THE SUSTAINABLE WATER MANAGEMENT TEAM

OF THE AREQUIPA NEXUS INSTITUTE

Presents:

AQP-Clima

User's Manual

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Arequipa Nexus Institute

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INTRODUCTION TO TOOL

Climate is a powerful driver of agricultural and natural systems, and climate information is often in great demand, because it can help stakeholders visualize and understand climate patterns and changes through time, and contribute to climate services that help to guide decision making. This is especially true in the Arequipa Department of Peru, a region with a large range in climate extremes a, significant topographic variability, and high demand for water resources in highly managed water systems.

AQP-Clima is a user-friendly, interactive web tool that provides access to historical weather data (1988 to 2017) of the Arequipa Department, Peru. In this tool, you can view, compare and download annual, monthly and daily weather data from any location within the department. The data offered by this tool can be used:

- To understand the climatic variation across the region and climate trends over time;
- In studies to understand the effect of the climate in:
    - Hydrology and water resources;
    - Crop management and food production;
    - Animal production; and
    - Economic decision-making and much more!

TOOL DEVELOPMENT

The tool is based on two gridded datasets: the Arequipa Climate Maps – Normals (ACM-N) and the Arequipa Climate Maps – Yearly, Monthly, and Daily (ACM-YMD). Together these datasets provide 30-year average annual and monthly maps of precipitation, and average, minimum and maximum daily air temperature (ACM-N), as well as yearly, monthly and daily (ACM-YMD) maps of precipitation, and minimum and maximum daily air temperature, from January 1, 1988, to December 31, 2017, at a spatial resolution of 1 km.

These data sets were created using weather station data from the Servicio Nacional de Meteorología e Hidrología del Perú (SENAMHI) and the National Ocean and Atmospheric Administration's (NOAA) Global Summary of the Day (GSOD). Topographic data, used as covariates for spatial interpolation, came from the ALOS World 3D DEM. Weather data went through extensive preprocessing for removal of implausible values, data gap filling, and inhomogeneity detection. After completion of all data quality checking, 53 Prec stations, 27 Tmin stations, and 27 Tmax stations were approved for use in developing of the ACM. Maps were created using a Regression Thin-Plate Splines (RTPS) method that made use of Polynomial and Potential Regression Models specifically developed for the region. Using locally fitted polynomial and potential regressions were found to best represent the spatial variability of precipitation and daily extreme temperatures, respectively, and helped compensate the bias resulting from the lack of weather stations at higher elevations. The method was also able to represents the main spatial climate-forcing factor affecting precipitation and temperature patterns in the region that include: elevation, terrain induced climate transitions and costal zones. Resulting precipitation and temperatures spatial and seasonal patterns are in accordance with other climate datasets and atmospheric patterns. The largest part of the annual rainfall occurs in the summer months and the smallest in winter. These are in part due to the more intense heating in the summer given the larger availability of solar energy that favors the development of convective clouds. However, the biggest factor influencing the seasonality of precipitation in Arequipa is the intensification of the northeast trade winds during the summer. These winds cross the Amazon basin and when they meet the Andes and undergo orographic uplift, they contribute substantially to precipitation in the high elevation areas of Arequipa. Temperature patterns are mostly dominated by elevation, with the exceptions of the buffer effect caused by the ocean in coastal areas. more information about the development of the datasets and discussion about its qualities and limitations are provided in Moraes et al. (2021).

In addition, annual scale trend analysis to help user visualize the overall tendency of climate variables versus time were estimated using the Theil-Sen slope estimator. A more in-depth analysis of regional climate changes is presented in Moraes et al. (2021). To facilitate visualization of the climatic trends, the mean of the trend line intercepts the mean of the observed data in the year of 2003 (center of the time frame analyzed).

The design intent of the AQP-Clima on-line tool is to present the data contained in the ACM-N and ACM-YMD in a user-friendly and insightful way. To achieve that goal, the tool is divided into "tabs", different screens where climate data is presented in different formats. The tool is a HUBzero component that employs AJAX (Asynchronous JavaScript and XML) to communicate between tool code running in the user's web browser and corresponding tool code running on the hub's web server. In the browser, the OpenLayers library is used to display a map and translate a user's mouse click into latitude and longitude values. These are transmitted via AJAX to the server where GDAL (Geospatial Data Abstraction Library) is used to extract data from GeoTIFF files to be sent back to the browser. Finally, in the browser tool code, the Highcharts library is used to display plots and graphs.

The tool is designed to work with popular, up-to-date, desktop browsers running on Windows, Mac, and Linux. It is not optimized for access via mobile devices.

USING THE TOOL

AQP-Clima can be accessed on-line at: https://www.agry.purdue.edu/hydrology/projects/nexus-swm/es/instrumentos_web.html

Data availability

Climate data is available for any location within the Arequipa Department at 1 km resolution. The initial map tab allows users to zoom in and click on a location of interest. Once selected, the longitude and latitude coordinates appear, and users can click the blue box to move to the data for that location.

Figure 1. Opening screen of AQP-Clima where users can select a point of interest.

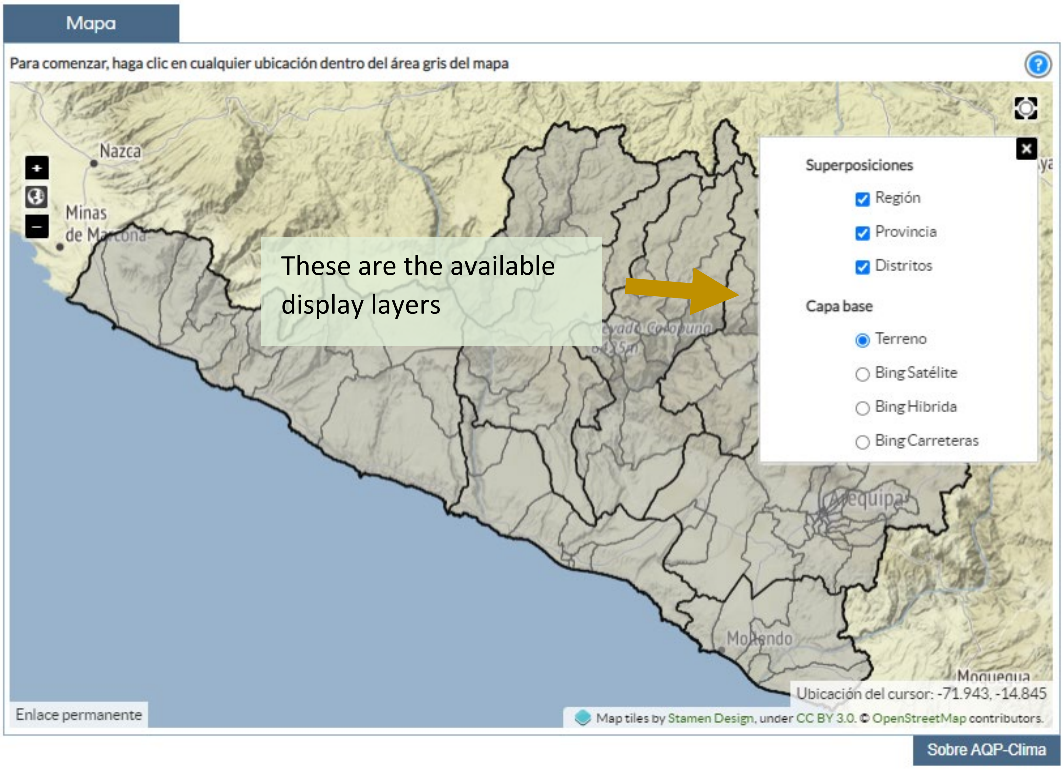

Figure 2. Opening screen of AQP-Clima showing the additional display layers available.

