Climate Change and Water Resources in the Tropical Andes

—MATHIAS VUILLE

Mathias Vuille is an associate professor in the Department of Atmospheric & Environmental Sciences at the University at Albany, State University of New York.

The mean climatic conditions in the tropical Andes underwent significant changes during the twentieth century. The temperature increased by about 0.7°Celsius between 1939 and 2006, although the increase varied, depending on elevation and slope. Several studies have documented similar warming trends on a more regional level. Precipitation trends are weaker and much less coherent, owing to the strong modulation of precipitation characteristics by the Andean topography.

Studies on future climate change are fairly limited and focus primarily on changes in temperature and precipitation by the end of the twenty-first century based on different scenarios. Temperature changes in the simulations show a strong elevation dependency, with the largest warming at high elevations, where glaciers are located. The tropical Andes might experience a warming on the order of 4.5–5°Celsius by the end of this century. Maybe even more disconcerting are projections of future interannual variability and the likelihood of extremely hot years. Future changes in precipitation amount or seasonality are more difficult to simulate.

CLIMATE CHANGE'S IMPACTS ON NATURAL SYSTEMS

The observed changes in temperature have led to a rapid and accelerated retreat of tropical glaciers throughout the tropical Andes. While a decline in precipitation may have contributed to that retreat on a regional scale, the lack of a coherent negative precipitation trend across the entire range of the tropical Andes suggests that precipitation changes were not the main driver of the observed change.

Changes in glacier volume will eventually lead to significant changes in the seasonal glacier hydrology downstream, with the most significant changes in streamflow expected during the dry season, when glacier meltwater accounts for a significant amount of total river flow. Glaciers play a vital role as critical buffers against seasonal precipitation and provide water during the dry season for a multitude of domestic, agricultural, or industrial uses.

The tropical Andes might experience a warming on the order of 4.5–5°Celsius by the end of this century.

The amplitude of the simulated streamflow change depends highly on the current degree of glaciation within the catchment. A currently heavily glaciated catchment will undergo a large change in its seasonal runoff behavior as glaciers become smaller. A catchment where the glacier is already small will not see a large change even if 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.

Wetlands known as *paramos*—neotropical alpine ecosystems—are a major water source for Andean highlands and provide water for a vast area of the much drier lowlands on the Pacific coast of Ecuador and northern Peru. *Paramos* are increasingly threatened by climate change, as higher temperatures will displace ecosystems upslope, coupled with biodiversity loss and increasing spatial isolation. Glacier retreat can also directly affect the species composition of ecosystems through changes in downstream water supply. Aquatic species may also be strongly affected.

The change in seasonality of streamflow and the reduction of river runoff during the dry season will have implications for water use in all its aspects, ranging from access to drinking

water to water availability for sanitation, irrigation and agriculture, mining operations, and hydropower production. The observed and projected future decreases in streamflow have already led to increased tensions between local peasants and mining companies. There are also significant social and economic impacts related to hydropower production in the high Andes. Future water scarcity may lead to increasing struggles for power to regulate and gain access to water; displacement of local populations and centuries-old water use practices may be the end result.

Struggles over access to sufficient water need to be discussed in the context of a growing Andean population, which will put additional pressure on resources. Indeed, the problems associated with climate change and impacts on water resources are of concern primarily in regions where large population pressure and significant economic activity are juxtaposed with large projected changes in water availability, thereby leading to increased competition for water rights. There is some concern that future water scarcity in some areas may lower the carrying capacity of the land and induce migration of large segments of the rural population to city centers, thereby enhancing water pressure.

CHALLENGES AHEAD

The current problems surrounding water availability in the tropical Andes require the swift development and implementation of adaptation and mitigation strategies, which could help alleviate the conflicts surrounding access to clean water. The main goal of such adaptation efforts should be to increase the resilience and reduce the vulnerability of local indigenous populations, who will likely be most heavily affected by future climate change impacts on the hydrologic cycle.

Unfortunately, there has historically been a general disconnect between the various groups involved in these discussions. Scientific studies, for example, have so far contributed little to improving the predictive understanding of future Andean water supply and demand and therefore have had virtually no impact on improving the livelihoods of affected populations. We still do not fully understand the varying importance of glaciers in different parts of the Andes. The same is true for ecosystems downstream of glaciers and their potential relevance for regulating water supply. Scientific studies have thus far also failed to provide useful metrics for planning purposes.

Much of this lack of progress is related to limitations imposed by an often inadequate environmental monitoring network in the region. Modeling studies also suffer from large uncertainties as far as changes in the hydrologic cycle are concerned, but there has been a general reluctance of many funding agencies to invest in impacts-related research, even though that is the only way to design and develop better downscaling techniques and scenarios.

Adaptation projects therefore often move forward without having received proper guidance from the scientific community. Some plans—such as painting mountain tops white to lower the albedo and thereby artificially induce glacier growth—go forward without adequate scientific evaluation. Similarly, projects often fail to acknowledge existing local adaptation strategies and therefore do not take advantage of traditional local knowledge. A better support framework for local and regional mechanisms, initiatives, and traditions would allow for a better integration of various actors. Up until now, adequate participation of the most vulnerable groups, the rural indigenous communities, has often been neglected.

One recent initiative, ACCION (Andean Climate Change Interamerican Observatory Network, funded by the US State Department), is working toward improved coordination and data sharing between actors and across disciplines, with the hope that it could help promote synergies, dialogue, and collaboration but also maximize the effectiveness of often rather limited financial

resources. A key aspect of this project is the recognition that real progress in the region requires better education and capacity building at all levels, promoting exchange of scientific expertise. This will be achieved through fellowships and through training and education of South American students at partner institutions in the United States and Europe.

In some instances, technical solutions may be able to alleviate some of the water stress, be it through building small reservoirs, reducing the fraction of polluted water that goes unused through construction of water treatment plants, tapping into new groundwater resources, or simply installing private water storage systems. Implementation of such measures, however, is often hampered by gaps in understanding of water availability, quality, and dynamics. Groundwater contribution, for example, has historically been considered negligible in glacierized valleys, but the real role of aquifers and their recharge rates are virtually unknown. In addition, new constructions, such as water reservoirs, would have to consider negative impacts such as loss of land, water loss due to evaporation, the potential for displacement of local populations, and the shortened lifetime of reservoirs in glacial watersheds due to high sedimentation rates. Water conservation, new irrigation methods, and sanitation projects may also provide some relief in certain regions.

Finally, it is important that the institutional standing of authorities involved in glacier research and water management be strengthened. In some instances environmental governance institutions may have to be modified or new entities may have to be created to better address changing water management requirements. Institutional arrangements, however, will have to include meaningful participation of local affected populations in watershed governance in order to avoid conflicts and water competition among economic sectors.

Adequate adaptation strategies regarding glacier retreat and anticipated water shortages in the Andes can only be implemented successfully if scientific results are transformed into information that is useful and relevant to local populations and national entities involved in water management.

In the end, only a combination of various approaches will lead to reduced vulnerability and increased resilience of water users affected by climate change. Collaboration and partnership between all the actors and stakeholders involved is critically important. It is the only way forward toward a more sustainable future in the tropical Andes—a future where sufficient access to clean water is guaranteed and where water allocation addresses the concerns of all water users.

A longer version of this article, including endnotes and a full reference list, is available at www.iadb.org/sustainability/vuille