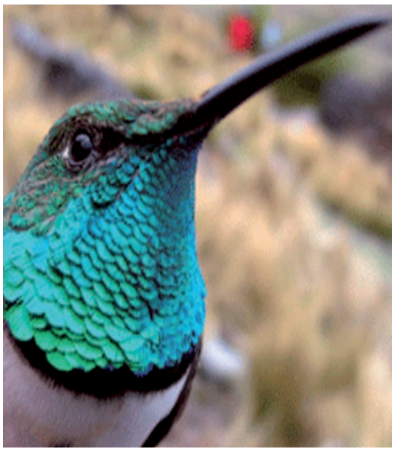





Climate Scenarios for the Santa River Basin to 2030


SECOND NATIONAL COMMUNICATION ON CLIMATE CHANGE

EXECUTIVE SUMMARY

Senamhi

GEF

UNDP

PERÚ | Ministry of Environment | National Metereology and Hidrology Service - SENAMHI




CLIMATE SCENARIOS FOR THE SANTA RIVER BASIN TO 2030
Executive Summary

SENAMHI
National Meteorology and Hydrology Service
Numerical Prediction Center – CPN
http://www.senamhi.gob.pe

TECHNICAL STAFF

Local Coordination:
Eng. Gabriela Rosas

Scientific Staff:
Ph. D. Guillermo Obregón
Ing. Amelia Díaz
Ing. Gabriela Rosas
Ing. Delia Acuña
Ing. Grinia Avalos
Ing. Clara Oria
Fis. Alan Llacza

Consultors:
Eng. Franklin Unsihuay
Eng. Renán Alegre

Computational Infraestructure:
Eng. Richard Miguel

GIS Staff:
Eng. Ever Castillo
Eng. Carmen Vassallo
Eng. Guillermo Tataje
Bach. Tania Sánchez

Logistical and administrative support:
Msr. Jenny Roca

Editing/Review:
Grinia Avalos
Gabriela Rosas
Amelia Díaz

Year: 2009

Edition: SENAMHI

The present publication is part of the Vulnerability and Adaptation Component within the framework of the Second National Communication on Climate Change to the UNFCCC, financed by the GEF and Coordinated through the Ministry of Environment of Peru.

Ministry Environment – MINAM
Av. Javier Prado Oeste 1440 - San Isidro - Lima - Perú
Phone: (511) 6116000
http://www.minam.gob.pe

National Meteorology and Hydrology Service – SENAMHI
Jr. Cahuide 785 Jesús María
Teléfonos: (51 – 1) 6141414 (central) y 6141408 (CPN)
http://www.senamhi.gob.pe

Done in the Legal Deposit National Library of Peru Nº 16102

Design : Q&P Impresores
Graphic Director : Ricardo Eslava Escobar
Digital edition : Hugo Negreiros Bezada
Text editing : Carlos Canales Zubizarreta
Printing : Omega Representaciones y Servicios S.R.L.
Av. Francisco Pizarro # 544 - Int. "J" - Rimac
First Edition : January 2010
Print run : 400
Printed in Peru

PERÚ | Ministry Environment - MINAM | National Meteorology and Hidrology Service - SENAMHI

EXECUTIVE SUMMARY

Climate Scenarios for the Santa River Basin

TO 2030

MINISTRY OF ENVIRONMENT

Dr. Antonio Brack Egg
Minister

Vice-minister for Strategic Development and Natural Resources
Eco. Rosario Gómez Gamarra

General Director for Climate Change, Desertification and Water Resources
Eduardo Durand López-Hurtado

SENAMHI

Executive President SENAMHI
Mag. FAP (ret.) Wilar Gamarra Molina

Scientific Director
Ph. D. Elizabeth Silvestre Espinoza

General Director of Meteorology
Eng. Amelia Díaz Pabló

EXECUTING UNIT OF THE PROJECT

General Coordinator:	Jorge Álvarez Lam
Vulnerability and Adaptation Coordinator:	Laura Avellaneda Huamán
Inventories and Mitigation Coordinator:	Rafael Millán García
Communications Coordinator:	Jenny Chimayco Ortega
Administrator:	Kelvin Orbegoso Contreras
Assistant:	Ruth Camayo Suárez

Background

In Peru there are approximately 10 major glacial basins that supply water to cities as Lima, Huaraz, Cusco, among others. One of the most important glacial basins in the country is the Santa river basin, that belongs to the Pacific Ocean drainage area and it extends from sea level up to the highest peaks of Peru, above 6 000 meters above sea level; it allows having a diversity of ecosystems along its more than 900Km2. However, continuous glacial retreat over the last 30 years, according to direct measurements and estimations on glacial mass variation, indicate that availability of this resource would be seriously affected in the future, if the observed trends continue to happen.

A joint initiative between SENAMHI and the IRD (The French Institute of Research for Development) about future climate change scenarios and water availability in the Santa river basin, within the framework of the National Capacities Strengthening Program for Climate Change Impact and Air Pollution Management – PROCLIM (2005), made it possible to establish that in the following 25 to 40 years glacial basins will increase their maximum discharge towards 2050 and then it will gradually decrease up to a level in which it will only depend on seasonal rainfall contributions, since glaciers would have already vanished by that time. Under this critical scenario it is necessary to start some adaptation measures to secure water supply indispensable for life and development of the affected population.

The Ministry of Environment, within the framework of the Second National Communication on Climate Change (SNCCC), a project supported by the United Nations Development Program – UNDP, has coordinated with SENAMHI to carry out a study on The Generation of Climate Scenarios in the Santa River Basin, which describe two important aspects of national climate: first, the characteristics of the present climate and climate trends in the last 40 years; and in a second part, future projections to 2030 based on global climate scenarios, using dynamical and statistical downscaling methods for the A2 emission scenario (high emissions).

In addition, the elaboration of regional scenarios considers an uncertainty element for both the limited knowledge on climate variability due to scarce available information, and the processes followed to generate information at regional level, same ones that incorporate errors which is typical of the adjusting and interpolation methods. For this reason, confidence levels indicated in the historical analysis are being considered, as well as a spectrum of probabilities considering the occurrence of the projected scenarios based on policies adopted by mankind from now on. Finally, this document will allow to orient the most adequate and coherent policies to face climate change within the regional scope.

Location and geographical characteristics of the basin

The Santa river basin is located in the northern mountain region of Peru and it is the largest basin of the Pacific Ocean drainage area. Its total surface is 12 005.50 Km2 and it has a reception area of 11 910 Km2 up to "Puente Carretera " hydrological station located in the lowest part of the basin (Pouyaud B., Yerren J., Zapata M. et al, 2005). The Santa River flows from south to north between two mountain ranges, the Cordillera Negra or Black Mountain Range to the west and the Cordillera Blanca or White Mountain Range to the east, it is here where the largest number of glaciers are located.

Politically, the basin is partially located in the departments of Ancash and La Libertad; and it is total or partially located in the provinces of: Bolognesi, Recuay, Huaraz, Carhuaz, Yungay, Huaylas, Corongo, Pallasca and Santa (in the department of Ancash), and the provinces of Santiago de Chuco and Huamachuco (in the department of La Libertad).

a. Socioeconomic context

Along the basin important economical activities are developed, from which the main ones are the generation of hydroelectric power and mining production. In the first case, the existence of a water fall in a narrow pass of 2 000 meters height in the Cañon del Pato, facilitates the generation of electric power through the Cañon del Pato Hydroelectric Power Plant, that benefits all the towns near the basin and the steel industry. In the second case, the mining production is developed by small and medium size mines dedicated to gold, zinc, copper and lead exploitation; they extract and process tens and hundreds of tons per day. Also, mining extractive activity generates contaminating process along the basin.

Concerning the agricultural activities, a total 47 807 ha are cultivated under irrigation control that use an annual mean water volume of 617.15 thousand m3 ; from this surface, 6 516 ha located in the coastal valley use 338.09 million m3 and 41 291 ha located along the Callejon de Huaylas use 278.17 million m3 (MINEM, 1998).

The population that lives in the low basin or valley is typically urban and it is located inChimbote, Santa, Casma and Huarmey. In these zones, as in all big cities in the coast, population growth has been higher than the natural increase rate, mainly due to migratory flow from the countryside to the city.

b. Water resources and glacial retreat

The Santa River originates in the Aguashcocha and Conococha lagoons, located in the southeast end of the Callejon de Huaylas. It has an approximate area of 316 Km from its source to its river mouth (estuary), it has an average slope of 1.4% which becomes steeper at the section between the river-mouths of the Cedro and Quitaracsa ravines called "Cañon del Pato", where it reaches a slope of 4%. From its sources, and in most part of its course, it forms a tectonic origin valley, which is flanked by the Cordillera Blanca and the Cordillera Negra. Studies carried out by MINEM, confirm that the surface of the catchment basin is 14 954 Km2 and 83% of this area corresponds to humid basin (12 412 Km2), that is, the area of the basin that is located over 2 000 meters above sea level, and that constitute a surface runoff area.

