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SCAR report

No 13
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Published by the

SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

at the

Scott Polar Research Institute, Cambridge, United Kingdom

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SCAR Group of Specialists on Global Change and theAntarctic (GLOCHANT)

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SCAR Group of Specialists on Global Change and the Antarctic (GLOCHANT)

Report of the 1995 bipolar meeting of the GLOCHANT / IGBP-PAGES Task Group 2 on Palaeoenvironments from Ice Cores (PICE)

Boston, Massachusetts, USA, 15-16 September, 1995

Members of the PICE Group present Dr. D. Raynaud (Chairman, France), Dr. D. Peel (Secretary, U.K.), Dr. J. White (U.S.A.), Mr. V. Morgan (Australia), Dr. V. Lipenkov (Russia), Dr. J. Jouzel (France), Dr. H. Shoji (Japan, proxy for Prof. O. Watanabe).

Apologies: Prof. O. Watanabe (Japan).

Other participants: Prof. P. Mayewski (U.S.A.), Prof. B. Stauffer (Switzerland), Dr. H. Zimmerman (PAGES), Prof. C. Hammer (Denmark), Prof. S. Johnsen (Denmark), Dr. H. Miller (Germany).

The meeting was held at the Airport Hilton Hotel, Boston, immediately prior to the joint GISP2-GRIP workshop held at Wolfeboro, New Hampshire, U.S.A. The Chairman of the task group, Dominique Raynaud, presided, together with David Peel who was nominated as Secretary of the group.

1. INTRODUCTION

1.1 H. Zimmerman briefly outlined the relationship between IGBP-PAGES (Past Global Changes) & SCAR-GLOCHANT. PAGES is designed to focus on the past global changes over the last 250 k yr. It has joined with the SCAR-GLOCHANT to formulate a coherent bipolar approach to the future strategies for polar ice-core drilling. We require a bipolar science plan which establishes the relationship between national ice-core drilling projects, and a framework for continental scale analyses of palaeoenvironmental changes.

1.2 D. Raynaud briefly reviewed the history of the group. Following the Col de Porte meeting of the GLOCHANT Planning Group on Palaeoenvironmental records (24-25 February, 1994), a draft Antarctic ice-coring strategy document had been prepared. A new document was now needed to make a much stronger case, and should especially emphasize bipolar aspects. An update of factual information is needed.

2. UPDATE OF MAJOR ANTARCTIC DRILLING PROJECTS

2.1 VOSTOK (V. Lipenkov)

Deep ice coring was initiated at Vostok Station in 1970; the latest borehole, Hole 5G was started in 1990 with a thermal drilling system and is now continuing with an electromechanical drill. Since 1989, drilling has been carried out as a joint Russian-French-American project. The aim of the project is to obtain high resolution climatic records covering approximately the past 500 k yr. These data are needed to validate the predictive climatic models, as well as to establish the interrelationships between climate change in Antarctica and climate changes over the Southern Ocean (registered in marine cores) and in the Northern hemisphere. The project also aims to elucidate the external forcing mechanisms and internal dynamics of the Earth's environmental systems.

Drilling reached a depth of 3100 m in September 1995, where the estimated age of the ice is 320 k yr BP. Drilling was then stopped over winter owing to a shortage of the densifier for the hole liquid. Drilling continued during the 1995/96 field season, and was intended to continue through the 1996 winter. In the event, it was decided to close the station for the 1996 winter, when the drilling had reached 3349.68 m depth in January 1996. According to guidelines recommended by the SCAR and Lake Vostok Workshop (Cambridge, May 1995), drilling should be stopped at a point ~25 m above the surface of the subglacial lake beneath Vostok (at ~3,650 m depth). To confirm the existence of the lake as well as to determine the thickness of the ice, water layer and lake sediments in the vicinity of the station, a seismic survey was undertaken during the 1995–96 field season in an area about 2 km^2 around the borehole. Plans have been made to reopen the station for the 1996–97 summer season. It was pointed out that modelling has not yet taken account of the lake, and dating is becoming more problematic.

The group congratulated all who had made this project such an outstanding success.

2.2 *DOME FUJI (H. Shoji, O. Watanabe)*

A new deep drilling programme commenced in 1994 at Dome Fuji, the highest point of the eastern Queen Maud Land ice sheet. At the centre of ice sheet flow, the deposited layers suffer minimal horizontal deformation by ice motion, and it is expected that an ice core from this site will clarify the climatic and environmental changes over the past 150,000 to 200,000 years.

Preparations for a deep ice coring operation at Dome Fuji started in 1991 and were completed with a successful camp construction by the JARE-35 party in 1995. The mean annual temperature at the site is -58°C, with a minimum of -78.1°C. The JARE-36 party started deep ice core drilling by extending the JARE-34 pilot hole from a depth of 112.6 m. Drilling has been continued by JARE-37, and by end of March 1996 had reached 840 m depth. The core quality is reported to be excellent and drilling is proceeding. A portion of the recovered core will be brought back to Japan by the JARE-36 party at the end of the field season. It is planned to reach 2500 m depth in 1997.

Once drilling is completed the focus will shift to mass balance studies in the Shirase drainage basin (1997-2001). The JARE-38 and -40 parties plan to drill several 100 m depth ice cores around the Dome Fuji site and along a flowline from Dome Fuji to Shirase Glacier, near the coast, and along an ice divide between the Shirase and Lambert drainage basins. These will be used to identify changes in surface mass balance during the past 200 years. These will investigations will contribute to the GLOCHANT-ITASE project. The shallow drillings will be coordinated with radio echo sounding and satellite remote sensing observations. There are also plans to perform atmospheric chemistry work after deep drilling is completed.

2.3 *US ANTARCTIC DRILLING PROGRAMMES (J. White, P. Mayewski)*

WAISCORES (West Antarctic Ice Sheet Program, ice cores)

WAISCORES, the ice coring part of WAIS (West Antarctic Ice Sheet Program), will address several fundamental questions concerning the nature and causes of climate change, the past variability of climate, and the stability of the West Antarctic ice sheet

The goals of WAIS are:

- to improve our understanding of how instabilities in the West Antarctic ice sheet may cause a rise in sea level and;
- to improve our understanding of the causes and characteristics of climate change.

The WAISCORES project proposes that two deep ice cores be drilled in West Antarctica. The first ice-core will be drilled at Siple Dome to a depth of 1000 m. This is a coastal dome in a location at the base of the main ice streams currently draining the southern part of the West Antarctic ice sheet, to the Siple Coast. This location is believed to be sensitive to potential changes in the extent of the West Antarctic ice sheet. It is expected to yield a precisely datable stratigraphic record, and enable a detailed interhemispheric comparison of prominent Holocene climatic features. Several research programmes have been funded to recover and analyse core from the Siple Dome site. Camp construction and shallow-drilling will commence in 1996-97. Reconnaissance surface studies, including stable isotopes, chemistry and accumulation rate, were conducted around Siple Dome in 1994-95 and around the Byrd region in 1995-96. As a strategy, there will be minimal field personnel - most scientists will go to national core lab at Denver to analyse the core. Drilling is due to start in 1997/98 and surface work in 1996/97. The scientific proposals have been reviewed scientifically but the schedule for drilling has still to be decided. Some surface studies have been done at Siple Dome. Radio echo sounding shows absolutely horizontal layering and well defined visible stratigraphic layering. The expected age of the core is 40-70 k yr with 7-11 cm ice/yr accumulation. The site shows good promise for a high resolution Holocene record, and evidence for several glacial age rapid climate change events. The second ice-core drilling site will be located in the centre of the West Antarctic ice sheet along the ice divide, near Byrd station. It is planned to drill one 2000 m deep core at this site. Accumulation rates of snow at this location are comparable to those in central Greenland, and hence it is believed to be a good location for replicating the high resolution Greenland palaeoenvironmental records in Antarctica. The ultimate age at this site is currently unknown, but is expected to be at least 100,000 years. It is hoped that the Siple Dome drilling may start in 1997. Currently, drilling on the Inland core is scheduled to begin in 1999.

In East Antarctica, an ~550 m core has been drilled to bedrock at Taylor Dome, near McMurdo Sound. The length of the record is ~140 k yr with +/- 350 yr error at the time of the Younger Dryas. Comparisons with the Vostok and GISP2 cores have been conducted and have revealed notable bipolar similarities.

2.4 *EPICA (J. Jouzel)*

EPICA is a long-term (ca seven years) European deep ice-core drilling project in Antarctica, to derive high resolution records of climate and atmospheric composition through several glacial-interglacial cycles. To achieve EPICA's goals it is planned to drill at two sites, in order to achieve the required resolution of the climate and gas records on different timescales, and an adequate continent-wide perspective.

The first four-years phase (1996-2000) will focus on a deep (3500 m) drilling at Dome C, East Antarctica with the aim to characterise the major climate shifts during the past several glacial-interglacial cycles. A core from this location, which is ideally placed to secure an undisturbed long record, will allow examination of the relative phasing of climate and climate-forcing parameters associated

with these major climate-change events. The core location is also optimal to put the Antarctic record into a global context and to produce a record for comparison with the ocean, continental and Greenland ice-core records. The project has been accepted by the European Union (EU) and funding approved for the first three years at the level of 90% of the original request.

During the second phase of the project, starting around 2000, a core will be obtained from Dronning Maud Land, an area of Antarctica most strongly influenced by the Atlantic ocean, and a region of somewhat greater annual snowfall rate and thinner ice cover, that will enable records of higher time resolution during the Holocene and last glaciation. This phase of the project is designed to focus specifically on the rapid climate oscillations, the Dansgaard/Oeschger events, that have been detected across Greenland especially during the later stages of the last glaciation.

Dronning Maud Land is also one of the least explored sectors of Antarctica, hence a large-scale framework of basic geophysical and geochemical survey will be undertaken during the first phase of the project, to gather the essential information that will be needed to locate an optimal deep drilling site, and to characterise the pattern of climate change across the region during the past centuries, and its representation in the ice-core record.

The direct costs for Phase 1 of EPICA, which will start in 1996, will be shared by ten national partners (Belgium, Denmark, France, Germany, Great Britain, Italy, Netherlands, Norway, Sweden and Switzerland) and by funding from the Framework 4 Programme of the EU. There may be opportunities for involvement of other countries, eg Russia and Australia, but extra money would be needed.

2.5 AUSTRALIAN DEEP DRILLING PROGRAMMES *(V. Morgan)*

Analysis of the 1200 m core from Law Dome Summit South (DSS) is continuing. The very high snow accumulation at DSS allows precision dating by layer-counting for a large part of the Holocene, however, the rapid thinning required to balance the accumulation leads to a layer thickness of only about 9 mm in the transition from the Last Glacial Maximum (LGM). There is 6 m of clear, isotopically warm ice at the bottom of the core above the silty basal ice. In 1995/96 an unsuccessful attempt was made to obtain silty ice from the bottom of the DSS borehole, due to slight borehole closure at depth. The borehole was successfully relogged to obtain vertical strain rates.

The record is ideal to extend the instrumental climate record for East Antarctica and to characterise in detail the climate during periods of important climatic fluctuations of large scale significance that have been documented in other parts of the world, such as the so-called European Little Ice Age and the Mediaeval warm period.

Field work to be carried out during the 1995–96 season covers:

- re-logging of the borehole for ice flow determination - temperature logging.
- surface strain grid re-measurement.
- shallow coring at DSS to extend the record up to the present, and to the west to investigate the accumulation gradient across the dome.
- radio echo investigations of the thickness of the basal ice and the internal layers.
- drilling for silty ice at the bottom of DSS with a rock cutting adaptor fitted to the drill motor section.

Plans are being developed for future deep drilling on the ice sheet inland of Law Dome. At a site some 600 km inland, ice thickness exceeds 4000 m, and a core to near bedrock could be expected to produce a record going back more than 400,000 years, before bedrock effects make the timescale unreliable. The area lies on the flank of the ice sheet, and the deep ice could come from near either the Dome C or Vostok depending on the exact location. Site surveys would be made around 1998, and drilling could start about 2002. The project does not have national support at this stage.

3. UPDATE OF MAJOR GREENLAND DRILLING PROJECTS

3.1 GISP2 (P. Mayewski) AND GRIP (B. Stauffer)

The GISP2 and GRIP deep ice core drilling projects in central Greenland collected parallel ice cores, each extending more than 3 k m deep and 110,000 years past. Findings have been detailed in roughly 200 refereed publications so far. A recent joint workshop (Wolfeboro, New Hampshire, September 1995) hosted by the US GISP2 project was designed to exchange data and ideas, finalize arrangements for a special joint issue of JGR Oceans and Atmospheres (due out in 1996), and to plan future analyses and ice-coring projects.

The earth has experienced large, rapid, regional-to-global climate oscillations throughout most of the last 110,000 years, of a scale that agricultural and industrial humans have not faced. A few of these stadial/interstadial oscillations, such as the Younger Dryas (YD) event, had been known for decades or longer from pollen and other records. Many more were found in the first Greenland deep ice cores, but most of the oscillations occurred in ice from close to the bed where ice flow may have disturbed the climatic record. These events are recorded far enough above the bed in the new cores that ice flow is unlikely to have altered the climatic record. Indeed, the new cores show an almost perfect match back to 110,000 years ago.

These millenial-scale events, which frequently begin or end rapidly, represent quite large climate deviations: probably many degrees C in temperature, twofold changes in snow accumulation; order-of-magnitude changes in wind-blown dust and sea-salt loading, roughly 100 ppbv in methane concentration, etc., with cold, dry, dusty, and low-methane conditions correlated.

The events also are regional to global: they are observed in local climatic indicators such as snow accumulation rate and the isotopic composition of snow linked to temperature; in regional climatic indicators such as windblown sea salt and continental dust, and in regional-to-global indicators such as atmospheric concentrations of methane, nitrate and ammonium. Some events are readily identified in the ocean-sediment record in regions critical to global ocean circulation. Furthermore, new correlation techniques involving the gaseous composition of the atmosphere demonstrate that the major events also are recorded in the isotopic temperature record of the Vostok core from central East Antarctica.

The latest investigations, based on an analysis of borehole temperatures, suggest that ice-age temperatures in central Greenland were roughly 20°C colder than today. This verifies the commonly held belief that climate changes are amplified in polar regions. Independent estimates based on the stable isotope analysis of the ice indicate that the calibration of the isotope thermometer may be non-linear in Greenland over glacial to interglacial timescales, with a considerably smaller $\partial 18O/T$ gradient in glacial times compared with the gradient calculated for the modern period.

Initial interpretation of the GRIP ice-core data indicated that the large, rapid climate oscillations that dominate the record of the last 110,000 years also persisted through the previous warm period, The Eemian interglacial. Careful physical examination of the cores shows that significant structural disturbances from ice flow occur at or slightly above the depth where the climate records from the two cores diverge. Details of the gas records and of the chemistry indicates that some Eemian ice is probably present but that the stratigraphic sequence is probably disturbed. Ultimately, just as these cores were needed to validate the rapid oscillations observed in older cores, a new core or cores from sites where the Eemian ice is further from the bedrock, and thus less sensitive to flow disturbance, will provide the best answer.

GISP2 has produced ~150 peer-reviewed papers to date covering a wide range of topics such as: site survey; analytical and statistical techniques; physical processes of snow and ice; ice core drilling design and operation; transfer functions (eg., snow/atmosphere); unique events (eg., volcanism, biomass burning, anthropogenic emissions); palaeoenvironmental reconstructions; and bipolar, Arctic and GISP2/GRIP comparisons.

The work on GRIP has left several major important questions:

The 'lead parameter' $\partial^{18}O$

Recent studies have indicated that the δ /T ratio may be strongly affected by changes in the moisture source. Now two new papers analysing the GRIP & GISP2 borehole T profiles indicate much smaller ratios in glacial times, with the implication that glacial-interglacial changes were much larger than previously deduced from isotopic profiles.

CH_4 record

Must be a global record. The Younger Dryas (YD) signal in CH_4 has to be a global and Vostok & Summit profiles overall agree well over YD, but there are quantitative differences in the early Holocene.

CO_2 record

There are problems in Greenland - with significant differences between the Greenland and Antarctic records during 1000-1600 AD, diverging with depth.

The Eemian

The GISP2 and GRIP records of the Eemian interglacial period disagree, most probably due to disturbances in the stratigraphy at one or both sites. Such disturbances, some 300 m above the bedrock, were unexpected. The series of rapid climate shifts in the last glacial, which were first detected within 50 m of bedrock in the Camp Century and Dye 3 records, were fully verified only halfway through the ice sheet in both Summit records. Understanding the causes of the disturbances in the deepest parts of the Summit records must be a priority.

3.2 North GRIP (C. Hammer)

Although both Summit cores in Greenland show an almost perfect correspondence in palaeoclimate system parameters, they differ markedly in the bottom 300 m. Thus it remains an open question, whether the last interglacial was characterized by rapid climate fluctuations as was determined from the GRIP core. Because of the far reaching consequences for our understanding of the climate system this question must be resolved. A further deep ice core is therefore necessary, preferably in a location where ice of Eemian age is further away from bedrock and less disturbed by bedrock undulations than is the case for the Summit cores. Denmark has secured national funding to drill a new deep core at such a site in North Greenland. The area has a lower precipitation than Summit, consequently Eemian ice may be 300 m above bedrock. Presite survey work, including German radio echo sounding of the North GRIP area has been carried out and drilling is planned to start in 1996. This core will, provide further evidence on Eemian climate, yield much information on spatial variability of past climate conditions in Greenland and extend the presently available Greenland climate record further back in time.

