Opportunities and challenges for the incorporation of climate change information for sustainable water resource management in Bolivia, South America

by

Vijay Ramprasad

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Faculty advisors:
Associate Professor Maria Carmen de Mello Lemos, Chair
Associate Professor Christopher J. Poulsen

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Dedication

To the people of three continents, where I’ve traveled and learned.

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1. Abstract

Negative impacts of climate variability and change are projected to cause havoc in water availability and quality around the world. Bolivia, South America, is vulnerable because it is home to one of the poorest populations in South America, and fresh water supplies are seriously endangered by changes in climatic variability and rapid glacier melt caused by climate change. At this point, Bolivia, similar to many less developed countries, is not prepared to cope with future climate change and lacks the capacity to respond to its impacts on water resources. Adaptive governance, in which individuals 'adapt' their decisions based on climate perturbations, is rapidly gaining importance and could critically shape Bolivia's ability to better respond to the effects of climate impact on its water resources. In principle, knowledge of future climate can contribute to more effective water adaptive management by informing stakeholders about expected stresses resulting from impacts of climate change. Policy makers and users could then plan to reduce water systems' sensitivity to these climate impacts and thereby increase the resilience of the social ecological systems (SES).

The study focuses on understanding the role of knowledge in adaptive water management in Bolivia in the context of climate variability and change. It was conducted in the Desaguadero watershed which is a part of the Lake **T**iticaca, **D**esaguadero river, Lake **P**oopo, and salt lake **S**alar de Coipasa (TDPS). The watershed of TDPS stretches over two countries - Bolivia and Peru in the South American Andes, covering an area of 143, 900 km^2 between the altitudes of 3,600 and 4,500 meters above sea level.

The study design had two phases. In phase one, we interviewed policy and decision makers in the water sector in Bolivia to understand water management institutions and organizations and the potential role of climate knowledge (especially downscaled climate model data) in informing response to climate variability and change. For this purpose, we carried out 36 interviews with decision makers and stakeholders who represented all scales of governance and stakeholders in the water sector. In year two, we selected a

subset of respondents from 2009 and provided this group with downscaled climate data. We then recorded their reactions and feedback, including their willingness to use this kind of knowledge in their decision-making. The data set consisted of climate data downscaled using RegCM ensemble data for two time periods a) 2048 – 2059 (short term) and b) 2089 – 2098 (long term).

Analysis indicates that management of water resources in Bolivia represents unique hierarchical and scalar properties. Four broad scales of management were identified namely a) bi-national (Bolivia and Peru), b) national (Bolivia), c) regional (nine departments/states in Bolivia), and d) local (community management). Information seeking was found to be a factor of respondent's level of decision-making. Climate information seeking depends on current information availability, its reliability, missing information, and accessible sources. Climate change information availability and reliability decreases with scale of governance from national to local. Paradoxically, the use of climate change information increases from national to local levels of governance. Opportunities for incorporation of downscaled climate information exist at higher scales of water management, since the decision-makers value reliable and low uncertainty data, while constraints exist in the form of socio-political barriers, organizational redundancies, lack of capacity, and sectoral differences. The study also suggests that downscaled climate information is a valuable tool that helps decision makers and communities increase their adaptive capacity by strengthening their ability to prepare and respond to extreme-weather.

2. Introduction

Tropical regions are susceptible to changes in hydrologic cycles and water availability due to climate change. Most South American countries are not prepared to cope for future climate change and lack the capacity to respond to the impacts of climate change in general and water resources in particular. Bolivia, South America, is vulnerable because it is home to one of the poorest populations in South America and fresh water supplies are seriously endangered by changes in climatic variability and rapid glacier melt caused by climate change (Ramirez, Francou et al. 2001; IPCC 2008; Vuille, Francou et al. 2008). The country is projected to face unprecedented climate change impacts on water resources (Thibeault, Seth et al. 2010), which are exacerbated by lack of management strategies, information on climate change and institutional constraints. In this context, mitigation and adaptation mechanisms for sustainable management of water resources are critically needed.

Currently, most climate policies and water management practices are based on several assumptions that may require re-thinking such as a) natural resource base is reasonably constant in the near and medium term, b) inter-generational and inter-developmental justice is an implicit positive externality, c) policy limitations will surpass socio-political-economic boundaries, and d) intensity of technology-based mitigation in the future will offset current inaction. Also, even if carbon dioxide emissions stop today, climate change and effects of anthropogenic additions will be irreversible for the next thousand years and current management efforts may not be sufficient to reduce risk of climate change on a decadal time scale (Arnell, Livermore et al. 2004). Water management and policy should therefore include innovative approaches that acknowledge the uncertainties and address the complexity of climate change impacts.

One such innovative approach is to enhance the response ability of systems or their 'adaptive capacity' - the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (Gallopin 2006) by increasing the use of climate knowledge (or ‘information’) in decision-making. Informed knowledge-based decisions could help adapt to climate change by advancing an understanding of vulnerabilities and assisting in adaptive management. Information mediated adaptive capacity development can also be one way to enhance the resilience of social (management) ecological (water and physical) systems (SES) [1] to climate change mediated perturbations.

Existing literature on usability of knowledge point to several factors that influence a) *uptake* of knowledge such as institutional constraints (Callahan, Miles et al. 1999), contextual and organizational drivers (Patt and Gwata 2002) , b) *production* of usable knowledge quality of climate projections (Ziervogel, Johnston et al. 2010), and c) *interactions* between information producers and consumers (Lemos and Morehouse 2005; Sarewitz and Pielke 2007; Kirchhoff 2010; Ziervogel, Johnston et al. 2010). However, questions about information use in decision-making persist because institutional and organizational opportunities and socio-economic, political, and cultural constraints for information production and its use are currently unclear. In addition, policy making in times of unprecedented climate change presents a substantial challenge since it involves making decisions under uncertainty, complexity, and non-linearity (Webster, Forest et al. 2003; Nordhaus 2007).

This study is an attempt to understand the factors influencing the use of climate information in Bolivia and adds to the existing literature on the usability of information and its role in building adaptive capacity. This research studies water managers and decision makers in the Bolivian water management system and the role of climate information. Climate information production in Bolivia is limited and mostly confined to its national meteorological entities. Consumption of such information faces stiff

[1] Social Ecological Systems (SES) or Coupled Human and Natural Systems (CHANS) are complex adaptive systems in which human and natural components interact to exhibit emergent properties such as resilience. Holling, C. S. (2001). "Understanding the complexity of economic, ecological, and social systems." Ecosystems **4**(5): 390-405, Folke, C. (2007). "Social-ecological systems and adaptive governance of the commons." Ecological Research **22**(1): 14-15, Liu, J. G., T. Dietz, et al. (2007). "Complexity of coupled human and natural systems." Science **317**(5844): 1513-1516, Alessa, L., A. Kliskey, et al. (2008). "Social-ecological hotspots mapping: A spatial approach for identifying coupled social-ecological space." Landscape and Urban Planning **85**(1): 27-39.

challenges despite the growing awareness of climate risks and widespread social movements to protect natural resources (Barr 2005; Perreault 2006; Andersson and Gibson 2007; Molina 2009). Rather than a result of lack of awareness or understanding of climate change, the limited production and use of climate information is a function of a myriad of other factors such as lack of resources for information production, failure to contextualize existing information, and gaps between producers and consumers of information.

While many authors have described the Bolivian 'water wars' (de la Fuente 2003; Barr 2005; Perreault 2005; Perreault 2007; Perreault 2008), the events that lead to the social uprising (Assies 2003; Molina 2009), urban and peri-urban water scarcity issues (Wutich and Ragsdale 2008), and forest governance (Andersson, Gibson et al. 2006; de Jong, Ruiz et al. 2006; Andersson and Gibson 2007), there has been limited research on the role of climate information in the decision making process of natural resource policy. This research aims to disaggregate the organizational and institutional drivers that present both opportunities and challenges for the incorporation of climate change information in decision-making. This two-year iterative study investigates both the status of climate information use in Bolivia and the usefulness of primary climate information produced within the study. Specifically, this research seeks to answer the following questions:

i. Who are the main actors in the water sector and how do they make water management decisions?
ii. What is the current role of climate information in decision-making?
iii. How might climate information influence decision-making in water management?

In the context of information-based policy making, the ability to transfer knowledge and adopt innovation is an essential factor in building adaptive capacity and resilience of communities to climate change. 'Adaptive governance', in which individuals 'adapt' their decisions based on climate perturbations, is rapidly gaining importance. Inclusion of climate change in existing development projects and call for synergistic development agendas that incorporate adaptation strategies in future projects highlights the importance of innovation and knowledge-based adaptation to climate change (Eakin and Lemos 2006; Pahl-Wostl, Craps et al. 2007; Lemos 2008). Yet, there has been virtually no research assessing the adaptive capacity of decision-makers in the natural resource management in Bolivia. Therefore, there is an urgent need to know the key actors in the water sector and the factors that influence their decision-making in order to understand the adaptive capacities of key-actors.

The first research question attempts at disaggregating the complex water sector in Bolivia, identifies key-actors, and makes informed conclusions of their adaptive capacities. In principle, knowledge of future climate can contribute to more effective natural resource management by informing stakeholders about expected stresses resulting from climate change impacts. Policy makers can then plan to reduce the sensitivity to these impacts thereby increasing the overall adaptive capacity to respond, cope and recover from negative impacts of climate change (Lemos 2008). In order to make policy making more informed, an understanding of not only the current information use in Bolivia but also the various stakeholders and their decision-making space is required. With little information is available on Bolivian policy making in general and water resources in particular, such an understanding will help identify the drivers, context, and barriers to information use.

The second research question addresses this gap in understanding of Bolivian decision-making system by describing the state of climate information use in Bolivia.
The third question addresses information use in decision-making from a theoretical perspective. This section draws on interdisciplinary approaches (e.g. natural resource policy, innovations policy, social ecological systems, and complex systems) and analyzes them within the Bolivian context. A conceptual model of information use is presented that posits a few innovative arguments for knowledge systems.

Format of the practicum

The practicum is organized into six chapters. It starts with a background of Bolivia and climate change and water systems following the introductory chapter. Chapter 2, which presents the literature review, includes an analysis of information systems and knowledge, current state of climate information production, factors that moderate information use, constraints and opportunities for the use of climate information, and challenges for knowledge uptake. Chapter 3 describes the research methodology interview and data collection and analysis. Chapter 4 is the main analytical section that discusses the research questions based on the questionnaire responses. Chapter 5 provides a summary of conclusions of the research followed by the final chapter that provides policy recommendations based on the results of this study.

1. 1. Background

1. 1. A. Climate change and water resources

Water resources are vital to all forms of life and for all human activities (UN 2011). Water systems are inextricably linked to climate change, which is one of the many stressors on water resources. Climate change mediated changes on water resources can lead to predictable and unprecedented changes in the water and climatic system. Climate change affects freshwater quantity and quality in both mean and averages such as seasonal changes in precipitation and frequency and duration of extreme events such as floods and droughts. The Third Assessment Report (IPCC 2001) of the Intergovernmental panel on Climate Change summarizes the state of knowledge on the impacts of climate change on hydrology and water resources as:

- Streamflow volume trends increases and decreases in many regions
- Peak streamflow is likely to move temporally, from spring to winter due to early snowmelt with lower flows in summer and autumn
- Glacier retreat is projected to exacerbate and may lead to disappearance of many glaciers
- Water quality is projected to degrade due to increase in temperature
- The magnitude and frequency of floods is likely to increase globally and low volume flows are likely to decrease in many regions
- Population growth and economic development has increased the demand for water, however, increase in water-use efficiency has decreased the demand in some regions
- System characteristics, dynamic pressures on the water system, changes in management and adaptation practices influence the impacts of climate change on water systems
- The most vulnerable water systems are those that are not managed
- The lack of experience in managing for climate change challenges existing water management practices and

- Coping capacity to climate related water stress is unevenly distributed across the world.

Current vulnerabilities to climate change are strongly correlated with climate variabilities in general and precipitation vulnerability in particular. Vulnerabilities are largest in arid and semi-arid regions and low-income countries, where precipitation and stream flow are concentrated over a few months and are characterized by high year-to-year variations, climate change mediated water vulnerabilities are high. River basins and lakes that are stressed due to non-climatic drivers are also likely to be vulnerable to climate change. Current sensitivities of components of global freshwater systems influence all components of the water system. Surface waters and runoff generation, which are dependent on catchment physiogeography and hydrogeographical characteristics, volume and timing of precipitation, snowmelt and type of precipitation, are exacerbated by anthropogenic pressures and climate variability. Growing human demand on ground water along with changes in precipitation and temperature exerts severe pressure on groundwater system. Therefore, vulnerabilities and negative impacts of water system, water quantity and quality mediated by human use and climate change, outweighs the benefits of climate change effects on water systems and presents unique challenges to water mangers and policy makers.

1. 1. B. Climate change and Bolivia

Bolivia ratified the Kyoto Protocol through its Law No. 1988, dated July 22, 1999. Bolivia's National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) considered three climate change scenario's: IS92 a (business as usual), IS92e (scenario that represents moderate population growth, high economic growth, high fossil fuel availability and eventual phase out of nuclear power), and IS92c (scenario that has a CO2 emissions path that eventually falls below its 1990 starting level, assumes that population first grows, then declines by the middle of next century, that economic growth is low, and that there are severe constraints on fossil fuel supply) developed by the Intergovernmental Panel of Climate Change (IPCC) (Palma, Trepp et al. 2000). Climate change is projected to have varied impacts to ecosystems in Bolivia. For example a 2° C temperature increase and 10% precipitation increase may cause a 65% increase of tropical moist forest area and a 60% decrease in subtropical moist forest area (Palma, Trepp et al. 2000). Under the scenario, IS92c changes are predicted in cool temperate desert zones, cool temperate thorn steppe, and tropical wet forests and no highly vulnerable zones are identified. However, scenario IS92e conditions predict that tropical moist forest, warm temperate dry forest, subtropical rain forest, tropical wet forest, subtropical thorn woodland, and cool- temperate desert areas would be vulnerable to climate change impacts.

Bolivia faces both direct and indirect anthropogenic effects of climate change Direct effects are experienced as increased floods in Santa Cruz, landslides in La Paz, forest fires in Guarayos - Santa Cruz, and storms in Cochabamba. Indirect effects are expressed in human health vulnerability such as increase in incidence and spread of malaria in the IS92a scenario.

Glacier retreat is well documented (Ramirez, Francou et al. 2001) and a symbol of climate change impacts in Bolivia. Glaciers in Bolivia are important providers of fresh water in the country. It is estimated that that thirty-five percent of the water supply for La Paz will disappear in the next thirty years due to the melting of the nearby glaciers (*VMEBC, Personal communication*). Since glaciers effectively buffer stream discharge seasonally, continued glacier melting is likely to result in more variable stream flows and less dry-season runoff.

The hydrological changes predicted by this study (refer the section 3.5) is likely to make agriculture on the Bolivian plateau more challenging, primarily through a reduction in rainfall and soil moisture. The fact that much of the drying occurs in the spring when many crops are planted and germinating presents an additional challenge to farmers, irrigation agencies, and community water managers. It is also likely that lake levels will be affected and may decrease due to enhanced evapotranspiration. Since, Lake Titicaca loses most of its water by evaporation, the increase in temperature and decrease in precipitation potentially decrease the lake levels. Consequently, the TDPS region, which is downstream of Lake Titicaca, is projected to receive less downstream flow.

Model predictions of this study indicate an increase in extreme rainfall events, making summer flooding more common in some regions of the Altiplano. Temperature increases will likely accelerate melting of mountain glaciers and is consistent with studies that predict rapid glacier retreat because of atmospheric temperature increase (Francou, Ramirez et al. 2000; Ramirez, Francou et al. 2001; Ceballos, Euscategui et al. 2006).

1. 1. C. Climate change and water management

In the wake of climate change, increased population demands, and ecosystem sustainability, there is a justified concern that water managers around the world are ill equipped to respond to these emerging threats. However, water mangers have historically been receptive to new management approaches. Several shifts in management techniques and experiments in public works have provided valuable lessons about different water management approaches (Engle and Lemos 2010). In this context, two approaches of managing water have been influential. The first approach is integrated water resource management (IWRM), which focuses on decentralized institutions around watersheds and river basins and bringing together the various aspects of water resource hydrology, ecological, and socio-economic aspects. The aim of IWRM is thus to integrate water management across multiple scales of governance while simultaneously incorporating the diversity of stakeholder needs. The second approach is adaptive management (AM) (Galaz 2007; Pahl-Wostl 2008), which originated in resilience theory (Holling 2001) and aims to manage for uncertainty by formalized experimentation and process-based learning (Lee 1993). Bolivia’s newly created water management institutions seek to apply IWRM in all water management decisions.

1. 2. Country Profile: Bolivia

Bolivia is a landlocked South American nation that was one of the first to break away from Spanish colonialism in 1825. The area that is now Bolivia was colonized by the Spanish and formed successively the viceroyalties of Peru and of Rio de la Plata (FAO 1983). Five countries border Bolivia, with a land area of 1098581 square kilometers. On the west, Bolivia shares the Titicaca Lake with Peru and the Cordillera Occidental with Chile. The Amazons of the eastern Bolivia abut Brazil and the shrub lands of the Chacho make way into Paraguay on the southeast. Argentina lies to the direct south of Bolivia.

A country of geographical contrasts, Bolivia has four main geographic regions: the Altiplano, the highland valleys, the Amazon, and the Chaco. Firstly, the cordillera of the Andes divides into two branches in western Bolivia, where they form a topographic boundary to the Altiplano, a high altitude plateau where altitudes range between 4200 to 4400 meters above sea level. Secondly, east of the Andes, the central highland valleys are characterized by semi-tropical climates, moderate elevation, and arable lands that are home to some of the largest cities including Cochabamba, Sucre, and Tarija. Amazonian rainforests, characterized by very high biodiversity lay to the east and north of the highland valleys where low elevations make way for tropical lowlands. Together with the highland valleys, the Amazonian rainforests make up the Amazon basin. Fourthly, to the southeast of the lowlands lie the arid scrublands of Chaco in La Plata basin, which receives less than 100 mm of annual rainfall. These four geographic and climatic zones are home to 4 biomes (jungle, forest, savannah, tundra, steppe, desert, and wetlands), 14 eco-regions and 199 ecosystems, where 22,000 plant species and 2,342 vertebrate species (CBD 2011). More than 14,000 higher plant species, 325 mammals, 186 amphibians, 260 reptiles, 550 fish species and 1,379 birds have been inventoried as of 2011 (CBD 2011). Endemism is high in each of these regions with 16% of mammals, 22% of fish, 20% of reptiles and 42% of birds endemic to Bolivia.

Economically, Bolivia is one of Latin America's weakest performers on both economic growth and poverty reduction. Based on the Human Development Index (HDI), a composite measure of three basic dimensions of development: health, education, and income, Bolivia scores 0.643. While the Latin America and Caribbean region has increased its HDI from 0.578 in 1980 to 0.706 in 2011 (UNDP 2011), Bolivia has stayed below the regional average underlining the substantial gaps in human well-being and life chances amongst the Bolivian population. The economic performance is typical of a natural resource based economies with low growth rates at about 1.1% per capita from

1997 to 2007 and low levels of productivity and investment (Congress 2006; Molina 2009).

Estimates suggest that 65% of Bolivia's population live in poverty (under $2/day), which accounts for 6.5 million people. Forty percent of Bolivia's poor live in extreme poverty (under $1/day). The main causes for the low economic growth and widespread poverty are a) high levels of income inequality - Bolivia has a one of the highest Gini coefficient values at 0.56, and b) a slow rate of poverty reduction which are significantly predicted by education levels and indegeneity of the population. Skill bias is hypothesized to raise education thresholds for meaningful employment and skew distribution of educational opportunities between urban and rural populations that creates education mediated income inequality (Molina 2009). In addition, internal colonialism, which excluded majority of the indigenous populations for centuries from development, politics, and participation, is responsible for poverty and inequality. A report by international donor agency Oxfam, suggests that being indigenous in Bolivia increases the likelihood of being poor: an indigenous man from rural Bolivia has a 70% likelihood of living in extreme poverty; half of all indigenous population live in poverty contrary to 24% poverty among non-indigenous Bolivians; 28% of indigenous children face chronic malnutrition compared with 16% among non-indigenous population; and infant mortality rates (62 deaths/1000 births) among indigenous Bolivians are twice the rate as non-indigenous Bolivians (Oxfam 2009).

Bolivia's population of 9,862, 860 (World WB 2009) is as diverse as its geographic regions. Sixty-two percent of Bolivia's population is of indigenous origin. Quechua (31%) and Aymara (25%) are the most populous of Bolivia's native populations followed by Chiquitano, Guarani, and Mojeno. Mestizos (more than one culture), and peoples of European and African descent make up the rest of Bolivia's population. Gender imbalances persist especially in rural areas, where a large percentage of people living in poverty are women. Even in urban centers, women work for very low wages, without social protection, and are twice as likely to be illiterate than men. However, Bolivia's literacy rate has steadily grown from 63% in 1976 to an impressive 91% in 2008.

Population migration has been increasingly common, especially following the agrarian reforms of 1950s and the ban on obligatory land labor. Migration patterns followed either to lowlands or urban centers following economic hardships in 1980's. During the 1990's urban squatter settlements increased in peri-urban areas. Urbanization, 62% of the population is urban, continues at a massive rate bringing about great societal transformation. For example, the 34% urban population (areas with populations greater than 2000 or more persons) in 1950 increased to 58% in 1992, and is predicted to be 75% urban by 2020. The population of three of the major cities in Bolivia - La Paz, Santa Cruz and El Alto - have increased at an unprecedented rate. El Alto remains one of the fastest growing urban areas populated by indigenous and poor people (from 30, 000 in 1950 to more than one million in 2011).

