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ACCOMPLISHMENT REPORT

THE IMPACT OF **GLACIER RETREAT** IN **THE ANDES**

International Multidisciplinary Network for Adaptation Strategies

INTERNATIONAL HYDROLOGICAL PROGRAMME
Division of Water Sciences

The Accomplishment Report is developed in the framework of the project "The Impact of Glacier Retreat in the Andes: International Multidsciplinary Network for Adaptation Strategies", executed by the International Hydrological Programme of UNESCO (IHP) and supported through the Flanders UNESCO Science Trust Fund (FUST).

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7, place de Fontenoy, 75352 Paris 07 SP, France

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This report was prepared under the coordination of
Anil Mishra, International Hydrological Programme, Division of Water Sciences, UNESCO Paris
Koen Verbist, International Hydrological Programme, Division of Water Sciences, UNESCO Paris

With assistance of
Jolien De Decker
Manoëlle Verschueren
Barbara Ávila

Design and layout: UNESCO / Sergio Baros
Cover photo: © koln21

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Preface

Water resources challenges to attain water security are increasing due to increasing water scarcity and uncertainty with the associated effects on water for people, energy, food and ecosystems. In the Andean region, runoff from glaciated basins is an important element of the regional water budget, and is essential to the integrity of mountain ecosystems. Many Andean valleys are seasonally dry and depend on glacier runoff to maintain extensive mountain biomes. Much of the snow falling in the Andes is initially stored as ice in mountain glaciers, before being gradually released over time. As such, Andean glaciers play a crucial role to sustain mountain ecosystems and livelihoods, but also rural population and large cities in the region receive the benefit of these water towers for sustained water provision.

With the support from Flanders Trust fund for Science (FUST) UNESCO initiated the project 'The Impact of Glacier Retreat in the Andes: International Multidsciplinary Network for Adaptation Strategies' with the main objective to establish a multi and transdisciplinary network which would help to enhance resilience to changes, particularly climate change, through improved understanding of vulnerabilities, opportunities and potentials for adaptation.

During the project, the scientific network and science policy base was established to identify the current state of the glaciers in the Andean region. Significant reductions in glacier masses were observed throughout the region causing the water security to deteriorate. The project also contributed by identifying the vulnerability of water resources in the Andes, by quantifying the contribution of glaciers to downstream rivers, and particularly its effect on drinking water in cities, agricultural water use, hydropower and industrial water usages. This furthers strengthened the message that glacier contributions are significant for a large part of the population, making their retreat a mayor concern for water security.

This has also driven the need to strengthen the policies in several of the Andean countries on glacier protection for strategic water reserves and to address water scarcity under progressing climate change. To support this process, the project has contributed on strengthening the science-policy dialogue and to raise awareness regarding the impact of retreating glaciers on water resources.

Capacity building has been the cornerstone of this project, involving more than 200 participants, of which 30% women, from 19 different countries, and which covered aspects of climate change scenarios, Andean hydrology, glacier mass balance assessment and water security vulnerability analysis. The project established synergies with funded projects, as such creating a multiplyer effect in project delivery.

Several publications in English and Spanish were also developed as a result of the project, providing a background on the status of glacier melt in the Andes and the overall vulnerability of the water resources, but also looking into aspects of research and educational needs, as well as adaptation strategies and policy needs to address these water security challenges.

You will learn more about the accomplishments of the Glacier Melt project in the following report, providing a baseline for other initiatives to start from and an example of regional collaboration to achieve water security in the Andean region. Through all these activities, the project was also able to contribute effectively to the objectives of the Eight phase of UNESCO-IHP (2014-2021): Water Security - Responses to Local, Regional, and Global Challenges, while strengthening at the same time the UNESCO Working Group on Snow and Ice in Latin America. The project outcomes also contributed to support the implementation of the Sustainable Development Goals (SDG)s, the Paris Agreement and the Sendai Framework for Disaster Risk Reduction.

I would like sincerely to thank the Government of Flanders for providing funds to the project.

Similarly, I would like to thank all stakeholders including scientists, participating countries and IHP colleagues involved in the project.

Blanca Jiménez-Cisneros,
Director, Water Sciences Division Secretary
International Hydrological Programme (IHP) UNESCO

Glacier Retreat in the Andean Countries

Introduction

The Andes – the world longest continental mountain range – extends in South America through seven different countries, namely Venezuela, Colombia, Ecuador, Peru, Bolivia, Chile and Argentina. The population of these countries accounts for more than 160 million people representing more than 40% of the continent's total population. Many Andean valleys are seasonally dry and glacier runoff is crucial to maintain a more constant flow of fresh water throughout the year. In fact, much of the snow falling is initially stored as ice in mountain glaciers before being gradually released over time. Therefore, glaciers act as critical buffers against highly seasonal precipitation and provide water for domestic, agricultural and industrial use during the dry season.

Glacier Retreat and Challenges for Water Resources

There is a scientific consensus that global climate change is accelerating glacier ablation in many regions worldwide. The rate of melting of Andean glaciers has increased considerably since 1970 and a rapid shrinkage of the glaciers throughout the 20th century can be observed. The main factor bringing glaciers out of their equilibrium are **temperature changes**. Indeed, an overall warming trend in the Andean countries can be observed. The mean annual temperature in the countries of the northern Andes (Venezuela, Colombia, Ecuador, and Peru) has increased by about 0.8°C during the 20th century (Marengo et al., 2011). Other observations show daily maximum temperatures exceeding the freezing point, even at altitudes above 5680m, e.g. Bradley et al. (2009) calculated that daily maximum temperatures above the Quelccaya Cap (Peru) are now above freezing most of the year.

Besides temperature, also **precipitation**, **humidity** and **El Niño** effects have been linked to increased glacier ablation. Humidity can have a severe impact on the mass balance of glaciers since melting has been found to

increase with higher humidity. Vuille et al. (2003) studied the near-surface humidity changes in the Andes and found a significant increase in relative humidity between 1950 and 1995 up to 2.5% per decade. This observed acceleration can also be explained by the more frequent and intense El Niño phases of the ENSO in recent years. The El Niño phase of ENSO is associated with comparatively dry summer conditions over the tropical Andes. As a result, El Niño events inhibit glacier accumulation and the lack of snowfall lowers the surface's albedo. This effect, combined with reduced cloud cover, permits more shortwave radiation to be absorbed by the glacier, accelerating the melting process.

The combination of these factors result in a generally negative mass balance of glaciers. Mass loss (by melt and sublimation) is outpacing mass gain (through snowfall). Mass balance records show a generally negative mass balance in the tropical Andes (Figure 1). In the Southern Andes, the same negative trends are observed during the last few decades and reported in detail for Patagonia, with values of several meters per year up to a maximum of 30m/y (Rignot et al., 2003).

