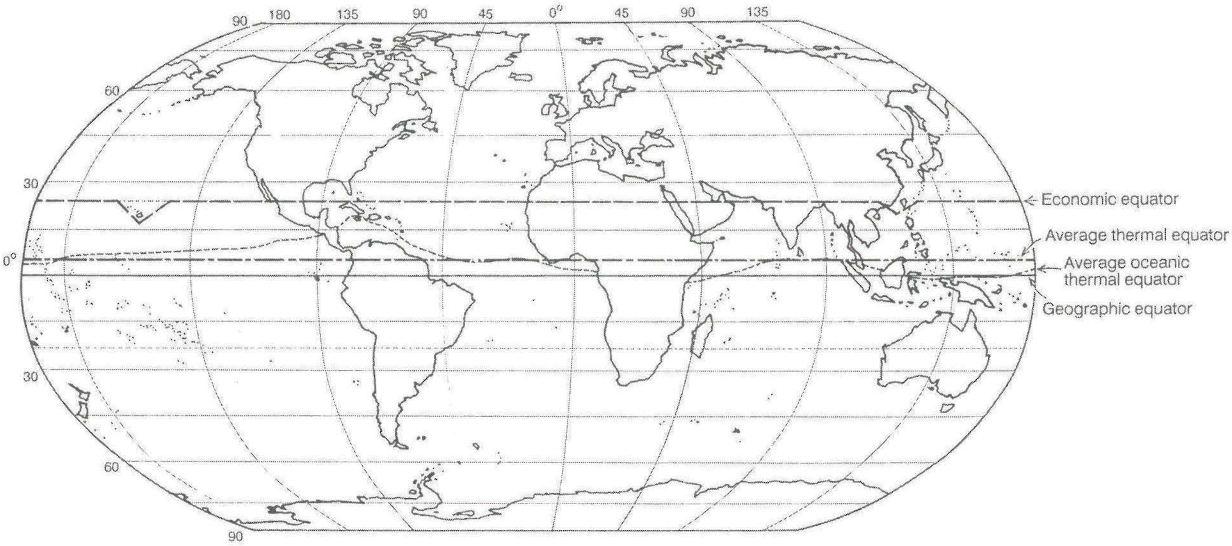
GLOBAL CHANGE

IGBP

REPORT No. 9



Southern Hemisphere Perspectives of Global Change

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP) of the International Council of Scientific Unions (ICSU)

GLOBAL
I G B P
CHANGE

REPORT No. 9

Southern Hemisphere Perspectives of Global Change:

Scientific Issues, Research Needs and Proposed Activities

Report from a Workshop held in Mbabane, Swaziland
11–16 December, 1988

Edited by B. H. Walker and R. G. Dickson

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)
of the International Council of Scientific Unions (ICSU)

The international planning for the IGBP is supported by grants from ICSU, the Andrew W. Mellon Foundation, UNEP, Unesco, CEC, Shell Netherlands and national contributions.

The workshop was supported through a grant arranged by Mr. A. W. Lea of the Anglo-American Corporation.

 ISSN 0284-8015

Printed by Lidingö Tryckeri KB, Lidingö, Sweden.

PREFACE

The predicted global warming trend is attributable almost entirely to the activities of human society in the Northern Hemisphere. The Southern Hemisphere will nevertheless have to suffer the consequences. It will, however, also play a major role in regulating the effects of these human-induced, atmospheric changes, by virtue of its vast ocean area and such phenomena as the El Niño-Southern Oscillation (ENSO) and Antarctic bottom water formation, which will dictate the rates and magnitudes of climate change.

The overwhelming proportion of people and wealth in the Northern Hemisphere is reflected in the distribution and focus of research into global change phenomena. All but one of the 19 member Special Committee of the International Geosphere-Biosphere Programme reside in the north, and the major thrust of the developing research programmes into the consequences of future atmospheric change is, not surprisingly, focused on Northern Hemisphere regions. Recognizing this imbalance, the IGBP organized a Southern Hemisphere workshop aimed at bringing together Southern Hemisphere scientists concerned with global change problems, with a view to establishing a series of collaborative projects to address the problems of the Southern Hemisphere.

The workshop took place in Mbabane, Swaziland, December 11-16, 1988. The proceedings of the first two days of symposium presentations will be published as a special edition of the journal "Climate Change". This report presents the findings of the working groups which followed the symposium. The proposed future activities for Southern Hemisphere collaborative research are presented at the end of the appropriate sections of the report.

The workshop was funded entirely through generous financial contributions from a number of private organizations and, as the workshop organizer, I wish to thank Mr A.W. Lea of the Anglo-American Corporation for arranging this support. I also wish to acknowledge the valuable contribution of the staff of Event Dynamics, Ltd, who assisted during the workshop.

B.H. Walker
May 1989

"There was a young man called Nix
Very learned in crops, climate, and ticks
At IGBP
He filled us with glee
When he sang us the blues just for kicks"

Winning limerick from The Southern Hemisphere Meeting by Basil Stanton of New Zealand, 1989.

CONTENTS

1. SOUTHERN-HEMISPHERE ENVIRONMENTS AND CHANGE IN GLOBAL CLIMATE

1.1 INTRODUCTION: THE SOUTHERN HEMISPHERE, BOUNDARY CONDITIONS AND CONTEXT

The Southern Hemisphere can be defined in three ways: geographically, meteorologically or economically (see Figure. 1.1).

The geographic equator passes through northern Brazil and bisects Indonesia. It passes through Kenya, Uganda and Zaire in Africa. The Southern Hemisphere temperature gradients generate a vigourous atmospheric circulation displacing the meteorological (thermal) equator northwards to between 0°N and 15°N and approximating 6°N as an annual average. The oceanic thermal equator varies seasonally and across oceans but annually averaged values are mostly north of the geographic equator. In economic terms, most areas south of the Tropic of Cancer are regarded as "South". Apart from Australia, New Zealand and South Africa, many Southern Hemisphere countries are socio-economically distinct from those of the Northern Hemisphere. Nutrition is low, health care is poor, education levels are low and public debt is high in the Southern Hemisphere. Most Southern Hemisphere nations also have a young demographic profile.

Do these north-south differences warrant the need for a collaborative southern-hemisphere component of the IGBP? This question prompted the identification of principal environmental matters of common interest to the nations of the Southern Hemisphere, with respect to the phenomenon of global climate change. They highlighted a number of physical, biological and socio-economic problems which are indeed peculiar to the Southern Hemisphere and which, considered together, constituted the scientific reason for this Southern Hemisphere meeting.

It is accepted here that national IGBP programmes would, or should, treat nationally unique problems and opportunities. The problems concern the likely impacts of global climate change, while the opportunities involve potential contributions that individual nations can, or could, make to the IGBP as a whole. Although this section places emphasis on the commonalities of southern-hemisphere environments, it is recognized that a hierarchy of subjects operates across national, regional, subcontinental, and continental areas.

This account is presented as a series of summary comments in four sections: physical characteristics, biological systems, socio-economics, and the needs arising from the preceding three.

1.2 PHYSICAL CHARACTERISTICS

The Southern Hemisphere is characterized by a large area of ocean relative to that of land (80% ocean, as opposed to <60% in the Northern Hemisphere, see Figure 1.2). The four continental land masses are separated by broad oceans and are smaller than the two large land masses of the Northern Hemisphere.

The oceans have a moderating influence on some aspects of the climates of the Southern Hemisphere land masses but also give rise to large interannual changes associated with the complex interactions of the atmosphere-ocean system (e.g., the El Niño - Southern Oscillation (ENSO) phenomenon).

The large interannual climate fluctuations, and the extensive arid areas, are associated with a highly variable surface-hydrology regime for the southern continental tropical and temperate zones.

The southern land masses are relatively old and basically stable, except for a few regions such as the mountainous parts of South America and New Zealand, and their surfaces tend to have large proportions of highly weathered and leached soils which are relatively infertile.

In the Southern Hemisphere there is a relatively larger number of small islands. Many of these may be adversely affected by global changes,

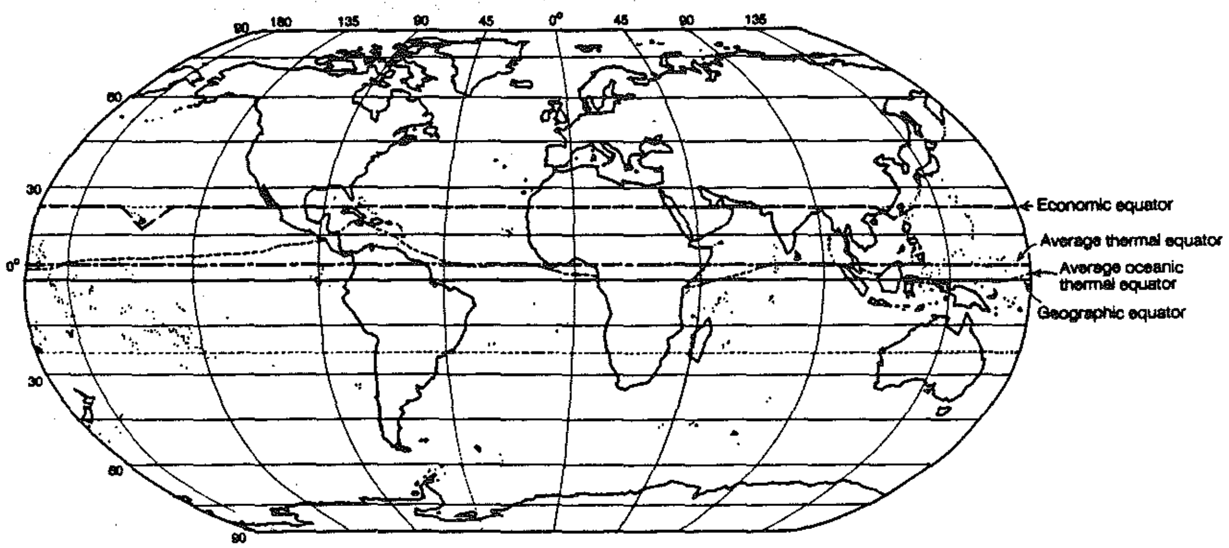


Fig. 1.1 **The hemispheric "equators". Division of North and South on three criteria: geographic, thermal and economic.**

The meterological equator varies seasonally between 0° and 15°N and approximates 6°N as an annual average *(from Flohn, 1980)*. The oceanic thermal equator was derived from averaging seasonal variations *(from Neuman and Pierson, 1966)*. The economic "equator" which has been taken to coincide with the Tropic of Cancer, is the consequence of a number of demographic, sociological and economic factors.

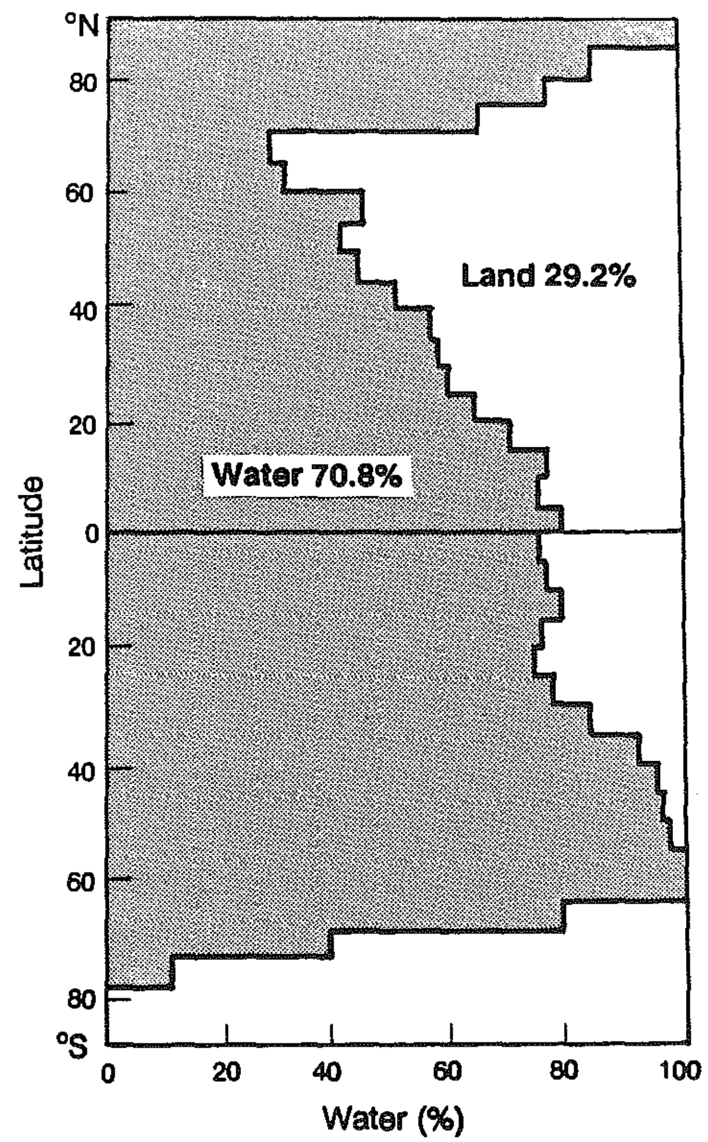


Fig. 1.2 **Distribution of water and land between parallels of latitude** ***(from Neuman and Pierson, 1966).***

such as an increase in sea level or changed frequencies of cyclones and storm surges.

The Antarctic continent, surrounded by the "Southern Ocean" (i.e., waters surronnding the Antartic comprised of the South Altantic, Sonth Pacific, Indian Oceans, plns the various seas), represents a complete contrast to the Arctic Ocean which is largely surrounded by land.

The Antarctic sea ice exhibits a large annual variation in area, practically doubling the extent of high albedo surface during winter.

The Antarctic sea ice is a very sensitive component of the climate system. The area of the sea ice is closely coupled to temperature changes and amplifies these changes by strong positive feedback. This mechanism can result in temperature changes in the Antarctic sea ice zone being mnch larger than most other regions of the globe.

The rejection of salt from the freezing of sea ice in winter is a major driving factor in the production of deep cold water currents for the world's oceans. This deep water mixing also transports dissolved gases such as oxygen and carbon dioxide. Any change in the sea ice distribution will therefore affect the deep ocean transport and the atmospheric gas sinks.

The mechanism of deep water production also controls the temperature of the deep ocean which affects sea level, and will also influence the rate of global warming.

Changes which may occnr in the mass balance of the Antarctic ice sheet will also have a significant impact on changes in sea level over the long term.

In contrast to the Northern Hemisphere, human habitation in the south is largely concentrated equator-ward of 40° latitude. Most of the Earth's hnman population lives in the Northern Hemisphere and is responsible for most of the anthropogenic influences on global change.

Currently, the marked reduction of stratospheric ozone over the Antarctic region is of major global concern. Rednction in the stratospheric ozone farther north can result in an increase in the intensity of ultra-violet (especially UV-B) radiation reaching the Earth's surface. This could have a major impact on the biosphere, particnlarly the phytoplankton of the "Southern Ocean" and sea ice zone, which could subsequently affect the whole of the marine food chain. In southern New Zealand and Australia there has been a 7% decrease in ozone over the past 20 years, which is higher than the global average decrease of 5%.

The atmosphere in the Southern Hemisphere at preseut is less turbid than that of the Northern Hemisphere and this needs to be taken into account in assessing rates of climate change.

Global cloudiness in the Southern Hemisphere could be influenced by dimethyl sulphide (DMS) - emitting algae in the Antarctic Ocean.

The unique circumpolar linking flow of the Southern Hemisphere oceans means that changes in the circulation of these areas could have impacts on a wide range of features such as sea surface temperatures, global climates, relative sea levels, upwelling and advection, and the functioning of marine ecosystems.

1.3 BIOLOGICAL SYSTEMS

The area of transformed ecosystems in the Southern Hemisphere is currently much less than in the Northern Hemisphere. This certainly holds in terms of the absolnte areas involved and is thought to hold as regards the relative proportion of the total areas of those biomes permanently occnpied by man. If the unoccupied areas (Antarctica and the open oceans) are included, then the relative proportion will certainly be smaller. The significance of this is that the modelling of biotic interactions with global climate change in the Southern Hemisphere will, to a large extent, depend on the modelling of natural and semi-natural ecosystems with all the inherent difficulties of spatial heterogeneity, multi-species interactions and imperfectly understood processes of biology and physiology that this implies.

As a result of the interaction of biogeographic and palaeohistoric factors, the Southern Hemisphere is currently the repository of a disproportionate amount of the world's total biological diversity. This discrepancy is enhanced if one uses the economic equator to define Southern Hemisphere thus inclnding the species-rich Central American and Indonesian regions. It is likely that levels of local endemism are also generally higher in the Southern Hemisphere. The significance of this is that the nature conservation implications of global climate change are particularly serious in the Southern Hemisphere.

The continental ecosystems of the Southern Hemisphere generally hold communities with higher levels of species richness than are found in the comparable ecosystems of the Northern Hemisphere. This complicates further the accurate prediction of biotic interactious with global climate change.

Savannas and, to some extent, shrublands, are particularly important on the inhabited continents of the Southern Hemisphere. As they are relatively less significant in the Northern Hemisphere, it is likely that Southern Hemisphere scientific expertise will be reqnired to predict the interactions of these vegetation types with global climate change.

