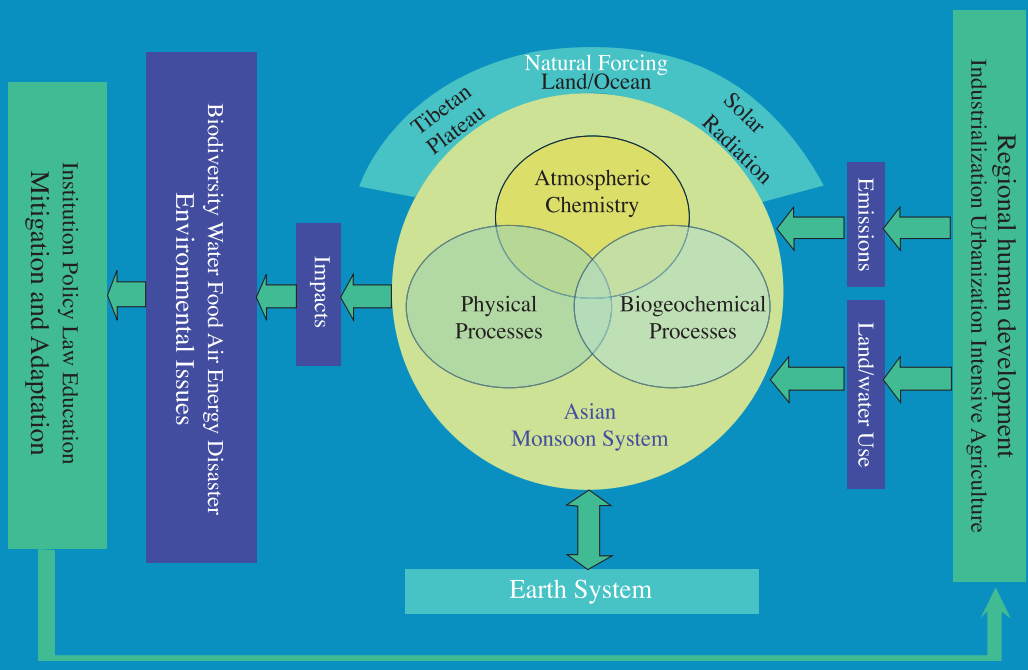
MAIRS Working Paper Series #3

Report of Planning Workshop on MAIRS Mountain Zone Implementation

Beijing, China

Michael Manton AND Ailikun

editors, 2007



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The diagram on the front cover illustrates the conceptual framework of the MAIRS program.

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Report of Planning Workshop on MAIRS Mountain Zone Implementation
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PREFACE

The concept of an integrated program of research on the Asian monsoon system has been developed over the last decade by Professor Congbin Fu of the Chinese Academy of Science. With the support of the System for Analysis Research & Training (START), this concept has now been adopted by the Earth System Science Partnership of the global environmental change programs as the Monsoon Asia Integrated Regional Study (MAIRS). The Initial Science Plan for MAIRS was published in October 2006, providing a strategy for advancing research activities for MAIRS that focus on major challenges arsing from the interactions between human actions and the monsoon in Asia. A structure for MAIRS has been developed by considering issues associated with four geographical zones: the urban zone, the coastal zone, the semi-arid zone and the mountain zone.

In preparing the Initial Science Plan, the task team for the mountain zone considered a number of issues that would affect the implementation of MAIRS, and so the team was well-placed to move from the strategic planning phase of MAIRS to the implementation phase. With the support of the International START Office, the MAIRS International Program Office (IPO) in Beijing hosted the first implementation workshop for the MAIRS mountain zone on 14-17 November 2006. Planning for the workshop was greatly enhanced by the involvement Dr Gregory Greenwood of the Mountain Research Initiative (MRI). Dr Ailikun and Ms Ying Yang of the IPO ensured that all the arrangements for the meeting went smoothly and that the workshop report was carefully finalised for publication.

A particular aim of the implementation workshop was to extend the range of scientists involved in the MAIRS mountain zone research, and this aim was achieved particularly through the collaboration with the MRI. However, the program of activities needs to include many more researchers interested in integrated studies across the mountains of monsoon Asia. It is anticipated that the publication of this workshop report will promote further interest in MAIRS by documenting a number of projects that cover the research priorities in the Initial MAIRS Science Plan.

Following a request from the MAIRS Scientific Steering Committee, a new executive group was proposed at the mountain workshop. Future activities of MAIRS mountain zone will be guided by a group comprised of Prof. Dr. Kedar Lal SHRESTA (Co-convenor), Prof. Tandong TAO (Co-

convenor), Dr AILIKUN (IPO), Dr Gregory GREENWOOD (MRI) and Prof. Michael MANTON. This group will ensure that the MAIRS mountain research activities extend across all monsoon Asia and are coordinated with the activities of the MRI. It is anticipated that a broad and robust program of integrated studies will evolve from the results of this first MAIRS mountain workshop.

Michael Manton
Initial Convenor, MAIRS Mountain Zone Task Team

20 May 2007

1. Introduction

The Initial Science Plan (ISP) of MAIRS has recently been published and formally launched at the Global Environmental Change Open Science Conference (OSC) in Beijing in November 2006. With the publication of the ISP, it is timely to commence the implementation process for MAIRS.

In order to provide some focus on the scope of MAIRS, the ISP identifies four research themes each of which relates to a significant geographical zone in monsoon Asia. The four themes are

- Rapid transformation of land and marine resources in the coastal zones
- Multiple stresses on high mountain ecosystems and biophysical resources
- Degradation of land and water resources in semi-arid regions as a result of changing climate and use
- Changes in resource use and emissions resulting from rapid urbanisation.

Following the OSC, a workshop was held in Beijing aimed at starting the implementation process for the mountain zone of the overall MAIRS program. In particular, the purpose of the meeting was to establish an initial set of projects on the MAIRS mountain zone, based on the conclusions of the ISP. This report documents the conclusions of the participants. A list of participants is given in Appendix 1 and the program for the workshop is given in Appendix 2.

The workshop was funded by the International START Office and hosted by the MAIRS IPO. The meeting benefited from the involvement of Mountain Research Initiative (MRI) in the planning phase and in the workshop itself. It is expected that MAIRS will continue to work closely with MRI as activities on the mountain zone are developed.

2. Background

The monsoon Asia region is defined as the contiguous region of Asia, including East, Southeast and South Asia, that is affected by the seasonally varying Asian monsoon circulation. The monsoon Asia region supports the largest populations on earth, being home to 3.6 billion persons. Societies in monsoon Asia are critically dependent on the variability of the monsoon circulation system. Monsoon Asia region is characterized by diverse geography that includes the world's highest

mountains and some of its longest rivers. The region has diverse habitats ranging from glaciers to deserts, extensive semi-arid zones to tropical rainforests. Significant fractions of these habitats are fragile for various reasons, including variable rainfall with frequent droughts and floods. The region is also well-known for its biodiversity which supplies the inhabitants with essential ecosystem goods and services.

Since the 1970s, monsoon Asia has been engaged in a process of rapid economic growth through industrialization, with urban populations growing rapidly. The intensification of human activities, with per capita resource-use and emission levels well below those of the United States or the European Union, will in aggregate have a major impact on the global environment. Humans have extensively modified the landscape, sometimes maintaining significant levels of biodiversity and other ecosystem functions. Rapid urbanization in Asia has been synchronous with dramatic rates of economic growth as well as severe environmental problems. Asia now has more major cities than any other region in the world. How urbanization and industrialization unfold will be critical. Demographic trends are also likely to be hugely important for future landscape change.

Regional-scale studies of global change provide the knowledge base for undertaking vulnerability analyses, identification of hotspots of risk and studies of environmental degradation which are crucial for the sustainable development. Regions may manifest significantly different environmental dynamics, and changes in regional biophysical, biogeochemical and anthropogenic components may produce considerably different consequences for the earth system at the global scale. Regions are not closed systems and thus the linkages between regional changes and the global earth system are crucial. Integrated Regional Studies (IRSs) should have relevance for people living in the regions and should provide a sound scientific basis for the sustainable development of the countries in the regions, and IRSs are also important from an earth system science perspective.

Monsoon Asia Integrated Regional Study (MAIRS) is an IRS research program over monsoon Asia under START and the Earth System Science Partnership (ESSP). It was established to address questions about the coupled human and environment system in the monsoon Asia region. The vision of MAIRS is to significantly advance understanding of the interactions between the human and natural components of the overall environment in the monsoon Asian region and implications for the global earth system, in order to support strategies for sustainable development.

To achieve its vision, the objectives of MAIRS are:

- To better understand how human activities in the monsoon Asia region interact with atmospheric, terrestrial and marine components of the environment, in particular with respect to irreversible thresholds and to major shifts in risks and vulnerabilities.
- To contribute to the provision of a sound scientific basis for sustainable regional development.
- To develop predictive capacity for estimating changes in global-regional linkages in the Earth System and to recognize the future consequences of such changes.

Key questions for MAIRS are:

- Is the Asian monsoon system resilient to this human transformation of land, water and air?
- Are societies in the region becoming more, or less, vulnerable to changes in the Asian monsoon?
- What are the likely consequences of changes in monsoon Asia on the global climate system?

To start answering these critical questions, we distinguish four research themes. Each theme addresses key integrated issues with a primary focus on a vulnerable geographic zone.

- Rapid transformation of land and marine resources in coastal zones.
- Multiple stresses on ecosystems and biophysical resources in high mountain zones.
- Vulnerability of ecosystems in semi-arid zones due to changing climate and land use.
- Changes in resource use and emissions due to rapid urbanization in urban zones.

The ISP identifies six priority research areas that will provide the focus for MAIRS research in the mountain zone. Each research area is of high scientific interest and is also relevant to important societal issues. The research areas are:

- Hydrology and water availability
- Ecosystems and biodiversity
- Agriculture, forestry and food security
- Natural disaster management
- Energy and transport
- Air quality and human health.

For the Beijing workshop, it was decided that the focus would be on the first two areas, but aspects of the second and third areas that relate to water or ecosystems would also be included. Appendix 3 lists the key science questions in the ISP that relate to the mountain zone. The projects developed

at the workshop are aimed to assist in answering each of these questions.

