BOOK OF ABSTRACTS

I TROPICAL GLACIERS SYMPOSIUM

Synthesis Workshop:
WEATHER: a scientific approach in Water sEcurity and climATe cHange adaptation in pEruvian glacieRs

August 16–17, 2019
Lima, Peru

Sponsored by:

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WEATHER: a scientific approach in Water sEcurity and climATe cHange adaptation in pEruvian glacieRs

THEME A

GLACIERS AND WATER SECURITY

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Universidad de Ingenieria y Tecnologia
August 16-17, 2019, Barranco, Lima

KEYNOTE LECTURE

ANDEAN GLACIER CHANGES DURING RECENT DECADES AND THEIR IMPACTS ON WATER RESOURCES

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ABSTRACT

The Andes have experienced strong and increasing glacier retreats since their maximum neoglacial position that was reached during the Little Ice Age (~150 years BP). Some glaciers along the region have experienced small changes, but in some areas they have almost disappearing like Chacaltaya in the Cordillera Real of Bolivia. The main driving force behind this glacier wastage is climate change, characterised by rising temperatures observed at high elevations where glaciers are located. However, many glaciers are capping volcanoes of the Northern, Central and Southern Volcanic Zones (respectively NVZ, CVZ and SVZ) and thus, have proven also vulnerable to geothermal fluxes and eruptive or explosive events recorded in historical times. As a result, glacier response to climate is amplified by the regional volcanism, usually in the form of enhanced retreat mainly due to surface albedo changes by tephra deposition. The sudden melting of glacier ice and snow taken place in the region is having an increasing hazard to the surrounding human settlements. On-going glacier changes are also affecting long term water runoff availability especially in the areas highly dependent on summer runoff originated by glaciers. Overall, high-altitude tropical glaciers are among the most vulnerable mountain ice masses to ongoing climate changes. In this talk a synthesis of present glaciers scientific knowledge will be presented including a discussion of the possible impacts of glacier area reductions for the hydrological resources availability.

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EVOLUTION OF THE GLACIER COVERAGE AND ITS INFLUENCE ON THE WATER AVAILABILITY OF THE BLANCO RIVER SUBBASIN – SANTA RIVER BASIN

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ABSTRACT

The objective of the research is to know the variation of glacier coverage in Blanco river subbasin order to establish its influence on water availability. For this, the glacial coverage of the Blanco river subbasin during the 1987-2016 period was evaluated as a first step. Then, the water behavior of the Blanco river subbasin was evaluated with the purpose of estimating the discharge by thaw. Finally, the future scenarios of glacier coverage, the glacial water reserve (volume) and the discharge by thaw (m^3/s) were determined. Techniques of GIS and Remote Sensing, the dependent-slope thickness method, hydroclimatic regionalization, flow analysis, duration curve, water balance and the deterministic-stochastic Lutz Scholz model were applied. From the results it was found that the glacial coverage has regressed by 23,5% (8,87 km^2) during the 1987-2016 period, with an average retreat rate of -0,35 km^2 /year. Likewise, the glacial water reserve (volume) was reduced by 30,4% (299,1 x 10^6 m^3) and with an average retreat rate of -13,1 x 10^6 m^3 / year. On the other hand, taking into account the months of low water, which show a significant decrease in rainfall, it was obtained that the discharge by thaw on average is 1.78 m^3/s, this type of flow being the main source of supply water of the rivers at this time of year. Finally, it was estimated that by 2050, the glacial coverage and glacial wáter reserve will be reduced by 44,7% and 57,0% respectively from the values found in the year 1987 and the discharge by thaw will have an approximate value of 1,2 m^3/s.

Keywords: Glacier coverage, glacier water reserve, discharge by thaw, water availability, Blanco river subbasin

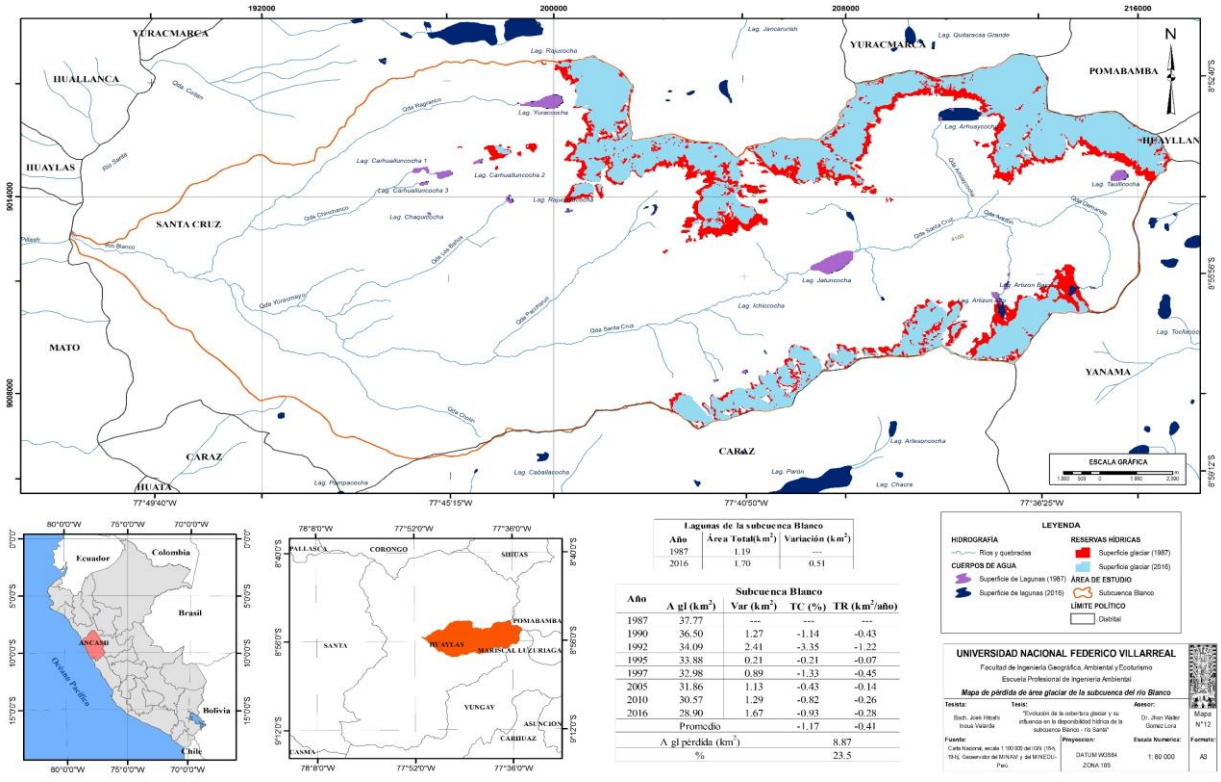

Figure 1. Pérdida del área glaciar de la subcuenca del río Blanco.

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INFLUENCE OF CLOUDINESS ON THE INCIDENT SHORTWAVE RADIATION OF NEVADO COROPUNA

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ABSTRACT

The Nevado Coropuna (NC) is located in the volcanic Cordillera Ampato, and it has glaciers that represent the most important freshwater for the Arequipa region. The aim of this work is to analyze the influence of cloud cover on shortwave radiation incident of NC, which is altered in the presence of clouds mainly in the rainy period, from 2015 to 2016. For this study, it was used hourly radiation data from Automatic Weather Station, conventional weather stations and meteorological satellite GOES 13 data, which has a high temporal resolution. To estimate the cloudiness, it was applied Spectral Composite Threshold (Jedlovec, 2009).