If the Southern Hemisphere is defined by the economic eqnator, then the tropical rainforest becomes virtually exclusive to the Southern Hemisphere. The major proportion of the world's two largest rainforest blocks - those of the Amazon and Congo basins are administered primarily by Southern Hemisphere nations. It is these two blocks which have the greatest role as sources of latent heat release, along with Indonesia. They are also critical regions for the storage of carbon dioxide and as water pumps for water vapour. Their management is accordingly most significant for ameliorating or exacerbating global climate changes.

Similarly, it is the exceptionally high levels of primary production in the oceans of the Southern Hemisphere that, in combination with its unique oceanographic features, make them the area of critical importance in the regulation of global carbon fluxes. It is essential that this primary production and the processes that govern it be adequately researched and monitored.

Another feature of the Southern Hemisphere's oceanic ecosystems is the occurrence of the highly productive boundary upwelling systems along the eastern coasts of Africa and South America. In so far as global climate change could potentially perturb these systems, it is important that they be adequately addressed within the IGBP.

The incidence of pathogenic and parasitic organisms affecting people, their domestic livestock and their crops is much higher in the Southern Hemisphere than in the north. The epidemiology of these organisms is strongly influenced by climatic factors. The prediction for a Southern Hemisphere nnder the influence of a rapidly changing climate is thus one of a rapid succession of epidemics and epizootics.

The proportion of untransformed ecosystems is high in the Southern Hemisphere compared to the north. Such ecosystems are particnlarly prone to invasion by introduced species of plants, particnlarly is the environment is altered (Kruger et al., 1989). As a result of historical patterns of international commerce, travel and agricultural/silvicnltural development, many of the same plant species now occur on all three continents as introductions from the Northern Hemisphere. The flow of species from the northern to the Southern Hemisphere has been much greater than the converse flow. Several important intra-Southern Hemisphere introductions have also occurred. Several recent studies have indicated that invasions by introduced species are promoted by changes in environmental conditions (Kruger et al., 1989; Macdonald et al., 1989). As regional climates change, therefore, it is likely that many of these introduced species will "swamp" native plant communities unless this phenomenon is specifically targeted for the application of appropriate preventative measures. Becanse this effect is likely to be more pronounced in the Southern Hemisphere, it needs to be addressed in the relevant strategic planning scenarios. If it is accepted that tropical oceanic islands are also primarily a Southern Hemisphere concern, then this influence of introduced plant species is even more significant, since insular biotas have been shown to be particularly prone to invasion by alien species.

1.4 SOCIO-ECONOMIC FACTORS

A predominance in the Southern Hemisphere of developing nations tends to set it apart from the Northern Hemisphere - and, it is convenient to make the distinction between the hemispheres on geo-economic criteria rather than on geographic criteria alone. It is this geo-economic subdivision of the world's nations which is addressed in this section. The preponderance of developing economies places significant constraints on a Southern Hemisphere contribution to the IGBP and appropriate strategies will have to be developed to overcome them.

The economies of Southern Hemisphere nations are more dependent on primary or natural resource based industries, such as crop production, pastoralism, and native timber extraction, than on secondary and tertiary manufacturing industries. This makes their economies particularly prone to any climate-change disturbances to this resource base.

Many Southern Hemisphere nations depend on aid from the Northern Hemisphere. Effects of climatically-induced stress on Northern Hemisphere economies will almost certainly generate flow-on effects to the Southern Hemisphere recipients of this aid.

As a corollary to the generally low level of development in the majority of Southern Hemisphere nations, there are relatively low levels of technology, scientific knowledge and scientific infrastructure. This will severely handicap the ability of these nations both to model the effects of global climate change and to adjust rapidly to the effects.

Given current trends, the inhabited Southern Hemisphere continents will have rapidly increasing human populations throughout the anticipated period of rapid, man-induced climate change. This will serve to exacerbate many of the predicted effects of this climate change and will introduce a new dimension of uncertainty into regional predictions. It makes the rapid achievement of realistic climate predictions an urgent matter for Southern Hemisphere countries.

Allied to the previous point, the Southern Hemisphere continents are currently experiencing much higher rates of increase in exploitation and degradation of the natural resource base than is the case in the Northern Hemisphere. This will have a feedback effect on global atmospheric change.

Finally, there is a low level of awareness of the potential seriousness of the effects of global climate change amongst Southern Hemisphere nations. This lack of awareness is exacerbated by the immediacy of many of the problems faced by such nations (e.g., the huge problem of international debt repayment, inflation, etc.). This, in combination with the preceding points, presents a particular challenge in having national governments accord the IGBP the significance it deserves - both in terms of local research direction, as well as in the field of national strategic planning.

1.5 SPECIAL NEEDS OF THE SOUTHERN HEMISPHERE NATIONS

It appears that many characteristics of man-induced climate change will differ between the two hemispheres and that current models generated in the Northern Hemisphere will be more appropriate there. Accordingly, there is a pressing need for the development of strategic plans for the Southern Hemisphere based on realistic, predictive regional models of environmental change in this hemisphere.

To help meet this overriding need, it is necessary to:

i) Improve the Southern Hemisphere database relating to global change. This should focus on key processes considered likely to influence or be influenced by such a change. The use of proxy data sources should be investigated in order to rectify the dearth of historic instrumental measurements of environmental parameters in the Southern Hemisphere. A hitherto neglected field is the contribution the Southern Hemisphere makes to changes in the composition of the atmosphere. This is particularly relevant to gases of a relatively short residence time in the atmosphere, such as methane. The approaches adopted must take cognisance of the Southern Hemisphere complications in regard to monitoring (e.g., the predominance of oceans and developing nations and the recent history of political instability in South America, Africa and Occania).

ii) Initiate information network systems that will maximize the usefulness of data retrieved from past sources as well as those collected in on-going and newly-initiated monitoring systems.

iii) Share the scarce scientific resources and expertise that characterize much of the Southern Hemisphere. This is particularly the case in areas of research which are uniquely southern hemispheric. Wherever possible attempts should be made to draw on the wealth of scientific resources available in the Northern Hemisphere. There is a need to share the benefits of North-South transfers within the Southern Hemisphere.

iv) Develop response functions appropriate to Southern Hemisphere systems. These should be both generic (i.e., cover the range of variations present within the hemisphere) and specific (i.e., cover the special characteristics of particular continents' biota and land-use characteristics).

v) Develop appropriate models for the biomes of the Southern Hemisphere. These should be generic (i.e., capable of intercontinental transfer) with the capability for adaptation based on specific site or ecosystem- parameterization.

There is a need to create a hierarchy of organization within the Southern Hemisphere IGBP effort. This should start with the global programme and all contributions should be framed within this programme (suitably modified, if necessary). At a continental scale nations should cooperate to form strong "continental" IGBP programmes. Then, particular nations that show strong interconnections (e.g., in the case of South America, those nations sharing the Amazon drainage system) should work towards integrating their IGBP efforts. Finally, national IGBP committees will need to address those aspects which are dictated by unique needs and opportunities.

There is a greater need in the Southern Hemisphere to take active measures to create an awareness of the significance of global climate change. The Australian National Committee for IGBP has made a start by organizing a national conference and the Commission for the Future and the CSIRO have jointly organized the Greenhouse '87 (Pearman, 1988) and Greenhouse '88 events, which led to wide media coverage and created a high level of public awareness. Without the creation of an informed body of public opinion it will be virtually impossible to carry out the necessary research and monitoring which will provide the database necessary for the orderly transition of nations through this unprecedented period of rapid climate and social change.

2. SOUTHERN HEMISPHERE CONTRIBUTION TO THE IGBP

2.1 INTRODUCTION

A primary goal of the Mbabane Workshop was the development and mobilization within Southern Hemisphere countries of a body of scientific expertise that will be competent to address the challenges of expected changes in the global climate. As described above, these changes and their impacts can be expected to differ in significant ways from those in the Northern Hemisphere. Furthermore, the small number of scientists and limited research facilities in the south, relative to those in the north, will place enormous demands on the Southern Hemisphere's scientific community.

The IGBP offers a valuable opportunity to bring focus to environmental research in the southern continents, and to the stimulation of collaboration within and between these regions. It was therefore important that the workshop focused on those scientific questions that are peculiar to, or need to be solved through research within, the Southern Hemisphere. In particular, issues that offer opportunities for mutually beneficial, co-operative studies, were emphasized. Furthermore, the achievement of believable global general circulation models will require particular information about the Southern Hemisphere.

In developing proposals for the Southern Hemisphere programme, the products of earlier IGBP planning activities, most importantly IGBP Report 4 were taken into account. Furthermore, attention was given to developing close linkages with existing international research projects, and where appropriate, influencing the orientation of such projects towards IGBP themes.

The main objective of this Chapter is to examine the IGBP proposals in the context of Southern Hemisphere problems and needs, and to note areas where the Southern Hemisphere will make particular contributions to the IGBP.

2.2 IGBP ACTION PLAN: SOUTHERN HEMISPHERE COMPONENT

A preliminary assessment of current IGBP proposals (contained in IGBP Report 4), indicated that a wide range of topics would need greater emphasis within the Southern Hemisphere component of the programme. These include the following which are considered here within the IGBP action plan framework.

2.2.1 Terrestrial biosphere/atmospheric chemistry. (Co-ordinating Panel 1).

Identification of key source areas of biogenic gases, especially CH_4 and N_2O, within Southern Hemisphere continents.

Quantification of biomass burning emissions.

Development of closer collaboration between scientists within the Southern Hemisphere, and between northern and Southern Hemispheres, in the measurement and monitoring of trace gas sources.

2.2.2 Marine biosphere/atmosphere interactions. (Co-ordinating Panel 2).

Further studies into the occurrence and role of dimethyl sulphide.

Research into the influence of UV-B on the productivity of marine plankton.

The interaction between global change processes and marine ecosystems and biota, especially with regard to marine fisheries and mariculture.

Increased emphasis on processes at the land/sea interface, including the impacts of sea level rise and changing hydrological/sedimentation and eutrophication processes.

2.2.3 Biospheric aspects of the hydrological cycle. (Co-ordinating Panel 3).

Potential impact of changes in the Andean snowline resulting from glacier and snowfield melt, changed snowfall/rainfall patterns, etc.

The role of the Amazon and Indonesian regions as the main sources of stratospheric moisture.

2.2.4 Effects of climate change on terrestrial ecosystems. (Co-ordinating Panel 4).

Although concern was expressed regarding the possible impact of UV-B on terrestrial biota in the Southern Hemisphere, it was agreed that the findings of the SCOPE International Union of Applied Physics (IUAP) study on this topic be awaited before specific studies on this be initiated within the IGBP - Southern Hemisphere programme.

The identification of a minimum set of Southern Hemisphere biomes and the development of generic models for these.

The need to address the impacts of global climate change on agricultural systems in the Southern Hemisphere context, a topic virtually neglected in IGBP Report 4.

2.2.5 Global geosphere/biosphere models. (Co-ordinating Panel 5).

Increased efforts to link physical models with models of environmental chemistry and biology, within a regional context, will be needed for Southern Hemisphere studies. There is a general need for the development of regional climate-change models, linked by or nested in GCM's.

2.2.6 Data management and information systems. (Working Group 2).

The limited technical expertise available in the Southern Hemisphere will make the sharing of research products, models and methodologies of special importance for the success of the programme.

The sharing of products will be especially important in terms of GCM's, where most Southern Hemisphere countries lack the computer facilities to develop such large models, but might have the capacity to test regional models and to participate in workshops, training exercises etc.

Furthermore, because normal communication media (air travel, mail, telephonic linkages) between the southern continents are irregular or inadequate, increased emphasis should be given to the establishment of electronic mailing networks between IGBP participants.

Note was taken of an offer by NASA to provide interested research groups with copies of their global Leaf Area Index (LAI) models, which provide, within a 5 x 5 km grid, monthly values of LAI. Southern Hemisphere countries with extensive areas of relatively homogeneous vegetation and topography, such as miombo, chaco, cerrado, mulga, rainforest, arid shrublands etc., might be able to test the usefulness of this NASA data.

The IGBP proposal for the development of a network of Geosphere/Biosphere Observations (GBO's) needs careful evaluation by southern hemispheric countries. In addition to the research associated with the GBOs, such an evaluation needs to consider also the selection of those facets of environmental processes that need long-term monitoring and how this monitoring might be achieved.

2.2.7 Scientific Steering Committee on Global Changes of the Past.

Deficiencies in the information base on past environments which could be rectified through studies on tree-ring and pollen data from tropical lowland forests, corals and Antarctic ice cores, need attention, and increased research funding. There should be some representation from the Southern Hemisphere on this SSC.

The synthesis of available information from a range of different sources (tree-rings, pollen profiles, sediments, etc.) needs to be undertaken in several southern hemispheric regions.

2.2.8 Effects of climate change on marine and coastal ecosystems and biota.

The Mbabane workshop recognized the need for an additional working group to bring focus to the ecological consequences of climate-change in marine and coastal environments. The importance of such influences on marine fisheries, mariculture, coastal development (especially human settlement, engineering, communication) estuarine ecology, the impact of changed hydrological regimes, eutrophication and sediment loading from terrestrial sources, etc. needs investigation.

3. DEVELOPING REGIONAL CLIMATE SCENARIOS

3.1 INTRODUCTION

General Circulation Models (GCMs) are, at present, unable to give reliable regional-scale predictions of changing climate. Southern Hemisphere nations and scientists must encourage, and contribute to, an international effort to overcome the existing model deficiencies, so as to provide reliable regional predictions. However, in the meantime endeavours should be made to provide the best possible advice now. Such advice must include all necessary caveats and be a balanced and self-critical statement of the present state of knowledge and its uncertainties.

Existing GCM simulations of the regional climate changes due to atmospheric change are inadequate because of a number of problems including poor treatment of interactive processes involving the oceans, vegetation, soil hydrology and variable cloudiness, and because of very coarse horizontal resolution, which is typically 500 - 700 km. Such resolution does not allow adequate representation of topographic and coastal influences, which are particularly important for rainfall estimates and hydrology.

Given the present inadequacy of GCM simulations, some useful information can be obtained by resorting to palaeoclimatic analysis, comparison of warm and cool epochs in the instrumental record, and use of arguments based on climatology and dynamic considerations. However, the possible deficiencies in such analogies and arguments need emphasis.

It must also be noted that other factors beside the greenhouse effect influence year-to-year climatic variations and indeed longer term trends. These factors include local and regional human-induced vegetation changes, volcanic eruptions, and such phenomena as the El Niño - Southern Oscillation (ENSO). It is noted also that the Earth's orbital variations, which occur on time-scales of many thousands of years, have significant effects on local and regional climates. However, the time-scale of these astronomical influences is much longer than that of the expected greenhouse effect, and so can be ignored over the next 50 years or so. Variations in solar output are unlikely to have a significant influence on the decadal to century time-scale, although there is some evidence in the instrumental record in southern Africa of quasi-cyclic influences having a period of about 18 years.

In the light of all the above it is expected that, on the basis of a range of estimates of increases in greenhouse gas concentrations by the year 2050, global average surface temperatures will have risen by 3-5°C or more, depending on the extent to which greenhouse gas emissions are limited. The warming through to 2050 will be accompanied by an average increase in evapotranspiration of around 10-15% and a similar increase in average rainfall. The rainfall changes will vary regionally. In some regions there will be little change and in others the change could be as large as ±50%. Resulting changes in soil moisture, runoff and river flow could be even larger. Although increased wetness is a positive factor in many areas there are also likely to be serious consequences for agriculture, water supplies, and other aspects of society. In addition, it is expected that thermal expansion of the oceans and melting of mountain glaciers will have led to a rise in the global average sea level of the order of 50cm.

While these estimates are uncertain, for the reasons noted above, they are indicative of the potentially serious impact on human society, food supplies and natural ecosystems.

There already exist several international research programmes which are relevant to the development of better regional climate scenarios, notably aspects of the World Ocean Circulation Experiment (WOCE), part of the World Climate Research Programme(WCRP).

As noted earlier, the countries of the Southern Hemisphere are influenced by several climatic mechanisms and factors to a greater extent than countries in the Northern Hemisphere. Regional climate scenarios in the Southern Hemisphere countries will therefore benefit from special attention being paid to these factors. Such factors include the ENSO phenomenon, tropical cyclones, the role of the "Southern Ocean" including sea-ice formation, the influence of the Antarctic continent, the destruction of stratospheric ozone and the accompanying increase in UV-B radiation, and the dominant role of tropical convection and monsoonal circulations in the predominantly low-latitude Southern Hemisphere land masses.

Prediction of future patterns of UV-B radiation is dependent on a developing understanding of stratospheric ozone chemistry, including the heterogeneous chemistry involved in the Antarctic 'ozone hole' phenomenon, and on predictions of the altered cloud climate. Rapid progress on the theory of ozone chemistry is being made by Northern Hemisphere scientists, but the prediction of cloud cover is dependent on improved GCM modelling. Further work is also needed on the UV radiative properties of clouds.

3.2 RESEARCH NEEDS

Development of useful and credible climate-change scenarios requires expansion of current efforts in several key research fields. In some of these the necessary research for the development of Southern Hemisphere scenarios will probably not be done unless by Southern Hemisphere scientists. For instance, joint work by atmospheric scientists and biological scientists will be needed to identify the climate variables that need to be predicted so that the impacts of climate change can be estimated. While such work will be carried out in the Northern Hemisphere many of the results will not be transferable to Southern Hemisphere ecosystems.