3. Presentations on existing work

To assist in the development of future projects, participants gave brief presentations on relevant work that has been carried out in their home institutes and on their future plans that could support MAIRS. Abstracts of the presentation are in Appendix 4 and they cover the topics of

- Impacts of climate change on hydrology of the Himalayan-Tibetan Plateau
- Global Land Ice Monitoring From Space (GLIMS) Project
- Research at the Institute of Tibetan Plateau Research
- Programs on global change in the mountain areas in IGSNRR
- Contribution of CAREERI to Global Change Study
- Mountain research in Indian Himalayan Region at G.B. Pant Institute of Himalayan Environment & Development
- Environmental changes, ecological stability and socio-economic sustainability in Indian Himalayas
- Global change studies on mountains in Japan and maritime East Asia
- Monsoon Asia mountain zone research in Pakistan - national perspective
- Glaciers and glacial lakes of Pakistan.

4. Implementation strategy

With knowledge of past and potential future activities in the mountain zone of monsoon Asia, the participants were well-placed to consider future MAIRS activities. The MAIRS Steering Committee has considered a number of implementation issues that should clarify the nature of MAIRS activities. These issues, which are outlined in the ISP, are listed below.

It has been decided that MAIRS will seek to establish specific activities that either fill gaps in the existing research activities in monsoon Asia or build on existing activities in a meaningful sense. It is vital that MAIRS is seen to be adding value to the overall research agenda in monsoon Asia. By definition, MAIRS has a focus on integrated regional studies. In particular, MAIRS aims to

promote studies that extend across the nations of the region and which are multi-disciplinary, in particular, MAIRS activities are expected to have links to societal issues. Within MAIRS, itself there will be studies that extend across the nominal zones of interest.

Integrated research studies in monsoon Asia will require data from a variety of sources. However, differences in geography and development mean that the availability of the required data vary significantly across the region. An important aspect of MAIRS projects will be to conduct an initial inventory of the availability of data required to carry out each project. Such investigations may lead to the development of field studies to collect and analyse new data. There may also be opportunities for MAIRS to promote the establishment of long-term monitoring sites to provide sustained observations of key variables in monsoon Asia.

Modelling is an essential aspect of MAIRS integrated studies, as it is the means for combining data and information from a range of sources to simulate processes in a consistent manner. Modelling also provides the means for dynamical prediction of future states of the environment in monsoon Asia. The development and evaluation of models will depend upon access to relevant observations across the region, and so modelling will be an integral component of any field project in MAIRS.

With its focus on integrated regional studies, MAIRS should provide many opportunities for capacity building across monsoon Asia. The current scientific capabilities vary greatly across the region. An objective of MAIRS is to promote the enhancement of research capability particularly in the institutions and regions where current capabilities are limited.

The establishment of MAIRS complements the activities of the global research programs in two ways. First it will add regional detail to the essentially large-scale studies of the global programs. In developing MAIRS projects, scientists will draw on the results of the global programs. However, they will also identify issues at the regional level that have global implications, and so there will be a variety of interactions with the global programs.

The issues described above are discussed in more detail in the MAIRS ISP. They were taken into account by the workshop participants in developing a suite of possible projects for the mountain zone component of MAIRS.

5. Proposed projects for the MAIRS mountain zone

Following discussion of existing research in the mountain zone of monsoon Asia and consideration of the overall strategy for the implementation of MAIRS, the participants formed working groups to develop outlines of specific projects that will provide the framework for mountain zone activities over the next few years. Twelve projects spanning the range of key science questions for the mountain zone (see Appendix 3) were developed as priority activities over the next few years. They vary in scope from a single workshop to activities that should extend over several years. The projects cover the following topics:

- Environmental change across the Himalayas and the Tibetan Plateau
- Glaciers in Monsoon Asia - Recent Changes and Future Projections
- Monitoring Land Use Changes
- Changes at the snowline across Mountain Areas of MAIRS
- Mountain ecosystems
- Modelling in mountain regions of monsoon Asia
- Vulnerable communities and ecosystems
- Downstream impacts of changes in the Himalayan-Tibetan Plateau 'Water Towers'
- Natural disaster management
- Permafrost change
- Snow-cover change
- Monitoring climate extremes and their impacts in mountain regions

Detailed descriptions of the projects are given below. The projects are not listed in priority order, because as a package they constitute the priority activities for the mountain zone. The projects all involve cooperation across the countries of monsoon Asia, and so a range of funding sources will need to be found. The participants believe that co-funding for the projects could come from a variety of agencies in Asia, USA and Europe with interests in the mountain zone of monsoon Asia.

1. Project title: Environmental change across the Himalayas and the Tibetan Plateau

Rationale

Over the last fifty years, and especially in the last thirty years, there have been many studies on

the physical characterization of the climate and land surface of the Himalayas and the Tibetan Plateau (HTP). Each of these studies has been valuable in its own right, but the overall value of the studies would be greatly enhanced if they could be consolidated to provide a comprehensive survey of variability and change across the HTP region. The HTP region is of great importance to the global climate system, and it is the source of much of the water used by millions of people from the major rivers that rise in the region. A survey of environmental change across the HTP would provide important information relevant to climate change on both global and regional scales. Such information is vital for the development of coping strategies that will allow nations and regions to adapt to climate change and, in particular, to reduce the negative effects of climate change.

Objectives

The primary objectives of the project are to document environmental change across the HTP region over the last fifty years and to promote accessibility to the relevant data. Consequently the project will provide an integrated survey of changes across the region which will provide the basis for continuing collaboration among the various groups involved in research in the HTP region.

Activities

The project will be initiated through an international workshop involving 30-40 participants from the countries across the HTP region: Bhutan, China, India, Mongolia, Nepal and Pakistan. Given the availability of data, the focus of the workshop would be on data related to climate, hydrology and land use. However, where possible, relevant data on biodiversity and livelihood would also be incorporated.

An important feature of the initial workshop will be the integration of results from individual studies to provide a comprehensive survey and assessment of environmental change, including where practical the impacts of change on the natural and social systems of the region. Variations in space and time across the HTP region will also be documented, and the possible sources of the variations discussed. While the initial workshop will be focus of the project, it is expected that the participants will consider future steps that should be taken to ensure continuing interaction and collaboration across all the institutions involved in studies in the HTP region. In particular, it may be appropriate to hold at least one additional meeting to complete the integrated study.

The output of the project will be a multi-author journal or book that will document the results. An editor and publisher will be identified before the meeting. In order to promote accessibility to the data presented and considered at the meeting, a meta-database of the data will be established and shared with the community through the MAIRS web site.

Timing

Provided that arrangements can be confirmed, it is proposed that the initial workshop will be held in November 2007 in Katmandu, Nepal with the publication being completed by November 2008.

Potential participants

The initial workshop will build on the earlier multi-national project of the APN that studied changes in the Himalayas. At the meeting, there should be key scientists from each of the institutions that have carried out substantial studies in the HTP region over the last fifty years. The actual list of participants will be determined by the organizing committee. However, institutions that could be involved include:

China: CAS IAP, CAS IGSNRR, CAS ITPR, CAS CAREERI, CMA

Participants will be selected on the basis of their historical data from studies in the HTP region which will be considered at the workshop.

The workshop will be directly supported by the MAIRS IPO, and it is anticipated the MRI will also assist the development of the activity. As a regional capacity-building activity, the workshop will be of direct interest to START. It will be important that the relevant programs of the global environmental research programs are aware of the workshop and participate in an appropriate fashion; in particular, WCRP, IGBP, IHDP and DIVERSITAS will be encouraged to participate, and this MAIRS activity is also expected to be of interest to NEESPI.

Next steps and responsibilities

Dr Kedar Lal Shrestha has agreed to convene a small international organizing committee to work

with the MAIRS IPO and MRI to organize the initial workshop.

2. Project title: Glaciers in monsoon Asia - Recent changes and future projections

Rationale

Glaciers are the major slowly-changing water-storage system of the mountain zone as they receive increments of fresh new snow storage annually. They are also potentially an early warning system ('a canary in a coal mine') for the prediction of future water-resource limitations because of the relatively slow response time of snow accumulation compared to ice wastage from melting. They have an alarming rate of retreat or down-wasting in some places, but not in others, with the result that they are of considerable concern to most MAIRS countries. Glaciers are also storehouses of paleo-environmental information (past greenhouse gases, precipitation & temperature fluctuations), as well as constituting a major revenue source associated with adventure and eco-tourism. Furthermore, they can also be a source of associated hazards and disasters such as glacial lake outburst floods (GLOFs), ice avalanches, and down-wasting or de-buttressing landslides. Because of their unique resources, data sources and forecasting potentials, glaciers are being assessed across the length and breadth of the Himalaya and the Tibetan Plateau by a number of workers, including the GLIMS Project of NASA, the US Geological Survey, and various national governments in whose territories the glaciers occur.

Objectives

The available information on the glaciers of the Himalaya and Tibetan Plateau obtained by many researchers up to now needs to be reviewed. This information includes data on the associated melt-water lakes and their potentially dangerous breakout behavior. The relative contribution of glaciers to available water resources in the MAIRS regions needs to be evaluated, as well as the associated hydrological and sediment load variations of glacier melt-water sources. New mass balance and terminus changes need to be evaluated throughout the MAIRS region, along with establishment of a series of monitoring, protocol-bound, benchmark glaciers in all countries of the region. Enhanced understandings of glacier dynamics and down-wasting potential and of altitude/latitude thermodynamics are needed, as are the development of modified protocols for future studies. Enhanced and standardized monitoring, analytical systems and methodologies need to

be established and suitable ASTER, SRS, and other satellite data need to be identified. Ground penetrating radar (GPR) ice- thickness determinations and supra-, en-, and sub-glacial debris-load estimations will enable debris discharge calculations and help forecast reservoir sediment-filling rates. Identification of geobiochemical cycles in glaciers will enable better determination of ecosystem and environmental effects with glacier change projections.

Activities

A workshop in summer or fall of 2007 on the Cryosphere of the Himalaya and Tibetan Plateau is proposed with support from the US National Science Foundation (NSF) through Drs. J. F. Shroder and M.P. Bishop of the University of Nebraska at Omaha, USA. Additional support will be required to bring in sufficient scientists from Asia and the USA, and such funding is already being sought.

Workshop participants should be prepared to share existing available information, especially in their own languages by bringing references, data, and translations where possible. All national data-collecting agencies need to be identified in each MAIRS country, or other interested nations, and the information on glaciers, trends and responses, and glacier lakes accessed. The methodologies and dataset protocols used in each country need to be discussed and standardized. Synthesis of findings and publication of workshop results as either refereed publication (journal or book) or edited proceedings would facilitate the effort. Transnational research groups need to be established for future collaborative initiatives and joint field excursions by multi-national parties encouraged.

Timing

Some initiatives are already underway through the GLIMS Project; a year or more will be required for other longer startups. The planned cryosphere workshop in fall of 2007 can provide the focus for the initiation of a number of relevant projects. Dr. Shroder will be discussing the MAIRS Project on glaciers with the assembled GLIMS scientists at the AGU meetings in December 2006.