During the austral summer, Peru has the rainy period from December to March, caused by the most humidity advection, an income of the East flux from the basin Amazon and the formation and intensification of High Bolivia. Besides in specific years, such as “El Niño” or “Coastal Niño”, anomalies positives of the sea surface temperature favors with an income of humidity and increase of rainfall in the occidental side of NC. Arequipa region has a diurnal cycle, during the day, has more clouds between December and March above 80%. At night the cloudiness diminishes significantly, hourly there are more clouds in the afternoon. The NC has a similar pattern, and there is a difference between the oriental and occidental side. The cloudiness has a high impact in the incident shortwave radiation, in clear days the average hourly radiation could reach up to 1200 W/m2; meanwhile, in cloudy days this does not pass the 600 W/m2. Meantime, in the dry period, generally there are not clouds; in the conventional meteorological stations are found predominantly high clouds, cirrus. In summary, the cloudiness in the occidental Tropical Andes plays an important role in the rainy period, blocking the incident radiation above the NC, protecting the West glaciers and diminished the available energy to ablation process.

Keywords: Nevado Coropuna, Cloudiness, Radiation, Tropical Andes.

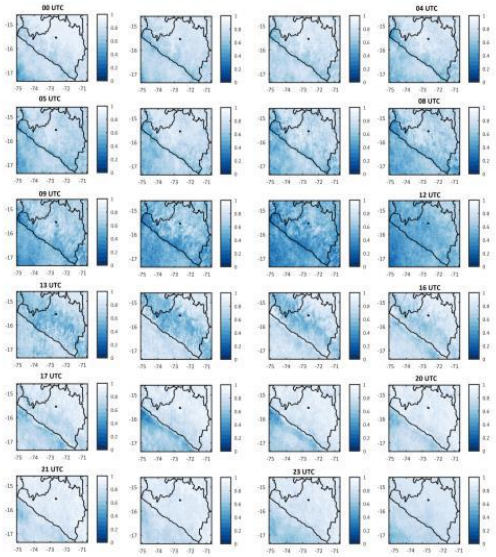

Figure 1. Diurnal and nocturnal variation of cloudiness in the summer of 2015, observe that in the early morning there no much cloud, but the afternoon and night is generally cloudy.

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INTEGRATED UPSTREAM AND DOWNSTREAM THINKING TO MITIGATE THE WATER SECURITY CHALLENGES OF PERUVIAN GLACIER RETREAT

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ABSTRACT

The Santa River is the first basin, at a national scale in Peru, where international aid organizations have offered humanitarian aid, because of the frequency of disaster events, many related to climate change and glacial retreat. Over recent years, NGOs and international institutions have begun work on mitigation activities e.g. environmental management adaption, changing agricultural practices, etc. but to date their impact has been point-specific, reactive and isolated. Although, the Santa basin is the most studied catchment system in Peru in this regard, the increasing rate of scientific publications has not yet translated into the development and improvement of management and adaption policies. For example, Morera et al. (2013) found that the Santa catchment has the highest erosion and sediment transport rates along the Pacific coast – reflecting the susceptible geology and intense mining activity - but to date there has been no policy response. In the face of identified problems, key policy questions remain unanswered; e.g. does transitioning of land use affect water balance (i.e. from bofedal, páramo, jalca into grassland, agriculture, mining, etc) and how are these changes augmented/affected by glacier hydrological processes and retreat, subsurface water and groundwater dynamics. These critical scientific-technical gaps are made worse by the lack of tools or strategy to integrate scientific evidence of spatial and temporal dynamics of basin changing basin processes with ecosystem service provision in the water-food-energy security nexus. Our strategy encompasses working with four key stakeholder groups: (1) National agencies and the management community; (2) water and hydropower industry; (3) NGOs and commercial practitioner companies; and (4) Peruvian and UK citizens and taxpayers; in order to fill the gaps above and bring real change in policy through a combination of stakeholder engagement, training and knowledge exchange activities. These are integrated with the research programme permitting research and impact to develop iteratively in parallel.

Keywords: glacier, stakeholder, soil erosion, mountain ecosystems

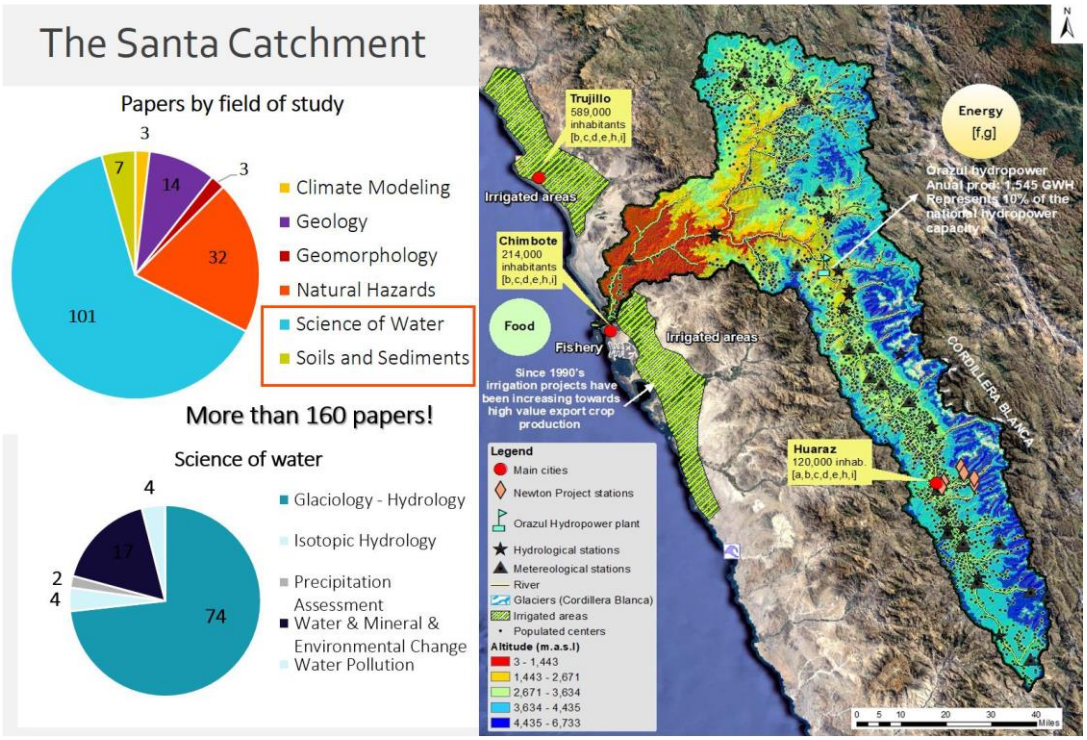

Figure 1. Water-energy-food-livelihood interconnectivity, and pressures on the nexus, in the Rio Santa catchment. Stakeholders include: a) National agencies, b) Decentralized administrations, c) Management community, d) Tourism and recreations, e) Third sector, f) Water industry, g) Hydropower, h) National research institutions and i) International research organizations (see Pathways to Impact).