The primary aim of the drilling will be to obtain Eemian ice. It will be a low budget operation, cutting down on the science in the field. Some scientists from other nations will be invited, although they will have to obtain funding. Planning is mapped over five years, but funding is for three years in the first instance. The EPICA drill test (to 300 m) will be carried out near the site next season. Drilling of the North GRIP core is planned for 1997-98.

4. ITASE *(P. Mayewski)*

The broad aim of ITASE is to establish how the modern atmospheric environment (climate and atmosphericcom-

position) is represented in the upper layers of the Antarctic ice sheet. Primary emphasis will be placed on the last ~200 years of the record through the recovery of closely spaced (~100 km) ice cores. This time period was chosen for study because it is relatively simple to recover many ice cores covering this period and to develop a spatially significant study. Further, this time period encompasses the onset of major anthropogenic influence on the atmosphere and the end of the Little Ice Age, two notable complexities in climate change records. Specific objectives include:

- Developing a high resolution spatial array of the major environmental parameters measured in ice cores to assess recent change (the last 200 years) and provide a baseline for future environmental change.
- Developing a proxy equivalent (e.g., temperature, accumulation, humidity, atmospheric composition, circulation path) for the incomplete Antarctic instrumental record to assess climate change.
- Investigating changes in accumulation rate as an aid to sea level prediction, ice sheet modelling and as a measure of climate change.

Scientific guide-lines for ITASE have been established by the ITASE Steering Committee. Traverse routes have been proposed in order to sample the broad range of geographic, glaciological and meteorological conditions that characterise the Antarctic ice sheet. These traverse routes are the product of several international planning meetings attended by the international representatives of ITASE.

A joint IGBP-PAGES and SCAR-GLOCHANT ITASE Workshop is scheduled for the 2-3 August, prior to the XXIV SCAR meeting to update ITASE activities and develop a Science and Implementation plan. A national US ITASE meeting is to be held in late May 1996.

5. THE GLOCHANT BIPOLAR DOCUMENT–DISCUSSION

There was a general discussion on updating and developing the GLOCHANT document on an international strategy for ice-core drilling.

The document should make a much stronger case for the need for multiple deep drillings in Antarctica—especially why there was a need for 3+ holes in East Antarctica and 2+ holes in West Antarctica. It should demonstrate how work in Antarctica is related to work in the north and generally emphasize the justifications for a bipolar approach. Modelling efforts in relation to site selection and core interpretation should be included, and the contribution of ice-core work to understanding the stability of the west Antarctic ice sheet highlighted.

A structure for the new document was agreed and contributions for the component sections were drafted. Progress reports for the individual projects were submitted and partly updated in April, 1996.

6. THE GLOCHANT BIPOLAR DOCUMENT–PREPARATION

First drafts for the document were criticized and a revised structure for the document agreed. The following authorships for producing the final document were agreed:

Actions

First draft - D. Peel and D. Raynaud
Conclusions - D. Peel and D. Raynaud
Figure on ice-core parameters revealing facets of environmental change - B. Stauffer and P. Mayewski
Comparative Figure of profiles of stable isotopes in different media: GRIP/GISP2/Vostok/Marine - J. Jouzel
Maps of Greenland & Antarctica showing all deep drilling sites

Future meetings

It was agreed that a meeting should continue to be held each year.
The composition of the group could be adapted to reflect the area of expertise needed.

The setting up of a workshop (GLOCHANT-PAGES) for ITASE could be a suitable focus for 1996.

David Peel
18 March, 1996

SCAR Group of Specialists on Global Change and the Antarctic (GLOCHANT)

Report of the 1995 meeting of the GLOCHANT Task Group 3 on Ice Sheet Mass Balance and Sea-Level (ISMASS)

Chamonix, France, 17 September 1995

Members of the ISMASS Group present: Professor C R Bentley (Chairman, USA), Dr C S M Doake (UK), Dr I D Goodwin (GLOCHANT coordinator, Australia), Dr P Holmlund (Sweden), Dr T H (J) Jacka (Australia), Dr B K Lucchitta (USA), Dr H Oerter (Germany), Professor G Orombelli (Italy).

Apologies: Dr F Nishio (Co-chairman, Japan), Dr Q Dahe (China).

Other participants: Professor W F Budd (Australia), Ms C Richardson (Sweden).

1. INTRODUCTION

The overall theme of the meeting was, primarily, the coordination of ice radar sounding surveys of the grounding zone of the entire Antarctic Ice Sheet, and secondarily, the coordination of surface mass balance measurements and surface ice velocities. No formal agenda was tabled.

The Chairman opened the meeting with a review and history of the development of SCAR GLOCHANT. He outlined the overall aim of Ice Sheet Mass Balance Programme (ISMASS), to evaluate the present Antarctic mass balance and its affect on global sea-level. I D Goodwin expressed a need for the group to establish a 3–5-year plan with milestones to enable a cooperative international approach to the execution of this aim.

The national representatives were then invited to make presentations of their country's present and future plans for radio-echo sounding (RES) and overall mass balance measurements. Each nation was previously assigned a sector of Antarctica to concentrate their RES surveys. The sectors were identified by the Chairman from the paper by Bentley and Giovinetto (1991) and are referred to alphabetically.

2. NATIONAL REPORTS

2.1 GERMANY (Presented by Dr. Hans Oerter)

The Chairman's proposed that Germany could contribute by carrying out ice thickness measurements in two sectors, namely $J^{II}K$ and KK^{II}, ie the southern and eastern boundary of Ronne–Filchner ice shelf approximately from Skytrain Ice Rise (80°W) to Vahsel Bay (35°W), and from there to the northeast as far as Cap Norvegia (12°W), respectively.

German activities have taken place within these two sectors, but especially between K and K^{II}. The UK (eg from Halley Station), Norway, and Sweden are also active in this sector making ground-based and airborne RES measurements. The grounding zone of sector K–K^{II} is not an area with special scientific interest to Germany.

Available measurements

The present knowledge of subglacial and seabed topography beneath Ronne–Filchner ice shelf was compiled in a map published by IfAG (1994). The corresponding ice surface topography was compiled in an earlier map by IfAG (1993).

During the 1994–95 field season new ice-thickness measurements by airborne RES were carried out along the grounding zone of the Ronne–Filchner Ice Shelf between Institute Ice Stream (approx 74°W) and Dufek Massif (approx 50°W) (see Hempel and Oerter, in press).

Ice-velocity measurements, available for the Foundation Ice Stream, were made by the Technical University of Braunschweig (see Riedel *et al*, in press).

Ice-thickness measurements were also made by Swedish glaciologists along Bailey Ice Stream during the Norwegian expedition of Dr M Kristensen in 1992, in the vicinity of the grounding zone of the Filcher Ice Shelf.

Also, in the 1994–95 season the grounding zone of the Brunt Ice Shelf was overflown several times during a combined airborne aeromagnetic and RES programme from Halley Station. Ice-thickness measurements in the grounding zone of Ekström Ice Shelf are also available from earlier measurements of the University of Munster (Thyssen and Grosfeld, 1988) and from a survey in 1994 by Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI) (Mayer and Huybrechts, 1994). Ice-velocity values were also published in the Hoppe and Thyssen (1988) report on ice-thickness measurements in Western Neuschwabenland by airborne RES (see also IfAG, 1989). The grounding line area of Riiser-Larsenisen (approx 15°–11°W) was included in these measurements.

Future plans of the German programme

During the next two field seasons (1995–96 and 1996–97) German activities will concentrate on the EPICA pre-site survey in Dronning Maud Land, but glaciological activities on the Ronne–Filchner ice shelf will continue in the 1996–97 field season. A flight line east of Dufek Massif and a flight line south of Neumayer Station or Cap

Norvegia, respectively, should also be possible during one of the forthcoming field seasons. A more detailed study of the grounding zone of the Filchner Ice Shelf, at the inflow of Recovery and Slessor glaciers, would need a fuel depot in the area. This is beyond the range of German logistics but is in near-future plans.

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2.2 UNITED KINGDOM (Presented by C S M Doake)

1. Ice thickness

The portion of the coast identified by the Chairman as being assigned to British Antarctic Survey (BAS) will be incorporated into the BAS field plans as high priority areas for airborne RES. During the 1995–96 field season, BAS will be concentrating on the area around the western coast of Ronne Ice Shelf. There might also be a chance to do some flying from the Argentine Marambio Station at the northern end of the Antarctic Peninsula, thereby covering the grounding line area of Larsen Ice Shelf. For 1996–97, there will be less opportunity to survey the grounding line as the radar will be flown in support of aerogravity and aeromagnetic surveys.

The latest BAS airborne radar operates at 150 MHz and uses an arbitrary waveform generator to provide a number of operational modes such as pulse, chirp or pcm.

Parameters such as pulse length, attenuation, integration time etc can be set in software. Data are recorded digitally. The radar is fitted to a Twin Otter aircraft with a four-dipole antenna beneath each wing.

2. Velocities

BAS experience with Synthetic Aperture Radar (SAR) interferometry suggests that obtaining accurate surface velocities near the grounding line requires good calibration data, probably best obtained from radar reflector arrays surveyed with GPS. The vertical velocity component can cause errors of 10% or more in the inferred horizontal velocity if left uncorrected because of the amplification due to the increased sensitivity to vertical motion. A minimum of five coherent images, in at least two different look directions, is necessary to separate topography from movement, but so far no one has demonstrated that this is sufficient. With additional data on surface slopes and/or velocities, fewer interferograms could be used. Caution should be exercised about the accuracies that can be obtained.

Feature tracking in satellite SAR and visible images will be used to give velocities over Ronne Ice Shelf and elsewhere. Surface velocities can be measured accurately with GPS techniques, but even with continuous profiling it would result in a patchy coverage along the grounding line and be time consuming. A few individual sites on the Zumberge Coast will be set up and some old ones reoccupied by BAS during 1995–96. Surface velocities need to be converted to depth averaged ones for flux calculations.

3. Accumulation

Measurements on shallow firn cores drilled in Dronning Maud Land in 1995–96 will be used to determine recent accumulation rates there.

4. Database

BAS is interested in helping to define the requirements for creating and running a database of relevant information, primarily ice thickness and surface elevation, but also encompassing accumulation, velocity and temperature. Thought should be given to how data from disparate sources can be combined in a proper way, so that a high-quality product can be provided.

2.3 RUSSIA

The Chairman presented a map showing the completed coverage of Russian/Soviet RES and aeromagnetic/aerogravity flight lines. Some of the aerial surveys were completed in 1993–94. There was a discussion about the need for the Russian SCAR delegates to inform the Russian scientists of the SCAR-related activities and to encourage participation in GLOCHANT Task Groups. The Chairman reported on a discussion that he had had recently with Dr V Masolov, Head of the Antarctic Division of Polar Marine Geological Research Expedi-

tions (PMGRE), in St Petersburg, Russia. Dr Masolov told the Chairman that he would recommend to his logistics people the Task Group's recommendations on future coast-parallel RES airflights. It was suggested that Dr Alexander Golynsky, a colleague of Dr Masolov at PMGRE, be invited to become a member of the ISMASS group.

2.4 SWEDEN (Presented by P Holmlund)

The following glaciological projects, planned within the Swedish Antarctic programme for the seasons 1996–97 and 1997–98, aim:

- to study the climatic development on different time scales in the western Dronning Maud Land;
- to study the present accumulation pattern;
- to execute a site survey for the European Project for Ice Coring in Antarctica (EPICA);
- to model the development of the Antarctic ice sheet over an ice-age cycle; and
- to study recent changes in atmosphere and surface conditions.

Present climate and present state of the ice sheet

It is proposed to conduct:

- snow radar soundings of spatial variations in snow accumulation in the top 10 m;
- firn coring for chemical analyses and to calibrate snow radar registrations in the top 10–20 m;
- ice-velocity measurements as a complement to RES surveys to study reasons for variations in snow layer thickness, to provide data for modelling and for balanced flow studies;
- RES at outlets and inlets for balanced flow studies, and the depths at the grounding line along the coast as directed by ISMASS;
- modelling of the present mass balance and ice flux situation.

The output from these studies will include: accumulation rates and trends, velocities and ice fluxes, physical data for decision on a drilling site for EPICA, and ice fluxes at the grounding line along the coast.

Last 500 years

It is intended to drill medium-depth firn cores for chemical analyses. The expected output is a climate record, detailing climate changes since the beginning of the Little Ice Age, and changes in anthropogenic-induced aerosols and tracers.

Last 100,000 years

A deep ice core will be drilled at the EPICA site in the future. Ice velocity, ice thickness and accumulation measurements will be collected to support modelling studies. The expected outcomes will include a model of climate changes and changes in ice fluxes and shape of the ice sheet over the last ice-age cycle.

Proposed fieldwork 1996–97

Using Norwegian logistics, a Scandinavian oversnow traverse is planned from the coast at SANAE Station inland to 3,000 m elevation, via Troll Station. Snow radar soundings will be carried out using a CW-radar (1–2 Ghz), with detailed calibration using firn cores. The cores will be analysed using density, conductivity (identification of volcanic horizons) and beta radioactivity horizons, to determine annual accumulation layers. A small number of firn cores will be returned to Sweden for further analysis. If logistics are available, airborne RES surveys will also be conducted using a CW-radar, 150–180 MHz.

Proposed fieldwork 1997–98

Using Swedish logistics, a Scandinavian oversnow traverse is planned from Wasa to 3,000 m elevation (Amundsenisen) via Kibergdalen. A survey of the EPICA site, ice velocities (GPS), shallow coring (accumulation rate, chemistry, oxygen isotope (^{18}O, ^{14}C and conductivity), snow radar (spatial distribution of snow cover) soundings (using a CW-radar, 1–2GHz) and RES soundings (bedrock topography and internal layering) using a CW-radar (150–180 MHz) will be conducted on the traverse. Shallow firn coring will also be conducted for snow radar calibration. A medium-length firn-coring programme is also planned to depths of 100–200 m. One site is planned at 500 m asl and one at 3,000 m asl. Duplicate cores will be drilled at each site. The cores will be analysed for radionuclides and concentrations of organic halogens in ice. Airborne RES surveys will be flown along the grounding line, either by fixed-wing aircraft or by helicopter.

The following Institutes are collaborating in the above projects:

Department of Physical Geography, Stockholm University, Sweden.
The Swedish Polar Research Secretariat, Stockholm.
Department of Meteorology, Stockholm University, Sweden.
Institute for Marine and Atmospheric Research Utrecht, The Netherlands.
Environmental Surveillance Technology Programme, Lillestrøm, Norway.
The Swedberg Laboratory, University of Uppsala, Sweden.
Water and Environmental Studies, Linkoping University, Sweden.
Institute for the Study of Earth, Oceans and Space, University of New Hampshire, USA.

Snow radar surveys of accumulation, Dronning Maud Land

Snow layers have been mapped successfully using a ground-based snow radar along two traverses from the coast up to 3,000 m asl. The recordings show large local and regional variations in the accumulation pattern along the 2,300 km measured profiles. These traverses were a part of the Swedish contribution to the International Trans-Antarctic Scientific Expedition (ITASE). In order to verify the geographical representation of firn cores, a detailed net of snow radar profiles was surveyed at the firn core drill sites.

The radio-echo sounder is a continuous wave step-frequency radar, based on a Hewlett-Packard Network Analyser (8753C). The antennae used were a pair of AEL APN-106AA. The snow radar was operated in the frequency range 800–2,300 MHz giving a penetration depth of 12–14 m. GPS positions were recorded every 5 km, ie at the beginning and end of each data file.

Distinct snow layers are visible in the radar images. The concept is to follow a specific snow layer from the coast to the polar plateau and to register changes in depth. The speed of the radar signal is a function of snow density, and the depth-scale of the radar images is calculated from density data obtained from firn cores. By correlating the radar registrations to core data the snow layers can be dated; also, these correlations make it possible to deal with problems caused by regions with disturbed snow stratigraphy. A coastal section of the traverse follows a stake line over a distance of 160 km. The accumulation pattern obtained from the snow radar soundings is consistent with the results from stake measurements made at several occasions between 1987 and 1994.

2.5 AUSTRALIA (Presented by J Jacka)

Australian Antarctic field activities concerning the ice sheet mass balance over the past few years have involved a tractor-train traverse from Mawson to the Larsemann Hills, approximately following the 2,500 m elevation contour around the southern end of the Lambert Glacier. The Lambert Glacier Basin Traverse measurements included ice surface and bedrock elevation using a 100 MHz ice radar, surface velocities (GPS), snow accumulation (canes placed every 2 km) and gravity. In addition, shallow cores were drilled for temporal accumulation variability studies, a pit was excavated for stratigraphy studies and six automatic weather stations were deployed around the basin.

With the completion of the Lambert Glacier basin project, Australian traverses over the past twenty years have (with the exception of one sector) completed surveys and examined the ice sheet mass balance along the 2,000 to 2,500 m elevation contour from Enderby Land to Porpoise Bay (eastern Wilkes Land). This survey extends from AI to near D, except for a gap from C halfway to CI, which will be completed in the near future. This missing sector is that between the Grove Mountains and a point inland of Mirny Station. Measurements (Sikorsky 76 helicopter-supported) for this sector are included in the current ANARE strategic plan and are expected to be carried out during the next five years.

During the 1995–96 austral summer, differential GPS measurements will be made to determine directly the mass budget of the Lambert Glacier – Amery Ice Shelf drainage basin by measuring elevation change since 1968 when measurements were made in the vicinity of the grounding zone. Measurements will also provide surface elevation data to ground truth profiles derived from satellite radar altimetry, reference locations for future airborne RES and accurate values of the geoid-ellipsoid separation.