Potential participants

Dr. Li Xin, Chinese Academy of Sciences & GLIMS

Dr. Liu Shiyin, Chinese Academy of Sciences & GLIMS

Dr. Shanggua Donghui, Chinese Academy of Sciences & GLIMS

Dr. Che Tao CAREERI & GLIMS

Dr. Syed Iqbal Hasnain, India, GLIMS South Asia Regional Center

Dr. Umesh Haritashya, India & GLIMS Southwest Asia Regional Center

Dr. Rakhshan Roohi, Pakistan, Steward to GLIMS Southwest Asia Regional Center

CLIC: Asia CLIC (co-chairs in China & Japan)

GLIMS Regional Centers

NSIDC (U CO - Boulder)

Lanzhou Cryosphere Program

ICIMOD and its partner countries specifically the MAIRS mountain areas such as Pakistan (Roohi), Nepal (Mool), India (G.B. Pant Institute of Himalayan Environment Development and other Himalayan Universities), China, Bhutan, Afghanistan

Department of Hydrology and Meteorology of Nepal ITP, China

GCISC, Pakistan

Next steps & responsibilities

Dr Shroder, who will lead this project, has already contacted Jeff Kargel (GLIMS Chief) and former Ambassador Harry Barnes about augmented funding for a possible Cryosphere Workshop in Nepal in 2007. Dr Haritashya at GLIMS Southwest Asia Regional Center is working on establishing new Stewards in India for population of the glacier database at NSIDC, Boulder, CO, USA. A new Asian GLIMS-linkage subgroup will be established for coordination of methodologies and population of NSIDC database. Dr Shroder has already contacted Dr Roohi about becoming an official GLIMS Steward with UNOmaha for Western Himalaya & Hindu Kush. Dr Yao will contact Asia CLIC about this project. Formulation of future plans needs to begin through the MAIRS IPO.

3. Project Title: Monitoring land use changes

Rationale

In the high mountains of monsoon Asia the terrain imposes severe limitations on the scale of

productive activities as well as on the efficiency of infrastructure. As a result, subsistence agricultural constitutes the main source of rural livelihood due to extremely limited availability of arable land and low agricultural productivity. This traditional subsistence agricultural system in the region is closely interlinked with forests, pastures, and rangelands. During the recent past, a variety of changes have emerged in traditional resource use mainly in response to increasing pressure of population and the resultant increased demand on natural resources, and increasing social, economic and political marginalization. As a result, the environmental components and natural resources in the region are leading to large scale and rapid land use changes. The detailed study of these land use changes is imperative on the following grounds:

- Land use changes are leading to environmental changes, including climate change or vice versa.
- Impact on geo-hydrology and water recharging capacity of land, including drying of springs and decrease in water flow in streams and rivers.
- Significant impact on natural resources i.e. forests, biodiversity and land resources, etc. and also on subsistence mountain economy.
- They affect all human activities, particularly, agriculture and food production, and resource utilization pattern.
- Direct impact on rural livelihood, food security, migration, agricultural productivity and human health.
- The detailed information on land use is not available.

Objectives

The main goal of the project is to interpret the overall trends and magnitude of land use dynamics and their steering factors, and to gain an overview of the impacts (current and probable) on the natural ecosystem and human sustainability in the monsoon Asia mountain zone. In order to attain this goal the following milestones have been proposed:

- Review of the information available on mountain land use and its dynamics across Monsoon Asia Mountain Region.
- Identification of information and research gaps.
- Interpretation of steering factors of land use changes on the basis (in natural, socio-economic and cultural back drops) regional studies and experiences.
- Development of a framework for monitoring land use changes and assessment of their impacts on natural ecosystems and human society and economy (i.e., livelihood, out-migration, women, cropping pattern,

productivity, food security, livestock, etc.).

- Development of meta database.

Activities

The following activities are proposed over a period of one year:

- A special session on 'Land Use Monitoring' is proposed to be held during the international workshop on 'Downstream Impacts of Changes in Water Towers' to be convened by Prof. K. L. Shrestha, in Katmandu, in 2007.
- Appropriate methodologies for monitoring land use changes will be identified, and standardized for their future applications in land use change monitoring, during the special session.
- Road map for the future activities will be prepared during the special session.
- The information, comments, observations and feed backs received during the meeting will be Synthesized and published in the form of proceeding.
- A full international workshop will be planned for the year 2008 for the formulation of final proposal.

Timing

One year will be required for the development of final project proposal

Potential participants

Experts from MAIRS mountain zone countries such as China, Nepal, India, Pakistan, Mongolia, Bhutan.

Next steps & responsibilities

Dr P.C. Tiwari will coordinate the project activities and will liaise with the MAIRS IPO and group members. He will also identify experts for Katmandu meeting to be held in 2007, and also groups/ persons, including institutions for the final formulation of proposal, in consultation with MAIRS IPO and group members.

4. Project title: Changes at the snowline across the mountain zone of MAIRS

Rationale

Changing snowlines can be sensitive indicators of climate change if at the end of each melt season they are higher or lower than previous years for significant periods of time, depending upon the response times and activity indexes of the glaciers they occur on. Off-glacier snowline behavior and fluctuations impact many other processes in the mountain regions. Fluctuations of snowline will strongly feed back to climatic changes by changing albedo on the Earth surface. The fluctuations of snowlines also impact the hydrological processes and the fate of the overall cryosphere and ecosystems. The snowline movement also can relate to the movement of the timberline and thus of land-use in the mountain region.

Snowline behavior and fluctuations are different under different climate regimes, particularly in the Himalayan-Tibetan Plateau region where the westerly and monsoon systems interact. Snowline behavior and fluctuations are not well understood. The study of variations in behavior of snowline is now being carried out at national and regional levels, but integrated studies being needed. It is particularly important to identify areas threatened by hazards (droughts, changing slope-failure conditions, snow avalanche increase or decrease) associated with snowline or timberline movement. With increasing monitoring and remote sensing progress (ASTER & SRS data, for example), tracking of snowlines is possible.

Snowline determinations on glaciers should avoid glaciers where large quantities of snow accumulate through avalanching, thereby producing a bias of the local snowline toward lower elevations. Snowlines on glaciers have been documented across all or parts of the Himalayas in the 1950s by German workers, in the 1980s by Chinese analysts, and in the 1990s by English researchers; such work should serve as a comparative basis with modern satellite imagery to identify any regional trends.

Objectives

The primary objectives of the project are to:

- Document dynamic and environmental changes of the snowline across the Himalaya, Tibetan

Plateau and Maritime Mountains

- Identify the availability and accessibility of data sources and the gaps
- Document the suspected relationship between snowline fluctuations and changes in timberline
- Identify vulnerable ecotones
- Develop the potential of remote-sensing data for snowline and timberline identification and monitoring.

Activities

The main activities of the project include an international cryosphere workshop reviewing data availability and accessibility (ecosystems, climate, hydrology, land-use), comparing regional differences in snowline behavior and fluctuations, publishing results from the workshop, and establishing a snowline data base.

Timing

It is suggested that a workshop should be planned for August 2008 at the latest. It could be incorporated into the proposed cryosphere workshop planned by Drs Shroder and Bishop in Katmandu for late 2007. Alternatively it could be incorporated into the proposed workshop of Project 5, which will be organised by Dr Kitayama in early 2008.

Potential participants

The potential institutional participants would be

- GLIMS Regional Centers & Stewards
- START
- MRI
- CIIC
- ICIMOD.

Relevant countries include

- Afghanistan & Pakistan - Shroder & Bishop
- Pakistan - Roohi
- India - Kulkarni, Hasnain, Haritashya, Joshi, Tiwari

- China - Yao Tandong
- Bhutan - Metrological Department
- Japan - Kitayama
- Nepal - M.L Shrestha
- Kazakhstan - I. Severskiy

Next steps and responsibilities

Dr Yao Tandong will coordinate the project. Working with the IPO, he will identify and lead an organising committee, which will identify groups and experts for the workshop. The workshop participants will hold snowline data with ground surfaces including glaciers (through mass balance studies and remote sensing), forests, and grassland (through remote sensing), as well as relevant meteorological data. The committee, which should include Drs Kitayama and Shroder, will plan and coordinate the workshop as well as a publication of the results of the workshop.

5. Project title: Mountain ecosystems

Rationale

The mountain zone has unique ecosystems associated with their rugged topography, high altitudes, low temperatures, low atmospheric oxygen concentrations, high erosion and scarcity of water. These factors impose harsh conditions on its inhabitants as well as on vegetation. The mountains support a rich assemblage of ecosystems and biodiversity within a short distance, and thus have high conservation value. The ecosystems can be either sensitive or resilient to global warming, and can have indicator value for change detection. The upland people obtain resources and energy for sustenance from the ecosystems. Some flora and fauna are under threat of extinction in the wake of intense anthropogenic pressure and increasing global temperatures. It is important to monitor changes in mountain ecosystems that can have consequences in the downstream ecosystems and in the local/synoptic climate schemes.

Objectives

The objectives of the project are to

- Detect recent shifts of timberlines and ecotones by locating the extant permanent plots across the mountains in monsoon Asia, and to bring out a protocol manual for a change detection
- Detect the recent shifts of overall ecosystem structure and function (such as NPP, water, energy and biogeochemical processes) across the mountains in monsoon Asia
- Identify and map potentially-vulnerable ecosystems (i.e. resilient and with high biodiversity and rich endemics)
- Identify migratory routes along mountain corridors for changing ecosystems under global warming
- Identify the region-specific factors influencing the ecosystem
- Study the effect of scenarios of future climate change on the ecosystems.

Activities

The activities of the project will include:

- An international workshop (proposed to be held in Japan) to review existing information and data relating to various parameters of ecosystem in the participating countries
- The establishment of a network and database of extant plots
- The establishment of a network and database of extant plots
- The preparation of a protocol manual for monitoring ecosystems.

Timing

The workshop will be held in early 2008 and it will provide the basis for a 3-5 year project to meet all the objectives.

Potential participants

Participants in the workshop will include:

- Individual researchers who study high mountains in India, Pakistan, Nepal, Bhutan, China, Mongolia, SE Asian countries, Taiwan, and Japan
- DIVERSITAS, IGBP, WCRP, GLORIA.

Next steps and responsibilities

Drs Iqbal and Kitayama will coordinate the project with the MAIRS IPO. They will identify a committee to organise the workshop and prepare reports from the workshop, including manuals on consistent monitoring practices and on potential adaptation policies for ecosystems.