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THE IMPORTANCE OF KNOWLEDGE OF THE ENERGY BALANCE IN THE TROPICAL GLACIERS OF PERU

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ABSTRACT

Currently, Peru has approximately to 72% of all tropical glaciers in the world, these glaciers are distributed from the center (White Mountain range or Cordillera Blanca) of Peru and borders with Bolivia's southern, the most studied and the central part were (White Mountain range or Cordillera Blanca, Central Mountain range or Cordillera Central and Huaytapallana), since 2010, the National Service of Meteorology and Hydrology of Peru (SENAMHI) with the support of a donation from the World Bank and different institutions began to monitor the climatic conditions in the glaciers by installing weather stations on the same ice; in 2011 the Quisoquipina glacier (Cusco region) at 5180 meters high and in 2013 the west face of the Coropuna snowy (Arequipa region) at 5800 meters high were chosen, these glaciers responded to different climatic conditions either precipitation or humidity. This paper shows the labor carried by SENAMHI in monitoring the climatic conditions on the cryosphere environment of southern Peru, as well as the relationship between the different climatic variables and the important role about shortwave radiation within the energy balance together with the albedo in the regular fusion of these, also shows the periods where theoretically the contributions of ice melting are more important for the management of water resources.

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Palabras Claves: Vilcanota, Coropuna, energy balance, glaciers.

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ANÁLISIS DE LA DISTRIBUCIÓN ESPACIAL Y CARACTERÍSTICAS MORFO-TÉRMICAS DE LOS GLACIARES DE ROCA EN EL SUR DEL PERÚ: CASO, CORDILLERAS HUANZO Y CHILA DE LOS ANDES DEL PERÚ

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ABSTRACT

El cambio climático genera impactos importantes en las regiones de alta montaña y los glaciares tropicales se ven particularmente afectados debido a su alta sensibilidad a estos cambios. A pesar de ello, la información respecto a los glaciares rocosos es muy escasa y hasta ahora no se ha generado una descripción sistemática de las características de dichos glaciares en el Perú, especialmente en el sur donde se encuentran mayormente distribuidos.

Las cordilleras Huanzo y Chila se ubican en los andes del sur del Perú, políticamente Huanzo se extiende en los departamentos de Apurímac, Arequipa, Cusco y Ayacucho, mientras que Chila dentro de Arequipa. Ambas cordilleras se extienden entre las coordenadas 15°39'41.36" a 14°03'17.54" latitud Sur y 73°24'12.55" a 71°27113.20" longitud Oeste. Para este estudio, se usaron herramientas de teledetección y Sistemas de Información Geográfica, haciendo uso de imágenes de Google Earth-Pro y de SASPlanet, DEM ALOS Palsar corregido (12.5m), MERIT DEM (90m) y datos WorldClim (1970-2000) a 1 km2.

El mapeo indica que en la cordillera Huanzo existen 317 glaciares de roca con una superficie total de 26.97 km2 y en la cordillera Chila 289 glaciares de roca con una superficie total de 17.96 km2. Los resultados preliminares indican que respecto a su actividad existen 295 glaciares de roca intactos distribuidos en una altitud promedio de 4,497 m s.n.m. a 5,221 m s.n.m y ubicados entre los rangos térmicos de -1.34°C a 3.97°C y 311 relictos o fósiles entre -1.34°C y 3.97°C. Los glaciares de roca de la cordillera Huanzo están localizados en una altitud promedio que va de los 4,497 m s.n.m. a 5,221 m s.n.m., mientras que en la cordillera Chila se extiende de 4,470m s.n.m. a 5,454 m s.n.m., todos ellos con una orientación predominante de Sur a Suroeste.

Los glaciares de roca contienen hielo que pueden ser una reserva potencial de agua que necesitan ser estudiados para conocer si son una fuente de agua significativa en regiones áridas como en el sur del Perú. La mayor distribución de estos recursos se encuentra en la cuenca Camaná (Vertiente del Pacífico), que tiene 17,6 km2 de glaciares rocosos. En menor proporción en la Vertiente del Atlántico, con 42.4 km2 de glaciares rocosos ubicados en las cuencas del Alto Apurímac y Ocoña.

Keywords: Glaciares de roca, permafrost, morfometría, temperatura, teledetección

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RAHU: IMPLICATIONS OF GLACIER SHRINKAGE ON FUTURE TROPICAL ANDEAN WATER SECURITY AND MANAGEMENT

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ABSTRACT

In the Tropical Andes, year-round streamflow from glaciers is an important water resource that supports human livelihoods and ecosystems further downstream. However, the advanced shrinking of glaciers, in combination with low adaptive capacity, makes this mountain region among the most vulnerable. A case in point is the vanishing of the second-largest tropical glacier fragment worldwide, in the Vilcanota-Urubamba river basin in southern Peru (*Fig. 1*), which leads to serious implications for local water security. However, the spatiotemporal variability and evolution of both the meltwater propagation through the terrestrial water cycle and its contribution to changing patterns in water availability at the catchment scale are complex, poorly understood, and highly uncertain. New approaches need to take into account the complex interactions and feedbacks between drivers of water supply and demand within an extended upstream-downstream perspective. In this context, the international project *RAHU* (*WateR security And climate cHange adaptation in PerUvian glacier-fed river basins; snowy mountain in Quechua*) aims at developing an integrated glacier-water-security-assessment approach to improve evidence and transform the understanding of glacier shrinkage impacts and human vulnerabilities on water security. *RAHU* includes an international consortium of scientists in close collaboration with local stakeholders and is supported by a new partnership between Peru and the United Kingdom. The project includes four components (*Fig. 2*) to be developed in a period of 34 months: WP1 foresees to develop a fully-distributed, physically-based glacier surface energy balance model that allows for a realistic representation of glacier dynamics in glacier melt projections; WP2 helps to design and implement a glacier-hydrology-water resources monitoring approach to quantify non-glacial contributions to water resources and the impact of catchments interventions; WP3 focuses on mapping of human water use at high spatiotemporal resolution and determining current and future levels of water (in)security; and, WP4 was built to integrate the aforementioned WP's to evaluate and support the implementation of locally embedded climate change adaptation strategies at the science-policy-operation interface. With this integrated set-up, it is expected to achieve important outcomes on new glaciohydrological and socioeconomic datasets, glaciohydrological modelling approaches integrated into operational practice and locally relevant methodologies to assess socio-ecological vulnerabilities. Within that framework *RAHU* will focus on specific opportunities to implement interventions based on natural infrastructure in order to support robust and adaptive climate change adaptation strategies.

Keywords: glacier shrinkage, water security, ecosystem monitoring, climate change adaptation.