Currently, the Australian programme does not have a digital ice radar suitable for airborne RES measurements. The present oversnow traverse ice radars are digital logging units based on a digital storage oscilloscope. These cannot sample the returned waveforms fast enough, receive only a fraction of return power and sample only an average over 10 m along track. This radar sampling is too slow to be used in aircraft at much higher speeds and rates of sampling. Development of an airborne digital ice radar system will be carried out over the next two years. With the recent introduction into the Australian programme of Sikorsky long-range helicopters and the possibility of fixed-wing aircraft availability over the coming five-year period, it is anticipated that an aerial ice radar capability will allow ice radar coverage of the grounding zone for the entire Australian sector over this period. Currently, the long-range helicopters operationally fly the legs Mawson – Davis, Davis – Bunger Hills and Bunger Hills – Casey, transporting personnel and equipment. It is anticipated that these flights may be utilized to carry out the ice thickness surveys, in the near future. There is a possibility of extending airborne RES coverage along the grounding zone in Terre Adélie and George V Land, toward D', by using the Sikorsky 76 helicopters from a ship base. These helicopters would have a range of 600 km. It is unclear whether the Australian ship, RV *Aurora Australis*, will be available. It is more likely that a cooperative programme using a ship such as the US RV *Nathaniel B Palmer* will be required. It is envisaged that the airborne RES surveys could be flown in conjunction with ANARE/international geological programmes in this sector, that are proposed for 1998–99.

2.6 ITALY (Presented by G Orombelli on behalf of Dr M Frezzotti, not attending)

The Italian programme has a SPRI digital ice radar which will be installed in a Twin Otter aircraft in the 1995–96 season. Flight lines are planned along the coast south from Terra Nova Bay to Mackay Glacier, and north to Rennick Glacier, along the western Ross Sea. Flights are also planned inland toward Dome C, in support of the EPICA deep drilling site selection. Future plans include transects of the main outlet glaciers and possibly further surveys around Dome C. It is likely that continuous coverage from McMurdo Sound to Cape Adare can be provided. It is logistically difficult to work west of Cape Adare. The Italian programme may have a Twin Otter in future years for logistic support, that may also be available for additional radar flights.

Recent mass balance data from northern Victoria Land

Snow accumulation

A shallow (10–40 m) firn core drilling programme was conducted at seven sites in northern Victoria Land. Snow accumulation ranges across these sites from

130–270 kg $m^{-2}yr^{-1}$ and was interpreted using oxygen isotope ($\delta^{16}O/^{18}O$), hydrogen peroxide (H_2O_2), and methyl sulphide (MSA) seasonal signals. The sites are located at: McCarthy Ridge 74°33'S, 163°01'E; Styx Glacier 73°55'S, 163°45'E; Hercules Névé 73°07'S, 164°58'E; Priestley Névé 73°38'S, 160°38'E; Rennick Glacier 73°15'S, 162°29'E; Pilot Glacier 73°15'S, 165°30'E; Niggli Névé 72°41'S, 166°58'E; Bowers Glacier 72°44'S, 168°50'E).

Snow temperature, at 10 m depth, was measured at four sites (Hercules Névé 73°07'S, 164°58'E; Priestley Névé 73°38'S, 160°38'E; Pilot Glacier 73°15'S, 165°30'E, Drygalski Ice Tongue 75°30'S, 165°18'E)

Ice-velocity measurements

Surface velocity was measured by GPS for:

David Glacier-Drygalski Ice Tongue (12 stations*), Priestley Glacier (3 stations), Reeves Glacier (2 stations*);

and by remote sensing for:

Mackay Glacier (OG*), Mawson Glacier (OG*), Marin Glacier, Harbour Glacier Tongue, Cheetham Ice Tongue, Clarke Glacier, David Glacier (OG*), Larsen Glacier (OG*), Reeves Glacier (OG*), Priestley Glacier (OG*), Campbell Glacier*, Random Hills Glacier, Tinker Glacier Tongue, Glacier Tongue, Parker Glacier Tongue, Icebreaker Glacier, Fitzgerald Glacier, Wylde Glacier, Suter Glacier, Ridgeway Glacier, Mariner Glacier Tongue, Borchgrevink Glacier Tongue, Tucker Glacier, Ironside Glacier, Moubray Glacier, Lillie Glacier Tongue, Barber Glacier*, Gannutz Glacier*, Rennick Glacier (OG), Pryor Glacier, Suvorov Glacier*, Gillet Ice Shelf, Tomlin Glacier* (OG) Outlet Glacier.

*Measurements close to grounding line.

GPS and remote sensing surface velocities differ by less than 2% in valley glaciers or near nunataks and lower than 10% on ice tongues and on ice shelves without reference points and with different path and row satellite orbits.

Ice tongue and ice shelf thickness were evaluated at the ice front with GPS:

Nansen Ice Sheet, Hells Gate, Larsen Glacier Tongue, Campbell Glacier Tongue, Random Hills Glacier Tongue, Tinker Glacier Tongue, Aviator Glacier Tongue, Suvorov Glacier Tongue*, Tomlin Glacier Tongue*.

*Measurements close to grounding line.

Preliminary RES data have been obtained for local glaciers.

A preliminary evaluation of the mass balance for the sector from Cape Crozier 77.5°S, 169°E (E of Giovinetto and Bentley, 1985) to Williamson Head 69.2°S 164°E (D' of Giovinetto and Bentley, 1985) suggests a positive value (M Frezzotti, in preparation). Surface elevation was measured by GPS at Tarn Flat and the Strandline Glaciers (1993) and along the traverse from Terra Nova Bay to the East Antarctic plateau 280 km (1993).

Italian Antarctic Programme 1996-1998

The following measurements will be conducted in 1996–98. Mass balance measurements will be made on the ITASE traverse in 1996–97, from Terra Nova Bay to Talos Dome, about 450 km inland. They will also be made in 1997–98 on a traverse from Terra Nova Bay to Dome C, about 1,300 km inland along the David Glacier drainage basin. Remote sensing measurements will include the determination of ice front fluctuations and ice flow from Williamson Head 69.2°S, 164°E (D' of Giovinetto and Bentley, 1985) to point west of Dibble Glacier Basin 66.1°S, 134°E (D of Giovinetto and Bentley, 1985). RES will be carried out in 1995-96 and the following seasons in northern Victoria Land and the Dome C area.

2.7 USA: Field surveys (Presented by C R Bentley)

The ability of the US Antarctic Program (USAP) to contribute to the planned RES of the Antarctic Ice Sheet grounding zone is problematic. Although the capability exists the operating time of the SOAR remote sensing Twin Otter aircraft is fully committed for the next year or two. Furthermore, it would be logistically difficult for the Twin Otter to cover the Amundsen and Bellingshausen Coasts (F to H[1]) because they are so far from any support base. He stated that he will pursue further the possibilities for covering the entire grounding zone of the Ross Ice Shelf. He will also investigate whether the SOAR aircraft could do a small amount of sounding in the Terra Nova Bay for comparison of results with those of the Italian airborne radar sounding to be initiated in the 1995–96 field season.

C R Bentley also discussed the opportunity raised by the potential availability of the long range Lockheed P-3 aircraft that has been used for many years by the US Naval Research Laboratory (NRL) for Project Magnet. The P-3 has a range of 5,000 km at a suitable low altitude flight height (7,000 km at high altitude), and thus in principle could be used to cover not only the FHI sector but also much of the rest of Antarctica, from a base at McMurdo Station. The P-3 is not ski-equipped. The challenge for using the P-3 is to find the financial support required for its operation, which must be found from sources outside the US Navy. USAP cannot support it alone, although a contribution to an internationally-supported activity might be possible. He circulated a paper giving more details on the P-3 and its potential with a 150 MHz radar antenna system installed, that he had received from Dr J Brozena, head of the Geodetic and Geophysical Systems Section, Marine Geoscience Division, NRL. The P-3 aircraft would potentially be available for RES in Antarctica between 1996 and 1998.

The members of the Task Group expressed an interest in pursuing a cooperative, internationally funded RES programme using the P-3 aircraft. Countries without an RES capability may be interested in contributing. Dr Brozena is a geophysicist, who is principally interested in simultaneous aeromagnetic and aerogravity

surveys for which the P-3 is equipped. A combined aeromagnetic, aerogravity and RES survey may be a selling point to the national programmes. It was decided that C R Bentley will work with Dr Brozena to develop a proposal to be circulated to all SCAR countries as an attempt to develop an internationally supported activity.

Dr J Sievers is doing repeat image velocity studies using ERS-1 SAR images and has asked the Germans in the field to emplace radar reflectors for geodetic control this season. Control using reflectors or nunataks is very important, as otherwise the accuracy of position determination between images is only about ±50 m. Since features tend to disappear after two years there is a 25 m yr^{-1} limit on the accuracy of velocity measurements. The geodetic control problem is more severe with ERS-1 radar images than with Landsat images because the smaller image size (100 km on a side vs 200 km) makes the chance of including a nunatak on each image less likely. Other expeditions should be urged to put out radar reflectors where possible. Other scientists doing ice-velocity studies from repeat image analysis are B K Lucchitta (USA), M Frezotti (Italy) and N Young (Australia). It is important to encourage similar remote sensing studies by other workers, since the United States Geological Survey (USGS) programme may be terminated before reaching its goal of complete circum-Antarctic coverage. The problem of a lack of geodetic control exists for interferometric SAR also. In principle, overlapping images could be extended to the nearest fixed point but this would be very expensive. ERS-1 and ERS-2 are in tandem mode with a one-day delay; the tandem mission will last a total of six or nine months. There will be a workshop in October on obtaining the greatest benefit from the ERS SARS generally (not just in Antarctica).

2.8 USA: Remote sensing (Presented by B K Lucchitta)

Establishing velocities of glaciers, ice streams, ice sheets, and ice shelves is essential to calculate the discharge of the mass balance equation. Velocities can be obtained on the ground, by satellite, or by a combination of the two. Ground measurements are time consuming and difficult logistically; nevertheless they exist already for many glaciers and ice streams that have been studied in the past. A need exists to have these measurements assembled in a readily available data base. Satellite-based velocities are obtained by tracking features that move with the ice (mostly crevasses) on repeat images covering the same area on the ground. A new satellite technique is radar interferometry, in which repeat images need to be closely aligned in space and time. Measuring velocities by a combination of satellite and ground efforts involves, for instance, tracking satellite radar images by corner reflectors placed on the ground, and tracking moving stations by GPS. Considering the difficult Antarctic environment, the vast area involved, and the cost of ground expeditions, the workshop members felt that obtaining velocities by satellite is the only feasible method for mass balance determinations within the near future.

Landsat

B K Lucchitta showed examples of velocity determinations made by Landsat along the Marie Byrd Land coast. Most of the measurements were made on images dating from the early 1970s to the late 1980s, spanning time intervals of as much as twenty years. As the early images are MSS (Multispectral Scanner) having 80 m resolution, only large crevasses in floating ice (shelves and tongues) can be tracked. However, regression lines on plots of velocity versus distance, when projected toward the grounding line, give approximate velocities at this line. B K Lucchitta gave the velocities along the Marie Byrd Land coast (projected to the grounding line) only to the nearest 0.1 km yr^{-1} because of errors introduced by irregularities in the internal geometry of early Landsat images and uncertainties in orbit determinations. (B K Lucchitta has shown in publications that velocities as accurate as ±0.02 km yr^{-1} can be obtained under optimum conditions, including the registration of MSS images to later and more stable Landsat TM (Thematic Mapper) images of 30 m resolution.) Velocities were obtained for the Dotson Ice Shelf, for five areas along the Getz Ice Shelf, and for three areas on the shelf in the Sulzberger Bay. Some areas could not be covered because suitable Landsat images without cloud cover were not available. Projected to the grounding line, velocities along the Dotson and Getz Ice Shelves are around 0.2 km yr^{-1}. Velocities on the shelf near the DeVicq Glacier increase westward to near 0.5 km yr^{-1} and reach 0.6 km yr^{-1} at the glacier. The Land Glacier, at 1.6 km yr^{-1}, is exceptionally fast for a glacier with a small drainage basin. Ice in the Sulzberger Bay, on the other hand, is very slow at less than 0.1 km yr^{-1}.

ERS

B K Lucchitta showed velocities obtained for the Pine Island and Thwaites Glaciers as examples of data that can be obtained with radar images (ERS-1). An automated cross-correlation technique was used for tracking patterns in the ice, and hundreds of points were obtained for each glacier both above and below the grounding line. (The 25 m ground resolution of ERS permits tracking patterns above the grounding line.) Findings include:

1. The velocity of the Pine Island Glacier increased across the grounding line (as located by radio-echo sounding by Crabtree and Doake, 1982) from about 1.5 km yr^{-1} to about 2.6 km yr^{-1}, an increase of about 1 km yr^{-1}.
2. The velocity of the Thwaites Glacier also increased across the grounding line from about 2.0 km yr^{-1} to about 3.0 km yr^{-1}, a similar increase.
3. Few trackable points were picked up by the computer programme in the region of both grounding lines, perhaps reflecting a grounding zone or movement across a steeper slope, where patterns were not preserved.

4. Neither glacier is buttressed by an ice shelf, and movements are exceptionally fast. The observations show that future RES bedrock traverse profiles near the grounding line have to be placed with care for fast-moving glaciers without shelves, because the velocities may change rapidly. The best place to locate the radar profile would be at the upstream side of the rapid velocity increase. Ice streams that merge with shelves, on the other hand, may show a velocity decrease, as pointed out by C S M Doake for the Rutford Ice Stream, or show no noticeable acceleration, as noted for Ice Stream E by Scambos (NSIDC, Boulder, Colorado, USA, not attending, personal communication). M Frezzotti (ENEA, Rome, Italy, not attending, personal communication) noticed an increase in velocity of about 0.1 km yr^{-1} where the David Glacier (northern Victoria Land) crosses the grounding line and becomes the Drygalski Ice Tongue. He thought that, for slow-moving glaciers (on the order of 0.5 km yr^{-1}), such an increase is insignificant and does not warrant special care in locating the grounding line.

Coastal Maps

B K Lucchitta mentioned that the Marie Byrd Land velocity measurements are part of a larger project by R S Williams, J G Ferrigno (USGS, Woods Hole and Reston, USA), C W M Swithinbank (SPRI, Cambridge, UK), and that B K Lucchitta is to make an inventory of the position of ice fronts and grounding lines of the entire Antarctic coastline, based on Landsat images of the 1970s and again of the 1980s. The results are to be published as twenty-four 1:1 000 000 scale maps covering the coastline. A prototype map of the Bakutis Coast has been compiled. The velocities are shown as scaled velocity vectors on the maps.

Limitations and Errors

Landsat images have limitations due to the coarse resolution of the MSS images, high cost of the TM images, current absence of a functioning system for Antarctic acquisitions, and obscured images due to cloud cover. Radar images from ERS and RADARSAT lack these limitations and they will probably provide most of the satellite-based velocity data in the future. However, ERS images also have limitations. The region south of about 80°S is not covered, and currently only two receiving stations are operational. In addition, they are manned only for short-time periods. The German station at O'Higgins on the Antarctic Peninsula covers the coastal regions from about 120°W eastward to about 0°, and the Japanese Station at Syowa from about 60°W eastward to about 110°E. The O'Higgins station has been manned once or twice a year for about one month each, providing good acquisition opportunities. The Syowa station has been less reliable, and scheduled acquisitions generally have not been received. The US McMurdo Station is now operational and covers the Antarctic coastline from about 70°E eastward to about 70°W. The station will be manned for the entire year, so that acquisition opportunities will be increased markedly. The memorandum of understanding (MOU) between the European Space Agency (ESA) and the United States Alaskan SAR Facility is about to be signed, and images received by McMurdo will be available in the near future. ERS images have a nominal ground-location accuracy of 50 m (Roth *et al*, 1993). This claim was verified by B K Lucchitta in her investigations. Where outcrops are available, images may be co-registered to near-pixel accuracy (12.5 m). Fast-moving glaciers tend to lose trackable points in the grounded part when time intervals increase beyond one year, whereas slowly moving ice readily preserves trackable points over a two-year interval. B K Lucchitta showed examples of measurements made on the grounded part of the Bailey Glacier in East Antarctica, which moves at about 0.1 to 0.2 km yr^{-1}. Assuming location errors in the images of 50 m, a glacier moving at 1 km yr^{-1} traced for one year would have a velocity error of ±5%, whereas a glacier moving at 0.1 km yr^{-1} traced for two years would have a velocity error of ±25%. For images co-registered by outcrops the possible errors would be reduced by one fourth to near ±1% for fast-moving glaciers, and near ±6% for slow-moving glaciers. At this point the Chairman raised the questions whether such potential errors would invalidate the entire effort to measure velocities with satellite images, because a 50 m yr -1 error around the entire continent amounts to some 15% of the total output flux. J Jacka objected to this assessment because 80% of the Antarctic ice is discharged through fast-moving ice streams, and approximate velocities for the remaining 20% would suffice. For instance, five major ice streams cover 80% of the outflow from the Amery Ice Shelf to the Napier Mountains. W F Budd added that ice sheets flowing out onto shelves move at a rate on the order of 10 m yr^{-1}, whereas ice streams may move at 800 m yr^{-1}, demonstrating that not all of the coast is important in terms of discharge and that efforts should be concentrated on the ice streams. B K Lucchitta further noted that slow-moving ice sheets generally show few trackable points, so that velocity measurements can only be made in selected places or on adjacent shelves. Thus velocities for the ice sheets will have to be projected from locations nearby. For slow velocities, SAR interferometry may help.

