NORWEGIAN POLAR INSTITUTE

CENTRE FOR ICE, CLIMATE AND ECOSYSTEMS

Book of abstracts

High mountain glaciers and challenges caused by climate change

8-10 June 2009, Tromsø, Norway

Table of Contents

High mountain glaciers and challenges caused by climate change

8-10 June 2009, Tromsø, Norway

Centre for ice, climate and ecosystems at the Norwegian Polar Institute is hosting a climate conference initiated by the *Norwegian Ministry of the Environment* in cooperation with the *United Nations Environment Programme (UNEP*). We have invited you to address the challenges and impacts created by melting glaciers in high-mountain regions, including effects on downstream countries. The conference offers the opportunity to discuss the latest research on high-mountain glacier melts and the consequent effects on downstream areas, and provides the possibility of offering recommendations to policy makers. It also serves as a meeting place for scientists working with high mountain glaciers and glaciers in polar regions.

We wish you welcome to Tromsø, the Polar Environmental Centre and the Norwegian Polar Institute. It is our hope that this conference will be the start of a new platform for co-operation and communication across geographic and thematic boundaries.

The organizers

NORWEGIAN POLAR INSTITUTE

CENTRE FOR ICE, CLIMATE AND ECOSYSTEMS

NORWEGIAN MINISTRY OF THE ENVIRONMENT

UNEP

Climate change in the high mountain regions of the world: Do climate models adequately describe glacier systems?

Georg Kaser, Institute of Geography, University of Innsbruck

Abstract

Climate causes the existence of glaciers and drives changes in their accumulated mass. These changes impact the glaciers' size, their role as seasonal water storage, and their contribution to sea level changes. Consequently, mass changes are in the focus of research in order to understand the respective drivers and to assess consequences. Linking mass changes of mountain glaciers with atmospheric conditions and processes by modelling is a multi-scale and multi-method effort and is, in its full complexity, still in its infancy. Scientific aims and challenges are sketched, concepts are developed, examples of first comprehensive studies are presented, and potential outlooks are given.

Glacial hazards and downstream effects of climate change on high mountain glaciers

John M. Reynolds, Reynolds Geo-Sciences Ltd
john.reynolds@geologyuk.com

Abstract

As climate changes, high mountain glaciers in many regions of the world are down wasting, resulting in the increasing formation of and growing volumes of glacial lakes. Catastrophic failure of dams retaining the lakes gives rise to Glacial Lake Outburst Floods (GLOFs) that, with other glacial hazards, are among the most obvious adverse effects of climate change. Many, often poor, communities in remote mountain areas are commonly the most affected by such events.

Given the physical and economic damage that glacial hazards can cause, it is important, therefore, to be able to identify and define the degree of hazard objectively. Over the last decade or so significant advances have been made in the use of Remote Sensing techniques to map, classify and categorise glacial lakes. These methods have been used not only to monitor changes in the glacial lake systems but also to identify areas where lakes have the potential to form and grow perhaps two to three decades into the future, based on the rate of ice flow, low surface gradient of the debris-covered glacier, and negative mass balance. Similarly, advances in ground-based survey methods, such as the use of geophysical techniques, have helped to provide information about the integrity of the moraines themselves. It has been demonstrated that by using Multi-Criteria Analysis it is possible to gauge the degree of glacial hazard quantitatively. By analysing a given glacial lake system, basic threshold parameters such as lake volume, moraine dimensions, *etc*., can be determined. Similarly, parts of the same environment that could trigger a lake outburst, for instance, can also be identified and rated so that a hazard score can be assigned by which it can be graded. This affords a method of prioritising lakes objectively within a whole catchment or region. As climate continues to change, the nature of glacial hazards in a given region also has the potential to alter with time. Debuttressing of steep rock slopes as glaciers down waste, thawing of permafrost, changes to the boundary between cold-based and polythermal glaciers, and potential buoyancy of previously submerged stagnant ice masses within lakes, are some of the features that might be expected to become evident.

Climate change is affecting the supply of water from down wasting glaciers with severe consequences in terms of water resource management. When a GLOF occurs it can cause major changes to the course and characteristics of an affected river system, often for many years afterwards. Communities can suffer damage to houses, bridges, paths, access to grazing lands, and valuable food-producing land can be destroyed. Increased geotechnical effects are observed such as more landslides resulting from greater erosion of the toes of unstable slopes, and loss of agricultural land and forestry. Suspended sediment loads increase in the river water, with effects on the river ecology and resulting in greater abrasion on

hydropower turbine blades and greater rates of sedimentation. All of these changes have economic as well as physical consequences.

Glacial hazards can impact directly on hydropower schemes through total destruction or inundation and loss of electricity generation, often resulting in many millions of dollars in losses. They also affect high altitude mining by changing the physical characteristics of open pits, or by glacial lakes threatening to inundate tailings dams or obstructing vital access routes.

As GLOFs can travel for many tens of kilometres downstream, there are geopolitical considerations where a major hazard can exist in one country but the bulk of the vulnerability and potential losses exist in another.

Ultimately, as questions are asked about growing numbers of communities suffering from water stress where their water is derived from high altitude glaciers, are glacial lakes potentially just a hazard or can they become a resource? This is a question that is perhaps best answered when considering possible remediation of hazardous glacial lakes.

Food security and high mountain glaciers

Christian Nellemann, UNEP GRID-Arendal, Norway
christian.nellemann@nina.no

Abstract

Abstract not available.

Impact of retreating glaciers in glacial run-off: a global assessment of high mountain regions

Gino Casassa[1], Paulina López[2, 3], Bernard Pouyaud[3]

[1]Centro de Estudios Cientí?ficos, Av. Prat 514, Valdivia, Chile
[2]Hydrosciences Montpellier UMR 5569 (CNRS, IRD, UM1, UM2), Maison des Sciences de l'Eau, Université Montpellier 2, 34095 Montpellier Cedex 5, France
[3]IRD, UR Great Ice, Maison des Sciences de l'Eau, 300 avenue Emile Jeanbrau, F-34095 Montpellier Cedex 5, France

Glaciers are complex hydrological systems. Water storage can occur in snow, firn, supraglacial channels and ponds, englacial pockets and conduits, and subglacial bodies. Storage occurs at all timescales, from days to centuries. Peak runoff occurs during the melt season. The compensation effect of glaciers produced by differential storage/release of water results in smoothing of streamflow variations at different timescales, which can be particularly relevant for downstream water availability during dry periods.

Atmospheric warming due to climate change has been recognised at the main driver for the observed enhanced melting of glaciers which is occurring in the main mountain regions at a global scale. At first the enhanced melting of glaciers is expected to lead to increased run-off and discharge peaks, with an extended melt season, while in the longer term ice mass loss and equilibrium line rise can be so severe that run-off starts decreasing.

A global assessment of run-off data from glacier basins is presented (Casassa et al., 2009). Published data series from 27 glacier basins are included in the study, covering periods from 5 to 89 years, with glacier cover ranging from 0.015 % to 75%. In addition new data from 13 stations from Chilean glacier basins are analysed. The data show that glacier basins with a decreasing run-off trend have been observed in south-central British Columbia, Canada, at low elevations in the Swiss Alps and in the central Andes of Chile, which is probably a combined effect of reduced melt from seasonal snow cover as the snow line rises, and relevant glacier area losses. In Alberta, north-western British Columbia and Yukon in Canada, in highly glacierised basins in the Swiss and Austrian Alps, the Tianshan Mountains and Tibet in central Asia, and in the tropical Andes of Peru, a run-off increase has been detected which is highly related to observed warming, indicating that enhanced glacier melting is occurring.