Data presentation options

Once a user selects a location, they are taken automatically to a graph of annual data. Precipitation and temperature data can be viewed in five different formats, accessible from tabs across the top of the page: Annual Data, Daily Data, Monthly Data, Monthly Averages, and Monthly Comparison. One can always return to the map selection screen by clicking “mapa” in the upper left-hand corner.

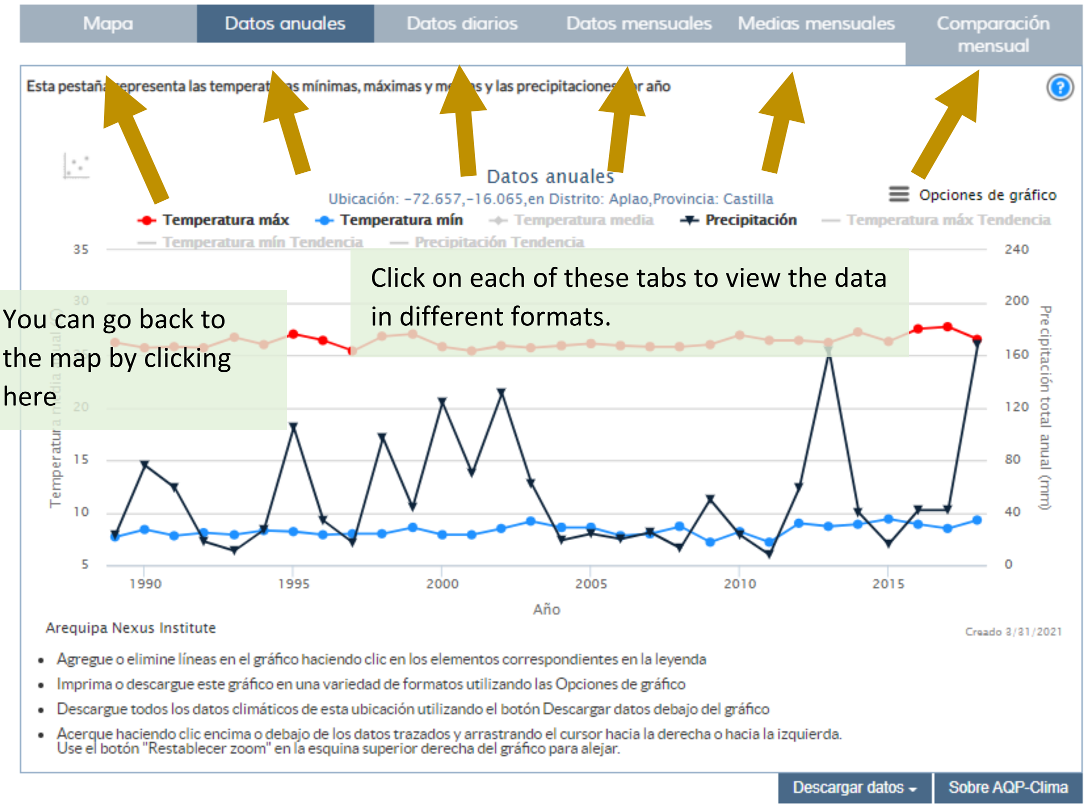

Figure 3. The Annual Data screen, highlighting tabs for selecting other display options.

Annual data

The annual data tab shows annual average maximum and minimum daily temperature and the annual sum of daily precipitation. Estimated trends in each variable from 1988 to 2017 can be shown by clicking on the gray text. All generated graphs can be downloaded by clicking on 'opciones de grafico" in the upper right (Figure 6).

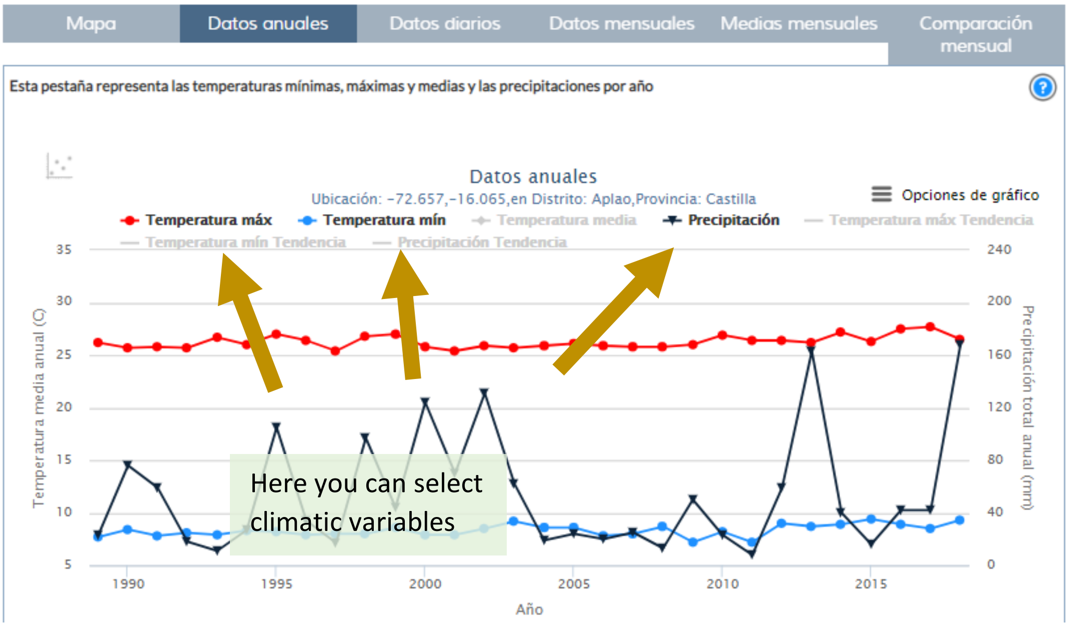

Figure 4. The Annual Data screen, highlighting the default variables.

Figure 5. The Annual Data screen, showing average annual minimum daily temperature and the estimated trend.

Figure 6. The Annual Data graphs can be downloaded by clicking in the upper right hand corner.

Daily data

The Daily Data tab displays daily data for the three climate variables for one year at a time. Users can change the year, as shown in Figure 7. One can zoom in on a particular time of the year by dragging over the area of interest (Figure 8).