Similarly, Northern Hemisphere scientists are using instrumental records and palaeoclimatic data to develop analogues that may be useful in predicting climate change, and to examine current climate trends. But again, this work cannot simply be transferred to the Southern Hemisphere, and Northern Hemisphere scientists are unlikely to carry out these studies for the South. Even the techniques and sources of data may differ. For instance, in the Southern Hemisphere, with its concentration of land at low and high latitudes, techniques for extracting palaeoclimatic information from coral cores, ocean sediment cores and ice cores may be relatively more important than those useful for analysing pollen cores, an approach which has so far been more useful in the Northern Hemisphere.

In some other research areas such as biosphere-climate feedback modelling, work is proceeding in the Northern Hemisphere which will be useful for the south but involvement of Southern Hemisphere scientists will be necessary to ensure effective transfer of techniques and results. In other areas, such as atmospheric general circulation modelling, the involvement of Southern Hemisphere scientists may lead to some redirection of priorities towards problems of concern to this hemisphere.

As available computer power increases the spatial resolution of general circulation models will improve. In the interim, the strategy of nesting high-resolution regional models within GCM's needs to be examined. This approach has been used in numerical weather prediction. It may be specially relevant in the Southern Hemisphere where available computer power will lag behind that available in the North.

Coupling of an ocean model to a GCM is more relevant to the Southern Hemisphere with its higher proportion of ocean. The larger ocean areas may delay warming relative to the Northern Hemisphere. The effect of the "Southern Ocean" and interaction between sea ice and climate change will also be more relevant to the Southern Hemisphere.

Inclusion of improved treatment of soil hydrology and interactive vegetation in GCM's is a high priority for the Southern Hemisphere. Most of the populated areas in this hemisphere are tropical and sub-tropical with relatively larger proportions of untransformed ecosystems compared with much of the north. Changes in albedo and evapotranspiration initiated by climate change may lead to considerable climate-vegetation feedback affecting local surface climate. The wider-scale climate effects of tropical deforestation also need to be quantified and included in the GCM's. As was mentioned earlier, deforestation in the Amazon, the Congo and Indonesia may have substantial effects on the major heat sources driving atmospheric circulation.

One aspect of GCM research which will receive little attention in the North is the identification and correction of inadequacies in the simulation of present-day Southern Hemisphere circulation. There are several such inadequacies. Northern Hemisphere atmospheric scientists will only focus on Southern Hemisphere inadequacies if their correction will have a substantial effect on the simulation of the Northern Hemisphere circulation. Until the present-day circulation can be adequately simulated, prediction of climate change with the GCM's will be suspect.

The GCMs ability to simulate past climatic change also need to be tested. Again, Northern Hemisphere scientists will concentrate on past climates of their hemisphere. Input from Southern Hemisphere scientists is needed to determine whether the models can simulate past climate changes in the Southern Hemisphere as well. Once again, unless the models can do this climate-change predictions will not be credible.

Finally, effects of one important climatic phenomenon, the El Niño - Southern Oscillation (ENSO), differentiates much of the Southern Hemisphere from most of the North. ENSO is a major control of climate fluctuations in much of the Southern Hemisphere. The possibility of changes in ENSO's behaviour needs to be considered in developing scenarios for the South but can largely be ignored for the mid-latitudes of the Northern Hemisphere. ENSO's presence also amplifies climatic variability over much of the Southern Hemisphere. Extreme climatic events associated with ENSO are likely to be important in producing changes in ecosystems in the Southern Hemisphere, in which case useful scenarios will need to include predictions of changes in extreme event frequency. In the less-variable mid-latitudes of the Northern Hemisphere extreme climatic events may be less of a concern. The Southern Hemisphere climate-change scenarios will therefore require more emphasis on predicting ENSO's reaction to the greenhouse effect as well as predictions of frequency distributions (not just the changes in the mean).

3.3 RESEARCH PROGRAMME

In the light of the above research needs, specific research programmes need to be developed in the following areas.

3.3.1 Instrument Records

3.3.1.1 Availability. The longest records in the Southern Hemisphere countries are of rainfall and temperature which date back to the middle of the last century in some South American countries, but in southern African countries the records date back only to the beginning of this century. However, there is a notably uneven distribution of recording sites. For example, in South America, sites in Brazil and Chile are concentrated along the coast. In southern Africa recording sites are concentrated along the main communication lines (rail and road) and in the more populated areas.

Measurement of other climatic elements is recent, particularly for upper air data. In South America, most countries started recording upper air characteristics around the 1950's and in most southern African countries it started much later. In all cases there is a sparse distribution of recording sites and there are great differences in densities between countries. There are also differences in the number of releases per day from country to country. Most South American countries have one release per day at 1200 GMT but some countries in southern Africa have as many as three radiosonde releases per day, particularly during the rainy season.

3.3.1.2 Accessibility. For South American countries at least some records are accessible as they are archived in the United States. For the African countries accessibility depends on the form in which the data are archived. Daily records in most cases are not easily accessible as they are archived in their original manuscript form. Monthly and annual records are fairly easily accessible since for some countries the data are now on magnetic tape. Some countries hold part records for other countries. For example, South Africa has data for Swaziland, Lesotho and some parts of Zimbabwe, and Britain has published data for Zimbabwe, Mozambique, Zambia and Malawi at the British meteorological office at Bracknell. Finally the World Climate Data Programme(WCDP) is a major repository of records.

3.3.1.3 Homogeneity. Homogeneity is a problem due to different authorities being responsible for recording climatic data in different Southern Hemisphere countries and to a diversity of instrument types and discontinuities in the data.

3.3.1.4 Suggested programme and recommendations regarding data.

(1) Establishment of centralised collection points for easy accessibility in South America and southern Africa.

(2) Assessment of the need to establish more recording stations in Southern Hemisphere

countries and the need to increase the range of elements recorded in line with IGBP's objectives.

(3) Improve comparability of records and results by encouraging each participating country to follow WMO recommendations in recording climatic elements.

(4) Analysis for homogeneity and correction of time series data with one person undertaking this task in each country. It is recommended that stations with the longest and most reliable records be used as control stations to monitor climate changes.

(5) Encourage increased use of internationally available data, e.g., satellite data (in the case of Africa, satellite information in Nairobi, Kenya).

(6) Recommend international bodies to assist participating Third World countries to establish data bases which will facilitate the implementation of IGBP's objectives. Assistance is needed in the form of finance, technology and expertise, and the Special Committee of IGBP should investigate this further.

3.3.2 Synoptic climatologies

Synoptic climatologies will be required on regional, subcontinental and even continental scales to link present day climates to the general circulation of the atmosphere in the various sectors of the Southern Hemisphere. Such climatologies, developed for monthly, seasonal or longer time scales, will enable the output fields from general circulation models to be validated and the models improved to take into account regional vagaries of circulation such as those related to ENSO, movements of the Inter-Tropical Convergence Zone, and the semi-stationary cloud bands connecting areas of tropical heat release to mid latitudes (i.e., the Southern Pacific Ocean Convergence Zone (SPCZ), South Atlantic Convergence Zone (SACZ) and Indian Ocean Convergence Zones (IOCZ)). At the same time the circulation climatologies will provide a basis for the exploration of regional palaeoclimatic variations.

At present, the resolution of the circulation models is too coarse to allow important regional features of the circulation to be reproduced. Until the resolution is improved, or nesting is shown to be practicable, synoptic climatologies provide a means of interpolating the output of the models for regional application.

While existing models are refined and new coupled models are developed, synoptic climatologies should be prepared. In both activities collaboration between modellers and climatologists will be beneficial.

Regional cooperation between scientists working in the various countries of South America, Africa, and the Pacific, would facilitate the development of relevant regional climatologies.

3.3.3 Palaeoclimatic and historical data from the Southern Hemisphere

The special committee for the IGBP has drawn attention to the fundamental importance of records of past environments in interpreting present trends and in evaluating Earth system models, and has established its first Scientific Steering Committee to co-ordinate research in this field. Within the framework already established by the IGBP Special Committee several hemispheric needs have been identified as requiring special emphasis.

(1) The integration of available palaeoclimatic data on a hemisphere basis. This problem may receive the attention of a proposed Working Group of the International Quaternary Association (INQUA) Commission on Palaeogeography, Atlas of the Quaternary, consisting of A. Velitchko (USSR - Convenor), M. McGlone, (New Zealand), J. Bowler (Australia) T. C. Partridge (South Africa) and M. H. Iriondo (Argentina). The objectives of the Working Group would be to prepare palaeogeographic maps of the Southern Hemisphere in critical time slices from 125,000 years BP to the Holocene.

(2) Making optimum use of the model simulations produced for the period since the Last Glacial Maximum by the Co-operative Holocene Mapping Project (COHMAP) (Southern Hemisphere members: J. Salinger, M. McGlone and J. Dodson) in Southern Hemisphere palaeoclimatic reconstructions. In this project, model simulations have been produced at 3000 year intervals. Local records should be used to check and refine these in terms of changes in the dominant elements of regional atmospheric circulation.

(3) The analysis of high resolution continental and marine records spanning the last 150,000 years. Few such records are available, though the Southern Hemisphere has the data from the Vostok ice core. More should be sought and studied. In particular, attention should be given to records for the Last Glacial Maximum (temperature minimum) the Holocene Maximum (temperature maximum) and seasonal distribution of precipitation during these periods. Isotopic data from ice cores, ocean cores, speleotherms, coral cores, glacial deposits and other sedimentary accumulations are likely to provide the most useful information. The potential for corals to provide low latitude data is an important recent development.

(4) Acquisition and analysis of data for the last millenium. This period is of vital importance in the identification of trends upon which anthropogenic effects have been superimposed. Valuable data are available from tree rings (national collections and series assembled by LaMarche at the University of Arizona), hyrax and owl middens, as well as instrumental records available from the 19th century onwards. Other potential data sources are listed in (3) above.

(5) The identification and analysis of past records of ENSO phenomena on a hemispheric basis.

(6) The analysis of sea-ice fluctuations around Antarctica since the Last Glacial Maximum.

It is recommended that these special Southern Hemisphere needs be specifically addressed by the IGBP Scientific Steering Committee on Global Changes of the Past, with a view to establishing priorities and developing collaboration with other groups such as the proposed INQUA Working Group.

3.3.4 Production of relevant climatic predictions

Any future climate scenarios produced by GCMs should be aimed at providing the data required by users such as ecologists, agricultural advisers and water supply engineers and modellers. This will best be done in collaboration with these potential users and may result in a demand for frequency distribution of temperature and rainfall, frost frequency and flood return periods, etc. (see Section 3.4.1). It is expected that improved GCMs will have the capability of generating such detailed climatologies for various future scenarios.

3.3.5 Oceanography

3.3.5.1 Ocean circulation and sea-ice formation. Successful prediction of global climate change beyond a few years will require the inclusion of the dynamics of the oceans through their full depth. Such an improved understanding of ocean circulation and processes requires unprecedented observation, modelling and monitoring programmes. Fortunately a number of programmes are in the planning or implementation stage within the World Climate Research Programme (WCRP). The principal programme which addresses directly those aspects of ocean research needed to improve present modelling on climate time scales is the World Ocean Circulation Experiment (WOCE). Another programme at an early stage of planning is the Global Energy and Water Cycle Experiment (GEWEX). The Joint Global Ocean Flux Study (JGOFS), a programme of the Scientific Committee on Oceanic Research (SCOR), is another project which will improve our understanding of ocean processes. Clearly it will be in the best interests of the Southern Hemisphere IGBP to support and be involved in these programmes.

The WOCE is at an advanced stage of planning with the 5 year Intensive Observational Period scheduled for 1990-1995. The WOCE Implementation Plan, published in July 1988 outlines the experimental needs and over the next two years, national commitments to the plan will be under consideration.

The WOCE contains a large Southern Hemisphere component, which reflects the importance of the large area of ocean in this hemisphere. It has recognized the fundamental importance of the "Southern Ocean" through the designation of its Core Project No 2. This project is concerned with the Antarctic Circumpolar Current and the regions of water mass formation to the north and south of it. The Antarctic Circumpolar current links the circulation of the Pacific, Atlantic and Indian

Oceans and provides the connection that transfers the ocean heat flux from a regional to a global phenomenon.

The other WOCE projects, which comprise the large scale hydrographic programme, the current meter moorings, drifting buoy measurements and satellite observations all have a large Southern Hemisphere component. The Southern Hemisphere IGBP group welcomes the WOCE programmes and encourages the full implementation of the Southern Hemisphere aspects.

Southern Hemisphere oceanographers will benefit from a co-ordinated approach to the experiment but at present WOCE national committees are at different stages of development. The South American countries held a WOCE planning meeting in August 1987 and the report for this meeting is now available (Contact - Dr. Yasunobu Matsuura, Oceanographic Institute, University of Sao Paulo, Sao Paulo, SP, Brazil). Australia has a WOCE national committee (Convenor - Dr. J. Church, CSIRO Division of Oceanography, PO Box 1538, Hobart, Tasmania 7001) as has South Africa (Convenor - Dr. J. Lutjeharms, CSIR, PO Box 320, Stellenbosch 7600, South Africa). New Zealand has yet to form a committee but has a national contact (Dr. R. Heath, Division of Water Sciences, DSIR, Private Bag, Kilbirnie, Wellington, New Zealand).

The extent and formation of sea-ice is an important study for Southern Hemisphere participants and ocean modellers as these processes are crucial in the deep convection which forms the abyssal waters in the ocean basins. Improved understanding of these processes will be important in the modelling of the extent to which the "Southern Ocean" will moderate temperature rises in the Southern Hemisphere, and the oceanic uptake of CO_2.

The JGOF Study is being carried out in close association with WOCE. Its aims are to improve the understanding of the global carbon flux in oceans including CO_2 exchanges with the atmosphere, sea floor and continental boundaries. There are four main elements of the programme-process studies, global studies, modelling and coastal ocean studies. The planning for JGOFS commenced early in 1987 and by the beginning of 1988 a pilot experiment for the North Atlantic was established. Planning for other ocean basins including the South Pacific is underway. It is perhaps worth noting that the JGOFS Committee has no Southern Hemisphere members.

3.3.5.2 Modelling the oceans. To understand the present climate system and to be able to simulate future climatic changes, coupled atmosphere and ocean models are needed. At present complete global ocean models capable of resolving individual eddies are not available. A major part of the WOCE programme will be the development of global ocean models. In the interim, there is a need for improved parameterized ocean models to be used for coupling with atmospheric models to study future climatic change.

Improvements are needed in the ocean models to better simulate the present annual cycle of changes in the distribution of temperature and salinity. Improvements are also needed in the modelling of the sea ice including leads, drift, and the fluxes of heat and salt and Improvements are also needed to adequately simulate ocean currents and vertical mixing. Parallel development and application of coupled models is needed to better evaluate their performance and to make improvements.

3.3.5.3 Monitoring and prediction of sea level rise in the Southern Hemisphere. The global rise in sea level predicted for the twenty-first century will not be uniform in either rate or magnitude at the local or regional scale. In fact, past records of sea level extending into the previous century show significant differences in local relative sea level change for this period from place to place. This is due to tectonic and other local or regional effects.

Estimates for future sea level rise based on extrapolations from the past are difficult for most locations in the Southern Hemisphere because of the dearth of long term records and the poor hemispheric distribution of the few stations available. Monitoring of expected future sea level rise is further hampered by an insufficiency of presently operating sea level gauges.

Operational sea level monitoring stations are particularly needed along the coasts of Africa and Antarctica and on islands in the vast ocean expanses of the Southern Hemisphere. All stations presently in operation should be continued. Also it is vital that countries in the

Southern Hemisphere which have not yet made their sea level records available to the international scientific community through the Permanent Service for Mean Sea Level (PSMSL), (Proudman Oceanographic Laboratory, Bidston Observatory, Birkenhead, Merseyside L43 7RA, England) should do so. PSMSL is a member of the Federation of Astronomical and Geophysical Services (FAGS) established by ICSU. They work in conjunction with the Intergovernmental Oceanographic Commission (IOC), a UN agency, and the IOC has recently put forward a proposal to establish a global network of sea level stations, reporting to PSMSL.

The prediction of sea level rise and enhanced sea level changes arising from storm surges, if tropical cyclone patterns change, or sea level changes induced by changes in ocean currents and atmosphere pressure patterns occur, will need to be undertaken. This will be of importance in the Southern Hemisphere as there are a number of low-lying island nations. As some of these nations, particularly in the Pacific, have only a low level of scientific expertise it will be necessary for countries in the region which support relatively large oceanographic programmes to assist in implementing such research activities.

3.3.5.4 Relevant Data for the Marine Biosphere. It will be important for the Southern Hemisphere IGBP group to include predictions of data relevant to marine ecological requirements in their programmes as identified in Chapter 6.