Under future warming scenarios, glacier run-off should decrease even in high-altitude basins, which may have relevant effects in water availability downstream, particularly in arid and semi-arid regions. The data presented agree with the collapse of the water stationarity principle (Milly et al., 2008) which has largely ruled present water management policies, and call for the need to consider climate change in future water planning.

References

Casassa, G., P. López, B. Pouyaud and F. Escobar. 2009. Detection of changes in glacial run-off in alpine basins: examples from North America, the Alps, central Asia and the Andes. Hydrological Processes, 23, 31–41.

Milly, P.C.D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier and R.J. Stouffer. 2008. Science, 319, 573-574.

Water flow regimes in high mountains and role of the cryosphere: Andes, Pamir and Himalayas

Dr. Pierre Chevallier, senior scientist IRD, Laboratoire Hydrosciences, Montpellier, France.

Abstract

Research teams of the *Institut français de Recherche pour le Développement* worked since 1991 in the high mountains of the low latitudes in order to assess the impact of the climate change on the water resources. Those researches are in all cases conducted in partnership with local scientific institutions or official technical agencies. This approach combines different competencies in climatology, glaciology and hydrology at several scales of time and space. It uses numerous tools: the three balances (mass, energy and water flow), remote sensing techniques, modeling methods, reanalysis data, proxies, etc.

In the current presentation, a focus will be given with some recent results concerning the water flow regimes influenced by the glacier and snow melting from the local scale to the continental scale. First, in the Central Andes, the water discharges are strongly linked with the temperature when the glacierized area in the concerned watershed is significant. Second, in the Pamir range, the role of the snow cover is a key-issue for the water regimes at the scale of the headwaters in the problematic Aral Sea Basin. Finally an exploratory view will be given, comparing the three large Himalayan basins: Indus, Ganges and Brahmaputra Rivers.

Glacier runoff and its change over China

Baisheng Ye and Yongjian Ding, Cold & Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, China

Abstract

The glacier runoff has been estimated based on glacier inventory in China and observation data at several typical glaciers. The annual glacier runoff is about 60 km3, about 2.2% of total annual water resources over China. The glacier runoff is an important part of water resource in west China, especially in the arid northwest China where the water resource is a key factor to economical and social development. The 38% of water resource are from glaciers in the largest interior river, the Tarim basin in the Northwest China. Also, the glacier runoff strongly regulates the river discharge and leads to low variation of streamflow in basin with high glacier coverage. The regulation effect is obvious when the basin glacier coverage is greater than 5%.

The recent climate warming has significantly affected the glacier runoff over China. The long-term observation at the Urumqi River glacier No.1 shows that the glacier runoff from glacier ice loss is over the part from precipitation. The annual precipitation is only 523mm, but the glacier mass balance reach -556mm during 1996-2003. The 1/3 of discharge increase is from precipitation increase and 2/3 is from enhanced glacier melting during 1980-2003. Relative to precipitation-mass balance relation, the regression between temperature and mass balance is much stronger, indicating that summer temperature controls glacier mass balance and runoff changes. The partly repeated glacier inventory in China indicates that glacier mass loss is contributed to about 5% of mean annual discharge in the Tarim Basin during 1960's-2000. The glacier runoff estimated indicates the 1/3 of discharge increase is from glacier mass loss in small tributary of the Tarim Basin, Tailan River, during the past 40 years.

The ice-flow model with hydrology model has been developed and validated at the Urumqi River glacier No.1, then applied in the Yili River in Tianshan Mountains in Northwest China. The simulation of glacier discharge indicates that the glacier runoff tends to increase and then to decrease with climate warming and glaciers retreat. The runoff peak and its timing depend not only on glacier size but also on the rate of air temperature rise. The small glacier and its runoff are sensitive to climate warming, having quickly retreat of glacier, high peak and subsequently quick decrease of glacier runoff.

Glaciers, glacial lakes, and GLOF in the Himalaya

Pradeep Mool, International Centre for Integrated Mountain Development, Nepal

Abstract

Glacial lakes dammed by moraines and or ice core of retreating glaciers in the Himalaya due to accelerated global warming. Sudden breach of the unstable moraine 'dams' resulting discharges of huge amounts of water and debris – known as Glacial Lake Outburst Flood or GLOF – often have catastrophic effects downstream. Even the small glacial lake associated with hanging glaciers poses high potential for breaching and resulting to GLOF. At least twenty GLOF events recorded in Himalaya in the last seven decades that resulted in heavy loss of human lives and their property, destruction of infrastructure besides damages to agriculture land and forests. Information and knowledge on glaciers, glacial lakes and GLOF is required for the planning for water resources and flood hazards management. International Centre for Integrated Mountain Development (ICIMOD) and its partner institutes carried out the study of glaciers, glacial lakes and GLOF of selected basins in Himalaya. The studies generated the baseline information for future monitoring of glaciers, glacial lakes and GLOFs of the region due to climate change, for the development of monitoring and early warning systems, for planning and prioritizing disaster mitigation efforts, for estimating future available water resources and their planning and management. Study also reviled several potential dangerous glacial lakes in Himalaya. Some of the past GLOF events have damaging effects in the lower riparian countries. Regional cooperation is required for knowledge management on GLOF issues due to trans-boundary nature of GLOF phenomena.

Impacts of climate change on high-mountain glaciers in the Alps: Observations and results from modelling studies

Frank Paul, Dept. of Geography, University of Zurich, Switzerland
frank.paul@geo.uzh.ch

Abstract

Alpine glaciers lost about 1/3 of their total area from 1850 until the 1970s, and almost one half was gone by the year 2000. Starting from the last glacier inventory of the 1970s, little change was observed in the area until 1985 (-1%), but then a strong decrease (-20%) until the year 2000 occurred (-1.4% per year). This area loss was accompanied by a strong loss of glacier mass of about -11 m w.e. or -0.8 m w.e. per year. This is more than three times the reconstructed long-term mean mass loss from 1850 to the 1970s (about -0.25 m w.e. per year). The strong glacier decline is most likely a response to the sudden increase in Alpine temperature of about 1 C in the 1980s, which has shifted the equilibrium line altitude (ELA) by about 150 m upwards (precipitation has not changed). This has reduced the accumulation area of most glaciers drastically and they react with an adjustment of their size to the new climatic conditions.

Simple models based on rules of thumb allow to determine the consequences of such step changes in climatic conditions on future glacier evolution over large regions. With an assumed steady-state accumulation area ratio (AAR0) of 0.6, it can be calculated that about 40% of the total glacier area has to disappear for a 150 m upward shift of the ELA0. At current rates and considering the already lost glacier area since 1985, area loss will at least continue until 2015 and much longer for large glaciers with a response time > 30 years. In particular the latter display strong evidence of downwasting (e.g. collapse holes, disintegration) rather than retreat of the terminus. Based on current climate scenarios as published in the last IPCC report, it can be expected that glacier decline will continue and most glaciers in the Alps will disappear by 2100. Because glaciers as well as their meltwater in summer plays an important economic role in the Alps (e.g. hydro-power, discharge regime, tourism, natural hazards), concern is growing that the currently observed and future glacier changes will have adverse effects on human welfare. In consequence, several projects have recently started that should improve the modelling of future climate change impacts on glaciers and run-off.