1. 2. A. Political situation in Bolivia

Much of Bolivia's post independence history has been marked by military dictatorships, coups, and counter-coups. This situation changed in 1982 when the first non-military government emerged. Widespread poverty, social unrest, illegal drug trafficking, and climatic disasters are some of the contemporary problems faced by elected leaders. Since the passage of the Popular Participation Law of 1994, Bolivia has seen more representation in the democracy and redistribution of national funds and responsibilities to local governance units by the creation of Grassroots Territorial Organizations (GTO), which are recognized organizations formed by the civil society. The decentralization and indigenous reforms passed in 1994 provided a political and resource impetus for local grass-roots organizations, thereby providing a political opportunity for disenfranchised indigenous groups. This in turn paved way for GTOs to utilize municipal and local budgets to further not only party goals but also larger normative and political goals. Currently, five such major regional political parties influence the Bolivian political arena: a) the Aymara separatists in La Paz, b) the Movimiento al Socialismo (MSM) in the high lands of Potosi, Oruro, La Paz, and Cochabamba, c) the eastern indigenous party of the March for Life, d) the culturally and politically distinct Santa Cruz party of Cambas, and

e) the Movement Toward Socialism party who champion the rights of Coca growers, and are represented by the first indigenous President of Bolivia, Evo Morales Ayama.
As a pluri-national state, all political and administrative units in Bolivia are decentralized and autonomous ensuring representation for all cultures and protecting the rights and identities of indigenous nationalities. Nine departments, Beni, Chuqisaca, Cochabamba, La Paz, Oruro, Pando, Potosi, Santa Cruz, and Tarija along with the capital city of La Paz oversee administration.

1. 2. B. Water sectors in Bolivia

The Bolivia water sector is complex and richly diverse. In assessing the state of knowledge of decision-makers, I asked them questions on the sources of water resources and dependent sectors (Table 1). Most commonly cited sources of water are glacial melt, Lake Titicaca, the river Desagaudero and its tributaries. In addition, interviewees have listed sources of water that are pertinent to them. These sources represent their geographic location and principal dependent sector. For example, the leader of the village of Villa Plata in the Altiplano lists the main source as the village dam, which is an important source of water for irrigation and animal farms. On the other hand, villages along the banks of the Desaguadero and Lake Poopo mention the former for irrigation and latter for fishing respectively. Regional and national managers are more aware of the sources of water at the national level and the sectors dependent on them. However, knowledge of sectors and existing polices that regulate water governance between sectors is low irrespective of the level of decision-making.

The main sector according to most key-informants is irrigation, followed by human consumption, and industrial use. This knowledge reflects the existing water sectors in Bolivia where, irrigation dominates the water sector, followed by water supply for urban and peri-urban areas. Industrial water needs and water requirements are rapidly growing sectors in Bolivia. Eco-tourism, water for fishing industry and ecosystems make-up the tail end of Bolivia's water sector demands.

Table 1. Water sources and sectors in Bolivia: range of responses

Water Sources	Sectors
Snows, glacial formations, lakes, river bodies	Irrigation is the main sector, followed by human consumption. Indirect uses such as industry, tourism and navigation, also demand water.
Lake Titicaca and precipitation	80% agriculturist, 6% mining, and 12% for the population.
Precipitation, lakes and rivers	Irrigation and human consumption. 40% goes to irrigation, the rest to industry and mining
Surface and ground water, precipitation	Agriculture and domestic consumption in rural an urban areas.
Surface, underground and rain water. Lake Poopo and irrigation systems	Irrigation and mining
Rivers and surface water. Mainly rivers	Irrigation is the most important, about 80%. Irrigation is the biggest consumer, almost 70 – 80%, followed by human consumption, industrial, domestic and mining
Mountain water (glacier melt), for irrigation, ground water through well drilling is also important.	Irrigation, human consumption and industry
Lake Titicaca, rivers	Irrigation, fishing, tourism, and mining
Lagoons, wells, and watersheds	Domestic use and farming (irrigation)
Water of rivers and dams	Irrigation is 80%, followed by mining, industry, human consumption, animal consumption, and hydroelectric plants
The surface and groundwater. Surface water is located in the Cordillera. There are 6500 wells approximately to extract groundwater	Human consumption, farmers (irrigation) and electric power production. Irrigation is the main thing, in the mountain range, there are many small lagoons and it is used mainly for irrigation, which is about 80%. The rest is potable water that consumption is distributed between surface and groundwater sources
Mauri river that feeds the Lake Poopo. Both sources are important	Irrigation and fisheries
Desagaudero river and Lake Poopo	Irrigation and consumption for the farm animals
The village dam	Irrigation of five communities, domestic consumption, and farm animal consumption
Precipitation in particular, which in turn leads to infiltration, trenching etc.	Agriculture, livestock, natural resources and human consumption, and mining
No water sources at local level. Titicaca is the main source followed by the Mauri river	The main irrigation systems in El Choro, Saucari, Toledo and Oruro
Under the TDPS System, the main source is Lake Titicaca and its tributaries, Lake Poopó, the Desaguadero and the Mauri rivers	Irrigation, followed by farming and mining in Oruro. Population demands in El Alto is also a growing sector

2. Literature Review

2.1 Climate information and knowledge systems

Climate change has seen an ascendency in its relative importance in policy agendas around the world. A consequence has been an increase in demand for science, science driven policy and specifically climate science. To answer societal, environmental, and policy dilemmas in uncertain and changing climatic conditions, decision-makers need climate knowledge and information. In these times when stationarity is perhaps dead (Milly, Betancourt et al. 2008), climate predictions are essential to assess climate impacts on natural resources, plan ahead for extreme events, effectively prepare preventive measures for disease outbreaks and associated health risks, and plan analytic strategies for future societal investments. Currently, global and regional climate models are the primary tools used for this purpose. To provide projections, climatologists mostly rely on general circulation models (GCMs) and regional circulation models (RCMs), which are mathematical models of the general circulation of planetary atmosphere and/or oceans on the rotating sphere of earth. These climate models are complex, powerful tools that can be and have been effectively used to provide predictions of future climate change. While GCMs have relatively coarse grid spacing ranging from 1 to 4° latitude and longitude, RCMs are run at high resolutions (typically 5 to 50 km) over small areas (Salathe 2003; Qian and Zubair 2010; Rauscher, Coppola et al. 2010), allowing them to capture regional and local climate forcings by downscaling GCMs under specific climate boundary conditions (Steiner, Pal et al. 2005). However, the global nature and coarse grid size focus of GCMs transcend geo-political and socioeconomic boundaries and fail to address local and regional consequences of global climatology thereby limiting their applicability. RCMs on the other hand are more likely to be used in a local or regional context, but their usability remains limited due to their lack of availability and applicability to decision-making.

2.2. CI: Opportunities

2. 2. A. Knowledge use and usability

The potential benefits of CI are numerous, including economic/commercial, societal, research, policy, and ecosystem benefits. Firstly, by helping reduce uncertainty in often volatile and high-risk commercial situations, CI may potentially increase economic benefits. In numerous sectors such as industry, tourism, and agriculture, the availability of CI may increase investor interest by guaranteeing returns. For example, evaluation of crop yield simulations with various seasonal climate data can improve the current practice of crop yield projections, help project crop yields, and predict and help prepare for water or temperature stress. In addition, the economy in general can benefit from higher predictability of local climate. For example, importers can plan and shift resource bases if necessary, thereby ensuring supply and sustaining profits.

Secondly, in addition to economic benefits, society can also benefit in other ways. For example, availability and use of CI may vastly increase response times to disasters such as floods or hurricanes, help prepare planning agencies for onset or outbreak of diseases that are climate dependent (such as water borne diseases), and help communities adapt by increasing their capacity to adapt to environmental change. However, since CI is applied technical knowledge, it creates an inequality in benefits of CI that is skewed towards sections of society that are more educated and have access to CI (Lemos et al. 2010).

Thirdly, various fields of research can increase their potential applicability and deployment of knowledge based innovations by incorporating CI in experiments or simulations. For example, elevated carbon dioxide and temperature experiments gave rise to breeding plant cultivars (by techniques such as genetic engineering) that are resistant to drought and anthropogenic carbon dioxide emissions. Alternatives and innovation can thus be demand driven, where CI drives the production of usable science.

Lastly, ecosystems and its services have better chances of being sustainably managed when natural resource managers are aware of climatic patterns (Cook, Terando et al. 2010). For example, awareness of fire regimes, pest outbreaks, and ability to predict changes in niche spaces of endangered species (France 1991) aids in effective management of ecosystems. In addition, the multiple ecosystem services (such as hydrology, carbon capture by forests, non-timber forest products) can be managed sustainably, when CI potentially predicts shifting dynamics in one of the multitude of ecosystem services. For example, in Western United States, prior knowledge of increase in forest fires may indicate significant losses to timber industry and local economy. CI may aid the timber dependent communities either temporarily shift economies, or harvest timber earlier, thereby sustaining ecosystems and their services.

2. 3. CI in Action: Constraints

2. 3. A. Challenges of CI Usability

The use and usability of climate information for natural resource management is modulated by several factors including availability of resources, perception of 'fit' between available information and decision-making needs, and institutional opportunities and constraints to adopt innovation (Kirchhoff 2010). The development of a long-term CI strategy requires firstly; an understanding of future climate change on regional scales, secondly; information on the impacts of climate change on specific issues (e.g. the hydrology at the scale of individual drainage basins since water management occurs at local scales), and thirdly; the role of institutional and organizational factors that play a pivotal role in the ability of policy makers and stakeholders to incorporate climate information in their decision making process (Lemos and Rood 2010; Dilling and Lemos 2011). Resource management would thus necessitate climate prediction models at regional and local scales, understanding institutional mechanisms, and role of climate information in policy making.

Practical application of climate forecasting has been constrained by a number of factors (Callahan, Miles et al. 1999) including access to information, communication and comprehension of probabilistic information; lack of availability of alternative technologies and low forecast skill (geographically and temporarily); and the formal and informal institutional and organizational environments that shape decision-making (Rayner, Lach et al. 2005; Galaz 2007). Yet, through all the criticisms, the expectation of utility of climate information for decision-making and planning has persisted and recent research has shed light on growing evidence of the positive impact climate predictions can have on natural resource management (Galaz 2007).

2. 4. Challenges in knowledge generation

Currently, downscaling is limited by access to supercomputers, computing time, uncertainties, and technological advances. Firstly, not many universities, institutions, and organizations that deal with natural resource management have access to supercomputing facilities. Many countries do not have abilities to generate primary data. In the United States, there has been an increase in supercomputing abilities for climate systems since 1990's (post IPCC discussions), but their availability is vastly low when compared to the potential demand for CI and climate experiments. In addition, financial resources required to set up supercomputing facilities are often beyond the budgets of university departments and are typically funded by universities themselves, or State/Federal agencies. Secondly, the computing time required for downscaling and CI production may range from weeks to many months depending on the technique and deliverable. Shortage of supercomputing abilities and limited data storage abilities (typical runs of CI take up many terra-bytes of computing space) increases the computing run time that limits CI production. Thirdly, uncertainties in CI are difficult to estimate because the climate system is dynamic, non-stationary, and constantly perturbed by internal (climate system) and external (anthropogenic). Hence even the most reliable CI, with the lowest degree of errors and uncertainty, CI is not fail-safe. As such, policy based on CI will be risky; reflecting the current low levels of CI/seasonal forecasting based decision-making. In addition, the costs of generating CI may not match the potential societal benefits when compared to other relatively inexpensive and risk-free policy options such as passive response or post-hoc relief (such as witnessed in Hurricane Katrina). Thus, the cost benefit analysis of CI is currently skewed towards high opportunity cost with uncertain social benefits. Lastly, technological advances in climate science may itself change the character of climate information and its usability. For example, current models will likely be replaced by GCM's of very high resolution and small grid size as newer, faster, and better data gathering and analysis technologies become available in the next ten – fifteen years. Hence, downscaling may not be necessary in the next twenty years, with the onset of climate information that is generated from bottom up rather than from top down.

2. 5. Challenges for knowledge uptake

Seasonal climate forecasting (SCF) has been traditionally used in management decisions (such as El Nino/ La Nina, ENSO) for which a rich empirical literature exists. Dilling and Lemos (2010) in their review of evidence from different areas of climate information use, especially seasonal climate forecasting (SCF), find that where forecasts have been used successfully in organizations, it has been due to:

i. Specific interventions such as the creation of forum or networks where forecasters and potential users come together;
ii. Users' perception of specific benefits such as cost savings;
iii. The existence of organizational resources such as technical capacity to understand climate information; or
iv. The presence of institutional support for incorporation of climate considerations in planning (e.g. in the water sector)

In many cases, information might seem relevant in a general sense, but will be less usable since it competes with many other factors shaping the decision context (Dilling and Lemos 2011). In these cases, information might be germane, but ultimately is not used, either because forecasts are less important than other kinds of information given certain decision goals or because it does not 'fit' policy goals (Skolnikoff 1999). In addition, organizational culture and individual reward structures can play a large role in whether or not decision-makers will use climate knowledge to inform their decisions (Lemos 2008). For example, Rayner et al. (2005) found that water managers in three different U.S. cities were not interested in using forecasts because of a combination of conservatism toward new ideas, the potential for public criticism, and the perception that forecasts were not relevant to improving ultimate outcomes.

The cultural context of information use critically shapes its adoption (Lemos 2008). For example, regarding forecast uncertainty, despite advances in forecasting, predictions still carry high degrees of uncertainty depending on the variable that is forecast, the time of year the forecast is issued, the region, and the length of lead-time (Lemos 2010). In Australian water management and in US agribusiness, decision makers were quite aware of the uncertainty of information and yet able to accept it as part of using the information in their decision-making (Power, Sadler et al. 2005; Changnon and Changnon 2010). However, in contrast, those who are risk averse and vulnerable may prefer not to use forecasts. Lastly, the availability of realistic alternative courses of action is a critical factor shaping usability. Even if CI is theoretically useful, it may not be usable if potential users lack the material means to implement alternatives that seasonal climate forecasting supports (Jasanoff 1993; Jasanoff 1996; vanAsselt and Rotmans 1996; Lundvall 1998; Azar and Dowlatabadi 1999; Cash, Clark et al. 2003; Etzkowitz 2003; Webster, Forest et al. 2003; Cash, Adger et al. 2006; Guston 2006; Milly, Betancourt et al. 2008; Jasanoff 2010; Troccoli 2010).

3. Methodology

3. 1. Description of the study site

The Desaguadero watershed is a part of the Lake Titicaca, Desaguadero river, Lake Poopo, and salt lake Salar de Coipasa (TDPS). The watershed of TDPS stretches over two countries Bolivia and Peru in the South American Andes (Figure 1), covering an area of 143, 900 km^2 between the altitudes of 3,600 and 4,500 meters above sea levels (Figure 2). Precipitation, which provides approximately 55% input into the TDPS system occurs upstream in the Lake Titicaca basin mainly during the months from December through March (UNESCO 2003). The principal tributaries Ramis and Huancane in Peru along with glacier melt provide residual water inputs. Groundwater leakage from coastal aquifers into the TDPS system is negligible. Removal of water from the TDPS system is mainly by evaporation, which accounts for 95% loss in Lake Titicaca alone. Residual water from Lake Titicaca is removed mainly via the Desaguadero River, which flows into Lake Poopo (Baucom and Rigsby 1999; Abbott, Wolfe et al. 2003; Hanselman, Gosling et al. 2005; Gosling, Bush et al. 2008). Overflow of Lake Poopo flows into the Salar de Coipasa. Other important water systems in TDPS include the Lake Uru Uru and rivers Mauri, Marques, Irpi Irpi, Umala, Ketho, Challa jahuira, and Lauca y el Laca jahuira. A detailed case study and hydrological characteristics of TDPS is provided in Chapter 21 of the first World Water Development Report (UNESCO 2003).

Figure 1 (left) and 2: TDPS system[2]

3. 2. Interviews

Between June 22 and August 8, 2009, I conducted eighteen structured interviews and eighteen semi-structured key informant interviews. All key informants were either in decision-making roles at international, national, regional or local levels of management in the water sector. The eighteen structured interviews were sampled from a modified snowball sampling technique, where a purposeful sample of key informants were requested names of three individuals that they consider as potential interviewees. The sampling thus 'snowballs' and the original list of people grows according to the recommendations of the informants themselves. Sampling is considered closed when no new individuals are referred and all interviews have been conducted thus indicating the sample boundary.

[2] Source: World Water Assessment Program (WWAP) by AFDEC, 2002.

In this study, the sampling was modified - snowball sampling since the key interviewees had very few individuals to refer, which indicated that the sampling strategy hit its boundaries. In addition, decision makers in particular sectors of natural resource management were few. Since I interviewed all key informants suggested by the original list of interviewees and conducted additional informal interviews in all levels of water management, I consider the sampling complete.

The eighteen semi-structured interviews and conversations enabled me to elucidate the history of water policy in Bolivia, the organizations involved in decision-making, and the decision-making process. These informal in-depth interviews were based on a scripted but unstructured questionnaire. Most of the respondents chosen were high-ranking government officials such as Governors of the Department, Ministers; held very high positions within NGO's; or were community organizers. Almost all of these informants were limited in their response time by their busy schedules. The community organizers were wary of the research and chose not to answer many questions, which limits their inclusion for analysis.

In 2010, six key informants were re-sampled from the informant list of 2009. Selection of the six informants was based on their demonstrated interest in water policy, decision-making roles, familiarity with water policy process, and established motivation to incorporate climate change information in decision-making process. Table 2 provides a summary of interviewees.

Table 2. Overview of interviews conducted in 2009 and 2010

Interviews		**Organization Type**				**Level of Occupation**		
2009		**Govt.**	**NGO**	**Intl.**	**Community**	**Mid-level**	**Directorial**	**Ministerial**
	Structured	11	1	3	3	4	14	0
	Semi-structured	9	6	0	3*	5	11	2
2010	Structured	5		1			5	1
Grand Total		**42**						

*Researchers at UMSA

In conducting the interviews, the best practices for informant interviews were followed as suggested by the Institutional Review Board (IRB) of the University of Michigan. Preparations preceding the interviews included approval of the questionnaire (for both 2009 and 2010) by the IRB, statement of non-Conflict of Interest status of researchers, justification of research methodology and sampling design, and explanation of benefits and risks to interviewees. While conducting the interviews, the informants were administered a pre-approved oral consent and informed their rights while agreeing to be recruited for the study. Informants did not receive any payments or incentives to participate in the study and were asked for their permission to audio record the interview using an Olympus DM 600 recording device.

3. 3. Key-Informant descriptors

Of the eighteen key informants interviewed in the structured interviews of 2009, eleven represented governmental organizations, three informants each represented international organizations and societal institutions, and one represented a non-governmental organization (Table 2). Of the eighteen semi-structured interviews, seven represented governmental organizations, six were from non-governmental organizations working in the field of natural resources, three were researchers from UMSA, followed by the Minister of Mining and the Governor of the department of Oruro. Five key-informants of 2010 held positions at governmental organizations and the sixth represented an international organization.

In 2009, fourteen of the eighteen key-informants in the structured interviews held high-ranking decision-making positions at either the directorial position or higher at all levels of governance. The remaining four interviewees held mid-level positions within the organizations or were managers of their respective organization at regional levels. In 2010, all five interviewees were directors of their respective organizations and one was the Vice-Minister of the Ministry of Environment and Water.

Post-hoc analysis of governance in the water sector indicates four levels of management namely: international (Bolivia and Peru), national (Bolivia), regional (nine departments), and local (village level societies and community organizations) even though their management jurisdictions may vary. For example, an international organization may administer regional and local areas, thereby reflecting the transboundary nature of management in water resources. Sampling in 2009 comprised all levels of governance and management that exists in the water sector in Bolivia. Of the structured interviewees, three belonged to international organizations that were either autonomous or donor agencies; six represented national organizations; six were regional decision-makers, and three were leaders of local community organizations. Of the eighteen semi-structured interviewees the scope and level of the organizations were diverse with representatives from all four levels of governance. In 2010, all six key-informants represented organizations of national scope or higher.

3. 4. Questionnaire design

During 2009, the aim of the interviews was to assess current management practices and knowledge need in Bolivian water management institutions. In contrast, in 2010, the aim was to present a sub-sample of the key-informants with downscaled climate - modeling based climate change information (CI) and solicit their opinions on the use and usability of the climate information provided. Of the available design choices, I chose an open-ended questionnaire that was primarily descriptive. This was done to minimize satisficing by informants, when they are asked to choose between 'yes' and 'no'; from a list of choices available; or given choices between 'know' and 'don't know'. All of these choices may frustrate the informant, facilitate the selection of the first answer or select an answer that truly does not reflect the state of informant knowledge. On the other hand, open ended questions though difficult to code and interpret for quantitative analysis, provides the informant with an opportunity to answer the questions to the best of their ability in a casual conversational scenario. The trade-off for this design was the amount of time required for completing the interview. On average, each interview was conducted over 60 minutes. Since all the interviewees were involved in the water sector, interested in understanding the role of climate information in decision-making, and eager to share their knowledge, most interviews were successfully completed. On the other hand, inability to obtain an hour-long appointment and unforeseen circumstances prevented some interviews from being completed. Incomplete interviews have been analyzed and described under the 'semi-structured' interviews section. The questionnaire of 2009 (Appendix 1) has the following six sections:

1. Organization and role: Questions 1 – 8 set the interview agenda in terms of the organizational scope and climate change.
2. Organizational norms: Questions 9 – 11 address organizational norms, structure and the decision-making process within the organization.
3. Knowledge and innovation: Questions 12 – 16 investigate the sources of information in general, mechanisms of access and current status of incorporation of information in decision-making.
4. Motivation and professional activity: Questions 17 – 19 discover the motivation of the key-informant.
5. Water use and decision making: Questions 20 – 29 probe the informant's knowledge on sources of water resources, its main use sectors and water management policy and governance.
6. Climate information: Questions 30 – 36 inquire the role of climate change information in decision-making, current use and future requirements.