3.3.6 General circulation models

3.3.6.1 Problems. General circulation models provide the main technique for producing estimates of regional climate change. Accordingly, for countries in the Southern Hemisphere it is important to assess the ways in which GCM's are deficient in simulating Southern Hemisphere climatology, to find reasons for this and to improve the models to minimize or eradicate these deficiencies. Because of the major role of the oceans in the Southern Hemisphere, adequate treatment of the oceans and of the interaction between oceans and atmosphere is likely to be particularly important. Other aspects likely to be critical are:

i) the specification (prediction) of clouds in sufficient detail for the accurate determination of their effect on patterns of adiabatic heating and cooling; and

ii) the parameterization of surface processes for the principal biospheric regions in the Southern Hemisphere.

3.3.6.2 Possibilities. GCM studies directed to understanding and predicting climate change are likely to be undertaken in many Northern Hemisphere centres over the next 10 years. The data produced by these models refer to the whole globe and will be enormous, and only a small proportion of the output will be able to be analysed. There would be a clear advantage if Southern Hemisphere scientists were able to compare GCM control run results with climate data for their own regions, and also have an input into improvements in parameterization. This would be facilitated by setting up a network of Southern Hemisphere collaborators, and establishing a special relationship between this network and a GCM group focussed on Southern Hemisphere problems.

At present the only GCM group in the Southern Hemisphere is in Australia. A modelling group is being developed at INPE in Brazil. The Australian group will be testing the nesting of a regional high-resolution model to be driven by one Australian GCM. If this is successful the technique could be used in several regions of the Southern Hemisphere to provide more detailed climate scenarios. A mixed layer ocean is already included in another Australian GCM but it is likely to be 5 to 10 years before a full ocean circulation component can be included. Nevertheless, both control climate data and climate change data from the first experimental runs with one or both of these GCMs should be available for analysis before the end of 1989.

3.3.6.3 Collaborative work. Four types of collaborative work on GCM data are desirable among Southern Hemisphere countries.

(1) Control run results for different parts of the Southern Hemisphere should be made available for local/regional analysis and comparison with climatological data.

(2) In the regions, techniques should be developed to enable climate statistics required for biospheric impact studies to be obtained from model output statistics. In this regard, countries intending to undertake such studies should be

encouraged to maintain (or to establish) climatological stations making the required observations for comparison with model control run output.

(3) The results from the Australian and several other GCMs are likely to be available; these will enable a comparison of results to determine whether one or more models are particularly representative of the region under study.

(4) Climatologists from countries unable to carry out GCM studies should be encouraged to seek the support of suitable international agencies to visit GCM modelling centres with which they have established a collaborative programme.

Three international initiatives relating to GCM climate change studies should be noted, with a view to taking advantage of them for Southern Hemisphere studies.

(1) The International Association of Meteorology and Atmospheric Physics (IAMAP) is planning a World Conference in 1991. The topic will be "Methodologies for estimating regional climate change". It is likely that an additional focus will be on obtaining consensus views on which regional climate change estimates may be the most reliable. Co-sponsorship will be sought from other agencies such as WMO and UNEP.

(2) A major GCM facility entirely devoted to climate change studies will be set up as part of a new International Centre for Science and High Technology to be established by the Italian government in Trieste. The International Centre for Theoretical Physics and the Third World Academy will be part of this, but not formally involved in the establishment. Special emphasis is likely to be given to estimating climate change in Third World Countries.

(3) The WMO and UNEP have set up an International Panel on Climate Change (IPCC) which is actively comparing GCM climate simulations with a view to a report to the United Nations in 1990. Unfortunately, comparisons are not planned by the IPCC for any region in the Southern Hemisphere.

3.4 ACTION PLAN

3.4.1 GCM and nested modelling

(1) The Australian group, at CSIRO, Division of Atmospheric Research together with the Bureau of Meteorology Research Centre in Melbourne, are progressively documenting and eliminating deficiencies in their models. Improved soil hydrology, variable cloudiness, simple coupled oceans, and interactive vegetation schemes will be developed and implemented during 1989-90. Runs will be carried out with diurnal and annual cycles, as time permits.

(2) The nesting scheme in the above models will be tested during 1989.

(3) Treatment of transient effects due to sea ice and ocean lags will be investigated at Melbourne University (W. Budd) and the CSIRO Division of Atmospheric Research, at least in sensitivity experiments from 1990 onwards.

(4) Relating GCM outputs to user needs will be progressively explored by B. Pittock at CSIRO Division of Atmospheric Research in conjunction with H. Nix at the Australian National University (ANU) and B. Walker, and D. Graetz at CSIRO Division of Wildlife and Ecology.

(5) Regional participation, analysis and training will be addressed at a Southern Hemisphere climate modelling workshop to be held in Melbourne, hopefully in 1990. This should be open but should involve A. Moura, C. Nobre and Dias of Instituto de Pesquisas Espaciaias (INPE) in Brazil, M. Nunez at University of Buenos Aires, Kidson and Mullan from the New Zealand Meterological Society (NZMS), the CSIRO Division of Atmospheric Research, and Melbourne University groups, Van Heeren from South African Weather Bureau, Chimonyo from the University of Zimbabwe, and the University of the South Pacific. B. Pittock, W. Budd, N. Nicholls, A. Moura, M. Nunez and R. Chimonyo will be coordinators and financial support will be sought from IGBP, UNEP, WMO and other agencies.

(6) Training in GCM modelling and applications. W. Budd (Australia) and A. Moura (Brazil) will develop a proposal with funding support, probably for training at Melbourne University and/or Instituto de Pesquisas Espaciaias (INPE) and will explore Australian overseas aid funding, and/or support from large multi-national corporations.

(7) Regional control and perturbed output data from GCM simulations will be made available to workers in relevant countries (Hunt, Frederiksen, Pittock in CSIRO Division of Atmospheric Research).

(8) Information on relevant conferences in Reading, UK (IAMAP), August 1989; Hamburg, Aug/Sept 1989; and Austria (on Methodologies for Regional Climatic Change Scenarios), 1991, will be noted and circulated. (B. Tucker).

3.4.2 Instrumental records

(1) Crucial to the success of modelling future global and regional climatic changes is the maintenance and possible extension of networks of climatological stations. This is particularly important in the developing countries of the Southern Hemisphere. Unless these data are readily available, countries will be unable to verify the capability of models to represent adequately the current regional climate and so to have confidence in estimates of future climate. The WMO via national meteorological services plays an essential role in ensuring the existence of such stations and the availability of these data. The workshop therefore agreed to the following statements.

(i) The present tendency of some Governments of Southern Hemisphere countries, in times of financial stringencies, to contract their network of stations is a false economy. Countries should be urged not to disestablish such stations but at least to maintain the network and to improve the quality and availability of data.

(ii) This workshop wishes to give support to WMO in its efforts to maintain a reliable and homogeneous climatological record, to improve its quality and to make the data readily accessible to potential users.

(2) Special climatic data of relevance to biological ecosystems should be identified by biome type (B. Walker, H. Nix, D. Graetz to initiate) with a view to ensuring its collection and availability.

(3) Note is taken of on-going analyses of climatic trends and patterns, and the desirability thereof, in Australia (Bureau of Meteorology and University of Melbourne), New Zealand and the South Pacific (New Zealand Meterological Society), Antarctica (University of Melbourne), southern Africa (Tyson) and Argentina (Hoffman and Barros).

3.4.3 Synoptic climatology

(1) There are a number of existing, on-going analyses in Australia CSIRO Division of Atmospheric Research, Melbonrne University and Bureau of Meteorology), New Zealand and the South Pacific (NZMS), southern Africa (Tyson, Chimonyo) and South America (Acetuno and Vaigas, Univ of Buenos Aires).

(2) Applications in verification of GCM output and in regional interpolation from GCM output will be stimulated by the planned Southern Hemisphere climate modelling conference in 1990, the establishment of a network connecting users and modellers, and the dissemination of model output into the regions.

3.4.4 Palaeoclimatic data

(1) The need for improved geographical coverage, especially of the Holocene maximum, would be stimulated by a palaeoclimatic conference, tentatively planned for Argentina in 1990 (T. Partridge and the INQUA Southern Hemisphere committee).

(2) An INQUA palaeoclimatic atlas for the Southern Hemisphere is expected in draft form during 1991. The COHMAP project is another significant initiative. B. Salinger

and B. Pittock are to initiate a critical appraisal of the COHMAP results during 1989.

(3) The coral palaeoclimatic technique developed by P. Isdale at the Australian Institute for Marine Science in Townsville for proxy records of major river flows in tropical regions has great potential. It is suggested that an international workshop be held to facilitate an extension of this technique to other regions (T. Partridge, Isdale).

(4) The existence of large collections of Southern Hemisphere tree ring samples and data at the University of Arizona, CSIRO Division of Atmospheric Research (G. Pearman) and in Bariloche, Argentina is of particular value. Efforts to make full use of this data source should be encouraged.

3.4.5 UV-B Climatology

A scenario for increasing UV-B radiation intensities taking into account ozone depletion and cloud cover should be developed and made available, (P. Fraser, CSIRO Division of Atmospheric Research to arrange for this).

3.4.6 Oceanography

(1) The workshop supports the need for a meeting in 1989 to coordinate the Australian and New Zealand participation in WOCE, and recommends that the IGBP promote this development.

(2) The on-going research in Australia and elsewhere to understand, simulate and predict ENSO is noted and supported.

3.4.7 Co-operation

The planned Southern Hemisphere climate modelling workshop in Melbourne in 1990 should be seen as an opportunity to develop plans for on-going scientist-scientist, and institute-institute cooperation, and the setting up of opportunities for training with appropriate financial support from aid agencies and other sources.

4. EFFECTS OF CLIMATE AND MAN ON AGRICULTURAL SYSTEMS

(In this section the Southern Hemisphere is defined according to the economic criteria, as described in Section 1).

4.1. WHAT ARE AGRICULTURAL SYSTEMS?

In defining agricultural systems in the Southern Hemisphere it is necessary to consider three levels: subsistence, mixed and commercial. All these systems may include food, tree and cash crops. The commercial crops commonly grown include sugar cane, maize, rice and wheat; whole tree crops include apples, citrus, bananas and pineapples. In subsistence agriculture the commonest staple crops include maize, wheat, sorghum and cassava. Mixed agriculture is an important feature of the Southern Hemisphere.

Pastoral systems occur in both tropical and temperate areas. One of the unique features of the pastoral system that distinguishes it from those of the Northern Hemisphere is that it is not necessary to house animals, nor to provide sown pasture or stored feed to livestock during winter periods. Livestock may also be maintained for reasons other than production (e.g., draught power, social value). The tropical areas which are wet are characterised by kikuyu (*Pennisetum clandestimum*), panic grass (*Panicum spp.*) and other tropical pastures, with beef production predominant. In the wet temperate areas, dairy products and sheep meat are produced, while in the dry areas beef, sheep for wool and angora goats are important.

Plantation forestry is another important activity with Pinus and Eucalyptus species dominating. With changes in the nature of ecosystems for plantation forestry, it may be necessary to develop indigenous species to replace the currently cropped species.

Finally, both irrigated and rain-fed systems are important in varying degrees in both subsistence and commercial agriculture.

4.2. IN WHAT WAYS ARE SOUTHERN HEMISPHERE AGRO-ECOSYSTEMS UNIQUE?

The range of farming systems in the Southern Hemisphere is diverse, as is the variety of environmental determinants. Some features are however more common to the southern continents than the farmlands of the Northern Hemisphere and thus provide a basis for collaborative research on shared problems. These include the following:

(i) Soil management. In the ancient shield areas of Africa, Australia and South America there is a predominance of highly weathered soils. These are characterised by low nutrient status and are easily degraded under cultivation.

(ii) Genetic resources. The southern land masses are the site of origin of many of the plant and animal species used in modern agriculture, particularly within the tropical zones. The gene pools have not been fully resourced and demand protection. This area is also a prime target in the search for new species for agricultural introduction.

(iii) Susceptibility to disease. The humid regions of the tropics provide environmental conditions which promote disease development under monoculture conditions. There is a high occurrence of endemic pests and diseases in Africa and South America. Australia by contrast, with a high proportion of crop and animal introductions has a less evolved balance between host and parasite and is particularly susceptible to introduction of new pests and pathogens.

(iv) Mixed farming. The predominance of semi-arid areas characterised by savanna has led to the adoption of mixed farming systems with high interdependence between arable and pastoral components, particularly in the subsistence sector but also in the commercial sectors of more temperate areas of South America, southern Africa, Australia and New Zealand.

(v) Island economies. The Southern Hemisphere, has a very high proportion of the world's islands. These are characterised by food economies dependent on protein of marine origin commonly mixed with a limited range of terrestrial food crops.

4.3 HOW TO IMPLEMENT PROGRAMMES FOR CLIMATE IMPACT ASSESSMENT?

For most practical purposes the impact of climate change on agricultural systems in the Southern Hemisphere should be addressed in terms of the effect of production (biomass accumulation). The optimal way of approaching this is through modelling potential changes on a geographic basis.

For wide application, generic models of agro-ecosystems are needed, i.e., the model must be able to successfully simulate system performance under any combination of environmental and management conditions. Such models are under development in a number of national and international programmes. Of particular relevance is International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) because it has models of the most important food crops and has siguificant Southern Hemisphere participation. While models are available for some tree crops, plantation forest species, crop-livestock systems and agriculture, most of them are location specific and not yet generic. IGBP should play a role in encouraging wider testing of and experimenting with models for Southern Hemisphere application.

Crop growth models depend on information from processes common to all such systems. Ecosystems in general and agroecosystems in particular may be conceived in terms of changes in biomass accumulation. Some processes are common to all, such as:

(i) Energy balance. Potential incident solar radiation is determined by latitude, time of year, slope, aspect and skyline. This in turn affects energy available for partitioning into latent and sensible heat and thus air temperatures and potential evaporation.

(ii) Water balance. Precipitation and evaporation are key climatic inputs, but these are modulated by terrain and soil attributes.

(iii) Biogeochemical cycles. Soil parent material, climatic regime and management treatments will influence key transformations such as nitrogen mineralisation, leaching and plant uptake.

(iv) Other processes that are unique to specific agroecosystems include the genetic programming that controls the growth, development and yield of specific crops, the management related inputs and outputs, and the legal and socio-political constraints that regulate area used, level of production, quality standards, price support, tariffs, marketing schemes and so on.

Thns the primary requirement is for a balanced development of data bases and models of agricultural systems. Primary attribute data common to all land use systems can be identified. These provide a relatively stable foundation for progressive development of operational geographic information systems (GIS's). The following attributes are identified.

(1) Terrain Attributes. Topographic maps are available for most Southern Hemisphere nations at least at 1:250000 scale and for some at a 1:100000 scale. Digital elevation models permit efficient storage of gridded elevation data which can be used to generate estimates of slope, aspect, position in slope, specific catchment area and other variables needed as input to water balance and runoff models. Several nations have digital elevation models and complete coverage of Southern Hemisphere land masses is available from N.O.A.A at 10 x 10 km. For some nations data are available at 5 x 5 km and for some local areas at 1 x 1km or even higher levels of resolution.

(2) Climatic Attributes. Existing meteorological station networks can provide the basis for the calculation of continuous functions or mathematical surfaces for data interpolation. Efficient algorithms exist and surfaces are available for Australia, New Guinea, New Zealand and Africa at 10 x 10 km H. Nix (ANU). Additional work is needed to calculate surfaces for South America and active participation of national scientists would be advantageous. Climatic normals (long term means) for monthly precipitation, maximum and minimum temperature, solar radiation, relative humidity and potential evaporation are required as data input to models. Additional interpolation methods can reduce monthly to weekly or shorter time steps.

(3) Regolith Attributes. The hydrological and biogeochemical attributes of the unconsolidated surface material (including soil) are important inputs to water balance, runoff and ground water models. Geological maps are often available at finer levels of resolution than soil maps. Many nations have or are digitizing geological and/or soil maps, but coverage is patchy.

(4) Hydrological Attributes. Stream flow, unit hydrograph and gronnd water table monitoring provides essential reference data for development and testing of models. Many Southern Hemisphere nations have digital hydrological data.

(5) Land Cover Attributes and Land Use. Of these landcover is a more dynamic property, changing through the year and from year to year. Changes in area used for crop, sown pasture and the area of undisturbed natural vegetation are important in determining the feed-back effect on climate. Remote sensing is a valuable tool for monitoring land cover, but requires ground truthing in each region. In conjunction with statistical data it will enable estimation of rates of change and changes in location of broad categories of primary production, crop sectors and agroecosystems.

(6) Land Tenure. Broad categories of land tenure (i.e., property ownership, cadastral boundaries, legal entitlements and responsibilities) have an important impact on actual and potential land use. Many nations in the Southern Hemisphere have or are developing digital land tenure data.

These data and other data that may be specified for individual agro-ecosystems are most efficiently stored in computer-based geographic information systems.

Each model identifies a specified minimum data set needed for its implementation. This will include the common or core data already identified plus other data specific to that system. The IBSNAT has published manuals and data sheets for collaborating scientists. This needs to be extended to cover other agricultural systems. The manuals give precise recommendations for sampling soils and analysing them for their fertility parameters. They also specify the climatic data required, and the information about particular crops.

4.4 DEVELOPMENT OF AN OPERATIONAL STRATEGY FOR IGBP IMPLEMENTATION

Implementation of IGBP to its fnll potential in the Southern Hemisphere requires development of a strategy that will make the best possible use of the limited economic resources and expertise available in the region, both at the national and international level.