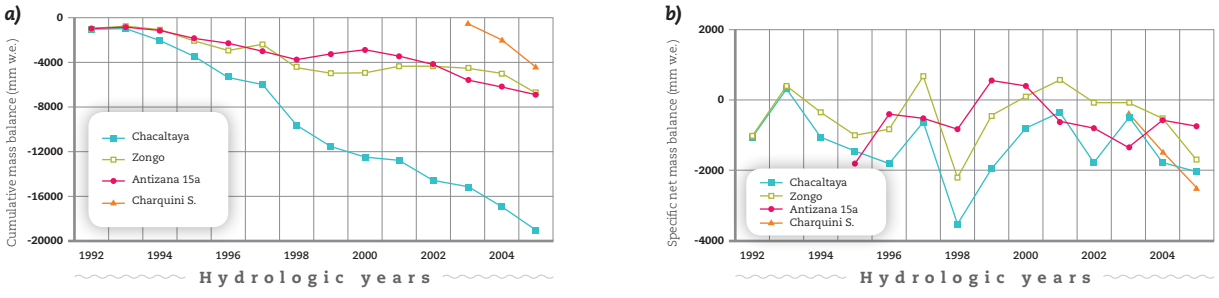


FIGURE 1 > **Comparison of a) cumulative and b) annual mass balance on glaciers in Bolivia and Ecuador. Note that the hydrological year is September-August in Bolivia and January-December in Ecuador.**

In Figure 2 a summary of the length and surface area changes of 10 Andean glaciers from Ecuador, Peru and Bolivia between 1930 and 2005 is shown. A clear retreat of the glaciers can be observed, which is the result of a generally negative mass balance of glaciers.

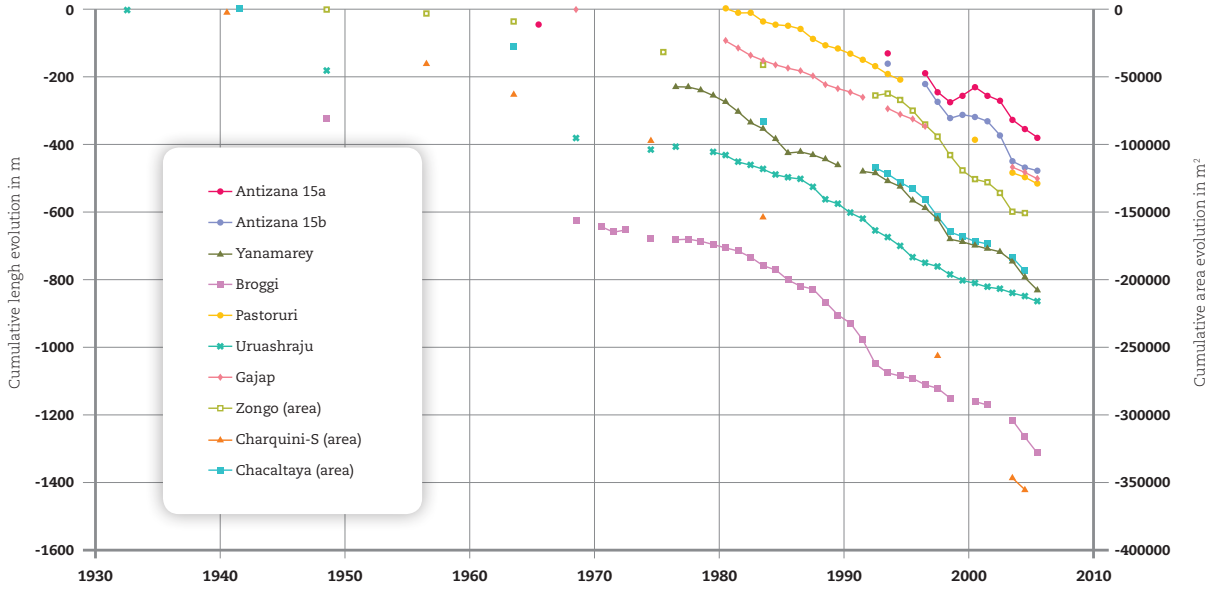


FIGURE 2 > **Change in length and surface area of 10 tropical Andean glaciers from Ecuador, Peru and Bolivia between 1930 and 2005.**

It is expected that this warming will continue under climate change scenarios, with substantial effects on Andean glaciers and associated glacial runoff and streamflow. Several small glaciers are expected to disappear completely.

Consequences of Glacier Retreat

Particularly in the Dry Andes glaciers can be relevant water resources during the dry season (Casassa et al., 2009). Moreover, glaciers are effective water reservoirs at different time scales, from hourly periods to multi annual scales (Jansson et al., 2003). Many Andean valleys are seasonally dry and glacier runoff is crucial to maintain a more constant flow of fresh water throughout the year. In response to atmospheric warming a glacier will lose mass and the variability in streamflow will increase, by reducing the buffer during the dry season. Kaser et al. (2003) showed that the percentage of glaciated area of tropical Andean catchments is highly correlated with their capacity to store precipitation. Thus, retreating glaciers have less capacity to store precipitation and therefore less buffering capacity to provide enough streamflow. This reduction in streamflow will affect the availability of drinking water, water for hydropower production, mining and irrigation.

However, while glaciers retreat and lose mass, streamflow may increase temporarily due to the rapid melting of the glaciers (Mark et al., 2005; Mark and McKenzie, 2007). This increase however, will not last very long as the storage term rapidly decrease. Once a maximum peak is reached, subsequently runoff is reduced when the glacier shrinks beyond a size where it is no longer able to produce large melt water volume. In a future scenario, where glaciers continue to recede, one can assume that most of the runoff will be concentrated in the wet season while little to no base flow will be available during the dry season.

In the Southern Andes there is no clear signal of changes in the glacier runoff production (Casassa et al., 2009), although the negative glacier mass balance suggests an increase in meltwater should occur. Therefore, in the future we should expect earlier runoff peaks, closer in time to the precipitation maximum. There is a real need for planning and adaptation measures in order to replace the natural regulation effect of snow and ice (Vergara et al., 2007). Moreover, it is important to implement adaptation strategies that take into account the long-term changes in seasonally available water resources rather than to adapt to a short term water surplus that is not sustainable into the future.

Changes in river runoff are generally expected to be largest in regions such as Peru, where rivers enter seasonally arid regions (Kaser et al., 2010). Figure 3 highlights one case study from selected catchments in the Cordillera Blanca, Peru, demonstrating how monthly runoff might change based on simulations of streamflow out to the years 2050 and 2080 using a low (SRES B1) and high (A2) emission scenario (Juen et al., 2007).

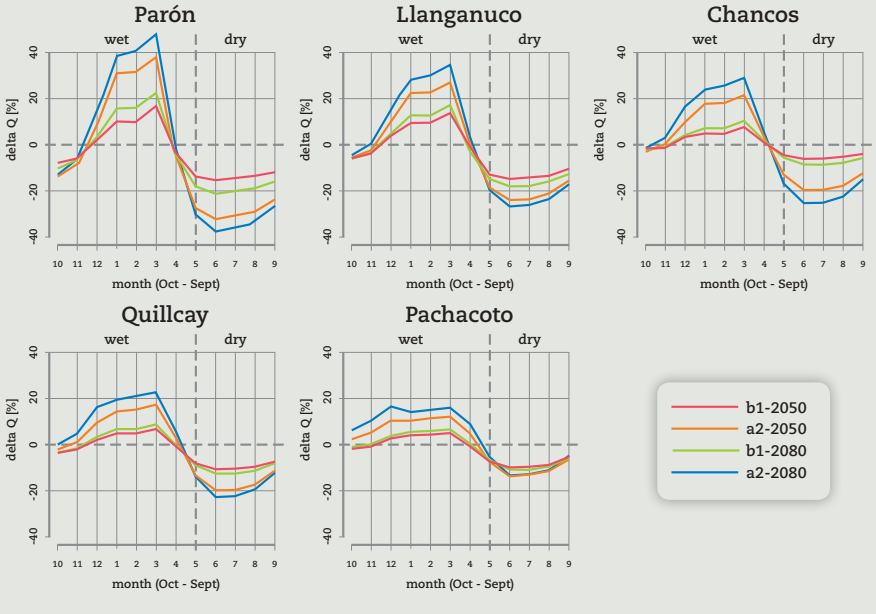


FIGURE 3 > **Simulated change in monthly runoff in 2050 and 2080 (in % compared with 1961-1990 average) in 5 different catchments of the Cordillera Blanca based on the IPCC data change scenarios B1 and A2.**