The output from regional climate models (RCMs) and their efficient coupling to the much higher resolution impact models (e.g. distributed mass balance or hydrologic models) is in the centre of the scientific investigations. Depending on the specific characteristics of the used impact models, a large number of downscaling strategies have been proposed to bridge the gap in spatial resolution. Thereby, the ability of RCMs to provide physically consistent fields of meteorological input parameters (e.g. temperature, precipitation and radiation) over large regions (e.g. the entire Alps) is a clear advantage for distributed applications to headwater catchments. To this end, the large size of an RCM grid box (e.g. 20 km) represents valuable mean values for smaller catchments that might not be available from a meteorological station located at a point that is not representative for the study site (e.g. a mountain top with frequent orographic clouds). From current applications of RCMs to glacier mass balance models it became clear that the major deficiency of RCMs is the correct modelling of

precipitation in both amount and season. It is thus concluded that major efforts should be spent on improving precipitation in RCMs in rugged high-mountain topography. The available long-term observations for glaciers will provide a good basis for the required calibration and validation.

High-mountain glaciers as climate archives

Margit Schwikowski, Paul Scherrer Institut, Switzerland

Abstract

Ice cores from high-mountain glaciers represent excellent natural archives for reconstructing regional past climatic and environmental changes for the time periods before the introduction of meteorological instruments. Quantitative and precise reconstructions are needed in order to understand if the currently observed magnitude and rate of climate change exceeds natural variability. Here, ice core records from three distinct regions, the Alps, the Altai, and the Andes, are compared, revealing pronounced regional differences in climate and air pollution regimes.

Increased runoff from melt from the Greenland ice

Konrad Steffen, CIRES University of Colorado, USA

Abstract

The Greenland Climate Network (GC-Net) automatic weather station (AWS) Swiss Camp (1,169 m above sea level) record was used to gauge temperature changes on the western flank of the Greenland Ice Sheet, where extensive seasonal melt and relatively high run-off from this relatively low elevation zone contribute a large proportion of the total run-off. This record, by far the longest GC-Net series, spans 19 years (1991-2009), and its inter-annual variability is significantly correlated with that of the mean of the seven Danish Meteorological Institute coastal stations (de-trended series $r = 0.65$, $p < 0.01$). Swiss Camp summer mean temperatures increased significantly by 2.4°C from 1991 to 2008, or 2.2°C for the time period 1993-2008, excluding the global cooling effect of the Mount Pinatubo eruption in 1992. The three summers, 2003-2004-2005, were almost equally record warm years (mean temperatures 0.3°C, 0.3°C, and 0.2°C, respectively) at Swiss Camp, alongside 1995 (0.5°C) and the record year 2007 (1.2°C). The latter season has been previously noted for its relatively high modeled run-off compared with most other years during 1958-2003. The latest data from the Swiss Camp GC-Net record show continuing warming with another record mean summer temperature of 1.2°C in 2007, 0.7°C above the previous maximum in 1995. There is a negative trend in surface mass balance (SMB) of the ice sheet -22.1 km3 over 1958-2006, compared with a standard deviation of 104.8 km3 for the annual SMB values. The SMB trend underlines the sensitive balance between increased snow accumulation in the interior of the ice sheet and increased meltwater runoff around the edges. Additional mass loss from ice dynamics due to accelerated flow of outlet glaciers was probably at least several times larger for the recent few warmest years and will be discussed in more detail.

Glacier and stream flow response to the changing climate: some observations from Indian Himalaya

Renoj J. Thayyen National Institute of Hydrology, India

Abstract

Himalaya is an important cryospheric system of the world. Not only it is the largest outside the polar region but also sustain a huge population depended on its water. It is a complex system with varying climate and Hydrology across the Himalayan arc dominated by winter snowfall, summer monsoon and cold – arid climates. Lack of data and knowledge on Himalayan cryospheric system present a serious challenge to understand the cryospheric system response to the climate change and necessary adaptive strategies in this part of the world. This paper discusses the major glacio- hydrological regimes of the Himalaya and presents an overview of glacier change. The paper also discusses the Impact of climate change on the river flow response in some Himalayan Rivers. Most of the assessment on this aspect is being performed in the Alpine perspective, considering that the Alpine and Himalayan glacier systems are characteristically synonyms. However, this paper suggests that the glacio- hydrological regime of Himalayan and Alpine mountain systems are distinctly different. Presence of monsoon during the summer glacier melt period is the single most important factor differentiating the Himalayan glacier system from the Alpine glacier system, which has direct bearing on the stream flow and glacier mass balance characteristics. With the data collected from Din Gad catchment in Garhwal Himalaya (Ganga basin) from 1998 to 2004, hydrological characteristics of the 'Himalayan glacier catchment' are discussed. It is suggested that the highest discharge in the glacier fed streams in the 'Himalayan catchment' could occur during the years of high precipitation and glacier component in the stream flow is highest during the period of lowest summer runoff. Other manifestations of the monsoon climate of Himalayan cryospheric system including the temporal variations in the slope lapse rate of temperature with a characteristic reduction in monsoon months, variations in wind direction, sunshine duration and humidity are also discussed.

The role, achievements and prospects of remote sensing for observing high mountain glaciers and related hazards

Andreas Kääb, Department of Geosciences, University of Oslo, Norway

Abstract

Spaceborne remote sensing has in recent years drastically improved the knowledge about glaciers and glacier changes worldwide. This has helped in assessing global sea level rise, climate change, glacial water resources and glacier hazards. Remote sensing provides globally uniform measurements and is able to cover inaccessible areas. It is thus the method of choice for global-scale glacier monitoring. However, the ability to perform investigations without contact to local institutions requires also a certain responsible conduct.

Impact of deglaciation on flow regimes of Bhutanese rivers

Karma Chophel, Head, Hydro-met Services Division, Department of Energy, Thimphu

Abstract

Water is the most important natural resource for Bhutan. Lying at the eastern fringes of the Himalayas, the rugged terrain of the country is highly dissected by numerous streams and rivers that flow in a general north-south direction. The snow capped mountains in the north are sources for majority of these rivers.

Traditionally, the most important use of water has been for irrigation of crops, consumption by animals and for domestic use by the rural households. With the inception and development of hydropower projects in mid '80s, the role of water resources shifted tremendously. Consequently, water resources have come to play a prominent role in the economic and social development of Bhutan.

Deglaciation is a worldwide problem, but it is a greater problem in the Himalayas. The rate of glacier retreat is accelerating. The rate of retreat of Bhutanese glaciers is between 35-50 metres. The danger of river flow being reduced due to glacier melt in the long run will obviously impact the hydropower industry. The presentation will focus on the assessment of the impact of deglaciation on seasonal and long term water resources in snow and glacier fed rivers of Bhutan

Flooding from glacier lakes outburst floods (GOLF) and flash floods are now dominant threats to water resources in Bhutan due to climatic change and as well as the changing monsoon pattern. There are 2674 glacial lakes and 677 glaciers in Bhutan. Out of these, 25 are potentially dangerous. Glacial lake outburst floods cause enormous damages. The presentation will also focus on the downstream impacts of the 1994 glacial lake outburst flood. This flood occurred due to partial breach of Lugge lake at the headwaters of Phochu river.