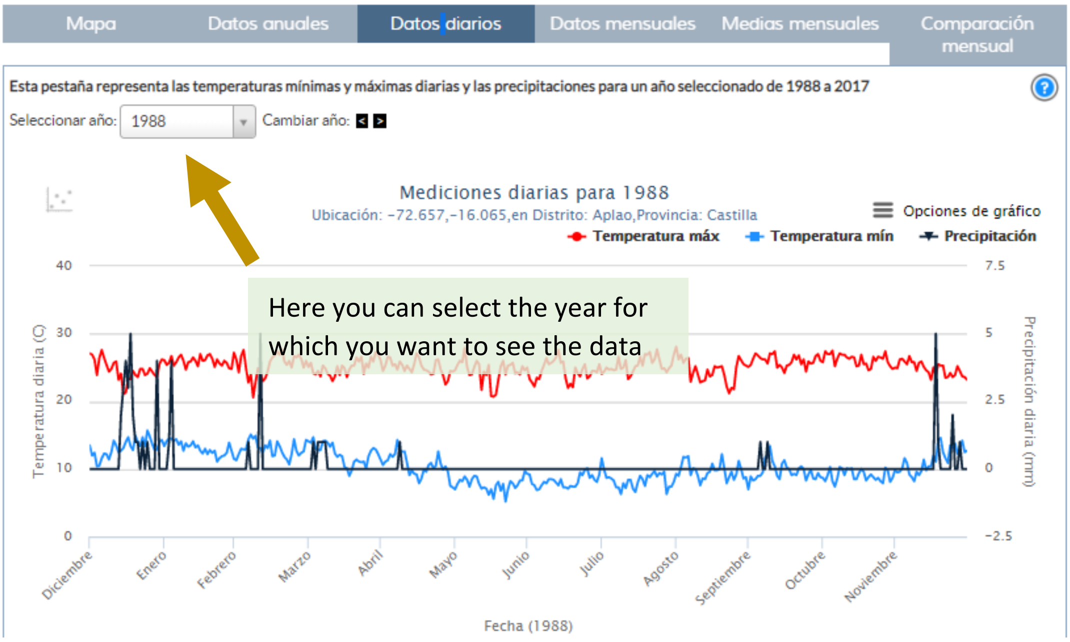

Figure 7. The Daily Data tab displays one year at a time, selected in the upper left.

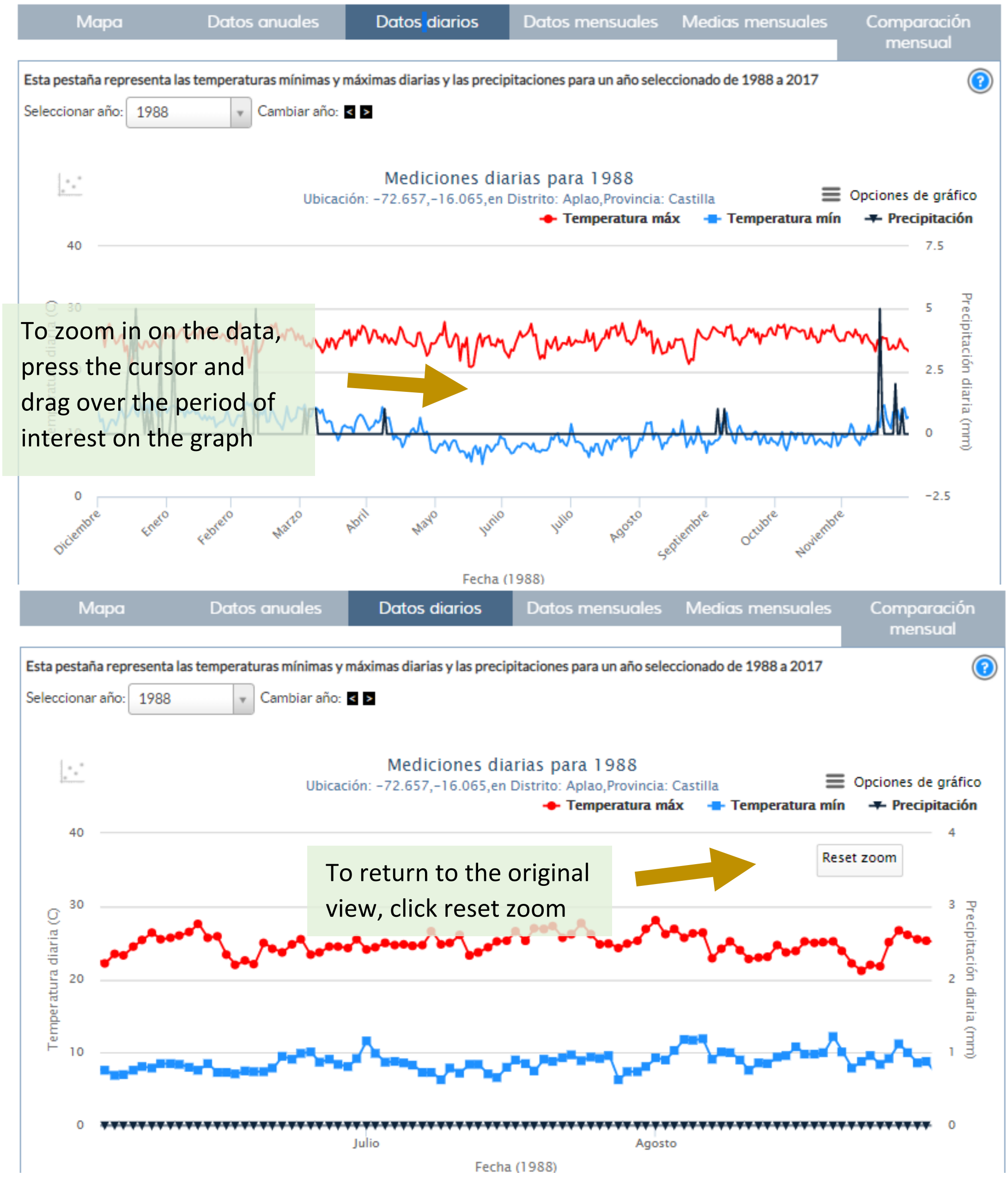

Figure 8. To zoom in on the daily data, press the cursor and drag over the period of interest (top). A 'reset zoom' button should appear, click here to return to the original data extent.

Monthy data

The Monthly Data tab shows monthly average maximum and minimum temperature and monthly total precipitation for the thirty year time series (Figure 9). Once again, one can zoom on a specific time period by pressing the cursor and dragging over the period of interest. As with each of the data display tabs, you can download the data appearing in the graph as a comma-delimited text file (csv) by clicking in the lower right hand corner (Figure 9).