As shown in Figure 3, dry season runoff is significantly reduced, particularly in the A2 scenario, while wet season discharge is higher due to the larger glacier-free areas and enhanced direct runoff. The overall discharge does not change very much, but the seasonality intensifies significantly. The difference in the amplitude of the simulated streamflow change between the five catchments is primarily a reflection of the current degree of glaciation within the catchments. The relative glacier covered area decreases from the top left (Paron, heavily glaciated) toward the lower right (Pachacoto, barely glaciated). Hence, a currently heavily glaciated catchment such as Paron is projected to undergo large changes in its seasonal runoff behavior as glaciers become smaller in the future. Changes for a catchment such as Pachacoto, which is already small and unable to provide for a substantial seasonal buffering of runoff today, will not be very large, regardless of whether the glacier disappears entirely in the future. These results clearly highlight the importance of considering future changes and hence any adaptation measures on a case by case basis, rather than implementing broad brush measures which may not be adequate for many watersheds.

Glacier retreat can also directly affect water quality. Indeed, Fortner et al. (2011) found that receding glaciers in the Cordillera Blanca induced sulfide weathering from newly exposed minerals and rocks which has profound effects on the water quality in nearby rivers.

The change in water supply is a problem that many local communities in the Andes are already observing today and they are adapting in a number of ways. For example, farmers in Peru noticed decreased water supplies during the dry season which negatively impacts pasture health and grass productivity. Also, animals are forced to into greater daily vertical movements in order to access sufficient water. As a result, herding intensity has increased and livestock growth rates have been negatively affected.

To contribute to these efforts, the project "The Impact of glacier retreat in the Andes: International Multidisciplinary Network for Adaptation Strategies" was implemented from 2012 until 2017 to establish an international multidisciplinary network to enhance resilience to changes, particularly climate change, through improved understanding of vulnerabilities, opportunities and potentials for adaptation.

The project focussed thereby on three different aspects. The first objective was to raise awareness and enhance capacities to assess, monitor and communicate the impacts of and responses to climate change on natural and socio-economic environments at local, national and regional level. A second aspect of the project focussed on the development of strategies and policy guidelines considering vulnerabilities, opportunities and potentials for adaptation, with particular reference to strengthening the role of local communities. A third component focussed on facilitating and strengthening on-going research activities in the region and provide education and training.

The implementation of the different components of the project have led to a large set of activities during the period 2012-2016 in collaboration with a large number of local and international partners. In this accomplishment report, a short overview of project outcomes and deliverables is presented, as well as the impact of the project in the Andean region.

Climate impact assessment on snow, glaciers and water resources

To support adaptation to climate change in the Region of Latin America and the Caribbean, an increased awareness on the impact of climate change on water resources is crucial. Indeed, this enables to define adaptation strategies to expected changes in water resources under the modified climatic conditions. Different activities were organized in which the impacts of climate change on water resources were explained. An overview of the activities is given below. It is an attempt to raise awareness among policy makers to enhance capacities to assess, monitor and communicate the impacts of and responses to climate change on the natural and socio-economic environments

at local, national and regional levels. It can also help to develop strategies and policy guidelines considering vulnerabilities, opportunities and potential for adaptation. Potential for action points can be the articulation in the region, identification of curricula needs for primary and secondary education, and learning from best practices applied in local adaptation projects.

Field course on glacier monitoring and mass balance

A field course on glacier monitoring and mass balance was organized in Valdivia, Chile in August 2012, in cooperation with the UNESCO Working Group on Snow and Ice of (GTNH-IHP) and the Andean Climate Change Inter-American Observatory Network (ACCION).

During the field course, 35 participants from seven Andean countries (Colombia, Ecuador, Peru, Bolivia, Chile, Argentina and Venezuela) gathered to discuss advances on glacier mass balance assessment in each country and to receive further capacitation in the more recent measuring methods. The participants included ten female participants (29%).

The training course allowed to determine the state-of-the-art in Glacier Mass Balance assessment and prepared the elaboration of an updated Spanish version of the Manual on Glacier Mass Balance Assessment, which was finalized in 2015.

The project has created a network of experts on aspects of climate change impact on glaciers, vulnerability of mountain ecosystems to melting glaciers and policy implications.

Climate School on "Andean Climate Variability and Change"

From the third until the sixth of September 2013 a Climate School was held in Lima, Peru, to 6 which addressed the topic of "Climate Variability and Change in the Andes region". The aim was to identify the consequences of climate change for the Andean environment and society. The climate school focused both on the uncertainties in our current understanding of the climate system as well as on the scientific challenges associated with future climate projections. The workshop was oriented towards enhancing the capabilities of young professionals on climate change evaluation and the formulation of adaptation strategies.

The course fostered cross-disciplinary connections and collaborations and covered a broad spectrum of climate change aspects. The school included a mix of plenary lectures, group work and individual computer-based assignments. It provided a platform where the next generation of scientists from the Andes gained professional experience and connections beyond their countries' borders.

The specific topics discussed at the workshop included:

- General concepts of Andean climate: mean state, variability and change
- Availability, applicability and limitations of data sets and methods for data analysis
- Theory of model development and analysis
- Key elements of regional atmospheric modelling (numerics, parameterization schemes, initial and boundary conditions)
- Downscaling methods (dynamical and empirical-statistical)
- Individual computer labs and group-based analysis of case studies

As an outcome of the meeting, the capacities of 27 participants from six Andean countries (Colombia, Ecuador, Peru, Bolivia, Chile and Argentina) were strengthened, including the representatives of the Working Group of Snow and Ice (GTNH). Although there was no specific gender-related focus of the workshop, female participants were encouraged to participate, resulting in 22% female participants during the workshop.

Symposium and Professional Training on Andean Hydrology

The ongoing drought disaster in some parts of the Central Andean region urges the need for seasonal and long term water availability predictions. Reliable discharge simulations are especially important for irrigation management in the intensively cultivated regions of central Chile and central western Argentina, but also for the water supply of megacities such as Santiago and Lima, as well as for industrial purposes. Water related decision makers and water users want to be enabled to select adequate tools for the provision of such predictions and to evaluate existent prognostics.

Therefore, a 4-day Symposium and Professional Training 'Understanding the role of central Andean climate and hydrology for water management: tools and concepts' was held in collaboration with the Institute for Technology and Resource Management in the Tropics and Subtropics (University of Applied Sciences, Cologne, Germany) and the Pontifical Universidad de Valparaiso (PUCV), in Santiago in November 2015.