Accordingly, first priority should be given to convincing the scientific commnnity, public opinion, and potential donors that:

i) Climate changes will occur soon throughout the Southern Hemisphere.

ii) Climate change will have a significant impact on all aspects of national life.

iii) The IGBP holds the key to essential hemisphere collaboration, technological transfer and development of generic methodology for impact assessment.

This can best be achieved through the following steps:

(i) Production of preliminary analyses of potential shifts in location of key agroecosystems, sectors and crops.

(ii) Development of national case studies that will help to identify basic needs in terms of data collecting, modelling, training and workshop topics.

(iii) Identification of key international and national programmes that can assist in achieving objectives. These programmes may greatly enhance the effectiveness and interdisciplinary scope of IGBP.

4.5 ACTION PLAN

(1) Develop a 10 x 10 km grid of estimated climatic normals (long-term monthly means) for precipitation, maximum temperature, minimum temperature, solar radiation, potential evaporation for Southern Hemisphere continents and major islands (Centre for Resource and Environmental Studies, Australian National University, Canberra. June 31, 1989)

(2) Geocode (latitude, longitude, elevation) selected representative locations within agricultural production zones for key crops in each continent and major island. This will require the development of a standard coding sheet and will be done by H. Nix, ANU. The key crops should include :

maize
soybean
wheat
sorghum
sugarcane
phaseolus bean
cotton
rice - upland
- paddy
pome fruit (apples, pears)
stone fruit
grapes - table
- wine
coffee
kiwifruit
citrus
sown pasture/beef
sown pasture/sheep

plantation forestry
Pinus radiata
P. patula
P. elliotti
Eucalyptus saligna
E. tereticornus
E. camaldulensis

agro-forestry (alley cropping fodderbank)
Leucaena

acquaculture
Chanos chanos - milkfish
Maciobeactiom rosenbeigi

From June 31, 1989 to December 1989 data collection will be carried out by the following in collaboration with H. Nix.

Professor Mike Swift - SADCC nations

Dr. Nomcebo Simelane - Swaziland

Professor Roland Schulze - South Africa

Dr. Enrique Bucher - Chile, Uruguay, Argentina

Dr. Luis Molion - Brazil

Professor Rafael Herrera - Venezuela

Dr. Jim Salinger - New Zealand

Professor Henry Nix - Australia, Papua New Guinea, Indonesia

(3) Generate predicted distributions of selected production systems given specified climatic scenarios and assess the implications for food and fibre production of national, regional, continental and Southern Hemisphere level.

(4) National and/or regional workshops to explore and discuss implications for planning and development of agricultural production and research needs. (IGBP 1990)

(5) There was a recommendation to have two regional joint IGBP/IBSNAT training workshops in application of generic models, one in Africa in late 1989, possibly in the Cameroons and one in South America mid 1990, possibly in Argentina.

5. INTERACTIVE EFFECTS OF CLIMATE AND MAN ON NATURAL AND SEMI-NATURAL SYSTEMS.

5.1 ECOSYSTEM CHANGE EXACERBATED BY MAN

5.1.1 Introduction

Many ecosystems in the Southern Hemisphere have been subjected to considerable change in the past due to the growth of human population and the consequent demands placed on these natural systems. Thus the impact of climate change will be superimposed on continuing change driven by an expanding human population and its efforts to improve living standards. Many Southern Hemisphere nations are unable to call upon technological innovation and other resources to minimize the impacts of population, climate and their interaction.

It is important to consider separately those ecosystems which will be subjected to the dual impacts of human exploitation and climate change and those likely to be affected by climatic change alone.

In the coming years, many areas of the Southern Hemisphere will continue to show changes related to human use, independently of any climate change. Climate change will therefore interact with the anthropogenic change and generate novel patterns of impact. In some cases, urbanization processes and emigrations will reduce human pressure; elsewhere it can be expected to increase. Whereas in the former, lands that are now being used for woodcutting or grazing may be abandoned to respond unhindered to new climatic conditions; in the latter, land uses will be intensified. Changes in the type and intensity of land use are most likely to result in deforestation or at least a reduction of vegetation cover. Therefore, independently of rainfall changes, these areas are likely to show changes in soil erosion regimes. In many areas of the Southern Hemisphere the relationships between the more intensively modified agricultural, agro-pastoral and pastoral systems will change. This transformation will involve representation on the landscape as well as the capacity to recover from human disturbance.

For many Southern Hemisphere ecosystems, particularly those in South America and Africa, their resilience to human impacts is largely unknown as are the likely responses of these systems to conditions of higher temperatures and/or rainfalls.

The ecosystem types requiring most urgent attention are tropical forests and the arid and semi-arid shrublands.

In Australia, Africa and South America there are areas in which all these ecosystem types are represented, and due to social and economic reasons they are likely to experience very different influences of climatic changes and human demands. Therefore, the comparative study of the responses of these ecosystems will provide a unique opportunity for scientific investigations unravelling the roles of climatic change and human impact. The combined effort of scientists working in the three continents provides the best and most economical way to increase our understanding of the expected changes.

5.1.2 Salinization

Salinization is a common feature of soils in parts of the Southern Hemisphere subjected to deforestation for agricultural purposes. Water tables are elevated due to increased percolation, leading to the upward migration of the soil water table.

Climatic changes might be expected to impact on these processes either by increasing or decreasing ground water levels. In those situations where salinized ground water can enter river systems, salinity problems will be either exacerbated or reduced, depending on concomittant changes in catchment and stream flow.

5.1.3 Air and water pollution

Air and water pollution is a common consequence of human population pressures, particularly in urban areas. The impact of the release of particular substances into the local environment depends on the effective size of the reservoir into which the release takes place. In the case of air pollution, this will depend on wind velocities and vertical mixing rates which in turn might be expected to change as a result of climatic change. Similarly, where pollutants are disposed of into rivers or streams, their deleterious effects will be modified by the stream flow which in turn will be expected to change with climatic change.

5.1.4 Volcanic activity

In a very wide sense volcanic activity is a simulation at local and regional level of rising levels of anthropogenic trace gases in the atmosphere, acidic deposition, deforestation by fire, by mass movements, by ash deposition and killing of vegetation by landslide, and inundations.

South and Central America are currently in a period of major volcanic eruption, and it is not known if they are linked with more regional patterns of biotic changes such as plankton extinction over wide areas. There are short term impacts such as ash deposition, changes in atmospheric chemistry, and turbidity which affect local and regional climate.

5.1.5 Fire

There are two types of response of vegetation to fire. One is the result of long periods of co-evolution with fire and the other, where the vegetation is not linked historically with fire. The latter response most commonly where Man has changed the frequency and intensity of fires such as the increased frequency of fires in the tropical rain forest. An understanding is required of the effects of fire regimes on the processes which govern vegetation change, i.e., germination and establishment, growth and competition, seed production, dispersal or removal of seed, mortality.

Fire is used to clear forests in subtropical and tropical South America at a rate of well over one million hectares/year, for example in the Province of Rondonia in Amazonia. This provides the opportunity for studying sensitive areas in which rapid changes are taking place through a massive use of fire for clearing.

The main fire-induced changes occur in soil properties, in atmospheric chemistry, and land use patterns. Recent research has shown that the common and widespread practice of biomass burning affects not only the exchange of CO_2 between hiosphere and atmosphere, but can be a major source of other important atmospheric trace gases.

It is suggested that Porto Velho in Rondonia, Brazil could be the site of an observatory for recording fire consequences on tropical rain forest and the Universities of Chile and Argentina will similarly observe temperate humid and Mediterranean-type vegetation of South America.

5.1.6 Grazing

Rangelands are an important land use in Southern Hemisphere continents; their importance is determined either by the number of people who use them (e.g., African nations) or the economic wealth that they generate (e.g., Australia, Argentina). Most of the rangelands are semi-arid grasslands or shrublands or subtropical savannas. Different land use systems have evolved to exploit the pastural resources of the various landscapes. The patterns of use, the livestock grazed etc. reflect both the social and climatic setting of the area. Climate change, however, expressed in these various rangelands will precipitate change in pastures, livestock, patterns of use and dependant human populations. These interactions are only qualitatively understood. Quantitative, predictive understanding is required to cope with climate change.

5.1.7 Inundation wetlands

In wide and flat areas of the wet savannas, inundation means a rapid change in land use, a seasonal or inter-annual change in biogenic activities including gases generated in shallow waters through decomposition of biogenic material and little is known of the distribution of plankton biomass or of the macrophyte biomass before, during and after inundation.

International co-operation is needed to mount regional and comparative observations and process studies of the following subjects.

(1) Seasonal distribution of the constituents of the CO_2 system in large wetlands.

(2) The physical, chemical and biological processes in regulating methane formation.

(3) Significance of the movement of shallow waters in transporting biogenic material and in the delivery of suspended sediment and dissolved material.

(4) Effects of patchiness of terrestrial ecosystems on survival of animals and plants.

(5) Study of water-borne diseases in wetlands or their borders which have been changed by man, mainly by rice culture. A suitable observation point would be the Institute of Applied Ecology from the CONICET in Argentina, which is well equipped for inundation studies located in the middle Pirahna river.

5.1.8 Exotic biota

From a practical point of view, introduced species which perform well in their new biographical areas can be considered as important either for economic primary production, or as pests. The exchange of genotypes, races and species have produced a certain impact on natural ecosystems that undoubtedly will change with climatic change as will the competition between exotic and local species.

In tropical South America, African pasture grasses such as *Panicum maximum, Pennisetum clandestinum, Hyparrhenia* spp. and possibly, *Imperata cylindrica* have successfully invaded large areas in the savanna and forest biomes (the latter following clearing). These invasions are of undoubted economic importance but have received scant attention from researchers. The same applies to the widespread replacement of native herbaceous species by European grasses in humid Mediterranean climate regions.

Finally, we know very little of the determinants of community dynamics in these invaded ecosystems with their recent admixture of species having widely divergent biogeographic origins.

5.1.9 Aquatic ecosystems

A wide variety of important aquatic ecosystems and wetlands occurs in most regions of the Southern Hemisphere. Obvious examples are rivers of the Amazon and Congo drainages, the former with exceptionally rich fish and other faunas. Remarkably diverse fish faunas are found in the lakes of central Africa, notably Lake Malawi. In Africa and South America, vast tropical wetlands such as the Okavango Swamps and the Pantanal dominate the terrestrial landscapes and local economies, and are already under threat from human development. The lakes of southern Chile are the basis for important economic development.

These aquatic ecosystems are extremely vulnerable to climate change because they depend on runoff which is the difference between two large quantities, rainfall and evapotranspiration. Small variations in either cause large fluctuations in aquatic habitats. It is likely that changes in these systems will provide early signals of greenhouse effects.

5.2 CONSEQUENCES FOR THE CONSERVATION OF ECOSYSTEMS AND THEIR BIOTA

The consequences of global climatic change for nature conservation are profound. Not only will the selective pressures on individual species change more rapidly than at any previous time in their evolution, but the opportunities for dispersal to more favourable habitats will be significantly reduced because of the extensive transformation of natural communities that has followed agricultural, industrial and urban development.

The challenge to conservation biologists includes developing an improved understanding of the climatic determinants of the distribution and abundance of species and ecosystems of special importance to the maintenance of biological diversity, and developing systems for the conservation of species and ecosystems that are not dependent only on networks of protected areas.

The latter challenge addresses the problem inherent in the limited size (less than five percent of the global terrestrial surface area) and disjunct distribution of potential parks and reserves. The location of such protected areas in transformed landscapes is analogous to islands in a vast sea. For many of the species within these islands, opportunities to disperse along changing environmental gradients will not exist, and local or regional extinction rates will rapidly increase.

Species with better dispersal capabilities (birds, wind dispersed plants, etc.) might be able to persist through 'island hopping' along chains of changing habitats. The most dramatic impacts of climate change on ecosystems and their biota might be expected in communities, where altitudinal migration is impossible, and in restricted wetland or estuarine habitats which will disappear through desiccation, through the advent of a warmer, drier climate or rapid inundation through a rise in sea-level.

5.3 THE FFEDBACK OF CLIMATE-INDUCED VEGETATION CHANGE ON FURTHER CLIMATE CHANGE.

At any point on the Earth the weather can be described by the exchange of electromagnetic energy (radiation), mass (H_2O, CO_2, CH_4) and momentum between the vegetated landscape and the atmosphere. These exchanges averaged over time provide a quantitative description of the climate experienced by that surface.

Climate is the dominant factor in determining the composition, abundance and dynamics of vegetation at any location. Its influence on the soils and geomorphology is also very important but is over far larger time scales.

The characteristics of the Earths surface, the vegetation and the underlying geomorphology influence the exchanges of energy, mass and momentum between the surface and the atmosphere. The land surface is not a passive component of the climate system.

The anthropogenic increase of greenhouse gases, principally CO_2, in the atmosphere will, by the processes of atmospheric warming, generate new spatial patterns and intensities of energy, mass and momentum with the Earth's surface, i.e., climatic change. This climate change will, in the short term, i.e., less than 25 years, catalyse change in vegetation structure, dynamics and composition. Where these vegetation changes significantly affect the patterns of energy, mass and momentum exchange between the surface and the atmosphere, they constitute a feed back on further climate change. The sign, strength and relative importance of this feedback can only be explored within GCMs. Within these models the vegetated landscape will interactively determine the boundary conditions of the lower part of the atmospheric circulation. To be represented, the three dimensions of vegetation, structure, dynamics and taxonomy must be parameterized in terms of energy, mass and momentum exchange. That is, the dimensions of vegetation familiar to ecologists must be translated into the parameters of albedo, evapotranspirations and surface roughness (Henderson-Sellers and McGuffie, 1987) at the very minimum. A model parameterized in such a fashion may be termed a General Biopshere Model (GBM).

A quantitative understanding of this feedback of vegetation on climate is critical to the development of realistic GCM/GBMs at all spatial scales. This realistic modelling capacity is the only source of spatially referenced forecasts suitable for managing the responses to climate change.

The scientific issues :

i) What are the relationships between vegetation structure, dynamics and taxonomy and the parameters of albedo, evapotranspiration and surface roughness?

ii) What data sources and methodologies are required to remap landscapes into units that are homogenous with respect to albedo, evaporations and roughness.

iii) How to scale up or represent spatially heterogenous landscapes to the level of aggregation (say 100 x 100km) used in GCM/GBMs?

iv) What is the significance to the global carbon cycle generally and the atmospheric CO_2 concentration in particular, of reforestation and harvesting for fuel wood?

5.4 FRAMEWORK FOR RESEARCH ON THE SENSITIVITY OF ECO-SYSTEMS AND THEIR COM-PONENTS TO THE EFFECTS OF HUMAN ACTIVITY AND CLIMATE CHANGE

5.4.1 Background

Certain Southern Hemisphere ecosystems and their species will inevitably disappear or diminish markedly with climate change. For example, the alpine and montane ecosystems and those confined to habitats along coastlines or other insurmountable barriers to migration.

In addition, some ecosystems and species will be more sensitive to the effects of human activity, whereas others will be most sensitive to climate change. For example, Mediterranean-type ecosystems that are shaped by the duration of summer droughts are likely to be supplanted by the communities of more arid habitats if climate change involves a lengthening of the summer drought. In contrast, the wet equatorial rainforest will likely be little affected by increases in ambient temperature of 2-3°C, but would be markedly favoured if temperature increases were accompanied by higher rainfall. In many cases, biomes extend over a wide range of climatic conditions, biogeographical theory notwithstanding. The mesic, dystrophic savannas of central and southern Africa and of central Brazil (the cerrado) are examples of systems whose distribution extends across a wide range of climates, and through much of their extent they are unlikely to respond quickly to anticipated climate change.

Surveys and experiments under contemporary conditions have indicated climatic factors which determine the boundaries between ecosystems or the limits to the distributions of the populations of individual species. But these studies have been confined to particular cases, and take little account of the fact that individuals at the limits of a species' range are subject to a variety of controlling factors, often stress-mediated, which act synergistically with climate to limit the spread of the species. Many examples are available which illustrate the lack of perfect correlations between climate and distribution, one of the most striking being the sclerophyllous shrublands of South Africa (the fynbos) and Australia (heathlands) which extend well beyond the limits of Mediterranean climate, wherever highly leached soils occur.

Also of importance is the fact that interannual variations in climate are important in mediating the co-existence of species. For example, the onset of monsoonal rains in north east Australia varies within about a six-week period. Depending on the time of their arrival, different plant species tend to dominate the seasonal wetlands of this region, but because the seasonal fluctuation persists, so do all the species of the community - none is allowed sufficient time to dominate and exclude others. Climate change involving a shift in regime could disrupt this balance.

The effects of human activity on ecosystems are obvious where land transformation is involved. But complicated interactions between disturbance and climate operate when less destructive activities such as grazing are involved, and also when ecosystems are recovering from disturbance. A good example of the former is the variable fluctuation on its eastern boundary of the Karoo in southern Africa, driven by climate variation and overgrazing acting together.

Ecotypic variation within a species is often very marked and will confer a capacity to adapt to climate change that will be important in many instances. Good examples are found among Eucalyptus species for both arid and semi-arid environments (*Eucalyptus camaldulensis*), and those of cooler, more humid habitats (*E. regnans, E. nitens*). This will be of little conseqnence if the rate of climate change exceeds the capacity for migration, or if populations are fragmented in their distributions by historical factors or by human disturbance.