GLOF hazards in Bhutan and the management of glacial lakes in high mountain environments

John M. Reynolds, Reynolds Geo-Sciences Ltd, UK
john.reynolds@geologyuk.com

Abstract

The potential for glacial lakes to cause devastation became reality in Bhutan on the 7th October 1994 when Luggye Tsho, one of the lakes in the Lunana region, burst through its left lateral moraine. The ensuring Glacial Lake Outburst Flood (GLOF), which contained an estimated 18 million cubic metres of water, debris and trees, swept downstream, killed 21 people, and travelled over 204 km before crossing the border into India and finally dissipating. On the 30th April 2009, Tshojo Glacier is thought to have been the source of an outburst that caused panic downstream at Punakha, where the fatalities occurred in the 1994 flood. No loss of life has been reported from this latest event. Over the last ten years a significant amount of work has been and is being done in Bhutan to address the issue of hazardous glacial lakes. Not only is this important in order to preserve life and protect property it is also vital if Bhutan is to develop its substantial hydro-electric power generation potential. Having identified and prioritised its hazardous glacial lakes, the Government of Bhutan has taken practical measures to mitigate Raphstreng Tsho between 1996 and 1998 by constructing an open channel to lower the lake level by several metres. However, in 1998 the adjacent Thorthormi Glacier was found to be downwasting, breaking up in parts, and developing interconnected supra-glacial ponds extremely rapidly. It was identified as being potentially the most hazardous glacial lake in Bhutan. Indeed, as predicted, the lakes have coalesced and enlarged; the ice-cored moraine dam separating them from the lower-lying Raphstreng Tsho has degraded significantly since 2004. It is estimated that if Thorthormi lakes burst into Raphstreng Tsho and thence downstream, it could generate a GLOF with a potential volume greater than 53 million cubic metres of water, nearly three times the volume of the 1994 flood, and cause substantial damage downstream and into northern India again. In recognition of the growing urgency to mitigate the situation, a $7.8 million programme to lower the Thorthormi Glacier lakes was sanctioned by the UNDP and is due to commence in June 2009.

Mitigation works both at Raphstreng Tsho and Thorthormi Glacier represent significant logistical and technical challenges in such remote locations. The cost of the latter project is over 2.5 times more expensive than that of the Tsho Rolpa GLOF Risk Reduction project to remediate the 110 million m^3 glacial lake in Rolwaling, Nepal, which was completed in July 2000. This comprised the excavation of a 100-m long open channel with sluice gates that allowed the controlled lowering of the lake by 3.5 m. Although a major piece of engineering construction, where all the heavy machinery had to be airlifted to site in parts and rebuilt, it represents only an interim remediation, with a further lowering of the lake by 11.5 m having been recommended to achieve sufficient volume reduction to afford an internationally accepted Factor of Safety. Tsho Rolpa was also significant in that it was the first place in the Himalayas where siphons had been used. Siphons were installed in 1995 and ran without significant maintenance for 18 months.

Siphons have also played a key role in remediation of lakes in the Cordillera Blanca, Peru, and have helped reduce the volume of a lake that, when it eventually breached, only affected the immediate area downstream, with no loss of life or significant damage. The affected lake was later safely remediated by constructing a series of four tunnels separated by 5 m vertically through bedrock into the base of the lake.

The Peruvian authorities have had substantial experience in the remediation of glacial lakes, having undertaken the first works in response to the catastrophic inundation of Huaraz in 1941, which resulted in over 5,000 fatalities. The types of engineering works undertaken since then include the construction of open channels, culverts within engineered dams, siphons and tunnels. Indeed, the remediation of Laguna Parón not only gave a way of controlling the lake for the purpose of hazard management but also to provide a means of controlling water flow into the local river system to use the water reservoir as a resource. There is now considerable interest in the control of glacial lakes as part of the management of water resources, and for local electrification and larger scale hydropower generation, as well as for protection of major infrastructure and downstream communities.

Climate change and development challenges in a downstream state: the case of Bangladesh

Haakon Lein, Department of Geography, Norwegian University of Science and Technology

Abstract

Bangladesh is commonly used as example of the dramatic effects of climate change. Since a large part of the country is a low lying delta the country is seen as especially vulnerable to the impact of sea level rise. And being a downstream state located at the end of the Ganges and Brahmaputra river systems the country is seen as particularly vulnerable to environmental changes in the upstream Himalayan areas.

In the first part of the presentation the basis for both these claims as well as potential consequences of climate change will be discussed. Besides climate change, Bangladesh is facing a rather complex set of development problems and in the second part of the presentation the potential impacts of climate change is discussed in relation these wider development challenges the country has to handle in the coming decades.

Impacts of climate change on water resources in the Hindu-Kush Himalaya

Mats Eriksson, International Centre for Mountain Integrated Development, Nepal

Abstract

Abstract not available.

The glaciers of central Asia: Tienshan and Pamir – trends and future

Ysmaiyl Dairov, Regional Mountain Centre of Central Asia, Kyrgyzstan

Abstract

Abstract not available

High noon: adaptation to changing water resources availability in northern India with Himalayan glacier retreat and changing monsoon

Eddy Moors, Alterra Wageningen UR, The Netherlands

Abstract

Earth System Science – Climate Change, Alterra – Wageningen UR, P.O. Box 47, 6700 AA Wageningen, The Netherlands.

Climate change is expected to have a profound impact on the availability of water in the Ganga Basin. The combined changes in glacier melt and monsoon precipitation will affect the total amount of water available. However, the magnitude of these changes are highly uncertain. The increasing in greenhouse gases is also likely to lead to the intensification of the water cycle, causing an increase in extremes events, especially in droughts.

Being largely an agrarian society, India is vulnerable to the adverse impacts of current and long-term changes in climate.

To improve the adaptive capacity in the Ganga River basin it is necessary (a) to improve the representation of feedback mechanisms of glacier melting within the regional and global climate predictions, (b) to understand the impacts and associated vulnerability at the local level and its relation to the district, state and national level, and (c) to develop new methods enabling a prioritization of adaptation measures.

The HighNoon project (www.eu-highnoon.org) has the objective to address these issues. For this HighNoon will assess the impact of Himalayan glaciers retreat and possible changes of the Indian summer monsoon on the spatial and temporal distribution of water resources in Northern India. The project will provide recommendations for appropriate and efficient response strategies to adapt to hydrological extreme events. Within the Ganges basin, a set of case study regions are selected to reflect different hydro-geographical, morphological and socio-economical conditions, determining the adaptation potentials in the fields of water supply, hydropower, agriculture, health and ecosystem aspects.

As the main focus is on possible adaptation measures, the central component of the project is to provide the necessary methods and information for a truly stakeholder driven participative measure development.

Climate resilience and adaptation in the Himalaya region

P. G. Dhar Chakrabarti, National Institute of Disaster Management, India

Abstract

Abstract not available

Impact of climate change in the Himalaya-Hindukush mountains on water resources and overall economy of Pakistan

Amir Muhammed, National University of Computer and Emerging Sciences, Islamabad, Pakistan

Abstract

Pakistan is a low income developing country with widespread poverty and related socio-economic problems. Agriculture is the dominant sector of the national economy. Being mainly an arid to semi-arid country, agriculture production is largely dependent on the availability of irrigation water. Pakistan has one of the largest man-made contiguous irrigation system in the Indus basin which is based on the water available from the Indus River and its tributaries. Major source of Indus river flows is the glacial melt from the glaciers of the Himalayan Mountains (44.8%).