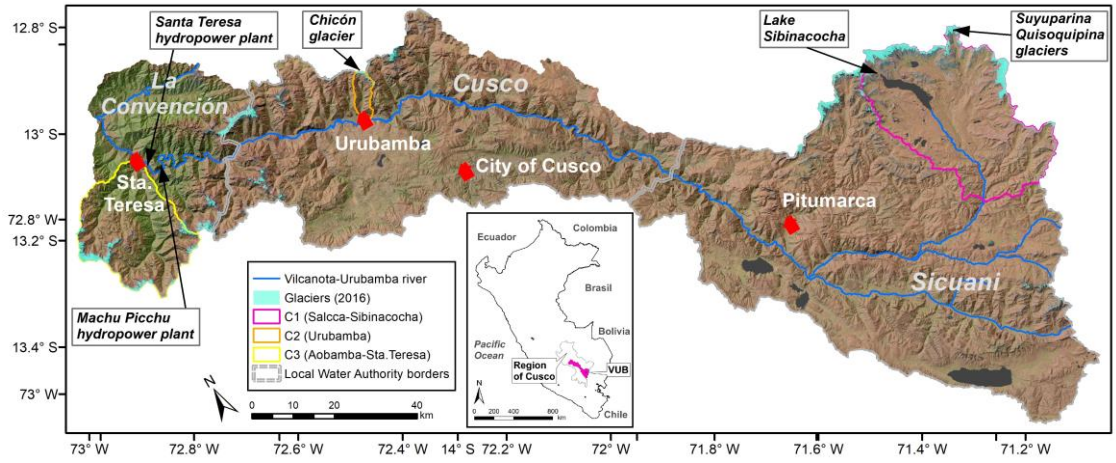

Figure 1. Study area including the three subbasins Salcca-Sibinacocha, Urubamba and Santa Teresa (Vilcanota-Urubamba river basin).

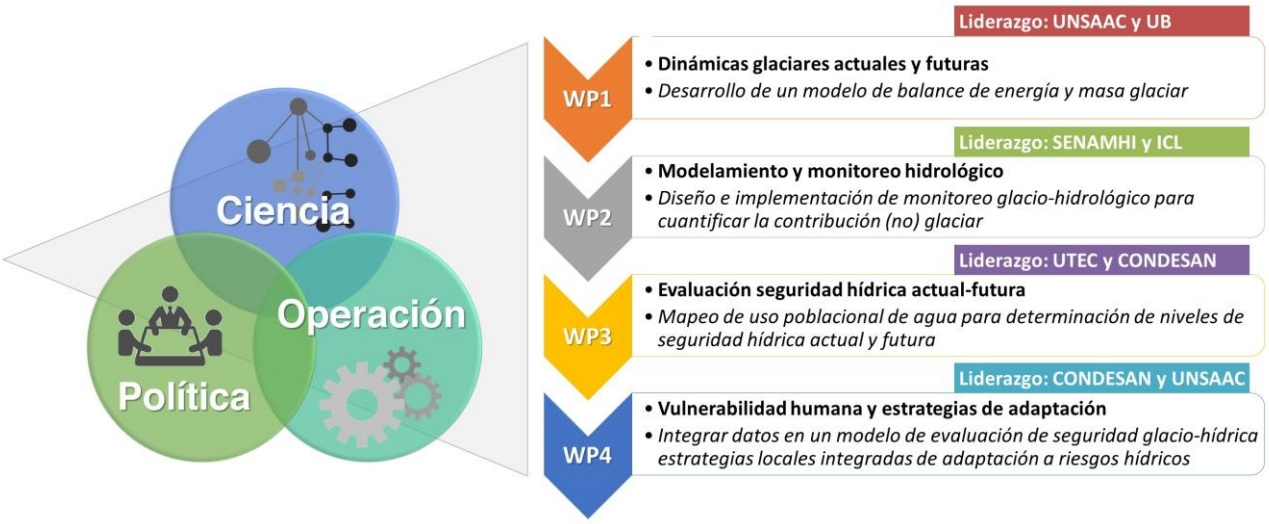

Figure 2. Workflow, components and interface of the project.

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SENSING QUELCCAYA: PALEO-GLACIOLOGY AND PASTORALISM IN A RETREATING ANDEAN GLACIER

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ABSTRACT

During most of the year, the grasslands that feed the herds of alpacas of nearly 100 families in Phinaya, a semi-nomadic pastoralist community in the Southern Andes of Perú, can only be irrigated by rivers that originate in the Quelccaya ice cap. As the largest tropical glacier in the world, and due to its location in a region climatologically sensitive to both the Pacific and Atlantic oceans, Quelccaya has also become a privileged site for climate science research. Ice cores obtained from Quelccaya are considered to be "the longest and highest resolution tropical ice core record to date" and, therefore, one of the most important pieces of evidence for scientific understanding of the last 2000 years of global climate history (Thompson et al. 2013). This paper presents an ethnographic exploration of the ways in which both Andean herders and one of the most influential paleo-glaciology research teams in the world -led by Lonnie Thompson from the Byrd Polar and Climate Research Center of the Ohio State University-, engage with the Quelccaya. By drawing on almost 15 months of accumulated fieldwork with herders in Phinaya, accompanying them on their interaction with alpacas (*vicugna paco*) and vicuñas (*vicugna vicugna*), and on my participation as a field assistant in three of Thompson's most recent scientific expeditions to Quelccaya, this paper seeks to contribute to anthropological knowledge about the Anthropocene by providing new insights into the worlds that are emerging in an Andean community where climate change is materially present. After showing how pastoral activities not only play a central role in the organization, constitution and understanding of social life and the physical environment, but also in the way that the seasonal and cyclical irregularities that we know as climate are experienced in Phinaya, and discussing interesting ways in which the scientific study of ice cores obtained from the Quelccaya complicate the notion of *scale*, my results question the apparent universality of the notion of climate, scientifically understood as the 'average' weather, which is not easily compatible with a subjective, spatially bounded, normative, or total experience of the seasonal cycles, as it happens in Phinaya.

Keywords: Quelccaya, Tropical Glaciers, Pastoralism, Local Perceptions, Glacier Retreat

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VALLEY-MOUNTAIN CIRCULATION ASSOCIATED WITH PRECIPITATION FORMATION IN THE TROPICAL ANDES (RIO SANTA BASIN)

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ABSTRACT

During the austral summer season, the precipitation in the Rio Santa basin, localized in the Tropical Andes, is strongly influenced by the interaction between large-scale circulation with local processes. However, this interaction has not been fully explored in the region. Therefore, the identification of the circulation patterns, and how occurs the interaction with local and regional-scale mechanisms influences the rainfall development is the main objective of this work. The analysis used fine resolution Weather Research and Forecasting (WRF) simulations nested in ERA5 reanalysis data. Different combinations of parameterizations were evaluated with a horizontal grid size of 5 km, in order to find the most suitable configuration for simulating the observed diurnal cycle of precipitation. Once identified the configuration, longer nested simulations (December 2012 until March 2013) with horizontal grid size of 6 km and 2 km were performed. Estimated (TRMM, CMORPH, PISCO, CHIRPS) and local observations were used to validate the simulations. The chosen WRF configuration consists mainly of the Goddard microphysics and the Betts-Miller-Janjic cumulus parametrization. This configuration is able to simulate the main features of the observed diurnal cycle of precipitation, according to the in-situ data. However, the model still overestimates precipitation. In assessing the circulation associated with the precipitation diurnal cycle it was identified as a westerly flow during the daytime, which is perpendicular to the Andes and enters through the north of the basin. This near surface flow is vital for the development of rainfall over the western slopes-highlands of the basin from noon to mid-afternoon. At same time, in eastern side of basin the coastal moisture transport converges with Amazon easterly flow over the mountains causing precipitation. On the other hand, between the late afternoon and early night, the rainfall predominates on the eastern slope associated with the upslope valley winds persisting in this period. These results contrast with most of studies that have indicated the Amazon basin as an exclusive source of moisture for the formation of precipitation over the Andes.