The discharge of the Santa River depends on precipitations that occur in its high basin and the contributions of 23 rivers originating from ice melting from 457 glaciers located in the Cordillera Blanca; they contribute to maintain a considerable discharge, even in the dry season, which makes the Santa River the most regular river of the Peruvian coast (MINEM, 1998). Four Hydroelectric Power Plants are located along the river between the Cordillera Blanca and the coastal strip (Mark, 2007).

One of the most dramatic impacts of global warming is the accelerated glacial retreat, and particularly the Andean tropical glaciers due to its "inefficient" water-recharge capacity. According to the Instituto Andino de Glaciología y Geo-Ambiente located in the Cordillera Blanca, the glacier inventory confirmed a total glacial area of 724 Km2 that store an estimated value of 22 600 MMC of water, but due to ablation processes (erosive action by which ice is lost) in the last 50 years it has decreased by 22%, according to the 1997 inventory carried out through satellite images.

If we consider that glacier water recharge depends on precipitations and temperatures and knowing that the global warming impact is associated with changes in climate conditions, evident through a larger climate variability; we consider that it is very likely that one of the biggest risks the Andean basins of Peru would be facing at a medium and long term is related to the impending shortage in water availability in all aspects (water for human consumption, for irrigation, for industrial use and electric power generation), setting up an scenario of social conflicts (Avalos 2008). According to MINEM (2008), about 60% of electric power in Peru is generated at hydroelectric power plants, so vulnerability of the energy sector to climate change is still of great concern.

According to studies made by Pouyaud et al. (2005), basins with large glaciers such as the Parón, Llanganuco, Chancos, Los Cedros, Quillcay and Colca have shown a runoff shortage, starting the second half of the 70's decade, which is the conclusive proof of the accelerated glacial retreat in the Cordillera Blanca. The retreat rate of the Yanamarey glacier has accelerated four-fold, from 5m/year, observed between 1948 and 1977, to 20 m/year between 1977 and 2003. (Mark et al, 2007).

How is the present climate?

Climate characteristics in the Santa river basin

According to Werren Thonrthwaite's climate classification developed by SENAMHI (1988), in both sides of the basin, over 3 500 meters above sea level, prevails a cold, humid climate; but at the same time dry in the winter, and towns as Julcán and Paccha belonging to the provinces of Huaylas and Carhuaz also have this type of climate. The Cordillera Blanca, the highest mountain range in the tropics is located in the eastern side of the Santa river basin and over this area prevails high mountain climate with perpetual snow, above 4 800 meters above sea level. The inter-Andean valley called Callejón de Huaylas or the Santa river valley, bordered to the east by the Cordillera Blanca to the west by the Cordillera Negra is located between 1 800 m and 2 800 m altitude, where there are situated important cities as Yungay, Caraz, Carhuaz and dry climate prevails in autumn, winter and spring, and temperate and humid in the summer.

Between 3 000 m and 3 500 m altitude dry conditions prevail during most part of the year, with low-frequency rainfall compared to the one occurring in the valley, and semi-cold thermal conditions. In these sectors, precipitation occurs in the summer and is mainly orographic, that is, it result from the condensation of water vapor of an air mass that as it rises releases most part of this moisture, specially over the inter-Andean valleys. Under these climate conditions important cities as Recuay, Corongo, Cabana and Santiago de Chuco are located.

Meanwhile, the eastern side of the basin, between 0 to 900 meters above sea level, in the lowest part of the basin it has an arid and semi-warm climate, where an intensive irrigated agriculture prevails.

In the basin, annual maximum temperature shows some variations between 18 ºC and 24 ºC. In the zone of the valley (Anta and Yungay) maximum temperatures above 24 ºC are registered, same as in the lower parts of the basin. While, in the zones of Salpo and Chavin located in the southern part of the basin and in the northern part near Quiruvilca, maximum temperature shows values lower than 18 ºC.

Multiannual minimum average temperature shows variations between 14 to 16 ºC in the lower part of the basin, next to the sea (Santa province). In the middle part, in the valley, annual minimum temperature oscillates between 4 and 14 ºC, and in the zones located over 4 000 meters above sea level, corresponding to the Santa river source (southern sector) and the glacial areas, minimum temperature is lower than 4 ºC.

Total multiannual precipitation shows values ranges from 5 mm/year-1 (in the coast, to the west and lower part of the basin) up to 1 400 mm/year-1 (to the north and high part of the Santa river basin).

Precipitation increases from west to east, accumulating more the 500 mm/year-1 in places located over 2 500 meters above sea level. The most intense precipitations occur over the northern border area and over 3 500 meters above sea level. Precipitations accumulate less than 400 mm a year west of the southern part of the basin; while east of the same zone (near Milpo) accumulated precipitation reaches between 1 000 - 1 200 mm a year-1

Is the glacial coverage of the Cordillera Blanca vanishing?

The warming trend observed in the last 40 years in the Santa River basin, both in maximum temperature and minimum temperature, explains the recession in the glacial coverage of the Cordillera Blanca, the highest and largest tropical glacier in the world (Morales Arnao, 1998) The high sensibility of glaciers to climate variability, allows to conclude they are highly vulnerable to climate change, and under this context, the occurrence of extreme climate events such as the ENSO, could limit its existence; as the studies made by Vuille et al. (2007), show that 50 to 70% of temperature increase in the Andes, is due to the increase in the Tropical Pacific temperature.

Climate trends in the Santa river basin

In order to know the climate trends in the Santa River basin, daily and monthly total data for precipitation as well as for daily and mean monthly, maximum and minimum temperature have been used for the period between 1965 and 2006 (42 years). These data are quality-controlled on a daily basis, as it is detailed in the National Document, trying to determine possible errors by means of temporal continuity analysis and graphics. It is worth mentioning that the stations with up to 15% missing data were included.

To make the investigations 4 (2) stations from the Santa River basin were selected with daily precipitation data (daily extreme temperatures). Two stations, Quiruvilca and Chiquián, were located out of the basin, exactly in the adjacent zones to the north and south ends, and were selected to make the most adequate and comprehensive analysis about this basin. Also, it is important to remark that the two series of extreme temperatures restrict the analysis only to the southern end of the basin.

Linear trend of rainfall

The Santa river basin shows a positive trend (increase) in total annual precipitation in the four stations considered for the analysis (Recuay, Mollepata, Quiruvilca and Chiquián). The Quiruvilca location, situated to the north, slightly out of the basin limits, shows a statistical significant trend, with values between 90 and 100% higher in relation to the multiannual average, the other locations show positive trends lower than 30%. In Recuay, the increase is slightly higher than in the other two stations, Mollepata and Chiquián, this last one is located to the south, out of the basin limits.

The distribution of seasonal trends in the basin, show similar patterns in summer and autumn, but in the spring and winter these patterns are just the opposite in the basin. In all the seasons of the year, Quiruvilca shows a positive trend with the highest values registered in spring and autumn, between +90% -100%. In the remaining part of the basin during the summer (DJF) and in autumn (MAM) increases do not exceed 30%.

In the winter (JJA) trends show a very intense gradient, with maximum positive values in the northern region and minimum (decreasing) in the southern end, which is the minimum value observed during the year, between -80% -70%.

During spring (SON), without considering the stations out of the basin, a contrast is observed between the trends in the northern region, with slightly negative values (lower than -20%) and the southern region with positive values lower than 20%.

On the other hand, from the drought analysis we can conclude that the effect caused by El Niño in the northern part of the basin is different from the one caused in the southern part; thus, in the south it is very likely the occurrence of rainfall shortages in the summer and autumn, while in the north, it has less probability of a drought occurrence. Maximum in the northern region and minimum in the southern end, which is the minimum value observed during the four seasons, with values between -80% - 70%.

Temperature increase

Due to the lack of extreme temperature data in this basin, linear trend for maximum and minimum temperature were only analyzed using the temporal distribution of the whole period for Recuay and Chiquián stations.

It is observed that in both locations there is a quick increase (positive) in maximum temperature, with statistically significant trends, but it is important to remark that the distribution of the data through the years shows well defined characteristics and very different. Chiquián shows a higher trend (1,5 ºC per decade) because the increase is constant (monotonic) during the whole period of study. In Recuay, apparently there is a stressed linear trend (0,67 ºC per decade) because it is influenced by very low temperatures observed at the end of the 1960's decade, but if we consider starting in the 1980's decade, it shows no trend.

On the other hand, there is evidence of the effects caused by the ENSO events in Recuay, particularly during the warm events of 1982/83 and 1991/92, which is not the case for Chiquián.

The distribution patterns of seasonal maximum and mean temperatures in the basin show a similar trend behavior with respect to the annual means. As it was remarked in the analysis of the annual means, also the seasonal trend in Recuay shows the same discontinuity problem and an apparently gap during the years with no information.