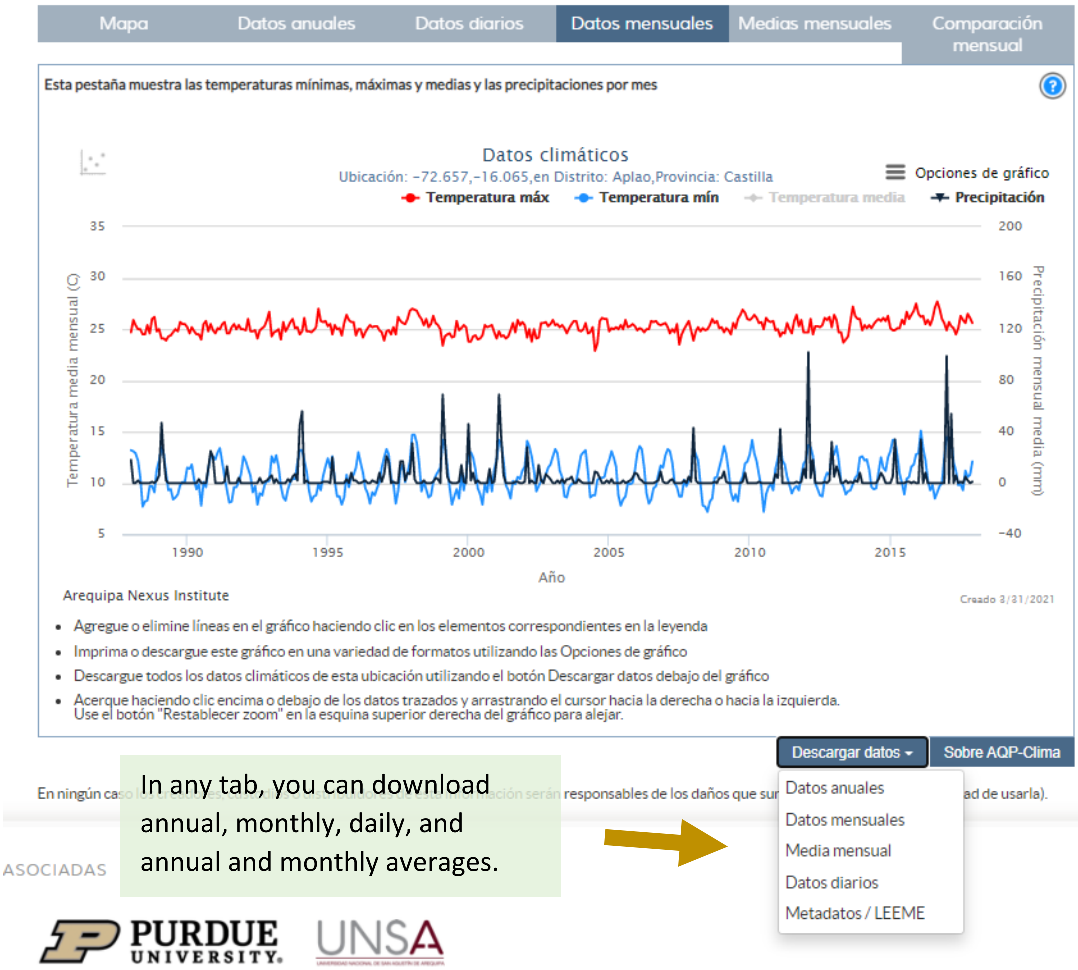

Figure 9. To download the data shown in the graph, click on the blue 'descargar datos' button.

Monthly averages

The Monthly Average tab shows the 30-year average of each month (1988-2017) with a colored line. The gray shading shows the range in monthly values observed over all years. The variable shown can be changed at the top of the screen (Figure 10). In addition, up to two specific years can be added to the graph, to show how average weather in that year compared to the long-term average.

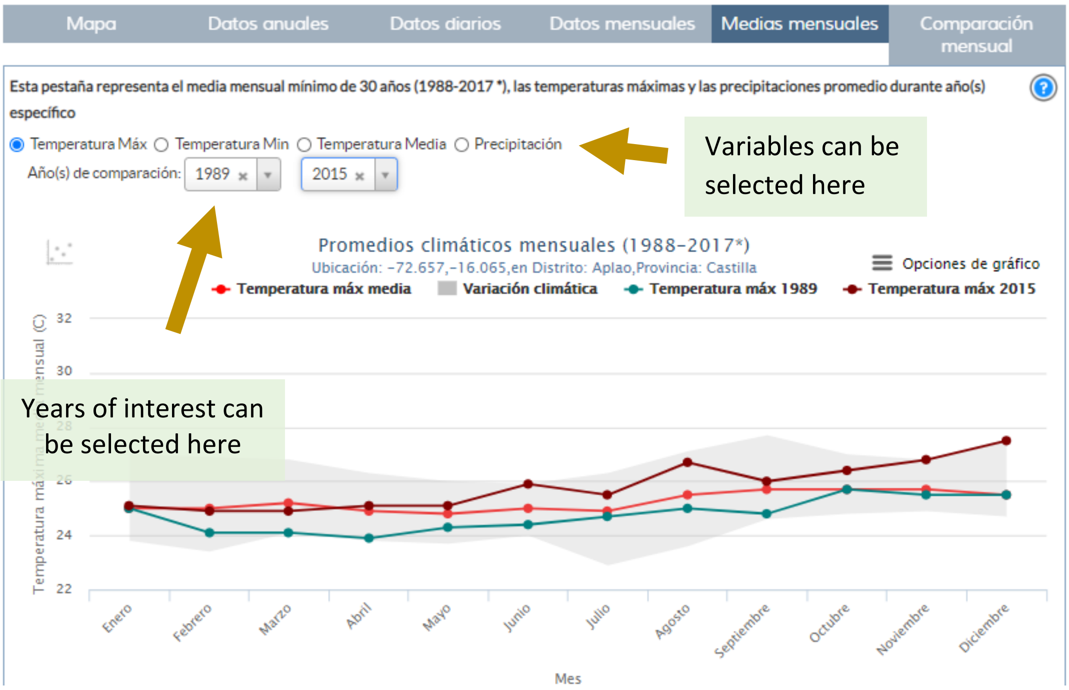

Figure 10. The monthly average tab shows the 30-year average of monthly variables. The variable displayed can be changed at the top, and up to two specific years can be displayed for comparison.

Monthly comparisons

The Monthly Comparison tab shows 30 year time -series for one month at a time across all the years, and also shows the annual climate trends for that month (Figure 11).