6. Project title: Modelling land-air interactions in the mountain zone

Rationale

The Asian monsoon is sensitive to variations in the large-scale atmospheric circulation over the Tibetan Plateau. Such variations arise because of the size of the Plateau and the extent of the seasonal variations in surface forcing on the Plateau. There remain some uncertainties about the role of Tibetan Plateau at regional and global scales. Modelling is an important technique for understanding the effect of the Himalaya-Tibetan Plateau on the Asian monsoon system, as well as the effect of climate change on processes occurring at the land surface (e.g. snow cover, vegetation morphology and vegetation carbon cycle). The remains some uncertainty in the simulations and forecasts of general circulation models (GCMs) in high mountain areas, such as Tibetan Plateau, because of the steep topography, complex land cover, a lack of in situ climate and terrestrial ecosystem observations, and limitations in our knowledge of physical and biological processes over high mountains areas.

Modelling of climate in the high mountains can be carried out by nesting a regional climate model (RCM) in a GCM using high-resolution topography and land cover datasets. While this approach yields great spatial resolution, it does not overcome the limitations of data on and knowledge of the various coupled physical and biological processes that operate in these regions.

To improve the capability of modelling land-air interactions in the high mountains in Asian monsoon region, a greater understanding of land-surface processes over these areas is necessary, especially processes involved with interactions between the hydrological and carbon cycles. More comprehensive in situ and satellite observations and high-resolution land-cover and land-use change datasets are needed. Observations of climate and terrestrial variables (e.g. soil moisture, albedo,

LAI and NPP) in the high mountains should be used as validation data for simulations from RCMs and GCMs. Through careful model development and validation, reliable climate models incorporating realistic land surface processes can be provided for the land-air studies over the Tibetan Plateau. Such models will also improve climate and terrestrial modelling in mountain regions in general.

Objectives

Modelling is a common element across all the MAIRS zones, and so some of the objectives of the mountain zone modelling program will be reflected in the overall modelling plans for MAIRS. The specific objectives for the mountain zone are to

- Enhance the accuracy of model simulations over Himalaya-Tibetan Plateau regions by improving understanding of relevant land-air physical and biological processes
- Identify landscape changes over high mountain regions for incorporation in models
- Develop consistent scenarios of future climate and land-use change across the region
- Simulate the impact of regional change on the Asian monsoon system, and improve understanding of the interactions between regional and global climate
- Enhance regional capability in modelling.

Activities

Modelling will be a continuing program in MAIRS. Some of the activities for the mountain zone will be:

- Workshops on the inter-comparison of regional climate models focusing on high mountain simulations
- Promoting the establishment of more comprehensive in situ observing sites over the high mountains of monsoon Asia
- Preparation of high-resolution land-cover change datasets from satellite monitoring and field observation
- Sharing data among high-mountain countries (especially meteorological, hydrological, land cover and change)
- Enhanced field experiments among countries in the mountain zone of monsoon Asia
- Enhanced capacity building across relevant countries and institutions.
- Establishment of regional working groups on modelling.

Timing

To help establish a longer-term program of activities, an initial workshop could be held in the spring of 2008. It is expected that at least 2 years will be needed to prepare for the workshop.

Participants

The initial workshop would aim to link the existing regional modelling activities with the relevant activities of the global environmental change research programs. Participants in the workshop could include:

- GEWEX, CLIVAR, iLEAPS, NESPPI
- IAP, CAREER, CMA,
- Global Change Impact Studies Center, Pakistan
- Nepal Hydrology and Meteorology Department, IDI
- GLIMS SW Asia Climate Modelling.
- Institute of Atmospheric Physics, CAS

Next steps and responsibilities

As modelling will be an important research element in all MAIRS zones, it will be important for the MAIRS Steering Committee and the IPO to ensure that the mountain zone activities are consistent with the overall program. The first step in the process should be for the Steering Committee to identify a small group to coordinate modelling across MAIRS. At that time, the nominated convener for the mountain zone modelling activities will be able to work with the IPO to prepare for the workshop in 2008. A particular function will be the identification of key modelling groups focused on the mountains of monsoon Asia.

7. Project title: Vulnerable communities and ecosystems

Rationale

The high mountains of monsoon Asia, particularly the Himalayas, are tectonically unstable, ecologically sensitive, and economically under-developed. They also represent the most densely

populated mountain ecosystems of the planet. They are particularly vulnerable to various types of environmental changes because of their highly fragile environment and tectonic instability. Besides the local effects of global climate and environmental changes, the densely populated and heavily urbanized and industrialized plains situated adjacent to the mountains are also affected by the sustainability of the high-mountain ecosystems, mainly through changes in surface heating, precipitation and the intensity of extreme events in the adjoining mountains. Moreover, the intensification of human activities and rapid urbanization, with increasing energy use, in the Himalayas are bringing about widespread and long-term environmental changes in the region. There is substantial evidence of environmental degradation in the mountain zone of monsoon Asia during the recent past, involving land and soil degradation, hydrological imbalances, losses of biodiversity, desertification, disappearing wetlands, grassland exploitation, and water pollution.

The productivity of rural ecosystems has declined and food and livelihood securities of rural poor have been affected adversely leading to environmental instability and community un-sustainability in the region. The land, water, forests and biodiversity of the mountain ecosystems in the region are now under a process of transformation due to the stress of environmental changes. These changes are leading to several kinds of natural disasters in the region. Mountain societies, their food systems, economies, livelihoods and resource development activities are highly vulnerable to such kinds of local, regional as well as global environmental changes. The high-population zones are particularly vulnerable to such types of environmental changes. It is therefore imperative to study the impact of environmental changes on the natural ecosystem as well on the communities and to examine their capacity to withstand such rapid changes. It is also essential to develop appropriate strategies to increase adaptation capacity in ecosystems and communities to adjust to future environmental changes in monsoon Asia

Objectives

The main objectives of the work are to assess the impact of environmental changes on ecosystems and communities and to analyse their resilience to such changes through inter-institutional and international research cooperation and partnership. A further aim is to develop appropriate strategies for increasing community adaptability under scenarios of future environmental changes. In order to attain these objectives the following works are proposed:

- A survey of research carried across the monsoon Asia mountain zone on environmental

changes and their impacts on mountain ecosystems and human communities that inhabit them

- Identification of data and information gaps
- Study of the nature and types on environmental changes in the region
- Assessment of environmental changes on mountain ecosystems and human society
- Development of a framework for improving ecosystem and social adaptability to cope with environmental changes.

Activities

The main activities will include:

- Organization of an international workshop. About 50 participants from ecology, botany, forestry, geography, geology, hydrology, climatology and other environmental sciences and social sciences will be invited to the workshop.
- Reviewing existing information and data with respect to various parameters of ecosystem and community vulnerability, and the status of their accessibility to collaborating countries (China, Nepal, Bhutan, Mongolia, India and Pakistan) and participating institutions and researchers involved.
- Developing a standard methodology for assessment of ecosystem and community vulnerability to Global Environmental and Climate change
- Planning future activities on the basis of the outcomes of workshop
- Formulating final project proposal
- Discussing how to facilitate access to and sharing of data and information in monsoon Asia countries
- Publishing the outcomes and recommendations of the international workshops in the form of a journal or book.

Timing

The international workshop will be organized at some appropriate location in Indian Himalaya in October 2008. Dr Tiwari will coordinate the workshop and make all necessary arrangements for the meetings including the selection of the venue of the workshop in consultation with MAIRS IPO and group members.

Potential Participants

Participants from China, India, Nepal, Bhutan, Mongolia, Pakistan and other relevant MAIRS countries are expected to contribute.

Next step and Responsibility

Dr P.C. Tiwari will coordinate the project activities and liaise with the MAIRS IPO and the group members. He will convene an organising committee, which will identify workshop participants prepare a detailed workshop proposal with the IPO.

8. Project title: Downstream impacts of changes in the Himalayan-Tibetan Plateau 'Water Towers'

Rationale

Changes in the water towers of the Himalayas and Tibetan Plateau (HTP) in general refer to changes in 'water-related ecosystem services' of the mountain regions. The 'water related ecosystem services' are identified as the water volume that runs through rivers originating from the mountains, the quality, the time variations of water flow and the frequency and nature of extreme events (such as cloud bursts and high floods). We will consider six major rivers of the HTP, viz. Indus, Ganges, Bhramaputra, Mekong, Yangzhe, and Huang Ho.

There is significant natural variability in each of the four aspects of the mountain ecosystem services. In addition, climate change and other environmental changes such as land use, water use and air pollution are also expected to causes changes in the water towers, and these changes are likely to intensify further in the days to come. Anthropogenic influences start to alter the ecosystem services also, e.g. by building dams. The changes in the water towers due to anthropogenic causes are likely to be already outside the range of the historic natural variability and these would have downstream impacts in unprecedented ways. Meanwhile, the demands for water in both the upstream and downstream regions are increasing due to population growth, rising urbanization and industrialization, as well as changing lifestyles.
Impacts of the changes will occur particularly on the human activities, viz. agriculture, hydro-

power generation, water consumption by industry and by cities, as well as on infrastructure. For instance, earlier melting of snow can change the cropping pattern in irrigated agricultural systems, more intensive rain can shorten the economic lifetime of reservoirs used for electricity generation, a more irregular distribution of river runoff leads to both the flooding and water scarcity at different times in cities, and Glacial Lake Outburst Floods (GLOFs) can bring extensive damage to infrastructure and farmlands. Such impacts bring significant consequences for livelihoods of people and for societies as a whole. These consequences give rise to the need for adaptations to maximize the benefits or to minimize the negative impacts. Most of the consequences bring increased cost and/or reduced wellbeing of people, but there are also cases where the impacts are positive on livelihoods, such as an expanded growing season and higher yields.

The downstream impacts of climate and environmental change in the mountain regions are well documented in some countries and much less in others. As there is a general lack of data and information on the resource and downstream usage of 'water' from the water towers, sharing the available data and information among the countries will provide valuable synergies and strategies for future adaptation to upcoming changes. Knowledge and experiences including those on water governance from several countries could be compared and complemented. Furthermore, as impacts are usually studied separately by sector, they need to be integrated to understand the full impact on development. The APN-project on the Himalayan Mountains, as well as others on the Indus and Ganges plains and the Mekong region, have collected some information, which will provide a basis for future activities.

Increased knowledge alone, however, is not sufficient. The new knowledge and insights should be shared and communicated through follow-up dialogues between scientists, policymakers, think-tanks, private sector representatives and other users for learning about potential changes in water towers and issues critical to the future of water resources, people and ecosystems dependent on the water towers and for implementing improved plans through inclusive water governance for adaptation to changes in the water towers.