SAR Interferometry

ERS-1 and 2 are currently in a tandem orbit, specifically designed to permit interferometry measurements. The spacecraft trail each other by one day, and their orbital tracks give an interferometry baseline of 50–600 m. This configuration is to be maintained through mid 1996. A special effort, spearheaded by F Carsey (ASF, Fairbanks, Alaska, US) and J Sievers (IfAG, Frankfurt, Germany) is underway to ensure that Antarctica will be adequately covered during the tandem-mission period (mostly using McMurdo Station). C S M Doake pointed out that interferometry may yield velocities accurate to 1 cm per

day (4 m yr^{-1}), but the calibration of the data (including separation of topography from velocity effects) remains a problem. Accurately located corner reflectors may help to calibrate the interferometry fringes. Even though acquisition of suitable images for interferometry appears assured, the question of who will exploit the data and how they will be exploited remains open.

RADARSAT

Accurately located corner reflectors (using GPS) are needed also for the calibration of the RADARSAT orbit. The satellite is to be launched in October 1995. A dedicated Antarctic Mapping Mission phase is planned for 1996 and 1998 and includes rotating the satellite so that the radar beam views south, thus permitting coverage of the entire Antarctic continent. Eighteen days of data acquisition are necessary to cover Antarctica utilizing "Standard Beam 2" (similar in geometry to ERS but looking south) and additional beams with greater look angles near the pole. The data are tape-recorded and can be downloaded at ASF in Alaska, so that Antarctic receiving stations are not essential. The RADARSAT Antarctic Mapping Mission seeks to produce mosaics controlled to better than 100 m. To accomplish this accuracy, good ground control is needed around the perimeter of the continent and south of 85°S. Corner reflectors, existing Digital Elevation Models (DEMs), and interferometry will be used to improve ground-location accuracy. The extent to which the RADARSAT maps will be useful for detailed velocity measurements remains to be seen.

ASTER

The problem of ground control is not unique to RADARSAT. Future spacecraft, such as the Japanese-American ASTER (Advanced Spaceborne Thermal Emission and Reflection radiometer), to be launched in June 1998 as part of the Earth Observing Mission (best ground resolution 15 m, stereo capability, fourteen spectral bands in the visible, near, and far IR), also need good ground control. This mission has a dedicated glacier monitoring programme that includes Antarctica. Multiple acquisitions are planned to minimize the effect of clouds. ASTER's along-track stereo capability can produce digital elevation models with 15–25 m vertical resolution where surface contrast (eg crevasses, nunataks) is available. One point per image is sufficient because the images are internally stable. To facilitate future ground control needs, H Kieffer (USGS, Flagstaff, USA) is promoting the establishment of a databank that lists all available Antarctic ground control points, documented by photos, satellite images, and digital information on pixel location within the images. Ideally, each Antarctic research party using GPS should thus document their measured locations. Even though such a databank would be very useful, it most likely will not be available in the near future. Other points of interest were discussed.

Miscellaneous

Other thoughts and concerns with respect to velocity requirements were expressed throughout the meeting:

H Oerter commented that German research groups have made measurements on the Foundation Ice Stream (0.5 km yr^{-1}), but that it is difficult to locate the grounding line because no high-resolution satellite images exist for the region and seismic and radar-echo investigations do not give the same results for the location of the line. In addition, flying aircraft into the region is difficult because of problems associated with fuel supply. He commented that the availability of a US C-130 aircraft would be very helpful for this region.

B K Lucchitta asked C S M Doake whether the UK is systematically measuring glacier velocities around the Antarctic Peninsula. C S M Doake replied that systematic efforts are being undertaken in the Ronne-Filchner ice shelf region but not on the peninsula, where velocity measurements and coastal monitoring is spotty. He mentioned that J Sievers of IfAG, Germany, may have systematic plans in that region.

J Jacka gave some data on ground measurements in the Lambert Glacier region. The Australians measured surface velocities by GPS every 30 km along the 2,500 m contour around the Lambert Glacier basin. On the SE side, inflow into the Lambert Glacier is 54 m yr^{-1}, on the NE side about 10 m yr^{-1}. Errors are within tens of centimetres.

N Young (Antarctic CRC, Hobart, Tasmania, not attending) is obtaining velocity measurements of several major outflow glaciers in the "Australian" sector of Antarctica. The Australian programme will concentrate on obtaining longitudinal velocity profiles on the coastal glaciers, in concert with radar sounding. Velocities of all major glaciers have been obtained. It also proposes to obtain some velocity-depth profiles on coastal glaciers to calibrate the surface velocities on outflows.

G Orombelli mentioned that the Italian groups are obtaining velocity values by GPS. In addition, M Frezzotti (not attending) measured velocities of most glaciers along the northern Victoria Land coast based on all available aerial and satellite images. This region may serve to calculate the mass balance of small glaciers, to assess whether such glaciers should be included into discharge and mass balance calculations for the Antarctic ice sheets. The results from such a study may also apply to the Antarctic Peninsula, where many small glaciers exist. However, on the peninsula minor glaciers are most likely important because of the high precipitation rate in this region. I D Goodwin expressed concern that the ice input data for mass balance calculations may not be registered temporarily with the output data. He suggested that mismatch in time may result in errors of as much as 25%. Velocities, however, most likely do not vary by that much in the time intervals covered by the anticipated mass balance investigations. Careful monitoring of velocities of selected ice streams may show to what extent velocities do indeed change.

B K Lucchitta encouraged all workshop participants to include in their reports the names of glaciers for which velocity measurements have been made by their respective countries, in order to get an idea to what extent the Antarctic coastline has been covered.

2.9 JAPAN (No report received)

The Chairman informed the Task Group that there was no information about the Japanese RES capabilities.

3. ACCUMULATION UPDATE AND MODELLING OVERVIEW

W F Budd reported that modelling of atmospheric moisture fluxes over Antarctica using all available observational data on and around the continent, including buoys, and a diagnostic atmospheric circulation model, can now yield values for small-scale average accumulation rates that are good to ±10%. Data exist to carry the annual average analyses back as far as 1988. W F Budd proposed that the ISMASS group set up a GLOCHANT databank comprising raw data and 10 km gridded data, including accumulation, ice thickness and velocities. He proposed that this databank be produced jointly by the Antarctic CRC and the SCAR Global Change Programme Office in Hobart. C S M Doake and H Oerter agreed with the proposal and recommended that it be a joint SCAR and EISMINT databank. I D Goodwin urged members to encourage field programmes to include shallow firn coring in preference to stake networks, to give a broad picture of temporal variation in snow accumulation. W F Budd suggested that national fieldwork programmes should aim to determine long-term estimates of accumulation rates from the stratigraphic use of a common bomb horizon. This would allow the determination of long-term accumulation rates for a common period across Antarctica.

4. ACTION ITEMS

The Chairman and I D Goodwin will prepare a proposal to be sent to national glaciology representatives and logistics operators (COMNAP) about seeking interest and support for an international cooperative RES and aerial geophysics programme, using the Lockheed P-3 aircraft. Countries that do not presently have an RES capability should be particularly encouraged to contribute financial support. The proposal should be distributed to key people including the respective SCAR National Committees, Managers of National Antarctic Programmes, and national logistics operators.

GLOCHANT-ISMASS plans for RES surveys around the grounding zone of the entire Antarctic Ice Sheet should be distributed to national operators to ensure they understand the importance of supporting this programme.

W F Budd will prepare a proposal for the establishment of a GLOCHANT/Antarctic CRC (Australia) data set, comprising raw data and 10 km gridded data on accumulation, ice thickness and surface velocity.

H Oerter and C S M Doake will encourage Weddell Sea regional workers to coordinate their RES efforts and their fuel depot requirements. B K Lucchitta and the Chairman suggested that there is a need to evaluate the contribution of small coastal glaciers to mass flux, especially in Victoria Land (E-D^{II}) and along the Antarctic Peninsula.

The Chairman and I D Goodwin will arrange for Dr A Golynsky of PMGRE in St Petersburg to be invited to become a member of the ISMASS Group.

B K Lucchitta identified that there was a large area where no RES coverage existed in Dronning Maud Land, since the Swedish survey area does not extend from A to A^{I}. It was suggested that the Japanese programme should be asked to make a contribution to this area.

J Jacka will arrange liaison between the Australian and Russian glaciology programmes to determine cooperative work in the sector between Mirny and Davis stations. The Russians should be encouraged to conduct RES parallel to the coast and along the grounding zone in this sector.

Australia will develop an aerial ice radar facility and complete RES surveys along the Lambert Glacier and Amery Ice Shelf system, and conduct two parallel surveys along the grounding zone of the ice sheet between Enderby Land and King George V Land.

B K Lucchitta agreed to prepare a summary on the accuracy of satellite-image analyses of ice-surface velocity determination. The purpose is to establish the minimum velocities that can be determined with reasonable confidence. She also agreed to prepare a general overview of the locations where various satellite image techniques are being used for velocity measurements.

All measured velocities are to be submitted to a GLOCHANT databank, listing latitude, longitude, magnitude, and direction of selected measured points. Current databanks exist at BAS (Dr D N Vaughan, UK), in Australia, and at the SAR facility at the USGS in Reston, Virginia, USA. No decision was made concerning the location of the envisioned databank for velocity values.

The use of satellite passive microwave data should be encouraged for the interpretation of accumulation data across the ice sheet. Research on the application of continuous snow layer profiling and accumulation rate interpretation from snow radar should be encouraged and used on all future ITASE traverses, in conjunction with shallow firn coring at regular intervals to enable the calibration of the radar data, with a known stratigraphic horizon such as a bomb horizon. It was recommended that the ISMASS Group should merge with ITASE on the planning of future traverses. The Chairman agreed to contact Dr P Mayewski and discuss future arrangements.

W F Budd recommended that measurement of velocity-depth profiles should be made, near the coast where possible, in future fieldwork programmes.

List of Acronyms and Abbreviations

ANARE	Australian National Antarctic Research Expedition
ASF	Alaska SAR Facility
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung
BAS	British Antarctic Survey
COMNAP	Council of Managers of National Antarctic Programmes
CRC	Cooperative Research Centre
CW-radar	Continuous Wave Radar
DEM	Digital Elevation Model
EISMINT	European Ice-Sheet Modelling Initiative
ENEA	Ente per le Nuove tecnologie, l'Energia e l'Ambiente (National Agency for New Technologies, Energy and the Environment)
EPICA	European Project for Ice Coring in Antarctica
ERS	European Remote-Sensing Satellite
ESA	European Space Agency
FRISP	Filchner–Ronne Ice Shelf Project
GLOCHANT	Group of Specialists on Global Change and the Antarctic
GPS	Global Positioning System
IfAG	Institut für Angewandte Geodasie
IR	Infra-Red
ISMASS	Ice Sheet Mass Balance and Sea-Level
ITASE	International Trans-Antarctic Scientific Expedition
MOU	Memorandum of Understanding
MSA	Methyl sulphide
MSS	Multispectral Scanner
NRL	US Naval Research Laboratory
NSIDC	National Snow and Ice Data Center
OG	Outlet Glacier
PMGRE	Polar Marine Geological Research Expeditions
RADARSAT	Radar Satellite
RES	Radio-Echo Sounding
RV	Research Vessel
SANAE	South African National Antarctic Expedition
SAR	Synthetic Aperture Radar
SCAR	Scientific Committee on antarctic Research
SOAR	Support Office for Aerogeophysical Research
SPRI	Scott Polar Research Institute
TM	Landsat Thematic Mapper
UK	United Kingdom
USA	United States of America
USAP	United States Antarctic Program
USGS	United States Geological Survey

SCAR Group of Specialists on Global Change and the Antarctic (GLOCHANT)

Report of the fourth meeting of the Group of Specialists (GLOCHANT IV)

University of Wisconsin, Madison Wisconsin, U.S.A.

April 10-14 1996

Members of the Group of Specialists in attendance: Ian Allison (ASPECT), Paulo Artaxo, Charles R. Bentley (GoS Convenor, and ISMASS), Howard Cattle, Arne Foldvik, Ian Goodwin (Programme Coordinator), Gerd Hubold, Fumihiko Nishio, Dominique Raynaud, (PICE), Mark R. Thorley, Paul Treguer, and Christian Schlüchter.

Other participants: Steve Ackley (ASPECT, ANZONE), John Anderson, Andrew Clarke (EASIZ), Eugene Domack, Paul Mayewski (ITASE), Ross Powell, Julian Priddle (SO-JGOFS).
(See Appendix 1 for a list of acronyms and abbreviations and Appendix 2 for a list of participants and their addresses).

1.0 INTRODUCTION

1.1 Opening Remarks

The fourth meeting of the Group of Specialists on Global Change and the Antarctic was opened on Wednesday 10th April 1996 by the Convenor, Prof. C.R. Bentley. The agenda was circulated. Bentley welcomed the participants and discussed the GLOCHANT Terms of Reference (ToR). Revised ToR were submitted to the SCAR executive in September 1995, for comment. As yet, they have not been formally approved. The revised ToR are as follows:

1 To provide SCAR Working Groups, Groups of Specialists and national programmes with the best available multidisciplinary advice regarding ongoing Antarctic global change research.
2 To provide liaison between SCAR and the other major international programmes on global change and to promote the applicable Antarctic component within those international programmes.
3 To identify research needs in Antarctic process studies, monitoring and modelling related to global change.
4 To plan, promote and monitor specific projects on problems of global change research in the Antarctic.

Goodwin circulated the minutes of the previous GLOCHANT 3 meeting and the Joint GoSSOE/EASIZ and GLOCHANT Planning Groups 1 and 5 meeting in Tokyo. The minutes have been published in SCAR Report 11.

2.0 OVERVIEW OF THE SCAR GLOBAL CHANGE PROGRAMME

Goodwin, the Programme Coordinator presented the following summary of the major activities of the programme and the establishment of the SCAR Global Change Programme office at the Antarctic CRC in Hobart, Australia.

2.1 Programme Name Clarification

As discussions with other international agencies and programmes progressed throughout 1995-96, it was apparent that SCAR needed a single voice on Global Change matters. Originally this was intended to be encompassed by GLOCHANT. However the changes in the direction of GLOCHANT which were made at the XXIII SCAR prevented this. In addition to GLOCHANT there are several SCAR groups which have developed research initiatives concerned with global change matters.

After discussions with the SCAR executive a clarification of the name of the programme office and the coordinators job was received, such that there was one focus for interaction between SCAR, IGBP, WCRP, START, IASC and SCOR on matters relating to global change. Hence the SGCP encompasses the GLOCHANT group, Ecology of the Antarctic Sea Ice Zone (EASIZ) and Biological Investigations of Terrestrial Ecosystems (BIOTAS).

2.2 Major Activities and Meetings involving GLOCHANT representatives

- First EASIZ Steering Committee Meeting, held at the British Antarctic Survey, Cambridge, UK, 25 August 1995 (minutes are available), Goodwin, Clarke attended;
- SO-JGOFS Towards Phase 2 Planning meeting, Brest, France, 30 August 1995, I. Goodwin, Treguer attended;
- GLOCHANT PICE and IGBP PAGES joint meeting on 'Bipolar palaeoenvironmental records', Boston, USA, 15-16 September 1995, Raynaud attended;

- GLOCHANT ISMASS Task Group meeting on 'Planning fieldwork and remote sensing of mass balance estimates', held at Chamonix, France, 17 September 1995, Bentley, Goodwin attended;
- SCAR/IASC meeting with START on linkages, Hanover, New Hampshire, USA, 15 December 1995, Bentley, Thorley attended;
- SCAR/IASC meeting with IGBP Core Project Officers, Texel, The Netherlands, 14-15 February 1995, Goodwin attended;
- WCRP ACSYS meeting, Montreal, 1995, Cattle attended;
- WCRP Joint Scientific Committee meeting, Toulouse, March 1996, Cattle attended;
- ANZONE Meeting, Barcelona, March 1996, Ackley represented GLOCHANT by proxy;

2.3 Hobart Office

Goodwin commenced work as the SCAR Global Change Programme Coordinator on 1st August 1995. The programme office was subsequently established at the Cooperative Research Centre (CRC) for the Antarctic and Southern Ocean Environment, in Hobart, Tasmania, Australia. The office is funded, by an Australian consortium including: the Antarctic CRC, Australian Antarctic Division, Bureau of Meteorology, Australian Antarctic Foundation, Tasmanian State Government, and the Commonwealth Department of Environment, Sport and Territories. It is logistically and operationally supported by the Antarctic CRC. Patricia McKeown was appointed as the office secretary and desktop publisher in December 1995, on 3 days per week, and later resigned (30 April 1996), and was replaced by research assistant, Miranda Carver.

2.4 Antarctic Global Change Research Newsletter

The first issue of the Antarctic Global Change Newsletter is being printed at present. It is a two colour 20 A4 page newsletter, which focuses on sea-ice research connected with the proposed ASPECT programme. Each issue will focus on one thematic area of global change research. It is expected that it will be produced three times per year and have a 500-1000 circulation, by mailout. It will also be posted on the programmes WWW home page.

2.5 EASIZ Newsletter

The first issue of the EASIZ newsletter is also being printed at present and will be distributed with the Antarctic Global Change Research Newsletter. It is an 8 page two colour A4 newsletter which was edited by Clarke, and produced at the programme office.

2.6 Home Page

The programme home page is under construction and should be operational by the end of April. The World Wide Web address is http://www.antcrc.utas.edu.au/scar/

2.7 Directory of Antarctic Global Change Researchers

The programme office is developing a directory of Antarctic researchers interested in environmental and global change issues within the Antarctic and Southern Ocean region. A proforma is being circulated with the newsletters. The directory will be linked to the programme WWW home page.

Goodwin urged the GoS to discuss output products and deliverables from the programme during the course of the meeting.