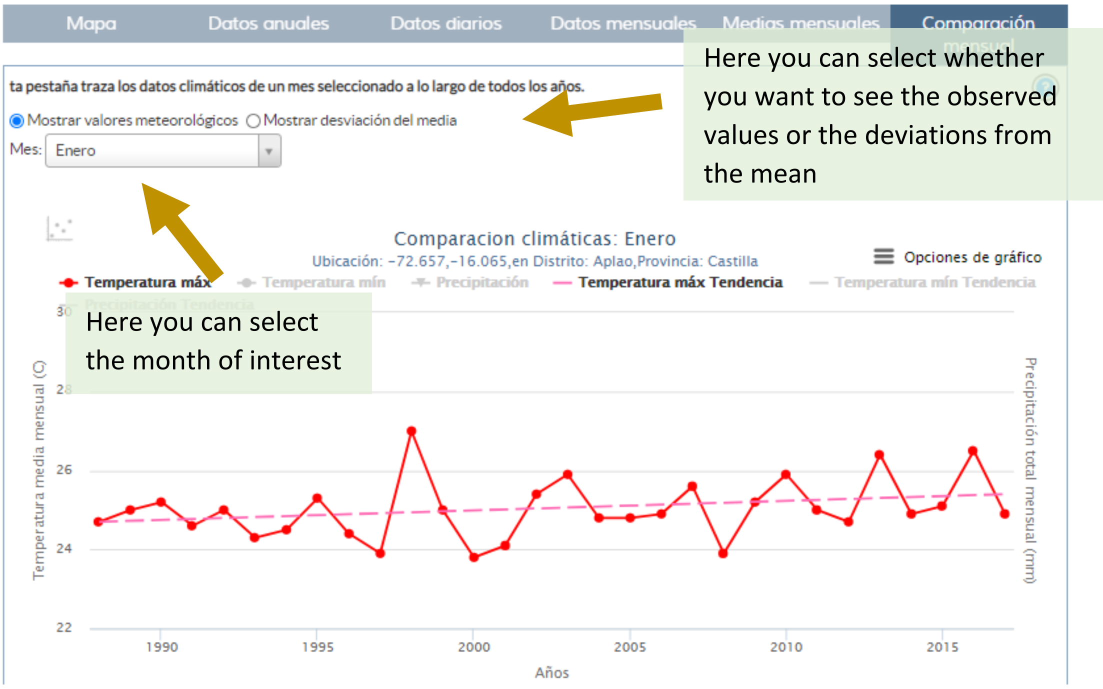

Figure 11. The monthly comparison tab shows the 30-year average of monthly variables. The month displayed can be changed at the top, and you can also display the observed values or deviations from the mean.

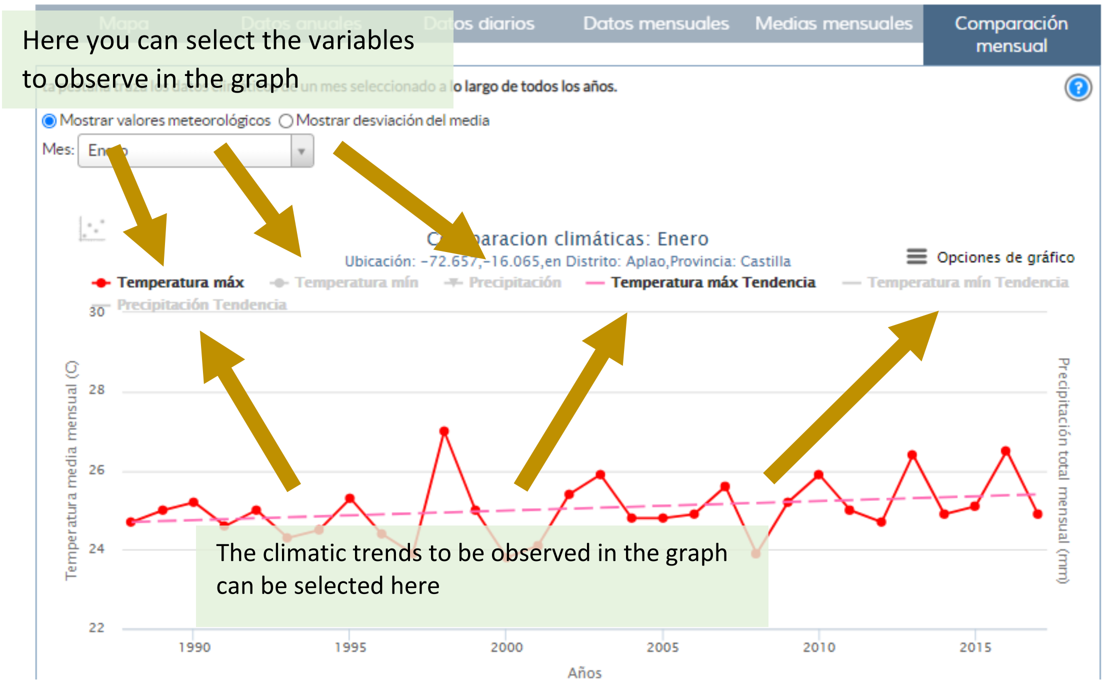

Figure 12. Similar to the Annual Data tab, variables can be turned on or off by clicking on the gray text.

APPLICATIONS

This section will present some application examples to demonstrate how AQP-Clima can be used to learn about and understand local climate patterns and trends that can affect decision making. For a better learning experience, open the AQP-Clima tool in your browser and try to replicate what is demonstrated here.

Understanding regional climate differences

The Arequipa Department can be roughly divided into two topographic/climatic regions: the desert and the Andean Altiplano. The desert corresponds to a 70-90 km wide strip between the Pacific Ocean coastline and the Andes. the Andean Altiplano is a wide high-altitude region with average elevations of more than 3,500 m. What are the main climatic differences between these regions? Let's use the monthly climate data graphs from the Majes area and Chivay to find out!

By looking at Figures 12 and 13 we can spot that Majes is hotter and dryer than Chivay. We can also see the effects of the seasons in the climate variables. Roughly 70% of the precipitation happens during the summer months (December to March) in both regions, however precipitation in Majes rarely exceeds 5 mm/month while precipitation in Chivay usually reaches 150 mm/month at least once every year during the rainy season. Also notice the strong precipitation seasonality in Chivay, which has almost no precipitation during the winter months.