Pakistan desperately needs to increase its agricultural production to meet the growing needs of the burgeoning population and to improve its economy. The country is already short of irrigation supplies to meet the current requirements. Climate change scenarios for the next about 50 years project higher temperatures in the high Himalayas resulting in more rapid melting of the glaciers which are the main source of water of the Pakistani rivers. It is projected that after initial increase in the river flows for 2-3 decades, the flows will decrease substantially resulting in greatly reduced supplies in the vast irrigation system. This will result in a major setback to the national agriculture and the overall economy. Several comprehensive studies have been undertaken on the overall availability of water supplies and the national requirements for the irrigation, domestic and industry sectors and these project a major shortfall in the availability of water even for the most urgent requirements. This critical situation requires comprehensive analysis and identification of measures to mitigate the situation arising mainly from the climate change in the high mountains resulting in rapid melting of the glaciers and eventually shrinking of the glacier size and reduction in the resulting river flows. Reduced water availability coupled with the increase in ambient temperature in most parts of Pakistan will result in a critical situation for the national economy. Some of the measures being considered are building of additional dams to store surplus water during monsoon season, change in the cropping patterns to suit the changed climatic situation and water availability, increased emphasis on water use efficiency and gradual reduction in area under water-intensive crops like rice and sugarcane.

Glacier resources of Pakistan - their response to climate change and associated hazards

Rakhshan Roohi, Principal Scientific Officer, Water Resources Research Institute, National Agricultural Research Center, Islamabad, Pakistan
Arshad Ashraf, Senior Scientific Officer, and Rozina Naz, Scientific Officer, Water Resources Research Institute, National Agricultural Research Center, Islamabad, Pakistan

Abstract

In Pakistan irrigation network and power generation is heavily dependent upon the snow and glacier melt in summer. The information about glaciers in the mountainous areas of the country was limited and the available data was only limited to few glaciers. Realizing the importance of this natural resource in the country's economy an inventory of glaciers and glacial lakes of Himalaya-Karakoram-Hindukush (HKH) region of Pakistan has been completed which is primarily based on Landsat ETM^+ image data supplemented with the topographic maps. For the inventory purposes the entire HKH region of the country was divided into 10 sub-river basins and the methodology proposed for WGIS was followed. Under this inventory, a total of 5,218 glaciers covering an area of about 15,000 sq. km have been registered and a detailed database has been developed (Figure 1). These glaciers house 2,738.5 cubic km of ice reserves (Table 1). There are 2,420 glacial lakes identified among which 1,328 are characterized as major lakes having surface area of greater than 0.02 sq. km each. Out of these major lakes, 52 are classified as potentially dangerous lakes having high risk of GLOF. The results of the inventory provide base line information for future monitoring of glaciers and potentially dangerous glacial lakes especially in the context of global warming.

Each sub-river basin behaves differently as far as the orientation of the glaciers in various ordinal directions is concerned. However, maximum glaciers are oriented towards N and NE. The glaciers in Indus, Jhelum and Shyok River basins are generally oriented towards northern and eastern aspects. In Shyok River basin besides the northern aspects the southern aspects have also higher number of glaciers. The Shigar River basin has glaciers in all direction but predominantly on northern and north eastern aspects. In this basin north western aspects also have higher number of glaciers.

Impacts and adaptation to climate change on food security and livehoods: can humans act in time?

Professor .Eng. Stella Maris Navone Ms.Sc, Buenos Aires University, Argentine
navone@agro.uba.ar

Abstract

Impacts of climate change on food security are global and local and will be worst for the future if humans don't act immediately The international crisis have driven 110 million people into poverty and added 44 million more to the undernourished (Nelleman et al, 2009). Water plays a crucial role in food production ,more than 80% of global agricultural land is rain-fed; there,crop productivity depends on enough precipitation, in arid and semi-arid regions in the tropics and subtropics,as well as in Mediterranean-type regions in Europe,Australia and South America, agricultural production is very vulnerable to climate change (FAO, 2008).

Smallholder and subsistence farmers, pastoralists and artisanal fisherfolk will suffer complex, localised impacts of climate change in developing countries, nearly 70% of people live in rural areas where agriculture is the largest supporter of livelihoods. We must take charge of the impact of different unsustainable crop or meat production on climate change ,land degradation water quantity and quality disminish ,loss of biodiversity and deforestation. "Floods and droughts are cyclical", but climate change increased their frequency and intensity. These events cause decrease of yields of grains and other cops ; soil erosion; land degradation ,biodiversity loss, eroded coasts, inability to cultivate land due to waterlogging of soils ,negative effects on quality of surface and groundwater; and contamination of water supply; water scarcity may be relieved increased risk of deaths, injuries and infectious, respiratory and skin diseases Disruption of settlements, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property. Global warming will confound the impact of natural variation on fishing activity and complicate management.
In South America, the impact of climate change is highlight by the ENSO phenomenon, for example in the most important and extensive crop production area which is La Plata river basin. There were floods since 1992 up to 2002 and droughts since 2006 with the lost of crop yields and animals death (Navone et al, 2005). Extensive farming activities in the region are producing side-effects that alter the climate of the region. On the other size in the Amazonas river basin, well known as the "lung" of the Earth, forests and biodiversity is lost by human actions and climate change. The land occupation organized in agricultural oases, depending on the ice melting water proceeding have problems too caused by global warming in South America, along the Andes and ,in Asia specially in the predicted scenarios for the 2050. Climate change increases the number of people at risk of hunger. Essentially, the entire

agricultural land expansion will take place in developing countries with most of it occurring in sub-Saharan Africa and Latin America. Droughts in Africa disminish yields of crops, overgrazing and desertification which should affect food security even more than actually is. Due to warming temperature and variations in the precipitation, crop productivity is likely to increase in northern Europe and decrease in Central Europe (Easterling et al,2008).
Human societies have, through the centuries, often developed the capacity to adapt to environmental change, and some knowledge about the implications of climate change adaptation for sustainable development can thus be deduced from our technologies, and research, historical analogues and for indigenous knowledge, whose adaptation practices are carrying on actually. Where there are better production systems there are opportunities to reduce the impact of the climate change, but it is very important to understand that climate change by itself is not the only driven force which prevents food security around the world.

Poster abstracts

Glacier retreats since last glacial maximum to the present

Maximiliano Bezada, Universidad Pedagógica Experimental Libertador, Caracas, Venezuela
O. Gonzales, Universidad Pedagógica Experimental Libertador, Programa Antártico Venezolano, D. Diaz, Instituto Nacional de Geología y Minería, Programa Antártico Venezolano and Ander De Abrisqueta, Instituto Nacional de Geología y Minería, Programa Antártico Venezolano.

Abstract

Glacier retreats since last glacial maximum to the present. Global warming in the Venezuelan Andes and their effects on social and economical activities, and flooding hazards on downstream areas.

Energy balance and hydrological modelling of Zongo

Martial Duguay, Stockholm University
Regine Hock, Jean-Emmanuel Sicart, Anne Coudrain

Abstract

A distributed energy balance model has been developed to model mass balance and melt induced discharge of tropical glaciers. We want to predict the changes in glacier melt discharge in response to future climate change for the region of La Paz, Bolivia and later regionalize the model to a larger area. The model operates on daily steps, has a 20 m grid resolution, and is forced by daily ERA-40 reanalysis data of air temperature, humidity, wind speed, global radiation and precipitation.