The highest trend values in Chiquián was registered in the summer months, with values of +1,53 ºC per decade and the lowest value in spring, with +1,38 ºC per decade. Long-term variability is the prevailing characteristic in this location, where interannual variability is observed in certain years, as in the spring time of the 1980's decade.

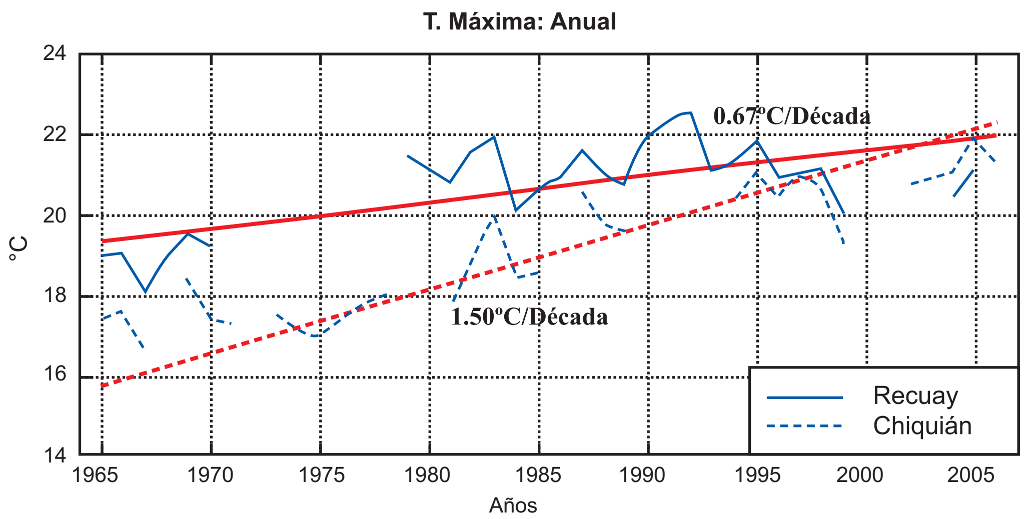
Distribution of the seasonal maximum mean temperatures in Recuay shows weak trends, almost null, after the 80's decade. High interannual variability is the most remarkable characteristic, modulated by the warm events of the ENSO, in all the seasons of the year, as it is observed in the years 1982/83 and 1991/92.

Annual mean minimum temperatures trends in Recuay and Chiquián show different characteristics. While in Recuay a slight non-significant increase is registered, in Chiquián a statistically significant negative trend (decrease) is observed, with value of -0,33 ºC per decade.

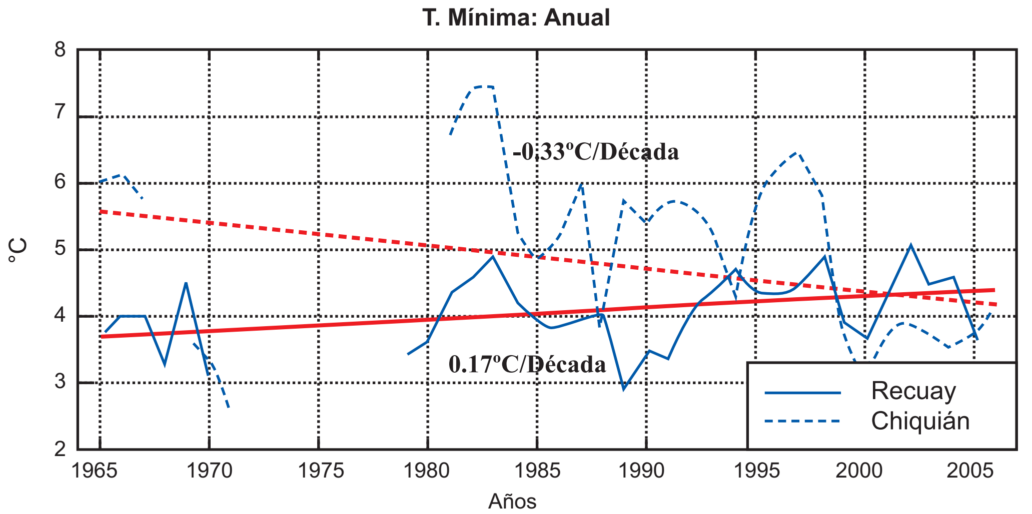
In addition, Recuay shows high interannual variability with high values, especially during the ENSO events of 1982/83, 1997/98 and 2001/2002. Similarly, Chiquián showed high interannual variability with positive and very intense anomalies than the ones observed in Recuay, related to the ENSO events, particularly during 1982/83 and 1991/92.

In general, during the seasons of the year, linear trends of seasonal mean minimum temperatures show similar characteristics to the ones observed in the annual mean minimum temperatures. Interannual variability is very intense in spring, summer and autumn in both places, with remarkable values related to the warm ENSO events. In the winter, interannual variability is low and the effects of the warm ENSO events are lower.

In Recuay, trends during the four seasons of the year are positive with a maximum value statistically significant of +0,32 ºC per decade, registered during autumn and a minimum value of 0,08 ºC per decade observe in spring. Conversely, in Chiquián trends are negative (decreasing) and statistically significant in spring, summer and winter. The highest value occurred in the summer with -0,55 ºC per decade.



Distribución temporal de la temperatura máxima media anual (1965-2006) de las estaciones de Recuay y Chiquián. Mejor ajuste de las tendencias lineales es indicado por líneas rojas.

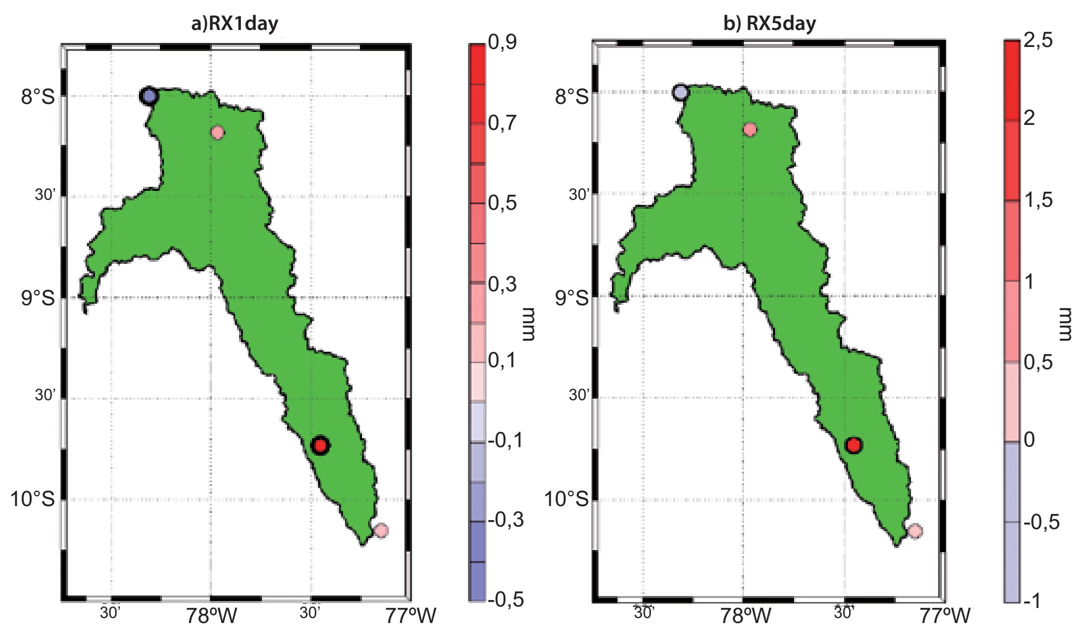


Distribución temporal de la temperatura mínima media anual (1965-2006) de las estaciones de Recuay y Chiquián. Para mejor ajuste de las tendencias lineales es indicado por líneas rojas.

Are rainy days increasing?

Spatial distribution of the CDD (consecutive days with no rain) and the CWD(consecutive dry days) indices trends in the Santa River basin show positive values, without statistical significance. The CDD trend shows low positive values that are almost null. The trends of the CWD reach values ten times higher than the CDD values, between 0,2 and 0,4 days/year, this would indicate that there is a great possibility that in the last years there could have been an increase of consecutive rainy days, particularly in the southern region of the basin.

Trends in the accumulated daily precipitation index (RX1day) and five days (RX5day) in the Santa river basin show similar spatial distributions. These distributions indicate that the southern region shows and increase in the amount of accumulated precipitation in one day and in five days, between 0,2 and 0,7 mm/year and 0,5 and 2,0 mm/year respectively, This indicates that the southern region of the basin, in Recuay's surroundings, there is more likely the occurrence of floods, landslides, flash floods, etc.



Spatial distribution indices trends: a) maximum accumulated precipitation in one day (RX1day) and b) maximum accumulated precipitation in 5 days (RX5day) estimated for the period 1965-2001. Trends with statistical significance at 5% level or lower are indicated in black.

