lends itself extremely well to programmes of outreach, and the community is generally ready and willing to share its knowledge, it is essential that a central coordinator be appointed to ensure that this aspect of the ARESSA Mission and Vision is properly developed.

- The development of innovative research programmes that benefit human quality of life are clearly a key requirement of the ARESSA. However, any commercialization ventures must bear in mind that as a signatory to the Antarctic Treaty and its associated protocols, as well as to several other international conventions, there are certain requirements to which South Africa must adhere.

4. Research Themes

4.1 Introduction

In keeping with the Mission and Vision of the Antarctic Research Strategy for South Africa, the Research Themes that will be addressed are concerned with understanding environmental variability to ensure quality of life via sustainable interactions with the earth system that supports human existence.

The rationale for this broad underlying theme is the realization that variability in the earth system, albeit intrinsic or extrinsic, has major impacts on human quality of life. These impacts range from the effects of variability of space weather on communications and power supply, to the impacts of changes in climate and its variability on the natural resources on which all humans depend. Understanding this natural variability, how it is changing relative to the past, and what form it is likely to take in the future is therefore a pressing concern of global significance.

Antarctic and the Southern Oceans present a unique opportunity for investigating this variability. These regions are not only essential contributors to, and in many cases, major drivers of, the global climate and flux of elements, but they also provide a unique window into the effects of variability on interactions between the abiotic and biotic components of the earth system. Moreover, they also present windows into the past, present and future of the planet that are unavailable elsewhere. Indeed, Antarctic and Southern Oceans research is a bellwether of our understanding of earth system variability and its implications.

In keeping with South Africa's strengths in the geosciences, physical sciences and life sciences, three key research themes are structured around variability in these systems on appropriate spatial and temporal scales. A fourth theme explores the requirements for and consequences of a suitably engineered and sustainable presence in the Antarctic, whilst a fifth is concerned with the history, sociology and politics of South Africa's long-term presence in the region.

4.2 Research Theme 1 – Antarctica: A Window into Geospace

The study of the geospace environment is central to the international effort to understand space weather and its impact on modern space technology. The relationship between processes in the solar wind and heliosphere, the magnetosphere, the ionosphere, and the neutral atmosphere is crucial to this understanding. The physics is that of a very complicated system involving energetic particles, and high and low energy plasmas, strongly controlled by changing magnetic fields. To understand it is necessary to make observations on a global scale of a variety of phenomena, by different techniques, both in space and on the ground. Because of the geometry of the geomagnetic field the polar regions are particularly important for ground based observations. No individual scientist, or scientific nation, can generate all the data needed for understanding. International and national collaboration is essential to the progress of the field.

The variability of the space environment occurs on several time scales. The physics of geospace is strongly influenced by solar activity, which varies substantially on the eleven year sunspot cycle. The consequence is that magnetospheric activity is very different at sunspot minimum and sunspot maximum. The investigation of this variability is an important goal. In addition there are longer period changes in solar activity; sunspot activity differs from cycle to cycle with consequential effect on geospace. On a much longer time scale the Earth's magnetic field reverses every few hundred thousand years. Although it is not to be anticipated that this will happen in our lifetime, the next reversal is overdue. The field has been steadily decreasing for 2000 years and the rate at which this happens seems to be increasing. The understanding of the consequences of geomagnetic variability is of considerable interest.

The objectives are (i) to increase understanding of the physics of geospace, including the solar wind, magnetosphere, ionosphere, and upper reaches of the atmosphere by the coordinated use of SANAE IV base as a well resourced ground based observatory, at a unique and favourable location for providing a wide suite of observations, (ii) to use these activities to educate the next generation of physicists working in this field, (iii) to extend cooperation to scientists from neighbouring countries to raise the general level of scientific activity in this field. In general, programmes will meet this objective by

encouraging collaboration between investigators and by participation in the international effort in this field. This will be achieved by exploiting those existing successful programmes that are an important part of the international networks and by the continued development of new experiments that complement the existing observations made by other ground based activities, and by spacecraft.

4.3 Research Theme 2 – Climate Variability: Past, Present and Future

There is a tremendous interest worldwide in better understanding the factors that control climate variability, both on global and regional scales. Antarctica and the surrounding Southern Oceans provide unparalleled natural laboratories to study both long-term and short-term climate change, and the likely impacts of this change on the earth system and the life it supports. Investigations of this variability require both investigations of current variability and its causes, and impacts, as well as patterns of past variability and the influence they had on the integrated earth system. Current monitors of environmental change and their relation to climate change are found, *inter alia*, in life forms, ocean currents, types of sedimentation and weather. Moreover, because an understanding of the past can provide much insight into the future, information on past events, obtained from the geological and geomorphological records is essential for understanding, and benchmarking, the impacts of climatic variability. In consequence, investigations of the causes and consequences of climatic variability and its long-term change require an interdisciplinary approach, bringing together the earth sciences, and physical and biological oceanography.