Keywords: Large-scale circulation, local processes, WRF, parameterizations

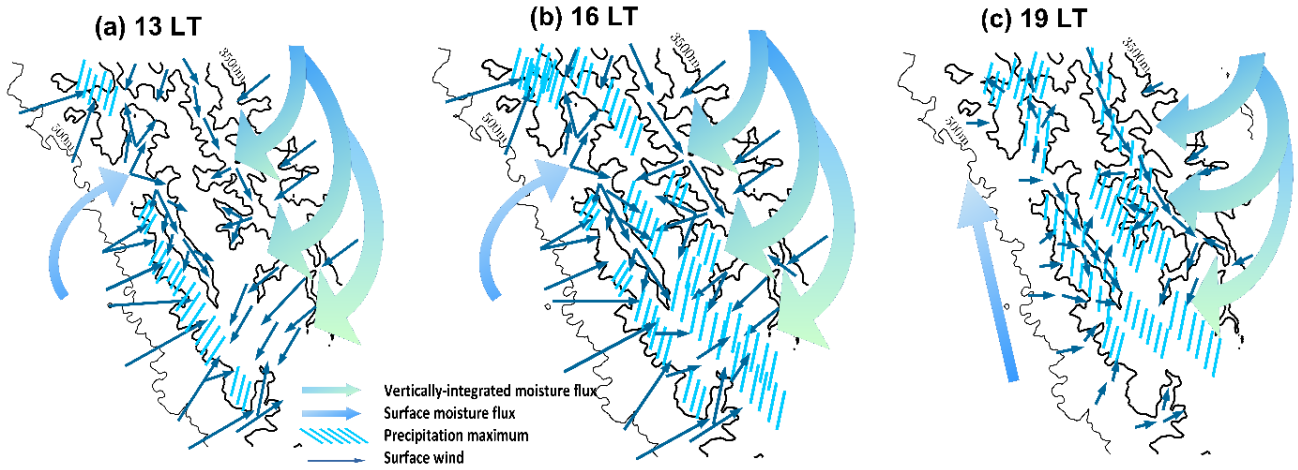

Figure 1. Schematic diagram of the main circulation from model outputs at (a) 13, (b) 16, and (c) 19 LT. Blue dashed zones correspond to precipitation maxima. Light blue-green arrows indicate vertically-integrated moisture flux, thin light blue arrows are surface moisture flux and thin dark blue arrows are surface winds.

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THEME B

NATURAL HAZARDS AND HEALTH RISKS FROM LAKES

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KEYNOTE LECTURE

ROCK GLACIERS AND CLIMATE CHANGE IN THE CENTRAL ANDES

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ABSTRACT

Rock glaciers are one of the main glacial landforms in the Central Andes due to the regional arid climate with a very low precipitation (>500 mm/year). Rock glaciers are largest, most densely spaced, have a greater density, and cover more area than glaciers in the Central Andes. These permafrost geoforms consisting on debris and ice constitutes a fundamental water resource storing in some cases more water than glaciers. The impact of global warming seems to affect greatly these ice bodies located in lower topographic positions. Rock glaciers could experience the most widespread disturbance to the thermal regime in the 21st century. Recent studies suggest that under future worst case warming, up to 95% of rock glaciers in the southern Desert Andes and the Central Andes will lie below the freezing level (areas above 0°C). This new scenario might move up more than twice as much (~500 m) as during the entire Holocene (~200m). Many active rock glaciers are already below the current zero isotherm, underlining and exemplify how local controls may confound regional prognoses. As a consequent of new warming conditions, rock glaciers might become instable increasing water and sediment release. Moreover, this permafrost degradation could trigger extreme events overwhelming regional natural hazard. Recently, violent debris flows have impacted Andean communities in the main valleys of the Chilean and Argentinean Central Andes.

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GLACIER EVOLUTION OF NEVADO HUAYTAPALLANA SINCE THE LITTLE ICE AGE, APPLYING GEOMORPHOLOGICAL RECORDS

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ABSTRACT

The aim of this work has been to assess the deglaciation of Nevado Huaytapallana (11º53'S, 75º, 03'W, 5558 m), the summit of a mountain range that extends along 18 km, with NW-SE direction in the Amazonian slope of the Eastern Central Andes of Peru. To this purpose, a geomorphological map has been made, defining the landforms generated by the last glacier advance. In the absence of absolute dating, it has been considered that this last expansion ended during the Little Ice Age (PEH), the last known phase of glacial advance on the Earth which came to an end in the 19th century. The geomorphological map has been made by drawing the glacier extension at the PEH in 1962 (using aerial photographs) and in 2016 (on a satellite image). The demarcation of the glaciers has allowed to evaluate the deglaciation, in terms of surface reduction (km^2), loss of ice volume (Mm3) and rise of the Equilibrium Line Altitude (ELA, m above sea level). During the PEH, the glaciers reached an area of 52 km^2 and a volume of 2041 Mm^3. In addition, the ELA depression dropped to 4985 m, so that the area of glacial accumulation covered an interval of 505 m between the ELA and the maximum altitude of the ice tongues (5490 m). These results allow to quantify the subsequent deglaciation, in regard to the dimensions reached in the last glacier expansion. In 1962, the area (32 km^2) had decreased by 62%, the volume (951 Mm^3) by 47% and the ELA (5038 m) had risen 53 m, shortening the interval of the accumulation zone to 452 m. Compared to the last advance (in 2016). The surface of the glaciers (14 km^2), was reduced by 73%, the volume (242 Mm^3) by 88% and the ELA (5164 m) had risen by 179 m. This meant that the range of the accumulation zone had decreased to 326 m. In percentage terms, the decrease in the surface area is similar in both periods, 1962-2016 (56%) and PEH-1962 (62%). However, the reduction in volume is significantly higher in 1962-2016 (75%) than in PEH-1962 (47%). The ELA trend also seems to confirm the acceleration of deglaciation, because its rise during the 1962-2016 period (126 m) doubled the increase observed during the PEH-1962 period (53 m).