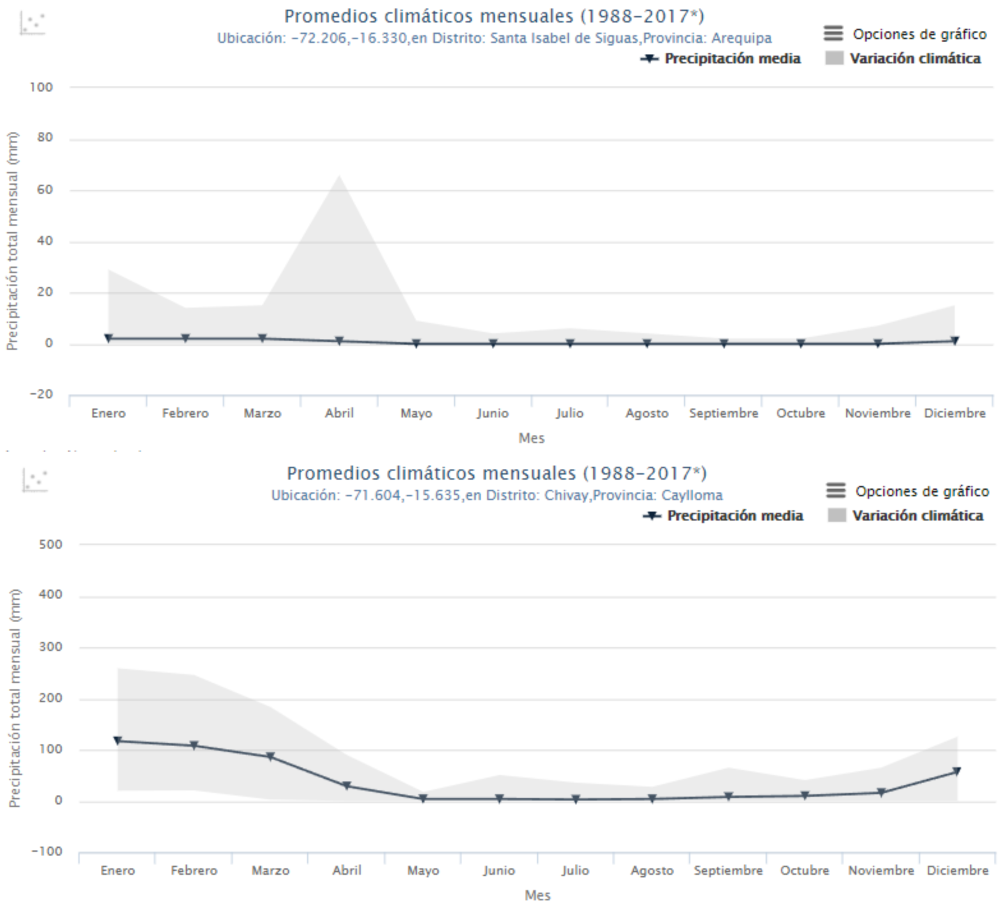

Figure 12: Monthly average precipitation for Chivay (bottom) and Majes (upper)

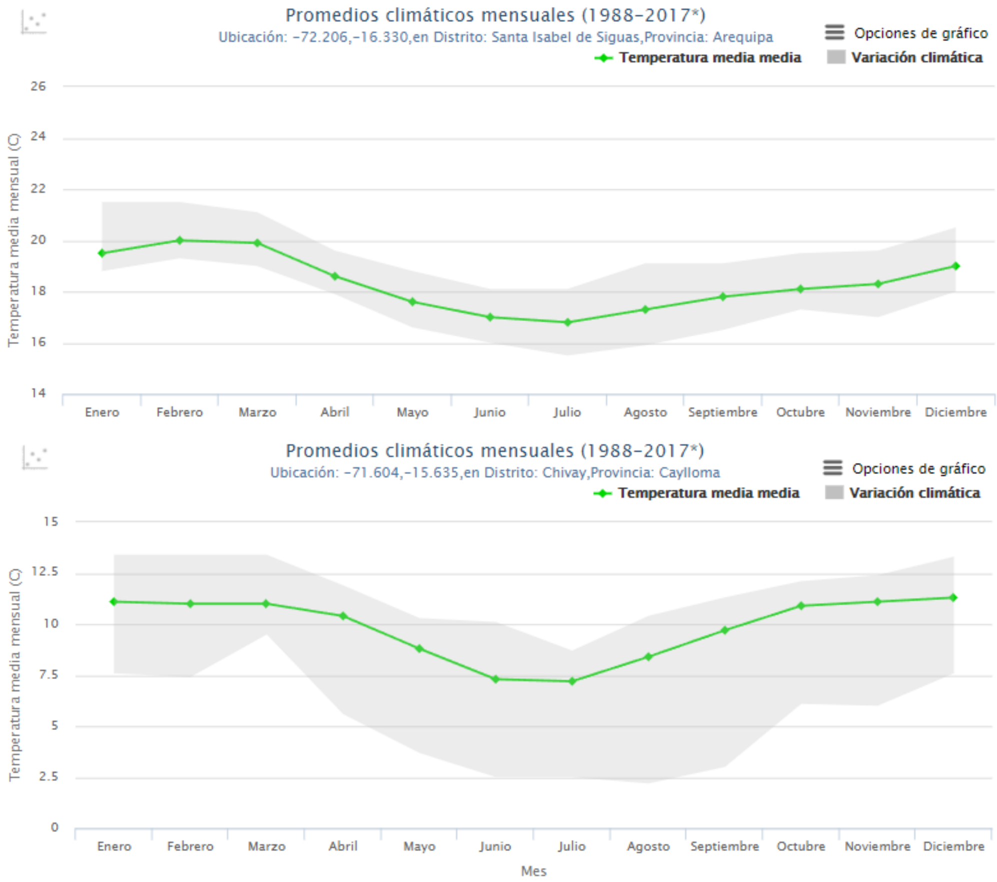

Figure 13: Monthly average temperature for Chivay (bottom) and Majes (upper)

In Figure 14, the relationship between precipitation and daily maximum temperature in Chivay is shown. Notice that Tmin and Precipitation follow a similar seasonal cycle, with both peaking during the summer months. In contrast, Tmax has two low points per year, one in July and another one during the summer months, usually January and February. This is due to the strong moderation Precipitation (moisture) has over daily Tmax because when moisture is available, excess energy goes to evaporation rather than warming the land surface. These drops in Tmax, added to the precipitation, makes it feel cooler in the summer and is one of the major causes of pneumonia in Alpacas and llamas at high altitudes in Arequipa.