In conclusion

- Annual precipitation trend shows very slight increases across the basin, lower than 30%, which becomes more evident in winter and spring
- Maximum and minimum temperatures in Recuay show slight increases, mainly after the 1980's decade, showing some significant alterations during the warm events of the ENSO.
- Maximum temperature in Chiquián has increased up to 6 ºC in the last 42 years. While minimum temperature shows a decrease. In both cases there are significant effects in the occurrence of the ENSO events.
- There is a more frequency of rainy days, especially in the southern part of the basin.
- Droughts are moderate in the basin during the period of study, but during an El Niño event is more likely that droughts will occur in the southern part of the basin.
- The orography of the basin determines a different impact in the northern and southern region of the basin with respect to the occurrence of dry periods. Inhibition or facilitation of rainfall in both region depend on which phase the ENSO or PDO are in.

Climate change projections to 2020 and 2030

Climate change scenarios are based on qualitative interpretations of General Circulation Models (GCMs) in which, an increase in the concentrations of CO_2 and other greenhouse gasses, that modify the behavior of the atmosphere is supposed to take place in determined period of time in the future (Nakicenovic and Swart, 2000). Since GCMs contain information on atmospheric and/or oceanic variables at global scale, (approximately 200 Km) which is too large for studies at regional level, it is necessary to improve their resolution, so it is used a technique called regionalization, local projection or downscaling, either dynamical or statistical are most commonly used.

In this study both techniques were used, the dynamical downscaling was carried out using the RAMS (Regional Atmospheric Modeling Systems – version 4.4), initialized with the global model NCAR-PCM T42 of the National Center Atmospheric Research – NCAR of the United States (SENAMHI, 2005). The RAMS was developed at Colorado State University (Pielke et al, 1992), it is a tridimensional non-hydrostatic model that offers several turbulence, radiation, initialization and boundary conditions schemes. Concerning statistical downscaling, it is an empirical model that relates large scale variables to local variables, in this case sea temperature was used to force precipitation in the basin.

Will there be regional warming?

By the end of the XXI century, in the Tropical Andes, model projections indicate a sustained warming in the tropical tropopause (Vuille, 2007). According to the A2 emission scenario, The Andes could experiment a massive warming of approximately 4,5 – 5,0 ºC by the end of the century. The A1B emissions scenario projects 80 – 90% of the range projected by the A2 scenario, while B1 scenario projects half of the warming showed in the A2 scenario. Thus, optimist scenarios as well as the pessimist project the same warming pattern, it only differs in the amplitude of the range. This report shows scenarios corresponding to change in temperature and precipitation for the Santa River basin, based on the A2 extreme scenario.

Would maximum and minimum temperatures increase?

Studies show the projections and changes in maximum temperature for 2020 and 2030 in the Santa River basin, both at annual level and seasonal. The expected changes in annual average for 2030, in relation to the period 1971 – 2000, are approximately 0,2- 0,9 ºC; this values are smaller in the low part of the basin (0,2 – 0,3 ºC), followed by the values in the middle part of the basin (0,3 – 0,6 ºC) and higher magnitude in high parts of the basin, reaching almost 1ºC increase with respect to current climate.

Expected changes for the period September – May in the high and low part of the basin are similar to what is expected for the annual average; however, they are slightly higher in the middle basin. The higher increase in maximum temperature in the high parts of the basin, in relation to the middle and low part, could accelerate ice melting of glaciers in the basin.

Locations as Recuay (3 450 meters above sea level) that are showing a warming rate of 0,65 ºC per decade 40 years ago, could experiment an increase of more than one degree in maximum temperature to 2030, situation that would be prolonged even up to spring time. In the middle part of the basin, increases would be more than half a degree (0,5 – 0,8 ºC) and more accentuated in the winter and spring, while in the lower part of the basin (province of Santa), the increases would be lower, reaching 0,3 to 0,5 ºC from autumn until spring and 0,1 – 0,3 ºC in the summer.

Seasonal trend observed for maximum temperature in the last 40 years in the high parts of the basin, show a progressive warming of around 0,59 – 0,69 ºC per decade, becoming more accentuated in the winter (0,69 ºC), which extrapolated to 2030, would mean an increase of more than (1,38 ºC), in relation to the current decade; however, projections of the regional model indicate an increase 1,1 ºC. This projected value would be related to the consolidations of the negative phase of the PDO, which would condition a warming rate less accentuated for at least in the next thirty years, compared to the past decades, in which prevailed the positive phase of this oscillation.

According to studies, a bigger change in minimum temperature would be registered in the high parts of the basin. These increases range between 0,2 – 0,6 ºC at an annual average rate, and from 0,5 to 0,7 ºC for the period from September – May. This higher warming during the rainy period is due to the presence of more cloud coverage during the night, which prevents the loss of surface heat; this is consistent with a slight increase in precipitation projected for this zone of the basin. In the middle and low basin a higher increase in minimum temperature is expected over the annual average (0,4 – 0,7 ºC) in relation to the period from September to May (0,1 – 0,5 ºC), it is even expected a minimum variation in the low part during the rainy period.

Seasonal change of minimum temperature for the year 2030 would show an average change rate of 0,4 – 0,6 ºC, showing a higher variation during autumn in the highest sector of the basin of approximately 0,6 to 1,0 ºC; followed by increases of half a degree in the middle and low basin. Also, during summer, the increase would range between 0,5 ºC to 0,8 ºC, also this would happen in the low and middle sector of the basin, corresponding to important provinces of Santa in the low part, and part of the provinces that form the valley in the middle part.

The increases in minimum temperature in the high basin, projected by the regional model for the next two decades, keep a relation with the extrapolation of the observed seasonal trend, that is, if the warming rate observed in the last forty years in locations such as Recuay, continues by the end of 2030 this sector of the basin would experiment increases of up to 0,64 ºC in autumn, 0,28 ºC in the summer and between 0,16 to 0,38 ºC between winter and spring. According to studies, annual mean trend in Recuay is 0,17 ºC per decade, it gets more accentuated in autumn with a value of 0,32 ºC per decade. Thus, the projected seasonal distribution would register a higher reduction of areas with low temperatures during autumn and spring, in the high part of the basin, and slightly lower temperatures than the current one, in the low sector adjacent to the sea, during the winter.

Will precipitations increase?

The spatial distribution of precipitation projected, both for 2020 and for 2030, show accumulated values in the easternmost part of the right margin of the Santa, with total annual values of 800 – 1000 mm, being the northern sector more humid for the year 2030.

The expected increase to 2030, in relation to 2020, would occur in the eastern and northern sector, up to 200 mm additional in the easternmost part of the basin. The isoyets (lines with the same precipitation) show a displacement from east to west in regions close to the lower basin (up to 900 meters above sea level), therefore, it would be expected that precipitation slightly increase between 2020 and 2030. It is important to remark that in the low basin, where arid climate conditions prevail with scarce precipitations during the year, the projected changes in percentages, do not show a perspective of significant changes as it does happen in the middle and high basin.

In conclusion:

- Annual accumulated precipitation would not show higher variations to 2030 with respect to the current climatology.
- Seasonally speaking, rainfall would increase in the high basin up to a 15% in autumn.
- Maximum and minimum temperature would increase up to 0,55 ºC in the basin, being the high basin the one showing the highest increase of up to 0,7 ºC.
- Seasonally speaking, autumn would show the highest intensities of warming, mainly in the high basin.
- The heaviest rainfall would be decreasing in intensity to 2030 and the highest temperatures would be increasing, because the nights and days would be warmer to 2030.

Bibliography

Avalos, G., 2008: Cambio climático y seguridad energética en el Perú. En: Chiri A. F. y Luyo J. E., La Seguridad Energética, un reto para el Perú en el Siglo XXI. Eds. Colegio de Ingenieros del Perú, 256 – 281.

Mark, B. G., 2007: Tracing Tropical Andean Glaciers, over space and time: some lessons and transdiciplinary implications, Global Planet Change.

Ministerio de Energía y Minas, 1998. Estudio de evaluación ambiental territorial y de planeamiento para la reducción o eliminación de la contaminación de origen minero en la Cuenca del río Santa (Online).

Morales-Arnao, B., 1998. Glaciers of Peru. In: Williams, R.S., Jr., and Ferrigno, J.G., eds., Satellite Image Atlas of Glaciers of the World: U.S. Geological Survey Professional Paper 1386 (Glaciers of South America).

Pielke et al., 1992. A Comprehensive Meteorological modeling System RAMS. Meteorol. Atmos. Phys. 49,69-9.