What we lack is a general theory of climatic control on the distribution of organisms and hence on the boundaries between biomes. Without this we will not predict the effects of climate change adequately, nor disentangle the relative roles of climate acting directly on organisms through recruitment, fecundity, and mortality on the one hand, and the indirect effects via the soil on the other.

It is likely that the sensitivity of ecosystems to climate change and human disturbance is a function of the following:

i) the number and kinds of plant functional types in the community;

ii) secondary responses in ecosystem processes, such as in the fire regime;

iii) physiographic and climate variables determining the rate of erosion following disturbance and climate change;

iv) the impact of disturbance on soil organic pools and mineralisation processes;

v) the patterns of disturbance in the landscape (insular effects, etc.).

5.4.2 Approaches

Improvement in predictions of ecosystem response to climate change requires improved understanding of ecosystem sensitivity. There are a number of approaches to achieve this.

(1) Surveys and monitoring. Examples include: i) The distribution of C3 and C4 grasses on the slopes of the Drakensberg in South Africa vary according to altitude and aspect. Responses may be inferred from this. ii) Surveys of the duration of the summer drought and the related changes in species performance in Mediterranean ecosystems, and also at the transition to arid formations. iii) Treeline areas, the effects on frost, recruitment, iv) to record the differential migrations of species in response to inter-annual climate variation.

(2) Conventional field experiments. The use of long-running field grazing trials which exist, for example, in South Africa (Middelburg) and in Australia (South Australia). The data should be re-analysed in relation to the Southern Oscillation Index (SOI)

(3) Novel field experiments. Omnibus trials and whole ecosystems experiments, using fertiliser/irrigation such as those conducted for plantation forests.

(4) Bioclimatic modelling

(5) Investigation of extinction processes.

5.5 METHODOLOGY

5.5.1 Extreme events

The significance of infrequent, extreme events in shaping ecosystems is gradually being recognized by ecologists. Owing to the nature of Southern Hemisphere climates these events have been given more attention by Southern Hemisphere ecologists than by their northern colleagues. The means of climatic variables such as temperature and precipitation, can be closely correlated with physiological performance, whereas the population dynamics or demographic aspects of ecology appear to be shaped by both the mean and variance of climatic variables. In particular, the extreme values of climate factors, e.g., the very wet or the very dry periods, determine the population dynamics by influencing natality or mortality. Similarly, the infrequent coincidence of two extremes, e.g., low rainfall combined with say low temperatures, may exert greater influence, determining the composition and abundance of communities for long after the event. Community structure and dynamics are event-oriented and event-driven.

Explicit recognition and acceptance of this concept has important implications for the design of field experiments and ecological modelling.

First, analysis of existing climate records for any proposed field site would reveal the expected frequency of hypothesized critical events. If this is so low that the probability of experiencing these within a five year experimental period is, say less than 20%, then experimental manipulation (e.g., rain out shelters, irrigation, fire, and so on) must be used.

The second and less common implication for field research concerns sampling frequency. If the objective is to observe the ecological response to an infrequent event, then frequency of sampling must be greater than those of the catalytic climatic event by (preferably) a factor of two. For example, if the hypothesized climate-driven event, a germination say, has a frequency of occurrence of twice a year then a sampling frequency of, preferably, four times a year is required to capture the ecological response to this event.

5.5.2 Scaling

The geosphere-biosphere can be characterised by scale-dependent processes; the scale dependency of the biosphere being particularly critical and less well understood compared with that of the atmosphere and oceans. Because we seek understanding of the interactive coupling of the geosphere and biosphere, we must be able to integrate across the space and time scales that are characteristic of each system. This task is therefore basic to IGBP. The pivotal nature and the difficulty of this task has been acknowledged but widely accepted conceptual- or empirical-methodologies are lacking (Rosswall, et al., 1988).

Two approaches appear profitable for ecologists contributing to the IGBP. The first is to critically examine the applicability of hierarchy theory to the design of field experiments (O'Neill et al., 1986). This theory is conceptually appealing and deserves the critical appraisal of practising field ecologists. Because it is hierarchical it offers a scaling in both time and space.

The second contribution may come from the empirical spatial scaling that can be derived from the application of fractals to the description of landscapes. Vegetation and landscapes appear to be fractal over restricted spatial scales. Therefore where there are changes in the self-similarity of landscapes or vegetation, this represents a 'natural' spatial scale for stratification. The assumption being that within the spatial scales of self similarity, aggregation is linear and additive (Krummel et al., 1987). A change or break in the self-similarity then requires an explicit reconciliation between the two scale domains of spatial scale.

The whole question of stratification of landscape is critical to the field ecological efforts of the IGBP. Stratification is essential and its basis must be explicit. For example when considering the feedback of vegetation on further climate change, the stratification required would be based on albedo, roughness or evapotranspiration; a classification and grouping of the landscape quite unfamiliar to ecologists. A new taxonomy will evolve to facilitate this and the other objectives of IGBP. For example, plant species will be grouped into plant functional types (PFTs) and structural communities grouped into vegetation functional types (VFTs) to catalyse the functional simplification of landscapes and facilitate integration across spatial scales.

5.5.3 Remote sensing

The IGBP has been created to address the interactions and influence of global change on local phenomenon. We face scientific tasks that are unique in the history of ecological research. The tools of traditional field ecology must be transformed and supplemented to tackle the problems of observation and analysis of locally-aggregated systems to global-systems. The single, most powerful addition to the methodologies to ecologists is that provided by remote sensing, especially that provided by spacecraft. The capacity of satellite data to contribute enormous insight into the functioning of terrestrial ecosystems on a global scale has been most convincingly demonstrated by Tucker et al., 1986.

The data gathering capacity of satellite systems varies from the high spatial and spectral resolution of the LANDSAT series of space craft which has a long (16 day) repeat cycle, to the coarse spatial and spectral resolution of the NOAA AVHRR series with a short (± 1 day) repeat cycle. New satellite systems with enormously enhanced observing capacity are being designed for the EOS programme to begin in 1995.

The power of satellite data is determined by its spectral, spatial and temporal dimensions. The key to its utility lies in the spectral dimension. Satellite spectral data can only be transformed to ecological information if there exists a quantitative model that relates how the landscape attributes of soil and vegetation are captured within the spectral space. Once this model has been developed it can be inverted; the spectral data from the satellite being used to produce estimates of the surface attributes, e.g., the cover, biomass of vegetation (Strahler et al., 1986)

Once this spectral modelling has been done, the considerable utility and power of the spatial and temporal dimensions of remotely sensed data can be harnessed. Satellite data are a 100% sample of the landscape ; aggregation or scaling up of such data within a GIS becomes a simple task. Most satellite systems have a repeat of 1 - 10 days, far smaller than most phenological timescales, 1 - 2 days, and so will capture most of the spectrum of dynamics of landscapes, isolated disturbance (1 day) excepted.

5.5.4 Modelling

The task facing the IGBP is to develop predictive models, at appropriate time and space scales, of the changes in vegetation which will occur in response to given changes in climate and atmospheric composition. These models will need to be biome-based, to take into account those features which are characteristic of the biomes concerned. The aim is to develop a minimum set of such "generic" biome models, each of which would be parameterized in different ways to represent particular sites.

The general structure of these models is to be developed further by the IGBP Co-ordinating Panel on Effects of Climate Change on Terrestrial Ecosystems. The Southern Hemisphere scientists need to be closely involved with this effort. The models should be as simple as possible, ensuring a combinatiou of a rule-based (expert system) approach and dynamic simulation modelling. They should build on existing models, but must include three important features, which have thus far been largely ignored :

i) the response times of species adaptation and dispersal relative to the rate of climate change (i.e., the transients),

ii) the changes in the nature and frequencies of rare/extreme events,

iii) the changes in secondary effects (such as fire, insect irruptions).

5.6 ACTION PLAN

5.6.1 Introduction

Substantial ecological programmes have been maintained in the savannas and the Mediterranean ecosystems. These should form the basis of ecosystem research in the IGBP Southern Hemisphere effort. Early contact should be made with the Responses of Savannas to Stress and Disturbance (RSSD) Programme of the Decade of the Tropics, and ISOMED.

Any new research and monitoring must be hypothesis-driven to ensure maximum effect. The appropriate hypotheses must be derived from conceptual as well as explicit numerical models of the systems of concern. Past work will allow for effective development of the necessary models, and indeed current thinking and modelling will readily accommodate the new needs arising from IGBP. The hypotheses derived from modelling will also allow the sensible selection and analysis of time-serial and other data from both old experiments and monitoring programmes as well as the proxy records from tree-rings, glacial cores, sediments, and hyrax middens.

5.6.2 The Feedback effect of Southern Hemisphere vegetation

High priority should be given to identify the so called 'vegetation prospective types' in the sense that they already are functioning in local or regional climatic conditions which are similar in several parameters to some future scenarios.

High priority should be given to improving the parameterization or description of Southern Hemisphere landscapes such that they can be better represented within GCMs/GBMs (most of which are located and operated in the Northern Hemisphere). A critical strategy for this is to:

(i) Use existing data sets of (structural) vegetation type and elevations to map the surface roughness of continents at a spatial resolution of less than 1 degree.

(ii) Use archived satellite data to map the mean and variance of landscape albedo at a spatial resolution of << 1 degree and relate this to vegetation structure, composition and phenology.

(iii) Use archived satellite vegetative index data to map the mean and variance of landscape "greenness" and relate this to evapotranspiration and primary productivity (e.g., Tucker et al., 1986).

It is equally important to ensure that these parameterizations are made available to the GCM/GBM as soon as is possible.

5.6.3 Development of conceptual and numerical models

A first task of the Southern Hemisphere programme is the identification of the minimum set of biomes for which generic models need to be developed. A preliminary suggestion, with possible organisations / individuals responsible for their development, is:

i) tropical rain forest;

ii) woodlands/moist savannas (RSSD; J.-C. Menaut, I. Noble, E. Medina);

iii) semi-arid savannas (RSSD; R. Scholes);

iv) Mediterranean-type vegetation (ISOMED, Fuentes, Kruger);

v) hydromorphic grasslands (hyperseasonal savannas).

Two parallel workshops should be held in early 1990 to develop the necessary approaches to and structure of the models needed to address the effects of global change in savannas and Mediterranean ecosystems, the latter understood to include the transition to adjacent arid lands. These workshops would build an the findings of the SCOPE and IGBP Woods Hole workshops due in April/May 1989, which plan to address the problem of the most appropriate modelling structure for IGBP purposes.

These workshops should achieve the following:

i) effective strategies for modelling the two biomes, including provision for spatial analysis (Geographic Information Systems), and prediction from locatioual data of ecosystem function (plant available moisture, available nutrients and their seasonalities), ecosystem structure (VFTs, PFTs), secondary responses, especially fire and the effects of herbivores, pathogens and predators on distribution, and formal linkages with weather and climate predictions;

ii) basic structures, or software suites, for the models;

iii) an approach to establishing the necessary data bases;

iv) experimental and monitoring protocols derived from model-based hypotheses, also includiug the links with remote-sensing experiments;

v) international coordination.

Global climate modellers should be involved in these workshops, with a view to developing the necessary specifications regarding climate data needed for ecological modelling, as well as to corroborate the modelling feedbacks.

It is recommended that the workshops receive core funding from IGBP but would otherwise be supported by funds raised nationally or bilaterally. F. J. Kruger and E. R. Fuentes could take the initiative for the workshop on Mediterranean ecosystems and R. J. Scholes for savannas.

5.6.4 Palaeo-environmental studies

Active groups are working on the palaeo-environments of South America (CONICET and Tucson), Australia, and South Africa. It is recommended that the SSC "Global Changes of the Past" should convene a meeting of the Southern Hemisphere groups.

5.6.5 Additional activities

(1) Exotic biota : Modelling of invasions.

(2) Diseases (Schistosomiasis, etc.) : Modelling of epidemiology.

(3) Links with Macro-economic scenarios. The GBO networks should be approached to devise monitoring strategies within the framework of the new models, as well as to re-analyze old data in the same light.

(4) Raiu forests. Very large national, bilateral, and international programmes are presently under way but the measure in which they relate to IGBP is not clear. T Rosswall to investigate.

(5) Aquatic systems. Linkages should be developed at first through the IGBP Co-ordinating Panel 3.

6. EFFECTS OF CLIMATE CHANGE ON MARINE AND COASTAL ECOSYSTEMS AND RESOURCES

6.1 RATIONALE

It is assumed that the Joint Global Ocean Flux Study (JGOFS), the World Ocean Circulation Experiment (WOCE) and other international as well as some national scientific programmes are making, or planning, contributions to the knowledge base that are needed for understanding and predicting global climate change. However, apart from cursory mention of the impacts of changing sea levels and mechanisms influencing primary prodnction, there is no specific brief within the IGBP for assessments of the potential impacts of climate change on marine and coastal ecosystems and their resources. This is a serious omission, as no other co-ordinated programme is yet addressing these issues on a global or hemisphere scale.

Future global changes during the next century may be expected to have large impacts on the oceans, which in turn can affect the marine ecosystem, particularly in the Southern Hemisphere where the oceans are so dominant.

6.2 DRIVING FORCES

The types of changes that may be expected include the following:

Temperature increases in the tropics could reach over 2°C, and around the Antarctic in excess of 5°C, for the annual mean. This change would be associated with a large reduction in the Antarctic sea ice and a reduction in the north-south temperature gradient, along with a shift in the pattern of sea-surface isotherms. As a result of this, there may be corresponding changes in the strength of the Southern Hemisphere westerly winds which affect the ocean currents, the strength of the circumpolar flow and the "Southern Ocean" gyres. The eastern boundary currents and coastal upwelling would also be affected with consequential major changes in marine habitats.

The reduction in the sea-ice formation could decrease the formation of deep water which is an important driving force of the deep ocean circulation. The sea-ice zone also plays an important role as a habitat for ice algae and for biota which play a central role in the antarctic marine food chain.

The changes in the ocean's physical properties and circulation are expected to be relatively large and rapid compared to past changes, which means that the marine biosphere may not be able to readily adapt to the changes.

A further change of major concern is the reduction in the stratospheric ozone already noticeable in the Antarctic, particularly in spring. If the reduction spreads farther north, the marine biosphere in the upper ocean could be strongly impaired by the increased Ultra-Violet radiation. Should phytoplankton be seriously affected, this would have an impact on the whole food chain.

6.3 LIKELY IMPACTS OF GLOBAL CLIMATE CHANGE

Some of the more obvious marine ecosystems, resources, processes or structures that are likely to be influenced by global climate change include coastlines and coastal developments, mariculture and marine fisheries, open sea marine habitats, biodiversity and primary production. These aspects are considered briefly below.

6.3.1 Coasts in the Southern Hemisphere

There is general scientific consensus that global climate warming will cause a rise in sea level of tens of centimetres by the year 2050. This will directly affect human settlements in coastal areas. Such coastal development in the Southern Hemisphere consists of a spectrum of hard first-world structures such as harbours, bridges and high-rise buildings through soft third-world habitats, e.g., those adjacent to coastal wetlands.

Sea level rise will erode soft coasts, cause increased salt penetration into estuaries and, in the case of extreme events such as cyclones and associated storm surges, a sea level increase may incrementally but significantly affect coastal processes as well as geographic coastal configurations.

General climate change will probably also affect the intensity, frequency and geographic range of extreme events, such as cyclones. This will have a direct impact on coastlines through a change in wave climate and change in sediment transport rates and patterns.

Ocean mining on coastlines, such as diamond mining off South West Africa/Namibia, may be strongly influenced by a rise in sea level, a change in wave climate and associated changes in littoral sand transport. Oil and gas exploration and exploitation on continental shelves will also have to take cognisance of changed wave climates in the design of structures and their operations.

In all the above cases where climate change will affect coastlines, Southern Hemisphere countries are hampered by a lack of data and understanding of present systems and processes, the ranges of present natural variability and therefore estimates of future impacts of rapid global change.

6.3.2 Marine fisheries and mariculture.

Fisheries are of considerable importance to many of the Southern Hemisphere's coastal nations. Annual harvests of marine fish from the Southern Hemisphere are of the order of 25 million tons, but are subject to considerable fluctuations and contribute a disproportionate share of the variability associated with the overall world catch of about 75 million tons per annum. Of particular importance are some of the epipelagic species, notably sardine and anchovy, associated with eastern boundary currents off Chile, Peru, South Africa and Namibia. For some species there is accumulating evidence from congruent patterns in widely separate parts of the world's oceans, and concordance of these with global environmental indices, that both levels of abundance and patterns of distribution are influenced by global climate change (e.g., Kawasaki 1983, Crawford and Shannon 1988).

Whereas early life stages are notably susceptible to processes that influence survival, such as advection and turbulence (Parrish et al., 1983), older forms have shown a remarkable propensity to extend or alter their distribution when changes in factors such as wind stress have resulted in an extension or alteration of favourable habitat (Gulland and Garcia 1984).

The dependence of early life stages on local conditions, and the mobility of populations as a whole, mean that both fish production and its distribution will be highly sensitive to changes in factors such as wind stress, the location of trade winds and their orientation relative to the coastline, inshore temperatures and the location of fronts.