The 2010 questionnaire has fourteen questions that directly address the role of climate information in decision-making (Appendix 2). Prof. Chris Poulsen, Department of Geological Sciences provided primary climate information as downscaled climate models for Bolivia (Appendix 3), which were presented as eleven images comprising maps and graphs along with a summary of the main points of these graphs (Appendix 3. a).

3. 5. Downscaled climate information

In this study, in order to evaluate the impact of future climate on water resources in South America, three decade-length simulations were performed at a 25km resolution (Figure 3) focused on the northern portion of South America:

1. Present day scenario (1989-1999)
2. Future climate simulations will be conducted for two time-slice experiments:
    - a short-term future simulation (2048-2059), and
    - a long-term future simulation (2089-2098).

The difference between average climate data between 1998 – 1999 and 2048 – 2059, 2089 – 2098 was calculated and downscaled data provided for surface temperature, precipitation, root-level soil root moisture, runoff and evapotranspiration. A summary of projected impacts of climate change and the list of figures provided to key-informants is provided in Appendix 3 and 3.a.

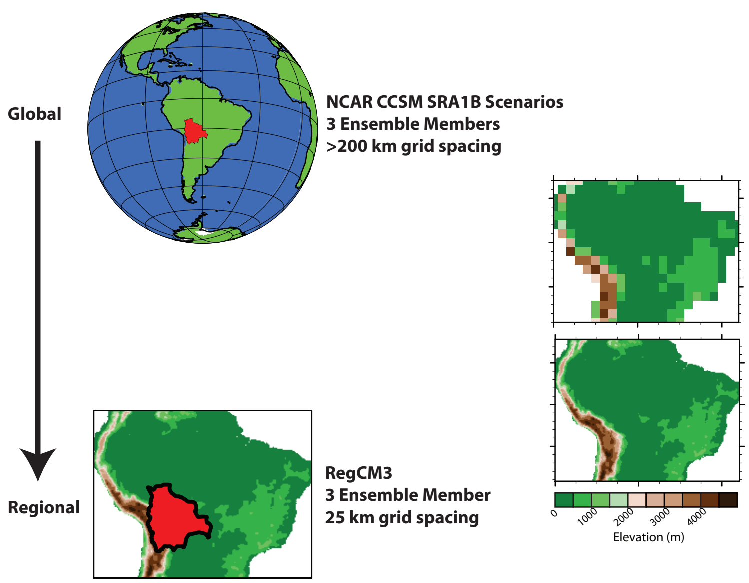

Figure 3. Climate downscaling from global to regional scales (*from Poulsen, personal communication*)

Key informants were first asked five questions that addressed current climate information use, its reliability and incorporation in decision-making followed by the climate information and the next nine questions that addressed the use and usability of the information provided.

3. 6. Interview Data Analysis

The interview notes and transcripts along with the transcribed audio files were checked for facts and accuracy as stated by the key informants. Dr. Maria Eugenia Garcia, UMSA, transcribed audio interviews - those interviews in Spanish into English, in consultation with me. I re-analyzed the audio files and transcribed files to correct translation errors and edit the documents. The interviews were then typed into Microsoft Word documents labeled by the interview date. A codebook was then developed in Microsoft Excel that formalized a procedure to systematically determine patterns in data and facilitate comparisons across scales of management, organizations, and information use.
The data analysis was complemented with extensive literature review and collection of supplemental information such as key documents, data about water management at regional and watershed level, and organization plans. Documents were reviewed to glean information about water sources, availability, and use in the study watershed; reviews of socio-economic data; climatic events, future climate predictions; predicted economic growth and its effects on water resources; donor funded projects in the water sector; biodiversity and ecosystems and the potential impacts they face due to climate change; and climate adaptation and mitigation plans of Bolivia. Together with the interviews, the literature review and document collection served to analyze the climate information use holistically.

3. 7. Limitations of the study

This study has four identified limitations. Firstly, the sampling strategy was non-random, purposeful, modified snowball sampling. The key-informants were chosen because of their positions in water sector organizations - both governmental and non-governmental; role in water policy and governance, leadership positions in natural resource sector in general and water resources in particular, and community leaders in the study area. This study may have inadvertently missed key-informants and water managers who were either not present at the time of the study or by circumstantial constraints. The results therefore must be generalized over the broader population with caution. However, the key-decision-makers represent all levels of management in the water sector and the sample fulfills the requirement of the primary research question, which was to understand the state of climate knowledge use in the water sector. Secondly, the interview questions may not truly capture the range of information use. Thirdly, the key-informants selected for the study were mostly the highest-ranking officials in their organizations and therefore may not reflect the information available to the organization as a whole. Fourthly, the civil unrest of 'water wars' in 2000 and the political backlash is reflected strongly in the interviews and now influences most of the decision-making process. Consequently, some of these decision-makers are political appointees and reflect the personal and political views of water management that may not be generalized within the organization and broader public.

4. Results and discussion

The results and discussion section follows the three main questions of the study as disaggregated from the interviews. Firstly, I discuss the main actors in the water sector, the type of organizations they work for, and describe the decision-making process. A section on multi-level governance in Bolivian water management follows the first section. The second section addresses the current role of climate information in decision-making. In addressing the last question, the observed results are discussed from a theoretical perspective of innovations policy and knowledge systems and a conceptual idea for climate information use is provided.

4. 1. Question 1: Who are the main actors in the water sector and how do they make water management decisions?

The data collected in this study specifically asks key-informants about their knowledge of their organization and functionally similar organizations. In addition, interviewees were asked to describe their organization structure and describe the flexibility of information intake and its impact on water management. The responses obtained were validated, post-hoc, to create an organogram of organizations in the water management sector in Bolivia between 2009 and 2010 (Figure 4). Owing to the dynamic political landscape in Bolivia, which has seen re-structuring of several ministries and vice-ministries, the presented organizational study is pertinent for current time.

4. 1. A. Institutions, organizations and decision-makers

In this study, rules and norms, or institutions, of decision-making apply to both organizations and decision systems. The organizational diversity represented in this study includes governmental, non-governmental (NGO), not-for-profit NGO's, issue-based NGO's (in water sector), and multi-national donor agencies (Table 3). Organizational scope that encompasses mission and objective cover a variety of agendas. For example, the Inter-American Development Bank (IADB) has significant presence in the water sector in general and irrigation development in particular. IADB assistance to the Bolivian government encompasses assistances in irrigation policies and developing strategies for climate change adaptation in the agriculture sector. On the other hand, national implementation agencies such as UOB (*Unidad Operativa Boliviana*) follow the plan of management as dictated by the autonomous ALT. Other organizations such as the stakeholder forum CONIAG represent one of the few facilitating organizations that encourage stakeholder involvement in order to improve the legal, technical, and institutional issues in water management. Community organizations such as the village irrigation committees (*Regantes*), the fisheries committees and village development committees are representative of the local institutions in a decentralized decision-making context of Bolivia.

Regarding management (Figure 4, Table 3) in Bolivia, the most powerful organization is the Ministry of Environment and Water (*Ministerio de Medio Ambiente y Agua*, MEW) that oversees planning and implementation of water management projects; setting criteria for monitoring and evaluation of projects; creating funds and organizational budgets, and is responsible for policy making. MEW, created in 2009 consists of three vice-ministries: 1) potable water and sanitation (*Viceministerio de Agua Potable y Saneamiento Básico,* VMPS), 2) water resources and irrigation (*Viceministerio de Recursos Hidricos y Riego,* VMWRI) and 3) environment, bio-diversity and climate change (*Viceministerio de Medio Ambiente y Cambios Climáticos,* VMEBC.

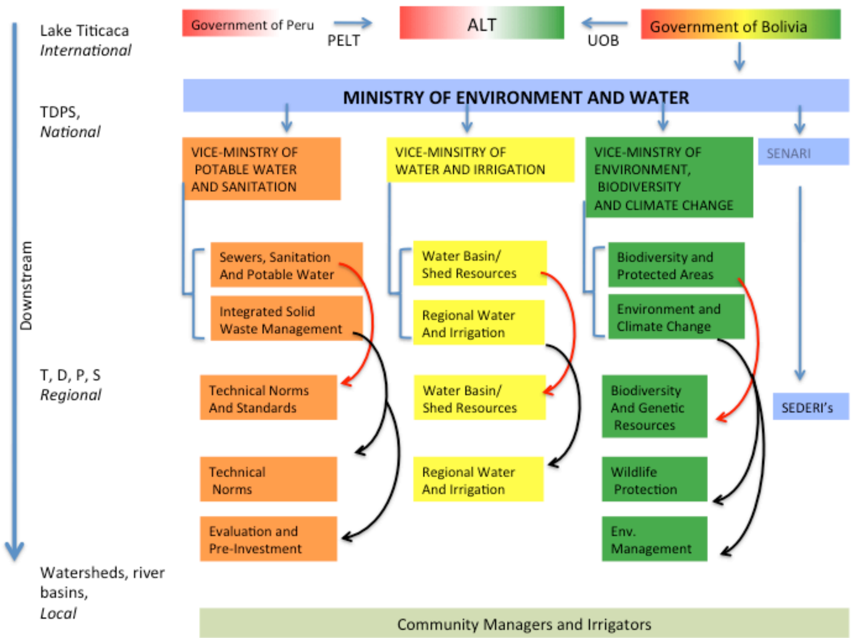

Figure 4. Organizational map of water sector in Bolivia. On the left is the water system (T, D, P, S) and scale of management (*italics*).

Table 3. Organizational diversity represented in this study

Organization	**Scale of management**	**Scope of organization**
ALT *(Autoridad Binacional Autonoma Del Sistema TDPS, Peru – Bolivia)*	International	Implementation of the bi-national actions in the context of the ALT plan, which sets norms to establish inter-institutional coordination and constructing a plan of bi-national management in agreement with the initial scheme established with the Master Plan for Flood Prevention and the Use of Water Resources of the TDPS System
IADB *(Inter-American Development Bank)*	International	Assisting irrigation policies and developing strategies for climate change adaptation specifically in agriculture based development projects
SENAMHI^ (*Servicio Nacional de Meteorología e Hidrología*)	National	Organize and direct the institutional policies and to implement the network of meteorological stations and to extend the use of the meteorological information bank
UOB (*Unidad Operativa Boliviana*)	National	Implementing the provisions of the Master Plan of ALT for Bolivia, which includes projects or proposals that involve the international gate (in Lake Titicaca), the gate at Aguayamalla, spillway of Lake Uru Uru, proposed groundwater and irrigation projects, dredging the lagoon, and the management of La Joya
MEW (*Ministerio de Medio Ambiente y Agua*)	National	Oversee planning and implementation of water management projects, set criteria for monitoring and evaluation of projects, create funds and organizational

		budgets, and policy making
	Regional	
CONIAG (*Consejo Inter-institucional del Agua*)	National	Create a forum for dialogue between all stakeholders to improve the legal, institutional and technical framework for water issues, that will provide a structure and help regulate water resources management
VMPS (*Viceministerio de Agua Potable y Saneamiento Básico*)	National	Implement sustainable sanitation (potable water, sanitary sewer, composting toilets, solid waste and storm drainage) to allow full access and expansion of services within the integrated management of water resources and solid waste
VMEBC (*Viceministerio de Medio Ambiente y Cambios Climáticos*)	National	Regulate, plan and oversee the integrated management of natural resources and environmental quality, to improve the quality of life of the population within the framework of sustainable development and under the philosophy of living well while reducing poverty
	Regional	Provide environmental licenses for mining and industrial areas, assesses the environmental quality and manage the wildlife in addition to conservation of the endangered species
VMWRI (*Viceministerio de Recursos Hidricos y Riego*)	National	Management of financing of irrigation operations
SENARI (*Servicio Nacional de Riego*)	National	Plan, promote the public investment, organize and execute irrigation projects in each department
UMA *(Unidad de Medio*)	Regional	Organize the water supply in El Alto
SEMAPA (*Servcio Municipal de Agua Potable de Cochabamba*)	Regional	To provide drinking water and sanitation to the municipality of Cochabamba
Asica-Sur	Regional	Co-ordination of communities and execution of Asica-Sur Projects
Community-I*	Local	Organize irrigation concerns of Oruro, central Oruro in the San Pedro de Charachollo while being a part of the SEDERI
Community-F**	Local	Organize the fishing co-operatives in the five Lake Poopo provinces: Cercado Sur, Saucari, Poopo, Pagador and Sur Carangas
Community***	Local	To bring projects within the Municipality that are community oriented and for village development

^ - Climate information provider, * - Irrigation organization, ** - Fisheries organization, *** - Village organization

4. 1. B. Functional classification of Bolivian water sector organizations

Water sector organizations can be broadly classified into three functional roles: producers, consumers and facilitators (or boundary organizations). In the Bolivian water sector, consumers of CI are well represented. Almost all key-informants indicated a need for climate change information. Across all the interviews three facts were striking: a) the acknowledgement of the importance of climate change information, b) its necessity and perception of potential positive effects in decision-making, and most importantly c) its lack of availability. At this point, a distinction between climate change information from climate models and observations needs to be made. Climate model based information, which is the subject of this study, is produced by theoretical mathematical models of the climate. These models can be used to project future climate, but also have inherent biases that add uncertainty to their predictions. In contrast, routine meteorological observations recorded at weather stations do not involve projections of climate and climate modeling techniques. Consumers of climate information in Bolivia are broadly familiar with the latter (routine meteorological observations) and have less exposure to climate information from models.
Decision-making environment in Bolivia's water sector is ripe and willing to incorporate CI because a) the decision-makers are familiar with CI and are aware of its potential to improve decision-making, but b) CI is not currently available which the forces the c) use of the less-desired but available meteorological information. However, as existing literature on information usage suggests (refer introduction and literature review sections) various factors in addition to the willingness to use CI influence information use.

On the other hand, climate change information producers are very few*,* and boundary organizations (bridging organizations are those organizations that communicate, mediate, or translate climate information to decision-makers) in the water sector – climate change information cross-section are virtually non-existent. Producers are those organizations that generate primary meteorological data that is used for weather and climate variability and change prediction for societal benefit and decision-makers. None of Bolivia's recognized climate and weather data providers fit this definition since the only Bolivian

organization *Servicio Nacional de Meteorología e Hidrología* (SENAMHI) does not generate model-based climate change information. However, SENAMHI is a part of several the Latin American and international climatological networks and generates daily data (precipitation and temperature), climatological data (precipitation and temperature) and monthly climate diagnostics bulletin, (UNFCCC 2006) which have been used in regional climate models. However, as this study shows, such information seldom 'fits' the requirements of decision makers.
ALT and its operative arms the UOB (*Unidad Operativa Boliviana,* Bolivia) and PELT (*Proyecto Especial del Lago Titicaca,* Peru) monitor meteorological stations in the TDPS area. Key-informants also mention *El Servicio Nacional de Geología y Técnico de Minas* (SERGEOTECMIN), the national geological service bureau as another source of information. Even though the data collected from meteorological stations of ALT inform the decisions of ALT, and few key-informants mention the use of SEGEOTECMIN data, it is unlikely that either of them generate model-based CI (Figure 4).

In addition, there are no *boundary organizations* to support the transfer of climate knowledge to potential users. Boundary organizations generally straddle the divide between science-based information producers and decision-making consumers by communicating, translating, and mediating science knowledge for policy and decision-making (Guston 1999; Cash, Clark et al. 2003). Bolivia faces a vacuum in this critical organizational realm and is therefore unable to facilitate production and use of CI in water resource management. However, excellent networks of community organizations, research universities, and highly specialized NGOs work on related areas of water management such as potable water, contamination of water, and indigenous rights who routinely translate and mediate the communication of complex legislations and scientific information to the decision-makers. These networks and boundary organizations can potentially be recruited to bridge the usability gap. In addition, the high awareness of SENAMHI and information availability (type and format) offers potential venues to link CI in decision-making by tapping the awareness for the benefit of CI.

4. 1. C. Key-organizations in the Bolivian water management

The following sections systematically describe the seven most important decision-making organizations in the water sector, their organizational scope and decision-making process in the order of the scale of water management (described in detail in Section 4.2). Even though various other non-governmental, non-profit, and international organizations influence decision-making in Bolivia, the purview of this study rests in the organizations that are responsible for decision-making by law and represent the entities that govern bulk water management. However, key-informants from these latter organizations were also interviewed and their responses inform the analysis.

1. *Autoridad Binacional Autonoma Del Sistema TDPS,* ALT – Peru Bolivia

Peru and Bolivia in their continued attempt at addressing the development of the Titicaca region, signed the first bi-lateral Preliminary Convention for the study of the Water Use of Lake Titicaca in 1957. Ratification of the convention however, was completed in 1986 following political processes and the extreme drought (1982/83) and flood events (1986/87). The outcome of this process was the creation of: a) Joint Sub-Commission (SUBICOMILAGO), b) the Lake Titicaca Special Projects (PELT) of Peru, and c) Bolivian Operating Unit (UOB) of Bolivia. Between 1991 and 1993, Peru and Bolivia solicited the co-operation of the European community to create a framework for the management of Titicaca basin. The resulting Master Plan for Flood Prevention and the Use of Water Resources of the TDPS System or 'Plan Director' or 'Master Plan' (1996 - 2008 and 2009 – 2016) [3] sets the objectives for the management and utilization of water resources of the TDPS system without adversely affecting ecology of the region while including regional development plans for both countries. The Master Plan in addition, seeks to minimize effects of droughts and floods in the region and alleviate the impacts of extreme climate events. The Master Plan is also considered as a tool to achieve the rational and comprehensive management of water and aquatic resources in the TDPS system; designed to enable the development of the Peruvian-Bolivian Altiplano, and must

[3] ALT has created two Master Plans. The first plan set objectives for management for 1996 – 2008 and the second plan, which is currently in use, informs the decisions for 2009 – 2013.

be closely linked to economic policy measures most appropriate for this region.

In order to execute and enforce the Master Plan, the bi-national autonomous authority of Lake Titicaca (ALT) was created in 1996. Both Bolivia and Peru have administrative entities (UOB and PELT respectively) that co-ordinate with the Ministries of Foreign Affairs of their respective countries and the Hydrological Resources Unit. The Master Plan Management Unit is in charge of monitoring the water resources and tracking development of the Master Plan, respectively (Figure 4 a).

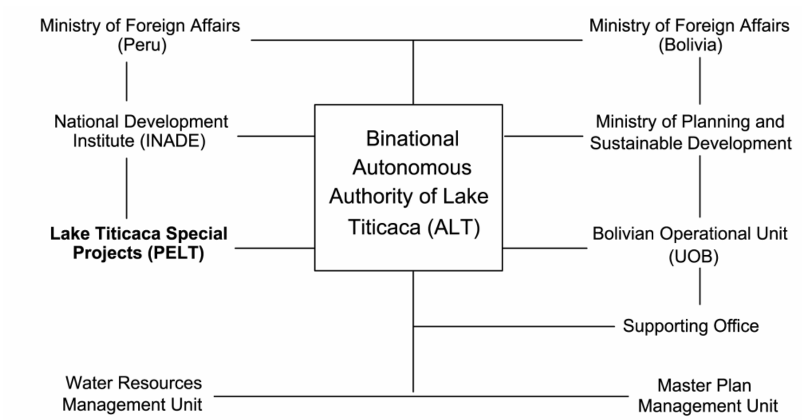

Figure 4 a. Organizational map of ALT – Peru Bolivia. Source: UNESCO 2003.

The territorial scope of ALT is an enclosed basin located between Peru, Bolivia and a small part in Chile. These are: a) basins of the tributaries of Lake Titicaca, b) the Lake Titicaca c) the Desaguadero River Basin d) the watershed basins of lakes Uru-Uru and Poopo. The common strategies for management as defined in the first Master Plan are as follows:

i. Management of water resources for multiple demands such as agricultural, urban, industrial, and mining.
ii. Develop actions to make proper use and management of water resources available in areas with irrigation infrastructure by undertaking actions such as: research, outreach, extension, training, technical and financial assistance and seeking alternative solutions to the land tenure problems.
iii. Implementation of new drainage and irrigation projects under the following rules.

iv. Ensure the availability of water resources-so, whether surface or underground sources, as well as natural runoff or regulated.
v. Establish ownership and land tenure in the project territorial scope.
vi. Use irrigation methods to ensure good efficiency of resource use in economic conditions of the sector.
vii. Identify the problems of prevention of soil salinity and its control by drainage
viii. Mitigate potential environmental impact issues.
ix. Foster engagement with the intended beneficiaries of the project, private owners, community and / or multiple communities.
x. Establish a permanent system of agricultural development; consider actions based on research, dissemination, outreach, capacity building, technical assistance and credit.
xi. Implement prevention and control measures to prevent sediment transport and flooding through the conservation of soils in the watershed, with mechanical and agronomic practices such as construction of river defenses, control gully, terracing; canalization of rivers, agroforestry, and others as provided in the research proposals from the Master Plan.
xii. Identify and coordinate management of water volumes possible transfer.
xiii. Set mining pollution controls.
xiv. Immediately initiate actions to promote and develop Camelids (Llama, Alpaca etc.), and sound management of wetlands, and greenhouse systems.

2. *Ministerio de Medio Ambiente y Agua*, Ministry of Environment and Water, MEW

The MEW is a unique organization with decentralized approaches as its core philosophy. Even though the MEW is a hierarchical organization with multiple autonomous entities, it is managed by community level organizations at the local level while MEW serves as a communicator and facilitator of policies and information dissemination. MEW is guided by the Water Law of 1906 [4], the Institutional Framework Regulation Act of 2004 (D.S.