Objectives

The objectives of the project are:

- To document the status of the human livelihood and other activities that are based on the

water-related ecosystem services in the countries directly affected by the HTP rivers, and to document the ongoing changes in the status (e.g. for the status in agricultural sector: how much water is used now by irrigated agriculture, how much is the value of its products, how many people are involved?, and for the trends: are cropping systems introduced that use water more efficiently and fit better in the new climate?)

- To exchange knowledge and experiences on the water governance in the region and to identify measures for promoting inclusive governance for adaptation to changes in the 'water towers'
- To assess projected trends in the water related ecosystem services and their impacts over the next 3-5 decades
- To analyze and integrate the changes in water related ecosystem services and their possible impacts across sectors, river basins and for the region
- To identify mechanisms for adaptation and mitigation by governments, private sector and by people at large
- To make available to policy and decision makers the science-based information for dialogue and implementation.

Activities

The activities for the project will be based on an initial international workshop that will establish the scientific basis for follow-on liaison with policy and decision makers in the participating countries. The specific activities are:

- Identify countries and key agencies relevant for the six HTP-rivers and for impacts of water related ecosystem services (i.e. national agencies, regional agencies (e.g. Mekong River Commission). The national agencies are to be identified by the governments; the key agency may involve other organizations. The key international organizations related to water issues (e.g. GWSP, GECAFS, GEWEX, CLIVAR, MRI, START) will also be identified, and a template for consistent documentation of the status of water-related ecosystem services will be prepared. Potential co-funding agencies and a location for the initial workshop will be determined.
- Prepare country papers (by national key agencies, on basis of the template) on the status and the trends of changes in water-related ecosystem services from the water towers, projected impacts and mechanisms for adaptation. Impacts are sought on households, agriculture, hydro-energy, cities and industry, infrastructure. Country papers will also specify sources and availability of data. The preparation of country papers may require specific funding. It would be desirable to

have participating policymakers prepare brief reports on their perspectives of downstream impacts and adaptations. The papers on the current status of water-related ecosystem services should be complemented by a paper on projected changes in these services from the HTP regions and on potential impacts of the changes.

- Organize the initial international workshop involving scientists and policy makers. The purpose of the workshop is to share knowledge and experiences, and to develop more consistent and integrated approaches in the countries and in the region. The meeting could be held in Thailand or Laos, and it would extend over three days for the technical sessions, with an additional day for dialogue with policy makers. The outputs of the meeting will be recommendations with respect to implementation, and an overview of metadata, documented in a draft publication. The results of the meeting would be published at two levels: for scientists and for policy makers.
- Follow national level implementation by networking of the national agencies. The results of national implementation would be compiled and disseminated internationally.

Timing

Preparation for the initial workshop may take 6 to 8 months, so that the meeting could be held in late 2007 at the earliest. The output of the meeting could be published within about three months. The follow-up national activities would be monitored over the following year.

Participants

The workshop would involve about 50 participants from

- National agencies (10 countries, with 2-4 scientists and policy makers from each)
- International agencies (scientific (IGBP, IHDP, WRCP, DIVERSITAS, MRI, USER, WWF), donor (APN, DFID, EU), investment banks (ADB, WB).
- MAIRS IPO and scientists from Mountain Zone and from the Coastal and Urban Zones, as this proposal links the three zones.
- Journalists

Responsibilities

Dr Penning de Vries will lead the project in collaboration with the mountain zone working group. A

small organising committee will be formed to prepare the template for the country reports and to prepare for the workshop.

9. Project title: Natural disaster management

Rationale

Human life, infrastructure and ecosystems are threatened by natural hazards that lead to disasters. In remote mountainous areas, difficult access leads to the delay of rescue activities and hence to secondary disasters. Reconstruction and development activities due to poor accessibility are costly and labour intensive. Intelligent long-range planning and mitigation measures are required. In the more developed world the standard treatment of such problems involve a five-fold approach: (1) identification and planning, (2) mitigation, (3) preparedness, (4) response, (5) recovery. Some MAIRS countries currently do not have such scientific and administrative structures in place to deal with disasters.

Objectives

In the MAIRS regions the vulnerabilities to hazards by type (seismic, landslides, cloudbursts, flooding, GLOFs, forest fires, etc.) need to be documented and mapped. Especially important are to:

- produce maps of landslide hazards by main type (rockfalls & slides, rapid wet debris/ mudflows, deep-seated slump)
- document the nature of glacial lakes (type, size, bathymetry, volume, spillway/dam type and condition, hazard potential)
- inventory, classify, and map flood-prone areas across region by flood magnitude and frequency
- create or update seismic hazards maps
- distinguish between human and natural factors in natural disasters
- access information about national monitoring and early warning systems available and emergency response plans across the region
- establish hazards databases and geographic information systems (GIS) across the region.

Activities

The MAIRS IPO could plan for a workshop on hazards and disasters that highlights:

- existing information available and the level of detail
- institutions in each MAIRS country responsible for different disasters
- existing seismic hazard maps across the region
- research design for the Mountain Hazards Mapping Project done for the Kathmandu Valley
- GLOF-potential data as mapped and described by participants in the ICIMOD effort in Nepal
- national and regional flood-plain maps.

Timing

The workshop could be held within the next two years, and it could be associated with other planned meetings relating to the cryosphere.

Potential partners

The workshop should involve scientists involved with natural hazard mapping and planning in the mountain zone of monsoon Asia. Specific organisations that could be represented at the workshop include ICIMOD, USGS, GLIMS Southwest Asia Regional Center, national geological surveys, and national flood forecasting agencies.

Next steps and responsibilities

Dr Shroder will investigate the possibility of combining this workshop with other cryosphere-related meetings. A small workshop committee will be formed in collaboration with the MAIRS IPO to plan the meeting, including investigation of funding sources.

10. Project title: Permafrost change

Rationale

In the permafrost regions of the world, both the rock temperature and the basic nature of the

ground ice are degrading significantly as global warming continues. The high-altitude plateau areas of Tibet, as well as the high mountain regions of the Hindu Kush, Himalaya and Mongolia, will continue to have degradation of permafrost that will result in a variety of problems, including:

- vegetation changes
- thermokarstic depressions
- disruptions of infrastructure
- increased solute and particulate load in rivers
- decreased river discharge
- rock-wall collapse and catastrophic landslides
- activation of the soil carbon pool and attendant emissions of greenhouse gases.

A continuing lack of permafrost data in parts of monsoon Asia will restrict planning and decision-making to adapt to changes in the permafrost. Research initiatives are needed to ensure that there will be sufficient data and knowledge to support future decision-making.

Objectives

The primary objective of the project is to document and model the extent and character of permafrost across high-altitude regions of monsoon Asia. Such work is being carried out in Mongolia, but there is less work south of there. Extensive ground temperature measurements in boreholes across the region are recommended, as well as mapping and modelling using the various algorithms developed by Swiss researchers (PERMAKART, ROCKFROST). A systematic search and mapping is advised using satellite imagery (ASTER and other large-scale systems) for landforms indicative of permafrost or its degradation (tundra polygons, baidjarakhs, thermokarst depressions, alases, etc). The Asian Conference on Permafrost held in Lanzhou, China in August 2006 emphasized themes which could be applied and developed for MAIRS.

Activities

A workshop in the second half of 2007 on the Cryosphere of the Himalaya and Tibetan Plateau, planned by the University of Nebraska at Omaha, could provide a start for the project.

Timing

Late 2007 would be an appropriate time for a small initial workshop on the status of current research, as well as planning for future permafrost research in the MAIRS region.

Participants

Participants in the initial workshop could include

- Individual scientists associated with the Karakoram-Kashmir Workshop Group and GLIMS Southwest Asia Regional Center (Afghanistan, Pakistan, India), and University of Nebraska at Omaha, USA.
- Frozen Ground Data Center (FGDC), National Snow and Ice Data Center (NSIDC), Boulder, CO, USA
- International Permafrost Association (IPA)
- Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou
- GCISC, Pakistan
- Northern Eurasia Earth Science Partnership Initiative (NEESPI)
- CLIC.

Next steps and responsibilities

Dr Shroder will work with the MAIRS IPO to develop the project. A small organising committee will be formed to prepare for the initial workshop.

11. Project title: Snow-cover change

Rationale

Winter snow cover of a region is highly sensitive to thermal variations, leading to spring flooding before the normal onset of the summer monsoon and middle-late summer maximum glacial melt. Snow cover has a direct relationship with annual stream flows, it provides an important albedo feedback to climate, and it is the most important single annual contribution to glaciers. Transient snow-cover is readily observed by satellite imagery (e.g. MODIS), and it is the focus of ongoing

research that could link with MAIRS initiatives. Significant spatial, temporal or volume changes in regional snow-cover in the Himalaya-Tibetan Plateau region due to global warming could lead to severe climate and ecological problems on regional and global scales.

Objectives

The primary objective of the project is to promote the collection and analysis of snow-cover data across monsoon Asia. This activity will require the development of close ties with the national meteorological and hydrological services of the region. Snow-depth and water-equivalent measurement stations originally in place in such countries as Afghanistan need to be re-established, and advanced satellite data-collection systems should be better calibrated with in situ data. Where required, training for snow-cover measurements in the field and from satellite imagery needs to be established for the relevant agencies.

Activities

A workshop in the second half 2007 on the Cryosphere of the Himalaya and Tibetan Plateau, planned by the University of Nebraska at Omaha, could provide a start for the project. Workshop participants would share existing available information by bringing references and data, where possible. National data-collecting agencies need to be involved in the workshop. A synthesis of findings and publication of the workshop results as either refereed publication or edited proceedings would provide a useful record.

Timing

Late 2007 would be an appropriate time for a small initial workshop on the status of current research, as well as planning for future permafrost research in the MAIRS region.

Potential participants

Participants in the initial workshop would include:

- Relevant national meteorological and hydrological services
- NASA Goddard Space Flight Center, Greenbelt, MD

- National Snow and Ice Data Center (NSIDC), Boulder, CO
- GLIMS Regional Centers and Stewards for Southwest Asia, India, China and elsewhere
- GCISC, Pakistan
- Individual researchers with relevant data

Next steps and responsibilities

Dr Shroder will initiate the activity through discussion with the GLIMS group in late 2006 in order to help identify sources of existing data. A small organising committee will be established in collaboration with the MAIRS IPO to plan for the workshop.