The objectives of this research are therefore to i) investigate how physical, chemical and biological processes associated with mesoscale and larger scale oceanographic features respond to and influence environmental variability; and ii) Examine the interplay between plate tectonic processes, degassing of the planet (and thus production of greenhouse gases), changes in palaeo-ocean chemistry (and consequently type of sedimentation, including economically significant metal enrichment), climate change and the evolution as well as distribution of life forms. The on- and offshore geology of East Antarctica is dominated by Proterozoic and Cenozoic rocks. Apart from the current glacial-interglacial cycles, the late Proterozoic Eon was characterized by the most extreme climate fluctuations recorded over the past 2 billion years of Earth's history. Thus Antarctic geology is particularly useful to obtain the information that is necessary for tackling the above issue.

4.4 Research Theme 3 – Biodiversity Responses to Earth System Variability

How life has responded to change and will do so in an increasingly uncertain climatic future is a major concern of both conservation and sustainable development. Antarctica and its surrounding oceans not only play major roles in the global climate system, but they are also subject to rapid change and this change is already visible. Moreover, it is becoming clear that impacts on biodiversity are increasing in the region as a consequence of interactions between climatic change, biological invasions, and human use of the region. As such, the region provides a model of changes that are occurring globally, and are likely to substantially alter ecosystem services and, consequently, human quality of life. Together with their Associated and Dependent Ecosystems, Antarctica and the Southern Oceans encompass a range of environments, from extremely simple to highly complex, that provide an unparalleled opportunity for investigating the effects of anthropogenic and natural variability on biological systems.

The objectives of this Research Theme are, therefore, to: i) understand the patterns in and physical and biological mechanisms underlying local and regional scale spatial and temporal variation in marine and terrestrial biodiversity; ii) comprehend functional and structural responses to environmental variability and change from the individual to ecosystem levels; iii) differentiate the effects of natural and anthropogenic influences on biodiversity and the resources it provides for sustaining human life; and iv) provide appropriate planning advice for developing an integrated system of protected areas in Antarctica. Addressing these themes will require careful integration of work by oceanographers, biologists and geoscientists, as well as dedicated projects that concentrate on specific themes. It will also require close collaboration with major international programmes and research activities that cover the full range of environments open to the Antarctic Programme, from Gough Island and its surrounding waters to the Continental Antarctic.

4.5 Research Theme 4 – Engineering a Sustainable Presence in Antarctica

Human activities in Antarctica and in its Associated and Dependent Ecosystems are an essential component of understanding the global environment, its natural variability, and its capacity to support human life. Moreover, an increasingly educated public is seeking access to Antarctica for reasons of curiosity and self-improvement. All of these activities must be managed in accordance with the Antarctic Treaty and its Protocols, which stipulate the conditions under which operations in Antarctica take place. South Africa has long been a leader in ensuring a sustainable and environmentally sensitive presence of humans in Antarctica by adopting stringent environmental protocols and developing appropriate engineering solutions.

This research theme seeks to enhance this capability by addressing two major research issues: i) Develop, test and implement the most appropriate engineering solutions for ensuring minimal impact, maximum efficiency, and cutting-edge technological support for human, and especially science-based, activities in Antarctica and its Associated and Dependent Ecosystems; ii) understand and develop policies to minimize the direct impacts of human activities on Antarctic environments.

4.6 Research Theme 5 – The History, Sociology and Politics of Antarctic Exploration and Research

South Africa has a longstanding engagement in Antarctic Research and Exploration. The International Geophysical Year (1957/8) included South African scientists, the bases in Antarctica and on Marion and Gough Islands have been active for more than half a century, and South Africa was an original signatory to the Antarctic Treaty. This activity has meant that South African researchers have participated in both National and International expeditions for more than 60 years, and this participation has reflected the changing dynamics of South African society. Moreover, the regions in which South Africa has been active have seen a much longer human presence, owing to sealing, whaling, and other commercial exploitation and exploration, much of which has likewise involved South Africans from all walks of life. The history, sociology and politics of this engagement has been remarkably poorly studied, and much of the role of South Africans in the region remains weakly understood and generally underappreciated.

The objectives and opportunities of this research theme are to: i) explore the historical, sociological and political dimensions of research and exploration of Antarctica and its Associated and Dependent Ecosystems, which includes South Africa's involvement; ii) examine the issues of gender and race, and the implications these have had for knowledge generation and policy focus of Antarctic Research and Exploration; and iii) broaden the platform leading to more scholarships and capacity in Antarctic research both in terms of the disciplinary base as well as the researcher communities and individuals who are actively engaged with Antarctica.