Atmospheric pollutions and its potential impacts on the glaciers of the North Western Himalaya, India

Khwairakpam Gajananda, Department of Land Resources Management and Environmental Protection (LaRMEP), College of Dryland Agriculture and Natural Resources, Mekelle University, Mekelle, Ethiopia and G.B. Pant Institute of Himalayan Environment and Development, Himachal Unit, Mohal-Kullu, India
gajkh@yahoo.com
Jagdish C. Kuniyal, G.B. Pant Institute of Himalayan Environment and Development, Himachal Unit, Mohal-Kullu, India

Abstract

Surface meteorology, total suspended particulate (TSP), particulate matter (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and surface ozone (O_3) were monitored at Mohal (Kullu) and Kothi (Manali) tourist complex, in the north western part of the Himalayas during April 2003 to September 2004. The changing pattern of TSP, PM_{10} and O_3 indicates the rising air pollution due to anthropogenic activities in this region. However, SO_2, NO_2 and O_3 are within the prescribed permissible limits. The concentrations of TSP and PM_{10} are higher in the lower altitude Mohal (207.3 µg/m^3 and 63.5 µg/m^3), than the higher altitude Kothi (100.7 µg/m^3 and 45.5 µg/m^3), suggesting more anthropogenic activities in the lower altitude region of the Himalaya. The pollutants are mainly influenced by the meteorological conditions, especially the wind and rainfall pattern. A small change in the climatic pattern in this region is likely to have adverse impacts due to atmospheric pollutions on the fragile ecosystem, glaciers, socio-economy and human health.

Three ice core records from Svalbard to reveal important differences in regional climate development during the past 700 years

Elisabeth Isaksson, Norwegian Polar Institute, Tromsø, Norway, elisabeth.isaksson@npolar.no
Dmitry Divine, Norwegian Polar Institute, Tromsø, Norway
Tonu Martma, Institute of Geology at Tallinn University of Technology, Tallinn, Estonia
Veijo Pohjola, Department of Earth Sciences, Uppsala University, Uppsala, Sweden
Björn Sjögren, Department of Earth Sciences, Uppsala University, Uppsala, Sweden
Harro Meijer, Centre for Isotope Research, Groningen, The Netherlands
Roderik .S.W. van de Wal, Institute for Marine and Atmospheric Research,Utrecht, The Netherlands
John Moore, Arctic Centre, University of Lapland, Finland
Makoto Igarashi, National Institute of Polar Research (NIPR), Tokyo, Japan
Hideaki Motoyama, National Institute of Polar Research (NIPR), Tokyo, Japan

Abstract

The Svalbard Archipelago, being situated in a climatically sensitive area at the turning point of the North Atlantic current, experiences substantial climate variations both in the spatial and temporal domains. A detailed study of the complicated nature of interactions within the climatic system is however hampered by shortness of the existing instrumental records from the area. It promotes the use of records from ice cores for making paleoclimatic reconstructions. This study of the regional climate variability spanning some 700 years is based on analysis of d18O data from three ice cores drilled in different locations on Svalbard during the past decade. Despite retrieved from the relatively low-altitude ice caps and therefore subject to summer melt, the cores from Lomonosovfonna (1255 m asl, drilled in 1997, covers some 800 years), Holtedahlfonna (1150 m asl, in 2005, 400 yrs) and Austfonna (750 m asl, in 1999, 800 yrs) were shown to contain a variety of climate records. The annual snow accumulation rate at the drilling sites of the order of 0.4 m w.eq. ensures a subannual resolution of the cores back to the 16th century. All three considered records show similar variations on century scales, with a gradual cooling associated with the onset of the Little Ice Age in the 1700s and abrupt warming in the beginning of the 20th century. The features of variability on the shorter time scales, as well as the magnitude of the LIA-associated decrease in d18O series, differ between the cores. It highlights the regional difference in the local climate between the core sites which is especially pronounced in the latitudinal direction. The two d18O records of Lomonosovfonna and Holtedahlfonna from the western Spitzbergen display nearly identical variations throughout the period of overlap. At the same time the Austfonna series from the eastern Svalbard shows much stronger LIA-associated cooling with a maximum offset between the records during 1780-1860. This is interpreted in terms of the extended sea ice cover during the LIA. This hypothesis is supported by a coincidence with a period of increased continentality on Svalbard during the LIA and generally colder North Atlantic, as evidenced by a deuterium excess record from Lomonosovfonna.

Climate change effects on glacier in the Himalayas

Vijay Kumar, CSRE, IIT Bombay, Mumbai, India
G. Venkataraman, CSRE, IIT Bombay, Mumbai, India

Abstract

Himalayan Arc and Tibetan plateau are the largest storehouse of freshwater outside the polar region. They are the sources of nine largest river systems of South and South-East Asia such as the Indus, Ganga,Yarlung-Tsangpo-Brahmaputra, the Makong and the Yangtze etc. whose basins are home to over 1.3 billion people (Chalies, 1994, Bahadur, 1992). Glacier and Ice cover in Himalayan region is around 113000 sqkms which are in general recession since 1850 (Paul et al., 1979) poses threat to heavily populated region in terms of availability of water in future. Warming in Himalayan and trans Himalayan region and Tibet increased progressively within a range of 0.2-0.6 degrees Celsius per decade between 1951 and 2001, particularly during autumn and winter (Shrestha et al. 1999). Various studies suggest that the warming in the Himalayas has been greater than the global average (Jianuchu et al. 2007). The length of the growing season (daily temperature greater than 10°Celsius) has increased by almost fifteen days over the past thirty years. Glacier melt in the Himalayas is likely to increase intensity and frequency of various environmental risks, including floods and avalanches and failure of moraine dammed lakes, and affect the water regime within the next couple of decades. The absence of long term reliable data base on climatic and hydrological parameters for the Himalayan mountainous region makes it difficult to categoarise climatic events and their impact on the hydrology of Himalayan waters. However government of India established 100s of observatories and automatic weather stations (AWS) in Himalayan region for continuous acquiring weather parameters for future trend prediction and monitoring the climate change effects in Himalayan region. Spaceborne synthetic aperture radar data provide an important tool for monitoring the fluctuation of the glaciers. Here attempt has been made for quantifying the glacier retreat using multitemporal synthetic aperture radar (SAR) data. SAR intensity and phase information will be exploited separately under SAR intensity tracking and interferometric SAR (InSAR) coherence tracking (Strozzi et al., 2002) techniques respectively. Glacier retreat study has been done using time series coregistered multi temporal SAR images. Simultaneously InSAR coherence thresholding is applied for tracking the snout of Gangotri glacier. It is observed that glacier is retreating at the rate of 21 m/a.

Analyzing climate change indicators in Himalaya

Dr. Shreedhar Maskey, UNESCO- IHE
Sunal Ojha, UNESCO-IHE

Abstract

Analyzing Climate Change Indicators in the Himalayan Region from Satellite Observations: The remote sensing snow cover data from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite from 2000 to 2007 have been used to analyze some climate change indicators in the Himalayan region. In particular, the variability in the fractional snow coverage with elevations, its temporal variability (8-day, monthly and seasonal) and its variation trends have been analyzed. The snow product used in this study is the maximum snow extent, which comes in 8-day temporal and 500 ? 500 m spatial resolutions. The results showed a tremendous potential of the MODIS snow product for studying the spatial and temporal variability of snow as well as in the study of climate change impact in large and inaccessible regions like the Himalayas. This study also showed that the variation of the snow coverage with elevation is not always monotonous. It showed that in the studied area in winter the elevation zone 3000-4000 m receives more snow coverage than higher elevation zones, 4000-5000 and 5000-6000, and similarly the elevation zone 6000-7000 m receives more snow coverage than the elevation zone above 7000 m. This was consistently observed in all 8 years. Some important trends on the alternation of the snow cover extent are also observed. In particular, the decreasing trend in January and increasing trend in March for some elevation zones may be interpreted as a signal of a possible seasonal shift in the maximum snowfall from mid-winter towards late-winter or early spring. However, it requires more years of data to verify this conclusion.