3.0 STATUS REPORTING ON SCAR-GLOCHANT LINKAGES

A brief report was made on each of the linkages with other SCAR groups and international organisations.

3.1 SCAR Working Groups

3.1.1 Biology

Hubold reported that there was nothing new to report since the Rome meeting. He reiterated the recommendations from Rome, which emphasised the need for more biological expertise to be represented on GLOCHANT, a greater level of liaison between EASIZ, GLOBEC, GOSEAC and BIOTAS, and the need for long-term monitoring programmes to be developed.

3.1.2 Geodesy and Geographic Information

Goodwin reported that Drew Clarke (Chairman of the WG on Geology and GIS) had asked for liaison between GLOCHANT and the WG on identifying the need for historical map and data analyses as baseline data for the determination of environmental change in the Antarctic.

3.1.3 Geology and Solid Earth Geophysics

Bentley reported that the Chief Officers of these two Working Groups were following with great interest the work of the GoS in the developing ANTIME project.

3.1.4 Glaciology

Allison reported that there was no new information.

3.1.5 PACA

Artaxo reported that a new project and a database on physical meteorology has commenced.

3.1.6 FROST

Allison reported that the observational programme on the troposphere has been completed. Drifting buoy and AWS data have been included in the analysis to assess the performance of present models.

3.2 SCAR Groups of Specialists

3.2.1 EASIZ

Clarke reported that EASIZ had held its first SSG meeting in August 1995 in Cambridge and the next meeting

would be held in Cambridge in August 1996. The 1st field season has been completed. Clarke reported that a close relationship between EASIZ and GLOCHANT had developed through the SGCP office. Hubold commented that the link between GoSSOE and EASIZ is now weak and is more suitable to be administered by the SGCP. Clarke replied that from the EASIZ perspective he believed that the links to GoSSOE were still very strong and would remain so, even with the programme administered through the SGCP. He also stated that GoSSOE could advise on several aspects of biology to SCAR. Priddle suggested that the focus of EASIZ should not be entirely on global change. This was a view accepted by Hubold and Clarke.

3.2.2 BIOTAS

Clarke reported that the 1st BIOTAS international expedition (BIOTEX1) had been successfully conducted in the austral summer 1995/96, from Terra Nova Bay.

3.2.3 APIS

Hubold tabled the APIS report of the 1995 programme planning meeting. The principal aim of the project is to estimate crabeater seal abundance and distribution from ships, aircraft and helicopters. The programme co-operates with SO-GLOBEC, CCAMLR-CEMP, EASIZ and IWC. Since the crabeater seal is the most common Antarctic species and has a close relationship to pack-ice distribution, its numbers may be a suitable indicator of changing sea-ice conditions. Two APIS meetings are planned, one on programme development and the other, a workshop on methods.

3.2.4 Cenozoic Palaeoenvironments

Goodwin reported that the group will be terminated in August at XXIV SCAR.

3.2.5 Lithosphere

Bentley reported that there was no new information

4.0 STATUS REPORTS ON WCRP PROGRAMMES

4.1 WOCE

Foldvik reported that the observational phase will be completed by the end of 1997 and the data analysis phase will continue until 2002.

4.2 ACSYS

Allison reported that the ACSYS JSC recently investigated the gaps in studies on Antarctic climate and sea-ice. Allison, Bentley, Foldvik, Cattle and Goodwin responded to the JSC, advising them of the present activities within GLOCHANT, and the scope for collaboration with ACSYS and CLIVAR.

4.3 IPAB, ITRP, GEWEX, ISCCP, GBSRN

Allison described the IPAB drifting buoy programme and that it had achieved mixed success, in that 8 moorings were lost out of a total of 19 deployed, and that only 7 had been recovered with good data so far.

4.4 SPARC

Artaxo reported that SPARC has a comprehensive and active newsletter and will hold the 1st General Assembly in Melbourne, 2-6 December 1996. They have achieved a standardised UV measurement programme at Antarctic Stations.

5.0 STATUS REPORTS ON IGBP PROGRAMMES

5.1 SO-JGOFS

Priddle tabled the 1994-95 report on the JGOFS Southern Ocean Regional Study and discussed the objectives of the Phase 2 study (1996-2000). The report lists a number of recommendations which involve SCAR. These are:

1. the deployment of automated surface-water pCO_2 on Antarctic logistics vessels should be encouraged through liaison with SCAR's GLOCHANT (global change) and COMNAP logistics groups;
2. collaboration should be established with SCAR's CZ-EASIZ programme on analysis of long-term variation;
3. SO-JGOFS should interact with other programmes, especially the ASPECT programme of SCAR-GLOCHANT, to develop a clearer picture of the role of ice biota in the carbon cycle;
4. SO-JGOFS should continue to build links with the Antarctic research community through the SCAR GLOCHANT programme, specifically through scientific interaction in the CS-EASIZ and proposed ASPECT programmes.

5.2 PAGES

Raynaud reported that PAGES has a new Director, SSC and Executive Director. A PAGES co-sponsored palaeoclimate data network for bipolar marine and lacustrine sediments (SEPAN) has been set up at AWI.

5.3 IGAC

Artaxo reported that PASC had not initiated any new projects. However, within IGAC, a new aerosol focus, called the Global Atmospheric Watch Programme (GAWP) had been established.

5.4 GAIM

Nothing to report on Antarctic or Southern Ocean modelling.

5.5 IGBP-DIS

Goodwin reported that IGBP-DIS have expressed an interest in Antarctic data and Thorley is liaising with them to discuss the Antarctic metadata directory.

5.6 LOICZ

Goodwin reported that LOICZ do not have any planned Antarctic projects.

5.7 GLOBEC

GLOBEC has recently been accepted as an IGBP core project. The US GLOBEC plan for 1995-2000 was tabled by Hubold. It focuses on the modelling of zooplankton (krill) only. An implementation plan has been produced for SO-GLOBEC, and consists of existing national programmes, primarily in UK and Germany, with partly dedicated cruise in 1995/96. Three projects were funded in 1995/96. No international programmes have been planned.

6.0 STATUS REPORTS ON OTHER MAJOR ORGANISATIONS INTERESTED IN GLOBAL CHANGE MATTERS

6.1 IASC

Bentley reported that plans have been initiated to establish a bipolar working group on effects of increased UV radiation. Planning has also been initiated for comparative studies on Arctic/Antarctic global change. A SCAR-IASC-ICSI-PAGES workshop on ice masses and sea-level will be held in Fjaerland in Norway, June 21-22 1996.

6.2 CCAMLR

Hubold reported that a status paper by David Agnew defines the past, present and future of the CEMP monitoring activities which have a strong aspect of environmental change and its effects on key species in the Antarctic marine ecosystem.

6.3 WCRP CLIVAR

Allison tabled the CLIVAR science plan. He stated that ASPECT will contribute to CLIVAR DEC-CEN (decadal-centennial climate variability), and that CLIVAR may become a joint sponsor of the sea-ice zone project. Cattle confirmed that WCRP's interest in Antarctica is confined to: how Antarctica impacts upon global change in other regions, rather than what changes are occurring in the Antarctic region.

6.4 SCOPE

Artaxo had nothing new to report on SCOPE.

6.5 SCOR

Priddle and Goodwin stated that the relationship between SCAR and SCOR needs to be strengthened and that the need for a SCAR-SCOR working group on Southern Ocean oceanography needs to be discussed within GLOCHANT and at the XXIV SCAR delegates meeting. Ackley discussed the recently completed ANZONE project, which was primarily focused on the physical oceanography and sea-ice interactions in the Weddell Gyre. ANZONE will probably be sponsored by SCOR and the present focus of interest is not as concerned with the sea-ice zone. Ackley also outlined the primarily completed US ANZFLUX study on the Maud Rise.

Ackley reported that there will be a Gordon Conference on sea-ice ecology in Ventura on 2-7 March 1997, which is being organised by the SCOR WG-86, of which he is chairman.

6.6 IPCC

Cattle reported that Working Group 1 has agreed that part of the present climate change signal is due to anthropogenic sources. This is a major breakthrough in governmental recognition of the existence of climate change.

6.7 GOOS, GCOS and GTOS

Allison stated that all these projects were in early development. Hubold reported that the GOOS Project office was coordinating the IOC's 1st Southern Ocean Forum in Bremerhaven on the 9-11 September 1996.

7.0 REPORTS ON SCAR AND START

7.1 Background

Thorley outlined the history of the development of a linkage between SCAR and START. At the GLOCHANT 2 meeting the GoS recommended that a linkage be investigated with the view to establishing a START Regional Committee for the Antarctic, and to investigate a mechanism for SCAR-IGBP interactions through START. As a result discussions between SCAR and START occurred during 1994/95 and culminated in a SCAR, IASC and START meeting at the ICARP conference in Hanover, New Hampshire, in December 1995. At this meeting it was recommended that SCAR and IASC both develop a Memorandum of Understanding (MoU) with START for the establishment of Regional Research Committees for the Antarctic and Arctic respectively. Thorley circulated a copy of the MoU for discussion (See Appendix 3).

7.2 Status of the Memorandum of Understanding

The status of the MoU is that it has been reviewed and approved in principle by the SCAR Executive, and was presented to the Deputy Director of START, Dr Hassan Virji, by Goodwin and Olav Orheim at the Texel IGBP Core Project Officers' meeting in February 1996. It has been approved in principle by Dr Hartmut Grassl, the Director of WCRP and Dr Chris Rapley, Executive Director of IGBP. Priddle suggested that the MoU be amended to include a statement on the uniqueness of Antarctica and to replace the existing matrix of the programme linkages, with a complete list of Antarctic Global Change programmes. Goodwin suggested that the proposed GLOCHANT outputs and functions of the START Regional Research Committee be attached before the final version is presented to the SCAR Executive. It was recommended that Goodwin and Thorley prepare a submission to SCAR Executive and Delegates to approve the establishment of a START Regional Committee for the Antarctic, and to outline that the function of the committee is to expand the national activities.

8.0 REPORTS ON SCAR AND IGBP LINKAGES

Goodwin circulated copies of his report on the SCAR-IGBP discussions at the IGBP Core Project Officers' meeting at Texel, The Netherlands, 14-15 February 1996 (see Appendix 4).

The Texel Meeting recognised:

1. That it is recognised that SCAR is responsible for a unique science agenda relating to a unique global region. Consequently there are a number of global change issues which relate to Antarctica alone and are not within the key foci of the IGBP Core Projects. This does not reduce the scientific importance of this Antarctic research but rather identifies a clear role for the coordination, facilitation and communication of this research by SCAR;
2. That some identified Antarctic research areas have clear and direct linkages with components of the following IGBP Core Projects; PAGES, IGAC, GCTE, IGBP-DIS and START. These should be explored between the IGBP Core Projects, START and the SCAR Global Change Programme office and directly between the SCAR programme committees, working scientists and their IGBP counterparts. It is expected that the protocols for this relationship with the IGBP CPOs will develop during 1996 after consultation with their steering committees, and within SCAR.
3. That SCAR is well on the way to being appointed to the responsibility for establishing and maintaining the START Regional Research Committee for the Antarctic.

9.0 REVIEW DISCUSSION ON THE SCAR GLOBAL CHANGE TASK GROUPS ON THEIR STATUS AND FUTURE DIRECTIONS

9.1 ISMASS

Bentley reported that the group had held their 3rd meeting in Chamonix, on the 17th September 1995. The completed minutes of the meeting will be published in SCAR Report No 12. He outlined the objectives of the ISMASS project, and that a draft science plan had been circulated to members of the task group for comment. Bentley stated that the 1st priority was to evaluate the present-day mass balance and the evaluate the accuracy of mass balance estimates. This 1st task will be achieved with the use of remote sensing and aerial radio-echo sounding along the ice sheet/glacier grounding zones. Goodwin commented that it may be more appropriate to focus the project on representative drainage basins rather than the whole continent, and that this would be more appealing to the national programmes. Bentley opined that such a focus would not represent a significant advance over what is already being done. Goodwin also asked whether it would be appropriate to tie the present mass balance to past changes in the ice sheet and dynamics. Bentley agreed that this may a second stage of the project. Allison questioned whether we can accurately determine the present mass balance.

9.2 PICE

Raynaud tabled the document which the PICE/PAGES group are preparing on a 'Bipolar strategy for ice core drilling', which outlines the science objectives for drilling at sites in Greenland and the Antarctic. Raynaud reported that the PICE group held its 3rd meeting in Boston, on the 14–15 September 1995. The completed minutes of the meeting will be published in SCAR Report No 12. Raynaud stated that the main function of PICE was to coordinate the drilling projects. To do this PICE will need an annual meeting for exchange of data, and to evaluate the drilling progress and analysis of ice cores.

9.3 ASPECT

The ASPECT planning group met throughout the main GLOCHANT meeting and produced a final draft science plan. See section 15.2 for a more comprehensive discussion.

9.4 EASIZ

Clarke presented a brief report of EASIZ activities. See section 3.2.1 for more detailed report.

9.5 BIOTAS

Clarke gave a brief report on BIOTAS activities, now in their 10th year. See section 3.2.2. Clarke reported on behalf of Dr Ron Lewis Smith the new chairman of BIOTAS. The group plans to sample ice core material collected on ITASE for biological propagules, to investigate how biological propagules are dispersed. BIOTAS also have a major focus on the effects of enhanced UV radiation on simple ecosystems, and also on the recolonisation of ecosystems subsequent to ice retreat.

10.0 DISCUSSION ON THE SCAR-IGBP (PAGES) SPONSORED ITASE PROJECT

Mayewski gave an outline and history of the ITASE project, and tabled the ITASE planning document, previously prepared in February 1992. ITASE is concerned with the high resolution interpretation and documentation of the last 100-200 years of the climate, atmosphere and surface conditions over the Antarctic ice sheet, by the 3-D mapping of major snow chemistry, stable isotopes, accumulation rate, high resolution radar and temperature. He explained that some ITASE traverses have been completed by national programmes since 1992. These include the Chinese and the Swedish/Norwegian programmes. A US workshop on ITASE is being held on May 22-23, in Baltimore, and an international workshop will be held in Cambridge, on August 2-3, prior to XXIV SCAR and will focus on the determination of an updated science and implementation plan, and the coordination of logistic support. The workshop has PAGES sponsorship and

Mayewski requested joint sponsorship by SCAR-GLOCHANT. This was discussed and recommended by the GoS.

ITASE has international linkages with: SCAR-GLOCHANT, PICE and ISMASS groups, SCAR-PACA, BIOTAS; IGBP/IGAC-PASC, SO-JGOFS, and WCRP CLIVAR.

The subject of how ITASE will fit into GLOCHANT was discussed. Similar to PICE it is jointly sponsored by GLOCHANT and PAGES. It forms a component of the PICE and ISMASS groups and directly contributes to their science objectives. Therefore it is an existing SCAR and PAGES sponsored activity which falls within GLOCHANT. Goodwin and Mayewski proposed to the group that a project on the 'Compilation of the existing ITASE data covering the last 200 years, and collected by expeditions over the last 30 years' could be sponsored by GLOCHANT and undertaken by the SCCP office in Hobart. This was discussed and it was recommended that GLOCHANT would ask XXIV SCAR to financially support the compilation project instead of support for an ITASE workshop in 1997/98. The proposed compilation data set would include: accumulation rate; stable isotopes; chemistry (major anions and cations, MSA), hydrogen Peroxide (H_2O_2), organic acids; trace metals; microparticles; cosmogenic isotopes; and borehole temperatures.

11.0 DISCUSSION ON STATUS OF OZONE AND TRACE GAS RESEARCH

Artaxo reported that ozone research and monitoring is being covered globally but not specifically by one programme in the Antarctic. The ozone monitoring and modelling is being covered mainly by three international programmes: GLONET, SPARC and GAIM. These have a global coverage including Antarctica.
Artaxo reported that trace gas research and monitoring is not being adequately covered by any international programmes. Individual projects are supported within some national Antarctic programmes, or by national agencies. These take care of the important issue of trace gas monitoring in Antarctica. Artaxo suggested that GLOCHANT should recommend to IGAC to integrate Antarctic and global trace gas monitoring programmes. He also believes that there is poor communications between IGAC and PAGES, on correlating the research on modern and past compositions.

12.0 DISCUSSION PAPER: "AFTER GLOCHANT PHASE 1: THE WAY AHEAD FOR THE SCAR GLOBAL CHANGE PROGRAMME"

Goodwin circulated copies of his discussion paper and discussed the issues relating to the interactions between SCAR and the global change community, and the need to redefine the direction of GLOCHANT and its structure (See Appendix 5). Goodwin suggested that GLOCHANT had fulfilled its initial role in establishing a programme and working towards linkages with other international programmes. He also suggested that GLOCHANT had so far failed to deliver products or defined outputs, and that this should be the new focus for a Phase 2.

13.0 OPEN DISCUSSIONS ON THE WAY AHEAD

13.1 Interactions with the global change community; the reorganisation of the GoS; and the interactions between GLOCHANT and other SCAR activities.

Cattle agreed and stated that GLOCHANT had not involved itself with the mainstream or high profile issues, and had only focused on its ToR 1 and 2 (section 1.1). He believed that GLOCHANT should have contributed to the recent IPCC assessment. This was supported by many members of the GoS, who agreed that the ToR 1 and 2 were being covered by the programme office, and that GLOCHANT should focus on 3 and 4 (see section 1.1). Mayewski and Cattle suggested that one useful role would be to produce a document on the 'Status of Global Change in the Antarctic' which would build on the original white book. This was discussed and agreed to in principle. For further comment see section 18.0.