12. Project title: Monitoring climate extremes and their impacts in mountain regions

Rationale

It is well recognized that most natural and human systems respond more dramatically to extreme climate events than to variations in mean climate. Over the last decade there has been a range of international activities aimed at improving the capability to monitor and analyse extreme climate events across the world. While there has been some good progress, much remains to be done to ensure that there are sustained mechanisms to continue the processes already started and to initiate activities where gaps remain. Recognizing the capacity-building aspects of these activities, START has maintained a program on Monitoring Extreme Climate Events (MECE), and it is appropriate that MAIRS develops a program of activities that supports MECE in monsoon Asia.

The problem of monitoring and analyzing extreme events is especially difficult in the mountain regions of monsoon Asia. Not only is the terrain rugged and the population sparse in many areas, but also the technical capability of some nations is inadequate to support the installation and maintenance of robust observing systems. Further problems arise when historical data are stored only as paper records, when adequate meta-data and consistent measurements are not maintained, or when adequate quality-control procedures are not implemented. Capacity-building activities have been shown to be effective in overcoming these problems at least in the short term.

While there has been an increase in collaboration in many parts of the world, data accessibility

does remain a concern in some regions. In particular it is sometimes found that hydrological and precipitation data are viewed as being either of substantial commercial value or sensitive for national security reasons. Under Resolution 40 of WMO, these data should be openly and freely available for research purposes. An important aspect of the work of MECE is to promote such free and open exchanges, so that both national and regional analyses of climate extremes can be readily carried out. The sharing of data across national and institutional borders greatly increases the overall utility, by ensuring that any local analysis is placed in a regional and global context.

It is valuable to analyse the climate record for trends and variations in extremes. However, the value is enhanced by extending the analysis to investigate first the relationships between variations in extremes and large-scale features of global climate and then to link observed extremes to possible impacts on natural and human systems. Such impact analyses should be carried out at high spatial resolution so that local effects can be identified and explained. The analyses obviously depend upon the availability of high-resolution climate data.

Objectives

The primary objectives of the project are to develop regionally-consistent analyses of climate extremes and to enhance the capacity of relevant agencies to maintain appropriate climate monitoring and analysis systems. A particular objective is to promote the free and open exchange of high-quality climate data for research across the region. The project will further aim to determine the relationship between the nature of extreme events and large-scale indicators of climate variability and change. The project should also raise awareness of the impacts of climate extremes on natural and human systems. While some activities will be appropriately confined to mountain regions, the project should also aim to carry out comparative studies across all the zones of MAIRS.

Activities

The main activities of this project are expected to be workshops focused on either collaborative studies or capacity building across the region. Initial meetings would need to develop consistent regional analyses by combining data from participants and to identify gaps and needs for further work. Meetings should also be used to promote the use of agreed international protocols for data collection, archive, quality control and analysis, including the treatment of meta-data.

Timing

The activities of this project should be coordinated across the MAIRS zones and with the START MECE program. There are currently proposals with APN for workshops on climate extremes in SE Asia and in South Asia in 2007 and 2008. The outcome of these meetings will influence the development of the specific MAIRS activities.

Participants

Participants in the activities will include

- START MECE
- CLIVAR ETCCD
- GCISC, Pakistan
- National meteorological services from each relevant country, and other appropriate research groups.

Next steps and responsibilities

Michael Manton will liaise with the coordinators of the proposed APN workshops and with START MECE to plan future activities for this MAIRS project.

6. Conclusions

The workshop was seen to be effective at different levels. Most importantly, a set of potential initial projects has been identified in section 5, and so it is clear that there are important and specific activities that should be carried out to advance the aims of MAIRS in the mountain zone. The nature of the proposed projects varies substantially. Some are quite focused, and they may involve a single workshop aimed at bringing together some outstanding data or issues. Ideally the workshop may lead to enhanced collaboration across institutions and nations in the region, so that either directly or indirectly other activities may evolve from the workshop. Some other proposed projects are broad ranging and they may require some years of planning before significant results are obtained. Such a mix of projects should encourage the evolution of MAIRS.

It is recognized that the number of participants in the workshop was quite small, and so there was

not a broad representation of disciplines, institutes, nations or programs. A significant aim of this report is to provide a basis for encouraging other individuals and institutes to join these initial MAIRS mountain zone activities. It is also important that MAIRS establishes effective links to existing international and regional research programs that relate to the aims of MAIRS; this report should assist in this process.

In order to establish a mechanism to continue the development of the proposed projects, the participants identified an individual who will take at least initial responsibility for progressing each project. Moreover an executive group was established to provide overall guidance to the process. The executive group is

Prof. Dr Kedar Lal SHRESTA (Co-convenor)
Prof. Tandong TAO (Co-convenor)
Prof. Michael MANTON
Dr Gregory GREENWOOD (MRI)
Dr AILIKUN (IPO).

The scientists with lead responsibility for each project will work with the executive group and the MAIRS IPO to refine and implement the plans for the projects. It is likely that the executive group will seek to optimise the available resources by combining some of the proposed activities in this report.

Appendix 1 - List of participants

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Appendix 2 - Program for Workshop

Tuesday 14 November

Introduction

Welcome - Roland Fuchs (Director, START)
MAIRS initial science plan - Frits Penning de Vries (Director, MAIRS IPO)
Purpose of meeting - Greg Greenwood (Director, MRI)
MAIRS mountain zone - Mike Manton (Convenor, MAIRS Mountain Group)

Background

Climate change in the Himalayas - Kedar Lal Shrestha (Nepal)
Integrated studies - Greg Greenwood (Switzerland)
GLIMS - John Schroder (USA)

Existing activities

YAO Tandong (Institute of Tibetan Plateau, China)
ZHANG Yili (Institute of Geography and Natural Resources, China)
WEN Jun (Institute of Cold and Arid Area Research, China)
Varun Joshi (India)
P.C. Tiwari (India)
Kanehiro Kitayama (Japan)
Mohsin Iqbal (Pakistan)
Rakhshan Roohi (Pakistan)
Discussion of program for rest of week

Wednesday 15 November
MAIRS mountain zone projects
Identification of gaps in current activities
Scope of new projects

Leaders and writing teams for projects

Thursday 16 November

Drafting of implementation plans

Friday 17 November

Consolidation of plans

Next steps

Appendix 3 - MAIRS mountain zone key science questions

The initial science plan for the mountain zone takes account of climatological, hydrological, ecological and social features. Six priority research areas are identified and key research questions proposed for each area. The priority areas are:

- Hydrology and water availability
- Ecosystems and bio-diversity
- Agriculture, forestry and food security
- Energy
- Natural disaster management
- Air quality and human health.

The key research questions corresponding to each priority area are listed below.

Hydrology and water availability

- Can past and current changes in the cryosphere (glaciers, snow and permafrost) be characterised and its future behaviour is projected in the Monsoon Asia Mountains?
- What are the impacts of climate change on water resources as a whole and in particular the contribution of glaciers and snow in river runoff?
- Can the impact of local human activities (rather the global climate change) on water resources in the Monsoon Asia mountain zone be identified and understood?
- Can regional bio-geo-chemical transport be identified in the high-altitude hydrological systems of monsoon Asia?
- What will be the impact of expected changes in water availability regimes on agriculture and food security of mountain areas as well as downstream?

Ecosystems and bio-diversity

- What is the response of ecosystems in Monsoon Asia Mountains to change and variability of the climate across the arid to maritime monsoon region?
- Can the most vulnerable ecotones in the Monsoon Asia Mountains be identified and understood?
- Can the impact of local human activities (rather the global climate change) on ecosystems in the Monsoon Asia Mountains area be identified and understood?

● Can we identify the consequences of upstream changes in nutrient transport in in-situ and downstream ecosystems?

Agriculture, forestry and food security

●Is there a real shift in cropping pattern and farming systems in the Monsoon Asia Mountains?

● How sustainable are subsistence and intensive agriculture systems in the mountain regions under changing climate?

● In regions where local vegetation or crop residue has traditionally been used as a source of energy, what could be the impact of climate change on the nature and availability of these resources?

Energy

●What is the impact of current hydro-electricity schemes on downstream flows and associated ecological and agricultural systems?

●What could be the impact of possible changes in flow regime under climate change scenarios on the efficiency and effectiveness of existing and planned hydro-electricity schemes?

●What is the impact of increased interaction between mountain communities and ecosystems due to improved transportation systems?

Natural disaster management

● Can we separately identify the human and climatic factors triggering natural disasters like landslides, floods and drought in mountainous regions?

● How can the potentially dangerous glacial lakes in Monsoon Asia Mountains be monitored to minimise damages associated with glacier lake outburst floods (GLOFs)?

Air quality and human health

● What are the common factors between settlements and air quality in mountain regions across monsoon Asia?

● Given the social and technical constraints on mountain communities, are there feasible strategies to maintain air quality in these areas?

Appendix 4 - Abstracts of presentations

The following eight abstracts are based on the presentations on existing research in the mountain zone of monsoon Asia. They are listed in the order in which they were presented at the workshop, as shown in the program (Appendix 2).

Impacts of Climate Change on Hydrology of the Himalayan-Tibetan Plateau
K.L. Shrestha

The Himalayan-Tibetan Plateau is the source of six major rivers in Monsoon Asia viz. Indus, Ganges, Brahmaputra, Ayeyarwady, Mekong, Yangtze and Hwang-ho and thus acts as water tower to billions of people living in the downstream regions.

Climate change is likely to change drastically the runoffs from these rivers because of consequent deglaciation and changed precipitation patterns as well as increases in water use in the upland areas. The impacts of all these factors particularly in the arid and semi-arid areas, wherein the runoff from the mountains constitutes a major component in the total runoff, are likely to be affected most adversely.

Hence studies on the ongoing and projected changes in the hydrology of Himalayan-Tibetan Plateau both through in situ measurements as well as remote sensing and modelling are the imperatives for charting and implementing necessary measures for adapting to the consequences of changes in the mountain river runoffs. In the interest of the downstream regions, it seems necessary to focus on the improvement of the health of mountain economies as well as on preserving the integrity of the mountain ecosystem and sustainable use of water resources in the mountain areas for maintaining to the extent possible the quality and quantity of the mountain runoff in the downstream areas.

Global Land Ice Monitoring From Space (GLIMS) Project
John F. Shroder, Jr.