> Participants at the Symposium and Professional Training on 'Andean Hydrology'

During the symposium, specialists from Latin America provided training on key aspects of monitoring and modeling in mountainous catchments, through overview presentations, successful case studies, lessons-learnt and trainings. During the presentations, different monitoring, assessment and prediction tools were introduced, whereas during the trainings, the different tools were applied in more detail, accompanied by a field trip to the mountainous catchment of the Mapocho basin. The symposium was attended by 75 water-related decision makers and water users from 10 different nationalities, as well as scientists working in the field of water resources in the Central Andean region. They aimed to select adequate methods to assess long and short-term discharge predictions for Andean catchments. Furthermore, the symposium aimed to intensify the science-policy dialogue regarding future availability of water resources in the Central Andean region, as impacted by the progressive reduction in glacier areas in the Andes.

Access to the presentations

Gauging demonstration at a measuring station during the field trip to the Mapocho Basin

Vulnerability assessment and adaptation strategy development

There is widespread concern about the potential impacts of accelerated glacier melt on various ecosystem services. Mountains contain ecosystems that are sensitive and highly vulnerable to natural risks, disasters and environmental changes including climate change. Several studies have shown that high elevation environments comprising glaciers, snow, permafrost, wetlands and upper limits of vegetation and dependent biota are among the most sensitive to climate change. In particular, there is concern about water related ecosystem services. The importance of mountain runoff to water resources globally is disproportionately high, particularly in arid and semiarid tropical regions, where 80% of freshwater resources may originate from mountain catchments. A large proportion of this water is stored as ice and gradually converted to runoff over time. Glaciers accumulate mass during cooler periods and release mass during warmer, drier periods, providing a buffer against the seasonal variability of precipitation. Tropical glaciers are particularly sensitive to climate change because they maintain a temperature near melting point throughout the year. Small changes in temperature, therefore, can have important consequences for glacier mass.

The main impact of glacier mass loss on water resources is the loss of storage capacity and subsequent increase in the seasonal variability of flow. Some changes can already be observed. For instance, upland communities of the Cordillera Blanca depend strongly on glacier melt water because of the arid climate and strong seasonality. The Yanamarey glacier in the southern portion of the Cordillera Blanca, which is representative of other small glaciers in the region, has undergone substantial mass loss in recent years. Local inhabitants indicate that livestock cultivation, agriculture, and, to a lesser extent, tourism, have been affected by increasing variability and decreasing river flow. There is also concern that the impact of reduced water security is affecting women and men differently, but additional scientific research is needed to look into the gender components of glacier retreat more specifically (Carey, 2016).

In recent years there has been a shift towards large scale, water intensive crop production as the export market for Peru's agricultural products has grown. In addition, many upland communities rely on small scale irrigation projects for subsistence crops. Bradley et al. (2006) highlight the fact that glacier melt contributes to the water supply of several major Andean cities, such as Quito, the capital of Ecuador, and La Paz in Bolivia. Buytaert and De Bièvre (2012a) also highlight the vulnerability of these cities to the effects of climate change and population growth. Further, Andean nations are strongly dependent on hydropower to generate electricity. As glacier melt accelerates and flow becomes more seasonal, with lower flows in the dry season, it may become necessary to invest in additional infrastructure to ensure regional energy security.

Despite the large number of studies devoted to the quantification of glacier mass loss and changes in flow at the base of the glacier there is far less information about the impact of changes to glacier melt on water resources further downstream. Indeed, the signal of glacier melt will propagate along a river reach and mix with that of other hydrological processes providing storage and regulation capacities similar to glaciers, such as wetlands and groundwater aquifers.

Such interaction can be highly idiosyncratic, depending not only on the seasonality of precipitation but also the nature and behaviour of the local hydrology. Similarly, the impact on water resources will depend on population density and location, the type and intensity of industry and local and regional agricultural practices. In regions where glacier melt flows into semi-arid and arid regions with intense, water dependent economic activities, such as the Santa valley in Peru, the impact is expected to be high. Conversely, where glacier melt flows into humid regions the glacier melt signal may not propagate downstream by any significant distance. Similarly, in regions with low population density and economic activity the importance of glacier melt to regional water resources may be negligible. In order to identify regions of critical impact it is necessary to perform a regional assessment of the impact of accelerated glacier melt on water resources and its value to local human activities.

Vulnerability assessment of glacier melt contribution to water resources in the Andes

To identify the vulnerability of Andean countries to the reduction in glacier mass, the glacier melt contribution to water resources in the Andean Countries needed to be estimated. To work towards this result, a regional assessment of the vulnerability of Andean natural resources (water and environmental resources) to glacier melt was developed by a vulnerability assessment group, involving the Imperial College of London, CONDESAN and the University of La Molina in Peru.

This assessment group developed a methodology for the regional assessment of the vulnerability of Andean water resources to glacier melt. It consisted of the implementation of a regional hydrological model to assess the propagation of the glacier melt signal downstream of glacier-fed rivers. The results of this model were combined with high-resolution data of water use, subdivided in 3 main uses: (1) urban and industrial use; (2) agricultural use (irrigation); and (3) hydropower. The combination of these two data sources enabled a quantitative and spatially explicit assessment of the contribution of glacier melt to the socio-economic activities of the Andes countries, and potential future changes thereof.

Although large seasonal and interannual variations were observed, it was found that a significant portion of the population in Andean Countries is dependent on glacier melt contributions for personal consumption, agricultural and energy production. The produced country maps enabled to identify areas with higher vulnerability to glacier retreat, and focal areas for follow-up activities targeting the development of adaptation strategies in those regions. A detailed analysis for the different countries in the Andes is provided in the report.

The online glacier to streamflow contribution portal

As an outcome of this activity, an online portal was created to present the vulnerability maps.

The portal provides an overview of the location of the glaciers in the Andes, the average precipitation amounts and the glacier contribution to streamflow at each location along the main rivers. Two options are provided for the glacier contribution. On one hand, it presents the average glacier contribution to streamflow, showing contributions to most rivers between 0-10%. The second option allows to visualize the contribution of glacier melt during the driest month of the driest year, considered its maximum contribution. Under that condition, glacier contribution is found to be much higher, reaching values over 50% for most glaciers in Peru, Bolivia, Chile and Argentina, especially in the dryland areas.

Access to the online portal

> Web portal presenting the contribution of glacier melt water to stream flow in the Andean Region

Policy assessment in the Andean Region

Science-policy links are more complex than it might be supposed. Especially when what is at stake is a common good, there are a number of stakeholders with legitimate interests. First of all, there are groups with specific economic interests (mining entrepreneurs in this case). Next, there are environmental groups and the state itself. Finally, scientists contribute to decision-making with information, analysis, scenarios and other evidence that will lead to more informed decisions.

In this complex scenario, delivering a solid scientific or technical report to a policy maker is just a fraction of what is needed to build an influential science-policy interface. However, whether scientific arguments are considered depend on the social and political context, with the risk of getting blurred amidst the game of social powers. The possibility of science to influence decision making also depends on cultural context, since traditional cultures of indigenous people often take precedence over scientific knowledge. On the other hand, shifts in worldviews in favor of the conservation of nature are an opportunity for science to achieve greater influence in conservation decisions.