[4] The main source of current water law in Bolivia are:
I. The Constitution, voted on 11/2/1967 that assigns the domain of water to the State;
II. The Decree of 9/8/1879 and converted into an Act on 11/28/1906 that provides detailed rules governing the ownership and use of water;

28817) [5], and the Irrigation Law 2878 of 2004 [6] and works in consultation with the technical and social advisory group of civil society organizations and the *Consejo Interinstitucional del Agua* (CONIAG), which is sort of a inter-sectoral stakeholder forum. Leadership of MEW is a political process and since the victory of MAS (*Movimiento al Socialismo*) political party headed by Evo Morales, leaders from the Cochabamba Water Wars have been frequently appointed as Ministers of MEW. However, leadership in these ministries is fluid as represented by the appointment of five ministers, each from a slightly different background and electorate representation since Evo Morales' election in 2004.

Specifically, the MEW "develops and implements policies, standards, plans, programs and projects for the conservation, adaptation and sustainable use of environmental resources and irrigation development and basic sanitation with integrated watershed approach, preserving the environment, which ensures priority use of water for life, respecting traditions and customs to live well" (MMAyA 2011). The MEW is guided by the Institutional Strategic Plan (PEI) that aims to provide the MEW a management tool for the period 2009 - 2013 that includes clear orientation of institutional development strategy, implementation of actions and allocation resources in compliance of the State Constitution, laws and regulations. The PEI, prepared with reference to the National

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III. The Civil Code of 10/25/1830, which covers the ownership of water, certain instances of water use rights, and servitudes and juridical implications of the natural action of water;
IV. The Criminal Code and the Electric Power Code;
V. The Mining Code, introduced by Decree-Law No 7.148 of 8/7/1935, which prescribes the rules for the mining uses of water;
VI. Decree-Law of 6/11/1937, establishing a government reserve on all water resources in public domain;
VII. Decree-Law No. 8424 of 7/17/1968 that governs navigation uses of water;
VIII. The General Forests Act, Decree-Law No. 11.086, of 8/13/1974 that enjoins upon the State to provide for the protection of watersheds;
IX. The Agrarian Reforms Act, introduced by Decree-Law No. 3464 of 8/2/1953, converted into an Act on 10/29/1956 that introduces changes in rules governing water uses;
X. The Act of 1/9/1945, that declares the special regime for the Cochabamba irrigation scheme;
XI. Decree-Law No. 7388 of 10/15/1965, instituting the National Water Management Directorate;
XII. Supreme Decree No. 8048, of July 1967, instituting the Municipal Drinking Water Supply, Sewerage and Rainwater Drainage Service and
XIII. Supreme Decree No. 14.367 of 2/14/1977 that set up the National Water Resources Directorate.

[5] Through the Decree-Law No. 28817 of 8/8/2004, the Bolivian government seeks the support and promotion of the irrigation sector.

[6] The Irrigation Law of 2004 is a decentralized institutional framework for management of water resources for irrigation by securing user rights for water resources.

Development Plan and sectoral development plans, is intended to help reverse the negative aspects identified in the initial diagnosis, recommend changes in the internal environment, assist in implementing policies, programs, projects and / or activities with internal and external financial resources for which the MEW should coordinate with national and international institutions. The main objectives of MEW are to:

i. Develop and issue policies and strategies, policy instruments and regulations to boost investment.
ii. Achieve decentralized institutional strengthening for the harmonious development and participatory subsector under the National Development Plan.
iii. Make sure that the multiple functions and sectors of water resources are managed in the nine departments of Bolivia. In recognition of this, merger and break-up of ministries and vice-ministries that existed before 2004 created the three vice-ministries.

Along with the VMWRI, the MEW oversees the formulation and approval of the irrigation development policies, regulations, plans and programs, and in coordination with the board of directors of *Servicio Nacional de Riego* (SENARI) manages the national financing and international financing to promote irrigation development. The next few paragraphs describe the three vice-ministries, the SENARI – implementation arm of irrigation, the *Autoridad Binacional Autonoma Del Sistema TDPS,* ALT – Peru Bolivia, and the community managers.

3. *Viceministerio de Agua Potable y Saneamiento Básico,* Vice-Ministry of Potable Water and Sanitation, VMPS [7]

The objective of VMPS is to implement sustainable sanitation (potable water, sanitary sewer, composting toilets, solid waste and storm drainage) to allow full access and expansion of services within the integrated management of water resources and solid

[7] Source: Supreme Decree No. 29894, 07/02/09
Organizational Structure of Multinational State Executive Branch
Article 96 - (Powers of the Vice Ministry of Water and Sanitation).

waste. The powers of the VMPS, under the powers delegated to the central level by the State Constitution, are as follows:

i. Assist in the formulation and implementation of policies, plans and standards for the development, provision and improvement of drinking water sanitation (sewerage, waste disposal, solid waste and storm drainage).
ii. Promote technical standards, regulations and instructions for the proper use and regulation of drinking water and basic sanitation.
iii. Promote and implement policies, plans, programs and projects and manage funding for investment to expand coverage of basic sanitation services throughout the country, particularly in rural and urban sectors and peri-urban low-income areas, and coordinating with the appropriate bodies.
iv. Disseminate and monitor the implementation of policies, plans, projects and technical standards for the establishment and operation of drinking water and basic sanitation.
v. Coordinate the enforcement and implementation of projects and programs relating to drinking water and basic sanitation at the national level.
vi. Coordinate with the different levels of territorial organization of the State, within the competence exclusive, shared and concurrent development and implementation and enforcement of policies, plans programs and projects relating to basic sanitation.
vii. Implement, maintain, and strengthen the National Sectoral Information System.
viii. Assist in the implementation of policies, plans, programs and institutional strengthening and technical assistance to entities that provide drinking water and basic sanitation.
ix. Promote cooperation and channel financial support to decentralized and autonomous local authorities, to develop policies, plans, programs and projects of drinking water and basic sanitation.
x. Managing through the Office of the Minister of Environment and Water funding for the establishment of programs, projects, drinking water and basic sanitation.

4. *Viceministerio de Medio Ambiente y Cambios Climáticos,* Vice Ministry of Environment Biodiversity and Climate Change, VMEBC

The objective of VMEBC is to regulate, plan and oversee the integrated management of natural resources and environmental quality, to improve the quality of life of the population within the framework of sustainable development and under the philosophy of living well while reducing poverty. Specifically, the VMEBC aims to:

i. Implement and administer the National Environmental Impact Assessment (SNEIA), National Environmental Information System (NARS), and the National Environmental Quality Control (SNCCA).
ii. Promote protection and conservation of the environment and resources; create evaluation instruments, regulatory mechanisms in particular scope of activities.
iii. Work towards projects that achieve the implementation of preventive measures and adaptation to climate change.
iv. Exercise control processes, control and surveillance activities under the inspection procedures and control mechanisms established by the Environment Act and related regulations.
v. Formulate and define policies, standards, plans and programs to facilitate the procedures for environmental management.

5. *Viceministerio de Recursos Hidricos y Riego,* Vice Ministry of Water Resources and Irrigation, VMWRI

Since 2008 the Vice Ministry of Water and Irrigation (VMWRI) was developed as a tool for information management sector under the National Irrigation and Watershed Plan. The purpose of VMWRI is to disseminate policy, plans and performance results; promote institutional linkages and cooperation between development agencies, donors and stakeholders. VMWRI is organized into four administrative units: a) sectoral standards and instruments, b) basic project information, c) publications discharge and referral, and d) public investment programs and cooperation in water resources and irrigation. The VMWRI is one of the few ministries in the world that has adopted an integrated water resource management (IWRM) plan. Bolivia's National Plan for Watershed Management

(*Plan Nacional de Cuencas*, 2006, PNC) contains strategic and political guidelines for the social, economic and ecological management of water resources. The PNC is a tool that promotes strategic alliances for the implementation of different modes of IWRM and initiative for the management of watersheds (*Iniciativas de Manejo de Cuencas,* IMC) in Bolivia and transboundary basins. The new modes of IWRM and IMC are developed based on the principles of social management, local participatory process, coordination of water uses and organization of users and stakeholders in watershed basins. The main goals of VMWRI and the PNC are to improve the quality of life of communities through integrated watershed management and IWRM, under modalities of participation and self-management as the foundation of human development and environmental development of the "good life" from the perspective of cultures and local livelihood systems.

The PNC is part of the national development plan and has five main objectives:

i. Reorganize the institutional landscape relating to watersheds as well as technical, procedural and organizational advice. This aims to:
    a. Promote coordination and cooperation processes between the various institutions
    b. Work with civil society to guarantee the integrated management of water resources
    c. Prevent conflicts arising over limited water resources

ii. Develop and implement plans, policies, standards and laws in order to improve the sustainable use of natural resources in Bolivia's watersheds.

iii. Develop and implement a corresponding program for raising awareness among the population about the key issues and the project.

iv. Introduce a knowledge management system to institutionalize organizational learning.

v. Promote and systematize the sustainable and integrated management of watersheds.

The PNC supports the creation and implementation of investment projects of local community initiatives selected for the development of IWRM and IMC methods, which is expected to a) develop skills, knowledge and social arrangements; b) strengthen organizational arrangements, coordination mechanisms, cross-cultural behaviors, and c) achieve greater coordination, participation, monitoring and strategic management plans and watershed management in the medium to long term. Thus, the PNC seeks to enhance the capacity of implementing agencies of PNC - VMWRI, departmental and regional agencies in general and community organizations in particular.

Both local and external financing funds the PNC and VMWRI. Local funding allocation includes input from departmental and municipal governments and direct contribution of beneficiaries. External funding is sourced through the Joint Funding Agreement (CFA) agreed with the cooperation of the Kingdom of the Netherlands, Kingdom of Denmark, Switzerland, Kingdom of Sweden and Germany, and the additional contribution defined by the " Sector Budget Support to PNC " from the European Union.

6. *Servicio Nacional de Riego* (SENARI)

SENARI with its departmental irrigation services (*Directorios Departamentales de los Servicios Departamentales de Riego,* SEDERI), was established in October 8, 2004 Law 2878, as an independent agency under the Ministry of Rural and Agricultural Affairs (currently under custody of Ministry of Environment and Water). SENARI is strengthened with administrative and management powers and has the responsibility to regulate, plan, manage and promote public investment in irrigation development, agricultural and forestry production. The specific objectives of SENARI are to:

i. Execute plans, programs and strategies approved by the Board of SENARI.
ii. Coordinate with the various bodies at national, departmental, municipal, local and watershed activities for the development of irrigation.
iii. Update the National Information System for Irrigation (SNIR).
iv. Develop and update the National Register of Irrigation Systems (PNSR).
v. Support the Board of SENARI, in all actions they undertake.
vi. Schedule and execute its own budget.
vii. Apprise the Board of the SENARI of financial and management reports.

7. *Regantes* – the decentralized irrigators and local decision makers

Bolivian irrigators or *Regantes*, decentralized irrigators who came into prominence following the protests against neoliberalization of resources mainly the ‘water wars’ and the ‘gas wars’ (Perreault 2005; Perreault 2006), have influenced the institutionalization and hence governance of water resources. Irrigators are recognized as legitimate partners in negotiations with the state, donor agencies and the private sector. In addition, the extensive network of irrigators includes the academic and intellectual population of Bolivia along with development practitioners and issue NGOs in the water sector. Since the uprising of 2000 against the neoliberalization of water management, the irrigators’ network has been a sounding board and anchor for other social movements and thereby extended its coalition of allies. Legitimacy of the irrigators also stems from their successful campaign for a Irrigation Law that was passed in 2004, which critically involves them as stakeholders in - a supposedly – transparent and participatory process of water governance. In essence the irrigator rights movement solidified the legitimacy of civil society actors and effectively worked towards and filled the “hollowed out” state of Bolivia where, anti-neoliberal, culture-based, decentralized and interconnected network of peasants have successfully re-configured the geometry of power and politics in natural resource governance (Perreault 2008).

4. 1. D. Decision-making and the Bolivian water sector organizations

In Bolivia, water resources management represents various combinations of rules and norms in decision-making systems. Firstly, the international organization ALT – Peru Bolivia, follows its Master Plan for its administrative and enforcement decisions, which was created after substantial multi decadal negotiations between Peru and Bolivia. Both nations differ in their approaches to water management and the organizational structure does not have provisions to addresses these disparities. Interviews with representatives from both countries, and UOB suggest a lack of trust on either side with respect to a) baseline levels of Lake Titicaca, which are used in water distribution decisions, b) the use of Lake Titicaca, c) consistent Peruvian leadership of ALT and d) purported high quality of research and efficient management, on the Peruvian side.

The nature of Lake Titicaca and its watersheds create unique economic, social, and resource challenges due to different national aspirations. In addition, decision-making in ALT is hampered by differences between indigenous populations and their cultural norms that make adoption of innovation and information difficult; legal differences and nature of land and water rights; and enforcement of pollution laws. Also, since ALT relies on its national entities, which are removed from national water mangers, an organizational overlap creates additional barriers for execution of the Master Plan. For example, the Bolivian Navy, whose technical officers are trained in maritime affairs but not in water management or policy, are the decision makers in UOB, the organization that administers the Bolivian part of the Master Plan. Overlap in organizational rules and dual goals – Bolivian maritime aspirations and water management add substantial barriers to the efficacy of decision systems. Decision-making at ALT is inflexible since the organization has efficient checks and balances represented by national representatives and entities, and any innovation has to be approved by both nations, which is organizationally challenging. Strict adherence of decision-makers to the Master Plan is a risk-averse strategy that makes confrontations based on differences above less frequent and operationalization of the Master Plan barrier free. In spite of these differences, (UNESCO 2003) the general scheme proposed in the Master Plan has been implemented. Because Lake Titicaca is upstream in the TDPS and represents a unique model of management, decisions of ALT have been instrumental in shaping the current polices and the socio-ecology of TDPS system.

Secondly, the MEW represents the decentralized approach towards natural resource governance and is a flag-bearer of development policies through irrigation projects. As such, the MEW is one of the most powerful ministries in the Bolivian cabinet. The MEW has grown rapidly into a network of national, regional, and local entities, whose representatives have various means of providing their input to policies devised by MEW. CONIAG serves as the 'forum' where MEW encourages disparate participation thereby representing the socialist electorate and constituents of the President Evo Morales. Ministers and Vice-Ministers of MEW routinely make decisions while balancing the needs of a multitude of stakeholders. This challenge of balancing needs is frequently played out in ministerial budgets, external support, and leadership changes. Thus, decision-making at ministerial level of MEW is highly political and less technical, thereby rendering decisions that are conservative, risk averse, and dependent on the dynamics of the political landscape.

Thirdly, the vice-ministries of MEW – VMWRI, VMEBC, VMPS and the independent irrigation agency SENARI represent similar albeit nuanced differences in decision-making. Of the vice-ministries, the VMWRI is the most powerful and has the largest operational budget (*Personal communication 2010*). The vice-ministries are implicitly hierarchical in political and socio-economic priorities as evidenced by the number of projects and budgetary allocations under each vice-ministry. However, all decision-makers acknowledge the importance of potable water and climate change issues irrespective of hierarchies amongst ministries.
Since irrigation is considered as one of the primary development goals of Bolivia and is supported by extensive financial support by internal and external agencies, VMWRI is not only important to external donors but also to the decentralized irrigators. The decision makers in VMWRI are thus highly visible political leaders and managers whose actions are closely followed by the *Regantes* (the local irrigators), electorate and NGOs. The

visibility of water managers in general and VMWRI and MEW particular is contrary to the invisibility of water managers in the United States (Rayner, Lach et al. 2005), where the water managers remain invisible to society by the high reliability, quality and lack of problems in water supply and escape the close scrutiny that other public offices are often subject to.

The visibility of Bolivian water managers stems from several intricately connected and often-conflicting issues. Bolivian water sector plays host to several issues not uncommon in water management such as transboundary water conflicts (with Peru), frequent problems in water supply and sanitation, powerful irrigation lobby groups and electorate, rise of water-intensive mining activities, and exploding urban population. Visible effects of climate change in form of receding glaciers and recent political upheaval riding on the political momentum created by the social unrest due to commercialization of water contribute to the attention that MEW and VMWRI receive. In addition, the fact that water issues reflect and have become a symbol of a) indigenous rights, b) societal inequality and c) portrayal of Bolivia as a victim of developed-country emissions critically shapes the politics of water management.

On the other hand, the VMEBC has seen several organizational changes. Once a powerful ministry itself, the VMEBC has been reduced to a vice-ministry whose decision-making capacities are now subsumed by the MEW. Decisions in VMEBC follow technical guidelines and the Bolivian constitution.

VMPS faces tremendous pressure to provide potable water to a rapidly growing urban population while maintaining low costs. In the context of this study, urban water supply represents one sector of water management and even though water supply, access, and equity though important issues, they are not the subject of this study. Interviews with the national water supply company EPSAS, regional water company of Oruro – SEMAPA, and the community water mangers indicate a tough balance between organizational goals, community water rights, and growing urban and peri-urban population that frequently lead to confrontation between government organizations and community managers. A lack of clear decision-making procedures and guidelines creates indecisiveness and results in maintaining status quo, which could be vastly improved. However, recent international investment in urban water supply and several development projects are aimed at solving the urban water management problems that may potentially iron out the existing challenges in potable water sector.

Lastly, the *Regantes* or the community irrigators are part of a National Water Service (*Servicio Nacional de Aguas*) that was formed in 2003 after a series of irrigator workshops that mobilized the defense of water rights and livelihoods threatened by privatization of natural resources during the water wars (Perreault 2006; Perreault 2007). As mentioned above, the focus of the *Regantes* is primarily securing peasant rights for management of water for irrigation and drinking water and sewerage not only in rural Bolivia but also in urban areas. Establishment of SENARI, the SEDERI's codified under the Irrigation Law of 2004 is a result of proposals by the irrigators when they achieved the legal recognition and protection of their *uses y costumbres* for water rights and management (Perreault 2008). Decision-making amongst community managers is inclusive and representative of community needs. Typically, community meetings, which are held frequently, serve as the basis for decision-making where a community-elected Board of Directors make decisions on water access and use. These decisions often reflect irrigator needs. Managers make decisions based on: a) individual area under irrigation b) equity among community members, c) availability of water, and d) seasonality. Other types of community organizations such as the fisheries committees and village development committees participate in decision-making even though some these community organizations have conflicting agendas.

Table 4. Decision-making and organizations

Organization	**Description of decision-making**
ALT Peru- Bolivia (*International*)	We have a specific regulation, called the Program of functions and attributions.
UOB (*National*)	Decisions are made at the suggestion of the principal heads of units, framed within the master plan and according to regulations.
MEW (*National*)	*At a regional level*: The Departmental and Ministerial leadership makes decisions, which are then hierarchically followed by the departmental secretaries. Regional decisions are based on that information.
VMWRI (*National*)	There are departmental plans for irrigation that systematizes the demands. We don't develop the studies, but the studies are developed by other requests. VMWRI regulate the normative and technical part. *At a regional level*: Technical and personnel decisions are made during meetings conducted every Monday. In addition, need based technical and

	formal supervisory meetings are conducted.
VMPS (*National*)	No clear method of decision-making exists. The Ministry of Development provides all decisions and directives to regional arm of VMPS.
VMEBC (*National*)	Follow technical and legal guidelines as present in the Bolivian constitution, the VMEBC and MEW. The VMEBC includes technical secretaries who guide decision-making. *At a regional level*: Decisions are made on a need-based basis. Projects are developed, budgeted, designed, and proposals are written to operationalize the project.
SENARI (*National*)	Follow the strategic plan laid down based on the Irrigation Law.
SEMAPA (*Regional*)	There are three levels of decision-making. The Director makes the institutional decisions, approves annual plans and establishes the control structure for the fulfillment of the organizational goals. The second level is the Management where, the managers make individual decisions based on the approved annual plan. The third level is the Committee of Management that is made up of the manager and the four managers of the area where the annual service is provided.
Community (*Local*)	Decisions are typically made in an Assembly that is comprised of representatives, which appoints Directors and Co-coordinators. The Director executes the decisions taken. Decisions are made by the bylaws, the regulations, and all decisions are made while respecting the provincial and central decisions. Minutes are taken. The decisions are made in the assemblies in each community. Later, the Assembly formed by the President, Vice President, Secretary of Treasury, Secretary of Minutes and two other members, authorizes the community decisions, based on a simple majority of 51%. All decisions must be recorded and details maintained. The organization is at the union level within the community. A Secretary General is responsible for the community; the indigenous group representatives, the magistrate, the school board, which comprises the educational unit, and the organizational core that is responsible for the records.
SENAMHI (*National*)	Decisions are based on the regulation, called the program of functions and attributions.

4. 2. Multi-level governance: state of scale

In Bolivia, organizations that are responsible for water management represent multiple scales of governance. Bolivia has experienced frequent physical and political re-scaling in the water sector between state and private contractors and more recently with local managers (Perreault 2005). Many of the institutional structures that oversaw these changes have either evolved, re-formed or are extinct. For example, the Ministry of Sustainable Development and Planning of Bolivia, which was involved in the management of TDPS along with ALT was dissolved and its duties re-distributed amongst the MEW and its Vice-Ministries. Also, several agencies are frequently created by Bolivia's government, which takes over functions previously administered by other agencies (Fretes-Cibilis, Giugale et al. 2006). Re-scaling organizational and agency functions thus represent environmental governance in Bolivia. This section discusses multi-scale governance and re-scaling politics in Bolivia's water sector.