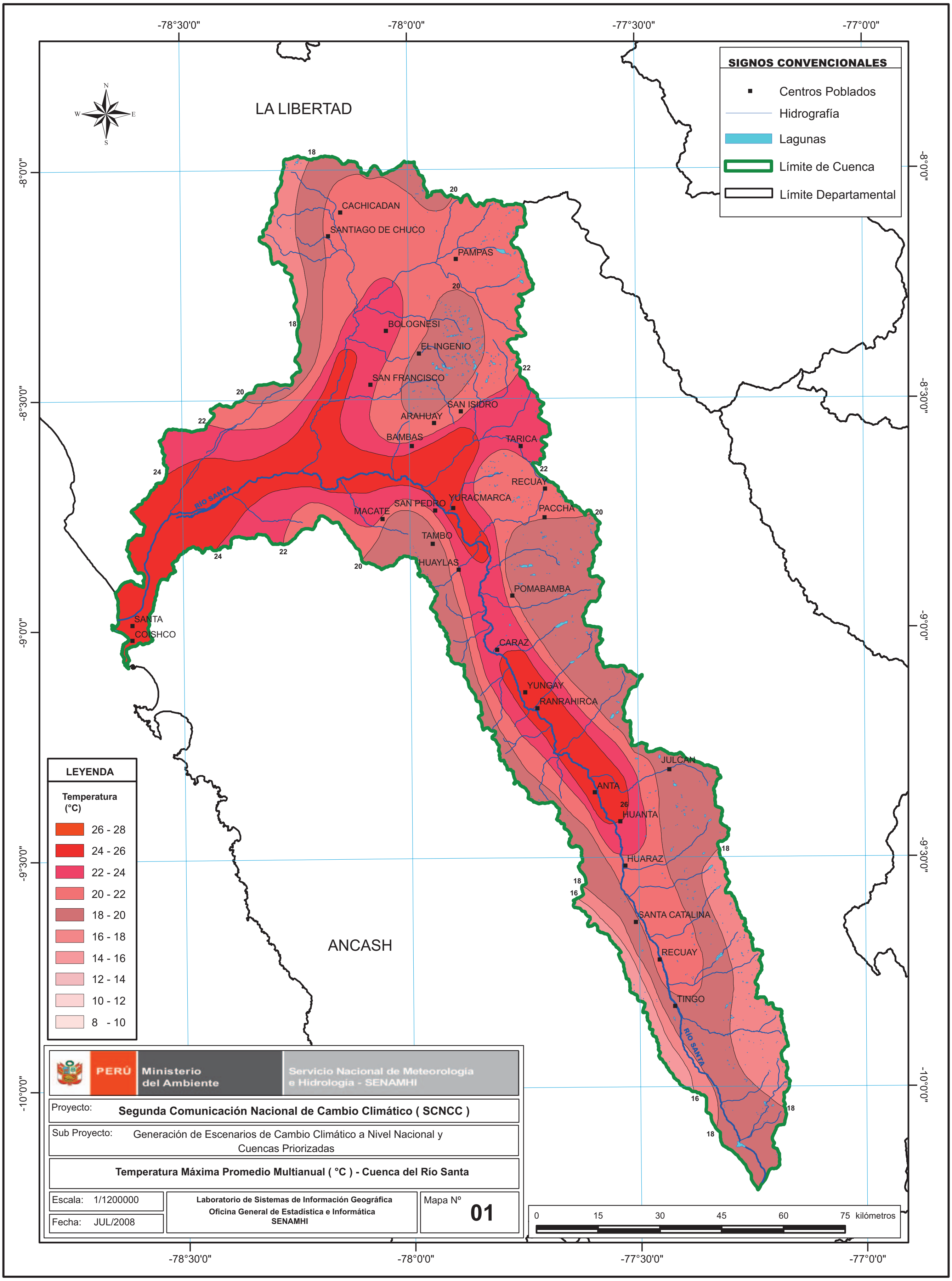
Pouyaud, B., Zapata, M., Yerren, J., Gomez, J., Rosas, G., Suarez, W., and Ribstein, P. (2005). Avenir des ressources en eau galciaire de la Cordillère Blanche. Hydrological Sciences - Journal - des Sciences Hydrologiques 50, 999-1021.

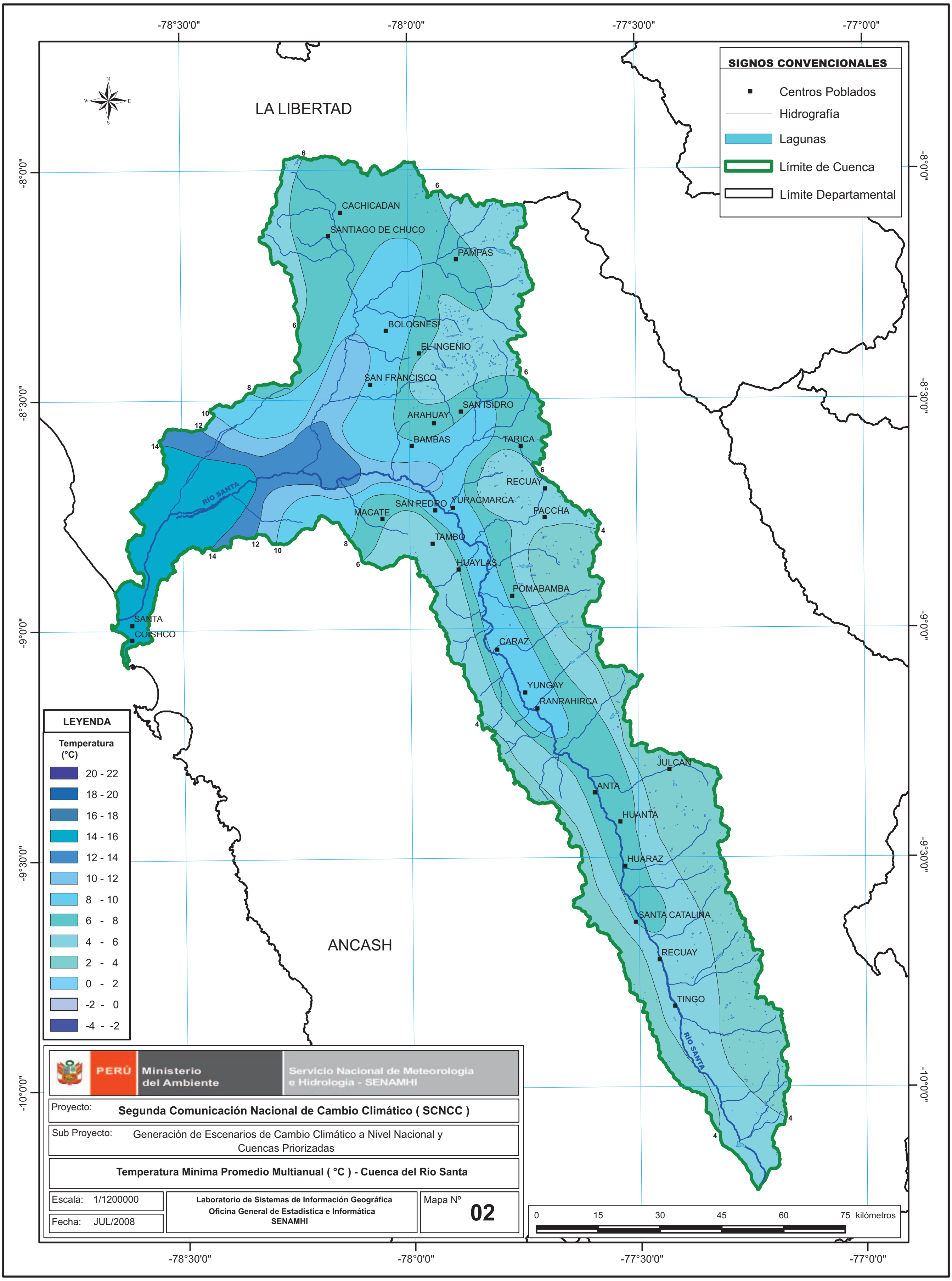
SENAMHI, 1988: Mapa de Clasificación Climática del Perú. Método de Thornthwaite. Eds. SENAMHI Peru,50 pp.

Vuille, M., 2007: Climate change in the Tropical Andes – Impacts and consequences for glaciation and water resources. Part I, II and III. A report for CONAM and the World Bank.