Such a broader view of the science-policy interface requires new roles for scientists, politicians and funders (Mendizabal, 2013; Crewe and Young, 2002) acting in the field of glaciers conservation:

Politicians, policy makers and decision makers should be capable of framing the problem and setting a public agenda in a way that the various stakeholders find a space for joint construction. Policy makers should also ask for scientific work to be carried out. After all, participation of all stakeholders (including researchers) is crucial for sustainable policy-making.

Scientists should make an effort to produce understandable and usable science that is problem/solution oriented. They may need to push-forward their scientific findings to connect with socially relevant issues. Researchers should be flexible to adjust to timing, since policy can't wait for scientific timelines. After all, decision making does not always require full scientific information but sometimes just orientation. It is necessary that researchers understand the agenda setting process and get a sense of the opinion formation and decision-making timings.

For **donors and scientific funding agencies** are challenged to balance all these demands made to science without losing the innovative power of excellence in science. Agencies should promote interdisciplinarity and orientation towards solution science by new evaluation and monitoring competencies.

At the initial workshop of the international multidisciplinary network in Lima in 2012, experts discussed policy and national framework conditions and reviewed future national strategies and their relevance to community and developed key recommendations. There was a need to translate the recommendations in to activities and identify programme and partnership linkages with on-going effort.

The workshop came up with key recommendations for policy advisers and decision makers of Andean countries, such as evaluating the regulatory role of glaciers in the region, raising awareness through education, training and dissemination of information and promoting dialogue and collaboration among scientists, decision makers and affected communities, as well as coordinate existing initiatives in the region.

Science Policy workshop in Quito (20-22 November 2013)

The goal of this meeting was to bring together communities from science and policy fields working on global change impacts on snow, glaciers and water resources in order to formulate policy recommendations for adaptation strategies. This science and policy workshop invited the participation of experts in natural sciences (e.g. glaciologists, hydrologists, water resources experts) and social sciences, but also policy makers (from local to national level) and practitioners (for example, mountain biosphere managers) and other local stakeholders to optimize research efforts and science-based policy needs for adaptation strategies in the region.

The objectives of the Science-Policy Workshop included:

- Raising awareness among policymakers in order to enhance capacities to assess, monitor and communicate the impacts of and responses to climate change on natural and socio-economic environments at local, national and regional levels;
- Development of strategies and policy guidelines considering vulnerabilities, opportunities and potential for adaptation,
- Facilitate the articulation in networks, and strengthen ongoing research and adaptation activities in the region;
- Identify curricula needs for primary and secondary education
- Learn from best practices applied in local adaptation projects

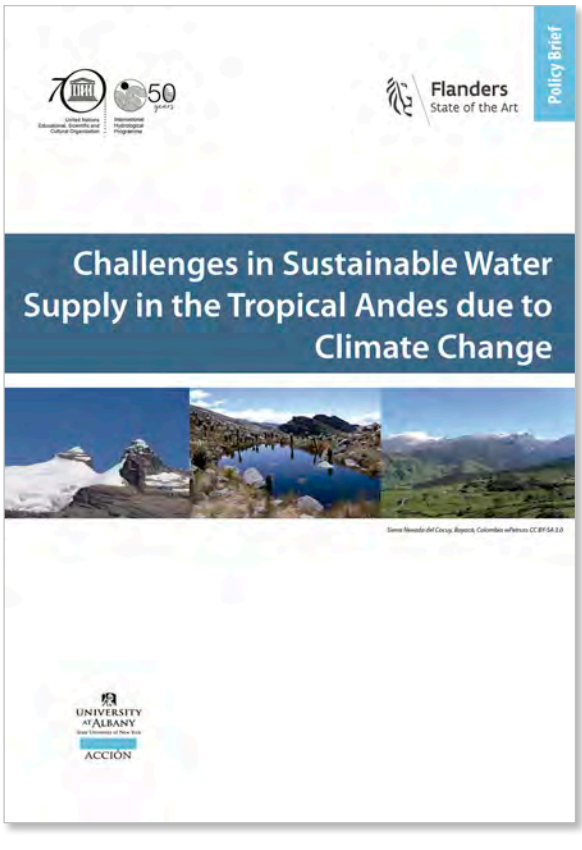
Furthermore, research agendas and strategies to successfully implement climate change adaptation and mitigation measures were identified. For this purpose, four background papers were prepared to be further discussed in the meeting.

Access to the Policy briefs

Two background papers developed for the Science-Policy meeting in Quito, Ecuador

As an outcome of the meeting 61 participants from scientific, educational and policy backgrounds joined efforts to identify a common vision on how to strengthen the science-policy interface, specifically targeting the topic of climate change, and the impact of melting glaciers, in order to move towards an agenda for climate change adaptation. As a result of this meeting, the four preliminary background papers were further consolidated, including the conclusions from the discussions held in Quito. Each of the background papers were also condensed into a Policy Brief format (4-6 pages).

The objective of these policy briefs is to raise awareness among policymakers in order to enhance capacities to assess, monitor and communicate the impacts of and responses to climate change on natural and socio-economic environments at local, national and regional levels.



The first policy brief dealt with 'Mapping of vulnerability of water resources to global changes in the Andean Region' and focussed on the physical environment. The second brief was oriented towards 'Policy needs for adaptation strategies in water resources management', and addressed current policies in different countries identifying possible gaps in addressing changing conditions. The third paper dealt with 'Education and curriculum needs' on water resources, and snow and glacier aspects, showing current gaps. The last paper documented 'Climate Change Adaptation - Local practices in the Andean Region' and showed the way forward. Currently, the policy briefs are being bundled into one document and are meant to highlight recommendations for scientists, policy advisers and decision makers from Member States of the region. Furthermore, research agendas and strategies to successfully implement climate change adaptation and mitigation measures are identified.

Outreach and dissemination

Exhibition “Climate change impacts on mountain regions of the world”

The UNESCO International Hydrological Programme (IHP) and Man and the Biosphere Programme (MAB), organized the exhibition ‘Climate change impacts on mountain regions of the world’ within the framework of the World Mountain Forum (WMF). The exhibition was opened on 22 May 2014 at Cusipata Square, in Cusco.

> **Exhibition catalogue of ‘Climate change impacts on mountain regions of the world’**

The exhibition used satellite images, provided mainly by the Japan Aerospace Exploration Agency (JAXA), to highlight the critical functions of mountains and the implications of climate change for mountain ecosystems, water resources and livelihoods.

The exhibition was opened jointly by the Director of Water Sciences Division of UNESCO, Ms. Blanca Jimenez Cisneros, the Mayor of Cusco, Mr. Luis Florez Garcia; and His Excellency the Swiss Ambassador in Peru, Mr. Hans-Ruedi Bortisand. During the ceremony, the Mayor, HE the Swiss Ambassador and the Director of Water Sciences Division provided an opening statement. Programme specialist of the UNESCO Water Sciences Division, Mr. Anil Mishra, introduced the exhibition panels to the audience. This exhibition was developed as a contribution to the International Year of Water Cooperation (2013) and was created with the support of the Japan Aerospace Exploration Agency (JAXA), The European Space Agency (ESA), The United States Geological Survey (USGS) and Planet Action.