In water resource management, re-scaling of physical (also known as geographic or positional) scale and political scale have been instrumental in shaping the role of state in water governance. The use of 'physical scale' to strengthen the role of state at the cost of local management and avoiding privatization has been achieved by physical re-scaling, where changes in a) horizontal - the size of the area covered by institutional structures or physical infrastructures, b) vertical - restructuring of nested institutions and associated infrastructure, and c) linkages between vertical and horizontal institutions, physical structures, and the environment leads to restructuring of water resources management (Gualini 2006; Thiel 2010). Re-scaling the physical attributes also refers to changes in the coverage of services, infrastructure, and institutional jurisdiction (Cash, Adger et al. 2006; Bakker 2007).

On the other hand, social construction of scale is political, where shifts in relationships between state and society occur. Political re-scaling has implications on resource governance, which has been highlighted by the lack of 'fit' and 'interplay' between institutional arrangements and the ecological systems they manage. While ‘fit’ refers to the compatibility between ecological systems and institutional arrangements created to manage human activities that affect the SES, ‘interplay’ refers to the horizontal (similar levels of social organizations) and vertical (cross-scale interactions between different social organizations) interactions among institutions (Young 2002). Lee posits that “where human responsibility does not match the spatial, temporal, or functional scale of natural phenomena, unsustainable management of resources is likely and will persist until mismatches of scales are cured” (Lee 1993). Other re-scaling implications such as variations in the number of actors, contexts, relationships of power, perception of natural resource problem, structure of relationships between actors, and uncertainty of system behavior influence natural resource governance (Young 2002). Thus, re-scaling of physical and political scales influence governance of SES and continues to re-shape water management in Bolivia.

Information availability, access to it, and its pertinence or ‘fit’ influence management decisions. However, few studies investigate the role of information and its influence across political and political scales. In addition, ‘interplay’ of information in horizontal and vertical levels of institutional arrangements creates both opportunities and challenges for information creation, dissemination, and its use. It is therefore necessary to pay attention to the dynamics of information across scales. Such attention cannot be attributed when information is considered a part of management or as one of the factors that influence water management. It is critical therefore, to attribute a scale of analysis to information and acknowledge informational scale as a driver of information use.

In addition to physical and political scales, this study introduces an informational scale, which refers to the dynamics and process of information production and use. Dynamics refer interplay of institutional arrangements between physical and political scales and process refers to the fit of information within the institutions and organizations that are involved in the production, dissemination, and use of information. This three-way classification system, adapted from the scales of politics (Lebel, Garden et al. 2005) takes into account the complexity of SES’s, actors, information use, and their action arenas.

This method of scale classification informs theoretical constructs of fit, interplay, and scale (Young 2002) among environmental regimes and their system counterparts and flexibility in of decision-making (Lemos 2008).

Within the purview of this research, climate information availability, its spatial breadth of coverage, frequency of CI, and access determine one frequently overlooked scalar dimension. Mismatches in information production and its use have implications in decision-making since decision-makers have to make decisions either with existing (and mismatched information) or no information.
By identifying attributes of the SES and differentiating scales of management and system properties, the analysis of complex multi-scalar governance systems are simplified. In other words, 'state and scale simplification' is used to potentially rationalize management and identify areas for effective policy intervention to foster climate information mediated building of adaptive capacity. This section describes water management in Bolivia using the lenses of multiple scales and identifies areas where scalar challenges can be solved by policy intervention.

Bolivia's recent neoliberal governments and its recent socialist successor have restructured the politics and the state. The state in its attempts to overcome economic and social crises has re-scaled the political administration and regulation, which is represented by an inherently unstable process that seeks political stability through popular decentralization (Perreault 2007). This instability has created a wider mobilization of society that challenges any state attempt at re-scaling natural resource governance. This paradoxical national political issue is increased by an order of magnitude when bi-national political scales are considered (Table 5). For example, in the study area the headwaters of the Lake Titicaca managed by an international entity – the ALT, international politics play out. A special audit of ALT for the periods between January 1996 and December 2006 concluded that Bolivian auditors:

> "(…) do not usually report findings but prepare a draft report which is submitted to the authorities allegedly responsible for said issues so they can provide the required

> clarifications. A Final Report is then submitted. Then, after some arrangements are initially made with the officers in charge of both Committees, a report is prepared; however, after the audit, some irregularities were disclosed which deserved the filing of civil and criminal proceedings. Therefore, lawyers will be required to prepare special reports and inform of their work involved in this matter" (ALT 2008)

The lack of trust influences bi-national water management between Bolivia and Peru and therefore adds barriers for effective management of TDPS watershed.

Following the Lake Titicaca, the TDPS system as a whole is administered at a national level by several contradictory decision-making organizations. For example, the MEW and its vice-ministries and regulatory agencies, such as the semi-autonomous UOB and regional arms of MEW, routinely make management decisions that overlap, influence, and sometimes conflict with each other. For example, a key informant from UOB explains the problems in international and national organizations of Bolivia's water sector –

> "(…) the executing agency UOB does not count as part of the ALT. The executive arm has not been participating in decision making because the statute provides that a Peruvian citizen must always run the institution. There have been several observations and oppositions to change the statute, to one, which is rotating; the management is made that is equal to Bolivia to Peru. However, progress on the Master Plan has been minimal, and then the other works (of the Master Plan) have not begun.
>
> Many people in Oruro claimed about the use of river water Desaguadero. Sectoral regulations are being made, such as irrigation, basic services, but there is no water bill. The most we can do is to suggest decrease of water use in mining and that it is best used in irrigation. But, the law is very difficult. It should be linked to integrated management legislation, which is lacking."

In addition, conflicts between national aspirations and local needs are apparent as key-informants from the village of El Choro in the Altiplano and the Ministry of Mining are compared -

Leader of community irrigation management:

> "(…) the company Intu Raymi monopolizes the river, it was full and now there is no water and the water has gone away to the right arm (*of the Desaugadero*). It necessitates migration of people"
>
> Contrastingly, key-informant from the Ministry of Mining opines "(…) the sustainability of water resources is always secondary to mining since the nation's development depends on it (*mining*)"

At the local and regional political scale that manages the components of TDPS (indicated by T, D, P, S) and watershed basins, decentralization policies play out in the arena of irrigators and community organizations that have managed to 'jump' the local political scale by creating a national organization, which in turn contradicts the essence of decentralization.

Table 5. Multi-level governance and multiple scales

Water System	**Scale of Politics**	**Scale of Position**	**Scale of Information**	
			Temporal	**Spatial**
Titicaca	International	Upstream	>10 Years	Macro
TDPS	National	Downstream	>10 Years, 5 - 10 Years	Macro and Meso
T, D, P, S	Regional	Downstream	1 – 5 Years	Meso
Watersheds, River Basins	Local	Downstream	Seasonal	Micro

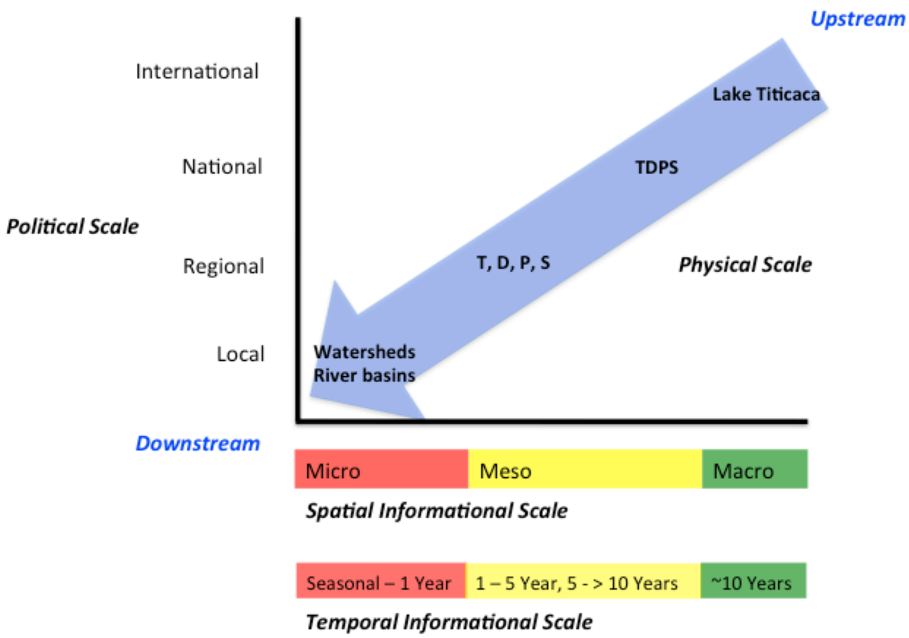


Figure 5. Multi scale governance of water resources in Bolivia

Secondly, the physical scale, which is perhaps the most widely understood of scale issues in water management, addresses the relative spatial position of actors and organizations that provide them with political and resource advantages or disadvantages unique to the organizations that are involved in that space. Since the geographic position determines availability and use of water, water systems are classified within the scales of position, or physical scale as referred above. The capacity to control and capture resources therefore manifests at the scale of position. Most of TDPS lies downstream with the *Salar de Coipsa* the farthest downstream from the Lake Titicaca. Any variability in water inflow in the Lake Titicaca, either natural or anthropogenic, affects the flows and quantities downstream. In addition, extraction of sub-surface water for and contamination by effluents from mining influences the downstream flow quantities and qualities. Natural stressors such as decreased precipitation and increased evaporation abets the decrease in downstream flows. Scales of position would therefore inform sustainable management decisions to foster equitable availability across water sectors and scales of politics.

Lastly, scales of information represent the climate information production, its characteristics, and use across political and physical scales. Scales of information are

classified in this study at temporal and spatial levels (Figure 5). Temporal information scale refers to CI that is both timely and applicable in decision-making. For example, CI should take into account decisions that are time-sensitive (e.g. seasonal water allocation,) and applicable with respect to the range of time for which predictions are made (e.g. seasonal forecasts range from weeks to months) and necessary (e.g. seasonal forecast cannot be used for long term planning and vise versa).
Spatial information scales represent the extent of CI coverage and its dissemination potential. Spatial scales of information correspond to the geographical area for which information is available and where such information is accessible for end users. Informational scales thus, define the information in range of time and extent geographical coverage. However, different decision-making systems seek different information within each sector. For example, short term CI may be used both for daily management of water resources and managing extreme events. It is likely, that contextual information requirement and use will create interplay between organizations that produce, mediate and use information. Furthermore, use of information will necessitate information at spatial scales that fit decision-making requirements. Scale of information crisscrosses physical and political scales and offers an opportunity to address dynamics and process of information production and use.

In the TDPS system, the producers of information represent international and national scale of information production while regional and local information is uncommon. End users of information are well-represented at all political and physical scales. Dissemination of CI produced in Bolivia is limited in dissemination since the objective of the main information provider SENAMHI is data generation and boundary organizations that transfer CI are absent Thus, scales of information, position, and politics are misaligned creating barriers to information use.

4. 3. Question 2: What is the current role of climate information in decision-making?

4. 3. A. Climate information: sources and access

This section analyzes the sources of CI in Bolivia and the factors that influence ability of decision-makers to access CI. The data collected enables a detailed analysis of the drivers and barriers of CI use and allows for a comparison of organizations and decision-makers. A caveat here is that CI as defined in this study is not available in Bolivia. Hence, CI use refers to meteorological, weather, and climatological data produced in Bolivia and currently used by decision-makers.

Of the eighteen key-informants (structured interviews), only two reported they did not seek climate information. Of the key-informants from the semi-structured interviews group, all eighteen subjects reported they sought climate information. This significant majority in CI seeking reflects the high demand for CI among decision-makers. However, what constitutes 'seeking' as described by both groups, varied substantially. The sources of CI range from mass media sources of generic climate information such as television and radio broadcasts to highly technical CI produced by technical organizations such as SENAMHI and UOB. In addition to the traditional sources, the respondents access a wide array of sources subject to resource (SERGEOTECMIN, internet access, information, contacts, organizational requirement) availability.

Accessibility to CI is an important variable that determines the use of CI. Accessibility to CI is categorized into three levels of increasing access based on available sources and potentially available sources (Table 6). The first level of access distinguishes access only to the sources mentioned as available by the key-informant. The second level of access describes the access to the sources mentioned (Table 6) and potential access to one other source. The third level of access is the universal access to all available and potential sources of CI. Sources such as MEW, ALT, VMEBC, the IPCC, PELT feature prominently among the sources in the higher scales of politics and position where organizations have the third level of access and almost unrestricted access to available and potentially available CI such as IPCC reports.

Contrastingly, decision-makers at regional and local scales of politics and position have the first and second level of access where SENAMHI, mass media, and municipal governments feature prominently as sources of CI. Several community managers mention logistical difficulty in obtaining CI since; they have to travel long distances at their own cost of time and money to obtain CI from municipal governments and regional offices of SENAMHI. The striking observation of the analysis of sources and access is the evidently high CI seeking by decision-makers and awareness of SENAMHI as the primary CI provider.

Table 6. Climate information: Sources and accessibility (2009)

		Climate information seeking		**Sources**					**Accessibility**		
		Y	**N**	**TV**	**Radio**	**Internet**	**SENAMHI**	**Other**	**1**	**2**	**3**
1	CONIAG		x					MEW	x		
2	ALT	x					x	ALT			x
3	IADB	x						IADB			x
4	VMEBC	x				x	x	MEW, VMEBC, IPCC			x
5	VEW(R)	x					x		x		
6	VMWRI	x					x				x
7	UM, VMPS (R)	x					x		x		
8	ALT (B)	x					x	ALT, PELT, UOB		x	
9	Asica-Sur	x		x		x		Mass Media		x	
10	SENARI	x					x		x		
11	SEMAPA	x					x				x
12	Com. (F)		x				x		x#		
13	Com. (I)	x					x	Municipal Govt.	x		
14	Com. (V)	x		x	x			Municipal Govt.	x		
15	VMEBC (R)	x					x	Bio-indicators			
16	L. Poopo Rest.	x				x		Personal res. ALT	x		

								UOB			
17	UOB	x				x	x	UOB			x
18	SENAMHI	x					x	Internet, International networks, Latin American networks			
TOTAL		**15**	**2**	**2**	**1**	**4**	**12**		**7**	**2**	**6**

*1= only the source mentioned, 2=at least two sources, 3=all available sources
- limited access to SENAMHI data, since villagers need to pay for their own transport to SENAMHI office.

Key - informants of interviews conducted in 2010 had universal access to CI and sought highly technical information via sources such as internet-based searches of international climate data, technical data generated in-house and CI produced by Bolivian research universities like UMSA (Table 7). In addition, SENAMHI was also a universal choice for CI amongst key-informants of 2010.

Table 7. Climate information: Sources and accessibility (2010)

		Climate information seeking		**Sources**					**Accessibility**		
		Y	**N**	**TV**	**Radio**	**Internet**	**SENAMHI**	**Other**	**1**	**2**	**3**
1	ALT Peru – Bolivia	x				**x**	**x**	International Climate data providers. Internal ALT technicians			**x**
2	UOB					**x**	**x**	UOB Technical Unit, and ALT tech			**x**
3	PNCC	x				**x**	**x**	Universities – IHH, IRD, IPCC, Peruvian Institutions			**x**
4	MEW	x				**x**	**x**				**x**
5	SENAMHI	x				**x**	**NA**				**x**
6	SENARI	x				**x**	**x**				**x**
Total		**6**	**0**			**6**	**6**				**6**

4. 3. B. Climate information: use

One of the questions we asked our key-informants in 2009 was if they used CI. Fifteen of the eighteen respondents used some variant of CI to inform their decisions (Table 8). None of the respondents mentioned either an organizational requirement or procedural need to use CI. This indicates that the organizations that the respondents represent are not subject to scrutiny for use of CI. However, the use of CI varied from enhancing the knowledge of the user at an individual level to informing policy decisions at an organizational level. Eight of the eighteen key-informants (structured interviews) had the ability to make new policy based on available CI, while five were able to modify existing policy. CI had no effect on decision making to four of the respondents due to lack of organizational capacity, non-requirement of inclusion, and existing norms.

Managers cite various reasons for the use or non-use of CI. One frequently mentioned factor was the confidence in CI. Interviews show that only five of the eighteen key-informants have high confidence (>75%) in available CI. Moreover, the analysis indicated that decision-makers at higher scales of politics generally had less-confidence in CI while the decision-makers at local scales of politics had higher confidence in CI. The fact that local scales of politics report higher confidence in sources of CI while their information is actually more uncertain (Table 8) than sources available to higher political scales indicates that local decision-makers are risk-takers. In addition, the risk-averse behavior of higher scales of politics has been observed in water governance systems elsewhere (Lemos 2008). When the decision-making risk and confidence in CI is compared, a scale – information paradox is observed where, the use of highly uncertain CI by decision-makers at local scales is relatively greater than that of their higher political scale counterparts who contrastingly have access to lower uncertainty data. The causal reasons for these observations require further study.

Table 8. Climate information: Usability in decision-making (2009)

	Climate information	Usability of climate information	Confidence in climate information

		use							
		Y	**N**	**No effect**	**Ability to modify existing policy**	**Ability to make new policy**	**<50%**	**50-75%**	**>75%**
1	CONIAG		x			x		x	
2	ALT	x				x		x	
3	IADB	NA				NA	NA		
4	VMEBC	x				x			x
5	VEW(R)	x			x			x	
6	VMWRI	x				x		x	
7	UM, VMPS (R)	x			x			x	
8	ALT (B)	x				x		x	
9	Asica-Sur		x	x			x		
10	SENARI	x				x		NA	
11	SEMAPA	x			x				x
12	Com. (F)	x			x				x
13	Com. (I)	x				x		x	
14	Com. (V)	x				x			x
15	VMEBC (R)	x			x		x		
16	L.Poopo Rest.	x		x			x		
17	UOB	x		x				x	
18	SENAMHI		x	x					x
TOTAL		**15**	**3**	**4**	**5**	**8**	**4**	**7**	**5**

CI producers (frequently scientists and technical organizations) make assumptions of what they think decision-makers need. However, does the CI producers' perception of decision-maker use of CI match? How close are these perceptions? In an attempt to answer these questions, the main goal of the interviews of 2010 was to assess the usability of CI produced by this study. This is necessary because different actors perceive CI differently, which influences the use of CI. In this context, usability of CI is about application and fit of provided CI in decision-making—usable information is that which has been actually deployed and useful information is that which is perceived as desirable but not deployed (either because it is not available or because of other constraints—see section 2.3). Table 9 shows that all key-informants find that CI provides desirable and functional meaning and that CI (especially weather and other meteorological data) has been overwhelmingly usable in their decision-making context. In addition, results show that Bolivian decision-makers seldom have access to model-based downscaled climate projections and any information that involves climate projections are perceived to be highly useful. Table 10 shows the CI and presentation requirements of decision-makers during 2009 and 2010.

Opportunities reported for use ranges from updating management plans (ALT), which will in-turn inform water managers at local levels of politics and information. Decision-makers perceived the downscaled CI provided by the project to have high potential (UOB) as supplemental information for making policy directives, which informs subsidiary implementing units.

Table 9. Usefulness and usability of model-based climate information (CI) provided to interviewees (2010)

	Usefulness of CI			**Usability of CI**
	Useful	No effect	Not useful	
ALT Peru – Bolivia	x			CI will be incorporated in decision-making, since decision-making is dependent on climate information. One way it will be used is to update the management plan (*Master Plan*) of Lake Titicaca.
UOB	x			Information is used and incorporated as technical information and provided to the technicians and managers to execute recommendations and policy directives. Such information is incorporated in tandem with other vice-ministries such as VMWRI and VMPS.
PNCC	x			The presented CI is very useful, but doubts exist about its accuracy and uncertainty estimates.
MEW	x			The Ministry does not have anything definitively to incorporate CI currently. But as interests in CI develop along with the capacities to incorporate CI, a national plan, along with sectoral plans within the national strategy of natural resource management can be modeled based on future climate change scenarios.

SENAMHI		x	NA
SENARI	x		Clearly, CI can be incorporated for irrigation projects in the high altitude plateau, for planning contingencies, dam area selection, and catchment area selection. SENARI can know how precipitation patterns and water availability may change. These changes (projected and real) directly influence the decision-making of SENARI. In addition, since most agriculture in Bolivia is seasonal, any change in seasonal precipitation patterns, will require planning efforts. SENARI now has an IWRM approach for water management necessitates CI.

Table 10. CI requirements of Bolivia's decision-makers in water sector

CI requirements (2009)	CI requirements (2010)	CI presentation requirements
Local level data, that will help planning	Meteorological, climate effects on diverse geographical regions, extreme events and decision support for extreme events and climate change events.	Control volume of rivers, volumes of draining waters from Lake Titicaca, TDPS lake levels,
Temperature, precipitation, radiation, winds, models of water availability and water levels in Lake Titicaca and Lake Poopo, sectoral water demands		Maps, graphs, charts
Climate scenarios, temperature, extreme events, precipitation projections,	Quality, amount, projects (mining etc.) that consume water, irrigation demands. An integrated study of all river basins and watersheds in Bolivia to relate climate change and observed changes in water levels. Water availability: demand and supply, monitoring of such data, since it is not regular. Data storage facilities. Access polices to collected and existing data. Sectoral demands of water. Changes in sectoral demands of water. Urban demands and projected water demands in urban areas. Irrigation requirements. Reliable CI.	Maps and statistics, graphs that is visual, and easy, that alerts people, so that such information aids people and decision-making.
Satellite maps with coverage of topics such as precipitation, solar radiation, winds, temperature, hailstones		The zones with negative projections are zones that indicate risk and it is necessary to develop policy to make use of available water and plan for adaptation to reduction in water levels. Such identification of regions would be necessary to explore water storage mechanisms and strategies to make efficient use of available water.
Water availability, maps that indicate climate change risks and vulnerabilities, especially in regions such as Chaco		
Climate change scenarios of TDPS, projected flows and volumes in TDPS.		
CI that indicates water measurements (*in main sources*) along with technological solutions for climate change problems	Scenarios of climate change and projected impacts, water demand and consumption statistics. Availability of water for various sectors. Precise analysis of effects of climate change, with high certainty.	