Ice velocity and climate variations for the Baltoro glacier, Karakoram

Duncan Quincey, Institute of Geography and Earth Sciences, Penglais Campus, Aberystwyth University, UK.
djq@aber.ac.uk
L. Copland, Department of Geography, University of Ottawa, Ottawa, Ontario, Canada
C. Mayer, Commission for Glaciology, Bavarian Academy of Sciences and Humanities, Germany
M. Bishop, Department of Geography and Geology, University of Nebraska at Omaha, USA
A. Luckman, School of the Environment and Society, Swansea University, UK
M. Belò, Trimble Navigation, Centro Torri Bianche, Milan, Italy

Abstract

The recent dynamic behaviour of Karakoram glaciers is reported to differ to that shown by glaciers in central and eastern regions of the Himalaya because of regional variations in the trends of precipitation and temperature. There has been, however, a paucity of quantitative data to support or confute such hypotheses. Here, remote sensing and field-based (dGPS) surface displacement data are presented for the Baltoro Glacier, one of the longest glaciers in the Karakoram, covering the period 1993 to 2008. These data indicate a gradual acceleration of the glacier during the early 2000s, in particular during winter months. Multi-seasonal data reveal a large difference between summer and winter flow characteristics, mainly in the upper ablation zone. Transverse velocity profiles suggest that the Baltoro Glacier undergoes 'block' flow across much of the upper ablation zone in the summer, which we interpret as evidence of widespread basal sliding. Modelled climatic data reveal decreasing summer temperatures and increasing precipitation and help to explain the interpretation of positive mass-balance conditions on the Baltoro Glacier in contrast to glaciers elsewhere in the Himalaya.

Snow and Ice Working Group GTNH-PHI-UNESCO

Edson Ramirez, Universidad Mayor de San Andres, GTNH,

Abstract

The Working Group of Snow and Ice (GTNH) brings together glaciological research teams in Latin America involving the following countries: Argentina, Bolivia, Brazil, Colombia, Chile, Ecuador, Mexico and Peru.

The working group was created in 2003 within the framework of the International Hydrological Programme activities of UNESCO (IHP), in collaboration with ICSI (International Commission on Snow and Ice), presently IACS (International Association of Cryospheric Sciences). GTNH has implemented a regional glacier monitoring network including several representative glaciers such as: Horcones Superior, Martial, Vinciguerra (Argentina); Zongo, Charquini (Bolivia), Santa Isabel (Colombia), Echaurren Norte, Mocho (Chile); Antisana (Ecuador); Orizaba, Iztaccíhuatl Volcano (Mexico); Artezonraju, Yanamarey (Peru) and Bahía del Diablo (Antarctic Peninsula, operated by Argentina).

In addition to research and glacier monitoring tasks, the members of GTNH are developing joint activities with national and international agencies of water resource management, contributing to the knowledge on glacier behavior and its impact on the water resources supply, natural hazards, and climate change.

Changes in glaciation of Central Asia and their probable impact on regional water resources

Igor V. Severskiy, Kazakh Institute of Geography, Kazakhstan
iseverskiy@gmail.com

Abstract

On the basis of data of the unified glaciers inventories of the Zailiyskiy-Kungei and Dzhunghar glacial systems, composed for 4-6 different years during the period from 1955 until 2006, and data of long-standing hydro-climatic and glaciological observations on three mountain research stations in Zailiyskiy Alatau range changes in the snowiness, glaciation and thermal regime of frozen ground during the recent decades are investigated.

Within the testified region, for the last decades the average maximum snow-water equivalent - the main component of snow resources - has not changed. Glacial systems of Central Asia Mountains develop in the same direction and have similar rates of modern changes. So, for the last decades the area of glaciers in different regions of Tien Shan, Gissar-Alai, Pamirs and Dzhunghar Alatau mountains has decreased at the average rate 0.6–0.8 % per year. The maximum rate of glaciers retreat, which is typical for the mid-1970s, by mid-1980s had declined to be reduced up to 2006.

Glacier retreat rate depends to a great extent on its size, a glacier area F=13-14 km^2 is threshold: with its exceeding, the self-regulation mechanism of the glacier is so vivid that it neutralizes the influence of local factors and its regime is determined by the background climatic conditions of the region.

The regime of each glacier is unique and can differ from not only average data for this morphological type of glacier, but also from that of a nearby glacier. The differences can be not only significant but also can have a different (negative/positive) sign. Glacier retreat rate does not depend on its exposition and morphological type. Territorial differences in the retreat rates are defined by the orientation of slopes in reference to the cardinal points and to the prevailing direction of air masses, which bring the precipitation and by the location of the region in the mountainous system. Taking into account stability in the rate of precipitation and especially in the rate of snow resources, one can suppose that glaciers in this region will not disappear during this century.

According to the 34-year-old geothermal monitoring in the area of the Zhusalykezen mountain pass in the Northern Tien Shan, the temperature of the permafrost layer (at a depth of 15 m) in the period from 1974 to 1995 increased by 0,5 º C. Within the same period, the thickness of the active layer has increased by more than 1 m. In the next 5 years, the process of warming of the permafrost has ceased, and the temperature of the permafrost to the end of

the last century, has remained stable. But from 2000 to 2008, the temperature in that layer of permafrost steadily fell. During the same period, the depth of seasonal frost has increased by 1.0 m on the northern slopes and 0.3 m in the southern.
The main reason for identified dynamics of the regional glaciation and the state of the permafrost is not so much to raise global temperatures, but rather the year-to-year variability of the snowiness characteristics.

Despite the reduction of glaciers, during the last decades the rates (norms) of annual runoff volumes of the main rivers in Central Asia and runoff distribution within a year remained unchanged. During the same period, rates of sums of precipitation and maximum snow water equivalent in the zone of runoff formation remained stable also. All this suggests the existence of a certain compensatory mechanism. Research based on data analysis of repeated photogrammetric surveys of glaciers and monitoring the temperature regime of permafrost in Zailiyskiy Alatau range, suggest that such a mechanism may be more and more significant (with climate warming) participation of melt waters of underground ices (buried glaciers, rock glaciers, ice in the permafrost) in the river runoff formation.

Taking into the consideration the fact that reserves of underground ice in high mountains of Central Asia are comparable with the present-day glacier resources of the terrestrial glaciation and in the Chinese mountains they are two times greater, and also considering that the rates of melting underground ice are much lower than those of the open glaciers, we believe that even if the present-day trends in climate warming are preserved, the above mentioned mechanism may work for hundreds of years. Hence, it is possible to believe that the ongoing degradation of glaciers will not lead to a considerable reduction in runoff and regional water resources at least up to nearest decades.

The recent past and future climate and glacier change in the Altai Mountains, Siberia, Russia

M. Shahgedanova, Walker Institute for Climate System Research, The University of Reading, UK
m.shahgedanova@reading.ac.uk
T. Khromova, G. Nosenka and A. Muravyev, Institute of Geography, Russian Academy of Science, Moscow, Russia.