Access to the brochure

The exhibition was first displayed on the exterior fences of UNESCO’s Headquarters in Paris, France during the 37th session of UNESCO’s General Conference (November 2014) and was shown in the Cusipata Square in Cusco, Peru from 19 to 25 May 2014 as an activity of the World Mountain Forum 2014. Then it was transferred on 26 May to the National University of San Antonio Abad in Cusco, where it was shown for another month. This exhibition contributed to the preparation of the Climate Summit, COP20.

As an outcome of the exhibitions on the impact of climate change on glaciers and mountains, the local population of vulnerable communities could be reached and awareness was raised on the changes occurring in the mountainous regions. These exhibitions also resulted in very high visibility for the project and the International Hydrological Programme, through radio and newspaper interviews for local (El Comercio, Publimetro, Terra) and international media (AP). All panels used in the exhibition were bundled in a brochure about climate change impacts on mountain regions of the world.

Glacier Mass Balance Manual

As an outcome of the 'Field course on glacier monitoring and mass balance' held in August 2012 in Valdivia, it was proposed to develop a manual on Glacier Mass Balance using the most recent techniques. The manual is the result of the effort of glaciology researches in Latin America with the aim of building capacity of students, technicians and professionals working on glacier monitoring by means of field techniques. This initiative is led by University of Albany, USA, and is executed in Latin America by the Centro de Estudios Científicos (CECs) de Valdivia, Chile.

The main objective is to train a broad spectrum of professionals involved in glaciological research, allowing the generation of new scientific knowledge, contributing to public decision making, water resources administration and public dissemination and awareness building on current and future water resources. Because on-going climate changes are causing increasing concern for snow and ice-covered areas in Andean countries, this encourages local science groups to pursue glaciological programs and improve monitoring capacities via qualified personnel and modern measurement techniques accompanied by appropriate infrastructure and financing.

The Mass Balance Manual was developed in partnership with the ACCION program, and the project supported the editing work of the manual, which proved crucial to its final impact as a reference manual for the region. The manual was sent to over 100 profesionals in the region of Latin America.

Project Website

In order to increase the visibility of the project and to create an interactive platform for discussion with stakeholders, the "Impact of Glacier Retreat in the Andes" project website was created. The website is available in Spanish and English and provides all the information about the project.

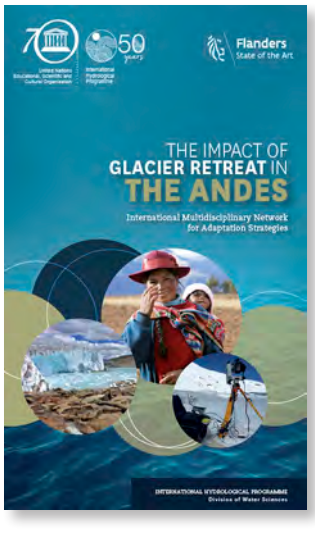
Access to the website

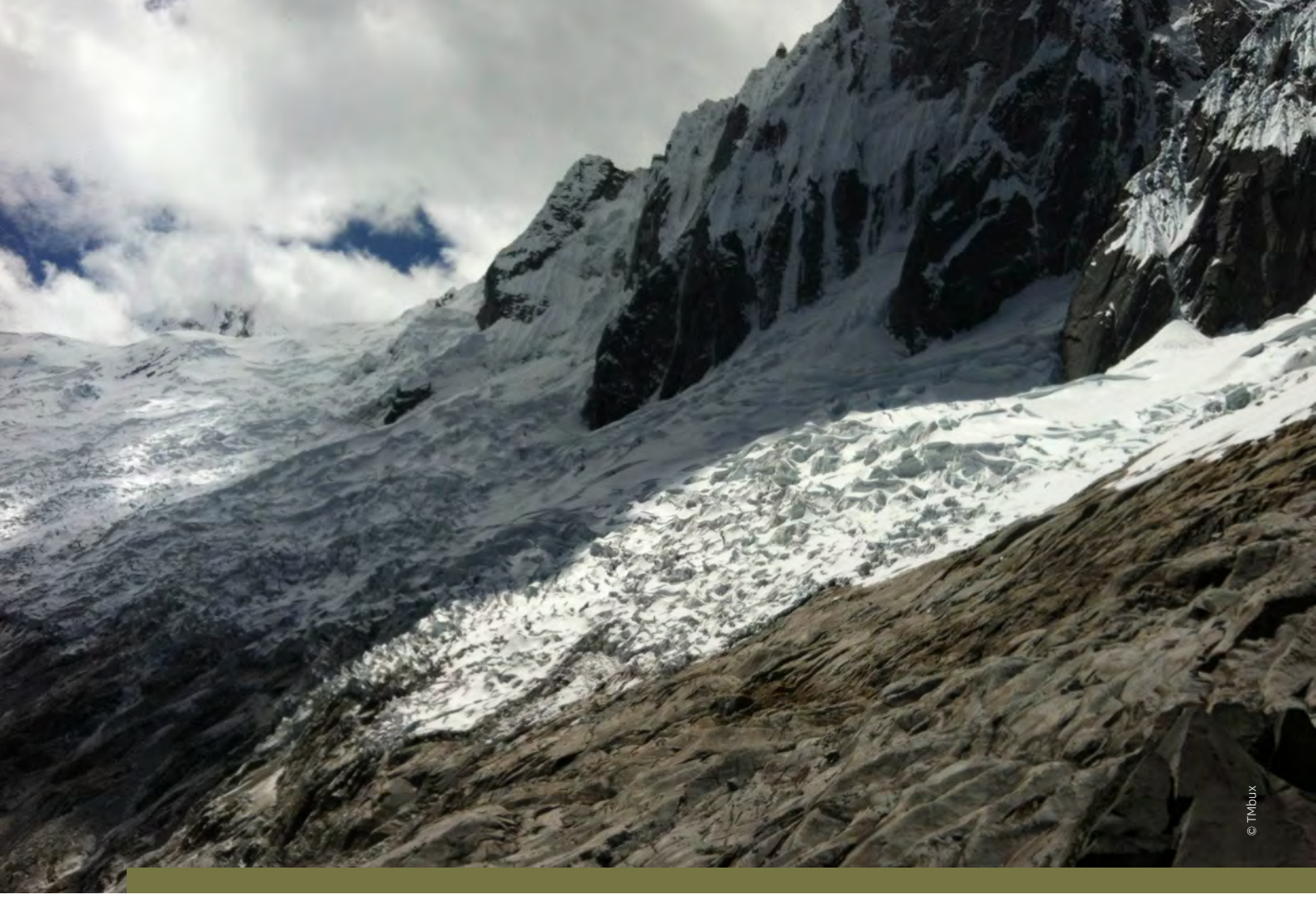
Project Brochure

In 2015 a brochure of the 'Impact of Glacier Retreat in the Andes' project was published presenting the project's developed products and outcomes, in order to reach a broader public. Digital versions are available for download at the UNESCO website and were widely disseminated through the newsletters.

The published brochure concerns the context of the overall Glacier project, a short overview of the different activities and the expected results. The dissemination of the brochures has led to an increased awareness about the Glacier project, as well as an increased use of the tools developed during the project.