	Temperature predictions and effects.	
Maximum and minimum temperature predictions, and precipitation projections	We need past, present, and future CI. Past CI need is meteorological, current CI needs are social conditions, and future CI refers to climate scenarios. All such CI will help in climate change adaptation. Risk analysis is needed.	We need contextual data, that can be molded into forms, which are easily understandable
Identification of areas that will face greatest climate change impact and that will have high water deficit		
Rainfall, Lake Titicaca levels, River (*Mauri*) levels, contamination, and yield estimates of fish	Climate data, that complement with the centers of observation in several places of Bolivia, and identification of areas that have similar problems that in turn would aid in specific policies for those zones.	
Rainfall, extreme events, water level, contamination levels. CI that will help planning for crops and prevent economic losses		
Socio-economic, land management, tenure, and climate change related threats faced by the region, cloudiness and wind, cold weather fronts, early warning systems		
Bathymetry, contamination, evaporation, water regulation, infiltration, daily volumes, monthly volume flow and regulation		
Precipitation, evapotranspiration, temperature, water quality,		

4. 3. C. Climate information: opportunities and challenges

Several opportunities are available for the incorporation of CI in decision-making (Table 11. a). The brightest opportunity of Bolivia's water sector is its interest in incorporating CI. Most organizations recognize the importance of CI and its positive effects on development of the nation. For example, decision-makers perceive CI use in irrigation sector as a pivotal to decrease crop losses and improvement of agro-industrial sector. Bolivia is also one of the first Latin American countries to include climate change effects in education curriculum and view CI as aiding in the 'perspective building' of the nation. The MEW as an institution is another opportunity that may facilitate the incorporation of CI. MEW; being a newly created ministry and the result of the water wars, institutional opportunity exists in its willingness to adopt new information. However, MEW finds that CI useful, which is legitimate and assists local and regional development and CI that 'fits' MEW needs, is currently unavailable. In addition, MEW and CONIAG provide an excellent venue for stakeholders in the water sector to share ideas, transfer technical skills, and build consensus. Such platforms for stakeholder activity may perhaps aid in an expedited and successful overhaul of Bolivia's water law.

Opportunities for inclusion of CI in new policies at multiple scale of governance are available since the key-informants in important decision-making positions are receptive to CI and expect technological solutions based on CI to foster development in water sector. Prospects for solving trans-boundary water issues (in TDPS basin) are presented if CI can predict lake and river levels based on which amiable bi-lateral agreements can be negotiated. CI can thereby increase the trust between operating partners of ALT.

Finally, existing informal networks among organizations (e.g. climate information network initiated by VMEBC, that involves IHH/other Universities and SENAMHI) represent a motivated decision-making community that strives to share existing CI. Fostering such networks by formalization of networks and providing resources and institutional foundation can significantly improve CI use and sharing in Bolivia's water sector.

Table 11. a. Opportunities for incorporation of CI in decision-making

Key - informant description of CI use opportunities
CI would allow improvement in decision-making priorities for climate change mitigation activities and enable information based budget decision-making.
CI will enable preparation efforts for better management of natural resources, (*provide*) perspective on guarantees and viability (of project and perhaps risk assessments?) plan for alternatives and seek new technology.
Water Laws and policies that enforce new mandates and regulation are necessary, but these need to be informed by CI. The Plans are outdated and newer and more reliable information based plans are necessary.
With awareness of CI, decision-making for agriculture, agro-industrial sector, health, water availability, and security will be better informed for which CI is important. SENARI is undertaking a program that would take into account CI.
I believe that as an institution we have a very important base in the shape of a ministry. This structure did not exist before. It was not possible and all the efforts were dispersed. That is in terms of as an institution. What would really please us is to open a type of space where we can discuss these subjects and I hope that it would translate into the training of personnel and specialization in order to improve the norm and politics. There are things that are obvious, for example reports of the effects of climate change. To point out a few aspects might help, but there are already more or less definite, established things.
Yes, CI is important in mainly those decisions that linked to the local level of development. Everything (*decision-making*) that has to do with the processes of short-term management processes of development planning, the regulations and territorial planning requires CI. This will be achieved through increased awareness of climate change and CI.
Scientific information is vital because it helps you develop the perspective of the country. For example, we are creating an inventory of greenhouse gases. We are of the first Latin American countries to include this information with emission factors of our own from the university. What we need is to make investments. It is possible that the rough/basic information already exists, but we have to continue investigating. Speaking of the subject of water, we know that there are restrictions on lakes, etc., and that this is all going to get worse. What we need is to make investments in small businesses (*micro-businesses*), in integrally managing basins, this kind of thing.
Obviously, we are in Bolivia and it's not very easy to obtain information, but they make the best efforts to try to supplement, let's say, with other parameters for helping make decisions. Also, DCI may perhaps help the water companies. They may be helpful because they are already living the problem in a more direct way. Also EPSAS because they live the problem from day to day, especially in the period of drought. Irrigation institutions might also be helpful. Such information will help in climate change adaptation planning. The Ministry (*MEW*), IADB, World Bank, NGOs are a part of the decision-making. Hence, climate change information is integral in analysis and maintaining food security through irrigation.
Such information would inform drawing baseline water levels in Lake Titicaca and its watershed, which in turn would help making decisions that concern both countries as well as local (*Bolivian*) decision making.
PNCC has created an informal network of CI sources that includes SENAMHI, Universities, and PNCC. We are not only exchanging CI, but also are planning to make some agreements.

Bolivia's water sector faces stiff challenges for incorporation of CI in decision-making (Table 11. b). In addition to organizational, informational, and scalar challenges (section 4.2 and 4.3) production of CI is a significant barrier since, Bolivia lacks the technical capacity and resources to produce usable CI. Incorporation of CI is ranked low in the list of priorities of decision-makers compared with societal challenges such as providing basic amenities and livelihoods. Decision-makers find inadequacies in prior attempts at incorporating available CI and attribute the lack of contextual CI as the cause.

In addition, the high demand for problem-specific CI such as fish yields estimates and seasonal planting times, and local information such as CI applicable in watersheds is seldom met. The lack of 'fit' therefore creates a CI use hurdle, which is difficult to bridge without boundary organizations that contextualize technical information to meet end-user needs (Table 11. b).

Also, since SENAMHI is the primary provider of CI, it faces tremendous pressure to produce information. However, SENAMHI is woefully understaffed and resource – starved, as one respondent observes

> "(…) we need more human resources. We have many projects and only four technicians. We lack resources in general. There is incoherence in that the weather stations require an investment. In Oruro, SENAMHI is composed of two people. It needs fixed (*permanent positions*) and many more personnel to produce realistic (*usable*) information."

Persistence of old laws and challenges in adopting new policies create few opportunities for CI use. In addition, most decision-makers face steep learning curves when new agencies are created and organizational agenda's are shifted, which happen quite frequently in Bolivia. Lastly, policy making tools such as climate scenarios balanced with uncertainty estimates that help understand the

> "(…) if I (*decision-maker*) chose this decision, then what are the climate change consequences and what alternatives do I have?"

question is not provided. The lack of validated CI that is suited for the diversity of decision-makers is perhaps the biggest challenge of CI incorporation in Bolivia.

Table 11. b. Challenges for the incorporation of CI in decision-making

Key – informant description of CI use challenges
CI is incorporated but is not a priority. Other subjects such as irrigation and CI effects on it such as evapotranspiration, precipitation is more important. Attempts have been made to incorporate CI, but are not adequate.
CI will remain important. However, other demands such as irrigation, political, reliability of CI will

prevent execution of incorporated changes.
There are no usage (*of CI*) barriers. However, the barrier is data production.
This is a challenge and it's something that one must examine for the formulation of public policy. The new constitution poses many challenges for us, and they're already starting to become apparent. They created the agency of irrigation planning, which adds another variable into the process of development. There is the national plan of climate change, which is institutionalized and has passed the Vice-Ministry of the Environment (*VMEBC*). So there is the consciousness of the necessity of treating the problem. There is demand from the executive power as well as demand from the social organizations. Whether it's climate change or natural disasters, one has to see how we can protect our cultivation. The demand (*for CI*) is out there and we have to face these challenges.
We are experiencing climate change every day. They are already forming policies at the international level to manage this subject. Concerning the uncertainty, there is always a degree in these kinds of investigations. There is a possibility of making a mistake in a figure or in a result. Now they are performing studies in order to make scenes (*scenario's*) of climate change for the next 20 and 50 years to see how to form policies and to make an analysis that sums things up to the moment. This is something that we don't have.
Since SENAMHI is the primary provider of climate information, based on which water budgets and balances are created by SENARI, incorporation of CI is lamentably minimal. The number of weather stations and data collection points limits the availability of CI. Also, the data provided by SENAMHI is very general and does not reflect the regional and sectoral information.
A lot of the information is concentrated because it did not spread through suitable channels. It's not just that it's posted on the web, there are so many websites and it can be difficult to get precise information quickly. What we need is to work on raising awareness so that the information can flow more easily. We are working on this, and it is precisely this component of National Communication that is making us do this work on education, in order to spread information through all possible channels.
Very little climate information exists currently, about modeling, and capacities. Developed information is subject to questioning (*by the ministry*) but is needed urgently. Everything depends on the quality and opportunity (*access*) to information. Origin of such information is very important.

4. 4. Question 3: How might climate information influence decision-making in water management?

This section analyses the influence of CI in decision-making from a theoretical perspective. Building on the organizations, decision systems, and opportunities and challenges provided by the interviews and integrating the responses within the innovations policy literature, this section provides a conceptual framework to better understand the factors that foster usability of CI.

Analysis of CI use and decision-systems indicate that decision-maker's interest in using CI is high and they find the CI produced by this study highly useful. This indicates a significant opportunity on the consumer end for CI use. However, use of CI faces several barriers as discussed in the literature review section. In Bolivia, the principal barriers for CI use are a) its lack of availability, b) lack of fit of existing CI, and c) inflexibility of decision-systems that render them impervious to CI. In addition, lack of boundary organizations to support the transfer of CI to users creates additional barriers to CI use.

Therefore the Bolivian information – decision-making system faces two general gaps. The first is the *usability gap* between the knowledge production and its use. The second gap is between the producers and consumers of CI - the *boundary organization gap*. The *boundary organization gap* is easily addressed by policy intervention that facilitates the creation of boundary organizations and is well documented for the United States (Guston 1999; Kirchhoff 2010; Dilling and Lemos 2011). However, addressing the usability gap is less tractable. The following sections provide a conceptual model for analyzing the factors that determine information use and four solutions to address the usability gap.

4. 4. A. Addressing the usability gap

The challenges of knowledge (CI) production and uptake foster a gap in the usability of climate information. Existing policies in Bolivia do not mandate knowledge generation and fail to address its usability. In addition, CI that is produced is seldom used. On the one hand, decision-makers do not perceive currently available CI as useful; on the other, the kind of information they think they need, is not available. In this sense, there is a gap between perceived need and available knowledge.

In order to bridge the usability gap, addressing use of knowledge and knowledge production is necessary. While the literature on factors that influence information uptake is robust, especially in analogous fields like seasonal climate forecasting (SCF), research on usability of knowledge and interaction patterns between knowledge producers and users is virtually non-existent, especially in non-market knowledge systems. In this study, I address the usability gap based on the characteristic of the knowledge system itself. To increase use, knowledge can either be *produced* to specification, that is, new knowledge can be produced to meet specific needs or existing knowledge can be *modified* to suit end user needs. Thus, policy makers can decide, based on decision-making environment and resources available to select solution for production of new knowledge, rendering existing knowledge usable or both. The next section discusses a conceptual model and four solutions for addressing the usability gap in terms of existing knowledge and generation of new knowledge.

4. 4. B. Conceptual framework: Usefulness, usability, and existing and new knowledge

Climate information (CI) is depicted on two axes: usability and usefulness (Figure 6). Usability is the measure of 'fit' of CI in decision-making, while usefulness is the CI property that renders it potentially usable in the opinions of producers of knowledge (blue arrows) and its consumers (red arrows). The shaded regions of blue and gray indicate *existing knowledge* that is defined based on the range of usability and usefulness. In this figure, existing knowledge is indicated at high levels of usability and usefulness. In order to move these highly usable, less useful (and vise versa) CI into the high usability and usefulness space (green area) four mechanisms are suggested: **retailing and value addition, customization and contextualization** (I use customization synonymously with contextualization). On the other hand, *new knowledge* production can become highly useful and usable when either of the mechanisms: **iterativity or co-production** is practiced. Policy makers can thus chose from the properties of existing knowledge and move them to usability/usefulness space by any of these mechanisms or choose to create polices that foster iterativity and co-production of new knowledge.

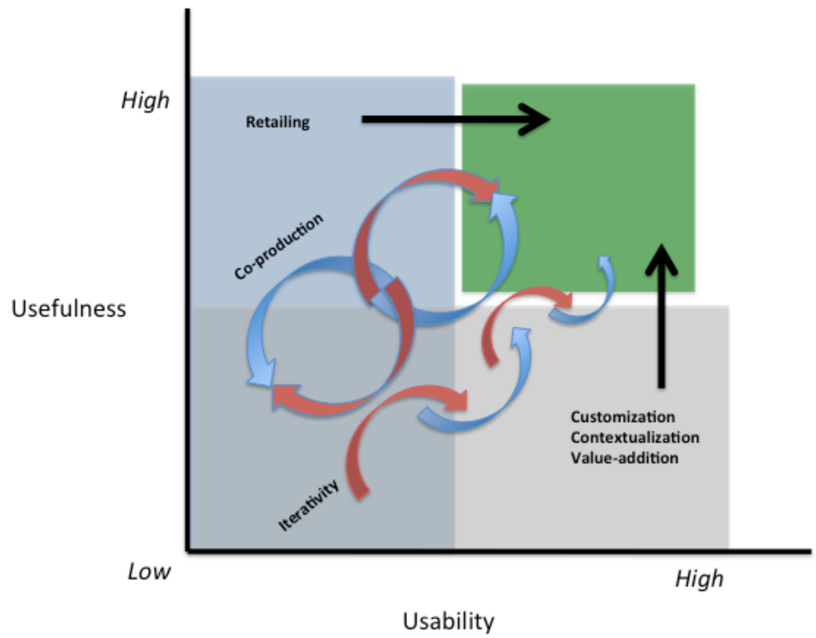


Figure 6. Mechanisms for making climate information usable

<u>4. 4. C. Solutions for production of *existing usable knowledge*</u>

<u>4. 4. C. i. Retailing</u>

In a knowledge producer – user context, retailing refers to supplying a subset of the original product in quantities that are required and easily taken up by the end user. In climate information systems, retailing has significant advantages over blanket climate information since retailing entails dealing with different end users. Blanket climate information may prevent user uptake due to reasons such as lack of applicability or perception of fit (previous section about 'fit'). Examples of retailing climate information are implicitly evident in SCF, traditional agricultural extension agencies, and urban planning agencies. Retailing would entail the knowledge producer to understand the needs of the user and provide sections of existing information that is easier to use. In addition, all climate information produced is not usable to everyone just, as all gloves produced do not fit everyone. By avoiding, a one-size fits all policy; retailing helps cater to the needs of the user and thereby increases participation of users in climate information uptake.

4. 4. C. ii. Customization/Contextualization and Value Addition

Of the many available methods to the efficient use of existing knowledge, customization and value addition are least explored in the context of science-generated knowledge. Several key-informants mention the lack of customization of existing meteorological information and CI. However, in disciplines such as business management and high-tech information companies customization and value addition are routinely invoked along the process of product design and value chain. In these fields, value addition refers to the increasing value of the product in the value chain. Structural and functional values are added in each stage of the value chain such that product meets the requirements of the user. Customization on the other hand refers to the deliverance of knowledge that meet individual user's needs. Scientific knowledge in general and climate information in particular is seldom customized or value added. However, examples of seasonal forecasts used in practical contexts indicate that the manner in which forecasts are communicated to users implicitly indicate either customized or value addition or both. For example, in decision-making context, uncertainties are framed as percent chance of an event occurring (or not occurring) which may influence a budgetary decision or; the conversion of climate information into end user terms such as crop productivity (Troccoli 2010) are examples of customization and value addition respectively. However, the enabling conditions that make either of these mechanisms functional are unclear.

4. 4. D. Solutions for production of ***new usable knowledge***

4. 4. D. i. Iterativity

In the knowledge – user context, iterativity is defined as the purposeful and strategic interaction between climate knowledge producers and users so as to increase knowledge usability (Lemos and Morehouse 2005). Dilling and Lemos (2010) call for science policy to foster conditions that not only purposefully incentivize producers and users to own the task of creating it but also by eliminating the constraints that inhibit it. Taking an institutional approach Dilling and Lemos (2010) address the various levels of iterativity that producers and users engage in, to produce and use science. They classify these institutions as information brokers, collaborative group processes, embedded organizational relationships, boundary organizations, and knowledge networks. In addition to institutions, the institutional incentives and research agenda shape the manner of iterativity between users and producers. In essence, the iteration process should decrease the amount of feedback, changes to the product, and increase efficiency at each iterative step such that by the time the product is finalized not only are user and producers' requirements satisfied but trust is also built between them. Knowledge thus produced reduces the need to customize, value add, and retail, after the knowledge is produced. However, since the knowledge produced is specific to the users, it may not be widely applicable but, iterativity makes a strong contender in areas such as climate change information where the needs of users are specific and diverse when enabling institutional and policy conditions foster responsible iterative behavior in users and producers of knowledge.

4. 4. D. ii. Co-production

In the sociology of science, two modes of knowledge production are recognized. Mode 1 recognizes the cleavage between academia and society, the autonomy of disciplines and universities, and importance of peer-review in the legitimizing knowledge produced (Shinn 2002; Jasanoff 2010). Contrastingly, Mode 2 or co-production perceives the weakening or collapsing of disciplinary science, fluent movement of task-force systems of experts to problem domains, and underlines the importance of social and economic problems in establishing the spheres of knowledge generation, thereby making society a controller of knowledge production and use. In the context of bridging the usability gap, Mode 2 type of knowledge generation or co-production is increasingly applicable since a) the knowledge produced is within the context of application b) science is inter-disciplinary, which is the nature of the climate change and its information c) such knowledge is generated in wider areas and not just in the traditional university systems and d) both producers and users have grown more aware of the social implications of their work (Jasanoff 2003). In other words, the process of knowledge generation and use is now more reflexive and accepting of value systems and thus renders socially robust knowledge systems as a viable solution to bridge the usability gap.

5. Conclusions

5. 1. Water resource management in Bolivia

The organizations in the Bolivian water sector are multiple and complex. Decision-making organizations are mainly governmental institutions even though they are strongly influenced by very-active stakeholders such as societal actors, non-governmental organizations, and donor agencies. The civil unrest following the 'water wars' and the indigenous rights movement has left an indelible institutional memory and is often cited by decision-makers as the pivotal moment for organizational reform, which has contributed to the organizational diversity seen in present day. Bolivia's legislation governing water is incomplete, outdated and falls short in clearly stating user rights. In addition, Bolivia has attempted with popular participation to create a new law to govern water resources, but has been unsuccessful to date (World Bank 2006b).

The organizations represent a unique scalar arrangement with clear delegation of duties to regional and local entities within each organization. This has, not surprisingly, created a hierarchy in decision-making through organizational rules and standard operating procedures, which decreases flexibility in decision-making at lower levels of management. Since most of TDPS is downstream of Lake Titicaca, which is managed by the autonomous ALT, international negotiations with Peru are vital for the sustainable management of TDPS system. Decision-making within organizations is varied and diverse and ranges from following a Management Plan to voting. Decision-making is generally inflexible within an organization and only the high-ranking officials have flexibility in decision-making. All organizations have checks and balances in place that foster organizational redundancy. Functional classification of water sector organizations indicates weak CI production and an almost non-existent boundary space between producers of CI and its consumers.

Any policy that seeks to develop adaptive capacity of decision-makers and organizations in the water sector by enhancing understanding of climate change needs to respect the institutional memory, recent political history and bi-national agreements between Peru and Bolivia. Limitations and persistence of outdated laws, and the organizational inflexibility that resists CI incorporation in decision-making are additional factors that should influence knowledge-based policy making.

5. 2. Multi-scale governance of Bolivian water resources

Analysis of scales of politics identifies policy levers and societal actors that can be utilized for sustainable management of water resources. In the multi-scalar water governance in Bolivia, mismatches occur at political, physical, and informational scales. Political scale mismatches are symptomatic of earlier re-scaling efforts and on-going political and indigenous movements. In addition, the subsuming of national politics of water governance in general and TDPS in particular within the bi-national politics adds additional layers of scale complexity. Physical scale issues such as natural stressors and its cascading effects in TDPS and frequent attempts at re-scaling infrastructure undermine efforts by organizations that strive for better water governance. In addition lack of regulatory agencies and pollution compliance challenges in upstream locations exacerbate existing quality and quantity issues. Lastly, lack of pertinent CI that matches the scale of water management creates informational scale barriers. In addressing policy for CI based water management, scales of politics, position, and information need to be analyzed for the triage of matches and potential and actual mismatches.

5. 3. Climate information use

All key-informants of 2009 (except two respondents) and 2010 seek CI from richly diverse sources. Availability of CI is a factor of both access to CI and its usability. The type of sources available is correlated with the scale of politics where, informants at higher political scales have access to all available sources of CI, especially those that are highly technical and generated mostly by SENAMHI, while informants at lower political scales access CI (or meteorological data) through popular mass media and municipal government offices. Certainty of CI decreases with scale of politics, while interestingly use of CI in decision-making increases. At lower political scales, higher use of uncertain data may be because a) decision-makers are not held accountable by society for their decisions or b) there are no alternatives to uncertain data. On the other hand, decision-makers at higher political scales frequently cite uncertainty in CI, lack of usability, and institutional barriers to use of CI. The CI generated by this study was perceived as highly useful by decision-makers, however it was not usable since a) the data presented did not include certainty measures, b) faced informational scale mismatch, i.e., the information provided was at national level, while decisions made were at diverse political scales, c) the presented data failed to 'fit' the decision-makers need or d) the organization did not have the capacity to incorporate CI.