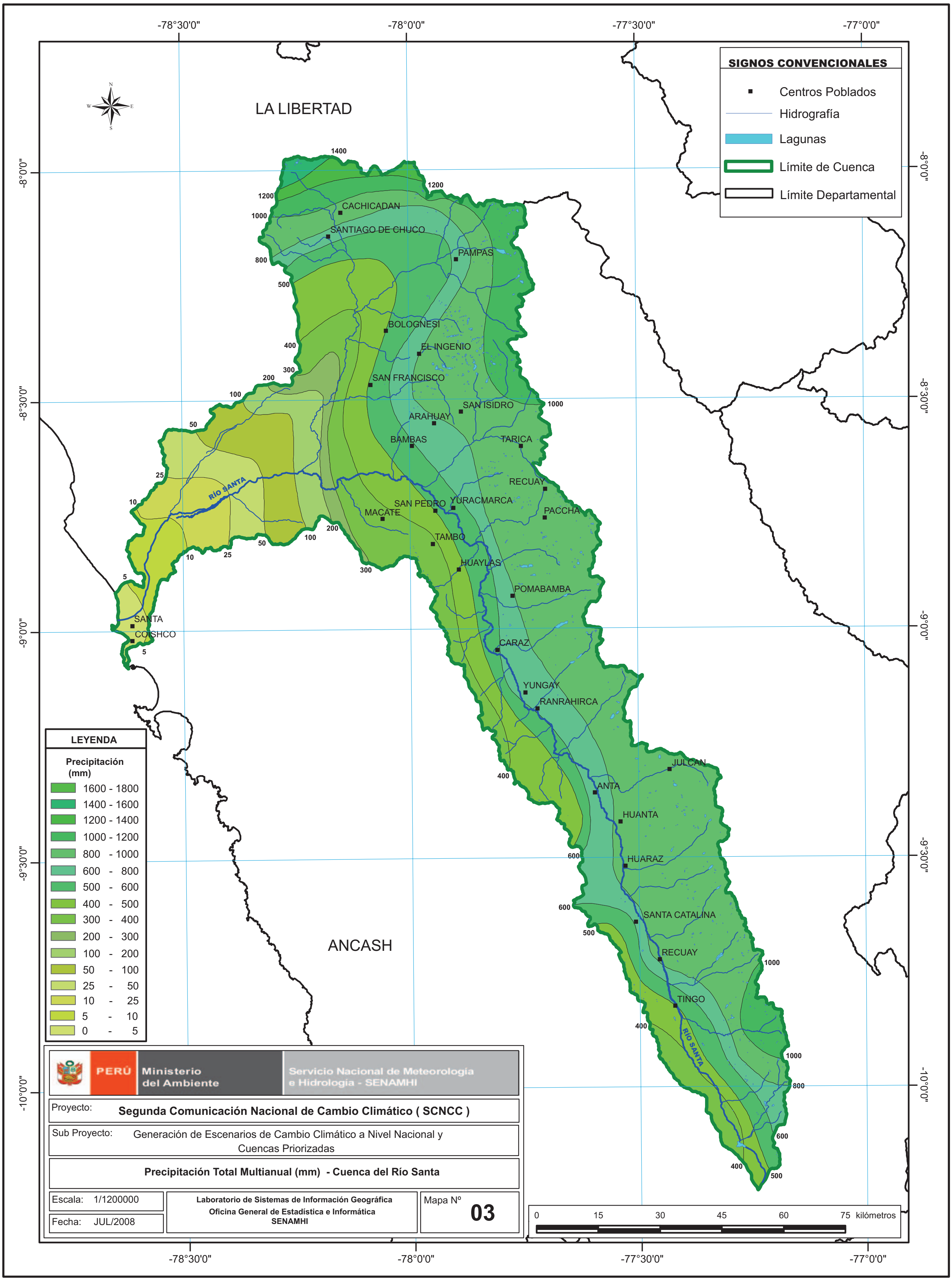
APPENDIX

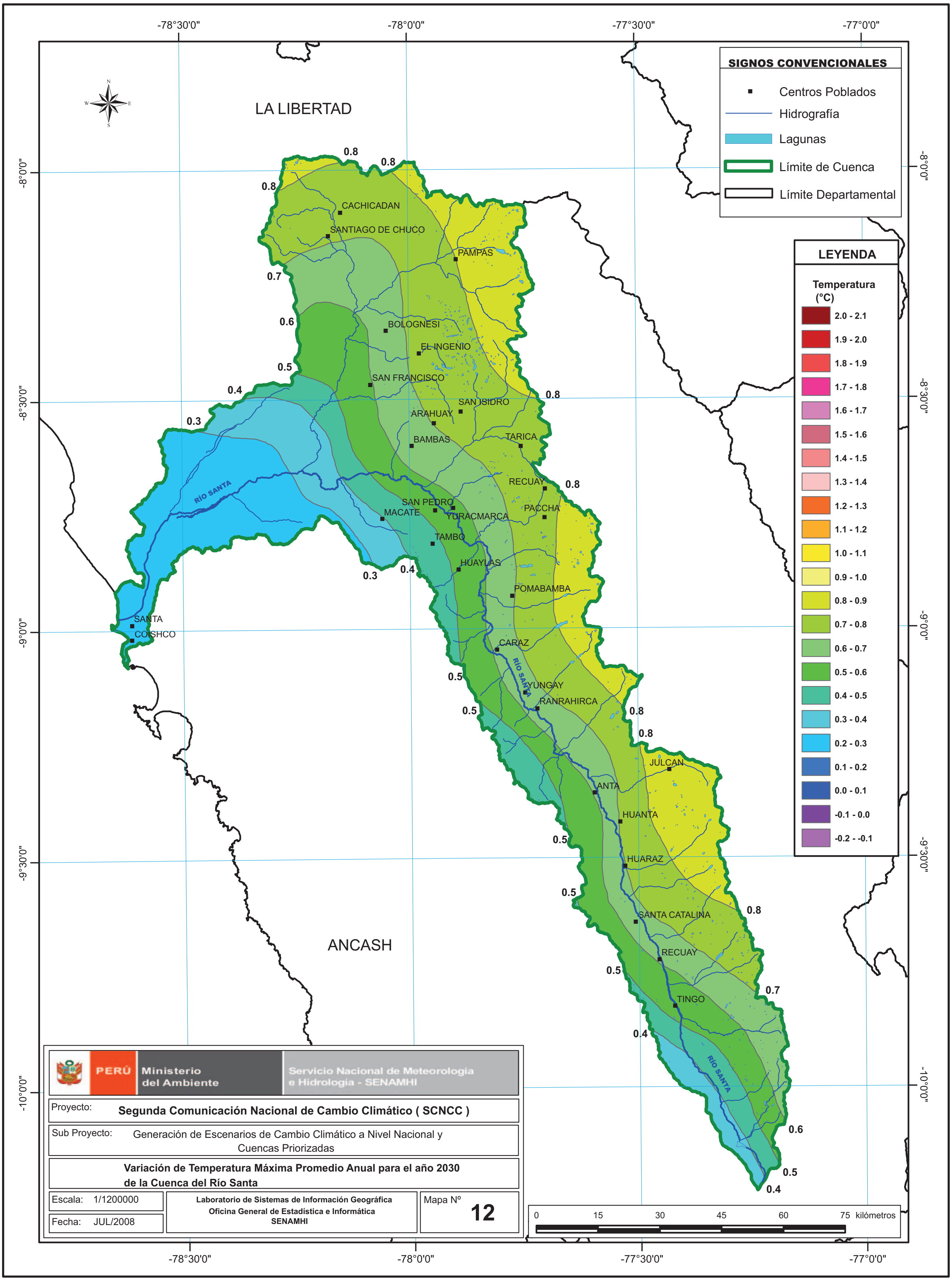
N° of Map	Name of Map
Map Nº 1:	Multiannual average maximum temperature (ºC)
Map Nº 2:	Multiannual average minimum temperature (ºC)
Map Nº 3:	Total multiannual precipitation (mm)
Map N° 12	Variation of maximum temperature to 2030
Map N° 30	Variation of minimum temperature to 2030
Map N° 48	Variation in percentage of precipitation to 2030