Keywords: deglaciation, glacier surface, glacier volume, ELA

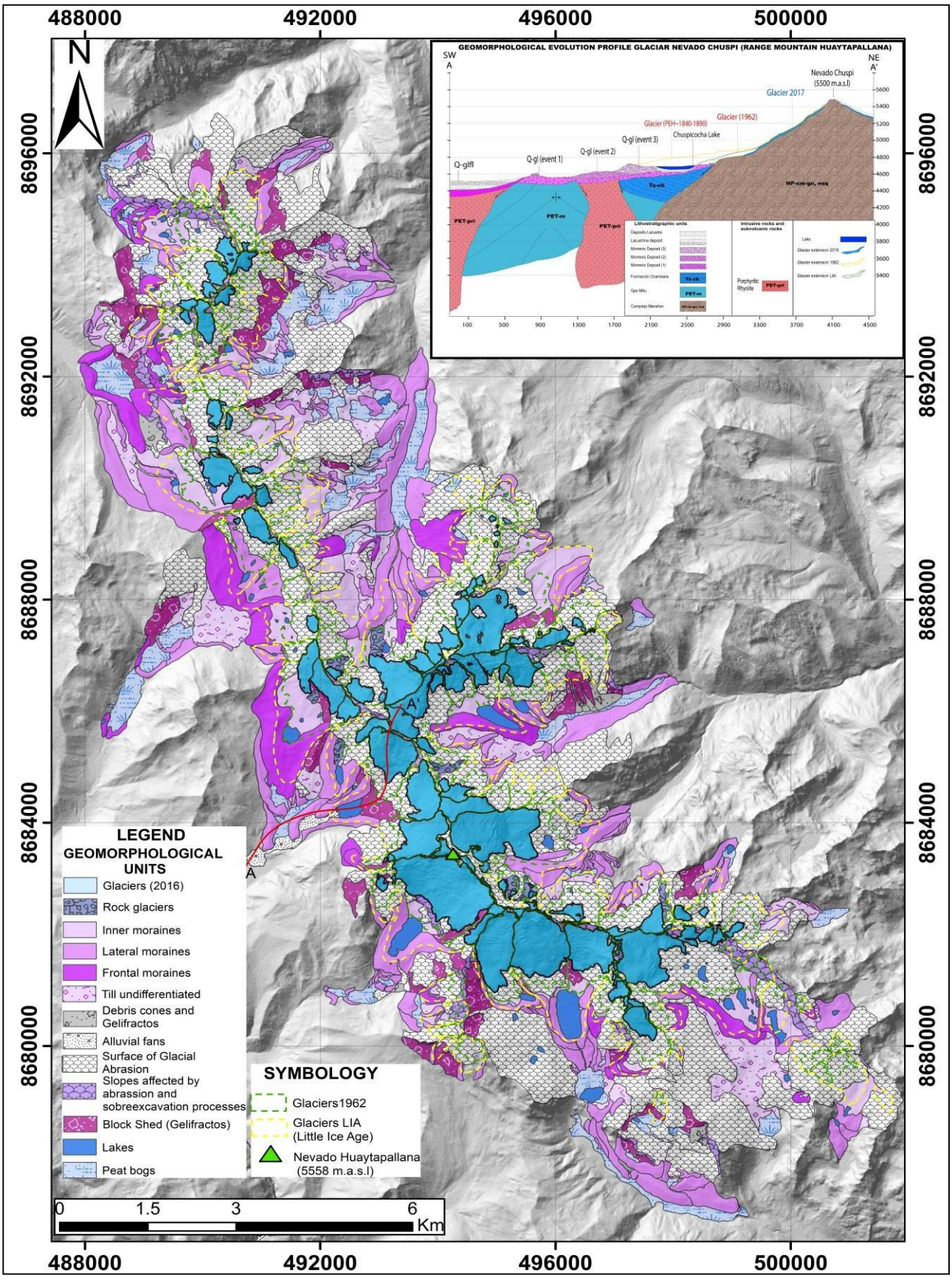

Figure 1. Map and profile (Nevado Chuspi) of glacial geomorphological evolution of the Huaytapallana mountain range.

COSMOGENIC RECORD OF THE EVOLUTION OF TROPICAL GLACIERS IN THE PITICOCHA VALLEY – PARIAQAQA MOUNTAIN RANGE (LIMA - PERU)

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ABSTRACT

The Piticocha Valley is located on the southwest side of Pariaqaqa Peak (11 ° 59'39.53 "S; 75 ° 59'35.74" W; 5758 m.s.n.m) in the Western Central Andes. 35 samples of moraines blocks and rock beds were obtained, to be dated by cosmogenic isotopes. Surface exposure ages based on the in-situ accumulation of Beryllium-10 isotopes were obtained from twenty moraines blocks and four polished rock beds and for the case of accumulation of Chlorine-36 isotopes were obtained from eight samples of moraines blocks and three polished rock beds. The main objective of cosmogenic dating is to investigate the different advances and setbacks that glaciers experienced from the Last Local Glacial Maximum to the most recent advances registered in the valley. The ages obtained propose three groups of moraines that are deposited along the valley. The oldest group of moraines is contemporary to the Last Global Glacial Maximum and is located on both banks at the end of the valley. Subsequently, the Piticocha valley glaciers endured minor pulsations far from their maximum position dating between 11 and 13 ka, which is attributed to the period known as the Younger Dryas in the northern hemisphere. This indicates that the glacier experienced an extensive deglaciation period between the LGM and the YD. Finally, the most recent ages correspond to moraines found at the head of the valley and very close to the current position of the glaciers. Probably, this was the last pulsation that the ice masses experienced in the vast valley of Piticocha. The cosmogenic record for the moraines of this last glacial advance, coincides chronologically with advances occurred during the period known worldwide as the Little Ice Age, which is recorded in greater detail in the northern hemisphere.

Keywords: Younger Dryas, Last Glacial Maximum, Little Ice Age, Geomorphology, beryllium isotopes, chlorine isotopes

I TROPICAL GLACIERS SYMPOSIUM

Synthesis Workshop:
WEATHER: a scientific approach in Water sEcurity and climATe cHange adaptation in pEruvian glacieRs

THEME C

CLIMATE CHANGE IN A DYNAMIC WORLD

KEYNOTE LECTURE

LOS GLACIARES COMO TERRITORIOS HIDROSOCIALES. CASO COLOMBIA

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RESUMEN

En el proceso de selección de mi ponencia para este evento, vienen a mi mente algunas frases interesantes que invitan a reflexionar sobre lo que tenemos, aún tenemos o estamos dejando de tener: “Los Andes Tropicales probablemente sean más ricos en biodiversidad que cualquier otra zona comparable de la Tierra” (Raven P. 2012); “Las proyecciones del cambio climático para los Andes también pronostican importantes alteraciones del caudal, con consecuencias tanto en el suministro de agua como en la integridad de los ecosistemas de agua dulce (Bradley et al. 2008); “Se ha alcanzado el ´pico hidrológico´ para muchos glaciares en los Andes, lo que significa que la escorrentía de aguas continuará disminuyendo en el futuro” (Unesco 2018), “En la medida en que se logre identificar y entender el potencial del capital natural como base para un desarrollo sostenible, se podrá vislumbrar un futuro promisorio para la región andina” (Díaz&Silva, 2018).

En este contexto, considero pertinente desarrollar un mensaje dirigido particularmente a la generación actual de jóvenes de montaña rurales y urbanos de los Andes que tienen y tendrán la misión de afrontar situaciones ambientales tal vez críticas -ligadas a las socioeconómicas- que probablemente dominarán la segunda mitad del presente siglo. Convertir la crisis en oportunidades dependerá del comportamiento individual y colectivo frente a los nuevos retos, así como de la comprensión de las diferentes interpretaciones del entorno y la innovación.

Se propone presentar el caso de Colombia, para dos áreas de alta montaña en zona de influencia glaciar, partiendo del análisis de la forma en que podrían verse afectadas las comunidades que habitan dichas zonas frente a los procesos de derretimiento glaciar.