Abstract

This paper examines changes in the extent of glaciers in the North and South Chuya Ridges of the Altai Mountains, Siberia in the context of the observed changes in air temperature and precipitation between the middle of the 20th and the beginning of the 21st century and presents the future regional climate change scenarios derived using PRECIS modelling system based on HadRM3 regional climate model. The Altai Mountains is the main centre of glaciation in Siberia with a combined glaciated area of about 900 km^2. The net changes in the extent of 126 glaciers in the North and South Chuya Ridges of the Altai have been evaluated using data published in the Catalogue of Glaciers of the USSR (World Glacier Inventory) based on the aerial photographs from 1952, the original photographs from 1952, and ASTER imagery for 2004. The net area of the studied glaciers declined by 19% in 2004 in comparison to the net area of these glaciers in 1952 as reported in the Catalogue of Glaciers. A comparison of the 1952 areas of twenty test glaciers published in the Catalogue of Glaciers with their areas derived from the original aerial photographs has shown that the Catalogue of Glaciers overestimated the extent of glaciers resulting in a possible overestimation of glacier reduction in the 1952-2004 period by 4%. The observed glacier retreat is linked to an increase in summer temperatures, which has been observed in the Altai since the mid-1980s. The future climate projections for A2 and B2 SRES CO_2 emission group of scenarios indicate that summer temperatures will increase in both regions in 2071-2100 by 3-7^{o}C in comparison with the baseline period of 1961-1990. The projected changes in solid precipitation will be insufficient to compensate for the enhanced glacier melt leading to further glacier retreat.

Future trend of permafrost – Mongolian

Ulziisaikhan Vanchindorj, MUST, Mongolia
Mijiddorj Renchin

Abstract

Recent research indicates that global warming is impacting Mongolian climate. Mean air temperature of Mongolia has increased 1.50C in the latest sixty years (Mijiddorj et al., 1998) and has caused changes in permafrost, snow cover, natural zones, and ground water resources. This paper examines the spatial relationship of permafrost with observed climate data, leading to estimates of the probability of the permafrost distribution changes induced by future climate change. The Logistic Regression Model was applied to the Mongolian territory using observed global climate data, permafrost distribution and results from global climate models developed by the UK Hadley Centre for Climate Prediction Model, and National Snow and Ice Data Center. The spatial phenomenon under investigation can only be described by a categorical variable such as permafrost distribution indicating presence or absence of permafrost. Logistic regression treats the distribution in a probabilistic manner, that is, the occurrence of the study phenomenon is evaluated in terms of probability (Arthur J. Lembo, 2002). The Spatial Analyst extensions of ArcView and ArcGrid were used to prepare logistic regression model input data, to conduct spatial interpolations, to generate GRID data from event themes created from tabular data, to calculate regression coefficients, and to estimate probability of phenomena. Results are that permafrost correlation coefficients were –0.8, and -0.7 with air temperature and solar radiation. The model results indicate that observed permafrost distributions have a strong correlation with the temperature increases and that permafrost areas are going to continue to decrease in the forecast years 2020, 2050, and 2080.

Dynamic-statistical modeling of climate induced glacier mass changes

Stefan Winkler, Department of Geography, University of Würzburg, Germany
Sebastian Mutz and Heiko Paeth, Department of Geography, University of Würzburg, Germany

Abstract

Maritime mountain glaciers are highly sensitive climatic indicators. In Norway, their meltwater is a vital source of sustainable energy from hydro-energetic power plants. The goal of this project is to develop a statistical model linking large scale climate phenomena of the northern hemisphere to the mass balance of Norwegian glaciers. Using robust statistical transfer functions in combination with climate simulations of the IPCC, a probabilistic estimate of glacier mass change will be generated on a larger regional scale, but under consideration of spatial differentiation.

Impact of change on Alpine tourism: perception of the tourists

Stefan Winkler, Department of Geography, University of Würzburg, Germany
Christina Wachler, Department of Geography, University of Würzburg, Germany

Abstract

Tourism owns an economic key-role in many mountain regions. Climate change and related glacier shrinkage have an impact on the tourism-sector that must not be underestimated. Strategies to adopt existing structures and ranges of activities to future climate change are necessary. In an empirical case study from the European Alps (Engadin; Ötztal), an attempt to investigate the perception of tourists has been performed. The first results showed a much higher sensitivity of tourists for environmental issues and acceptance of new “green” concepts than many local actors had expected.

Climate and Cryosphere (CliC) project update

Daqing Yang, CliC International Project Office, Norway

Konrad Steffen, University of Colorado, USA

Tony Worby, ACE CRC, Australia

Abstract

The cryosphere is an important and dynamic component of the global climate system. The global cryosphere is changing rapidly, with changes in the Polar Regions receiving particular attention during the International Polar Year 2007-2008. The Climate and Cryosphere (CliC) Project is a core project of the World Climate Research Programme (WCRP) and is co-sponsored by WCRP, SCAR (Scientific Committee for Antarctic Research) and IASC (International Committee for Antarctic Research). The principal goal of CliC is to assess and quantify the impacts that climatic variability and change have on components of the cryosphere and the consequences of these impacts for the climate system. To achieve its objectives, CliC coordinates international and regional projects, partners with other organizations in joint initiatives, and organizes panels and working groups to lead and coordinate advanced research aimed at closing identified gaps in scientific knowledge about climate and cryosphere. CliC has advanced significantly over the last several years. This poster will provide an update of recent developments of research themes, including changes in mountain glacier and water resources over the arid regions.

Monitoring ice-capped volcanoes with satellite imagery in the southern volcanic zone of the Andes

Pablo Zenteno, Centro de Estudios Científicos, Valdivia
A. Rivera, Centro de Estudios Científicos, Valdivia, Centro de Ingeniería de la Innovación del CECS, Valdivia, Chile, Departamento de Geografía, Universidad de Chile
C. Bravo, Centro de Estudios Científicos, Valdivia
F. Bown, Centro de Estudios Científicos, Valdivia
C. Rada, Centro de Estudios Científicos, Valdivia

Abstract

The main aim of this research is updating glacier inventories, analysing areal, frontal and elevation changes of glaciers located at the flanks of active volcanoes of the Southern Volcanic Zone of the Andes. Co-registered multispectral satellite images from the Landsat MSS, TM, ETM+ and Terra/ASTER sensors, were analysed in combination with digital elevation models produced from topographic maps and SRTM data, in order to quantify areal, frontal and elevation changes of several glaciers. Thermal infrared bands of ASTER satellite images were used to detect geothermal activity and to characterize the possible effects of explosive eruptions on glacier surfaces. Results confirms that these glaciers had undergone significant area losses, with a maximum negative area change detected at the Nevados de Chillán volcano, one of the most active volcanoes of the Southern Volcanic Zone, with a total area loss rate of -0.35 ± 0.11 $km^2\ a^{-1}$ between 1976 and 2004. Maximum frontal retreats of -1130 ±64 m were observed at the Nevados de Sollipulli volcano between 1976 and 2005. A maximum mean ice thinning was observed at the glacier located SE of volcano Callaqui at a rate of -1.28 ±0.6 m a^{-1} between 1961 and 2000. ASTER thermal bands, acquired both during day and night passes, showed hot spots of up to 89.4ºC at the south eastern flank of Nevados de Chillán volcano, where significant glacier retreat had been observed since 1976 in synchronicity with the last eruptive cycle. Maximum temperatures of 100.9ºC were detected at Llaima volcano during the last eruption on April 2009. These glaciers are retreating according to the recent climate changes observed in this region during most of the twentieth century, characterized by atmospheric warming and precipitation decrease. However, some of the studied glaciers on active volcanoes present accelerated rates of shrinkage and retreat of terminus position in comparison to other mountain glaciers of Chile. Hence, the recent volcanic activity and explosive eruptions can cause severe changes on the glacier structure, enhancing melting and water production at the bedrock, resulting in negative ice elevation changes. Ongoing progress of this research is the application of supervised classifications of ASTER images by means of spectral signatures in order to differentiate snow/ice glacier facies and mapping partially debris-covered ice at volcanic flanks.

High mountain glaciers and challenges caused by climate change

8-10 June 2009, Tromsø, Norway