With respect to the structure of the SCAR Global Change Programme and its representation within GLOCHANT or another replacement body, Priddle asked that the group define the programme. He stated that the programme is the sum of the relevant SCAR projects, and that he believed that more aspects should be included in the GoS, in order to promote and develop projects as they are required. This was discussed by the group and a proposed new structure for GLOCHANT, as the START Regional Research Committee for the Antarctic, emerged as follows:

- An independent chairman;
- A chairman of each of the SCAR groups; ASPECT, ISMASS, PICE, ITASE, EASIZ, BIOTAS, and other task groups such as ANTIME when they become approved;
- Scientific representatives from other key international programmes; SO-JGOFS (SCOR/IGBP), PAGES (IGBP), and ACSYS/CLIVAR DEC-CEN (WCRP);
- Three scientific experts chosen from important global change research areas not covered; Arctic, atmospheric, modelling, higher trophic biology, data user/policy or management fields such as the Antarctic Treaty.

There was extensive discussions on whether this structure would be best suited to the GoS structure or would require an executive type structure within SCAR. It was recommended that the best structure would be the GoS, and recommended that Phase 2 of GLOCHANT should have a change of personnel which reflects the make-up of the above organisations, groups and specialists.

Clarke urged GLOCHANT to actively provide a specialist role on global change matters to the Antarctic Treaty.

13.2 Future global change conferences

Goodwin tabled the 1st circular for the Antarctica and Global Change Conference, to be held in Hobart, Australia, 13-18 July 1997. GLOCHANT had previously agreed to co-sponsor the conference. Most of the participants expressed some disappointment that it would not be a truly multi-disciplinary meeting since it concentrated on physical sciences, with the Annals of Glaciology chosen as a publication venue. Bentley stated that when GLOCHANT had agreed to co-sponsor the conference, the intention was to hold a truly multidisciplinary conference. Bentley suggested that in future GLOCHANT sponsorship should only be decided when the subtopics/ themes for a conference have been finalised. It was recommended for GLOCHANT to prepare a review paper on global change in the Antarctic and a paper on the SCAR Global Change Programme for presentation at the Hobart conference.

Most of the GoS and participants expressed the opinion that arrangements should be initiated to hold a multidisciplinary conference on Antarctic global change as soon as possible. Bentley proposed holding a SCAR Global Change Symposium in Christchurch in 2000, which will coincide with the XXVI SCAR meeting. This was agreed to by all present. Other opportunities for GLOCHANT participation include, the 'Global change and Polar Regions Conference' to be held in Tromsø, Norway, in July 1998, and C. Schlüchter suggested that the INQUA Congress in Durban, South Africa in July 1999, would be a suitable venue.

13.3 Task group requirements

Bentley asked all Task Group chairmen to submit the 1996-98 budget requests to Goodwin, as soon as possible. Task Groups need to prioritise their projects within the science and implementation plan framework, taking into account the known/probable national logistics contribution.

13.4 COMNAP interactions

It was recommended to make a presentation of GLOCHANT programmes to COMNAP in August 1996, in Cambridge, U.K.. The presentation will outline the logistics requirements of international SCAR global change research. The chairmen of Task Groups were asked to submit a list of logistic requirements to the programme office, to be discussed with COMNAP in August 1996, in Cambridge, U.K..

13.5 Handling and dissemination of Antarctic global change data

Thorley reported that the *ad hoc* SCAR-COMNAP data management group will evolve to a 2nd phase at XXIV SCAR. He stated that there is an urgent need for the management and rescue of historical data for the global change community to use as baseline data in the assessment of change.

13.6 Mapping support for global change task groups

Allison proposed that the chairmen of ITASE and ISMASS send a letter requesting the WG on Geodesy and Geographic Information System to assist GLOCHANT with mapping support of historical data sets. This was recommended by the GoS. Goodwin presented an outline of the BEDMAP project to produce an updated bedrock map of Antarctica, which has been proposed as an ISMASS product. David Vaughan, Chris Doake of BAS and Hans Oerter of AWI have prepared a prospectus which was tabled. The GoS agreed to endorse the proposal and encourage its establishment.

13.7 Future directions for SCAR involvement in global change modelling

Cattle stated that the WCRP and IGBP GAIM modelling was broad-scale, coarse resolution and that the needs of the Antarctic community may not be met by the global based modelling. Consequently there is a need to develop specific regional models. Foldvik commented that the Antarctic has many specific and unique ice-atmosphere-ocean boundary conditions which need to be communicated to the modellers. Similarly the models require detailed validation with field or remotely sensed data.

14.0 DISCUSSION ON THE NEED FOR A NEW SCAR INITIATIVE: ANTARCTIC ICE MARGIN EVOLUTION (ANTIME) ON THE CORRELATION OF RESEARCH ON THE MARINE AND TERRESTRIAL SEDIMENTARY RECORDS

14.1 Short papers on the overall concept, aims, scientific emphasis and framework

Goodwin circulated a discussion paper entitled: 'The need for a SCAR-GLOCHANT / IGBP-PAGES regional project on the Late Quaternary evolution of the Antarctic ice margin' (See Appendix 6). Goodwin then gave a short presentation and spoke about the paper. The central issue is that it was intended from the outset that SCAR-GLOCHANT would establish a task group to look at the Quaternary palaeoenvironmental record from both ice cores and the sedimentary record. However, only a task group on the ice cores had been established, jointly with PAGES. It is crucial in our understanding of ice sheet fluctuations and response to changing forcings that we correlate the palaeoenvironmental history from the ice cores and the marine and terrestrial sedimentary records.

Domack then presented a paper on Holocene environmental/climate changes in the Antarctic Peninsula region from high resolution fjord bottom sedimentary records. These palaeoenvironmental records demonstrate a high

correlation with those from Antarctic ice cores and to some extent bipolar ice core evidence. Anderson followed with a presentation on the West Antarctic Ice Sheet Initiative (WAIS) and raised a number of important questions/issues which the proposed ANTIME initiative could make a significant contribution to solving. These questions/issues are:

- What are the controlling agents on marine ice sheet stability? Climate, eustasy and ice sheet/bed interactions need to be considered.
- Have the ice sheets had a history of rapid and/or episodic retreat?
- What are the mechanisms? Rapid sea-level changes?

Anderson reported that the evidence suggests a complex system of ice sheet/ice stream grounding and retreat episodes. He suggested that the trough mouth fans which occur at the edge of the shelf breaks for many of the major drainage basins, are perhaps the best targets for drilling, since they have escaped grounding and could provide a continuous Quaternary record. There was a consensus that the ANTOSTRAT project had successfully obtained a comprehensive seismic survey coverage of many parts of the continental shelf. However, the Quaternary record is just in the bubble pulse of the ANTOSTRAT seismic records. Anderson suggested that the proposed ANTIME initiative on the Quaternary could be used to 'ground truth' the earlier geological record.

Anderson summarised some of the research contributions which are needed to be made:

- Better high resolution multi-channel sub-bottom profiling
- A long core (several hundred metres) close to the continent, presently there is only sparse data from glacial troughs
- A coordinated international effort to retrieve multiple shallow cores in different geographic regions

Powell gave a presentation on the modes and rates of change at the grounding zones of glaciers and marine ending ice sheets. He demonstrated the results on the morphology and sedimentology of these zones from his work with remote observation vehicles (ROV). This work is enabling the documentation of modern grounding lines; and assists in the prediction of the response of modern ice bodies to sea-level, climate and bed forcings; and assists in the interpretation of the past grounding and retreat episodes on the shelf. He also commented on the future applicability of emplacing ROV through ice shelf boreholes to explore the morphology and processes beneath ice shelves. Clarke commented that these ROV observations would be useful to EASIZ and suggested a collaboration between EASIZ and ANTIME, particularly on benthic evolution following deglaciation of the shelf.

14.2 Potential interactions between ANTIME and PICE

Schlüchter commented that a large gap in knowledge exists with respect to the correlation of ice core stratigraphy with the sedimentary record close to the ice sheets and outlet glaciers. Raynaud commented that we need to have a main focus on whether a type of Heinrich event, or some rapid events occurred in the Southern Ocean between 20-40 k yr B.P. Anderson agreed and stated that he and J. Andrews were in fact researching that, but that it is difficult to interpret ice rafting north of the shelf break. Raynaud also stated that we should bear in mind that the atmosphere and oceans were probably operating out of phase during the glacial cycles. He also strongly supported the establishment of an ANTIME project as he believed that the correlation of the ice core and sedimentary records was long overdue.

14.3 Recommendations for proceeding with the ANTIME proposal

The GLOCHANT group and the other participants recommended that a proposal to hold an International ANTIME workshop be presented to the delegates at XXIV SCAR. It was agreed following a subsequent session that the aim of the workshop would be to bring together representatives of all the marine and terrestrial glacial geological programmes together with those representatives of the ice core programmes. The workshop would focus on the Late Quaternary, particularly the last few glacial cycles and the Holocene. The five key themes for the workshop are as follows:

- What was the extent, timing and regional differences of the Last Glacial Maximum in Antarctica?
- What rapid or episodic events occurred during the Late Quaternary?
- What are the key forcings and feedbacks which influence the retreat and re-advance of the Antarctic ice sheet?
- What changes have occurred to the ice shelves and outlet glaciers during the Holocene?
- Technology coordination

It was recommended that Goodwin would coordinate the preparation of a proposal for the ANTIME workshop, (with Anderson, Domack, Powell, Schlüchter and Foldvik) to be completed by June 1996. The proposal would the be sent to all SCAR glacial and marine geologists for comment, before being presented to the joint meeting of the Working Groups on Geology and Solid Earth Geophysics at Cambridge. Following this, the proposal will be presented by GLOCHANT to SCAR and PAGES for approval.

There was a discussion on whether joint sponsorship of the workshop with INQUA and or IGCP would be of benefit. It was agreed that Goodwin should contact the presidents of INQUA and IGCP and inform them of the pro-

posal and seek a letter of support for the initiative. In the longer term Schlüchter suggested that part of the ANTIME initiative could form a joint SCAR-IGCP correlation project.

15.0 MARINE RESEARCH IN THE SOUTHERN OCEAN AND ON THE ANTARCTIC CONTINENTAL MARGIN

15.1 Discussion on carbon cycle issues

P. Treguer presented the following report on recent developments in carbon cycle research.

Under the of the European Institute for Marine Studies (University of Western Brittany), of the National Institute for Sciences of Universe (INSU-CNRS) and of the French Polar Institute, together with sponsorships of SCOR and SCAR, a symposium on "*carbon fluxes and dynamic processes: present and past*" was held in Brest on 28-31 August 1995. The Organising Committee was chaired by J. Le Fèvre, CNRS. 210 scientists, originating from 19 countries, took part in 16 sessions and in 2 round-tables, discussing the advancement of Antarctic science during Phase I (1990-1995) of SO-JGOFS.

During this symposium the SO-JGOFS community demonstrated that Phase I provided enough data to describe and to model the variations of the carbon cycle, at different time scales, and for the different subsystems that composed the Southern Ocean. This is important because the Southern Ocean responded very fast to climate changes in the past. It is now clear that the Southern Ocean as a whole is at present a small net sink for atmospheric CO_2: about 0.2-0.4 GCT yr-1 (i.e. about 10-20 % of the world ocean total). Iron fertilisation experiments, comparable to those that have been conducted in the Equatorial Pacific, are now planned at an international level for Antarctic environments, possibly involving experiments from the US and from an Australian-French-New Zealand collaboration. There has also been major progress made in process studies, especially in the carbon transport through the trophic network. The results also place attention on mechanisms which explain the relatively good preservation of biogenic material in abyssal antarctic sediments, compared to coastal sediments. One crucial outcome of the symposium relates to the use of proxies for palaeoproduction in Antarctic environments: long-term opal accumulation appears to be decoupled to primary production, but sedimentary uranium concentrations in anoxic sediments appear to give good responses to carbon fluxes delivered to the sea-bed.

15.2 Presentation of the ASPECT science plan

At the GLOCHANT-III meeting it was determined that EASIZ, WCRP, and other programmes, do not together cover the full scope of required Antarctic sea ice zone research. There is a special role for the SCAR Global Change Programme in the shelf to ice-edge area (pack ice) that is not being adequately covered by other programmes, and for providing information on the sea ice system for development of coupled models: current models do not include all of the sea ice processes that are important and many important parameters are not available. The role of sea ice (including albedo feedback, ice thickness, flux correction and ice dynamics) has not been well addressed and sea ice should be incorporated into both climate and ecological models. SO-JGOFS would welcome development of models that include sea ice.

Important problems, that are not being adequately covered by existing Antarctic research programmes include:

1. Broad climatology of sea ice physical characteristics. Satellite derived data provide large scale estimates of ice extent and concentration, but not of the thickness of ice and snow, which are the primary variables affecting many physical and biological processes, as well as climate processes.
2. Pack ice ecology, a key component of the polar marine environment.
3. Processes such as ice formation, water mass modification, the maintenance of polynyas, ice edge and coastal fronts, gas exchange, and air-sea interaction.
4. Modelling sea-ice processes (physics and ecology) in coupled atmosphere-ice-upper ocean models. Linking scales (local scale to regional scale to global scale models).

ASPECT (Antarctic Sea Ice Processes, Ecosystems and Climate) is proposed as a programme of multidisciplinary Antarctic sea ice zone research within the SCAR Global Change Programme, specifically addressing these key identified deficiencies in our understanding and data from the zone. ASPECT is designed to complement the other international programmes in this region, whilst carefully avoiding duplication.

A task group of Allison, Ackley, Clarke, Foldvik, Priddle, Treguer and Goodwin met in conjunction with GLOCHANT-IV on Tuesday 9 April, and at several evening sessions to draft a Science Plan for the ASPECT programme. Allison presented the draft plan to GLOCHANT-IV The draft science plan has been written to complement other programmes such as: EASIZ, SCOR WG-86, SO-JGOFS, SO-GLOBEC, CLIVAR and ACSYS. The ASPECT programme will achieve its aims by:

- defining a framework of the priority Antarctic sea ice zone research required to address global change and related issues
- promoting and fostering coordinated contributions to this plan from within National research programs and by building on ongoing projects
- liaising with other international programmes requiring data and research products from the Antarctic sea ice zone, and

- convening workshops.

It is intended that the plan will include a "data rescue component" and will also enable new sea-ice projects to be established within SCAR national programmes.

The final draft science plan will be edited by the programme office in Hobart. It was recommended that the plan should be circulated to the SCAR Executive, the WG's on Glaciology and Biology and GoSSOE by late June 1996, to allow their review of the plan prior to the XXIV SCAR meeting.

15.3 Research needs on ice shelf-ocean interactions and response to climate change

Foldvik lead the discussion by making a short presentation to highlight some of the issues with our present understanding of ice shelf-ocean interactions. His presentation was entitled: 'Why is the Weddell Sea dominating the Antarctic bottom water formation?' He discussed shelf-break mixing, the role of offshore polynyas, coastal polynyas, wind and tidally driven circulation and their role in ice shelf stability and oceanic circulation. Foldvik concluded that a warming of only 0.2°C in the ice shelf bottom water may have significant effects on the production of bottom water and grounding line stability.

There was considerable discussion on this suggested mechanism for ice shelf melting and all participants recommended that research on ice shelf-ocean interaction should be receiving more attention within GLOCHANT and SCAR. Anderson commented that geologists provide boundary conditions for ice shelf bottom water production and ask modellers to then determine the oceanographic conditions. In view of this remark Bentley recommended that ice shelf and bottom water history should be included in the ANTIME initiative, and that GLOCHANT should recommend to the WG on Glaciology and the ISMASS task group to develop a research focus on ice shelf-ocean interactions.

15.4 Discussion on Antarctic oceanography within the SCAR Global Change Programme. Is a joint SCAR-SCOR initiative required?

Ackley stated that presently much polar marine science takes place outside SCAR. In Rome at XXIII SCAR continental science was supported at the expense of marine science within GLOCHANT. Ackley suggested that SCAR should extend its scientific coverage north to the Antarctic Treaty boundary at 60°S, and that this could be coordinated with SCOR. Foldvik suggested that a workshop on air-ice-ocean interaction and boundary processes was a high priority for GLOCHANT. Allison and Clarke stated that the approval of ASPECT together with EASIZ would be a good foundation for SCAR's polar marine science effort. Ackley suggested that we should recommend a joint SCAR-SCOR sponsorship of ANZONE. Ackley will follow this up with SCOR and ANZONE. Cattle commented that there was also no present advocacy for WCRP CLIVAR in the Antarctic and that GLOCHANT should develop that linkage with CLIVAR.

It was recommended by the participants that Priddle and Goodwin should work towards formalising and re-initiating the relationship between SCOR and SCAR, particularly between SCOR and the SCAR Global Change programme. It was also recommended that Goodwin, Foldvik and Priddle draft a letter to COMNAP and the SCAR Executive, informing them that oceanography is a large gap in our research and that a coordinated initiative in polar marine science should be pursued between SCAR and SCOR.

16.0 RESOLUTION OF THE WAY AHEAD AND DETERMINATION OF RECOMMENDATIONS TO XXIV SCAR FOR ANTARCTIC GLOBAL CHANGE RESEARCH

In summary, the GoS resolved that GLOCHANT should continue as a GoS rather than be replaced with an executive structure. It was recommended that the membership composition of GLOCHANT be reviewed by SCAR and be replaced with the following structure:

- An independent chairman;
  A chairman of each of the SCAR groups; ASPECT, ISMASS, PICE, ITASE, EASIZ, BIOTAS, and other task groups such as ANTIME when they become approved;
- Scientific representatives from other key international programmes; SO-JGOFS and GLOBEC (SCOR/IGBP), and ACSYS/CLIVAR DEC-CEN (WCRP);
- Three scientific experts chosen from important global change research areas not covered; Arctic, atmospheric, modelling/data, higher trophic biology, data user/policy or management fields such as the Antarctic Treaty.