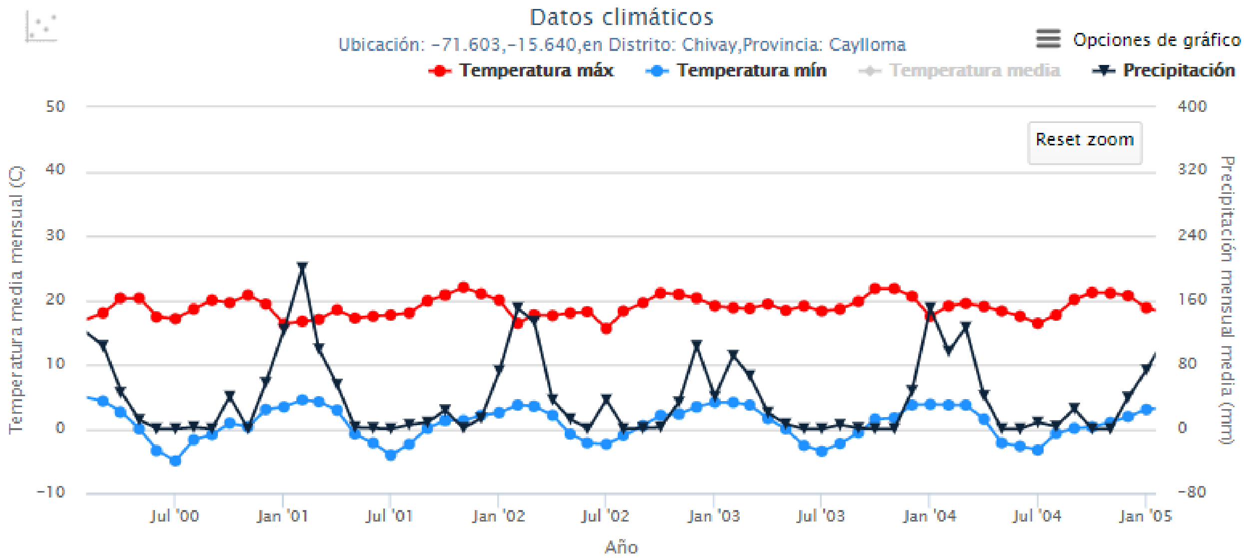

Figure 14: Zoom over 2000 to 2005 monthly climate data in Chivay

Observing climate trends

In this example data from Chivay is used to understand how to use AQP-Clima to observe long term climate changes. Figure 15 shows that annual average Tmax has increased from around 20°C in 1988 to about 22 °C in 2017. Hovering over the line in the tool the exact numbers appear, and one can calculate that the trend is +2.1°C/30 years. Tmin is also increasing, but faster than Tmax with a rate of +2.6°C/30 years (Figure 16). Precipitation is also increasing, at a rate of +158 mm/30 years (Figure 17). In this arid region, an increase in precipitation is a good thing, however, increasing precipitation trends must be considered in context with the increases in air temperature. The increase in temperature will likely lead to greater evaporation from reservoirs and soil, transpiration from crops and other vegetation and faster glacier melt. Actual affects will depend a lot on when during the year these changes in temperature and precipitation are occurring.

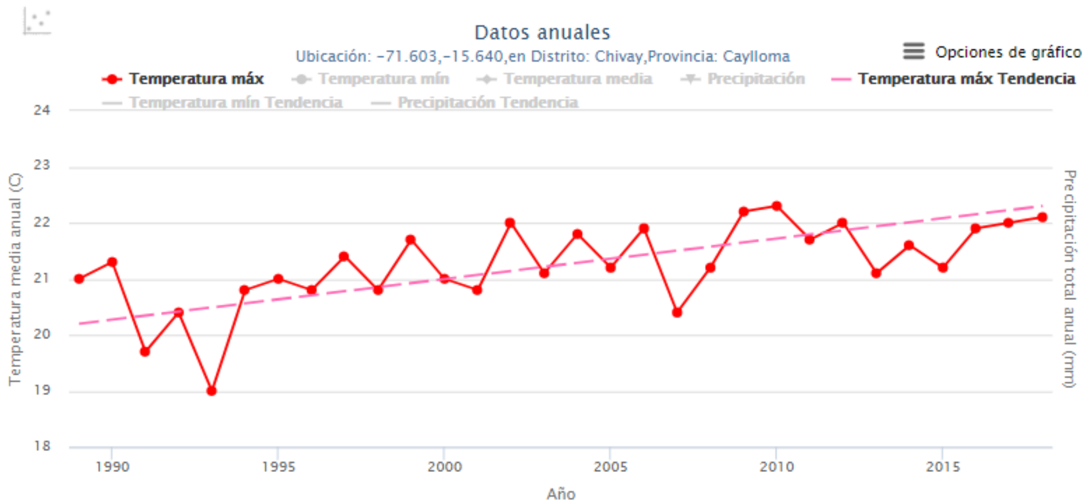

Figure 15: Annual average Tmax and the estimated trend in Chivay (+2.1°C/30 years)

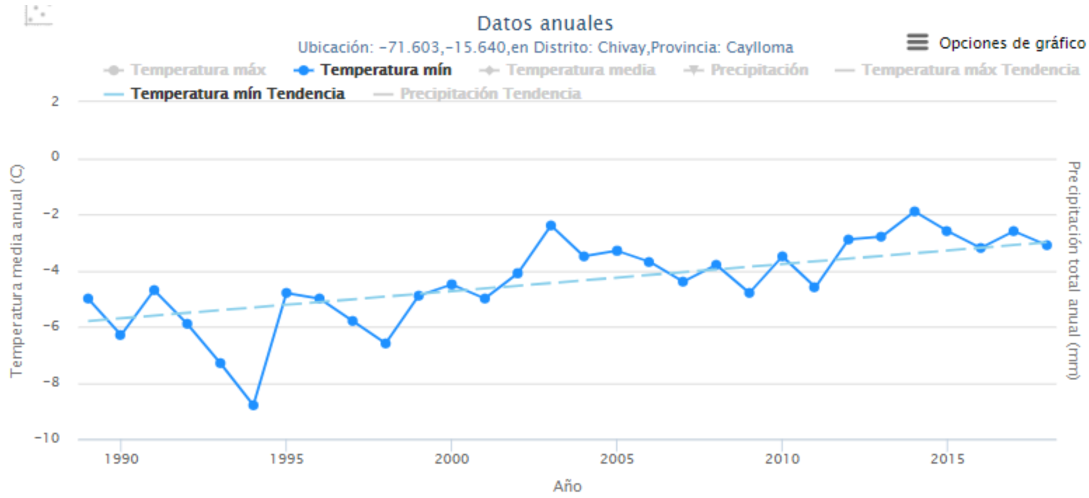

Figure 16: Annual average Tmin and the estimated trend in Chivay (+2.6°C/30 years)

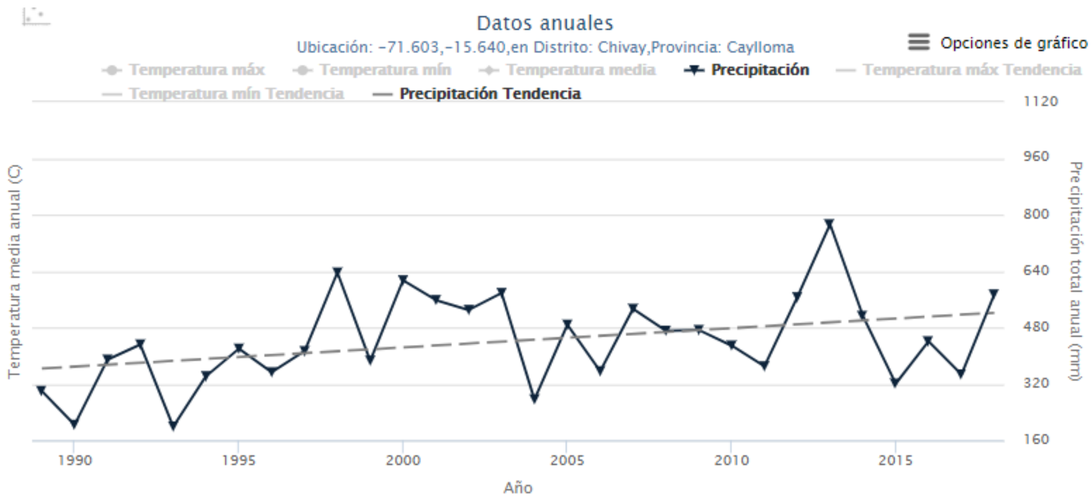

Figure 17: Annual precipitation and the estimated trend in Chivay (+158 mm/30 years)

Finally, figures from the monthly comparison tab can demonstrate how global and regional climatic changes are not evenly distributed throughout the year. Figure 18 shows that the already wet month of February is getting wetter, and accounting for two-thirds of the observed increase in annual precipitation. As shown in Figure 19, there is little change occurring in the dry months. The result is an increase in the seasonality of precipitation. We can also see that precipitation trends are negative in November, the month when the rainy season typically starts. This is indicative of a shift in the rainy season, with more precipitation falling later in the traditional wet season.