Expatriation of pelagic fish larvae from their preferred spawning grounds, will disrupt their ontogenetic pattern of migration, affecting the viability of populations as a whole.

The reduction in size of habitats shared by several species will, during the transient phase of climatic change, necessarily increase the rates of intra- and interspecific encounters, and could exacerbate competitive and predatory interactions. These effects, in time, could start a sequence of events affecting the species composition of large, very productive ecosystems.

Changes in the species composition of phytoplankton might have a direct impact on the production of higher tropic levels by changing permanently the size composition of food for herbivorous fish.

Valuable inshore resources include rock lobsters which apparently depend on basin-scale gyres to return juvenile life forms to breeding grounds (Pollock 1989). Any slowing in the circulation of these gyres as a result of their spin up/down due to changing wind patterns could have significant implications for the viability of the resources.

Mariculture is an important source of protein and, in the Southern Hemisphere, is a rapidly expanding industry. It is often dependent on relatively stable sea conditions and, because preferred sites are coastal, likely to be greatly influenced by changes in sea level and intensity or frequency of storms.

6.3.3 Marine primary production

The predicted change in global climate is expected to influence primary production in the marine environment. The effects should be more readily detectable at high latitudes in the "Southern Ocean" and in Southern Hemisphere eastern boundary current systems than elsewhere. A major reason for this is that the potential strength of factors, such as UV radiation and wind stress, is likely to be greater in high southern latitudes than elsewhere.

A change in primary production will affect the global CO_2 budget. A further possibility is a change in cloud cover, as a result of altered concentrations in the "Southern Ocean" of algae emitting dimethyl sulphide (DMS).

6.3.4 Marine habitats

One of the most direct effects of climate change in the oceans will be the expansion/contraction of pelagic habitats, both neritic and oceanic, affecting the distribution and survival of many species.

Most marine organisms have early stages in their life cycles that are small-sized, fragile and planktonic, and therefore vulnerable to changed environments.

Habitat modification will not only be mediated by changing patterns of temperature and salinity distribution, but most importantly, by changes in the circulation. Accordingly, the prediction and selection of realistic scenarios with respect to the patterns, intensity and variability of ocean currents is an intermediate goal within the continuing efforts for modelling global climate of particular importance for marine ecosystems.

In the interannual domain of variability, ENSO represents a perturbation for marine ecosystems that, from a physical point of view, has strong similarities with scenarios that can be reasonably inferred from expected trends in global climate change. Therefore it is suggested that ENSO can be used, with great advantage, as an analogue of those changes. The monitoring and further understanding of the effects of ENSO on pelagic ecosystems is a task highly relevant in the context of IGBP.

Finally, inshore marine habitats are significantly influenced by the discharge of fresh water, nutrients and silt from rivers. Changes in the terrestrial hydrological cycles under climate change will lead to marked changes in the kinds and amounts of river discharge into the ocean.

6.3.5 Marine biodiversity.

Species dependent on estuaries or islands will probably be especially sensitive to global climate change. The properties of estuaries may be substantially changed leading to species extinctions. In this context, the highly specialised communities of mangroves deserve special attention. The distribution of seabirds and seals may be altered if islands of low-elevation are swamped, and species may be forced to breed at localities far removed from their feeding grounds. Equally, shifts in the locations of prey distributions may mean that present breeding sites become no longer favourable for species such as penguins that have limited foraging ranges.

The sex of some turtle hatchlings is determined by the ambient temperature during their incubation (Hughes 1988). Altered temperatures of a few degrees could skew the sex ratios with significant consequences for populations. Turtles generally return to the same nesting beaches and with the relatively very rapid rate of climate change (compared to past changes) may not of their own accord move to areas where ambient temperatures prove more suitable.

These few examples suggest that global climate change could have a significant impact on biodiversity.

6.4 PALAEOCLIMATIC MARINE RECORDS

The need for extending climatic records into the past is of particular importance for the data-sparse Southern Hemisphere. The use of proxy data obtainable from coral reefs, for example, is a technique that could be applied with considerable success to certain specific sites in the Southern Hemisphere such as East Africa and eastern Australia.

The same need exists for the biological response of marine ecosystems. Varved sediment deposits in anoxic basins in eastern boundary currents provide a unique record of past changes of the species composition and abundance of major components of pelagic ecosystems, in particular fish populations.

6.5 ACTION PLAN

6.5.1 Coasts

(1) Detailed case studies on the effects of sea level rise on a few generic coastal regimes in the Southern Hemisphere. These might include a characteristic coastal wetland, a large river and a beach resort. The purpose of the reports on these case studies would be to establish suggestive scenarios to stimulate further national studies of the kind. A possible mechanism would be an ad hoc working group with international participation to select the areas and initiate the studies.

(2) It is recommended that the Special Committee for the IGBP should approach the Permanent Service for Mean Sea Level (PSMSL) with an offer to help in encouraging certain countries to make their tidal records available to the PSMSL, and should also support and encourage the establishment of new sea level gauges, particularly along the African and Antarctic coasts and at remote Southern Hemisphere islands.

6.5.2 Fisheries and mariculture

Establish a working group to define a study of a limited number of marine pelagic ecosystems in the Southern Hemisphere that are expected to be strongly affected by global climatic change. The selection of these ecosystems should be based upon the following criteria:

i) the magnitude of the potential impact of climatic change on their structure and function;

ii) the importance of their main biotic components as renewable resources;

iii) the feasibility of conducting comparisons and sensitivity analyses of goal-oriented single process models to global climate change; and

iv) the potential for developing a generic coupled-process model, that on the basis of the high level of commonality of oceanographic and ecological processes structuring them, could increase the basic understanding of their dynamics, in an effort to predict their response to global climatic change.

The following areas of research have high priority within the project.

1) The study of distributional changes of key species, their early life history stages, and some functional groups, by simulating the expansion, contraction or dislocation of their normal habitats as derived from predicted changes in the temperature and salinity fields, and changes in wind stress and ocean circulation.

2) Comparative studies among selected ecosystems with regard to processes shown by such modelling to be of special importance.

3) Design of a programme to monitor the temporal and spatial variability of chlorophyll and primary production using remote sensing, and to validate the information through ground truth studies. The further development of experimental work to improve existing algorithms for primary production is a relevant goal in this context. Collaboration with JGOFS is essential, since this study has similar goals, though the scale of interest may differ.

Initiators: P. Bernal, P. Shannon and R. J. M. Crawford

6.5.3 Primary production

Two preliminary modelling studies are tractable.

(1) Investigating the likely influence of global climate change on the distribution and magnitude of primary production and carbon flux in the highly productive areas of (i) the "Southern Ocean" and (ii) the eastern boundary current systems. Collaboration with the work of CP2 is important.

(2) A working group be convened to investigate the possibility of using simple models to simulate changes in the two major eastern boundary current systems in the Southern Hemisphere. The group should finalise planning in 1989 and modelling in 1990. Suggested participants from South Africa are P. Brown, K. Cochrane and M. Lucas. Suggestions for participants from other nations are called for.

6.5.4 Biodiversity

A working group be established to inventory areas that would be especially sensitive to ecosystem change in regard to conservation and to suggest scenarios for modelling the impact of expected global climate change. A final report would be prepared in December 1989 immediately after the Conference on Geosphere-Biosphere Change in southern Africa to be held in Cape Town. Suggested participants from South Africa are W. R. Siegfried, R. J. M. Crawford and G. Hughes, and suggestions for other participants are called for.

6.5.5. Marine palaeo-records

A working group be established to examine the feasibility of a project to recover climatic information (run off) recorded in coral reefs and marine biological information from varved sediments and deposits of sea-bird "guano" in the Southern Hemisphere, with sufficient resolution (annual to decadal) for characterising the ecosystems response to climate change. The IGBP SSC on Global Changes of the Past is asked to address the composition and operation of this working group.

7. HYDROLOGICAL RESPONSES TO LONG TERM CLIMATIC CHANGE

7.1 INTRODUCTION

Hydrological response has been postulated to be second only to agriculture in its sensitivity to climatic variations (Chen and Perry, 1987).

The objectives of hydrological response studies are to produce sufficient information in the proper form for rational decisions in planning, design and operation of water resources systems and their development. In an IGBP context, the need is to address questions of system equilibrium regarding the dynamic interactions between climate forcing, soil hydrology and vegetation (natural and agricultural crops) in response to abrupt changes brought about by climate change, on a decadal time scale.

Hydrological response has to be considered in two time- space scales. In the short term and on a fine scale, the responses are dominantly feed-forward (i.e., uni-directional) and impacts are local. In the long term and at a regional or continental scale, feedback effects become operational and significant. In addition, there is a complex mix of changing anthropogenic forcing functions superimposed on changing climatic forcing functions which affect hydrological response. For example, anthropogenic influences on streamflow can operate totally unrelated to forthcoming climatic change, as with urbanisation, irrigation schemes, sedimentation or land use changes. Such influences may override, exaggerate or diminish hydrological response induced simultaneously by global climatic change.

Historical hydrological time series, particularly streamflow series on flood peaks or low flows, used in design of hydraulic structures such as reservoirs, will become progressively non-usable in the future. Already many observed hydrological data and time series are in a non-steady state because monitored catchments have frequently undergone man-induced changes affecting the series, such as overgrazing, irrigation extractions, urbanisation, conservation, construction of dams or afforestation. Future climate induced change is likely to distort time series even more.

It is not yet clear, over long time periods, to what extent hydrological responses will be self regulatory, and if so, where they may be self regulatory and where not. For example with more rainfall, it could be argued that proportionally more runoff is expected because of non-linear runoff responses. A counter argument is that more rainfall implies greater biomass and thus more transpiration, which could cause a reduction of antecedent soil water content, hence less runoff. Higher temperatures and associated evaporation rates imply longer stress periods and drier soils thus antecedent conditions for runoff are drier and even the higher rainfall may not necessarily produce more runoff.

A major concern with changing hydrological response is that hydraulic structures being constructed at present, and those already existing, are often designed with life spans of decades to centuries. While hydraulic design tends to be conservative with a high risk built in, such designs have not taken into account possible extremes of future hydrological regimes.

7.2 SYSTEMS INPUT AND RESPONSES

All of the systems inputs and responses discussed in this section are important regardless of which part of the world is being considered. Some have been identified below as of particular significance in the Southern Hemisphere but all need investigation.

7.2.1 Rainfall

Rainfall may be considered the driving force behind runoff response. As the runoff response is non-linear (e.g., 10% rainfall increase may produce 15 - 30% runoff increase, all else being held constant) any changes in rainfall may have major repercussions on other components of the hydrological system.

The following general questions concerning rainfall changes need investigation. They are not peculiar to the Southern Hemisphere but will be of particular importance in any study of hydrological impacts.

(1) To what degree will annual rainfall amounts change at different latitudes and locations?

(2) Will the changes be distributed unevenly over seasons, and if so will the seasonality vary regionally or with summer and winter rainfall areas?

(3) How will the number of actual raindays change?

(4) Will "extreme" events become more extreme because increased temperatures imply higher saturated vapour pressures and hence potentially higher amounts of precipitable water?

(5) Will rainfall variability change intra-annually, inter-annually or both?

(6) What will changes of wet-wet, wet-dry and dry-dry rain day sequences and spells be?

Aspects of rainfall mechanisms, specific or of particular importance to the Southern Hemisphere, that need to be addressed include the following:

i) The interactions between ENSO and rainfall patterns, both now and with possible latitudinal shifts associated with climatic warming, will have to be assessed;

ii) The Southern Hemisphere continents straddle the 20 - 35°S latitudinal zone. This zone has already been shown by McMahon et al., (1987) to be critical, with higher rainfall variability than over most other latitudes and with resultant higher flood peaks. The question arises whether rainfall variability will decrease or increase and what the hydrological consequences would be;

iii) In two of three Southern Hemisphere continents the winter rainfall regions are at the southern tips of the continents. Will these regions migrate polewards, possibly even "out" of the continents, or will they become more pronounced winter rainfall regions? What would the hydroeconomic repercussions in regard to existing and future water resources structures be in present winter rainfall regions?

iv) To what extent will snowlines move to higher elevations and what impacts would this have on 'feeding' the hydrological system, particularly in western South America, in eastern Australia or New Zealand?

Southern Hemisphere scientists need answers to these and many other questions in order to assist in further planning.

7.2.2 Evaporation and evapotranspiration

There is general consensus in the literature that an anticipated rise of 1-4°C in temperature would induce a 5-15% change in potential evaporation. However, such statements are highly simplistic. What impacts would global warming have, for example, on open water bodies in terms of inter-seasonal and inter-regional evaporation changes, or on bare soil evaporation rates should temperatures rise or more frequent wetting cycles occur? In addition to open water and bare soil evaporation changes, hydrological impact may be most significant through changes in soil water content and its associated responses. Whether consumptive water use of plants would be higher or not, or whether plant biomass would increase in certain areas while decreasing in others or whether plant species would adapt to climate change to become either water conservers or water wasters are all questions which have hydrological repercussions.

7.2.3 Catchment Water Yield

Under natural catchments one needs to consider, *inter alia*, the following aspects of hydrological response:

i) Whether different regional runoff responses would occur, for example, in humid regions compared with arid regions or in summer rainfall compared with winter rainfall regions;

ii) Whether different seasonal responses would occur, for example, dry season flow changes compared with wet season flow changes;

iii) Whether flow duration curves, a vital tool in planning reservoir operations, would change to any significant extent;

iv) Whether the changing land cover brought about by climate change (either in natural vegetation or new agricultural crops or different land management practices) would have an effect on runoff.

In an ecologically conscious 21st century, questions on the impact of changing hydrological regimes on wetlands (as flood attenuators, as sediment traps or as nutrient traps) and on estuarine systems in terms of the fresh water supply and aquatic ecosystem balances will become increasingly important.

7.2.4 Floods

For flood rains of short duration, (i.e., less than one day), one would assume greater amounts of rainfall within an "extreme" event in those Southern Hemisphere latitudes where most development has taken place and where population is concentrated, viz. 20-40°S, because of temperature induced increases in vapour pressure and thus precipitable water. Whether, however, the flood rains would be more intense, remains open to speculation.

For flood rainfalls of long duration, further questions arise. For example, will there be longer sequences of consecutive raindays? will this produce more severe large-scale regional flooding? to what extent will extreme rainfall and runoff series become distorted? or will there be more frequent medium floods or less frequent but more severe floods?

7.2.5 Reservoirs

Reservoirs, despite being constructed with an inherent margin of safety because they are high-cost long-term structures, will no doubt be affected severely by changing hydrological regimes if global warming takes place at projected rates. Reservoir evaporation, already alarmingly high over large tracts of the Southern Hemisphere, is anticipated to rise a further 5 - 15%. With an already highly variable hydrological regime in the Southern Hemisphere latitude range 20-35°S (McMahon et al., 1987), changing flow regimes and higher uncertainty would require even larger and costlier reservoirs to be constructed in future for safe yields and drafts. Demands are likely to increase, particularly if dams supply irrigation schemes. Siltation rates may change. Increased water temperatures are likely to promote algal growth possibly resulting in new levels of eutrophication. A possible proliferation of small farm dams in subsistence/rural areas (used for local water demands) would affect water resources available for major reservoirs downstream. This already happens in important catchments in southern Africa. All these factors may result in new and more complex reservoir operating rules.

7.2.6 Irrigation Water Demand and Supply

A warmer climate implies higher water demands, particularly peak demands, when crops are grown under irrigation. Greater water supplies are likely to be required, with implications in reservoir sizing. Modes of irrigation scheduling may then have to be adapted, for example, different cycles and amounts would be required, or present supplementary irrigation might have to change to full irrigation. There are possible irrigation return flow and salinization changes which might have repercussions downstream.

7.2.7 Sedimentation

The transient factors in sediment production are controlled by the interaction between rainfall kinetic energy and vegetative cover. In addition, sediment production increases exponentially with rainfall energy input. So that climatic change as manifested by any changes in rainfall intensity (and consequently rainfall kinetic energies) would have significant potential impact on sediment production rates, with repercussions in, for example, reservoir siltation and estuarine systems.

7.2.8 Other possible impacts

Other possible hydrological impacts include effects on water quality, where river regime changes would affect dilution processes or irrigation return flows may increase, and effects on groundwater, where hydrological responses could change equilibria between groundwater abstractions and recharge.

7.2.9 International repercussions in the Southern Hemisphere

As in the Northern Hemisphere, a number of important rivers in South America and Africa are "international" in that they flow through more than one country. Climatic manifestations with hydrological consequences therefore become international issues, which can only effectively be addressed by international collaboration.

7.3 INTERACTION BETWEEN IGBP AND OTHER INTERNATIONAL PROGRAMMES

A number of key international programmes linked closely to IGBP objectives exist. Interaction between these programmes on hydrological response questions is necessary to avoid duplication and to combine resources and scientific expertise in order co-ordinate research to enhance decision making on potential impacts of climatic change. These linked programmes are listed and discussed in Global Change Report 4, 1988. There is a need to stress that IGBP holds the key to collaboration (both intra-nationally and internationally), technology transfer and development of relevant expertise to assess hydrological impacts of global climatic change.