Bentley commented that a balance must be achieved in the political and national representation. Artaxo replied that the chairmen of the above science programmes were essentially from English speaking countries and that their appointment to GLOCHANT would be politically too narrow. Raynaud raised the same concerns and suggested the possibility of some non-English speaking chairmen coupled with the appointment of corresponding English speaking secretaries. Cattle reminded the group that the most important criteria for membership selection should be the level of an individuals motivation to contribute. Goodwin agreed and commented that the success of the whole SCAR Global Change Programme relies heavily on the participation of member scientists outside of annual meetings. Thorley added that the main reason for a new membership structure is to establish a suitable com-

mittee to fulfil the role required by START to form the START Regional Research Committee for the Antarctic. Foldvik reminded the group that SCAR originally selected the GoS/GLOCHANT group according to nationality and scientific expertise.

It was recommended that GLOCHANT propose to SCAR that the membership and scientific representation of GLOCHANT should be re-evaluated and replaced with a substantial representation from the global change activities within SCAR, and that those individuals are required to be motivated and willing to participate widely. It was also decided that a name change may be suitable, but that this was a matter for SCAR.

Raynaud recommended that the GLOCHANT task groups and other related SCAR groups be consulted about the proposed changes and request their suggestions for membership of the new GoS. He also reminded the group that some of the task groups and related SCAR groups were jointly sponsored by other international organisations, such as IGBP PAGES and JGOFS and that there is a need for continued co-chairmanship from both organisations. It was recommended to send a copy of the Report to SCAR to the IGBP Secretariat and the PAGES and JGOFS CPOs.

17.0 GLOCHANT REPORT TO XX ANTARCTIC TREATY CONSULTATIVE MEETING

Thorley presented a draft report. Bentley asked all participants to review the report and to make contributions where necessary. He asked that these changes be made quickly and sent to Goodwin at the Hobart Office.

18.0 CARRYOVER ITEMS FROM EARLIER DISCUSSIONS

There was a summary discussion on the proposal for GLOCHANT to produce a document on the Assessment of Global Change in Antarctica.

It was recommended that the GoS/GLOCHANT will prepare a short (5 page) prospectus on the assessment of global change in Antarctica (i.e, updating the "white book"). This will accompany a report to XXIV SCAR requesting their support for a full 2 year Assessment of Global Change in the Antarctic region. The document will be coordinated and edited by Goodwin in the Hobart office. Topics to be covered by the initial prospectus are:

1. Seasonal to interannual climate variability (Cattle, Ackley and Allison)
2. Decadal scale changes (Nishio, Bentley, Foldvik, Clarke and Priddle)
3. Changes in ozone, UV and atmospheric chemistry (Artaxo)
4. Detecting changes in ice cover and terrestrial and marine ecosystems (Hubold, Priddle, Wynn-Williams, Clarke and Cattle)
5. Past changes and future views (Raynaud and Domack)

Bentley recommended that GLOCHANT could endorse the Polar Regions and Global Change meeting in Tromsø, in 1998, if it can demonstrate a truly multi-disciplinary agenda. He recommended that GLOCHANT urge the SCAR Executive to request the Tromsø conference organisers to make the conference multi-disciplinary. GLOCHANT Task Group and EASIZ chairman (Bentley, Allison, Raynaud and Clarke) were asked to submit suitable session topics to the Tromsø organisers.

19.0 STATEMENT OF GLOCHANT FINANCES

Bentley presented a statement of finances and the funds held for a meeting of the now defunct Planning Group 4 were discussed. It was recommended to transfer the funds to the next financial year to support ASPECT.

20.0 SUMMARY AND OVERVIEW OF MEETING DEVELOPMENTS

Bentley summarised the meeting developments, especially with regard to the second phase of GLOCHANT. He thanked all present for their contributions to a very successful meeting.

21.0 NEXT MEETING

The next formal meeting will be held in Hobart, Australia, 9-12 July 1997.

There will be scope for informal meetings at XXIV SCAR between some GLOCHANT representatives and the SCAR WGs and other GoS.

The meeting closed at 1330 hours on Saturday 13 April 1996.

Rapporteur
Dr Ian D. Goodwin
SCAR Global Change Programme Coordinator

APPENDIX 1

List of Acronyms and Abbreviations

ACoPS	Antarctic Coastal Polynya Study
ACSYS	Arctic Climate System Study
ADOX	Atlantic Deep Ocean Exchange
AnITMP	Antarctic Ice Thickness Monitoring Project
AnZone	International Coordination of Oceanographic Research within the Antarctic Zone
APIS	Antarctic Pack-Ice Seals programme
ASPECT	Antarctic Sea-Ice Processes, Ecosystems and Climate (GLOCHANT)
ANTOSTRAT	Antarctic Offshore Stratigraphy
ATOC	Acoustic Thermometry of Ocean Climate
AUV	Automatic Underwater Vehicle
AWI	Alfred Wegener Institute for Polar and Marine Research (Germany)
BAS	British Antarctic Survey
BIOMASS	Biological Investigations of Marine Antarctic Systems and Stocks
BIOTAS	Biological Investigations of Terrestrial Antarctic Systems
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources (Antarctic Treaty System)
CEMP	CCAMLR Ecosystem Monitoring Programme
CG	Coordinating Group (GLOCHANT)
CG-1	Coordinating Group 1 on Data Management (GLOCHANT)
CG-2	Coordinating Group 2 on Numerical Modelling (GLOCHANT)
CLIVAR	Climate Variability and Prediction Research (WCRP)
CNRS	National Centre for Scientific Research (France)
COMNAP	Council of Managers of National Antarctic Programmes
CS-EASIZ	Coastal and Shelf Ecology of the Antarctic Sea-Ice Zone (GoSSOE)
DIC	Dissolved inorganic carbon
DIS	Data and Information System
DOC	Dissolved organic carbon
ENSO	El Niño - Southern Oscillation
EPICA	European Ice Coring in Antarctica
FRISP	Filchner-Ronne Ice Shelf Programme
FROST	First Regional Observing Study of the Troposphere
GAIM	Global Analysis, Interpretation and Modelling (IGBP)
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GCTE	Global Change and Terrestrial Ecosystems (IGBP)
GEWEX	Global Energy and Water Cycle Experiment
GLOBEC	Global Ocean Ecosystems Dynamics Research
GLOCHANT	Group of Specialists on Global Change and the Antarctic (SCAR)
GLODAR	Global Data Archive Rescue
GOOS	Global Ocean Observing System
GoS	Group of Specialists (SCAR)
GoSSOE	Group of Specialists on Southern Ocean Ecology (SCAR)
GRIP	Greenland Research Ice Core Project
GSBRN	Global Surface Baseline Radiation Network (GEWEX)
GTS	Global Telecommunication System
IAG	International Association for Geodesy
IAMAP	International Association for Meteorology and Atmospheric Physics
IAPSO	International Association for the Physical Sciences of the Ocean
IASC	International Arctic Science Committee
ICAIR	International Centre for Antarctic Information and Research (New Zealand)
ICAP	International Circum-polar Arctic Ice Drilling Project
ICSU	International Council of Scientific Unions
IGAC	International Global Atmospheric Chemistry Programme (IGBP)
IGBP-DIS	IGBP - Data and Information System
IGS	International Glaciological Society
IPAB	International Programme for Antarctic Buoys
IPCC	Intergovernmental Panel on Climate Change
ISCCP	International Satellite Cloud Climatology Project (GEWEX)
ISMASS	Ice Sheet Mass balance
ITASE	International Trans-Antarctic Scientific Expedition
IUGG	International Union of Geodesy and Geophysics
JEISSO	Joint Expeditions in the Indian Ocean Sector of the Southern Ocean
JGOFS	Joint Global Ocean Flux Study (SCOR and IGBP)

LOICZ	Land-Ocean Interactions in the Coastal Zone (IGBP)
MAST	Marine Scientific Technology
NATO	North Atlantic Treaty Organization
NIPR	National Institute of Polar Research (Japan)
NOAA	National Oceanic and Atmospheric Administration (USA)
PACA	Working Group on Physics and Chemistry of the Atmosphere (SCAR)
PAGES	Past Global Environmental Changes Programme (IGBP)
PASC	Polar Air and Snow Chemistry Programme
PASE	Polar Air-Snow Experiment
PIC	Particulate inorganic carbon
POC	Particulate organic carbon
PG	Planning Group (GLOCHANT)
PG-1	Planning Group 1 on Sea Ice (GLOCHANT)
PG-2	Planning Group 2 on Global Palaeoenvironmental Records from the Antarctic Ice Sheet and Marine and Land Sediments (GLOCHANT)
PG-3	Planning Group 3 on Antarctic Mass Balance and Sea Level (GLOCHANT)
PG-4	Planning Group 4 on Trace Gases, Aerosol Particles, and UV Radiation in the Antarctic Atmosphere (GLOCHANT)
PG-5	Planning Group 5 on Biogeochemical Cycles (GLOCHANT)
RRC	Regional Research Centre (START)
RRN	Regional Research Network (START)
SAGE	Stratospheric Aerosol and Gas Experiment
SAR	Synthetic Aperture Radar
SCALOP	Standing Committee on Antarctic Logistic Operations
SCAR	Scientific Committee on Antarctic Research
SCOPE	Scientific Committee on Problems of the Environment (ICSU)
SCOR	Scientific Committee on Oceanic Research
SeaWIFS	Sea Viewing Wide Field-of-View Sensor
SIEFS	Sea Ice Ecology and Flux Study
SO-GLOBEC	Southern Ocean - GLOBEC
SO-JGOFS	Southern Ocean - JGOFS
SPARC	Stratospheric Processes and their Role in Climate (WCRP)
START	System for Analysis, Research and Training (IGBP)
TOGA	Tropical Ocean and Global Atmosphere Experiment
ULS	Upward-Looking Sonar
UV	Ultraviolet Radiation
WG	Working Group
WAIS	West Antarctic Ice Sheet Initiative
WOCE	World Ocean Circulation Experiment (WCRP)
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WWW	World Wide Web

APPENDIX 2

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APPENDIX 3

Memorandum of Understanding between SCAR and START, for SCAR-GLOCHANT to become the START Regional Committee for the Antarctic, within the START Regional Research Network .

PREAMBLE

The polar regions are known to have a key role to play in the investigation of a range of global environmental problems. The existing international committees responsible for co-ordinating scientific research in the Antarctic (Scientific Committee for Antarctic Research - SCAR) and the Arctic (International Arctic Science Committee - IASC) and share common objectives in promoting scientific research on global change in the polar regions. They both recognise that to realise the full research potential of the polar regions, the existing and proposed regional research programmes will need to be linked firmly to established international programme frameworks.

OBJECTIVES

Existing global framework programmes that share the objectives addressed by the SCAR and IASC regional programmes are the International Geosphere-Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP), and, for the Arctic only, the Human Dimensions of Global Change Programme (HDP). To ensure truly global research coverage it is essential to provide a formal relationship between the existing and proposed research programmes for the polar regions and the programmes of IGBP, WCRP and HDP.

Any such agreement must provide not only for planning and implementation of programmes but also for data issues (including access, quality, and management) and training. Such an agreement must also incorporate clear mechanisms for adequate cross-representation and information transfer between appropriate committees of SCAR and these global programmes.

AGREEMENT

A formal international link between SCAR and the global programmes can be most appropriately developed through the System for Analysis, Research and Training of IGBP, WCRP, and HDP (START). In this context it is agreed that SCAR will become an affiliated regional organisation to START with the responsibility for implementing START objectives, where appropriate, in Antarctic research programmes.

The development of the relationships between existing and proposed Antarctic programmes as well as the provision of advice to START on the Antarctic aspects of global change will be the responsibility of the SCAR Group of Specialists on Global Change and the Antarctic (SCAR-GLOCHANT), who will become the *de facto* START Regional Committee for the Antarctic. The membership of this regional committee will be jointly endorsed by SCAR and START.

There will be representation of SCAR-GLOCHANT at appropriate START meetings, including those of Regional Directors, and liaison with the START Secretariat will be undertaken through SCAR's Global Change Programme Coordinator.

The location and implementation of any Regional Research Centres and Regional Research Sites will be the subject of joint discussions between SCAR and START.

It is recognised by SCAR that START normally expects regional committees to promote the principal programs of IGBP, WCRP and HDP in that region. It is recognised by START that SCAR has a wider portfolio of interests than those of START. However, there is a close congruence of major interests between the two parties which indicates the value of joint planning and implementation for the good of global science. SCAR have identified those Antarctic programmes that are directly relevant to existing IGBP and WCRP objectives and, through START, will seek formal acceptance of these programmes by the appropriate committees.

Major research themes that are currently identified as of joint interest include:

- the effects of enhanced UV on ecosystems
- the effects of present climate change on mass balance of ice sheets and thus on sea level
- the characterisation of past global changes
- the changing chemistry of the atmosphere
- the flux of carbon in pelagic and coastal marine ecosystems

The relationship between SCAR, IGBP, and WCRP for these general themes are outlined as Annex 1.

This Memorandum of Understanding will be subject to review every five years, although details of the agreement may be revised sooner by mutual agreement. Either party may revoke the agreement by giving six months written notice.

Annex 1

The relationships between SCAR, IGBP and WCRP Core Projects

SCAR	IGBP	WCRP
ANTOSTRAT	PAGES	
ASPECT	LOICZ, SO-JGOFS	ACSYS, CLIVAR
BIOTAS	GCTE	
CS-EASIZ	LOICZ, SO-JGOFS	
ISMASS	LOICZ, PAGES	CLIVAR
PICE	PAGES	
GLOCHANT	IGBP	WCRP

APPENDIX 4

Report on SCAR-IGBP discussions at the IGBP Core Project Officers' meeting at Texel, The Netherlands,

14-15 February 1996

BACKGROUND

In December, 1995 SCAR and the International Arctic Science Committee (IASC) held a workshop with representatives of START to determine whether the START framework provided the best mechanism for the development of linkages between the regional programmes of SCAR/IASC and the global scale programmes of IGBP/WCRP/HDP. The outcomes of this meeting were: the preparation of a Memorandum of Understanding (MOU) for the establishment of a START regional Antarctic committee through which the inter-organisational linkages (SCAR to IGBP/WCRP) could be developed; and, an invitation for SCAR representatives to attend the 1996 IGBP Core Projects Officers (CPO) annual meeting, to discuss direct linkages between SCAR global change research projects and the IGBP core projects.

The 1996 IGBP CPO meeting was held at the Netherlands Institute for Sea Research from the 13th to the 15th February, 1996. SCAR and IASC were invited to attend discussions on the evening of the 14th and to make a presentation on the SCAR and IASC Global Change Programmes and their potential linkages to the IGBP Core Projects on the morning of the 15th. The remainder of the meeting was closed to SCAR and IASC representatives. Dr Ian Goodwin represented the SCAR Global Change Programme, Professor Manfred Lange, the IASC Global Change Programme, and Dr Olav Orheim represented the SCAR and IASC executives, and the overall interests of the polar programmes.

MEETING AGENDA AND DISCUSSIONS

Professor Chris Rapley, Executive Director of IGBP outlined that there has been a long history of discussions between SCAR and IGBP about formalising the relationship between the two organisations. There was a general attitude amongst the IGBP, START and SCOR representatives that SCAR's commitment to Global Change research has been erratic over the last three years. They had interpreted from the observed changes to GLOCHANT following the XXIII SCAR meeting in Rome that Antarctic Global Change research had had its 'wings clipped' and was therefore significantly less of a force. Chris Rapley stated that the purpose of the meeting was to investigate once and for all, whether there were any substantial linkages between the two programs, that were worthy of pursuit.

Olav Orheim presented a brief history of SCAR and the development of a SCAR Global Change Programme. Ian Goodwin then presented a detailed overview of the SCAR Global Change Programme, based on the component projects, their key scientific objectives and their potential linkages to IGBP core projects. The component projects discussed were:

- Group of Specialists on Global Change and the Antarctic (GLOCHANT);
- 3 GLOCHANT Science Task Groups;
- Palaeoenvironments from Ice Cores (PICE);
- Ice Sheet Mass Balance and Sea-Level (ISMASS);
- Antarctic Sea-Ice Processes, Ecosystems and Climate (ASPECT)*;
- Coastal and Shelf Ecology of the Antarctic Sea-Ice Zone (CS-EASIZ);
- Biological Investigations of Terrestrial Antarctic Systems (BIOTAS);
- Antarctic Ice Margin Evolution (ANTIME)*.

Note: programmes denoted by * are in development and have not been presented to the SCAR executive for approval.

The overall response from the IGBP CPOs was very positive, with obviously greater interest from some CPOs, whose projects had a greater disciplinary overlap. It was recognised that SCAR's science agenda was focused towards a unique regional environment and that embedded in this agenda was the SCAR global change agenda. The CPOs suggested that they will now take the SCAR presentation and table it at their next science steering committee meetings to determine whether we need to formalise the following linkages with the core projects.

Past Global Changes (PAGES) Linkages

It was recognised that the greatest potential linkages were with the Past Global Changes (PAGES) project, particularly if SCAR could contribute a programme on Palaeoenvironments from the sedimentary record, such as the proposed ANTIME programme, in addition to the operational joint SCAR/PAGES PICE programme, and the SCAR/PAGES endorsed International Trans-Antarctic Science Expedition (ITASE). The most appropriate linkage for ISMASS was also recognised as with PAGES. The ISMASS programme through its research on the evolution of the ice sheet over the last 2,000 years will con-

tribute to PAGES Focus 2 on Variability in the Polar Regions, Temporal Stream 1, (the last 2,000 years).