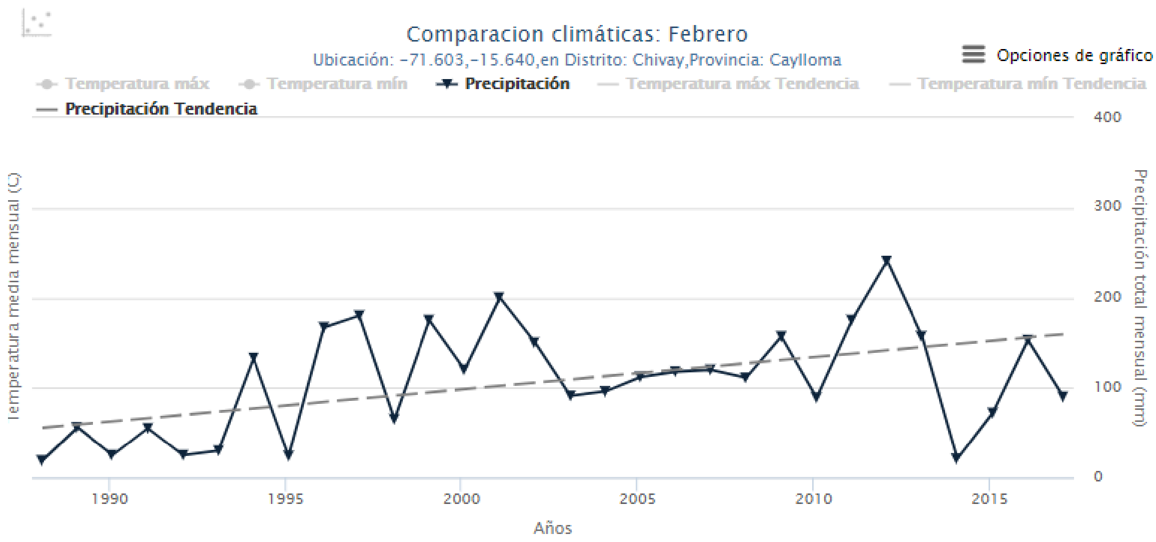

Figure 18: February precipitation and the estimated trend in Chivay (+103.9 mm/30 years)

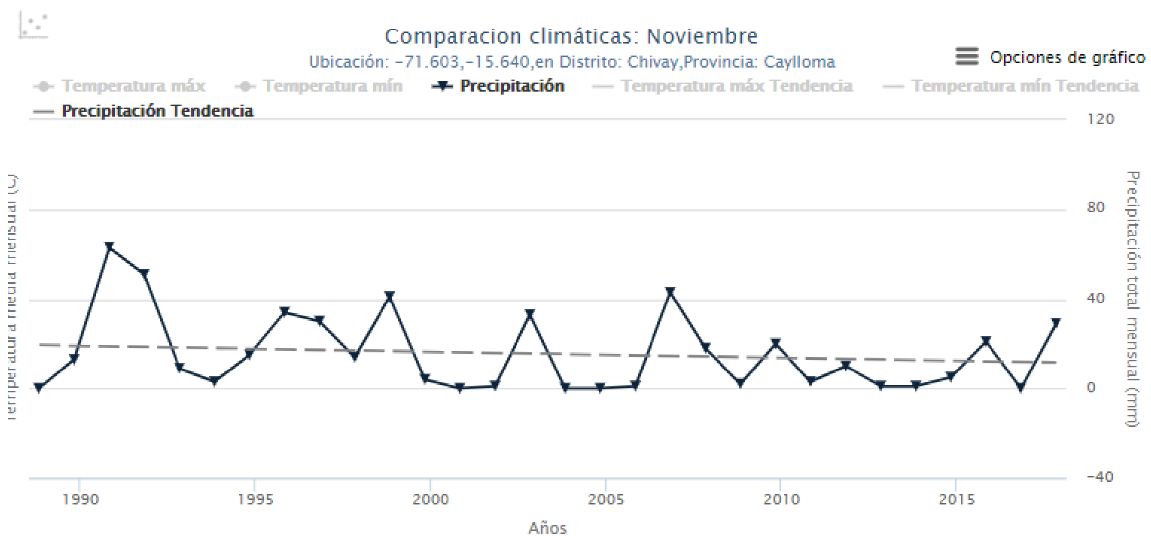

Figure 19: November precipitation and the estimated trend in Chivay (-7.7 mm/30 years)

FOR MORE INFORMATION

This tool was part of the Sustainable Water Management project of the Arequipa Nexus Institute. To see more of our tools and learn more about the SWM team, please visit our website at https://www.agry.purdue.edu/hydrology/projects/nexus-swm/es/index.html.

Together with this manual, there three more sources (formats) of information of how to use the tool: 1) an introduction video to the tool, 1) a tool quick guide document, and 3) the guided tour imbedded in the tool web site.

Data accessibility

The data presented in the AQP-Clima tool went through extensive preprocessing for removal of implausible values, data gap filling, and inhomogeneity detection. Although it is mostly a spatially interpolated product, it is based on local observations and can be used for a wide variety of applications. Being "homogeneous" means that no station data that failed the quality checks were used in the interpolation processes and "gap filled" means that the data is serially complete, in other words, there is no gap in the 30-year record for daily, monthly or annual data. This "clean" data product was preprocessed and is ready to use! As mentioned before, you can download it straight from the tool and use it in any analyses, just be sure to cite the source of the datasets (Moraes et al. 2020). If you desire to run spatial-temporal climate analyses in this data or use it in any application, you can download the Arequipa Climate Maps – Normals (ACM-N) and the Arequipa Climate Maps – Yearly, Monthly, and, Daily (ACM-YMD) spatial climate datasets.

ABOUT THE TEAM

Development team

Andre G. de Lima Moraes is a Post-doctoral Researcher in the Agriculture and Biologic Engineering (ABE) Department at Purdue University. His work focuses on the use of remote sensing and spatial analysis in climate and soil and water management and conservation applications.

Laura C. Bowling is a Professor of hydrology in the Department of Agronomy at Purdue University. Her research investigates the water resources impact of environmental change across multiple scales, climate regimes, and ecosystems and communicates these findings to stakeholders.

Carlos Zeballos-Velarde is an architect, urban planner, and professor at the Faculty of Architecture and Urbanism at the Universidad Nacional de San Agustín in Arequipa, Peru. He conducts GIS analyses about various topics related to environmental urban planning and works in several research projects about participatory risk management with different communities

Keith A. Cherkauer is a Professor of Agricultural and Biological Engineering at Purdue University. He works to facilitate the integration of field-based observations, remote sensing products, and hydrology models to address questions and concerns related to environmental change and to further understanding of land-atmosphere interactions and the hydrologic cycle.

Carol Song, Larry Biehl, and **Robert Campbell** are part of Information Technology at Purdue (ITAP), and they collaborated with our team to create AQP-Clima.

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