Access to the brochure

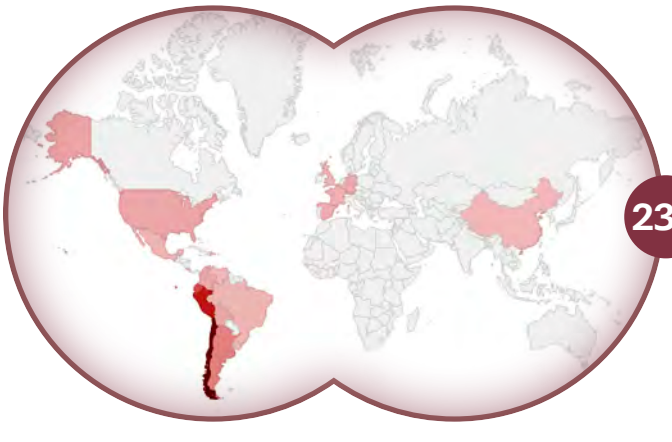




The Project in Numbers

Countries involved in Capacity Building

Participants from 19 countries received training



235 participants were involved

Argentina / Belgium / Bolivia / Brazil / Chile / China / Colombia / Costa Rica / Dominician Republic / Ecuador / France / Germany / Mexico / Peru / Spain / United Kingdom / Uruguay / United States / Venzuela

Detailed Overview of Activities and Partners

1. *Inception workshop on "The Impact of Glacier Retreat in the Andes: International Multidisciplinary Network for Adaptation Strategies"*

Location: Lima, Peru

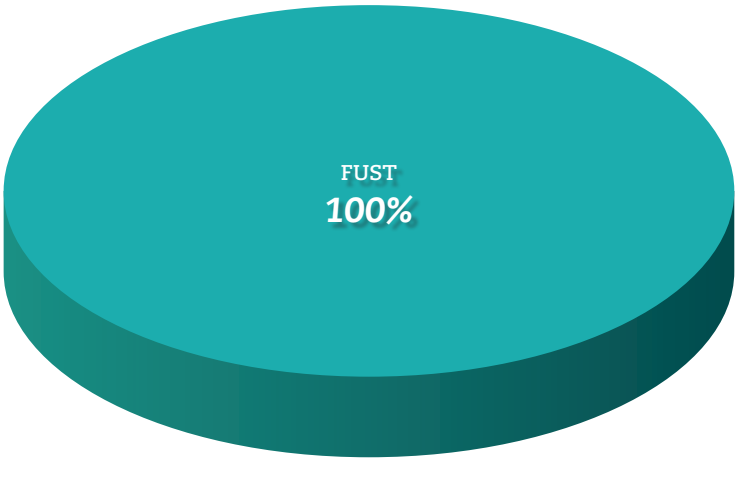
Date: 29-30 May 2012

Total Number of Participants: 41

Description: The main objective of the project was to establish a multidisciplinary network which will help to enhanced resilience to changes, particularly climate change, through improved understanding of vulnerabilities, opportunities and potentials for adaptation. The network will develop strategies and policies policy advice based on sound scientific knowledge for the Andean region. The inception workshop gathered experts from IHP and MAB networks as well as social scientists, and decision makers from governments of the region. Following plenary presentations, 3 breakout working groups focused on the three following three thematic groups: climate impact assessment: snow, glacier, and water resources; vulnerability assessment in the Andean region; and policy assessment in the Andean region. A set of key recommendations were identified as an outcome of the workshop

Countries: Argentina, Bolivia, Chile, Ecuador, Peru, Belgium, China, Spain, USA.

Co-funding and co-organization: UNESCO, FAO Mountain Partnership Secretariat, CONDESAN, the Snow and Ice Working Group (GNTH), the Third Pole Environment (TPE) and ACCION.



Funding Sources

2. *Field course on glacier monitoring and mass balance*

ACCIÓN

United Nations Educational, Scientific and Cultural Organization

CECs CENTRO DE ESTUDIOS CIENTÍFICOS

UNIVERSITY AT ALBANY State University of New York

Location: Valdivia, Chile

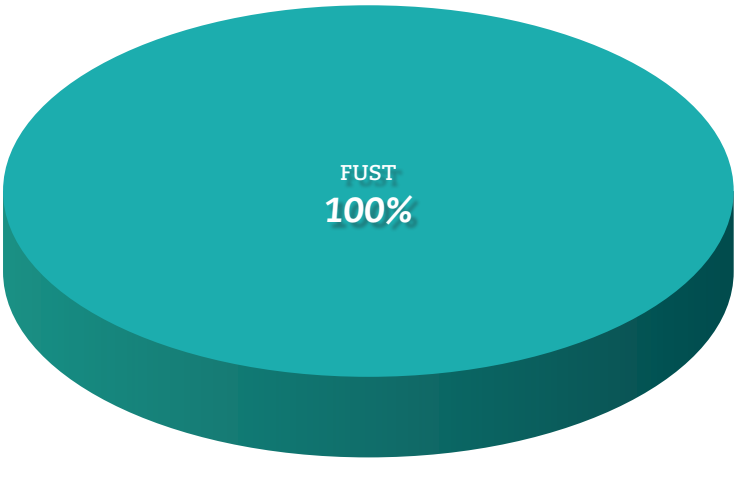
Date: 28 August – 1 Sept 2012

Total Number of Participants: 35

Description: During the field course, the participants gathered to discuss advances on glacier mass balance assessment in each country and to receive further capacitation in the more recent measuring methods. The training course allowed to determine the state-of-the-art in Glacier Mass Balance assessment and prepared the elaboration of an updated Spanish version of the Manual on Glacier Mass Balance Assessment, which was finalized in 2015. The project has created a network of experts on aspects of climate change impact on glaciers, vulnerability of mountain ecosystems to melting glaciers and policy implications.

Countries: Colombia, Ecuador, Peru, Bolivia, Chile, Argentina and Venezuela

Co-funding and co-organization: UNESCO Working Group on Snow and Ice (GTNH-IHP) and the Andean Climate Change Inter-American Observatory Network (ACCION).



Funding Sources

3. *Climate School on "Andean Climate Variability and Change"*

ACCIÓN

Location: Lima, Peru

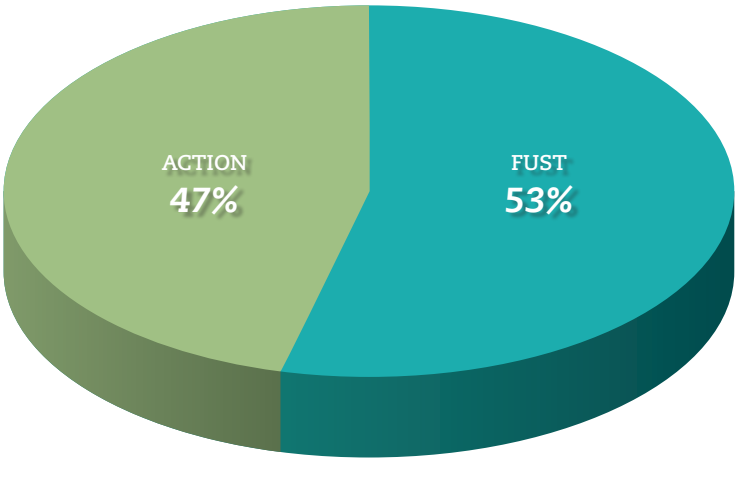
Date: 3-6 September 2013

Total Number of Participants: 27

Description: The main objective of the climate school was to identify the consequences of climate change for the Andean environment and society. The climate school focused both on the uncertainties in our current understanding of the climate system as well as on the scientific challenges associated with future climate projections. The workshop was oriented towards enhancing the capabilities of young professionals on climate change evaluation and the formulation of adaptation strategies. The course fostered cross-disciplinary connections and collaborations and covered a broad spectrum of climate change aspects. The school included a mix of plenary lectures, group work and individual computer-based assignments. It provided a platform where the next generation of scientists from the Andes gained professional experience and connections beyond their countries' borders.