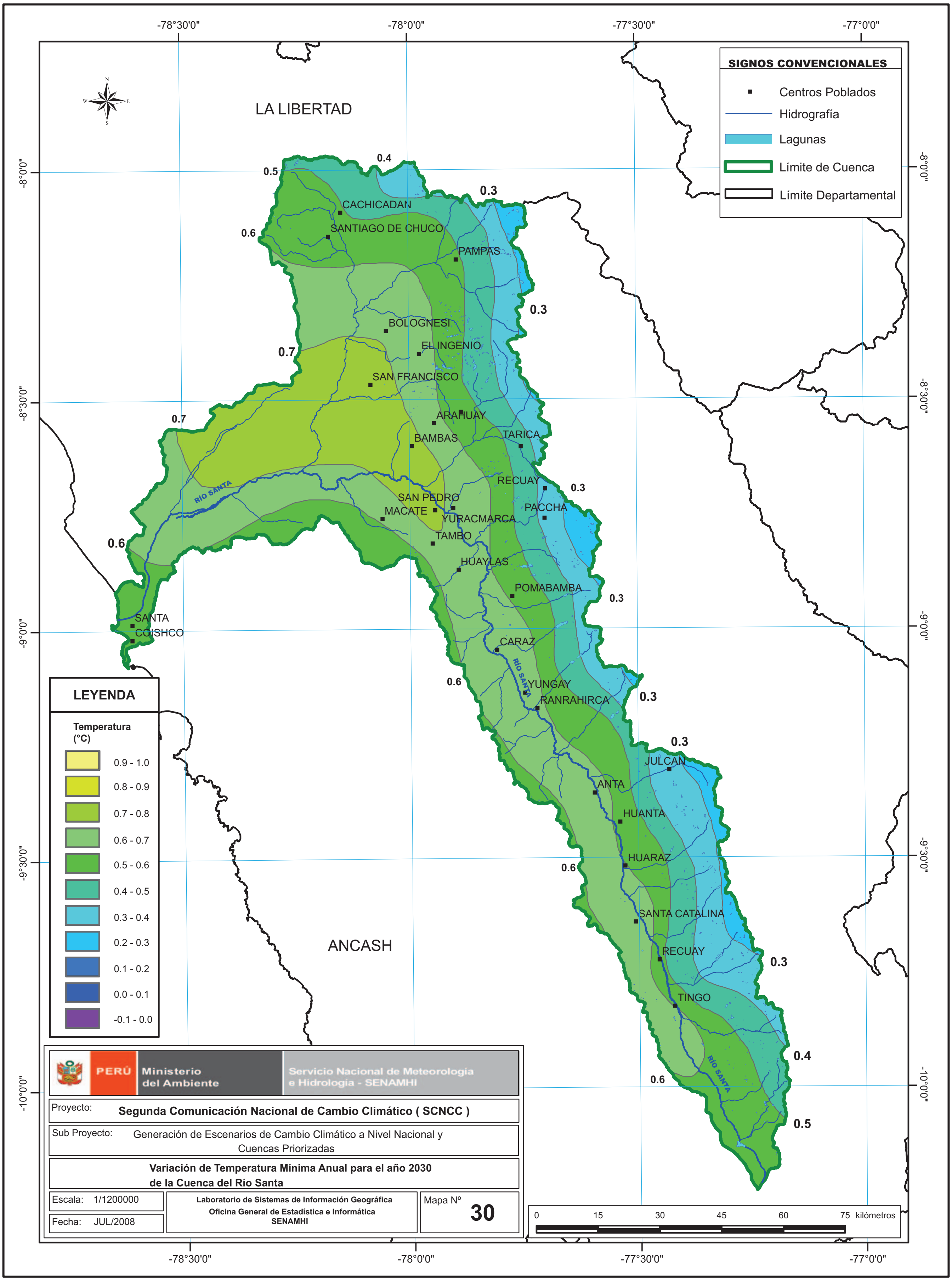

-78°30'0"
-78°0'0"
-77°30'0"
-77°0'0"
-8°0'0"
-8°30'0"
-9°0'0"
-9°30'0"
-10°0'0"
N
S
E
W
LA LIBERTAD
ANCASH
SIGNOS CONVENCIONALES
Centros Poblados
Hidrografía
Lagunas
Límite de Cuenca
Límite Departamental
CACHICADAN
SANTIAGO DE CHUCO
PAMPAS
BOLOGNESI
EL INGENIO
SAN FRANCISCO
SAN ISIDRO
ARAHUAY
BAMBAS
TARICA
RECUAY
YURACMARCA
SAN PEDRO
MACATE
PACCHA
TAMBO
HUAYLAS
POMABAMBA
SANTA
COISHCO
CARAZ
YUNGAY
RANRAHIRCA
JULCAN
ANTA
HUANTA
HUARAZ
SANTA CATALINA
RECUAY
TINGO
RÍO SANTA
RÍO SANTA
18
20
22
24
26
16
LEYENDA
Temperatura (°C)
26 - 28
24 - 26
22 - 24
20 - 22
18 - 20
16 - 18
14 - 16
12 - 14
10 - 12
8 - 10
PERÚ
Ministerio del Ambiente
Servicio Nacional de Meteorología e Hidrología - SENAMHI
Proyecto: Segunda Comunicación Nacional de Cambio Climático (SCNCC)
Sub Proyecto: Generación de Escenarios de Cambio Climático a Nivel Nacional y Cuencas Priorizadas
Temperatura Máxima Promedio Multianual (°C) - Cuenca del Río Santa
Escala: 1/1200000
Fecha: JUL/2008
Laboratorio de Sistemas de Información Geográfica
Oficina General de Estadística e Informática
SENAMHI
Mapa N° 01
0 15 30 45 60 75 kilómetros

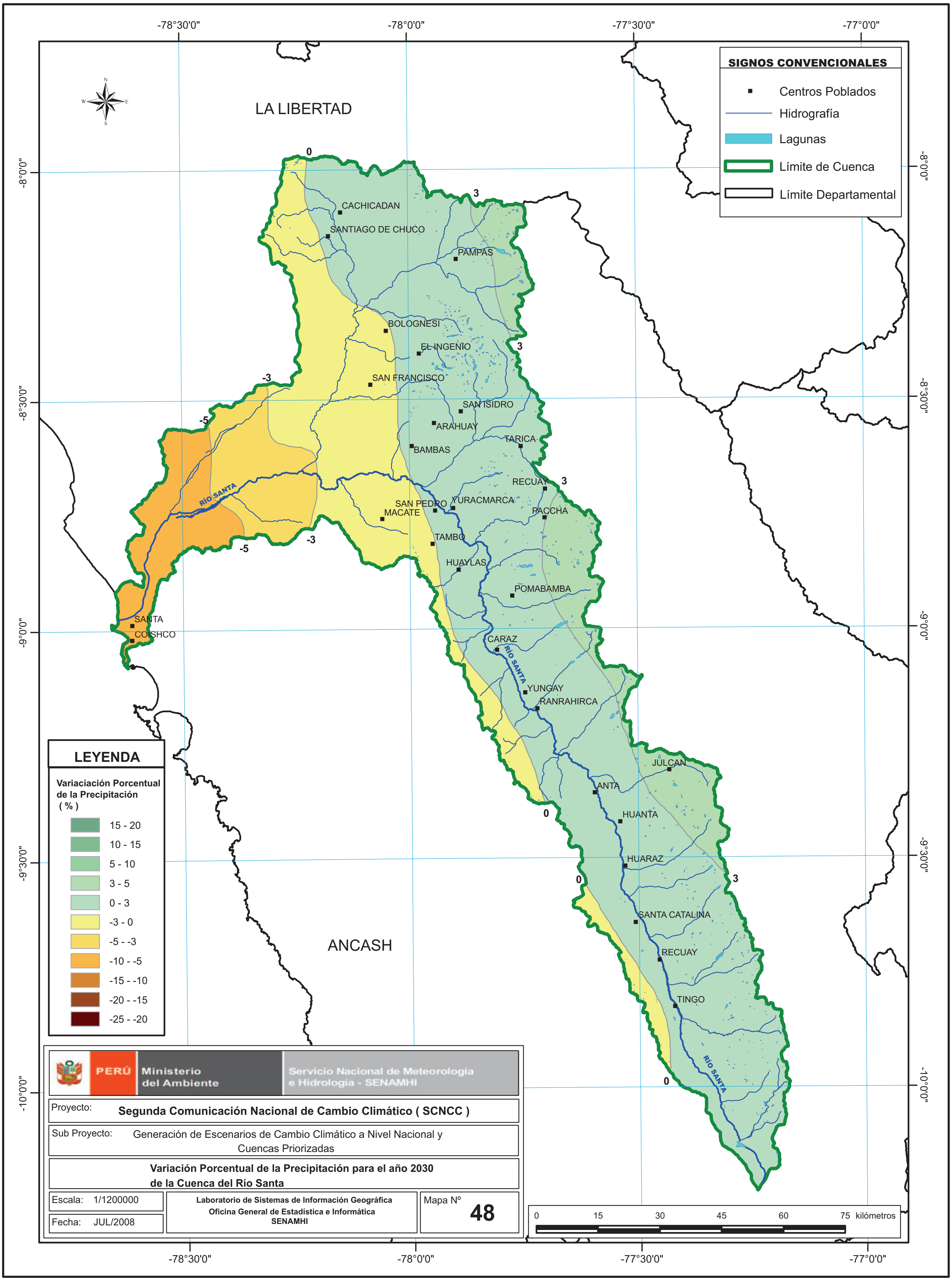


-78°30'0"
-78°0'0"
-77°30'0"
-77°0'0"
-8°0'0"
-8°30'0"
-9°0'0"
-9°30'0"
-10°0'0"
N
S
E
W
LA LIBERTAD
ANCASH
SIGNOS CONVENCIONALES
Centros Poblados
Hidrografía
Lagunas
Límite de Cuenca
Límite Departamental
CACHICADAN
SANTIAGO DE CHUCO
PAMPAS
BOLOGNESI
EL INGENIO
SAN FRANCISCO
SAN ISIDRO
ARAHUAY
BAMBAS
TARICA
RECUAY
SAN PEDRO
YURACMARCA
MACATE
PACCHA
TAMBO
HUAYLAS
POMABAMBA
SANTA
COISHCO
CARAZ
YUNGAY
RANRAHIRCA
JULCAN
ANTA
HUANTA
HUARAZ
SANTA CATALINA
RECUAY
TINGO
RIO SANTA
LEYENDA
Temperatura (°C)
20 - 22
18 - 20
16 - 18
14 - 16
12 - 14
10 - 12
8 - 10
6 - 8
4 - 6
2 - 4
0 - 2
-2 - 0
-4 - -2
PERÚ
Ministerio del Ambiente
Servicio Nacional de Meteorología e Hidrología - SENAMHI
Proyecto: Segunda Comunicación Nacional de Cambio Climático (SCNCC)
Sub Proyecto: Generación de Escenarios de Cambio Climático a Nivel Nacional y Cuencas Priorizadas
Temperatura Mínima Promedio Multianual (°C) - Cuenca del Río Santa
Escala: 1/1200000
Fecha: JUL/2008
Laboratorio de Sistemas de Información Geográfica
Oficina General de Estadística e Informática
SENAMHI
Mapa N° 02
0 15 30 45 60 75 kilómetros