Concerns over world-wide loss of ice have resulted in the GLIMS (Global Land Ice Measurements from Space) Project wherein glaciers are being mapped and monitored from space with the ASTER

satellite sensor. A combined American and Japanese satellite system allows all countries with glaciers to receive free, large-scale (15-m resolution) satellite imagery. The Governments of Afghanistan and Pakistan expressed little initial interest to the U.S. Geological Survey (USGS) or to the U.S. National Aeronautics and Space Administration (NASA) who were funding GLIMS. The University of Nebraska at Omaha (UNOmaha), with its three decades of research association in both countries, became the Southwest Asia (Afghanistan and Pakistan) GLIMS Regional Center for the Hindu Kush and Western Himalaya. In these ranges we selected transects of glaciers from west to east. All glaciers were mapped by geoscientists in the past half century and are now being reassessed for change detection. Deconvoluting original cartographic error from real change is problematic. Nonetheless, evidence of serious glacial retreat has major implications for downstream melt-water irrigation in this chronically drought-torn region. Most significant related events, however, are the debuttressing of valley walls that can cause massive landslides, and glacier lake outburst floods (GLOF) which threaten much of the Himalaya. Overall between Afghanistan and Pakistan we can say that the loss of significant glacier ice in coming decades may be becoming progressively more serious unless global warming ultimately generates greater marine evaporation that increases precipitation or augments precipitation. The GLIMS Project will continue monitoring glaciers but the task must be passed on to newly trained specialists from Afghanistan and Pakistan. World-wide glacier monitoring underway for decades is at last capable of achieving significant results with high resolution, stereographic satellite imagery in the GLIMS Project. ASTER data is also available for diverse research into natural hazards and other needs on a specialized basis through associations established with Regional Center personnel. Seed money is available through RCSWA for a Himalayan workshop.

Research at the Institute of Tibetan Plateau Research
YAO Tandong

Tibetan Plateau is a key region in the mountain zone of the MAIRS. Two issues are important on the Tibetan plateau:

- The impact of the Tibetan Plateau on global change. Recently, the most important impact of the Tibetan plateau is the impact of ground surface changes. The ground surface change caused by glaciers and snow cover is critical. The cause-consequence relationship between the heavy snow on the Tibetan Plateau in 1997 and flood in Yangtze River in 1998 is a good example.
- Impact of global change on the Tibetan Plateau. Particularly attention should be paid to

glacier retreat, lake fluctuations, vanishing wetlands, and grasslands deterioration.

The Tibetan Plateau's most serious problem is the significant glacier retreat observed during the last several decades. Due to the retreat of glaciers observed by field studies and satellite images, the glacial mass balance is found to be negative for several decades which is attributed to the change in climate in glacier basins.

Several consequences are related to the glacier retreat and their alpine conditions:

- Runoff regimes range from glacial-nival to pluvial supplied by snow and glacier melt which drive floods during spring till early summer.
- Glacier lake outburst floods (GLOFs) and floods from storm rainfall as well as summer droughts, are typical hydrological threats to the livelihoods of people.
- The role of ground ice (i.e. ice-rich permafrost) in the hydrological cycle is largely unknown.
- Permafrost melt could be additional water resources (similar to retreating glaciers).
- Retreating glaciers and thawing permafrost are exposing uncovered land to erosion and reduce slope stabilities leading to land-slides and mud flows.
- Water quality is deteriorated by urban and industrial development as well as by agriculture.
- Hydropower potential is high and competes with demands from other water users and the environment.
- The alpine mountain environment & ecosystem need protection and preservation.
- Present climate change impacts are likely to exaggerate during the forthcoming years.

Glacier retreat on the Tibetan plateau indicates the importance of the snow and glacier melting triggered by rising temperatures. The glacial retreat also elaborate vulnerability of environment in this region and the importance of river basin management that requires develop approaches and technologies for adaptive estimate and resilience. The ITPR is now focusing on four major aspects:

1. Analyses of snow and glacier distribution and change detection

Optical and SAR remote sensing data combined with CORONA imagery from the 60′s and 70′s are used to classify the historical spatial distribution of snow and glaciers together with their melting dynamics. The RS-based assessment will be validated by station time series provided by local partners. Change detection will be carried out by means of GIS analysis to classify the spatial distribution of glacier retreat. Snow and glacier melting water obtained from measuring stations

will be applied together with the digital elevation model to estimate river discharge.

2. Monitoring and Research Program
The program in called the Monitoring and Research Program (MORP) on the Tibetan Plateau. The final goal of the MORP is to set up at least 5 permanent stations on the Tibetan Plateau to intensively and continuously observe the changes over the plateau.

3. Organizing program and projects.
A program funded by the MOST has been carrying out.

4. Developing international cooperation.
Multi-lateral cooperation is well developing with many countries such as the US, Germany, Japan, Great Britain, Nepal and others.

Programs on global change in the mountain areas in IGSNRR
ZHANG Yili

Global change is a hot research topic in geography, environment and ecology sciences and is paid more attention by lots of research organizations, such as IGBP, IHDP and so on. In the Institute of Geographic Sciences and Natural Resources Research (IGSNRR) many researchers give contributions to global change researches in different aspects.

There are several foundations supporting the global change research in the IGSNRR. The National Basic Research Program of China is the most important project. Prof. Zhang Yili and his team have been studying the subject of 'Global change and human activities in the Tibetan Plateau' in the program since 1998.

Prof. Zhang Yili and his team have worked in different places in the Tibetan Plateau. They studied global change and its effects in the Mt. Qomolangma (Everest) area, along the Qinghai-Tibet Railway, in the source region of Yellow River and Yangtze River and Lhasa watershed by means of fixed ecological and environmental observations and investigation. There are different points of interest in these researches. The studies in the Mt. Qomolangma (Everest) area focused on the environmental disasters due to global change and on the adaptation to global change. The studies

along the Qinghai-Tibet Railway focused on LUCC and its effects. The studies in the source region of Yellow River focused on the grassland degradation caused by human being and climate change. The studies in the source region of Yangtze River focused on the effects of global change on wild animals. And the studies in the Lhasa watershed focus on the changing of water resources under the global change.

In the future, Prof. Zhang Yili and his team will pay more attention to the research of global change and adaptation strategies in Tibetan Plateau. First they will continue their work in different areas of Tibetan Plateau. Second they will focus on the Mt. Qomolangma (Everest) area, to carry out integrated researches with the support of the National Basic Research Program of China and other foundations. Another major and integrated research area is along the Qinghai-Tibet Railway, which goes through the plateau and almost all the ecological zones. The study covers the vegetation influencing climate change, vegetation reaction to global change and the adaptation to global change.

There are other researches on Tibetan Plateau in the IGSNRR, such as LUCC in the source region of Yellow River, Yangtze River and Lancang River. Most researches in the IGSNRR are carried out by Prof. Zhang Yili and his team. It is expected that the group will continue their work on global change research in the mountain areas.

Contribution of CAREERI to Global Change Study
Jun WEN

Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences is focused on studies over the cold and arid regions in Northwest China, mainly over the Tibetan Plateau regions. In the past several decades (more than 30 years), our research projects (funded by CAS, MOST, NSFC and the international cooperation programs) focused on the following:

- Climate and environment change studies over the Tibetan Plateau (by using field surveys, analyses and numerical simulations)
- Land surface process studies over the Tibetan Plateau (by using field experimental data, land surface process modeling, meso-scale numerical atmospheric modelling and satellite remote sensing)
- Land surface process studies over the Loess Plateau (by using field experimental data,

land surface process modelling and satellite remote sensing)

- Glaciology and geo-cryology over the Tibetan Plateau (by using field sampling and laboratory analyses)

In the future, CAREERI will carry out the following studies based on its accumulated scientific knowledge and ongoing projects in the past decades:

- Ground measurement and data collection for the environment and land surface process studies over the Tibetan Plateau
- Development of satellite remote sensing algorithms and exploration of the ongoing field experiment data for validating the algorithms to assess the Tibetan Plateau land surface process
- Link studies between land surface process and climate change, water resource over the Tibetan Plateau and its adjacent regions
- Link studies between climate changes and glaciology and geo-cryology.

Mountain Research in Indian Himalayan Region at G. B. Pant Institute of Himalayan Environment & Development

Varun Joshi

The presentation started with the aim, objectives and structure of the institute. The strength and uniqueness of the institute are based on multidisciplinary teams, blending of natural and social sciences, attention on fragile ecosystems, indigenous knowledge and optimal use of resources and aerial extent encompassing entire length and breadth of Indian Himalayan Region emphasized. The important issues for the institute include natural resource management, livelihood options and hazard mitigation. Challenges in achieving the objectives were also pointed out. The thrust areas of institute focused on

- Sustainable development of rural ecosystems
- Conservation of biological diversity
- Ecological economics and environmental impact assessment
- Environmental physiology & biotechnology
- Institutional networking & human investment
- Indigenous knowledge systems.

In general the identified areas for future work in the mountain zone of MAIRS well matches with the over all objectives and thrust areas of the institute.

The work carried out (past and present) by the institute which is more relevant to MAIRS includes:

- Snow & Glaciers,
- Climate Change,
- Catchment Area Conservation,
- Timberline Zone,
- Sensitive, Rare & Endangered Species,

The glaciers of IHR in general are receding and the institute has selected Gangotri, Milam and Dokriani glaciers in Western Himalaya for various studies. The broad findings of these studies were presented in few slides.

The results of climate change studies carried out for APN funding project for in Alaknanda river valley were also presented. Study based on long term available secondary data on rainfall and temperature in the study area indicates change of rainfall and temperature pattern in different altitude. CTL and GHG model studies carried out with the help of IITM, Pune data for future projection also indicated a shift as well as a change in the pattern of rainfall and temperature. The extreme events also increasing in the area and future projection based on CTL and GHG model also projecting increase in these phenomena in coming decades.

The past work on catchment-area conservation has been carried out by institute, and replication of this work for the Uttaranchal government was highlighted. Also highlighted was the need of this work for future sustainability of the drinking water sources of the mountain region.
The work related to disaster being carried out in the institute presented, as well as work on he shift of timberline zone in the higher Himalayan zone. The techniques used for biotechnology for mass propagation of rare and endangered plant Rhododendron maddeni in Sikkim Himalaya were presented.

The work carried out by the institute in the past is mainly need-based research. The past data obtained in the field of glaciers, catchment-area conservation and climate change would be very helpful in the future research in MAIRS program. It has been pointed out in the APN mountain

project of Himalaya that the climate of Nepal, Pakistan and India is changing. Enough data are available from this study and could be used as baseline information. Coping mechanisms for extreme events in the region may be considered well in advance by the MAIRS program, as they have their own emphasis on extreme events. The decline of water resources have been reported from many south Asian countries, and so catchment-area conservation could be one of the thrust areas for the sustainability of drinking water sources.

Glaciers are receding and much work on region basis is required. The data generated by various Asian countries may be pooled, and the interpretation of such data could be utilized by MAIRS to predict the future consequences in Asia region. Change in snowfall patterns, snowline and timber line is equally important to get an idea of climatic change across the entire HKH region.