5. 4. Further Research

This research of Bolivian decision systems in the water sector highlights several knowledge gaps and provides insights for future research. Firstly, the causal mechanisms that encourage use of highly uncertain data in lower political scales of management need to be investigated. This will likely shed light on differences in uptake of CI among various political levels. Secondly, Bolivia faces innumerable societal challenges and current decision-making is burdened by a multitude of aspirations – indigenous, development, national and regional identity, and decentralized management. A study of importance of CI in comparison to these aspirations and CI's contribution for achieving these aspirations will enhance the understanding of the priority of CI when stacked up against other societal goals. Thirdly, the intersection of water resource management and policy with other sectors will potentially provide for a holistic approach to natural resource management that will enhance resource use efficiency, identify common areas of management, and prevent repetitive inter-sector programs. Lastly, a study of natural resource laws and its comparison with countries that face similar governance challenges will provide an adequate baseline for law and policy reform.

From a theoretical view, iterative and interdisciplinary studies such as this study, should be repeated in various contexts such as *in situ*, experimental, and computer simulations so that the mechanisms of CI use can be fully analyzed for integration into policy making.

6. Policy recommendations

Climate information and decision-making: the promise and the challenges

Use of climate information in decision-making boosts the adaptive capacity and helps social ecological systems prepare for the adverse and imminent effects of climate change. However, the incorporation of climate information requires information that will fit decision-maker needs and match physical and political scales of management. Bolivia's water management strategies need to be based on assessment of user needs and seek to involve the producers and consumers of information in a common platform. Boundary organizations are critical to the use of information and will be essential for ensuring producer – consumer interaction for the creation of new information and enabling the fit of existing climate information.

Recommendations

1. To promote climate information producer – consumer interaction the Ministry of Environment and Water should mandate that decision-making at all levels of management involve SENAMHI.

Under current decision-making systems, Bolivia's water managers actively seek climate and meteorological information. However, information seeking is dependent on the decision-maker and not an organizational requirement. By mandating climate information based decision-making, SENAMHI will need to be actively involved thereby increasing the accountability of both decision-making and climate information.

2. To foster creation of usable information, an appraisal of existing climate information must to be conducted that will inform the data gaps.

Existing use of climate information and production of such information needs to be apprised for current producer capabilities and future need. Appraisals will identify gaps in data production and fit of existing data with decision-maker needs. Identification of data need and use priorities will help create economic conditions that will realize the full potential of climate information in decision-making.

3. To maximize the use of available institutional and infrastructural capacities and minimize the adverse effects of climate change on the water sector, main water use sectors such as irrigation, mining, fisheries and domestic use will be the area of focus for incorporation of climate information in decision-making.

Bolivia has a unique opportunity to combine its development plans, increase its economic growth and reduce poverty by focusing on water - based sectors such as agriculture, fisheries, and mining. Urban and rural water needs are critical to economic development. By focusing on efforts to minimize the projected impacts of climate change by incorporating climate information in decision-making, Bolivia can potentially synergize its development and climate change agenda's. However, achieving positive synergies will demand high quality climate information that fits user needs produced with interactive climate information consumer and producer interface.

4. To facilitate the use of climate information and creation of new usable information, boundary organizations need to be created that will simultaneously increase the interaction of producer – consumers of climate information an the fit of climate information in decision-making.

Boundary organizations that communicate, mediate, or translate climate information to decision-makers are a critical need in Bolivia's water management landscape. Creation of boundary organizations can be modeled on either similar organization in other sectors such as irrigation or the socially active water rights movement. Modeling of new boundary organizations based on successful examples of other countries will potentially replicate the success of climate information use in Bolivia.

5. To prevent mismatches of information production and use, a framework of decision-making that fosters linkages based on similarities of information need needs to be developed.

Identification of linkages and similarities of institutional arrangements that create, disseminate, and use climate information will prevent mismatches of scale and increase efficiency of resources required for information production and use. Addressing cross – scale interactions will help design a framework that addresses effective implementation of information-based policy.

6. To promote a reform in decision-making, existing laws and policies need the complete involvement of societal groups, donor agencies, and climate information providers.

Bolivia needs urgent reform in water laws and policies. Involvement of stakeholders that include societal and interest groups, donor agencies, and critically climate information providers, will legitimize the role of society in reformation of existing laws by inclusive politics. Climate information produced together by SENAMHI and society informs law and policy making by shaping climate change agenda, enhancing accountability of decision-makers and stakeholders, and ensuring the equity of multitude of actors in Bolivia's water sector.

Appendices

Appendix 1. The 2009 Questionnaire

Section 1. Organization and role
Sección 1. Organization y función

1. Name of the Respondent (Nombre del demandado)
2. Organization (Organización)
3. Position within the organization (Posición dentro de la organización)
4. Could you briefly explain your role within the organization? (¿Podría explicar brevemente su papel dentro de la organización?)
5. Are you aware of any similar organizations with similar roles? (¿Tiene usted conocimiento de cualquier similares con organizaciones similares funciones?)
6. What is the scope of your organization in relation to other organizations if any? (¿Cuál es el alcance de su organización en relación con otras organizaciones si las hubiere?)
7. Are you aware of climate change? (¿Es usted consciente del cambio climático?)
8. Can you describe a few personal observations of climate change implications? (¿Puede describir algunas observaciones personales repercusiones del cambio climatic?)

Section 2. Organizational Norms
Sección 2. Normas de organización

9. Could you describe your organizational structure? (¿Podría describir su estructura organica)
10. How are decisions typically made within your organization? Can you provide any examples? (¿Cómo se toman las decisiones normalmente dentro de su organización? ¿Puede ofrecer algunos ejemplos?)
11. What are the rules you have to follow when making a decision? Examples: authorization, preliminary analysis, permits, reports etc (¿Cuáles son las normas que han de seguir en el de tomar una decisión? Ejemplos: la autorización, los análisis preliminares, permisos, informes, etc)

Section 3. Knowledge and innovation
Sección 3. El conocimiento y la innovación

12. What are the sources of information for your organization? (¿Cuáles son las fuentes de información para su organización?)
13. How do you typically access information? (¿Cómo acceder a la información general?)

14. What types of information do you seek? What are the current information needs? (¿Qué tipo de información que está buscando hacer? ¿Cuáles son las actuales necesidades de información?
15. How is information incorporated into decision-making process? (¿Cómo es la información incorporada en el proceso de toma de decisiones?)
16. How does availability of new information affect your decision-making? (¿Cómo funciona la disponibilidad de nueva información afectar su toma de decisiones?)

Section 4. Motivation and professional activity
Sección 4. La motivación y la actividad profesional

17. How motivated are you towards your profession and job? ? (¿Cómo estás motivado hacia su profesión y trabajo)
18. What motivates you to do a good job? How do you know you do a good job? (¿Cómo estás motivado hacia su profesión y trabajo)
19. What information, changes in institutional structure (any other change) would help motivate you further? (¿Qué tipo de información, los cambios en la estructura institucional (cualquier otro cambio) que ayudará a motivar a seguir?)

Section 5. Water use, allocation and decision-making.
Sección 5. El uso del agua, la asignación y la toma de decisiones

20. What are the main water sources at national/regional/local levels? Depending on the respondent (¿Cuáles son las principales fuentes de agua en los planos nacional, regional o local? Dependiendo de la parte demandada)
21. What are the main water use sectors at national/regional/local levels? Depending on the respondent (¿Cuáles son los principales sectores de uso del agua a nivel nacional / regional / local? Dependiendo de la parte demandada)
22. Who manages the water at local, regional, and national levels? Are they linked and how? (¿Quién gestiona el agua a nivel local, regional y nacional? ¿Están vinculados y cómo?)
23. What is the current water policy at national/regional/ levels of governance? (¿Cuál es la actual política del agua en los planos nacional, regional y los niveles de gobierno?)
24. What are the historical and recent polices that have shaped current water governance? (¿Cuáles son los antecedentes históricos y recientes que han dado forma a las políticas actuales de gestión del agua?)
25. What are the historical and recent past changes in water availability? (¿Cuáles son los antecedentes históricos y recientes cambios en la disponibilidad de agua?)
26. Are you aware of any effects of climate change on water availability? (¿Es usted consciente de los posibles efectos del cambio climático sobre la disponibilidad de agua?)
27. What are the sectors that currently use water (at the particular level, from earlier question)? What is their proportion/percentage of use? ¿Cuáles son los sectores que actualmente utilizan el agua (en el nivel particular, a partir de la pregunta anterior)? ¿Cuál es su proporción y porcentaje de uso?)

28. How is water allocated among these sectors? Which organization oversees allocation? What is the justification for water allocation? (¿Cómo se reparten entre el agua de estos sectores? Organización que supervisa la asignación? ¿Cuál es la justificación para la asignación de los recursos hídricos?)
29. Has diversification of water been constant or dynamic? What are the factors that have governed the patterns of constancy or dynamics? (Diversificación ha sido una constante de agua o dinámico? ¿Cuáles son los factores que han regido los patrones de constancia o dinámica?)

Section 6. Climate information
Sección 6. Información sobre el clima

30. Do you routinely seek climate information for your decision-making? (¿Te buscan habitualmente información sobre el clima para su toma de decisiones?)
31. What is/are the source/s of climate information? (¿Qué es / son la fuente / s de información sobre el clima?)
32. How reliable is this information? Have there been any inconsistencies? (¿Cuán confiable es esta información? ¿Ha habido alguna incoherencia?)
33. Do you incorporate climate information into the decision-making process? (¿Se incorporará información sobre el clima en el proceso de toma de decisiones?)
34. What kind of climate information do you require? (¿Qué tipo de información sobre el clima que necesita hacer?)
35. Would you incorporate climate information into decision-making process if provided? (¿Le incorporar información sobre el clima en el proceso de toma de decisiones si se proporciona?)
36. What may be probable changes in decision-making if climate information is provided? (Lo que puede ser probables cambios en la toma de decisiones si se proporciona información sobre el clima?)

Appendix 2: The 2010 Questionnaire

1. Do you routinely seek climate information for your decision-making? (¿Te buscan habitualmente información sobre el clima para su toma de decisiones?)
2. What is/are the source/s of climate information? (¿Qué es / son la fuente / s de información sobre el clima?)
3. How reliable is this information? Have there been any inconsistencies? (¿Cuán confiable es esta información? ¿Ha habido alguna incoherencia?)
4. Do you incorporate climate information into the decision-making process? (¿Se incorporará información sobre el clima en el proceso de toma de decisiones?)
5. Would you incorporate climate information into decision-making process if provided? (¿Le incorporar información sobre el clima en el proceso de toma de decisiones si se proporciona?)

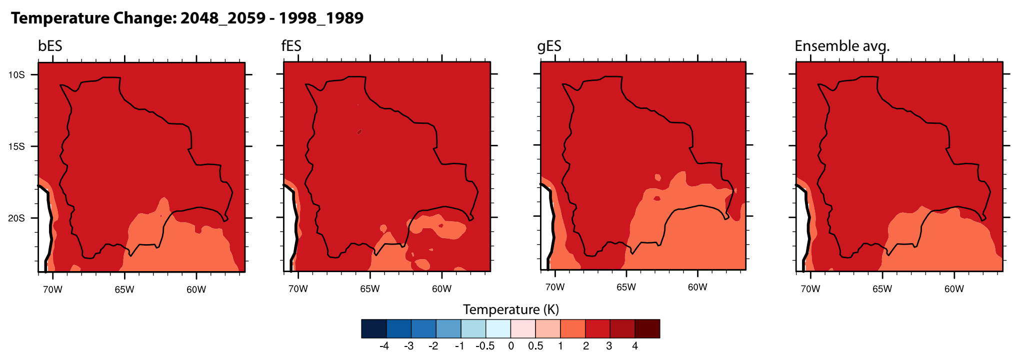
Present climate information (described in Appendices 3 and 3a)

6. How useful is this dataset to you? (¿Qué tan útil es este conjunto de datos para usted?)
7. Who do think the climate information provided would affect most? (Based on graph's/data provided?) (¿Quién creo que la información sobre el clima siempre afectaría a la mayoría? (Basado en gráfico / datos aportados?)
8. Would you incorporate this data in your decision-making? (¿Le incorporar estos datos en su toma de decisiones?)
9. If yes, how? (En caso afirmativo, ¿cómo?)
10. What may be probable changes in decision-making if climate information is provided? (Lo que puede ser probables cambios en la toma de decisiones si se proporciona información sobre el clima?)
11. Do you foresee a change in climate information as a function of greater awareness of climate change risks as shown in the downscaled data? (¿Cree que un cambio en la información sobre el clima en función de una mayor conciencia de los riesgos del cambio climático, como se muestra en los datos de reducción de escala?)
12. How does climate information compare with other priorities in water management? (¿Cómo comparar la información climática con otras prioridades en la gestión del agua?)
13. What other data would you like? And how would it help you make better management decisions? (¿Qué otros datos que te gusta? ¿Y cómo lo ayudará a tomar mejores decisiones de manejo?)
14. How would you like your data presented? For example as maps, numbers, brochures or publications? (¿Cómo le gustaría que sus datos que se presentan? Por ejemplo, como mapas, números, folletos o publicaciones?)

<u>Appendix 3. Downscaled climate information produced by this study: summary of projected impacts: summary of downscaled climate data to be provided to respondents</u>

<u>Figure 1. Climate Downscaling</u>
Regional model experiments are completed using RegCM that is driven by output from global climate model NCAR Community Climate Model. The reason to downscale is that global models are very coarse and do not capture small-scale processes or features. This is the same as Figure 3, p. 29.

<u>Figure 2. Summer average, maximum, and minimum surface air temperature for 1990s, 2050s, and 2090s.</u>
These panels show the ensemble-average surface temperature during Dec-Jan-Feb for 3 time periods.



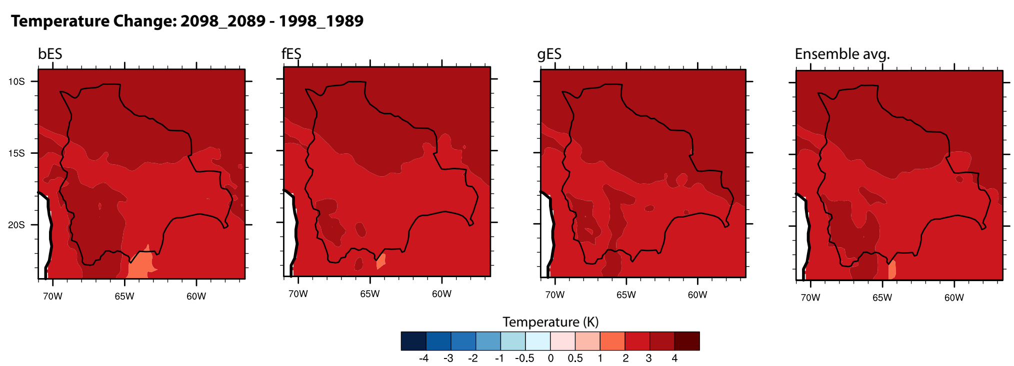


Figure 3. Summer average, maximum, minimum surface air temperature, and precipitation change from 1990s.
These panels show the ensemble-average surface temperature change during Dec-Jan-Feb for the periods 2050s – 1990s and 2090s – 1990s.

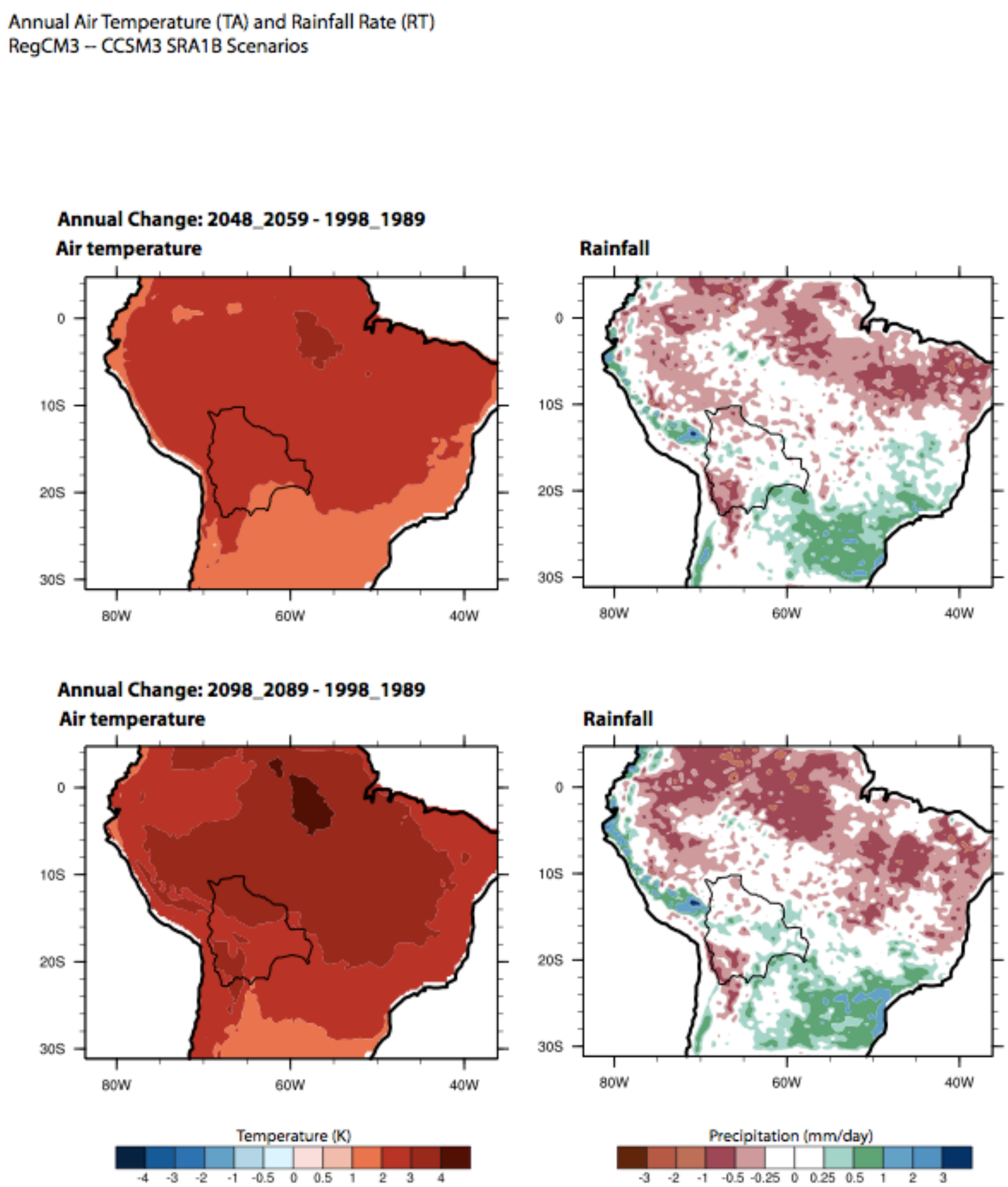


Figure 4. Annual surface temperature change from 1990s

These panels show the ensemble member and ensemble-average annual surface temperature change. In both scenarios, the surface temperature will increase. In the 1950s, the surface temperature is predicted to increase by 2-3 C. By the 1990s, the increase is predicted to be 2-3 C in central Bolivia, and 3-4 C in southern and northern Bolivia.

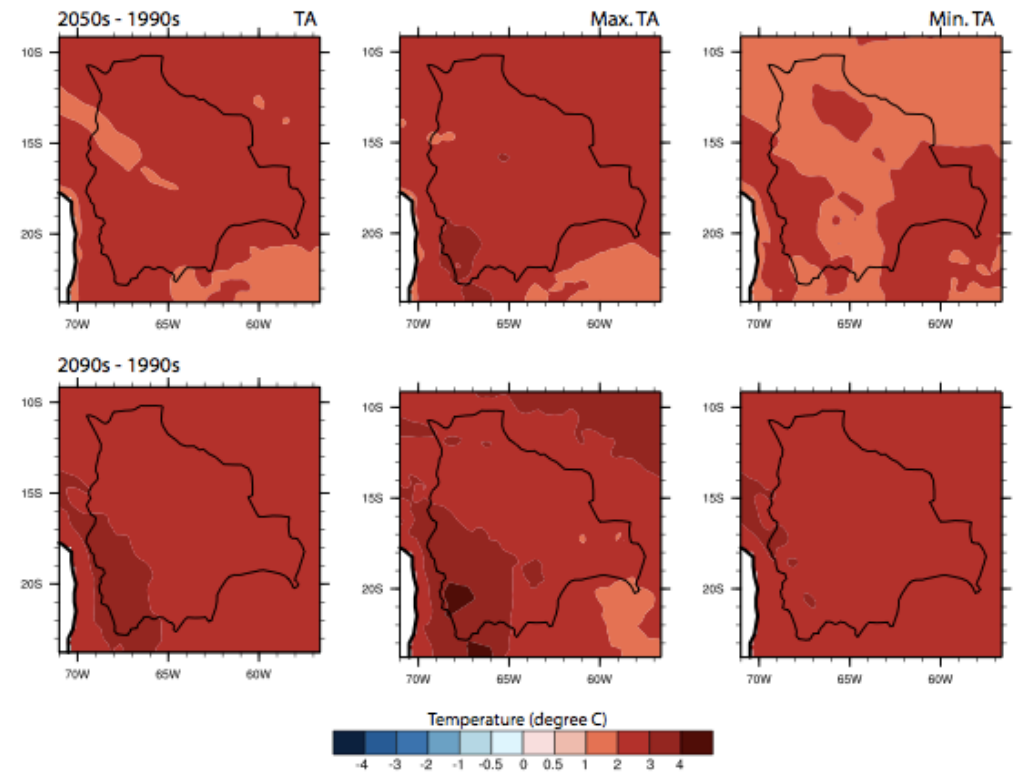
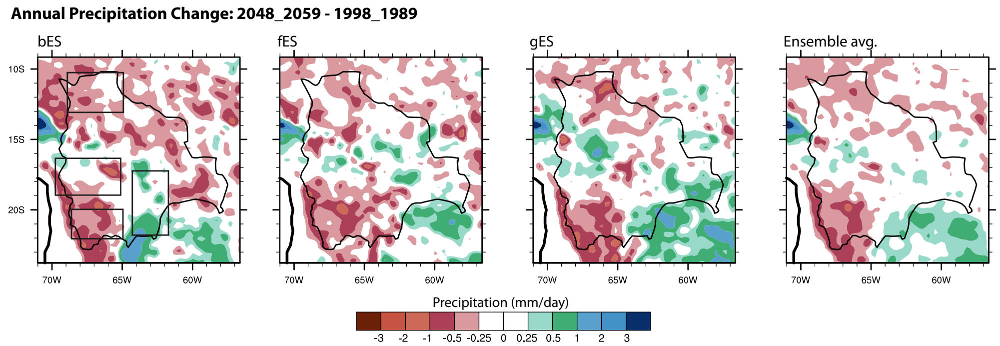


Figure 5. Annual precipitation change from 1990s

These panels show the ensemble member and ensemble-average annual precipitation change. Northern Bolivia and the southern Bolivian Plateau are consistently predicted to have less precipitation.