El análisis se enfocó en términos de vulnerabilidad y se estructuró teórica y metodológicamente desde la perspectiva ambiental. Según dicha perspectiva, existen relaciones entre los ecosistemas y las comunidades, que se trastocan por cualquier cambio en alguna de estas dos dimensiones. De esta manera, un cambio en los glaciares suscitado por cambios atmosféricos, por ejemplo, generará transformaciones en la forma cómo las comunidades humanas usan y perciben el agua de fusión glaciar. Para esto, es fundamental entender las relaciones existentes entre las comunidades locales y las aguas de derretimiento.

De acuerdo con Gleik (2000), desde los años noventa del siglo pasado, se reconoce la dimensión social del agua a partir del paradigma del manejo integrado de recursos, que integra los aspectos culturales, económicos y ecológicos asociados al agua, distinto al enfoque que sólo asume el carácter hidrológico, propendiendo por la inclusión de los diferentes actores en la toma de decisiones.

Entender los procesos de transformación de un paisaje a lo largo del tiempo implica la interacción de diferentes áreas del conocimiento; esta tarea ha dejado de ser exclusiva de la geografía y la geomorfología; los procesos sociales relacionados con el uso y la percepción del recurso permiten entender el porqué de las intervenciones antrópicas que han tenido lugar en él. (Winiwarter, Schmid y Dressel, 2013).

El concepto de ciclo hidrosocial se construye a partir de la relación dialéctica que se establece entre el agua y la sociedad en su permanente interacción con el ciclo hidrológico; la forma en que las acciones antrópicas y las manifestaciones de poder reconfiguran el ciclo natural del agua y viceversa (Linton y Budds, 2014; Banister y Widdifield, 2014).

STATISTICAL DOWNSCALING OF CLIMATE SCNEARIOS IN PERUVIAN CENTRAL ANDES

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ABSTRACT

The Chillón, Rímac, Lurín and High Mantaro basins are very important because they supply surface water for consumption in Lima and Callao, which are located in arid areas. Is expected that water demand in this area will increase in the coming decades, for this reason is necessary to study the water availability in these basins under climate change conditions. In this research, statistical downscaling methods for precipitation and extreme temperatures have been developed to calculate the changes in the Chillón, Rímac, Lurín and High Mantaro basins in the period 2036- 2065 in order to get knowledge how the climate could change in the future. The statistical models are based on analog method for precipitation and multiple linear regressions for maximum temperatures and minimum temperatures. We explored ten geographical domains and a set of 33 predictors, which are the physical large-scale forcing for precipitation and extreme temperatures of representative locations in the basins. Predictors and optimal domains were selected under the principle that should have a significant and physically interpretable association with the predictand, in addition to the necessary statistical support. The downscaled scenario shows a significant increase of the mean precipitation by about 20-100mm under a moderate emission scenario (RCP 4.5) and a high emission scenario (RCP 8.5). The main increase of precipitation amounts occur during winter in the High Mantaro basin which could change the future water availability. In case of maximum temperature, the downscaling provides warming values in the range from 1°C to 4°C; the most pronounced changes correspond to the highest emission scenario. Finally, some locations have a slightly warming of the minimum temperature by about 1°C-2°C; however, locations over the High Mantaro basin don't show a significant change. The evident increasing of temperatures over highlands regions of these basins may will have a significant impact in ecosystems and Glaciers located in these regions.

Keywords: Climate change scenarios, statistical downscaling, precipitations, temperature.

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THEME D

MOUNTAIN ECOSYSTEMS

WEATHER: a scientific approach in Water sEcurity and climATe cHange adaptation in pEruvian glacieRs
Universidad de Ingenieria y Tecnologia
August 16-17, 2019, Barranco, Lima

FIRST MAIZE AQUACROP MODELING FOR ADAPTATION TO CLIMATE CHANGE FOR ANDEAN AND ARID ZONES PRODUCTION

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ABSTRACT

The Adaptation to climate change in agriculture is a priority for water conservation because is a key factor for crop production and food security. Only 20% percent of crop production areas has water sources, most of crop land suffer water deficit, and the projection for the next 50% years is critical. Due to water scarcity, there is a need to research in adaptation of crops in order to avoid crop failure due to the new climatic conditions and assure food production. The climate change laboratory at INIA-Peru (Instituto Nacional de Innovación Agraria) began the modelling of the principal maize varieties in the coast and the Andean highlands of Peru using the Acuacrop modelling which is predictive model of yield under different climatic conditions from FAO. The application of this model is very important in Peru due to our microclimate conditions, and the resulting information can be used to avoid crop failure of small farmers under future water scarcity conditions. We modelled maize accounting the climate and crop data from two crop campaigns in INIA, the former in arid zone in La Molina Station (Lima) and the second highland Andean zone in Santa Ana Station (Huancayo). In the first zone we modelled the culture of maize under well-watered conditions, and in the Andean zones we testes both well-watered and water deficit condition. In the first case we realized that the high temperature effect accelerated the crop development; and in the Andean station we found that the high precipitation retarded the crop cycle and enhanced the weed development. Both factors of temperature and high precipitations affect significantly the crop cycle and vary the grain yield. So this grain production may strongly affect the farmer income. Also the reformulation of how many crop seasons must develop each year and the variation in yield production may affect that food availability in local markers.

Keywords: Maize, adaptation, climate change yield, model

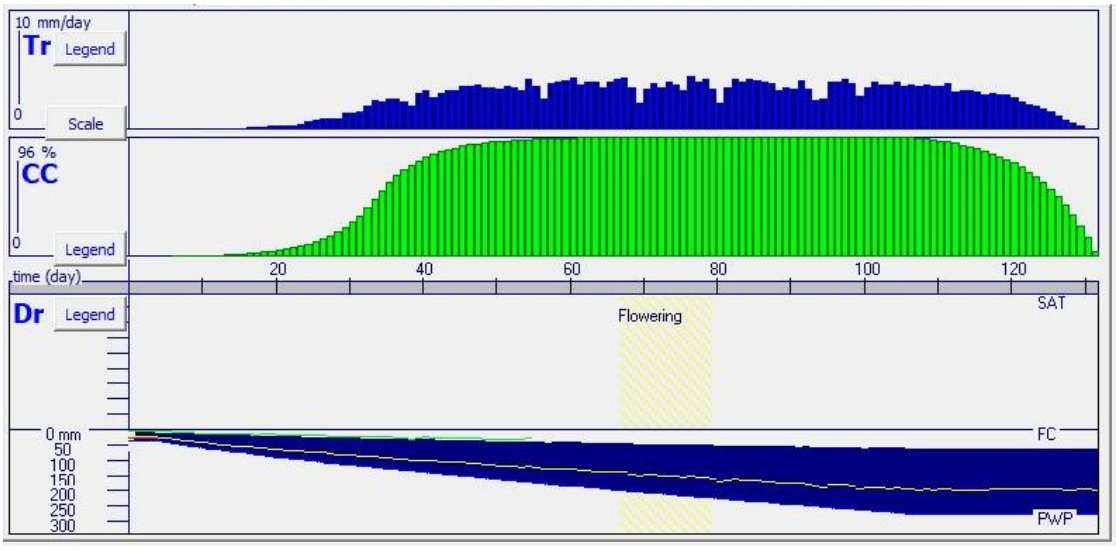

Figure 1. Peruvian Maize AquaCrop Modelling in arid zones under well watering conditions at La Molina INIA station. The production model shows the acceleration of the crop cycle for a crop production of 14,16 tons/Ha and the variation of Transpiration (Tr), Canopy cover (CC) and Water in root zone (Dr).