Himalaya is inherently prone to various natural disasters, and every year we have one or another type of disaster occurring in the region. Now there is a need for prevention/ preparedness. Awareness and identifying the gap areas across the country in this direction is required urgently.

Environmental Changes, Ecological Stability and Socio-economic Sustainability in Indian Himalayas
P.C. Tiwari

The Himalaya is tectonically unstable, ecologically fragile, economically underdeveloped and represents the most densely populated mountain ecosystem of the planet. As a result, the region is highly prone to several kinds of natural risks and disasters, such as earthquakes, landslides, floods, avalanches, cloud bursts, and forests fires.
Due to the constraints of terrain, the subsistence biomass-based agriculture constitutes the main source of rural livelihood and more than 75 percent of the total population is solely dependent on the agriculture. However, the availability of arable land is severely limited and productivity is considerably poor. The cropping intensity is very high which symbolizes the distress cultivation in compelling circumstances.

During the recent past the traditional resource-use structure has changed mainly in response to increase in population and resultant increased demand of natural resources, such as, cultivable land, pastures, fodder and fuel wood, as well as due to increasing social and economic

marginalization in the region. This started the process of exploitation of natural resources beyond their ecological carrying capacity. As a result, the land use pattern is changing fast and leading to the conversion of productive land and forests into waste and degraded area. This has a great adverse impact on the local climate, productivity of rural ecosystem and community sustainability and in the entire region.

At the same time, there has been rapid expansion of the road network, development of tourism and growth of urbanization in the region leading to further depletion of natural resources and disruption of ecosystem in the region. The urban growth is totally unplanned and unregulated rendering the vast areas highly vulnerable and prone to natural disasters and climate changes.

Many of these critical issues are now have been brought into the focus of the research and development activities of Kumaon University, and the researchers from various departments of the university are currently engaged in carrying out applied scientific and interdisciplinary research in mountain hydrology, geomorphology, sustainable agriculture, food systems, livelihood security, integrated natural resource management, disaster and risk management etc. with financial support from national and international funding agencies. The university has well equipped GIS and Remote Sensing laboratories to help in the implementation of ongoing research and development activities. For the coming years the research agenda of the university includes study of land use dynamics, glacial studies, livelihood development, disaster management, water availability particularly in collaboration with international organizations.

Global change studies on mountains in Japan and maritime East Asia
Kanehiro Kitayama

The project Terrestrial Ecosystem of Monsoon Asia (TEMA) was conducted as one of the core projects of GCTE (Global Change on Terrestrial Ecosystems) of IGBP to predict the effects of elevated CO2 and climate change on the distribution and structure of forests in monsoon Asia, and to determine the associated feedback effects to the global carbon cycle. Many ecologists from various universities participated in the project. The research strategy of the project was based on the environmental gradient concept along a transect in monsoon Asia from boreal forests in Siberia and Hokkaido, through cool and warm temperate forests in mainland Japan and eastern China, to tropical rain forests in Southeast Asia. This transect included two high priority areas of

GCTE: boreal forests, which were expected to change significantly because of increased temperature due to increasing concentrations of greenhouse gases in the atmosphere, and tropical rain forests, which were endangered by the rapid change in land use due to deforestation and high population pressure. A particular emphasis was placed on the linkage between physiological processes of foliage canopy and landscape-scale processes of plant demography and plant community dynamics, where plant individual processes were integrated from physiology, which in turn were projected to geographic patterns.

Follow-up research and the interactions of natural systems with land-use changes need to be studied in the next phase. We seek collaboration with international programs.

Monsoon Asia Mountain Zone in Pakistan - National Perspective
M. Mohsin Iqbal

The existing land and water use patterns and the farming and cropping systems of Northern Areas (NAs) of Pakistan, together with their constraints, are presented. The NAs are home to three mountain ranges, namely Hindu Kush - Karakoram - Himalaya (HKH region) which contain the loftiest mountain peaks and the biggest glaciers of the world. The glaciers are the source of water for the Indus river and its tributaries. The Indus Basin produces 80% of Pakistan's agricultural produce and hence serves as the country's food bowl. Water scarcity is the top problem of the area combined with small size of farms (97% subsistence farms), increasing land fragmentation and poor storage, marketing facilities and the high cost of transportation.

Various government organizations and NGOs are working in NAs and a number of development projects are underway with different objectives. An outline of the future strategy for development of NAs in the areas of water use, land use, crop culture, livestock, livelihood improvement and outreach activities is given. The NAs are facing a threat of 27% reduction in water supply by 2050 due to receding glaciers and changes in pattern and amount of precipitation as a result of climate change (IPCC, 2001).

The Islamabad-based Global Change Impact Studies Centre (GCISC) is studying the impact of climate change on important sectors of economy such as water resources, agriculture, climate, environment, biodiversity, etc. For these studies, appropriate global and regional models relating

to climate and water, and crop simulation models are being used. The Centre is willing, and will like, to contribute to various projects developed by MAIRS.

Glaciers and Glacial lakes of Pakistan
Rakhshan Roohi

Pakistan Agricultural Research Council (PARC) is the peak body responsible for coordinating multidisciplinary research focused on agriculture, livestock, natural resources and socio-economic aspects of the complex system. Besides having the National Agricultural Research Center (NARC), it has several research establishments distributed all over the country responsible for site-specific research. Further, PARC is also linked with the provincial agricultural research system.

Water Resources Research Institute (WRRI) is one of more than 12 theme or discipline oriented institutes at NARC focusing research on irrigation water management, water harvesting and conservation, resource use planning and management of hill flood-water in Rod-Kohi areas. One of the important activities of WRRI is the use of geo-informatics for agricultural planning and natural resource management.

In reference to the MAIRS mountain zone, Pakistan is blessed with three major mountain ranges namely Hindu Kush, Karakoram and Himalaya. These ranges store the snow and glacial ice reserves which are valuable resources of freshwater for the Indus River System (IRS). During most of the summer season, high flows in the IRS are due to snow and ice melt. In the past no comprehensive study has been carried out to register the details of this glacier resource. In collaboration with ICIMOD, APN, START and UNEP an inventory of glaciers and glacial lakes has been completed and based on the data generated the potentially dangerous glacial lakes are identified.

The watershed of Indus River within the country boundary can be divided into distinct ten river basins. The Landsat ETM+ and other supportive data were used to identify the glaciers and glacial lakes of these basins. The total geographic area of all these ten river basins is about 128,730.8 sq. km. Altogether 5,218 glaciers were identified which cover a total area of about 15,040 sq. km. These glaciers contribute total ice reserves of about 2,738.5 km3. The north and north eastern basins like Shyok, Hunza and Shigar basins contribute the major part of these ice

reserves (about 83%).

There are altogether 2,420 glacial lakes in the mountain areas of Pakistan. The highest number of lakes is in the southern basin especially in Gilgit (614) and minimum in northern basins like Shigar (54). The total area covered by these lakes is around 126 sq. km. Based on the detailed characteristics of each lake, 52 lakes are identified as potentially dangerous. Most of these potentially dangerous glacial lakes are situated at the headwaters of the river basins, while settlements, agricultural fields and infrastructure are mostly concentrated along the river valley downstream. When the location of potentially dangerous glacial lakes was correlated with the land cover, most of these lakes are in the area classified as bare ground. Furthermore, the correlation of this information with major fault lines running through the mountainous areas reveals that some of these lakes are either at the fault line or are very close to the line. These factors make these lakes more threatening through secondary factors, and they therefore need to be regularly monitored.

This study provides baseline information for future global climate change and glacier behavior studies, planning for water resources, biodiversity and environmental studies, infrastructure development, hazard mitigation and early warning system, irrigated agricultural planning for food security for poverty reduction, etc.

Appendix 5 - List of acronyms

ADB-Asia Development Bank
AGU-American Geographical Union
APN -Asia Pacific Network for Global Change Research
ASTER-Advanced Spaceborne Thermal Emission and Reflection Radiometer
CAREERI -Cold and Arid Regions Environmental and Engineering Research Institute, CAS
CAS -Chinese Academy of Sciences
CLAC -Cold Land & Arctic Coast
CLIC-Climate and Cryosphere
CLIVAR -Climate Variability and Predictability Research Programme
CMA -China Meteorological Administration
DFID -Department for International Development
DIVERSITAS-An Integrated Programme of Biodiversity Science
EC -European Commission
ESSP-Earth System Science Partnership
ETCCD-Expert Team on Climate Change Detection (CLIVAR)
EU -European Union
FAO-Food and Agriculture Organization of the United Nations
FGDC-Frozen Ground Data Center
GCM-General Circulation Model
GCP -Global Carbon Project
GECAFS -Global Environmental Change and Food Systems
GEWEX-Global Energy and Water Cycle Experiment
GIS-Geographic Information System
GLIMS-Global Land Ice Monitoring From Space
GLOF-Glacial Lake Outburst Flood
GLORIA -The Global Observation Research Initiative in Alpine
GPR-Ground Penetrating Radar
GWSP -The Global Water System Project
HTP -Himalayas and the Tibetan Plateau
IAP -Institute of Atmospheric Physics (CAS)
ICIMOD-International Center for Integrated Mountain Development

IDI-International Development Institute

IGBP -International of Geosphere-Biosphere Programme

IGSNRR -Institute of Geographical Sciences and Natural Resources Research (CAS)

IHDP-International Human Dimensions Programme of Global Environmental Change

iLEAPs-Integrated Land Ecosystem-Atmosphere Processes Study

IPA -International Permafrost Association

IPO-International Project Office

IRS-Integrated Regional Study

ISP - Initial Science Plan

ITPR -Institute of Tibetan Plateau Research (CAS)

LAI-Leaf Area Index

MAZ - Monsoon Asia Zone

MECE -Monitoring Extreme Climate Events

MODIS-Moderate Resolution Imaging Spectroradiometer

MOST-Ministry of Science and Technology of China

MRC - Mekong River Commission

MRI-Mountain Research Initiative

NASA-National Aeronautics and Space Administration

NCAR-National Center for Atmospheric Research

NEESPI-Northern Eurasia Earth Science Partnership Initiative

NPP-Net Primary Production

NSF -US National Science Foundation

NSIDC-National Snow and Ice Data Center

OSC - Open Science Conference

RCM -regional climate model

SRS-Synchrotron Radiation Source

START-SysTem for Analysis Research and Training

UNEP-United Nations Environment Programme

USGS-US Geological Survey

WB-World Bank

WCRP -World Climate Research Programme

WMO-World Meteorological Organization

WWF -World Wildlife Fund

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