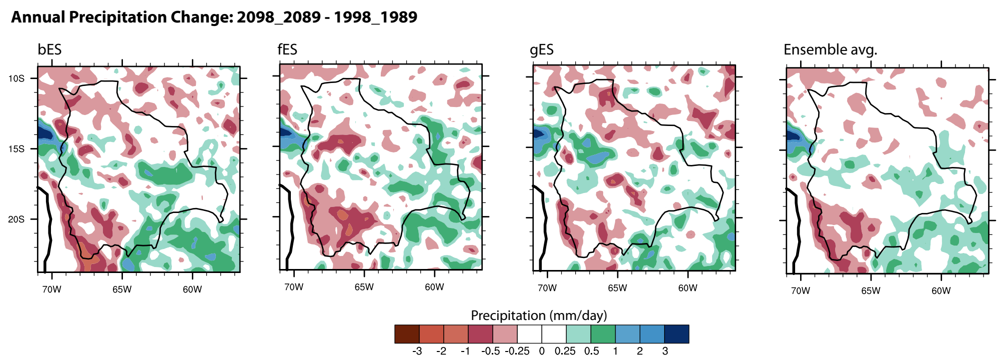


Figure 6. Seasonal precipitation change from 1990s

These panels show the ensemble-average precipitation change for spring (Sept-Oct-Nov), summer (Dec-Jan-Feb), and winter (Mar-Apr-May). Precipitation is reduced on the southern Bolivian Plateau in all seasons. The largest change is in the spring. Precipitation on the northern Bolivian Plateau decreases in the spring, but increases in the summer. However, the increases in summer precipitation are compensated by an increase in evapotranspiration (see Figure 5).

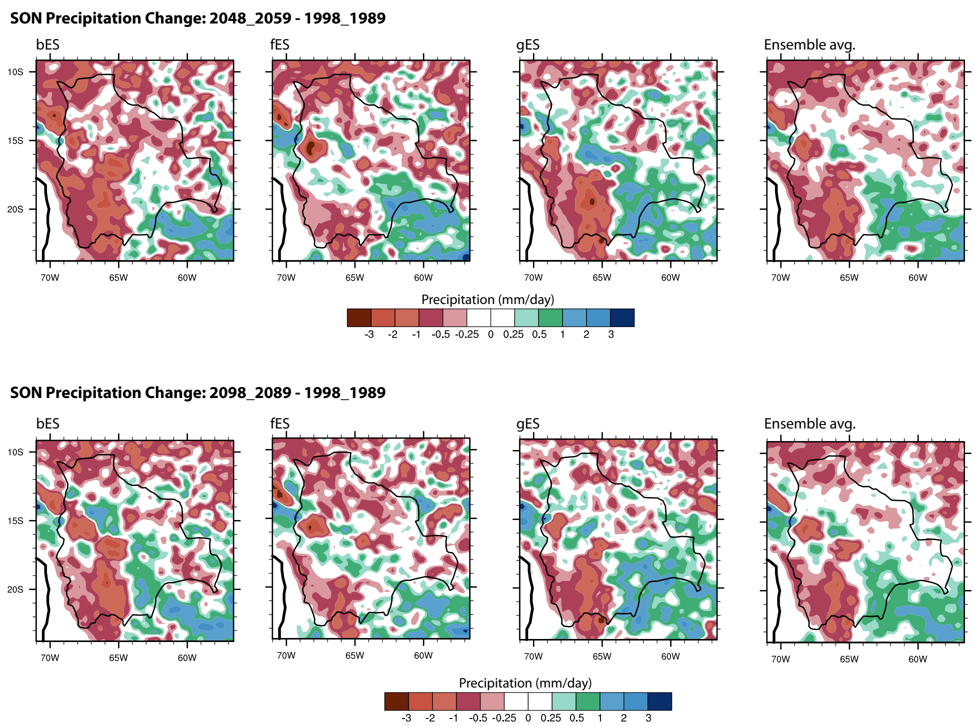
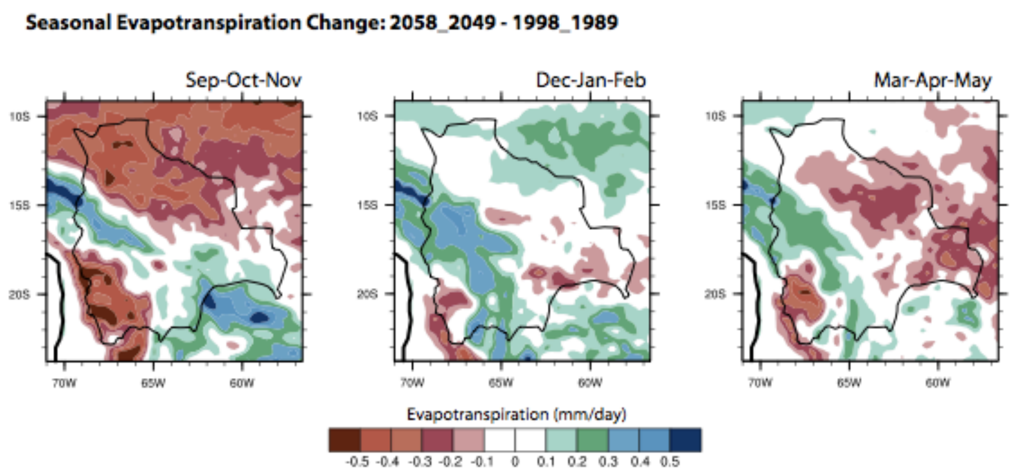


Figure 7. Seasonal evapotranspiration change from 1990s
These panels show the ensemble-average evapotranspiration change for spring (Sept-Oct-Nov), summer (Dec-Jan-Feb), and winter (Mar-Apr-May).
Evapotranspiration on the southern Bolivian Plateau is reduced. This is because there is less precipitation (see F6), so less water to evaporate. The reduction in precipitation wins out, as a result this region will be dryer. Evapotranspiration on the northern Bolivian Plateau increases, because surface temperatures are higher. This compensates for the small increases in precipitation. As a result, the northern Bolivian plateau will become somewhat dryer.



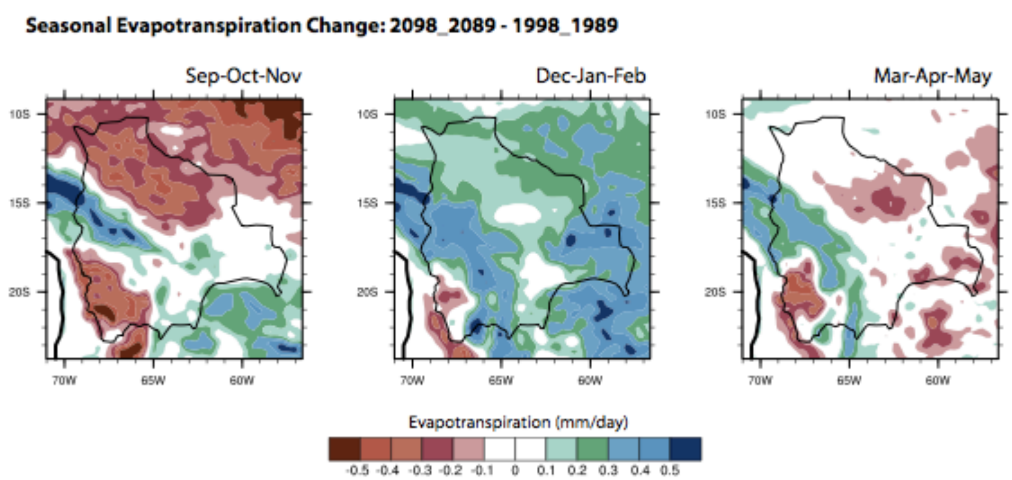


Figure 8. Change in seasonal runoff from 1990s

These panels show the ensemble-average runoff change for spring (Sept-Oct-Nov), summer (Dec-Jan-Feb), and winter (Mar-Apr-May). Runoff will be reduced over most of the Bolivian plateau. The exception is the northern Bolivian Plateau. In this region, the summer precipitation is predicted to increase. Most of this precipitation will occur in heavy storms, and as a result will not saturate the soil profile, but rather will runoff.

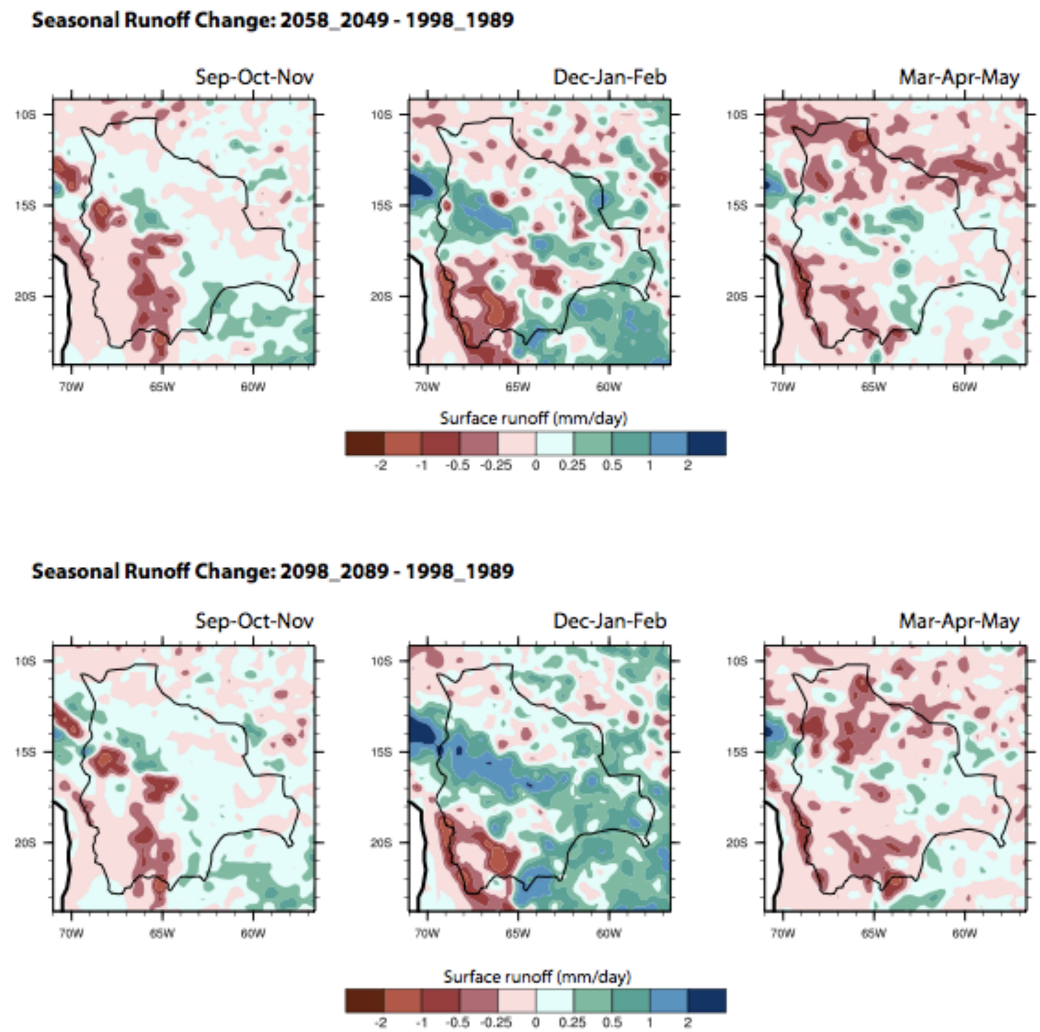


Figure 9. Change in annual root-level soil-moisture from 1990s

These panels show the annual ensemble-average runoff change. Over most of Bolivia the soil will become dryer. This, of course, will make agriculture more difficult. The change will be most severe in southern and central Bolivian Plateau. The reason for the decrease in soil moisture is directly related to the decrease in rainfall (for most regions) and the change from low- to extreme-rainfall events, and enhanced evapotranspiration.

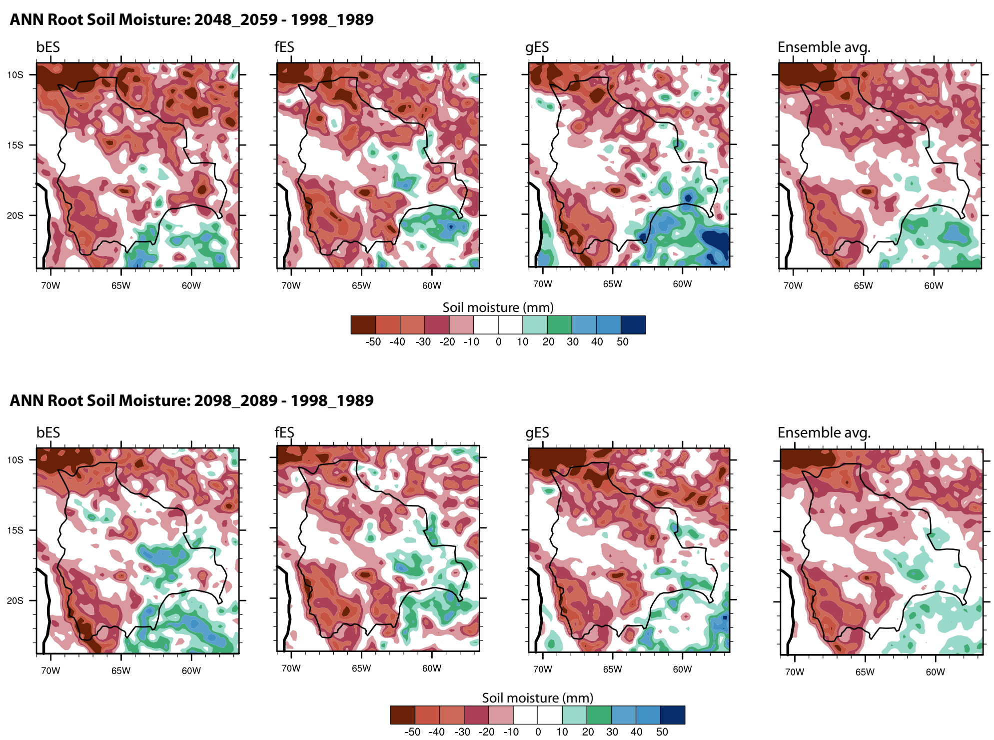
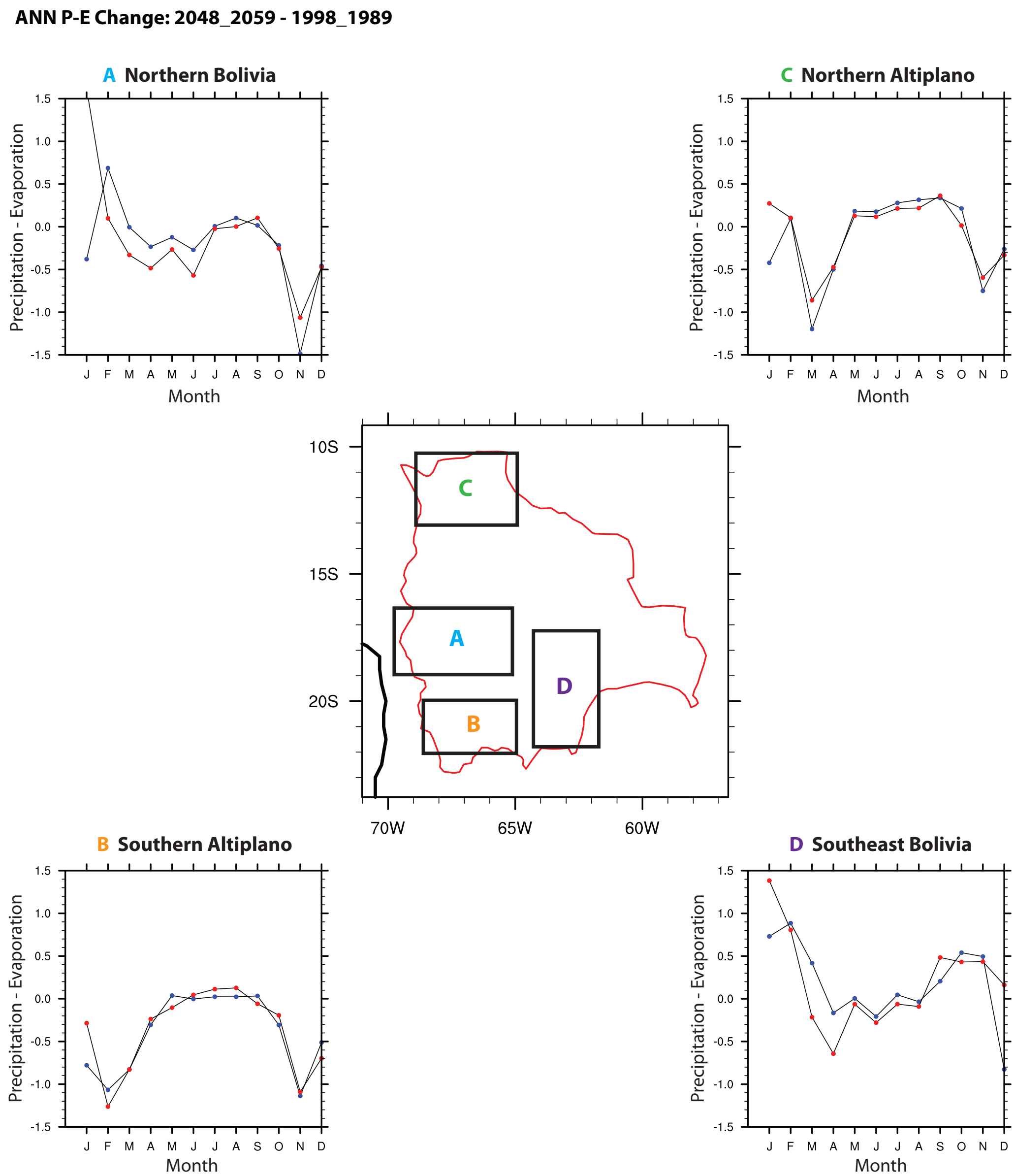


Figure 10. Change in monthly precipitation minus evaporation from 1990s
The plot shows the seasonal change in precipitation minus evaporation for 4 regions. The model predicts that the summer monsoon rains will be delayed in regions A, B, and C. The precipitation minus evaporation change is similar for the 1950s and 1990s. This is related to the fact that most of the temperature change is predicted to occur between the 1990s and 1950s. The model predicts that surface temperatures will increase between 2-4 C across Bolivia. The model also predicts that most of the plateau region will become dryer either due to a decrease in rainfall or an increase in evapotranspiration.



Appendix 3. a: Downscaled climate information produced by this study: summary of projected impacts of climate change

1. The hydrological changes reported here are likely to make agriculture on the plateau more challenging, primarily through a reduction in rainfall and soil moisture.
2. The fact that much of the drying occurs in the spring when many crops are planted and germinating presents an additional challenge to farmers, irrigation agencies, and community water managers.
3. It is also likely that lake levels will be affected and may decrease due to enhanced evapotranspiration. Since, Lake Titicaca loses most of its water by evaporation, the increase in temperature and decrease in precipitation will decrease the lake volume and as a result downstream flow.
4. The model predicts an increase in extreme rainfall events, making summer flooding more common in some regions. The downscaled data helps communities increase extreme-weather preparedness thereby increasing the adaptive capacity. However, the methods for increasing adaptive capacity will face common barriers of resources, capacity, institutions, and response time.
5. Temperature increases will likely accelerate melting of mountain glaciers. Several studies in Bolivia have documented glacier melting, and almost all respondents from last year made a reference to melting of Chacalataya glacier. In the next few days I will summarize a few reports that illustrate this impact.
6. It is not clear whether the temperature increases will affect crops. A more detailed analysis of specific crop tolerances is necessary to come to any conclusions. (For example, in 2008, quinoa production was down 40% due to frosts in November. The warming predicted here would make this outcome less probable. However, water shortages can also lead to a reduced yield).

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