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CLIMATIC DRIVERS OF SPATIO-TEMPORAL VARIATION IN PLANT COMMUNITIES IN HIGH-ANDEAN ECOSYSTEMS OF AYACUCHO AND HUANCAVELICA, PERU

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ABSTRACT

Ecologists have explored the relationship between climate and vegetation at several spatial scales for decades. Ecosystems subjected to extreme climatic events (e.g. droughts), may experience strong changes in response to seasonality and environmental gradients, modifying the relative effects of climatic variables. In mountain ecosystems, such relationships had received less attention in comparison with other tropical biomes. Here we assessed how spatio-temporal variation in community composition correlates with climatic variables along a ~200 km transect in high-Andean ecosystems of Ayacucho and Huancavelica. We aimed to determine how climate shape plant grassland communities between 3800 – 4500 m a.s.l, as part of the Biodiversity Monitoring and Assessment Program (BMAP). We used species composition data from 10 sites with annual records of plant cover from 2013 to 2016. We extracted monthly precipitation and temperature records from "Peruvian Interpolated data of the SENAMHI's Climatological and hydrological Observations" (PISCO), and derived 20 variables based on precipitation, potential evapotranspiration (PET) and temperature for each site and year. In addition, we gathered soil data from four 10 cm depth samples at each site. We performed a multivariate constrained model, through Redundancy Analysis (RDA), with climate and soil data to determine the best explanatory variables. To avoid collinearity we checked for Variance Inflation Factor (VIF) and developed a model selection procedure to find the most parsimonious models. Finally we build a global model with selected variables and performed a Variance partitioning analysis to assess the contribution of climate and soil components. We found a major contribution of temperature and precipitation, explaining 21% and 14% of the variance, respectively. Precipitation variables that accounted for seasonality where retained in the RDA with 4% to 8% of explained variance. Variables of PET explained between 6% and 9% of the variance, while temperature explained between 3% to 12%. Soil variables accounted 25% of variance, with variables ranging from 3% to 8%. Variance partitioning showed that climate variables accounted for 21% of explained variance, while soil 8%. Together, soil and climate explained 36% of plant composition changes. Our results show how climate variability, coupled with substrate characterization, correlates with plant communities changes across the Andes. Moreover, we highlight the relevance of seasonality to explain those changes, which in turn can improve the predictability of vegetation changes and address potential impacts due to "El Niño" or extreme cold events in high-Andean ecosystems.

Keywords: Andes, vegetation, species turnover, climatic gradient.

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TOWARDS THE UNDERSTANDING OF THE DYNAMIC AND STRUCTURE OF THE INTERACTIONS PEOPLE-NATURE AS SOCIO-ECOSYSTEM AT THE SOUTHEAST OF THE AUSANGATE GLACIER (CUSCO REGION, PERU)

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ABSTRACT

The Quechua communities located in the surroundings of the Ausangate mountain chain have managed, transformed and used the landscape for hundreds of years. Signs of it are, e.g., the trails and different edaphic, hydraulic and pasture/grazing structures; many of them are still in use. In this geographic space, impacts on the natural system directly affect the quality of life of the Quechua people. During the last decade, this socio-ecosystem has been submitted to major pressure, caused by different internal and external drivers of environmental and social change. The Ausangate area has become an object of interest and has been intervened by different socio-economic and environmental projects. In this context, the local Quechua communities have not been able to follow the rhythm of change, and as a consequence, their cultural and socio-economic organization system got transformed precipitously, what impacted the natural environment at different temporal and spatial scales. The current model of environmental management and policies of the Municipality of Pitumarka and the communities at the southeast of the Ausangate glacier is separated/unlinked in two lines of action: one targeted on economic-productive aspects and another one directed towards health and environmental issues. Furthermore, the actions taken so far have been focused on the limitation or the compensation of negatively impacting, anthropogenic activities. Sustained by the integral concept of a so called “socio-ecosystem”, and assuming that the local Quechua communities and the natural environment of the High-Andes are co-evolving, this research project proposes to develop a characterization of this socio-ecosystem, with the aim to understand the inherent processes that take place in the interrelation between the local communities and their natural surroundings, and to evaluate their management tools, in order to complement them and/or to generate new ones. First, preliminary results of the characterization process of the Ausangate socio-ecosystem will be presented.

Keywords: resilience, adaptation, socio-ecosystem, Quechua communities, Ausangate

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THE ROLE OF THE *BOFEDALES* IN HIGH-ANDEAN WATERSHEDS – EXPERIENCES AND PRELIMINARY RESULTS FROM AN ECOHYDROLOGICAL MONITORING SYSTEM IN ABANCAY (APURIMAC, PERU)

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ABSTRACT

The *bofedales* are a diverse group of hybrid (aquatic-terrestrial) ecosystems, which are found in an altitudinal range from about 3,500-4,900 m.a.s.l. in the humid and dry Puna region of the Central Andes, from the north of Peru to the border between Chile, Bolivia and Argentina. They provide an important set of ecosystem services, among them, the (temporal) retention of freshwater, that is used for livestock farming and other agricultural activities. Apart from the direct anthropogenic impacts (overgrazing, construction of roads and dams, peat digging and extraction, etc.), the *bofedales* and their ecosystem services are also impacted by climate change - causing higher temperatures and changes in the precipitation regime/patterns – what, on the long term, could result in their drying-out, especially when they do not receive glacier meltwater. Under these conditions and in the context of the implementation of a mechanism of payment for ecosystem services (in Peru called *Mecanismo de Retribución por Servicios Ecosistémicos*, MRESE) for the city of Abancay (Apurimac region), an eco-hydrological monitoring system was installed in 2015/2016. This eco-hydrological monitoring system consists of the frequent measurements of hydrological and ecological/botanical key parameters in a total of seven *bofedales*. Six of them are located inside the area called Rontoccocha, where the methodology of paired-watersheds (as it is known from the Regional Initiative of Hydrological Monitoring of Andean Ecosystems, or iMHEA for its Spanish acronym) is applied: one watershed is intervened with recuperation and restauration actions (e.g. creation of small, semi-natural ponds,call ed *q'ochas*; reforestation of remaining forest patches and repopulation of pastures, including at the slopes), while the other watershed is not intervened and is still receiving the same or similar anthropogenic impacts as years/decades ago. A preliminary analysis shows that in the course of one year of monthly measurements in a total of 18 observation wells (three in each of the six *bofedales*), the water level dropped deeper in the three *bofedales* from the intervened watershed than in the three *bofedales* from the not-intervened (control) watershed, reaching maximum values of about 90 cm below soil surface. It is hypothesized that there might be a time lag in the intervened watershed till improvements in the water level in the three studied bofedales will be visible. In the presentation, these preliminary results will be put in relation and analyzed with the local run-off and precipitation measurements.

Keywords: *bofedales*, eco-hydrological monitoring system, Iniciativa Regional de Monitoreo Hidrológico de Ecosistemas Andinos (iMHEA), Mecanismo de Retribución por Servicios Scosistémicos (MRESE), Rontoccocha-Abancay