7.4 ACTION PLAN

Specific actions, which should be considered in the time scale of 3-5 years for Southern Hemisphere scientists acting institutionally, nationally and internationally include the following.

(1) Enhancing GCMs and their potential hydrological applications in regard to spatial resolution, feedbacks, basic input to other modules (e.g., CSIRO, Australia).

(2) Further development of generic, deterministic and interactive hydrological modelling systems, based on both biological and physical controls, which can simulate, vegetation / land-use / land-management influences and soil variable responses to changing forcing functions (e.g., rainfall properties, net radiation budget/temperature changes). These systems would need to handle different levels of sophistication of data input (to facilitate 'universal' use under First and Third World conditions of information availability). They would need to be designed for multiple purposes, including runoff response, irrigation supply and demand, inter catchment transfers, sediment yield and crop yield estimations. It is important that the systems can operate at different spatial scales from point to small catchments to larger, heterogeneous distributed catchments and be coupled to GIS on climate, soils vegetation/land use (e.g., University of Natal, Pietermaritzburg and Australian National University, Canberra). It is recommended that the IGBP Co-ordinating Panel 3 should take responsibility for further workshops to develop these generic models such that they can be applied in Third World, southern hemisphere countries.

(3) Regional case studies applying the above modelling systems to, for example, impacts of vegetation change on hydrological response in central Chile. (Collaborative research between the University of Natal and University Catolica de Chile, Santiago).

(4) Special studies on the deforestation of the Amazon and its feedbacks into GCMs. Of all the terrestrial regions in the world, it appears (given our present level of understanding and present resolution of GCMs) that changes in the Amazon basin will have the greatest feedback effect on the atmosphere. These studies are therefore of particular concern to the IGBP and must be given high priority in Southern Hemisphere hydrological research programmes. (INPE, Brazil and others).

(5) Local case studies. For example, uni-directional impacts of climatic change on catchment responses to urban systems, irrigation systems, groundwater recharge, wetlands regimes, estuary regimes and so on.

APPENDIX 1

REFERENCES

Chen, R.S. and Perry, M.L. (1987). Policy-oriented impact assessment of climatic variations. International Institute for Applied Systems Analysis, Laxenburg, Austria. p. 54.

Crawford, R.J.M. and Shannon, L.V. (1988). Long term changes in the distribution of fish catches in the Benguela. In Wyatt, T. and M.G. Larraneta (eds) Long term changes in marine fish populations. Instituto de Investigaciones Marinas de Vigo, Vigo, Spain. pp. 449-480.

Flohn, H. (1980). "Possible climate consequences of a man-made global warming" IIASA, Laxenburg

Gulland, J.A. and Garcia, S. (1984). Observed patterns in multi-species fisheries. In May, R.M. (ed) Exploitation of marine communities. Springer-Verlag, Berlin. p. 155-190.

Henderson-Sellers, A. and McGuffie, K. (1987). "A climate modelling primer", Wiley, New York.

Hughes, G.R. (1989). Sea turtles. In Payne, A.I.L. and R.J.M. Crawford (eds) Oceans of life off southern Africa. Vlaeberg, Cape Town. p. 230-243.

Kawasaki, T. (1983). Why do some pelagic fishes have wide fluctuations in their numbers? Biological basis of fluctuation from the viewpoint of evolutionary ecology. In Sharp, G.D. and J. Csirke (eds) Proceedings of the expert consultation to examine changes in abundance and species composition of neritic fish resources, San Jose, Costa Rica, April 1983. FAO Fish. Rep. 291(3), p. 1065-1080.

Kruger, F.J., Breytenbach, G.J., Macdonald, I.A.W. and Richardson, D.M. (1989). The characteristics of invaded Mediterranean climate regions. In Drake, J. and Mooney, H.A. (eds) Biological Invasions: A Global Perspective. Wiley, New York.

Krummel, J.R., Gardner, R.H., Sugihara, G. O'Neill, R.V. and Coleman, P.R. (1987)

Macdonald, I.A.W., Loope, L.L., Usher, M.B. & Hamann, O. (1989). Wildlife conservation and the invasion of nature reserves by introduced species: A Global Perspective. In Drake, J. & Mooney, H.A. (eds) Biological Invasions: A Global Perspective.

McMahon, T.A., Finlayson, B.A., Haines, A. and Srikanthan, R. (1987). Runoff variability: A global perspective. In: The influence of climate change and climatic variability on the hydrological regime and water resources. IAHS Publication No.168, pp. 3-11.

Neumann, G. and Pierson W J (1966). "Principles of Physical Oceanography" Prentice Hall, New Jersey p. 545

O'Neill, R.V., DeAngelis, D.L., Waide, J.B. and Allen, T.F.H. (1986) A heirachical concept of ecosystems. Monographs in Population Biology 23. Princeton UP, New Jersey

Parrish, R.A., Bakun, A., Husby, D.A. and Nelson, C.S. (1983). Comparative climatology of selected environmental processes in relation to eastern boundary current pelagic fish reproduction. In Sharp, G.D. and J. Csirke (eds) Proceedings of the expert consultation to examine changes in abundance and species composition of neritic fish resources, San Jose, Costa Rica, April 1983. FAO Fish. Rep. 291(3), pp. 731-777.

Pearman, G.I. (1988). Greenhouse: Planning for climate change. CSIRO, Australia.

Pollock, D.E. (1989). Spiny lobsters. In Payne, A.I.L. and R.J.M. Crawford (eds) Oceans of life off southern Africa. Vlaeberg, Cape Town. pp. 70-80.

Rosswall, T., Woodmansee, R.G. and Risser, P.G. (1988) "Scales and global change" SCOPE 35, John Wiley, New York.

World Climate Programme (1985). Report of the International Study Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts. WMO, Geneva.

APPENDIX 2

LIST OF PARTICIPANTS

Professor W.B. Banage
Department of Biology
University of Zambia
P.O. Box 32379
Lusaka
South Africa

Telex: ZA44370
Phone: 254755

Dr. Robert Crawford
Sea Fisheries Research Institute
Private Bag X2
0812 Rogge Bay
Zambia

Phone:21-4023143

Dr. Patricio Bernal
BIOTECMAR
Universidad Catolica de Chile
Talcahuauo
Chile

Telex: 260191 PUCST-CL
Phone: 56-41-542592 X 34
56-41-331625

Professor Eduardo Fuentes
Laboratorio de Ecologia
Universidad Catolica de Chile
Casilla 114-D, Santiago
Chile

Telex:240395 PUCVACL
Phone:2224516 X 2614

Dr. Enrique Bucher
Centro de Zoologia Aplicada
Universidad Nacional de Cordoba
Cordoba 5000
Argentina

Dr. Humberto Fuenzalida
Departamento de Geofisica
Universidad de Chile
Santiago
Chile

Telex:243302 INGEN CL
Phone:6968790

Professor William Budd
Department of Meteorology
University of Melbourne
Parkville, Vic. 3052
Australia

Phone:03-3446909
Fax:03-3473329

Dr. Dean Graetz
CSIRO
Division of Wildlife & Ecology
P.O. Box 84,
Lyneham, A.C.T. 2602
Australia

Phone:062-421600
Fax:062-413343
Telex:62284

Professor Juan J. Burgos
Centro de Investigaciones
Biometeorologicas
Caja Postal 5233
Correo Central
1000 Buenos Aires
Argentina

Telex:18694 IBUBA
Phone:01-8554858

Mr. Rindayi Chimonyo
Department of Geography
University of Zimbabwe
P.O. Box MP 167
Mount Pleasant, Harare
Zimbabwe

Telex:4-152ZW
Phone:303221 X 1587

Dr. W. Livingston
National Solar Observatory
P.O. Box 26732
Tucson, Arizona 85719
U.S.A.

Telex:666484 AURA KPNO TUC
Phone:1-602-3275511
Fax:1-602-3259278

Dr. Johann Lutjeharms
CSIR, P.O. Box 320
Stellenbosch 7600
South Africa

Telex:5727126Telex:30434
Phone:27-2231-75101
Fax:27-2231-75142

Mr. John R. Masson
Managing Director
Swaziland Milling
P.O. Box 158
Manzini
Swaziland

Phone:52261
42066 (A/H)
Telex:2061 WD

Mr. Brian Huntley
FRD, CSIR,
P.O. Box 395
Pretoria 0001
South Africa

Phone:27-12-8413731
Fax:8412418
Telex:3-21312 SA

Professor S. Imbamba
Department of Botany
University of Nairobi
Nairobi
Kenya

Dr. Jorge Morello
Direccion a Parques Nationales
Av. Santa Fe 690
1059 Beunos Aires
Argentina

Phone:01-311-6633
01-331-8855
01-772-6749 (Home)

Dr. Neville Nicholls
Bureau of Meteorology Research
Centre
GPO Box 1289K
Melbourne, Vic. 3001
Australia

Phone:03-6694407
03-4598659 (Home)

Professor Henry Nix
Centre for Resource &
Environmental Studies
ANU, P.O. BOX 4
Canberra, A.C.T. 2601
Australia

Phone:062-494588
062-478548 (Home)
Fax:062-574012

Mr. Ian Macdonald
Percy Fitzpatrick Institute
of African Ornithology
University of Capetown
Rondebosch 7700
South Africa

Phone:021-650330
021-6892285 (Home)

Dr. H. Mkhwanazi
Department of Physics
University of Swaziland
Private Bag
Kwaluseni
Swaziland

Dr. Luiz Molion
INPE C. Postal 545
12201 Sao Jose Dos Campos-SP
Brazil

Telex:1233530 INPE BR
Phone:55-123-229977
Fax:55-123-218743

Dr. Jose Rodrigues Pereira
Faculty of Agricultural Studies
University Eduardo Mondland
CP 257, Maputo
Mozambique

Dr. Barrie Pittock
CSIRO
Div. Atmospheric Research
Private Bag No. 1
Mordialloc, Vic. 3195
Australia

Phone:03-5867666
Telex:34463
Fax:03-5867600

Dr. Mario Nunez
Departamento de Meteorologia
Universidad de Buenos Aires
Pabellon 2-Ciudad Universitaria
1428 Buenos Aires
Argentina

Phone:01-7826528
01-481571 (Home)
Telex:18694 IBUBA AR

Professor Tim Partridge
Department of Palaeontology and
Palaeoenvironmental Studies
Transvaal Museum
Pretoria
South Africa

Phone:011-6463324

Dr. Graeme Pearman
CSIRO
Division of Atmospheric Research
Private Bag No.1
Mordialloc, Vic. 3195
Australia

Phone:61-3-5867650
Fax:61-3-5867600

Dr. Nomcebo Simelane
Department of Geography
University of Swaziland
Private Bag
Kwaluseni
Swaziland

Telex:2087 WD
Phone:84011

Dr. Basil Stanton
Oceanographic Institute
DSIR
Private Bag, Kilbirnie
Wellington 3
New Zealand

Phone:861189
Telex:NZ32076 RESEARCH
Fax:03-862153

Professor Thomas Rosswall
Royal Swedish Academy of Sciences
POB 50005
S-104 05 Stockholm
Sweden

Telex:17509 IGBP S
Phone:46-8-150430
Fax:46-8-166405

Dr. Jim Salinger
New Zealand Meteorological Service
P.O. Box 722, Wellington 1
New Zealand

Phone:64-4-729379
64-4-326863 (Home)
Fax:64-4-735231
Telex:NZ31392

Professor Roland Schulze
Dept. of Agric. Engineering
University of Natal
P.O. Box 375
Pietermaritzburg 3200
South Africa

Phone:0331-63320 X 489
Telex:643719
Fax:0331-63497

Professor Roy Siegfried
Percy Fitzpatrick Institute of African Ornithology
University of Capetown
Rondebosch 7700
South Africa

Phone:021-6503290/1
Fax:021-6503726

Professor Mike Swift
Dept. of Biological Sciences
University of Zimbabwe
P.O. Box MP167
Mt Pleasant, Harare
Zimbabwe

Telex:4152 ZW
Phone:303211

Sam Tewungwa
P.O. Box 47074
Nairobi
Kenya

Phone:2542-333930
2542-520711
Telex:22068

Dr. Brian Tucker
CSIRO
Div. Atmospheric Research
Private Bag No 1
Mordialloc, Vic 3195
Australia

Phone:62-3-5867650
Fax:62-3-5867600

Professor Peter Tyson
Deputy Vice Chancellor
University of the Witwatersrand
P.O. Wits 2050
South Africa

Phone:11-7163400
Fax:27-11-3398215
Telex:450937 VCWITS

Dr. Brian Walker
CSIRO, Div. Wildlife & Ecology
P.O. Box 85
Lyneham, A.C.T. 2602
Australia

Phone:62-421724
Fax:62-413343
Telex:62284

Dr. Jeremy Anderson
Kangwane Parks Corporation
P.O. Box 1990
Nelspruit 1200
South Africa

Ms. Nan Czank
Event Dynamics Pty. Ltd.
P.O. Box 32730
Braamfontein 2017
South Africa

Dr. Fred Kruger
South African Forestry Research Institute
P.O. Box 727
Pretoria 0001
South Africa

Phone:012-287120

Dr. Butch Smuts
Anglo American Corporation
44 Main Street
Johannesburg 2000
South Africa

Telex:95264791 CHARTR.G
Fax:27-11-6383221

Mr. Keith Cooper
Wildlife Society of South Africa
100 Brand Street
Durban 4001
South Africa

Mrs. Vera Harvey
Event Dynamics Pty. Ltd.
P.O. Box 32730
Braamfontein 2017
South Africa

Dr. Robbie Robinson
National Parks Board
P.O. Box 774
George 6530
South Africa

APPENDIX 3

GLOSSARY OF ACRONYMS

ANU	Australian National University
AVHRR	Advanced Very High Resolution Radiometer
COHMAP	Co-operative Holocene Mapping Project
CSIR	Council for Scientific and Industrial Research (South Africa)
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
DSIR	Department of Scientific and Industrial Research (New Zealand)
ENSO	El Niño - Southern Oscillation
EOS	Earth Observing System
FAGS	Federation of Astronomical and Geophysical Services
GBO	Geosphere/Biosphere Observations
GCM	General Circulation Model
GEWEX	Global Energy and Water Cycle Experiment
GIS	Geographic Information System
IAMAP	The International Association of Meteorology and Atmospheric Physics
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Program
INPE	Instituto de Pesquisas Espaciaias
INQUA	International Quaternary Association
IOC	Intergovernmental Oceanographic Commission
IOCZ	Indian Ocean Convergence Zones
IPCC	International Panel on Climate Change
ISOMED	International Society of Mediterranean Ecologists
JGOFS	Joint Global Ocean Flux Study
NASA	National Aeronautics and Space Administration

NOAA	National Oceans and Atmospheres Administration
NZMS	New Zealand Meteorological Society
PSMSL	Permanent Service for Mean Sea Level
RSSD	Responses of Savannas to Stress and Disturbance
SACZ	South Atlantic Convergence Zone
SADCC	Southern African Development and Co-operation Council
SCAR	Scientific Committee on Antarctic Research
SCOPE	Scientific Committee on Problems of the Environment
SCOR	Scientific Committee on Oceanic Research
SOI	Southern Oscillation Index
SPCZ	Southern Pacific Ocean Convergence Zone
SSC	Scientific Steering Committee
UNEP	United Nations Environment Program
WCDP	World Climate Data Program
WCRP	World Climate Research Program
WMO	World Meterological Organization
WOCE	World Ocean Circulation Experiment

IGBP Reports

No. 1. The International Geosphere-Biosphere Programme: A Study of Global Change. Final Report of the Ad Hoc Planning Group, ICSU 21st General Assembly, Berne, Switzerland 14-19 September, 1986 (1986)

No. 2. A Document Prepared by the First Meeting of the Special Committee, ICSU Secretariat, Paris 16-19 July, 1987 (1987)

No. 3. A Report from the Second Meeting of the Special Committee, Harvard University, Cambridge, MA, USA 8-11 February, 1988 (1988)

No. 4. The International Geosphere-Biosphere Programme. A Study of Global Change (IGBP). A Plan for Action. A Report Prepared by the Special Committee for the IGBP for Discussion at the First Meeting of the Scientific Advisory Council for the IGBP, Stockholm, Sweden 24-28 October, 1988 (1988)

No. 5. Effects of Atmospheric and Climate Change on Terrestrial Ecosystems. Report of a Workshop Organized by the IGBP Coordinating Panel on Effects of Climate Change on Terrestrial Ecosystems at CSIRO, Division of Wildlife and Ecology, Canberra, Australia 29 February - 2 March, 1988. Compiled by B. H. Walker and R. D. Graetz (1989)

No. 6. Global Changes of the Past. Report of a Meeting of the IGBP Working Group on Techniques for Extracting Environmental Data of the Past held at the University of Berne, Switzerland 6-8 July, 1988. Compiled by H. Oeschger and J. A. Eddy (1989)

No. 7. A Report from the First Meeting of the Scientific Advisory Council for the IGBP. Volumes I and II. (1989)

No. 8. Pilot Studies for Remote Sensing and Data Management. Report from Working Group Workshop held in Geneva, Switzerland 11 through 13 January 1989. Editted by S. I. Rasool and Dennis S. Ojima (1989)

IGBP Secretariat, Royal Swedish Academy of Sciences
Box 50005, S-10405 Stockholm, Sweden.