Land Ocean Interactions in the Coastal Zone (LOICZ), Southern Ocean-Joint Global Ocean Flux Study (SO-JGOFS), and Southern Ocean-Global Ocean Ecosystem Dynamics (SO-GLOBEC) Linkages

Dr John Pernetta, the LOICZ CPO stated that LOICZ does not presently have an interest in Antarctica. The primary reasons for this are that the LOICZ steering committee does not comprise any members with an Antarctic background, and that the LOICZ project was at capacity in coordinating research in the temperate and tropical regions. However, he agreed that LOICZ would be interested in the results from SCAR research relevant to LOICZ science objectives, such as that outlined in the CS-EASIZ science plan and the current draft of the ASPECT science plan, which would potentially contribute to the LOICZ focus 1 on *External Forcing and Boundary Conditions* and Focus 3 on *Carbon Fluxes and Trace Gas Emissions*. In addition the ASPECT project could potentially contribute to the joint JGOFS/LOICZ Continental Margin Task Team. It was recognised that the ISMASS programme would contribute to the LOICZ Framework Activity 6 on *Rates, Causes and Impacts of Sea-Level Change*.

CS-EASIZ has potential linkages to SO-GLOBEC and SO-JGOFS, although the exact nature of the linkages is not clear and Ian Goodwin has requested that Ms Elizabeth Gross, the GLOBEC CPO and Executive Director of SCOR, and Dr Roger Hansen, the new JGOFS CPO, prepare a response document on where potential SCAR linkages need to be developed with these projects.

However, the linkages between the proposed ASPECT programme and IGBP, SCOR and WCRP are unclear. A major thrust of the ASPECT programme is its multidisciplinary focus on the sea-ice zone, by combining research on physical sea ice processes, ocean-atmosphere interaction and sea-ice biology. This focus suffered a set back at the meeting when Elizabeth Gross informed the meeting that SCOR has recently endorsed its Working Group 86 on Sea-Ice Biology with Dr Steve Ackley as chairman. Dr Ackley has also been instrumental in the development of the ASPECT science plan, with his submissions on sea-ice biology. Other SCAR scientists (including Dr Ian Allison, Dr Harvey Marchant) working on the draft ASPECT science plan were unaware of the developments in SCOR. Ms Gross went further to outline to the meeting that the sea-ice research community was indeed a small group and that we must avoid duplication of effort in the establishment of research initiatives. Consequently it is apparent the SCAR ASPECT group needs to re-evaluate its approach to the problem, especially in the light of recent correspondence between representatives of the WCRP CLIVAR and ACSYS programmes, who have indicated to Dr Ian Allison that WCRP is interested in joint initiatives with SCAR on research on Antarctic sea-ice physical processes, ocean-atmosphere interaction and climate. Dr Allison (GoS/GLOCHANT) and Dr Howard Cattle (GoS/GLOCHANT and ACSYS Steering Committee) will continue discussions with WCRP about the nature of future collaboration, prior to and during the WCRP meeting in Toulouse, France, in March, 1996. Dr Howard Cattle will represent both SCAR-GLOCHANT and WCRP-ACSYS at the Toulouse meeting and will present the case for a joint sponsorship of research in the Antarctic sea-ice zone. In view of the SCOR Working Group 86 initiative on Sea-Ice Biology it may be necessary for SCAR to repackage its CS-EASIZ project to include the pack-ice zone biology together with the existing coastal and shelf focus, and to investigate joint sponsorship with SCOR. Alternatively, SCAR-GLOCHANT needs to investigate the possibility of the joint sponsorship of ASPECT with the SCOR Working Group 86. Exactly what contribution or commitment SCOR could make, is unclear and is the subject of discussions between Dr Goodwin and Ms Gross and between Drs Allison and Ackley. Discussions will also continue between Dr Goodwin and Dr Hansen and Ms Gross about the need for ASPECT and/or CS-EASIZ to contribute to SO-JGOFS by forming an extension of the SO-JGOFS project into the pack-ice and coastal zones.

International Global Atmospheric Chemistry (IGAC)

Dr Alex Pszenny the IGAC CPO confirmed that there is a direct linkage between the SCAR/PAGES ITASE project and the Polar Atmosphere Snow Chemistry (PASC) within IGAC. ITASE has a strong focus on snow chemistry, snow accumulation rate, stable isotopes and microparticles over the last 100-200 year time-scale. Dr Pszenny recognised the importance of this program in proving a baseline for the PASC project. There is also a direct linkage between the PICE project and PASC through the need for detailed experiments on snow/atmospheric exchange processes around every deep ice-core drilling site.

Global Change and Terrestrial Ecosystems (GCTE)

Dr Will Steffen the GCTE CPO expressed interest in the BIOTAS programme and suggested that there was a potential direct linkage between BIOTAS and the GCTE Focus 4 on Ecological Complexity. Dr Steffen was very enthusiastic about the BIOTAS programme and its focus on simple ecosystems, their colonisation and response to harsh conditions such as aridity, enhanced UV-B radiation and cold temperatures.

IGBP Data and Information System (IGBP-DIS)

Dr Gerard Szejwach the Director of IGBP-DIS expressed an interest in Antarctic environmental data sets. He suggested that the first linkage between SCAR and IGBP-DIS would be the submission of a metadata directory of SCAR Global Change data. Mr Mark Thorley (GoS/

GLOCHANT and Co-Chairman of the SCAR-COMNAP ad hoc Planning Group on Antarctic Data Management) has informed me that ICAIR is hosting presently a metadata directory on behalf of SCAR. Mr Thorley will discuss with IGBP-DIS the requirements and methods of sharing information about data sets.

System for Analysis, Research and Training (START)
Dr Goodwin had fruitful discussions with Dr Hassan Virji, Deputy Director START. As a result, the Final Draft of the Memorandum of Understanding (MOU) between SCAR and START, for SCAR-GLOCHANT to become the START Regional Committee for the Antarctic, within the START Regional Research Network, was submitted to START. The MOU will be discussed at the START executive committee meeting in April, and then pending modifications, and approval by the SCAR Delegates in August, will be proposed at the START Joint Standing Committee meeting in November.

MEETING OUTCOMES

The meeting proved to be fruitful from a number of aspects, not least from the point of view of determining the similarities and differences, opportunities and limitations for linking global change research between SCAR and IGBP in an open exchange. The major outcomes were:

- That it is recognised that SCAR is responsible for a unique science agenda relating to a unique global region. Consequently there are a number of global change issues which relate to Antarctica alone and are not within the key foci of the IGBP Core Projects. This does not reduce the scientific importance of this Antarctic research but rather identifies a clear role for the coordination, facilitation and communication of this research by SCAR;
- That the remaining research areas discussed above have clear and direct linkages with the specific IGBP Core Projects, which should be explored between the IGBP Core Projects and the SCAR Global Change Programme Office and directly between the SCAR programme committees, working scientists and their IGBP counterparts. It is expected that the protocols for this relationship with the IGBP CPO's will develop over the next few months after consultation with their steering committees, and within SCAR.
- That SCAR is well on the way to being appointed to the responsibility for establishing and maintaining the START Regional Research Committee for the Antarctic.

Dr Ian D. Goodwin
SCAR Global Change Programme Coordinator
22 February, 1996

APPENDIX 5

SCAR Global Change Programme - an interpretation for the way ahead

The outcomes on SCAR-IGBP interactions from the Texel meeting, are the culmination of at least three years of effort from SCAR-GLOCHANT and more recently the SCAR Global Change Programme Office. They represent a significant advancement and a turning point for the administration of global change research in Antarctica and for the way in which SCAR needs to plan future research programmes. It is suggested that these outcomes represent the completion of Phase 1 of the GLOCHANT programme, which essentially was to develop external linkages and communications with the global programmes.

The SCAR Global Change Programme now includes aspects of SCAR programmes from within and without the GLOCHANT programme and from a number of SCAR working groups. This structure has evolved over the last few years, in addition to the activities of the GoS/GLOCHANT. Each of these groups represent evolving global change interests and will be asked to liaise directly with the relevant IGBP CPOs directly, in addition to liaising through the SCAR Global Change Programme Office. As a result of these developing linkages, there is a need for each of the SCAR programmes with a defined global change component to be represented on a SCAR Global Change Steering Group or Executive, which may evolve from the current GoS/GLOCHANT structure and composition. This is a key issue which must be resolved during the course of this meeting. I suggest that a SCAR Global Change Executive, which would primarily comprise *ex officio* chairpersons of the representative SCAR programmes with a substantial role in global change research, may be an appropriate solution. These persons would presently be drawn from GLOCHANT/PICE, GLOCHANT/ISMASS, CS-EASIZ, BIOTAS, GLOCHANT/ASPECT and ANTIME (when approved by the SCAR Executive or Delegates meetings).

This composition may be a more appropriate representation for the development of a START Regional Research Committee for the Antarctic. The START framework is based upon the START Standing Committee deferring the regional management responsibilities to the START Regional Research Committee, whilst it retains the direct relationship with the IGBP/WCRP/HDP Executive Committees. Under the proposed MOU on SCAR-START relationships, SCAR would be required to provide a committee to form the START Regional Research Committee for the Antarctic. The proposed structure of this committee would benefit from the inclusion of a nominated scientist from IGBP, WCRP and SCOR to ensure good communication and cooperation between the organisations. The proposed SCAR Global Change Executive may also need to include one or two (no more) additional people to represent key disciplines in which SCAR does not have a specific programme but maintains a clear interest.

As we are now entering Phase 2 of the SCAR Global Change Programme we need to collectively determine research priorities upon which we can develop COMNAP support and programme implementation within the national programmes. Do we need to limit the projects, and initially direct resources to complete science and implementation plans, on priority projects at this stage. Do we need to develop a comprehensive science plan for the SCAR Global Change Programme. Clearly defined outputs need to developed within the science plans. These preferred outputs include:

- Implementation of science plans, through multi-national field expeditions
- Facilitating and organising key international workshops to develop science and implementation plans, and/or discussion and analysis of field results
- Establishment of key linkages with other relevant international global change programmes
- Communication of Antarctic global change research to a broad interdisciplinary audience.

It is also hoped that this meeting can determine a well defined role for the programme office, and discuss the necessary resources to meet this role. The office is funded for another two years. What is the expected life span of the programme and how will its success be judged. The production of outputs or milestones is necessary if further funding is requested and campaigned for. These are the major questions which this group needs to answer during the next couple of days in Madison.

Dr Ian D. Goodwin
SCAR Global Change Programme Coordinator

3 April, 1996

APPENDIX 6

A Proposal for a SCAR-GLOCHANT Initiative on the Late Quaternary Evolution of the Antarctic Ice Margin (ANTIME)

INTRODUCTION

The physical and dynamical processes controlling the nature of the Antarctic ice sheet and the surrounding oceans have been found to be highly variable, both temporally, on interannual to interdecadal time-scales, and geographically. Because of this large background variability and because the instrumental records span such a short time span, it is difficult to predict the responses of the ice sheet and the ocean to future forcings such as global warming. Attempts to determine this variability on century to millennial time scales by medium depth ice core drilling and analysis have only been partially successful. Ice cores have provided detailed information on climate and temperature variability over periods covering just the last few hundred years to the last 10,000 years, at Law Dome and Taylor Dome, East Antarctica and Dyer Plateau, Antarctic Peninsula. The new Law Dome summit core may provide a detailed climate record over the Holocene and perhaps the Late Pleistocene transition. However, the ice coring projects to date have experienced significant difficulties in dating and in providing temporal data on changes in ice sheet elevation and fluctuations in ice dynamics during the Holocene and Late Pleistocene. This information is vital if we are to understand the response of the ice sheet to climate variability. This difficulty might be overcome by utilizing the geological record. The Antarctic sedimentary record in the marine, coastal, lacustrine and glacial environments has already yielded high resolution information on palaeoenvironmental changes, particularly in ice marginal and outlet glacier fluctuations. We believe that a coordinated SCAR initiative on palaeoenvironmental research focused on the Late Quaternary (last 200-250,000 years) Antarctic sedimentary record, particularly a detailed component on the last 20,000 years, including the very high resolution Holocene records, would provide a solid basis for the understanding of present and future variability in the Antarctic.

PROPOSED ANTIME INITIATIVE

SCAR-GLOCHANT has developed a joint initiative with IGBP-PAGES on ice core drilling in Antarctica. This project is entitled, "An international strategy for ice-core drilling in Antarctica — Reducing uncertainty in global environmental change". This project will investigate ice sheet palaeoenvironments on the two time scales, Stream 1 (the last 2,000 years), and Stream 2 (the last 250,000 years). It was the original intention of SCAR-GLOCHANT in 1991 to also develop a sister project on Palaeoenvironments from the Antarctic sedimentary record. However, this has not been initiated to date, and this proposal outlines the need and context for such a project and probable linkages with other organisations such as the IGBP-PAGES.

At present, Quaternary and in particular Holocene research is conducted around the Antarctic ice margin by scientists from a number of nations. Quaternary sequences have been drilled on the continental shelf by marine geological programmes, and have been extensively recorded by seismic surveys conducted by the SCAR-ANTOSTRAT programme. However, most of the Late Quaternary and Holocene research has been focused on the inner continental shelf, in the coastal zone in fjords and beach sequences, and in the vicinity of the terrestrial ice margin and adjacent lakes. Similar to the GLOCHANT-PAGES programme on ice coring, there is a strong need to coordinate the international research on the variability and evolution of the Antarctic ice margin, to maximise the international resources and target the Antarctic areas of most mutual interest. A coordinated effort would allow international resources to be available for specific regional projects, and allow for efficient exchange and correlation of findings between the sedimentary and ice core science communities. The latter could be a major focus for the ANTIME initiative.

We propose that GLOCHANT and the Working Groups on Geology and Solid Earth Geophysics jointly develop a SCAR initiative to coordinate research on the Antarctic sedimentary record, which we refer to at this stage as ANTIME (Antarctic Ice Margin Evolution). We envisage that ANTIME together with the ice core project will form the SCAR contribution to PAGES, and that it will complement the IGBP/SCOR IMAGES transects in the circum-Antarctic regions. We are investigating a joint sponsorship of the initiative with the International Union for Quaternary Research (INQUA), and that some aspects may contribute to the International Geological Correlation Project (IGCP). It is also important for SCAR to produce a coordinated request to the Scientific Steering Committee of the Ocean Drilling Project (ODP) to publicise the importance of Antarctica in the global ocean-atmosphere system, and to encourage further targeted deep drilling sites in the Antarctic. A priority for ANTIME is the drilling and retrieval of a long core which spans the entire Quaternary sequence.

It is proposed to commence this initiative by organising a SCAR sponsored International Workshop, in late 1996 or early 1997 to discuss the planning of future multi-national fieldwork programmes and the coordination of technology and stratigraphic correlations. It is intended that representatives from all the marine and glacial geological programmes in SCAR countries should be invited to the proposed workshop, together with representatives from IGBP-PAGES. The key themes for the workshop are outlined below.

SOME KEY QUESTIONS FOR ANTIME TO ANSWER OR CONTRIBUTE TO INCLUDE:

- What was the extent of the East and West Antarctic ice sheets during the last glacial cycle, especially during the last interglacial (LIG) and the last glacial maximum (LGM)? This is a crucial question for the resolution of sea-level fluctuations, and the calibration of ice sheet models.
- Have the ice sheets, ice shelves and outlet glaciers fluctuated in extent since the LGM?
- If so, were these fluctuations abrupt events similar to the Younger Dryas in the Northern Hemisphere? What forced them ?
- How have the ice shelves and outlet glaciers varied in response to changes in oceanic circulation and temperature?
- What is the extent of fluctuations in the marginal sea-ice zone over the last glacial cycle?
- What does the sedimentary record tell us about fluctuations in Antarctic bottom water production?
- What is the geographic distribution and magnitude of post-glacial isostatic uplift, on the inner shelf and coastal zone? What effect have changes in relative sea-level had on the stability of the outlet glaciers and marine ice sheets?
- What has been the nature of climate change during the Holocene in Antarctica?

Dr Ian D. Goodwin
SCAR Global Change Programme Coordinator
26 March, 1996

SCAR Report

SCAR Report is an irregular series of publications, started in 1986 to complement *SCAR Bulletin*. Its purpose is to provide SCAR National Committees and other directly involved in the work of SCAR with the full texts of reports of SCAR Working Group and Group of Specialists meetings, that had become too extensive to be published in the *Bulletin*, and with more comprehensive material from Antarctic Treaty meetings.

SCAR Bulletin

SCAR Bulletin, a quarterly publication of the Scientific Committee on Antarctic Research, is published on behalf of SCAR by Polar Publications, at the Scott Polar Research Institute, Cambridge. It carries reports of SCAR meetings, short summaries of SCAR Working Group and Group of Specialists meetings, notes, reviews, and articles, and material from Antarctic Treaty Consultative Meetings, considered to be of interest to a wide readership. Selections are reprinted as part of *Polar Record*, the journal of SPRI, and a Spanish translation is published by Instituto Antártico Argentino, Buenos Aires, Argentina.

Polar Record

Polar Record appears in January, April, July, and October each year. The Editor welcomes articles, notes and reviews of contemporary or historic interest covering the natural sciences, social sciences and humanities in polar and sub-polar regions. Recent topics have included archaeology, biogeography, botany, ecology, geography, geology, glaciology, international law, medicine, human physiology, politics, pollution chemistry, psychology, and zoology.

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The journal may also be used to advertise new books, forthcoming events of polar interest, etc.

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