Countries: Colombia, Ecuador, Peru, Bolivia, Chile and Argentina

Co-funding and co-organization: UNESCO, Andean Climate Change Interamerican Observatory Network" (ACCION)



Funding Sources

4. *Professional Training 'Andean Hydrology'*

Location: Santiago, Chile

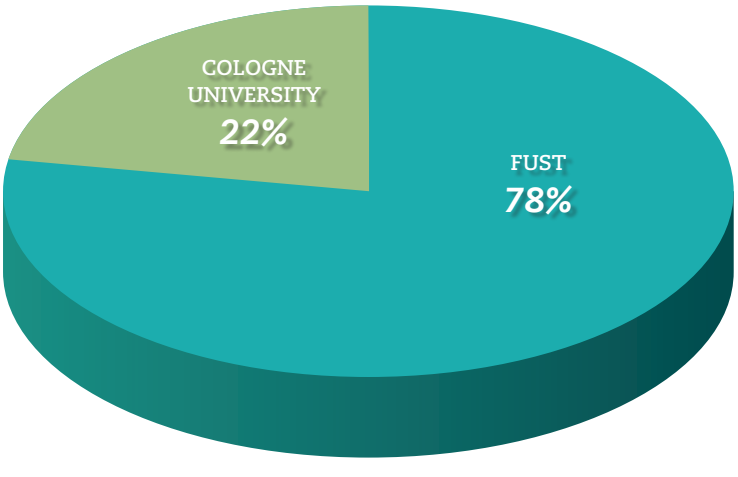
Date: 17-20 November 2015

Total Number of Participants: 70

Description: The main objective of this professional training was to understand the role of central Andean climate and hydrology for water management. The ongoing drought events in some parts of the Central Andean region urges the need for seasonal and long term water availability predictions. During this training the participants were trained on adequate tools for the provision of such predictions and to evaluate existing forecasts.

Countries: Argentina, Belgium, Bolivia, Brazil, Chile, Costa Rica, Dominican Republic, Germany, Mexico and Peru.

Co-funding and co-organization: UNESCO, Cologne University of Applied Sciences



Funding Sources

5. *Science Policy Workshop 'Impacts of Global Climate Change on Snow, Glaciers and Water Resources in the Andes'*

ACCIÓN

UNIVERSITY AT ALBANY
State University of New York

CONDESAN

United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

Location: Quito, Ecuador

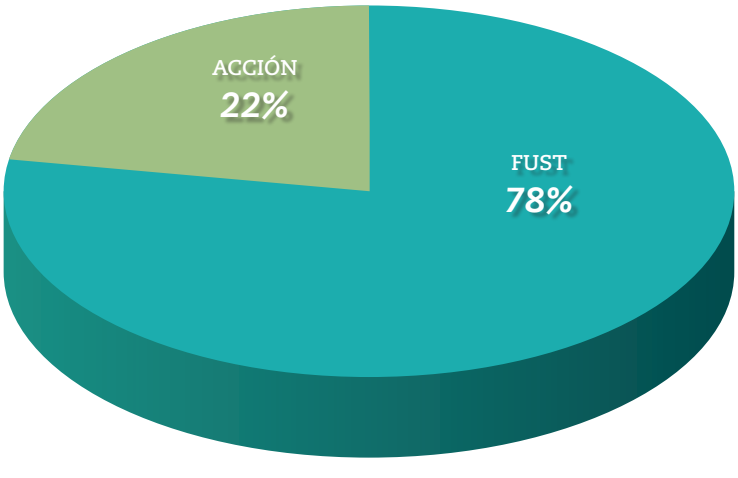
Date: 20-22 November 2013

Total Number of Participants: 61

Description: The goal of this meeting was to bring together communities from science and policy fields working on global change impacts on snow, glaciers and water resources in order to formulate policy recommendations for adaptation strategies. This science and policy workshop invited the participation of experts in natural sciences (e.g. glaciologists, hydrologists, water resources experts) and social sciences, but also policy makers (from local to national level) and practitioners (for example, mountain biosphere managers) and other local stakeholders to optimize research efforts and science-based policy needs for adaptation strategies in the region.

Countries: Chile, Peru, Mexico, Bolivia, Colombia, Brazil, Ecuador, Argentina, Uruguay, USA, UK, Belgium, France, Germany

Co-funding and co-organization: UNESCO, Andean Climate Change Interamerican Observatory Network" (ACCION) and the Consortium for the sustainable development of the Andean Eco-region (CONDESAN)



Funding Sources

6. *Exhibition "Climate change impacts on mountain regions of the world"*

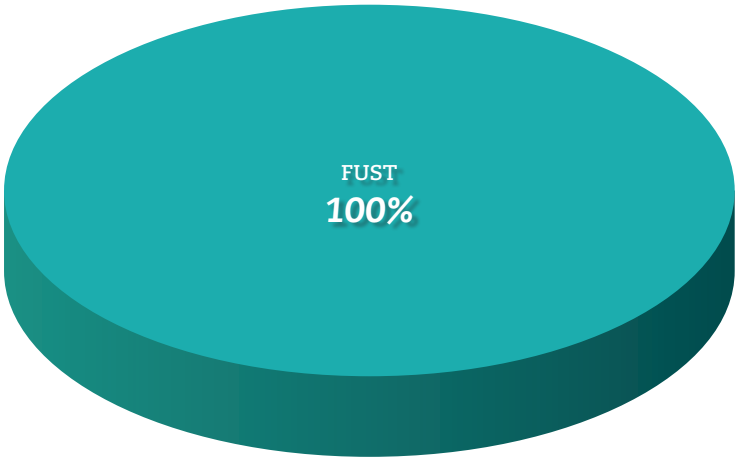
Location: Cusipata Square, Cusco, Peru

Date: 19-25 May 2014

Description: The exhibition used satellite images to highlight the critical functions of mountains and the implications of climate change for mountain ecosystems, water resources and livelihoods. Next, the panels were transferred to the National University of San Antonio Abad in Cusco, where it was shown for another month. This exhibition contributed to the preparation of the Climate Summit, COP20.

Country: Peru

Co-funding and co-organization: The UNESCO International Hydrological Programme (IHP) and Man and the Biosphere Programme (MAB), the Japan Aerospace Exploration Agency (JAXA), The European Space Agency (ESA), The United States Geological Survey (USGS) and Planet Action.



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CONTACT INFORMATION:

INTERNATIONAL HYDROLOGICAL PROGRAMME (IHP)

UNESCO / DIVISION OF WATER SCIENCES
7, PLACE DE FONTENOY
F-75352 PARIS 07 SP
TEL : (+33) 1 45 68 40 01

ihp@unesco.org – www.unesco.org/water/ihp

COORDINATION:
Anil Mishra, UNESCO-IHP, **a.mishra@unesco.org**
Koen Verbist, UNESCO-IHP, **k.verbist@unesco.org**