LA LIBERTAD
ANCASH
SIGNOS CONVENCIONALES
Centros Poblados
Hidrografía
Lagunas
Límite de Cuenca
Límite Departamental
LEYENDA
Precipitación (mm)
1600 - 1800
1400 - 1600
1200 - 1400
1000 - 1200
800 - 1000
600 - 800
500 - 600
400 - 500
300 - 400
200 - 300
100 - 200
50 - 100
25 - 50
10 - 25
5 - 10
0 - 5
CACHICADAN
SANTIAGO DE CHUCO
PAMPAS
BOLOGNESI
EL INGENIO
SAN FRANCISCO
SAN ISIDRO
ARAHUAY
BAMBAS
TARICA
RECUAY
SAN PEDRO
YURACMARCA
MACATE
PACCHA
TAMBO
HUAYLAS
POMABAMBA
SANTA
COISHCO
CARAZ
YUNGAY
RANRAHIRCA
JULCAN
ANTA
HUANTA
HUARAZ
SANTA CATALINA
RECUAY
TINGO
RÍO SANTA
-78°30'0"
-78°0'0"
-77°30'0"
-77°0'0"
-8°0'0"
-8°30'0"
-9°0'0"
-9°30'0"
-10°0'0"
PERÚ
Ministerio del Ambiente
Servicio Nacional de Meteorología e Hidrología - SENAMHI
Proyecto: Segunda Comunicación Nacional de Cambio Climático (SCNCC)
Sub Proyecto: Generación de Escenarios de Cambio Climático a Nivel Nacional y Cuencas Priorizadas
Precipitación Total Multianual (mm) - Cuenca del Río Santa
Escala: 1/1200000
Fecha: JUL/2008
Laboratorio de Sistemas de Información Geográfica
Oficina General de Estadística e Informática
SENAMHI
Mapa N° 03
0 15 30 45 60 75 kilómetros


LA LIBERTAD
ANCASH
SIGNOS CONVENCIONALES
Centros Poblados
Hidrografía
Lagunas
Límite de Cuenca
Límite Departamental
LEYENDA
Temperatura (°C)
2.0 - 2.1
1.9 - 2.0
1.8 - 1.9
1.7 - 1.8
1.6 - 1.7
1.5 - 1.6
1.4 - 1.5
1.3 - 1.4
1.2 - 1.3
1.1 - 1.2
1.0 - 1.1
0.9 - 1.0
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0.0 - 0.1
-0.1 - 0.0
-0.2 - -0.1
CACHICADAN
SANTIAGO DE CHUCO
PAMPAS
BOLOGNESI
EL INGENIO
SAN FRANCISCO
SAN ISIDRO
ARAHUAY
BAMBAS
TARICA
RECUAY
SAN PEDRO
MACATE
YURACMARCA
PACCHA
TAMBO
HUAYLAS
POMABAMBA
SANTA
COISHCO
CARAZ
YUNGAY
RANRAHIRCA
JULCAN
ANTA
HUANTA
HUARAZ
SANTA CATALINA
RECUAY
TINGO
RIO SANTA
-78°30'0"
-78°0'0"
-77°30'0"
-77°0'0"
-8°0'0"
-8°30'0"
-9°0'0"
-9°30'0"
-10°0'0"
PERÚ Ministerio del Ambiente
Servicio Nacional de Meteorología e Hidrología - SENAMHI
Proyecto: Segunda Comunicación Nacional de Cambio Climático (SCNCC)
Sub Proyecto: Generación de Escenarios de Cambio Climático a Nivel Nacional y Cuencas Priorizadas
Variación de Temperatura Máxima Promedio Anual para el año 2030 de la Cuenca del Río Santa
Escala: 1/1200000
Fecha: JUL/2008
Laboratorio de Sistemas de Información Geográfica
Oficina General de Estadística e Informática
SENAMHI
Mapa N° 12
0 15 30 45 60 75 kilómetros


-78°30'0"
-78°0'0"
-77°30'0"
-77°0'0"
-8°0'0"
-8°30'0"
-9°0'0"
-9°30'0"
-10°0'0"
LA LIBERTAD
ANCASH
SIGNOS CONVENCIONALES
Centros Poblados
Hidrografía
Lagunas
Límite de Cuenca
Límite Departamental
CACHICADAN
SANTIAGO DE CHUCO
PAMPAS
BOLOGNESI
EL INGENIO
SAN FRANCISCO
ARAHUAY
BAMBAS
TARICA
RECUAY
SAN PEDRO
MACATE
PACCHA
YURACMARCA
TAMBO
HUAYLAS
POMABAMBA
SANTA
COISHCO
CARAZ
YUNGAY
RANRAHIRCA
JULCAN
ANTA
HUANTA
HUARAZ
SANTA CATALINA
RECUAY
TINGO
RIO SANTA
0.3
0.4
0.5
0.6
0.7
LEYENDA
Temperatura (°C)
0.9 - 1.0
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0.0 - 0.1
-0.1 - 0.0
PERÚ Ministerio del Ambiente
Servicio Nacional de Meteorología e Hidrología - SENAMHI
Proyecto: Segunda Comunicación Nacional de Cambio Climático (SCNCC)
Sub Proyecto: Generación de Escenarios de Cambio Climático a Nivel Nacional y Cuencas Priorizadas
Variación de Temperatura Mínima Anual para el año 2030 de la Cuenca del Río Santa
Escala: 1/1200000
Fecha: JUL/2008
Laboratorio de Sistemas de Información Geográfica
Oficina General de Estadística e Informática
SENAMHI
Mapa N° 30
0 15 30 45 60 75 kilómetros


-78°30'0"
-78°0'0"
-77°30'0"
-77°0'0"
-8°0'0"
-8°30'0"
-9°0'0"
-9°30'0"
-10°0'0"
LA LIBERTAD
ANCASH
SIGNOS CONVENCIONALES
Centros Poblados
Hidrografía
Lagunas
Límite de Cuenca
Límite Departamental
CACHICADAN
SANTIAGO DE CHUCO
PAMPAS
BOLOGNESI
EL INGENIO
SAN FRANCISCO
SAN ISIDRO
ARAHUAY
BAMBAS
TARICA
RECUAY
SAN PEDRO
MACATE
YURACMARCA
PACCHA
TAMBO
HUAYLAS
POMABAMBA
CARAZ
YUNGAY
RANRAHIRCA
JULCAN
ANTA
HUANTA
HUARAZ
SANTA CATALINA
RECUAY
TINGO
SANTA
COISHCO
RÍO SANTA
LEYENDA
Variación Porcentual de la Precipitación (%)
15 - 20
10 - 15
5 - 10
3 - 5
0 - 3
-3 - 0
-5 - -3
-10 - -5
-15 - -10
-20 - -15
-25 - -20
PERÚ
Ministerio del Ambiente
Servicio Nacional de Meteorología e Hidrología - SENAMHI
Proyecto: Segunda Comunicación Nacional de Cambio Climático (SCNCC)
Sub Proyecto: Generación de Escenarios de Cambio Climático a Nivel Nacional y Cuencas Priorizadas
Variación Porcentual de la Precipitación para el año 2030 de la Cuenca del Río Santa
Escala: 1/1200000
Fecha: JUL/2008
Laboratorio de Sistemas de Información Geográfica
Oficina General de Estadística e Informática
SENAMHI
Mapa N° 48
0 15 30 45 60 75 kilómetros

PERÚ Ministry of Environment

Ministry of Environment - MINAM
Av. Javier Prado Oeste 1440 - San isidro - Lima - Perú
Phone: (511) 6116000
www.minam.gob.pe

National Meteorology and Hidrology Service - SENAMHI
Jr. Cahuide 785, Jesús María, Lima - Perú
Phone: (511) 6141414
www.senamhi.gob.pe